The *OceanoScientific*® *Programme*: Scientific Data Acquisition by Sailing Ships

Margot Choquer[1], Pierre Blouch[2], Fabienne Gaillard[3], Thierry Reynaud[3], Gilles Reverdin[4], Nicolas Metzl[4], Martin Kramp[5], Pierre Branellec[3], Denis Diverrès[6]

SailingOne - OceanoScientific® Programme (FRANCE)[1]
Météo-France - E-SURFMAR (EUMETNET), Brest (FRANCE)[2]
IFREMER, Laboratoire de Physique des Oceans, UMR 6523, CNRS/Ifremer/IRD/UBO, Plouzané (FRANCE)[3]
LOCEAN-IPSL, CNRS, UPMC, Paris (FRANCE)[4]
JCOMMOPS, Ramonville (FRANCE)[5]
IRD, Plouzané (FRANCE)[6]

Abstract

The *OceanoScientific*® *Programme* provides via the MEROCEANS foundation the international scientific community free of charge with scientific data collected at the ocean - atmosphere interface in data scarce areas - thanks to innovative underway technology.

The *OceanoScientific*® *Programme* carries out expeditions on sailing vessels, in particular on 16-metre sailing ships especially designed for scientific use, the NAVOSE® - meaning in French: **N**avire **A** **V**oile d'**O**bservation **S**cientifique de l'**E**nvironnement. The aim is to collect scientific data at the ocean-atmosphere interface and to release autonomous scientific equipment in data sparse areas. Based on first trials in former years, successful expeditions onboard the first NAVOSE® (North Atlantic) and the three-master *Bark EUROPA* (Drake Passage, Cape Horn, Antarctic, South Pacific) were recently carried out in 2013 and continue in 2014. The emerging data proved to be of good quality and were gathered on transocean transects partially without any observation from other vessels throughout 2013.

The focus here is on the technology developed by the *OceanoScientific*® *Programme*. The *OceanoScientific*® *System* (hereafter referred as OSC System) is an innovative "Plug & Play" equipment for the automatic acquisition and satellite transmission of ten to twelve scientific parameters at sea. It is designed for smaller vessels on which existing systems (such as Ferryboxes) are not suitable due to size, weight, power consumption and other issues. Methods and data formats follow the recommendations and standards of UN agencies related to climate change and operational oceanography/meteorology, in particular JCOMM's Ships Observation Team (WMO/IOC-UNESCO). Measured parameters are: wind speed, wind direction, air relative humidity, air temperature, sea level pressure, SST, SSS, pCO_2, fluorescence and pH. Several test and development campaigns have been organized for the various prototypes of the OSC System, named *OceanoScientific*® *Campaigns*. Data collected during these missions are complementary to data from other sources (scientific cruises, volunteer ships, drifters, buoys and satellite observations) and will participate in enhancing the knowledge of ocean-atmosphere fluxes in particular, as well as bridge the gaps in the global data coverage.

The overall approach is based on a solid collaboration with the French institutes IFREMER, Météo-France and LOCEAN (IPSL - INSU/CNRS), which started in 2006. Other international institutes such as GEOMAR (Ger.) and the University of Maine (USA) later joined in.

The *OceanoScientific*® *System* was awarded the 2013 French - German Prize of Economy in last December to reward the association of a French company (SailingOne, leader in the *OceanoScientific*® *Programme*) and a German company (SubCtech, the main industrial partner) within a consortium also gathering the French scientific institutes IFREMER and Météo-France, de facto included in this achievement.

Text

The *OceanoScientific*® *Programme* provides via the MEROCEANS foundation the international scientific community with scientific free of charge data collected at the ocean-atmosphere interface in data scarce areas - thanks to innovative underway technology.

Context

The *OceanoScientific*® *Programme* carries out expeditions on sailing vessels, in particular on 16-metre sailing ships especially designed for scientific use, the NAVOSE® - meaning in French: **N**avire **A** **V**oile d'**O**bservation **S**cientifique de l'**E**nvironnement. The aim is to collect scientific data at the ocean - atmosphere interface and to release autonomous scientific equipment in data sparse areas. Based on first trials in former years, successful expeditions onboard the first NAVOSE® (North Atlantic) and the three-master *Bark EUROPA* (Drake Passage, Cape Horn, Antarctic, South Pacific) were recently carried out in 2013 and continue in 2014. The emerging data proved to be of good quality and were gathered on transocean transects partially without any observation from other vessels throughout 2013.

The *OceanoScientific*® *System* (hereafter referred as OSC System) is an innovative "Plug & Play" equipment for the automatic acquisition and satellite transmission of ten to twelve scientific parameters at sea. It is designed for smaller vessels on which existing systems (such as Ferryboxes) are not suitable due to size, weight, power consumption and other issues. Methods and data formats follow the recommendations and standards of UN agencies related to climate change and operational oceanography/meteorology, in particular JCOMM's Ships Observation Team (WMO/IOC-UNESCO).

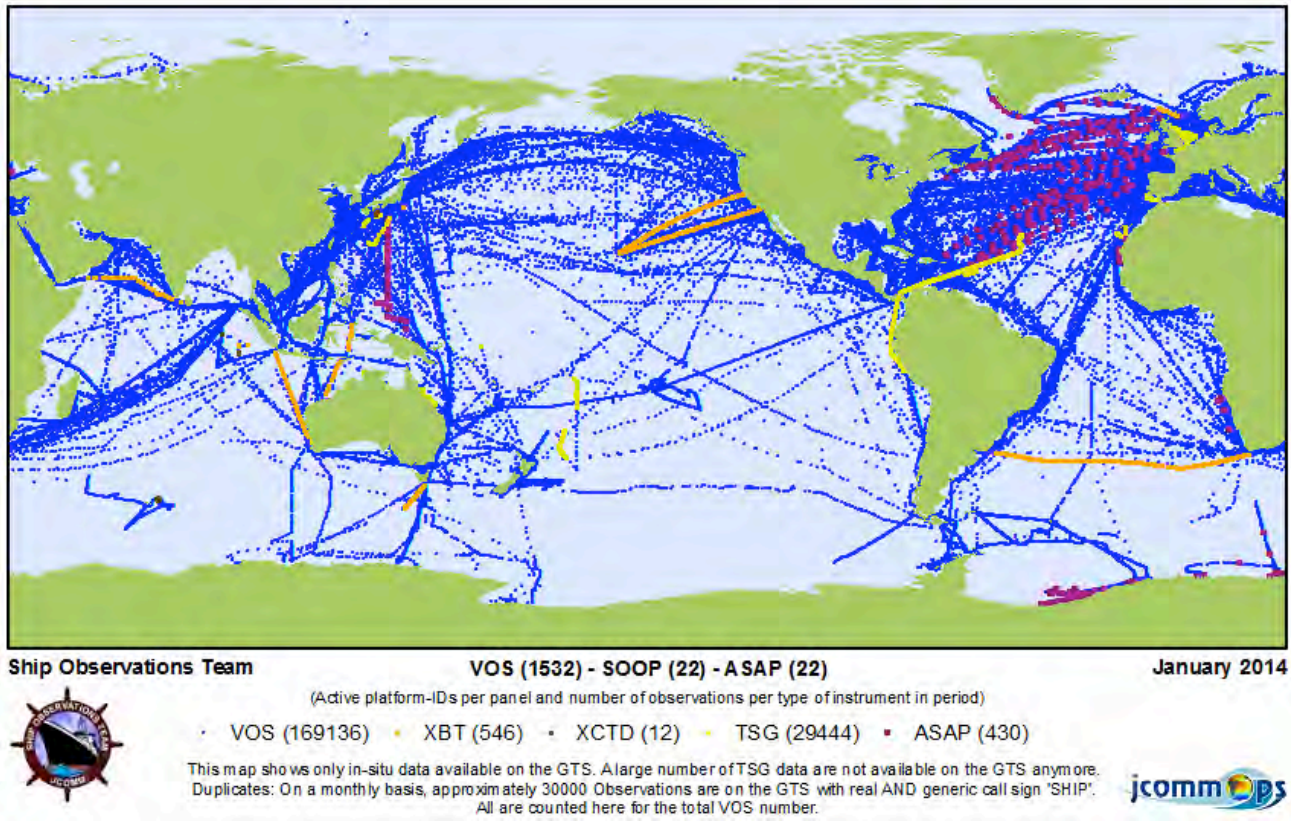

Figure 1: SOT chart for in-situ data contribution for January 2014 - Chart JCOMMOPS

Partnerships

The overall approach is based on a solid collaboration with the French institutes IFREMER, Météo-France and LOCEAN (IPSL - INSU/CNRS), which started in 2006.

Other international institutes such as GEOMAR (Ger.) and the University of Maine (USA) later joined in. Every institute has its own speciality and mentors the *OceanoScientific® Programme* from the technical issues such as picking the right sensor to the end of the data collection and the data processing.

The development of the *OceanoScientific® System* is based on the expertise of the two industrial partners. It was awarded the 2013 French - German Prize of Economy to reward the association of a French company (SailingOne, Cabourg, France, leader in the *OceanoScientific® Programme*) and a German company (SubCtech, Kiel, Germany, the main industrial partner). Indeed, SubCtech has been the only industrial partner able to put up with such challenges as building an innovative, robust and reliable underway system that would operate onboard a sailing vessel. SubCtech is specialized in flow-trough-systems and underway technology.

SailingOne also teamed up with Mer Agitée (a ship design company and shipyard, recognized for breeding successful offshore sailing boats and sailors, Port-la-Forêt, France) to develop the proper software to datalog (full dataset sampled at 6 seconds) and broadcast (hourly reduced dataset) the data via satellite. Their offshore sailing racing team also prepeared the boat and installed onboard the NAVOSE® *Boogaloo* the proper equipment to manage the power production and supply of the *OceanoScientific® System* onboard.

(Funding)

The *OceanoScientific® Programme* is currently supported by the FEDER fund of Lower-Normandy (regional district) and complies with the disposals of the ERA-MARTEC II call for proposals, making it eligible for the support of the French Minister for Ecology, Sustainable Development and Energy - General Direction of Infrastructures, Transports and Sea.
These funds are crucial to the research and development phase currently ongoing to develop the underway system and to ensure the quality of data collected and to ensure they are free of charge for the scientific community.

Parameters collected and technology implemented

In this framework, the scientists working with the *OceanoScientific® Programme* decide which parameters are to be collected. The current parameters collected onboard the NAVOSE® *Boogaloo* are:

In the atmosphere:
- Wind speed,
- Wind direction,
- Air relative humidity,
- Air temperature,
- Sea level pressure.

In the sea surface water:
- Sea Surface Temperature (hereafter SST),
- Sea Surface Salinity (hereafter SSS),
- pCO_2,
- Fluorescence,
- pH.

The list was reduced down to these ten parameters following the suggestions of our scientific partners based on the relevance of each of them for climate change monitoring.

Additional parameters can easily be added. On the atmospheric side, only an additional serial port is needed (which is easy enough to add when we run out of it) and a quick software development to configure the I/O to that specific sensor. On the oceanographic side, sensors can be added into the water circuit (extra tubes and connectors required) or into the debubbler (see following paragraph about the debubbler) with minimum mechanical and software adjustments to make the sensor fit in the system.

Extra parameters that could be added are - for instance - photoactive radiation, seawater turbidity, dissolved oxygen, etc. - depending on the needs of the scientific community.

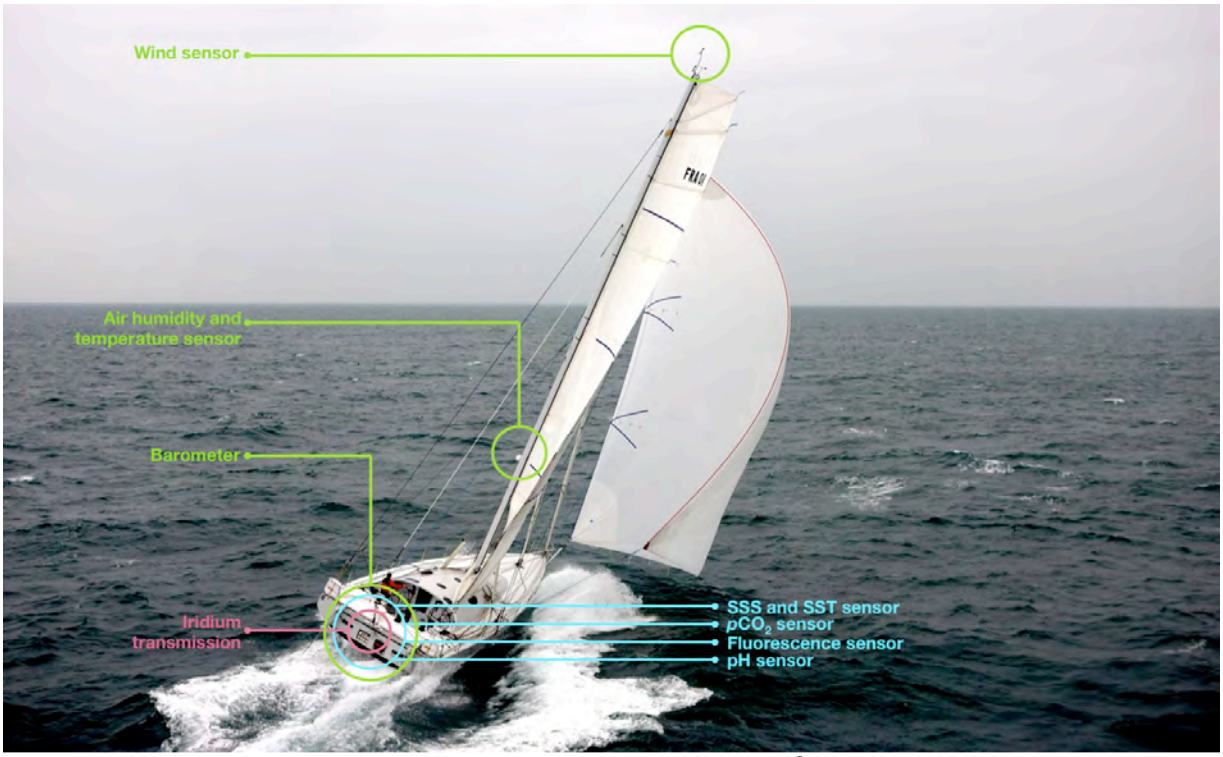

Figure 2: Sensors onboard the NAVOSE® *Boogaloo*

The actual material mobilised onboard is depicted below:

Figure 3: OSC System modules and sensors onboard

The *OceanoScientific*® *System* includes the sensors and their surroundings such as software infrastructure, water circuit and mechanical stands.

The thermosalinograph is a Seabird OEM designed for the SeaKeepers Society. It is based on the same technology as the SBE45. The SBE45 is an evolution of the SBE21 used onboard oceanographic vessels for scientific cruises. The SST and SSS data provided are used for both oceanographic and for atmospheric data sets. A significant gain in weight and volume was achieved from the SBE21 to the SBE45 and more recently with the SeaKeepers OEM device. The electrodes remain the same. The only difference consists in a smaller bath in which they dive resulting in a reduced flow through the sensor.

The Finnish manufacturer Vaisala was selected for the barometer as well as the air temperature and humidity probe following Météo-France's suggestion. The barometer is located inside the boat, away from any sea water sprays. The air temperature and humidity probe is located on the mast looking forward, four metres above deck in its multiplate radiation housing.

The wind is measured from the ship navigation sensor, located on top of the mast (about 22 metres above deck when the boat is not pitching or rolling). It is already computed from the apparent measured wind to the true wind for navigation purposes. The OSC System picks up the corrected signal.

Additional oceanographic sensors are included in the flow-through system: Trios, Meinsberg and SubCtech pCO_2 Analyzer to collect respectively Chlorophyl *a* Fluorescence, pH and dissolved CO_2 data.

The water intake of the OSC System is the same intake than the one for the ballasts of the vessel with a dedicated derivation installed to feed the OSC System with fresh water at all times. The movement of the vessel fills up the scoops deployed under the hull and the pressure created makes the water flow through the pipes.

Some additional valves enable to isolate the ballasts from the rest of the circuit or the OSC System from the ballasts, so the OSC System water is not polluted by stagnant water from the ballasts when decided to empty/fill them.

The measurements take place approximately three metres from the water intake. There are no temperature measurements at the water intake. The SST is measured only once, at the same spot that each other oceanic parameters are.

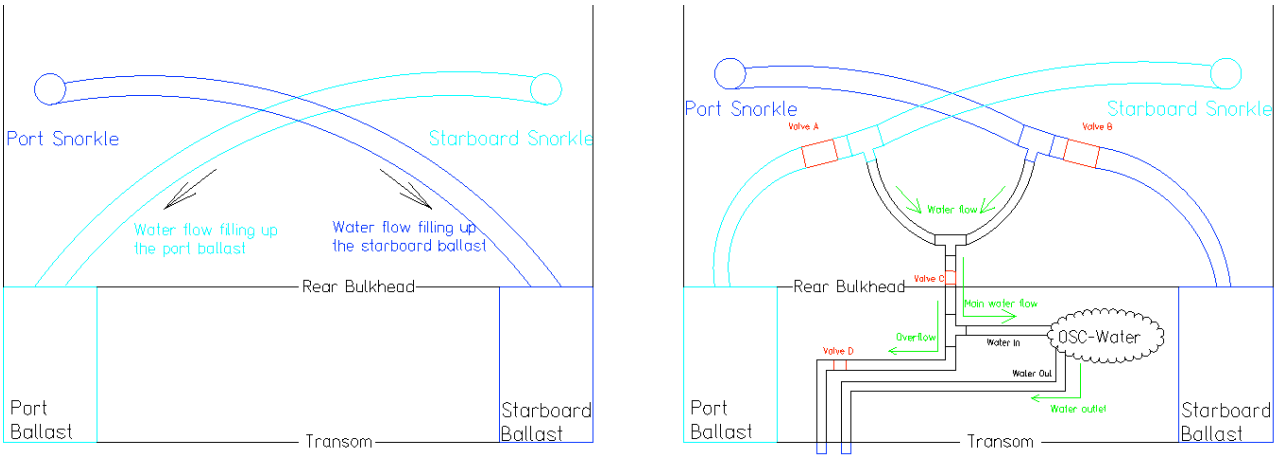

Figure 4: Original and modified water circuit to feed the OSC System onboard the sailing vessel

Then the water circulates into the circuit from the water intake to the filtering and the pumping system, then into the debubbler and through the thermosalinograph before heading to the pCO_2 Analyzer. After circulating into the circuit, water is evacuated and continuously replaced by new incoming seawater.

Involvement in Scientific Programmes

Several test and development campaigns have been organized for the various prototypes of the OSC System, named *OceanoScientific® Campaigns*. Data collected during these missions are complementary to data from other sources (scientific cruises, volunteer ships, drifters, buoys and satellite observations) and will participate in enhancing the knowledge of ocean-atmosphere fluxes in particular, as well as bridge the gaps in the global data coverage.

In particular the SSS and SST data are fed into the Global Ocean Surface Underway Data (herafter GOSUD) Project. It is an initiative of the International Oceanographic Data and Information Exchange (IODE) of the Intergovernmental Oceanographic Commission (IOC) programme designed as an end to end system for data collected by ships along their ocean tracks. The goal of the GOSUD Project is to develop and implement the data system for ocean surface data, to acquire and manage these data and to provide a mechanism to integrate these data with other types of data collected in the world oceans. For the purposes of this project, the data concerned are those collected as a platform is underway from the ocean surface down to about 15 metres depth. The main objective of GOSUD is to collect, process, archive and disseminate in real time and delayed mode, sea surface salinity and other variables collected underway, by research and opportunity ships.

Real-time hourly data are sent ashore through Iridium SBD in the E-SURFMAR #100 format, intended to be broadly implemented. They are then decoded and made available to CORIOLIS and other users through internet via an FTP webpage. In parallel, SST and the atmospheric parameters are forwarded onto the Global Telecommunication System (GTS) of WMO by Météo-France. Delayed mode data transit from the boat end to the CORIOLIS data center where they are archived and made available for the GOSUD programme for instance.

Evaluation and validation

In this study we will focus on the *OceanoScientific® Campaign* 2013 - 2014 in the North Atlantic.

From November 28th, 2013, the *OceanoScientific® System*, prototype version 3.0, mobilised onboard the NAVOSE® *Boogaloo*, sailed into its very first large scale navigation across the Atlantic to carry on some extensive tests. By sailing through this very well surveyed area, the vessel encountered many other in situ data sources such as Argo floats, volunteer ships, SVP buoys and anchored weather buoys. Prior to this large navigation some coastal navigations and tests were conducted off the French coast.

These in situ data sources as well as weather and oceanographic data modelling are many sources of comparisons and validation of the data collected with the OSC System in order to demonstrate that this is a robust system that can be relied on.

The expedition departed Brest, France on the 28th of November 2013 and arrived in Saint George's, Grenada on the 12th of December 2013, usually referred as Leg 1.

The vessel then sailed back from Grenada to Horta in the Azores between the 28th of January 2014 and the 12th of February, usually referred as Leg 2.

The vessel then sailed back to Europe form Horta to Monaco via Palma in April 2014. Those parts are usually referred as Leg 3 and Leg 4 respectively.

The crew onboard also collected water samples for SSS comparisons. Due to the early deadline of this paper, those results will not be included but will be available in July.

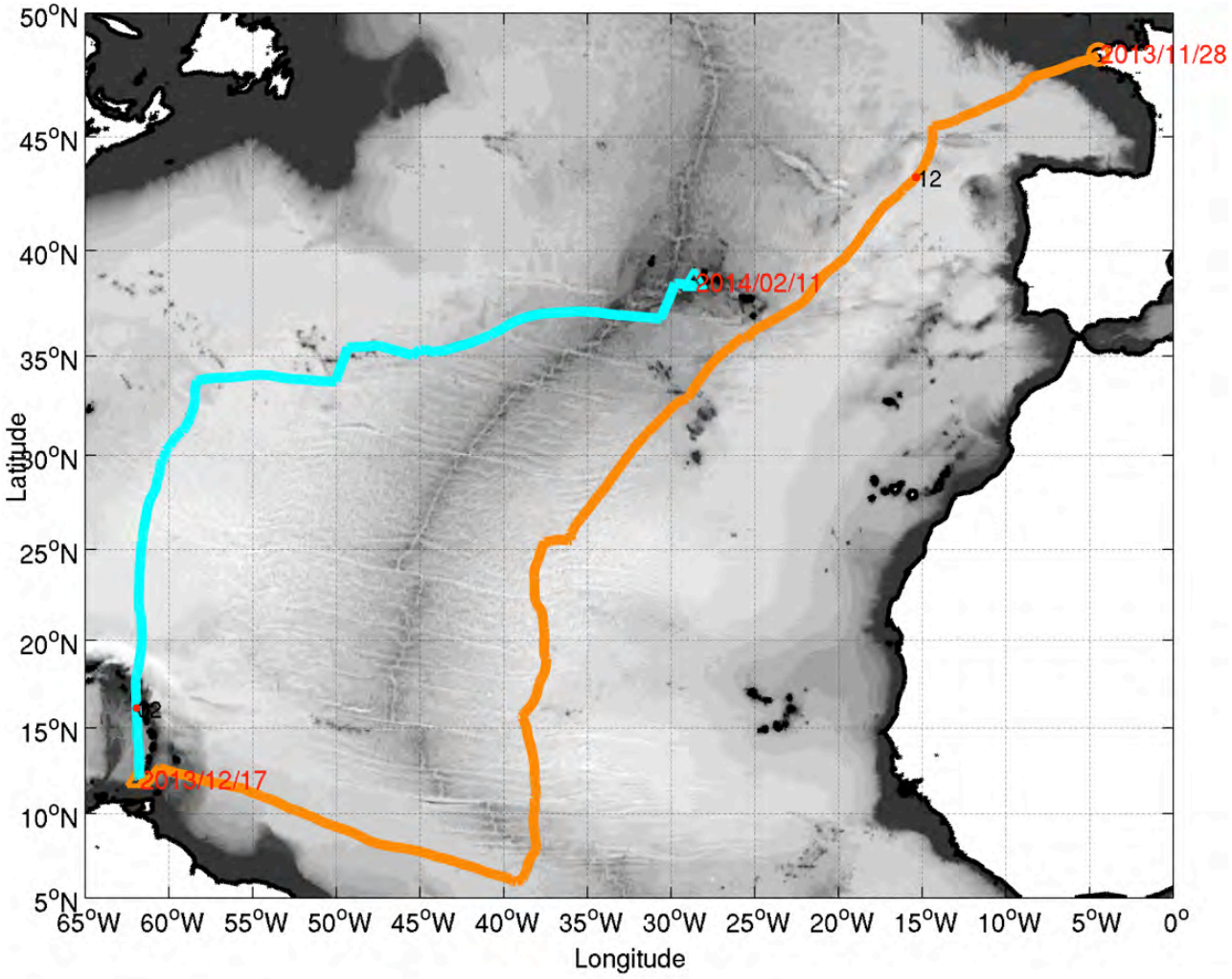

Figure 5: North Atlantic expedition November 2013 to February 2014 - Chart LPO - IFREMER

SST and SSS comparisons prior departure

Some seawater samples were taken in order to check the salinity measurements from the thermosalinograph onboard. The water samples collection and analysis were performed by Pierre Branellec from IFREMER.

20/11/2013	Measured by OSC System		External measurments	
	SST	SSS	Thermometer Ebro	Water samples
12h46	13.19 °C	34.62 PSS	13.1°C	K19 34.637 PSS K20 34.651 PSS
13h11	13.24 °C	34.83 PSS	13.3 °C	K23 35.050 PSS K24 35.063 PSS
13h30	13.37 °C	35.00 PSS	13.3 °C	K27 35.024 PSS K28 35.042 PSS

Table 1: SSS and SST comparisons conducted on the Brest, France coastal area, prior departure

Given the accuracy of the measuring devices and the sampling conditions on board, the equipment was confirmed to provide absolute surface measurements of salinity within 0.1 PSS, which is about the best of what can be reached from underway vessels in a strongly varying environment such as Brest.

Atmospheric data comparisons prior departure

Measurements performed onboard the NAVOSE® *Boogaloo* were conducted during two short navigations (on 19th and 20th November 2013). They were compared to watch towers or Météo-France weather stations in the vicinity of the boat (see pictures 7 to 9). Small differences were observed but no outliers since measurements were not done at the same place. Temperature values reported by the NAVOSE® *Boogaloo* on the 20th of November were 1°C higher in average than those reported by land stations but the air was warmed by the sea on that day.

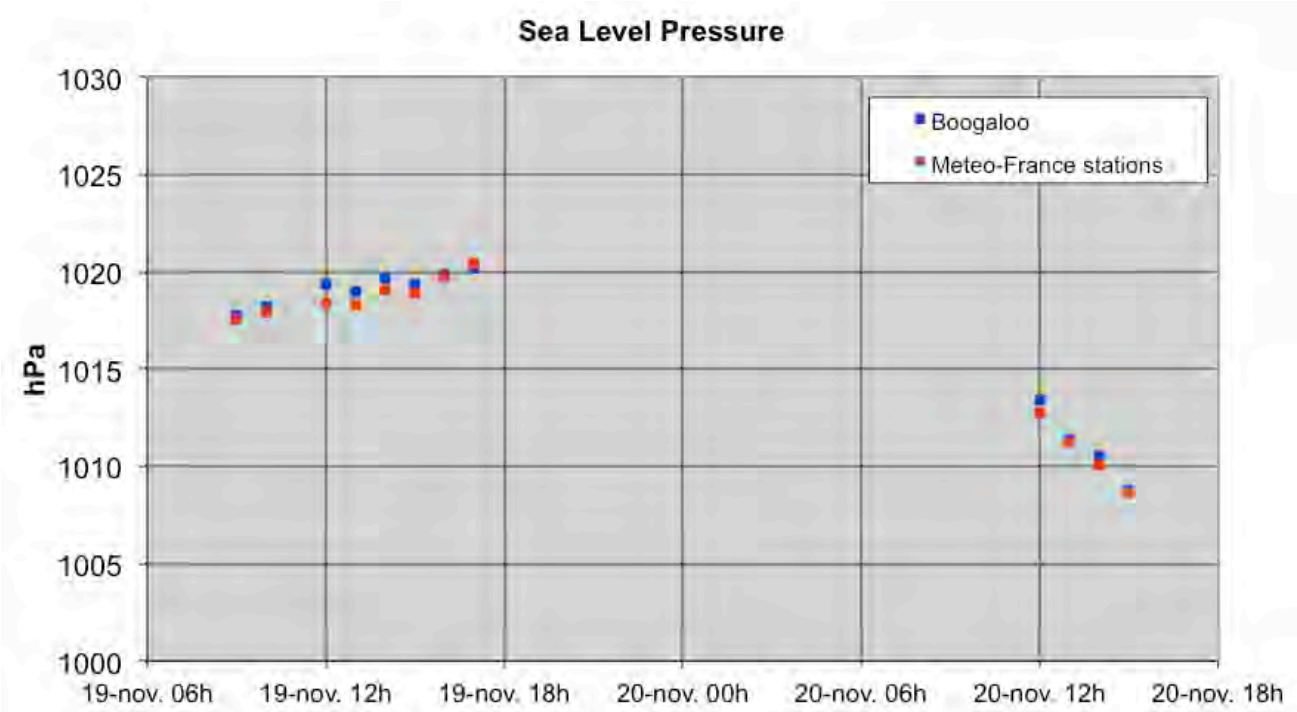

Figure 6: Atmospheric pressure measured onboard and collected from a Météo-France Weather station time series

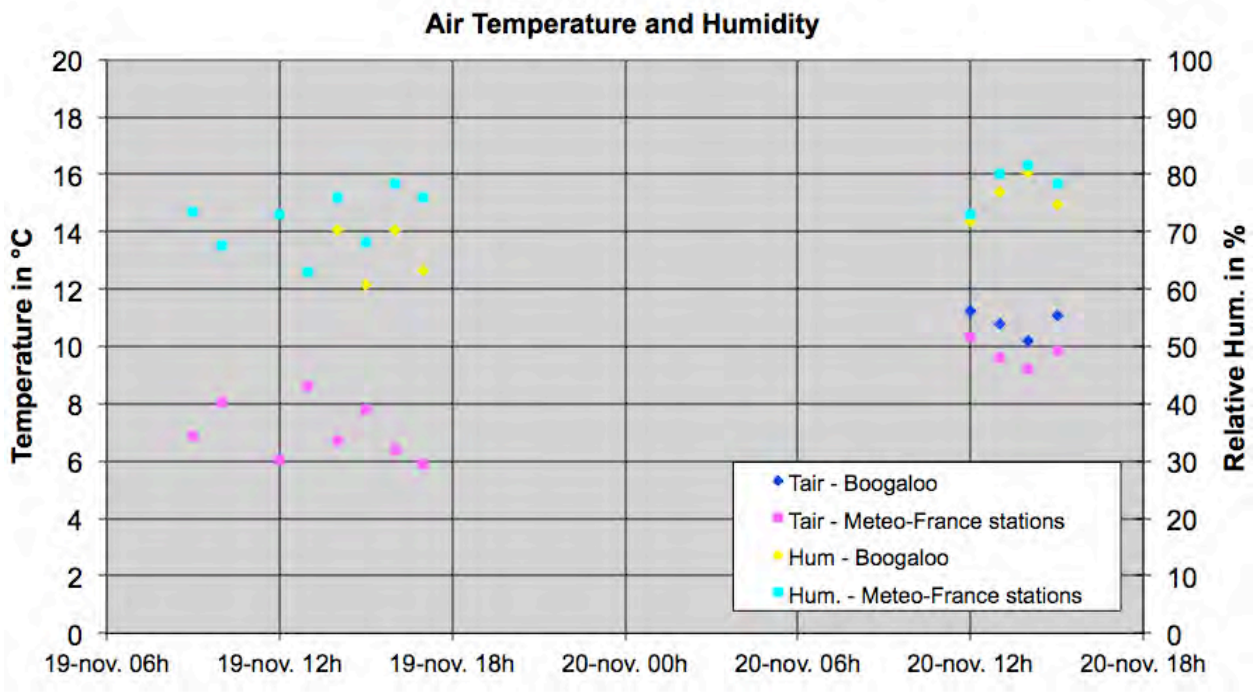

Figure 7: Air temperature and relative humidity measured onboard and collected from a Météo-France Weather station time series

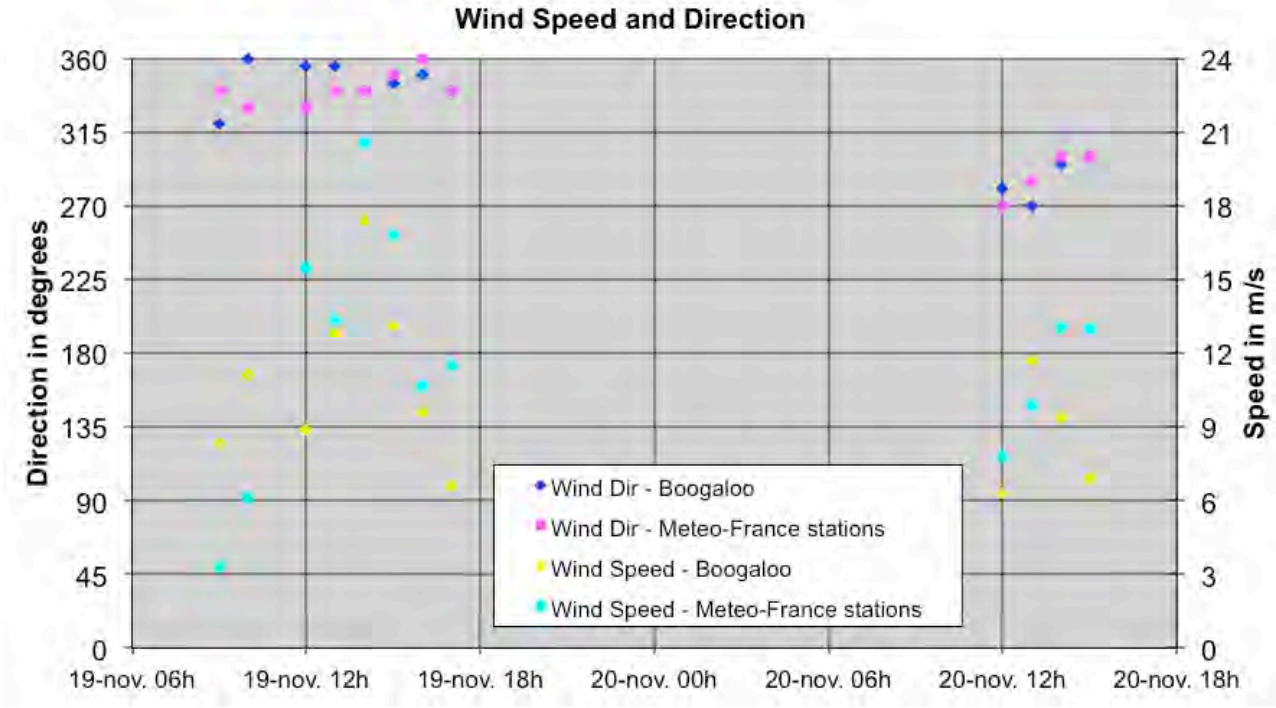

Figure 8: Wind speed and direction measured onboard and collected from a Météo-France weather station time series

Underway data comparisons with colocalised cargos

During the first Leg from Brest to Grenada, the NAVOSE® *Boogaloo* sailed across the Atlantic, sometimes alongside cargos that were fitted with thermosalinograph, by IRD-US-Imago, as part of the National Observing Network SNO-SSS, see Reverdin et al (2007).

Two cargos had routes with common points or sections with the NAVOSE® *Boogaloo* trajectory, as shown on the following map.

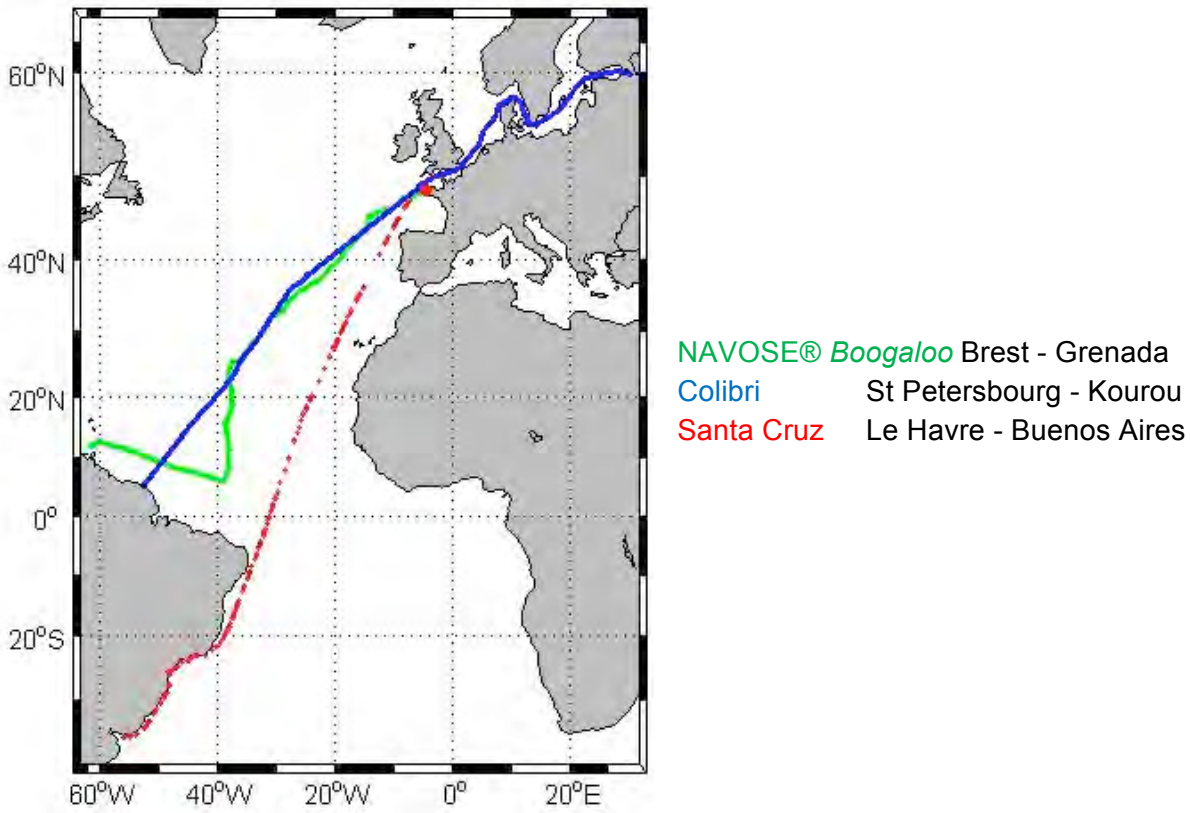

Figure 9: the NAVOSE® *Boogaloo*, Colibri and Santa Cruz trajectories across the Atlantic

There is a common point in the NAVOSE® *Boogaloo* and Santa Cruz trajectories, westbound of Brest, France.

Santa Cruz	47° 45'N 07° 01'W	29/11 - 06h13	SST = 13.233	SSS = 35.555
NAVOSE® *Boogaloo*	47°45'N 07°00'W	30/11 - 07h50	SST = 13.225	SSS = 35.565

Table 2: Santa Cruz and the NAVOSE® *Boogaloo* SSS and SST data comparisons at a single crossing point

Despite the 24h hour delay between the two boats sailing in the same place, SST and SSS values are very close.

There is also a common point in the NAVOSE® *Boogaloo* and Colibri trajectories near 9°04' N - 49°33'W.

Colibri	9°04' N 49°36'W	13/12 – 00h22	SST = 28.22	SSS = 34.914
NAVOSE® *Boogaloo*	9°04' N 49°31'W	14/12 – 21h22	SST = 27.97	SSS = 35.101

Table 3: Colibri and the NAVOSE® *Boogaloo* SSS and SST data comparisons at a single crossing point

Here the difference between the values is significant, but this is not a surprise as the crossing point of the trajectories is located in a highly instable area.

On the long run, we can see that the Colibri and the NAVOSE® *Boogaloo* shared a very similar trajectory between 10 W and 20 W and later between 30 W and 38 W.

We can see that on those two sections, SSS and SST data are matching together quite well.

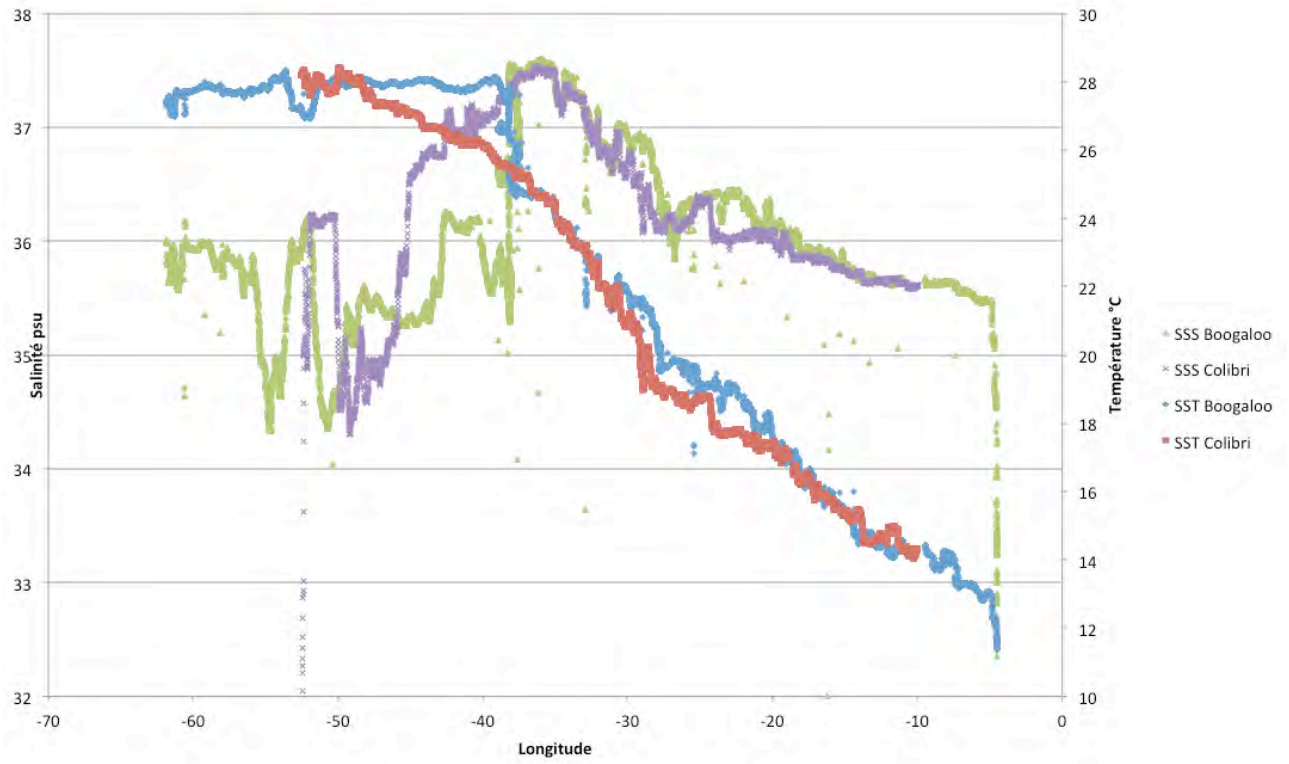

Figure 10: Colibri and the NAVOSE® *Boogaloo* SSS and SST data comparisons between the longitudes 10W and 38W

Underway data comparisons with standardized indicators

The SSS and SST datasets have entered the usual processing applied to research vessels and commercial ships. The first stage is the decoding of the time series at the sampling frequency, then the median over two minutes is extracted. The next stage would be the removal of anomalous data and the adjustment on water samples or other measurements if needed.

Since the final dataset is not available yet, a comparison of the nearly raw SSS/SST from the OSC System with the ISAS-13 monthly climatology at a 5-metre depth is presented. ISAS-13 is an in-situ based re-analysis of the ARGO data set, complemented by a few CTDs and mooring data, over the period 2002-2012 (Gaillard, 2012). The variance is estimated on the same data set. The monthly mean climatology and variance were horizontally interpolated at the ship positions.

The green envelopes that appear on the curves are limited by one standard deviation around the monthly mean. Statistically, 68% of the data fall within this envelope.

The leap on the temperature curve for Leg 1 shows the transition from one month to the next since no time interpolation was performed. The NAVOSE® *Boogaloo* measurements are in good

agreement with the climatology, there seems to be no obvious long term drift and the short term variability is compatible with the climatological variance, as shown in figures 11 and 12.

As soon as the water samples are analysed, the validation/correction will proceed until a final dataset is delivered to GOSUD. A specific ISAS-surface analysis will be performed by including all surface measurements collected over the period 2010-2013 as part of a study involving comparisons with the SMOS data.

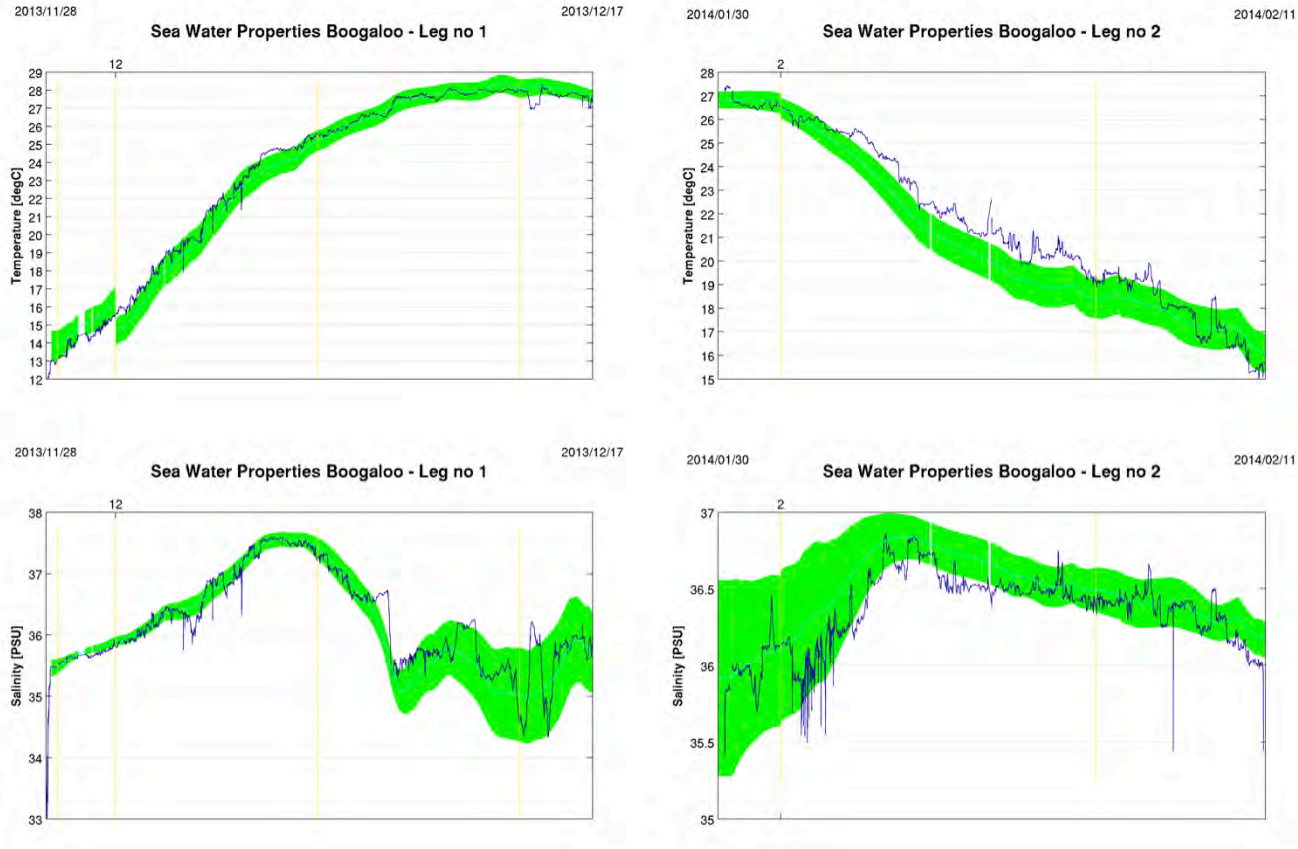

Figure 11: SST and SS compared to monthly climatology and annual variance

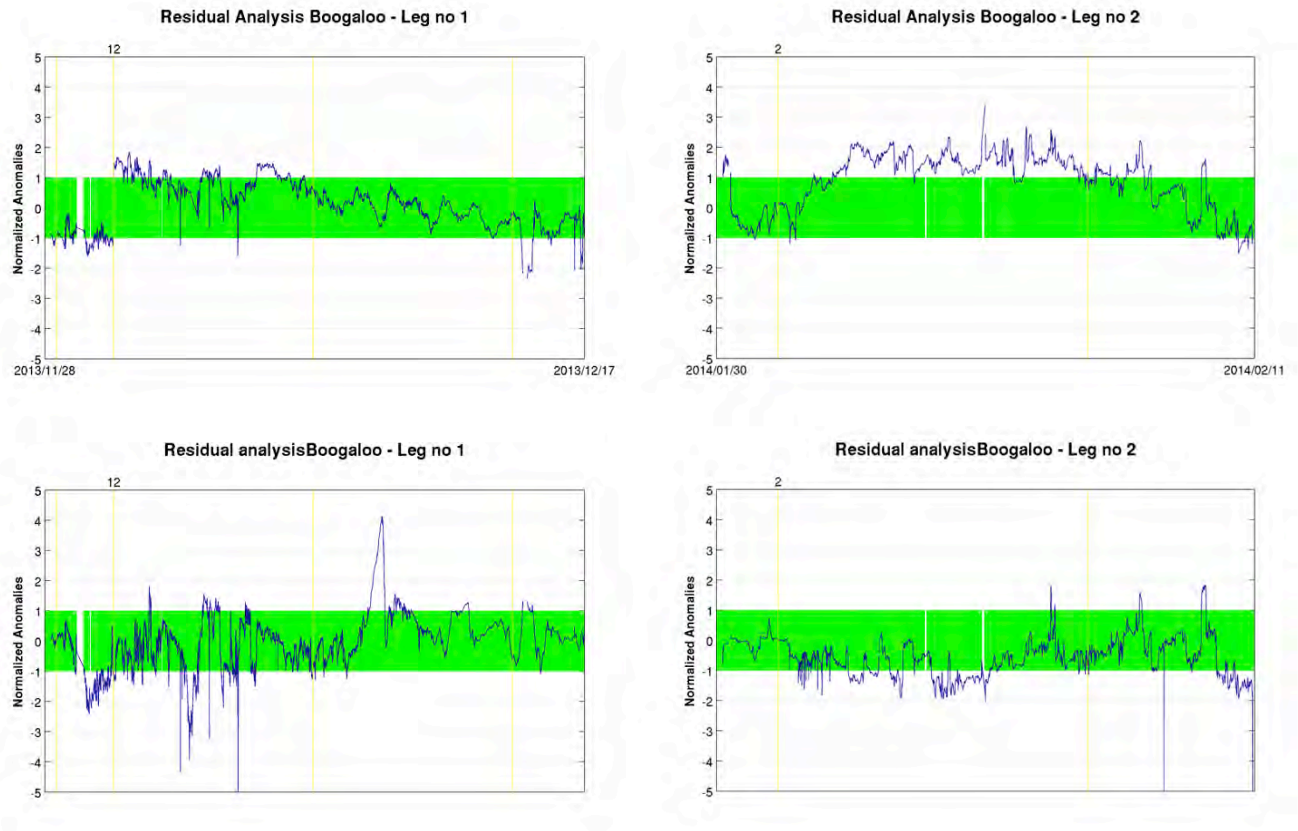

Figure 12: SST and SSS data distribution

Underway atmospheric data comparisons

Météo-France provides quality control tools on the web which allow monitoring surface marine observations in near real-time (12 to 36 hours delay - see http://www.meteo.shom.fr/qctools/). Among the data received from many buoys and ships, hourly atmospheric and SST data from the OSC System are compared to co-located analysis model outputs (ECMWF, Mercator and Météo-France). Graphs of differences between observations and operational models may serve to quickly detect potential problems and to possibly correct them. This functionality was made available as from Leg 2 between Grenada and Horta and later until on the way back to Europe.

As the NAVOSE® *Boogaloo* is transmitting data according to the E-SURFMAR proprietary format, the real time comparison functionalities required some developments so the data could be dealt alongside with the usual data in the SHIP format coming in from the others vessel.

During Leg 1, the NAVOSE® *Boogaloo* sailed closed by drifting and moored buoys which provided data to compare with.

On the following table, the Brittany buoy westbound of Brest, provided a couple hours of data worth comparing with. The salinity collected onboard the NAVOSE® *Boogaloo* was also compared to Mercator model outputs.

	29/11/2013					
	11H UTC			12H UTC		
	NAVOSE® *Boogaloo*	Brittany	Mercator	NAVOSE® *Boogaloo*	Brittany	Mercator
Pressure (hPa)	1037.4	1037.5		1036.7	1036.9	
Air Temperature (°C)	11.75	12.1		11.95	11.9	
Dew Point (°C)	8.35	8.3		8.35	8.4	
SST (°C)	13.94	13.6		13.77	13.5	
SSS (PSS)	35.63		35.58	35.64		35.58
Wind Direction (°)	020	360		015	350	
Wind Speed ($m.s^{-1}$)	8.5	5.1		7.6	6.7	

Table 4: the NAVOSE® *Boogaloo* data comparisons with the Brittany moored buoy and Mercator model output

On the following table, we can see the comparisons with the drifting buoy 41734 (SVP-BS) deployed underway and the moored buoy 13009 as *Boogaloo* sailed passed them.

	12/12/2013					
	15H UTC					11H UTC
	NAVOSE® *Boogaloo* (Average 14-16h)	Buoy 41734	Mercator	ECMWF	Buoy 13009	Buoy 13009
Pressure (hPa)	1013.2	1013.2		1013.0		
Air Temperature (°C)	28.15			26.3	26.9	
Humidity (%)	81%			82%	82%	
Dew Point (°C)		8.3				
SST (°C)	28.11					27.51
SST Buoy hull (°C)		28.05		27.8		
SST Seabird (°C)		28.047				
SSS (PSS)	35.64	35.659	35.24			

Table 5: the NAVOSE® *Boogaloo* data comparisons with a drifting and a moored buoys and Mercator and ECMWF models output

Wind speed put apart, différences between OSC System measurements and buoy data are not significant. The difference observed on wind speed is due to the heights at which it is measured: 22 metres for the NAVOSE® *Boogaloo*, 4.5 metres for the Brittany buoy.

During leg 2, atmospheric measurements were compared to ECMWF model analysis. Figure 17 shows the high degree of coherency between the two sets of data.

Wind speed values from ECMWF model appear lower than those measured by the OSC System but measurements are performed up to 22 metres above the sea on the boat whilst ECMWF data are for 10 metres.

The missing data on the 8th and 9th of February were properly logged and sent via the Iridium SBD but due to an error in the compression onboard, the day was encoded as a 0. As a matter of fact, when decoded as a 0 by Météo-France in France, it raised an alarm and was not made available to the users and to the GTS.

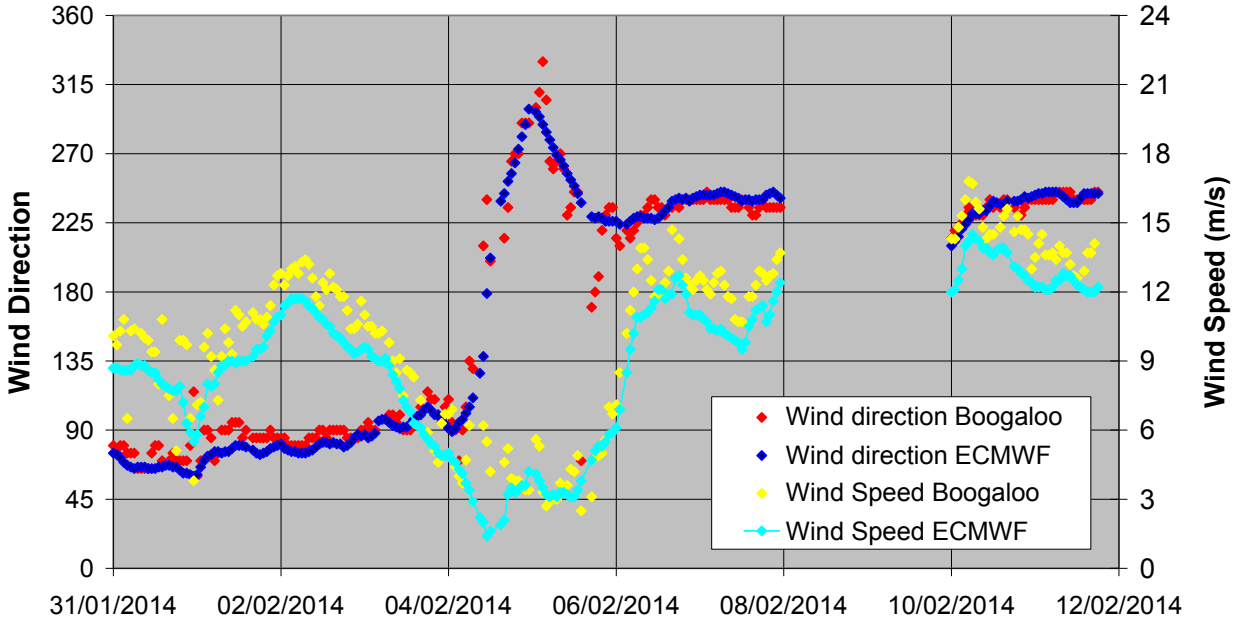

Figure 13: Grenada - Horta - Wind Direction and Speed, Comparisons with ECMWF analysis

On that leg, the air temperature and humidity sensor failed after two days of sailing and the pressure data were missing in the treatment chain for half the length of the leg, so the data for these three parameters will not be shown here.

However, the data sets for the Leg 3 (between Horta and Palma) are complete on the atmospheric side.

Figures 14 and 15 show atmospheric pressure, air temperature and humidity measured by the OSC System, compared to co-located ECMWF model analysis outputs.

Whilst pressure values are fully in accordance during the whole leg, this is not the case for air humidity and air temperature. Differences could be partially due to the influence of the Iberian Peninsula and of the Balearic Islands, on the model (dryer and warmer air) when the boat was approaching these countries. Model outputs are not to be considered to be true. However, the sensor will be re-calibrated to detect any possible trend.

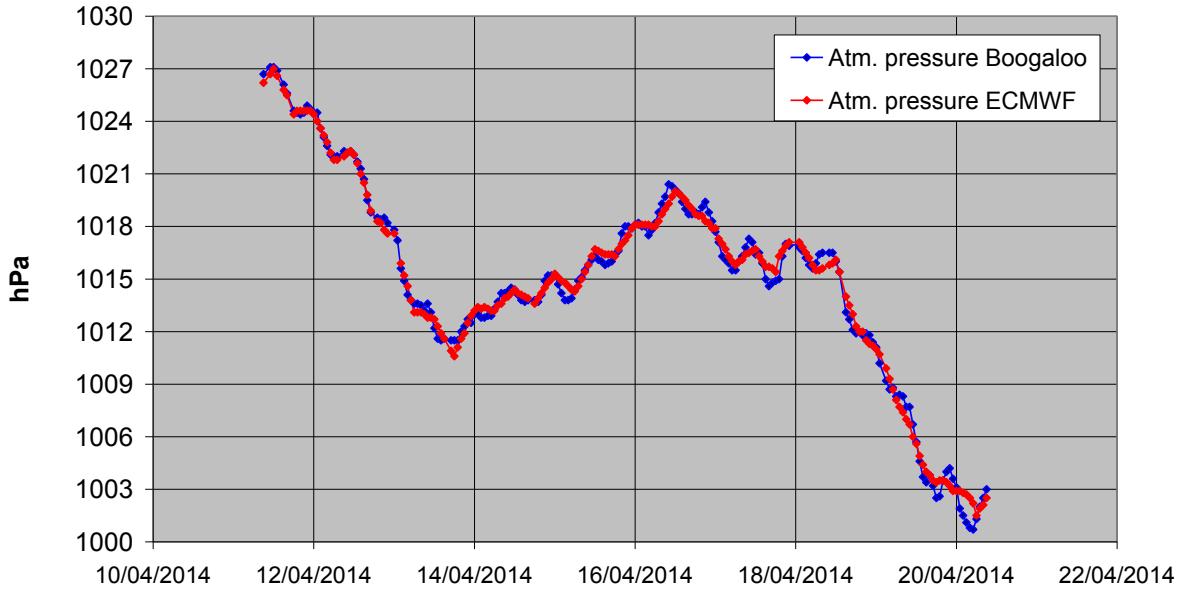

Figure 14: Atmospheric pressure measured onboard Boogaloo and compared to the ECMWF values

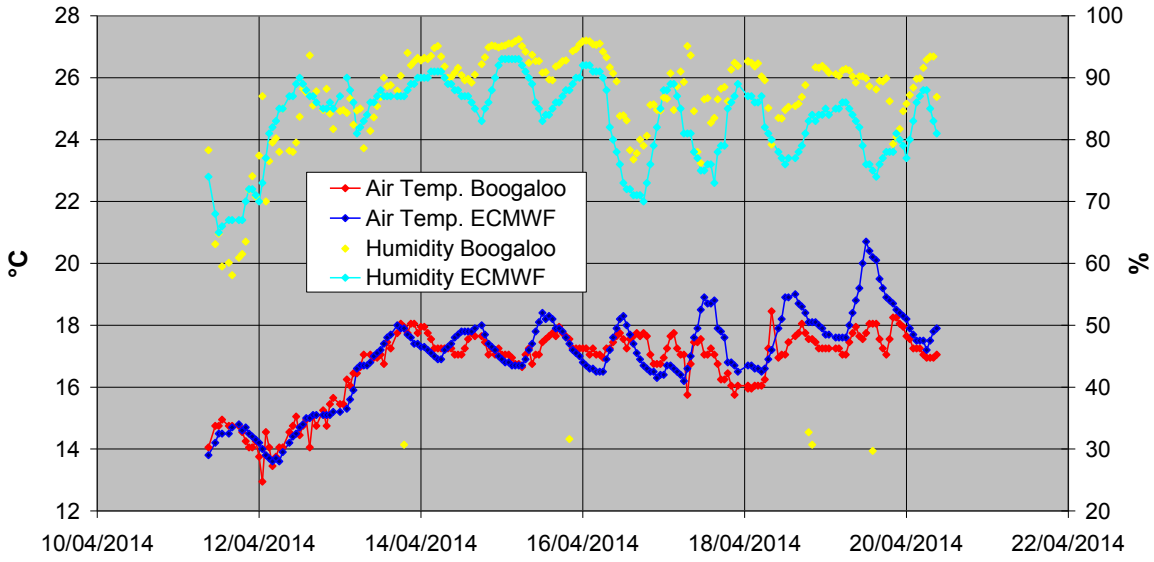

Figure 15: Air temperature and humidity measured onboard Boogaloo and compared to ECMWF values

Conclusion

The main validation process remains to be done on the oceanographic data, as the water samples were not analysed yet. Given the good results observed so far, with the preliminary water samples comparisons prior departure from France and the good performances noted form the primary comparisons to the climatology and the annual variance, there is good confidence the dataset will be of good quality.

The atmospheric data entered the usual circuit of atmospheric data collected from volunteer ships as from Leg 2. The NAVOSE® *Boogaloo* being at the moment one of the first vessels to transmit only in the E-SURFMAR #100 format, it required some adjustments to enter the same treatment and quality check process than the other volunteer ships, which are still transmitting in the SHIP format. The E-SURFMAR #100 format will spread and soon become a widely use standard.

The concept of the OSC System and its innovative way to collect scientific data at sea has proven its reliability and robustness in rough conditions. It is expected it will be a steady actor to enhance the grid of in-situ data collected.

Acknowledgments

We thank Caroline Le Bihan, Laboratoire Détection, Capteurs et Mesures, IFREMER, Plouzané (FRANCE) for the upcoming salinity controls of the water samples and Simon Morisset, LOCEAN-IPSL, CNRS, UPMC, Paris (FRANCE) for the preliminary Argo floats colocalisation with the OSC System data after the completion of Leg 1 that showed good results in terms of SSS and SST.

We thank as well Christophe Billon, Météo-France - CNRM, Brest (FRANCE) for his availability and expertise in the implementation of the E-SURFMAR #100 format and Gilbert Emzivat, Météo-France - CNRM, Brest (FRANCE) for his valuable advice in the Iridium Short Burst Data transmission at sea.

We are grateful to Jean-Baptiste Cohuet, Météo-France - DSO, Toulouse (FRANCE) for his continuous overseeing and involvement in the project from the very beginning and Clément Testa, Météo-France - DSO, Toulouse (FRANCE) for his technical support in deploying and maintaining atmospheric sensors.

We thank the MEROCEANS foundation presided by Jean-François Leprince-Ringuet as well as skipper of the NAVOSE® *Boogaloo* Yvan Griboval who led the *OceanoScientific® Campaign* - Atlantic Mission 2013 - 2014.

References

Gaillard Fabienne (2012). ISAS-Tool Version 6: Method and configuration. http://dx.doi.org/10.13155/22583

ISAS: http://wwz.ifremer.fr/lpo/La-recherche/Projets-en-cours/GLOSCAL/Global-T-S-analysis

Reverdin, G., E. Kestenare, C. Frankignoul, T. Delcroix, 2007. In situ surface salinity in the tropical and subtropical Atlantic Ocean. Part I. Large scale variability. Progress in Oceanogr., 73, 3, 311-340.