2002 AVIRIS Workshop

Review Part 1:

Imaging Spectroscopy, AVIRIS, Calibration, & Atmospheric Correction

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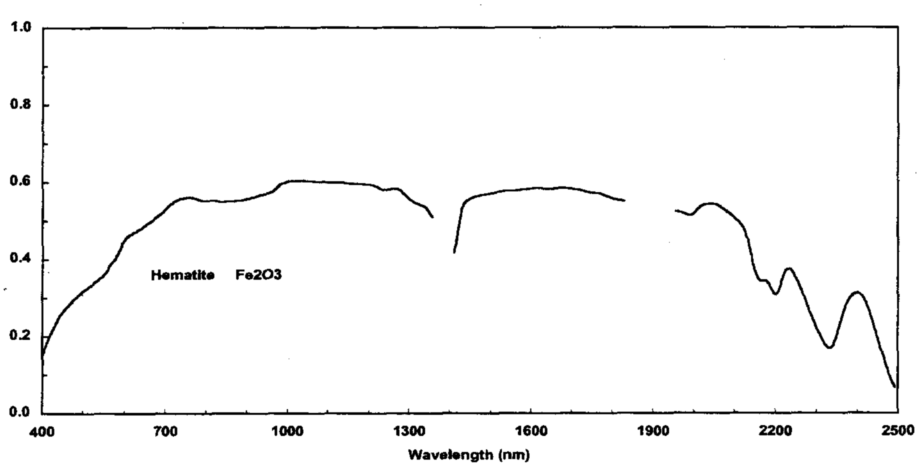
Overview

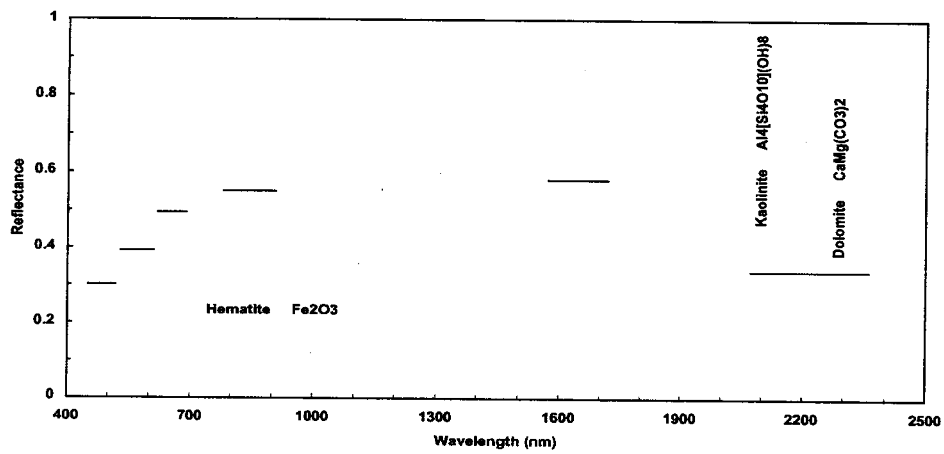
- Imaging Spectroscopy
- AVIRIS
- Calibration
- Atmospheric Correction
- Research and Applications
- Summary

Imaging Spectroscopy

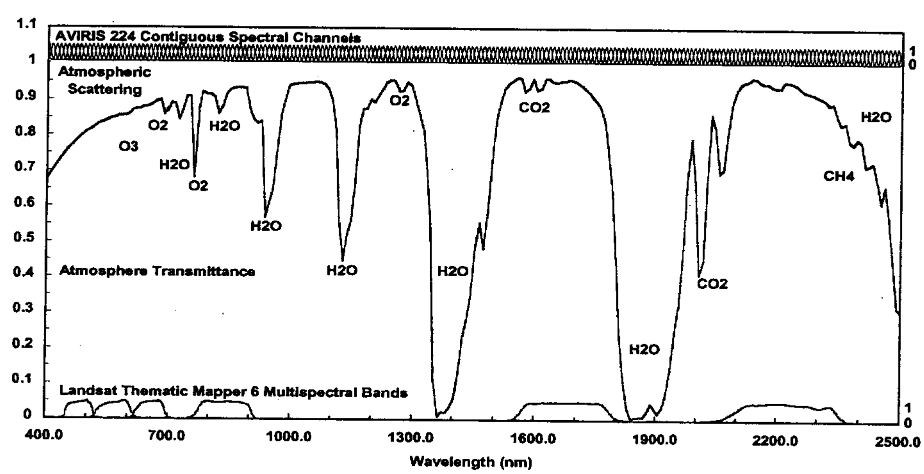
THREE MINERAL SPECTRUM



SPECTRUM CONVOLVED TO TM BANDS



Earth Imaging Spectroscopy



IMAGING SPECTROSCOPY CONCEPT (I)

- Determining the composition and inferring processes on the Earth surface by counting photons at the top of the atmosphere is an improbable objective.
- Spectroscopy provides a framework based in physics to achieve this remote measurement (not sensing) objective in the context of the interaction of photons with matter.
- The physics, chemistry and biology of spectroscopy have been validated through more that 100 years of laboratory and astronomical research and applications. (Fraunhofer 1814)

IMAGING SPECTROSCOPY CONCEPT (II)

- An alternate view of the imaging spectroscopy concept hinges on the general problem of solving for unknowns from measurements.
- If one has fewer measurements than unknowns, then the problem is underdetermined. Six or Ten measurements (e. g. bands) are almost never enough to account for the unknowns effecting the radiance at the top of the atmosphere.
- Furthermore, one can not simply solve for the a single unknown of interest (the magic band). One must solve for all the unknowns that may effect the expression of the unknown of interest.
- If there are more measurements than unknowns (Imaging Spectroscopy) then the problem is likely over determined and solvable.

IMAGING SPECTROSCOPY CONCEPT (III)

- Imaging Spectroscopy takes advantage of and pushes:
  - optical, detector, and design technology
  - computer communication, analysis and storage technology
  - satellite onboard processing and downlink technology
  - hard science research and applications algorithms

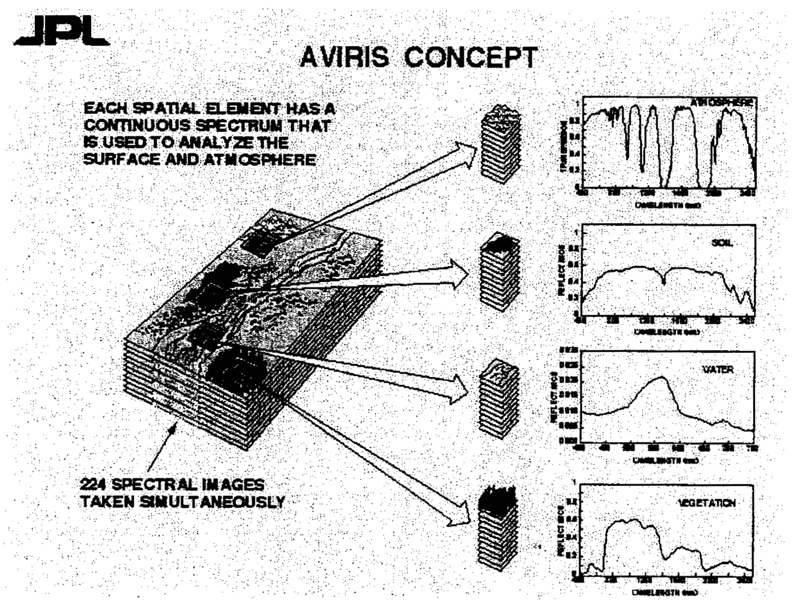
H. G. Wells, The Outline of History

"The telescope has released the human imagination as no other implement has ever done. If there is any other apparatus worthy to be compared to its enlarging influence, it is the spectroscope, which was developed after the discoveries of Fraunhofer, the glass-worker, in 1814. Since man has lived on earth he has seen rainbows, but who could have told him that those bands of colour held in them a promise that one day he should be able to anlyze the stars? But the spectroscope receives the rays from any luminous source, passes them through prisms and breaks them up into rainbow-like bands. These bands reveal under examination transverse lines of brightness and darkness which vary with the heat and the chemical composition of the source of light and of any intervening vapour. So that men can now sit in observatories and learn the composition and take the temnperature of stars incalculable billions of miles away."

IMAGING SPECTROSCOPY APPROACH

- Measure the calibrated upwelling radiance spectra as images.
- Based upon the molecular absorptions and constituent scattering characteristics expressed in the spectra:
  - Detect and identify the surface and atmospheric constituents present
  - Assess and measure the expressed constituent concentrations
  - Assign proportions to constituents in mixed spatial elements
  - Delineate spatial distribution of the constituents
  - Monitor changes in constituents through periodic data acquisitions
  - Simulate, calibrate and inter compare sensors

Imaging Spectrometer Instrument: AVIRIS



Instrument System Requirements

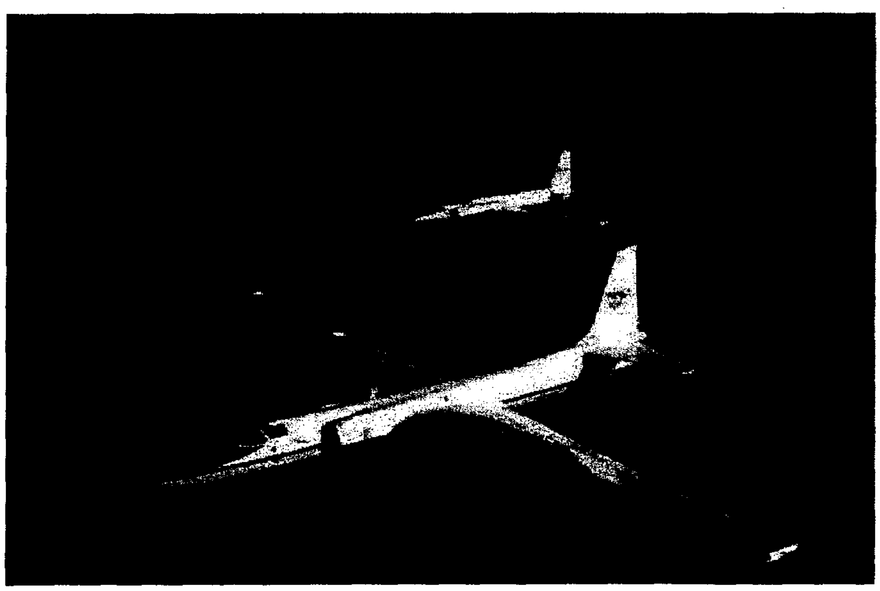
- High Precision (SNR)
  - Identification of materials based on spectroscopy
- Stability (spectral, radiometric, spatial)
  - Makes calibration possible
- Uniformity (spectral, radiometric, spatial)
  - Enables spectroscopy across the image
- Calibration (spectral, radiometric, spatial)
  - Required for the physics, chemistry, and biology of spectroscopy
  - Allows autonomous compensation for the atmosphere

AVIRIS Instrument

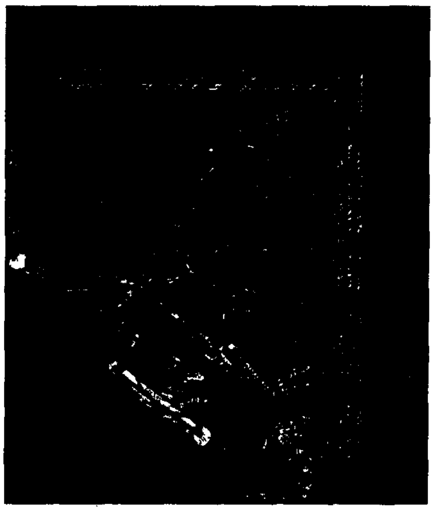
AVIRIS Technology Status
- •Thermal control 1997
- •Low Altitude 1998
- •INU/GPS 1998
- •Geo rectification 1998
- •Onboard calibrator 1999
- •Detector arrays 2000
- •Digital signal chain 2001
- •Onboard data storage 2001

AVIRIS is designed with 200 μm detectors and F/1 optics.
It is hard to imagine larger detectors or faster optics.
The AVIRIS design is in the advanced technology zone of the physics of spectroscopic measurements

Platform



AVIRIS: PEARL HARBOR, HAWAII



Spectral

Range	370 to 2500
Sampling	9.8 nm
Accuracy	0.5 nm

Radiometric

Range	0 to Max Lambertian
Sampling	12 bits
Accuracy	96 percent

Spatial (ER-2 / Twin Otter aircraft)

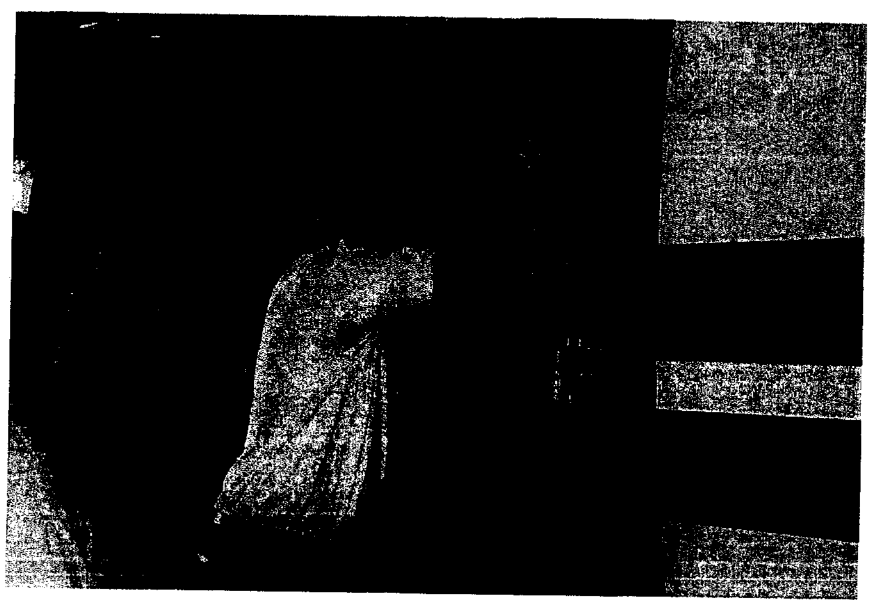
Swath	11/2.2 km ER-2/TO
Sampling	20/4 m ER-2/TO
Accuracy	20/4 m ER-2/TO

Full INU/GPS geo rectification

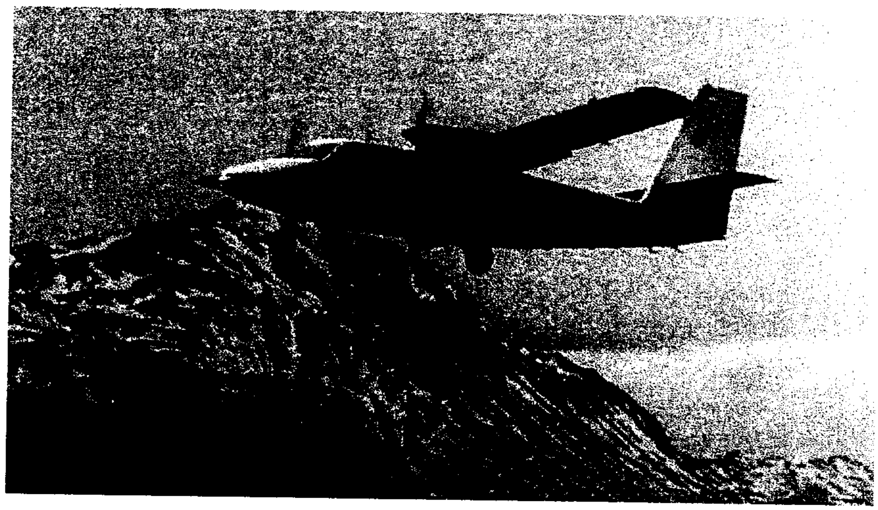
Implementation: AVIRIS Preparations

Twin Otter

Implementation: AVIRIS Installation



Implementation: Twin Otter



AVIRIS Low Altitude Capability

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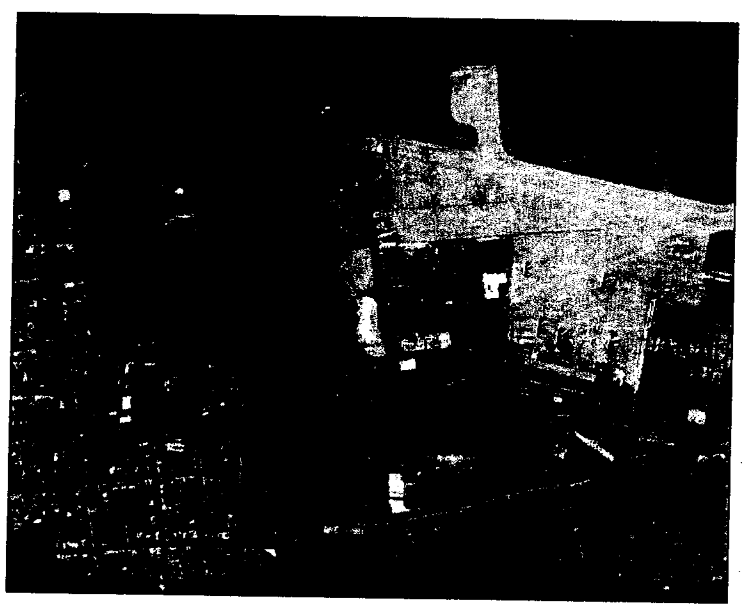


AVIRIS Science Data Acquisition

	FY98	FY99	FY00	FY01	FY02*
Months of Maintenance	4	5	4	4	5
Months of Science Data	8	7	8	8	7
Flights ER-2/Twin Otter	35/29	45/31	58/30	50/40	55/45
Flight Lines	429	517	589	600	650
Gigabytes	647	840	906	1000	1100
Scenes Acquired**	2757	3579	3860	4260	4686
Scenes Delivered	3249	5206	5734	6000	6500

*Projected **Scene: 512 lines by 614 samples

AVIRIS Task Structure at JPL

- The AVIRIS task at JPL has all the following elements
  - Task Management and Outreach
  - Calibration and Validation Science
  - Mission Planning and Experiment Coordination
  - Instrument Operations, Calibration, and Maintenance
  - Data Quality, Archiving, Calibration, Distribution
- These include all the elements of a satellite remote sensing instrument.

Calibration

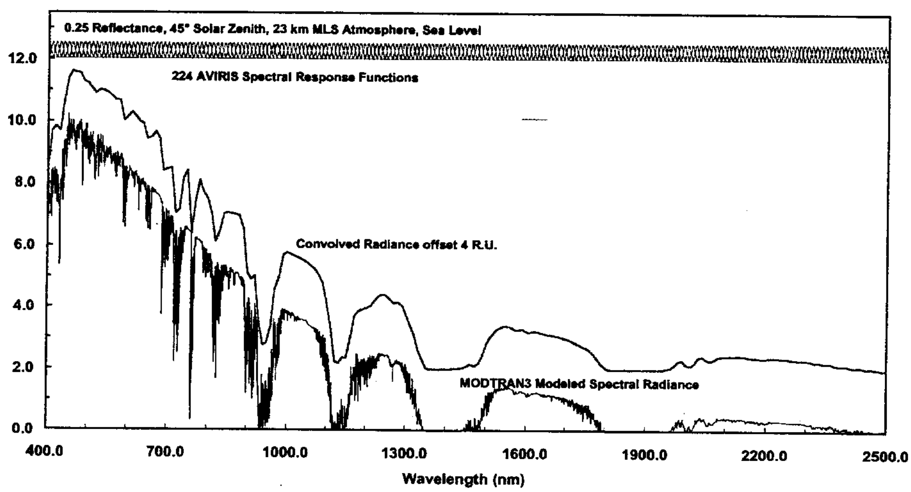
CALIBRATION REQUIREMENT

- Imaging spectroscopy data must be spectrally, radiometrically and spatially calibrated in order to:
  - Derive physical parameters from measured radiance
  - Compare data acquired from different regions and from different times
  - Compare and analyze imaging spectroscopy data with data acquired by other instruments
  - Compare and analyze data with results from computer models

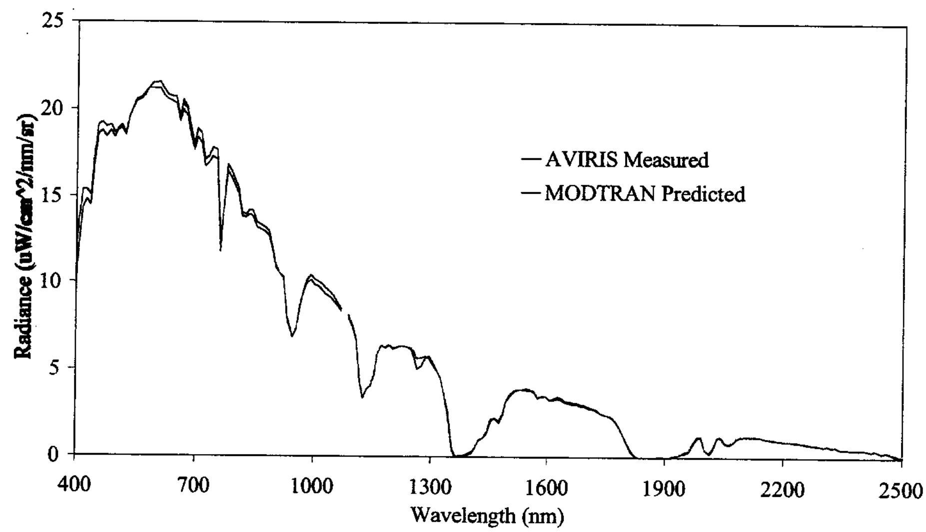
- Calibration bottom line
  - Calibration only counts when measuring real data that will be used to answer the real questions of interest.
  - Three months can be spent calibrating a sensor in the laboratory only to find that the flight data are NOT calibrated.
  - <u>Calibration in the flight environment is all that counts.</u>

Calibration Site, Ivanpah Playa, CA

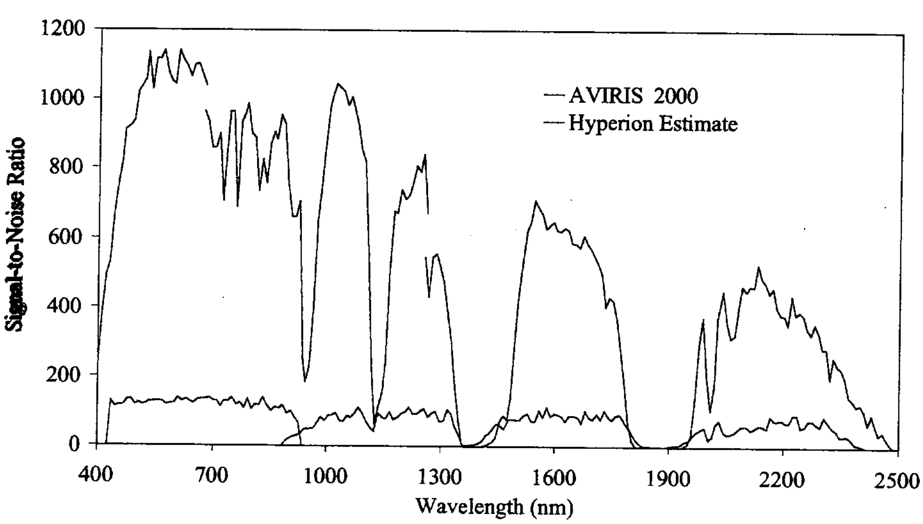
Nature of the Upwelling Spectral Radiance



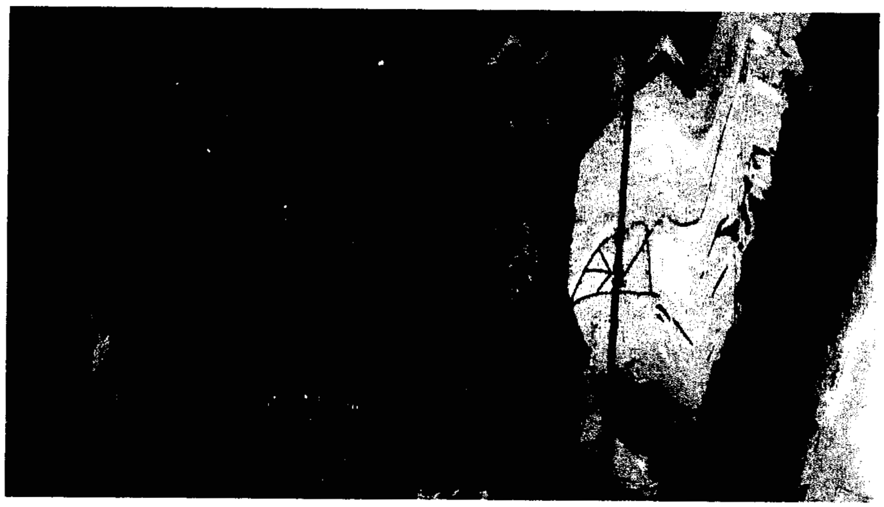
AVIRIS Inflight Calibration Experiment



AVIRIS SNR Status



AVIRIS Twin Otter Performance:
No INS/GPS Geometric Correction



AVIRIS Twin Otter Performance:
With INS/GPS Geometric Correction

Two Problems with Spaceborne Imaging Spectrometers

•Spectral Smile

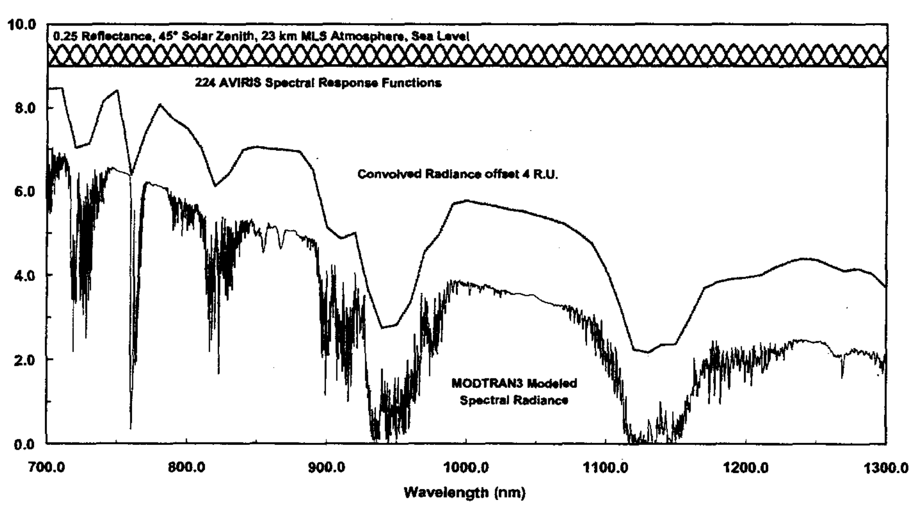
-Change in spectral calibration with cross track position

•Spatial-Spectral purity

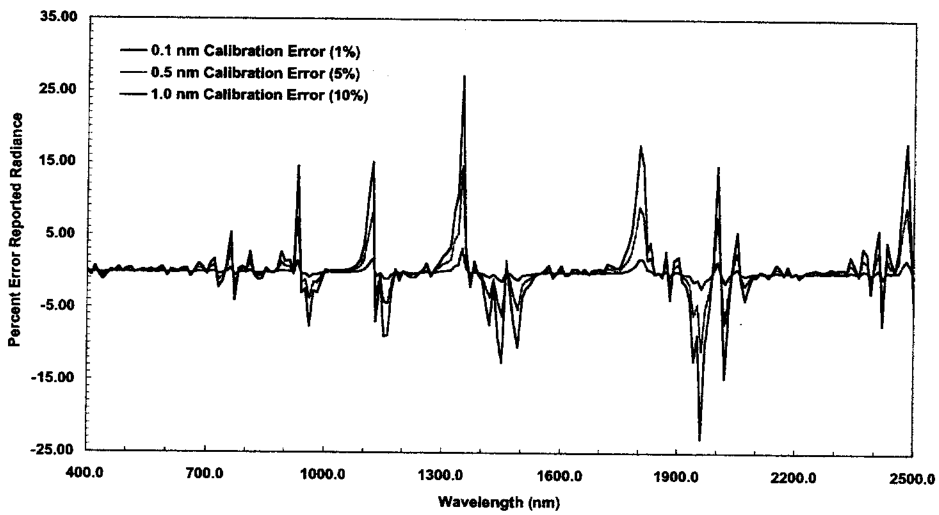
-Change in IFOV with spectral wavelength

•These are present in Hyperion and were in Warfighter

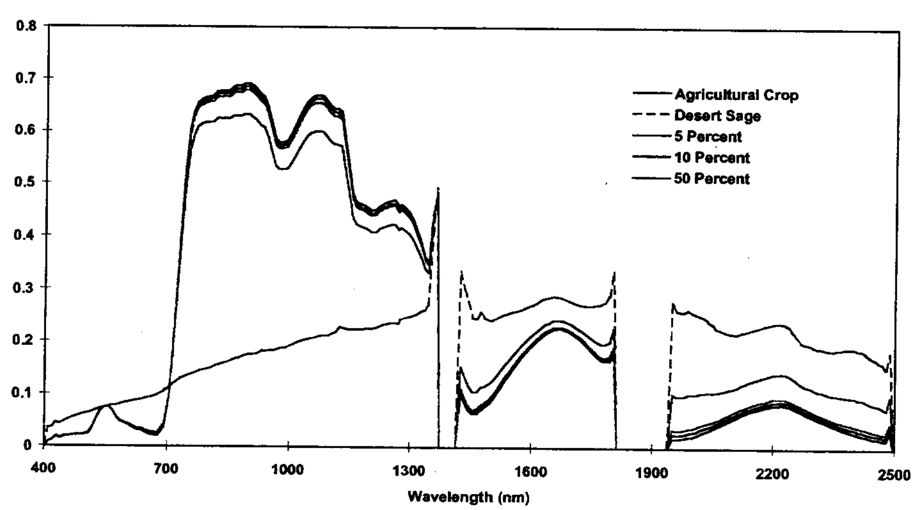
The spectral smile issue is tied to the fine spectral detail in the upwelling spectrum



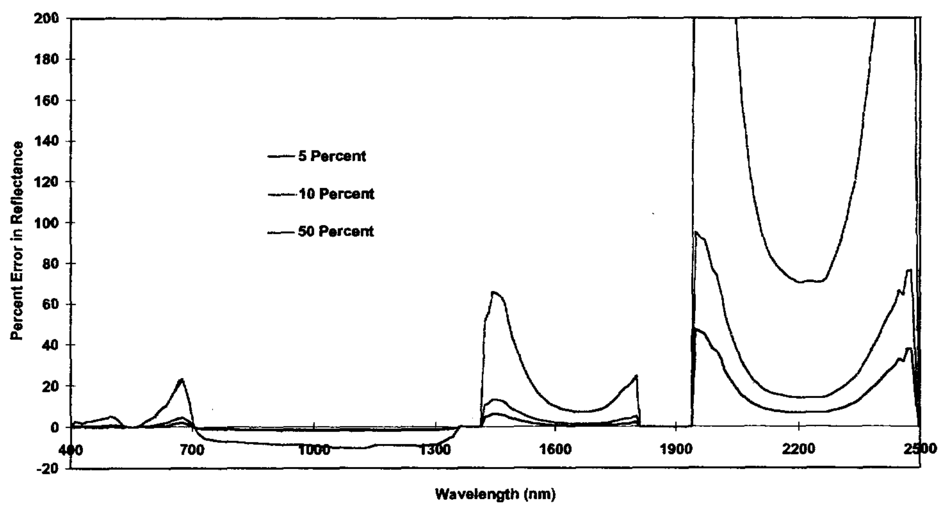
Effect of spectral calibration error on derived reflectance



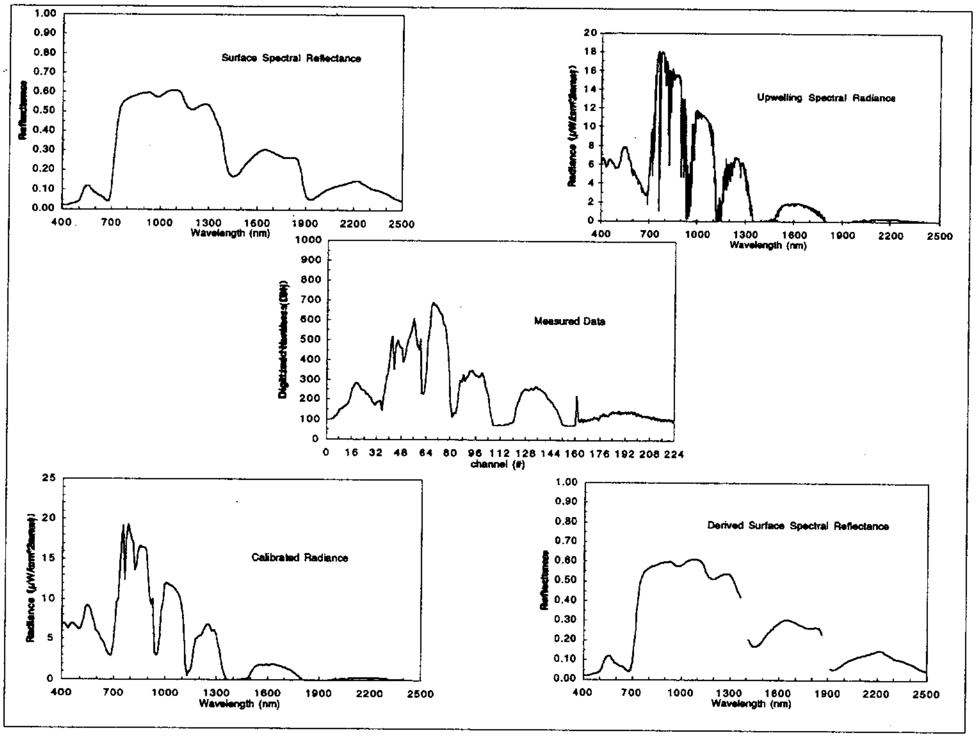
Effect of IFOV change with wavelength



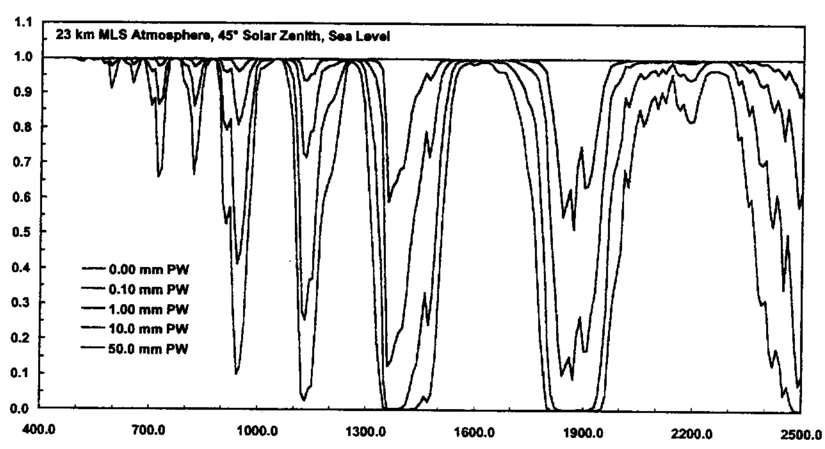
Error from spectral IFOV shift



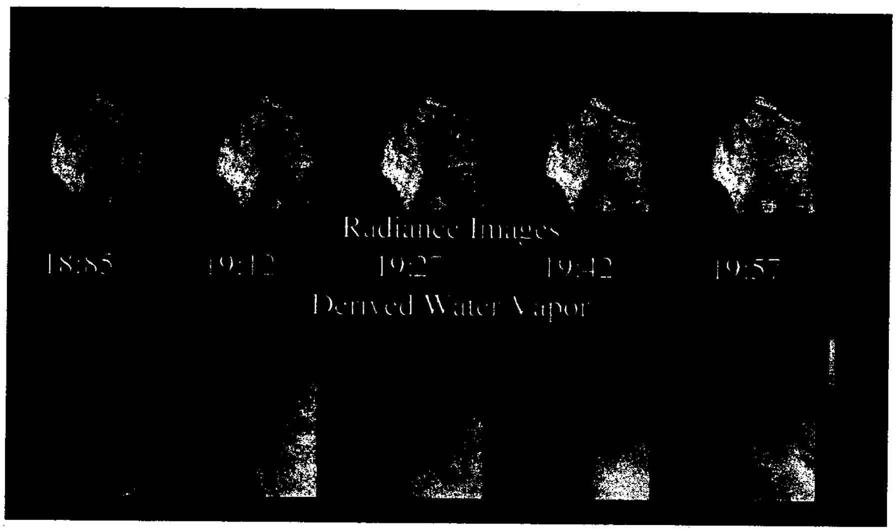
Atmospheric Correction



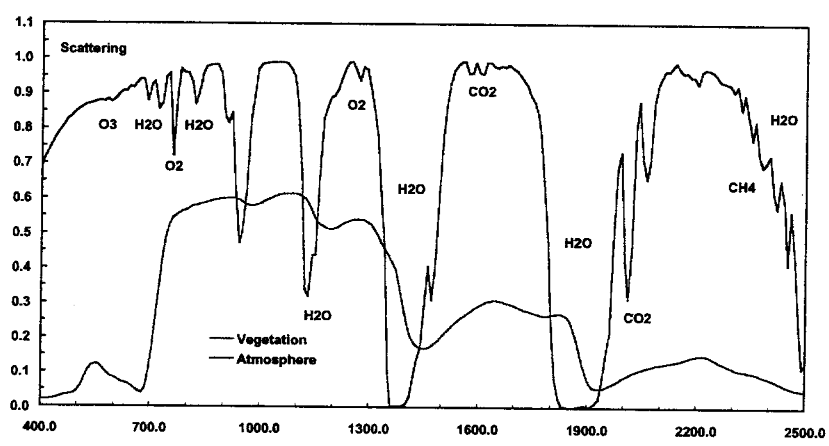
INFLUENCE OF WATER VAPOR



AVIRIS Water Vapor at Rogers Dry Lake, CA

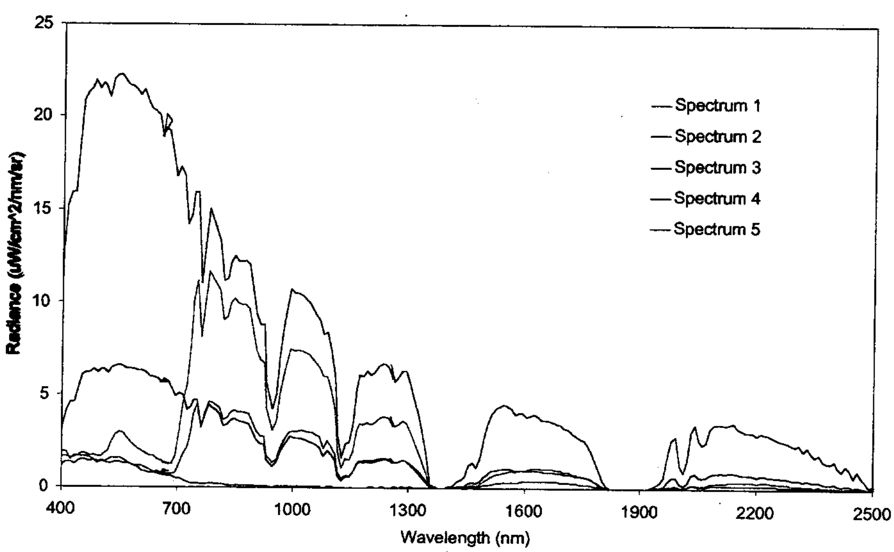


WATER VAPOR AND VEGETATION

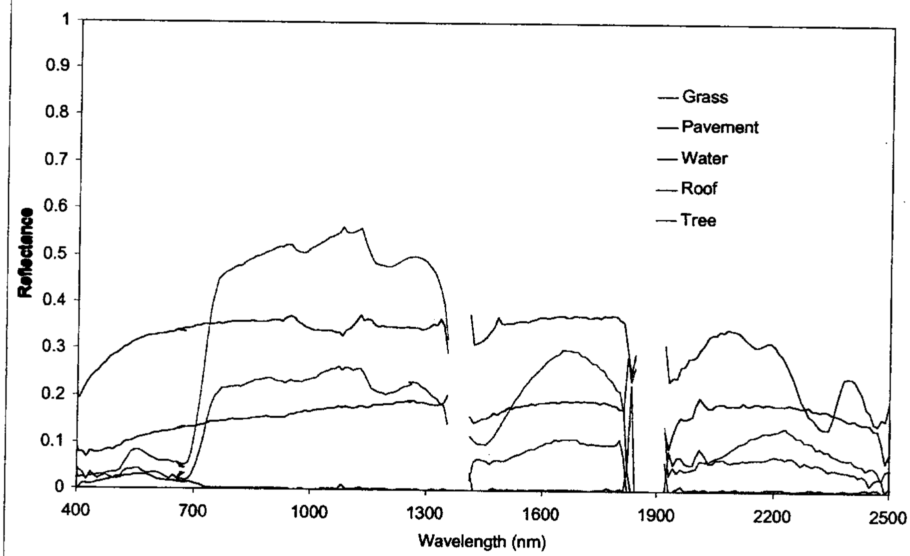


AVIRIS Image New York

AVIRIS Radiance



AVIRIS Reflectance Spectra



Some Atmospheric Correction Options

Name	Source
• ACORN	AIG
• ATCOR2/3/4	ReSe Applications Schlaepfer
• ATREM	need someone who has it
• FLASH	RSI
• HATCH	UC-Boulder
• TSR	Andrew Rogers, CSIRO
• Others	

Research and Applications

Research and Applications

- Atmosphere: water vapor, clouds properties, aerosols, absorbing gases...
- Ecology: chlorophyll, leaf water, lignin, cellulose, pigments, structure, nonphotosynthetic constituents...
- Geology and soils: mineralogy, soil type...
- Coastal and Inland waters: chlorophyll, plankton, dissolved organics, sediments, bottom composition, bathymetry...
- Snow and Ice Hydrology: snow cover fraction, grainsize, impurities, melting...
- Biomass Burning: subpixel temperatures and extent, smoke, combustion products...
- Environmental hazards: contaminants directly and indirectly, geological substrate...
- Calibration: aircraft and satellite sensors, sensor simulation, standard validation..
- Modeling: radiative transfer model validation and constraint...
- Commercial: mineral exploration, agriculture and forest status...
- Algorithms: autonomous atmospheric correction, advance spectra derivation...
- Other: human infrastructure...

AVIRIS Literature

- A citation search for "AVIRIS" in titles and abstract shows 231 refereed journal articles currently published.
- The AVIRIS workshops contain over 473 papers. These are available on-line at the AVIRIS web site.
- There are many additional AVIRIS papers in SPIE, IGARSS, ERIM and other conference proceedings

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Instrument System Requirements

- High Precision (SNR)
  - Identification of materials based on spectroscopy
- Stability (spectral, radiometric, spatial)
  - Makes calibration possible
- Uniformity (spectral, radiometric, spatial)
  - Enables spectroscopy across the image
- Calibration (spectral, radiometric, spatial)
  - Required for the physics, chemistry, and biology of spectroscopy
  - Allows autonomous compensation for the atmosphere

SUMMARY

- Imaging Spectroscopy is a new approach to remote sensing based in the physic, chemistry, and biology of spectroscopy

- Imaging Spectroscopy leads to over determined solutions for the composition of the surface and atmosphere.

- Imaging Spectroscopy requires advanced sensor, computer, and algorithm technology

- Imaging Spectroscopy requires an instrument with high SNR, high stability, high uniformity,

SUMMARY

- Imaging Spectroscopy requires an instrument with
  - High SNR
  - High stability
  - High uniformity
  - Excellent calibration

- With these instrument and corresponding data characteristics atmospheric correction is possible

- With high fidelity imaging spectrometer data, a range of new research and application become possible...

Information

- AVIRIS website: http://aviris.jpl.nasa.gov
- Email: rog@spectra.jpl.nasa.gov
- AVIRIS Workshop Proceedings: On-line at website
- AVIRIS Workshop: March 2003