Project	AtlantOS – 633211
Deliverable number	3.20
Deliverable title	Drifter network improvement report
Description	An improvement in drifting buoy coverage is proposed in the South Atlantic, achieved by deployments using ships of opportunity. A study report on benefits of the improved network will be included in this deliverable. Deployments will be coordinated with NOAA (Third party to Ifremer) and Met Office.
Work Package number	3
Work Package title	Enhancement of autonomous observing networks
Lead beneficiary	EUMETNET
Lead authors	Paul Poli (EUMETNET/Météo-France)
Contributors	Bernard Bourlès (IRD) Steve Bond (Met Office) Sabine Hafner (EUMETNET/DWD) Stefan Klink (EUMETNET/DWD) Eric Petermann (EUMETNET)
Submission data	
Due date	December 2018 (PM 45)
Comments	[in case the deliverable is late please explain why]

Abstract

This deliverable deals with deployments of drifters in the South Tropical Atlantic. A total of 52 buoys were funded by the project. All buoys were equipped with barometers. Most buoys were deployed by PIRATA maintenance cruises. The data collected indicate that drifters work generally shorter there than when deployed in other regions such as the North Atlantic. However, the value of the data assimilated in global weather forecasts proved to be significant, explaining on average 0.0024 % of the ECMWF total 24-hour forecast reduction. This places the cost-benefit ratio of these buoys at 1:138. This seminal work has led EUMETNET members to commit to funding continued drifter deployments in the Tropical Atlantic, beyond the AtlantOS project, in collaboration with NOAA via the barometer upgrade scheme.

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I. Introduction

While moored buoys have been used since the mid-20th century (e.g., Selinger, 1985), drifting buoys have only become of age with the advent of a global positioning and data acquisition system (Gründlingh, 1977). Such system was tried as the Tracking and Data Relay Experiment on Nimbus-6 (launched in 1975), and then became standard as the Argos system on all operational meteorological polar-orbiting satellites, starting with TIROS-N (launched in 1978), until MetOp-C (launched in 2018). In parallel, other global systems have developed, for positioning (e.g., Global Positioning System) and for telecommunications (e.g., Iridium). Most drifting buoys deployed nowadays use GPS and Iridium, but the principles remain unchanged (Blouch and Poli, 2018): to acquire, from an expendable platform called Surface Velocity Platform (SVP), essential data of the marine environment, tracking near-surface currents, in order to feed numerical studies and models and improve weather forecasts.

Several international programs have been assembled to exploit such observing system, organizing deployments as networks, with centralized data processing. At the time of writing, the NOAA Global Drifter Program counts over 1400 active platforms, including regional contributions such as from the European Economic Interest Group (EIG) EUMETNET, with around 170 buoys.

While all buoys report sea-surface temperature (SST) and position (to track currents), only a fraction carry barometers (around 60% globally; though all EUMETNET buoys do carry barometers).

The South Tropical Atlantic has traditionally been rather data-void in this respect. Most drifters were deployed away from the Tropics, under the argument that these platforms would not deliver much useful data in these regions, as compared to the extra-tropics.

Since April 2015, the AtlantOS project has assessed additional deployments of drifters with barometers in the Tropical South Atlantic. The outline of this report is as follows. Section 2 presents the methodology. Section 3 summarizes the results. Section 4 assesses the impact of data collected by these buoys in global numerical weather forecasts. Section 5 indicates how this seminal project has given birth to a new component of the global observing system. Section 6 presents conclusions.

II.   Methodology

This section describes the equipment used and the methods of deployments.
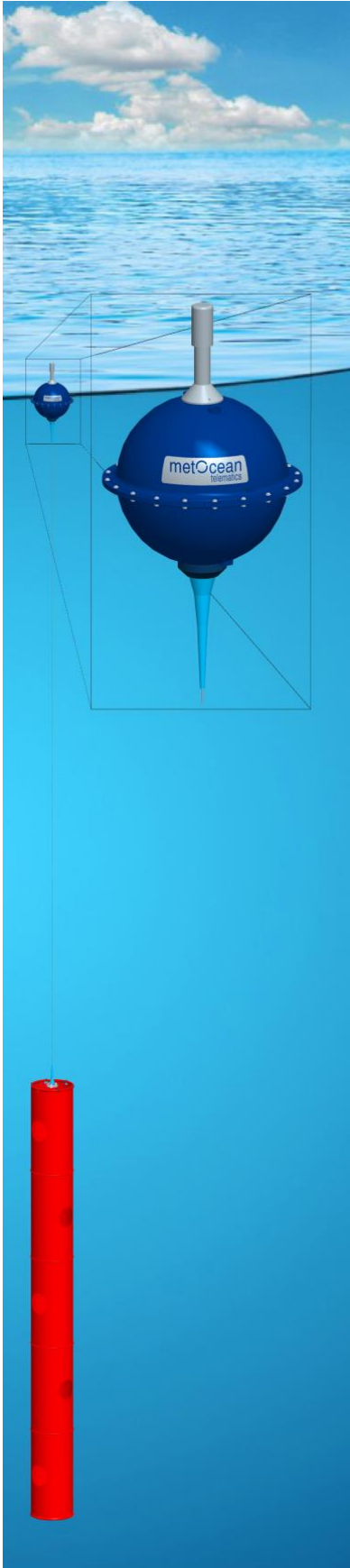
Equipment

Figure 1: Sketch of a SVP-B drifter (Drawing courtesy of metOcean Telematics, drawn by Paul Jakobsen)

Figure 1 shows the type of surface drifters used in the project: SVP with Barometer (SVP-B), in line with an internationally-agreed design (Sybrandy et al., 2009). The buoys are about 40 cm diameter. A tether connects the surface float to a drogue centered at 15-meter depth.

All such buoys carry the following instruments:

- A barometer, to measure air pressure at sea-level,

- A thermometer, to measure sea water temperature,

- A GPS module, to measure time and position,

- A strain gauge, to detect drogue loss.

The barometer is located inside the buoy hull, at the water line level. This ensures that the platform measures as exactly as possible the air pressure at sea-level. The air intake is connected via small tube to a port (atop the buoy) where a Gore-Tex membrane prevents water from entering the tube.

These buoys have a strong potential, if equipped with more sensors, to measure air-sea interactions and assist in the ongoing development of coupled ocean-atmosphere models and data assimilation systems.

In the AtlantOS projects, two other types of buoys were studied: drifting buoys with bathythermic strings (Deliverable D3.5), and drifting buoys measuring salinity (Deliverable D3.4). A

new-generation buoy of this type was developed. Two such units, including barometers, will be deployed at sea just before the AtlantOS project ends. These 2 buoys were analyzed in a metrology laboratory. The results indicate departures within the range of -0.3 to -0.6 hPa, within the instrument (Vaisala PTB110) specifications in the range 0 to 40°C.

Deployments

The deployments were arranged with partners. At the time of writing:

- 50 of the 52 buoys had been deployed,

- the last 2 buoys had been sent out already and were on their way to the deployment area.

The table thereafter shows the deployment dates and deployment vessels. The performance in terms of numbers of days in operation (i.e., reporting valid parameters) is also shown. For buoys still in operation, the number (N) indicated below is a minimum (e.g., at least N days).

WMO identifier	Deployment date	Number of days in operation for air pressure (left) and SST (right)		Note (e.g., cause of death)	Deployment vessel	Deploy-ment partner (*)
1500683	16/04/2015	925	925		MSC Rita	M
1500682	17/04/2015	740	740		MSC Rita	M
1500684	17/04/2015	367	365	Ran ashore	MSC Rita	M
1500681	18/04/2015	612	585	Ran ashore	MSC Rita	M
1500685	26/08/2015	701	701	Ran ashore	MSC Abidjan	M
1500686	27/08/2015	450	391	Ran ashore	MSC Abidjan	M
1500688	28/08/2015	253	253	Ran ashore	MSC Abidjan	M
1500687	29/08/2015	0	0	Buoy faulty	MSC Abidjan	M
1300881	10/03/2016	223	223	Ran ashore	Thalassa	P
1300882	11/03/2016	218	218	Ran ashore	Thalassa	P
1500689	13/03/2016	186	186	Picked-up/captured	Thalassa	P
1500690	14/03/2016	82	82	Picked-up/captured	Thalassa	P
1500692	15/03/2016	237	At least 968	Still functional for SST	Thalassa	P
1500691	15/03/2016	783	270	Ran ashore	Thalassa	P
1500693	16/03/2016	473	473	Ran ashore	Thalassa	P
1500694	17/03/2016	283	283	Ran ashore	Thalassa	P
1500697	18/03/2016	468	458	Ran ashore	Thalassa	P
1500695	21/03/2016	73	73		Thalassa	P
1500696	23/03/2016	628	376	Ran ashore	Thalassa	P

1501600	16/11/2016	135	124	Picked-up/captured	Pourquoi Pas ?	R
1501601	16/11/2016	294	294	Picked-up/captured	Pourquoi Pas ?	R
1501603	17/11/2016	480	250	Ran ashore	Pourquoi Pas ?	R
1501602	18/11/2016	598	310	Battery failed	Pourquoi Pas ?	R
1501604	09/03/2017	At least 609	At least 609	Still functional	Thalassa	P
1501605	10/03/2017	517	492	Ran ashore	Thalassa	P
1501606	11/03/2017	At least 607	345	Still functional	Thalassa	P
1501607	14/03/2017	369	364	Ran ashore	Thalassa	P
1501608	15/03/2017	144	144		Thalassa	P
1501609	23/03/2017	482	At least 595	Barometer faulty	Thalassa	P
1501610	24/03/2017	242	242	Ran ashore	Thalassa	P
1501611	26/03/2017	337	215	Ran ashore	Thalassa	P
1301602	29/03/2017	524	48	Ran ashore	Thalassa	P
1301600	30/03/2017	116	116	Ran ashore	Thalassa	P
1301601	31/03/2017	145	145	Ran ashore	Thalassa	P
1301613	03/02/2018	At least 278	At least 278	Still functional	Hurst Point	O
1501612	04/02/2018	At least 277	At least 277	Still functional	Hurst Point	O
1501613	07/02/2018	241	241	Picked-up/captured	Hurst Point	O
1501614	08/03/2018	165	165		Thalassa	P
1501615	09/03/2018	At least 244	At least 244	Still functional	Thalassa	P
1501616	10/03/2018	At least 243	At least 243	Still functional	Thalassa	P
1501617	11/03/2018	151	151		Thalassa	P
1501618	12/03/2018	8	40		Thalassa	P
1501619	17/03/2018	31	25		Thalassa	P
1501621	18/03/2018	7	7		Thalassa	P
1501620	18/03/2018	186	186		Thalassa	P
1501622	18/03/2018	At least 235	At least 235	Still functional	Thalassa	P
1501623	18/03/2018	At least 235	At least 235	Still functional	Thalassa	P
1301615	21/03/2018	At least 232	At least 232	Still functional	Thalassa	P
1301614	21/03/2018	0	222	Barometer faulty	Thalassa	P
1501624	26/03/2018	At least 227	At least 227	Still functional	Thalassa	P
1301616		*Deployment underway*				
1301617		*Deployment underway*				
Average, over all buoys deployed		***At least 322***	***At least 275***			

Table 1: List of drifting buoys with barometers funded by AtlantOS and deployed during the project. The number of days in operation are separated by parameter/instrument. In the last column, M indicates merchant vessel, P indicates PIRATA maintenance cruise research vessel, O indicates arranged by the Met Office, and R indicates research vessel.

III.   Results

This section presents the data collected and the regions covered after deployments (buoy tracks). The buoy lifetimes shown in Table 1 are lower than those found for buoys deployed in the

extra-tropics (where the mean life-time is around 500 days). This is explained by buoys drifting quickly (fast currents) and running ashore faster on the Western boundary of the basin (Brazil or Caribbean islands), or being advected into ocean recirculation in the Gulf of Guinea (and running ashore in West Africa). There are also several cases of buoys picked-up/captured at sea, while still operational (again, this is in higher proportion than encountered in the North Atlantic).

Data collected

After deployment, the buoys report data hourly, via the Iridium constellation. The messages are received within minutes and decoded. The raw format is documented (Blouch et al., 2018). The data are then re-encoded for dissemination in BUFR format, template 3-15-009 (WMO, 2017). The data thus re-encoded feed the WMO Global Telecommunication System (GTS), where they are then picked-up by national weather agencies to update their prediction models. The data policy is completely open, these data being listed under Annex I of WMO Resolution 40 among "data and products to be exchanged without charge and with no conditions on use" (an early version of today's 'open-access'; WMO, 1995).

The data are ingested also by two Global Data Acquisition Centers (GDAC) for drifting buoys in the Marine Climate Data System (MCDS). There, the data can be quality-controlled a posteriori, with the benefit of a complete time-series and additional ancillary data, to better appreciate changes in data quality.

The buoy positions and data can be visualized on several websites:

- E-SURFMAR and Météo-France QCtools: http://esurfmar.meteo.fr/qctools/

- JCOMMOPS: http://www.jcommops.org/board?t=DBCP

- EMODnet Physics: http://www.emodnet-physics.eu/map/

- ERRDAP: http://osmc.noaa.gov/erddap (note this website can serve the data history, e.g. by modifying the elements in bold/italics thereafter: http://osmc.noaa.gov/erddap/tabledap/OSMC_30day.csv?platform_code,time,latitude,longitude,sst,slp,observation_depth&platform_code=%22*1501624*%22&time%3E=*now-5days*&orderBy(%22time,observation_depth%22)

- Copernicus In-situ Thematic Assembly Centre (TAC, which can serve the data

history): http://www.coriolis.eu.org/Data-Products/Data-Delivery/Data-selection

In order to select data from the buoys mentioned in this report, it is necessary to use the WMO identifiers mentioned in the first column of Table 1, and to consider the approximate dates.
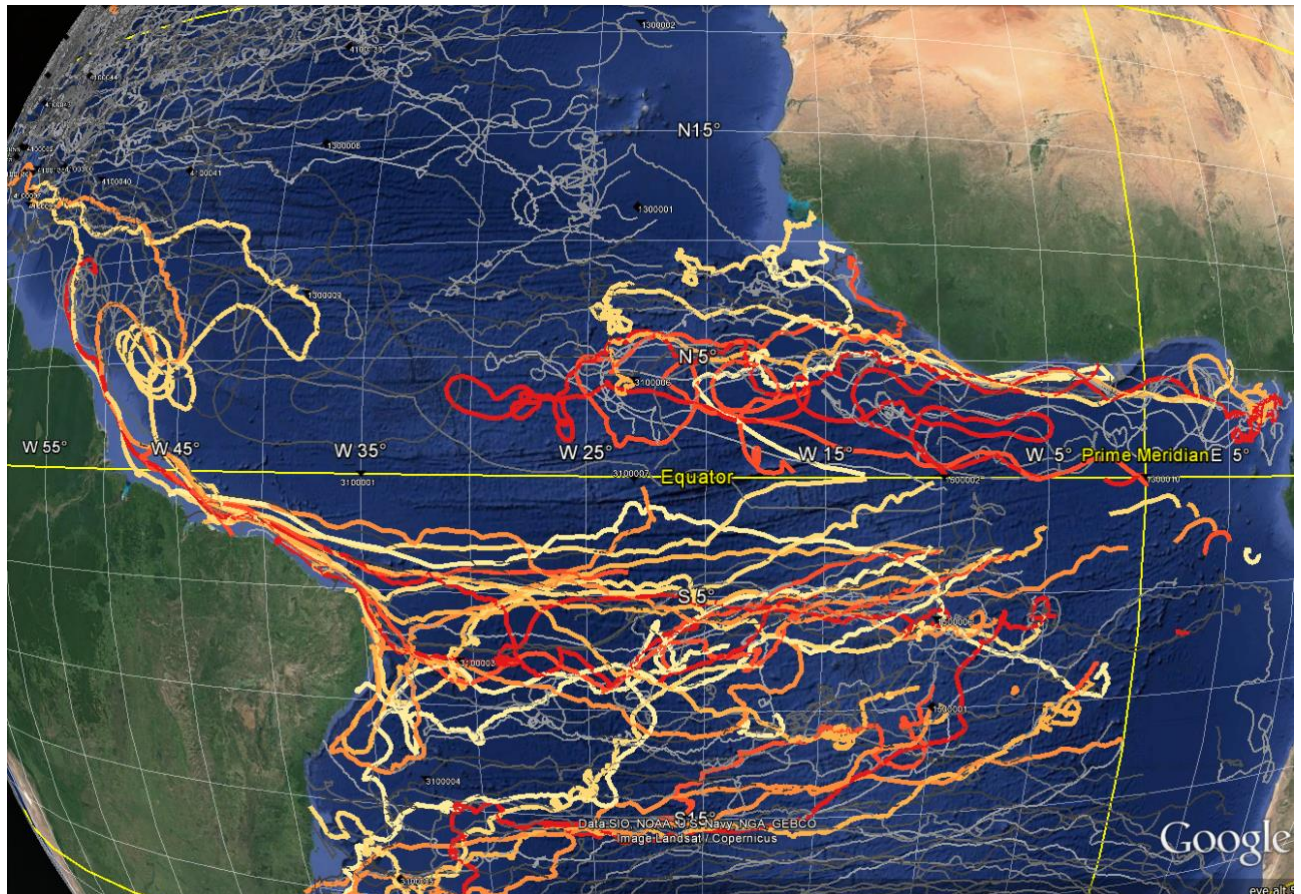
Trajectories

Figure 2: Trajectories of SVP-B drifters funded by AtlantOS, between April 2015 and September 2018. In grey are trajectories of other SVP-B drifters, during the same time period (Author: Paul Poli; Source: EUMETNET and Météo-France; Credits: Google Earth, Map background data and images: SIO, NOAA, U.S. Navy, NGA, GEBCO, Landsat/Copernicus)

As shown in Figure 2, the buoys deployed by AtlantOS have patched an area seldom observed by SVP-B. This complements well the background network of the NOAA Global Drifter Program (GDP).

IV.   Benefits of the data collected

Approach

The "value chain" from our environment to our societies covers several essential blocks:

Figure 3: The "weather value chain", adapted from Lazo (2016). Essential inputs (on the left) are actual weather and climate events, and outputs (on the right) are outcomes, with economic and social impacts.

To add value to this chain, each block must operate in collaboration with the other blocks, and add useful information (i.e., filter noise and errors), in order to reduce uncertainties caused by the weather and climate events. Note, this value chain does not consider environment modification also known as geoengineering (Royal Society, 2009).

This section considers how adding platforms (drifting buoys), to collect observations (SST, currents, air pressure), adds value to this chain.

The first element is to consider previous works that has placed an economic value on weather forecasts. Several studies have been conducted already. One may cite Lazo et al. (2011) who estimated that U.S. weather variability influenced U.S. economic output up to $485 billion per year (2008 gross domestic product), or 3.4% of its total value. The total value of forecasts was estimated at $31.5 billion per year in the U.S.A. (US Department of Commerce, 2014). In Europe, the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT, 2014) estimated the annual value of forecasts at €64 billion per year, for the EU27 zone.

The second element is to consider how much of that value comes from observations collected in near-real-time to update the analyses (say, in contrast to the value of running super-computers and creating weather bulletins). EUMETSAT (2014) estimated for example that MetOp explained 25% of the 24-hour reduction in global forecast error. This is from ECMWF studies, using the Forecast Sensitivity to Observations (FSO: Cardinali, 2009). Based on these numbers, the benefit for MetOp was estimated, for European citizens, at €4.9 billion per year.

With these two elements assumed to be in place, the last bit of work is to assess the value

of the additional drifters to improve the numerical weather forecasts, using the same metrics employed for MetOp.

Results

ECMWF calculates in its operational suite the FSO for all data assimilated. Extracting these data from the operational observation feedback was carried out for this project. The observations considered are assimilated by the ECMWF high-resolution operational numerical weather prediction system. The time period considered is between May 2015 and April 2018, for 216 assimilation cycles (days number 1, 10, and 20 of the month), with two assimilation cycles per day. However, because data were not available for 3 assimilation cycles, only 213 assimilation cycles were considered. Satellites were found to contribute the vast majority of the forecast error reduction (at 68%), with upper-air observations the second largest benefactor (at 23%), land-surface observations contributing much less (at 5%), the rest being contributed by surface marine observations. More details are given by Poli (2018).

Considering only the drifters deployed by AtlantOS, their contribution to the total 24-hour forecast error is much more modest, at 0.024% on average.

However, this means, by proportionality with MetOp, that the value of these observations for European citizens (assuming a sustained contribution to the global observing system, as evaluated here over a 3-year time period) is around €0.004704 billion per year (4.9 / 25 * 0.024), or €4.7 million per year.

V.   Continuing the legacy beyond the project

Cost to benefit ratio

Considering only the external costs of the additional deployments carried out in the project (buoy purchases and satellite telecommunications) represents a total sum of k€ 136 (over the course of the project, 4 years). This represented an annual spending of k€ 34. Compared to the economic benefits estimated in the previous section, this represents a cost-benefit ratio of **1:138 for the AtlantOS drifters**. Note, this number is a conservative estimate, as buoys continue to report (hence continue to deliver value, at marginal incremental cost now, the cost of communications, 30 cents per message). In addition, two buoys (already procured) have yet to be deployed.

These numbers are similar to those presented to EUMETNET members to study the continuation of a surface marine observation component (E-SURFMAR) over the years 2019-2023. For drifters deployed away from the Tropics (in the North Atlantic) by E-SURFMAR, the cost-benefit ratio had been estimated at **1:700**. The lower benefits of AtlantOS drifters are explained by shorter lifetimes and by the data having comparatively less impact on the forecasts. The latter is expected because pressure variations are not the primary source of information to explain circulation and weather evolution near the Equator. Nevertheless, the ratio of 1:138 is still very high.

Mitigation measures

One option to improve the cost-benefit ratio is to fund only the barometer on the drifter. This is in fact possible with the NOAA GDP barometer upgrade scheme.

Decisions

In accordance with the high impact found for the AtlantOS drifters, the EUMETNET members have agreed to continue the legacy of the AtlantOS project, and to fund barometers for upgrade on NOAA drifting buoys, to be deployed in the Tropics, over the coming years.

VI.   Conclusions

The AtlantOS project has funded 52 buoys over a 4-year time-frame using opportunities offered by PIRATA maintenance cruises and other partners such as the Met Office.

The data collected by the drifters are available in open access from various sources listed in the report. The data were assimilated by operational Numerical Weather Prediction centers.

The data were found to deliver benefits to society at a cost-benefit ratio estimated at 1:138. Based on the results obtained, members of EUMETNET have agreed to continue funding drifters in the Tropical Atlantic after the project ends, in collaboration with NOAA, using the barometer upgrade scheme.

VII.   References

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Stakeholder engagement <u>relating to this task</u>*

WHO are your most important stakeholders?	☐ Private company If yes, is it an SME ☐ or a large company ☐? ☐ National governmental body ☐ International organization ☐ NGO ◼ others: Economic Interest Group (EIG) under Belgian law Please give the name(s) of the stakeholder(s): EUMETNET
WHERE is/are the company(ies) or organization(s) from?	☐ Your own country ◼ Another country in the EU ☐ Another country outside the EU Please name the country(ies): Belgium
Is this deliverable a success story? If yes, why? **If not, why?**	◼ Yes, because it demonstrated that surface drifters deployed in an area generally avoided (South Tropical Atlantic) can collect surface pressure data that were proven to be highly beneficial to improve global weather forecasts; as a result, the EUMETNET members have agreed to take over funding this activity after the project ends, in collaboration with NOAA. ☐ No, because …..
Will this deliverable be used? **If yes, who will use it?** **If not, why will it not be used?**	◼ Yes, by EUMETNET, in its communication. ☐ No, because …..

NOTE: This information is being collected for the following purposes:
1. To make a list of all companies/organizations with which AtlantOS partners have had contact. This is important to demonstrate the extent of industry and public-sector collaboration in the obs community. Please note that we will only publish one aggregated list of companies and not mention specific partnerships.
2. To better report success stories from the AtlantOS community on how observing delivers concrete value to society.

*For ideas about relations with stakeholders you are invited to consult D10.5 Best Practices in Stakeholder Engagement, Data Dissemination and Exploitation.