

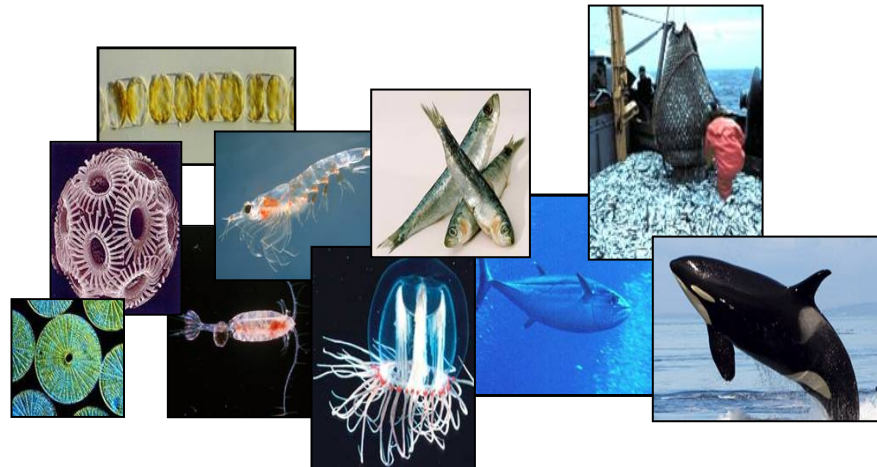


## HyspIRI Combined (CQ) VSSWIR and TIR Science Questions

[Http://HyspIRI.jpl.nasa.gov](http://HyspIRI.jpl.nasa.gov)

### **CQ1: Coastal, ocean, and inland aquatic environments**

Frank Muller-Karger, David Siegel, Kevin Turpie, Paul Bissett, Heidi Dierssen, Chuanmin Hu, Simon Hook, and many others





# OUTLINE



- 1) Review overarching question and sub questions**
- 2) Review science traceability matrix
- 3) Review the science associated with question
- 4) Alignment with Decadal Survey
- 5) Level 3 products (spatial, temporal res., etc.)
- 6) Validation approach for Level 3 products
- 7) Identify the precursor science needed



## Overarching Question (CQ1)



How are local and landscape-scale changes in inland, coastal, and open ocean aquatic ecosystems related to changes in variability in regional and global climate?



## Subquestions (CQ1)



- What are the feedbacks between a warming climate and changes and disturbance in habitat structure, biogeochemical cycling, biodiversity, and ecosystem productivity of landscape-scale aquatic habitats, including ice-covered habitats? [DS 201/Table 7.1, DS 208; DS 338; GEO 2007; USCOP 2004]
- How are small-scale processes in water column, shallow benthic, and ice-covered habitats related to changes in functional community types (including harmful algal blooms and vector-borne diseases), productivity, and biogeochemical cycling including material fluxes and water quality, at local scales? [DS 195; DS 200; DS 276; DS 313]
- How can these observations be used to guide the wise management of living marine and other aquatic resources? [DS 179-185; USCOP 2004]
- **Encompasses VSWIR and TIR questions in:**
  - **VQ1a-f** (ecosystem diversity, distribution),
  - **VQ2a-e** (ecosystem function, change, disturbance)
  - **VQ6b** (shallow bottom composition),
  - **TQ5b,d,e** (water surface temp.)



# OUTLINE



- 1) Review overarching question and sub questions
- 2) Review science traceability matrix**
- 3) Review the science associated with question
- 4) Alignment with Decadal Survey
- 5) Level 3 products (spatial, temporal res., etc.)
- 6) Validation approach for Level 3 products
- 7) Identify the precursor science needed



# Objectives



- **Science and Science Objectives:**

- **CQ1 and**

- **VQ1a-f** (ecosystem diversity, distribution)
    - **VQ2a-e** (ecosystem function, change, disturbance)
    - **VQ6b** (shallow bottom composition),
    - **TQ5b,d,e** (water surface temp.)

- **Measurement Objectives:**

- Measure/compare selected habitats and spatial patterns of different communities, Functional Groups, bottom types, and assess the effects of physical environmental variability (e.g. water surface temperature)
  - Understand processes that lead to change in these communities, due to natural and human forcing
  - Understand linkages to Land Use/Land Use Change, atmospheric variations
  - Develop practical and accurate atmospheric correction strategy



# Measurement Requirements



- Select freshwater and coastal marine ecosystems in different seasons and geographic settings
- Measure diagnostic VSWIR and TIR spectral signature to characterize and derive plant functional types, chlorophyll and other pigments, macro-algae, colored dissolved organic matter (CDOM), bottom type, sediment concentration and type, relationship of temperature to physical forcing
- Characterize surface temperatures and relationship to vertical physical structure in the water
- Augment existing coastal time series observations (seasonal, through several years)
- Patch scales of <100's m near coasts and inland water; 10's km offshore/deep waters
- Measure regionally/globally (i.e. across a range of latitudes)
- Frequent (less than 20 day) revisit
  
- Examples (not comprehensive):
  - Coral reefs: 1-2 clear, non-sun-glint images per year of all shallow tropical reefs
  - High latitude coastal regions: 2-3 images per year during high illumination periods
  - Estuaries: all possible collections of major US estuaries, year round



# Instrument Requirements



## – VSWIR

- Spectral measurement from 380 to 900 nm at 10 nm
  - **[NOTE: Longer wavelengths required for atmospheric correction (through 1650 nm)]**
- > 95% Spectral cal uniformity
- SNR 200-400 VNIR (45ZA 0.01-0.05 R, 60 m)
- 14 bit precision: >95% abs cal: > 98% on orbit stability
- no saturation of ecosystem targets
- <2% polarization sensitivity 380 to 700 nm
- >99% linearity 2 to 98% saturation
- <60 m spatial sampling
- >95% Spectral IFOV uniformity
- <20 day revisit to minimize cloud obscuration, seasonal coverage
- Equatorial crossing time: 10:30 am to 1:30 pm; LEO

## – TIR

- 1 band at 3.98  $\mu\text{m}$  and
- 3+ bands in 8–12  $\mu\text{m}$  range
- $\text{NE}\Delta\text{T} < 0.2 \text{ K}$
- Water surface temperature calibration to <0.5C accuracy
- Spatial resolution 60–500 m
- Temporal repeat - weekly





# Other Mission and Measurement Requirements



## – VSWIR

- Rigorous cal/val program: Monthly lunar cals: Daily solar cals: 6 per year vcal
- Surface reflectance in the solar reflected spectrum for elevation angles  $>20$
- Product definition and validation for variety of inland water bodies, coastal zones including benthic types, blooms
- Radiometric calibration
- Atmospheric Correction and validation
- Geolocation/Pointing strategy to minimize sun glint (**Goal: Minimal sunglint contamination while maximizing signal**)
- Ground processing
- Seasonal latency
- Direct Broadcast of reduced bandset

## – TIR

- [Similar as above]
- Day and night



# OUTLINE



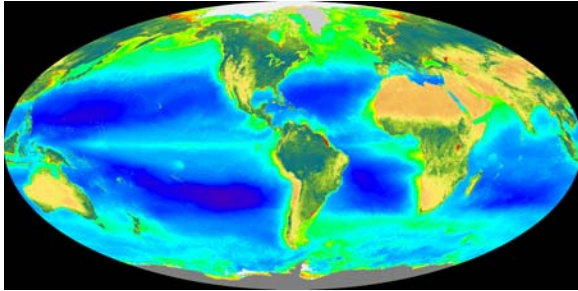
- 1) Review overarching question and sub questions
- 2) Review science traceability matrix
- 3) Review the science associated with question**
- 4) Alignment with Decadal Survey
- 5) Level 3 products (spatial, temporal res., etc.)
- 6) Validation approach for Level 3 products
- 7) Identify the precursor science needed



## Primary Science Justification



*The combined use of HyspIRI TIR and VSSWIR will provide significant insight on biological and biogeochemical controls by small-scale physical processes, and how these translate into small-scale ecosystem changes, globally*



## Rationale (CQ1)



### Geographic scope:

- Aquatic environments: Inland, coastal, and ocean waters, including ice-covered environments
- The oceans cover over 70% of the Earth's surface and about half of the globe's primary productivity occurs within them.
- Coastal zones (inland and marine) include:
  - coastal watersheds, dunes and wooded coastal areas, beaches and cliffs, wetlands, estuaries, barrier islands, and shallow submerged lands like seagrass beds, kelp beds, coral reefs, and ice cover



## Rationale (CQ1)



### Aquatic environments:

- Play a critical role in Earth's climate, the hydrological cycle, and biogeochemical cycles
- Are part of ecosystems that span the land, and are affected by changes on land and the atmosphere
- Contain habitats that are defined by the interaction between small physical processes and large-scale processes
- Provide important ecosystem services, exceeding \$1 trillion in a narrow strip along the coastal zone (land and water)



## Rationale (CQ1)



### Ecosystem Services Provided by Aquatic environments:

- Purification of water through nutrient recycling,
- Sediment storage,
- Shoreline protection,
- Habitat and food for migratory and resident animals, humans
- Industrial resources: pharmaceutical, oil, gas, sand and gravel, fisheries, maritime operations including ports.
- Recreation
- Cultural values

### Issues:

Climate change, land subsidence, aerosol production, and sea level rise complicate our understanding of the processes of pollution, development, and structures that alter sediment flow.



## Science (CQ1)

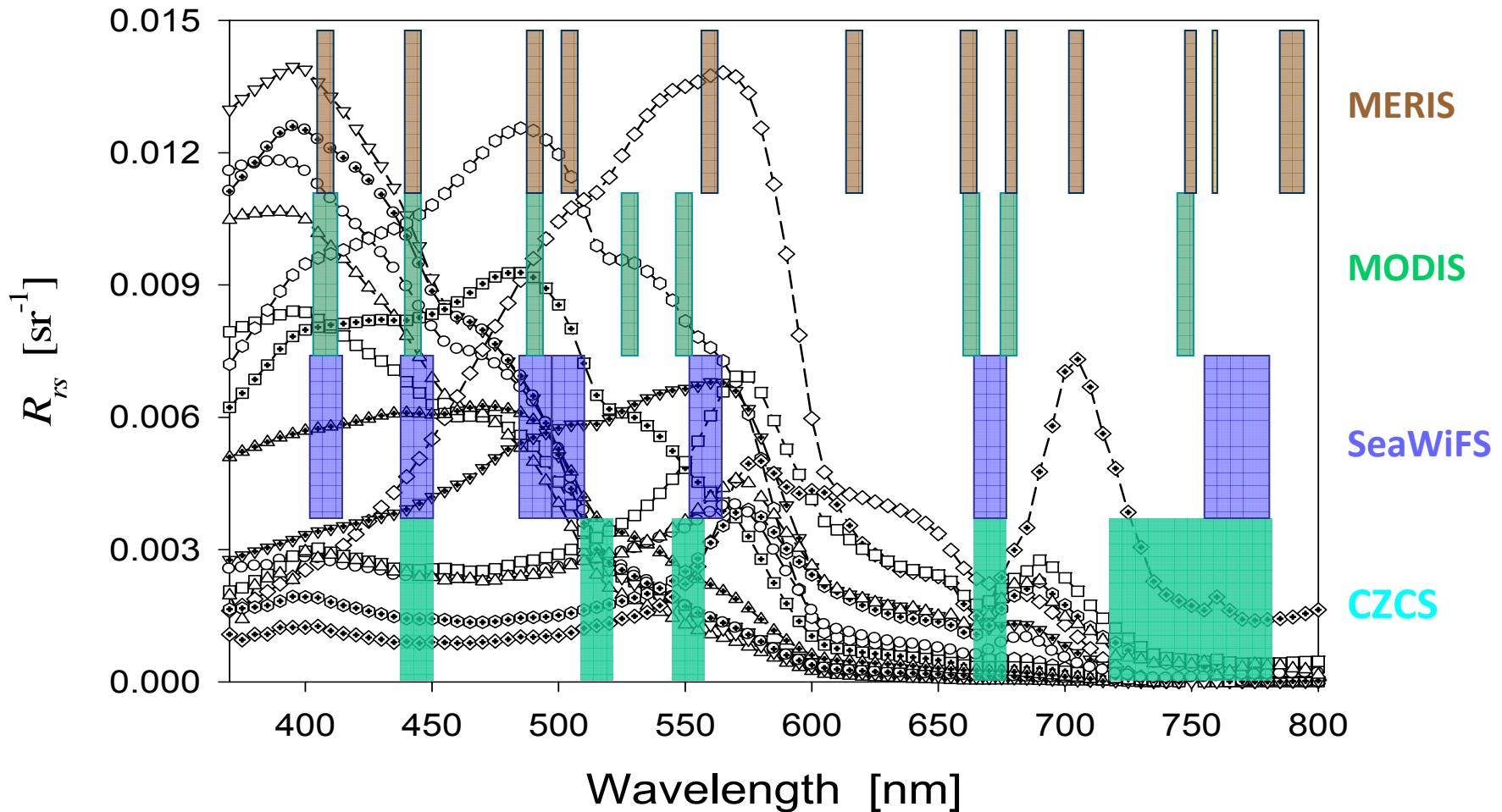


HypSIIRI imaging spectroscopy and high spatial resolution data allow:

- The study of the interaction between small-scale physical variability and biological / biogeochemical variability
- Separation of phytoplankton pigments, separation of phytoplankton functional groups, and assessment of the physical environment affecting their abundance and distribution
- Improve the accuracy and diversity in retrievals of Chlorophyll-a, absorption and backscattering coefficients and of other environmental properties:
  - Chl-a estimates can improve through traditional spectra-matching optimization using blue-green wavelengths, and also from additional data in red wavelengths between 660 and 720 nm (reflectance peak shifts from 680 nm to 710 nm with increasing concentrations)
  - colored dissolved organic matter, phytoplankton concentration and composition, suspended sediments, bottom type, physical properties (e.g., temperature, bathymetry, light attenuation; GEO 2007).



# Bands of existing operational sensors miss some important features in aquatic Rrs



From Z. P. Lee

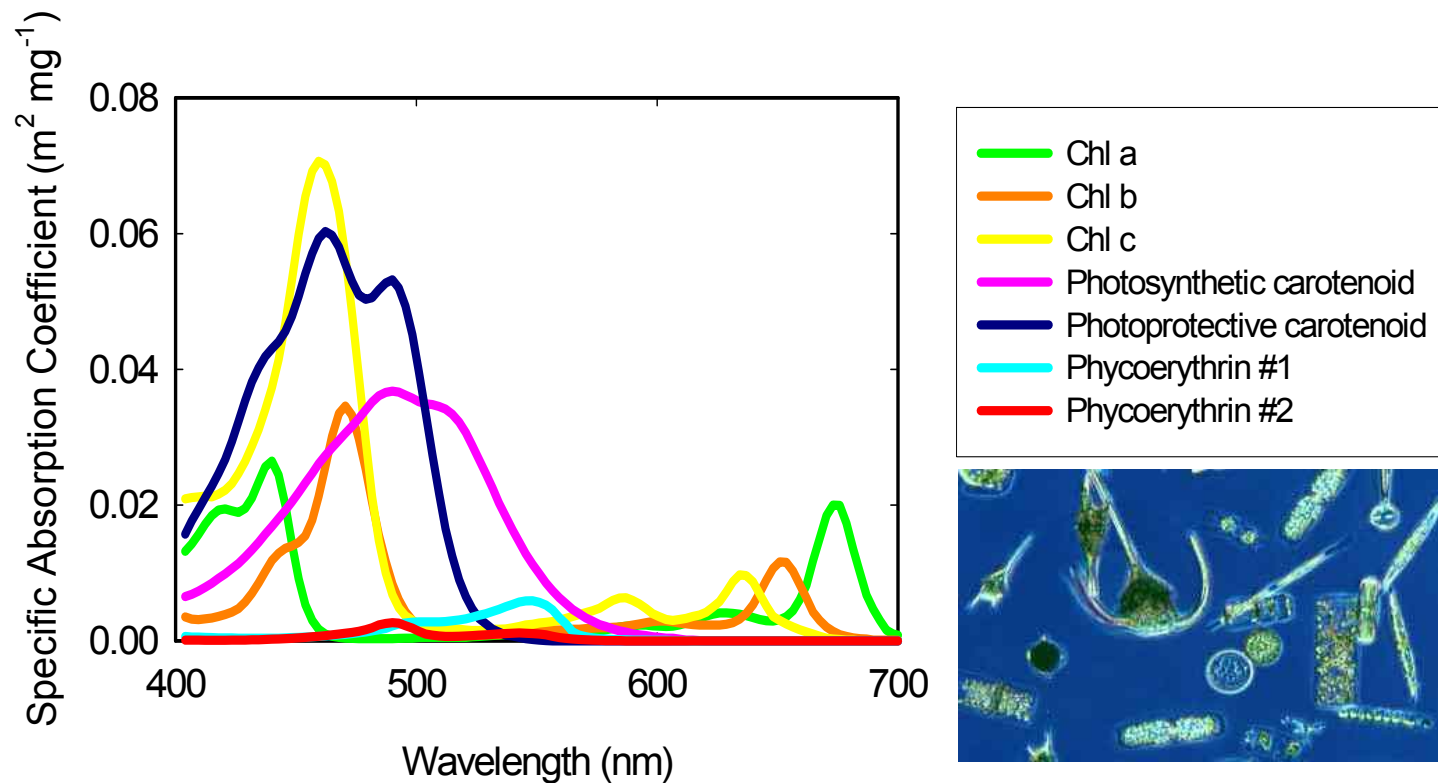




# Examples



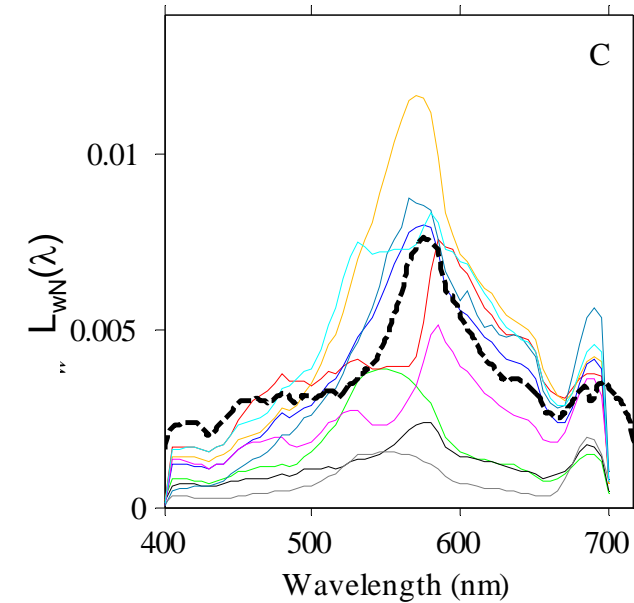
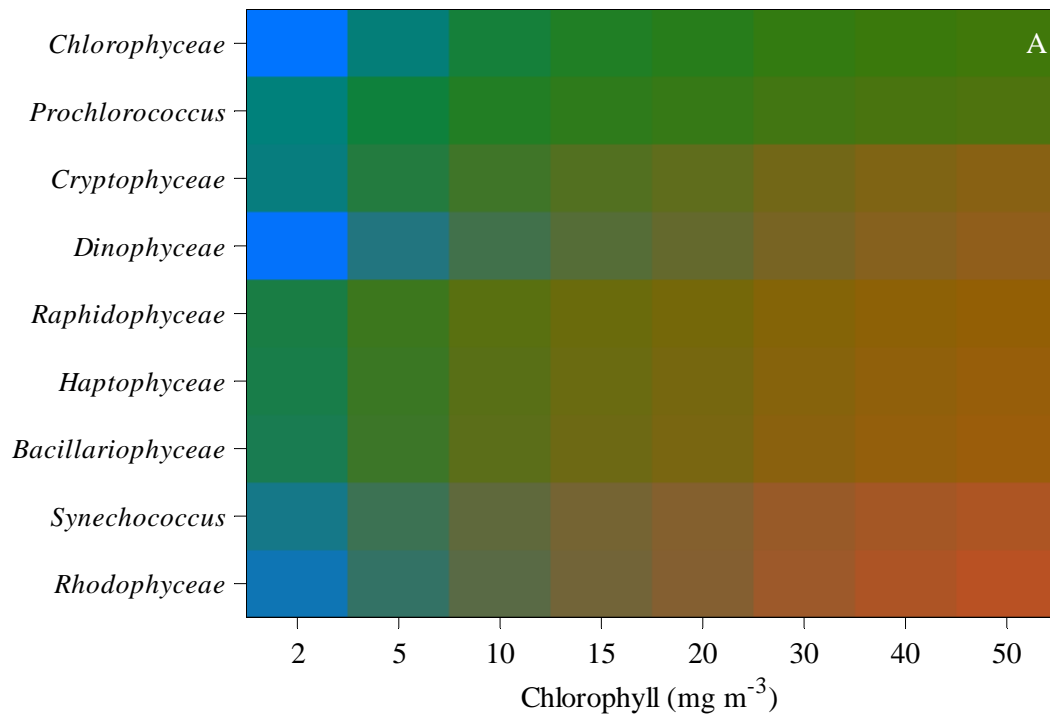
## Phytoplankton functional groups



Weight-specific absorption coefficients (m<sup>2</sup> mg<sup>-1</sup>) derived for the major pigment types found in marine phytoplankton (from Bidigare et al. 1989).

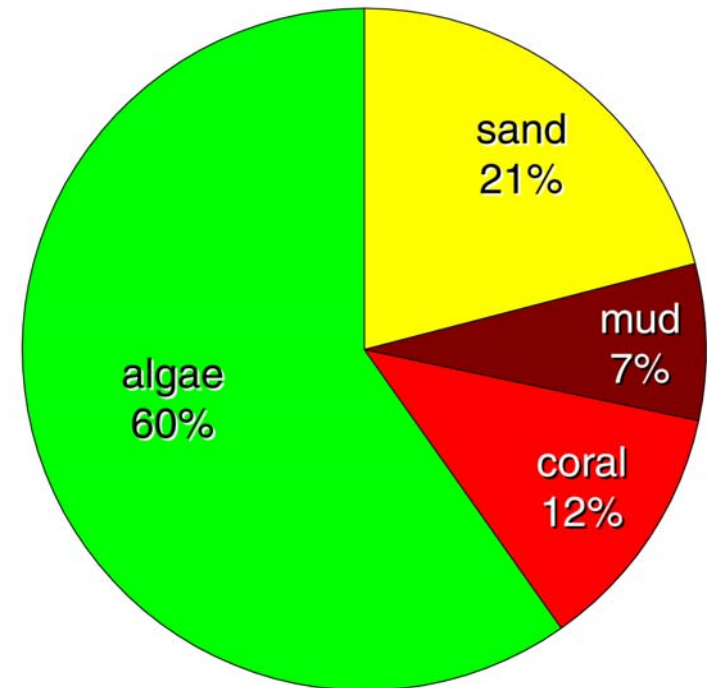
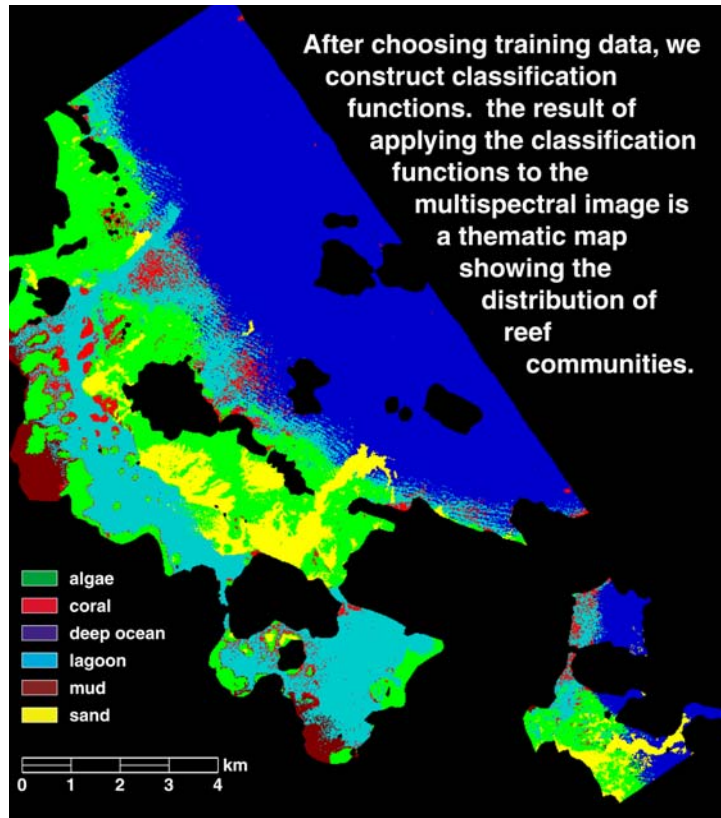


# Phytoplankton Spectroscopy and Functional Groups



(A) Color of the sea surface as a function of surface biomass concentration (Chl *a* used as a proxy) for different phytoplankton taxa. Color was modeled from water-leaving radiance using the CIE color matching functions and mean absorption and backscattering properties for each taxa. (B) Water-leaving radiance,  $L_w$ , modeled for dense phytoplankton bloom conditions (30  $\text{mg Chl a m}^{-3}$ ) from a variety of phytoplankton taxa. (Dierssen et al. 2006)

**Dierssen et al., 2006**



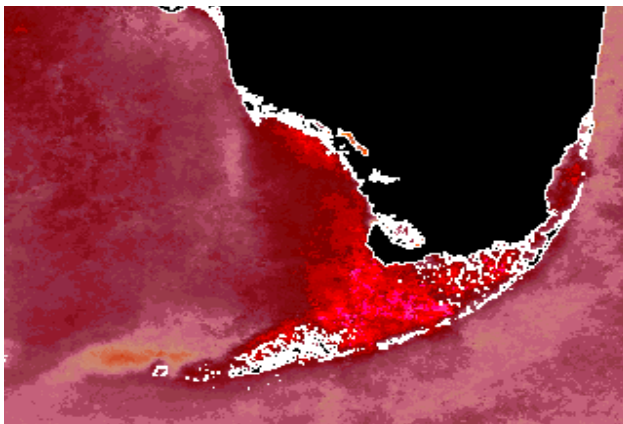
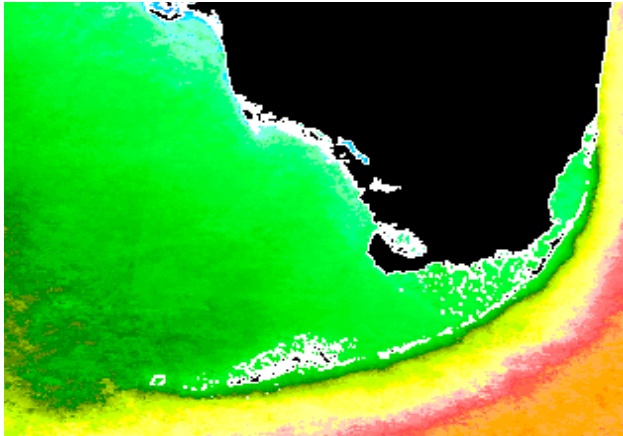
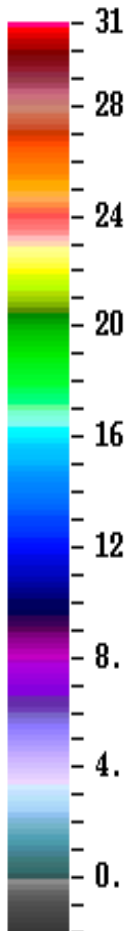
Fractional cover of bottom types derived from AVIRIS imagery of Kaneohe bay, Hawaii. (Courtesy: Eric Hochberg)



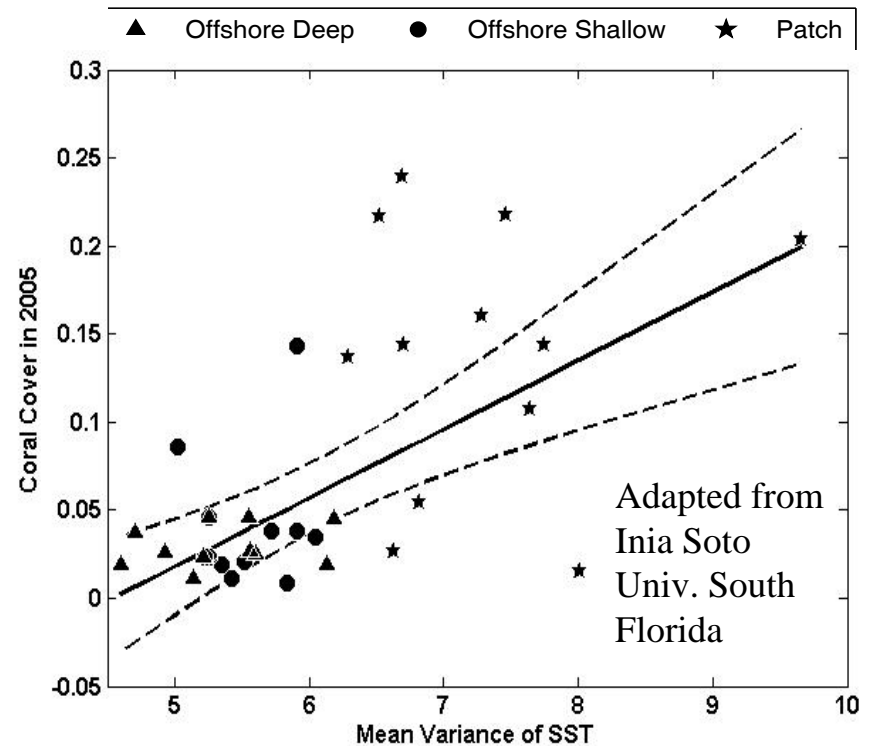
# Temperature Variability & Coral Reef Cover in the Florida Keys National Marine Sanctuary



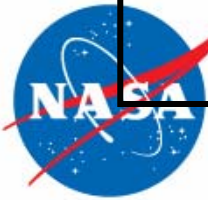
Deg C



AVHRR weekly mean sea surface temperature composites. TOP) February 5, 1998 to February 11, 1998. BOTTOM) June 4, 1998 to June 10, 1998.



Comparison between coral cover in 2005 and variability of SST from 1994 to 2005. The dotted lines represent the 95% confidence intervals

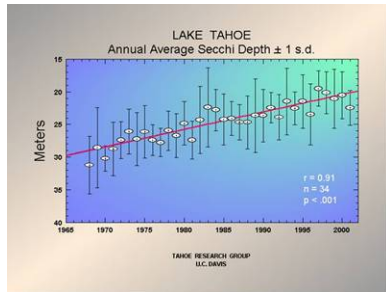


# Characterizing Partial Upwellings and Surface Circulation at Lake Tahoe CA/NV

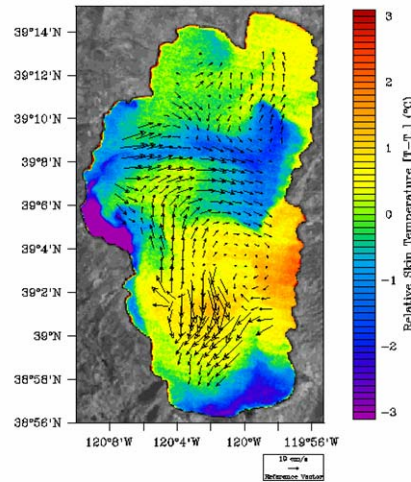
(Steissberg et al, Geophysical Research Letters vol. 32, 2005)



Clarity is declining over time shown by decreasing Secchi depth



Circulation Map from ETM+ and ASTER



## Science Issue:

•Clarity of Lake Tahoe CA/NV is declining. Decline due to multiple causes (e.g. fine sediment input, phytoplankton growth). Need to understand how heat, solutes, and particles are transported in the lake by circulation and upwelling to reduce the rate of decline. Previous research using AVHRR concluded circulation controlled by two counter-rotating gyres. Little previous information on upwellings (e.g. size, frequency, source depth).

## Tools:

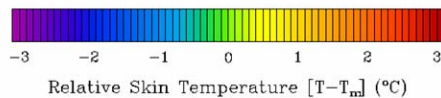
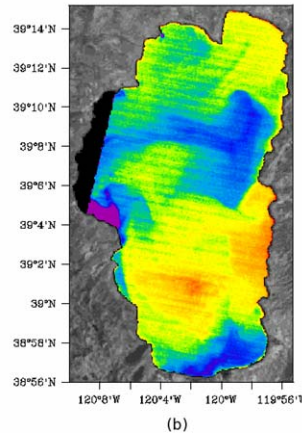
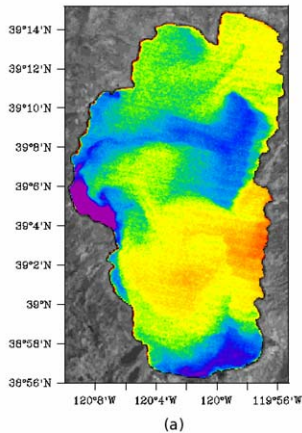
- Satellite observations from ASTER, Landsat ETM+ and MODIS
- Physical model that describes circulation and upwelling driven by satellite and *in situ* inputs
- In situ* measurements from validation activities at Lake Tahoe (meteorology and skin and bulk water temperature) and underwater drogues.

## Approach:

- Develop algorithm that tracks movement of water parcels between Landsat and ASTER data to provide synoptic views of circulation and current speeds. Use Landsat, ASTER and MODIS to monitor upwellings.
- Confirm current speeds with *in situ* drogues and upwellings with *in situ* temperature measurements.
- Model circulation patterns with downscaled meteorology and satellite data.

ETM+

ASTER



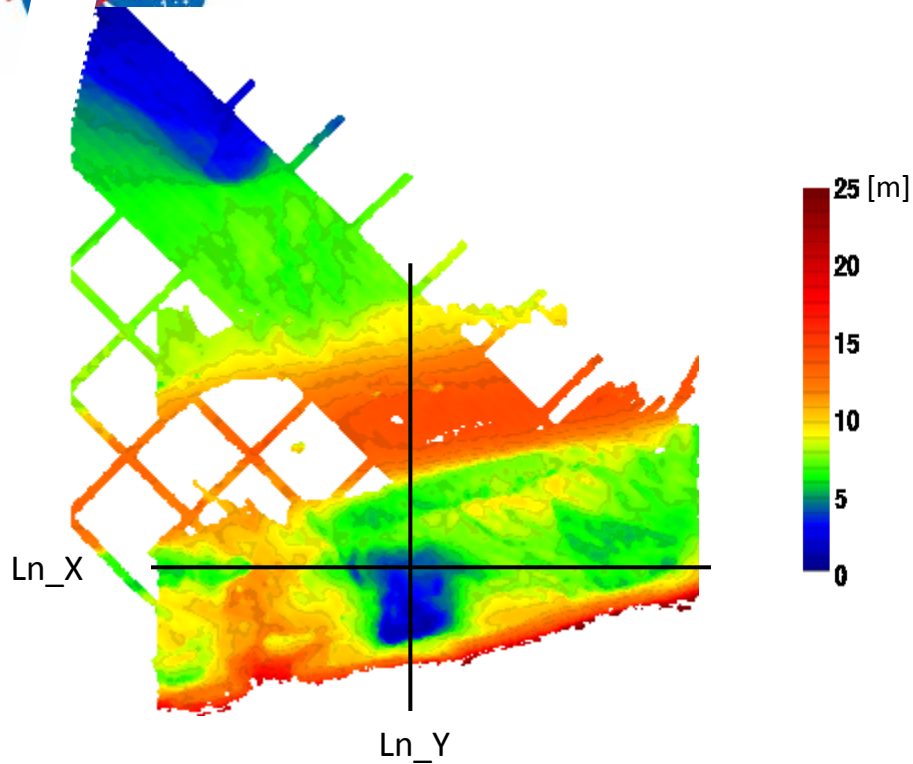
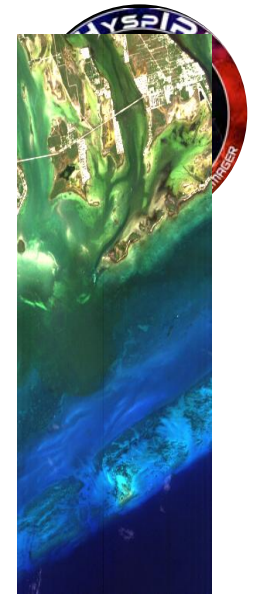
Thermal data show large upwelling jet of cool water transported from west to east

## Results:

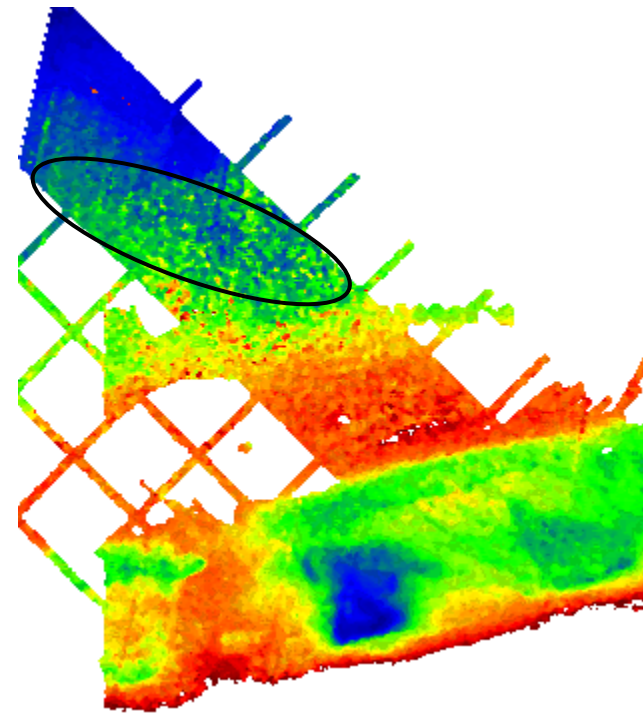
Counter-rotating gyres move in the opposite sense to what had previously been determined. Partial upwellings occur every few days throughout spring and summer, transporting water from 10–30 m below the surface to the surface layer. They display a jet-like appearance, traveling from the upwind to the downwind side of the lake, with current speeds of 12–30 cm/s. Partial upwellings were found to generally decrease lake clarity, although deeper upwelling events can increase clarity. Sinking zones, other convergence areas, and divergence areas were also observed.



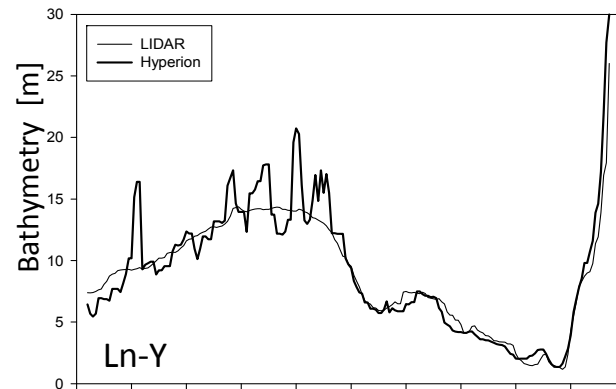
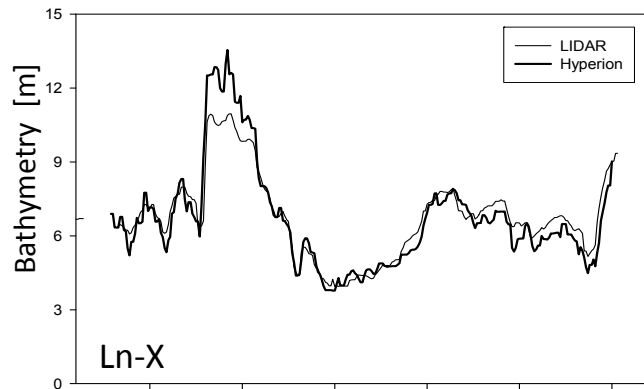
# BATHYMETRY from imaging spectroscopy Hyperion data



Bathymetry from LIDAR



Bathymetry from Hyperion



(Lee et al. 2007)



# OUTLINE



- 1) Review overarching question and sub questions
- 2) Review science traceability matrix
- 3) Review the science associated with question
- 4) Alignment with Decadal Survey**
- 5) Level 3 products (spatial, temporal res., etc.)
- 6) Validation approach for Level 3 products
- 7) Identify the precursor science needed



# Decadal Survey



- Ecosystem diversity, distribution
- Ecosystem function, change, disturbance
- Shallow bottom composition
- Surface temperatures of aquatic areas (inland, coastal, ocean)
  
- DS 179-185 (Human Health and Security):
  - Algal blooms and waterborne diseases, coastal discharges incl. river plumes, characterizing/mapping coastal resources
- DS 195 (Changing ecosystems, ocean acidification, C and N cycles)
- DS 201/Table 7.1 (Land-Use Change and Ecosystem Dynamics Panel Priority New Missions)
  - *Impacts on coastal ecosystems*
- DS 200 (Ocean color time series)
- DS 276, 208 (Coastal ecosystem dynamics)
  - (Tables 9.1.1, 9.1.2, 9.1.3)
  - Applications: Carbon reservoirs, harmful algal blooms, fisheries, ecosystem-based management, aquaculture, impacts of extreme events, productivity
- DS 313 Table 10.1. Aerosol discovery/characterization (composition, radiative properties)
- DS 338 (Hydrology, water cycles, linkages to nutrient cycles and ecology)





# OUTLINE



- 1) Review overarching question and sub questions
- 2) Review science traceability matrix
- 3) Review the science associated with question
- 4) Alignment with Decadal Survey
- 5) Level 3 products (spatial, temporal res., etc.)**
- 6) Validation approach for Level 3 products
- 7) Identify the precursor science needed



# Possible Level 3 products



- Inland / Coastal: 60 m resolution; every 19 days or more frequent as possible
- Global deep ocean: 1 km; every 19 days or more frequent as possible
  
- Atmospheric correction
  - 1) Cloud flag/mask, include cloud shadow flag
  - 2) Rayleigh scattering radiance
  - 3) Aerosol type and concentration (color, size distribution, scattering phase function)
  - 4) Ancillary data: absorption by key gases, atmospheric pressure, sun glint warnings, land / other flags
  
- Ecosystem indices
  - 1) Water Surface Temperature (Sea-Surface Temperature, Lake Surface Temperature)
  - 2) Phytoplankton concentration (pigment concentration)
  - 3) Functional groups
    - Spectral signatures
    - Size distribution of phytoplankton
    - (N-fixers, pico-, nano-, micro-phytoplankton /large and small cells)
  - 4) Dissolved organic carbon concentration
  - 5) Coastal benthos:
    - a) Bathymetry
      - (shallow coastal, 60 m, once per year; using multiple images, tide-corrected)
    - b) Benthic types:
      - Submerged Aquatic Vegetation (SAV)
      - Tidal marshes
      - Coral reefs
      - Seagrass beds
      - Aquaculture regions
  - 6) Coastal habitat classification schemes / maps (combining various products above)
  - 7) Time series of habitat and ecosystem types / component characteristics



# OUTLINE



- 1) Review overarching question and sub questions
- 2) Review science traceability matrix
- 3) Review the science associated with question
- 4) Alignment with Decadal Survey
- 5) Level 3 products (spatial, temporal res., etc.)
- 6) Validation approach for Level 3 products**
- 7) Identify the precursor science needed



# Validation



- NASA should consider developing a coordinated, integrated cal/val program that supports the range of Earth Observing missions
- Campaigns to collect inland and coastal reflectance and atmospheric data in a range of ecosystems around globe (high and low latitudes):
  - Major lakes and some smaller lakes
  - Phytoplankton blooms (including Harmful algal blooms)
  - Coastal sediment plumes / various river plumes
  - Coral reefs
  - Estuaries
  - Bathymetry
- Enhance / support existing ocean time series to collect relevant data
- Develop an integrated land/ocean/atmosphere science and cal/val program targeting key sites



# OUTLINE



- 1) Review overarching question and sub questions
- 2) Review science traceability matrix
- 3) Review the science associated with question
- 4) Alignment with Decadal Survey
- 5) Level 3 products (spatial, temporal res., etc.)
- 6) Validation approach for Level 3 products
- 7) Identify the precursor science needed**



# Precursor Science



- Imaging spectroscopy characterization of inland and coastal waters for:
  - Surface temperature and vertical temperature profiles
  - Atmospheric correction (VSWIR, TIR)
  - Benthic types
  - Bathymetry
  - Phytoplankton blooms: concentration and type
  - Phytoplankton functional types (size, C and N cycling role, trophic role)
  - Colored dissolved organic matter (concentration, type)
  - Sediment load, type
- Develop an integrated land/ocean/atmosphere science and cal/val program targeting key sites
- Sun glint assessment:
  - impacts in and around tropical coral reef areas, other tropical/subtropical areas
- Enhance / support existing ocean time series to collect relevant data
- **IF HypIRI flies concurrently with GEO-CAPE and ACE, or similar international missions, consider preparing to address ecosystem processes and change over a range of time and space scales**