SBG Applications: Aquatic Ecosystems including Corals, Harmful Algal Blooms, Water Quality, Restoration

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MARINE AND TERRESTRIAL ECOSYSTEMS AND NATURAL RESOURCES MANAGEMENT PANEL

Societal or Science Question/Goal	Earth Science/Application Objective	Sci/App Importance
QUESTION E-1. What are the structure, function, and biodiversity of Earth's ecosystems, and how and why are they changing in time and space?	**E-1a.** Quantify the global distribution of the functional traits, functional types, and composition of vegetation and marine biomass, spatially and over time.	Very Important
	E-1b. Quantify the global three-dimensional (3-D) structure of terrestrial vegetation and 3-D distribution of marine biomass within the euphotic zone, spatially and over time.	Most Important
	E-1c. Quantify the physiological dynamics of terrestrial and aquatic primary producers.	Most Important
	E-1d. Quantify moisture status of soils.	Important
	E-1e. Support targeted species detection and analysis (e.g., foundation species, invasive species, indicator species, etc.).	Important
QUESTION E-2. What are the fluxes (of carbon, water, nutrients, and energy) ***between*** ecosystems and the atmosphere, the ocean and the solid Earth, and how and why are they changing?	**E-2a.** Quantify the fluxes of CO_2 and CH_4 globally at spatial scales of 100-500 km and monthly temporal resolution with uncertainty < 25% between land ecosystems and atmosphere and between ocean ecosystems and atmosphere.	Most Important
	E-2b. Quantify the fluxes from land ecosystems between aquatic ecosystems.	Important
	E-2c. Assess ecosystem subsidies from solid Earth.	Important
QUESTION E-3. What are the fluxes (of carbon, water, nutrients, and energy) ***within*** ecosystems, and how and why are they changing?	**E-3a.** Quantify the flows of energy, carbon, water, nutrients, etc. sustaining the life cycle of terrestrial and marine ecosystems and partitioning into functional types.	Most Important
	E-3b. Understand how ecosystems support higher trophic levels of food webs.	Important
QUESTION E-4. How is carbon accounted for through carbon storage, turnover, and accumulated biomass, and have we quantified all of the major carbon sinks and how are they changing in time?	**E-4a.** Improve assessments of the global inventory of terrestrial C pools and their rate of turnover.	Important
	E-4b. Constrain ocean C storage and turnover.	Important
QUESTION E-5. Are carbon sinks stable, are they changing, and why?	**E-5a.** Discover ecosystem thresholds in altering C storage.	Important
	E-5b. Discover cascading perturbations in ecosystems related to carbon storage.	Important
	E-5c. Understand ecosystem response to fire events.	Important

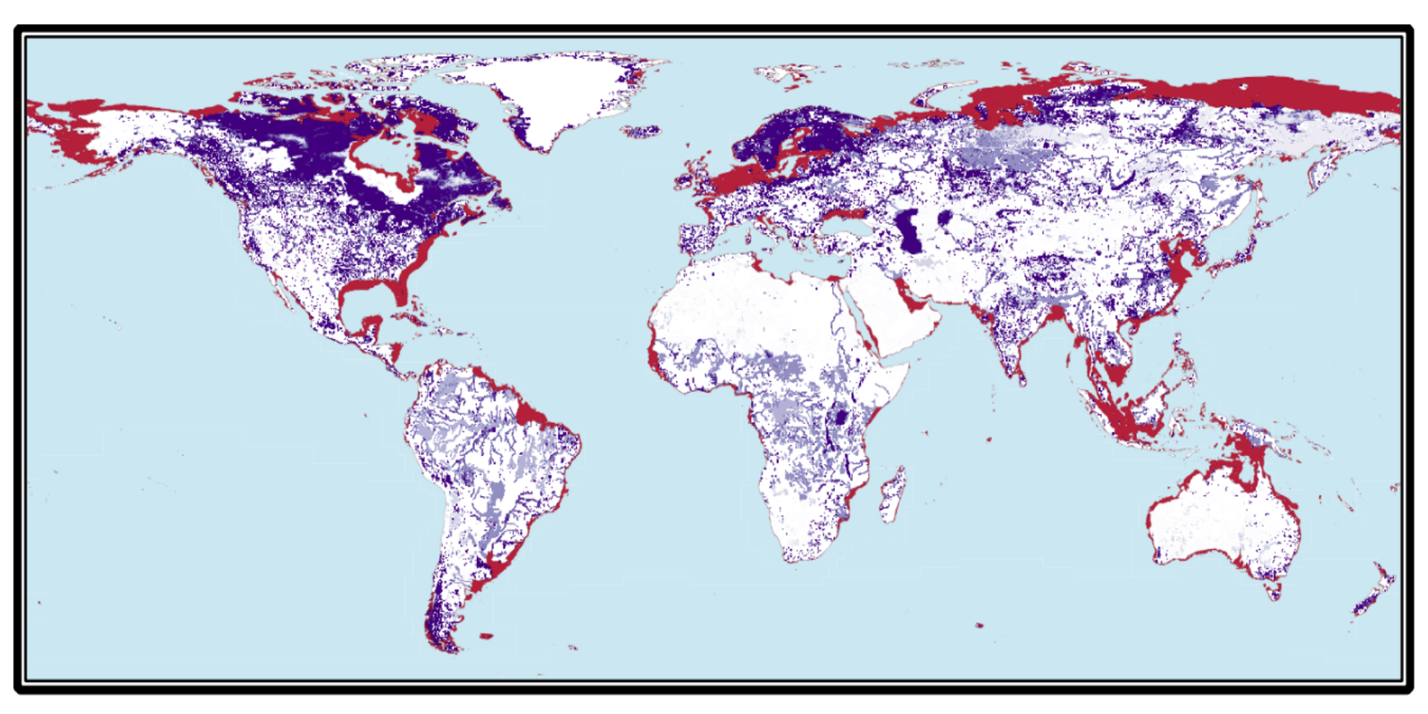


Figure 1 – Global distribution of coastal and inland aquatic ecosystems. Red indicates regions where water depth is less than 50 m and where land elevation is less than 50 m. Light to dark violent gives the concentration of inland wetlands, lakes, rivers and other aquatic systems. Increased darkness means greater percentage of areal coverage for inland aquatic ecosystems (UNEP-WCMC, 2005).

Turpie et al 2016, Global Observations of Coastal and Inland Aquatic Systems

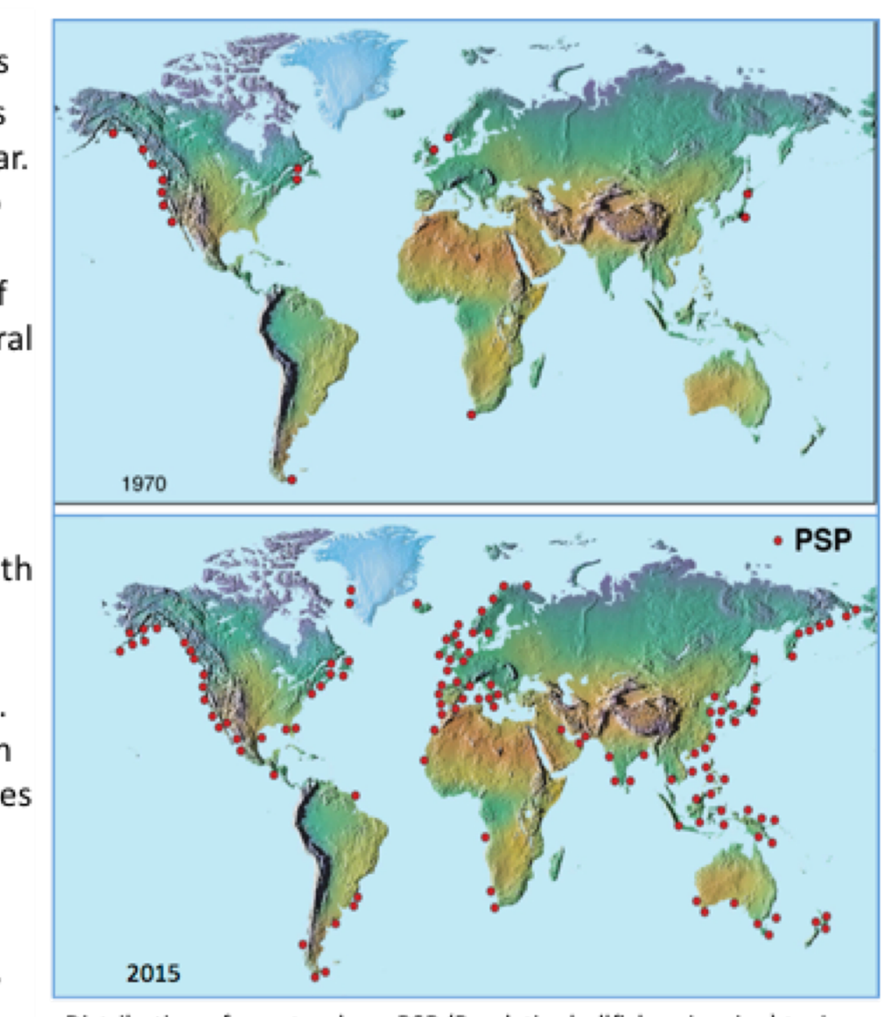
Harmful Algal Blooms

Societal Challenge: Coastal HAB events have been estimated to result in economic impacts in the United States of at least $82 million each year. The impacts of HABs range from environmental, to human health (e.g., illness through shellfish consumption, asthma attacks through inhalation of airborne HAB toxins), to socio-economic and cultural (e.g., commercial fisheries, tourism, recreation).

Opportunity: improved identification and quantification of specific phytoplankton groups, with ***hyperspectral observations*** would allow us to identify HABs and track their evolution and variability over seasonal to interannual time scales. ***High spatial resolution*** measurements (better than 100 m) would allow to capture intense small patches of HABs in estuaries and inland waters.). 30-m needed for estuaries and inland waters, aquaculture.

Temporal. Weekly to bi-weekly. Targeting for HAB events/oil spills.

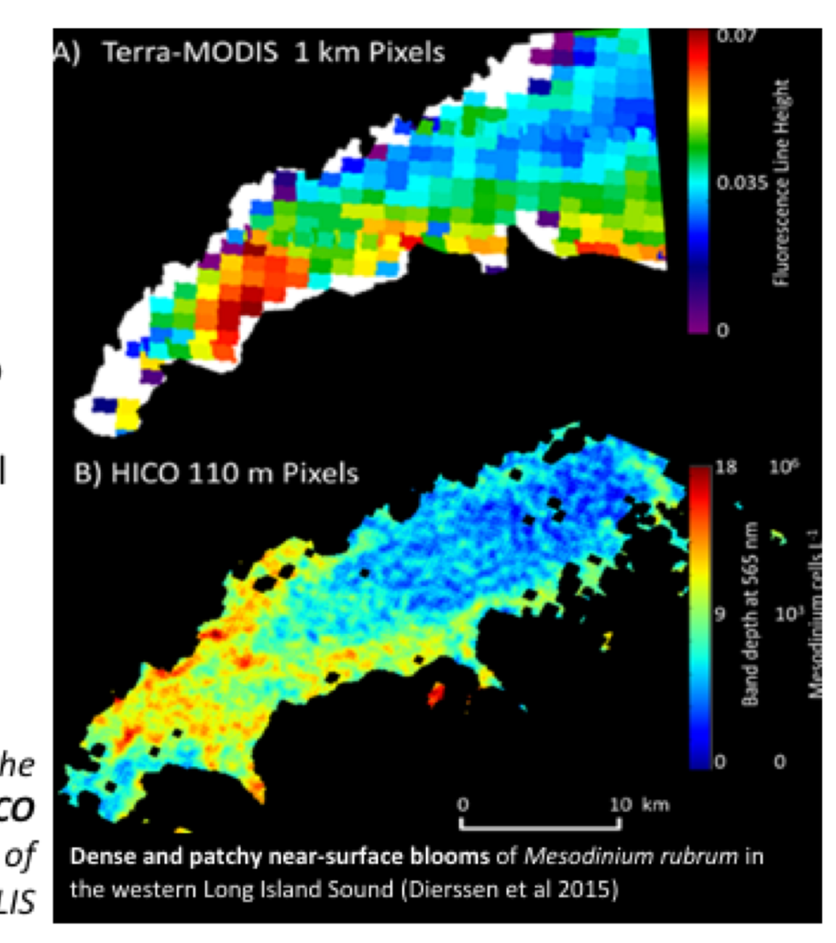
DS: H2b, 2c, E1a, 1b, 1c, E2a, E3a, 3b, 5b



Distribution of events where PSP (Paralytic shellfish poisoning) toxins were detected in shellfish or fish– 1970 versus 2009

End Users: NOAA, USGS, EPA (e.g., Gulf of Mexico Program), and other state environmental agencies and local health departments are interested in improved monitoring and understanding of HAB events.

Among the main goals of these end-users is to provide coastal communities with advance warning, so they can adequately plan and deal with the adverse environmental and health effects associated with a harmful bloom.



Dense and patchy near-surface blooms of *Mesodinium rubrum* in the western Long Island Sound (Dierssen et al 2015)

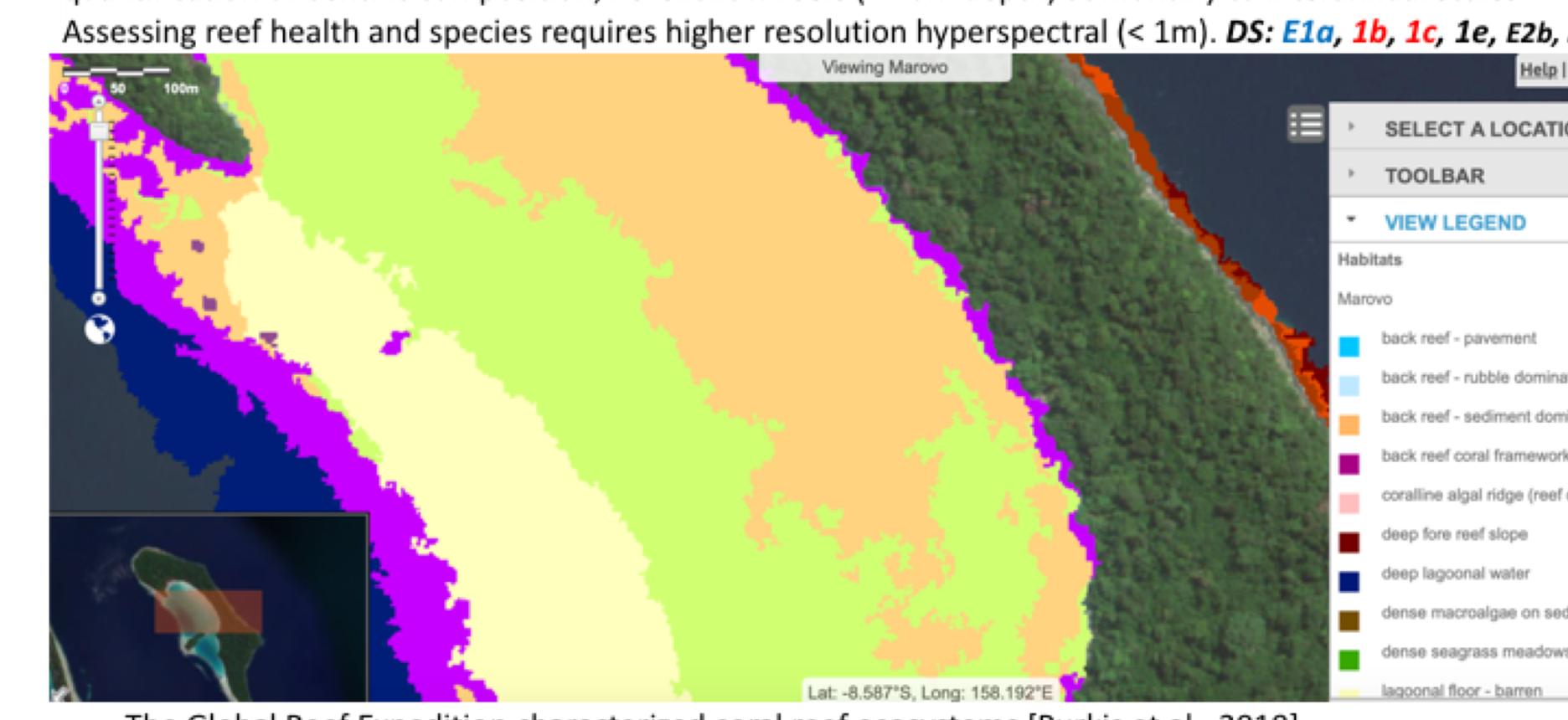
*Compared with the 1-km MODIS image, the **higher spatial resolution (110 m) of the HICO image revealed intense small patches** of yellow fluorescing Mesodinium in WLIS*

Some algal blooms reduce the ability of fish and other aquatic life to find food and can cause entire populations to leave an area or even die. Credit: EPA

Coral Reefs

Societal Challenge: Coral reefs are threatened by warming temperatures, acidification, physical damage, and land based pollutants such as sediments, nutrients, and contaminants.

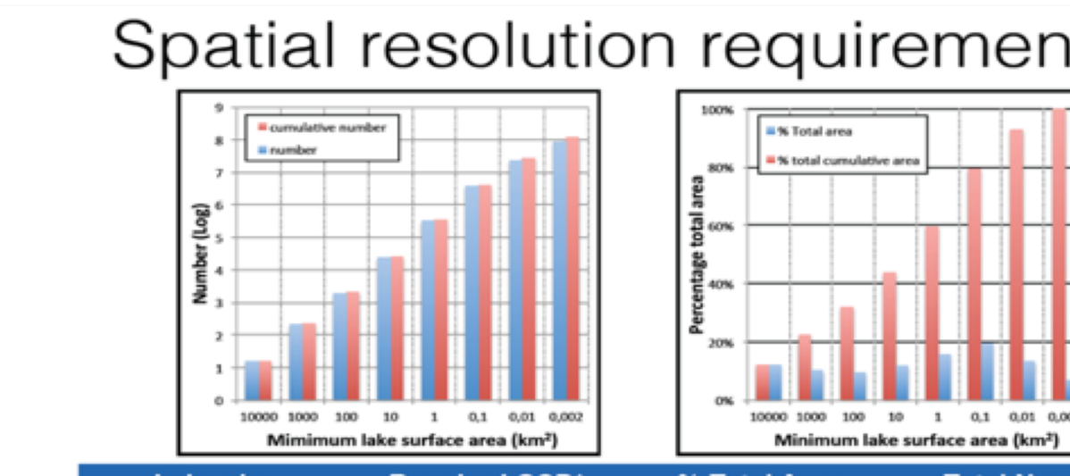
Opportunity: ***High spatial resolution hyperspectral observations*** (< 30 m) enable identification and quantification of benthic composition, i.e. shallow reefs (< 40m depth) at monthly to interannual scales. Assessing reef health and species requires higher resolution hyperspectral (< 1m). ***DS: E1a, 1b, 1c, 1e, E2b, E3b***



The Global Reef Expedition characterized coral reef ecosystems [Purkis et al., 2019]

Water Quality Assessment

Spatial resolution requirements



Lake size	Required GSD*	% Total Area	Total Number
≥ 1 km²	333 m	60	353,552
≥ 0.1 km²	**105 m**	80	4,123,552
≥ 0.01 km²	33 m	90	**27,523,552**
≥ 0.002 km²	15 m	100	**117,423,552**

- GSD less than 30 m likely too high
- GSD of 100 m likely sufficient for 80% surface area of world lakes
- Sheer number of lakes means GSD < 100 m prohibitive without pre-selection criterion (but desirable for regional implementations)
- Rivers currently excluded.

Data from Verpoorter at al. (2014) * calculated for a box of nine pixels

Verpoorter C., Kutser, T., Seekell, D. a., & Tranvik, L. J. (2014). A Global Inventory of Lakes Based on High-Resolution Satellite Imagery. Geophysical Research Letters.

by Mark Mattthews (CyanoLakes)

DS Question	Focused Science Topic	Application Focus Group	Application Concept	Decision Approach	L2+ VSWIR (one row) and TIR (another row)	Spatial	Temporal	Latency	Other Design Considerations	End Users	Auxillary	Additional Comments
E-1. What are the structure, function, and biodiversity of Earth's ecosystems, and how and why are they changing in time and space?	Ecosystem traits and biodiversity - marine/coastal	Conservation	Restoration of habitats for endangered or keystone species (coastal aquatic), like wetlands, mangroves, marshes	Mapping benthic composition or veg species composition, structure, health at coastal interface to inform restoration efforts like removing invasive or detrimental weeds. Track improvement/changes in water quality.	L4-Emergent and Submerged Macrophytes/Species L4-Benthic Mapping L4-Bathymetry L3,4-Colored Dissolved Organic Matter L3-Dissolved Ograric Carbon L3-Particualte Ogranic Carbon L3 -Dissolved lignin phenols L3,4-Light Attenuation L3-Chlorophyll L3-Phycocyanin L3-Phycoerythrin L3-Total Suspended Matter L2-Benthic Reflectance L3-Plant degradation products: Chlorophyllide or Phaeo(phorbide/phytin) L3-Evapotranspiration L2-Water or Sea Surface Temperature	(better than) 30m x 30m 30m x 30m	Min: 7 days Max: hourly	12 hours to 7 days	sun-synchronous	US Fish and Wildlife State Agency - FWS NOAA Conservation Organizations USGS EPA Natural Resources Conservation Service National Audubon Society	LiDAR, RADAR for sea level and change in coastal geomorphology Atmospheric Measurements (aerosols and trace gases) for accurate atmospheric correction	need for sea level height for tracking rise? And tracking aspects of extreme events interconnected with sea level rise and vulnerability of coastal marine ecosystems?
E-1. What are the structure, function, and biodiversity of Earth's ecosystems, and how and why are they changing in time and space?	Ecosystem traits and biodiversity - marine/coastal	Conservation	Mitigating / addressing coral reef degradation	Use of benthic composition and coral species composition, structure, health to inform protective/restoration efforts, like marine protected areas and protection of tourism, fisheries	L3-Benthic v sand v coral v algae Mapping L3-Chlorophyll L3-Colored Dissolved Organic Matter L3-Algal classes identided by visible derivative spectroscopy L3-Phytoplankton Accessory Pigments L2-Benthic Reflectance L2-Water or Sea Surface Temperature	1-10 m in estuaries	Min: 15 days Max: daily	12 hours to 7 days		NOAA UN Environment Programme Pew Charitable Trusts / Lenfest U.S. Coral Reef Task Force (CRTF) National Center for Coral Reef Research (NCORE) International Coral Reef Initiative (ICRI)	Atmospheric Measurements (aerosols and trace gases) for accurate atmospheric correction	
E-1. What are the structure, function, and biodiversity of Earth's ecosystems, and how and why are they changing in time and space?	Ecosystem traits and biodiversity - marine/coastal	Conservation	Improving ecosystems based fisheries management	Apply chlorophyll and other optical properties into ecosystems models for improved catch limit sets.	L4-Colored Dissolved Organic Matter L4-Light Attenuation L4-Emergent and Submerged Macrophytes/Species L4-Benthic Mapping L4-Bathymetry L3-Chlorophyll L3-Phycocyanin L3-Phycocyanin L3-Phycoerythrin L3-Total Suspended Matter L3-Turbidity L2-Remote Sensing Reflectance L3 -Sediment plumes identified by mineral compostion using visible derivative spectroscopy L3 -Algal classes identided by visible L2-Water or Sea Surface Temperature	30m x 30m Min: 1 km x 1 km Max 30 x 30 m	annual Min: 7 days Max: hourly	NA 12 hours to 7 days	sun-synchronous	NOAA UN Environment Programme Pew Charitable Trusts / Lenfest U.S. Coral Reef Task Force (CRTF) National Center for Coral Reef Research (NCORE) International Coral Reef Initiative (ICRI) North American Fisheries Councils State Fish and Wildlife agencies	Atmospheric Measurements (aerosols and trace gases) for accurate atmospheric correction	
E-2. What are the fluxes (of carbon, water, nutrients, and energy) between ecosystems and the atmosphere, the ocean and the solid Earth, and how and why are they changing?	Ecosystem traits and biodiversity - terrestrial	Conservation	Impacts of biogeochemical exchanges on coastal habitat, ecology and water quality	Apply measurements and models to imrpove management of inalnd and coastal water resources and ecosystem services	L4 - Colored Dissolved Organic Matter L4 - Light Attenuation L3 - Chlorophyll L3 - Phytoplankton pigments L3 - Phycocyanin L3 - Phycoerythrin L3 - Total Suspended Matter L3 - Turbidity L3 - DOC L3 - POC L3 - PIC L2 - Remote Sensing Reflectance L2-Water or Sea Surface Temperature	Better than 30 x 30 m for lakes/reservoirs, Better than 200 m in estuaries	Min: 2 days Max: hourly	12 hours to 7 days		NOAA EPA WQ Monitoring Programs North American Fisheries Councils State Fish and Wildlife agencies	Atmospheric Measurements (aerosols and trace gases) for accurate atmospheric correction	
H-2. How do anthropogenic changes in climate, land use, water use, and water storage, interact and modify the water and energy cycles locally, regionally and globally and what are the short- and long-term consequences?	Ecosystem traits and biodiversity - terrestrial and marine/coastal	Disasters	Oil Spill Monitoring	Apply measurements to monitor and mitigate impacts of environmental disasters	L2 - Remote Sensing reflectance L2-Water or Sea Surface Temperature	5-10 m for rivers, 30 m for lakes/reservois 200 m for estuaries	Min: 2 days Max: hourly	6 hours to 1 day		NOAA EPA WQ Monitoring Programs North American Fisheries Councils State Fish and Wildlife agencies FWS	Atmospheric Measurements (aerosols and trace gases) for accurate atmospheric correction	
H-2. How do anthropogenic changes in climate, land use, water use, and water storage, interact and modify the water and energy cycles locally, regionally and globally and what are the short- and long-term consequences?	Ecosystem traits and biodiversity - marine/coastal	Water Management	Mitigating detrimental effects of harmful algal bloom events	Use of chlorophyll, phycocyanin, and other pigment information to characterize extent and location of HABs; use this to inform site closures, shutdown water intakes, prevent exposure/illness	L4 - Floating Algal Index L3 - Chlorophyll L3 - Phycocyanin L3 - Phycoerythrin L3 - Algal classes identided by visible derivative spectroscopy L3 - Colored Dissolved Organic Matter L3 - Total Suspended Matter L3 - Phytoplankton Accessory Pigments L2 - Remote Sensing Reflectance L2-Water or Sea Surface Temperature	Better than 30 x 30	weekly during algal bloom season, monthly otherwise Min: 2 days Max: hourly	< 1 day 6 hours to 1 day	sun-synchronous	Environmental Protection Agency NOAA State and local public health agencies, parks/recreational agencies Water utilities National Environmental Health Association Department of Environmental Conservation U.S. Department of Health & Human Services	Atmospheric Measurements (aerosols and trace gases) for accurate atmospheric correction	

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