Sentinel 3 Science Products: A US Contribution

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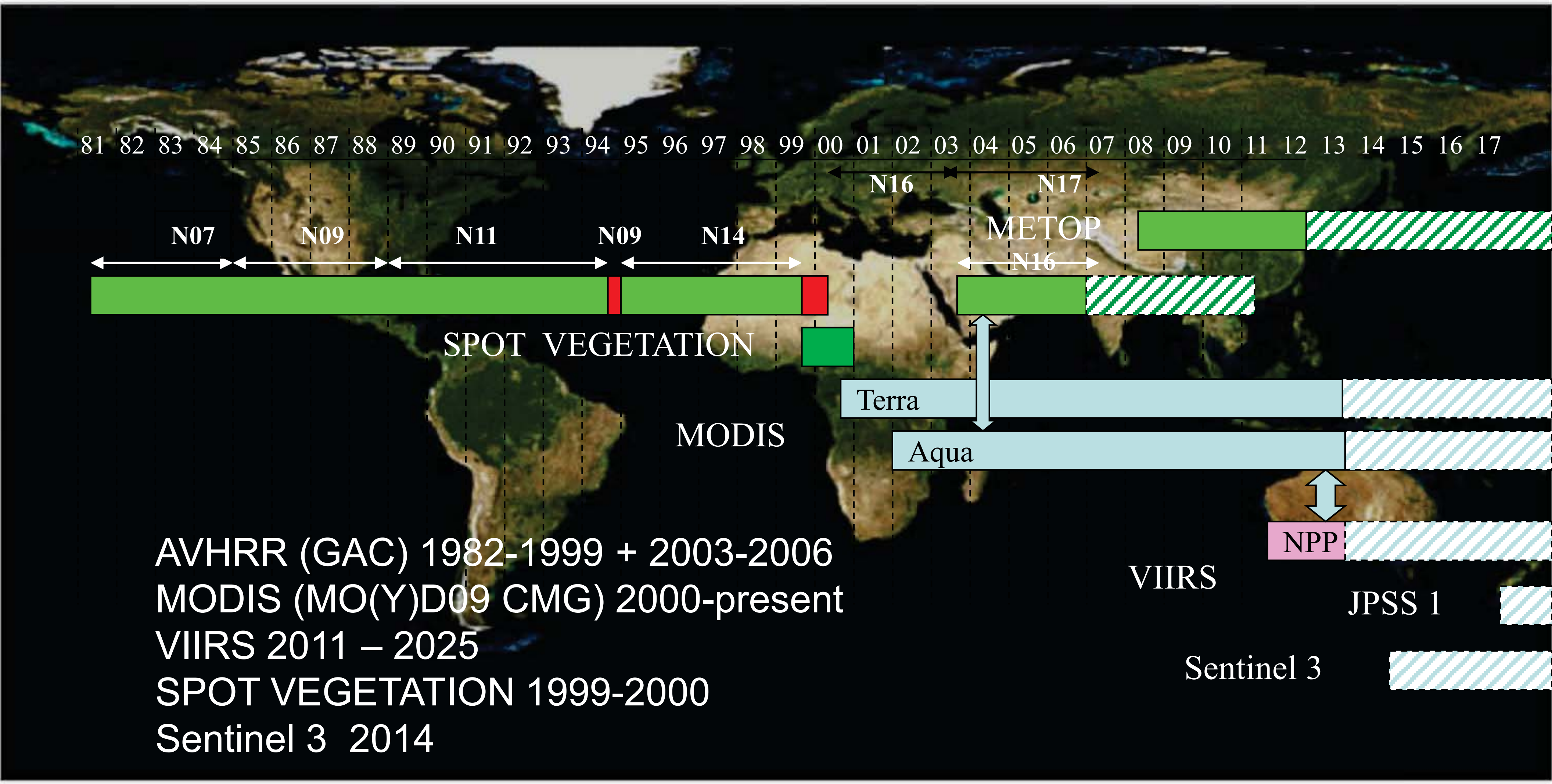
Land Product Validation and Evolution Workshop, Frascati, Italy, January 28-30, 2014

A Land Climate Data Record

Multi instrument/Multi sensor Science Quality Data Records used to quantify trends and changes



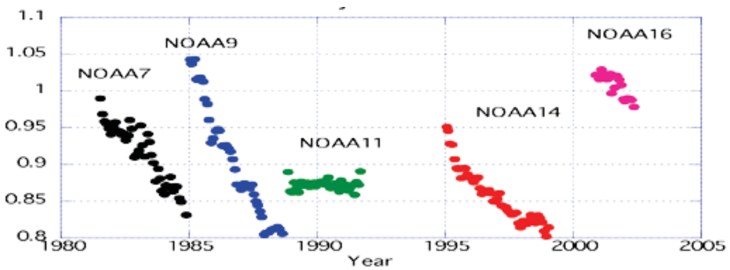
Emphasis on data consistency – characterization rather than degrading/smoothing the data

Land Climate Data Record (Approach)

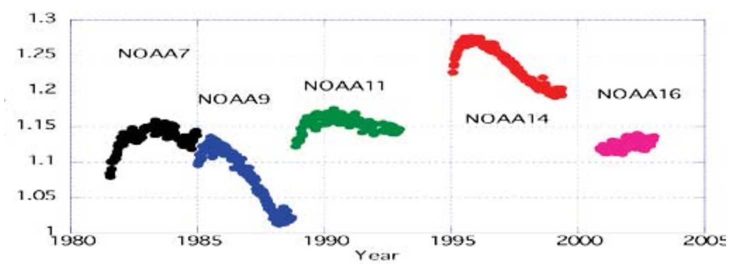
Needs to address geolocation,calibration, atmospheric/ BRDF correction issues

CALIBRATION

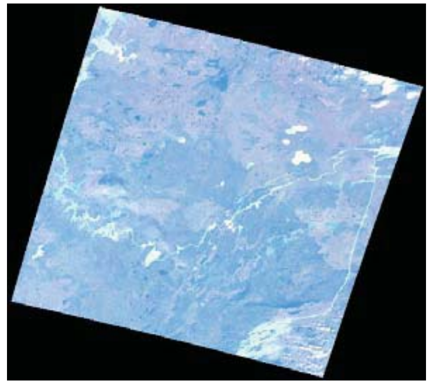
Degradation in channel 1
(from Ocean observations)

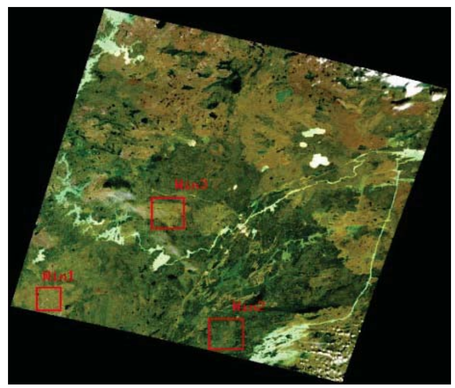


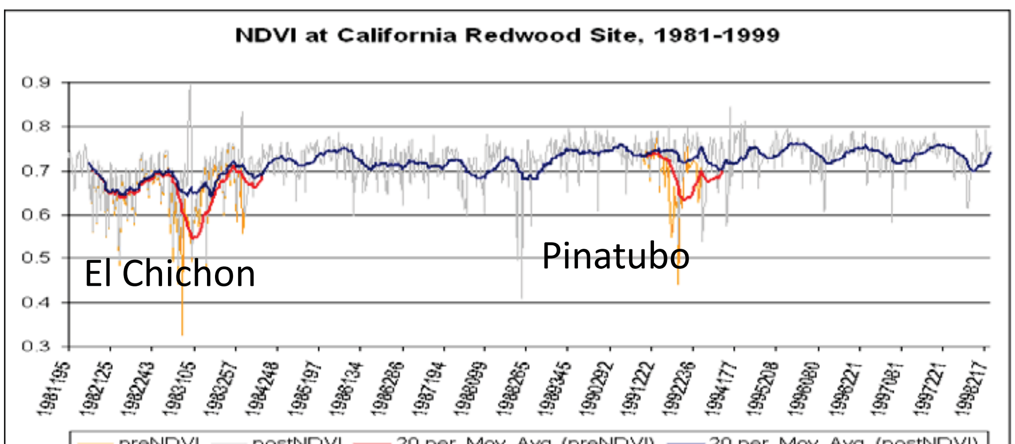
Channel1/Channel2 ratio
(from Clouds observations)



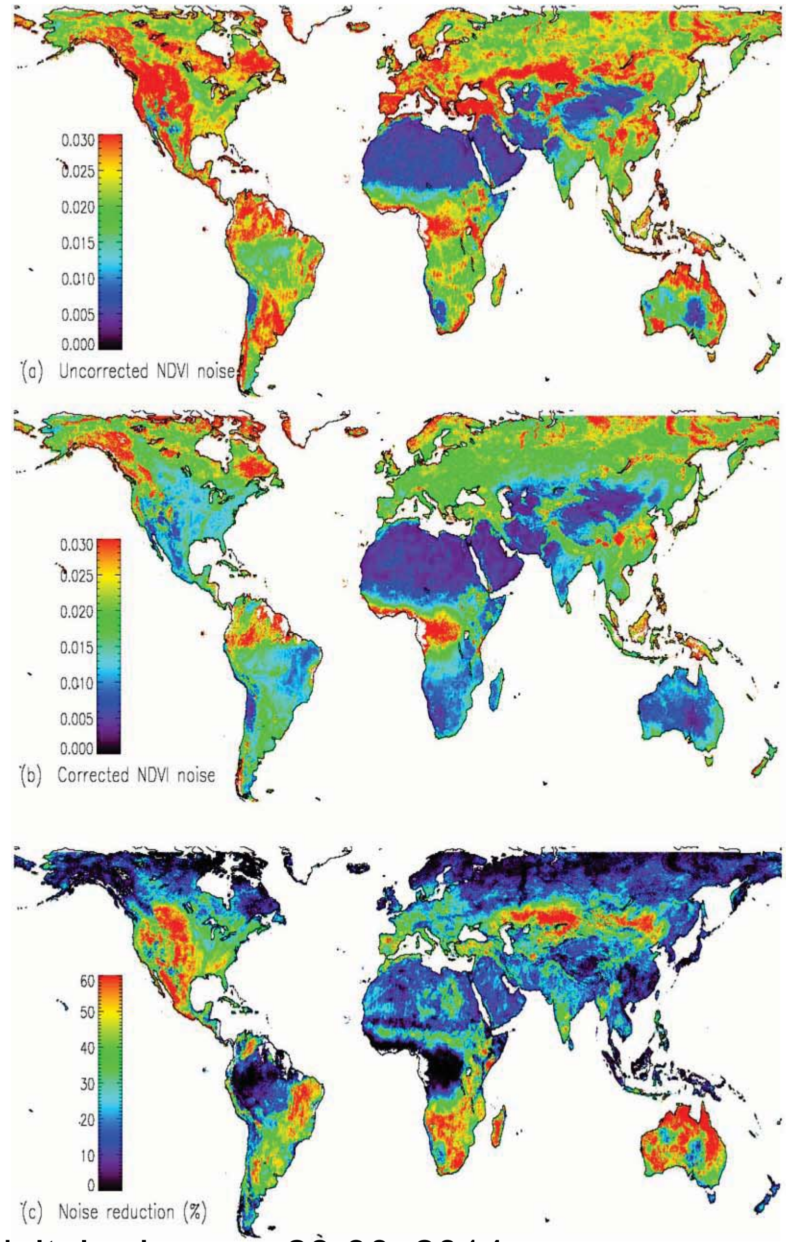
ATMOSPHERIC CORRECTION





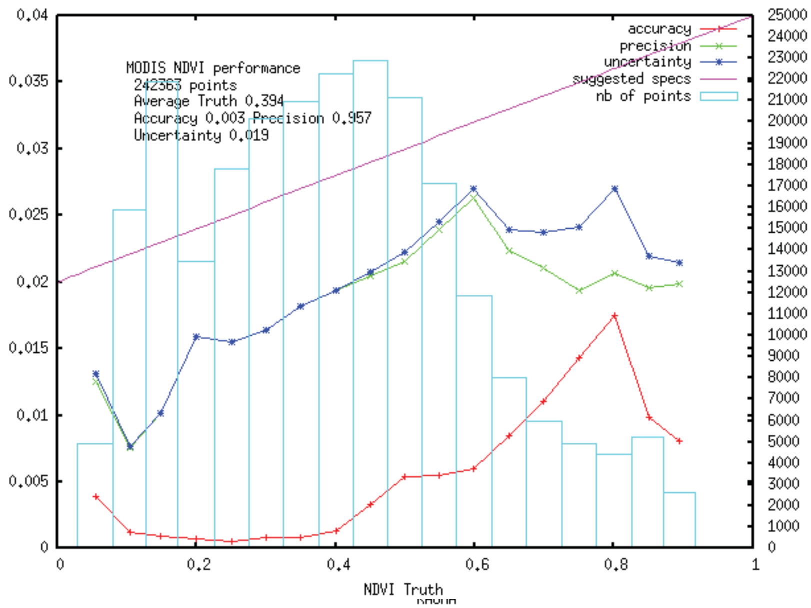


BRDF CORRECTION

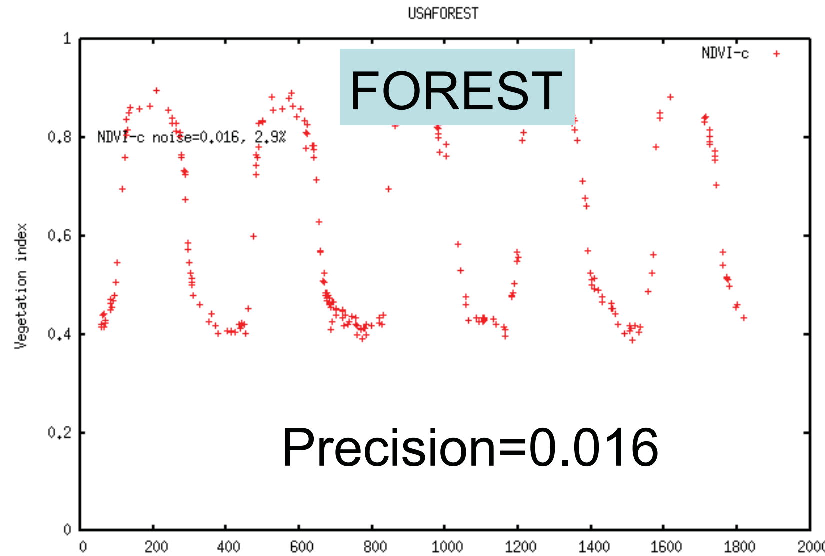


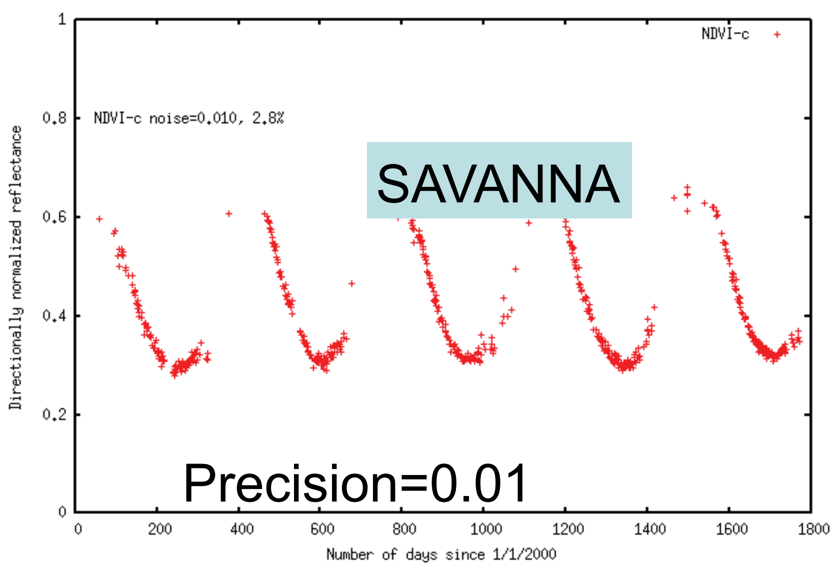
MODIS used as a reference for past and future land data record (example NDVI)

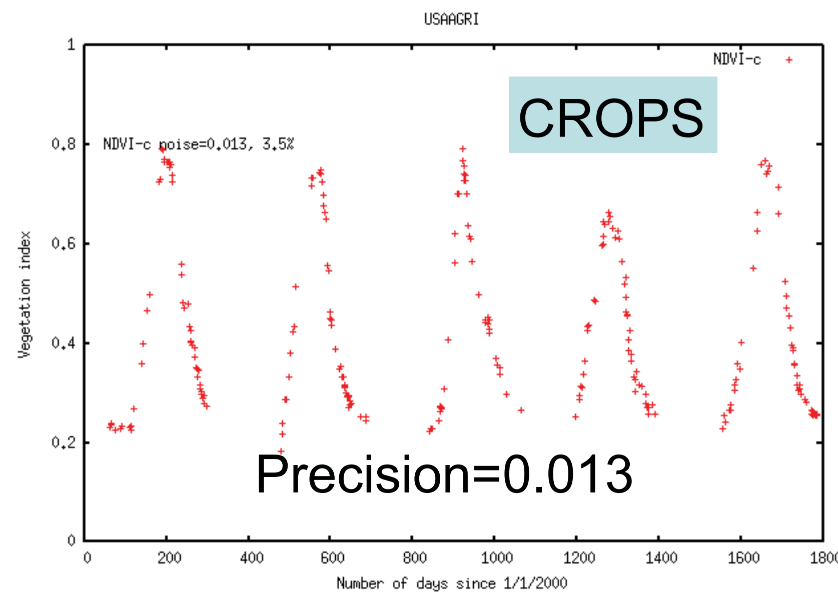
Evaluation over AERONET (2003)
0.007 <Precision < 0.017



Independent evaluation of the precision
Over 2000-2004 CMG daily time series







MODIS product and validation methodology used to evaluate other surface reflectance product: example LANDSAT TM/ETM+

- WELD (D. Roy) 120 acquisitions over 23 AERONET sites (CONUS)

  Junchang Ju, David P. Roy, Eric Vermote, Jeffrey Masek, Valeriy Kovalskyy, Continental-scale validation of MODIS-based and LEDAPS Landsat ETM+ atmospheric correction methods, **Remote Sensing of Environment** (2012), Available online 10 February 2012, ISSN 0034-4257, 10.1016/j.rse.2011.12.025.

- GFCC: Comparison with MODIS SR products
  - GLS 2000 demonstration

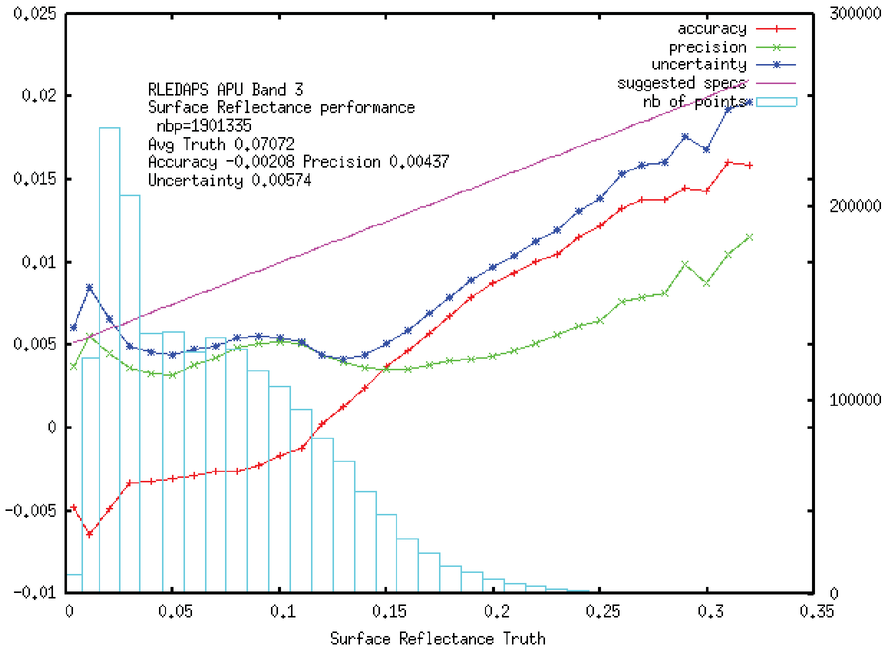
    Min Feng, Chengquan Huang, Saurabh Channan, Eric F. Vermote, Jeffrey G. Masek, John R. Townshend, Quality assessment of Landsat surface reflectance products using MODIS data, **Computers & Geosciences**, Volume 38, Issue 1, January 2012, Pages 9-22, ISSN 0098-3004, 10.1016.

  - GLS 2005 (TM and ETM+)

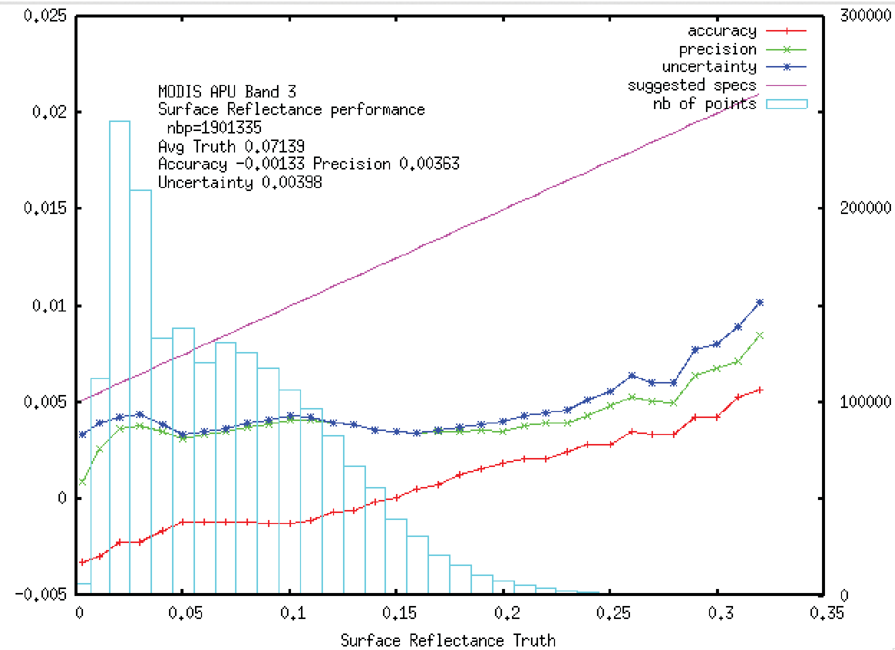
    Min Feng Joseph O. Sexton, Chengquan Huang, Jeffrey G. Masek, Eric F. Vermote, Feng Gao, Raghuram Narasimhan, Saurabh Channan, Robert E. Wolfe, John R. Townshend ,Global, long-term surface reflectance records from Landsat: a comparison of the Global Land Survey and MODIS surface reflectance datasets. **Remote Sensing of the Environment (in review)**

WELD/LEDAPS results (Red-band3)

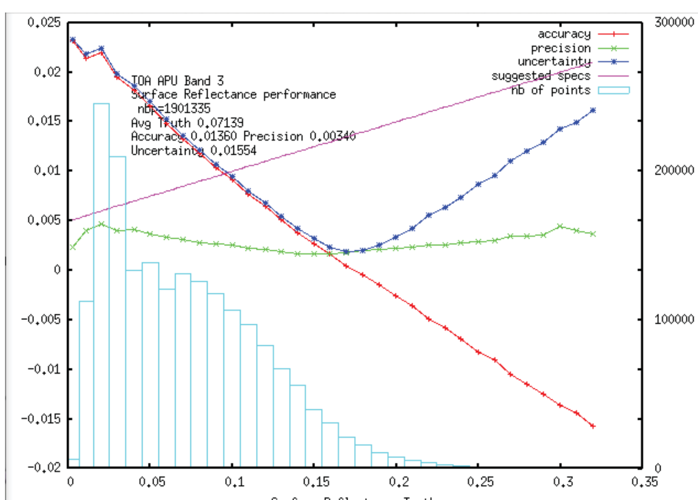
LEDAPS



WELD uses MODIS aerosol

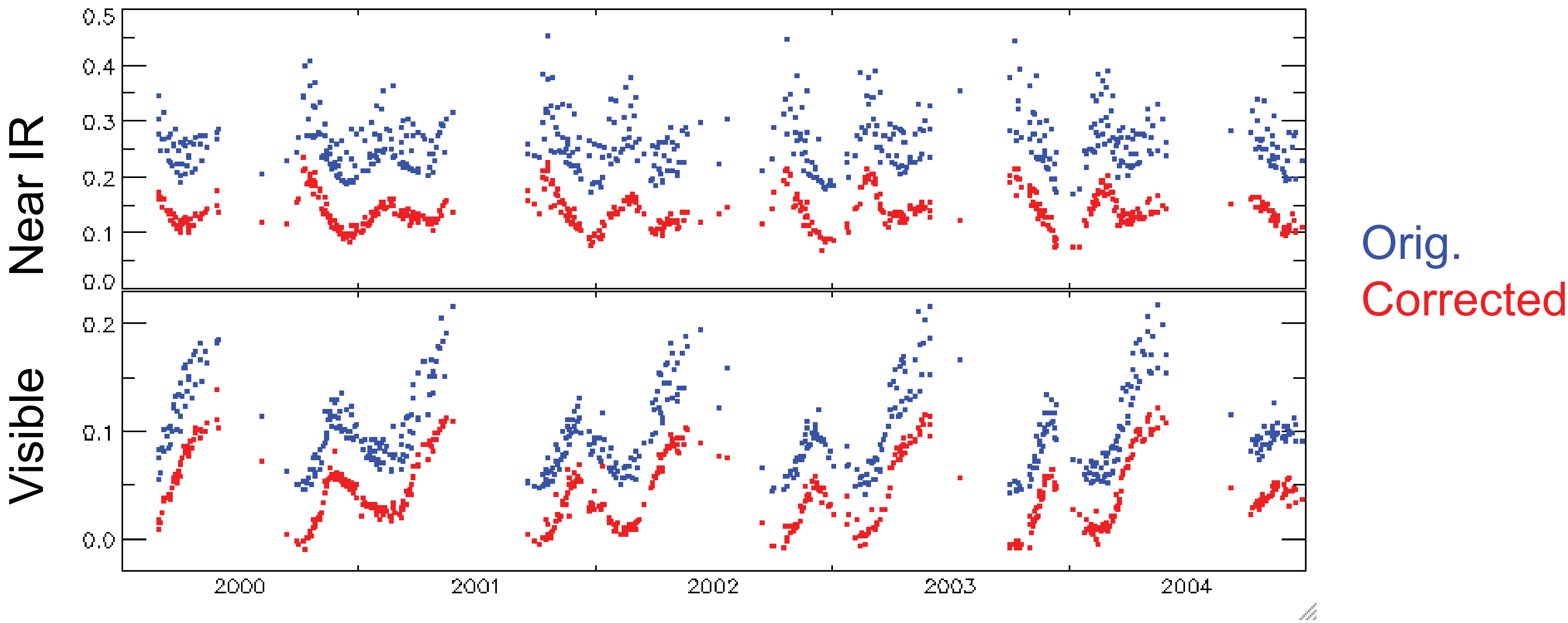


Top of the atmosphere



MODIS Reflectance time series

- Reflectance time series show high-frequency variability
- The “noise” is partly due to directional effects.
- Selection of specific geometries decreases temporal coverage
- Can we correct for the directional effect and retain the original temporal resolution ?



François-Marie Bréon, LSCE

Analytical model and correction

Linear models :

$$\rho\ (\theta_s, \theta_v, \phi) = k_0 + k_1\ F_1(\theta_s, \theta_v, \phi) + k_2\ F_2(\theta_s, \theta_v, \phi)$$

Several choices for F_1 and F_2

F_1: Model surface effects (soil roughness)

F_2: Model volume effects (R.T. within canopy)

$$\rho\ (\theta_s, \theta_v, \phi) = k_0(t)\ [\ 1 + k_1/k_0\ F_1(\theta_s, \theta_v, \phi) + k_2/k_0\ F_2(\theta_s, \theta_v, \phi)\ ]$$

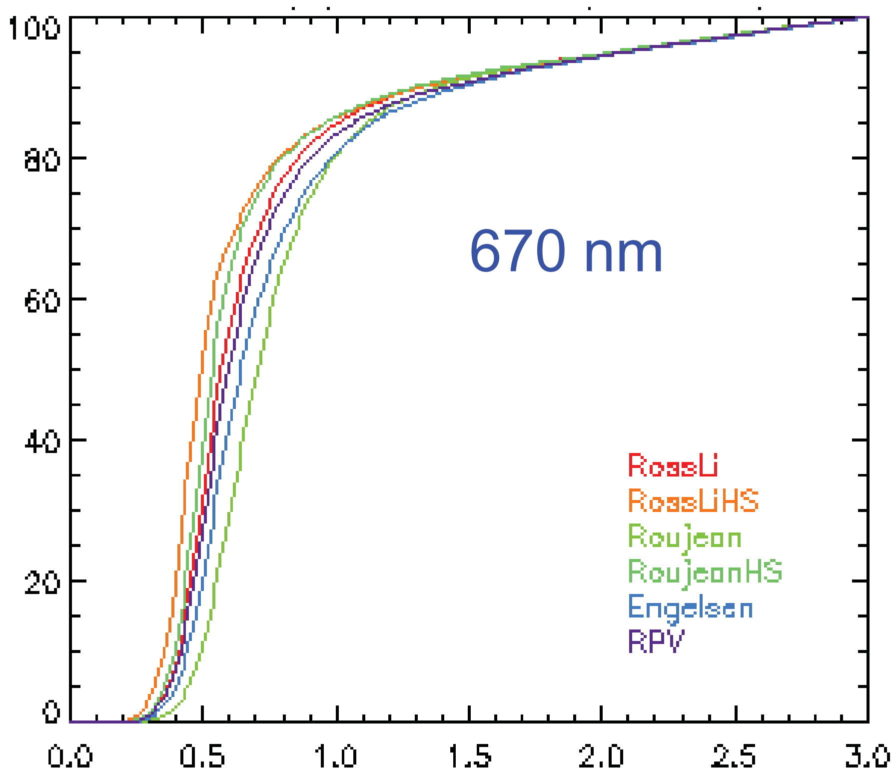
$$= k_0(t)\ [\ 1 + R\ F_1(\theta_s, \theta_v, \phi) + V\ F_2(\theta_s, \theta_v, \phi)\ ]$$

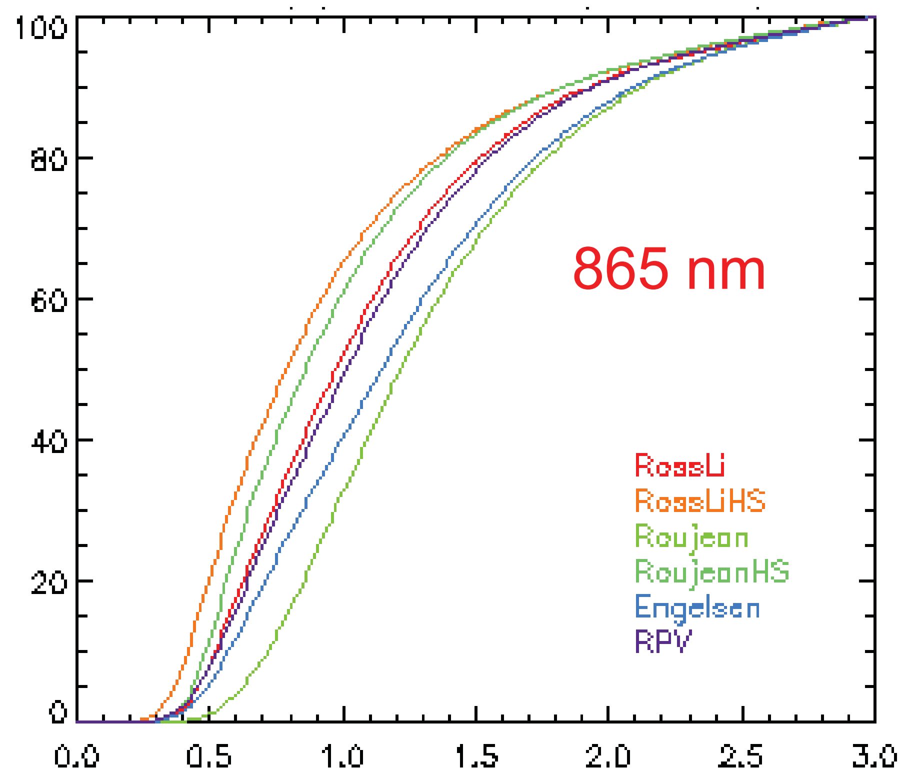
Correction:

$$\rho^{cor} = \rho(\theta_s, \theta_v, \phi)\ [\ 1 + R\ F_1(45,0,0) + V\ F_2(45,0,0)\ ]\ /\ [\ 1 + R\ F_1(\theta_s, \theta_v, \phi) + V\ F_2(\theta_s, \theta_v, \phi)\ ]$$

Maignan et al., Rem. Sens. Env., 2004

Which is the “best” model ?





Cumulative histogram of reflectance [%] error of fit.

- Look for the parameters for a best fit (invert the model)
- Compute error of fit
- Among the 6 tested models, RossLiHS allows the best fit
- Clear improvement when using Hot Spot correction

Maignan et al., Rem. Sens. Env., 2004

BRDF model inversion

$$R = \alpha_R + \lambda_R \, n_i$$

$$\Delta\rho_i = \frac{\rho_{i+1} - \rho_i}{\sqrt{t_{i+1} - t_i}}$$

$$\Delta F_1^i = \frac{\Delta F_1^{i+1} \, \rho_i - \Delta F_1^i \, \rho_{i+1}}{\sqrt{t_{i+1} - t_i}}$$

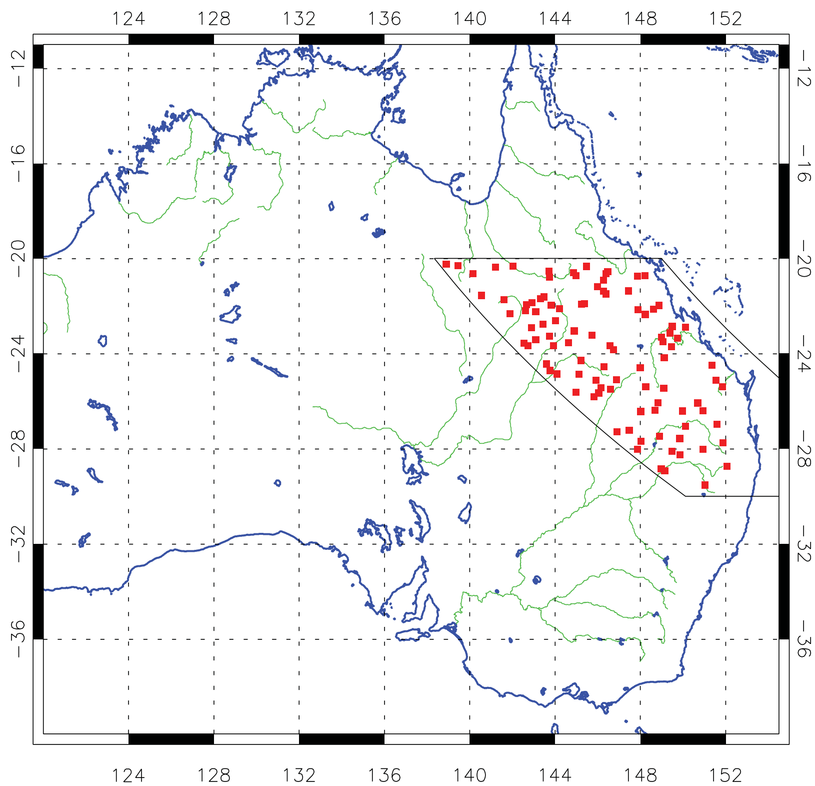
$$\Delta F_2^i = \frac{\Delta F_2^{i+1} \, \rho_i - \Delta F_2^i \, \rho_{i+1}}{\sqrt{t_{i+1} - t_i}}$$

- R and V are linear function of the NDVI
- We look at the difference between successive measurements
- Notations used here for an easy inversion of the model parameters

- Matrix writing:

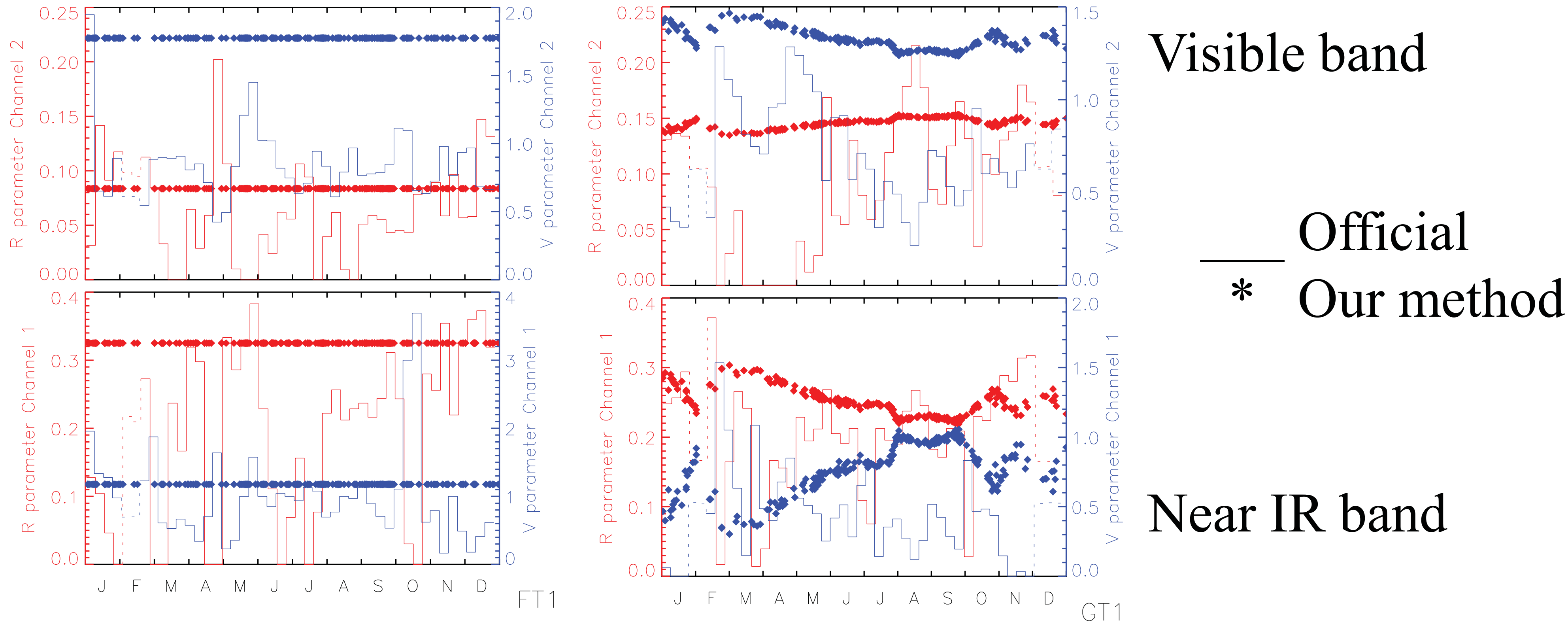
$$\begin{bmatrix} \sum (\Delta F_1^i)^2 & \sum n_i (\Delta F_1^i)^2 & \sum \Delta F_1^i \, \Delta F_2^i & \sum n_i \, \Delta F_1^i \, \Delta F_2^i \\ \sum n_i (\Delta F_1^i)^2 & \sum (n_i \, \Delta F_1^i)^2 & \sum n_i \, \Delta F_1^i \, \Delta F_2^i & \sum n_i^2 \, \Delta F_1^i \, \Delta F_2^i \\ \sum \Delta F_1^i \, \Delta F_2^i & \sum n_i \, \Delta F_1^i \, \Delta F_2^i & \sum (\Delta F_2^i)^2 & \sum n_i (\Delta F_2^i)^2 \\ \sum n_i \, \Delta F_1^i \, \Delta F_2^i & \sum n_i^2 \, \Delta F_1^i \, \Delta F_2^i & \sum n_i (\Delta F_2^i)^2 & \sum (n_i \, \Delta F_2^i)^2 \end{bmatrix} \begin{bmatrix} \alpha_V \\ \lambda_V \\ \alpha_R \\ \lambda_R \end{bmatrix} = \begin{bmatrix} \sum \Delta\rho_i \, \Delta F_1^i \\ \sum n_i \, \Delta\rho_i \, \Delta F_1^i \\ \sum \Delta\rho_i \, \Delta F_2^i \\ \sum n_i \, \Delta\rho_i \, \Delta F_2^i \end{bmatrix}$$

Data location



- MODIS data are distributed as “tiles” (10° of lat.)
- To limit data volume, we focus on a single tile
- Select a tile over Eastern Australia for (i) variety of surface cover, (ii) number of clear observations, (iii) low aerosol load

BRDF parameters: R and V



- Analyzed the BRDF parameters distributed in the official MODIS products
- Parameters show very unrealistic temporal variations.
- Our method shows more realistic results

Quantification of time series noise

- For each triplet of observations, one can estimate middle one from the earlier and later:

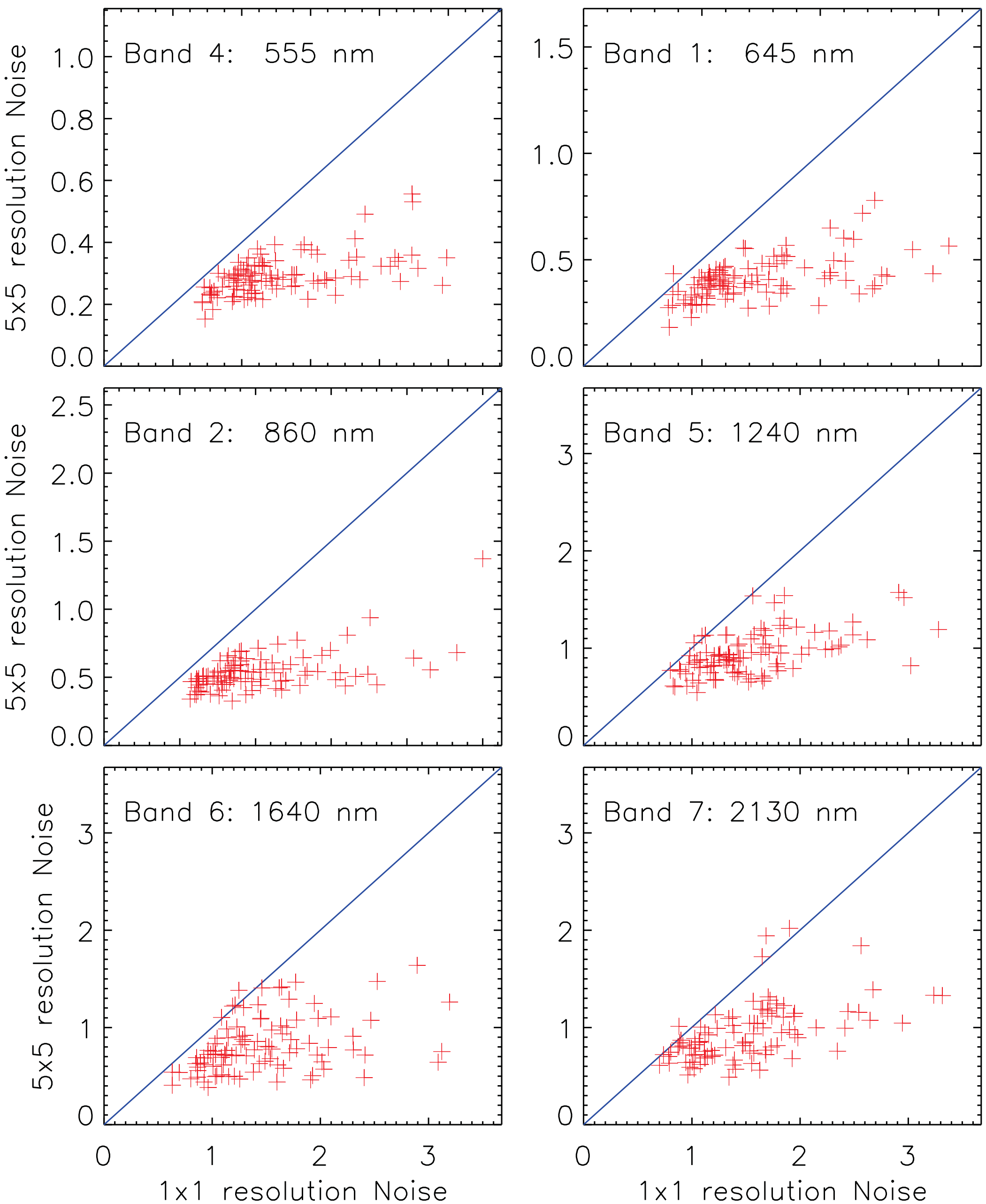
$$\rho_i^* = \frac{(t_i - t_{i-1})\rho_{i+1} + (t_{i+1} - t_i)\rho_{i-1}}{t_{i+1} - t_{i-1}}$$

One can then compute a "noise" from the quadratic sum of the difference between the measurement and their interpolated counterpart:

$$\sigma^2(\rho) = \frac{\sum_{i=2}^{N-1} \frac{1}{t_{i+1} - t_{i-1}} (\rho_i^* - \rho_i)^2}{\sum_{i=2}^{N-1} \frac{1}{t_{i+1} - t_{i-1}}}$$

We use this definition in the following to quantify the time series quality

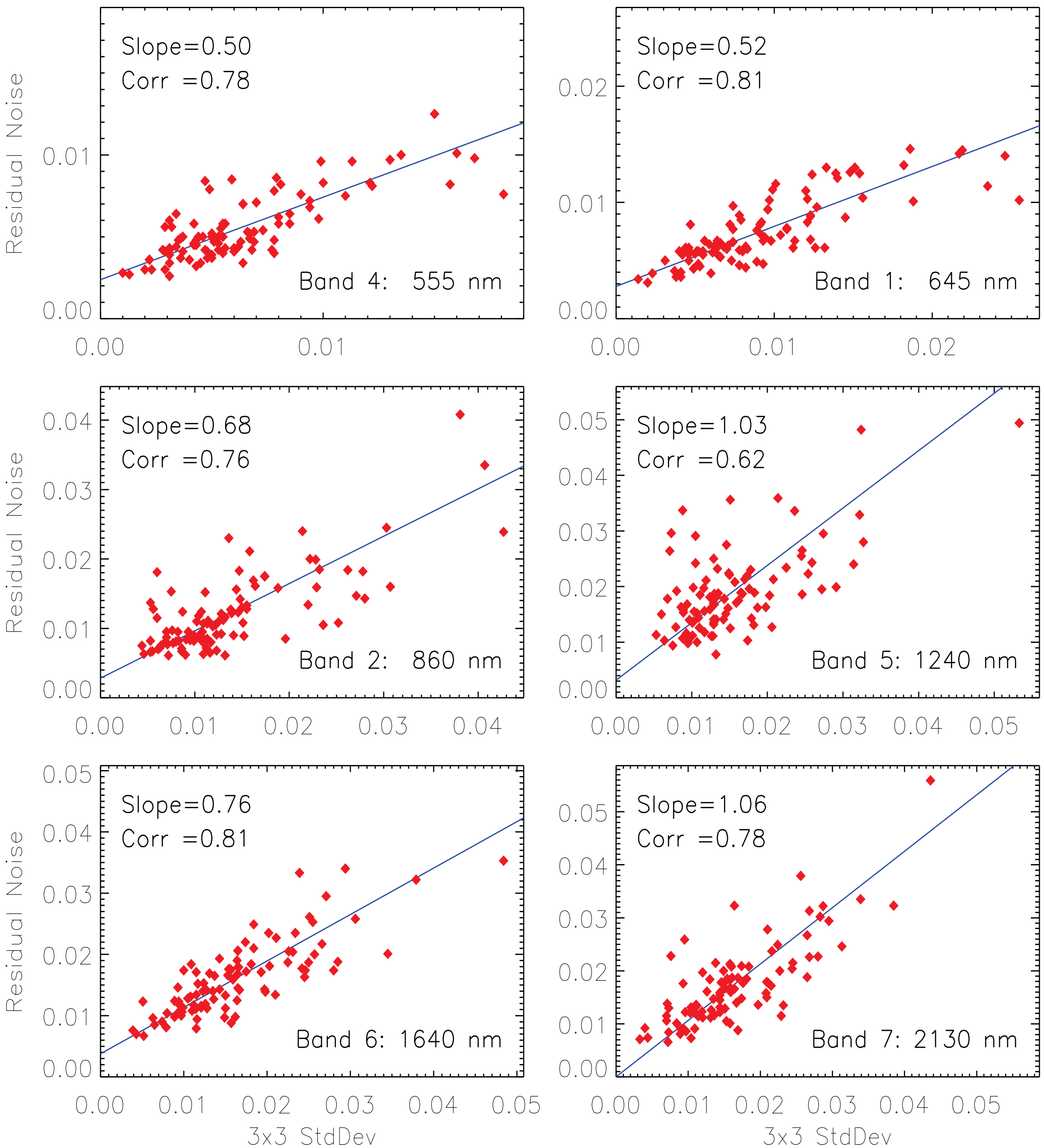
Impact of spatial scale



- The noise of the corrected time series is much larger than that we obtained earlier using CMG (Climate Modeling Grid : 5 km) lower resolution data.

- We show here a comparison of the noise obtained at the full resolution against that obtained when aggregating 5x5 pixels.

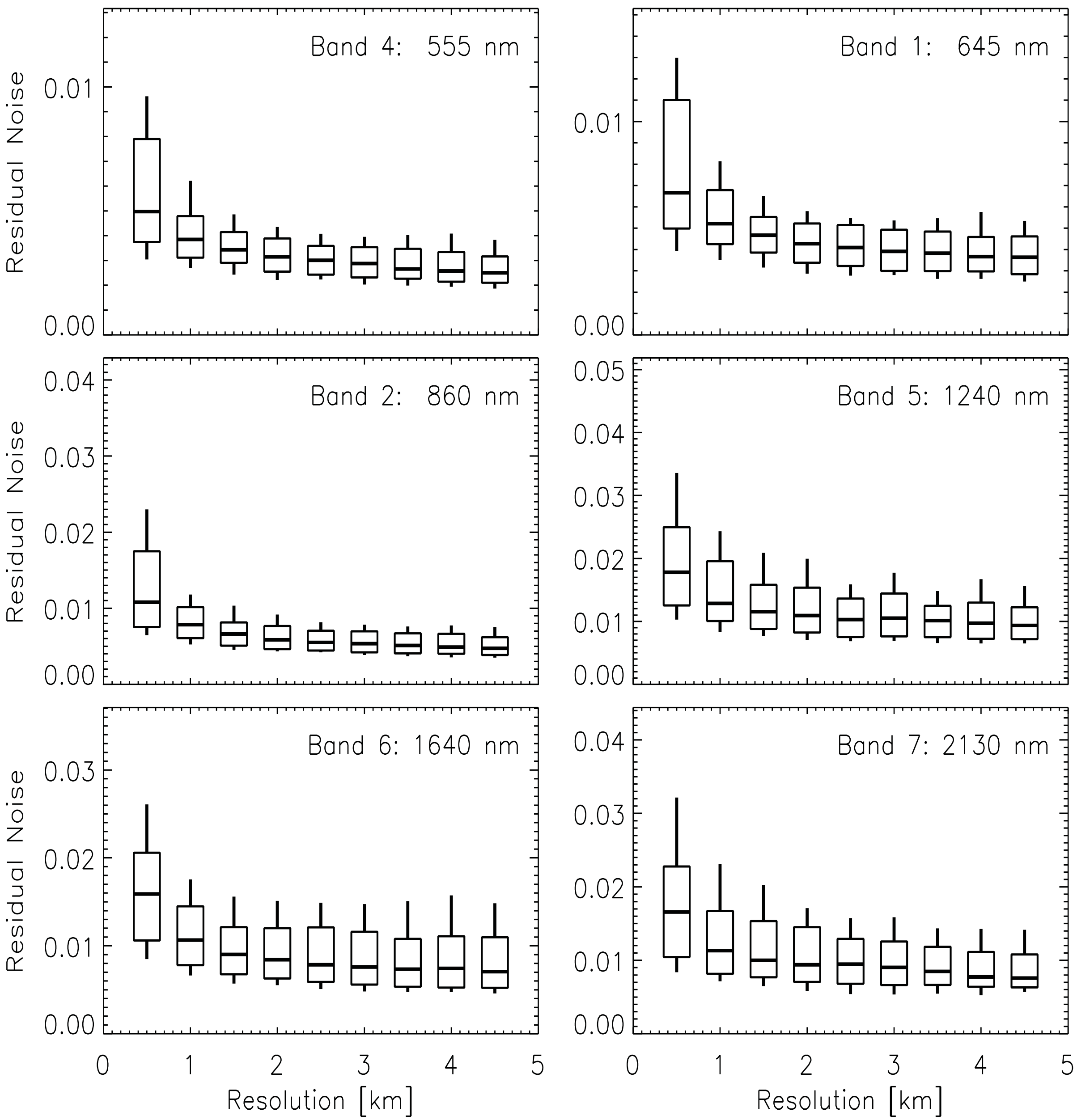
Noise vs Spatial heterogeneity



- There is a very strong correlation between the spatial heterogeneity (quantified here as the 3x3 standard deviation) and the noise on the corrected time series.

- Clearly, the spatial heterogeneity affects the quality of the time series and there is an easy explanation for that

Impact of spatial scale



- The "noise" of the time series decreases when the spatial aggregation increases. There seems to be an optimal scale at 2 km (4x4 pixels)

Conclusions (1/2)

- Directional effects on the Earth reflectances are large (factor of 2 to 4 depending on wavelength)
- There are simple analytical models (3 parameters) that reproduce accurately the observed signatures
- The reflectance is modelled as the product of a normalized reflectance, that may vary rapidly, and a BRDF model (2 parameters) that varies more slowly.
- The two model parameters can be parameterized as a linear function of the NDVI.
- We have developed a method to estimate easily these parameters from the reflectance time series
- Corrected time series are much smoother than their original counterpart, and can be used to extract fine signal

Conclusions (2/2)

- The official MODIS BRDF parameters are unreliable
- The time series at the full (500 m) resolution appear noisier than at lower resolution
- Spatial heterogeneity of the reflectance is the driving factor for this additional noise
- We suggest an optimal resolution of 2 km for the use of MODIS data time series

Use of BRDF correction for product cross-comparison

Comparison of aggregated FORMOSAT-2 reflectance and MODIS reflectance. No BRDF correction. Density function from light grey (minimum) to black (maximum); white = no data.

Comparison of aggregated FORMOSAT-2 reflectance and BRDF corrected MODIS reflectance. Corrections were performed with Vermote al. (2009) method using for each day of acquisition, the angular configuration of FORMOSAT-2 data.

Cross-Calibration of NOAA 16 AVHRR

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Calibration of NOAA16 AVHRR over a desert site using MODIS data

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Abstract

This paper presents a new approach to AVHRR-sensors cross-calibration in the visible to shortwave-infrared spectral domain using an a-priori, well calibrated sensor (MODIS). The approach has been tested over a stable Sahara desert site and was initially applied to compare the absolute calibration coefficients of three different bands of the Terra and Aqua MODIS instruments. The observed agreement was better than 1% for bands 1 (0.67 μm), 2 (0.87 μm) and 7 (2.13 μm). The approach was then applied to cross-calibrate the AVHRR sensor onboard NOAA16. The absolute calibration coefficients derived for bands 1 and 2, using the Terra MODIS as a reference, were compared to the vicarious coefficients derived using the ocean and clouds method [Vermote E.F. and Kaufman Y.J. (1995). Absolute calibration of AVHRR visible and near-infrared channels using ocean and cloud views, International Journal of Remote Sensing, 16, 13, 2317–2340.]. The coefficients were consistent within less than 1%.

Keywords: Calibration; AVHRR; MODIS

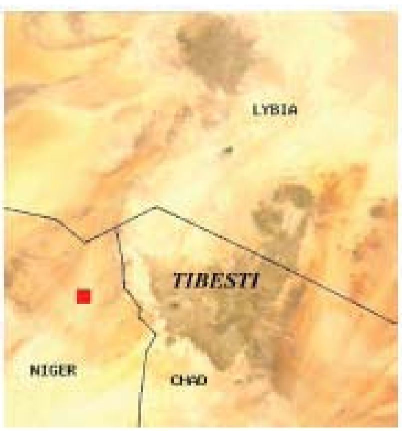


Fig. 2. Location of the 20 km by 20 km calibration site (centered on the red square) The image represents an area of 1000 km by 1000 km.

The coefficients were consistent within less than 1%

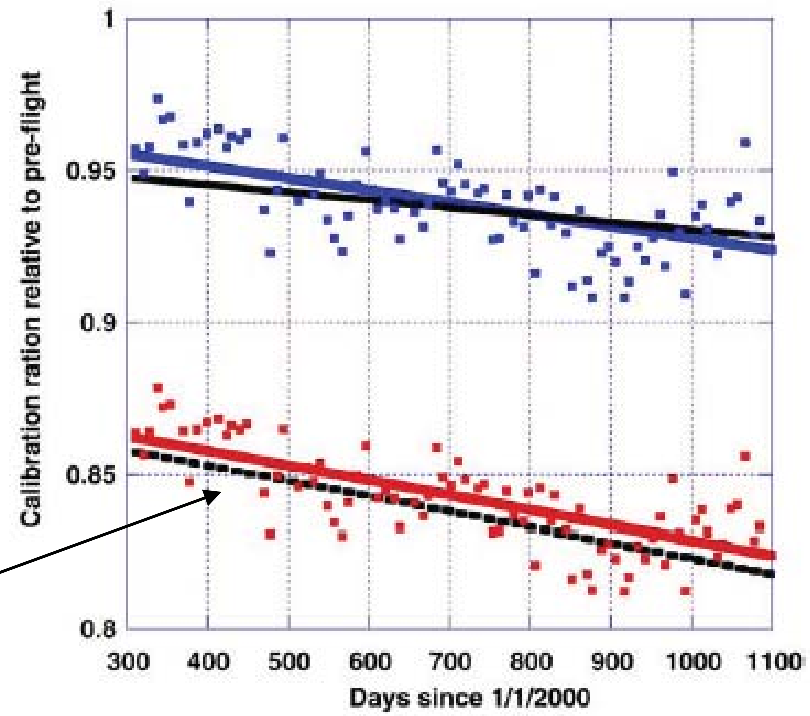
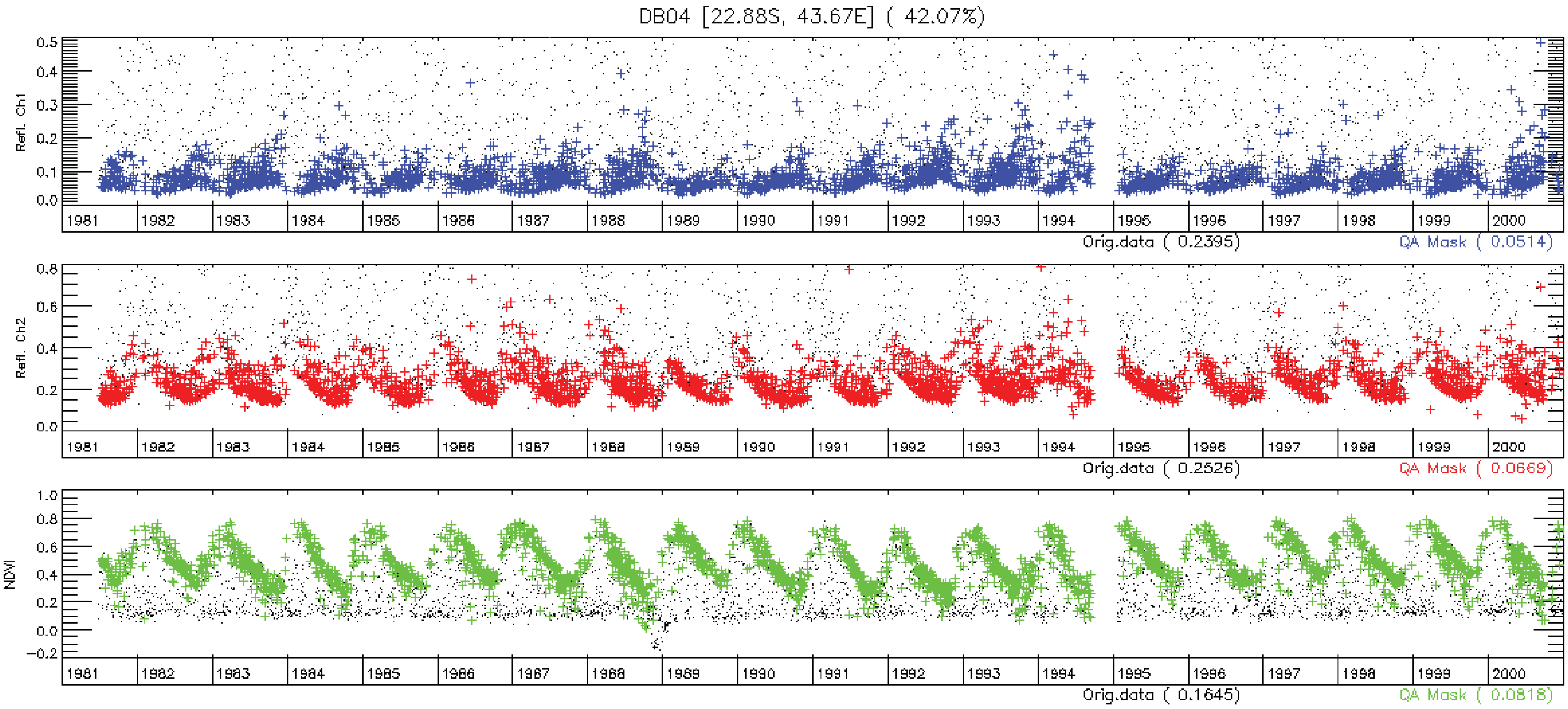


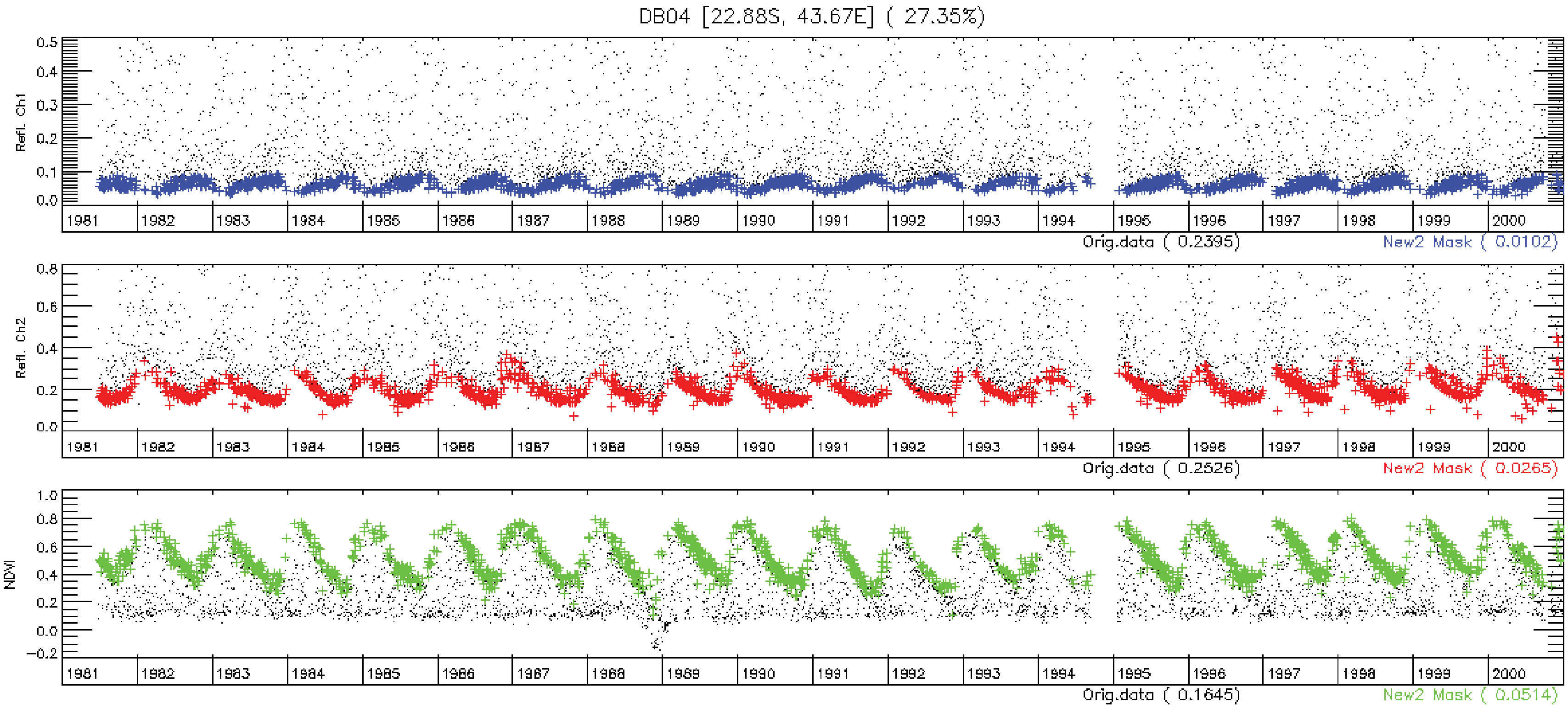
Fig. 11. Comparison of the desert calibration trends for band 1 (black solid line) and band 2 (black interrupted line), with the trends obtained using the Ocean and Clouds method (Vermote and Kaufman, 1995) for band 1 (blue line and square) and band 2 (red line and square).

Use of BRDF corrected reflectance for cloud mask evaluation of AVHRR Time Series



CLAVR (Pathfinder II) cloud mask

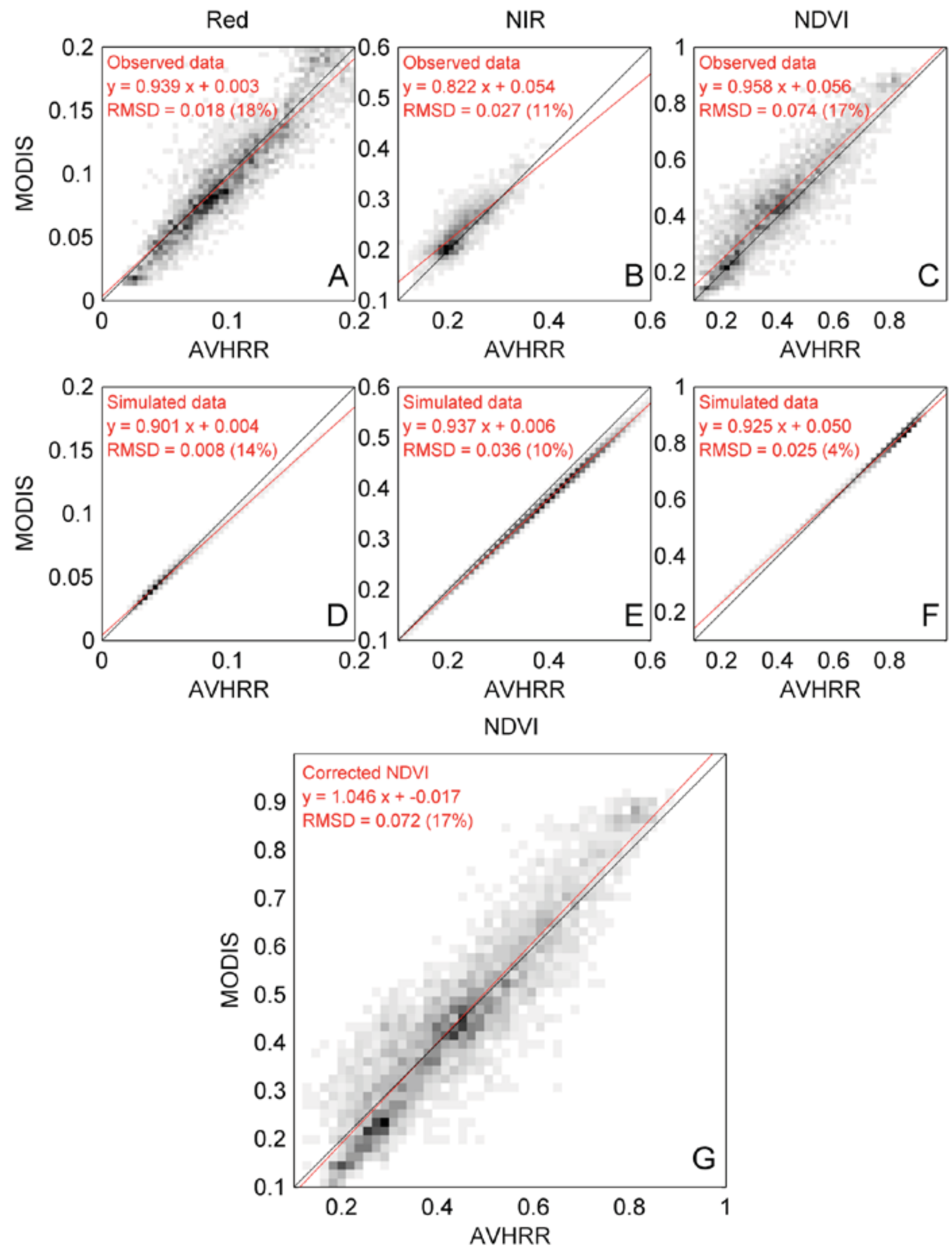
Use of BRDF corrected reflectance for cloud mask evaluation of AVHRR Time Series

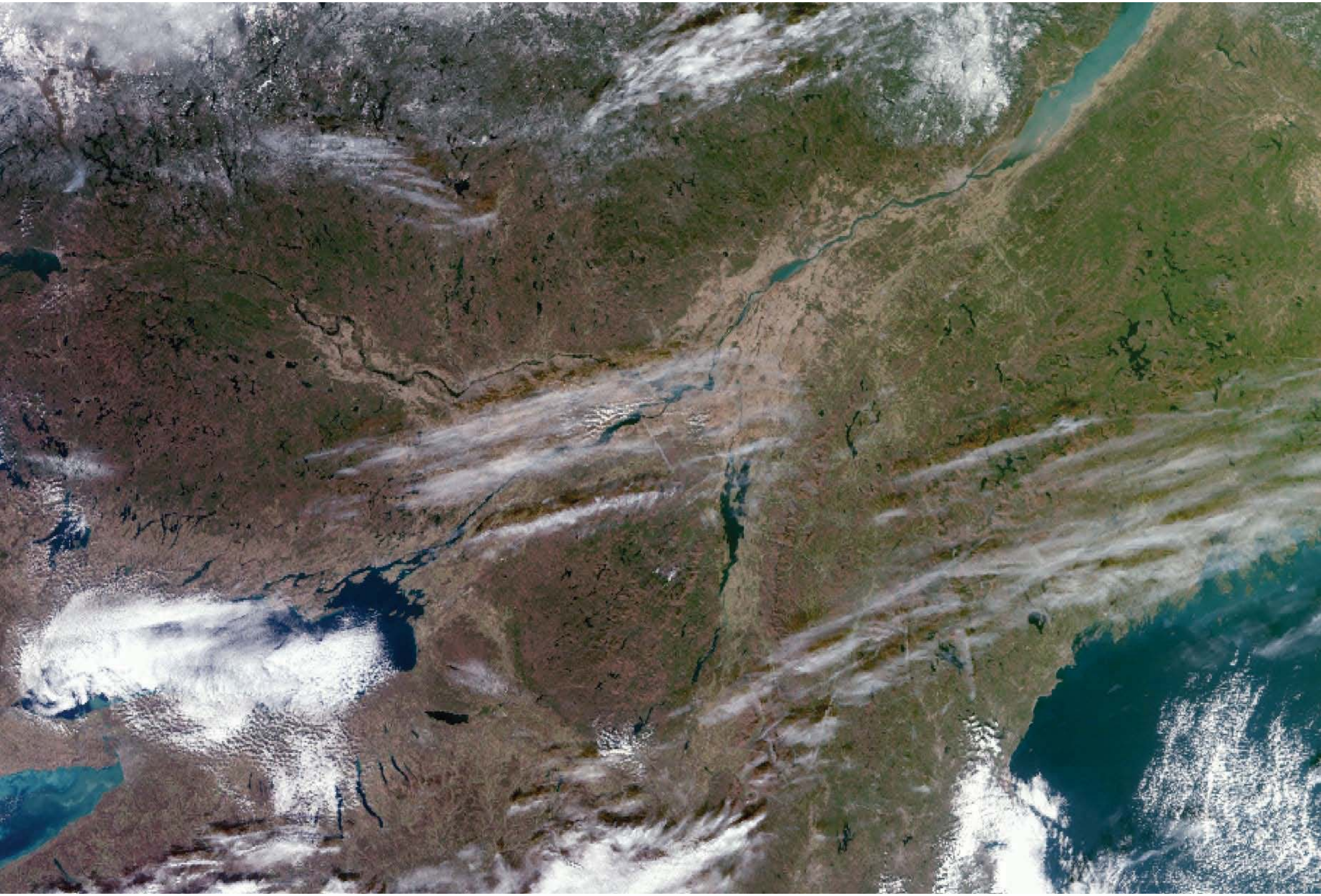


AVHRR Time series LTDR V3.0 cloud mask

Using Direct comparison with MODIS Aqua for validation

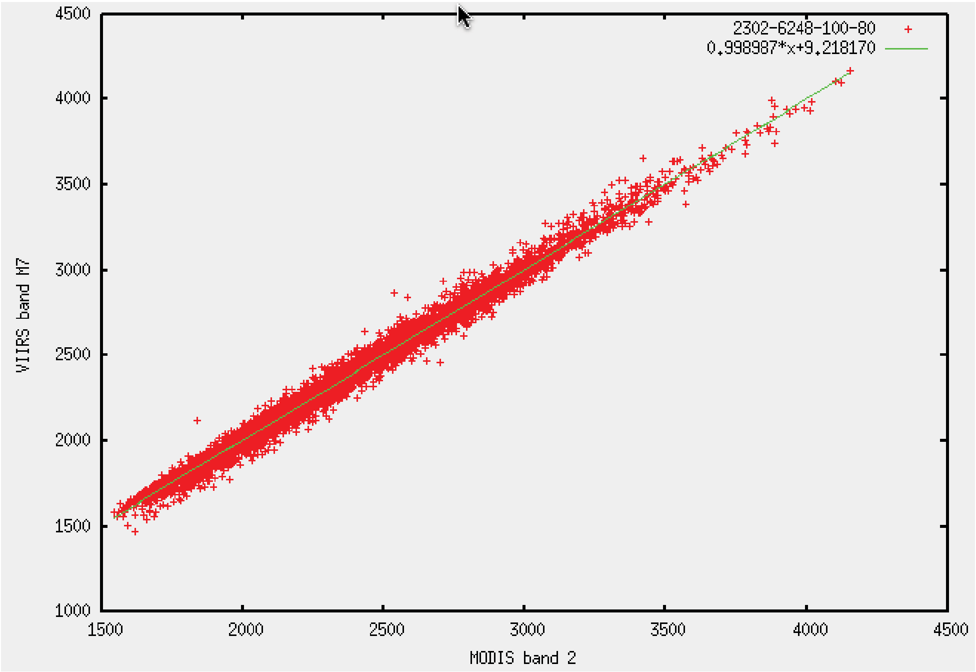
Comparison of MODIS Aqua and NOAA16 AVHRR data, A (Red) ,B (NIR) ,C (NDVI) are observed over AERONET sites for 2003-2004, D (Red), E(NIR), F(NDVI) are simulated using a vegetation model that account for spectral difference between MODIS and AVHRR bands. G shows over the AERONET sites MODIS NDVI versus corrected AVHRR NDVI computed from spectrally adjusted AVHRR surface reflectance.





One of the VIIRS First light images generated by UMD/NOA

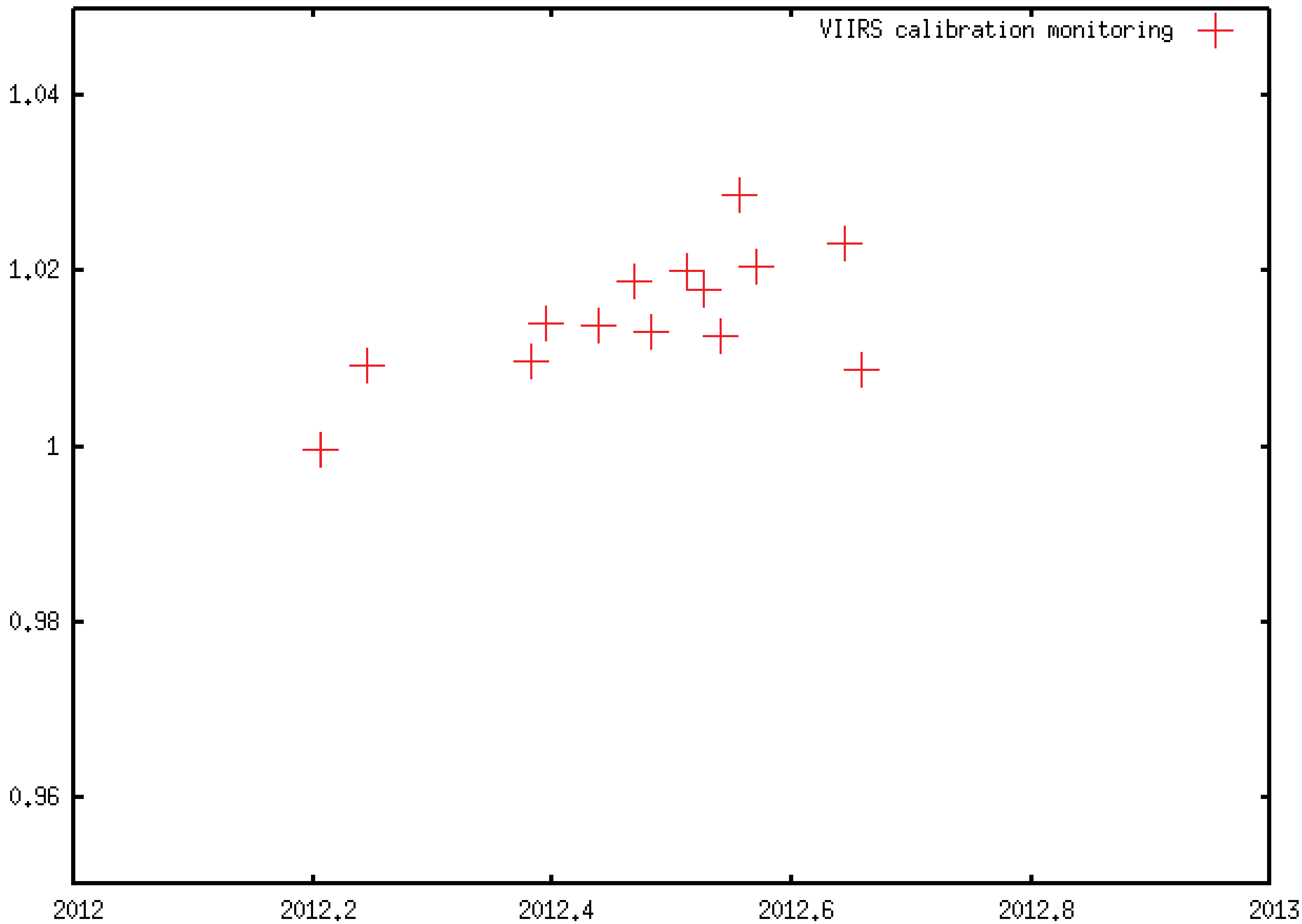
Use of BRDF correction (VIIRS)



VIIRS SR product   Aqua SR product

A ~50km x 50km site in Australia

VIIRS calibration is being monitored on a continuous basis (selected daily obs)



Conclusions

- Surface reflectance algorithm is mature and pathway toward validation and automated QA is clearly identified.
- Algorithm is generic and tied to documented validated radiative transfer code enabling easier inter-comparison and fusion of products from different sensors (MODIS,VIIRS,AVHRR, LDCM, Landsat, Sentinel 2 …)