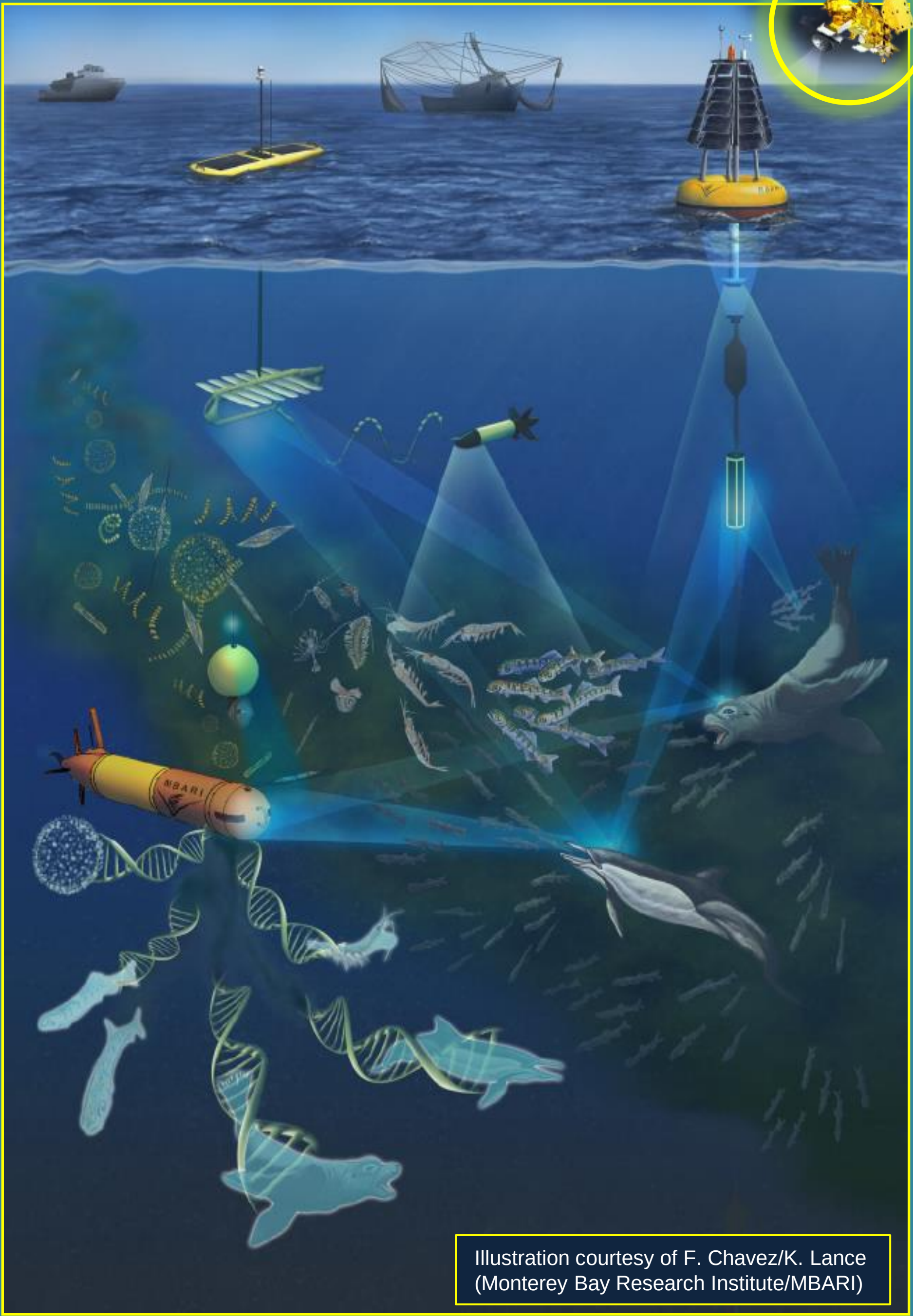


Illustration courtesy of F. Chavez/K. Lance (Monterey Bay Research Institute/MBARI)

GEO BON

MBON

Marine Biodiversity Observation Network

Overview of Marine BON activities, EBVs and EOVs

http://www.marinebon.org/

Contact:
-Frank Muller-Karger (carib@usf.edu)
-Isabel Sousa Pinto (ispinto@ciimar.up.pt)
-Mark Costello (m.costello@auckland.ac.nz)

NASA

NOPP
National Oceanographic Partnership Program

BOEM
Bureau of Ocean Energy Management

NOAA

Atlantic Oceanographic & Meteorological Laboratory
Miami, Florida

IOOS®
Integrated Ocean Observing System

National Marine Sanctuaries

NOAA FISHERIES

OFFICE OF OCEAN EXPLORATION AND RESEARCH

Vision and Goal

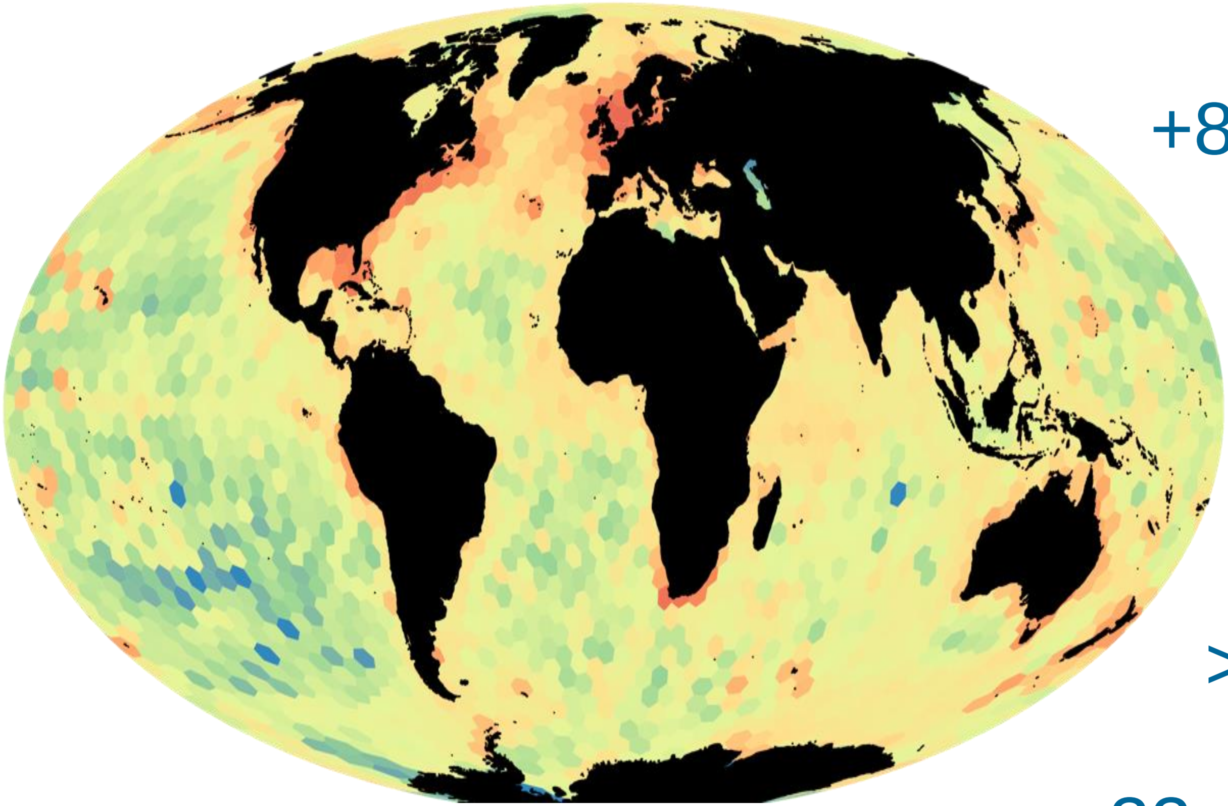
MBON
Marine Biodiversity Observation Network

Develop a community of practice to understand changes in marine biodiversity

Focus:

- US Integrated Ocean Observing System
- National Marine Sanctuaries
- Intergovernmental Oceanographic Commission (IOC/UNESCO: GOOS, OBIS, Ocean Best Practices)
-GEO BON: help develop EBVs

OBIS – THE Ocean Biogeographic Information System



>50 million records

+8600 records daily in 2017

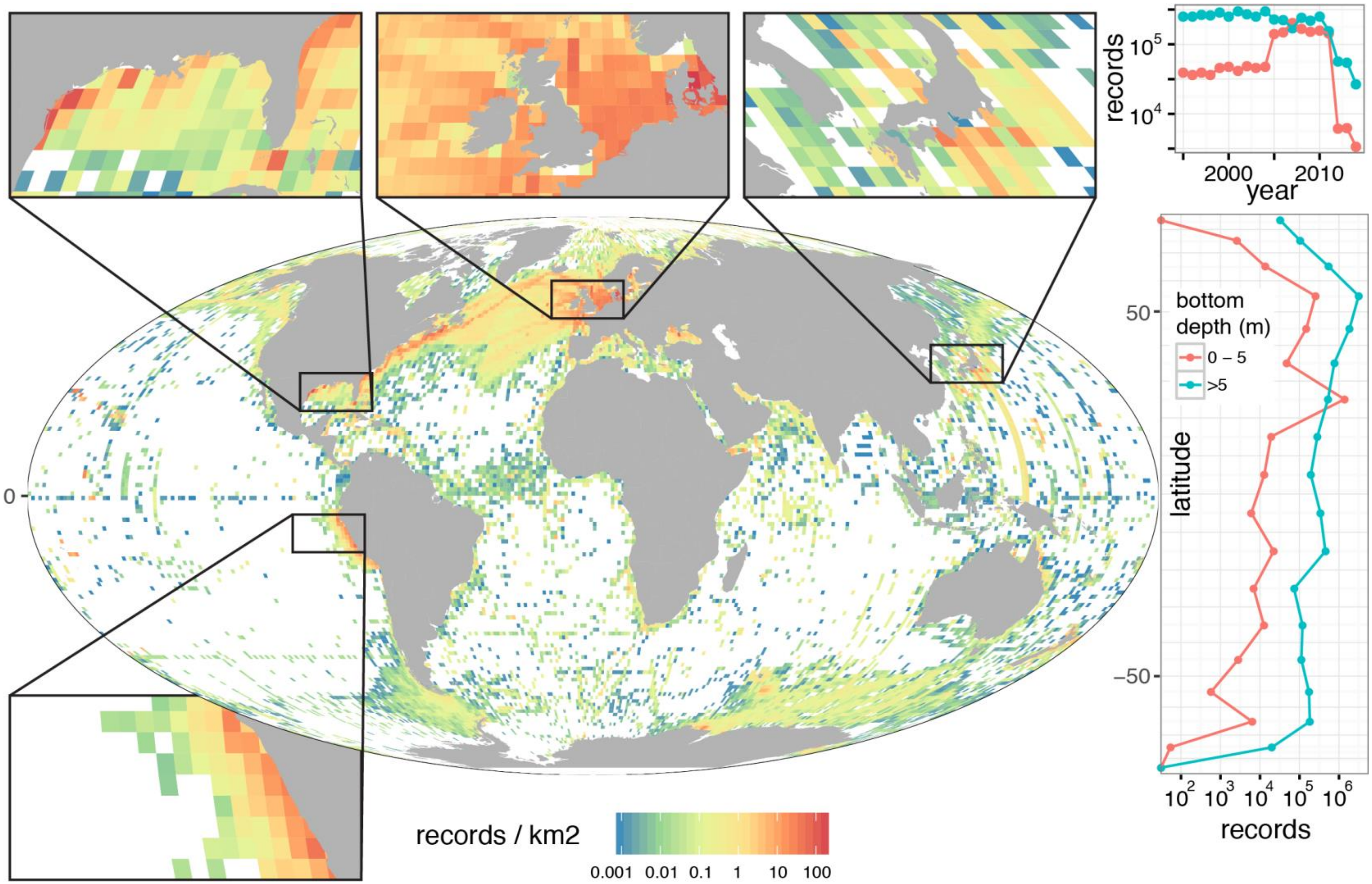
120,000 marine species

>2500 datasets

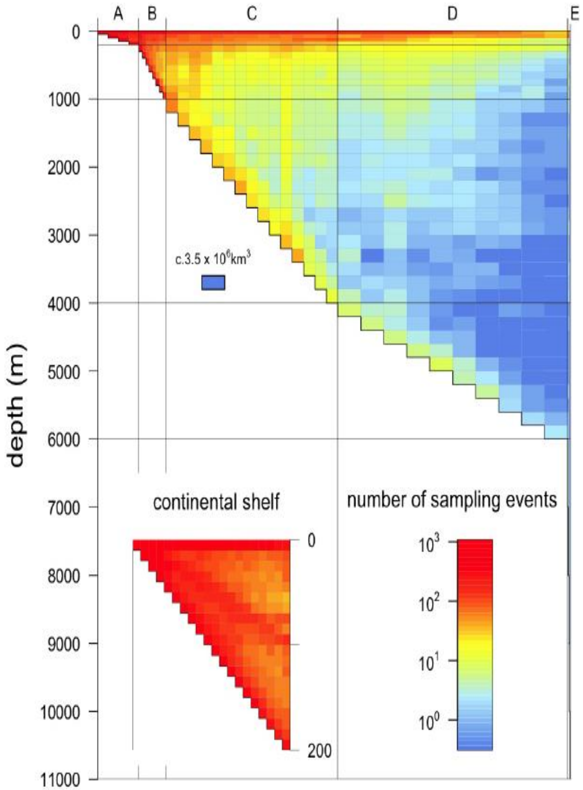
>600 institutions

33 OBIS nodes

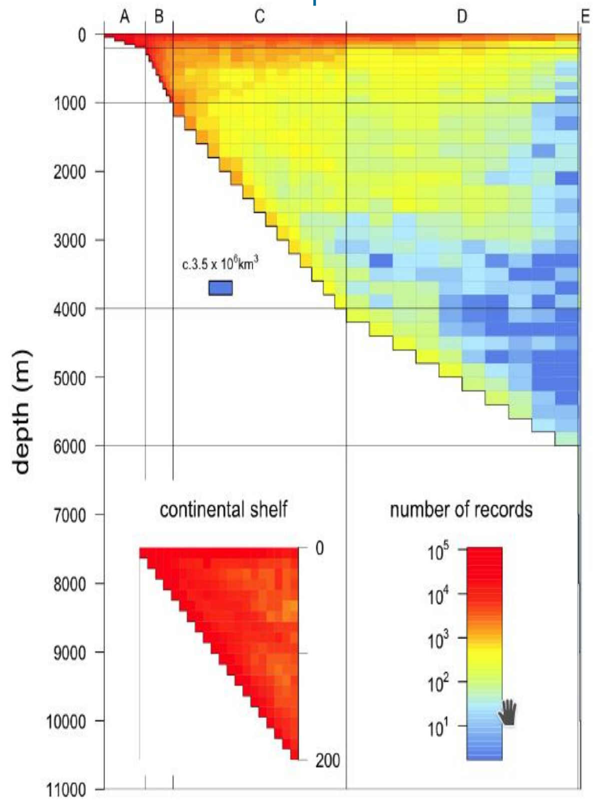
Present SURFACE OCEAN (upper 20 m) OBIS records



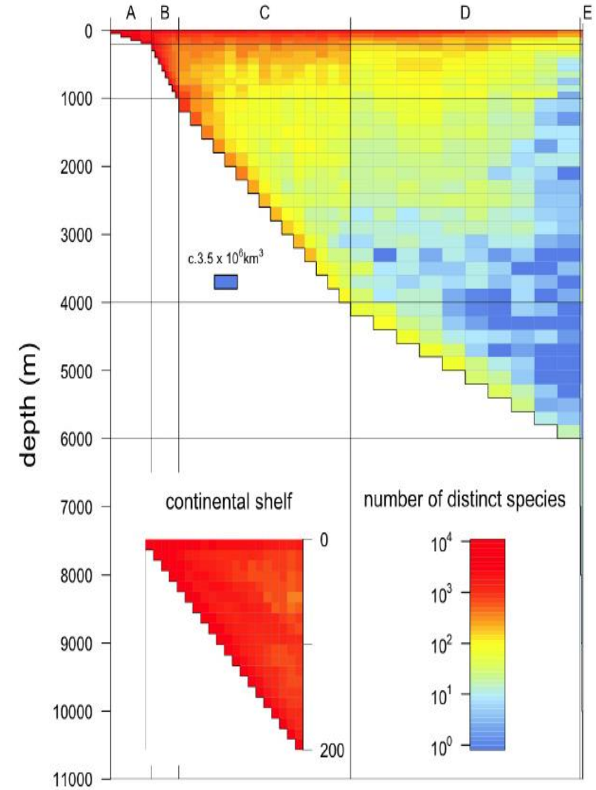
Records



Species



Sampling Events



2/3 of our knowledge is in the upper layer (5% of the ocean)

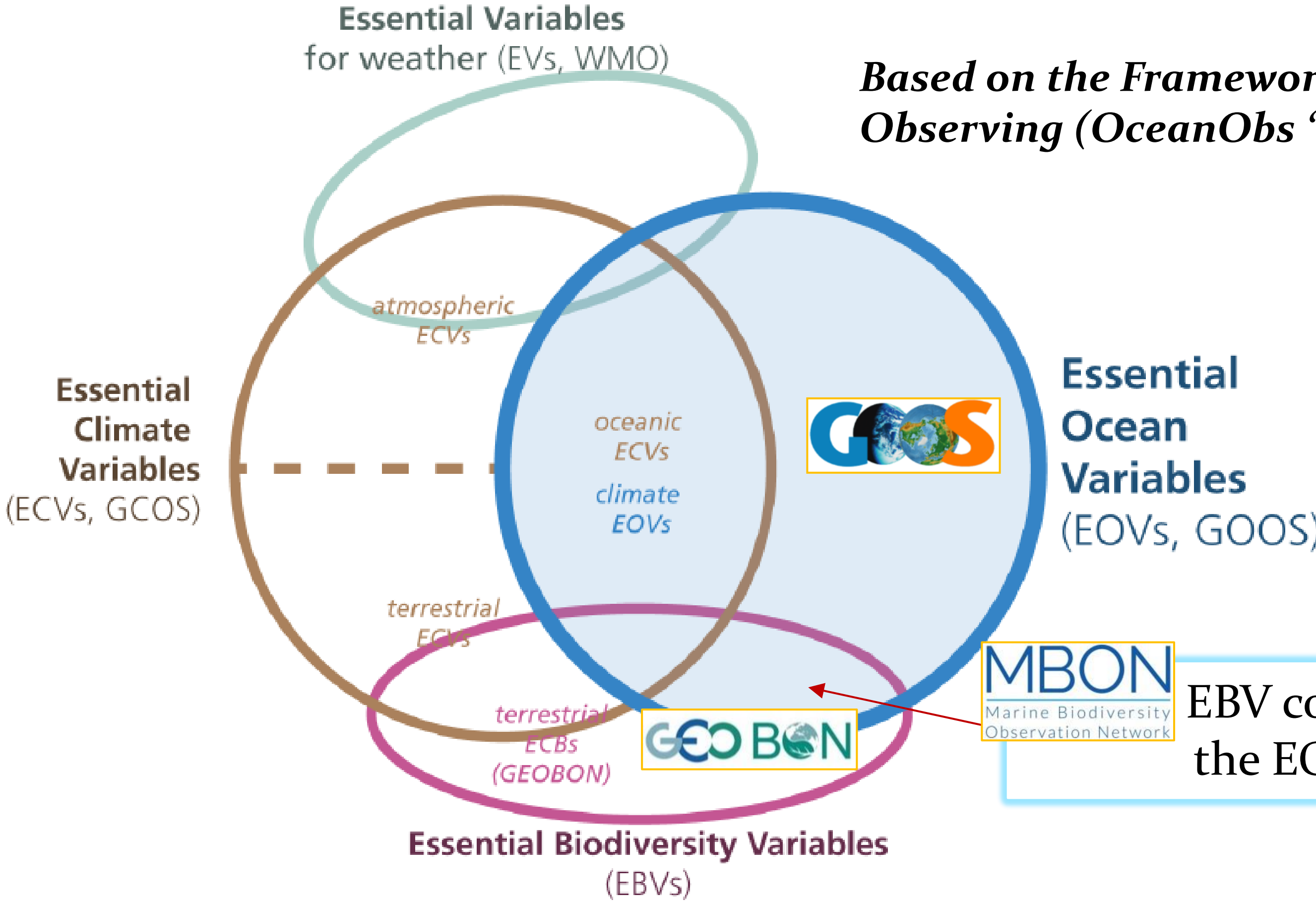
UNESCO IOC and UNEP (2016). The Open Ocean: Status and Trends. United Nations Environment Programme (UNEP),Nairobi. D1 No.: 16-06580
.

Same issues of lack of coverage and minimal biodiversity observations in coastal areas:

-wetlands
-estuaries
-rocky shores
-beaches

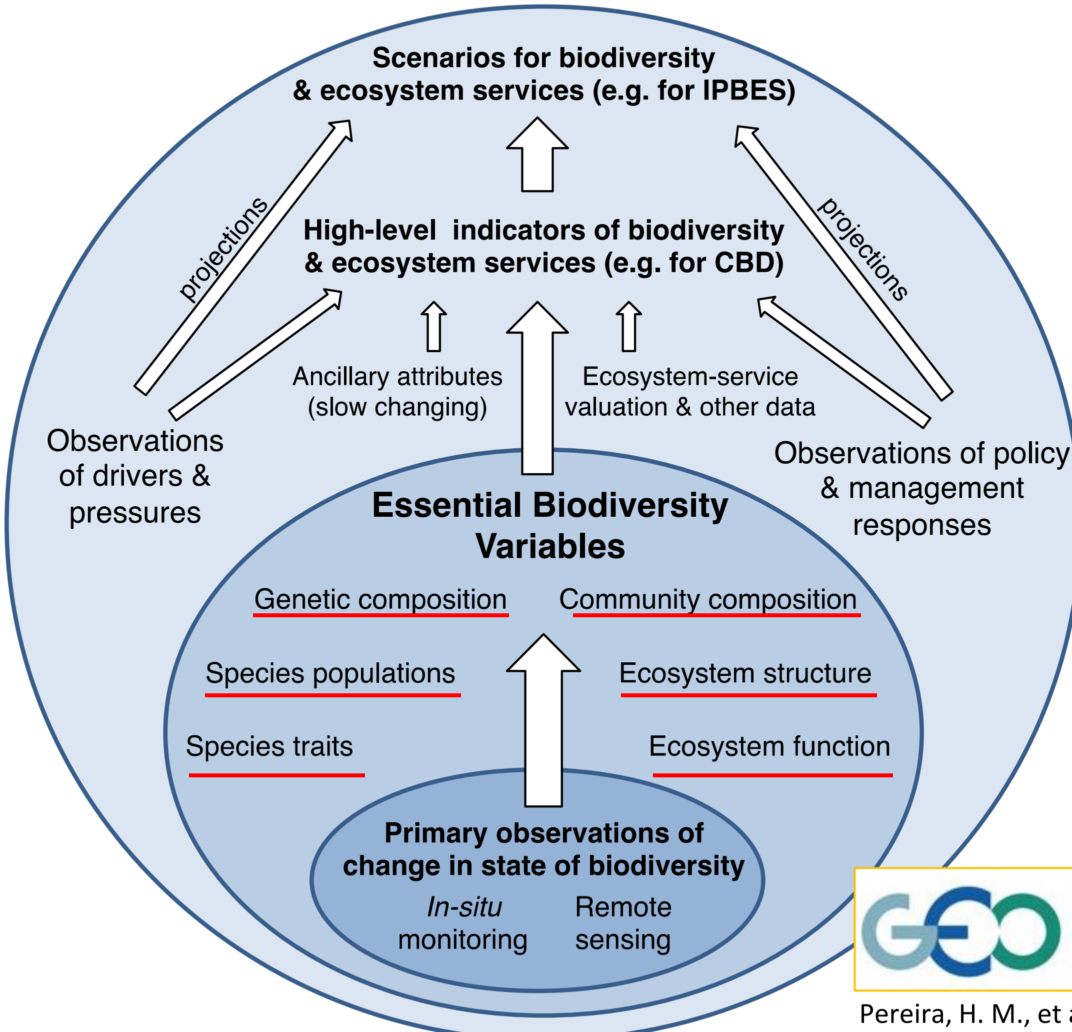
Linking Essential Biodiversity Variables (EBVs) and Essential Ocean Variables

Based on the Framework for Ocean Observing (OceanObs '09):

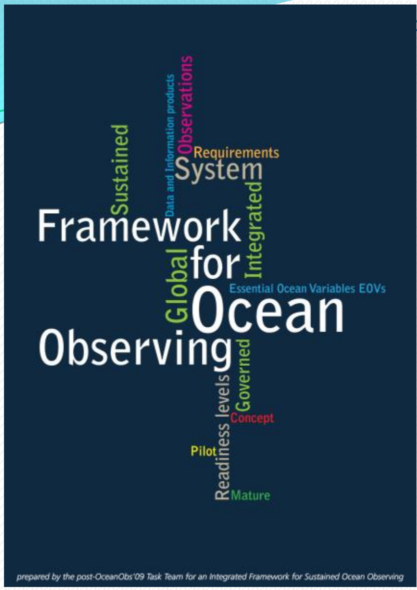


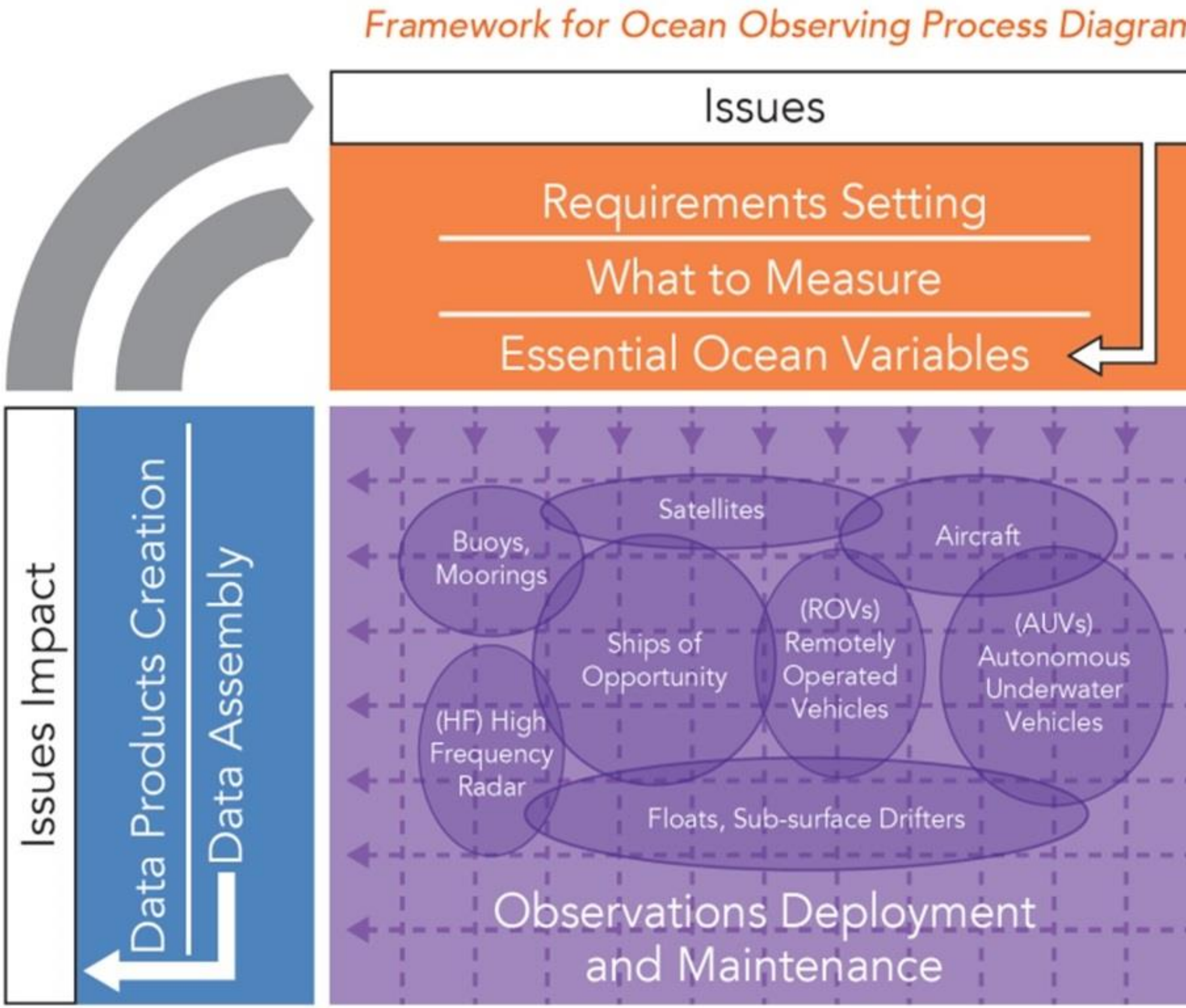
EBV complement the EOV

Essential Biodiversity Variables (EBV)



Pereira, H. M., et al. 2013. Essential Biodiversity Variables. Science. Vol. 339. 277-278.



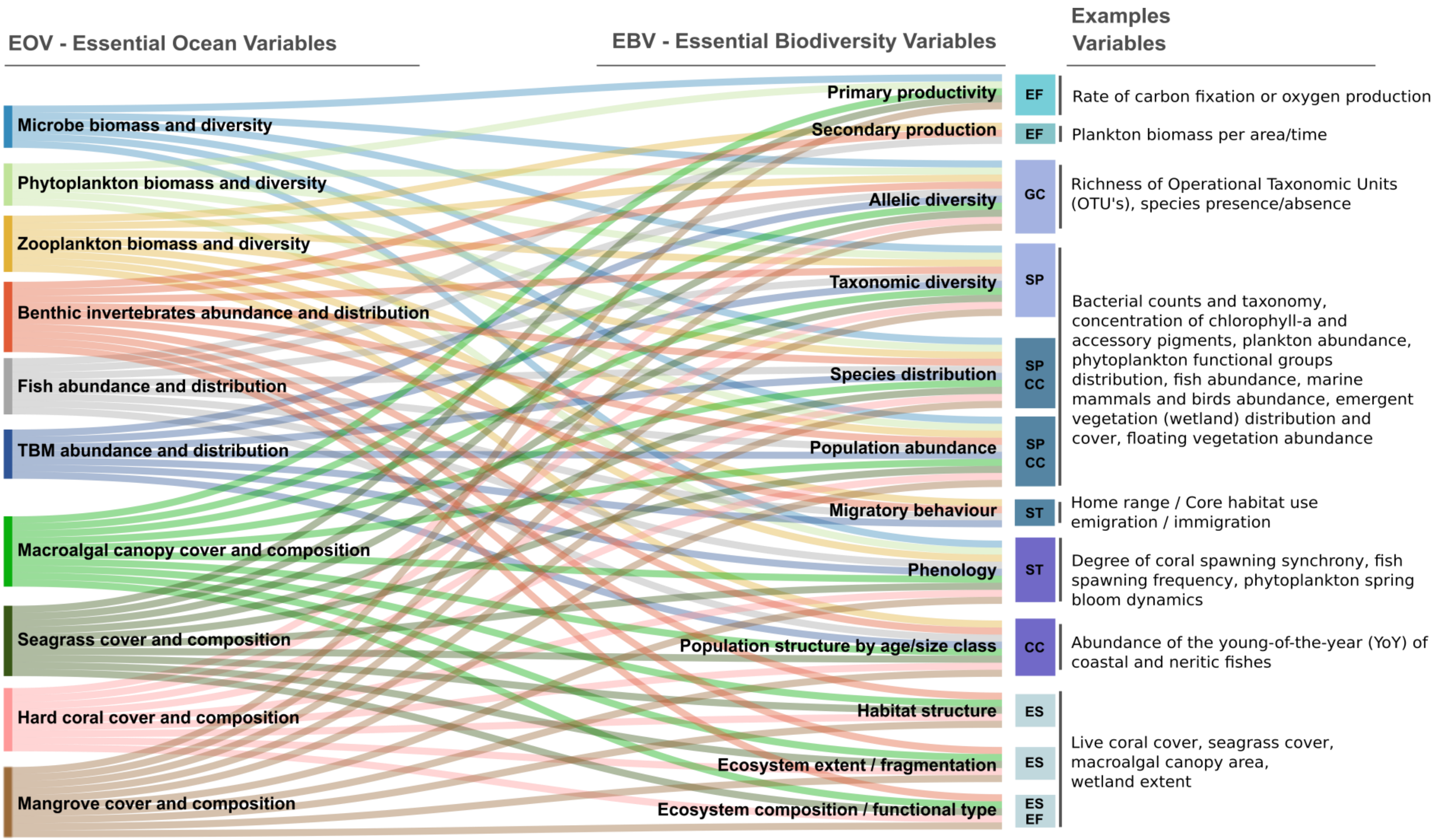


FOO, 2012. A Framework for Ocean Observing. By the Task Team for an Integrated Framework for Sustained Ocean Observing, UNESCO 2012, IOC/INF-1284, doi: 10.5270/OceanObs09-FOO

Global Ocean Observing System (GOOS)

Essential Ocean Variables (EOVs)

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	Particulate matter	Hard coral cover and composition
Subsurface temperature	Nitrous oxide	Seagrass cover
Surface currents	Stable carbon isotopes	Macroalgal canopy cover
Subsurface currents	Dissolved organic carbon	Mangrove cover
Sea surface salinity	Ocean colour *(Spec Sheet under development)*	Microbe biomass and diversity (*emerging)
Subsurface salinity		Benthic invertebrate abundance and distribution (*emerging)
Ocean surface heat flux		



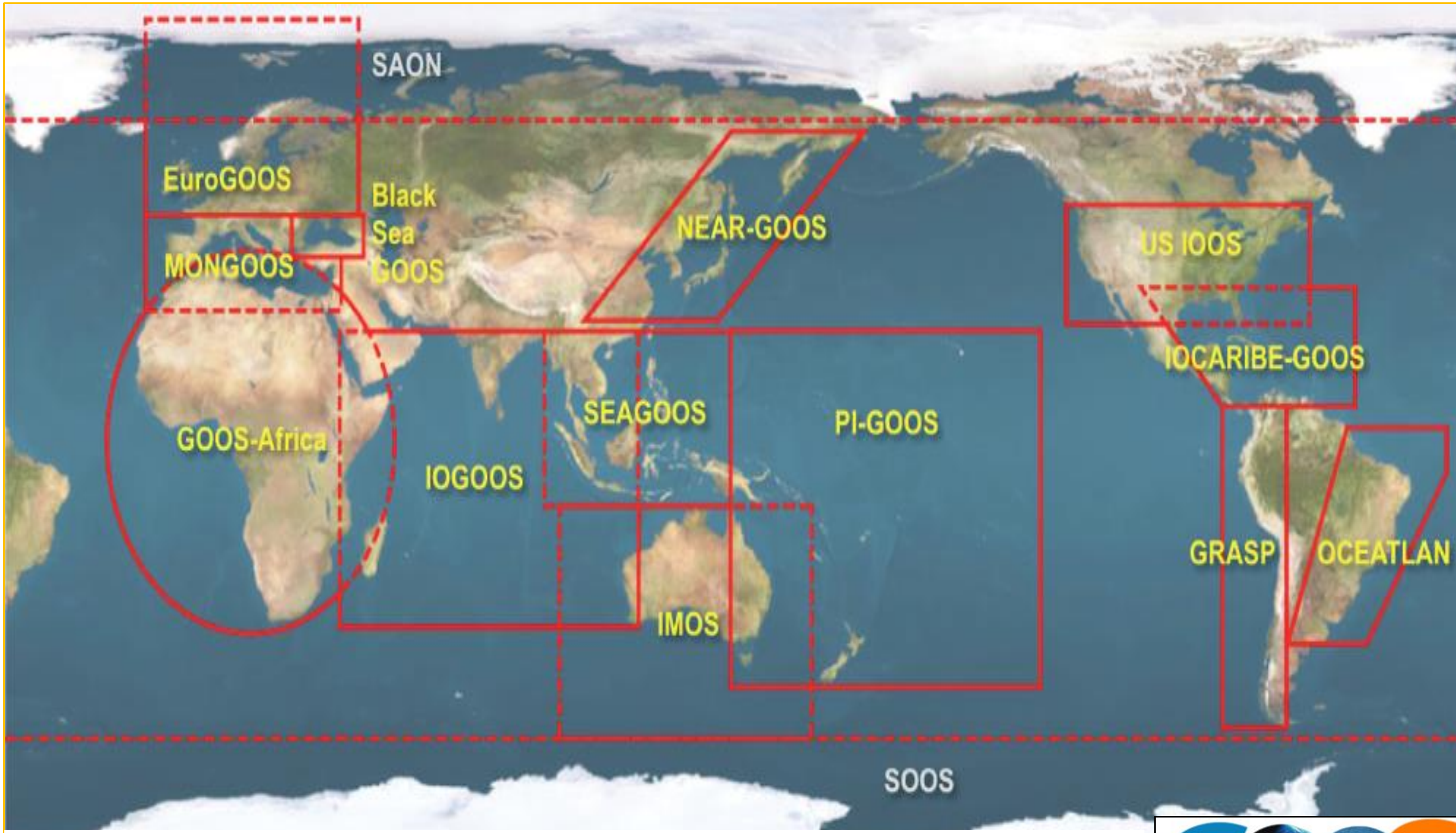
Conceptual, complementary relationship between EOVs and EBVs

(TBM: marine turtles, birds, and mammals)

Example EBVs: GC – Genetic composition; SP – Species populations; ST – Species traits; CC – Community composition; ES – Ecosystem structure; EF – Ecosystem function.

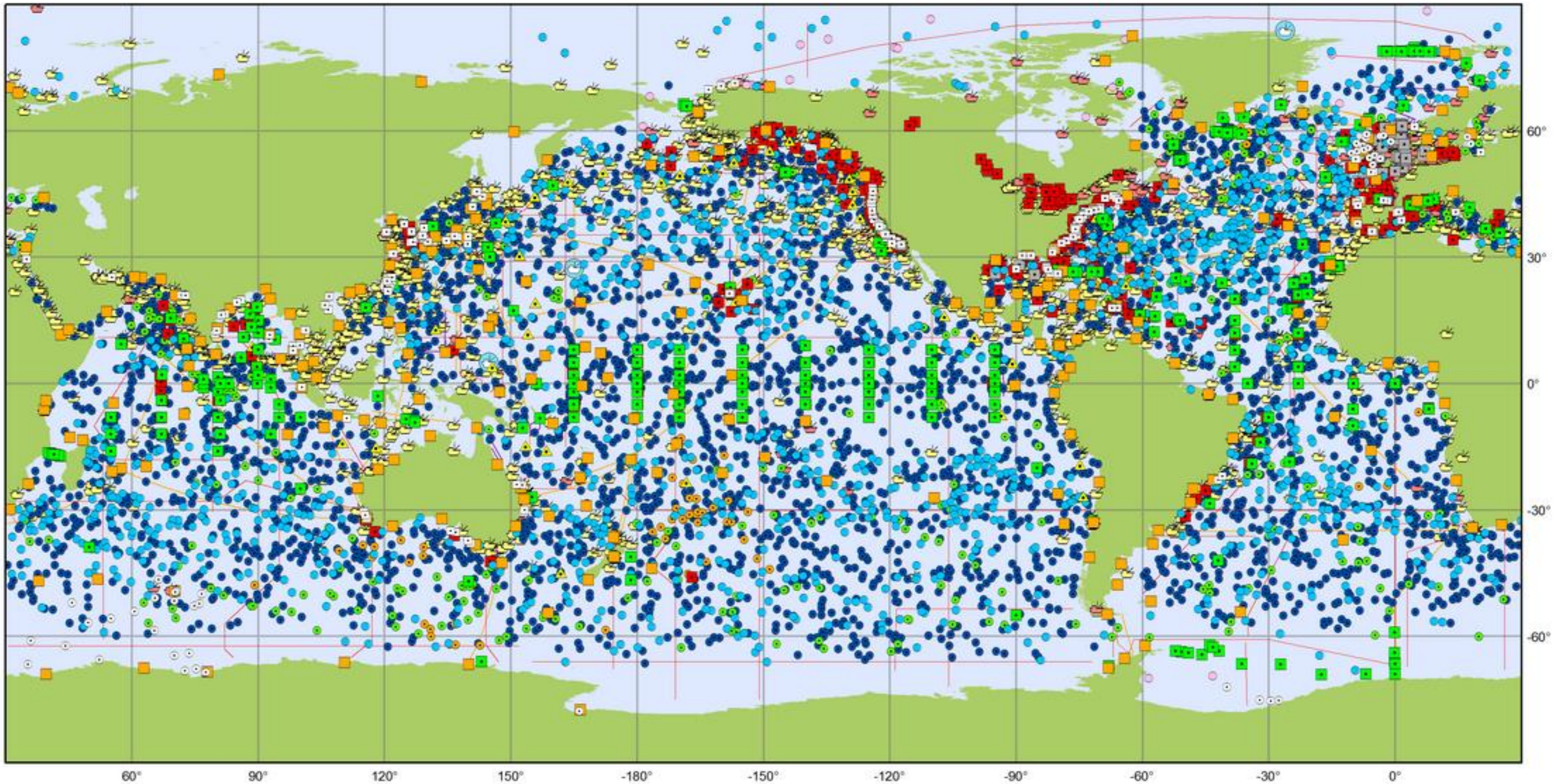
[Muller-Karger et al., 2018. Frontiers in Marine Science. https://doi.org/10.3389/fmars.2018.00211]

Building a global ocean biodiversity observing system:
Use what already exists: 15 GOOS Regional Alliances + LTER, etc.



Global Ocean Observing System

In situ elements of GOOS



Main in situ Elements of the Global Ocean Observing System

July 2018

Profiling Floats (Argo)
- Core (3757)
- Deep (66)
- BioGeoChemical (286)

Data Buoys (DBCP)
- Surface Drifters (1394)
- Offshore Platforms (97)
- Ice Buoys (20)
- Moored Buoys (394)
- Tsunameters (37)

Timeseries (OceanSITES)
- Interdisciplinary Moorings (438)

Repeated Hydrography (GO-SHIP)
- Research Vessel Lines (61)

Sea Level (GLOSS)
- Tide Gauges (252)

Ship based Measurements (SOT)
- Automated Weather Stations (251)
- Manned Weather Stations (1787)
- Radiosondes (7)
- eXpendable BathyThermographs (37)

Other Networks
- HF Radars (270)
- Animal Borne Sensors (53)
- Ocean Gliders (31)

Generated by www.jcommops.org, 20/08/2018

http://www.jcommops.org/reportcard/

Scales of variation and observation

- Physical processes at different scales affect different biological processes

- Different technologies are suited for different observations

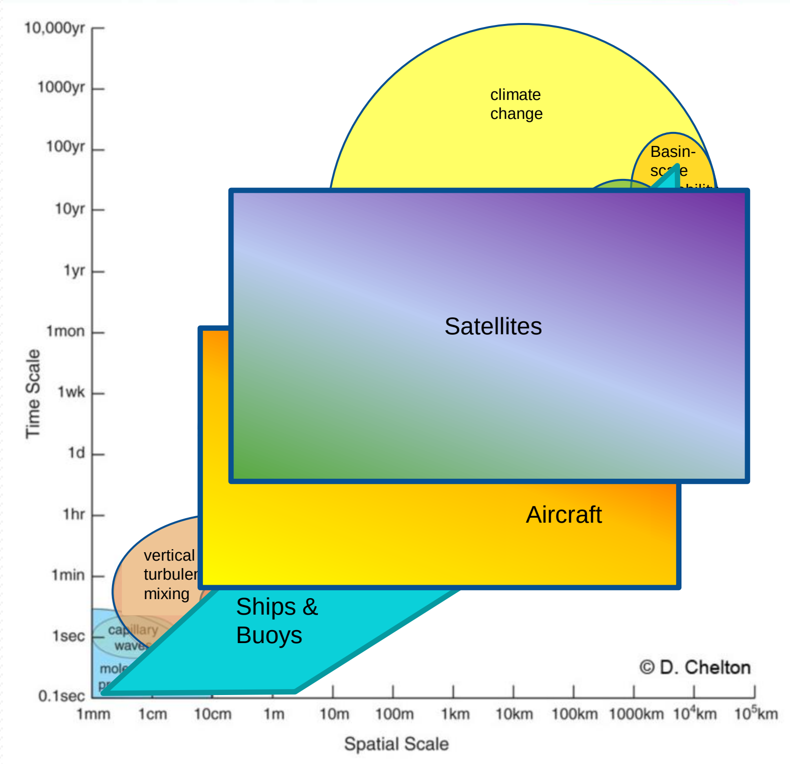
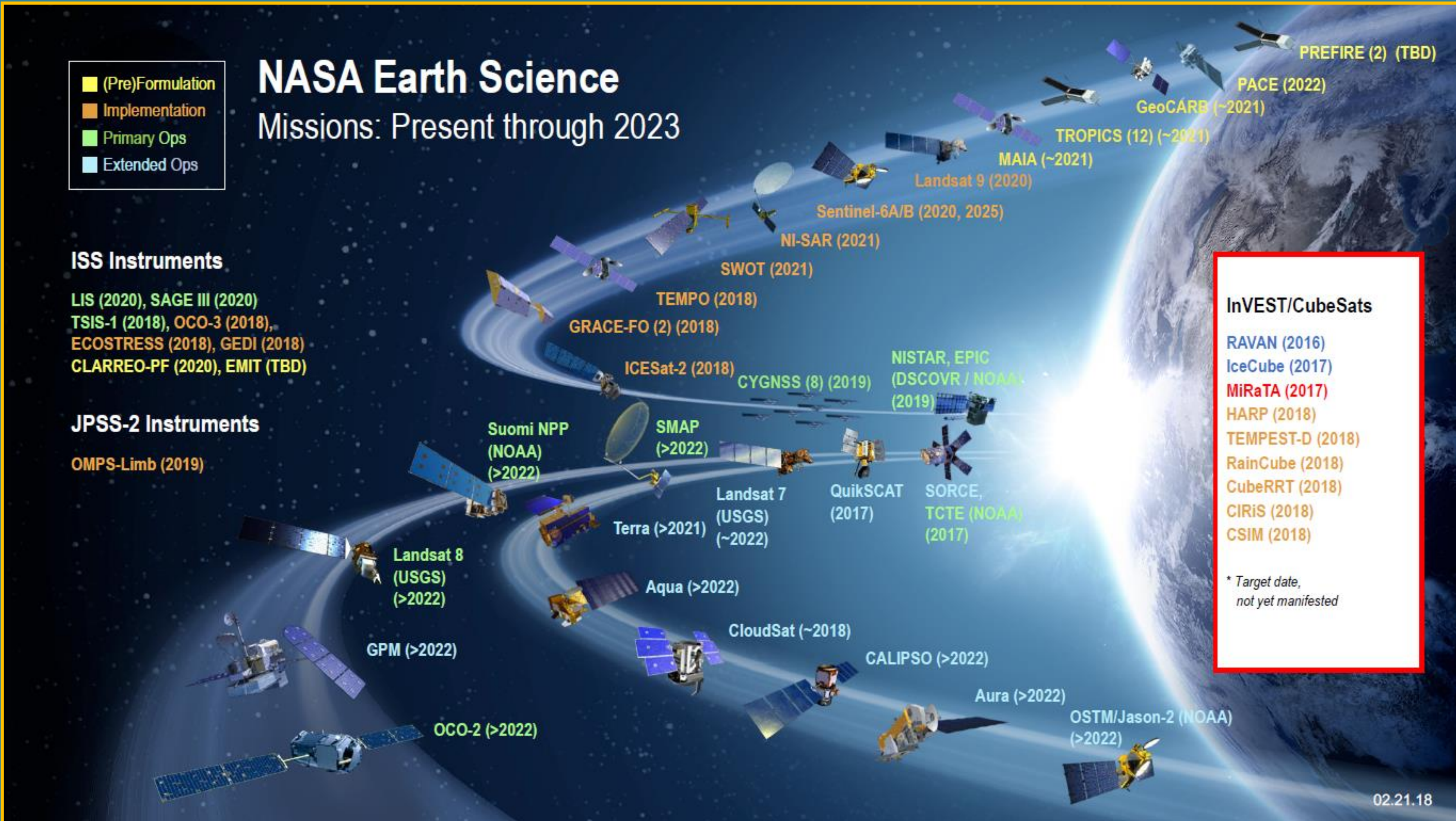


Table 1. Main ranges of spatial, temporal, and spectral resolutions used in the terrestrial and global environment, including marine and atmospheric domains.

Resolution	Environment	Low resolution	Medium resolution	High resolution
Spatial	Terrestrial	30 – 1000 m	4 – 30 m	0.4 – 4 m
	Marine	10 – 50 km	2 – 10 km	$\leq$ 1 km
Temporal	Terrestrial	$>$ 16 d	4 – 16 d	1 – 3 d
	Marine	$>$ 5 d	1 – 5 d	$\leq$ 1 d
Spectral	–	1 channel (e.g. panchromatic	3 – 10 channels	$\geq$ 10 channels (hyperspectral)

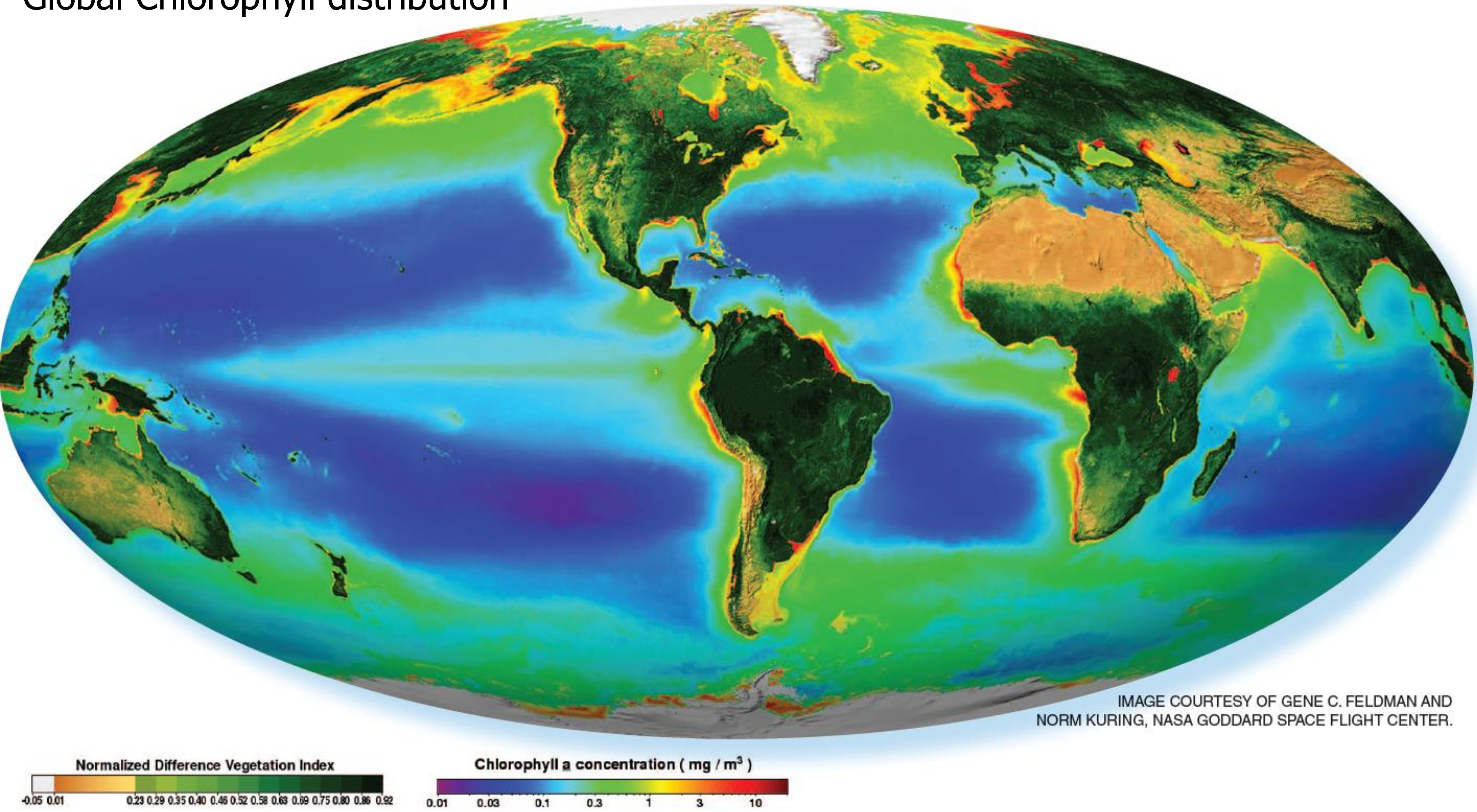
Remote sensing elements for Earth Observation



<u>Other constellations</u>:

European Commission / ESA
China
Japan / JAXA
Russia
India

Global Chlorophyll distribution



Ocean covers large area of our planet (>70%)
Coastal zones are critical for humans and biodiversity

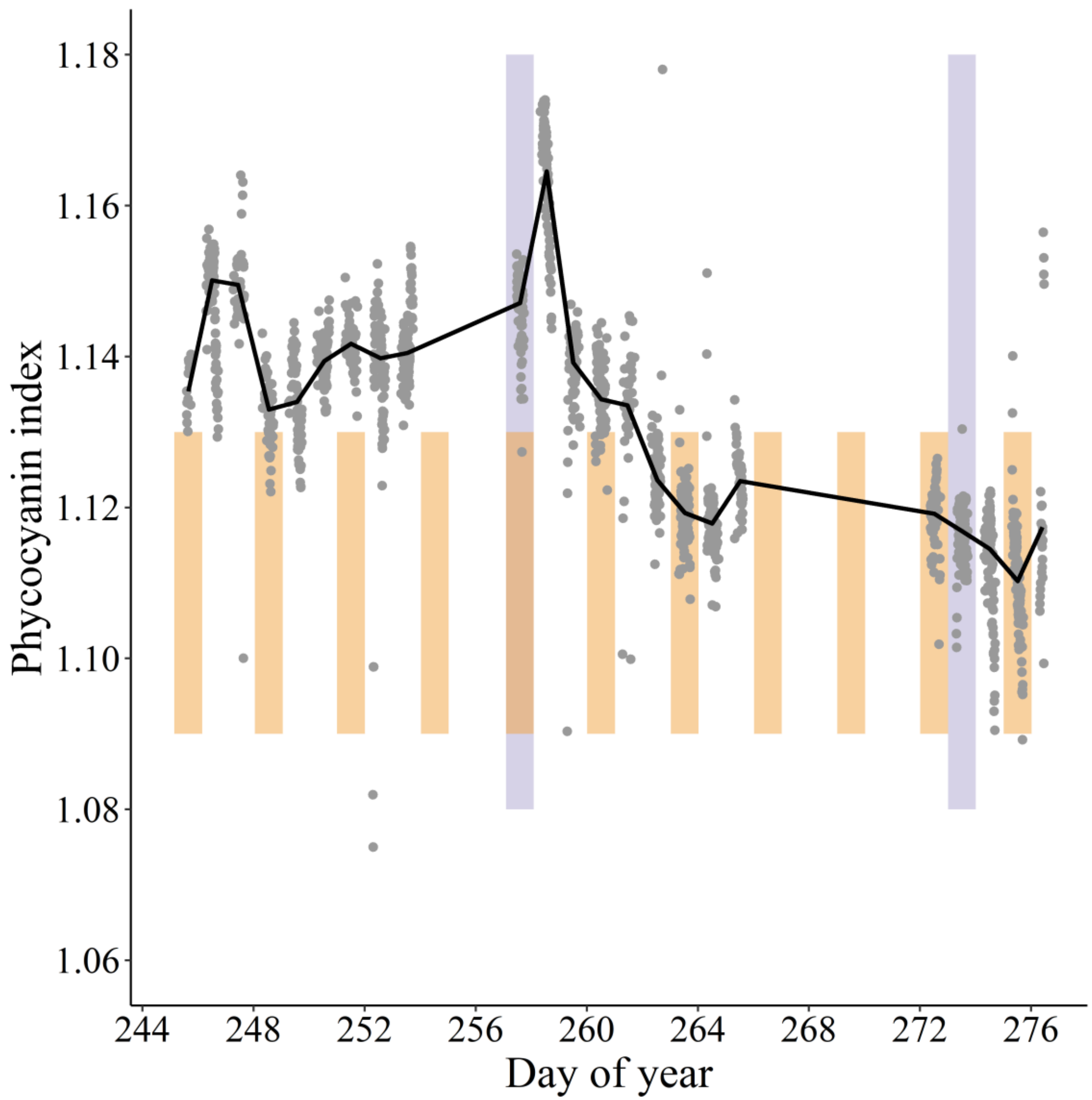
Remote Sensing of Aquatic Essential Biodiversity Variables (EBV): More could be achieved with *H4** sensors (orange boxes)

*<u>H4</u>: High spectral High spatial
High Temporal High quality

EBV class	EBV	Habitat Type							
		Wetland Vegetation	*Benthic Communities*			*Pelagic Organisms*			
		Mangrove/ salt marsh	Seagrass	Macroalgae	Coral	Phytoplankton	HAB	Fish, Zoo-plankton	Apex predator
Genetic composition	Population genetic diversity								
Species populations	Distribution								
	Abundance								
	Size/vertical distribution								
Species traits	Pigments							NA	NA
	Phenology								
Community composition	Taxonomic diversity								
Ecosystem structure	Functional type								
	Fragmentation/ heterogeneity					ROUTINE USE FOR OPEN OCEAN			
Ecosystem function	Net primary production							NA	NA
	Net ecosystem production						NA	NA	NA

Legend
- Unproven
- Demonstrated limited cases
- Routine use
- Habitat model required

MULLER-KARGER ET AL., ACCEPTED. 2017. Satellite Sensor Requirements for Monitoring EBV of Coastal Ecosystems. Ecological Applications.

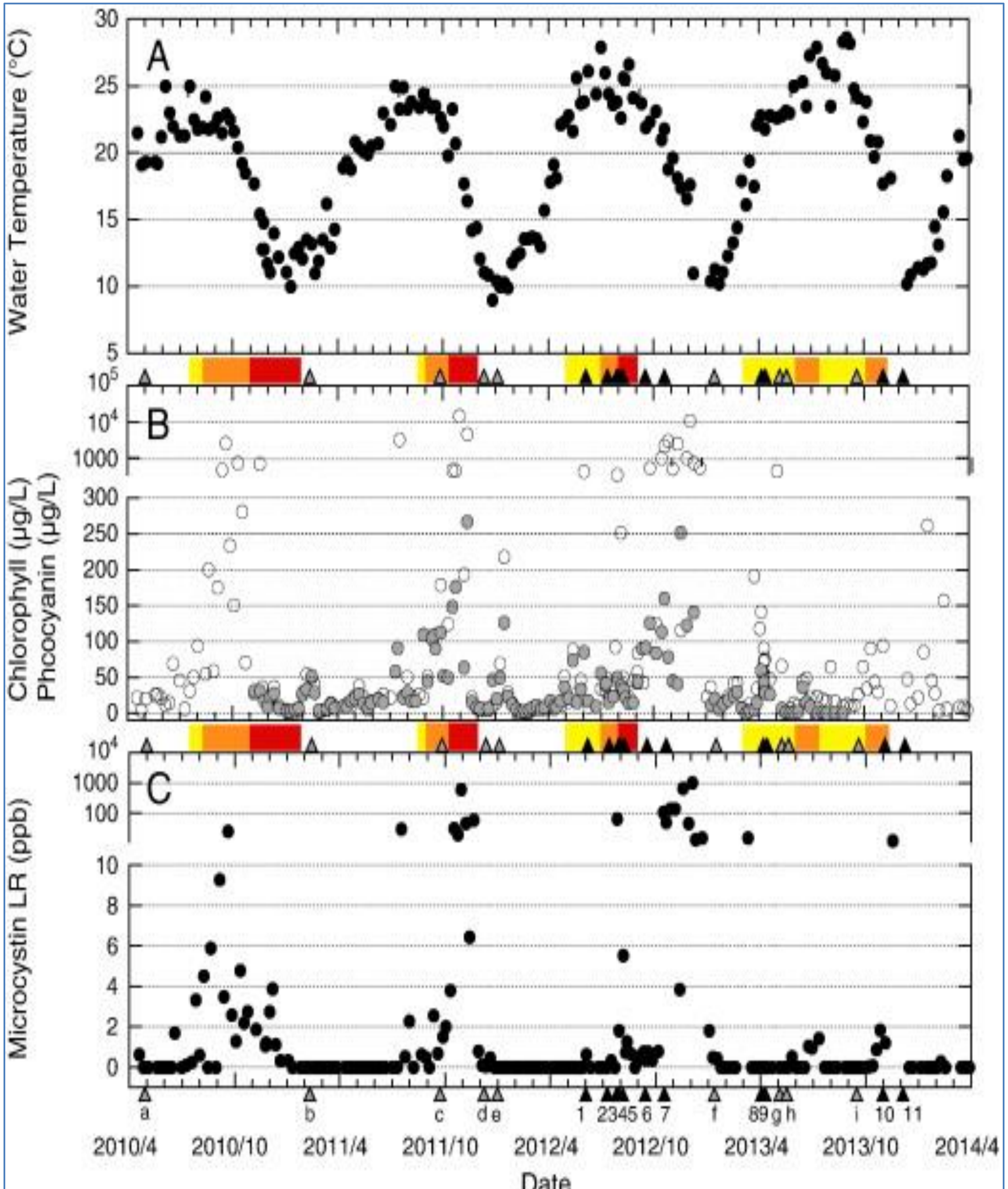


Rapid changes in nuisance cyanobacteria (*phycocyanin pigment index)*

In situ measurements every 15 minutes daily with hand-held spectrometer used to identify the organism in Upper Mantua Lake (Italy).

16 days: grey vertical bars
3-day: Orange vertical bars

From Hestir et al 2015



Many examples of **rapid change in aquatic cyanobacteria and harmful algae** concentrations

Identification of cyanobacteria using spectral info from the ground

(graph: Kudela et al. 2015).

HICO shows *Mesodinium rubrum* bloom because it has fluorescence information provided by hyperspectral data

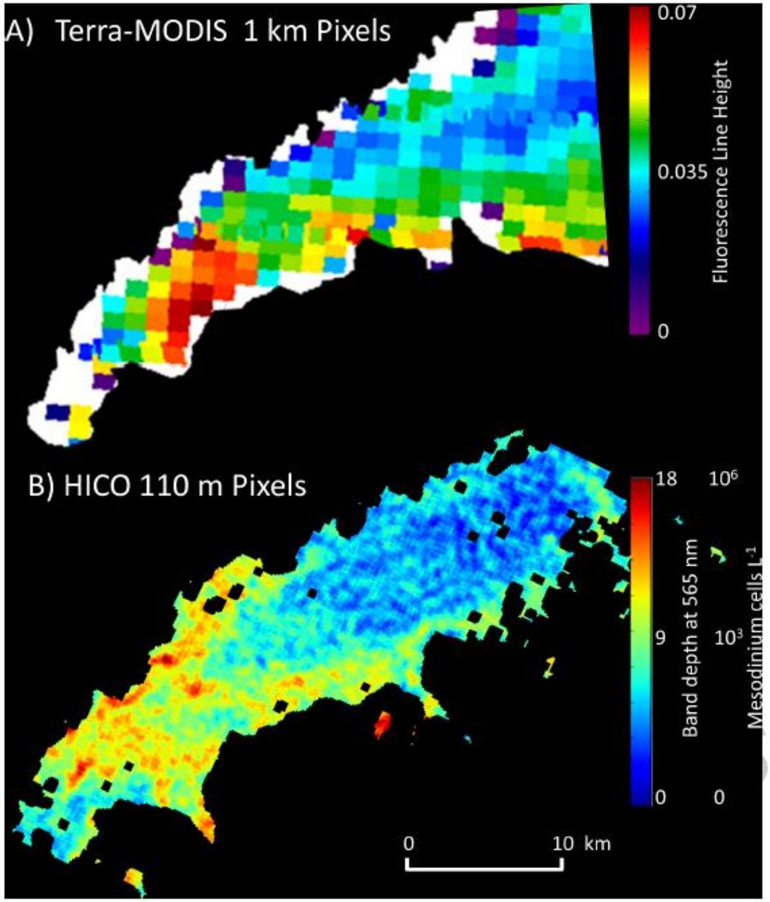
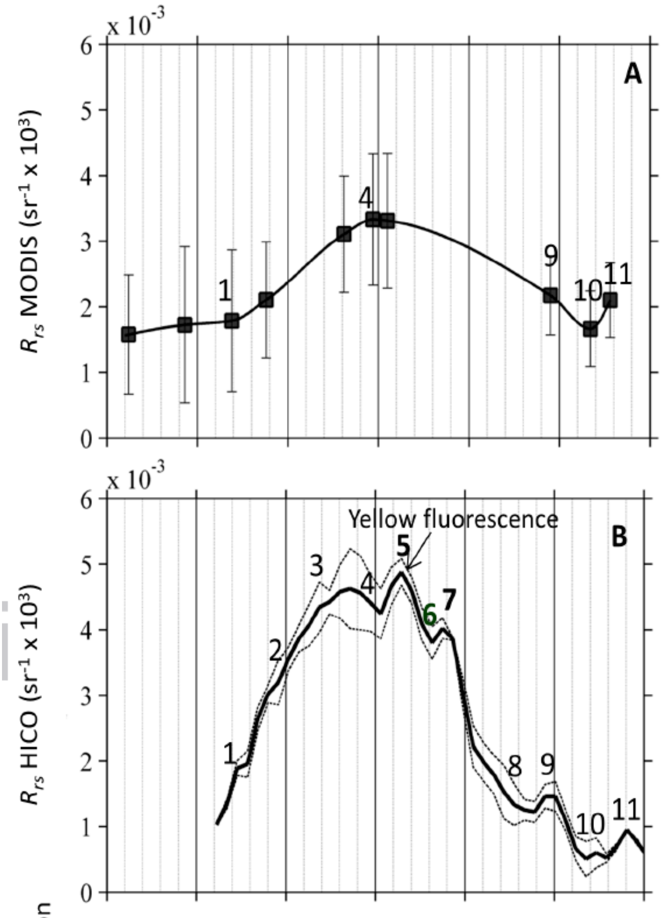


Fig. 3. *.A)* The 1-km resolution image of western Long Island Sound from the MODIS Terra sensor shows an elevated chlorophyll *a* fluorescence patch on 23 September 2012, but the type of bloom cannot be distinguished from the limited spectral bands. *B)* In contrast, hyperspectral HICO imagery from the International Space Station reveals characteristic yellow fluorescence due to phycoerythrin pigment within the enslaved chloroplasts of the ciliate *Mesodinium rubrum*. Dense, patchy near-surface blooms of this motile and actively photosynthesizing mixotrophic marine protist (>1×10^6 cells L^{-1}) periodically dominate primary productivity in the region.cells L^{-1}.



Dierssen et al 2015

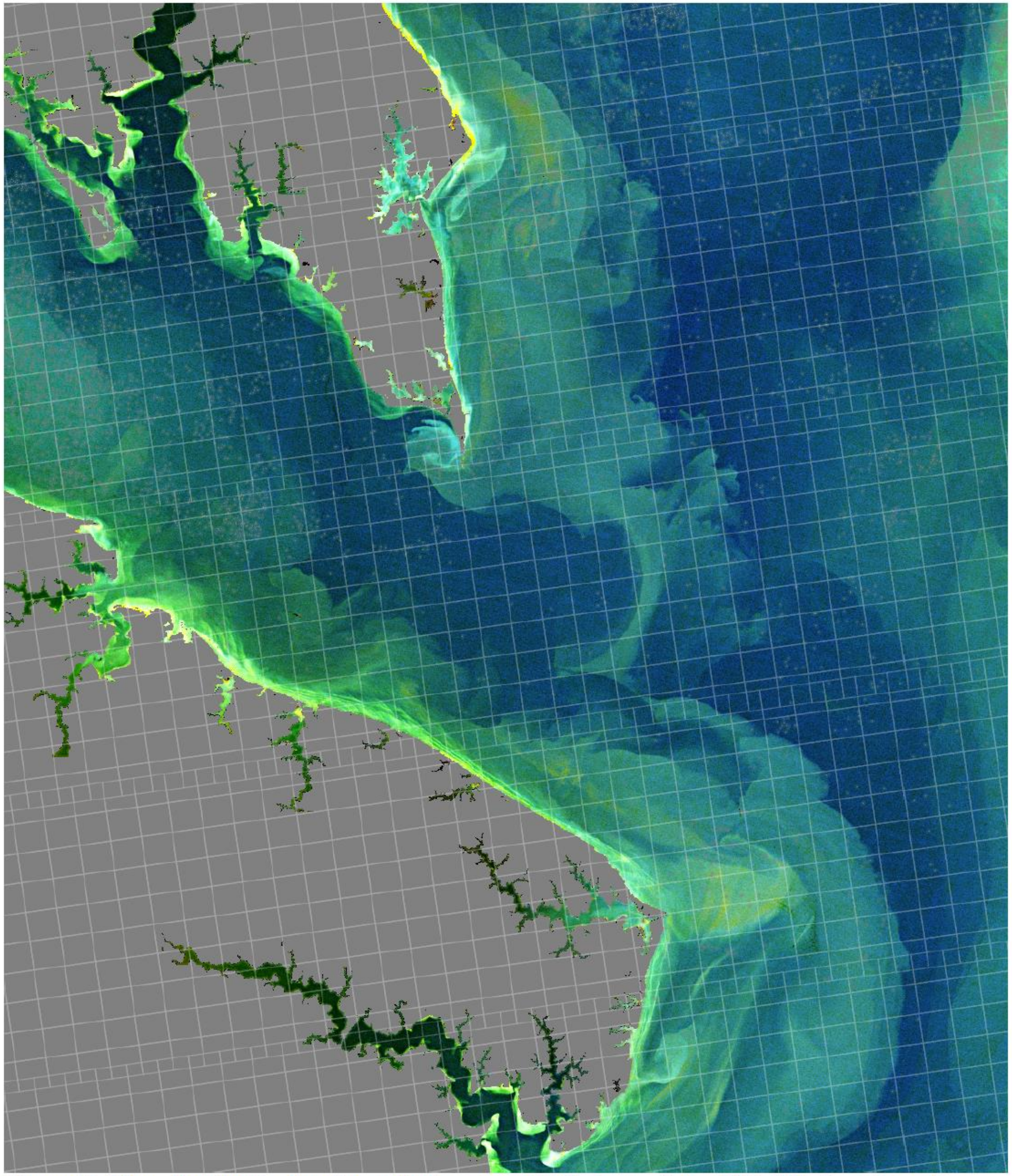
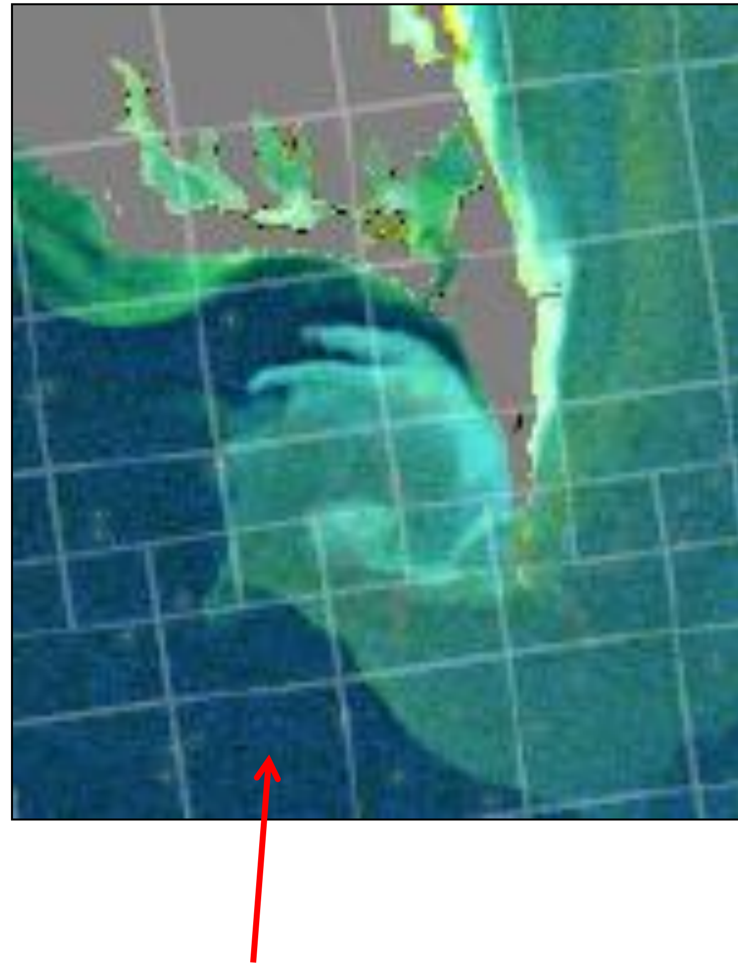


Figure 5: *Three-band water-leaving reflectance composite image from OLI at the location where the Potomac River enters Chesapeake Bay. MODIS Aqua scan pixel boundaries for the same date are overlaid to demonstrate the sub-pixel variability revealed by the higher spatial resolution of OLI. The Rrs(λ)were retrieved using standard NASA ocean color processing in SeaDAS, and red, green, and blue reflectances at λ=(655, 561, 443nm) were combined to form the image.*



MODIS 1 km pixel grid on
30 m Landsat-8 OLI image

From Franz et al., 2014

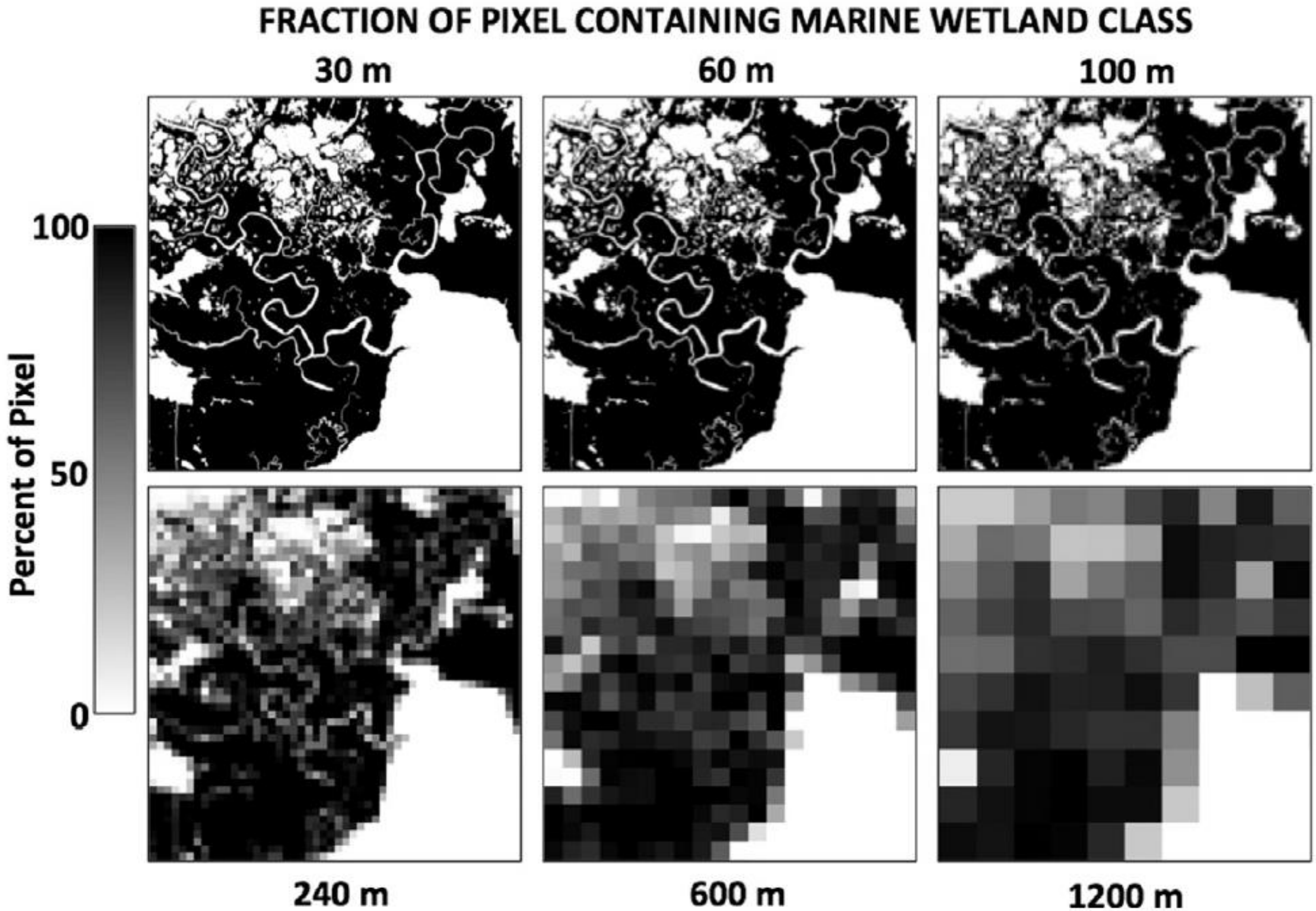


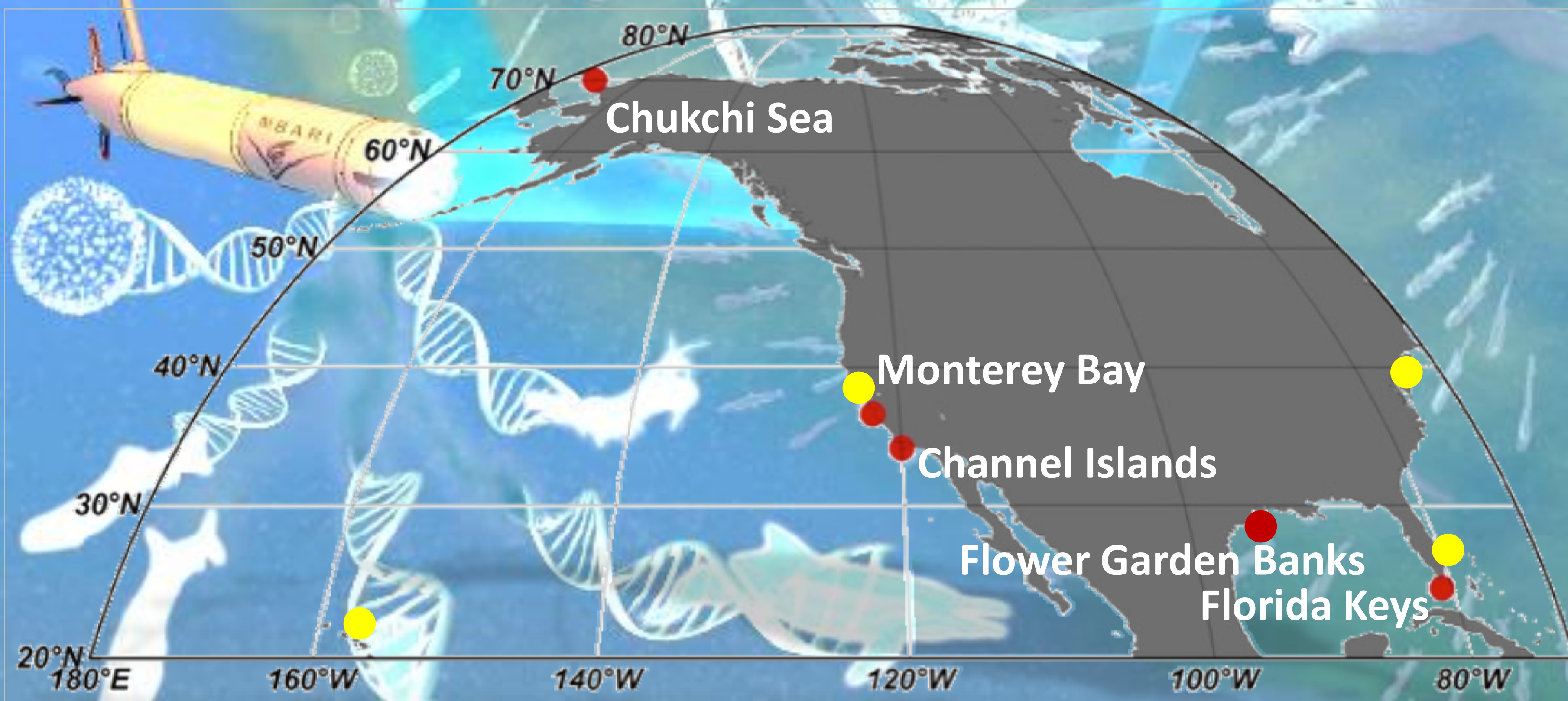
Fig. 3. Effects of increasingly coarser resolution on spatial representation of an example wetland. Shown is an inset of a rasterized layer from polygon data mapped in Fig. 2 for the Estuarine and Marine Wetland type (see the double-line box in Fig. 2).

From Turpie et al 2015

Coastal / Great Lakes aquatic remote sensing priorities

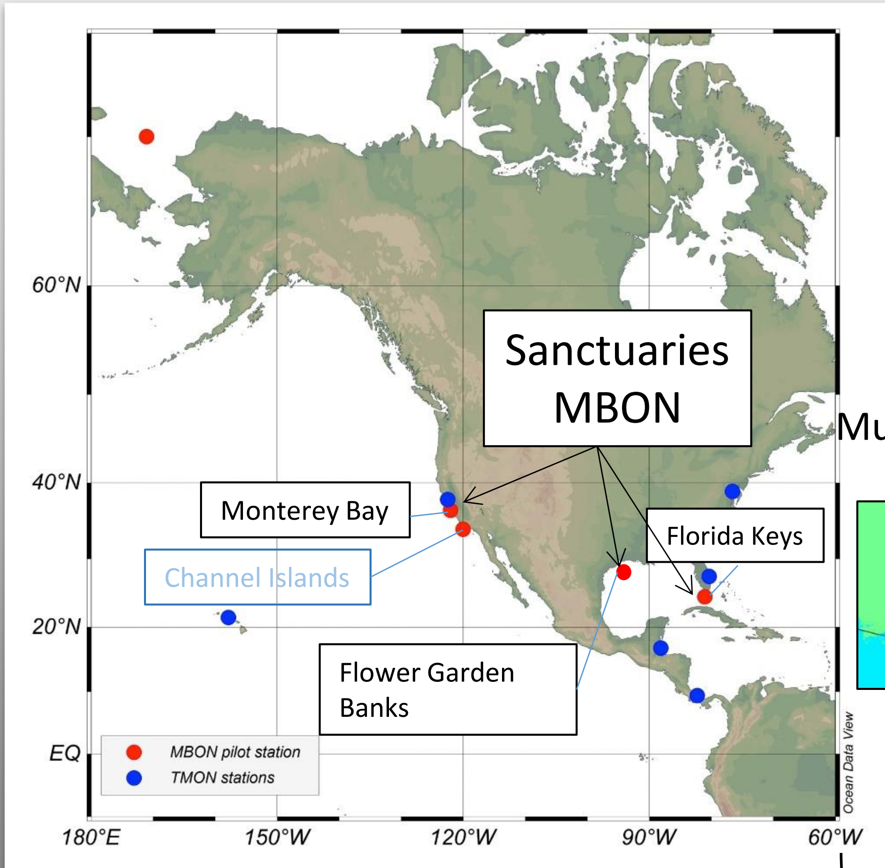
- High temporal
  - At some representative locations: twice weekly or more
- High spatial (~30-90 m)
  - Global + regional intensive
  - Consistency with Landsat history and global coverage
- High spectral (VIS and SWIR)
  - VIS can be ~5 nm except higher (~2 nm or better) in key areas such as around chlorophyll fluorescence (~685 nm) and O2 absorption bands
- Radiometric/geolocation: high quality
  - High SNR (ocean color class), high digitization/quantitization, minimal polarization sensitivity, minimal cross-talk or other out-of band, atmospheric correction scheme (including adjacency), sun-glint avoidance, cloud screening/masking, etc.
  - High geolocation accuracy
- Robust and data processing and distribution

IOOS/NASA/BOEM/NSF/SI MBON Demonstration

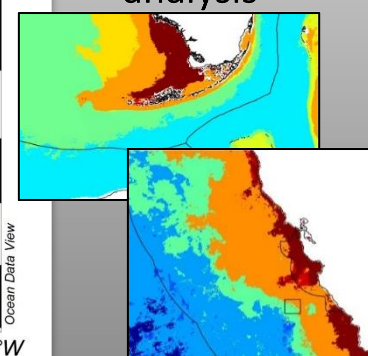


US MBON stations
Tennenbaum/MarineGEO stations (Smithsonian)

The US MBON demonstration program



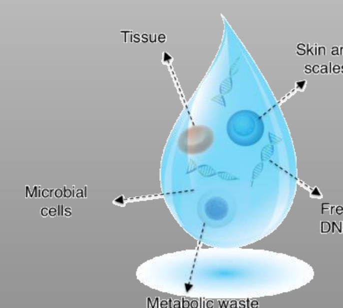
Multivariate seascape analysis



Data Integration:

- IOOS/GOOS
- I-OBIS
- GEO BON

eDNA



- Sanctuary Condition Reports
- Resource managers and policy makers
- Scientists and educators

Supports

Web-based information system

Pole to Pole MBON

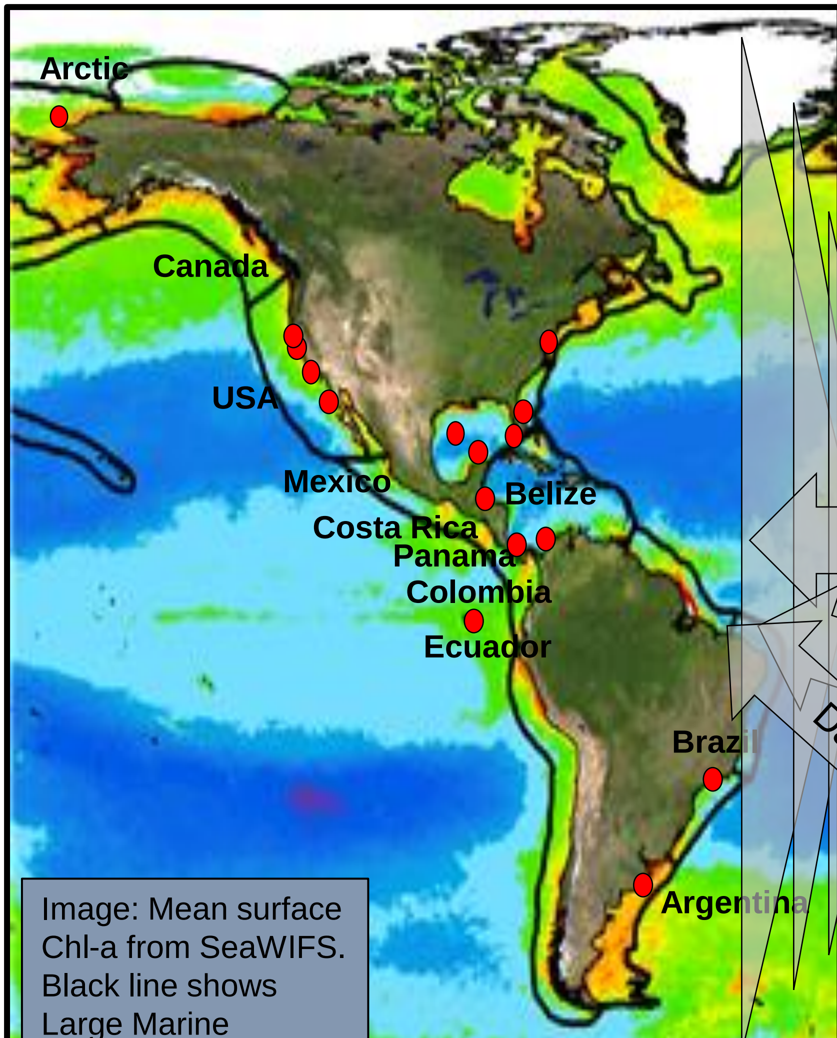


Image: Mean surface Chl-a from SeaWIFS. Black line shows Large Marine Ecosystems.

EBV's / EOV's

Methods / Tools

Data

Partners

invemar

CONABIO

Smithsonian TMON - MarineGEO

NASA

Universidade de São Paulo

Fundación Charles Darwin Foundation

AmeriGEOSS

CONICET

MBON

SPINCAM

NOAA

The Global Ocean Observing System GOOS

OBIS OCEAN BIOGEOGRAPHIC INFORMATION SYSTEM

BON IN A BOX

GEO BON

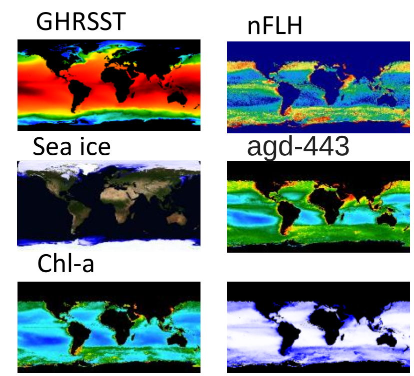
Evolving technology matrix: *Biology ‘beyond fluorescence’*

	Microbes/ Phyto	Zooplankton	Fish	Top Predators	Benthos, habitat forming
Data archaeology, data management (*Darwin Core*), Products/indicators 	X (<u>*beyond fluorescence*</u>)	X	X	X	X
Optics/Imaging	X	X	X Benthic		X
Animal tracking (satellite, underwater)			X	X	
Acoustics		X active	X Active, passive	X Tags, passive	X Active, passive (noise)
Genomics	X	X	X	X	X
Platforms with samplers	AUVs, floats, moorings, satellites	AUVs, moorings	AUVs, moorings	AUVs, moorings, tags	AUVs, moorings, satellites
Biological-physical / ecological *models*	X	*X?*	X??	X??	X??

Societally-relevant products need linked data pipelines

At least 5 pipelines need to be linked:

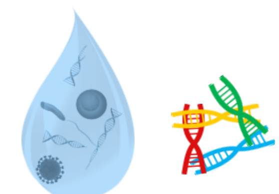
Satellite data (space agencies)



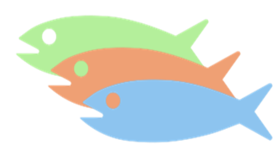
COVERAGE

In situ environmental data (NCEI, DataOne, GOOS)

Genetic (GenBank/NCBI, RefSeq, Gene Home, SRA, etc.)



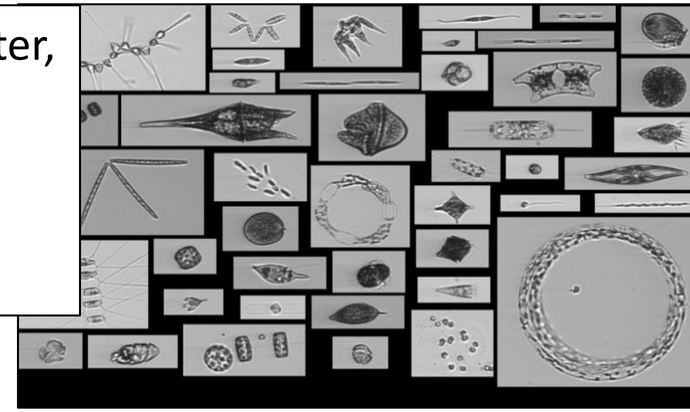
Biodiversity (OBIS, GBIF, others)



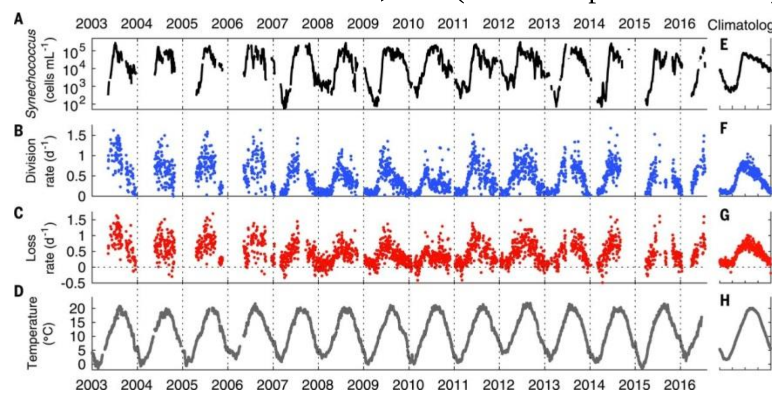
Socio-economic data

Maps, jurisdictions, census, economy

Automated flow cytometer, *FlowCytobot* (FCB): Phytoplankton taxa, size, abundance (moored, flow-through)



Phytoplankton cells automatically identified and categorized by the IFCB analysis software, from samples collected at Port Aransas, TX. (Lisa Campbell - TAMU)

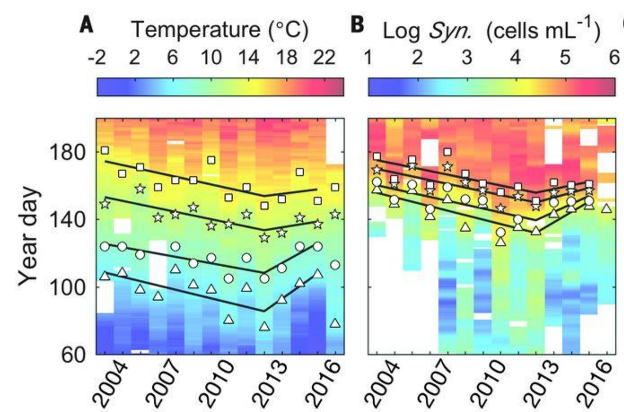


Daily time series at MVCO from 2003 to 2016

The Imaging Flow Cytobot (above) and basic specs (below). (Heidi Sosik – WHOI)

Weight	32 kg
Diameter	26 cm
Height	102 cm
Max Depth	40 m
Duration	Up to 6 mo.
Frequency	5 mL/20 min
Power	35W, 18-36VDC
Comms	10/100/1000-BaseT Ethernet

Hunter-Cevera et al. 2016. Science. Vol. 354, Issue 6310, pp. 326-329 DOI: 10.1126/science.aaf8536



Changes in phenology with changes in temperature

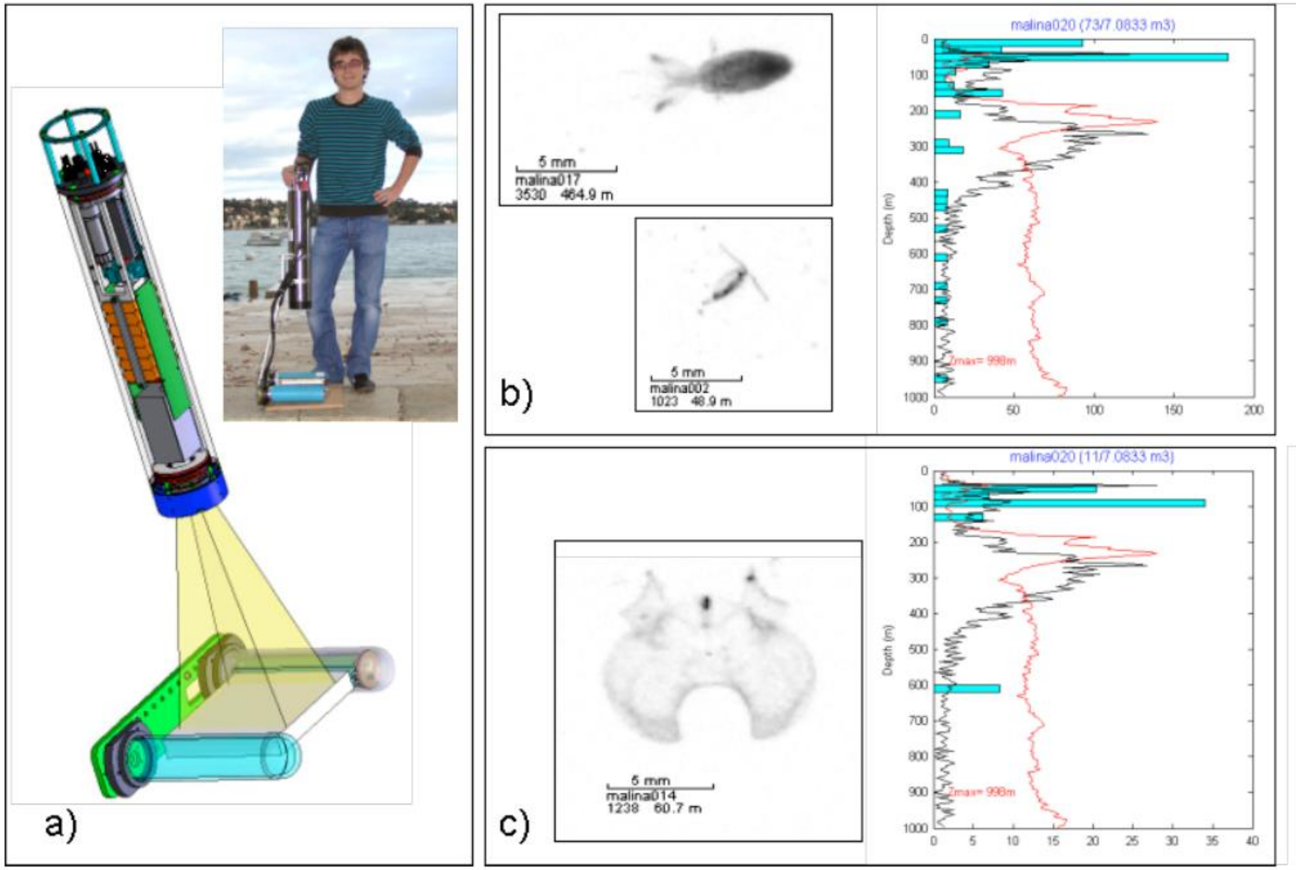
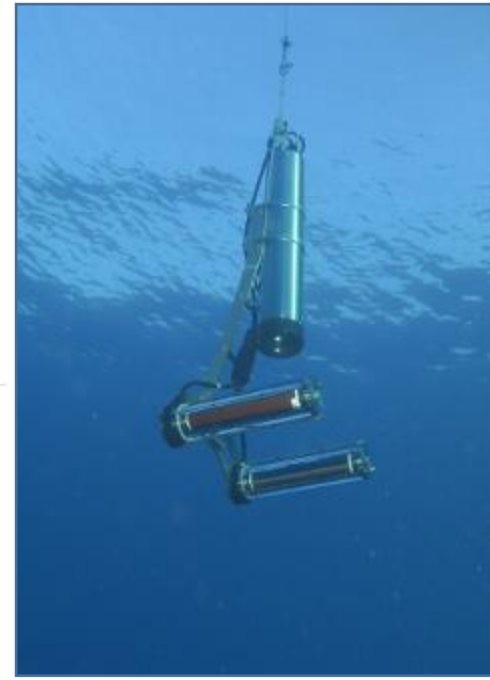
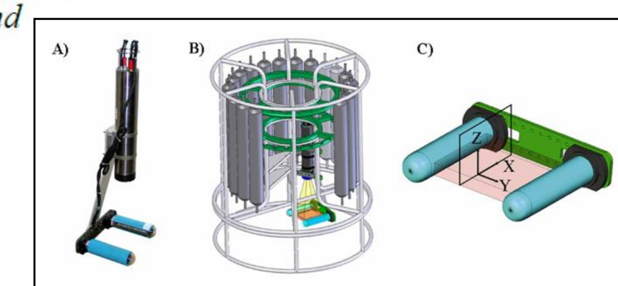


Figure 1: a) UVP5, b) specimens and vertical distribution of copepods (blue), particles below 200 µm (black) and particles above 500 µm (red) at station 20 of Malina cruise, c) specimen and vertical distribution of appendicularia (blue), particles below 200 µm (black) and particles above 500 µm (red) at station 20 of Malina cruise.



http://www.hydroptic.com/index.php/public/Page/product_item/UVP5-DEEP

Underwater Vision Profiler (UVP): Zooplankton taxonomy, size, and counts

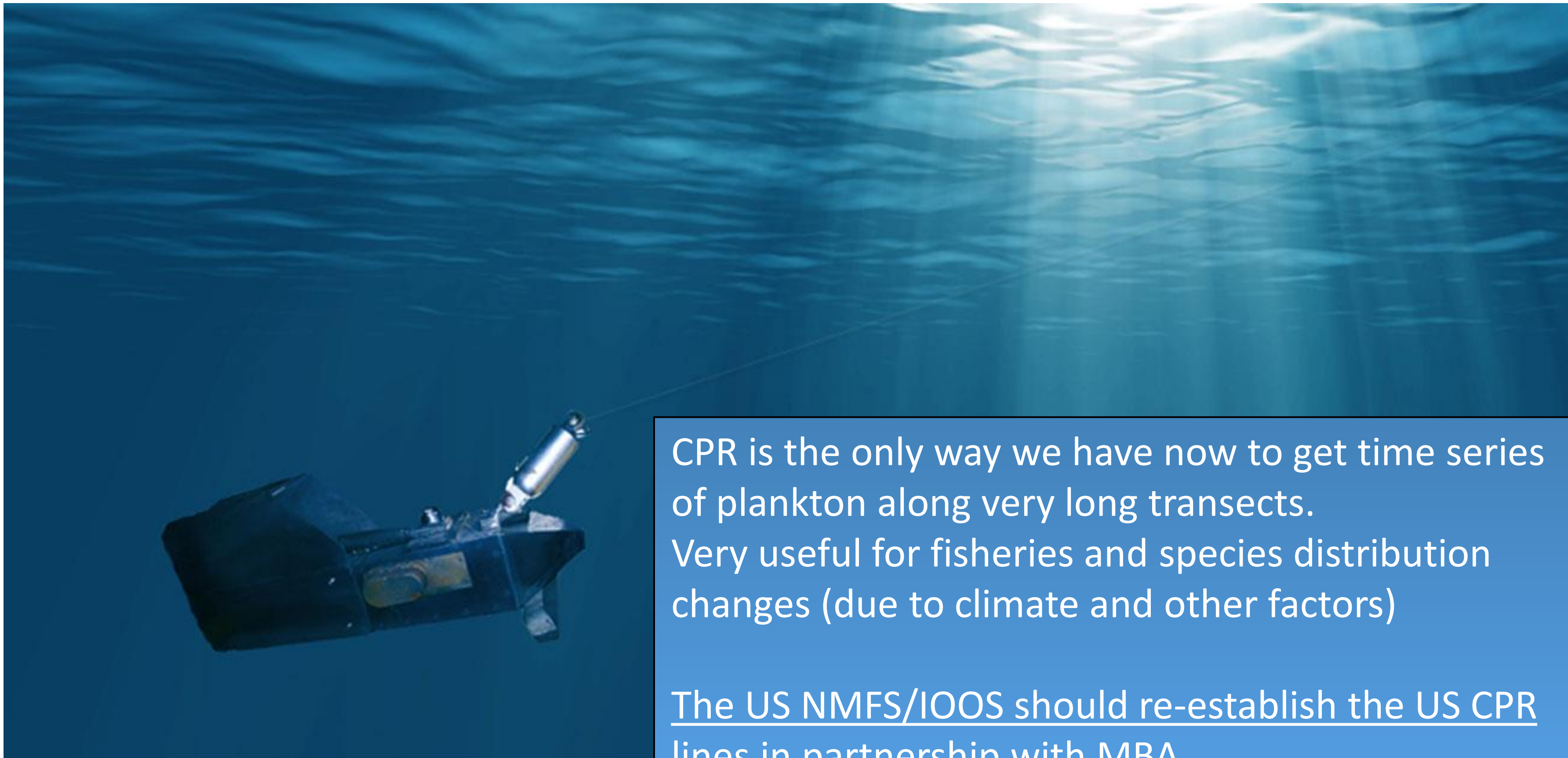


Picheral et al., 2010. Limnol. Oceanogr.: Methods 8, 2010, 462–473

THE CONTINUOUS PLANKTON RECORDER (CPR)

The Marine Biological Association of the UK

https://www.mba.ac.uk/fellows/cpr-survey

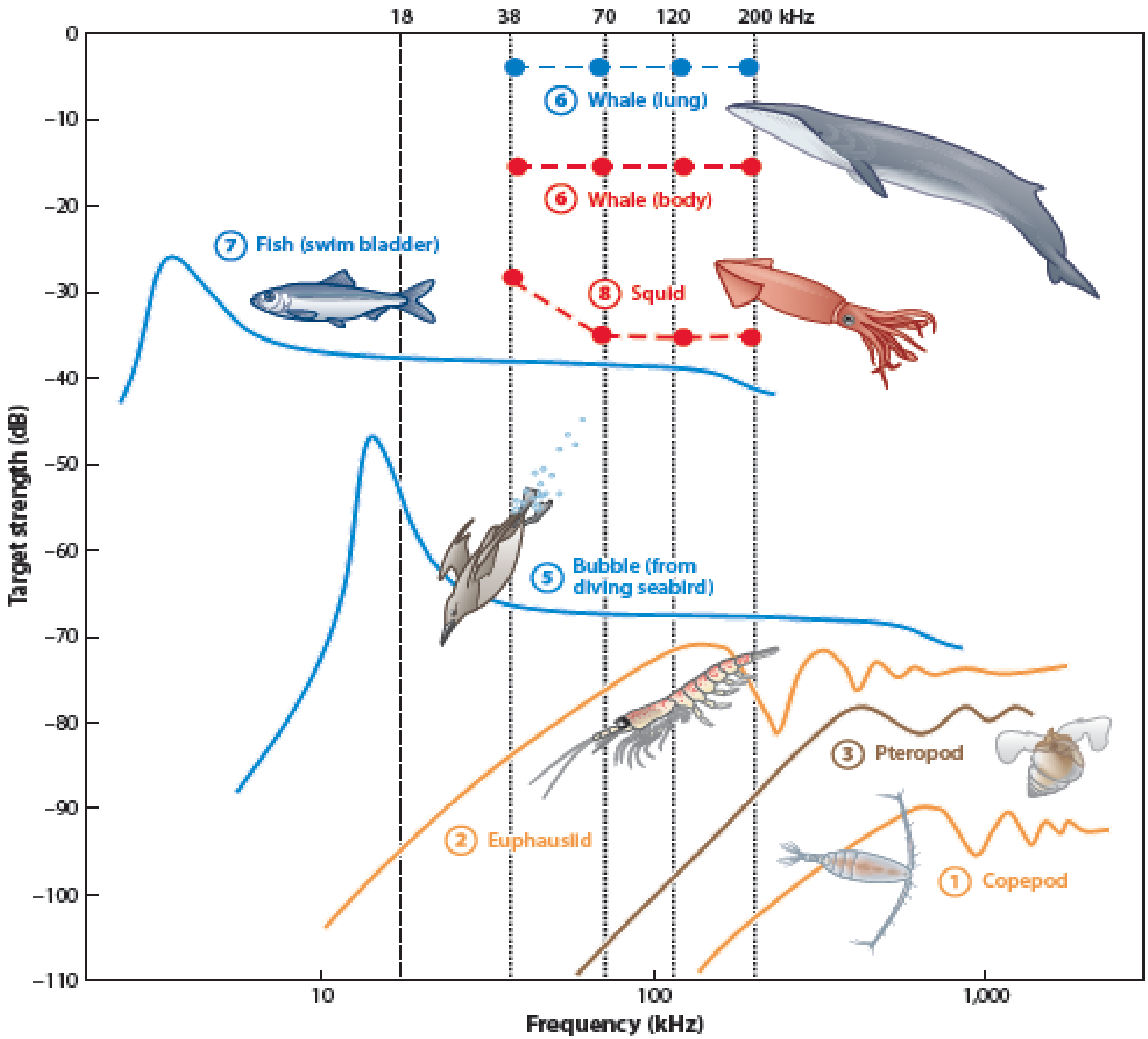


CPR is the only way we have now to get time series of plankton along very long transects.
Very useful for fisheries and species distribution changes (due to climate and other factors)

The US NMFS/IOOS should re-establish the US CPR lines in partnership with MBA

…with a commitment to process the data (zooplankton and phytoplankton),
release it to Darwin Core

Active Acoustics

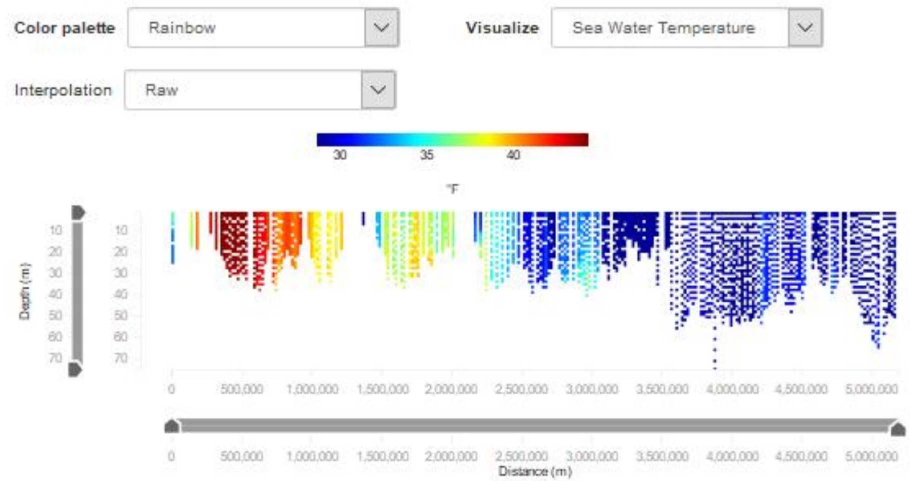


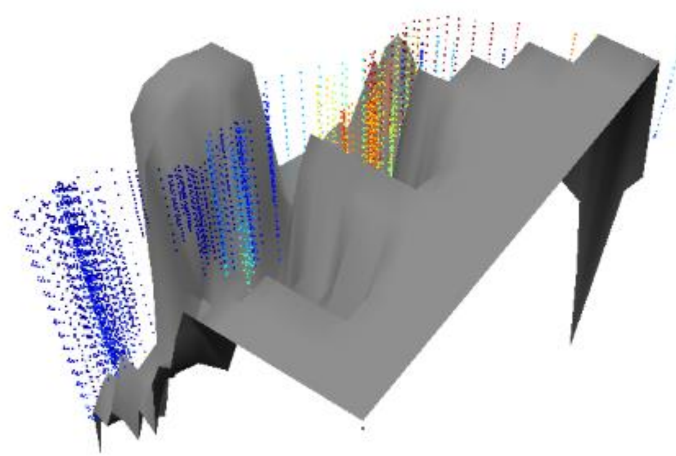
Animal borne sensors and telemetry

Animal Telemetry Network: ***ATN***
https://atn.ioos.us

eb03-061-15

Date range	Sep 11, 2015 07:26 (EST) - Feb 22, 2016 04:02 (EDT)
Depth range	2 (m) - 75 (m)
Points	4,149
Institution	MARES
Authority	uk.ac.st-andrews.smru

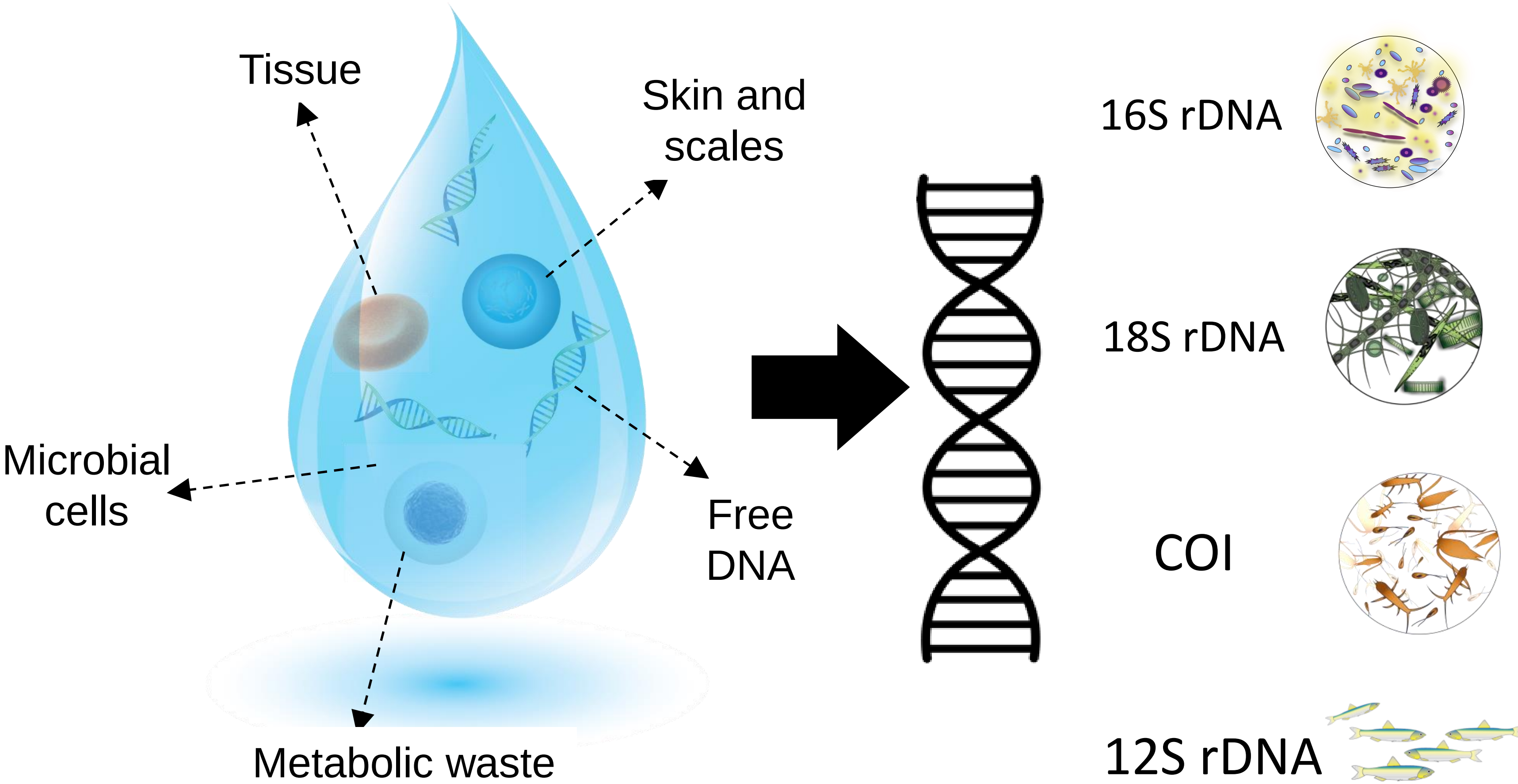




Many other things can be learned about marine animal movement and behavior using telemetry capabilities:
-migration corridors
-breeding behavior
-feeding behavior
-biodiversity hotspots

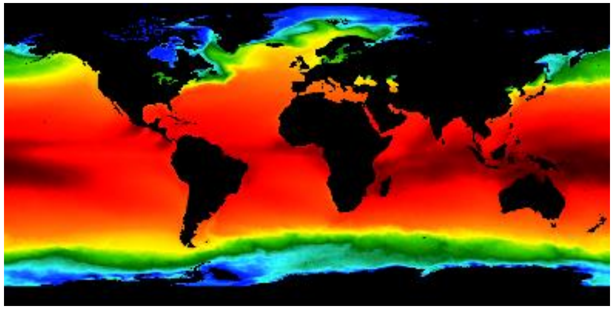
Environmental DNA (eDNA)

A cheaper, less invasive and larger scale approach to monitor species diversity - Each marker is most sensitive towards detecting different groups of organisms

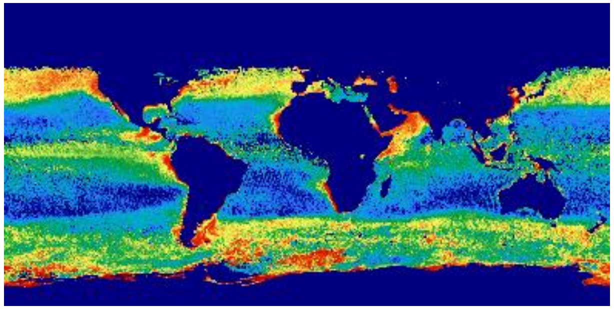


Global and regional satellite-derived environmental fields (weekly, monthly, seasonal climatologies)

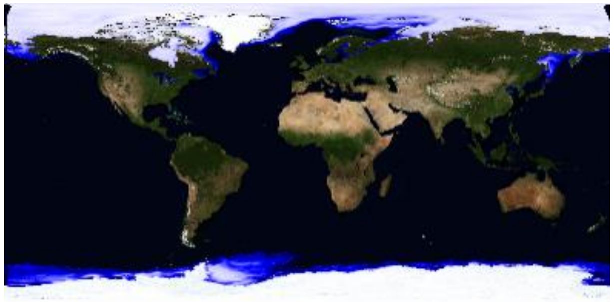
Sea Surface Temperature



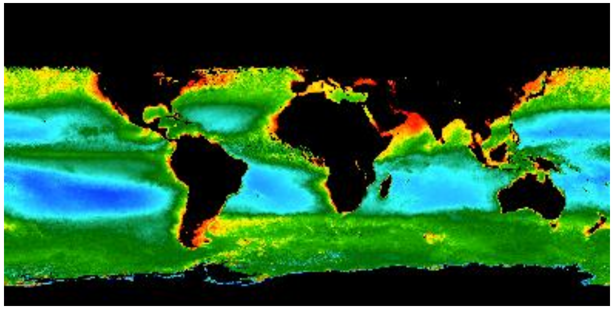
Phytoplankton fluorescence



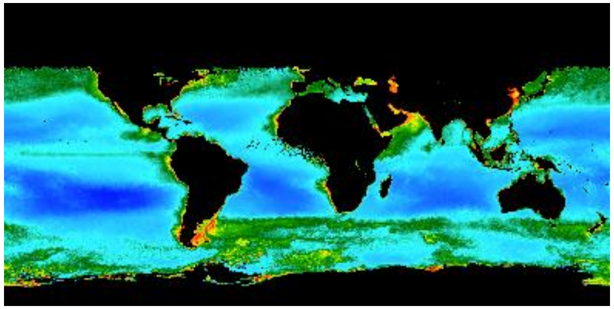
Sea ice



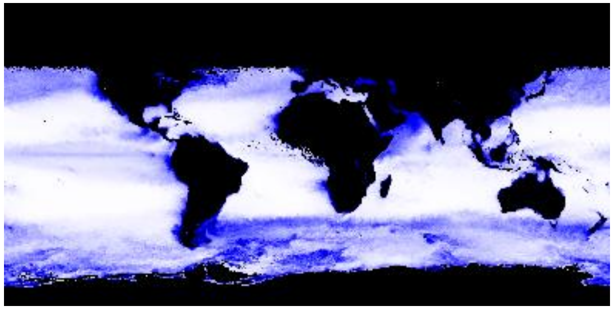
Dissolved org. C index



Chlorophyll-a



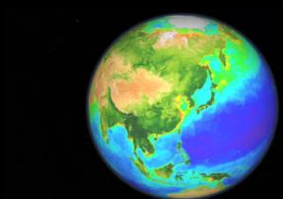
+ other fields…



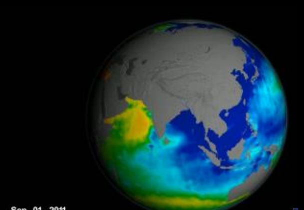
Dynamic seascapes: biogeographic framework for global and regional MBONs

Maria Kavanaugh (OSU)
mkavanau@ceoas.oregonstate.edu
J. Grebmeier (U. MD), D. Otis, E. Montes, F. Muller Karger (USF), D. Wright (ESRI), R. Sayre (USGS), G. Canonico (NOAA), V. Tsontos & J. Vasquez (NASA JPL)

Multiple biophysical synoptic datasets



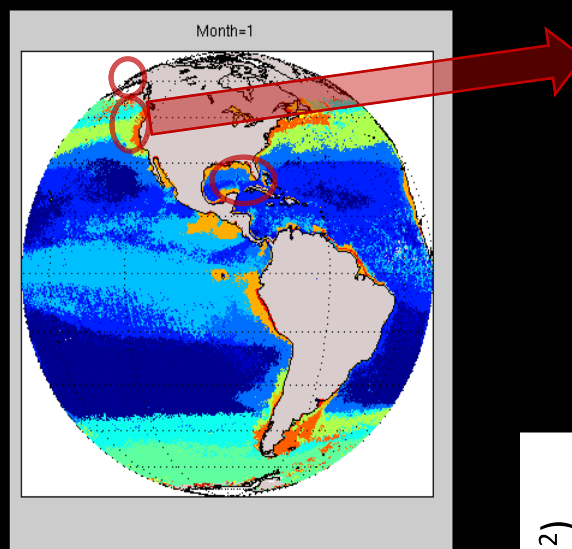
Biology: Ocean Color



Physics: e.g. SSS, SST, winds, SSHa

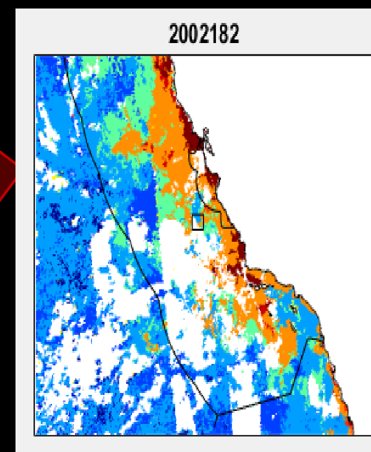
Global classification

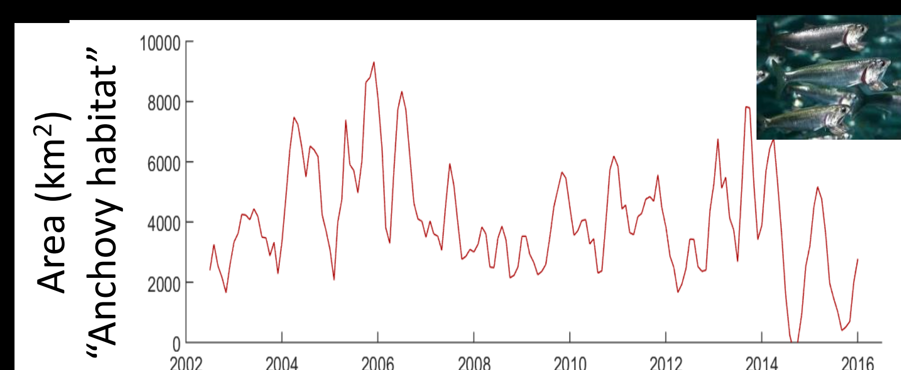
Dynamic+2D



Regional downscaling
High resolution, local validation

Regional relevance,





Dynamic habitat maps: forage fish community, NOAA SWFSC

Objectives

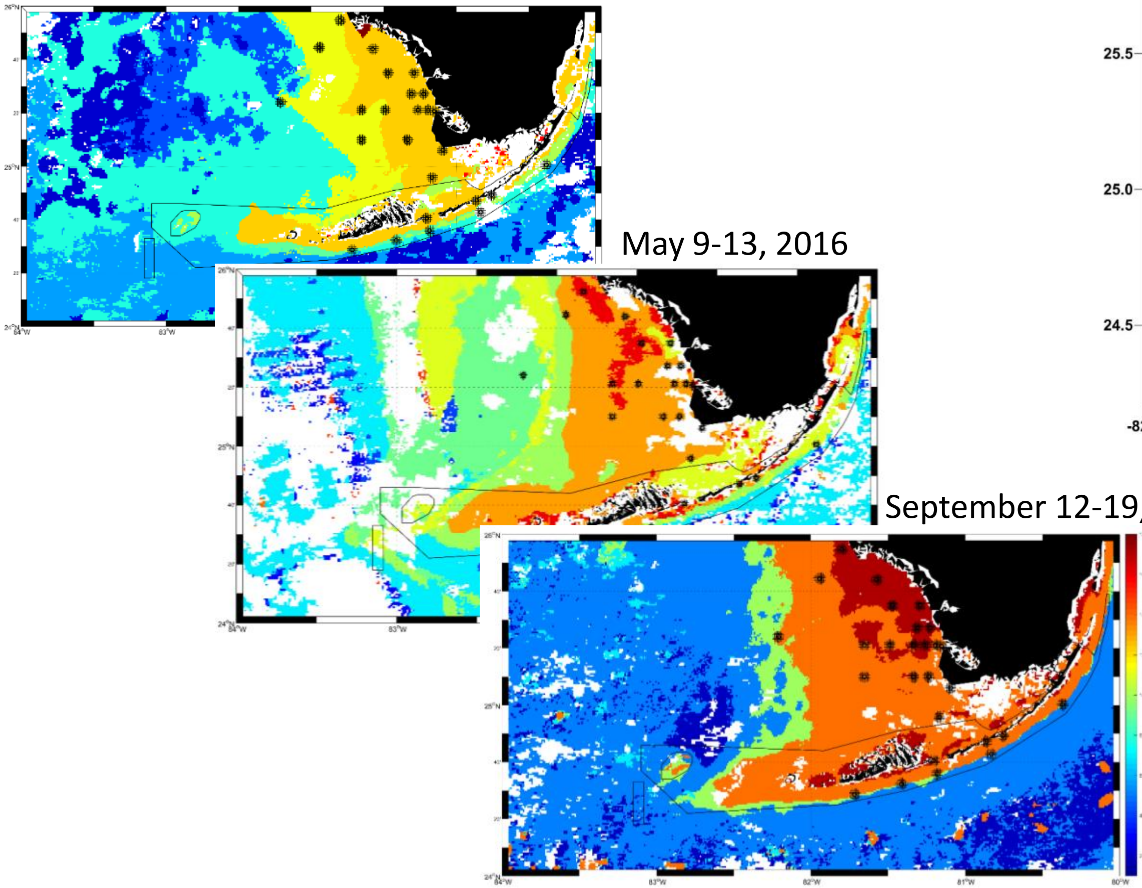
- **Multiscale classification**
- **Case Studies:**
  polar, temperate, subtropic
- **Habitat –species relationships:**
  plankton to fish
- **Operational products:**
  NOAA CoastWatch, Axiom, NASA COVERAGE

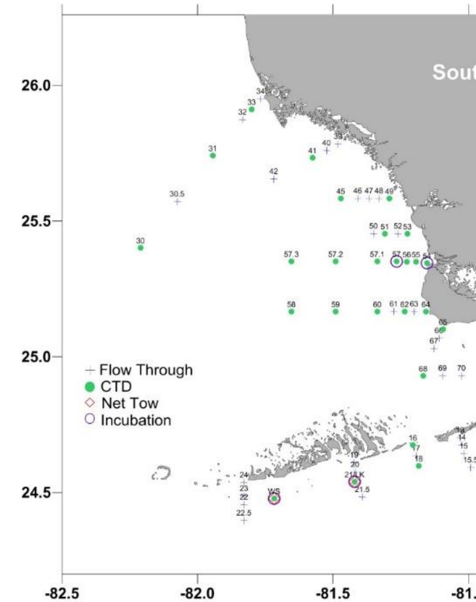
Seascape validation in south Florida waters

March 14-18, 2016

May 9-13, 2016

September 12-19, 2016





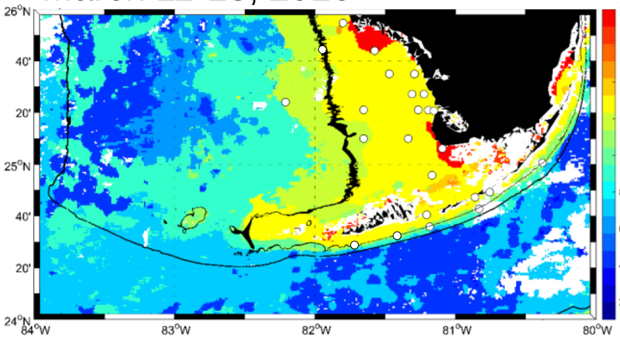
R/V Walton Smith (U. Miami)
MBON
South Florida Program (AOML)

<u>In situ variables:</u>

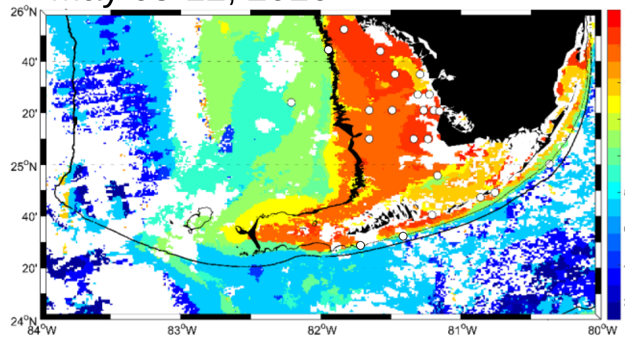
- Pigments (HPLC)
- Bio-optics (a_{phy})
- eDNA
- Zooplankton (64, 200, 500 um)
- Phytoplankton taxa (microscopy)
- Environmental variables (nuts, temp., salinity, etc)

Seascape validation: south Florida

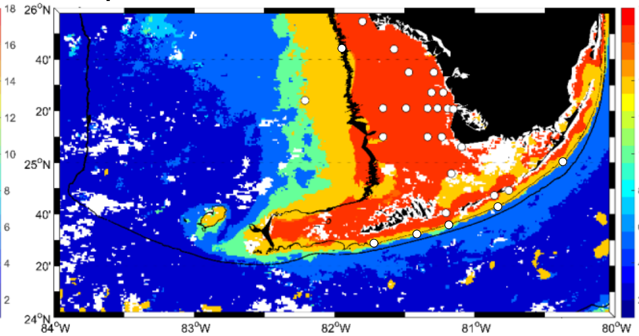
March 11-18, 2016



May 05-12, 2016

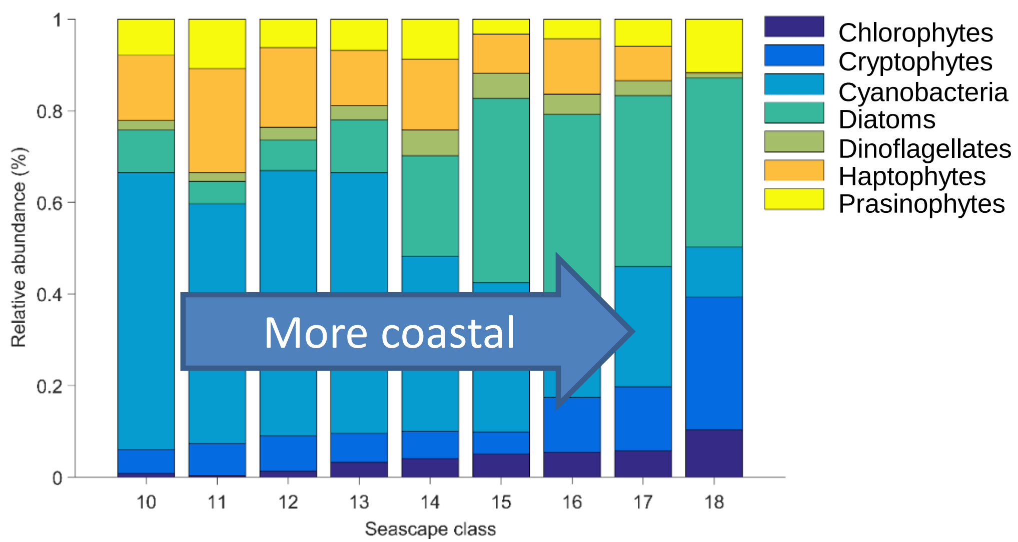


September 12-19, 2016

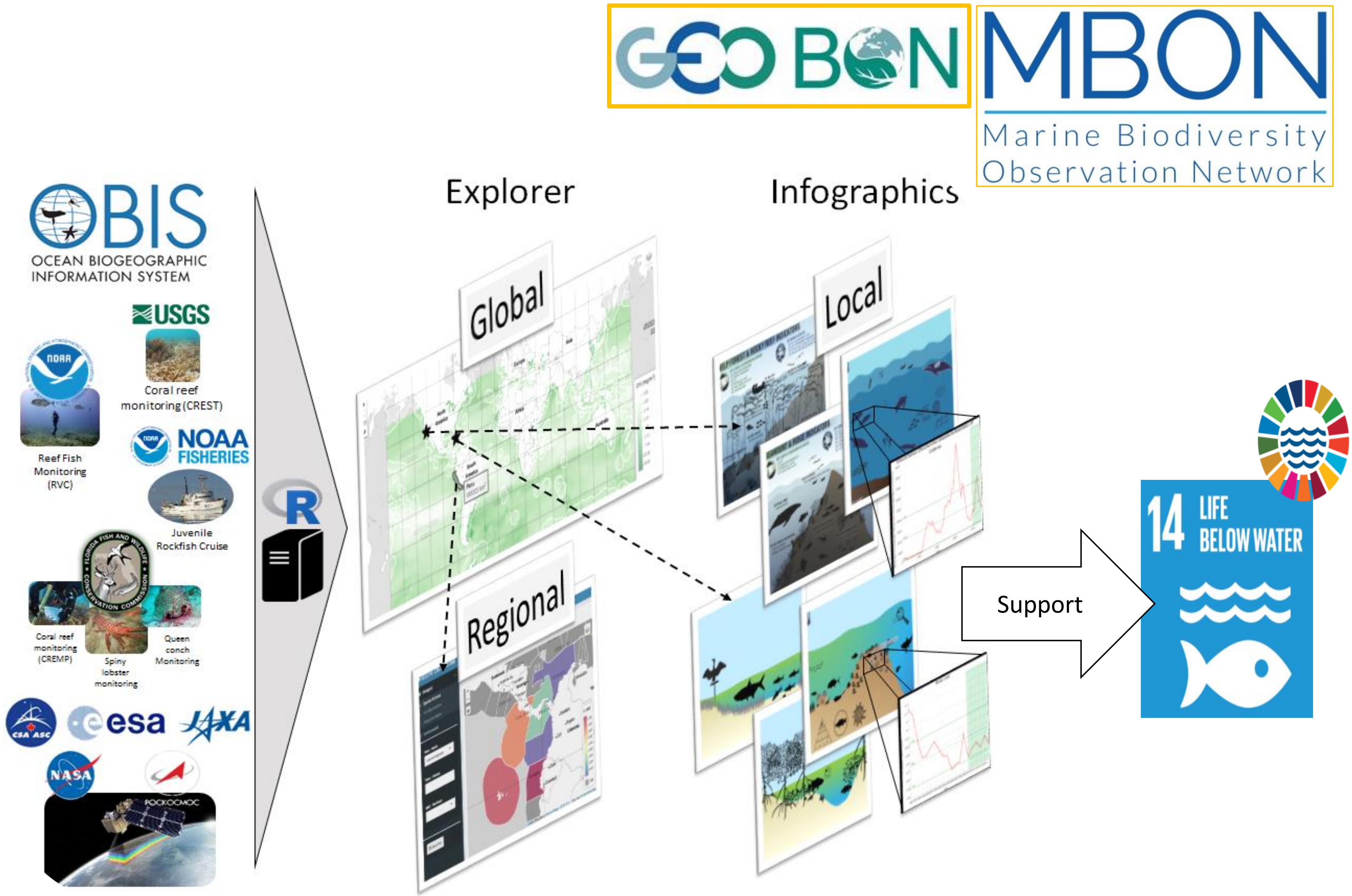


Seasonal shifts of phytoplankton assemblages

Also validating: eDNA, zooplankton

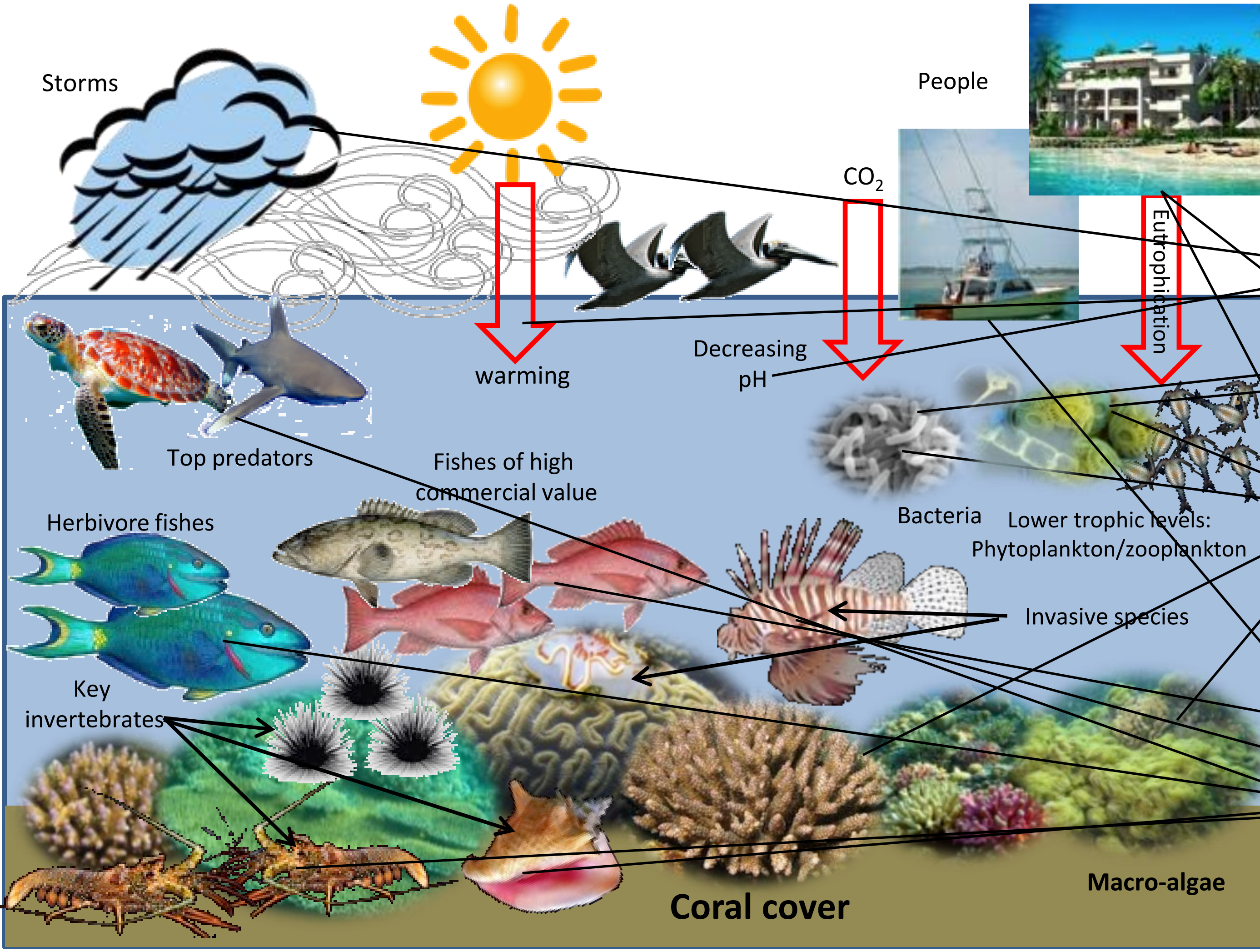


In prep: Dynamic satellite seascapes as predictors of seasonal shifts of phytoplankton assemblages in south Florida waters. Enrique Montes, Anni Djurhuus, Christopher R. Kelble, Daniel Otis, Frank E. Muller-Karger, and Maria T. Kavanaugh



GEO BON
MBON
Marine Biodiversity Observation Network
OBIS
OCEAN BIOGEOGRAPHIC INFORMATION SYSTEM
USGS
Coral reef monitoring (CREST)
Reef Fish Monitoring (RVC)
NOAA FISHERIES
Juvenile Rockfish Cruise
Coral reef monitoring (CREMP)
Spiny lobster monitoring
Queen conch Monitoring
esa
JAXA
NASA
R
Explorer
Infographics
Global
Local
Regional
Support
14 LIFE BELOW WATER

Information for Sanctuary Condition Reports



Condition Report Questions

WATER:
- Q4: Stressors
- Q1: Eutrophication
- Q2: Human health risks

HABITAT:
- Q5: Habitat dist. / health
- Q14: Human impacts

LIVING RESOURCES:
- Q10: Biodiversity status
- Q17: Fishing status
- Q9: Invasive species
- Q7: Keystone species
- Q8: Focal species
- Q17: Human impacts

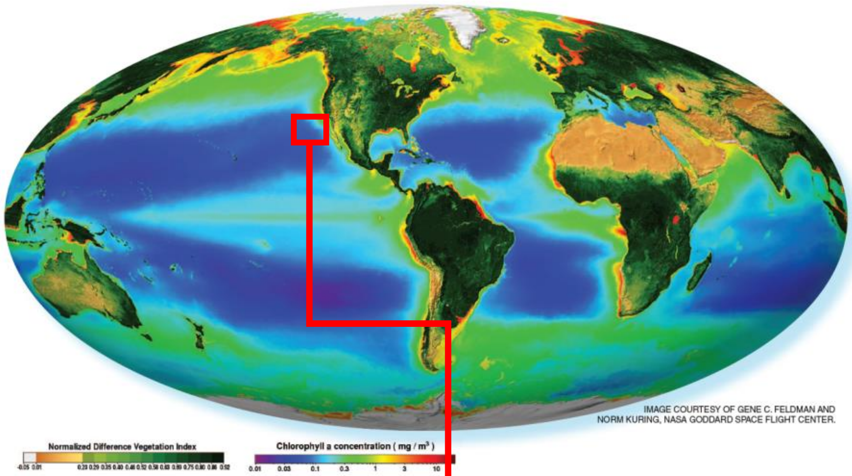
Good	Good/Fair	Fair	Fair/Poor	Poor	Undet.

Conceptual Model

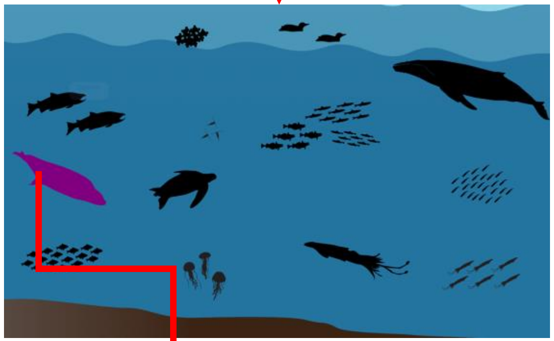
<u>NCEAS Global Marine Ecosystems layers</u>:

Beach
Coral Reefs
Deep Hard Bottom
Deep Soft Benthic
Deep Waters
Hard Shelf
Hard Slope
Intertidal Mud
Kelp
Mangroves
Rocky Intertidal
Rocky Reef
Salt Marsh
Seagrass
Seamounts
Soft Shelf
Soft Slope
Sub-tidal Soft Bottom
Surface Waters
Suspension-Feeder Reef

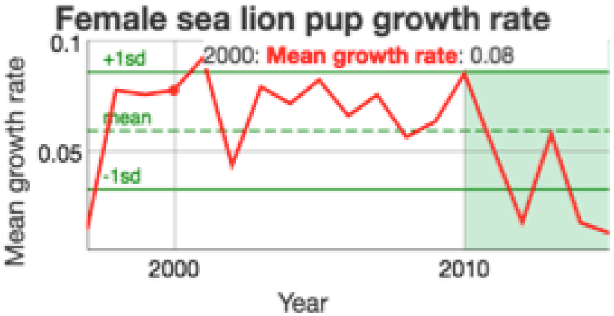
Note: Abyssal-Hadal layers to be created



NASA, other regional/global data



Infographic of local habitats (EEZ, LME)

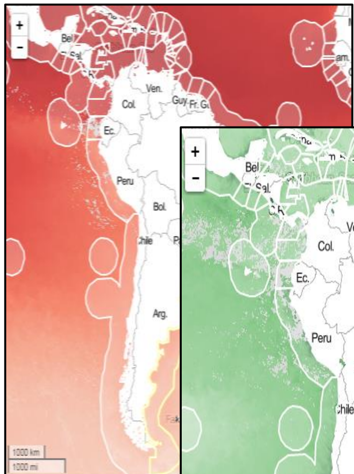


Local data/time series

Collaborators:
B. Best, J. Brown,
L. McEachron,
E. Montes

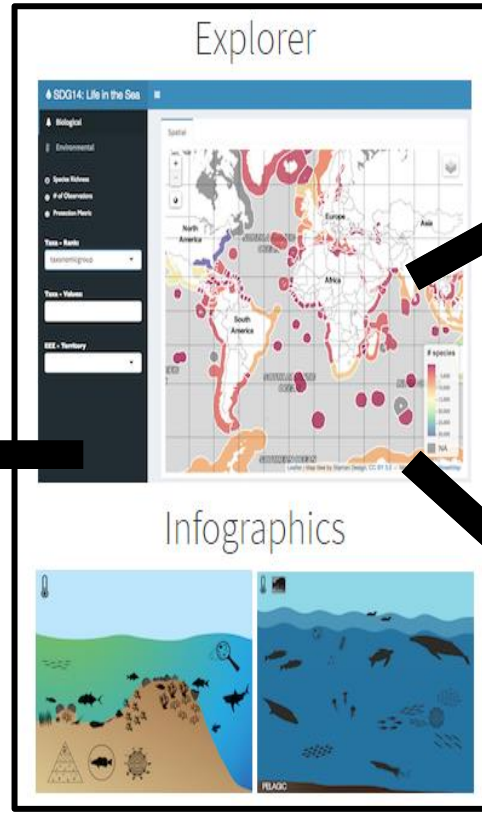
Web-based interactive tools for Pole to MBON

SST

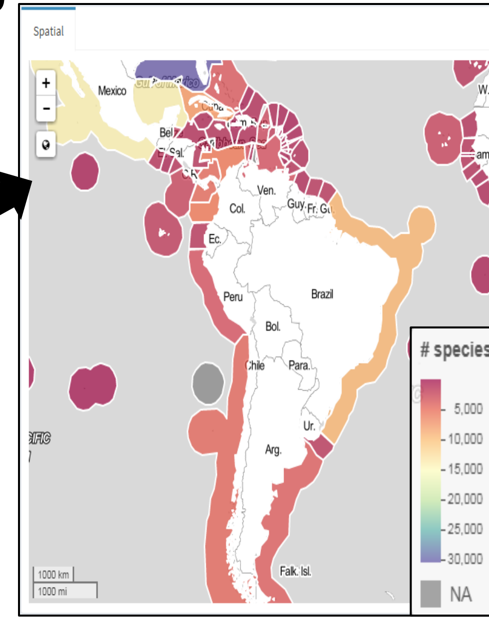


Chl-a

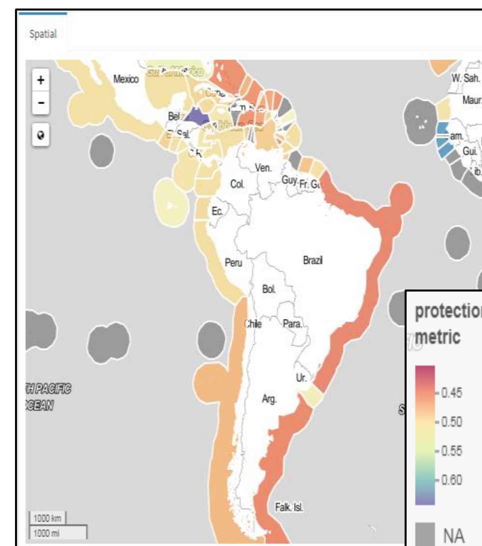
www.marinebon.org

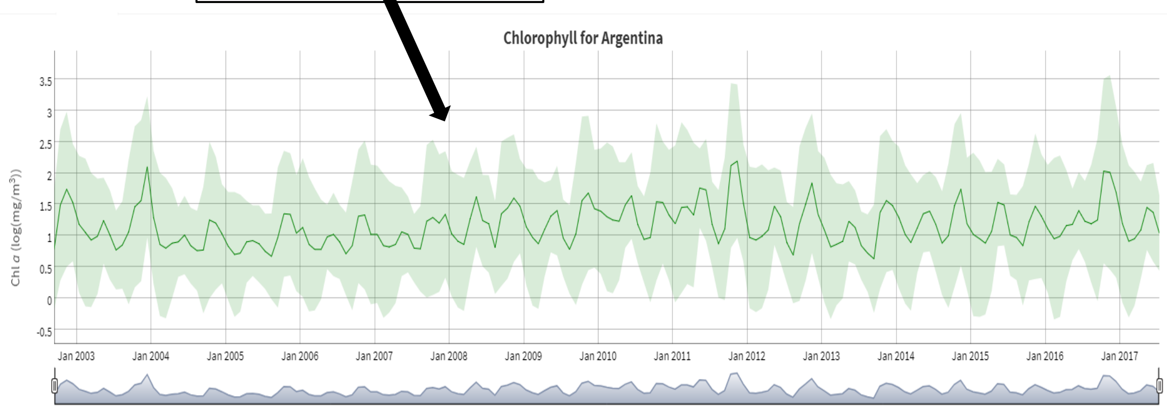


Number of species (OBIS)



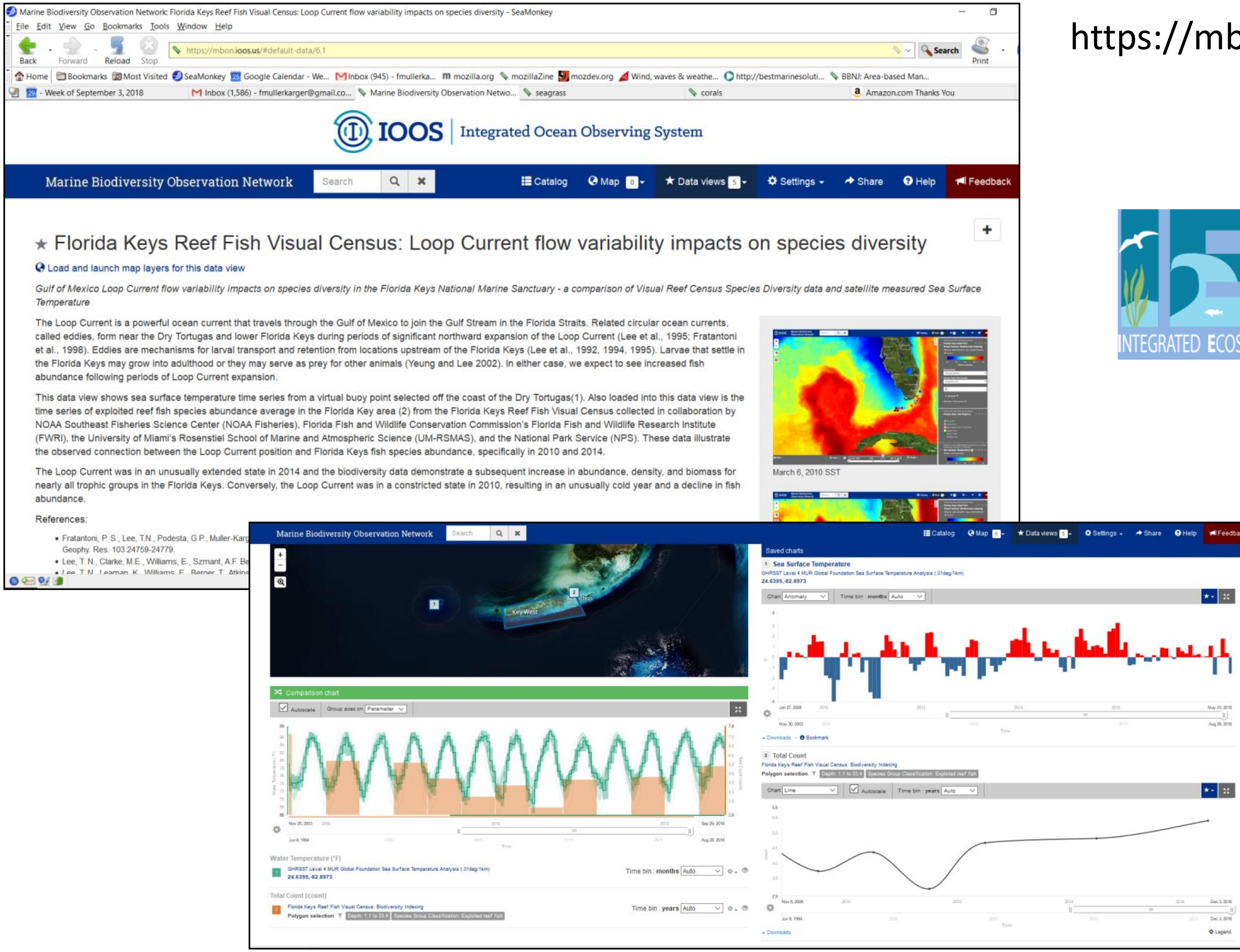
Redlist protection level (OI





Dynamically updating status and trends:

https://mbon.ioos.us/

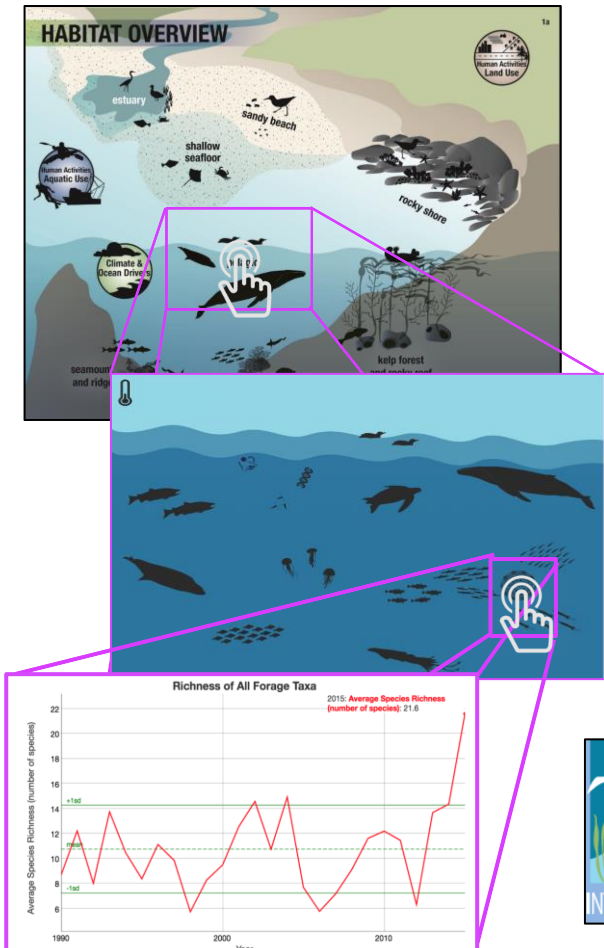


https://mbon.ioos.us/#default-data/6.1

Dynamically updating status and trends

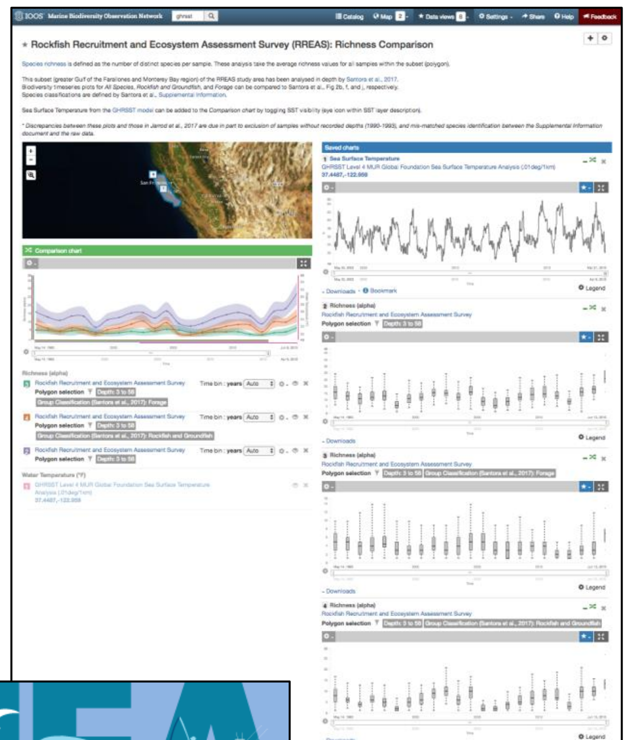
Infographics

Audience:
Public, managers, educators



Curated Data Views

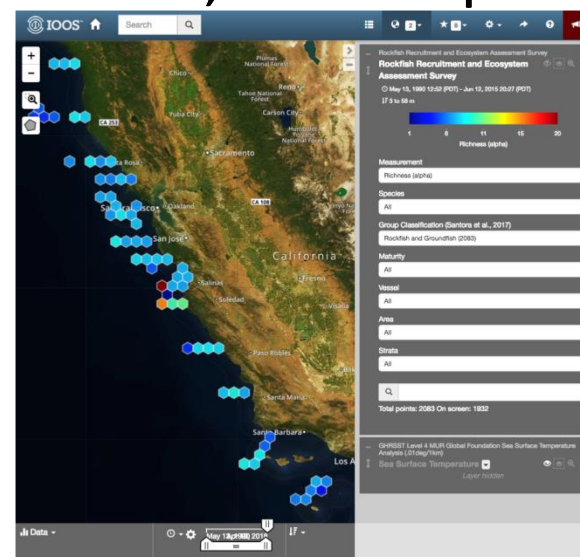
Audience:
Advisory groups, researchers, teams

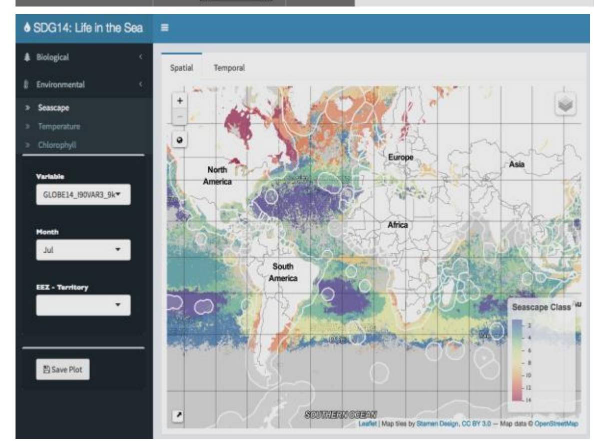


INTEGRATED ECOSYSTEM ASSESSMENT

Data portals

Audience:
Scientists, technical experts





Key messages

- MBON is developing a community of practice to monitor life in the sea with GEO BON IOC (GOOS, OBIS, Ocean Best Practices)
- Biodiversity Observing System need to focus on:
  - Promote standards for a manageable number of variables
  - integrate biodiversity, physical, chemical, geological obs.
  - Sensor development for biodiversity (beyond fluorescence)
  - deliver data to linked databases (use DarwinCore schema)
- Product development: Scale ancillary data matrices, offer in a format accessible to many applications in addition to RS product
- Integrate land, ocean and other aquatic areas in truly 'global' biodiversity cover and trends / maps
- Continue to integrate land/aquatic communities