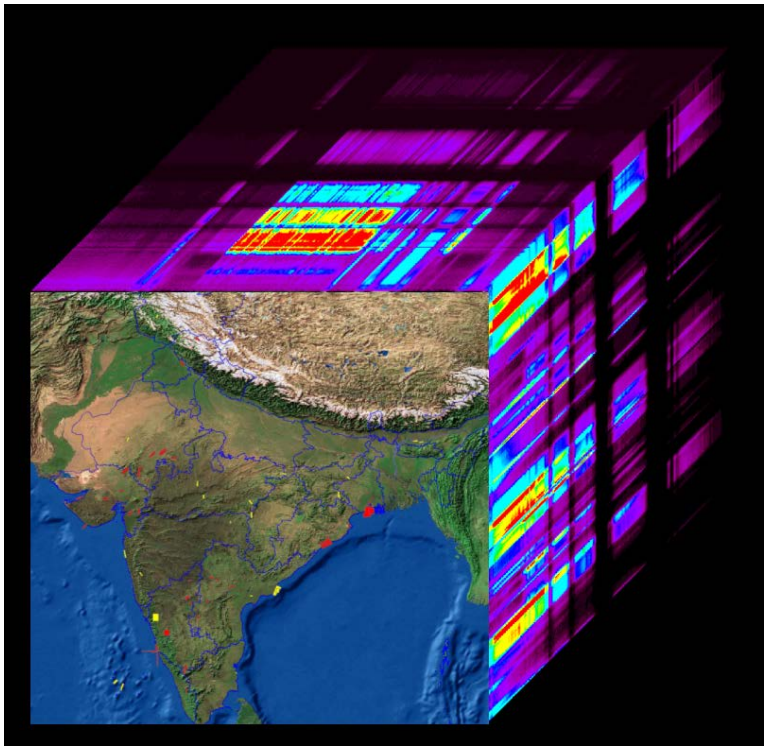
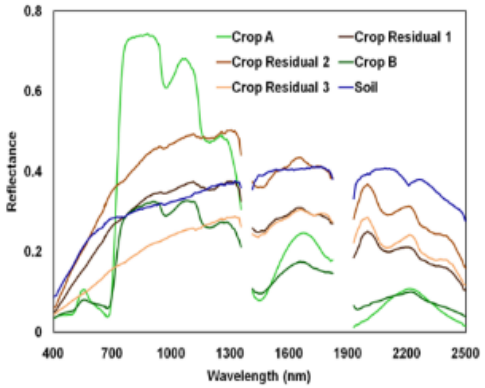
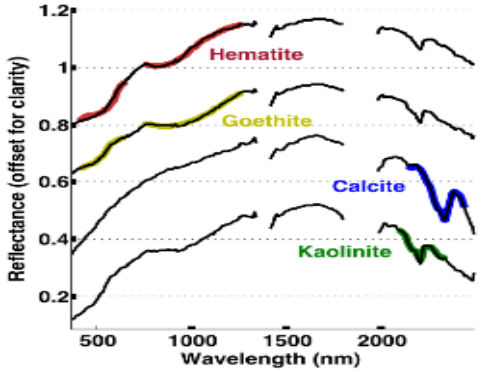
NEW MEASUREMENTS OF THE EARTH'S SPECTROSCOPIC DIVERSITY ACQUIRED DURING THE AVIRIS-NG CAMPAIGN TO INDIA



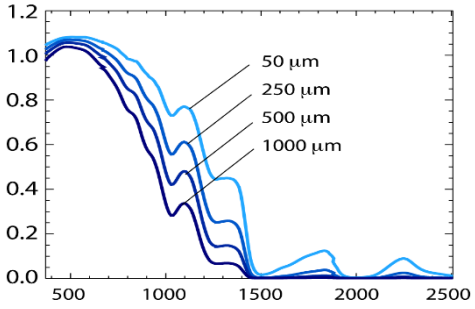
Agriculture and Ecosystems



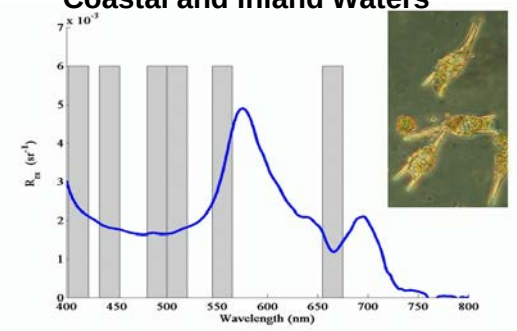
Geology and Soils



Snow and Ice



Coastal and Inland Waters



Robert O. Green, David R. Thompson, Michael Eastwood and Campaign Team

Jet Propulsion Laboratory, California Institute of Technology

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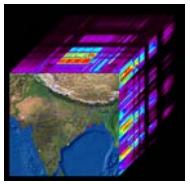
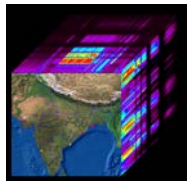
Overview



- Imaging Spectroscopy
- Joint Campaign Objectives
- Science and Applications Research Objectives
- The Airborne Campaign
- Science Investigations
- Summary and Conclusions

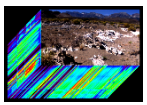
Imaging Spectroscopy: Detect, Identify, Quantify and Monitor



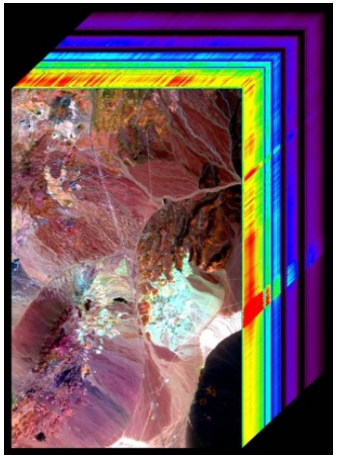
Space

Airborne

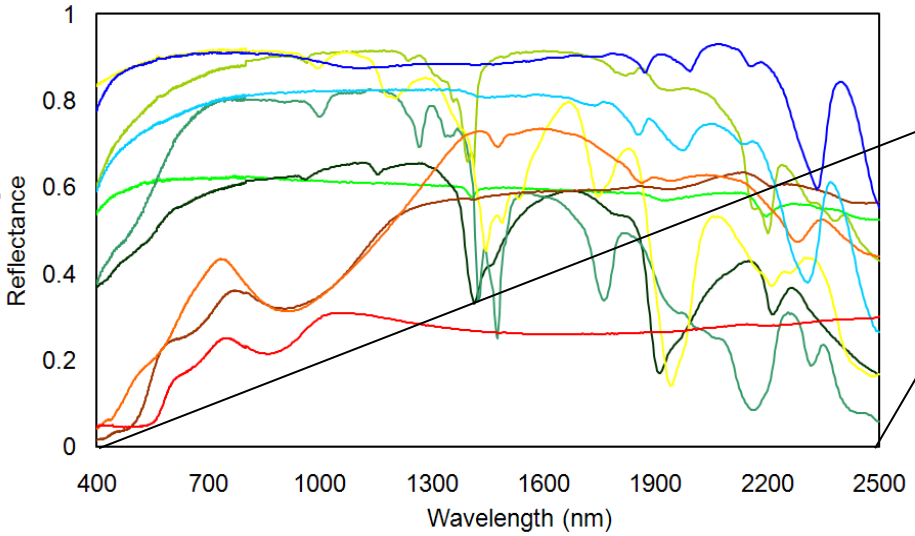
Ground

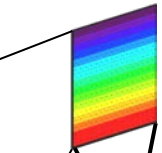


Calibrated Image Cube



100s of Parallel Spectrometers





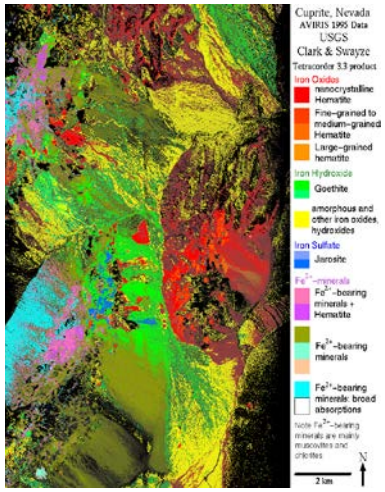
Detector Array

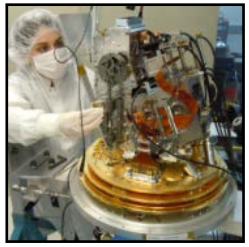
Spectrometer

Slit

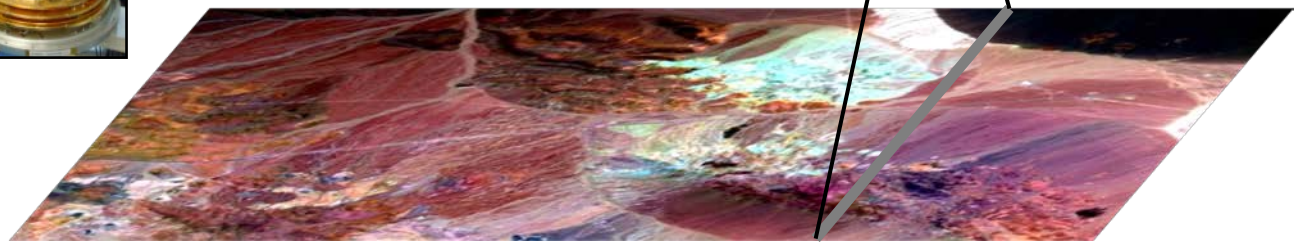
Telescope

Material Map

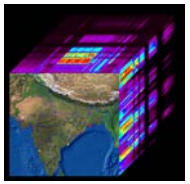


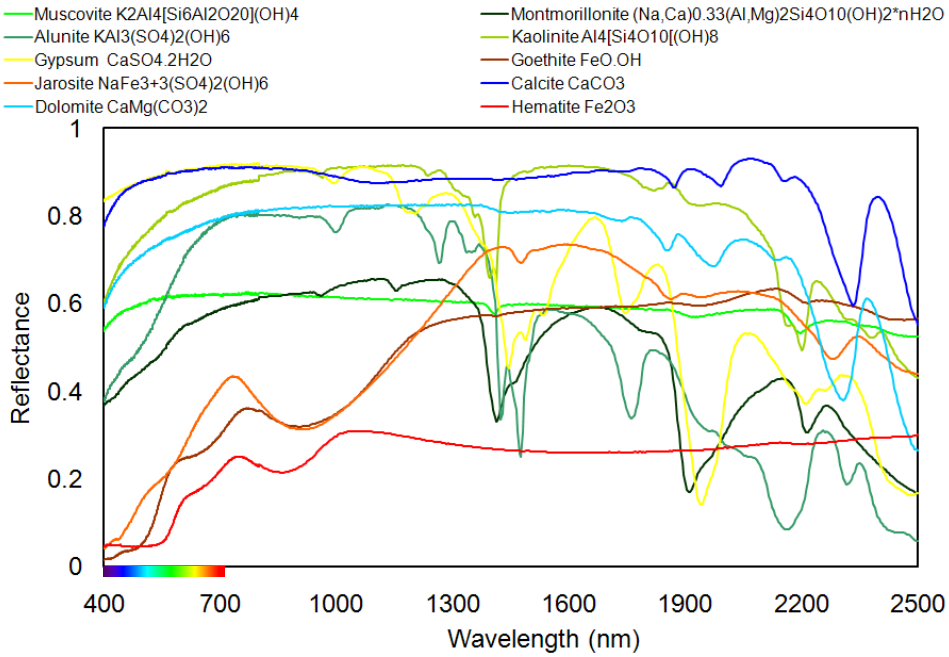


AVIRIS-NG



Example Spectroscopic Measurement of Minerals

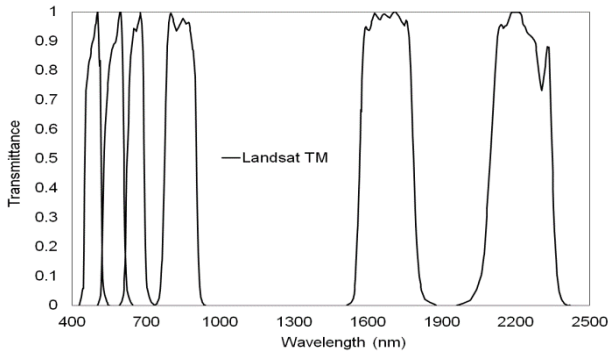




← Spectroscopy is required

Material detection, identification, measurement and monitoring

Multi-Spectral under samples the spectral signatures



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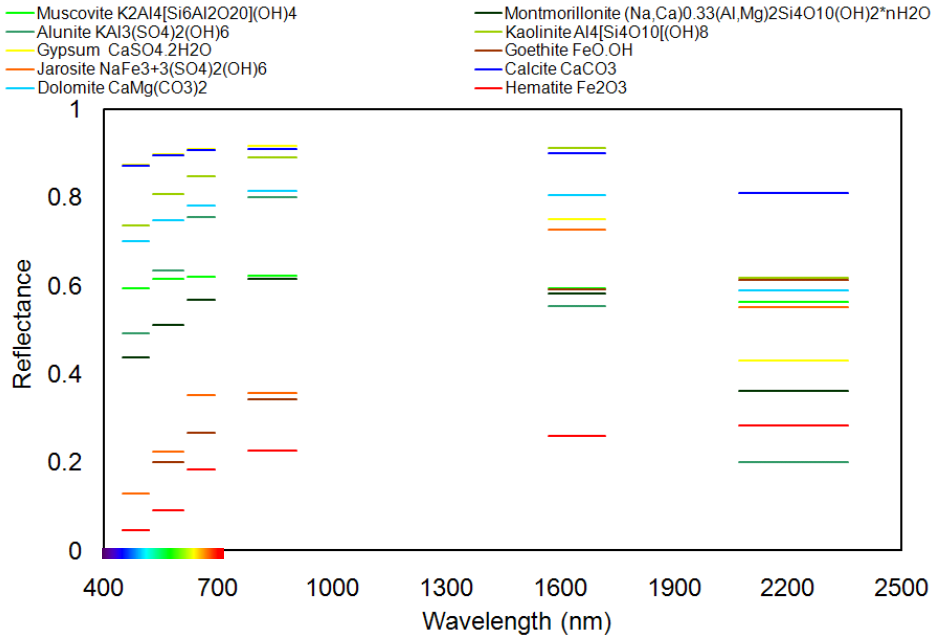
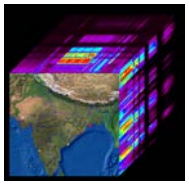
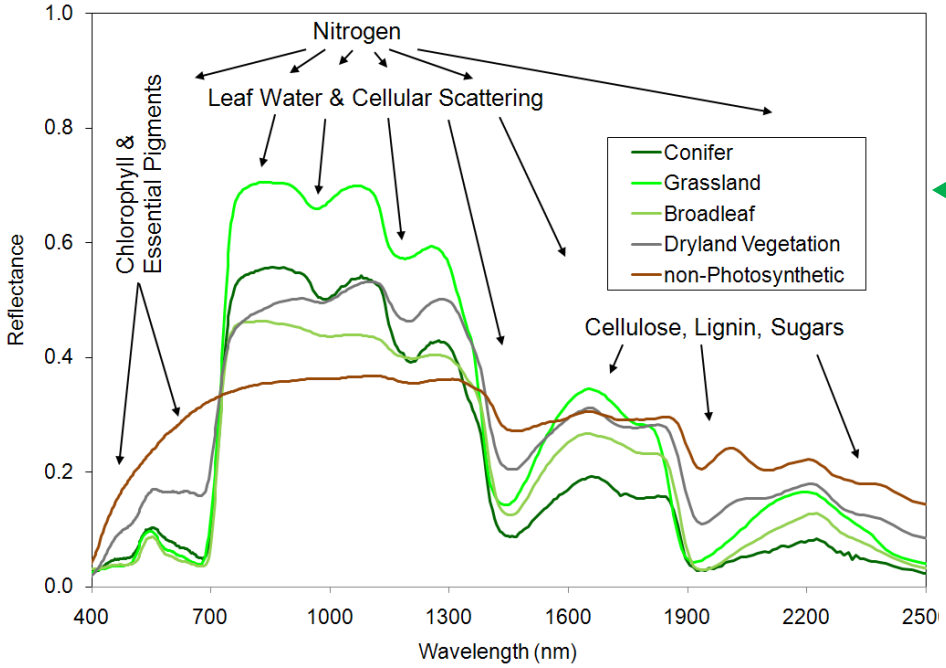


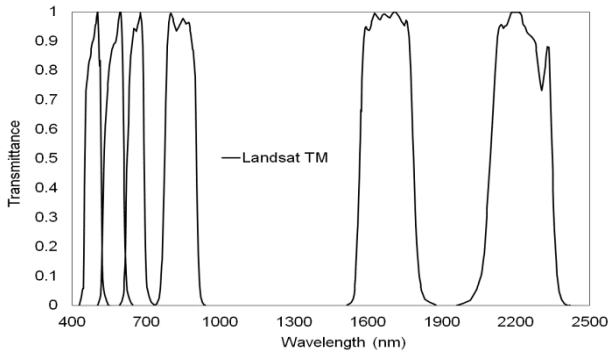
Measuring the Terrestrial Biosphere

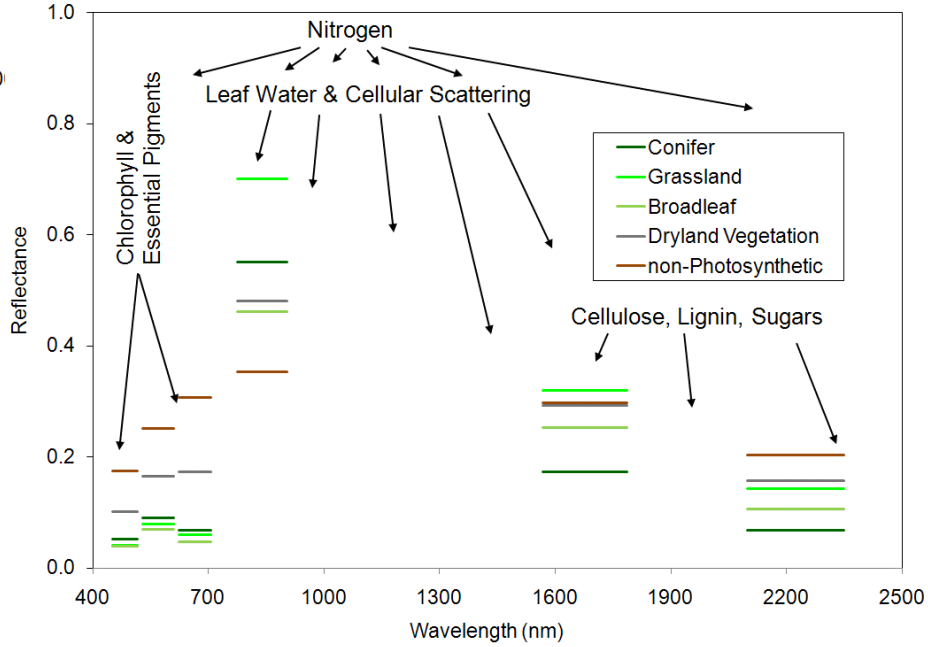




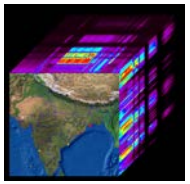
Imaging Spectroscopy is required to measure critical variables of the terrestrial biosphere.

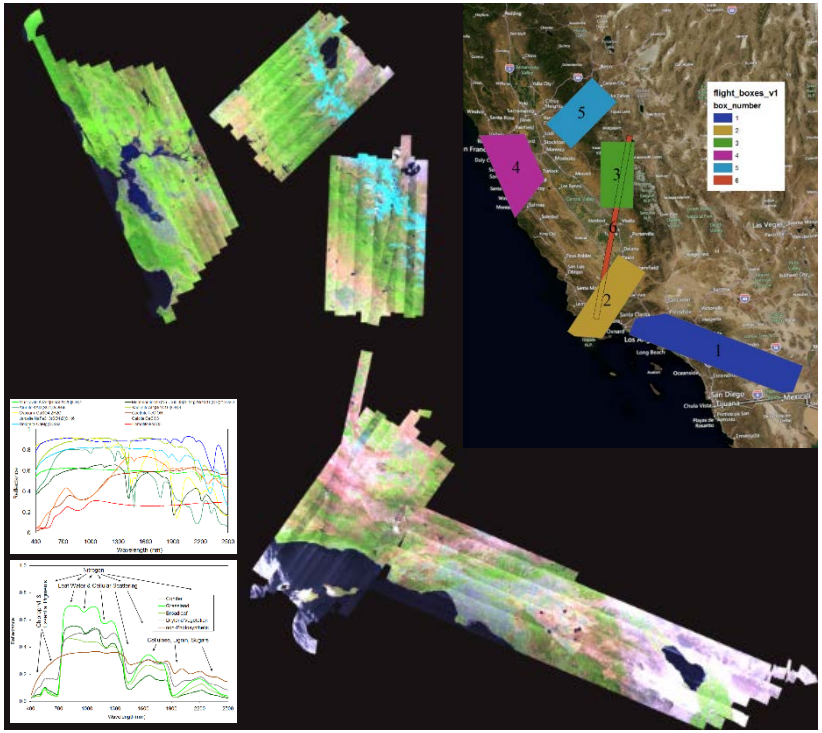
Multi-spectral under samples the spectral information.

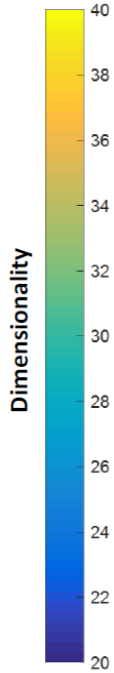


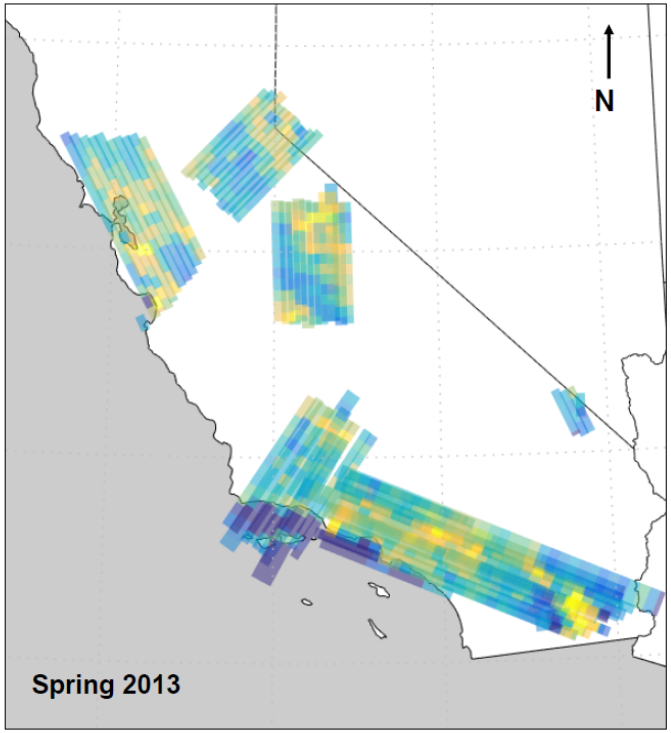


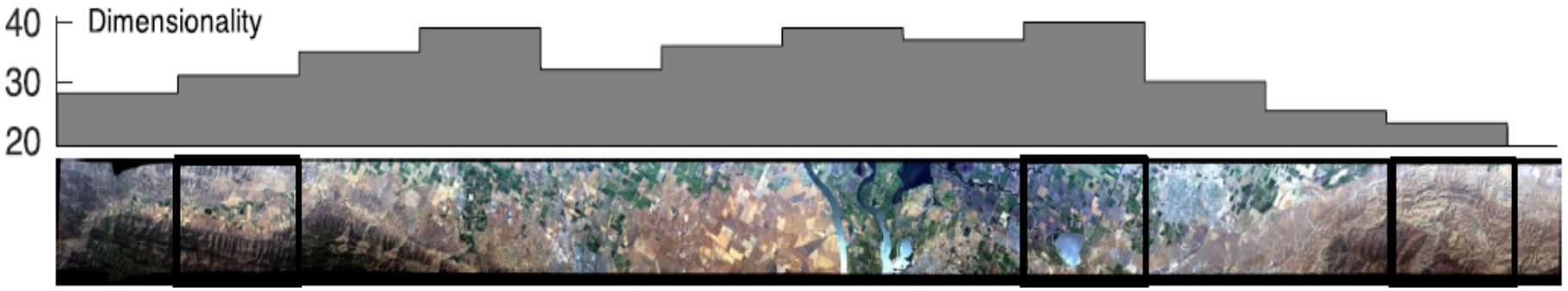
Information Richness Spanning Earth System Environments





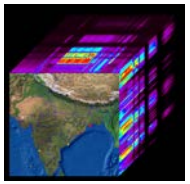






D. R. Thompson, J. W. Boardman, R. O. Green, M. Eastwood. A Large Airborne Survey of Earth's Visible-Infrared Spectral Dimensionality. Optics Express, Vol. 25, Issue 8, pp. 9186-9195, 2017.

Campaign Objectives

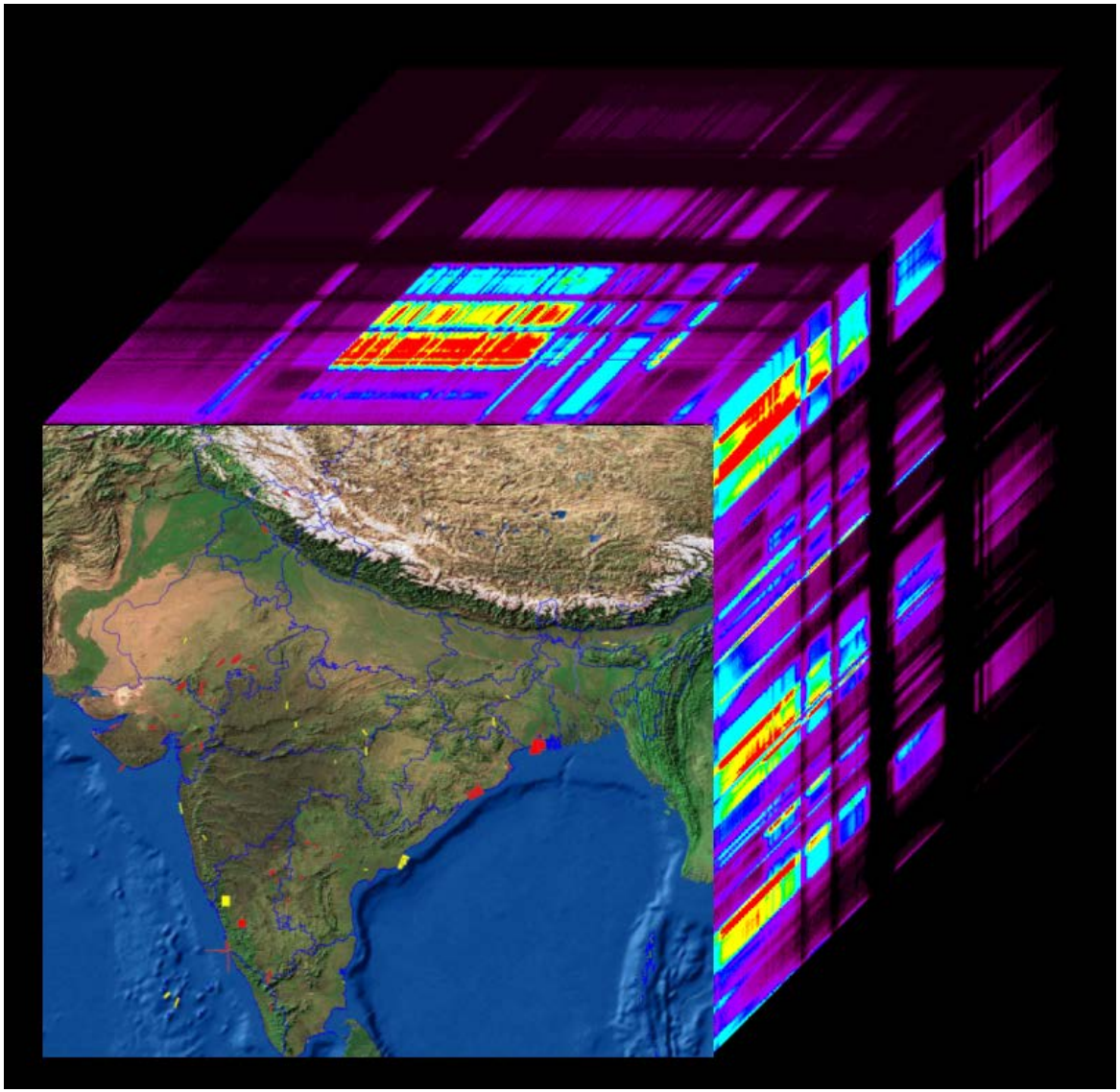


The mission's target areas for imaging spectroscopy science, application investigation, and demonstration shall be over Indian territory. The mission's targeted applications shall address:

- Agriculture and Ecosystems
- Mineral Resource Mapping and Geochemistry
- Coastal Oceans
- Rivers and Water Quality
- Urban and Cities
- Snow, Ice Hydrology, and Glaciers

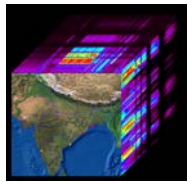
Extraordinary Diversity

57 Diverse Target Sites

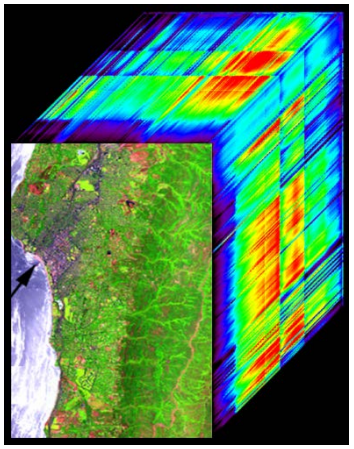


Imaging Spectroscopy: Ecosystem Example

Provides unique access to detailed composition and process understanding via spectroscopy for every sample in the image

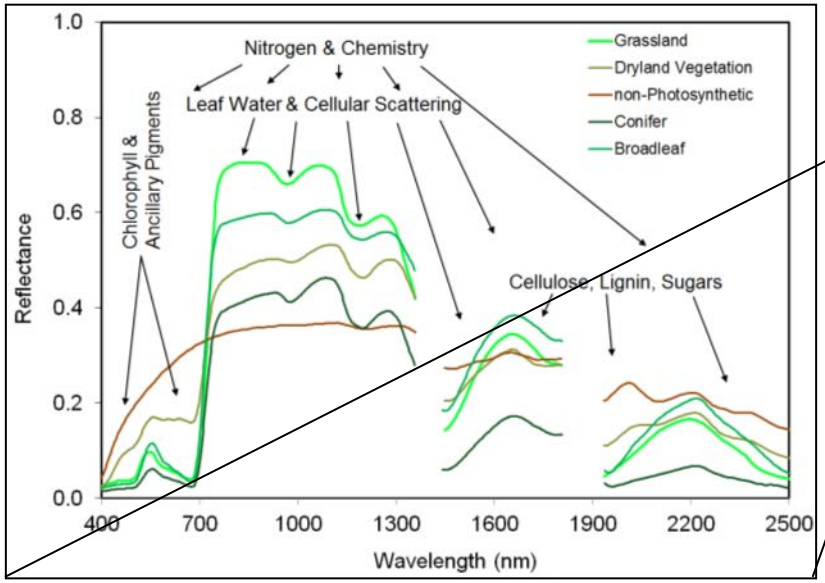


Calibrated Image Cube

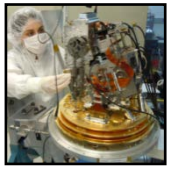


Ecosystem composition, function, chemistry, diversity etc.

≥100's of Parallel Spectrometers



AVIRIS-NG

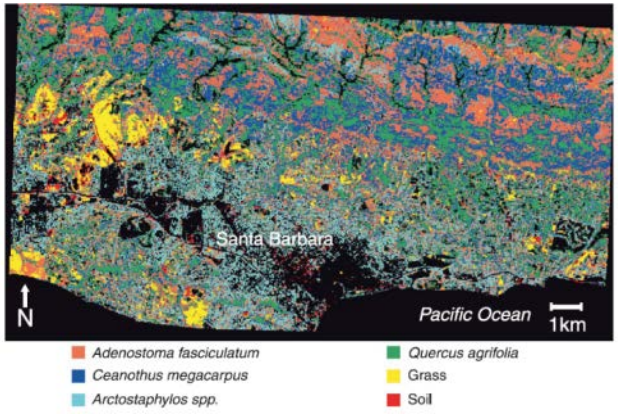


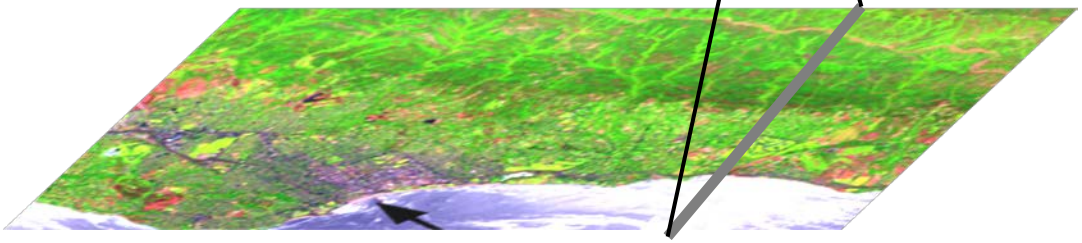
Area Array Detector

Spectrometer

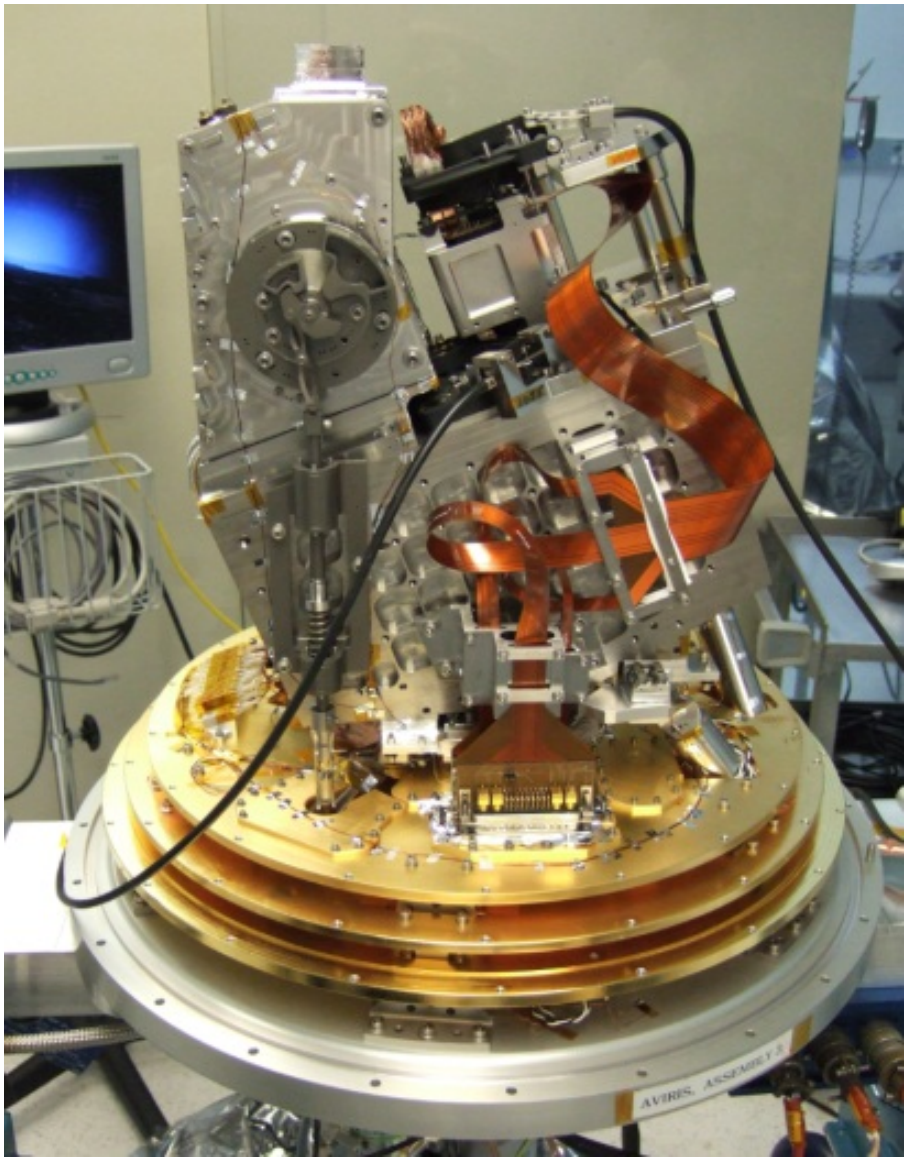
Slit

Telescope

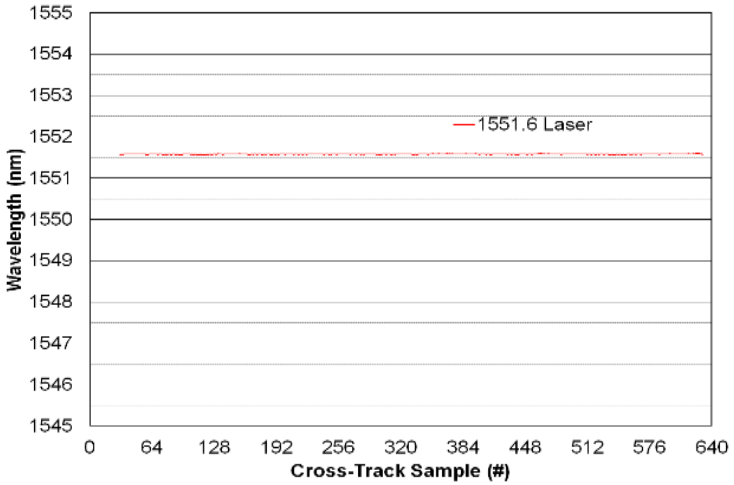




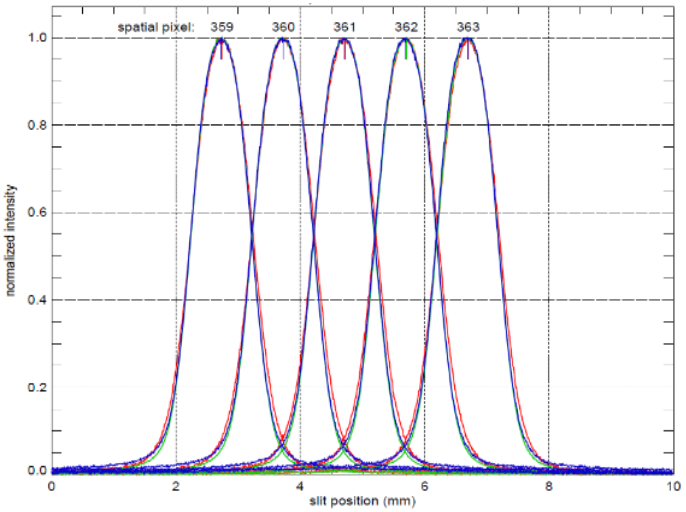
AVIRIS-NG



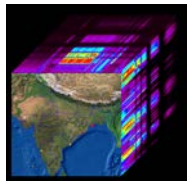
High Spectral Cross-Track Uniformity



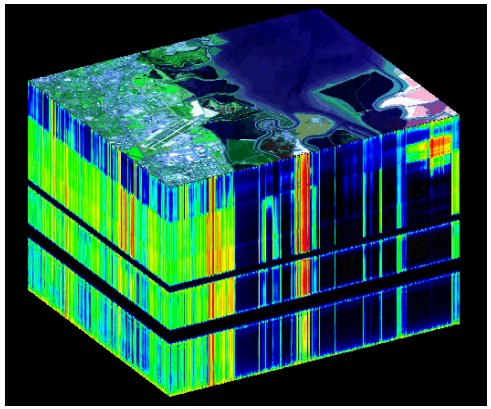
High Spectral IFOV Uniformity



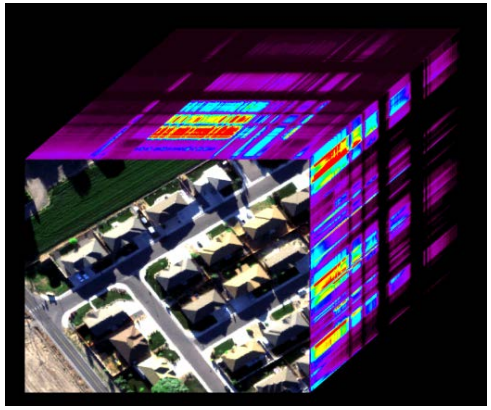
AVIRIS Measurement Characteristics



AVIRIS-C



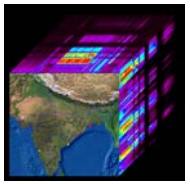
AVIRIS-NG



	AVIRIS-Next Generation	AVIRIS-Classic
SPECTRAL		
Range	380 to 2510 nm	380 to 2500 nm
Position	5 nm	10 nm
Response	1 to 1.5 X sampling	1 to 1.5 X sampling
Calibration	+-0.1 nm	+-0.1 nm
RADIOMETRIC		
Range	0 to max Lambertian	0 to max Lambertian
Precision (SNR)	>2000 @ 600 nm	>1000 @ 600 nm
	>1000 @ 2200 nm	>400 @ 2200 nm
Accuracy	95% (<5% uncertainty)	90% (<10% uncertainty)
Linearity	>=99% characterization	>=99% characterization
SPATIAL		
Range	34° field-of-view	34° field-of-view
Sampling	1 milliradian	1 milliradian
Response	1 to 1.5 X sampling	1 to 1.5 X sampling
Sample Distance	0.3 m to 20 m	4 m to 20 m
Geom Model	Full 3 Axes cosines	Full 3 Axes cosines
UNIFORMITY		
Spectral Cross-Track	>95% across FOV	>98% across FOV
Spectral-IFOV-Variation	>95% Spectral Direction	>98% Spectral Direction

Campaign Enabled by ISRO B200 Aircraft

NASA AVIRIS-NG Installed on the ISRO B200 Aircraft

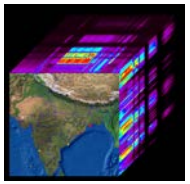


- 11 Dec 2015, AVIRIS-NG installed on the ISRO B200 and cooling down to operational temperatures (~150K).
- AVIRIS-NG Imaging Spectrometer
  - Spectral: 380 to 2510 nm @ 5 nm
  - Radiometric: ≥95% calibration with high SNR
  - Spatial: 2 to 8 m sampling

AVIRIS-NG in the hanger prior to installation

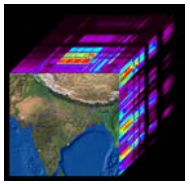
AVIRIS-NG Installed 11 Dec 2015

AVIRIS-NG Radiometric Calibration Test in Hyderabad



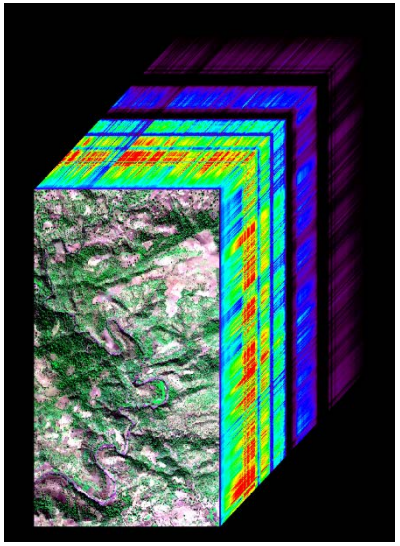
During the week of January 11th, 2016 the AVIRIS-NG team (Ernesto Diaz, Peter Sullivan, and Andrew Thorpe) acquired NIST traceable radiometric calibration and flat-field measurements for AVIRIS-NG at the Hyderabad hanger while the aircraft was undergoing routine maintenance.

A spectacular success thanks to a joint ISRO and NASA team effort!

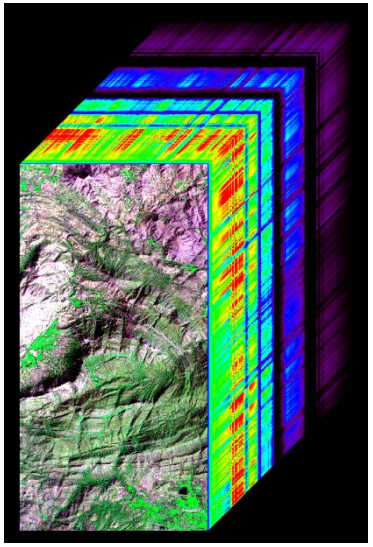


- AVIRIS-NG measurements were acquired for <u>all</u> 57 priority 1 sites (Dec 17th to Mar 8th)
- All measurements have been calibrated to radiance and atmospherically corrected and delivered to the NASA and ISRO data systems.

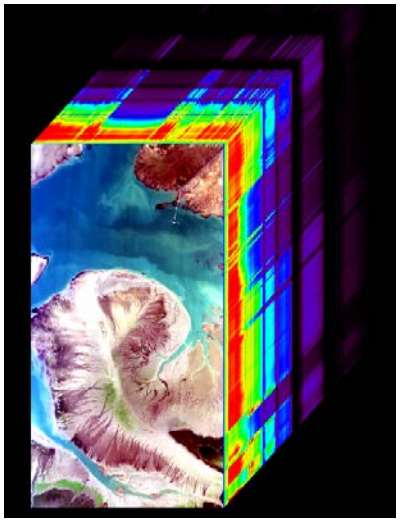
Forestry: Shoolpaneshwar, Gujarat



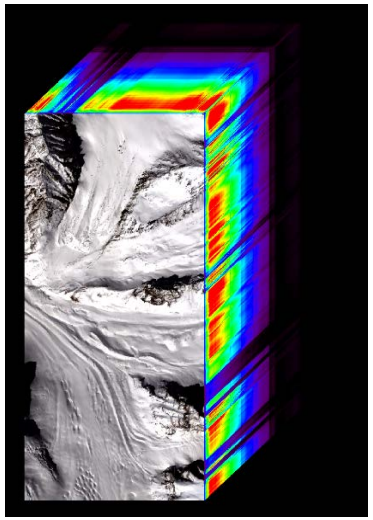
Geology: Ambaji, Gujarat



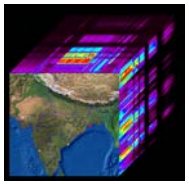
Costal Ocean: Pirotan

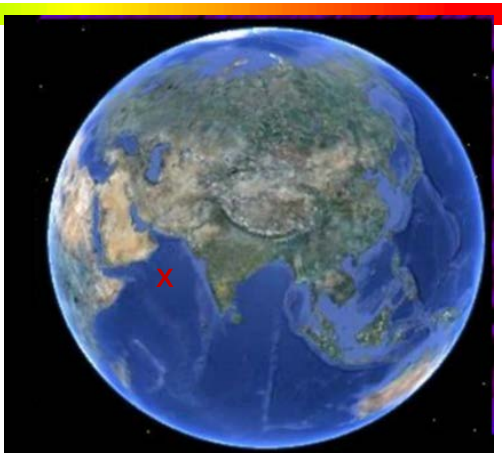


Snow/Ice: Himachal Pradesh



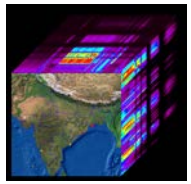
AVIRIS-NG India Cal/Val Result (>97%)



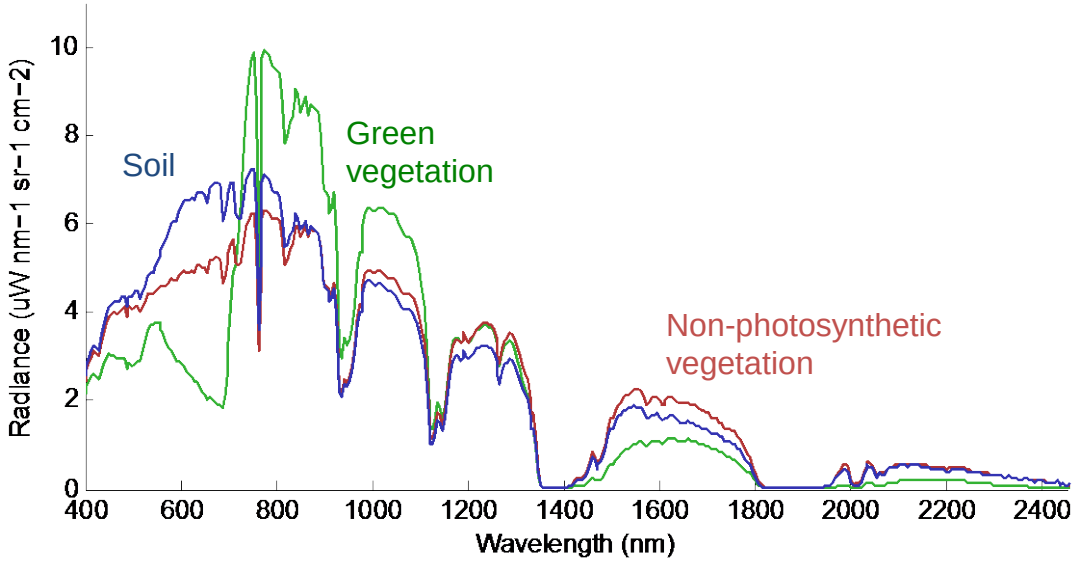


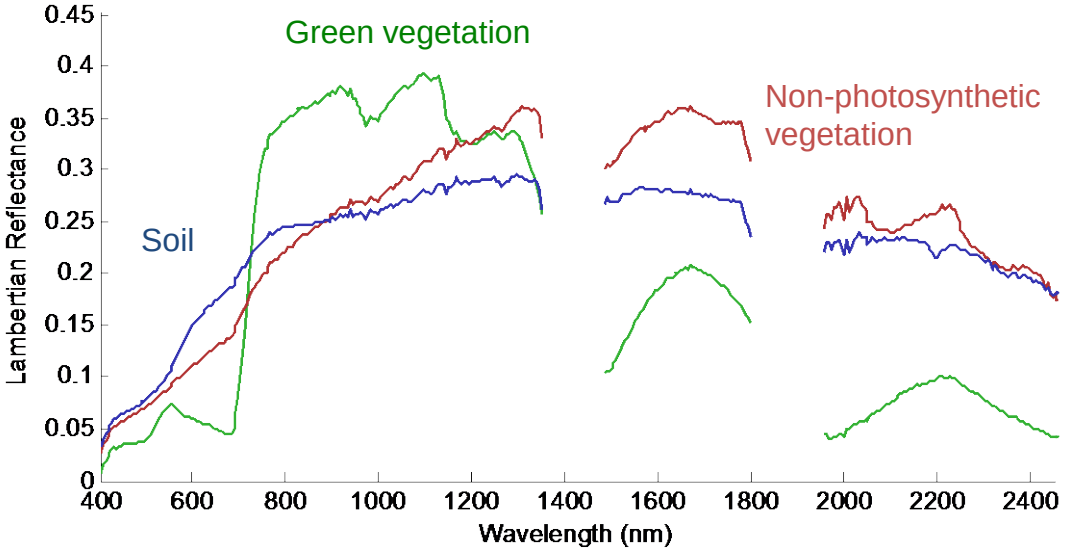
Imaging Spectrometer Calibration / Validation Results at Desalpar, India, David R. Thompson1, K. N. Babu2, Bimal K. Bhattacharya2, Michael L. Eastwood1, Robert O. Green1, Aloke Mathur2, Manish Saxena2Amit Sen1
1Jet Propulsion Laboratory, California Institute of Technology, 2Indian Space Research Organization

Measurements are Available and Calibrated Radiance and Corrected Reflectance



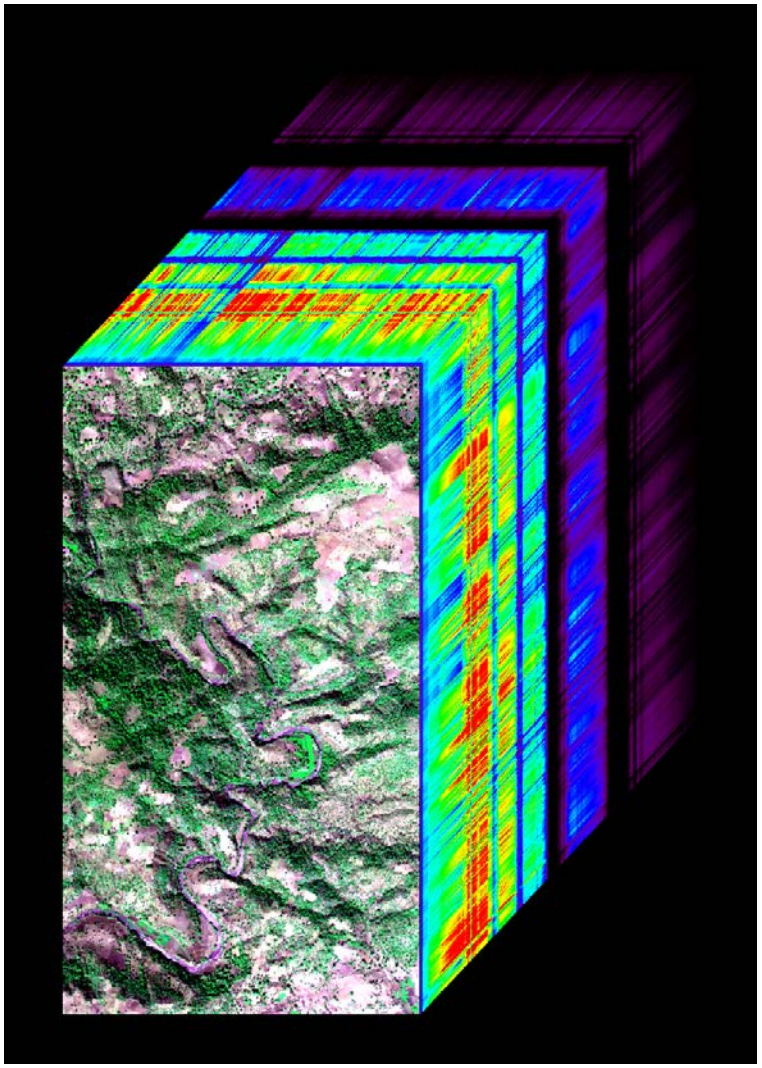
Radiance & reflectance for three surface types in a Feb 3 flight line



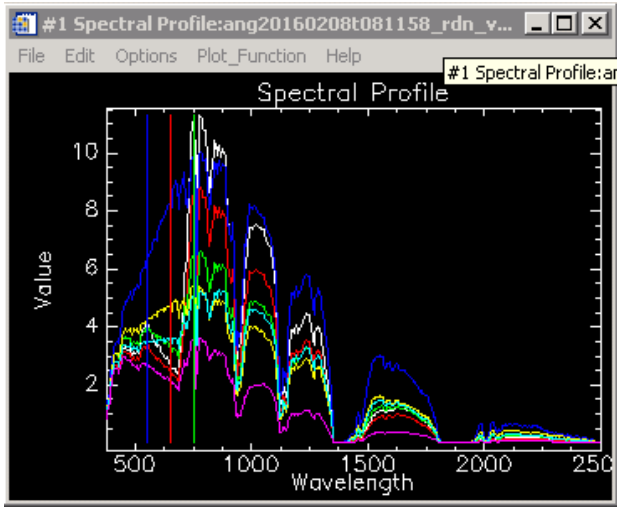


Thompson, David R., et al. "Atmospheric correction for global mapping spectroscopy: ATREM advances for the HyspIRI preparatory campaign." *Remote Sensing of Environment* 167 (2015): 64-77.

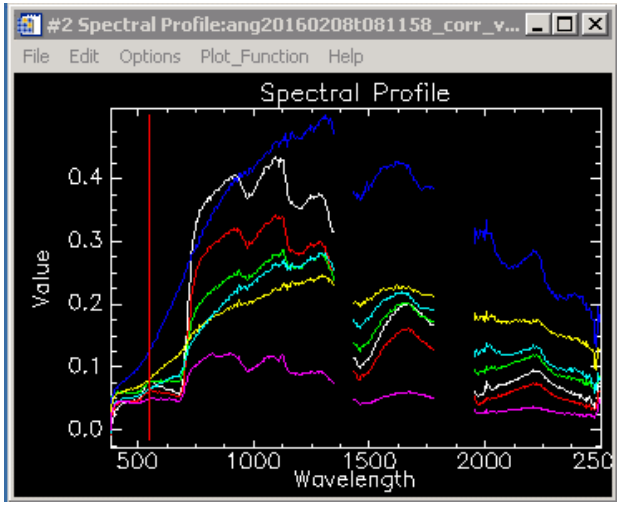
AVIRIS-NG Imaging Spectroscopy
Forestry: Shoolpaneshwar, Gujarat, India



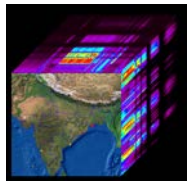
L1 Radiance (μW/cm^2/nm/sr)

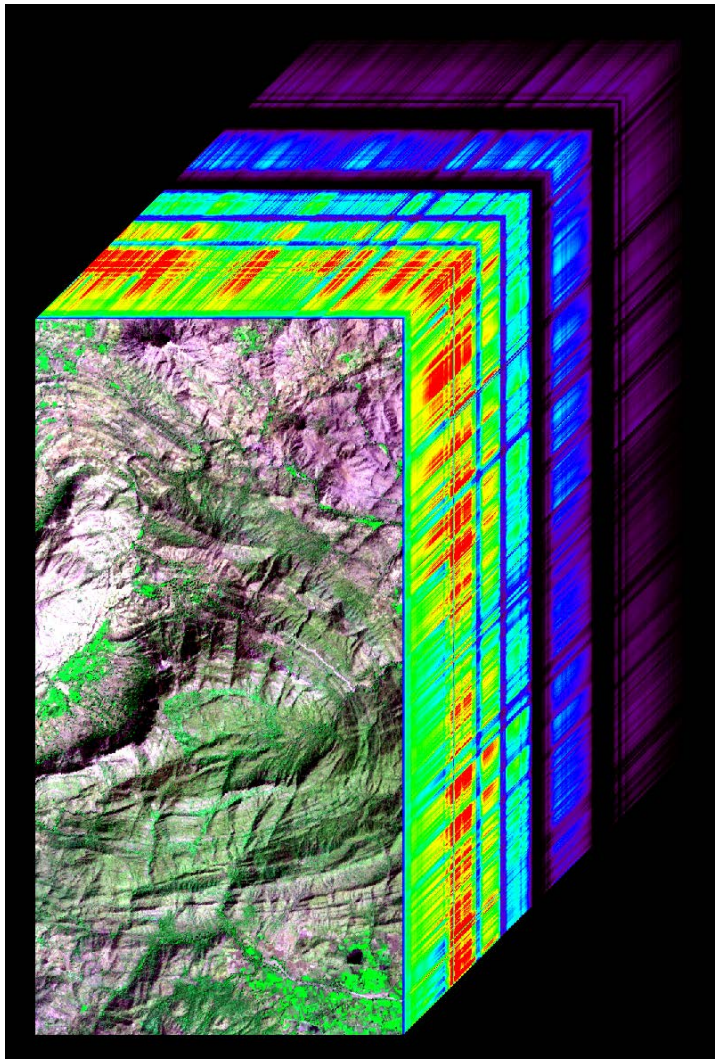


L2 Reflectance

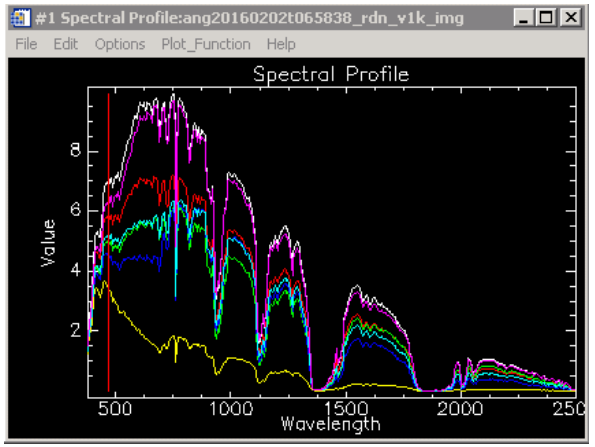


AVIRIS-NG Imaging Spectroscopy
Geology: Ambaji, Gujarat, India

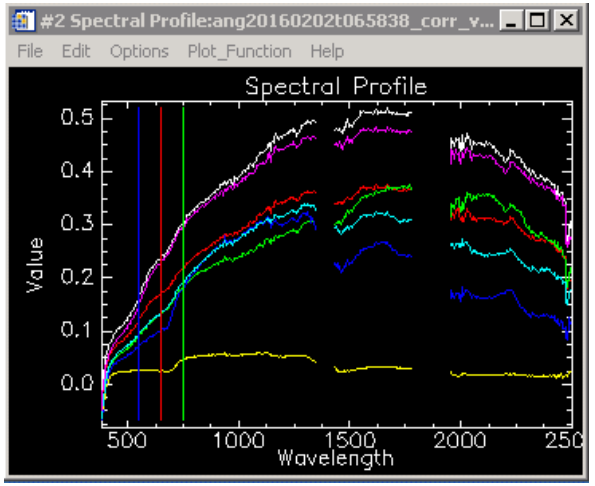




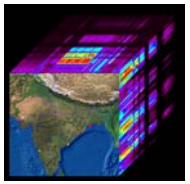
L1 Radiance (μW/cm^2/nm/sr)

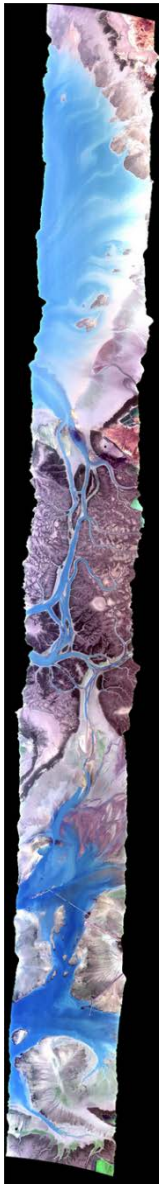


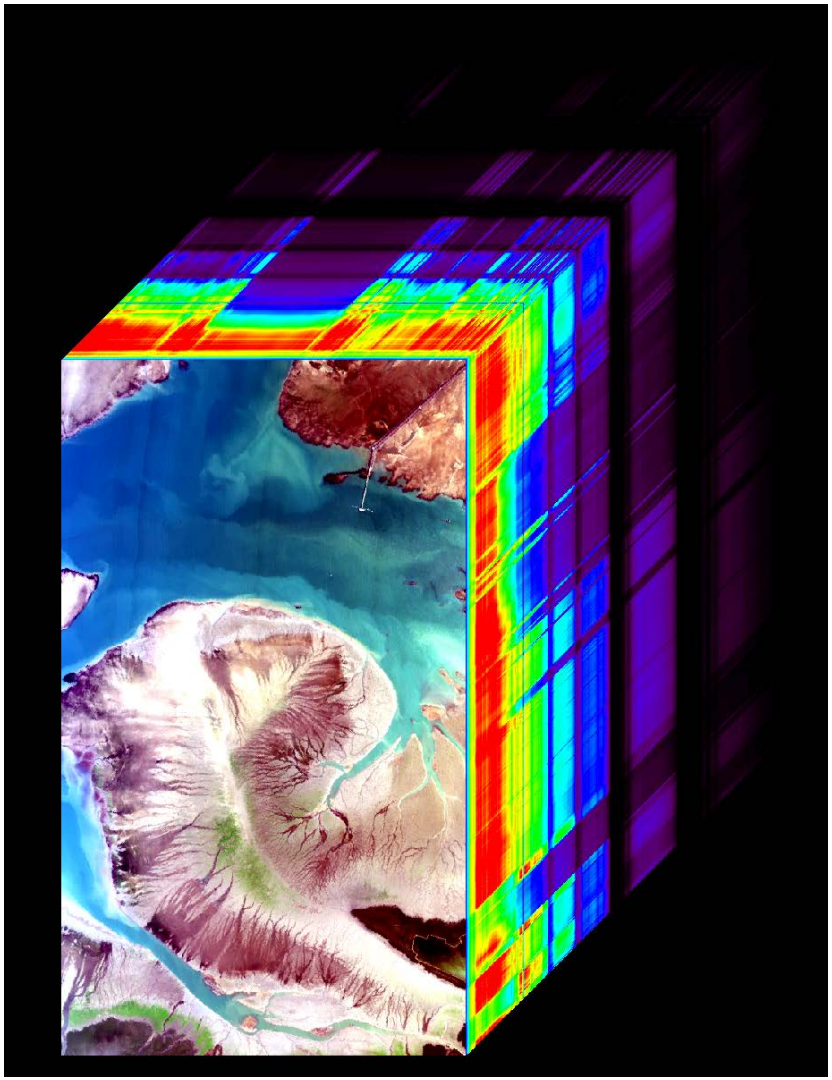
L2 Reflectance



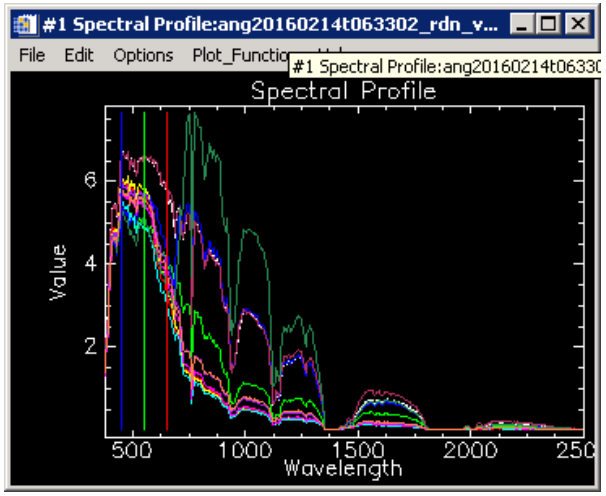
AVIRIS-NG Imaging Spectroscopy
Costal Ocean: Pirotan, India



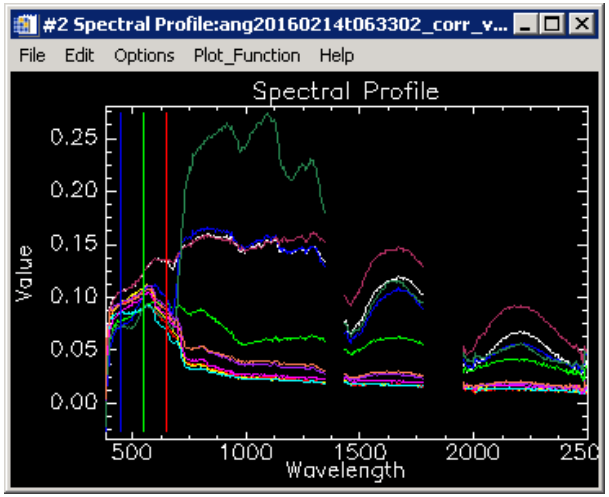




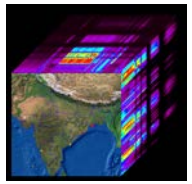
L1 Radiance (μW/cm^2/nm/sr)

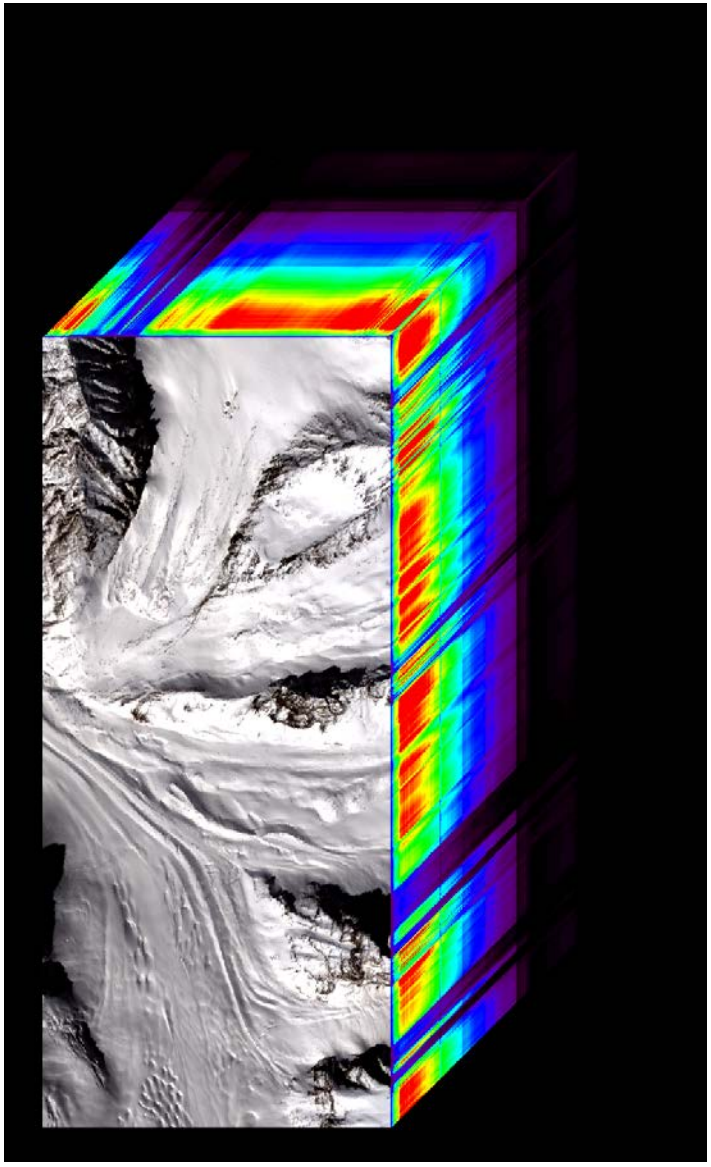


L2 Reflectance

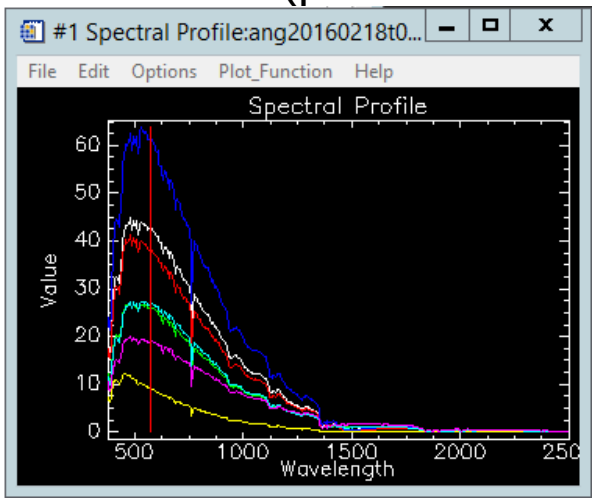


AVIRIS-NG Imaging Spectroscopy
Snow/Ice: Himachal Pradesh, India

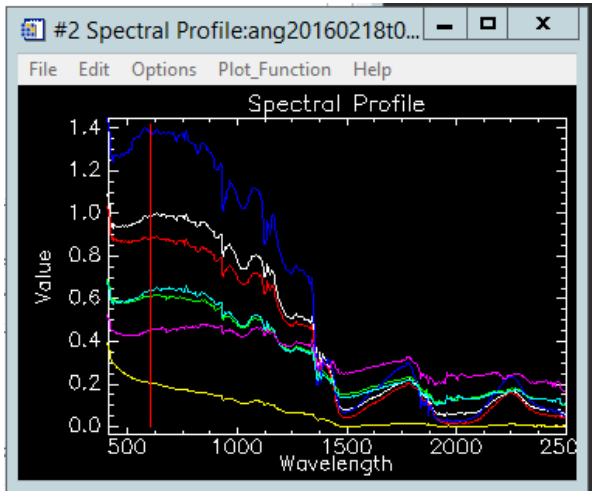




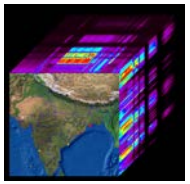
L1 Radiance (μW/cm^2/nm/sr)

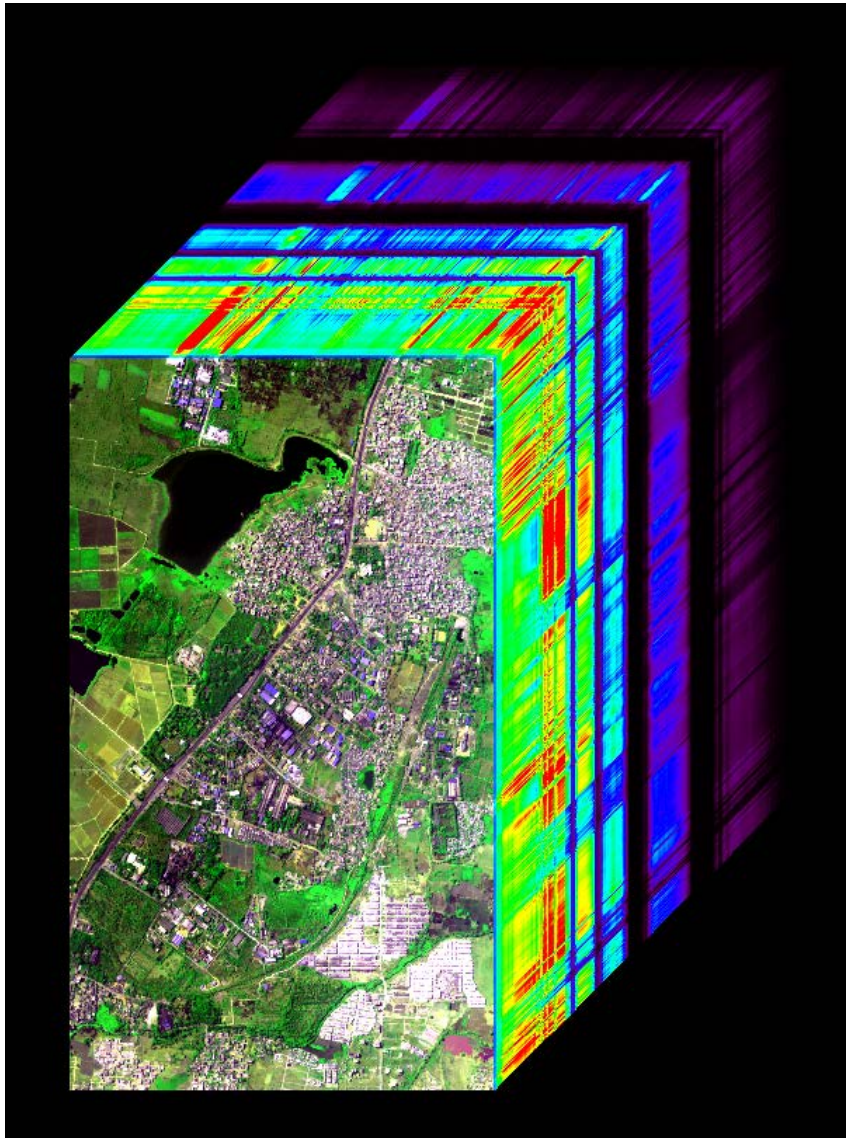


L2 Reflectance

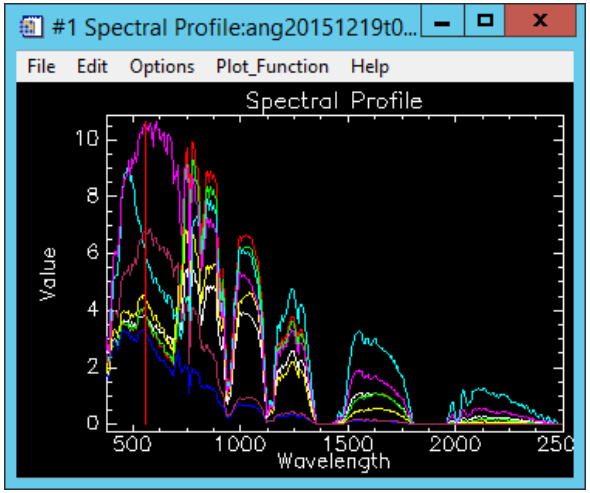


AVIRIS-NG Imaging Spectroscopy
Urban Mixed: ICIRSAT, India

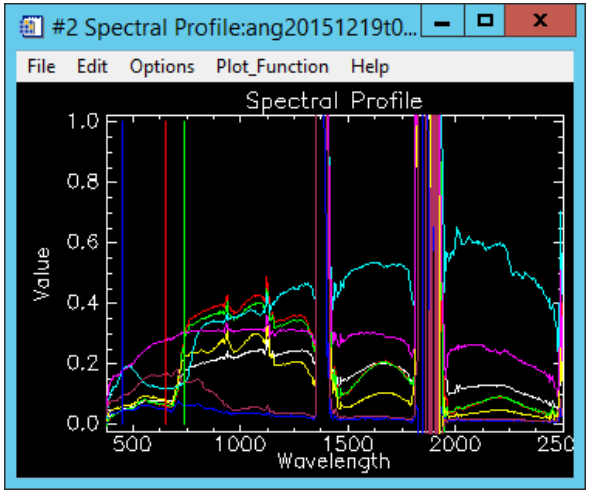




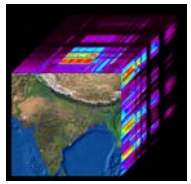
L1 Radiance (μW/cm^2/nm/sr)



L2 Reflectance



ISRO Science and Applications Research Topic Areas



Geology & soils : Mineral, rock & soil types and extent, abundance, chemistry soil nutrients

End use : Fertilizer prospects, new mining areas, Hydrothermal alteration, soil fertility & quality

Agriculture & Ecosystem : Species / community discrimination, density, extent biophysical & biochemical properties governing processes, phenology, abiotic & biotic stresses, disease, forest fuel

End use : Precision farming, crop insurance, carbon cycle & nutrient dynamics

Water (Coastal / Ocean / river) : Chlorophyll, Transparency, suspended sediments, turbidity

Coral reef : Macrophytes / macroalgae, Habitat discrmination, water column characterization

Urban : Roof-type classification, composition, pervious & Impervious surface

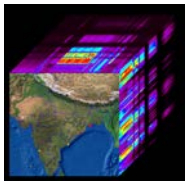
Snow & Glacier : Snow type, albedo, grain size, snow density & pack

End use : Hydrological & environmental modelling, climate change

Atmosphere : Aerosol, water vapour, cloud microphysics

End use : Air quality monitoring, enhanced cloud characterization

NASA Investigations



Woody Turner: NASA lead for AVIRIS-NG Science and Applications Research Campaign, NASA HQ

Thomas Painter: Spatial Dynamics of Grain Size, Radiative Forcing by Impurities, and Spectral Albedo from AVIRIS-NG Data in the Indian Himalaya, JPL

David Thompson: Improving Atmospheric Correction across the Indian Subcontinent, JPL

Margarita Huesca Martinez: Biodiversity assessment along a moisture gradient in tropical deciduous forests in India using AVIRIS-NG data, UC Davis

Bruce Kindel: The quantification and analyses of AVIRIS-India aerosol atmospheric correction, University of Colorado, Boulder

Philip Townsend: Vegetation functional amplitudes along a rainfall gradient in Indian ecosystems using AVIRIS-NG, University of Wisconsin, Madison

William Farrand: Using AVIRIS-NG Data to Assess the Role of Mining Activities in Affecting Water Quality in Gujarat and Rajasthan, India, Space Science Institute

Bo-Cai Gao: Use of AVIRIS-NG Data Collected from the Airborne Campaign in India for the Study of Inland Lake, River, and Coastal Waters, Naval Research Lab

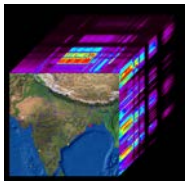
Sakthi Kumaran Subburayalu: Using AVIRIS Imagery to Map Spatial Variability of Soil Carbon Across Diverse Agricultural Management Systems, (Ohio State University) now Central State University

Philip Dennison: Improved Trace Gas Plume Detection using Indian and US AVIRIS-NG Data , University of Utah, Salt Lake City

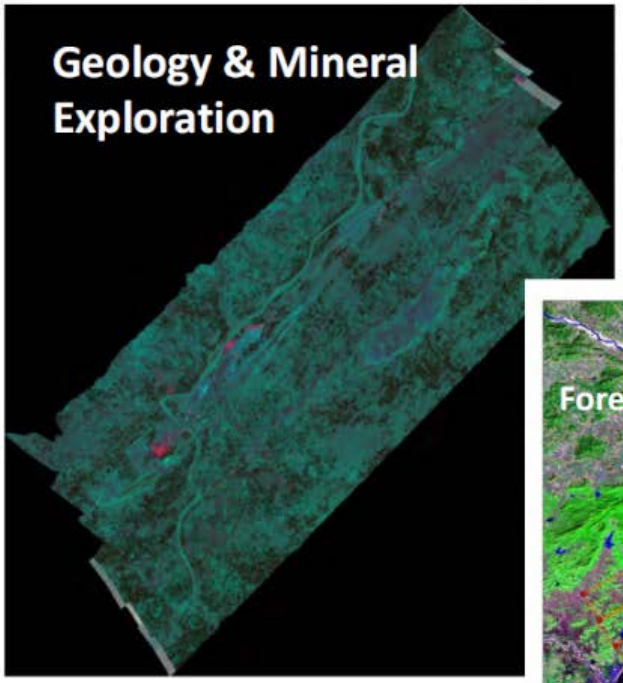
Snehamoy Chatterjee: Minerals and rock type mapping using Airborne Visible/Infrared Imaging Spectrometer-Next Generation (AVIRIS-NG) data, Michigan Tech

Robert O. Green, David Thompson, Aloke Mathur, K N Babu: Early joint results regarding the calibration and validation of the AVIRIS-NG joint campaign data set, JPL and SAC

Early Assessments



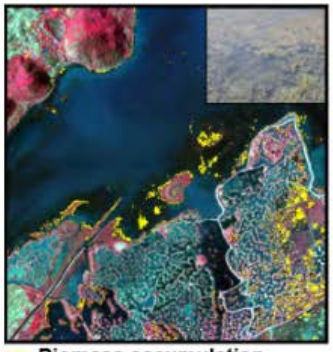
Geology & Mineral Exploration



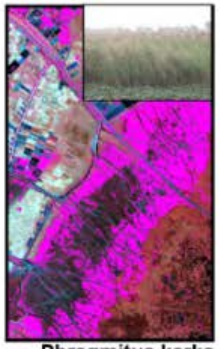
IBD-FCC of Jahazpur mosaic Highlighting talc/carbonates In Red, Montmorillonite in Green and Kaolinite in Cyan to Blue

Coastal Applications

Ecological mapping (Chilika region)



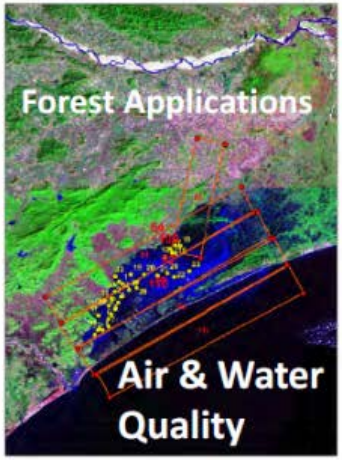
Biomass accumulation Eutrophication



Phragmitus karka (invader species)

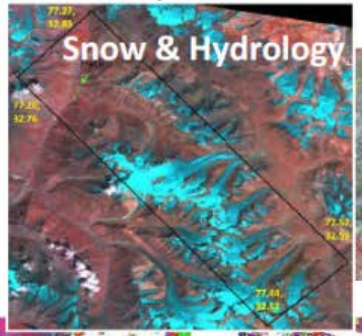
Dead seagrass (floating)

Forest Applications



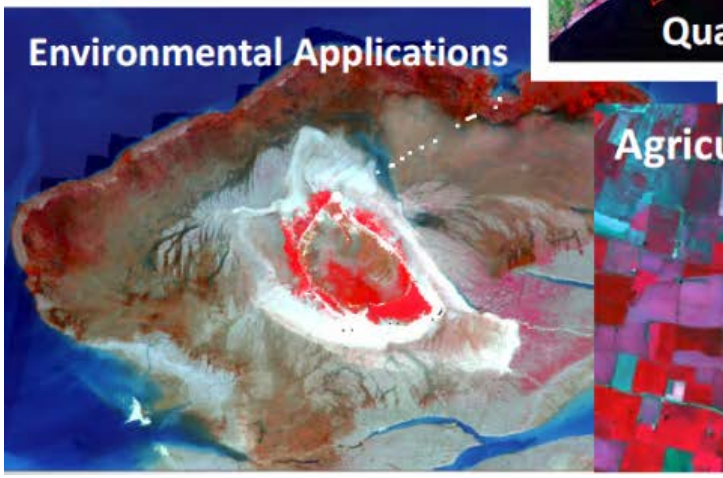
Air & Water Quality

Snow & Hydrology

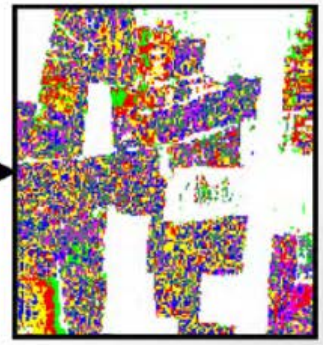


UrbanApplications

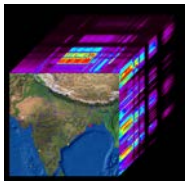
Environmental Applications



Agriculture & Soil

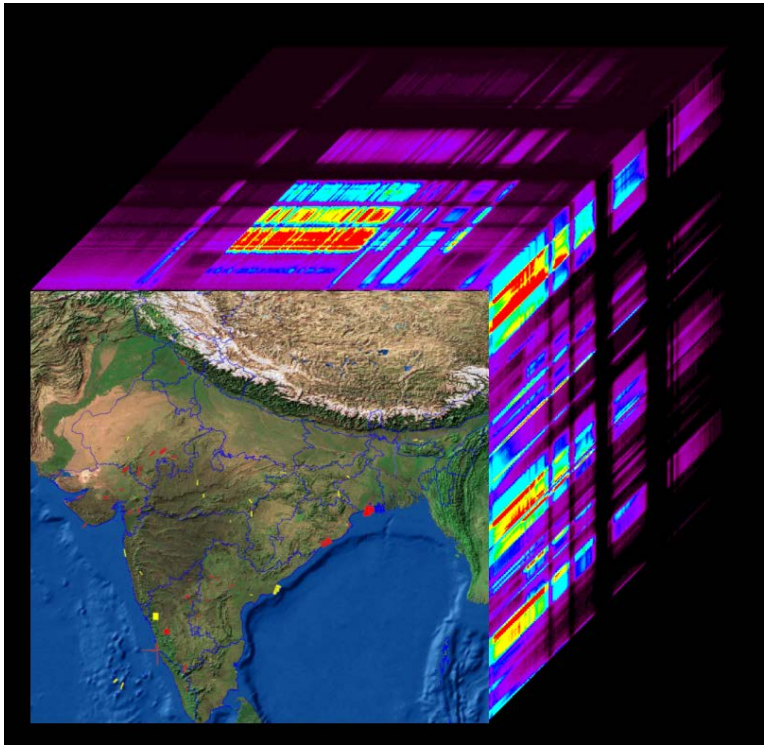


AVIRIS-NG Joint Campaign Conclusions and Summary

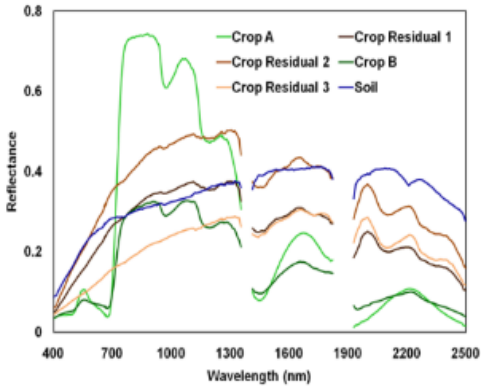


- An exceptionally diverse imaging spectroscopy data set has been acquired in India with the joint investment of ISRO and NASA. 317 AVIRIS-NG flight lines were collected from the 17th of December to 8th of March.
- Sites collected have science and applications objectives spanning: the coastal zone; rivers and inland waters, diverse terrestrial ecosystems (tropical to dryland); mangroves; snow/ice hydrology, hydrocarbon alteration; mineralogy; soils, agriculture; urban environments; calibration/validation; etc.
- All 317 flight lines for the 57 sites imaged have been received and processed. Copies of the L1-radiance and L2-reflectance are delivered NASA and ISRO.
  - A 2017 refinement has been shipped to ISRO
- A set of ISOR investigations have been initiated.
- A set of NASA investigations have been selected to pursue science and applications research in full collaboration.
- There is broad and enthusiastic interest in the joint science and applications research that can be pursed with these first of their kind measurements.

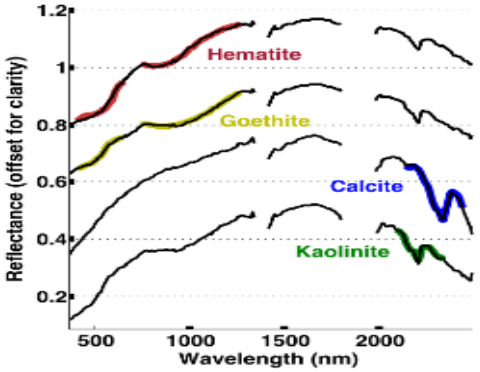
Thank You



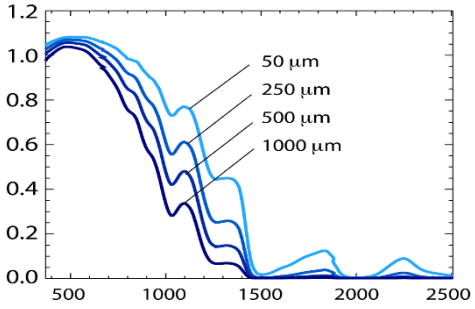
Agriculture and Ecosystems



Geology and Soils



Snow and Ice



Coastal and Inland Waters