Defining essential ocean variables (EOVs) for biogeochemistry

11–12 June 2015, Bari–Italy

Societal Benefit Area: Ecosystems
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Institution: GEOMAR

Coordinating an Observation Network of Networks EnCompassing saTellite and IN-situ to fill the Gaps in European Observations
Questionnaire

Describing the monitoring networks currently operational:

- Is your community developing a set of area-specific EVs? – Yes.

The process underlying EV definition:

- What criteria, methodology, and processes are used to identify EVs? Bottom up or top-down? – Both ways. See separate slides.
- Do you have a template to document a EV? – Yes. See separate slides.

EVs validation and use:

- To what extent these EVs are validated and used?
- Are the EVs linked to applications and users?
- Who are the users?
- How is a community agreement reached? Townsville, 2013, and follow ups
- Is a community review process in place? Yes.
- Are the EVs linked to an international body (i.e. a UN convention or similar) and is this body involved in accepting the EVs? – FOO/GOOS/IOCCP/IOC/
Questionnaire, continued:

Status of existing EVs in the domain:
- Do you have a database with information on the EVs? – Website.
- Do you know network currently operational for medium-term/long-term monitoring? – (Yes, e.g., GO-SHIP/repeat hydrography, time series, …)
- Are the current operational networks operated by your community measuring the EVs?

Assessing EV observational needs and readiness:
- For some Use Case, have you already focused on EV’s features (temporal and spatial resolution, accuracy? – Yes, see slides
- Challenges and how these are addressed (if any).

Gaps and requirements:
- Have you already carried out a gap analysis utilizing the EVs to identify gaps and priorities (data availability, extraction, repositories, …)

Conclusions
Essential Ocean Variables For Biogeochemistry

See also www.ioccp.org/foo
A brief timeline / some milestones of EOV definition

- **2009: OceanObs ’09, Venice, Italy**
  Call for international integration and coordination of interdisciplinary ocean observations. Sponsors commissioned Task Team to develop

- **2012: Integrated Framework for Sustained Ocean Observing (FOO)**
  Three Ocean Observing System Panels (Physics, Biology/Ecology and Carbon/Biogeochemistry), interacting through virtual and in-person meetings and workshops, to propose a set of Essential Ocean Variables (EOVs). Each panel has a lead organization, which is tentatively tasked to consult the community and create a loose consortium of relevant and interested experts and/or organizations, helping to justify and negotiate the inclusion of certain parameters in the final list of EOVs.

- Task Team asked IOCCP to lead Biogeochemistry Panel for EOV
  To kick-start the process, the Global Ocean Observing System (GOOS) sponsored, through IOCCP, an expert meeting which was carried out side by side with the Biology and Ecosystem Panel meeting.

- **2013: First Technical Experts Workshop for Biology and Ecosystem and Biogeochemistry Panels, Townsville, Australia, 2013**
  Starting from identification of major societal and scientific challenges that require sustained observations of ocean biogeochemistry variables; identification of candidate biogeochemical Essential Ocean Variables (EOVs).

  Input of a wider community was invited before, during and after the town hall meeting organized during the OSM’14 in Honolulu.

- **2014: GOOS Webinar**
2012: Framework for Sustained Ocean Observing (FOO)

GOOS Steering Committee

Observing System Panels
Physics
Carbon/Biogeochemistry (IOCCP)
Biology/Ecosystems
coordination for observing system elements

Technical Advisory Groups
observing technologies and networks
data and products
synthesis, link to models

see www.ioc-goos.org
FOO: Structure of Framework

Input (requirements)

Process (observations)

Output (data products)
FOO: Structure of Framework

Can data constrain scientific and societal questions?

requirements
feasibility
Essential Ocean Variables
EOVs

observations, deployment, maintenance

ARGO
SOOP
satellites
VOS
OceanSITES
IMOS
IOOS

data assembly
data products

ConnectInGOO
Iris Kriest, Essential Ocean Variables for Biogeochemistry
Workshop 2013

First Technical Experts Workshop of the GOOS Biogeochemistry Panel: Defining Essential Ocean Variables for Biogeochemistry

13–16 November 2013, Townsville, Australia

• agreed on EOVs for biogeochemistry: well-reasoned, widely-reviewed, community-shaped
• implementation driven by feasibility and impact
The process underlying EOV definition

What are the relevant topics and questions on a societal and scientific basis?

- The role of ocean biogeochemistry in climate
  - Q1.1 How is the ocean carbon content changing?
  - Q1.2 How does the ocean influence cycles of non-CO$_2$ greenhouse gases?

- Human impacts on ocean biogeochemistry
  - Q2.1 How large are the ocean’s “dead zones” and how fast are they changing?
  - Q2.2 What are rates and impacts of ocean acidification?

- Ocean ecosystem health
  - Q3.1 Is the biomass of the ocean changing?
  - Q3.2 How does eutrophication and pollution impact ocean productivity and water quality?
The process underlying EOV definition

What are the relevant variables to address these questions?

The role of ocean biogeochemistry in climate

- **Q1.1 How is the ocean carbon content changing?**
  - Carbonate system
  - DOC
  - Transient Tracers
  - $O_2$
  - Macronutrients ($NO_3$, $PO_4$, Si, NH$_4$, NO$_2$)
  - $^{13}$DIC, $^{14}$DIC

- **Q1.2 How does the ocean influence cycles of non-$CO_2$ greenhouse gases?**
  - $N_2O$
  - CH$_4$ (regional)
  - DMS
  - Halocarbons/O$_3$–depleting substances
  - $O_2$
What are the relevant variables to address these questions?

Human impacts on ocean biogeochemistry

- **Q2.1** How large are the ocean’s “dead zones” and how fast are they changing?
  - O$_2$
  - Macronutrients (NO$_3$, PO$_4$, Si, NH$_4$, NO$_2$)
  - Transient Tracers
  - Export rates and/or Ar/O$_2$
  - Carbonate system

- **Q2.2** What are rates and impacts of ocean acidification?

**Detection**
- Carbonate system
- O$_2$
- Macronutrients (NO$_3$, PO$_4$, Si, NH$_4$, NO$_2$)
- Atmospheric deposition of anthropogenic sulfates
- Transient Tracers
- $^{13}$DIC
- PON, POP, DON, DOP
- Ra isotopes (coastal)

**Impact**
- Carbonate System
- Dissolution Rates
- PIC, POC
- Phytoplankton Functional Groups
- Benthic and Pelagic Species
- $^{231}$Pa, $^{230}$Th
The process underlying EOV definition

What are the relevant variables to address these questions?

Ocean ecosystem health

- **Q3.1a Is production of the ocean changing?**
  - Macronutrients (NO$_3$, PO$_4$, Si, NH$_4$, NO$_2$)
  - Micronutrients (e.g., Fe)
  - O$_2$
  - Carbonate System
  - O$_2$/Ar
  - O$_2$ isotopes
  - Opal, POC, CaCO$_3$

- **Q3.1b Is biomass of the ocean changing?**
  - POM (POC, PON, POP)
  - Chlorophyll
  - Macronutrients (NO$_3$, PO$_4$, Si, NH$_4$, NO$_2$)
  - Particle size spectra

- **Q3.2 How does eutrophication/pollution impact ocean productivity and water quality?**

**Eutrophication**

- Macronutrients (NO$_3$, PO$_4$, Si, NH$_4$, NO$_2$)
- O$_2$
- POC, DOC
- $^{18}$O/$^{16}$O
- Ra isotopes (coastal)

**Pollution**

- Dioxin
- POPs (particulate organic pollutants)
- Plastics
- Heavy Metals
Assessing EOVs’ observational needs and readiness

So far, this is a wishlist; balance impact against feasibility

TOP 8 candidates:
1. Oxygen
2. Macro Nutrients
3. Carbonate System
4. Transient Tracers
5. Suspended Particulates
   Particulate Matter Transport
6. Nitrous Oxide
7. Carbon-13
8. Dissolved Organic Matter
Model projections of future changes of ocean “dead zones” (low oxygen)

Projected volume change, individual models

Projected oxygen 100–600m, ensemble mean

Oxygen and indicators of stress for marine life in multi-model global warming projections

V. Cocco\(^1,2\), F. Joos\(^1,2\), M. Steinacher\(^1,2\), T. L. Frölicher\(^3\), L. Bopp\(^4\), J. Dunne\(^5\), M. Gehlen\(^6\), C. Heinze\(^6,7,8\), J. Orr\(^4\), A. Oschlies\(^9\), B. Schneider\(^10\), J. Segschneider\(^11\), and J. Tjiputra\(^7,9,11\)

Biogeosciences, 10, 1849–1868, 2013
Expanding Oxygen-Minimum Zones in the Tropical Oceans

Lothar Stramma, Gregory C. Johnson, Janet Sprintall, Volker Mohrholz

Oxygen-poor waters occupy large volumes of the intermediate-depth eastern tropical oceans. Oxygen-poor conditions have far-reaching impacts on ecosystems because important mobile macroorganisms avoid or cannot survive in hypoxic zones. Climate models predict declines in oceanic dissolved oxygen produced by global warming. We constructed 50-year time series of dissolved-oxygen concentration for select tropical oceanic regions by augmenting a historical database with recent measurements. These time series reveal vertical expansion of the intermediate-depth low-oxygen zones in the eastern tropical Atlantic and the equatorial Pacific during the past 50 years. The oxygen decrease in the 300- to 700-m layer is 0.09 to 0.34 micromoles per kilogram per year. Reduced oxygen levels may have dramatic consequences for ecosystems and coastal economies.
Finding, defining, and presenting an EOV: Example $O_2$

Types of measurements and platforms

- **gliders**
- **floats**
- **CTD with Niskin bottles**
- **moorings**
Finding, defining, and presenting an EOV: Example $O_2$

Current (2013) data distribution from ship based (bottle) measurements

Finding, defining, and presenting an EOV: Example O\(_2\)

Specification spreadsheets define responsibilities and derivatives, ...

<table>
<thead>
<tr>
<th>Table 1: EOV Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name of EOV</td>
</tr>
<tr>
<td>Sub-Variables</td>
</tr>
<tr>
<td>Derived Products</td>
</tr>
<tr>
<td>Supporting variables</td>
</tr>
<tr>
<td>Contact/Lead Expert(s)</td>
</tr>
</tbody>
</table>
Finding, defining, and presenting an EOV: Example $O_2$

<table>
<thead>
<tr>
<th>Table 2: Requirements Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsible GOOS Panel</td>
</tr>
</tbody>
</table>
| Societal drivers             | 1. The role of ocean biogeochemistry in climate  
|                              | 2. Human impacts on ocean biogeochemistry  
|                              | 3. Ocean ecosystem health |
| Scientific Application(s)    | Q 1.1. How is the ocean carbon content changing?  
|                              | Q 2.1. How large are the ocean’s “dead zones” and how fast are they changing?  
|                              | Q 3.1. Is the biomass of the ocean changing?  
|                              | Q 3.2: How do the eutrophication and pollution impact ocean productivity and water quality? |
| Readiness Level              | Mature |
| Phenomena to capture         | 1. Air-sea fluxes of $O_2$  
|                              | 2. Changes in storage of $O_2$  
|                              | 3. Extent of hypoxia  
|                              | 4. Net community production (NCP)/export |
| Temporal scales of the phenomenon | Monthly  
|                              | Seasonal-decadal  
|                              | Coast: seasonal  
|                              | OO: annual  
|                              | Weekly to Monthly |
| Spatial scales of the phenomenon | Rossby radius;  
|                              | 2-100 km  
|                              | 100-1000 km  
|                              | Coast: 0.1-100 km  
|                              | OO: 100-1000km  
|                              | Coast: 1-100 km  
|                              | OO: 100-1000km |
| Magnitudes/range of the signal | 100 Tmol yr$^{-1}$  
|                              | 0.4 Pmol decade$^{-1}$  
|                              | Number of areal extent of hypoxic regions (400)  
|                              | 8 Pg C year$^{-1}$ |
| Desired detection limit relative to the signal | +/- 10 %  
|                              | +/- 10 %  
|                              | +/- 10 %  
|                              | +/- 25 % |
Finding, defining, and presenting an EOV: Example $O_2$

Table 3: Current Observing Elements

<table>
<thead>
<tr>
<th>Observing Element</th>
<th>Profiling Floats</th>
<th>Repeat Hydrography</th>
<th>Moorings</th>
<th>Gliders</th>
<th>Ship based Time-Series</th>
<th>Ships Of Opportunity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phenomena addressed</td>
<td>1,2,3,4</td>
<td>2</td>
<td>1,4</td>
<td>1,3,4</td>
<td>3,4</td>
<td>1,4</td>
</tr>
<tr>
<td>Spatial scales captured by the observing element</td>
<td>Global Every 3°</td>
<td>Global Along section: 30nm</td>
<td>Local Coastal (10-100 km)</td>
<td>Local Coastal and Open Ocean (10-100km)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temporal scale captured by the observing element</td>
<td>Bi-weekly</td>
<td>Decadal</td>
<td>Hourly</td>
<td>Hourly</td>
<td>Monthly Sub-weekly to Monthly</td>
<td></td>
</tr>
<tr>
<td>Supporting variables measured</td>
<td>T, S, MLD, Stratification</td>
<td>T, S, MLD, Stratification</td>
<td>T, S, MLD, Stratification</td>
<td>T, S, MLD, Stratification</td>
<td>T, S, MLD, Stratification</td>
<td></td>
</tr>
<tr>
<td>Sensor(s)/ Technique</td>
<td>Optical Oxygen Sensor</td>
<td>Wet chemistry (Winkler)/ Polarographic</td>
<td>Optical Oxygen Sensor</td>
<td>Optical Oxygen Sensor (Winkler)/ Polarographic</td>
<td>Optical Oxygen Sensor</td>
<td></td>
</tr>
<tr>
<td>Accuracy/Uncertainty estimate (units)</td>
<td>$\pm 2 \mu$mol kg$^{-1}$</td>
<td>$\pm 0.5 \mu$mol kg$^{-1}$</td>
<td>$\pm 2 \mu$mol kg$^{-1}$</td>
<td>$\pm 2 \mu$mol kg$^{-1}$</td>
<td>$\pm 0.5 \mu$mol kg$^{-1}$</td>
<td>$\pm 2 \mu$mol kg$^{-1}$</td>
</tr>
<tr>
<td>Reporting Mechanism(s)</td>
<td>GOOS Implementation Plan. IOCCP Report.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

...methodology and platforms, with links to phenomena captured, their spatial and temporal scales.

![Graph showing oceanographic observations and scales](image)

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Finding, defining, and presenting an EOV: Example $O_2$

Authorities responsible for coordination, quality control and data stream delivery are presented platform-wise.

<table>
<thead>
<tr>
<th>Table 5: Data &amp; Information Creation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Responsible entity and readiness level in each category per observing element</strong></td>
</tr>
</tbody>
</table>
| **Profiling floats** | Bio-Argo |  |  | CORIOLIS | Global NCP maps  
Global $O_2$ flux maps  
Global eutrophication maps |
| Pilot |  |  | Pilot |  |  |
| **Repeat Hydrography Cruises** | GO-SHIP | National Programs | CCHDO | National data centres |  |
| Mature | Mature |  |  |  |  |
| **Moorings** |  | Principal Investigators |  | National data centres  
CORIOLIS/GODAE |  |
Finding, defining, and presenting an EOV: Example O₂

Finally, links point towards the corresponding websites for further information.

<table>
<thead>
<tr>
<th>Table 6: Links &amp; References</th>
</tr>
</thead>
<tbody>
<tr>
<td>(especially regarding</td>
</tr>
<tr>
<td>Background and</td>
</tr>
<tr>
<td>Justification)</td>
</tr>
<tr>
<td><strong>Links for</strong></td>
</tr>
<tr>
<td><strong>Contributing</strong></td>
</tr>
<tr>
<td><strong>Networks</strong></td>
</tr>
</tbody>
</table>

| **Data References**        | http://www.coriolis.eu.org/ (ARGO) |
|                           | http://cchdo.ucsd.edu/ (repeat hydrography) |
|                           | http://www.bco-dmo.org/ (time series) |
Conclusion

Although still in draft mode, definition of EOVs for biogeochemistry quite advanced, due to community effort.

Have a look at www.ioccp.org/foo for further information and updates.

In case of questions, also contact

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