Advancement of the Biogeochemistry (BGC) Essential Ocean Variables (EOVs)

Rik Wanninkhof, NOAA/AOML, Miami

With input from:
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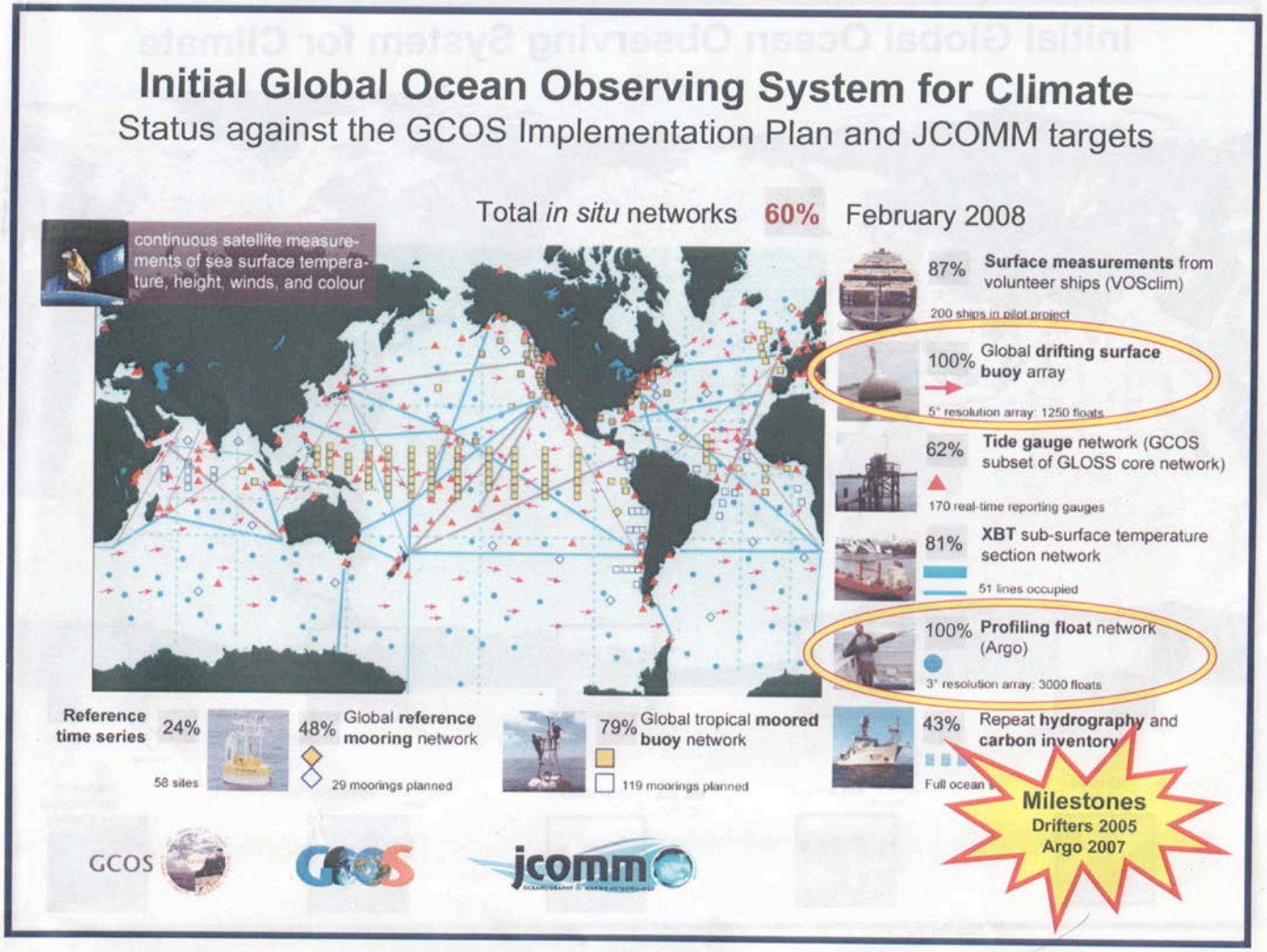
Maciej Telszewski and Artur Palacs, International Carbon Coordination Project (IOCCP) and GOOS BCG Panel

The Global Ocean Observing System

Platform based targets

from OCO PI meeting 2008



- NOAA (OGP,OCO, CPO, COD,OOMD….) has been the leader in implementing the GOOS framework for sustained ocean observations (FOO)
- Building is more fun than maintaining

Essential Ocean Variables

Essential Ocean variables are part of the Framework of Ocean Observations (FOO)

The Framework is designed to approach ocean observations with a focus on Essential Ocean Variables, ensuring assessments that cut across platforms and recommend the best, most cost effective plan to provide an optimal global view for each theme.

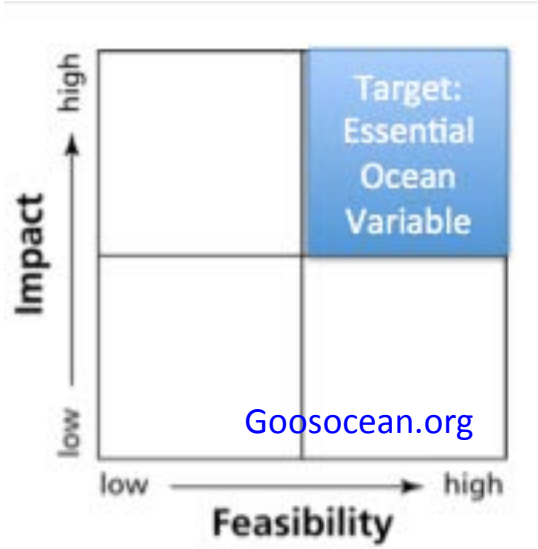
Criteria for EOVs:

Relevance The variable is effective in addressing the overall GOOS Themes – Climate, Real-Time Services, and Ocean Health.

Feasibility Observing or deriving the variable on a global scale is technically feasible using proven, scientifically understood methods.

Cost effectiveness Generating and archiving data on the variable is affordable, mainly relying on coordinated observing systems using proven technology

Expert Panels recommend what measurements are to be made needed to address key scientific/societal issues, various observing options, and data management practices and documented in EOV's specification sheets.



"Variables that need to be measured everywhere, all the time"

REPORT

First Technical Experts Workshop of the GOOS Biogeochemistry Panel:

Defining Essential Ocean Variables for Biogeochemistry

13-16 November 2013
Townsville, Australia

The Global Ocean Observing System

Name (Gender)	Home Institution	Country of residence	Main Expertize
Dr Matthew Church (M)	University of Hawaii	USA	Defining how ocean biology couples or decouples carbon and nitrogen cycles in the ocean
Dr Katja Fennel (F)	Dalhousie University	Canada	Development of coupled physical-biogeochemical models
Prof. Christoph Heinze (M)	University of Bergen	Norway	Three-dimensional modelling and quantification of marine biogeochemical cycles
Dr Masao Ishii (M)	JMA-MRI	Japan	Understanding of the natural and anthropogenic changes in ocean carbon and oxygen cycles based on observations
Dr Iris Kriest (F)	GEOMAR	Germany	Parameterization of marine biogeochemical processes in local and large-scale models
Dr Andrew Lenton (M)	CSIRO	Australia	Reanalysis and parameterization of carbon and biogeochemistry variables. Data-model fusion.
Dr Keith Rodgers (M)	Princeton University	USA	Using models to identify and understand dynamical controls on seasonal to inter-annual to decadal variability in the marine carbon cycle
Dr Toste Tanhua (M)	GEOMAR	Germany	Cycling and transport of biogeochemical properties within the ocean interior. Measurements of transient tracers, such as CFC-12 and SF_6, in the interior ocean and deliberate tracer release experiments.
Dr Bronte Tillbrook (M)	CSIRO	Australia	Observationalist binding the physical, chemical and biological processes that drive the carbon cycle
Dr Rik Wanninhof (M)	NOAA - AOML	USA	Ocean biogeochemistry observations and parameterization of ocean carbon variables
Dr Maciej Telszewski (M)	IOCCP	Poland	Ocean biogeochemistry observations and parameterization of ocean carbon variables

Societal needs and scientific requirements for the global ocean observing system (BGC)

More knowledge

1. The role of ocean biogeochemistry in climate

1.1. How is the ocean carbon content changing?

1.2. How does the ocean influence cycles of non-CO_2 greenhouse gases?

2. Human impacts on ocean biogeochemistry

2.1.How large are the ocean's "dead zones" and how fast are they changing?

2.2. What are rates and impacts of ocean acidification?

3. Ocean ecosystem health

3.1 Is the biomass of the ocean changing?

3.2 How does eutrophication and pollution impact ocean productivity and water quality?

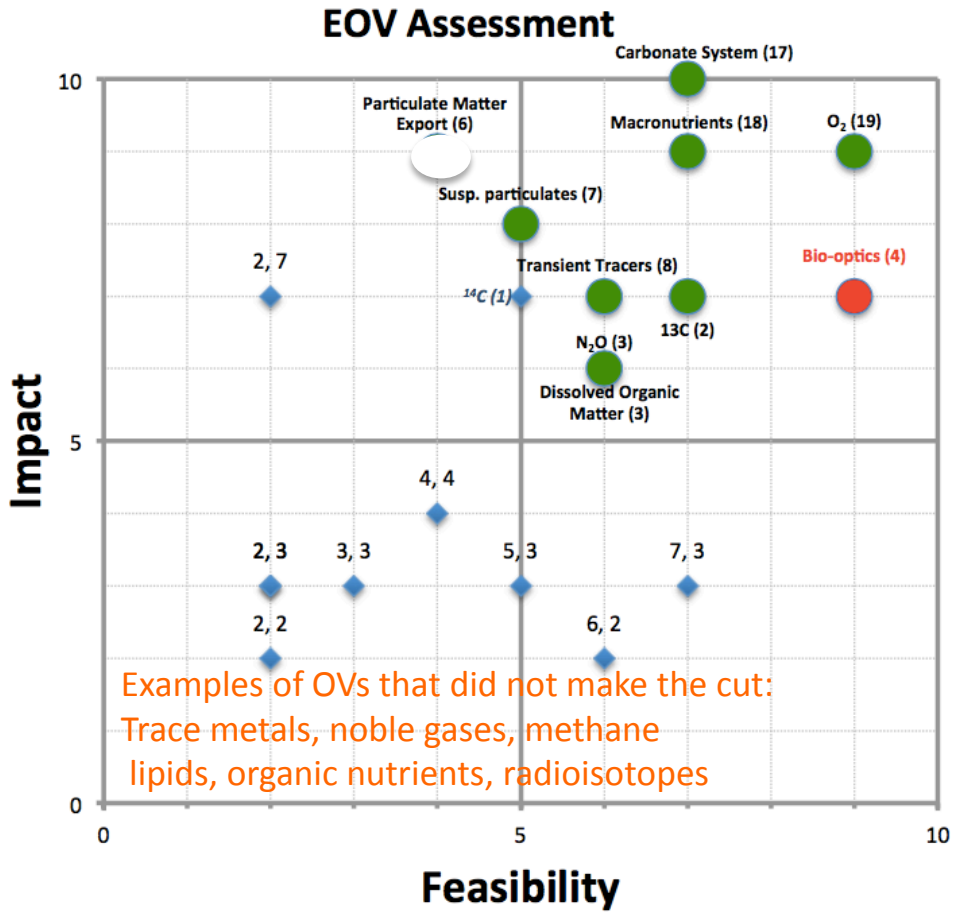
Less Knowledge

Excluded direct input of manmade materials (pollutants & plastics) [Under IMO purview]

EOVs for Biogeochemistry

Developed by a panel of experts based on:

1. Addressing global biogeochemical issues (Key themes)
2. Impact and feasibility



The separation of EOVs is merely for [management] convenience

PHYSICS	BIOGEOCHEMISTRY	BIOLOGY AND ECOSYSTEMS
Sea state	Oxygen	Phytoplankton biomass and diversity
Ocean surface stress	Nutrients	Zooplankton biomass and diversity
Sea ice	Inorganic carbon	Fish abundance and distribution
Sea surface height	Transient tracers	Marine turtles, birds, mammals abundance and distribution
Sea surface temperature	Suspended particulates	Live coral
Subsurface temperature	Nitrous oxide	Seagrass cover
Surface currents	Stable carbon isotopes	Macroalgal canopy
Subsurface currents	Dissolved organic carbon	Mangrove cover
Sea surface salinity	Ocean colour *(Spec Sheet under development)*	
Subsurface salinity		
Ocean surface heat flux		

Readiness level: CONCEPT (red)| PILOT (orange) | MATURE (green)

Essential Biodiversity Variables

http://goosocean.org/

Essential Ocean Variables are central to the GOOS strategic mapping, which describes the observing system in terms of its relation to the GOOS mandates.

EOV Specification Sheet

Version: 2016.02.22

The Global Ocean Observing System

Essential Ocean Variable (EOV): Dissolved Oxygen

Background and Justification
Table 1: EOV Information
Table 2: Requirements Setting
Table 3: Current Observing Networks
Table 4: Future Observing Networks
Table 5: Data & Information Creation
Table 6: Links & References

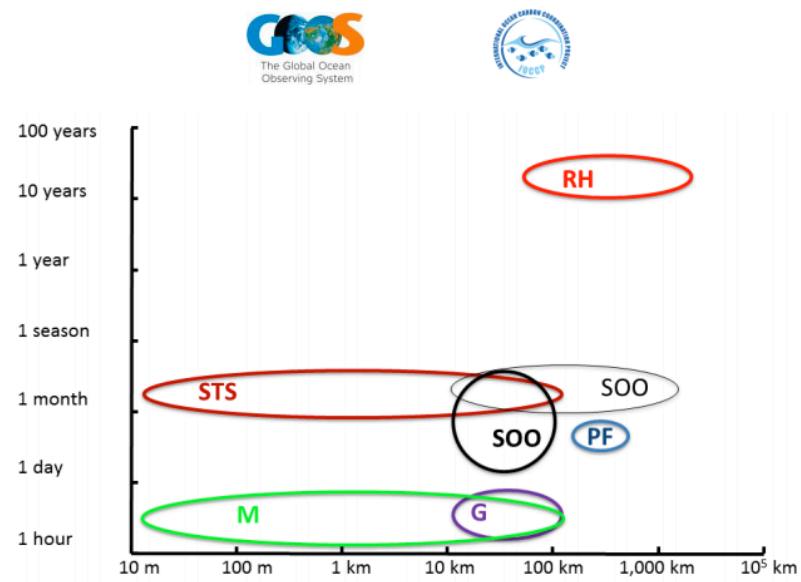
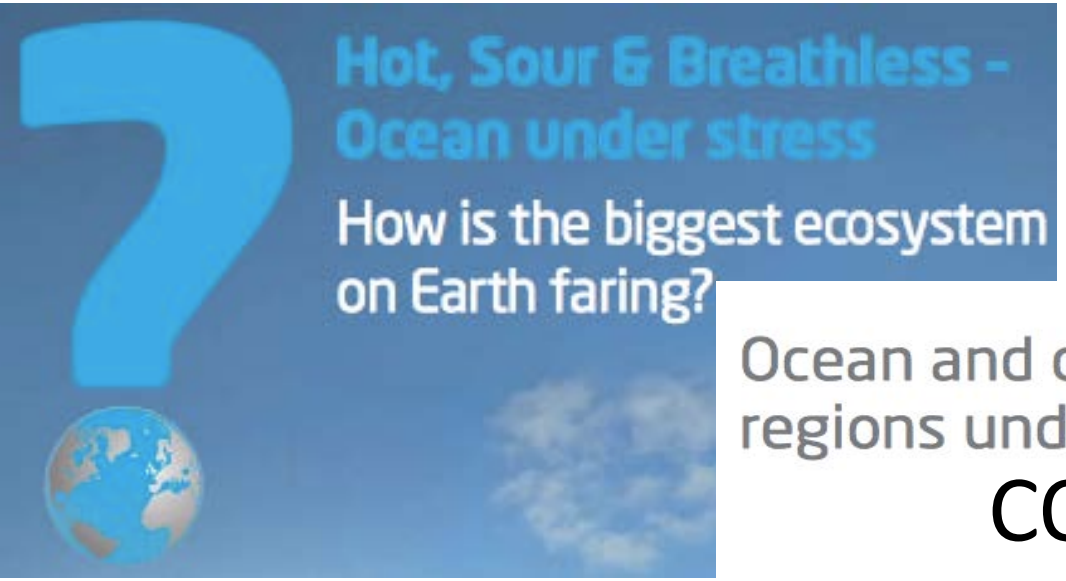


Figure 2. Spatial and temporal observation scales of component networks listed in Table 3 (thick coloured circles) and in Table 4 (thin black circles).

Observing Network	Profiling Floats (PF)	Repeat Hydrography (RH)	Moorings (M)	Gliders (G)	Ship-based Time-Series (STS)	Ship Of Opportunity (SOO)

The Global Ocean Observation System (GOOS) is a permanent global system for observations, modelling and analysis of marine and ocean variables to support operational ocean services worldwide. GOOS provides accurate descriptions of the present state of the oceans and continuous forecasts of the future conditions of the sea.

EOVs applied to Ocean Ecosystem Health

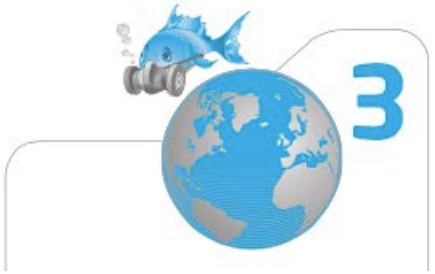


Ocean and coastal regions under stress

CO_2

Heat

Oxygen



And others: eutrophication (nutrient cycle), pollutants, plastics

Mapping of EOVs to addressing ocean health

Ocean Stress Guide

What the ocean will experience this century without urgent and substantial reduction in greenhouse gas emissions.

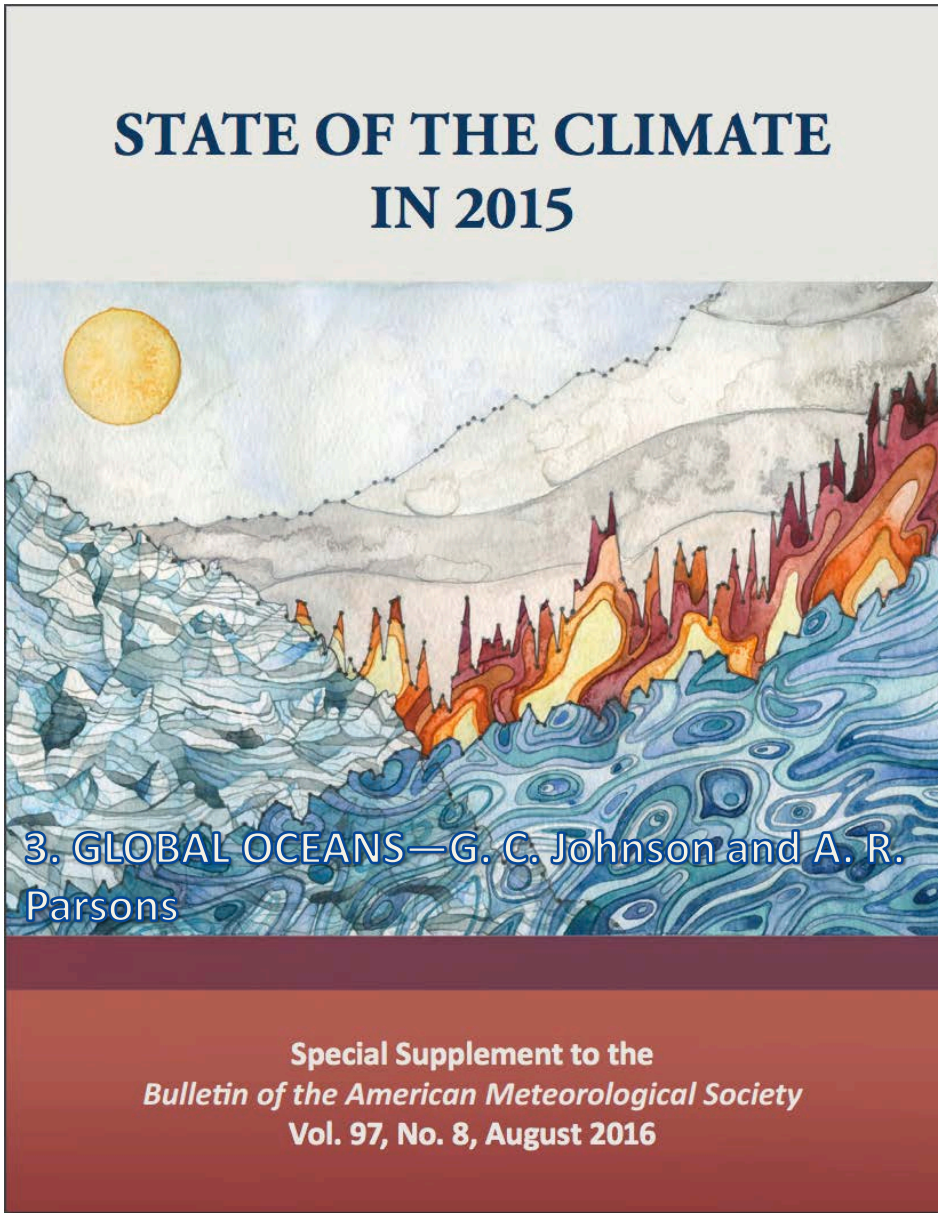
Stressor	Causes	Result	Direct effects	Impacts	Feedback to climate
Warming ● A relatively mature study area in terms of physical changes and physiology but poorly studied at ecosystem and biogeochemical level	● Increasing greenhouse gas emissions to the atmosphere	● Temperature increase, particularly in near-surface waters ● Less ocean mixing due to increased stratification ● Increased run-off and sea-ice melt will also contribute to stratification in Arctic waters	● Decreased carbon dioxide solubility ● Increased speed of chemical and biological processes ● Reduced natural nutrient re-supply in more stratified waters	● Stress to organism physiology, including coral bleaching ● Extensive migration of species ● More rapid turnover of organic matter ● Nutrient stress for phytoplankton, particularly in warm waters ● **Changes to biodiversity, food webs and productivity, with potential consequences for fisheries, coastal protection**	● Reduced ocean uptake of carbon dioxide due to solubility effect ● Increased oxygen consumption, carbon dioxide production and decrease in oxygen transfer to the deep ocean ● Potential decrease in the export of carbon to the ocean's interior ● Decreasing primary production except in the Arctic where sea-ice loss may result in an increase
T, Flux	CO_2, Flux	T,S,nuts	CO_2, part, nuts phyto, zoo		CO_2, O_2, part.
Acidification ● Developed as a research topic in past decade	● Increasing atmospheric carbon dioxide emissions ● Coastal nutrient enrichment, methane hydrates and acid gases from industrial emissions may also contribute locally	● Unprecedented rapid change to ocean carbonate chemistry ● Much of the ocean will become corrosive to shelled animals and corals, with effects starting in the Arctic by 2020	● Reduced calcification, growth and reproduction rates in many species ● Changes to the carbon and nitrogen composition of organic material	● Impeded shell or skeletal growth and physiological stress in many species, including juvenile stages ● Change to biodiversity and ecosystems, and the goods and services they provide ● **Cold and upwelling waters currently supporting key fisheries and aquaculture likely to be especially vulnerable**	● Reduced ocean uptake of carbon dioxide due to chemical effects ● Changes to the export of carbon to the ocean's interior ● Higher oxygen use throughout the water column due to changing composition of organic material
Deoxygenation ● Emerging issue, poorly studied	● Reduced oxygen solubility due to warming ● Decreased oxygen supply to the ocean interior due to less mixing ● Nutrient rich land run-off stimulating oxygen removal locally	● Less oxygen available for respiration especially in productive regions, and in the ocean interior ● Extended areas of low and very low oxygen	● Reduced growth and activity of zooplankton, fish and other oxygen-using organisms ● Endocrine disruption	● Stress to oxygen-using organisms ● Risk of species loss in low oxygen areas ● Impacts on reproductive success ● **Shift to low oxygen-tolerant organisms, especially microorganisms and loss of ecosystem services in these areas**	● Enhanced production of the two greenhouse gases methane and nitrous oxide
All three together ● Few studies	● Increasing greenhouse gas emissions, especially carbon dioxide, to the atmosphere	● More frequent occurrence of waters that will not only be warmer but also have higher acidity and less oxygen content	● Damage to organism physiology, energy balance, shell formation: e.g. coral reef degradation	● Ocean acidification can reduce organisms' thermal tolerance, increasing the impact of warming ● **Combined effects further increase risk to food security and industries depending on healthy and productive marine ecosystems**	● Major change to ocean physics, chemistry and ecosystems ● Risk of multiple positive feedbacks to atmosphere, increasing the rate of future climate change

http://www.oceanacidification.org.uk/pdf/ous_latest_Nov13-pdf.pdf

EOVs cover:
- measured
-derived parameters (e.g. rates (Fluxes))

EOVs cover:
Stressor
Causes
Results
Impacts
Feedbacks

Highlights of implementation of the GOOS EOV concept



2016 is in the works!

EOVs facilitate systematic reporting of changes over time of key climate variables : SST

Climate modes and natural variability

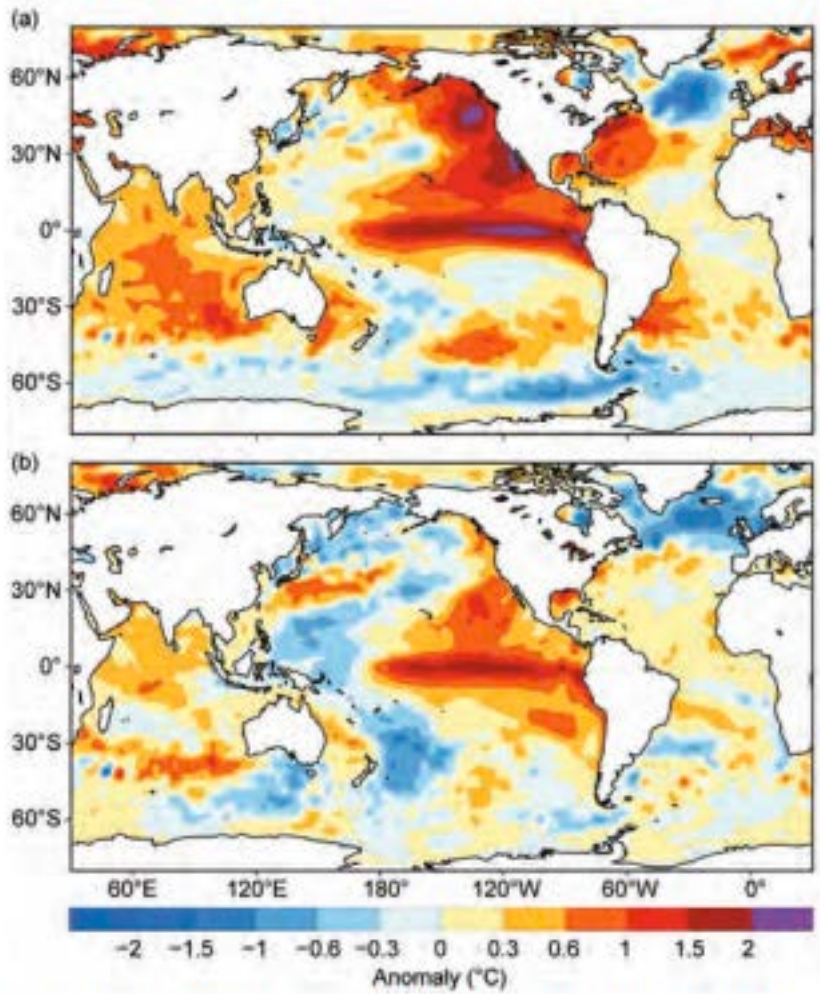


Fig. 3.1. (a) Yearly mean OISST anomaly in 2015 (°C, relative to the 1981–2010 average) and (b) 2015–2014 OISST difference.

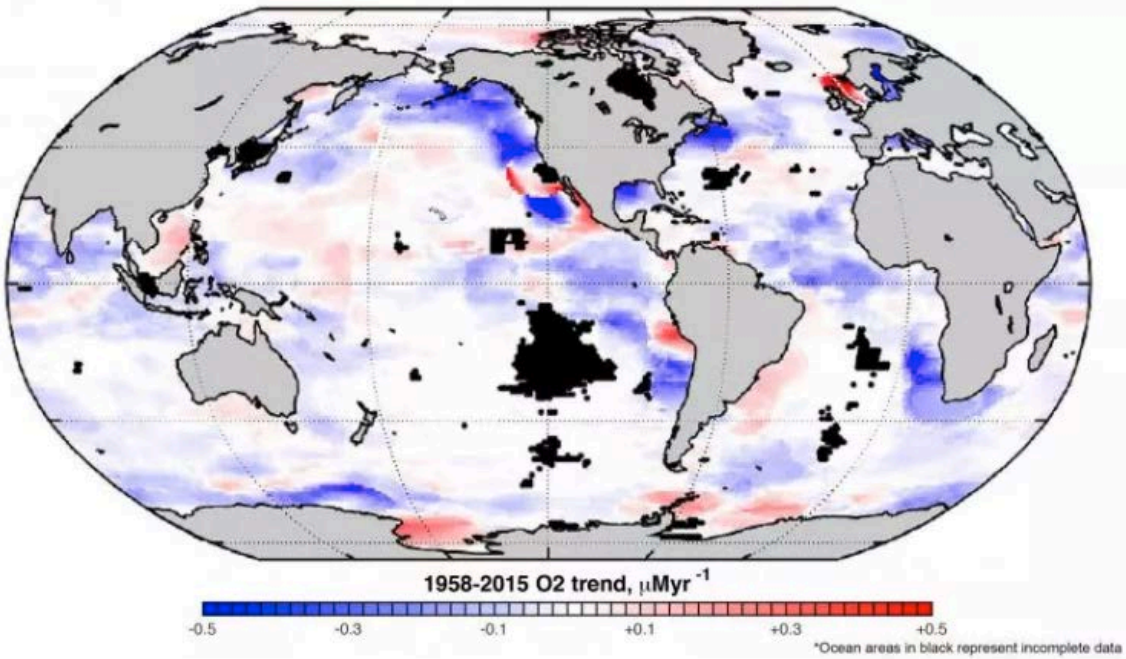
2015 – (1981-2010)

2015-2014

Anthropogenic warming ≈0.1 ˚C/decade

Sea surface temperatures—B. Huang, J. Kennedy, Y. Xue, and H.-M. Zhang

EOVs facilitate systematic reporting of changes over time of key climate variables : O_2



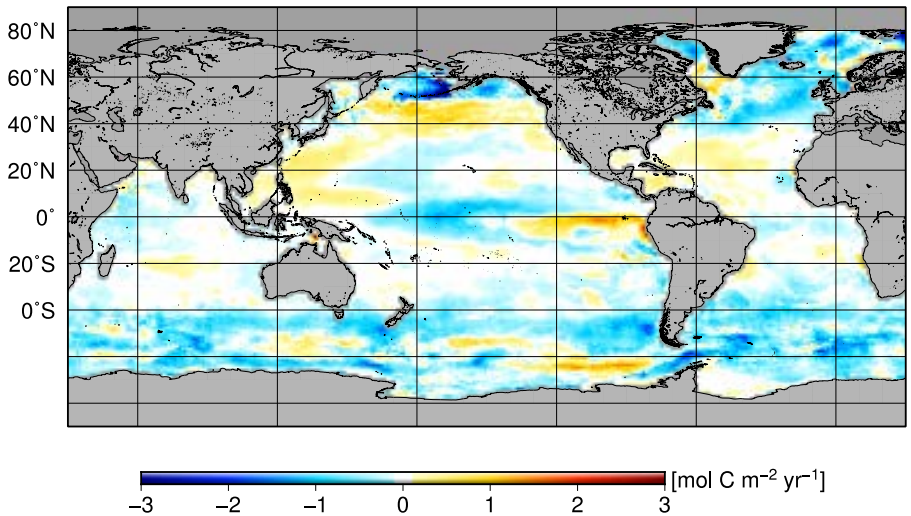
Global map of the linear trend of dissolved oxygen at the depth of 100 meters. Photo: Georgia Tech

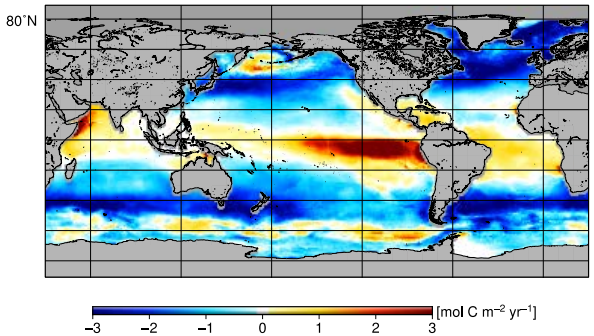
Causes:

- Ocean warming (Small contribution)
- Increase AOU (respiration + change in ventilation)

Ito, T., S. Minobe, M. C. Long and C. Deutsch (2017). "Upper Ocean O_2 trends: 1958-2015." Geophysical Research Letters: 10.1002/2017GL073613

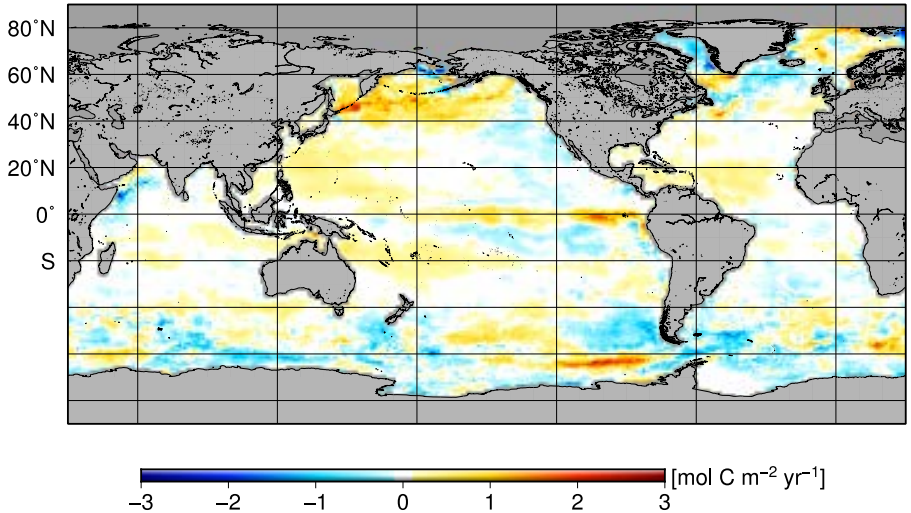
A systematic reporting of changes over time of key climate products: Air-sea CO_2 Flux f(CO_2,SST,stress)





2016 – (1995-2015)

Anthropogenic CO_2 uptake ≈0.5 mol C m^{-2} yr^{-1}



2016-2015

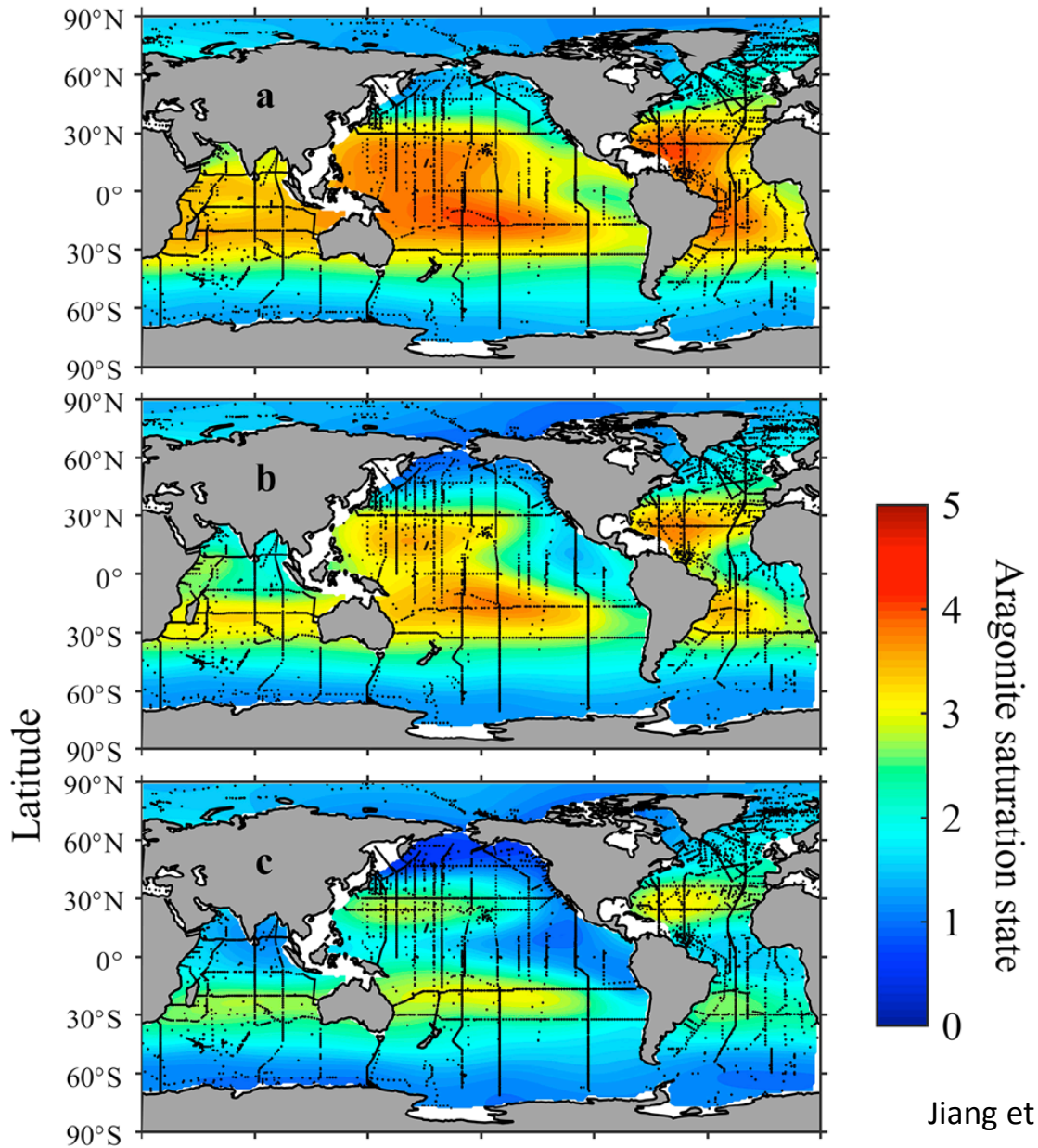
Global ocean carbon cycle—R. A. Feely, R. Wanninkhof, P. Landschützer, B. R. Carter, and J. A. Triñanes

Utilization of EOVs to create products: Aragonite saturation State f(T, S, C)

50 m

100 m

200 m



Jiang et al., GBC, 2015

Utilization of EOVs to elucidate causes and processes : Chlorophyll (Ocean Color and SST)

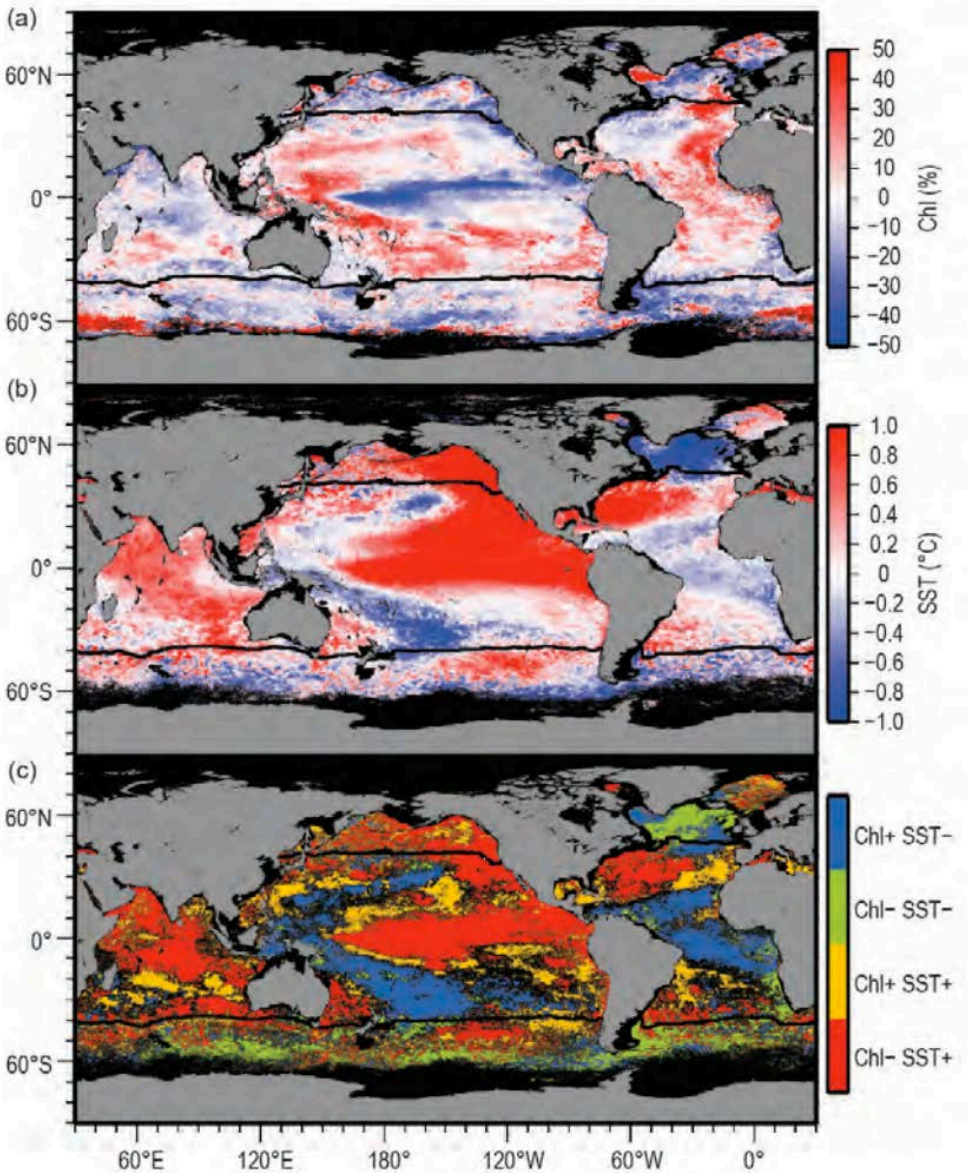


Fig. 3.26. Spatial distribution of summed monthly 2015 (a) VIIRS Chl*a*

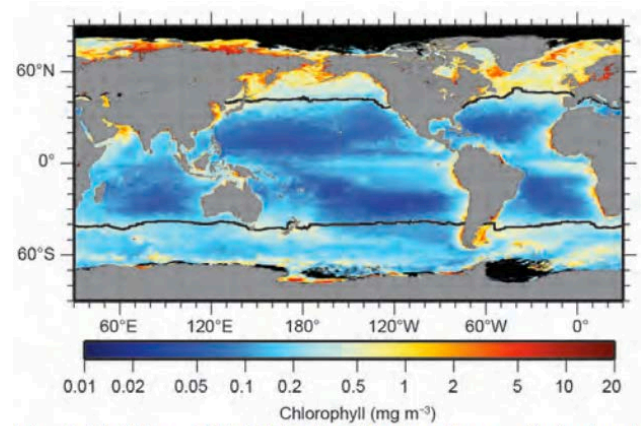


Fig. 3.25. Mean 2015 Chl*a* distribution (mg m^{-3}) derived

Strong coherence in biogeographical provinces

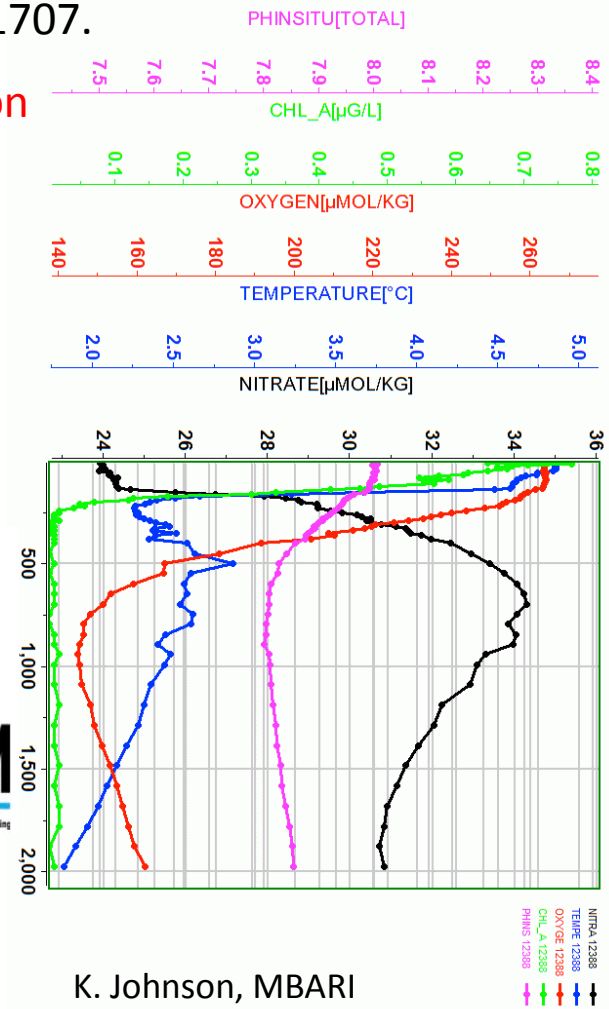
Global ocean phytoplankton—B. A. Franz[1], M. J. Behrenfeld[2], D. A. Siegel[3], and S. R. Signorini[1,4]

Utilization of EOVs to guide new platform and sensor development "fit for purpose"

Autonomous platforms and sensors

12388 profile data near 60 ˚S, 170˚W 4/21/201707.

Inorganic carbon
Color
O_2
T
Nutrients



SOCCOM
Southern Ocean Carbon and Climate Observations and Modeling

K. Johnson, MBARI

Summary

- EOVs are a useful approach to fully utilize the platform-based observing approach of GOOS FOO and JCOMM
- EOVs are critical for systematic observations of key parameters, processes, and interconnectivity between processes and properties
- (BGC) EOVs (and their specification sheets) will be critical in incorporating new platform designs and instruments

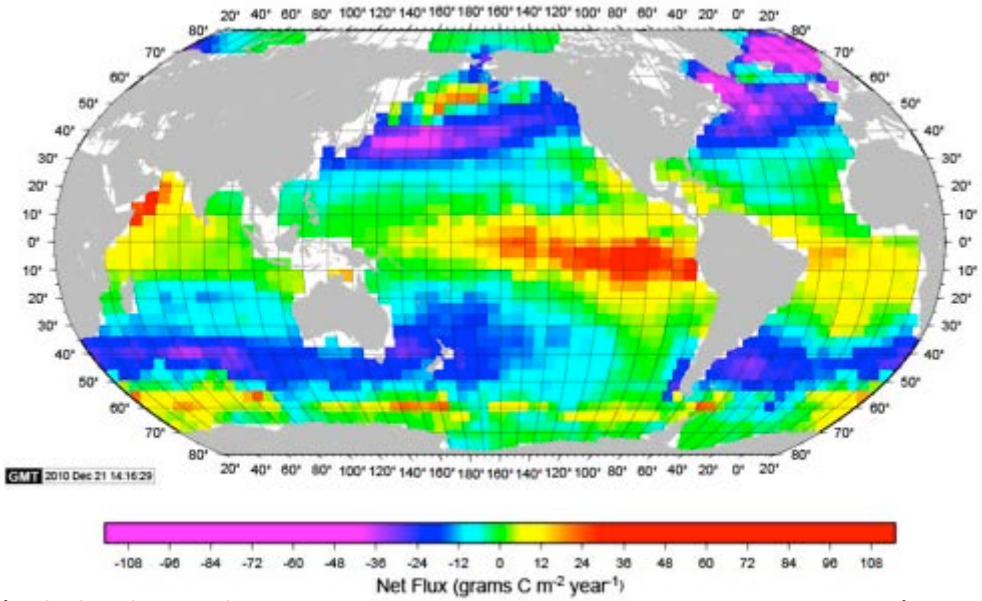
The Global Ocean Observing System

Closing thought regarding performance based frameworks

The problem with the bean counters is what's being counted. It's a focus on solely counting things, rather than the scientific products and advances in understanding"

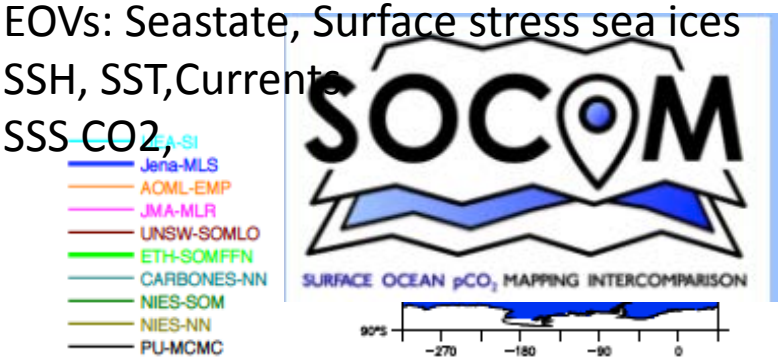
Highlights of products and required EOVs

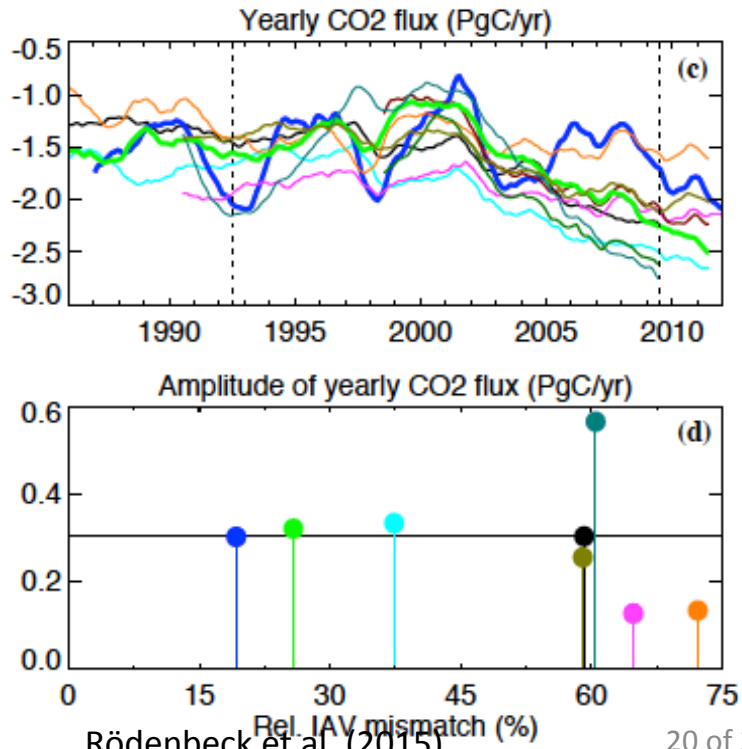
Global air-sea CO_2 fluxes: from climatology to pCO_2 data-based near real time flux maps



(Takahashi et al., 1997; 1999; 2002; 2006; 2007; 2009; 2014)

EOVs: Seastate, Surface stress sea ices
SSH, SST,Currents
SSS CO2,





Rödenbeck et al. (2015)

Significant improvements in estimates of global climatological CO_2 uptake:

- Current estimate (2006-2015) 2.6 Pg C y^{-1} (26%)
- Decrease in uncertainty from ± 1 to 0.5 Pg C y^{-1}
- Advances in near real-time fluxes

A systematic reporting of changes over time of key climate product: Ocean heat content

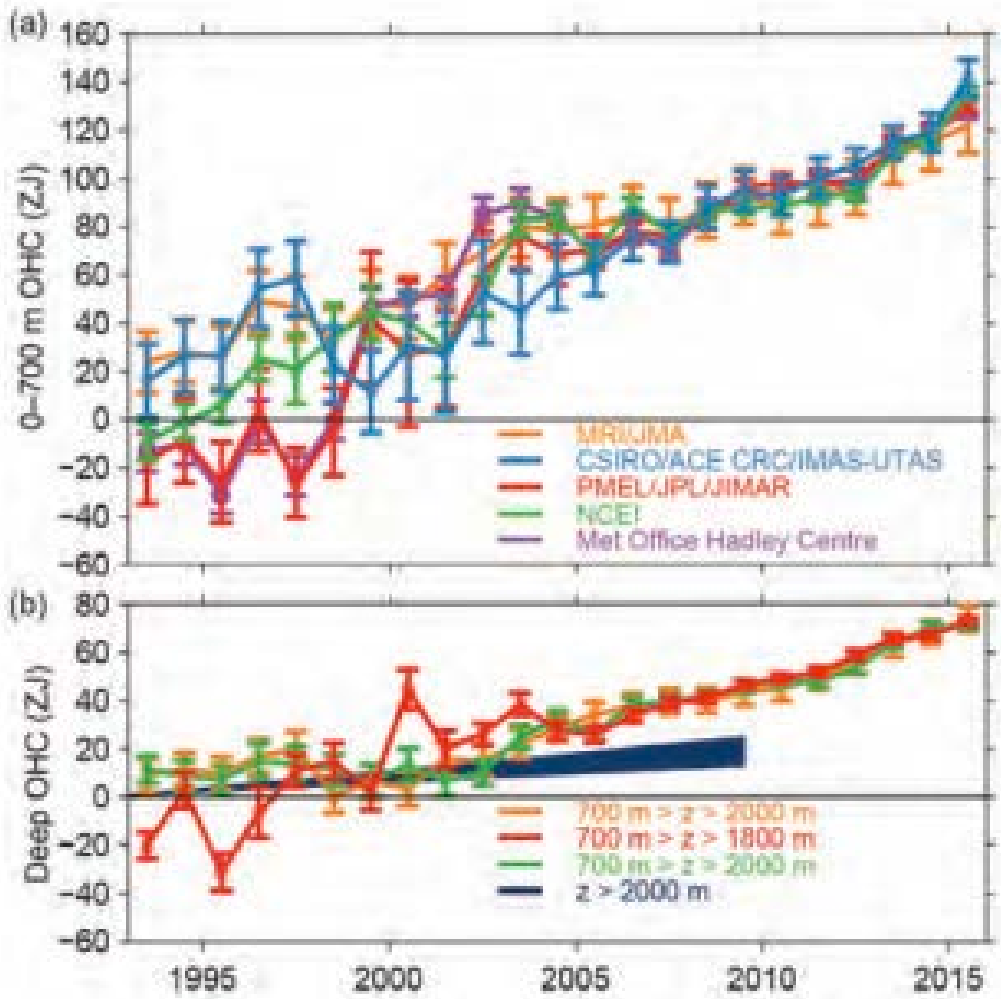
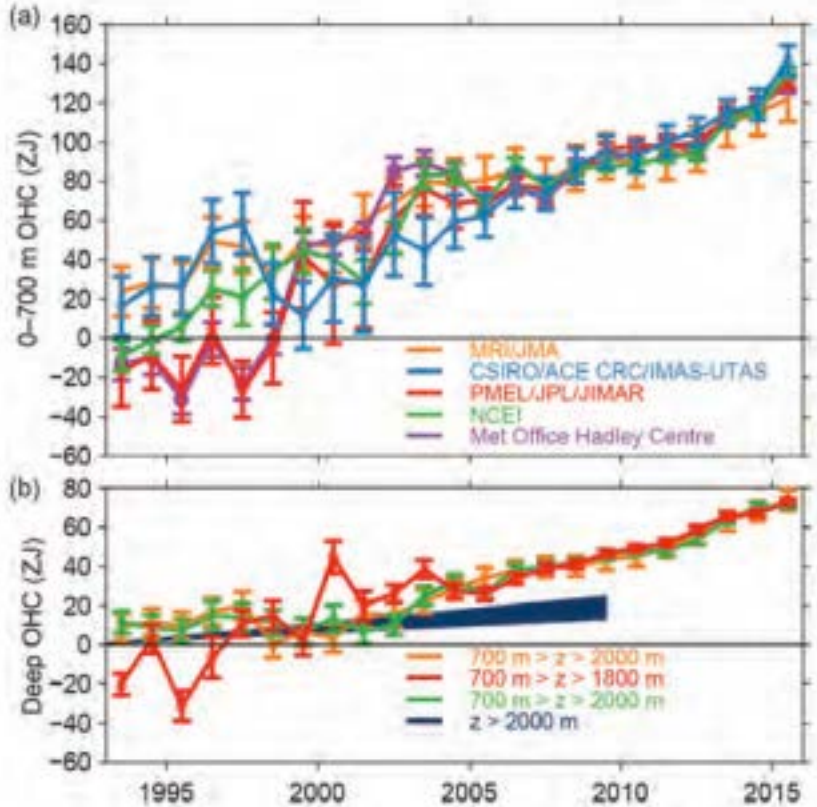


Fig. 3.6. (a) Time series of annual average global integrals of in situ estimates of upper (0–700 m) OHCA



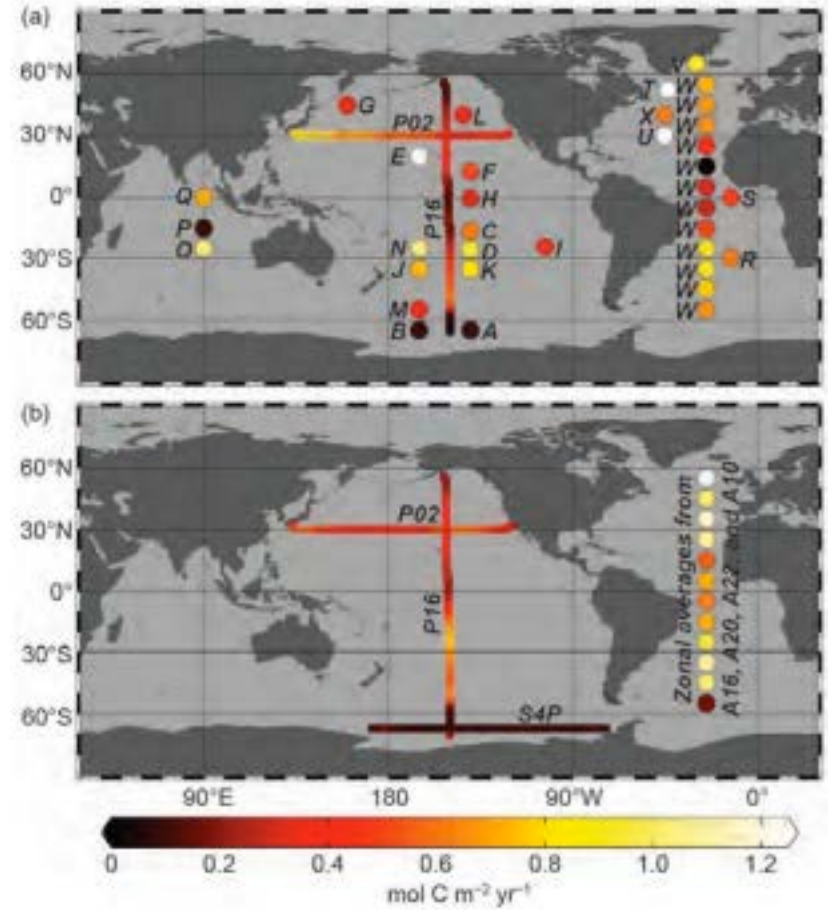


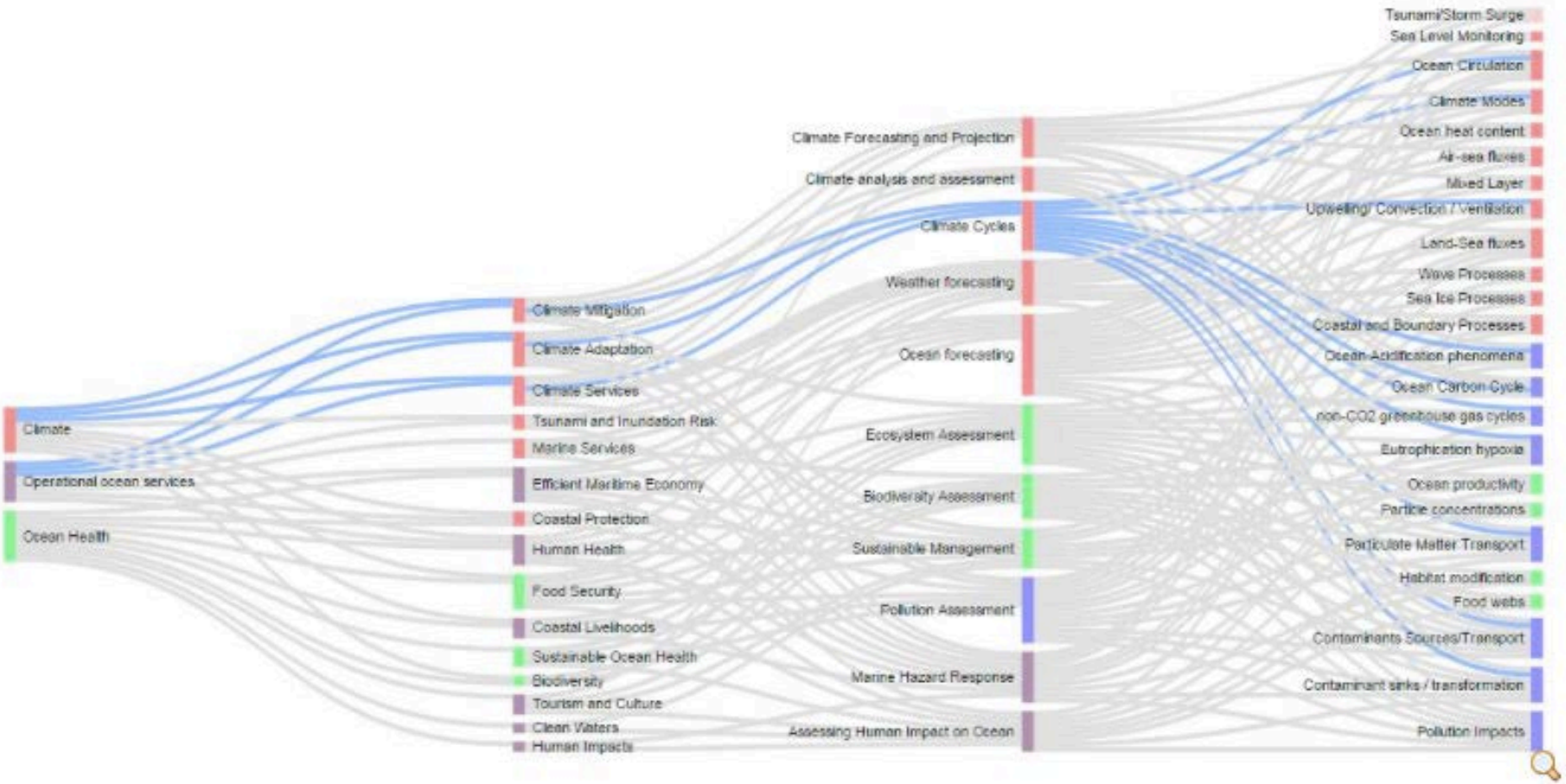
Fig. 3.6. (a) Time series of annual average global integrals of in situ estimates of upper (0–700 m) OHCA

Challenges

- Implementation
- Expansion to other key interlinking areas (operational oceanography, commerce, ocean health
- Maintaining climate quality data
- Instrumentation/platforms

- EOVs lead the way

Societal Benefits : Applications : Phenomena



://www.forbes.com/sites/stevedenning/2011/02/18/whats-wrong-with-bean-counting/#4c7b553e11a5

What's wrong with bean counting?
It's important to note what's wrong with bean counting. It's not that counting is wrong. Counting is good. We desperately need to know what's working and what isn't.

The problem with the bean counters is what's being counted. It's a focus on solely counting things, rather than dimensions of life related to people.