# A. Cruise narrative

## Highlights

Cruise designation: RF21-06, RF21-07, RF21-08 (WHP-P03 revisit)

a. EXPOCODE: RF21-06 49UP20210719

RF21-07 49UP20210827

RF21-08 49UP20210920

b. Chief scientist: NAGAI Naoki

Atmospheric Environment and Ocean Division

Atmosphere and Ocean Department

Japan Meteorological Agency (JMA)

c. Ship name: R/V Ryofu Maru

d. Ports of call: RF21-06: Leg 1: Tokyo (Japan) – Shimizu (Japan)

Leg 2: Shimizu (Japan) – Tokyo (Japan)

RF21-07: Tokyo (Japan) –Tokyo (Japan)

RF21-08: Tokyo (Japan) – Tokyo (Japan)

e. Cruise dates (JST): RF21-06: Leg 1: 19 July 2021 – 24 July 2021

Leg 2: 28 July 2021 – 17 August 2021

RF21-07: 27 August 2021 – 16 September 2021

RF21-08: 20 September 2021 – 14 October 2021

f. Principal Investigator (Contact person):

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## Cruise Summary

RF21-06, RF21-07 and RF21-08 cruises were carried out during the period from July 19 to October 14, 2021. The cruises started from the east of Okinawa Island, Japan, and sailed eastern, thereafter to 179°E along approximately 24°N. This line (WHP-P03) was observed by JMA in 2013 as CLIVER (Climate Variability and Predictability Project) / GO-SHIP (Global Ocean Ship-based Hydrographic Investigations Program). In the cruises, we also conducted hydrographic observation along other sections (see Figure A.1). For some parameters, we included these data to determine coefficients to calculate data and to evaluate data quality. These data were not reported here, but available from the JMA (https://www.data.jma.go.jp/gmd/kaiyou/db/vessel\_obs/data-report/html/ship/ship\_e.php?year  
=2021&season=summer).

A total of 89 stations were occupied using a Sea-Bird Electronics (SBE) 36 position carousel equipped with 10-liter Niskin water sample bottles, a CTD system (SBE911plus) equipped with SBE35 deep ocean standards thermometer, JFE Advantech oxygen sensor (RINKO III), Teledyne Benthos altimeter (PSA-916D), and Teledyne RD Instruments L-ADCP (300kHz). To examine consistency of data, we carried out the observation repeatedly twice at stations of 24°15’N, 144°50’E (Stns.42 and 43) and 24°00’N, 165°00’E (Stns.70 and 71) at the cross points of each cruise. Station location and cruise track are shown in Figure A.1.

At almost all station, full-depth CTDO2 (temperature, conductivity (salinity) and dissolved oxygen) profile were taken, and up to 36 water samples were taken and analyzed. Water samples were obtained from 10 dbar to approximately 10 m above the bottom. In addition, surface water was sampled by a stainless steel bucket at each station. Sampling layer is designed as so-called staggered mesh as shown in Table A.1 (*Swift*, 2010). The bottle depth diagram is shown in Figure A.2.

Water samples were analyzed for salinity, dissolved oxygen, nutrients, dissolved inorganic carbon (DIC), total alkalinity (TA), pH, CFCs (CFC-11, CFC-12, and CFC-113), SF6 and phytopigments (chlorophyll-a and phaeopigment). Underway measurements of partial pressure of carbon dioxide (*p*CO2), temperature, salinity, chlorophyll-*a*, subsurface current, bathymetry and meteorological parameters were conducted along the cruise track.

At RF21-06, R/V Ryofu Maru departed from Tokyo (Japan) on July 19, 2021. We deployed an underwater glider of Meteorological Research Institute (MRI) in the south of Honshu, thereafter she called for Shimizu (Japan) on July 24 (Leg 1). She left Shimizu on July 28. After X-BT observation was conducted along Tokara Channel (JMA-Line), the hydrographic cast of CTDO2 was started at the first station (Stn.1 (26°04’N, 127°54’E; RF6860)) in the east of Okinawa Island on July 31. RF21-06 consisted of 42 stations from Stn.1 to Stn.42 (24°15’N, 144°50’E; RF6901). Observation at Stn.42 was finished on August 13. She returned at Tokyo on August 17 (Leg 2).

At RF21-07, she departed from Tokyo on August 27. After the hydrographic cast of CTDO2 was observed in north of 32°N along 137°E meridian (JMA-Line), restarted at the same station (Stn.43 (24°15’N, 144°50’E; RF6910)) with the RF21-06 last station on August 31. RF21-07 consisted of 28 stations from Stn.43 to Stn.70 (40°00’N, 165°00’E; RF6937). Observation at Stn.70 was finished on September 10. She returned at Tokyo on September 16.

At RF21-08, she departed from Tokyo on September 20. After the hydrographic cast of CTDO2 was observed off the Boso Peninsula (JMA-Line), restarted at same station (Stn.71 (24°00’N, 165°00’E; RF6956)) with the RF21-07 last station on September 28. RF21-08 consisted of 19 stations from Stn.71 to Stn.89 (24°00’N, 179°00’E; RF6974). Observation at Stn.89 was finished on October 5. She returned at Tokyo on October 14. Location data of stations is shown in Table A.2.

Seven Argo floats were deployed along the cruise track. The information of deployed the float is listed in Table A.3.

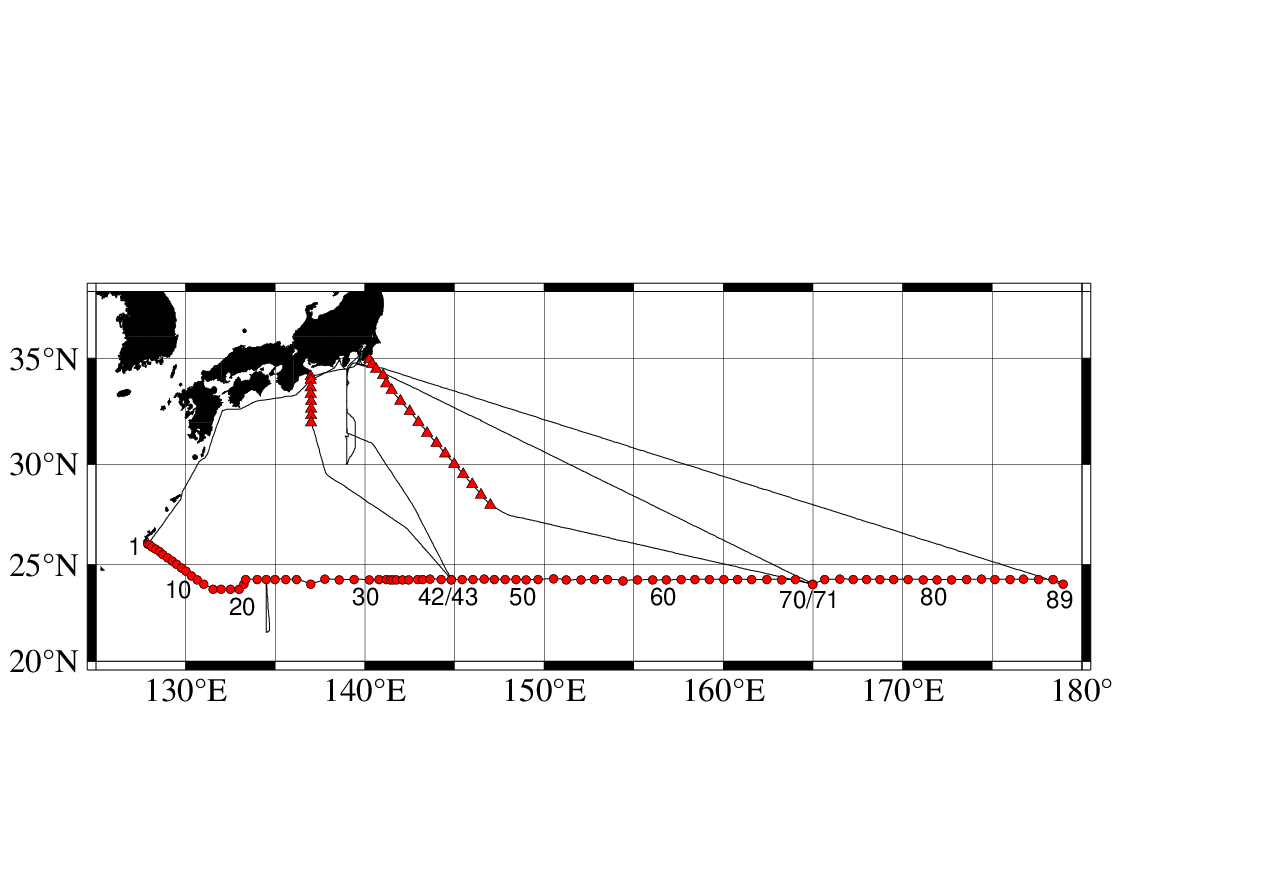


Figure A.1. Location of hydrographic stations and cruise track of RF21-06, RF21-07 and RF21-08. Circles indicate stations along WHP-03. Triangles show stations along other sections. These data are available from the JMA (https://www.data.jma.go.jp/gmd/kaiyou/db/vessel\_obs/data-report/html/ship/ship\_e.php?year=2021&season=summer).

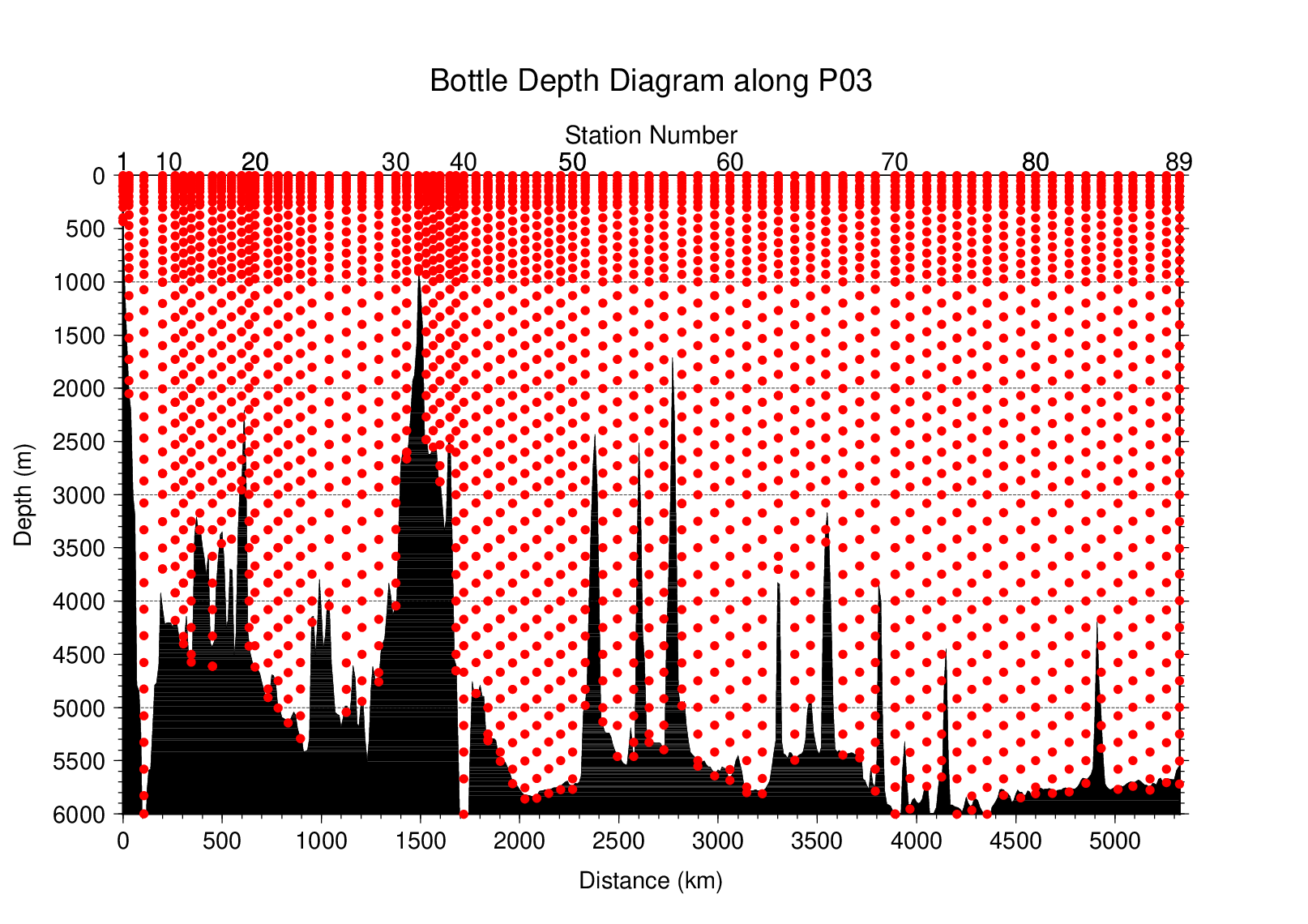


Figure A.2. The bottle depth diagram for WHP-P03 revisit.

Table A.1. The scheme of sampling layer in meters.

|  |  |  |  |
| --- | --- | --- | --- |
| ***Bottle***  ***count*** | ***Scheme 1*** | ***Scheme 2*** | ***Scheme 3*** |
| ***1*** | 10 | 10 | 10 |
| ***2*** | *25*  *50*  *75*  *100*  *125*  *150*  *200*  *250*  *300*  *400*  *500*  *600*  *700*  *800*  *900*  *1000*  *1200*  *1400*  *160050* | *25* | *25* |
| ***3*** | 50 | 50 | 50 |
| ***4*** | *75* | *75* | *75* |
| ***5*** | 100 | 100 | 100 |
| ***6*** | *125* | *125* | *125* |
| ***7*** | 150 | 150 | 150 |
| ***8*** | 200 | 200 | 200 |
| ***9*** | 250 | 250 | 250 |
| ***10*** | 300 | 330 | 280 |
| ***11*** | 400 | 430 | 370 |
| ***12*** | 500 | 530 | 470 |
| ***13*** | 600 | 630 | 570 |
| ***14*** | 700 | 730 | 670 |
| ***15*** | 800 | 830 | 770 |
| ***16*** | 900 | 930 | 870 |
| ***17*** | 1000 | 1070 | 970 |
| ***18*** | 1200 | 1270 | 1130 |
| ***19*** | 1400 | 1470 | 1330 |
| ***20*** | 1600 | 1670 | 1530 |
| ***21*** | 1800 | 1870 | 1730 |
| ***22*** | 2000 | 2070 | 1930 |
| ***23*** | 2200 | 2270 | 2130 |
| ***24*** | 2400 | 2470 | 2330 |
| ***25*** | 2600 | 2670 | 2530 |
| ***26*** | 2800 | 2870 | 2730 |
| ***27*** | 3000 | 3080 | 2930 |
| ***28*** | *3250* | *3330* | *3170* |
| ***29*** | 3500 | 3580 | 3420 |
| ***30*** | *3750* | *3830* | *3670* |
| ***31*** | 4000 | 4080 | 3920 |
| ***32*** | *4250* | *4330* | *4170* |
| ***33*** | 4500 | 4580 | 4420 |
| ***34*** | *4750* | *4830* | *4670* |
| ***35*** | 5000 | 5080 | 4920 |
| ***36*** | 5250 | 5330 | 5170 |
| ***37*** | 5500 | 5580 | 5420 |
| ***38*** | 5750 | 5830 | 5670 |
| ***39*** | 6000 | 6000 | 6000 |

At some deep stations over 36 layers, some layers shown in italic may be skipped.

Table A.2(a). Station lists of RF21-06 cruise. The ‘RF’ column indicates the JMA station identification number.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***Station*** | | ***Location*** | |  | ***Station*** | | ***Location*** | |
| *Stn.* | *RF* | *Latitude* | *Longitude* |  | *Stn.* | *RF* | *Latitude* | *Longitude* |
| 1 | 6860 | 26-03.90 N | 127-53.90 E |  | 22 | 6881 | 24-15.17 N | 134-30.04 E |
| 2 | 6861 | 25-59.98 N | 127-59.72 E |  | 23 | 6882 | 24-14.75 N | 135-00.08 E |
| 3 | 6862 | 25-54.10 N | 128-08.83 E |  | 24 | 6883 | 24-15.01 N | 135-36.90 E |
| 4 | 6863 | 25-46.45 N | 128-20.85 E |  | 25 | 6884 | 24-15.10 N | 136-11.81 E |
| 5 | 6864 | 25-38.14 N | 128-32.74 E |  | 26 | 6885 | 24-00.04 N | 136-59.82 E |
| 6 | 6865 | 25-30.20 N | 128-44.77 E |  | 27 | 6886 | 24-15.07 N | 137-47.76 E |
| 7 | 6866 | 25-20.14 N | 128-59.86 E |  | 28 | 6887 | 24-14.83 N | 138-34.74 E |
| 8 | 6867 | 25-10.18 N | 129-15.11 E |  | 29 | 6888 | 24-14.85 N | 139-24.96 E |
| 9 | 6868 | 25-00.13 N | 129-29.84 E |  | 30 | 6889 | 24-14.76 N | 140-16.00 E |
| 10 | 6869 | 24-50.19 N | 129-45.10 E |  | 31 | 6890 | 24-14.97 N | 140-47.95 E |
| 11 | 6870 | 24-39.93 N | 130-00.22 E |  | 32 | 6891 | 24-15.00 N | 141-11.78 E |
| 12 | 6871 | 24-26.92 N | 130-19.88 E |  | 33 | 6892 | 24-14.92 N | 141-24.02 E |
| 13 | 6872 | 24-15.01 N | 130-39.86 E |  | 34 | 6893 | 24-14.90 N | 141-34.13 E |
| 14 | 6873 | 23-59.90 N | 131-00.01 E |  | 35 | 6894 | 24-14.86 N | 141-46.03 E |
| 15 | 6874 | 23-45.01 N | 131-32.94 E |  | 36 | 6895 | 24-14.98 N | 142-06.96 E |
| 16 | 6875 | 23-45.10 N | 131-59.84 E |  | 37 | 6896 | 24-14.88 N | 142-26.86 E |
| 17 | 6876 | 23-44.95 N | 132-29.96 E |  | 38 | 6897 | 24-14.89 N | 142-57.16 E |
| 18 | 6877 | 23-45.08 N | 133-00.07 E |  | 39 | 6898 | 24-15.11 N | 143-14.01 E |
| 19 | 6878 | 24-00.15 N | 133-15.02 E |  | 40 | 6899 | 24-15.19 N | 143-37.94 E |
| 20 | 6879 | 24-15.08 N | 133-21.93 E |  | 41 | 6900 | 24-14.99 N | 144-15.03 E |
| 21 | 6880 | 24-15.14 N | 134-00.02 E |  | 42 | 6901 | 24-14.98 N | 144-50.05 E |

Table A.2(b). Same as Table A.2(a) but for RF21-07 cruise.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***Station*** | | ***Location*** | |  | ***Station*** | | ***Location*** | |
| *Stn.* | *RF* | *Latitude* | *Longitude* |  | *Stn.* | *RF* | *Latitude* | *Longitude* |
| 43 | 6910 | 24-14.78 N | 144-50.00 E |  | 57 | 6924 | 24-10.81 N | 154-26.73 E |
| 44 | 6911 | 24-15.11 N | 145-26.81 E |  | 58 | 6925 | 24-15.09 N | 155-13.86 E |
| 45 | 6912 | 24-14.81 N | 146-02.93 E |  | 59 | 6926 | 24-14.92 N | 156-03.88 E |
| 46 | 6913 | 24-15.03 N | 146-40.09 E |  | 60 | 6927 | 24-14.81 N | 156-49.67 E |
| 47 | 6914 | 24-15.14 N | 147-14.89 E |  | 61 | 6928 | 24-14.88 N | 157-39.82 E |
| 48 | 6915 | 24-14.87 N | 147-50.69 E |  | 62 | 6929 | 24-15.11 N | 158-26.83 E |
| 49 | 6916 | 24-15.01 N | 148-26.77 E |  | 63 | 6930 | 24-15.48 N | 159-13.96 E |
| 50 | 6917 | 24-14.68 N | 149-01.31 E |  | 64 | 6931 | 24-14.87 N | 160-02.89 E |
| 51 | 6918 | 24-15.60 N | 149-39.81 E |  | 65 | 6932 | 24-15.23 N | 160-49.31 E |
| 52 | 6919 | 24-17.72 N | 150-31.21 E |  | 66 | 6933 | 24-15.18 N | 161-35.27 E |
| 53 | 6920 | 24-14.88 N | 151-15.01 E |  | 67 | 6934 | 24-15.07 N | 162-26.71 E |
| 54 | 6921 | 24-14.87 N | 152-03.97 E |  | 68 | 6935 | 24-14.75 N | 163-15.97 E |
| 55 | 6922 | 24-14.84 N | 152-49.86 E |  | 69 | 6936 | 24-15.16 N | 164-02.68 E |
| 56 | 6923 | 24-14.96 N | 153-33.80 E |  | 70 | 6937 | 24-00.15 N | 164-59.83 E |

Table A.2(c). Same as Table A.2(a) but for RF21-08 cruise.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***Station*** | | ***Location*** | |  | ***Station*** | | ***Location*** | |
| *Stn.* | *RF* | *Latitude* | *Longitude* |  | *Stn.* | *RF* | *Latitude* | *Longitude* |
| 71 | 6956 | 23-59.86 N | 164-59.97 E |  | 81 | 6966 | 24-14.81 N | 172-44.88 E |
| 72 | 6957 | 24-14.86 N | 165-39.84 E |  | 82 | 6967 | 24-15.01 N | 173-34.91 E |
| 73 | 6958 | 24-14.90 N | 166-29.97 E |  | 83 | 6968 | 24-15.05 N | 174-24.87 E |
| 74 | 6959 | 24-15.07 N | 167-14.91 E |  | 84 | 6969 | 24-14.94 N | 175-10.02 E |
| 75 | 6960 | 24-15.06 N | 167-59.83 E |  | 85 | 6970 | 24-15.06 N | 175-59.99 E |
| 76 | 6961 | 24-14.86 N | 168-44.95 E |  | 86 | 6971 | 24-14.98 N | 176-44.72 E |
| 77 | 6962 | 24-15.06 N | 169-30.04 E |  | 87 | 6972 | 24-14.74 N | 177-34.95 E |
| 78 | 6963 | 24-15.19 N | 170-19.50 E |  | 88 | 6973 | 24-15.03 N | 178-24.76 E |
| 79 | 6964 | 24-14.78 N | 171-10.02 E |  | 89 | 6974 | 23-59.83 N | 178-59.81 E |
| 80 | 6965 | 24-14.89 N | 171-55.00 E |  |  |  |  |  |

Table A.3. Information of deployed float and buoy.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| ***Float*** | ***Date and Time*** | ***Position of deployment*** | | ***PI*** | ***Manufacturer*** |
| ***WMO number*** | ***of Deployment (UTC)*** | *Latitude* | *Longitude* |  |  |
| 2903684 | July 21, 2021  02:30 | 30-00.12 N | 138-58.76 E | JMA | ARVOR |
| 2903686 | August 1, 2021  18:50 | 25-00.07 N | 129-29.98 E | JMA | ARVOR |
| 2903687 | August 9, 2021  03:40 | 24-01.10 N | 136-57.35 E | JMA | ARVOR |
| 2903688 | August 11, 2021  07:35 | 24-14.46 N | 141-43.86 E | JMA | ARVOR |
| 2903691 | August 28, 2021  22:53 | 31-59.28 N | 137-00.83 E | JMA | ARVOR |
| 2903664 | October 1, 2021  00:32 | 24-17.32 N | 170-17.53 E | JAMSTEC | APEX |
| 2903665 | October 3, 2021  03:59 | 24-16.74 N | 175-06.94 E | JAMSTEC | APEX |

ARVOR: NKE Instrumentation (France)

APEX: Teledyne Webb Research (USA)

## List of Principal Investigators for Measurements

The principal investigators for each parameter are listed in Table A.4.

|  |  |  |
| --- | --- | --- |
| Table A.4. List of principal investigators for each parameter. | | |
| Hydrography | CTDO2 | CHIBA Yasuomi |
|  | Salinity | WADA Koichi |
|  | Dissolve oxygen | KAKUYA Keita |
|  | Nutrients | KAKUYA Keita |
|  | Phytopigments | KAKUYA Keita |
|  | DIC | ENYO Kazutaka |
|  | TA | ENYO Kazutaka |
|  | pH | ENYO Kazutaka |
|  | CFCs | ENYO Kazutaka |
|  | SF6 | ENYO Kazutaka |
|  | LADCP | CHIBA Yasuomi |
| Underway | Meteorology | NAGAI Naoki |
|  | Thermo-Salinograph | ENYO Kazutaka |
|  | *p*CO2 | ENYO Kazutaka |
|  | Chlorophyll *a* | KAKUYA Keita |
|  | ADCP | CHIBA Yasuomi |
|  | Bathymetry | CHIBA Yasuomi |
| Float | JMA | NAKAMURA Tetsuya |
|  | JAMSTEC | HOSODA Shigeki |

***Reference***

Swift, J. H. (2010): Reference-quality water sample data: Notes on acquisition, record keeping, and evaluation. *IOCCP Report No.****14****, ICPO Pub. 134, 2010 ver.1*