# The Portable Remote Imaging Spectrometer (PRISM) Coastal Ocean Sensor

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# The PRISM Team

## Instrument team

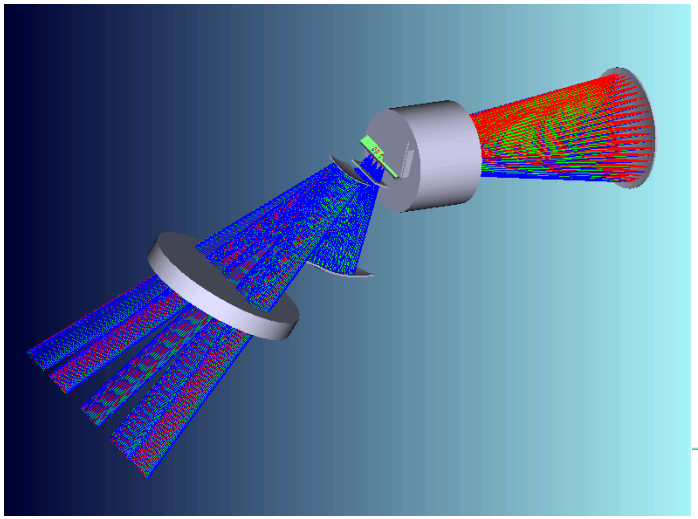
Pantazis (Zakos) Mouroulis: *PI, optics*
Byron Van Gorp: *System engineer & mechanics*
Robert O. Green: *Calibration, radiative transfer*
Daniel Wilson: *Diffraction grating*

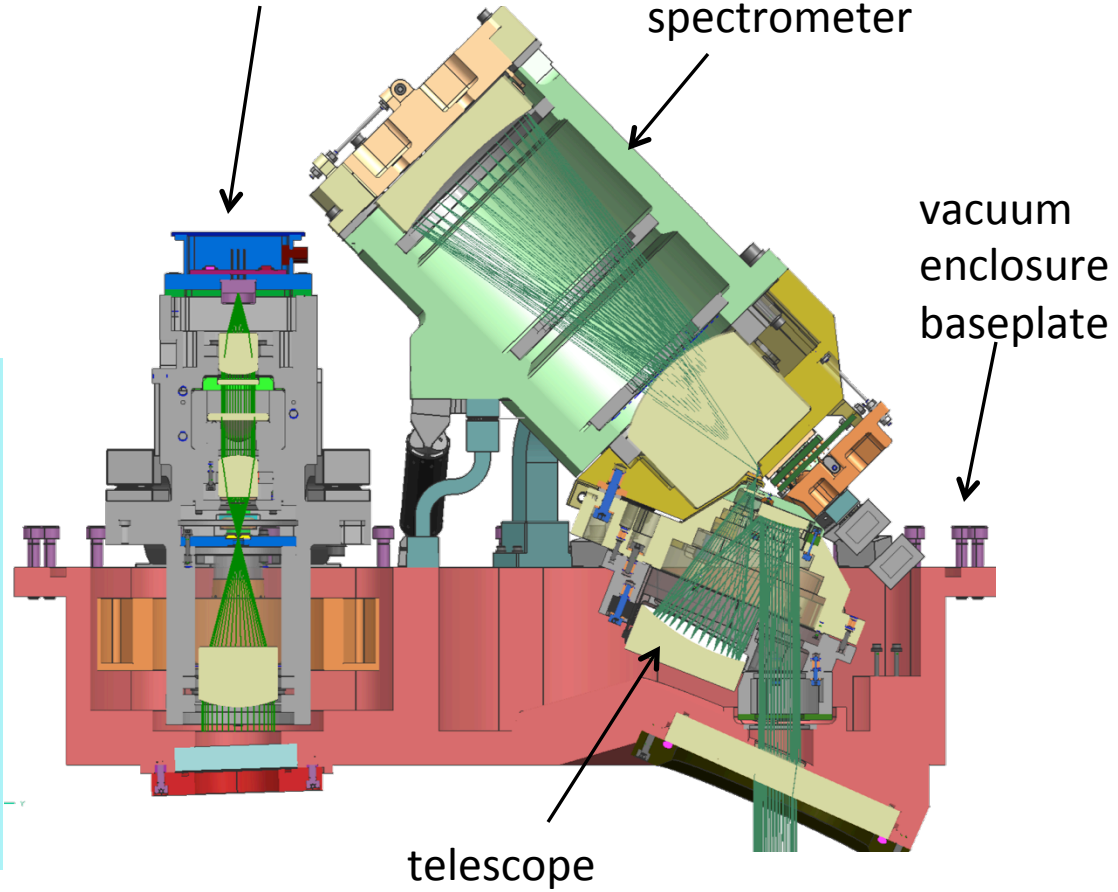
K. Balasubramanian, David Cohen, Michael Eastwood, Brian Franklin, Linley Kroll, Scott Leland, Frank Loya, Alan Mazer, Ian McCubbin, Doug Moore, Scott Nolte, Otto Polanco, David Randall, Brandon Richardson, Jose Rodriguez, Chuck Sarture, Eugenio Urquiza, Rudy Vargas, Victor White, Karl Yee

## Science team

Heidi Dierssen (UConn): *Science lead*
Bo-Cai Gao (NRL): *Atmospheric correction algorithm*
Joe Boardman (AIG): *Orthorectification, geolocation*

# PRISM schematic





# Spectrometer parameters

| | | |
|---|---|---|
| Spectral | Range | 350-1050 nm |
| | Sampling | 2.85 nm |
| | Resolution (FWHM) | 3.5 nm |
| | Calibration uncertainty | < 0.1nm |
| Spatial | Field of view | 31.7° |
| | Instantaneous FOV sampling | 0.882 mrad |
| | IFOV resolution (FWHM) | 0.97 mrad |
| | Cross-track spatial pixels | 608 |
| | Ground resolution | 0.35 – 20 m |
| Radiometric | Range | 0 to max. beach R |
| | Sampling | 14 bit |
| | Stability | >99% |
| | Calibration uncertainty | <2% |
| | SNR | 2000 @450 nm* |
| | Polarization variation: | < 1% |
| Uniformity | Spectral cross-track uniformity | >95% |
| | Spectral IFOV mixing uniformity | >95% |

* At AVIRIS equivalent integration time and spectral sampling

# SWIR channel parameters

| Parameter | Channel 1 | Channel 2 |
|---|---|---|
| Channel center (nm) | 1242 | 1608 |
| Bandwidth FWHM (nm) | 22 | 56 |
| FOV (mrad, FWHM) | 2.4 | 2.4 |
| Boresight knowledge (mrad, relative to spectr.) | 0.05 | 0.05 |
| Radiometric stability | 99% | 99% |
| SNR @ 1.2mW/cm$^2$ sr | 325 | 390 |

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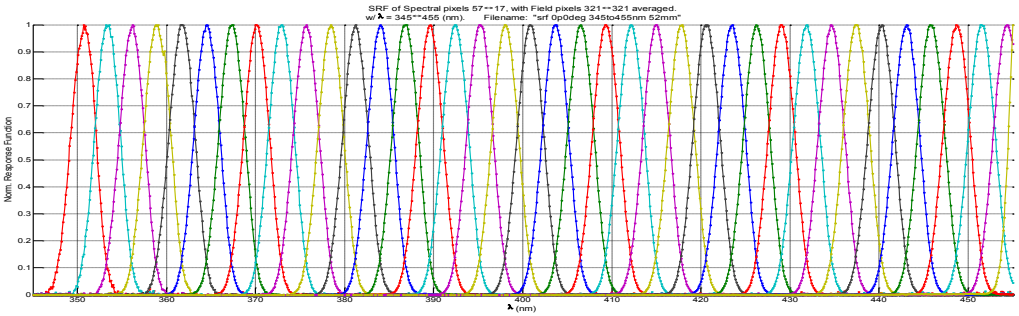
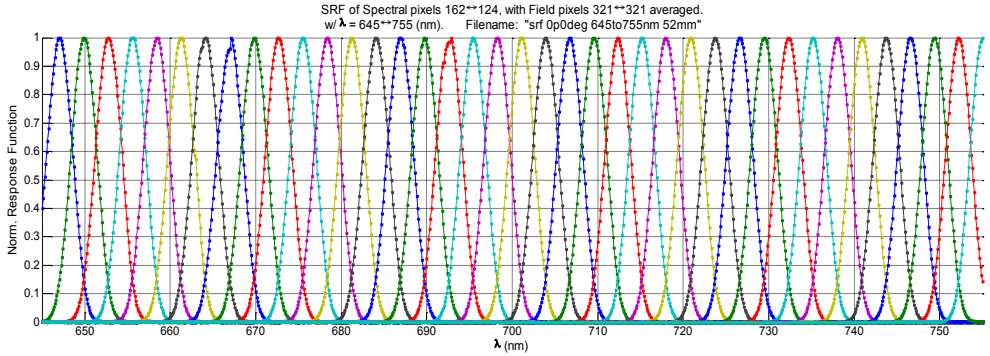
## PRISM integrates new technologies and design techniques to achieve performance

| Performance metric | System parameter | Enabling technology |
|---|---|---|
| SNR | Throughput (F/No=1.8) | Dyson spectrometer and two-mirror telescope design |
| Dynamic range | Readout rate (176 Hz) | Teledyne HyViSI detector and JPL readout electronics |
| Polarization insensitivity | Angles of incidence, grating response | Optical design, grating groove design, coatings |
| Uniformity | Optical prescription | Dyson design, concave grating, lithographic slit |
| Stray light suppression | Optical surfaces, slit, grating | Coating and filter design, black Si slit, low scatter grating |
| Calibration stability | Operating temperature (~22$^{o}$ C), vibration response | Optomechanical design, detector mount, athermalization |

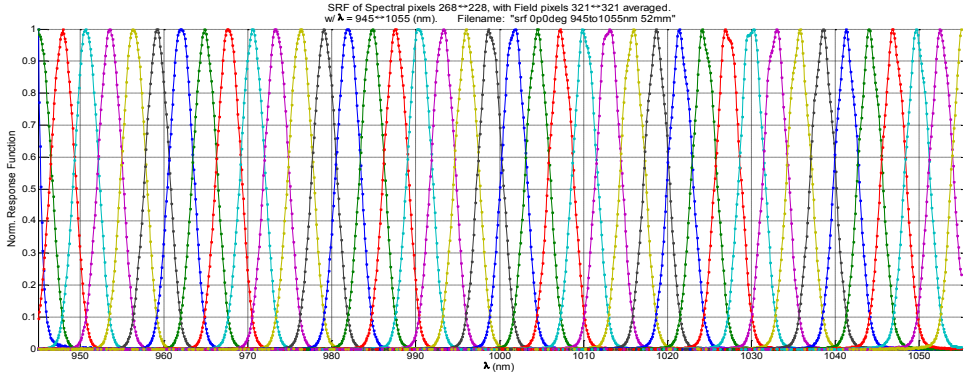
# PRISM spectral characteristics: spectral response functions




350-450 nm

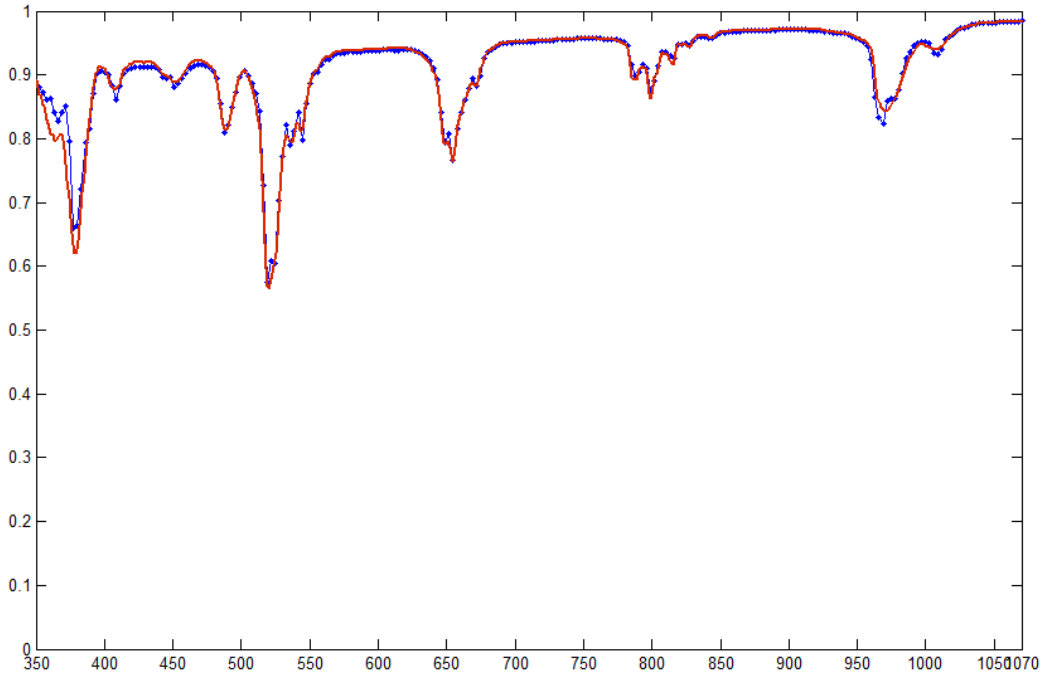



650-750 nm



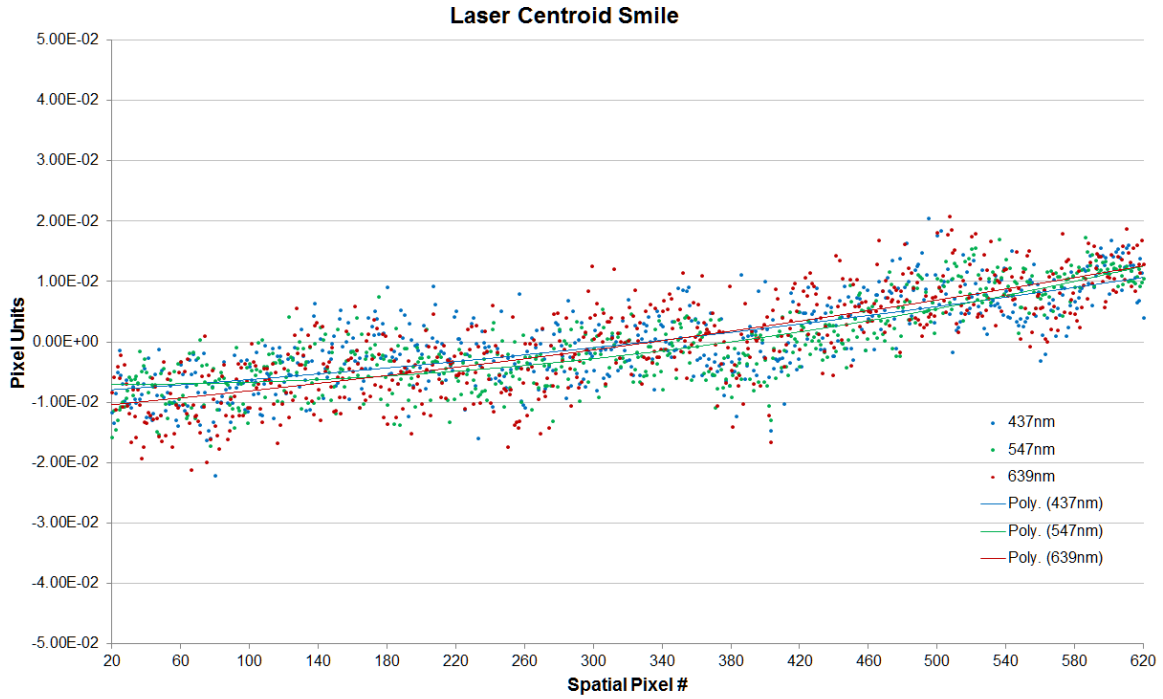

950-1050 nm

# Test spectrum extraction



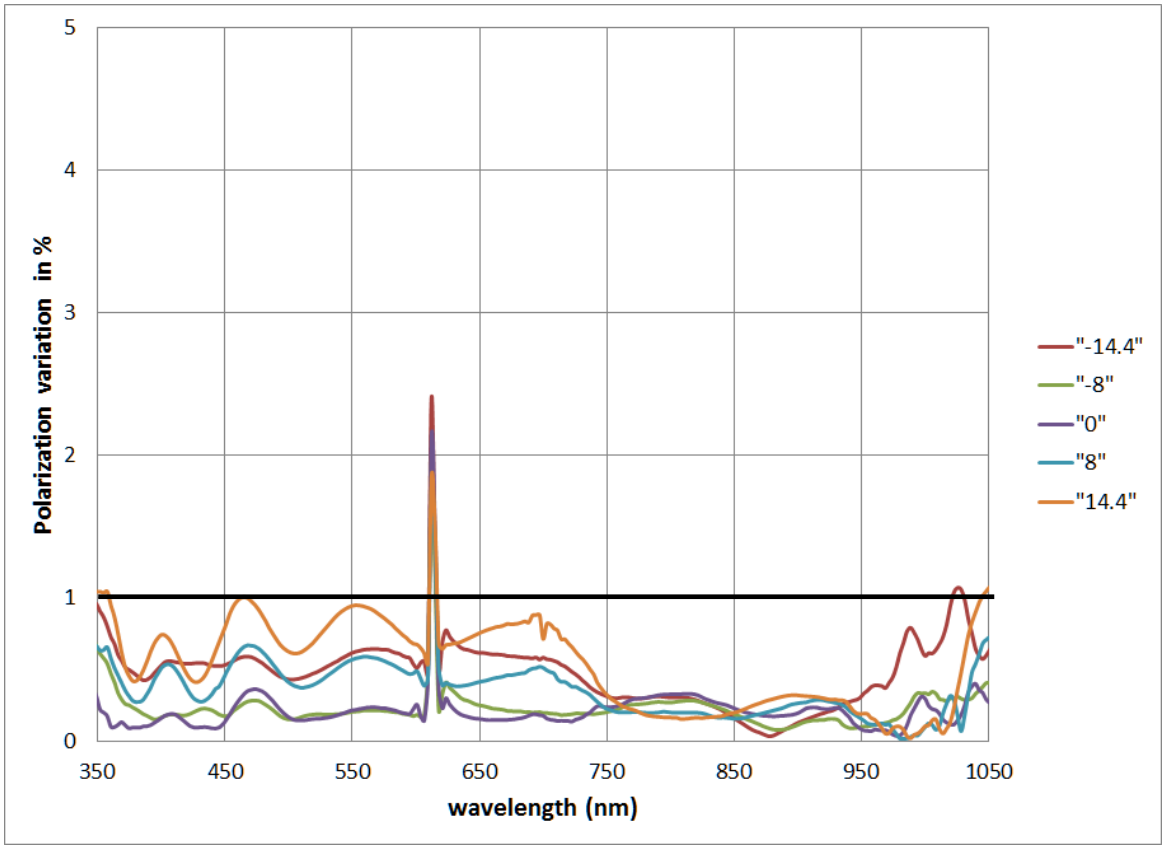

Spectrum of Er-doped spectralon panel received through PRISM (blue curve) and through reference ASD spectrometer (red curve).

# Spectral uniformity




Scatter plot of spectral channel centroids as a function of spatial location for three isolated wavelengths (Hg lamp 437 nm and 547 nm, and laser at 639 nm).

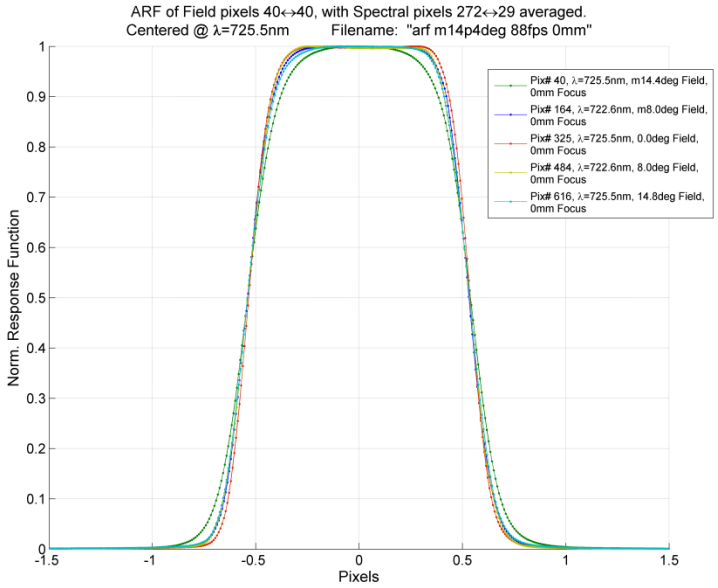
# Polarization characteristics



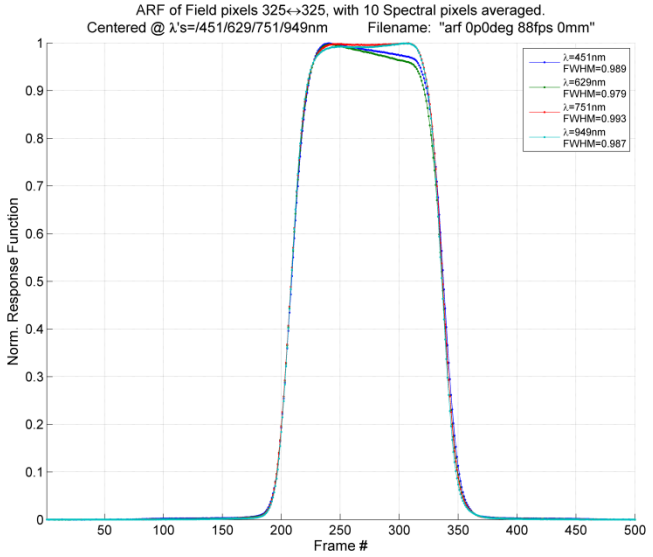

Polarization variation throughout the spectral range for five positions spanning the field of view.

Variation = $(I_{max} - I_{min})/(I_{max} + I_{min})*100$

# Spatial characteristics: Along-track response



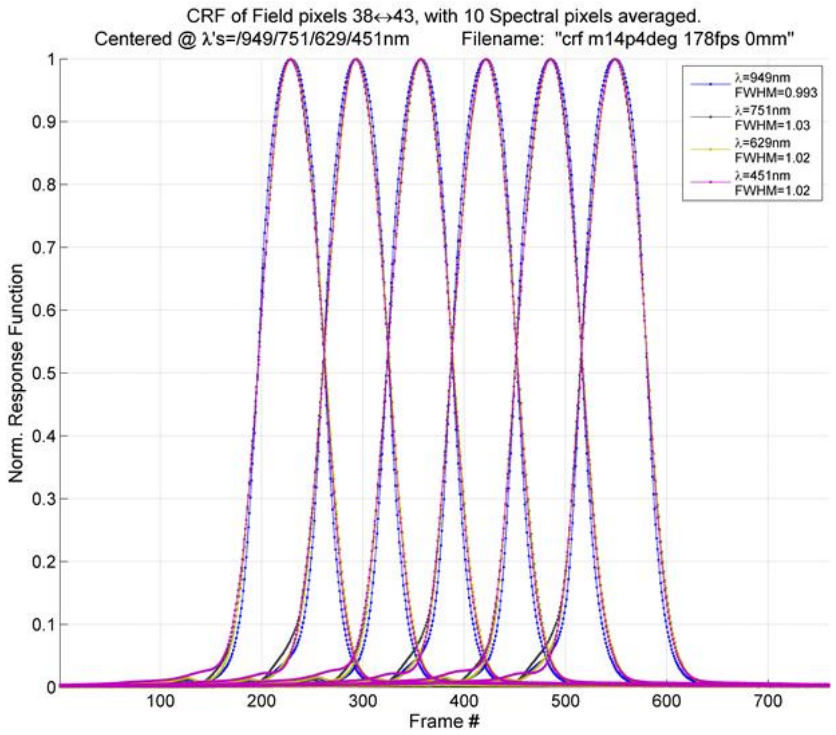

Along-track spatial response functions (without flight motion blur) for all field positions.




Example along-track spatial response functions (without flight motion blur) for four wavelengths spanning the PRISM spectral range at a single field position.

FWHM =~1.1 pixel

# Spatial characteristics: Cross-track response



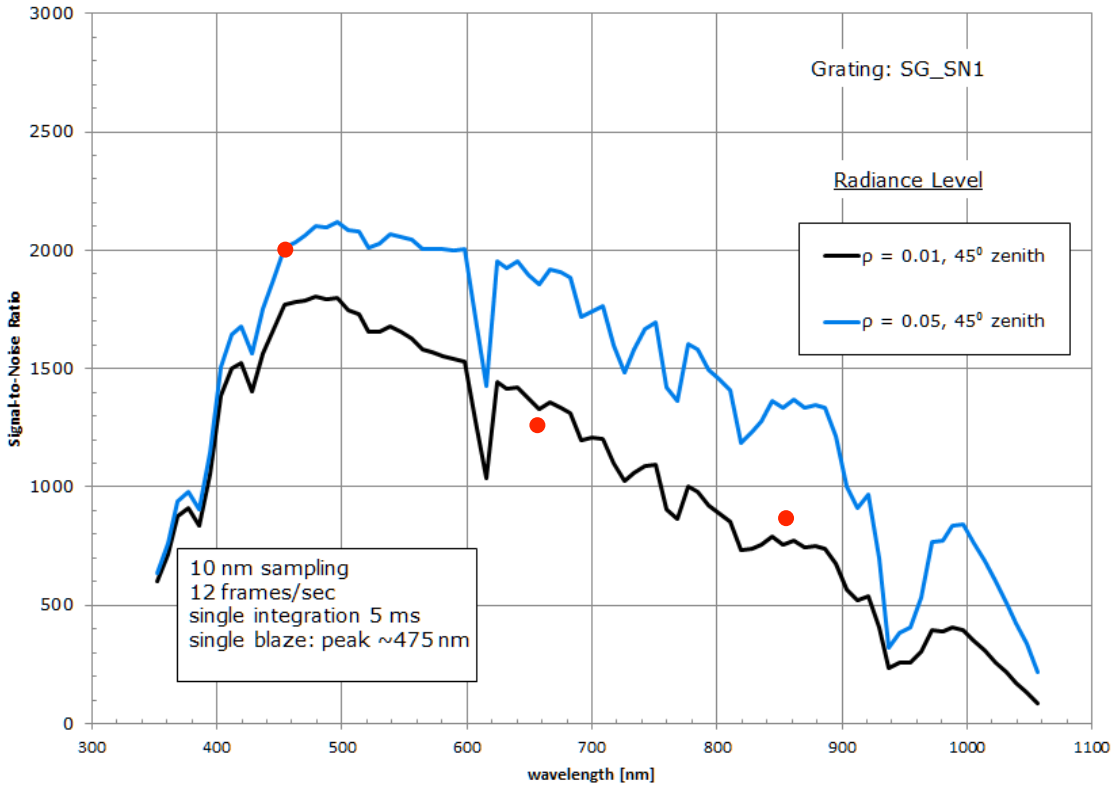

Example cross-track spatial response functions for four wavelengths spanning the PRISM spectral range at a single field position.

FWHM resolution =~1.05 pixel

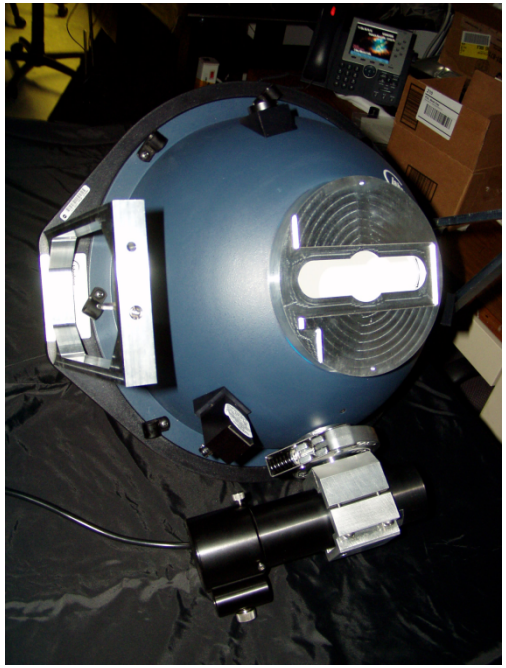
Spatial/spectral IFOV mixing

Combined CRF non-uniformity with wavelength (containing both geometric “keystone” and FWHM variation) is <5% of a pixel

# Predicted flight SNR based on lab calibration

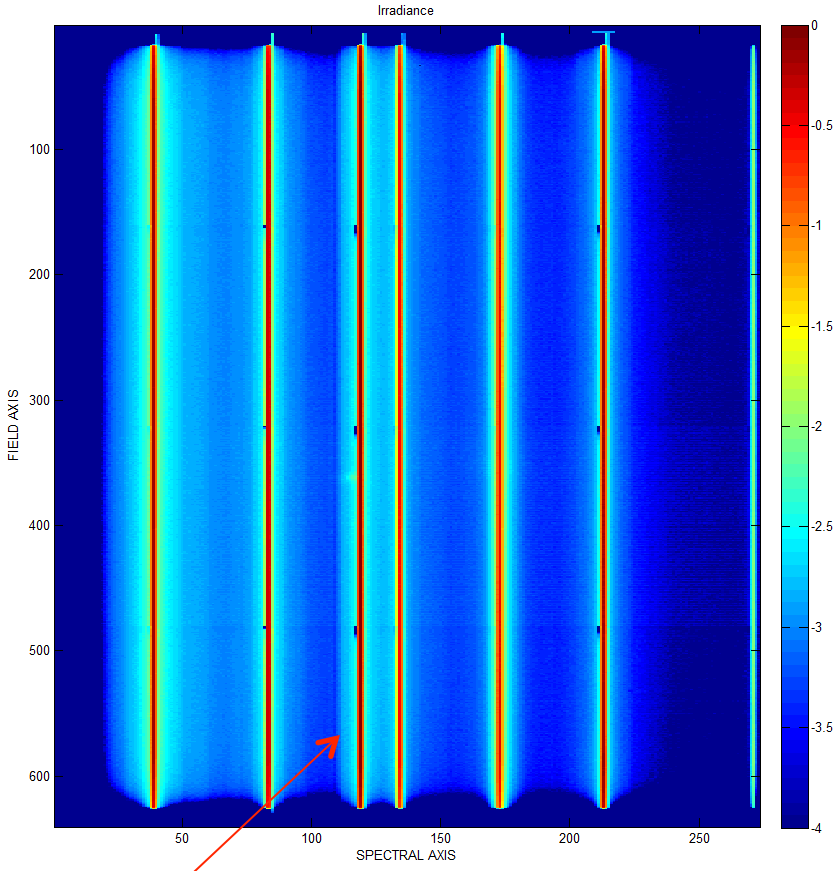



Predicted in-flight PRISM SNR incorporating measured data from known radiance of NIST-traceable lamp illuminated spectralon panel.



Integrating sphere for spectral and radiometric field calibration

# Stray light assessment



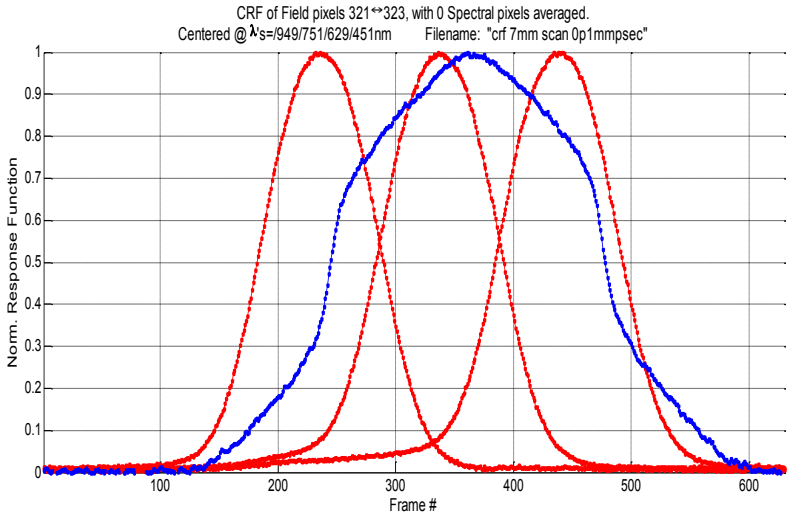

Order-sorting filter seam location

Image of several laser lines covering the entire field of view.

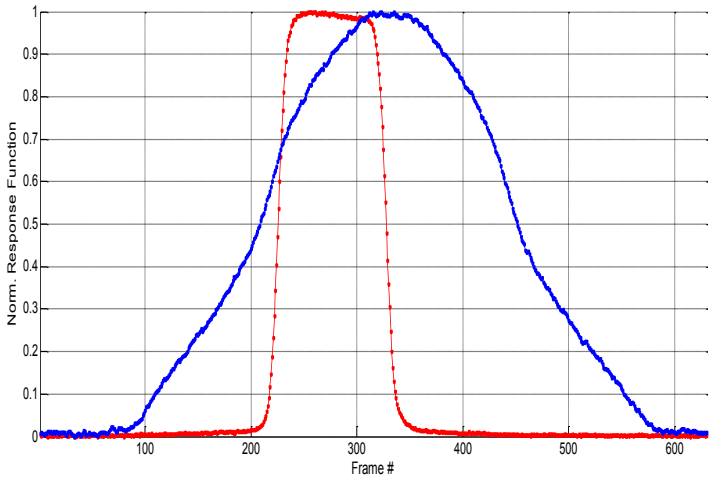
(image taken at room temperature, small residual imperfections disappear at operating temperature)

# SWIR geometry and spatial characteristics

## Boresight alignment of SWIR radiometer (blue) and spectrometer (red)

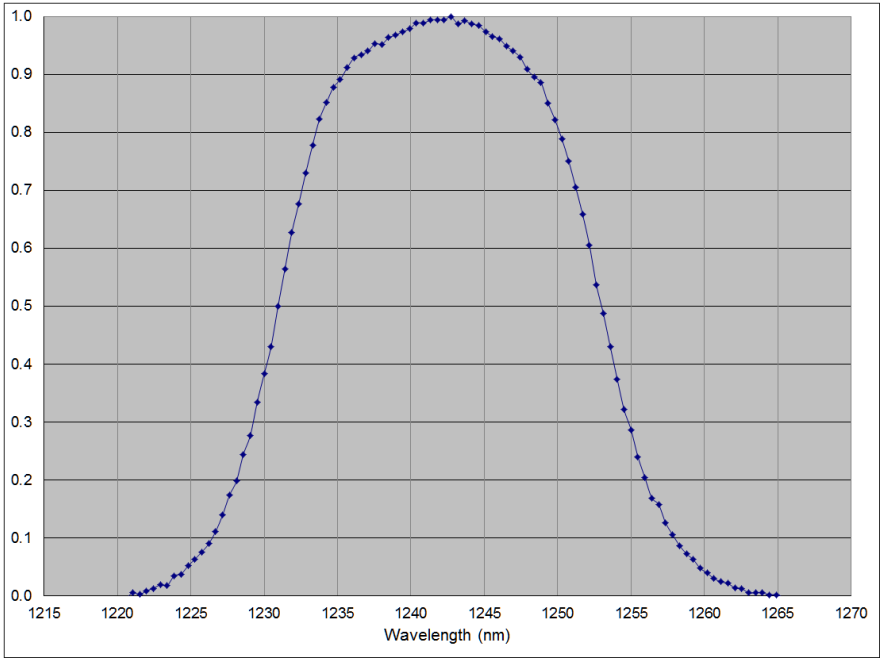


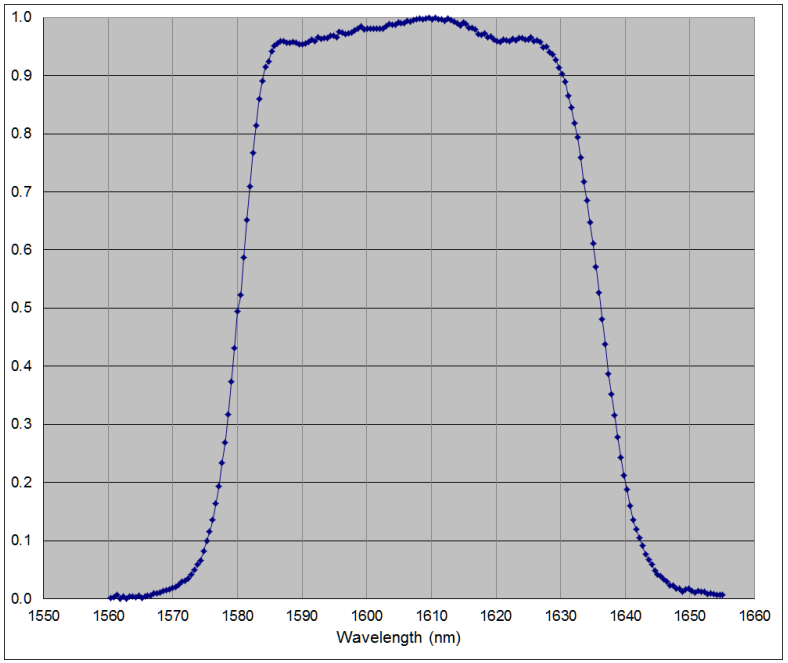

Cross-track, spectrometer channels 321-323



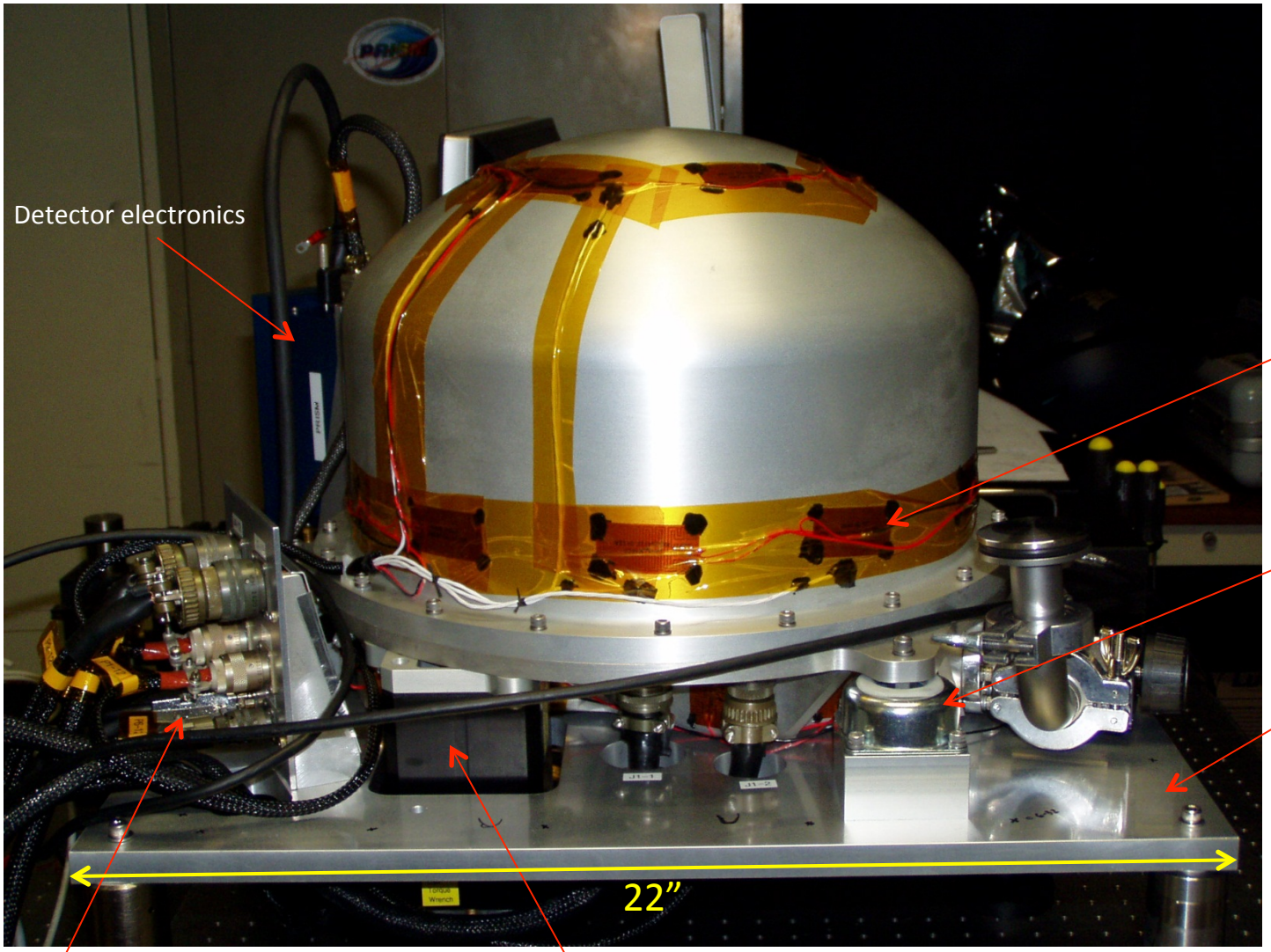

Along-track, without motion blur

# SWIR spectral bands measured at instrument level



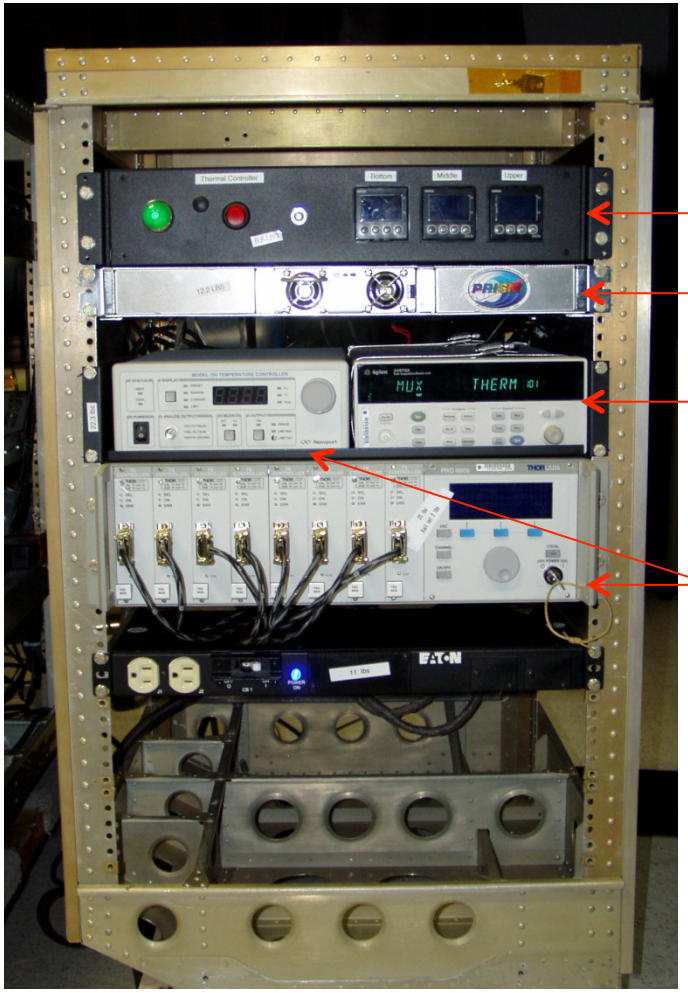



# SENSOR HEAD AND AIRCRAFT MOUNTING PLATE



# ELECTRONICS


Operator rack

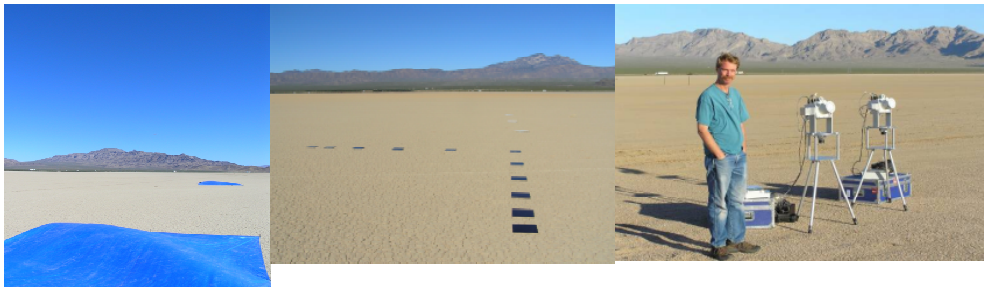



Control rack

# TEST FLIGHT SCHEDULE

## Calibration/engineering flight May 2012:

- Ivanpah Playa (spatial properties, radiometry high-R targets)
- Lake Tahoe (low R water target)

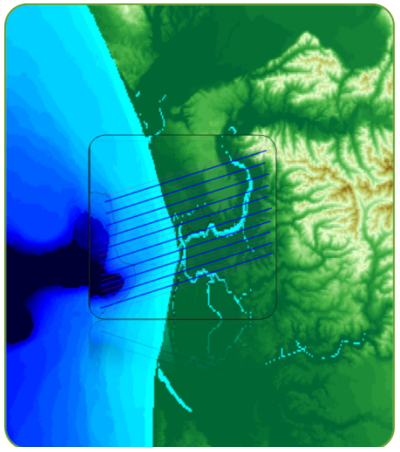


From left to right, Ivanpah Playa calibration site marked with tarps, dark tile targets, portable solar radiometers.

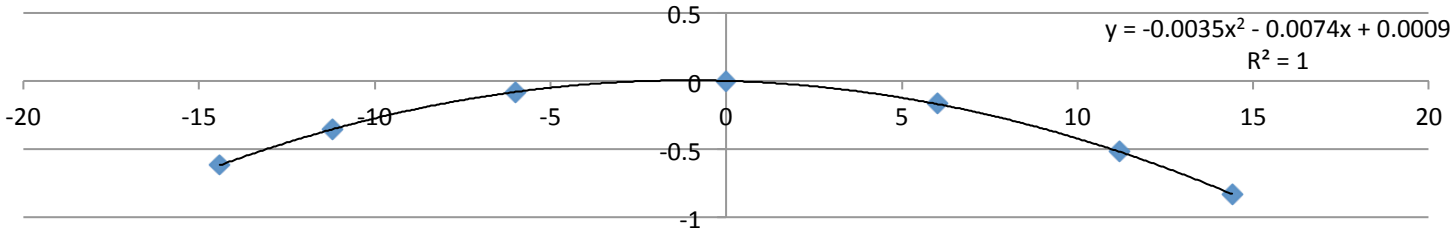
Lake Tahoe buoy

## First test/science flight July 2012:

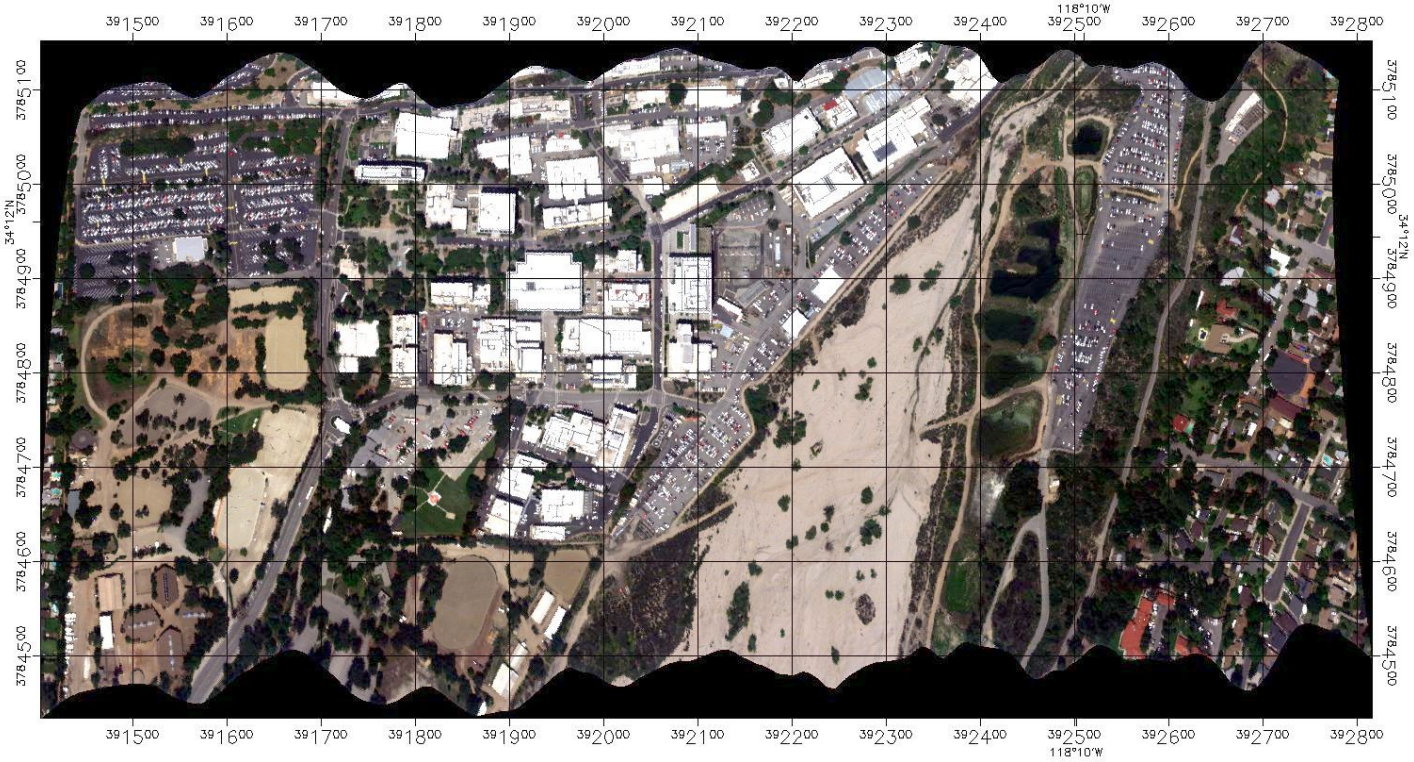
- Monterey Bay/Elkhorn Slough: seagrass coastal habitat

# Slit curvature projected on ground (corrected in post-processing)



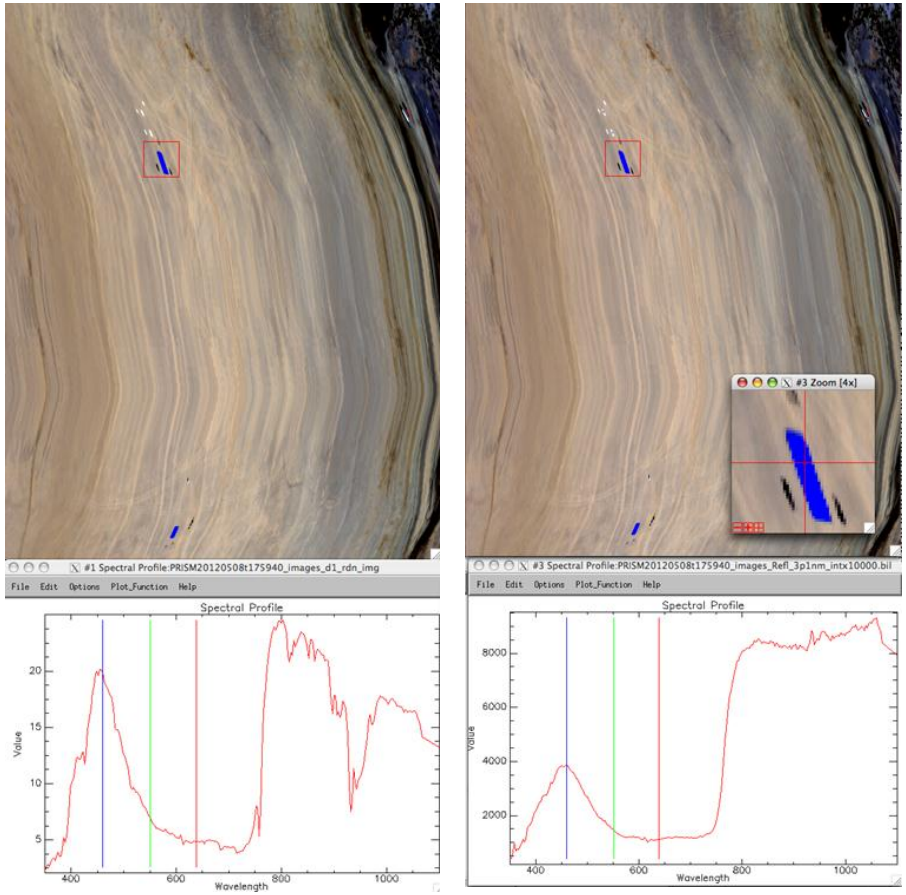

Agrees well with theoretical prediction of 0.82°




First rectified PRISM image of JPL/Arroyo Seco area

Preliminary atmospheric removal algorithm and radiometric calibration show good results

(Bo-Cai Gao, R. Green)

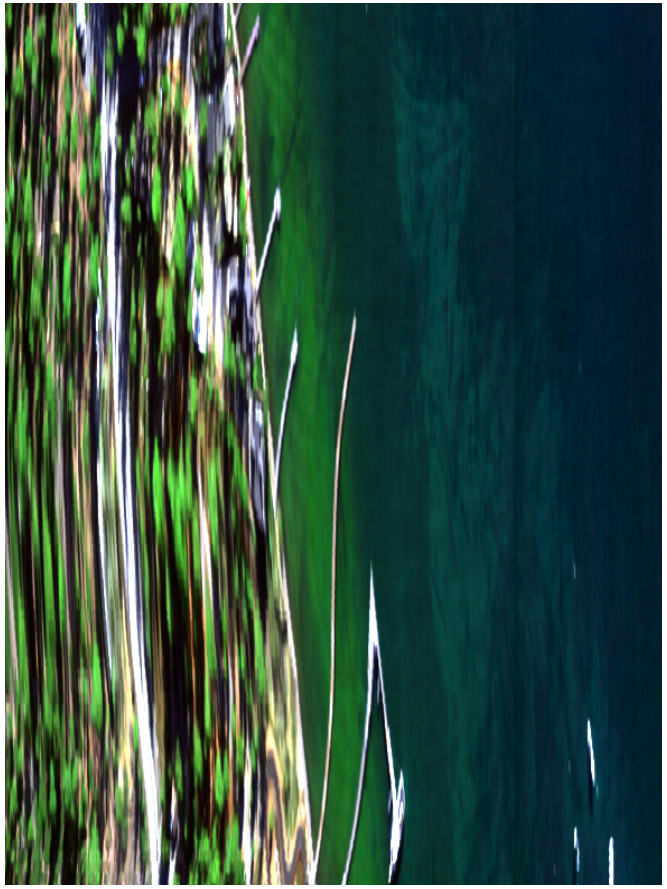



Apparent radiance

Reflectance after radiometric correction and atmospheric removal

PRISM non-rectified image from Ivanpah with blue tarp spectrum

Retrieved spectrum is remarkably smooth at a single integration and without any applied spectral smoothing. Features above 900 nm are temporarily attributed to database inaccuracies in water vapor line parameters. Improved atmospheric correction algorithm will attempt better mitigation of these effects.



PRISM raw image from Lake Tahoe shows apparent elongation due to along-track oversampling.

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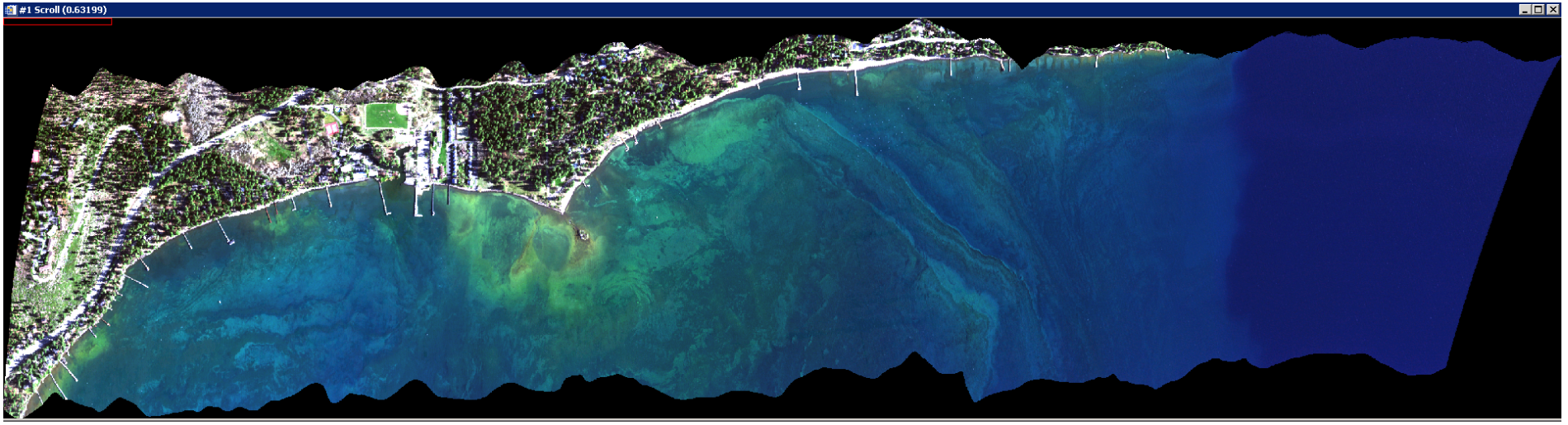
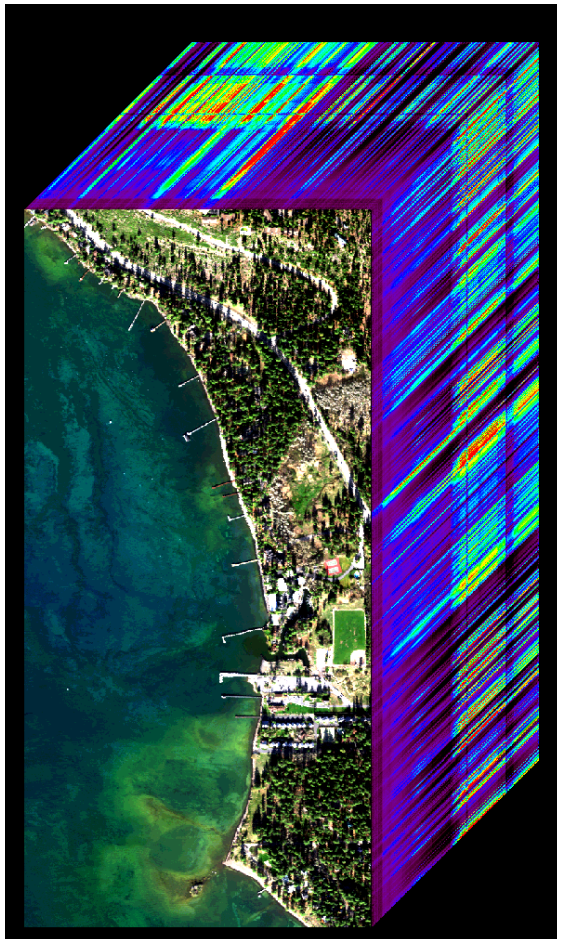
# PRISM Tahoe Radiance before and after orthorectification

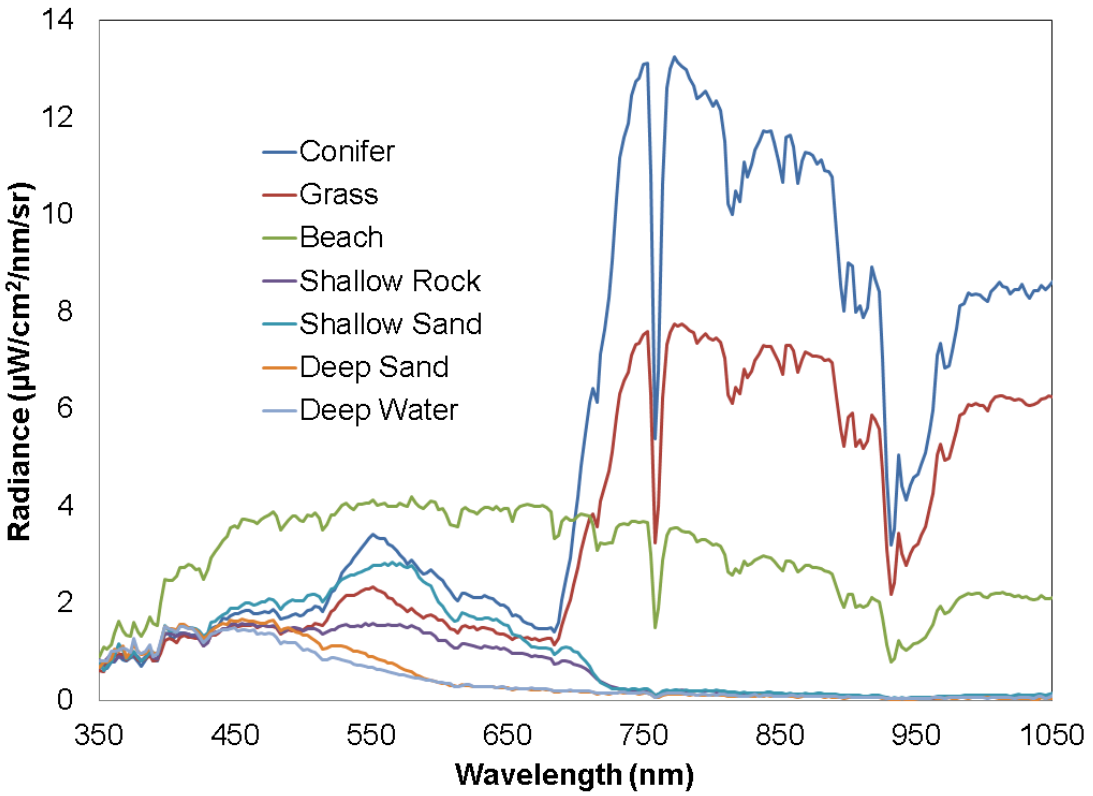
# PRISM along track oversampling increases SNR




RGB image of Dollar Point (650, 550, 450 nm). Every spectrum is tagged with latitude, longitude, and elevation.



Radiance spectra from Lake Tahoe (R. Green)




**Data processing and algorithm refinement continuing.**

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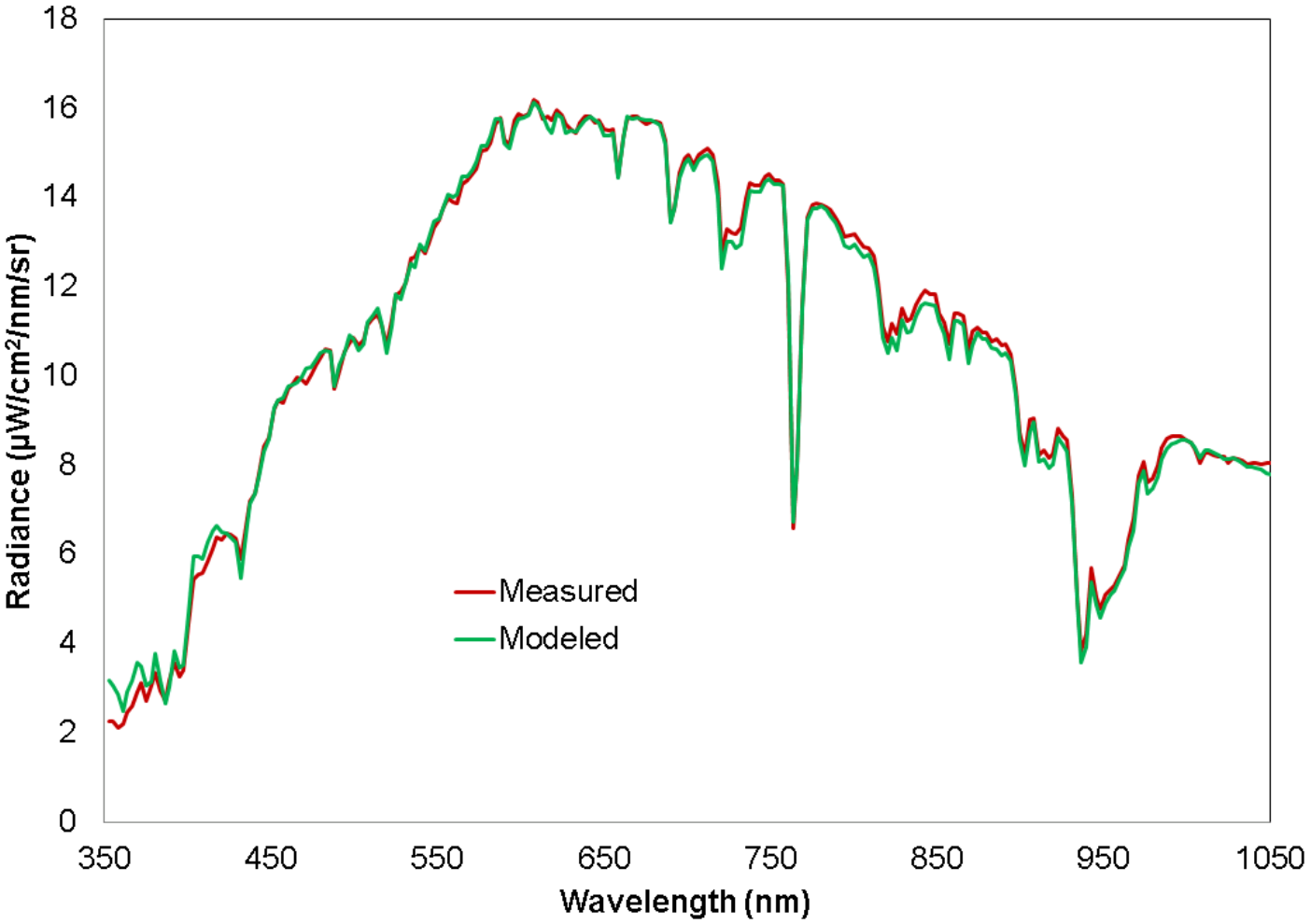
# Calibration/validation PRISM to MODTRAN from Ivanpah data (against measured ground reflectance and atmospheric parameters)



# Conclusions

- PRISM has demonstrated unique properties and outstanding performance in terms of signal to noise ratio, response uniformity, accurate radiometry, and recovery of high quality spectra.
- PRISM is available to serve the needs of the coastal ocean science community.

This work has been performed at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. Funding has been provided by NASA's Earth Science and Technology Office, and the Airborne Science and Ocean Biology and Biogeochemistry programs.