Project	AtlantOS – 633211
Deliverable number	D9.3
Deliverable title	Report on assessment of the performance of AtlantOS observing system
Description	A report providing an overall assessment of the performance of the AtlantOS observing system and recommendations to optimize AtlantOS and its European component
Work Package number	WP9
Work Package title	System evaluation and sustainability
Lead beneficiary	IOC
Lead authors	Michael Ott
Contributors	Mathieu Belbéoch, Vicente Fernández, Erik Buch, Antonio Novellino
Submission data	13 November 2018
Due date	30 October 2018
Comments	It has taken longer than anticipated to develop and realise a number of the metrics and graphics used in the report.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement nº 633211.

Stakeholder engagement relating to this task*

WHO are your most important stakeholders?	☐ Private company If yes, is it an SME ☐ or a large company ☐? ☐ National governmental body ☐ International organization ☐ NGO x others (JCOMMOPS and EMODnet) Please give the name(s) of the stakeholder(s): We worked with JCOMMOPS and EMODnet to provide sample graphics to show the capability of the monitoring tools and to develop recommendations for observing programmes on how to make the best use of the tools (mainly by building key performance indicators)
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):
Is this deliverable a success story? If yes, why? **If not, why?**	x Yes, because the report demonstrates the capabilities and power of the monitoring assessment tools and provides recommendations for observing programmes to develop metrics and key performance indicators to better assess their performance
Will this deliverable be used? **If yes, who will use it?** **If not, why will it not be used?**	x Yes, by: 1) national government bodies to assess the monitoring system in relation to their level of funding; 2) manufacturers of instrumentation to compare the performance of their equipment to other builders; and 3) monitoring networks and programmes to learn how they can use the tracking tools to better assess their performance

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.

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Executive Summary

The present state of ocean observing in the Atlantic, as well as the Global, Ocean is one of a disparate array of individual monitoring programmes at different levels of maturity regarding funding stability, collection of metadata, adherence to measurement and processing standards and best practices, and timeliness of data provision to publicly-accessible data portals. The result is an ocean information value chain which is not as effective and cost-efficient as it should be in providing ocean information and products to end users.

The AtlantOS project was initiated to encourage the development of an integrated user-driven observing system for the Atlantic Ocean, and to leave a legacy of tools and a framework so that this observing system can be sustained into the future. A number of Work Packages examine user needs, develop plans for observing networks, harmonise standards and best practices, and test observation scenarios using ocean simulation experiments. Work Package 9 of AtlantOS, System Evaluation and Sustainability, has developed two online tools that can monitor the effectiveness of the observation networks in deploying platforms. These tools are working toward monitoring the networks' effectiveness in meeting their targets as well as the combined effectiveness of the overall system in measuring Essential Ocean Variables.

Work Package 9 is also producing two reports detailing the current status of the overall monitoring system: one (D9.4) focuses on how effectively the observation system meets the needs of end users for ocean information and products, and the current report (D9.3) examines how the observing networks meet their design targets for platforms and how they combine to meet the needs to measure Essential Ocean Variables. This report uses outputs from the two monitoring tools, mentioned above and detailed in the next section, to examine many of the observing networks, a number in detail. The Argo Programme is studied with the greatest detail, as it is one of the most mature networks in terms of design goals, and thus has the clearest tracking metrics.

From the measures and metrics examined in this report, one can make a number of conclusions and targeted recommendations for specific observation networks.

> Recommendation #1: A number of metrics indicate that the intensity of Argo floats may be too high (compared to targets) in Atlantic, particularly the North Atlantic, without substantially improving the coverage. The network should consider whether a few tens of North Atlantic floats would be better deployed in the Pacific or Southern Ocean, or in the envisioned extension areas such as the Gulf Stream where a double density would be ideally required.

A number of historical networks, such as the Global Drifter Program, do not yet globally share their data in netCDF format (or in other Internet "standards") which clearly limits uptake by potential users. In general, data processing and harmonization are too often given a low priority. If this first brick of the data system is not working, all initiatives for global data portals will fail to serve integrated datasets to the users.

> Recommendation #2: More observation networks, including those providing wave, river, optical, or underwater noise data, need to make their data available in standard formats on data portals for free and fair access.

The JCOMMOPS and EMODnet monitoring tools, and the value they provide, will continue to improve as the networks evolve and as our understanding of the ocean information and products that end-users need is more clearly defined. The following recommendations aim to improve the monitoring process itself.

Recommendation #3: Observation programmes and networks need to clearly define observation targets. Specific, measurable, achievable, relevant, and time-based (SMART) targets provide greater confidence and likelihood of funding success, and will allow JCOMMOPS and EMODnet to develop relevant metrics, thus facilitating more effective performance tracking. These targets can vary seasonal and across geographical areas (e.g., eco-regions), as suggested by studies in Work Package 7 of AtlantOS.

Accurate tracking of the observing system requires appropriate metadata and knowledge of upcoming deployments and cruises. Unfortunately, many observing networks do not make their metadata available to data portals or provide information on planned observations. Some progress was made regarding cruise plans through the cooperation of POGO, JCOMMOPS and others, but this is not yet optimal.

Recommendation #4: Observation networks should provide (more) metadata to the data portals in order to more accurately determine which platforms are (not) currently working up to specification. As a first step, every single instrument deployed in the ocean should be registered at JCOMMOPS.

Recommendation #5: To improve the cooperation for the implementation of AtlantOS components, the availability of cruise plans should be centrally available and routinely updated. Very basic information on cruise plans should be communicated as early as possible to JCOMMOPS.

Tracking platform activity is a good first step in monitoring the ocean observation system. Combined metrics allow network operators to more clearly diagnose the observing system. Key performance indicators (KPIs) do the same for the end-user outputs of the ocean observation system, tracking what the system is ultimately designed to accomplish.

Recommendation #6: JCOMMOPS and EMODnet should work with observation networks and end-users to develop more sophisticated metrics, as well as appropriate EOV-based Key Performance Indicators (KPIs), to more effectively track how well ocean information and services are being developed and utilised.

Introduction

Long term sustainability of ocean observing systems requires adequate stable support from government, non-government, and private funders, which will only be provided for an efficient and well-coordinated observing system that effectively meets the needs of existing and future end-users, including those in science, government, society, and industry. Currently, the observation system in the Atlantic Ocean is composed of a great number of disparate observing programmes, some of which have only loosely defined targets. They do not generally coordinate well among themselves and are typically funded through short-term research initiatives.

The overall goal of the AtlantOS project is to encourage the development of an integrated user-driven observing system for the Atlantic Ocean, and to leave a legacy of tools and a framework so that this observing system can be sustained into the future. To this end, AtlantOS used the ideas of the *Framework for Ocean Observing* (2012) to examine the multiple components of the entire observation system (or information value chain); the *Initial AtlantOS Requirements Report* collected information on user needs (including societal drivers), applications, major scientific questions, ocean phenomena, Essential Ocean Variables (EOVs), and the many loosely coordinated observation programmes. Other strategic studies have examined: what the current ocean observing system can and cannot do (the *Capacities and Gap Analysis*); the funds required to extend presently-needed programmes to cover the entire Atlantic (the *Cost and Feasibility Study*); and, through numerical model simulations, which extensions of current programmes will provide the most cost-effective improvements in mapping the current state of the ocean (the *Synthesis of OSSE Results*).

Other AtlantOS Tasks have examined how to improve individual monitoring programmes (Work Packages 2 and 3); how to connect to coastal observing systems (Work Package 5); and how to improve data flow and integration (Work Package 7); as well as provided examples of how society benefits from ocean applications (Work Package 8). However, continuous monitoring of the observing system performance is required to ensure that the variables needed to meet different end-user needs are being measured at the correct spatial and temporal scales. One of the tasks of Work Package 9 (WP9), *System Evaluation and Sustainability*, therefore, is to provide quantitative updated information, in near real time, of the state and variability of the in-situ observing system in the Atlantic Ocean, including monitoring key performance indicators.

As part of Task 9.1 of WP9 of AtlantOS, two complementary authoritative web-based monitoring tools have been developed to monitor ocean observations. In Deliverable 9.1 (D9.1, see http://www.jcommops.org/board/?t=atlantos), the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology Observing Programmes Support Centre (JCOMMOPS) adapted its existing global monitoring tool to focus on observations in the Atlantic Ocean. In Deliverable 9.2 (D9.2, see http://www.emodnet-physics.eu/atlantos/dashboard/Default.aspx), the European Marine Observation and Data Network (EMODnet) Physics developed a web-based monitoring tool focused on the European contribution to the Atlantic Observing system and on data availability, data accessibility, user experience and feedback.

These two monitoring tools for ocean observing in the Atlantic Ocean are critical elements in the continuous and ongoing assessment of the observing system's capacity to provide ocean information products. Individual monitoring programmes and European Member States can immediately discover what part of the observing system they are supporting, how their investment is leveraged by similar contributions by other countries and regions, and what gaps in monitoring coverage and data availability exist. This report, then, provides an update of the monitoring status of the ocean observing system in the Atlantic Ocean, by examining a number of representative observation programmes.

Methodology: Web monitoring tools

For each of a number of observation networks, D9.1 provides a real-time monitoring dashboard, dedicated monthly monitoring maps, interactive maps, performance Indicators, and various statistic and monitoring tools, all of which are exportable, customizable, and embeddable. While the Atlantic Ocean focus was funded by the AtlantOS project, the tool itself will be maintained and improved (e.g., to include EOV-based monitoring) in the future as a legacy of AtlantOS. At the present time, JCOMMOPS monitors Argo profiling floats, the DBCP surface drifters, the OceanSITES moorings time-series, the GO-SHIP hydrographic reference lines, the SOT met/ocean ship based observations, and the GLOSS sea level tide gauges. A number of other observing systems are gradually being added, including ocean glider, marine mammals and HF radars. [More details can be found in the D9.1 report, available online at: https://www.atlantos-h2020.eu/download/deliverables/9.1%20Web%20based%20monitoring%20tool%20of%20the%20Atlantic%20ocean%20observing%20system.pdf].

EMODnet Physics is based on the cooperation and collaboration with the three established pillars of the European Oceanographic Data Community: EuroGOOS and its Regional Operational Oceanographic Systems (ROOSs), responsible for the collection of regional data; the In Situ Thematic Assemble Center (INSTACS) under the Copernicus Marine Environmental Service (CMEMS); and the SeaDataNEt network of National Oceanographic Data Centers (NODCs). EMODnet Physics makes available near real time and historical validated marine and ocean data as monitored by fixed and moving platforms such as fixed stations, mooring buoys, tide gauges, surface drifters, ferryboxes, Argo floats, gliders, marine mammals and HF radars, and provides a combined array of services and functionalities, including a facility for viewing and downloading, dashboard reporting and machine-to-machine communication services. The web-monitoring tool, D9.2, focuses on the European contributions to monitoring in the Atlantic Ocean; the dashboard allows users to view and export various statistics about the data portal content and usage, including measures presenting how much data and how many platforms are made available on a daily basis, and extracts statistics on page access and data downloads, etc. [More details are available online at: https://www.atlantos-h2020.eu/download/deliverables/9.2%20Web-based%20monitoring%20tool%20of%20the%20Atlantic%20Ocean%20observing%20system.pdf].

As ocean observing programmes and networks are at different stages of maturity in their implementation, the range of monitoring and performance statistics available on D9.1 and D9.2 varies by programme. For example, metrics, developed in cooperation with network experts, rely on design targets; for observing programmes that have not yet established well-defined targets, ratios are not possible and only measures (raw counts) are displayed. Measures and, where possible, metrics are available for each observing network coordinated through JCOMMOPS, with common vocabulary and algorithms across the various networks. In the case of the European Regional Operational Oceanographic Systems (ROOSs) monitored by EMODnet physics, observation targets are not defined, so only an analysis of the temporal evolution of the number of available data can be performed. Both of these monitoring tools will continue to evolve as observing networks mature and develop more concrete targets, providing additional statistics and, in particular, more integrated metrics (e.g., EOV oriented) and key performance indicators. In addition, work is ongoing to harmonise the two monitoring approaches to provide a common look and feel, as well as to allow the merging of certain metrics, understanding their different foci.

In the following sections, a representative set of the observational programmes are monitored, tracked, and analyzed, including one which is very well defined and mature (i.e., the Argo Programme). Many others, unfortunately, are not as well developed; they have not defined clear observation targets and they have a lack of metadata. As a result, their tracking is necessarily considerably simpler. In addition, some integrated results are provided. Section 3 examines monitoring levels, including the number of active platforms and, where applicable, metrics. Section 4 considers the status of instrumentation, including market players and platform reliability. Section 5 looks at data flow, including data availability and downloads.

Output from Monitoring Tools

As noted above, the JCOMMOPS and EMODnet physics monitoring tools (Deliverables 9.1 & 9.2), delivered earlier in the AtlantOS project, will continue to evolve as networks and the coordination among them mature, as work progresses to harmonise some of the features between the two tools, and as, for example, some EOV-based metrics are developed. Nevertheless, a sample of the capability of the tools included here shows that there is already considerable functionality, which continues to grow.

Design and Definitions

Assessing the performance of any system requires continuous measurements of appropriate parameters. The easiest measurements to make and report on are pure numbers (i.e., measures or counts), such as the number of Argo profilers currently in the Atlantic Ocean or the average lifetime of a drifting buoy. Unfortunately, these measures are the least effective in assessing the performance of the observing system because they do not involve comparison to, or even knowledge of, the needs, targets, or design of the system.

A more effective type of parameter (i.e., a metric) compares the measure to a design target, resulting in, for example, a parameter indicating what percentage of the target is reached (within a time period and/or over a certain geographical domain). Unfortunately, for ocean monitoring, most observing programmes have not yet defined clear design targets, and measures are the best the two monitoring tools can provide at the present time. In the case of the Argo programme, however, clear design targets have been established and metrics can be produced to track Argo activity (i.e., number of operational units), intensity (i.e., yearly deployments to meet the target), and coverage (spatial and temporal availability of data). The three figures below show dashboards indicating these measures and metrics for the Global, Atlantic, and North Atlantic Oceans, respectively, for the year 2017. Using metrics (i.e., comparison of measures to targets) for the Atlantic Ocean clearly suggests a misbalance that deserves to be examined more closely and possibly addressed – too many floats are deployed compared to the target.

Implementation				
Activity Argo Global	100.56% 9/2018 ↗	3777 Raw count	3756 Target	# of operational units in the design vs target (Global Argo)
Coverage (Yearly) Argo Global	68.65% 2017 ↗	68 Raw count	66% Target	# of well sampled 3°x3° design grid elements over last calendar year vs total
Intensity Argo Global	88.35% 9/2018 ↗	857 Raw count	970 Target	# of registered deployments in the design over last 12 months (Global Argo)

Figure 1: Three key measures to monitor Argo's implementation in the Global Ocean for 2017: the real time activity, intensity, and coverage in data available to users. [Graphic courtesy of JCOMMOPS]

Implementation				
Activity Argo Global - Atlantic Ocean	118.54% 9/2018 ↗	940 Raw count	793 Target	# of operational units in the design vs target (Global Argo) - Atlantic
Coverage (Yearly) Argo Global - Atlantic Ocean	74.65% 2017 ↗	74 Raw count	66% Target	# of well sampled 3°x3° design grid elements over last calendar year vs total - Atlantic
Intensity Argo Global - Atlantic Ocean	121.76% 9/2018 ↗	235 Raw count	193 Target	# of registered deployments in the design over last 12 months (Global Argo) - Atlantic

Figure 2: As in Figure 1, but for the Atlantic Ocean. [Graphic courtesy of JCOMMOPS]

Implementation				
Activity Argo Global - Atlantic Ocean - North	136.44% 9/2018 ↗	468 Raw count	343 Target	# of operational units in the design vs target (Global Argo) - Atlantic North
Coverage (Yearly) Argo Global - Atlantic Ocean - North	77.84% 2017 ↘	77 Raw count	66% Target	# of well sampled 3°x3° design grid elements over last calendar year vs total - Atlantic North
Intensity Argo Global - Atlantic Ocean - North	150.6% 9/2018 ↗	125 Raw count	83 Target	# of registered deployments in the design over last 12 months (Global Argo) - Atlantic North

Figure 3: As in Figure 1, but for the North Atlantic Ocean. [Graphic courtesy of JCOMMOPS]

When targets are defined for implementation, dataflow, instrumentation and other categories, they can be adapted to different perspectives (e.g., basin, sub-basins, customised geographical areas; networks, sub networks; regional, national, international); the JCOMMOPS and EMODnet monitoring tools allow users to develop their own perspectives. The targets have to be reviewed regularly (e.g., yearly) within the network's governance and the traffic light style meaning adapted to the challenges that the networks can reasonably achieve and progress toward.

The most effective parameters are key performance indicators (KPIs), which are metrics directly tied to the success of the overall observation programme. In the case of ocean observing, where the goal is timely, accurate, reliable, and accessible ocean information and products, key performance indicators should be tied to the parameters that need to be measured (e.g., temperature, dissolved Carbon, or fish abundance), rather than the platforms. That is, KPIs should be based on how well the measurements of temperature over a certain time period and within a defined geographical area match the defined targets (of a certain number of measurements meeting accuracy and precision levels needed for subsequent analysis). These KPIs will differ for different end-users, according to their particular needs.

The Global Ocean Observing System (GOOS) Physics, Biogeochemistry, and Biology / Ecosystem Panels have developed a set of Essential Ocean Variables (EOVs), which can be understood as a minimum set of ocean parameters (e.g., temperature, dissolved Carbon, and algal cover) needed to understand the state and variability of the ocean and to provide useful ocean information to end-users. In some cases, the required accuracy and spatial and temporal scales have also been defined. These requirements have not yet been converted into targets by JCOMMOPS or EMODnet, one step in producing KPIs. A separate step is determining how to combine measurements of the same type (e.g., temperature) from different platforms in order to compare it to the defined targets. Work has begun on both of these aspects, but KPIs cannot yet be analysed from the monitoring tools at this stage.

Number of Observations

From the EMODNet Physics AtlantOS dashboard, one can extract information about the data availability and the performance of the observing infrastructures behind the portal (i.e., the European EuroGOOS ROOSs platforms feeding CMEMS INSTAC), together with the other data from JCOMMOPS observing programs whose data are available through EMODNet physics. Note that there are no targets defined in the EMODnet physics portal, it is just a portal through which all accessible data flow. As a result, ithe graphics below show only the trend for different platforms and measured variables during the last year and the last 5 years.

Table 1 shows the average number of active platforms in the AtlantOS area, grouped according to type, for the last 5 years and for the end of August 2018. An active platform means, essentially, a platform that have provided a monthly file for a determined month.

Type of Platform	2013	2014	2015	2016	2017	2018	Aug 2018
Argo / profilers	692	714	790	852	908	935	938
Bathy messages on GTS	8	6	5	5	6	5	5
CTD profiles	321	331	299	311	144	238	14
drifting buoys	685	859	849	645	534	561	611
ferrybox / ship	27	23	23	25	41	41	41
gliders	5	5	6	8	7	3	2
marine mammals	1	8	2	6	10	10	8
mooring time series	292	314	336	535	551	536	549
HF Radar	0	0	0	11	32	14	17
TESAC messages on GTS	56	51	58	59	55	57	64
tide gauges	138	233	260	233	197	256	328
XBT or XCTD profiles	1	1	1	1	2	0	-

Table 1: Number of active platforms during the last 5 years (monthly means for each year), except last column which is actual numbers of active platforms at the end of August 2018. CTD numbers accounts for the number of single profiles performed for every month. Note that if a platform provides more than one parameter (the usual situation), it is counted more times. [Graphic courtesy of EMODnet]

According to Table 1, the most abundant platforms, whose data are available, are ARGO profilers, drifting Buoys, mooring time series and sea level tide gauges. Note that some platforms, such as gliders or marine mammals have very low data availability in the AtlantOS region. It can be said that the low number of glider vehicles in the AtlantOS observing system reflects the lack of maturity of the OcenGlider GOOS program (as in October 2018), but the community is working to coordinate this observing platform at European and Global level. This situation will improve considerably after a hiring of a Technical Coordinator in June 2019 thanks to EMODnet financial support. Figure 4 graphically represents the same data, more clearly showing the slight increase of ARGO profiles and moorings and decrease in the number of available drifting buoys.

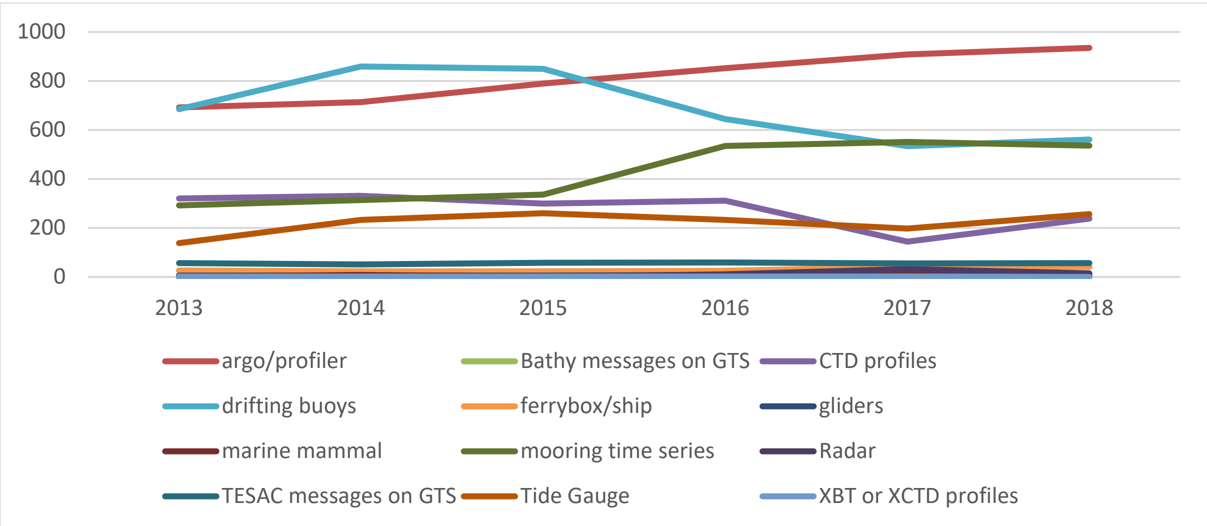

Figure 4: Temporal evolution of the number of active platforms (monthly means) over the last 5 years. [Graphic courtesy of EMODnet].

The number of active platforms (providing a monthly file for the month of August 2018) by observed variable is shown in Table 2. Note that if a platform provides more than one variable (the usual situation) it is counted more times (which is why the total number in Table 2 is different from the number of platforms).

Observed Variable	# platforms
Water Temperature	2060
Atmospheric parameter	1153
Water salinity	1136
Currents	630
Sea Level	395
Winds	312
Waves	308
Water conductivity/ BioGeoChemical	259
River	96
Optical Properties	13
Underwater noise	1

Table 2: Number of platforms by variable (month of August 2018). [Graphic courtesy of EMODnet]

Water temperature and salinity are the most commonly observed ocean variables in the Atlantic, as expected, with around 2k and 1k observations by month, respectively. In contrast, there are only 259 platforms providing some type of biogeochemical parameter. Very few platforms providing river data, optical data, or underwater noise data are available in the European data portals.

Number of Platforms (and compared to targets where they exist)

The Argo programme was designed to address specific scientific questions and, as part of the design, observing targets were established for the number of profilers within each 3 by 3 degree grid of ocean. The JCOMMOPS monitoring tool allows the user to track how the Argo program has met these targets over time, in any of a number of predefined geographical subdomains; the user can also furnish a custom geographical mask. Figure 5 reveals that the Argo programme essentially meets the targets in both the North and South Atlantic Oceans. It also suggests, given the over-reach in the Global Ocean, that it might be reasonable to shift some buoys from “oversampled” areas to regions of higher scientific interest, including, perhaps, to undersampled subregions in the Atlantic Ocean.

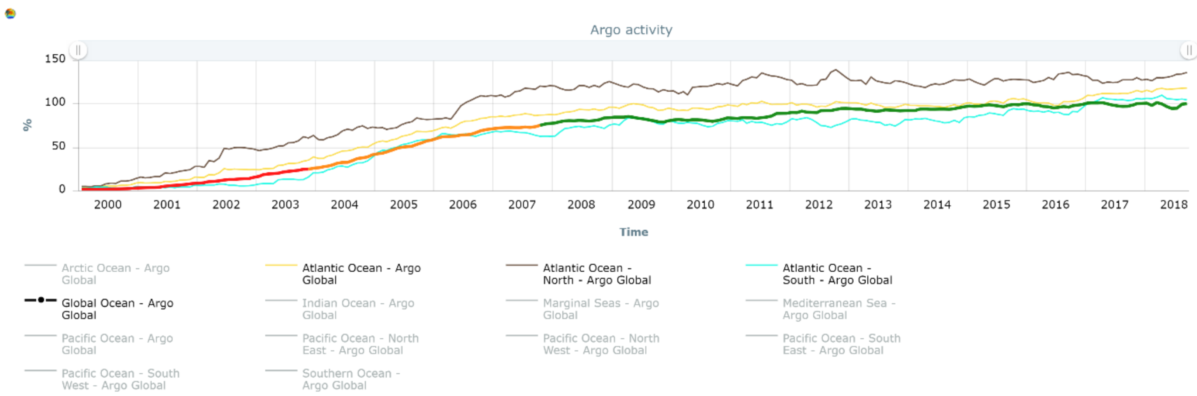

Figure 5: Evolution of Active Argo Buoys vs. Target with a focus on the Atlantic (yellow), North Atlantic (brown), South Atlantic (cyan) and global (red-orange-green) [Graphic courtesy of JCOMMOPS]

In addition to absolute numbers of Argo profilers, the Argo Programme has, based on general ocean circulation and platform lifetime, established targets related to activity, the number of new profilers that must be added on a regular basis, to maintain the array. The JCOMMOPS monitoring tool also tracks Argo activity; Figure 6 focuses on the Atlantic region, with the Global Ocean for comparison – whereas Argo activity in the Global Ocean is under target, activity in the South Atlantic is barely above target, and in the North Atlantic is about 50% above target.

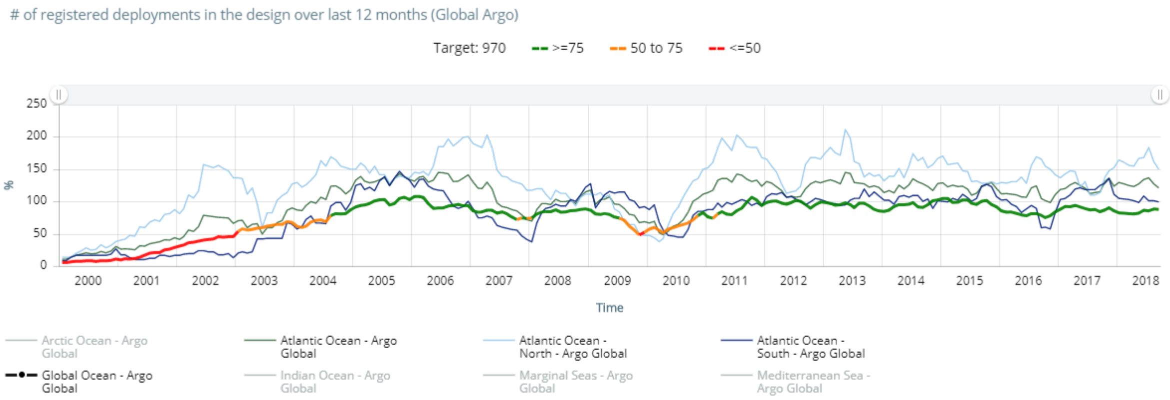

Figure 6: Evolution in Activity (buoys deployed) compared to Targets [Graphic courtesy of JCOMMOPS]

The Argo, DBCP, SOT, and GLOSS Programmes have established a number of observation targets, and a dashboard (see Figure 7) provides a quick indication of how well these programmes are meeting their goals. Unfortunately, they are among the few to have defined any targets, so this level of analysis is not possible for most observing programmes. As others mature and develop these targets, the JCOMMOPS and EMODnet tools will begin to track these platforms as well.

	Argo			DBCP				SOT	GLOSS
	Argo Core	Argo Global	Argo BioGeoChemical	Global Drifter Program	Coastal/National MB	Tropical Moored Buoy	Tsunami Buoy	VOS	
Implementation									
Activity Global Ocean	86.87% 9/2018 ↗	100.56% 9/2018 ↗	35.42% 9/2018 ↗	110.66% 9/2018 ↗	103.67% 9/2018 ↘	72.27% 9/2018 ↗	59.38% 9/2018 ↘	102.65% 7/2018 ↗	84% 3/2017

Figure 7: Activity status and trends for selected JCOMMOPS Observing Systems [Graphic courtesy of JCOMMOPS]

Uniformity of Platforms (overall, N vs. S Atlantic, coast vs. open ocean)

Global, or even basin-wide, tracking of the number of platforms compared to targets are only the first step in monitoring how well the platforms of an observation programme are distributed. General current patterns and uneven geographical seeding due to disparity in national funding levels can lead to suboptimal congregations of platforms in some area and lacks in others. Whether a uniform distribution is required to survey the background conditions or whether a concentration in a particular region of scientific interest in warranted, it is important to track how the platforms are distributed.

The Argo Programme, as noted above, is one of the few to have defined targets for distribution (i.e., 66% of 3 by 3 degree boxes sampled every month (averaged over the calendar year). Figure 8 depicts how the network has grown since its inception to meet this overall distribution target. It also shows that the coverage better meets the target in the North Atlantic than the South Atlantic (and that both outperform the Global Ocean).

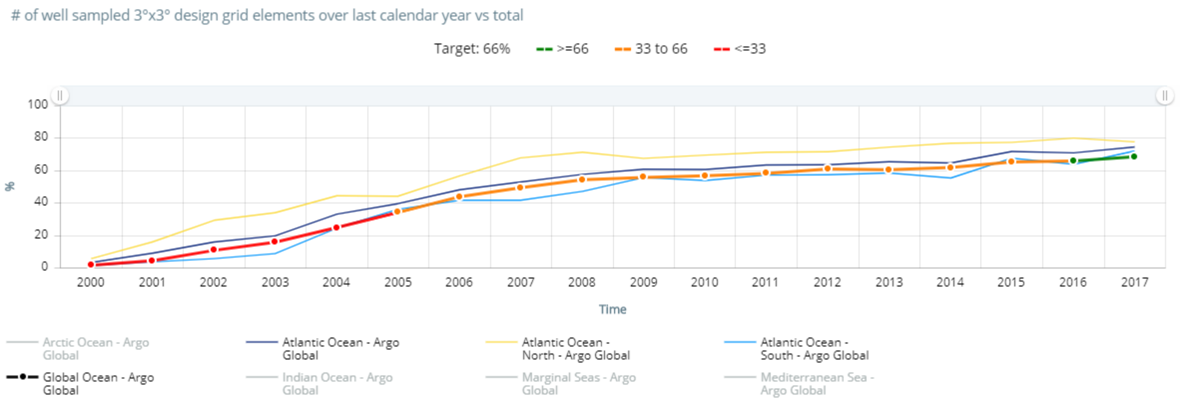

Figure 8: Intensity (coverage) of Argo Floats [Graphic courtesy of JCOMMOPS]

It is possible to drill down even further on how evenly distributed the Argo floats are by examining a distribution map for a particular month or averaged over a year (as in Figure 9). Here, focusing on the Atlantic, one can see the lack of profilers in the middle of the South Atlantic (i.e., open ocean; there is a smaller lack in the open ocean of the North Atlantic) and the concentration of floats in the Labrador Sea and U.S. coastal regions (with a similar concentration off the coast of South Africa). As noted above, there may be scientific reasons to opt for a non-uniform distribution of platforms, and, indeed, the Argo Programme is considering a Western Boundary Current enhancement (already occurring to some extent in the Gulf Stream) and a Deep Argo programme to ocean heat content. The JCOMMOPS tool will allow users to focus on these Argo profilers, as well as Argo profilers equipped with biogeochemical sensors, to track how the platforms are distributed and whether they are meeting their design targets.

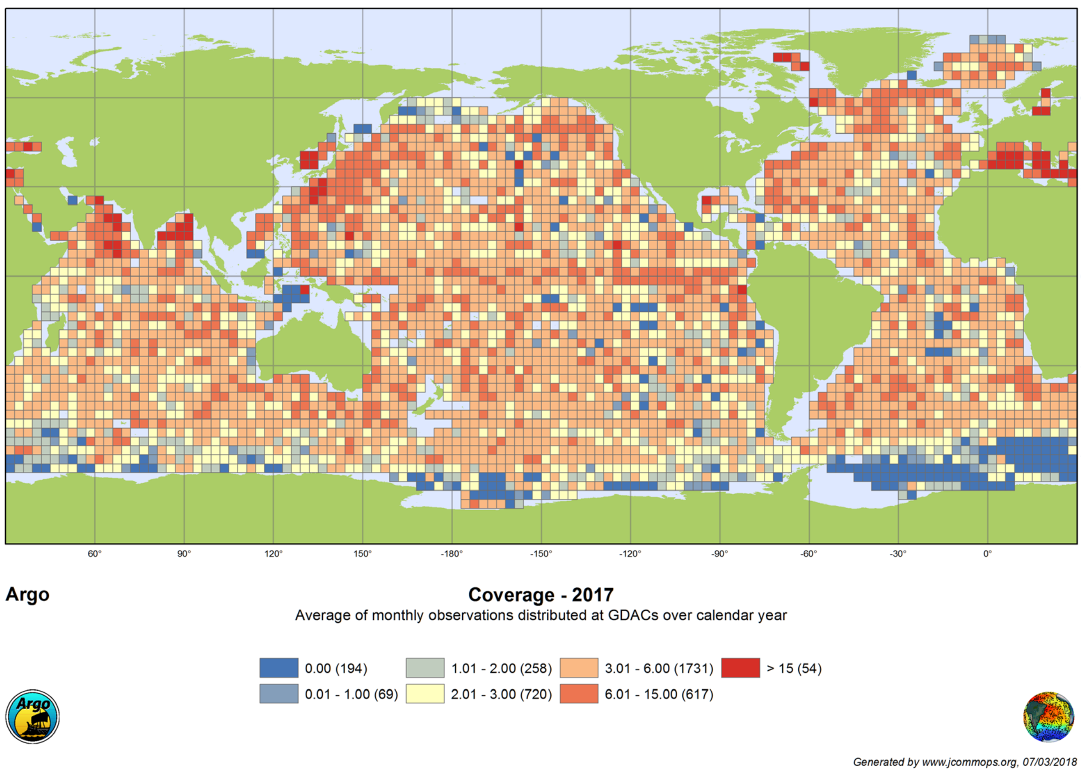

Figure 9: Spatial Distribution of Argo Profiles (2017) vs. Target. A few gaps remain (Azores, central south) and a few areas are oversampled (such as the subpolar gyre) [Graphic courtesy of JCOMMOPS]

Other observation programmes do not have such well-defined targets, but one can get an idea of the distribution of various platforms by comparing how many are in each region to the global total. The EMODnet physics global monitoring tool, for example, tracks the number of platforms measuring various parameters (see legend in Table 3) within defined regions. A sample of the data available from this tracking tool (see Table 3), for platforms in the Atlantic Ocean for September 2018, indicates that, for most data types, the Atlantic Ocean holds between 28% and 38% of the globally-allocated platforms (with up to 45% for platforms measuring winds). The percentage for river data is similar, but the breakdown (i.e., all on the Bay of Biscay and Celtic Sea) suggests that the geographical distribution should be examined more closely.

	T	S	C	H	L	A	C	Wa	Wi	R	N	Total
Atlantic (North)	944	415	212	0	40	428	156	81	225	0	0	2501
Atlantic (South)	2266	1198	351	4	0	848	119	13	26	0	0	4825
Atlantic, Bay of Biscay, Celtic Sea	4339	1821	932	9	183	1738	496	335	417	198	1	10469
TOTAL (global)	25629	12619	4886	71	764	10816	2083	1120	1488	564	2	60042
% Atlantic	29.5	27.2	30.6	18.3	29.2	27.9	37.0	38.3	44.9	35.1	50.0	29.6

Table 3: Number of platforms providing a physical parameter for a given geographical regions of the Atlantic Ocean – data from September 2018. (T: Water Temperature; S: Water Salinity / Conductivity / Density; C: Currents; H: Light Attenuation; A: Atmosphere; C: Chemical Parameters; Wa: Waves; Wi: Winds; R: Rivers; N: Underwater Noise). [Graphic courtesy of EMODnet]

Contribution by Country and Organization

The geographical size and economic ability of a nation are important considerations when each country decides how to contribute to national or regional / global observation programmes. Nonetheless, countries also realise the benefit of leveraging other nations' contributions (i.e., the overall benefit can be greater than the sum of the parts) and there is likely also a desire not to be seen as not contributing where others are. Thus, nations like to track how they are doing in many areas compared to other countries, and the monitoring tools allow for such comparisons in the domain of ocean observing at global and at regional and smaller scales. In the Atlantic Ocean, for example, the data indicates (Figure 10) that Europe contributes over 50% of the Argo floats, with Canada and the United States making up almost 40%.

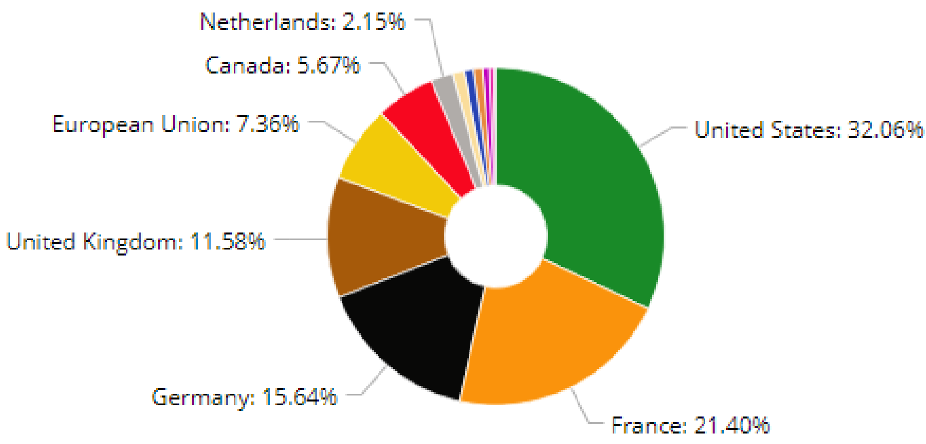

Figure 10: Present Argo Implementers in the Atlantic Ocean (deployments since 2014). This figure shows statistics of national contributions from countries, plus specific floats funded by European Projects, tagged by 'European Union', and operated by Euro ARGO ERIC. [Graphic courtesy of JCOMMOPS]

One can also track how nations compare over time in the deployment of Argo profilers or in other areas of ocean observing. Figure 11 tracks the number of floats operating in the Atlantic Ocean over the past 20 years. It shows how the United States was an outsized contributor early on, but that Europe and other regions are catching up. A more detailed analysis, including by region of the Atlantic, and with the European contributions summed together, can be performed at the JCOMMOPS and EMODnet websites.

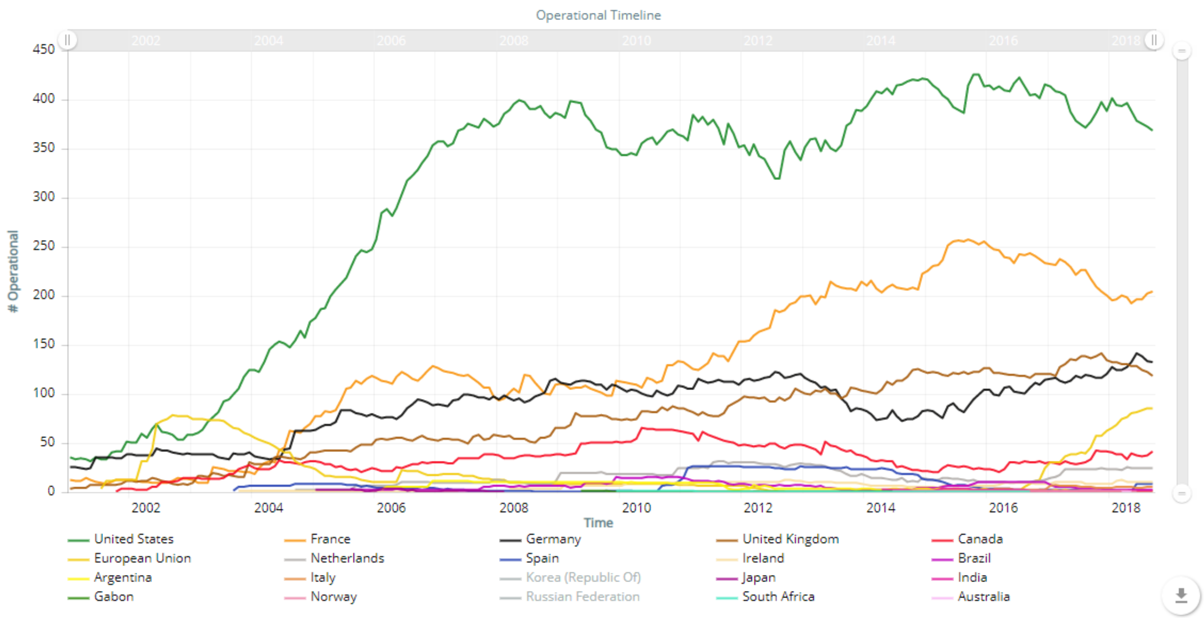

Figure 11: Evolution of National Contribution (operational floats in the Atlantic Ocean). This figure shows statistics of national contributions from countries, plus specific floats funded by European Projects, tagged by 'European Union', and operated by Euro ARGO ERIC. [Graphic courtesy of JCOMMOPS]

In some cases, it is possible to obtain more detail, even beyond monitoring programme within a country. Figure 12, for example, shows the research vessels from which Argo profilers have been deployed over the past four years.

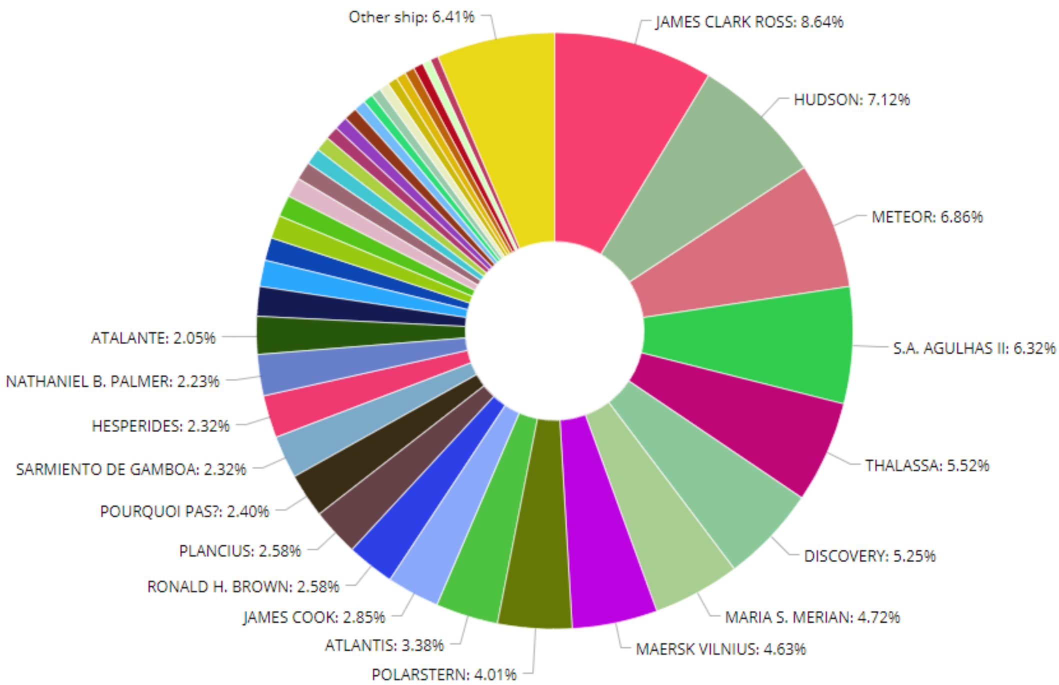

Figure 12: Key Ships for Argo Deployments (deployments since 2014) [Graphic courtesy of JCOMMOPS]

From the EMODnet physics dashboard, one can display statistics (raw numbers) regarding which countries provide platforms in the Atlantic, and thus about the European vs. Non-European contributions. One can see more clearly in Table 4 than above that the European contribution to ARGO in the Atlantic exceeds 50%. The 90% for tide gauges is likely due to a lack of access to U.S. data at EMODnet (since the U.S. has a well-established tidal gauge array), but this should be examined. Note also the 37% European contribution for moorings and very small relative contribution for drifting buoys. However, in many cases there is a large number of Non-Defined providers; there is missing metadata, which is an issue that needs to be resolved.

Type of platforms	#platforms from European Country	#platforms from non-European Country	#platforms Other/null/ND*	#total
Argo / profilers	543	388	7	938
drifting buoys	42	68	501	611
mooring time series	204	87	258	549
tide gauges	290	5	33	328
TESAC messages on GTS	-	20	44	64
ferrybox / ship	17	5	19	41
HF Radar	17	0	0	17
CTD profiles	14	0	0	14
marine mammals	-	0	8	8

Bathy messages on GTS	-	1	4	5
gliders	-	2	0	2

Table 4: Number of platforms by European and non-European countries. *: lacking information in the Metadata, both for Country and Data provider [Graphic courtesy of EMODnet]

Status of Instrumentation

Even with a single observing programme using one type of platform (e.g., the Argo Programme), there are often multiple private and academic manufacturers of monitoring equipment. This free-market approach, which is favoured by a number of countries and financially supported, results in quicker, more innovative, and, hopefully, more cost-effective, approaches to ocean observation. However, standards and reliability are not uniform. Organisations such as GOOS, as well as tasks within the AtlantOS project itself, are working to help define common standards, protocols, and best practices for ocean observing. The JCOMMOPS and EMODnet tools can encourage reliability improvements by tracking metrics related to instrument lifetime and sensor drift.

Market Share

Figure 13 indicates how the market share of the various manufacturers of Argo floats has changed over time. Knowing which manufacturers are trusted, and the reasons (including reliability, discussed below) why, can help observation programmes make more effective decisions regarding capital purchases, and help manufacturers understand user needs.

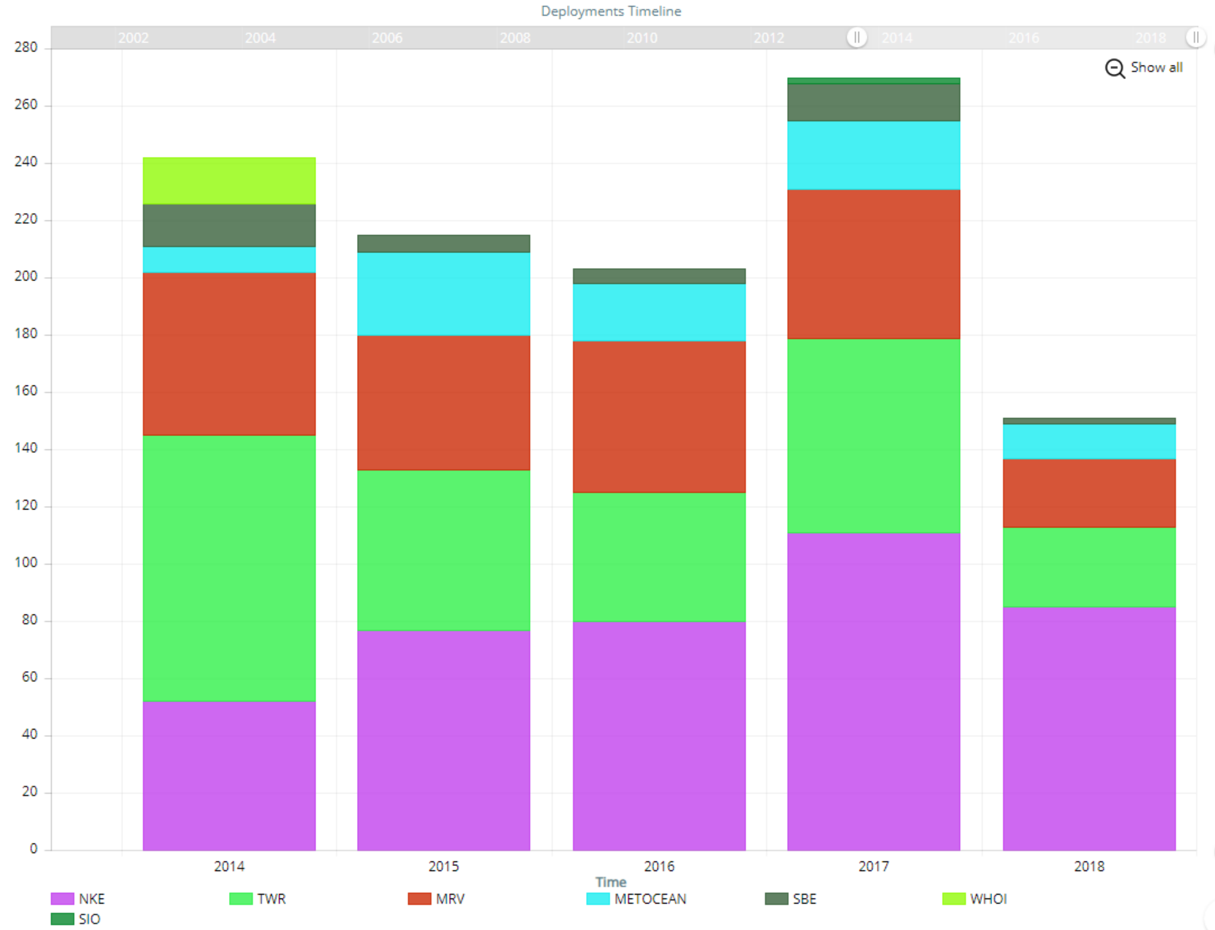

Figure 13: Float Market for Atlantic Ocean (deployment by manufacturer; NKE is the only European float maker) [Graphic courtesy of JCOMMOPS]

Instrument Reliability

One of the main factors driving down per-profile costs for Argo profilers is increased instrument longevity. Figure 14 shows how the average life expectancy (in years, from demographic studies) weighted across manufacturers according to number of deployed profilers, has varied over the past 18 years, with most of the increase occurring in the first 10 years.

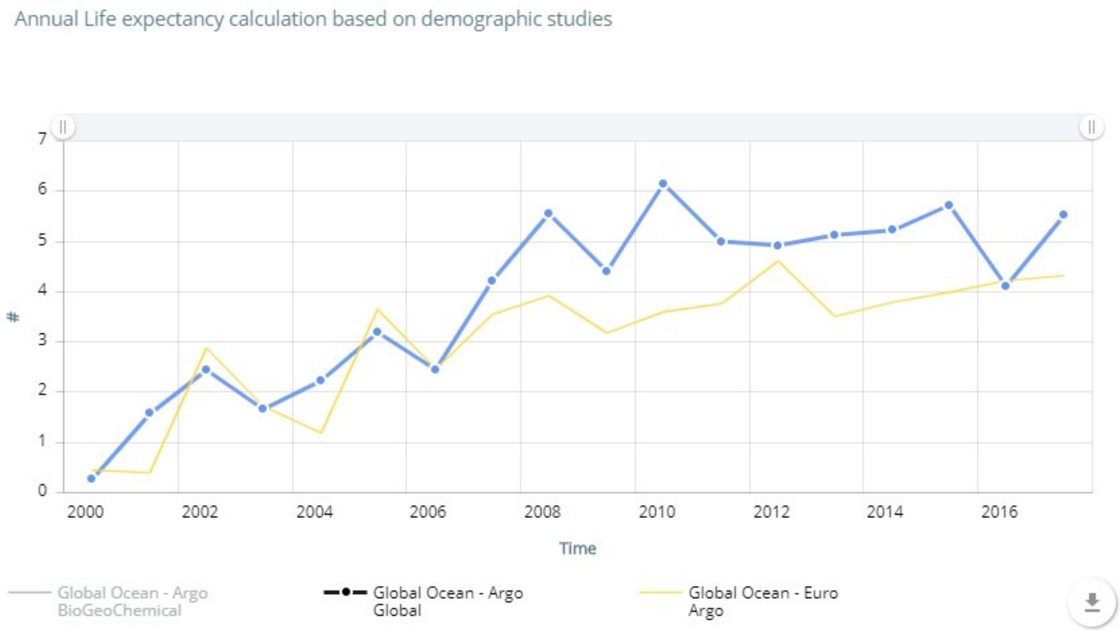

Figure 14: Average Life Expectancy (years) for Argo Floats [Graphic courtesy of JCOMMOPS]

This overall life expectancy can be studied in more detail through the use of a range of measures and metrics available through the monitoring tools. In the dashboard reproduced as Figure 15, for example, the overall lifetime of Argo floats is examined via the average age at failure, half-life, number of platforms surviving different number of cycles, and other similar concepts.

Instrumentation				
Age of failure Argo Global	3.16 2016 ↗	- Raw count	4.1 Target	Average age of failures (excluding launch failures)
Deployment Success Argo Global	98.15% 2017 ↘	794 Raw count	95% Target	% of deployment surviving one cycle over last calendar year deployments
Half Life Argo Global	1584.16 2010 ↗	1584 Raw count	- Target	Half Life in days (Global)
Life Expectancy Argo Global	5.52 2017 ↗	5 Raw count	- Target	Annual Life expectancy calculation based on demographic studies
Mortality Rate Argo Global	25.23% 2017 ↘	25 Raw count	- Target	The mortality rate, or death rate, is the ratio between the yearly failures and the average float population that year (arithmetic mean of monthly operational floats).
Reliability (010) Argo Global	78.5% 9/2018 ↘	752 Raw count	90% Target	% of deployment surviving 10 cycles (12 months moving window)
Reliability (025) Argo Global	80.1% 9/2018 ↘	813 Raw count	90% Target	% of deployment surviving 25 cycles (12 months moving window)
Reliability (050) Argo Global	87.59% 9/2018 ↗	833 Raw count	90% Target	% of deployment surviving 50 cycles (12 months moving window)

Figure 15: Various measures and metrics of instrument performance [Graphic courtesy of JCOMMOPS]

This can be further broken down by comparing survival rates among the different manufacturers. Figure 16 suggests that a large number of extra profiles that can be obtained by choosing models with higher survival rates. Longevity is, of course, only one factor that needs to be considered – others include cost, and sensor reliability (including sensor drift).

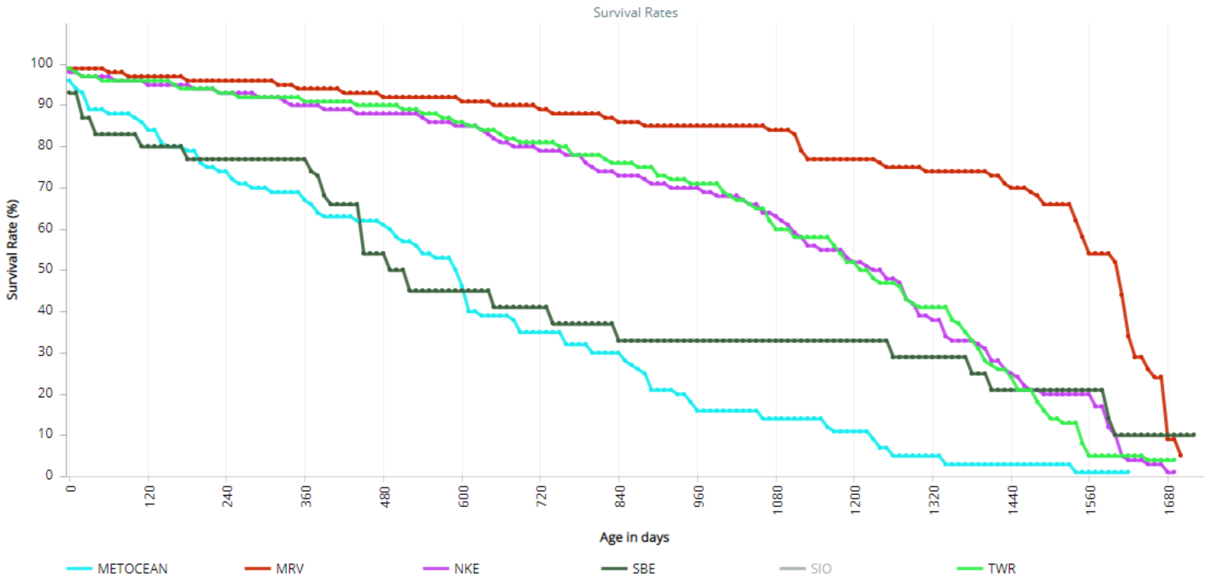

Figure 16: Survival Rate for Atlantic Ocean Floats (deployments since 2014) [Graphic courtesy of JCOMMOPS]

Data Flow

Timeliness and Quality of Data

JCOMMOPS also tracks the delivery of data (in addition to the platforms that are operating), the timeliness of delivery (at different distribution nodes) and the quality of sensor data. Figure 17 reveals how the median delay per Argo manufacturer varied over six months. This careful monitoring of delays, for example, allows for the optimisation of data services to operational users and will be used to reasonably raise the threshold target from 24 hours to, for example, 3 to 6 hours.

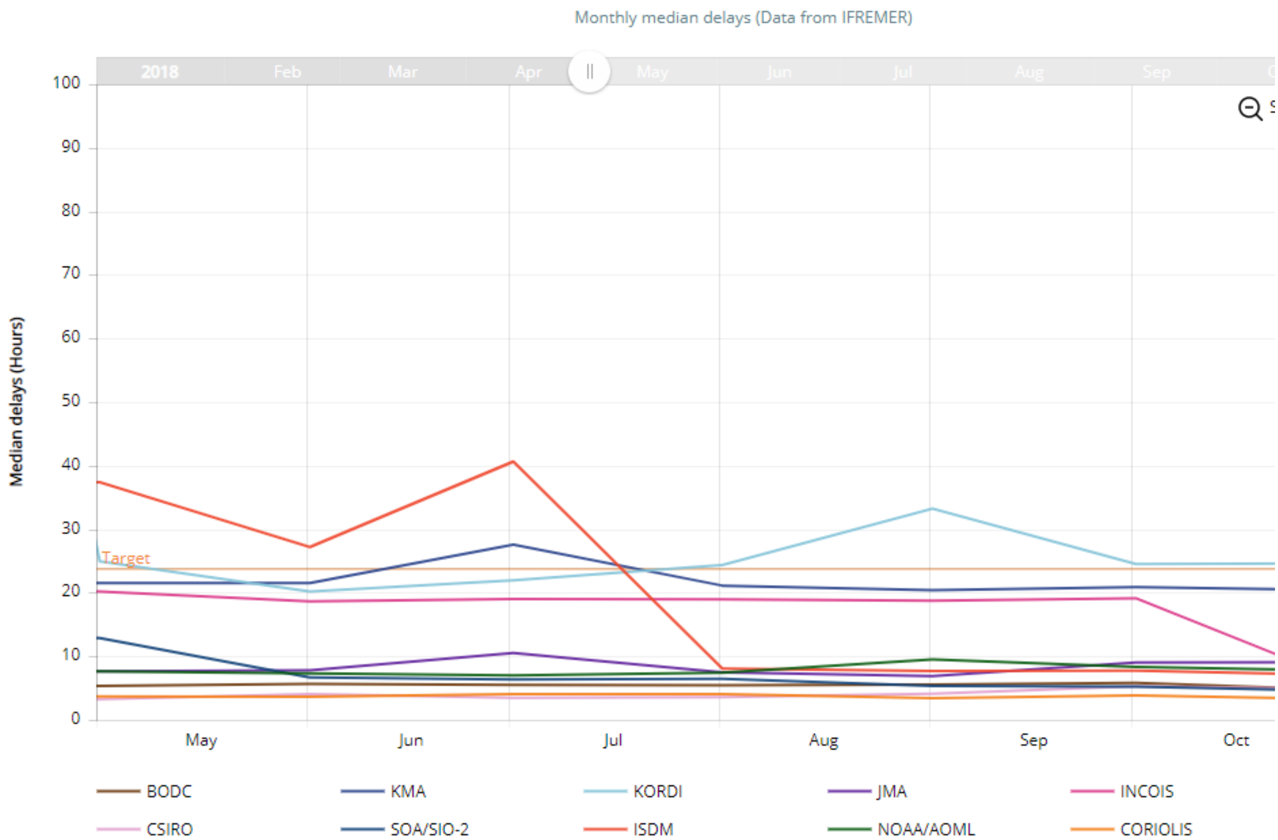

Figure 17: Evolution of timeliness for each float data producer, compared to the target (24 hours). [Graphic courtesy of JCOMMOPS]

Data quality can be tracked in a similar way. The dashboard of Figure 18 combines various measures and metrics of timeliness and data quality for the Argo program. The last metric, whitelisted (the opposite of blacklisted) implies that data can be used without waiting for delayed mode quality control (QC).

Data Flow

Delivery Argo Global	95.6% 9/2018 ↘	- Raw count	95% Target	# of registered units vs number of operational units (Global Argo)
Metadata Quality - Sensor Argo Global	98.77% 9/2018	3864 Raw count	100% Target	Indicator counting the number of operational platforms with at least one sensor recorded, thus enabling the EOV perspective on the global observing system.
Quality (DM Processing) Argo Global	74.75% 9/2018 ↗	- Raw count	75% Target	# of DM obs vs # of DM eligible obs (> 12 months)
Quality (PSAL) Argo Global	78.72% 9/2018 ↘	- Raw count	90% Target	# of monthly obs of best quality - PSAL
Quality (TEMP) Argo Global	91.15% 9/2018 ↘	- Raw count	90% Target	# of monthly obs of best quality - TEMP
Timeliness (GDAC FR) Argo Global	91.75% 9/2018 ↘	13298 Raw count	90% Target	% of monthly observations distributed within 24h (GDAC FR)
Timeliness (GDAC US) Argo Global	92.46% 9/2018 ↗	13869 Raw count	90% Target	% of monthly observations distributed within 24h (GDAC US)
Timeliness (GTS FR) Argo Global	95.85% 9/2018 ↗	13686 Raw count	90% Target	% of monthly observations distributed within 24h (GTS) (Global Argo)
Whitelist Argo Global	93.62% 9/2018 ↘	3686 Raw count	95% Target	% of platforms whitelisted platforms vs operational platforms

Figure 18: Argo data timeliness and quality. [Graphic courtesy of JCOMMOPS]

A similar dashboard (Figure 19) amalgamates a number of measures and metrics of timeliness, quality, and quantity for the SOOP, VOS, and ASAP Programmes.

Data Flow

Delivery SOOP XBT	88% 2016	15506 Raw count	17541 Target	# of profiles submitted to GTS
Delivery VOS	61.6% 7/2018 ↘	860 Raw count	100% Target	% of operational VOS units delivering more than 20 observations per month
Delivery (SOCAT) SOOP CO2	50% 2016	- Raw count	- Target	% data into SOCAT annualy; target = 2 M data points
Format (BUFR) VOS	45.32% 7/2018 ↗	154759 Raw count	100% Target	% of observations available in BUFR vs. all available observations
Metadata Quality - Sensor ASAP	0% 9/2018	- Raw count	100% Target	Indicator counting the number of operational platforms with at least one sensor recorded, thus enabling the EOV perspective on the global observing system.
Metadata Quality - Sensor VOS	85.26% 9/2018	1145 Raw count	100% Target	Indicator counting the number of operational platforms with at least one sensor recorded, thus enabling the EOV perspective on the global observing system.
Quantity ASAP	158 7/2018 ↘	158 Raw count	- Target	# of monthly observations
Quantity ASAP	9661 2016 ↗	- Raw count	- Target	# of yearly observations
Quantity VOS	154759 7/2018 ↗	154759 Raw count	- Target	# of monthly observations (BUFR)
Timeliness (GTS FR) VOS	93.83% 7/2018 ↘	145217 Raw count	90% Target	% of monthly observations distributed within 120 min (MF)
Timeliness (GTS FR) VOS	99.91% 7/2018 ↗	24469 Raw count	95% Target	% of VOSClim monthly observations distributed within 120 min (MF)

Figure 19: Ship of Opportunity data timeliness and quality. [Graphic courtesy of JCOMMOPS]

An often-overlooked component of data quality is the completeness and quality of the metadata. As noted above, metadata are key to proper tracking of the ocean observing system and its observing network components, yet metadata quality varies widely among various observation networks, as the following dashboard (Figure 20) shows.

	Argo	DBCP				SOT
	Argo Global	Global Drifter Program	Coastal/National MB	Tropical Moored Buoy	Tsunami Buoy	VOS
Data Flow						
Metadata Quality - Sensor Global Ocean	98.77% 9/2018	2.08% 9/2018	1.3% 9/2018	77.91% 9/2018	0% 9/2018	85.26% 9/2018

Figure 20: Metadata quality at JCOMMOPS (selected observing systems). [Graphic courtesy of JCOMMOPS]

Under the AtlantOS project framework, EMODnet Physics is developing an AtlantOS-specialized data portal (Figure 21) with webGIS features to: facilitate data use, integration and interoperability, attract / unlock new providers and better quality data; and facilitate the link between users and providers (e.g., visibility, source acknowledgment).

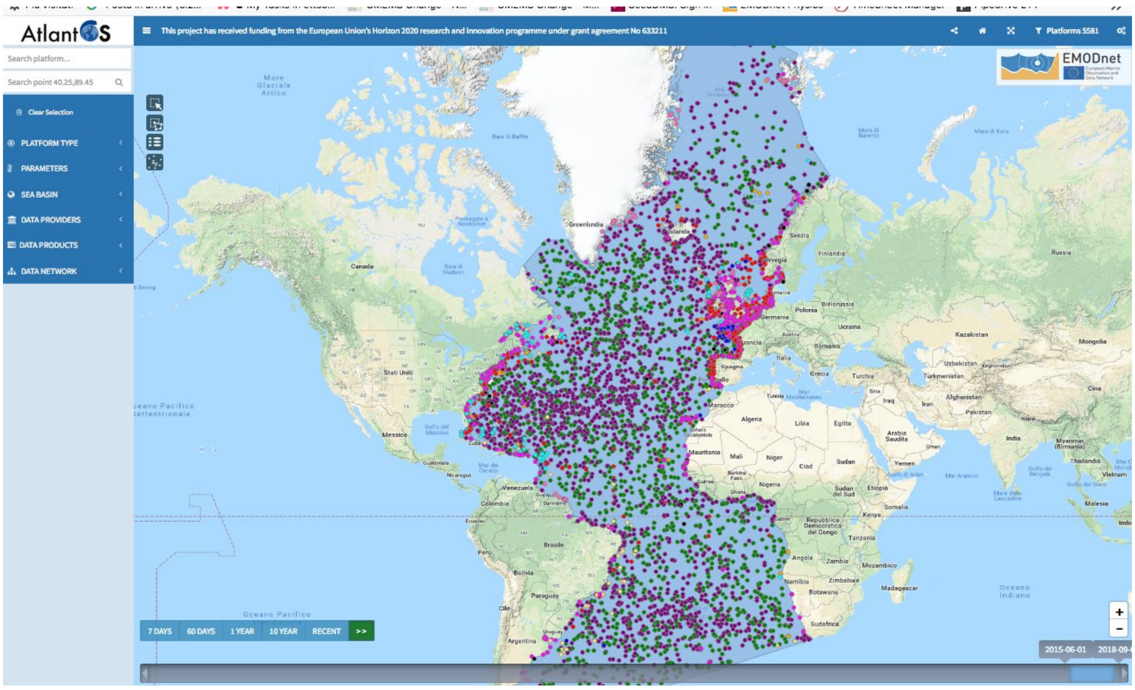

Figure 21: EMODnet webGIS data portal. [Graphic courtesy of EMODnet]

For each specific platform type, the EMODnet-Physics/AtlantOS web portal is developing a customized page (Figures 22 and 23) and is in the process of implementing tracking tools to: monitor the adoption of AtlantOS recommendations for metadata (platform ID and EDMO codes for Institution) and parameters (agreed vocabularies); monitor and report on quantitative and graphical information on the accessibility of data in terms of temporal distribution; enable the providers check which and how many of their platform are fully integrated and accessible at the integrator level; and enable the provider to retrieve information on data use and data users (from the EMODnet Physics/AtlantOS portal). In addition, these tracking tool are being updated to implement the traceability of services to provide statistics on data usage to data providers. Collaborative work between partners is underway on common data service log information that could be shared between the integrated system actors and processed to produce harmonized statistics dashboards using common tools.

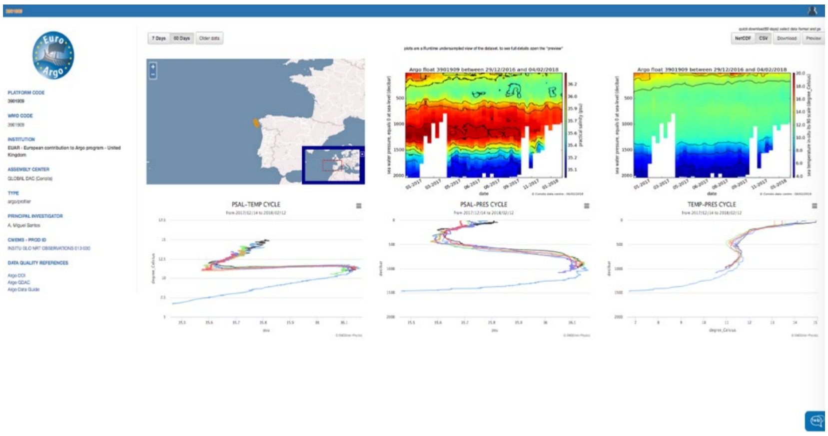

Figure 22: EMODnet's Argo platform page. [Graphic courtesy of EMODnet]

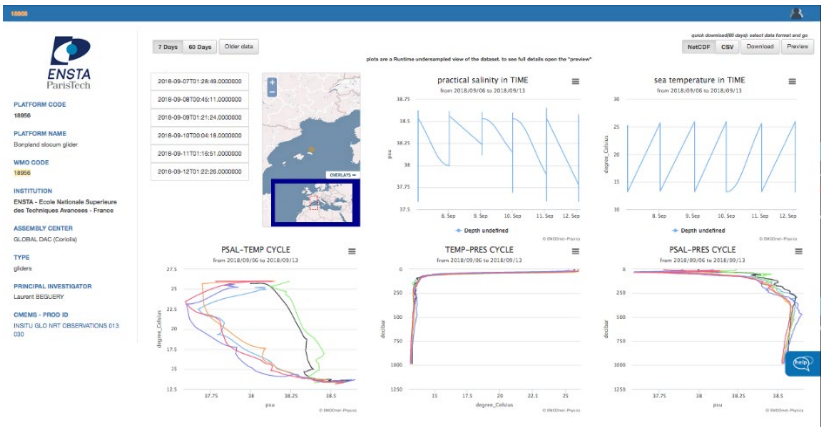

Figure 23: EMODnet's Glider platform page. [Graphic courtesy of EMODnet]

Data Access and Uptake

Figure 24 reveals the evolution in the number of downloads (per month) from the EMODnet Physics portal since January 2017. There is no clear trend, but more recent months have seen almost 9k downloads.

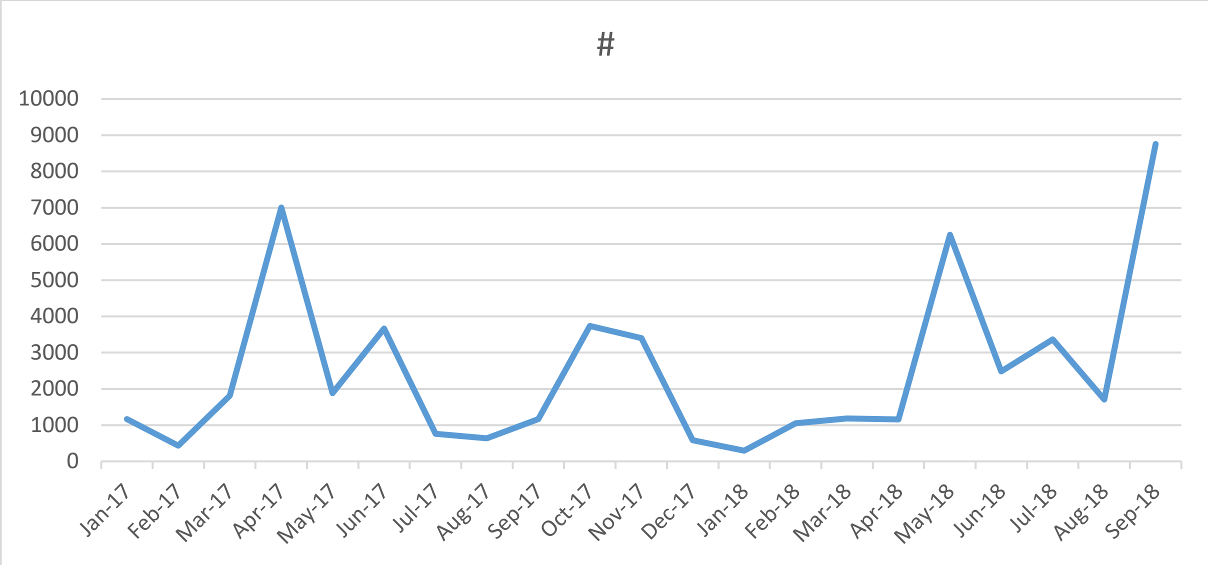

Figure 24: Number of downloads per month since January 2017. [Graphic courtesy of EMODnet]

The ultimate goal is for data to be used in scientific research, in ocean applications, and in informing management and industry decisions. A graph of the annual number of scientific papers citing Argo Programme data (Figure 25) indicates that the rate is currently more than one per day.

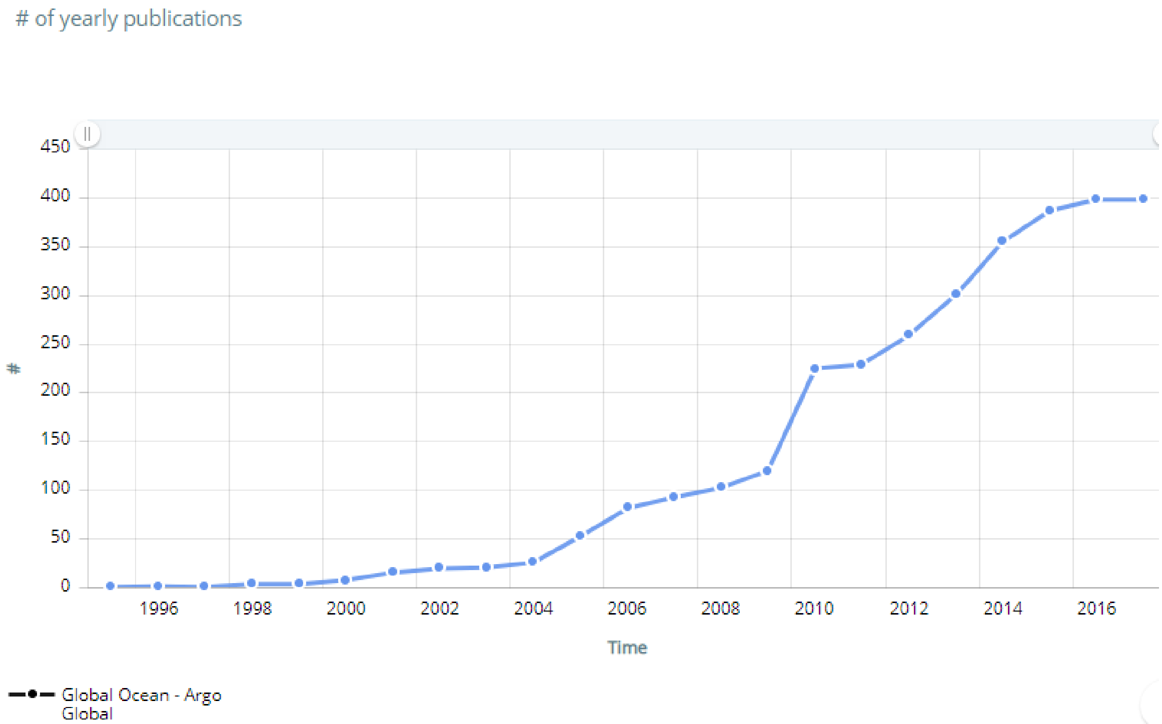

Figure 25: Annual publications citing Argo Programme data. [Graphic courtesy of JCOMMOPS]

Data Integration

Work Package 7 (WP7) of the AtlantOS project (Data Flow and Data Integration), has a number of tasks and deliverables devoted to improving the ocean observation and information system by harmonising work flows, data processing and distribution, and by integrating observations in existing European and International data infrastructures and databases. In particular, WP7 has advanced notably in these areas.

a) *Data Harmonization*

In Deliverable 7.1 (D7.1 – Data Harmonization Report), WP7 has identified a number of areas where interoperability can be significantly improved, including standards to enhance cross-platform coherence, metadata including vocabularies, and quality control. D7.1 has also developed a Data Management Plan, which includes standards and the prioritization of Essential Ocean Variables (EOVs). In addition, D7.1 has worked to improve basin-wide sharing of Atlantic Ocean data, including through partners such as GEOSS. Since the data networks and integrators in the AtlantOS project are mature networks, the goal of WP7 was not to impose standards, but rather to identify areas of improvements. The main finding relevant to the present study is prioritizing a list of EOVs across the networks.

D7.1 notes the large amount and variety of Atlantic Ocean data collected and stored, from standard parameters such as temperature to newer, less traditional parameters such as N2, each one with multiple observation instruments / techniques and spatial and temporal scales. Given this large heterogeneity, as well as an increase in autonomous sampling creating ever more data, there needs to be a focus on key essential measurements in the ocean – the EOVs. The Global Ocean Observing System (GOOS), a body of the Intergovernmental Oceanographic Commission, has developed a set of EOVs covering the physical, biogeochemical, and biological / ecosystem realms, linking them to important ocean phenomena, ocean applications, and societal benefit areas.

The web-based monitoring tools (D9.1 and D9.2) are primarily based on tracking the number and spatial coverage of observing platforms by platform type. This first step is a good tool for the networks themselves, enabling them to continuously monitor performance against targets. However, there are multiple methods and techniques to measure each variable, and the blue value chain will benefit more from the development and tracing of key performance indicators based on EOVs. For example, knowledge that subsurface O_2 values in the tropical Atlantic are scarce, will enable observation programmes as diverse as bioArgo, mooring arrays, and XBT surveys to consider how they might alter or enhance near-future deployments / servicing to address the problem. JCOMMOPS and EMODnet are considering / beginning to develop EOV-based metrics for their monitoring tools which will allow network operators and others to more readily track how adequately EOVs are being measured.

b) EOV *Reports*

Task 7.5, Product Development (EOV-based assessments), aims to develop EOV synthesis products (e.g., merging different types of data from different platforms, including in situ and satellite data) for ecosystem and climate research. They have and are producing a number of different syntheses, including: 1) three-dimensional fields of chlorphyll-a and optical backscattering to, among other things, better examine primary production and the carbon pump [D7.9 – BIO EOV Report]; 2) statistical techniques to estimate surface carbon and resolve its seasonal and inter-annual variability to understand ocean acidification and to help design an optimal multi-platform observing system for surface ocean pCO2 [D7.10 – Surface Carbon EOV Report]; 3) syntheses (of ship-based and autonomous data) of interior ocean carbon data for the Global Ocean Data Analysis Project for Carbon (GLODAP) [D7.11 – Interior Carbon EOV Report]; 4) T, S, and O2 synthesis in order to compute ocean climate indices such as heat and freshwater content and steric sea level variations [D7.12 - T,S,O2 EOV Report]; 5) ecological EOVs based on Continuous Plankton Recorder and other biodiversity data to develop indicators for scientists and policy-makers to target human health, biodiversity, and fishery issues and to better understand ecoregions [D7.13 - CPR EOV Report]; and 6) multivariate analysis of current data from SST, SSH, drifters, ADCP, and satellites to validate ocean current products [D7.14 – Current EOV Report].

D7.9, for example, notes that results from their studies using neural networks show that a basic set of vertically-resolved variables (which they identify) can be used to estimate with relatively good accuracy a series of variables that are critical to understand ocean biology and biogeochemistry. In addition, D7.9 indicates the timing of the export (i.e., out of the surface layer) of fresh algal material in relation to peak productivity. D7.13 shows that regions within the Atlantic Ocean can be better defined by ecological function or response rather than by physical structure, that these regions respond differently to stressors and climate variability, and that these regions “will help the community target observations to measure regional variation in the Atlantic.” The type of variable needed, the timing of the potential increased surveillance, and the delineation of ecoregions are factors that can help networks develop seasonally-adjustable observation programmes to address societal and scientific needs, and JCOMMOPS and EMODnet can develop appropriate platform- and EOV-based metrics, along with the appropriate geographical masks, to track them.

These reports are timely for a number of reasons, including the increased attention to the importance of ecosystem and ecosystem-based management, and to the realities of climate change. As satellites can only sense about 20% of the sunlit ocean layer, new and different types of in situ observations are needed to produce needed ocean information – each of these syntheses shows how combining different types of data, or data from different platforms, can increase our understanding of the ocean. The reports note that there are already a number of “quasi-operational” products and that the rate at which biogeochemical and biological observations measurements are being made is increasing – indeed, as D7.9 notes, “the outlines of the future BGC-Argo network are already defined and its implementation, already initiated on a regional scale (pilot projects including a strong focus in the North Atlantic)”. As the number of these synthesised products, as well as their value to end-users, increases, it will become increasingly important to track not only the various types of platforms making the component observations, but the EOV-based metrics not yet in place.

Summary and Recommendations

Improvements in the ocean information value chain, from the provision to end-users of ocean information and products to the observation standards and instrumentation collecting information at sea, are best managed by accurately monitoring how well the overall system is performing. A great number of platform-based measures and, increasingly, metrics for ocean observation programmes and networks in the Atlantic Ocean are available through both the JCOMMOPS and EMODnet physics monitoring tools, developed as part of Work Package 9 of the AtlantOS Project. Monitoring Dashboards and graphics outputs are customisable (including with different geographic masks), exportable, and freely available to all stakeholders, including manufacturers, funding agencies, and the general public, as well as the observation networks themselves.

Individual Networks

A sample of the many measures and metrics available through these two monitoring tools have been included in this report. From these, one can make a number of targeted recommendations for specific observation networks.

> Recommendation #1: A number of metrics indicate that the intensity of Argo floats may be too high (compared to targets) in Atlantic, particularly the North Atlantic, without substantially improving the coverage. The network should consider whether a few tens of North Atlantic floats would be better deployed in the Pacific or Southern Ocean, or in the envisioned extension areas such as the Gulf Stream where a double density would be ideally required.

A number of historical networks, such as the Global Drifter Program, do not yet globally share their data in netCDF format (or in other Internet “standards”) which clearly limits uptake by potential users. In general, data processing and harmonization are too often given a low priority. If this first brick of the data system is not working, all initiatives for global data portals will fail to serve integrated datasets to the users.

> Recommendation #2: More observation networks, including those providing wave, river, optical, or underwater noise data, need to make their data available in standard formats on data portals for free and fair access.

Assessment of Ocean Observation

The JCOMMOPS and EMODnet monitoring tools, and the value they provide, will continue to improve as the networks evolve and as our understanding of the ocean information and products that end-users need is more clearly defined. The following recommendations aim to improve the monitoring process itself.

> Recommendation #3: Observation programmes and networks need to clearly define observation targets. Specific, measurable, achievable, relevant, and time-based (SMART) targets provide greater confidence and likelihood of funding success, and will allow JCOMMOPS and EMODnet to develop relevant metrics, thus facilitating more effective performance tracking. These targets can vary seasonal and across geographical areas (e.g., eco-regions), as suggested by studies in Work Package 7 of AtlantOS.

Accurate tracking of the observing system requires appropriate metadata and knowledge of upcoming deployments and cruises. Unfortunately, many observing networks do not make their metadata available to data portals or provide information on planned observations. Some progress was made regarding cruise plans through the cooperation of POGO, JCOMMOPS and others, but this is not yet optimal.

Recommendation #4: Observation networks should provide (more) metadata to the data portals in order to more accurately determine which platforms are (not) currently working up to specification. As a first step, every single instrument deployed in the ocean should be registered at JCOMMOPS.

Recommendation #5: To improve the cooperation for the implementation of AtlantOS components, the availability of cruise plans should be centrally available and routinely updated. Very basic information on cruise plans should be communicated as early as possible to JCOMMOPS.

Tracking platform activity is a good first step in monitoring the ocean observation system. Combined metrics, such as Figure 26 below showing how well the Argo Programme is performing across three dimensions, allow network operators to more clearly diagnose the observing system. Key performance indicators (KPIs) do the same for the end-user outputs of the ocean observation system, tracking what the system is ultimately designed to accomplish.

Recommendation #6: JCOMMOPS and EMODnet should work with observation networks and end-users to develop more sophisticated metrics, as well as appropriate EOV-based Key Performance Indicators (KPIs), to more effectively track how well ocean information and services are being developed and utilised.

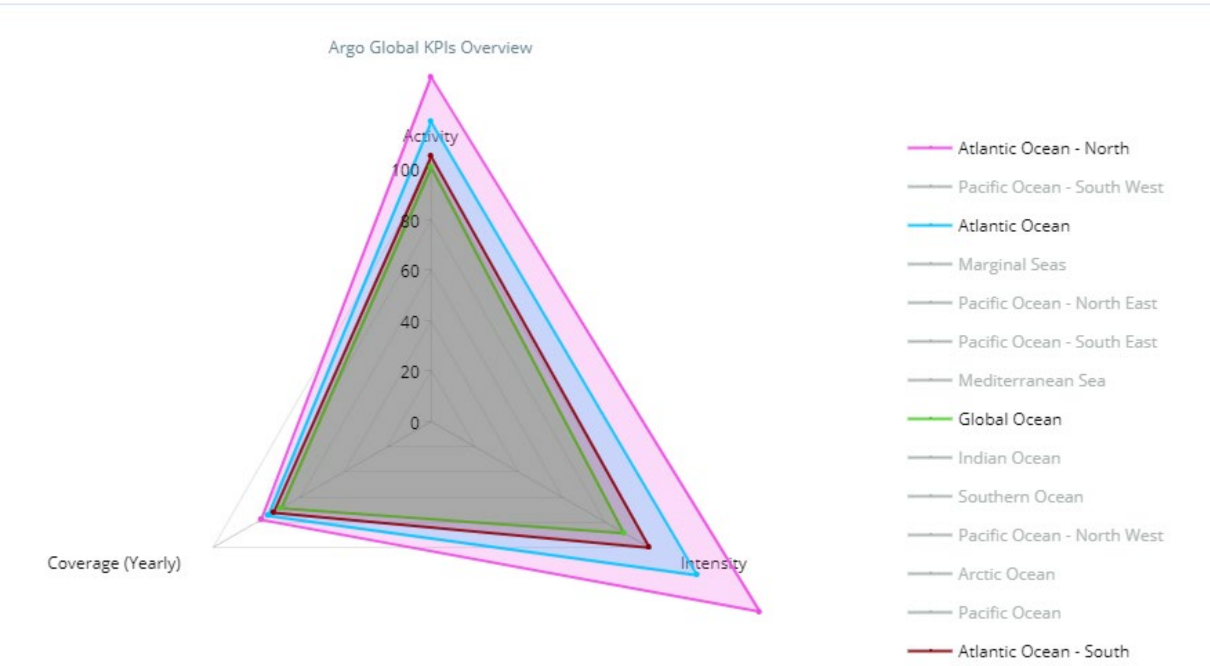

Figure 26: Summary of Argo Activity, Intensity and Coverage (2017), focusing on the Atlantic Ocean [Graphic courtesy of JCOMMOPS]

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