5.2.Description of LEG2

Date de rédaction du dossier : 15 JANVIER 2007

Année demandée : 2009	**Chef de mission principal**		**Autre(s) chef(s) de mission**
Durée des travaux (hors transits port-zone de travail) : 35.6 days without transits			
Période *(si impératif) : Jan.-Feb. 2009 (austral summer)*	**Nom Prénom :**	Xavier CARTON	
Zone : continental margin south of South Africa (within the Agulhas Current)	**Organisme :**	IUEM-UBO	
Pays dont les eaux territoriales sont concernées: South Africa	**Laboratoire :**	Laboratoire de Physique des Océans- UMR6523 CNRS/IFREMER/UBO	
Pays dont la zone économique est concernée : South Africa	**Adresse :**	UFR Sciences, 6 avenue le Gorgeu, CS93837, 29238 Brest Cedex 3	
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Travaux : Hydrological samplings (CTD/Niskin and Go-Flo casts, in situ pumping), physical observations (XBTs, surface floats, ADCP, Seasor, currentmenter moorings collection), Rafos float seeding, acoustic source mooring, atmospheric observations, surficial sediments sampling.

Navire(s) souhaité(s) par ordre de préférence : *Pourquoi Pas ?*

Engin(s) sous-marin(s) : No
Gros équipements: winches, rosette(s), Seasor, Okthopus surficial sediments corer, moorings recovery, ADCP, XBTs, aerosols collector, containers.

Nécessité d'une campagne pour récupération d'engins ? No. The currentmeter moorings will have been deployed from a South African ship in January 2008; funding for this operation was requested from the LEFE program end of 2006. Leg 2 will recover the moorings.

Equipes scientifiques et techniques embarquées
En France : LPO (Brest), LEMAR (Brest), LEGOS (Toulouse), CEREGE (Aix-en-Provence), LOV (Villefranche-sur-Mer), LSCE (Gif-sur-Yvette), IPGP-Univ.P7 (Paris), LOBB (Banyuls-sur-Mer), LMGEM (Marseille)
A l'étranger : Univ. of Liverpool (UK), Univ. of Cape Town (SA), Rhodes Univ. (SA), Univ. Autonoma de Barcelona (Spain), AWI (GR), Univ. Federal Fluminense (Brazil), RSMAS (USA), Lamont-Doherty/Columbia Univ. (USA)

Equipes scientifiques et techniques à terre
En France : the same as here above + IRD (Brest) + LOCEAN (Paris)
A l'étranger: the same as here above + Univ. of East Anglia (UK), CSIR (SA)

Type de campagne : Recherche scientifique - ~~Recherche technologique~~ - ~~Essai technique~~

Thème de la campagne : Specific study of the physical and bio- and geo-chemical exchanges across the continental margin of South Africa in the context of the BONUS-GOODHOPE project. The whole BONUS-GOODHOPE project addresses study of the physics and bio-geochemistry of the Southern Ocean south of South Africa during the International Polar Year to acquire key data sets on dynamics and processes and for better understanding the role of the Southern Ocean in the global climate. This project has strong links with the International Polar Year (IPY), with the International CLIVAR Southern Ocean GOODHOPE project, the IPY-GEOTRACES, the IPY-ICED and the IPY-CASO, as well with the CLIVAR/CliC/SCAR-Southern Ocean, International IMBER, GOOS and GODAE. The BONUS-GOODHOPE project is based on two LEG's, the first one at large scale in 2008 from South of Africa towards the southern branch of the Antarctic Circumpolar Current in the Southern Ocean, and the second at meso- and sub-meso-scales, one year later in 2009 within the continental margin south of South Africa. Both LEG's complete each other since they are essential to understand the dynamical and bio-geochemical exchanges between the Southern Ocean with the south Atlantic and the Indian Ocean as a whole. The specificity of LEG 2 is to measure shelf-deep ocean exchanges through the continental margin of the Agulhas Bank. In particular, physical structures (eddies and filaments) will be sampled at high resolution via Seasoar and VMADCP transects, and associated heat and momentum fluxes will be quantified. The mechanisms underlying these exchanges (cyclonic eddies of the Agulhas Current or cold tongue of the shelf extruding offshore) will be analyzed. TEI's will be measured to quantify the cross-slope exchanges and the sources regions and the transport of tracers measured offshore. Physical measurements will be complemented by satelilte data and model output to interpret the synoptical structure of the oceanic variability near the Agulhas Bank.

Cette proposition s'inscrit dans une série de campagnes : OUI - ~~NON~~ (2 missions= LEG1 et LEG2)
Si oui nom du programme ou du chantier : BONUS-GOODHOPE (2007-2011)
Année de démarrage : 2008 (LEG1) Année prévue de fin : 2009 (LEG2)

Cette proposition est rattachée à des programmes nationaux ou internationaux avec comité scientifique : OUI ~~NON~~
Si oui lesquels : LEFE (actions IDAO et CYBER), International Polar Year, CLIVAR, GEOTRACES, IMBER, GOOS, CORIOLIS-MERCATOR
Envoyer une copie de ce dossier de proposition de campagne aux responsables des programmes concernés

S'agit-il d'une première demande ? : ~~OUI~~ - NON (2ème demande)
Si il y a eu une précédente demande fournir une copie du rapport de la commission l'ayant évaluée (voir Paragraphe D)

Sampling strategy and stations description

The general sampling strategy of LEG-2 consists of measuring and characterizing the water masses along several sections across the Agulhas Current, the Agulhas Bank shelf and slope, at high resolution. This will allow the investigation of the processes governing physical and bio-geochemical exchanges across the continental margin south of South Africa. The high resolution proposed here will help us resolve meso- and submeso-scale structures which achieve the turbulent variability on and along the shelf, and which participate in the exchanges. They will be related to the upstream variability of the Agulhas Current measured by currentmeters.

More specifically, the **sampling physical strategy** of LEG-2 consists of four distinct parts:

1°) A currentmeter mooring transect upstream the Agulhas Current (***RC*** in Figure 2) in order to monitor the

variability advected by the current before it reaches the Agulhas Bank. This transects extends from 27.30E; 34.20S to 27E ; 33.40S. Four currentmeter moorings will be installed for an one year duration; water and solid samples will be collected either. One mooring will be installed on the continental shelf ; composed of a 300 kHz ADCP in a lander at about 120m depth, its beams will span the whole water column upwards. A SBE25 probe will provide T and S near the bottom. The second mooring will be similar, but located on the continental slope near 450m depth and comprising a 75kHz ADCP instead of a 300 kHz ADCP. Its beams will also mesure currents in the whole water column locally. The third and fourth moorings are composed of classical currentmeters (a priori Aquadopp6000's). The currentmeters on mooring 3 will be at depths 150, 400, 800, 1200, 2000m on the outer edge of the continental slope, with SBE25 probes at 250, 600, 1000 and 1600m so as to measure the internal (cyclonic shear) side of the Agulhas Current and the STSW and RSW. The currentmeters on mooring 4 will be at depths 150, 400, 600, 1200, 3000m on the abyssal plain, with SBE25 probes at 250 and 900m so as to measure the external (anticyclonic shear) side of the Agulhas Current and the STSW, SICW, AAIW and NADW. The objective is to relate fluctuations measured at this location with fluctuations (and in particular meanders and cyclonic eddies) of the Agulhas Current downstream.
These moorings will be deployed for one year; the present project is to deploy them early 2008 with a South African R/V ship (chartered for 3 days) from MCM and to recover them during LEG-2.

2°) Three sections perpendicular to the continental slope, to assess the evolution of the Agulhas Current proper and of its associated mesoscale features downstream – on the one hand – and the zonal differences of the shelf circulation – on the other hand. These three sections and the currentmeter transect will comprise hydrological and biogeochemistry stations to characterize the water masses, the tracers and their evolution due to entrainment, mixing, turbulence and cross-slope exchanges. High resolution is recommended on the shelf and slope to identify small-scale features such as filament, but also in the deep ocean to obtain a precise transect of the Agulhas Current, for computation of its sensitivity to barotropic and baroclinic instabilities. Therefore a 5MN resolution was chosen. Also, surface to bottom CTD and LADCP measurements will be performed at each station to determine the 3D structure of water masses and of currents and to complement the deep Lagrangian float measurements proposed by L Beal in her project. Finally, correlations of the deep structure of transverse currents with surface variability measured by satellite will be achieved. Note that en-route VM-ADCP measurements will be performed between each station, which will allow a finer correlation of deep flow with surface signals.
These three sections and the currentmeter transect will comprise hydrological and as well as biogeochemistry stations to characterize the water masses, the tracers and their evolution due to mixing, turbulence and cross-slope exchanges.

3°) Three sections along the continental slope:

(3.1) one on the continental shelf (***RS***), which will cross the Port Alfred upwelling and which will be continued much farther west to obtain a complete view of the zonal structure of the water masses and circulation on the shelf (in particular the cold ridge and the features due to the upwellings). This section will be achieved at high resolution (with a seasoar) due to the small scales of the circulation on the shelf. Technical feasibility of use of a seasoar in shallow areas is being tested by our SHOM partners. If this feasibility is not reachable, a glider will be used, since shelf currents are not as intense as the Agulhas Current. In particular, the cold ridge on the shelf will be crossed.

(3.2) one along the continental slope (***RM***) which will provide estimates of cross-slope exchanges at high resolution (with a seasoar). The method will associate TS and fluorimetry measurements by the Seasoar with velocity measurements by VM-ADCP. Therefore measurements will be performed as much as possible along the 400m isobath.

(3.3) one offshore of the Agulhas Current which will provide information on the alongstream structure of the Agulhas Current (on its southern flank) and therefore in southward turbulent fluxes (***RE***). Hydrological boxes will thus be constitued by the hydrological sections for heat, salt and tracer budgets. An inverse model will be applied to these boxes to compute the local recirculations.

4°) A focused and detailed study of a cyclone with biogeochemical measurements, fast hydrological transect (XBT) and deployment of GPS-tracked buoys (Surdrifts) drogued at subsurface (in Central Waters).

We will also benefit from a collaboration with L Beal's project of measuring the NADW eddies south of Africa. This project was proposed to NSF (Annexe 2). It aims at tracking NADW from the slope current west of South Africa with the help of 30 RAFOS floats (10 isopycnic, 20 isobaric) deployed at depths ranging between 2600 and 3000m. 6 sound sources will be moored in the Cape Basin and in Natal Valley to insonify both basins and the whole vicinity of the Agulhas Bank (see Figure 3). These floats are supposed to be in part trapped in deep NADW eddies and to follow either the Agulhas Return Current or to drift into the Natal Valley where they may be sampled by the CTD/LADCP sections. The presence of these sound sources may be used to locate floats at shallower depths (the Beal's project shows that the SOFAR channel rises close to the surface in the Agulhas Current.

Specific strategy for the TEIs: in order to constrain the evolution of the distribution of the TEIs in response to the shelf input, we need to collect samples upstream from, within and downstream from the contact area (ie zonal sections) together with about 5 sediment cores (including the pore waters). In addition, the quantification of coast-open ocean gradients requires meridional sections. As a whole, *9 super stations* are required, identified as the red stars in Figure 2. At these stations, Niskin, Go-Flo and in situ pumps will be deployed for a complete documentation of the dissolved and particulate phases.

This strategy aims to help answer the main questions proposed in the previous section: what is the 3D structure of water masses on the Agulhas Bank and how can they extend towards shelf break? how do meanders and cyclones of the Agulhas Current grow? How do they, and the continental shelf features, participate in cross-slope exchanges? How do these exchanges alter the water masses along the Agulhas Bank? And finally, what are the tracer sources and distributions along the South African continental margin?

Information gathered by hydrological and LADCP stations of Leg1 will provide a complementary view of the water masses and currents on the western side of the Agulhas Bank. Also they will provide an estimate of the inflow of NADW before deep eddies of NADW are formed (they are hypothesized to form by entrainment under Agulhas rings or by instabilitity of the slope current at the southern tip of the Agulhas Bank). Thus we will have a complete view of the surface and deep currents in the region (warm and cold routes) and the largest possible view of the (surface and deep) eddy variability associated with the boundary currents (Agulhas Current and slope current).

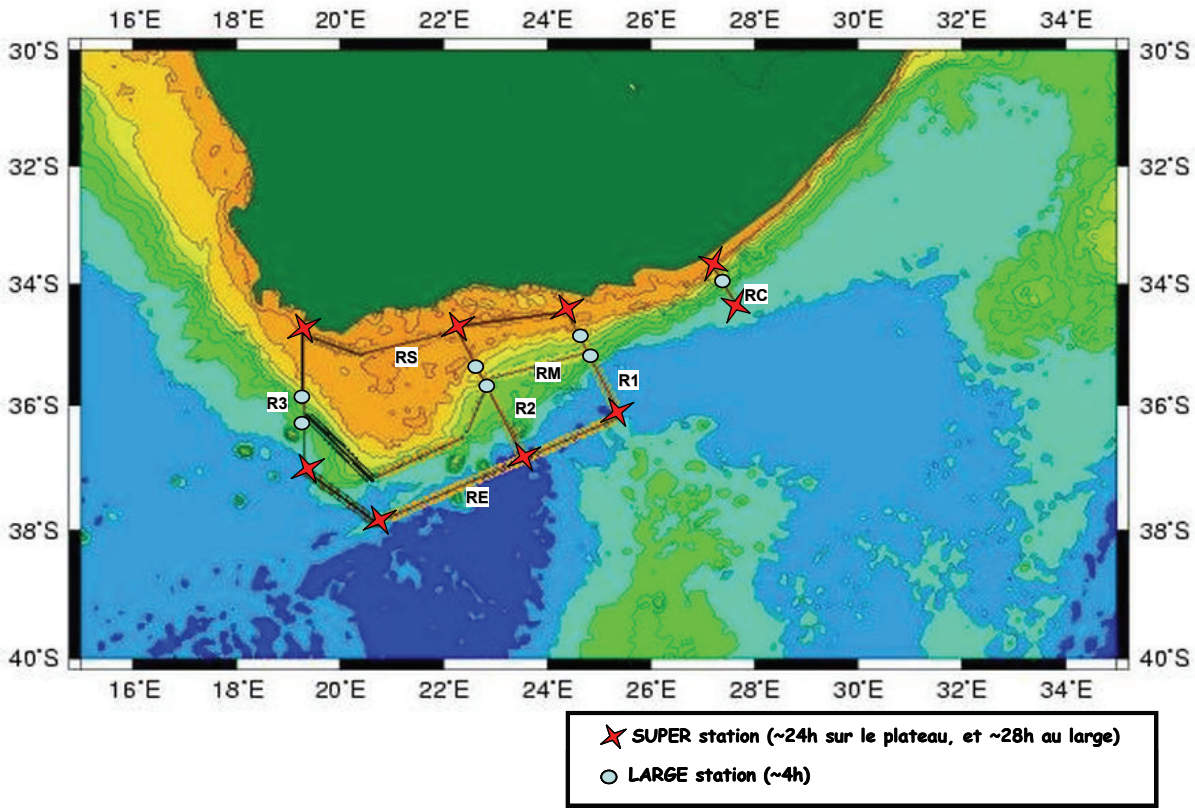

***Figure 2**- Sampling map of LEG-2*

Cruise track and stations for LEG2 are shown in Figure 2.
According to differences in the sampling, its time consumption and the analytical resolution/performance for the several parameters, **two types of stations for the TEI's and bio-geochemical parameters** are planned (Figure 2): LARGE stations (7 in total, ~4h each) and SUPER station (9 in total, with 5 deep stations in the open ocean of ~28 h each and 4 shallow stations above the continental margin of ~24 h each). These stations are described as following:

- *LARGE station*: one CTD/ Niskin rosette cast (0 m-bottom) and one Go-Flo cast (0-bottom), PVM5 deployment (0-max. 3000 m). Parameters: CTD parameters, biological parameters (chl-a, pigments, primary production, plankton taxonomy), macro- and micro-nutrients, tracers and isotopes, particles levels, DIC, TA, pH, DOC/POC/PIC. 7 large stations will be achieved in total = **7 large stations** of **4 hours** each, ie **1.2 days**.
- *SUPER station*: one cast for *in-situ* pumps (0 m-bottom), two CTD/Rosette casts (0 m-bottom), one cast with multiple corer (0 m-bottom), one Go-Flo cast (0 m-bottom), PVM5 deployment (0 m-max. 3000 m), large volume sampling for process studies (~40 L sampled at one sampling-depth at the chl-a maximum using an additional Go-Flo shallow cast). Parameters: CTD parameters, biological parameters (chl-a, pigments, taxonomy of phytoplankton, primary production), macro- and micro-nutrients, tracers and isotopes, particles levels, sediments & core parameters, DIC, TA, pH, POC/DOC/PIC, process studies (Fe bioavailability, zooplankton feeding, Si regeneration, N uptake). A total of **9 super stations** will be achieved, with 5 super stations of 28 hours each away from the continental margin (deep stations), and 4 super stations of 24 hours each within the continental margin (shallow stations), representing thus a total of **10 days**.

The **schedule of LEG2** is as following:

Departure from Cape Town.
- PRELIMINARY TRANSIT towards median point of section R3 (18.50E, 36.10S) – about 120 Nq, or 12h
- SECTION Continental Margin RM with Seasoar, 360 Nq at 5 knots or 72h. End at 24.40E, 35.10S.
- TRANSIT towards the southernmost point of section RC (27.30E, 34.20S), 160 Nq, or 16h
- Currentmeter SECTION RC: One Super station (28h) at the southern point, one large station above the slope (4h), one Super station (24h) on the continental shelf, installing four currentmeter moorings (2 classical in the open ocean, two moored ADCP in anti-trawling cages on the slope and on the shelf). One CTD-LADCP station at each mooring. Total mooring time 36h (including transit).

- TRANSIT from the northernmost point of RC (27N, 33.40S) to the north of section R1 (24.15E, 34.15S): 150 Nq, or 30h with seasoar (crossing Port Alfred upwelling in its largest extent)
- SECTION R1 from North to South: 120 Nm. One Super station (28h) on the continental shelf, two large stations above the slope (2x4h), one Super station (24h) at the southern point, hydrological stations (CTD/LADCP) every 5 Nm (or 22 stations): 36h for stations, 12h for transit
- External SECTION RE (first part from 25.15E, 36.10S to the southern point of R2: 23.30E, 36.50S: 120 Nm. Hydrological stations (CTD/LADCP) every 20 Nm (or 5 stations): 15h for stations, 12h for transit
- SECTION R2 from South to North (to 22E, 34.40N): 140 Nm. One Super station (28h) at the southern point, two large stations above the slope (2x4h), one Super station (24h) on the continental shelf, hydrological stations (CTD/LADCP) every 5 Nm (or 26 stations): 40h for stations, 14h for transit
- TRANSIT towards the north of section R1 (24.15E, 34.15S): 120 Nq, or 12h
- Seasoar SECTION RS on the continental shelf from the north of R1 to the north of R3: 480 Nm at 6 knots, or 80h
- SECTION R3 from (18.50E, 34.40S) to (18.50E, 37S): 140 Nm. One Super station (28h) on the continental shelf, two large stations above the slope (2x4h), one Super station (24h) at the southern point, hydrological stations (CTD/LADCP) every 5 Nm (or 26 stations): 40h for stations, 14h for transit
- End of external SECTION RE from (18.50E, 37S) to (23.30E, 36.50S): 250 Nm. Hydrological stations (CTD/LADCP) every 20 Nm (or 12 stations): 36h for stations, 12h for transit
- SPECIFIC STUDY of a CYCLONE west of section R3. 1 Super station: 28 h + XBT casts: 30h + buoy seeding : 12h : total 70 h
- Deploying 6 acoustic sound sources and 30 floats : 6 days (144h) – see Figure 3.
- Final TRANSIT towards Cape Town: 52 h.

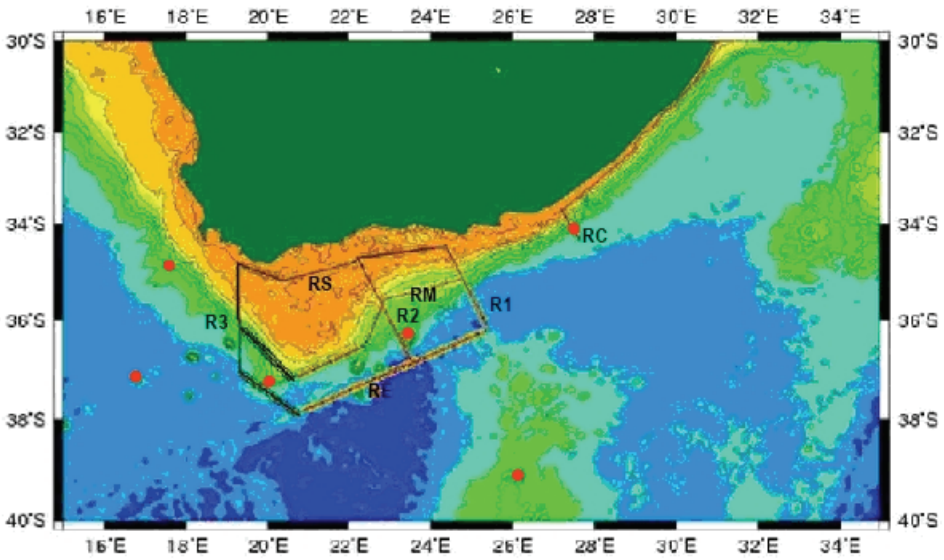

***Figure 3**- Position of acoustic (red circles) proposed by L. Beal (RSMAS, Miami) to insonify the region for Rafos float deployment (poitions superimposed on the hydrological network*

Underway measurements

Along the section, the 38 kHz VM ADCP will record currents down to 1000m depth ; salinity, temperature, pCO_2 are also recorded in surface waters, as well as meteorological conditions (including wind speed, air temperature, air-masses trajectories,…), aerosols and rain events. Remote sensing will provide near-real time satellite data support.

Ship-time for LEG2

It must be recalled that additional ship time (with a chartered vessel from MCM) will be requested end of 2007, early 2008 to deploy the currentmeter moorings.

Type of stations	Number of station	Time per station (hours)	Time (days)
HYDROGRAPHIC	91	1.72	6.55
LARGE	7	4	1.2
SUPER	5 deep & 4 shallow	28 & 24	10
XCTD Casts	45	0.67	1.25
Total station time			**20**
Seasor survey			**7.6**
Moorings	4		**1.5**

Acoustic sources, floats and buoys			**6.5**
Total transit time[a]			**3**
Total shiptime for LEG-2			**38.6**

[a] Including the inter-stations transit and the transit on the way-back to Cape Town, calculated using 10 knots ship-speed.

Notes importantes sur la durée des stations LARGE et SUPER, et donc sur le temps bateau:

(1°) En ce qui concerne les opérations sur Go-Flo, une demande d'équipement du Parc Instrumental de l'INSU a été formulée de notre part en décembre 2006 auprès de N. Papineau, sous le suivi du dossier par P. Raimbault, pour l'acquisition d'une Rosette « propre », de 24 bouteilles Go-Flo avec des joints en Téflon, d'un câble Kevlar d'au moins 4000 m, d'un treuil et d'un container de prélèvement « propres » adaptés. Si nous obtenons cet équipement de prélèvement « ultra-propre » (au moins la Ti-frame avec 24 bouteilles Go-Flo attachées sur cette frame + câble aramide + treuil), les durées des stations LARGE et SUPER seront réduites du fait de la réduction du temps des Go-Flo-casts, d'environ 2.75 jours pour le LEG-2.

(2°) Les personnes travaillant au laboratoire Océanographique de Villefranche/mer (LOV) sur le PVM5 (G. Gorsky, M. Picheral et L. Stemman) veulent développer un système de Profileur de Vidéo Marin miniaturisé qui pourra d'une part aller jusqu'à 6000 m et d'autre part qui pourra s'attacher sous la rosette-Niskin (6 kE sont demandés à LEFE dans le projet BONUS-GOODHOPE pour développer cet appareillage avec des co-financements par ailleurs). Le développement de cet outil permettrait également de réduire les durées des stations LARGE et SUPER d'environ 0.67 jours pour le LEG-2.

Ainsi avec l'acquisition du système de prélèvement propre et la miniaturisation du PVM5, le temps bateau pour le LEG-2 passerait de ***38.6 jours*** *à* ***35.18 jours.***