Cruise Report
PIRATA Northeast Extension 2015 & AEROSE X

NATO Ship Alliance

November 15 to December 14, 2015

Las Palmas to Las Palmas (Gran Canaria)

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1 Participants

Hydrography:

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Moorings:

Steven Paul Kunze (NOAA/PMEL), William L. Higley (NOAA/JISAO)

AEROSE:

Vernon Morris, Ebony Roper, Mayra Oyola and Kafayat Olayinka (Howard University); Nicholas Nalli (NESDIS/STAR); Miguel Angel Izaguirre and Malgorzata Szczodrak (RSMAS/UM); Sarah Sammy (Guest Scientist)

Note: this cruise report addresses only the hydrographic and mooring work associated with the PIRATA Northeast Extension collaboration between AOML and PMEL. A detailed separate report is available for the mooring operations. All work performed by the AEROSE team is in a separate document. Figures and results reported here are subject to revision after quality control and final calibration.

We thank the personnel at CMRE as well as the crew and officers of the Alliance for their tireless work and input before and during the cruise.

2 Overview

The 2015 PIRATA Northeast Extension (PNE) and Aerosols and Ocean Science Expedition (AEROSE) Cruise was designed to: (1) collect a suite of oceanographic and meteorological observations in the northeast Tropical Atlantic; (2) recover and redeploy the four moorings that belong to the Northeast Extension of the PIRATA array; (3) recover the TFlex mooring near 4°N, 23°W; and (4) to perform a sensor swap for the PIRATA mooring at 0°N, 23°W. The oceanographic component includes the collection of data along 23°W using CTD-O2/rosette/LADCP and XBTs. The 23°W section cuts through the climatologically significant Tropical North Atlantic region, including the southeast corner of the subtropical North Atlantic (a region of subduction for the subtropical cell circulation); the Guinea Dome and oxygen minimum shadow zone where the subtropical and tropical gyres meet, and the Tropical Atlantic current system. The meteorological component focuses on the measurement of aerosols, ozone and atmospheric conditions.

3 Introduction

3.1 PIRATA Northeast Extension (PNE)

The Pilot Research Moored Array in the Tropical Atlantic (PIRATA, Fig. 1) is a three-party project involving Brazil, France and the United States that seeks to monitor the upper ocean and near surface atmosphere of the Tropical Atlantic via the deployment and maintenance of an array of moored buoys and automatic meteorological stations. The array consists of a backbone of ten moorings that run along the equator and extend southward along 10°W to 10°S, and northward along 38°W to 15°N. Given the widely varying dynamics of various sub-regions of the Tropical Atlantic the PIRATA array was extended into the Northeast, Southeast and Southwest.

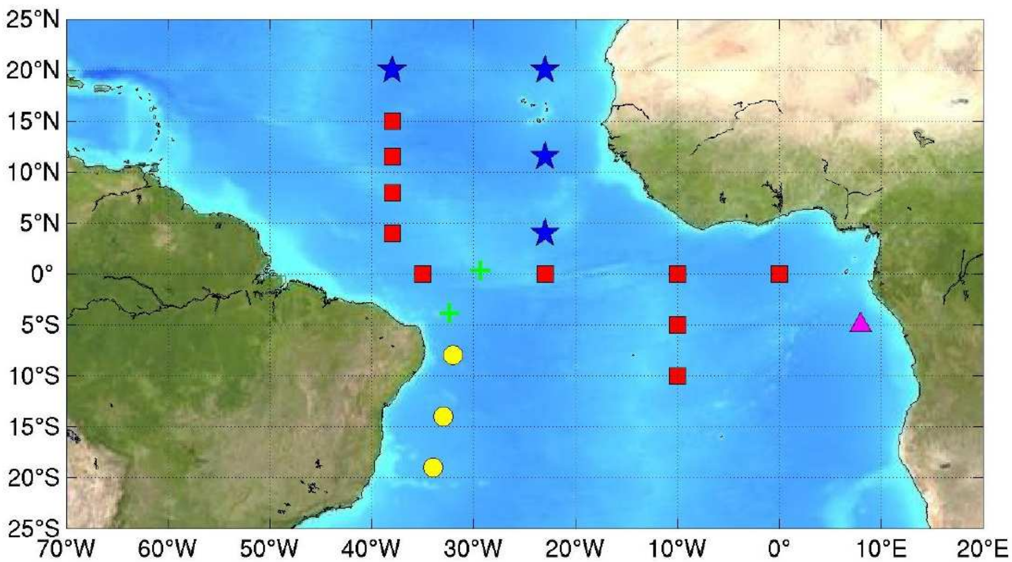

FIG. 1: The Tropical Atlantic, showing the PIRATA backbone (red squares), automatic meteorological stations (green +), southwest extension (yellow circles), southeast extension pilot site (magenta triangle), and the Northeast Extension (blue stars).

The Northeast Extension is important for the collection of data in a region of strong climate variations from intraseasonal to decadal scales, with impacts upon rainfall rates and storms for the surrounding regions of Africa and the Americas. Moored observations in these regions will improve our knowledge of atmosphere-ocean heat exchanges and dynamics impacting the West African Monsoon, marine Intertropical Convergence Zone, upper ocean dynamics affecting heat content and sea surface temperature variability in the Tropical North Atlantic, possible connections between sea surface temperature patterns and North Atlantic climate regimes of variability, and the development of atmospheric easterly waves into tropical cyclones. A better understanding of the processes driving sea surface temperature anomalies in the Tropical North Atlantic region will lead to better predictions of rainfall and other climate signals across a broad geographical domain at timescales from seasonal to decadal.

3.2 Aerosols and Ocean Science Expedition (AEROSE)

The African continent is one of the world's major source regions of mineral dust and biomass burning aerosols. Saharan dust storms are estimated to inject over three billion metric tons of mineral aerosols into the troposphere annually, with large quantities advecting over the tropical North Atlantic within outflows caused by tropical easterly winds and waves. These aerosols impact phenomena ranging from cloud seeding and precipitation, to ocean fertilization, and to downstream air quality and ecosystem impacts in the Caribbean and U.S. eastern seaboard. Red tides, increasing rates of asthma, and precipitation variability in the eastern Atlantic and Caribbean have been linked to increases in the quantities of Saharan dust transported across the Atlantic. The contribution of the Saharan air layer (SAL) to the development of the West African Monsoon (WAM) and its role in tropical cyclogenesis are just beginning to be understood. The interplay between thermodynamics, microphysics, and aerosol chemistry are currently unknown and these field measurements represent a unique data set for unraveling these complex interactions. These issues make the need for understanding the mobilization, transport, and impacts of aerosols originating from natural and anthropogenic processes in Africa a high priority. Unfortunately, large uncertainties remain in our full understanding of the impact of Saharan mineral dust and sub-Saharan biomass burning aerosols on the weather and climate of the tropical Atlantic. It is thus important that we address these gaps in our understanding of regional and trans-boundary aerosol issues.

The NOAA Aerosols and Ocean Science Expeditions (AEROSE) constitute a comprehensive measurement-based approach for gaining understanding of the impacts of long-range transport of mineral dust and smoke aerosols over the tropical Atlantic (Morris et al., 2006; Nalli et al., 2011). The project, involving international coordination of monitoring in Puerto Rico, Mali, the Canary Islands, and Senegal, hinges on multi-year, trans-Atlantic field campaigns conducted in extended collaboration with PNE project over the tropical Atlantic. AEROSE is supported through collaborative efforts with NOAA's National Environmental Satellite Data and Information Service, Center for Satellite Applications and Research (NESDIS/STAR) and the National Weather Service (NWS), as well as NASA and several academic institutions linked through the NOAA Center for Atmospheric Sciences at Howard University.

The AEROSE campaigns (to date, comprised of nine separate trans-Atlantic Project legs) have thus provided a set of in situ measurements to characterize the impacts and microphysical evolution of continental African aerosol outflows (including both Saharan dust and sub-Saharan and biomass burning) across the Atlantic Ocean (Nalli et al., 2011). AEROSE has sought to address three central scientific questions (Morris et al., 2006):

- How do Saharan mineral dust aerosols, biomass burning aerosols, and/or the SAL affect atmospheric and oceanographic parameters during trans-Atlantic transport?

- How do the aerosol distributions evolve physically and chemically during transport?
- What is the capability of satellite remote sensing and numerical models for resolving and studying the above processes?

4 Order of operations:

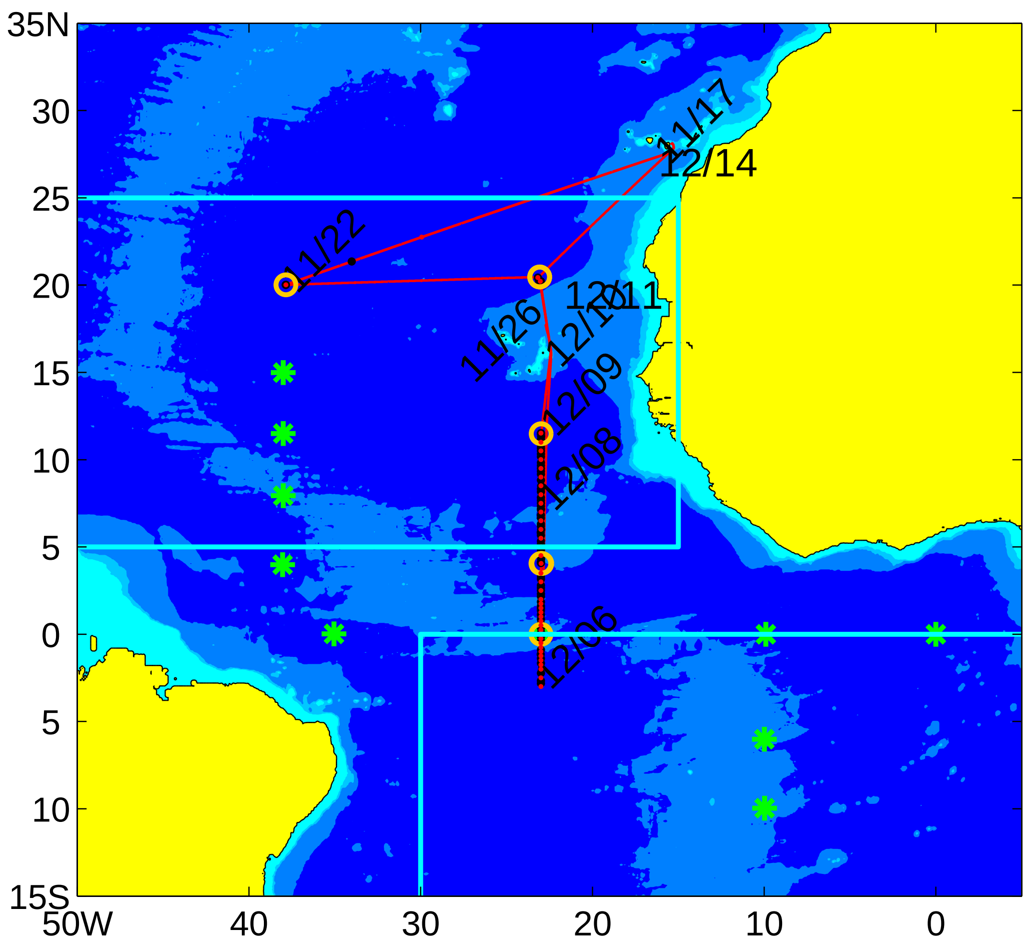

FIG. 2: cruise track of the R/V Alliance. Track (red line) with PNE recovery and deployment sites (circles), CTD stations (red dots) and XBT profiles (black dots).

The R/V Alliance departed from Las Palmas, Gran Canaria on November 16, one day later as planned due to a delay in the customs clearance of the container with the hydrographic gear, and proceeded to steam west-southwestward towards the first mooring site (Fig. 2). Throughout the whole cruise, the AEROSE team kept busy by collecting atmospheric data, skin sea surface temperature and launching rawinsondes and ozonesondes (up to four sonde launches per day during S-NPP and MetOp satellite overpasses). In the following, the oceanographic and mooring work are described. Details on the work of the AEROSE team are reported in a separate document.

The first days of cruise were used to set up the XBT and the CTD-O2/rosette/LADCP system (called CTD hereinafter). The latter was a bit more challenging, because there was a problem with the communication between our deck unit and the data acquisition computer from the ship. Thanks to a deck unit provided by Marina Ampolo Rella from CMRE, we could perform a CTD test cast with our package on November 19. The test revealed that all sensors with the exception of the primary temperature sensor worked well. The rosette, which had been equipped with 14 niskin bottles, worked well but it was found that two niskin bottles had a problem. These issues were resolved later by fixing the niskin bottles and replacing the primary temperature sensor. The niskin bottles were used to collect water samples at 12 to 14 depths during the up-cast throughout the cruise.

The CTD cast was followed by a test of the XBT systems to be used for two XBT experiments. One of these experiments was designed to test the impact of the drop height on the profile by simultaneously dropping two XBTs from different heights (XBT fall height experiment). The heights are 14 m (bridge deck) and 4 m (fantail). The goal of the other experiment was to test the new enhanced Deep Blue XBTs from Sippican in collaboration with the manufacturer (XBT new probe experiment). The XBT system test was done by dropping the first two XBTs for the XBT fall height experiment.

On November 21 in the morning the site of the first mooring, 20° 1'N, 37° 51'W, was reached. The recovery of the Atlas mooring went smoothly and was completed at about 12:00 UTC. The afternoon was used to deploy an Atlas mooring at the same location. While the mooring settled, a CTD cast was performed. The replacement primary temperature sensor worked very well. Simultaneously, four XBTs were dropped one by one for the XBT new probe experiment. This was followed by the XBT fall height experiment and a fly-by of the newly deployed mooring to get an accurate position and ensure all data are transmitted. Then, the ship steamed eastward towards the Atlas mooring near 20°N, 23°W. A CTD profile was taken near that location on November 25 and the mooring work was postponed to the return trip to Las Palmas due to strong trade winds. Another CTD profile was taken farther south, just before entering the Exclusive Economic Zone (EEZ) of the Cape Verde Islands. At both locations, an XBT new probe and an XBT fall height experiment were done.

After exiting the Cape Verde EEZ, the 23°W CTD section and a XBT new probe test were done in the early morning of November 28 at about 11.5°N. Near this location, the Atlas mooring was replaced with a TFlex mooring and XBT were dropped for the fall height experiment around noon. This work was completed in the evening and the ship continued south at 23°W towards the next mooring site near 4°N. Along the way, a CTD cast was done every half a degree and the XBT fall height experiment was performed half way between CTD stations. In addition, selected CTD stations were used to do

FIG. 3: Group photo showing the hydrographic team, the mooring team and the AEROSE team. From left to right: Goshka, Miguel, Nick, Eric, Davide, Marina, Vernon, Kafayat, Tom, Claudia, Steve, Sarah, Bill, Mike, Ebony, Vera, Shaun, Mayra.

the XBT new probe experiment.

To reach 4°N during daylight hours, the 4.5°N CTD station was postponed until after the recovery of the TFlex mooring near 4°N. During the night of December 1, the ship steamed back to 4.5°N the CTD cast was done and then the ship returned to 4°N to deploy an Atlas mooring at the location where the TFlex mooring had been, and to recover the near-by Atlas mooring that was there to allow data comparisons between the two different mooring designs.

In the evening of December 2, the ship continued south along 23°W to continue the CTD casts and XBT experiments. At the equator, the relative humidity sensor on the French PIRATA mooring was replaced because it had failed. At 3°S the CTD section was ended to allow enough time to replace the Atlas mooring near 20.5°N, 23°W. On December 11, this work was completed under good weather conditions.

5 Data collected on this cruise

5.1 Near real-time distribution of oceanic data (PNE)

On this cruise, XBT temperature profiles and CTD temperature/salinity profiles were transmitted in near real-time via the Global Telecommunication System (GTS) for data assimilation into numerical models as well as model validation. Within this project, this was first done during the 2006 PNE/AMMA cruise.

ATLAS and TFlex moorings

Six mooring sites were visited during this cruise (as listed in Table 1). Five moorings were recovered and four moorings were deployed. In addition, the relative humidity sensor on a French PIRATA mooring was replaced because it had stopped to work, and it was attempted to restore the data flow from a couple of subsurface sensors. The latter was not possible which indicates that there may be a problem with the sensor itself.

Pictures of the radiometers from the moorings were taken for those that were impacted by dust deposits. These moorings include the sites near 20°N, 38°W; 20.5°N, 23°W and 11.5°N, 23°W. Afterwards, the dust was sampled for an analysis targeted at finding out where the dust originated.

CTD-O2/rosette/LADCP stations

Problems were encountered during setting up of the system. Initially, the data from the CTD (with all sensors installed) were received by the deck unit and the computer. However, that did not work anymore a few hours later. After many tests with both CTD units (fish) and different cable connections it was determined that the communication between the deck unit and the data acquisition computer from the ship caused the problem (different connector layout). Marina Ampolo Rella from CMRE offered their deck unit to us, which was set up in a way that was not compatible with our CTD. Marina Ampolo Rella and Thomas Sevilla worked out how to change their deck unit back to the original factory settings and got it to work well with our fish.

During the test cast the primary temperature did not work. It was replaced after the cast.

South of 10 degree latitude GGA string from NMEA received by the deck unit had a space in front of the single digit latitude instead of a zero. This format problem caused the deck unit for the CTD to not recognize the NMEA feed (green lamp on deck unit remained off). Marina Ampolo Rella was able to fix this by switching from COM port 7 to another COM port without the mistake, which solved the problem (impacted by this in terms of a delay was cast 8 at 9.5°N). For more information on the NMEA issue see section 7.

During cast 13 (7°N, 23°W) the CTD hit the bottom at a maximum pressure of 1467 dbar. Contributing factors for this were: (1) the echo sounder indicated that the water depth is 2900 to 3000 m (more information can be found in section 7) and (2) we did not have an altimeter (one more thing that was supposed to be in the container but was not there). The nautical chart of the ship does show shallow areas in the vicinity, but not at the station location itself. Also, in previous years when this station was occupied the profiles reached the 1500 dbar. The problem was noticed because the pressure stopped increasing while more wire was going out. The maximum pressure reading was 1467 dbar (conversion to depth results in 1453.7 m). The winch reading for the wire out was 1550 m. During earlier casts, the difference between wire out and pressure reading was about 60. This indicates that about 30 m too much wire were out. When the CTD came out of the water, there were no apparent signs of tangling. Once the CTD was on deck, one could see two kinks in the wire. One of them was secured with an additional line to be on the safe side. The other one was marked with tape for monitoring.

During cast 18, the data became very bad at 1500 dbar, just prior to the beginning of the up cast (before the first bottle was fired). I decided that we should not do bottle stops until we figured out what is going on, because it did not look like a jellyfish was sucked into the sensors. Monitoring the data indicated that only the primary temperature had a problem (which also yielded bad primary salinity and oxygen, and interestingly enough, also bad secondary oxygen. At about 900 dbar the reception of bad data stopped and we started doing bottle stops. After the cast, we replaced the cable for the primary temperature sensor.

Autosal: the primary autosal was not performing well (strong drift). A potential reason could be unstable room temperature. We could not use our portable AC unit, because the heat it generates could not be piped to the outside. A comparison of the salinity from the samples with those from the CTD revealed very bad results. Because of this, I decided to take as many samples home as possible. From casts 22 to 29, half of the salt samples were analyzed to free up sample bottles for the rest of the casts. While these samples were analyzed, the primary autosal eventually failed to drain the cell. The secondary autosal experienced similar problems with strong drift while running a subset of samples from casts 24-29. Because we had only 7 cases of sample bottles, we only have 6 to 12 samples per cast for the remaining casts.

LADCP: the Linux-based software that was brought to try it out could not be used due to missing of some files. Therefore, the BBTALK software was used for communication with the ADCPs. For some reason the logging of the pre-cast information was lost for most casts. It seems like BBTALK was overwriting the log files. Aside from the first 3 casts, the clock was always set correctly. Note was taken on how to adjust the time for casts 0-2 to get good velocity profiles. Problematic casts in terms of processing are number 13 (CTD hit bottom, which causes problems in the software used for initial processing), number 20 and 28 (both times the up-looker had not recorded any data). It is expected that all three casts will allow deriving a good velocity profile during post-cruise processing.

expendable bathythermograph (XBT) casts

A total of 168 XBTs were dropped during the cruise (Tables 3, 4 and 5) along 23°W and at selected locations near CTD casts.

After dropping the first four enhanced Deep Blue XBTs for the new probe experiment it was found out that no data files were stored on the computer. The reason for that was the absence of output directory. This directory was not created during the installation of the new software provided by Sippican for this experiment. After installing this software a second time on the same computer the directory was created. This is a systematic problem of the software (i.e., it could be reproduced on another computer). Sippican was made aware of this issue.

The times in edf files from the new deep blue experiment are off by five hours after the computer for the XBT drops from the fantail was replaced due to frequent crashes. The new computer was on Miami time (UTC plus 5 h). The files affected are from drops 13 to 48.

Ship ADCP

Shortly before the cruise started we were informed that the RDI 75 hull-mounted ADCP had problems. It turned out that it could not produce useful data due to issues with poor performance of beams 3 and 4. The RDI 300 hull-mounted ADCP worked well, but is limited to measuring currents in the upper about 60 m. For more details see section 7.

True wind

True wind has been recorded throughout the cruise, but for a while the algorithm failed (upon crossing 10°N to the south). For more details see section 7.

Preliminary figures of the data

Surface features in the temperature section include the shallow tropical surface water layer and show the cooler water in the equatorial cold tongue (Fig. 4). Below the mixed layer the temperature drops rapidly within the thermocline to less than 10°C. Between 200 dbar and 500 dbar one can see two areas in the northern part of the section where the isotherms shoal and deepen quite strongly (they are centered at about 8°N and 10°N). These features can be associated with the two transitions from westward to eastward flow in the section of the zonal velocity from the LADCP (Fig. 5). Below that layer, near 700 dbar, the isotherms mostly slope downward from south to north and the flow is mostly eastward, north of 5°N. Near the equator, the latitude with the shallowest isotherms is at about 1°N, at the transition between the equatorial regime and the currents to the north (North Equatorial Countercurrent and Northern Intermediate Countercurrent).

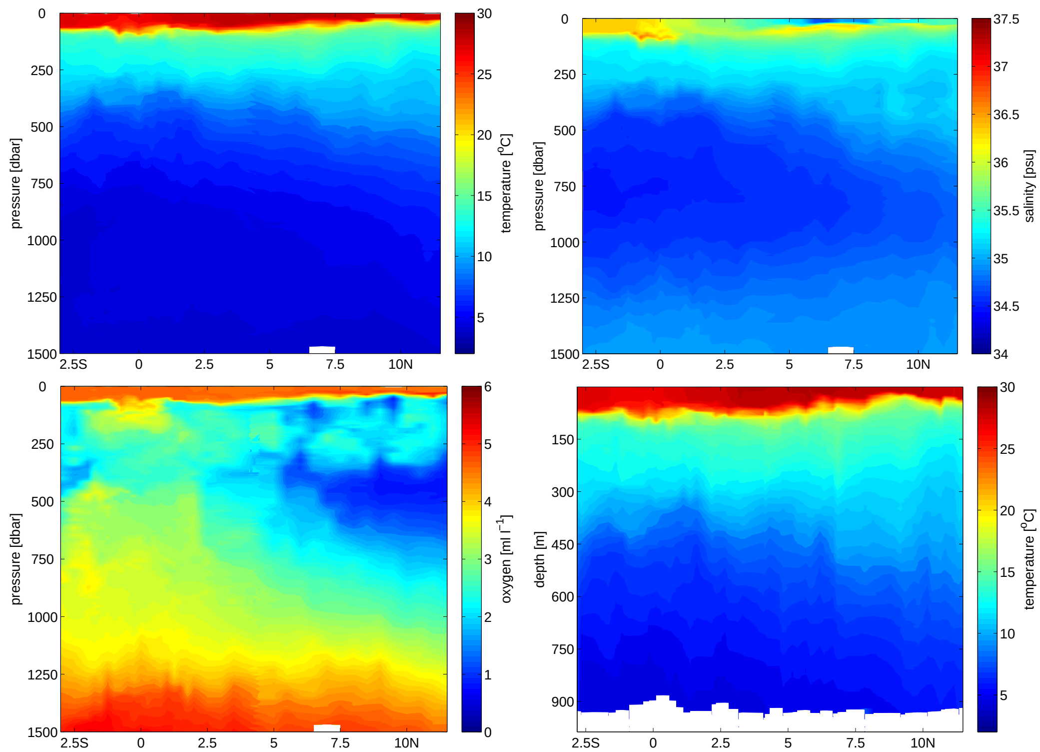

FIG. 4: Sections along 23°W: temperature (top left), salinity (top right) and oxygen (bottom left) from CTD; temperature section from XBT profiles between CTD casts (bottom right).

The salinity section (Fig. 4) reveals the low-salinity core of the Antarctic Intermediate Water coming in from the south between 500 and 1000 dbar as well as the high-salinity subtropical water in the north below the fresh near-surface water in the latitude range that is under influence of the seasonally migrating Intertropical Convergence Zone. The lowest surface salinity was encountered between 5 and 8°N.

The oxygen section shows the subsurface oxygen minimum zone of the northern hemisphere, which is of interest due to the impact of the low oxygen of the ecosystem, very clearly. This water is in the stagnant shadow zone of the North Atlantic, that is not participating in the circulation associated with the ventilated thermocline of the subtropical gyre (e.g., Luyten and Stommel, 1986). In the equatorial regime, within 1° of the equator, the subsurface oxygen concentration is higher, especially in the westward flow under the Equatorial Undercurrent. South of the equator, the subsurface oxygen above 500 dbar decreases again. Below that depth, the oxygen concentration is quite high in the

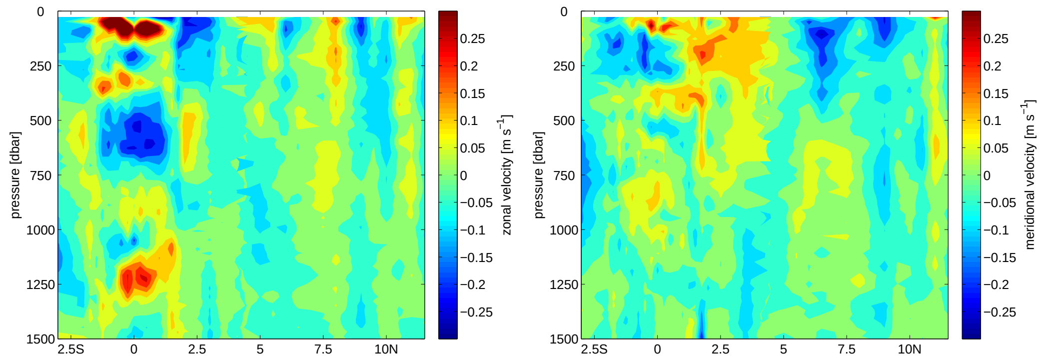

FIG. 5: LADCP section along 23°W.

Antarctic Intermediate Water up to about 2°N. The quite sharp increase of the oxygen below about 1200 dbar is due to the influence of the North Atlantic Deep Water. The transition to this water mass can also be seen in the salinity section (sharp increase of salinity below the Antarctic Intermediate Water).

Comparison of the oxygen measured by the CTD with that from the water samples shows that post-cruise calibration will result in robust estimates that will allow analyzing temporal changes of the oxygen (Fig. 6). With the exception of a few outliers, the scatter at each station is due to the quite typical depth-dependence of the necessary correction.

Aside from the features described above, the LADCP section in Figure 5 also shows equatorial deep jets underneath the Equatorial Undercurrent. These jets are alternating westward and eastward currents stacked in the vertical within 1 degree of the equator. The equatorial profile goes to 3200 dbar, which is not shown in this figure. The westward current north of the Equatorial Undercurrent is the northern South Equatorial Current with the eastward Northern Intermediate Countercurrent below it. Just north of that is the eastward North Equatorial Countercurrent at the surface. South of the equator, one can see the central South Equatorial Current and the Southern Intermediate Countercurrent underneath it. The meridional velocity reveals the equatorial near-surface divergence that gives rise to the equatorial cold tongue due to the upwelling caused by it. Southward near-surface velocity can be seen south of 1°S while northward near-surface velocity is present between that latitude and 5°N. Farther north the meridional velocity near the surface is southward once again.

XBT profiles from two XBT comparison experiments are shown in Figure 7. One of the experiments was targeted at investigating how the fall height might impact profiles. The profiles in the left panel show the collected profiles for a fall height of 14 m (listed in Table 5) and 4 m (listed in Table 4). The goal of the other experiment is the testing of a new type of XBT. For this experiment four XBTs were dropped (listed in Table 3) during selected CTD casts.

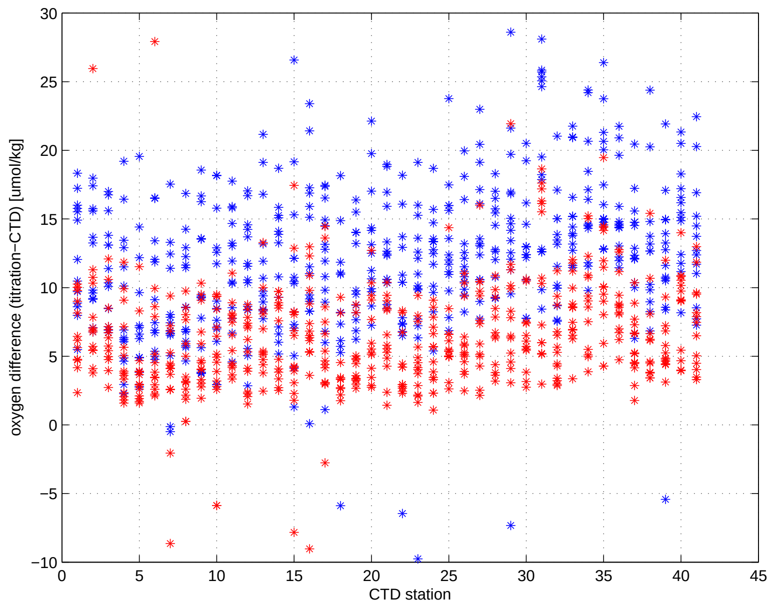

FIG. 6: Comparison of oxygen from CTD with oxygen from water samples. The colors indicate which sensor the measured the oxygen (blue = primary oxygen sensor, red = secondary oxygen sensor).

For the new XBT experiment, Sippican developed a new software that allows the application of depth calculation based on the serial number. This software failed to install properly which resulted in a loss of data from the first set of four dropped XBTs. The reason is, that the software does not create the output directory during a first installation, and it does not give an error message about the absence of that directory. When the software is installed a second time the output directory is created.

6 Research clearance

A misunderstanding occurred with respect of the research clearance for the Cape Verde Islands and African Nations through whose EEZ the ship needs to pass. NOAA requires such clearance as a civilian agency and initially, CMRE agreed to request clearance. Because it was CMRE's understanding that the R/V Alliance as a NATO vessel does not require clearance for doing any research in the EEZ of another country CMRE did not request any clearances for research. The problem is that I only found out about this decision after arriving in Las Palmas, which was too late to do anything about it. For this reason the 17 CTD casts planned for the Cape Verde EEZ could not be done.

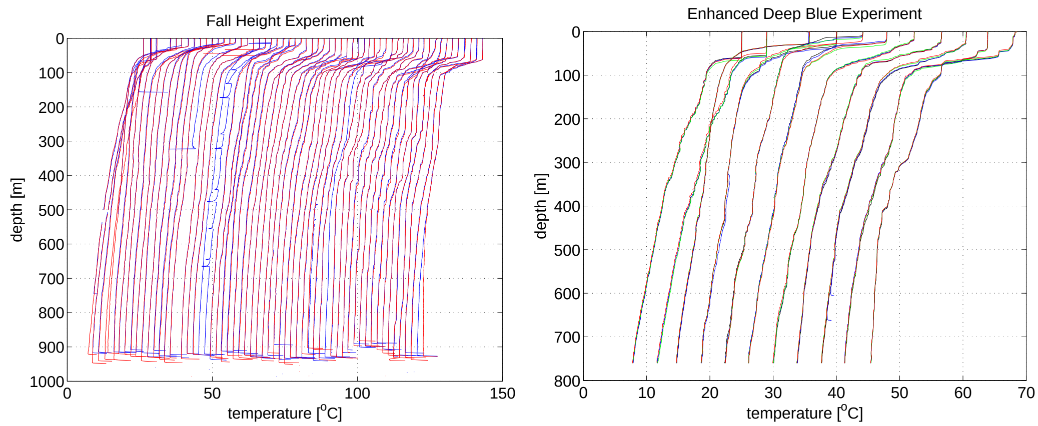

FIG. 7: XBT comparison experiments. Left panel: profiles with a fall height of 4 m are shown in red while the blue ones represent profiles obtained with a fall height of 14 m. Right panel: 11 sets of 4 profiles each were collected with the new enhanced Deep Blue XBTs in collaboration with the manufacturer of the XBTs (Sippican). Profiles were shifted between sets by 2°C in the left panel and 4°C in the right panel to allow showing the sets together.

7 Ship

Overall

Officers and deck crew worked very well together with the scientists to accomplish the goals of the cruise. The engineers worked efficiently to keep the ship moving at a good speed.

IT support

IT support was provided quickly and efficiently by Davide Bertagna from CMRE.

Data support

Marina Ampolo Rella from CMRE provided expertise and equipment throughout the cruise to deal with whatever problems arose.

Internet access from ship

24/7 Internet access was available at the beginning of the cruise, until we left the range of the VSAT service. Once out of range we had access via FBB 500 for about 6 hours per day. On the way back we were in range of the VSAT starting in the late evening of December 11 or early morning of December 12, but the 24/7 connectivity was not restored until Monday (December 14) because nobody was available onshore during the weekend to flip a switch.

Ship ADCP

Shortly before the cruise started we were informed that the RDI 75 hull-mounted ADCP had problems. It turned out that it could not produce useful data due to issues with poor performance of beams 3 and 4. Interactions between the ship and RDI resulted in the conclusion that the ADCP can only be fixed in dry dock. Attempts at using the RDI 75 were terminated on November 21.

The RDI 300 hull-mounted ADCP worked well, but is limited to measuring currents in the upper about 60 m.

Echo-sounder

The ship has a Deso 35 single beam echo sounder. The Alliance was not very accustomed to working in deep ocean environments and this cruise tested the capabilities of the system which required frequent tweaking of parameters (e.g., adjusting range limits and signal strength). It is not clear if the limitations of the system do not allow proper depth readings through a wide range of water depths that keep changing. This caused a problem during on CTD cast when the depth reading was consistently between 2900 m and 3000 m with strong echoes. It turned out that this was the second echo and the water depth was actually slightly more than 1450 m. The nautical chart indicated that the depth can be anywhere between 1600 m and 3000 m. This depth reading was a contributing factor to the CTD hitting the bottom during cast 13.

NMEA issues for true wind and CTD deck unit

The Alliance had not previously operated at latitudes in single digits. It was found that south of 10 degree latitude the true wind calculation failed because the GGA string from NMEA used by the software has '..., 9.xxx,...' instead of '...,09.xxx,...' for latitude. This problem was eventually fixed. For files with the error, the true wind has to be calculated during post cruise processing.

The formatting must also be the cause for the issue with the CTD deck unit described above.

Autosal room

The Alliance would benefit from a temperature controlled room that can be used for analyzing salt samples.

TABLE 1: List of Mooring operations.

date	start	end	latitude	longitude	
11/21/2015	08:00	13:30	20° 1’ N	37° 51’ W	Atlas recovery
11/21/2015	15:00	22:00	20° 0.9’ N	37° 51.4’ W	Atlas deployment
11/28/2015	07:30	13:00	11° 29’ N	22° 59’ W	Atlas recovery
11/28/2015	14:30	20:30	11° 28.2’ N	22° 59.9’ W	TFlex deployment
12/01/2015	15:00	20:00	4° 3’ N	22° 59’ W	TFlex recovery
12/02/2015	09:00	12:30	4° 2.9’ N	22° 59.7’ W	Atlas deployment
12/02/2015	13:00	17:30	4° 5’ N	23° 0’ W	Atlas recovery
12/04/2015	09:00	12:00	0° 0.4’N	23° 0’ W	Atlas, RH sensor swap
12/11/2015	07:30	11:30	20° 28’ N	23° 6’ W	Atlas recovery
12/11/2015	12:30	18:30	20° 26.6’ N	23° 8.5’ W	Atlas deployment

TABLE 2: List of CTD stations.

cast	date	time	latitude	longitude
0	11/19/2015	15:42	22.75017	-29.9375
1	11/21/2015	21:05	20.014	-37.84733
2	11/25/2015	13:15	20.4275	-23.18333
3	11/25/2015	16:31	20.21133	-23.0345
4	11/28/2015	06:02	11.51733	-23.00017
5	11/28/2015	23:27	10.99983	-23.00167
6	11/29/2015	03:52	10.50017	-23.00033
7	11/29/2015	08:27	10.0035	-22.99967
8	11/29/2015	13:21	9.5005	-23.00167
9	11/29/2015	17:57	9.0005	-22.9985
10	11/29/2015	22:50	8.49917	-22.99917
11	11/30/2015	03:06	7.99967	-23.00017
12	11/30/2015	07:56	7.5015	-23.00033
13	11/30/2015	12:13	7.0015	-22.99983
14	11/30/2015	17:9	6.49967	-22.99917
15	11/30/2015	21:43	6.00183	-22.99917
16	12/1/2015	02:13	5.50033	-22.99967
17	12/1/2015	06:54	5.00017	-22.99933
18	12/1/2015	13:28	4.05467	-22.98733
19	12/2/2015	00:11	4.5	-22.99983
20	12/2/2015	21:45	3.49983	-23.00033
21	12/3/2015	02:09	3.00017	-22.99983
22	12/3/2015	06:47	2.49983	-23.00067
23	12/3/2015	11:08	2	-23.00017
24	12/3/2015	13:50	1.74983	-22.99967
25	12/3/2015	16:54	1.49917	-23.001
26	12/3/2015	19:52	1.24983	-23.00067

cast	date	time	latitude	longitude
27	12/3/2015	22:37	1.001	-23.0005
28	12/4/2015	01:25	0.74967	-23
29	12/4/2015	04:20	0.49983	-23.00033
30	12/4/2015	07:24	0.24933	-23.0005
31	12/4/2015	12:04	0.00067	-23.00033
32	12/4/2015	16:37	-0.25017	-23.0005
33	12/4/2015	19:37	-0.49917	-22.99967
34	12/4/2015	22:22	-0.75	-23
35	12/5/2015	01:03	-0.99983	-23.00017
36	12/5/2015	04:01	-1.25017	-22.99983
37	12/5/2015	07:00	-1.5	-23.00067
38	12/5/2015	09:38	-1.74933	-23.00017
39	12/5/2015	12:16	-1.99983	-23.00017
40	12/5/2015	16:40	-2.4995	-23
41	12/5/2015	21:10	-3	-23.00067

TABLE 3: List of XBT profiles for the enhanced Deep Blue experiment. No data were saved for the first four dropped XBTs due to a software issue (see text for details).

cast	date	time	latitude	longitude
1	11/21/2015	21:21	20.01333	37.8466
2	11/21/2015	21:24	20.014183	37.847483
3	11/21/2015	21:28	20.0142	37.8475166
4	11/21/2015	21:33	20.014116	37.84746
5	11/25/2015	13:20	20.2565	-23.1099
6	11/25/2015	13:25	20.2565	-23.10994
7	11/25/2015	13:29	20.2566	-23.11
8	11/25/2015	13:33	20.2566	-23.11
9	11/25/2015	16:58	20.127	-23.0209
10	11/25/2015	17:01	20.127	-23.0209
11	11/25/2015	17:05	20.1271	-23.021
12	11/25/2015	17:09	20.1272	-23.0211
13	11/28/2015	06:22	11.51861	-23.00111
14	11/28/2015	06:29	11.51861	-23.00111
15	11/28/2015	06:32	11.51861	-23.00111
16	11/28/2015	06:36	11.51861	-23.00111
17	11/29/2015	04:06	10.50003	-23.00008
18	11/29/2015	04:18	10.5	-23.00008
19	11/29/2015	04:23	10.5	-23.00001
20	11/29/2015	04:27	10.5	-23.00001

cast	date	time	latitude	longitude
21	11/29/2015	13:37	9.50194	-23.00361
22	11/29/2015	13:43	9.50194	-23.00361
23	11/29/2015	13:47	9.50194	-23.00361
24	11/29/2015	13:52	9.50194	-23.00361
25	11/29/2015	22:53	8.486	-22.98598
26	11/29/2015	23:03	8.48598	-22.98596
27	11/29/2015	23:09	8.48597	-22.98596
28	11/29/2015	23:13	8.48602	-22.986
29	11/30/2015	08:23	7.50361	-23.00056
30	11/30/2015	08:27	7.50361	-23.00056
31	11/30/2015	08:31	7.50361	-23.00056
32	11/30/2015	08:34	7.50361	-23.00056
33	11/30/2015	21:45	6.00004	-22.01666
34	11/30/2015	21:49	6.00004	-22.98359
35	11/30/2015	21:53	6.00005	-22.01664
36	11/30/2015	21:59	6.00005	-22.01664
37	12/01/2015	07:15	5.00139	-22.98583
38	12/01/2015	07:19	5.00139	-22.98583
39	12/01/2015	07:24	5.00139	-22.98583
40	12/01/2015	07:28	5.00139	-22.98583
41	12/03/2015	07:20	2.50056	-23.00056
42	12/03/2015	07:25	2.50056	-23.00056
43	12/03/2015	07:28	2.50056	-23.00056
44	12/03/2015	07:32	2.50056	-23.00056
45	12/03/2015	17:19	1.48583	-23.00139
46	12/03/2015	17:23	1.48583	-23.00139
47	12/03/2015	17:27	1.48583	-23.00139
48	12/03/2015	17:31	1.48583	-23.00139

TABLE 4: List of 59 XBT profiles for the fall height experiment, dropped from a height of 4 m. One profile is missing due to a computer crash.

cast	date	time	latitude	longitude
1	11/20/2015	14:37	21.352	-34.014
2	11/21/2015	23:05	20.01317	-37.8575
3	11/25/2015	14:36	20.4245	-23.18
4	11/25/2015	17:54	20.21183	-23.0035
5	11/28/2015	13:16	11.47833	-22.99667
6	11/28/2015	21:15	11.333	-22.9885
7	11/28/2015	22:37	11.15283	-22.99467
8	11/29/2015	01:59	10.81583	-23.001

cast	date	time	latitude	longitude
9	11/29/2015	02:49	10.65733	-23.00267
10	11/29/2015	06:29	10.33	-22.99833
11	11/29/2015	07:24	10.16667	-23
12	11/29/2015	10:53	9.83333	-22.99833
13	11/29/2015	11:52	9.66683	-23
14	11/29/2015	15:50	9.33333	-23.00217
15	11/29/2015	16:49	9.16667	-22.99833
16	11/29/2015	20:44	8.8175	-22.99983
17	11/29/2015	21:42	8.3225	-22.99983
18	11/30/2015	02:02	8.1595	-22.99983
19	11/30/2015	05:42	7.83483	-22.99983
20	11/30/2015	06:42	7.66667	-23
21	11/30/2015	10:08	7.33167	-23
22	11/30/2015	11:04	7.16667	-23.001
23	11/30/2015	11:12	7.145	-23.001
24	11/30/2015	14:23	6.82333	-23
25	11/30/2015	15:52	6.65667	-23
26	11/30/2015	19:32	6.31767	-23
27	11/30/2015	20:21	6.17867	-23
28	11/30/2015	23:58	5.82667	-23.01017
29	12/01/2015	00:58	5.6615	-23
30	12/01/2015	04:37	5.33333	-23
31	12/01/2015	05:44	5.16233	-23
32	12/01/2015	09:02	4.80833	-22.99667
33	12/01/2015	09:52	4.65	-22.9945
34	12/01/2015	11:34	4.315	-22.98833
35	12/01/2015	12:39	4.13333	-23.00017
36	12/02/2015	17:26	4.08333	-23.001
37	12/02/2015	23:54	3.31	-23
38	12/03/2015	00:49	3.15917	-23
39	12/03/2015	04:45	2.79983	-23
40	12/03/2015	05:33	2.66117	-23
41	12/03/2015	09:02	2.32083	-22.99983
42	12/03/2015	09:58	2.16667	-22.99983
43	12/03/2015	13:08	1.85	-22.99983
44	12/03/2015	16:08	1.61333	-23
45	12/03/2015	19:02	1.36267	-22.99983
46	12/03/2015	21:37	1.123	-22.99983
47	12/04/2015	00:32	0.8545	-22.99983
48	12/04/2015	03:32	0.60217	-22.99983
49	12/04/2015	06:32	0.3625	-22.99833
50	12/04/2015	09:20	0.10333	-22.9915
51	12/04/2015	15:55	-0.15667	-22.99983
52	12/04/2015	18:39	-0.3715	-22.99983
53	12/05/2015	00:10	-0.89167	-23
54	12/05/2015	03:12	-1.14533	-23.01217
55	12/05/2015	06:15	-1.39167	-23
56	12/05/2015	08:57	-1.65833	-22.99833
57	12/05/2015	15:02	-2.2275	-23
58	12/05/2015	19:00	-2.67083	-23
59	12/05/2015	19:55	-2.8195	-23

TABLE 5: List of 60 XBT profiles for the fall height experiment, dropped from a height of 14 m.

cast	date	time	latitude	longitude
1	11/20/2015	14:23	21.37483	-33.94667
2	11/21/2015	23:07	20.01317	-37.8575
3	11/25/2015	14:37	20.4245	-23.18
4	11/25/2015	17:55	20.21183	-23.03517
5	11/28/2015	13:17	11.47833	-22.99667
6	11/28/2015	21:15	11.333	-22.9885
7	11/28/2015	22:38	11.15283	-22.99467
8	11/29/2015	01:59	10.81583	-23.001
9	11/29/2015	02:50	10.65733	-23.00267
10	11/29/2015	06:27	10.33	-22.99983
11	11/29/2015	07:25	10.16667	-22.99833
12	11/29/2015	10:53	9.83333	-22.99833
13	11/29/2015	11:52	9.66667	-23
14	11/29/2015	15:51	9.33333	-23.00217
15	11/29/2015	16:49	9.16667	-22.99983
16	11/29/2015	20:45	8.8175	-22.99983
17	11/29/2015	21:42	8.66117	-22.99983
18	11/30/2015	01:04	8.3225	-22.99983
19	11/30/2015	02:03	8.1595	-22.99983
20	11/30/2015	05:43	7.83483	-22.99983
21	11/30/2015	06:43	7.66667	-23
22	11/30/2015	10:08	7.33167	-23
23	11/30/2015	11:05	7.16667	-23.01067
24	11/30/2015	11:13	7.145	-23.00983
25	11/30/2015	14:53	6.82333	-23
26	11/30/2015	15:53	6.65667	-23
27	11/30/2015	19:32	6.31767	-23
28	11/30/2015	20:22	6.17867	-23
29	11/30/2015	23:59	5.82667	-23.00017
30	12/01/2015	00:59	5.6615	-23
31	12/01/2015	04:38	5.33333	-23
32	12/01/2015	05:44	5.16233	-23
33	12/01/2015	09:04	4.80833	-22.99717
34	12/01/2015	09:52	4.65	-22.9945
35	12/01/2015	11:35	4.315	-22.9945
36	12/01/2015	12:40	4.13333	-23.00117
37	12/02/2015	17:27	4.08333	-23.001
38	12/02/2015	23:55	3.31	-23
39	12/03/2015	00:49	3.15917	-23
40	12/03/2015	04:45	2.79067	-23
41	12/03/2015	05:34	2.66117	-23
42	12/03/2015	09:03	2.32083	-22.99983
43	12/03/2015	09:59	2.16667	-22.99983
44	12/03/2015	13:08	1.85	-22.99983

cast	date	time	latitude	longitude
45	12/03/2015	16:08	1.61333	-23
46	12/03/2015	19:02	1.36267	-22.99983
47	12/03/2015	21:38	1.123	-22.99983
48	12/04/2015	00:33	0.8545	-22.99983
49	12/04/2015	03:33	0.60217	-22.99983
50	12/04/2015	06:33	0.3625	-22.99833
51	12/04/2015	09:20	0.10333	-22.9915
52	12/04/2015	15:55	-0.15667	-22.99983
53	12/04/2015	18:39	-0.3715	-22.99983
54	12/05/2015	00:11	-0.89167	-23
55	12/05/2015	03:12	-1.14533	-23.012
56	12/05/2015	06:16	-1.39167	-23
57	12/05/2015	08:58	-1.65833	-22.99983
58	12/05/2015	15:03	-2.2275	-23
59	12/05/2015	19:00	-2.67083	-23
60	12/05/2015	19:51	-2.8195	-23

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