Project	AtlantOS – 633211
Deliverable number	D7.6
Deliverable title	**Impact study design**
Description	Precise design of impact studies carried out in interaction with WP2 and WP3
Work Package number	WP7 – T7.4
Work Package title	Integration in models and impact
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Submission date	5 October 2017
Due date	30 September 2017
Comments	

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement n° 633211.

WP7 – T7.4 Integration in models and impact

Description of Work

Task 7.4 partners will assess the impact of AtlantOS networks and their improvements for the Copernicus Marine Service [D7.6, D7.16]. From these analyses, we will be able to quantify the contributions of AtlantOS in-situ observations for the Copernicus Marine Environment Monitoring Service (CMEMS) and its applications. This will be a key aspect for observing system sustainability issues. The near real-time assessment for the Copernicus Marine Service will assess the value of all WP2 and WP3 AtlantOS in-situ observations (physical and biogeochemical) both for model validation and for data assimilation. Impact for data assimilation will use Observing System Evaluations and other alternative techniques (e.g. influence matrices). These impact studies will take into account synergy with satellite observations as they rely on data assimilation systems that merge in-situ observations together with satellite observations. MERCATOR will focus its activities on the impact of the AtlantOS in-situ observation array on its high resolution global ocean analysis and forecasting system at 1/12°. The Met Office will use its coupled ocean-atmosphere data assimilation system (1/4° resolution). The assessment will be focused on upper layer measurements that are essential for short-term coupled prediction. Impact of the different AtlantOS observing systems providing temperature and salinity profiles will also be analysed with the ARMOR3D data analysis system [CLS]. The ECMWF centre will carry out a specific study to assess the role of the Atlantic in-situ observing system for seasonal prediction. Further, several low resolution (1°) ocean reanalyses will be conducted with/without the different in-situ observing systems and will be used to provide initial conditions for a series of coupled seasonal forecasts.

Design of the studies to be carried out with Copernicus analysis and forecasting systems

Enhancements of the Atlantic observing network in terms of additional or improved instruments and/or sensors are carried out during AtlantOS, and provide new observations, the so called “AtlantOS observations”. T7.4 is in continuity with the T1.3 and will allow to assess the impact of AtlantOS observations that will be available in real-time for the Copernicus systems.
The “AtlantOS observations” will be identified in the Copernicus and the so called *In Situ* Thematic Assembly Center (TAC). This *in situ* TAC, Coriolis, collects and distributes observations mainly from EuroGOOS and JCOMM. Only observations that are transmitted in real time to the Coriolis data centre will be available for assimilation in analysis and forecasting systems. Some of the “AtlantOS observations” will only be available in delayed time due to the need of an accurate post-processing, more advanced quality control or simply due to transmission in real time that is restricted. This first step will be done in collaboration with *in situ* networks involved in WP2 and WP3. Then, based on the inputs from the *in situ* networks (reports and discussions are coming soon) impact studies will be defined depending on the status of the platform deployments, their availability and the data quality.

Impact of the AtlantOS in-situ observation array on the 1/12° Mercator Ocean analysis and forecast

Mercator-Ocean is operating the Copernicus global ocean monitoring and forecasting system in real-time, at 1/12° horizontal resolution. This system produces each week an analysis and a 10-day forecasts, in which satellite (sea surface height and sea surface temperature) and *in situ* temperature and salinity observations are assimilated. The in situ observations are coming from the Copernicus *In Situ* Thematic Assembly Center (Coriolis). Within WP1-T1.3, assimilation experiments of synthetic observations (OSSE) that are mimicking the potential evolution of different *in situ* observation networks foreseen during AtlantOS were conducted.

They allow estimating the impact of future extensions of the current *in situ* networks in the Atlantic on the global ¼° ocean analysis and short-term forecasts (7 days). Within WP7.4, impact of the AtlantOS observations that will be available in real time for data assimilation in the global ocean analysis and forecasting system will be assessed. Note that observations, which are not assimilated (e.g., current velocity from mooring), are crucial for the monitoring and forecasting system because these independent observations are involved in the validation process.

Impact of physical observations that are relevant for short-term ocean analysis and prediction will be assessed using usual metrics. Comparison of model forecasts with observations will be conducted as well as estimation of the forecast error reduction due to the assimilation of the "AtlantOS observations". Statistics on the model-observation misfits depending on the platform family will also be done using the Coriolis database.

Here are some examples of scheduled impact studies:
1. The Argo network is extending at depth (4000m and 6000m) for physical and biogeochemical measurements. A deployment of 7 deep-oxygen and 7 Bio-Argo floats is planned in the North-Atlantic in the framework of AtlantOS. After the identification of these physical observations in the data assimilation system, their role in reducing the forecast error model at depth could be assessed. Note that this only could be done, if the data quality allows it.

2. Some PIRATA moorings will benefit from an increased vertical resolution in the mixed layer by addition of Thermo-Conductivity sensors. Those moorings are located at 0°N-35°W, 4°N-38°W and 8°N-38°W, where Amazon plumes and associated low salinity are present along with the subsurface central waters salinity maximum. By looking at the observation misfits, the impact of the enhanced vertical resolution on reducing the model forecast error could be estimated in this region.

3. Up to now surface drifters are not assimilated in the Mercator system, a model – observation comparison will be conducted to better define the representability error that should be used for an efficient data assimilation of those data. Sea deployments of new drifter type with thermistor chain are planned in 2017 during the Peacetime research cruise in the Mediterranean Sea for test and qualification purpose.

As said previously, several datasets such as current meter datasets are not assimilated but extensively used for validation. The use of the different AtlantOS physical data type for validation of the 1/12° analysis and forecasts will be documented.

The Mercator Ocean global BGC analysis and forecasting system is in development. The first version only assimilates Ocean Colour data from satellites. *In situ* biogeochemical data are only used to validate the simulations performed with the PISCES model coupled with the NEMO OGCM. Chlorophyll and Oxygen are the major variables used for PISCES model simulation validation. They help to better identify the model weaknesses and allow the tuning of different parametrisations. Comparison of PISCES model simulations with AtlantOS bio-Argo will be conducted and analysed.

Impact of the AtlantOS in-situ observation array on the MetOffice prediction system

The UK Met Office runs an operational global ocean analysis and forecasting system, providing daily analyses and 7-day forecasts of the 3-D ocean temperature, salinity, currents, and sea surface height. This system runs every day and uses a 75-vertical level, 0.25degree global ocean configuration forced by 3-hourly Met Office NWP fluxes. Using a 24-hour assimilation window, we assimilate observations of the sea surface temperature (SST), sea level anomaly (SLA), sea-ice concentration (SIC), and in situ measurements of the temperature and salinity.

We assimilate swath SST observations from several satellites available through GHRSST in addition to SST measurements from in situ platforms, ships, and drifting buoys distributed over the global telecommunications service (GTS). The assimilated in situ sub-surface measurements of temperature and salinity (available over the GTS) include observations from the Argo array, XBTs, CTDs, gliders, moored buoys and marine mammals. We also assimilate along-track SLA observations provided through CMEMS and sea-ice concentration measurements provided by OSI-SAF.

This system is being used in AtlantOS WP1-task1.3 to perform observing system simulation experiments (OSSEs) designed to investigate the potential impact of extensions to the existing Atlantic observing network. Similarly, for AtlantOS WP7, the Met Office operational system will be used to investigate the use of new AtlantOS observations made available for use in real-time systems.

Initially, we will work with the other centres involved in WP7 to identify the "AtlantOS observations" from newly deployed platforms, or from increased sampling by existing platforms. Since the observations assimilated in the Met Office systems are distributed over the GTS, and not all of the new observations will be supplied in near real-time, we will likely be assimilating a subset of the upgraded network.

The additional in situ temperature and salinity observations identified will be assessed by comparing innovation statistics (observation-minus-model background) and, if possible, observation-minus-forecast residuals from consecutive forecasts. Depending on the additional observations identified in our operational system, we could investigate the impact of the increase in number of surface drifters, which are assimilated in the Met Office system, and also of the new salinity measurements available from the PIRATA array. After identifying the small number of deep Argo profiles deployed in the North Atlantic, we will assess the model increments applied in the almost-unconstrained deep ocean and to what extent the model retains this information.

Impact of the AtlantOS in-situ observation array on ARMOR3D data analysis

CLS is operating ARMOR3D, the multi observations component of CMEMS which is a multivariate data analysis system. ARMOR3D provides 3D global fields of temperature, salinity and geostrophic velocities in near-real time on a 1/4° horizontal grid. ARMOR3D uses statistical methods that combine the information provided by satellite observations of sea level and sea surface temperature and in-situ observations of temperature and salinity profiles.

Impact of the different AtlantOS observing systems providing temperature and salinity profiles (Argo, Gliders, XBTs, CTDs, mooring) will be analysed using the ARMOR3D system. This is a complementary approach to OSE studies based on data assimilation systems as the ones provides by Mercator Ocean and the UK MetOffice. We plan to perform near real time assessment over a 6-month time period.

The impact of the specific AtlantOS observations will be first evaluated through Degree of Freedom for Signal diagnostics which is an influence matrices diagnostic. Twin experiments, with and without the AtlantOS

observations will be then carried out. The two ARMOR3D solutions will be first compared to quantify the differences between the two solutions in terms of amplitude of the signals and geographical coherences. Comparison of ARMOR3D solutions with in-situ observations (independent if possible) will then be conducted.

Planed impact studies using the ARMOR3D system are the same as the ones scheduled by Mercator Ocean.

Impact of the AtlantOS in-situ observation array for ECMWF seasonal prediction

ECMWF has developed a new high-resolution (1/4° degree) Ocean ReAnalysis System 5 (ORAS5) with ensemble generation. ORAS5 is used to initialise the ocean and sea-ice components of all ECMWF coupled forecasting systems. It will also initialize the ECMWF next seasonal forecasting system 5 (SEAS5). ECMWF will carry out a series of OSEs with/without the different in-situ observing system using a ORAS5 equivalent low resolution system (ORAS5-LR, in 1 degree) to identify important ocean regions and observations. The reanalysis results from these OSEs will be used to provide initial conditions for a series of coupled seasonal forecasts.

Here are some examples for the OSEs designed to be carried using ORAS5-LR system

1. Blanket OSEs by removing observing system components everywhere

- Removal of Argo float observations
- Removal of tropical moorning arrays
- Removal of XBT/MBT and CTD observations
- Removal of all in-situ observation types (Argo, XBT/MBT, CTD, mooring, Seals)
- Removal of satellite altimeter sea-level observations

2. Specific OSEs by remove observing system components in a given area

- Removal of all in-situ observations within shallow water areas
- Removal of altimetry observation of Sea Levels in different ocean regions (i.e. Atlantic Ocean)
- Removal of ocean in-situ observation of mooring profiles (T/S) in the Tropics (i.e. Atlantic Ocean and/or Pacific Ocean)

The ECMWF seasonal forecasting system SEAS5, which will be operational at the end of 2017, will be the basis for the AtlantOS WP activities at ECMWF. The ensemble of seasonal forecasts is being analysed in order to identify which errors in the atmospheric circulation over the North Atlantic are related with errors/uncertainty in the ocean variables. Also a selection of impact indicators with high forecasting skills (i. e. Atlantic Tropical Cyclones indicator) and their relation with ocean variables (i.e. T20 thermocline depth) will be studied using the SEAS5 system when initialized from different ORAS5-LR OSEs experiments.