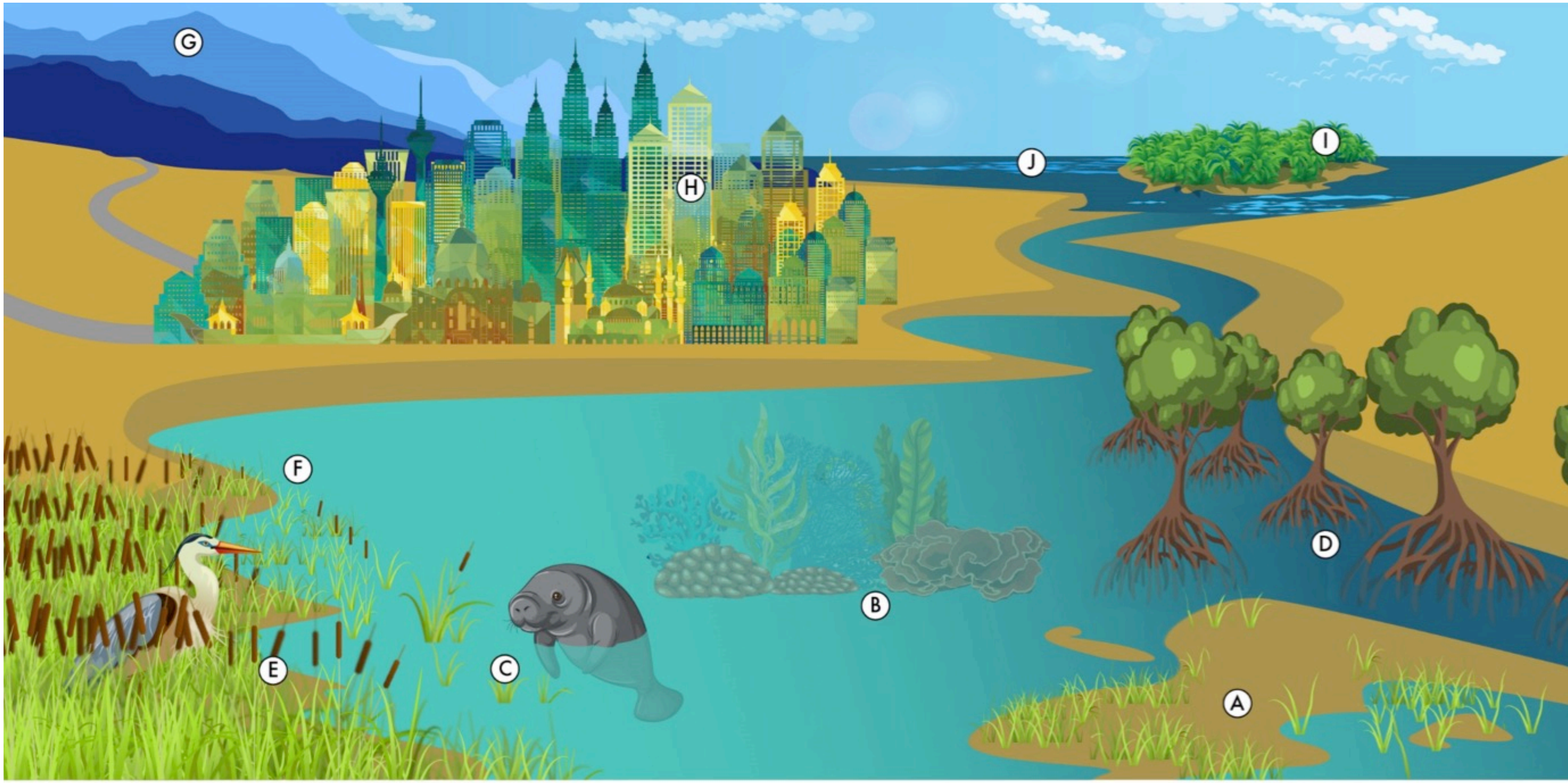
Coastal and Wetland Essential Biodiversity Variables (EBV) from Space

Frank E. Muller-Karger, Erin Hestir, Kevin Turpie, Dar Roberts, David Humm, Steve Ostermann, Noam Izenberg, Mary Keller, Frank Morgan, Robert Frouin, Arnold Dekker, Royal Gardner, James Goodman, Blake Schaeffer, Brian Franz, Heidi Dierssen, Ray Najjar, Natassa Romanou, Maria Tzortziou

Water and life – no two features more completely define planet Earth



Biology thrives where water and land come together

Organisation for Economic Co-operation and Development (OECD)

OECD 2016
The Ocean Economy in 2030
DOI:10.1787/9789264251724-en

Table 1.1. **Established and emerging ocean-based industries**

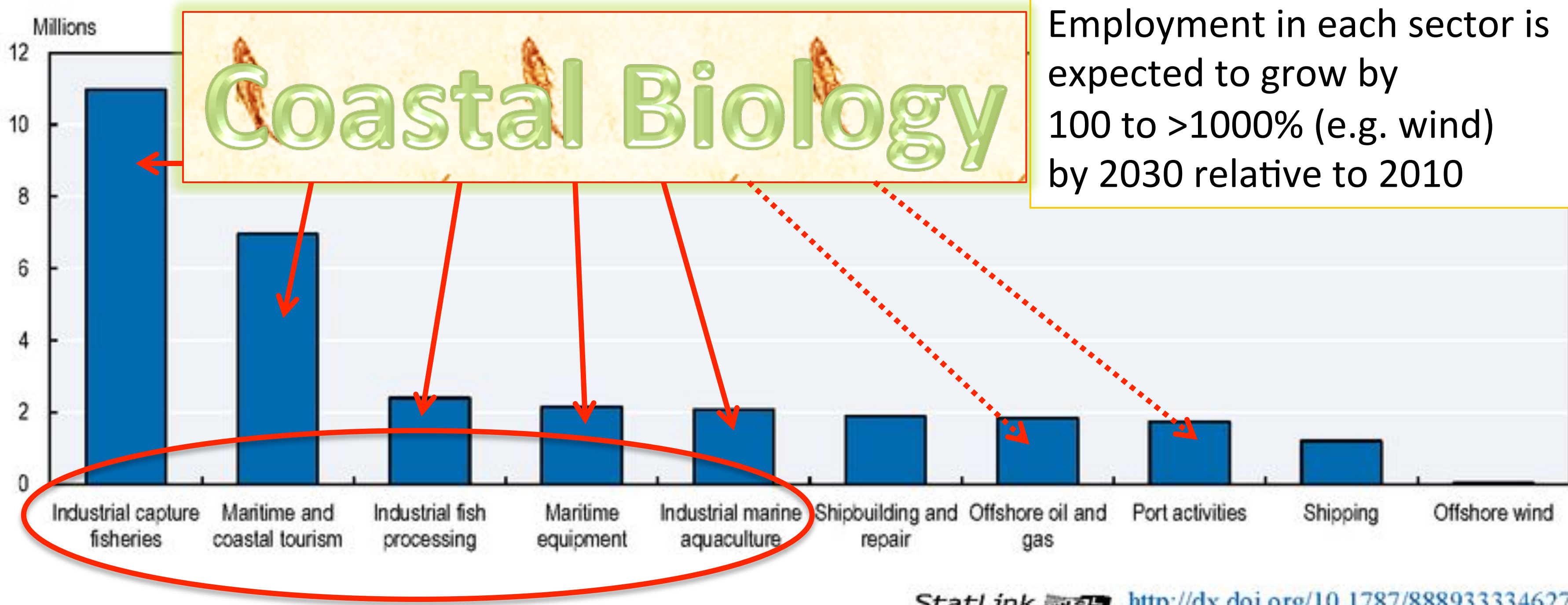
Established	Emerging
Capture fisheries	Marine aquaculture
Seafood processing	Deep- and ultra-deep water oil and gas
Shipping	Offshore wind energy
Ports	Ocean renewable energy
Shipbuilding and repair	Marine and seabed mining
Offshore oil and gas (shallow water)	Maritime safety and surveillance
Marine manufacturing and construction	Marine biotechnology
Maritime and coastal tourism	High-tech marine products and services
Marine business services	Others
Marine R&D and education	
Dredging	

2010: US$ 1.5-2.5 trillion

2030 Ocean economy: US$ >3 trillion

OECD 2016
The Ocean Economy in 2030
DOI:10.1787/9789264251724-en

Figure 1.3. **Employment in the ocean-based industries in 2010 by industry**



Employment in each sector is expected to grow by 100 to >1000% (e.g. wind) by 2030 relative to 2010

StatLink http://dx.doi.org/10.1787/888933334627

Note: Artisanal fisheries are not included in this overview.

Source: Authors' calculations based on OECD STAN, UNIDO INDSTAT, UNSD, World Bank (2013); IEA (2014); OECD (2014); and various industry reports.

National and International Frameworks

European Union Marine Strategy Framework Directive
Canada Oceans Act and Oceans Strategy
US Oceans Act of 2000 and National Ocean Policy Implementation Plan
Agenda 2030 – United Nations Sustainable Development Goals (SDG)

SUSTAINABLE DEVELOPMENT GOALS





Boundary ecosystems: services at the edge of land, ice, and water

Ecosystem services

- Provision of fresh water
- Nutrient and carbon cycling, biodiversity
- Flood and erosion control
- Cultural amenities

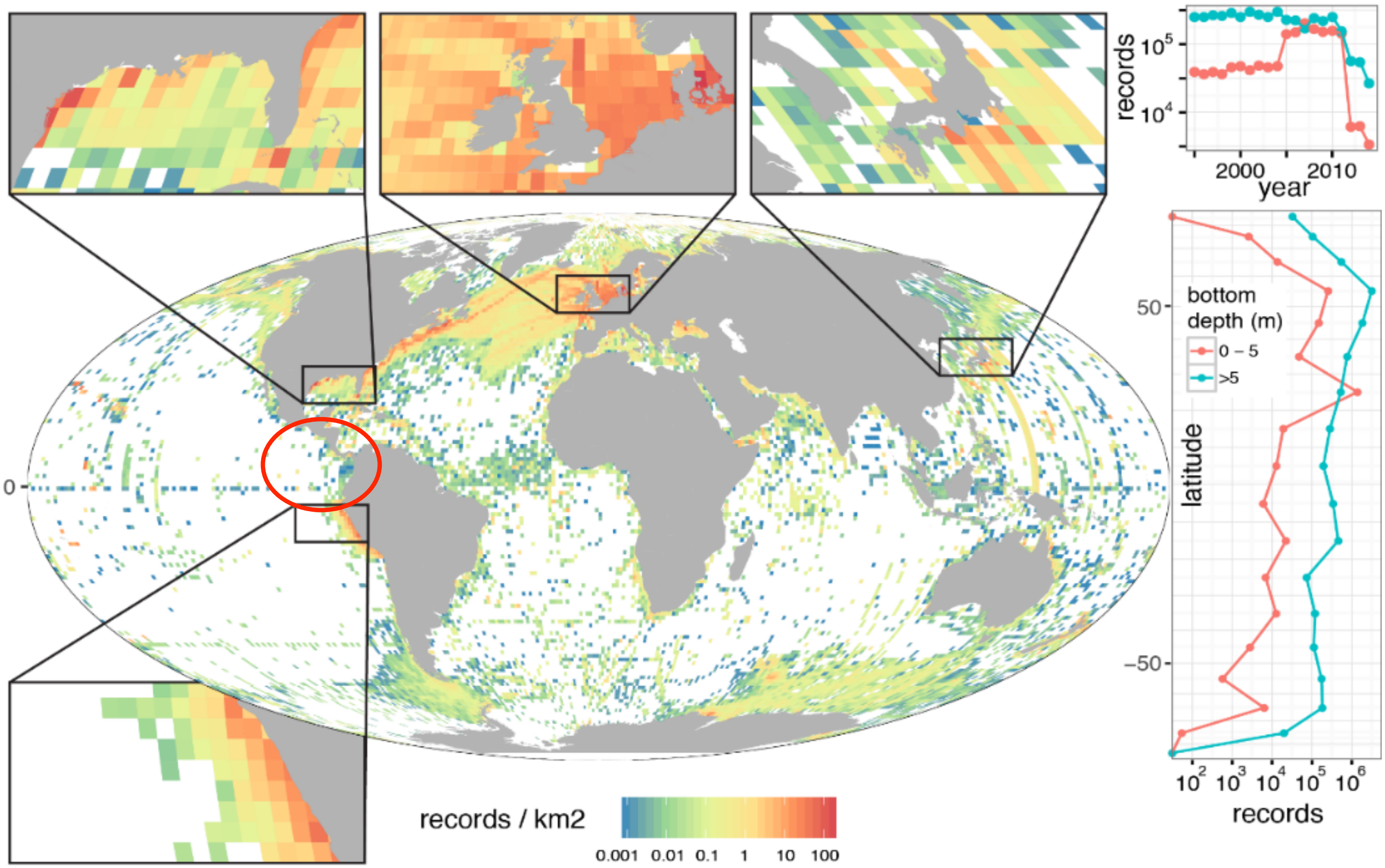
The most biologically diverse places on Earth
The most productive places on Earth

Some of the most endangered ecosystems in the world

Openly-available biodiversity records in the upper ocean (20 m)

OCEAN BIOGEOGRAPHIC INFORMATION SYSTEM

Marine Biodiversity Observation Network



Sparse biological/biodiversity data

Few time series

Data latency > 5 years

How can we inform decisions?

Coastal and inland aquatic science

Questions:

- How does biodiversity affect productivity and viceversa?
- How do changes in diversity affect:
  - Water quality and chemical cycles?
- How do changes in biodiversity translate to societal value

- HyspIRI: CQ1,4,5,6, TQ3,4,5, VQ1-6

We need coastal and inland aquatic observations

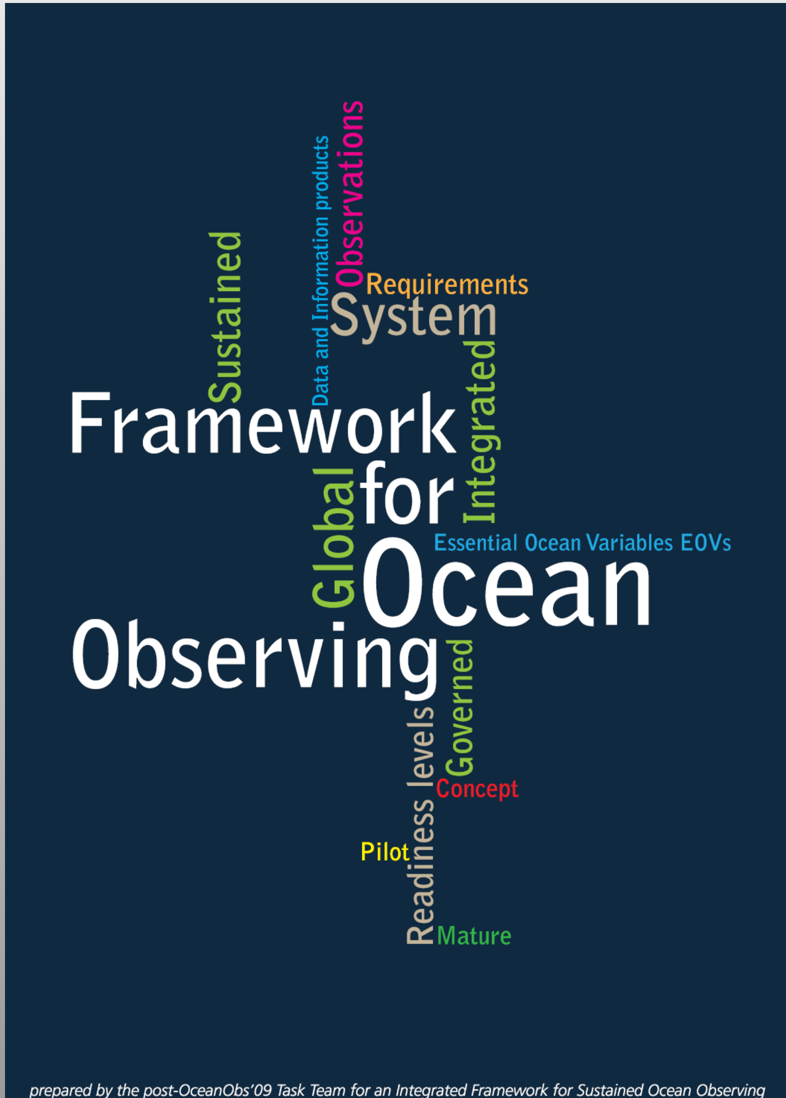
Beyond biomass indices:

- Surface phytoplankton functional types
- Wetland composition
- Coral reef composition
- Assessments of change in time
  - Phenology, anomalies relative to baselines

GOOS

OBIS
OCEAN BIOGEOGRAPHIC INFORMATION SYSTEM

MBON
Marine Biodiversity Observation Network



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

Image courtesy of Francisco Chavez / MBARI

Essential Ocean Variables (EOVs)

PHYSICS	BIOGEOCHEMISTRY	BIOLOGY AND ECOSYSTEMS
Sea state	Dissolved Oxygen	Phytoplankton biomass and diversity
Ocean surface vector stress	Inorganic macro nutrients	Zooplankton biomass and diversity
Sea ice	Carbonate System	Fish abundance and distribution
Sea surface height	Transient tracers	Marine turtle, bird and mammal abundance and distribution
Sea surface temperature	Suspended particulates	Live coral
Subsurface temperature	Nitrous oxide	Seagrass cover
Surface currents	Carbon isotope (^{13}C)	Macroalgal canopy
Subsurface currents	Dissolved organic carbon	Mangrove cover
Sea surface salinity		
Subsurface salinity		
Heat flux / radiation		

Many EOV can be examined using remote sensing

Readiness level: CONCEPT | PILOT | MATURE

GROUP ON EARTH OBSERVATIONS

Established 2005 to build the Global Earth Observation System of Systems (GEOSS)

Over 100 national governments
+ over 100 Participating Organizations

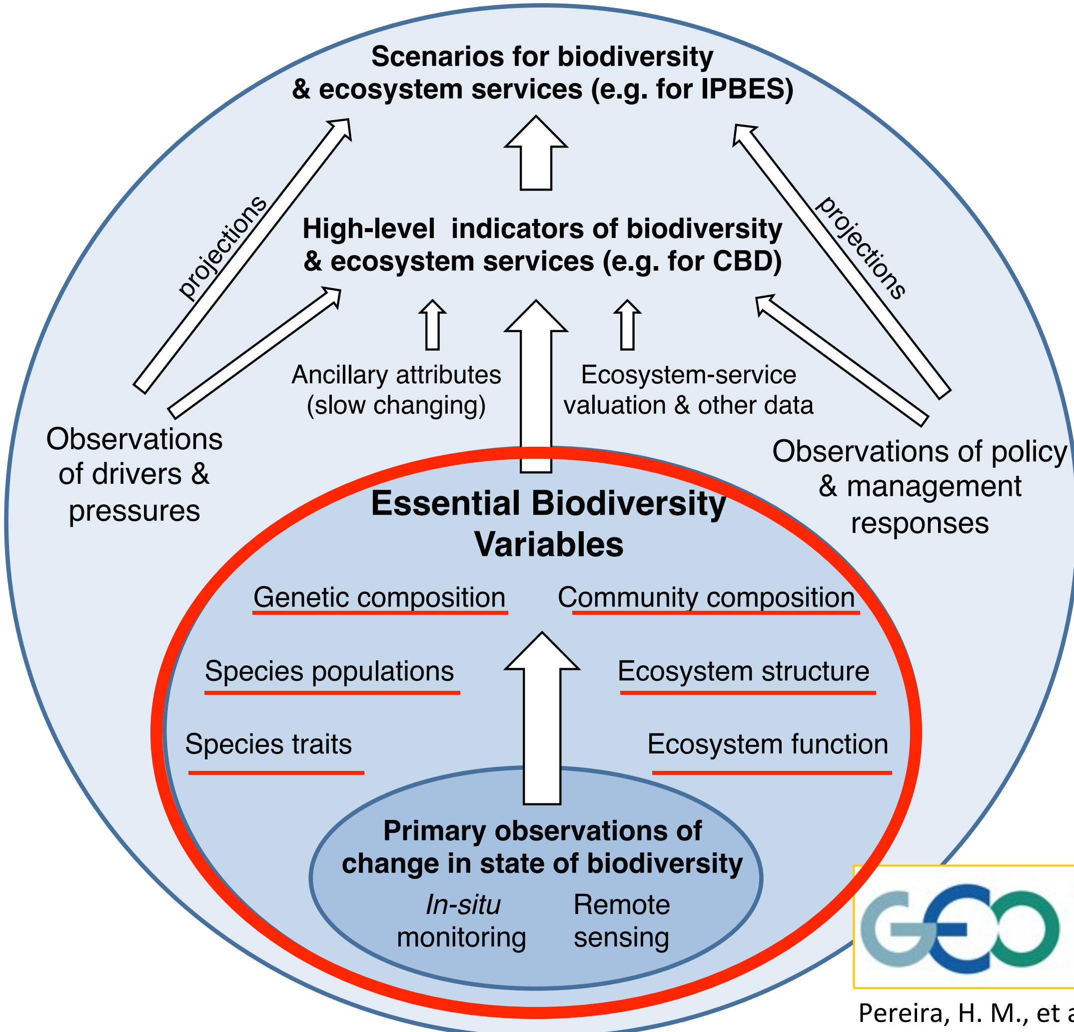
Vision: decisions/ actions are informed by Earth obs.

GEO BON

8 Societal Benefit Areas (SBA)

GEO Biodiversity Observation Network (GEO BON): Organize terrestrial, freshwater, & marine biodiversity data and make observations available

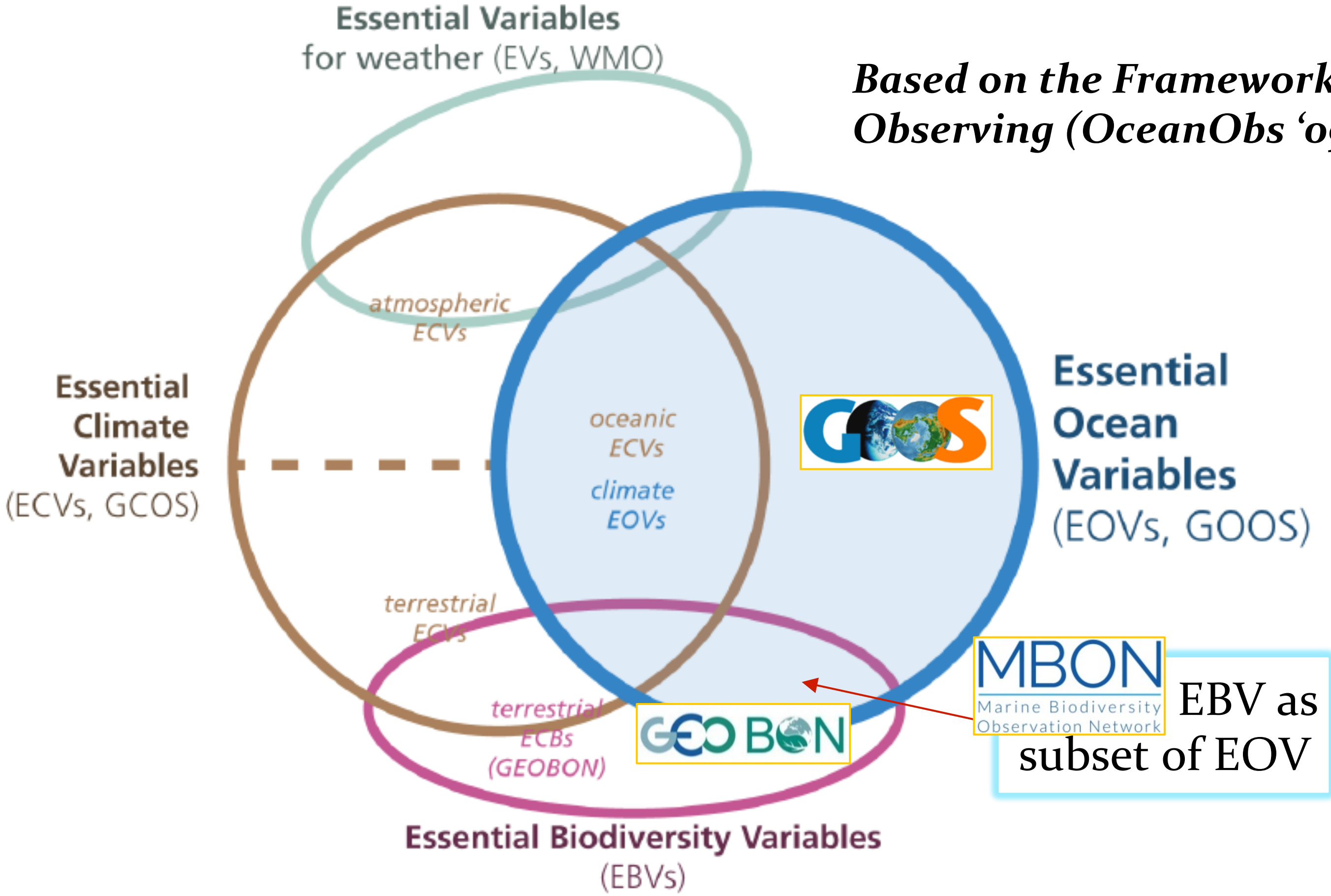
Essential Biodiversity Variables (EBV)



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

Linking Essential Biodiversity Variables (EBVs) and Essential Ocean Variables

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



Life in the Sea (EBV as part of EOV)

MBON
Marine Biodiversity Observation Network

Biodiversity: the variety of life and habitats

- Species: and functional group distribution
- Populations: abundance, biomass, distribution
- Traits (phenology, color, size, C, N, pigments…)
- Ecosystem structure (e.g., integrity)
- Ecosystem function (e.g., productivity)

*These '**Essential Biodiversity Variables**' require <u>synoptic spectral data</u>*

Remote sensing of Aquatic Essential Biodiversity Variables (EBV)

EBV class	EBV	Habitat Type					
		Wetland Vegetation	*Benthic Communities*			*Pelagic*	
		Mangrove/ salt marsh	Seagrass	Macroalgae	Coral	Phytoplankton	HAB
Genetic composition	Population genetic	Unproven	Unproven	Unproven	Unproven	Unproven	Unproven
Species populations	Distribution	Demonstrated limited cases	Demonstrated limited cases	Demonstrated limited cases	Demonstrated limited cases	ROUTINE USE FOR OPEN OCEAN	Demonstrated limited cases
	Abundance	Demonstrated limited cases	Demonstrated limited cases	Demonstrated limited cases	Demonstrated limited cases		Demonstrated limited cases
	Size/vertical distribution	Demonstrated limited cases	Unproven	Demonstrated limited cases	Unproven	Demonstrated limited cases	Unproven
Species traits	Pigments	Demonstrated limited cases	Demonstrated limited cases	Demonstrated limited cases	Unproven	Demonstrated limited cases	Demonstrated limited cases
	Phenology	Demonstrated limited cases	Demonstrated limited cases	Demonstrated limited cases	Unproven	ROUTINE USE FOR OPEN OCEAN	Demonstrated limited cases
Community composition	Taxonomic diversity	Unproven	Unproven	Unproven	Unproven	Demonstrated limited cases	Demonstrated limited cases
Ecosystem structure	Functional type	Demonstrated limited cases	Unproven	Unproven	Demonstrated limited cases	Demonstrated limited cases	Demonstrated limited cases
	Fragmentation/ heterogeneity	Demonstrated limited cases	Demonstrated limited cases	Demonstrated limited cases	Demonstrated limited cases	ROUTINE USE FOR OPEN OCEAN	Demonstrated limited cases
Ecosystem function	Net primary production	Habitat model required	Habitat model required	Habitat model required	Unproven		Unproven
	Net ecosystem production	Habitat model required	Unproven	Unproven	Unproven	Demonstrated limited cases	NA

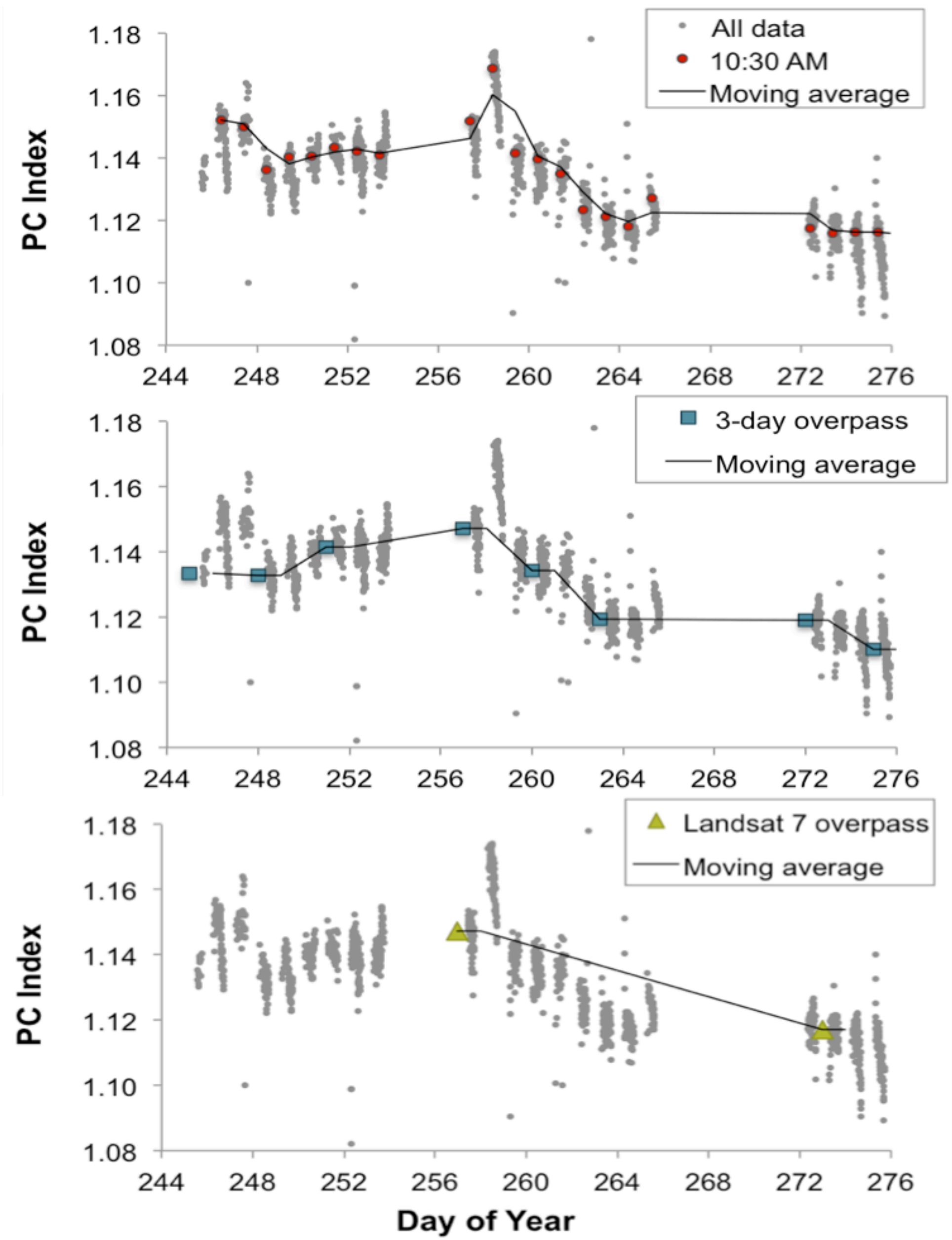
Legend
Unproven
Demonstrated limited cases
Routine use
Habitat model required

Ocean/Aquatic RS_EBV Require

Calibrated surface <u>spectral</u> remote sensing reflectance

- 1. Bottom (benthic) spectral RS reflectance
- 2. Surface spectral RS reflectance (open water, coast, wetlands)

Harmful Algae Blooms

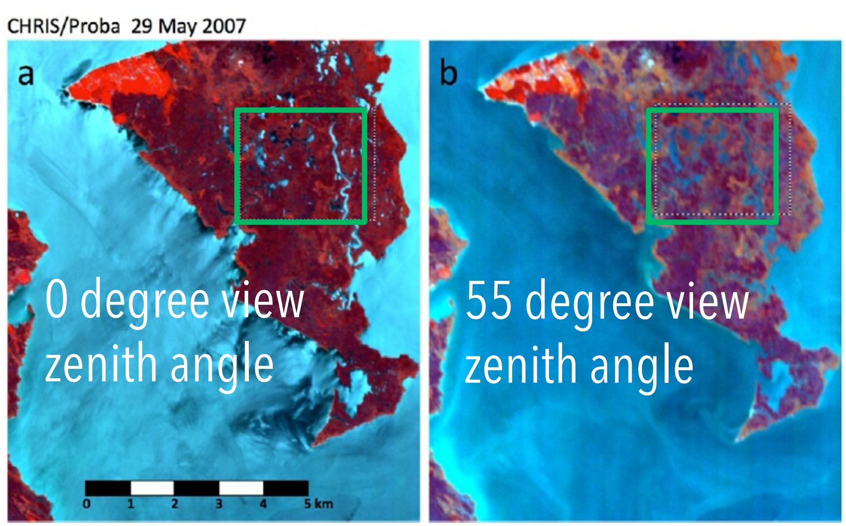


Cyanobacteria concentrations in Mantua Lake (Italy)

[after Hestir et al. 2015].

Wetlands and aquatic targets at different view angles

Higher reflectance when looking straight down because you see water in addition to vegetation



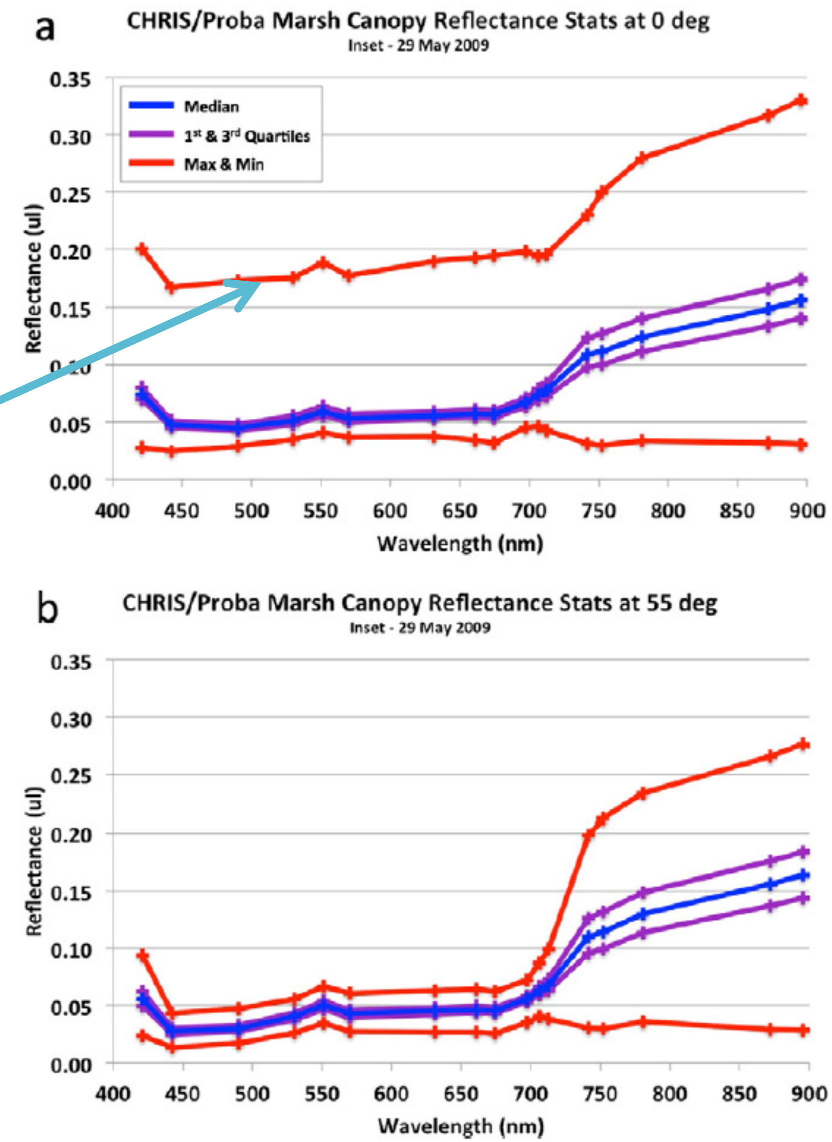
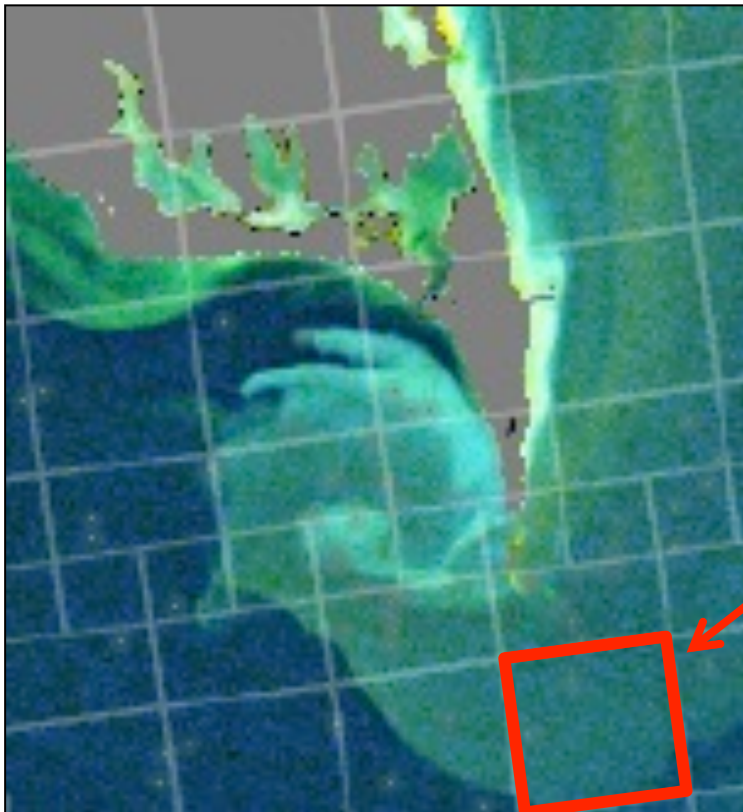


Fig. 6. Spectra extracted from regions highlighted by boxes in Fig. 5. (a) At 0° nominal view zenith angle, glint produces very high values across the spectrum, evidenced by the maximum spectral curve. (b) At 55° nominal view zenith angle, the glint effect is greatly reduced.

[Turpie et al 2015]

Issue: spatial resolution



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

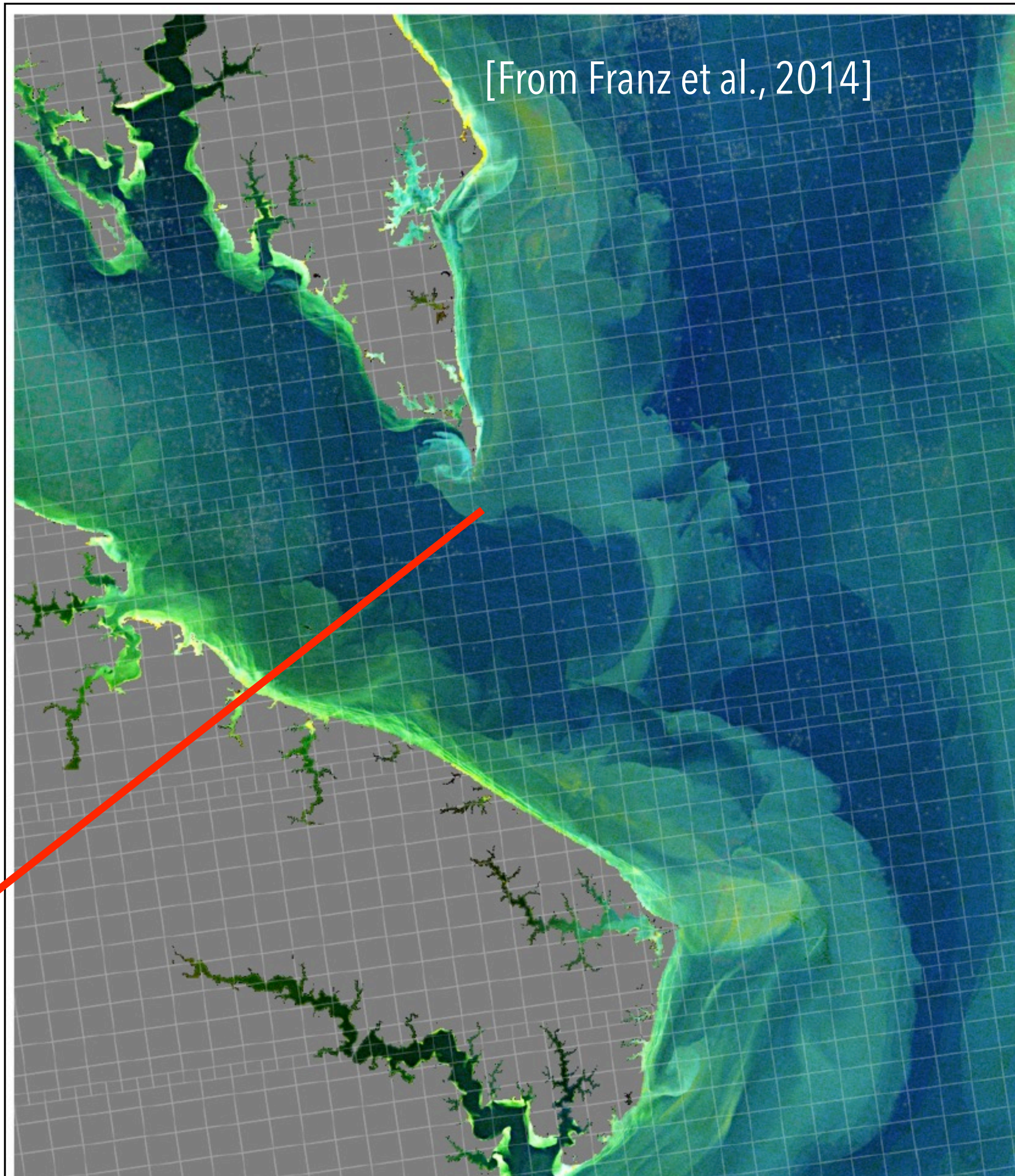


Figure 5: *Three-band water-leaving reflectance composite image from OLI at the location where the Potomac River enters Chesapeake Bay. MODIS Aqua scan pixel boundaries for the same date are overlaid to demonstrate the sub-pixel variability revealed by the higher spatial resolution of OLI. The Rrs(λ)were 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.*

Winter: species hard to separate

↓

Spring: species easier to separate

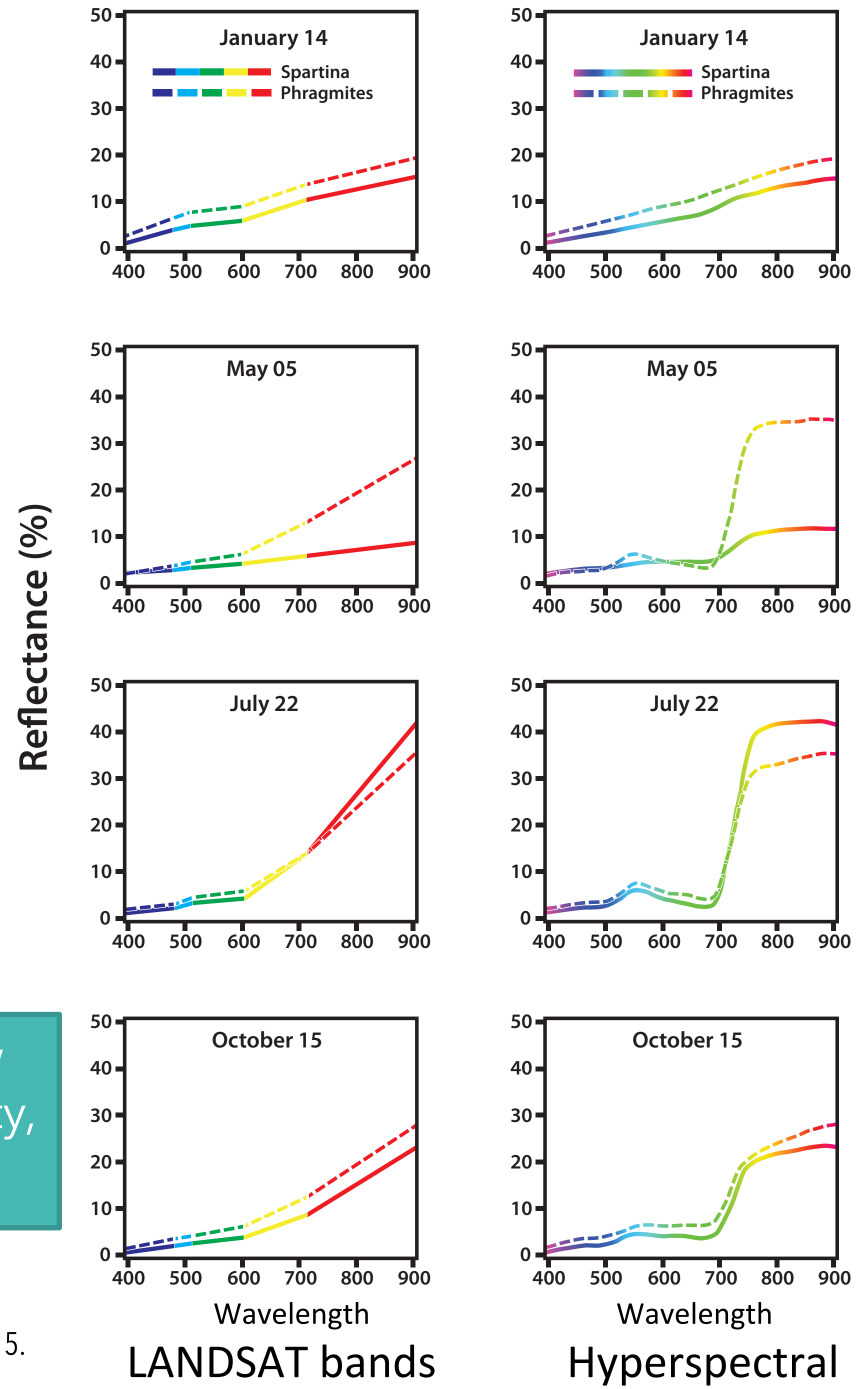
↓

Summer: further differentiation

High spectral resolution helps differentiate organisms

Organisms show different phenology

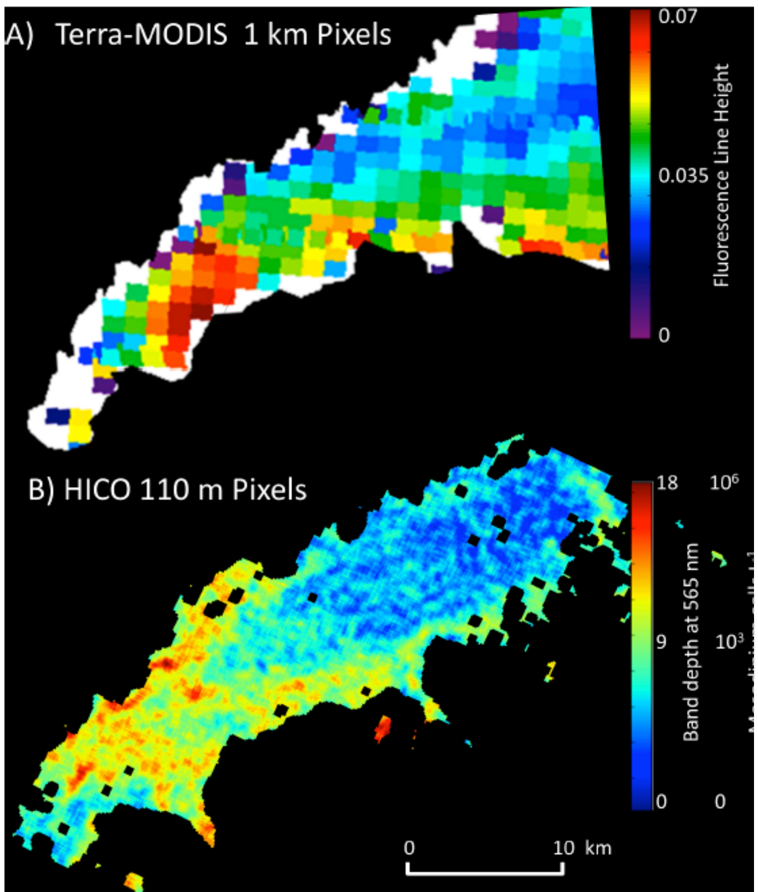
Relative changes allow evaluation of biodiversity, invasive species, etc.

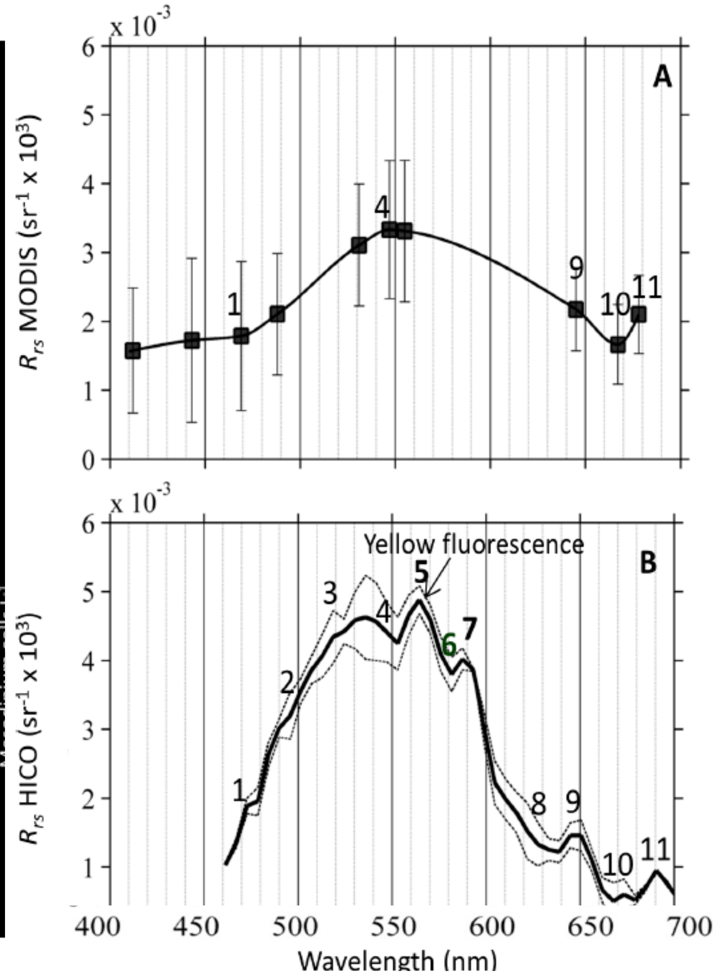


From: Ouyang Z-T, et al. 2013. Spectral Discrimination of the Invasive Plant Spartina alterniflora at Multiple Phenological Stages in a Saltmarsh Wetland. PLoS ONE 8(6): e67315. doi:10.1371/journal.pone.0067315)

High spectral resolution helps separate living from non-living water constituents

-Chlorophyll from CDOM
-Different small organisms (ciliates from phytoplankton)





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

[Dierssen et al 2015]

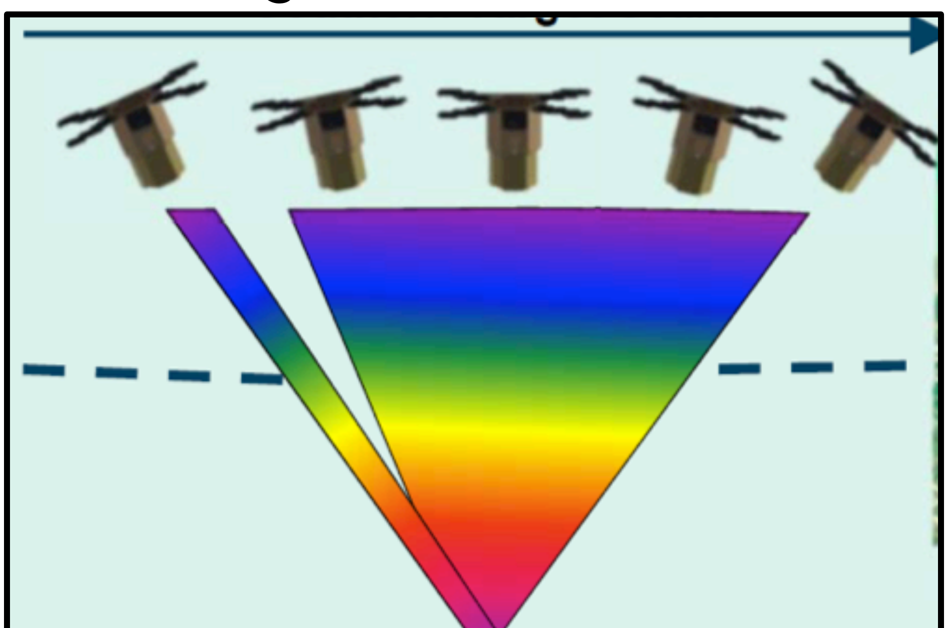
Coastal and inland aquatic observation priorities

- High temporal
  - At some representative locations: weekly
- 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

Possible observation technique:
(Technology Readiness Level: TRL >6-7, now!)

→Current HyspIRI global concept

Increase temporal coverage through:
-Agile spacecraft (pointing)
-Multiple spacecraft (e.g., Sentinel 2a,b & 3; commercial)




G
High Latitude Environments experience extremes in temperatures, insolation, and UV radiation.
H
Coastal Megacities have an important influence on the biodiversity and the water quality of areas near them. Three quarters of the world's largest cities are situated in coastal zones and large deltas.
J
Clear Ocean Water Targets in the major ocean gyres are characterized by relatively uniform and clean atmospheres, and low variability in reflectance, biooptical properties, and Chlorophyll-a concentration.
I
Small Islands support about 20% of the biodiversity on Earth, with endemic communities evolving in isolation to occupy empty niches.
D
Mangrove Forests are tropical habitats that serve as nurseries for invertebrates and fish, rookeries for birds, and protect low-lying coastal areas from erosion and storm surges.
These observations would :
-Provide EBV (land, aquatic, ecosystem)
-Inform international frameworks
-Advance app's: resource management
F
Fresh Water Environments are essential for life on Earth. They support human and wild-life populations, and are conduits of nutrients, including carbon and other elements, to the coastal ocean
E
Salt Marshes and Salt Flats are widely distributed along the coasts of many of the world's estuaries. They help prevent erosion and serve as habitat for numerous animals.
C
Seagrasses are submerged flowering plants found in shallow subtidal, mostly clear and sheltered, soft-bottomed marine and estuarine environments.
B
Corals are among the most biologically diverse ecosystems on Earth. Higher than normal seawater temperatures, pollution, high sediment load, indiscriminate fishing, and algae blooms are reducing the diversity and productivity of these systems worldwide.
A
Estuaries are areas where fresh water mixes with marine waters. Diminished habitat quality is common due to excess sediment, nutrient load, and debris that promote bacteria or algae growth.

Let's do it!

There are no existing or planned missions that can provide these coastal land and aquatic observations

There is existing spectrometer technology NOW

→[=lead to a revolution in applications