Consistency of SPOT4 (Take 5) surface reflectance data

Comparison with MODIS surface reflectance data

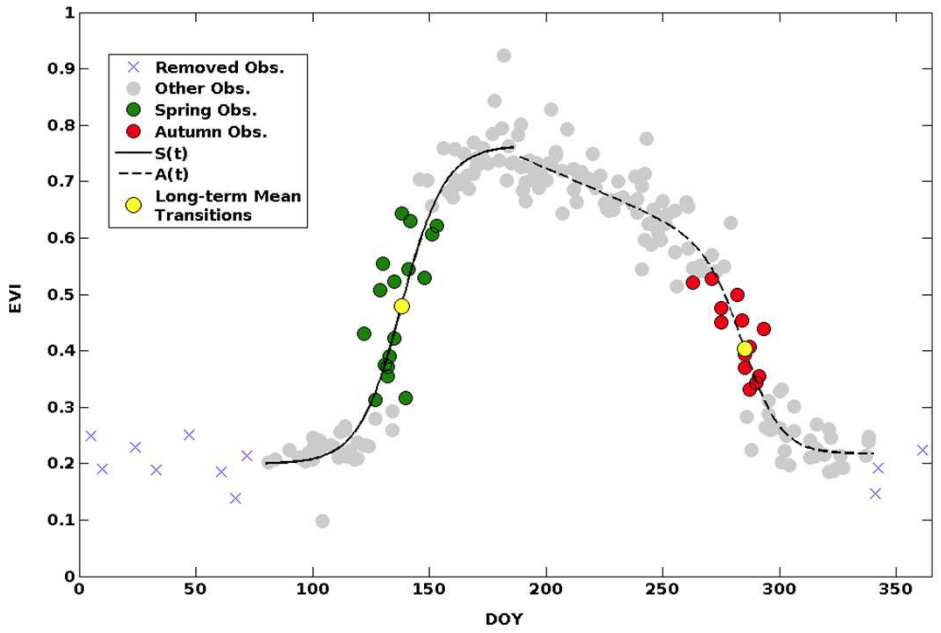
M. Claverie[1,2], E. Vermote[1], J. Masek[1]

1- NASA Goddard Space Flight Center
2- UMD, Dep. of Geographical Sciences

Introduction to the Landsat & Sentinel-2 Synergy Project

Since the opening of the USGS Landsat archive, there has been increased interest in ***intra-annual*** time series applications at 30m resolution

- Agricultural monitoring (e.g. GEO-GLAM)
- Vegetation biophysics (LAI, fPAR, productivity)
- Phenology and climate linkages
- WELD data products

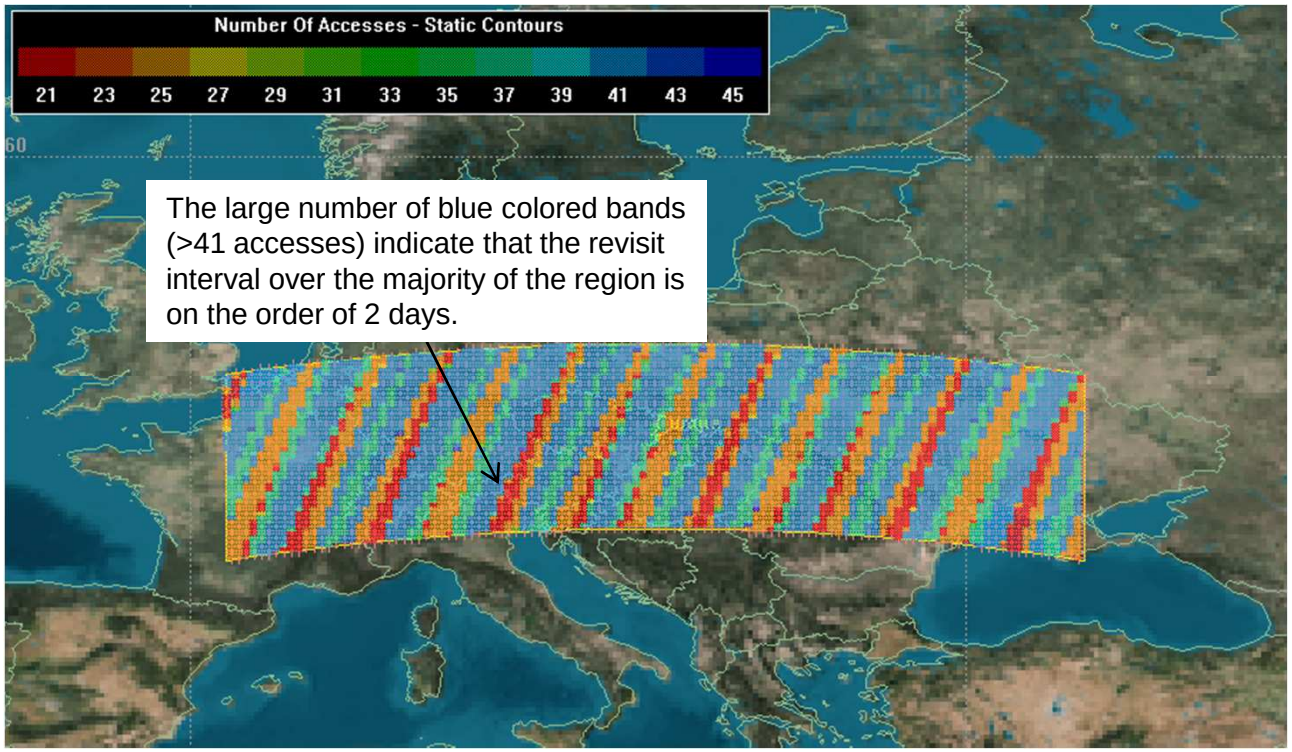


Example: New England forest phenology from multi-annual Landsat observations, courtesy Mark Friedl (BU)

Sentinel-2 and Landsat Fusion

Merging Sentinel-2 and Landsat data streams could provide < 5-day coverage required for Ag monitoring

- Both sensors have 10-30m coverage in VNIR-SWIR
- S-2a launch in mid-2014; S-2b launch late-2015

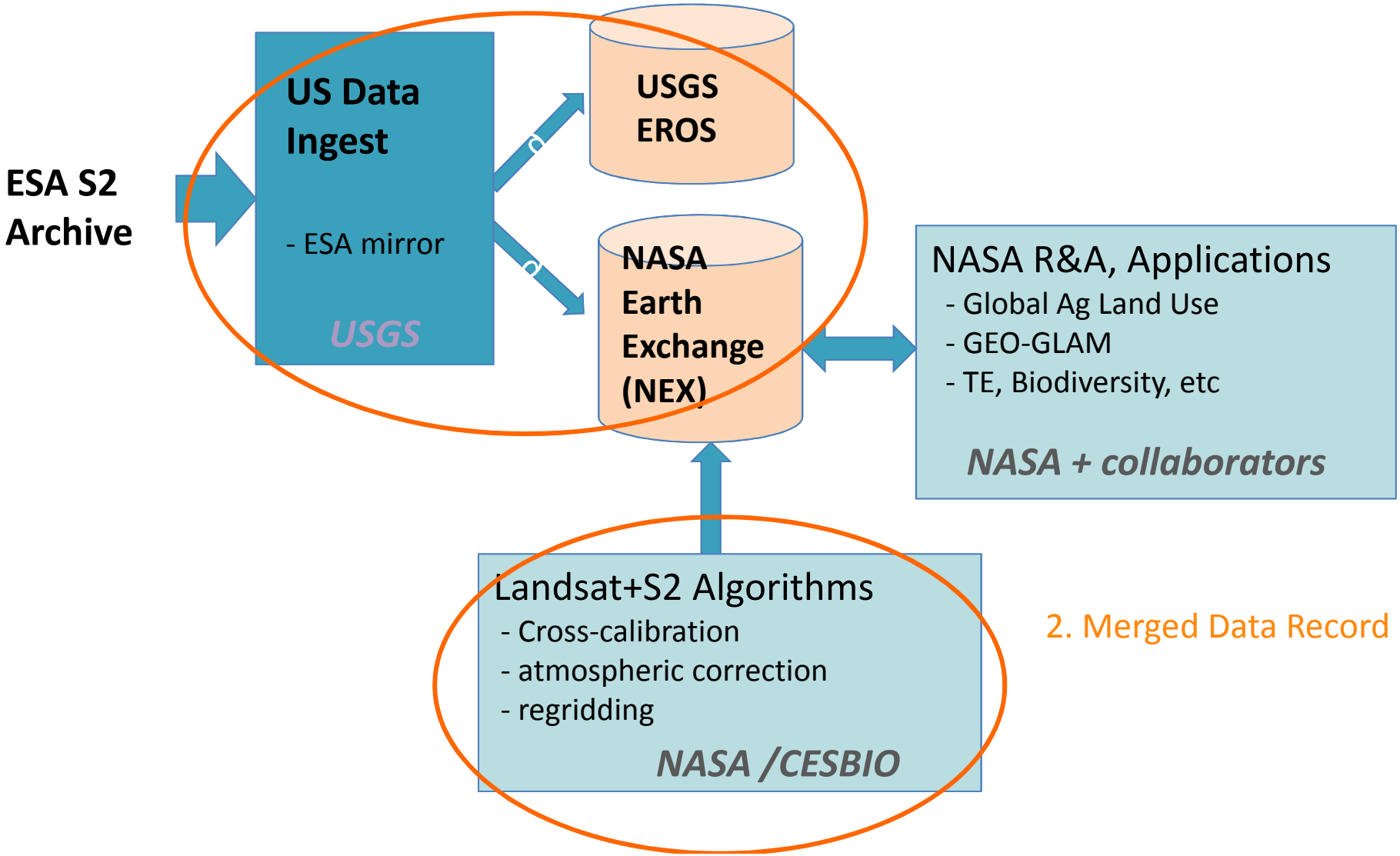


Number of times LDCM and the Sentinel 2 satellites accessed areas on the ground over an 80 day period of time.

- 21 accesses indicates a maximum revisit interval of ~3 days 19 hours
- 46 accesses indicates a minimum revisit interval of ~1 day 18 hours

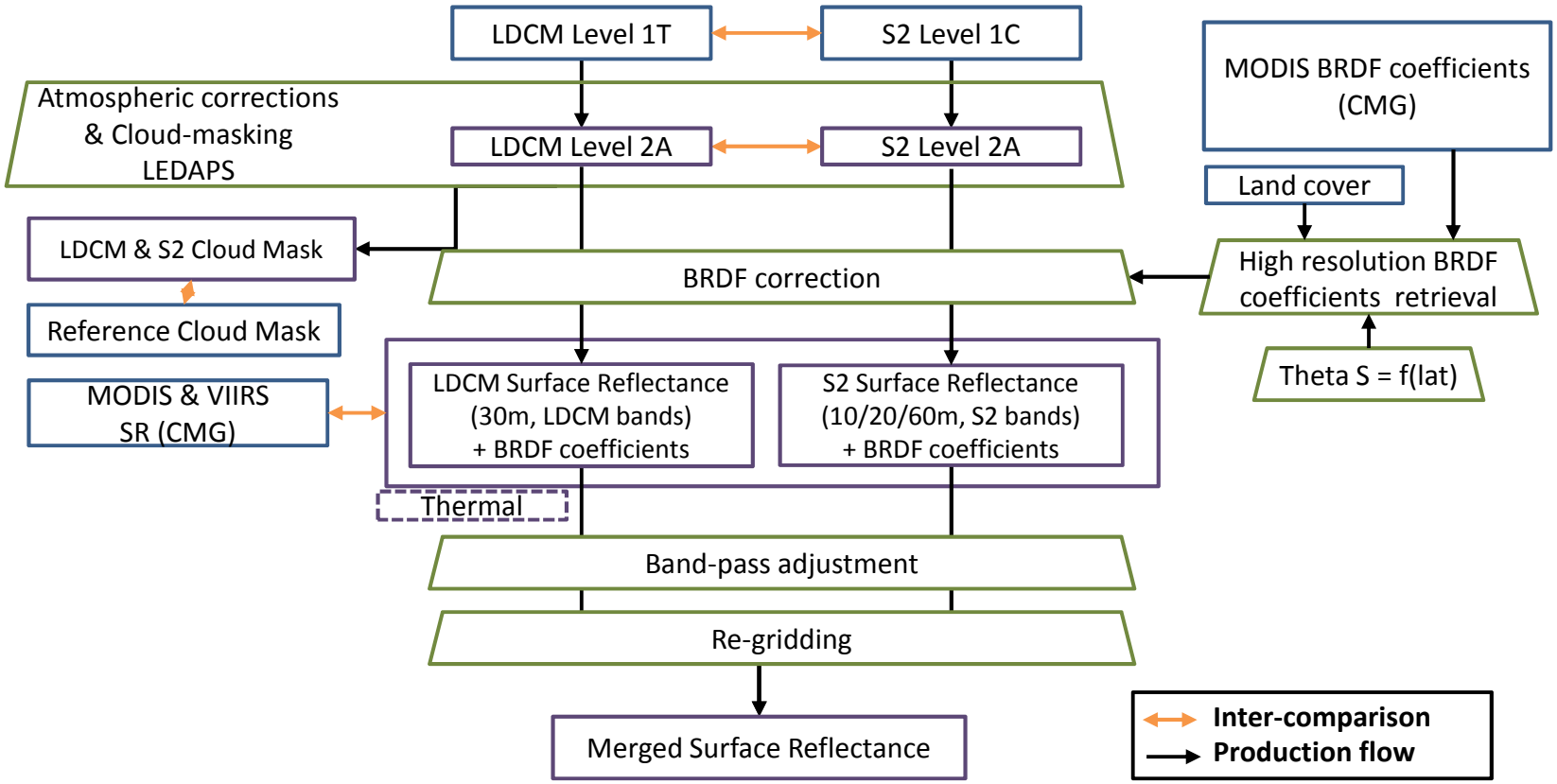
Proposed Sentinel-2 / Landsat Architecture

1. Data Provisioning



2. Merged Data Record

LDCM / Sentinel-2 Fusion



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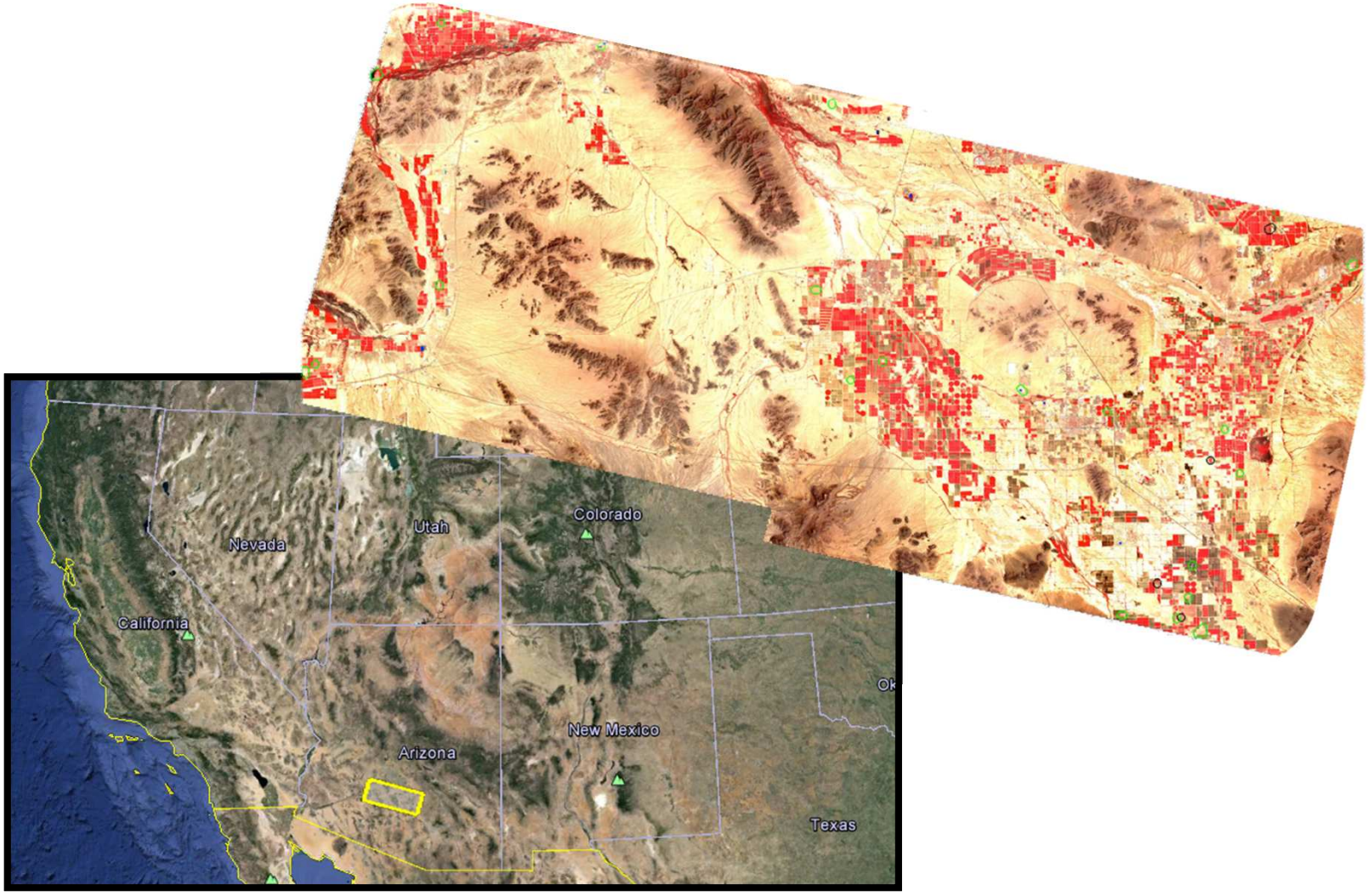
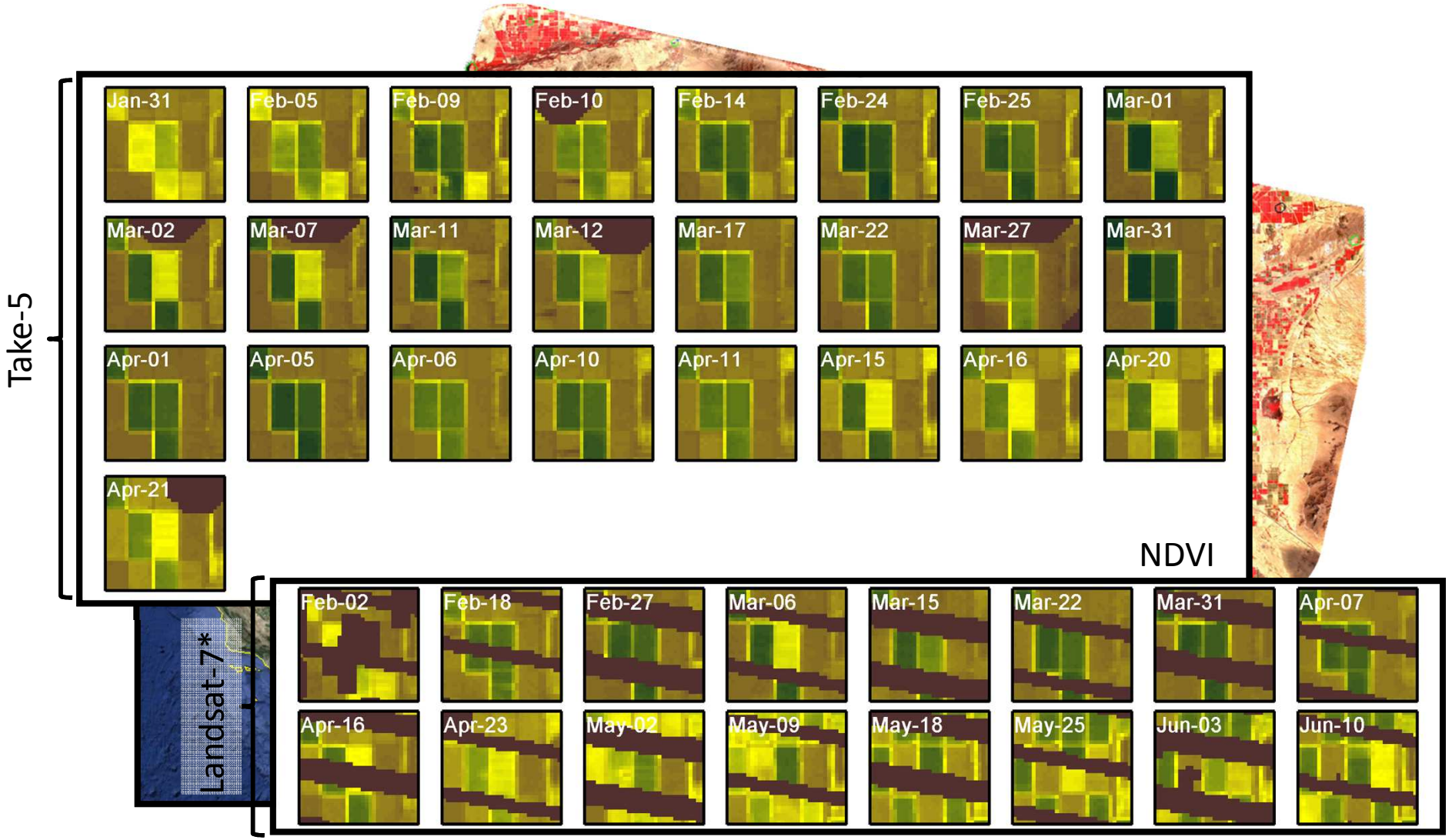
Introduction – Maricopa site

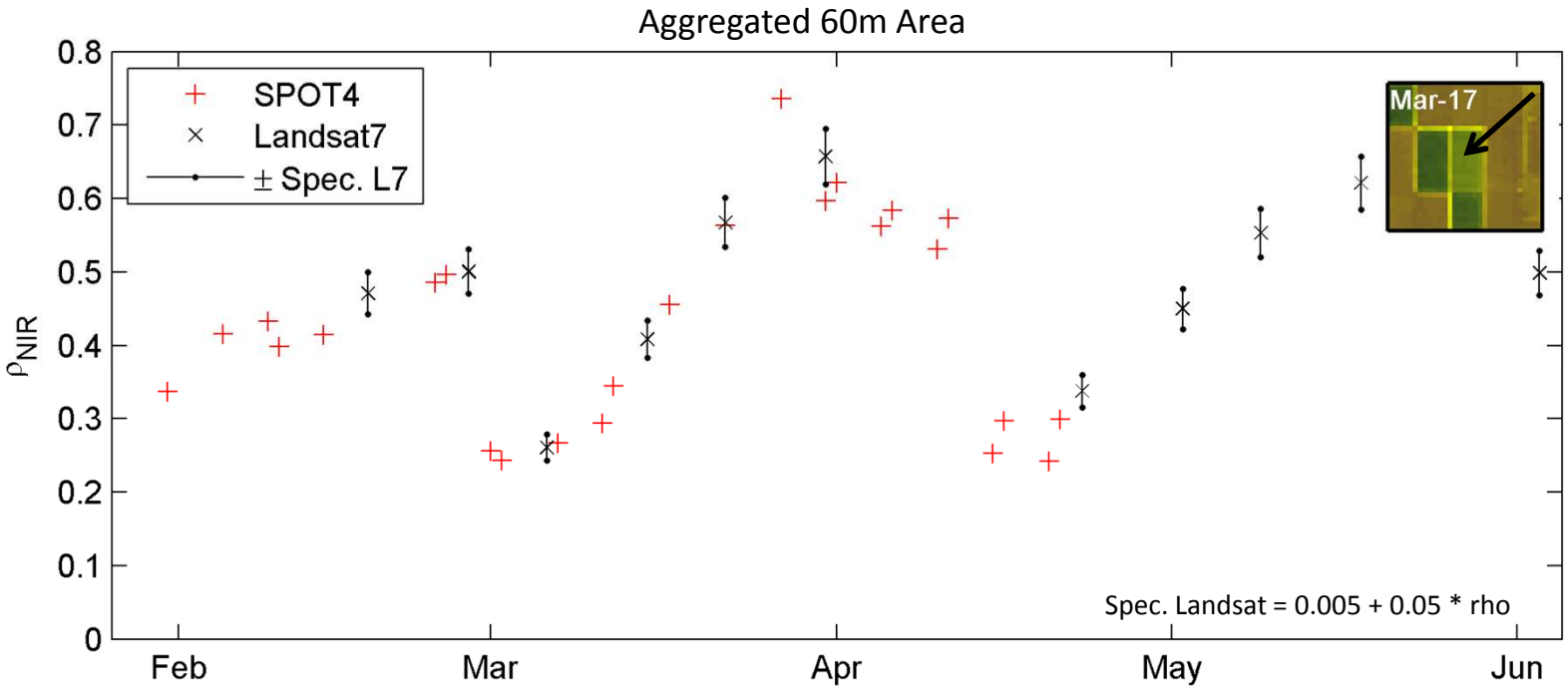


Introduction – Maricopa site



* 2 tiles from 2 paths

Introduction – Maricopa site



Multiple factors which can impact observed changes:

- Surface itself
- Spectral (~ 100 nm vs ~ 35 nm)
- Spatial (20 m vs 30 m + PSF)
- Directional (4 viewing Angles in total)
- Temporal (sun angle and atmospheric condition)

Introduction

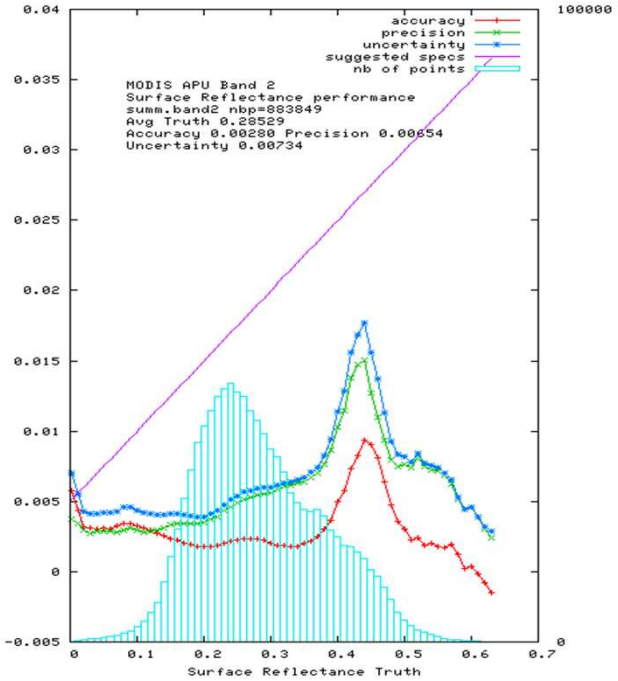
- => need to validate (or inter-compare) Surface Reflectance (SR) products.
- Currently, validation of SR are mostly validating over Aeronet sites.
- => need a more systematic method to evaluate the consistency of the products
- Inter-Comparison SPOT-4 Take-5 SR data with MODIS SR data

Why MODIS?

- Daily global observation
- On board on 2 active platforms
- More than 13 years of data

- MODIS SR (MOD09) products benefit from a long term validation strategy over Aeronet sites.

Terra 2002-2009 Validation Results

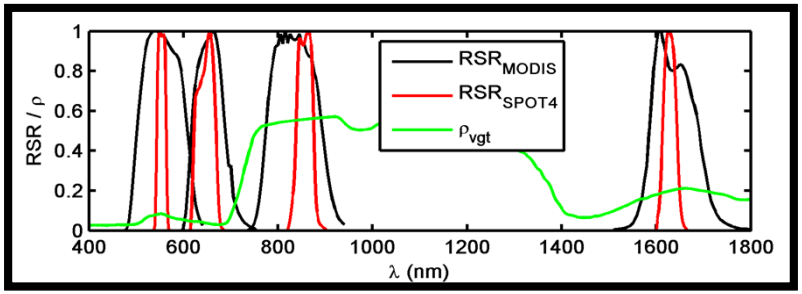


Accuracy (red line), precision (green line), and uncertainty (blue line) over the directional surface reflectance in MODIS/TERRA band 2 binned in 0.01 increments of reflectance. Also shown are the number of points in each bin (blue bars) with the value on the left and the error budget of suggested uncertainties (magenta line).

http://modis-sr.ltdri.org/cgi-bin/vMYDall_APUmain_nofilter_match_altitude_refi550.cgi

Dealing with various characteristics

- Comparing SR products is not an easy task since differences in term of acquisitions and sensors characteristics has to be taken in account:



Mission/Sensors	SPOT-4 Take-5	MODIS (Terra & Aqua)
Spatial	20m	250-1000m
Spectral	4 bands	7 bands
Directional	θv = [0° – 30°]	θv = [0° – 60°]
Temporal	5-day revisit period (constant viewing angle) AM overpass	1-day revisit period (variable viewing angle) AM & PM overpass

✓

✓

Need a method to correct from directional effect

- 2 various Atmospheric correction method:
  - SPOT-4 Take-5: MACCS (Hagolle et al., 2008)
  - MODIS: 6S-based (Vermote & Saleous, 2006)

VJB model to correct BRDF

(Bidirectional Reflectance Distribution Function)

- VJB Model (Vermote et al. 2009)
  - Relate BRDF parameter to NDVI
  - Simplification of BRDF Kernels using 2 proxy: R & V

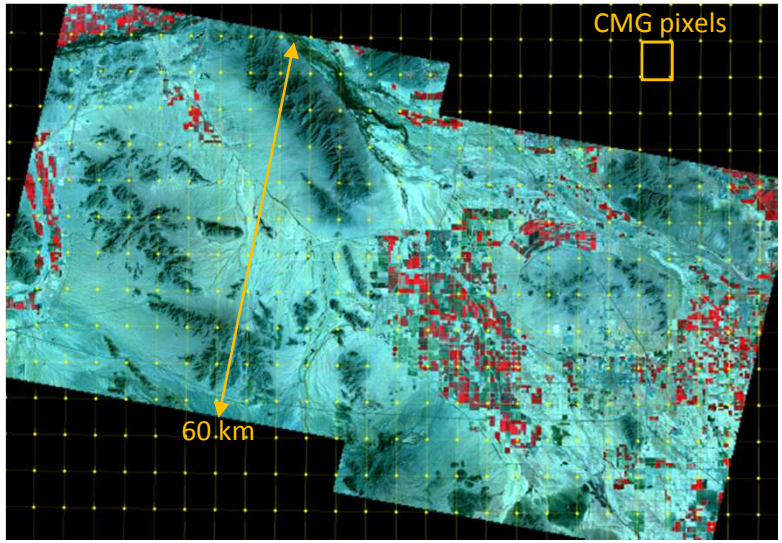
$$\rho(\theta_{out}) = \rho(\theta_{in}) \times K(\theta_{out}, \theta_{in}, R, V)$$

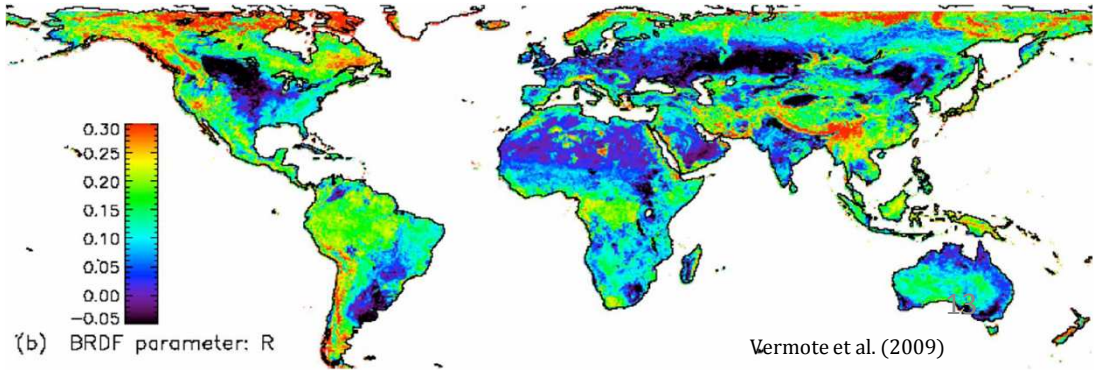
θ *Stands for* $\theta_V, \theta_S, \Delta\phi$

  - using MODIS CMG (0.05°), R & V were found well-correlated to NDVI

$$R = a_1 \times NDVI + b_1$$
$$V = a_2 \times NDVI + b_2$$

  - a_1,b_1,a_2,b_2 parameters were retrieved at global scale (at 0.05°) for each MODIS band

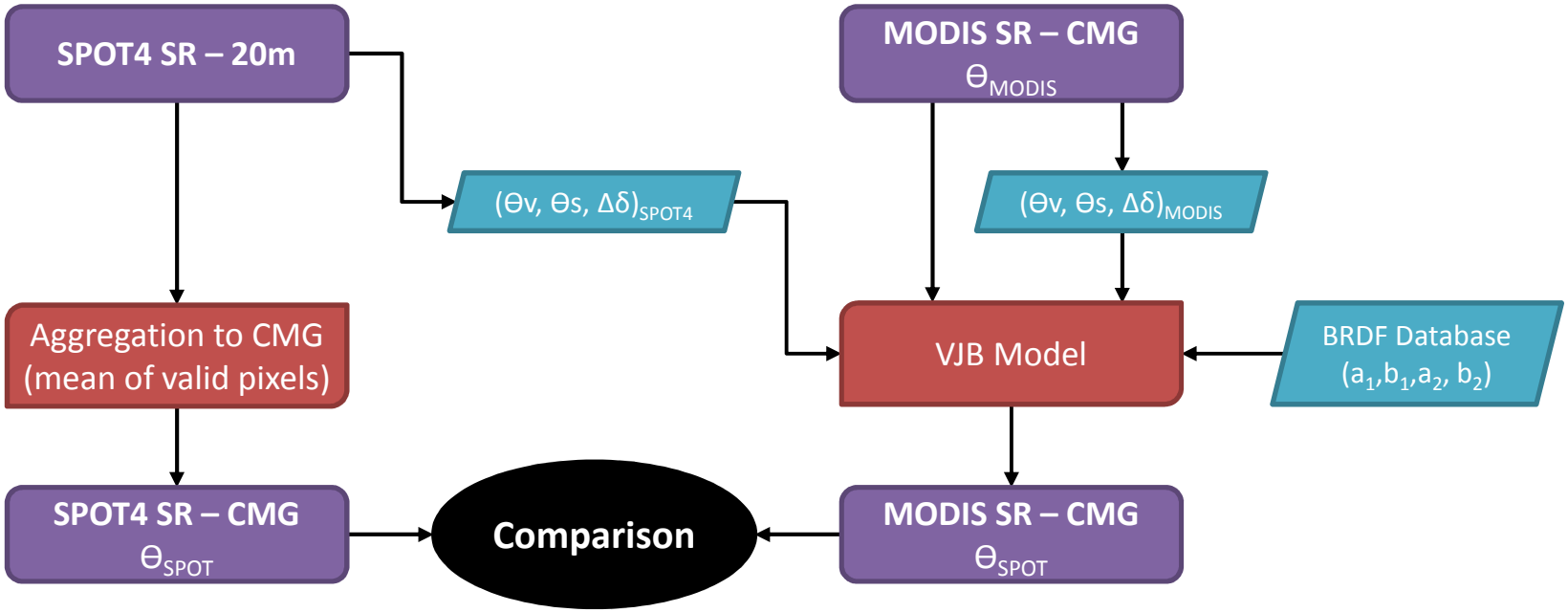




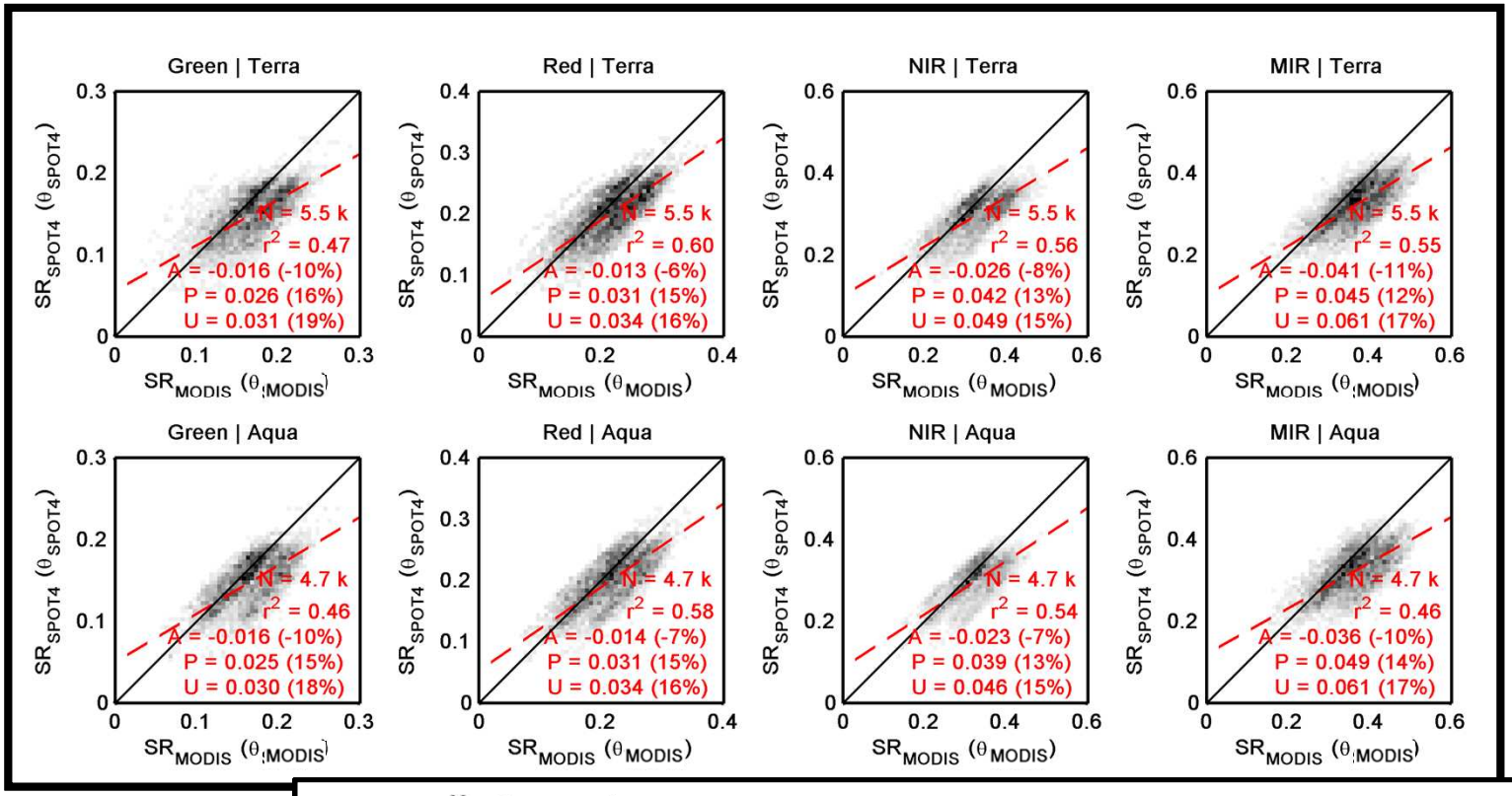
Vermote et al. (2009)

Method of the inter-comparison

- inter-comparison was conducted at the CMG resolution = VJB model resolution
- Same day comparison
- cloud-, cloud/shadow-, snow- and water-free from both products



Results – Maricopa sites – Without BRDF correction



$$A = \frac{\sum_{i=1}^{N} \left(\mu_i^e - \mu_i^t\right)}{N}$$

$$P^2 = \frac{\sum_{i=1}^{N} \left(\mu_i^e - \mu_i^t - A\right)^2}{N-1}$$

$$U^2 = \frac{\sum_{i=1}^{N} \left(\mu_i^e - \mu_i^t\right)^2}{N} = \frac{N-1}{N} P^2 + A^2$$

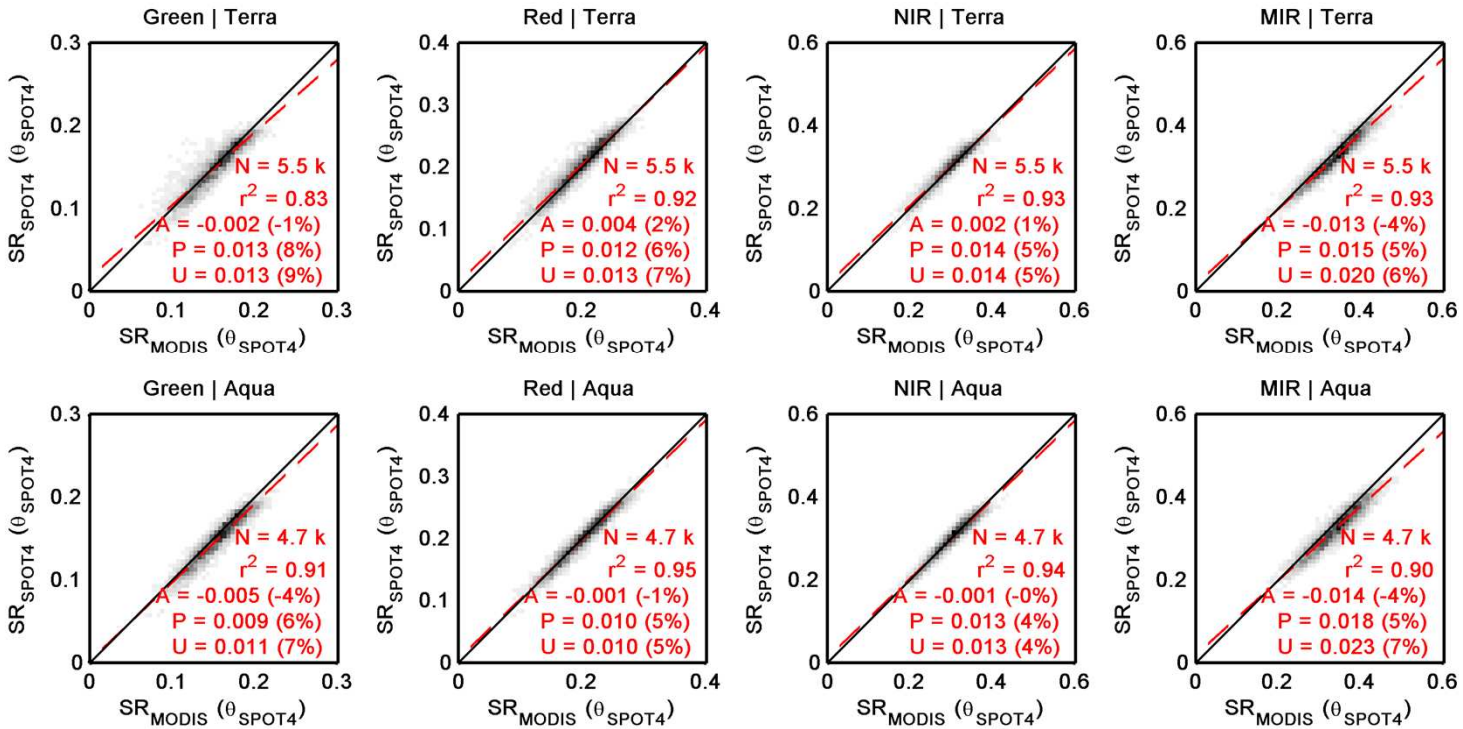
The **Accuracy** represents the mean bias of the estimates

The **Precision** represents the repeatability of the estimate

The **Uncertainty** represents the actual statistical deviation of the estimate

Vermote and Kotchenova (2008)

Results – Maricopa sites – With BRDF correction



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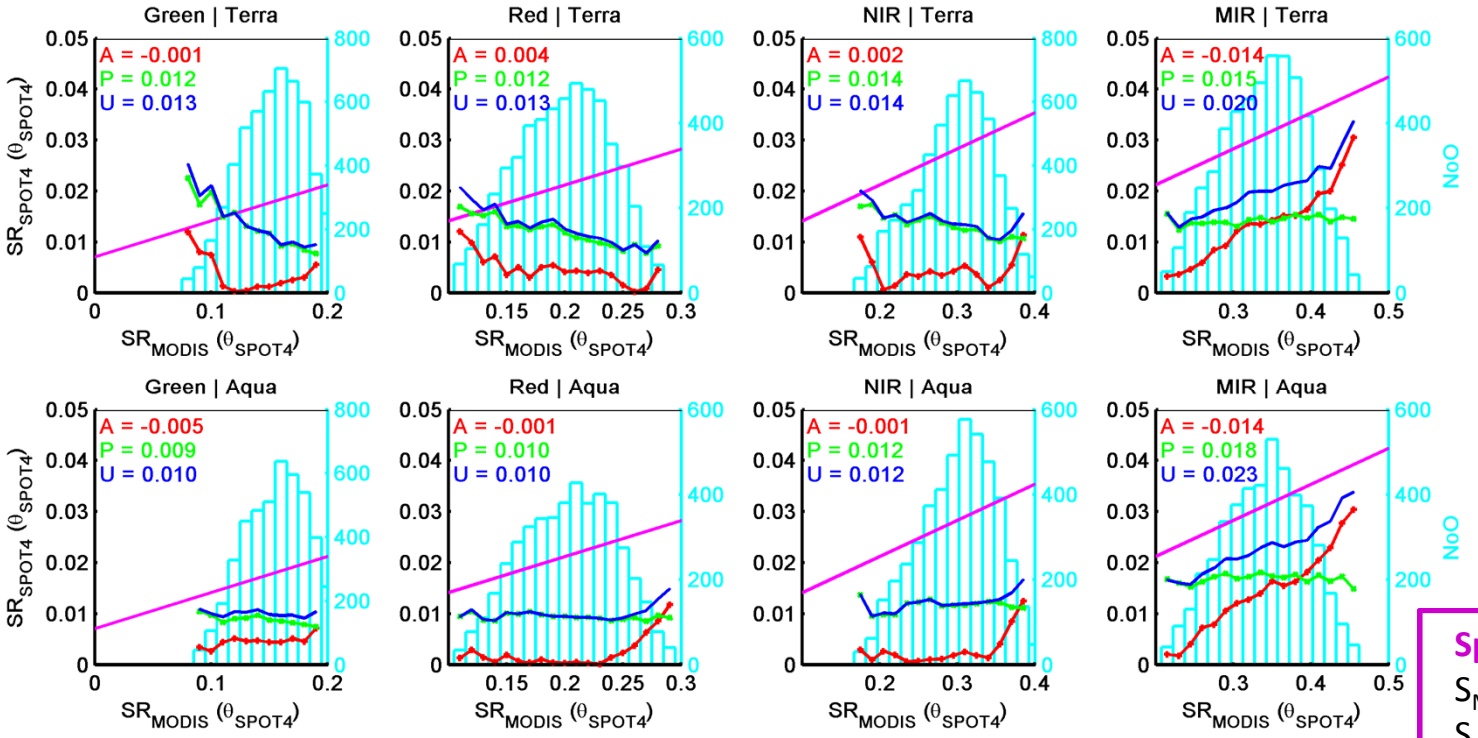

Specification MODIS:

$S_{MODIS} = 0.005 + 0.05\ \rho$

$S_{SPOT} = S_{MODIS}$

$$S = \sqrt{S^2_{MODIS} + S^2_{SPOT}}$$

$$A = \frac{\sum_{i=1}^{N} \left(\mu_i^e - \mu_i^t\right)}{N}$$

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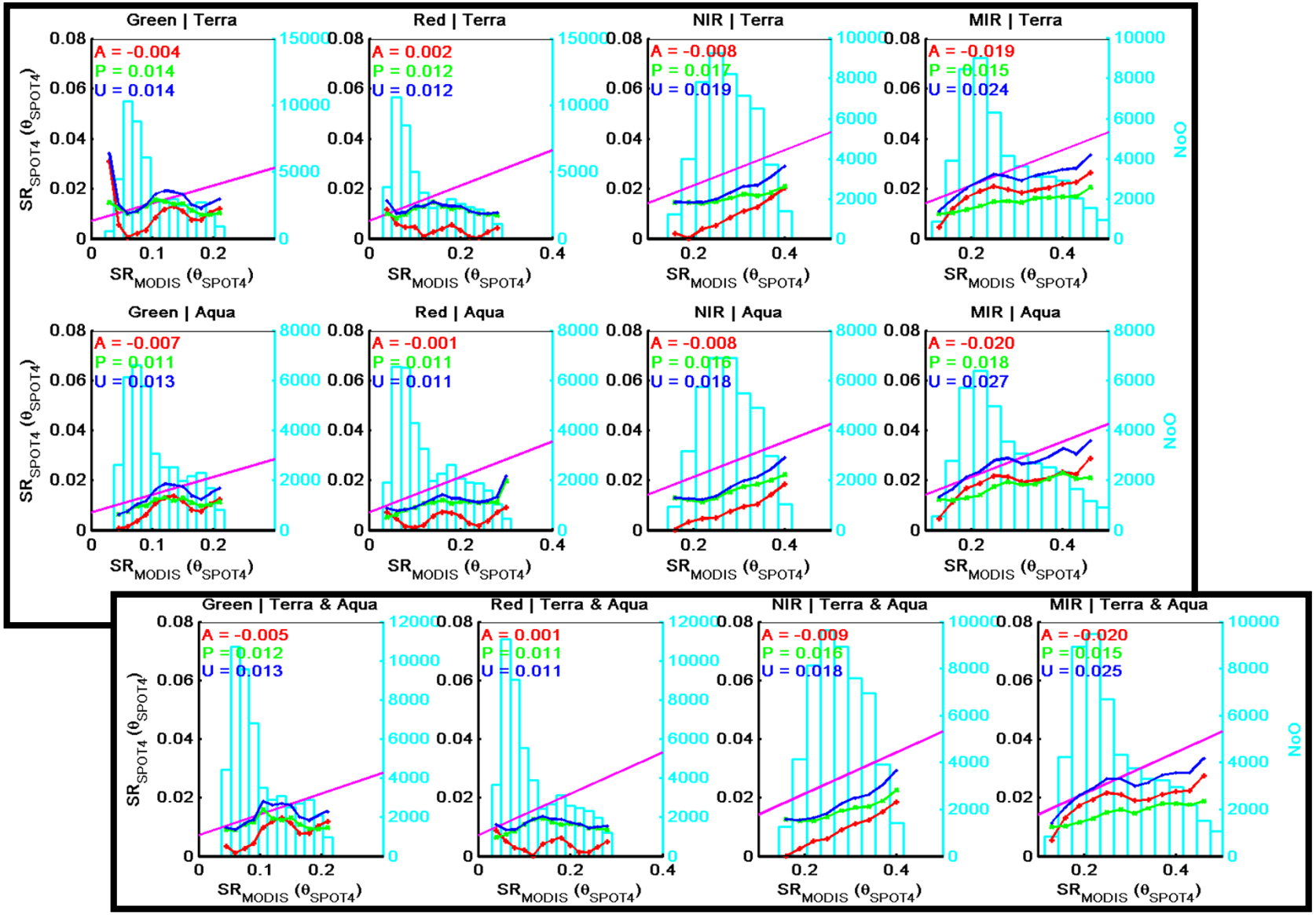
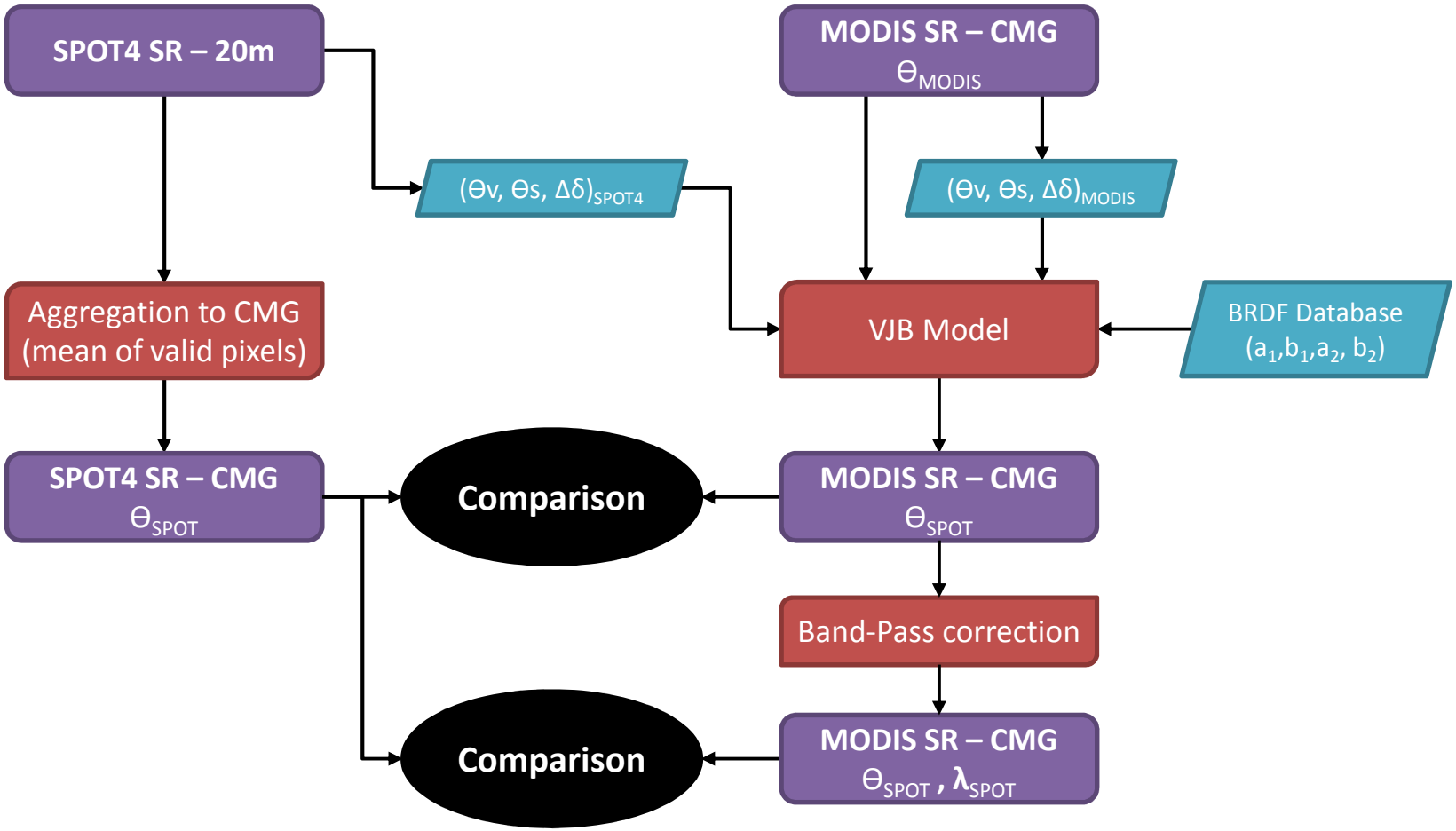
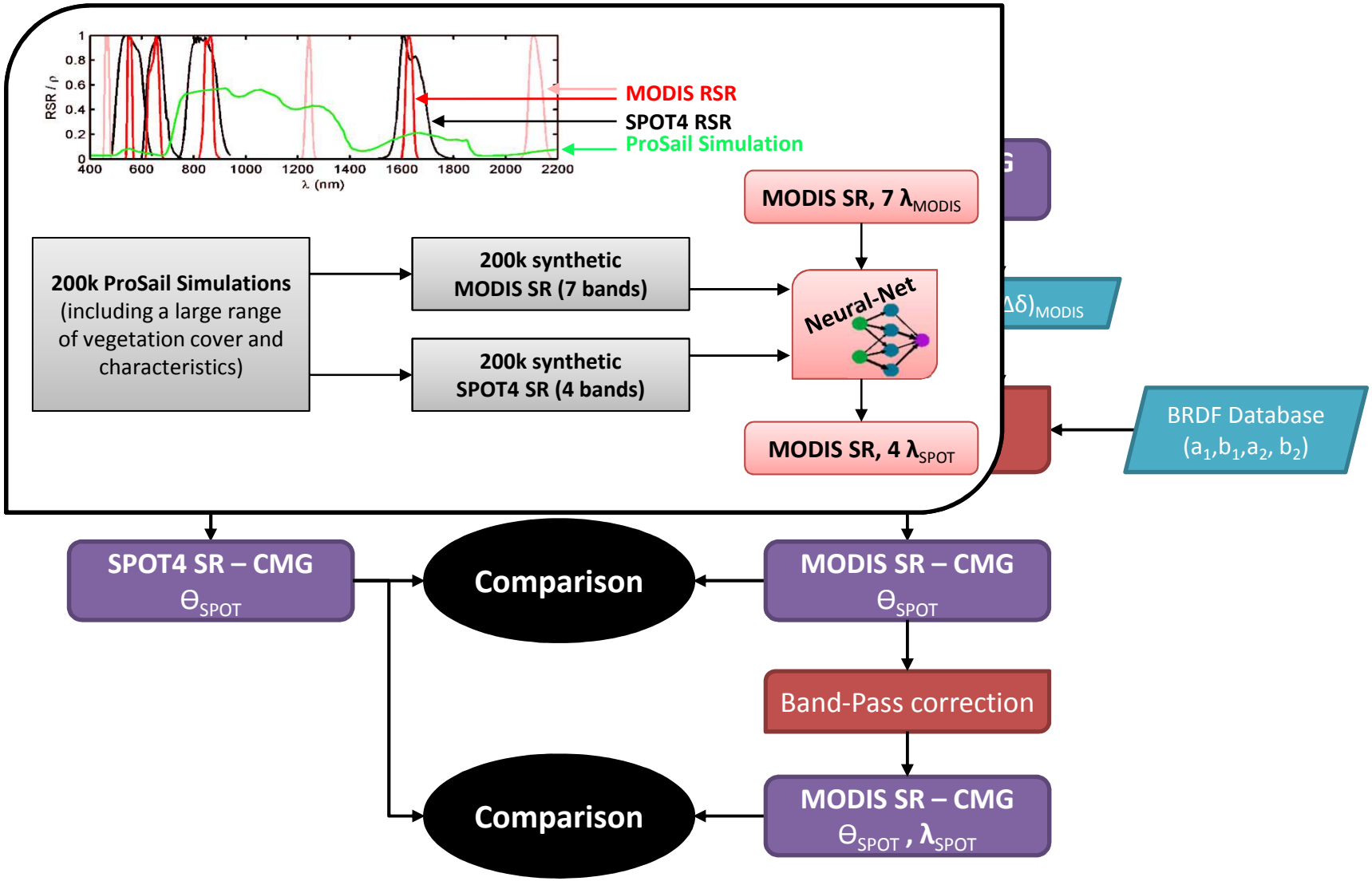
Results – All sites



Band-Pass correction

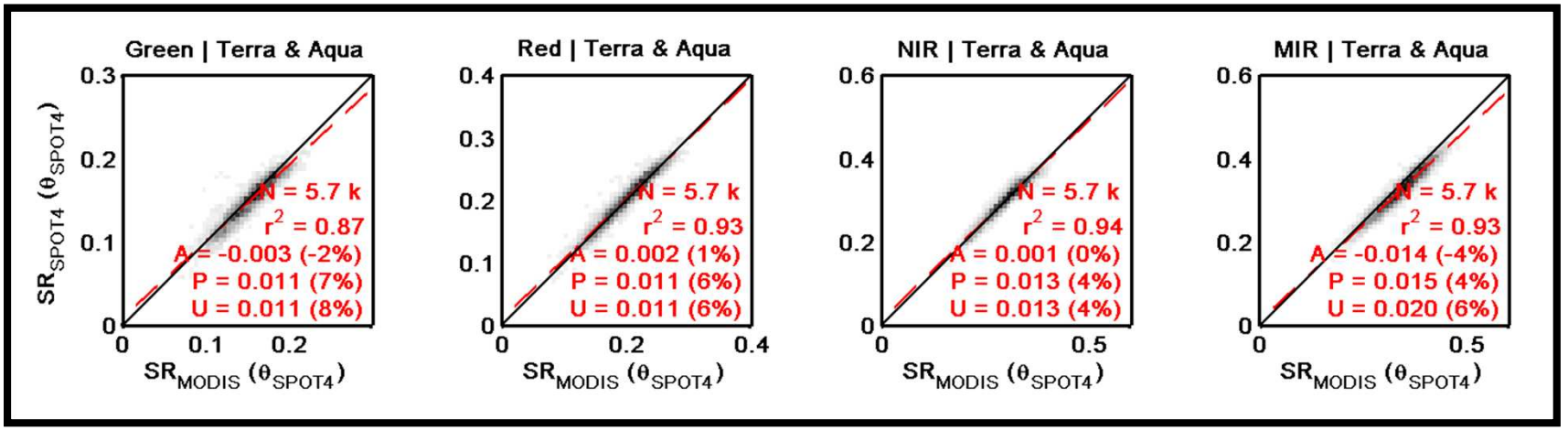


Band-Pass correction

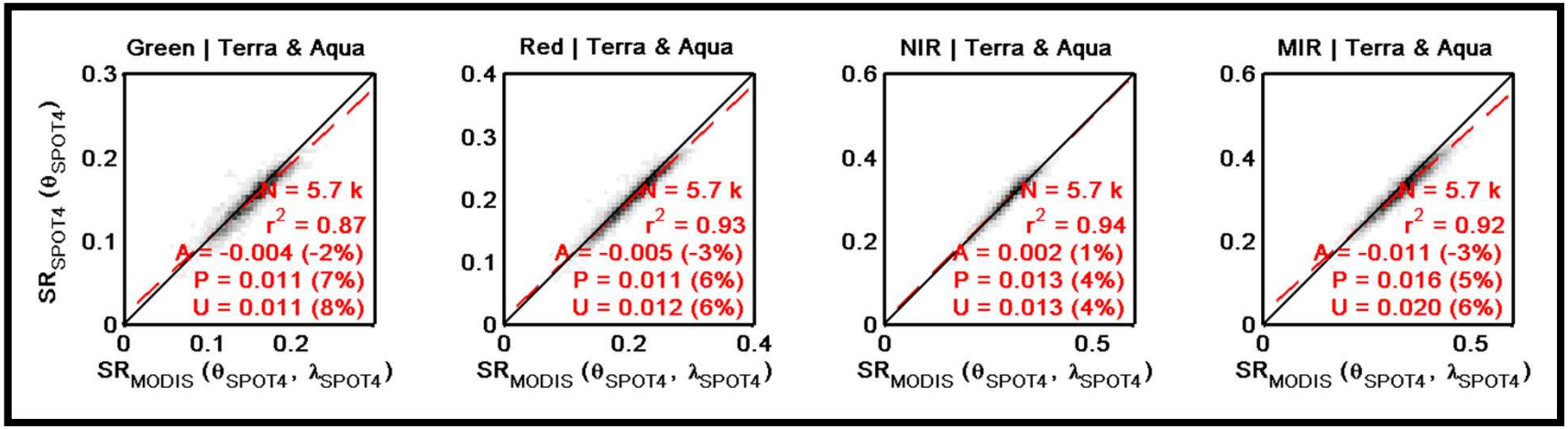


Results – All sites – With Spectral Correction

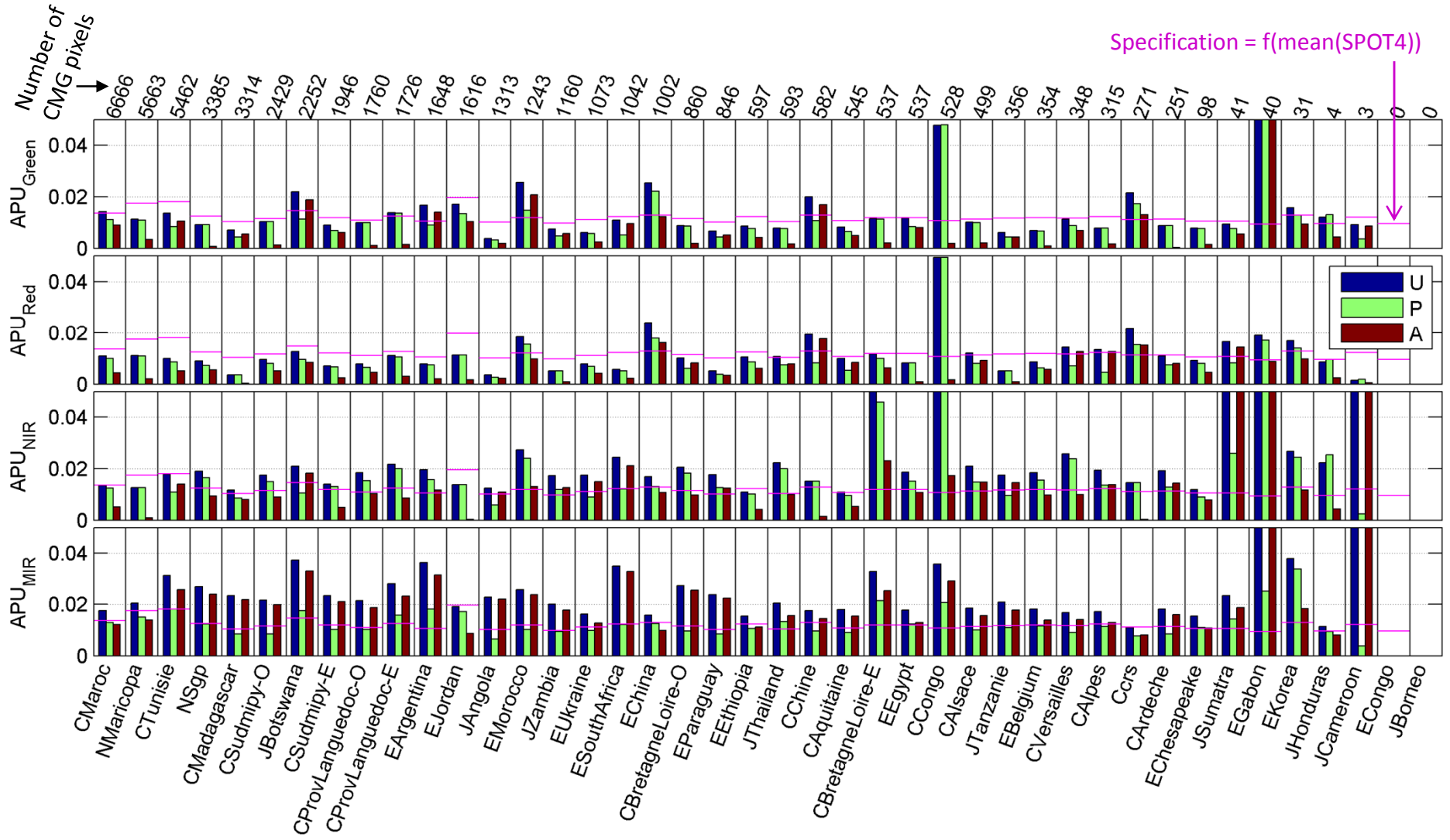
Without Spectral Correction



With Spectral Correction



Results – site by site



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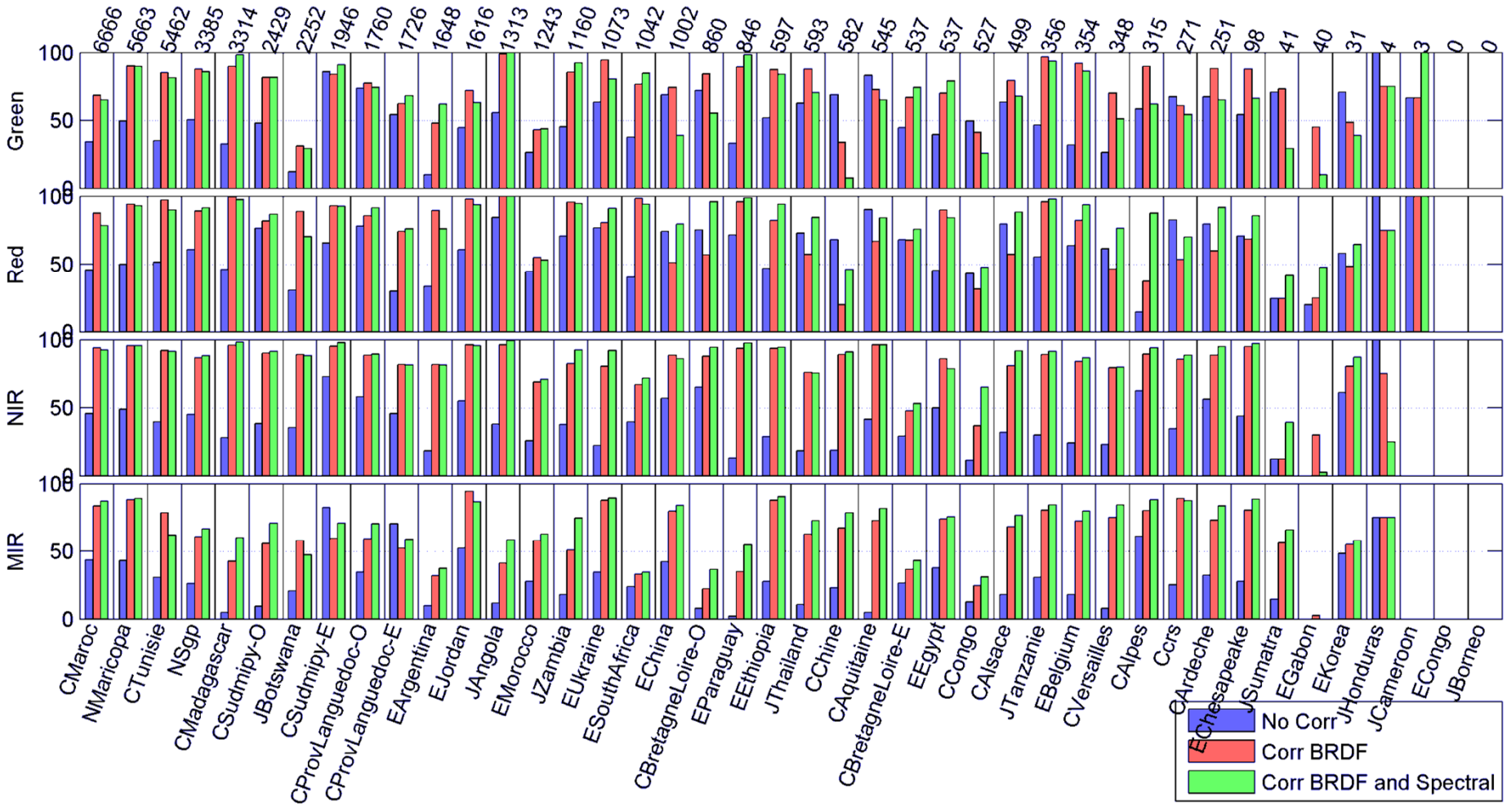
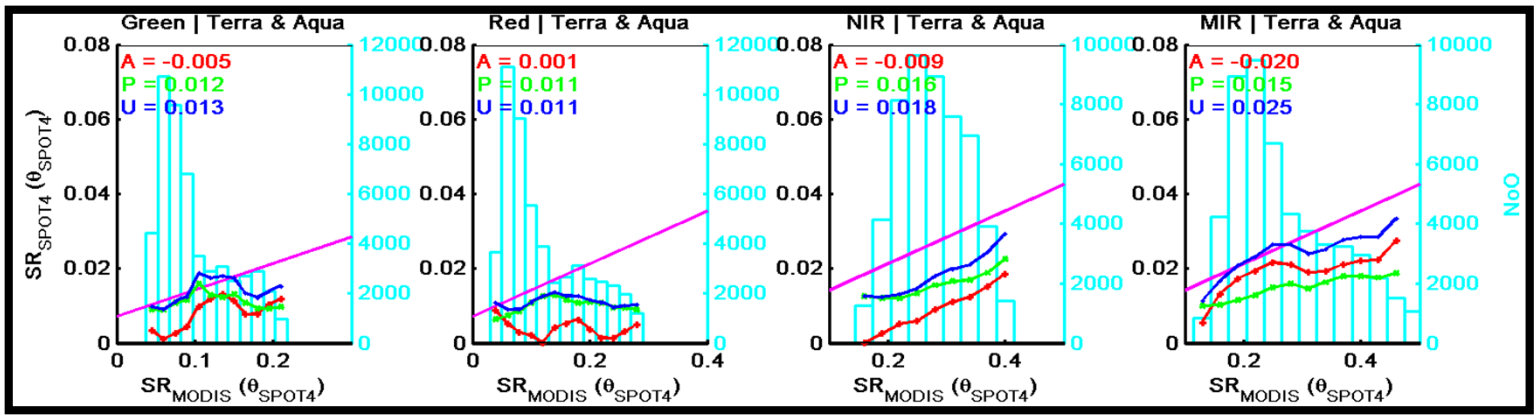
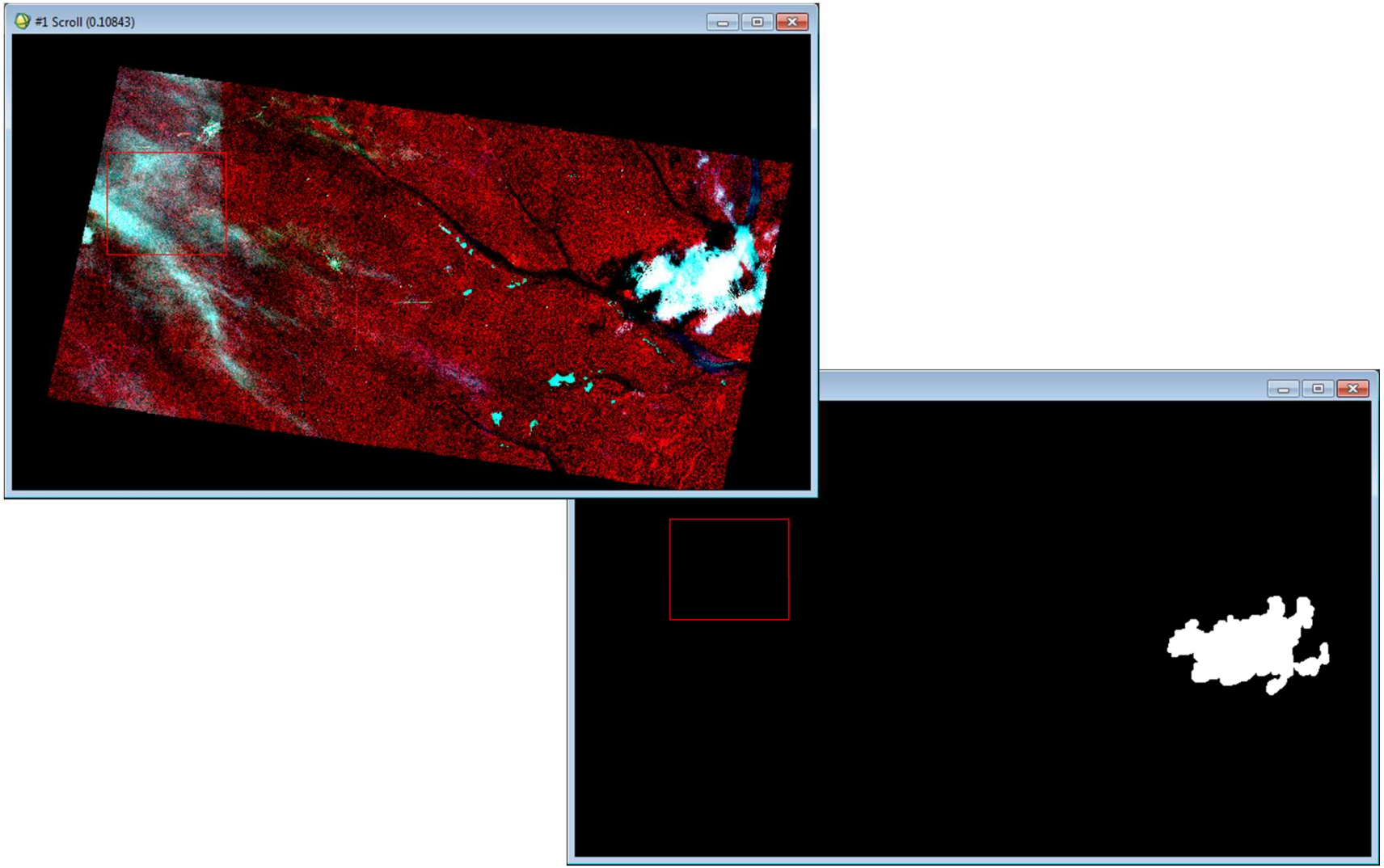


Conclusion

- We develop an operational tool to evaluate Surface Reflectance consistency
- … but also detect SR inconsistency due to Atmospheric correction issues, Cloud / Cloud-shadow / Snow / Water omission (SPOT-4 and MODIS sides)
- This is not a validation strategy but benefit of the long term MODIS validation strategy.
- MODIS / SPOT-4 Take-5 comparison displayed
  - Overall very good repeatability
  - Some biases related to mainly to not optimal bandpass correction
- SPOT-4 Take-5 site by site and scene by scene are available.



Cloud Omission exemple – Congo 03/19/2013



Results – site by site– With Spectral Correction