Observing Coastal and Inland Aquatic Ecosystems from Space

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Decadal Survey Reports

NEW NEED TO UNDERSTAND CHANGING COASTAL AND INLAND AQUATIC ECOSYSTEM SERVICES
Kevin Turpie, David W. Allen, Steven Ackelson, Thomas Bell, Heidi Dierssen, Kyle Cavanaugh, Joshua B. Fisher, James Goodman, Liane Guild, Eric Hochberg, Victor V. Klemas, Samantha Lavender, Christine Lee, Tiffany Moisan, Frank Muller-Karger, Joseph Ortiz, Sherry Palacios, David R. Thompson, Richard Zimmerman

GLOBAL OBSERVATIONS OF COASTAL AND INLAND AQUATIC HABITATS
Kevin Turpie, Steven Ackelson, Thomas Bell, Heidi Dierssen, James Goodman, Robert Green, Liane Guild, Eric Hochberg, Victor V. Klemas, Samantha Lavender, Christine Lee, Peter Minnett, Tiffany Moisan, Frank Muller-Karger, Joseph Ortiz, Sherry Palacios, David R. Thompson, Richard Zimmerman

MONITORING COASTAL AND WETLAND BIODIVERSITY 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
Ecosystem services:

- Support among the most biologically diverse places on Earth.
- Buffer human and animal habitats against storms and floods.
- Provide erosion control; can build or preserve land.
- Support fisheries that provide food, livelihood, and recreation to roughly half of the global population (Barbier et al 2011).
- Have cultural and recreation value.
- Per unit area, amongst the most productive places on Earth.
- Play a key role in the cycling of carbon, minerals and nutrients.
- Inland waters provide critical freshwater resources for human consumption, irrigation, sanitation, industry, recreation, and play a vital role in human health and safety.
- **Support industry worth hundreds of billions of USD.**
- **Support hundreds of thousands of jobs in the USA.**
- **Coasts provide over $56 trillion in benefits**

These are also some of the most endangered ecosystems in the world.
Coastal ecosystems, from high latitudes to the tropics are undergoing massive change NOW.

- **Sea Grasses** losses have risen to 7% yr\(^{-1}\) since 1990 (Waycott et al., 2009), having major impact on coastal productivity, biodiversity, and fisheries.
- Globally, **wetland habitats** have declined 64–71% and the degradation rate continues to increase due to climate change, sea level rise, and human encroachment. (Davidson et al., 2014).
- Many **coral reef** systems are currently in decline due to direct human impacts and changing ocean conditions linked to climate change, e.g., mechanical erosion by storms, elevated water temperature, and acidification (Hughes et al., 2003).
- **HAB events** are being introduced through human activities or being driven by climatic change (Anderson et al., 2002).
- **Invasive species** are influenced by climate change (Guareschi et al., 2013) can have profound impact on ecosystem function (Rahel and Olden, 2008).

Over 70% of humanity faces **high** risk of losing benefits from coasts by 2025.
2015 Florida Bay Seagrass Die-Off
National Park Service, U.S. Department of the Interior
South Florida Natural Resources Center Everglades National Park
May 2016

• 40,000 Acre Die-Off of Sea Grass.
• 2nd major seagrass die off in three decades.
• Die-off was more rapidly than 1987-90.
• Tied to drought and poor water management.
• Threatens a $1.2 billion sport fishing industry.

This massive seagrass die-off is the latest sign we’re failing to protect the Everglades
Washington Post, Chris Mooney, April 27 2016
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This massive seagrass die-off is the latest sign we’re failing to protect the Everglades
Washington Post, Chris Mooney, April 27 2016
Most of the world’s population share watersheds with wetlands, depend on their services, but likewise threaten these resources, directly or indirectly.

Wetlands are highly vulnerable to human activities, exploitation, and climate change.

Nearly 1/2 of all American wetlands lost since colonial times.

Louisiana lost about 60 sq km/yr during the 1990’s.

260 sq km were lost in from Rita and Katrina.

From Uncertain Threats to Saltmarshes of the Delaware Inland Bays
Chris Bason, Delaware Center for the Inland Bays (2006)
Legislation in the 1970’s has mitigated most of the direct destruction of American wetlands.

Nonetheless, a new inter-agency task force was established this year to address reports of higher than expected wetland loss in the USA.

Wetlands are still at risk in other regions of the globe and other threat processes exist.

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**THREATS TO COASTAL WETLANDS**

- Louisiana lost about 60 sq km/yr during the 1990’s.
- 260 sq km were lost in from Rita and Katrina.

Before and after: satellite images show marshland lost in Breton Sound, Louisiana, one of the areas hit hardest by Hurricane Katrina.

From Uncertain Threats to Saltmarshes of the Delaware Inland Bays
Chris Bason, Delaware Center for the Inland Bays (2006)

Objective: Develop knowledge to promote well-planned, healthy and resilient coastal communities globally.

...This requires space-based observation technologies
Coastal and inland aquatic science

Questions:

– What are the distribution, abundance, function, and state of coastal and inland aquatic ecosystems on regional and global scales? At what rate are these quantities changing?

– What are the material fluxes across the boundaries between land, water, and air; how are they changing?

– What are the linkages of these changes to climate, human activities or natural processes?

– How are these changes interconnected and what are the consequences to important ecological services, e.g., fish stocks and water quality and availability?
Issue: spatial resolution

From Franz et al., 2014

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, 443 nm) were combined to form the image.
Landsat 8 scene: Venice lagoon, Italy
Binning improves SNR
But we lose detail about sediment, CDOM, and interactions in coastal wetlands & plumes.
High spectral resolution helps differentiate organisms because they show different phenology.

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

Issues: detecting temporal change

• A global mapping mission with 30m resolution and 16-day revisit period can detect secular changes at pixel scales over a mission duration of three or more years.

• This includes long-term response to disturbances, climate change, human activities, and other drivers of change.
Issues: detecting temporal change

**Passive RS** - classification, composition, condition.
- **Multi-band Optical** - discrimination of cover type; may require higher spatial resolution.
- **Hyperspectral Optical** - improved discrimination, possibly better detection of change at subpixel scales; better observations of fluorescence.
- **Thermal** - would provide additional wetland and watershed conditions (e.g., soil moisture).

**Active RS** - (SAR and LIDAR) provide vegetation structure (e.g., Sentinel 1); LIDAR can provide water column optical constituents.
Issues: detecting temporal change

• High temporal resolution is required to see changes in phenology, another key indicator of response to environmental changes. (e.g., sampling every couple of days, depending targeted phase of growth cycle)

• Very high temporal sampling (hourly sampling) is required to characterize and monitor changes in response to tidal and diel cycles and immediate response to disturbances. (e.g., GeoCAPE).
Coastal and inland aquatic observation strategies

High spatial resolution $\leq 30$ m for foundational species, rivers and small water bodies; $\leq 100$ m for open water phytoplankton.

High-performance radiometry
- High SNR, large radiometry range and resolution, minimal polarization sensitivity, minimal cross-talk or other out-of-band, atmospheric correction scheme (including adjacency), sun-glint avoidance, cloud screening/masking, etc.

Highly accurate geolocation and band-to-band registration

Obs Strategy 1 - Foundational species areal extent and secular change (e.g., HyspIRI)
- Low temporal
- High spectral (VIS, SWIR and TIR)

Obs Strategy 2 - Phenology characterization and change (see next slide)
- High temporal (<2 days)
- High spectral (VIS, SWIR)

Obs Strategy 3 - Tidal and diel processes (GeoCAPE?)
- Very-high temporal (hourly)
- High spectral (VIS, SWIR and TIR)
Possible observation technique:
(Technology Readiness Level: TRL >6-7, now!)

- Hyperspectral 30 m spatial resolution sensor
- Sample several hundred 30x30 km areas every 3 days
- 3-day exact repeat orbit
- 1 ‘slow’ and 1 ‘fast’ scan of same target per acquisition
- Off-nadir for land vegetation
- Maximizes signal-to-noise ratio over land and over water

(Muller-Karger et al., OCRT presentation, May 2016)
Conclusions

• Decadal Survey reports indicate that multiple strategies (=multiple RS assets) are needed to study coastal and inland aquatic environment.
• A mission like HyspIRI can address global extent, distribution and secular change.
• A mission like GeoCAPE may cover diel and tidal responses, but the spatial resolution may not be high enough for foundational species response.
• Technology exists to support RS observations of phenological change.
• Active RS could enhance information, especially in wetlands and terrestrial components.
THANK YOU
Tidal marshes provide valuable ecological services, estimated at $14,397 USD per hectare per year globally.*

**BIOGEOCHEMICAL CYCLING:**
- One of the most productive biomes for **Carbon** uptake per area.
- Uptake nutrients **N** & **P** from further up the watershed.
- Can take up toxic substances before entering open water.
- Major source of **CDOM** in coastal waters. (blue carbon)
- Filter suspended sediment.

**IMPORTANT ECOLOGICALLY:**
- Habitat or nursery for many birds, fish, and other fauna.
- Up to **1/2** of **N**. American bird species nest or feed in wetlands.*
- **31%** of all plants species in ConUS.*

**IMPORTANT ECONOMICALLY:** *
- Support industry worth hundreds of billions of USD.
- Support hundreds of thousands of jobs in the USA.

**PROTECT HUMAN HABITAT AND PROPERTY:**
- Can absorb wind wave energy of major storms.
- An acre of wetland can store **1-1.5 x 10^6** gallons of flood water.*

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* 2009 inflation-adjusted value (Bromberg-Gedan 2009)
Coral reefs do not influence the short-term global carbon cycle, but...

Concern

...they are among the first ecosystems to respond critically and dramatically to climate change.

Climate change may exacerbate local impacts, leading to reef degradation worldwide.
Eleven of the 15 largest cities in the world lie in coastal regions.

In the US, 53% of the population lives near the coast.
Our life and economy depend on freshwater supply and healthy coastal ecosystems.
Phenology of terrestrial and wetland vegetation shows quick change with season and events.

Rapid change in cyanobacteria concentrations in Lake Pinto, CA

Detectable using hyperspectral field data

[Kudela et al., 2015]
Cyanobacteria concentrations in Mantua Lake (Italy)

Rapid changes over a few days

Measurements every 3 days would capture changes in the concentration of phytoplankton, sediment load, and other water quality factors at five times the Landsat frequency

[after Hestir et al. 2015]
Example: EnMAP

*If EnMAP were to be a global mission*

- 27 day repeat **with ±5 deg cross-track pointing**
- 4-5 day revisit **by ± 30 deg cross-track pointing**
  - Issue: limited revisit for time series, and if so, at different cross-track angles for every collection.
  - Possibly uninterpretable!!

*But:*
- 5% or worse polarization sensitivity (bad news for ocean color since ocean radiance signal is ~1% of Top of Atmosphere radiance)
- EnMap is on-demand only, like PRISMA, when launched
Coastal and inland aquatic science

Coastal and inland ecosystems are distributed world-wide, but actual areal extent for any particular kind of habitat is currently highly uncertain.

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).
For instance, only a small fraction of all coral reefs have been surveyed to determine their health, or the impact of increasing temperature and acidity.
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]
Wetland BRDF effects (bidirectional reflectance distribution function)

1) Emergent vegetation:
More reflective off-nadir than at nadir

Issue:
You see water (specular reflection) when looking straight down on wetland vegetation

2) Open water:
Smaller radiance differences across wide range of view angles (c.f. SeaWiFS, MODIS scans, etc.)

[From Kevin Turpie]
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]
Same geometry for each target including glint avoidance

PISCES employs 4 unique scan types during observations to optimize science return from each target. Each scan produces a high SNR image of ocean/aquatic environments as well as a faster image focused on land and emergent vegetation. The S/C rotates through a pre-defined attitude profile to maintain the required instrument pointing and integration time (Ex. F-2F).

For northern latitudes the high SNR scan is produced first, vice versa for southern targets. Where sunlight glint is an issue due to solar zenith angle, the pointing profile is adjusted and the order of images reversed. Normal scans take ~117 sec and glint avoidance scans ~124 sec. Scan types for each observation are predetermined by the mission planning software for each 6-month profile.
## International Planned OC Sensors

<table>
<thead>
<tr>
<th>SENSOR</th>
<th>AGENCY</th>
<th>SATELLITE</th>
<th>SCHEDULED LAUNCH</th>
<th>SWATH (km)</th>
<th>SPATIAL RESOLUTION (m)</th>
<th># OF BANDS</th>
<th>SPECTRAL COVERAGE (nm)</th>
<th>ORBIT</th>
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<tbody>
<tr>
<td>OLCI</td>
<td>ESA/ EUMETSAT</td>
<td>Sentinel 3A</td>
<td>Oct 2015</td>
<td>1270</td>
<td>300/1200</td>
<td>21</td>
<td>400 - 1020</td>
<td>Polar</td>
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<tr>
<td>COCTS CZI</td>
<td>CNSA (China)</td>
<td>HY-1C/D (China)</td>
<td>2015</td>
<td>2900-1000</td>
<td>1100/250</td>
<td>10</td>
<td>402 - 12,500</td>
<td>Polar</td>
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<tr>
<td>SGLI</td>
<td>JAXA (Japan)</td>
<td>GCOM-C</td>
<td>2016</td>
<td>1150-1400</td>
<td>250/1000</td>
<td>19</td>
<td>375 - 12,500</td>
<td>Polar</td>
</tr>
<tr>
<td>COCTS CZI</td>
<td>CNSA (China)</td>
<td>HY-1E/F (China)</td>
<td>2017</td>
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<td>10</td>
<td>402 - 12,500</td>
<td>Polar</td>
</tr>
<tr>
<td>HSI</td>
<td>DLR (Germany)</td>
<td>EnMAP</td>
<td>2017</td>
<td>30</td>
<td>30</td>
<td>242</td>
<td>420 - 2450</td>
<td>Polar</td>
</tr>
<tr>
<td>OCM-3</td>
<td>ISRO (India)</td>
<td>OCEANSAT-3</td>
<td>2018</td>
<td>1400</td>
<td>360 / 1</td>
<td>13</td>
<td>400 - 1,010</td>
<td>Polar</td>
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<tr>
<td>OLCI</td>
<td>ESA/ EUMETSAT</td>
<td>Sentinel-3B</td>
<td>2017</td>
<td>1265</td>
<td>260</td>
<td>21</td>
<td>390 - 1040</td>
<td>Polar</td>
</tr>
<tr>
<td>VIIRS</td>
<td>NOAA / NASA (USA)</td>
<td>JPSS-1</td>
<td>2017</td>
<td>3000</td>
<td>370 / 740</td>
<td>22</td>
<td>402 - 11,800</td>
<td>Polar</td>
</tr>
<tr>
<td>GOCI-II</td>
<td>KARI/KIOST (South Korea)</td>
<td>GeoKompasat 2B</td>
<td>2019</td>
<td>1200 x 1500</td>
<td>250/1000</td>
<td>13</td>
<td>412 - 1240 TDB</td>
<td>Geostationary</td>
</tr>
<tr>
<td>OCI</td>
<td>NASA</td>
<td>PACE</td>
<td>2022/2023</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>Polar</td>
</tr>
<tr>
<td>HYSI-VNIR</td>
<td>ISRO (India)</td>
<td>GISAT-1</td>
<td>*(planned)</td>
<td>250</td>
<td>320</td>
<td>60</td>
<td>400-870</td>
<td>Geostationary (35.786 km) at 93.5°E</td>
</tr>
<tr>
<td>OES</td>
<td>NASA</td>
<td>ACE</td>
<td>&gt;2020</td>
<td>TBD</td>
<td>1000</td>
<td>26</td>
<td>350-2135</td>
<td>Polar</td>
</tr>
<tr>
<td>Coastal Ocean Color Imaging Spec (Name TBD)</td>
<td>NASA</td>
<td>GEO-CAPE</td>
<td>&gt;2022</td>
<td>TBD</td>
<td>250 - 375</td>
<td>155 TBD</td>
<td>340-2160</td>
<td>Geostationary</td>
</tr>
</tbody>
</table>
### Observational Regime

#### Marine Coastal:
- Water and water-land boundary areas
  - Estuaries
  - Corals
  - Seagrasses
  - Mangrove Forests
  - Salt Marshes and Salt Flats
  - Clear ocean
  - Small Islands

#### Inland Coastal:
- Wetlands and Marsh
  - Fresh Water Environments

#### Atmosphere above coastal marine and inland environments, rural and urban

### Organic/Physical Features

<table>
<thead>
<tr>
<th>Aquatic Habitats</th>
<th>Organic/Physical Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phenology, community composition, and changes in water quality, including specifically those listed below.</td>
<td>SNR &gt; 1000, ocean radiance 400-710 nm</td>
</tr>
<tr>
<td>Phytoplankton, diatoms, other water-borne life: Concentration, size, functional groups</td>
<td>Abs. radm. cal &lt; 5%, Relative cal &lt; 0.5%</td>
</tr>
<tr>
<td>Colored dissolved organic matter (CDOM); Total suspended solids, detritus</td>
<td>Polarization sensitivity &lt; 1.2%</td>
</tr>
<tr>
<td>Turbid waters</td>
<td>Spatial resolution &lt; 60 m/pix</td>
</tr>
<tr>
<td>Bathymetry</td>
<td>Field of View (FOV) &gt; 20x20 km</td>
</tr>
<tr>
<td>Benthos, shallow reefs, submerged vegetation, kelp and seagrass beds</td>
<td>Stray light &lt;0.5% at 5 pixels from edge of bright area, &lt;0.1% at 33 pixels</td>
</tr>
<tr>
<td>Floating vegetation</td>
<td>VNIR does not saturate on clouds</td>
</tr>
</tbody>
</table>

| Land Habitats |
|------------------|---------------------------|
| Plant life form (tree, grass, canopy, etc) | Emission angle variation < 5 deg in image |
| Biogeochemistry | Spatial resolution < 60 m/pix |
| Vegetation density and structure | Field of View (FOV) > 20x20 km |
| Inundation level, soil type, carbon content | Spectral range 400-885 nm, < 2 nm/band (3 nm FWHM), stability < ±0.3 nm, keystone < 0.1 pixel |

<table>
<thead>
<tr>
<th>Atmospheric</th>
<th>Oxygen A and B bands, &lt; 2 nm/band</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerosol type and composition variations</td>
<td>Spectral range 400-885 nm, 20 nm/band SWIR 1240 and 2125 nm</td>
</tr>
<tr>
<td>Optical thickness, vertical distribution</td>
<td>Polarization sensitivity &lt; 1.2%</td>
</tr>
<tr>
<td>Short term/local change</td>
<td>Spatial resolution &lt; 150 m/pix</td>
</tr>
<tr>
<td>Atmospheric correction/adjacency</td>
<td>VNIR does not saturate on clouds</td>
</tr>
<tr>
<td>Cloud cover and cloud detection</td>
<td></td>
</tr>
</tbody>
</table>

### Measurement Requirement

<table>
<thead>
<tr>
<th>SNR &gt; 250, &gt; 100</th>
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<td>Phytoplankton, diatoms, other water-borne life: Concentration, size, functional groups</td>
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<td>(&lt; 3 nm FWHM), stability &lt; ±0.3 nm, keystone &lt; 0.1 pix</td>
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</table>

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<thead>
<tr>
<th>VNIR does not saturate on clouds</th>
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<tr>
<td>Colored dissolved organic matter (CDOM); Total suspended solids, detritus</td>
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<td>Spectral range 400-600 nm, 50 nm/band</td>
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<table>
<thead>
<tr>
<th>Emission angle variation &lt; 5° in image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Differentiate land and water-borne vegetation</td>
</tr>
<tr>
<td>Spectral range 400-885 nm, SWIR</td>
</tr>
<tr>
<td>Relative fraction of water, vegetation, soil, sediment</td>
</tr>
<tr>
<td>Spectral range 400-885 nm, SWIR</td>
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</tbody>
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<table>
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<tr>
<th>Emission angle variation &lt; 5° in image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Managed wetlands, farmlands, wastewater</td>
</tr>
<tr>
<td>VNIR does not saturate on clouds</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>All physical and organic features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measure seasonal changes</td>
</tr>
<tr>
<td>Frequency of clear observations 5/month</td>
</tr>
<tr>
<td>Observe several of each type of target</td>
</tr>
</tbody>
</table>

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**Goal:** Characterize short-term changes in the functional biodiversity and biogeochemical cycles of coastal and wetland ecosystems, from canopy to benthos, and trace these changes to their underlying environmental influences.

**Objectives:**

**Overall:**
- Determine how phenologies of key coastal, wetland, and inland water ecosystems change in response to natural and human-induced environmental factors.

**Coastal Zone Blooms:**
- Evaluate the quality, diversity, and productivity of coastal aquatic habitats as a function of nutrient inputs, light, and other physical & biotic factors.

**Wetland Vegetation:**
- Determine drivers of wetland phenology & the relationship between wetland phenology and organic & inorganic material inputs to adjacent waters.

**Benthic Communities:**
- Measure the relationship between the composition and health of shallow submerged (benthic) communities and the ecology of adjacent wetlands.

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**Science Traceability Matrix (partial)**

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- **Objectives:**
  - **Overall:** Determine how phenologies of key coastal, wetland, and inland water ecosystems change in response to natural and human-induced environmental factors.
  - **Coastal Zone Blooms:** Evaluate the quality, diversity, and productivity of coastal aquatic habitats as a function of nutrient inputs, light, and other physical & biotic factors.
  - **Wetland Vegetation:** Determine drivers of wetland phenology & the relationship between wetland phenology and organic & inorganic material inputs to adjacent waters.
  - **Benthic Communities:** Measure the relationship between the composition and health of shallow submerged (benthic) communities and the ecology of adjacent wetlands.
Sample (mock) target locations showing seasonal changes in hemisphere for high latitude acquisitions based on illumination

Sample monthly target acquisitions showing seasonal changes, accounting for regional cloud cover

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<tbody>
<tr>
<td>3-Day Total</td>
<td>16</td>
<td>37</td>
<td>11</td>
<td>18</td>
<td>29</td>
<td>26</td>
<td>44</td>
<td>5</td>
<td>25</td>
<td>8</td>
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<tr>
<td>Monthly Total</td>
<td>160</td>
<td>370</td>
<td>110</td>
<td>180</td>
<td>290</td>
<td>260</td>
<td>440</td>
<td>50</td>
<td>250</td>
<td>80</td>
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<tr>
<td>Cloud Losses</td>
<td>45%</td>
<td>37%</td>
<td>42%</td>
<td>40%</td>
<td>43%</td>
<td>46%</td>
<td>52%</td>
<td>46%</td>
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<tr>
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<td>72%</td>
<td>551%</td>
<td>80%</td>
<td>200%</td>
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<td>174%</td>
<td>494%</td>
<td>30%</td>
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