The Ship Of Opportunity Program

Gustavo Jorge Goni, Molly Baringer, and Silvia Garzoli
NOAA/Atlantic Oceanographic and Meteorological Laboratory, Miami, FL

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1. Project Summary

The Ship Of Opportunity Program (SOOP) supports the implementation of the international XBT network carried out from cargo vessels, cruise ships, and research vessels; the XBT data acquisition and transmission through the Shipboard Environmental Data Acquisition System (SEAS), data quality control, and support to other observational networks such as ThermoSalinoGraphs (TSGs), global drifter array, and Argo profiling floats. XBTs deployments supported by this project are performed in High Density mode along fixed transects recommended by the international community at the OceanObs09 Conference. The SEAS component of this project is also used for the acquisition and transmission of marine meteorological observations made from the Voluntary Observing Ships (VOS). The SOOP project includes the following components:

- A system called SEAS (Shipboard Environmental Acquisition System) consisting of a software developed for commercial and research vessels to acquire and transmit oceanographic and meteorological observations;
- Upper ocean temperature observations using XBTs deployed closely spaced (high-density mode) in order to measure the mesoscale field;
- Data management, including data acquisition, processing, and distribution;
- Support of AOML TSG operations;
- Support of drifter and Argo float deployment opportunities.

The SOOP project is necessary and essential to the Department of Commerce's mission as evidenced by two of the three strategic goals that comprise the Department's mission statement:

- Keep America competitive with cutting-edge science and technology and an unrivaled information base; and,

- Provide effective management and stewardship of our nation's resources and assets to ensure sustainable economic opportunities.

Highlights of work

The highlights of work carried out by the Ship Of Opportunity Program during FY12 were:

- Maintenance of all XBT transects and deployments as planned;
- Transmission of almost 100% of all XBT data acquired in the deployments;
- Scientific quality control of all Atlantic XBTs and submission of data to NODC;
- Strong scientific use of XBT data for studies of currents and meridional heat transport;
- Realization of the first winter AX25 (Cape Town to Antarctica) XBT deployments;
- Collaboration with NASA in the SPURS (Salinity Processes in the Upper ocean Regional Studies) Project;
- Carried out XBT fall rate experiment at Stennis Space Center water tank and
- Collaboration with Sippican to design a climate quality XBT probe.

2. Scientific and Observing System Accomplishments

2.1. The SEAS System

The Shipboard Environmental data Acquisition System (SEAS) is a real time application developed and maintained at NOAA/AOML, which combines acquisition and transmission of environmental data collected over several platforms. The system acquires atmospheric and oceanographic data, such as meteorological parameters, sea surface salinity and temperature. It operates on vessels of the SOOP, VOS, NOAA vessels, University-National Oceanographic Laboratory System (UNOLS) ships, and Coast Guard vessels, to produce high quality marine weather, and oceanographic observations. NOAA and Scripps Institution of Oceanography (SIO) are the main users of the software. SEAS reports are transmitted using Standard-C to the US Coast Guard and included in the Automated Mutual Assistance Vessel Rescue System (Amver), a real-time search and rescue database.

SEAS is installed on more than 500 ships of the VOS program to transmit over three million meteorological messages, constituting the largest source of marine meteorological observations, which are used in weather forecast prediction models and analysis by university and government laboratories, such as the NOAA National Weather Service. SEAS is also installed in more than 50 ships of the SOOP, which participate with NOAA/AOML in acquiring and transmitting data from approximately 10,000 XBTs per year. The data acquired by the SEAS system are transmitted in real-time to the Global Telecommunication System (GTS) and to global data distribution centers (NODC, Coriolis) to be used by scientists and operational centers.

During FY2012 AOML continued the SEAS system upgrades, which included the development of a newer version compatible with state of the art hardware and software requirements. These upgrade included: a) SEAS XBT Data Recorder, b) SEAS TSG Data Recorder, c) SEAS Transceiver Interface, and d) SEAS Met Observations Logger and SEAS AutoIMET Data Logger.

a) SEAS XBT Data Recorder

The SEAS XBT Data Recorder component is a real time data acquisition, data processing, and data

recording application. This module allows the deployment of XBT using a hand launcher or the AOML developed automated XBT launcher (auto-launcher) with a capacity of 8 probes. The new version of this module includes the integration in a single application of the XBT data reception, recording and transmission, as well as the metadata administration.

b) SEAS TSG Data Recorder

The SEAS TSG Data Recorder is a real time data acquisition, data processing, and data recording application to operate TSG units to collect sea surface salinity and temperature along ship tracks. This software continuously receives measured data values and archives these values for real-time transmission or delayed-mode processing, and manages all the associated metadata. Several setup options are now available, including the sampling frequency for archival and transmission and the transmission intervals. New options have been included to facilitate communications and data sharing via socket, including GPS information, between applications.

c) SEAS Transceiver Interface

The SEAS Transceiver Interface is a real time application that combines reception of GPS data and transmission of recollected data over several devices. It reads time, position, velocity, and course heading, and puts all of this information in a shared memory to be used for other SEAS applications. New options have been included in this component allowing data transmission to an ftp server using Iridium or any other type of Internet connection. This feature allows a reduction in the transmission cost since ftp data transference can be resumed in case of a loss of connection.

d) SEAS Met Observations Logger, and SEAS AutoIMET Data Logger

The SEAS MET module comprises the SEAS Met Observations Logger and SEAS AutoIMET Data Logger and constitutes one of the three world wide used electronic logbooks for data acquisition and transmission of meteorological observations. It is a real time data acquisition, recording, processing and transmission application for meteorological bulletins of high quality marine weather observations. The most important improvements on this component, as recommended by the National Weather Service, include the generation of IMMT formatted messages as required by the VOSClim program, generation and transmission of Meta-data reports in binary format, and software compatibility with Windows 7. The automated MET system is complete for integration with the Woods Hole Oceanographic Institute Automated METeorological station (Automated MET). Approximately 1200 merchant ships currently have SEAS MET software installed, and supported through the NWS/NDBC (John Wasserman and Richard Crout) VOS Program. These ships transmitted approximately 300,000 meteorological observations using SEAS software during FY2012. This contribution constitutes a large fraction of non-satellite global marine weather observations.

2.2. XBT Operations

The XBT transects were recommended by the international community (Figure 1). Several of these transects are maintained by NOAA/AOML alone or with the collaboration of US and international partners (Table 1). The global XBT network is an effort maintained by 9 countries (US, France, Australia, South Africa, Brazil, Germany, Japan, Argentina, and Canada). The XBT operations address both operational and scientific goals of the NOAA program for building a sustained ocean observing

system for climate. Specifically, AOML support a global XBT network that provides subsurface temperature data.

During FY2012, due to budget restrictions and scientific and climate research data requirements, AOML finalized the termination of its XBT operation in Frequently Repeated (FR) mode, to focus the resources and efforts on the XBT operation in High Density (HD) mode, where XBT deployments are done every 20-25 km and transects are repeated 2 to 10 times per year, depending on scientific requirements and logistics.

During FY2012, NOAA/AOML collaborated with its partners by providing probes, equipment, logistics, and/or data processing and transmission capabilities. A total of 9,697 XBT deployments were done with AOML involvement during FY2012 (Figure 2).

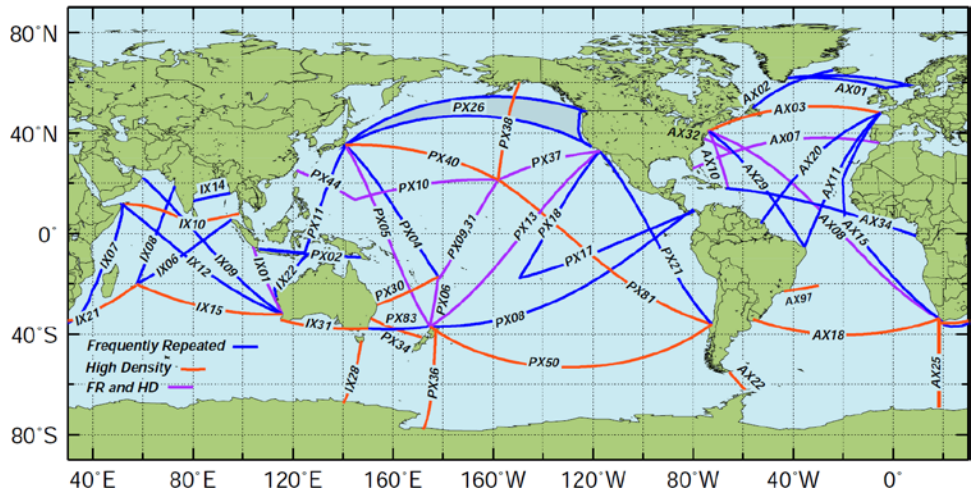

Figure 1. Location of the High Density and Frequently Repeated XBT transects recommended by OceanObs 2009. The countries leading the efforts to carry out each transect are indicated in Table 1.

Scientific and Operational Goals

Currently, the main focus of the XBT network is to maintain the High Density transects. The strength of the XBT data set currently lies on its length and on its ability to estimate transports across entire ocean sections and key choke-points, such as Drake Passage, Indonesian Throughflow, ACC south of Africa, etc. The scientific objectives of HD are summarized below:

- Measure the seasonal and interannual fluctuations in the transport of mass, heat, and freshwater across transects which define large enclosed ocean areas and investigate their links to climate indexes.
- Determine the long-term mean, annual cycle and interannual fluctuations of temperature, geostrophic velocity and large-scale ocean circulation in the top 800 m of the ocean. However, in some regions, XBTs reaching 800 m cannot depict the complete vertical structures of fine but intense oceanic jets and a combined approach in terms of high density and deeper profiling float measurements is necessary.
- Obtain long time-series of temperature profiles at approximately repeated locations in order to unambiguously separate temporal from spatial variability.

- Determine the space-time statistics of variability of the temperature and geostrophic shear fields.
- Provide appropriate *in situ* data (together with Argo profiling floats, tropical moorings, air-sea flux measurements, sea level etc.) for testing ocean and ocean-atmosphere models.
- Determine the synergy between XBT transects, satellite altimetry, Argo, and models of the general circulation.
- Identify permanent boundary currents and fronts, describe their persistence and recurrence and their relation to large-scale transports.
- Estimate the significance of baroclinic eddy heat fluxes.

The implementation of the XBT transects and of data management requirements is done by the WMO-IOC Ship Of Opportunity Programme Implementation Panel (SOOPIP). Although the SOOPIP implements data management practices, they are usually not uniform as each Laboratory and country currently sets up procedures that are not standardized across the network.

Transect	Agency	Status	Year
AX01	5, 1, 23	Active	
AX02	1, 3, 23	Active	
AX03	10	Active	
AX04		Active	
AX07	1	Active	1995
AX08	1, 6	Active	2000
AX10	1	Active	1997
AX11	10	Active	
AX15	5	Active	
AX18	1, 11, 6	Active	2002
AX19	1	Active	
AX20	5, 1	Active	
AX22	2, 1, 11	Active	1996
AX25	1, 6, 20	Active	2004
AX29	1		
AX32	1, 3	Active	1981
AX34			
AX97	1, 13	Active	2004

Transect	Agency	Status	Year
IX01	9, 1	Active	1987
IX02		Active	
IX06	6		
IX08	12		1992
IX09	14, 17		
IX10	14, 16, 17		
IX12	9, 1	Active	1986
IX14	12	Active	1990
IX15	2, 4, 6	Active	1994
IX21	2, 4, 6	Active	1994
IX22	9	Active	1986
IX28	4, 2, 1	Active	1993
IX29		Active	
IX31	2		
MX01	21, 9, 1	Active	2007
MX02	21, 9, 1	Active	2007
MX04	21, 9, 1	Active	2007
MX05	21, 22	Active	
MX07	21, 24	Active	

Transect	Agency	Status	Year
PX02	9	Active	1983
PX04	7		
PX05	2, 16, 17, 7	Active	2009
PX06	2, 7, 1	Active	1986
PX08	2, 1	Active	2004
PX09	2, 1	Active	1987
PX10	2, 1	Active	1991
PX11	9	Active	1986
PX12	7	Active	
PX13	2, 7, 1	Active	1986
PX30	4, 2, 7	Active	1991
PX31	2, 7, 1	Active	1986
PX32	4	Active	
PX33	4	Active	
PX34	4, 2	Active	1991
PX37	2, 1	Active	1991
PX38	2	Active	1993
PX39	25	Active	
PX40	8, 17	Active	1998
PX44	2, 1	Active	1991
PX45	8, 16	Active	
PX46	16		
PX50	18, 2		1993
PX53	9		
PX81	2		1997

Agency key

1 USA-AOML
2 USA-SIO
3 USA-NMFS
4 AUS-CSIRO
5 FRA-IRD/BREST
6 ZAF-UCT
7 FRA-IRD/NOUMEA
8 JPN-TOHOKU-U
9 AUS-BOM
10 GER-BSH
11 ARG-SHN
12 IND-NIO
13 BRA-FURG
14 UK-UKMO
15 IND
16 JPN-JMA
17 JPN-JAMSTEC
18 NZL-MSNZ
19 JPN
20 UK-BAS
21 IT-ENEA
22 IT-INOGS
23 FRA-UP
24 CY–U.Cyprus
25 CAN-DFO

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Table 1. XBT transects performed by the international community during FY2012, including their current status and the year in which operations on these transects started.

High Density XBT transects

This operation is designed to measure the upper ocean thermal structure in key regions of the Atlantic Ocean with the objective of investigating the temporal variability of key surface and subsurface currents and of meridional heat transport in the Atlantic Ocean. XBT transects in HD mode are repeated every approximately 3 months with XBTs deployed 20 to 25 km apart in order to measure the

mesoscale structure of the ocean to diagnose the ocean circulation responsible for redistributing heat and other water properties globally. HD XBT transects are carried out globally (Table I) with AOML taking the lead in most of the operations in the Atlantic Ocean. In addition AOML contributes with the HD data transmission and distribution of SIO HD XBT operations and has current international collaboration efforts with Australia, France, Brazil, Argentina, and Italy. For example, during FY2011 and FY2012 AOML implemented 3 new HD transects (AX20, AX01, AX02) as part of its international collaboration efforts, and increased the number of cruises per year in two transects in the North Atlantic.

AOML is currently carrying out 10 XBT transects in HD mode in the Atlantic Ocean (Figure 3). The continuation of AX07 and AX10 and the implementation of AX08 and AX18 were recommended by the Upper Ocean Thermal Review Panel in St. Raphael in 1999, and supported by OceanObs09 recommendations. The HD transects AX07 and AX10 have been maintained since 1994 and 1996, respectively, providing a homogeneous data set for more than a decade. In addition, HD observations in AX08, AX01, AX02, AX18, AX25, AX20, and AX97 provide observations in poorly surveyed regions. The XBT transect AX32 is maintained in support of the M/V Oleander operations.

The locations of XBT deployments in HD mode along each transect during FY2012 are shown on the AOML HD XBT web page (*http://www.aoml.noaa.gov/phod/hdenxbt/*). A summary of all the observations conducted in FY2012 can be found in Table 2. With the exception of AX18, where finding ships covering that route continues to be a challenge, all HD transects are operating normally.

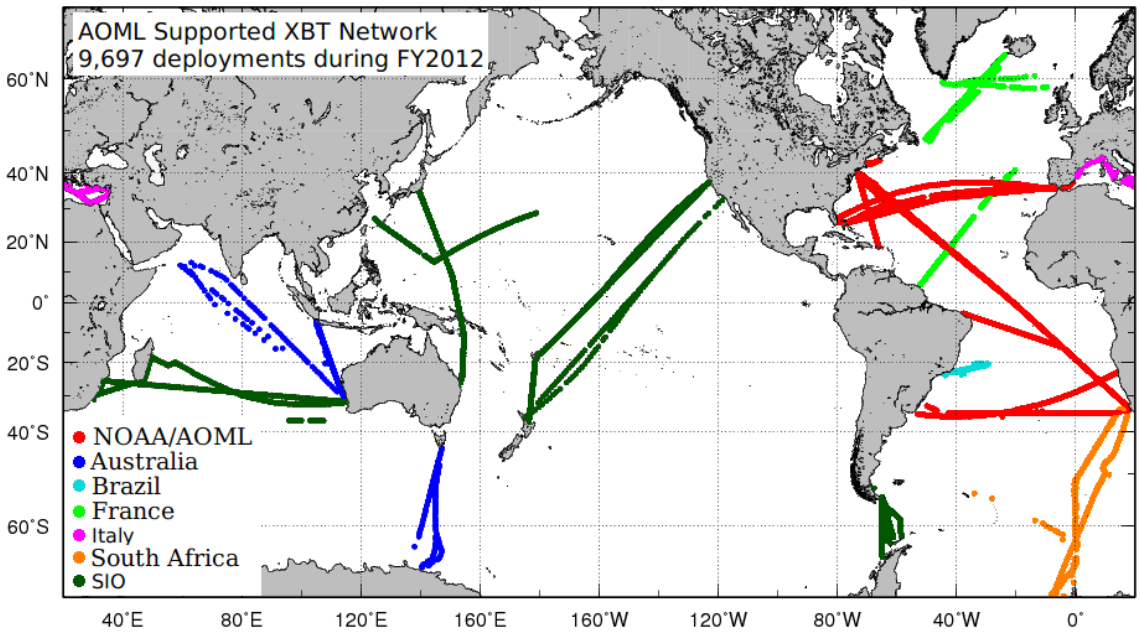

Figure 2. Location of the AOML XBT deployments and AOML-supported XBT deployments/transmissions during FY2012 carried out in collaboration with national and international collaborators.

International Collaboration

The collaboration between AOML and its international partners include the sharing of resources, such as XBT probes, ship recruiting and logistics, equipment, and scientific riders. AOML Provides probes to oceanographic institutions that have demonstrated reliability in logistics and operations. These probes are used to carry out recommended transects in HD mode.

AOML continues its strong collaboration with the Australian CSIRO and BOM. During FY2012, 650 XBTs were provided to CSIRO, in addition to AOML regular collaboration, to conduct an XBT fall rate experiment in the Pacific Ocean. In FY2012 4 transects were implemented in HD mode: AX20 in collaboration with IRD/France and the University of Paris, and MX01, MX02 and MX04 in collaboration with ENEA/Italy (Figure 3).

During FY2012 AOML provided the following number of probes to its international collaborators:

- **IRD, Brest,** 2 pallets (648 probes for AX01 and AX20), collaborators: Diverres and Gilles Reverdin
- **FURG, Brazil,** 1 pallet (324 probes for AX97), collaborator: Mauricio Mata
- **CSIRO and Bureau of Meteorology, Australia,** 2 pallets (648 probes for IX01, IX12, and IX28), collaborators: Susan Wijffels and Graeme Ball
- **ENEA/Italy**, 1 pallet (324 probes for MX01 and MX04), collaborator: Franco Reseghetti
- **University of Cape Town**, 4 pallets (1296 probes for AX25), collaborators: Isabelle Ansorge and Sebastiaan Swart.

Transect	Realizations	No. of XBTs	Avg. No. of XBT per Transect	% of successful deployments	Argo Floats Deployed	Drifters Deployed	XBT Fast Deep Probes
AX01	4	157	39.3	86.7	0	0	0
AX02	4	225	56.3	96.8	0	0	0
AX07	4	958	239.5	96.2	6	29	140
AX08	4	1645	411.3	92.3	6	26	0
AX10	4	390	97.5	94.6	0	0	0
AX18	2	427	213.5	92.3	0	0	0
AX20	1	162	162.0	86.4	0	0	0
AX25	3	402	134.0	94.3	0	0	0
AX32*	12	324	27	90.0	0	0	0
AX97	7	333	47.6	97.0	0	0	0
IX01, 12, 28*		648			0	0	0
MX01	2	106	53.0	94.3	0	0	0
MX02	2	44	22	97.2	0	0	0
MX04	5	114	22.8	85.0	0	0	0
Fall rate	N/A	700					
Total	41	6,635			12	55	140

Table 2: Summary of the number of XBTs, Argo and drifters deployed on the XBT transects operated by AOML or with direct AOML participation during FY2012. ***** Indicates partial contribution to the full sampling. Note: There are currently (October 2012) three transects underway (AX08, AX18, and AX07) that will increase the total number of deployed XBTs by approximately 950 XBTs.

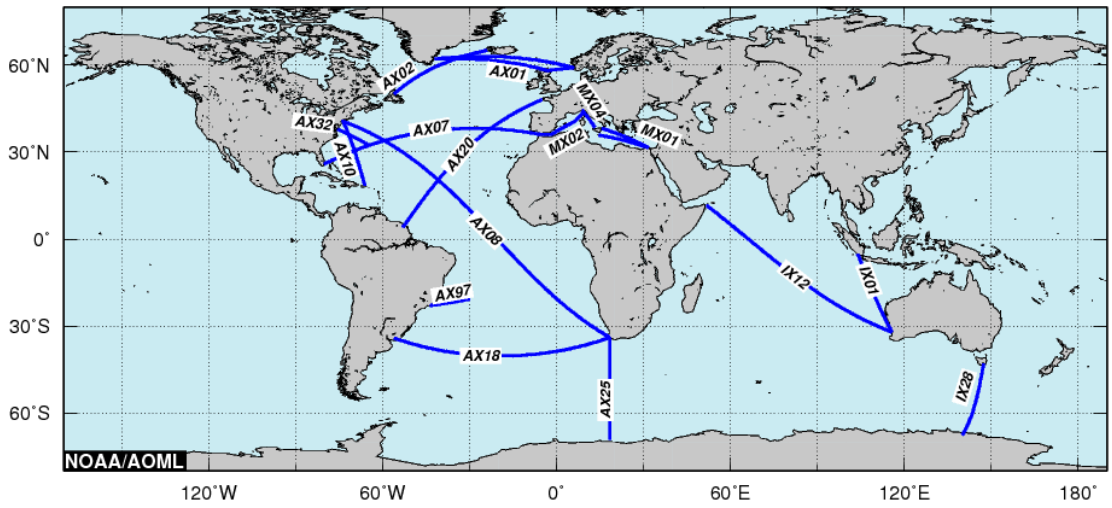

Figure 3. Location of the 4 High Density XBT transects (AX07, AX08, AX10, and AX18) maintained solely by NOAA/AOML, and the 7 transects (AX01, AX02, AX20, AX25, AX32, AX97, IX01, IX12, IX28, MX01, MX02, and MX04) maintained by NOAA/AOML in collaboration with the University of Paris, IRD/France, NOAA/NEFSC, University of Cape Town, Federal University of Rio Grande, Australia's Bureau of Meteorology and CSIRO, and ENEA/Italy.

The probes provided to IRD/France were deployed along transects in the North Atlantic Ocean (AX01 and AX20). The probes provided to Australia are used in a basin wide transect in the Indian Ocean that crosses the equator and to partly support a High Density transect between Tasmania and Antarctica. The XBTs provided to Brazil are used along the AX97 transect in the subtropical South Atlantic that monitors the Brazil Current. The XBTs provided to Italy are deployed in important regions of the Mediterranean Sea. The probes provided to South Africa are deployed along AX25 to study and monitor the Antarctic Circumpolar Current and associated fronts. For the first time since the collaboration started, XBTs were deployed along AX25 during the winter season. AOML provided a total of 10 pallets (3240 XBTs) to these partners. Additionally, several agencies are currently collaborating with this project. The Argentine Hydrographic Naval Office (SHN) provides personnel to deploy the XBTs on AX18; the University of Cape Town provides the riders for the deployments along AX08 and AX25. The South African Weather Service is our contact in Cape Town and Durban to store the equipment in between transects and to provide ship riders. Deployments along AX97 are carried out in collaboration with the Federal University of Rio Grande, Brazil. AOML has been in continuous communication with the Brazilian Navy and has provided the technical expertise needed for transmitting XBT data during the realization of the AX97 transects. Drs. Gustavo Goni and Molly Baringer are involved in data analysis and scientific collaboration activities with scientists from University of Cape Town, South Africa, and University of Rio Grande, Brazil. Most of the data obtained from these XBTs were placed into the GTS in real-time. For those ships that are not currently transmitting the data in real-time, we are exploring the possibility of installing computers and transmitting antennas for real-time data distribution. Most of the data collected from these deployments were submitted to NODC. Figure 2 shows the location of all the XBTs deployed by AOML or any of its collaborators during FY2012.

XBT Fall Rate Experiments

In an effort to improve XBT data quality and to investigate possible issues in the XBT data related to uncertainties in the XBT fall rate equation two XBT fall rate experiments were carried out during FY2012. The first experiment was done in collaboration with CSIRO, where more than 300 XBT probes were deployed simultaneously with CTD casts. During this experiment old (~1980's and 1990's) XBT probes were provided to CSIRO by AOML to investigate temporal changes in XBT fall rates. Data are currently being processed and will start being analyzed during 2013.

A second experiment was conducted in July 2012 at the NOAA/Southeast Fisheries Science Center test tank (Figure 4) within the Stennis Space Center facility in Mississippi. The experiment was designed to study the fall rate and terminal velocity of XBTs during the first meters of their fall. The analysis of the data obtained from the approximately 300 deployments done as part of this experiment is underway. The results from this experiment will allow scientists to better understand the dynamic of an XBT on the first meters after the probe hits the water, and to reduce the errors of observations taken with XBTs.

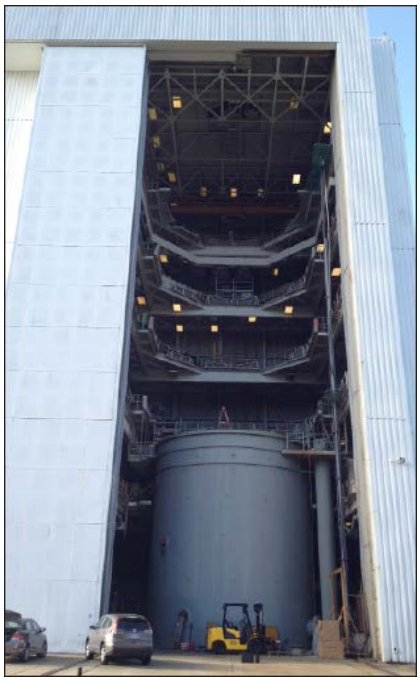

Figure 4. Water tank were XBT fall rate experiments were held in July 2012.

Prototype of new XBT probes

During the Western Boundary Time Series (WBTS) cruise carried out in February 2012, 64 XBT test probes containing upgraded thermistor sensors were tested and data are being compared against simultaneous CTD casts. This experiment was part of a larger NOAA – Sippican collaborative effort to design a new XBT probe that will contain pressure switches and improved thermistors. This new XBT will be able to provide climate quality temperature profile observations. A second test is scheduled for January 2013 during the PIRATA Northeast Extension (PNE) cruise when an additional 102 test probes plus 6 XCTDs will be tested.

XBT Science Team

Members of the SOOP are active participants of the XBT Science Team, which was formally established and held its first meeting in 2010. The report of the first meeting was finalized and is now placed in the AOML XBT Network web page located at: *http://www.aoml.noaa.gov/phod/goos/xbt_network/*. The formation of this team is critical to address issues related to the new goals of the XBT network and to enhance the natural synergy that exists among the other components of the observing system that carry out temperature measurements of the upper ocean.

2.3. TSG Operations

During FY2012 the TSG operations at AOML were carry out in support of the pCO_2 operations. AOML is currently receiving, processing and distributing TSG data from 7 ships of the SOOP (Semester at Sea's *MV Explorer*, *MV Oleander*, *MV Barcelona Express*, *MV Reykjafoss*, *Las Cuevas*, and Royal Caribbean's *Explorer of the Seas* and *Allure of the Seas*) and 10 ships of the NOAA fleet. More than 25 million TSG records were processed at AOML during FY2012, and distributed through several data centers.

The operation of TSG equipment is performed with the SEAS software. During FY2012 the development of the TSG component continued and the software was installed in one ship (*MV Barcelona Express*) to conduct final tests before the operational release of the 9.0 version. Modifications made to the 9 version enable a reduction in the cost of the operation.

Work continued during FY2012 for the installation of a TSG system provided by AOML/PhOD on the former WHOI's *Atlantis*, now commissioned as an oceanographic research vessel in Argentina and operated by the Prefectura Naval Argentina (Coast Guard) as the *Dr. Bernardo A. Houssay*. The installation of this system is currently completed and tests of the data acquisition and transmission are underway. Data from this TSG will be crucial for the calibration of the upcoming NASA Aquarius satellite mission.

2.4. SOOP Data Management and Distribution

Data flow

XBT profiles are acquired and transmitted in real-time through the Thrane Standard C units. AOML also uses Iridium transmission on some XBT realizations and on all TSG operations. The ratio of XBTs deployed to real time data transmitted is essentially 100% in ships with XBT transects directly implemented and maintained by AOML.

The XBT profiles undergo near-real time automatic quality control (AQC) procedures at AOML. The profiles that fail the AQC are submitted to visual quality control (VQC) using a MATLAB based code developed at AOML, in which a trained operator decides whether or not to send the data to the GTS. Probe failure (as measured by the AQC) remains consistently between 5% and 10% with greater higher failure rates at higher latitudes during winter months. Approximately 80% of the profiles that fail the QWC are approved during the VQC. Typically about 95% of all profiles are approved during the quality control process and submitted to the GTS. In addition, all the XBT data obtained are submitted to NODC for archival and distribution.

Similar to XBT profiles, all the TSG data received at AOML is quality controlled through several steps based on the GOSUD (Global Ocean Surface Underway Data Pilot Project) real-time control tests. The whole data set is distributed by the National Oceanographic Data Center (NODC) and Coriolis. This system is currently fully functional in real-time, providing important tools to automatically detect problems in data transmission, equipment calibration and marine operations of ships with TSG data transmission in real-time in general.

A data tracking operation is conducted with the aim to verify the data flow from the source (observation platform) to the processing centers, where the data is analyzed, quality controlled, and disseminated. The tracking of these data flow ensure that the information obtained by different observation platforms are received and that they are generated with the correct codification so that it can be successfully disseminated through the GTS. Routinely, the flow of different kinds of oceanographic data, including XBT, TSG, buoys, drifters and TAO/PIRATA arrays are verified in a daily basis.

Details of this project, such as logistics, equipment, software, and data distribution, are provided through links that can be accessed through the main NOAA/AOML Global Ocean Observing System (GOOS) web page *www.aoml.noaa.gov/phod/goos*, or directly through the NOAA/AOML SOOP web page *www.aoml.noaa.gov/phod/soop*.

- XBT Network: *www.aoml.noaa.gov/phod/goos/xbt_network/*
- XBT HD: *www.aoml.noaa.gov/phod/hdenxbt*
- SEAS: *www.aoml.noaa.gov/phod/trinanes/SEAS/*
- TSG: *www.aoml.noaa.gov/phod/tsg*

The XBT Network website features the latest information on operational XBT transects along with specific web pages showing the latest XBT, Meteorological, and TSG observations, available online at: *www.aoml.noaa.gov/phod/goos/seas/latest/***.** The GOOS website now features a Google Earth layer displaying Global Marine and Meteorological Observations available online at *www.aoml.noaa.gov/phod/VOS/GE/GE_AOML_DT.kmz***.** This application is a powerful tool to visualize the global extent of ocean and meteorological observations interactively. Other web sites were also developed for more specific aspects of the SOOP operation, including the display of real-time TSG data from the *MV Explorer* (*www.aoml.noaa.gov/phod/tsg/sas/*), the *Explorer of the Seas* (*www.aoml.noaa.gov/phod/tsg/xpls/*), and for the Oleander Project displaying XBT products and data obtained from this ship (*www.aoml.noaa.gov/phod/goos/oleander*).

Data quality control and distribution to NODC

All Atlantic Ocean High Density XBT data collect by AOML or AOML partners undergo delayed mode quality control. For this quality control, bad profiles are identified, spikes are removed and profiles are evaluated for representativeness of the surrounding physical oceanography issues known for the region. Similar procedures are employed as other delayed mode quality control such as Scripps and CSIRO. For example, subsurface temperature inversions found near the high salinity/higher temperature Mediterranean outflow might fail automatic quality control procedures, but are perfectly acceptable, expected oceanographic profiles. Occasionally, some data are filtered to remove the small-scale unphysical electrical noise that can occur in the profiles. All modifications to the XBT profiles are logged and available via the AOML web site. Final quality controlled profiles are delivered to NOAA NODC for archival and replacement into the “Best Quality” GTSPP data set, typically within one-two months of the data being collected.

BUFR format

Work on the migration of data transmissions to the GTS in BUFR format continued during FY2012. The main accomplishments related to this migration were:

- Detect and correct the inconsistencies presented in the XBT template under validation.
- Attend and participate in the IPET/DRC meeting that took place in Melbourne (Australia)
- Development and test of a new template that better fits BUFR regulations and prevents decoding conflicts.
- Test and validation of the template using different software packages in collaboration with NOAA/NCEP, ECMWF and the Czech Hydrometeorological Institute.
- Test the transmission to GTS using global distribution headers and real operational profiles

2.5. SOOP Collaboration with other Programs

NASA SPURS (Salinity Processes in the Upper Ocean Regional Studies)

AOML enhanced its AX08 and AX10 expendable bathythermograph (XBT) transects from Cape Town, South Africa to New York and from Spain to Miami, respectively, in support of SPURS. In addition, AOML is also collaborating with researchers at the University of Paris to gather data along the AX20 XBT transect, which runs between France and French Guyana. These XBT transects will provide temperature data five times during 2012 and 2013 across the region of salinity maximum in the tropical Atlantic, which will be key to assessing the tropical ocean current system partly responsible for the fresh water budget. Key to the SPURS experiment and to understanding and assessing the value of the salinity satellite missions will be the deployment of surface drifters in the regions containing salinity sensors, of which AOML will be leading the data processing efforts.

Global Drifter Program

The Surface Drifter Program is helped to maintain its drifter array using contributions from national and international SOOP partners that deploy the drifters worldwide. Many drifters are deployed from vessels cooperating with the SOOP (see Table 2 for drifters deployed during HD cruises in FY2012). SOOP personnel (J. Trinanes) also support AOML efforts to collect hurricane drifter data for subsequent quality control and redistribution.

Argo Program

Ships recruited through SOOP to deploy XBTs are also used as a platform to deploy Argo profiling floats. Between October 2011 and September 2012, a total of 12 floats were deployed from ships of the SOOP (see Table 2). XBT-derived temperature profiles were also used to identify problems in Argo floats [Willis *et al.*, 2008] highlighting the importance of maintaining independent observing systems for ocean subsurface temperature.

Other domestic collaboration in which AOML SOOP is also actively involved includes:

- Support of the NOAA-funded "Surface pCO_2 Measurements from Ships" (Drs. Rik Wanninkhof, Richard Feely, and G. Goni, PIs), AOML provided 1.5 pallets (486 XBTs) to NOAA/NEFSC in

Rhode Island to be deployed along the pCO_2 transects AX32 and AX02. During FY2011 the XBT operation along AX02 was transitioned to a HD XBT transect.

- AOML provides equipment support to one ship of SIO HD XBT operations.
- AOML provides the software to SIO for data acquisition and transmission and carries out the real-time quality control of all SIO HD XBT data.
- AOML collaborates with the National Weather Service to provide maintenance of SEAS software to transmit marine meteorological observations.
- Through an agreement with the U.S. Coast Guard, NOAA/AOML provide real-time information about the location of ships with the SEAS software installed, which is used for search and rescue operations.
- AOML provides hardware equipment (computer for data acquisition and transmission antenna) for the *Oleander* operation, a joint project between NOAA/AOML, NOAA/NEFSC, University of Rhode Island, and SUNY/Stony Brook. Approximately 350 XBTs are deployed by this ship between New York and Bermuda. A web page displaying the data obtained from this project has been created at *www.aoml.noaa.gov/phod/goos/oleander*. The TSG data obtained from this ship can be seen on the TSG web page at AOML: *www.aoml.noaa.gov/phod/tsg*

2.6. XBT-related Panel Memberships

Ship Of Opportunity Programme Implementation Panel (SOOPIP)

The NOAA/AOML SOOP Program is a participating member of JCOMM and JCOMMOPS. The AOML SOOP XBT program is represented bi-annually at the WMO/IOC Ship Observations Team (SOT) meeting. Participation on these international panels provides an important mechanism for integrating and coordinating with other national or regional programs which, in the long run, improves our national climate mission by making more efficient and effective use of available resources.
Dr. Gustavo Goni continues being the Chairman of the WMO/IOC Ship Of Opportunity Program Implementation Panel (SOOPIP), Dr. Joaquin Trinanes is a member of the Meta-T panel and the JCOMM Data Management Programme Area (DMPA) Task Team on Table Driven Code Forms, and Dr. Francis Bringas is a member of the JCOMM DMPA Task Team on Table Driven Code Forms and the SOT Task Team on Instrument Standards.

XBTST Science Steering Team

Drs. Goni and Baringer and active members of the newly formed XBT Science Steering Team. Dr. Goni is the co-chair for operations of this team, together with Dr. Janet Sprintall (for science), and Dr. Thresher (CSIRO, for data management).

SPURS

Dr. Gustavo Goni is an active member of the NASA SPURS (Salinity Processes in the Upper Ocean Regional Studies) Science Steering Team and lead of the Sustained Ocean Observations Working Group. The SOOP is closing collaborating with NASA maintaining the XBT observations in the tropical North Atlantic that are of interest for this project.

2.7. AOML XBT Data Scientific Applications

Several scientific research projects are currently taken place at AOML using the data within the SOOP program. These projects include:

- Variability of the Atlantic equatorial currents
- Variability of the Southern Ocean current system
- North and South Atlantic Meridional Fluxes
- Brazil Current variability
- Fall rate studies

Section 3 below contains the list of publications including results from the above projects as well as other related publication using data obtained from the SOOP program. Results were also presented in several scientific meetings and conference as indicated in the following section.

2.8. Meetings and Workshops organized or attended by SOOP PIs

An annual meeting was held at NOAA/AOML on April 3, 2012. The main goal of this meeting was to bring together the main players of the NOAA/AOML XBT network, SEAS, and TSG project. This workshop was attended by more than 30 participants from AOML, CIMAS, NOAA/SEFSC, NOAA/NESFC, and NOAA/NWS. A total of 27 short presentations were given during this meeting, with most of the time reserved for discussions and planning. The participation of science and science support personnel of the NMFS was done with the goal of coordinating activities on the *Oleander*, in support of pCO_2 activities. John Wasserman, chair of the NOAA/VOS program, the main used of the SEAS MET and autoIMET components, also participated in the discussions via conference call.

Other Meetings attended by SOOP PIs

- Drs. Silvia Garzoli and Molly Baringer attended the South Atlantic Meridional Overturning Circulation Workshop in Simons Town, South Africa on September 27-29th;
- Drs. Baringer, and Garzoli also attended the Climate Research in Service to Society Conference in Denver, Colorado on October 24-28, 2011.
- Dr. Goni attended a Principal Investigator Planning Meeting for the Salinity Processes in the Upper Ocean Regional Study (SPURS) in Seattle, Washington on January 18-19, 2012.
- Dr. Goni attended the Third U.S.-Brazil Joint Commission Meeting on Science and Technology Cooperation in Brasilia, Brazil on March 12-13, 2012.
- Dr. Goni attended a NASA-Aquarius/SAC Satellite D Science Team meeting and met with representatives of the Argentine Coast Guard and Argentine Fisheries Service in Buenos Aires, Argentina on April 11-21, 2012.
- Drs. Baringer and Garzoli attended the 8th Annual Principal Investigator's meeting of the NOAA Climate Observations Division in Silver Spring, Maryland on June 24-27, 2012.
- Drs. Baringer, Garzoli, and Goni attended the U.S. Atlantic Meridional Overturning Circulation Annual Principal Investigators meeting in Boulder, Colorado on August 15-17, 2012.
- Drs. Goni, Garzoli, and Baringer made presentations that used XBT observations during the Physical Oceanography Division retreat in 2013.

3. Publications and Reports

3.1. XBT-related Publications by Principal Investigators in 2011 and 2012

- **Baringer, M.O.**, S.A. Cunningham, C.S. Meinen, **S. Garzoli**, J. Willis, M. Lankhorst, A. Macdonald, U. Send, W. R. Hobbs, T. O. Kanzow, D. Rayner, W. E. Johns, H. L. Bryden, and J. Marotzke, 2012: State of the Ocean in 2011: Meridional Overturning Circulation Observations in the Subtropical North Atlantic. Blunden, J., D.S. Arndt (eds.), Bulletin of the American Meteorological Society, 93(7):S78-S81.
- **Garzoli, S.**, P. Abrahamsen, I. Ansorge, A. Biastoch, E. Campos, M. Mata, C. Meinen, J. Pelegri, R. Perez, A. Piola, C. Reason, M. Roberts, S. Speich, J. Sprintall, R. Watts, and all of the SAMOC IV participants, 2012: South Atlantic Meridional Overturning Circulation (SAMOC) - Fourth Workshop. CLIVAR Exchanges, 58:2-4.
- **Garzoli, S.,M.O. Baringer**, S. Dong,R. Perez, and Q. Yao, 2012: South Atlantic meridional fluxes. Deep-Sea Research, in press.
- Lumpkin R., **G. Goni** and K. Dohan, 2012: State of the Ocean in 2011: Surface Currents. In "State of the Climate in 2011", M. Gregg and J. Levy (eds), Bulletin of the American Meteorological Society, 93(7):S75-S78.
- Srokosz, M., **M. Baringer**, H. Bryden, S. Cunningham, T. Delworth, S. Lozier, J. Marotzke, and R. Sutton, 2012: Past, present, and future change in the Atlantic meridional overturning circulation. Bulletin of the American Meteorological Society, doi:10.1175/BAMS-D-11-00151.1.
- M.M. Mata, M. Cirano, M.R. van Caspel1, C.S. Fonteles, **G. Goni**, and **M. Baringer**, 2012. Observations of the Brazil Current Baroclinic Transport Variability near 22°S. CLIVAR Exchanges 58(17):5-10.
- **Baringer, M.O.**, T.O. Kanzow, C.S. Meinen, S.A. Cunningham, D. Rayner, W.E. Johns, H.L. Bryden, E. Faika-Williams, J. J-M. Hirschi, M.P. Chidichimo, L.M. Beal and J. Marotzke, 2011: Meridional Overturning Circulation Observations in the Subtropical North Atlantic, in "State of the Climate in 2010", Bulletin of the American Meteorological Society, 92:S95-S98, doi: 10.1175/1520-0477-92.6.S1
- Di Nezio, P.N., and **G. Goni**, 2011: Direct Evidence of Changes in the XBT Fall-rate Bias During 1986-2008. Journal of Atmospheric and Oceanic Technology, 28(11), 1569-1578,doi:10.1175/JTECH-D-11-00017.1.
- Dong, S., **M. Baringer**, **G. Goni**, and **S. Garzoli**, 2011: Importance of the assimilation of Argo Float Measurements on the Meridional Overturning Circulation in the South Atlantic. Geophys. Res.Lett., 38, L18603, doi:10.1029/2011GL048982.
- Dong, S., **S.L. Garzoli**, and **M.O. Baringer**, 2011: The role of inter-ocean exchanges on decadal variations of the northward heat transport in the South Atlantic. Journal of Physical Oceanography, 41(8):1498-1511.
- **Garzoli, S.L** and R. Matano, 2011: The South Atlantic and the Atlantic Meridional Overturning Circulation. Deep-Sea Research II, 58(17-18):1837-1847, doi:10.1016/j.dsr2.2010.10.063.
- **Goni, G.J.**, F. Bringas, and P.N. Di Nezio, 2011: Observed Low Frequency Variability of the Brazil Current Front. Journal of Geophysical Research, 116, C10037, doi:10.1029/2011JC007198.
- Johns, W.E., **M.O. Baringer**, L.M. Beal, S.A. Cunningham, T. Kanzow, H.L. Bryden, J. Hirschi, J. Marotzke, C. Meinen, B. Shaw, and R. Curry, 2011: Continuous, array-based estimates of Atlantic Ocean heat transport at 26.5°N. Journal of Climate, 24(10):2429-2449.
- Lee, S.-K., W. Park, E. van Sebille, **M.O. Baringer**, C. Wang, D.B. Enfield, S. Yeager, and B.P.. Kirtman, 2011: What caused the significant increase in Atlantic ocean heat content since the mid-20th century? Geophysical Research Letters, 38, L17607, doi:10.1029/2011GL048856.

- Longworth, H.R., H.L. Bryden, **M.O. Baringer**, 2011: Historical Variability in Atlantic meridional baroclinic transport at 26.5°N from boundary dynamic height observations. Deep-Sea Research Part II, Topical Studies in Oceanography, Volume 58:1754-1767, ISSN 0967-0645, DOI: 10.1016/j.dsr2.2010.10.057.
- Lumpkin, R. and **S. L. Garzoli**, 2011: Interannual to Decadal Variability in the Southwestern Atlantic's Surface Circulation. Journal Geophysical Research - Oceans, 116, C01014, doi:10.1029/2010JC006285.
- Lumpkin R., **G. Goni** and K. Dohan, 2011: State of the Ocean in 2010: Surface Currents. In "State of the Climate in 2010", Bulletin of the American Meteorological Society, 92(6):S92-S95.
- Perez, R.C., **S.L. Garzoli**, C.S. Meinen, and R.P. Matano, 2011: Geostrophic Velocity Measurement Techniques for the Meridional Overturning Circulation and Meridional Heat Transport in the South Atlantic. Journal of Atmospheric and Oceanic Techology, 28:1504-1521.
- Rayner, D., J.J-M. Hirschi, T. Kanzow, W.E. Johns, S.A. Cunningham, P.G. Wright, E. Frajka-Williams, H.L. Bryden, C.S. Meinen, **M.O. Baringer**, J. Marotzke, and L.M. Beal, 2011: Monitoring the Atlantic meridional overturning circulation. Deep-Sea Research, Part II, Topical Studies in Oceanography, Volume 58;1744-1753, ISSN 0967-0645, DOI: 10.1016/j.dsr2.2010.10.056.
- Van Sebille, E., **M.O. Baringer**, W.E. Johns, C.S. Meinen, L.M. Beal, M. Femke de Jong, and H.M. van Aken, 2011: Propagation pathways of classical Labrador Sea Water from its source region to 26°N. Journal of Geophysical Research - Oceans, 116, C12027, doi:10.1029/2011JC007171.

Other manuscripts currently in preparation or recently submitted by authors founded by the SOOP project:

- **Domingues R.**, **G. Goni**, S. Swart and S. Dong. Atmospheric forced variability on the Antarctic Circumpolar Current south of Africa during 1993-2010. To be submitted to the Journal of Geophysical Research.
- **Goes, M.**, **G. Goni**, K. Keller. How to reduce biases in XBT measurements by including discrete information from pressure switches. Submitted to J. Atmos. Ocean. Tech.
- **Goes, M.**, **G. Goni**, V. Hormann, R. Perez. Variability of eastward currents in the equatorial Atlantic during 1993-2010. Submitted to J. Geophys. Res.-Oceans.
- **Goes, M.**, S. Dong, **G. Goni**. An optimal array design of the AX18 XBT transect for monitoring the AMOC and heat transport across 34°S. To be submitted to J. Geophys. Res.-Oceans.

Several publications make use of the data obtained through this program. These publications include approximately 300 articles in refereed journals since 2000. For a comprehensive list of other related publications using SOOP data please visit our XBT bibliography page at *http://www.aoml.noaa.gov/phod/goos/bib*