



# **HyspIRI**

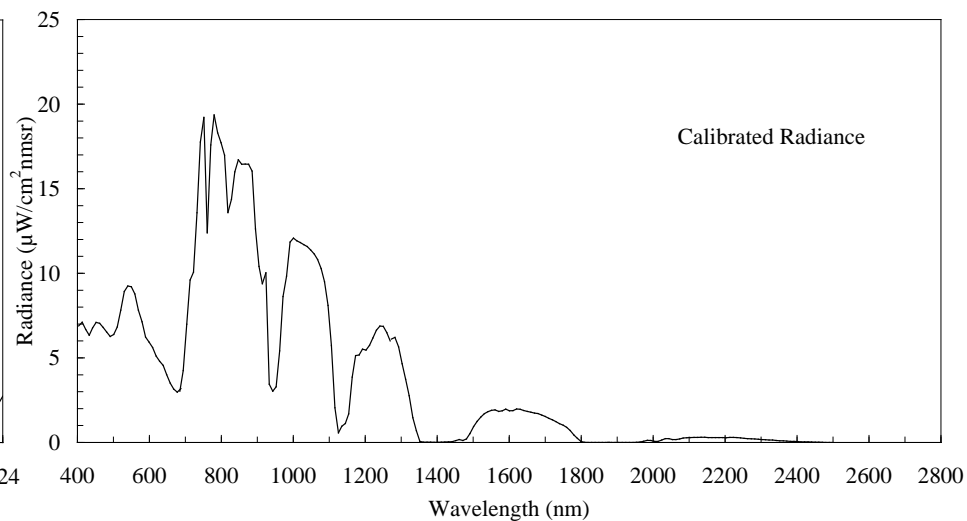
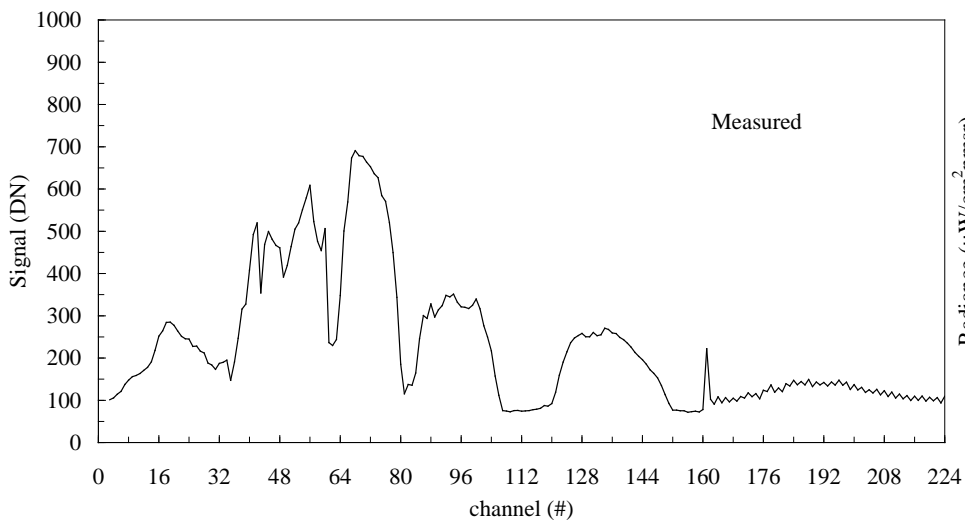
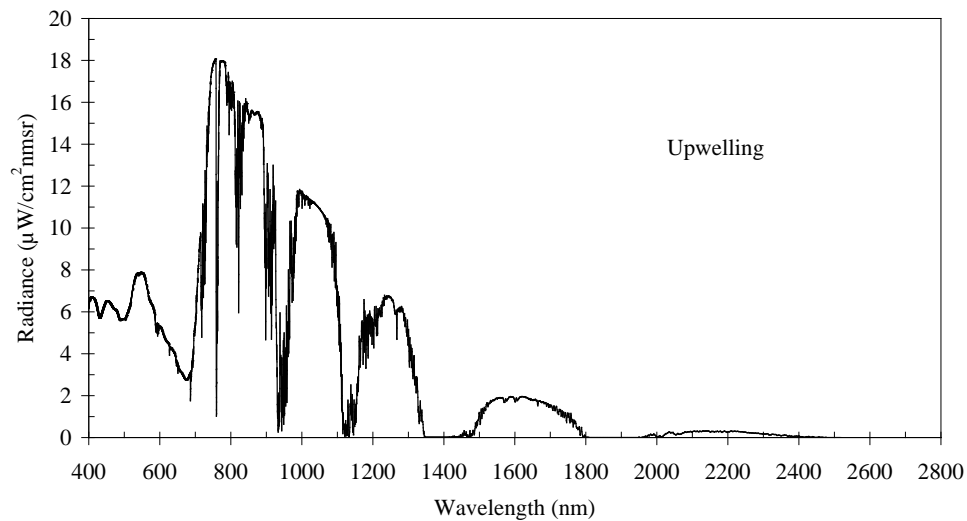
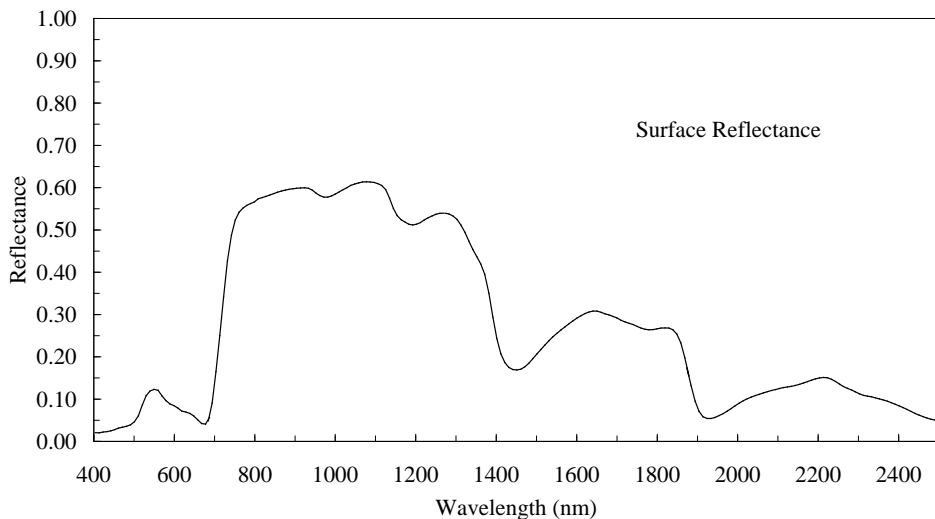
## **VSWIR Calibration and Validation**

**NASA Earth Science and Applications  
Decadal Survey**

Robert Green and HyspIRI Team



# Calibration and the Signal





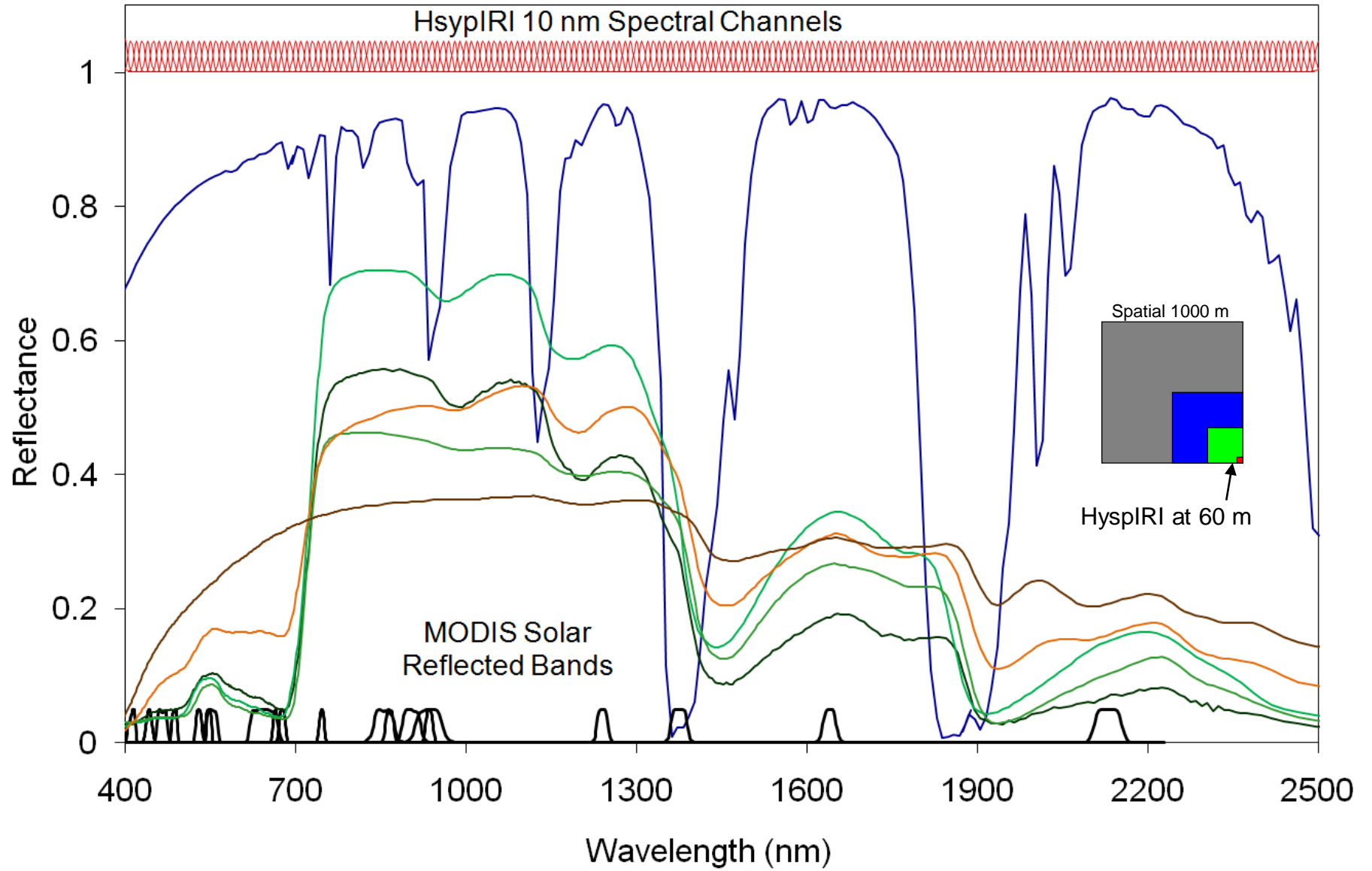
# **HyspIRI VSWIR Imaging Spectrometer Measurement Characteristics**



# HyspIRI VSWIR

## Key Science Measurements

### Characteristics





# HyspIRI VSWIR

## Science Measurement Characteristics

### Spectral

Range	380 to 2500 nm in the solar reflected spectrum
Sampling	$\leq 10$ nm {uniform over range}
Response	$\leq 1.2$ 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
Cross-Track Samples	$> 2500$
Sampling	$\leq 60$ m
Response	$\leq 1.2$ X sampling (FWHM)

### Uniformity

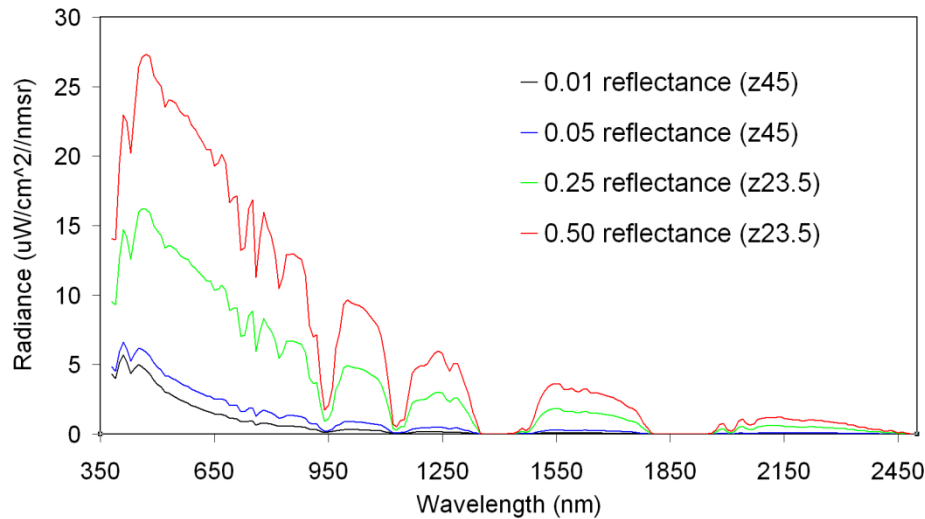
Spectral Cross-Track	$> 95\%$ cross-track uniformity { $< 0.5$ nm min-max over swath}
Spectral-IFOV-Variation	$> 95\%$ spectral IFOV uniformity { $< 5\%$ variation over spectral range}



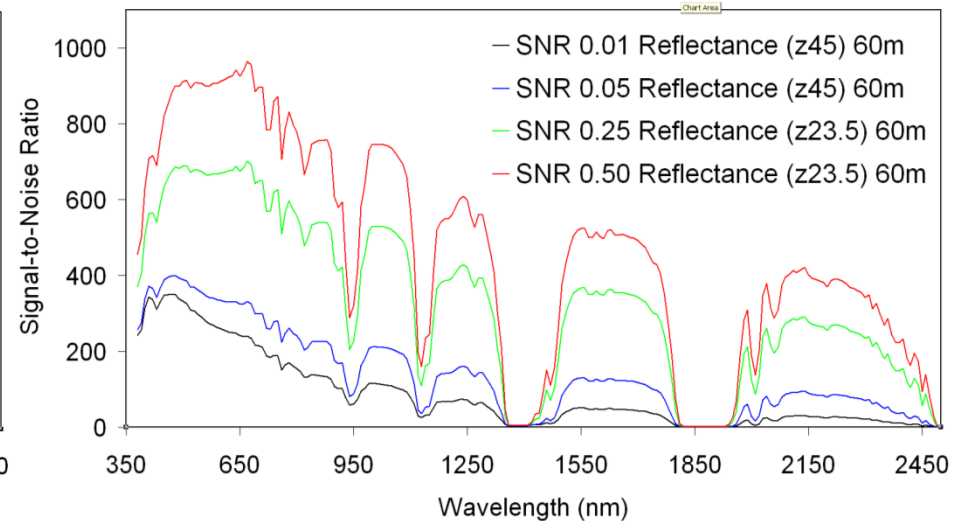
# HypIRI VSWIR Science Measurements Key SNR and Uniformity Requirements



## Benchmark Radiances

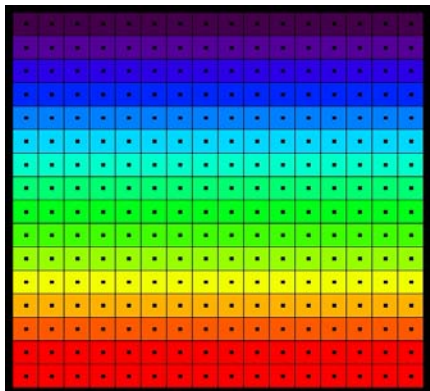


## Required SNR



## Uniformity Requirement

### Cross Track Sample



### 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}



# Laboratory Calibration



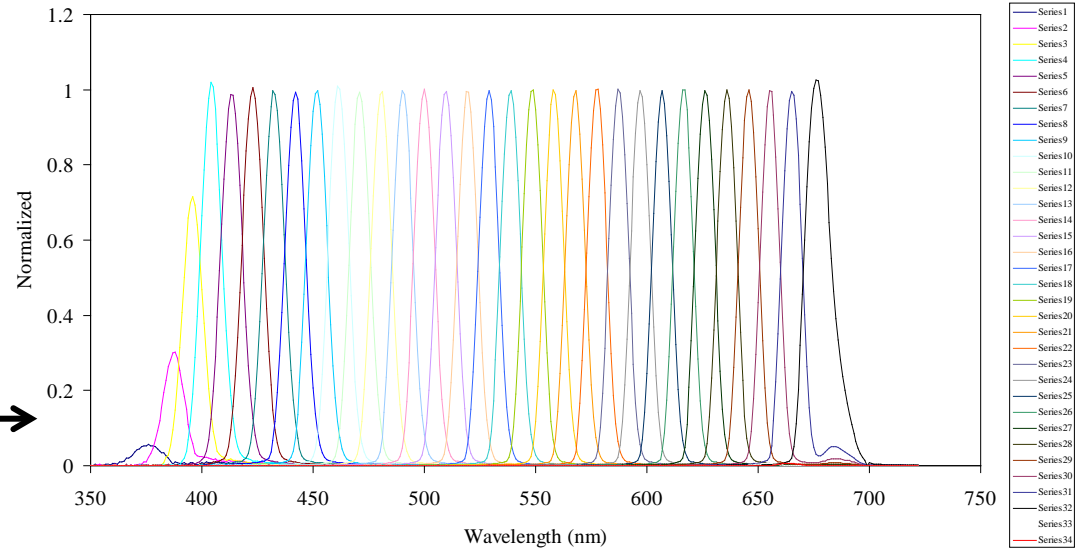
- Imaging Spectrometers have unique spectral, radiometric, and spatial characteristics
- Each calibration characteristic has response, range, and corresponding uncertainty factors
- With 100s of spectral channels and 100,000s of detector elements, imaging spectrometers present special challenges for calibration
  - HypIRI 532,500 detector elements



# Spectral Calibration



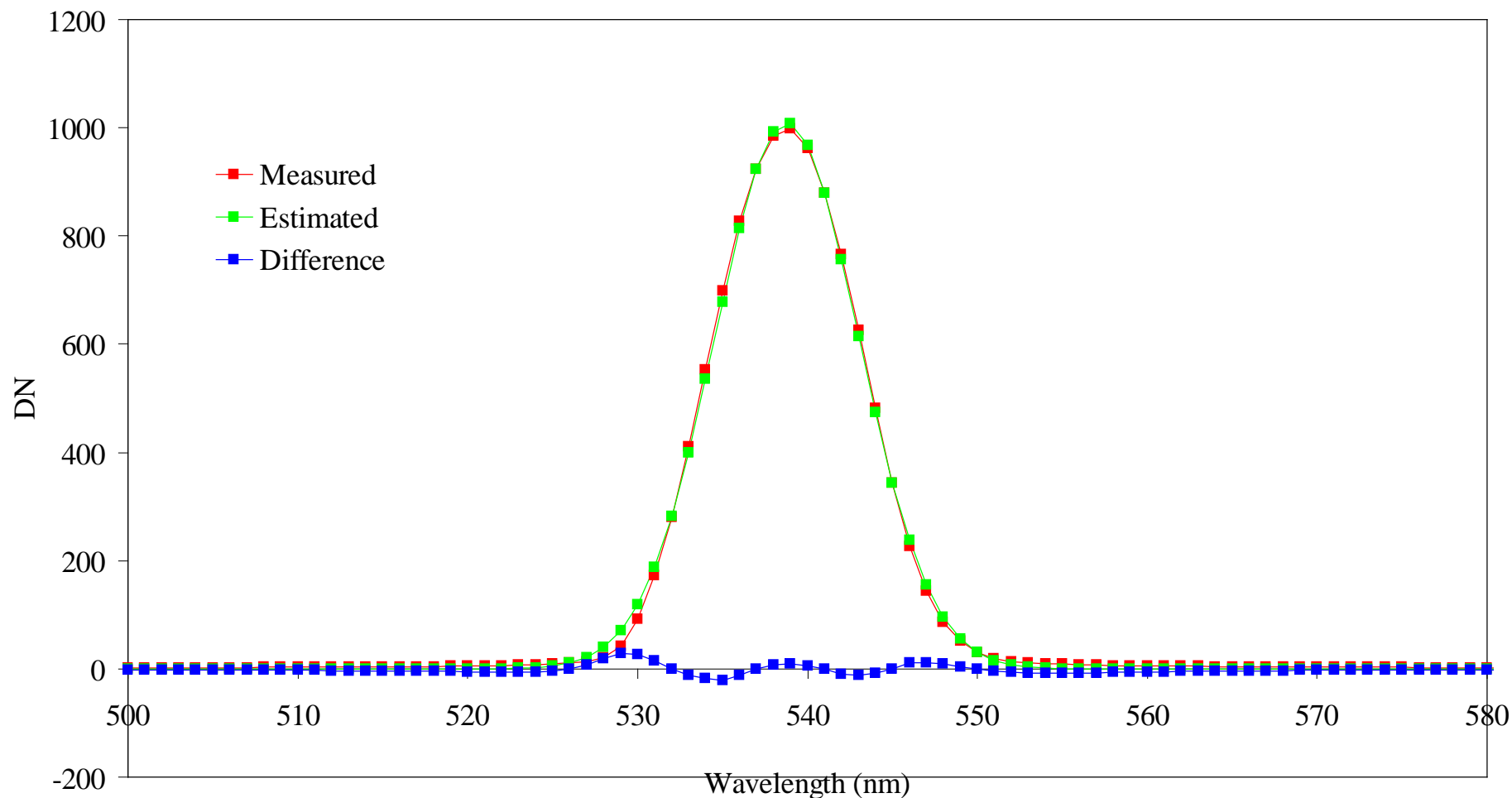
- Standards
  - Emission lamps, lasers and rare-earth target
- Approach
  - Collimator fed by scanned monochromator
  - Laser fed integrating sphere
  - Illuminated neodymium panel
- Calibration Analysis Output
  - 2D spectral calibration file with uncertainties for Global and Target modes
- Example
  - AVIRIS Spectral Response Functions (from ~2001)





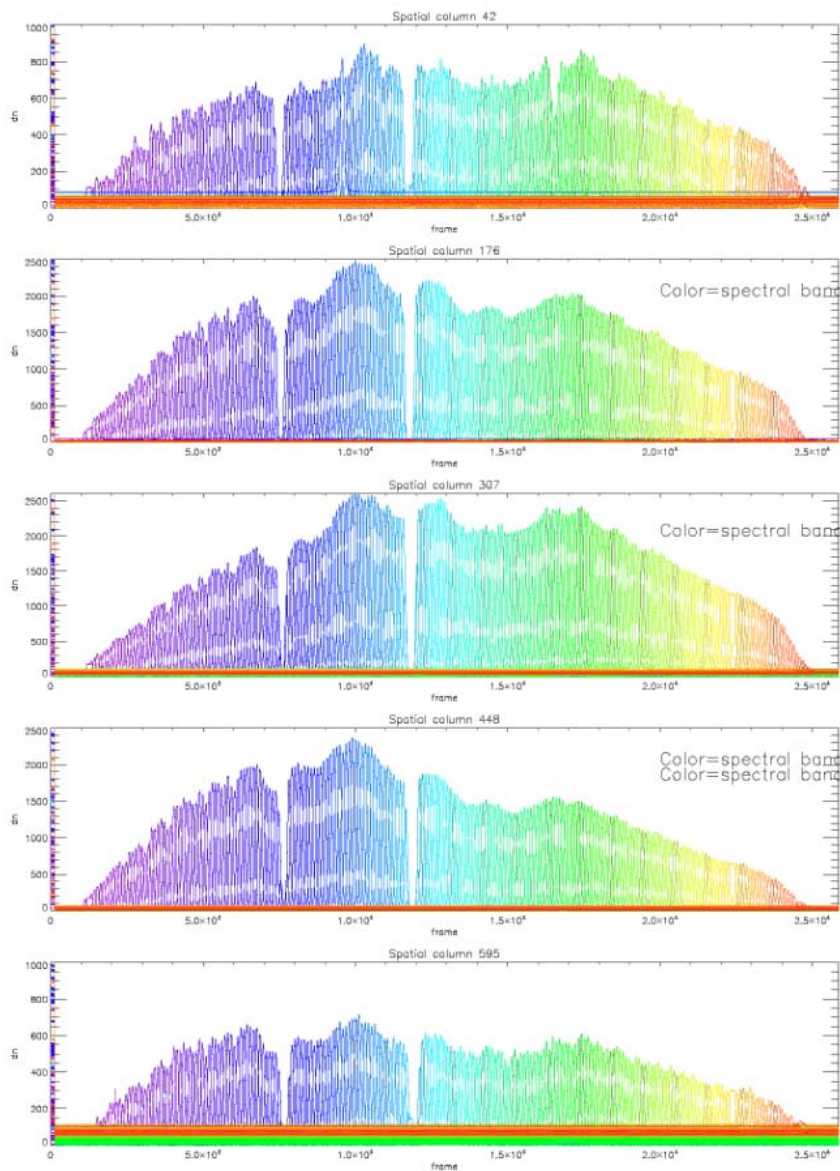


# Spectral Fit for Determination of Best Gaussian Function





# 2010 Spectral Response Function Measurements

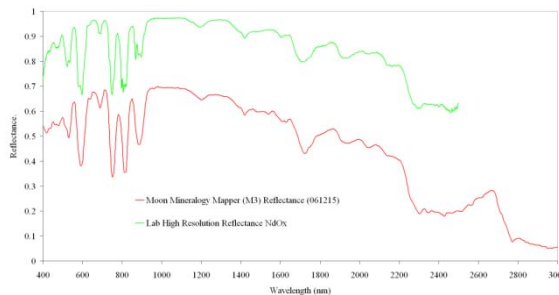




# Spectral Equipment



### Illuminated Nd Panel



### Custom Scanning Monochromator with Collimator

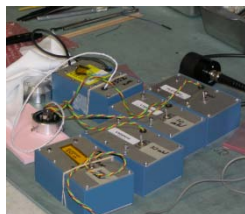


### Laser-fed Integrating Sphere



### Sphere In Use

- 407 nm
- 532 nm
- 632 nm
- 780 nm
- 830 nm
- 1064 nm
- 1a550 nm
- 2050 nm

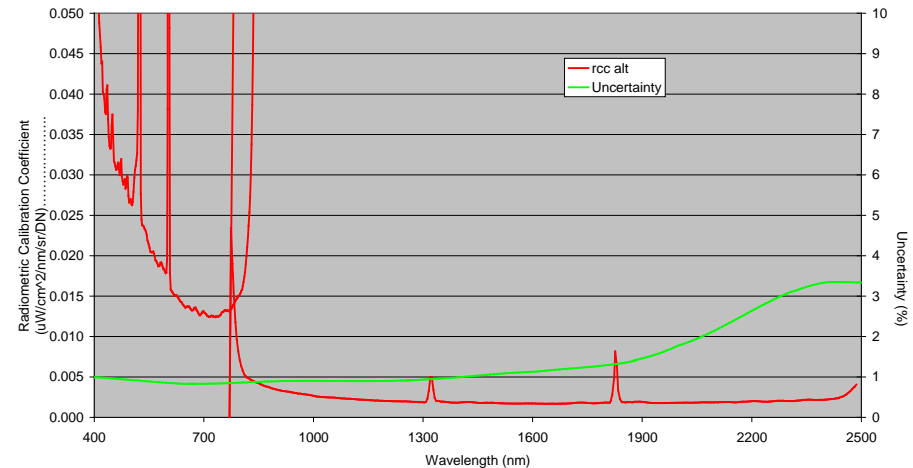




# Radiometric Calibration



- Standards
  - NIST traced lamp panel 400 to 2500 nm
  - Blackbody (BB) 1500 to 3000 nm
  - Stable integrating sphere
- Approach
  - Direct view of NIST lamp panel, integrating sphere, and BB
- Calibration Analysis Output
  - 2D radiometric calibration coefficients and uncertainties
- Example
  - Airborne-IS :  
321000 radiometric calibration coefficients and uncertainty

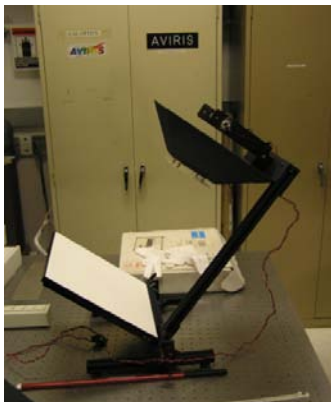




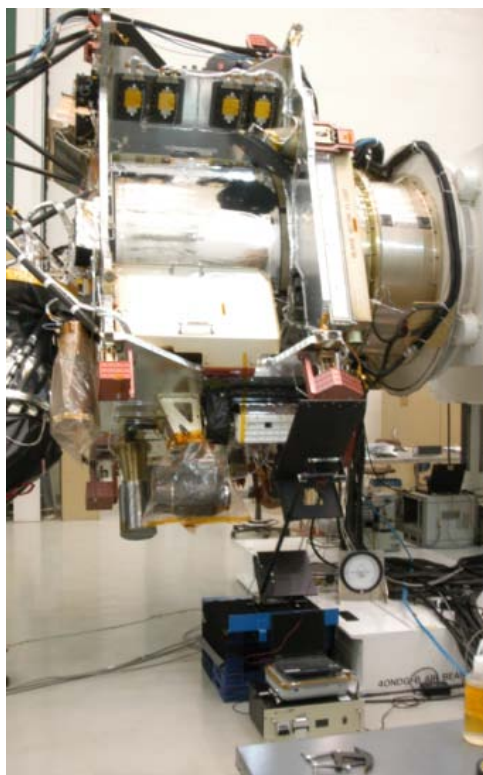
# Radiometric Equipment



NIST Traced Lamp-Panel  
400 to 2500 nm



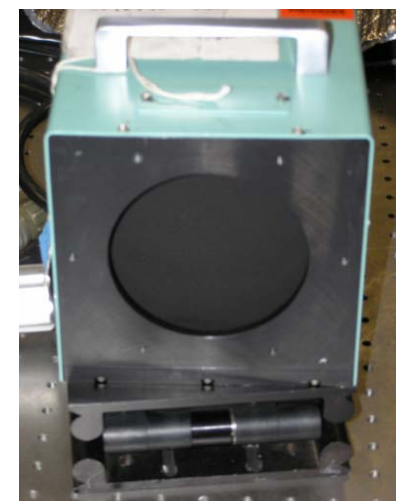
NIST Traced Lamp-Panel  
used for CRISM Check



White-light Integrating Sphere  
for Vignetting and Flat Field



Extended Area Blackbody  
1500 to 3000 nm

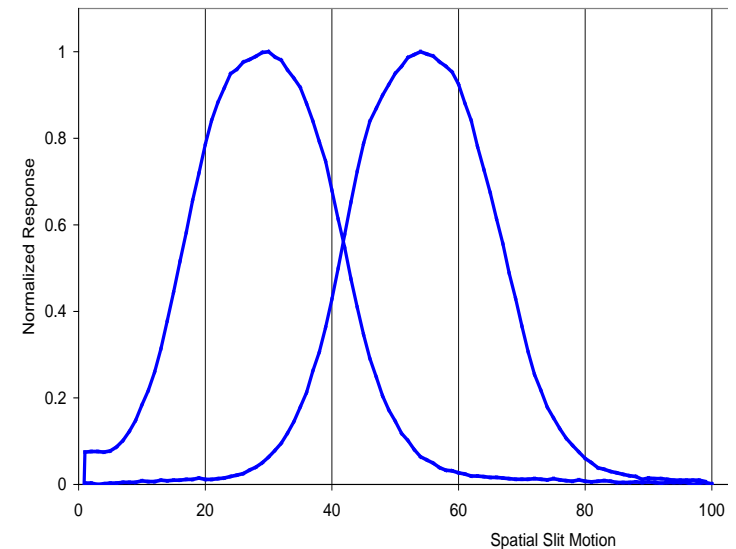




# Spatial Calibration



- Standards
  - White light illuminated slit
- Approach
  - Collimator fed by scanned white light slit
- Calibration Analysis Output
  - 2D spatial response functions and uncertainties
- Example
  - Airborne-IS spatial response functions





# Geometric Calibration



- Standards
  - Spatial targets plus validated optical design
- Approach
  - Use optical design plus selected lab collimator fed spatial targets
  - Theodolite measurements of telescope projected slit
- Calibration Analysis Output
  - Camera model cosines
- Example
  - Airborne-IS georectification





# HyspIRI Uniformity Calibration



- Standards

- Laser-fed integrating sphere
- Neodymium panel
- Scanning monochromator
- Scanning white light slit

- Approach

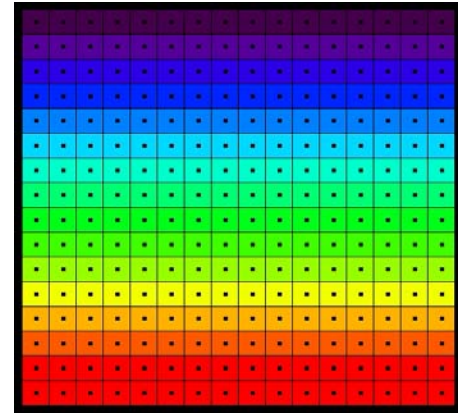
- Use optical design plus selected collimator-fed spatial targets
- Use Laser-fed integrating sphere to cover FOV

- Calibration Analysis Output

- Spectral cross-track uniformity
- Spectral IFOV uniformity

- Example

- M3 cross-track uniformity







# HyspIRI Example from Airborne-IS 2005

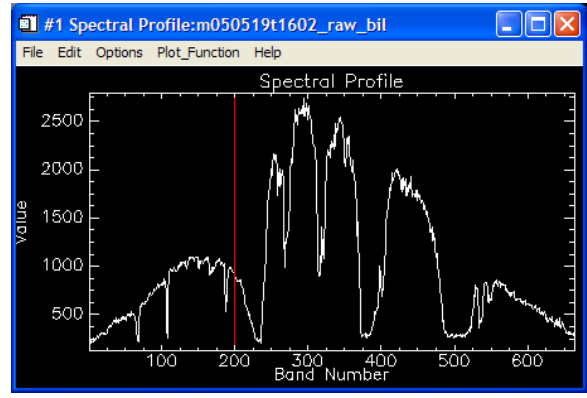


- Airborne-IS example from Ivanpah Playa
- Solar reflected spectrum
- Offner spectrometer
- TCM6604a detector array
- HyspIRI calibration standards and approach

### Level 0



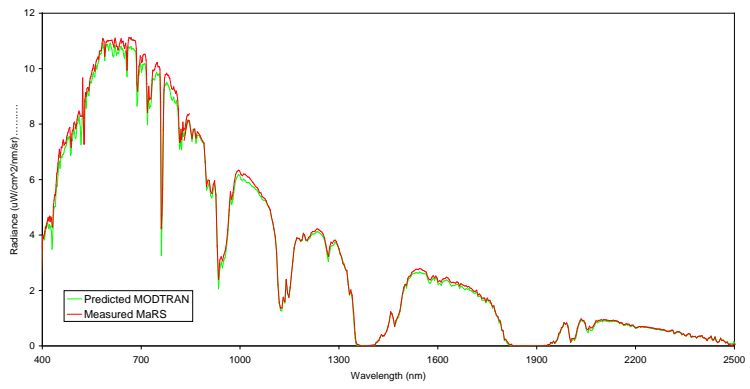
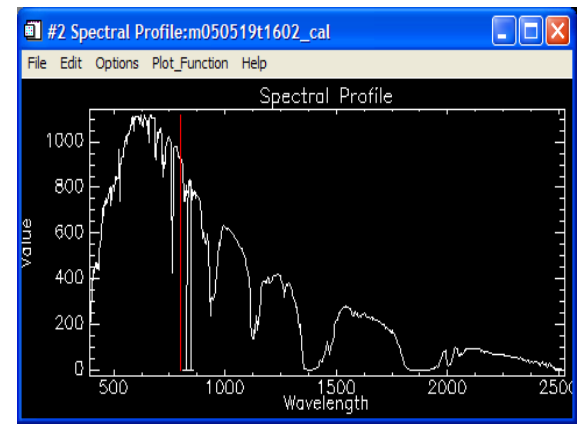
### DN versus Band



### Level 1



### Radiance versus Wavelength





# HyspIRI VSWIR Science Measurements On-Orbit Calibration Baseline



## On-Orbit Calibration

Lunar View

1 per month {radiometric}

Solar Cover Views

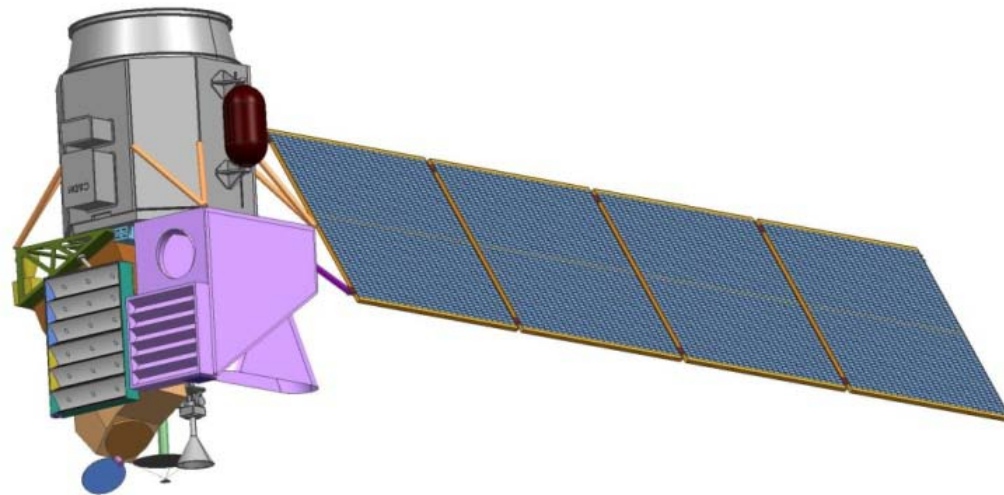
1 per day {radiometric}

Dark signal measurements

1 per orbit and edge detector tracking

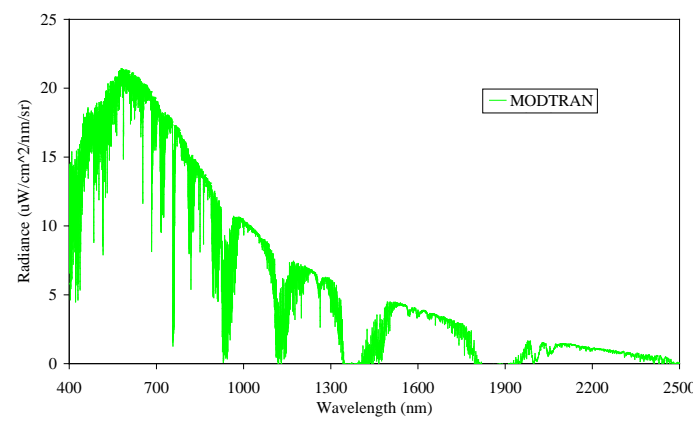
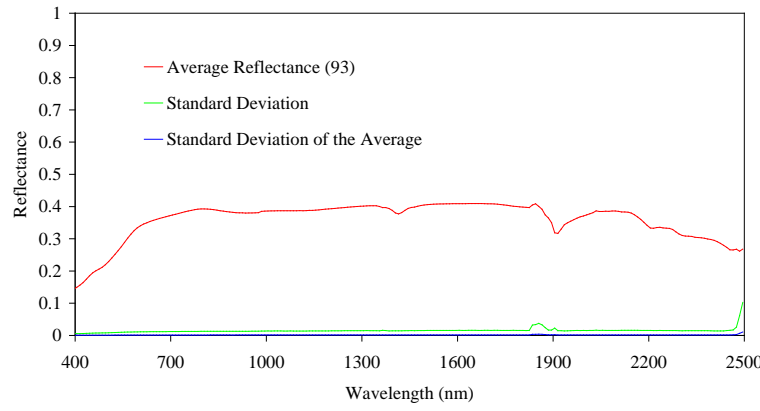
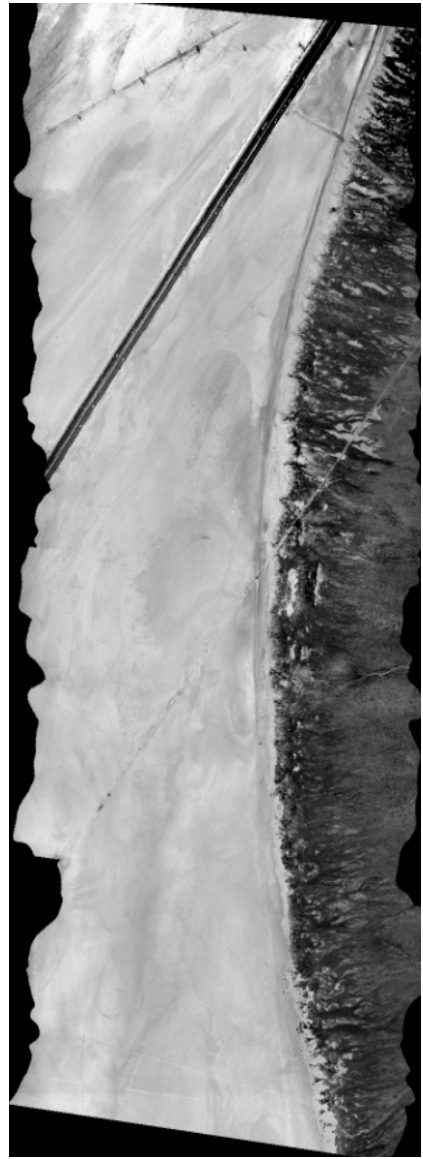
Surface Cal Experiments

>3 per year {spectral & radiometric}



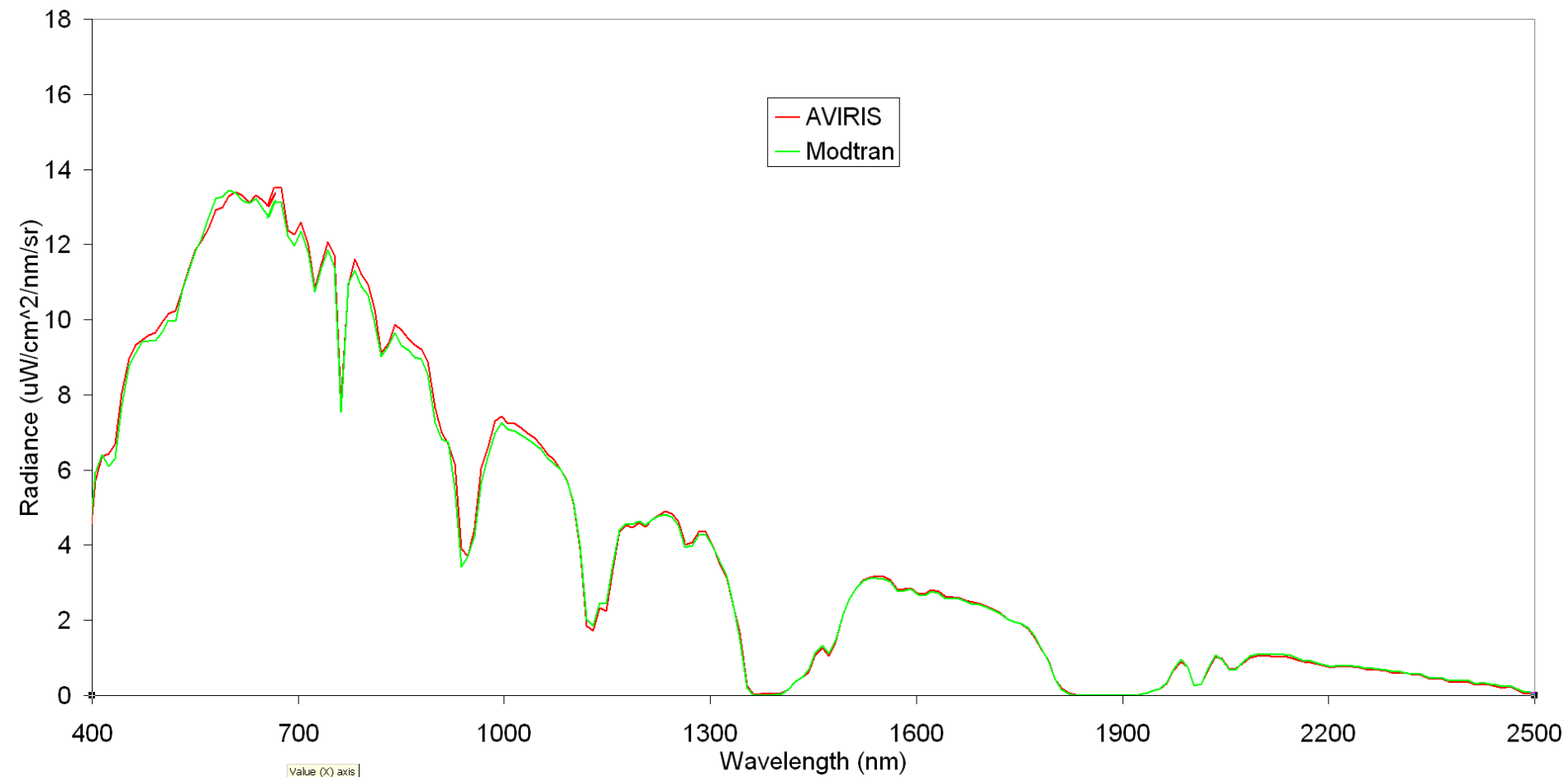


# Inflight Calibration Validation Experiment



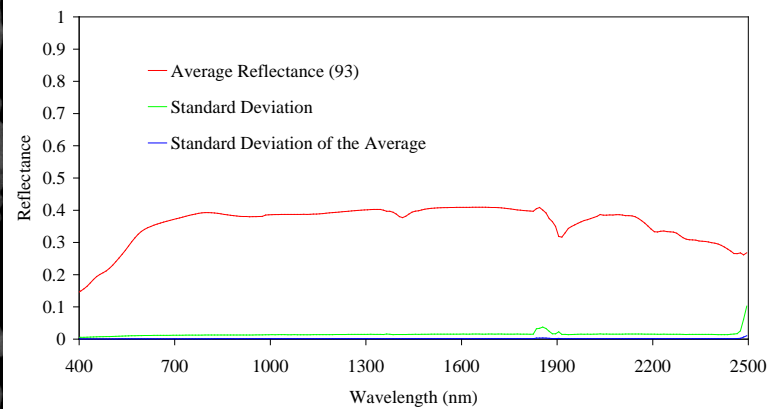
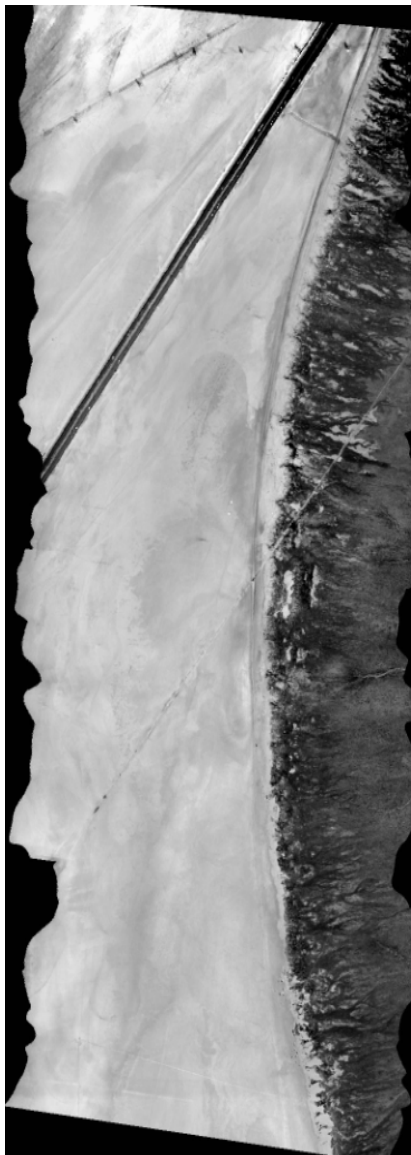


# AVIRIS Calibration Experiment 060506



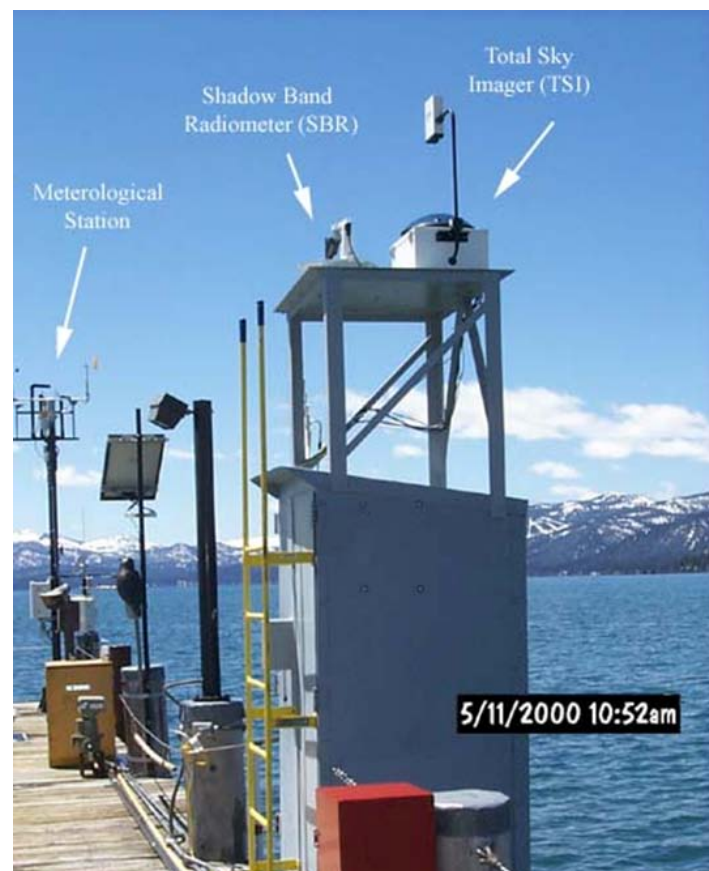
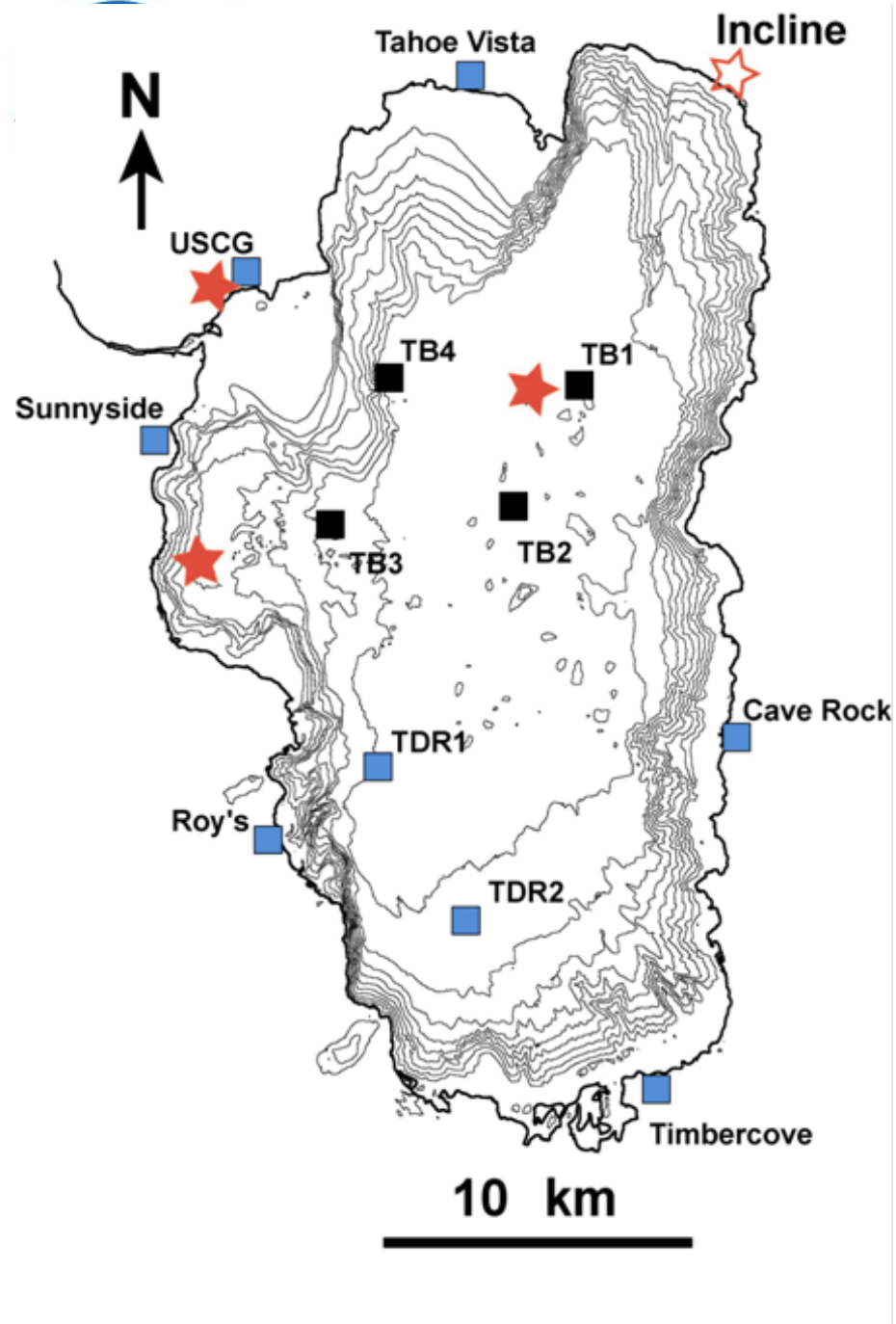


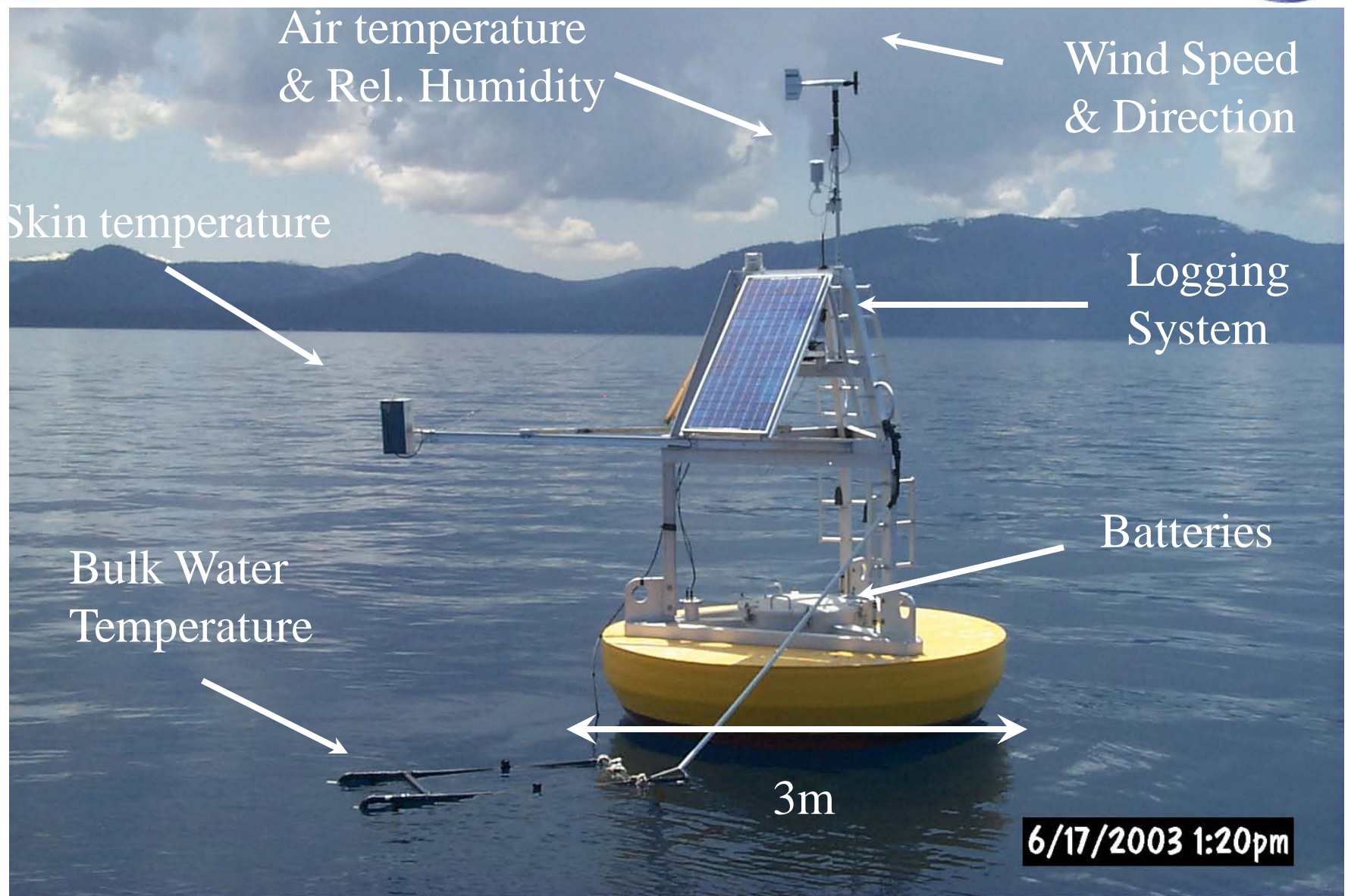
# Level 2 Reflectance Validation





# Candidate Dark Target Validation Site





Air temperature  
& Rel. Humidity

Wind Speed  
& Direction

Skin temperature

Logging  
System

Bulk Water  
Temperature

Batteries

3m

6/17/2003 1:20pm



# International Interaction for Calibration and Validation



- Australia
  - **Calibration Validation**, Carbon, Coastal Ocean GBR
  - Data Processing
- Canada
  - Product validation, Forestry,
  - Data Processing
- Israel
  - **Calibration Validation**
- Europe
  - EnMap, PRISMA, Product validation
  - Data Processing
- Brazil
  - Product validation
- Argentina
  - **Calibration Validation**, Product validation
- India
  - Agriculture, Himalaya, Product validation





# HyspIRI Calibration Summary



- The HyspIRI calibration requirements are well understood.
- The imaging spectrometer calibration history for HyspIRI is strong.
  - AVIRIS, WarFighter, Hyperion, CRISM, Airborne-IS, M3, etc.
- Detail ground calibration procedures and practices are in understood
- The HyspIRI VSWIR instrument includes a solar calibration panel (Hyperion derivative), Monthly lunar views, and ground calibration validation.
- On-Orbit Calibration experiments are core to the baseline mission
- Level 2 product validation will be performed for a range of surface types from bright to dark.
- Extensive international collaboration is planned for calibration and validation of level 1 and level 2 products