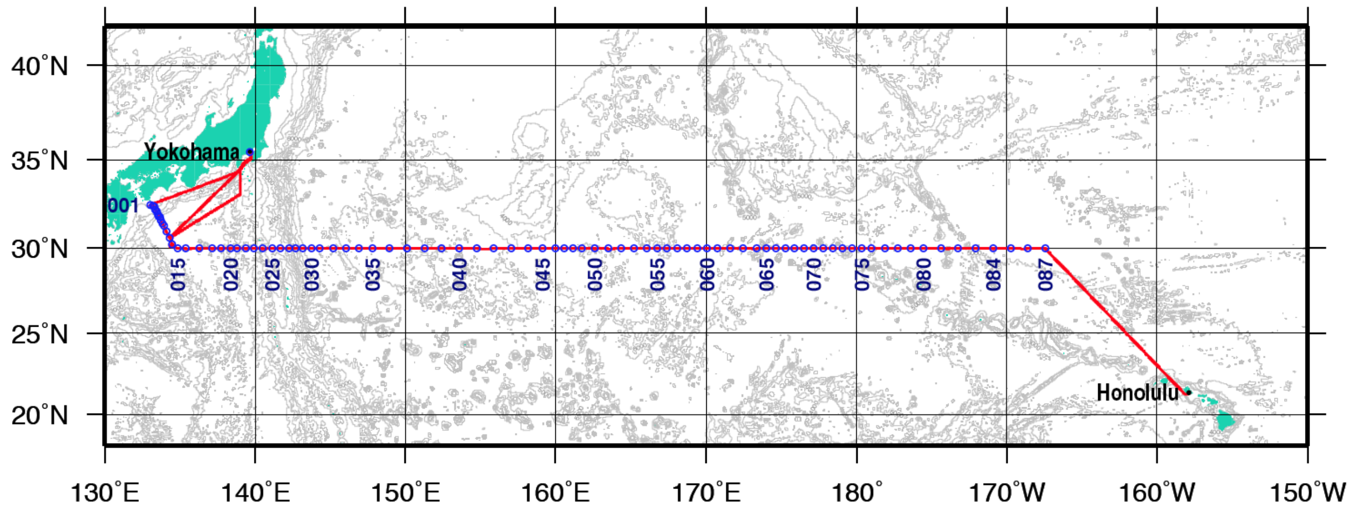
CRUISE REPORT: P02W

(Updated JUL 2013)



Highlights

Cruise Summary Information

WOCE Section Designation	P02W
Expedition designation (ExpoCodes)	318M20130321
Chief Scientist	Dr. James H. Swift / SIO
Co-Chief Scientist	Dr. Sachiko Yoshida / WHOI
Dates	21 March 2013 - 5 May 2013
Ship	R/V Melville
Ports of call	Yokohama, Japan - Honolulu, HI
Geographic Boundaries	32° 30.41' N 133° 1.75' E 167° 27.12' W 29° 58.22' N
Stations	87
Floats and drifters deployed	1 Argo float deployed
Moorings deployed or recovered	0

Contact Information:

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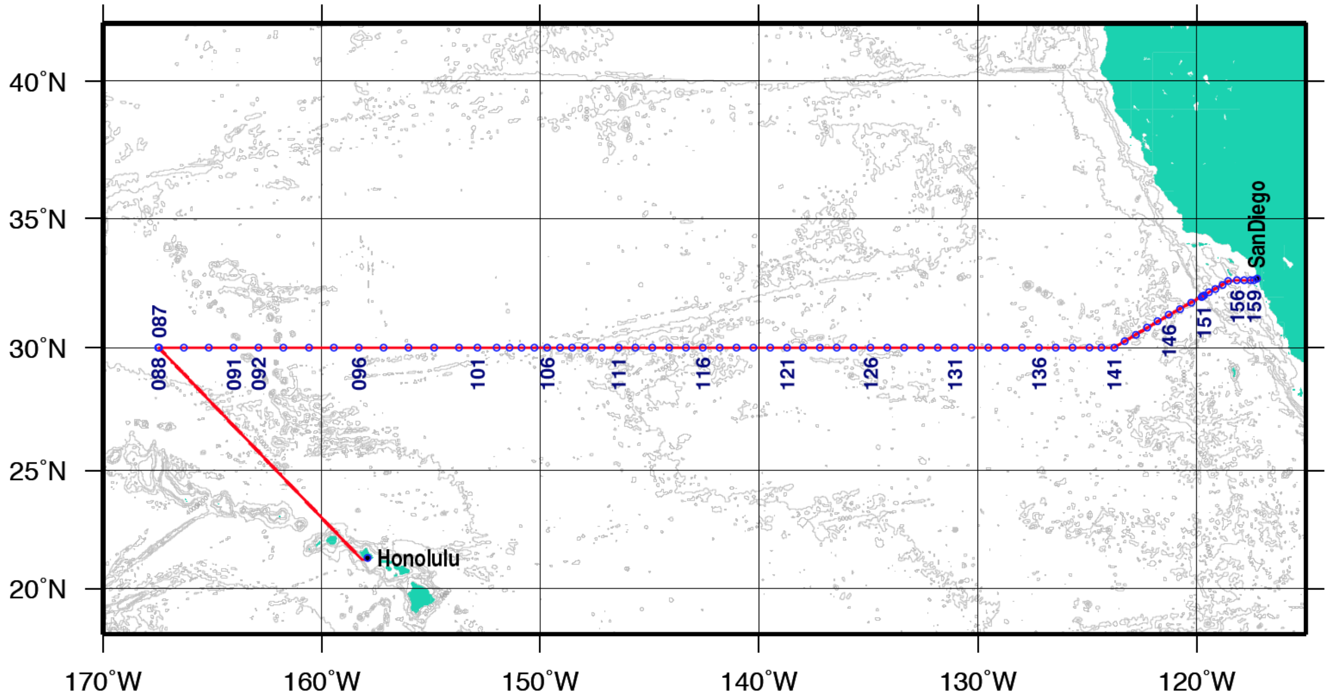
Links To Select Topics

Shaded sections are not relevant to this cruise or were not available when this report was compiled.

CRUISE REPORT: P02E

(Updated AUG 2013)



Highlights

Cruise Summary Information

WOCE Section Designation	P02E
Expedition designation (ExpoCodes)	318M20130321
Chief Scientist	Dr. Sabine Mecking / UW
Co-Chief Scientist	Dr. Gunnar Voet / UW
Dates	2013 MAY 08 - 2013 JUN 01
Ship	R/V Melville
Ports of call	Honolulu, HI - San Diego, CA
Geographic Boundaries	32° 38.5' N 167.45° W 117° 23' W 30°N
Stations	72
Floats and drifters deployed	3 Argo floats deployed
Moorings deployed or recovered	0

Contact Information:

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Links To Select Topics

Shaded sections are not relevant to this cruise or were not available when this report was compiled.

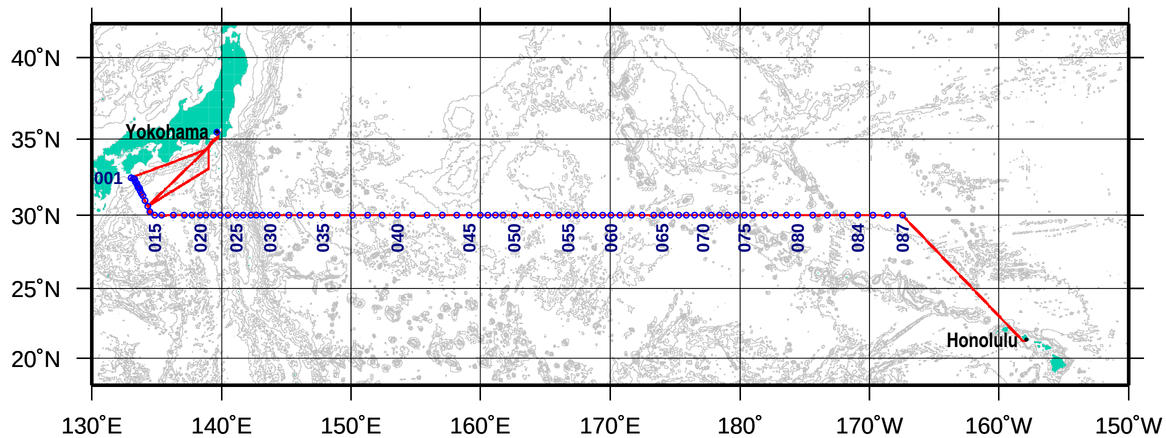
Cruise Summary Information	Hydrographic Measurements
Description of Scientific Program	**CTD Data:**
Geographic Boundaries	Acquisition
Cruise Track (Figure): PI CCHDO	Processing
Description of Stations	Calibration
Description of Parameters Sampled	Temperature Pressure
Bottle Depth Distributions (Figure)	Salinities Oxygens
Floats and Drifters Deployed	**Bottle Data**
Moorings Deployed or Recovered	Salinity
	Oxygen
Principal Investigators	Nutrients
Cruise Participants	Carbon System Parameters
	CFCs
Problems and Goals Not Achieved	Helium / Tritium
Other Incidents of Note	Radiocarbon
Underway Data Information	**References**
Navigation Bathymetry	CTD/BTL
Acoustic Doppler Current Profiler (ADCP) LADCP	CFCs & SF6
Thermosalinograph	DIC
XBT and/or XCTD	pH
Meteorological Observations	137CS
Atmospheric Chemistry Data	Iodine
Data Processing Notes	

CLIVAR/Carbon P02W
R/V Melville MV1305

21 March 2013 - 5 May 2013
Yokohama, Japan - Honolulu, HI

Chief Scientist: Dr. James H. Swift
Scripps Institution of Oceanography, UC San Diego

Co-Chief Scientist: Dr. Sachiko Yoshida
Woods Hole Oceanographic Institution



Cruise Report
5 May 2013
Rev. 12 July 2013

Summary

A hydrographic survey was conducted in the western North Pacific Ocean aboard the UNOLS vessel R/V Melville from 21 March 2013 - 5 May 2013. A total of 87 rosette/CTD/LADCP stations were occupied on a transect running roughly along latitude 30°N. CTD casts extended to within 10 meters of the seafloor, and up to 36 water samples were collected throughout the water column on all but one upcast. CTDO (conductivity, temperature, pressure, oxygen), transmissometer, fluorometer, and LADCP (lowered acoustic Doppler current profiler) electronic data; rosette water samples; and underway shipboard ADCP and carbon dioxide (CO_2) measurements were collected during the survey. In addition, one Argo float was deployed during this leg for NOAA/PMEL.

Salinity and dissolved oxygen samples, drawn from most bottles on every full cast, were analyzed and used to calibrate the CTD conductivity and oxygen sensors. Water samples were also analyzed on board the ship for nutrients (silicate, phosphate, nitrate, nitrite), total CO_2/TCO2 (aka dissolved inorganic Carbon/DIC), pH, total alkalinity, and transient tracers (CFCs and SF_6).

Additional water samples were collected and stored for analysis onshore: ^{3}Helium / Tritium, ^{13}C / ^{14}C, dissolved organic Carbon and total dissolved Nitrogen (DOC / TDN), $\delta^{15}N$-NO_3 / $\delta^{18}O$-NO_3, ^{137}Cs / ^{134}Cs / ^{90}Sr, ^{129}I, density and Calcium.

Underway measurements included GPS navigation, multibeam bathymetry, ADCP, meteorological parameters, sea surface measurements (including temperature, conductivity/salinity, dissolved oxygen, fluorescence), and gravity. In addition to the permanently installed R/V Melville systems, there was a Univ. of Washington Equilibrator Inlet Mass Spectrometer (EIMS) system, sampling ion currents of N_2, O_2, Ar and CO_2, and a NOAA GO 8050 underway pCO_2 system running throughout the leg.

P02 Leg 1 Narrative - J. Swift, Chief Scientist

The March-May 2013 P02 Leg 1 cruise for the NSF- and NOAA-sponsored U.S. Global Ocean Carbon and Repeat Hydrography Program was carried out from the Scripps Institution of Oceanography's global-class ship R/V Melville from Yokohama, Japan, to Honolulu, Hawaii. The CTD, hydrographic, ocean carbon, tracer, and underway measurements repeated those from Japanese-led cruises in 1994 and from R/V Melville in 2004, enabling comparisons from the different years.

The scientific party numbered 28: chief and co-chief scientist, res tech, computer tech, 4 student CTD watchstanders, 1 LADCP specialist, 8 STS/ODF techs (including temporary appointees), 7 ocean carbon techs, 2 CFC techs plus one CFC student assistant, and 1 He/Tr tech.

At the time the science team boarded and began loading in Yokohama, some of the expedition's equipment was already on board, having been loaded on in San Diego - some was used on one or more previous cruise legs. The bulk of the scientific cargo arrived in Yokohama in two lab vans, one cargo van, and various palletized and loose cargo shipments. The vans were loaded onto the ship and secured the day before official loading began. All shipments arrived by the first day of official loading - the Chief Scientist could not recall a more effortless shipping and loading experience. Equipment installations and all other aspects of set-up went very smoothly, thanks to untiring efforts from the SIO Shipboard Technical Support group, the ship's officers and crew, and all in the science team - one of the most satisfactory cruise set-ups in the Chief Scientist's experience.

R/V Melville departed Yokohama at 1242 local time on 21 March 2013 in good weather. There was a day and a half steam to the first station. Test/training stations underway were not feasible due to lack of clearance for activities in the Japanese EEZ at any positions other than those for the planned scientific stations. The locations of the first two stations were altered from the 2004 locations because the Japanese government did not permit the location of the first station, even though they had in 2004 (within Japanese territorial waters, i.e. within 12 nautical miles).There was deck staff training underway; and, at the first station for each watch, launch and recovery procedures were thoroughly reviewed. At station 001 there was a test cast to 50 meters to leak-test the bottles and check for the expected CTD and pylon performance. After minor adjustments the P02 transect began with station/cast 001/02.

Seas were gentle for the first 12 stations. During the crossing of the Kuroshio, attempts were made to predict ship drift during stations so that the final station positions were close to those planned. Problems during the first 12 stations were few, mostly relatively minor (but unusual) data noise glitches. All shipboard measurement and sample collection programs worked well.

A few minutes after the start of station 013, minor CTD acquisition data glitches escalated into untenable levels of CTD noise. After troubleshooting and tests it was determined that (1) the main DESH-6 CTD winch itself (motor and/or its power supply) was the source of that data noise, (2) water and corrosion were found inside the main CTD winch motor housing (and motor), and (3) neither the main nor backup DESH-5 CTD winch was in operable condition (the backup winch suffered control problems under heavy load). Neither winch could be repaired at sea. The data noise problems were not solved.

Thus the ship headed back to Yokohama at high cruise speed and delivered the main CTD winch motor to the selected repair facility. The ship operator also arranged for a manufacturer's winch specialist to travel from the U.S. to the ship. Under direction of the winch specialist, repairs to the backup (DESH-5) CTD winch went well and that winch passed a series of dockside load handling and data noise tests.

Most unfortunately, after the repaired main CTD winch motor was reinstalled, the debilitating noise in the CTD data was still there in dockside tests: whenever the repaired main CTD winch electric drive motor was turning (drawing current), with or without the CTD drum turning, it was still generating noise. The noise was then being picked up by the CTD. The main CTD instrument (#796) itself had not been suspect because during testing at station 013 it was found to work perfectly with the backup CTD winch. But during dockside tests it was eventually found that the backup CTD (#914) worked well with the main CTD winch (and also with the backup CTD winch). The ship left Yokohama for a second time at 2010 local time on 04 April 2013. Why one CTD was sensitive to this noise and the other not was puzzling, and so tests continued as the ship was underway back to the site of station 013.

During those tests an electrical configuration was determined that provided clean CTD data in on-deck tests from the main CTD (#796) with the main CTD winch (DESH-6). During launch and initial descent at resumed station 013/04 there were some data noise problems, but the CTD data acquisition computer was dealing acceptably with the data stream. But later during the cast data noise rose to very high levels, far beyond the capacity to produce science-quality data, and so the cast was aborted with 1700 meters wire out. After the rosette was returned to the deck, the backup CTD (#914) was switched into the rosette. There was some noise during launch (especially) and the upper hundreds of meters of 013/05, but only one serious data dropout (an artifact of real-time processing which resolved during post-cast re-averaging and spike-filtering). Otherwise, however, station 013 was finally completed.

Meanwhile winds were rising; although at station 014 the backup CTD was launched, massive data noise problems - related to the slow winch descent speeds required in heavier seas - finally forced cancellation of that cast.

It was time to switch to the backup CTD winch. In worsening weather the res tech, captain, and others moved the rosette to the launch/recovery point for that winch. There was then a wait for weather (winds rose to >45 knots) and seas to improve. When winds and seas abated station 014 was reattempted, this time with the backup winch. Smiles were wide all around when completely noise- and error-free CTD data was observed. But joy was short-lived when it was found that the DESH-5 backup CTD winch itself - despite having been repaired and groomed by a company expert in port and handily passing its tests there - could not be controlled when pay-out speeds exceeded about 13-16 meters per minute (*versus* 60 m/min expected), or haul-in speeds exceeded 6-7 (again *versus* 60 m/min expected). At those speeds, a 6000 meter cast could take one day! The winch specialist and others were immediately contacted, and many hours of tests and adjustments ensued. Meanwhile parallel efforts continued to obtain a clean (or clean enough) CTD data stream using the DESH-6 (main) CTD winch.

At this point excellent data quality was obtained from the backup CTD (and probably would have been from the main CTD) when connected through the backup CTD winch. But that winch was not controllable in the standard manner required. The main CTD winch itself worked well, in a mechanical sense, but neither CTD would pass noise-free data to the CTD data acquisition computer when used with it. [It was later speculated that the increased susceptibility of CTD #796 to the electrical/data noise, compared to #914, may have been because it contained additional communications circuitry which was sensitive to that noise. It seems likely that #796 was in good working order at the time.]

The continued problems, delays, and uncertainty only worsened the lack of knowledge and confidence in those ashore that the problems would be solved. The latest issues were rapidly heading the ship operator, program officers, and others ashore toward cancelling the cruise outright, with the aim of a new attempt in 2014. But one more day was requested because the experienced SIO Shipboard Technical Support engineer was well along with what amounts to a rebuild of the data pathway from the winch to the CTD computer and also systematically re-grounding everything that could possibly benefit. And the ship's talented Chief Engineer and his staff, working with the manufacturer's representative over the satellite telephone, were making daily progress on regaining control of the backup winch at any desired speed.

Indeed, about 10 hours after being granted one more day, a test cast was made with the main CTD winch: zero data noise, zero winch problems. The science team immediately went into full, normal operations. And within a day the backup winch was back in full, normal operation.

By the time station 014 was completed, the cruise delay had reached more than two weeks. The Chief Scientist had worked earlier with the science team ashore on a revised science and station plan that addressed the key scientific objectives of the program while using a minimum of ship days. Still, adding even those minimum days into the schedule meant a 10-day delay in port arrival in Honolulu, and similarly for Leg 2, which together posed a nearly impossible situation for the U.S. ship operators and schedulers. For example, R/V Melville was scheduled shortly after the original arrival in San Diego (from the second leg of the expedition) for a complex, long-planned three-ship operation that was hard-scheduled to coordinate with a fixed-in-time set of non-ship observations. R/V Melville already had expensive X-band radar installed for that operation. There were key events and fiscal decisions needed to make a revised Leg 2 feasible. This was not whatsoever a matter of changing the minds of people saying "no", but instead of intricate timing, expensive equipment and ship days, and mind-boggling complexity. In the end, new schedules were published for both P02 legs, to run consecutively in 2013 on R/V Melville.

The P02 Leg 1 section includes some of the deepest main basin waters of the World Ocean, with bottom depths at many station locations along the P02 Leg 1 track near or exceeding 6000 meters. CTD cable tension on such deep casts is an ongoing concern among scientists, research vessel operators, funding agencies, and UNOLS coordinating groups. A 20Hz recording tensiometer system was installed on R/V Melville in advance of the expedition. A brief report on observed CTD cable tensions is included with the cruise documentation. A more complete version of that report will be provided to interested parties.

Water depths along P02 somewhat exceeded 6000 meters over portions of the western part of the section; the ship's multibeam sonar recorded a 9640-meter reading in the Izu-Ogasawara Trench. Some components of the deployed rosette/CTD/LADCP system had manufacturer's maximum depth ratings of 6000 meters. Hence the deployed package was not lowered deeper than that level, as measured by the real-time package depth calculated from the CTD data. Except in the Trench, in most cases the LADCP was able to "see" the bottom, and so it should later be feasible to construct full-depth transport calculations from the data, except over the trench itself.

Winds and seas during the P02 Leg 1 cruise were not the near-continual impediment they can be in the Southern Ocean, but they did come up somewhat for a day or two mid-cruise. Winds stayed under 30 knots, and there was no gap in CTD operations. The somewhat higher seas led to the need for slower haul-up speeds at the very deepest reaches of casts below 5500 meters. Still, the recommended maximum CTD cable tension of 5000 lbs. was never exceeded.

A nagging problem up through station 033 was recurring failures each cast of up to several of the 10-liter bottles on the rosette to close promptly when triggered (a "post trip"). [These are easily detected in North Pacific Ocean waters due to strong vertical gradients in key water properties.] There were one or two repeat offenders, but the problem tended to move around each cast to different bottles, albeit mostly in the deepest, coldest waters. The rosette team steadily experimented with small adjustments to the bottle up-down positions on the frame and with the lanyards to improve the angles and position of the lanyards with respect to the release mechanisms. Yet some post-trips still took place. The thought was that the problem could be related to a new lanyard material which was in use for the first time - the manufacturer discontinued the material previously used. It was stiffer (less pliable) and thus less well able to release from the pylon mechanism. Indeed, the final fix to the post-trip problem did not take place until a partial spool of the old material was located on board and new release-connecting sections were installed on every bottle.

The rosette's pylons were an ongoing concern for much of the cruise. The 36-place rosettes are rare machines, as are their 36-place pylons which control bottle closures. SIO/STS owns two 36-place pylons, both of which were at sea on this cruise. Through the cruise there were signs of deteriorating reliability of the main pylon - failure to release a bottle when signaled to do so (not a lanyard failure) - although without serious data loss. But the time came, ahead of station 056, for the STS engineer to swap out the main pylon with the spare. The spare worked flawlessly for two casts and then the cast at station 058 came up with no bottles closed. (A surprise at the time because trip confirmations were received.) The spare pylon had suffered an internal communications failure which could not be repaired with the spare parts available at sea.

It was necessary to decide whether or not to repeat the cast. A quick review was made of the CTDO data from station 058 *vis-à-vis* those from the previous stations, and also the water sample partial data from the previous few stations. The CTDO data indicated that the water mass characteristics of the bottom water at station 058 were the same as those at the previous two stations, except that at 056 the characteristic signals of "new" bottom water were very slightly more extreme. The silicate data also suggested that the bottom water at 056 was very slightly more extreme in this characteristic signal than at 055 and 057. The abyssal density signature calculated from the CTD data was essentially flat between 057 and 058. Therefore it was judged unnecessary to re-do station 058, which, with the pylon replacement, would have cost about 7.5 hours. (The data loss was to CFCs, ocean carbon, and nutrients.) The ship instead moved to 059, resulting in a net time loss of only one hour.

Meanwhile, in checking out the main pylon, the engineer found seal leaks on three of its 36 solenoids (#1, #12, and #35). Emergency sealing repairs (with Scotchkote) were made to those solenoids, and the main pylon was put back into service. One of the 36 positions (#12) was unrecoverable, leaving 35 working positions. Position #35 did not work reliably and so beginning with station 059 #35 was closed at the surface and #36 at the level immediately below (easily done with the computer file for the pylon) to help ensure that #35 closes (by visual check; the plan was that if it didn't close, it would be re-triggered until it closed). Later #1 went out, and finally #35. This had little impact on the expedition's science goals. Colleagues at NOAA/PMEL responded quickly to a query and shipped one of their two 36-place pylons to Honolulu to be used as a spare on Leg 2. By station 084 the engineer returned positions #1 and #12 to operation, and the cruise leg was completed with, in effect, a 35-place rosette. The engineer also planned to address what repairs he could on the two SIO 36-place pylons with parts sent from the mainland to Honolulu.

On the science side, SIO/STS CTD data processor Mary Johnson discovered something rare at station 022/01: genuine instability (in density) in some unusual near-boundary (Izu-Ogasawara Ridge) deep interactions between warm/fresh & cold/salty waters. Steve Howell (University of Hawaii), who is along as LADCP specialist, noted that the near-bottom data were near the top of the ridge, so mixing is certainly a possibility. He also noticed that the inversion coincided with a bit of shear in the velocity profile.

At station 075, near the date line, an Argo float was deployed for NOAA/PMEL. Meanwhile the science team enjoyed a repeated day on the ship. This was fortuitously timed because this happened to be a Sunday and as a result there were two "Sunday steak nights". Many of those on board who had not previously crossed the date line on a ship were "initiated" in a short, fun ceremony, which was followed by a quoits tournament.

The first leg of the 2013 P02 expedition completed sampling with station 087, near 167.45°W. This was followed by an approximately 2.5-day steam to port in Honolulu, arriving the University of Hawaii Marine Center at approximately 0800 on Sunday, 05 May. In port the ship was refueled and reprovisioned, and about one-half the science team exchanged.

The plan for Leg 1 submitted with the original proposal had stations at no further apart than 30 nautical miles, and extended east to 158°20'W with a total of 121 stations. Time was tight because the Chief Scientist, when editing the ship time request form in January 2012, misunderstood what UNOLS meant on the form by the undefined term "science days", thinking in error that the term did not include port days. Therefore nominally the scheduled time for Leg 1 was already short, implying that some Leg 1 stations might need to be cut between Yokohama and 158°20'W. But team members and the chief scientist realized that the original station time estimates were too conservative and that the 121 station total was indeed feasible.

Overall, due to additional delays following adoption of the revised/reduced P02 station plan, it was necessary to increase station spacing (remove some Leg 1 stations) in along-track zones less sensitive to station spacing, and also to complete Leg 1 further west than planned. This left carryover effects on Leg 2: two days were added to Leg 2 above and beyond the two contingency days in the first version of the revised schedule, to carry out stations dropped on the east end of Leg 1. The total station count to 167.45°W in the original plan would have been 104, and in that same distance 87 were completed. Because data quality was consistently excellent, the revised station plan is expected to have successfully achieved key program objectives, though the loss of horizontal resolution may be felt for some science.

The reinstated two-consecutive-leg ship schedule for P02 was made possible only through tireless efforts and good will from many persons ashore - program managers, ship operators, the schedulers, and many PIs. These persons dealt with seemingly endless downstream effects on other investigators and cruises, and their efforts were crucial to the expedition's success.

It is worth noting in the records that this was an exceptional cruise in terms of a united, all-hands commitment to seeing the work through together. Possibly this arose out of the shared concerns and hard work to solve early problems, with the ship's engineers and the STS engineer in particular devoting very long hours. But when normal operations finally began, it showed on every face that the officers, crew, and science team alike were delighted to be back to work, united in confidence and enthusiasm. This outstanding attitude and cooperation among all hands continued unabated throughout the cruise.

We are deeply appreciative of our support for this venture from the National Science Foundation and the National Oceanic and Atmospheric Administration, and the ship backing from the US Navy. Our program managers did a phenomenal job of seeing this through and dealing with a panoply of downstream effects related to rescheduling to complete the program.

Principal Programs of CLIVAR/Carbon P02W

Program	Affiliation*	Principal Investigator	email
CTDO/Rosette, Nutrients, O_2, Salinity, Data Management	UCSD/SIO	James H. Swift	jswift@ucsd.edu
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pH , Total Alkalinity	UCSD/SIO	Andrew Dickson	adickson@ucsd.edu
DOC , TDN	UCSB	Craig Carlson	carlson@lifesci.ucsb.edu
Radiocarbons (^{13}C , ^{14}C)	WHOI Princeton	Ann McNichol Robert Key	amcnichol@whoi.edu key@princeton.edu
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^{137}Cs , ^{134}Cs , ^{90}Sr	WHOI	Ken Buesseler Alison Macdonald	kbuesseler@whoi.edu amacdonald@whoi.edu
^{129}I , ^{127}I	LLNL	Tom Guilderson	guilderson1@llnl.gov
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Dissolved Calcium	UCSD/SIO	Todd Martz	trmartz@ucsd.edu
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pCO_2 Underway Data	NOAA	Geoffrey Lebon	Geoffrey.T.Lebon@noaa.gov
EIMS Underway Data (N_2, O_2, Ar and CO_2)	UWash	Paul D. Quay Hilary Palevsky	pdquay@uw.edu palevsky@uw.edu
Ship's Underway Data	UCSD/SIO	Frank Delahoyde	fdelahoyde@ucsd.edu

* Affiliation abbreviations listed on page 7

Shipboard Personnel on CLIVAR/Carbon P02W

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Cassidy Curl	SIO/SOMTS	Ordinary Seaman	
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Alejandro Quintero	SIO/STS/ODF	O2 / Data Processing	a1quintero@ucsd.edu
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* Affiliation abbreviations are listed on page 7

KEY to Institution Abbreviations	
CR	Computing Resources (SIO/STS)
LDEO	Lamont-Doherty Earth Observatory (Columbia University)
LLNL	Lawrence Livermore National Laboratory
MPL	Marine Physical Laboratory (SIO)
NOAA	National Oceanic and Atmospheric Administration
ODF	Oceanographic Data Facility (SIO/STS)
PMEL	Pacific Marine Environmental Laboratory (NOAA)
Princeton	Princeton University
RSMAS	Rosenstiel School of Marine and Atmospheric Science (UMiami)
RT	Research Technicians (SIO/STS)
SIO	Scripps Institution of Oceanography (UCSD)
SOMTS	Ship Operations and Marine Technical Support (SIO)
STS	Shipboard Technical Support (SIO)
TAMU	Texas A&M University
UCSD	University of California, San Diego
UCSB	University of California, Santa Barbara
UFlorida	University of Florida
UHawaii	University of Hawaii
UMiami	University of Miami
UWash	University of Washington
WHOI	Woods Hole Oceanographic Institution

Core Hydrographic Measurements: CTD Data, Salinity, Oxygen and Nutrients

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The CLIVAR/Carbon P02W repeat hydrographic line was reoccupied for the CLIVAR/Carbon Program from 21 March 2013 - 5 May 2013 aboard R/V Melville during a survey consisting of rosette/CTD/LADCP stations and a variety of underway measurements. The ship departed Yokohama, Japan on 21 March 2013 and arrived Honolulu, HI on 5 May 2013 (UTC dates).

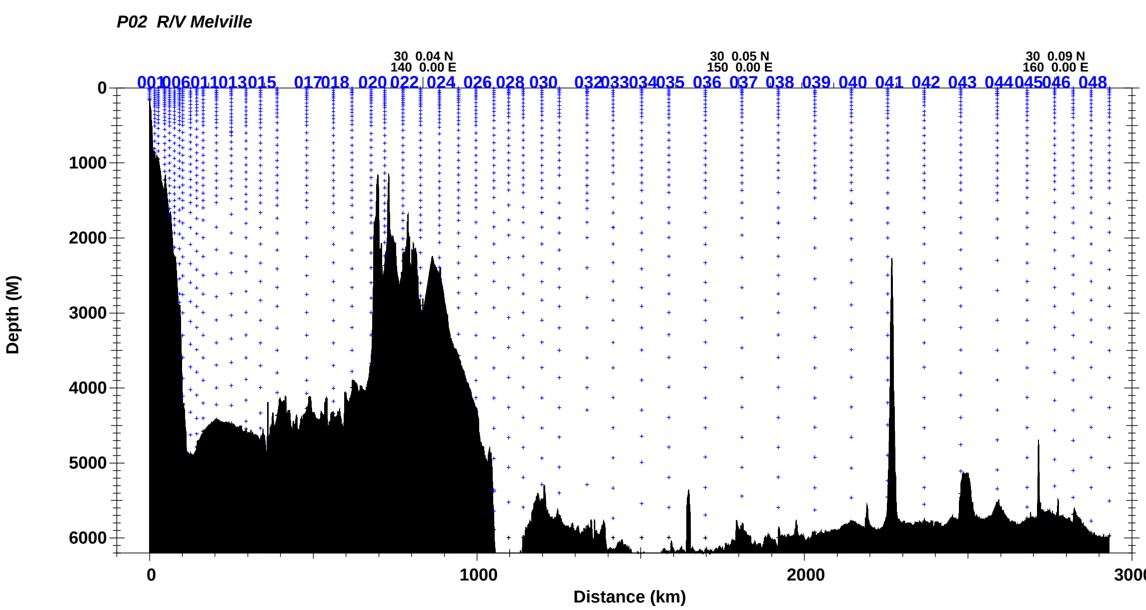
A sea-going science team gathered from 10 oceanographic institutions participated on the cruise. The programs and PIs, and the shipboard science team and their responsibilities, are listed in the Narrative section.

Description of Measurement Techniques

1. CTD/Hydrographic Measurements Program

A total of 87 stations were occupied with one rosette/CTD/LADCP cast completed at each. 1 test cast(s) (1/1) and 9 aborted cast(s) (13/1-13/4 and 14/1-14/3) were not reported. CTDO data and water samples were collected on each rosette/CTD/LADCP cast, usually to within 10 meters of the bottom. Water samples measured on board or stored for shore analysis are tabulated in the Bottle Sampling section.

Pressure, temperature, conductivity/salinity, dissolved oxygen, fluorometer and transmissometer data were recorded from CTD profiles. Current velocities were measured by the RDI workhorse LADCP. Core hydrographic measurements consisted of salinity, dissolved oxygen and nutrient water samples taken from each rosette cast. The distribution of samples are shown in the following figures.



Sample

Figure 1.0 P02W Sample Distribution, Stations 1-49.

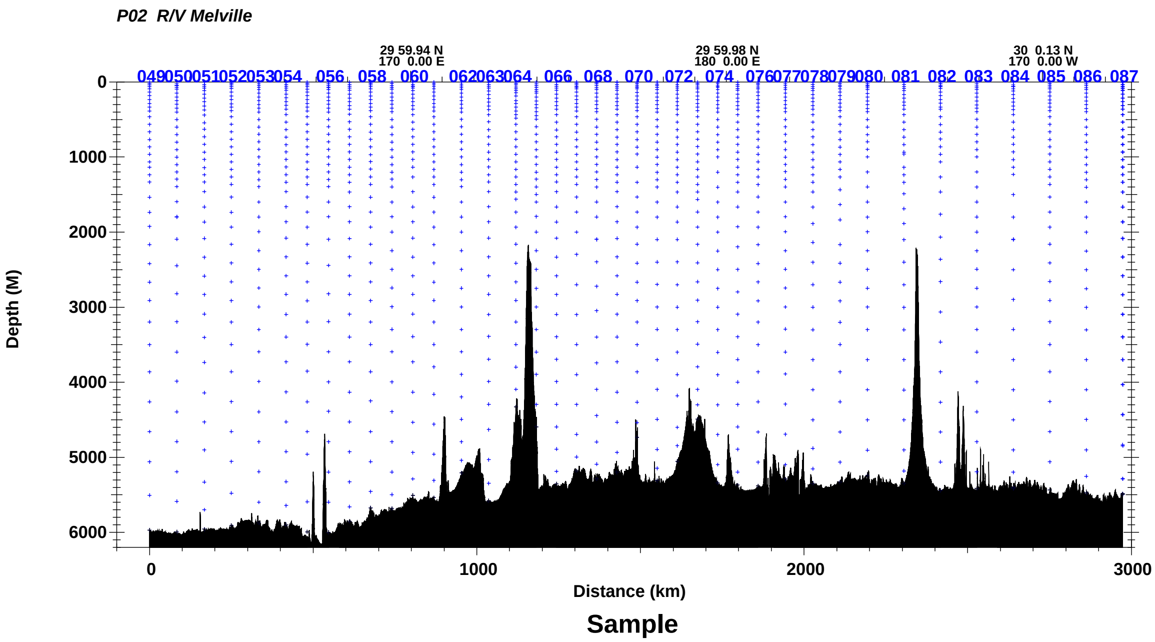


Figure 1.1 P02W Sample Distribution, Stations 49-87.

1.1. Water Sampling Package

Rosette/CTD/LADCP casts were performed with a package consisting of a 36-bottle rosette frame (SIO/STS), a 36-place carousel (SBE32) and 36 10.0L Bullister-style bottles (SIO/STS) with an absolute volume of 10.4L. Underwater electronic components consisted of a Sea-Bird Electronics SBE9*plus* CTD with dual pumps (SBE5), dual temperature sensors (SBE3*plus*), dual conductivity sensors (SBE4C), dissolved oxygen (SBE43), chlorophyll fluorometer (Seapoint), transmissometer (WET Labs), altimeter (Simrad), reference temperature (SBE35RT) and LADCP (RDI).

The CTD was mounted vertically in an SBE CTD cage attached to the bottom of the rosette frame and located to one side of the carousel. The SBE4C conductivity, SBE3*plus* temperature and SBE43 Dissolved oxygen sensors and their respective pumps and tubing were mounted vertically in the CTD cage, as recommended by SBE. Pump exhausts were attached to the CTD cage on the side opposite from the sensors and directed downward. The transmissometer was mounted horizontally, and the fluorometer was mounted vertically near the bottom of the rosette frame. The altimeter was mounted on the inside of the bottom frame ring. The 150 KHz downward-looking Broadband LADCP (RDI) was mounted vertically on one side of the frame between the bottles and the CTD. Its battery pack was located on the opposite side of the frame, mounted on the bottom of the frame. Table 1.1.0 shows height of the sensors referenced to the bottom of the frame:

Instrument	Height in cm
Pressure Sensor, inlet to capillary tube	27
Temperature (probe tip at TC duct inlet)	15
SBE35RT (centered between T1/T2 on same plane)	15
Rinko DO	11
Transmissometer	12
Fluorometer	12
Altimeter	2
LADCP (paddle center)	7
Outer-ring (odd #s) bottle centerline	124
Inner-ring (even #s) bottle centerline	111
Reference (Surface Zero tape on wire)	280

Table 1.1.0 Heights referenced to bottom of rosette frame

The rosette system was suspended from a UNOLS-standard three-conductor 0.322" electro-mechanical sea cable. The sea cable was terminated at the beginning of P02W. The R/V Melville's DESH-6 winch was used for all but one aborted cast (station 14/3).

The deck watch prepared the rosette 10-30 minutes prior to each cast. The bottles were cocked and all valves, vents and lanyards were checked for proper orientation. Once stopped on station, the rosette was moved out from the aft hangar to the deployment location under the A-frame using an air-powered cart and tracks. The CTD was powered-up and the data acquisition system started from the computer lab. The rosette was unstrapped from the cart. Tag lines were threaded through the rosette frame and syringes were removed from CTD intake ports. The winch operator was directed by the deck watch leader to raise the package.

The A-frame and rosette were extended outboard and the package was quickly lowered into the water. Tag lines were removed and the package was lowered to 10 meters, until the console operator determined that the sensor pumps had turned on and the sensors were stable. The winch operator was then directed to bring the package back to the surface, at which time the wire-out reading was re-zeroed before descent.

Most rosette casts were lowered to within 10 meters of the bottom, using the CTD depth and multibeam echosounder depth to estimate the distance, and the altimeter and wire-out to direct the final approach.

For each up cast, the winch operator was directed to stop the winch at up to 36 pre-determined sampling depths. These standard depths were staggered every station using 3 sampling schemes. To ensure package shed wake had dissipated, the CTD console operator waited 30 seconds prior to tripping sample bottles. An additional 10 seconds elapsed before moving to the next consecutive trip depth, to allow the SBE35RT time to take its readings. The deck watch leader directed the package to the surface for the last bottle trip.

Recovering the package at the end of the deployment was essentially the reverse of launching, with the additional use of poles and snap-hooks attached to tag lines for controlled recovery. The rosette was secured on the cart and moved into the aft hangar for sampling. The bottles and rosette were examined before samples were taken, and anything unusual was noted on the sample log.

Each bottle on the rosette had a unique serial number, independent of the bottle position on the rosette. Sampling for specific programs was outlined on sample log sheets prior to cast recovery or at the time of collection.

Routine CTD maintenance included soaking the conductivity and oxygen sensors with 1% Triton-X solution between casts to maintain sensor stability and eliminate accumulated bio-films. Rosette maintenance was performed on a regular basis. Valves and o-rings were inspected for leaks. The rosette, CTD and carousel were rinsed with fresh water as part of the routine maintenance.

1.2. Navigation and Bathymetry Data Acquisition

Navigation data were acquired at 1-second intervals from the ship's Furuno GP150 GPS receiver by a Linux system beginning 21 March 2013 at 0350z, as the R/V Melville left the dock in Yokohama, Japan.

Center-beam bathymetric and hull-depth correction data from the Kongsberg EM-122 multibeam echosounder system were acquired by the ship, and fed into the ODF Linux systems through a serial data feed. A minor change in STS/ODF software was required to read in the depth feed with the correction. Bathymetry and navigation data were merged and stored on the ODF systems, and data were made available as displays on the ODF acquisition system during casts. Bottom depths associated with rosette casts were recorded on the Console Logs during deployments.

Corrected multibeam center depths are reported for each cast event in the WOCE and Exchange format files.

1.3. CTD Data Acquisition and Rosette Operation

The CTD data acquisition system consisted of an SBE-11*plus* (V2) deck unit and three networked generic PC workstations running CentOS-5.8 or -5.9 Linux. Each PC workstation was configured with a color graphics display, keyboard and trackball. The systems each had a Comtrol Rocketport PCI multiple port serial controller providing 8 additional RS-232 ports. The systems were interconnected through the ship's network. These systems were available for real-time operational and CTD data displays, and provided for CTD and hydrographic data management.

One of the workstations was designated the CTD console and was connected to the CTD deck unit via RS-232. The CTD console provided an interface and operational displays for controlling and monitoring a CTD deployment and closing bottles on the rosette. Another of the workstations was designated the website and database server and maintained the hydrographic database for P02W. Redundant backups were managed automatically.

The SBE9*plus* CTD supplied a standard SBE-format data stream at a data rate of 24 frames/second. The sensors and instruments used during CLIVAR/Carbon P02W, along with pre-cruise laboratory calibration information, are listed below in Table 1.3.0. Copies of the pre-cruise calibration sheets for various sensors are included in Appendix D.

Instrument/Sensor*	Mfr.§/Model	Serial Number	CTD Channel	Stations Used	Pre-Cruise_Calibration Date	Facility§
Carousel Water Sampler	SBE32†	3213290-0113	n/a	1-55,59-87	n/a	
Carousel Water Sampler	SBE32†	3216715-0187	n/a	56-58	n/a	
Reference Temperature	SBE35	3528706-0035	n/a	1-87	7-Dec-2012	SIO/STS
CTD	SBE9*plus*	09P39801-0796	n/a	1-13/4	n/a	
Pressure	Paroscientific Digiquartz 401K-105	796-98627	Freq.2	1-13/4	18-Dec-2012	SIO/STS
CTD	SBE9*plus*	09P52161-0914	n/a	13/5-87	n/a	
Pressure	Paroscientific Digiquartz 401K-105	914-110547	Freq.2	13/5-87	14-Jun-2012	SIO/STS
Primary Pump Circuit						
Temperature (T1)	SBE3*plus*	03P-4138	Freq.0	1-87	24-Jan-2013	SIO/STS
Conductivity (C1)	SBE4C	04-2569	Freq.1	1-87	16-Jan-2013	SBE
Dissolved Oxygen	SBE43	43-0275	Aux2/V2	1-19	12-Jul-2012	SBE
Dissolved Oxygen	SBE43	43-1071	Aux2/V2	20-87	12-Jul-2012	SBE
Pump	SBE5T	05-4890	n/a	1-87	n/a	
Secondary Pump Circuit						
Temperature (T2)	SBE3*plus*	03P-4226	Freq.3	1-87	24-Jan-2013	SIO/STS
Conductivity (C2a)	SBE4C	04-2112	Freq.4	1-66/2	24-Jan-2013	SBE
Conductivity (C2b)	SBE4C	04-3058	Freq.4	66/3-87	2-Nov-2012	SBE
Pump	SBE5T	05-4377	n/a	1-87	n/a	
Optical Diss. Oxygen Rinko O2 Temperature	{‡Rinko III ARO-CAV}	105	Aux3/V4 Aux3/V5	25-87	7-Aug-2012	{JFE Advantech}
Chlorophyll Fluorometer	Seapoint	SCF2748	Aux1/V1	1-87	n/a	
Transmissometer (TAMU)	WET Labs C-Star	CST-327DR	Aux2/V3	1-87	19-Jul-2012	WET Labs
Altimeter (500m range)	Simrad 807	9711091	Aux1/V0	1-87	n/a	
Deck Unit (in lab)	SBE11*plus* V2	11P9852-0366	n/a	1-87	n/a	

* All sensors belong to SIO/STS, unless otherwise noted.
§ SBE = Sea-Bird Electronics
† 36-place version
‡ Optical oxygen sensor, new to SIO/STS; installed for evaluation purposes

Table 1.3.0 CLIVAR/Carbon P02W Rosette Underwater Electronics.

An SBE35RT reference temperature sensor was connected to the SBE32 carousel and recorded a temperature for each bottle closure. These temperatures were used as additional CTD calibration checks. The SBE35RT was utilized using Sea-Bird Electronics' recommendations (*http://www.seabird.com*).

The SBE9*plus* CTD was connected to the SBE32 36-place carousel, providing for sea cable operation. Power to the SBE9*plus* CTD and sensors, SBE32 carousel and Simrad altimeter was provided through the sea cable from the SIO/STS SBE11*plus* deck unit in the main lab.

CTD deployments were initiated by the console watch after the ship stopped on station. The acquisition program was started and the deck unit turned on at least 3 minutes prior to package deployment. The watch maintained a console operations log containing a description of each deployment, a record of every attempt to close a bottle and any relevant comments. The deployment and acquisition software presented a short dialog instructing the operator to turn on the deck unit, to examine the on-screen CTD data displays and to notify the deck watch that this was accomplished.

Once the deck watch had deployed the rosette, the winch operator lowered it to 10 meters, or deeper in heavier seas. The CTD sensor pumps were configured with a 5-second start-up delay after detecting seawater conductivities. The console operator checked the CTD data for proper sensor operation and waited for sensors to stabilize, then instructed the winch operator to bring the package to the surface and descend to a specified target depth, based on CTD pressure available on the winch display.

The CTD profiling rate was at most 30m/min to 100m and up to 60m/min deeper than 100m, depending on sea cable tension and sea state. As the package descended toward the target depth, the rate was reduced to 30m/min at 100m from the bottom.

The progress of the deployment and CTD data quality were monitored through interactive graphics and operational displays. Bottle trip locations were transcribed onto the console and sample logs. The sample log was used later as an inventory of samples drawn from the bottles. The altimeter channel, CTD depth, winch wire-out and bathymetric depth were all monitored to determine the distance of the package from the bottom, allowing a safe approach to 8-10 meters.

Bottles were closed on the up-cast by operating an on-screen control. The expected CTD pressure was reported to the winch operator for every bottle trip. Bottles were tripped 30-40 seconds after the package stopped to allow the rosette wake to dissipate and the bottles to flush. The winch operator was instructed to proceed to the next bottle stop no sooner than 10 seconds after closing bottles to ensure that stable CTD data were associated with the trip and to allow the SBE35RT temperature sensor to measure bottle trip temperature.

It can be necessary at some stations in higher sea states to close shallower bottles (normally only the shallowest bottle) on the fly due to the need to keep tension on the CTD cable. At such closures - always noted on the CTD Console Log Sheet - the SBE35RT temperature is typically not usable.

The package was directed to the surface by the deck for the last bottle closure, then the package was brought on deck. The console operator terminated the data acquisition, turned off the deck unit and assisted with rosette sampling.

1.4. CTD Winch and Sea Cable Issues

The R/V Melville's Markey DESH-6 (aft) winch was used for all reported casts. Typically, one conductor in the DESH-6 UNOLS-standard three-conductor 0.322" electro-mechanical sea cable was used for power and signal; the sea cable armor was used for ground. A full (electrical and mechanical) re-termination was done on the DESH-6 sea cable before P02W started.

The Markey DESH-5 (forward) winch was available as a spare, and only used for one aborted cast during P02W. Its cable had 50-60m of rusty wire removed prior to full re-termination before the leg began.

There was CTD signal noise in short (less than 1-second) bursts during stations 1/1 (test), 1/2, and 2, all near-surface on the downcasts. Prior to station 7, a full re-termination (electrical and mechanical) was done to the DESH-6 wire because of a kink.

CTD signal noise returned on station 8 upcast, 20m below the third bottle-trip stop. It was frequent and persistent, and ended just as suddenly as it started a few minutes after the trip.

Prior to going in-water on station 12, there was much signal noise following a large fantail slam/shudder. It continued through two near-surface yo-yos, then stopped completely after a few short noisy bursts just below the surface start.

Before station 13 cast 1, an electrical retermination was done as part of troubleshooting the observed electrical noise on station 12. In addition, a separate winch-to-lab-JBox cable was run to bypass the standard one, to eliminate one more possible source of signal interference. The cast was aborted at 10m due to excessive noise and inability to find a usable signal. Two more casts were attempted after various checks and adjustments, and both were aborted at 10m for excessive noise.

After extensive testing with various CTD and wire combinations, the DESH-6 was determined to be the source of the problem. The Chief Engineer and his team opened up the DESH-6 winch and found water inside the housing and motor. The DESH-5 was not usable due to speed-control issues using a 500-pound test weight. The ship returned to Yokohama for winch repairs, where the DESH-5 motor was also found to be flooded. Winch motor repairs were accomplished in Yokohama through a local company (DESH-6 motor), as well as by the Melville engineering team, with the assistance of a Markey technician who was flown in to assist.

During the transit back to station 13, signal noise problems persisted. An experimental retermination using two of the three inner conducting wires was attempted before station 13 cast 4. In addition, the armor was grounded to the unistrut in the main lab. There were random signal cutouts in short bursts during the downcast, but at 1410 decibars down, the pumps started turning off/on repeatedly. The winch was stopped near 1700 mwo while the winch-to-lab-JBox bypass cable was re-installed; but this did not solve the problem. The cast was aborted, and the pump cutout issues were traced to a water leak/short on the CTD #796 endcap under a dummy plug.

A standard electrical retermination was done prior to station 13 cast 5, and CTD #914 was installed to replace CTD #796. Data noise persisted, appearing to increase with winch deceleration, on both downcast (during the bottom approach) and upcast (slowing for each bottle stop). The cast was completed despite the noise, opting to clean up the data post-cast and get moving eastward and away from jinxed station 13.

Station 14 cast 1 was aborted near 600 mwo due to excessive data noise. Station 14 cast 2 was attempted with the DESH-5 winch; but speed-control issues (jumping from 10 to 140 m/min in sudden spurts) caused this cast to be aborted near 750 mwo.

Weather delays gave more time for diagnosis, and the DESH-6 winch ground to deck was found to be faulty. After this was fixed, station 14 cast 3 had to be aborted at 50m due to a sea critter invading (and clogging) the primary pump tube - arrgghhh! Then, at last, no more CTD noise problems.

The DESH-5 winch speed-control issues were repaired within the next few days by the engine crew, and it was available as a spare for the rest of the leg.

A final DESH-6 mechanical termination was done prior to station 47 when it was discovered that residual torque was causing the outer armor to unlay.

A much smaller winch issue was the LCI-90i (winch tension, speed and payout) display, which became intermittently non-responsive mid-cast, both at the winch control station and in the lab. If the freeze-up happened for more than a few seconds, the winch operator would slow down or stop until the display returned. The display usually reset itself after a few seconds, but at other times, someone in the main lab needed to turn a circuit breaker off and on to fix the display. A few times, when the winch did not stop and the circuit-breaker reset was required, the winch payout "offset", causing a bit of extra arithmetic for the console operator. When payout was substantially different from 0m by the time the rosette returned to the surface on the upcast, it could cause some confusion (and extra tension) for the winch operator as well.

1.5. CTD Cable Tension on Deep Casts

As the P02 Leg 1 cruise progressed into deeper and deeper water, significant R/V Melville science and operations issues hinged on actual CTD cable tension and cast time performance on very deep CTD casts (maximum cast depths deeper than 5000 meters). Although all the U.S. work for this program since it began in 2003 had transpired without CTD cable parting or functionality loss, new UNOLS/NSF cable tension rules went into effect shortly before this cruise. It was thought pre-cruise by some at the operator and agency level that the maximum CTD cable tensions on deep casts on this cruise would exceed the new rules. Two questions in particular loomed in planning: (1) under what conditions would CTD cable tensions exceed 5000 lbs., and (2) what would be the impacts on P02 station times and operations due to efforts to keep maximum observed CTD cable tension less than 5000 lbs.? The cruise had a waiver permitting CTD operations to continue under some conditions if higher CTD cable tensions were observed, but there was general concurrence that sustained P02 CTD operations with cable tensions above 5000 lbs. should be avoided if possible.

The ship was equipped with a new 20Hz recording tensiometer, which provided the real-time data for cast operations and the recorded data for further study.

Experiments with step-wise increasing winch haul speed at early P02 stations in waters 4000-5000 meters deep, in good weather, showed that maximum CTD cable tensions stayed near or less than ca.

4000 lbs. with any haul speeds to the maximum desired haul speed of 60 meters/minute.

The first station with water depth exceeding 5000 meters was 027 (5825 meters), where 5848 meters of CTD cable were deployed. (At calculated package depth 5860 meters, winch speed zero, cable tension ranged 3840-4380 lbs., mostly in the middle of that range.) In this case the winch operator began to haul up at 20 meters/minute with maximum wire out, slowly increasing speed while carefully observing cable tension. But long before there was less than 5000 meters of wire out the winch operator was able to increase haul speed to 60 meters per minute. Over succeeding stations the winch operators quickly gained confidence working at higher winch speeds, finding they could rapidly ease speeds up to 60 meters/minute haul speeds with more than 5800 meters of wire out, meanwhile keeping maximum cable tension below 4500 lbs.

The skill of the Melville's winch operators (two of them were the best overall in the Chief Scientist's UNOLS experience) and their rapidly-gained experience with the 36-place rosette in deep water with greater than 5000 meters of CTD cable deployed, permitted the faster haul speeds and shorter net station times than the chief scientist had used in pre-cruise planning.

It is important to note that most 5000-6000 meter casts during P02 Leg 1 took place in good weather (winds 10-20 knots; low swell). During slightly more than one day of winds in the 20-25 knot range (with periods of 25-30 knots) seas rose somewhat. Associated with the higher level of ship motion there were several casts that day where cable tensions rose to nearer but still under 5000 lbs., with maximum cable deployed, even with lowered winch haul-up speeds.

Frank Delahoyde, the STS computer engineer on board, made histograms of the 20Hz winch tension data for each day's stations, binned in 50-lb increments. The example from a day with some of the highest observed tensions is shown in Figure 1.5.0. It can be seen that no tensions greater than 5000 lbs. were observed, and very few with more than 4500 lbs.

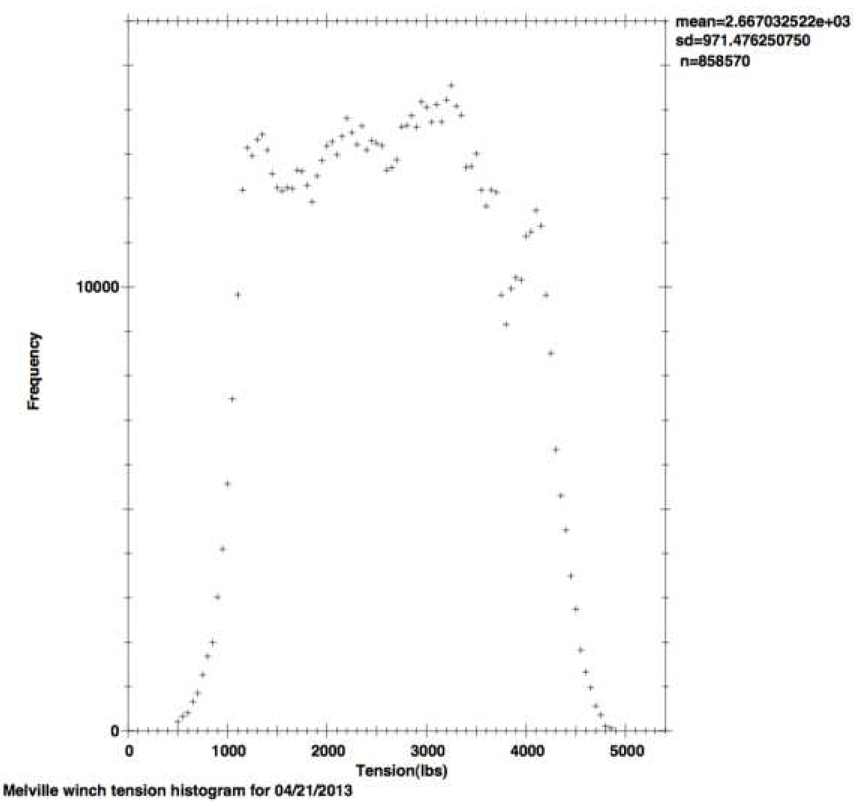


Figure 1.5.0 Melville 20 Hz winch tension histogram for 21 April 2013, a day when some of the highest cable tensions of the P02 Leg 1 cruise were recorded.

As noted above, there was little increase in CTD cable tension observed as haul speed was increased from 30 to 60 meters per minute (or payout speed decreased from 60 to 30 meters per minute). To demonstrate this, Steve Howell, University of Hawaii, made a plot of all 20 Hz cable tension readings for one day (three total CTD casts) *versus* wire out, colored by winch speed -60 to +60 meters per minute (Figure 1.5.1) There was only 125-150 lb. increase in tension when reducing deploy speed from 60 to 30 meters per minute during the deepest 100 meters of deployment, and when increasing the speed from 30 to 60 meters per minute when hauling up.

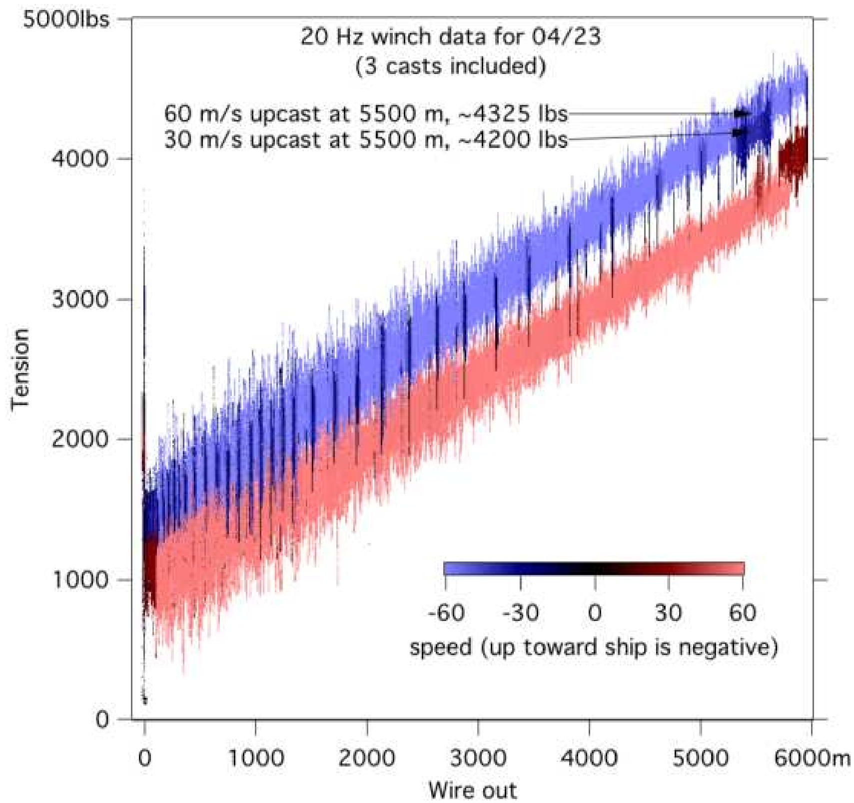


Figure 1.5.1 20 Hz CTD winch cable tensions *versus* wire out for one day (23 April 2013), colored by winch speed.

The narrow dark blue bands in Figure 1.5.1 arise from a single up-cast operated by a cautious winch operator who slowed the winch much earlier (and hence for a longer time) than did his comrades. The "fast" winch operators brought the package much closer to the desired bottle depth before rapidly slowing the winch, and so their bottle stops do not show on their casts. R/V Melville's "fast" winch operators saved appreciable time.

The cable tension observations during P02 Leg 1 also serve to demonstrate that when large lengths of CTD cable are deployed the main cause of cable tension spikes is ship motion (ship roll and heave). Vertical motions of the sheave in higher seas is thought to be in the ±2 meter/second range. These high sheave motions create large impulse loads and high drag on upward sheave motion and slack loads on downward sheave motion. (Near the sea surface, cable tension spikes and slack wire are nearly solely due to sheave motion.) Use of a heave-compensating rosette deployment system should then be useful in reducing maximum cable tension on operations in higher sea states, for example those often experienced in the Southern Ocean.

1.6. CTD Data Processing

Shipboard CTD data processing was performed automatically during and after each deployment using SIO/STS CTD processing software v.5.1.6-1.

During acquisition, the raw CTD data were converted to engineering units, filtered, response-corrected, calibrated and decimated to a more manageable 0.5-second time series. Pre-cruise laboratory calibrations for pressure, temperature and conductivity were also applied at this time. The 0.5-second time series data were used for real-time graphics during deployments, and were the source for CTD pressure and temperature data associated with each rosette bottle. Both the raw 24 Hz data and the 0.5-second time series were stored for subsequent processing. During the deployment, the raw data were backed up to another Linux workstation every 5 minutes.

At the completion of a deployment a sequence of processing steps were performed automatically. The 0.5-second time series data were checked for consistency, clean sensor response and calibration shifts. A 2-decibar pressure series was generated from the down cast data. The pressure-series data were used by the web service for interactive plots, sections and CTD data distribution. Time-series data were also available for distribution through the website.

CTD data were routinely examined for sensor problems, calibration shifts and deployment or operational problems. On-deck pressure values were monitored at the start and end of each cast for potential drift. Alignment of temperature and conductivity sensor data (in addition to the default 0.073-second conductivity "advance" applied by the SBE11*plus* deck unit) was optimized for each pump/sensor combination to minimize salinity spiking, using data from multiple casts of various depths after acquisition. If the pressure offset or conductivity "advance" values were altered after data acquisition, the CTD data were re-averaged from the 24Hz stored data.

The primary and secondary temperature sensors (SBE3*plus*) were compared to each other and to the SBE35 temperature sensor. CTD conductivity sensors (SBE4C) were compared to each other, then calibrated by examining differences between CTD and check-sample conductivity values. CTD dissolved oxygen sensor data were calibrated to check-sample data.

As bottle salinity and oxygen results became available, they were used to refine shipboard conductivity and oxygen sensor calibrations. Theta-Salinity and theta-O_2 comparisons were made between down and up casts as well as between groups of adjacent deployments.

A total of 87 full casts were made using the 36-place CTD/LADCP rosette. Further elaboration of CTD procedures specific to this cruise are found in the next section.

1.7. CTD Acquisition and Data Processing Details

Adjustments to the conductivity "advance" time (default: 0.073 seconds) were examined by re-averaging data from the stored 24 Hz data at various time intervals, then evaluating salinity spiking and noise levels in sharp gradients and in deep water for multiple casts. An additional 0.08-second "advance" was applied to the primary conductivity sensor. The same 0.06-second "advance" was used for both secondary conductivity sensors, since the same temperature sensor and pump were used and no differences in salinity spiking were noted after replacing the sensor.

The new "advance" times were applied real-time starting station 53. Casts acquired before then were re-processed from the raw 24 Hz data into the 0.5-second time-series.

Primary T/C sensors were used for all reported CTD data because the same sensor pair was used through-out the cruise, and there were no remarkable problems with either sensor.

The following table identifies problems or comments noted during specific casts (NOTE: mwo = meters of wire out on winch):

Sta/Cast	Comment
start	full (electrical + mechanical) retermination of both wires. Markey DESH-5/fwd winch had 50-60m rusty wire removed prior to retermination. Using Markey DESH-6/aft winch for rosette casts.

Sta/Cast	Comment
1/1	Test cast (not reported): trip all bottles at 50m to test bottle integrity. Transmissometer caps not removed. Signal noise in bursts, downcast only.
1/2	Transmissometer caps not removed. Signal noise on downcast, again in bursts.
4/1	2kn current toward East: set ship 1 mile West of intended station posn.
5/1	cart/track issues at launch, 10-minute delay. Restarted cast 3x after "pylon not responding" messages continued. Rebooted acquisition system. Lost 30 minutes for delays.
7/1	Possibly before this cast: full electrical and mechanical retermination after wire got kinked. (Not logged, so exact station not known.) Transmissometer calibration check a few hours after cast.
8/1	MANY missed frames 20m before stop for 3933 dbar/trip 3; first occurrence deep or on an upcast.
12/1	Much signal noise before going in, following big fantail slam/shudder. 2 surface yo-yos to check it out; then only a few short bursts of noise below surface start.
13/1	Standard electrical retermination, and separate winch-to-lab-JBox cable run prior to cast, attempting to eliminate electrical noise. Too much signal noise to find good data. Cast aborted at 10m.
13/2	Delayed start due to electrical noise. Cast aborted at 10m.
13/3	Aborted cast: starts/ends at 10m, appears to continue where 13/2 left off,
13/4	prior to cast: experimental electrical retermination with two inner conductors for signal, and ground to unistrut inside lab. Random signal cutouts in short bursts during downcast; however, at 1410db down: pumps turned off and on repeatedly. Stopped winch near 1700m while winch-to-lab bypass cable installed again, test showed same problem. Cast aborted and brought back aboard. Found leaking dummy plug on aux4; this probably caused shorts that shut things down and turned the pumps off/on, a new problem.
13/5	Standard electrical retermination prior to cast. Now using CTD #914. Data noise appears to coincide with slower winch speeds, down and up. Despite lots of noise, continued with cast and cleaned up data later.
14/1	Wind 28-33 kn at launch. During launch, 1 tagline broke, 2 others kept control. Cast aborted near 600m due to excessive data noise.
14/2	Only cast with DESH-5 winch: clean signal, but winch speeds out of control: cast aborted near 750mwo.
14/3	DESH-6 from this point forward. Cast aborted at 50m: organic matter clogged sensor plumbing, brought back on-board and cleaned.
20/1	SBE43 Oxygen sensor S/N 43-1071 replaces S/N 43-0275 prior to cast. Sea cable re-aligned on rosette prior to cast to improve/eliminate bottles 13/15 lanyard hangups.
21/1	Winch display reset between 300-250m depth bottles; winch readings are 35m high for each bottle shallower than that.
22/1	Deep anomalies seen in CTDO data, 1760 dbars to bottom, particularly below 2100 dbars. Features appear to be real, including ~0.02 sigma 2 inversion area between 2160-2260 dbars. Station located just before ridge at west side of trench.
25/1	Rinko III Optical Oxygen sensor and temperature thermistor installed prior to cast. (Found the missing adapter cable to connect it up to the CTD.)
27/1	fluorometer very noisy on launch; transmissometer also, but not so much.
33/1	returned to deck at launch before rosette in-water due to closed bottle - forgot to re-cock after adjustment.
42/1	T/S differ down/up at surface.
43/1	T/S differ down/up near surface. Near seamount.
47/1	Mechanical retermination prior to cast (outer armor unwinding).
48/1	down/up T/S differences 300-450db.
49/1	Winch display out at 1858m down, winch did not stop. 50m offset in winch readings.
51/1	T/S differ down/up 100-350db.
53/1	transmissometer calibration check prior to cast.

Sta/Cast	Comment
54/1	+0.045 sigma theta at surface, both sensor pairs, downcast only; top 6 dbars coded questionable.
56/1	spare carousel S/N 0187 installed prior to cast.
57/1	Surface water warmer/saltier than water underneath, down and up (deeper on up).
58/1	No bottles tripped, despite confirmations by acquisition software. Very salty water 65-90m.
59/1	carousel replaced with original S/N 0113 prior to cast.
60/1	very high T/S gradient at bottle 36 trip (1 below surface).
63/1	cast aborted due to C1/C2 difference, unresolved by taking rosette down/up 20m after soak at 10m.
63/2	cleaned out pump tubes before cast 2; cast aborted - same problem as cast 1. C2 sensor S/N 04-2112 removed after cast. No obvious problem noted by ET during close inspection.
63/3	New C2 sensor S/N 04-3058 installed prior to cast.
66/1	30-45 minute delay for carousel maintenance.
84/1	Significant down/up T/S/O differences, 750-200m. Sudden rain squall a few minutes before surface on upcast.
87/1	transmissometer calibration check the morning after this last cast.

1.8. CTD Sensor Laboratory Calibrations

Laboratory calibrations of the CTD pressure, temperature, conductivity and dissolved oxygen sensors were performed prior to CLIVAR/Carbon P02W. The sensors and calibration dates are listed in Table 1.3.0. Copies of the calibration sheets for Pressure, Temperature, Conductivity, and Dissolved Oxygen sensors, as well as factory and deck calibrations for the TAMU Transmissometer, are in Appendix D.

1.9. CTD Shipboard Calibration Procedures

Two different SBE9*plus* CTDs were used for rosette/CTD/LADCP casts during CLIVAR/Carbon P02W: S/N 796 at stas 1/1-13/4, and S/N 914 at stas 13/5-87/1. The CTDs were deployed with all sensors and pumps aligned vertically, as recommended by SBE.

The SBE35RT Digital Reversing Thermometer (S/N 3528706-0035) served as an independent calibration check for T1 and T2 sensors. *In situ* salinity and dissolved O_2 check samples collected during each cast were used to calibrate the conductivity and dissolved O_2 sensors.

1.9.1. CTD Pressure

The Paroscientific Digiquartz pressure transducers (S/N 796-98627 and S/N 914-110547) were calibrated in December and June 2012 (respectively) at the SIO/STS Calibration Facility. The calibration coefficients provided on the reports were used to convert frequencies to pressure. The SIO/STS pressure calibration coefficients already incorporate the slope and offset term usually provided by Paroscientific.

The initial deck readings for pressure indicated a pressure offset was needed, typically because CTDs are calibrated horizontally but deployed vertically. An additional -0.7 decibar offset was applied during data acquisition/block-averaging for stations 1-39. A review after station 39 showed that -0.9 decibars was a better choice for the second CTD. Stations 13/5-39 were re-averaged with the larger offset, and the new offset was used during acquisition for the remaining stations on Leg 1/P02W.

Residual pressure offsets (the difference between the first and last submerged pressures, after the offset corrections) varied from -0.3 to +0.2 decibars. Pre- and post-cast on-deck/out-of-water pressure offsets varied from -0.2 to +0.2 decibars before the casts, and -0.3 to +0.4 decibars after the casts. The in/out pressures within a cast were very consistent.

1.9.2. CTD Temperature

The same SBE3*plus* primary temperature sensor (T1: 03P-4138) and secondary temperature sensor (T2: 03P-4226) were used during P02W. Calibration coefficients derived from the pre-cruise calibrations, plus shipboard temperature corrections determined during the cruise, were applied to raw primary and secondary sensor data during each cast.

A single SBE35RT (3528706-0035) was used as a tertiary temperature check. It was located equidistant between T1 and T2 with the sensing element aligned in a plane with the T1 and T2 sensing elements. The SBE35RT Digital Reversing Thermometer is an internally-recording temperature sensor that operates independently of the CTD. It is triggered by the SBE32 carousel in response to a bottle closure. The SBE35RT on P02W was set to internally average over 4 sampling cycles (a total of 4.4 seconds).

According to the manufacturer's specifications, the typical stability for an SBE35RT sensor is 0.001°C/year. A post-cruise calibration for this sensor (18-Jun-2013) showed essentially no change (at most 0.0001°C) over the 6 months since the pre-cruise calibration.

Two independent metrics of calibration accuracy were examined. At each bottle closure, the primary and secondary temperature were compared with each other and with the SBE35RT temperature. CTD temperature calibrations for P02W were re-evaluated during Leg 2/P02E, with the added benefit of seeing data from more stations.

Both temperature sensors were examined for drift with time, using the more stable SBE35RT at a smaller range of deeper trip levels (4000-5000 decibars). Even in this small pressure range, the time drift was impacted by the pressure effect on the sensors. In order to better align deeper and shallower data, a second-order pressure correction was first applied to each temperature sensor, using all bottles where the T1-T2 difference was less than ±0.005 (to omit high-gradient bottles that might skew the results),

Neither of the sensors exhibited a temperature-dependent slope. But both T1 and T2 had a residual time dependence (offset drift) that flattened out after the first half of Leg 1. T2 differences shifted slightly around day 35, after the C2 sensor was replaced.

All casts together were used for the T1 drift corrections, but stations 1-62 and 63-159 were fit separately for the T2 drift. Data deeper than 1800 decibars were used to determine second-order corrections to pull deeper T2 differences in line with shallower differences.

A final check of corrected data showed that T2 was still slightly off for the first few casts following the C2 sensor change-out. Assuming that the sensor was jostled slightly, an additional +0.0003°C offset was applied to T2 temperature data for stations 63-68 only.

Pressure-dependent corrections were then re-checked, and no further adjustments were warranted.

The final corrections for T1 temperature data reported on P02W are summarized in Appendix A. Corrections made to both temperature sensors had the form:

$$T_{ITS90} = T + tp2 * P^2 + tp1 * P + t0$$

Residual temperature differences after correction are shown in figures 1.9.2.0 through 1.9.2.8.

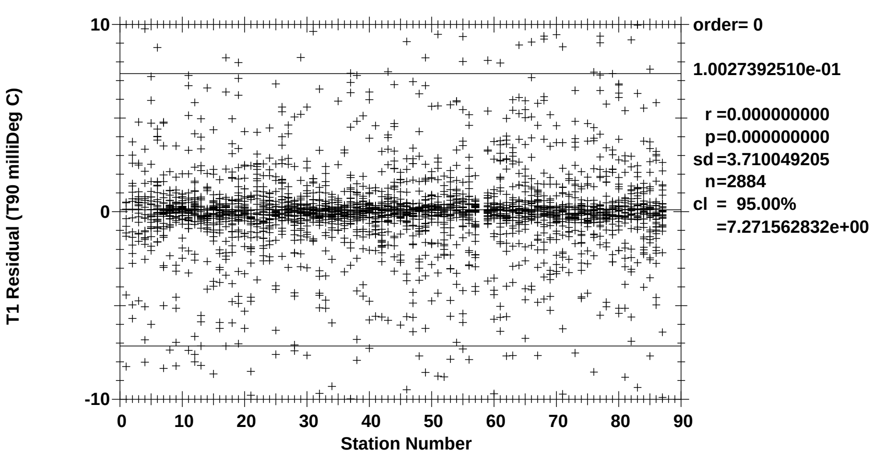


Figure 1.9.2.0 SBE35RT-T1 by station (-0.01°C ≤ T1 – T2 ≤ 0.01°C).

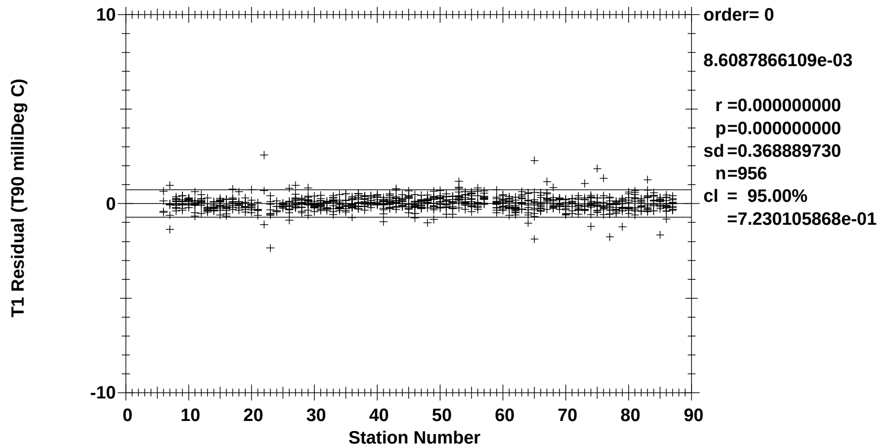


Figure 1.9.2.1 Deep SBE35RT-T1 by station (Pressure >= 1800 dbars).

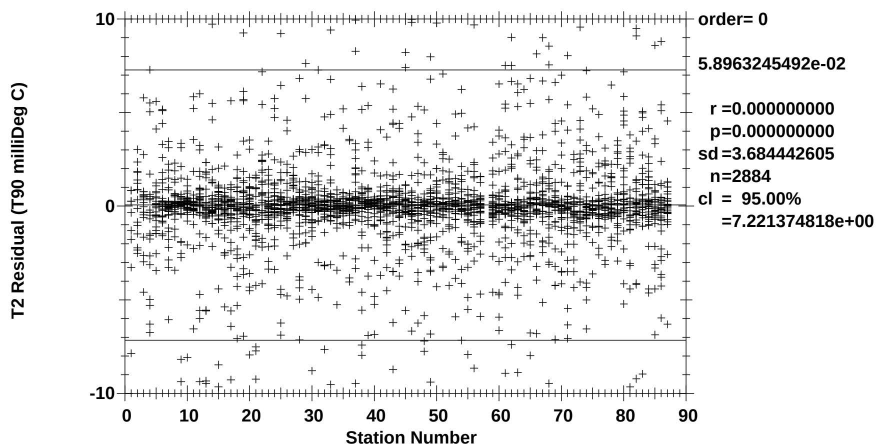


Figure 1.9.2.2 SBE35RT-T2 by station (-0.01°C ≤T1 – T2≤0.01°C).

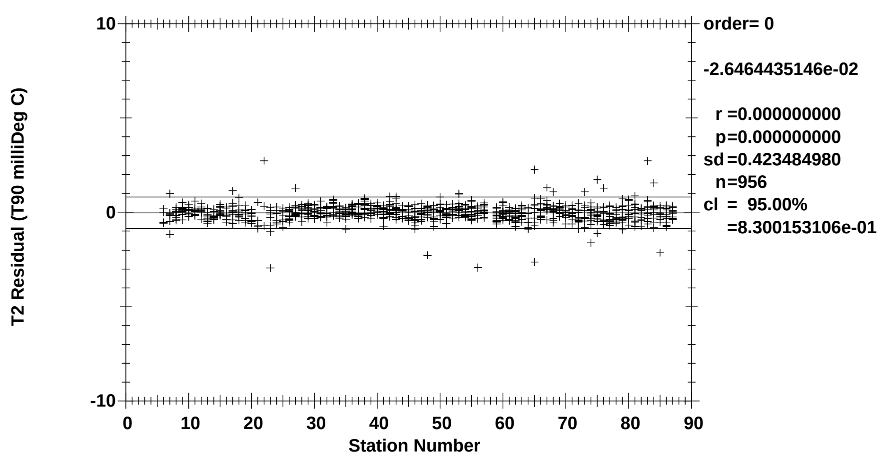


Figure 1.9.2.3 Deep SBE35RT-T2 by station (Pressure >= 1800 dbars).

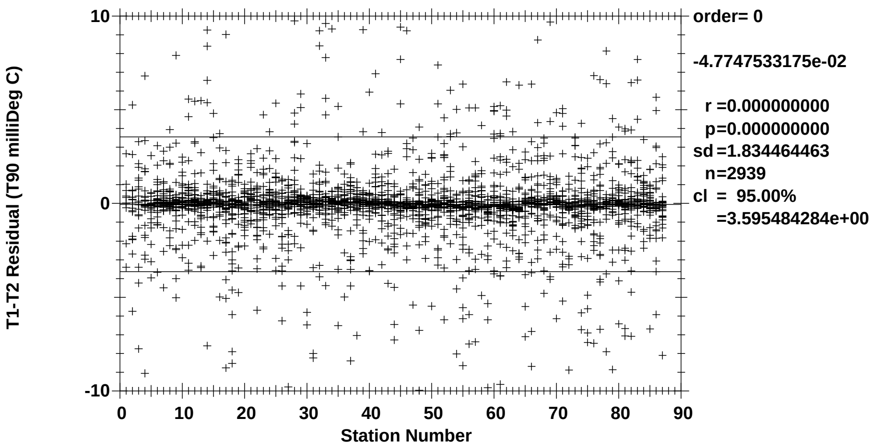


Figure 1.9.2.4 T1-T2 by station (-0.01°C ≤T1 – T2≤0.01°C).

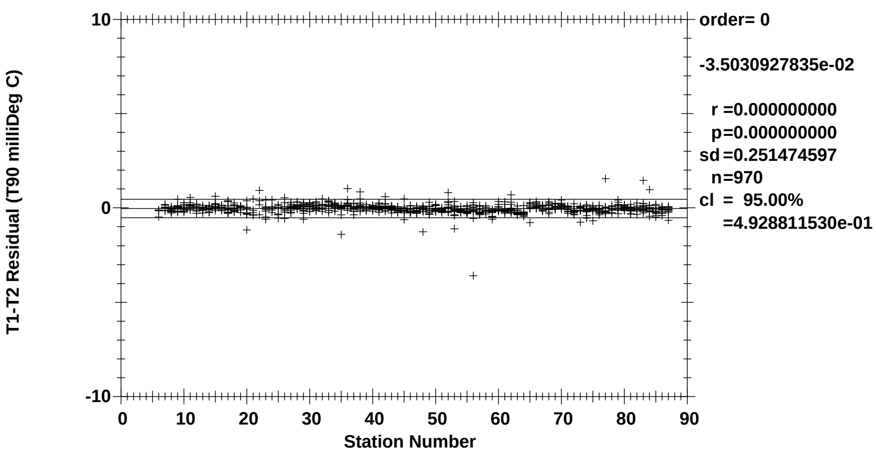


Figure 1.9.2.5 Deep T1-T2 by station (Pressure >= 1800 dbars).

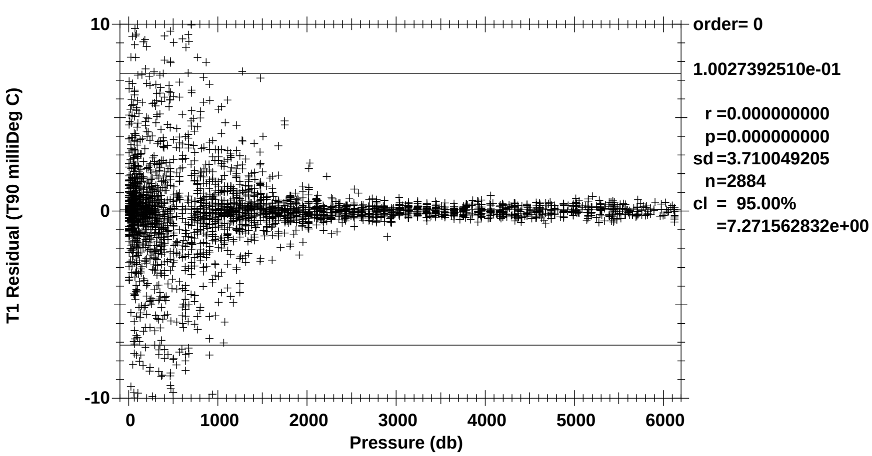


Figure 1.9.2.6 SBE35RT-T1 by pressure (-0.01°C ≤T1 – T2≤0.01°C).

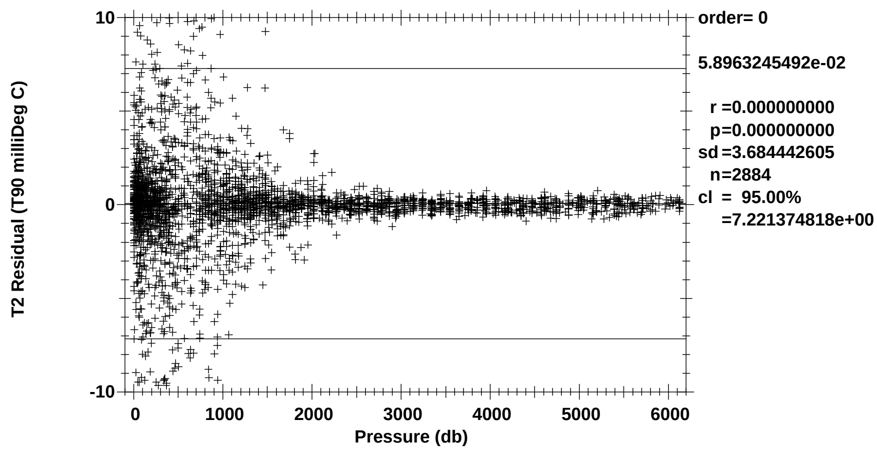


Figure 1.9.2.7 SBE35RT-T2 by pressure (-0.01°C ≤T1 – T2≤0.01°C).

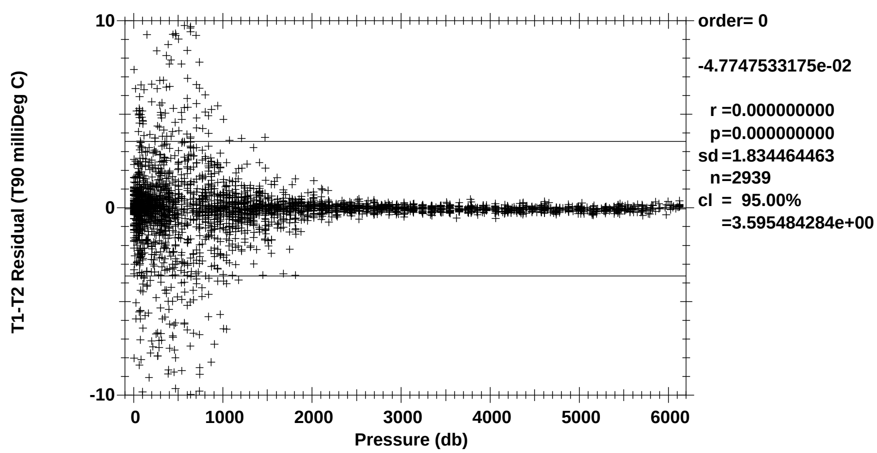


Figure 1.9.2.8 T1-T2 by pressure (-0.01°C ≤T1 – T2≤0.01°C).

The 95% confidence limits for the mean low-gradient differences are ±0.00727°C for SBE35RT – T1 and ±0.00360°C for T1 – T2. The 95% confidence limit for deep temperature residuals (where pressure > 1800 dbars) is ±0.00072°C for SBE35RT – T1 and ±0.00049°C for T1 – T2.

1.9.3. CTD Conductivity

A single SBE4C primary conductivity sensor (C1/04-2569) and two SBE4C secondary conductivity sensors (C2a/04-2112 at stations 1-62, and C2b/04-3058 at stations 63/3-87) were used during P02W. Conductivity sensor C2a was removed after 2 attempts to start station 63 because it would not stabilize at the surface soak, and cleaning the pump circuit out did not fix the problem. Primary TC sensor data were used to report final CTD data because the same sensor pair was used during the entire leg.

Calibration coefficients derived from the pre-cruise calibrations were applied to convert raw frequencies to conductivity. Shipboard conductivity corrections, determined during the cruise, were applied to primary and secondary conductivity data for each cast. Conductivity corrections for Leg 1/P02W were re-evaluated at the end of Leg 2/P02E, and included stations from both legs in order to determine better corrections.

Corrections for both CTD temperature sensors were finalized before analyzing conductivity differences. Two independent metrics of calibration accuracy were examined. At each bottle closure, the primary and secondary conductivity were compared with each other. Each sensor was also compared to conductivity calculated from check sample salinities using CTD pressure and temperature.

There was some shifting back-and-forth of bottle-CTD differences throughout the cruise. An investigation indicated it was typically the result of bottle salinity differences of 0.001-0.002 from run-to-run. No cause or resolution was ever determined. Theta-Salinity comparisons showed that cast-to-cast deep CTD data were well-aligned before applying any offsets. Differences from all stations were included in the fits for conductivity corrections, despite the rapid decline of C2a starting with stations in the late 50s until that sensor was removed.

The differences between primary and secondary temperature sensors were used as filtering criteria for all conductivity fits to reduce the contamination of conductivity comparisons by package wake. The coherence of this relationship is shown in figure 1.9.3.0.

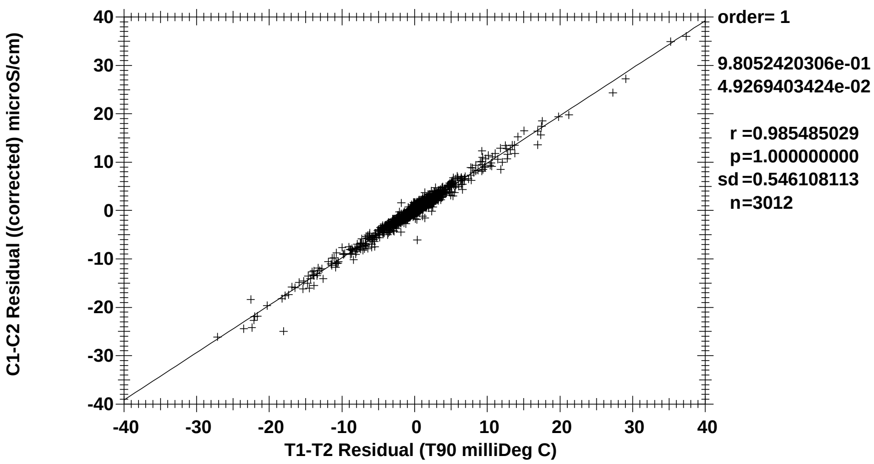


Figure 1.9.3.0 Coherence of conductivity differences as a function of temperature differences.

Uncorrected conductivity comparisons are shown in figures 1.9.3.1 through 1.9.3.3.

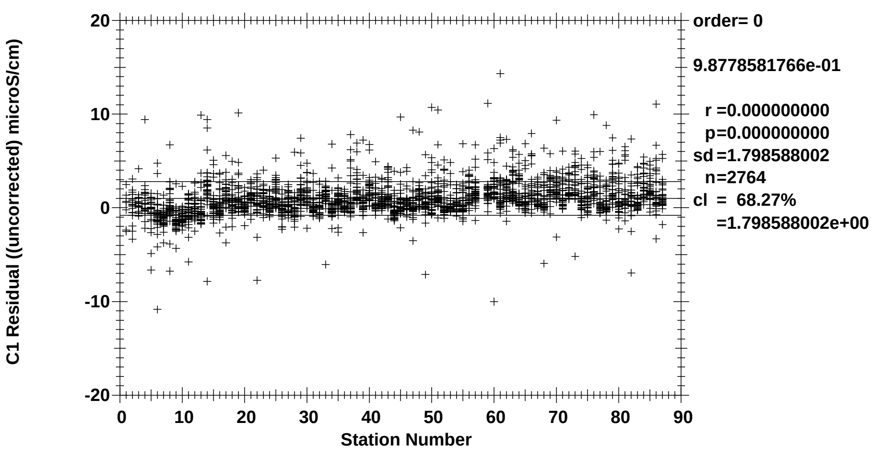


Figure 1.9.3.1 Uncorrected $C_{Bottle} - C1$ by station ($-0.01°C \leq T1 - T2 \leq 0.01°C$).

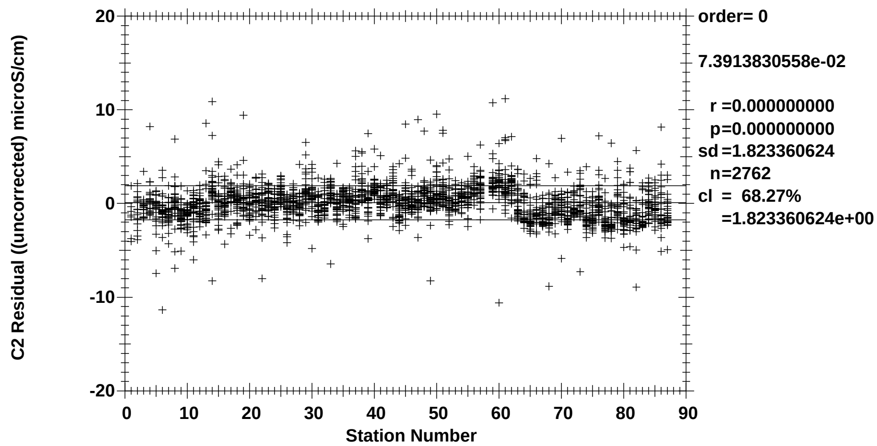


Figure 1.9.3.2 Uncorrected $C_{Bottle} - C2$ by station (-0.01°C ≤T1 – T2≤0.01°C).

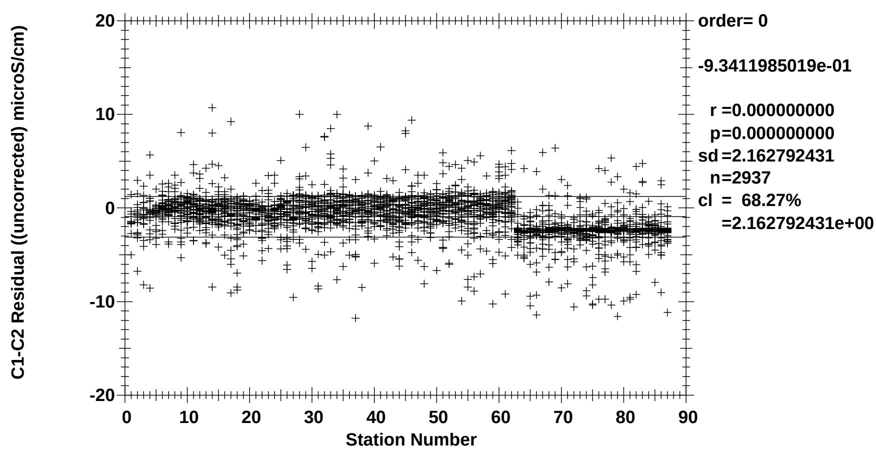


Figure 1.9.3.3 Uncorrected C1 – C2 by station (-0.01°C ≤T1 – T2≤0.01°C).

Offsets for each C sensor were evaluated for drift with time using $C_{Bottle} - C_{CTD}$ differences from a smaller range of deeper pressures (2800-4800 decibars), in order to exclude most of the pressure effect on the sensors. A second-order fit of differences vs time was determined for each sensor, accounting for a slower rate of change partway through Leg 1. Sensor C2a was drifting faster just before it was changed out, so stations 56-62 were excluded from those drift calculations. The offset drift calculated for C2a/stations 1-55 was applied to all C2a stations.

$C_{Bottle} - C_{CTD}$ differences were then evaluated for response to pressure and/or conductivity, which typically shifts between pre- and post-cruise SBE laboratory calibrations. A comparison of the residual differences indicated that a parabolic conductivity-dependent correction was required for each sensor. Small adjustments to the time-dependent corrections for C1 and C2a were re-calculated using stations 1-159 and 1-62, respectively.

After applying time- and conductivity-dependent corrections, the pressure-dependent coefficients for conductivity were calculated. The correction was linear for C1, and parabolic for each C2 sensor, in order to pull in the differences from very deep data (below 5800 decibars) on P02W casts.

Sensor C2a, which completely failed at the start of station 63, was apparently misbehaving for most of its use (in hindsight). This was very evident when checking a plot of residual S1-S2 vs Pressure: differences slid to a +0.001 max around 400 decibars, then dropped to -0.001 around 700 decibars. The deeper residual differences had a mild parabolic shape. The C2a pressure-dependent correction was recalculated, using only bottle data below 800 decibars. Then the C2a conductivity coefficients were recalculated using all bottle data; this substantially reduced the "wave" in the S1-S2 differences below

1000 decibars. Fortunately, these C2a data were only used as a secondary calibration check for the primary conductivity sensor, and were not used for any reported data.

A few small offset adjustments, based on Theta-Salinity comparisons with adjacent casts, were applied as follows:

+0.0002 mS/cm to C1/stations 43, 57-58
+0.0003 mS/cm to C2a/stations 54-62
+0.0002 mS/cm to C2b/station 63

After adjustments, deep Theta-Salinity profiles of adjacent casts agreed well for both sensor pairs.

The residual conductivity differences after correction are shown in figures 1.9.3.4 through 1.9.3.15.

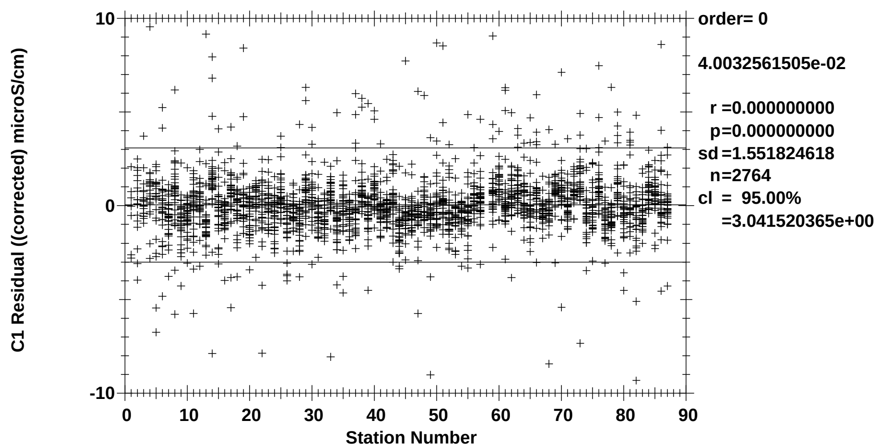


Figure 1.9.3.4 Corrected $C_{Bottle} - C1$ by station ($-0.01°C \leq T1 - T2 \leq 0.01°C$).

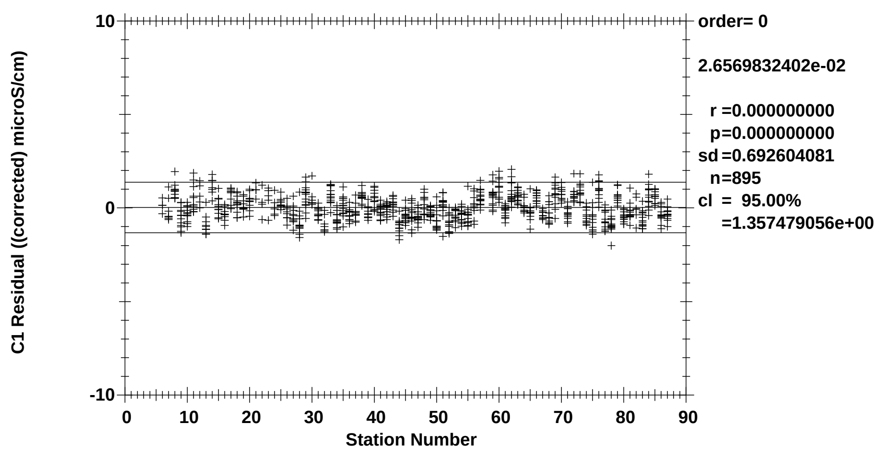


Figure 1.9.3.5 Deep Corrected $C_{Bottle} - C1$ by station (Pressure >= 1800 dbars).

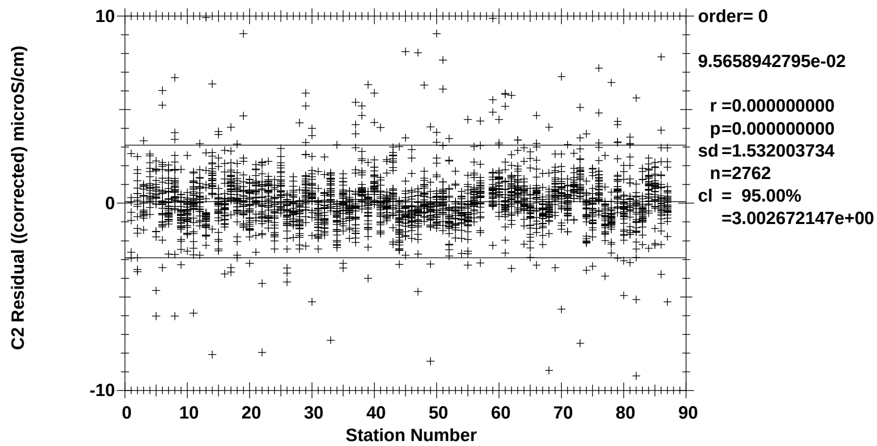


Figure 1.9.3.6 Corrected C_{Bottle} – C2 by station (-0.01°C ≤T1 – T2≤0.01°C).

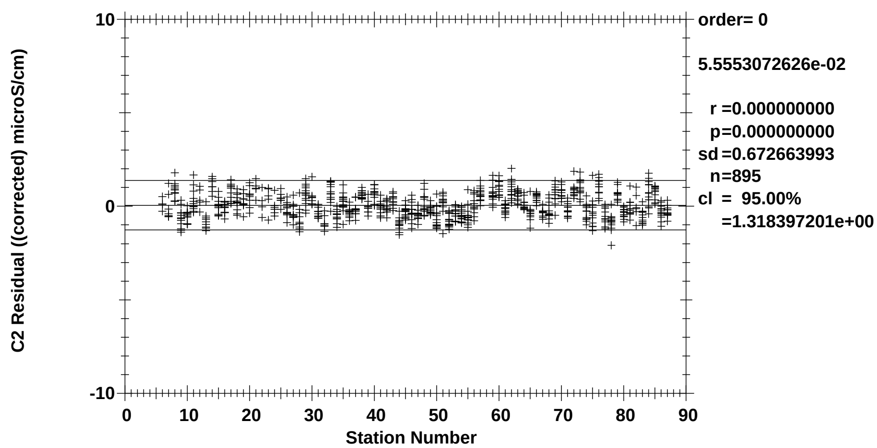


Figure 1.9.3.7 Deep Corrected C_{Bottle} – C2 by station (Pressure >= 1800 dbars).

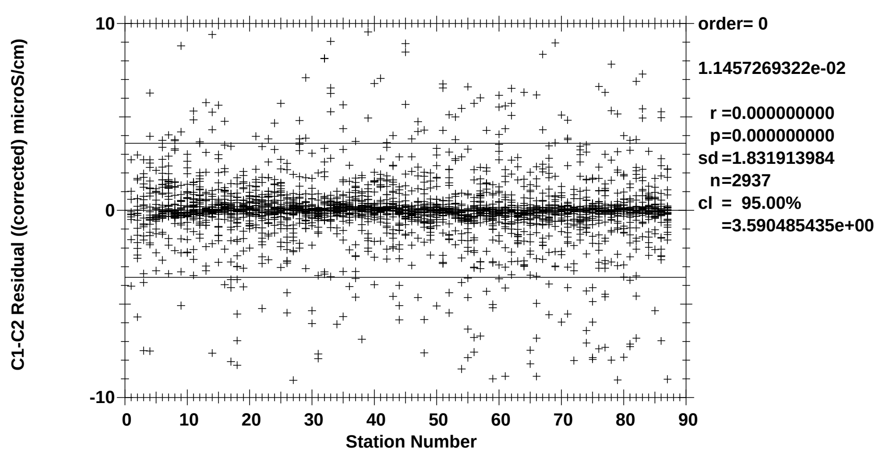


Figure 1.9.3.8 Corrected C1 – C2 by station (-0.01°C ≤T1 – T2≤0.01°C).

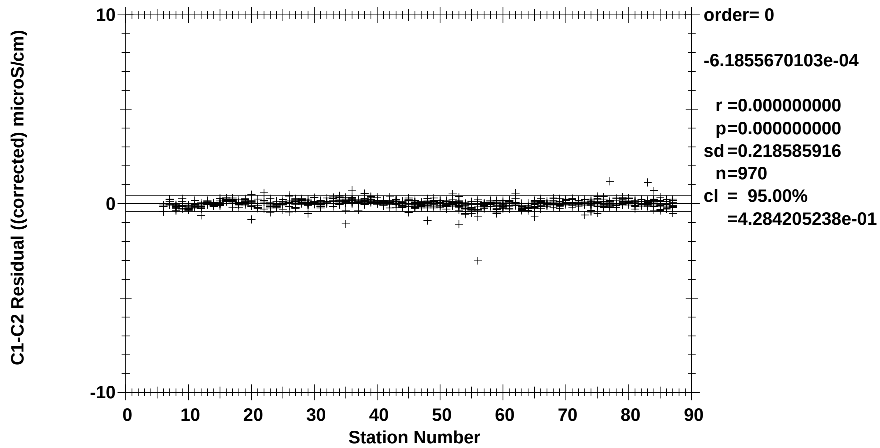


Figure 1.9.3.9 Deep Corrected C1 – C2 by station (Pressure >= 1800 dbars).

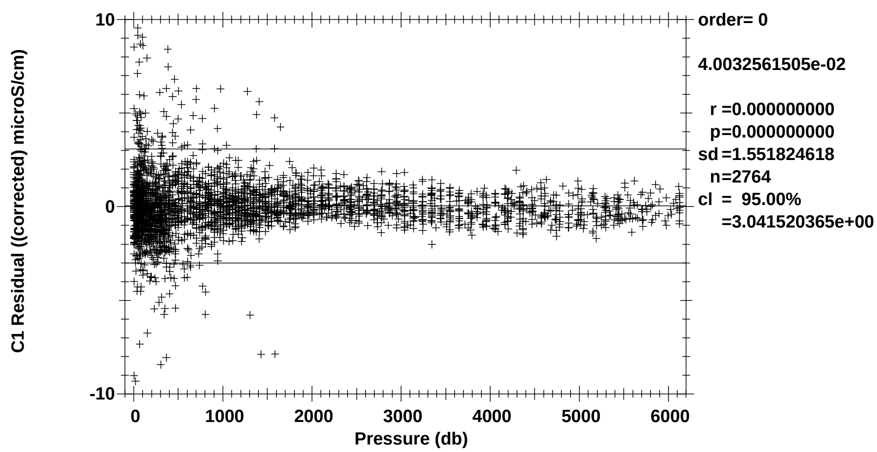


Figure 1.9.3.10 Corrected C_{Bottle} – C1 by pressure (-0.01°C ≤T1 – T2≤0.01°C).

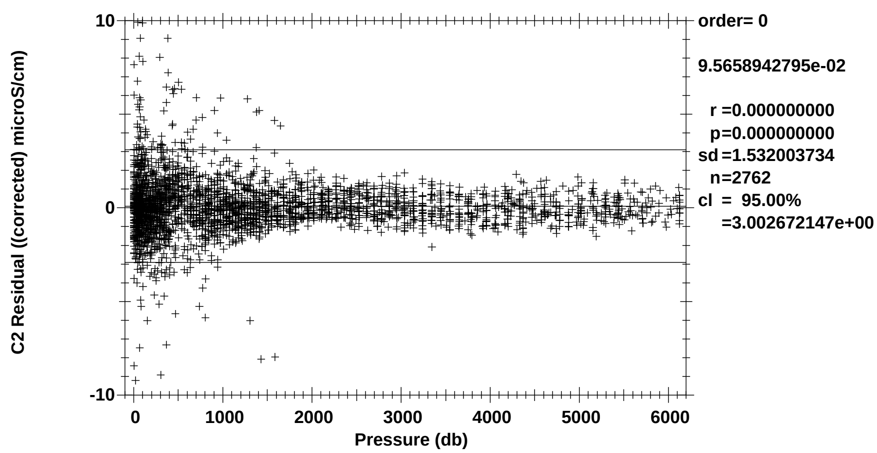


Figure 1.9.3.11 Corrected C_{Bottle} – C2 by pressure (-0.01°C ≤T1 – T2≤0.01°C).

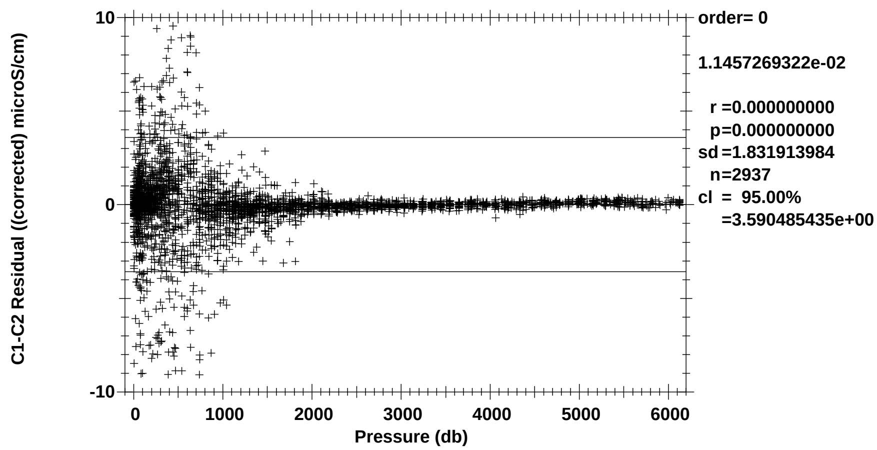


Figure 1.9.3.12 Corrected C1 – C2 by pressure (-0.01°C ≤T1 – T2≤0.01°C).

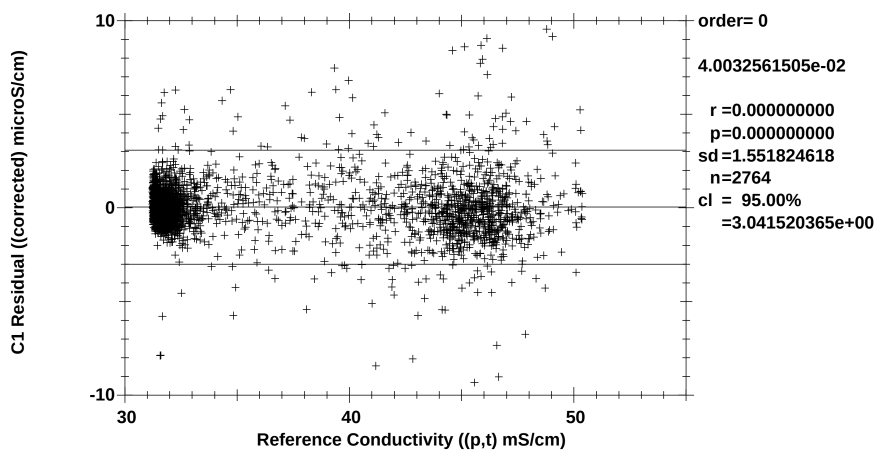


Figure 1.9.3.13 Corrected C_{Bottle} – C1 by conductivity (-0.01°C ≤T1 – T2≤0.01°C).

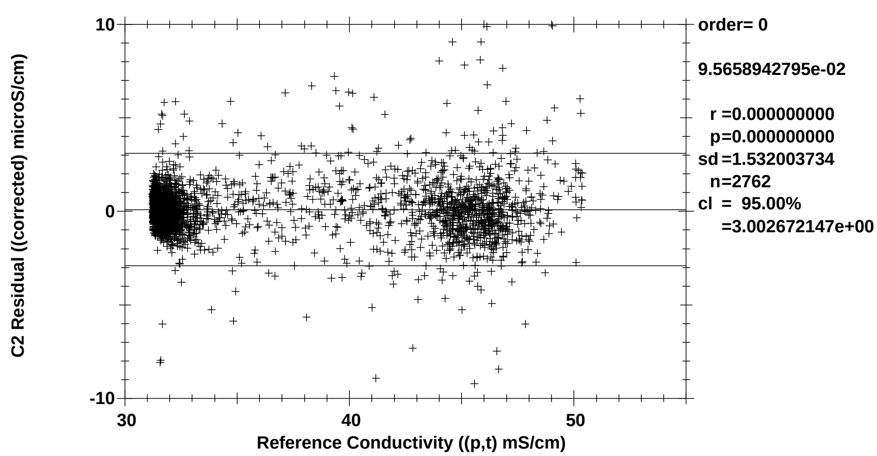


Figure 1.9.3.14 Corrected C_{Bottle} – C2 by conductivity (-0.01°C ≤T1 – T2≤0.01°C).

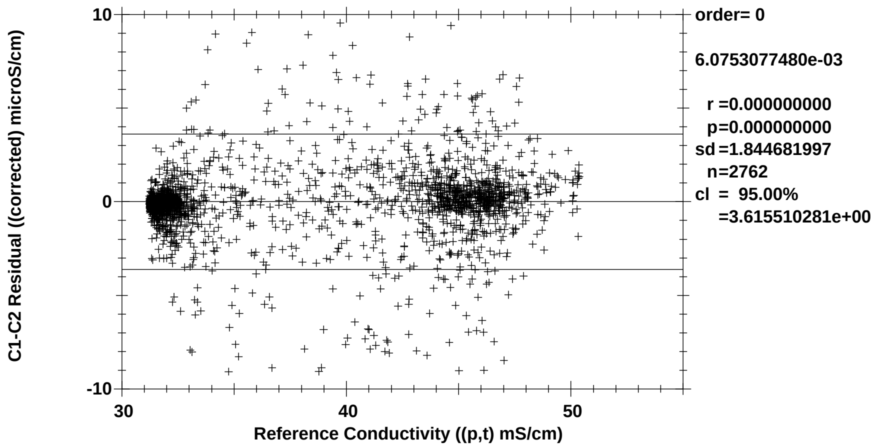


Figure 1.9.3.15 Corrected C1 – C2 by conductivity (-0.01°C ≤T1 – T2≤0.01°C).

The final corrections for the sensors used on P02W are summarized in Appendix A. Corrections made to the primary conductivity sensor had the form:

$$C_{cor} = C + cp1 * P + c2 * C^2 + c1 * C + c0$$

Corrections made to the secondary conductivity sensors had the form:

$$C_{cor} = C + cp2 * P^2 + cp1 * P + c2 * C^2 + c1 * C + c0$$

Salinity residuals after applying shipboard P/T/C corrections are summarized in figures 1.9.3.16 through 1.9.3.18. Only CTD and bottle salinity data with "acceptable" quality codes are included in the differences.

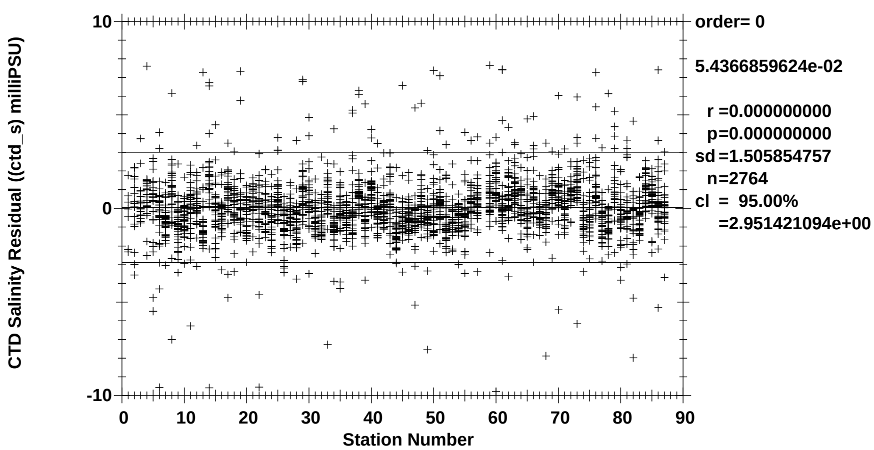


Figure 1.9.3.16 Salinity residuals by station (-0.01°C ≤T1 – T2≤0.01°C).

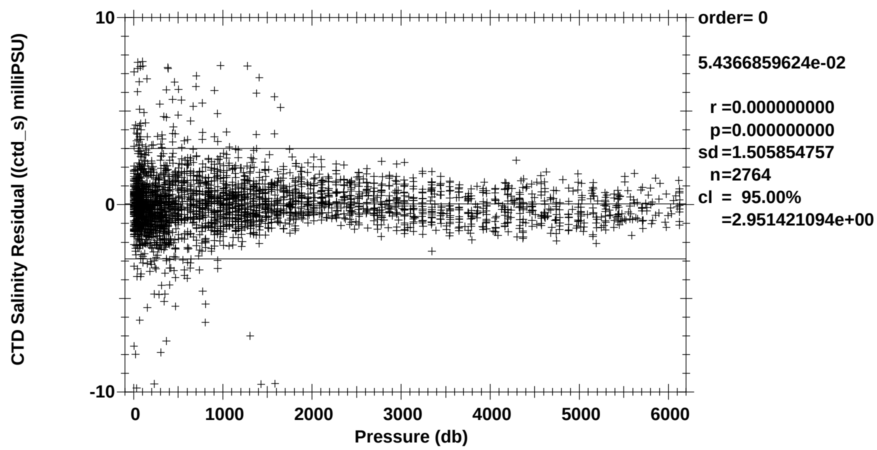


Figure 1.9.3.17 Salinity residuals by pressure (-0.01°C ≤T1 – T2≤0.01°C).

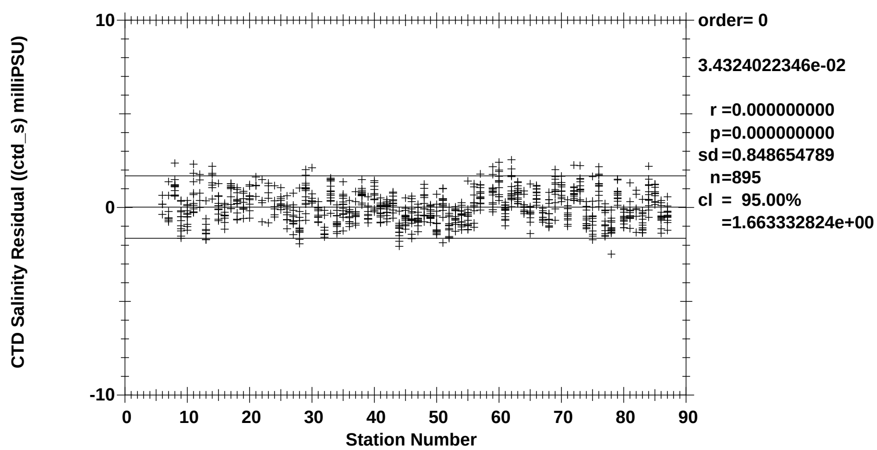


Figure 1.9.3.18 Deep Salinity residuals by station (Pressure >= 1800 dbars).

Figures 1.9.3.17 and 1.9.3.18 represent estimates of the salinity accuracy of P02W. The 95% confidence limits are ±0.00295 relative to bottle salinities for all salinities, where T1-T2 is within ±0.01°C; and ±0.00166 relative to bottle salinities for deep salinities, where pressure is more than 1800 decibars.

Post-Cruise Conductivity Calibrations

Post-cruise calibrations for all 3 conductivity sensors were done and available before finishing this last revision of the data report.

Sensor C1 appears to have had a large change: more than 0.007 mS/cm at 60 mS/cm. The maximum conductivity measured during Leg 1/P02W was 50.5 mS/cm, and only 45 mS/cm by the end of Leg 2/P02E. The post-cruise shift in the conductivity residual (SBE4C-Standard on SBE Lab.Cal. plots) was approximately +0.0045/+0.003 (C1/C2b) at 50 mS/cm, and +0.003/+0.0015 (C1/C2b) at 45 mS/cm. This is consistent with what was seen in uncorrected near-surface conductivities at the end of leg 2.

The fact that sensor C2a did not require any repairs and had barely changed from its pre-cruise calibration was surprising. This did not reflect what was observed during P02W, where there appeared to be a weird pressure effect on this sensor. Pressure effects on SBE4C sensors have never been evaluated in a laboratory, so far as we know. All calibrations are done at atmospheric pressure, plus the pressure caused by a meter or so of water. It is a moot point for P02W, since sensor C2a was never used for any reported data on this leg.

1.9.4. CTD Dissolved Oxygen

Two different SBE43 dissolved O_2 sensors, DO/43-0275 and DO/43-1071, were used during P02W. Sensor 43-0275 was used from station 1 through station 19. This sensor was replaced by 43-1071 for the remainder of the P02W stations due to increasing noise observed, especially at higher pressures. The SBE43 dissolved O_2 sensor was plumbed into the primary T1/C1 pump circuit after C1.

Each SBE43 DO sensor was calibrated to dissolved O_2 bottle samples taken at bottle stops by matching the down cast CTD data to the up cast trip locations on isopycnal surfaces, then calculating CTD dissolved O_2 using a DO sensor response model and minimizing the residual differences from the bottle samples. A non-linear least-squares fitting procedure was used to minimize the residuals and to determine sensor model coefficients, and was accomplished in three stages.

The time constants for the lagged terms in the model were first determined for the sensor. These time constants are sensor-specific but applicable to an entire cruise. Next, casts were fit individually to bottle sample data. Bottle oxygens from nearby casts with similar deep TS structure were used to help fit CTD O_2 data for casts with one or more mis-tripped bottles, and for station 58, where no bottles tripped at all. Finally, consecutive casts were compared on plots of Theta vs O_2 to verify consistency over the course of P02W.

At the end of the cruise, standard and blank values for bottle oxygen data were smoothed, and the bottle oxygen values were recalculated. The changes to bottle oxygen values were less than 0.01 ml/l for most stations. CTD O_2 data were re-calibrated to the smoothed bottle values after the leg.

Final CTD dissolved O_2 residuals are shown in figures 1.9.4.0-1.9.4.2.

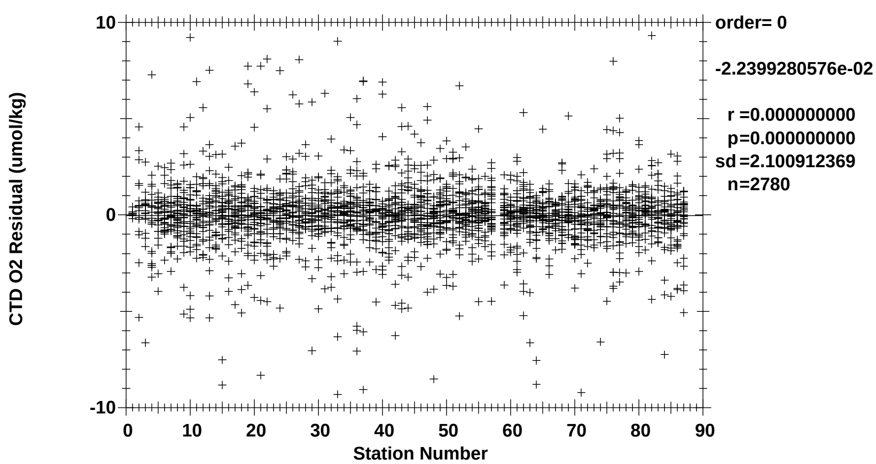


Figure 1.9.4.0 O_2 residuals by station (-0.01°C ≤T1 – T2≤0.01°C).

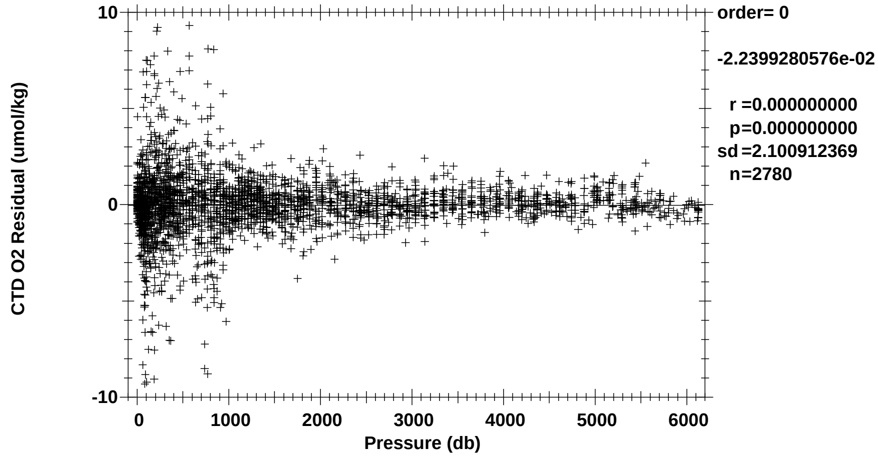


Figure 1.9.4.1 O_2 residuals by pressure (-0.01°C ≤T1 – T2≤0.01°C).

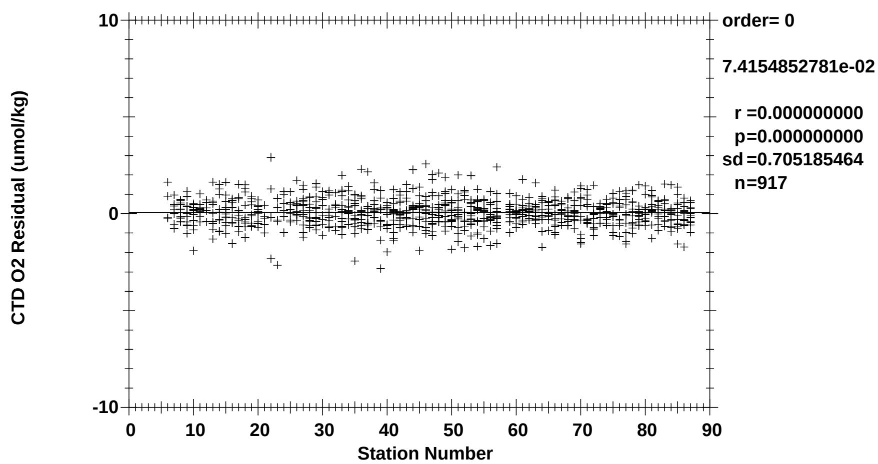


Figure 1.9.4.2 Deep O_2 residuals by station (Pressure >= 1800 dbars).

The standard deviations of 2.101 μmol/kg for all oxygens and 0.705 μmol/kg for deep oxygens are only presented as general indicators of goodness of fit. SIO/STS makes no claims regarding the precision or accuracy of CTD dissolved O_2 data.

The general form of the SIO/STS DO sensor response model equation for Clark-style cells follows Brown and Morrison [Brow78], Millard [Mill82] and Owens & Millard [Owen85]. SIO/STS models DO sensor responses with lagged CTD data. *In situ* pressure and temperature are filtered to match the sensor responses. Time constants for the pressure response (τ_p), a slow (τ_{Tf}) and fast (τ_{Ts}) thermal response, package velocity (τ_{dP}), thermal diffusion (τ_{dT}) and pressure hysteresis (τ_h) are fitting parameters. Once determined for a given sensor, these time constants typically remain constant for a cruise. The thermal diffusion term is derived by low-pass filtering the difference between the fast response (T_s) and slow response (T_l) temperatures. This term is intended to correct non-linearities in sensor response introduced by inappropriate analog thermal compensation. Package velocity is approximated by low-pass filtering 1st-order pressure differences, and is intended to correct flow-dependent response. Dissolved O_2 concentration is then calculated:

$$O_2 ml/l = [C_1 \cdot V_{DO} e^{(C_2 \cdot \frac{P_h}{5000})} + C_3] \cdot f_{sat}(T,P) \cdot e^{(C_4 \cdot T_l + C_5 \cdot T_s + C_7 \cdot P_l + C_6 \cdot \frac{dO_c}{dt} + C_8 \cdot \frac{dP}{dt} + C_9 \cdot dT)} \quad (1.9.4.0)$$

where:

$O_2 ml/l$	Dissolved O_2 concentration in ml/l;
V_{DO}	Raw sensor output;
C_1	Sensor slope
C_2	Hysteresis response coefficient
C_3	Sensor offset
$f_{sat}(T,P)$	O_2 saturation at T,P (ml/l);
T	*in situ* temperature (°C);
P	*in situ* pressure (decibars);
P_h	Low-pass filtered hysteresis pressure (decibars);
T_l	Long-response low-pass filtered temperature (°C);
T_s	Short-response low-pass filtered temperature (°C);
P_l	Low-pass filtered pressure (decibars);
$\frac{dO_c}{dt}$	Sensor current gradient (μamps/sec);
$\frac{dP}{dt}$	Filtered package velocity (db/sec);
dT	low-pass filtered thermal diffusion estimate (T_s - T_l).
$C_4 - C_9$	Response coefficients.

CTD O_2 ml/l data are converted to μmol/kg units on demand.

Manufacturer information on the SBE43 DO sensor, a modification of the Clark polarographic membrane technology, can be found at *http://www.seabird.com/application_notes/AN64.htm*.

A faster-response JFE Advantech Rinko III ARO-CAV Optical DO sensor, with its own oxygen temperature thermistor, was installed on the rosette and integrated with the SIO/STS CTD from station 25 onward. ODF intends to evaluate it side-by-side with the SBE43 data, considering its possible use for future expeditions. Please contact ODF (odfdata@sts.ucsd.edu) for further information. Manufacturer information about the Rinko III sensor can be found at:
http://www.jfe-advantech.co.jp/eng/ocean/rinko/rinko3.html.

1.10. Bottle Sampling

At the end of each rosette deployment water samples were drawn from the bottles in the following order:

- CFC-12, CFC-11, CFC-113 and SF_6
- ^{3}He
- Dissolved O_2
- Dissolved Inorganic Carbon (DIC)
- pH
- Total Alkalinity
- ^{13}C and ^{14}C
- Dissolved Organic Carbon (DOC) and Total Dissolved Nitrogen (TDN)
- Tritium
- Nutrients
- $\delta^{15}N\text{-}NO_3$ / $\delta^{18}O\text{-}NO_3$
- Salinity
- ^{137}Cs / ^{134}Cs / ^{90}Sr
- ^{129}I
- Millero Density
- Dissolved Calcium

Bottle serial numbers were assigned at the start of the leg, and typically corresponded to their rosette/carousel position. Aside from various repairs to bottles along the way, two bottles were replaced during this leg:

Carousel position	Original Bottle S/N	Replacement Bottle S/N	Before Station	Reason for Change
5	05	37	15	Damage on bottle near O-ring seat.
22	22	38	40	Vent could not be reliably tightened.

Table 1.10.0 P02W Summary of Replaced Bottles

The correspondence between individual sample containers and the rosette bottle position (1-36) from which the sample was drawn was recorded on the sample log for the cast. This log also included any comments or anomalous conditions noted about the rosette and bottles. One member of the sampling team was designated the *sample cop*, whose sole responsibility was to maintain this log and ensure that sampling progressed in the proper drawing order.

Normal sampling practice included opening the drain valve and then the air vent on the bottle, indicating an air leak if water escaped. This observation, together with other diagnostic comments (e.g., "lanyard caught in lid", "valve left open") that might later prove useful in determining sample integrity, were routinely noted on the sample log. Drawing oxygen samples also involved taking the sample draw temperature from the bottle. The temperature was noted on the sample log and was sometimes useful in determining leaking or mis-tripped bottles.

Once individual samples had been drawn and properly prepared, they were distributed for analysis. Oxygen, nutrient and salinity analyses were performed on computer-assisted (PC) analytical equipment networked to the data processing computer for centralized data management.

1.11. Bottle Tripping Issues

Numerous bottle tripping and/or carousel issues occurred during P02W. Most mis-trips occurred shallower than the trigger depth, and were attributed to lanyards failing to fully slide off the latches, or snagging somewhere on the rosette during the release process. Most of these problems were resolved within a few casts by either re-aligning the center-point of some bottles on the rosette, to get a better lanyard angle when the carousel latch was released; or by re-aligning the lanyards during cocking to avoid obstructions or snagging points.

There were far more bottle tripping problems in the first 15 (deeper) bottles, raising the possibility that temperature or pressure were affecting the SBE32 carousel or the pliability of the lanyard material. Around station 40, some of the "tried and true" lanyard line (no longer made, but less "stiff" than the new line) was found and used to re-rig the release-connecting lanyard sections on all of the bottles. Only a few minor "tweaks" were required after that point to end the lanyard release / snagging issues.

All but two mis-tripped samples closed shallower in the water column than the trigger depth. Table 1.11.0 is a summary of bottle mis-trips (code 4) by carousel position.

Carousel Position	Number Carousel Mis-Trips	Number of Position	Carousel Mis-Trips	Number of Position	Mis-Trips
1	2	13	5	25	0
2	2	14	2	26	0
3	0	15	12	27	0
4	3	16	0	28	0
5	4	17	0	29	0
6	3	18	0	30	0
7	8	19	0	31	1
8	0	20	0	32	0
9	0	21	0	33	0
10	0	22	1	34	0
11	1	23	0	35	0
12	0	24	1	36	1

Table 1.11.0 P02W Summary of Mis-Trips

Occasionally, repeat "problem" bottles (leaking, mis-trips or latch trigger issues) were intentionally tripped at the same depth as another bottle in order to check for proper closure before tripping them at a unique depth on future casts. These planned "double" trip levels are documented in Table 1.11.1 below.

Carousel Position	Applies to Station(s)	Bottle Tripped at Same Depth
1	84	2
12	68,84	11
15	30-33,38-41	14 (16 for station 41 only)
35	68,72	36

Table 1.11.1 P02W Summary of Planned Same-Depth Bottle Trips.

A new problem reared its ugly head later in the leg: a few of the carousel latches failed to trigger because of building corrosion from water seepage into some of the individual magnetic releases (solenoids). The spare 36-place carousel was pulled out of the spare rosette and placed into the primary rosette between stations 55 and 56, a very labor-intensive task. The new carousel fired reliably for exactly two casts - and on the third cast, after 36 positive confirmations on the acquisition display, all 36 bottles came up open. In addition, the SBE35RT failed to store any samples, indicating the carousel never triggered it to take readings, either. It was determined that the carousel was spitting out gibberish for confirmations, was flooded, and was not repairable at sea.

The original carousel was patched up and put back into service, minus position 35. The leaks were temporarily plugged with Scotchkote, but three positions failed to fire reliably. These positions were sealed up, and their respective bottles were removed from the rosette and eliminated from the tripping scheme until/unless the leaks could be stopped.

Table 1.11.2 summarizes when carousel positions were re-ordered or completely pulled from the default tripping line-up during P02W.

Carousel Position	Stations Affected	Comment
1	78-83	Bottle removed from rosette (carousel position skipped)
12	69-83	Bottle removed from rosette (carousel position skipped)
35	59-81	Bottle intentionally tripped out-of-order (last/at surface)
35	82-87	Bottle removed from rosette (carousel position skipped)

Table 1.11.2 P02W Summary of Unusual Tripping Sequences.

Several backup plans were pursued ashore for the second leg of P02, but SBE32 36-place carousels are few and far between compared to the 24-place carousels. Eventually a spare 36-place carousel was found/borrowed from NOAA/PMEL and sent to the Hawaii port stop, to be used only if all else failed.

Individual mis-tripped bottles and samples taken from them have been quality-coded 4; more detailed comments appear in Appendix C.

1.12. Bottle Data Processing

Water samples collected and properties analyzed shipboard were centrally managed in a relational database (PostgreSQL 8.1.23) running on a Linux system. A web service (OpenACS 5.5.0 and AOLServer 4.5.1) front-end provided ship-wide access to CTD and water sample data. Web-based facilities included on-demand arbitrary property-property plots and vertical sections as well as data uploads and downloads.

The sample log information and any diagnostic comments were entered into the database once sampling was completed. Quality flags associated with sampled properties were set to indicate that the property had been sampled, and sample container identifications were noted where applicable (e.g., oxygen flask number). Acquisition and sampling details were also made available on the ODF shipboard website post-cast with scanned versions of the Console and Sample logs.

Analytical results were provided on a regular basis by the various analytical groups and incorporated into the database. These results included a quality code associated with each measured value and followed the coding scheme developed for the World Ocean Circulation Experiment Hydrographic Programme (WHP) [Joyc94].

Table 1.12.0 shows the number of samples drawn and the number of times each WHP sample quality flag was assigned for each basic hydrographic property:

Rosette Samples Stations 1- 87								
	Reported levels	WHP Quality Codes 1	2	3	4	5	7	9
Bottle	3021	0	2904	13	50	0	0	54
CTD Salt	3021	0	3021	0	0	0	0	0
CTD Oxy	3021	0	3021	0	0	0	0	0
Salinity	2930	0	2840	32	58	1	0	90
Oxygen	2915	0	2858	7	50	2	0	104
Silicate	2942	0	2889	0	53	1	0	78
Nitrate	2942	0	2890	0	52	1	0	78
Nitrite	2942	0	2890	0	52	1	0	78
Phosphate	2942	0	2887	2	53	1	0	78

Table 1.12.0 Frequency of WHP quality flag assignments.

Additionally, data investigation comments are presented in Appendix C.

Various consistency checks and detailed examination of the data continued throughout the cruise. Chief Scientist, Dr. James H. Swift, reviewed the data and compared it with historical data sets.

1.13. Salinity Analysis

Equipment and Techniques

One salinometer, a Guildline Autosal 8400B (S/N 69-180), was used throughout P02W. This salinometer utilized the typical National Instruments interface to decode Autosal data and communicate with a Windows-based acquisition PC. All discrete salinity analyses were done in the R/V Melville's Photo Lab.

Samples were analyzed after they had equilibrated to laboratory temperature, usually within 6-20 hours after collection. The salinometer was standardized for each group of analyses (typically 1 cast, sometimes 2; up to 72 samples) using two fresh vials of standard seawater per group.

Salinometer measurements were made by a computer using LabVIEW software developed by SIO/STS. The software maintained an Autosal log of each salinometer run which included salinometer settings and air and bath temperatures. The air temperature was monitored via digital thermometer and displayed on a 48-hour strip-chart via LabVIEW in order to observe cyclical changes. The program guided the operator through the standardization procedure and making sample measurements. The analyst was prompted to change samples and flush the cell between readings.

Standardization procedures included flushing the cell at least 2 times with a fresh vial of Standard Seawater (SSW), setting the flow rate to a low value during the last fill, and monitoring the STD dial setting. If the STD dial changed by 10 units or more since the last salinometer run (or during standardization), another vial of SSW was opened and the standardization procedure repeated to verify the setting.

Each salt sample bottle was agitated to minimize stratification before reading on the salinometer. Samples were run using 2 flushes before the final fill. The computer determined the stability of a measurement and prompted for additional readings if there appeared to be drift. The operator could annotate the salinometer log, and would routinely add comments about cracked sample bottles, loose thimbles, salt crystals or anything unusual in the amount of sample in the bottle.

After warming to near bath temperature, the next or current case to be run sat to the left of the Autosal, next to the standard seawater. The amount of time each case spent at each location varied depending on sample temperature and rate of analysis by the operator.

Sample Collection, Equilibration and Data Processing

A total of 2930 rosette salinity samples were measured. An additional 14 samples were run for calibrating the underway TSG system. 162 vials of standard seawater (IAPSO SSW) were used.

Salinity samples were drawn into 200 ml Kimax high-alumina borosilicate bottles, which were rinsed three times with the sample prior to filling. The bottles were sealed with custom-made plastic insert thimbles and kept closed with Nalgene screw caps. This assembly provides very low container dissolution and sample evaporation. Prior to sample collection, inserts were inspected for proper fit and loose inserts replaced to ensure an airtight seal.

After samples were brought back to the analysis lab, the full case was placed on a wooden frame and sealed around all edges to the workbench top. Salt bottle storage boxes have either an open grid pattern material or have holes drilled between bottle locations to facilitate air circulation between the bottles from bottom to top. A fan circulated warm air drawn from behind the Autosal to the underside of the salt case.

A thermometer was placed between two bottles that represent cooler but not the coldest temperatures, typically bottles 9 and 15 for the square cases and alongside bottle 3, on the inner side, for the rectangular cases. Warm air circulated through the case until indicated glass temperature was within 1°C of bath temperature. The case was removed from the warming frame and allowed to stand for 10 to 30 minutes before analyzing the salts.

Equilibration times were logged for all casts. Laboratory temperatures were logged at the beginning and end of each run.

PSS-78 salinity [UNES81] was calculated for each sample from the measured conductivity ratios. The difference between the initial vial of standard water and the next one run as an unknown was applied as a linear function of elapsed run time to the measured ratios. The corrected salinity data were then incorporated into the cruise database.

Data processing included double checking that the station, sample and box number had been correctly assigned, and reviewing the data and log files for operator comments. Discrete salinity data were compared to CTD salinities and were used for shipboard sensor calibration.

Laboratory Temperature

The salinometer water bath temperature was maintained at 24°C . The ambient laboratory air temperature varied from 20 to 25.5°C during the sample analyses , typically between 21 and 24°C.

Standards

IAPSO Standard Seawater Batch P-153 was used to standardize all stations.

Analytical Problems

No analytical problems were encountered on CLIVAR/Carbon P02W.

Results

After the first two runs of this leg, where the standard dial was higher, the setting rarely changed and only by small amounts. Aside from the first run, where there was some confusion about the end standardization, the drift in readings within any single run was very low (within ±0.00003) for the rest of P02W (about ±0.0005 in salinity). There were up to 0.0015 shifts in Bottle-CTD salinity differences observed between the runs of the two analysts, but no cause could be determined other than possible day/night room temperature variations. These differences would not be unusual in the less-than-ideal shipboard laboratory environment. The results fall within the estimated accuracy of bottle salinities run at sea - usually better than ±0.002 relative to the particular standard seawater batch used.

1.14. Oxygen Analysis

Equipment and Techniques

Dissolved oxygen analyses were performed with an SIO/ODF-designed automated oxygen titrator using photometric endpoint detection based on the absorption of 365nm wavelength ultraviolet light. The titration of the samples and the data logging were controlled by ODF PC software compiled in LabVIEW. Thiosulfate was dispensed by a Brickman Dosimat 765 buret driver fitted with a 1.0 mL buret. The ODF method used a whole-bottle modified-Winkler titration following the technique of Carpenter[Carp65] with modifications by Culberson *et al.* [Culb91], but with higher concentrations of potassium iodate standard (~0.012N) and thiosulfate solution (~55 gm/l). Standard KIO_3 solutions prepared ashore were run daily (approximately every 2-4 stations), unless changes were made to the system or reagents. Reagent/distilled water blanks were also determined daily, or more often if a change in reagents required it to account for presence of oxidizing or reducing agents.

Sampling and Data Processing

2915 samples were analyzed from 87 stations on P02W. Samples were collected for dissolved oxygen analyses soon after the rosette was brought on board. Six different cases of 24 flasks each were rotated by station to minimize any potential flask calibration issues. Using a silicone drawing tube, nominal 125ml volume-calibrated iodine flasks were rinsed 3 times with minimal agitation, then filled and allowed to overflow for at least 3 flask volumes. The sample drawing temperatures were measured with an electronic resistance temperature detector (Omega™ HH370 RTD) embedded in the drawing tube. These temperatures were used to calculate μmol/kg concentrations, and as a diagnostic check of bottle integrity. Reagents ($MnCl_2$ then NaI/NaOH) were added to fix the oxygen before stoppering. The flasks were shaken to assure thorough dispersion of the precipitate, once immediately after drawing, and then again after about 20 minutes. A water seal was applied to the rim of each bottle in between shakes.

The samples were analyzed within 1 hour of collection, and the data incorporated into the cruise database.

Thiosulfate normalities were calculated from each standardization and corrected to 20°C. The thiosulfate normalities and blanks were monitored for possible drifting or other problems when new reagents were used. An average blank and thiosulfate normality were used to recalculate oxygen concentrations. The thiosulfate was changed between stations 42 and 43. The first set of averages were performed on Stations 1 through 42. The second set was done on Stations 43 through 87. The difference between the original and "smoothed" data averaged 0.06% over the course of the cruise.

Bottle oxygen data were reviewed to ensure station, cast, bottle number, flask, and draw temperature were entered properly. Comments made during analysis were reviewed, and anomalies were investigated and resolved. If an incorrect end point was encountered, the analyst re-examined raw data and the program recalculated a correct end point.

After the data were uploaded to the database, bottle oxygen was graphically compared with CTD oxygen and adjoining stations. Any points that appeared erroneous were reviewed and comments made regarding the final outcome of the investigation. These investigations and final data coding are reported in Appendix C.

Volumetric Calibration

Oxygen flask volumes were determined gravimetrically with degassed deionized water to determine flask volumes at ODF's chemistry laboratory. This was done once before using flasks for the first time and periodically thereafter when a suspect volume is detected. The volumetric flasks used in preparing standards were volume-calibrated by the same method, as was the 10 mL Dosimat buret used to dispense standard iodate solution.

Standards

Liquid potassium iodate standards were prepared and tested in 6 liter batches and bottled in sterile glass bottles at ODF's chemistry laboratory prior to the expedition. The normality of the liquid standard was determined by calculation from weight of powder temperature of solution and flask volume at 20°C. The standard was supplied by Alfa Aesar (lot B05N35) and has a reported purity of 99.4-100.4%. All other reagents were "reagent grade" and were tested for levels of oxidizing and reducing impurities prior to use.

Analytical Problems

No analytical problems were encountered on CLIVAR/Carbon P02W.

1.15. Nutrient Analysis

Summary of Analysis

2942 samples from 87 CTD stations were analyzed.

The cruise started with new pump tubes; they were changed twice, after stations 27 and 55. Four sets of Primary/Secondary standards were made up over the course of the cruise. The cadmium column efficiency was checked periodically and ranged between 95%-100%. When the efficiency was found to be below 97%, the column was replaced.

Equipment and Techniques

Nutrient analyses (phosphate, silicate, nitrate plus nitrite, and nitrite) were performed on a Seal Analytical continuous-flow AutoAnalyzer 3 (AA3). The analytical methods used are described by Gordon *et al.* [Gord92], Hager *et al.* [Hage68] and Atlas *et al.* [Atla71]. The details of modification of analytical methods used for this cruise are also compatible with the methods described in the nutrient section of the GO-SHIP repeat hydrography manual [Hyde10].

Nitrate/Nitrite Analysis

A modification of the Armstrong *et al.* [Arms67] procedure was used for the analysis of nitrate and nitrite. For nitrate analysis, a seawater sample was passed through a cadmium column where the nitrate was reduced to nitrite. This nitrite was then diazotized with sulfanilamide and coupled with N-(1-naphthyl)-ethylenediamine to form a red dye. The sample was then passed through a 10mm flowcell and absorbance measured at 540nm. The procedure was the same for the nitrite analysis but without the cadmium column.

REAGENTS

Sulfanilamide

Dissolve 10g sulfanilamide in 1.2N HCl and bring to 1 liter volume. Add 2 drops of 40% surfynol 465/485 surfactant. Store at room temperature in a dark poly bottle.

Note: 40% Surfynol 465/485 is 20% 465 plus 20% 485 in DIW.

N-(1-Naphthyl)-ethylenediamine dihydrochloride (N-1-N)

Dissolve 1g N-1-N in DIW, bring to 1 liter volume. Add 2 drops 40% surfynol 465/485 surfactant. Store at room temperature in a dark poly bottle. Discard if the solution turns dark reddish brown.

Imidazole Buffer

Dissolve 13.6g imidazole in ˜3.8 liters DIW. Stir for at least 30 minutes to completely dissolve. Add 60 ml of $CuSO_4$ + NH_4Cl mix (see below). Add 4 drops 40% Surfynol 465/485 surfactant. Let sit overnight before proceeding. Using a calibrated pH meter, adjust to pH of 7.83-7.85 with 10% (1.2N) HCl (about 20-30 ml of acid, depending on exact strength). Bring final solution to 4L with DIW. Store at room temperature.

NH_4Cl + $CuSO_4$ mix

Dissolve 2g cupric sulfate in DIW, bring to 100 m1 volume (2%). Dissolve 250g ammonium chloride in DIW, bring to l liter volume. Add 5ml of 2% $CuSO_4$ solution to this NH_4Cl stock. This should last many months.

Phosphate Analysis

Ortho-Phosphate was analyzed using a modification of the Bernhardt and Wilhelms [Bern67] method. Acidified ammonium molybdate was added to a seawater sample to produce phosphomolybdic acid, which was then reduced to phosphomolybdous acid (a blue compound) following the addition of dihydrazine sulfate. The sample was passed through a 10mm flowcell and absorbance measured at 820nm.

REAGENTS

Ammonium Molybdate

H_2SO_4 solution: Pour 420 ml of DIW into a 2 liter Ehrlenmeyer flask or beaker, place this flask or beaker into an ice bath. SLOWLY add 330 ml of concentrated H_2SO_4. This solution gets VERY HOT!! Cool in the ice bath. Make up as much as necessary in the above proportions.

Dissolve 27g ammonium molybdate in 250ml of DIW. Bring to 1 liter volume with the cooled sulfuric acid solution. Add 3 drops of 15% DDS surfactant. Store in a dark poly bottle.

Dihydrazine Sulfate

Dissolve 6.4g dihydrazine sulfate in DIW, bring to 1 liter volume and refrigerate.

Silicate Analysis

Silicate was analyzed using the technique of Armstrong *et al.* [Arms67] Acidified ammonium molybdate was added to a seawater sample to produce silicomolybdic acid which was then reduced to silicomolybdous acid (a blue compound) following the addition of stannous chloride. The sample was passed through a 10mm flowcell and measured at 660nm.

REAGENTS

Tartaric Acid

Dissolve 200g tartaric acid in DW and bring to 1 liter volume. Store at room temperature in a poly bottle.

Ammonium Molybdate

Dissolve 10.8g Ammonium Molybdate Tetrahydrate in ~ 900ml DW. Add 2.8ml H_2SO_4* to solution, then bring volume to 1000ml.

Add 3-5 drops 15% SDS surfactant per liter of solution.

Stannous Chloride stock (as needed)

Dissolve 40g of stannous chloride in 100 ml 5N HCl. Refrigerate in a poly bottle.

NOTE: Minimize oxygen introduction by swirling rather than shaking the solution. Discard if a white solution (oxychloride) forms.

Working (every 24 hours): Bring 5 ml of stannous chloride stock to 200 ml final volume with 1.2N HCl. Make up daily - refrigerate when not in use in a dark poly bottle.

Sampling

Nutrient samples were drawn into 40 ml polypropylene screw-capped centrifuge tubes. The tubes and caps were cleaned with 10% HCl and rinsed 2-3 times with sample before filling. Samples were analyzed within 1-3 hours after sample collection, allowing sufficient time for all samples to reach room temperature. The centrifuge tubes fit directly onto the sampler.

Data collection and processing

Data collection and processing was done with the software (AACE ver. 6.07) provided with the instrument from SEAL Analytical. After each run, the charts were reviewed for any problems during the run, any blank was subtracted, and final concentrations (μM) were calculated, based on a linear curve fit. Once the run was reviewed and concentrations calculated a text file was created. That text file was reviewed for possible problems and then converted to another text file with only sample identifiers and nutrient concentrations that was merged with other bottle data.

Standards and Glassware calibration

Primary standards for silicate (Na_2SiF_6), nitrate (KNO_3), nitrite ($NaNO_2$), and phosphate (KH_2PO_4) were obtained from Johnson Matthey Chemical Co. and/or Fisher Scientific. The supplier reports purities of >98%, 99.999%, 97%, and 99.999 respectively.

All glass volumetric flasks and pipettes were gravimetrically calibrated prior to the cruise. The primary standards were dried and weighed out to 0.1 mg prior to the cruise. The exact weight was noted for future reference. When primary standards were made, the flask volume at 20°C, the weight of the powder, and the temperature of the solution were used to buoyancy correct the weight, calculate the exact concentration of the solution, and determine how much of the primary was needed for the desired concentrations of secondary standard. Primary and secondary standards were made up every 7-10 days. The new standards were compared to the old before use.

All the reagent solutions, primary and secondary standards were made with fresh distilled deionized water (DIW).

Quality Control

All data were reported in μM (micromoles/liter). NO_3, PO_4, and NO_2 were reported to two decimal places and SiO_3 to one. Accuracy is based on the quality of the standards; the levels were:

Parameter	Accuracy (μM)
NO_3	0.05
PO_4	0.004
SiO_3	2-4
NO_2	0.05

Table 1.15.1 CLIVAR/Carbon P02W Nutrient Accuracy

Precision numbers for the instrument were the same for NO_3 and PO_4 and a little better for SiO_3 and NO_2 (1 and 0.01 respectively).

The detection limits for the methods/instrumentation were:

Parameter	Detection Limits (μM)
NO_3+NO_2	0.02
PO_4	0.02
SiO_3	0.5
NO_2	0.02

Table 1.15.2 CLIVAR/Carbon P02W Nutrient Detection Limits

As is standard ODF practice, a deep calibration *check* sample was run with each set of samples and the data are tabulated below.

Parameter	Concentration (μM)
NO_3	41.7 +/- 0.21
PO_4	2.94 +/- 0.01
SiO_3	162.15 +/- 0.58

Table 1.15.3 CLIVAR/Carbon P02W RMNS cruise-averaged data

Reference materials for nutrients in seawater (RMNS) were also used as a check sample run with each set of seawater samples. The RMNS preparation, verification, and suggested protocol for use of the material are described by Aoyama *et al.* [Aoya06] [Aoya07] [Aoya08] and Sato *et al.* [Sato10]. RMNS batch BX was used on this cruise, with each bottle being used once or twice before being discarded and a new one opened. Data are tabulated below, along with the assigned values.

Parameter	Concentration (μmol kg^{-1})	Assigned
NO_3	43.08 +/- 0.16	43
PO_4	2.9 +/- 0.02	2.906
SiO_3	138.7 +/- 0.55	136
NO_2	0.04 +/- 0.006	0.034

Table 1.15.0 CLIVAR/Carbon P02W Concentration of RMNS standard (μM)

Analytical Problems

The phosphate channel was a source of trouble, requiring nearly everything but the glassware to be replaced before samples from station 060 could be analyzed. Peaks were shaky and the baseline jumped up and recovered later, causing uncertain sample values that necessitated reruns of individual samples and sometimes even of whole stations. The flowcell, reagents, and control module were switched out for spares in succession, but problems persisted. No 820nm spare filter was available so an 880nm was traded in and settings adjusted, resulting in no issues until station 87. Prior to that station's analysis, the baseline again became inconsistent. The original photometer, flowcell, filter and lamp were replaced on the machine for the final sample run. Further trouble-shooting between legs will take place.

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Transmissometer Shipboard Procedures

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Instrument: WET Labs C-Star Transmissometer – S/N **CST-327DR**

Air Calibration:

- Calibrated the transmissometer in the lab at beginning, middle and end of leg 1 with a pigtail cable attachment to CTD.
- Washed and dried the windows with Kimwipes and distilled water.
- Recorded the final values for unblocked and blocked voltages plus air temperature on the Transmissometer Calibration/Cast Log.
- Compared the output voltage with the Factory Calibration data.
- Computed updated calibration coefficients.

Deck Procedures:

- Washed the transmissometer windows before every cast. Rinsed both windows with a distilled water bottle that contains 2-3 drops of liquid soap. This was the last procedure before the CTD went in the water.
- Rinse instrument with fresh water at end of cruise.

Summary:

Deck calibrations were carried out 3 times during P02W – near the start of the leg, the middle of the leg and the morning after the last station was completed. Results of the pre-cruise laboratory calibration, and deck calibrations done during this cruise, appear at the end of Appendix D with the other instrument/sensor laboratory calibrations.

After preparing the transmissometer for deployment (see Deck Procedures above), CST-327DR was sent with the rosette for every CTD cast during P02W (Leg 1) on R/V Melville. Data were reported through a CTD a/d channel, then converted to raw voltages without applying any corrections. The data were averaged into half-second blocks with the CTD data, and later converted into 2-dbar block-averaged data files. The raw voltage data will be reported to Wilf Gardner for further processing post-cruise, and later merged in with the CTD data at CCHDO.

No problems were encountered with the transmissometer during this leg.

Cruise Report: LADCP data from CLIVAR PO2W 2013

Steven Howell

Personnel

UH LADCP group: Eric Firing (PI), François Ascani, and Julia Hummon

Shipboard operators Steven Howell, UH and Katinka Bellomo, University of Miami

System description

The University of Hawaii (UH) ADCP group used a Teledyne/RDI Workhorse 150 kHz Lowered Acoustic Doppler Current Profiler (LADCP, serial number 16283, with beams 20° from vertical) to measure ocean currents during the spring 2013 CLIVAR/Carbon P02W cruise from Yokohama, Japan to Honolulu, Hawaii. The instrument was held near the base of the rosette by an anodized aluminum collar connected to three struts that were in turn bolted to the rosette frame. Secondary restraint was provided by a ratchet strap tightened around the instrument and tied to an upper strut of the frame. Power for the LADCP was provided by a Deep Sea Power & Light sealed oil-filled marine battery (model SB-48V/18A, serial number 01527). It was fastened with cord to the rosette frame. Figure 1 shows the arrangement of instruments in the rosette.

Between casts, a single power/communications cable connected the LADCP and battery to a computer and a DC power supply to initialize the LADCP, collect data after casts, and recharge the battery. Communication with the instrument was managed by a custom serial communication package.

Operating parameters

The LADCP used nominal 16 m pulses and 8 m receive intervals (assuming a standard $1500\,\mathrm{m\,s^{-1}}$ speed of sound). The blanking interval (distance to first usable data) was 16 m.

A staggered pinging pattern was used, with alternating 1.2 s and 1.6 s periods between pings. This was to avoid a problem referred to as Previous Ping Interference (PPI), which happens when a strong echo off the bottom from a previous ping overwhelms the weak scattering signal from the water column. PPI occurs at a distance above the ocean floor of $\Delta z = \frac{1}{2} c \Delta t \cos\theta$ where Δt is the period between pings, c is the speed of sound, and θ is the beam angle from vertical. With constant ping rates, the artifact hits a single depth, essentially invalidating all data at that depth. By alternating delays, we lose half the data at two depths, but have some data through the entire column.

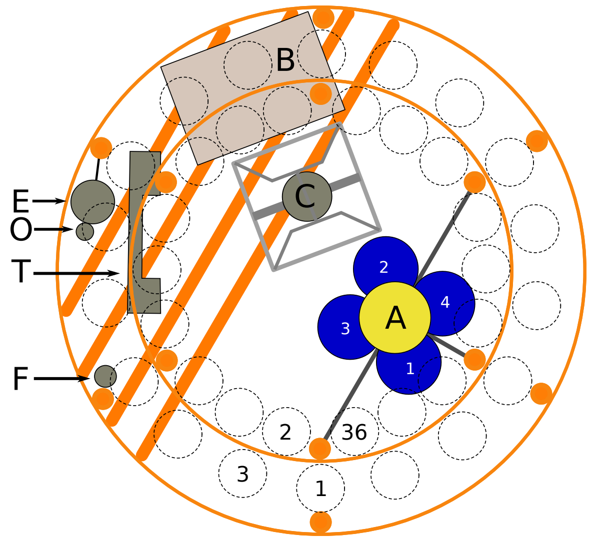

Figure 1: Schematic plan view of instrument and bottle locations on the rosette. Orange elements are parts of the rosette frame. Bottle locations are indicated by dashed circles and numbers. Instruments are identified by letters: A, ADCP; B, Battery for ADCP power; C, CTD;E, Echosounder (120 kHz Benthos altimeter); O, oxygen sensor (secondary); T, transmissometer; and F, Fluorometer for chlorophyll-A. White numerals show ADCP beam positions after the 90° clockwise twist on April 23.

The LADCP control file

```
CR1     # factory defaults
PS0     # Print system serial number and other info.
WM15    # sets LADCP mode; WB -> 1, WP -> 001, TP -> 000100, TE -> 00000100
TC2     # 2 ensembles per burst
TB 00:00:02.80      ### also try old BB settings, 2.6 and 1.0
TE 00:00:01.20
TP 00:00.00
WN40     # 40 cells, so blank + 320 m with 8-m cells
WS0800   # 8-m cells
WT1600   # 16-m pulse
WF1600   # Blank, 16-m
WV330       # 330 is max effective ambiguity velocity for WB1
EZ0011101   # Soundspeed from EC (default, 1500)
EX00100     # No transformation (middle 1 means tilts would be used otherwise)
CF11101     # automatic binary, no serial
LZ30,230    # for LADCP mode BT; slightly increased 220->230 from Dan Torres
CL0         # don't sleep between pings (CL0 required for software break)
```

Data processing

Data were processed using version IX.8 of Andreas Thurnherr's implementation of Martin Visbeck's LADCP inversion method, developed at the Lamont-Doherty Earth Observatory of Columbia University. The LDEO code is written in Matlab, and performs a long chain of calculations, including transforming the raw LADCP data to Earth coordinates; editing out suspect data; meshing with CTD data from the cast and simultaneous shipboard ADCP and GPS data; then running both an inverse method and a shear-based algorithm to obtain ocean currents throughout the profile. The shear-based calculation is used as a check on the inverse method–if they agree, confidence in the solution is enhanced. The LDEO code is available at `ftp://ftp.ldeo.columbia.edu/pub/LADCP`.

Only preliminary data processing was performed during the cruise; full processing takes more time than was available. The automatic data editing is not completely adequate, as ocean bottom reflections are not always edited out and the algorithms for detecting and discarding PPI require more work. When the data are fully processed, they will be made available on the UH ADCP website, `http://currents.soest.hawaii.edu` as part of the CLIVAR ADCP archive.

Data gathered

Data were successfully obtained in every cast at each station. Since the LADCP operated independently from the CTD data system, it was not affected by the noise problems that bedeviled the first 14 stations. Preliminary vertical profile plots of each station were made available on the ship's website within 12 hours of each cast.

Problems encountered

We had no major hardware or software problems during the cruise, but there were a few glitches. The ADCP twice slipped down in its collar and had to be lifted up and re-secured. We also experienced an odd noise problem. One of the beams (#4) appeared to be getting weak, with decreased signal:noise and reduced range. After some email discussion, Eric Firing opined that it was more likely an acoustic or electronic interference problem than a failing transducer. This was confirmed when we rotated the instrument 90°. The suspect beam improved while its neighbor (#2) deteriorated. There was a net improvement, however, so we left the LADCP in its new position.

It is possible that the Benthos 120 kHz altimeter caused acoustic interference, but exactly the same altimeter and rosette were used during the CLIVAR A20/A22 cruises without the same symptoms. Another possibility is that some instrument on the rosette or along the cable introduced electrical noise. Noise from the winch caused major problems with the CTD system, but that was fixed with no obvious change in beam 4 performance. The secondary O_2 sensor is grounded to the rosette, so could perhaps be at fault, but the beam weakness was visible in the data before that sensor was installed. We have not really resolved the problem, but are satisfied that the effects on the data are small.

Sample data plots

We made both vertical profiles of individual plots and contour plots along the cruise track available on the ship's network. A contour plot of data from the entire cruise may be the best capsule summary of the preliminary data. The Kuroshio current, with a maximum speed of about $1.4\,\mathrm{m\,s^{-1}}$ is at the far left of Figure 2, together with a countercurrent, presumably an eddy, immediately to the east. Currents through the rest of the basin are much weaker, fading to the east. There are often local maxima between 3000 and 5000 km depth, and currents near the bottom frequently exceed $10\,\mathrm{cm\,s^{-1}}$.

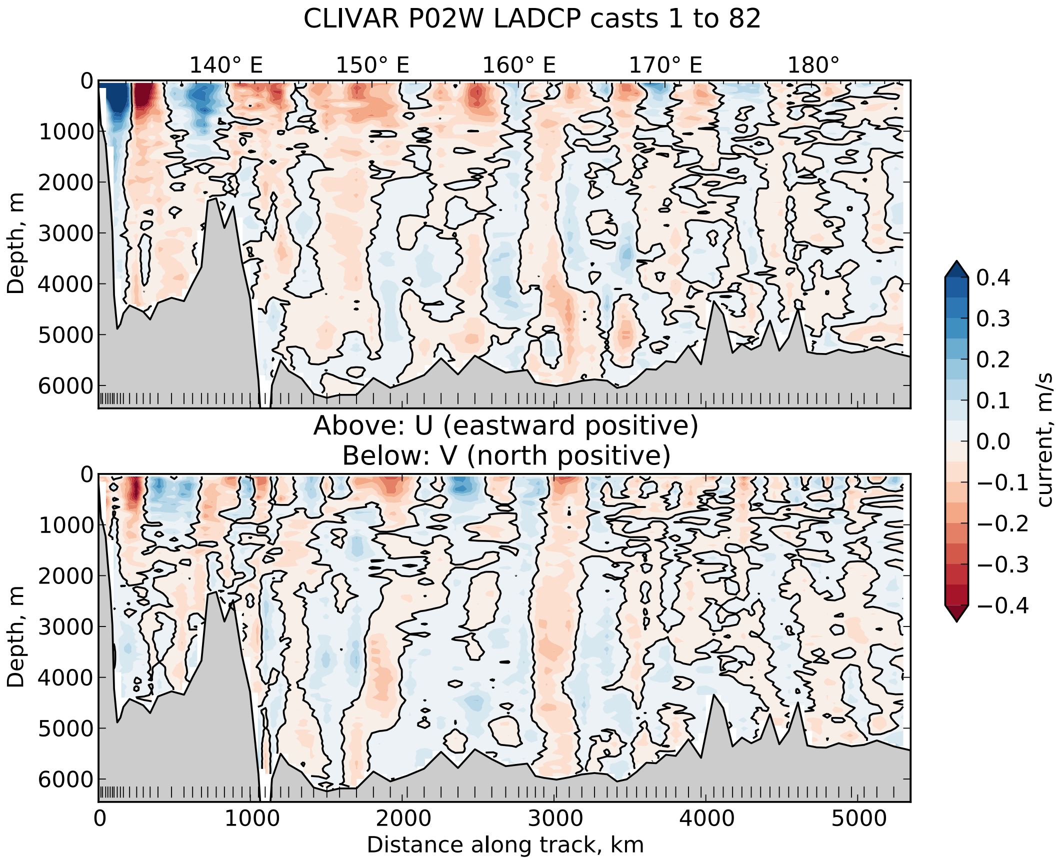

Figure 2: Contour plot of P02W stations 1 to 82. Tick marks along the bottom of each plot are station locations.

One unusual feature discovered by Mary Johnson while reviewing CTD data was a density inversion near the crest of the Izu-Ogasawa ridge (Figure 3). Such inversions are unstable, so it must indicate that turbulent mixing was occurring. The LADCP shows considerable shear near the bottom and a peak in the current coincident with the middle of the inversion region. We are curious to see whether more careful examination of the LADCP data can reveal the turbulence that must be present.

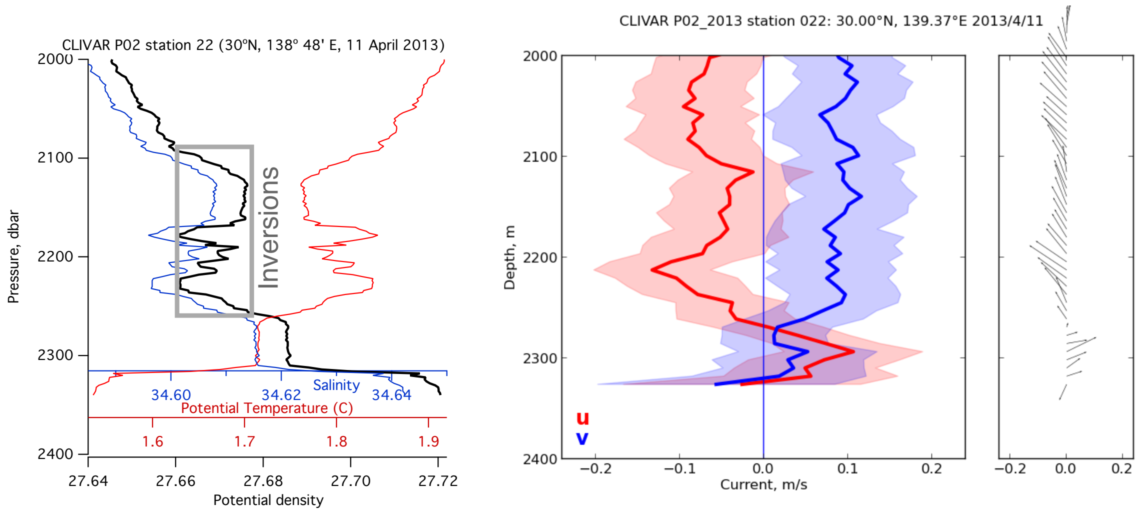

Figure 3: Turbulence at the Izu-Ogasawa Ridge. On the left is data from the CTD, showing relatively warm, fresh water interleaved with cooler, saltier layers. On the right is the LADCP data. The red and blue lines are east/west and north/south velocities, respectively; the shaded regions are error estimates. The arrows show current direction and speed at the depths of the arrow bases.

Acknowledgements Many thanks are due to Jim Swift for leading the science effort with equanimity in the face of some rather difficult problems at the start of the cruise. Robert Palomares actually mounted the LADCP in the rosette and made sure it was safe. Mary Johnson and Frank Delahoyde made the CTD data available so quickly and easily that I hardly had to think about it.

More thanks to the entire crew and science complement of the *Melville*, who were unfailingly helpful and made the ship a clean and pleasant place to work. They strove hard, and successfully, to cope with the hardware breakdowns that plagued the first weeks of the cruise. The cooks, Mark and Jeremy, not only made good food, but in such variety that I often marveled at their inventiveness.

CFC-11, CFC-12, CFC-113, and SF_6
PI: *David Ho, University of Hawaii*
Analysts: *Eugene Gorman, Gabrielle Weiss, Benjamin Hickman*

Sample Collection
CFC-11, CFC-12, CFC-113, and SF_6 were measured for 77 stations (number of samples per station varied with depth and other extenuating circumstances). All samples were collected from depth using 10.4 liter Niskin bottles. All bottles in use remained inside the CTD hanger between casts. CFC/SF_6 samples were the first samples to be collected from the Niskin bottles after each cast according to WOCE protocol. Water samples were collected in 300 ml BOD bottles. BOD bottles were filled from the Niskin bottles petcock using viton tubing. The viton tubing was flushed of air bubbles. The BOD bottle was placed in a plastic overflow container which was large enough so that when full, the BOD bottle could be caped while submerged. Water was allowed to fill BOD bottle from the bottom and overflow into the overflow container. Once water started overflow the overflow container the viton tubing was removed and the BOD bottle was stoppered (using a ground glass stopper) while under water in the overflow container. A plastic clamp was snapped on to hold the ground glass stopper in place. Duplicate samples were taken on some stations from random Niskin bottles. Air samples were collected, using a 100 mL glass syringe, when time permitted.

Sample Analysis
Analyses were performed on a Hewlett Packard 6890 gas chromatography system equipped with an electron capture detector (ECD). Samples were introduced into the GC-EDC via a duel purge and trap system. Water samples were purged with nitrogen and the purged compounds were trapped on either a Porapack N or Carboxen 1000 trap (trap material intended for CFCs and SF_6 respectively) held at ~ -65°C via a CO_2 cooling system. The traps were isolated and heated by resistive heating to ~150°C. The desorbed contents of the traps were back-flushed and transferred, with nitrogen gas, to a precolumn used to capture interfering compounds. After the precolumn the compounds flowed into the main column for separation and detection by the ECD. After running the samples for each station, measurements were followed by a blanks and a standard to monitor changers in the systems performance over time.

Calibration
Gas phase standards, 35060 and 72645, were used for calibration. Calibration loops filled with the standard gases of a known volume, temperature, and pressure where run at varying intervals during the curse. The GC-ECD response to each of the compounds of interest was recorded for each of the different size calibration loops. A calibration curve was generated via a nonlinear fit to the calibration data.

Results/Data
The preliminary data submitted to the onboard database should not be considered accurate until further data analysis and quality control can be performed.

HELIUM AND TRITIUM
PI: William Jenkins
Sampler: Kevin Cahill

Helium and Tritium samples were collected roughly every four degrees on CLIVAR leg P02.

Helium Sampling
16 helium samples were drawn at 16 of the stations and 24 niskins were sampled at 2 stations. Although all 36 niskins were not sampled, depths were chosen to obtain an accurate cross-section of the upper 2000m of the water column. On the two stations where 24 niskins were sampled, the samples were taken to get a profile of the entire water column down to the bottom. A duplicate was taken roughly every third station. Helium samples were taken in custom-made stainless steel cylinders and sealed with rotating plug valves at either end. The sample cylinders were leak-checked and backfilled with N2 prior to the cruise. Samples were drawn using tygon tubing connected to the niskin bottle at one end and the cylinder at the other. Cylinders are thumped with a bat while being flushed with water from the niskin to remove bubbles from the sample. After flushing roughly 1 liter of water through them, the plug valves are closed. Due to the nature of the o-ring seals on the sample vessels, they must be extracted within 24 hours. Eight samples at a time were extracted using our At Sea Extraction line in the Helium Van on main deck. The stainless steel sample cylinders are attached to the vacuum manifold and pumped down to less than 2e-7 Torr using a diffusion pump for a minimum of 1 hour to check for leaks. The sections are then isolated from the vacuum manifold and introduced to the reservoir cans which are heated to >80C for roughly 10 minutes. Glass bulbs are attached to the sections and immersed in ice water during the extraction process. After 10 minutes each bulb is flame sealed and packed for shipment back to WHOI. The extraction cans and sections are cleaned with distilled water and isopropanol, then dried between each extraction. Prior to the cruise, all vacuum components were cleaned, serviced and checked for leaks. The glass bulbs are baked to 640C for 6 hours and cooled slowly in an oven receiving a steady flow of nitrogen. 324 helium samples were taken on Leg 1. This includes 20 samples and their duplicates taken solely for sampling technique comparisons as well as 5 regular duplicates. Helium samples will be analyzed using a mass spectrometer at WHOI.

Vibrations due to waves crashing into the fantail created difficulties extracting helium samples during extremely bad weather. At times the shaking in the van was so intense that it cracked some glass sample bulbs on the extraction line. Once the weather cleared, all of our samples were extracted while still remaining within the prescribed 24 hour time window.

TRITIUM SAMPLING
Tritium samples were drawn from the same stations and bottles as those sampled for helium. Since there was not a water shortage on this cruise, a duplicate was taken from the same niskin as the helium duplicate. Tritium samples were taken using tygon tubing to fill 1 liter glass jugs. The jugs were baked in an oven, backfilled with argon, and the caps were taped shut prior to the cruise. While filling, the jugs are place on the deck and filled to about 2 inches from the

top of the bottle, being careful not to spill the argon. Caps were replaced and taped shut with electrical tape before being packed for shipment back to WHOI. 304 tritium samples were taken, including 5 duplicates. Tritium samples will be degassed in the lab at WHOI and stored for a minimum of 6 months before mass spectrometer analysis. No issues were encountered while taking tritium samples.

DISSOLVED INORGANIC CARBON (DIC)

The DIC analytical equipment (DICE) design was based upon the original SOMMA systems (Johnson, 1985, '87, '92, '93). This new design has improved on the original SOMMA by use of more modern National Instruments electronics and other available technology. These 2 DICE systems (PMEL-1 and PMEL-2) were set up in a seagoing container modified for use as a shipboard laboratory on the aft working deck of the *R/V Melville.* In the coulometric analysis of DIC, all carbonate species are converted to CO_2 (gas) by addition of excess hydrogen to the seawater sample. The evolved CO_2 gas is carried into the titration cell of the coulometer, where it reacts quantitatively with a proprietary reagent based on ethanolamine to generate hydrogen ions. These are subsequently titrated with coulometrically generated OH-. CO_2 is thus measured by integrating the total charge required to achieve this. (Dickson, et al 2007).

Each coulometer was calibrated by injecting aliquots of pure CO_2 (99.999%) by means of an 8-port valve outfitted with two calibrated sample loops of different sizes (~1ml and ~2ml) (Wilke et al., 1993). The instruments are each separately calibrated at the beginning of each ctd station with a minimum of two sets of these gas loop injections.

Secondary standards were run throughout the cruise (at least one per station) on each analytical system. These standards are Certified Reference Materials (CRMs), consisting of poisoned, filtered, and UV irradiated seawater supplied by Dr. A. Dickson of Scripps Institution of Oceanography (SIO). Their accuracy is determined manometrically on land in San Diego. DIC data reported to the database have been corrected to the batch 124 CRM value. The CRM certified value for this batch is 2015.72 µmol/kg. The average measured values (in µmol/kg during this cruise) were 2015.87 for PMEL-1 and 2016.08 for PMEL-2.

The DIC water samples were drawn from Niskin-type bottles into cleaned, pre-combusted 300mL borosilicate glass bottles using silicon tubing. Bottles were rinsed once and filled from the bottom, overflowing by at least one-half volume. Care was taken not to entrain any bubbles. The tube was pinched off and withdrawn, creating a 5mL headspace, and 0.12mL of 50% saturated HgCl2 solution was added as a preservative. The sample bottles were sealed with glass stoppers lightly covered with Apiezon-L grease, and were stored in a 20°C water bath for a minimum of 20 minutes to bring them to temperature prior to analysis.

Over 2,000 samples were analyzed for discrete DIC. Greater than 10% of these samples were taken as replicates as a check of our precision. These replicate samples were typically taken near the surface, oxygen minimum, and bottom bottles. The replicate samples were interspersed throughout the station analysis for quality assurance and integrity of the coulometer cell solutions. Preliminary analysis of these replicates indicates that there was a slight drift during the course of some of the cells. Closing gas calibrations confirmed this drift and further shoreside analysis will determine the extent of this drift. However, before any correction for this drift, the absolute average difference from the mean of these replicates is 1.0 µmol/kg.

The DIC data reported at sea is to be considered preliminary until a further shoreside analysis is undertaken.

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Discrete pH Analyses
PI: Dr. Andrew Dickson
Ship technicians: Kristin Jackson and Britain Richardson

Sampling
Samples were collected in 250 mL borosilicate glass bottles and sealed using grey butyl rubber stoppers held in place by aluminum crimp caps. Each bottle was rinsed a minimum of 2 times, then filled and allowed to overflow by approximately one full volume. A 1% headspace was then removed from the bottles using an Eppendorf pipette and poisoned with 60 µL of mercuric chloride (HgCl2) prior to sealing with the aluminum caps. Samples were collected from the same Niskin bottles as total alkalinity or dissolved inorganic carbon in order to completely characterize the carbon system, and 2 duplicate bottles were also taken on random Niskins for each station throughout the course of the cruise. All data should be considered preliminary.

Analysis
pH (µmol/kg H_2O) on the total scale was measured using an Agilent 8453 spectrophotometer according to the methods outlined by Clayton and Byrne (1993). A Thermo NESLAB RTE-7 recirculating water bath was used to maintain spectrophotometric cell temperature at 25.0°C during the analyses. A custom 10cm flow through jacketed cell was filled autonomously with samples using a Kloehn V6 syringe pump. The sulfonephthalein indicator m-cresol purple (mCP) was used to measure the absorbance of light measured at two different wavelengths (434 nm, 578 nm) corresponding to the maximum absorbance peaks for the acidic and basic forms of the indicator dye. A baseline absorbance was also measured and subtracted from these wavelengths. The baseline absorbance was determined by averaging the absorbances from 730-735nm. The samples were run using the tungsten lamp only. The blank and absorbance spectrum were measured 6 times in rapid succession and then averaged. The ratios of absorbances at the different wavelengths were input and used to calculate pH on the total scales, incorporating temperature and salinity into the equations. The salinity data used was obtained from the conductivity sensor on the CTD. The salinity data was later corroborated by shipboard measurements. Temperature of the samples was measured immediately after spectrophotometric measurements using a Direct Temp USB surface temperature probe and a Direct Temp USB immersible probe.

Reagents
The mCP indicator dye was made to a concentration of 2.0 mM in 100ml batches as needed. A total of 3 batches were used during the cruise. The pHs of the batches were adjusted to approximately 7.6-7.7 using dilute solutions of HCl and NaOH and a pH meter calibrated using NBS buffers. The indicator was provided by Dr. Michael Degrandpre at the University of Montana, and was purified using the HPLC technique described by Liu et al., 2011.

Standardization/Results
The precision of the data can be accessed from measurements of duplicate analyses, certified reference material (CRM) Batch 124 (provided by Dr. Andrew Dickson, UCSD), and TRIS buffer Batch 11 (provided by Dr. Andrew Dickson, UCSD). CRMs were measured at least once every 12 hours, and bottles of TRIS buffer were measured once a week. The precision obtained from 172 duplicate analyses was found to be ±0.0004.

Data Processing

The addition of an indicator dye perturbs the pH of the sample, and the degree to which pH is affected is a function of the differences between the pH of the seawater and the pH of the indicator. Therefore, a correction is applied to all samples measured for a given batch of dye. To determine this correction samples of varying pH and water composition were randomly run with a single injection of dye and then again with a double injection of dye on a single bottle. To determine this correction the change in the measured absorbance ratio R where R = (A578-Abase)/ (A434-Abase) is divided by the change in the isosbestic absorbance (Aiso at 488nm) observed from two injections of dye to one. (R''-R') / (Aiso''-Aiso') is plotted against the measured R value for the single injection of dye and fitted with a linear regression. From this fit the slope and y-intercept (b and a respectively) are determined by:

$$\Delta R/\Delta Aiso = bR' + a \qquad (1)$$

From this the corrected ratio (R) corresponding to the measured absorbance ratio if no indicator dye were present can be determined by:

$$R=R' - Aiso' (bR' + a) \qquad (2)$$

Preliminary data has not been corrected for the perturbation.

Problems

Very few problems occurred during the course of the cruise. The biggest problem that did occur was tiny bubbles forming inside the cell due to cold samples de-gassing as they were heated up rapidly. To combat this, the cell was instead flushed with air and then filled with DI water or occasionally 2-propanol and allowed to soak in-between stations. This proved the most effective method. Prior to running a given station, 3-4 junk surface seawater pH measurements were made to ensure that the system was functioning as expected. Stations were additionally analyzed starting with the surface samples and finishing with the deep cold bottom samples to reduce the build-up of bubbles.

References

Clayton, T. D. and Byrne, R. H., “Spectrophotometric seawater pH measurements: Total hydrogen ion concentration scale calibration of m-cresol purple and at-sea results,” Deep-Sea Res., 40, pp. 2315-2329, 1993.

Liu, X., Patsvas, M.C., Byrne R.H., “Purification and Characterization of meta Cresol Purple for Spectrophotometric Seawater pH Measurements,” Environmental Science and Technology, 2011.

P02 leg 1 Alkalinity
(Laura Fantozzi and David Cervantes, laboratory of Andrew G. Dickson, Marine Physical Laboratory, Scripps Institution of Oceanography)

Samples were taken at every station, depending on cast depth the number of niskins sampled varied. Bottles were chosen to match DIC's sample choices. Samples were collected in 250 ml Pyrex bottles. A headspace of approximately 5 milliliters was removed and 0.06 milliliters of saturated mercuric chloride solution was added to each sample. The samples were capped with a glass stopper with a Teflon sleeve. All samples were equilibrated to 20 degrees Celsius using a Thermo Scientific RTE7 water bath.

Samples were dispensed using a volumetric pipette and a system of relay valves and air pumps controlled by a laptop using LabVIEW 2011. The temperature of the samples at time of dispensing was taken automatically by a computer using a DirecTemp surface probe placed on the pipette to convert this volume to mass for analysis. During instrument set up it was discovered that the sample dispensing unit (SDU) was dispensing less than the calibrated volume. This was determined by running titrations using the calibrated manual pipette to dispense reference seawater of known alkalinity and getting correct alkalinity values while the SDU was giving incorrect alkalinity values with the same reference seawater of the same alkalinity. An adjustment ratio of 1.00087 was applied to the original calibrated volume of 92.258 ml. Therefore, the volume dispensed for stations 1-12 was 92.178 ml. Between station 12 and 13 one of the valves on the SDU failed and the manual pipette was used again to calculate an adjustment ratio for the volume dispensed. The ratio of 0.99983 was applied to the previous calculated volume. The new calibrated volume dispensed for stations 13-87 would then be 92.193 ml.

Samples were analyzed using an open beaker titration procedure using two thermostated 250ml beakers; one sample being titrated while the second was being prepared and equilibrating to the system temperature close to 20^{o}C. After an initial aliquot of approximately 2.3-2.4 ml of standardized hydrochloric acid (~0.1M HCl in ~0.6M NaCl solution), the sample was stirred for 5 minutes to remove liberated carbon dioxide gas. The stir time was minimized by bubbling air into the sample at a rate of 200 scc/m. After equilibration, 19 aliquots of 0.04 ml were added. The data within the pH range of 3.5 to 3.0 were processed using a non-linear least squares fit from which the alkalinity value of the sample was calculated (Dickson, et.al., 2007). This procedure was performed automatically by a computer running LabVIEW 2011.

Two duplicates were taken and analyzed for each station. Throughout the cruise, a total of 168 duplicates were analyzed and gave a pooled standard deviation of 0.77 μmol kg^{-1}.

Dickson laboratory Certified Reference Materials (CRM) Batch 124 was used to determine the accuracy of the analysis. The certified value for Batch 124 is 2215.08 ± 0.49 μmol kg^{-1}. The reference material was analyzed 184 times throughout the stations.

The data should be considered preliminary since the correction for the difference between the CRMs stated and measured values has yet to be finalized and applied. Additionally, the correction for the mercuric chloride addition has yet to be applied.

REFERENCE:
Dickson, Andrew G., Chris Sabine and James R. Christian, editors, "Guide to Best Practices for Ocean CO2 Measurements", Pices Special Publication 3, IOCCP Report No. 8, October 2007, SOP 3b, "Determination of total alkalinity in sea water using an open-cell titration"

^{13}C /^{14}C (Radiocarbon)
***PIs**: Ann McNichol, Al Gagnon WHOI*
Technician: Leg 1 – Maverick Carey, MSI, UC Santa Barbara

The goal of this sampling is to adequately measure the distribution of radiocarbon in order to estimate the penetration of bomb-produced ^{14}C and quantify the ^{13}C decrease due to the influx of anthropogenic CO^2.

Samples were collected at 24 stations, roughly every 2-4, alternating between a full profile (32 samples) and shallow profiles (16 samples in the upper 1500-2000m of the water column). 24 stations were sampled, with a total of 560 bottles collected. Samples were collected in 500ml glass bottles through silicone tubing. The bottles were rinsed 2x with seawater, allowed to fill and overflow about half the volume. Once collected, a small volume was poured out for headspace, and ~100 μl of saturated mercuric chloride solution was added. The stoppers were carefully dried, greased (with M-Apiezon grease), sealed, and secured with a rubber band.

All samples will be shipped to WHOI from San Diego to be analyzed in the AMS lab.

Dissolved Organic Carbon and Total Dissolved Nitrogen
PI: Craig Carlson, MSI, UC Santa Barbara
Technician: Leg 1 - Maverick Carey, MSI, UC Santa Barbara

The goal of this group is to obtain Dissolved Organic Carbon (DOC) and Total Dissolved Nitrogen (TDN) values along the P02 line in order to better understand the carbon cycle in the ocean on spatial and temporal scales.

DOC/TDN samples were collected at all odd-numbered stations (with the addition of Station 28 over the Izu-Ogasawara Trench). 30-36 Niskin bottles were sampled at most stations, with as few as 8 bottles sampled at shallow stations. A total of 1360 samples were collected.

All samples were collected in 60 ml high-density polyethylene (HDPE) bottles. Bottles were previously cleaned with 10% HCl solution and rinsed 3 times with Mili-Q water. Once collected, samples were frozen at -20^{o} C in the onboard freezer. Samples in the top 500m of the water column were filtered using a glass fiber filter (GF/F) through an inline cartridge. Cartridges were previously cleaned with 10% HCl solution and rinse with Mili-Q water. The filtering is done in order to avoid the inclusion of particulate matter in the samples.

All frozen samples will be shipped back to UC Santa Barbara for analysis. TDN will be determined from the same samples in the upper 300m of the water column.

137Cs, 134Cs and 90Sr sampling

PI: Ken Buesseler, Alison Macdonald, Woods Hole Oceanographic Institution

Participant: Sachiko Yoshida, Woods Hole Oceanographic Institution

137Cs, 134Cs and 90Sr surface samples were drawn routinely from the Rosette cast, approximately every 2.5 degrees of longitude. In total 19 stations were sampled (19 samples). Surface samples were collected in 20L cubitainer from the Niskin bottles at about 65dbar depth. Tygon tube was used to fill the cubitainer. Two 10L Niskin bottles were tripped at the same depths for Cs surface sampling.

Cs profile samples consisted four 20L cubitainers. Eight profile samples were collected approximately every 6 degrees of longitude. Depths were roughly surface-100m, 100-200m, 250-350m, 400-600m, and filled from three or four Niskin bottles at that depth. Each of cubitainers was filled by the mixed volume from multiple Niskin bottles at close depth. After finishing one Niskin bottle, sample level was marked on the side of cubitainer using waterproof marker.

All the samples were secured in deck boxes placing 9 per layer with cardboard sheets between layers for stability. Three deck boxes will be shipping back to Woods Hole Oceanographic Institution at the end of leg 2.

References:

Buesseler, K. O., S. R. Jayne, N. S. Fisher, I. I. Rypina, H. Baumann, Z. Baumann, C. F. Breier, E. M. Douglass, J. George, A. M. Macdonald, H. Miyamoto, J. Nishikawa, S. M. Pike, and S. Yoshida (2012) Fukushima-derived radionuclides in the ocean and biota off Japan. *Proc. Nat. Acad. Sci.*, **109**, 5984–5988, doi:10.1073/pnas.1120794109.

Casacuberta, N., P. Masqué, J. Garcia-Orellana, R. García-Tenorio, and K. O. Buesseler (2013) ^{90}Sr and ^{89}Sr in seawater off Japan as a consequence of the Fukushima Dai-ichi nuclear accident. *Biogeosciences Discuss.,* **10**, 2039–2067.

Pike, S. M., K. O. Buesseler, C. .F. Breier, H. Dulaiova, K. Stastna, and F. Sebesta (2012) Extraction of cesium in seawater off Japan using AMP-PAN resin and quantification via gamma spectroscopy and inductively coupled mass spectrometry. *J. Radioanal. Nucl. Chem.*, doi:10.1007/s10967-012-2014-5.

^{137}Cs / ^{134}Cs / ^{90}Sr Cubitainer Contents (Niskins Sampled)

Station/Cast	Cubitainer ID	Niskins Sampled	Station/Cast	Cubitainer ID	Niskins Sampled
1/2	#20 *	9-10	56/1	#49	32-33
4/1	#21 *	22-23	60/1	#50	33-34
7/1	#22 *	32-33	64/1	#51	21-24
12/1	#23	33-34	64/1	#52	25-28
16/1	#24	32-33	64/1	#53	29-32
19/1	#25	32-33	64/1	#54	33-36
24/1	#26	33-34	67/1	#55	31-32
28/1	#27	32-33	70/1	#56	31-32
32/1	#28	33-34	72/1	#57	23-25
35/1	#29	24-26	72/1	#58	26-28
35/1	#30	27-29	72/1	#59	29-31
35/1	#31	30-32	72/1	#60	32-34, 36
35/1	#32	33-36	74/1	#61	33-34
37/1	#33	32-33	78/1	#62	24-26
39/1	#34	33-34	78/1	#63	27-29
41/1	#35	24-26	78/1	#64	30-32
41/1	#36	27-29	78/1	#65	33-36
41/1	#37	30-32	80/1	#66	33-34
41/1	#38	33-36	82/1	#67 *	31-32
44/1	#39	32-33	84/1	#68	32-33
46/1	#40	22-25	86/1	#69	23-25
46/1	#41	26-29	86/1	#70	26-28
46/1	#42	30-32	86/1	#71	29-31
46/1	#43	33-36	86/1	#72	32-34, 36
50/1	#44	33-34			
54/1	#45	24-26			
54/1	#46	27-29			
54/1	#47	30-32			
54/1	#48	33-34, 36			

* Cubitainer ID on Sample Log matches Niskins Sampled. Probably re-numbered as listed

129 Iodine sampling

PI: Tom Guilderson, UC Santa Cruz & Lawrence Livermore National Laboratory

The goal of 129I sampling is to track Fukushima derived 129I release and to describe general large-scale 129I gradient originated from the atmospheric nuclear weapons testing.

129I surface water samples were drawn routinely from Rosette casts, approximately every 2.5 degrees of longitude. In total, 27 stations were sampled (27 samples and one duplicate). Surface samples were collected in 500ml amber bottles at about 65dbar depth. Samples were taken from the same Niskins bottle for Cs samples (PI: Ken Buesseler, WHOI) since 129I/134Cs and 129I/137Cs ratio can be used positively identify the presence of Fukushima origin radionuclide. Bottles were rinsed 2-3 times with sample before filling. Electrical tape was used to seal caps and all the samples were refrigerated.

One hydrocast profile was obtained at 160°E station 46 (72 samples). Samples were collected in 250ml HDPE bottles and taken from 36 Niskin bottles. Duplicates were also taken form all 36 Niskins. Refrigerated samples will be shipping back to UC Santa Cruz at the end of leg 2.

References:

Tumey, S. J., T. P. Guilderson, T. A. Brown, T. Broek, and K. O. Buesseler (2012) Input of I-129 into the western Pacific Ocean resulting from the Fukushima nuclear event. *J. Radioanal. Nucl. Chem.*, doi:10.1007/s10967-012-2217-9.

$\delta^{15}N-NO_3$ / $\delta^{18}O-NO_3$ Sampling

752 $\delta^{15}N-NO_3$ / $\delta^{18}O-NO_3$ samples were collected during Leg 1 / P02W. Full profiles were sampled at 22 stations. Since no rack was sent with the sampling containers, a plastic bucket and packing styrofoam were modified to secure the 25 ampoules during rosette sampling. 14 ml ampoules (Niskins 1-25) or 60 ml bottles (Niskins 26-36) were minimally rinsed twice, then filled to ~85% of capacity with seawater. The samples were stored frozen in a standard commercial freezer on-board. Samples will be shipped frozen after the ship completes Leg 2 in San Diego, then analyzed at Princeton University (PI Dr. Daniel Sigman - sigman@princeton.edu).

Density Sampling

68 density samples were taken at Stations 25, 63, and 85 from the same depths as Alkalinity. Sample bottles and caps were rinsed 3 times with approximately 10 mL of water, then filled to the beginning of the neck to leave a headspace of 1-2 mL. Samples will be analyzed by Ryan Woosley (PI Dr. Frank Millero - fmillero@rsmas.miami.edu) at University of Miami at the end of the second leg of P02.

Calcium Sampling

Calcium samples were taken at Stations 55 and 84 from 18 depths with 2 duplicates at each station. Sample bottles and caps were rinsed 3 times with approximately 10 mL of water, then filled to the beginning of the neck to leave a headspace of 1-2 mL. Samples will be analyzed by John Ballard (PI Dr. Todd Martz - trmartz@ucsd.edu) at Scripps Institution of Oceanography at the end of the second leg of P02.

Katinka Bellomo
University of Miami

As a graduate student in climate dynamics, I often used data retrieved by ships at sea, though I never had a clear understanding of how the data are collected. My duties onboard involved deployment and recovery of the rosette, preparing and fixing the Niskin bottles when they had problems, taking water samples, running the CTD console, and initialize and recovery of the LADCP. We also deployed one ARGO float. These activities helped me to understand how data are taken, how instruments work, and what are the problems and errors that occur when working at sea.

The biggest challenge in climate research is to have global-scale observations. During this cruise I learned that taking measurements of the ocean properties, especially the deep ocean, is even more challenging than measuring atmospheric variables, which can be more easily retrieved by satellites and land-based instrumentation. Knowing about the ocean, however, is extremely important to climate variability and change. The heat capacity of the ocean is much larger than the atmosphere, thus the oceans can store heat much more efficiently than the atmosphere and mitigate climate changes. Moreover, ocean carbon uptake reduces the amount of carbon dioxide in the atmosphere. The P02W cruise as the other oceanic campaigns provide us with valuable information about the ocean since our knowledge of the deep ocean is limited.

Therefore, being part of a team exploring the depths of the oceans, of which the entire scientific community knows so little about, has been an extremely rewarding experience. Moreover, participating in this cruise significantly improved my understanding of at-sea measurements.

Greg Ikeda
University of Washington

It's easy to take high quality data for granted. Seemingly endless collections of samples back on land make one feel as though they're swept up in a matter of seconds, and every CTD cast is always flawless. Setting out for sea reminds the young scientist that this is rarely the case. My time aboard the R/V Melville was split between relentless troubleshooting, clumsy CTD deployment/recovery, and ultimately a heightened sense of awareness for the gritty footwork behind the scientific process.

During the cruise I was tasked with three primary jobs: maintain and take samples for an Underway Equilibrator Inlet Mass Spectrometer, monitor an underway pCO2 system, and act as a "CTD Watchstander". The two underway systems had the amicable quality of essentially running themselves, which translated to easy living peppered with massive spikes in stress and frustration when something went wrong. As a CTD watchstander, my basic responsibilities were to assist with everything CTD related, from tossing it over the side to dismantling the rosette, piece by piece. I worked alongside a cabal of scientists, other watchstanders, and technicians- all very experienced and competent at their work- and thus received a varied educational experience on board; where I would normally cast off an issue as somebody else's job, a wrench would be slapped in my hand to help with mechanical issues well beyond my skill set. From these unexpected responsibilities, and the subsequent triumphs over scientific hiccups, I gained a greater appreciation for the hundreds of unprocessed DIC samples sitting peacefully back home.

Cruz St.Peter '11
Texas A&M University

My experience as a CTD Watchstander on the R/V Melville has been great. I have been on three previous research cruises through other programs, and I can say without hesitation that this has been my favorite cruise so far. I think anyone on board would agree that Jim Swift has done a superior job as Chief Scientist and that his many stories of past cruises and his genuinely positive attitude have made him a joy to sail with. The rest of the science team, as well as the ship's crew, are the best I have experienced – especially given our ten-day delay in science operations. I have worked with CTDs and Niskin water sampling on past cruises, but my time on the Melville has only served to increase my understanding of the technical aspects regarding CTD casts. As a recent graduate I have been exploring career options along with graduate school programs in the Earth sciences, and I know that the friends and professional connections that I have made on this cruise have furthered my interest in ocean research. Many thanks to the ship's Captain and crew as well as the entire science party of P02 – Leg 1!

Amanda Waite

The CLIVAR P02W cruise aboard the R/V Melville proved to be an excellent opportunity for seagoing learning and also influential to my development as an early career (paleo)oceanographer. While my research has focused on the application of geochemical proxies to the skeletons of marine organisms for the reconstruction of oceanographic conditions through time, one of my primary goals is to integrate this paleo information with observational data in order to improve our interpretation of reconstructions from the past and future predictions of change in the world's oceans and climate. As such, P02W enabled me to participate in the collection of hydrographic data and samples and learn how these are processed, analyzed, QA/QCed, and compiled. With exceptional training and leadership from experienced (and patient) personnel, my fellow CTD watch standers and I were able to play an active role in nearly all parts of the process, from CTD/rosette assembly and preparation, to deck operations including CTD deployment and recovery, cast console operations, and the coordination and collection of water samples for a number of parameters.

I continue to be impressed and inspired by the unification of the science party and crew aboard Leg 1 of P02W in the face of numerous unfortunate equipment related challenges. The tireless efforts of the team yielded solutions to nearly all of these obstacles and allowed the science to continue uncompromised. For me, witnessing and partaking in troubleshooting many of these trials provided an invaluable platform for learning and a far deeper understanding of the technical aspects of the CTD/rosette, shipboard operations, cruise planning and adaptation than would have been achieved in a 'business as usual' scenario. My involvement with this program has given me a greater appreciation for the effort that goes in to large scale basin oriented hydrographic research and sparked numerous ideas for integrated studies which advance our understanding of water mass distribution and change in the Pacific and beyond. I see great potential for insight that may be gained from the comparison of CLIVAR data and paleo-records and feel much better equipped to effectively communicate and collaborate with the physical and chemical oceanographic communities in the future. On a personal level, this cruise has also reaffirmed my desire to continue to pursue hands on, field-based, applied research which improves our understanding of both the oceans and climate in a changing world.

Gabrielle Weiss
University of Hawaii

As we left Yokohama, Japan (for the first time) I was overjoyed at the prospect of finally getting underway and learning the various scientific procedures adopted by the technicians and scientists onboard the R/V Melville. I had been on previous research cruises before, but none had included such a wide range of measurements and techniques to better understand the physical oceanography of the North Pacific. My role was to help run CFC and SF6 samples in addition to comparing underway versus rosette water samples. This work was also new to me but a subject that I had much interest in, especially for its role as a tracer of water masses and ages as well as its potential to help understand the fate of anthropogenic carbon in the oceans. Not only was this work immensely fulfilling but also proved to be an introduction to physical oceanography that I had only briefly considered. As we began our journey everyone worked to get onto their shift schedule and as soon as we had established an efficient routine our winches took a turn for the worst requiring us to return to Yokohama, Japan for repairs. It can best be summed as a limerick:

> There once was a ship named Melville,
> It seemed she had danced with the devil,
> While trying to sample,
> Our backups weren't ample,
> Now we long for Revelle.

In spite of the troubles faced, everyone maintained a positive attitude and we left Japan for a second time. It took several days for the winches to finally operate correctly while at sea; however, the engineers worked continuously and we finally had two reliable winches. We were finally able to conduct CTD/rosette casts and really learn about the positions scientists had on the ship. Included in this were tag line and A-frame ops for equipment deployment; yet jobs ranged from sampling Niskins to analyze pH, TALK, DIC, CFCs, SF6, salts, nutrients to interpreting what the data meant. The technicians aboard were incredibly helpful, taking the time to explain the methods they employed for their specific analyses and why that process was chosen. Additionally, the STS P02 website was a great resource for studying the waters we had recently sampled and provided an exciting opportunity to look at data fresh off the press.

This trip has provided me with an incredible experience I will never forget and wish could continue longer. I could not imagine having better colleagues on a cruise and a more levelheaded, fun PI. This cruise has greatly affirmed my excitement regarding oceanography and understanding climate variability through various proxies. I know that I will use my experiences from the cruise in the future and look forward to seeing the final results that will be interpreted from the data in the near future.

Cruise Report: Shipboard ADCP measurements during CLIVAR PO2W 2013

Steven Howell

Personnel

UH LADCP group: Eric Firing (PI), Julia Hummon, and François Ascani

Shipboard operators Frank Delahoyde, SIO and Steven Howell, UH

System description

The *R/V Melville* normally has two Acoustic Doppler Current Profilers (ADCPs) mounted in instrument wells in the hull. One, a 150 kHz Teledyne RD Instruments Ocean Surveyor, was at the manufacturer for repair so was unavailable for the cruise. The other, a 75 kHz Ocean Surveyor (OS75) was present and produced data through the entire cruise (except in Japan's EEZ).

An additional ADCP, a 300 kHz Work Horse (WH300, also from Teledyne RD), was installed temporarily while the ship was in Yokohama before the cruise. it was mounted in the open instrument well on a pipe string. It was initially placed 2 feet below the hull, but two of the beams were compromised, presumably by the keel, so the assemply was lowered to 2.5 feet for the remainder of the cruise on March 23rd. A minimal extension below the hull is desirable because the pipe string tends to vibrate while steaming.

Because ship speeds are much faster than typical ocean currents, precise knowledge of the speed and orientation of the ship is required to calculate currents from the raw data. To this end, the ADCP data acquisition system gathered data from 4 additional devices: a Furuno GP-150 GPS for position, a Sperry MK 37 gyro for reliable but coarse heading, and two GPS-assisted attitude sensors for high-precision heading, an Ashtech ADU and a CodaOctopus F185 motion reference unit. The Ashtech heading was inoperative for the entire cruise, so we had to rely on the CodaOctopus, which performed well most of the time.

Data acquisition from the ADCPs and the other devices was done using UHDAS (University of Hawaii Data Acquisition System), an open source software system developed by the ADCP group at UH. It automatically updates a website on the ship's network that presents near real time plots of current depth profiles, contoured sections for the previous few days, and provides a variety of data products ranging from raw data to near-final currents. For extensive documentation about UHDAS, visit the UH ADCP web page, `http://currents.soest.hawaii.edu`.

While the output of UHDAS is suitable for shipboard use, it is by no means a final product as some manual intervention is inevitably necessary to deal with issues that arise. The data produced during the cruise must be regarded as preliminary; fully processed data will be made available within 6 months at the UH website.

Operating parameters

Both the OS75 and WH300 were operated in their default UHDAS configurations through the entire cruise.

The OS75 (CPU firmware 23.16, beam angle 30°) can operate in two modes. Narrow band pings provide greater range, while broadband pings have much better accuracy. These two ping types were alternated throughout the cruise. Bottom track mode was not used at all. Narrowband mode used nominal 16 m pings and depth ranges below an 8 m blanking interval, while the broadband mode used 8 m cells and blanking intervals. Pings were 1.8 s apart.

The WH300 (serial number 9806, firmware version 16.28, beam angle 20°) used 2 m cells and blanking intervals with 0.8 s between pings.

The following control files do not contain the entire set of commands sent to the instrument, but these are the ones most frequently changed.

OS75 control file

```
# Bottom tracking
BP0          # BP0 is off, BP1 is on
BX10000      # Max search range in decimeters; e.g. BX10000 for 1000 m.

# Narrowband watertrack
NP1          # NP0 is off, NP1 is on
NN60         # number of cells
NS1600       # cell size in centimeters; e.g. NS2400 for 24-m cells
NF800        # blanking in centimeters; e.g. NF1600 for 16-m cells

# Broadband watertrack
WP1          # WP0 is off, WP1 is on
WN80         # number of cells
WS800        # cell size in centimeters
WF800        # blanking in centimeters

# Interval between pings
TP00:01.80  # e.g., TP00:03.00 for 3 seconds
```

```
# Triggering
CX0,0       # in,out[,timeout]
```

WH300 control file

```
BP0          #  Bottom track on (BP1) or off (BP0)
BX2000       #  BT max search range in decimeters (BX02000 for 200 m)
WN70         #  number of cells
WS200        #  cell size in centimeters
WF200        #  blanking in centimeters
TP00:00.80   #  ping interval; TP00:00.80 is 0.8 seconds
```

Data gathered

Both instruments ran continuously and produced data throughout the cruise. Aside from the aforementioned lowering of the WH300 on March 23rd, the only intervention required was to start and stop logging. On station, all of the instruments generally worked very well. The WH300 profiled to 100 m or so while the OS75 broadband and narrowband modes generally reached 650 and 850 m, respectively.

Problems encountered

Steaming increases acoustic noise and vibration, reducing ADCP range. That was particularly true during this cruise, where the ship steamed faster than usual to make up for time lost due to hardware failures early on. The WH300 was particularly affected, becoming nearly useless during transits between stations. It is not clear why it had such problems; an earlier *Melville* cruise enjoyed success with a nearly identical installation. Bubbles can cause problems, but the WH position well aft and 2.5 feet below the hull makes that seem unlikely. I looked down the instrument well several times, but there appeared to be few if any bubbles coming up. The most likely explanation is vibration, but we have no direct evidence of that. Poor data quality combined with only a preliminary calibration of installation angle meant that what little current data could be retrieved was obviously flawed, with large along-track biases. It may be possible to clean up some of the data during transits, but the WH300 data should probably only be used on station.

The OS75 suffered much less during transit. Narrowband mode still exceeded 600 m while broadband sometimes had trouble below 200 m but usually managed 500 m. I understand from the First Mate, David Cook, that the *Melville* is typically ballasted so the bow rides a bit low, reducing bubble noise during transit. We appreciate this attention to our needs, and it evidently works.

While the weather was fine for most of P02W, there were a couple of episodes with high winds (up to $23\,\mathrm{m\,s^{-1}}$) and significant seas. Under those conditions the OS75 produced little useful data, as it was overwhelmed by bubbles at its forward location, even while hove to on station. Data are therefore missing for parts of April 5–6 and 18. The WH300 mounting locationwas much less vulnerable to bubbles so it has on-station data for most of those periods.

We were surprised to note occasional problems with the OS75 on station during very calm weather. There would be short periods, usually a minute or less, where the signal strength would drop to near zero. There was one extended period with this problem, from April 7–8 (UTC), when there was no signal for over 12 hours. Diagnostic tests failed to find the problem. At the moment, our best guess is that bubbles filled the instrument well, disrupting the instrument's contact with the water. The OS75 well is blind–there is no way for bubbles to exit out the top. The OS150 installation on the *Melville* suffered badly from this in previous years, so a similar situation for the OS75 is plausible. If this is really the problem, it requires venting the top of the well. The weak beam problem resolved as soon as the ship started moving. It recurred frequently thereafter, but for very short periods that will not affect the data much.

As noted above, with the Ashtech ADU heading mode unusable, UHDAS relied exclusively on the CodaOctopus F185 for precision heading. There were two occasions when the F185 lost its heading and the preprocessed ADCP data were plainly unrealistic. The first was on March 22nd, and the second was on April 30th. Processing after the cruise will correct the wild data, albeit with higher uncertainty than surrounding time periods.

The F185 had numerous very short data dropouts that will have little effect on the fully processed data.

Despite this series of small problems, gaps in the shipboard ADCP data occurred over a small fraction of the cruise, so the processed data will cover nearly the entire period.

P02W Underway pCO_2 report

Greg Ikeda

The GO 8050 underway pCO_2 system is capable of taking continuous pCO_2 measurements while the ship is underway. The system consists of several different components that prepare gas samples and standards to be sent to a detector, ultimately providing real time pCO_2 data.

Three types of gases are run through the system, consisting of: gas standards for the correction of raw data, deck air taken from a diaphragm pump, and air samples equilibrated with seawater from the underway supply. A Licor 7000 infrared analyzer is used as a CO_2 detector. It passes IR light through a reference gas cell, which is supplied with air stripped of CO_2, and a sample gas cell, which is supplied with the gas being measured. CO_2 concentrations are measured by the difference in absorption between the two cells. A linear fit between standards is used to calculate the CO_2 concentration of seawater and atmospheric samples.

For more information, contact Geoff Lebon at geoffrey.t.lebon@noaa.gov.

P02W Cruise report for EIMS system

Greg Ikeda

Background

The Equilibrator Inlet Mass Spectrometer (EIMS) system allows for continuous sampling of ion currents of Nitrogen, Oxygen, Argon, and CO_2 dissolved in seawater. The resulting samples provide real-time on O_2/Ar, N_2/Ar, and CO_2 data, which can be used to estimate net community production and pCO_2.

Samples are collected continuously from the ship's underway seawater supply. Along the cruise track, water flowed from the seawater intake into a temperature-controlled reservoir and then was subsampled through a small diameter tube that pumped underway seawater to an equilibrator cartridge. Within the graduated cylinder is a small diameter tube that pumps underway seawater to an equilibrator cartridge. The cartridge equilibrated the dissolved gases in the seawater with its headspace, which were then passed through a capillary into a mass spectrometer. Ion current measurements from the mass spectrometer reflect the partial pressure of the dissolved gases in the underway seawater intake. In addition to underway sampling, discrete ^{17}O samples were collected daily in containers that have been pre-treated with $HgCl_2$ and brought to a vacuum. The necks of these bottles are purged with N_2 gas to prevent atmospheric contamination from entering the bottle. At roughly every 2 degrees of longitude, the discrete sample of surface water is collected via the underway seawater supply. Measures are taken to prevent air from the lab from entering the sample. These samples are sent back to Paul Quay's Stable Isotope Lab (University of Washington) to calibrate EIMS O_2/Ar ratios and supplement the study of net community production.

For more information, contact Hilary Palevsky at palevsky@uw.edu

CLIVAR P02W 2013 Ship's Underway Measurements

Frank Delahoyde
SIO Shipboard Technical Support

R/V Melville has a collection of permanently installed sensors and data acquisition systems, most of which were used during P02W 2013, MV1305. The collected data consist of GPS navigation, Multibeam echosounder tracks, ADCP sections, meterological and sea surface measurements time series and gravity time series. A detailed description of these systems is included with the MV1305 data distribution.

GPS navigation data were collected from Furuno GP150, Ashtech ADU5 and CodaOctopus F185 GPS devices. The Furuno GP150 and Ashtech ADU5 data have a resolution of 1hz, and the F185 a resolution of 5 hz. The GP150 was the primary navigation device for P02W deployment positions, P02W hydrographic sections and track maps provided by the Melville bridge and by the shipboard CLIVAR website. The F185 was the primary navigation device for the EM122 multibeam and the shipboard ADCP systems.

The multibeam echosounder acoustic data were collected from a Kongsberg EM122 multibeam echosounder system running SIS 3.9.2. The EM122 was run continuously and the centerbeams used for all acoustic depth determinations on P02W. The multibeam data were corrected using sound speed profiles that were calculated from CTD deployments. Two of the 24 36-channel transmitter cards in the EM122 failed in the first week of the leg and were relocated to the outer-most beam positions. A third card failed in the third week. The card failures resulted in decreased resolution and increased noise levels but did not impact the accuracy of depth determinations. Bad weather during parts of the leg also contributed to less than optimal mapping.

ADCP data were collected from a hull-mounted RDI OS-75 ADCP and from an RDI WH300 ADCP deployed through the Melville's aft hanger pipe well. The Melville's hull-mounted NB150 ADCP was not operational and was not used. The ADCP data were acquired and processed using UHDAS from University of Hawaii.

Meteorological and sea surface measurement were made using the shipboard Met system. This system continuously makes measurements and generates a time series, which had a 15 second data period for P02W. Sea surface temperature measurements are made with two hull-mounted thermistors, (port and starboard). Other measurements, including salinity, dissolved oxygen and fluorometer, are determined by sensors located in the analytical lab. The salinity measurement is made with a SBE45 thermosalinograph (TSG), which measures temperature and conductivity and calculates PSS78 salinity. Seawater supplied to these sensors is pumped from the bow intake to the lab through CA. 30m of pipe inside the ship.

This cruise presented a unique opportunity to examine the flow characteristics of this arrangement by comparing Met system bow and analytical lab measurements to CTD surface data. CTD data from each surface bottle trip on each cast were compared to Met system data matched by time. The results of these comparisons are presented in Figure 1. The X axis on this plot is “Normalized Day”, where 0 is the time and date of the surface bottle trip on cast 1/1. The data from the first 12 stations are excluded for clarity because of the 2 week return trip to Yokohama but this doesn't significantly change the picture. The last two Y axis are differences between CTD temperature and the port and starboard hull-mounted temperature sensors. The Met sensors are in good agreement, and the major differences with CTD data occur during periods of bad weather. The first Y axis is the difference between CTD and TSG temperatures. Here, temperature differences are more extreme and distortion due to the interior ship temperature is evident. Finally, the second Y axis is the difference between CTD and TSG salinity.

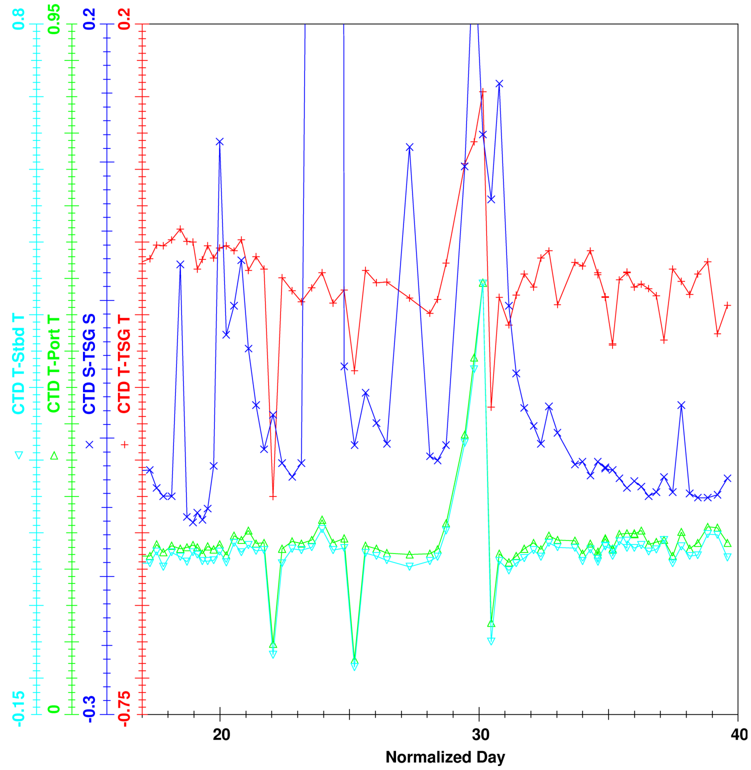

Figure 1. CTD and TSG T and S Comparisons

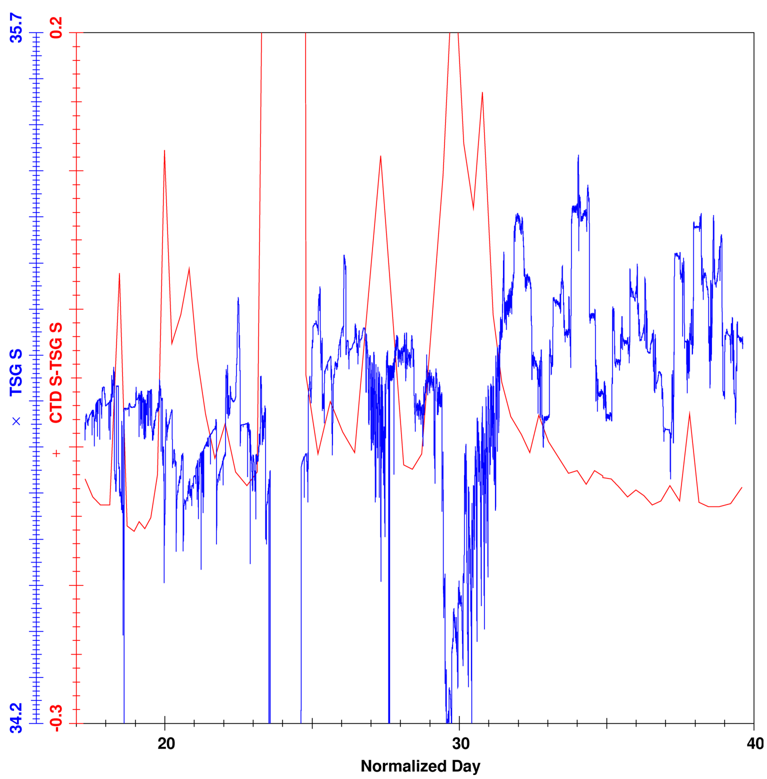

Figure 2. TSG Salinity

Figure 2 shows the difference between CTD and TSG salinity from Figure 1 on the first Y axis, and TSG salinity on the second Y axis. There are evidently some flow issues affecting TSG salinity perhaps as a result of air or bubbles becoming entrained in the seawater supply pipe.

Salinity check samples were collected to calibrate the TSG at the ends of stations 46-57 (12 check samples). The calculated calibration offset of -0.1108 PSU is consistent with the CTD differences in Figures 1 and 2 .

There were two additional Met system sensor problems on P02W. The air temperature sensor began to behave erratically on 4/19 and then returned to normal by 4/21. There have been no further problems with this sensor. The barometer sensor was reported by NOAA to have an offset of -12.0 mbars on 5/1.

Earth's gravity field measurements were also collected from the Melville's BellAero BGM-3 gravimeter.

Appendix A

CLIVAR/Carbon P02W: CTD Temperature and Conductivity Corrections Summary

Sta/ Cast	ITS-90 Temperature Coefficients corT = tp2∗corP^2 + tp1∗corP + t0			Conductivity Coefficients corC = cp1∗corP + c2∗C^2 + c1∗C + c0			
	tp2	tp1	t0	cp1	c2	c1	c0
001/02	-2.6347e-11	1.3997e-08	-0.001039	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.027718
002/01	-2.6347e-11	1.3997e-08	-0.001037	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.027712
003/01	-2.6347e-11	1.3997e-08	-0.001036	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.027704
004/01	-2.6347e-11	1.3997e-08	-0.001034	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.027694
005/01	-2.6347e-11	1.3997e-08	-0.001032	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.027683
006/01	-2.6347e-11	1.3997e-08	-0.001030	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.027672
007/01	-2.6347e-11	1.3997e-08	-0.001028	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.027659
008/01	-2.6347e-11	1.3997e-08	-0.001025	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.027644
009/01	-2.6347e-11	1.3997e-08	-0.001022	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.027627
010/01	-2.6347e-11	1.3997e-08	-0.001019	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.027609
011/01	-2.6347e-11	1.3997e-08	-0.001016	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.027593
012/01	-2.6347e-11	1.3997e-08	-0.001013	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.027576
013/05	-2.6347e-11	1.3997e-08	-0.000885	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026769
014/04	-2.6347e-11	1.3997e-08	-0.000865	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026609
015/01	-2.6347e-11	1.3997e-08	-0.000863	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026595
016/01	-2.6347e-11	1.3997e-08	-0.000862	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026581
017/01	-2.6347e-11	1.3997e-08	-0.000860	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026565
018/01	-2.6347e-11	1.3997e-08	-0.000858	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026547
019/01	-2.6347e-11	1.3997e-08	-0.000856	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026534
020/01	-2.6347e-11	1.3997e-08	-0.000855	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026521
021/01	-2.6347e-11	1.3997e-08	-0.000854	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026511
022/01	-2.6347e-11	1.3997e-08	-0.000853	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026501
023/01	-2.6347e-11	1.3997e-08	-0.000852	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026491
024/01	-2.6347e-11	1.3997e-08	-0.000851	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026481
025/01	-2.6347e-11	1.3997e-08	-0.000850	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026469
026/01	-2.6347e-11	1.3997e-08	-0.000849	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026458
027/01	-2.6347e-11	1.3997e-08	-0.000847	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026445
028/01	-2.6347e-11	1.3997e-08	-0.000846	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026432
029/01	-2.6347e-11	1.3997e-08	-0.000845	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026418
030/01	-2.6347e-11	1.3997e-08	-0.000843	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026403
031/01	-2.6347e-11	1.3997e-08	-0.000842	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026390
032/01	-2.6347e-11	1.3997e-08	-0.000841	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026373
033/01	-2.6347e-11	1.3997e-08	-0.000839	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026357
034/01	-2.6347e-11	1.3997e-08	-0.000838	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026339
035/01	-2.6347e-11	1.3997e-08	-0.000837	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026322
036/01	-2.6347e-11	1.3997e-08	-0.000835	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026304
037/01	-2.6347e-11	1.3997e-08	-0.000834	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026286
038/01	-2.6347e-11	1.3997e-08	-0.000833	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026268
039/01	-2.6347e-11	1.3997e-08	-0.000831	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026249
040/01	-2.6347e-11	1.3997e-08	-0.000830	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026231
041/01	-2.6347e-11	1.3997e-08	-0.000829	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026213
042/01	-2.6347e-11	1.3997e-08	-0.000828	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026196

Sta/ Cast	ITS-90 Temperature Coefficients $corT = tp2*corP^2 + tp1*corP + t0$ tp2	tp1	t0	Conductivity Coefficients $corC = cp1*corP + c2*C^2 + c1*C + c0$ cp1	c2	c1	c0
043/01	-2.6347e-11	1.3997e-08	-0.000827	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025979
044/01	-2.6347e-11	1.3997e-08	-0.000826	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026160
045/01	-2.6347e-11	1.3997e-08	-0.000826	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026144
046/01	-2.6347e-11	1.3997e-08	-0.000825	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026125
047/01	-2.6347e-11	1.3997e-08	-0.000825	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026113
048/01	-2.6347e-11	1.3997e-08	-0.000824	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026101
049/01	-2.6347e-11	1.3997e-08	-0.000824	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026089
050/01	-2.6347e-11	1.3997e-08	-0.000823	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026075
051/01	-2.6347e-11	1.3997e-08	-0.000823	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026061
052/01	-2.6347e-11	1.3997e-08	-0.000823	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026048
053/01	-2.6347e-11	1.3997e-08	-0.000823	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026035
054/01	-2.6347e-11	1.3997e-08	-0.000823	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026023
055/01	-2.6347e-11	1.3997e-08	-0.000823	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.026013
056/01	-2.6347e-11	1.3997e-08	-0.000823	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025999
057/01	-2.6347e-11	1.3997e-08	-0.000823	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025789
058/01	-2.6347e-11	1.3997e-08	-0.000823	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025779
059/01	-2.6347e-11	1.3997e-08	-0.000823	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025966
060/01	-2.6347e-11	1.3997e-08	-0.000823	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025956
061/01	-2.6347e-11	1.3997e-08	-0.000823	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025947
062/01	-2.6347e-11	1.3997e-08	-0.000824	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025936
063/03	-2.6347e-11	1.3997e-08	-0.000824	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025924
064/01	-2.6347e-11	1.3997e-08	-0.000824	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025913
065/01	-2.6347e-11	1.3997e-08	-0.000825	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025905
066/01	-2.6347e-11	1.3997e-08	-0.000825	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025895
067/01	-2.6347e-11	1.3997e-08	-0.000826	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025886
068/01	-2.6347e-11	1.3997e-08	-0.000826	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025877
069/01	-2.6347e-11	1.3997e-08	-0.000827	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025869
070/01	-2.6347e-11	1.3997e-08	-0.000827	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025860
071/01	-2.6347e-11	1.3997e-08	-0.000828	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025853
072/01	-2.6347e-11	1.3997e-08	-0.000828	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025844
073/01	-2.6347e-11	1.3997e-08	-0.000829	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025836
074/01	-2.6347e-11	1.3997e-08	-0.000830	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025828
075/01	-2.6347e-11	1.3997e-08	-0.000830	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025820
076/01	-2.6347e-11	1.3997e-08	-0.000831	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025812
077/01	-2.6347e-11	1.3997e-08	-0.000832	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025803
078/01	-2.6347e-11	1.3997e-08	-0.000833	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025794
079/01	-2.6347e-11	1.3997e-08	-0.000834	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025785
080/01	-2.6347e-11	1.3997e-08	-0.000835	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025777
081/01	-2.6347e-11	1.3997e-08	-0.000837	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025768
082/01	-2.6347e-11	1.3997e-08	-0.000838	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025758
083/01	-2.6347e-11	1.3997e-08	-0.000839	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025749
084/01	-2.6347e-11	1.3997e-08	-0.000841	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025740
085/01	-2.6347e-11	1.3997e-08	-0.000842	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025731
086/01	-2.6347e-11	1.3997e-08	-0.000844	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025722
087/01	-2.6347e-11	1.3997e-08	-0.000846	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025714

Appendix B

Summary of CLIVAR/Carbon P02W CTD Oxygen Time Constants

(time constants in seconds)

Pressure	Temperature		Pressure	O_2 Gradient	Velocity	Thermal
Hysteresis (τ_h)	Long(τ_{Tl})	Short(τ_{Ts})	Gradient (τ_p)	(τ_{og})	(τ_{dP})	Diffusion (τ_{dT})
50.0	300.0	4.0	0.50	8.00	200.00	300.0

CLIVAR/Carbon P02W: Conversion Equation Coefficients for CTD Oxygen

(refer to Equation 1.9.4.0)

Sta/ Cast	O_c Slope (c_1)	Offset (c_3)	P_h coeff (c_2)	T_l coeff (c_4)	T_s coeff (c_5)	P_l coeff (c_6)	$\frac{dO_c}{dt}$ coeff (c_7)	$\frac{dP}{dt}$ coeff (c_8)	T_{dT} coeff (c_9)
001/02	3.996e-04	-0.0916	3.0818	3.843e-03	1.775e-02	-9.717e-04	2.758e-03	-9.717e-04	2.093e-02
002/01	6.089e-04	-0.1999	-0.6488	-5.380e-03	8.528e-03	-2.331e-02	-1.110e-02	-2.331e-02	-3.707e-03
003/01	9.103e-04	-0.3781	0.3963	-7.222e-03	-6.974e-03	1.699e-02	3.149e-04	1.699e-02	8.599e-03
004/01	6.868e-04	-0.3955	3.4994	2.785e-02	-2.164e-02	-3.325e-02	-6.473e-03	-3.325e-02	-6.618e-03
005/01	4.593e-04	-0.2076	1.4911	2.011e-02	-1.397e-03	2.473e-02	2.634e-03	2.473e-02	-1.249e-02
006/01	5.476e-04	-0.2308	0.5031	9.997e-03	-2.586e-04	2.679e-02	1.432e-03	2.679e-02	-1.478e-03
007/01	7.453e-04	-0.3202	0.1212	-3.928e-03	8.227e-04	-3.807e-03	3.102e-03	-3.807e-03	-2.531e-03
008/01	6.258e-04	-0.2279	-0.1260	8.566e-03	-6.235e-03	-1.658e-02	-1.853e-03	-1.658e-02	2.044e-02
009/01	6.510e-04	-0.2456	-0.1116	6.802e-04	1.368e-03	-3.216e-02	5.215e-03	-3.216e-02	5.609e-03
010/01	8.316e-04	-0.4215	0.3490	-3.928e-02	3.385e-02	3.512e-02	-8.662e-03	3.512e-02	-6.686e-02
011/01	6.067e-04	-0.2033	-0.1610	1.362e-02	-9.966e-03	-1.063e-02	-1.875e-03	-1.063e-02	4.057e-02
012/01	6.643e-04	-0.2479	-0.0190	5.832e-03	-5.373e-03	-4.298e-03	-8.636e-03	-4.298e-03	2.738e-02
013/05	7.846e-04	-0.3691	0.2891	-2.558e-02	2.093e-02	1.030e-02	-3.838e-03	1.030e-02	-3.922e-02
014/04	7.412e-04	-0.3171	0.0286	-9.149e-03	6.600e-03	-4.381e-03	1.269e-03	-4.381e-03	-5.543e-03
015/01	7.206e-04	-0.3033	0.3944	1.679e-02	-2.033e-02	3.016e-02	5.264e-03	3.016e-02	3.450e-02
016/01	6.278e-04	-0.2268	-0.1997	8.951e-03	-6.284e-03	-7.943e-03	1.856e-03	-7.943e-03	2.666e-02
017/01	7.313e-04	-0.3188	0.2993	-4.633e-03	2.446e-03	2.552e-02	-2.331e-03	2.552e-02	1.712e-03
018/01	7.495e-04	-0.3905	0.8249	-1.369e-02	1.347e-02	3.132e-02	-6.008e-04	3.132e-02	-3.966e-02
019/01	7.966e-04	-0.3574	0.2733	-1.633e-02	1.010e-02	3.069e-02	-7.434e-03	3.069e-02	-6.563e-03
020/01	6.178e-04	-0.3238	0.7110	-4.254e-03	4.065e-03	3.428e-02	7.629e-04	3.428e-02	-1.802e-02
021/01	5.726e-04	-0.3286	1.0056	-3.896e-03	9.695e-03	6.057e-03	2.530e-03	6.057e-03	-5.314e-02
022/01	6.779e-04	-0.3303	0.4791	-3.294e-03	-2.568e-03	1.768e-02	3.411e-03	1.768e-02	-3.022e-03
023/01	5.861e-04	-0.2416	0.0251	5.947e-03	-6.694e-03	5.050e-03	2.462e-03	5.050e-03	2.145e-02
024/01	5.302e-04	-0.2558	0.8490	1.561e-02	-8.412e-03	1.124e-02	4.348e-04	1.124e-02	9.772e-03
025/01	5.629e-04	-0.2197	-0.1502	6.544e-03	-5.729e-03	-5.999e-03	-6.424e-03	-5.999e-03	3.321e-02
026/01	5.562e-04	-0.2303	0.1154	7.037e-03	-4.915e-03	6.293e-03	-5.348e-03	6.293e-03	2.085e-02
027/01	5.552e-04	-0.2223	0.0449	1.558e-03	2.893e-04	1.184e-02	8.508e-04	1.184e-02	2.445e-02
028/01	5.751e-04	-0.2387	0.0021	-2.355e-04	6.767e-04	8.108e-03	-3.700e-03	8.108e-03	8.630e-03
029/01	6.214e-04	-0.2782	0.2556	-5.460e-03	3.514e-03	2.936e-02	-2.056e-03	2.936e-02	3.099e-03
030/01	5.445e-04	-0.2074	-0.1635	1.163e-02	-8.566e-03	-3.644e-02	-6.262e-03	-3.644e-02	2.884e-02
031/01	6.339e-04	-0.2850	0.1302	-9.677e-03	6.261e-03	2.539e-02	-5.848e-04	2.539e-02	-1.017e-02
032/01	6.101e-04	-0.2841	0.4825	3.328e-03	-3.749e-03	3.515e-02	-2.150e-04	3.515e-02	1.044e-02
033/01	6.013e-04	-0.2445	-0.0030	9.047e-03	-1.029e-02	1.214e-03	-9.221e-04	1.214e-03	3.314e-02
034/01	5.940e-04	-0.2502	-0.0324	-9.896e-04	6.463e-04	-5.524e-03	-5.759e-03	-5.524e-03	6.818e-03
035/01	5.875e-04	-0.3018	0.8036	-1.118e-03	4.105e-03	4.894e-02	-2.166e-03	4.894e-02	-2.082e-02
036/01	5.929e-04	-0.2506	-0.0734	-2.806e-03	2.942e-03	-2.264e-02	-4.246e-03	-2.264e-02	-4.202e-03

Sta/ Cast	O_c Slope (c_1)	Offset (c_3)	P_h coeff (c_2)	T_l coeff (c_4)	T_s coeff (c_5)	P_l coeff (c_6)	$\frac{dO_c}{dt}$ coeff (c_7)	$\frac{dP}{dt}$ coeff (c_8)	T_{dT} coeff (c_9)
037/01	6.263e-04	-0.3666	1.0382	-4.046e-02	4.313e-02	2.210e-02	-7.637e-03	2.210e-02	-1.082e-01
038/01	5.677e-04	-0.2273	-0.0685	5.473e-03	-3.834e-03	2.592e-03	-1.269e-03	2.592e-03	2.533e-02
039/01	5.730e-04	-0.2333	-0.0433	1.172e-02	-1.040e-02	-2.550e-03	-3.052e-03	-2.550e-03	2.938e-02
040/01	5.843e-04	-0.2435	0.0188	3.968e-03	-3.310e-03	1.260e-02	-8.967e-03	1.260e-02	1.280e-02
041/01	5.859e-04	-0.2397	-0.0699	6.289e-03	-5.929e-03	-8.747e-03	-5.336e-03	-8.747e-03	2.001e-02
042/01	5.944e-04	-0.2410	0.0535	2.103e-02	-2.197e-02	2.379e-03	1.883e-03	2.379e-03	4.981e-02
043/01	5.784e-04	-0.2361	0.0009	2.769e-03	-1.380e-03	9.303e-03	2.359e-04	9.303e-03	1.774e-02
044/01	6.205e-04	-0.2910	0.4881	-4.102e-03	3.267e-03	1.602e-02	3.112e-04	1.602e-02	-1.339e-02
045/01	5.942e-04	-0.2529	0.1088	1.584e-03	-1.279e-03	2.419e-02	-4.092e-03	2.419e-02	1.623e-02
046/01	5.833e-04	-0.2524	0.3557	8.073e-03	-6.946e-03	5.400e-02	2.745e-03	5.400e-02	3.165e-02
047/01	6.210e-04	-0.2843	0.2874	-3.408e-05	-1.017e-03	2.974e-02	7.227e-04	2.974e-02	-1.212e-03
048/01	5.894e-04	-0.2394	-0.0634	2.626e-03	-2.536e-03	6.738e-03	2.922e-03	6.738e-03	1.442e-02
049/01	5.841e-04	-0.2982	0.8232	-2.495e-03	6.214e-03	4.192e-02	7.850e-04	4.192e-02	-1.861e-02
050/01	6.228e-04	-0.3149	0.6370	-1.637e-02	1.665e-02	4.290e-02	-4.425e-03	4.290e-02	-2.954e-02
051/01	5.838e-04	-0.2654	0.4685	9.509e-03	-7.340e-03	4.337e-02	-2.089e-03	4.337e-02	2.820e-02
052/01	6.005e-04	-0.3051	0.7748	3.266e-03	-1.002e-03	4.055e-02	-1.741e-03	4.055e-02	-3.787e-03
053/01	6.366e-04	-0.2800	0.1280	-1.928e-02	1.685e-02	1.581e-02	-5.188e-03	1.581e-02	-1.131e-02
054/01	5.832e-04	-0.3235	1.1047	-4.642e-03	1.062e-02	2.483e-02	-4.068e-03	2.483e-02	-3.240e-02
055/01	6.578e-04	-0.3008	0.3101	1.003e-03	-4.869e-03	1.513e-02	4.551e-05	1.513e-02	6.339e-03
056/01	6.247e-04	-0.2845	0.3268	-5.848e-03	4.880e-03	3.260e-02	1.785e-03	3.260e-02	3.806e-03
057/01	6.165e-04	-0.2735	0.1877	-6.264e-03	5.560e-03	2.287e-02	-2.238e-03	2.287e-02	-2.740e-03
058/01	5.751e-04	-0.2302	-0.0168	1.596e-02	-1.502e-02	4.946e-02	-1.445e-02	4.946e-02	4.645e-02
059/01	6.323e-04	-0.2753	0.0778	-2.607e-03	5.854e-04	-1.533e-05	-3.738e-03	-1.533e-05	4.688e-03
060/01	6.390e-04	-0.2893	0.2769	-9.915e-03	7.719e-03	9.950e-03	-9.224e-03	9.950e-03	-7.566e-03
061/01	6.413e-04	-0.2868	0.2333	-6.654e-03	4.360e-03	1.020e-02	5.964e-05	1.020e-02	4.522e-04
062/01	6.050e-04	-0.2560	0.1227	1.350e-02	-1.447e-02	7.040e-03	-1.586e-02	7.040e-03	3.653e-02
063/03	5.829e-04	-0.2937	0.8174	5.469e-03	-1.541e-03	2.717e-02	-1.143e-03	2.717e-02	-6.912e-03
064/01	5.779e-04	-0.2380	-0.0772	-1.802e-03	3.160e-03	-3.077e-03	4.889e-03	-3.077e-03	-3.344e-03
065/01	5.876e-04	-0.2803	0.5682	3.505e-03	-1.399e-03	2.499e-02	-1.013e-02	2.499e-02	-9.879e-03
066/01	5.953e-04	-0.2905	0.7118	1.545e-02	-1.330e-02	3.514e-03	1.400e-03	3.514e-03	1.426e-02
067/01	6.113e-04	-0.2606	0.1077	1.546e-02	-1.665e-02	7.422e-03	1.370e-03	7.422e-03	3.728e-02
068/01	6.293e-04	-0.2739	0.0737	-8.830e-03	6.566e-03	9.234e-03	3.825e-03	9.234e-03	-8.396e-03
069/01	6.377e-04	-0.2846	0.2163	-2.972e-03	7.374e-05	1.383e-02	2.089e-03	1.383e-02	3.613e-03
070/01	6.070e-04	-0.2790	0.4471	1.241e-02	-1.197e-02	2.803e-03	2.230e-03	2.803e-03	2.186e-02
071/01	6.039e-04	-0.2583	0.1184	4.945e-03	-5.362e-03	1.693e-02	-4.905e-03	1.693e-02	1.967e-02
072/01	6.114e-04	-0.2814	0.2954	-9.042e-03	9.401e-03	2.397e-02	5.028e-04	2.397e-02	-1.733e-02
073/01	6.410e-04	-0.2747	0.0447	-4.529e-03	9.636e-04	-5.022e-03	-3.328e-03	-5.022e-03	1.223e-03
074/01	6.183e-04	-0.2600	0.0585	8.893e-03	-1.073e-02	-8.004e-04	9.954e-03	-8.004e-04	2.284e-02
075/01	6.126e-04	-0.2718	0.3918	4.226e-03	-4.854e-03	2.753e-02	3.333e-03	2.753e-02	2.711e-02
076/01	5.908e-04	-0.2486	-0.0722	-3.259e-02	3.372e-02	1.395e-02	-3.340e-03	1.395e-02	-2.539e-02
077/01	5.190e-04	-0.2912	1.3692	2.114e-02	-9.648e-03	6.228e-02	1.641e-02	6.228e-02	-5.215e-03
078/01	6.035e-04	-0.2710	0.2845	2.653e-04	7.646e-05	3.257e-02	6.393e-03	3.257e-02	3.035e-03
079/01	6.488e-04	-0.2853	0.1709	8.365e-03	-1.180e-02	8.172e-04	4.428e-03	8.172e-04	2.122e-02
080/01	6.129e-04	-0.2631	0.1327	7.027e-03	-7.696e-03	8.747e-03	8.419e-04	8.747e-03	2.793e-02
081/01	6.147e-04	-0.2915	0.6658	1.043e-02	-1.035e-02	1.587e-02	2.237e-04	1.587e-02	1.369e-02
082/01	6.168e-04	-0.2723	0.1482	-3.248e-03	2.435e-03	1.855e-02	-1.480e-03	1.855e-02	2.982e-03
083/01	5.894e-04	-0.2455	-0.1023	-9.014e-03	9.982e-03	-2.225e-02	-7.703e-04	-2.225e-02	-1.636e-02
084/01	5.744e-04	-0.2411	-0.0316	-1.251e-02	1.444e-02	1.150e-02	-6.268e-03	1.150e-02	-2.533e-02

Sta/ Cast	O_c Slope (c_1)	Offset (c_3)	P_h coeff (c_2)	T_l coeff (c_4)	T_s coeff (c_5)	P_l coeff (c_6)	$\frac{dO_c}{dt}$ coeff (c_7)	$\frac{dP}{dt}$ coeff (c_8)	T_{dT} coeff (c_9)
085/01	6.173e-04	-0.2602	-0.0313	-1.795e-04	-1.716e-03	-3.911e-03	5.345e-03	-3.911e-03	3.868e-03
086/01	6.162e-04	-0.2682	0.1876	3.656e-03	-4.691e-03	3.209e-02	1.942e-04	3.209e-02	1.942e-02
087/01	6.148e-04	-0.2685	0.2210	5.091e-03	-5.686e-03	1.645e-02	-1.903e-04	1.645e-02	2.203e-02

Appendix C

CLIVAR/Carbon P02W: Bottle Quality Comments

Comments from the Sample Logs and the results of STS/ODF's data investigations are included in this report. Units stated in these comments are degrees Celsius for temperature, Unless otherwise noted, milliliters per liter for oxygen and micromoles per liter for Silicate, Nitrate, Nitrite, and Phosphate. The sample number is the cast number times 100 plus the bottle number. Investigation of data may include comparison of bottle salinity and oxygen data with CTD data, review of data plots of the station profile and adjoining stations, and re-reading of charts (i.e. nutrients).

Station /Cast	Sample No.	Property	Quality Code	Comment
1/2	201	salt	2	Ending worm bad, 4 attempts for a reading, first two appeared good and were used.
1/2	202	reft	3	SBE35RT +0.025/+0.02 vs CTDT1/CTDT2; somewhat unstable SBE35RT reading in a gradient.
1/2	202	salt	2	Ending worm bad, 4 attempts for a reading, first two appeared good and were used.
1/2	203	salt	2	Ending worm bad, 4 attempts for a reading, first two appeared good and were used.
1/2	204	salt	3	Bottle salinity 0.011 high, no problems noted by analyst
1/2	205	salt	2	Ending worm bad, 4 attempts for a reading, first two appeared good and were used.
1/2	206	salt	2	Ending worm bad, 4 attempts for a reading, first two appeared good and were used.
1/2	207	salt	2	Ending worm bad, 4 attempts for a reading, first two appeared good and were used.
1/2	208	salt	2	Ending worm bad, 4 attempts for a reading, first two appeared good and were used.
2/1	115	bottle	9	"empty, did not close (jammed)"
3/1	114	bottle	3	"slight leak O-ring on 14"
3/1	115	reft	3	SBE35RT -0.08/-0.06 vs CTDT1/CTDT2; unstable SBE35RT reading in gradient.
4/1	118	o2	2	Bottle O2 12 umol/kg high, matches upcast
5/1	115	bottle	4	O2 Draw temp high; O2, nutrients and salt indicate bottle closed shallower than expected; mistrip.
5/1	115	no2	4	Bottle mistrip, nutrients do not fit profile
5/1	115	no3	4	Bottle mistrip, nutrients do not fit profile
5/1	115	o2	4	Bottle mistrip, o2 does not fit profile, o2 was 65.61 too high
5/1	115	po4	4	Bottle mistrip, nutrients do not fit profile
5/1	115	salt	4	Bottle mistrip, salt does not fit profile, 0.493 high
5/1	115	sio3	4	Bottle mistrip, nutrients do not fit profile
6/1	124	reft	3	SBE35RT +0.04/+0.045 vs CTDT1/CTDT2; unstable SBE35RT reading in a gradient.
7/1	115	bottle	4	O2 and nutrients indicate bottle closed shallower than expected; mistrip.
7/1	115	no2	4	Bottle mistrip, nutrients do not fit profile
7/1	115	no3	4	Bottle mistrip, nutrients do not fit profile
7/1	115	o2	4	Bottle mistrip, o2 11 umol/kg too high and does not fit profile
7/1	115	po4	4	Bottle mistrip, nutrients do not fit profile
7/1	115	salt	4	Bottle mistrip, salt -0.07 vs CTDS1/CTDS2.
7/1	115	sio3	4	Bottle mistrip, nutrients do not fit profile

Station /Cast	Sample No.	Property	Quality Code	Comment
7/1	127	o2	2	Bottle O2 14 umol/kg high, matches upcast
8/1	133	reft	3	SBE35RT -0.075/-0.085 vs CTDT1/CTDT2; very unstable reading, in a gradient.
10/1	106	bottle	4	bottom lanyard disconnected, bottom end cap may have been closed for duration of cast, O2 and salinity values off
10/1	106	no2	4	Bottle did not close properly
10/1	106	no3	4	Bottle did not close properly
10/1	106	o2	3	Discrete value 2 umol/kg high. Likely sampling error.
10/1	106	po4	4	Bottle did not close properly
10/1	106	salt	4	Deep salinity 0.002 low, bottle issues noted
10/1	106	sio3	4	Bottle did not close properly
10/1	127	o2	2	bottle o2 19 umol/kg high vs CTDOXY; agrees with upcast CTDO, data ok.
10/1	131	o2	2	bottle o2 11 umol/kg low vs CTDOXY; agrees with upcast CTDO, data ok.
11/1	122	bottle	3	"vent open prior to sampling"
12/1	102	bottle	3	vents and spigots left open on niskins 2 through 6, all streaming water during rosette recovery. None were sampled.
12/1	103	bottle	3	vents and spigots left open on niskins 2 through 6, all streaming water during rosette recovery. None were sampled.
12/1	104	bottle	3	vents and spigots left open on niskins 2 through 6, all streaming water during rosette recovery. None were sampled.
12/1	105	bottle	3	vents and spigots left open on niskins 2 through 6, all streaming water during rosette recovery. None were sampled.
12/1	106	bottle	3	vents and spigots left open on niskins 2 through 6, all streaming water during rosette recovery. None were sampled.
12/1	126	salt	2	Samples in wrong order in box, sample bottle numbers appear to correspond to Niskin bottle number, sample numbers changed and now fit CTDS profile
12/1	127	salt	2	Samples in wrong order in box, sample bottle numbers appear to correspond to Niskin bottle number, sample numbers changed and now fit CTDS profile
12/1	128	salt	2	Samples in wrong order in box, sample bottle numbers appear to correspond to Niskin bottle number, sample numbers changed and now fit CTDS profile
13/5	501	bottle	3	Leaking due to unset O-ring on valve
13/5	501	no2	4	Bottle leaking, nutrient analyst reports that nutrients do not fit profile
13/5	501	no3	4	Bottle leaking, nutrient analyst reports that nutrients do not fit profile
13/5	501	o2	4	Bottle leaking, bottle o2 does not fit profile, -23 umol/kg too low
13/5	501	po4	4	Bottle leaking, nutrient analyst reports that nutrients do not fit profile
13/5	501	salt	4	Bottle leaking, bottle salinity -0.05 vs CTDS1/CTDS2.
13/5	501	sio3	4	Bottle leaking, nutrient analyst reports that nutrients do not fit profile
13/5	521	reft	3	SBE35RT -0.08/-0.09 vs CTDT1/CTDT2; unstable SBE35RT reading in a gradient.
13/5	529	o2	2	bottle o2 18 umol/kg low vs CTDOXY; agrees with upcast CTDO, data ok.
13/5	531	o2	2	O2 matches a feature in CTD o2, data ok.
13/5	536	bottle	2	surface bottle tripped on-the-fly.
14/4	404	bottle	4	O2 and Nutrients indicate bottle closed shallower than expected; mistrip.
14/4	404	no2	4	Bottle mistrip
14/4	404	no3	4	Bottle mistrip
14/4	404	o2	4	Oxygen 13 umol/kg low, bottle mistrip
14/4	404	po4	4	Bottle mistrip
14/4	404	salt	4	Bottle mistrip, 0.014 low
14/4	404	sio3	4	Bottle mistrip
14/4	405	bottle	3	Damage on bottle near O-ring seat, bottle replaced with s/n 37 before station 15

Station /Cast	Sample No.	Property	Quality Code	Comment
14/4	405	no2	4	Bottle leaking
14/4	405	no3	4	Bottle leaking
14/4	405	o2	4	Oxygen 92 umol/kg low, bottle leaking at o-ring.
14/4	405	po4	4	Bottle leaking
14/4	405	salt	4	Bottle leaking, 0.275 low
14/4	405	sio3	4	Bottle leaking
14/4	406	bottle	4	O2 Draw temp high, O2 and Nutrients indicate bottle closed shallower than expected; mistrip.
14/4	406	no2	4	Bottle mistrip
14/4	406	no3	4	Bottle mistrip
14/4	406	o2	4	Oxygen 54 umol/kg high, mistrip
14/4	406	po4	4	Bottle mistrip
14/4	406	salt	4	Bottle mistrip, 0.061 low
14/4	406	sio3	4	Bottle mistrip
14/4	408	salt	3	Deep bottle salinity +0.003 compared to CTDS1/CTDS2.
14/4	411	salt	3	Deep bottle salinity +0.004 compared to CTDS1/CTDS2.
14/4	413	bottle	4	O2 and Nutrients indicate bottle closed shallower than expected; mistrip.
14/4	413	no2	4	Bottle mistrip
14/4	413	no3	4	Bottle mistrip
14/4	413	o2	4	Oxygen 25 umol/kg low, bottle mistrip
14/4	413	po4	4	Bottle mistrip
14/4	413	salt	4	Bottle mistrip, 0.199 low
14/4	413	sio3	4	Bottle mistrip
14/4	414	bottle	4	O2 and Nutrients indicate bottle closed shallower than expected; mistrip.
14/4	414	no2	4	Bottle mistrip
14/4	414	no3	4	Bottle mistrip
14/4	414	o2	4	Oxygen 8 umol/kg low, bottle mistrip
14/4	414	po4	4	Bottle mistrip
14/4	414	salt	4	Bottle mistrip, 0.051 low
14/4	414	sio3	4	Bottle mistrip
14/4	425	reft	3	SBE35RT -0.03/-0.04 vs CTDT1/CTDT2; somewhat unstable SBE35RT reading in a gradient.
15/1	102	bottle	4	O2 and Nutrients indicate bottle closed shallower than expected: mistrip
15/1	102	no2	4	Bottle mistrip
15/1	102	no3	4	Bottle mistrip
15/1	102	o2	4	Discrete o2 is approx. 15 umol/kg low, consistent with a mistrip
15/1	102	po4	4	Bottle mistrip
15/1	102	salt	4	Bottle mistrip, 0.020 low
15/1	102	sio3	4	Bottle mistrip
15/1	114	bottle	4	O2 and Nutrients indicate bottle closed shallower than expected: mistrip
15/1	114	no2	4	Bottle mistrip
15/1	114	no3	4	Bottle mistrip
15/1	114	o2	4	Discrete o2 is approx. 20 umol/kg low, consistent with a mistrip
15/1	114	po4	4	Bottle mistrip
15/1	114	salt	4	Bottle mistrip, 0.101 low
15/1	114	sio3	4	Bottle mistrip
15/1	117	bottle	9	Sample Log: "Bottle 17 did not trip".
15/1	124	bottle	4	O2 and Nutrients indicate bottle closed shallower than expected: mistrip
15/1	124	no2	4	Bottle mistrip
15/1	124	no3	4	Bottle mistrip
15/1	124	o2	4	Discrete o2 is approx. 20 umol/kg high, consistent with a mistrip

Station /Cast	Sample No.	Property	Quality Code	Comment
15/1	124	po4	4	Bottle mistrip
15/1	124	salt	4	Bottle mistrip, 0.087 high
15/1	124	sio3	4	Bottle mistrip
15/1	128	reft	3	SBE35RT -0.04/-0.03 vs CTDT1/CTDT2; unstable SBE35RT reading in a gradient.
16/1	130	o2	2	O2 matches feature in CTD data, ok.
17/1	106	salt	3	Deep bottle salinity 0.0025 high vs CTDS1/CTDS2
17/1	123	reft	3	SBE35RT -0.03/-0.02 vs CTDT1/CTDT2; unstable SBE35RT reading in a gradient.
17/1	125	reft	3	SBE35RT +0.03/+0.01 vs CTDT1/CTDT2; somewhat unstable SBE35RT reading in a gradient.
18/1	113	bottle	4	O2 and Nutrients indicate bottle closed shallower than expected: mistrip
18/1	113	no2	4	Bottle mistrip
18/1	113	no3	4	Bottle mistrip
18/1	113	o2	4	O2 8 umol/kg high, consistent with a mistrip.
18/1	113	po4	4	Bottle mistrip
18/1	113	salt	4	Bottle mistrip, 0.241 low
18/1	113	sio3	4	Bottle mistrip
18/1	136	bottle	3	"leakage due to no o-ring on top cap"
19/1	115	bottle	4	O2 draw Temp, O2, nutrients and salinity indicate bottle closed shallower than expected: mistrip.
19/1	115	no2	4	Bottle mistrip
19/1	115	no3	4	Bottle mistrip
19/1	115	o2	4	O2 127 umol/kg high, mistrip
19/1	115	po4	4	Bottle mistrip
19/1	115	salt	4	Bottle mistrip, 0.092 low
19/1	115	sio3	4	Bottle mistrip
19/1	120	reft	3	SBE35RT -0.03/-0.04 vs CTDT1/CTDT2; very unstable SBE35RT reading in a gradient.
20/1	131	bottle	4	O2, PO4, and salts indicate bottle closed near surface, shallower than expected; mistrip.
20/1	131	no2	4	Bottle mistrip
20/1	131	no3	4	Bottle mistrip
20/1	131	o2	4	Bottle mistrip, o2 approx 3 umol/kg low
20/1	131	po4	4	Bottle mistrip
20/1	131	salt	4	Bottle mistrip, 0.068 low
20/1	131	sio3	4	Bottle mistrip
21/1	115	bottle	4	O2 and nutrients indicate bottle closed 75m shallower than expected: mistrip
21/1	115	no2	4	Bottle mistrip
21/1	115	no3	4	Bottle mistrip
21/1	115	o2	4	O2 13 umol/kg high. Likely mistrip.
21/1	115	po4	4	Bottle mistrip
21/1	115	salt	4	Bottle mistrip, 0.005 low
21/1	115	sio3	4	Bottle mistrip
21/1	122	salt	4	Bottle salinity 0.010 high, analyst notes that "thimble loose when cap removed, very wet. Possible contamination"
22/1	102	reft	3	SBE35RT -0.01/-0.01 vs CTDT1/CTDT2; very unstable SBE35RT reading in a deep gradient.
22/1	105	bottle	4	O2 and nutrients indicate bottle closed shallower than expected; mistrip.
22/1	105	no2	4	Bottle mistrip
22/1	105	no3	4	Bottle mistrip

Station /Cast	Sample No.	Property	Quality Code	Comment
22/1	105	o2	4	Bottle mistrip, O2 8 umol/kg low
22/1	105	po4	4	Bottle mistrip
22/1	105	salt	4	Bottle mistrip, 0.028 low
22/1	105	sio3	4	Bottle mistrip
22/1	122	bottle	4	Leaking, lower O-ring fouled
23/1	105	bottle	9	Niskin did not close.
23/1	106	bottle	4	O2 and nutrients indicate bottle closed shallower than expected; mistrip.
23/1	106	no2	4	Bottle mistrip.
23/1	106	no3	4	Bottle mistrip.
23/1	106	o2	4	Bottle mistrip. O2 30 umol/kg low
23/1	106	po4	4	Bottle mistrip.
23/1	106	salt	4	Bottle mistrip. 0.079 low
23/1	106	sio3	4	Bottle mistrip.
23/1	107	bottle	4	O2 and nutrients indicate bottle closed shallower than expected; mistrip.
23/1	107	no2	4	Bottle mistrip.
23/1	107	no3	4	Bottle mistrip.
23/1	107	o2	4	Bottle mistrip. O2 6 umol/kg low
23/1	107	po4	4	Bottle mistrip.
23/1	107	salt	4	Bottle mistrip. 0.011 low
23/1	107	sio3	4	Bottle mistrip.
23/1	115	bottle	4	O2 and nutrients indicate bottle closed shallower than expected; mistrip.
23/1	115	no2	4	Bottle mistrip.
23/1	115	no3	4	Bottle mistrip.
23/1	115	o2	4	Bottle mistrip. 02 8 umol/kg high
23/1	115	po4	4	Bottle mistrip.
23/1	115	salt	4	Bottle mistrip. 0.060 low
23/1	115	sio3	4	Bottle mistrip.
24/1	126	salt	5	analyst reports that sample bottle was empty
26/1	107	bottle	4	O2 low, po4 high, indicate bottle closed shallower than expected: mistrip
26/1	107	no2	4	Bottle mistrip.
26/1	107	no3	4	Bottle mistrip.
26/1	107	o2	4	Bottle mistrip.
26/1	107	po4	4	Bottle mistrip.
26/1	107	salt	4	Bottle mistrip. 0.008 low
26/1	107	sio3	4	Bottle mistrip.
26/1	115	bottle	4	Salt and nutrients indicate bottle closed shallower than expected (near bottle 16 depth): mistrip
26/1	115	no2	4	Bottle mistrip
26/1	115	no3	4	Bottle mistrip
26/1	115	o2	4	Bottle mistrip
26/1	115	po4	4	Bottle mistrip
26/1	115	salt	4	Salt -0.055 vs CTDS1/CTDS2.
26/1	115	sio3	4	Bottle mistrip
26/1	130	o2	2	Bottle O2 12 umol/kg high, matches upcast
26/1	131	o2	2	Bottle O2 15 umol/kg high, matches upcast
26/1	132	o2	2	Bottle O2 8 umol/kg high, matches upcast
27/1	101	salt	4	Salinity 0.008 high at bottom, analyst notes that "thimble popped"
27/1	104	bottle	2	Bottle 4 tripped on-the-fly slightly shallower than bottle 3; operator error.
27/1	105	bottle	4	O2 and nutrients indicate bottle closed shallower than expected; mistrip.
27/1	105	no2	4	Bottle mistrip
27/1	105	no3	4	Bottle mistrip

Station /Cast	Sample No.	Property	Quality Code	Comment
27/1	105	o2	4	Bottle mistrip, o2 9 umol/kg low
27/1	105	po4	4	Bottle mistrip
27/1	105	salt	4	Bottle mistrip, 0.007 low
27/1	105	sio3	4	Bottle mistrip
27/1	111	salt	3	Salinity 0.008 low in low gradient, no issues noted by analyst
27/1	115	bottle	9	Bottle did not close
27/1	122	reft	3	SBE35RT +0.025 vs CTDT1/CTDT2; in a gradient.
27/1	125	reft	3	SBE35RT -0.095/-0.07 vs CTDT1/CTDT2; somewhat unstable SBE35RT reading in a gradient.
27/1	125	salt	2	Samples were in wrong order in case, run in reverse order, fixed in data file
27/1	126	salt	2	Samples were in wrong order in case, run in reverse order, fixed in data file
27/1	127	salt	2	Samples were in wrong order in case, run in reverse order, fixed in data file
27/1	128	salt	2	Samples were in wrong order in case, run in reverse order, fixed in data file
27/1	129	salt	2	Samples were in wrong order in case, run in reverse order, fixed in data file
27/1	136	bottle	2	No soak at surface trip.
28/1	115	bottle	4	O2 Draw Temp about 1 degree elevated; O2 and nutrients indicate bottle closed shallower than expected (750-800m): mistrip
28/1	115	no2	4	Bottle mistrip
28/1	115	no3	4	Bottle mistrip
28/1	115	o2	4	Bottle mistrip, o2 approx 74 umol/kg high
28/1	115	po4	4	Bottle mistrip
28/1	115	salt	4	Bottle mistrip, 0.309 low
28/1	115	sio3	4	Bottle mistrip
28/1	126	o2	2	bottle o2 24 umol/kg low vs CTDOXY: agrees with upcast, data ok.
28/1	127	o2	2	bottle o2 19 umol/kg low vs CTDOXY: agrees with upcast, data ok.
28/1	136	bottle	4	O2 Draw Temp, O2 and nutrients indicate bottle closed deeper than expected (650-700m): mistrip. (Top o-ring was found unseated/fixed; but that would not cause a pre-trip.)
28/1	136	no2	4	Bottle mistrip
28/1	136	no3	4	Bottle mistrip
28/1	136	o2	4	Bottle mistrip, o2 approx 87 umol/kg low
28/1	136	po4	4	Bottle mistrip
28/1	136	salt	4	Bottle mistrip, 0.067 low
28/1	136	sio3	4	Bottle mistrip
29/1	115	bottle	4	O2, nutrients and salt indicate bottle closed shallower than expected: mistrip
29/1	115	no2	4	Bottle mistrip
29/1	115	no3	4	Bottle mistrip
29/1	115	o2	4	Bottle mistrip, o2 approx 10 umol/kg high
29/1	115	po4	4	Bottle mistrip
29/1	115	salt	4	Bottle mistrip, 0.319 low
29/1	115	sio3	4	Bottle mistrip
29/1	128	o2	5	Operator error. Sample lost.
29/1	129	o2	5	Operator error. Sample lost.
29/1	130	o2	2	Bottle O2 10 umol/kg low, matches upcast
30/1	101	bottle	4	O2, nutrients and salt indicate bottle closed shallower than expected: mistrip
30/1	101	no2	4	Bottle mistrip
30/1	101	no3	4	Bottle mistrip
30/1	101	o2	4	Bottle mistrip, Oxygen 28 umol/kg low
30/1	101	po4	4	Bottle mistrip
30/1	101	salt	4	Bottle mistrip, 0.020 low
30/1	101	sio3	4	Bottle mistrip

Station /Cast	Sample No.	Property	Quality Code	Comment
30/1	104	bottle	4	O2, nutrients and salt indicate bottle closed shallower than expected: mistrip
30/1	104	no2	4	Bottle mistrip
30/1	104	no3	4	Bottle mistrip
30/1	104	o2	4	Bottle mistrip, Oxygen 48 umol/kg low
30/1	104	po4	4	Bottle mistrip
30/1	104	salt	4	Bottle mistrip, 0.040 low
30/1	104	sio3	4	Bottle mistrip
30/1	105	bottle	4	O2, nutrients and salt indicate bottle closed shallower than expected: mistrip
30/1	105	no2	4	Bottle mistrip
30/1	105	no3	4	Bottle mistrip
30/1	105	o2	4	Bottle mistrip, Oxygen 117 umol/kg low
30/1	105	po4	4	Bottle mistrip
30/1	105	salt	4	Bottle mistrip, 0.314 low
30/1	105	sio3	4	Bottle mistrip
30/1	107	bottle	4	O2, nutrients and salt indicate bottle closed shallower than expected: mistrip
30/1	107	no2	4	Bottle mistrip
30/1	107	no3	4	Bottle mistrip
30/1	107	o2	4	Bottle mistrip, Oxygen 102 umol/kg low
30/1	107	po4	4	Bottle mistrip
30/1	107	salt	4	Bottle mistrip, 0.303 low
30/1	107	sio3	4	Bottle mistrip
30/1	113	bottle	9	Bottle did not close.
30/1	115	bottle	2	trip 14/15 at same depth for bottle 15 integrity check.
31/1	101	bottle	4	O2, nutrients and salt indicate bottle closed shallower than expected: mistrip
31/1	101	no2	4	Bottle mistrip
31/1	101	no3	4	Bottle mistrip
31/1	101	o2	4	Bottle mistrip, Oxygen 112 umol/kg low.
31/1	101	po4	4	Bottle mistrip
31/1	101	salt	4	Bottle mistrip, 0.467 low
31/1	101	sio3	4	Bottle mistrip
31/1	106	bottle	4	O2, nutrients and salt indicate bottle closed shallower than expected: mistrip
31/1	106	no2	4	Bottle mistrip
31/1	106	no3	4	Bottle mistrip
31/1	106	o2	4	Bottle mistrip, Oxygen 82 umol/kg high.
31/1	106	po4	4	Bottle mistrip
31/1	106	salt	4	Bottle mistrip, 0.052 high
31/1	106	sio3	4	Bottle mistrip
31/1	107	bottle	4	O2, nutrients and salt indicate bottle closed shallower than expected: mistrip
31/1	107	no2	4	Bottle mistrip
31/1	107	no3	4	Bottle mistrip
31/1	107	o2	4	Bottle mistrip, Oxygen 88 umol/kg low.
31/1	107	po4	4	Bottle mistrip
31/1	107	salt	4	Bottle mistrip, 0.146 low
31/1	107	sio3	4	Bottle mistrip
31/1	115	bottle	4	trip 14/15 at same depth for bottle 15 integrity check. O2, nutrients and salt indicate bottle closed shallower than expected: mistrip
31/1	115	no2	4	Bottle mistrip
31/1	115	no3	4	Bottle mistrip
31/1	115	o2	4	Bottle mistrip, Oxygen 129 umol/kg high.
31/1	115	po4	4	Bottle mistrip
31/1	115	salt	4	Bottle mistrip, 0.079 high

Station /Cast	Sample No.	Property	Quality Code	Comment
31/1	115	sio3	4	Bottle mistrip
31/1	123	reft	3	SBE35RT +0.035/+0.02 vs CTDT1/CTDT2; very unstable SBE35RT reading in a gradient.
32/1	102	bottle	4	O2 and nutrients indicate bottle closed shallower than expected: mistrip
32/1	102	no2	4	Bottle mistrip
32/1	102	no3	4	Bottle mistrip
32/1	102	o2	4	Bottle mistrip, O2 79 umol/kg low.
32/1	102	po4	4	Bottle mistrip
32/1	102	salt	4	Bottle mistrip, 0.096 low
32/1	102	sio3	4	Bottle mistrip
32/1	105	bottle	4	O2 and nutrients indicate bottle closed shallower than expected: mistrip
32/1	105	no2	4	Bottle mistrip
32/1	105	no3	4	Bottle mistrip
32/1	105	o2	4	Bottle mistrip, O2 43 umol/kg low.
32/1	105	po4	4	Bottle mistrip
32/1	105	salt	4	Bottle mistrip, 0.056 low
32/1	105	sio3	4	Bottle mistrip
32/1	107	bottle	4	O2 and nutrients indicate bottle closed shallower than expected: mistrip
32/1	107	no2	4	Bottle mistrip
32/1	107	no3	4	Bottle mistrip
32/1	107	o2	4	Bottle mistrip, O2 64 umol/kg low.
32/1	107	po4	4	Bottle mistrip
32/1	107	salt	4	Bottle mistrip, 0.093 low
32/1	107	sio3	4	Bottle mistrip
32/1	115	bottle	2	trip 14/15 at same depth for bottle 15 integrity check.
32/1	122	bottle	4	O2 and nutrients indicate bottle closed shallower than expected: mistrip
32/1	122	no2	4	Bottle mistrip
32/1	122	no3	4	Bottle mistrip
32/1	122	o2	4	Bottle mistrip, O2 40 umol/kg low.
32/1	122	po4	4	Bottle mistrip
32/1	122	salt	4	Bottle mistrip, 0.018 low
32/1	122	sio3	4	Bottle mistrip
32/1	132	o2	2	O2 draw temp typo (entered as 175 not 17.5), fixed.
33/1	105	bottle	9	Bottle did not close
33/1	111	bottle	4	O2 draw temp high, O2 value high; indicate bottle closed shallower than expected (near bottle 30 depth): mistrip
33/1	111	no2	4	Bottle mistrip
33/1	111	no3	4	Bottle mistrip
33/1	111	o2	4	o2 approx 70 umol/kg too high
33/1	111	po4	4	Bottle mistrip
33/1	111	salt	4	Bottle mistrip, 0.070 high
33/1	111	sio3	4	Bottle mistrip
33/1	115	bottle	2	trip 14/15 at same depth for bottle 15 integrity check.
33/1	133	o2	2	Bottle O2 9 umol/kg low, matches upcast
33/1	134	reft	3	SBE35RT +0.04/+0.02 vs CTDT1/CTDT2; somewhat unstable SBE35RT reading in a gradient.
34/1	103	salt	3	Salinity does not appear to fit profile, code questionable as per chief scientist
34/1	122	bottle	4	"Bad O-ring on bottle 22"
36/1	101	o2	2	O2 appears slightly high, but raw CTDO and transmissometer show a small feature at cast bottom.

Station /Cast	Sample No.	Property	Quality Code	Comment
36/1	107	bottle	4	O2 indicate bottle closed shallower than expected (same as 108 depth): mistrip
36/1	107	o2	4	O2 low, similar to data at bottle 108. Probable mistrip.
36/1	107	salt	4	Bottle mistrip, salinity 0.005 low
36/1	113	bottle	4	O2 indicate bottle closed shallower than expected (same as 114 depth): mistrip
36/1	113	o2	4	O2 low, similar to data at bottle 114. Probable mistrip.
36/1	113	salt	4	Bottle mistrip, salinity 0.035 low
36/1	115	bottle	4	O2 indicate bottle closed shallower than expected (same as 116 depth): mistrip
36/1	115	o2	4	O2 low, similar to data at bottle 116. Probable mistrip.
36/1	115	salt	4	Bottle mistrip, salinity 0.062 low
36/1	128	o2	2	Bottle O2 13 umol/kg low, fits upcast
37/1	113	bottle	4	O2 indicate bottle closed shallower than expected (near bottle 14 depth): mistrip
37/1	113	no2	4	Bottle mistrip
37/1	113	no3	4	Bottle mistrip
37/1	113	o2	4	O2 7 umol/kg low. Bottle mistrip.
37/1	113	po4	4	Bottle mistrip
37/1	113	salt	4	Bottle mistrip, 0.053 low
37/1	113	sio3	4	Bottle mistrip
37/1	115	bottle	4	O2 and salinity indicate bottle closed shallower than expected: mistrip
37/1	115	no2	4	Bottle mistrip
37/1	115	no3	4	Bottle mistrip
37/1	115	o2	4	O2 7 umol/kg high. Bottle mistrip.
37/1	115	po4	4	Bottle mistrip
37/1	115	salt	4	Bottle mistrip, 0.148 low
37/1	115	sio3	4	Bottle mistrip
37/1	122	salt	3	High gradient salinity 0.009 high
37/1	126	o2	2	Bottle O2 6 umol/kg low, matches upcast
37/1	127	o2	2	Bottle O2 12 umol/kg low, matches upcast
37/1	128	o2	2	Bottle O2 6 umol/kg low, matches upcast
38/1	104	bottle	4	O2 and nutrients indicate bottle closed deeper than expected (near bottle 3 depth): mistrip
38/1	104	no2	4	Bottle mistrip
38/1	104	no3	4	Bottle mistrip
38/1	104	o2	4	O2 high, bottle mistrip, O2 2 umol/kg high
38/1	104	po4	4	Bottle mistrip
38/1	104	salt	4	Bottle mistrip, 0.003 low, deep
38/1	104	sio3	4	Bottle mistrip
38/1	113	bottle	4	O2 draw temp, o2, nutrients and salinity indicate bottle closed shallower than expected: mistrip
38/1	113	no2	4	Bottle mistrip
38/1	113	no3	4	Bottle mistrip
38/1	113	o2	4	O2 high, bottle mistrip, O2 114 umol/kg high
38/1	113	po4	4	Bottle mistrip
38/1	113	salt	4	Bottle mistrip, 0.331 low
38/1	113	sio3	4	Bottle mistrip
38/1	115	bottle	4	trip 14/15 at same depth for bottle 15 integrity check. Salinity indicates bottle closed shallower than expected: mistrip
38/1	115	no2	4	Bottle mistrip

Station /Cast	Sample No.	Property	Quality Code	Comment
38/1	115	no3	4	Bottle mistrip
38/1	115	o2	4	Bottle mistrip, O2 3 umol/kg low
38/1	115	po4	4	Bottle mistrip
38/1	115	salt	4	Bottle mistrip, salinity 0.013 low
38/1	115	sio3	4	Bottle mistrip
38/1	134	d15n	5	"d15N-NO3/d18O-NO3 A0197 from number 34 is empty"
38/1	134	d18o	5	"d15N-NO3/d18O-NO3 A0197 from number 34 is empty"
39/1	101	salt	4	Deep salinity 0.006 high, analyst notes that "thimble came off with cap"
39/1	115	bottle	2	trip 14/15 at same depth for bottle 15 integrity check.
39/1	122	bottle	3	Bottle leak, vent not tight
39/1	122	o2	4	o2 4 umol/kg high, sample log reports bottle leak
39/1	123	salt	2	Salinity 0.008 high, high gradient
40/1	115	bottle	2	trip 14/15 at same depth for bottle 15 integrity check.
40/1	122	o2	2	o2 6 umol/kg high, in high gradient
40/1	131	o2	2	in region of high variability
40/1	133	o2	2	in region of high variability
41/1	108	salt	3	deep salt 0.006 high, analyst notes that thimble came off with cap
41/1	115	bottle	2	trip 15/16 at same depth for bottle 15 integrity check.
41/1	122	o2	2	o2 5 umol/kg low, in high gradient
41/1	130	o2	2	in region of high variability
42/1	102	salt	3	Salinity does not appear to fit trend of bottle salinity
42/1	123	salt	3	salinity 0.010 high, in gradient
42/1	129	o2	2	in region of high variability
42/1	133	o2	2	in region of high variability
43/1	101	salt	3	Salt 0.003 high, deep
43/1	103	salt	3	Salt 0.003 high, deep
43/1	126	o2	2	in region of high variability
44/1	121	o2	2	O2 on high gradient, consistent with CTD data
44/1	126	o2	3	O2 9.6 umol/kg low, gradient
45/1	106	o2	3	Bad endpoint, however data seems acceptable. Coded questionable.
45/1	133	o2	2	o2 in region of large gradients, 12 umol/kg high, matches upcast
45/1	135	bottle	9	Bottle did not close
46/1	133	o2	2	o2 10 umol/kg high, in highly variable region, matches upcast
46/1	133	reft	3	SBE35RT +0.05/+0.02 vs CTDT1/CTDT2; very unstable reading, in a gradient.
47/1	130	o2	2	o2 5 umol/kg high, in highly variable region
48/1	107	bottle	4	Salinity, o2 indicate bottle closed shallower than expected (near bottle 8 depth): mistrip
48/1	107	no2	4	Bottle mistrip
48/1	107	no3	4	Bottle mistrip
48/1	107	o2	4	Bottle mistrip, O2 4 umol/kg low
48/1	107	po4	4	Bottle mistrip
48/1	107	salt	4	Bottle mistrip, 0.003 low, deep
48/1	107	sio3	4	Bottle mistrip
48/1	120	bottle	4	O2, salt, and nutrients indicate bottle closed shallower than expected: mistrip
48/1	120	no2	4	Bottle mistrip
48/1	120	no3	4	Bottle mistrip
48/1	120	o2	4	Bottle mistrip, oxygen 5 umol/kg low.
48/1	120	po4	4	Bottle mistrip
48/1	120	salt	4	Bottle mistrip, salinity 0.05 low
48/1	120	sio3	4	Bottle mistrip

Station /Cast	Sample No.	Property	Quality Code	Comment
48/1	123	o2	2	o2 8 umol/kg low, on high gradient
48/1	134	reft	3	SBE35RT -0.05 vs CTDT1/CTDT2; very unstable reading, in a gradient.
51/1	132	o2	2	Bottle O2 10 umol/kg low, matches upcast
51/1	133	o2	2	Bottle O2 15 umol/kg low, matches upcast
53/1	112	salt	3	Deep salinity is -0.0025 vs CTDS1/CTDS2.
53/1	127	reft	3	SBE35RT +0.05 vs CTDT1/CTDT2; unstable reading, in a gradient.
53/1	134	bottle	2	winch to 35m, back down to 40m for bottle 34 trip.
53/1	135	bottle	9	Bottle did not close
54/1	125	reft	3	SBE35RT +0.04/+0.065 vs CTDT1/CTDT2; very unstable reading, in a gradient.
54/1	125	salt	3	Bottle salt 0.011 high, no problems noted by analyst
54/1	135	bottle	9	Bottle did not close
55/1	134	bottle	2	bottle 34 triggered 100m shallower than planned - op.error.
56/1	107	salt	3	Bottle salt 0.005 high, deep
56/1	122	salt	3	Bottle salt 0.008 high, in a gradient
56/1	135	reft	3	SBE35RT -0.14 vs CTDT1/CTDT2; very unstable reading, in a gradient.
56/1	135	salt	3	Salinity 0.04 vs CTDS1/CTDS2; in a gradient.
57/1	134	o2	2	O2 redrawn due to sampling error
57/1	136	bottle	3	Bottle had bad leak
58/1	101	bottle	9	No bottles closed
58/1	102	bottle	9	No bottles closed
58/1	103	bottle	9	No bottles closed
58/1	104	bottle	9	No bottles closed
58/1	105	bottle	9	No bottles closed
58/1	106	bottle	9	No bottles closed
58/1	107	bottle	9	No bottles closed
58/1	108	bottle	9	No bottles closed
58/1	109	bottle	9	No bottles closed
58/1	110	bottle	9	No bottles closed
58/1	111	bottle	9	No bottles closed
58/1	112	bottle	9	No bottles closed
58/1	113	bottle	9	No bottles closed
58/1	114	bottle	9	No bottles closed
58/1	115	bottle	9	No bottles closed
58/1	116	bottle	9	No bottles closed
58/1	117	bottle	9	No bottles closed
58/1	118	bottle	9	No bottles closed
58/1	119	bottle	9	No bottles closed
58/1	120	bottle	9	No bottles closed
58/1	121	bottle	9	No bottles closed
58/1	122	bottle	9	No bottles closed
58/1	123	bottle	9	No bottles closed
58/1	124	bottle	9	No bottles closed
58/1	125	bottle	9	No bottles closed
58/1	126	bottle	9	No bottles closed
58/1	127	bottle	9	No bottles closed
58/1	128	bottle	9	No bottles closed
58/1	129	bottle	9	No bottles closed
58/1	130	bottle	9	No bottles closed
58/1	131	bottle	9	No bottles closed
58/1	132	bottle	9	No bottles closed

Station /Cast	Sample No.	Property	Quality Code	Comment
58/1	133	bottle	9	No bottles closed
58/1	134	bottle	9	No bottles closed
58/1	135	bottle	9	No bottles closed
58/1	136	bottle	9	No bottles closed
59/1	106	salt	3	salt 0.003 high, deep
59/1	119	salt	3	salt 0.006 high, on gradient
59/1	125	reft	3	SBE35RT +0.035/+0.015 vs CTDT1/CTDT2; unstable reading, in a gradient.
59/1	128	reft	3	SBE35RT -0.02/-0.025 vs CTDT1/CTDT2; unstable reading, in a gradient.
59/1	132	salt	2	salt 0.009 high, highly variable region
59/1	135	bottle	2	bottle 35 intentionally tripped out of order (last/at surface).
60/1	106	salt	3	salt 0.004 high, deep
60/1	124	salt	2	Salt 0.006 high, in highly variable region
60/1	125	salt	2	Salt 0.008 high, in highly variable region
60/1	135	bottle	2	bottle 35 intentionally tripped out of order (last/at surface).
61/1	127	reft	3	SBE35RT +0.011/+0.009 vs. CTDT1/CTDT2, unstable reading in a gradient
61/1	129	salt	4	Bottle salinity 0.010 high, analyst notes "bottle overfilled, thimble loose, came off with cap"
61/1	135	bottle	2	bottle 35 intentionally tripped out of order (last/at surface).
62/1	126	reft	3	SBE35RT +0.022/+0.029 vs CTDT1/CTDT2, unstable reading in gradient
62/1	128	reft	3	SBE35RT +0.028/+0.026 vs CTDT1/CTDT2, unstable reading
62/1	131	o2	2	Bottle O2 5 umol/kg high, matches upcast
62/1	133	o2	2	Bottle O2 5 umol/kg low, matches upcast
62/1	135	bottle	2	bottle 35 intentionally tripped out of order (last/at surface).
63/3	324	reft	3	SBE35RT -0.017/-0.014 vs CTD1/CTD2, unstable reading in a gradient
63/3	334	reft	3	SBE35RT -0.017/-0.018 vs CTD1/CTD2, unstable reading
63/3	335	bottle	2	bottle 35 intentionally tripped out of order (last/at surface).
64/1	135	bottle	9	bottle 35 intentionally tripped out of order (last/at surface). Bottle 35 did not close.
64/1	135	no2	9	Bottle 35 did not close
64/1	135	no3	9	Bottle 35 did not close
64/1	135	o2	9	Bottle 35 did not close
64/1	135	po4	9	Bottle 35 did not close
64/1	135	salt	9	Bottle 35 did not close
64/1	135	sio3	9	Bottle 35 did not close
65/1	125	bottle	9	bottom cap did not close: lanyard hangup, re-routed.
65/1	132	o2	3	Bottle O2, 10 umol/kg low, does not appear to fit up or down cast
65/1	133	bottle	2	bottle 33 taken just below strong gradient (big down/up difference).
65/1	133	reft	3	SBE35RT -0.04/-0.045 vs CTDT1/CTDT2; very unstable reading, in a gradient.
65/1	135	bottle	2	bottle 35 intentionally tripped out of order (last/at surface).
66/1	101	bottle	2	Leaking carousel solenoid coated with Scotchkote prior to cast.
66/1	106	salt	3	Salt 0.003 high, deep
66/1	112	bottle	2	Leaking carousel solenoid coated with Scotchkote prior to cast.
66/1	112	salt	3	Salinity 0.01 high vs CTDS1/CTDS2, deep.
66/1	135	bottle	9	Leaking carousel solenoid coated with Scotchkote prior to cast. Bottle 35 intentionally tripped out of order (last/at surface); did not close despite 3 attempts to trigger it.
67/1	112	bottle	9	bottle 12 did not trip
67/1	135	bottle	9	bottle 35 intentionally tripped out of order (last/at surface). 7 attempts to trigger it failed to close it.

Station /Cast	Sample No.	Property	Quality Code	Comment
68/1	112	bottle	2	trip 11/12 at same depth for bottle 12 integrity check. Niskin 12 did not trip; bottle 12 removed for subsequent casts.
68/1	126	reft	3	SBE35RT -0.045/-0.03 vs CTDT1/CTDT2; in a gradient.
68/1	129	o2	2	Bottle O2 matches up cast, highly variable region
68/1	135	bottle	2	trip 36/35 at same depth (surface) for bottle 35 integrity check. bottle 35 intentionally tripped out of order (last/at surface).
69/1	125	salt	3	Salinity 0.008 high compared to CTD Salinity, in a gradient
69/1	129	reft	3	SBE35RT -0.04/-0.055 vs CTDT1/CTDT2; in a gradient.
69/1	135	bottle	2	bottle 35 intentionally tripped out of order (last/at surface).
70/1	135	bottle	2	bottle 35 intentionally tripped out of order (last/at surface).
71/1	135	bottle	2	bottle 35 intentionally tripped out of order (last/at surface).
72/1	117	no2	5	nutrient sample bottle was empty - sampling error, lost.
72/1	117	no3	5	nutrient sample bottle was empty - sampling error, lost.
72/1	117	po4	5	nutrient sample bottle was empty - sampling error, lost.
72/1	117	sio3	5	nutrient sample bottle was empty - sampling error, lost.
72/1	132	o2	3	Bottle O2 15 umol/kg high, in highly variable region
72/1	133	salt	3	Bottle salinity 0.009 high, in gradient
72/1	135	bottle	2	bottle 35 intentionally tripped out of order (last/at surface). Trip 36/35 at same depth (surface) for bottle 35 integrity check.
73/1	129	bottle	9	lanyard hooked on recovery, bottle empty
73/1	135	bottle	2	bottle 35 intentionally tripped out of order (last/at surface).
74/1	135	bottle	2	bottle 35 intentionally tripped out of order (last/at surface).
75/1	110	salt	4	Salinity 0.016 low vs CTD Salinity, no problems noted by analyst, other bottle parameters OK
75/1	135	bottle	2	bottle 35 intentionally tripped out of order (last/at surface).
76/1	101	bottle	9	Niskin 1 did not close
76/1	129	o2	2	Bottle o2 11 umol/kg high, matches upcast
76/1	135	bottle	2	bottle 35 intentionally tripped out of order (last/at surface).
77/1	101	bottle	9	bottle 1 triggered twice "just in case", but Niskin 1 did not close; bottle 1 removed for subsequent casts.
77/1	133	salt	3	Salinity 0.018 low, high gradient
77/1	135	bottle	2	bottle 35 intentionally tripped out of order (last/at surface).
78/1	122	salt	4	Bottle salinity 0.032 high, analyst notes "Thimble popped, probable water intrusion"
78/1	131	o2	3	Bottle Oxygen 22 umol/kg high, in highly variable region
78/1	135	bottle	2	bottle 35 intentionally tripped out of order (last/at surface).
79/1	102	salt	3	bottle salinity 0.004 high, deep
79/1	118	bottle	3	"NB 18 has decent leak"
79/1	133	reft	3	SBE35RT -0.19/-0.18 vs CTDT1/CTDT2; extremely unstable reading, in a gradient.
79/1	133	salt	3	Bottle salinity 0.007 high, in a gradient
79/1	135	bottle	2	bottle 35 intentionally tripped out of order (last/at surface).
80/1	118	bottle	2	new O-rings on bottoms of niskins 18 and 19 prior to cast.
80/1	119	bottle	2	new O-rings on bottoms of niskins 18 and 19 prior to cast.
80/1	130	salt	3	Salinity 0.008 high, in gradient
80/1	135	bottle	2	bottle 35 intentionally tripped out of order (last/at surface).
81/1	115	salt	3	Bottle salt 0.014 high, no problems noted by analyst, CTD salinity channels in agreement and stable, other parameters ok
81/1	120	bottle	2	bottle 20 fired at 960m instead of 1035m; op. error.
81/1	126	reft	3	SBE35RT +0.025 vs CTDT1/CTDT2; somewhat unstable SBE35RT reading in a mild gradient.

Station /Cast	Sample No.	Property	Quality Code	Comment
81/1	127	salt	3	Bottle salt 0.010 high, no problems noted by analyst
81/1	128	reft	3	SBE35RT -0.025/-0.030 vs CTDT1/CTDT2; very unstable SBE35RT reading in a gradient.
81/1	129	reft	3	SBE35RT -0.020/-0.025 vs CTDT1/CTDT2; very unstable SBE35RT reading in a gradient.
81/1	135	bottle	9	bottle 35 intentionally tripped out of order (last/at surface); did not close, despite 3 attempts to trigger it. Bottle 35 removed for rest of leg 1.
82/1	102	salt	3	Salinity 0.004 high, deep
82/1	104	salt	4	Deep salinity 0.004 high, analyst notes "Severe bubble sticking, used approx 50 percent of sample"
82/1	105	salt	4	Deep salinity 0.005 high, analyst notes "Thimble came out with cap. Severe bubble sticking, used approx 50 percent of sample"
82/1	106	salt	3	Salinity 0.007 high, deep
82/1	121	o2	2	Bottle matches up cast, value appears to be ok
83/1	132	o2	2	Bottle O2 15 umol/kg high, matches up cast
84/1	101	bottle	2	trip 1/2 at same depth (bottom) for bottle 1 integrity check.
84/1	112	bottle	2	trip 11/12 at same depth for bottle 12 integrity check.
84/1	120	bottle	2	bottle 20 fired at 960m instead of 1035m; op. error.
84/1	136	bottle	2	Sudden rain squall a few minutes before top bottle trip.
85/1	124	o2	2	Bottle O2 4 umol/kg low, matches up cast, on gradient
85/1	130	o2	3	Bottle O2 8 umol/kg high, matches up cast, in region of high variability
87/1	107	bottle	4	O2 draw temp high, O2 Value high, indicate bottle closed shallower than expected: mistrip
87/1	107	no2	4	Bottle mistrip
87/1	107	no3	4	Bottle mistrip
87/1	107	o2	4	Bottle mistrip, bottle O2 75 umol/kg high
87/1	107	po4	4	Bottle mistrip
87/1	107	salt	4	Bottle mistrip, 0.422 low
87/1	107	sio3	4	Bottle mistrip

Appendix D

CLIVAR/Carbon P02W: Pre-Cruise Sensor Laboratory Calibrations

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Pressure Calibration Report
STS/ODF Calibration Facility

SENSOR SERIAL NUMBER: 0796
CALIBRATION DATE: 18-DEC-2012
Mfg: SEABIRD Model: 09P CTD Prs s/n: 98627

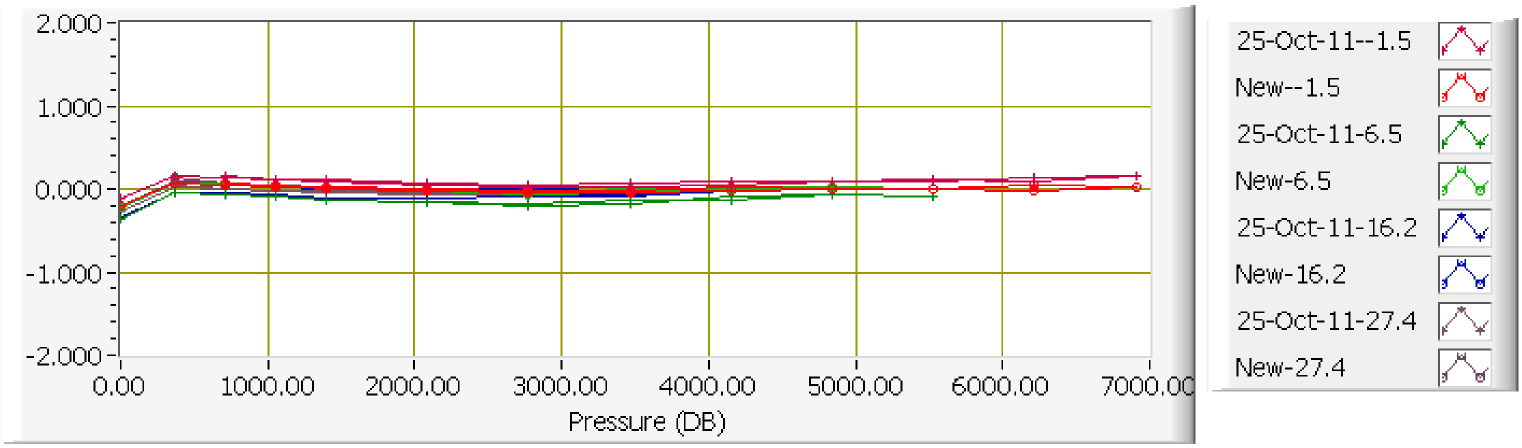
C1= -4.967155E+4
C2= 7.752805E-1
C3= 1.116556E-2
D1= 3.856757E-2
D2= 0.000000E+0
T1= 2.989470E+1
T2= -1.433939E-4
T3= 4.730200E-6
T4= -1.357591E-8
T5= 0.000000E+0
AD590M= 1.28520E-2
AD590B= -8.71454E+0
Slope = 1.00000000E+0
Offset = 0.00000000E+0

Calibration Standard: Mfg: RUSKA Model: 2400 s/n: 34336
t0=t1+t2*td+t3*td*td+t4*td*td*td
w = 1-t0*t0*f*f
Pressure = (0.6894759*((c1+c2*td+c3*td*td)*w*(1-(d1+d2*td)*w)-14.7)

Sensor Output	Standard	Sensor New_Coefs	Standard-Sensor Prev_Coefs	Standard-Sensor NEW_Coefs	Sensor_Temp	Bath_Temp
33455.672	0.16	0.37	-0.11	-0.21	-1.22	-1.479
33633.110	364.95	364.88	0.16	0.07	-1.21	-1.479
33799.673	709.13	709.08	0.13	0.04	-1.21	-1.479
33965.288	1053.30	1053.28	0.11	0.02	-1.21	-1.479
34130.002	1397.55	1397.53	0.11	0.02	-1.20	-1.479
34456.687	2086.03	2086.03	0.07	-0.00	-1.20	-1.479
34779.839	2774.56	2774.60	0.05	-0.03	-1.20	-1.479
35099.547	3463.19	3463.20	0.06	-0.01	-1.20	-1.479
35415.915	4151.88	4151.86	0.09	0.01	-1.20	-1.479
35729.045	4840.62	4840.61	0.10	0.01	-1.20	-1.479
36039.021	5529.43	5529.43	0.10	-0.00	-1.18	-1.479
36345.902	6218.31	6218.28	0.14	0.03	-1.17	-1.479
36649.793	6907.24	6907.21	0.16	0.03	-1.17	-1.479
36345.924	6218.31	6218.33	0.10	-0.01	-1.17	-1.479
36039.021	5529.43	5529.42	0.10	0.01	-1.17	-1.479
35729.060	4840.62	4840.63	0.08	-0.01	-1.17	-1.479
35415.942	4151.87	4151.91	0.05	-0.03	-1.17	-1.479

Sensor Output	Standard	Sensor New_Coefs	Standard-Sensor Prev_Coefs	Standard-Sensor NEW_Coefs	Sensor_Temp	Bath_Temp
35099.572	3463.18	3463.24	0.02	-0.05	-1.17	-1.479
34779.855	2774.56	2774.61	0.02	-0.05	-1.17	-1.479
34456.706	2086.02	2086.06	0.04	-0.03	-1.17	-1.479
34130.016	1397.55	1397.55	0.09	0.01	-1.17	-1.478
33965.287	1053.30	1053.26	0.12	0.04	-1.17	-1.478
33799.672	709.13	709.06	0.15	0.06	-1.17	-1.478
33633.103	364.95	364.85	0.19	0.10	-1.17	-1.478
33456.738	0.16	0.39	-0.35	-0.23	6.81	6.529
33634.195	364.95	364.88	-0.05	0.07	6.83	6.529
33800.777	709.13	709.06	-0.06	0.06	6.83	6.530
33966.420	1053.30	1053.26	-0.09	0.04	6.84	6.529
34131.180	1397.55	1397.55	-0.13	-0.00	6.84	6.529
34457.912	2086.02	2086.04	-0.15	-0.02	6.84	6.529
34781.118	2774.56	2774.60	-0.17	-0.05	6.85	6.529
35100.866	3463.18	3463.18	-0.13	-0.00	6.86	6.530
35417.299	4151.87	4151.88	-0.12	-0.01	6.86	6.529
35730.459	4840.61	4840.58	-0.07	0.03	6.86	6.529
36040.487	5529.42	5529.42	-0.09	-0.00	6.86	6.530
35730.458	4840.61	4840.58	-0.07	0.03	6.86	6.529
35417.284	4151.87	4151.84	-0.09	0.02	6.86	6.530
35100.888	3463.18	3463.23	-0.17	-0.05	6.86	6.529
34781.132	2774.56	2774.63	-0.20	-0.07	6.86	6.529
34457.922	2086.02	2086.05	-0.16	-0.03	6.86	6.529
34131.180	1397.55	1397.55	-0.13	0.00	6.86	6.529
33966.422	1053.30	1053.26	-0.09	0.04	6.86	6.530
33800.776	709.13	709.05	-0.06	0.07	6.86	6.529
33634.188	364.95	364.86	-0.03	0.09	6.86	6.530
33457.163	0.16	0.39	-0.34	-0.24	16.50	16.169
33634.656	364.95	364.88	-0.04	0.07	16.50	16.169
33801.275	709.13	709.07	-0.05	0.06	16.51	16.169
33966.957	1053.30	1053.27	-0.08	0.02	16.51	16.169
34131.747	1397.55	1397.56	-0.11	-0.01	16.53	16.169
34458.546	2086.02	2086.04	-0.11	-0.02	16.53	16.169
34781.799	2774.56	2774.57	-0.09	-0.01	16.53	16.169
35101.634	3463.18	3463.19	-0.08	-0.01	16.54	16.169
35418.113	4151.87	4151.85	-0.03	0.02	16.54	16.169
35101.638	3463.18	3463.20	-0.09	-0.02	16.54	16.169
34781.797	2774.56	2774.56	-0.08	-0.00	16.54	16.169
34458.552	2086.02	2086.05	-0.12	-0.03	16.54	16.169
34131.746	1397.55	1397.55	-0.10	-0.00	16.55	16.169
33966.957	1053.30	1053.27	-0.08	0.02	16.54	16.169
33801.280	709.13	709.08	-0.06	0.05	16.55	16.169
33634.645	364.95	364.86	-0.01	0.09	16.55	16.169
33456.555	0.16	0.36	-0.27	-0.20	27.93	27.386
33634.102	364.95	364.86	0.02	0.09	27.94	27.386

Sensor Output	Standard	Sensor New_Coefs	Standard-Sensor Prev_Coefs	Standard-Sensor NEW_Coefs	Sensor_Temp	Bath_Temp
33800.770	709.13	709.05	0.01	0.08	27.94	27.386
33966.495	1053.30	1053.25	-0.02	0.05	27.94	27.386
34131.325	1397.55	1397.53	-0.03	0.03	27.94	27.386
34458.221	2086.02	2086.03	-0.05	-0.01	27.94	27.386
34781.571	2774.56	2774.58	-0.05	-0.02	27.94	27.386
35101.491	3463.18	3463.21	-0.04	-0.03	27.94	27.386
34781.576	2774.56	2774.59	-0.06	-0.03	27.94	27.386
34458.227	2086.02	2086.04	-0.06	-0.02	27.94	27.386
34131.329	1397.55	1397.53	-0.04	0.02	27.93	27.386
33966.502	1053.30	1053.26	-0.03	0.03	27.93	27.386
33800.779	709.13	709.07	-0.01	0.06	27.93	27.386
33634.088	364.95	364.83	0.05	0.12	27.93	27.386
33456.538	0.16	0.32	-0.24	-0.16	27.93	27.386



Pressure Calibration Report
STS/ODF Calibration Facility

SENSOR SERIAL NUMBER: 0914
CALIBRATION DATE: 14-JUN-2012
Mfg: SEABIRD Model: 09P CTD Prs s/n: 110547

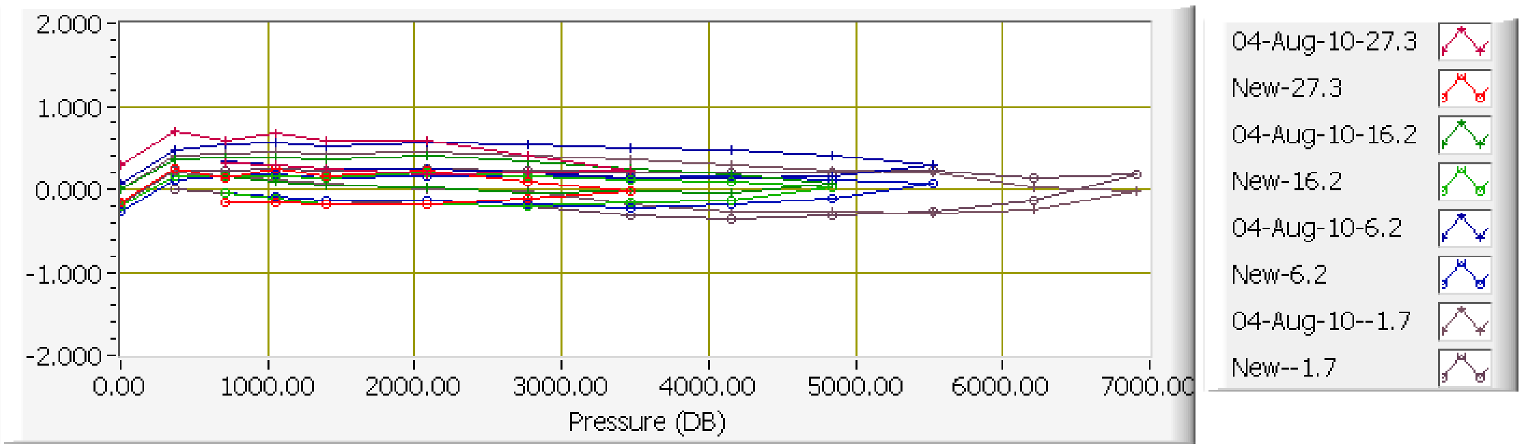
C1= -4.348919E+4
C2= 1.845929E-2
C3= 1.285114E-2
D1= 3.610893E-2
D2= 0.000000E+0
T1= 3.006810E+1
T2= -2.604375E-4
T3= 3.050306E-6
T4= 3.013015E-8
T5= 0.000000E+0
AD590M= 1.28789E-2
AD590B= -8.81353E+0
Slope = 1.00000000E+0
Offset = 0.00000000E+0

Calibration Standard: Mfg: RUSKA Model: 2400 s/n: 34336
t0=t1+t2*td+t3*td*td+t4*td*td*td
w = 1-t0*t0*f*f
Pressure = (0.6894759*((c1+c2*td+c3*td*td)*w*(1-(d1+d2*td)*w)-14.7)

Sensor Output	Standard	Sensor New_Coefs	Standard-Sensor Prev_Coefs	Standard-Sensor NEW_Coefs	Sensor_Temp	Bath_Temp
33268.311	0.17	0.33	0.30	-0.16	27.13	27.334
33469.730	364.96	364.72	0.70	0.24	27.17	27.334
33658.765	709.13	708.99	0.59	0.14	27.20	27.334
33846.469	1053.30	1053.05	0.68	0.25	27.22	27.334
34033.137	1397.55	1397.39	0.58	0.16	27.25	27.334
34402.840	2086.02	2085.81	0.58	0.22	27.27	27.334
34768.150	2774.56	2774.48	0.39	0.08	27.30	27.334
35129.097	3463.18	3463.19	0.22	-0.01	27.32	27.335
34768.251	2774.55	2774.66	0.20	-0.11	27.34	27.334
34403.060	2086.03	2086.21	0.19	-0.19	27.34	27.334
34033.328	1397.56	1397.73	0.25	-0.18	27.38	27.334
33846.696	1053.30	1053.46	0.29	-0.15	27.39	27.334
33658.930	709.13	709.28	0.31	-0.15	27.40	27.334
33469.936	364.96	365.08	0.36	-0.12	27.43	27.334
33267.305	0.17	0.36	0.01	-0.20	16.22	16.201
33468.719	364.96	364.80	0.37	0.16	16.24	16.201
33657.662	709.13	708.97	0.38	0.16	16.25	16.201

Sensor Output	Standard	Sensor New_Coefs	Standard-Sensor Prev_Coefs	Standard-Sensor NEW_Coefs	Sensor_Temp	Bath_Temp
33845.400	1053.30	1053.15	0.37	0.15	16.26	16.201
34031.996	1397.56	1397.42	0.36	0.14	16.26	16.201
34401.640	2086.03	2085.83	0.40	0.20	16.30	16.201
34766.833	2774.56	2774.40	0.33	0.16	16.30	16.201
35127.694	3463.19	3463.07	0.25	0.12	16.31	16.201
35484.333	4151.88	4151.78	0.18	0.09	16.33	16.201
35836.896	4840.62	4840.59	0.06	0.03	16.34	16.201
35484.449	4151.87	4152.00	-0.05	-0.14	16.35	16.201
35127.844	3463.19	3463.34	-0.02	-0.16	16.35	16.201
34767.039	2774.57	2774.78	-0.04	-0.21	16.35	16.201
34401.847	2086.03	2086.20	0.03	-0.17	16.36	16.201
34032.184	1397.56	1397.73	0.04	-0.18	16.36	16.201
33845.563	1053.30	1053.42	0.10	-0.12	16.36	16.201
33657.801	709.13	709.19	0.16	-0.05	16.39	16.201
33468.843	364.96	364.98	0.19	-0.03	16.40	16.201
33265.457	0.17	0.44	0.08	-0.27	6.65	6.224
33466.819	364.95	364.83	0.48	0.12	6.65	6.224
33655.717	709.12	708.97	0.53	0.16	6.65	6.224
33843.418	1053.29	1053.11	0.56	0.18	6.67	6.224
34030.002	1397.54	1397.41	0.51	0.13	6.65	6.224
34399.609	2086.00	2085.84	0.55	0.16	6.68	6.224
34764.734	2774.52	2774.37	0.54	0.15	6.68	6.224
35125.528	3463.14	3462.99	0.50	0.15	6.68	6.224
35482.106	4151.83	4151.68	0.47	0.15	6.68	6.224
35834.600	4840.55	4840.44	0.40	0.12	6.68	6.224
36183.152	5529.36	5529.30	0.28	0.06	6.68	6.224
35834.723	4840.56	4840.68	0.17	-0.11	6.68	6.224
35482.277	4151.83	4152.01	0.14	-0.19	6.68	6.224
35125.723	3463.15	3463.37	0.14	-0.22	6.68	6.224
34764.918	2774.54	2774.71	0.21	-0.18	6.68	6.224
34399.772	2086.01	2086.14	0.26	-0.13	6.68	6.224
34030.154	1397.55	1397.68	0.26	-0.13	6.68	6.224
33843.570	1053.29	1053.39	0.29	-0.09	6.68	6.224
33655.838	709.13	709.17	0.33	-0.04	6.68	6.224
33466.887	364.96	364.94	0.37	0.01	6.68	6.224
33263.296	0.17	0.34	0.00	-0.18	-1.21	-1.724
33464.641	364.96	364.74	0.41	0.22	-1.21	-1.724
33653.544	709.13	708.91	0.42	0.22	-1.21	-1.724
33841.219	1053.30	1053.04	0.45	0.25	-1.21	-1.724
34027.781	1397.55	1397.32	0.43	0.23	-1.21	-1.724
34397.362	2086.02	2085.76	0.44	0.25	-1.21	-1.724
34762.473	2774.55	2774.32	0.40	0.23	-1.21	-1.724
35123.237	3463.15	3462.94	0.35	0.21	-1.21	-1.724
35479.792	4151.84	4151.64	0.30	0.20	-1.21	-1.724
35832.258	4840.59	4840.39	0.24	0.19	-1.21	-1.724

Sensor Output	Standard	Sensor New_Coefs	Standard-Sensor Prev_Coefs	Standard-Sensor NEW_Coefs	Sensor_Temp	Bath_Temp
36180.738	5529.38	5529.17	0.19	0.22	-1.21	-1.724
36525.423	6218.24	6218.11	0.03	0.13	-1.21	-1.725
36866.316	6907.18	6907.01	-0.02	0.17	-1.21	-1.724
36525.566	6218.26	6218.40	-0.24	-0.14	-1.21	-1.725
36180.980	5529.38	5529.65	-0.29	-0.26	-1.21	-1.724
35832.516	4840.59	4840.90	-0.27	-0.31	-1.21	-1.725
35480.090	4151.85	4152.22	-0.26	-0.36	-1.21	-1.724
35123.522	3463.17	3463.49	-0.18	-0.32	-1.21	-1.724
34762.705	2774.55	2774.76	-0.03	-0.21	-1.21	-1.724
34397.597	2086.02	2086.20	0.01	-0.18	-1.21	-1.724
34027.987	1397.56	1397.70	0.06	-0.14	-1.21	-1.724
33841.409	1053.30	1053.39	0.11	-0.09	-1.21	-1.725
33653.691	709.13	709.18	0.15	-0.04	-1.21	-1.724
33464.760	364.96	364.95	0.19	0.00	-1.21	-1.724
33263.359	0.17	0.46	-0.11	-0.29	-1.21	-1.724



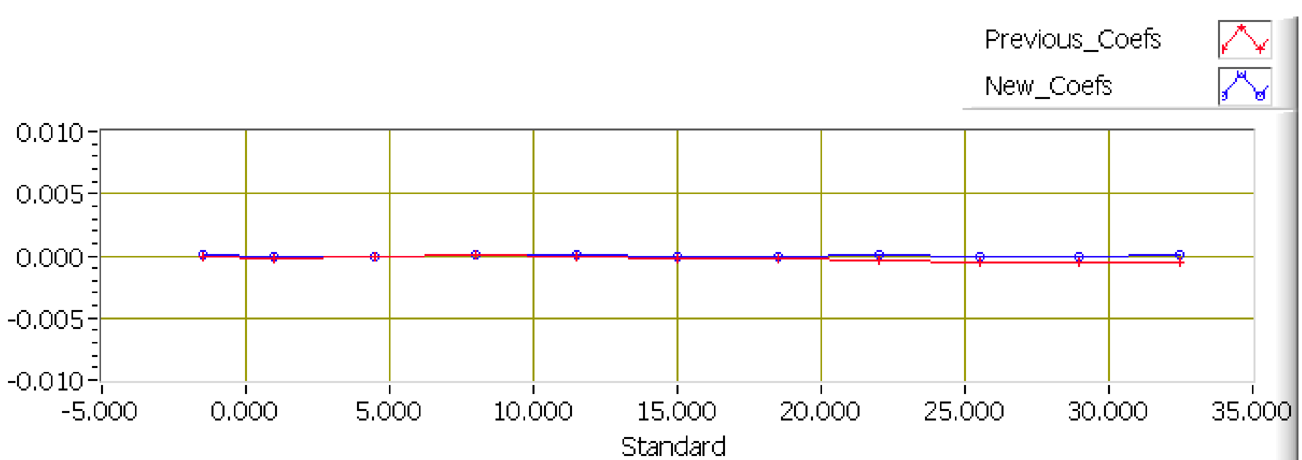
Temperature Calibration Report
STS/ODF Calibration Facility

SENSOR SERIAL NUMBER: 4138
CALIBRATION DATE: 24-Jan-2013
Mfg: SEABIRD Model: 03
Previous cal: 21-Jun-12
Calibration Tech: CAL

ITS-90_COEFFICIENTS	IPTS-68_COEFFICIENTS ITS-T90	
g = 4.40192731E-3	a = 4.40214027E-3	
h = 6.50694840E-4	b = 6.50911856E-4	
i = 2.33977600E-5	c = 2.34309522E-5	
j = 2.04988124E-6	d = 2.05142804E-6	
f0 = 1000.0	Slope = 1.0	Offset = 0.0

Calibration Standard: Mfg: ASL Model: F18 s/n: 245-5149
Temperature ITS-90 = 1/{g+h[ln(f0/f)]+i[ln2(f0/f)]+j[ln3(f0/f)]} - 273.15 (°C)
Temperature IPTS-68 = 1/{a+b[ln(f0/f)]+c[ln2(f0/f)]+d[ln3(f0/f)]} - 273.15 (°C)
T68 = 1.00024 * T90 (-2 to -35 Deg C)

SBE3 Freq	SPRT ITS-T90	SBE3 ITS-T90	SPRT-SBE3 OLD Coefs	SPRT-SBE3 NEW Coefs
3159.0572	-1.5059	-1.5060	-0.00002	0.00008
3339.5971	0.9941	0.9943	-0.00017	-0.00013
3604.7395	4.4949	4.4949	-0.00001	-0.00001
3884.7240	7.9964	7.9963	0.00005	0.00007
4179.9450	11.4983	11.4983	-0.00005	0.00003
4489.8693	14.9906	14.9906	-0.00022	-0.00005
4816.6766	18.4936	18.4936	-0.00026	0.00000
5159.4338	21.9930	21.9930	-0.00034	0.00003
5518.8820	25.4929	25.4929	-0.00048	-0.00001
5895.1896	28.9917	28.9918	-0.00059	-0.00003
6288.9059	32.4918	32.4917	-0.00060	0.00002



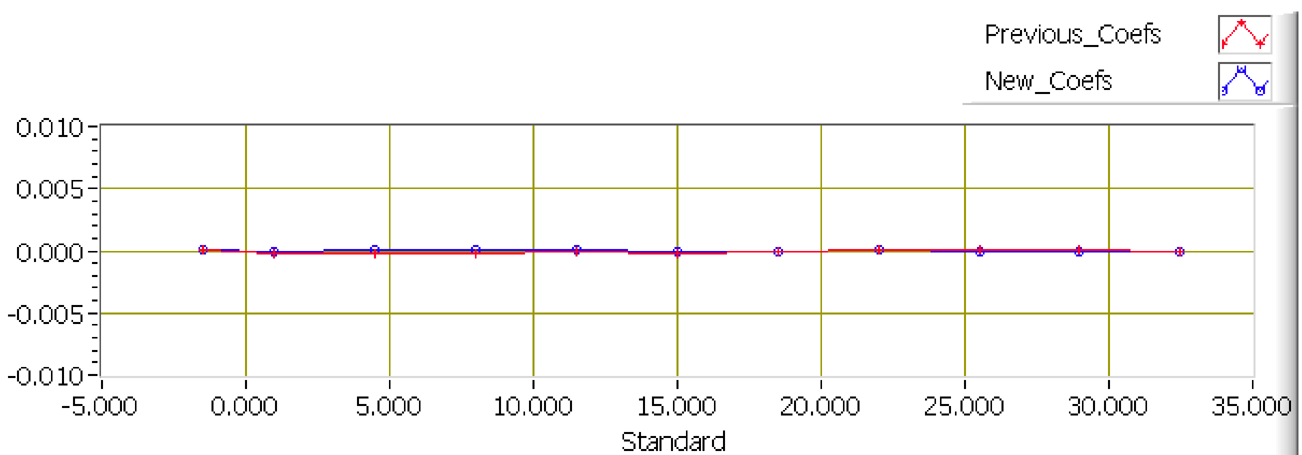
Temperature Calibration Report
STS/ODF Calibration Facility

SENSOR SERIAL NUMBER: 4226
CALIBRATION DATE: 24-Jan-2013
Mfg: SEABIRD Model: 03
Previous cal: 30-Aug-12
Calibration Tech: CAL

ITS-90_COEFFICIENTS	IPTS-68_COEFFICIENTS ITS-T90	
g = 4.38186818E-3	a = 4.38207455E-3	
h = 6.46712520E-4	b = 6.46926865E-4	
i = 2.24590277E-5	c = 2.24918559E-5	
j = 1.80204389E-6	d = 1.80355746E-6	
f0 = 1000.0	Slope = 1.0	Offset = 0.0

Calibration Standard: Mfg: ASL Model: F18 s/n: 245-5149
Temperature ITS-90 = 1/{g+h[ln(f0/f)]+i[ln2(f0/f)]+j[ln3(f0/f)]} - 273.15 (°C)
Temperature IPTS-68 = 1/{a+b[ln(f0/f)]+c[ln2(f0/f)]+d[ln3(f0/f)]} - 273.15 (°C)
T68 = 1.00024 * T90 (-2 to -35 Deg C)

SBE3 Freq	SPRT ITS-T90	SBE3 ITS-T90	SPRT-SBE3 OLD Coefs	SPRT-SBE3 NEW Coefs
3074.5391	-1.5059	-1.5060	0.00005	0.00004
3250.8215	0.9941	0.9942	-0.00020	-0.00008
3509.7895	4.4949	4.4949	-0.00020	0.00001
3783.3395	7.9964	7.9963	-0.00017	0.00006
4071.8662	11.4983	11.4983	-0.00015	0.00004
4374.8712	14.9906	14.9906	-0.00022	-0.00010
4694.4865	18.4936	18.4936	-0.00006	-0.00000
5029.8229	21.9930	21.9930	0.00007	0.00006
5381.6290	25.4929	25.4929	0.00001	-0.00003
5750.0697	28.9917	28.9917	0.00002	-0.00001
6135.7193	32.4918	32.4917	-0.00005	0.00000



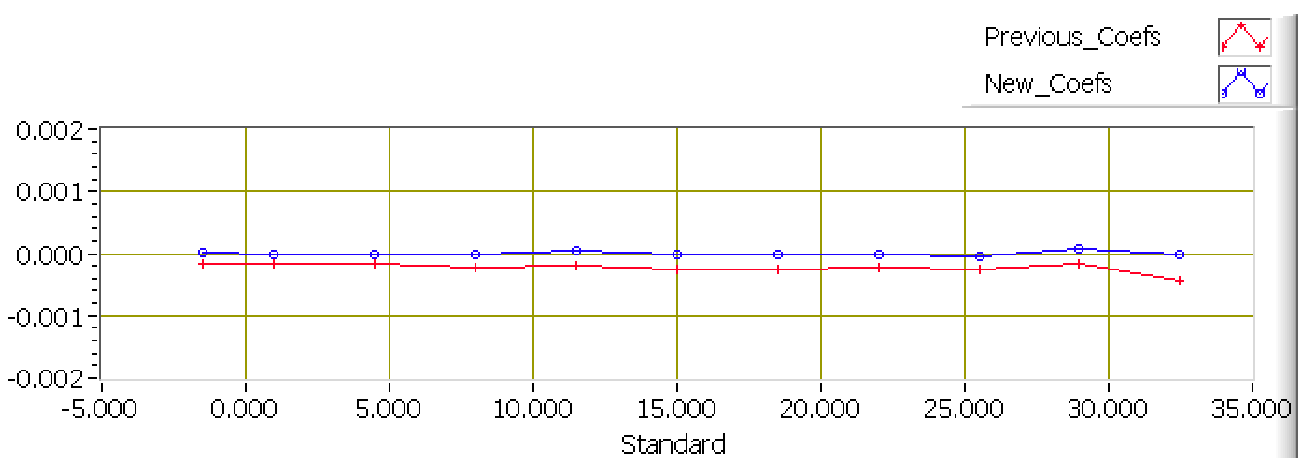
Temperature Calibration Report
STS/ODF Calibration Facility

SENSOR SERIAL NUMBER: 0035
CALIBRATION DATE: 07-Dec-2012
Mfg: SEABIRD   Model: 35
Previous cal: 16-Feb-12
Calibration Tech: CAL

ITS-90_COEFFICIENTS
a0 = 4.000167576E-3
a1 = -1.059556581E-3
a2 = 1.660155451E-4
a3 = -9.317019546E-6
a4 = 2.012171620E-7
Slope = 1.000000 Offset = 0.000000
Calibration Standard: Mfg: ASL   Model: F18   s/n: 245-5149

Calibration Standard: Mfg: ASL   Model: F18   s/n: 245-5149
Temperature ITS-90 = 1/{a0+a1[ln(f)]+a2[ln2(f)]+a3[ln3(f)]+a4[ln4(f)} - 273.15 (°C)

SBE35 Count	SPRT ITS-T90	SBE35 ITS-T90	SPRT-SBE35 OLD Coefs	SPRT-SBE35 NEW Coefs
659026.9626	-1.5061	-1.5061	-0.00017	0.00002
590645.0049	0.9940	0.9940	-0.00017	-0.00002
507826.0283	4.4948	4.4948	-0.00018	-0.00001
437800.2467	7.9959	7.9959	-0.00022	-0.00001
378447.0872	11.4975	11.4974	-0.00020	0.00005
328138.6418	14.9902	14.9902	-0.00027	-0.00001
285167.6485	18.4922	18.4922	-0.00026	-0.00002
248489.8620	21.9930	21.9930	-0.00023	-0.00001
217083.1315	25.4946	25.4947	-0.00026	-0.00005
190153.3418	28.9931	28.9930	-0.00017	0.00008
166967.0072	32.4934	32.4934	-0.00044	-0.00003



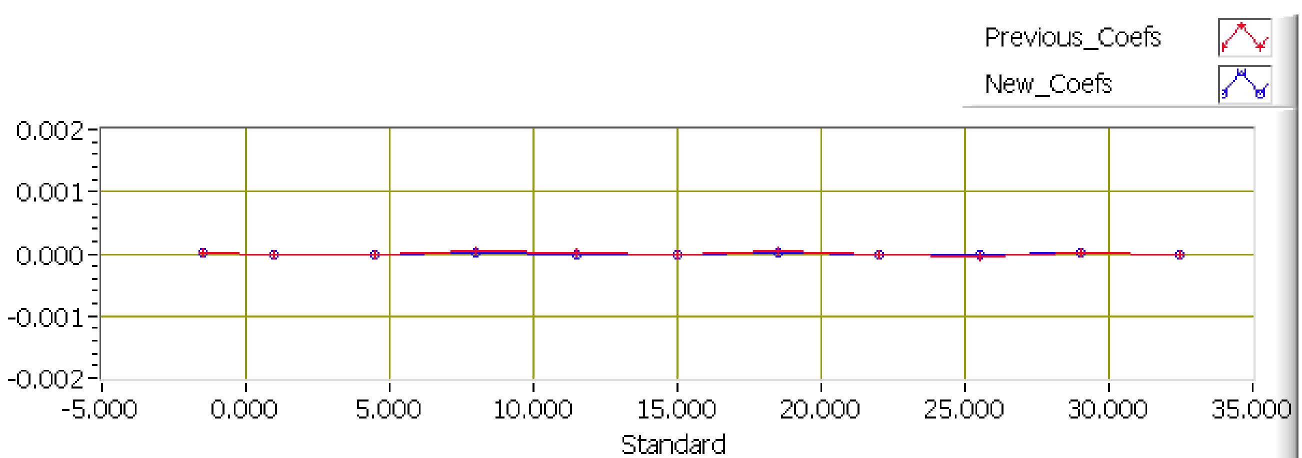
Temperature Calibration Report
STS/ODF Calibration Facility

SENSOR SERIAL NUMBER: 0035
CALIBRATION DATE: 18-Jun-2013
Mfg: SEABIRD   Model: 35
Previous cal: 07-Dec-12
Calibration Tech: CAL

ITS-90_COEFFICIENTS
a0 = 3.891166934E-3
a1 = -1.025343400E-3
a2 = 1.619908097E-4
a3 = -9.106715094E-6
a4 = 1.970986285E-7
Slope = 1.000000 Offset = 0.000000
Calibration Standard: Mfg: ASL   Model: F18   s/n: 245-5149

Calibration Standard: Mfg: ASL   Model: F18   s/n: 245-5149
Temperature ITS-90 = 1/{a0+a1[ln(f)]+a2[ln2(f)]+a3[ln3(f)]+a4[ln4(f)} - 273.15 (°C)

SBE35 Count	SPRT ITS-T90	SBE35 ITS-T90	SPRT-SBE35 OLD Coefs	SPRT-SBE35 NEW Coefs
658922.3875	-1.5025	-1.5025	0.00002	0.00001
590549.0466	0.9977	0.9977	-0.00003	-0.00003
507746.8714	4.4985	4.4985	0.00000	-0.00000
437739.1860	7.9993	7.9992	0.00004	0.00003
378386.6850	11.5013	11.5013	0.00001	-0.00001
328059.0624	14.9962	14.9962	-0.00001	-0.00003
285109.7253	18.4974	18.4974	0.00004	0.00003
248451.9833	21.9969	21.9969	-0.00001	-0.00001
217070.6508	25.4961	25.4962	-0.00004	-0.00002
190139.8707	28.9949	28.9949	0.00001	0.00003
166964.4934	32.4938	32.4938	-0.00000	-0.00001



Sea-Bird Electronics, Inc.

13431 NE 20th Street, Bellevue, WA 98005-2010 USA

Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 2569
CALIBRATION DATE: 16-Jan-13

SBE4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Seimens/meter

GHIJ COEFFICIENTS

g = -1.04780154e+001
h = 1.58729908e+000
i = 8.38055330e-005
j = 9.23998766e-005
CPcor = -9.5700e-008 (nominal)
CTcor = 3.2500e-006 (nominal)

ABCDM COEFFICIENTS

a = 1.51027111e-004
b = 1.58729073e+000
c = -1.04779766e+001
d = -8.43958712e-005
m = 3.8
CPcor = -9.5700e-008 (nominal)

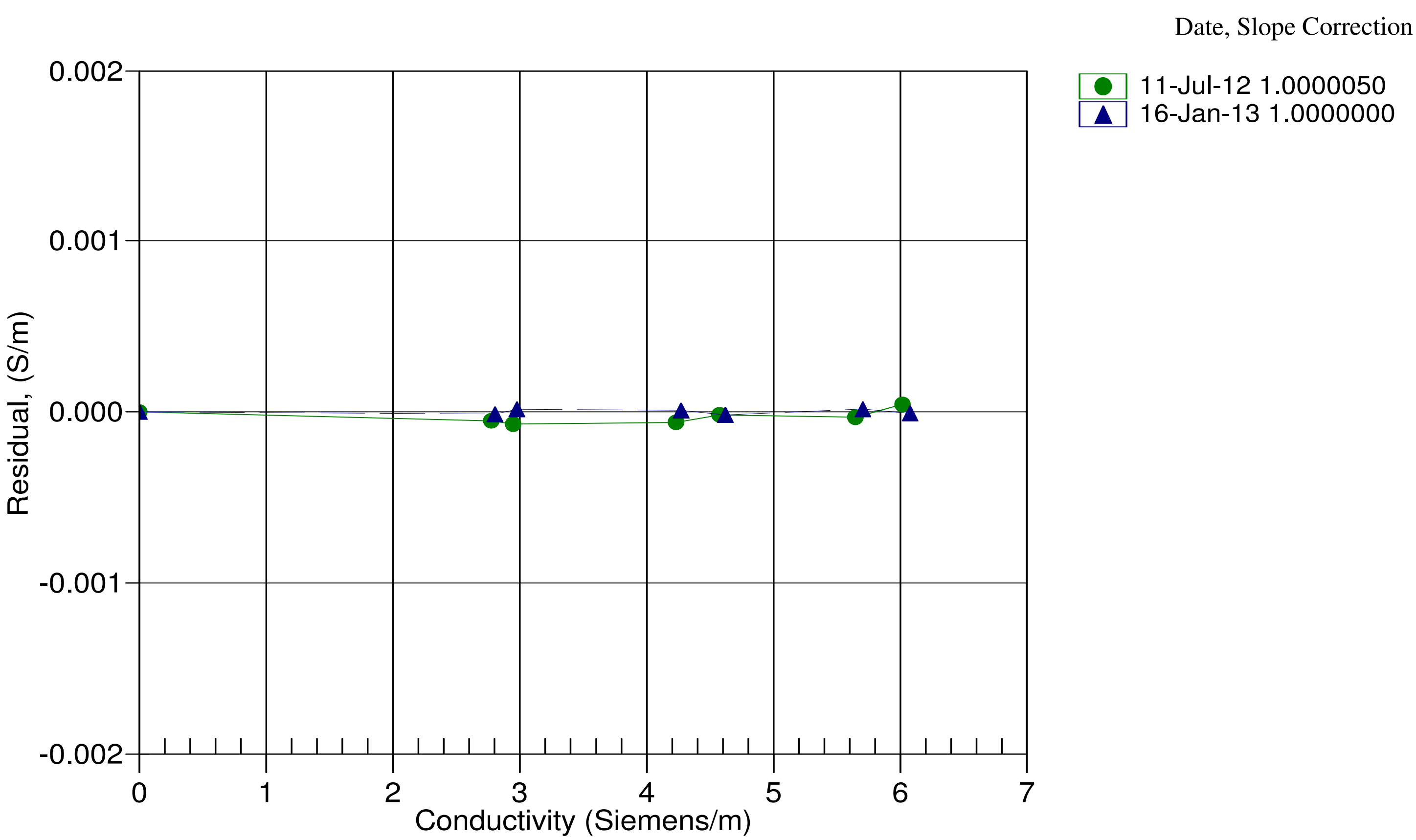
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.56860	0.00000	0.00000
-0.9999	34.8204	2.80488	4.92253	2.80487	-0.00001
1.0001	34.8203	2.97628	5.03070	2.97630	0.00002
15.0001	34.8201	4.27204	5.78283	4.27205	0.00001
18.5001	34.8200	4.61882	5.96794	4.61880	-0.00002
29.0001	34.8176	5.70252	6.51239	5.70253	0.00002
32.5001	34.8087	6.07483	6.68912	6.07482	-0.00001

Conductivity = $(g + hf^2 + if^3 + jf^4) /10(1 + \delta t + \varepsilon p)$ Siemens/meter

Conductivity = $(af^m + bf^2 + c + dt) / [10 (1 + \varepsilon p)$ Siemens/meter

t = temperature[°C)]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = (instrument conductivity - bath conductivity) using g, h, i, j coefficients



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SENSOR SERIAL NUMBER: 2569
CALIBRATION DATE: 26-Jun-13

SBE4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Seimens/meter

GHIJ COEFFICIENTS

```
g = -1.04789607e+001
h =  1.58771515e+000
i = -6.94755467e-005
j =  1.09916171e-004
CPcor = -9.5700e-008 (nominal)
CTcor =  3.2500e-006 (nominal)
```

ABCDM COEFFICIENTS

```
a =  1.26022700e-004
b =  1.58740731e+000
c = -1.04782939e+001
d = -8.29428062e-005
m =  3.9
CPcor = -9.5700e-008 (nominal)
```

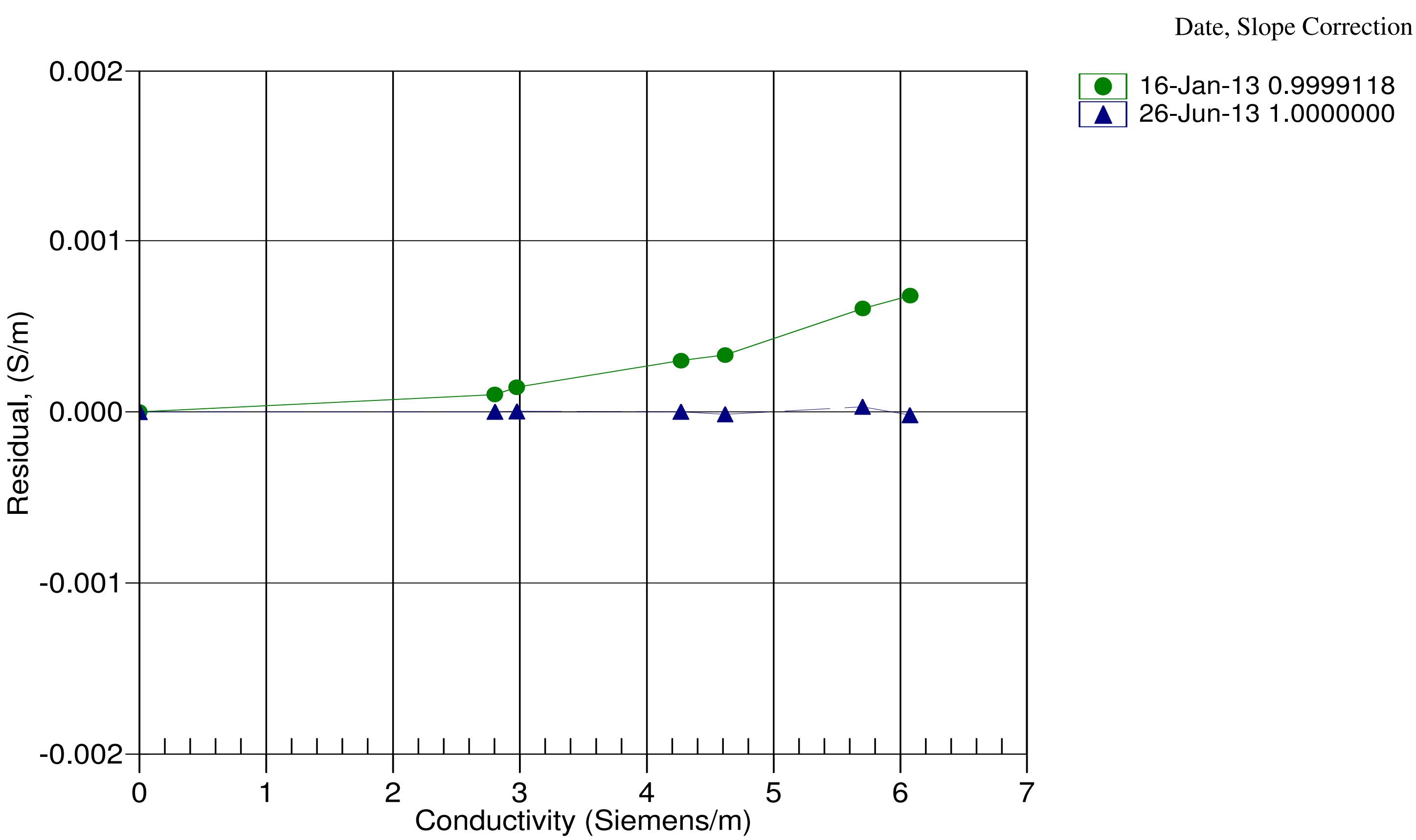
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.56861	0.00000	0.00000
-1.0000	34.7933	2.80290	4.92120	2.80290	0.00000
1.0000	34.7936	2.97421	5.02932	2.97421	0.00000
15.0000	34.7943	4.26920	5.78113	4.26920	0.00000
18.5000	34.7942	4.61575	5.96615	4.61574	-0.00001
29.0000	34.7933	5.69898	6.51041	5.69900	0.00003
32.5000	34.7892	6.07180	6.68737	6.07178	-0.00002

Conductivity = $(g + hf^2 + if^3 + jf^4) / 10(1 + \delta t + \varepsilon p)$ Siemens/meter

Conductivity = $(af^m + bf^2 + c + dt) / [10 (1 + \varepsilon p)$ Siemens/meter

t = temperature[°C)]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = (instrument conductivity - bath conductivity) using g, h, i, j coefficients



Sea-Bird Electronics, Inc.

13431 NE 20th Street, Bellevue, WA 98005-2010 USA

Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 2112
CALIBRATION DATE: 24-Jan-13

SBE4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Seimens/meter

GHIJ COEFFICIENTS

g = -1.01532895e+001
h = 1.46969882e+000
i = -2.39585191e-003
j = 2.51170488e-004
CPcor = -9.5700e-008 (nominal)
CTcor = 3.2500e-006 (nominal)

ABCDM COEFFICIENTS

a = 1.56489138e-007
b = 1.46309451e+000
c = -1.01391372e+001
d = -8.31878451e-005
m = 6.8
CPcor = -9.5700e-008 (nominal)

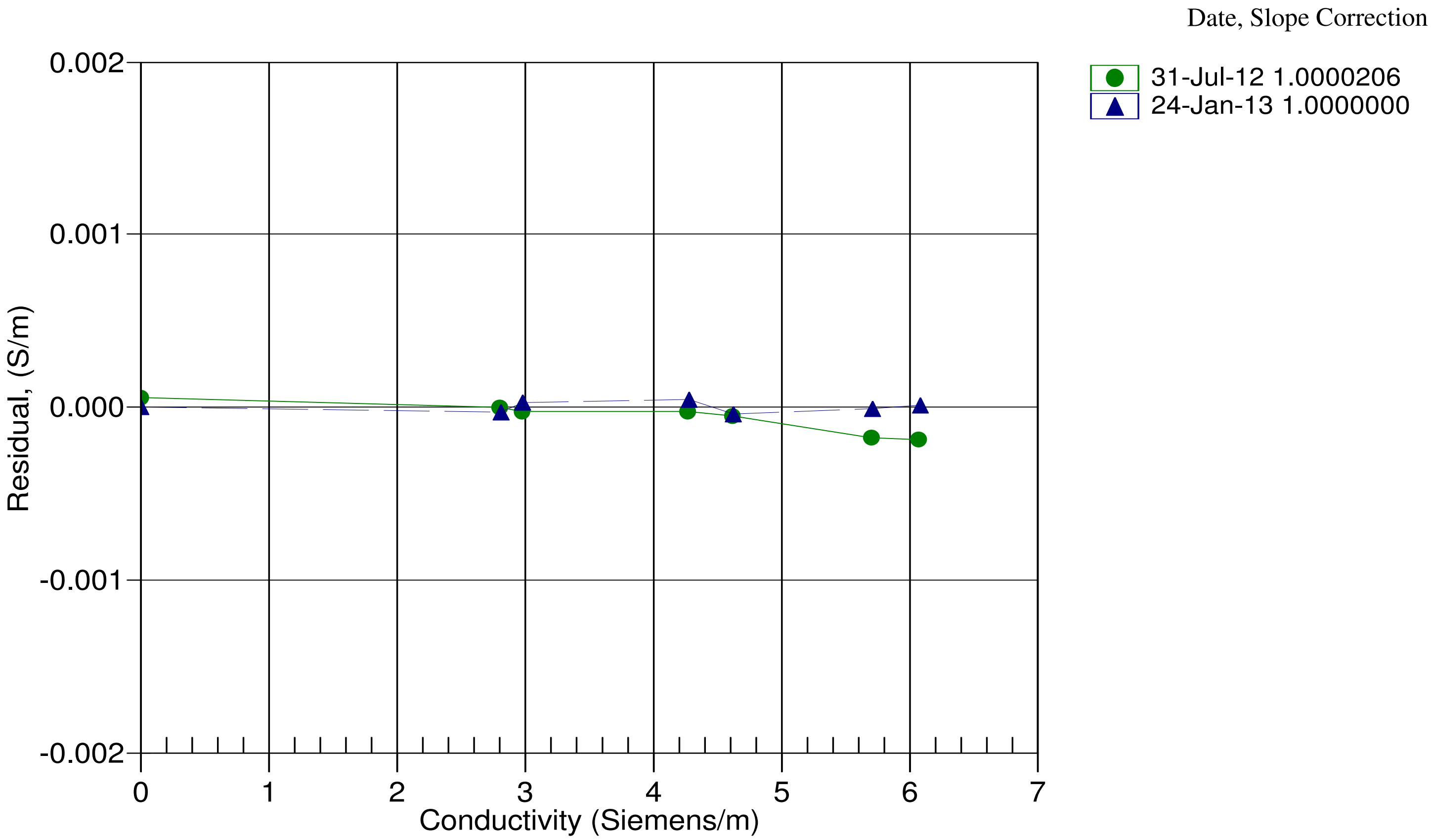
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.63248	0.00000	0.00000
-0.9999	34.8556	2.80746	5.10993	2.80742	-0.00003
1.0000	34.8554	2.97899	5.22333	2.97901	0.00003
15.0001	34.8557	4.27594	6.01125	4.27599	0.00004
18.5001	34.8562	4.62310	6.20502	4.62306	-0.00004
29.0001	34.8539	5.70779	6.77461	5.70778	-0.00001
32.5000	34.8454	6.08049	6.95944	6.08050	0.00001

Conductivity = $(g + hf^2 + if^3 + jf^4) / 10(1 + \delta t + \varepsilon p)$ Siemens/meter

Conductivity = $(af^m + bf^2 + c + dt) / [10 (1 + \varepsilon p)$ Siemens/meter

t = temperature[°C)]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = (instrument conductivity - bath conductivity) using g, h, i, j coefficients



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SENSOR SERIAL NUMBER: 2112
CALIBRATION DATE: 26-Jun-13

SBE4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Seimens/meter

GHIJ COEFFICIENTS

```
g =  -1.01604596e+001
h =   1.47208707e+000
i =  -3.07497725e-003
j =   3.03406167e-004
CPcor = -9.5700e-008 (nominal)
CTcor =  3.2500e-006 (nominal)
```

ABCDM COEFFICIENTS

```
a =   4.69528311e-008
b =   1.46322073e+000
c =  -1.01401284e+001
d =  -7.54295391e-005
m =   7.4
CPcor = -9.5700e-008 (nominal)
```

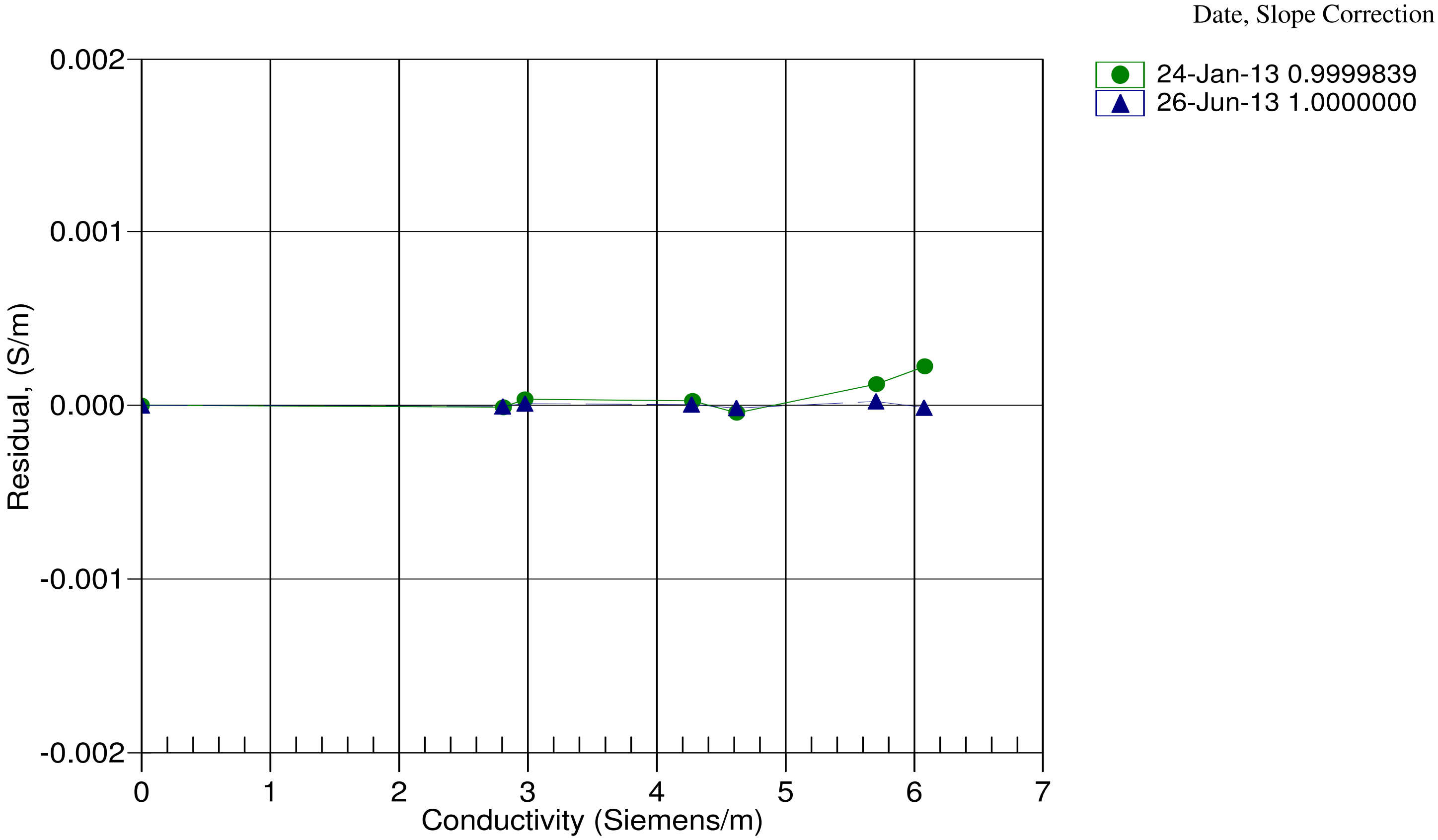
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.63254	0.00000	0.00000
-1.0000	34.7933	2.80290	5.10689	2.80289	-0.00001
1.0000	34.7936	2.97421	5.22019	2.97422	0.00001
15.0000	34.7943	4.26920	6.00741	4.26920	0.00000
18.5000	34.7942	4.61575	6.20100	4.61574	-0.00002
29.0000	34.7933	5.69898	6.77013	5.69900	0.00002
32.5000	34.7892	6.07180	6.95507	6.07179	-0.00001

Conductivity = $(g + hf^2 + if^3 + jf^4) /10(1 + \delta t + \varepsilon p)$ Siemens/meter

Conductivity = $(af^m + bf^2 + c + dt) / [10 (1 +\varepsilon p)$ Siemens/meter

t = temperature[°C)]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = (instrument conductivity - bath conductivity) using g, h, i, j coefficients



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13431 NE 20th Street, Bellevue, WA 98005-2010 USA

Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 3058
CALIBRATION DATE: 02-Nov-12

SBE4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Seimens/meter

GHIJ COEFFICIENTS

```
g = -1.01005228e+001
h =  1.43975781e+000
i =  2.43997621e-004
j =  5.27890498e-005
CPcor = -9.5700e-008 (nominal)
CTcor =  3.2500e-006 (nominal)
```

ABCDM COEFFICIENTS

```
a =  2.29519565e-004
b =  1.43971195e+000
c = -1.00999619e+001
d = -8.13316861e-005
m =  3.5
CPcor = -9.5700e-008 (nominal)
```

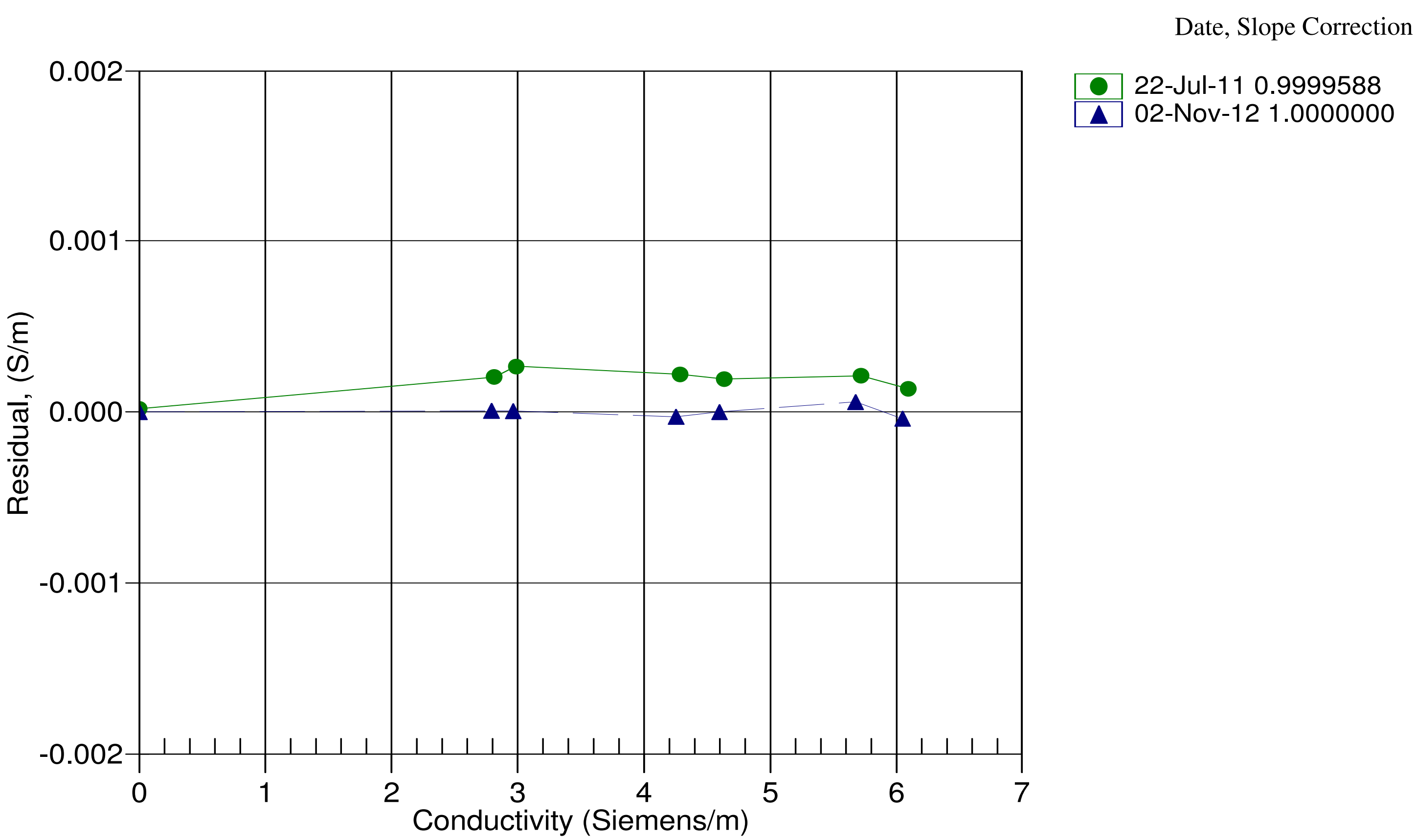
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.64773	0.00000	0.00000
-1.0000	34.6226	2.79042	5.13305	2.79043	0.00001
1.0000	34.6231	2.96102	5.24684	2.96102	0.00000
15.0000	34.6240	4.25051	6.03764	4.25048	-0.00003
18.5000	34.6236	4.59556	6.23217	4.59556	-0.00000
29.0000	34.6223	5.67411	6.80424	5.67417	0.00006
32.5000	34.6186	6.04540	6.99022	6.04536	-0.00004

Conductivity = $(g + hf^2 + if^3 + jf^4) / 10(1 + \delta t + \varepsilon p)$ Siemens/meter

Conductivity = $(af^m + bf^2 + c + dt) / [10 (1 + \varepsilon p)$ Siemens/meter

t = temperature[°C)]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = (instrument conductivity - bath conductivity) using g, h, i, j coefficients



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SENSOR SERIAL NUMBER: 3058
CALIBRATION DATE: 27-Jun-13

SBE4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Seimens/meter

GHIJ COEFFICIENTS

```
g = -1.01015993e+001
h =  1.44026434e+000
i =  7.16368682e-005
j =  6.93263690e-005
CPcor = -9.5700e-008 (nominal)
CTcor =  3.2500e-006 (nominal)
```

ABCDM COEFFICIENTS

```
a =  1.14409422e-004
b =  1.44029202e+000
c = -1.01017161e+001
d = -8.46230813e-005
m =  3.8
CPcor = -9.5700e-008 (nominal)
```

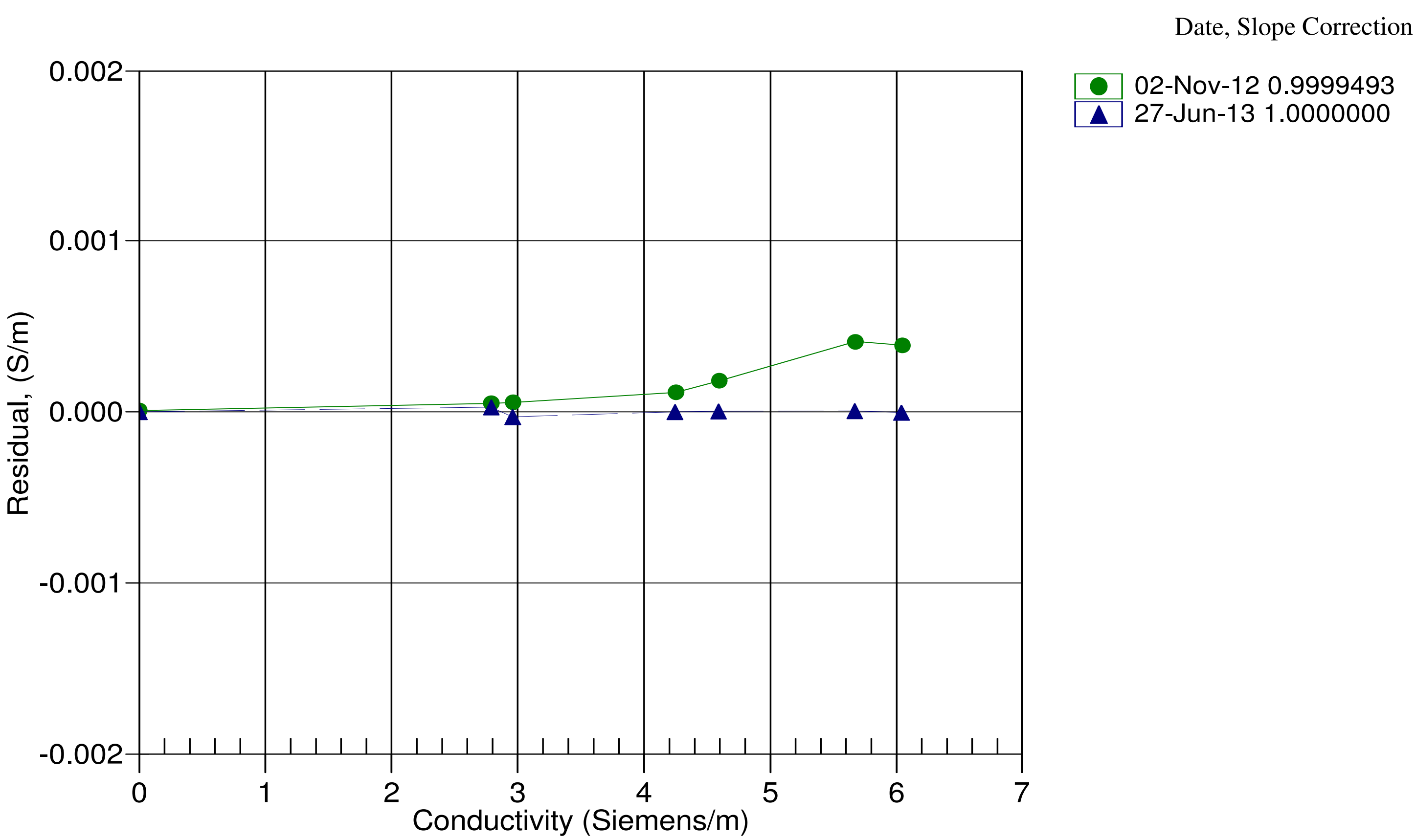
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.64772	0.00000	0.00000
-1.0000	34.5637	2.78612	5.13013	2.78614	0.00003
1.0000	34.5649	2.95652	5.24381	2.95649	-0.00003
15.0000	34.5654	4.24408	6.03389	4.24408	-0.00000
18.5000	34.5652	4.58864	6.22823	4.58864	0.00000
29.0001	34.5647	5.66574	6.79979	5.66574	0.00001
32.5001	34.5602	6.03637	6.98556	6.03637	-0.00000

Conductivity = $(g + hf^2 + if^3 + jf^4) / 10(1 + \delta t + \varepsilon p)$ Siemens/meter

Conductivity = $(af^m + bf^2 + c + dt) / [10 (1 + \varepsilon p)$ Siemens/meter

t = temperature[°C)]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = (instrument conductivity - bath conductivity) using g, h, i, j coefficients



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SENSOR SERIAL NUMBER: 0275
CALIBRATION DATE: 21-Jul-12

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS

Soc = 0.5465
Voffset = -0.4908
Tau20 = 2.09

A = -2.1850e-003
B = 6.0447e-005
C = -1.1869e-006
E nominal = 0.036

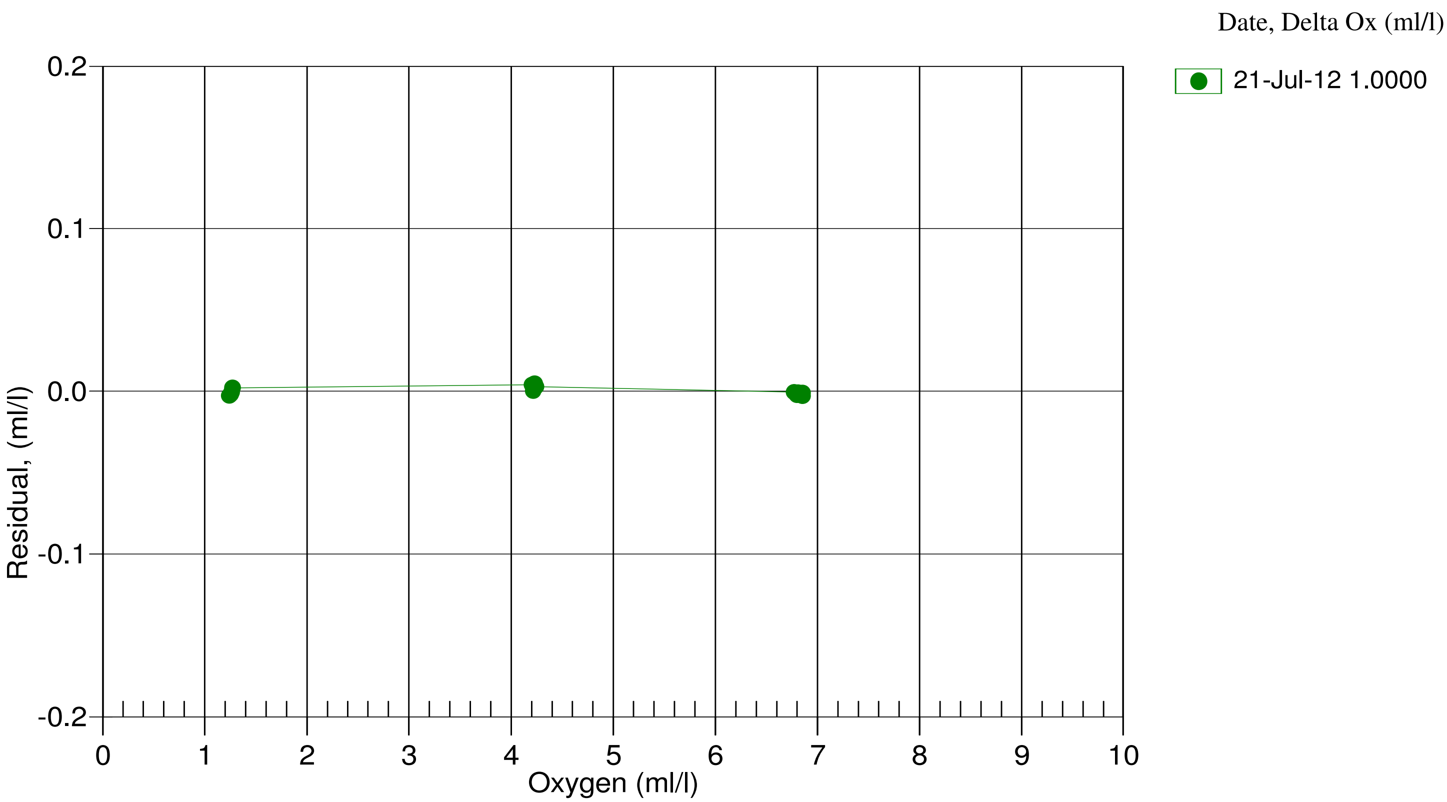
NOMINAL DYNAMIC COEFFICIENTS

D1 = 1.92634e-4
D2 = -4.64803e-2

H1 = -3.30000e-2
H2 = 5.00000e+3
H3 = 1.45000e+3

BATH OX (ml/l)	BATH TEMP ITS-90	BATH SAL PSU	INSTRUMENT OUTPUT(VOLTS)	INSTRUMENT OXYGEN(ml/l)	RESIDUAL (ml/l)
1.24	2.00	0.05	0.726	1.24	-0.00
1.25	6.00	0.05	0.756	1.25	-0.00
1.26	12.00	0.04	0.801	1.25	-0.00
1.27	20.00	0.04	0.866	1.26	-0.00
1.27	26.00	0.04	0.916	1.27	-0.00
1.27	30.00	0.04	0.952	1.28	0.00
4.20	2.00	0.05	1.290	4.21	0.00
4.21	6.00	0.05	1.386	4.21	0.00
4.22	20.00	0.04	1.742	4.22	0.00
4.23	30.00	0.04	2.021	4.23	0.00
4.23	12.00	0.04	1.539	4.23	0.00
4.24	26.00	0.04	1.911	4.24	0.00
6.77	12.00	0.04	2.168	6.77	-0.00
6.79	20.00	0.04	2.502	6.79	-0.00
6.80	6.00	0.05	1.936	6.80	-0.00
6.81	2.00	0.05	1.783	6.80	-0.00
6.85	30.00	0.04	2.969	6.85	-0.00
6.86	26.00	0.04	2.785	6.85	-0.00

Oxygen (ml/l) = Soc * (V + Voffset) * (1.0 + A * T + B * T^2 + C * T^3) * OxSol(T,S) * exp(E * P / K)
V = voltage output from SBE43, T = temperature [deg C], S = salinity [PSU], K = temperature [Kelvin]
OxSol(T,S) = oxygen saturation [ml/l], P = pressure [dbar], Residual = instrument oxygen - bath oxygen



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SENSOR SERIAL NUMBER: 1071
CALIBRATION DATE: 21-Jul-12

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS

Soc = 0.4611
Voffset = -0.5086
Tau20 = 1.25

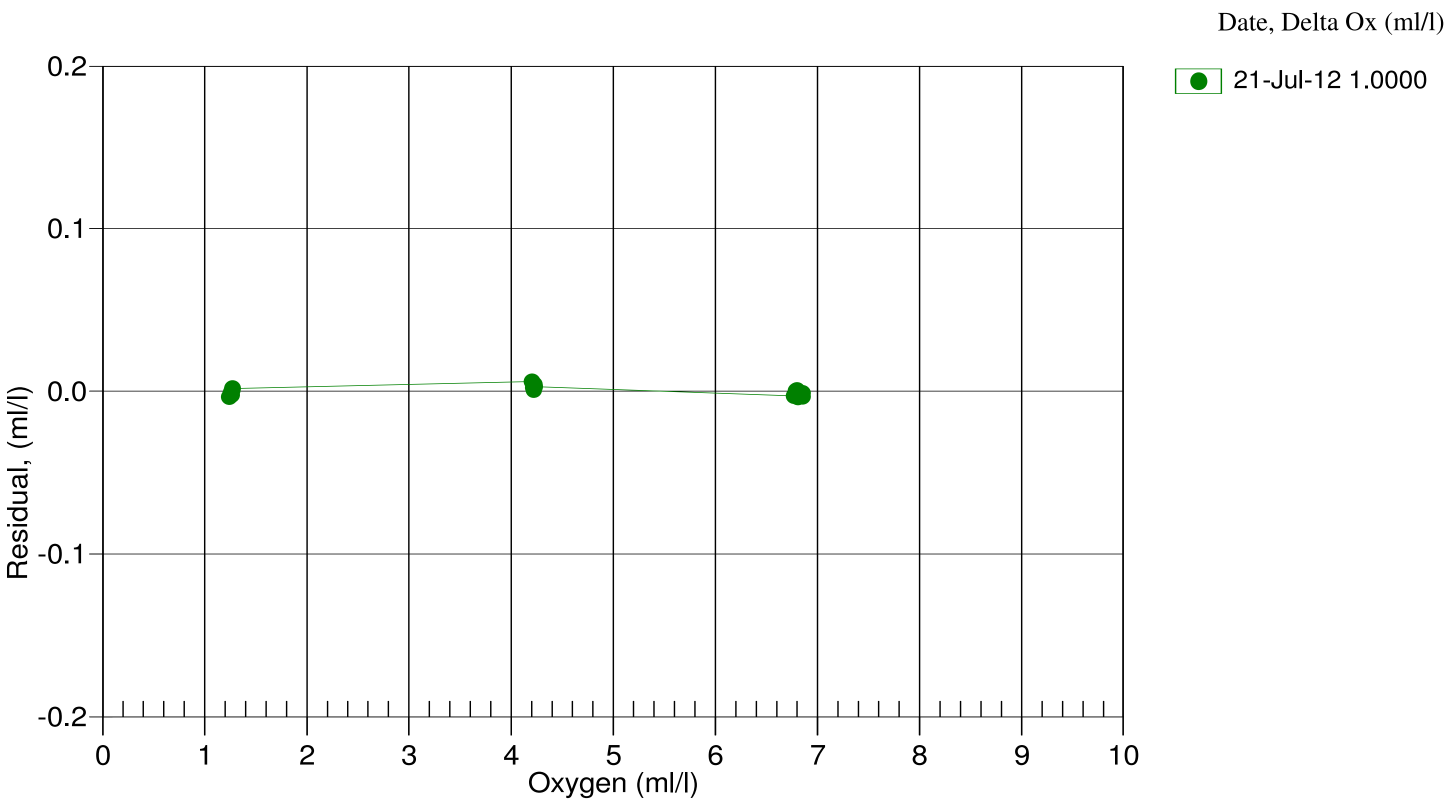
A = -1.6343e-003
B = 3.9125e-005
C = -8.4413e-007
E nominal = 0.036

NOMINAL DYNAMIC COEFFICIENTS

D1 = 1.92634e-4 H1 = -3.30000e-2
D2 = -4.64803e-2 H2 = 5.00000e+3
H3 = 1.45000e+3

BATH OX (ml/l)	BATH TEMP ITS-90	BATH SAL PSU	INSTRUMENT OUTPUT(VOLTS)	INSTRUMENT OXYGEN(ml/l)	RESIDUAL (ml/l)
1.24	2.00	0.05	0.787	1.24	-0.00
1.25	6.00	0.05	0.822	1.25	-0.00
1.26	12.00	0.04	0.875	1.26	-0.00
1.27	20.00	0.04	0.950	1.26	-0.00
1.27	26.00	0.04	1.009	1.27	0.00
1.27	30.00	0.04	1.052	1.28	0.00
4.20	2.00	0.05	1.455	4.21	0.01
4.21	6.00	0.05	1.568	4.22	0.00
4.22	20.00	0.04	1.983	4.22	0.00
4.23	30.00	0.04	2.311	4.23	0.00
4.23	12.00	0.04	1.745	4.23	0.00
4.24	26.00	0.04	2.181	4.24	0.00
6.77	12.00	0.04	2.486	6.77	-0.00
6.79	20.00	0.04	2.880	6.79	0.00
6.80	6.00	0.05	2.217	6.80	0.00
6.81	2.00	0.05	2.038	6.80	-0.00
6.85	30.00	0.04	3.424	6.85	-0.00
6.86	26.00	0.04	3.211	6.85	-0.00

Oxygen (ml/l) = Soc * (V + Voffset) * (1.0 + A * T + B * T^2 + C * T^3) * OxSol(T,S) * exp(E * P / K)
V = voltage output from SBE43, T = temperature [deg C], S = salinity [PSU], K = temperature [Kelvin]
OxSol(T,S) = oxygen saturation [ml/l], P = pressure [dbar], Residual = instrument oxygen - bath oxygen



Dissolved Oxygen

MODEL : ARO-CAV

SERIAL : 105

DATE : August 7, 2012

Loaction : Calibration office of manfacture department at Kobe

Method : 2 points calibration of span and zero is carried out with 100% saturation water and nigrogen gas. Calibration should be done after making the instruments accustomed in the water and keeping saturation with air-bubbling. Outputs in saturated water and nitr

Film No= 16008A

A =	-40.0057	E =	0.0045
B =	130.010	F =	0.00
C =	-0.42837	G =	0.00
D =	0.0112	H =	1.00

Results :

Temperature at calibration[℃]	25
Air pressure at calibration[hPa]	992.2
Air saturation at calibration[%]	97.9

	Span output [%]	zero output [%]	Span Error [%]	Zero Error [%]
1st	97.3	0.0	-0.6	0.0
2nd	97.3	0.0	-0.6	0.0
3rd	97.3	0.0	-0.6	0.0

Judgement : **Good**

Calibration group,

Manufacture department at Kobe

JFE Advantech Co., LTD

Temperature

MODEL : ARO-CAV

SERIAL : 105

DATE : August 7, 2012

Loaction : Calibration office of manfacture department at Kobe

Method : The instrument is calibrated in a constant temperature water tank.
5 outputs in n-value corresponding to 5 water temperature ranging from 3 to 31 degrees C are computed by least square method.
(To make the tank temperature constant, water is stirred. The reference temperature is measured by a thermometer)

Reference device : JFE Advantech self-made temperature probe calibrated by 'HART SCIENTIFIC' 1575A Super Thermometer (Platinum Thermo Resistance Probe NSR160)
(certified bv JCSS and ITS90)

Temperature : Temperature(℃) $= A+B \times N+C \times N^2+D \times N^3$

A = -5.455093E+00
B = 1.6693247E+01
C = -2.144412E+00
D = 4.5669980E-01

Reference [℃]	Output [V]	Calculated [℃]	Error [℃]
3.564	0.57794	3.564	0.000
10.433	1.06415	10.431	-0.002
17.167	1.56513	17.170	0.003
24.220	2.08868	24.218	-0.002
31.285	2.58698	31.286	0.001

Criteria for acceptability : 1. The errors in above form must be within ±0.02℃
2. After writing the calibration coefficients into instrument, one point check at any temperature must agree with the accuracy declared by the instrument.

Output Check :

Reference [℃]	Calculated [℃]	Error [℃]
23.251	23.256	0.005

Judgement : **Good**

武 '12.8.-8 石

下 '12.8.10 川

Calibration group,

Manufacture department at Kobe

西村 '12.8.10 (達)

JFE Advantech Co., LTD

PO Box 518
620 Applegate St.
Philomath, OR 97370

WET Labs

(541) 929-5650
Fax (541) 929-5277
www.wetlabs.com

C-Star Calibration

Date July 19, 2012 S/N# CST-327DR Pathlength 25

	Analog output
V_d	**0.059 V**
V_{air}	**4.613 V**
V_{ref}	**4.523 V**

Temperature of calibration water	**20.1** °C
Ambient temperature during calibration	**22.0** °C

Relationship of transmittance (Tr) to beam attenuation coefficient (c), and pathlength (x, in meters): $\mathbf{Tr = e^{-cx}}$

To determine beam transmittance: $\mathbf{Tr = (V_{sig} - V_{dark}) / (V_{ref} - V_{dark})}$

To determine beam attenuation coefficient: $\mathbf{c = -1/x * \ln (Tr)}$

V_d Meter output with the beam blocked. This is the offset.
V_{air} Meter output in air with a clear beam path.
V_{ref} Meter output with clean water in the path.
Temperature of calibration water: temperature of clean water used to obtain V_{ref}.
Ambient temperature: meter temperature in air during the calibration.
V_{sig} Measured signal output of meter.

CLIVAR P2 - 2013

LEG 1

Transmissometer Air Calibration M&B Calculator
CST-327-DR

23-Mar-13

	Factory Cal Sheet Info			AVG Deck/Lab Readings		
Air Reading	4.613			4.546		
Water Reading	4.523			N/A		
Blocked Reading	0.059			0.06		
Air Temp.	17.096	17.100	17.081	17.068	17.063	17.048
M	20.512		Air Temp. Average			17.076
B	-1.231					

22-Apr-13

	Factory Cal Sheet Info			AVG Deck/Lab Readings		
Air Reading	4.613			4.554		
Water Reading	4.523			N/A		
Blocked Reading	0.059			0.059		
Air Temp.	20.277	20.767	20.305	20.281	20.275	20.270
M	20.471		Air Temp. Average			20.363
B	-1.208					

2-May-13

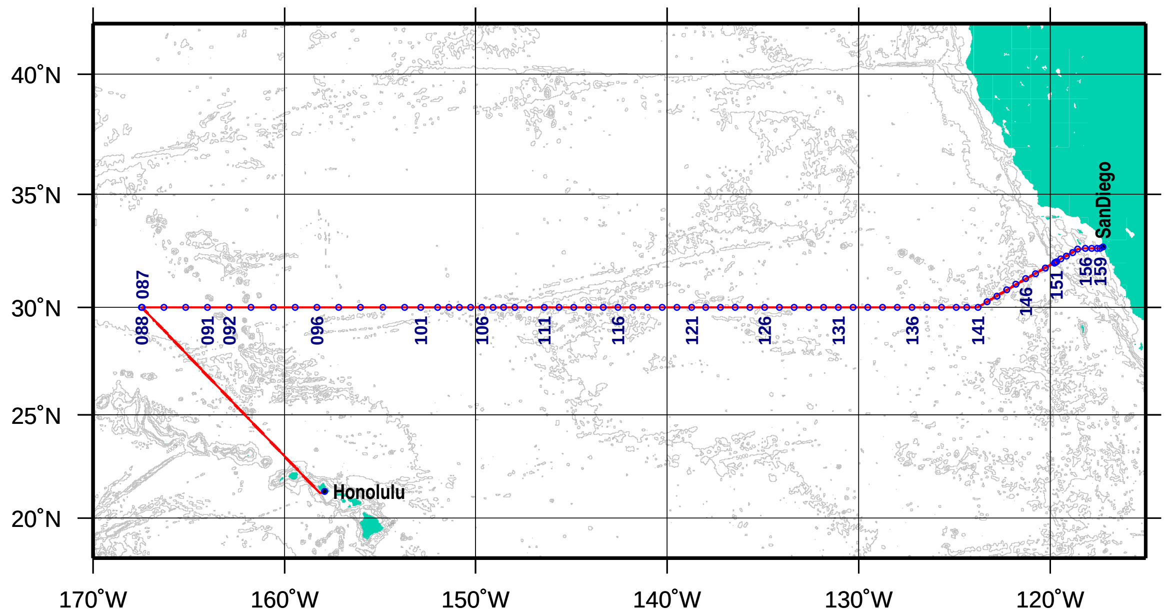
	Factory Cal Sheet Info			AVG Deck/Lab Readings		
Air Reading	4.613			4.513		
Water Reading	4.523			N/A		
Blocked Reading	0.059			0.059		
Air Temp.	20.624	20.618	20.613	20.626	20.647	20.653
M	20.660		Air Temp. Average			20.630
B	-1.219					

CLIVAR/Carbon P02E
R/V Melville MV1306

8 May 2013 - 1 June 2013
Honolulu, HI - San Diego, CA

Chief Scientist: Dr. Sabine Mecking
University of Washington

Co-Chief Scientist: Dr. Gunnar Voet
University of Washington



Cruise Report
1 June 2013
Rev. 23 July 2013

Summary

A hydrographic survey (P02, leg 2) was conducted in the eastern North Pacific Ocean aboard the UNOLS vessel R/V Melville from 8 May 2013 - 1 June 2013. A total of 72 rosette/CTD/LADCP stations were occupied on a transect running roughly along latitude 30°N. CTD casts extended to within 10 meters of the seafloor, and up to 35 water samples were collected throughout the water column on all casts. CTDO (conductivity, temperature, pressure, oxygen), transmissometer, fluorometer, and LADCP (lowered acoustic Doppler current profiler) electronic data; rosette water samples; and underway shipboard ADCP and carbon dioxide (CO_2) measurements were collected during the survey. In addition, 3 Argo floats were deployed during this leg for NOAA/PMEL.

Salinity and dissolved oxygen samples, drawn from most bottles on every full cast, were analyzed and used to calibrate the CTD conductivity and oxygen sensors. Water samples were also analyzed on board the ship for nutrients (silicate, phosphate, nitrate, nitrite), total CO_2/TCO_2 (aka dissolved inorganic Carbon/DIC), pH, total alkalinity, and transient tracers (CFCs and SF_6).

Additional water samples were collected and stored for analysis onshore: ^{3}Helium / Tritium, ^{13}C / ^{14}C, dissolved organic Carbon and total dissolved Nitrogen (DOC / TDN), ∂^{15}N-NO_3 / ∂^{18}O-NO_3, ^{137}Cs / ^{134}Cs / ^{90}Sr, ^{129}I, density and Calcium.

Underway measurements included GPS navigation, multibeam bathymetry, ADCP, meteorological parameters, sea surface measurements (including temperature, conductivity/salinity, dissolved oxygen, fluorescence), and gravity. In addition to the permanently installed R/V Melville systems, there were a Univ. of Washington Equilibrator Inlet Mass Spectrometer (EIMS) system, (which, however, ended up nonfunctional due to a broken filament when turning it back on in port), and a NOAA GO 8050 underway pCO_2 system which ran throughout the leg.

P02 Leg 2 Narrative - S. Mecking, Chief Scientist

Leg 2 of the 2013 P02 cruise was the continuation of a repeat hydrography section that runs the through the center of the North Pacific subtropical gyre along nominally 30°N. Leg 1 went from Yokohama, Japan to Honolulu, HI, and leg 2 from Honolulu, HI to San Diego, CA. Earlier occupations of the P02 section were conducted in 1993/1994 as part of the Japanese WOCE program and in 2004 as part of the NSF- and NOAA-sponsored U.S. Global Ocean Carbon and Repeat Hydrography Program that supports the objectives of the U.S. CLIVAR and U.S. Carbon Cycle Programs.

The 2013 re-occupation of P02 is also part of the U.S. Global Ocean Carbon and Repeat Hydrography Program and in support of CLIVAR/CO_2. Goals of the reoccupation are to monitor oceanic inventories of CO_2, heat, and freshwater and to examine changes in transports and ventilation fluxes.

The start of leg 2 of 2013 P02, originally planned for 28 April, was delayed by 10 days to 8 May due to mechanical problems with both the main aft winch (DESH-6) and the back-up forward winch (DESH-5) on leg 1 of the cruise. Fortunately, these problems could all be resolved during leg 1 (fixing the winches included a return to Yokohama for several days), and the main winch was used throughout leg 2.

However, the fate of leg 2 was up in the air for a while due to the delays. Postponing leg 2 to August 2013 or until 2014 was being discussed. Thanks to the efforts of ship scheduling, the funding agencies and others, as well as to significant rearrangement of the cruise that followed P02, leg 1 and leg 2 of 2013 P02 could be conducted back-to-back as planned.

During the port stop between legs 1 and 2 at the University of Hawaii Marine Center (May 5-8, 2013), the leg 1 CFC equipment was unloaded, and the CFC system of Dr. Dong-Ha Min at the University of Texas was loaded and installed instead. All other measurement systems remained the same for legs 1 and 2.

Many of the "leg 1 & 2" science party members (14 out of 28) could enjoy a couple of well-deserved days off in Honolulu after their extended leg 1 journey. 14 "new leg 2" members moved on-board, and R/V Melville departed from UHMC at 1000 on May 8, 2013 for the start of leg 2.

Leg 2 began with a 2.5-day steam northwestward toward 30°N, 167.45°W to repeat station 087, the last station occupied on leg 1. One mid-depth test cast (1500m) was performed on day 2 of the steam. Both the test cast and the following regular leg 2 stations were carried out without much problem since procedures were already in place thanks to leg 1. Station numbering is consecutive between legs 1 and 2 with the leg 2 station numbers ranging from 088 at the leg 1/2 repeat location to 159.

Station spacing was 60nm at first -- as outlined in a revised science plan ("March-29 science plan") that was provided by Dr. Jim Swift, chief scientist on leg 1, for legs 1 and 2 during the wait period for winch repairs in Yokohama to accommodate at-sea days lost. Shorter station spacing followed at a deep ocean trench at 150°W (Murray Fracture Zone), dropping to 45nm after station 100 and to 30nm after station 102.

After the trench (onward from station 109), we continued at 40nm spacing (down from 60 nm in the revised science plan, but still larger than the 30nm spacing in the original P02 proposal) since the station timing in the revised plan had been estimated conservatively and this is approximately the same spacing as done along this portion of P02 in 2004. Two stations before the northeastward jog from 30°N to San Diego, the spacing was further reduced to 30nm (at station 139). The last 19 stations of leg 2 (141-159) along the northeastward stretch were an exact repeat of P02 stations occupied in 2004 on and before the shelf with station spacing ranging from 3nm (shelf break) to 30nm.

During leg 2, we continued to operate with the primary SIO pylon that had been used and repaired on leg 1. At the start of leg 2, this resulted in effectively a 35-place rosette with bottle 35 dismounted due to a defective, but sealed solenoid. A 36-place pylon had been borrowed from NOAA/PMEL and shipped to Honolulu as a spare (the original back-up pylon had failed on leg 1). Since 35 bottles still were sufficient to resolve the vertical structure of the water column, the primary SIO pylon was left on the rosette, and the NOAA/PMEL pylon was kept as a true spare.

During the initial steam from Honolulu to 30°N, it was also discussed whether to replace and rewire the damaged solenoid plus other suspicious ones on the primary SIO pylon. However, since this is not a standard repair done at sea, but usually would require shipping the pylon back to the manufacturer (Seabird Electronics), a decision was made by the chief scientist not to take the risk involved with the repair despite the excellent skills of the SIO STS electronics engineer on-board, but to continue with the pylon as is.

As leg 2 went on, the solenoids of bottle 1 (as of station 095) and of bottle 28 (as of station 115) failed as well, and the bottles were dismounted. Since bottom depths were already getting shallower by station 115, we decided to continue with just 33 bottles rather than putting in the spare pylon, and the rosette held up in this condition until the end of the cruise. Communication to shore was maintained regarding all pylon decisions made on leg 2, and the "going with the problems we know rather than the ones we don't know"-approach (i.e. keeping the current pylon) confirmed.

Other than the uncertainties regarding the pylon, there were little technical problems on leg 2. At some point (after station 108), an exchange of the block on the A-frame of the aft winch became necessary due to increasingly loud noises coming from a broken bearing. The Captain and crew dealt with this in a very professional manner and replaced the block with the one from the forward winch while staying on station.

The weather on leg 2 also provided little problem. We encountered somewhat rougher weather when heading into stronger trade winds around station 111, and then again toward the end of the cruise (stations 144-149) in the California Current region. In the latter case wind speeds peaked at >35 knots, and the ships rolls were heavy enough so that winch speeds could not exceed 30m/min for the duration of at least one entire station. But operations could still continue throughout.

Leg 2 of 2013 P02 arrived at SIO's Nimitz Marine Facility at 1130 on 1 June after a quick stop at the fuel dock. This was two days ahead of a 3 June arrival day published in the most recent UNOLS schedule because the two contingency days that had been added by NSF to the leg 2 timing were not needed (two extra days added to compensate for bad weather encountered on leg 1, however, were used). The total duration of leg 2 was 25 UNOLS days.

Preliminary results indicate a freshening trend of the waters above the salinity minimum associated with North Pacific Intermediate Water from 2004 to 2013. An increase in salinity is observed below. In addition, the oxygen data (mostly decrease) and nutrient data (mostly increase) exhibit obvious signs of decadalscale variability in the thermocline. These will need to be brought into context with earlier observations of North Pacific ventilation changes in a more detailed investigation of the new data set.

We would like to extend our thanks from Jim Swift, the Captain, and the leg 1 and 2 science parties and crew, to ship scheduling, NSF, NOAA, and the Navy, and everyone involved in making a back-to-back occupation of legs 1 and 2 of 2013 P02 possible despite the delays and timing difficulties encountered. We are very grateful for these efforts and the support received from all involved.

Principal Programs of CLIVAR/Carbon P02E

Program	Affiliation*	Principal Investigator	email
CTDO/Rosette, Nutrients, O_2, Salinity, Data Management	UCSD/SIO	James H. Swift	jswift@ucsd.edu
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pH, Total Alkalinity	UCSD/SIO	Andrew Dickson	adickson@ucsd.edu
DOC, TDN	UCSB	Craig Carlson	carlson@lifesci.ucsb.edu
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$\partial^{15}N$-NO_3 , ^{18}O-NO_3	Princeton	Daniel Sigman	sigman@princeton.edu
^{137}Cs, ^{134}Cs, ^{90}Sr	WHOI	Ken Buesseler Alison Macdonald	kbuesseler@whoi.edu amacdonald@whoi.edu
^{129}I, ^{127}I	LLNL	Tom Guilderson	guildersonl @llnl.gov
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EIMS Underway Data (N_2, O_2, Ar and CO_2)	UWash	Paul D. Quay Hilary Palevsky	pdquay@uw.edu palevsky@uw.edu
Ship's Underway Data	UCSD/SIO	Frank Delahoyde	fdelahoyde@ucsd.edu

* Affiliation abbreviations listed on page

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* Affiliation abbreviations are listed on page 5

KEY to Institution Abbreviations	
CR	Computing Resources (SIO/STS)
LDEO	Lamont-Doherty Earth Observatory (Columbia University)
MPL	Marine Physical Laboratory (SIO)
NOAA	National Oceanic and Atmospheric Administration
ODF	Oceanographic Data Facility (SIO/STS)
PMEL	Pacific Marine Environmental Laboratory (NOAA)
RT	Research Technicians (SIO/STS)
SIO	Scripps Institution of Oceanography (UCSD)
SOMTS	Ship Operations and Marine Technical Support (SIO)
STS	Shipboard Technical Support (SIO)
UCSD	University of California, San Diego
UCSB	University of California, Santa Barbara
U.Hawaii	University of Hawaii
U.Texas	University of Texas
U.Washington	University of Washington
WHOI	Woods Hole Oceanographic Institution
Yale U.	Yale University

Core Hydrographic Measurements: CTD Data, Salinity, Oxygen and Nutrients

Oceanographic Data Facility and Research Technicians
Shipboard Technical Support
Scripps Institution of Oceanography
UC San Diego
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The CLIVAR/Carbon P02E repeat hydrographic line was reoccupied from 8 May 2013 - 1 June 2013 aboard R/V Melville during a survey consisting of rosette/CTD/LADCP stations and a variety of underway measurements. The ship departed Honolulu, HI on 8 May 2013 and arrived San Diego, CA on 1 June 2013 (UTC dates).

A sea-going science team gathered from 9 oceanographic institutions participated on the cruise. The programs and PIs, and the shipboard science team and their responsibilities, are listed in the Narrative section.

Description of Measurement Techniques

1. CTD/Hydrographic Measurements Program

A total of 72 stations were occupied with one rosette/CTD/LADCP cast completed at each. 1 test cast(s) and 4 aborted cast(s) were not reported. CTDO data and water samples were collected on each rosette/CTD/LADCP cast, usually to within 10 meters of the bottom. Water samples measured on board or stored for shore analysis are tabulated in the Bottle Sampling section.

Pressure, temperature, conductivity/salinity, dissolved oxygen, fluorometer and transmissometer data were recorded from CTD profiles. Current velocities were measured by the RDI workhorse LADCP. Core hydrographic measurements consisted of salinity, dissolved oxygen and nutrient water samples taken from each rosette cast. The distribution of samples is shown in the following figures.

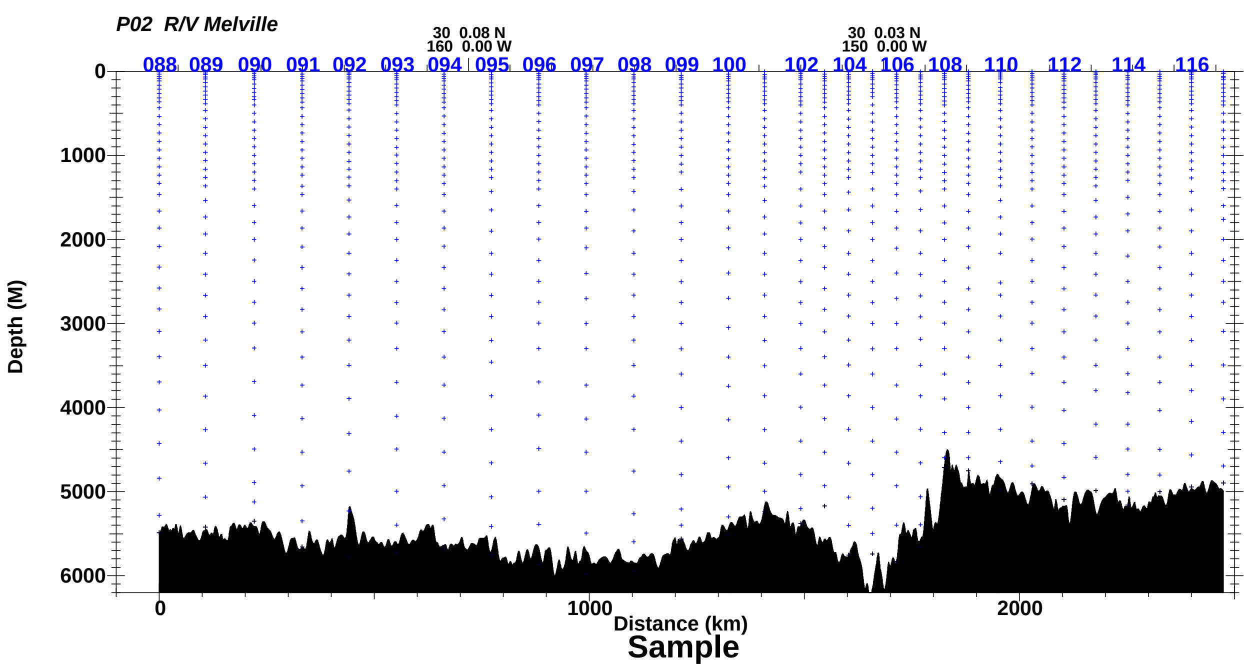

Figure 1.0 P02E Sample Distribution, Stations 88-117

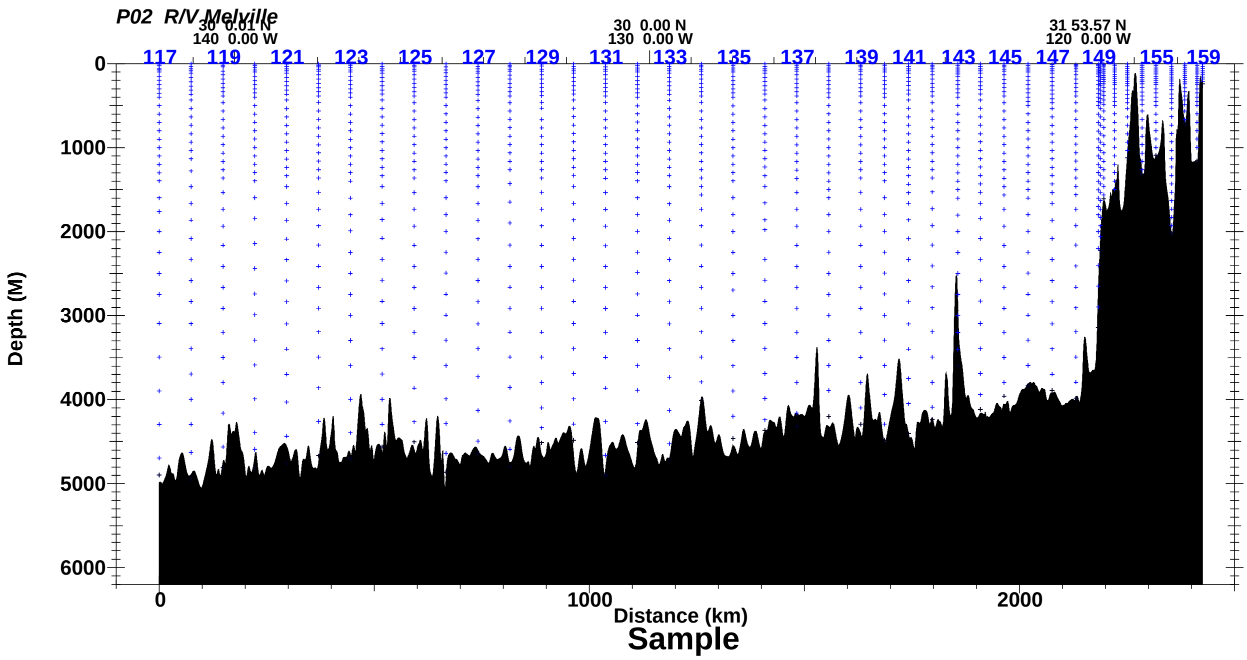

Figure 1.1 P02E Sample Distribution, Stations 117-159

1.1. Water Sampling Package

Rosette/CTD/LADCP casts were performed with a package consisting of a 36-bottle rosette frame (SIO/STS), a 36-place carousel (SBE32) and 10.0L Bullister-style bottles (SIO/STS) with an absolute volume of 10.4L. Underwater electronic components consisted of a Sea-Bird Electronics SBE9*plus* CTD with dual pumps (SBE5), dual temperature sensors (SBE3*plus*), dual conductivity sensors (SBE4C), dissolved oxygen (SBE43), chlorophyll fluorometer (Seapoint), transmissometer (WET Labs), altimeter (Simrad), reference temperature (SBE35RT) and LADCP (RDI).

The CTD was mounted vertically in an SBE CTD cage attached to the bottom of the rosette frame and located to one side of the carousel. The SBE4C conductivity, SBE3*plus* temperature and SBE43 Dissolved oxygen sensors and their respective pumps and tubing were mounted vertically in the CTD cage, as recommended by SBE. Pump exhausts were attached to the CTD cage on the side opposite from the sensors and directed downward. The transmissometer was mounted horizontally, and the fluorometer was mounted vertically near the bottom of the rosette frame. The altimeter was mounted on the inside of the bottom frame ring. The 150 KHz downward-looking Broadband LADCP (RDI) was mounted vertically on one side of the frame between the bottles and the CTD. Its battery pack was located on the opposite side of the frame, mounted on the bottom of the frame. Table 1.1.0 shows height of the sensors referenced to the bottom of the frame:

Instrument	Height in cm
Pressure Sensor, inlet to capillary tube	27
Temperature (probe tip at TC duct inlet)	15
SBE35RT (centered between T1/T2 on same plane)	15
Rinko DO	11
Transmissometer	12
Fluorometer	12
Altimeter	2
LADCP (paddle center)	7
Outer-ring (odd #s) bottle centerline	124
Inner-ring (even #s) bottle centerline	111
Reference (Surface Zero tape on wire)	280

Table 1.1.0 Heights referenced to bottom of rosette frame

The rosette system was suspended from a UNOLS-standard three-conductor 0.322" electro-mechanical sea cable. The sea cable was terminated at the beginning of P02E. The R/V Melville's DESH-6 winch was used for all casts.

The deck watch prepared the rosette 20-30 minutes prior to each cast. The bottles were cocked and all valves, vents and lanyards were checked for proper orientation. Once stopped on station, the rosette was moved out from the aft hangar to the deployment location under the A-frame using an air-powered cart and tracks. The CTD was powered-up and the data acquisition system started from the computer lab. The rosette was unstrapped from the cart. Tag lines were threaded through the rosette frame and syringes were removed from CTD intake ports. The winch operator was directed by the deck watch leader to raise the package.

The A-frame and rosette were extended outboard and the package was quickly lowered into the water. Tag lines were removed and the package was lowered to 10 meters, until the console operator determined that the sensor pumps had turned on and the sensors were stable. The winch operator was then directed to bring the package back to the surface, at which time the wire-out reading was re-zeroed before descent.

Most rosette casts were lowered to within 10 meters of the bottom, using the CTD depth and multibeam echosounder depth to estimate the distance, and the altimeter and wire-out to direct the final approach.

For each up cast, the winch operator was directed to stop the winch at up to 35 pre-determined sampling depths. These standard depths were staggered every station using 3 sampling schemes. To ensure package shed wake had dissipated, the CTD console operator waited 30 seconds prior to tripping sample bottles. An additional 10 seconds elapsed before moving to the next consecutive trip depth, to allow the SBE35RT time to take its readings. The deck watch leader directed the package to the surface for the last bottle trip.

Recovering the package at the end of the deployment was essentially the reverse of launching, with the additional use of poles and snap-hooks attached to tag lines for controlled recovery. The rosette was secured on the cart and moved into the aft hangar for sampling. The bottles and rosette were examined before samples were taken, and anything unusual was noted on the sample log.

Each bottle on the rosette had a unique serial number, independent of the bottle position on the rosette. Sampling for specific programs was outlined on sample log sheets prior to cast recovery or at the time of collection.

Routine CTD maintenance included soaking the conductivity and oxygen sensors with 1% Triton-X solution between casts to maintain sensor stability and eliminate accumulated bio-films. Rosette maintenance was performed on a regular basis. Valves and o-rings were inspected for leaks. The rosette, CTD and carousel were rinsed with fresh water as part of the routine maintenance.

1.2. Navigation and Bathymetry Data Acquisition

Navigation data were acquired at 1-second intervals from the ship's Furuno GP150 GPS receiver by a Linux system beginning 8 May 2013 at 0350z, as the R/V Melville left the dock in Honolulu, HI.

Center-beam bathymetric and hull-depth correction data from the Kongsberg EM-122 multibeam echosounder system were acquired by the ship, and fed into the ODF Linux systems through a serial data feed. A minor change in STS/ODF software was required to read in the depth feed with the correction. Bathymetry and navigation data were merged and stored on the ODF systems, and data were made available as displays on the ODF acquisition system during casts. Bottom depths associated with rosette casts were recorded on the Console Logs during deployments.

Corrected multibeam center depths are reported for each cast event in the WOCE and Exchange format files.

1.3. CTD Data Acquisition and Rosette Operation

The CTD data acquisition system consisted of an SBE-11*plus* (V2) deck unit and three networked generic PC workstations running CentOS-5.8 or -5.9 Linux. Each PC workstation was configured with a color graphics display, keyboard and trackball. The systems each had a Comtrol Rocketport PCI multiple port serial controller providing 8 additional RS-232 ports. The systems were interconnected through the ship's network. These systems were available for real-time operational and CTD data displays, and provided for CTD and hydrographic data management.

One of the workstations was designated the CTD console and was connected to the CTD deck unit via RS-232. The CTD console provided an interface and operational displays for controlling and monitoring a CTD deployment and closing bottles on the rosette. Another of the workstations was designated the website and database server and maintained the hydrographic database for P02E. Redundant backups were managed automatically.

The SBE9*plus* CTD supplied a standard SBE-format data stream at a data rate of 24 frames/second. The sensors and instruments used during CLIVAR/Carbon P02E, along with pre-cruise laboratory calibration information, are listed below in Table 1.3.0. Copies of the pre-cruise calibration sheets for various sensors are included in Appendix D.

Instrument/Sensor*	Mfr.§/Model	Serial Number	CTD Channel	Stations Used	Pre-Cruise Calibration Date	Facility§
Carousel Water Sampler	SBE32 (36-place)	3213290-0113	n/a	88-72	n/a	n/a
Reference Temperature	SBE35	3528706-0035	n/a	88-72	7-Dec-2012	SIO/STS
CTD	SBE9*plus* SIO	09P52161-0914		88-72		
Pressure	Paroscientific Digiquartz 401K-105	914-110547	Freq.2	88-72	14-Jun-2012	SIO/STS
Primary Pump Circuit						
Temperature (T1)	SBE3*plus*	03P-4138	Freq.0	88-72	24-Jan-2013	SIO/STS
Conductivity (C1)	SBE4C	04-2569	Freq.1	88-72	16-Jan-2013	SBE
Dissolved Oxygen	SBE43	43-1071	Aux2/V2	88-72	12-Jul-2012	SBE
Pump	SBE5T	05-4890		88-72		
Secondary Pump Circuit						
Temperature (T2)	SBE3*plus*	03P-4226	Freq.3	88-72	24-Jan-2013	SIO/STS
Conductivity (C2b)	SBE4C	04-3058	Freq.4	88-72	2-Nov-2012	SBE
Pump	SBE5T	05-4377		88-72		
Optical Diss. Oxygen† Rinko O2 Temperature†	Rinko III ARO-CAV	105	Aux3/V4 Aux3/V5	88-72	7-Aug-2012	JFE Advantech
Chlorophyll Fluorometer	Seapoint	SCF2748	Aux1/V1	88-72		
Transmissometer (TAMU)	WET Labs C-Star	CST-327DR	Aux2/V3	88-72	19-Jul-2012	WET Labs
Altimeter (500m range)	Simrad 807	9711091	Aux1/V0	88-72		
Deck Unit (in lab)	SBE11*plus* V2	11P9852-0366		88-72		

* All sensors belong to SIO/STS, unless otherwise noted.
§ SBE = Sea-Bird Electronics
† Optical oxygen sensor, new to SIO/STS; installed for evaluation purposes

Table 1.3.0 CLIVAR/Carbon P02E Rosette Underwater Electronics.

An SBE35RT reference temperature sensor was connected to the SBE32 carousel and recorded a temperature for each bottle closure. These temperatures were used as additional CTD calibration checks. The SBE35RT was utilized using Sea-Bird Electronics' recommendations (*http://www.seabird.com*).

The SBE9*plus* CTD was connected to the SBE32 36-place carousel, providing for sea cable operation. Power to the SBE9*plus* CTD and sensors, SBE32 carousel and Simrad altimeter was provided through the sea cable from the SIO/STS SBE11*plus* deck unit in the main lab.

CTD deployments were initiated by the console watch after the ship stopped on station. The acquisition program was started and the deck unit turned on at least 3 minutes prior to package deployment. The watch maintained a console operations log containing a description of each deployment, a record of every attempt to close a bottle and any relevant comments. The deployment and acquisition software presented a short dialog instructing the operator to turn on the deck unit, to examine the on-screen CTD data displays and to notify the deck watch that this was accomplished.

Once the deck watch had deployed the rosette, the winch operator lowered it to 10 meters, or deeper in heavier seas. The CTD sensor pumps were configured with a 5-second start-up delay after detecting seawater conductivities. The console operator checked the CTD data for proper sensor operation and waited for sensors to stabilize, then instructed the winch operator to bring the package to the surface and descend to a specified target depth, based on CTD pressure available on the winch display.

The CTD profiling rate was at most 30m/min to 100m and up to 60m/min deeper than 100m, depending on sea cable tension and sea state. As the package descended toward the target depth, the rate was reduced to 30m/min at 100m from the bottom.

The progress of the deployment and CTD data quality were monitored through interactive graphics and operational displays. Bottle trip locations were transcribed onto the console and sample logs. The sample log was used later as an inventory of samples drawn from the bottles. The altimeter channel, CTD depth, winch wire-out and bathymetric depth were all monitored to determine the distance of the package from the bottom, allowing a safe approach to 8-10 meters.

Bottles were closed on the up-cast by operating an on-screen control. The expected CTD pressure was reported to the winch operator for every bottle trip. Bottles were tripped 30-40 seconds after the package stopped to allow the rosette wake to dissipate and the bottles to flush. The winch operator was instructed to proceed to the next bottle stop no sooner than 10 seconds after closing bottles to ensure that stable CTD data were associated with the trip and to allow the SBE35RT temperature sensor to measure bottle trip temperature.

It can be necessary at some stations in higher sea states to close shallower bottles (normally only the shallowest bottle) on the fly due to the need to keep tension on the CTD cable. At such closures - always noted on the CTD Console Log Sheet - the SBE35RT temperature is typically not usable.

The package was directed to the surface by the deck for the last bottle closure, then the package was brought on deck. The console operator terminated the data acquisition, turned off the deck unit and assisted with rosette sampling.

The R/V Melville's Markey DESH-6 (aft) winch was used for all reported casts. One conductor in the DESH-6 UNOLS-standard three-conductor 0.322" electro-mechanical sea cable was used for power and signal; the sea cable armor was used for ground. A full (electrical and mechanical) re-termination was done on the DESH-6 sea cable before P02E started. The Markey DESH-5 (forward) winch was available as a spare but was never needed.

1.4. CTD Cable Tension on Deep Casts

As CLIVAR/Carbon P02E progressed into deeper and deeper water, significant science operations issues hinged on actual CTD cable tension and cast time performance on very deep CTD casts (maximum cast depths deeper than 5000 meters). Although all the U.S. work for this program since it began in 2003 had transpired without CTD cable parting or functionality loss, new UNOLS/NSF cable tension rules went into effect shortly before this cruise. It was thought pre-cruise by some at the operator and agency level that the maximum CTD cable tensions on deep casts on this cruise would exceed the new rules. Two questions in particular loomed in planning: (1) under what conditions would CTD cable tensions exceed 5000 lbs., and (2) what would be the impacts on P02 station times and operations due to efforts to keep maximum observed CTD cable tension less than 5000 lbs.? The cruise had a waiver permitting CTD operations to continue under some conditions if higher CTD cable tensions were observed, but there was general concurrence that sustained P02 CTD operations with cable tensions above 5000 lbs. should be avoided if possible.

The ship was equipped with a new 20Hz recording tensiometer, which provided the real-time data for cast operations and the recorded data for further study.

On the previous leg, experiments with step-wise increasing winch haul speed at early stations in waters 4000-5000 meters deep, in good weather, showed that maximum CTD cable tensions stayed near or less than ca. 4000 lbs. with any haul speeds to the maximum desired haul speed of 60 meters/minute.

It is important to note that most 5000-6000 meter casts during P02E took place in good weather (winds 10-20 knots; low swell). During slightly more than one day of winds in the 20-25 knot range (with periods of 25-30 knots) seas rose somewhat. Associated with the higher level of ship motion there were several casts that day where cable tensions rose to nearer but still under 5000 lbs., with maximum cable deployed, even with lowered winch haul-up speeds.

1.5. CTD Data Processing

Shipboard CTD data processing was performed automatically during and after each deployment using SIO/STS CTD processing software v.5.1.6-1.

During acquisition, the raw CTD data were converted to engineering units, filtered, response-corrected, calibrated and decimated to a more manageable 0.5-second time series. Pre-cruise laboratory calibrations for pressure, temperature and conductivity were also applied at this time. The 0.5-second time series data were used for real-time graphics during deployments, and were the source for CTD pressure and temperature data associated with each rosette bottle. Both the raw 24 Hz data and the 0.5-second time series were stored for subsequent processing. During the deployment, the raw data were backed up to another Linux workstation every 5 minutes.

At the completion of a deployment a sequence of processing steps were performed automatically. The 0.5-second time series data were checked for consistency, clean sensor response and calibration shifts. A 2-decibar pressure series was generated from the down cast data. The pressure-series data were used by the web service for interactive plots, sections and CTD data distribution. Time-series data were also available for distribution through the website.

CTD data were routinely examined for sensor problems, calibration shifts and deployment or operational problems. On-deck pressure values were monitored at the start and end of each cast for potential drift. Alignment of temperature and conductivity sensor data (in addition to the default 0.073-second conductivity "advance" applied by the SBE11*plus* deck unit) was optimized for each pump/sensor combination to minimize salinity spiking, using data from multiple casts of various depths after acquisition. If the pressure offset or conductivity "advance" values were altered after data acquisition, the CTD data were re-averaged from the 24Hz stored data.

The primary and secondary temperature sensors (SBE3*plus*) were compared to each other and to the SBE35 temperature sensor. CTD conductivity sensors (SBE4C) were compared to each other, then calibrated by examining differences between CTD and check-sample conductivity values. CTD dissolved oxygen sensor data were calibrated to check-sample data.

As bottle salinity and oxygen results became available, they were used to refine shipboard conductivity and oxygen sensor calibrations. Theta-Salinity and theta-O_2 comparisons were made between down and up casts as well as between groups of adjacent deployments.

A total of 72 full casts were made using the 36-place CTD/LADCP rosette. Further elaboration of CTD procedures specific to this cruise are found in the next section.

1.6. CTD Acquisition and Data Processing Details

Adjustments to the conductivity "advance" time (default: 0.073 seconds) were examined during Leg 1 by re-averaging data from the stored 24 Hz data at various time intervals, then evaluating salinity spiking and noise levels in sharp gradients and in deep water for multiple casts. An additional 0.08-second "advance" was applied to the primary conductivity sensor, and a 0.06-second "advance" was used for the secondary. The new "advance" times were applied real-time for all of P02E.

Primary T/C sensors were used for all but two casts of reported CTD data because the same sensor pair was used through-out the cruise. Secondary TS data were used for stations 149 and 151, where primary data were distinctly noisier than secondary for most of both casts. The deck noted a large amount of kelp in the water at station 151. There was also a primary pump circuit flow obstruction during the up-cast of station 93; the down-cast primary data were fine and used for reporting CTD data, but up-cast secondary data had to be used for CTD trip data in the bottle reports.

The following table identifies problems or comments noted during specific casts (NOTE: mwo = meters of wire out on winch):

Sta/Cast	Comment
start	Using Markey DESH-6/aft winch for rosette casts; full (electrical + mechanical) retermination of wire prior to start of Leg 2/P02E.
999/2	Not reported: Test cast, trip 12 bottles each at 1500m, 1000m and 500m to test carousel and bottle integrity.
88/1	Same position as station 87 on Leg 1/P02W.
91/1	Ship was 1100m East of desired station position: bridge error.
92/1	Next to seamount, slow approach to bottom to be careful.
93/1	CTDS/CTDO2 noise/offsets 1220-700dbar upcast: major sea slime; still noisy until about 150dbar. Primary values returned at trips to within 0.01 (S1-S2); used T2/S2 for all CTD trip data and for time-series CTD report for LADCP. Deck/post-cast: Primary side: detached/TC sensors rinsed with fresh water/re-attached. Secondary side: cleaned the clogged air release valve, and flushed valve and sensors with fresh water.
96/1	Not reported: Cast aborted at 2m due to caught tag line.
96/2	Prior to station: carousel inspection/repair: removed all latches, inspected all positions, resealed position 1. Tested position 1: satisfactory. Re-assembled all latches.
105/1	Mixed layer temperature/density had structure with lots of small steps.
108/1	Multibeam frozen at cast start.
113/1	Stopped at 4942 mwo before updating final cast target depth to 14m deeper.
114/1	Deck Unit found "on" (with SBE pumps running) several hours after cast completed.
125/1	Deck Unit found "on" (with SBE pumps off) 2.5 hours after cast finished.
128/1	Not reported: Cast aborted near surface due to large conductivity offset at surface soak: C1/C2 flushed.
136/1	Double yo-yo to 10m at cast start: rosette pulled out a little too far re-surfacing.
145/1	Not reported: Cast aborted near surface due to 0.20 conductivity offset at surface soak: C1/C2 flushed.
147/1	Rough seas, no yo-yo at surface start, but did soak at 13m. Ship-roll went back to 2db for good TS data; CTDO fairly well equilibrated, even before soak.
148/1	Rough seas, no yo-yo at surface start, but did soak at 13m. Ship-roll back to 4db for good TS data, but CTDOXY low until 16dbar (after surface soak), CTDOXY quality-coded 4 (bad) for 0-14dbar. Stopped winch at 100mwo downcast: wire rubbing against the hull; resumed cast after several minutes of re-positioning. Speeds low top 2500+m due to low tension on downcast.
149/1	Rough seas, no yo-yo at surface start, but did soak at 13m. Ship-roll back to 2-3dbar for good TS data, but CTDOXY low until 14dbar (after surface soak), CTDOXY quality-coded 4 (bad) for 0-12dbar. winch speeds 36-48 m/min down to 1500m. Primary data noisy, secondary data cleaner: use T2/S2 for all reported CTD data, including trips.
151/1	Noise in primary C sensor starting 22dbar downcast, and higher noise level through-out cast. Apparently lots of kelp in the water. Use T2/S2 for all reported CTD data, including trips. Deck flushed sensors several times before next deployment.
152/1	Yo-yo back only to 6db vs surface after surface soak due to large swell.
156/1	Not reported: Cast aborted at 400m: rosette down to 10m, 20m, 40m until sensors finally agreed. Offsets again later on downcast. Salp found in pump tube, removed; sensors flushed.

1.7. CTD Sensor Laboratory Calibrations

Laboratory calibrations of the CTD pressure, temperature, conductivity and dissolved oxygen sensors were performed prior to CLIVAR/Carbon P02E. The sensors and calibration dates are listed in Table 1.3.0. Copies of the calibration sheets for Pressure, Temperature, Conductivity, and Dissolved Oxygen sensors, as well as factory and deck calibrations for the TAMU Transmissometer, are in Appendix D.

1.8. CTD Shipboard Calibration Procedures

A single SBE9*plus* CTD (S/N 914) was used for all rosette/CTD/LADCP casts during CLIVAR/Carbon P02E. The CTD was deployed with all sensors and pumps aligned vertically, as recommended by SBE.

An SBE35RT Digital Reversing Thermometer (S/N 3528706-0035) served as an independent calibration check for T1 and T2 sensors. *In situ* salinity and dissolved O_2 check samples collected during each cast were used to calibrate the conductivity and dissolved O_2 sensors.

1.8.1. CTD Pressure

The Paroscientific Digiquartz pressure transducer (S/N 914-110547) was calibrated in June 2012 at the SIO/STS Calibration Facility. The calibration coefficients provided on the report were used to convert frequencies to pressure. The SIO/STS pressure calibration coefficients already incorporate the slope and offset term usually provided by Paroscientific.

During Leg 1/P02W, the initial deck readings for pressure indicated a pressure offset was required, typically because CTDs are calibrated horizontally but deployed vertically. An offset of -0.9 decibars was applied to all casts during acquisition on Leg 2/P02E.

Residual pressure offsets (the difference between the first and last submerged pressures, after the offset corrections) varied from -0.1 to +0.2 decibars. Pre- and post-cast on-deck/out-of-water pressure offsets varied from -0.1 to +0.2 decibars before the casts, and -0.2 to +0.2 decibars after the casts. The in/out pressures within a cast were very consistent.

1.8.2. CTD Temperature

The same SBE3*plus* primary temperature sensor (T1: 03P-4138) and secondary temperature sensor (T2: 03P-4226) were used during both legs of P02. Calibration coefficients derived from the pre-cruise calibrations, plus shipboard temperature corrections determined during the cruise, were applied to raw primary and secondary sensor data during each cast.

A single SBE35RT (3528706-0035) was used as a tertiary temperature check. It was located equidistant between T1 and T2 with the sensing element aligned in a plane with the T1 and T2 sensing elements. The SBE35RT Digital Reversing Thermometer is an internally-recording temperature sensor that operates independently of the CTD. It is triggered by the SBE32 carousel in response to a bottle closure. The SBE35RT on P02E was set to internally average over 4 sampling cycles (a total of 4.4 seconds).

According to the manufacturer's specifications, the typical stability for an SBE35RT sensor is 0.001°C/year. A post-cruise calibration for this sensor (18-Jun-2013) showed essentially no change (at most 0.0001°C) over the 6 months since the pre-cruise calibration.

Two independent metrics of calibration accuracy were examined. At each bottle closure, the primary and secondary temperature were compared with each other and with the SBE35RT temperature. CTD temperature calibrations for P02E were re-evaluated during Leg 2/P02E, with the added benefit of seeing data from more stations.

Both temperature sensors were examined for drift with time, using the more stable SBE35RT at a smaller range of deeper trip levels (4000-5000 decibars). Even in this small pressure range, the time drift was impacted by the pressure effect on the sensors. In order to better align deeper and shallower data, a second-order pressure correction was first applied to each temperature sensor, using all bottles where the T1-T2 difference was less than ± 0.005 (to omit high-gradient bottles that might skew the results),

Neither of the sensors exhibited a temperature-dependent slope. But both T1 and T2 had a residual time dependence (offset drift) that flattened out after the first half of Leg 1/P02W. T2 differences shifted slightly around day 35, after the C2 sensor was replaced.

All casts together were used for the T1 drift corrections, but stations 1-62 and 63-159 were fit separately for the T2 drift. Data deeper than 1800 decibars were used to determine second-order corrections to pull deeper T2 differences in line with shallower differences.

Pressure-dependent corrections were then re-checked, and no further adjustments were warranted.

The final corrections for T1 temperature data reported on P02E are summarized in Appendix A. Corrections made to both temperature sensors had the form:

$$T_{ITS90} = T + tp2 * P^2 + tp1 * P + t0$$

Residual temperature differences after correction are shown in figures 1.8.2.0 through 1.8.2.8.

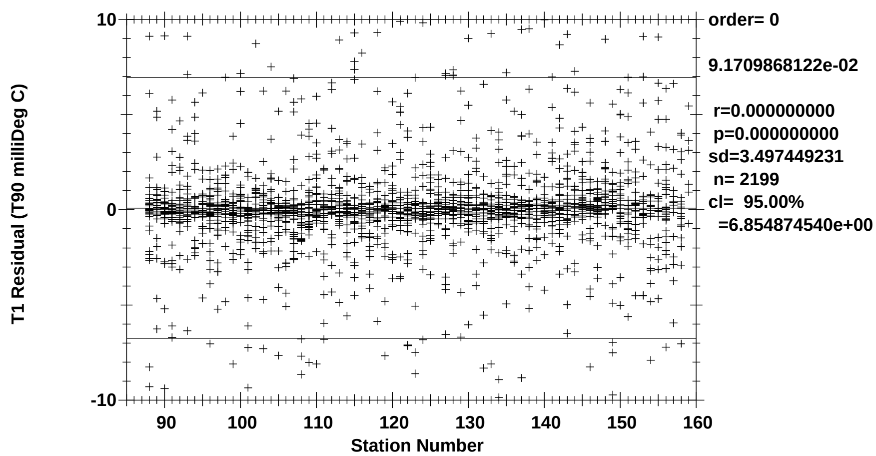

Figure 1.8.2.0 P02E SBE35RT-T1 by station (-0.01°C ≤T1 – T2≤0.01°C).

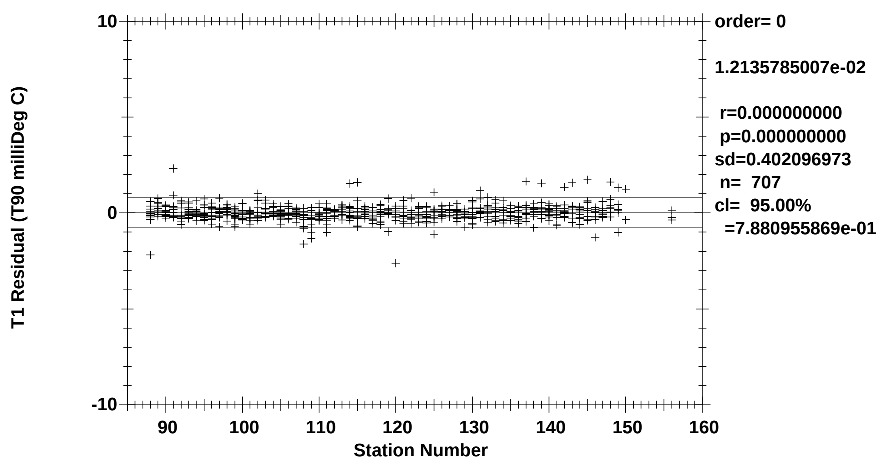

Figure 1.8.2.1 P02E Deep SBE35RT-T1 by station (Pressure >= 1800 dbars).

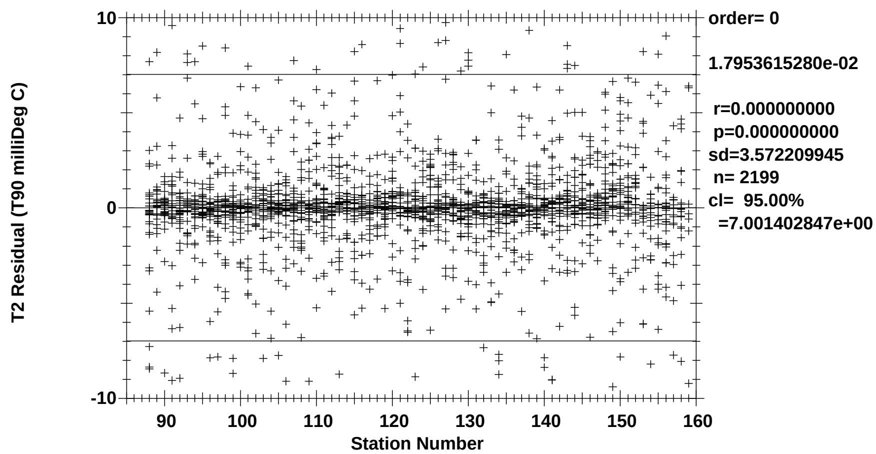

Figure 1.8.2.2 P02E SBE35RT-T2 by station (-0.01°C ≤T1 – T2≤0.01°C).

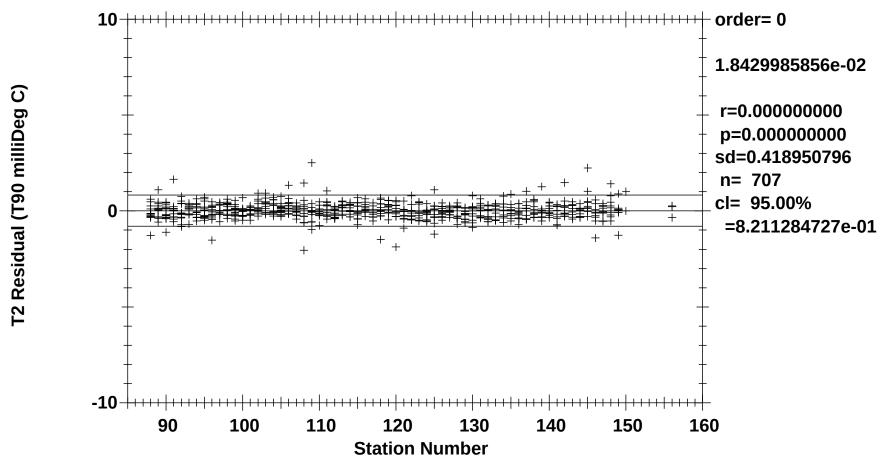

Figure 1.8.2.3 P02E Deep SBE35RT-T2 by station (Pressure >= 1800 dbars).

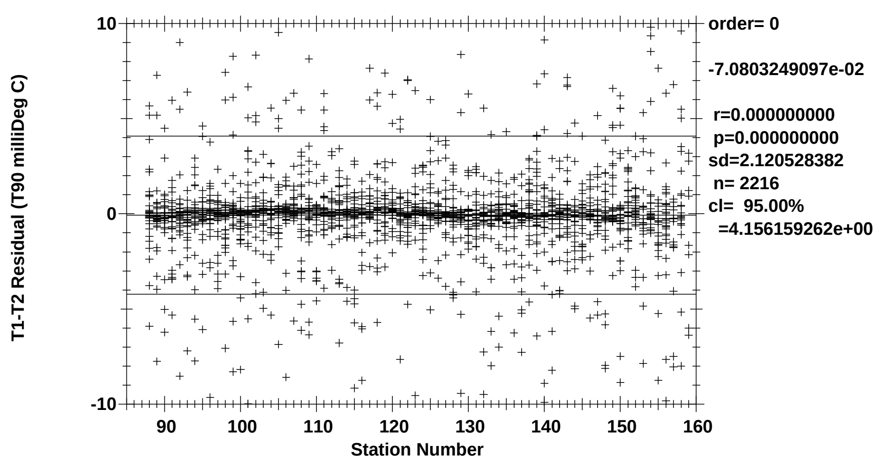

Figure 1.8.2.4 P02E T1-T2 by station (-0.01°C ≤T1 – T2≤0.01°C).

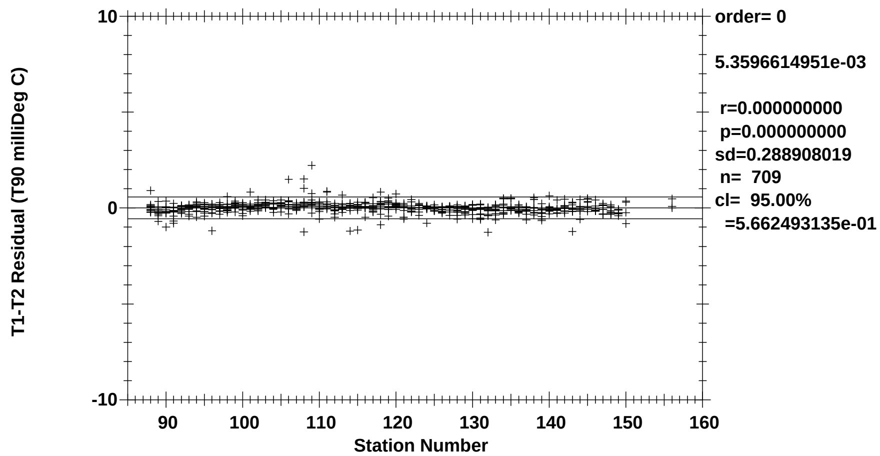

Figure 1.8.2.5 P02E Deep T1-T2 by station (Pressure >= 1800 dbars).

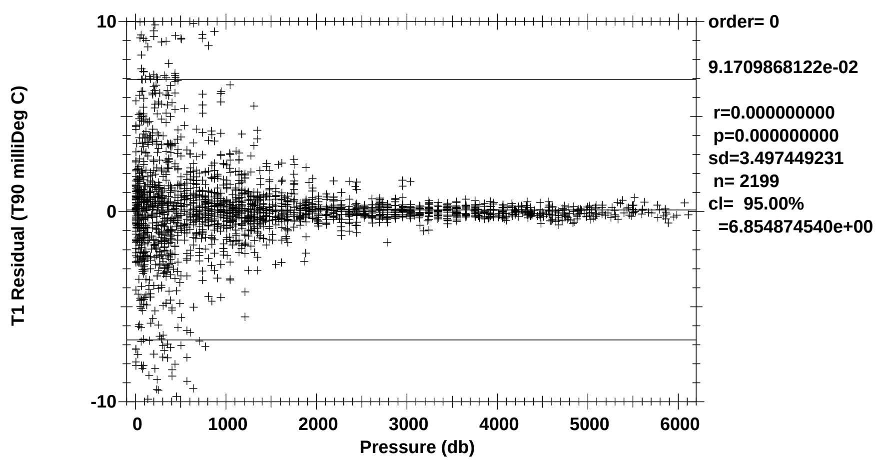

Figure 1.8.2.6 P02E SBE35RT-T1 by pressure (-0.01°C ≤T1 – T2≤0.01°C).

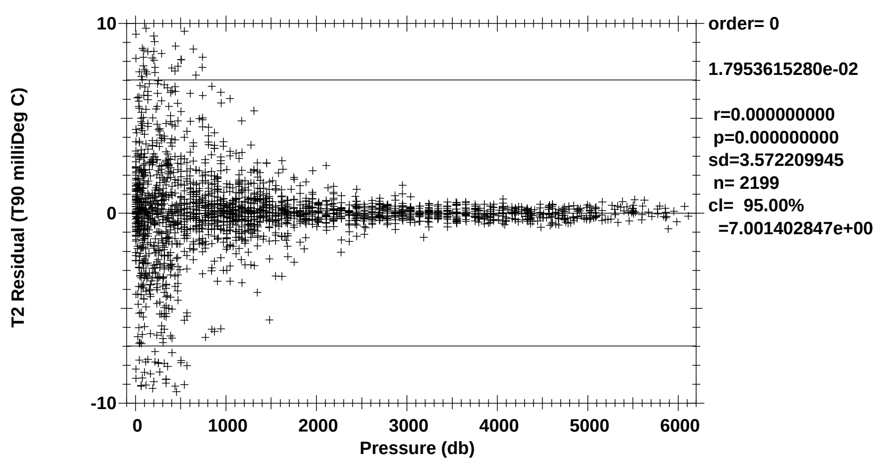

Figure 1.8.2.7 P02E SBE35RT-T2 by pressure (-0.01°C ≤T1 – T2≤0.01°C).

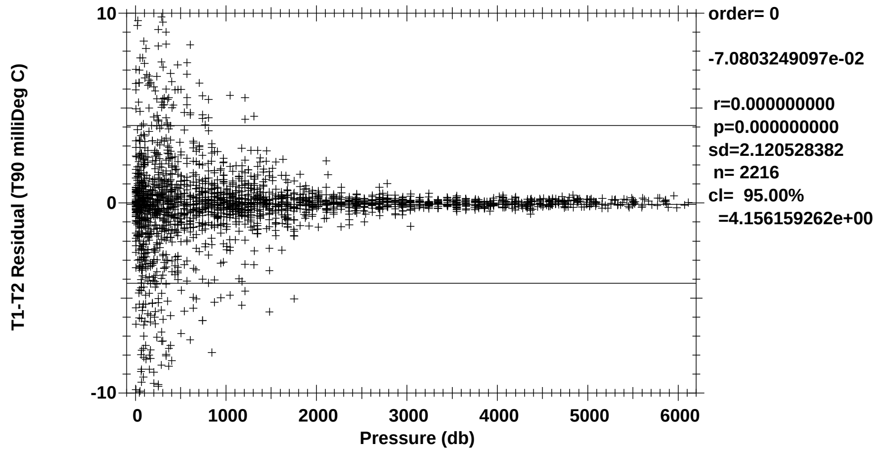

Figure 1.8.2.8 P02E T1-T2 by pressure (-0.01°C ≤T1 – T2≤0.01°C).

The 95% confidence limits for the P02E mean low-gradient differences are ±0.00686°C for SBE35RT – T1 and ±0.00416°C for T1 – T2. The 95% confidence limit for deep temperature residuals (where pressure > 1800 dbars) is ±0.00079°C for SBE35RT – T1 and ±0.00057°C for T1 – T2.

1.8.3. CTD Conductivity

The same SBE4C primary (C1/04-2569) and secondary (C2b/04-3058) conductivity sensors were used for all of Leg 2/P02E. Sensor C1 was used for all stations of P02, and C2b was first used at station 63 on Leg 1/P02W. Primary TC sensor data were used to report final CTD data for all but two casts because the same sensor pair was used throughout both legs. Secondary TC sensor data were used for stations 149 and 151 due to excessive noise in the primaries, likely caused by organic matter (kelp?) in the pump circuit.

Calibration coefficients derived from the pre-cruise calibrations were applied to convert raw frequencies to conductivity. Shipboard conductivity corrections, determined during the cruise, were applied to primary and secondary conductivity data for each cast. Conductivity corrections for both P02 legs were re-evaluated at the end of Leg 2/P02E, and included stations from both legs in order to determine more consistent corrections.

Corrections for both CTD temperature sensors were finalized before analyzing conductivity differences. Two independent metrics of calibration accuracy were examined. At each bottle closure, the primary and secondary conductivity were compared with each other. Each sensor was also compared to conductivity calculated from check sample salinities using CTD pressure and temperature.

There was some shifting back-and-forth of bottle-CTD differences throughout the cruise. An investigation indicated it was typically the result of bottle salinity differences of 0.001-0.002 from run-to-run. Starting with station 126, it was found that using a small space heater to bring the samples close to the bath temperature greatly reduced this oscillation. This suggests that this shifting was due to a relatively large difference between the water sample temperature and the salinometer bath temperature. Theta-Salinity comparisons showed that cast-to-cast deep CTD data were well-aligned before applying any offsets. Differences from all stations were included in the fits for conductivity corrections.

The differences between primary and secondary temperature sensors were used as filtering criteria for all conductivity fits to reduce the contamination of conductivity comparisons by package wake. The coherence of this relationship is shown in figure 1.8.3.0.

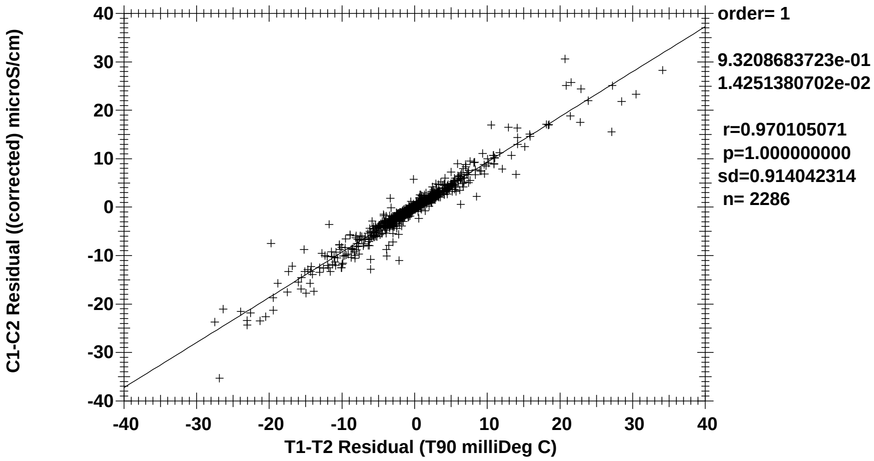

Figure 1.8.3.0 P02E Coherence of conductivity differences as a function of temperature differences.

Uncorrected conductivity comparisons are shown in figures 1.8.3.1 through 1.8.3.3.

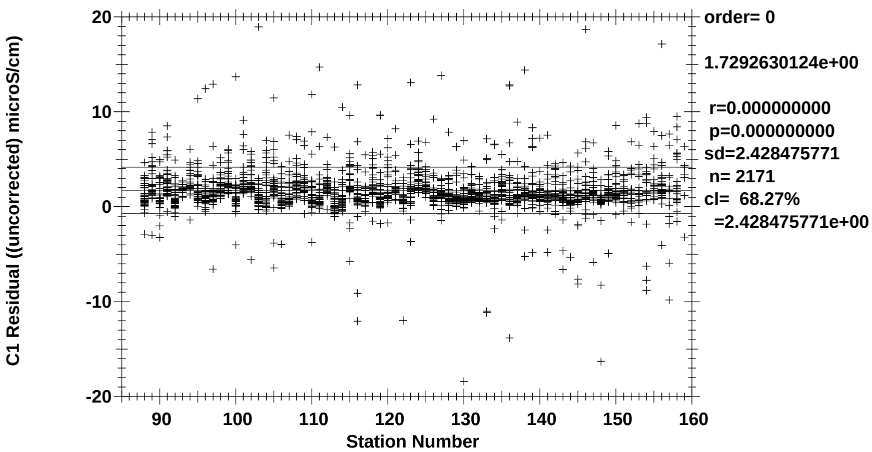

Figure 1.8.3.1 P02E Uncorrected C_{Bottle} – C1 by station (-0.01°C ≤T1 – T2≤0.01°C).

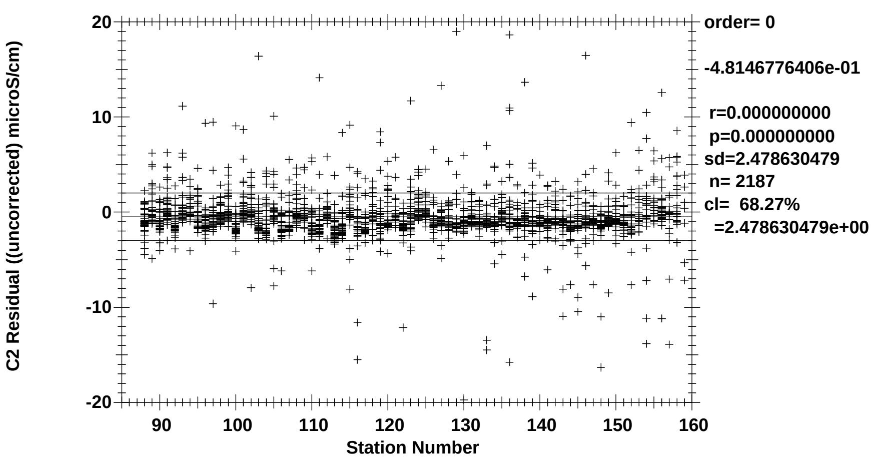

Figure 1.8.3.2 P02E Uncorrected C_{Bottle} – C2 by station (-0.01°C ≤T1 – T2≤0.01°C).

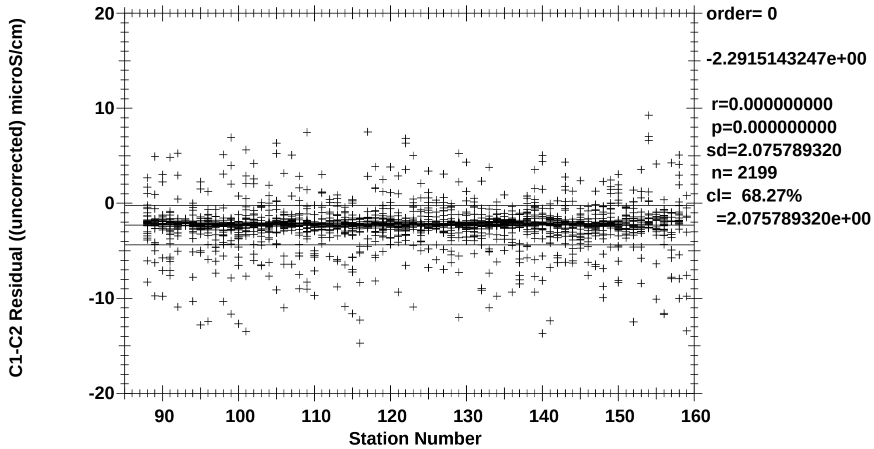

Figure 1.8.3.3 P02E Uncorrected C1 – C2 by station (-0.01°C ≤T1 – T2≤0.01°C).

Offsets for each C sensor were evaluated for drift with time using $C_{Bottle} - C_{CTD}$ differences from a smaller range of deeper pressures (2800-4800 decibars), in order to exclude most of the pressure effect on the sensors. A second-order fit of differences vs time was determined for each sensor, accounting for a slower rate of change partway through Leg 1/P02W.

$C_{Bottle} - C_{CTD}$ differences were then evaluated for response to pressure and/or conductivity, which typically shifts between pre- and post-cruise SBE laboratory calibrations. A comparison of the residual differences indicated that a parabolic conductivity-dependent correction was required for each sensor. Small adjustments to the time-dependent corrections for C1 were re-calculated using stations 1-159.

After applying time- and conductivity-dependent corrections, the pressure-dependent coefficients for conductivity were calculated. The correction was linear for C1, and parabolic for C2b, in order to pull in the differences from very deep data (below 5800 decibars) on P02E casts.

A few small offset adjustments, based on Theta-Salinity comparisons with adjacent casts, were applied as follows:

+0.0002 mS/cm was applied to C2b/stations 88-92
+0.0003 mS/cm was applied to C2b/station 93
-0.0001 mS/cm was applied to C2b/stations 110-127
+0.0005 mS/cm was applied to C2b/stations 153-154,156-158
+0.001 mS/cm was applied to C2b/stations 155

After adjustments, deep Theta-Salinity profiles of adjacent casts agreed well for both sensor pairs.

The residual conductivity differences after correction are shown in figures 1.8.3.4 through 1.8.3.15.

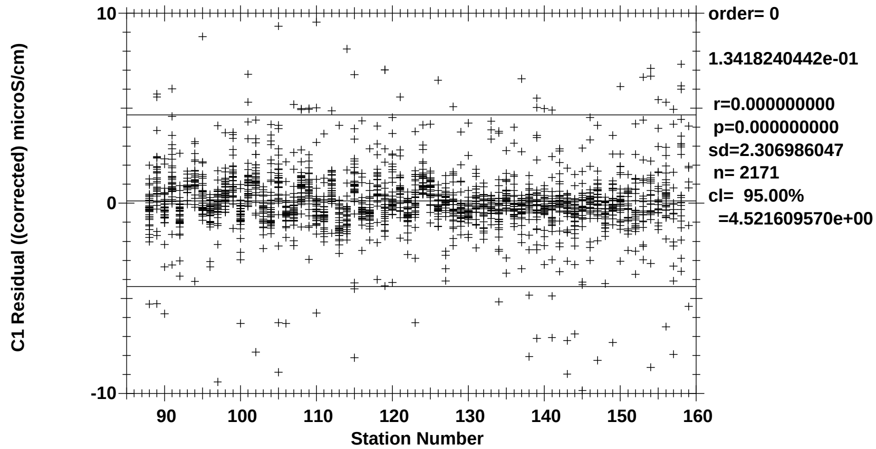

Figure 1.8.3.4 P02E Corrected $C_{Bottle} - C1$ by station (-0.01°C ≤T1 – T2≤0.01°C).

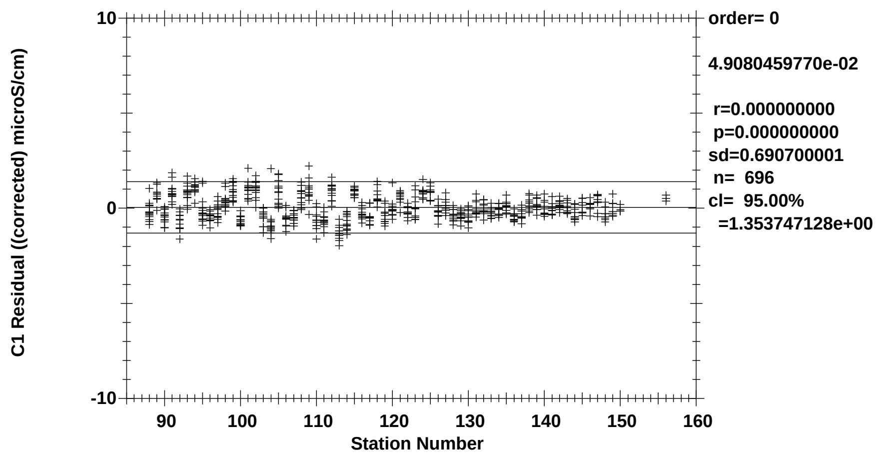

Figure 1.8.3.5 P02E Deep Corrected $C_{Bottle} - C1$ by station (Pressure >= 1800 dbars).

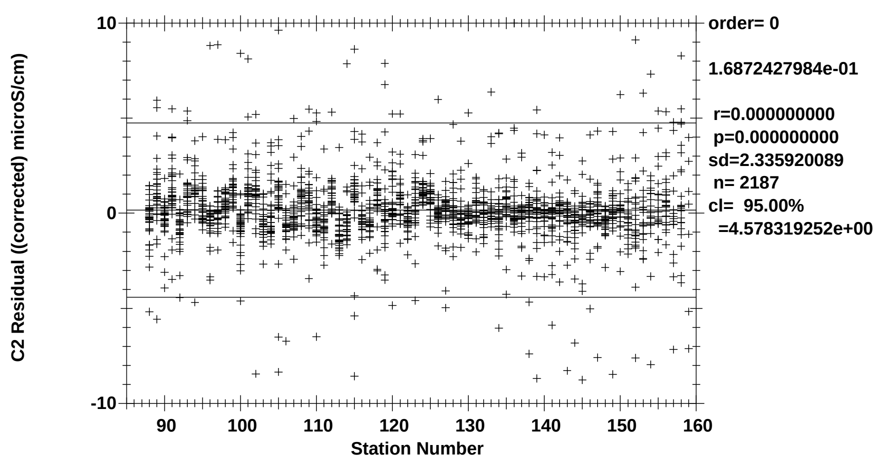

Figure 1.8.3.6 P02E Corrected $C_{Bottle} - C2$ by station (-0.01°C ≤T1 – T2≤0.01°C).

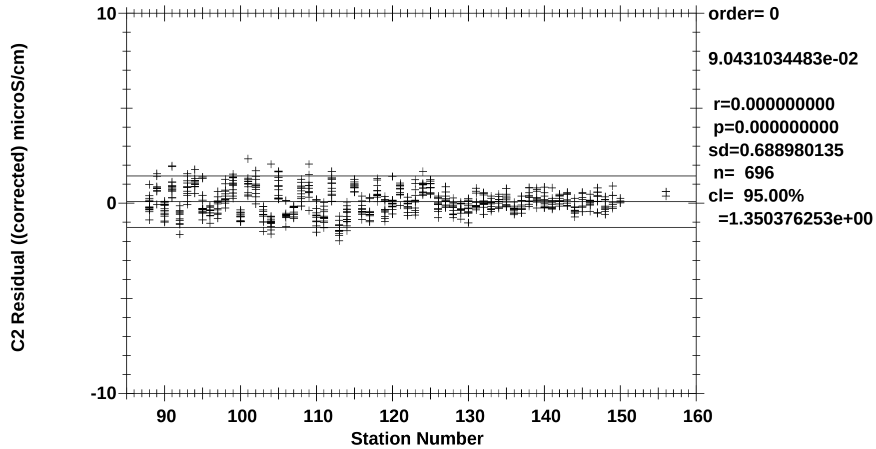

Figure 1.8.3.7 P02E Deep Corrected C_{Bottle} – C2 by station (Pressure >= 1800 dbars).

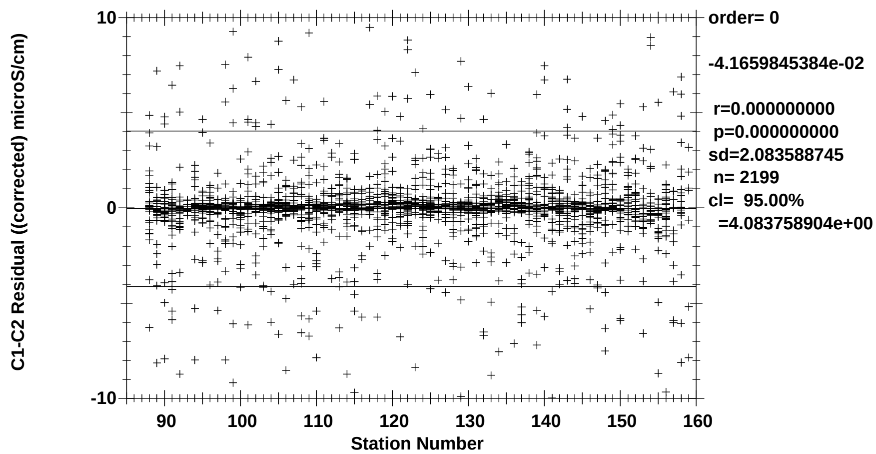

Figure 1.8.3.8 P02E Corrected C1 – C2 by station (-0.01°C ≤T1 – T2≤0.01°C).

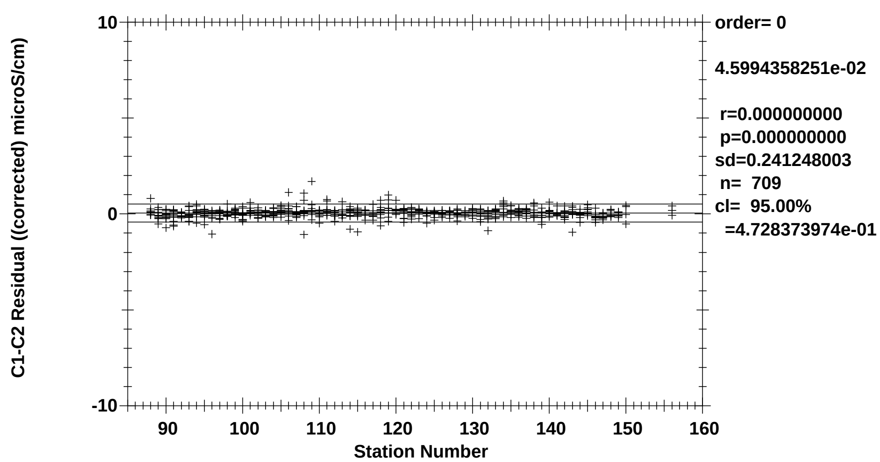

Figure 1.8.3.9 P02E Deep Corrected C1 – C2 by station (Pressure >= 1800 dbars).

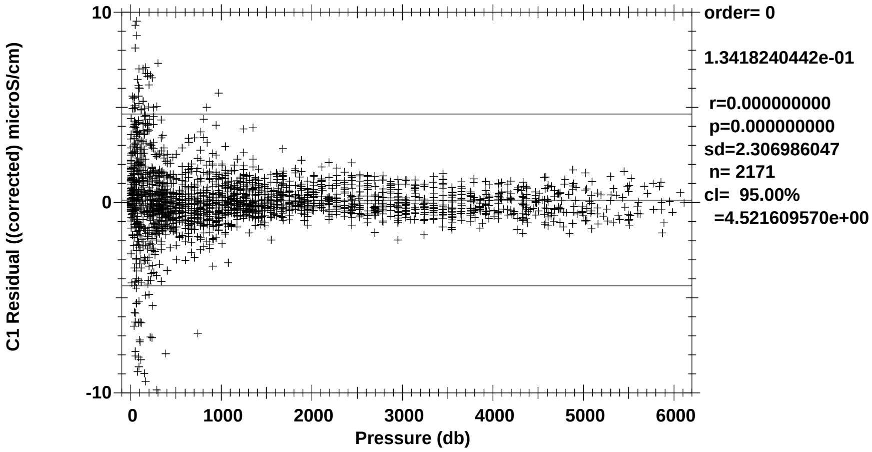

Figure 1.8.3.10 P02E Corrected $C_{Bottle} - C1$ by pressure (-0.01°C ≤T1 – T2≤0.01°C).

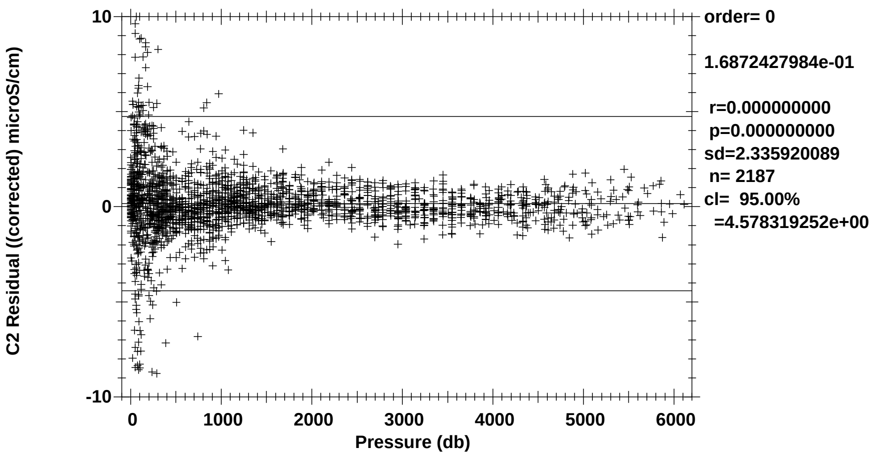

Figure 1.8.3.11 P02E Corrected $C_{Bottle} - C2$ by pressure (-0.01°C ≤T1 – T2≤0.01°C).

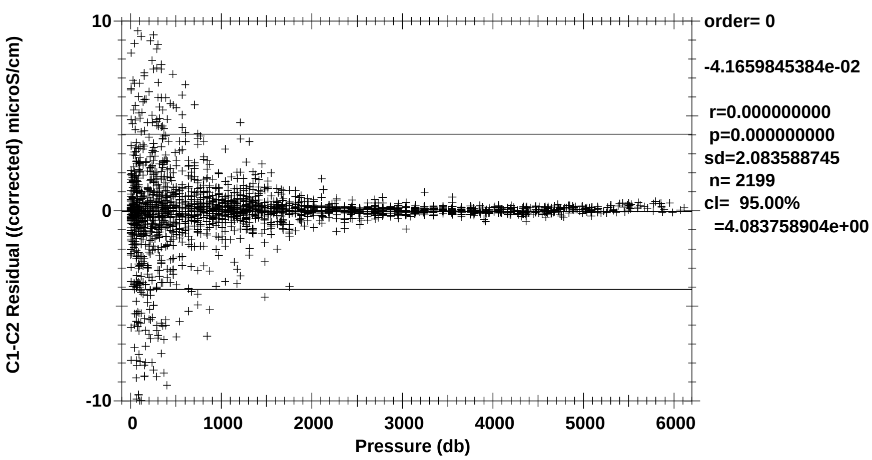

Figure 1.8.3.12 P02E Corrected C1 – C2 by pressure (-0.01°C ≤T1 – T2≤0.01°C).

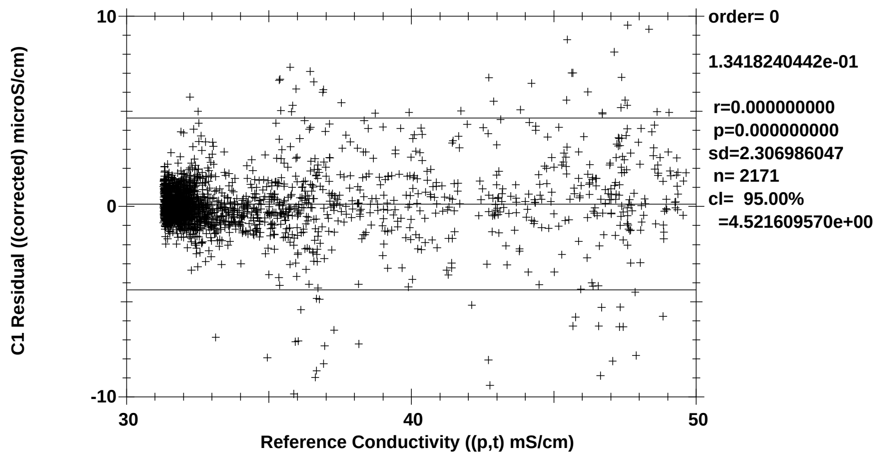

Figure 1.8.3.13 P02E Corrected C_{Bottle} – C1 by conductivity (-0.01°C ≤T1 – T2≤0.01°C).

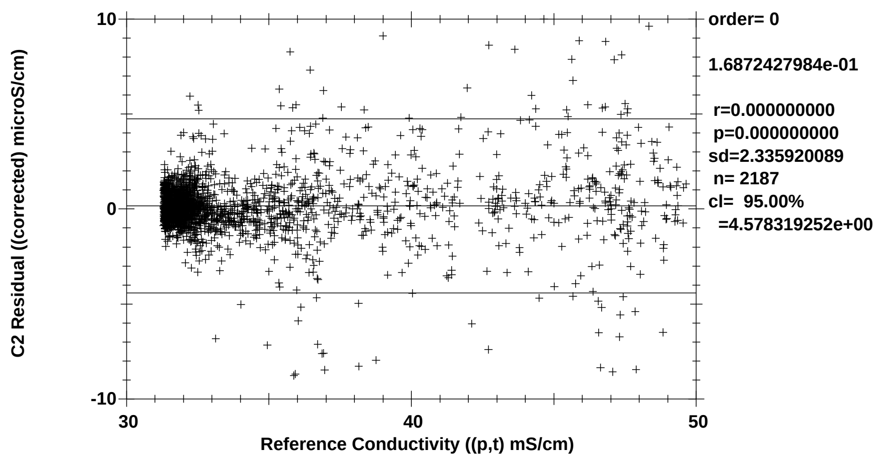

Figure 1.8.3.14 P02E Corrected C_{Bottle} – C2 by conductivity (-0.01°C ≤T1 – T2≤0.01°C).

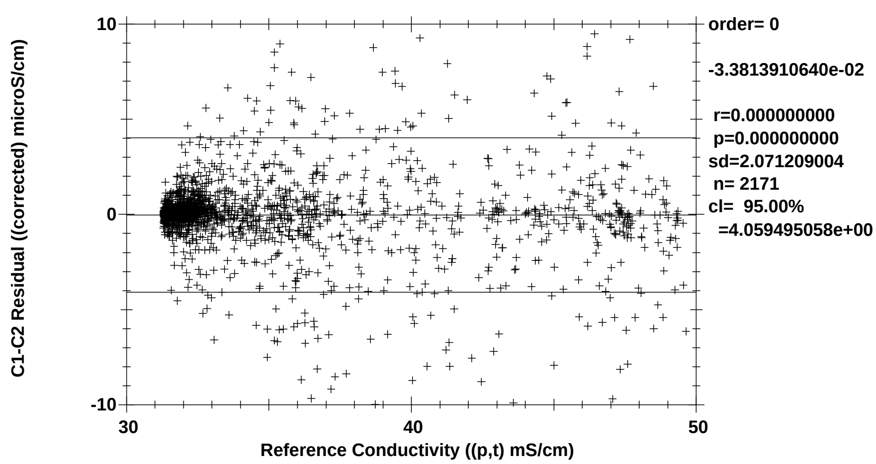

Figure 1.8.3.15 P02E Corrected C1 – C2 by conductivity (-0.01°C ≤T1 – T2≤0.01°C).

The final corrections for the sensors used on P02E are summarized in Appendix A. Corrections made to the primary conductivity sensor had the form:

$$C_{cor} = C + cp1 * P + c2 * C^2 + c1 * C + c0$$

Corrections made to the secondary conductivity sensor had the form:

$$C_{cor} = C + cp2 * P^2 + cp1 * P + c2 * C^2 + c1 * C + c0$$

Salinity residuals after applying shipboard P/T/C corrections are summarized in figures 1.8.3.16 through 1.8.3.18. Only CTD and bottle salinity data with "acceptable" quality codes are included in the differences.

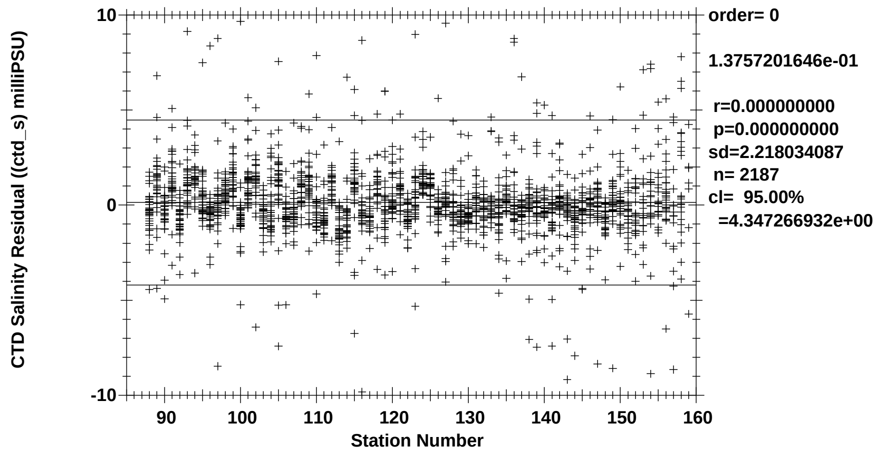

Figure 1.8.3.16 P02E Salinity residuals by station (-0.01°C ≤T1 – T2≤0.01°C).

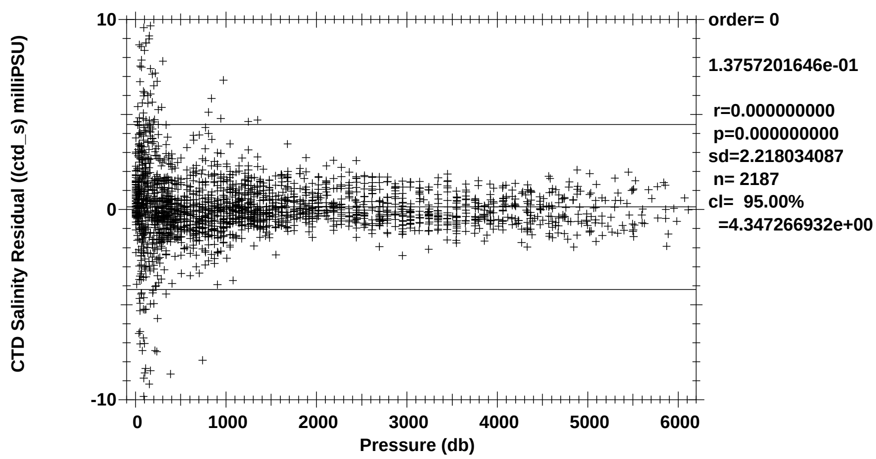

Figure 1.8.3.17 P02E Salinity residuals by pressure (-0.01°C ≤T1 – T2≤0.01°C).

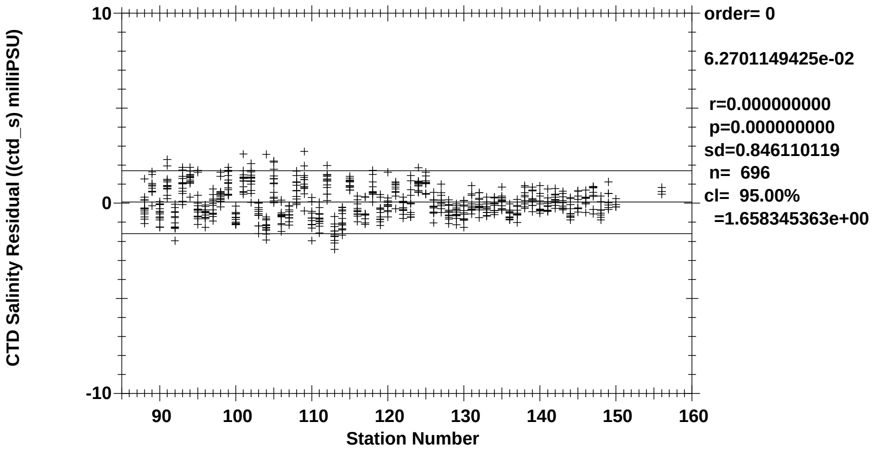

Figure 1.8.3.18 P02E Deep Salinity residuals by station (Pressure >= 1800 dbars).

Figures 1.8.3.17 and 1.8.3.18 represent estimates of the salinity accuracy of P02E. The 95% confidence limits are ±0.00435 relative to bottle salinities for all salinities, where T1-T2 is within ±0.01°C; and ±0.00166 relative to bottle salinities for deep salinities, where pressure is more than 1800 decibars.

Post-Cruise Conductivity Laboratory Calibrations

Post-cruise laboratory calibrations for all 3 conductivity sensors were done and available before finishing this cruise report.

Sensor C1 appears to have had a large change: more than 0.007 mS/cm at 60 mS/cm. The maximum conductivity measured during Leg 1/P02W was 50.5 mS/cm, and only 45 mS/cm by the end of Leg 2/P02E. The post-cruise shift in the conductivity residual (SBE4C-Standard on SBE Lab.Cal. plots) was approximately +0.0045/+0.003 (C1/C2b) at 50 mS/cm, and +0.003/+0.0015 (C1/C2b) at 45 mS/cm. This is consistent with what was seen in uncorrected near-surface conductivities at the end of leg 2.

Note that pressure effects on SBE4C sensors have never been evaluated in a laboratory, so far as we know. All calibrations are done at atmospheric pressure, plus the pressure caused by a meter or so of water.

1.8.4. CTD Dissolved Oxygen

A single SBE43 dissolved O_2 sensor (DO/43-0275) was used during P02E. This dissolved O_2 sensor was plumbed into the primary T1/C1 pump circuit after C1.

The SBE43 DO sensor was calibrated to dissolved O_2 bottle samples taken at bottle stops by matching the down cast CTD data to the up cast trip locations on isopycnal surfaces, then calculating CTD dissolved O_2 using a DO sensor response model and minimizing the residual differences from the bottle samples. A non-linear least-squares fitting procedure was used to minimize the residuals and to determine sensor model coefficients, and was accomplished in three stages.

The time constants for the lagged terms in the model were first determined for the sensor. These time constants are sensor-specific but applicable to an entire cruise. Next, casts were fit individually to bottle sample data. Bottle oxygens from nearby casts with similar deep TS structure were used to help fit CTD O_2 data for casts with one or more mis-tripped bottles. Furthermore, consecutive casts were compared on plots of Theta vs O_2 to verify consistency over the course of P02E.

At the end of the cruise, standard and blank values for bottle oxygen data were smoothed, and the bottle oxygen values were recalculated. The changes to bottle oxygen values were less than 0.01 ml/l for most stations. CTD O_2 data were re-calibrated to the smoothed bottle values after the leg.

Final CTD dissolved O_2 residuals are shown in figures 1.8.4.0-1.8.4.2.

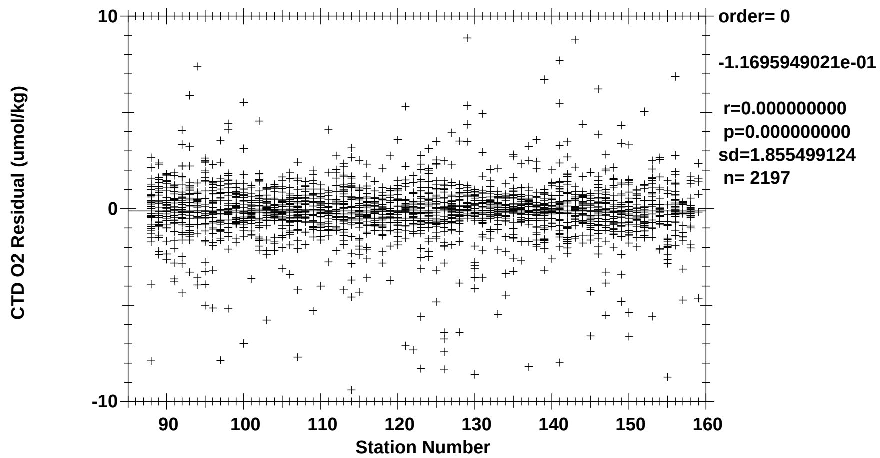

Figure 1.8.4.0 P02E O_2 residuals by station (-0.01°C ≤T1 – T2≤0.01°C).

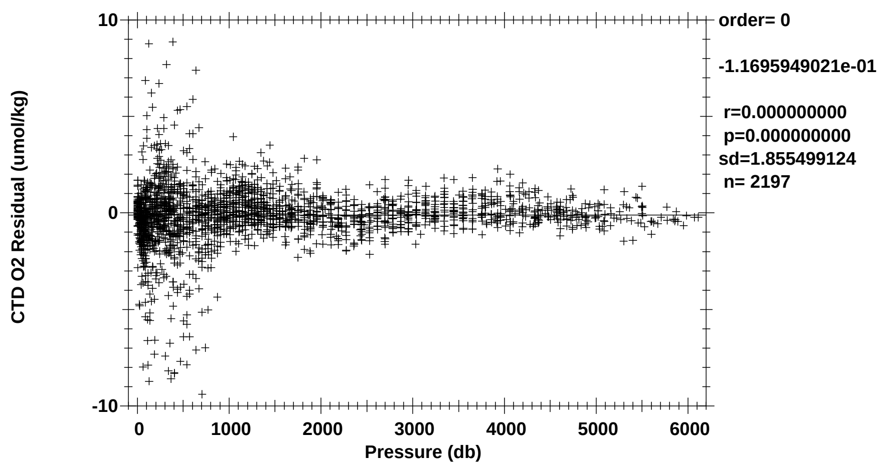

Figure 1.8.4.1 P02E O_2 residuals by pressure (-0.01°C ≤T1 – T2≤0.01°C).

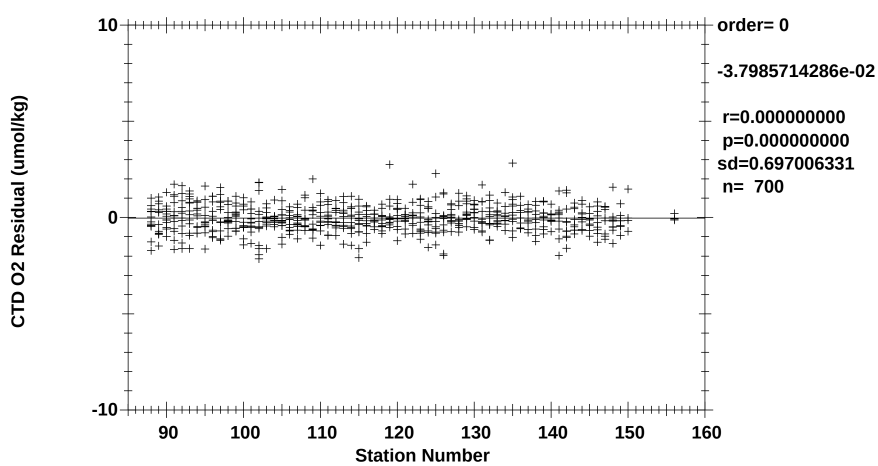

Figure 1.8.4.2 P02E Deep O_2 residuals by station (Pressure >= 1800 dbars).

The standard deviations of 1.855 μmol/kg for all oxygens and 0.697 μmol/kg for deep oxygens are only presented as general indicators of goodness of fit. SIO/STS makes no claims regarding the precision or accuracy of CTD dissolved O_2 data.

The general form of the SIO/STS DO sensor response model equation for Clark-style cells follows Brown and Morrison [Brow78], Millard [Mill82] and Owens & Millard [Owen85]. SIO/STS models DO sensor responses with lagged CTD data. *In situ* pressure and temperature are filtered to match the sensor responses. Time constants for the pressure response (τ_p), a slow (τ_{Tf}) and fast (τ_{Ts}) thermal response, package velocity (τ_{dP}), thermal diffusion (τ_{dT}) and pressure hysteresis (τ_h) are fitting parameters. Once determined for a given sensor, these time constants typically remain constant for a cruise. The thermal diffusion term is derived by low-pass filtering the difference between the fast response (T_s) and slow response (T_l) temperatures. This term is intended to correct non-linearities in sensor response introduced by inappropriate analog thermal compensation. Package velocity is approximated by low-pass filtering 1st-order pressure differences, and is intended to correct flow-dependent response. Dissolved O_2 concentration is then calculated:

$$O_2ml/l = [C_1 \cdot V_{DO} e^{(C_2 \cdot \frac{P_h}{5000})} + C_3] \cdot f_{sat}(T,P) \cdot e^{(C_4 \cdot T_l + C_5 \cdot T_s + C_7 \cdot P_l + C_6 \cdot \frac{dO_c}{dt} + C_8 \cdot \frac{dP}{dt} + C_9 \cdot dT)} \qquad (1.8.4.0)$$

where:

O_2ml/l	Dissolved O_2 concentration in ml/l;
V_{DO}	Raw sensor output;
C_1	Sensor slope
C_2	Hysteresis response coefficient
C_3	Sensor offset
$f_{sat}(T,P)$	O_2 saturation at T,P (ml/l);
T	*in situ* temperature (°C);
P	*in situ* pressure (decibars);
P_h	Low-pass filtered hysteresis pressure (decibars);
T_l	Long-response low-pass filtered temperature (°C);
T_s	Short-response low-pass filtered temperature (°C);
P_l	Low-pass filtered pressure (decibars);
$\frac{dO_c}{dt}$	Sensor current gradient (μamps/sec);
$\frac{dP}{dt}$	Filtered package velocity (db/sec);
dT	low-pass filtered thermal diffusion estimate (T_s - T_l).
$C_4 - C_9$	Response coefficients.

CTD O_2 ml/l data are converted to μmol/kg units on demand.

Manufacturer information on the SBE43 DO sensor, a modification of the Clark polarographic membrane technology, can be found at *http://www.seabird.com/application_notes/AN64.htm*.

A faster-response JFE Advantech Rinko III ARO-CAV Optical DO sensor, with its own oxygen temperature thermistor, was installed on the rosette and integrated with the ODF CTD from station 25 onward. ODF intends to evaluate it side-by-side with the SBE43 data, considering its possible use for future expeditions. Please contact ODF (odfdata@sts.ucsd.edu) for further information. Manufacturer information about the Rinko III sensor can be found at:

http://www.jfe-advantech.co.jp/eng/ocean/rinko/rinko3.html.

1.9. Bottle Sampling

At the end of each rosette deployment water samples were drawn from the bottles in the following order:

- CFC-12, CFC-11, and SF_6
- ^{3}He
- Dissolved O_2
- Dissolved Inorganic Carbon (DIC)
- pH
- Total Alkalinity
- ^{13}C and ^{14}C
- Dissolved Organic Carbon (DOC) and Total Dissolved Nitrogen (TDN)
- Tritium
- Nutrients
- $\delta^{15}N$-NO_3 / $\delta^{18}O$-NO_3
- Salinity
- ^{137}Cs / ^{134}Cs / ^{90}Sr
- ^{129}I
- Millero Density
- Dissolved Calcium

Bottle serial numbers were assigned at the start of the leg, and corresponded to their rosette/carousel position. Aside from various repairs to bottles along the way, no bottles were replaced during this leg. However some were removed due to carousel problems, which are addressed in the next section.

The correspondence between individual sample containers and the rosette bottle position (1-36) from which the sample was drawn was recorded on the sample log for the cast. This log also included any comments or anomalous conditions noted about the rosette and bottles. One member of the sampling team was designated the *sample cop*, whose sole responsibility was to maintain this log and ensure that sampling progressed in the proper drawing order.

Normal sampling practice included opening the drain valve and then the air vent on the bottle, indicating an air leak if water escaped. This observation together with other diagnostic comments (e.g., "lanyard caught in lid", "valve left open") that might later prove useful in determining sample integrity were routinely noted on the sample log. Drawing oxygen samples also involved taking the sample draw temperature from the bottle. The temperature was noted on the sample log and was sometimes useful in determining leaking or mis-tripped bottles.

Once individual samples had been drawn and properly prepared, they were distributed for analysis. Oxygen, nutrient and salinity analyses were performed on computer-assisted (PC) analytical equipment networked to the data processing computer for centralized data management.

1.10. Bottle Tripping Issues

The first leg of P02 experienced carousel problems that were inherited by this second leg, P02E. On Leg 1/P02W, a few of the carousel latches failed to trigger because of building corrosion from water seeping into some of the individual magnetic releases (solenoids). These leaks were plugged with Scotchkote as a temporary fix, which succeeded for all but one of the positions. Thus, P02E started with Niskin bottle 35 removed from the rosette. As the cruise progressed, Niskin bottles 1 and 28 were eventually removed for the same reason. After these bottles were removed, the positions on the carousel were sealed up as to prevent further damage due to leaking.

Table 1.10.0 summarizes when carousel positions were re-ordered or completely removed from the default tripping line-up during P02E:

Carousel Position	Stations Affected	Comment
35	88-159	Bottle removed from rosette (carousel position skipped)
34	91	Bottle intentionally tripped out-of-order (last/at surface)
1	96	Bottle intentionally tripped third (2 tripped at bottom, 3 tripped next, then 1
1	97-159	Bottle removed from rosette (carousel position skipped)
28	116-159	Bottle removed from rosette (carousel position skipped)

Table 1.10.0 P02E Summary of Unusual Tripping Sequences.

Several backup plans were pursued ashore but SBE32 36-place carousels are few and far between compared to the 24-place carousels. Eventually a spare 36-place carousel was borrowed from NOAA/PMEL and sent to the Hawaii port stop, to be used only if all else failed.

Numerous other minor bottle tripping and/or carousel issues occurred during P02E. Most and were attributed to lanyards failing to fully slide off the latches, or snagging somewhere on the rosette during the release process. Most of these problems were resolved by re-aligning the lanyards during cocking to avoid obstructions or snagging points. Individual mis-tripped bottles and samples taken from them have been quality-coded 4. More detailed comments appear in Appendix C.

1.11. Bottle Data Processing

Water samples collected and properties analyzed shipboard were centrally managed in a relational database (PostgreSQL 8.1.23) running on a Linux system. A web service (OpenACS 5.5.0 and AOLServer 4.5.1) front-end provided ship-wide access to CTD and water sample data. Web-based facilities included on-demand arbitrary property-property plots and vertical sections as well as data uploads and downloads.

The sample log information and any diagnostic comments were entered into the database once sampling was completed. Quality flags associated with sampled properties were set to indicate that the property had been sampled, and sample container identifications were noted where applicable (e.g., oxygen flask number). Acquisition and sampling details were also made available on the ODF shipboard website post-cast with scanned versions of the Console and Sample logs.

Analytical results were provided on a regular basis by the various analytical groups and incorporated into the database. These results included a quality code associated with each measured value and followed the coding scheme developed for the World Ocean Circulation Experiment Hydrographic Programme (WHP) [Joyc94].

Table 1.11.0 shows the number of samples drawn and the number of times each WHP sample quality flag was assigned for each basic hydrographic property:

Rosette Samples Stations 88- 159								
	Reported levels	WHP Quality Codes 1	2	3	4	5	7	9
Bottle	2322	0	2317	1	0	0	0	4
CTD Salt	2322	0	2322	0	0	0	0	0
CTD Oxy	2322	0	2320	0	2	0	0	0
Salinity	2316	0	2280	33	3	1	0	5
Oxygen	2313	0	2304	5	4	4	0	5
Silicate	2317	0	2315	0	2	0	0	5
Nitrate	2317	0	2315	0	2	0	0	5
Nitrite	2317	0	2315	0	2	0	0	5
Phosphate	2317	0	2315	0	2	0	0	5

Table 1.11.0 Frequency of WHP quality flag assignments.

Additionally, data investigation comments are presented in Appendix C.

Various consistency checks and detailed examination of the data continued throughout the cruise. Chief Scientist, Dr. Sabine Mecking, reviewed the data and compared it with historical data sets.

1.12. Salinity Analysis

Equipment and Techniques

One salinometer, a Guildline Autosal 8400B (S/N 69-180), was used throughout P02E. This salinometer utilized the typical National Instruments interface to decode Autosal data and communicate with a Windows-based acquisition PC. All discrete salinity analyses were done in the R/V Melville's Photo Lab.

Samples were analyzed after they had equilibrated to laboratory temperature, usually within 6-20 hours after collection. The salinometer was standardized for each group of analyses (typically 1 cast, sometimes 2; up to 72 samples) using two fresh vials of standard seawater per group.

Salinometer measurements were made by a computer using LabVIEW software developed by SIO/STS. The software maintained an Autosal log of each salinometer run which included salinometer settings and air and bath temperatures. The air temperature was monitored via digital thermometer and displayed on a 48-hour strip-chart via LabVIEW in order to observe cyclical changes. The program guided the operator through the standardization procedure and making sample measurements. The analyst was prompted to change samples and flush the cell between readings.

Standardization procedures included flushing the cell at least 2 times with a fresh vial of Standard Seawater (SSW), setting the flow rate to a low value during the last fill, and monitoring the STD dial setting. If the STD dial changed by 10 units or more since the last salinometer run (or during standardization), another vial of SSW was opened and the standardization procedure repeated to verify the setting.

Each salt sample bottle was agitated to minimize stratification before reading on the salinometer. Samples were run using 2 flushes before the final fill. The computer determined the stability of a measurement and prompted for additional readings if there appeared to be drift. The operator could annotate the salinometer log, and would routinely add comments about cracked sample bottles, loose thimbles, salt crystals or anything unusual in the amount of sample in the bottle.

Sample Collection, Equilibration and Data Processing

A total of 5248 rosette salinity samples were measured. An additional 14 samples were run for calibrating the underway TSG system. 158 vials of standard seawater (IAPSO SSW) were used.

Salinity samples were drawn into 200 ml Kimax high-alumina borosilicate bottles, which were rinsed three times with the sample prior to filling. The bottles were sealed with custom-made plastic insert thimbles and kept closed with Nalgene screw caps. This assembly provides very low container dissolution and sample evaporation. Prior to sample collection, inserts were inspected for proper fit and loose inserts replaced to ensure an airtight seal.

After samples were brought back to the analysis lab, the full case was placed on a wooden frame and sealed around all edges to the workbench top. Salt bottle storage boxes have either an open grid pattern material or have holes drilled between bottle locations to facilitate air circulation between the bottles from bottom to top. A fan circulated warm air drawn from behind the Autosal to the underside of the salt case.

A thermometer was placed between two bottles that represent cooler but not the coldest temperatures, typically bottles 9 and 15 for the square cases and alongside bottle 3, on the inner side, for the rectangular cases. Warm air circulated through the case until indicated glass temperature was within 1°C of bath temperature. The case was removed from the warming frame and allowed to stand for 10 to 30 minutes before analyzing the salinities. Equilibration times were logged for all casts and laboratory temperatures were logged at the beginning and end of each run.

PSS-78 salinity [UNES81] was calculated for each sample from the measured conductivity ratios. The difference between the initial vial of standard water and the next one run as an unknown was applied as a linear function of elapsed run time to the measured ratios. The corrected salinity data were then incorporated into the cruise database.

Data processing included double checking that the station, sample and box number had been correctly assigned, and reviewing the data and log files for operator comments. Discrete salinity data were compared to CTD salinities and were used for shipboard sensor calibration.

Laboratory Temperature

The salinometer water bath temperature was maintained at 24°C . The ambient laboratory air temperature varied from 20 to 25.5°C during the sample analyses , typically between 21 and 24°C.

Standards

IAPSO Standard Seawater Batch P-153 was used to standardize all stations.

Analytical Problems

No analytical problems were encountered on CLIVAR/Carbon P02E.

Results

The Autosal standard dial setting rarely changed during P02E, and then only by small amounts (a total of -6 points from start to finish). The drift in readings within any single run was very low (within ±0.00002) for all of P02E (about ±0.0004 in salinity).

Nevertheless, there were up to 0.0015 shifts in Bottle-CTD salinity differences observed between the runs of the two analysts, which abruptly stopped from station 126 onward, when they started using a space heater to bring the samples to near-bath temperature. This suggests that this shifting was due to a relatively large difference between the water sample temperature and the salinometer bath temperature. The results, both before and after staion 126, fall within the estimated accuracy of bottle salinities run at sea - usually better than ±0.002 relative to the particular standard seawater batch used.

1.13. Oxygen Analysis

Equipment and Techniques

Dissolved oxygen analyses were performed with an SIO/ODF-designed automated oxygen titrator using photometric endpoint detection based on the absorption of 365nm wavelength ultraviolet light. The titration of the samples and the data logging were controlled by ODF PC software compiled in LabVIEW. Thiosulfate was dispensed by a Brickman Dosimat 765 buret driver fitted with a 1.0 mL buret. The ODF method used a whole-bottle modified-Winkler titration following the technique of Carpenter[Carp65] with modifications by Culberson *et al.* [Culb91], but with higher concentrations of potassium iodate standard (~0.012N) and thiosulfate solution (~55 gm/l). Standard KIO_3 solutions prepared ashore were run daily (approximately every 2-4 stations), unless changes were made to the system or reagents. Reagent/distilled water blanks were also determined daily, or more often if a change in reagents required it to account for presence of oxidizing or reducing agents.

Sampling and Data Processing

5234 samples were analyzed from 72 stations on P02E. Samples were collected for dissolved oxygen analyses soon after the rosette was brought on board. Six different cases of 24 flasks each were rotated by station to minimize any potential flask calibration issues. Using a silicone drawing tube, nominal 125ml volume-calibrated iodine flasks were rinsed 3 times with minimal agitation, then filled and allowed to overflow for at least 3 flask volumes. The sample drawing temperatures were measured with an electronic resistance temperature detector (Omega™ HH370 RTD) embedded in the drawing tube. These temperatures were used to calculate μmol/kg concentrations, and as a diagnostic check of bottle integrity. Reagents ($MnCl_2$ then NaI/NaOH) were added to fix the oxygen before stoppering. The flasks were shaken to assure thorough dispersion of the precipitate, once immediately after drawing, and then again after about 20 minutes. A water seal was applied to the rim of each bottle in between shakes.

The samples were analyzed within 1 hour of collection, and the data incorporated into the cruise database.

Thiosulfate normalities were calculated from each standardization and corrected to 20°C. The thiosulfate normalities and blanks were monitored for possible drifting or other problems when new reagents were used. An average blank and thiosulfate normality were used to recalculate oxygen concentrations. The thiosulfate was changed between stations 99 and 100, then again between stations 127 and 128. Thus, the first set of averages were performed on Stations 88 through 99, the second set was done on Stations 100 through 127, and the third set was done on stations 128 through 159. The difference between the original and "smoothed" data averaged 0.07% over the course of the cruise.

Bottle oxygen data were reviewed to ensure station, cast, bottle number, flask, and draw temperature were entered properly. Comments made during analysis were reviewed, and anomalies were investigated and resolved. If an incorrect end point was encountered, the analyst re-examined raw data and the program recalculated a correct end point.

After the data were uploaded to the database, bottle oxygen was graphically compared with CTD oxygen and adjoining stations. Any points that appeared erroneous were reviewed and comments made regarding the final outcome of the investigation. These investigations and final data coding are reported in Appendix C.

Volumetric Calibration

Oxygen flask volumes were determined gravimetrically with degassed deionized water to determine flask volumes at ODF's chemistry laboratory. This was done once before using flasks for the first time and periodically thereafter when a suspect volume is detected. The volumetric flasks used in preparing standards were volume-calibrated by the same method, as was the 10 mL Dosimat buret used to dispense standard iodate solution.

Standards

Liquid potassium iodate standards were prepared and tested in 6 liter batches and bottled in sterile glass bottles at ODF's chemistry laboratory prior to the expedition. The normality of the liquid standard was determined by calculation from weight of powder temperature of solution and flask volume at 20°C. The standard was supplied by Alfa Aesar (lot B05N35) and has a reported purity of 99.4-100.4%. All other reagents were "reagent grade" and were tested for levels of oxidizing and reducing impurities prior to use.

Analytical Problems

Occasionally, samples were lost due to an occasional problem with the Dosimat. After these occurred, the analyst paused the analyses until the problem was resolved. A summary of these lost samples can be found in Appendix C.

1.14. Nutrient Analysis

Summary of Analysis

5260 samples from 72 CTD stations were analyzed.

The cruise started with new pump tubes; they were changed twice, after stations 110 and 141. Three sets of Primary/Secondary standards were made up over the course of the cruise. The cadmium column efficiency was checked periodically and ranged between 97%-100%. When the efficiency was found to be below 97%, the column was replaced.

Equipment and Techniques

Nutrient analyses (phosphate, silicate, nitrate plus nitrite, and nitrite) were performed on a Seal Analytical continuous-flow AutoAnalyzer 3 (AA3). The analytical methods used are described by Gordon *et al.* [Gord92], Hager *et al.* [Hage68] and Atlas *et al.* [Atla71]. The details of modification of analytical methods used for this cruise are also compatible with the methods described in the nutrient section of the GO-

SHIP repeat hydrography manual [Hyde10].

Nitrate/Nitrite Analysis

A modification of the Armstrong *et al.* [Arms67] procedure was used for the analysis of nitrate and nitrite. For nitrate analysis, a seawater sample was passed through a cadmium column where the nitrate was reduced to nitrite. This nitrite was then diazotized with sulfanilamide and coupled with N-(1-naphthyl)-ethylenediamine to form a red dye. The sample was then passed through a 10mm flowcell and absorbance measured at 540nm. The procedure was the same for the nitrite analysis but without the cadmium column.

REAGENTS

Sulfanilamide

Dissolve 10g sulfanilamide in 1.2N HCl and bring to 1 liter volume. Add 2 drops of 40% surfynol 465/485 surfactant. Store at room temperature in a dark poly bottle.

Note: 40% Surfynol 465/485 is 20% 465 plus 20% 485 in DIW.

N-(1-Naphthyl)-ethylenediamine dihydrochloride (N-1-N)

Dissolve 1g N-1-N in DIW, bring to 1 liter volume. Add 2 drops 40% surfynol 465/485 surfactant. Store at room temperature in a dark poly bottle. Discard if the solution turns dark reddish brown.

Imidazole Buffer

Dissolve 13.6g imidazole in ˜3.8 liters DIW. Stir for at least 30 minutes to completely dissolve. Add 60 ml of $CuSO_4$ + NH_4Cl mix (see below). Add 4 drops 40% Surfynol 465/485 surfactant. Let sit overnight before proceeding. Using a calibrated pH meter, adjust to pH of 7.83-7.85 with 10% (1.2N) HCl (about 20-30 ml of acid, depending on exact strength). Bring final solution to 4L with DIW. Store at room temperature.

NH_4Cl + $CuSO_4$ mix

Dissolve 2g cupric sulfate in DIW, bring to 100 m1 volume (2%). Dissolve 250g ammonium chloride in DIW, bring to l liter volume. Add 5ml of 2% $CuSO_4$ solution to this NH_4Cl stock. This should last many months.

Phosphate Analysis

Ortho-Phosphate was analyzed using a modification of the Bernhardt and Wilhelms [Bern67] method. Acidified ammonium molybdate was added to a seawater sample to produce phosphomolybdic acid, which was then reduced to phosphomolybdous acid (a blue compound) following the addition of dihydrazine sulfate. The sample was passed through a 10mm flowcell and absorbance measured at 820nm.

REAGENTS

Ammonium Molybdate

H_2SO_4 solution: Pour 420 ml of DIW into a 2 liter Ehrlenmeyer flask or beaker, place this flask or beaker into an ice bath. SLOWLY add 330 ml of concentrated H_2SO_4. This solution gets VERY HOT!! Cool in the ice bath. Make up as much as necessary in the above proportions.

Dissolve 27g ammonium molybdate in 250ml of DIW. Bring to 1 liter volume with the cooled sulfuric acid solution. Add 3 drops of 15% DDS surfactant. Store in a dark poly bottle.

Dihydrazine Sulfate

Dissolve 6.4g dihydrazine sulfate in DIW, bring to 1 liter volume and refrigerate.

Silicate Analysis

Silicate was analyzed using the technique of Armstrong *et al.* [Arms67] Acidified ammonium molybdate was added to a seawater sample to produce silicomolybdic acid which was then reduced to silicomolybdous acid (a blue compound) following the addition of stannous chloride. The sample was passed through a 10mm flowcell and measured at 660nm.

REAGENTS

Tartaric Acid

Dissolve 200g tartaric acid in DW and bring to 1 liter volume. Store at room temperature in a poly bottle.

Ammonium Molybdate

Dissolve 10.8g Ammonium Molybdate Tetrahydrate in ~ 900ml DW. Add 2.8ml H_2SO_4* to solution, then bring volume to 1000ml.

Add 3-5 drops 15% SDS surfactant per liter of solution.

Stannous Chloride stock (as needed)

Dissolve 40g of stannous chloride in 100 ml 5N HCl. Refrigerate in a poly bottle.

NOTE: Minimize oxygen introduction by swirling rather than shaking the solution. Discard if a white solution (oxychloride) forms.

Working (every 24 hours): Bring 5 ml of stannous chloride stock to 200 ml final volume with 1.2N HCl. Make up daily - refrigerate when not in use in a dark poly bottle.

Sampling

Nutrient samples were drawn into 40 ml polypropylene screw-capped centrifuge tubes. The tubes and caps were cleaned with 10% HCl and rinsed 2-3 times with sample before filling. Samples were analyzed within 1-3 hours after sample collection, allowing sufficient time for all samples to reach room temperature. The centrifuge tubes fit directly onto the sampler.

Data collection and processing

Data collection and processing was done with the software (AACE ver. 6.07) provided with the instrument from SEAL Analytical. After each run, the charts were reviewed for any problems during the run, any blank was subtracted, and final concentrations (μM) were calculated, based on a linear curve fit. Once the run was reviewed and concentrations calculated a text file was created. That text file was reviewed for possible problems and then converted to another text file with only sample identifiers and nutrient concentrations that was merged with other bottle data.

Standards and Glassware calibration

Primary standards for silicate (Na_2SiF_6), nitrate (KNO_3), nitrite ($NaNO_2$), and phosphate (KH_2PO_4) were obtained from Johnson Matthey Chemical Co. and/or Fisher Scientific. The supplier reports purities of >98%, 99.999%, 97%, and 99.999 respectively.

All glass volumetric flasks and pipettes were gravimetrically calibrated prior to the cruise. The primary standards were dried and weighed out to 0.1 mg prior to the cruise. The exact weight was noted for future reference. When primary standards were made, the flask volume at 20°C, the weight of the powder, and the temperature of the solution were used to buoyancy correct the weight, calculate the exact concentration of the solution, and determine how much of the primary was needed for the desired concentrations of secondary standard. Primary and secondary standards were made up every 7-10 days. The new standards were compared to the old before use.

All the reagent solutions, primary and secondary standards were made with fresh distilled deionized water (DIW).

Quality Control

All data were reported in μM (micromoles/liter). NO_3, PO_4, and NO_2 were reported to two decimal places and SiO_3 to one. Accuracy is based on the quality of the standards; the levels were:

Parameter	Accuracy (μM)
NO_3	0.05
PO_4	0.004
SiO_3	2-4
NO_2	0.05

Table 1.14.1 CLIVAR/Carbon P02E Nutrient Accuracy

Precision numbers for the instrument were the same for NO_3 and PO_4 and a little better for SiO_3 and NO_2 (1 and 0.01 respectively).

The detection limits for the methods/instrumentation were:

Parameter	Detection Limits (μM)
NO_3+NO_2	0.02
PO_4	0.02
SiO_3	0.5
NO_2	0.02

Table 1.14.2 CLIVAR/Carbon P02E Nutrient Detection Limits

As is standard ODF practice, a deep calibration *check* sample was run with each set of samples and the data are tabulated below.

Parameter	Concentration (μM)
NO_3	35.86 +/- 0.14
PO_4	2.50 +/- 0.01
SiO_3	148.08 +/- 0.51

Table 1.14.3 CLIVAR/Carbon P02E RMNS cruise-averaged data

Reference materials for nutrients in seawater (RMNS) were also used as a check sample run with each set of seawater samples. The RMNS preparation, verification, and suggested protocol for use of the material are described by Aoyama *et al.* [Aoya06] [Aoya07] [Aoya08] and Sato *et al.* [Sato10]. RMNS batch BX was used on this cruise, with each bottle being used once or twice before being discarded and a new one opened. Data are tabulated below, along with the assigned values.

Parameter	Concentration (μmol kg^{-1})	Assigned
NO_3	43.13 +/- 0.12	43
PO_4	2.89 +/- 0.02	2.906
SiO_3	138.8 +/- 0.56	136
NO_2	0.04 +/- 0.005	0.034

Table 1.14.0 CLIVAR/Carbon P02E Concentration of RMNS standard (μM)

Analytical Problems

The phosphate channel was an ongoing source of trouble, with the baseline and peaks being bumpy and/or the baseline jumping up and recovering later, causing uncertain sample values that necessitated reruns of individual samples and sometimes even of whole stations. No samples were lost. Prior to station 95 the sample probe and heater were replaced with spares. The probe was switched back prior to station 114. The pump, flowcell, control module and 880nm filter were switched out for spares in succession before station 115.

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Transmissometer Shipboard Procedures

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Instrument WET Labs C-Star Transmissometer – S/N **CST-327DR**

Air Calibration:

- Calibrated the transmissometer in the lab at beginning, middle and end of leg 2 with the complete sea cable set up.
- Washed and dried the windows with Kimwipes and distilled water.
- Recorded the final values for unblocked and blocked voltages plus air temperature on the Transmissometer Calibration/Cast Log.
- Compared the output voltage with the Factory Calibration data.
- Computed updated calibration coefficients.

Deck Procedures:

- Washed the transmissometer windows before every cast. Rinsed both windows with a distilled water bottle that contains 2-3 drops of liquid soap. This was the last procedure before the CTD went
- in the water.
- Rinse instrument with fresh water at end of cruise.

Summary:

Deck calibrations were carried out 3 times during P02E – near the start of the leg, the middle of the leg and the morning after the last station was completed. Results of the pre-cruise laboratory calibration, and deck calibrations done during this cruise, appear at the end of Appendix D with the other instrument/sensor laboratory calibrations.

After preparing the transmissometer for deployment (see Deck Procedures above), CST-327DR was sent with the rosette for every CTD cast during P02 E (Leg 2) on R/V Melville. Data were reported through a CTD a/d channel, then converted to raw voltages without applying any corrections. The data were averaged into half-second blocks with the CTD data, and later converted into 2-dbar block-averaged data files. The raw voltage data will be reported to Wilf Gardner for further processing post-cruise, and later merged in with the CTD data at CCHDO.

No problems were encountered with the transmissometer during this leg.

Cruise Report: LADCP data from CLIVAR/Carbon PO2E 2013

Steven Howell

Personnel

UH LADCP group: Eric Firing (PI), François Ascani, and Julia Hummon

Shipboard operators Steven Howell, UH, and Gunnar Voet, University of Washington

System description

The University of Hawaii (UH) ADCP group used a Teledyne/RDI Workhorse 150 kHz Lowered Acoustic Doppler Current Profiler (LADCP, serial number 16283, with beams 20° from vertical) to measure ocean currents during the spring 2013 CLIVAR/Carbon P02E cruise from Honolulu, Hawaii to San Diego, California. The instrument was held near the base of the rosette by an anodized aluminum collar connected to three struts that were in turn bolted to the rosette frame. Secondary restraint was provided by a ratchet strap tightened around the instrument and tied to an upper strut of the frame. Power for the LADCP was provided by a Deep Sea Power & Light sealed oil-filled marine battery (model SB-48V/18A, serial number 01527). It was fastened with cord to the rosette frame. Figure 1 shows the arrangement of instruments in the rosette.

Between casts, a single power/communications cable connected the LADCP and battery to a computer and a DC power supply to initialize the LADCP, collect data after casts, and recharge the battery. Communication with the instrument was managed by a custom serial communication package.

Operating parameters

The LADCP used nominal 16 m pulses and 8 m receive intervals (assuming a standard $1500\,\mathrm{m\,s^{-1}}$ speed of sound). The blanking interval (distance to first usable data) was 16 m.

A staggered pinging pattern was used, with alternating 1.2 s and 1.6 s periods between pings. This was to avoid a problem referred to as Previous Ping Interference (PPI), which happens when a strong echo off the bottom from a previous ping overwhelms the weak scattering signal from the water column. PPI occurs at a distance above the ocean floor

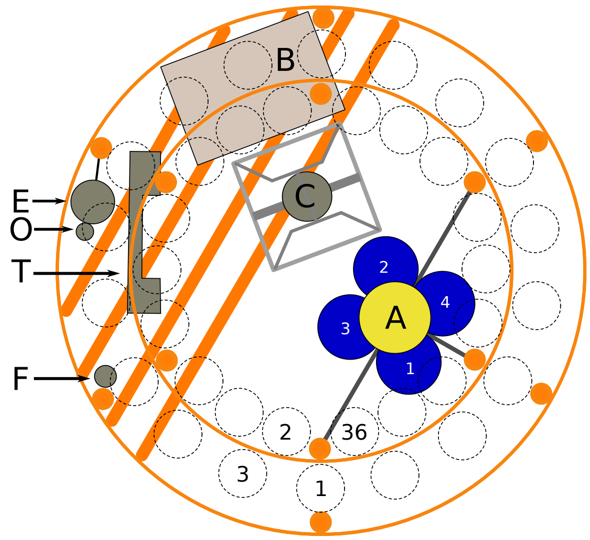

Figure 1: Schematic plan view of instrument and bottle locations on the rosette. Orange elements are parts of the rosette frame. Bottle locations are indicated by dashed circles and numbers. Instruments are identified by letters: A, ADCP; B, Battery for ADCP power; C, CTD;E, Echosounder (120 kHz Benthos altimeter); O, oxygen sensor (secondary); T, transmissometer; and F, Fluorometer for chlorophyll-A. White numerals show ADCP beam positions after the 90° clockwise twist on April 23.

of $\Delta z = \frac{1}{2} c \Delta t \cos\theta$ where Δt is the period between pings, c is the speed of sound, and θ is the beam angle from vertical. With constant ping rates, the artifact hits a single depth, essentially invalidating all data at that depth. By alternating delays, we lose half the data at two depths, but have some data through the entire column.

The LADCP control file

```
CR1    # factory defaults
PS0    # Print system serial number and other info.
WM15   # sets LADCP mode; WB -> 1, WP -> 001, TP -> 000100, TE -> 00000100
TC2    # 2 ensembles per burst
TB 00:00:02.80     ### also try old BB settings, 2.6 and 1.0
TE 00:00:01.20
TP 00:00.00
WN40    # 40 cells, so blank + 320 m with 8-m cells
WS0800  # 8-m cells
WT1600  # 16-m pulse
WF1600  # Blank, 16-m
WV330      # 330 is max effective ambiguity velocity for WB1
EZ0011101  # Soundspeed from EC (default, 1500)
EX00100    # No transformation (middle 1 means tilts would be used otherwise)
CF11101    # automatic binary, no serial
LZ30,230   # for LADCP mode BT; slightly increased 220->230 from Dan Torres
```

```
CL0       # don't sleep between pings (CL0 required for software break)
```

Data processing

Data were processed using version IX.8 of Andreas Thurnherr's implementation of Martin Visbeck's LADCP inversion method, developed at the Lamont-Doherty Earth Observatory of Columbia University. The LDEO code is written in Matlab, and performs a long chain of calculations, including transforming the raw LADCP data to Earth coordinates; editing out suspect data; meshing with CTD data from the cast and simultaneous shipboard ADCP and GPS data; then running both an inverse method and a shear-based algorithm to obtain ocean currents throughout the profile. The shear-based calculation is used as a check on the inverse method–if they agree, confidence in the solution is enhanced. The LDEO code is available at `ftp://ftp.ldeo.columbia.edu/pub/LADCP`.

Only preliminary data processing was performed during the cruise; full processing takes more time than was available. The automatic data editing is not completely adequate, as ocean bottom reflections are not always edited out and the algorithms for detecting and discarding PPI require more work. When the data are fully processed, they will be made available on the UH ADCP website, `http://currents.soest.hawaii.edu` as part of the CLIVAR ADCP archive.

Data gathered

Data were successfully obtained in every cast at each station. Preliminary vertical profile plots of each station were made available on the ship's website within 12 hours of each cast.

Problems encountered

We had no major hardware or software problems during the cruise, but there were a few glitches. The ADCP twice slipped down in its collar and had to be lifted up and re-secured. The odd noise problem from the last leg continued. Beam 2 was conspicuously weaker than the others. As before, the noise was related to instrument position. Since beam 2 was in the what appeared to be the bad spot, before the test cast we tried turning the instrument about 30° clockwise to get all beams as far from the CTD frame as possible. The test cast was not deep enough for an unequivocal test of the orientation, but the next 3 casts revealed that beam 2 was worse than before, so we turned it back before station 92.

It is possible that the Benthos 120 kHz altimeter caused acoustic interference, but exactly the same altimeter and rosette were used during the CLIVAR A20/A22 cruises without the same symptoms. Another possibility is that some instrument on the rosette or along the cable introduced electrical noise. We have not really resolved the problem, but are satisfied that the effects on the data are small.

We had a more fundamental problem through much of the deep basin. Data from individual pings are noisy; many pings must be averaged together to get useful information. This becomes the limiting factor in determining current velocities deep in the ocean, where particles of sufficient size to scatter the 1 cm wavelength of the WH150 are scarce. The effective range of the instrument dropped to roughly 80 m. This was much worse than in P02E, where range was typically > 150 m, even in the deep ocean. Range dropped gradually; it does not appear to be due to failing transducers, but rather to a lack of scatterers.

The net effect is that deep currents are poorly constrained and the inversions indicate improbably strong shear, more likely inaccurate inversions than real ocean current velocities. We will attempt to tune the inversions and constraints to yield more physically plausible results, but there may not be sufficient data density to constrain deep currents within error bounds of $10\,\mathrm{cm\,s^{-1}}$.

Sample data plots

Figure 2 compares the last station of Leg 1 with the first of Leg 2, which was a replicate, occurring in the same spot 9 days later. The two profiles differ quite a bit. In the absence of strong currents, motion is dominated by tides, internal waves, and inertial motion. These all have time scales of a day or less, so features seen by the LADCP cannot be expected to last much longer than that. It also means that comparisons with geostrophic velocities tendto be messy, as Sabine Mecking and Gunnar Voet showed in their last cruise update.

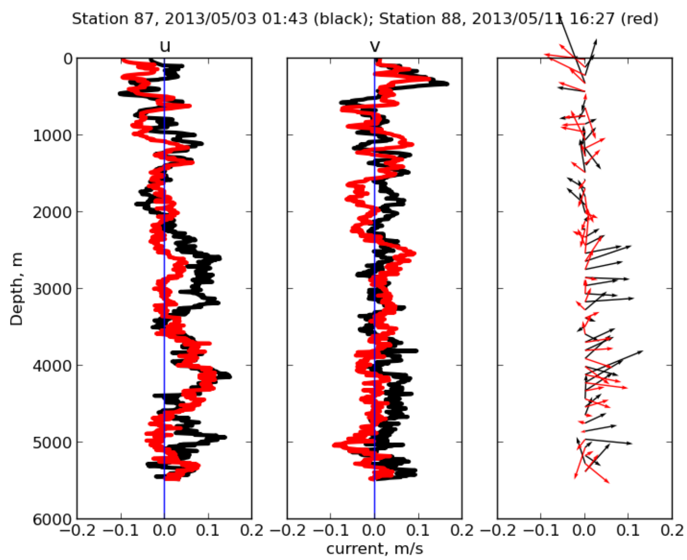

Figure 2: Comparison between the last station of P02W (station 87) and the first station of P02E (station 88). The left plot is ocean velocity in the east-west direction. Positive values are to the east. The middle plot is similar, but north is positive. The third plot has the same data, where the arrows represent horizontal speed and direction at the depth of the arrow origin.

We made both vertical profiles of individual plots and contour plots along the cruise track available on the ship's network. A contour plot of data from the entire cruise may be the best capsule summary of the preliminary data (Figure 3). The strongest well-known current crossed was the California current, at about 121°W. Current speed was about $0.27\,\mathrm{m\,s^{-1}}$ to the SE. As mentioned above, some of the deep currents (below 3000 m or so) may be artifacts of the inversion rather than actual currents.

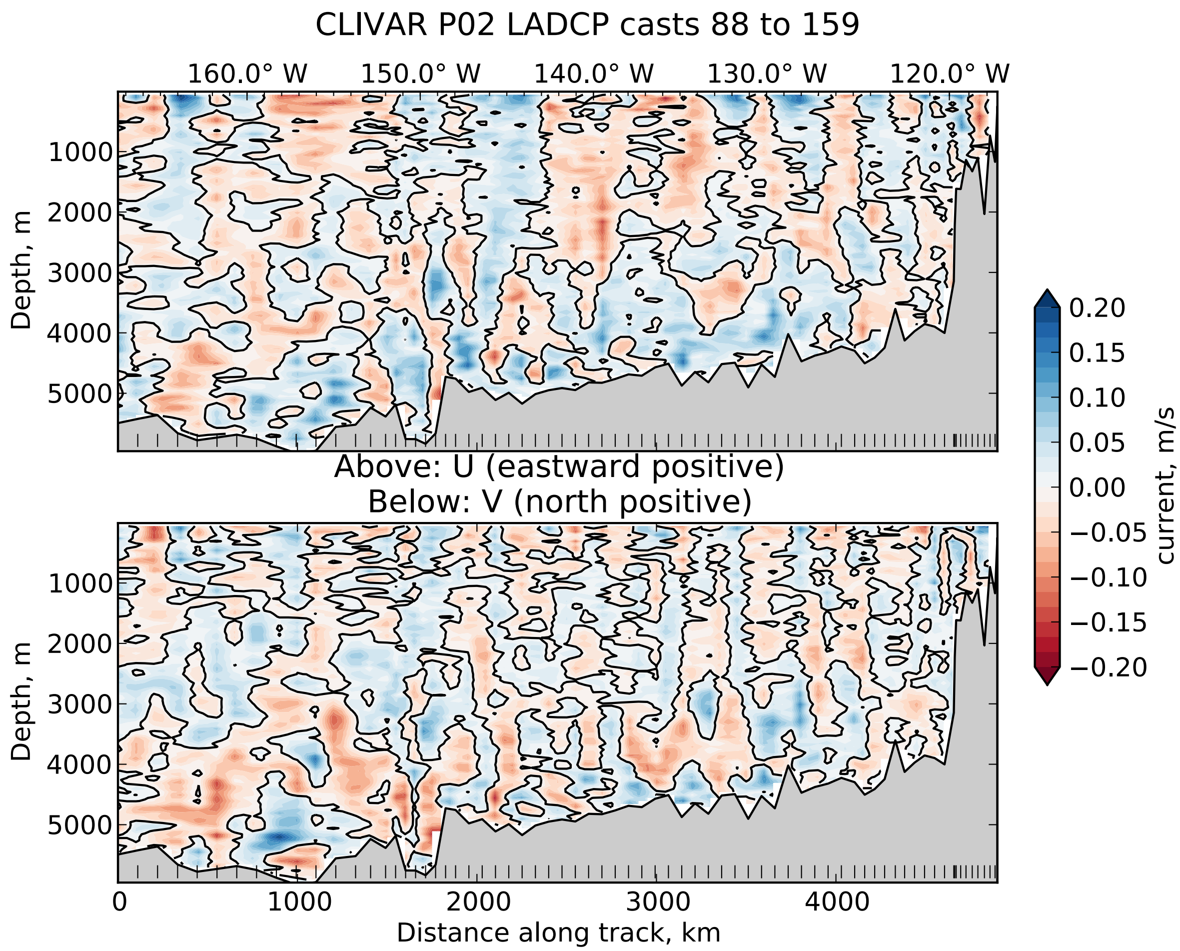

Figure 3: Contour plot of P02E stations 88 to 159. Tick marks along the bottom of each plot are station locations. The California current is indicated by the blue CC.

CHLOROFLUOROCARBON AND SULFUR HEXAFLUORIDE MEASUREMENTS

University of Texas (Austin)

PI: Dong-Ha Min

Analysts: David Cooper, Patrick Mears and Andrew Shao

Samples for the analyses of the dissolved chlorofluorocarbons (CFCs, freons) CFC-11 and CFC-12 and sulfur hexafluoride (SF6) in seawater and air were collected during MV-1306. Seawater samples were taken from all casts, with full profiles generally taken from alternating casts and strategically determined bottles sampled from the remaining casts. These results complement the P2 Leg1 data obtained by Lamont-Doherty Earth Observatory (PI: W. Smethie). Full integration of the data sets will be made at a later date when intercalibration has been completed.

Seawater samples were drawn from specially designed Niskin bottles that use a modified end-cap design to minimize the contact of the water sample with the end-cap O-rings after closing. O-rings were baked before use to further reduce potential contamination. Stainless steel springs covered with a nylon powder coat were substituted for the internal elastic tubing provided with standard Niskin bottles. Samples for CFC and SF6 were the first samples drawn from the 10-liter bottles. Care was taken to coordinate the sampling analysts to minimize the time between the initial opening of each bottle and the completion of sample drawing. In most cases, 3He, dissolved oxygen and DIC samples were collected within several minutes of the initial opening of each bottle. To minimize contact with air, the CFC samples were drawn directly through the stopcocks of the 10-liter bottles into 250 ml precision glass syringes. Syringes were rinsed and filled via three-way plastic stopcocks. The syringes were subsequently immersed in holding buckets of clean seawater held at 0-10 degrees C until 30 minutes before being analyzed. At that time, the syringe was placed in a bath of surface seawater heated at approximately 25 degrees C.

For atmospheric sampling, a ~90 m length of 3/8" OD Dekaron tubing was run from the main lab to the bow of the ship. A flow of air was drawn through this line into the main laboratory using an air-cadet pump. The air was compressed in the pump, with the downstream pressure held at ~1.5 atm. using a backpressure regulator. A tee allowed a flow (100 ml min-1) of the compressed air to be directed to the gas sample valves of the CFC analytical systems, while the bulk flow of the air (>7 l min-1) was vented through the backpressure regulator. Air samples were only analyzed when the relative wind direction was within 60 degrees of the bow of the ship to reduce the possibility of shipboard contamination. Analysis of bow air was performed at several locations along the cruise track. Approximately five measurements were made at each location to increase the precision. Atmospheric data were not submitted to the database, but were found to be in good agreement with current global databases and independent measurements made by LDEO during P2 leg 1.

Concentrations of CFC-1l, CFC-12 and SF6 in air samples, seawater samples and gas standards were measured by shipboard electron capture gas chromatography (ECD-GC) using techniques described by Bullister and Wisegarver (2008). For seawater analyses, water was transferred from a glass syringe to a glass-sparging chamber (~190 ml). The dissolved gases in the seawater sample were extracted by passing a supply of CFC-free purge gas through the sparging chamber for a period of 6 minutes at 120 - 175 ml min-1. Water vapor was removed from the purge gas during passage through a Nafion drier, backed up by a 18 cm long, 3/8" diameter glass tube packed with the desiccant magnesium perchlorate. The sample gases were concentrated on a cold-trap consisting of a 1/16" OD stainless steel tube with a ~5 cm section packed tightly with Porapak Q (60-80 mesh) and a 22 cm section packed with Carboxen 1004. A neslab cryocool was used to cool the trap, to below -50°C. After 6 minutes of purging, the trap was isolated, and it was heated electrically to ~175°C. The sample gases held in the trap were then injected onto a precolumn (~60 cm of 1/8" O.D. stainless steel tubing packed with 80-100 mesh Porasil B, held at 80°C) for the initial separation of CFC-12 and CFC-11 from later eluting peaks. After the F12 had passed from the pre- column through the second precolum (5 cm of 1/8" O.D. Stainless steel tubing packed with MS5A, 80°C) and into the analytical column #1 (~170 cm of 1/8" OD stainless steel tubing packed with MS5A and held at 80°C) the outflow from the first precolumn was diverted to the second analytical column (~150 cm 1/8" OD stainless steel tubing packed with Carbograph 1AC, 80-100 mesh, held at 80°C). After CFC-11 had passed through the first precolumn, the remaining gases were backflushed from the precolumn and vented. The analytical columns and the precolumns were in held isothermal at 80 degrees C in an Agilent (HP) 6890N gas chromatograph with two electron capture detectors (250°C).

The analytical system was calibrated frequently using a standard gas of known CFC and SF6 composition. Gas sample loops of known volume were thoroughly flushed with standard gas and injected into the system. The temperature and pressure was recorded so that the amount of gas injected could be calculated. The procedures used to transfer the standard gas to the trap, precolumn, main chromatographic column, and EC detector were similar to those used for analyzing water samples. Four sizes of gas sample loops were used. Multiple injections of these loop volumes could be made to allow the system to be calibrated over a relatively wide range of concentrations. Air samples and system blanks (injections of loops of CFC-free gas) were injected and analyzed in a similar manner. The typical analysis time for seawater, air, standard or blank samples was ~12 minutes. Concentrations of the CFCs in air, seawater samples, and gas standards are reported relative to the SIO98 calibration scale (e.g. Bullister and Tanhua, 2010). Concentrations in air and standard gas are reported in units of mole fraction CFC in dry gas, and are typically in the parts per trillion (ppt) range. Dissolved CFC concentrations are given in units of picomoles per kilogram seawater (pmol kg-1). CFC concentrations in air and seawater samples were determined by fitting their chromatographic peak areas to multi-point calibration curves, generated by injecting multiple sample loops of gas from a working standard (PMEL cylinder 45181) into the analytical instrument. The response of the detector to the range of moles of CFC passing through the detector remained relatively constant during the cruise. Full-range calibration curves were run at the beginning and the end of the cruise. Single injections of a fixed volume of standard gas at one atmosphere were run much more frequently (at intervals of ~90 minutes) to monitor short-term changes in detector sensitivity.

Results from 1758 seawater samples are reported, mostly for all three measured compounds. Random duplicates were taken from 40 casts to estimate precision and run variability tests. From the samples from the surface to the thermocline (the highest concentrations), we calculate the deviation to be 0.7% from the mean of the pairs for CFC-12 and SF6 measurements, and 0.4% from the mean for CFC-11 measurements. Deviation from the mean of pairs from deeper samples ranged from similar levels to approximately 0.01 fM for CFC-12 and CFC-11. Due to the exceedingly low levels of SF6 present in deeper water, accurate estimates of precision are not possible. A very small number of additional water samples had anomalous CFC concentrations relative to adjacent samples. These samples occurred sporadically during the cruise and were not clearly associated with other features in the water column (e.g., anomalous dissolved oxygen, salinity, or temperature features). This suggests that these samples were probably contaminated with CFCs during the sampling or analysis processes. Measured concentrations for some anomalous samples are included in the preliminary data, but are given a quality flag value of either 3 (questionable measurement) or 4 (bad measurement). A quality flag of 5 was assigned to samples which were drawn from the rosette but lost due to a variety of reasons (transfer loss, operator error or system fault).

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Bullister, J.L. and D.P. Wisegarver. 2008. The shipboard analysis of trace levels of sulfur hexafluoride, chlorofluorocarbon-11 and chlorofluorocarbon-12 in seawater. Deep-Sea Res. I, v. 55, pp. 1063-1074.

HELIUM AND TRITIUM

PI: William Jenkins

Sampler: Zoe Sandwith

Helium and tritium samples were collected roughly every 4.5 degrees on CLIVAR leg P02E. A total of 13 stations were sampled. 219 samples and 5 duplicates were taken on this leg.

HELIUM SAMPLING

16 helium samples were drawn at 11 of the stations and 24 niskins were sampled at 2 stations. Although all 36 niskins were not sampled, depths were chosen to obtain an accurate cross-section of the upper 2000m of the water column. On the two stations where 24 niskins were sampled, the entire water column profile was sampled. Duplicate helium and tritium samples were taken off of one niskin every third station. Helium samples were taken in custom-made stainless steel cylinders and sealed with rotating plug valves at both ends. The sample cylinders were leak-checked and backfilled with N2 prior to the cruise, and used on the western portion of the line. Samples were drawn using tygon tubing connected to the niskin bottle at one end and the cylinder at the other. Cylinders are thumped with a bat while being flushed with water from the niskin to remove bubbles from the sample. After flushing roughly 1 liter of water through them, the plug valves are closed. Due to the nature of the o-ring seals on the sample vessels, they must be extracted within 24 hours. Eight samples at a time were extracted using our At Sea Extraction line in the Helium Van on the main deck. In preparation for extraction, the stainless steel sample cylinders are attached to the vacuum manifold and pumped down to less than 2e-7 Torr using a diffusion pump for a minimum of 1 hour to check for leaks. The sections are then isolated from the vacuum manifold and introduced to the reservoir cans which are heated to >80C for roughly 10 minutes. Glass bulbs are attached to the sections and immersed in ice water during the extraction process. After 10 minutes each bulb is flame sealed and packed for shipment back to WHOI. The extraction cans and sections are cleaned with distilled water and isopropanol, then dried between each extraction. Prior to the cruise, all vacuum components were cleaned, serviced and checked for leaks. The glass bulbs are baked to 640C for 6 hours and cooled slowly in an oven receiving a steady flow of nitrogen. 224 helium samples were taken on Leg 2, which includes 5 duplicates. Helium samples will be analyzed using a mass spectrometer at WHOI.

Vibrations due to waves crashing into the fantail still caused difficulty on leg 2. Only once was the shaking bad enough to cause any glass sample bulbs to crack on the extraction line.

TRITIUM SAMPLING

Tritium samples were drawn from the same stations and bottles as those sampled for helium. Since there was not a water shortage on this cruise, a duplicate was taken from the same niskin as the helium duplicate. Tritium samples were taken using tygon tubing to fill 1 liter glass jugs. The jugs were baked in an oven, backfilled with argon, and the caps were taped shut prior to the cruise. While filling, the jugs are place on the deck and filled to about 2 inches from the top of the bottle, being careful not to spill the argon. Caps were replaced and taped shut with electrical tape before being packed for shipment back to WHOI. 224 tritium samples were taken, which includes 5 duplicates. Tritium samples will be degassed in the lab at WHOI and stored for a minimum of 6 months before mass spectrometer analysis. No issues were encountered while taking tritium samples.

DISSOLVED INORGANIC CARBON (DIC)

The DIC analytical equipment (DICE) design was based upon the original SOMMA systems (Johnson, 1985, ’87, ’92, ‘93). This new design has improved on the original SOMMA by use of more modern National Instruments electronics and other available technology. These 2 DICE systems (PMEL-1 and PMEL-2) were set up in a seagoing container modified for use as a shipboard laboratory on the aft working deck of the *R/V Melville.* In the coulometric analysis of DIC, all carbonate species are converted to CO_2 (gas) by addition of excess hydrogen to the seawater sample. The evolved CO_2 gas is carried into the titration cell of the coulometer, where it reacts quantitatively with a proprietary reagent based on ethanolamine to generate hydrogen ions. These are subsequently titrated with coulometrically generated OH-. CO_2 is thus measured by integrating the total charge required to achieve this. (Dickson, et al 2007).

Each coulometer was calibrated by injecting aliquots of pure CO_2 (99.999%) by means of an 8-port valve outfitted with two calibrated sample loops of different sizes (~1ml and ~2ml) (Wilke et al., 1993). The instruments are each separately calibrated at the beginning of each ctd station with a minimum of two sets of these gas loop injections.

Secondary standards were run throughout the cruise (at least one per station) on each analytical system. These standards are Certified Reference Materials (CRMs), consisting of poisoned, filtered, and UV irradiated seawater supplied by Dr. A. Dickson of Scripps Institution of Oceanography (SIO). Their accuracy is determined manometrically on land in San Diego. DIC data reported to the database have been corrected to the batch 124 CRM value. The CRM certified value for this batch is 2015.72 µmol/kg. The average measured values (in µmol/kg during this cruise) were 2014.9 for PMEL-1 and 2015.5 for PMEL-2.

The DIC water samples were drawn from Niskin-type bottles into cleaned, pre-combusted 300mL borosilicate glass bottles using silicon tubing. Bottles were rinsed twice and filled from the bottom, overflowing by at least one-half volume. Care was taken not to entrain any bubbles. The tube was pinched off and withdrawn, creating a 5mL headspace, and 0.12mL of 50% saturated $HgCl_2$ solution was added as a preservative. The sample bottles were sealed with glass stoppers lightly covered with Apiezon-L grease, and were stored in a 20°C water bath for a minimum of 20 minutes to bring them to temperature prior to analysis.

Over 1500 samples were analyzed for discrete DIC. About 10% of these samples were taken as replicates as a check of our precision. These replicate samples were typically taken near the surface, DIC maximum, and bottom bottles. The replicate samples were interspersed throughout the station analysis for quality assurance and integrity of the coulometer cell solutions. Preliminary analysis of these replicates indicates that there was a slight drift during the course of some of the cells. Closing gas calibrations confirmed this drift and further shoreside analysis will determine the extent of this drift. However, before any correction for this drift, the absolute average difference from the mean of these replicates is 0.7 µmol/kg.

The DIC data reported at sea is to be considered preliminary until a further shoreside analysis is undertaken.

References:

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Lewis, E. and D. W. R. Wallace (1998) Program developed for CO2 system calculations. Oak Ridge, Oak Ridge National Laboratory. http://cdiac.ornl.gov/oceans/co2rprt.html

Wilke, R.J., D.W.R. Wallace, and K.M. Johnson (1993): "Water-based gravimetric method for the determination of gas loop volume." Anal. Chem. 65, 2403-2406.

Discrete pH Analyses

PI: Dr. Andrew Dickson
Ship technicians: Kristin Jackson and John Ballard

Sampling

Samples were collected in 250 mL borosilicate glass bottles and sealed using grey butyl rubber stoppers held in place by aluminum crimp caps. Each bottle was rinsed a minimum of 2 times, then filled and allowed to overflow by approximately one full volume. A 1% headspace was then removed from the bottles using an Eppendorf pipette and poisoned with 60 μL of mercuric chloride ($HgCl_2$) prior to sealing with the aluminum caps. Samples were collected from the same Niskin bottles as total alkalinity or dissolved inorganic carbon in order to completely characterize the carbon system, and 2 duplicate bottles were also taken on random Niskins for each station throughout the course of the cruise. All data should be considered preliminary.

Analysis

pH (μmol/kg H_2O) on the total scale was measured using an Agilent 8453 spectrophotometer according to the methods outlined by Clayton and Byrne (1993). A Thermo NESLAB RTE-7 recirculating water bath was used to maintain spectrophotometric cell temperature at 25.0°C during the analyses. A custom 10cm flow through jacketed cell was filled autonomously with samples using a Kloehn V6 syringe pump. The sulfonephthalein indicator m-cresol purple (mCP) was used to measure the absorbance of light measured at two different wavelengths (434 nm, 578 nm) corresponding to the maximum absorbance peaks for the acidic and basic forms of the indicator dye. A baseline absorbance was also measured and subtracted from these wavelengths. The baseline absorbance was determined by averaging the absorbances from 730-735nm. The samples were run using the tungsten lamp only. The blank and absorbance spectrum were measured 6 times in rapid succession and then averaged. The ratios of absorbances at the different wavelengths were input and used to calculate pH on the total scales, incorporating temperature and salinity into the equations. The salinity data used was obtained from the conductivity sensor on the CTD. The salinity data was later corroborated by shipboard measurements. Temperature of the samples was measured immediately after spectrophotometric measurements using a Direct Temp USB immersible probe.

Reagents

The mCP indicator dye was made to a concentration of 2.0 mM in 100 mL batches as needed. A total of 2 batches were used during the cruise. The pHs of the batches were adjusted to approximately 7.7 using dilute solutions of HCl and NaOH and a pH meter calibrated using NBS buffers. The indicator was provided by Dr. Michael Degrandpre at the University of Montana, and was purified using the HPLC technique described by Liu et al., 2011.

Standardization/Results

The precision of the data can be accessed from measurements of duplicate analyses, certified reference material (CRM) Batch 124 (provided by Dr. Andrew Dickson, UCSD), and TRIS buffer Batch 11 (provided by Dr. Andrew Dickson, UCSD). CRMs were measured at least once every 12 hours, and bottles of TRIS buffer were measured once a week. The precision obtained from 172 duplicate analyses was found to be ±0.0004.

Data Processing
The addition of an indicator dye perturbs the pH of the sample, and the degree to which pH is affected is a function of the differences between the pH of the seawater and the pH of the indicator. Therefore, a correction is applied to all samples measured for a given batch of dye. To determine this correction samples of varying pH and water composition were randomly run with a single injection of dye and then again with a double injection of dye on a single bottle. To determine this correction the change in the measured absorbance ratio R where R = (A578-Abase)/ (A434-Abase) is divided by the change in the isosbestic absorbance (Aiso at 488nm) observed from two injections of dye to one. (R''-R') / (Aiso''-Aiso') is plotted against the measured R value for the single injection of dye and fitted with a linear regression. From this fit the slope and y-intercept (b and a respectively) are determined by:

$$\Delta R/\Delta Aiso = bR' + a \qquad (1)$$

From this the corrected ratio (R) corresponding to the measured absorbance ratio if no indicator dye were present can be determined by:

$$R=R' - Aiso' (bR' + a) \quad (2)$$

Preliminary data has not been corrected for the perturbation.

Problems
Very few problems occurred during the course of the cruise. The biggest problem that did occur was tiny bubbles forming inside the cell due to cold samples de-gassing as they were heated up rapidly. To combat this, the cell was instead flushed with air and then filled with DI water or occasionally 2-propanol and allowed to soak in-between stations. This proved the most effective method. Prior to running a given station, 3-4 junk surface seawater pH measurements were made to ensure that the system was functioning as expected. Stations were additionally analyzed starting with the surface samples and finishing with the deep cold bottom samples to reduce the build-up of bubbles.

References
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Liu, X., Patsvas, M.C., Byrne R.H., “Purification and Characterization of meta Cresol Purple for Spectrophotometric Seawater pH Measurements,” Environmental Science and Technology, 2011.

P02 leg 2 Alkalinity

(Laura Fantozzi and David Cervantes, laboratory of Andrew G. Dickson, Marine Physical Laboratory, Scripps Institution of Oceanography)

Samples were taken at every station, depending on cast depth the number of niskins sampled varied. Bottles were chosen to match DIC's sample choices. One or two extra samples were taken on certain stations to make sure the alkalinity minimum was captured. Samples were collected in 250 ml Pyrex bottles. A headspace of approximately 5 milliliters was removed and 0.06 milliliters of saturated mercuric chloride solution was added to each sample. The samples were capped with a glass stopper with a Teflon sleeve. All samples were equilibrated to 20 degrees Celsius using a Thermo Scientific RTE7 water bath.

Samples were dispensed using a volumetric pipette and a system of relay valves and air pumps controlled by a laptop using LabVIEW 2011. The temperature of the samples at time of dispensing was taken automatically by a computer using a DirecTemp surface probe placed on the pipette to convert this volume to mass for analysis. During instrument set up it was discovered that the sample dispensing unit (SDU) was dispensing less than the calibrated volume. This was determined by running titrations using the calibrated manual pipette to dispense reference seawater of known alkalinity and getting correct alkalinity values while the SDU was giving incorrect alkalinity values with the same reference seawater of the same alkalinity. An adjustment ratio of 1.00087 was applied to the original calibrated volume of 92.258 ml. Therefore, the volume dispensed for stations 1-12 was 92.178 ml. Between station 12 and 13 one of the valves on the SDU failed and the manual pipette was used again to calculate an adjustment ratio for the volume dispensed. The ratio of 0.99983 was applied to the previous calculated volume. The new calibrated volume dispensed for stations 13-159 would then be 92.193 ml.

Samples were analyzed using an open beaker titration procedure using two thermostated 250ml beakers; one sample being titrated while the second was being prepared and equilibrating to the system temperature close to 20ºC. After an initial aliquot of approximately 2.3-2.4 ml of standardized hydrochloric acid (~0.1M HCl in ~0.6M NaCl solution), the sample was stirred for 5 minutes to remove liberated carbon dioxide gas. The stir time was minimized by bubbling air into the sample at a rate of 200 scc/m. After equilibration, 19 aliquots of 0.04 ml were added. The data within the pH range of 3.5 to 3.0 were processed using a non-linear least squares fit from which the alkalinity value of the sample was calculated (Dickson, et.al., 2007). This procedure was performed automatically by a computer running LabVIEW 2011.

Two duplicates were taken and analyzed for each station. Throughout the cruise, a total of 138 duplicates were analyzed and gave a pooled standard deviation of 0.91 $\mu mol\ kg^{-1}$.

Dickson laboratory Certified Reference Materials (CRM) Batch 124 was used to determine the accuracy of the analysis. The certified value for Batch 124 is 2215.08 ± 0.49 $\mu mol\ kg^{-1}$. The reference material was analyzed 130 times throughout the stations.

The data should be considered preliminary since the correction for the difference between the CRMs stated and measured values has yet to be finalized and applied. Additionally, the correction for the mercuric chloride addition has yet to be applied.

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Dickson, Andrew G., Chris Sabine and James R. Christian, editors, "Guide to Best Practices for Ocean CO2 Measurements", Pices Special Publication 3, IOCCP Report No. 8, October 2007, SOP 3b, "Determination of total alkalinity in sea water using an open-cell titration"

13C /14C (Radiocarbon)

PIs: Ann McNichol, Al Gagnon WHOI

Technician: Leg 2 – J. Blake Clark, MSI, UC Santa Barbara

The goal of this sampling is to adequately measure the distribution of radiocarbon in order to estimate the penetration of bomb-produced 14C and quantify the 13C decrease due to the influx of anthropogenic CO_2. Samples were collected at 17 stations determined by a desired longitude with ten stations having a full profile (32 samples) and shallow profiles (16 samples in the upper 1500-2000m of the water column) at the remaining 7 stations. 432 sample bottles were collected at the 17 stations. Samples were collected in 500ml Pyrex style glass bottles through silicone tubing. The bottles were rinsed 2x with seawater, allowed to fill and overflow with half of the total volume of the bottle. A small volume was poured out for headspace, and 120 μl of saturated mercuric chloride solution was added. The stoppers and necks of the bottles were carefully dried, greased (with M-Apiezon grease), sealed, and secured with a rubber band.

All samples will be shipped to WHOI from San Diego to be analyzed in the AMS lab.

Dissolved Organic Carbon and Total Dissolved Nitrogen

PI: Craig Carlson, MSI, UC Santa Barbara

Technician: Leg 2 – J Blake Clark, MSI, UC Santa Barbara

The goal of this group is to obtain Dissolved Organic Carbon (DOC) and Total Dissolved Nitrogen (TDN) values along the P02 line in order to better understand the carbon cycle in the ocean on spatial and temporal scales. DOC/TDN samples were collected at all odd-numbered stations, beginning on station number 89. 30 Niskin bottles were sampled at most stations, with a full profile of bottles being sampled at various stations through out the cruise. The stations with a full profile of samples being collected were determined by anomalous depth-profile features observed on the CTD down-cast or odd bathymetric features determined pre-cast. Upon approach and arrival to the North-American continental shelf as the number of bottles being fired were reduced on each cast, DOC/TDN samples collected were also reduced accordingly. All samples were collected in 60 ml high-density polyethylene (HDPE) bottles. Bottles were previously cleaned with 10% HCl solution and rinsed 3 times with Mili-Q water. Seawater is introduced to the samples through pre-cleaned silicon tubing, the bottles are rinsed three times and the samples are immediately frozen after collection in a −20 C freezer. Samples in the top 500m of the water column were filtered using a 400 nm glass fiber filter (GF/F) through an inline cartridge fitted with silicon tubing. Cartridges were previously cleaned with 10% HCl solution and rinse with Mili-Q water. Filtering of the samples is conducted to exclude particulate organic matter from the samples due to it's relatively high prevalence in the surface waters.

All frozen samples will be shipped back to UC Santa Barbara for analysis. TDN

137Cs

PI: Ken Buesseler, Alison Macdonald, Woods Hole Oceanographic Institution

Cs profile samples consisted of three to four 20L cubitainers. Five profile samples were collected during leg 2 approximately every 10 degrees of longitude. Depths were roughly surface-100m, 100-200m, 250-350m, 400-600m, and filled from three or four Niskin bottles at that depth. Each of the cubitainers was filled by the mixed volume from multiple Niskin bottles at close depth. After finishing one Niskin bottle, sample level was marked on the side of the cubitainer using waterproof marker.

All the samples were secured in deck boxes with cardboard sheets between layers for stability.

References:

Buesseler, K. O., S. R. Jayne, N. S. Fisher, I. I. Rypina, H. Baumann, Z. Baumann, C. F. Breier, E. M. Douglass, J. George, A. M. Macdonald, H. Miyamoto, J. Nishikawa, S. M. Pike, and S. Yoshida (2012) Fukushima-derived radionuclides in the ocean and biota off Japan*. Proc. Nat. Acad. Sci.*, **109**, 5984–5988, doi:10.1073/pnas.1120794109.

Casacuberta, N., P. Masqué, J. Garcia-Orellana, R. García-Tenorio, and K. O. Buesseler (2013) ^{90}Sr and ^{89}Sr in seawater off Japan as a consequence of the Fukushima Dai-ichi nuclear accident. *Biogeosciences Discuss.,* **10**, 2039–2067.

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^{137}Cs Cubitainer Contents (Niskins Sampled)

Station/Cast	Cubitainer ID	Niskins Sampled
94/1	#73	23-25
94/1	#74	26-28
94/1	#75	29-31
94/1	#76	32-34, 36
102/1	#77	23-25
102/1	#78	26-28
102/1	#79	29-31
102/1	#80	32-34, 36
116/1	#81	22-24
116/1	#82	25-27
116/1	#83	29-31
116/1	#84	32-34, 36
128/2	#85	23-25
128/2	#86	26, 27, 29
128/2	#87	30-32
128/2	#88	33, 34, 36
146/1	#89	23-26
146/1	#90	27, 29-31
146/1	#91	32-34, 36

129 Iodine sampling

PI: Tom Guilderson, UC Santa Cruz & Lawrence Livermore National Laboratory

The goal of 129I sampling is to track Fukushima derived 129I release and to describe general large-scale 129I gradient originated from the atmospheric nuclear weapons testing.

129I surface water samples were drawn from surface Niskins. In total, 7 stations were sampled during leg 2 (stations 94, 98, 109, 116, 126, 128, 147). Surface samples were collected in 500ml amber bottles. Most surface samples were taken from the same Niskins as for Cs samples (PI: Ken Buesseler, WHOI) since 129I/134Cs and 129I/137Cs ratio can be used to positively identify the presence of Fukushima origin radionuclide. Surface samples not taken from the same Niskins as Cs samples were duplicated. Bottles were rinsed 2-3 times with sample before filling. Electrical tape was used to seal caps and all the samples were refrigerated.

Two hydrocast profiles were obtained at 152°W station 102 (68 samples) and 126°W station 138 (66 samples). Samples were collected in 250ml HDPE bottles and taken from all Niskin bottles. Duplicates were also taken form all Niskins.

References:

Tumey, S. J., T. P. Guilderson, T. A. Brown, T. Broek, and K. O. Buesseler (2012) Input of I-129 into the western Pacific Ocean resulting from the Fukushima nuclear event. *J. Radioanal. Nucl. Chem.*, doi:10.1007/s10967-012-2217-9.

$\delta^{15}N-NO_3$ / $\delta^{18}O-NO_3$ Sampling

394 $\delta^{15}N-NO_3$ / $\delta^{18}O-NO_3$ samples were collected during P02E (Leg 2). Full profiles were sampled at 12 stations. Since no rack was sent with the sampling containers, a plastic bucket and packing styrofoam were modified to secure the 25 ampoules during rosette sampling. 14 mL ampoules or 60 mL bottles were minimally rinsed twice, the filled to approximately 85% of capacity with seawater. The samples were stored frozen in a standard commercial freezer on board. Samples will be shipped frozen after the ship arrives in San Diego, then analyzed at Princeton University (PI Dr. Daniel Sigman – sigman@princeton.edu).

Density Sampling

73 density samples were taken at Stations 104, 138, 154, and 158 from the same depths as Alkalinity. Sample bottels and caps were rinsed 3 time with approximately 10 mL of water, then filled to the beginning of the neck to leave head space of 1-2 mL. Samples will be analyzed by Ryan Woosley (PI Dr. Frank Millero – fmillero@rsmas.miami.edu) at the University of Miami at the end of the second leg of P02.

Calcium Sampling

Calcium samples were taken at Stations 095, 107, 120, 132, 148, 151, 153, 157, 158, and 159 from an average of 15 depths with 2 duplicates at each station. Sample bottles and caps were rinsed 3 times with approximately 10 mL of water, and then filled to the beginning of the neck to leave a headspace of 1-2 mL. Samples will be analyzed by John Ballard (PI Dr. Todd Martz – trmartz@ucsd.edu) at Scripps Institution of Oceanography at the end of the second leg of P02.

Argo Float Deployment

Three autonomous profiling CTD floats, provided by Dr. Gregory C. Johnson of NOAA/PMEL, were deployed as the ship departed their designated station locations. The floats began executing their programmed missions after self-activation by pressure. Communication with two of the floats was established shortly after launch. The third float (F0183) was eventually able to communicate in early July after a log-in problem was fixed on the receiving end. All three floats were operating normally, returning data at the time of this writing.

UTC Date:Time	Float ID	Station	GPS Position at Launch
20130515:1858	F0185	98	30°0.00'N 156°0.75'W
20130516:1420	F0183	100	30°0.00'N 153°43.835'W
20130525:1239	F0184	129	30°0.00'N 132°35.22'W

This floats are Navis floats manufactured by SBE, equipped with SBE-41CP CTDs. They are part of the U.S. Argo Program (www.argo.ucsd.edu), a global network of over 3500 profiling floats. Data from all Argo floats are publicly available in near real-time via the two global servers at www.usgodae.org and www.coriolis.eu.org.

The floats are designed to dive to a depth of about 1000 m. They then drift with the currents at depth for about 10 days before sinking to 2000 m. Upon reaching 2000 m, they then ascend to the surface, collecting CTD data as they ascend. At the surface, before the next dive begins, the position of the float is determined, and acquired data are transmitted via satellite. The life time of the floats in the water is 4-5 years.

Angelica Gilroy
University of California

Participating in the CLIVAR/CO2 P02E cruise was an experience unlike any I have had thus far. As this was my first time going to sea, almost everything was new to me. Through preparing the rosette, sampling, and watching others play their roles on the ship, I realized how much work goes into collecting good data for public use. I recognized the importance of fostering good communication and relationships between the crew and the science party. Being in an environment where my curiosity was well-received was particularly enjoyable. Conversations in the lab and at meal-times were invaluable. My knowledge of the Pacific Ocean grew immensely, but perhaps more importantly, I will take words of wisdom about oceanography with me as I embark upon my first year of graduate work this fall.

Georgy Manucharyan
Yale University

As many things in our world, participating in this cruise was quite a random decision for me as my research has been theoretical so far. And I must say it was a very worthy decision. Perhaps the best part of this cruise for me was the interaction with all the people on board from which I learned a lot. It started with making knots, progressing to the detailed overview of all the sensors on the Rosette and to analysis techniques involving a plethora of technical 'tricks' to squeeze out the important information from a sample of water taken from the deep ocean. I've learned to appreciate the notorious labor that needs to be performed in order collect and analyze the water samples, as opposed to just downloading the data with a mouse click without having much thought about how exactly these things are measured. I have enjoyed being a part of a multidisciplinary science team which widened my perspective on the important characteristics of the ocean, for example, the carbon cycle its associate chemistry processes, and the biological activity. At last, I enjoyed the scientific and philosophical overnight discussions with my teammates, making this cruise a unique experience that I'd recommend to any science student.

Andrew Shao
University of Washington

A large part of my motivation for participating in this cruise was to learn how the tracer data that I've been using in my research were actually produced. Needless to say, this CLIVAR repeat of P02E has been an extraordinary opportunity to achieve that goal. As the CFC student on board, I was introduced to the intricacies of how the data are collected, processed, corrected, and published. Moreover, I gained something else that I had not anticipated: perspective. Before when I looked at the bottle data from a hydrographic section, I saw the concentration values as useful but impersonal numbers. Now having been a member of this cruise, I now understand that each and every data point has a distinct human component and is the product of many people's extraordinary labors. The crew and science party take the time away from friends and family, shirk the comforts of land, and set out on into the isolation of the open ocean all to serve the needs of the oceanographic community and advance the science. I cannot help but have profound respect and appreciation for the men and women I have sailed with on this cruise and will remember them and their colleagues whose continuing hard work enables my own research.

Yongming Sun
Lamont-Doherty Earth Observatory

First of all, I want to say it is a great honor for me to take part in this cruise. The cruise is a part of a very good repeat hydrography program, with a cooperative team and advanced ocean observation technology. While on the ship, the science team has been like a family. I have received much help, especially on my language. I must thank everyone on the cruise. I accepted the rigorous training as a CTD student, which has given me further understanding of ocean field observations. Previously, I participated in another oceanographic cruise on a Chinese vessel. This experience has allowed me to compare Chinese practices with those learned on this ship. I will be very glad to introduce the standard instruction and advanced technology to Chinese oceanographers when I go back to China. Working with the capable and professional staff in many oceanographic and atmospheric specialties has improved my knowledge of oceanography, giving me a better perspective of the real ocean. I believe this will benefit my future research. Working with great partners made the job easier, and we completed our tasks as a team. Additionally, the food on ship is delicious. It gives us energy and puts us in a good mood in the lab. I've gained knowledge, experience and friendship. What can I say except, this has been an amazing cruise?

Yeping Yuan
University of Washington

As a coastal/estuarine oceanography major student, I have been on several research trips before, but none of them had such a long duration of time – three weeks in the sea with limited connection to the land - and a wide range of measurements – including many of the hydrographic instruments/sensors and chemical analyses. The cruise began with many uncertainties to me, including the delay due to mechanical problems in the previous leg, the seasickness that I might face to, the CTD rosette that I have only seen in the oceanography book, and so on. It is the great efforts from the chief and co-chief scientist, all the science party, technicians and crews in the R/V Melville that make the journey an incredible experience in my life, both in the scientific aspect and personal level. My main task in this cruise is as a CTD watch stander, which includes the rosette preparation, deck operation (rosette deployment and recovery), CTD console operation, water samples coordination and collections during each cast and also helping technicians on CTD/rosette repair as needed. This hands-on experience makes me understand how to get the accurate and precise oceanographic data and how to solve unpredicted in-situ problems. I also gained knowledge beyond the physical oceanography area: the impact of oceanic variability on the climate change, global warming and carbon cycles. From the discussion with chemistry technicians and scientists and watching how they collect and analyze water samples, the deep ocean water is now more vivid to me: we could understand the water mass distributions from their compositions and even know the 'age' of the water from CFCs and/or isotope measurement. In the science part, I worked with my fellow CTD watch stander and scientists on processing some of the data from the CTD/ADCP/MET and look forward to seeing the comparison between our preliminary results and the previous CLIVAR data and possible interpretation on the climate variability in the future.

Cruise Report: Shipboard ADCP measurements CLIVAR/Carbon PO2E 2013

Steven Howell

Personnel

UH LADCP group: Eric Firing (PI), Julia Hummon, and François Ascani

Shipboard operators Frank Delahoyde, SIO and Steven Howell, UH

System description

The *R/V Melville* normally has two Acoustic Doppler Current Profilers (ADCPs) mounted in instrument wells in the hull. One, a 150 kHz Teledyne RD Instruments Ocean Surveyor, was at the manufacturer for repair so was unavailable for the cruise. The other, a 75 kHz Ocean Surveyor (OS75) was present and produced data through the entire cruise.

An additional ADCP, a 300 kHz Work Horse (WH300, also from Teledyne RD), was installed temporarily while the ship was in Yokohama before P02W. it was mounted in the open instrument well on a pipe string at about 2.5 feet below the hull. Approximate locations of the ADCPs are shown in Figure 1. The WH300 installation is shown in Figure 2.

Because ship speeds are much faster than typical ocean currents, precise knowledge of the speed and orientation of the ship is required to calculate currents from the raw data. To this end, the ADCP data acquisition system gathered data from 4 additional devices: a Furuno GP-150 GPS for position, a Sperry MK 37 gyro for reliable but coarse heading, and two GPS-assisted attitude sensors for high-precision heading, an Ashtech ADU and a CodaOctopus F185 motion reference unit. The Ashtech heading was inoperative for the entire cruise, so we had to rely on the CodaOctopus, which performed well most of the time.

Data acquisition from the ADCPs and the other devices was done using UHDAS (University of Hawaii Data Acquisition System), an open source software system developed by the ADCP group at UH. It automatically updates a website on the ship's network that presents near real time plots of current depth profiles, contoured sections for the previous few days, and provides a variety of data products ranging from raw data to near-final currents. For extensive documentation about UHDAS, visit the UH ADCP web page, `http://currents.soest.hawaii.edu`.

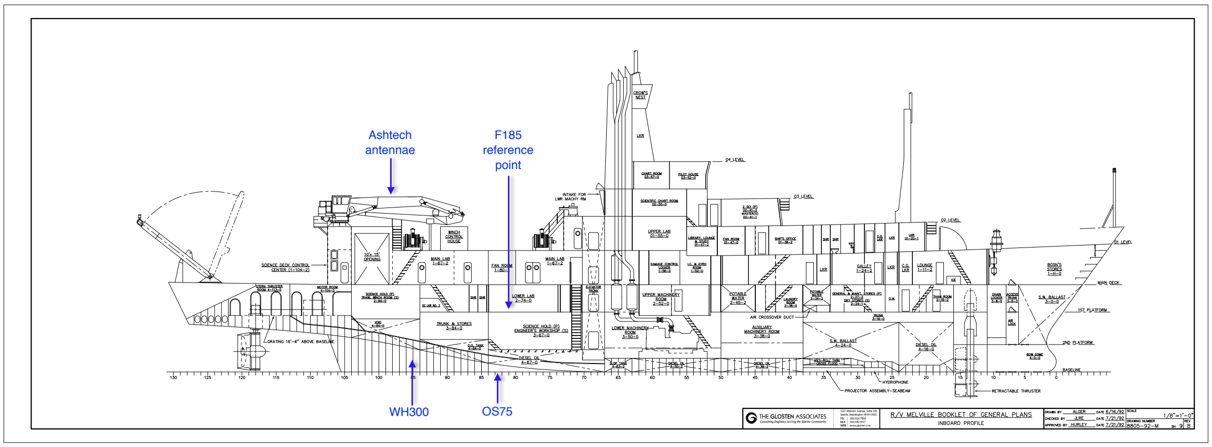


Figure 1: Locations of shipboard ADCPs on the *Melville* during P02W and P02E. Also shown are the two GPS-referenced heading device reference locations. The GP-150 GPS antenna is located in the mast above the stacks.

Figure 2: The WH300 mounted on the pipe string. The picture was taken on the port side looking forward from near the position of the stern thruster. Photo by Drew Cole, who used a pole-mounted GoPro Hero 300 videocamera.

While the output of UHDAS is suitable for shipboard use, it is by no means a final product as some manual intervention is inevitably necessary to deal with issues that arise. The data produced during the cruise must be regarded as preliminary; fully processed data will be made available within 6 months at the UH website.

Operating parameters

Both the OS75 and WH300 were operated in their default UHDAS configurations through the entire cruise except for the first few hours out of Honolulu when both instruments were run with bottom track mode turned on.

The OS75 (CPU firmware 23.16, beam angle 30°) can operate in two modes. Narrow band pings provide greater range, while broadband pings have much better accuracy. The OS75 was operated in interleaved mode, which alternates broadband and narrowband pings. Bottom track mode was used for the first few hours while leaving Honolulu. Narrowband mode used nominal 16 m pings and depth ranges below an 8 m blanking interval, while the broadband mode used 8 m cells and blanking intervals. Pings were 1.8 s apart.

The WH300 (serial number 9806, firmware version 16.28, beam angle 20°) used 2 m cells and blanking intervals with 0.8 s between pings.

The following control files do not contain the entire set of commands sent to the instrument, but these are the ones most frequently changed.

OS75 control file

```
# Bottom tracking
BP0         # BP0 is off, BP1 is on
BX10000     # Max search range in decimeters; e.g. BX10000 for 1000 m.

# Narrowband watertrack
NP1         # NP0 is off, NP1 is on
NN60        # number of cells
NS1600      # cell size in centimeters; e.g. NS2400 for 24-m cells
NF800       # blanking in centimeters; e.g. NF1600 for 16-m cells

# Broadband watertrack
WP1         # WP0 is off, WP1 is on
WN80        # number of cells
WS800       # cell size in centimeters
WF800       # blanking in centimeters

# Interval between pings
TP00:01.80  # e.g., TP00:03.00 for 3 seconds

# Triggering
CX0,0       # in,out[,timeout]
```

WH300 control file

```
BP0           #  Bottom track on (BP1) or off (BP0)
BX2000        #  BT max search range in decimeters (BX02000 for 200 m)
WN70          #  number of cells
WS200         #  cell size in centimeters
WF200         #  blanking in centimeters
TP00:00.80    #  ping interval; TP00:00.80 is 0.8 seconds
```

Data gathered

Both instruments ran continuously and produced data throughout the cruise. On station, all of the instruments generally worked very well. The WH300 profiled to 80 m or so while the OS75 broadband and narrowband modes generally reached 650 and 850 m, respectively.

Problems encountered

Steaming increases acoustic noise and vibration, reducing ADCP range. The WH300 was particularly affected, becoming nearly useless during transits between stations. It is not clear why it had such problems, but a review of a couple of earlier *Melville* cruises with nearly identical WH300 installations revealed similar problems. Bubbles can wreak havoc by scattering the beams, but the WH position well aft and 2.5 feet below the hull makes that seem unlikely. I looked down the instrument well several times, but there appeared to be few, if any, bubbles coming up. The most likely explanation is vibration, but we have no direct evidence of that. It may be that fairing the pipe or the instrument itself could help.

Poor data quality combined with only a preliminary calibration of installation angle meant that what little current data could be retrieved was obviously flawed, with large along-track biases. It may be possible to clean up some of the transit data during postprocessing, but the WH300 data should probably only be used on station.

The OS75 suffered much less during transit. Narrowband mode still exceeded 600 m while broadband sometimes had trouble below 200 m but usually managed 500 m. I understand from the First Mate, David Cook, that the *Melville* is typically ballasted so the bow rides a bit low, reducing bubble noise during transit. We appreciate this attention to our needs, and it evidently works.

While the weather was fine for most of P02E, there were a couple of episodes with high winds and significant seas. Unlike P02W, the OS75 was never overwhelmed by bubbles, though its range was occasionally reduced to about 500 m in narrow band mode.

We were surprised to note occasional problems with the OS75 on station during very calm weather. There would be short periods, usually a minute or less, where the signal strength would drop to near zero. Unlike P02W, I never observed this to last more than a minute or so. At the moment, our best guess is that bubbles filled the instrument well, disrupting the instrument's contact with the water. The OS75 well is blind–there is no way for bubbles to exit out the top. The OS150 installation on the *Melville* suffered badly from this in previous years, so a similar situation for the OS75 is plausible. If this is really the problem, it requires venting the top of the well. The weak beam problem resolved as soon as the ship started moving. Since these gaps in the data were always short, they will have little effect on the final dataset.

As noted above, with the Ashtech ADU heading mode unusable, UHDAS relied exclusively on the CodaOctopus F185 for precision heading. The Ashtech had been the default. At the beginning of P02E, the UHDAS configuration was changed to use the F185 as the primary precision heading device. The precise alignment between the F185 and the OS75 was unknown, so a proper heading correction could not be applied. The alignment difference appears to be about 0.3°, which introduced errors that will not be corrected until final processing.

When the ship is turning, there is a velocity difference between the ADCP and the GPS unless the GPS is co-located with the ADCP. CODAS processing can correct for this velocity difference. The reference point of the CodaOctopus 185 is in the lower lab, within 4 m or so of the ADCP location. This is much closer that the Ashtech antenna locations (Figure 1), so a minor correction will be needed in the final processing.

On May 26, Mary Johnson noticed problems with the EM122 multibeam that were traced to the F185, which had lost its bearings. Frank Delahoyde cycled the power, and it re-established heading and attitude. The data were bad from roughly 0640 to 0855 UTC. The Sperry gyro feed did continue, so current data from that period will be produced during post-processing, although with greater errors than usual.

2013 P02E Underway pCO_2 report

Andrew E. Shao

The NOAA underway pCO_2 measurement system is designed to autonomously take continuous measurements of CO_2 both in the air and the ocean surface while the ship is underway. The system has been designed for deployment on non-scientific vessels and as such is meant to be self-contained and interfere only minimally with normal ship operations. Onboard the R/V Melville, deck air is sampled via a diaphragm pump with the intake mounted on the science mast on the bow of the ship and seawater is provided using the ship's unfiltered seawater line. Standards are run regularly to ensure continued accuracy of the measured data.

The actual pCO_2 measurement is performed using a Licor 7000 infrared analyser. IR passes through a reference gas cell flooded with air stripped of CO_2 and a sample gas cell filled either with deck air or air that has equilibrated with a seawater sample. Using a linear fit to the known standards, the difference in transmitted IR between the two cells is used to determine concentrations.

These CO_2 measurements were successfully taken over the course of the leg. Checking the data every 3 days, no significant anomalies in the standard measurements were observed, the measured atmospheric CO_2 values were approximately 400ppm, and the surface pCO_2 was slightly undersaturated with respect to the atmosphere. However, the meteorological, GPS, and oxygen measurements were not collected between 8 May (the departure date) and 22 May. These problems are tentatively ascribed to a loss of power to the system while in port during a test of the ships' emergency generators. However with the assistance of Frank Delahoyde (computer and system technician) and Robert Palomares (resident technician), these problems were resolved when I turned off and cold-started the system.

For further details, contact Geoff Lebon at Geoffrey.T.Lebon@noaa.gov

2013 P02E Underway EIMS report

Andrew E. Shao

The University of Washington Underway Equilibrator Inlet Mass Spectrometry (EIMS) system, measuring dissolved nitrogen, oxygen, argon, and CO_2, was intended to be run over the entirety of this line. However upon startup after leaving Honolulu, both filament 1 and 2 in the gas spectrometer were found to be defective. This failure may potentially be ascribed to a loss of power during a test of the ship's emergency generators resulting in a hard shutdown of the system. On 10 May, the decision was made to shutdown EIMS for the remainder of the cruise. No data were collected on P02E. For further technical information see the P02W cruise report and/or contact Hilary Palevsky at hpalevsky@uw.edu.

CLIVAR P02E 2013 Ship's Underway Measurements

Frank Delahoyde
SIO Shipboard Technical Support

R/V Melville has a collection of permanently installed sensors and data acquisition systems, most of which were used during P02E 2013, MV1306. The collected data consist of GPS navigation, Multibeam echosounder tracks, ADCP sections, meterological and sea surface measurements time series and gravity time series. Detailed description of these systems are included with the MV1306 data distribution.

GPS navigation data were collected from Furuno GP150, Ashtech ADU5 and CodaOctopus F185 GPS devices. The Furuno GP150 and Ashtech ADU5 data were collected at a 1hz data period, and the F185 at 5 hz. The GP150 was the primary navigation device for P02E deployment positions, hydrographic sections and various track maps. The F185 was the primary navigation device for the EM122 multibeam and the shipboard ADCP systems.

The multibeam echosounder acoustic data were collected with a Kongsberg EM122 multibeam echosounder, with the acquisition system running SIS 3.9.2. The EM122 was run continuously and the centerbeams used for all acoustic depth determinations on P02E. The multibeam data were corrected using sound speed profiles that were calculated from CTD deployments. Three of the 24 36-channel transmitter cards in the EM122 had failed iduring the first leg and were relocated to the outer-most beam positions. The card failures resulted in decreased resolution and increased noise levels but did not impact the accuracy of depth determinations. Good weather during much of P02E contributed to better multibeam data quality than on the previous leg.

ADCP data were collected with a hull-mounted RDI OS-75 ADCP and with an RDI WH300 ADCP deployed through the Melville's aft hanger pipe well. The Melville's hull-mounted NB150 ADCP was not operational and was not used. The ADCP data were acquired and processed using UHDAS software from University of Hawaii.

Meteorological and sea surface measurement were made using the shipboard Met system. This system continuously made measurements and generated a 15 second time series. Sea surface temperature measurements were made with two hull-mounted thermistors, (port and starboard). Other measurements, including salinity, dissolved oxygen and fluorometer, were determined by sensors located in the analytical lab. The salinity measurements were made with a SBE45 thermosalinograph (TSG), which measured temperature and conductivity and calculated PSS78 salinity. Seawater supplied to these sensors was pumped from the bow intake to through CA. 30m of pipe inside the ship.

This cruise presented a unique opportunity to examine the flow characteristics of this underway system by comparing Met system bow and analytical lab measurements to CTD surface data. CTD data from each surface bottle trip on each cast were compared to Met system data matched by time. The results of these comparisons are presented in Figure 1. The X axis on this plot is "Normalized P02E Day", where 0 is the time and date of the surface bottle trip on cast 88/1. The last two Y axis are differences between CTD temperature and the port and starboard hull-mounted temperature sensors.

The Met sensors are in good agreement, and the major differences with CTD data occur during periods of bad weather. The first Y axis is the difference between CTD and TSG temperatures. Here, temperature differences are more extreme and distortion due to the interior ship temperature is evident. Finally, the second Y axis is the difference between CTD and TSG salinity.

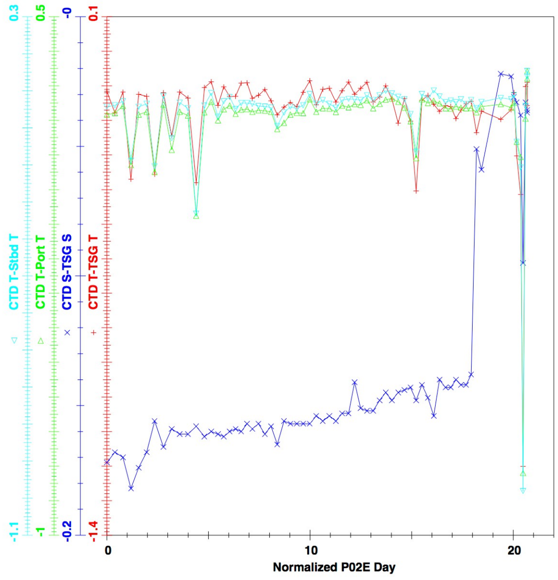


Figure 1. CTD and TSG T and S Comparisons

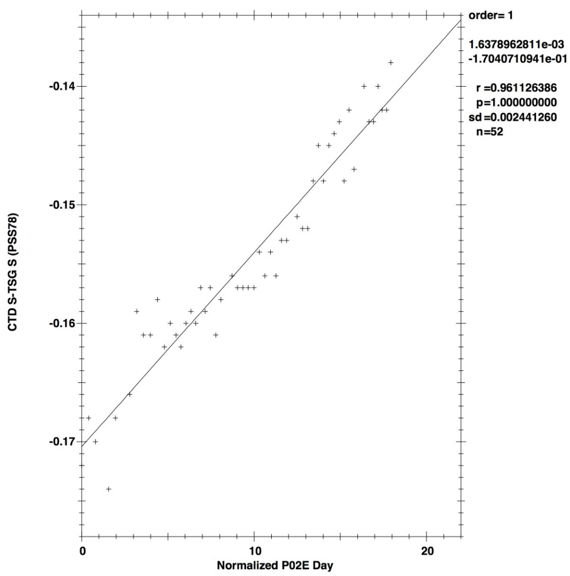


Figure 2. TSG Salinity

The abrupt change in salinity differences on day 18 was later found to be due to biological growth in the Met system pump that had clogged the filter over the intake. Discounting the salinity differences after day 17, the comparison shows a linear time dependence (drift). Figure 2 is a least-squares polynomial fit of the differences.

Earth's gravity field measurements were also collected from the Melville's BellAero BGM-3 gravimeter.

Appendix A

CLIVAR/Carbon P02E: CTD Temperature and Conductivity Corrections Summary

Sta/	ITS-90 Temperature Coefficients $corT = tp2*corP^2 + tp1*corP + t0$			Conductivity Coefficients $corC = cp1*corP + c2*C^2 + c1*C + c0$			
Cast	tp2	tp1	t0	cp1	c2	c1	c0
088/01	-2.6347e-11	1.3997e-08	-0.000902	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025570
089/01	-2.6347e-11	1.3997e-08	-0.000905	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025566
090/01	-2.6347e-11	1.3997e-08	-0.000909	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025562
091/01	-2.6347e-11	1.3997e-08	-0.000912	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025558
092/01	-2.6347e-11	1.3997e-08	-0.000916	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025554
093/01	-2.6347e-11	1.3997e-08	-0.000919	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025551
094/01	-2.6347e-11	1.3997e-08	-0.000923	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025548
095/01	-2.6347e-11	1.3997e-08	-0.000927	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025544
096/02	-2.6347e-11	1.3997e-08	-0.000931	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025541
097/01	-2.6347e-11	1.3997e-08	-0.000935	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025539
098/01	-2.6347e-11	1.3997e-08	-0.000939	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025536
099/01	-2.6347e-11	1.3997e-08	-0.000943	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025534
100/01	-2.6347e-11	1.3997e-08	-0.000947	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025532
101/01	-2.6347e-11	1.3997e-08	-0.000951	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025530
102/01	-2.6347e-11	1.3997e-08	-0.000955	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025529
103/01	-2.6347e-11	1.3997e-08	-0.000958	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025528
104/01	-2.6347e-11	1.3997e-08	-0.000961	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025527
105/01	-2.6347e-11	1.3997e-08	-0.000964	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025526
106/01	-2.6347e-11	1.3997e-08	-0.000968	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025525
107/01	-2.6347e-11	1.3997e-08	-0.000971	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025524
108/01	-2.6347e-11	1.3997e-08	-0.000974	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025524
109/01	-2.6347e-11	1.3997e-08	-0.000978	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025524
110/01	-2.6347e-11	1.3997e-08	-0.000981	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025523
111/01	-2.6347e-11	1.3997e-08	-0.000985	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025523
112/01	-2.6347e-11	1.3997e-08	-0.000989	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025523
113/01	-2.6347e-11	1.3997e-08	-0.000993	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025523
114/01	-2.6347e-11	1.3997e-08	-0.000997	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025523
115/01	-2.6347e-11	1.3997e-08	-0.001001	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025523
116/01	-2.6347e-11	1.3997e-08	-0.001005	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025524
117/01	-2.6347e-11	1.3997e-08	-0.001009	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025524
118/01	-2.6347e-11	1.3997e-08	-0.001013	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025525
119/01	-2.6347e-11	1.3997e-08	-0.001017	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025526
120/01	-2.6347e-11	1.3997e-08	-0.001022	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025527
121/01	-2.6347e-11	1.3997e-08	-0.001026	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025528
122/01	-2.6347e-11	1.3997e-08	-0.001030	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025529
123/01	-2.6347e-11	1.3997e-08	-0.001035	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025530
124/01	-2.6347e-11	1.3997e-08	-0.001039	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025532
125/01	-2.6347e-11	1.3997e-08	-0.001043	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025533
126/01	-2.6347e-11	1.3997e-08	-0.001047	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025535
127/01	-2.6347e-11	1.3997e-08	-0.001052	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025536
128/02	-2.6347e-11	1.3997e-08	-0.001056	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025538
129/01	-2.6347e-11	1.3997e-08	-0.001061	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025540

Sta/ Cast	ITS-90 Temperature Coefficients corT = tp2∗corP^2 + tp1∗corP + t0 tp2	tp1	t0	Conductivity Coefficients corC = cp1∗corP + c2∗C^2 + c1∗C + c0 cp1	c2	c1	c0
130/01	-2.6347e-11	1.3997e-08	-0.001065	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025542
131/01	-2.6347e-11	1.3997e-08	-0.001070	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025545
132/01	-2.6347e-11	1.3997e-08	-0.001074	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025547
133/01	-2.6347e-11	1.3997e-08	-0.001079	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025549
134/01	-2.6347e-11	1.3997e-08	-0.001083	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025552
135/01	-2.6347e-11	1.3997e-08	-0.001088	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025555
136/01	-2.6347e-11	1.3997e-08	-0.001092	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025557
137/01	-2.6347e-11	1.3997e-08	-0.001096	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025560
138/01	-2.6347e-11	1.3997e-08	-0.001101	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025563
139/01	-2.6347e-11	1.3997e-08	-0.001106	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025566
140/01	-2.6347e-11	1.3997e-08	-0.001110	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025569
141/01	-2.6347e-11	1.3997e-08	-0.001114	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025571
142/01	-2.6347e-11	1.3997e-08	-0.001118	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025574
143/01	-2.6347e-11	1.3997e-08	-0.001122	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025577
144/01	-2.6347e-11	1.3997e-08	-0.001126	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025580
145/02	-2.6347e-11	1.3997e-08	-0.001131	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025583
146/01	-2.6347e-11	1.3997e-08	-0.001135	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025587
147/01	-2.6347e-11	1.3997e-08	-0.001139	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025590
148/01	-2.6347e-11	1.3997e-08	-0.001143	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025593
149/01	-2.6347e-11	1.3997e-08	-0.001148	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025597
150/01	-2.6347e-11	1.3997e-08	-0.001152	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025600
151/01	-2.6347e-11	1.3997e-08	-0.001155	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025603
152/01	-2.6347e-11	1.3997e-08	-0.001158	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025606
153/01	-2.6347e-11	1.3997e-08	-0.001161	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025608
154/01	-2.6347e-11	1.3997e-08	-0.001163	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025610
155/01	-2.6347e-11	1.3997e-08	-0.001166	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025612
156/02	-2.6347e-11	1.3997e-08	-0.001169	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025614
157/01	-2.6347e-11	1.3997e-08	-0.001172	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025617
158/01	-2.6347e-11	1.3997e-08	-0.001173	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025619
159/01	-2.6347e-11	1.3997e-08	-0.001176	-5.33815e-08	-1.63132e-05	1.36096e-03	-0.025621

Appendix B

Summary of CLIVAR/Carbon P02E CTD Oxygen Time Constants

(time constants in seconds)

Pressure Hysteresis (τ_h)	Temperature Long(τ_{Tl})	Temperature Short(τ_{Ts})	Pressure Gradient (τ_p)	O_2 Gradient (τ_{og})	Velocity (τ_{dP})	Thermal Diffusion (τ_{dT})
50.0	300.0	4.0	0.50	8.00	200.00	300.0

CLIVAR/Carbon P02E: Conversion Equation Coefficients for CTD Oxygen

(refer to Equation 1.9.4.0)

Sta/ Cast	O_cSlope (c_1)	Offset (c_3)	$P_h$coeff (c_2)	$T_l$coeff (c_4)	$T_s$coeff (c_5)	$P_l$coeff (c_6)	$\frac{dO_c}{dt}$coeff (c_7)	$\frac{dP}{dt}$coeff (c_8)	T_{dT}coeff (c_9)
088/01	5.992e-04	-0.2562	-0.0037	-4.147e-03	4.141e-03	4.880e-03	-3.308e-03	4.880e-03	-1.210e-03
089/01	5.674e-04	-0.2838	0.9055	1.176e-02	-7.022e-03	3.630e-02	3.775e-03	3.630e-02	6.402e-03
090/01	6.247e-04	-0.2724	0.1678	1.008e-02	-1.236e-02	1.651e-02	-2.003e-03	1.651e-02	3.258e-02
091/01	5.953e-04	-0.2481	-0.0606	5.318e-03	-5.362e-03	-1.374e-02	1.533e-04	-1.374e-02	1.186e-02
092/01	4.637e-04	-0.2694	1.7051	2.153e-02	-4.299e-03	5.038e-02	5.009e-03	5.038e-02	-1.609e-02
093/01	5.738e-04	-0.2409	-0.1037	-1.344e-03	3.065e-03	-3.744e-03	1.789e-03	-3.744e-03	-6.313e-03
094/01	5.862e-04	-0.2470	0.0190	-5.296e-03	6.048e-03	2.618e-02	-2.812e-03	2.618e-02	-8.739e-04
095/01	6.420e-04	-0.2792	0.1175	3.977e-03	-7.254e-03	1.425e-02	7.757e-03	1.425e-02	2.222e-02
096/02	6.170e-04	-0.2666	0.1003	-5.085e-03	3.678e-03	2.173e-02	1.701e-03	2.173e-02	-1.755e-04
097/01	4.950e-04	-0.2773	1.4583	6.601e-03	5.771e-03	6.628e-02	5.829e-04	6.628e-02	-2.288e-02
098/01	6.407e-04	-0.2879	0.1966	-2.812e-03	6.902e-05	3.604e-02	-4.061e-03	3.604e-02	1.024e-02
099/01	6.061e-04	-0.2546	-0.0216	2.952e-03	-3.753e-03	-8.914e-03	-9.249e-04	-8.914e-03	1.092e-02
100/01	6.088e-04	-0.2594	0.0377	-3.128e-03	2.152e-03	1.649e-02	-4.152e-04	1.649e-02	-1.133e-04
101/01	6.226e-04	-0.2642	0.0501	-1.190e-03	-8.983e-04	6.503e-03	-2.214e-03	6.503e-03	7.623e-03
102/01	4.769e-04	-0.2634	1.5242	2.217e-02	-8.206e-03	5.295e-02	8.278e-03	5.295e-02	2.016e-03
103/01	6.369e-04	-0.2888	0.3397	1.697e-03	-3.855e-03	8.181e-03	1.596e-03	8.181e-03	8.572e-03
104/01	6.088e-04	-0.2589	0.0327	3.959e-04	-1.303e-03	1.178e-02	6.207e-04	1.178e-02	8.546e-03
105/01	6.369e-04	-0.2778	0.1563	1.314e-03	-4.136e-03	1.519e-02	-1.022e-03	1.519e-02	1.426e-02
106/01	5.837e-04	-0.2498	0.0943	5.019e-03	-4.059e-03	4.524e-02	9.334e-03	4.524e-02	1.707e-02
107/01	6.352e-04	-0.2771	0.1155	5.110e-04	-3.217e-03	1.438e-02	2.767e-03	1.438e-02	1.095e-02
108/01	6.131e-04	-0.2607	0.0766	1.589e-03	-2.762e-03	-3.010e-03	1.869e-03	-3.010e-03	8.311e-03
109/01	6.355e-04	-0.2756	0.1403	-3.851e-04	-2.187e-03	3.184e-03	4.799e-03	3.184e-03	9.563e-03
110/01	6.314e-04	-0.2747	0.1011	-1.763e-03	-4.614e-04	-1.493e-03	-6.353e-04	-1.493e-03	2.770e-03
111/01	5.975e-04	-0.2487	-0.1168	-4.371e-03	4.175e-03	-8.966e-03	-1.094e-03	-8.966e-03	-6.234e-03
112/01	6.161e-04	-0.2555	-0.0869	2.817e-03	-4.078e-03	-2.074e-02	2.247e-03	-2.074e-02	1.647e-02
113/01	6.089e-04	-0.2700	0.2035	1.072e-04	-4.766e-04	2.332e-02	-2.648e-03	2.332e-02	8.120e-03
114/01	6.484e-04	-0.2823	0.0837	-6.217e-03	2.615e-03	5.771e-03	-2.625e-03	5.771e-03	-2.205e-03
115/01	6.213e-04	-0.2737	0.2757	-4.639e-03	3.115e-03	1.994e-02	1.049e-03	1.994e-02	-5.161e-03
116/01	4.724e-04	-0.2494	1.4301	1.155e-02	3.108e-03	4.974e-02	-5.481e-03	4.974e-02	-2.108e-02
117/01	6.002e-04	-0.2559	0.0414	-6.326e-05	4.921e-05	7.181e-03	2.452e-03	7.181e-03	2.189e-03
118/01	6.021e-04	-0.2555	0.0622	-4.851e-03	4.775e-03	8.513e-03	-4.312e-03	8.513e-03	-8.366e-03
119/01	5.916e-04	-0.2489	0.1056	5.716e-03	-4.991e-03	1.074e-02	4.070e-03	1.074e-02	2.057e-02
120/01	5.725e-04	-0.2875	0.9480	3.703e-03	9.473e-04	1.856e-02	-2.132e-03	1.856e-02	-1.325e-02
121/01	6.275e-04	-0.2680	0.1019	-4.095e-03	1.796e-03	3.053e-03	-2.700e-03	3.053e-03	2.113e-03
122/01	6.310e-04	-0.2676	0.1080	6.388e-03	-9.185e-03	1.923e-02	1.897e-03	1.923e-02	3.309e-02
123/01	6.440e-04	-0.2881	0.2869	4.253e-03	-7.537e-03	2.871e-02	3.252e-03	2.871e-02	2.109e-02

Sta/ Cast	O_cSlope (c_1)	Offset (c_3)	$P_h$coeff (c_2)	$T_l$coeff (c_4)	$T_s$coeff (c_5)	$P_l$coeff (c_6)	$\frac{dO_c}{dt}$coeff (c_7)	$\frac{dP}{dt}$coeff (c_8)	T_{dT}coeff (c_9)
124/01	6.266e-04	-0.2614	-0.0132	-1.558e-03	-9.281e-04	-6.901e-03	-6.394e-04	-6.901e-03	1.426e-02
125/01	6.155e-04	-0.2612	0.0883	1.675e-03	-3.056e-03	1.155e-02	6.532e-03	1.155e-02	1.149e-02
126/01	6.246e-04	-0.2728	0.1968	-1.346e-02	1.161e-02	1.383e-02	-1.261e-02	1.383e-02	-6.840e-03
127/01	6.411e-04	-0.2746	0.0796	-6.051e-03	2.418e-03	5.537e-03	-6.554e-03	5.537e-03	3.332e-03
128/02	6.169e-04	-0.2591	-0.0097	-4.780e-03	3.220e-03	-9.346e-03	9.107e-06	-9.346e-03	-8.205e-03
129/01	6.136e-04	-0.2610	0.2059	-3.920e-03	2.440e-03	2.533e-02	-3.197e-03	2.533e-02	4.137e-02
130/01	6.347e-04	-0.2779	0.1775	-5.052e-03	2.237e-03	1.226e-02	-4.525e-03	1.226e-02	-5.311e-03
131/01	6.536e-04	-0.2752	0.0076	-3.353e-03	-1.349e-03	-1.588e-02	-1.804e-04	-1.588e-02	2.038e-02
132/01	6.380e-04	-0.2721	0.1553	1.702e-03	-5.110e-03	5.678e-03	4.181e-04	5.678e-03	3.909e-02
133/01	6.194e-04	-0.2643	0.0521	-3.546e-03	1.712e-03	-1.912e-03	1.331e-03	-1.912e-03	-2.264e-03
134/01	6.061e-04	-0.2546	-0.0024	-3.747e-03	2.920e-03	1.242e-04	3.113e-03	1.242e-04	-2.574e-03
135/01	6.444e-04	-0.2710	-0.0412	-5.588e-03	1.074e-03	-1.157e-02	-1.072e-03	-1.157e-02	1.149e-02
136/01	6.095e-04	-0.2690	0.2339	-8.266e-03	7.685e-03	1.669e-02	-8.011e-03	1.669e-02	-9.647e-03
137/01	6.137e-04	-0.2541	-0.0847	-1.254e-03	-3.322e-04	-2.303e-03	3.478e-03	-2.303e-03	3.428e-03
138/01	6.349e-04	-0.2742	0.1367	-6.287e-03	3.065e-03	1.199e-02	6.343e-04	1.199e-02	1.509e-03
139/01	6.507e-04	-0.2805	-0.0016	-6.958e-03	2.433e-03	-7.975e-03	2.471e-03	-7.975e-03	-9.671e-03
140/01	6.241e-04	-0.2709	0.1758	-3.560e-03	1.561e-03	6.093e-03	2.191e-03	6.093e-03	9.326e-03
141/01	5.483e-04	-0.2310	0.3398	2.538e-02	-2.050e-02	4.416e-02	2.708e-03	4.416e-02	7.109e-02
142/01	5.844e-04	-0.2620	0.5071	-1.571e-03	3.978e-03	2.673e-02	-2.800e-03	2.673e-02	1.035e-02
143/01	5.729e-04	-0.2538	0.5565	2.363e-03	7.476e-04	3.248e-02	-2.881e-03	3.248e-02	3.849e-02
144/01	6.153e-04	-0.2636	0.0252	4.990e-03	-7.155e-03	4.709e-03	1.191e-02	4.709e-03	-4.585e-03
145/02	5.992e-04	-0.2490	-0.1728	-2.477e-03	2.201e-03	-1.207e-02	6.284e-03	-1.207e-02	-3.786e-02
146/01	6.420e-04	-0.2646	0.0420	-1.189e-02	7.023e-03	5.346e-03	4.720e-03	5.346e-03	2.866e-02
147/01	5.990e-04	-0.2615	0.2953	2.348e-02	-2.347e-02	3.685e-02	-3.828e-04	3.685e-02	4.650e-02
148/01	6.578e-04	-0.2775	0.0234	-3.621e-02	2.936e-02	-3.136e-03	-9.827e-03	-3.136e-03	-1.035e-02
149/01	6.146e-04	-0.2597	0.0622	-4.034e-03	3.114e-03	1.640e-02	4.659e-03	1.640e-02	5.797e-03
150/01	6.368e-04	-0.2655	0.0104	-2.914e-04	-4.239e-03	-5.459e-03	3.017e-03	-5.459e-03	-2.875e-03
151/01	3.892e-04	-0.1711	0.4325	2.996e-02	1.217e-03	-9.397e-03	2.206e-03	-9.397e-03	-2.857e-02
152/01	4.182e-04	-0.1889	0.6290	2.680e-02	-8.021e-04	7.638e-05	3.594e-03	7.638e-05	-3.738e-02
153/01	4.711e-03	-2.1566	0.8849	-1.055e-01	-2.817e-02	4.656e-02	6.316e-03	4.656e-02	1.696e-01
154/01	7.853e-04	-0.3448	0.4294	-2.433e-02	9.002e-03	-2.878e-02	-7.962e-03	-2.878e-02	-1.596e-02
155/01	3.301e-05	-0.0133	-0.1555	1.502e-01	1.989e-02	-1.476e-01	1.182e-03	-1.476e-01	-1.968e-01
156/02	8.704e-04	-0.3711	0.0880	-1.979e-02	-1.723e-03	7.604e-03	3.356e-03	7.604e-03	4.312e-02
157/01	1.227e-04	-0.0493	-0.3142	8.471e-02	3.713e-03	-3.036e-01	7.465e-04	-3.036e-01	-8.978e-02
158/01	3.416e-04	-0.1494	0.3926	3.523e-02	-3.001e-03	4.627e-02	4.282e-03	4.627e-02	-2.149e-02
159/01	8.757e-04	0.0612	-12.2943	-3.912e-02	8.024e-03	3.672e-02	-1.210e-03	3.672e-02	2.437e-02

Appendix C

CLIVAR/Carbon P02E: Bottle Quality Comments

Comments from the Sample Logs and the results of STS/ODF's data investigations are included in this report. Units stated in these comments are degrees Celsius for temperature, Unless otherwise noted, milliliters per liter for oxygen and micromoles per liter for Silicate, Nitrate, Nitrite, and Phosphate. The sample number is the cast number times 100 plus the bottle number. Investigation of data may include comparison of bottle salinity and oxygen data with CTD data, review of data plots of the station profile and adjoining stations, and re-reading of charts (i.e. nutrients).

Station /Cast	Sample No.	Property	Quality Code	Comment
89/1	109	salt	3	Deep bottle salinity 0.0035 high vs CTDS1/CTDS2
89/1	111	salt	3	Deep bottle salinity 0.004 high vs CTDS1/CTDS2
89/1	123	o2	3	Bottle O2 5 umol/kg low, does not fit profile, other parameters ok
89/1	130	o2	3	Bottle O2 10 umol/kg low, on high gradient feature
90/1	126	bottle	2	Winch overshot bottle 26 target: tripped 15m shallower than planned.
90/1	131	o2	3	Bottle O2 8 umol/kg low, value identical to bottle 32, possible sampling error
91/1	116	bottle	2	Misread bottle 16 target: 30m deeper than planned.
91/1	136	bottle	2	Bottle 36 tripped next-to-last to test new end cap (one level deeper than usual).
93/1	101	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	102	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	103	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	104	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	105	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	106	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	107	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	108	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	109	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	110	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	111	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	112	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	113	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	114	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	115	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	116	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	117	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	118	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	119	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	120	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	121	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	122	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	123	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	124	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	125	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	126	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	127	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	128	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	128	reft	3	SBE35RT -0.04/-0.05 vs CTDT1/CTDT2; unstable SBE35RT reading in a gradient.

Station /Cast	Sample No.	Property	Quality Code	Comment
93/1	129	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	130	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	131	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	132	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	133	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	133	salt	3	Salinity 0.015 low, matches upcast, high variability region
93/1	134	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
93/1	136	ctdt/ctds	2	Secondary TS data used for CTD trips: primaries fouled by sea slime.
94/1	101	bottle	9	Bottle 1 did not close, solenoid checked by ET after sampling.
94/1	123	o2	2	Bottle O2 7 umol/kg high, high gradient
94/1	133	reft	3	SBE35RT +0.05/-0.025 vs CTDT1/CTDT2; somewhat unstable SBE35RT reading in a gradient.
94/1	133	salt	3	Bottle salinity 0.027 high, unstable reading of CTDC1/CTDC2, high gradient
94/1	134	salt	3	Bottle salinity 0.018 high, matches upcast, highly variable region
95/1	102	o2	4	Problem with instrument. Endpoint bad.
95/1	103	o2	4	Problem with instrument. Endpoint bad.
95/1	104	o2	4	Problem with instrument. Endpoint bad.
95/1	108	bottle	2	Winch went 40m past target, bottle 8 tripped 40m shallower than planned.
95/1	120	bottle	2	Nutrients sampled before DOC
95/1	122	o2	2	O2 5 umol/kg low, matches upcast, high gradient
95/1	132	bottle	2	spigot was already pushed in when O2 went to sample. o2 and salinity values ok.
96/2	201	bottle	9	Bottle 1 tripped third from bottom to test re-sealed carousel latch. Bottle did not close, bottle removed for remainder of cruise.
96/2	202	bottle	2	Bottles 2/3 tripped at bottom/next-to-bottom until bottle 1 position passes tripping tests.
96/2	203	bottle	2	Bottles 2/3 tripped at bottom/next-to-bottom until bottle 1 position passes tripping tests.
96/2	206	bottle	3	vent open, leaking
96/2	210	o2	5	O2 292 high, forgot stir bar, sample lost
96/2	222	o2	2	O2 5 umol/kg low, high gradient
97/1	124	o2	2	O2 8 umol/kg low, high gradient
97/1	136	salt	5	Analyst reports that the sample was lost
98/1	123	o2	2	O2 4 umol/kg high, high gradient
98/1	124	o2	2	O2 4 umol/kg high, high gradient
98/1	131	o2	2	O2 5 umol/kg low, matches upcast
99/1	131	reft	3	SBE35RT -0.055/-0.03 vs CTDT1/CTDT2; unstable SBE35RT reading in a gradient.
99/1	131	salt	2	Bottle salinity 0.010 high compared to CTDS1/CTDS2, in a gradient
100/1	122	o2	2	O2 7 umol/kg low, matches upcast
100/1	124	o2	2	O2 5 umol/kg high, high gradient, matches upcast
102/1	133	reft	3	SBE35RT +0.03/+0.035 vs CTDT1/CTDT2; unstable SBE35RT reading in a gradient.
103/1	105	salt	3	Deep bottle salinity 0.004 high vs CTDS1/CTDS2
103/1	129	salt	2	Bottle salinity 0.015 high vs CTDS1/CTDS2
105/1	111	salt	4	Deep bottle salinity 0.010 high vs CTDS1/CTDS2, analyst notes that "thimble came out with cap. Possible contamination"
105/1	130	salt	2	Bottle salinity 0.017 high vs CTDS1/CTDS2, high gradient
106/1	130	reft	3	SBE35RT -0.01/-0.045 vs CTDT1/CTDT2; somewhat unstable SBE35RT reading in a gradient.
107/1	105	salt	3	Deep bottle salinity 0.007 high vs CTDS1/CTDS2.

Station /Cast	Sample No.	Property	Quality Code	Comment
107/1	130	reft	3	SBE35RT +0.035/+0.11 vs CTDT1/CTDT2; extremely unstable SBE35RT reading in a gradient.
108/1	128	reft	3	SBE35RT -0.025 vs CTDT1/CTDT2; unstable SBE35RT reading in a gradient.
109/1	128	reft	3	SBE35RT +0.015/+0.07 vs CTDT1/CTDT2; unstable SBE35RT reading in a gradient.
111/1	129	salt	2	Bottle salinity 0.012 high vs CTDS1/CTDS2
111/1	133	salt	3	Bottle salinity 0.036 high vs CTDS1/CTDS2
112/1	133	salt	3	Bottle salt 0.013 high compared to CTDS1/CTDS2
114/1	104	bottle	2	Winch overshot target by 7m and came back down before stopping/tripping bottle 4.
114/1	107	bottle	2	Winch overshot stop, tripped bottle 7 at 75m shallower than planned.
114/1	109	o2	4	Bottle O2 127 umol/kg low
114/1	131	reft	3	SBE35RT +0.05/+0.045 vs CTDT1/CTDT2; unstable SBE35RT reading in a gradient.
114/1	131	salt	3	Bottle salt 0.013 high compared to CTDS1/CTDS2
115/1	106	salt	3	Deep bottle salinity 0.010 high vs CTDS1/CTDS2
115/1	128	bottle	9	Bottle did not close. Carousel solenoid problems: remove bottle 28 for rest of leg.
116/1	108	salt	2	Salts appear to have been sampled from the wrong bottle, box position being correct, corrected
116/1	109	salt	2	Salts appear to have been sampled from the wrong bottle, box position being correct, corrected
116/1	130	reft	3	SBE35RT -0.05/-0.03 vs CTDT1/CTDT2; somewhat unstable SBE35RT reading in a gradient.
116/1	130	salt	3	Bottle salinity 0.070 high compared to CTDS1/CTDS2
116/1	131	salt	2	Bottle salinity 0.010 high compared to CTDS1/CTDS2
116/1	132	salt	2	Bottle salinity 0.012 high compared to CTDS1/CTDS2
117/1	112	bottle	2	Winch overshot target, tripped bottle 12 at 38m shallower than planned.
117/1	129	reft	3	SBE35RT +0.06/-0.08 vs CTDT1/CTDT2; very unstable SBE35RT reading in a gradient.
117/1	132	reft	3	SBE35RT +0.055/+0.06 vs CTDT1/CTDT2; unstable SBE35RT reading in a gradient.
117/1	134	salt	3	Bottle salinity 0.097 high compared to CTDS1/CTDS2
118/1	113	salt	3	Deep bottle salinity 0.0025 high vs CTDS1/CTDS2
118/1	134	reft	3	SBE35RT +0.08/+0.10 vs CTDT1/CTDT2; unstable SBE35RT reading in a gradient.
118/1	134	salt	3	Bottle salinity 0.025 high compared to CTDS1/CTDS2
119/1	130	reft	3	SBE35RT +0.02/+0.08 vs CTDT1/CTDT2; very unstable SBE35RT reading in a gradient.
119/1	130	salt	3	Bottle salinity 0.025 high compared to CTDS1/CTDS2
120/1	117	bottle	2	Winch overshot target by 10m and came back down before tripping bottle 17.
120/1	129	reft	3	SBE35RT +0.065/+0.04 vs CTDT1/CTDT2; very unstable SBE35RT reading in a gradient.
121/1	102	salt	3	Deep bottle salinity 0.004 high compared to CTDS1/CTDS2
121/1	126	salt	4	Bottle salinity 0.042 low compared to CTDS1/CTDS2, analyst notes that thimble came out with cap and was probably contaminated
121/1	130	reft	3	SBE35RT -0.03/-0.045 vs CTDT1/CTDT2; unstable SBE35RT reading in a gradient.
121/1	133	salt	3	Bottle salinity 0.027 high compared to CTDS1/CTDS2
122/1	102	o2	5	Oxygen rig error. Sample lost.

Station /Cast	Sample No.	Property	Quality Code	Comment
122/1	130	salt	3	Bottle salinity 0.020 high compared to CTDS1/CTDS2
122/1	131	reft	3	SBE35RT -0.04/+0.02 vs CTDT1/CTDT2; somewhat unstable SBE35RT reading in a gradient.
122/1	132	reft	3	SBE35RT +0.055/+0.04 vs CTDT1/CTDT2; very unstable SBE35RT reading in a gradient.
122/1	133	salt	2	Bottle salinity 0.010 low compared to CTDS1/CTDS2
123/1	125	reft	3	SBE35RT +0.025 vs CTDT1/CTDT2; somewhat unstable SBE35RT reading in a mild gradient.
124/1	124	o2	2	Bottle O2 11 umol/kg high, on very high gradient, ok
124/1	129	o2	5	Analyst reports the sample was lost
124/1	130	reft	3	SBE35RT -0.025 vs CTDT1/CTDT2; unstable SBE35RT reading in a gradient.
124/1	133	salt	3	Bottle salinity 0.023 high compared to CTDS1/CTDS2
125/1	129	salt	3	Bottle salinity 0.020 low compared to CTDS1/CTDS2
126/1	131	salt	3	Bottle salinity 0.033 high compared to CTDS1/CTDS2
127/1	105	bottle	2	Winch overshot target by 10m, back down 7m before stop/trip bottle 5.
127/1	129	reft	3	SBE35RT -0.075/-0.08 vs CTDT1/CTDT2; unstable SBE35RT reading in a gradient.
127/1	130	salt	3	Bottle salinity 0.040 low vs CTDS1/CTDS2, high gradient
127/1	132	bottle	2	Op.error: bottles 32, 33 target/trip 4m deeper than planned.
127/1	133	bottle	2	Op.error: bottles 32, 33 target/trip 4m deeper than planned.
128/2	222	salt	3	Bottle salinity 0.103 high compared to CTDS1/CTDS2, other parameters ok
128/2	233	reft	3	SBE35RT +0.055 vs CTDT1/CTDT2; unstable SBE35RT reading in a gradient.
129/1	123	bottle	2	Winch shift change: overshot target, bottle 23 tripped 35m shallower than planned.
129/1	131	reft	3	SBE35RT +0.015/+0.045 vs CTDT1/CTDT2; unstable SBE35RT reading in a gradient.
129/1	132	reft	3	SBE35RT +0.01/-0.03 vs CTDT1/CTDT2; unstable SBE35RT reading in a gradient.
131/1	131	salt	3	Bottle salinity 0.025 low vs CTDS1/CTDS2. High gradient
132/1	113	no2	4	Sampling error. Sampled from niskin 12.
132/1	113	no3	4	Sampling error. Sampled from niskin 12.
132/1	113	po4	4	Sampling error. Sampled from niskin 12.
132/1	113	sio3	4	Sampling error. Sampled from niskin 12.
132/1	130	no2	4	Sampling error. Sampled from niskin 29.
132/1	130	no3	4	Sampling error. Sampled from niskin 29.
132/1	130	po4	4	Sampling error. Sampled from niskin 29.
132/1	130	sio3	4	Sampling error. Sampled from niskin 29.
132/1	131	salt	3	Bottle salinity 0.369 high vs CTDS1/CTDS2
133/1	134	salt	3	Bottle salinity 0.023 low vs CTDS1/CTDS2
134/1	133	reft	3	SBE35RT +0.03/+0.02 vs CTDT1/CTDT2; unstable SBE35RT reading in a gradient.
134/1	133	salt	3	Bottle salinity 0.022 low vs CTDS1/CTDS2, high gradient
136/1	111	no2	2	Samples from niskins 11-12 interchanged; sampler error.
136/1	111	no3	2	Samples from niskins 11-12 interchanged; sampler error.
136/1	111	po4	2	Samples from niskins 11-12 interchanged; sampler error.
136/1	111	sio3	2	Samples from niskins 11-12 interchanged; sampler error.
136/1	112	no2	2	Samples from niskins 11-12 interchanged; sampler error.
136/1	112	no3	2	Samples from niskins 11-12 interchanged; sampler error.
136/1	112	po4	2	Samples from niskins 11-12 interchanged; sampler error.

Station /Cast	Sample No.	Property	Quality Code	Comment
136/1	112	sio3	2	Samples from niskins 11-12 interchanged; sampler error.
136/1	130	reft	3	SBE35RT +0.04/+0.03 vs CTDT1/CTDT2; unstable SBE35RT reading in a gradient.
137/1	129	reft	3	SBE35RT +0.015/+0.05 vs CTDT1/CTDT2; very unstable SBE35RT reading in a gradient.
139/1	131	reft	3	SBE35RT -0.055/-0.06 vs CTDT1/CTDT2; very unstable SBE35RT reading in a gradient.
141/1	127	bottle	2	Winch stopped 10m short of bottle 27 target, then on up to correct target.
143/1	122	salt	4	Bottle salinity 0.053 high vs CTDS1/CTDS2, analyst notes a low water level in bottle, about half full
143/1	132	reft	3	SBE35RT +0.015/+0.04 vs CTDT1/CTDT2; somewhat unstable SBE35RT reading in a gradient.
145/2	202	salt	3	Deep bottle salinity 0.0025 high vs CTDS1/CTDS2
145/2	227	o2	3	Bottle o2 23 umol/kg low
145/2	231	reft	3	SBE35RT +0.06/+0.05 vs CTDT1/CTDT2; very unstable SBE35RT reading in a gradient.
145/2	231	salt	3	Bottle salinity 0.020 high vs CTDS1/CTDS2
147/1	104	salt	3	Deep bottle salinity 0.0025 high vs CTDS1/CTDS2
147/1	131	reft	3	SBE35RT -0.04/-0.045 vs CTDT1/CTDT2; very unstable SBE35RT reading in a gradient.
147/1	132	reft	3	SBE35RT +0.11/+0.15 vs CTDT1/CTDT2; very unstable SBE35RT reading in a gradient.
148/1	129	reft	3	SBE35RT -0.035/-0.04 vs CTDT1/CTDT2; very unstable SBE35RT reading in a gradient.
148/1	130	salt	2	Bottle salinity 0.020 low vs CTDS1/CTDS2, in a gradient
148/1	132	reft	3	SBE35RT -0.13/-0.15 vs CTDT1/CTDT2; very unstable SBE35RT reading in a gradient.
148/1	136	bottle	2	Surface bottle tripped at 10m due to high swell.
148/1	136	o2	2	Bottle O2 60 umol/kg high vs CTDO, CTDO is bad and bottle o2 matches other mixed layer values.
149/1	102	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	103	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	104	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	105	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	106	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	107	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	108	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	109	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	110	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	111	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	112	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	113	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	114	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	115	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	116	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	117	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	118	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	119	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	120	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	121	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	122	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.

Station /Cast	Sample No.	Property	Quality Code	Comment
149/1	123	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	124	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	125	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	126	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	127	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	129	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	130	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	131	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	132	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	132	o2	3	Bottle O2 48 umol/kg low, in gradient, matches upcast
149/1	132	reft	3	SBE35RT -0.035/-0.10 vs CTDT1/CTDT2; very unstable SBE35RT reading in a gradient.
149/1	133	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	133	reft	3	SBE35RT -0.085 vs CTDT1/CTDT2; very unstable SBE35RT reading in a gradient.
149/1	134	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	136	bottle	2	Surface bottle tripped at 10m due to high swell.
149/1	136	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
149/1	136	o2	2	Bottle O2 52 umol/kg high vs CTDO, CTDO is bad and bottle o2 matches other mixed layer values.
150/1	103	reft	3	deep SBE35RT +0.003/+0.0025 vs CTDT1/CTDT2; unstable SBE35RT reading.
150/1	105	reft	3	deep SBE35RT +0.003 vs CTDT1/CTDT2; unstable SBE35RT reading.
150/1	132	o2	2	Bottle o2 20 umol/kg low, matches upcast, in high gradient
150/1	132	salt	3	Bottle salinity 0.051 low vs CTDS1/CTDS2
150/1	133	bottle	2	Op. error: bottle 33 tripped early/on the fly 2m above stop (cons.op. distracted).
151/1	102	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
151/1	103	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
151/1	104	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
151/1	105	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
151/1	106	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
151/1	107	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
151/1	108	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
151/1	109	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
151/1	110	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
151/1	111	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
151/1	112	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
151/1	113	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
151/1	114	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
151/1	115	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
151/1	116	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
151/1	117	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
151/1	118	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
151/1	119	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
151/1	120	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
151/1	121	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
151/1	122	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
151/1	123	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
151/1	124	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
151/1	125	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.

Station /Cast	Sample No.	Property	Quality Code	Comment
151/1	126	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
151/1	127	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
151/1	129	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
151/1	130	ctdt/ctds	2	Secondary TS data used for CTD trips: primary data noisy.
153/1	122	reft	3	SBE35RT -0.04/-0.035 vs CTDT1/CTDT2; very unstable SBE35RT reading in a gradient.
154/1	118	reft	3	SBE35RT -0.04/-0.01 vs CTDT1/CTDT2; very unstable SBE35RT reading in a gradient.
154/1	118	salt	3	Bottle salinity 0.026 low vs CTDS1
154/1	125	o2	2	Bottle O2 31 umol/kg low, matches upcast, high gradient
154/1	125	reft	3	SBE35RT +0.175/+0.185 vs CTDT1/CTDT2; very unstable SBE35RT reading in a gradient.
157/1	120	reft	3	SBE35RT +0.225/+0.055 vs CTDT1/CTDT2; very unstable SBE35RT reading in a gradient.
159/1	107	o2	5	Operator error. Sample lost.
159/1	109	reft	3	SBE35RT +0.04/+0.025 vs CTDT1/CTDT2; unstable SBE35RT reading in a gradient.
159/1	110	reft	3	SBE35RT -0.07/-0.01 vs CTDT1/CTDT2; unstable SBE35RT reading in a gradient.

Appendix D

CLIVAR/Carbon P02E: Pre-Cruise Sensor Laboratory Calibrations

Table of Contents

† NOTE: station numbers below 88 indicate sensors/instruments were used starting Leg 1/P02W

Pressure Calibration Report
STS/ODF Calibration Facility

SENSOR SERIAL NUMBER: 0914
CALIBRATION DATE: 14-JUN-2012
Mfg: SEABIRD Model: 09P CTD Prs s/n: 110547

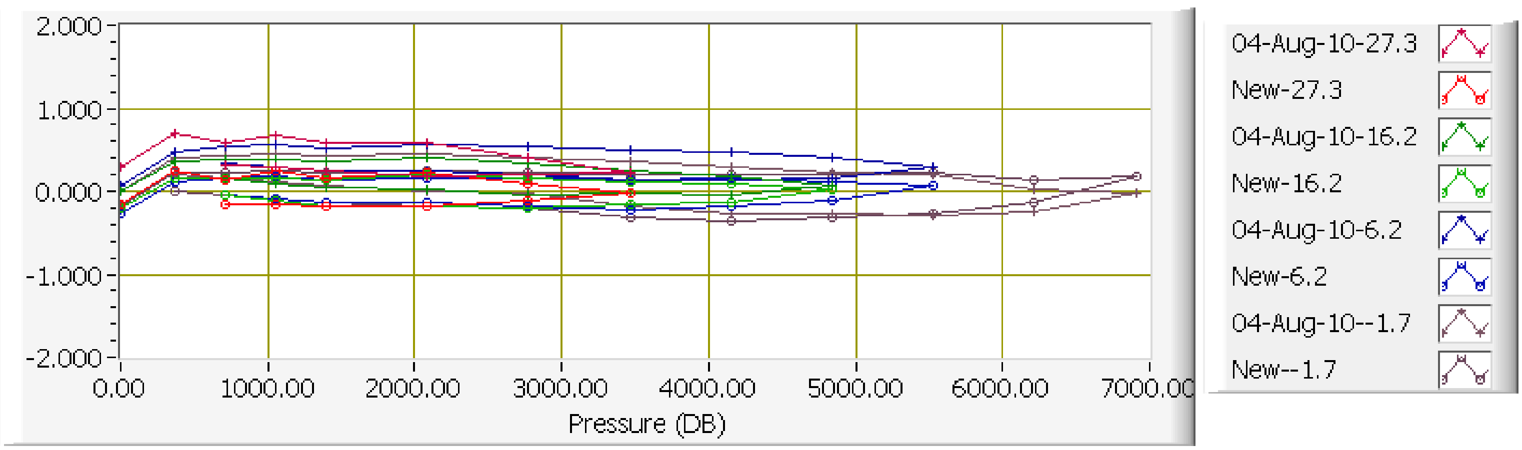
C1= -4.348919E+4
C2= 1.845929E-2
C3= 1.285114E-2
D1= 3.610893E-2
D2= 0.000000E+0
T1= 3.006810E+1
T2= -2.604375E-4
T3= 3.050306E-6
T4= 3.013015E-8
T5= 0.000000E+0
AD590M= 1.28789E-2
AD590B= -8.81353E+0
Slope = 1.00000000E+0
Offset = 0.00000000E+0

Calibration Standard: Mfg: RUSKA Model: 2400 s/n: 34336
t0=t1+t2*td+t3*td*td+t4*td*td*td
w = 1-t0*t0*f*f
Pressure = (0.6894759*((c1+c2*td+c3*td*td)*w*(1-(d1+d2*td)*w)-14.7)

Sensor Output	Standard	Sensor New_Coefs	Standard-Sensor Prev_Coefs	Standard-Sensor NEW_Coefs	Sensor_Temp	Bath_Temp
33268.311	0.17	0.33	0.30	-0.16	27.13	27.334
33469.730	364.96	364.72	0.70	0.24	27.17	27.334
33658.765	709.13	708.99	0.59	0.14	27.20	27.334
33846.469	1053.30	1053.05	0.68	0.25	27.22	27.334
34033.137	1397.55	1397.39	0.58	0.16	27.25	27.334
34402.840	2086.02	2085.81	0.58	0.22	27.27	27.334
34768.150	2774.56	2774.48	0.39	0.08	27.30	27.334
35129.097	3463.18	3463.19	0.22	-0.01	27.32	27.335
34768.251	2774.55	2774.66	0.20	-0.11	27.34	27.334
34403.060	2086.03	2086.21	0.19	-0.19	27.34	27.334
34033.328	1397.56	1397.73	0.25	-0.18	27.38	27.334
33846.696	1053.30	1053.46	0.29	-0.15	27.39	27.334
33658.930	709.13	709.28	0.31	-0.15	27.40	27.334
33469.936	364.96	365.08	0.36	-0.12	27.43	27.334
33267.305	0.17	0.36	0.01	-0.20	16.22	16.201
33468.719	364.96	364.80	0.37	0.16	16.24	16.201
33657.662	709.13	708.97	0.38	0.16	16.25	16.201

Sensor Output	Standard	Sensor New_Coefs	Standard-Sensor Prev_Coefs	Standard-Sensor NEW_Coefs	Sensor_Temp	Bath_Temp
33845.400	1053.30	1053.15	0.37	0.15	16.26	16.201
34031.996	1397.56	1397.42	0.36	0.14	16.26	16.201
34401.640	2086.03	2085.83	0.40	0.20	16.30	16.201
34766.833	2774.56	2774.40	0.33	0.16	16.30	16.201
35127.694	3463.19	3463.07	0.25	0.12	16.31	16.201
35484.333	4151.88	4151.78	0.18	0.09	16.33	16.201
35836.896	4840.62	4840.59	0.06	0.03	16.34	16.201
35484.449	4151.87	4152.00	-0.05	-0.14	16.35	16.201
35127.844	3463.19	3463.34	-0.02	-0.16	16.35	16.201
34767.039	2774.57	2774.78	-0.04	-0.21	16.35	16.201
34401.847	2086.03	2086.20	0.03	-0.17	16.36	16.201
34032.184	1397.56	1397.73	0.04	-0.18	16.36	16.201
33845.563	1053.30	1053.42	0.10	-0.12	16.36	16.201
33657.801	709.13	709.19	0.16	-0.05	16.39	16.201
33468.843	364.96	364.98	0.19	-0.03	16.40	16.201
33265.457	0.17	0.44	0.08	-0.27	6.65	6.224
33466.819	364.95	364.83	0.48	0.12	6.65	6.224
33655.717	709.12	708.97	0.53	0.16	6.65	6.224
33843.418	1053.29	1053.11	0.56	0.18	6.67	6.224
34030.002	1397.54	1397.41	0.51	0.13	6.65	6.224
34399.609	2086.00	2085.84	0.55	0.16	6.68	6.224
34764.734	2774.52	2774.37	0.54	0.15	6.68	6.224
35125.528	3463.14	3462.99	0.50	0.15	6.68	6.224
35482.106	4151.83	4151.68	0.47	0.15	6.68	6.224
35834.600	4840.55	4840.44	0.40	0.12	6.68	6.224
36183.152	5529.36	5529.30	0.28	0.06	6.68	6.224
35834.723	4840.56	4840.68	0.17	-0.11	6.68	6.224
35482.277	4151.83	4152.01	0.14	-0.19	6.68	6.224
35125.723	3463.15	3463.37	0.14	-0.22	6.68	6.224
34764.918	2774.54	2774.71	0.21	-0.18	6.68	6.224
34399.772	2086.01	2086.14	0.26	-0.13	6.68	6.224
34030.154	1397.55	1397.68	0.26	-0.13	6.68	6.224
33843.570	1053.29	1053.39	0.29	-0.09	6.68	6.224
33655.838	709.13	709.17	0.33	-0.04	6.68	6.224
33466.887	364.96	364.94	0.37	0.01	6.68	6.224
33263.296	0.17	0.34	0.00	-0.18	-1.21	-1.724
33464.641	364.96	364.74	0.41	0.22	-1.21	-1.724
33653.544	709.13	708.91	0.42	0.22	-1.21	-1.724
33841.219	1053.30	1053.04	0.45	0.25	-1.21	-1.724
34027.781	1397.55	1397.32	0.43	0.23	-1.21	-1.724
34397.362	2086.02	2085.76	0.44	0.25	-1.21	-1.724
34762.473	2774.55	2774.32	0.40	0.23	-1.21	-1.724
35123.237	3463.15	3462.94	0.35	0.21	-1.21	-1.724
35479.792	4151.84	4151.64	0.30	0.20	-1.21	-1.724
35832.258	4840.59	4840.39	0.24	0.19	-1.21	-1.724

Sensor Output	Standard	Sensor New_Coefs	Standard-Sensor Prev_Coefs	Standard-Sensor NEW_Coefs	Sensor_Temp	Bath_Temp
36180.738	5529.38	5529.17	0.19	0.22	-1.21	-1.724
36525.423	6218.24	6218.11	0.03	0.13	-1.21	-1.725
36866.316	6907.18	6907.01	-0.02	0.17	-1.21	-1.724
36525.566	6218.26	6218.40	-0.24	-0.14	-1.21	-1.725
36180.980	5529.38	5529.65	-0.29	-0.26	-1.21	-1.724
35832.516	4840.59	4840.90	-0.27	-0.31	-1.21	-1.725
35480.090	4151.85	4152.22	-0.26	-0.36	-1.21	-1.724
35123.522	3463.17	3463.49	-0.18	-0.32	-1.21	-1.724
34762.705	2774.55	2774.76	-0.03	-0.21	-1.21	-1.724
34397.597	2086.02	2086.20	0.01	-0.18	-1.21	-1.724
34027.987	1397.56	1397.70	0.06	-0.14	-1.21	-1.724
33841.409	1053.30	1053.39	0.11	-0.09	-1.21	-1.725
33653.691	709.13	709.18	0.15	-0.04	-1.21	-1.724
33464.760	364.96	364.95	0.19	0.00	-1.21	-1.724
33263.359	0.17	0.46	-0.11	-0.29	-1.21	-1.724



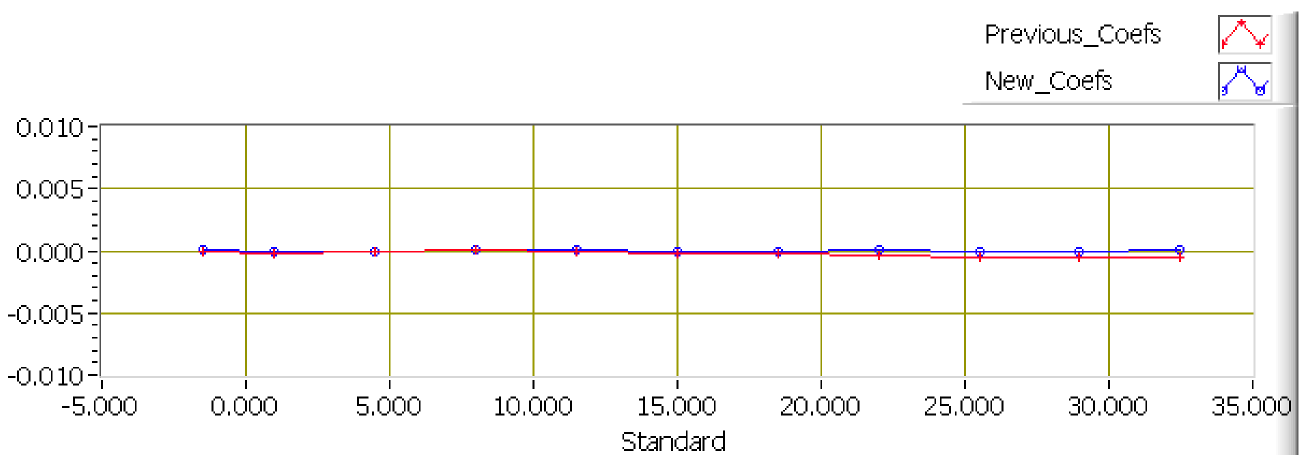
Temperature Calibration Report
STS/ODF Calibration Facility

SENSOR SERIAL NUMBER: 4138
CALIBRATION DATE: 24-Jan-2013
Mfg: SEABIRD   Model: 03
Previous cal: 21-Jun-12
Calibration Tech: CAL

ITS-90_COEFFICIENTS	IPTS-68_COEFFICIENTS ITS-T90	
g = 4.40192731E-3	a = 4.40214027E-3	
h = 6.50694840E-4	b = 6.50911856E-4	
i = 2.33977600E-5	c = 2.34309522E-5	
j = 2.04988124E-6	d = 2.05142804E-6	
f0 = 1000.0	Slope = 1.0	Offset = 0.0

Calibration Standard: Mfg: ASL   Model: F18   s/n: 245-5149
Temperature ITS-90 = 1/{g+h[ln(f0/f)]+i[ln2(f0/f)]+j[ln3(f0/f)]} - 273.15 (°C)
Temperature IPTS-68 = 1/{a+b[ln(f0/f)]+c[ln2(f0/f)]+d[ln3(f0/f)]} - 273.15 (°C)
T68 = 1.00024 * T90 (-2 to -35 Deg C)

SBE3 Freq	SPRT ITS-T90	SBE3 ITS-T90	SPRT-SBE3 OLD Coefs	SPRT-SBE3 NEW Coefs
3159.0572	-1.5059	-1.5060	-0.00002	0.00008
3339.5971	0.9941	0.9943	-0.00017	-0.00013
3604.7395	4.4949	4.4949	-0.00001	-0.00001
3884.7240	7.9964	7.9963	0.00005	0.00007
4179.9450	11.4983	11.4983	-0.00005	0.00003
4489.8693	14.9906	14.9906	-0.00022	-0.00005
4816.6766	18.4936	18.4936	-0.00026	0.00000
5159.4338	21.9930	21.9930	-0.00034	0.00003
5518.8820	25.4929	25.4929	-0.00048	-0.00001
5895.1896	28.9917	28.9918	-0.00059	-0.00003
6288.9059	32.4918	32.4917	-0.00060	0.00002



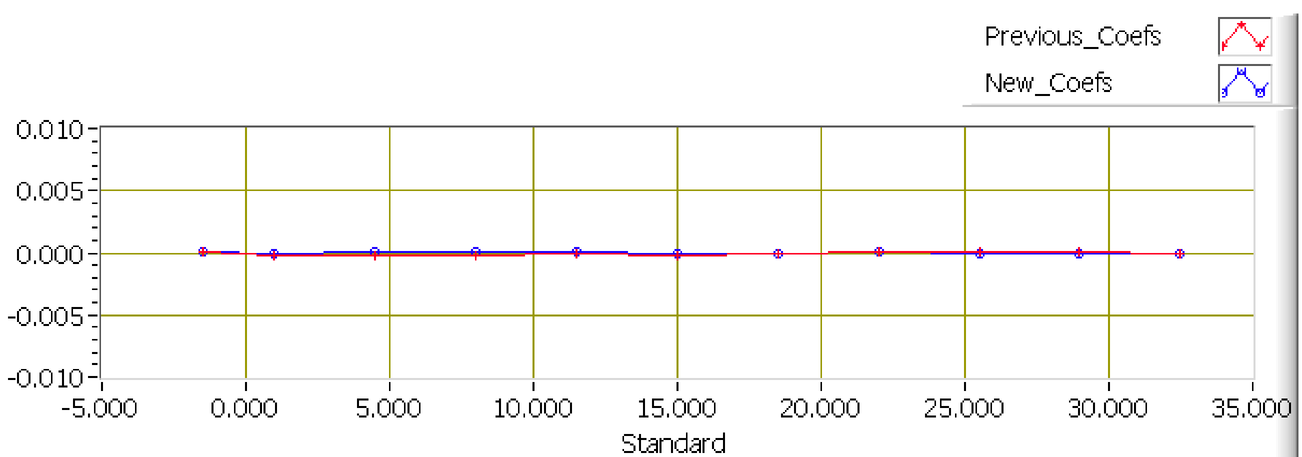
Temperature Calibration Report
STS/ODF Calibration Facility

SENSOR SERIAL NUMBER: 4226
CALIBRATION DATE: 24-Jan-2013
Mfg: SEABIRD Model: 03
Previous cal: 30-Aug-12
Calibration Tech: CAL

ITS-90_COEFFICIENTS	IPTS-68_COEFFICIENTS ITS-T90	
g = 4.38186818E-3	a = 4.38207455E-3	
h = 6.46712520E-4	b = 6.46926865E-4	
i = 2.24590277E-5	c = 2.24918559E-5	
j = 1.80204389E-6	d = 1.80355746E-6	
f0 = 1000.0	Slope = 1.0	Offset = 0.0

Calibration Standard: Mfg: ASL Model: F18 s/n: 245-5149
Temperature ITS-90 = 1/{g+h[ln(f0/f)]+i[ln2(f0/f)]+j[ln3(f0/f)]} - 273.15 (°C)
Temperature IPTS-68 = 1/{a+b[ln(f0/f)]+c[ln2(f0/f)]+d[ln3(f0/f)]} - 273.15 (°C)
T68 = 1.00024 * T90 (-2 to -35 Deg C)

SBE3 Freq	SPRT ITS-T90	SBE3 ITS-T90	SPRT-SBE3 OLD Coefs	SPRT-SBE3 NEW Coefs
3074.5391	-1.5059	-1.5060	0.00005	0.00004
3250.8215	0.9941	0.9942	-0.00020	-0.00008
3509.7895	4.4949	4.4949	-0.00020	0.00001
3783.3395	7.9964	7.9963	-0.00017	0.00006
4071.8662	11.4983	11.4983	-0.00015	0.00004
4374.8712	14.9906	14.9906	-0.00022	-0.00010
4694.4865	18.4936	18.4936	-0.00006	-0.00000
5029.8229	21.9930	21.9930	0.00007	0.00006
5381.6290	25.4929	25.4929	0.00001	-0.00003
5750.0697	28.9917	28.9917	0.00002	-0.00001
6135.7193	32.4918	32.4917	-0.00005	0.00000



Temperature Calibration Report
STS/ODF Calibration Facility

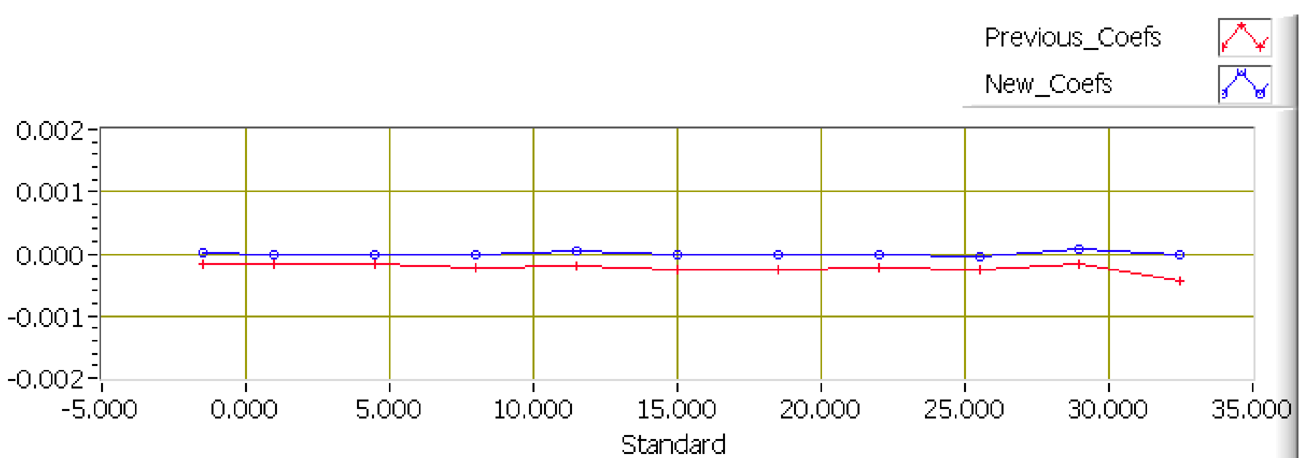
SENSOR SERIAL NUMBER: 0035
CALIBRATION DATE: 07-Dec-2012
Mfg: SEABIRD   Model: 35
Previous cal: 16-Feb-12
Calibration Tech: CAL

ITS-90_COEFFICIENTS
a0 = 4.000167576E-3
a1 = -1.059556581E-3
a2 = 1.660155451E-4
a3 = -9.317019546E-6
a4 = 2.012171620E-7
Slope = 1.000000 Offset = 0.000000
Calibration Standard: Mfg: ASL   Model: F18   s/n: 245-5149

Calibration Standard: Mfg: ASL   Model: F18   s/n: 245-5149

Temperature ITS-90 = 1/{a0+a1[ln(f)]+a2[ln2(f)]+a3[ln3(f)]+a4[ln4(f)} - 273.15 (°C)

SBE35 Count	SPRT ITS-T90	SBE35 ITS-T90	SPRT-SBE35 OLD Coefs	SPRT-SBE35 NEW Coefs
659026.9626	-1.5061	-1.5061	-0.00017	0.00002
590645.0049	0.9940	0.9940	-0.00017	-0.00002
507826.0283	4.4948	4.4948	-0.00018	-0.00001
437800.2467	7.9959	7.9959	-0.00022	-0.00001
378447.0872	11.4975	11.4974	-0.00020	0.00005
328138.6418	14.9902	14.9902	-0.00027	-0.00001
285167.6485	18.4922	18.4922	-0.00026	-0.00002
248489.8620	21.9930	21.9930	-0.00023	-0.00001
217083.1315	25.4946	25.4947	-0.00026	-0.00005
190153.3418	28.9931	28.9930	-0.00017	0.00008
166967.0072	32.4934	32.4934	-0.00044	-0.00003



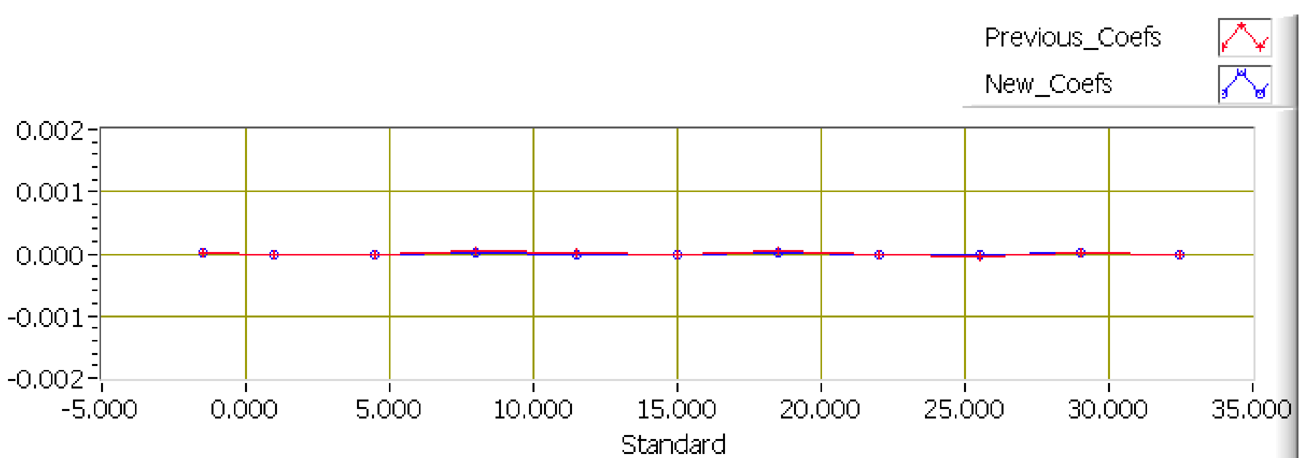
Temperature Calibration Report
STS/ODF Calibration Facility

SENSOR SERIAL NUMBER: 0035
CALIBRATION DATE: 18-Jun-2013
Mfg: SEABIRD Model: 35
Previous cal: 07-Dec-12
Calibration Tech: CAL

ITS-90_COEFFICIENTS
a0 = 3.891166934E-3
a1 = -1.025343400E-3
a2 = 1.619908097E-4
a3 = -9.106715094E-6
a4 = 1.970986285E-7
Slope = 1.000000 Offset = 0.000000
Calibration Standard: Mfg: ASL Model: F18 s/n: 245-5149

Calibration Standard: Mfg: ASL Model: F18 s/n: 245-5149
Temperature ITS-90 = 1/{a0+a1[ln(f)]+a2[ln2(f)]+a3[ln3(f)]+a4[ln4(f)} - 273.15 (°C)

SBE35 Count	SPRT ITS-T90	SBE35 ITS-T90	SPRT-SBE35 OLD Coefs	SPRT-SBE35 NEW Coefs
658922.3875	-1.5025	-1.5025	0.00002	0.00001
590549.0466	0.9977	0.9977	-0.00003	-0.00003
507746.8714	4.4985	4.4985	0.00000	-0.00000
437739.1860	7.9993	7.9992	0.00004	0.00003
378386.6850	11.5013	11.5013	0.00001	-0.00001
328059.0624	14.9962	14.9962	-0.00001	-0.00003
285109.7253	18.4974	18.4974	0.00004	0.00003
248451.9833	21.9969	21.9969	-0.00001	-0.00001
217070.6508	25.4961	25.4962	-0.00004	-0.00002
190139.8707	28.9949	28.9949	0.00001	0.00003
166964.4934	32.4938	32.4938	-0.00000	-0.00001



Sea-Bird Electronics, Inc.

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Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 2569
CALIBRATION DATE: 16-Jan-13

SBE4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Seimens/meter

GHIJ COEFFICIENTS

```
g = -1.04780154e+001
h =  1.58729908e+000
i =  8.38055330e-005
j =  9.23998766e-005
CPcor = -9.5700e-008 (nominal)
CTcor =  3.2500e-006 (nominal)
```

ABCDM COEFFICIENTS

```
a =  1.51027111e-004
b =  1.58729073e+000
c = -1.04779766e+001
d = -8.43958712e-005
m =  3.8
CPcor = -9.5700e-008 (nominal)
```

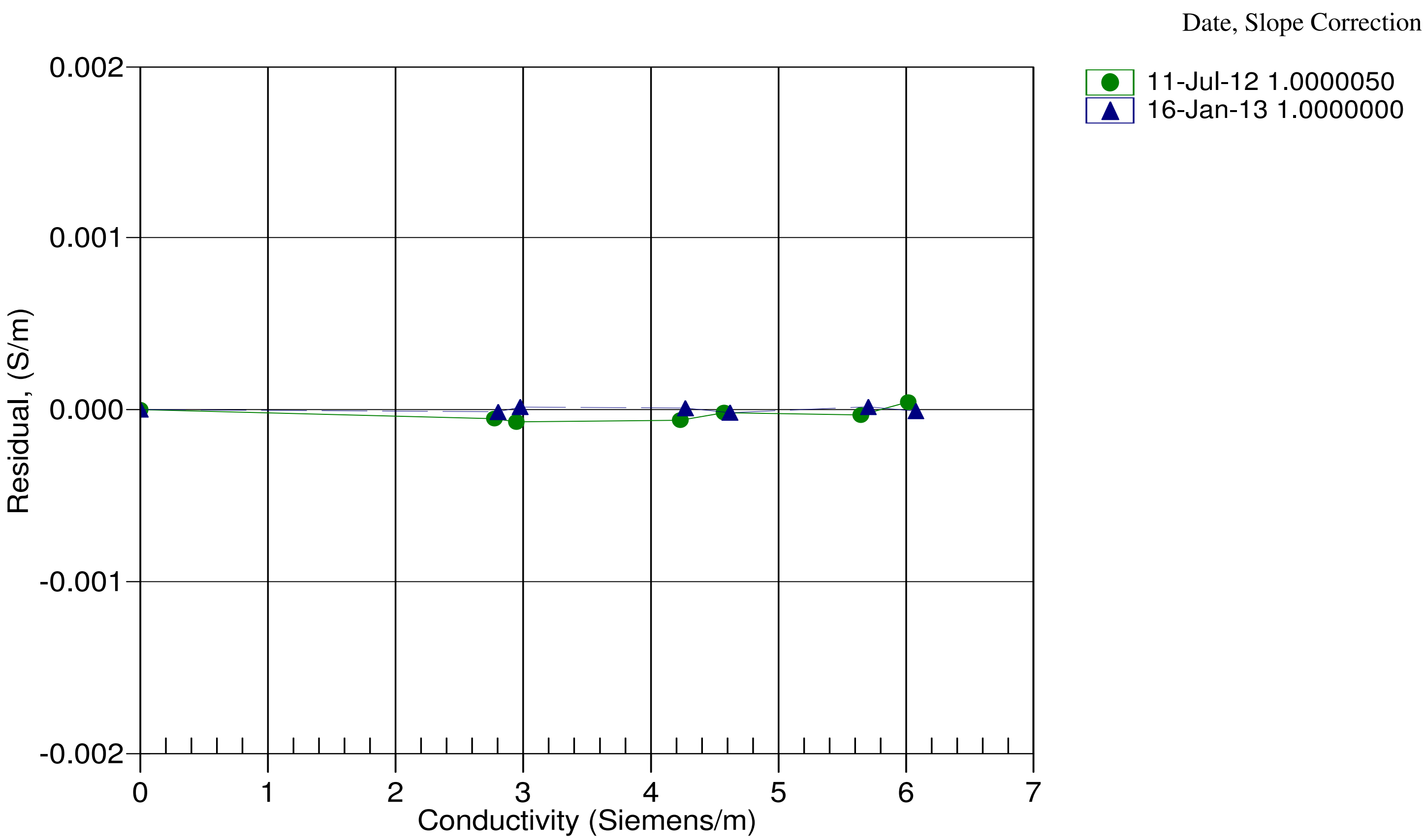
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.56860	0.00000	0.00000
-0.9999	34.8204	2.80488	4.92253	2.80487	-0.00001
1.0001	34.8203	2.97628	5.03070	2.97630	0.00002
15.0001	34.8201	4.27204	5.78283	4.27205	0.00001
18.5001	34.8200	4.61882	5.96794	4.61880	-0.00002
29.0001	34.8176	5.70252	6.51239	5.70253	0.00002
32.5001	34.8087	6.07483	6.68912	6.07482	-0.00001

Conductivity = $(g + hf^2 + if^3 + jf^4) / 10(1 + \delta t + \varepsilon p)$ Siemens/meter

Conductivity = $(af^m + bf^2 + c + dt) / [10 (1 + \varepsilon p)$ Siemens/meter

t = temperature[°C)]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = (instrument conductivity - bath conductivity) using g, h, i, j coefficients



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SENSOR SERIAL NUMBER: 2569
CALIBRATION DATE: 26-Jun-13

SBE4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Seimens/meter

GHIJ COEFFICIENTS

g = -1.04789607e+001
h = 1.58771515e+000
i = -6.94755467e-005
j = 1.09916171e-004
CPcor = -9.5700e-008 (nominal)
CTcor = 3.2500e-006 (nominal)

ABCDM COEFFICIENTS

a = 1.26022700e-004
b = 1.58740731e+000
c = -1.04782939e+001
d = -8.29428062e-005
m = 3.9
CPcor = -9.5700e-008 (nominal)

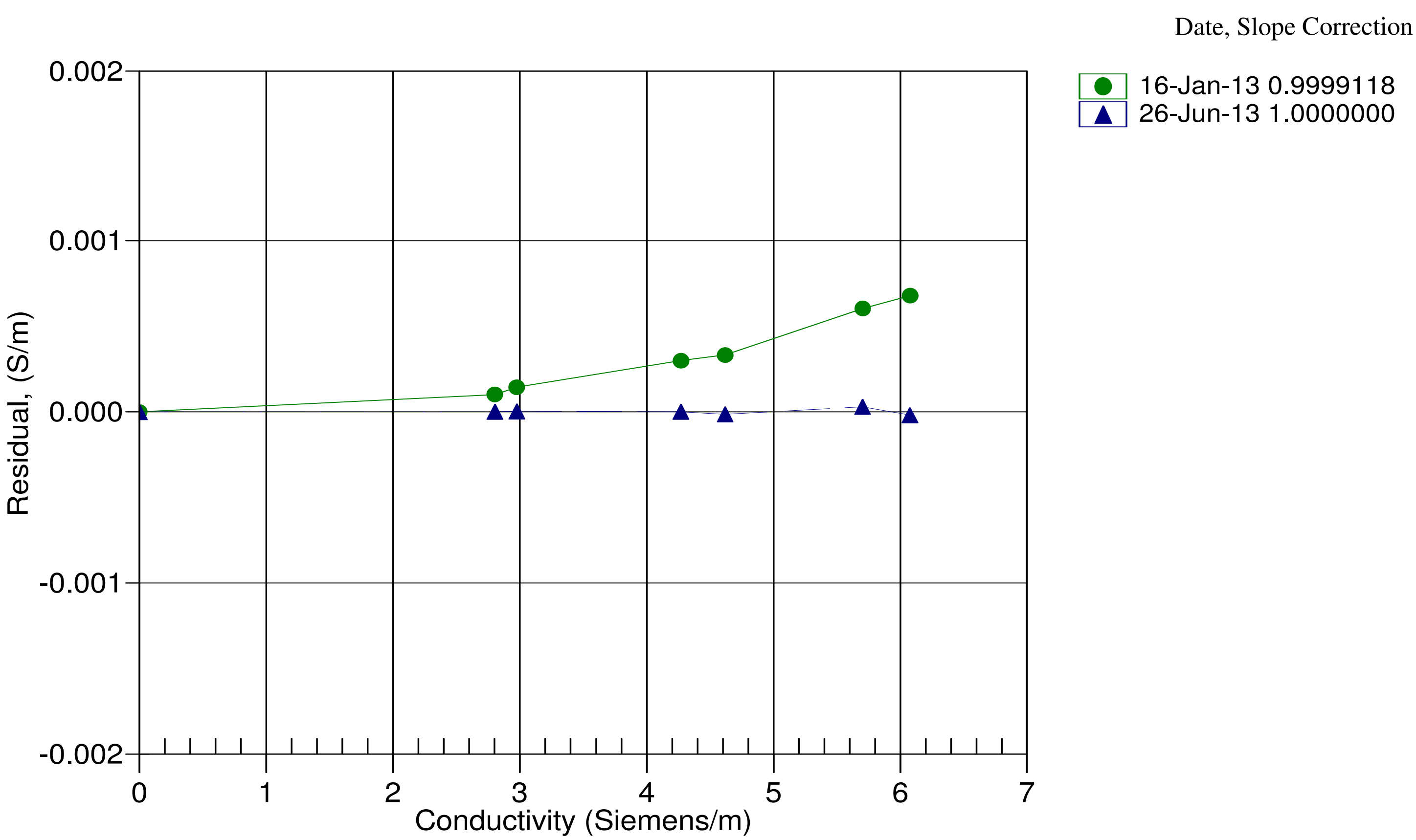
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.56861	0.00000	0.00000
-1.0000	34.7933	2.80290	4.92120	2.80290	0.00000
1.0000	34.7936	2.97421	5.02932	2.97421	0.00000
15.0000	34.7943	4.26920	5.78113	4.26920	0.00000
18.5000	34.7942	4.61575	5.96615	4.61574	-0.00001
29.0000	34.7933	5.69898	6.51041	5.69900	0.00003
32.5000	34.7892	6.07180	6.68737	6.07178	-0.00002

Conductivity = $(g + hf^2 + if^3 + jf^4) / 10(1 + \delta t + \varepsilon p)$ Siemens/meter

Conductivity = $(af^m + bf^2 + c + dt) / [10 (1 + \varepsilon p)$ Siemens/meter

t = temperature[°C)]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = (instrument conductivity - bath conductivity) using g, h, i, j coefficients



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SENSOR SERIAL NUMBER: 3058
CALIBRATION DATE: 02-Nov-12

SBE4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Seimens/meter

GHIJ COEFFICIENTS

```
g = -1.01005228e+001
h =  1.43975781e+000
i =  2.43997621e-004
j =  5.27890498e-005
CPcor = -9.5700e-008 (nominal)
CTcor =  3.2500e-006 (nominal)
```

ABCDM COEFFICIENTS

```
a =  2.29519565e-004
b =  1.43971195e+000
c = -1.00999619e+001
d = -8.13316861e-005
m =  3.5
CPcor = -9.5700e-008 (nominal)
```

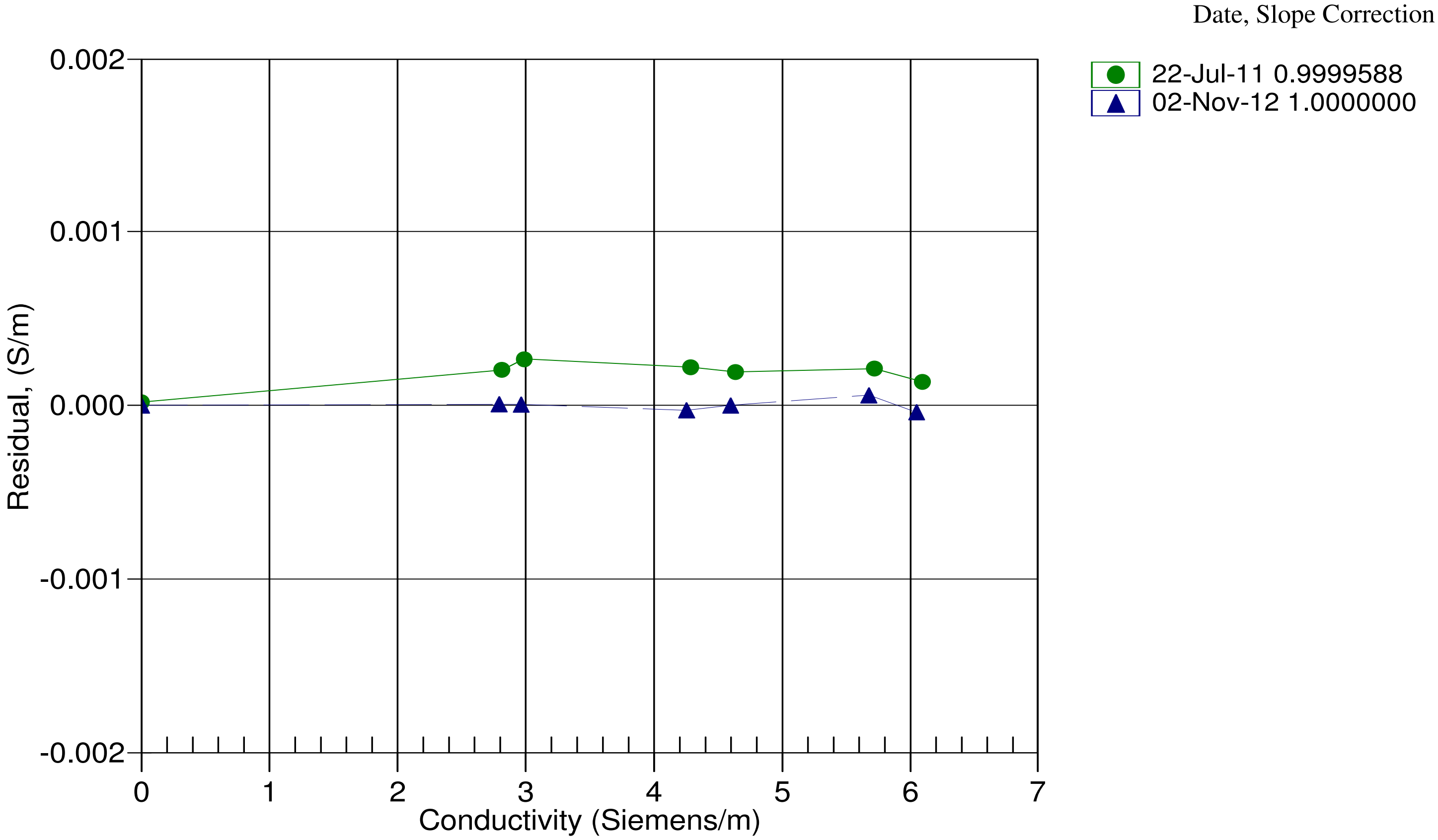
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.64773	0.00000	0.00000
-1.0000	34.6226	2.79042	5.13305	2.79043	0.00001
1.0000	34.6231	2.96102	5.24684	2.96102	0.00000
15.0000	34.6240	4.25051	6.03764	4.25048	-0.00003
18.5000	34.6236	4.59556	6.23217	4.59556	-0.00000
29.0000	34.6223	5.67411	6.80424	5.67417	0.00006
32.5000	34.6186	6.04540	6.99022	6.04536	-0.00004

Conductivity = $(g + hf^2 + if^3 + jf^4) /10(1 + \delta t + \varepsilon p)$ Siemens/meter

Conductivity = $(af^m + bf^2 + c + dt) / [10 (1 + \varepsilon p)$ Siemens/meter

t = temperature[°C)]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = (instrument conductivity - bath conductivity) using g, h, i, j coefficients



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SENSOR SERIAL NUMBER: 3058
CALIBRATION DATE: 27-Jun-13

SBE4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Seimens/meter

GHIJ COEFFICIENTS

```
g = -1.01015993e+001
h =  1.44026434e+000
i =  7.16368682e-005
j =  6.93263690e-005
CPcor = -9.5700e-008 (nominal)
CTcor =  3.2500e-006 (nominal)
```

ABCDM COEFFICIENTS

```
a =  1.14409422e-004
b =  1.44029202e+000
c = -1.01017161e+001
d = -8.46230813e-005
m =  3.8
CPcor = -9.5700e-008 (nominal)
```

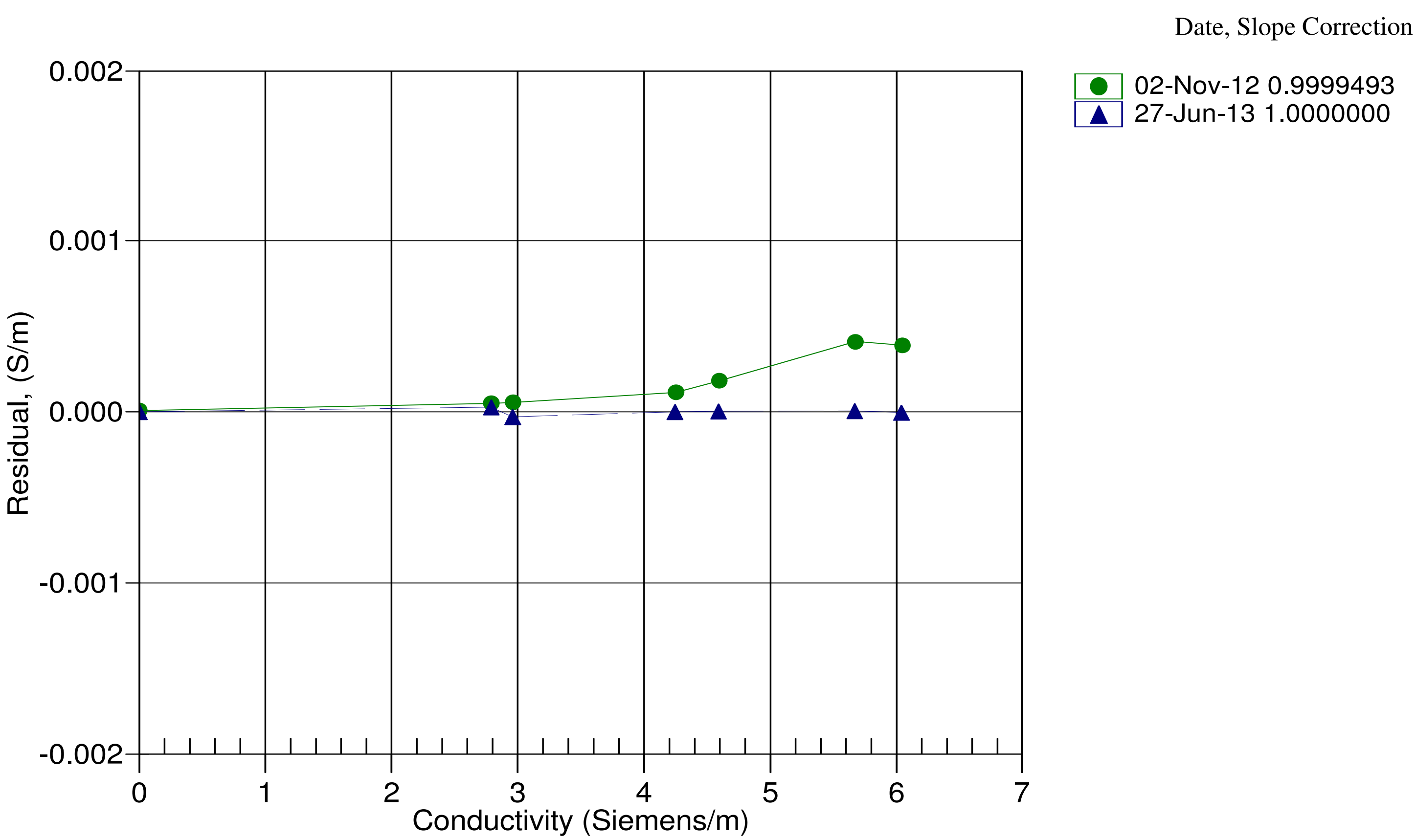
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.64772	0.00000	0.00000
-1.0000	34.5637	2.78612	5.13013	2.78614	0.00003
1.0000	34.5649	2.95652	5.24381	2.95649	-0.00003
15.0000	34.5654	4.24408	6.03389	4.24408	-0.00000
18.5000	34.5652	4.58864	6.22823	4.58864	0.00000
29.0001	34.5647	5.66574	6.79979	5.66574	0.00001
32.5001	34.5602	6.03637	6.98556	6.03637	-0.00000

Conductivity = $(g + hf^2 + if^3 + jf^4) / 10(1 + \delta t + \varepsilon p)$ Siemens/meter

Conductivity = $(af^m + bf^2 + c + dt) / [10 (1 + \varepsilon p)$ Siemens/meter

t = temperature[°C)]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = (instrument conductivity - bath conductivity) using g, h, i, j coefficients



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SENSOR SERIAL NUMBER: 1071
CALIBRATION DATE: 21-Jul-12

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS

Soc = 0.4611
Voffset = -0.5086
Tau20 = 1.25

A = -1.6343e-003
B = 3.9125e-005
C = -8.4413e-007
E nominal = 0.036

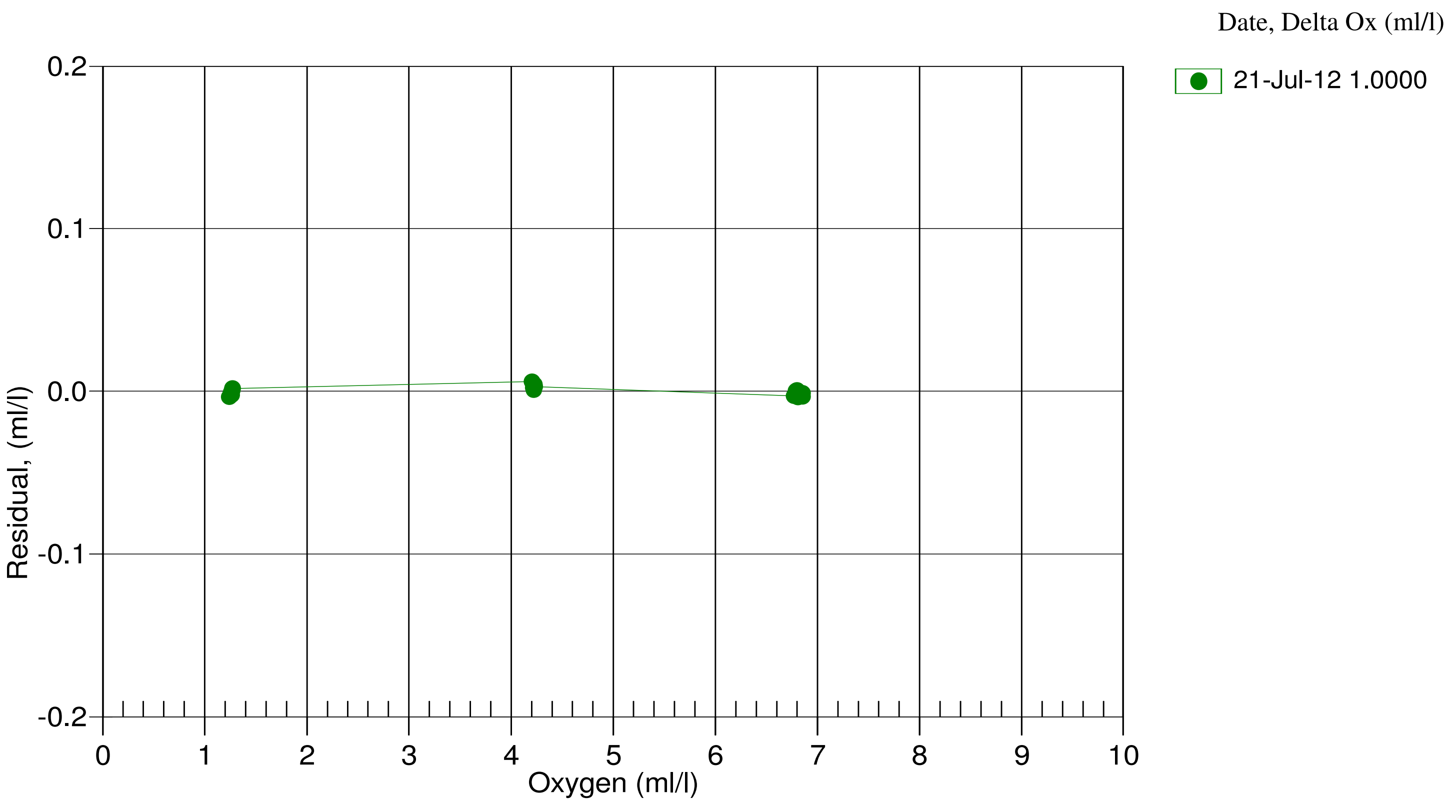
NOMINAL DYNAMIC COEFFICIENTS

D1 = 1.92634e-4
D2 = -4.64803e-2

H1 = -3.30000e-2
H2 = 5.00000e+3
H3 = 1.45000e+3

BATH OX (ml/l)	BATH TEMP ITS-90	BATH SAL PSU	INSTRUMENT OUTPUT(VOLTS)	INSTRUMENT OXYGEN(ml/l)	RESIDUAL (ml/l)
1.24	2.00	0.05	0.787	1.24	-0.00
1.25	6.00	0.05	0.822	1.25	-0.00
1.26	12.00	0.04	0.875	1.26	-0.00
1.27	20.00	0.04	0.950	1.26	-0.00
1.27	26.00	0.04	1.009	1.27	0.00
1.27	30.00	0.04	1.052	1.28	0.00
4.20	2.00	0.05	1.455	4.21	0.01
4.21	6.00	0.05	1.568	4.22	0.00
4.22	20.00	0.04	1.983	4.22	0.00
4.23	30.00	0.04	2.311	4.23	0.00
4.23	12.00	0.04	1.745	4.23	0.00
4.24	26.00	0.04	2.181	4.24	0.00
6.77	12.00	0.04	2.486	6.77	-0.00
6.79	20.00	0.04	2.880	6.79	0.00
6.80	6.00	0.05	2.217	6.80	0.00
6.81	2.00	0.05	2.038	6.80	-0.00
6.85	30.00	0.04	3.424	6.85	-0.00
6.86	26.00	0.04	3.211	6.85	-0.00

Oxygen (ml/l) = Soc * (V + Voffset) * (1.0 + A * T + B * T^2 + C * T^3) * OxSol(T,S) * exp(E * P / K)
V = voltage output from SBE43, T = temperature [deg C], S = salinity [PSU], K = temperature [Kelvin]
OxSol(T,S) = oxygen saturation [ml/l], P = pressure [dbar], Residual = instrument oxygen - bath oxygen



Dissolved Oxygen

MODEL : ARO-CAV

SERIAL : 105

DATE : August 7, 2012

Loaction : Calibration office of manfacture department at Kobe

Method : 2 points calibration of span and zero is carried out with 100% saturation water and nigrogen gas. Calibration should be done after making the instruments accustomed in the water and keeping saturation with air-bubbling. Outputs in saturated water and nitr

Film No= 16008A

A =	-40.0057	E =	0.0045
B =	130.010	F =	0.00
C =	-0.42837	G =	0.00
D =	0.0112	H =	1.00

Results :

Temperature at calibration[℃]	25
Air pressure at calibration[hPa]	992.2
Air saturation at calibration[%]	97.9

	Span output [%]	zero output [%]	Span Error [%]	Zero Error [%]
1st	97.3	0.0	-0.6	0.0
2nd	97.3	0.0	-0.6	0.0
3rd	97.3	0.0	-0.6	0.0

Judgement : **Good**

武石 '12.8.-8 下川 '12.8.10

Calibration group,

Manufacture department at Kobe

西村 '12.8.10 (達)

JFE Advantech Co., LTD

Temperature

MODEL : ARO-CAV

SERIAL : 105

DATE : August 7, 2012

Loaction : Calibration office of manfacture department at Kobe

Method : The instrument is calibrated in a constant temperature water tank.
5 outputs in n-value corresponding to 5 water temperature ranging from 3 to 31 degrees C are computed by least square method.
(To make the tank temperature constant, water is stirred. The reference temperature is measured by a thermometer)

Reference device : JFE Advantech self-made temperature probe calibrated by 'HART SCIENTIFIC' 1575A Super Thermometer (Platinum Thermo Resistance Probe NSR160) (certified bv JCSS and ITS90)

Temperature : Temperature(℃) $= A + B \times N + C \times N^2 + D \times N^3$

A = -5.455093E+00
B = 1.6693247E+01
C = -2.144412E+00
D = 4.5669980E-01

Reference [℃]	Output [V]	Calculated [℃]	Error [℃]
3.564	0.57794	3.564	0.000
10.433	1.06415	10.431	-0.002
17.167	1.56513	17.170	0.003
24.220	2.08868	24.218	-0.002
31.285	2.58698	31.286	0.001

Criteria for acceptability : 1. The errors in above form must be within ±0.02℃
2. After writing the calibration coefficients into instrument, one point check at any temperature must agree with the accuracy declared by the instrument.

Output Check :

Reference [℃]	Calculated [℃]	Error [℃]
23.251	23.256	0.005

Judgement : **Good**

Calibration group,

Manufacture department at Kobe

JFE Advantech Co., LTD

武 '12.8.-8 石

下 '12.8.10 川

西村 '12.8.10 (達)

PO Box 518
620 Applegate St.
Philomath, OR 97370

WET Labs

(541) 929-5650
Fax (541) 929-5277
www.wetlabs.com

C-Star Calibration

Date July 19, 2012 S/N# CST-327DR Pathlength 25

	Analog output
V_d	**0.059 V**
V_{air}	**4.613 V**
V_{ref}	**4.523 V**

Temperature of calibration water	**20.1** °C
Ambient temperature during calibration	**22.0** °C

Relationship of transmittance (Tr) to beam attenuation coefficient (c), and pathlength (x, in meters): $\mathbf{Tr = e^{-cx}}$

To determine beam transmittance: $\mathbf{Tr = (V_{sig} - V_{dark}) / (V_{ref} - V_{dark})}$

To determine beam attenuation coefficient: $\mathbf{c = -1/x * ln (Tr)}$

V_d Meter output with the beam blocked. This is the offset.
V_{air} Meter output in air with a clear beam path.
V_{ref} Meter output with clean water in the path.
Temperature of calibration water: temperature of clean water used to obtain V_{ref}.
Ambient temperature: meter temperature in air during the calibration.
V_{sig} Measured signal output of meter.

CLIVAR P2 - 2013

LEG 1

Transmissometer Air Calibration M&B Calculator
CST-327-DR

23-Mar-13

	Factory Cal Sheet Info			AVG Deck/Lab Readings		
Air Reading	4.613			4.546		
Water Reading	4.523			N/A		
Blocked Reading	0.059			0.06		
Air Temp.	17.096	17.100	17.081	17.068	17.063	17.048
M	20.512		Air Temp. Average			17.076
B	-1.231					

22-Apr-13

	Factory Cal Sheet Info			AVG Deck/Lab Readings		
Air Reading	4.613			4.554		
Water Reading	4.523			N/A		
Blocked Reading	0.059			0.059		
Air Temp.	20.277	20.767	20.305	20.281	20.275	20.270
M	20.471		Air Temp. Average			20.363
B	-1.208					

2-May-13

	Factory Cal Sheet Info			AVG Deck/Lab Readings		
Air Reading	4.613			4.513		
Water Reading	4.523			N/A		
Blocked Reading	0.059			0.059		
Air Temp.	20.624	20.618	20.613	20.626	20.647	20.653
M	20.660		Air Temp. Average			20.630
B	-1.219					

CLIVAR P2 - 2013

LEG 2

Transmissometer Air Calibration M&B Calculator
CST-327-DR

22-May-13

	Factory Cal Sheet Info			AVG Deck/Lab Readings		
Air Reading	4.613			4.528		
Water Reading	4.523			N/A		
Blocked Reading	0.059			0.059		
Air Temp.	18.203	18.265	18.334	18.379	18.398	18.365
M	20.590		Air Temp. Average			18.324
B	-1.215					

1-Jun-13

	Factory Cal Sheet Info			AVG Deck/Lab Readings		
Air Reading	4.613			4.512		
Water Reading	4.523			N/A		
Blocked Reading	0.059			0.059		
Air Temp.	17.652	17.659	17.677	17.635	17.633	17.650
M	20.664		Air Temp. Average			17.651
B	-1.219					

CCHDO Data Processing Notes

Date	Person	Data Type	Action	Summary
2013-05-15	Johnson, Mary	CTD/BTL/SUM	Submitted	to go online

P02W / Leg 1 Bottle and CTD data - very few updates expected, but possible, in the next month. Documentation is nearly ready, will be submitted within the next day or two after a few more comments on the numerous problems are added to it.

2013-05-21	Johnson, Mary	CrsRpt	Submitted	to go online

Documentation for P02W Leg 1 in 3 parts (numbered in sequence). It is probably near-final, pending Jim Swift's (chief scientist's) approval.

2013-05-21	Staff, CCHDO	CrsRpt	Website Update	Available under 'Files as received'

The following files are now available online under 'Files as received', unprocessed by the CCHDO.

P02W-2013_Report_part3.pdf
P02W-2013_Report_part2.pdf
P02W-2013_Report_part1.pdf

2013-05-21	Staff, CCHDO	CTD	Website Update	Available under 'Files as received'

The following files are now available online under 'Files as received', unprocessed by the CCHDO.
p02w_ctd.zip

2013-05-21	Staff, CCHDO	CTD	Website Update	Available under 'Files as received'

The following files are now available online under 'Files as received', unprocessed by the CCHDO.
p02w_nc.zip

2013-05-21	Staff, CCHDO	BTL/CTD	Website Update	Available under 'Files as received'

The following files are now available online under 'Files as received', unprocessed by the CCHDO.

p02w_ct1.zip
p02w_bottle_files.zip
p02w_event_files.zip

2013-05-22	Kappa, Jerry	CrsRpt	Website Update	Preliminary PDF version online

I've placed a new PDF version of the cruise report:

p02_318M20130321do.pdf

into the directory: /co2clivar/pacific/p02/p02_318M20130321/.

It includes all the reports provided by the cruise PIs, summary pages and CCHDO data processing notes, as well as a linked Table of Contents and links to figures, tables and appendices.

2013-05-22	Johnson, Mary	CrsRpt	Submitted	to go online - all pts in one pdf

Documentation for P02W Leg 1 with all 3 parts in a single pdf. It is probably near-final, pending Jim Swift's (chief scientist's) approval. (this is my 6th or 7th attempt to get the 3-in-1 merged documentation in... internet keeps cutting out on the ship)

2013-06-07	Staff, CCHDO	CrsRpt	Website Update	Available under 'Files as received'

The following files are now available online under 'Files as received', unprocessed by the CCHDO.

P02W-2013_Report_All.pdf

Date	Person	Data Type	Action	Summary
2013-07-10	Johnson, Mary	BTL	Submitted	P02W Data updates to go online

Updates to various parameters and codes for bottle data (oxygen and nutrients) and CTD data. CTD T,S,O corrections have been updated since the original submission. Bottle date and time stamps are now the bottom date/time for each cast instead of the date/time for each trip. Updated documentation will be submitted within the week.

2013-07-10	Johnson, Mary	CTD	Submitted	P02W Data updates to go online

Updates to various parameters and codes for CTD data; CTD T,S,O corrections have been updated since the original submission. CTD date and time stamps are now the bottom date/time for a cast instead of the start date/time of the cast. Updated documentation will be submitted within the week.

2013-07-10	Johnson, Mary	BTL	Submitted	P02E Final data to go online

This is the "final" ODF version of bottle data; any further updates will be submitted by each group directly to CCHDO. Cruise documentation will be submitted within the week.

2013-07-10	Johnson, Mary	CTD	Submitted	P02E Final data to go online

This is the "final" ODF version of P02E CTD data. The PI for transmissometer data is Wilf Gardner (TAMU). We have only submitted "raw" data converted to voltages for transmissometer and fluorometer in these files. Cruise documentation will be submitted within the week.

2013-07-11	Staff, CCHDO	CTD	Website Update	Available under 'Files as received'

The following files are now available online under 'Files as received', unprocessed by the CCHDO.

p02w_nc.zip
p02w_ctd.zip
p02w_ct1.zip

2013-07-11	Staff, CCHDO	BTL	Website Update	Available under 'Files as received'

The following files are now available online under 'Files as received', unprocessed by the CCHDO.

p02w_bottle_files.zip

2013-07-12	Johnson, Mary	CrsRpt	Submitted	Final STS/ODF documentation for P02W

Final STS/ODF documentation for P02W in 2 zip files:

1. p02w_CruiseReport.zip (contains the pdf and .txt versions of the cruise report)
2. p02w_ForJKappa.zip (contains the Figures in .eps or .ps formats, and the original .pdf, .doc or .xls files submitted to us, which we converted to pdf files for the final cruise report)

2013-07-17	Kappa, Jerry	CrsRpt	Website Update	Final leg 1 PDF online

I've placed a new PDF version of the cruise report:

p02_318M20130321do.pdf

into the directory: /co2clivar/pacific/p02/p02_318M20130321/.

It includes all the reports provided by the cruise PIs, summary pages and CCHDO data processing notes, as well as a linked Table of Contents and links to figures, tables and appendices.