Eurofleets+

An alliance of European marine research infrastructure to meet the evolving needs of the research and industrial communities

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°. 824077

Cruise Report

FIGURE-CARING

RV Atlantic Explorer, Cruise No. 2215,

21/7/2022 – 30/7/2022

St Georges (Bermuda) – St Georges (Bermuda)

Mar Benavides and Lidia Carracedo

Table of Content s

1 Summary

The FIGURE-CARING cruise departed from Bermuda on 21st July 2022 towards the Gulf Stream. After a test station, we proceeded to sample two transects:

- North (crossing a cyclonic eddy and the Gulf Stream), 8 stations (8x2000m casts + 6x200m casts)
- South (crossing the Gulf Stream ~1º latitude below), 4 stations (4x1600m casts)

Once the station transects were completed, we proceeded to repeat the North transect performing underway sampling at 6 kn navigation speed. We arrived back to Bermuda on 30th July 2022.

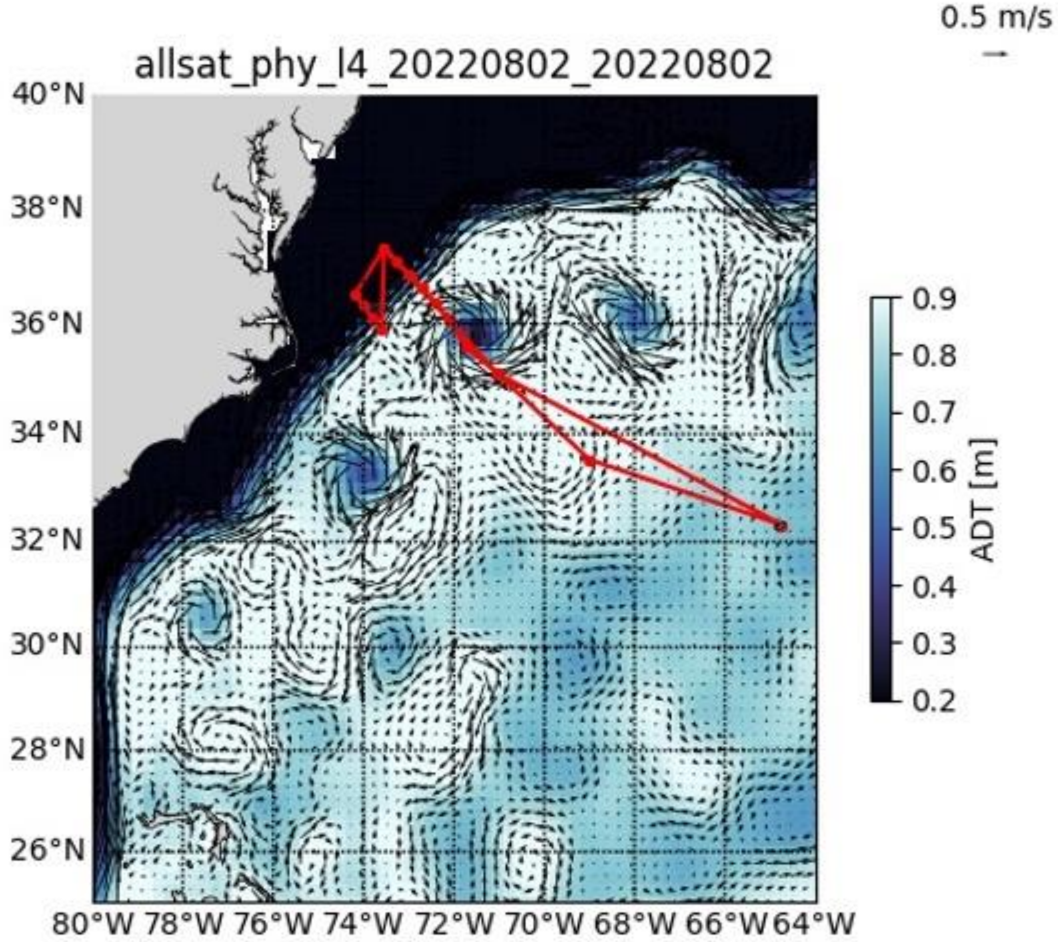


Fig. 1 *Working area and track chart of R/V Atlantic Explorer Cruise 2215 superimposed on ADT field.*

The changes in our sampling programme with respect to the original proposal include:

- **Reduction from 34 to 12 stations.** We note that to improve our water sampling budget, we performed 2 casts at each station (one shallow, one deep) instead of 1. Hence, the actual reduction is from 34 to 24. The reduction is due to a conjunction of causes including withdrawal of 5 participant researchers who could not find the funds to join our cruise, rough weather (see Captain reports in section 3.5), together with a need to slow down navigation speed (from 10.5 to 6 knots) due to the poor performance of the ship's ADCP (see section 3.3.1).
- **Cancellation of the ARGO deployment**. A BGC-Argo (temperature, salinity, pressure, oxygen, nitrate) was initially requested as part of the original program, but not granted by the funding agencies. We did count instead with the availability of more standard core-Argo floats (temperature, salinity, pressure). However, due to the surge in transportation costs linked to the ongoing energetic crisis, the shipment-

deployment cost-benefit of these core-Argo was not enough to overcome the tight budget restrictions of the project. Not being critical for achievement of the main scientific goals, the core-Argo shipment/deployment was thus discarded.

2 Research Programme/Objectives

This cruise is a merger of two projects: FIGURE and CARING. The objectives of each project are outlined below.

2.1. FIGURE-Fine scales shaping nitrogen flxation in the GUlf stREam

The biological fixation of dinitrogen (N2) by marine microbes called 'diazotrophs' sustains ~50% of primary production in the ocean, boosting CO2 absorption and mitigating climate change. Our knowledge of diazotroph diversity and activity (diazotrophy) derives from studies conducted at very distant spatiotemporal scales: i) discrete and short duration measurements in small seawater volumes isolated from the environment, and ii) spatial extrapolations and global models of diazotrophy projected over decades to centuries. The knowledge gap between these spatiotemporal scales impedes constraining nitrogen inputs and thus quantify and predict the ocean's potential to withdraw CO2. This gap lies at the fine scales: dynamic seawater structures <200>10-50 times faster than those available today, focusing on the Gulf Stream. Fine scales will be characterized by underway sensors of current speed, temperature and salinity, vertical nutrient fluxes and satellite altimetry data. The community composition will be examined by molecular biology methods. Diazotroph activity will be measured using high sensitivity trace gas analysis. Physical and biological data will be correlated to elucidate the effect of fine scales on diazotrophy and to assess their impact on nitrogen inputs to the ocean. The achievements of FIGURE will imply a break-through advance in oceanography and stimulate applications in biotechnology and environmental science, providing new tools, approaches and knowledge for climate change adaptation and mitigation.

2.2 CARING-CARbon Irrigation to the North-atlantic by the Gulf stream

Over the past 200 years human activities have emitted large amounts of CO2 into the atmosphere (namely anthropogenic carbon, C_{ant}) increasing the atmospheric CO2 content to unprecedented levels. The ocean absorbs about 30% of these emissions, acting as a net sink. Of the ocean basins, the North Atlantic is the one with the highest storage of C_{ant} per area. Yet, it is still uncertain how much of the Cant uptake occurs (locally) at subpolar latitudes or (remotely) in the subtropics; or what are the driving mechanisms ultimately regulating its storage at different temporal scales. CARING will provide a contemporary novel assessment of the downstream Gulf Stream carbon and nutrient transport and carbon uptake capacity conveyed by Gulf Stream intermediate waters poleward, so as to elucidate its role as first-order far field control to the nutrient and carbon irrigation to the North Atlantic. The sampling strategy comprises CTD and discrete sampling of the first 2000 dbar of the water-column, and continuous high-resolution underway sampling, the latter targeted at assessing the impact of the fine scale. The achievements of CARING will provide a small but significant step-forwards into narrowing down the current gap of knowledge about the Cant sink and storage variability, drivers, and related timescales.

3 Narrative of the Cruise

3.1 Sampling strategy

3.1.1 FIGURE sampling strategy

The cruise track was designed to cross sub/mesoscale features associated with the Gulf Stream such as rings and filaments. Such features are dynamic in space and time. To track their evolution, we used satellite images processed by the SPASSO software (https://spasso.mio.osupytheas.fr/). A SPASSO report was received onboard on a daily basis, permitting us to adjust the coordinates of our stations to target key sub/mesoscale features as well as the edges of the Gulf Stream.

For N2 fixation measurements, we sampled from CTD casts at ST0, ST1, ST2, ST3, ST4, ST6 and ST8. The transect between stations ST8 and ST1 was repeated on the way back to land at the end of the cruise as high spatial resolution underway sampling: sampling every 1h for DNA, every 3h for N2 fixation, at 6 kn navigation speed. The goal of combining discrete sampling (CTD-Rosette casts) with continuous sampling (underway) was to compare how low- and high-resolution sampling affects N2 fixation

3.1.2 CARING sampling strategy

CARING sampling plan was designed so as to highlight the role of the Gulf Stream as first-order far field control to the nutrient and carbon irrigation to the North Atlantic. Therefore, the sampling strategy consisted of two individual transects crossing the Gulf Stream zonally, spatially distanced by 110 km (~60nm). In addition, and with the same purpose as FIGURE of sampling sub/mesoscale features, we also targeted a cyclonic eddy as part of the northward section. In total, the N-section consisted of 8 CTD stations, and the S-section of 4- CTD stations. The focus of the CARING CTD-Rosette data collection comprised the first 2000-dbar of the water column. Additionally, continuous SADCP data; underway T, S, Chlorophyll and pCO2 data; and discrete pH samples from the underway system every 10-km, were collected.

3.2 General cruise narrative

After leaving Bermuda we steamed to ST0, a test station intentionally located in the center of an anticyclonic eddy (Fig. 1) where we performed a 2000 m CTD cast combining FIGURE and CARING sampling to test equipment and sample processing procedures.

Subsequently, our sampling program consisted of 12 stations arranged in a northern and southern transect (Fig. 1.1) followed by underway sampling by sailing backwards along the northern transect (stations ST8 to ST1). Ship operations including times and coordinates of all CTD casts are listed in Table 1. Science party operations (sampling, sample processing, analyses) are listed in Table 2.

3.3.1 Cruise logbook

(date as YYYYMMDD, time as HHMM local Bermuda time)

20220720

- 1000 start mob
- 1500 finished mob
- 1500 setting equipment in labs onboard

20220721

- 1400 safety briefing by RVAE crew
- 1600 leave BIOS
- 1900 co-chief scientist feeling bad, proceed to return to Bermuda
- 2320 offload scientist to St Georges by zodiac

20220722

- 0005 zodiac back onboard
- 0030 steaming to ST0
- 0815 science+crew meeting to explain cruise objectives and planning
- 1700 started DNA underway sampling
- 1700 taken test pH underway sample from main lab outlet causing decreased pressure in chemical lab's outlet (impaired DNA underway autosampling)
- 1800 reached edge of anticyclonic eddy centered at -67.855N 33.1955W
- 20040 ADCP is not working properly and provides data only down to ~300 m and very sparsely. UHDAS proposed slowing navigation speed to 6 kn to see how the system behaves.
- 2103 ADCP signal sailing at 6 kn does improve significantly

20220723

- 0020 arrival to ST0
- 0040 CTD in the water
- 0130 CTD at 2000 m
- 0241 CTD on deck
- 0245 depart to ST1
- 0700 Chief sci remarks after discussion with captain: Swell is coming from the west. When we were at ST0 the ship bow was pointing west so the pitching was highest and that affects ADCP data acquisition. Now we're sailing towards ST1 and we have a ~45º angle with the swell, so the pitching decreases and ADCP data looks better even when sailing at 10 kn.
- 0756 end underway DNA sampling
- 1005 decrease navigation speed from 10 kn to 7 kn for 15min to test ADCP performance
- 1032 increase navigation speed 8 kn for 15min to test ADCP performance
- 1050 increase navigation speed 10 kn
- 1646 arrival to ST1
- 1655 CTD-deep in water
- 1735 CTD-deep at bottom
- 1758 winch cable tangling up at 1300 m during downcast, proceeded to spin down some meters again to untangle and come back up to 1200 m
- 1850 CTD-deep at surface
- 1900 CTD-deep on deck - sampling begins, bottle 2 (supposedly at 2000 m) did not close properly as temperature measured in its water with a hand thermometer is 23ºC - started sailing back to original position
- 2007 CTD-deep sampling completed
- 2027 CTD-shallow in water
- 2125 CTD-shallow on deck
- 2138 depart to ST2

20220724

- 0217 arrival to ST2
- 0225 CTD-deep on water
- 0312 CTD-deep at bottom
- 0430 CTD-deep on deck
- Recovering position
- 0615 CTD-deep sampling complete
- 0617 CTD-shallow on water
- 1100 arrival to ST3
- 1105 CTD-deep in water
- 1150 CTD-deep at bottom
- 1305 CTD-deep on deck-recovering position
- 1415 CTD-deep sampling completed
- 1417 CTD-shallow in water
- 1434 CTD-shallow at bottom
- 1545 CTD-shallow on deck
- 1700 arrival to ST4
- 1705 CTD-deep in water
- 1915 CTD-deep sampling completed - departing to ST5
- 2150 arrival to ST5
- 2154 CTD-deep in water
- 2315 CTD-deep on deck - depart to ST6

20220725

- 0130 arrival to ST6
- 0133 CTD-deep in water
- 0212 CTD-deep at bottom

- 0305 CTD-deep on deck - start recovering position (current speed is 3.6 kn, so even with ship at full speed, we sail more slowly)
- 0425 CTD-shallow in water - it's raining a lot!!
- 0500 CTD-shallow on deck - depart to ST7
- 0710 arrival to ST7
- 0715 CTD-deep in water
- 0834 CTD-deep on deck - depart to ST8
- 1037 arrival to ST8 - wild waves
- 1045 CTD-deep on water
- 1117 CTD-deep at bottom
- 1205 CTD-deep on deck
- 1305 CTD-deep sampling completed - one bottle misfired, Lydia proceeds to repair it
- 1332 misfired bottle repaired
- 1335 CTD-shallow in water
- 1410 CTD-shallow on deck - depart to ST9
- 2220 arrival to ST9
- 2230 CTD-deep on water
- 2306 CTD-deep at bottom

20220726

- 0030 CTD-deep on deck
- 0115 arrival to ST10
- 0128 CTD-deep on water
- 0245 CTD-deep on deck - depart to ST11
- 0530 arrival to ST11
- 0542 CTD-deep on water
- 0700 CTD-deep on deck - depart to ST12
- 0925 arrival to ST12
- 0930 CTD-deep on water
- 1006 CTD-deep at bottom
- 1055 CTD-deep on deck
- 1100 start transit to ST13 at 9 knots
- 2100 arrival to ST13 (former ST8)
- Proceed to underway diazotrophy sampling at 6 knots

20220727

- Continued underway sampling every 1h for DNA and pH, every 3h for N2 fixation
- Sailing in zig zag because sailing straight into our route is against weather, 5 m tall waves, >20 knots wind

20220728

- 0800 last underway sampling time point
- 0800 finished transect at 6kn to cover the cyclonic eddy (ST1) - proceed to steam to Bermuda at 10-11 kn, weather permitting
- Continued filtration of 24h deck incubations
- Packing up

20220729

- 0800 Finished filtration of deck incubations
- Packing up
- 1930 arrival at Pennos Wharf (stay overnight due to low tide impeding entrance to BIOS)

20220730

- 0900 depart from Pennos Wharf

- 1000 arrival to BIOS
- 1030 demob starts
- 1500 demob ends

Table 1: Ship operations time course

Action	Date [YYYYMMDD]	Time [local]	Time [UTC]	Latitude [ºN]	Longitude [ºW]
Start mobilisation	20220720	9:30	12:30	32.32	64.75
End mobilisation	20220720	14:00	17:00	32.32	64.75
Steaming	20220721	16:00	19:00	32.32	64.75
Return to Bermuda	20220721	19:00	22:00	32.32	64.75
Offload scientist to St Georges by zodiac	20220721	23:20	2:20	32.32	64.75
Zodiac back onboard	20220722	0:05	3:05	32.32	64.75
Steaming	20220722	0:30	3:30	32.32	64.75
ST0 (test)	20220723	0:20	3:20	33.49	69.00
Steaming	20220723	2:45	5:45	33.49	69.00
ST1 deep cast	20220723	16:55	19:55	35.10	71.00
ST1 shallow cast	20220723	20:27	23:27	35.10	71.00
Steaming	20220723	21:38	0:38	35.10	71.00
ST2 deep cast	20220724	2:25	5:25	35.59	71.73
ST2 shallow cast	20220724	6:17	9:17	35.59	71.73
Steaming	20220724	7:02	10:02	35.59	71.73
ST3 deep cast	20220724	11:05	14:05	36.11	72.14
ST3 shallow cast	20220724	14:17	17:17	36.11	72.14
Steaming	20220724	14:52	17:52	36.11	72.14
ST4 deep cast	20220724	17:05	20:05	36.36	72.39
Steaming	20220724	19:15	22:15	36.36	72.39
ST5 deep cast	20220724	21:54	0:54	36.63	72.71
Steaming	20220724	23:15	2:15	36.63	72.71
ST6 deep cast	20220725	1:33	4:33	36.89	73.00
ST6 shallow cast	20220725	4:25	7:25	36.89	73.00
Steaming	20220725	5:00	8:00	36.89	73.00
ST7 deep cast	20220725	10:42	13:42	37.07	73.28
Steaming	20220725	11:56	14:56	37.07	73.28
ST8 deep cast	20220725	10:45	13:45	37.34	73.55

ST8 shallow cast	20220725	13:35	16:35	37.34	73.55
Steaming	20220725	14:10	17:10	37.34	73.55
ST9 deep cast	20220725	22:30	1:30	36.52	74.19
Steaming	20220726	0:30	3:30	36.52	74.19
ST10 deep cast	20220726	1:15	4:15	36.34	74.19
Steaming	20220726	2:45	5:45	36.34	74.19
ST11 deep cast	20220726	5:30	8:30	36.10	73.81
Steaming	20220726	7:00	10:00	36.10	73.81
ST12 deep cast	20220726	9:30	12:30	35.89	73.44
Steaming	20220726	11:00	14:00	35.89	73.44
Underway sampling start	20220726	21:00	0:00	35.10	71.00
Underway sampling end	20220728	8:00	11:00	36.11	72.14
Steaming	20220728	8:00	11:00	36.11	72.14
Arrival at St Georges	20220729	9:00	18:00		
Arrival at BIOS	20220730	10:00	9:30	32.32	64.75
Start demobilisation	20220730	11:00	10:00	32.32	64.75
End demobilisation	20220730	12:00	15:00	32.32	64.75

Table 2: Science party operations time course

Operation	Scientists involved	Date [YYYYMMDD]	Time [local]	Time [UTC]
start mobilisation	All	20220720	9:30	12:30
end mobilisation	All	20220720	14:00	17:00
safety briefing by RVAE crew	All	20220720	14:00	17:00
labs installation, equipment testing	All	20220720	15:00	18:00
science+crew meeting to explain cruise objectives and planning	All	20220722	8:30	11:30
started DNA underway sampling	Cora Hörstmann	20220722	17:00	20:00
taken test pH underway sample from main lab outlet causing decreased pressure in chemical lab's outlet (impaired DNA underway autosampling)	Marta López-Mozos, María Jesús Álvarez	20220722	17:00	20:00
test sailing at 6kn to improve ADCP data quality	Stéphanie Barrillon	20220722	21:03	0:03
arrival to ST0		20220723	0:20	3:20
sampling CTD ST0	All	20220723	2:41	5:41
incubation for nitrogen fixation ST0 CTD1	Olivier Grosso, Cora Hörstmann	20220723	3:45	6:45

Test pH analysis CTD ST0	Marta López-Mozos, María Jesús Álvarez	20220723	4:04	7:04
end underway DNA sampling of anticyclonic eddy centered at ST0	Cora Hörstmann	20220723	7:56	10:56
arrival to ST1		20220723	16:50	19:50
sampling ST1 deep cast	Marta López-Mozos, María Jesús Álvarez, Caroline Le Bihan, STéphanie Barrillon	20220723	19:07	22:07
ST1 shallow cast		20220723	21:25	0:25
Sampling ST1 shallow cast	Olivier Grosso, Cora Hörstmann, Angelina Klett	20220723	22:05	1:05
incubation for nitrogen fixation ST1 CTD2	Olivier Grosso, Cora Hörstmann	20220723	23:10	2:10
pH analysis CTD ST1 deep cast	Marta López-Mozos, María Jesús Álvarez	20220723	22:55	1:55
arrival to ST2		20220724	2:56	5:56
Filtration nitrogen fixation ST0 CTD1	Olivier Grosso	20220724	4:50	7:50
sampling ST2 deep cast	Marta López-Mozos, María Jesús Álvarez, Caroline Le Bihan, STéphanie Barrillon	20220724	4:38	7:38
ST2 shallow cast		20220724	6:17	9:17
Sampling ST2 shallow cast	Olivier Grosso, Cora Hörstmann, Angelina Klett	20220724	7:05	10:05
pH analysis CTD ST2 deep cast	Marta López-Mozos, María Jesús Álvarez	20220724	7:32	10:32
incubation for nitrogen fixation ST2 CTD2	Olivier Grosso	20220724	9:00	12:00
arrival to ST3		20220724	10:49	13:49
sampling ST3 deep cast	Marta López-Mozos, María Jesús Álvarez, Caroline Le Bihan, STéphanie Barrillon	20220724	12:30	15:30
ST3 shallow cast		20220724	14:17	17:17
pH analysis CTD ST3 deep cast	Marta López-Mozos, María Jesús Álvarez	20220724	14:48	17:48
Sampling ST3 shallow cast	Olivier Grosso, Cora Hörstmann, Angelina Klett, Mar Benavides	20220724	15:05	18:05
incubation for nitrogen fixation ST3 CTD2	Olivier Grosso, Cora Hörstmann, Angelina Klett, Mar Benavides	20220724	15:54	18:54
arrival to ST4		20220724	16:57	19:57

sampling ST4 deep cast	Marta López-Mozos, María Jesús Álvarez, Caroline Le Bihan, STéphanie Barrillon	20220724	18:26	21:26
pH analysis CTD ST4 deep cast	Marta López-Mozos, María Jesús Álvarez	20220724	20:53	23:53
arrival to ST5		20220724	20:48	23:48
filtration nitrogen fixation ST1 CTD2	Olivier Grosso	20220724	23:00	2:00
sampling ST5 deep cast	Marta López-Mozos, María Jesús Álvarez, Caroline Le Bihan, STéphanie Barrillon	20220724	23:15	2:15
pH analysis CTD ST5 deep cast	Marta López-Mozos, María Jesús Álvarez	20220725	1:04	4:04
arrival to ST6		20220725	1:28	4:28
sampling ST6 deep cast	Marta López-Mozos, María Jesús Álvarez, Caroline Le Bihan, STéphanie Barrillon	20220725	2:59	5:59
ST6 shallow cast		20220725	4:25	7:25
Sampling ST6 shallow cast	Olivier Grosso, Cora Hörstmann, Angelina Klett, Mar Benavides	20220725	5:00	8:00
pH analysis CTD ST6 deep cast	Marta López-Mozos, María Jesús Álvarez	20220725	5:29	8:29
incubation for nitrogen fixation ST6 CTD2	Olivier Grosso	20220725	6:00	9:00
arrival to ST7		20220725	7:00	10:00
filtration nitrogen fixation ST2 CTD2	Olivier Grosso	20220725	8:59	11:59
sampling ST7 deep cast	Marta López-Mozos, María Jesús Álvarez, Caroline Le Bihan, STéphanie Barrillon	20220725	9:30	12:30
pH analysis CTD ST7 deep cast	Marta López-Mozos, María Jesús Álvarez	20220725	11:47	14:47
arrival to ST8		20220725	10:37	13:37
sampling ST8 deep cast	Marta López-Mozos, María Jesús Álvarez, Caroline Le Bihan, STéphanie Barrillon	20220725	12:14	15:14
ST8 shallow cast		20220725	13:35	16:35
Oxygen analysis CTD ST0 to ST3 deep cast	Caroline Le Bihan	20220725	13:15	16:15
Sampling ST8 shallow cast	Olivier Grosso, Cora Hörstmann, Angelina Klett, Mar Benavides	20220725	14:00	17:00

incubation for nitrogen fixation ST8 CTD2	Olivier Grosso	20220725	14:55	17:55
pH analysis CTD ST8 deep cast	Marta López-Mozos, María Jesús Álvarez	20220725	14:59	17:59
filtration nitrogen fixation ST3 CTD2	Olivier Grosso	20220725	18:21	21:21
arrival to ST9		20220725	22:20	1:20
sampling ST9 deep cast	Marta López-Mozos, María Jesús Álvarez, Caroline Le Bihan, STéphanie Barrillon	20220725	0:00	3:00
pH analysis CTD ST9 deep cast	Marta López-Mozos, María Jesús Álvarez	20220726	1:29	4:29
arrival to ST10		20220726	1:15	4:15
sampling ST10 deep cast	Marta López-Mozos, María Jesús Álvarez, Caroline Le Bihan, STéphanie Barrillon	20220726	2:43	5:43
pH analysis CTD ST10 deep cast	Marta López-Mozos, María Jesús Álvarez	20220726	4:32	7:32
arrival to ST11		20220726	5:30	8:30
sampling ST11 deep cast	Marta López-Mozos, María Jesús Álvarez, Caroline Le Bihan, STéphanie Barrillon	20220726	6:58	9:58
filtration nitrgen fixation ST6 CTD2	Olivier Grosso	20220726	7:30	10:30
pH analysis CTD ST11 deep cast	Marta López-Mozos, María Jesús Álvarez	20220726	9:53	12:53
arrival to ST12		20220726	9:25	12:25
sampling ST12 deep cast	Marta López-Mozos, María Jesús Álvarez, Caroline Le Bihan, STéphanie Barrillon	20220726	10:55	13:55
filtration nitrogen fixation ST8 CTD2	Mar Benavides	20220726	15:00	18:00
pH analysis CTD ST12 deep cast	Marta López-Mozos, María Jesús Álvarez	20220726	15:59	18:59
Oxygen analysis CTD ST4 to ST6 deep cast	Caroline Le Bihan	20220726	21:43	0:43
Underway sampling start	Marta López-Mozos, María Jesús Álvarez, Mar Benavides, Olivier Grosso, Angelina Klett, Cora Hörstmann	20220726	21:00	0:00
Oxygen analysis CTD ST7 to ST9 deep cast	Caroline Le Bihan	20220727	15:39	18:39
filtration underway nitrogen fixation incubations start	Mar Benavides, Olivier Grosso, Angelina Klett, Cora Hörstmann	20220727	21:23	0:23
Oxygen analysis CTD ST10 to ST12 deep cast	Caroline Le Bihan	20220727	21:30	0:30

Underway sampling end	Marta López-Mozos, María Jesús Álvarez, Mar Benavides, Olivier Grosso, Angelina Klett, Cora Hörstmann	20220728	8:00	11:00
filtration underway nitrogen fixation incubations end	Mar Benavides, Olivier Grosso, Angelina Klett, Cora Hörstmann	20220729	8:00	11:00
packing up	All	20220729	13:00	16:00
start demob	All	20220730	10:30	13:30
finish demob	All	20220730	15:00	18:00

3.3.2 Captain daily reports

20220722

0800 ADT
AE Cruise: 2215
Science Cruise: EUROFLEET2022
Good Morning,
Position: 32-52.320’N, 065-46.604’W; Approx. 65nm NWxW oF Bermuda
Speed: 10.3 kts
Course: 283 deg. T
Skies:4/8 covered, Partly cloudy; Cumulus w/ moderate vertical extent
Visibility: 10+ nm
Winds: SSW @ 7 – 10 kts
Seas: 2 - 3 ft
Swell: W’ly 4 - 6 ft
Baro: 1024.1 MB
Air Temp: 27.6* C
Sea Surface Temp: 27.0* C
Relative Humidity: 80 %
Remarks –
Vsl pitching moderately in slight seas and moderate short period swell. Enroute to test station in pos: 33-30.0’N, 068-48.0’W for equipment checks & test CTD cast before continuing on to first station. U/W from BIOS dock at 1555 yesterday afternoon. At approx. 2000 vsl turned around for return to BDA to transfer science member off vsl at request of chief scientist. Arrived S/B @ 2300LT and transferred scientist ashore via small boat after conferring w/ Bermuda Radio. All crew aboard, small boat secured, and U/W for sea again @ 0010 this morning w/ 23 POB.
All is well.

20220723

Captain report
0800 ADT
AE Cruise: 2215
Science Cruise: EUROFLEET2022
Position: 34-06.869’N, 069-45.439’W; Approx. 290nm ExS of Cape Hatteras, NC
Speed: 9.9 kts
Course: 313 deg. T
Skies:4/8 covered, Partly cloudy; Cumulus w/ little vertical extent & Cirrus
Visibility: 10+ nm

Winds: SW @ 11 – 16 kts
Seas: 2 - 4 ft
Swell: W'ly @ 5 - 6 ft
Baro: 1023.1 MB
Air Temp: 27.5* C
Sea Surface Temp: 27.4* C
Relative Humidity: 86 %
Remarks –
Vsl pitching & rolling moderately in moderate seas and swell. Enroute to 1st CTD station to perform 2000m and 200m casts. This morning's test of CTD and equipment successful; all equipment working well. Should enter outer of gulf stream waters by tomorrow morning. Beginning to see increasing commercial ship traffic.

20220724

Captain report
0800 ADT
AE Cruise: 2215
Science Cruise: EUROFLEET2022
Good Morning,
Position: 35-42.912'N, 071-50.092'W; Approx. 178nm ExN of Cape Hatteras, NC
Speed: 9.9 kts
Course: 328 deg. T
Skies:3/8 covered, Partly cloudy; Cumulus w/ moderate to great vertical extent, Cumulonimbus, Cirrus
Visibility: 10+ nm
Winds: SW @ 8 - 12 kts
Seas: 3 - 4 ft
Swell: SW'ly 4 - 6 ft
Baro: 1022.6 MB
Air Temp: 27.3* C
Sea Surface Temp: 26.7* C
Relative Humidity: 90 %
Remarks –
Vsl rolling moderately in choppy seas and swell. Enroute to Eurofleet ST#3 (36.112N, 072.138W) for 2000 & 200m CTD casts on outer edge of Gulf Stream. Yesterday's operations all successful and equipment behaving nicely.
All is well.

20220725

Captain report
0800 ADT
AE Cruise: 2215
Science Cruise: EUROFLEET2022
Good Morning,
Position: 37-07.188'N, 073-16.844'W; Approx. 130nm E of Cape Henry, VA
Speed: Hove to
Course: Hdg: 220 deg. T
Skies:3/8 covered, Partly cloudy with haze; Cumulus and Altocumulus
Visibility: 8 - 10 nm
Winds: SW @ 22 - 26 kts; Gusts to 35 kts
Seas: 4 - 6 ft
Swell: SW'ly 6 - 8 ft
Baro: 1019.5 MB
Air Temp: 27.4* C
Sea Surface Temp: 26.8* C

Relative Humidity: 84 %
Remarks –
Vsl holding station at ST7, conducting 1600m CTD cast. Seas growing increasingly angry, but wind, seas and current are in line, making operations manageable. Equipment continues to operate well and operations successful, but have fallen a bit behind schedule. Will continue to hit as many stations as possible before departing op. area for return to BDA around 1200 tomorrow, 26 July.

20220726

Captain report
0800 ADT
AE Cruise: 2215
Science Cruise: EUROFLEET2022
Good Morning,
Position: 36-01.974'N, 073-41.270'W; Approx. 100nm ENE of Cape Hatteras, NC
Speed: 8.9 kts
Course: 153 deg. T
Skies:5/8 covered, Partly sunny with haze; Cumulus, Nimbostratus, Cirrostratus
Visibility: 8 - 10 nm
Winds: WSW @ 32 - 36 kts; Gusts to 40 kts
Seas: 9 - 11 ft
Swell: SW'ly 6 - 8 ft
Baro: 1019.5 MB
Air Temp: 29.2* C
Sea Surface Temp: 28.9* C
Relative Humidity: 76 %
Remarks –
Vsl rolling & pitching excessively in Gale conditions, enroute to final CTD Station (at long last). Will conduct final 1600m CTD before heading back to northern transect for underway sampling as we retrace our steps back to BDA. Equipment continues to operate well, but some stations removed or shortened due to time constraints and weather factors. Science seems to be enjoying the show, but I can't wait to get out of this slop.

20220727

Captain report
0800 ADT
AE Cruise: 2215
Science Cruise: EUROFLEET2022
Good Morning,
Position: 36-33.538'N, 072-34.230'W; Approx. 172nm NExE of Cape Hatteras, NC
Speed: 6.0 kts
Course: 105 deg. T
Skies:6/8 covered, Mostly Cloudy; Cumulus, Cumulonimbus, Altocumulus
Visibility: 8 nm
Winds: W @ 24 - 28 kts; Gusts to 35
Seas: 12 - 14 ft
Swell: SW'ly 8 - 10 ft
Baro: 1016.0 MB
Air Temp: 28.7* C
Sea Surface Temp: 28.6* C
Relative Humidity: 84 %
Remarks –
Vsl rolling & yawing hard in near gale conditions, steering weather course w/ seas on stbd quarter. Counter currents in outer edges of gulf stream seem to have compounded wave heights very quickly. Attempting to hit science waypoints for underway sampling as best we can, but seas slowing us down considerably. Still aiming for

ETA to Sea Buoy @ 1600/29JUL, but that time quickly becoming very optimistic. Will keep all informed of any changes to schedule.

20220728

Captain report
0800 ADT
AE Cruise: 2215
Science Cruise: EUROFLEET2022
Good Morning,
Position: 35-06.860'N, 071-01.534'W; Approx. 350nm WNW of Bermuda
Speed: 11.5 kts
Course: 117 deg. T
Skies:7/8 covered, Mostly Cloudy; Stratus, Cumulus, Cirrocumulus
Visibility: 8 nm
Winds: W'ly @ 16 – 20 kts
Seas: WSW @ 6 – 8 ft
Swell: SW'ly 6 - 9 ft
Baro: 1017.4 MB
Air Temp: 28.9* C
Sea Surface Temp: 28.6* C
Relative Humidity: 88 %
Remarks –
Vsl rolling lightly moderate to rough seas, enroute to Bermuda sea buoy. Finished u/w sampling at 0800 this morn; now at full sea speed for BDA. Vsl will not make the current ETA of 1600/29JUL @ sea buoy. Will advise on new arrival time once confirmed with BDA Radio and Pilots.

20220729

Captain report
0800 ADT
AE Cruise: 2215
Science Cruise: EUROFLEET2022
Good Morning,
Position: 33-15.365'N, 066-18.443'W; Approx. 90nm NWxW of North Rock Lt.
Speed: 10.3 kts
Course: 114 deg. T
Skies:5/8 covered, Partly Sunny; Cumulus, Altocumulus, Cirrocumulus
Visibility: 8 - 10 nm
Winds: W @ 8 – 10 kts
Seas: W'ly @ 2 – 3 ft
Swell: WSW'ly 4 - 5 ft
Baro: 1021.7 MB
Air Temp: 28.9* C
Sea Surface Temp: 27.6* C
Relative Humidity: 84 %
Remarks –
Vsl rolling easy in slight following seas and light swell, enroute to Bermuda sea buoy w/ good speed. Have confirmed revised ETA w/ Bermuda Radio and Pilots:
ETA Sea Buoy: 1845 / 29 July
ETA Pennos W.: 1915 / 29 July
ETD Pennos for BIOS: 0930 / 30 July
ETA BIOS Dock: 1030 / 30 July

4 Preliminary Results

4.1 CTD data

(L. Carracedo, C. LeBihan)

For the hydrology acquisition, we used the RV/ Atlantic Explorer's CTD System consisting of a Seabird Electronics, Inc. (SBE) SBE9 underwater unit and SBE11+ Deck Units. The CTD carried a variety of additional sensors including: dissolved oxygen, transmissometer, fluorometer, PAR, carousel, altimeter, digital reversing thermometer and Bottom-contact Switch. In conjunction with a modified SBE Rosette frame, the CTD system utilised a SBE32 Full-size Carousel Water Sampler, equipped with 24 12L Niskin type bottles attached to the frame. Each Niskin bottle was equipped with two Delrin drain valves sized ¼" and 3/8" and a Delrin air bleed-valve. Throughout the duration of the cruise, we had neither failure nor noise on the signal of the CTD (CTD raw data shown in Figs. 1 and 2). During the upcast, the CTD-frame is stopped at predefined levels of closure (between surface and 2000 dbar as a maximum depth) for sampling and measuring different parameters (section 4.5), including salinity and oxygen for CTD calibration purposes (subsections 4.1.1 and 4.1.2). On board, the probe data were pre-calibrated with Seabird post-processing software, and once ashore, final calibration will be performed at LOPS (Ifremer, France) with the calibration code developed in Matlab (CADHYAC, Kermabon et al., 2012).

North transect

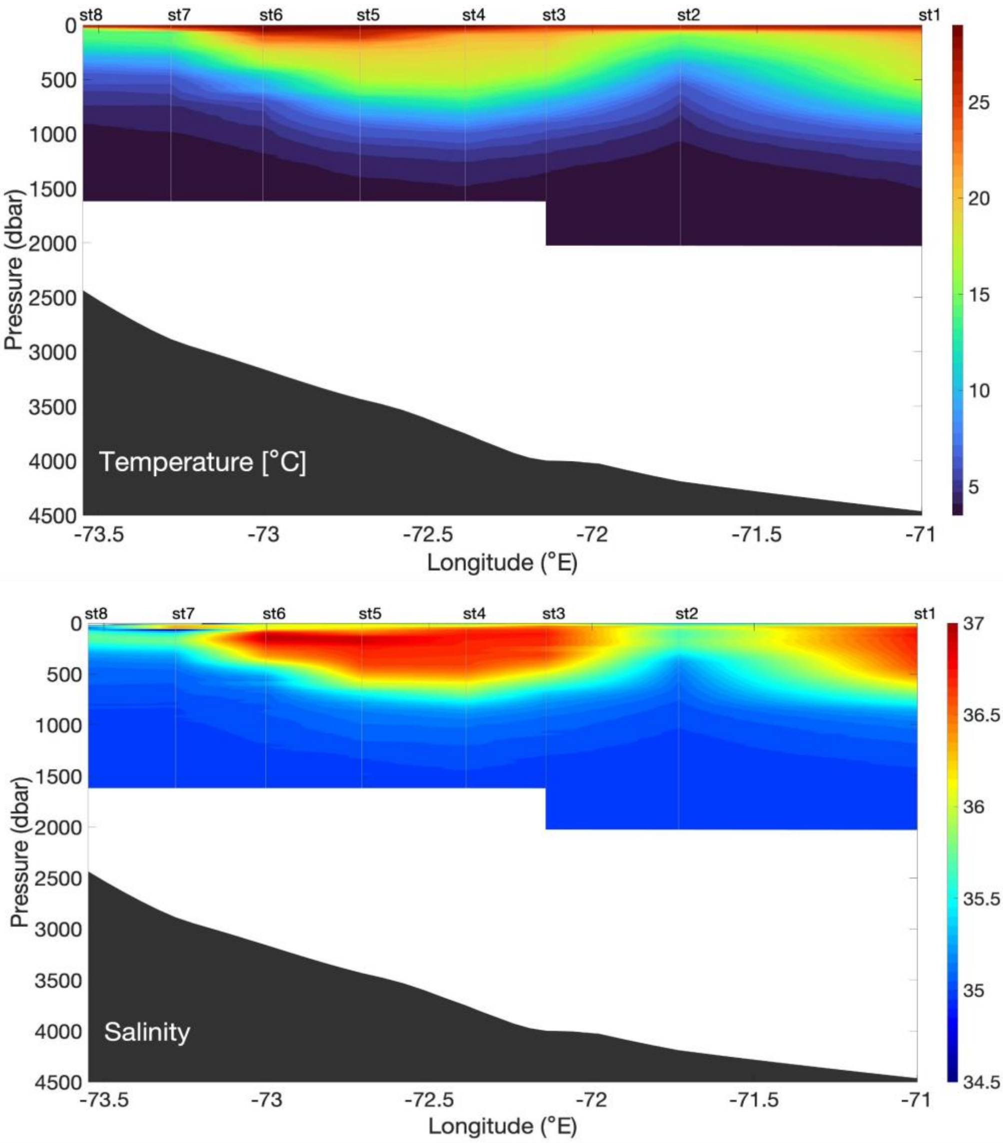
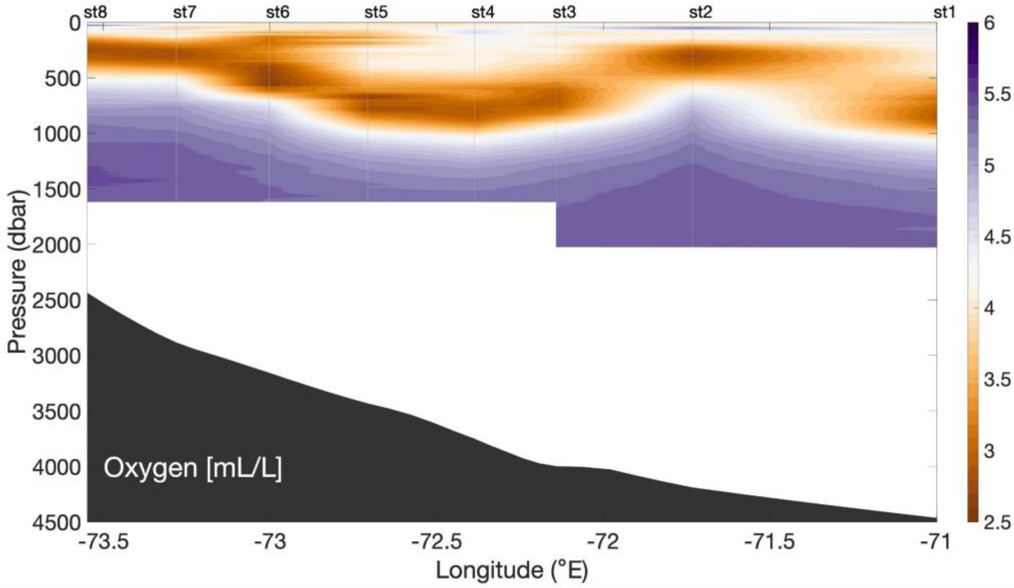


Fig. 2. *CTD temperature [ITS-90, °C] and salinity contours (primary sensor) for the north FIGURE-CARING section.*

North transect (cont.)



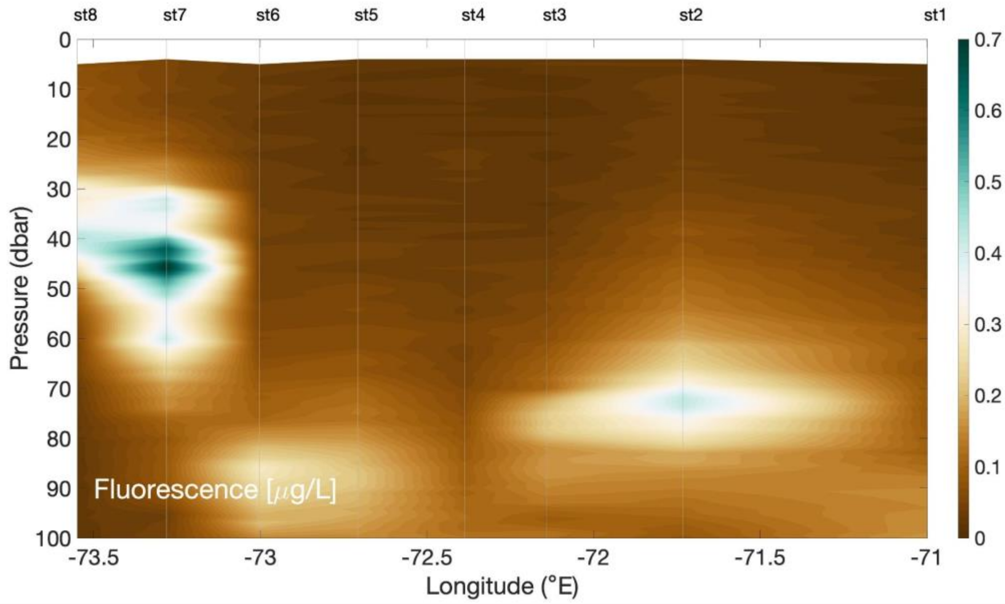


Fig. 2 (cont.). *CTD oxygen [SBE 43, mL/L] and fluorescence [Chelsea Aqua 3 Clh Con, µg/L] contours (primary sensor) for the north FIGURE-CARING section.*

South transect

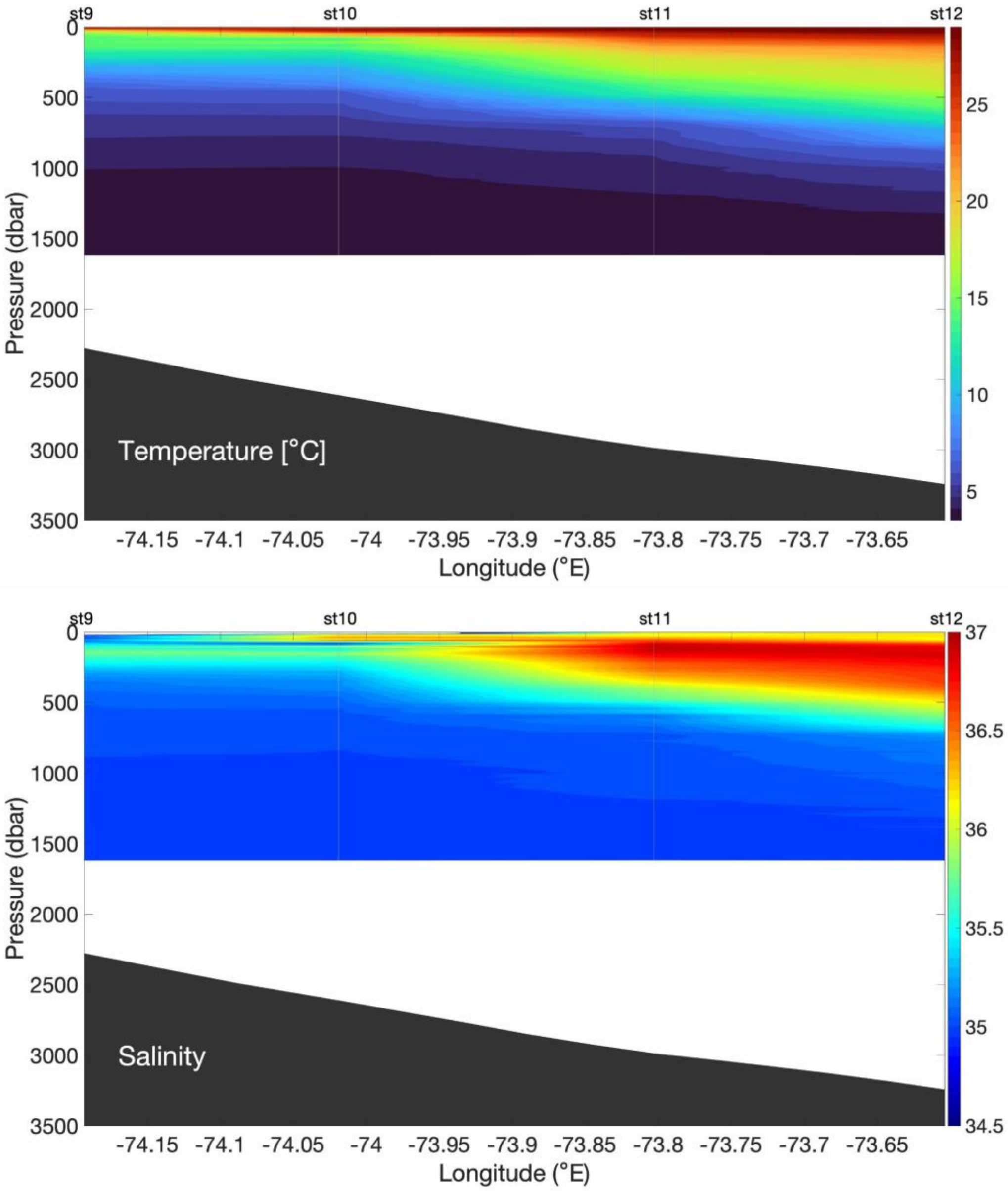


Fig. 3. *CTD temperature [ITS-90, °C] and salinity contours (primary sensor) for the south FIGURE-CARING section.*

South transect (cont.)

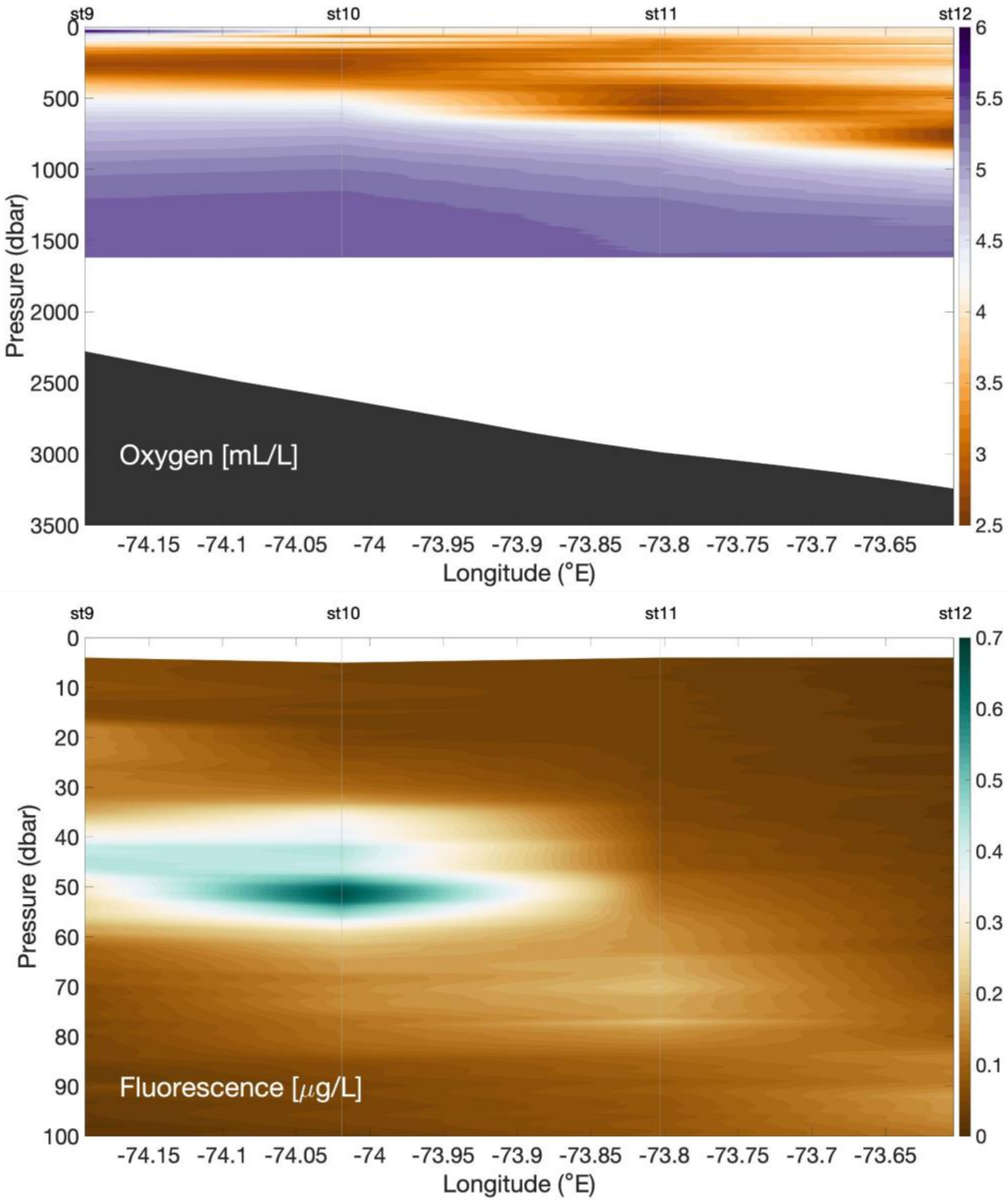


Fig. 3 (cont.). *CTD oxygen [SBE 43, mL/L] and fluorescence [Chelsea Aqua 3 Clh Con, µg/L] contours (primary sensor) for the south FIGURE-CARING section.*

4.1.1 Calibration of CTD salinity: analysis salinity bottle samples

(C. Le Bihan, L. Carracedo)

During the 12 hydrological stations (deep casts), 288 bottles were closed, of which 214 salinity samples were taken (~128 125-ml flasks from LOPS, ~86 200-ml flasks from BIOS) and stored on board at the RV/AE Aft Lab to be analysed ashore at BIOS facilities right after the cruise (temperature-controlled lab at 23.5 °C ± 0.5 °C), with a Guildline Portasal salinometer from LOPS.

4.1.2 Calibration of CTD oxygen: analysis oxygen bottle samples

(C. Le Bihan)

To determine the dissolved oxygen concentration of the seawater (Winkler method, e.g. Dickson 1995), dissolved oxygen samples were analyzed on board at the RV/AE Aft Lab, with a Metrohm 798 titrino from LOPS.

Air conditioning allowed regulation of the room temperature (23 °C ± 2.0 °C). Water samples were collected in 120 ml bottles with a plunger cap. After filling the bottle, the temperature of the sample was immediately recorded while overflowing a volume of water three times equivalent to the bottle. Two reagents (MnCl2 and NaOH-NaI) were added successively right afterwards and the bottle was capped and shaken for 30 seconds, in order to capture (fix) as part of the precipitate all the oxygen present in the sample. Once all the samples were taken, the bottles were shaken a second time one by one to resuspend the precipitate and allow for any remaining oxygen to be fixed. The samples were then stored in the Aft Lab and analysed after a delay of approximately 24 hours. During sample analysis, the sample was acidified and the liberated iodine was dosed with a solution of sodium thiosulfate of 0.02 N. Its normality was determined before the start of the analysis series, by comparison to a potassium iodate solution, whose normality, obtained by weighing, is 0.02. The dosage was controlled by a 798 Metrohm titrino, with a platinum titrode measuring the reaction potential and a 20 ml burette delivering the sodium thiosulfate. The volume of thiosulfate necessary for the reduction of the iodine is subtracted from the automatic determination of the inflection point on the potential curve at equivalence, and oxygen determined by stoichiometry. During the cruise, 214 oxygen samples were analysed into two analyses round sets. A detailed report on the CTD calibration procedure and related results will be made publicly available at https://doi.org/10.17600/18002940.

References

Dickson, A. D. 1995. Determination of dissolved oxygen in sea water by Winkler titration. WOCE Operations Manual, Part 3.1.3 Operations & Methods, WHP Office Report WHPO 91-1.

Kermabon, C., P. Le Bot, V. Thierry, P. Lherminier, P. Branellec. CADHYAC Chaine d'Ajustage des Données d'HYdrologie après Campagne. Rapport interne ODE/LPO, 2015-36.

4.2 ADCP data

(S. Barrillon, L. Carracedo)

A Teledyne RDI vessel-mounted Acoustic Doppler Current Profilers (ADCP) Ocean Surveyor 75 kHz, installed on the starboard side of the hull around approximately 1/3 of the RV/ Atlantic Explorer length aft of the bow, was operated during the FIGURE-CARING cruise to measure the velocity field (u-zonal, v-meridional, w-vertical, components). ADCP data acquisition was made with UHDAS (https://currents.soest.hawaii.edu/), developed at University of Hawaii. The OS75 is set to have about 2 seconds between pings, broadband (BB) and narrowband (NB) mode interleaved: NB 16m bins (60 nbins, 8m blank, range up to 800m), and BB 8m bins (100 nbins, 8m blanck, range up to 500m). The ADCP data (OS75, BB and NB) were treated and calibrated automatically by UHDAS (further details in Appendix I: UHDAS Summary Report), and updated every 5 minutes for the scientific team to download them.

Figs. 4 to 6 show the ADCP processed data: overall ADCP surface data (BB, second bin) superimposed with the satellite geostrophic currents, the maximum intensity as a function of time, ADCP-temperature vector plots (NB, 46-126m), and the ADCP u, v, and w components as a function of depth and time (NB).

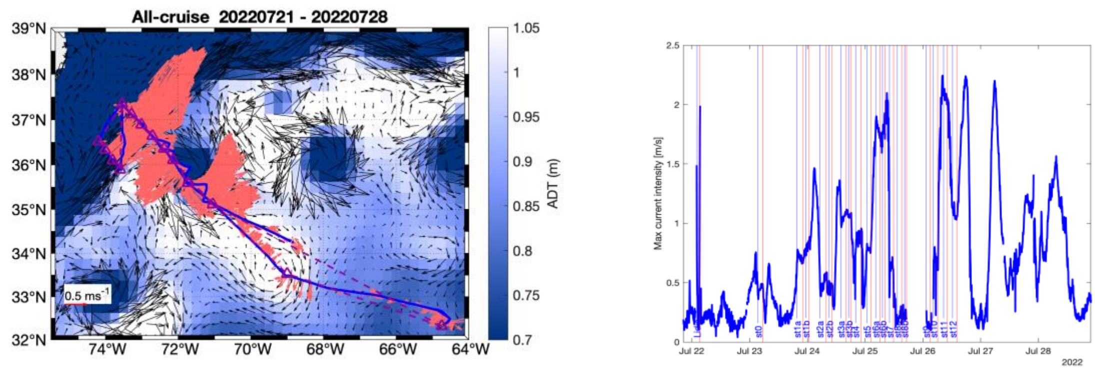


***Fig. 4.** ADCP data from July 21 to July 28. Left: overall ADCP surface data (BB, second bin) superimposed with the satellite geostrophic currents derived by altimetry. Right : maximum current intensity (NB) as a function of time.*

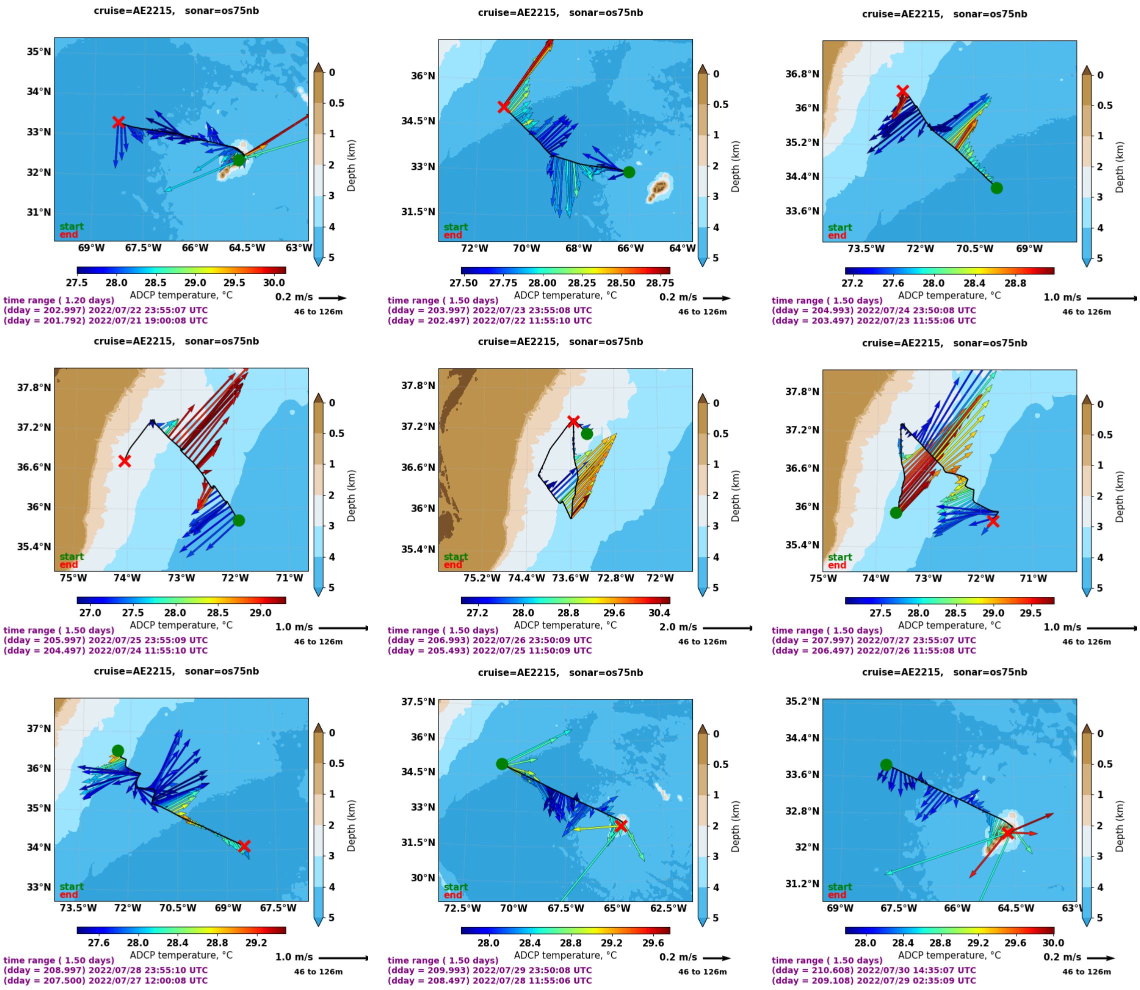


Fig. 5. *ADCP (NB) vector plots from July 21 (upper left) to July 30 (bottom rigth), for the depth range 46-126 m. Colour legend represents the ADCP temperature.*

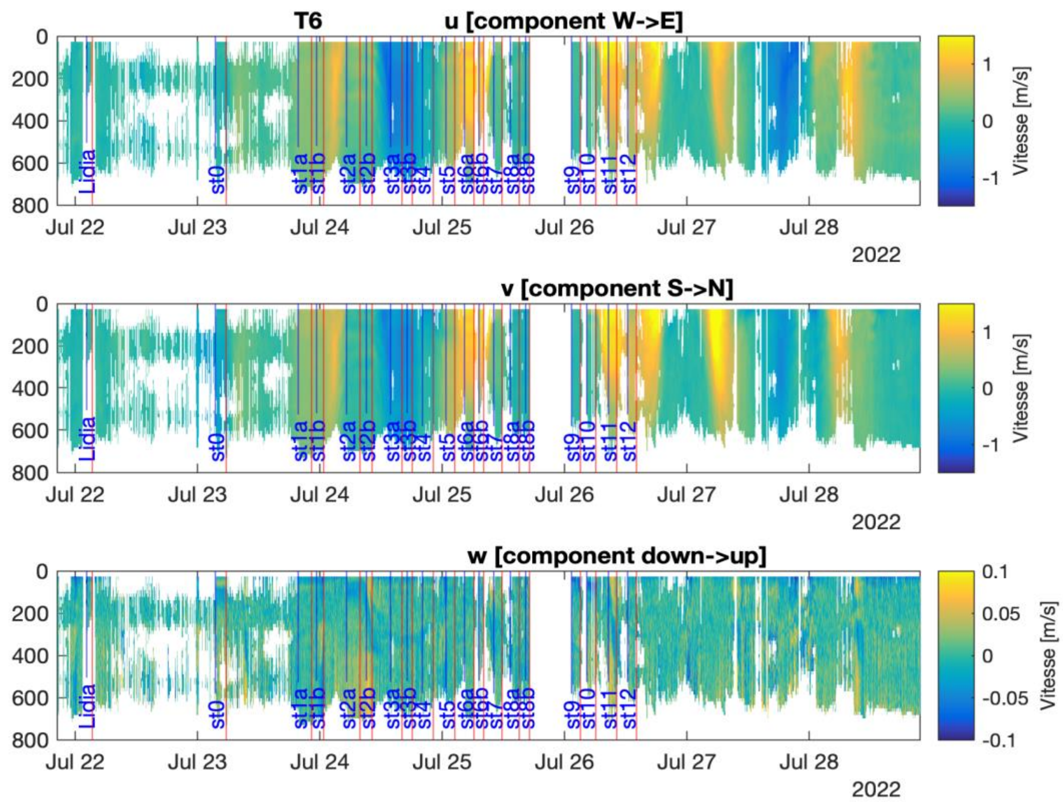


Fig. 6. *ADCP data from July 21 to July 28. ADCP currents (NB) eastward (u), northward (v), and vertical upward (w) corrected for the ship's vertical movement, as a function of depth and time.*

References

Firing, E and Hummon, J. M. (2010) Shipboard ADCP Measurements. In, The GO-SHIP Repeat Hydrography Manual: A Collection of Expert Reports and Guidelines. Version 1, (eds Hood, E.M., C.L. Sabine, and B.M. Sloyan). 11pp. (IOCCP Report Number 14; ICPO Publication Series Number 134). Available online at: http://www.go-ship.org/HydroMan.html. DOI: https://doi.org/10.25607/OBP-1352

4.3 Underway system data: thermosalinograph and pCO2 system

(L. Carracedo)

The RV/AE was equipped with an Underway Science Sea Water System (USSWS) located in an air-conditioned laboratory (RV/AE End Lab), comprising:

- Seabird SBE45 uTSG Thermosalinograph (Primary and Secondary)
- Seabird WETStar. Model WSCHL Fluorometer (Primary and Secondary)
- Seabird SBE38 Remote Temperature (Primary and Secondary)
- Gems RFO 155481 RotorFlow Sensor Flow Meters (4 total)
- Seabird C-Star Transmissometers (Primary and Secondary)

The USSWS functioned uninterruptedly during the entire cruise, recording data automatically. Temperature and salinity data from the thermosalinograph and fluorometer sensors are shown in Fig. 6.

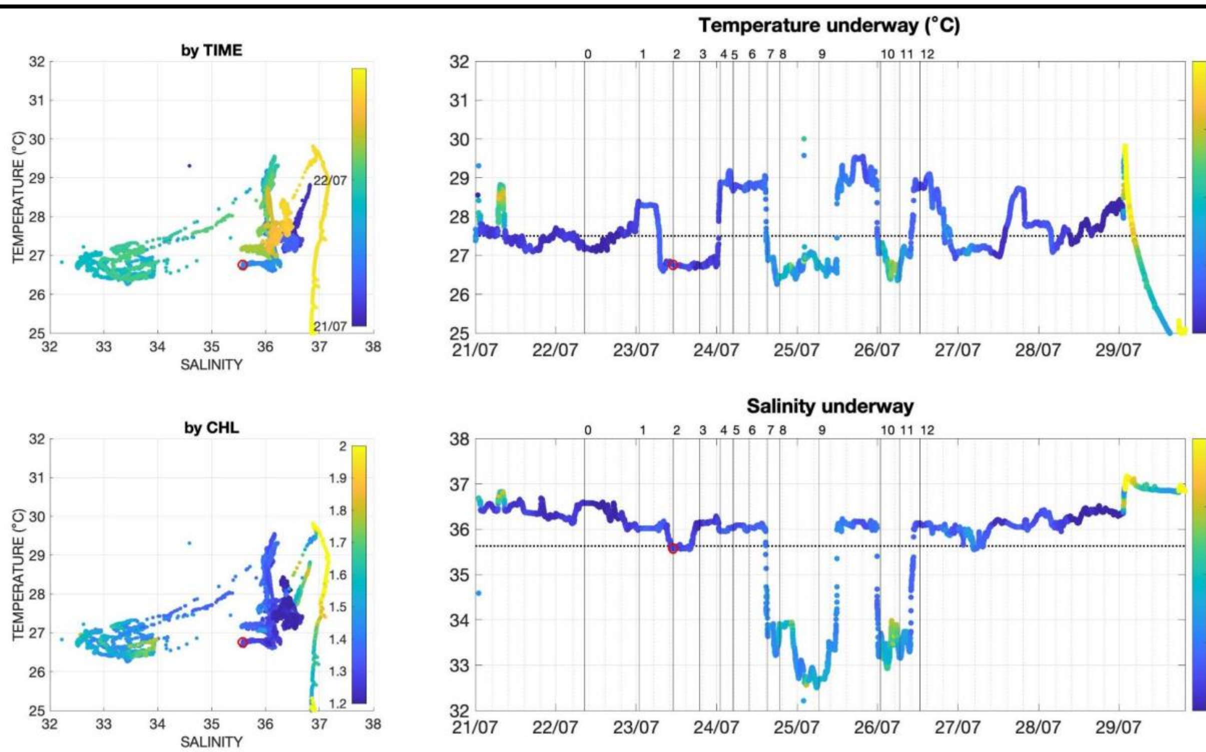


Fig. 7. *Thermosalinograph data from July 21 to July 29. Left panels: TS diagrams by time (upper panel) and by chlorophyll (lower panel). Right panels: Temperature and salinity as a function of time. Colour scale refers to chlorophyll concentration [µg/L]. Numbers 0-12 indicate CTD station numbers.*

In addition to the before-mentioned parameters, continuous underway measurements of pCO2 were additionally taken during the cruise by means of an autonomous General Oceanics LI-COR 7000 pCO2 system (measurement method IR) located in an air-conditioned laboratory (RV/AE End Lab). Raw data were automatically stored to be calibrated and QCd for outliers *a posteriori* by BIOS CARING project collaborators (M. Enright, N. Bates), following the method by Pierrot et an (2009). The pCO2 data will be merged with position, and underway temperature and salinity data. A detailed report on the data QC and processing procedure, as long as related data, will be made publicly available at https://doi.org/10.17600/18002940.

References

Pierrot, D., C. Neil, K. Sullivan, R. Castle, R. Wanninkhof, H. Lueger, T. Johannessen, A. Olsen, R. A. Feely, and C. E. Cosca (2009), Recommendations for autonomous underway pCO2 measuring systems and data reduction routines, Deep-Sea Res II, 56, 512-522.

4.4 Processed satellite data (SPASSO)

(S. Barrillon)

Satellite images and data files of altimetry, chlorophyll, temperature and derived Lagrangian products (Finite Size Lyapunov Exponent, latitudinal advection, longitudinal advection) were provided automatically on a daily basis by the SPASSO software (https://spasso.mio.osupytheas.fr), and are available from the SPASSO website https://spasso.mio.osupytheas.fr/FIGURE/. The satellite data was extracted from Copernicus https://marine.copernicus.eu). The images from July 27 are shown in Fig. 7, superimposed to the surface ADCP current (bb, second bin) for the return transect.

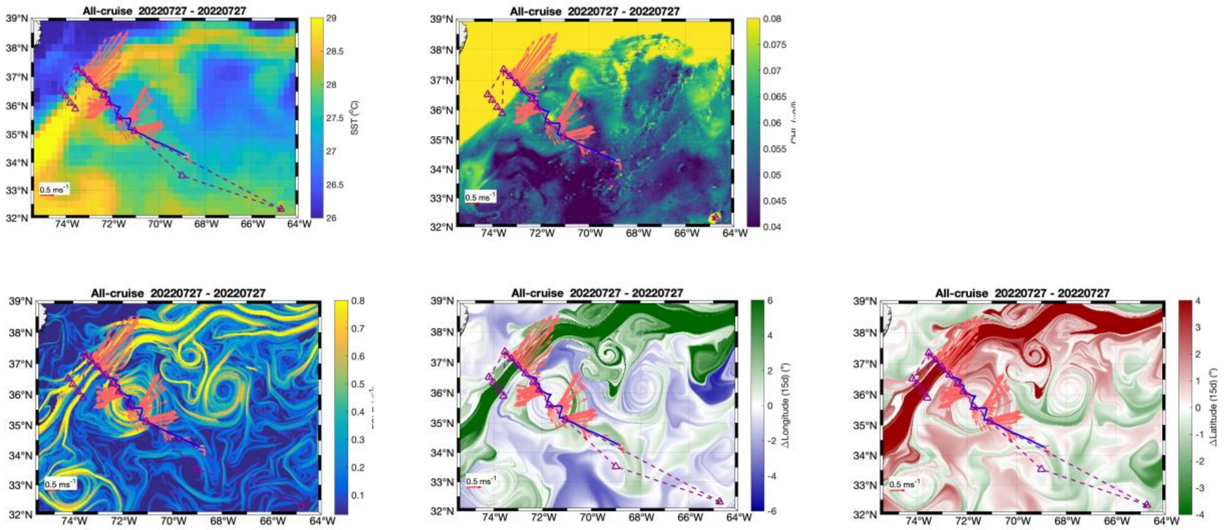


Fig. 8. *SPASSO satellite images from July 27, superimposed with ADCP surface data (bb, second bin). Top left : Sea Surface Temperature (L4). Top middle: Chlorophyll (L4). Bottom left: Finite Size Lyapunov Exponents. Bottom middle: longitude advection (15 days). Bottom right: latitude advection (15 days).*

4.5 Water and Plankton Sampling with CTD/Rosette

4.5.1 CTD sampling for pH

(M.J. Álvarez, M. López-Mozos)

Spectrophotometric pH in seawater was measured following Clayton and Byrne (1993). The pH was reported at 25°C on the Total scale (pH_{25T}). pH samples were taken immediately after oxygen and directly from the Niskin bottles into cylindrical special optical glass Hellma cells of 28 mL of volume and 100 mm of path length, by overflowing the water and immediately sealing the cell. The cells were rinsed three times, then filled slowly from the bottom and overflown a minimum of a full bottle volume. After sampling, the cells were carefully stored in an incubator, in which the temperature was controlled at 25 °C by a cryostatic bath, around one hour before the analysis. pH samples were measured using the fast, precise and commonly used spectrophotometric method described by Clayton and Byrne (1993). This method consists in adding a known volume of coloured indicator dye to the seawater sample and measuring the absorbance of the sample at controlled temperature of 25°C. The indicator was a solution of m-cresol purple (Sigma Aldrich) prepared in seawater and maintained at dark, with no air contact. All the absorbance measurements were obtained in the thermostatic (25 ± 0.2°C) cell compartment of the V-750 UV-Visible JASCO double beam spectrophotometer.

Indicator effect over samples was previously calculated by second additions of the indicator over samples within a wide range of pH. The correction in the absorbance ratio of every sample (R_{real}) resulted from a linear function of the absorbance ratio measured (R_m). This function also corrects for deviations in the linear relationship between absorbance and the indicator concentration. In addition, a precision test was performed by taking nine underway samples (mean = 8.049, STD = 0.0015). The preliminary pH results obtained are shown in Fig. 8. The upper panel shows the pH distribution along the N-section (+cyclonic eddy), and the lower panel shows the S-section. A detailed report on the data QC and processing procedure, as long as related data, will be made publicly available at https://doi.org/10.17600/18002940.

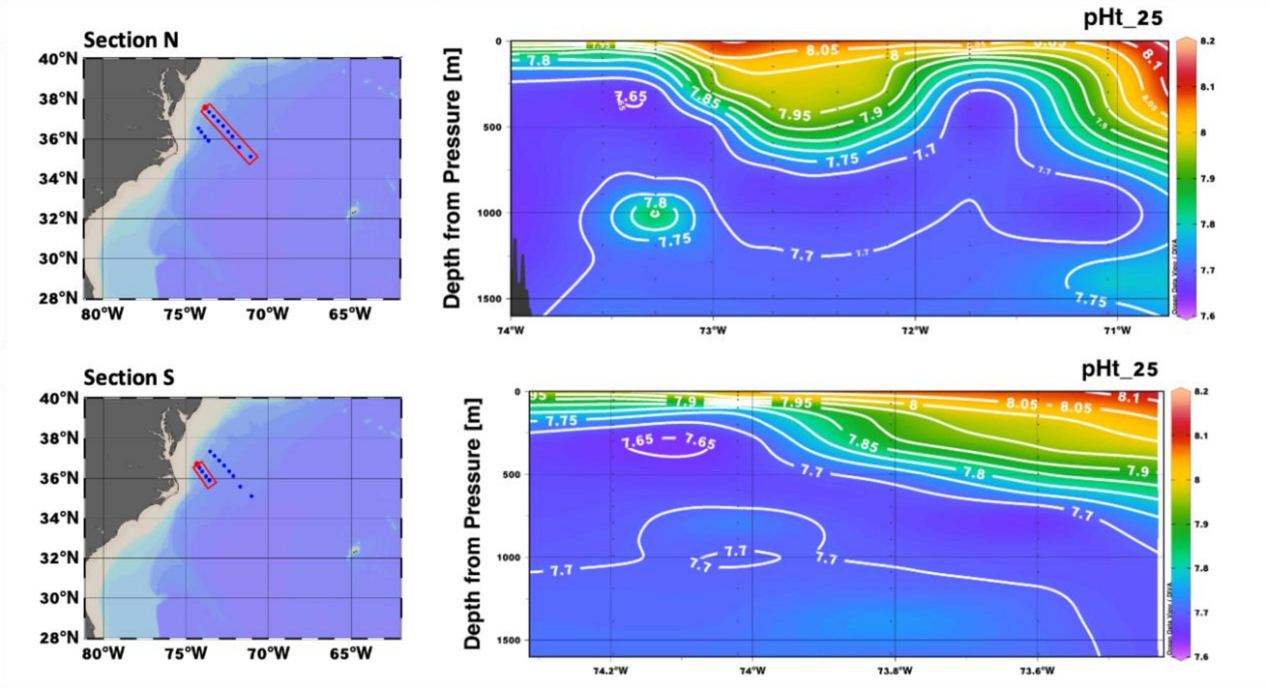


Fig. 9. *Vertical distribution of pHT25 along the FIGURE-CARING north (upper panel) and south (bottom panel) sections.*

References
Tonya D. Clayton, T.D., Byrne, R.H. Spectrophotometric seawater pH measurements: total hydrogen ion concentration scale calibration of m-cresol purple and at-sea results, Deep Sea Research Part I: Oceanographic Research Papers, 40, Issue 10, 1993, 2115-2129, ISSN 0967-0637, https://doi.org/10.1016/0967-0637(93)90048-8.

4.5.2 CTD sampling for total alkalinity

(M.J. Álvarez, M. López-Mozos)

A total of 12 stations were sampled (108 samples in total) for total alkalinity (TA), with 8 to 10 depth levels between surface and 2000 dbar being collected per station. In each case 600 mL borosilicate glass bottles supplied by the Marine Research Institute of Vigo (where samples will be analysed afterwards) were used to collect seawater from the rosette immediately after oxygen and pH samples were taken. A short piece of Tygon tubing was attached to the Niskin spigot and used to draw water into the pre-washed bottles. Bottles were rinsed three times, then filled slowly from the bottom and overflown a minimum of a full bottle volume. The stopper was washed using overflowing water prior to being inserted into the bottle, making sure to not trap any bubbles. Samples were fixed in the temperature controlled laboratory (under the hood) by first creating a headspace (by removing 1% of bottle volume using Pasteur pipette) prior to preserving with 0.30 mL of saturated mercuric (II) chloride (HgCl2) (following Dickson et al., 2007). The ground glass of the bottle neck and stopper were then dried with a lint free highly absorbent wipe, Apiezon grease applied and the stopper inserted completely. The stopper was twisted to remove residual air from the grease and to ensure a complete seal was made. Finally, a securing elastic band was placed on the bottle and the sample preservative mixed through by inverting the bottle three/four times. Samples were stored in the temperature controlled laboratory (approximately 22±3°C) until the end of the cruise.

References
Dickson, A.G., Sabine, C.L. and Christian, J.R. (Eds.) 2007. Guide to best practices for ocean CO_2 measurements. PICES Special Publication 3, 191 pp.

4.5.3 CTD sampling for inorganic nutrients

(C. LeBihan)

A total of 202 discrete water samples (30 ml plastic flasks) were collected from the Niskin bottles for inorganic nutrients (nitrate, phosphate and silicate) and pasteurised onboard for posterior analysis ashore at IRD/IMAGO (Ifremer, Plouzané, France). The samples were taken so that the sample flask did not touch the Nisking spigot (2-3 cm space between both when taking the sample). Bottles were rinsed three times, then filled leaving 1 cm space in the flask head and flask lid closed. Once all samples for each station were collected, they were carried to the Aft Lab and introduced in the oven to be Pasteurised at 80°C for 2h30 at the least (Daniel et al., 2012) prior to storage. The table below indicates the duration of each sampling set (by CTD station) in the oven :

	Start time (hh:mm)	End time (hh:mm)	Time in oven (hh:mm)
station 0	03:30	09:10	05:40
station 1	20:11	03:40	07:29
station 2	05:50	11:40	05:50
station 3	14:00	18:40	04:40
station 4	19:55	22:50	02:55
station 5	00:10	02:55	02:45
station 6	04:00	08:25	04:25
station 7	09:25	13:05	03:40
station 8	13:10	17:05	03:55
station 9	01:09	04:00	02:51
station 10	04:05	08:00	03:55
station 11	08:00	12:30	04:30
station 12	12:30	16:25	03:55

References

Daniel, A., Kérouel, R., Aminot, A. Pasteurization: A reliable method for preservation of nutrient in seawater samples for inter-laboratory and field applications, Marine Chemistry, 128–129, 2012, 57-63, ISSN 0304-4203, https://doi.org/10.1016/j.marchem.2011.10.002.

4.5.4 CTD sampling for DNA

(C. Hörstman, M. Benavides)

Seawater was collected from 4 depths (typically 5, 35, 75 and 100 m) at 6 stations and filtered onto 0.2 µm polysulfone filters, subsequently stored in bead beater tubes containing 300 µl RNAlater and stocked at -80ºC. DNA samples will be further processed and analysed in home laboratories at the Mediterranean Institute of Oceanography (MIO, France). This will include the following steps: 1) DNA extraction 2) qPCR and library preparation for DNA sequencing, 3) DNA sequencing and 4) statistical analyses along other chemical and physical parameters taken onboard and final publication.

4.5.5 CTD sampling for N2 fixation measurements

(O. Grosso, M. Benavides, C. Hörstmann)

Seawater was collected from 4 depths (typically 5, 35, 75 and 100 m) at 6 stations, spiked with 15N2 gas and incubated in shaded deck incubators for 24 h. After incubation, the bottles' content was filter onto precombusted GFF filters and stored at -20ºC. Analyses will proceed at the Mediterranean Institute of Oceanography (MIO, France) including EA-IRMS and MIMS.

4.5.6 CTD sampling for NO3, NH4 and AA uptake measurements
(A. Klett)

Seawater was collected from up to three depths (same as above 5, 35, and 75 m) at 5 stations, spiked with 13C-DIC, 15NO3, 15NH4 and 15N and 13C amino acid mix (AA) and incubated during the mid day for 1 - 4 hours in shaded deck incubators. Each 15N tracer (NO3, NH4, AA) incubation was processed separately. After incubation the water was filtered onto precombused GFF filters and stored at -20°C until drying at 60°C for 24 h. Analysis will proceed at the Leibniz Institute for Baltic Sea Research in Warnemuende (IOW, Germany) using EA-IRMS.

4.6 Water and Plankton Sampling from underway

4.6.1 Underway sampling for pH
(M.J. Álvarez, M. López-Mozos)

Underway (UW) seawater samples were collected every hour from ST8 to ST1 on the return transect to Bermuda at 6 kn speed. A total of 36 UW pH samples were taken and analysed on board following the procedure described in Section 4.5.1.

4.6.2 Underway sampling for DNA
(C. Hörstman, O. Grosso, A. Klett, M. Benavides)

Underway seawater samples were collected every hour from ST8 to ST1 on the return transect to Bermuda at 6 kn speed. Samples were filtered onto 0.2 µm polysulfone filters, subsequently stored in bead beater tubes containing 300 µl RNAlater and stocked at -80ºC. DNA samples will be further processed and analysed in home laboratories at the Mediterranean Institute of Oceanography (MIO, France). These samples will be processed in the same way as the DNA samples from the CTD with a particular focus on high spatial resolution measurements.

4.6.3 Underway sampling for N2 fixation measurements
(C. Hörstman, O. Grosso, A. Klett, M. Benavides)

Underway seawater samples were collected every 3 hours from ST8 to ST1 on the return transect to Bermuda at 6 kn speed. Underway N2 fixation samples will be processed and analysed in home laboratories at the Mediterranean Institute of Oceanography MIO. Measured biological rates will be ultimately linked to diazotroph' fine-scale patterns. These samples will be processed in the same way as the N2 fixation samples from the CTD with a particular focus on high spatial resolution measurements.

5 Data and Sample Storage / Availability

CTD, ADCP, navigation and meteorology data have been submitted to EMODnet and will therefore be freely available for public access. Biogeochemical data will also be made publicly available through the same means at due time. The information about the current state of data availability will be updated/centralised via https://doi.org/10.17600/18002940.

6 Participants

The EUROFLEETS+ funds received were not sufficient to cover travel and accommodation, nor the totality of the sample shipment needed for the cruise. The totality of the funds (12000 Euro for FIGURE, 4750 Euro for CARING) were used to ship part of the sampling gear. All participants travel and accommodation were funded by other sources as follows:

No.	Name	Early career (Y/N)	Gender	Affiliation	On-board tasks	Funding
1	Mar Benavides	N	F	MIO-IRD	Chief scientist, nitrogen fixation, DNA	ANR FIESTA
2	Lidia Carracedo	N	F	LOPS	Chief scientist, ADCP	ISBlue CARING
3	Stéphanie Barrillon	N	F	MIO-CNRS	SPASSO, ADCP, oxygen, nutrients, salinity	LEFE-CYBER DEFINE2
4	Cora Hörstmann	Y	F	MIO-AMU	Nitrogen fixation, DNA	ANR FIESTA
5	Angelina Klett	Y	F	IOW	Nitrate, ammonium and amino acid uptake	NOTION
6	Caroline Le Bihan	N	F	LOPS-IFREMER	Oxygen, salinity, nutrients	ISBlue CARING
7	Marta López-Mozos	Y	F	IIM-CSIC	pH, alkalinity	LEFE-CYBER CARING
8	María Jesús Álvarez	N	F	IIM-CSIC	pH, alkalinity	LEFE -CYBER CARING
9	Olivier Grosso	N	M	MIO-CNRS	Nitrogen fixation, DNA	LEFE-CYBER DEFINE2

Remote participants include:

Participant	Institution	Role
María Dolores Pérez-Hernández	Universidad de Las Palmas de Gran Canaria, Spain	ARGO and satellite data processing
Borja Aguiar-González	Universidad de Las Palmas de Gran Canaria, Spain	ARGO and satellite data processing
Nick Bates	BIOS, Bermuda	pCO2 data processing

7 Station List

Station No.	Time [UTC]	Date [YYYYMMDD]	Latitude [ºN]	Longitude [ºW]	WaterDepth [m]	Gear	Remarks/Recovery
ST0	342	20220723	33.49	69.00	5327	ROS/CTD	
ST1	1954	20220723	35.10	71.00	4453	ROS/CTD	winch cable tangling up at 1300 m during downcast, proceeded to spin down some meters again to untangle and come back up to 1200 m bottle 2

							(supposedly at 2000 m) did not close properly as temperature measured in its water with a hand thermometer is 23ºC
ST2	530	20220724	35.59	71.73	4188	ROS/CTD	
ST3	1407	20220724	36.11	72.14	3998	ROS/CTD	
ST4	2011	20220724	36.36	72.39	3749	ROS/CTD	
ST5	55	20220725	36.63	72.71	3433	ROS/CTD	
ST6	435	20220725	36.89	73.00	3156	ROS/CTD	
ST7	1020	20220725	37.07	73.28	2882	ROS/CTD	
ST8	1345	20220725	37.34	73.55	2436	ROS/CTD	one bottle misfired
ST9	130	20220726	36.52	74.19	2276	ROS/CTD	
ST10	435	20220726	36.34	74.19	2608	ROS/CTD	
ST11	835	20220726	36.10	73.81	2983	ROS/CTD	
ST12	1231	20220726	35.89	73.44	3248	ROS/CTD	

8 Acknowledgements

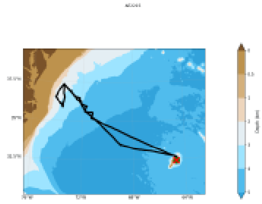
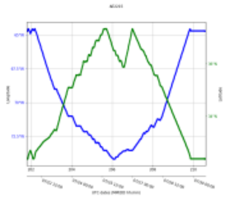
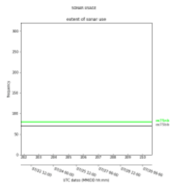
The FIGURE-CARING ship time was granted to MB and LC by Eurofleets+. Research conducted during this cruise was funded by projects ANR-21-CE01-0021-01 FIESTA, LEFE-CyBER DEFINE2 and BNP Paribas Foundation for Climate and biodiversity NOTION to MB, and projects LEFE-CyBER CARING and ISBlue CARING to LC.

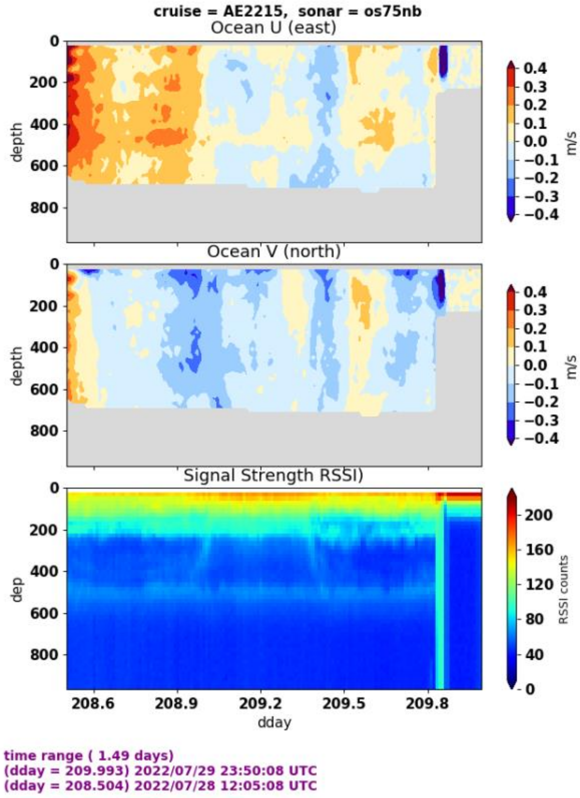
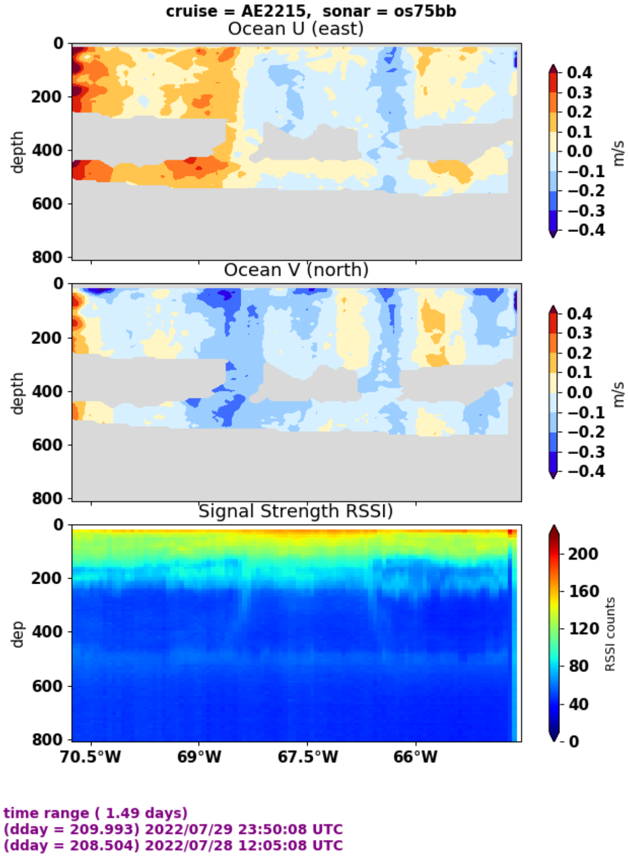
9 References

Added by subsection.

10 Appendix

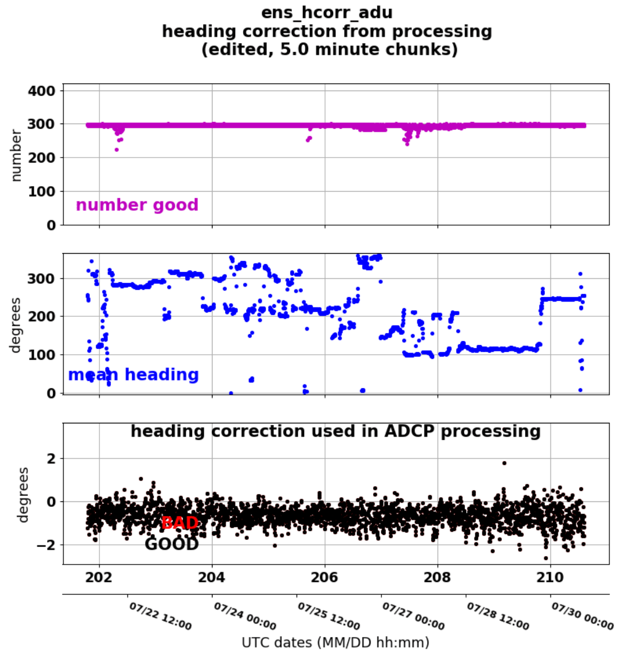
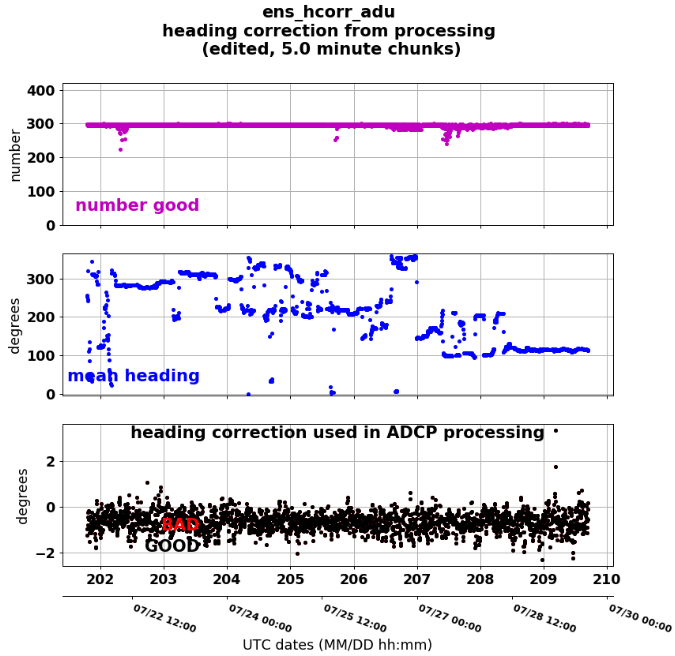
FIGURE-CARING (AE2215) SADCP UHDAS Summary Report

CATEGORY	DESCRIPTION	FILE
overview	  	nav_plot_all_topo.png nav_plot_all_txy.png db_timerange.png (Annex I)
overview	-------raw------- raw: abxtwo 107 files (ae2022_201_68107 - ae2022_210_50400) raw: adu800 107 files (ae2022_201_68107 - ae2022_210_50400) raw: jrc_hdg4800 107 files (ae2022_201_68107 - ae2022_210_50400) raw: jrc_port 107 files (ae2022_201_68107 - ae2022_210_50400) raw: jrc_stbd 107 files (ae2022_201_68107 - ae2022_210_50400) adcp: os75 .raw 107 files (ae2022_201_68107 - ae2022_210_50400) adcp: os75 .raw.log 107 files (ae2022_201_68107 - ae2022_210_50400) adcp: os75 .raw.log.bin 107 files (ae2022_201_68107 - ae2022_210_50400) -----rbin------- rbin: abxtwo:adu 107 files (ae2022_201_68107 - ae2022_210_50400) rbin: abxtwo:gps 107 files (ae2022_201_68107 - ae2022_210_50400) rbin: adu800:adu 107 files (ae2022_201_68107 - ae2022_210_50400) rbin: adu800:gps 107 files (ae2022_201_68107 - ae2022_210_50400) rbin: jrc_hdg4800:hdg 107 files (ae2022_201_68107 - ae2022_210_50400) rbin: jrc_port:gps 107 files (ae2022_201_68107 - ae2022_210_50400) rbin: jrc_port:hdg 107 files (ae2022_201_68107 - ae2022_210_50400) rbin: jrc_stbd:gps 107 files (ae2022_201_68107 - ae2022_210_50400) rbin: jrc_stbd:hdg 107 files (ae2022_201_68107 - ae2022_210_50400) -----gbin------- gbin: os75 (abxtwo,jrc_hdg4800,adu800,time,jrc_port,jrc_stbd) ------ database time ranges -------- proc: os75bb 201.792 - 210.608 (2022/07/21 to 2022/07/30)	uhdas_overview.txt

<table>
<tr><td></td><td><code>proc: os75nb 201.792 - 210.608 (2022/07/21 to 2022/07/30)</code></td><td></td></tr>
<tr><td>processed ADCP</td><td>
</td><td>Example figure (full dataset os75nb.nc)</td></tr>
<tr><td>processed ADCP</td><td>
</td><td>Example figure (full dataset os75bb.nc)</td></tr>
<tr><td>processed ADCP</td><td><code>================ ADCP calibrations ==============</code>

<code>cal: os75nb BT none</code></td><td>ADCP_cals.txt</td></tr>
</table>

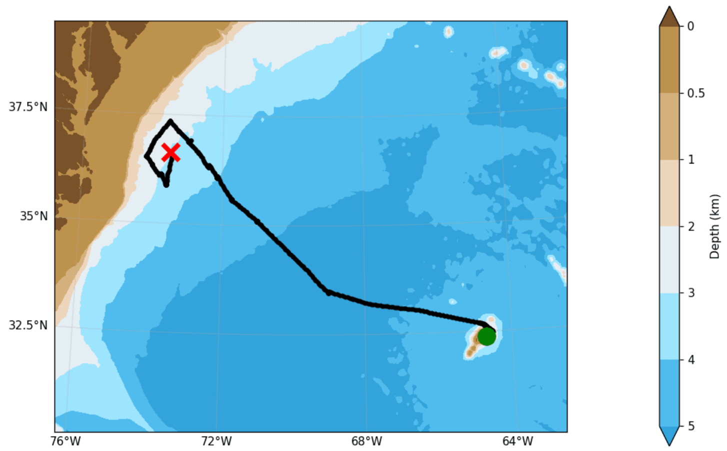
```
cal: os75nb   WT  Number of edited points:  35 out
of  42
cal: os75nb   WT              median     mean
std
cal: os75nb   WT  amplitude   1.0020   1.0009
0.0095
cal: os75nb   WT  phase       0.0970   0.0173
0.7728
-------------
cal: os75nb   DXDY  guessing ADCP (dx=starboard,
dy=fwd) meters from GPS
cal: os75nb   DXDY  positions from a_ae.gps
cal: os75nb   DXDY  calculation done at 2022/07/30
14:35:33
cal: os75nb   DXDY  xducer_dx = 0.348232
cal: os75nb   DXDY  xducer_dy = 0.386815
cal: os75nb   DXDY  signal = 982.958890
------------------------------------------
cal: os75bb   BT  none
cal: os75bb   WT  Number of edited points:  28 out
of  40
cal: os75bb   WT              median     mean
std
cal: os75bb   WT  amplitude   1.0040   1.0011
0.0143
cal: os75bb   WT  phase      -0.0275   0.0214
0.8076
-------------
cal: os75bb   DXDY  guessing ADCP (dx=starboard,
dy=fwd) meters from GPS
cal: os75bb   DXDY  positions from a_ae.gps
cal: os75bb   DXDY  calculation done at 2022/07/30
14:35:23
cal: os75bb   DXDY  xducer_dx = 2.280338
cal: os75bb   DXDY  xducer_dy = 5.609641
cal: os75bb   DXDY  signal = 982.960916
------------------------------------------
```

quality	 	os75nb_hcorr.png os75bb_hcorr.png

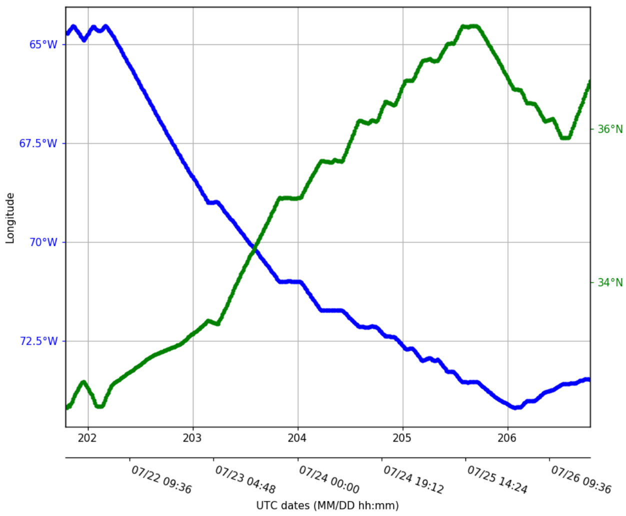
raw ADCP	`===== os75 settings: chunked by configuration ===`
	
	`index num startdday enddday BT (ping, nbins,binsize, blank, pulse) (...)`
	`---- --- --------- -------- ---`
	`0 107 201.788327 210.608986 off (bb, 100, 8.0, 8.0, 8.0) (nb, 60, 16.0, 8.0, 16.0)`
		ADCP_settings.txt

UHDAS settings	ADCP CODAS processing settings	AE2215_proc.py.txt (Annex II)
UHDAS settings	UHDAS serial acquisition settings	AE2215_sensor.py.txt (Annex III)

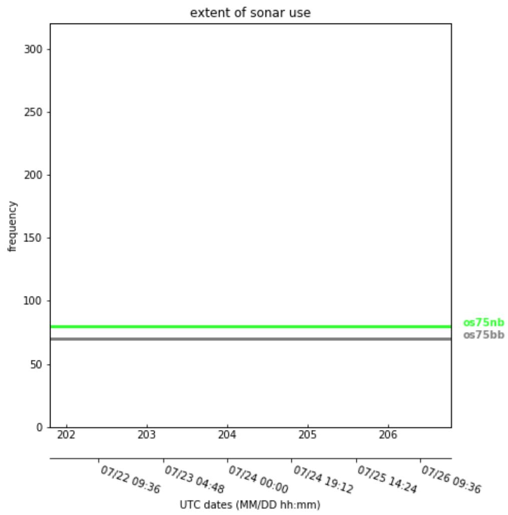
Annex I



nav_plot_all_topo.png



nav_plot_all_txy.png



db_timerange.png

Annex II

AE2215_proc.py.txt

```
shipname = 'Atlantic Explorer'
cruiseid = 'AE2215'
yearbase = 2022
uhdas_dir = '/home/data/AE2215'

# from proc_cfg.*:

## for processing
##----------------
## ship name: shipname = "Atlantic Explorer"
## at-sea "proc_cfg.*" initialized date = "2022/02/22 03:35:19"
##
## This file starts as /home/adcp/config/proc_cfg.py or .toml and
## includes the following information.  Uncomment, left-justify
## and fill these in if you are attempting to generate proc_cfg.*
## from this template.  The file must be named {cruiseid}_proc.py or *.toml
## or for this example, kk1105_proc.py or kk1105_proc.toml.
##
## example values: fill in for your cruise...
#
# yearbase = 2011               # usually year of first data logged
# uhdas_dir = "/home/data/kk1105"  # path to uhdas data directory
# shipname = "Ka`imikai O Kanaloa" # for documentation
# cruiseid = "kk1105"           # for titles
#

#======== serial inputs =========

# choose position instrument (directory and rbin message)

pos_inst = "jrc_port"
pos_msg = "gps"

# choose attitude instruments (directory and rbin message)

pitch_inst = "abxtwo"    # pitch is recorded, but NOT used in transformation
pitch_msg = "adu"     # disable with "" (not None)

roll_inst = "abxtwo"     # roll is recorded, but NOT used in transformation
roll_msg = "adu"      # disable with "" (not None)

hdg_inst = "jrc_hdg4800"      # reliable heading, used for beam-earth transformation
hdg_msg = "hdg"


## heading correction
## all heading+msg pairs, for hbin files
hdg_inst_msgs = [
    ('jrc_hdg4800', 'hdg'),
    ('abxtwo', 'adu'),
    ('adu800', 'adu'),
    ('jrc_port', 'hdg'),
```

```
   ('jrc_stbd', 'hdg'),]

## instrument for heading correction to ADCP data (dir and msg)
hcorr_inst = "abxtwo"      # disable with "" (not None)
hcorr_msg = "adu"       # disable with "" (not None)
hcorr_gap_fill = -1   ## fallback correction for hcorr gaps
                ## calculate hdg_inst - hcorr_inst, eg gyro - ashtech
                ## SAME SIGN CONVENTION as cal/rotate/ens_hcorr.ang

## if there is a posmv
acc_heading_cutoff = 0.02

# =========== ADCP transformations========

# heading alignment:  nominal - (cal/watertrack)
h_align = dict(
     os75 = 45.2,)

# transducer depth, meters
ducer_depth = dict(
     os75 = 3,)

# velocity scalefactor
# see SoundspeedFixer in pycurrents/adcp/pingavg.py
scalefactor = dict(
   os75bb = 1.0,
   os75nb = 1.0,)

# soundspeed
# Soundspeed is usually None, and should ALWAYS be left as None for Ocean Surveyor
# (it is remotely possible that soundspeed for a WH, BB, or NB might need to
#         be set to a number, but usually that just results in an erroneous
#         scale factor.
soundspeed = dict(
   os75bb = None,
   os75nb = None,)

# salinity
salinity = dict(
   os75bb = None,
   os75nb = None,)

#=================================================================
# =========          values for quick_adcp.py         ==========
# ========= These are set here for at-sea procesing,    ==========
# ========= but are REQUIRED in quick_adcp.py control   ==========
# =========  file for batch mode or reprocessing.       ==========

## choose whether or not to use topography for editing
## 0 = "always use amplitude to guess the bottom;
##        flag data below the bottom as bad"
## -1 = "never search for the bottom"
## positive integer: Only look for the bottom in deep water, where
##     "deep water" is defined as "topo database says greater than this".

max_search_depth = dict(
   os75bb = 2000,
```

```
    os75nb = 2000,)

# special: weakprof_numbins
weakprof_numbins = dict(
    os75bb = None,
    os75nb = None,)

# set averaging intervals
enslength = dict(
    os75bb = 300,
    os75nb = 300,)

# Estimate of offset between ADCP transducer and gps:
# - Specify integer values for 'xducer_dx' and 'xducer_dy' for each instrument
# - xducer_dx = ADCP's location in meters, positive starboard with the GPS
#   location as origin
# - xducer_dy = ADCP's location in meters, positive forward with the GPS
#   location as origin
#
# There should be one set of xducer_dx, xducer_dy values per instrument
# Ex. (python version):
#   xducer_dx = dict(
#   wh300 = -2,
#   os38 = 16, )
# Ex. (toml version)
#   xducer_dy = { wh300 = 1, os38 = 6 }
#
# Note that estimates of xducer_dx, xducer_dy can be found in
# cal/watertrk/guess_xducerxy

xducer_dx = dict(
     os75 = 0,)
xducer_dy = dict(
     os75 = 0,)

## If there is a bad beam, create a dictionary modeled after
## enslen (i.e. Sonar-based, not instrument based) and use the
## RDI number (1,2,3,4) to designate the beam to leave out.
```

Annex III

AE2215_sensor.py.txt

```
# This configuration file is Python code.  You should not
# need to change it; but if you do, you need to know that
# in Python, the *indentation matters*.

# The following will normally be empty lists, like this:
#
#ignore_ADCPs = []
#ignore_other_sensors = []
#
# But if you want to run with only a subset of the ADCPs
# and/or ancillary sensors that are defined in this file,
# you can list the ones you want to ignore like this:
#
#ignore_ADCPs = ['wh300', 'os75']
#ignore_other_sensors = ['GPS']
#
# In this case, you are listing the 'instrument' field of each
# ADCP or sensor you wish to exclude.
#

ignore_ADCPs = []
ignore_other_sensors = []
use_publishers = False
#use_publishers = True

# 2-letter abbreviation for logging file prefix and constructing dbase name;
# read by procsetup.py
shipabbrev = "ae"

ADCPs = [
    { 'instrument'  :  'os75',
      'setup'       :  'rdi_setup',      ## RENAME ?? rdi_setup.py
      'terminal'    :  'oswh_term',
      'defaultcmd'  :  'os75_default.cmd',
      'commands'    :  ('EA04500',),
      'datatypes'   :  ('os75bb', 'os75nb'),
      'wakeup_baud' :  9600 }, ]

# Do not edit the next three lines:
common_opts = '-f %s -F -m 1 -H 2 ' % (shipabbrev,)
nb_opts =   '-lE -c -I'        # raw data, write a log file, log errors
oswh_opts = '-lE -c -O -I'      # -O for OS/WH data format
                           # -c for checksum, -I to initiate pinging

sensors = [
    { 'instrument'  :  'os75',      # Passive logging of OS
      'device'      :  'ttyUSB3',
      'baud'        :   19200,      # Some errors at 115200.
      'format'      :  'binary',
      'subdir'      :  'os75',
      'ext'         :  'raw',       # zmq for speedlog:
```

```
  'opt'       : oswh_opts, },


{ 'instrument'  : 'ADU800',
  'device'     : 'ttyUSB5',
  'baud'       :  115200,
  'format'     : 'ascii',
  'subdir'     : 'adu800',   ## do not change dir name
  'ext'        : 'paq',
  'strings'    : ('$GPGGA', '$PASHR,ATT'),
  'messages'   : ('gps', 'adu',),
  'opt'        : '-c -Y2'},    # $PYRTM

{ 'instrument'  : 'ABXTWO',
  'device'     : 'ttyUSB1',
  'baud'       :  115200,
  'format'     : 'ascii',
  'subdir'     : 'abxtwo',   ## do not change dir name
  'ext'        : 'adu',
  'strings'    : ('$GPGGA', '$PASHR,ATT'),
  'messages'   : ('gps', 'adu',),
  'opt'        : '-c -Y2'},    # $PYRTM


{ 'instrument'  : 'JRC_hdg_4800',
  'device'     : 'ttyUSB4',
  'baud'       :  4800,
  'format'     : 'ascii',
  'subdir'     : 'jrc_hdg4800',   #reliable heading device
  'ext'        : 'hdg',
  'strings'    : ('$GPHDT',),
  'messages'   : ('hdg',),
  'opt'        : '-c -Y2'},    # $PYRTM

{ 'instrument'  : 'JRC_JLR21_port',
  'device'     : 'ttyUSB0',
  'baud'       :  38400,
  'format'     : 'ascii',
  'subdir'     : 'jrc_port',    # primary position device
  'ext'        : 'hdg',
  'strings'    : ('$GPHDT', '$GPGGA',), # others were not useful
  'messages'   : ('hdg','gps'),
  'opt'        : '-c -Y2'},   #JRC JLR-21 GPS


{ 'instrument'  : 'JRC_JLR21_stbd',  # spare
  'device'     : 'ttyUSB7',
  'baud'       :  38400,
  'format'     : 'ascii',
  'subdir'     : 'jrc_stbd',
  'ext'        : 'hdg',
  'strings'    : ('$GPHDT', '$GPGGA',), # others were not useful
  'messages'   : ('hdg','gps'),
  'opt'        : '-c -Y2'},   #JRC JLR-21 GPS  ]


## enabling or disabling this occurs in uhdas_cfg.py
```

```
## speedlog: enabled in /home/adcp/config/uhdas_cfg.py
speedlog_config = {
   'instrument'       : 'os75',
   'serial_device'    : '',     # no serial out (else: '/dev/ttyUSB1',)
   'baud'             : 9600,
   'eth_port'         : 'eno2',   # this is the NIC to serve web_speedlog.py
   'zmq_from_bin'     : "tcp://127.0.0.1:38010",  # port to read os75 indexing
   'pub_addr'         : "tcp://127.0.0.1:38020",  # port to publish speedlog #NO SPACES
#   'heading_offset'    : xx.x,  # uses h_align; better would be from EA_estimator.py
   'scale'            : 1.0,     # multiplies velocity measurement
   'bins'             : (1,3),   # zero-based; input to python slice()
   'navg'             : 5,       # pings to average}

## this section describes...
publishers = [
           {
           'subdir'      :  'jrc_port',
           'pub_addr'    :  'tcp://127.0.0.1:38000', # uses this port
           'sample_opts' :  '-c -Y2 -s60',     # $PYRTM}, ]

#### DO NOT CHANGE the following ################

ADCPs = [A for A in ADCPs if A['instrument'] not in ignore_ADCPs]
sensors = [S for S in sensors if S['instrument'] not in ignore_ADCPs]
sensors = [S for S in sensors if S['instrument'] not in ignore_other_sensors]

from uhdas.uhdas import make_publishers

# append zmq_from_bin port to opts in appropriate ADCP sensor block
make_publishers.modify_sensors_for_speedlog(sensors, speedlog_config)

# substitute publishers into sensors for zmq publishing
if use_publishers==True:
   make_publishers.modify_sensors_and_publishers(sensors, publishers)
```