VQ1. Pattern and Spatial Distribution of Ecosystems and their Components

Dar Roberts[1], Elizabeth Middleton[2]

1) UC Santa Barbara Department of Geography
dar@geog.ucsb.edu, 805-893-2276

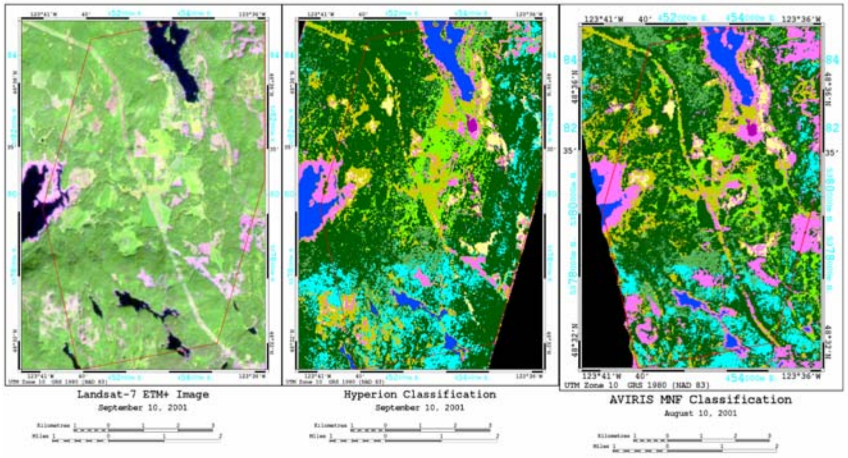
2) Goddard Space Flight Center
elizabeth.m.middleton@nasa.gov, 301-614-6670

Members/contributors: Bob Knox, Kevin Turpie, Martha Anderson, John Gamon, Greg Asner, Alex Checkaluk, Heidi Dierssen, Phil Townsend, Woody Turner

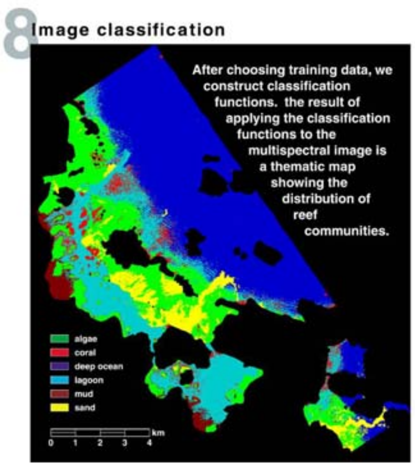
VQ1: Overarching Question

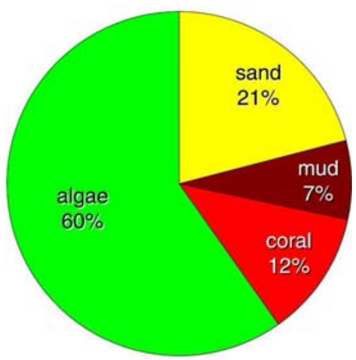
- **What is the global spatial pattern of ecosystem and diversity distributions and how do ecosystems differ in their composition or biodiversity? [DS 195]**
  - **DS195: Box 7.1 *Observing Conditions and Trends in Ecosystems***

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.

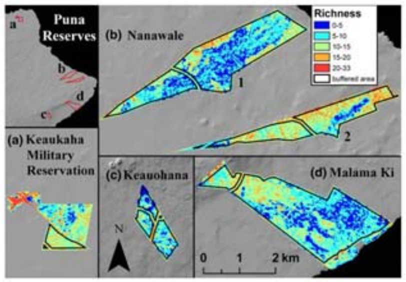
•Utilize mixing algorithms to **estimate sub-pixel fractions of ecosystems**

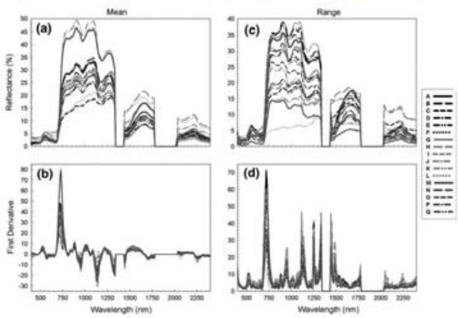
•Link to well established calibration/validation sites for validation

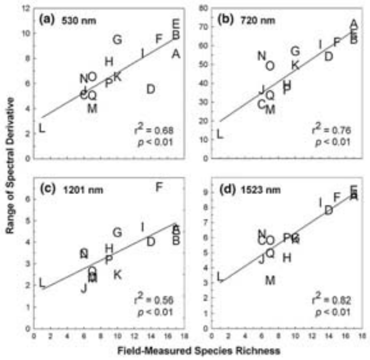
•Develop products that are readily assimilated in to models.

***DS191/203: Specific call for a ecosystem mapping/function mission**

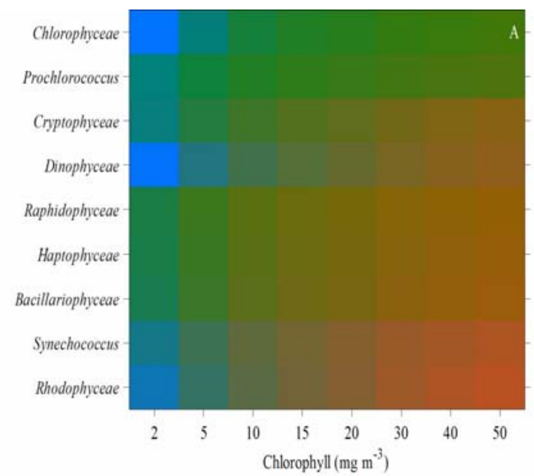
VQ1b: How do **similar ecosystems differ** in size, **species composition, fractional cover and biodiversity** across terrestrial and aquatic biomes and on different continents? [DS 195]

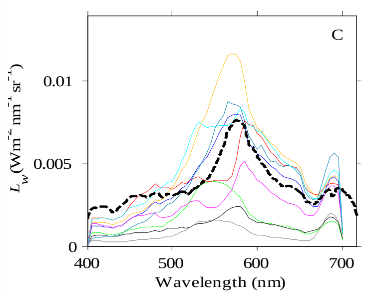






Spectral variability is directly related to canopy species diversity
From Carlson et al., 2007





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**.

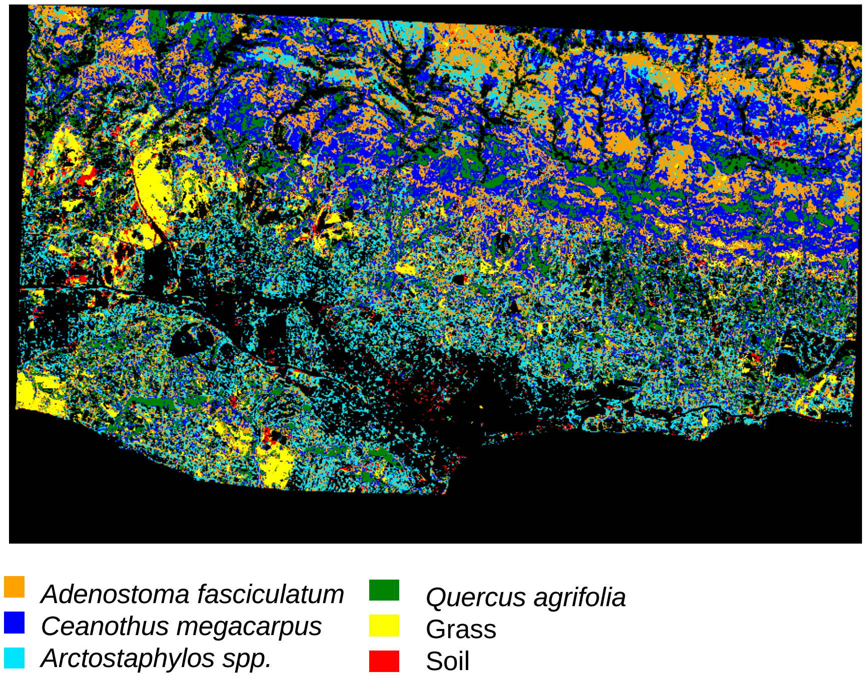
•*Tools:*

•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.**

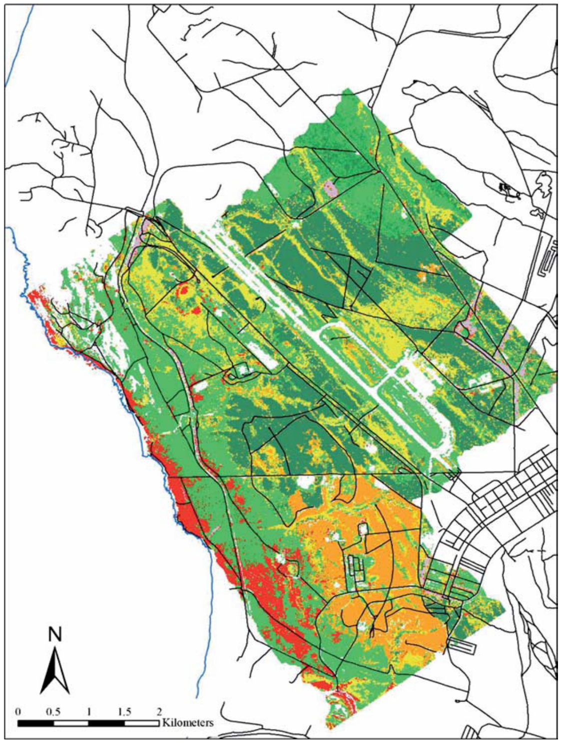
•*Tools:*

•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.

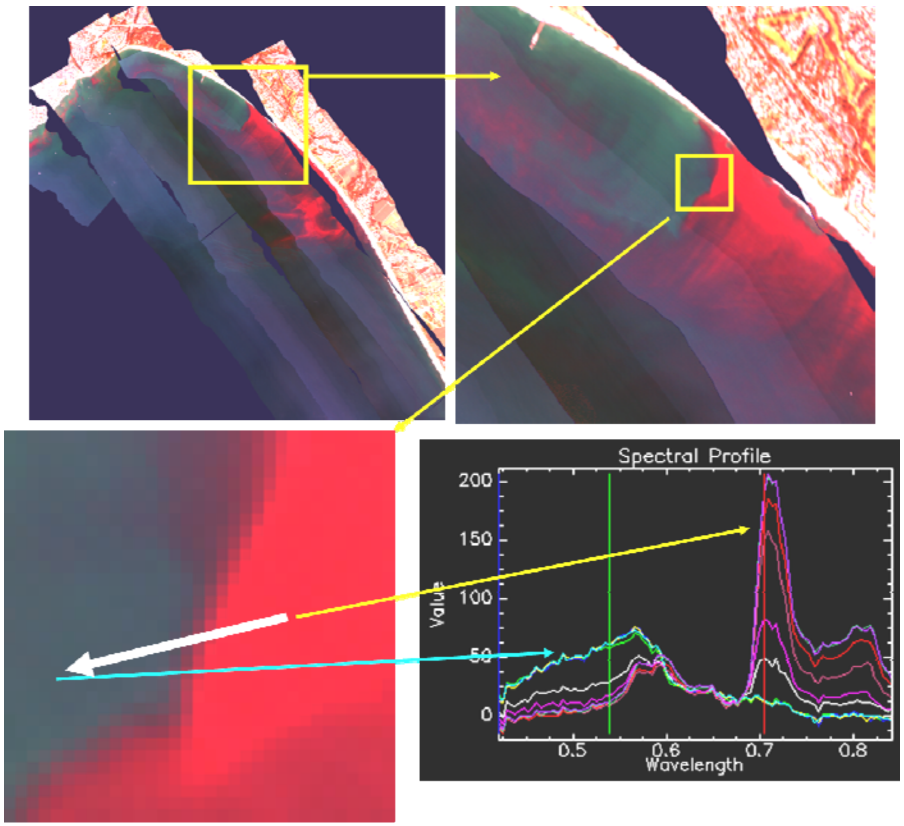
•*Tools:*

•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 Monterrey 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:*

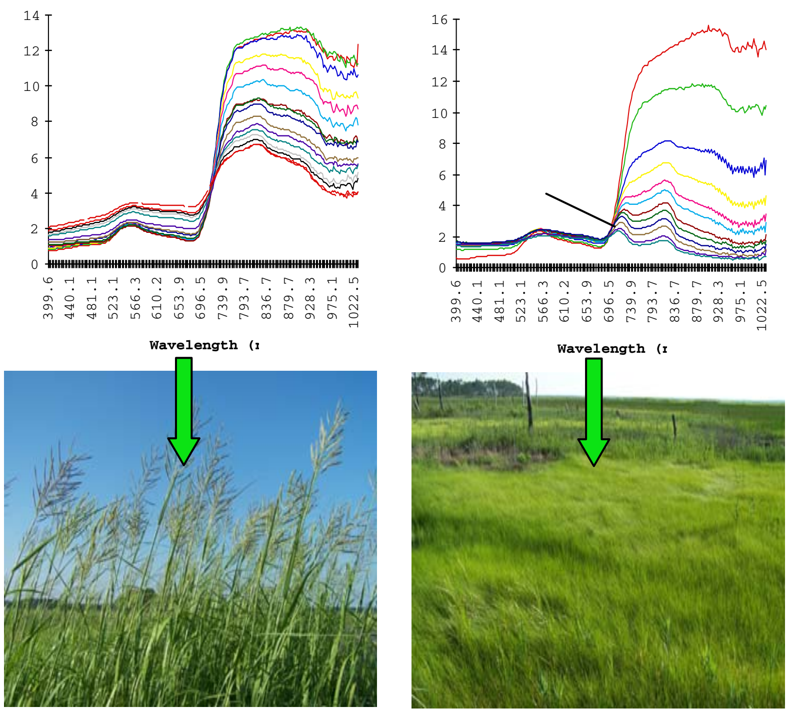
•Retrieve water level spectral radiance using atmospheric radiative transfer

•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.

***DS201/208: Table 7.1 & Coastal Ecosystem Dynamics**

VQ1f: How do **changes in coastal morphology and surface composition** impact **coastal ecosystem composition, diversity and function** [DS 191]?



Measured spectral reflectance 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**.

Science Traceability Matrix

Q ID	Science Objectives		Data Products	Requirements	
	Science Question	*Scientific (Measurement) Objective*	*Data Products Requirements*	*Mission Functional Requirement*	*Scientific Measurement Requirement*
VQ1 - Spatia	**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? [DS 195]**				
VQ1-1	How are ecosystems organized within different biomes associated with temperate, tropical, and boreal zones, and how are these changing? [DS 191, 203]	Measure globally vegetation covered regions seasonally and on a multi-year scale. Derive Fractional Cover of Plant Functional Types and Species where possible (terrestrial): e.g. tree, shrub, herbaceous, cryptogam; thick/thin leaves; broad/needle leaves; deciduous/evergreen; nitrogen-fixer/non-fixer; C3/C4 physiology.	L2 atmospherically corrected spectral reflectance with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask).	Surface reflectance in the solar reflected spectrum for elevation angles >20; rigorous cal/val program; Monthly lunar cals; Daily solar cals; 6 per year vcals; >3X zeroloss compression; ~11 am sun sync LEO orbit; Radiometric calibration; Atmospheric Correction; AC validation; Parameter Ground Validation; Geolocation; Pointing strategy to minimize sun glint; Avoid terrestrial hot spot; Ground processing; latency: seasonal, multi-year; 30m (3s) Pointing knowledge;	Measure diagnostic spectral signature (400-2500@10nm) with high precision and accuracy to derive plant functional type and species where possible. Selected wavelengths (760+/-20 - oxygen for surface pressure and atm aerosols; 940 +/- 50 and 1150+/-50 - for water vapor; 1380 +/-20 for cirus clouds) to allow for atmospheric correction for terrestrial and aquatic observations. Measure patch scales of <100 m. Measure seasonally (90 day revisit) through several (3) years to observe the seasonal regional occurrence and trends. Measure regionally-important Plant Functional Type with a revisit time of at most 20 days.
VQ1-2	How do similar ecosystems differ in size, species composition, fractional cover and biodiversity across terrestrial and aquatic biomes? [DS 195]	Measure globally fraction of dominant Plant Functional Types and Species where possible (terrestrial): e.g. tree, shrub, herbaceous, cryptogam; thick/thin leaves; broad/needle leaves; deciduous/evergreen; nitrogen-fixer/non-fixer; C3/C4 physiology. Sample globally dominant aquatic phytoplankton functional types e.g. phytoplankton (diatoms, dinoflagellates, coccolithophores, N-fixers) Measure dominant submerged aquatic communities (i.e., coral, sea grass, kelp) Sample aquatic biogeochemical constituent: (phytoplankton, sediment, CDOM, benthos)	L2 atmospherically corrected spectral reflectance with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask). L2 water leaving radiance spectrum between 380 - 900 with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask).	Surface reflectance in the solar reflected spectrum for elevation angles >20; Rigorous cal/val program; Monthly lunar cals; Daily solar cals; 6 per year vcals; >3X zeroloss compression; ~11 am sun sync LEO orbit; Radiometric calibration; Atmospheric Correction; AC validation; Parameter Ground Validation; Geolocation; Pointing strategy to minimize sun glint; Avoid terrestrial hot spot; Ground processing; latency: seasonal, multi-year; 30m (3s) Pointing knowledge ;	Measure diagnostic spectral signature (400-2500@10nm) with high precision and accuracy to derive terrestrial functional groups, species and critical measurable abiotic components. Selected wavelengths (760+/-20 - oxygen for surface pressure and atm aerosols; 940 +/- 50 and 1150+/-50 - for water vapor; 1380 +/-20 for cirus clouds) to allow for atmospheric correction for terrestrial and aquatic observations. Measure diagnostic spectral signature (380-900@10nm) to derive aquatic functional groups, species and critical measurable abiotic components. Selected wavelengths in the short wavelength infrared (1250, 1650, 2250) to enable atmospheric correction for aquatic observations. Measure with spatial resolution of <100 m. Measure seasonally (90 day revisit) through several (3) years to capture baseline Measure regionally-important Plant Functional Type with a revisit time of at most 20 days.
VQ1-3	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]	Measure Fractional Cover of Plant Functional Types and Species where possible (terrestrial): e.g. tree, shrub, herbaceous, cryptogam; thick/thin leaves; broad/needle leaves; deciduous/evergreen; nitrogen-fixer/non-fixer; C3/C4 physiology.	L2 atmospherically corrected spectral reflectance with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask).	Surface reflectance in the solar reflected spectrum for elevation angles >20; Rigorous cal/val program; Monthly lunar cals; Daily solar cals; 6 per year vcals; >3X zeroloss compression; ~11 am sun sync LEO orbit; Radiometric calibration; Atmospheric Correction; AC validation; Parameter Ground Validation; Geolocation; Pointing strategy to minimize sun glint; Avoid terrestrial hot spot; Ground processing; latency: seasonal, multi-year; 30m (3s) Pointing knowledge	Measure diagnostic spectral signature (400-2500@10) with high precision and accuracy to derive plant functional type and species. Selected wavelengths (760+/-20 - oxygen for surface pressure and atm aerosols; 940 +/- 50 and 1150+/-50 - for water vapor; 1380 +/-20 for cirus clouds) to allow for atmospheric correction for terrestrial and aquatic observations. Measure patch scales of <100 m. Measure seasonally (90 day revisit) through several (3) years to observe the seasonal regional occurrence and trends. Measure regionally-important Plant Functional Type with a revisit time of at most 20 days.
VQ1-4	What are the extent and impact of invasive species in terrestrial and aquatic ecosystems? [DS 192, 194, 196, 203, 204, 214]	Measure globally vegetation covered regions seasonally and on a multi-year scale. Derive Fractional Cover of Plant Functional Types and Species where possible focusing on invasive species types (terrestrial and aquatic)	L2 atmospherically corrected spectral reflectance with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask). L2 water leaving radiance spectrum between 380 - 900 with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask).	Surface reflectance in the solar reflected spectrum for elevation angles >20; Rigorous cal/val program; Monthly lunar cals; Daily solar cals; 6 per year vcals; >3X zeroloss compression; ~11 am sun sync LEO orbit; Radiometric calibration; Atmospheric Correction; AC validation; Parameter Ground Validation; Geolocation; Pointing strategy to minimize sun glint; Avoid terrestrial hot spot; Ground processing; latency: seasonal, multi-year; 30m (3s) Pointing knowledge;	Measure diagnostic spectral signature (400-2500@10nm) with high precision and accuracy to derive terrestrial functional groups, species and critical measurable abiotic components. Selected wavelengths (760+/-20 - oxygen for surface pressure and atm aerosols; 940 +/- 50 and 1150+/-50 - for water vapor; 1380 +/-20 for cirus clouds) to allow for atmospheric correction for terrestrial and aquatic observations. Measure diagnostic spectral signature (380-900@10nm) to derive aquatic functional groups, species and critical measurable abiotic components. Selected wavelengths in the short wavelength infrared (1250, 1650, 2250) to enable atmospheric correction for aquatic observations. Measure with spatial resolution of <100 m. Measure seasonally (90 day revisit) through several (3) years to observe the seasonal regional occurrence and trends in the coastal regions. Measure regionally-important Plant Functional Type with a revisit time of at most 20 days.
VQ1-5	What is the spatial structure and species distribution in a phytoplankton bloom? [DS 201, 208]	Sample globally algal blooms (including harmful) species and spatial structure in the coastal regions and in the deep oceans with reduced spatial resolution.	L2 water leaving radiance spectrum between 380 - 900 with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask).	Surface reflectance in the solar reflected spectrum for elevation angles >20; Rigorous cal/val program; Monthly lunar cals; Daily solar cals; 6 per year vcals; >3X zeroloss compression; ~11 am sun sync LEO orbit; Radiometric calibration; Atmospheric Correction; AC validation; Parameter Ground Validation; Geolocation; Pointing strategy to minimize sun glint; Avoid terrestrial hot spot; Ground processing; latency: seasonal, multi-year; 30m (3s) Pointing knowledge;	Measure diagnostic spectral signature (380-900@10) with high precision and accuracy of aquatic vegetation in coastal regions. Selected wavelengths in the short wavelength infrared (1250, 1650, 2250) to allow atmospheric correction. Measure deep ocean with spatial resolution of <1000 m. Measure coastal aquatic with spatial resolution of <100 m. Measure seasonally (90 day revisit) through several (3) years to observe the seasonal regional occurrence and trends in the coastal regions. Measure regionally-important Plant Functional Type with a revisit time of at most 20 days.
VQ1-6	How do changes in coastal morphology and surface composition impact coastal ecosystem composition, diversity and function [DS 41]?	Measure coastal ecosystem functional characteristics and diversity at the seasonal and multiyear time scale.	L2 atmospherically corrected spectral reflectance with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask). L2 water leaving radiance spectrum between 380 - 900 with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask).	Surface reflectance in the solar reflected spectrum for elevation angles >20; Rigorous cal/val program; Monthly lunar cals; Daily solar cals; 6 per year vcals; >3X zeroloss compression; ~11 am sun sync LEO orbit; Radiometric calibration; Atmospheric Correction; AC validation; Parameter Ground Validation; Geolocation; Pointing strategy to minimize sun glint; Avoid terrestrial hot spot; Ground processing; latency: seasonal, multi-year; 30m (3s) Pointing knowledge;	Measure diagnostic spectral signature (400-2500@10) with high precision and accuracy of terrestrial vegetation in coastal regions. Selected wavelengths (760+/-20 - oxygen for surface pressure and atm aerosols; 940 +/- 50 and 1150+/-50 - for water vapor; 1380 +/-20 for cirus clouds) to allow for atmospheric correction for terrestrial and aquatic observations. Measure diagnostic spectral signature (380-900@10) with high precision and accuracy of aquatic ecosystems in coastal regions. Selected wavelengths in the short wavelength infrared (1250, 1650, 2250) to enable atmospheric correction for aquatic observations. Measure with spatial resolution of <100 m. Measure seasonally (90 day revisit) through several (3) years to observe the seasonal regional occurrence and trends in the coastal regions. Measure regionally-important Plant Functional Type with a revisit time of at most 20 days.

Science Objectives (1-3)

Science Objectives

	Science Question	*Scientific (Measurement) Objective*
VQ1-1	How are ecosystems organized within different biomes associated with temperate, tropical, and boreal zones, and how are these changing? [DS 191, 203]	Measure globally vegetation covered regions seasonally and on a multi-year scale. Derive Fractional Cover of Plant Functional Types and Species where possible (terrestrial): e.g. tree, shrub, herbaceous, cryptogam; thick/thin leaves; broad/needle leaves; deciduous/evergreen; nitrogen-fixer/non-fixer; C3/C4 physiology.
VQ1-2	How do similar ecosystems differ in size, species composition, fractional cover and biodiversity across terrestrial and aquatic biomes? [DS 195]	Measure globally fraction of dominant Plant Functional Types and Species where possible (terrestrial): e.g. tree, shrub, herbaceous, cryptogam; thick/thin leaves; broad/needle leaves; deciduous/evergreen; nitrogen-fixer/non-fixer; C3/C4 physiology. Sample globally dominant aquatic phytoplankton functional types e.g. phytoplankton (diatoms, dinoflagellates, coccolithophores, N-fixers) Measure dominant submerged aquatic communities (i.e., coral, sea grass, kelp) Sample aquatic biogeochemical constituent: (phytoplankton, sediment, CDOM, benthos)
VQ1-3	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]	Measure Fractional Cover of Plant Functional Types and Species where possible (terrestrial): e.g. tree, shrub, herbaceous, cryptogam; thick/thin leaves; broad/needle leaves; deciduous/evergreen; nitrogen-fixer/non-fixer; C3/C4 physiology.

Science Objectives (4-6)

Science Objectives

	Science Question	*Scientific (Measurement) Objective*
VQ1-4	What are the extent and impact of invasive species in terrestrial and aquatic ecosystems? [DS 192, 194, 196, 203, 204, 214]	Measure globally vegetation covered regions seasonally and on a multi-year scale. Derive Fractional Cover of Plant Functional Types and Species where possible focusing on invasive species types (terrestrial and aquatic)
VQ1-5	What is the spatial structure and species distribution in a phytoplankton bloom? [DS 201, 208]	Sample globally algal blooms (including harmful) species and spatial structure in the coastal regions and in the deep oceans with reduced spatial resolution.
VQ1-6	How do changes in coastal morphology and surface composition impact coastal ecosystem composition, diversity and function [DS 191?	Measure coastal ecosystem functional characteristics and diversity at the seasonal and multiyear time scale.

Data Products

Data Products Requirements
L2 atmospherically corrected spectral reflectance with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask).
L2 water leaving radiance spectrum between 380 - 900 with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask).

Mission Functional Requirements

Mission Functional Requirement
Surface reflectance in the solar reflected spectrum for elevation angles >20; Rigorous cal/val program; Monthly lunar cals; Daily solar cals; 6 per year vcals; >3X zeroloss compression; ~11 am sun sync LEO orbit; Radiometric calibration; Atmospheric Correction; AC validation; Parameter Ground Validation; Geolocation; Pointing strategy to minimize sun glint; Avoid terrestrial hot spot; Ground processing; latency: seasonal, multi-year; 30m (3s) Pointing knowledge;

Scientific Measurement Requirements

Scientific Measurement Requirement
Measure diagnostic spectral signature (400-2500@10nm) with high precision and accuracy to derive plant functional type and species where possible.
Selected wavelengths (760+/-20 - oxygen for surface pressure and atm aerosols; 940 +/- 50 and 1150+/-50 - for water vapor; 1380 +/-20 for cirus clouds) to allow for atmospheric correction for terrestrial and aquatic observations.
Measure patch scales of <100 m.
Measure seasonally (90 day revisit) through several (3) years to observe the seasonal regional occurrence and trends.
Measure regionally-important Plant Functional Type with a revisit time of at most 20 days.

Measure diagnostic spectral signature (400-2500@10nm) with high precision and accuracy to derive terrestrial functional groups, species and critical measurable abiotic components.
Selected wavelengths (760+/-20 - oxygen for surface pressure and atm aerosols; 940 +/- 50 and 1150+/-50 - for water vapor; 1380 +/-20 for cirus clouds) to allow for atmospheric correction for terrestrial and aquatic observations.
Measure diagnostic spectral signature (380-900@10nm) to derive aquatic functional groups, species and critical measurable abiotic components.
Selected wavelengths in the short wavelength infrared (1250, 1650, 2250) to enable atmospheric correction for aquatic observations.
Measure with spatial resolution of <100 m.
Measure seasonally (90 day revisit) through several (3) years to capture baseline
Measure regionally-important Plant Functional Type with a revisit time of at most 20 days.

Aquatic

Level 3 Products

- **Maps of species composition/Plant Functional Types**
  - **Examples: C4 vs C3 plants, Nitrogen/Non-nitrogen fixing, shade tolerant/intolerant, Obligate vs Facultative Seeder**
- **Fine spatial scale ecosystem maps with improved discrimination**
- **Seasonal spectral libraries of species/PFT**
- **Presence/absence of invasive species**
  - **Measures of confidence?**
- **Estimates of fractional cover and confidence (i.e. MCU)**
  - **Compositional (i.e., PV, NPV)**
  - **Water fraction (wetland)**
  - **PFT/Species**
- **Standard suite of biophysical/physiological narrow-band indices (i.e. PRI, EVI, MCARI, EWT)**
- **Time series for all measures above**
- **Possible L4 products**
  - **Regional carbon/water balance through model simulations**
  - **Regional ecosystem succession predictions using functional/species maps and climate parameters under various climate change scenarios**

L3 Validation

- **Leverage existing core validation sites**
  - **LTERs**
  - **Flux networks (i.e. Euroflux, Ameriflux)**
  - **EOS Validation Core Sites**
  - **FIA/USFS/International LC databases**
  - **CEOS/GEOSS**
  - **Coastal/marine**
- **Supporting sub-orbital missions/field campaigns**
- **International Collaborations**

Precursor Science

- **Spatial/Spectral/Temporal requirements must be determined for discriminating PFT & Species in terrestrial, coastal and marine environments and for sub-pixel mixing**
- **Evaluation/development of current/new approaches for invasive species mapping in marine, coastal and terrestrial ecosystems**
- **Classification/algorithm development and assessment across a diversity of ecosystems, leveraging phenological/seasonal/spectral information**
- **Evaluate and adopt a globally applicable vegetation and coastal classification and validation scheme**
- **Temporal compositing of hyperspectral data**
- **Fully integrated terrestrial/coastal/marine campaigns across latitudinal gradients and ecosystems with stages of succession, and contrasting similar ecosystems on different continents using suborbital assets**

Discussion/Questions