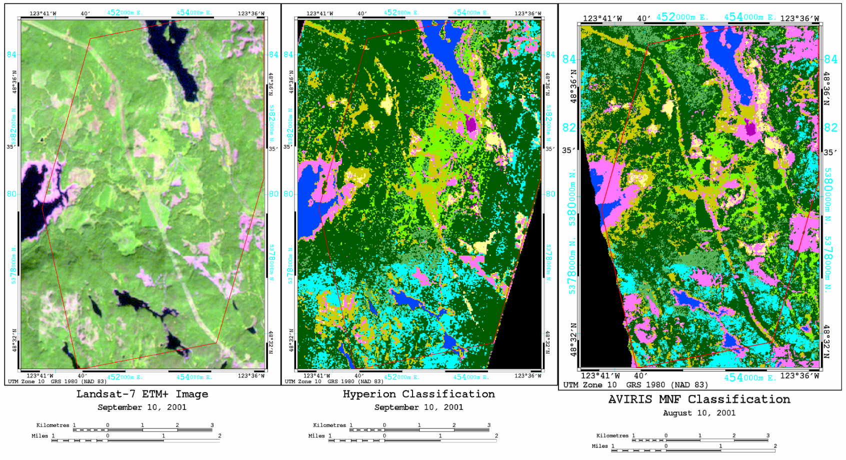
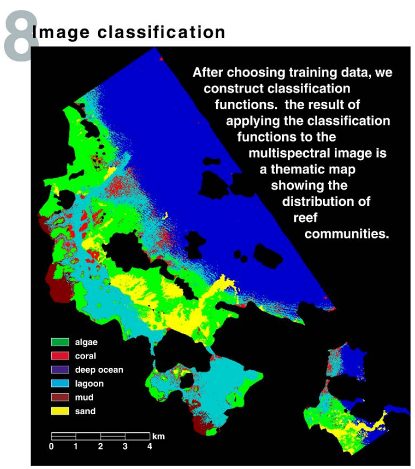
# VQ1. Pattern and Spatial Distribution of Ecosystems and their Components

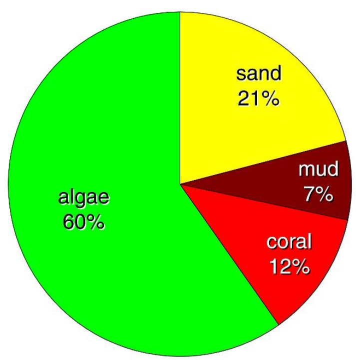
What is the global spatial pattern of ecosystem and diversity distributions and how do ecosystems differ in their composition or biodiversity?

# VQ1a: How are ecosystems organized within different biomes associated with temperate, tropical, and boreal zones, and how are these changing? [DS 191, 203]




Classification of dominant plant functional types in the Pacific Northwest using Landsat, Hyperion and AVIRIS. From Goodenough et al., 2003.




Map of the distribution of important reef communities. From Hochberg.

## *Science Issue:*

•Ecosystems play a critical role in the cycling of water, carbon, nitrogen and nutrients and by providing critical habitats to many organisms. While our knowledge of the large scale distribution of ecosystems is good, knowledge of their distributions at finer scales is generally poorer. Furthermore, the rate at which they are changing in response to multiple stressors, including anthropogenic disturbance and climate change is insufficient.

## •*Tools:*

•Satellite observations from HyspIRI. Requires fine spectral sampling (~ 10 nm) from the ultra-violet to Short-Wave-Infrared (380-2500 nm) to discriminate functional types and species in terrestrial and aquatic ecosystems, correct for atmospheric impacts and retrieve bi-directional reflectance. Requires high signal to noise for aquatic systems (300:1 at 45Z, 0.01 reflectance target) and fine spatial resolution (at least 60 m) to map uniform patches in the landscape. Requires high frequency repeat sampling (19 days) to provide a minimum of one acquisition per season globally and improve discrimination of species through phenology.

•Requires radiometric stability for multi-year monitoring.

•Requires supplemental spectral libraries to inform mapping.

## •*Approach:*

•Retrieve bi-directional reflectance and surface spectral radiance using atmospheric radiative transfer

•Develop seasonal compositing approaches to generate a seamless global product for terrestrial systems and coastal waters.

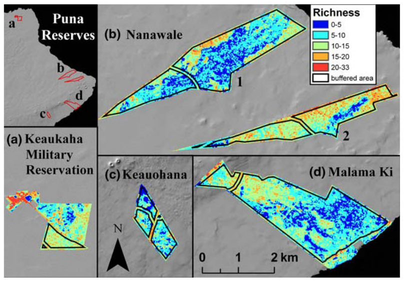
•Apply standard and developed classification algorithms for mapping ecosystems in terrestrial and coastal aquatic or inland water systems.

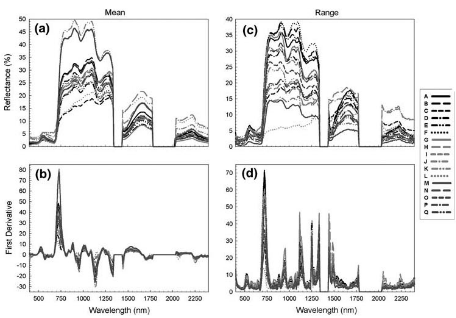
•Utilize mixing algorithms to estimate sub-pixel fractions of ecosystems

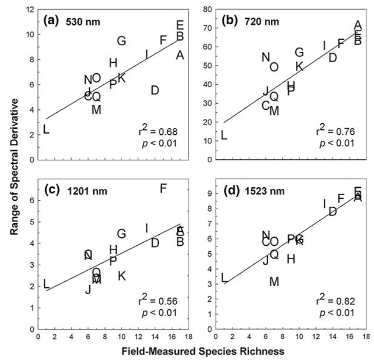
•Link to well established calibration/validation sites for validation

•Develop products that are readily assimilated in to models.

# VQ1b: How do similar ecosystems differ in size, species composition, fractional cover and biodiversity across terrestrial and aquatic biomes and on different continents? [DS 195]

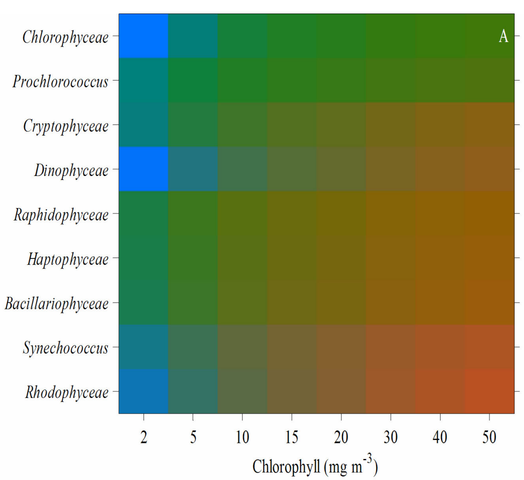


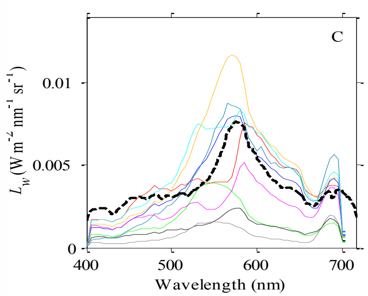




Spectral variability is directly related to canopy species diversity

From Carlson et al., 2007




Phytoplankton functional groups can be discriminated based on spectroscopic differences due to pigments. From Dierssen et al., 2006.

## *Science Issue:*

•Ecosystems differ in spatial extent, biophysical properties and in the types of organisms within them. The manner in which an ecosystem responds to changing environmental conditions and disturbance is, in part, dependent upon the organisms within the ecosystem. The resilience of an ecosystem to external stressors is also dependent upon organisms within the ecosystem. Biophysical attributes, such as fractional cover, and biodiversity measures are critical elements that quantify ecosystem function and response to environmental change.

## •*Tools:*

•Satellite observations from HyspIRI. Requires fine spectral sampling (~ 10 nm) from the ultra-violet to Short-Wave-Infrared (380-2500 nm) to discriminate functional types and species in terrestrial and aquatic ecosystems, correct for atmospheric impacts and retrieve bi-directional reflectance. Requires high signal to noise for aquatic systems (300:1 at 45Z, 0.01 reflectance target) and fine spatial resolution (at least 60 m) to map uniform patches in the landscape. Requires high frequency repeat sampling (~19 days) to provide at least one acquisition per season globally, with preferably multiple acquisitions within a season.

•Requires radiometric stability for multi-year monitoring.

•Requires supplemental spectral libraries to inform mapping.

## •*Approach:*

•Retrieve bi-directional reflectance and surface spectral radiance using atmospheric radiative transfer

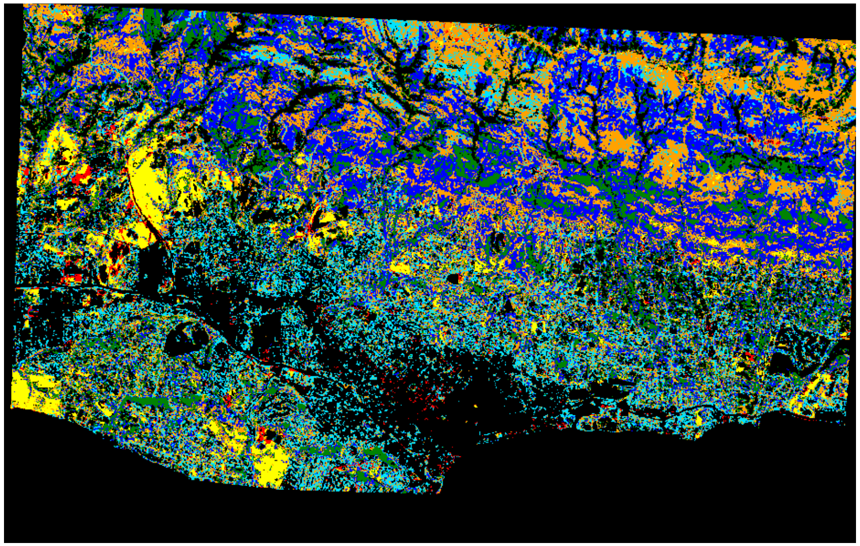
•Develop seasonal compositing approaches to generate a seamless global product for terrestrial systems and coastal waters.

•Utilize mixing algorithms to estimate sub-pixel fractions of cover, including exposed soil, photosynthetic and non-photosynthetic components

•Develop spectroscopic means for quantifying biodiversity

•Link to well established calibration/validation sites for validation

# VQ1c: What is the current spatial distribution of ecosystems, functional groups, or key species within major biomes including agriculture, and how are these being altered by climate variability, human uses, and other factors? [DS 191, 203]





Map showing the distribution of dominant species within the Santa Barbara front range. Edaphic controls are strongly evident. Chaparral species shown differ in their effects on fire spread and post-fire response. Ceanothus is a nitrogen fixing genus, while Quercus, Arctostaphylos and Adenostoma are genera that do not fix nitrogen. From Dennison and Roberts, 2003.

## *Science Issue:*

•Ecosystem response to anthropogenic disturbance and climate variability depends upon ecosystem spatial extent, factors that govern ecosystem distribution and the species or functional groups within them. Current space-borne assets are incapable of discriminating numerous critical functional groups, such as nitrogen and non-nitrogen fixing plants, C3 and C4 grasses, fire resistant vs intolerant species and coastal reef communities.

## *•Tools:*

•Satellite observations from HyspIRI. Requires fine spectral sampling (~ 10 nm) from the ultra-violet to Short-Wave-Infrared (380-2500 nm) to discriminate functional types and species in terrestrial and aquatic ecosystems, correct for atmospheric impacts and retrieve bi-directional reflectance. Requires high signal to noise for aquatic systems (300:1 at 45Z, 0.01 reflectance target) and fine spatial resolution (at least 60 m) to map uniform patches in the landscape. Requires high frequency repeat sampling (19 days) to provide a minimum of one acquisition per season globally and improve discrimination of species through phenology.

•Requires radiometric stability for multi-year monitoring.

•Requires supplemental spectral libraries to inform mapping.

## *•Approach:*

•Retrieve bi-directional reflectance and surface spectral radiance using atmospheric radiative transfer

•Develop seasonal compositing approaches to generate a seamless global product for terrestrial systems and coastal waters.

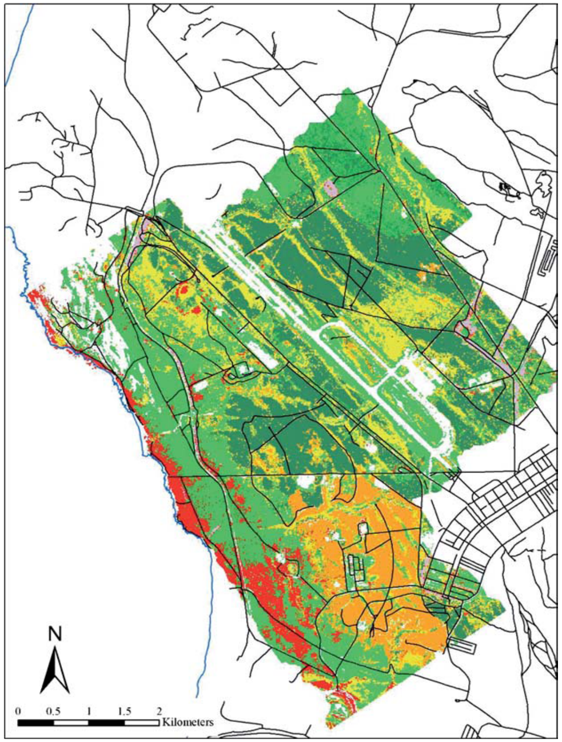
•Apply standard and developed classification algorithms for mapping ecosystems in terrestrial and coastal aquatic or inland water systems.

•Develop new tools that leverage phenological information for species/ functional group discrimination.

•Link to well established calibration/validation sites for validation

•Develop products that are readily assimilated in to models.

# VQ1d: What are the extent and impact of invasive species in terrestrial and aquatic ecosystems? [DS 192, 194, 196, 203, 204, 214]




Map from Vandenberg Airforce Base showing the distribution chaparral and shrub communities in the presence and absence of an iceplant understory. Also shows the distribution of Jubatagrass, a highly invasive plant species. From Ustin.

## *Science Issue:*

•Invasive organisms are increasingly modifying terrestrial and aquatic ecosystems and are anticipated to become a leading cause of species extinction and ecosystem change in the future. Invasive species can, and often do modify disturbance regimes in a way that promotes their spread. Early detection and monitoring of the spread of invasive species is critical for mitigation and improving our knowledge of mechanisms that facilitate spread.

## •*Tools:*

•Satellite observations from HyspIRI. Requires fine spectral sampling (~ 10 nm) from the ultra-violet to Short-Wave-Infrared (380-2500 nm) to discriminate functional types and species in terrestrial and aquatic ecosystems, correct for atmospheric impacts and retrieve bi-directional reflectance. Requires high signal to noise for aquatic systems (300:1 at 45Z, 0.01 reflectance target) and fine spatial resolution (at least 60 m) to map specific species in the landscape. Requires high frequency repeat sampling (19 days) to improve discrimination of species through phenology.

•Requires radiometric stability for multi-year monitoring.

•Requires supplemental spectral libraries to inform mapping.

•Requires regional knowledge of important invasive organisms and a knowledge of conditions/attributes that facilitate their spread.

## •*Approach:*

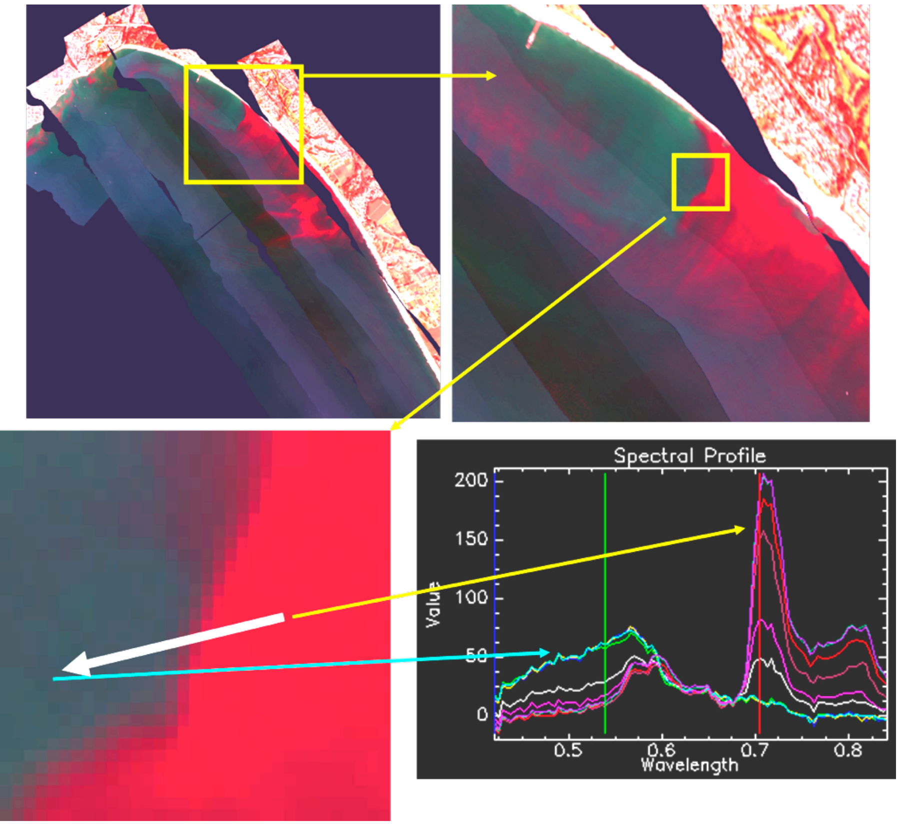
•Retrieve bi-directional reflectance and surface spectral radiance using atmospheric radiative transfer

•Develop new tools that leverage phenological information for species/ functional group discrimination.

•Develop approaches for mapping sub-pixel abundance of a specific species or functional group including detection thresholds.

•Link satellite-based mapping with modeling approaches, such as the use of climate envelopes for species predictions.

# VQ1e: What is the spatial structure and species distribution in a phytoplankton blooms? [DS 201, 208]




Imaging spectrometry data acquired by the PHYLLS-2 airborne sensor showing the abundance and distribution of *Ceratium sp*., within Monterey Bay. Supplied by Bissett.

## *Science Issue:*

•In coastal ecosystems and inland waters, changes in nutrient inputs, often associated with terrestrial land-use (ie, agricultural or aquaculture nutrient inputs) often result in explosive growth of phytoplankton., which can be detrimental (ie, eutrophication). Knowledge of the spatial distribution of specific phytoplankton will improve scientific knowledge regarding factors that create phytoplankton blooms and govern bloom spatial structure.

## *•Tools:*

•Satellite observations from HyspIRI. Requires fine spectral sampling (~ 10 nm) from the ultra-violet to Near-Infrared (380-900 nm) to discriminate functional types in aquatic ecosystems. Requires < 2% polarization sensitivity. Requires 300:1 SNR at 45Z for 0.01 reflectance target and for correction of atmospheric path radiance components. Requires fine spatial resolution (at least 60 m) to map bloom structure. Requires high frequency repeat sampling (19 days) to improve probability of acquiring data in coastal zones frequently contaminated by coastal fog or clouds.

•Requires radiometric stability for multi-year monitoring.

•Requires supplemental spectral libraries to inform mapping.

• Link satellite observations to physical measurements/models of coastal winds and currents.

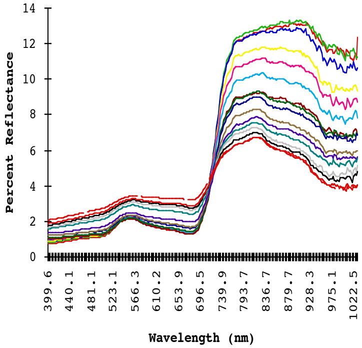
## *•Approach:*

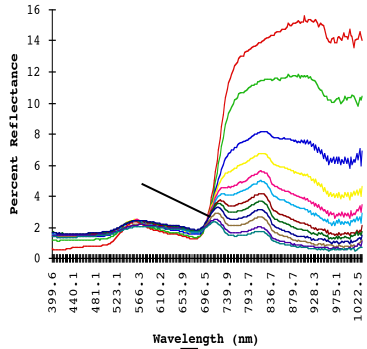
•Retrieve water level spectral radiance using atmospheric radiative transfer

•Develop approaches for mapping abundance and presence of aquatic functional groups.

•Link satellite-based mapping with hydrology modeling nutrient inputs from near-water terrestrial sources.

# VQ1f: How do changes in coastal morphology and surface composition impact coastal ecosystem composition, diversity and function [DS 41]?




Radiative transfer simulations of two species of *Spartina* (*cynosuroides*, left, *patens* right) in the coastal zone. Reflectance spectra from these two species are highly sensitive to the depth of water beneath the canopy, which causes significantly lower NIR reflectance in *patens* than in *cynosuroides*. Radiative transfer can be used to determine species type, structure, and water level. Mapping these parameters provides information about ecosystem response to changing stressors.
From Kearney et al., in press.

## *Science Issue:*

•Coastal ecosystems are highly sensitive to sea level rise, either due to a net increase due to thermal expansion or fresh-water inputs, or short-term increases due to storm events. These ecosystems, which are some of the most productive on Earth, are also highly sensitive to changes in salinity and sediment transport, which can modify the distribution of sensitive species or lead to expansion or contraction of the coastal zone.

## *•Tools:*

•Satellite observations from HyspIRI. Requires fine spectral sampling (~ 10 nm) from the ultra-violet to Short-Wave-Infrared (380-2500 nm) to discriminate functional types and species in coastal ecosystems, correct for atmospheric impacts and retrieve bi-directional reflectance. Requires 600:1 SNR at 23Z for 0.25 reflectance target and fine spatial resolution (at least 60 m) to map specific species in the landscape. Requires high frequency repeat sampling (19 days) to ensure data collection in regions frequented by coastal fog or clouds.

•Requires radiometric stability for multi-year monitoring.

•Requires supplemental spectral libraries to inform mapping.

•Requires detailed knowledge of the state of tides to quantify the impacts of the presence or absence of sub-canopy water.

## *•Approach:*

•Retrieve bi-directional reflectance and using atmospheric radiative transfer

•Apply standard approaches for classification and sub-pixel mixtures, especially needed to account for the presence of sub-pixel water. .

•Leverage availability of vertical height information acquired from active sensors such as LIDAR or interferometric SAR.