HyspIRI

VSWIR Science Measurement Baseline

NASA Earth Science and Applications Decadal Survey

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NRC Decadal Survey HyspIRI

Visible ShortWave InfraRed (VSWIR) Imaging Spectrometer + Multispectral Thermal InfraRed (TIR) Scanner

VSWIR: Plant Physiology and Function Types (PPFT)

Multispectral TIR Scanner

Map of dominant tree species, Bartlett Forest, NH

Red tide algal bloom in Monterey Bay, CA
HyspIRI Imaging Spectroscopy
Science Measurements

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 channels
• Accurate 60 m sampling
• 19 days revisit mapping mission
• Global land and shallow water

Map of dominant tree species, Bartlett Forest, NH

Red tide algal bloom in Monterey Bay, CA
VSWIR Overarching Science Questions

- **VQ1. Pattern and Spatial Distribution of Ecosystems and their Components, (EM,JG)**
  - What is the pattern of ecosystem distribution and how do ecosystems differ in their composition or biodiversity? [DS 195]

- **VQ2. Ecosystem Function, Physiology and Seasonal Activity, (EM,JG)**
  - What are the seasonal expressions and cycles for terrestrial and aquatic ecosystems, functional groups and diagnostic species? How are these being altered by changes in climate, land use, and disturbances? [DS 191, 195, 203]

- **VQ3. Biogeochemical Cycles (SO, SU)**
  - How are biogeochemical cycles for carbon, water and nutrients being altered by natural and human-induced environmental changes?

- **VQ4. Changes in Disturbance Activity (RK,GA)**
  - How are disturbance regimes changing and how do these changes affect the ecosystem processes that support life on Earth?

- **VQ5. Ecosystem and Human Health, (PT,GG)**
  - How do changes in ecosystem composition and function affect human health, resource use, and resource management?

- **VQ6. Land Surface and Shallow Water Substrate Composition (RG, HD)**
  - What is the land surface soil/rock and shallow water substrate composition?
Plant and phytoplankton functional types and species have biochemical and biophysical properties that are expressed as reflectance and absorption features spanning the spectral region from 380 to 2500 nm.

Individual bands do not capture the diversity of biochemical and biophysical signatures of plant functional types or species.

Changes in the chemical and physical configuration of ecosystems are often expressed as changes in the contiguous spectral signatures that relate directly to plant functional types, vegetation health, and species distribution.

Other constituents of the Earth system (Minerals, Soils, Snow, etc) have spectral characteristics allow use of this spectroscopic measurement approach for corresponding science questions.

Important atmospheric correction information and calibration feedback is contained within the spectral measurement.
Vegetation Functional Type Analysis, Santa Barbara, CA

Dar Roberts, et al, UCSB

MESMA Species Type 90% accurate

Species Fractional Cover
Biogeochemical Cycles

Canopy Nitrogen from imaging spectroscopy.

AVIRIS

HYPERION

R² = 0.83
R² = 0.79

Observed %N

Predicted %N

VEGETATION

Reflectance

Wavelength (nm)

0.02 0.4 0.6 0.8 1.0

400 800 1200 1600 2000 2400

Plot-level canopy N measured on a wide variety of sites. GPS coordinates allow plots to be identified on images. Reflectance spectra extracted for each plot. PLS Regressions relate spectral features to measured %N.
Interannual changes in canopy moisture show significant stand age differences up to 30 years (shown as the difference in canopy moisture between spring98 and spring 97 – blue, and spring97 and spring 95 - green). These results indicate that seasonal drought response is age dependent in shrublands, with older stands less impacted by drought. These results require seasonal imaging spectroscopy observations.
Airborne imaging spectrometer measurements
Red tide in Monterey Bay, CA

A spectral measurement is required to determine the species type including species that cause potential harmful algal blooms.
Spectral Measurements of Shallow Water Benthic Composition (E. Hochberg, Nova Southeastern University, FL)
HyspIRI VSWIR – PPFT
Imaging Spectrometer
Measurement Characteristics
HyspIRI VSWIR Science Measurements

- Measure the **global** land and coastal/shallow water (> -50m).
- 19 day equatorial revisit to generate seasonal and annual products.

- Measure the molecular absorption and constituent scattering signatures in the spectral range from 380 to 2500 nm at 10 nm, and at 60 m spatial sampling.
HyspIRI VSWIR
Science Measurement Characteristics

Spectral
- Range: 380 to 2500 nm in the solar reflected spectrum
- Sampling: <= 10 nm {uniform over range}
- Response: <= 1.2 X sampling (FWHM) {uniform over range}
- Accuracy: <0.5 nm

Radiometric
- Range & Sampling: 0 to 1.5 X max benchmark radiance, 14 bits measured
- Accuracy: >95% absolute radiometric, 98% on-orbit reflectance, 99.5% stability
- Precision (SNR): See spectral plots at benchmark radiances
- Linearity: >99% characterized to 0.1 %
- Polarization: <2% sensitivity, characterized to 0.5 %
- Scattered Light: <1:200 characterized to 0.1%

Spatial
- Range: >150 km (12 degrees at 700 km altitude)
- Cross-Track Samples: >2500
- Sampling: <=60 m
- Response: <=1.2 X sampling (FWHM)

Uniformity
- Spectral Cross-Track: >95% cross-track uniformity {<0.5 nm min-max over swath}
- Spectral-IFOV-Variation: >95% spectral IFOV uniformity {<5% variation over spectral range}
**HyspIRI VSWIR Science Measurements Characteristics**

<table>
<thead>
<tr>
<th>Temporal</th>
<th>11 am sun synchronous descending</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orbit Crossing</td>
<td>19 days at equator</td>
</tr>
<tr>
<td>Global Land Coast</td>
<td>3 days (cross-track pointing)</td>
</tr>
<tr>
<td>Repeat</td>
<td></td>
</tr>
<tr>
<td>Rapid Response Revisit</td>
<td></td>
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**Sunglint Reduction**

| Cross Track Pointing | 4 degrees in backscatter direction |

**OnOrbit Calibration**

| Lunar View | 1 per month {radiometric} |
| Solar Cover Views | 1 per day {radiometric} |
| Dark signal measurements | 1 per orbit and edge detector tracking |
| Surface Cal Experiments | 3 per year {spectral & radiometric} |

**Data Collection**

| Land Coverage          | Land surface above sea level excluding ice sheets |
| Water Coverage         | Coastal zone -50 m and shallower |
| Solar Elevation        | 20 degrees or greater |
| Open Ocean/Ice Sheets  | Averaged to 1km spatial sampling |
| Compression            | >=3.0 lossless |
HyspIRI VSWIR Science Measurements
Key SNR and Uniformity Requirements

**Benchmark Radiances**

- 0.01 reflectance (z45)
- 0.05 reflectance (z45)
- 0.25 reflectance (z23.5)
- 0.50 reflectance (z23.5)

**Required SNR**

- SNR 0.01 Reflectance (z45) 60m
- SNR 0.05 Reflectance (z45) 60m
- SNR 0.25 Reflectance (z23.5) 60m
- SNR 0.50 Reflectance (z23.5) 60m

**Uniformity Requirement**

**Depiction**
- Grids are the detectors
- Dots are the IFOV centers
- Colors are the wavelengths

**Requirement**

- Spectral Cross-Track: >95% cross-track uniformity {<0.5 nm min-max over swath}
- Spectral-IFOV-Variation: >95% spectral IFOV uniformity {<5% variation over spectral range}
HyspIRI: Building on NASA Hyperion Technology Demonstration

SNR > 10X

Uniformity > 10X

Wavelength

Cross Track Sample

Swath > 10X

Soil C:N Ratio

White Mountain National Forest, NH

Global Coverage >> 10X
Heritage: NASA Moon Mineralogy Mapper

Passed Pre-ship review 3 May 2007
- Mouroulis Offner Design (HyspIRI)
- Convex e-beam grating (HyspIRI)
- 6604a MCT full range detector array, multiplexor & signal chain (HyspIRI)
- Uniform slit (HyspIRI)
- 0.5 micron adjustment mounts lockable for flight
- Aligned to 95% cross-track uniformity (HyspIRI)
- Aligned to 95% spectral IFOV uniformity (HyspIRI)
- Meets high SNR requirements (HyspIRI)
- Passive radiator (HyspIRI)

Mass 8 kg, Power 15 Watts

Cross-track uniformity > 95%

First spectrum 18 Months from funding start
Heritage: M3 NASA Imaging Spectrometer

M3 Installed on ISRO Chandraayan-1 spacecraft, Launched 22 Oct 2008

- First light in lunar orbit 19 Nov 2008
Moon Mineralogy Mapper

Quick Spectral Content Analysis
M3 Nearside
31 Jan to 14 Feb 2009
Optical Period 1 of 4

Dr. Joseph Boardman
Image of Earth from the Moon acquired by the NASA Discovery Moon Mineralogy Mapper (M3) that is a guest instrument onboard the ISRO Chandrayaan-1 Mission to the Moon. Australia is visible in the lower center of the image. The image is presented as a false color composite with oceans dark blue, clouds white, and vegetation enhanced green. The data were acquired on the 22nd of July 2009.
Summary

We have developed a set of VSWIR science questions that are well aligned with the HyspIRI Mission called for in the NASA Earth Science and Applications Decadal Survey.

We have reviewed and refined these questions that relate to both science and applications objectives and developed traceability to a set of science measurements.

In preparation for a NASA Mission Concept Review (MCR) we have established a high heritage and low risk approach for acquiring the HyspIRI VSWIR science measurements.