Monitoring Hyperion stability and sub-pixel heterogeneity in a pseudo-invariant desert site

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Introduction

Objectives/Questions

- How stable is Hyperion through time with atmospherically corrected land surface reflectance from multiple correction approaches?
- Can Hyperion be used to cross calibrate a virtual constellation for land surface imaging?
- Can high-resolution commercial data be used to understand sub 30m pixel variability in Hyperion data?

Study Area

- CEOS – core validation sites
  - Hyperion data has been routinely collected in the Libyan desert (Libya-4)
  - Other studies have used this site to monitor sensor degradation and cross-calibrate measurements
  - Landsat ETM+, MSS, SRTM, MODIS, EO-1

Chander et al. 2010

Libya-4 Data comparison background

Chander et al. 2010 RSE

- TOA reflectance from MODIS 2000-2008 (161 scenes) and Landsat 7 1999-2008 (86 scenes)

  both < 0.479% yr^{-1} from all bands
- MODIS within image standard deviation < 0.014, Landsat 7 < 0.022

Choi et al. 2013 JARS

- Hyperion within Libya-4 study area TOA reflectance < 5%
- Hyperion spectrally stable TOA reflectance < 0.625% yr^{-1} from all bands 2004 - 2012

Prior studies have not investigated co-registered and atmospherically corrected Hyperion data for a long-time series in Libya-4 CEOS validation site. Does more information exist about the quality of Hyperion data in this region?

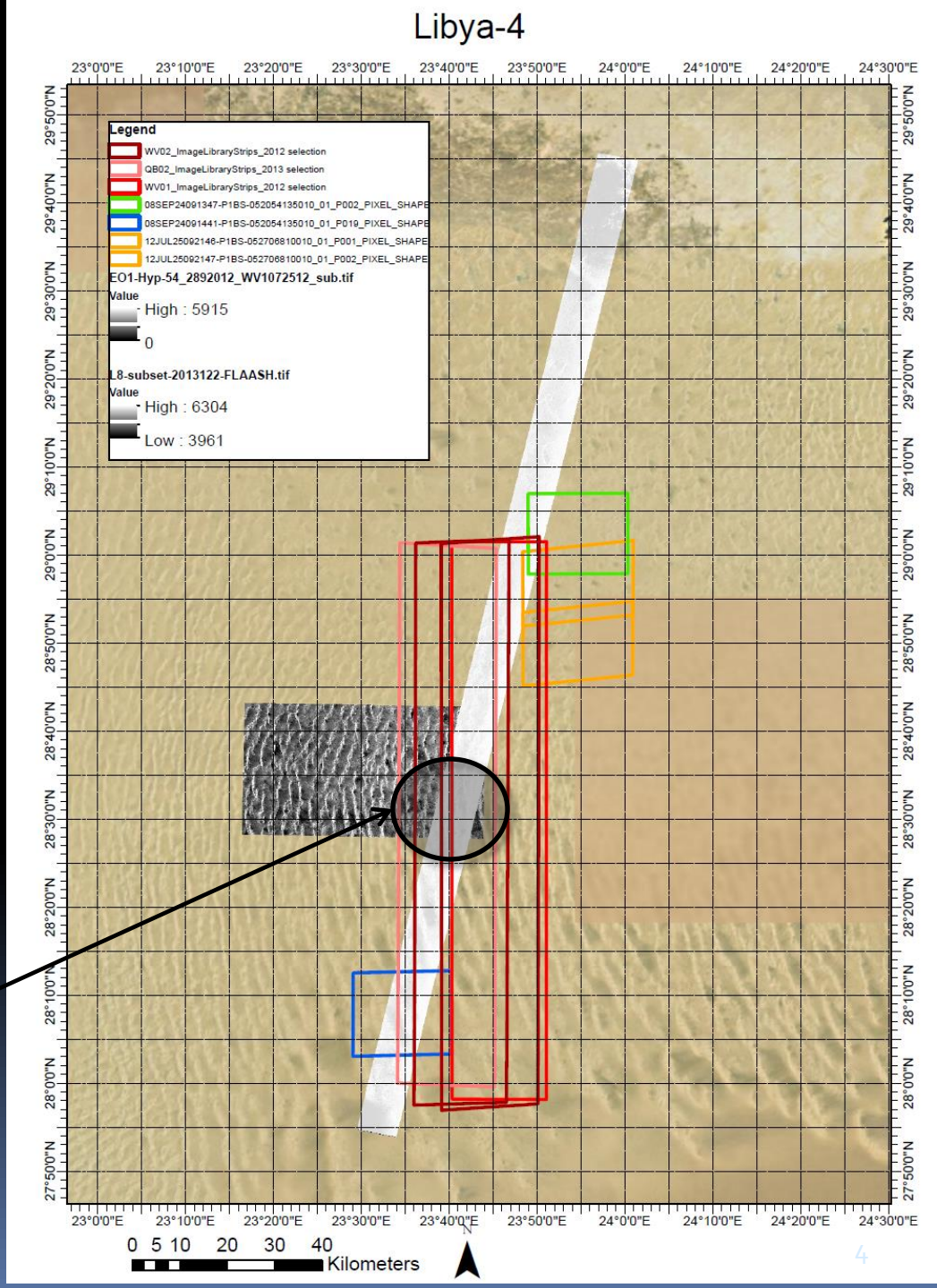
Methods: Data Overlap

High Resolution (temporally sparse):
WorldView-1 42 cm pan
WorldView-2 46 cm pan 1.8 m MSI

Moderate Resolution (temporally dense):
Landsat-8 30 m(FLAASH)
Hyperion 30 m (FLAASH)

Issues not accounted for or not completely mediated:

1. Resampling
2. BRDF, seasonal & off nadir viewing
3. Co-registration sub 30 m pixel
4. Instrument spectral degradation



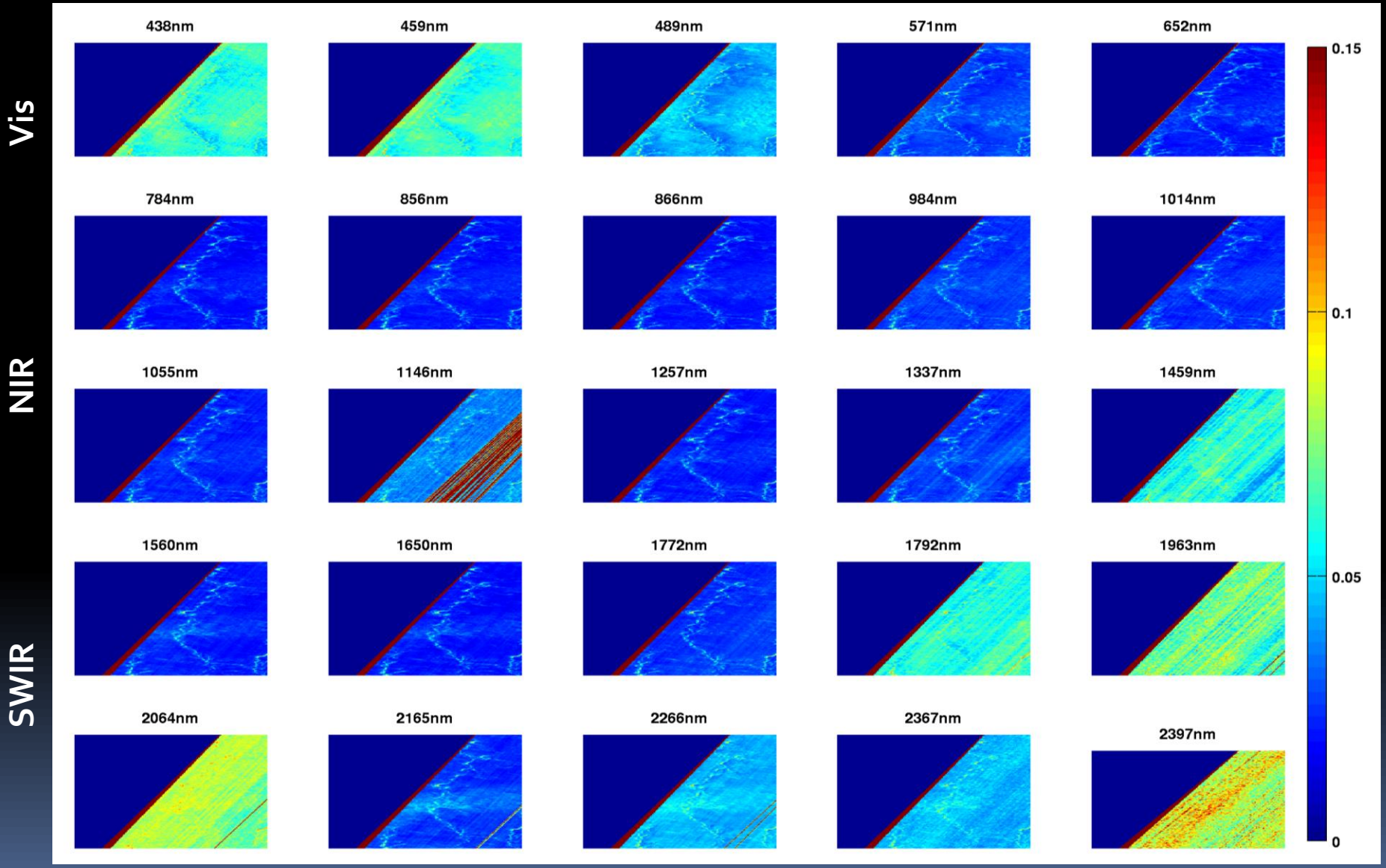
Methods: Hyperion Image Processing

- Data Selection
  - Only May through September
  - < 10° Off Nadir (to reduce BRDF)
  - 260+ images filtered to 38 (2004-2013)
- Atmospheric Correction
  - Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes (FLAASH) – no polishing
  - Atmospheric REMoval program (ATREM)
  - Atmospheric CORection Now (ACORN)
- Co-registration
  - >20 tie points per image < 0.6 RMSE to Landsat 8
  - Cloudy images and bad pixels removed with Coef . Var. >0.5
  - Subset to 159 x 458 pixels
    - Center lower portion of strip within Libya-4 (Chander et al. 2010 RSE) CEOS core validation site.
    - Corresponds to WV-1 and WV-2 overlapping area.
- Convolved to WV-2
  - 8-Bands
  - Co-registered to WV-2

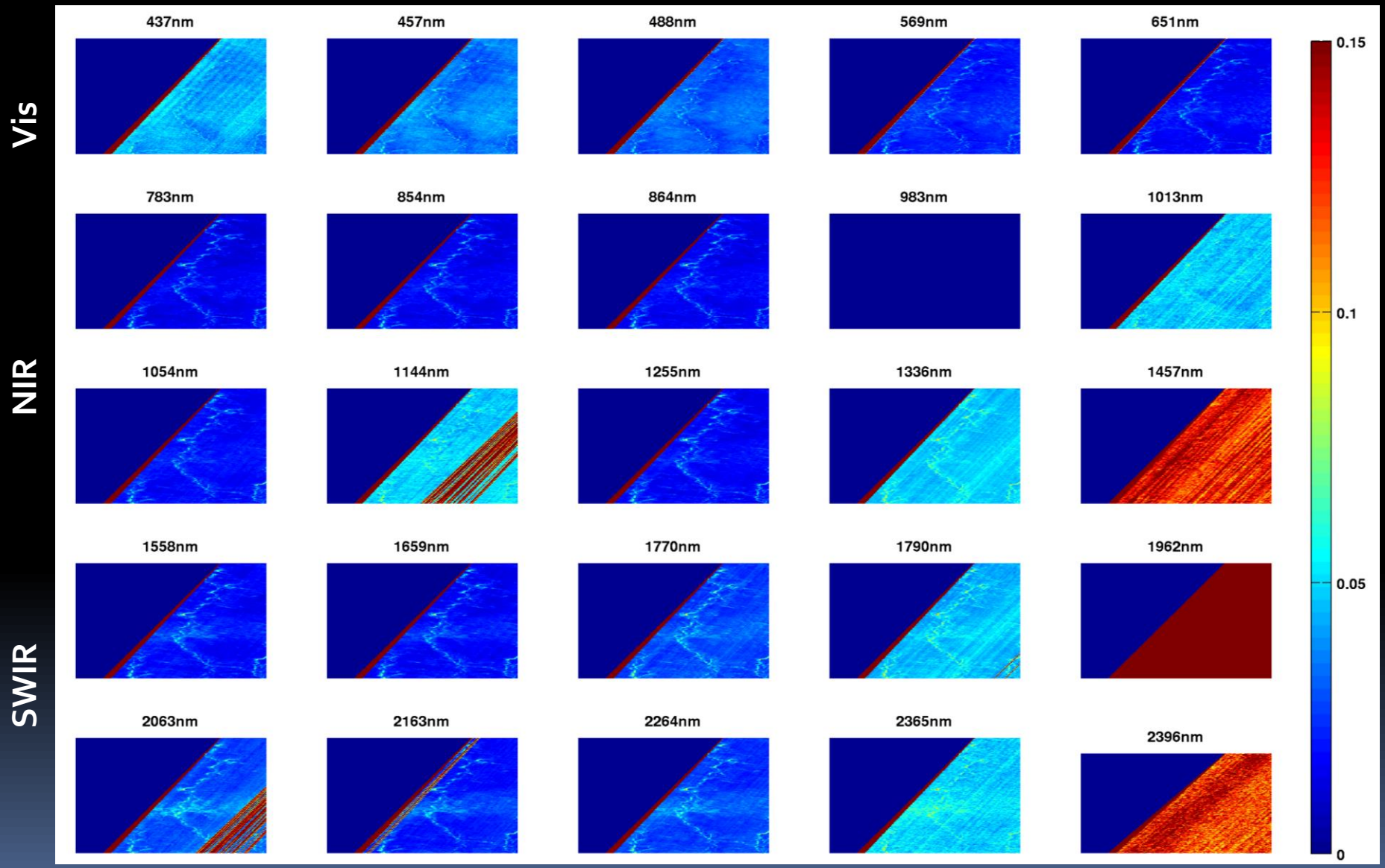
Methods: WorldView Image Processing

- Data Selection
  - Nearest coincident date to the Hyperion time-series with WorldView-1 and WorldView-2
  - Hyperion 8/9/2012
  - WorldView-1 and WorldView-2 both 8/12/2012
- Atmospheric Correction
  - WV-2 8 Band FLAASH
    - Viewing geometry included
    - No water vapor or aerosol correction
- Digital Terrain Model
  - ENVI DEM extraction module
    - WorldView-1 and WorldView-2 Pan Bands 50 cm (cross track stereo)
    - > 50 tie points, no ground control points
    - RMSE < 3.5 m relative to RPCs
    - 2 m resolution

Hyperion FLAASH Coef. of Variation by band



Hyperion ATREM Coef. of Variation by band



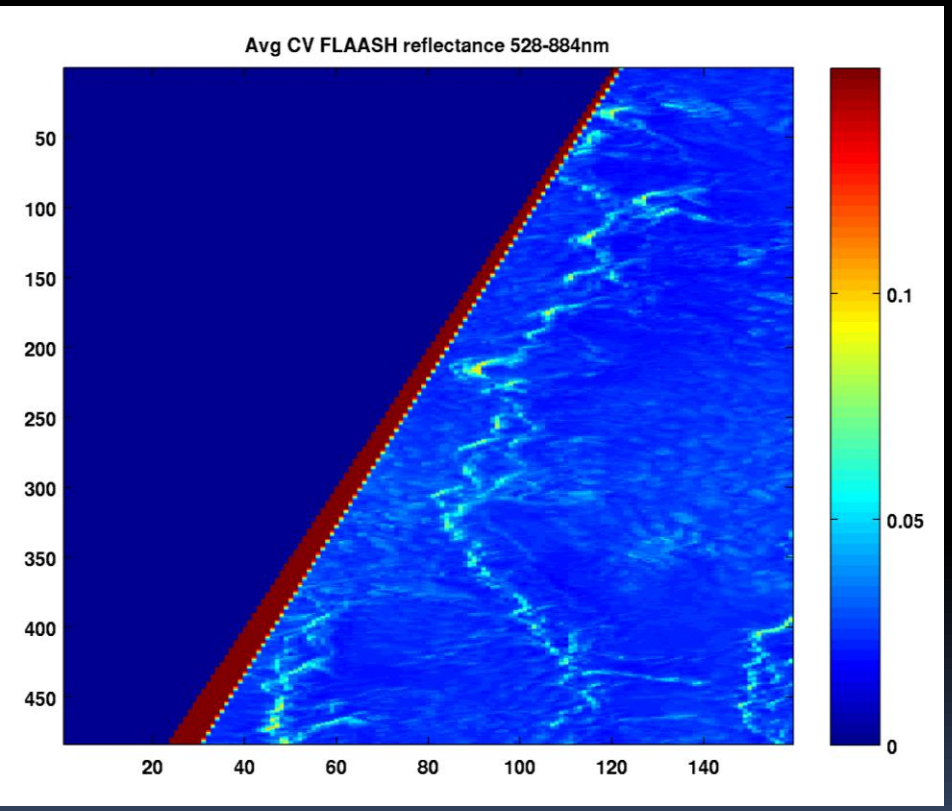
28° 0' 49.68" N 23° 46' 27.89" E Longitudinal Dunes in Calanscio Sand Sea (Libya)

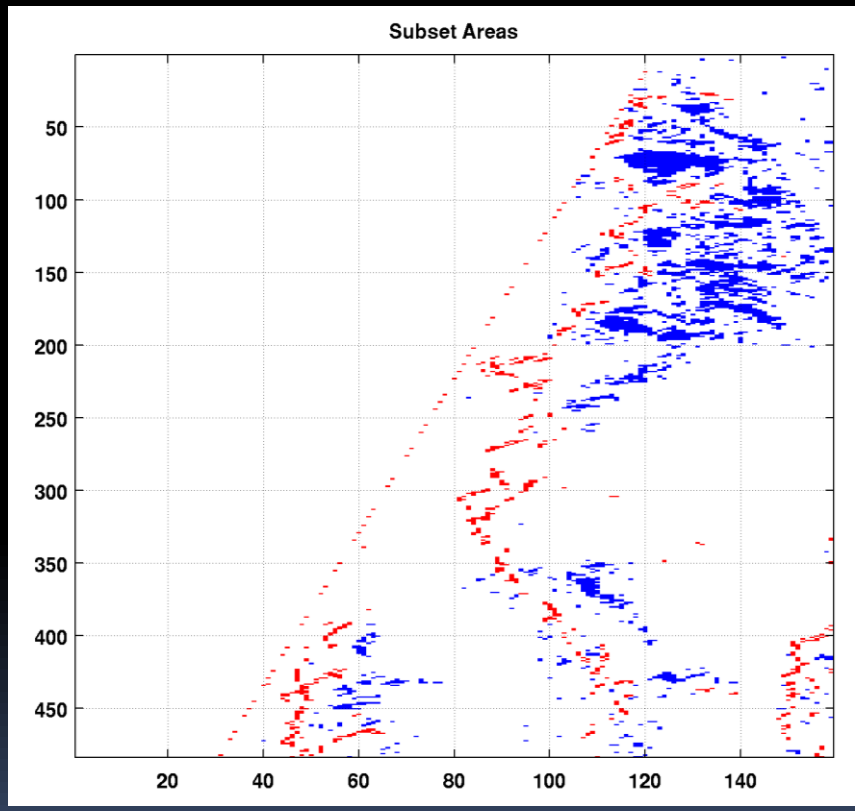
http://www.panoramio.com/photo/59315749 138 m elevation

Sampling by CV Threshold

Hyperion FLAASH
Avg. Coef. of Variation from 2004-2013
528-864 nm

Subset Areas
Red = Avg. Coef. of Variation 5-7%
Blue = Avg. Coef of Variation <2%





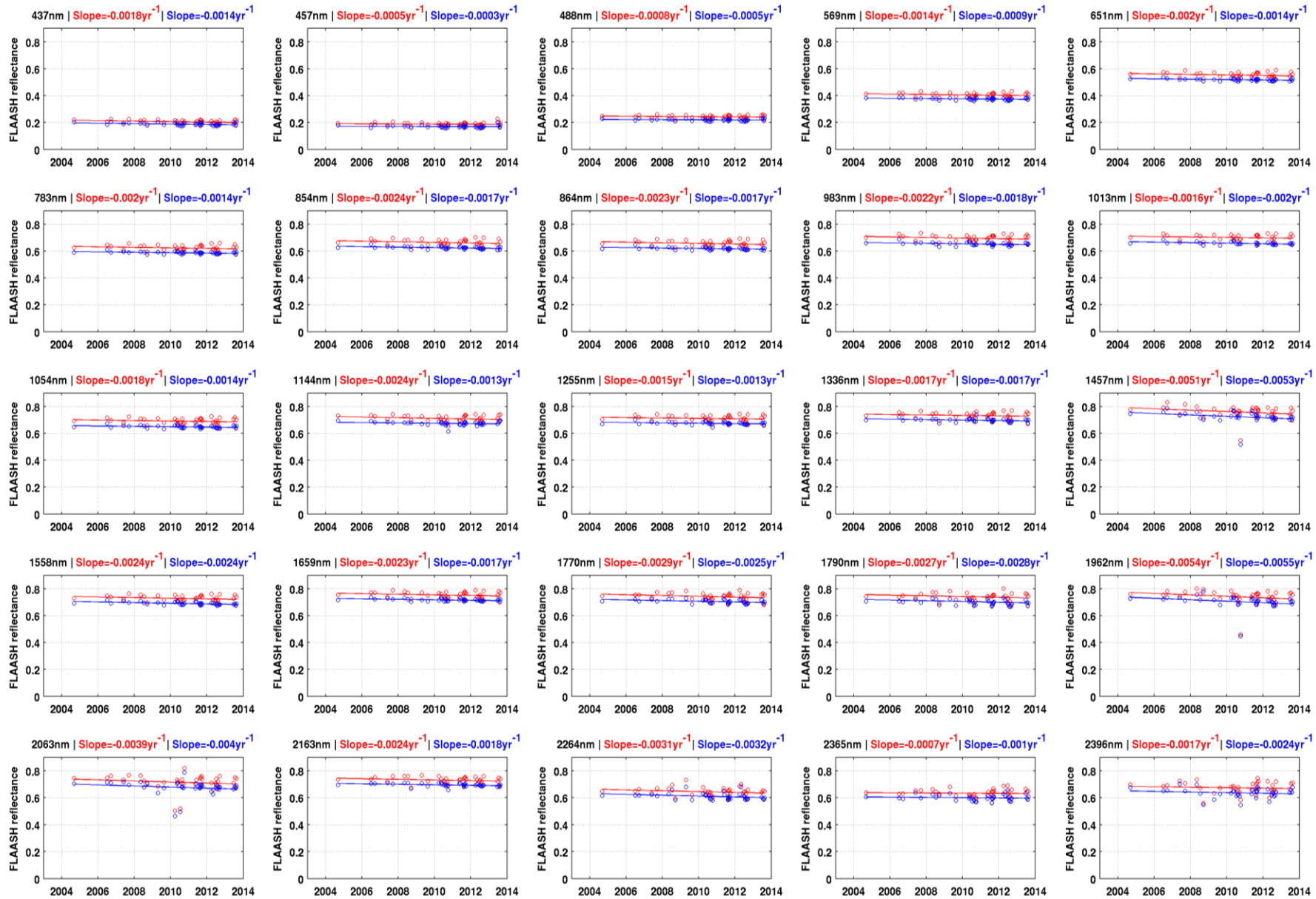
Green through NIR bands have less pixel noise to define subsets to capture differences in the landscape. >5% variation on the peaks of dunes, <2% variation in the valleys.

Hyperion FLAASH Trends

Vis

NIR

SWIR

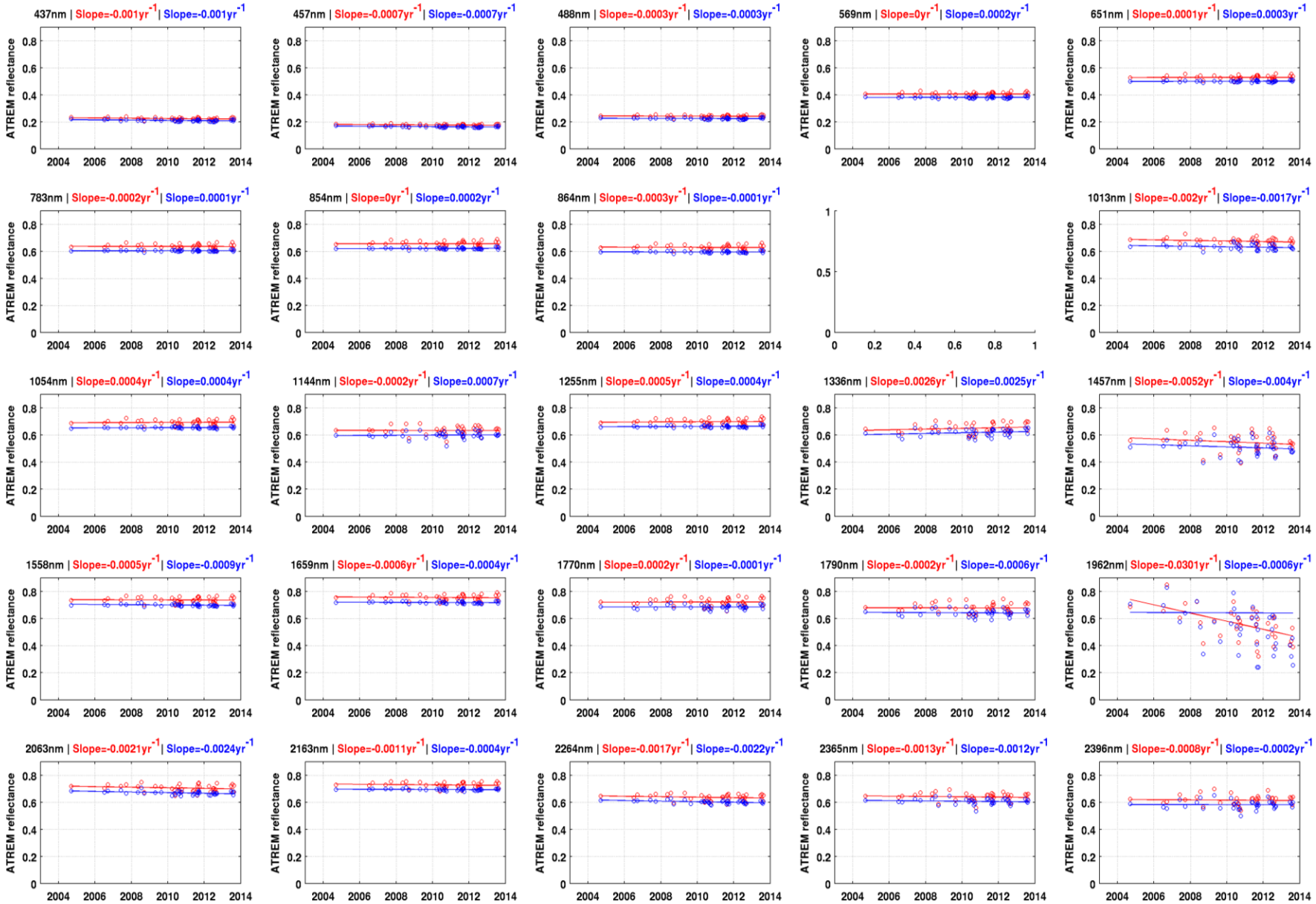


Hyperion ATREM Trends

Vis

NIR

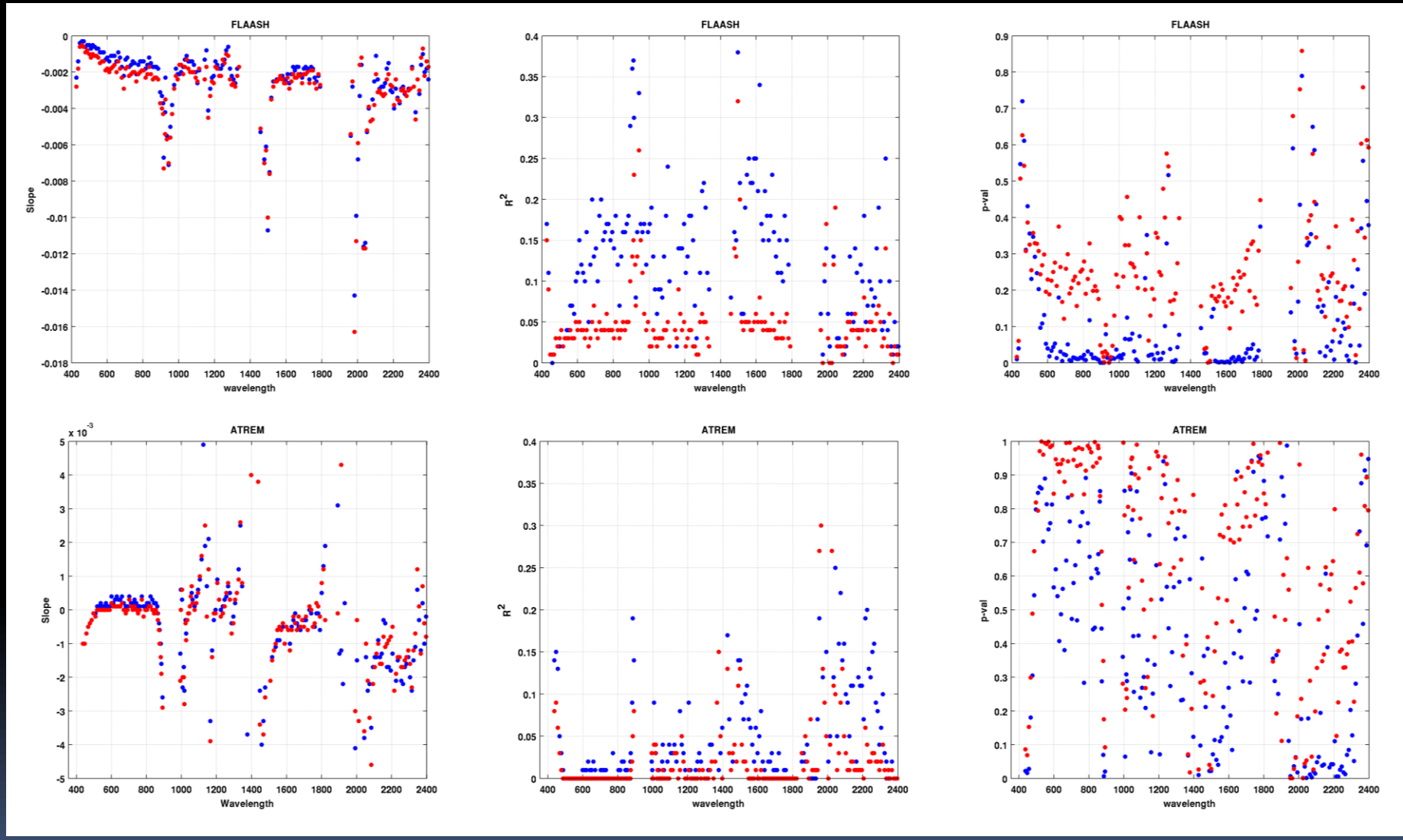
SWIR



Hyperion Least Squares Fit Band Statistics

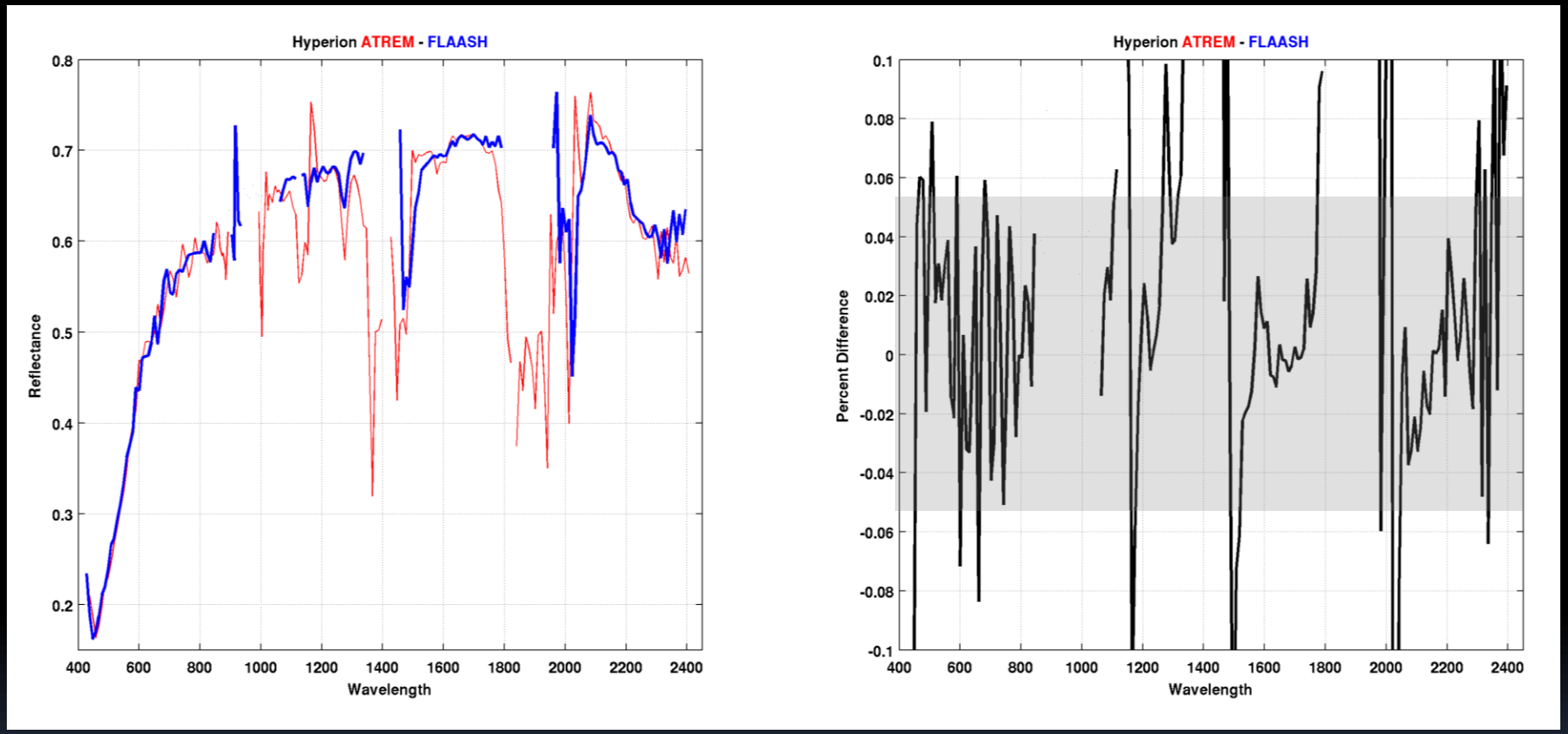
FLAASH

ATREM



FLAASH shows consistent declining slopes for all wavelengths.
ATREM shows declining slopes for some Vis wavelengths but is variable in all wavelengths.

Hyperion Median Wavelength Value of Time Series ATREM vs. FLAASH



Results are consistent with Kruse 2004 JPL. A majority of the bands are within ±5%.

The worst matches occur in the NIR and SWIR wavelengths.

Subset example of Hyperion vs. WorldView-2

Linear stretch applied to enhance image visualization , Hyperion co-registered to WV-2

Hyperion True Color Convolved
FLAASH
8/9/2012

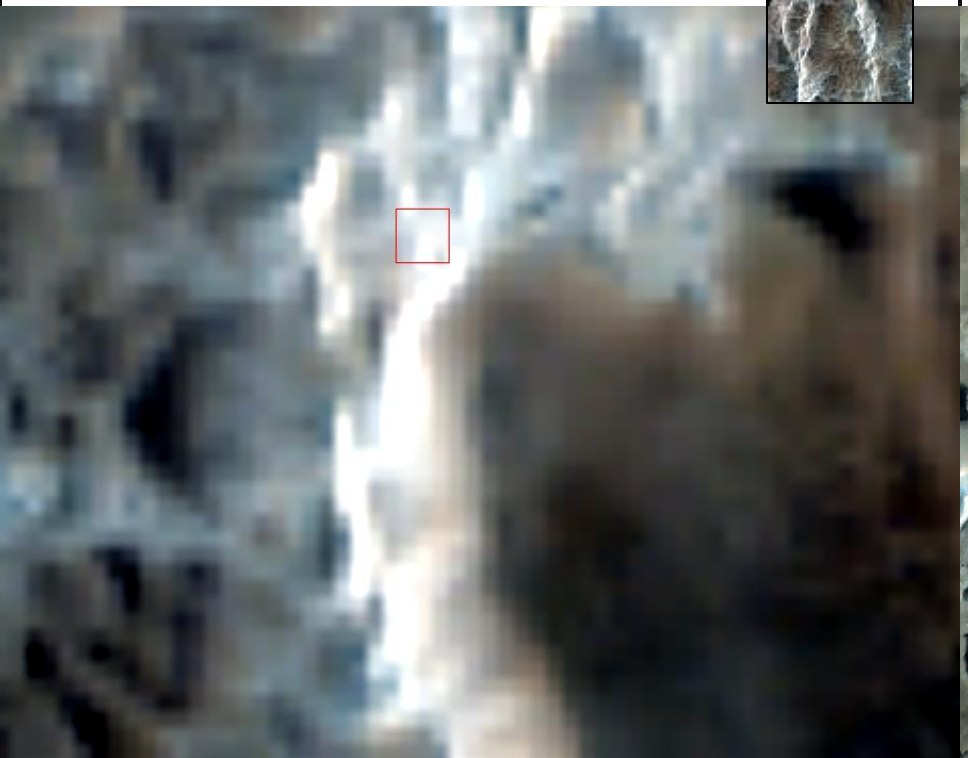
Red	630-690 nm
Green	510-580 nm
Blue	450-510 nm

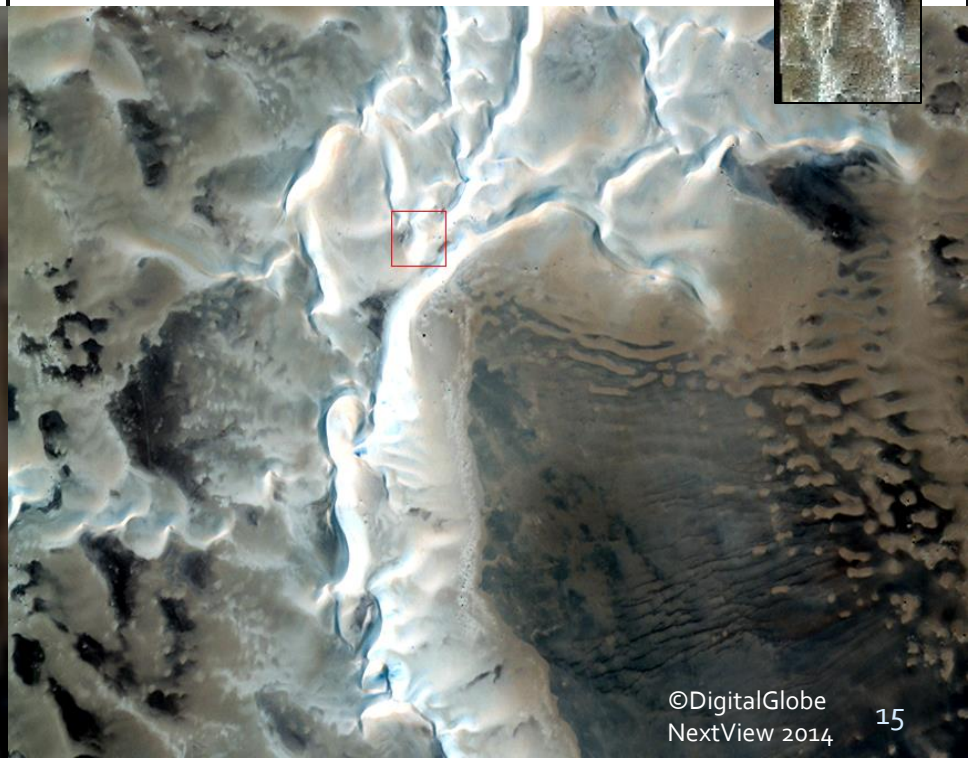
Cubic Convolution 2m

WorldView-2 True Color
FLAASH
8/12/2012

Red	Band 5 630-690 nm
Green	Band 3 510-580 nm
Blue	Band 2 450-510 nm

2m





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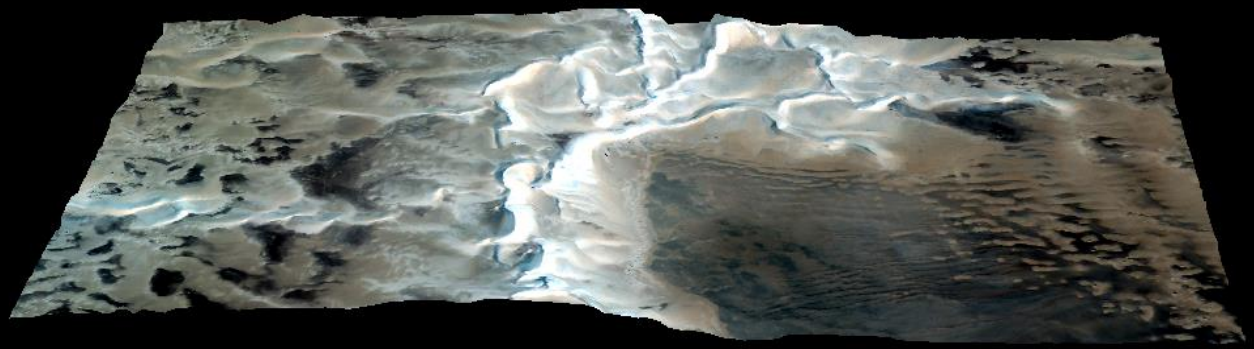
3D Surface View of Subset Area

Hyperion True Color Convolved
8/09/12
Red 630-690 nm
Green 510-580 nm
Blue 450-510 nm
Cubic Convolution 2m

WorldView-2 True Color 8/12/12
Red Band 5 630-690nm
Green Band 3 510-580nm
Blue Band 2 450-510 nm
2m



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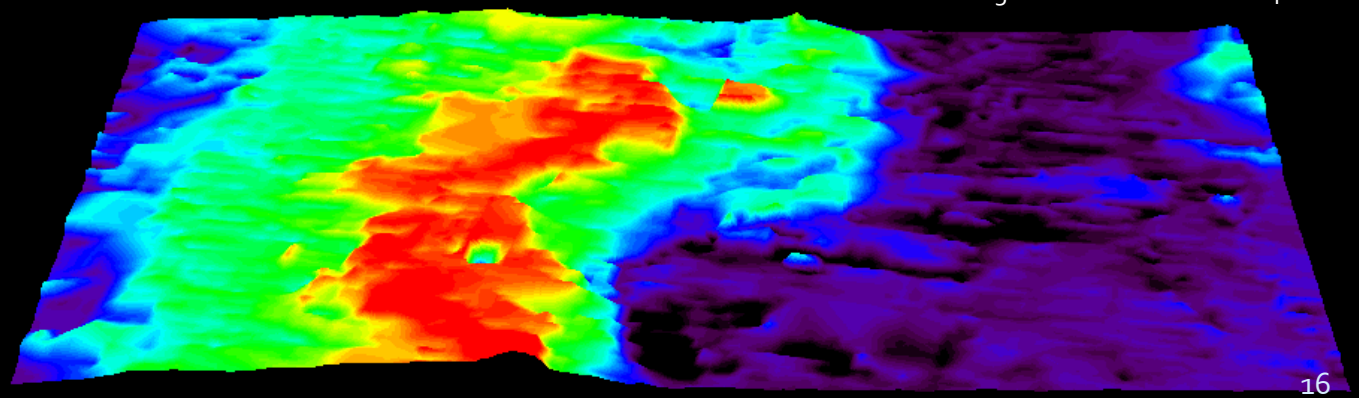
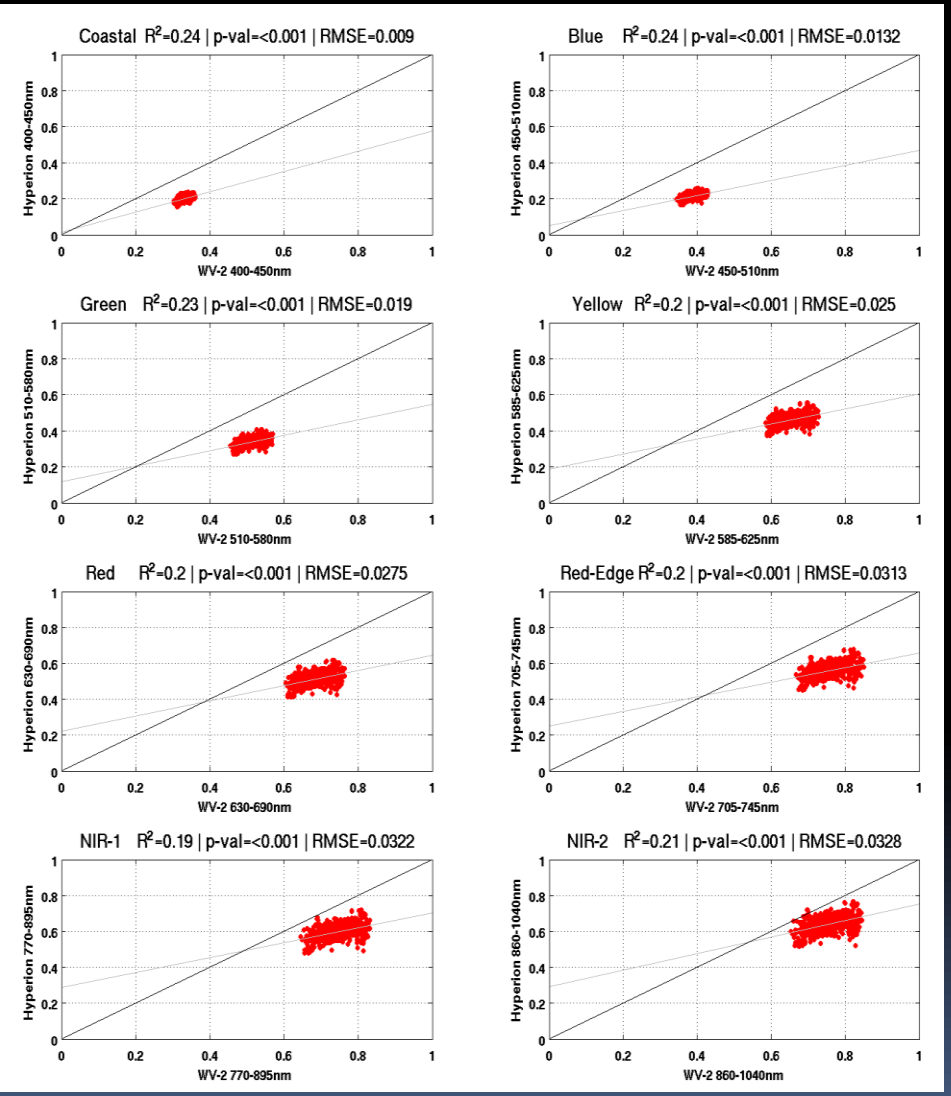
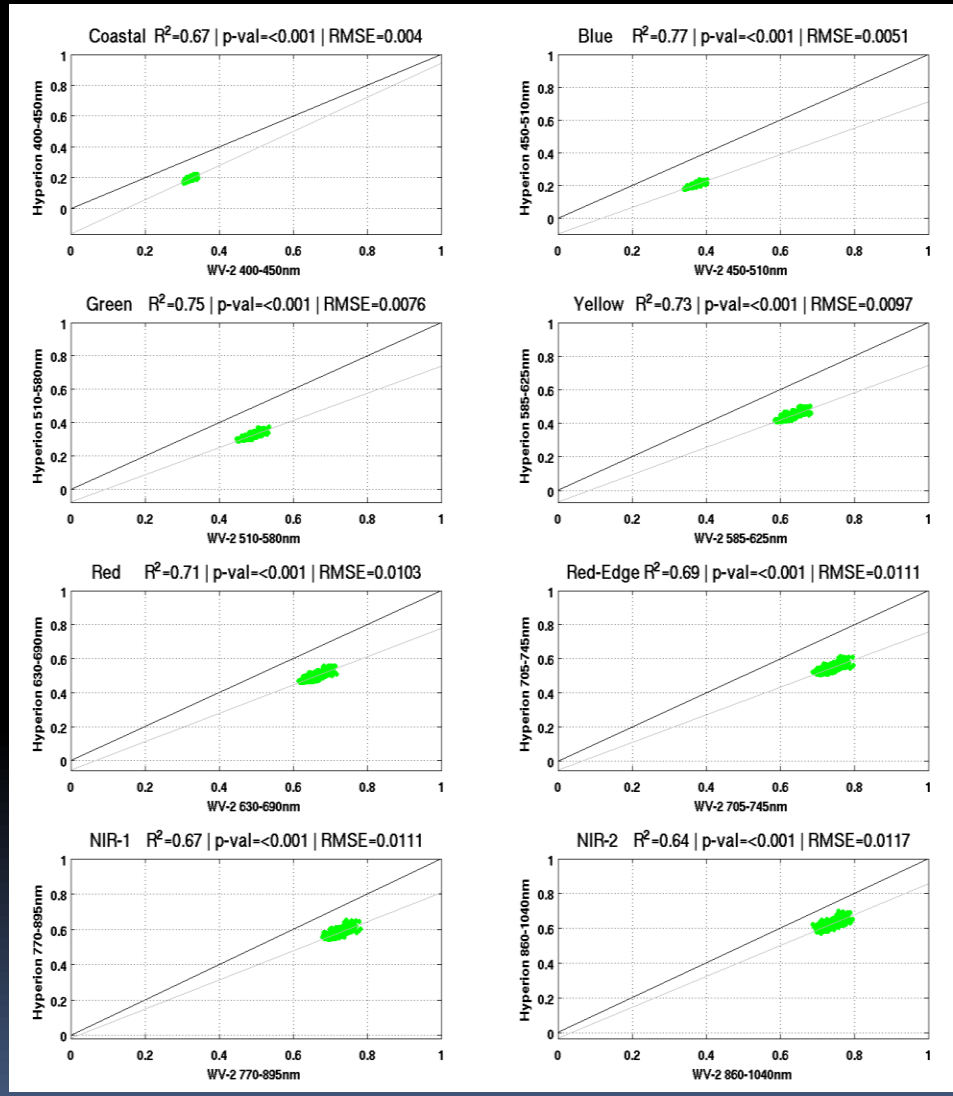
WorldView-2 – WorldView-1
Digital Terrain Model
2m



FLAASH WorldView-2 and Hyperion Correlation Convolved and Co-registered to WV-2





Red = Coef. Variation 5-7%

Green = Coef. Variation <2%

Summary

- Hyperion is very stable through time.
  - CV< 2% locations, FLAASH most Vis bands < 0.18% yr^{-1} most other bands <0.4% yr^{-1}
  - CV 5-7% locations, FLAASH most Vis bands < 0.24% yr^{-1}, most other bands <0.4% yr^{-1} compared to other TOA reflectance studies >0.675% yr^{-1}

- FLAASH vs. ATREM
  - Consistent in Vis and variable in NIR and SWIR

- Libya-4 CEOS site exhibits variability from 30m to 2m that can be quantified with a high resolution digital terrain model
  - Variation in dune topography impacts BRDF and observed reflectance
  - Future work: ACORN and ATCOR can be used with the WV DTM to improve viewing geometry

- Is a virtual constellation possible with hyperspectral measurements?
  - We provide enhanced estimates of instrument stability useful for cross calibration studies from 30m to 2m resolution. FLAASH reflectance between convolved Hyperion and WorldView-2 are reasonably good in homogenous areas (CV <2%).

    (R2 > 0.64-0.77, p-val < 0.001)

    Low correlation heterogeneous areas (CV 5-7%).

    (R2 <0.19-0.24, p-val < 0.001)
  - Libya-4 heterogeneity should be considered when convolving and or cross-calibrating data.

Thank You