Future Global Ocean Observing System

Built on requirements, promoting alignment, delivering relevant information

Maciej Telszewski, IOCCP and GOOS

Institute of Oceanology of Polish Academy of Sciences, ul. Powstańców Warszawy 55, 81-712 Sopot, Poland
Phone: +48 58 731 16 10 / Fax: +48 58 551 21 30, **www.ioccp.org**

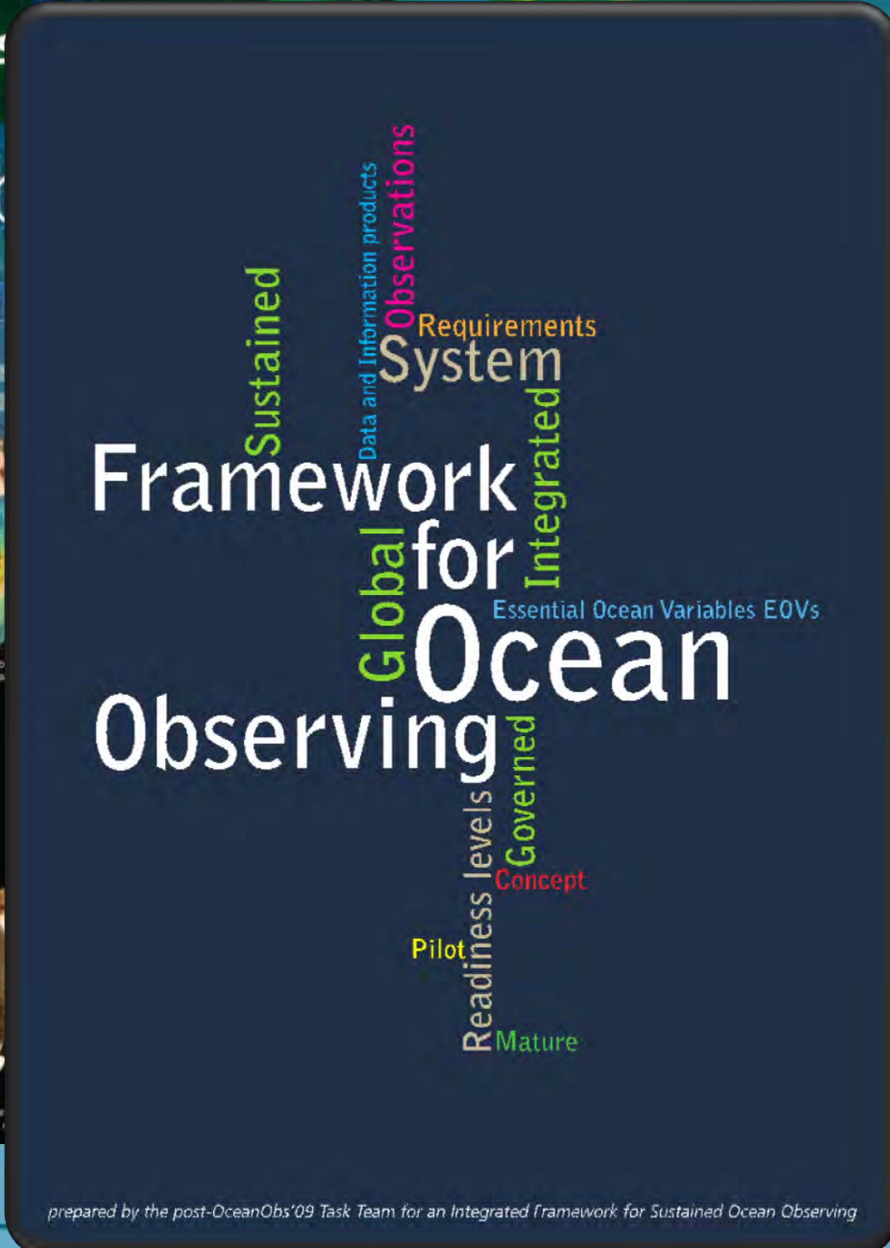
The Global Ocean Observing System

- the system GOOS
  - **collaborative system** of **sustained observations**
    - built on requirements
    - in situ and satellite
    - operational and research funding
    - linked to data management and product generation activities
    - global-scale and coastal
- the GOOS programme
  - advocacy for all elements of the system
  - provide a **platform for collaboration through development of common observing strategies**
  - promote **global participation** through capacity development

Framework for Ocean Observing
Why a Framework?

- OceanObs' 09 identified tremendous opportunities and significant challenges for the global ocean observing system

- Called for **a framework for planning and moving forward with an enhanced global sustained ocean observing system over the next decade**, integrating new physical, biogeochemical, biological observations while sustaining present observations



Observing

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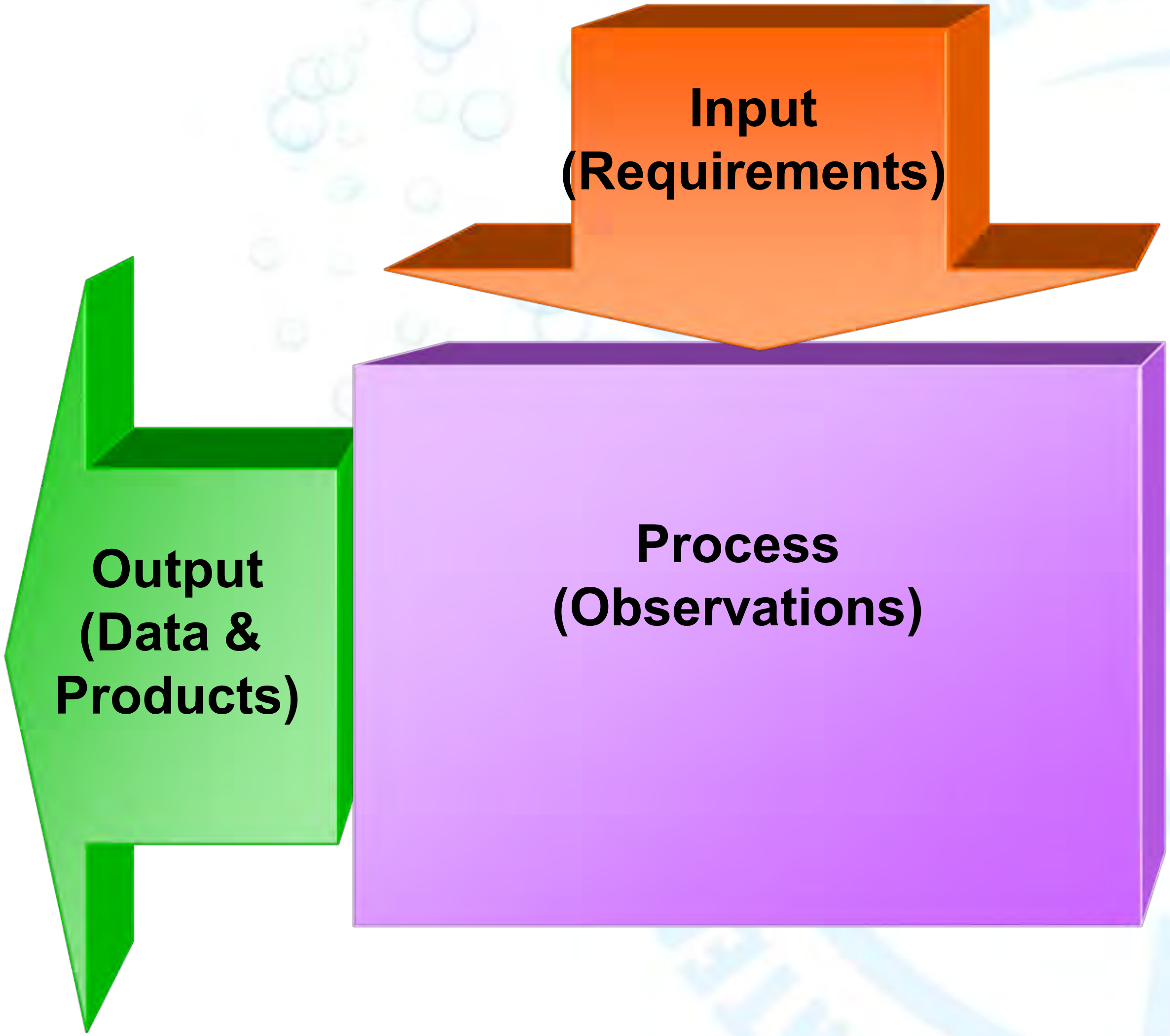
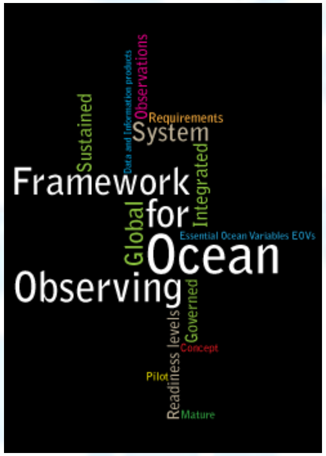
Framework for Ocean Observing

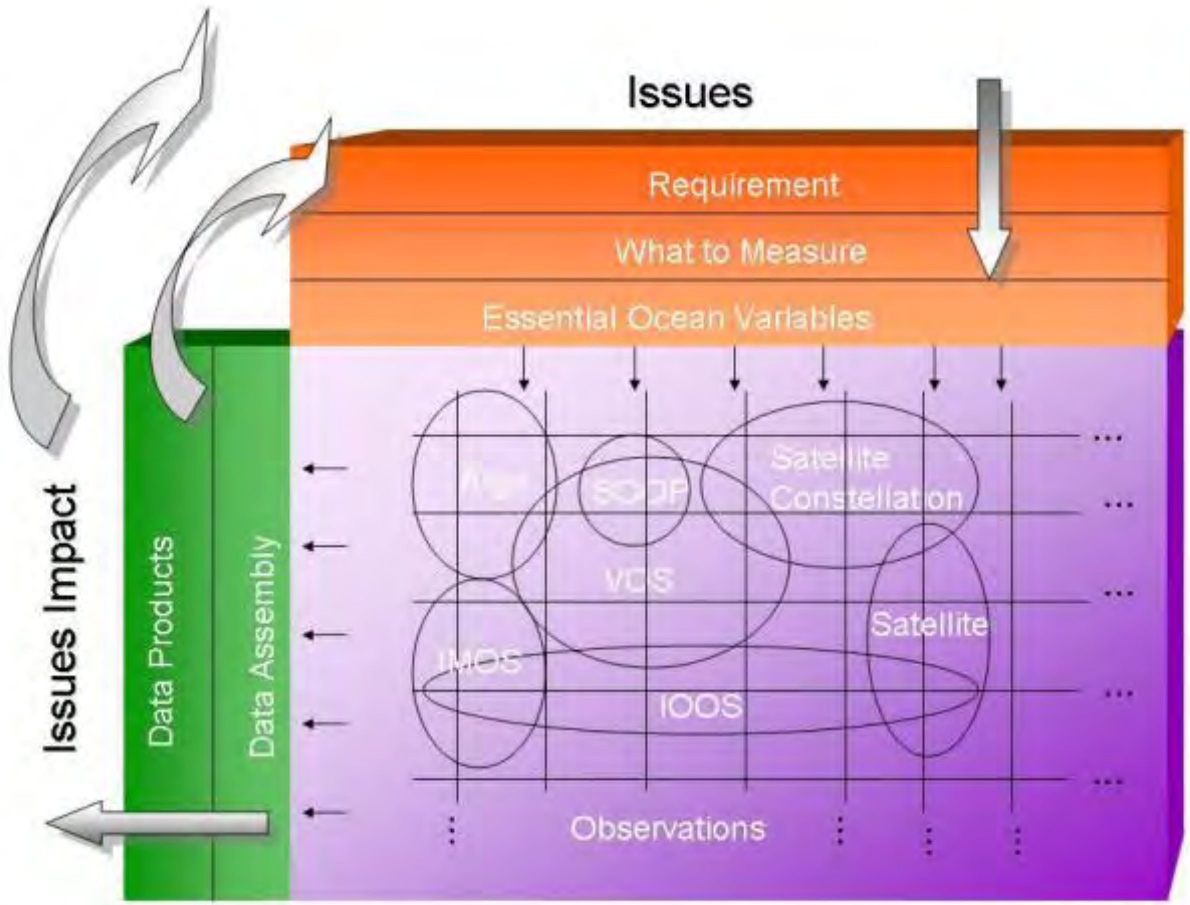
A simple system





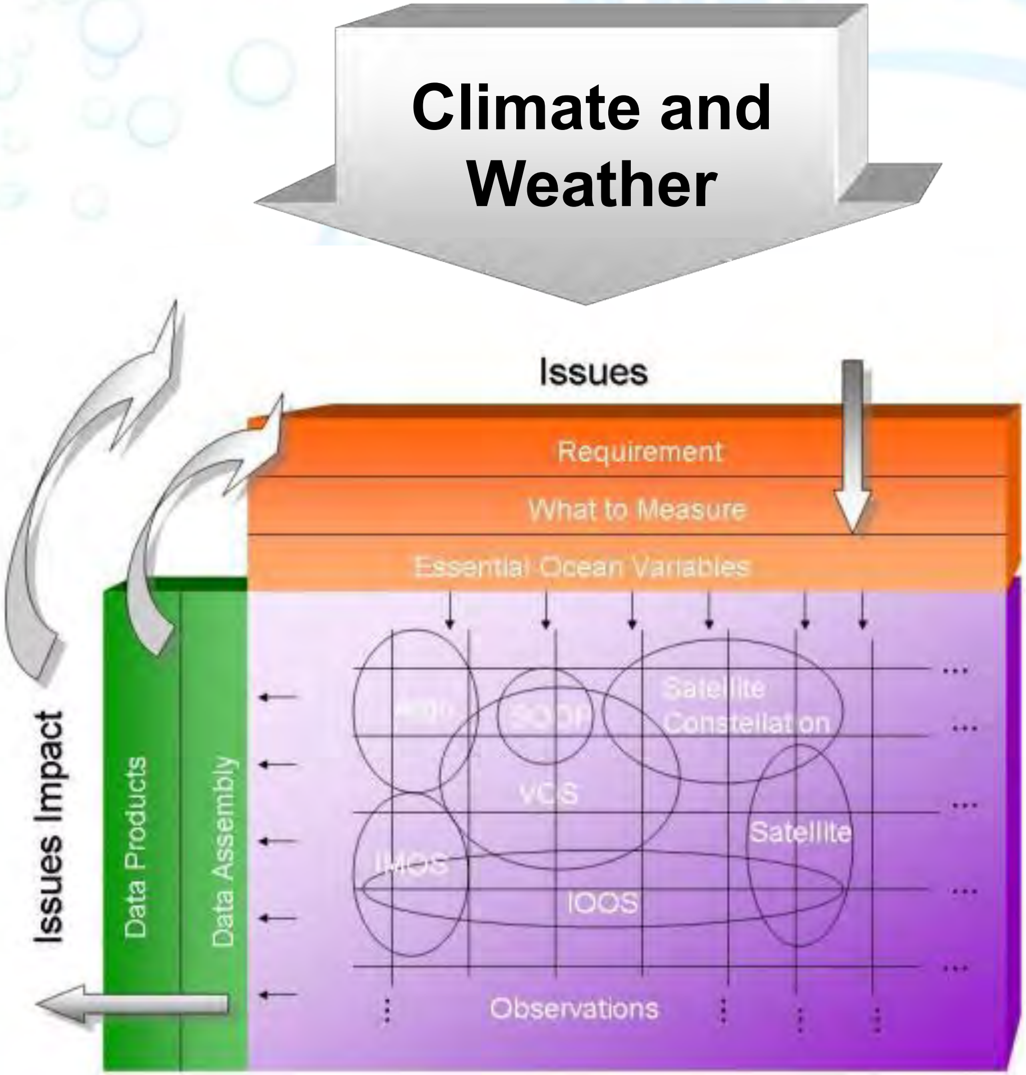
Framework for Ocean Observing

A simple system



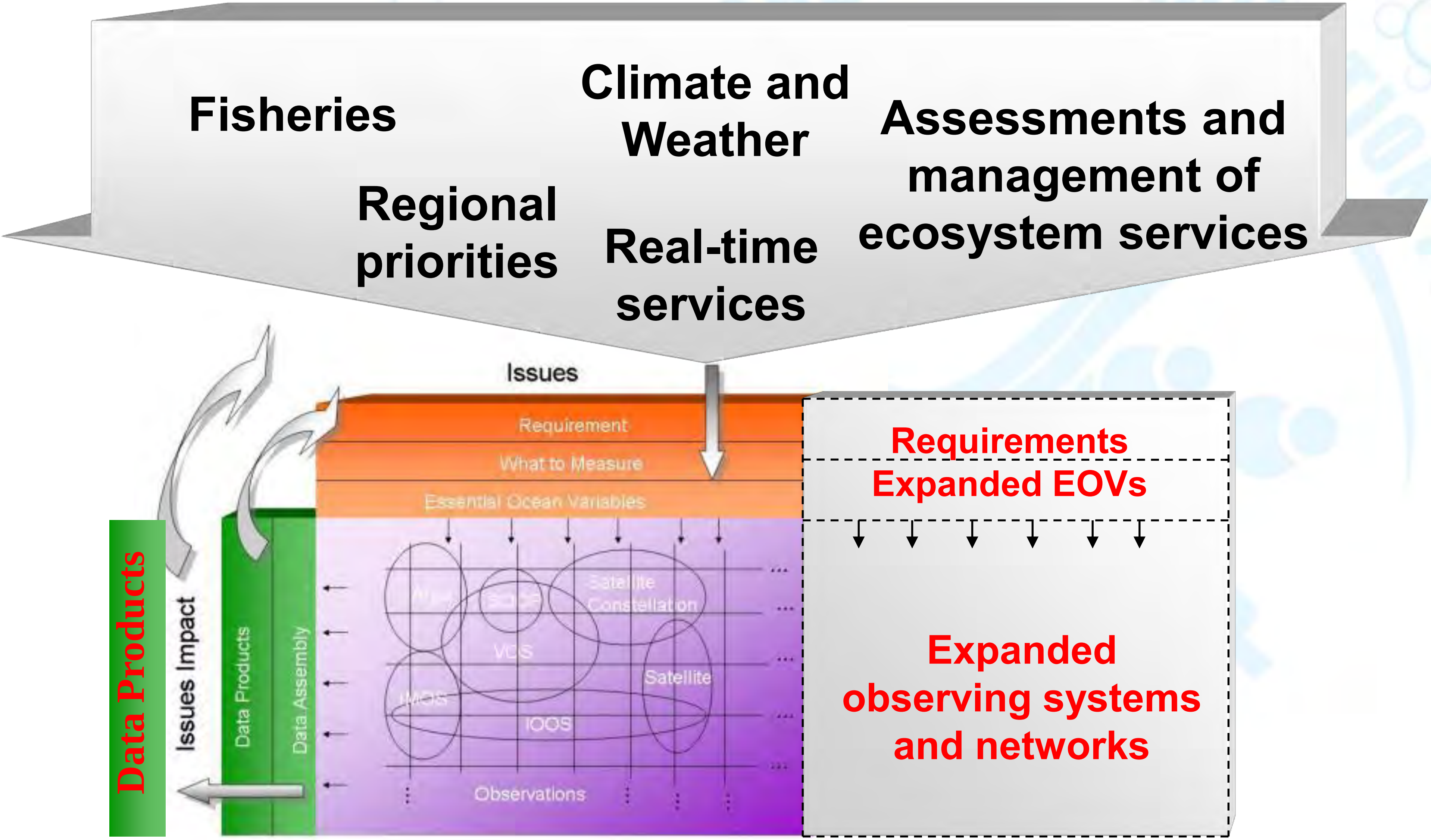
Framework for Ocean Observing

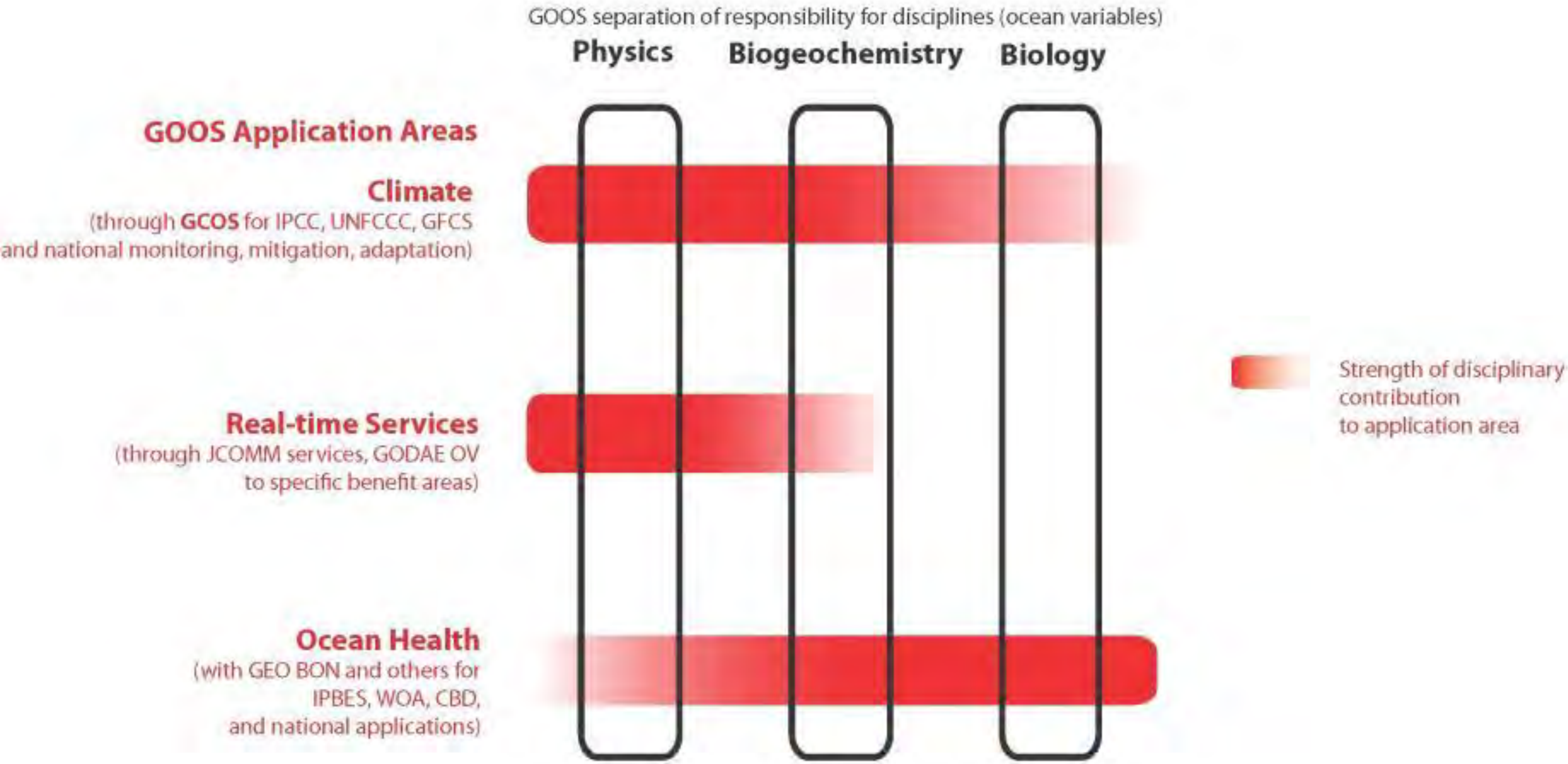
Societal drivers prior to OceanObs'09

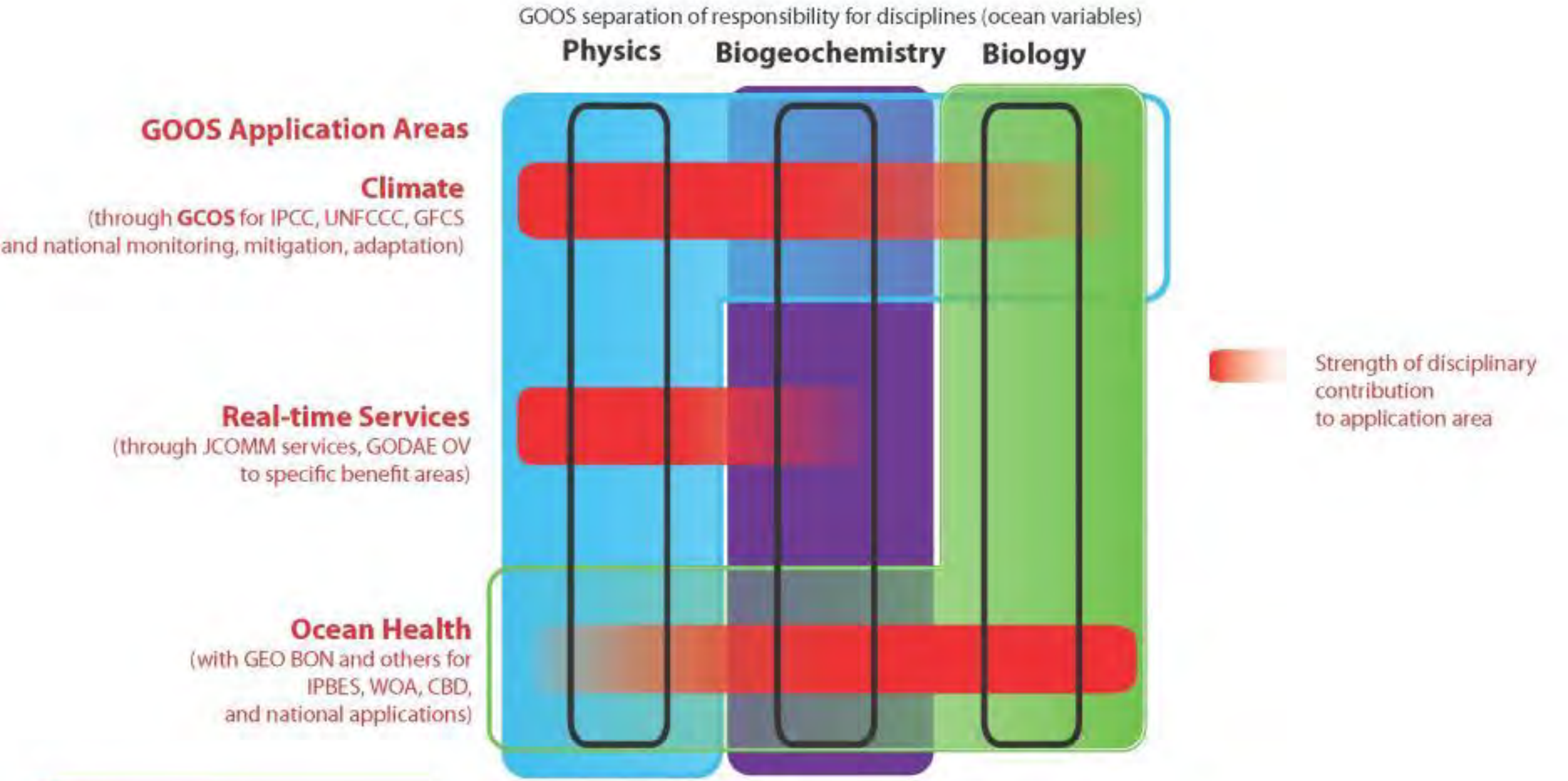


Framework for Ocean Observing

Societal and scientific drivers expanded




GOOS separation of responsibility for disciplines (ocean variables)
Physics
Biogeochemistry
Biology
GOOS Application Areas
Climate
(through GCOS for IPCC, UNFCCC, GFCS
and national monitoring, mitigation, adaptation)
Real-time Services
(through JCOMM services, GODAE OV
to specific benefit areas)
Ocean Health
(with GEO BON and others for
IPBES, WOA, CBD,
and national applications)
Strength of disciplinary
contribution
to application area

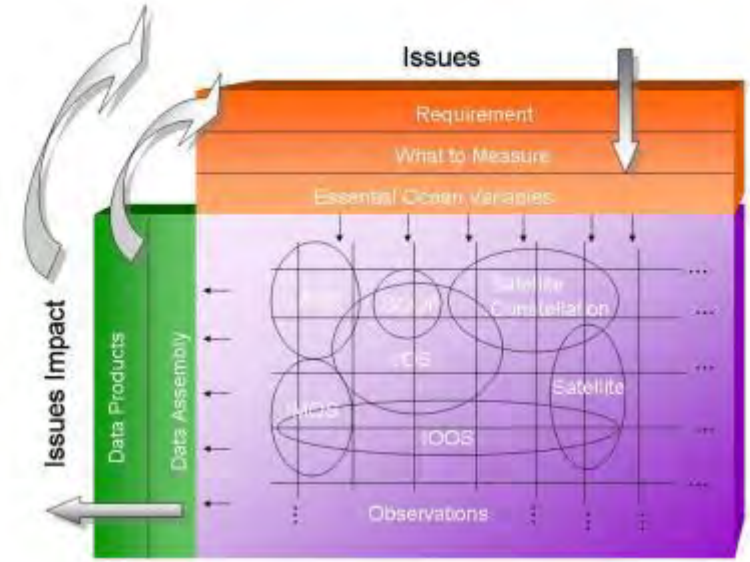


GCOS-GOOS-WCRP
OOPC: Panel for Physics variables, and
Climate Theme Lead
RT Services Theme Lead.
Ocean Health Theme Support

GOOS **Biogeochemistry**: Panel for Biogeochemical Variables and
Climate Theme Support
Ocean Health Theme Support

GOOS **Biology**: Panel for Biology Variables, and
Ocean Health Theme Lead
Climate Theme Support

Societal needs and scientific requirements for the global ocean observing system



Physics

- The ocean component of the earth's <u>energy balance and freshwater cycle</u>;
- The ocean ability to <u>redistribute key climate variables</u> and the change and variability of this circulation
- Ocean and <u>Ocean-Atmosphere exchange</u> as controls, driver, and mediator of major climate model. High, mid and low latitude <u>climate modes</u>
- <u>Severe climate</u> – sea level rise, coast inundation, wave and storm damage

Societal needs and scientific requirements

Biology and Ecosystem

International organizations / conventions*

U N D P

UNEP

FIAT PANIS

United Nations Educational, Scientific and Cultural Organization

OCEANS & LAW OF THE SEA UNITED NATIONS

United Nations Framework Convention on Climate Change

GEO GROUP ON EARTH OBSERVATIONS

SUSTAINABLE DEVELOPMENT GOALS

INTERNATIONAL SEABED AUTHORITY

IMO INTERNATIONAL MARITIME ORGANIZATION

TWAP TRANSBOUNDARY WATERS ASSESSMENT PROGRAMME

CMS

Convention on Biological Diversity

CAFF

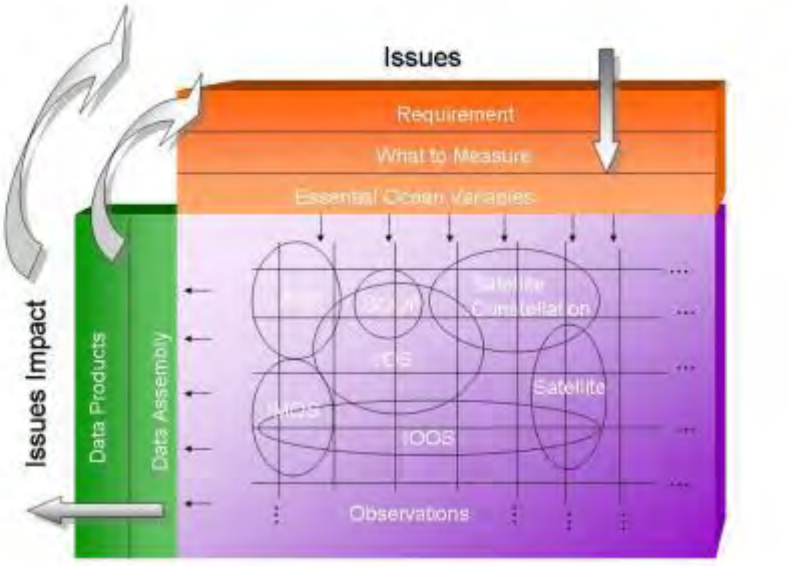
ipbes Science and Policy for People and Nature

CITES 1973-2013

CCAMLR Commission for the Conservation of Antarctic Marine Living Resources

Societal needs and scientific requirements

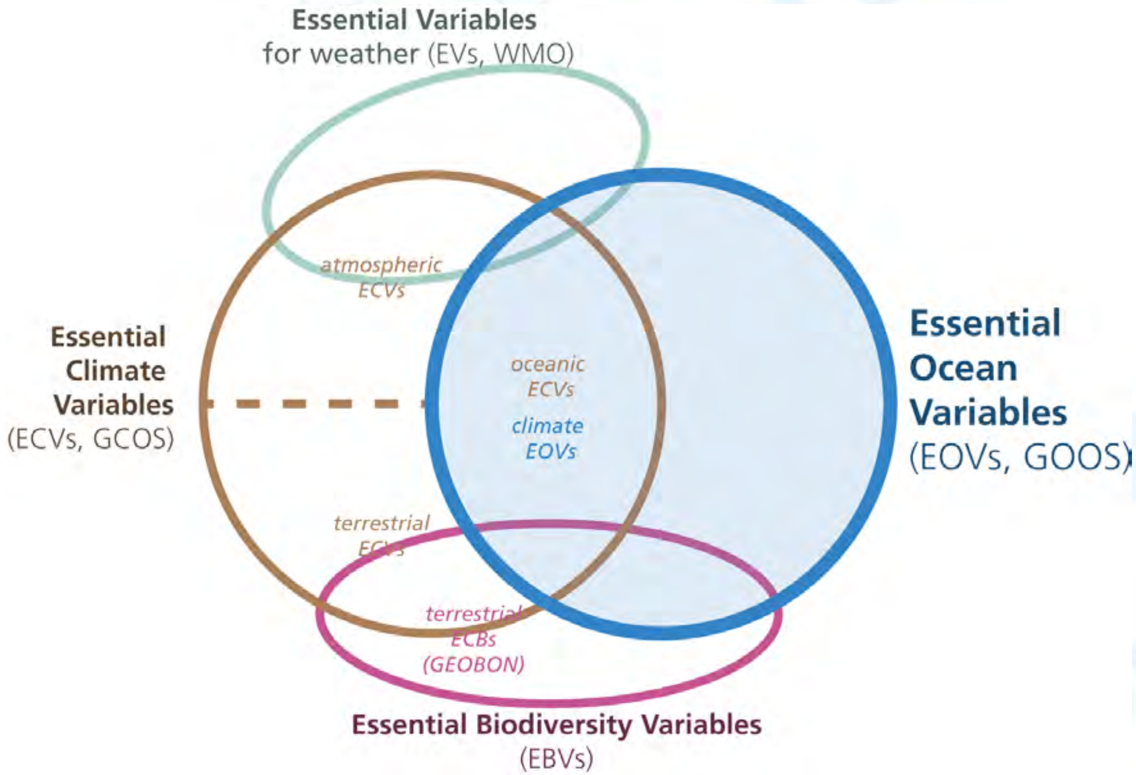
Biogeochemistry



- **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?**

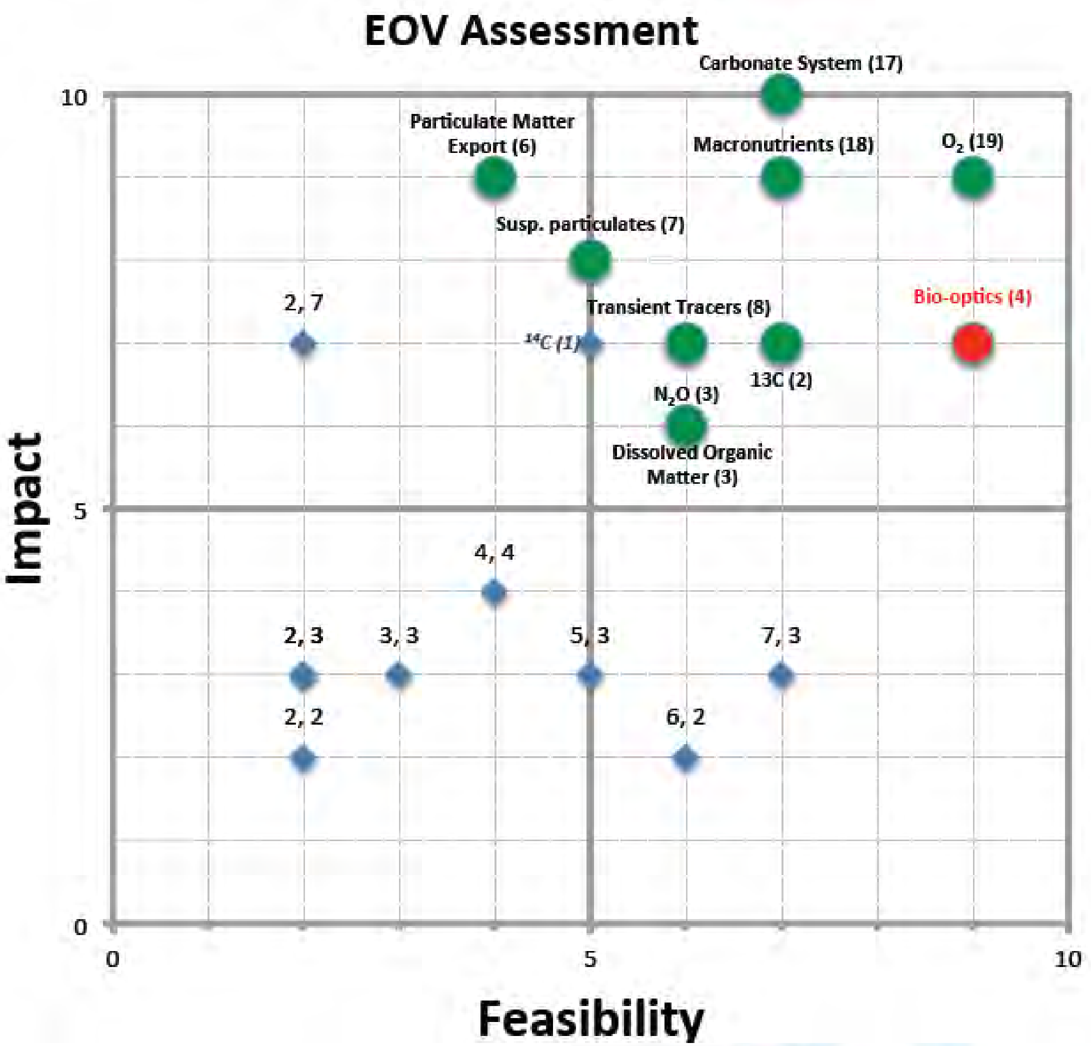
Driven by requirements, negotiated with feasibility

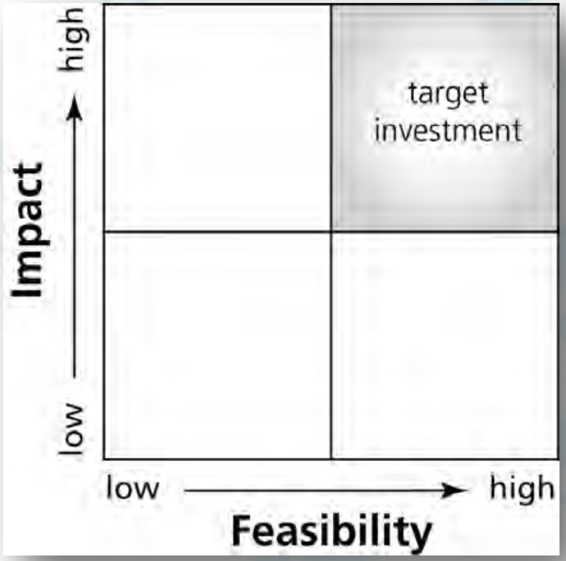
Essential Ocean Variables



- **We cannot measure everything, nor do we need to**
- **Driven by requirements, negotiated with feasibility**
- **Allows for innovation in the observing system over time**

Feasibility vs. Impact



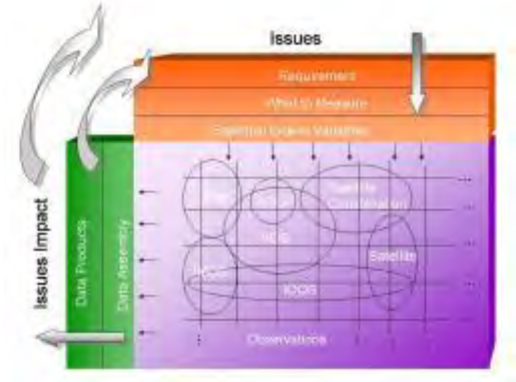


We cannot measure everything,

nor do we need to…

EOVs and readiness level

CONCEPT PILOT MATURE



Physics

- Sea State
- Ocean surface vector stress
- Sea Ice
- Sea level
- SST
- Subsurface temperature
- Surface currents
- Subsurface currents
- SSS
- Subsurface salinity

Biology and Ecosystems

- Phytoplankton biomass and productivity
- HAB incidence
- Zooplankton diversity
- Fish abundance and distribution
- Apex predator abundance and distribution
- Live coral cover
- Seagrass cover
- Mangrove cover
- Microalgal canopy cover

Biogeochemistry

- Oxygen
- Inorganic macro nutrients
- Carbonate system
- Transient tracers
- Suspended particulates
- Nitrous oxide
- Carbon isotope (^{13}C)
- Dissolved organic carbon

The Essential Ocean Variables Specification Sheets

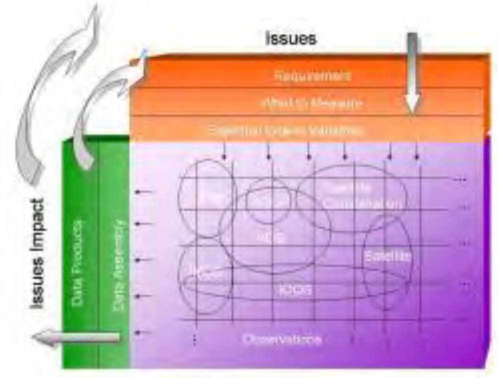


Table 1: EOV Information	
Name of EOV	Carbonate System
Sub-Variables	Dissolved Inorganic Carbon (DIC), Total Alkalinity (TA), Partial pressure of carbon dioxide (pCO_2) and pH; *[At least two of the four Sub-Variables are needed.]*
Derived Products	Saturation state (aragonite, calcite), Dissolved carbonate ion concentration, Air-sea flux of CO_2, Anthropogenic carbon, Change in total carbon
Supporting Variables	Temperature (T), Salinity (S), Wind speed, Atmospheric column-averaged dry-air mole fraction of CO2 (xCO_2), Barometric pressure (P), Oxygen (O_2), Nutrients, Calcium concentration, Transient tracers, Oxygen to argon ratio (O_2/Ar)
Contact and Lead Expert(s)	Contact: IOCCP Lead Experts: Ute Schuster (University of Exeter, United Kingdom), Masao Ishii (JMA-MRI, Japan), Richard Feely (NOAA PMEL, USA)

Combined performance of current and future networks (Carbonate system)

Table 3: Current Observing Networks*

Observing Network	Ship of Opportunity (SOO)	Repeat Hydrography (RH)	Surface Moorings (Msurf)	Drifters (D)	Ship-based Time-Series (STS)
Phenomena Addressed	1,3	2,3	1,3,4	1,3	1,3,4,5
Readiness Level of the Network (as defined in the FOO)	Mature	Mature	Mature	Mature	Mature
Spatial Scales Currently Captured by the Observing Network	Every 10°, Denser in the coastal domain, Surface	20°, Full depth	Local	Regional	Local
Typical Observing Frequency	Weekly to decadal	Decadal	Sub-daily to seasonal and annual	Hourly to annual	Weekly to decadal
Supporting Variables Measured	Atmospheric / ocean pCO_2, T, S, Desired: TA or DIC (pH)	DIC, TA, pH, pCO_2	T, S, Wind speed, P, Atmospheric CO_2	T,S	Wind speed, TA/DIC , Atmospheric and ocean pCO_2
Sensor(s)/Technique	Equilibrator, Permeable membrane, Infra-red, CRDS	Benchtop instruments	Equilibrator, Permeable membrane	Spectro-photometric	Titration, equilibrator
Accuracy/Uncertainty Estimate (units)	pCO_2 ±2 µatm	TA/DIC ±2 µmol kg^{-1} pH ±0.005 pCO_2 ±2 µatm	pCO_2 ±5 µatm	pCO_2 ±5 µatm pH ±0.005	TA/DIC ±2 µmol kg^{-1} pH ±0.005 pCO_2 ±2 µatm
Reporting Mechanisms(s)	GOOS Implementation Plan (?) IOCCP Report				

*By an Observing Network we understand a number of reasonably well coordinated observing platforms equipped with technology allowing measurements of this particular EOV.

Table 4: Future Observing Networks

Observing Network	Profiling Floats (PF)	Surface gliders (Gsurf)	Subsurface moorings (Msubsurf)	Subsurface gliders (Gsubsurf)	Extended Ships Of Opportunity (ExtSOO)
Phenomena Addressed	?	?	?	?	?
Readiness Level of the Observing Network (as defined in the FOO)	<u>pH</u> Pilot <u>pCO_2</u> Conceptual <u>DIC</u> Conceptual <u>TA</u> Conceptual	<u>pCO_2</u> Pilot <u>pH</u> Pilot	Conceptual	Conceptual	<u>pCO_2</u> Mature <u>Underway DIC/TA</u> ? <u>Underway pH</u> ?
Spatial Scales Captured by the Observing Network	Every 10°, Denser in the coastal domain, Surface	20°, Full depth	1 km	10-1000 km	Every 10°, Denser in the coastal domain, Surface
Typical Observing Frequency	Weekly to annual	Daily to monthly	Sub-daily to seasonal and annual	Daily to monthly	Weekly to annual
Time-Scale Until Part of Observing System					
Supporting Variables Measured	pH, pCO_2, DIC, TA	pCO_2, pH	pH, pCO_2	pH, pCO_2	pH, pCO_2, DIC, TA
Sensor(s)/Technique	Spectro-photometry Variety of sensors are being developed	Spectro-photometry & Equilibrator Very dynamic field, variety of sensors are being developed	Permeable membrane Very dynamic field, variety of sensors are being developed	Spectro-photometry Very dynamic field, variety of sensors are being developed	<u>DIC</u> NDIR (?CRDS) <u>pCO_2</u> Equilibrator <u>pH</u> Permeable membrane

Networks*

	Ship of [O]pportunity (SOO)	Repeat Hydrography (RH)	Surface Moorings (Msurf)	Drifters (D)	Ship-based Time-Series (STS)
	1,3	2,3	1,3,4	1,3	1,3,4,5
	Mature	Mature	Mature	Mature	Mature
	[E]very 10°, [D]enser in the [coa]stal domain, Surface	20°, Full depth	Local	Regional	Local
	[Wee]kly to decadal	Decadal	Sub-daily to seasonal and annual	Hourly to annual	Weekly to decadal
	[At]mospheric / [oce]an pCO_2, T, S, [desi]red: TA or DIC (pH)	DIC, TA, pH, pCO_2	T, S, Wind speed, P, Atmospheric CO_2	T,S	Wind speed, TA/DIC, Atmospheric and ocean pCO_2
	[E]quilibrator, [P]ermeable [mem]brane, Infra-[red], CRDS	Benchtop instruments	Equilibrator, Permeable membrane	Spectro-photometric	Titration, equilibrator
	<u>pCO_2</u> ±2 µatm	<u>TA/DIC</u> ±2 µmol kg^{-1} <u>pH</u> ±0.005 <u>pCO_2</u> ±2 µatm	<u>pCO_2</u> ±5 µatm	<u>pCO_2</u> ±5 µatm <u>pH</u> ±0.005	<u>TA/DIC</u> ±2 µmol kg^{-1} <u>pH</u> ±0.005 <u>pCO_2</u> ±2 µatm
	GOOS Implementation Plan (?) IOCCP Report				

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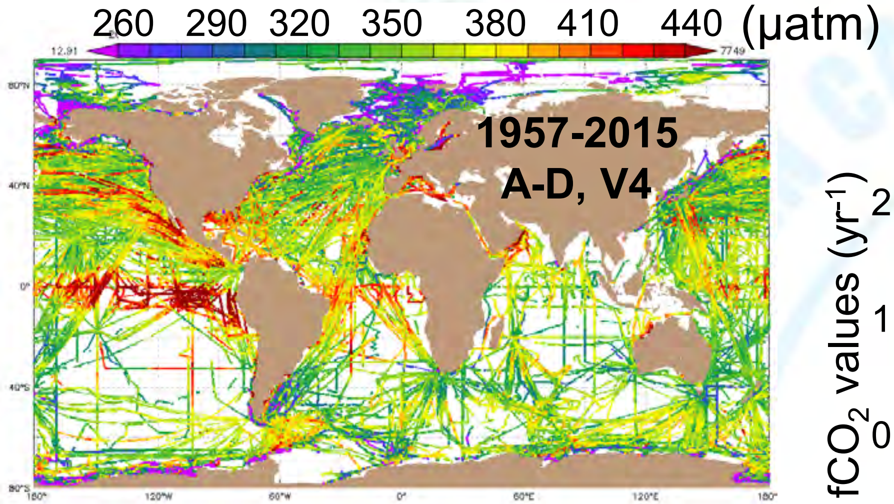
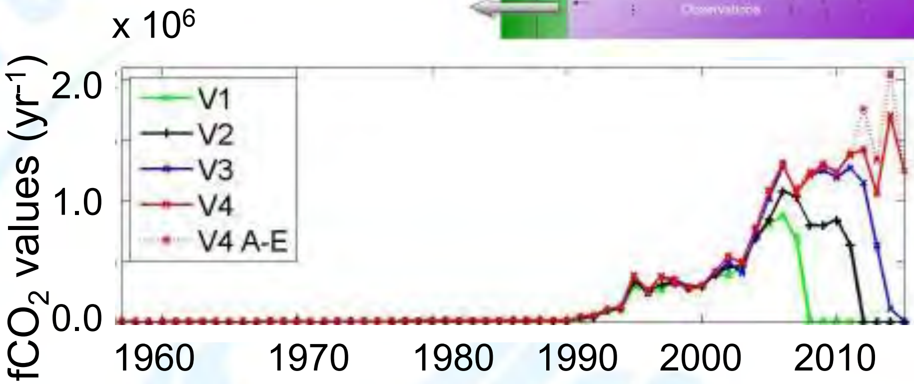
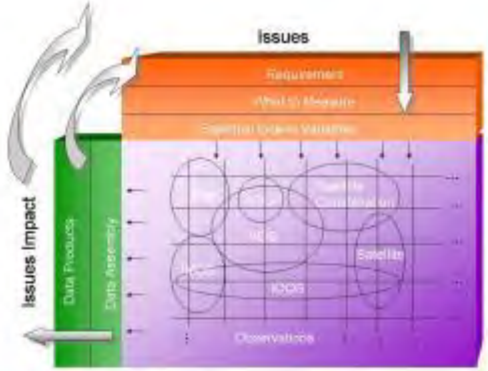
Surface Ocean CO_2 Atlas (version 4)

public on 1 September 2016







Global synthesis and gridded products of surface ocean fCO_2

- in uniform format with quality control;
- V4: 18.5 million fCO_2 values, accuracy < 5 µatm from 1957-2015 (flags of A-D);
- Plus calibrated sensor data (< 10 µatm, flag of E);
- Interactive online viewers;
- Downloadable (text, NetCDF, ODV, Matlab);
- Documented in ESSD articles;
- Community activity with >100 contributors worldwide.

www.socat.info

Bakker et al. (2016) ESSD

Ocean Interior Data Synthesis

Endelig!

Finalmente!

最終的に

Schließlich!

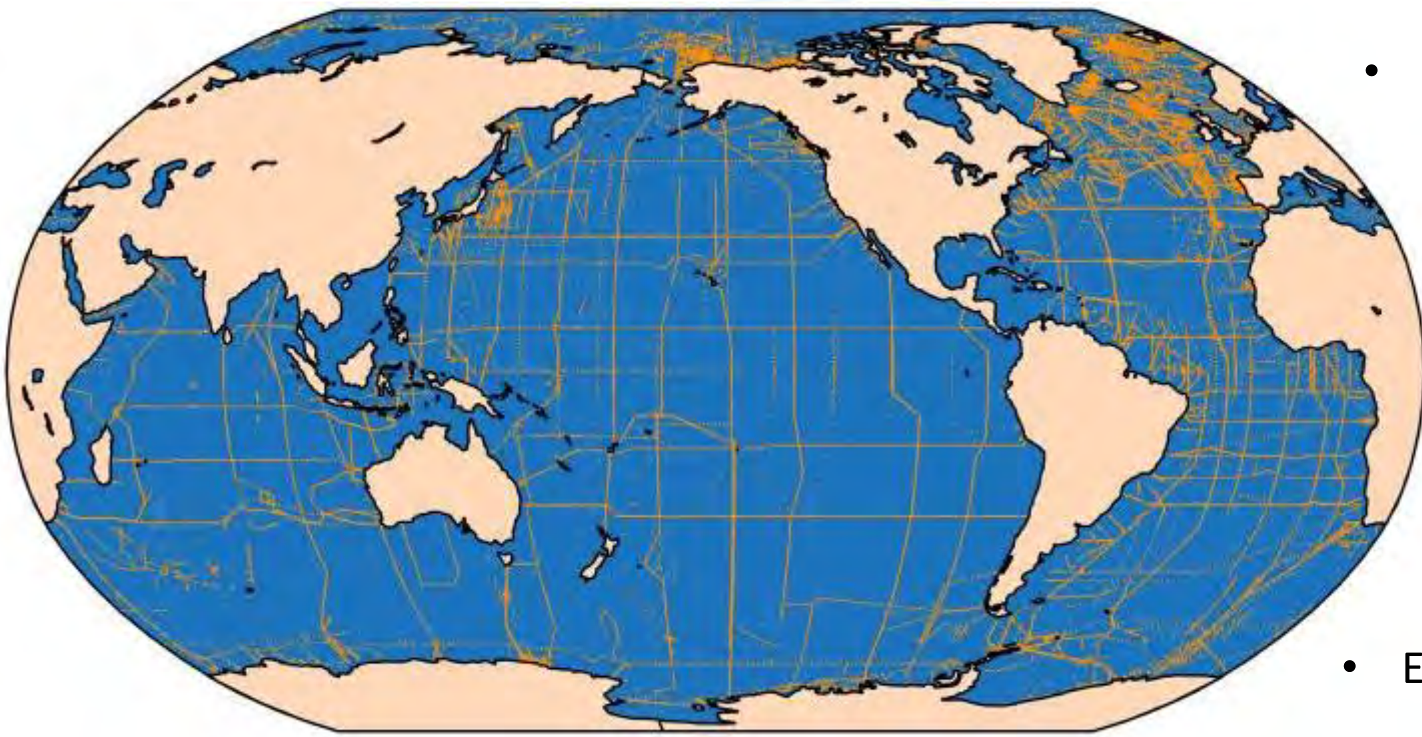
Hopea!

Finally!

Äntligen!

Wreszcie!

glodap v2



- A global collection of CO_2 relevant data from 724 cruises
- 45 306 stations
- 999 488 sampling depths
- 1972 -2013 GEOSECS-TTO-WOCE-CLIVAR
- Corrected for biases
- Extensively documented
- **Released Jan 19. 2016**

Ocean Acidification

GOA-ON
Global Ocean Acidification Observing Network

Ocean Acidification Data Portal

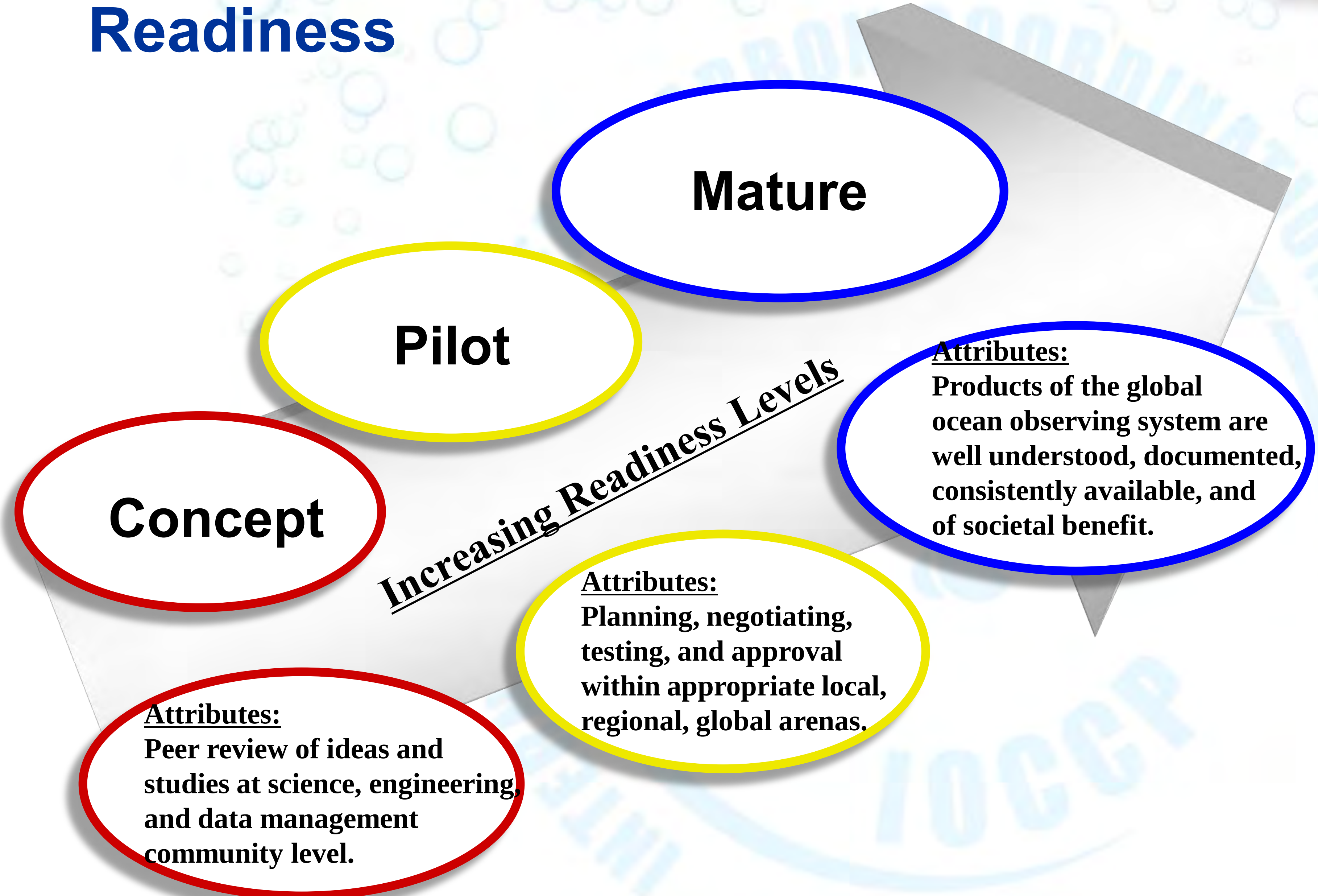
A small technical working group lead by Benjamin Pfeil (IOCCP Data Manager) was established to investigate possibilities to create a dedicated portal for ocean acidification observing data. A workplan and initial goals of this group were turned into an agenda for a small workshop held in Monaco in June 2015. The group works on the report that will incorporate the recommendations made by the OA-ICC Advisory Board, the GOA-ON Executive Council and workshop participants. This document will be distributed across the community for comments and will serve as a baseline for a data portal implementation plan, which will be hopefully developed before May 2016.

Ocean Acidification Data Synthesis Products

As a global approach similar to SOCAT was deemed not feasible at the moment for such a fragmented and mostly coastal community, it was suggested that effort might initially be directed at a regional synthesis for the western Pacific (primarily involving China, Taiwan, Japan and Rep Korea), and for the NE Atlantic/European seas (expanding on a UK/North Sea synthesis that has just been finished by NERC/Defra and ICES).

Towards sustained system: requirements, observations, data management

Readiness



Towards … a management

Read…

FRAMEWORK PROCESSES BY READINESS LEVELS

Readiness Levels	Requirements Processes	Coordination of Observational Elements	Data Management & Information Products
Mature			
Level 9 "Sustained"	Essential Ocean Variable: • Adequate sampling specifications • Quality specifications	System in Place: • Globally • Sustained indefinitely • Periodic review	Information Products Routinely Available: • Product generation standardized • User groups routinely consulted
Level 8 "Mission qualified"	Requirements "Mission Qualified:" • Longevity/stability • Fully scalable	System "Mission Qualified:" • Regional implementation • Fully scalable • Available specifications and documentation	Data Availability: • Globally available • Evaluation of utility
Level 7 "Fitness for purpose"	Validation of Requirements: • Consensus on observation impact • Satisfaction of multiple user needs • Ongoing international community support	Fitness-for-Purpose of Observation: • Full-range of operational environments • Meet quality specifications • Peer review certified	Validation of Data Policy • Management • Distribution
Pilot			
Level 6 "Operational"	Requirement Refined: • Operational environment • Platform and sensor constraints	Implementation Plans Developed: • Maintenance schedule • Servicing logistics	Demonstrate: • System-wide availability • System-wide use • Interoperability
Level 5 "Verification"	Sampling Strategy Verified: • Spatial • Temporal	Establish: • International commitments and governance • Define standardized components	Verify and Validate Management Practices: • Draft data policy • Archival plan
Level 4 "Trial"	Measurement Strategy Verified at Sea	Pilot project in an operational environment	Agree to Management Practices: • Quality control • Quality assurance • Calibration • Provenance
Concept			
Level 3 "Proof of concept"	Proof of Concept via Feasibility Study: • Measurement strategy • Technology	Proof of Concept Validated: • Technical review • Concept of operations • Scalability (ocean basin)	Verification of Data Model with Actual Observational Unit
Level 2 "Documentation"	Measurement Strategy Described • Sensors • Sensitivity • Dependencies	Proof of Concept: • Technical capability • Feasibility testing • Documentation • Preliminary design	Socialization of Data Model • Interoperability strategy • Expert review
Level 1 "Idea"	Environment Information Need and Characteristics Identified: • Physical • Chemical • Biological	System Formulation: • Sensors • Platforms • Candidate technologies • Innovative approaches	Specify Data Model • Entities, Standards • Delivery latency • Processing flow

Figure 9. A Detailed View of Framework Processes for Varying Levels of Readiness.

Conc…

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…rving system are
…stood, documented,
…y available, and
…benefit.

Attribu…
Peer rev…
studies …
and dat…
commu…

THANK YOU!

The Global Ocean Observing System

Institute of Oceanology of Polish Academy of Sciences, ul. Powstańców Warszawy 55, 81-712 Sopot, Poland
Phone: +48 58 731 16 10 / Fax: +48 58 551 21 30, **www.ioccp.org**