The role of phenomena in setting requirements for an integrated ocean observing system
What do we mean by phenomena?

- Dynamic aspects of a system,

- Vary in space and/or time (i.e. changes / trends / shifts are their inherent properties).

- What we need to capture with observations (and models) in order to deliver to key applications and/or answer key scientific questions.
GOOS definition of phenomena

At 1st GOOS Cross-panel meeting in Oostende in 2016 defined as:

‘A GOOS 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.’
Phenomena translate the high-level requirements for **WHAT** to measure into requirements for the observing system for **HOW** to measure.
Multiple applications require measurements of the same phenomenon.

Each phenomenon sets requirements for multiple EOVs.
More practical than setting requirements for EOVs directly – because a single EOV inform multiple phenomena operating on very different spatio-temporal scales.
Why articulate phenomena?

• They are what determines our space/time **sampling needs, observing system design**

• Key concept for setting observing requirements for EOVs

• They are **the** element of the FOO in which cross-disciplinary synergies must be discussed
  – i.e. Stratification, Deoxygenation, Primary production, Eutrophication

• Will enable us to develop **a framework for ongoing evaluation of the observing system**
  – OOPC is scoping a review on observations for capturing changes in ocean heat and freshwater content
    *(rather than reviewing observations of temperature and salinity against requirements)*
# Sea Surface Temperature EOV

<table>
<thead>
<tr>
<th>Requirements Settings</th>
<th>OOPC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsible GCOS/GOOS Panel Reporting Mechanism</td>
<td>Reporting through GCOS to UNFCCC Technical Reporting through CEOS SST-VC, GHRSSST and ICOADS</td>
</tr>
<tr>
<td>Readiness Level&lt;sup&gt;5&lt;/sup&gt;</td>
<td>Mature</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Phenomena to capture.</th>
<th>Air-Sea Fluxes</th>
<th>Fronts and eddies</th>
<th>Coastal Shelf Exchange Processes</th>
<th>Upwelling</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Temporal Scales of the Phenomena</th>
<th>daily</th>
<th>weekly</th>
<th>&gt; hourly</th>
<th>weekly</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Spatial Scales of the Phenomena (order)</th>
<th>100km</th>
<th>10km</th>
<th>1km</th>
<th>10km</th>
</tr>
</thead>
</table>
Phenomena set requirements for spatio-temporal observing scales.
<table>
<thead>
<tr>
<th>Phenomena to Capture</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Air-Sea Fluxes</strong></td>
<td><strong>Storage / inventory</strong></td>
<td><strong>Ocean Acidification</strong></td>
<td><strong>Primary production</strong></td>
<td><strong>Export fluxes</strong></td>
</tr>
<tr>
<td>Temporal Scales of the Phenomena</td>
<td>Monthly</td>
<td>Annual</td>
<td>Coastal Daily</td>
<td>Seasonal to decadal</td>
<td>Seasonal to decadal</td>
</tr>
<tr>
<td>Spatial Scales of the Phenomena</td>
<td>1-250 km</td>
<td>100-1000 km</td>
<td>Coastal 0.1-100 km</td>
<td>Coastal 1-100 km</td>
<td>Coastal 1-100 km</td>
</tr>
<tr>
<td>Magnitudes/Range of the Signal to Capture</td>
<td>2 Pg C yr(^{-1})</td>
<td>20 Pg C decade(^{-1})</td>
<td>Saturation states 0.1 decade(^{-1})</td>
<td>0.5 Pg C yr(^{-1}) decade(^{-1}) (net community production)</td>
<td>1 Pg C yr(^{-1}) decade(^{-1})</td>
</tr>
<tr>
<td>Current Uncertainty Relative to the Signal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Target Uncertainty Relative to the Signal</td>
<td>±10%</td>
<td>±10%</td>
<td>±20%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Ocean Colour EOV (draft)

<table>
<thead>
<tr>
<th>Phenomena to Capture</th>
<th>1 Primary production</th>
<th>2 Phenology</th>
<th>3 Eutrophication</th>
<th>4 Calcification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temporal Scales of the Phenomena</strong></td>
<td>annual to decadal</td>
<td>seasonal</td>
<td>weekly to decadal</td>
<td>monthly</td>
</tr>
<tr>
<td><strong>Spatial Scales of the Phenomena</strong></td>
<td>basin scale</td>
<td>0.01-10 mg-Chl/m³</td>
<td>coastal zones 1-100 km</td>
<td>1-250 km</td>
</tr>
<tr>
<td><strong>Magnitudes/Range of the Signal to Capture</strong></td>
<td>0-2500 g-C/m²/yr</td>
<td>max(0.03 mg-Chl/m³, 30%)</td>
<td>10-100 mg-Chl/m³</td>
<td>0.00001 - 0.02 mol-PIC/m³</td>
</tr>
<tr>
<td><strong>Current Uncertainty Relative to the Signal</strong></td>
<td>max(70%)</td>
<td>30%</td>
<td>same</td>
<td>30%</td>
</tr>
<tr>
<td><strong>Target Uncertainty Relative to the Signal</strong></td>
<td>50%</td>
<td>same</td>
<td>same</td>
<td>30%</td>
</tr>
</tbody>
</table>
Phenomena hotspots - physics

1. Circulation
2. Fronts and Eddies
3. Tides
4. Coastal Processes
5. Air-Sea Fluxes
6. Surface Waves
7. Freshwater Cycle
8. Sea Level
9. Upwelling
10. Riverine
11. Heat Storage
12. Stratification
13. Mixed layer
14. Water Masses
15. Sea Ice Extent
16. Extreme events
Phenomena:
1. Air-sea fluxes
2. Ventilation (water mass age)
3. Cross-shelf interactions
4. Acidity
5. Hypoxia
6. Anthropogenic carbon sequestration
7. Organic matter cycling
8. Inorganic nutrient cycling
9. Eutrophication
10. Contamination/pollution

Biomes:
- SPSS: subpolar seasonally stratified
- STSS: subtropical seasonally stratified
- STPS: subtropical permanently stratified
- EQU: equatorial
- other

Ocean Data View

AtlantoS
Perspective from BGC

• Phenomena that appear under BGC EOVs are *NOT strictly biogeochemical phenomena*. They are *ocean phenomena* which are being observed through one or more BGC EOV measurements.
  – **Ventilation (water masses)** is being observed with Transient Tracers, Oxygen, Nutrients EOVs – but a *‘physical’* phenomenon?
  – **Remineralization** is being observed with Oxygen, Nutrients, Particulate Matter, DOC EOVs – but a *‘biological’* phenomenon?
• They help narrow down the list of EOVs needed to measure to address an application/oberving objective
Perspective from BGC

- Requirements to observe phenomena need to be translated into tangible targets for the observing system design:

- Phenomena-based targets idea explored by the Biogeochemistry Panel in the AtlantOS project.

An **observing target** is set to allow the observing system to detect changes in a given phenomenon sufficiently to meet the societal (or scientific) requirements. 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.
A first go at setting phenomena-based targets for BGC
Phenomenon #1: Air-sea fluxes

Processes contributing to the phenomenon:
- Oxygen air-sea fluxes
- Carbon dioxide air-sea fluxes
- Nitrous oxide flux to the atmosphere
- Atmospheric/dust deposition of nutrients (nitrogen, phosphorus, iron)

Relevant BGC EOVs:
Oxygen, Nutrients, Inorganic Carbon, Nitrous Oxide, Particulate Matter

+ other EOVs...
Target #1: To constrain air-sea fluxes of CO₂ to within 10% of the total flux. [To be aligned with GCOS requirements.]

Resultant sampling scheme targets:

- Sea surface pCO₂ measurement accuracy to within 2 µatm.
- Lower atmospheric pCO₂ 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 pCO₂ needs improving in the South Atlantic to match the North Atlantic coverage of every 10º latitude coast to coast.
- Temporal resolution: 6 hours
Phenomenon #1: Air-sea fluxes

TARGET #2: To constrain the uncertainty of air-sea fluxes of N₂O to within 10% of the total annual flux variability. [To be aligned with GCOS requirements.]

Resultant sampling scheme targets:

- Accuracy of sea surface N₂O concentration measurement < +/- 1%
- Atmospheric N₂O 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 ~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 N₂O measurements at selected time-series sites with N₂O analysers on moored platforms

Target vs current capacity → readiness level
Targets for air-sea fluxes – issues

• How do the sampling scheme targets identified for CO$_2$ fluxes match with targets set for other aspects of measuring air-sea fluxes, e.g. N$_2$O? Need to reconcile them.

• Can’t look at biogeochemical requirements in isolation from the physical requirements for measuring air-sea fluxes. How do we reconcile them?

• How does this exercise fit into OOPC plans for scoping reviews around air-sea fluxes?

• BGC would need some more information on the rationale and exactly what OOP plans to do and how for the evaluation of storage and air-sea fluxes.
Oxygen
Nutrients
Particulate matter
Phytoplankton biomass and diversity

Physics
Ocean surface vector stress
Sea surface height
Sea surface temperature
Subsurface temperature
Surface currents
Subsurface currents
Sea surface salinity
Subsurface salinity

Biogeochemistry
Oxygen
Nutrients
Particulate matter
Ocean colour

Satellite: Chl-a & SST

National products
Regional & Local Model Forecasts
NMP
1. Biotoxin Levels
2. HAB Distribution & Abundance
3. Phytoplankton Distribution & Abundance

CMEMS MCS
MERCATOR Initial Conditions

ROMS (Regional Ocean Modelling System)
1. Hydrodynamics
2. Lagrangian

CMEMS MCS
Ocean colour

Shot Head cross section: High inflow (>40 m$^3$/s).
Mouth cross section: High inflow (>60 m$^3$/s)
Forecast for next 3 days

Bantry Bay
T1
T2

Depth
CURRENT inflow
Inflow is greater than 106% Long Term Mean at mouth of Bay
Inflow is greater than 42% Long Term Mean at Shot Head
Phenomena and GOOS strategic objectives

• What are the phenomena-based case studies that GOOS would like to select to enable an integrated implementation work plan in response to some specific GOOS strategic objectives:

  1) Engagement and observing system design

  3) Expand understanding and use of information about observing system requirements (...EOVs, phenomena,..)

  8) Regularly evaluate the ocean observing system to assess it is fit for purpose
Phenomena identified by GOOS Panels

**Physics**
- Circulation
- Air-sea fluxes
- Watermass
- Upwelling
- Riverine
- Fronts and eddies
- Tides
- Coastal processes
- Surface waves
- Near inertial oscillations
- Freshwater cycle
- Sea level
- Heat storage
- Stratification
- Mixed layer
- Sea ice extent
- Extreme events

**BGC**
- Circulation
- Air-sea fluxes
- Ventilation
- Upwelling
- Land-sea fluxes
- Ant. C sequestration
- Primary production
- Storage
- Deoxygenation
- Eutrophication
- Ocean acidification
- Remineralization
- Export fluxes
- Calcification
- Contamination/pollution
- Benthic fluxes

**BioEco (synthesis attempt)**
- Status and trends
- Severe decline/mass mortalities
- Coral bleaching
- Recovery/restoration
- Element cycling/transport
- Carbon sequestration
- Ocean production (incl. fish)
- Phenology/life cycle shifts
- Biogeographical shifts
- Invasions/HABs events
- Ecological regime shift
- Functional role of species
- Recruitment
- Size-composition
- Biodiversity
- Resilience
- Extreme events
Possible synergies concept map used to identify common interest phenomena.
### System evaluation ongoing/potential future evaluation

#### Physics
- Circulation
- Air-sea fluxes
- Watermass
- Upwelling
- Riverine
- Fronts and eddies
- Tides
- Coastal processes
- Surface waves
- Near inertial oscillations
- Freshwater cycle
- Sea level

#### BGC
- Circulation
- Air-sea fluxes
- Ventilation
- Upwelling
- River & run-off?
- Storage (carbon)
- Ant. C sequestration
- Primary production
- Deoxygenation
- Eutrophication
- Ocean acidification
- Remineralization
- Export fluxes
- Calcification
- Contamination/pollution
- Benthic fluxes

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From opportunistic to designed BioEco component of the observing system

What are some of the use cases that we as GOOS could build on to move in that direction?

• More involvement of BioEco panel in the ongoing VOICE project?

Topics suggested yesterday:
• Marine coastal habitats – e.g. POGO WG on Macroalgae
• Ice-edge dynamics?
• HABs?
Discussion

• How relevant is the concept of phenomena for moving the BioEco component from opportunistics to a designed observing system?

• What are the use cases that can demonstrate the value of an integrated system?

• Potential high readiness level example: storage and air-sea fluxes evaluation – more details from OOPC?

• How do we go about building the use cases that are more relevant to the BioEco Panel?