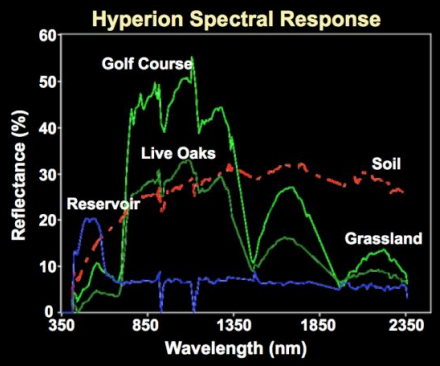
Monitoring EO-1 Hyperion surface reflectance stability and sub-pixel heterogeneity in a pseudo-invariant desert site



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EO-1 Science Team

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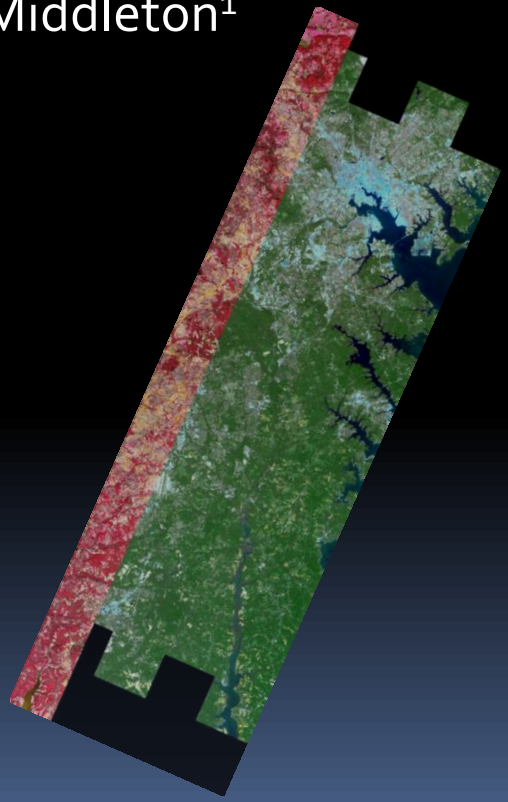
JACIE

5/6/2015

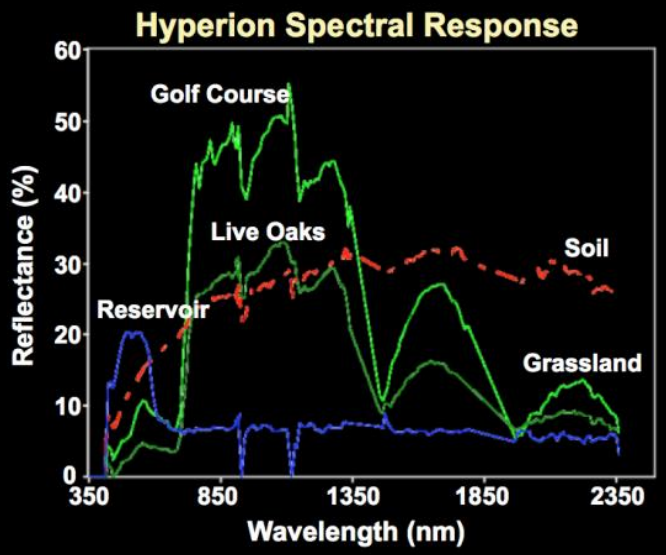


Hyperion (red) overlay on ALI Image (green), Oct 2012 Baltimore, MD

Background:
What EO-1 Offers that no other NASA Mission Provides

EO-1 is a fundamentally unique NASA asset, providing capabilities not available with any existing space platform.

- EO-1 is a highly maneuverable *testbed* asset which can be (and has been) assigned a variety of high priority tasks of critical interest to the NASA Earth Science Division.
- Hyperion is the only spaceborne satellite imaging spectrometer (IS), uniquely providing a 14+ year archive of spectroradiometric observations. Data from Hyperion continue to be used as a source for understanding how spectroradiometric properties relate to the physical state (and disturbances) of the Earth's surface.
- Hyperion paves the way for future IS missions, providing unprecedented quantitative assessments of terrestrial and aquatic ecosystems.



Introduction

Objectives/Questions

1. Can high-resolution commercial data be used to understand sub 30m pixel variability in Hyperion data?

2. How stable is Hyperion through time with atmospherically corrected land surface reflectance from multiple correction approaches?

3. Can Hyperion be used to cross calibrate a virtual constellation for land surface imaging?

Study Area

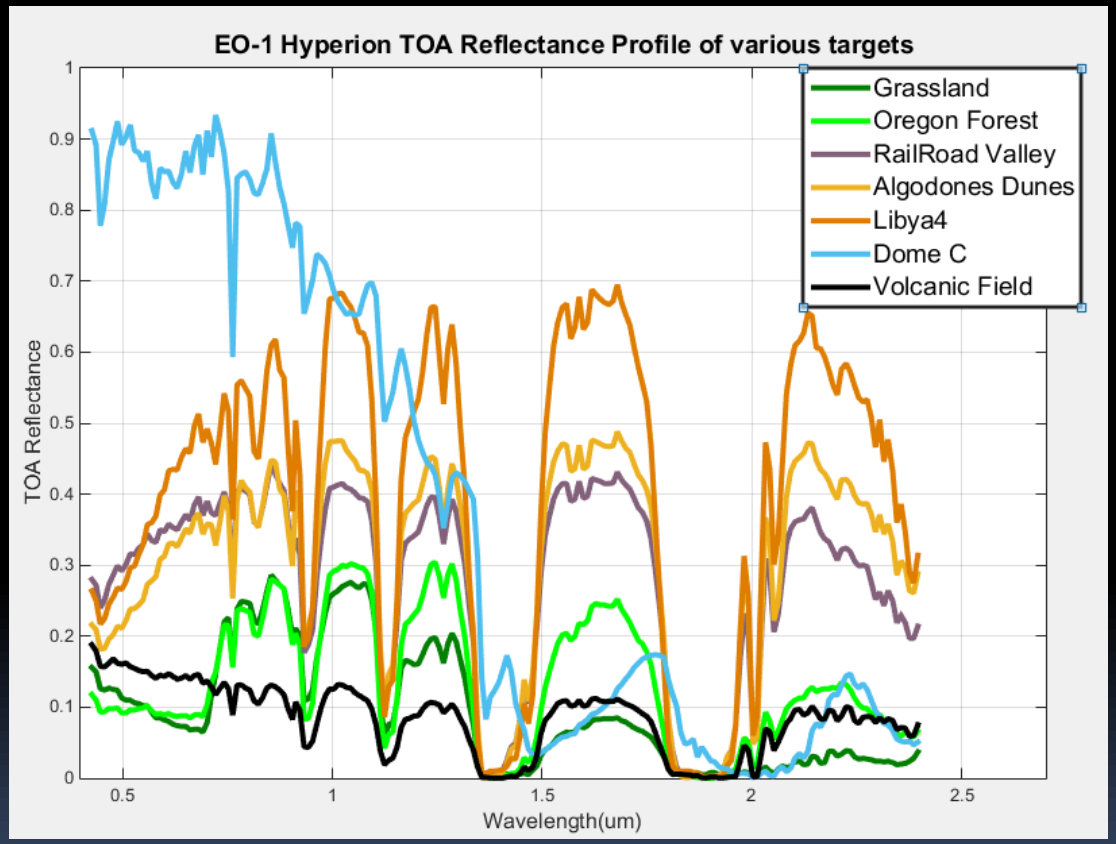
- CEOS – core validation sites
  - Hyperion data has been routinely collected in the Libyan desert (Libya-4)
  - Other studies have used this site to monitor sensor degradation and cross-calibrate measurements
  - Landsat ETM+, MSS, SRTM, MODIS, EO-1

Chander et al. 2010

Spectral Signature Impact on Cross Calibration

From:
On-orbit calibration: Use of psuedo invariant calibraiton sites (PICS), vicarious campaigns, and global averaging

- Hyperion acquisitions over different land cover types have been collected and evaluated.
  - Bright Deserts PICS (Libya 4, Algodones Dunes)
  - Medium Bright Playa PICS (RVPN)
  - Vegetation (Oregon Forest, SDSU test vegetation site)
  - Snow (Dome C)
  - Dark PICS (Volcanic field in Libya)



*D. Helder, N. Mishra, **L. Leigh and** D. Aaron. Update on Pre-Cursor Calibration Analysis of Sentinel 2. April 23, 2015 - LCLUC*

Prior Moderate Resolution Studies of Libya-4 PICS

Chander et al. 2010 RSE

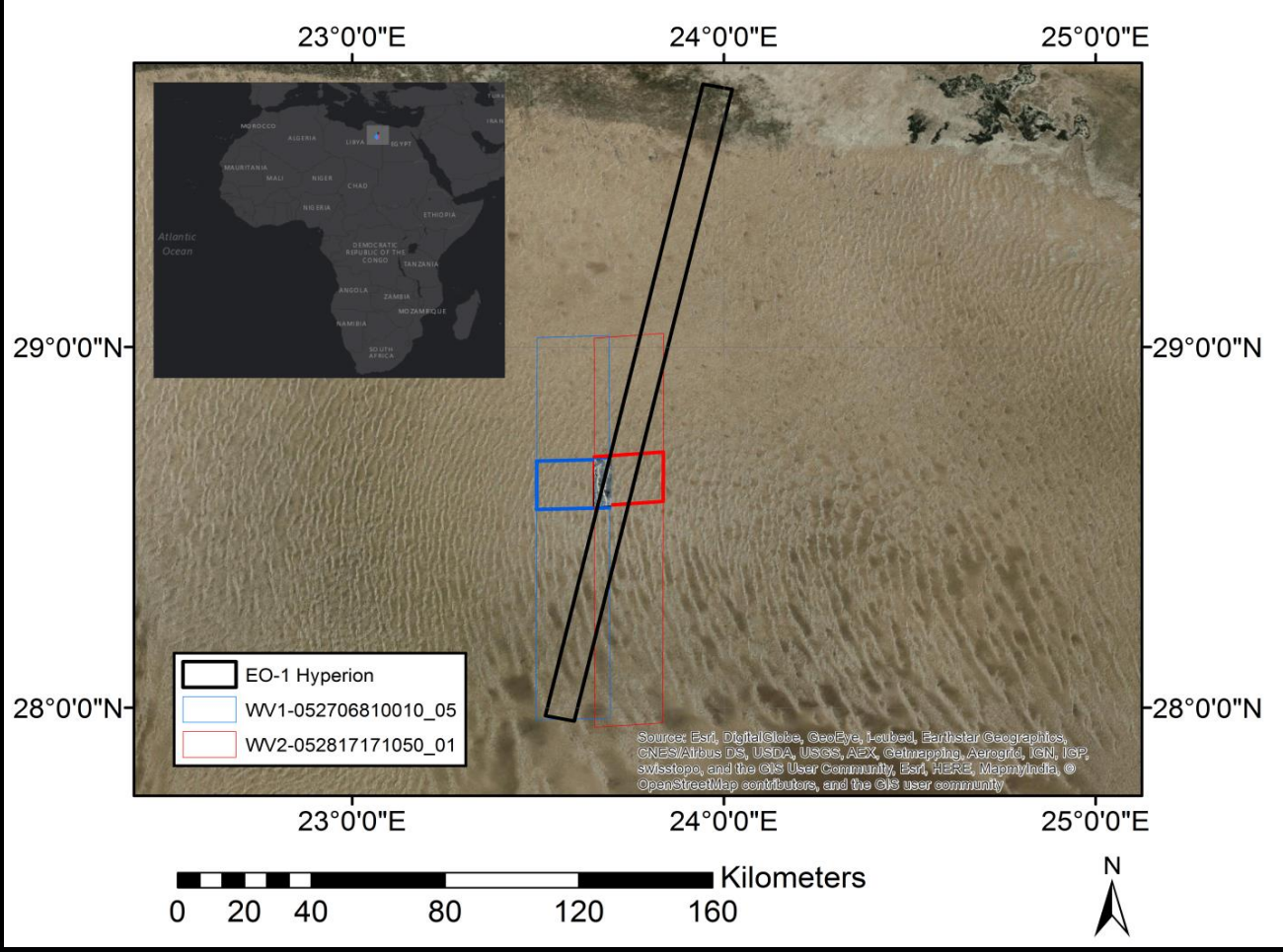
- TOA reflectance from MODIS 2000-2008 (161 scenes) and Landsat 7 1999-2008 (86 scenes) both < 0.479% yr^{-1} from all bands
- MODIS within image standard deviation < 0.014, Landsat 7 < 0.022

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

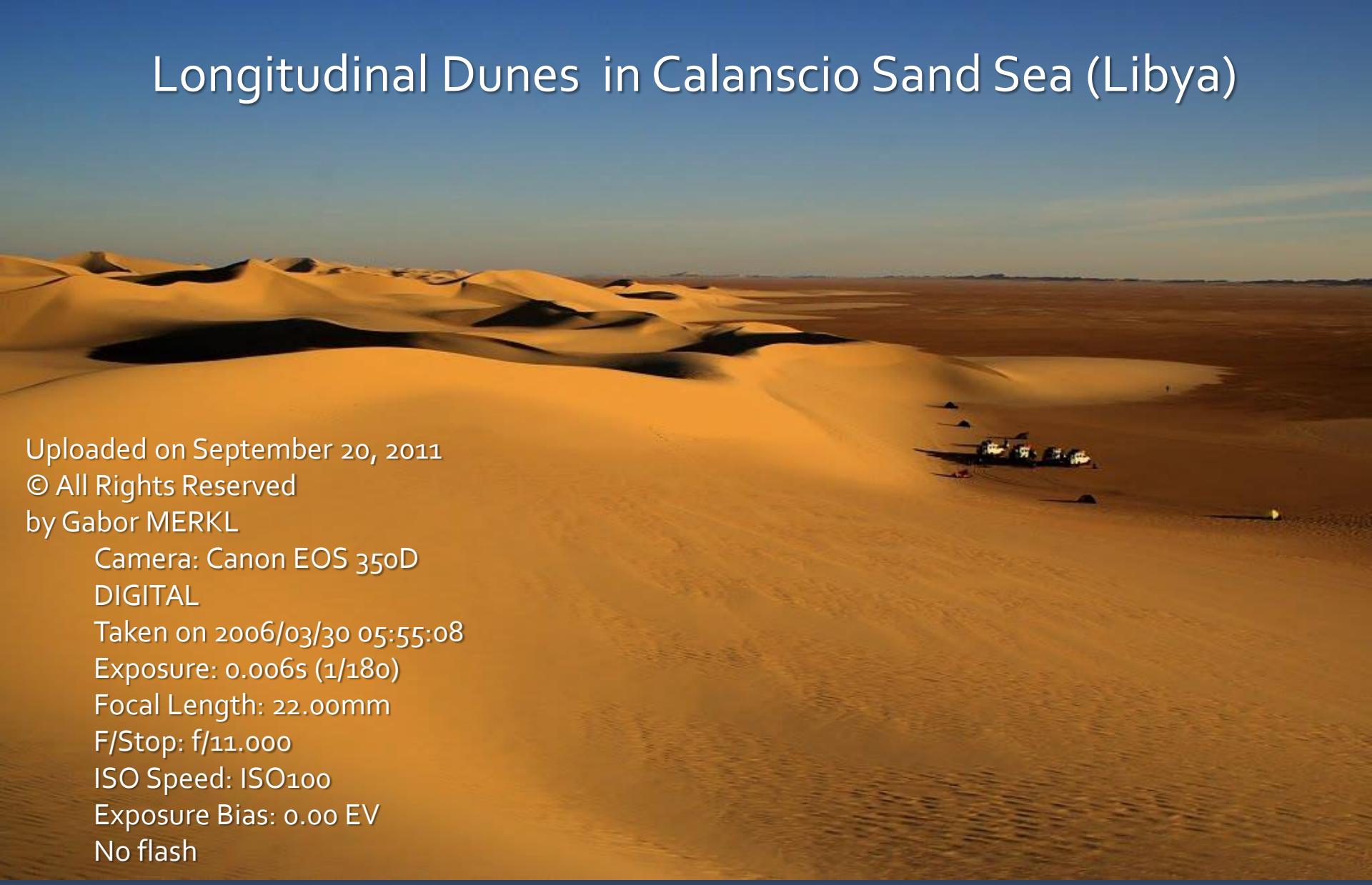
Moderate Resolution (temporally dense):
Landsat-8 30 m(FLAASH)
Hyperion 30 m (FLAASH)

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

Among others…

Longitudinal Dunes in Calanscio Sand Sea (Libya)



Uploaded on September 20, 2011
© All Rights Reserved
by Gabor MERKL

Camera: Canon EOS 350D DIGITAL
Taken on 2006/03/30 05:55:08
Exposure: 0.006s (1/180)
Focal Length: 22.00mm
F/Stop: f/11.000
ISO Speed: ISO100
Exposure Bias: 0.00 EV
No flash

28° 0' 49.68" N 23° 46' 27.89" E
http://www.panoramio.com/photo/59315749

138 m elevation

Methods: Hyperion Image Processing

- Data Selection (minimize error)
  - Only May through September
  - < ±10° Off Nadir
  - (to reduce BRDF)
  - 300+ images filtered to 28
  - (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 L1T
  - 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

Hyperion FLAASH Co-registered Surface Reflectance Time-series

Vis

NIR

SWIR

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

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

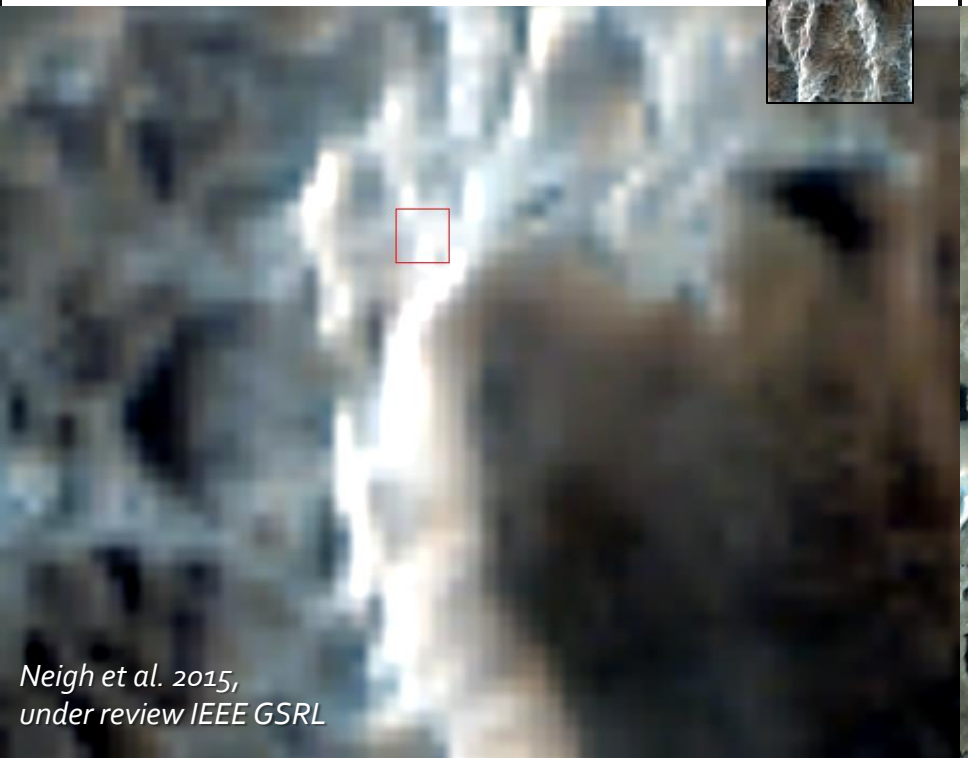
Red	630-690 nm
Green	510-580 nm
Blue	450-510 nm

Cubic Convolution 2m

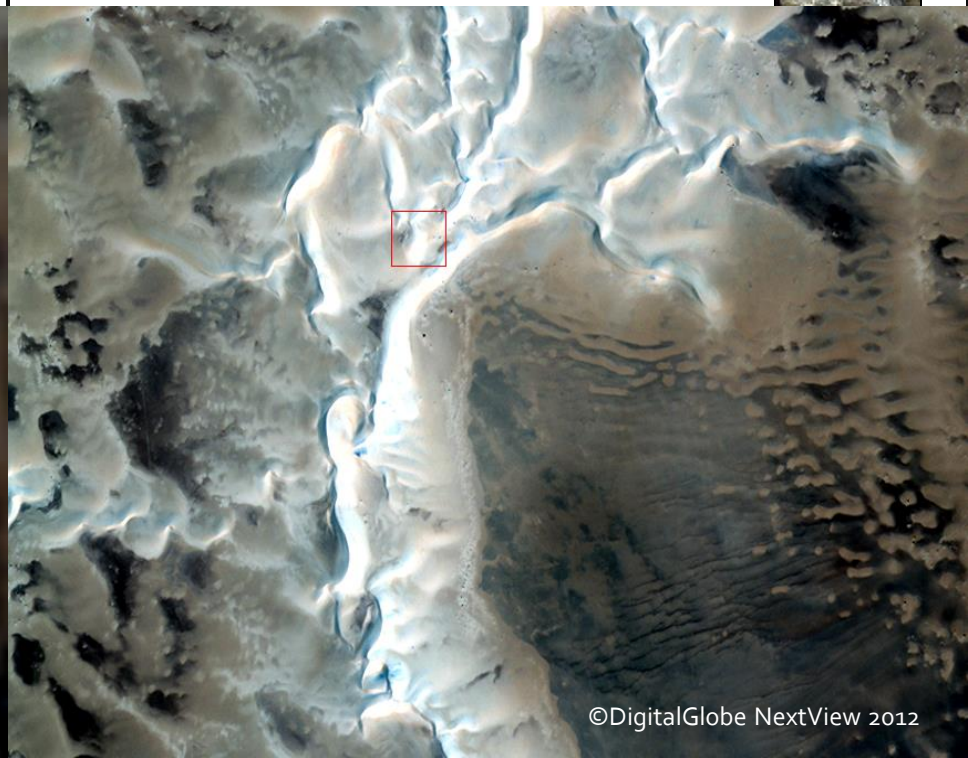
WorldView-2 True Color
FLAASH
8/12/2012

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

2m



Neigh et al. 2015,
under review IEEE GSRL



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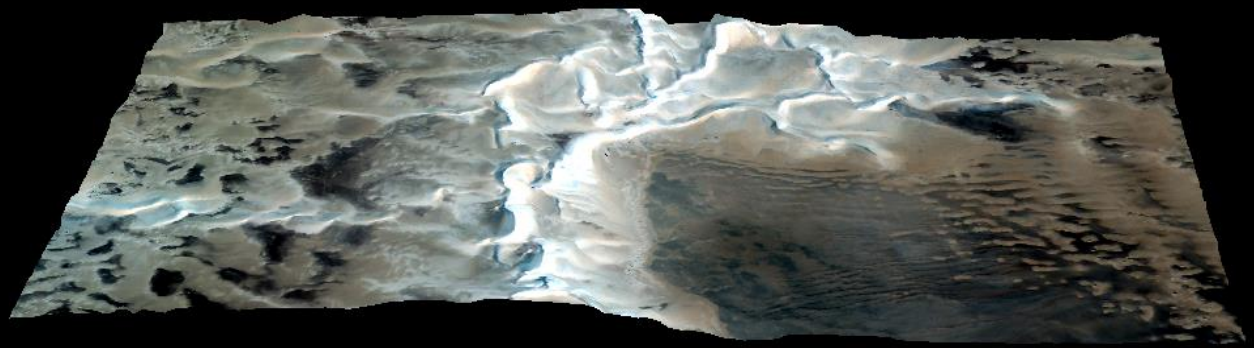
3D Surface View of Subset Area

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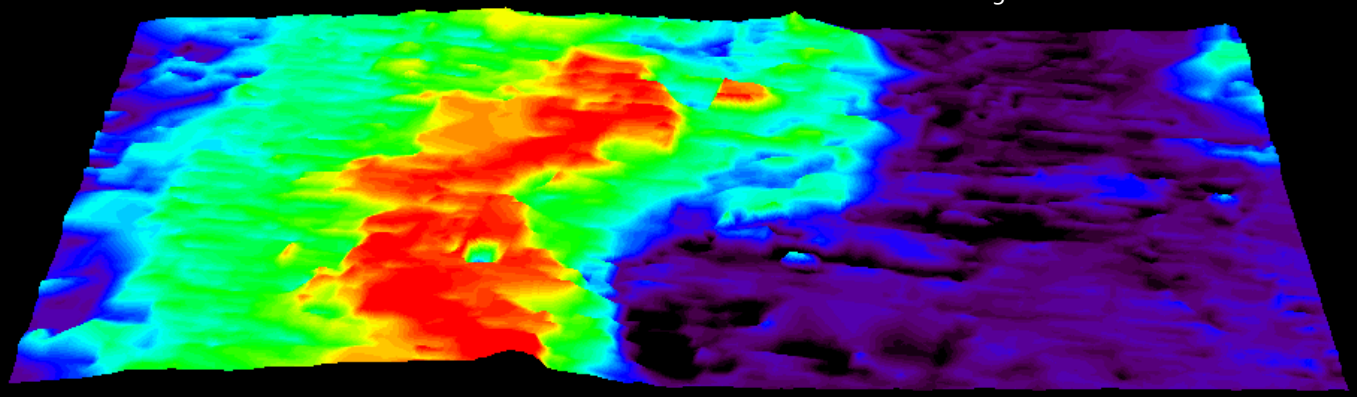
WorldView-2 – WorldView-1
Digital Terrain Model
2m



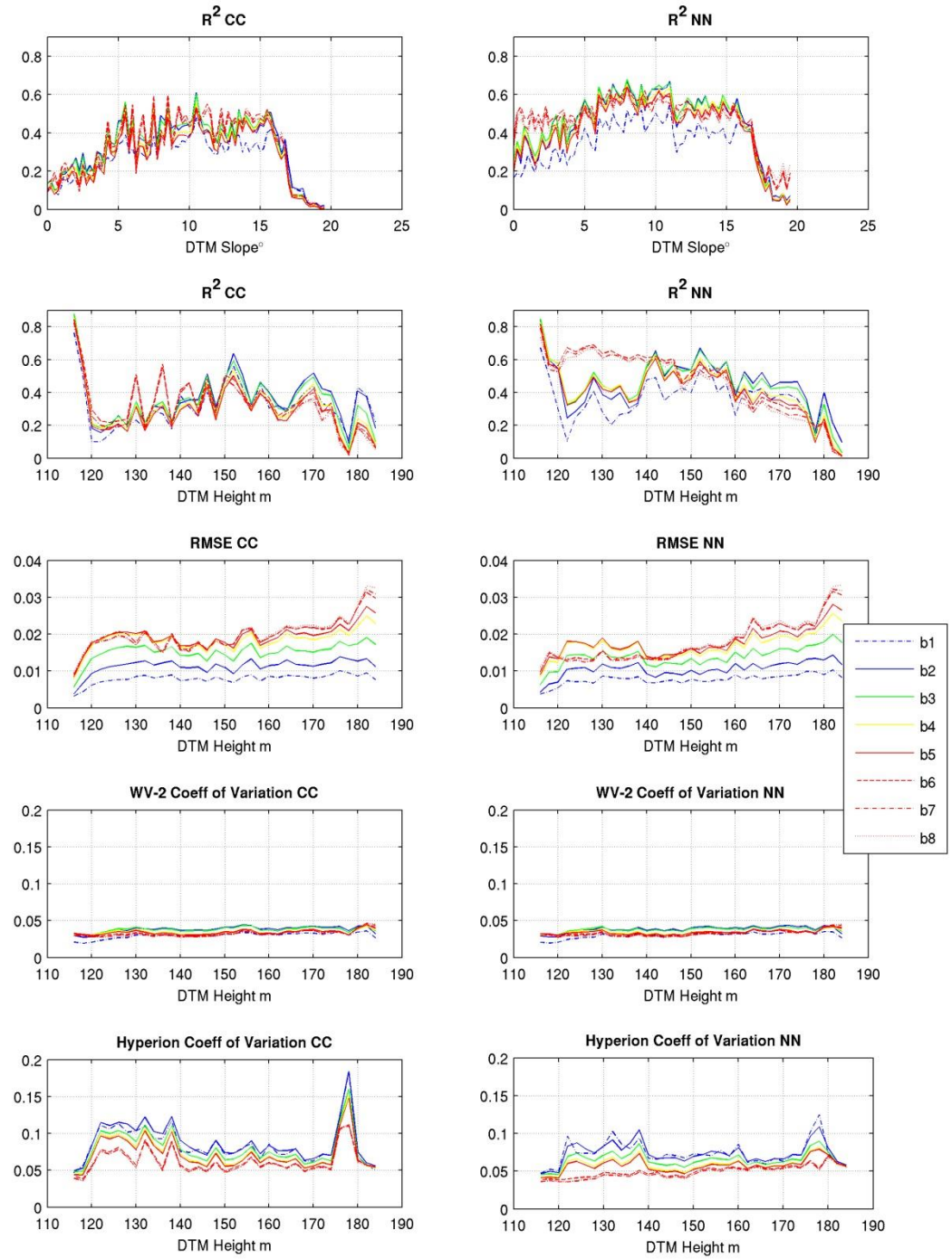
Neigh et al. 2015,
under review IEEE GSRL

Results Part 1:

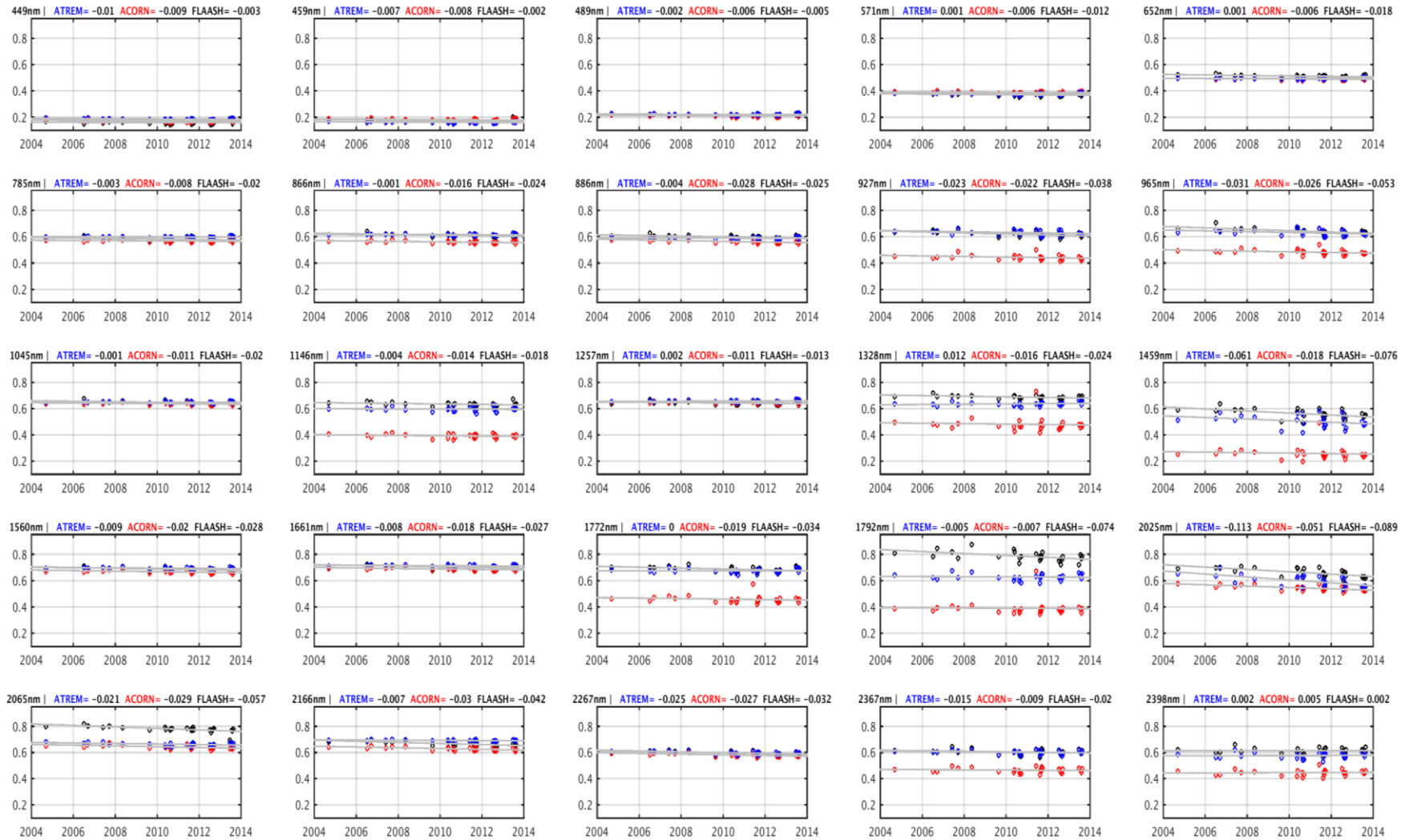
Terrain Impacts Cross Calibration in Libya-4 at sub 30m resolution

1. Elevation and slope have a strong influence on WV-2 band agreement with Hyperion data, ranging from very low agreement at the transition to dune tops ($R^2 < 0.05$) but high agreement in the sand flats ($R^2 > 0.6, P < 0.001$). Consequently, the RMSEs increased with height as well.
2. WV-2 observations at 2 m resolution are more homogenous (Coefficient of Variation (CV) = standard deviation/mean CV < 5%) compared to convolved 2-m NN Hyperion (CV < 15%)
3. Good agreement between Hyperion data convolved to WV-2 bands when resampled with the NN method within specific sub-portions of the Libya-4 PICS ($R^2 > 0.7$).

Neigh et al. 2015, under review IEEE GSRL



Results Part 2: Hyperion Median Trends



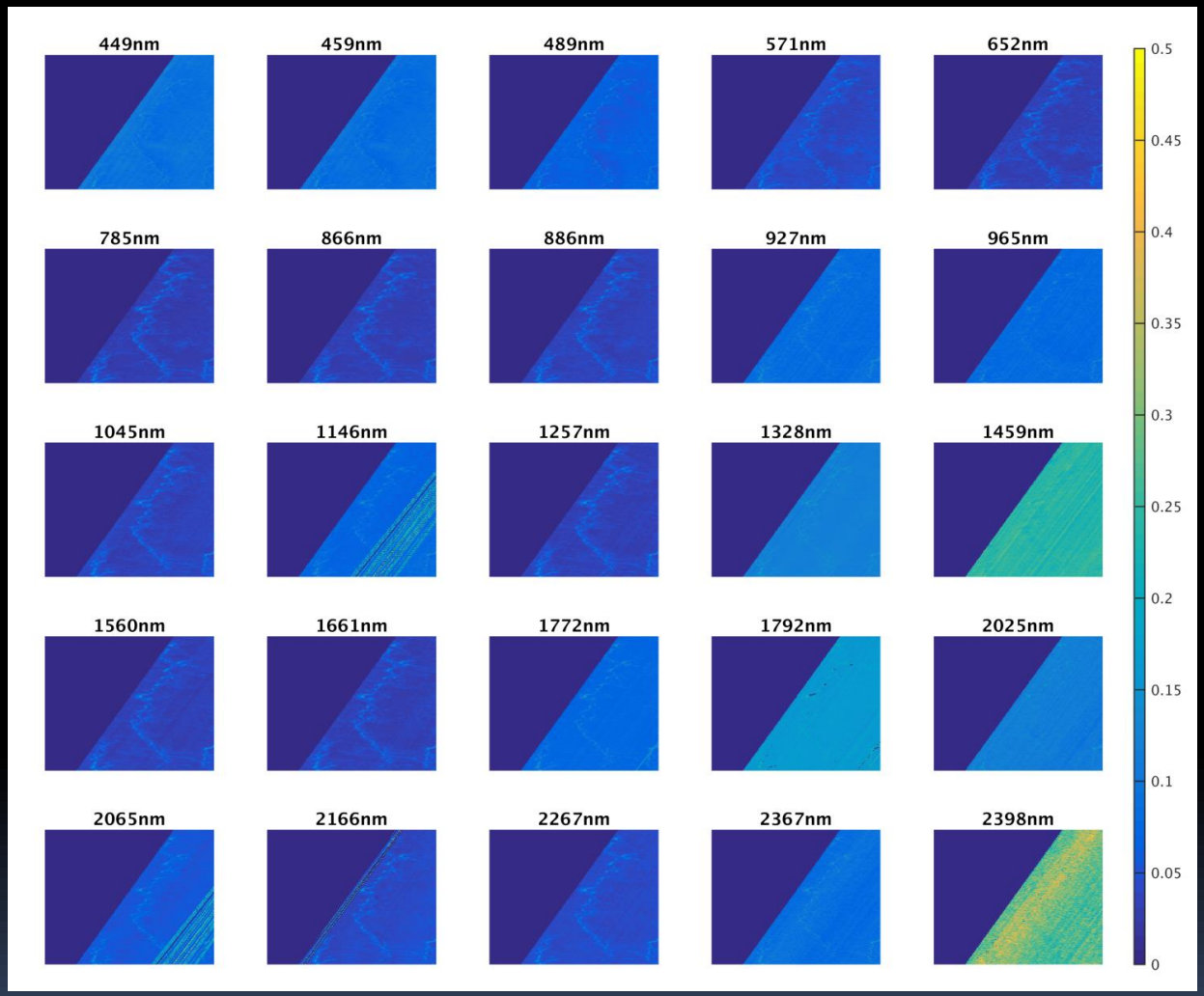
From 2004-2013 maximum change for specific models: Visible < 5.3%, NIR < 7.6%, SWIR < 8.9%

Neigh et al. 2015, in prep

Results Part 2: Hyperion Surface Reflectance Uncertainty

Neigh et al. 2015, in prep

Do the dunes increase uncertainty between atmospheric correction models?

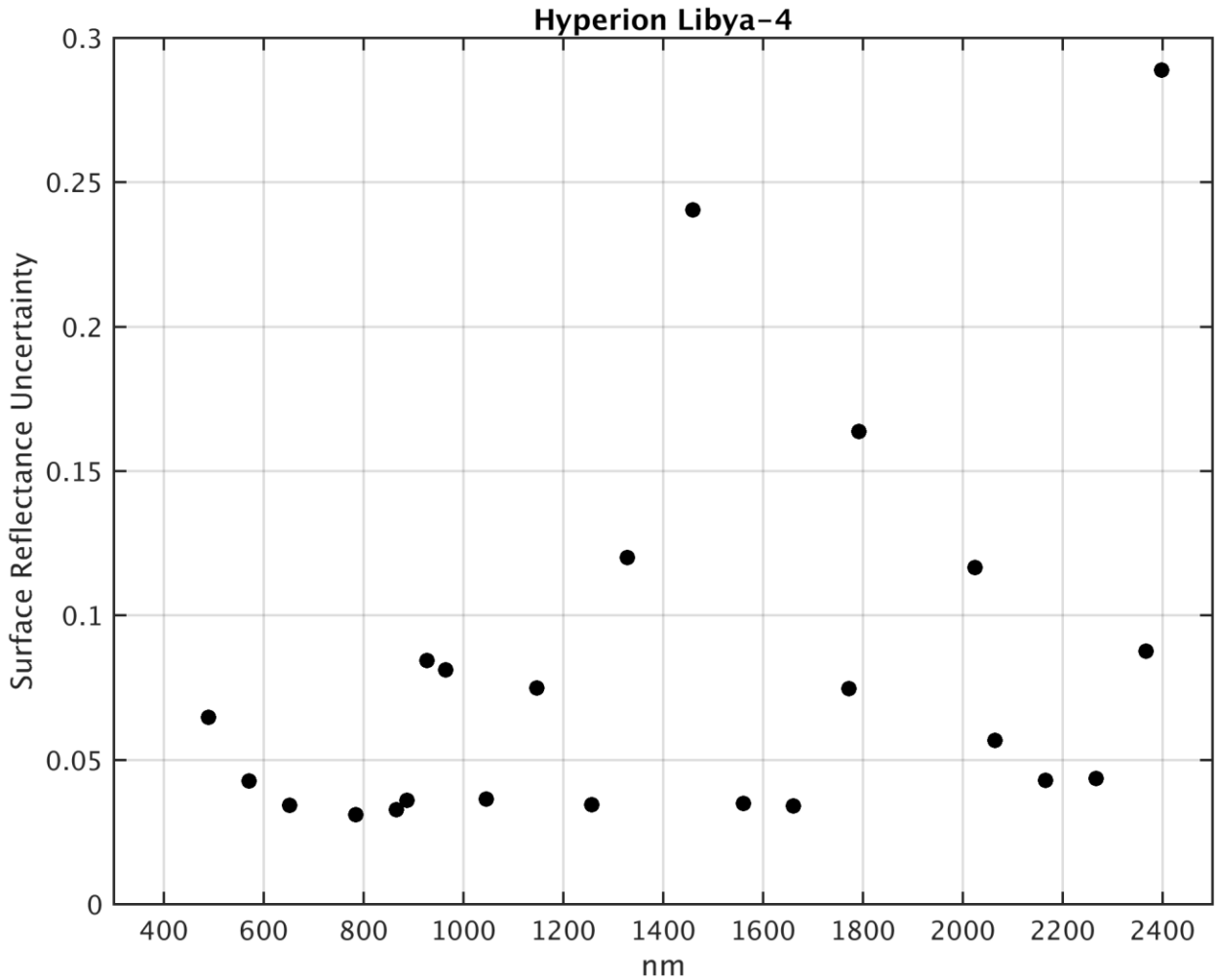


Temporal uncertainty by pixel calculated as: Coefficient of Variation (CV) = standard deviation/mean

Combined Uncertainty = $\sqrt{FLAASH_{CV}^2 + ATREM_{CV}^2 + ACORN_{CV}^2}$

Results Part 2: Hyperion Temporal Uncertainty

Can errors be minimized by removing pixels with greater temporal uncertainty?



Combined Uncertainty = $\sqrt{FLAASH_{CV}^2 + ATREM_{CV}^2 + ACORN_{CV}^2}$

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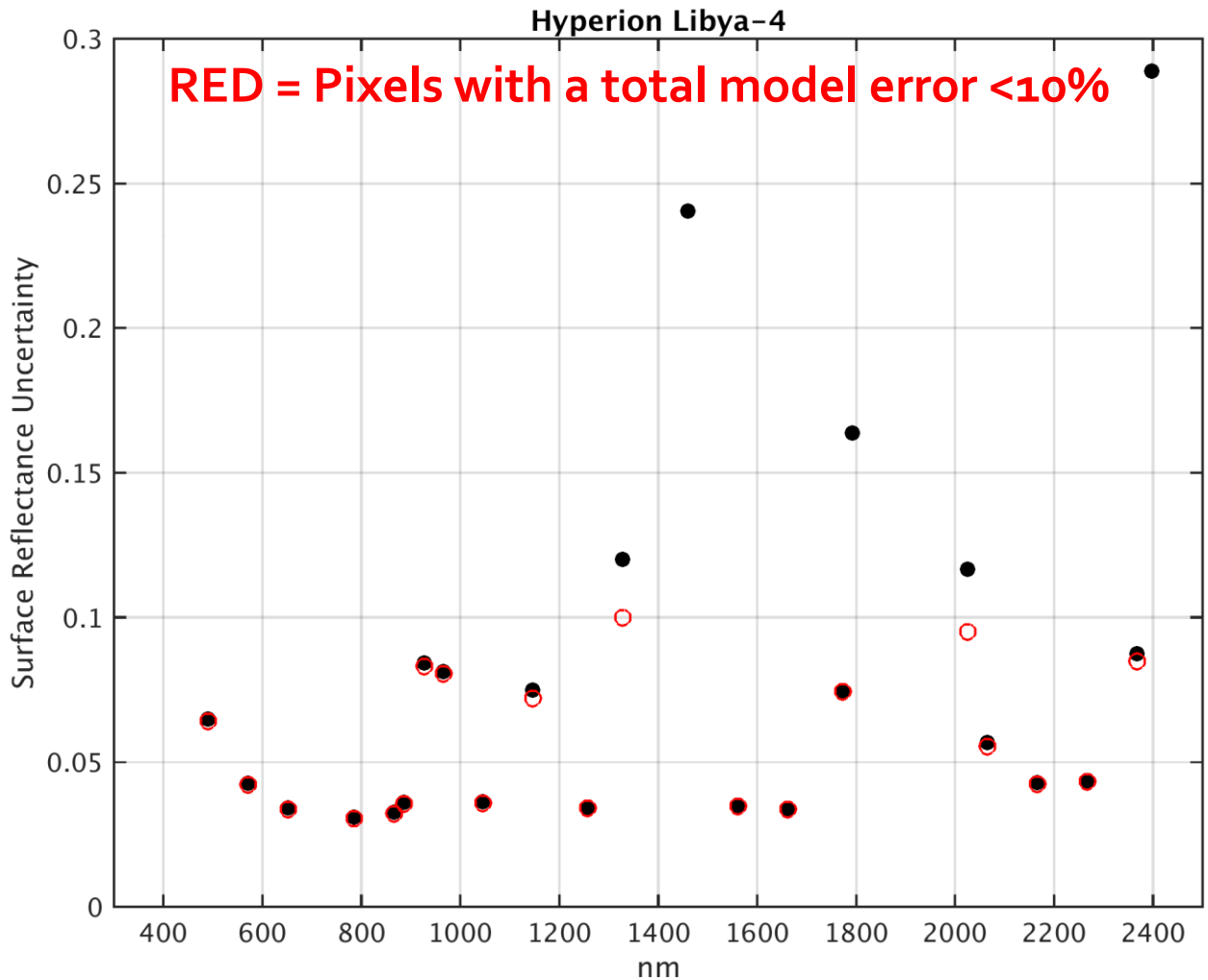
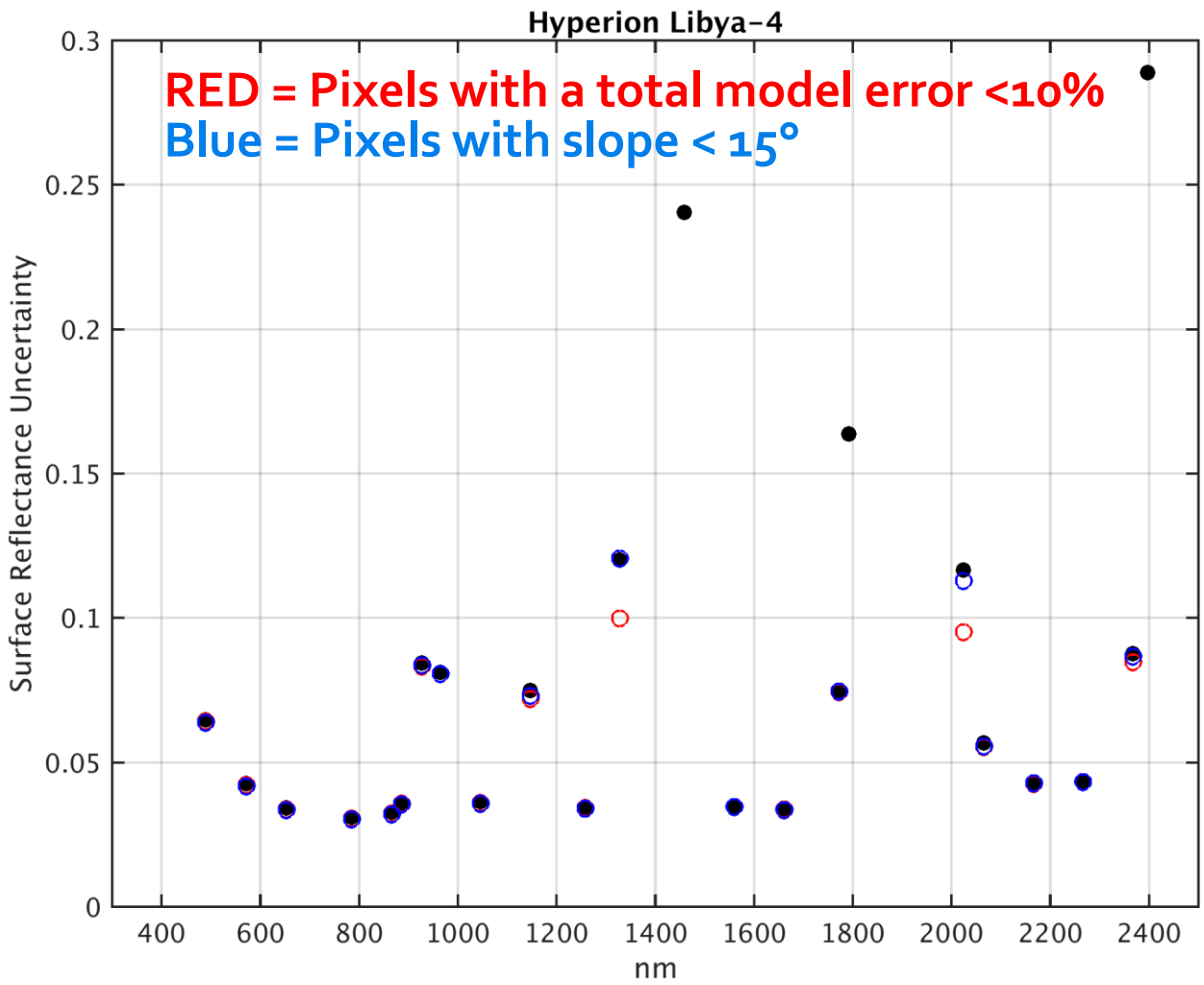


Combined Uncertainty = $\sqrt{FLAASH_{CV}^2 + ATREM_{CV}^2 + ACORN_{CV}^2}$

Results Part 2: Hyperion Temporal Uncertainty

Can errors be minimized by removing pixels with greater temporal uncertainty?



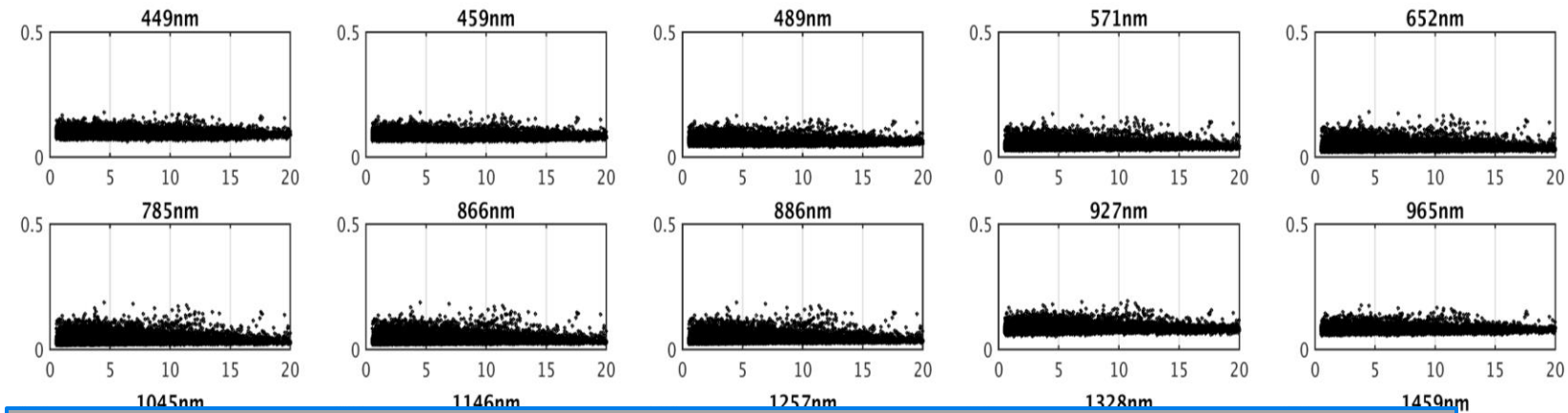
Combined Uncertainty = $\sqrt{FLAASH_{CV}^2 + ATREM_{CV}^2 + ACORN_{CV}^2}$

Results Part 2: Hyperion Slope Uncertainty

Vis

NIR

SWIR



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

Among others…

Uncertainty within slope bin is greater than filtering by slope at 30m due to high grade data selection

High graded pixels still have greater uncertainty due to other factors than slope at 30 m

Summary

- Hyperion is very stable through time.
  - CV< 2% locations, in most Vis bands < 0.18% yr^{-1} most other bands <0.4% yr^{-1}
  - CV 5-7% locations, in 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 vs. ACORN
  - 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

- 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 at high resolution or efforts should be made to minimize site conditions that introduce errors.

Thank You

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Neigh C.S.R., McCorkel J., Campbell P., Ong L., Ly V., Landis D., Fry S., and Middleton E. IEEE Geoscience and Remote Sensing Letters, 2015 in prep.

Neigh C.S.R, McCorkel J., Middleton E. Quantifying Libya-4 surface reflectance heterogeneity with WorldView-1, 2 and EO-1 Hyperion IEEE Geoscience and Remote Sensing Letters, 2015 under review.

Neigh C.S.R., Masek J., and Nickeson J. (2013) High Resolution Satellite Data Open to Government Scientists. *AGU EOS Transactions* **94** (13), 121-123.