Requirements-driven global ocean observing system for Ocean Acidification

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Biogeochemistry Panel

GOA-ON
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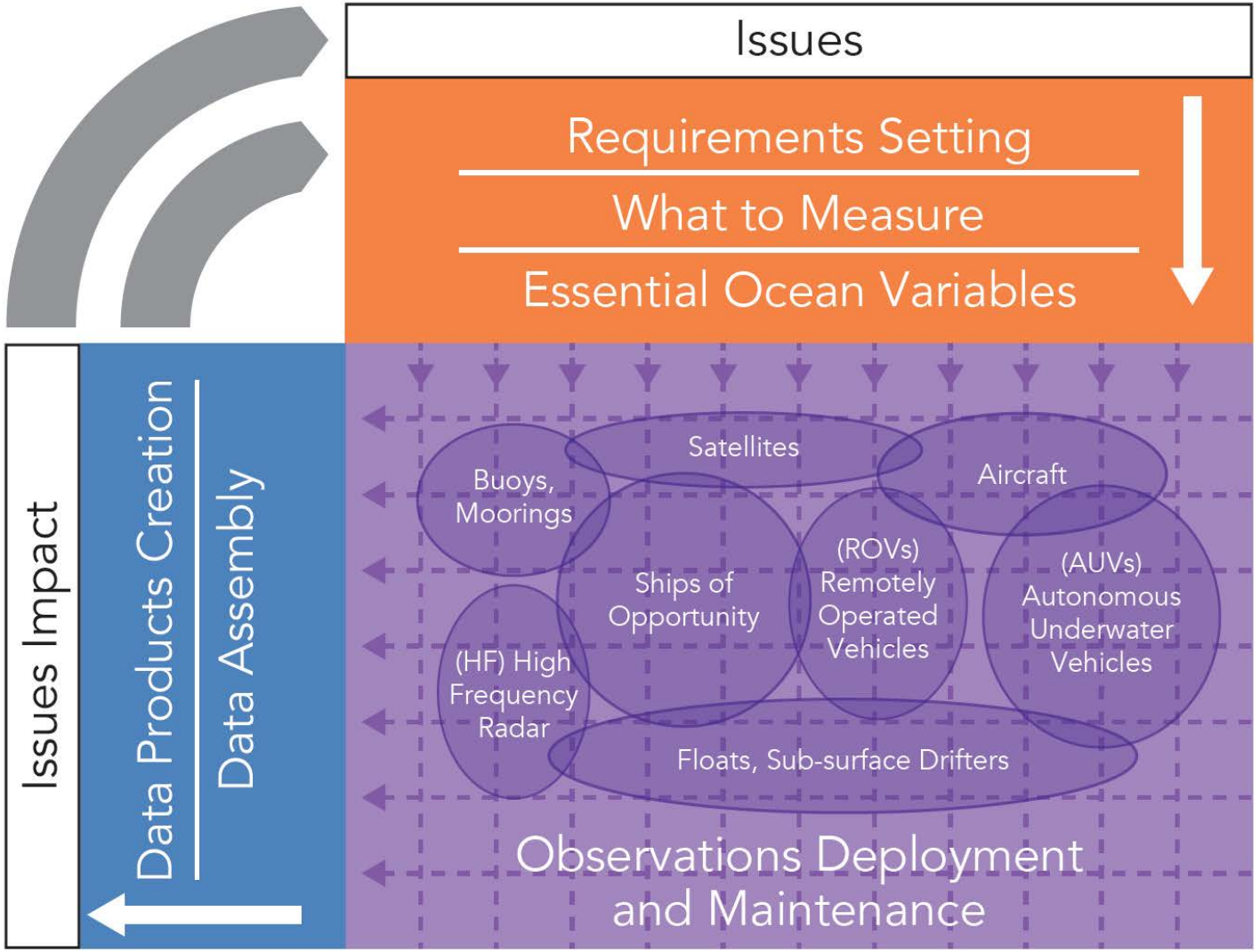
Biogeochemistry Panel

Framework for Ocean Observing Process Diagram



United Nations Educational, Scientific and Cultural Organization

Intergovernmental Oceanographic Commission

14 LIFE BELOW WATER

17 objectives to transform our world: Agenda 2030 (September 2015, New York)

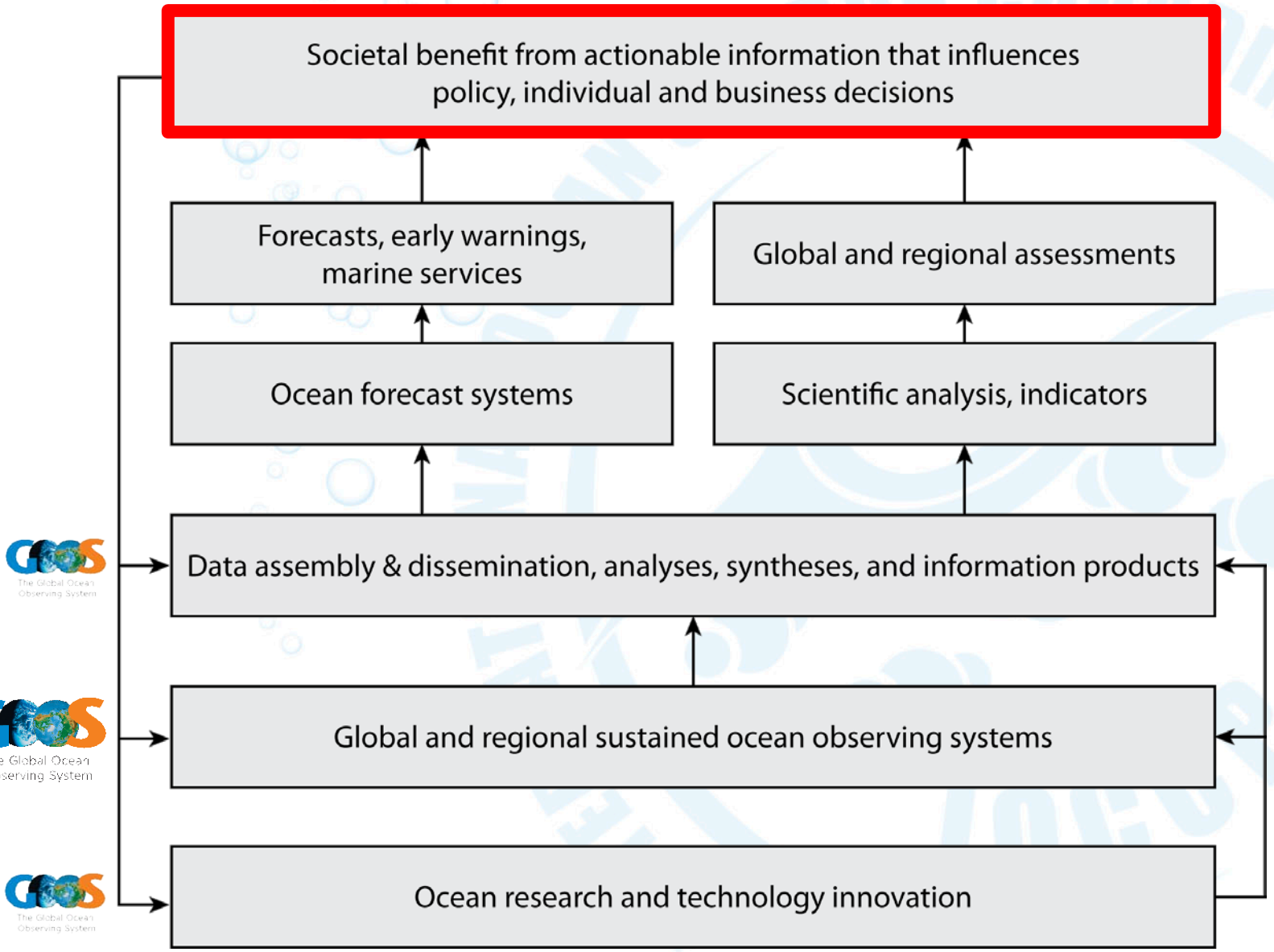
- After years of work and negotiations, the Paris Climate Agreement was signed on 12 December 2015, marking a historic moment for the Planet.
- For the first time, the mention of the ocean as an ecosystem vital for the climate is a symbolic victory for all involved advocates and stakeholders. Many organizations and individuals have worked for many years creating the momentum required for this recognition.
- Appearing in the preamble of the final text ***("noting that it is important to ensure the integrity of all ecosystems, including oceans…"***) which is not however a binding part of the agreement, this reference is sign of a global awareness of the oceans' major role in climate change. This awareness is also reflected at the level of heads of state and national delegations with the signing of the declaration 'Because The Ocean'.

The S&T Ministers of the G7 and the EU met in May 2016 to discuss science, technology and innovation aspects across global challenges such as health, energy, agriculture and the environment. They issued a Communiqué:

- Support the development of an initiative for **enhanced global sea and ocean observation** required to monitor inter alia climate change and marine biodiversity,
- Support an enhanced system of ocean assessment through the UN Regular Process to develop a consensus view on the state of the oceans and enable **sustainable management strategies** to be developed and implemented
- Promote open science and the improvement of the global data sharing infrastructure to ensure the discoverability, accessibility, and interoperability of a wide range of ocean and marine data;
- Strengthen collaborative approaches to encourage the development of **regional observing capabilities** and knowledge networks in a coordinated and coherent way, including supporting the capacity building of developing countries; and
- Promote increased G7 political cooperation by identifying additional actions needed to enhance **future routine ocean observations**.

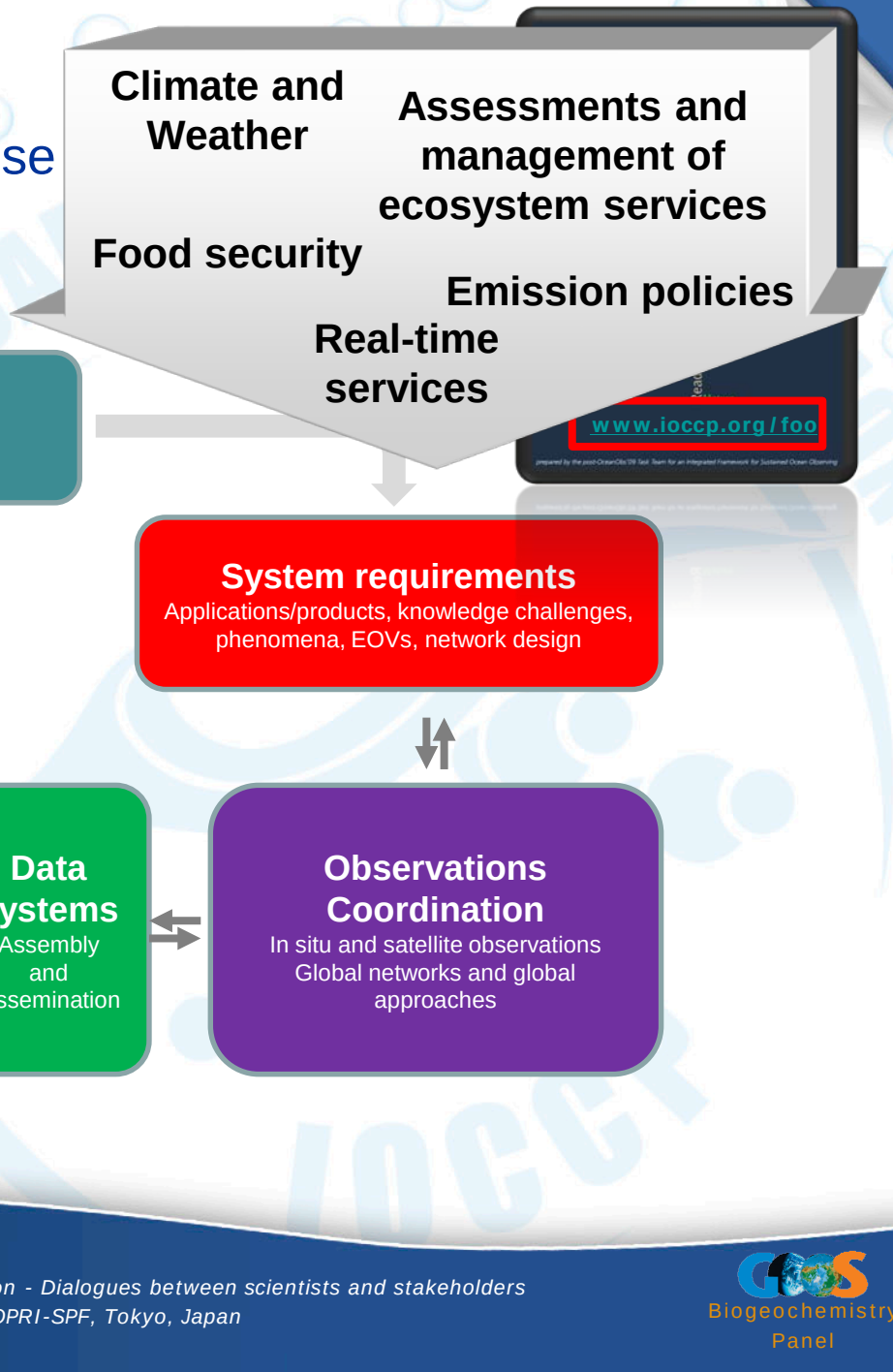
Societal benefit value chain

Adapted from G7 Think Piece on Ocean Observations

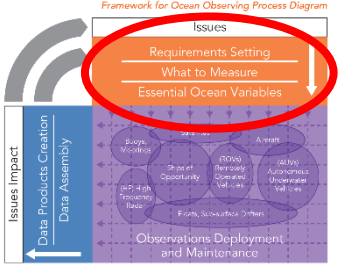


System

A schematic of a sustained fit-for-purpose system, including the full value chain



Requirements for GOOS Biogeochemistry

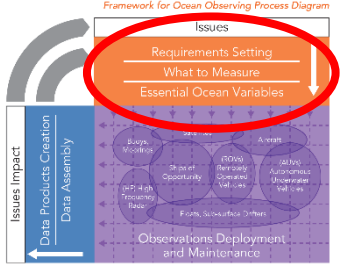


- **The role of ocean biogeochemistry in climate**
  - **Q1.1 How is the ocean carbon content changing?**
  - **Q1.2 How does the ocean influence cycles of non-CO_2 greenhouse gases?**

- **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?**

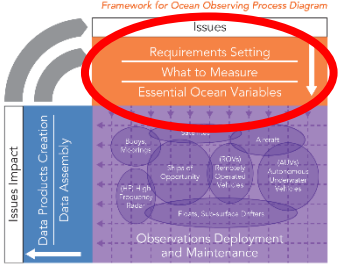
- **Ocean ecosystem health**
  - **Q3.1 Is the biomass of the ocean changing?**
  - **Q3.2 How does eutrophication and pollution impact ocean productivity and water quality?**

GOOS Phenomena - Biogeochemistry



- ANTHROPOGENIC CARBON SEQUESTRATION
- AIR-SEA FLUXES
- LAND-SEA FLUXES
- VENTILLATION
- OCEAN ACIDIFICATION
- EUTROPHICATION
- CIRCULATION
- DEOXYGENATION
- CONTAMINATION /POLLUTION
- PRIMARY PRODUCTION
- UPWELLING
- BENTHIC FLUXES
- REMINERALI-ZATION
- STORAGE / INVENTORY
- EXPORT FLUXES
- CALCIFICATION

GOOS Essential Ocean Variables



Physics & Climate

- Sea State
- Ocean Surface Stress
- Sea Ice
- Sea Surface Height
- Sea Surface Temperature
- Subsurface Temperature
- Surface Currents
- Subsurface Currents
- Sea Surface Salinity
- Subsurface Salinity
- Ocean Surface Heat Flux

Biogeochemistry

- Oxygen
- Nutrients
- Inorganic Carbon
- Transient Tracers
- Particulate Matter
- Nitrous Oxide
- Stable Carbon Isotopes
- Dissolved Organic Carbon
- Ocean Colour

Biology & Ecosystems

- Phytoplankton Biomass & Diversity
- Zooplankton Biomass & Diversity
- Fish Abundance & Distribution
- Marine Turtles, Birds, Mammals Abundance & Distribution
- Hard Coral Cover & Composition
- Seagrass Cover
- Macroalgal Canopy
- Mangrove Cover
- Microbe Biomass & Diversity
- Benthic Invertebrate Abundance & Distribution

Emerging EOVs

EOV Specification Sheets:
www.goosocean.org/eov
www.ioccp.org/foo

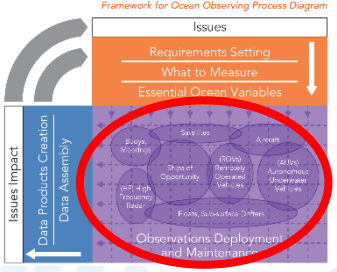
GLOBAL OCEAN OBSERVING SYSTEM

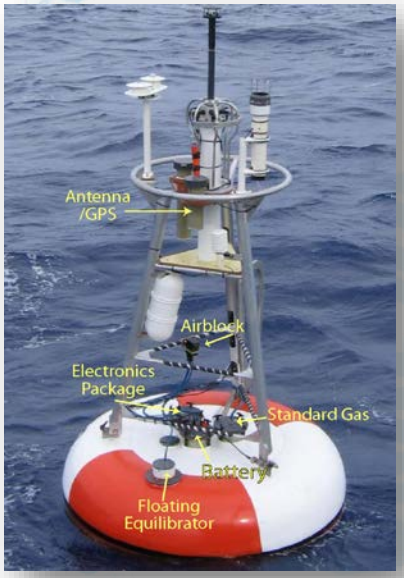
www.ioc-goos.org

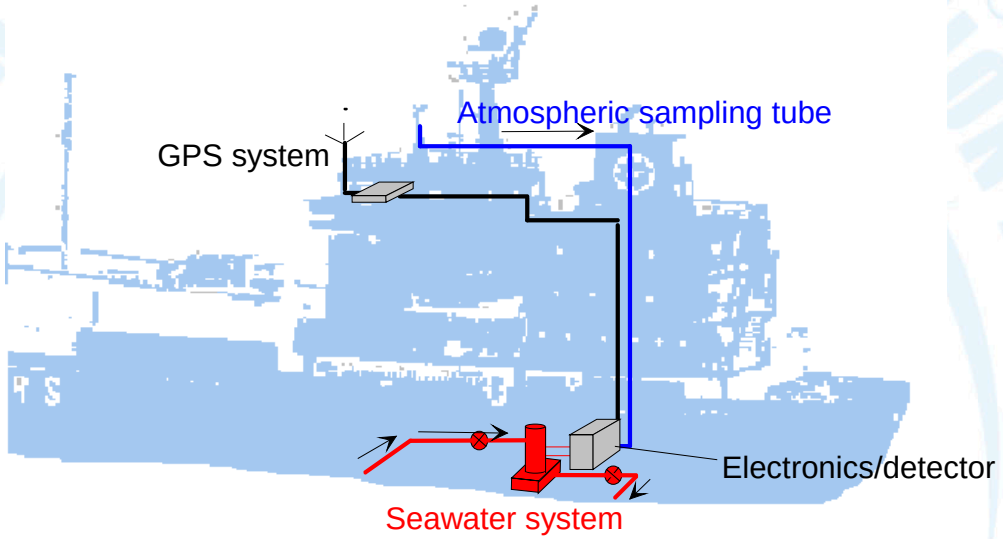
The oceans are the basis of the life support system. GOOS measures ocean warming and provides an opportunity for the human system to respond.

soconet

• SURFACE OCEAN CO_2 OBSERVING NETWORK •





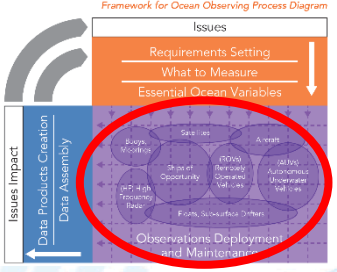


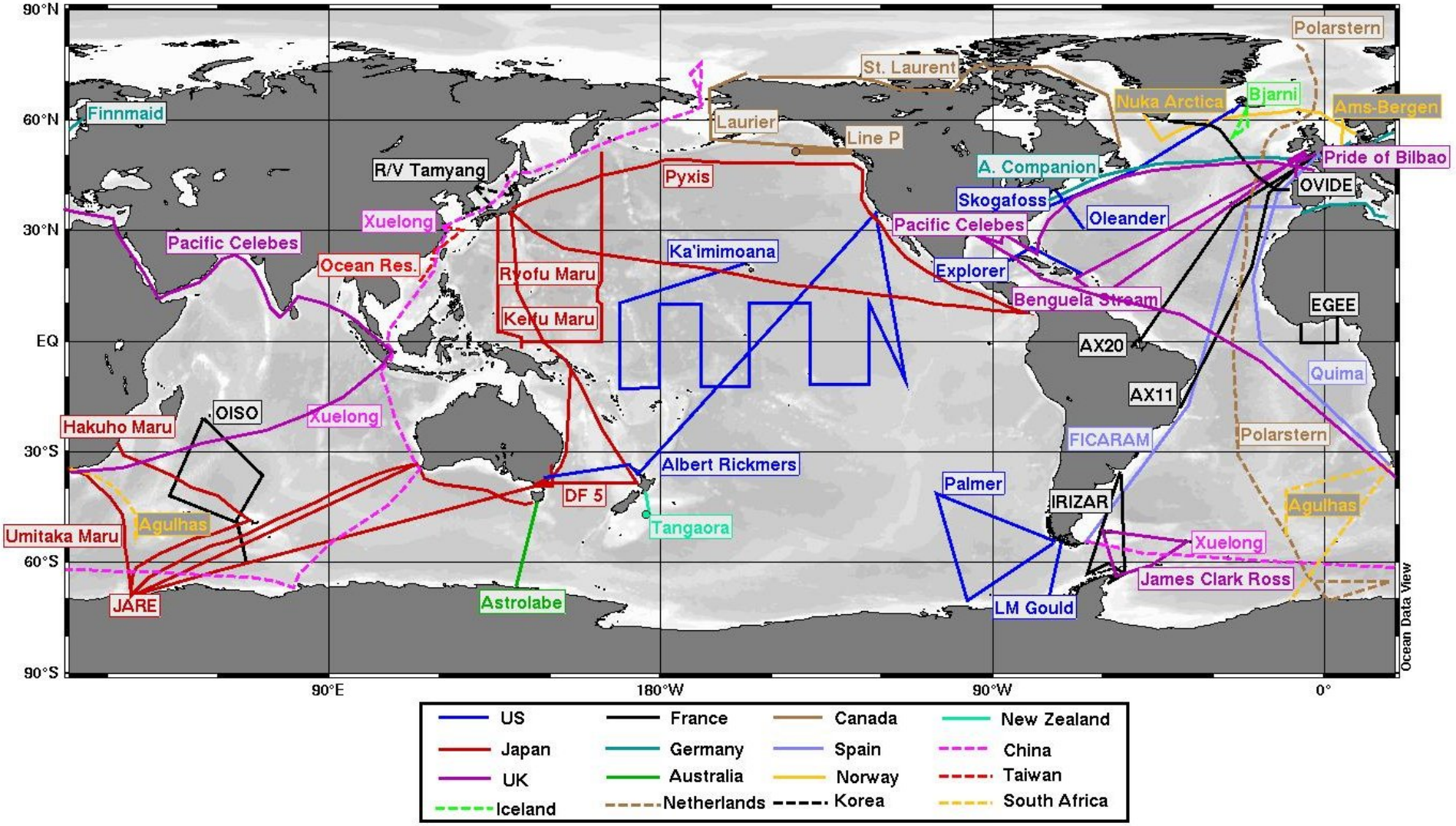
SOCONET:

- **Surface ocean CO_2 measurements** from moving and fixed platforms (With other parameters in concept and pilot phase pH, TA, DIC);
- **Atmospheric CO_2** from some data originators (discussions with GAW);
- Checked sea surface temperature and salinity as well as other BGC parameters (oxygen, nutrients)

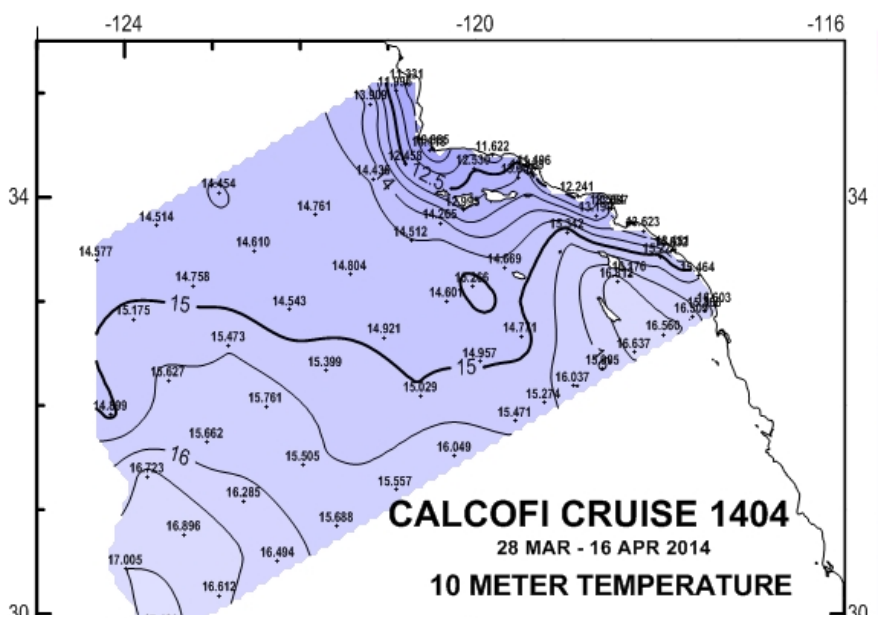
SOCONET

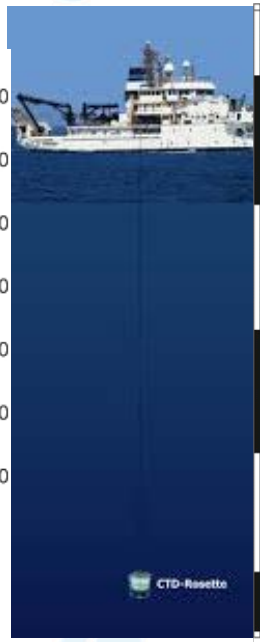
• SURFACE OCEAN CO_2 OBSERVING NETWORK •

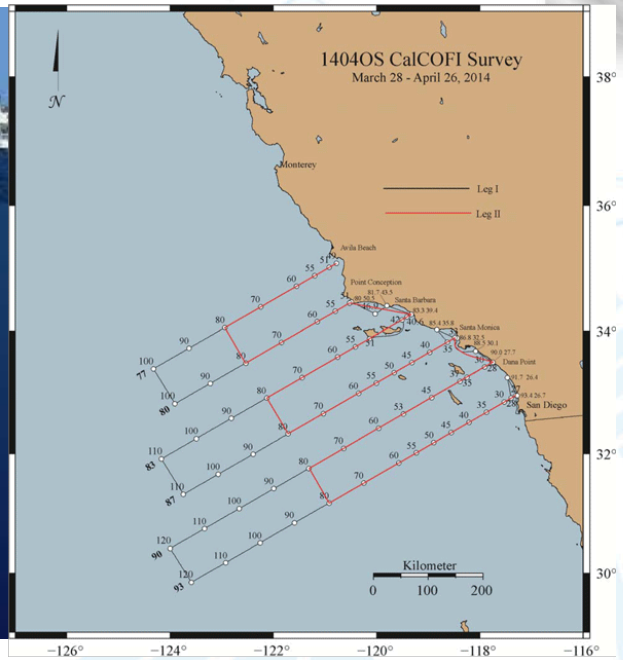


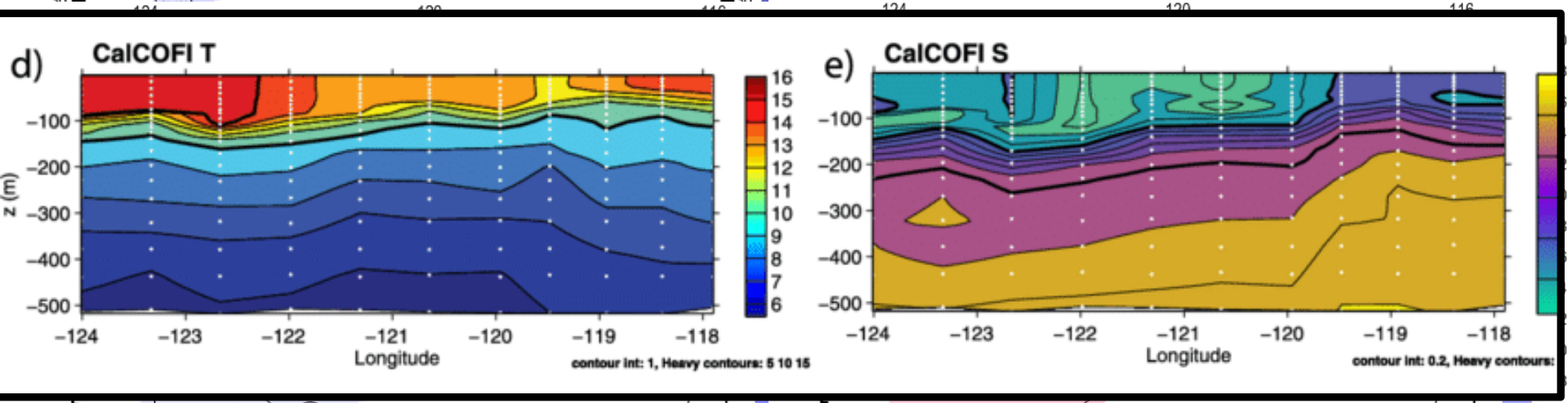


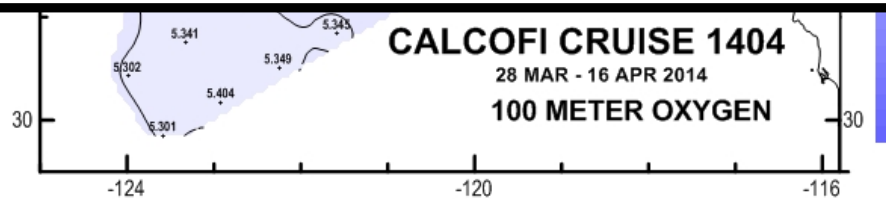
Ocean Interior Observations

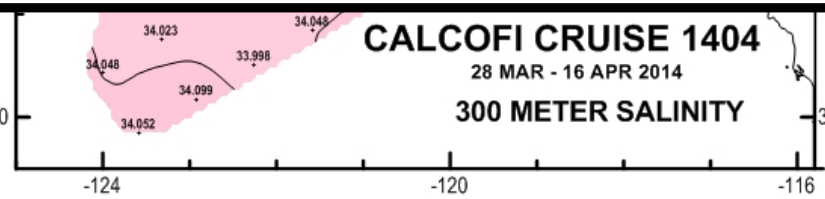






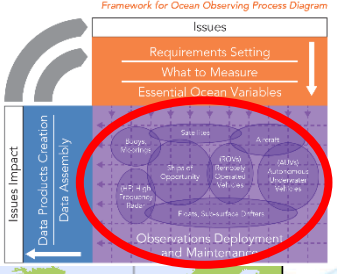


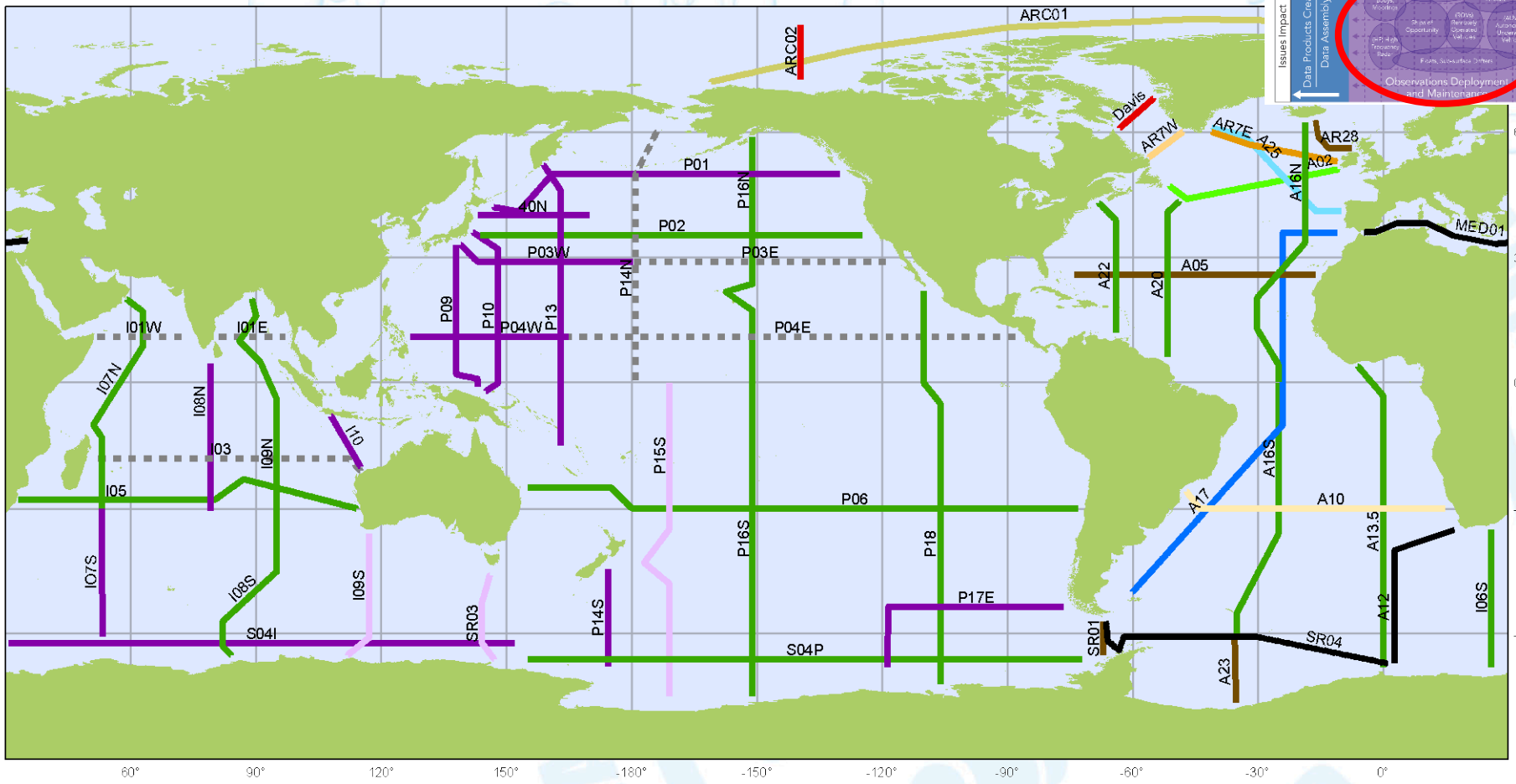




Interior Ocean Observations

(GO-SHIP, The Global Ocean Ship-based Hydrographic Investigations Program)





GO-SHIP

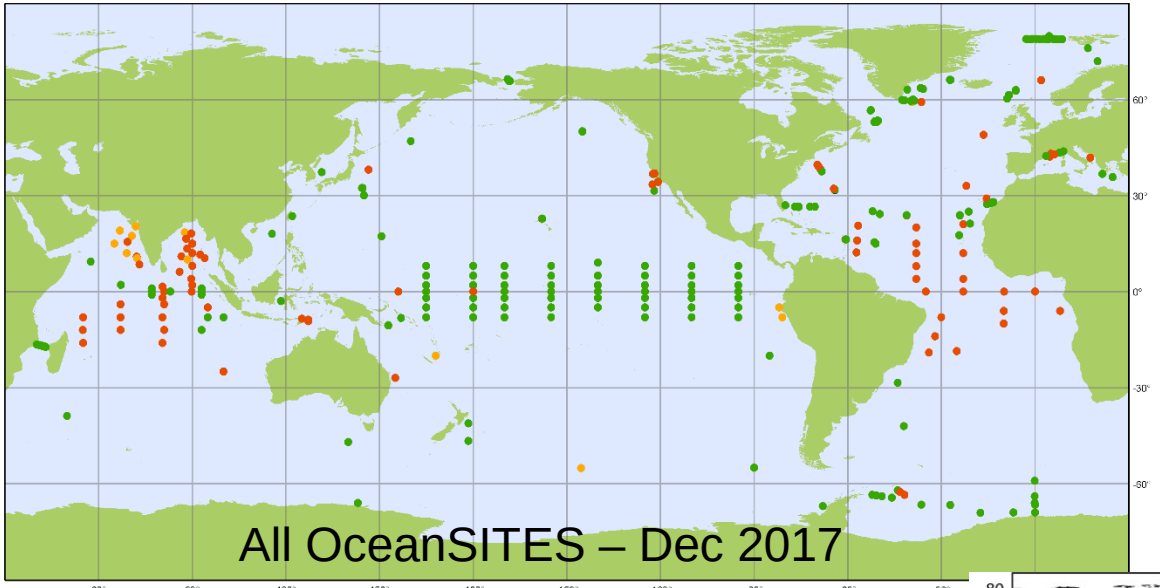
2012-2023 Survey (55 Core Lines): Lines by Nation

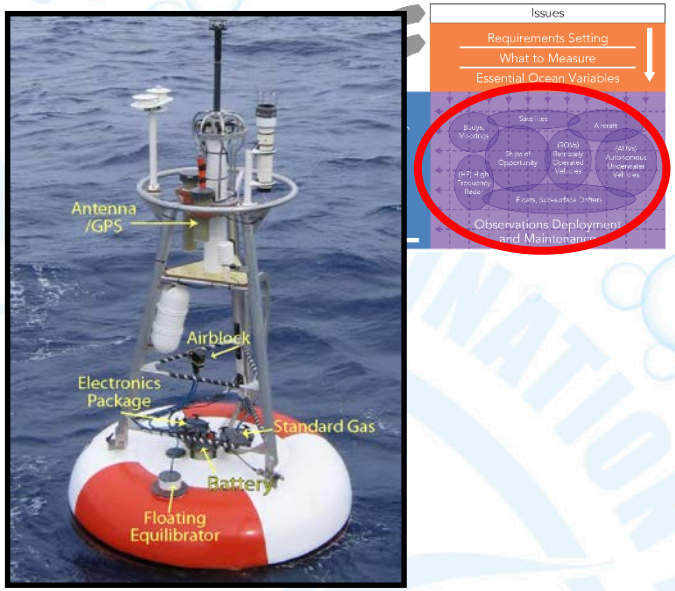
October 2018

AUS	ESP	IRE	NOR-UK	USA-GER
CAN-USA	FRA-ESP	JAP	UK	USA-UK-GER
CAN-UK	GER	NOR	USA	nil

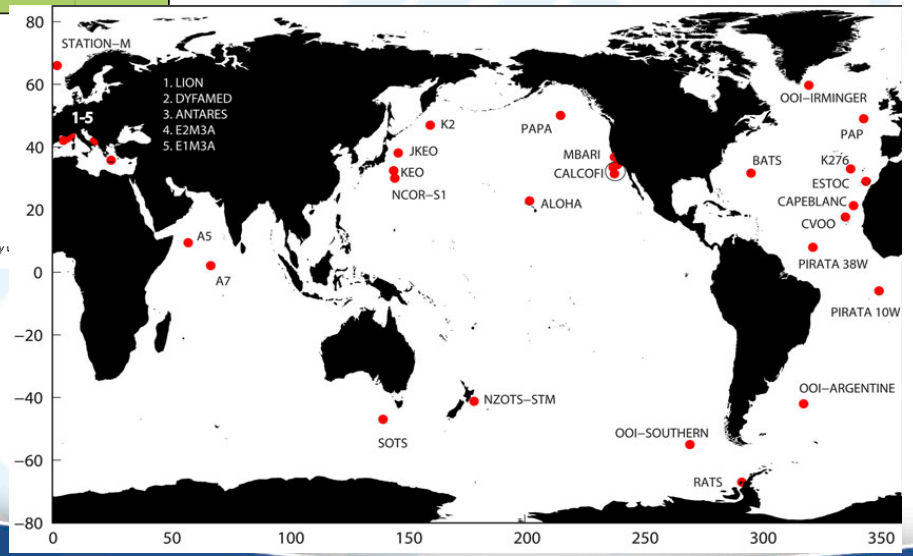
Generated by www.jcommops.org, 16-Oct-18

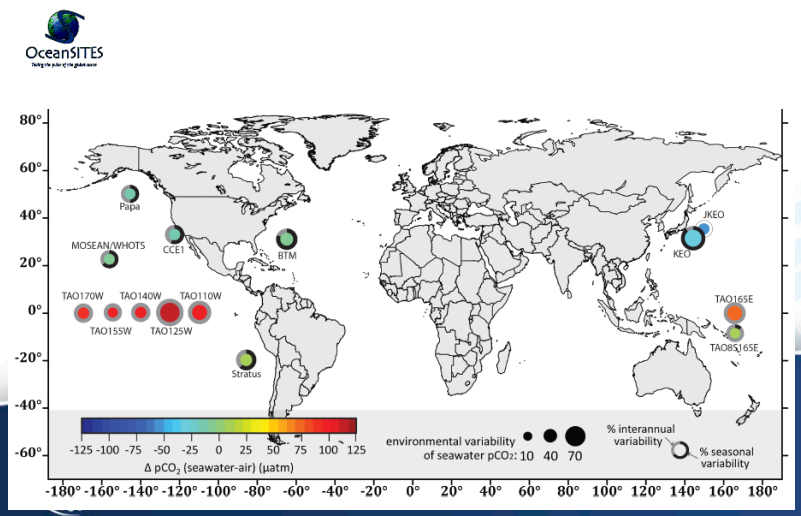
Biogeochemical Time Series





BGC OceanSITES
(Henson et al. (2016))

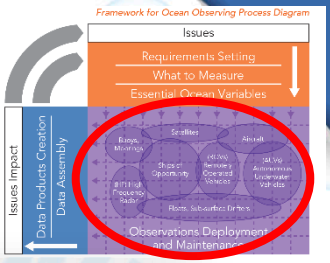


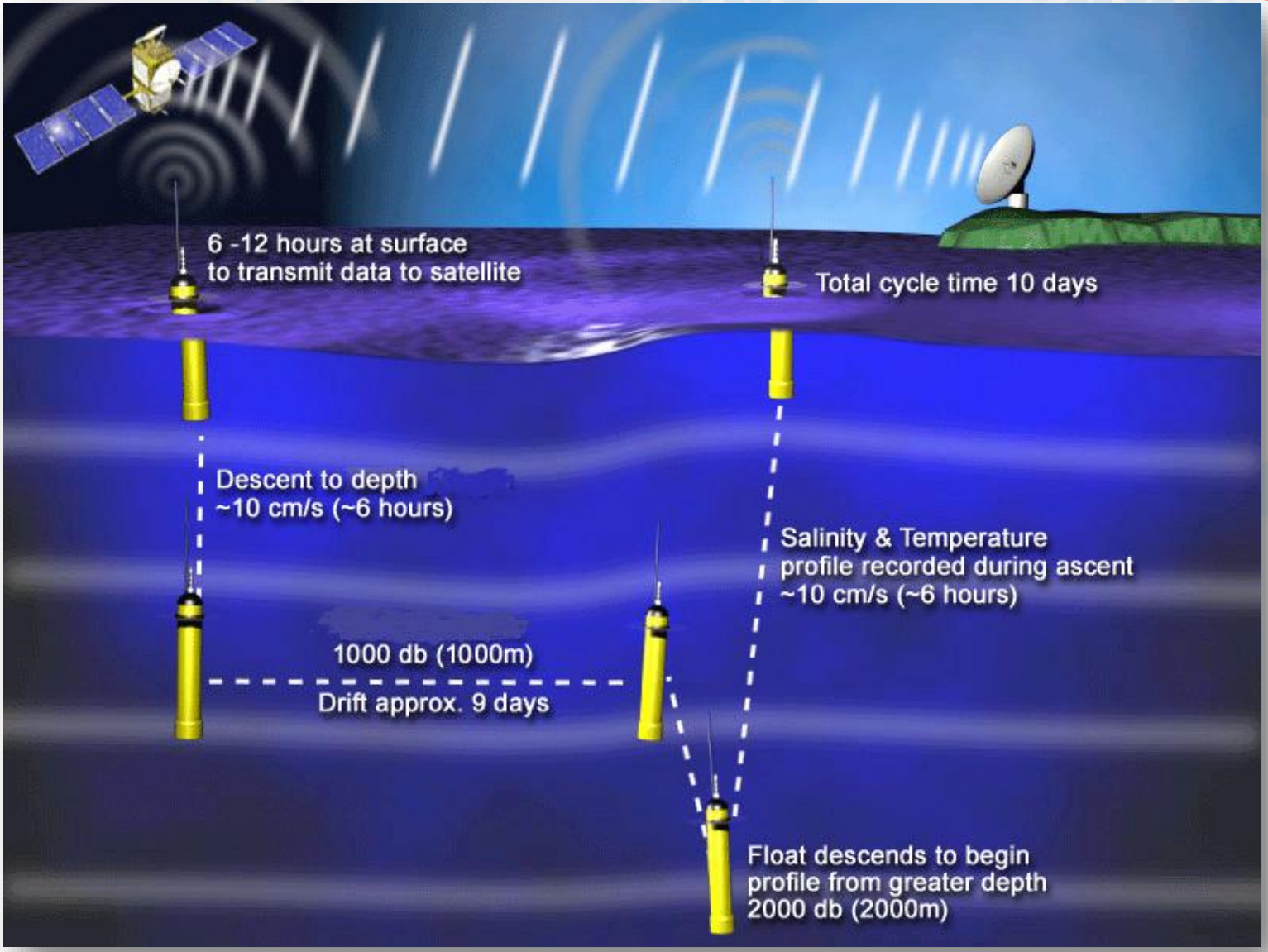


MapCO$_2$ sites (Sutton et al. 2014)

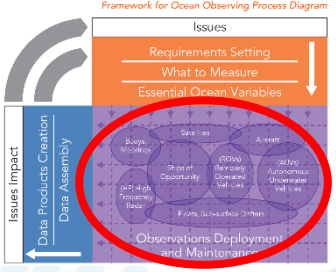
biogeochemical Argo

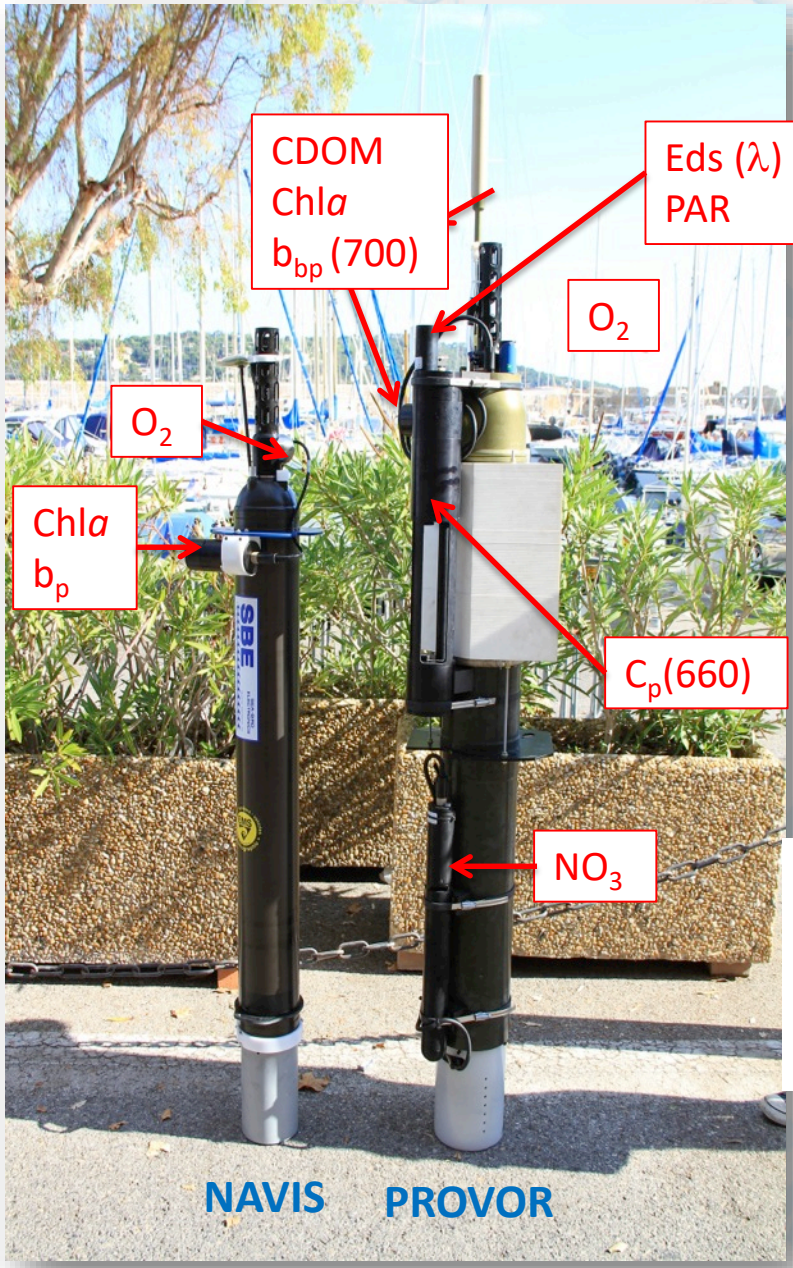
Biogeochemical Profiling Floats





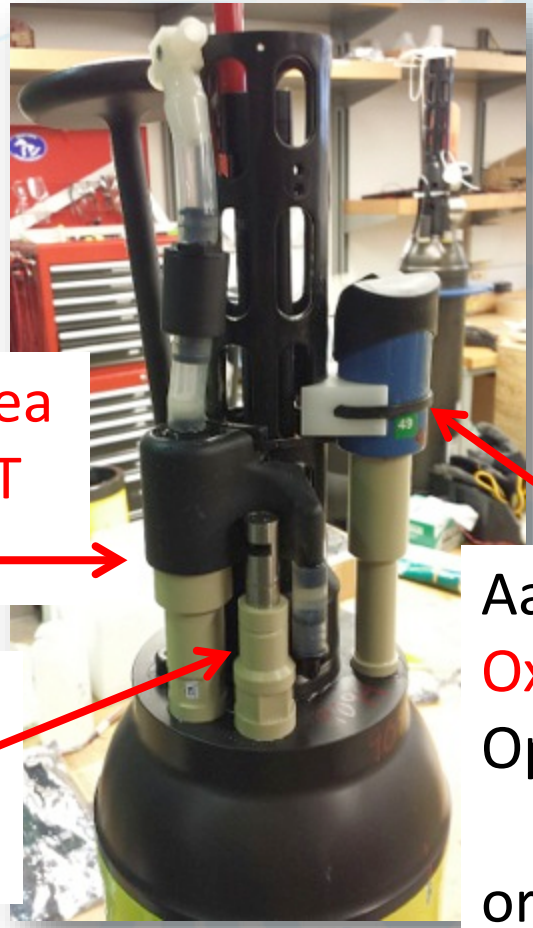
biogeochemical Argo





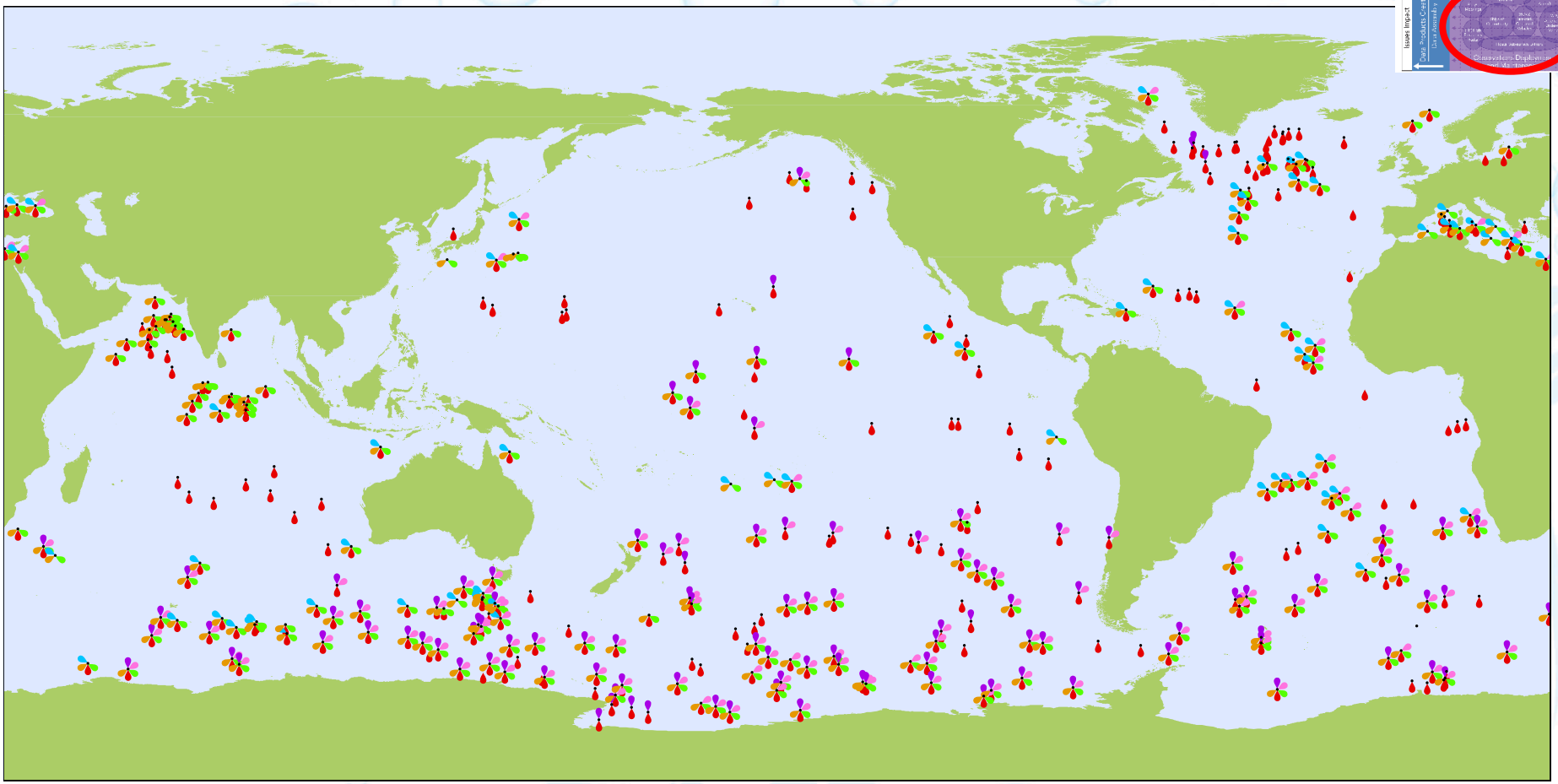
Deep-Sea
DuraFET
pH

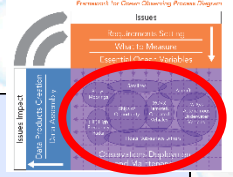
MBARI
ISUS
Nitrate



Aanderaa
Oxygen
Optode

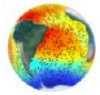
or SBE 63
Oxygen



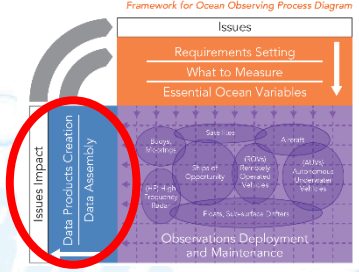


Sensor Types

biogeochemical Argo



Biogeochemistry Data Management



National Centers for Environmental Information

Ocean CO2 CDIAC

CCHDO

Bjerknes Centre for Climate Research
BCDC Bjerknes Climate Data Centre

BCO-DMO

INTERNATIONAL OCEAN CARBON COORDINATION PROJECT
IOCCP

GOA-ON
Global Ocean Acidification Observing Network

IMBeR

solas

The Global Ocean Observing System
GOOS

United Nations Educational, Scientific and Cultural Organization

Intergovernmental Oceanographic Commission

WMO

jcommops

ICOS
Ocean Thematic Centre

IOOS
INTEGRATED OCEAN OBSERVING SYSTEM

FixO3
FIXED-POINT OPEN OCEAN OBSERVATORIES

GO-SHIP

OceanSITES

Argo

SHIP OBSERVATIONS TEAM
JCOMM
VOS
Voluntary Observing Ship Scheme

SeaDataNet

EMODnet
European Marine Observation and Data Network

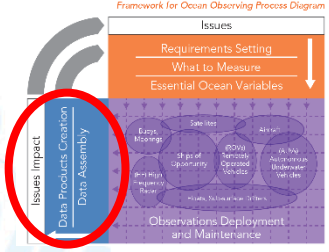
World Ocean Database

GEO

SOCAT
SURFACE OCEAN CO2 ATLAS

glodap v2

Global Data Assembly Centre for Marine Biogeochemistry



Network Pillars

Data Centers

National Centers for Environmental Information · Ocean CO_2 CDIAC · CCHDO · BCO-DMO

Data Products

glodap v2 · CARINA · SOCAT

Observing Networks

Argo · GO-SHIP · OceanSITES · VOS

Data Networks

SeaDataNet · EMODnet · World Ocean Database

Integrated Networks

ICOS Ocean Thematic Centre · FixO3 · IOOS Integrated Ocean Observing System

Acquire:
- Data
- Metadata

GDAC BGC

Interact with:
- User groups
- GDACs
- IODE/JCOMM

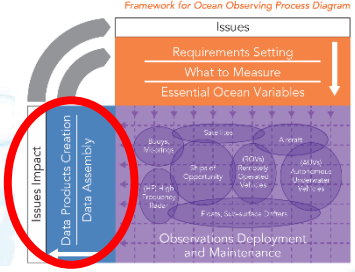
Assemble:
- Data harmonisation, integration, interoperability
- Identifying duplicates
- Quality control
- Usage tracking, indexing
- Metadata completeness

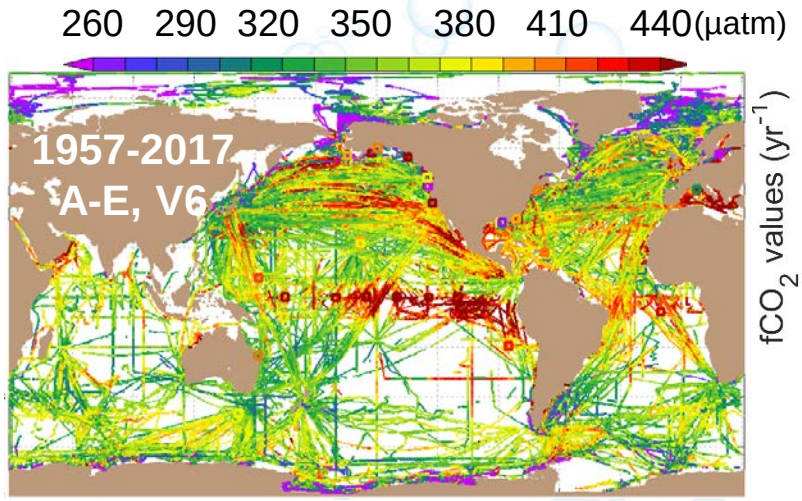
Network services:
- Feedback on quality issues and data usage
- Data exchange

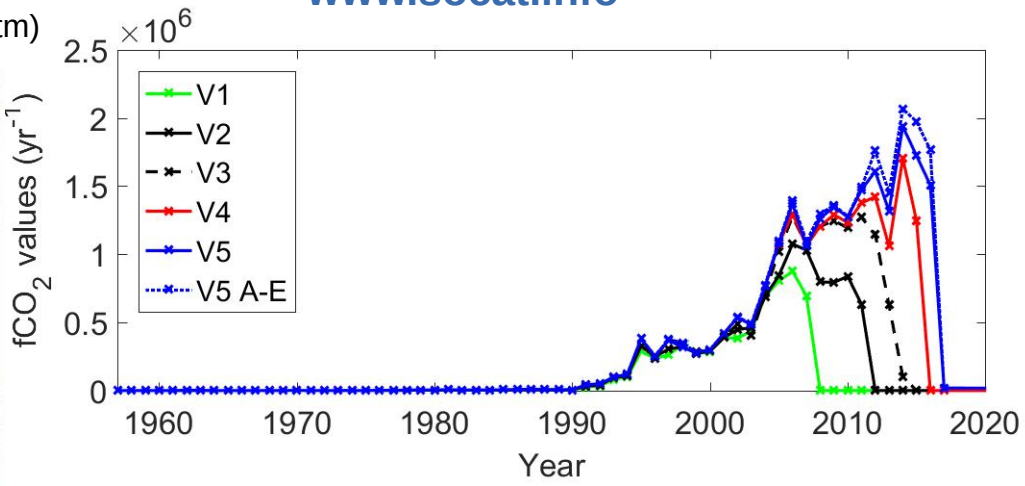
User services:
- Easy search and data access
- Reproducibility
- Citation procedures
- Data submission

Data synthesis products
Surface Ocean CO_2 Atlas

SOCAT
SURFACE OCEAN CO_2 ATLAS
www.socat.info







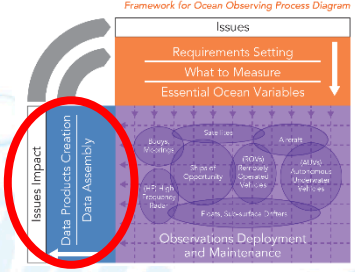
Global synthesis and gridded products of surface ocean fCO_2

- in uniform format with quality control;
- V6: 23.4 million fCO_2 values from 1957-2017, accuracy < 5 µatm (flags A-D);
- Plus 1.2 million calibrated sensor data (< 10 µatm, flag of E);
- Interactive online viewers;
- Online viewers, downloadable (text, NetCDF, ODV, Matlab);
- Documented in ESSD articles;
- Community activity with >100 contributors worldwide.

(**Pfeil et al., 2013; Sabine et al., 2013; Bakker et al., 2014, 2016, all in ESSD**)

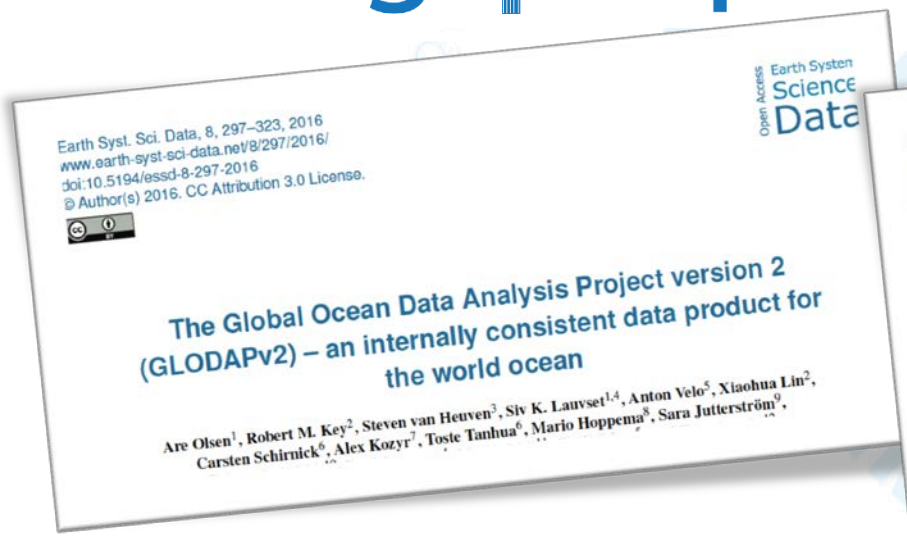
Data synthesis products

Global Ocean Data Analysis Project v2



glodap v2

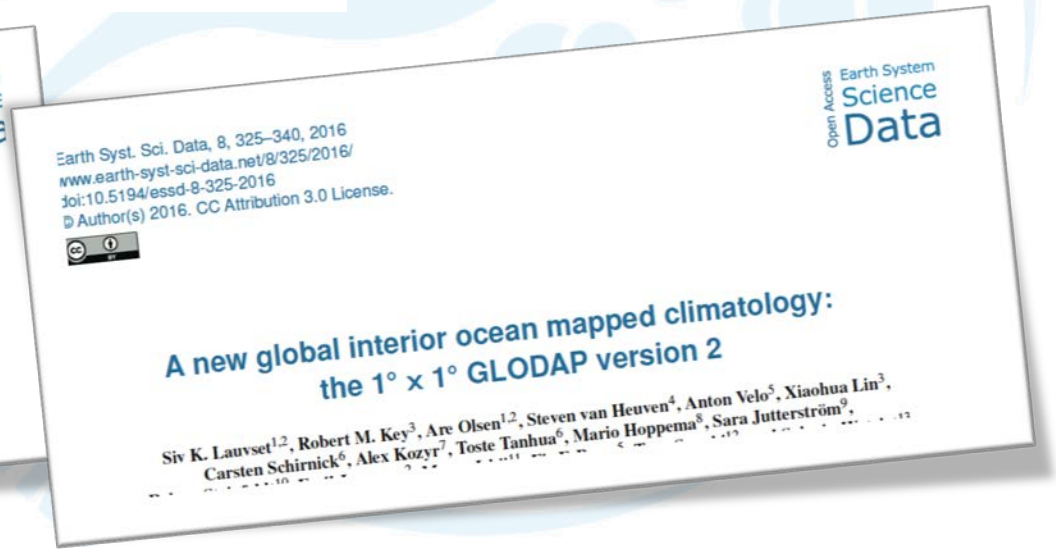
- A global collection of Sal., O_2, Nitr., Sil., Phos., DIC, Talk, pH data
  - 45 306 stations (724 cruises)
    - 999 488 sampling depths
    - 1972 – 2013 GEOSECS – TTO –WOCE - CLIVAR
  - Corrected for biases
- Extensively documented


Earth Syst. Sci. Data, 8, 297–323, 2016
www.earth-syst-sci-data.net/8/297/2016/
doi:10.5194/essd-8-297-2016

Open Access Earth System Science Data

The Global Ocean Data Analysis Project version 2 (GLODAPv2) – an internally consistent data product for the world ocean

Are Olsen[1], Robert M. Key[2], Steven van Heuven[3], Siv K. Lauvset[1,4], Anton Velo[5], Xiaohua Lin[2], Carsten Schirnick[6], Alex Kozyr[7], Toste Tanhua[6], Mario Hoppema[8], Sara Jutterström[9],

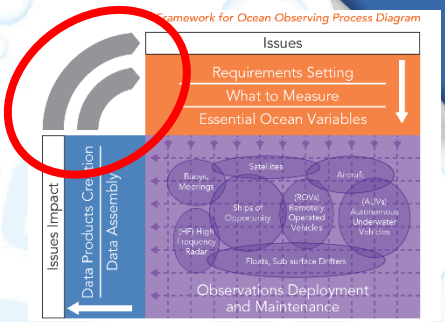

Earth Syst. Sci. Data, 8, 325–340, 2016
www.earth-syst-sci-data.net/8/325/2016/
doi:10.5194/essd-8-325-2016

Open Access Earth System Science Data

A new global interior ocean mapped climatology: the 1° x 1° GLODAP version 2

Siv K. Lauvset[1,2], Robert M. Key[3], Are Olsen[1,2], Steven van Heuven[4], Anton Velo[5], Xiaohua Lin[3], Carsten Schirnick[6], Alex Kozyr[7], Toste Tanhua[6], Mario Hoppema[8], Sara Jutterström[9],

GOA-ON



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- ***ir ation g***
- ir s
- ***surem***
- ***y assu***
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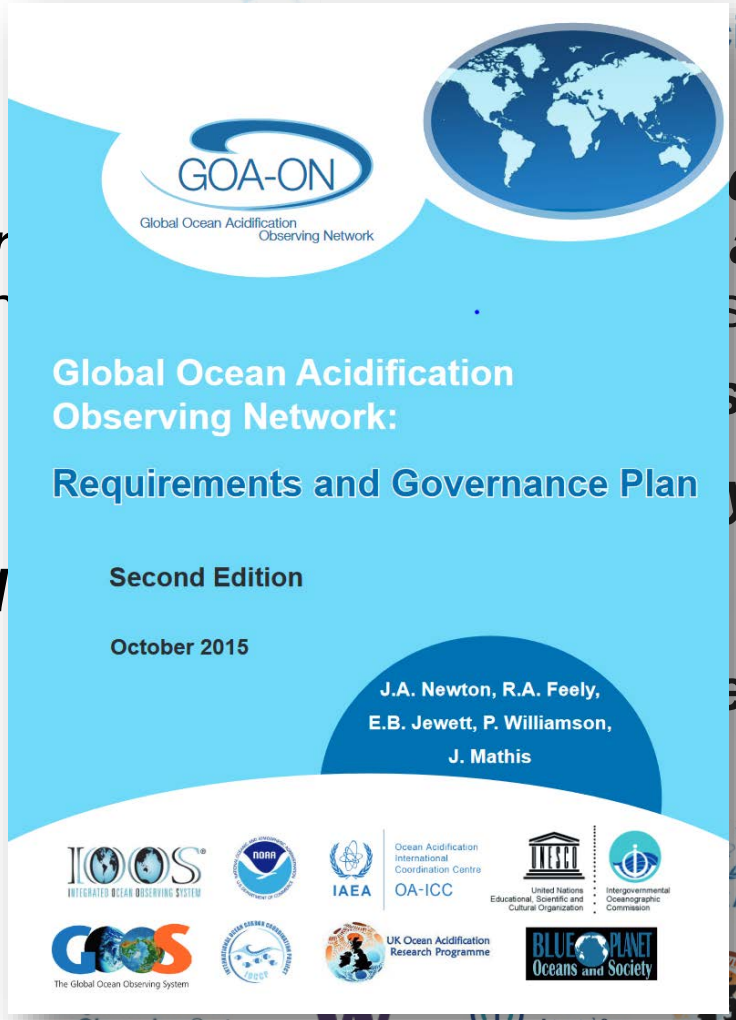
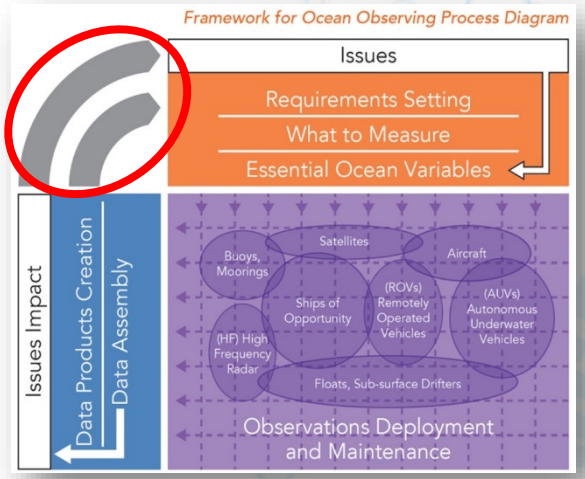
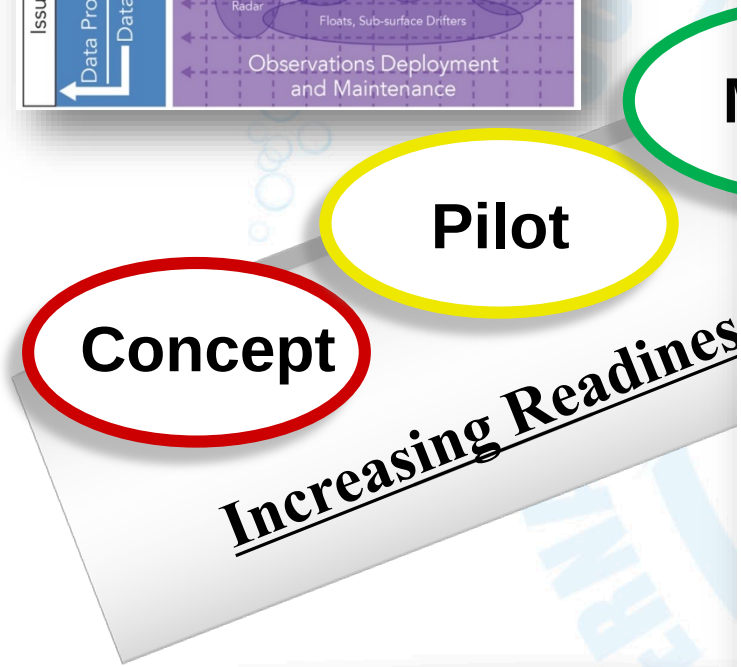


Increasing readiness of the sustained system

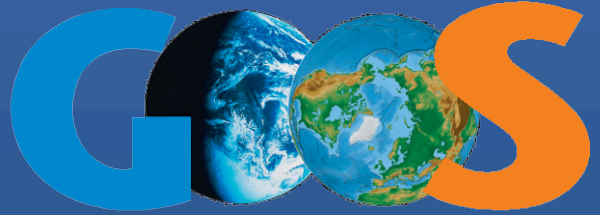




FRAMEWORK PROCESSES BY READINESS LEVELS

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.



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