SETTING OBSERVING TARGETS FOR BIOGEOCHEMICAL OBSERVING SYSTEM IN THE ATLANTIC

EU H2020 AtlantOS project workshop

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WORKSHOP REPORT

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Introduction

Motivation for the workshop
The EU Horizon2020 AtlantOS project aims to optimize and enhance the Integrated Atlantic Ocean Observing System using the Framework for Ocean Observing (FOO) to obtain an international, more sustainable, more efficient, more integrated, and fit-for-purpose system. As such, the project provides a regional realization of the new multidisciplinary Global Ocean Observing System (GOOS), and contributes towards the implementation of the FOO through the concept of Essential Ocean Variables (EOVs). The development and maintenance of the Biogeochemical EOVs and their specification sheets is an effort carried out by the GOOS Biogeochemistry (BGC) Expert Panel, led by the International Ocean Carbon Coordination Project (IOCCP).

With ongoing advances in observing technology, and a set of BGC EOVs already in place, priorities for designing an optimum observing system for marine biogeochemistry are now shifting towards a system-wide definition of a set of accepted observing targets for BGC phenomena and EOVs developed in a process driven by relevant scientific and societal requirements.

Within the AtlantOS project, Work Package 1 (WP1) is charged with the task of defining the high level requirements, analysing the gaps and costs of existing systems and planned upgrades, and carrying out system design studies. A comprehensive gap analysis is currently hindered by the lack of observing targets set not just for individual observing networks but for the system as a whole, relevant to a particular phenomenon and in response to a specific scientific question and associated societal benefit product requirements. Similarly, analysis of system design studies requires a reference point – a target describing the desired level of knowledge of a given phenomenon.

Objectives
The challenge is for the observing targets to simultaneously take into account the myriad of spatio-temporal scales of the distinct BGC phenomena of interest and the complex array of corresponding observing elements. The AtlantOS workshop “Setting Observing Targets for Biogeochemical Observing System in the Atlantic”, co-organized by the Institute of Oceanology of the Polish Academy of Sciences (IO PAN) and the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO), responded to this challenge by bringing together experts in biogeochemical observations and modelling to fulfil the following goals:

- Define what an observing target is in the context of the BGC observing system
- Decide phenomena for which to set observing targets (based on the list of phenomena developed by AtlantOS WP1)
Anticipated outcomes of the workshop included a set of targets for BGC phenomena accompanied by a set of targets for relevant BGC EOVs. Comparing the targets developed during this workshop with the current observing capabilities would enable a comprehensive gap analysis aimed at providing recommendations for designing optimized and enhanced Atlantic Ocean observing system.

Workshop structure
The workshop, held on November 29 – December 1, 2016 at IO PAN, Sopot, Poland, brought together 15 experts (and two remote participants) in biogeochemical observations and modelling, representing several countries from around the Atlantic basin. Please see the Appendix for a full list of participants and their affiliations.

The broad expertise of workshop participants, reaching across the different ocean disciplines and including a perspective on data requirements for societal benefit product, was critical to meeting the ambitious goals of this workshop.

Majority of the time during this 3-day workshop was spent in breakout groups tasked with assigning quantitative and qualitative targets for each of the key biogeochemical phenomena to observe in the Atlantic.

Defining ‘phenomena’ and observing ‘targets’
In this workshop we used the following definition of a phenomenon adopted by GOOS in the context of EOVs and setting targets for their observations.

A **phenomenon** is an observed process, event, or property, with characteristic spatial and time scale(s), measured or derived from one or a combination of EOVs, and needed to answer at least one of the GOOS Scientific Questions.

Prior to the workshop, the Organizing Committee drafted a working definition of an observing target. This definition was approved during the workshop as follows:

An **observing target** is set to allow the observing system to detect changes in a given phenomenon sufficiently to address the relevant scientific questions and societal needs. Such a target needs to be set at the spatial and temporal scales the
phenomenon is sensitive to, and at a desirable/known level of uncertainty, with consideration of all relevant EOVs.

In setting biogeochemical observing targets for an enhanced and optimized Atlantic observing system we considered first of all those phenomena, knowledge of which relies on biogeochemical measurements. Additionally, we considered selected phenomena which have high impact on biogeochemical cycles in the ocean, but which are not necessarily regulated by biogeochemical processes, events or properties.
Outcomes

Requirements for BGC observations in the Atlantic Ocean

In Table 1 below we summarize the links between Societal Drivers, Scientific Questions and corresponding identified BGC EOVs. Drivers and questions were determined by the GOOS BGC Expert Panel while the corresponding phenomena were refined during this workshop. This table indicates the central role of phenomena in the process of implementing the concepts of FOO.

Table 1. Links between Societal Drivers, Scientific Questions and corresponding identified biogeochemical EOVs in the Atlantic Ocean. Expanded and updated based on initial linkages identified in Annex 3 in AtlantOS D1.1 report.

<table>
<thead>
<tr>
<th>Societal Drivers</th>
<th>Scientific Questions</th>
<th>Biogeochemical Phenomena to Capture</th>
<th>EOVs</th>
</tr>
</thead>
<tbody>
<tr>
<td>The role of ocean biogeochemistry in climate</td>
<td>How is the ocean carbon content changing?</td>
<td>Ventilation (water mass age)</td>
<td>Transient tracers, Oxygen</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Air-sea fluxes</td>
<td>Oxygen, Inorganic carbon, Nutrients, Particulate matter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Anthropogenic carbon sequestration</td>
<td>Inorganic carbon, Transient tracers</td>
</tr>
<tr>
<td></td>
<td>How does the ocean influence cycles of non-CO2 greenhouse gases?</td>
<td>Organic matter cycling</td>
<td>Oxygen, Inorganic carbon, Nutrients, Particulate matter, Dissolved organic carbon, Transient tracers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cross-shelf interactions</td>
<td>Oxygen, Nutrients, Inorganic carbon, Particulate matter, Dissolved organic Carbon</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Air-sea fluxes</td>
<td>Nitrous oxide, Oxygen</td>
</tr>
</tbody>
</table>
## Human impacts on ocean biogeochemistry

<table>
<thead>
<tr>
<th>Human impacts on ocean biogeochemistry</th>
<th>How large are the ocean’s “dead zones” and how fast are they changing?</th>
<th>Hypoxia</th>
<th>Oxygen, Nitrous oxide</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>What are the rates and impacts of ocean acidification?</td>
<td>Ocean acidity</td>
<td>Inorganic carbon</td>
</tr>
</tbody>
</table>

### Ocean ecosystem health

<table>
<thead>
<tr>
<th>Ocean ecosystem health</th>
<th>Is the biomass of the ocean changing?</th>
<th>Organic matter cycling</th>
<th>Oxygen, Nutrients, Inorganic carbon, Particulate matter, Dissolved organic carbon</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>How does eutrophication and pollution impact ocean productivity and water quality?</td>
<td>Inorganic nutrient cycling</td>
<td>Nutrients</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Eutrophication</td>
<td>Oxygen, Nutrients, Particulate matter, Dissolved organic carbon</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hypoxia</td>
<td>Oxygen, Nitrous oxide</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Contamination/Pollution</td>
<td>NA</td>
</tr>
</tbody>
</table>

For a brief description of each phenomenon considered during the workshop, please refer to the AtlantOS Deliverable Report 1.3: “Capacities and gaps analysis”. You can view and download the report as PDF from the following link: [www.atlantos-h2020.eu/download/deliverables/1.3%20Capacities%20and%20Gap%20analysis.pdf](http://www.atlantos-h2020.eu/download/deliverables/1.3%20Capacities%20and%20Gap%20analysis.pdf)

It is important to keep in mind that observing and modelling each of the phenomena considered requires measurements of physical, biogeochemical and biological EOVs alike. However, in this document we only list the relevant BGC EOVs needed to observe a given phenomenon. Further work in collaboration with experts from other disciplines is needed to generate a comprehensive, multidisciplinary list of relevant EOVs per phenomenon of interest.
Moreover, the decision to include Ocean Colour as a BGC EOV was taken and approved after this workshop, hence this EOV is not listed anywhere in the document, despite being relevant to several of the phenomena considered. At the same time, note that measurement of products derived from ocean colour radiometry also appear in existing BGC EOVs, e.g. Particulate Matter.

Figure 1, taken from AtlantOS D1.3. report, illustrates the key BGC phenomena to observe in the Atlantic, and their selected key geographical areas.

![Figure 1](image_url)

Figure 1. A conceptual map roughly delineating potential hot spots for observing the 10 biogeochemical phenomena considered in this report, distributed with respect to areas of mean annual biomes adapted from Fay & McKinley (2014). Other areas not included on this map could be equally important to study given phenomena on a regional basis. Phenomena are likely to operate on different spatio-temporal scales when compared across the hot spots. Mean biome map created from mean climatologies of maximum mixed layer depth, sea surface temperature, summer Chl-a concentration, and maximum ice fraction. Blue: subpolar seasonally stratified biome (SPSS); green: subtropical seasonally stratified biome (STSS); yellow: subtropical permanently stratified biome (STPS); orange: equatorial biome (EQU); purple: other ocean areas that do not fit the criteria for any of the above biomes.
List of phenomena and associated targets

1. Air-sea fluxes

Processes contributing to the phenomenon:

- Oxygen air-sea fluxes
  
  *Key geographic areas:* places of strongest winter ventilation (see Ventilation above), and in western boundary currents

- Carbon dioxide air-sea fluxes
  
  *Key geographic areas:* North Atlantic

- Nitrous oxide flux to the atmosphere
  
  *Key geographic areas:* coastal and equatorial upwelling regions, shelf areas/river plumes

- Atmospheric/dust deposition of nutrients (nitrogen, phosphorus, iron, particles)
  
  *Key geographic regions:* tropical and sub-tropical Atlantic, Patagonian shelf

Relevant BGC EOVs:

Oxygen, Nutrients, Inorganic Carbon, Nitrous Oxide, Particulate Matter.

Phenomenon-based targets:

TARGET #1:

To constrain air-sea fluxes of CO$_2$ to within 10% of the total flux.

Spatio-temporal and other targets:

- Sea surface pCO$_2$ measurement accuracy to within 2 μatm.
- Lower atmospheric pCO$_2$ measurements at sea: every 10º latitude and at two longitudinal points (enter and exit),
- 0.1 μatm accuracy is required for atmospheric inversions but the air-sea flux related target would be 2 μatm.
- Spatial coverage of ocean pCO$_2$ needs improving in the South Atlantic to match the North Atlantic coverage of every 10º latitude coast to coast.
- Temporal resolution: 6 hours
TARGET #2:
To constrain air-sea fluxes of O$_2$ to within 10% of the total flux.

Spatio-temporal and other targets:
- Temporal resolution for seawater oxygen measurements is bi-weekly (to account for bloom activities).
- Target spatial resolution is to put optical oxygen on all Argo profiling floats (3° resolution), with additionally increased density outside the subtropical gyres and in key geographical regions (see above).
- Targets for atmospheric O$_2$ measurements [to be verified].

TARGET #3:
To constrain the uncertainty of air-sea fluxes of N$_2$O to within 10% of the total annual flux variability.

Spatio-temporal and other targets:
- Accuracy of sea surface N$_2$O concentration measurement $< +/− 1\%$
- Atmospheric N$_2$O dry mole fraction $< +/− 0.2$ ppb (to capture signals of oceanic sources such as upwelling against the high atmospheric background dry mole fraction)
- Average sampling frequency $\sim 1$ min$^{-1}$ (to capture small scale variabilities in the sea surface)
- Large scale (regional) surveys should be repeated at least on a weekly to monthly basis
- High resolution (see above) atm. and dissolved N$_2$O measurements at selected time-series sites with N$_2$O analysers on moored platforms

TARGET #4:
To constrain atmospheric deposition of aerosol iron.

Spatio-temporal and other targets:
- Characterize size-resolved concentration of iron and organic acids in the marine boundary later aerosols. Aerodynamic diameters should range between 0.02 to 10 µm.
- Measure of sub-0.02 µm iron and organic acid concentration in rain water.
- Characterize particulate (PFe $> 0.2$ µm in diameter), dissolved (DFe $< 0.2$ µm), colloidal (0.02 µm $<$ CFe $< 0.2$ µm), and soluble (SFe $< 0.02$ µm) forms of Fe in seawater
- Measure iron-binding organic ligand concentrations in seawater
- Temporal resolution of the measurements should be less than 1 day to account for episodic nature of mineral dust deposition to the oceans
- Better than 0.1 nM accuracy is required for iron measurements
- Better than 0.01 ng m$^{-3}$ accuracy is required for organic Fe-binding ligands in the aerosols and 0.1 nM for the ocean
- Iron measurements should be done through iron extraction onto chelating resin columns followed by trace metal quantification using graphite furnace atomic absorption spectrometry (GFAAS) or inductively coupled plasma mass spectrometry (ICPMS)
- Organic ligand concentrations should be determined by a Competitive Ligand Exchange-Adsorptive Cathodic Stripping Voltammetry (CLE-ACSV)

TARGET #5:
To constrain atmospheric deposition of nutrients and particles and its coupling with marine ecosystems and C export.

Spatio-temporal and other targets:
- Systematic measurements of atmospheric deposition and nutrients: use data from time-series (BATS, CVOO in Cape Verde) where these measurements are coupled with marine measurements (link with 5. Inorganic nutrient cycling)
- Consider link between atmospheric deposition and export in traps (drifting traps during cruises, fixed moorings at time-series stations mentioned above) and all parameters measured or from remote sensing to evaluate biological production (pCO$_2$, Chla, etc.).
- Consider simultaneous remote sensing of atmosphere and ocean: use recent remote sensing measurements such as lidar, polarimeters and hyper-spectral imagers to better constraint deposition at large scale.

In addition to acquire new data, regional coupled modelling between the atmosphere and the ocean with chemistry modules in both the atmosphere will allow to evaluate the impact of inputs of new nutrients at different time scale (see for ex. Richon et al., 2017). Considering for example that dust deposition occur at short time scale it is important that a better representation of ‘events’ (vs climatology) is taken into account. Also, several recent findings still need to be implemented or improved in biogeochemical models: dust particles can be both a source and a sink for nutrients and this scavenging parameter need to be better constrain in particular because this changes the bioavailable fraction of atmospheric nutrient: the ‘lithogenic carbon pump’ that allow fast POC export following
the aggregation/ballasting between organic matter and particles (not linked to fertilisation, see Louis et al., 2017) need to be taken into account.

Selected references:


2. Ventilation (water mass age)

Processes contributing to the phenomenon:

Water mass age and ventilation, depending on the spatial scale considered, is affected by a series of downward physical transport mechanisms such as but not limited to:

- Deep water formation (convection)


- Subduction processes

  Key geographic areas: sub-tropical fronts

- Seasonal mixed layer dynamics

  Key geographic areas: sub-polar gyres

Relevant BGC EOVs:

Transient Tracers, Oxygen
Phenomenon-based targets:

TARGET #1:

A water parcel’s ventilation is determined by its transit time distribution (TTD), recognizing that mixing lends each water parcel a range of the “ages, i.e. its TTD. To constrain the TTD of a water parcel is the first level target for ventilation studies and can be achieved by measurements of a range of transient tracers with different input history or decay time scales. There are a few different numeric that can be used to characterize a water parcel’s TTD, in addition to knowledge of the shape of the TTD: one is the mean-age, i.e. the mean of the TTD. Another useful metric is the mode-age, i.e. the age of the dominant fraction of the TTD.

TARGET #2

To determine short-term and long-term changes in water mass age, i.e. its TTD, with a target uncertainty of 10% the mean age, or mode age.

Temporal scale targets:

- Decadal repeat hydrography measurements are required to determine changes in ocean ventilation strength on a basin scale. Depending on the tracer, a different target uncertainty can be set on decadal change in ocean ventilation strength / water mass residence time.
- Short-term scale observations are needed for studying annual changes in ventilation on regional scales (< 1000 km) associated with deep water formation and other downward physical transport mechanisms, both in the open ocean and in the shelf region.

Spatial coverage/resolution targets:

It is important to note that this phenomenon is not exclusive to the open ocean (see key geographic areas above) but should be observed in the shelf region as well, though on different spatio-temporal scales. Compared to the basin-scales, decadal changes in Atlantic water mass ages, annual ventilation patterns are more important from the perspective of the changing biogeochemical properties of the waters transported away from the surface, and their role in regulating seasonality in biological phenomena. Spatial extent of observations is local, covering an area of ca. 100 km, with a sampling resolution of 20 km, covering the full water column. In order to design such an observing system one would need to consider the co-location of existing physical arrays measuring transports, and arrange for a combination of observing platforms with
moorings providing the necessary temporal coverage and resolution aided by
siders and/or surface autonomous vehicles deployed as needed to be in the
right place and time.

It is also important to distinguish areas where bathymetry plays a major role
in shaping the downward physical transport.

Selected references:
Talley, L. et al., 2015. Changes in Ocean Heat, Carbon Content, and
Ventilation: A Review of the First Decade of GO-SHIP Global Repeat

Fine RA 2011. Observations of CFCs and SF6 as Ocean Tracers. Annual
Review of Marine Science 2011 3:1, 173-195, doi:
10.1146/annurev.marine.010908.163933

3. Biogeochemical exchanges with shelf and marginal seas (cross-shelf
interactions)

Processes contributing to the phenomenon:
- Shelf-water formation and export
- Point and non-point nutrient and carbon fluxes
- Shelf-break fronts, eddies, boundary current and other upwelling features
- Sediment-water interactions

Key geographic areas: all major Atlantic shelf regions (e.g. Patagonia, NW and
NE North Atlantic) and marginal seas (e.g. North Sea, Mediterranean Sea,
Caribbean), but also regions of near-direct coastal inputs (Congo and Amazon
river deltas).

Relevant BGC EOVs:

Nutrients [Fe as high impact measurement, currently not an EOV], Inorganic
Phenomenon-based targets:

TARGET #1:
To obtain a baseline for current magnitude of biogeochemical (nutrients and carbon) exchanges with shelf and marginal seas.

Rationale: Baseline will provide boundary conditions for biogeochemical models, used for example for HAB forecasting (AtlantOS WP8).

Spatio-temporal targets:
There are North West shelf (NWS) regional model experiments planned to quantify the influence of the open boundary conditions on variability on the NWS in AtlantOS Task 8.6, the results of which will be linked through to Marine Strategy Framework Directive (MSFD)/ International Council for the Exploration of the Sea (ICES) applications.

Nutrient flux across the shelf break is unlikely to be directly measured in a routine way. Therefore, observations that will indirectly help to constrain this are needed. Task 1.3 of AtlantOS is performing some coordinated Observing System Simulation Experiments to assess the impact of various potential observation types (including biogeochemical) on ocean state estimates through assimilation into models.

Riverine input regions as additional key geographical areas determining the target spatial and temporal scales of observations.

Other targets:
To interact with the terrestrial observing system to provide boundary conditions for land-sea interaction component of the biogeochemical exchanges.

To interact with the Deep Ocean Observing System (DOOS) to provide as close to bottom as possible measurements for boundary conditions at the sediment-water interface in coastal waters and shelf seas.

To measure submarine groundwater discharge (with the use of tracers?) to estimate its role on particulate material fluxes.

TARGET #2:
To detect long-term change in the relative contribution of shelf (and marginal seas) carbon sequestration (i.e. out of contact with the atmosphere) to total oceanic carbon sequestration.
Rationale: Continental margins are only about 10% of ocean regions, but account for some 40% of primary production and 80% of organic matter sequestration.

Other targets:
To interact with the terrestrial observing system to provide boundary conditions for land-sea interaction component of the biogeochemical exchanges.

Selected references:

4. Ocean acidity

Processes contributing to the phenomenon:
- Acidification
  
  Key geographic areas: tropical and cold-water coral reef sites (N. Atlantic continental margins), upwelling areas, coastal regions (due to land-sea fluxes)

- Depth of calcite/aragonite saturation horizon
  
  Key geographic areas: tropical and cold-water coral reef sites (N. Atlantic continental margins), upwelling areas, coastal regions (due to land-sea fluxes)

- Particulate Inorganic Carbon (PIC) distribution and inventory

Relevant BGC EOVs:
Inorganic Carbon, Particulate Matter

Phenomenon-based targets:
TARGET #1: [Global Ocean Acidification Observing Network (GOA-ON)]
To be able to detect the change in pH to 0.005 pH unit in open ocean, and to detect the change in pH to 0.02 pH unit in coastal ocean.
Spatio-temporal and other targets:
- Sub-daily to weekly temporal resolution.
- Spatial coverage between 0.1 to 100km.

TARGET #2: [GOA-ON]
To be able to detect the aragonite horizon ($\Omega_{\text{arag}}$) to a given level of uncertainty.

Spatio-temporal and other targets:
- For DIC and Total Alkalinity temporal and spatial resolution of repeat-hydro inorganic carbon measurements design.
- Temporal target of monthly DIC/Alkalinity (sensors) measurements where we have highest variability (see Jiang et al., 2015).

TARGET #3:
To define a baseline for a global distribution of PIC.

Rationale: There is a need to discuss the qualitative aspects of the impact of changes in the PIC distribution on Ocean Acidification.

Comments:
Observations in the coastal zone are very complicated as there are humic substances in the water and calcium carbonate bedrock to contend with.
Coastal acidity is also driven by eutrophication processes.
There is also a need to communicate with GOA-ON Biology to inquire about setting targets for Ocean Acidification chemical observations from the perspective of changing ecosystem distributions.

Selected references:
5. Inorganic nutrient cycling

Processes contributing to the phenomenon:
- Denitrification/Nitrification/Anammox
  *Key geographical areas:* low oxygen eddies, Benguela upwelling, high denitrification in the North Sea, Oxygen minimum zones, river and point source locations.
- Phosphate availability
- N₂ fixation
  *Key geographical areas:* low nitrogen regions, western boundary currents.

Relevant BGC EOVs:

Nutrients

Phenomenon-based targets:

**TARGET #1:**
To be able to resolve the seasonal cycle of macronutrients in the mixed layer depth/euphotic zone.

**TARGET #2:**
To provide relevant on-board phosphate measurements when needed to monitor changes in N₂ fixation.

6. Hypoxia

Processes contributing to the phenomenon:
- Hypoxia is defined here as waters with O₂ concentrations below 80 µmol/l (refer to literature for opportunity to decrease this number).
  *Key geographical areas:* Eastern Tropical North Atlantic, Gulf of Mexico, Benguela Upwelling

Relevant BGC EOVs:

Oxygen, Nitrous Oxide, Particulate Matter
Phenomenon-based targets:

TARGET #1:
Establish the baseline number of OMZs (with 3D distribution of oxygen levels within them) in the Atlantic Ocean.

TARGET #2:
Establish the baseline volume of OMZs in the Atlantic Ocean.

TARGET #3:
Establish vertical extent of OMZs with specific focus on their shallowing.

Spatio-temporal and other targets:
- The observing system focus needs to be in the key geographical areas.
- The observing system should resolve horizontal scales within the entire OMZ 1-10 km, and observe at monthly time scales in order to resolve the seasonal cycle.
- Episodic suboxic (low oxygen) eddies: an element of observing system should be focused on “monitoring” the fronts and eddies region that is known to “produce” suboxic eddies, combined with a “response” element of the obs system which would then be responsible for describing these water masses.
- Target accuracies: according to figures provided in the Oxygen EOV Specification Sheet.

Comments:
- One should look into the connection of hypoxia with other phenomena such as the inorganic nutrient cycling, and redistribution of species.
7. Anthropogenic carbon sequestration

Observations of this phenomenon are tightly linked to observations of air-sea fluxes, ventilation and organic matter cycling phenomena.

*Key geographical areas:* high latitude North and South Atlantic

**Relevant EOVs:**
Oxygen, Inorganic Carbon, Transient Tracers, Nutrients, Stable carbon isotopes

**Phenomenon-based targets:**

**TARGET #1:**
Constrain the spread of the anthropogenic signal in deep water (e.g. AABW).

**Spatio-temporal and other targets:**
- With the GO-SHIP design as background, Increase frequency of observations in areas of mode and deep water formation (adhere to high frequency GO-SHIP).
- All data accuracy requirements to be copied from GO-SHIP.
- Sensors are needed to work towards this target.

8. Organic carbon cycling

**Processes contributing to the phenomenon:**

- Dissolved Organic Carbon (DOC) and Particulate Organic Carbon (POC) Export
  *Key geographical areas:* entire Atlantic basin
- Organic carbon storage
- Respiration of organic to inorganic carbon
- Photooxidation:
  Consider adding this phenomenon as 3rd phenomenon to the Dissolved Organic Carbon EOV; to be consulted with Denis Hansell.
As with photosynthesis what is needed is: substrate concentration, light dose in appropriate part of the spectrum, quantum yield of the reaction (typically determined in the lab or in deck incubations).

An observing system could provide the first two as well as monitor the net change in time (to which photo-oxidation contributes but is usually not the sole process).

**Relevant BGC EOVs:**

Oxygen, Nutrients (also Fe currently not included as a sub-variable in the EOV), Particulate Matter (including atmospheric lithogenic fraction aggregating dissolved organic material (lithogenic carbon pump)), Stable Carbon Isotopes, Dissolved Organic Carbon

**Phenomenon-based targets:**

**TARGET #1:**

Consensus on particulate organic carbon export below the euphotic zone down to 1000 meters.

**Comments:**

- Look into NASA’s EXPORTS program docs for possible targets
- Fleet of floats with UVPs and backscattering on them would provide standing stocks down to 2,000 m.
- The DOC EOV is in a lower readiness levels. It’s one of the largest unknowns in the models and in global data based estimates. Its directly linked to sequestration.
- There are technologies that you can put on floats. Drifting sediment traps.

9. **Eutrophication**

**Processes contributing to the phenomenon:**

- Riverine and point source nutrient fluxes
- Overgrowth of primary producers – algal blooms
- Oxygen inventory
Key geographical areas: coastal ocean around the basin. It’s a local phenomenon with some impact on the open ocean.

Relevant BGC EOVs:

Oxygen, Nutrients, Particulate Matter

Phenomenon-based targets:

TARGET #1:
To promote shared databases, standards and best practices to ensure intercomparability of relevant parameter measurements for the benefit of determining eutrophication status.

TARGET #2:
To identify gaps in in situ measurement coverage of relevant eutrophication indicators, acknowledging regional differences in the requirements. Particularly, increase the number of in situ measurements of nutrient concentrations used as eutrophication indicators, as currently, the majority of nutrient data used for assessments come from models.

Comments:
- There is a number of management targets already set for eutrophication. These targets differ from country to country, even within the EU. This makes setting global eutrophication-based observing targets irrelevant.
- Management targets are set based on thresholds assigned to a set of indicators that correspond to a number of GOOS EOVs or their sub-variables.
- Decision to set targets is more politically driven than observation driven.
- Currently used indicators and targets for coastal management purposes around the Atlantic Basin can be found in the following reports:
  - HELCOM
    - indicators and assessment of Good Ecological Status (GES)
    - European Environment Agency (EEA) State of Europe’s Seas report
  - OSPAR (Convention for the Protection of the Marine Environment of the North-East Atlantic), e.g. OSPAR Quality Status Report 2010
- PICO (Panel for Integrated Coastal Observation) · Requirements for Global Implementation of the Strategic Plan for Coastal GOOS (GOOS/193 Report)
- TWAP (Transboundary Waters Assessment Programme) Large Marine Ecosystem report

- There is a need for model analysis of point source and non-point sources contributions to eutrophication which could help guide the design of the geographic scale of measurements.

10. Contamination (pollution)

Processes contributing to the phenomenon:
- Plastics contamination (floating macroplastics, mid-water microplastics)
- PBT/POP contamination
- Heavy metals (including mercury) contamination
- Underwater noise – should be considered by the Physics panel. Better call it Sound because Noise implies a negative impact. Sound would have a wider set of applications.
- Hydrocarbon contamination
- Atmospheric inputs of Nr (reactive nitrogen) and metals (both from continents and ship plumes)

Key geographical areas: boundary currents, equatorial gyres, major river inputs, industrialised/high population coastlines/shelves, shipping lanes

Relevant BGC EOVs:

Extensions to existing EOVs or a new EOV to be determined? EOVs should include the following variables: plastics, PBTs/POPs, metals, underwater noise, artificial radionuclides.

GOOS is currently considering creating an emerging EOV(s) “Human pressure variables.” Pollutants/contaminants would constitute one if the elements.
Phenomenon-based targets:

TARGET #1:

To enhance the capability to monitor changes in contamination levels of key marine pollutants.

TARGET #2:

Set up a coordinated monitoring system for marine contamination.

Comments:
- There is insufficient information about the extent of the problems, key locations and impacts.
- Need to analyse the trade-offs in case of some of the expensive measurements.
- In case of disasters, e.g. like Fukushima, would there be a monitoring activity initiated in response to such events, especially for countries less well-off than Japan.
- IAEA – capacity to rapidly set up monitoring programs in response to such events. That happened in Monaco in collaboration with Japanese measurements.
- There are two MSFD contaminant related indicators.
- Environmental Quality Standards (EQS) for priority substances and certain other pollutants – European Commission Directive 2013/39/EU
- Eutrophication is ‘pollution’ in the BGC sense. We don’t see effects of pollution on BGC cycles yet.
- Through satellites monitoring of illegal oil discharges/ oil slicks. + natural hydrocarbon sources of interest to the industry.
- Bermuda Atlantic Time-series Study (BATS) started to do towed net measurements of microplastics.
- Noise: need to distinguish between natural and artificial noise.
- Tech specs for monitoring noise given by MSFD. Passive acoustic receivers.
- Plastics and acoustics (main focus in EU), methyl mercury (mangroves taking mercury into methyl mercury) focus in the US.
- The project COOP+ [http://www.coop-plus.eu] plan to do a review on 12 Global Challenges (Earth System), including the issue of plastic contamination.
- Operational detectors for a number of determinants. Technique allows to measure very low concentrations.
Conclusions

This workshop was the first step towards setting phenomena-based targets for biogeochemical observations in the Atlantic Ocean. The combined knowledge and expertise of the workshop participants enabled outlining the priorities for designing the BGC observing system in the context of key scientific questions and societal requirements posed. However, it was beyond the capacity of this workshop to consider all phenomena and their targets in equal breadth and with sufficient level of detail to connect to existing and planned observing network operations. Additional work to refine and expand on the current list of targets will be carried out within the AtlantOS project in the near future.

Comparing the developed targets with the current observing capabilities will enable a comprehensive gap analysis aimed at providing recommendations for designing optimized and enhanced Atlantic Ocean observing system. The outcomes of the workshop will not only inform the project deliverables, but will also be further socialized with the community for input and expansion to other basins.

An important lesson from the workshop is the need to simultaneously account for the requirements in collocated physical and biological measurements necessary to observe and model a given biogeochemical phenomenon. Proper consideration of targets related to measuring all relevant EOVs is fundamental to developing an optimal sampling design. Such a multidisciplinary approach would further promote synergies between the observing networks and communities traditionally confined to a single discipline – a prerequisite to a successful implementation of any phenomenon-based target.

Outcomes and lessons learned from this workshop will also provide recommendations and directions for future efforts aiming at setting phenomena-based observing targets in the global ocean.
Appendices

Agenda

Setting Observing Targets for Biogeochemical Observing System in the Atlantic – EU H2020 AtlantOS project Workshop

29 November - 1 December 2016

Institute of Oceanology Polish Academy of Sciences (IO PAN)
Powstańców Warszawy 55, 81-712 Sopot, Poland

WORKSHOP AGENDA

Meeting Participants

The full list of workshop participants is provided on the workshop website at:

As much as possible we aimed at having expertise for each major observing network and each Essential Ocean Variable (EOV)/phenomenon discussed. We considered the presence of observationalists and modellers equally important.

Workshop Goals

- Decide on the biogeochemical (BGC) phenomena for which to set observing targets, based on the list of phenomena developed by AtlantOS WP1.
- Define what an observing target is in the context of the BGC observing system
- Set observing targets for BGC phenomena (described by relevant variables)
- Analyse feasibility of set targets with respect to current capacities to enable a comprehensive gap analysis
- Provide recommendations for designing an optimized Atlantic Ocean observing system

Tuesday, 29 November 2016

08.30–09.00: Arrival and Setup
09.00–09.10: Welcome & Local logistics Information
09.10–10.30: Workshop goals in the context of the EU Horizon 2020 AtlantOS project

- What are the overall goals of AtlantOS? Why are BGC targets needed, in what form? (10 min)
- Short introduction to the Framework for Ocean Observing (FOO) and EOV implementation process. (15 min)
- Walk through an exemplary EOV Specification Sheet. (20 min)
- Explain carefully the EOV definition and associated terms (sub-variables, phenomena, observing networks, detection limit,
uncertainty) and where and how the BGC targets fit into such a specification sheet. (15 min)

10.30-11.00: Coffee Break
11.00-13.00: List of all BGC Phenomena relevant for the Atlantic Ocean
  • List of science questions and societal requirements which determine which phenomena need to be observed to address these requirements. This is necessary to put the list of phenomena in a high-level context.
  • Discuss the proposed list of phenomena.
  • Make sure that each phenomenon is clearly understood by all experts.
  • Finish the session with a consensus on the list of phenomena to address during the workshop.

13.00-14.00: Lunch Break
14.00-15.30: List of all BGC Phenomena relevant for the Atlantic Ocean - continued
15.30-16.00: Coffee Break
16.00-17.30: Define what an observing target is in the above context
  • Approach centred around phenomena. Targets per phenomena, including consideration of EOVs measured for each phenomenon.

We propose the following draft definition of an observing target:

An observing target is set to allow the observing system to detect changes in a given phenomenon sufficiently to address the relevant scientific questions and societal needs. Such a target needs to be set at the spatial and temporal scales the phenomenon is sensitive to, and at a desirable/known level of uncertainty, with consideration of all relevant EOVs.

This description is up for discussion at the workshop, and might need additional criteria for observing target included.

~18.30 Non-hosted group dinner in Sopot

Wednesday, 30 November 2016

09.00-11.00: Breakout groups to establish BGC targets for the first set of phenomena (1-4, total number of phenomena to be decided at the meeting but around 10) and relevant EOVs
  • Aim for 2 groups with at least 6 experts in each.
  • Each group should tackle at least 2 phenomena by the end of the day.
  • Each expert can migrate between groups if necessary.

11.00-11.30: Coffee Break
11.30-13.00: Discussion of breakout group outcomes
  • Max. 10 min presentations for each phenomenon.
  • Feedback and discussion.
  • Finalize targets for the first set of phenomena and relevant EOVs.
13.00–14.00: **Lunch Break**

14.00–15.30: Breakout groups to establish BGC targets for the second set of phenomena (5–10, total number of phenomena to be decided at the meeting but around 10) and relevant EOVs

15.30–16.00: **Coffee Break**

16.00–17.30: Previous session continued

**Thursday, 1 December 2016**

09.00–11.00: Discussion of breakout group outcomes

- Max. 10 min presentations for each phenomenon.
- Feedback and discussion.
- Finalize targets for the second set of phenomena and relevant EOVs.

11.00–11.30: **Coffee Break**

11.30–13.00: Set targets versus current capabilities

Feasibility analysis and discussion for each phenomenon based on current observing capacities as described in the EOV spec sheets and targets set during breakouts (pre-prepared tabular form).

13.00–14.00: **Lunch Break**

14.00–15.30: Suggestions for metrics allowing to assess the progress towards meeting set targets.

15.30–16.00: Wrap-up & Adjourn

**List of participants**

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*Joined remotely*: Stephanie Henson (NOC · Southampton, UK), Christoph Heinze (Uni. Bergen, Norway)