On-Orbit Radiometric Calibration and Monitoring the On-Orbit Spectral Calibration of Hyperion

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Overview

- Objective and Justification
- On-Orbit Calibration Approach
- Hyperion, AVIRIS, and In Situ Measurements
- Analysis and Results
  - Absolute Radiometric Calibration
  - Cross-track Radiometric Properties
  - Radiometric Precision
  - Absolute Spectral Calibration
  - Spectral Calibration Stability
- Summary and Conclusions

Objective

- Assess the on-orbit radiometric and spectral calibration of EO-1 Hyperion
- If necessary, provide a basis for improved on-orbit radiometric and spectral calibration
- Extend and establish techniques that may be used with future imaging spectrometer missions

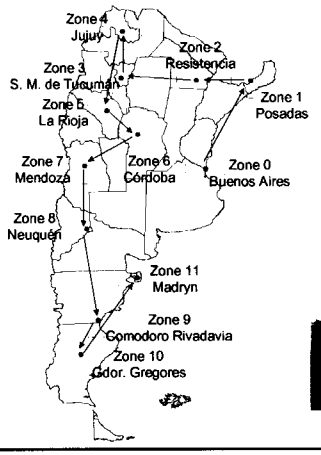
Justification

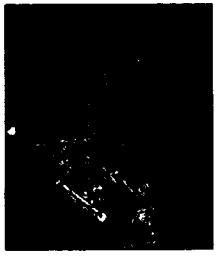
- Imaging spectroscopy data must be spectrally, radiometrically and spatially calibrated in order to:
  - Derive physical parameters from measured radiance
  - Compare data acquired from different regions and from different times
  - Compare and analyze imaging spectroscopy data with data acquired by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

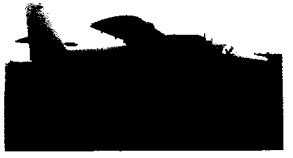
Hyperion On-orbit Calibration Approach

- Orchestrate a simultaneous AVIRIS underflight of Hyperion over a large uniform calibration target.
- Collect supporting in situ atmospheric and surface measurements at the target.
- Use these data to predict the upwelling radiance field at Hyperion.
- With the predicted incident radiance, assess the on-orbit radiometric and spectral characteristics of Hyperion.

Measurements: To support EO-1 Hyperion calibration and science validation, a 2001 AVIRIS campaign to Argentina was organized





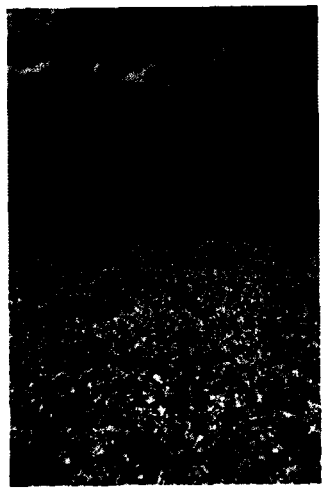


Two Primary Calibration Experiments

- Leoncito, 22 January 2001
  - Dry lakebed (silt composition) similar in surface and climate to the classic lakebeds of the western United States (Ivanpah, Railroad Valley, Lunar Lake, Rogers Dry Lake, etc.)
  - Logistically well situated near Mendoza
- Arizaro, 7 February 2001
  - High altitude dry lakebed (salt composition) with very different surface
    - Bright in the blue, extreme micro topography and BRDF
  - Logistically challenging
    - 6 hour paved plus 8 hour dirt road from City of Salta
    - no hotel, no gas, no restaurant

Leoncito, Team Argentina

Arizaro, Argentina



ARIZARO, Argentina

High altitude (~12,000ft) dry salt lakebed.

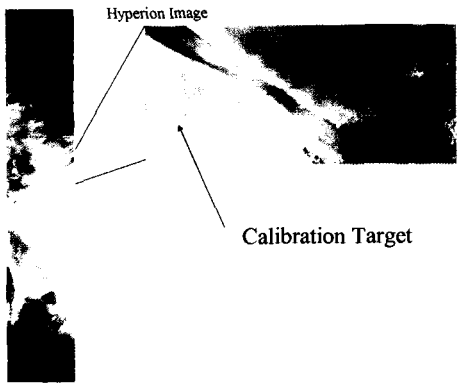
Surface: extremely rough, locally uniform, and bright.

Some years no rain at all!

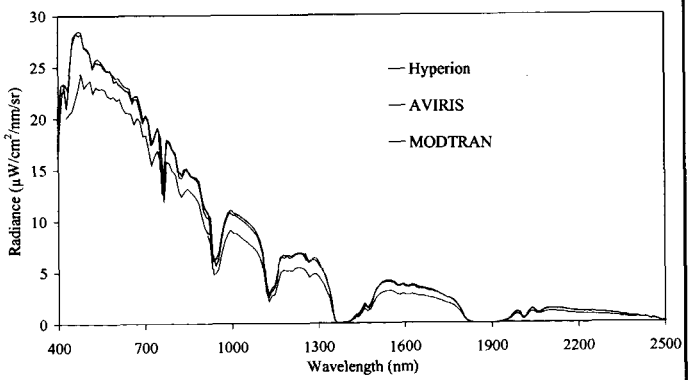
It rained the day we arrived

Conditions were good for the experiment on the 7th of February 2001.

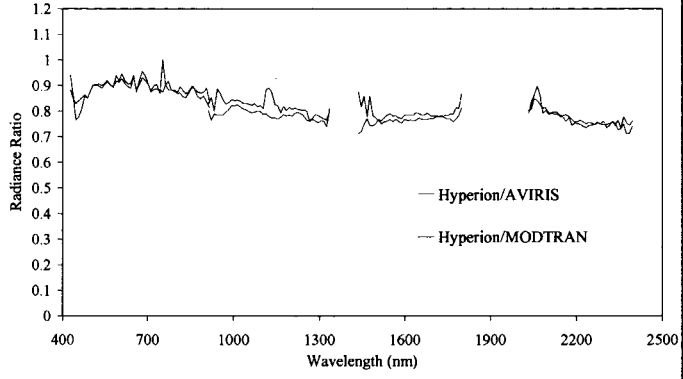
Hyperion Measurements Arizaro 010207



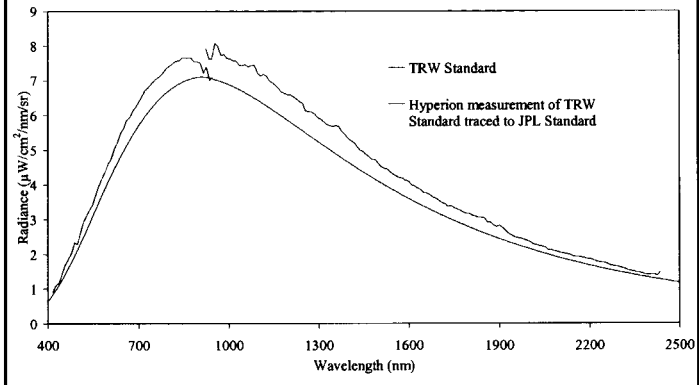
Hyperion, AVIRIS, and Ground Based Radiance for Arizaro Calibration Target



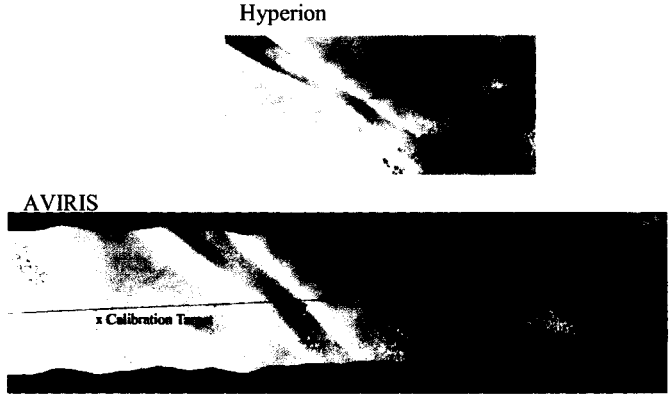
Comparison of Hyperion Measured and Predicted Radiance



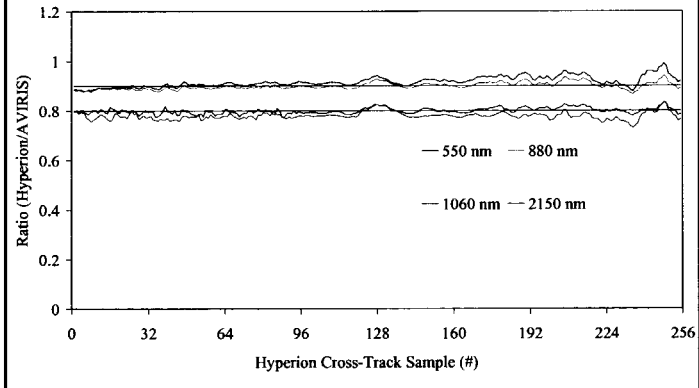
Comparison of Laboratory Radiometric Standards



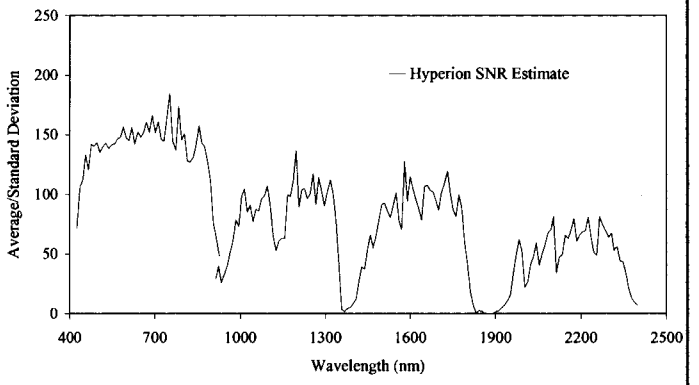
Investigation of Hyperion Cross-Track Uniformity



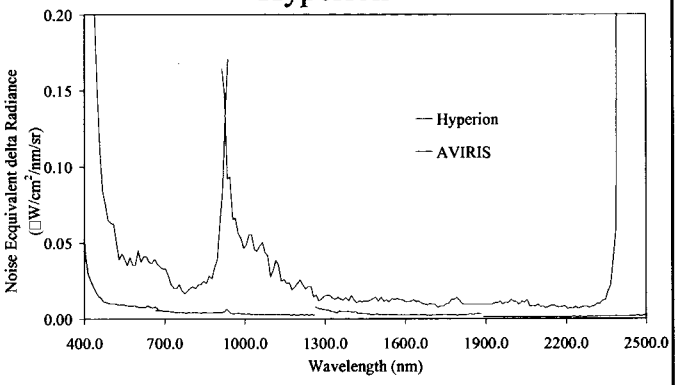
Hyperion Shows a Uniform Cross-Track Response in the VNIR and SWIR



Hyperion SNR Estimate for Homogeneous Portion of Arizaro



Precision Comparison of AVIRIS and Hyperion



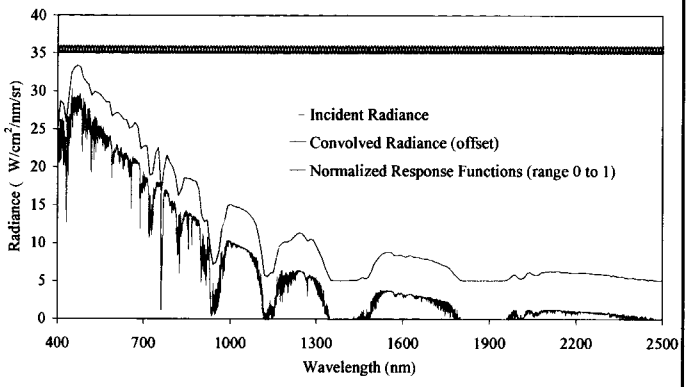
Hyperion met its technology demonstration goals

On-orbit Radiometric Assessment

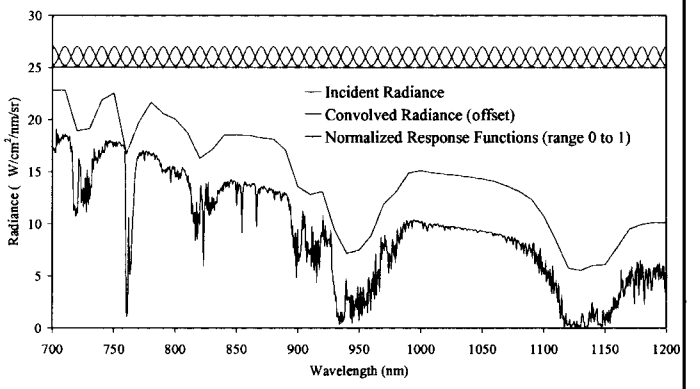
- The Arizaro experiment indicates Hyperion was under reporting the total upwelling spedtral radiance by ~10% in the VNIR and ~20% in the SWIR.
- A 10 percent value is consistent with uncertainties in the laboratory calibration data.
- In November of 2001 the Hyperion radiometric calibration was adjusted by 8% in the VNIR and 18% in the SWIR
- Hyperion cross-track radiometric response is uniform.
- Hyperion precision is a fifth to a tenth of AVIRIS.

Hyperion on-orbit Spectral Calibration Assessment

Spectral Convolution

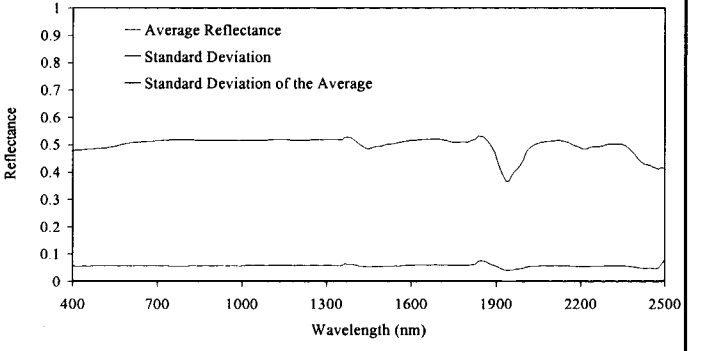


Expanded Spectral Convolution

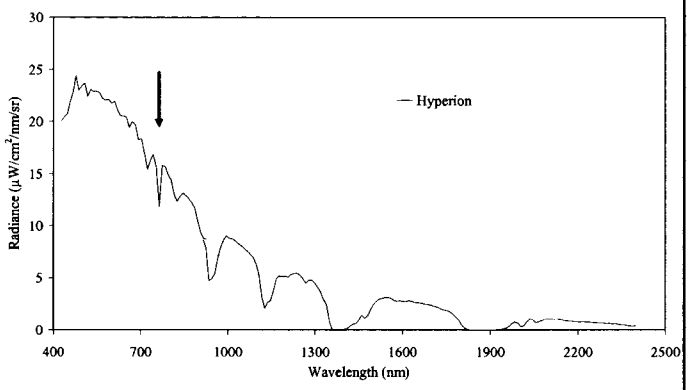


Arizaro In Situ

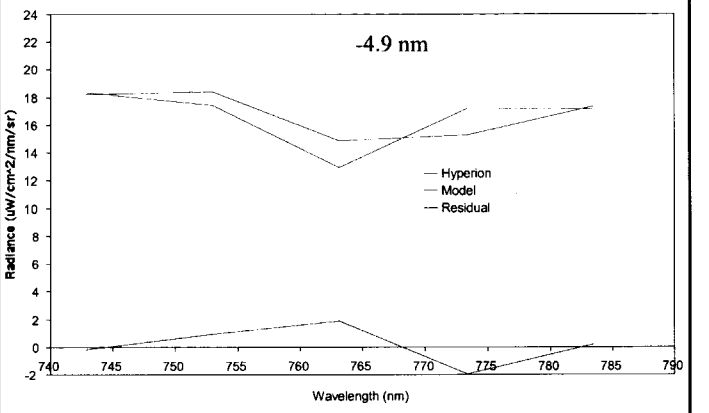
Arizaro Calibration Target Measured Surface Reflectance



760 nm Oxygen Band

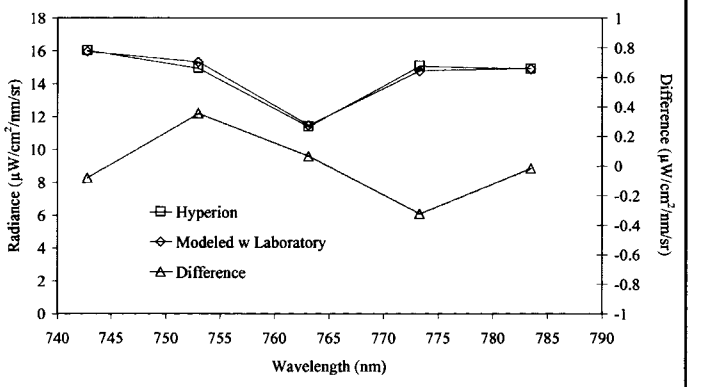


Arizaro Calibration Experiment



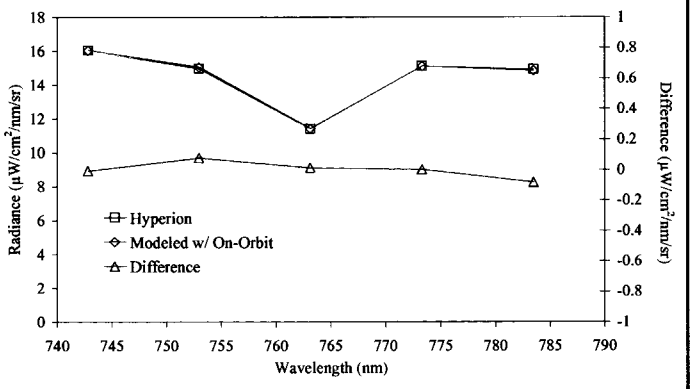
Arizaro Calibration Experiment

Fit with nm shift from laboratory calibration

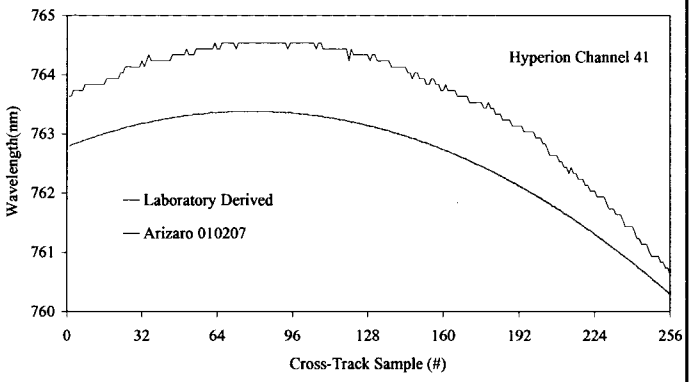


Arizaro Calibration Experiment

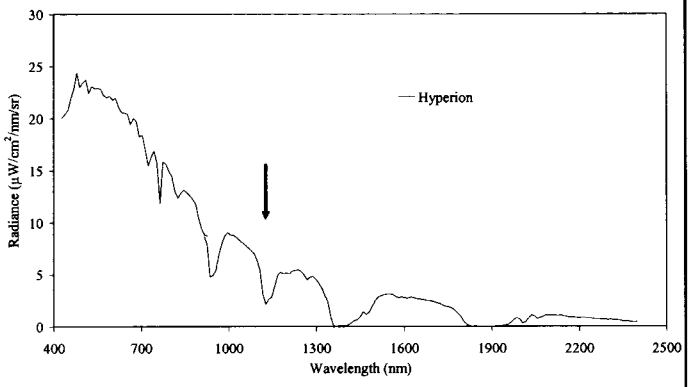
Sample 2 with 0.5 nm shift from laboratory calibration



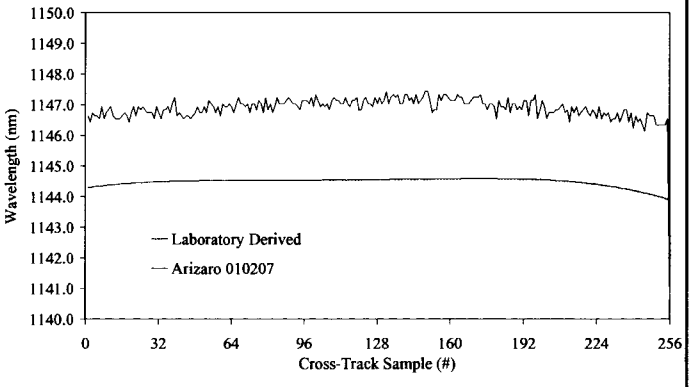
Spectral Calibration VNIR



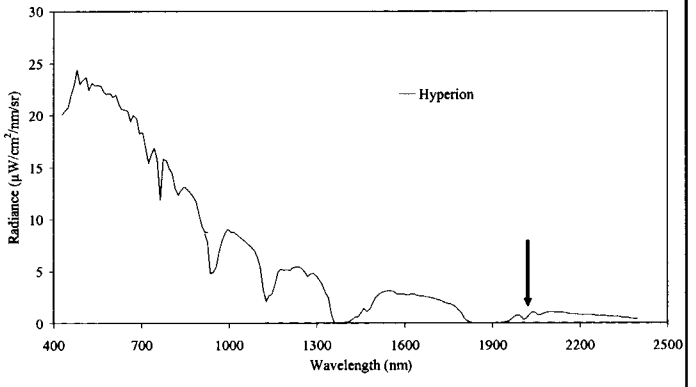
1140 nm Water Vapor Band



Arizaro Calibration Experiment

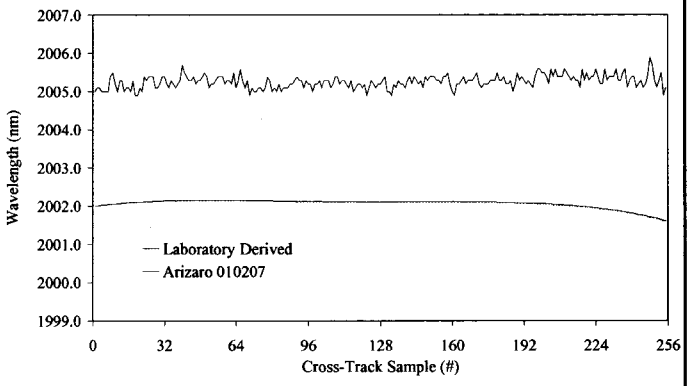


2000 nm Carbon Dioxide



Arizaro Calibration Experiment

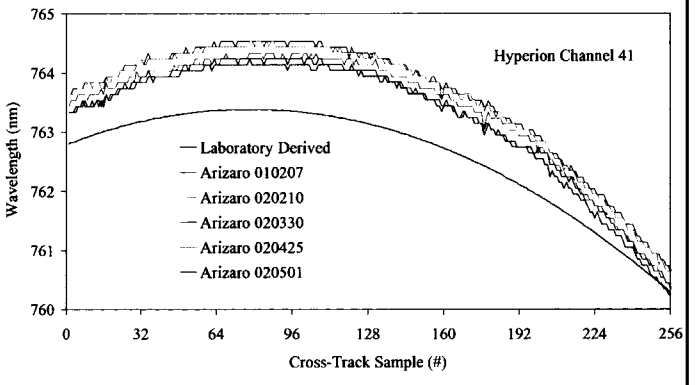
Spectral Smile from 2005 nm Carbon Dioxide Band



Hyperion On-Orbit Spectral Stability

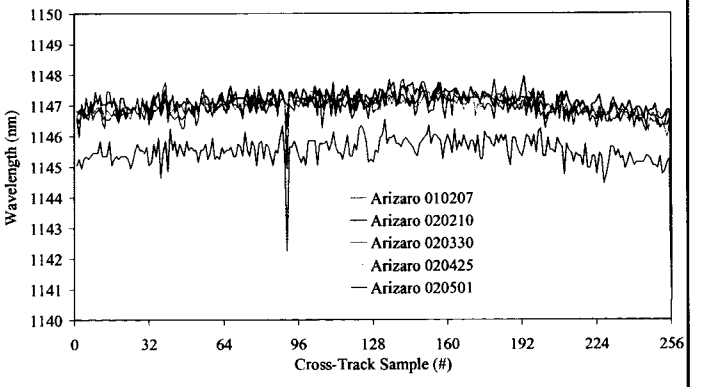
- Hyperion data provided and analyzed Arizaro for
  - 7 February 2001
  - 10 February 2002
  - 30 March 2002
  - 25 April 2002
  - 1 May 2002

Spectral Calibration Stability VNIR 760nm Oxygen Band



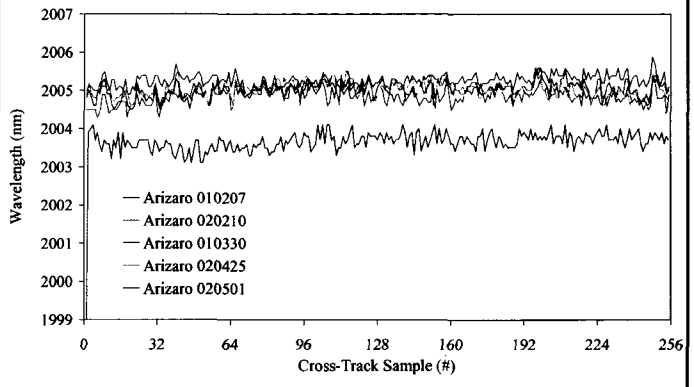
Spectral Calibration Stability SWIR

1140 nmWater Vapor Band



Spectral Calibration Stability SWIR

2000 nm Carbon Dioxide Band



Hyperion On-Orbit Spectral Assessment for Calibration Experiment at Arizaro, Argentina

- A spectral fitting approach with high resolution modeled spectra was successfully used to assess the Hyperion on-orbit spectral calibration.
- At 760 nm (VNIR) the cross-track spectral smile was confirmed and found shifted from 0.5 to 1.5 nm with respect to the laboratory determined values.
- At 1140 nm in the SWIR, a weak spectral calibration smile was derived, though the calibration was shifted from 2.5 to 3 nm with respect to the laboratory calibration
- Analysis of a time series of Hyperion data from Arizaro showed largely stable spectral calibration ±0.5 nm in the VNIR and SWIR spectrometers with a possible 1.5 nm shift in the SWIR in May 2002.

Summary

•The on-orbit radiometric assessment of Hyperion with both AVIRIS and in situ measurements showed Hyperion to be low by ~10% in the VNIR and ~20% in the SWIR spectrometer. These results in conjunction with results from other radiometric calibration investigations were used to adjust the on-orbit radiometric calibration of Hyperion. (8% VNIR and 18% SWIR in November 2001)

•The cross-track radiometric response was found to be uniform at the 5% level.

•The on-orbit precision assess via NEdL was between a fifth to a tenth of AVIRIS.

•The on-orbit spectral calibration of Hyperion was assessed in the VNIR and SWIR spectrometers(O2, H2O, CO2). Shifts of 1 to 1.5 nm were found in the VNIR and from 2.5 to 3 nm in the SWIR compared to the laboratory calibration.

•The spectral calibration was found to be largely stable with evidence of a 1.5 nm shift in the SWIR in May 2002.

Conclusions

•Useful strategies for determination of the on-orbit radiometric and spectral calibration characteristics of Imaging Spectrometers were demonstrated.

•These results provide an improved on-orbit calibration of Hyperion data for research and application investigations.

•For future instrument builders

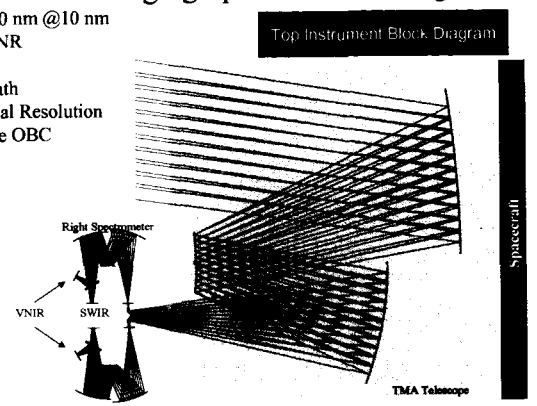
- •The focus must be Precision (SNR), Stability, Uniformity
- •These enable calibration
- •Spectral smile in pushbroom instruments is a function of design, alignment, and stability.
- •Hyperion was designed to be nearly smileless. This was achieved in the SWIR spectrometer.

Conclusions

- With a high precision, stable, uniform spaceborne imaging spectrometer the laboratory focus should be on spectral, radiometric, and spatial characterization.
- A rapid/rigorous on-orbit calibration activity should follow launch.
- It should be expected that analysis of the on-orbit calibration results in concert with the laboratory characterization will provide the best on-orbit calibration.
- Laboratory calibration/characterization is important, but not sufficient.
- The only calibration that counts is the on-orbit calibration.
- Dominant factors:
  - Precision (low F/#, large detector area)
  - Stability (Design, Thermal)
  - Uniformity (Advanced Offner-like Design)

Future? 2003 Imaging Spectrometer Design

350 to 2500 nm @10 nm
AVIRIS SNR
<2% smile
40 km Swath
30 m Spatial Resolution
0.1% stable OBC



F/2.8 Offner with dual blaze grating

Thanks to Steve, the Hyperion Team, and all.