HyspIRI Science Question Review

VSWIR Question 6

Earth Surface Rock/Soil and Shallow Aquatic Substrate Composition

Robert O. Green, Heidi Dierssen and
the SSG

VQ6 Overview

- Overarching Question and Subquestions
- Examples of the Science
- Science Traceability Matrix
- Alignment with Decadal Survey
- Example Level 3 Products
- Validation Approaches
- Precursor Science

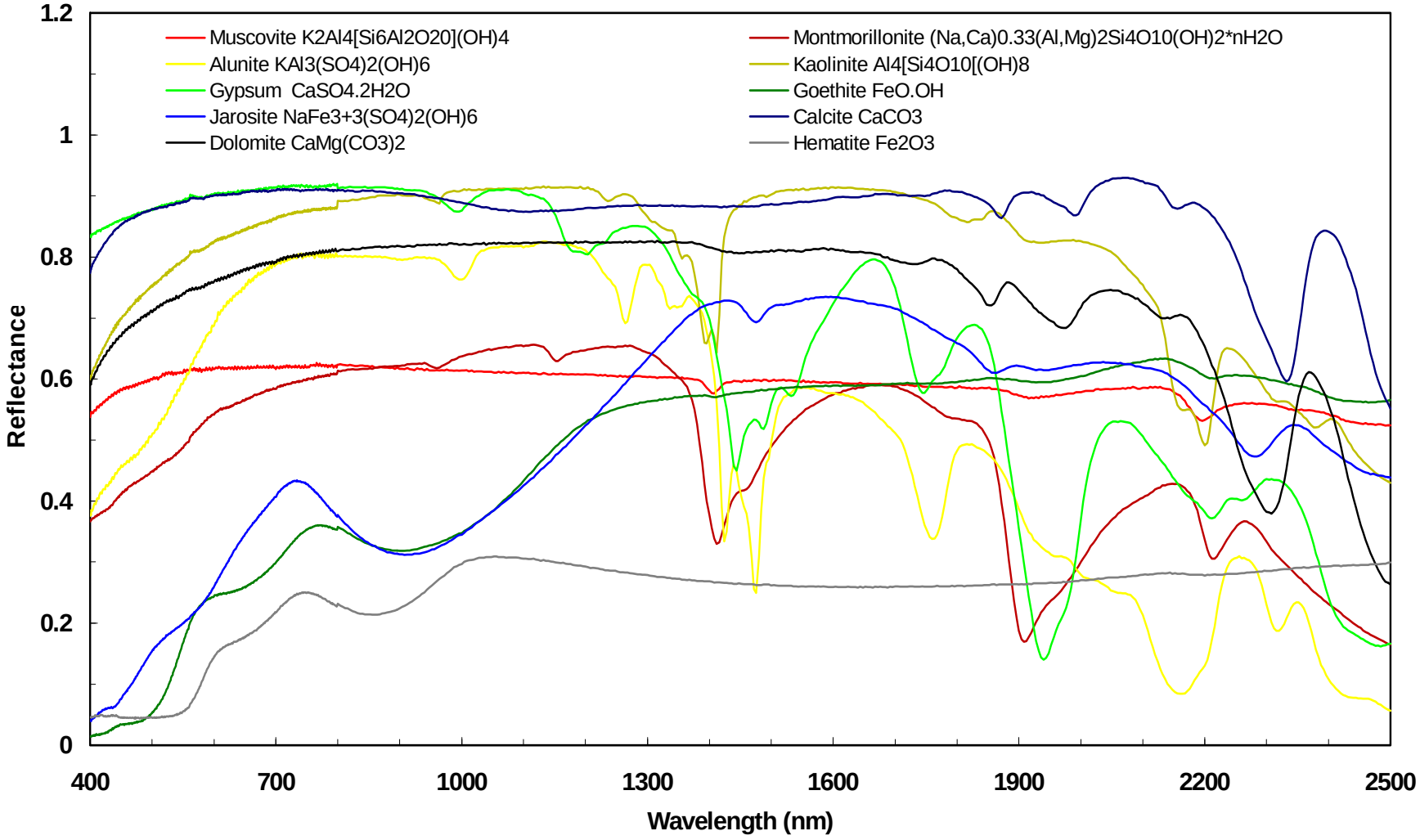
VQ6. Earth Surface Rock/Soil and Shallow Aquatic Substrate Composition

- What is the composition of the exposed terrestrial rock/soil and shallow aquatic substrate and how does compositional understanding of this relate to alteration, crustal processes, hazards, resources and understanding of change?

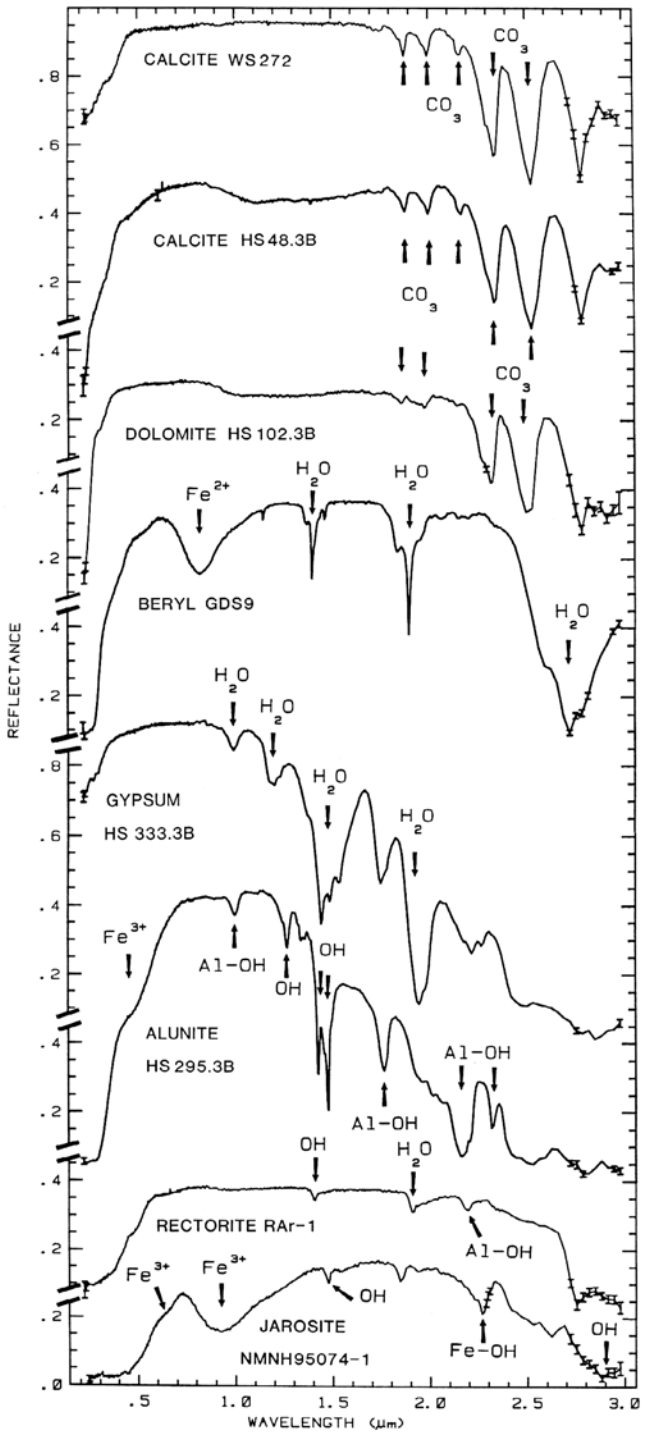
VQ6. Earth Surface and Shallow Water Substrate Composition (RG, HD)

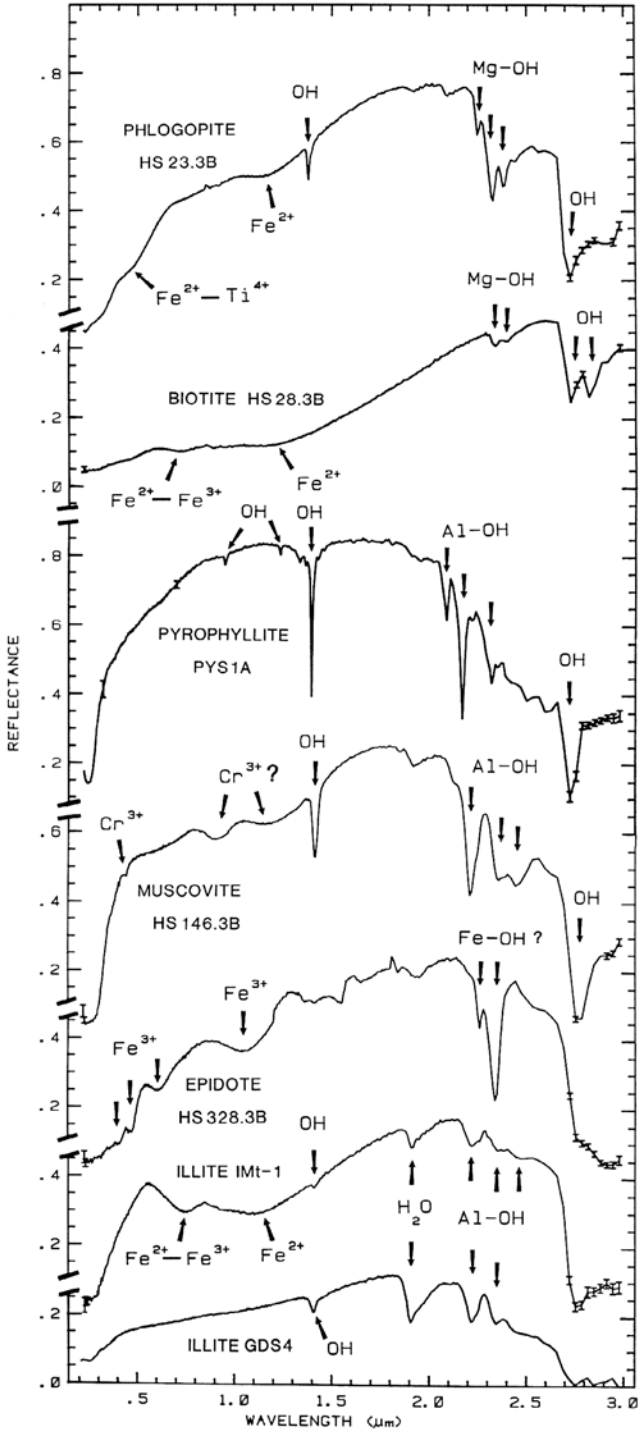
- What does a new level of understanding of the distribution of the minerals and mineral groups on the exposed terrestrial surface tell us about geological processes? [DS 218]
- What does the composition and distribution of the substrate of shallow water regions tell us about the status and processes of the coastal and marine environment? [DS 114]
- How will results from consistent and detailed global exposed mineral and geochemistry mapping lead to fundamentally concepts for mineral and hydrocarbon research and resource exploration[DS227]
- What can we learn about event and seasonal process driven responses that occur in shallow coastal and inland aquatic environments? [DS 25]
- How can new more accurate measurements of rock and soil composition and physical state be used to understand and mitigate geohazards? [DS227]
- How does the spatial distribution of snow & ice and the related properties of grain size, dust impurities, and albedo inform our knowledge of regional energy balance, hydrology and related surface processes?

Mineral Spectral Signatures in the Solar Reflected Spectrum

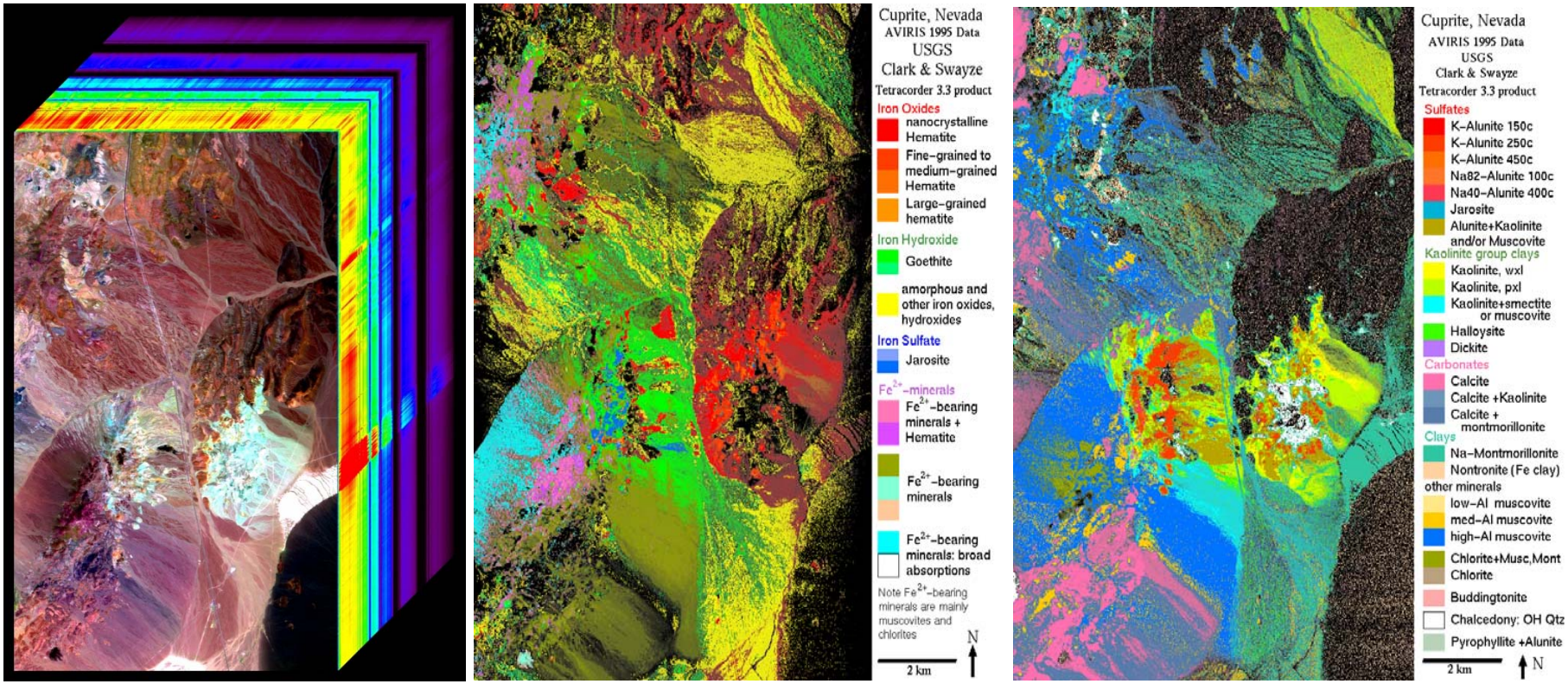


Geochemistry link to spectral signatures



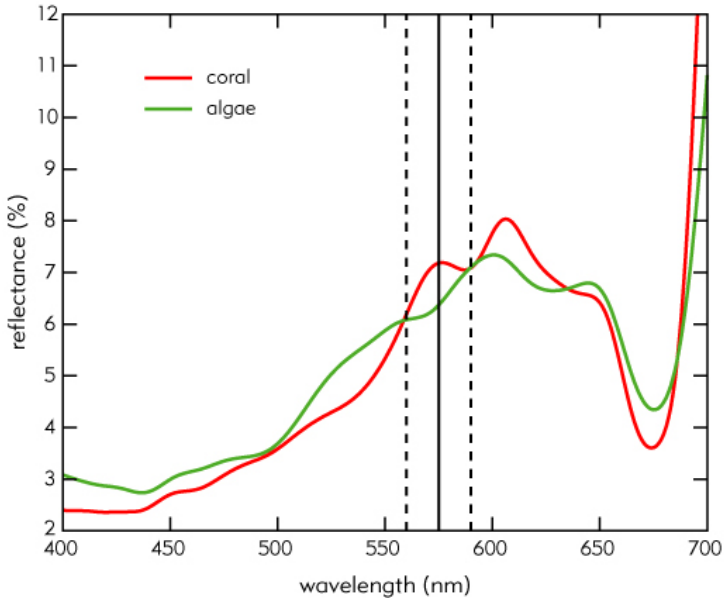


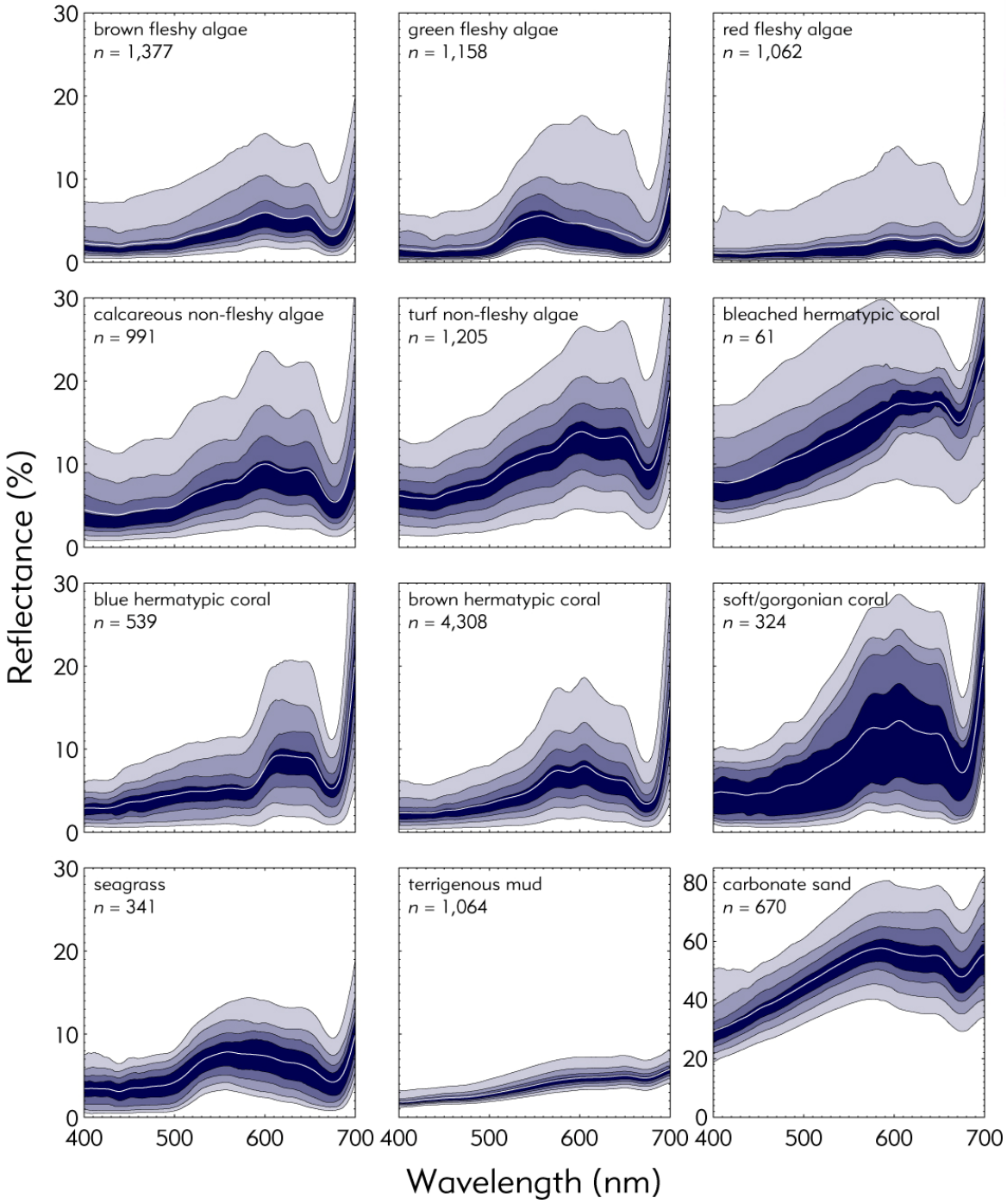
Classic Surface Composition Mapping with Imaging Spectrometer Measurements



- Roger Clark and Gregg Swayze, USGS

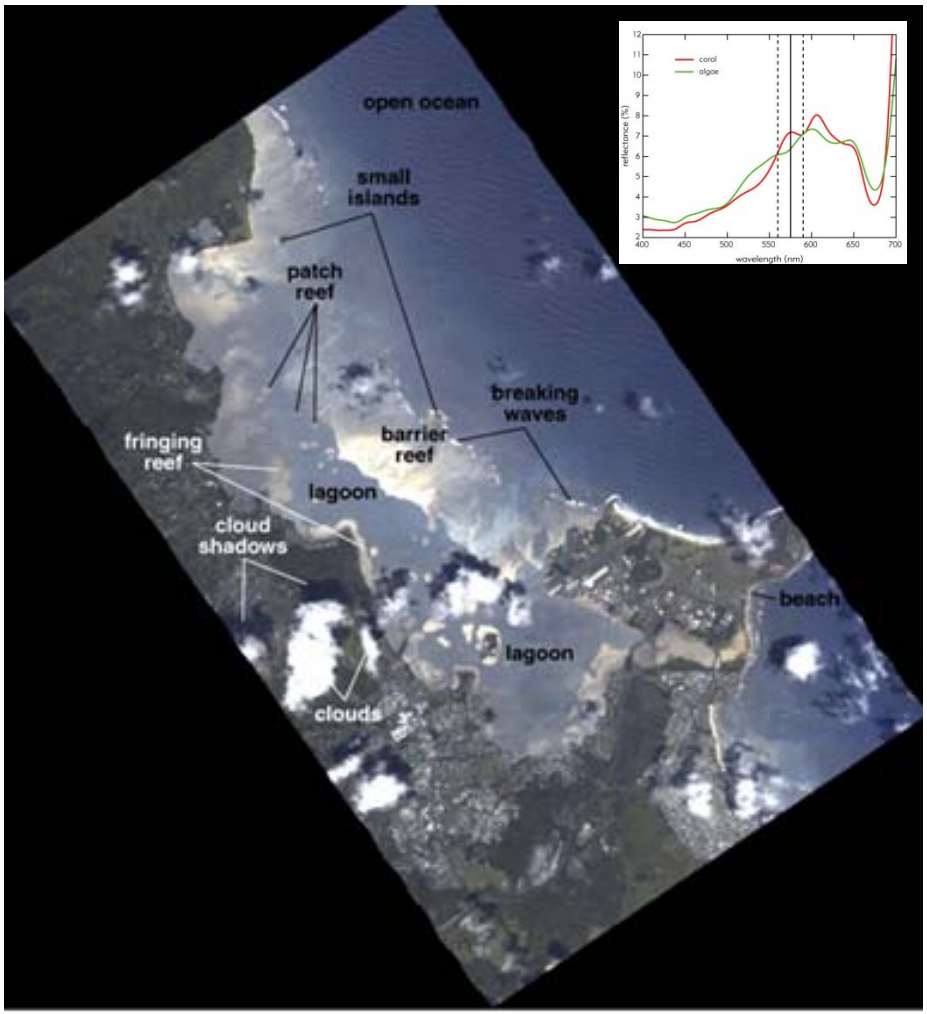
In Situ Spectral Measurements of Shallow Water Bottom Composition (E. Hochberg, Nova Southeastern University, FL)

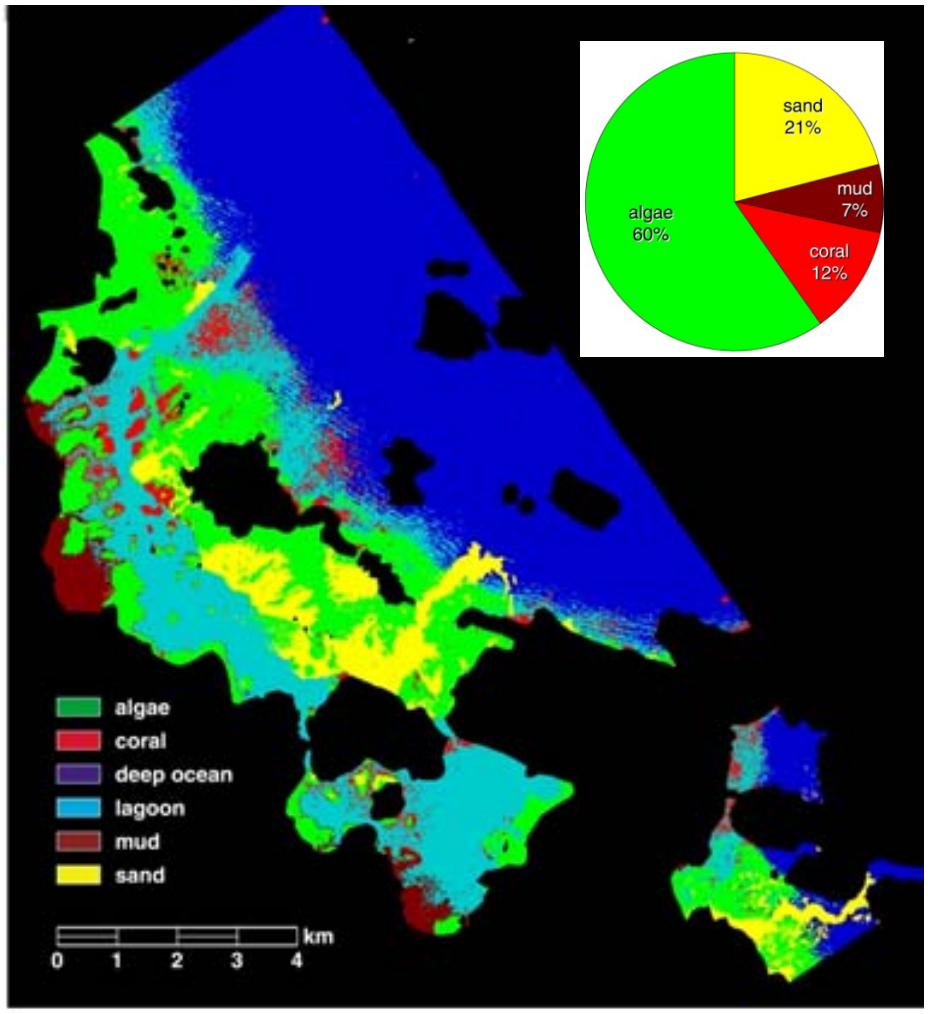




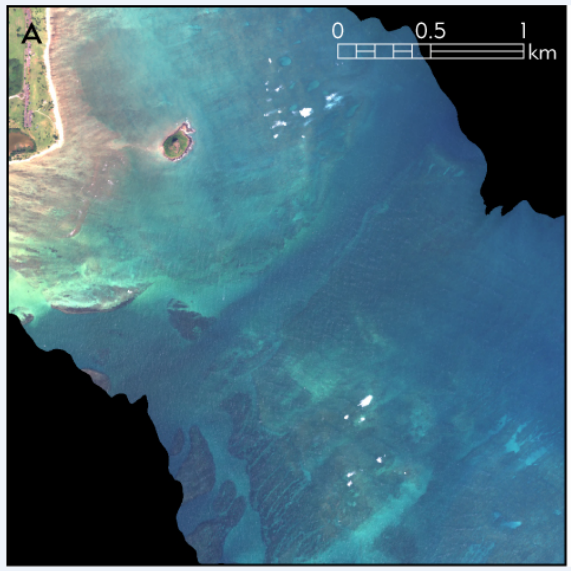
LDF analysis of AVIRIS measurements for shallow water bottom composition, Kaneohe Bay, HI

(E. Hochberg, Nova Southeastern University, FL)

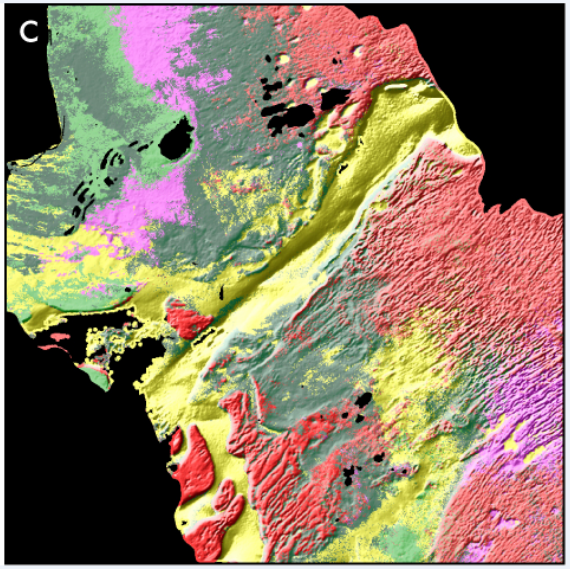


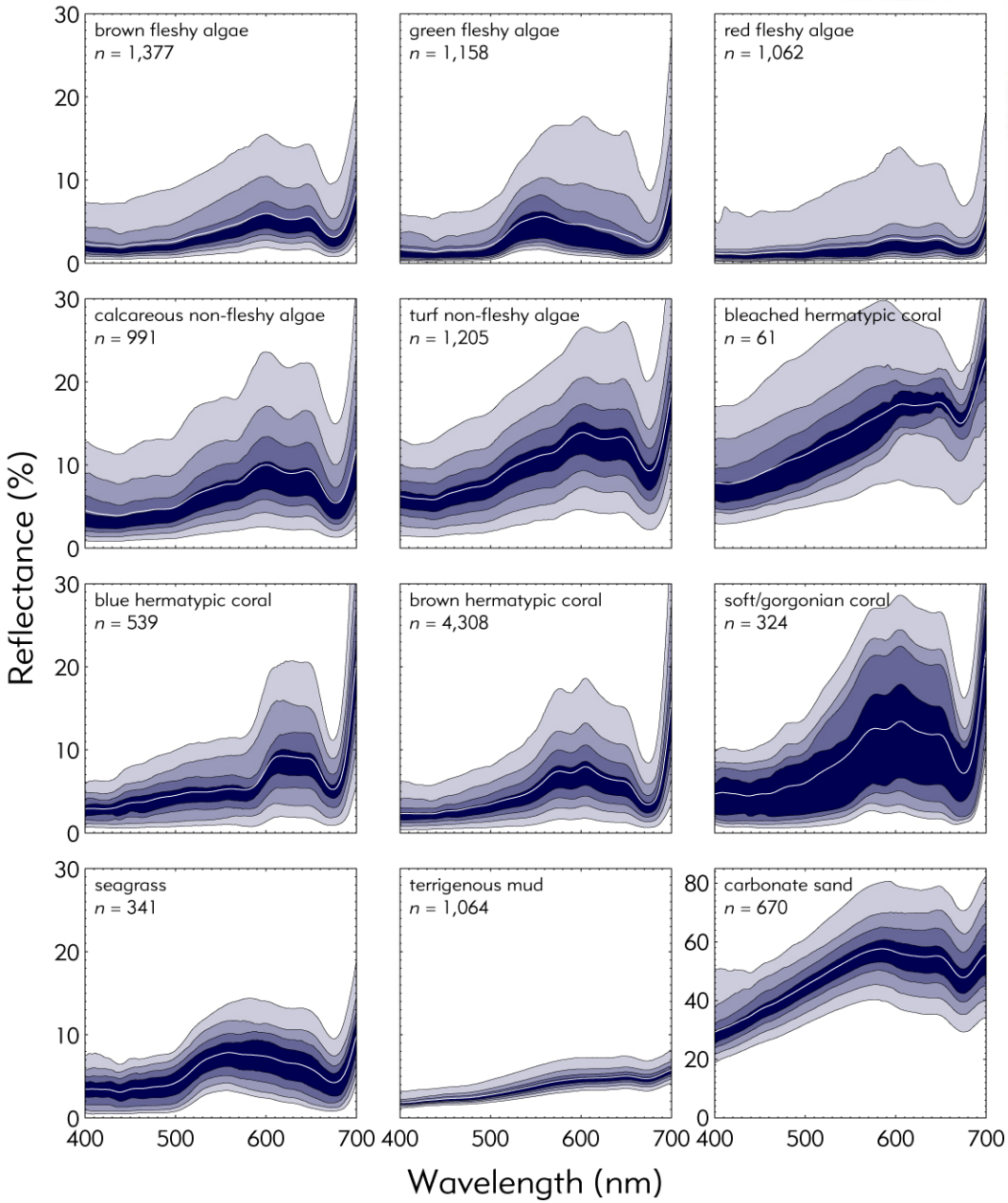


Imaging Spectrometer Measurement



Benthic Compositional Mapping

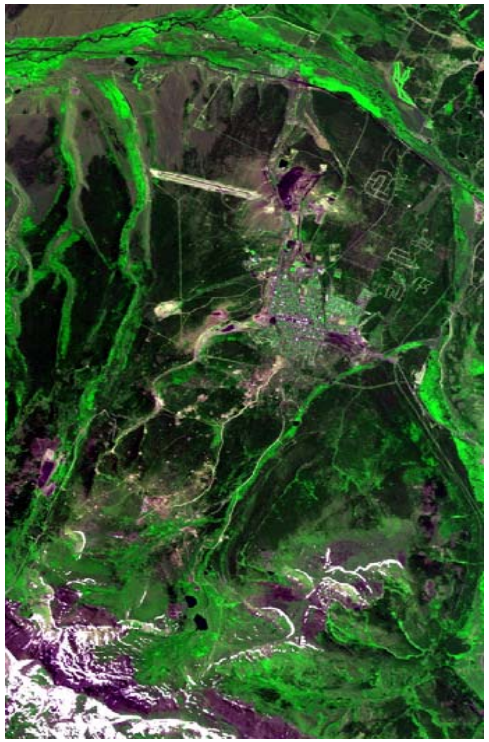




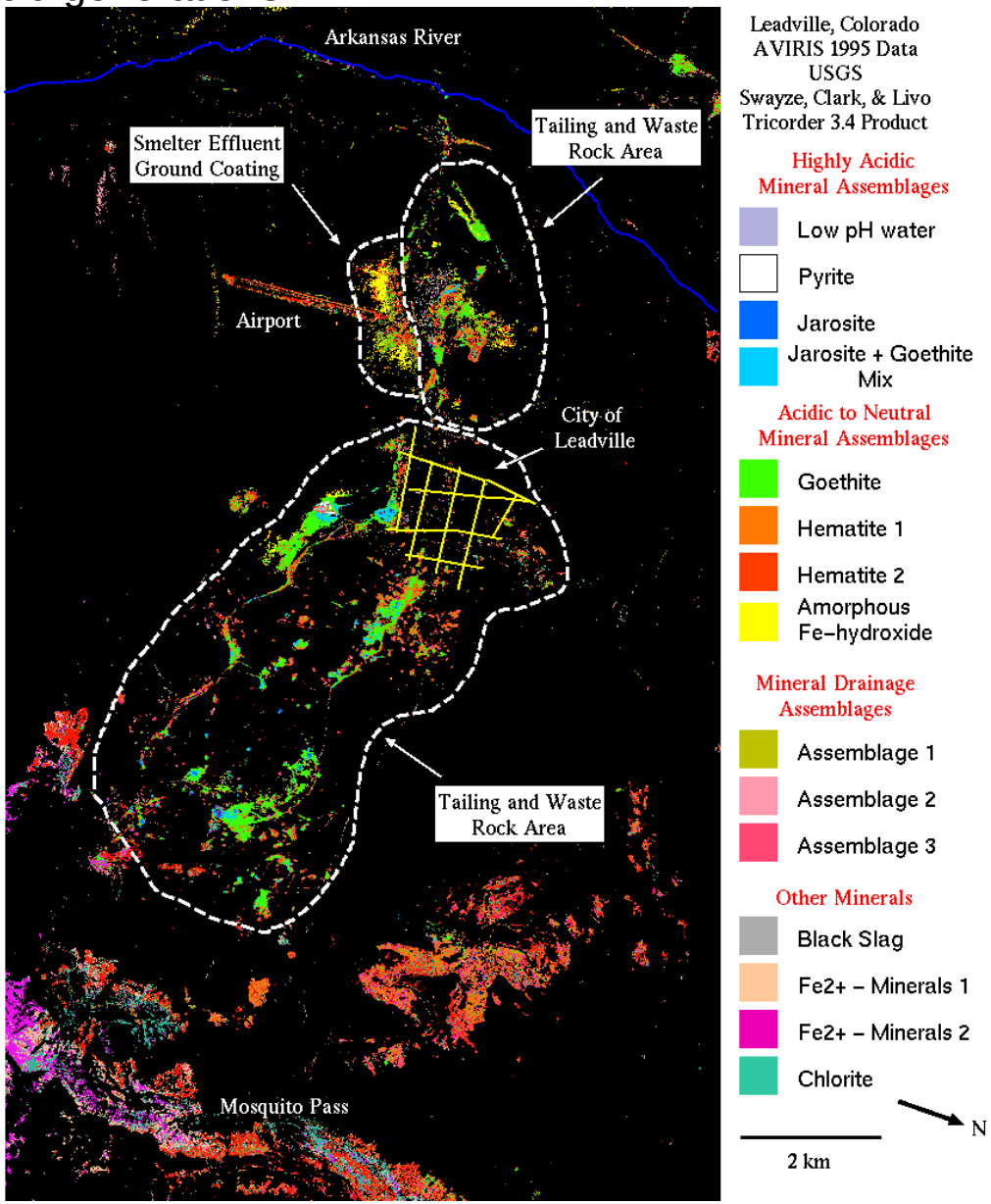
Spectral Measurements of Shallow Water Benthic Composition (E. Hochberg, Nova Southeastern University, FL)

Mapping Superfund Hazards at Leadville, CO

AVIRIS Leadville, CO Image



Surface mineral/geochemistry related to acid generations

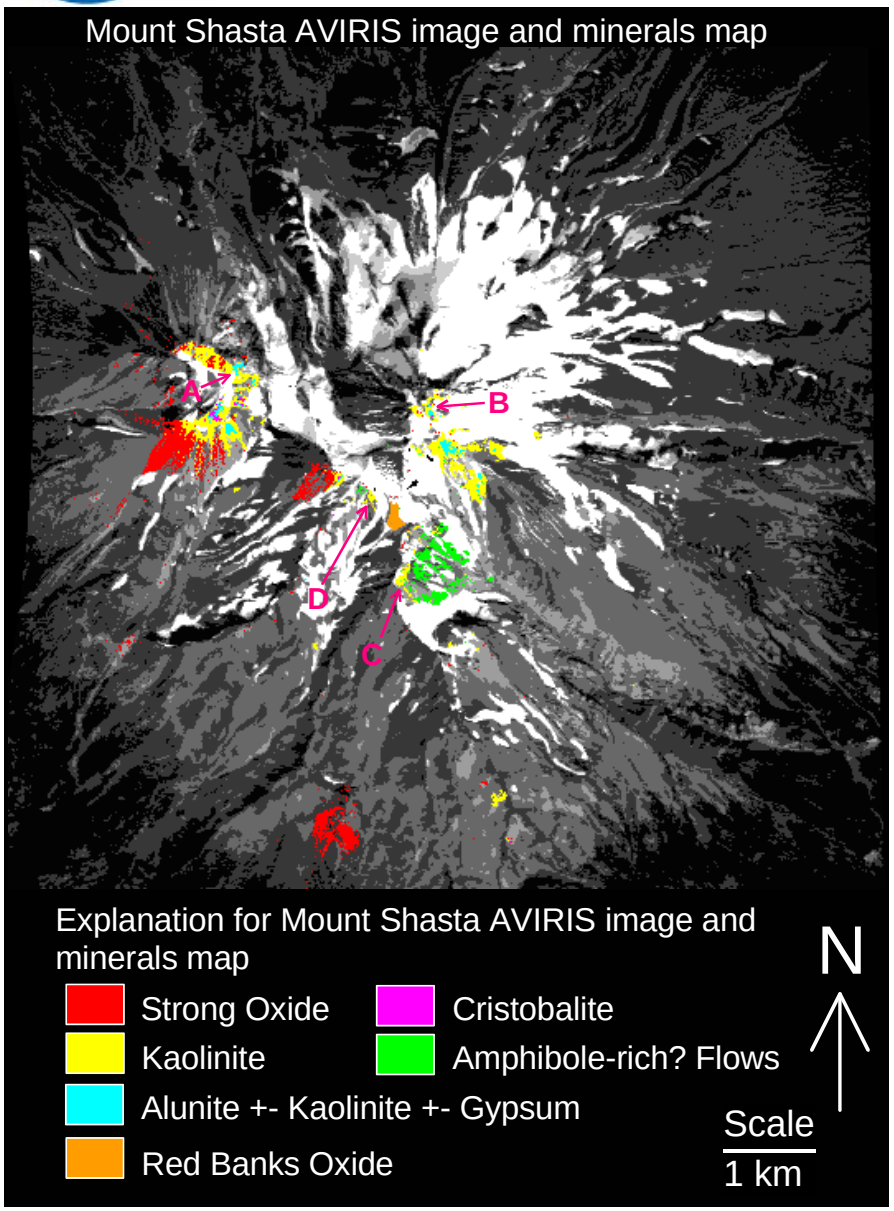


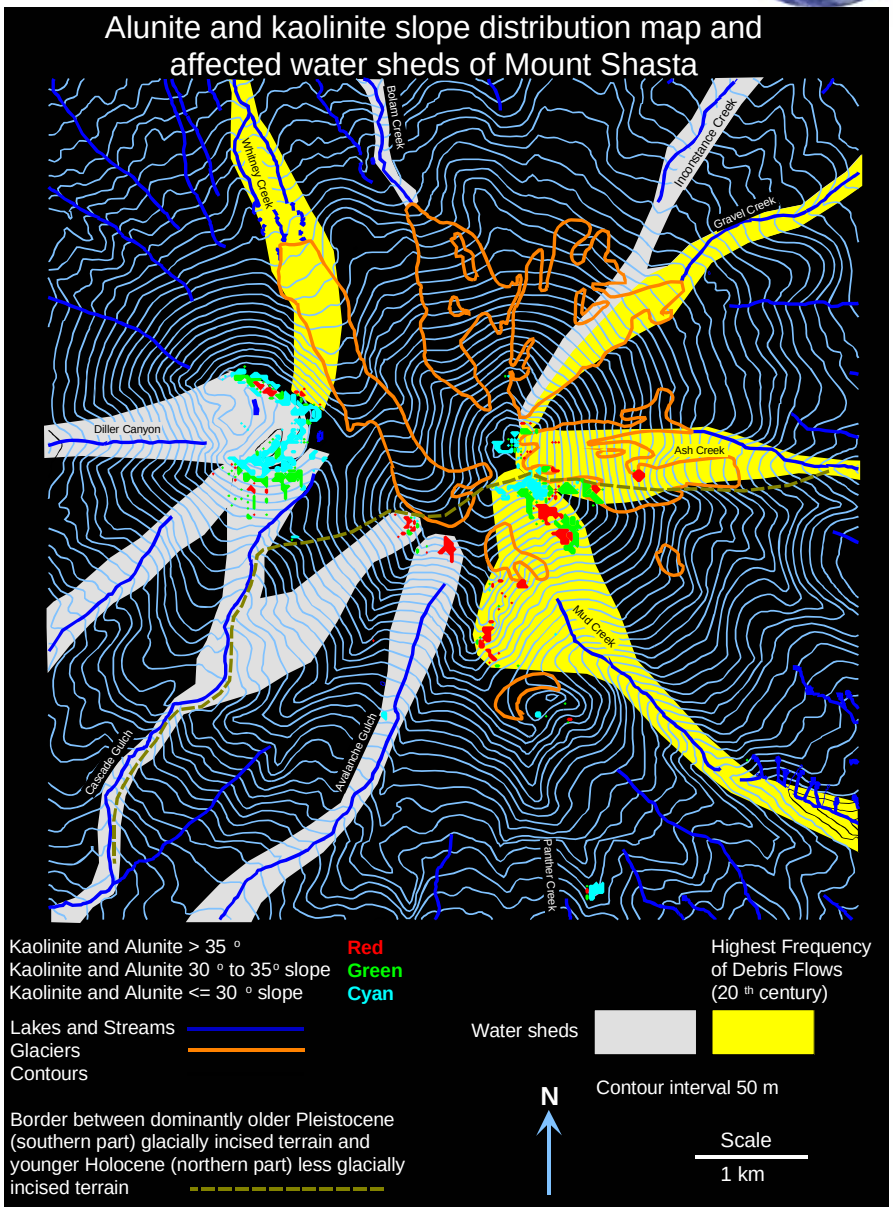
Comment from EPA regarding us of imaging spectroscopy measurement for acid mine hazard remediation

I am writing to convey the support of my office and staff for the AVIRIS program. Remote sensing data collected by NASA/JPL with the Airborne Visible-Infrared Imaging Spectrometer (AVIRIS) instrument of the California Gulch NPL Site near Leadville, Colorado has provided information aiding in the to remediation of heavy metal contamination at this site. AVIRIS data was collected in July of 1995 and was calibrated and mapped using the Tricorder algorithm at the USGS. Similar work was done at the Summitville NPL site and is beginning in the Upper Animas Basin. This work has resulted in, and will continue to produce significant cost savings in site investigations and cleanup activities.

Use of the AVIRIS data and technology has provided an estimated $2 million dollar saving in site investigation study expenditures. The AVIRIS technology has also resulted in shortening of the site investigation process by an estimated 2 ½ years.

Mt Shasta, CA: AVIRIS used to assess volcano debris flow hazard (J. Crowley, USGS)





Science Traceability Matrix

Q ID	Science Objectives		Data Products	Requirements		Spectral Requirements						Resolution Requirements			Radiometric Requirements			
						Spectrum Coverage		Spectral Resolution		Cross-Track Min. Spectral Uniformity	Spectral IFOV Uniformity	Spatial Sampling	Spatial Response	Min. Temporal Resolution	Min. Absolute Calibration	Min. On-orbit Stability	Saturation Radiance	M
	Science Question	*Scientific (Measurement) Objective*		*Mission Functional Requirement*	*Scientific Measurement Requirement*	Start	End	No. of Channels	Bandwidth									
Filter	Filter	Filter		Filter	Filter	nm	nm	-	nm	%	%	m	m	Days	%	%	%	
VQ6 - Composition	**Earth Surface and Coastal Benthic Composition: What is the land surface soil/rock and shallow coastal benthic compositions?**					380	2500	210										
VQ6-1	What does a new level of understanding of the distribution of the minerals and mineral groups on the exposed terrestrial surface tell us about geological processes? [DS 218]	Measure the exposed surface rock and soil compositions globally. Measure the available rock forming and alteration minerals and subtle changes in composition via spectral absorption position and shape. Derive fractional abundance through spectral mixture analysis and related approaches.	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: Atmospheric Correction: Atmospheric Correction validation: Geolocation: Ground processing: latency: yearly 30m (3s) Pointing knowledge	Measure surface reflectance in the VSWIR region (400-2500@10nm) with high precision and accuracy to capture the diagnostic absorptions features of clay, iron, carbonate and other rock/soil forming minerals.	400	2500	210	10	90	90				95	98	0.75	
					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.	740	780	4	10	90	90				95	98	0.75	
						900	1000	10	10	90	90				95	98	0.75	
						1100	1200	10	10	90	90				95	98	0.75	
						1360	1400	4	10	90	90				95	98	0.75	
					Measurements at a spatial scale to resolve material patches at <100m.							60	100					
					Measure yearly (365 day revisit) through several (3) years to observe any changes.									365				
														80				
VQ6-2	What does the composition and distribution of the substrate of shallow water regions tell us about the status and processes of the coastal and marine environment? [DS 114]	Measure globally the shallow water regions and inland waters. Derive the composition of the optically available (e.g. non-turbulent) shallow water bottom regions of the coastal oceans and inland waters.	L2 water leaving radiance and reflectance 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: Atmospheric Correction: Atmospheric Correction validation: Geolocation: Ground processing: latency: yearly 30m (3s) Pointing knowledge	High precision and accuracy spectral signatures in the visible to near infrared (380-900 @10nm sampling) to capture the bottom composition interaction with light.	380	900	52	10	90	90				95	98	0.25	
					Selected wavelengths in the short wavelength infrared (1250, 1650, 2250) to enable atmospheric correction for aquatic observations.	1200	1300	1	100	90	90				95	98	0.25	
						1600	1700	1	100	90	90				95	98	0.25	
						2200	2300	1	100	90	90				95	98	0.25	
					Measurements at a spatial scale to resolve material patches at <100m.							60	100					
					Measure yearly (365 day revisit) through several (3) years to observe the seasonal regional occurrence and trends in the coastal regions.									365				
														80				
VQ6-3	How will results from consistent and detailed global exposed mineral and geochemistry mapping lead to fundamentally concepts for mineral and hydrocarbon research and resource exploration[DS227]	Measure the exposed surface rock and soil compositions globally. Derive mineral and geochemical information (i.e. ion substitution espressed as spectral signature shifts.)	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: ~700mbs downlink: >3X zeroloss compression: ~11 am sun sync LEO orbit: Radiometric calibration: Atmospheric Correction:	Measure surface reflectance in the VSWIR region (400-2500@10nm) with high precision and accuracy to capture the diagnostic absorptions features shifts of clay, iron, carbonate and other rock/soil forming minerals due to variations in geochemistry.	400	2500	210	10	90	90				95	98	0.75	
					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	740	780	4	10	90	90				95	98	0.75	
						900	1000	10	10	90	90				95	98	0.75	

Science Traceability Matrix (1-3)

Q ID	Science Objectives		Data Products	Requirements	
	Science Question	*Scientific (Measurement) Objective*		*Mission Functional Requirement*	*Scientific Measurement Requirement*
Filter	Filter	Filter		Filter	Filter
VQ6-1	What does a new level of understanding of the distribution of the minerals and mineral groups on the exposed terrestrial surface tell us about geological processes? [DS 218]	Measure the exposed surface rock and soil compositions globally. Measure the available rock forming and alteration minerals and subtle changes in composition via spectral absorption position and shape. Derive fractional abundance through spectral mixture analysis and related approaches.	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: Atmospheric Correction: Atmospheric Correction validation: Geolocation: Ground processing: latency: yearly 30m (3s) Pointing knowledge	Measure surface reflectance in the VSWIR region (400-2500@10nm) with high precision and accuracy to capture the diagnostic absorptions features of clay, iron, carbonate and other rock/soil forming minerals. 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. Measurements at a spatial scale to resolve material patches at <100m. Measure yearly (365 day revisit) through several (3) years to observe any changes.
VQ6-2	What does the composition and distribution of the substrate of shallow water regions tell us about the status and processes of the coastal and marine environment? [DS 114]	Measure globally the shallow water regions and inland waters. Derive the composition of the optically available (e.g. non-turbulent) shallow water bottom regions of the coastal oceans and inland waters.	L2 water leaving radiance and reflectance 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: Atmospheric Correction: Atmospheric Correction validation: Geolocation: Ground processing: latency: yearly 30m (3s) Pointing knowledge	High precision and accuracy spectral signatures in the visible to near infrared (380-900 @10nm sampling) to capture the bottom composition interaction with light. Selected wavelengths in the short wavelength infrared (1250, 1650, 2250) to enable atmospheric correction for aquatic observations. Measurements at a spatial scale to resolve material patches at <100m. Measure yearly (365 day revisit) through several (3) years to observe the seasonal regional occurrence and trends in the coastal regions.
VQ6-3	How will results from consistent and detailed global exposed mineral and geochemistry mapping lead to fundamentally concepts for mineral and hydrocarbon research and resource exploration[DS227]	Measure the exposed surface rock and soil compositions globally. Derive mineral and geochemical information (i.e. Ion substitution expressed as spectral signature shifts.)	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: ~700mbs downlink: >3X zeroloss compression: ~11 am sun sync LEO orbit: Radiometric calibration: Atmospheric Correction: AC validation: Geolocation: Ground processing: latency: yearly 30m (3s) Pointing knowledge	Measure surface reflectance in the VSWIR region (400-2500@10nm) with high precision and accuracy to capture the diagnostic absorptions features shifts of clay, iron, carbonate and other rock/soil forming minerals due to variations in geochemistry. 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. Measurements at a spatial scale to resolve material patches at <100m. Measure yearly (365 day revisit) through several (3) years to observe changes.

Science Traceability Matrix (VQ4-6)

Q ID	Science Objectives		Data Products	Requirements	
	Science Question	*Scientific (Measurement) Objective*		*Mission Functional Requirement*	*Scientific Measurement Requirement*
Filter	Filter	Filter	Filter	Filter	Filter
VQ6-4	What can we learn about event and seasonal process driven responses that occur in shallow coastal and inland aquatic environments? [DS 25]	Measure the composition of the optically available shallow water bottom regions of the coastal oceans and inland waters. Bottom substrate composition of sand, coral, mud, SAV,etc. More detailed specificity as possible with the available signal.	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: Atmospheric Correction: Atmospheric Correction validation: Geolocation: Ground processing: latency: seasonal 30m (3s) Pointing knowledge	Measure surface reflectance in the visible to near infrared (380-900 @10nm) at high precision and accuracy to capture the bottom composition interaction with light. Selected wavelengths in the short wavelength infrared (1250, 1650, 2250) to enable atmospheric correction for aquatic observations. Measurements at a spatial scale to resolve material patches at <100m. Measure seasonally (90 day revisit) through several (3) years to observe the seasonal regional occurrence and trends in the coastal regions.
VQ6-5	How can new more accurate measurements of rock and soil composition and physical state be used to understand and mitigate geohazards? [DS227]	Measure the exposed surface rock and soil compositions globally to determine the occurrence of hazard associated minerals (For example, Acid generating minerals, Asbestos, etc.). Derive fractional abundance of hazardous minerals through spectral mixture analysis and related approaches.	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: Atmospheric Correction: Atmospheric Correction validation: Geolocation: Ground processing: latency: yearly 30m (3s) Pointing knowledge	Measure surface reflectance in the VSWIR region (400-2500@10nm) with high precision and accuracy to capture the diagnostic absorptions features of acid generating (sulfates), asbestos, minerals. 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. Measurements at a spatial scale to resolve material patches at <100m. Measure at least seasonally through several (3) years to observe baseline and new hazards and changes in hazards.
VQ6-6	How does the spatial distribution of snow & ice and the related properties of grain size, dust impurities, and albedo inform our knowledge of regional energy balance, hydrology and related surface processes?	Measure the exposed regionally snow covered area seasonally Derive snow covered area, grain size, dust impurites.	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: Atmospheric Correction: Atmospheric Correction validation: Geolocation: Ground processing: latency: yearly 30m (3s) Pointing knowledge	Measure surface reflectance in the VSWIR region (400-2500@10nm) with high precision and accuracy to capture the diagnostic absorptions features of acid generating (sulfates), asbestos, minerals. 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. Measurements at a spatial scale to resolve material patches at <100m. Measure at least seasonally through several (3) years to observe baseline and change.

VQ6 Alignment with Decadal Survey

- The VQ6 science questions are aligned with the HyspIRI mission of the Decadal Survey [DS114, etc.]
- The science traceability matrix for VQ6 links the science question to the measurement requirements through the required products.
- The measurement requirements for VQ6 are aligned with the Decadal Survey baseline mission.

Example Level 3 products

- Level 3 fraction exposed rock and soil
- Level 3 surface dominant mineralogy in orthorectified format
- Level 3 surface mineral mixture map
- Level 3 surface mineral acid generation potential map
- Level 3 soil composition map
- Level 3 shallow water substrate composition
- Level 3 shallow water substrate fractions
- Level 4 change is shallow water substrate

Validation Approaches

- Rigorous Level 2 product validation is required
  - Surface reflectance
    - spectral, radiometric, spatial, uniformity…
  - Water leaving radiance and water reflectance
    - With glint and foam correction
    - spectral, radiometric, spatial, uniformity…
- Level 3 surface mineral and mineral fractions validation
  - Focused ground truth over range of surface, atmosphere and observation conditions
- Level 3 soil composition validation
    - Focused ground truth over range of surface, atmosphere and observation conditions
- Level 3 shallow water substrate composition validation
    - Focused ground truth over range of surface, atmosphere and observation conditions
    - Close coordination with existing in situ measurement activities
      - Domestic
      - International

Validation Approaches

- Rigorous Level 2 product validation is required
  - Surface reflectance
    - spectral, radiometric, spatial, uniformity…
  - Water leaving radiance and water reflectance
    - spectral, radiometric, spatial, uniformity…
- Level 3 surface mineral map validation
  - Focused ground truth over range of surface, atmosphere and observation conditions
- Level 3 soil composition map validation
    - Focused ground truth over range of surface, atmosphere and observation conditions
- Level 3 shallow water substrate composition validation
    - Focused ground truth over range of surface, atmosphere and observation conditions

Precursor Science

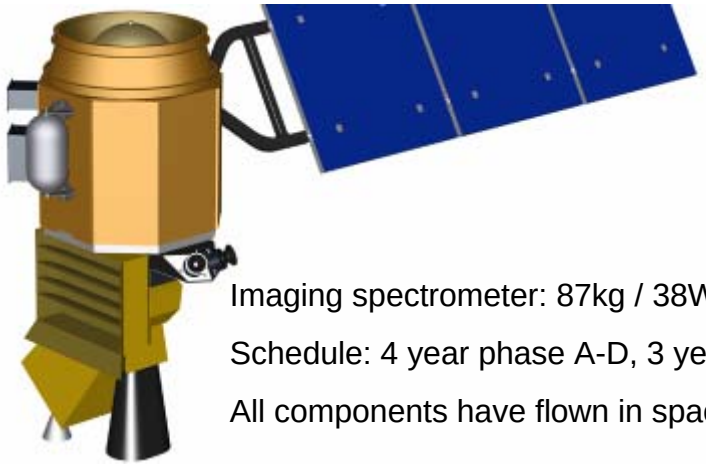
- Surface mineral geochemistry regional experiment.
  - Refine spectral absorption shift connection to subtle geochemistry
- Shallow water substrate algorithm research, refinement and testing
  - Validation with ongoing activities
  - Inland water experiments
- Surface geohazards regional experiment utilizing VSWIR type measurements.
  - Acid surface material
  - Problematic surface materials
  - other

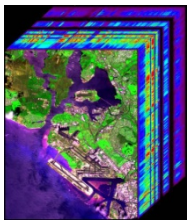
VQ6 Summary

- Within the time available we have covered the requested topics for review of the HyspIRI VQ6 science questions
  - Overarching Question and Subquestions
  - Examples of the Science
  - Science Traceability Matrix
  - Alignment with Decadal Survey
  - Example Level 3 Products
  - Validation Approaches
  - Precursor Science

Questions and Discussion

HyspIRI Imaging Spectroscopy (VSWIR) Science Measurements





Imaging spectrometer: 87kg / 38W

Schedule: 4 year phase A-D, 3 years operations

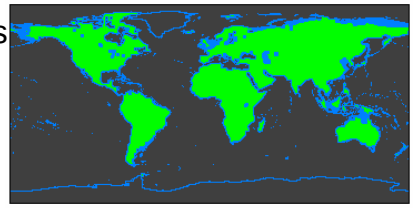
All components have flown in space

Science Questions:

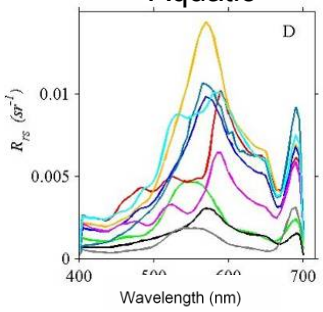
- *What is the composition, function, and health of land and water ecosystems?*
- *How are these ecosystems being altered by human activities and natural causes?*
- *How do these changes affect fundamental ecosystem processes upon which life on Earth depends?*

Measurement:

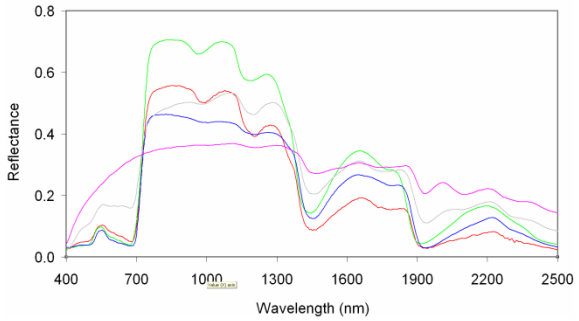
- 380 to 2500 nm in 10nm bands
- Accurate location 60m spatial
- 19 days revisit
- Global land and shallow water



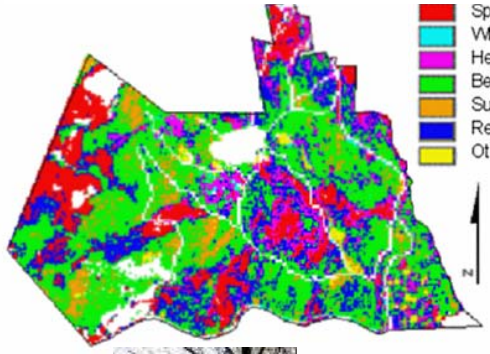
Aquatic

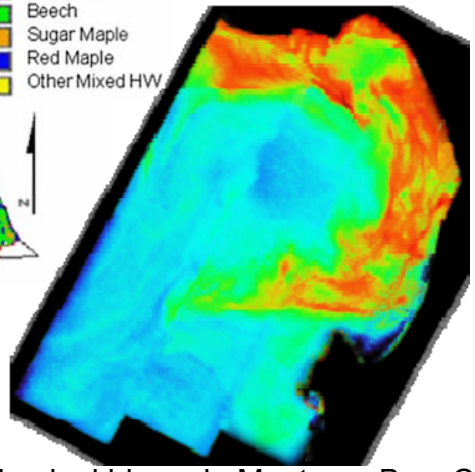


Terrestrial



Map of dominant tree species, Bartlett Forest, NH





Red tide algal bloom in Monterey Bay, CA