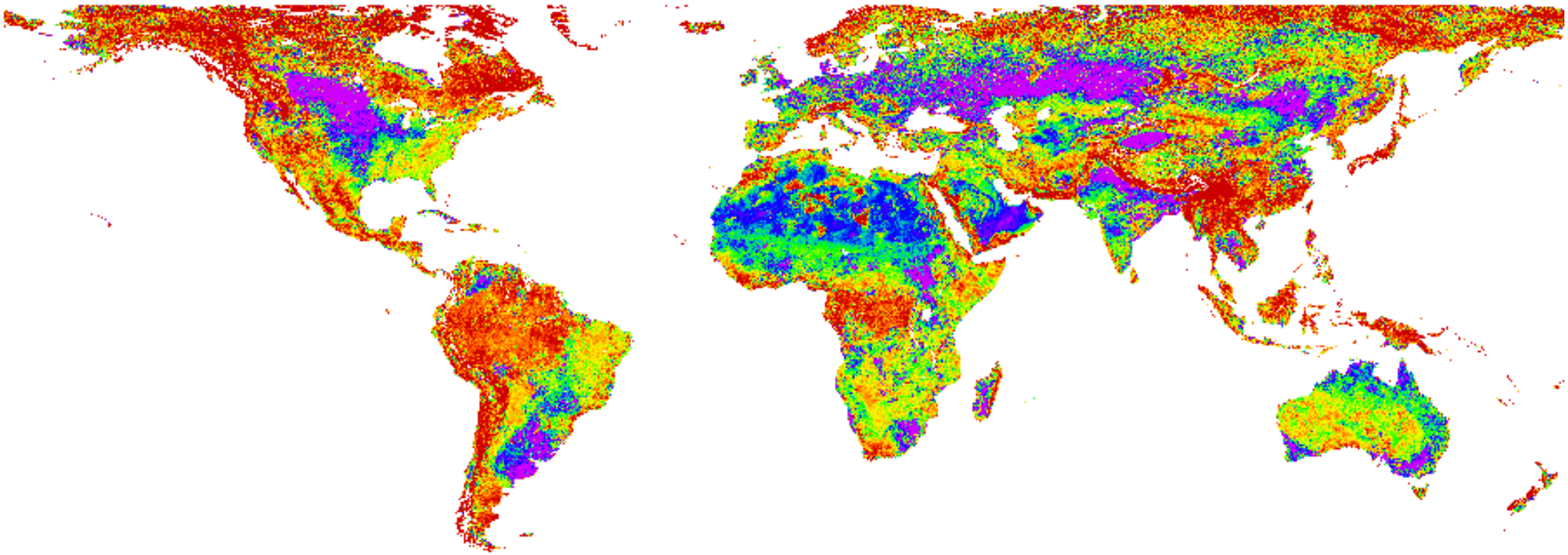
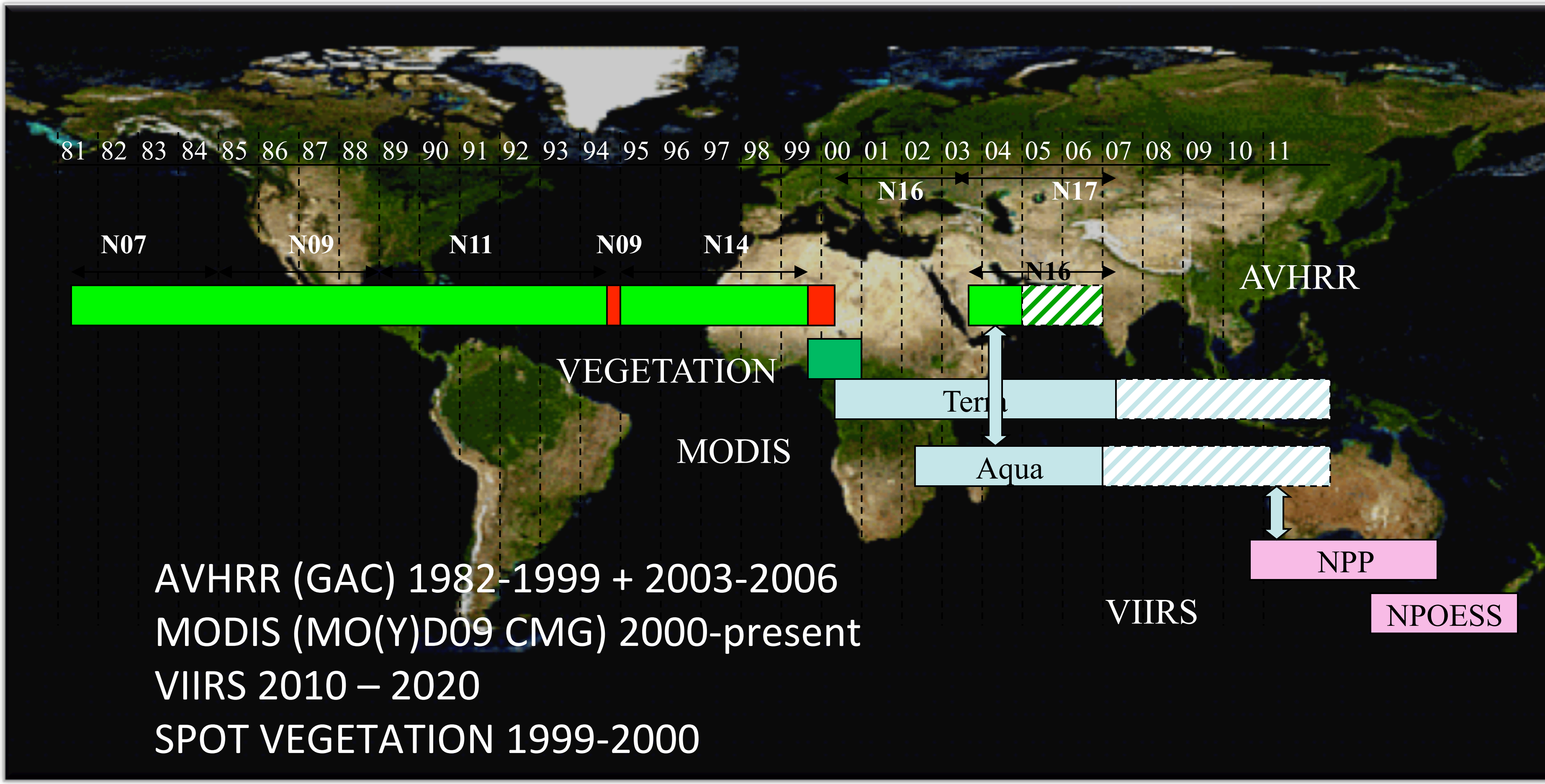
“Generation of time series of directionnaly normalized spectral surface reflectance from MODIS: Method, Accuracies and Applications”



Eric Vermote
UMCP

Land Climate Data Record

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



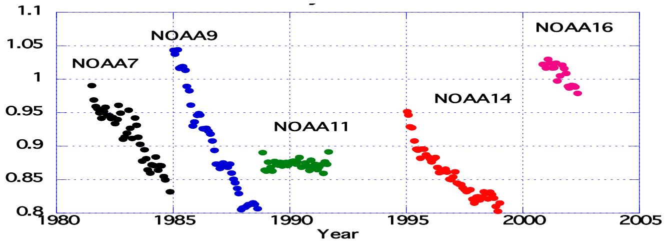
Emphasis on data consistency – characterization rather than degrading/smoothing the data

Land Climate Data Record

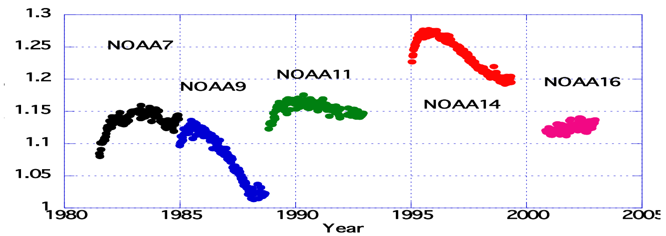
Needs to address calibration, atmospheric/BRDF correction issues

CALIBRATION

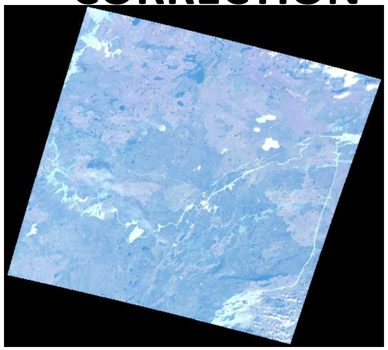
Degradation in channel 1
(from Ocean observations)

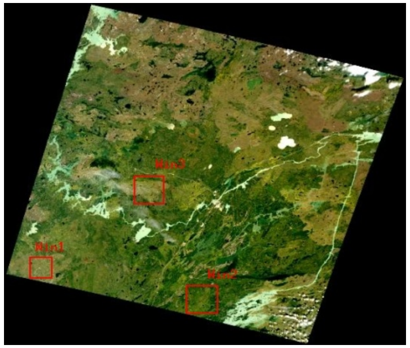


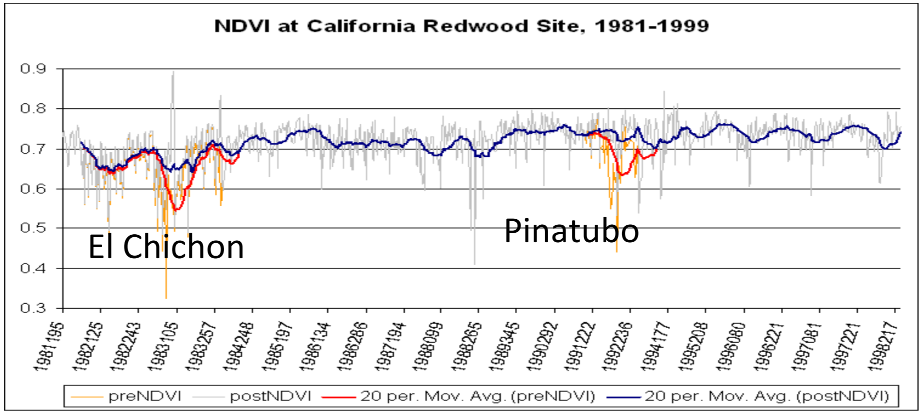
Channel1/Channel2 ratio
(from Clouds observations)



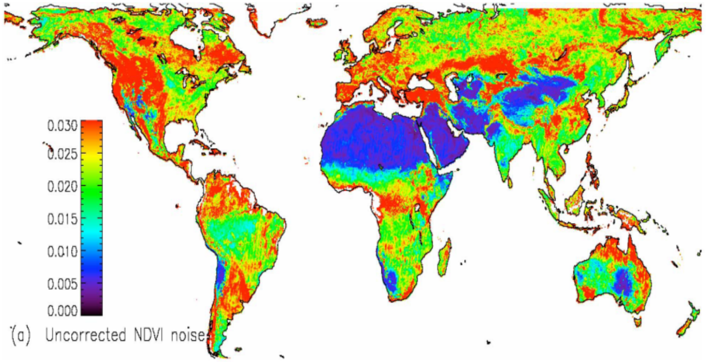
ATMOSPHERIC CORRECTION

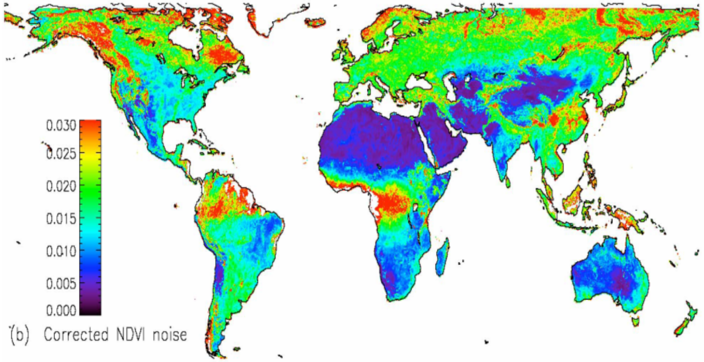


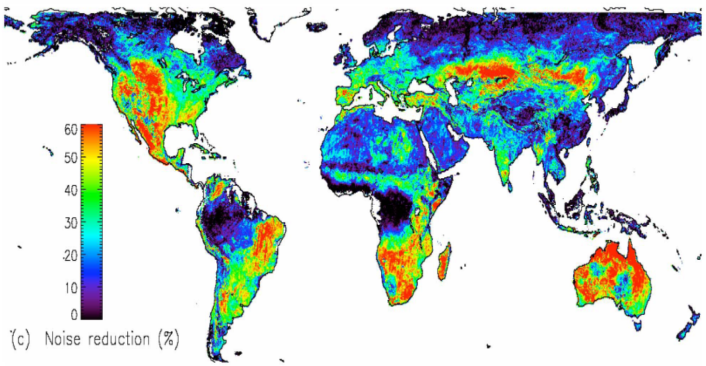




BRDF CORRECTION

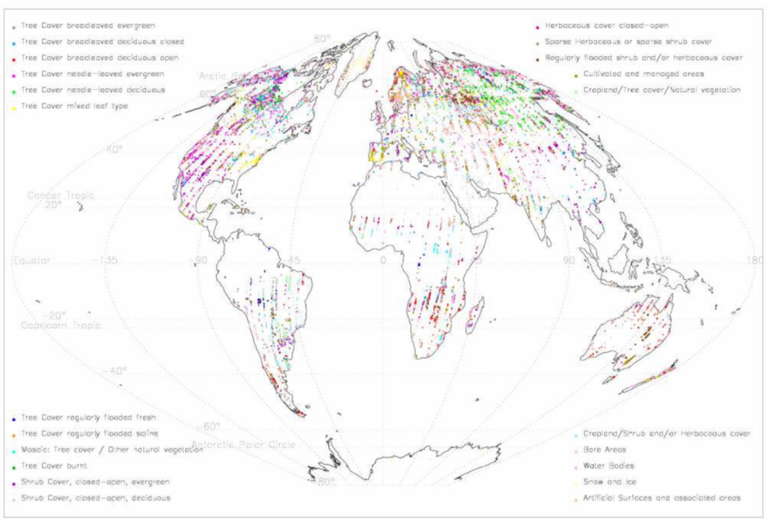






The Polarization and Directionality of the Earth's Reflectances results from POLDER

- Using multi-directional Parasol POLDER data at coarse resolution (6 km) over a large set of representative targets, POLDER showed that simple models with only 3 free parameters permit an accurate representation of the BRDFs. The best results (low RMS residuals) were obtained with the linear Ross-Li-HS model, a version of the Ross-Li model that accounts for the Hot-Spot process



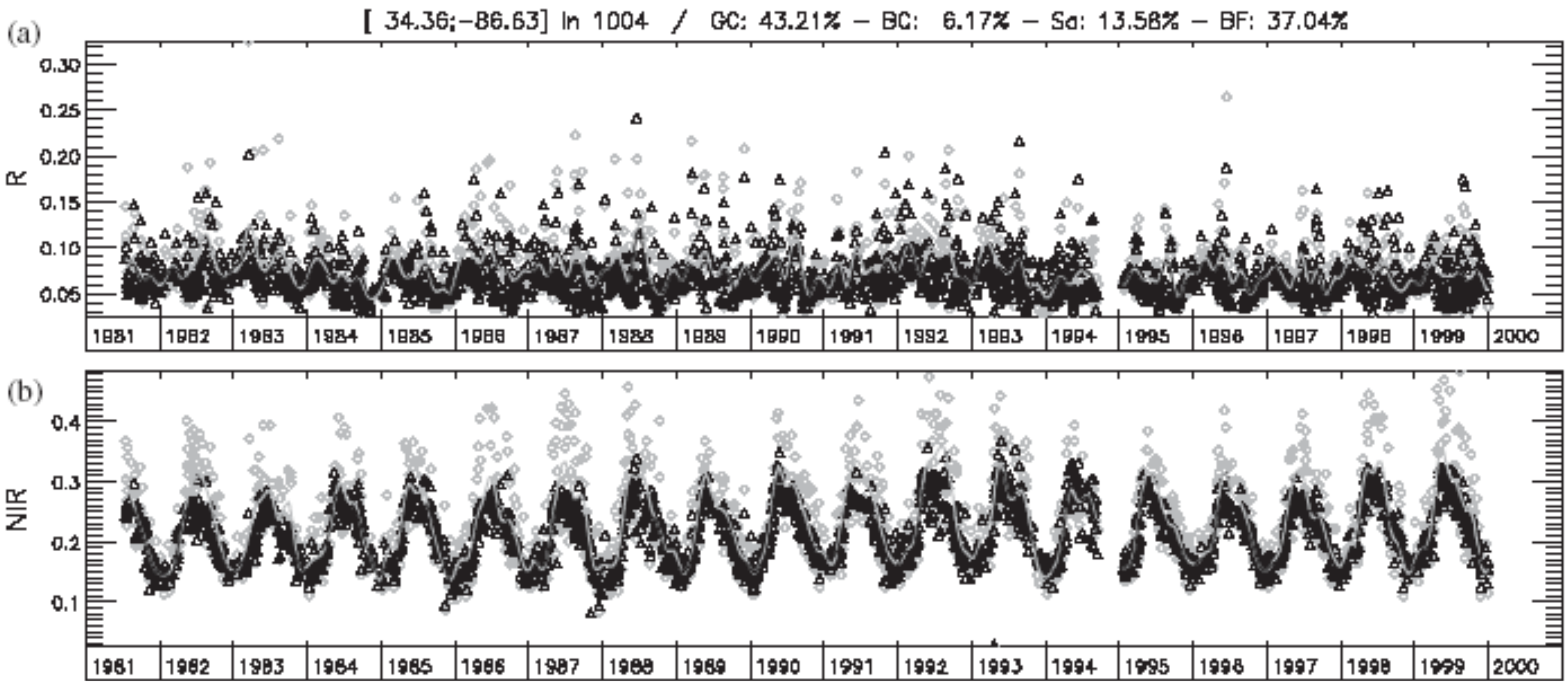
$$\rho(\theta_s,\theta_v,\phi) = k_0 + k_1\,F_1(\theta_s,\theta_v,\phi) + k_2\,F_2(\theta_s,\theta_v,\phi)$$

$$= k_0\left[1 + \frac{k_1}{k_0}\,F_1(\theta_s,\theta_v,\phi) + \frac{k_2}{k_0}\,F_2(\theta_s,\theta_v,\phi)\right]$$

The ability of simple, linear, models to reproduce the BRDF of natural targets opens the way for the correction of directional effects on reflectance time series data (MODIS and AVHRR). However, the question remains as to the choice of the BRDF model, i.e. the determination of its free parameters.

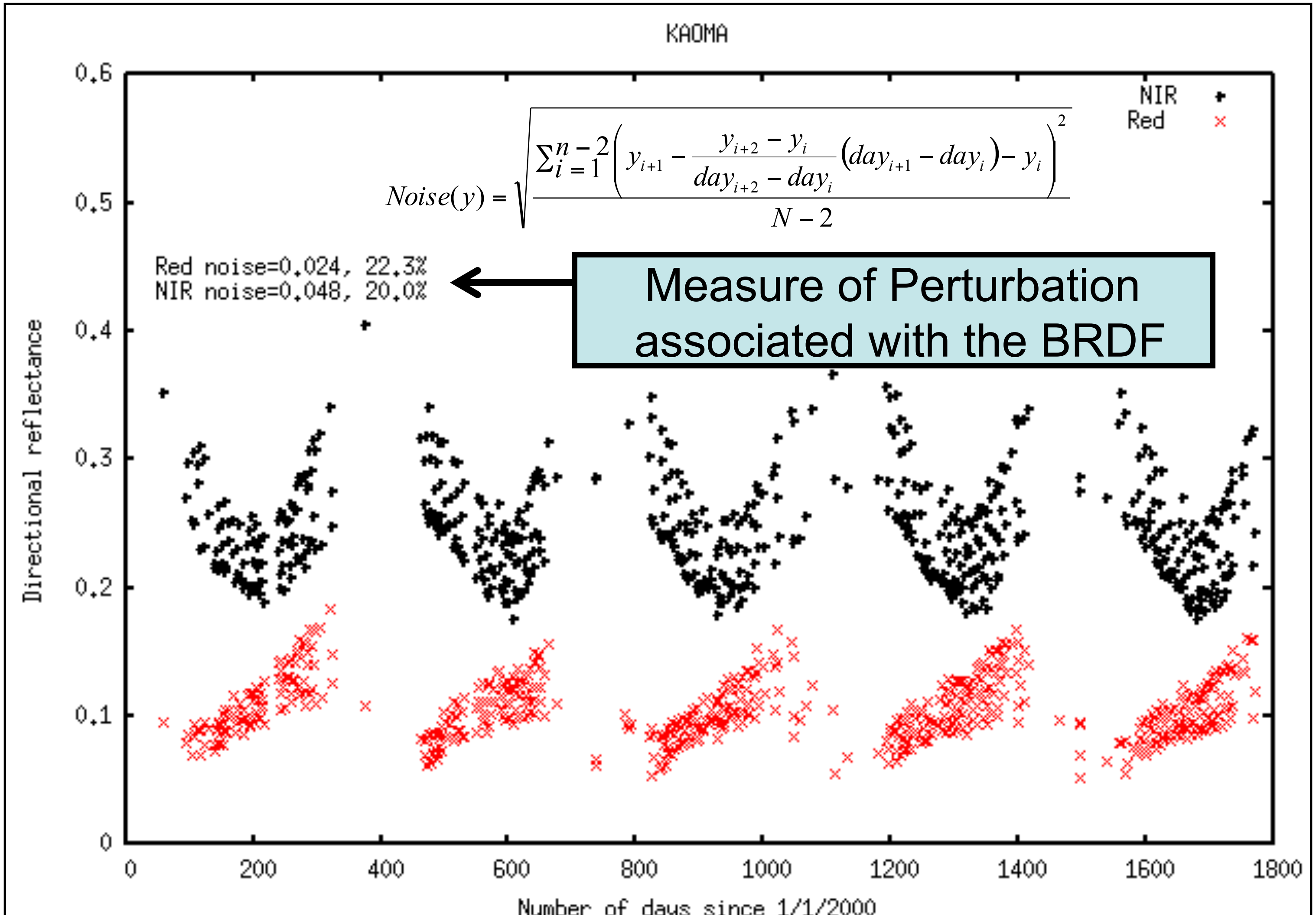
The POLDER results toward a generic BRDF

- Measurements from the Polarization and Directionality of the Earth's Reflectances (POLDER) BRDF database, have shown that it is possible to assume a typical BRDF signature on a biome basis and therefore apply a-priori correction of the BRDF effect. This approach has been applied successfully on wide-swath data from polar orbiting satellite systems (e.g. AVHRR)



Application to MODIS Surface Reflectance CMG daily data

Time series (2000 to 2004) MODIS CMG daily Red and Nir reflectance data over a southern Africa Tropical Savanna site



$$Noise(y) = \sqrt{\frac{\sum_{i=1}^{n-2}\left(y_{i+1} - \frac{y_{i+2} - y_i}{day_{i+2} - day_i}\left(day_{i+1} - day_i\right) - y_i\right)^2}{N-2}}$$

A new approach to invert BRDF on times series

Classic approach assumes the reflectance does not vary within the inversion time interval and BRDF correction minimizes the classic merit function

$$\rho(\theta_s,\theta_v,\phi) = k_0 + k_1\ F_1(\theta_s,\theta_v,\phi) + k_2\ F_2(\theta_s,\theta_v,\phi)$$
$$= k_0\left[1 + \frac{k_1}{k_0}\ F_1(\theta_s,\theta_v,\phi) + \frac{k_2}{k_0}\ F_2(\theta_s,\theta_v,\phi)\right]$$

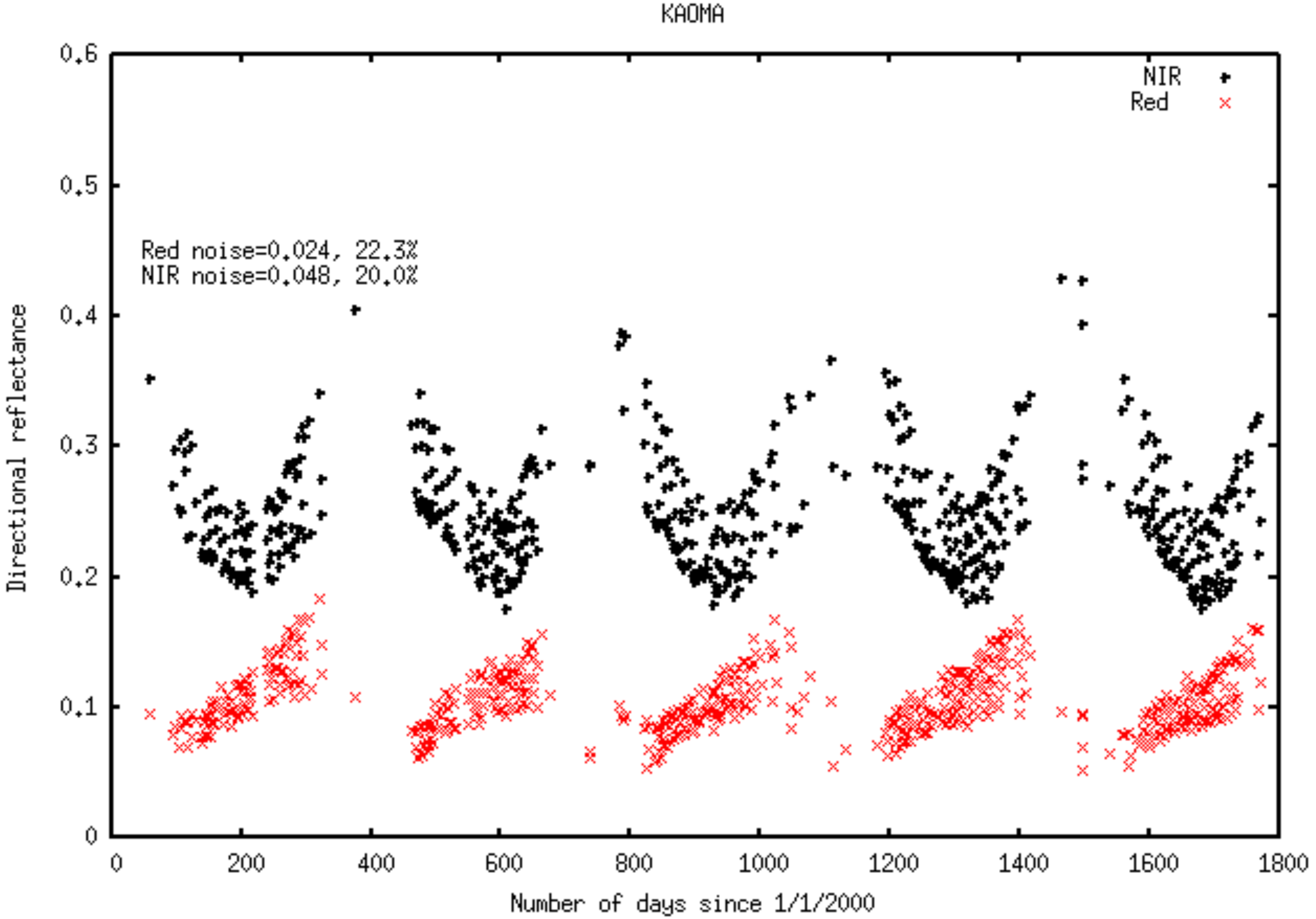
$$\sum_{i=1}^{N}\left(k_0 + k_1\ F_1^i + k_2\ F_2^i - \rho_i\right)^2$$

Our new approach allows the reflectance to vary slowly within the interval and minimization of a more complicated merit function

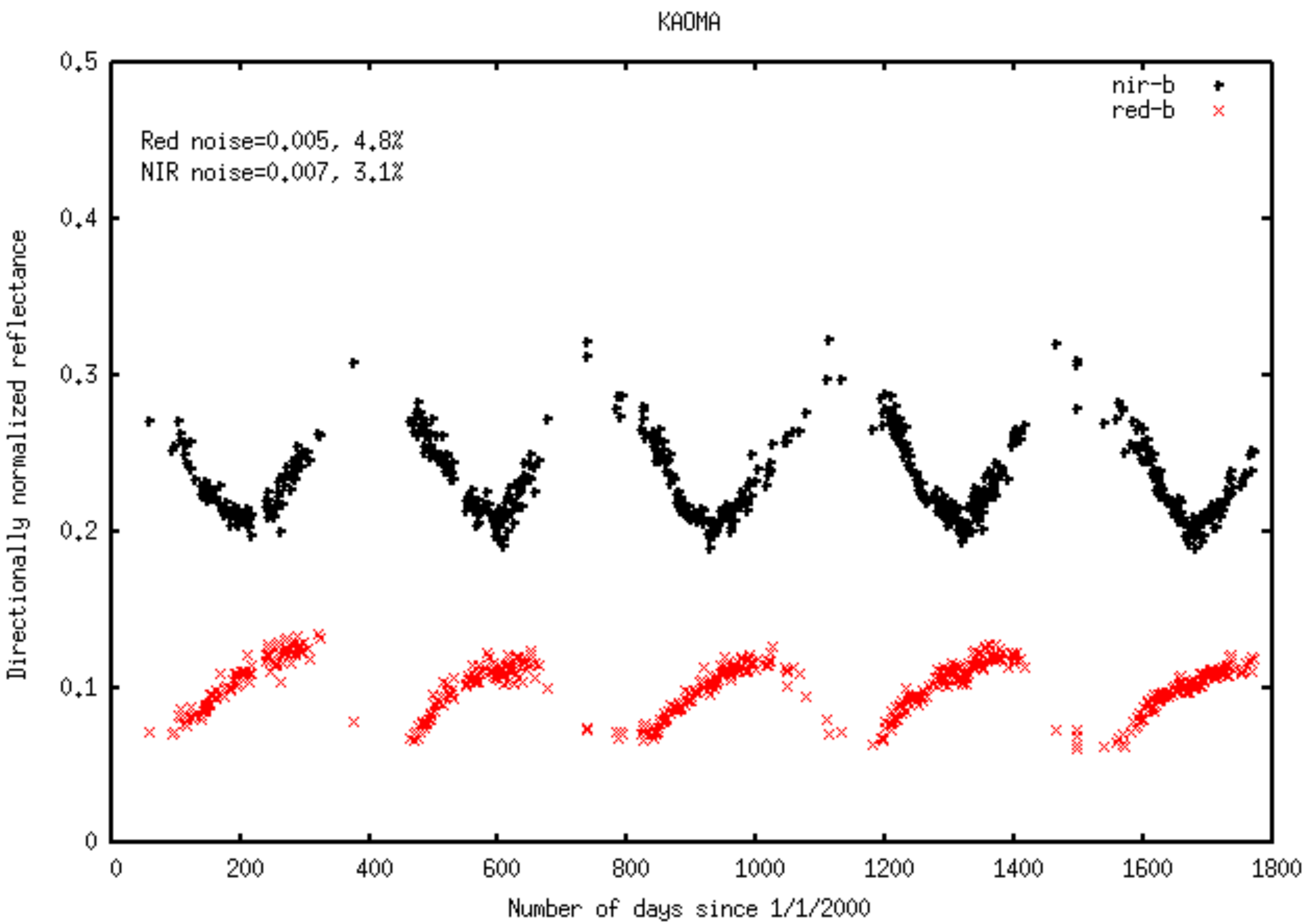
$$\frac{\rho(t_i)}{\left[1 + V\ F_1^i + R\ F_2^i\right]} \approx \frac{\rho(t_{i+1})}{\left[1 + V\ F_1^{i+1} + R\ F_2^{i+1}\right]}$$

$$M = \sum_{i=1}^{N-1} \frac{\left(\rho_{i+1}\left[1 + VF_1^i + RF_2^i\right] - \rho_i\left[1 + VF_1^{i+1} + RF_2^{i+1}\right]\right)^2}{day^{i+1} - day^i + 1}$$

Uncorrected Reflectance Data

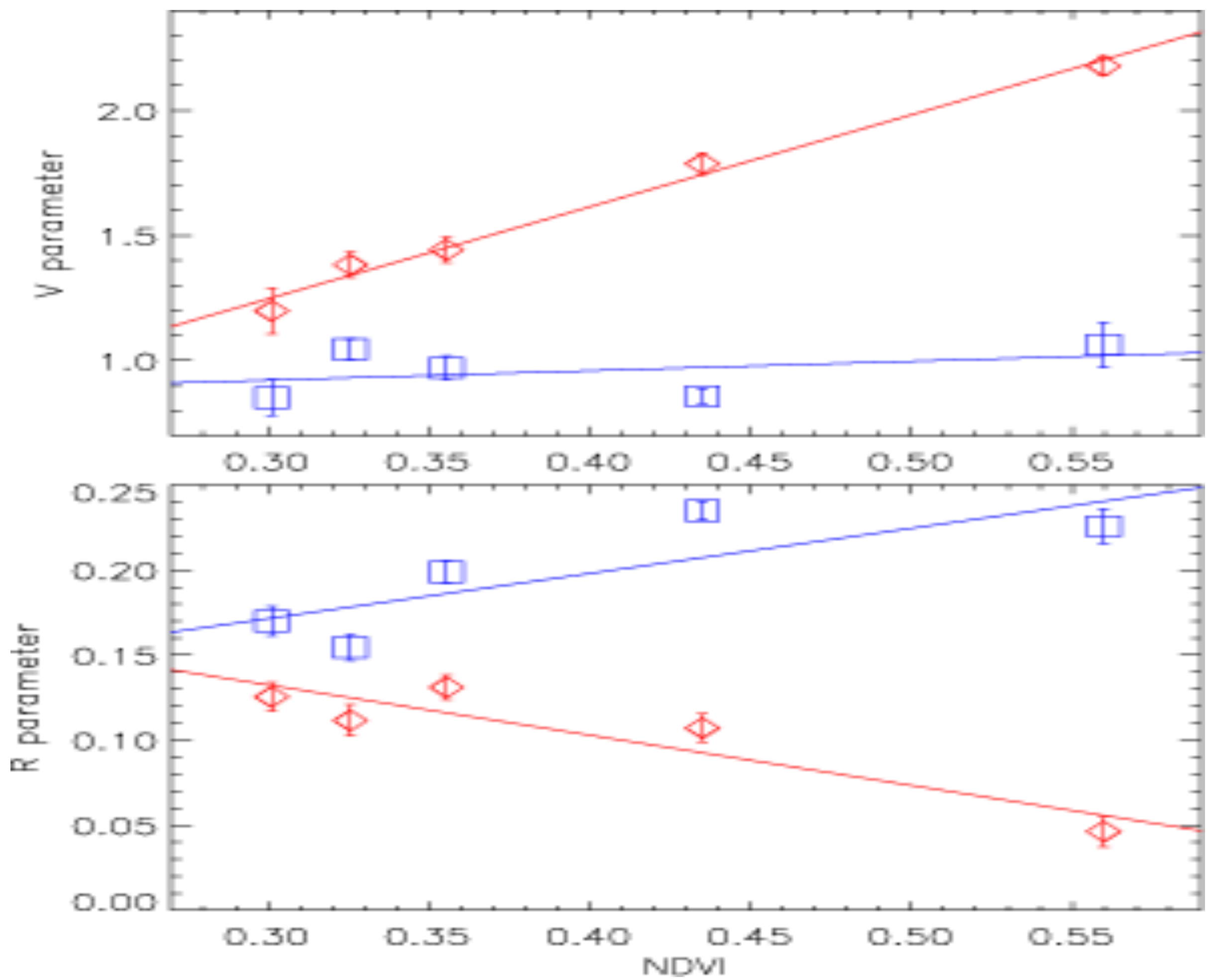


Time-series of normalized reflectance using the new approach



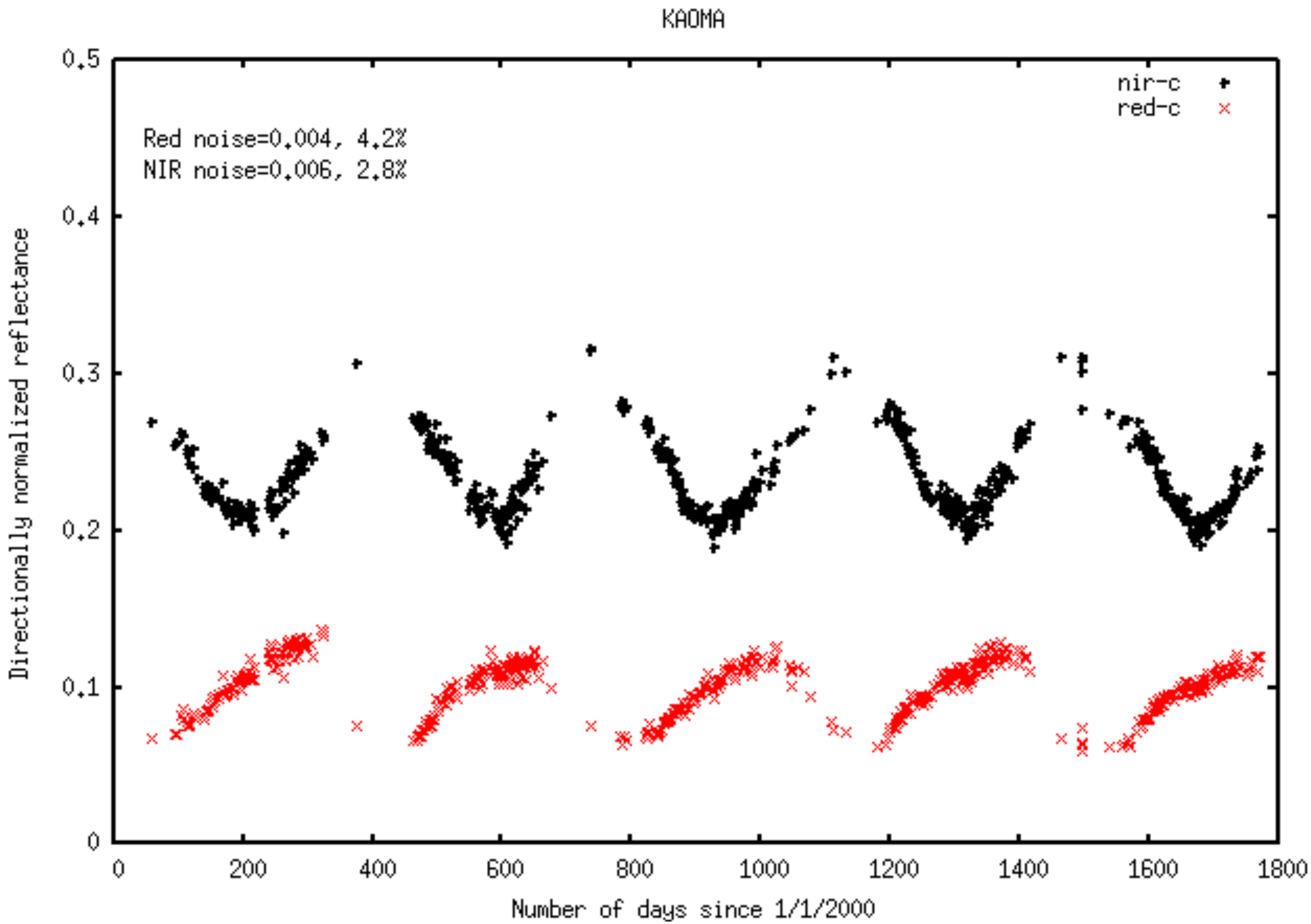
Further improvements allow the V (volume parameter) and R (roughness parameter) to vary as a function of NDVI

Red: band 2
Blue: band 1

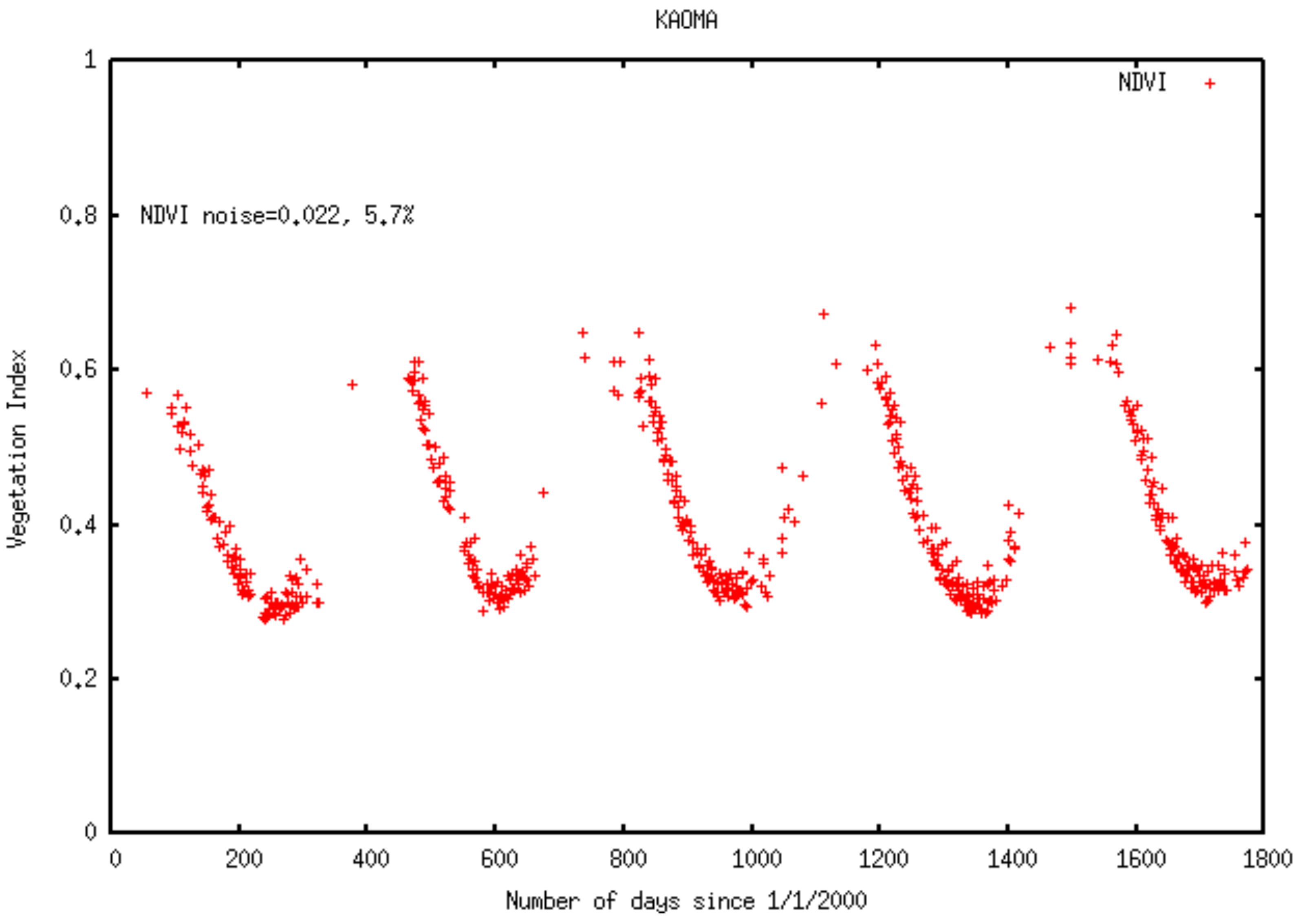


Improving Correction by Stratifying by Vegetation ‘Amount’ over Time

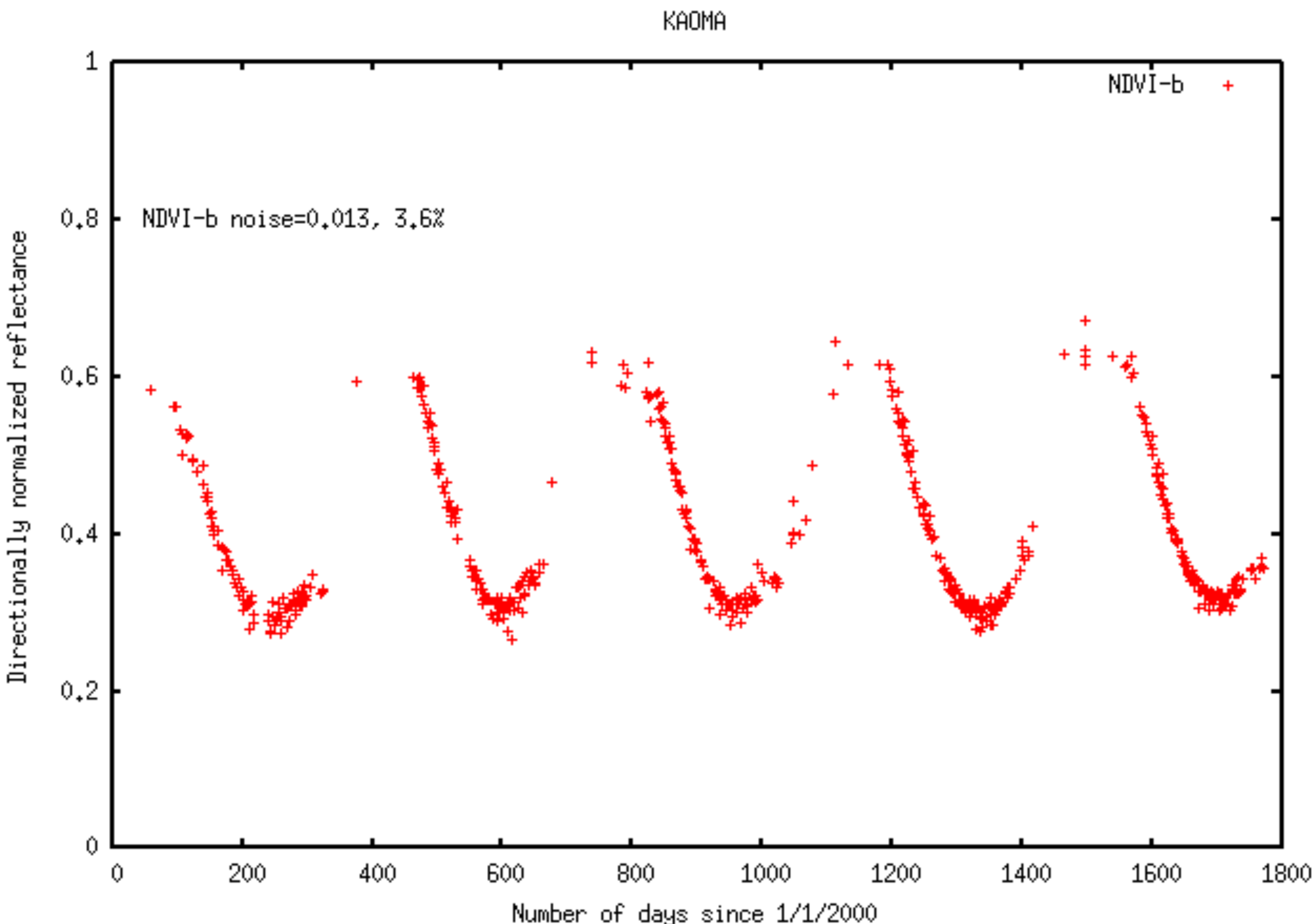
Results of final BRDF Correction



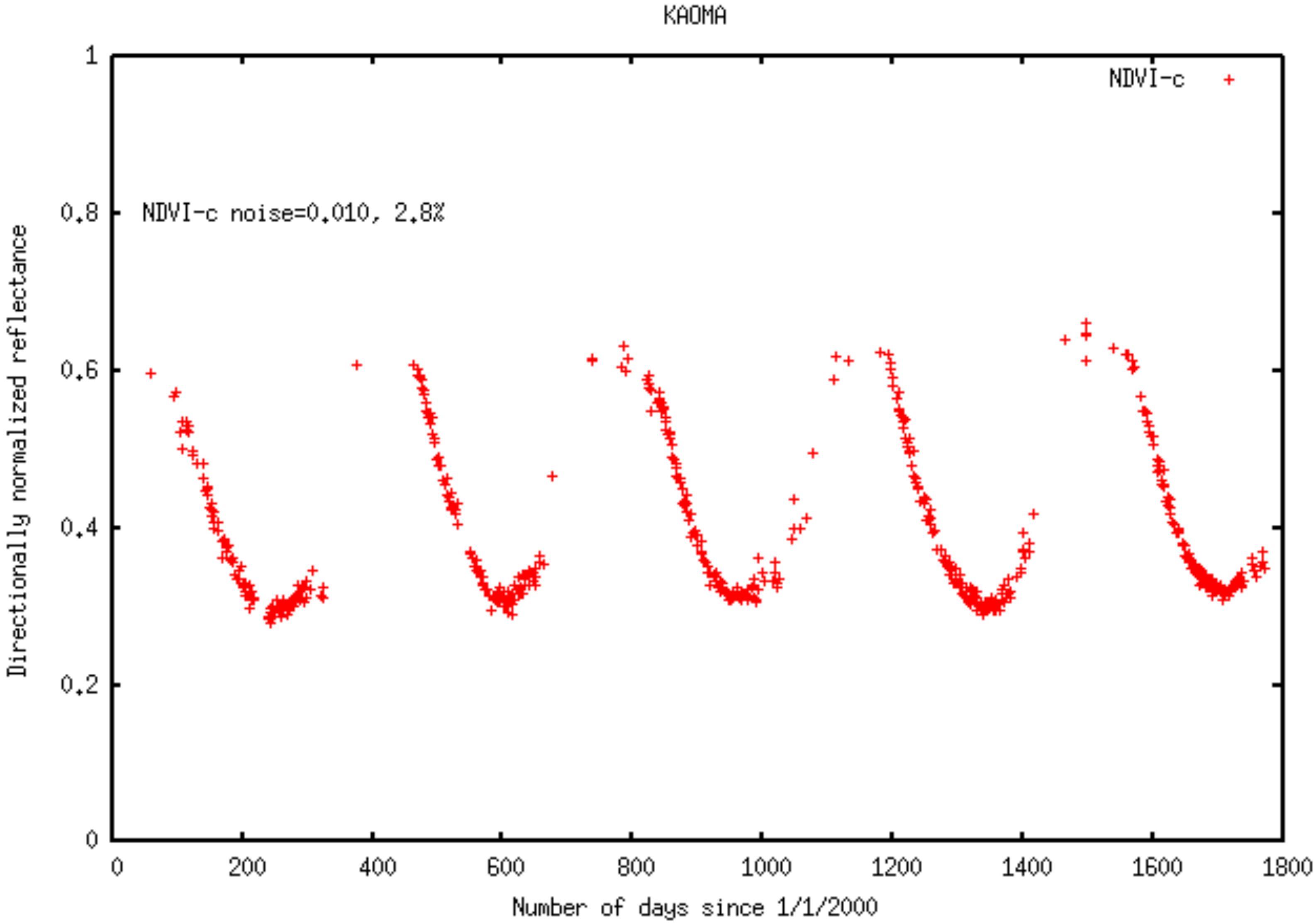
Original NDVI



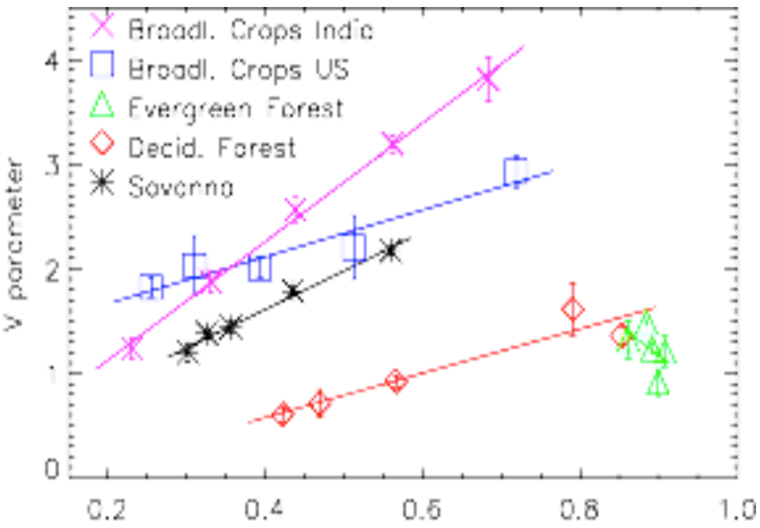
NDVI computed from new BRDF inversion (V and R fixed)

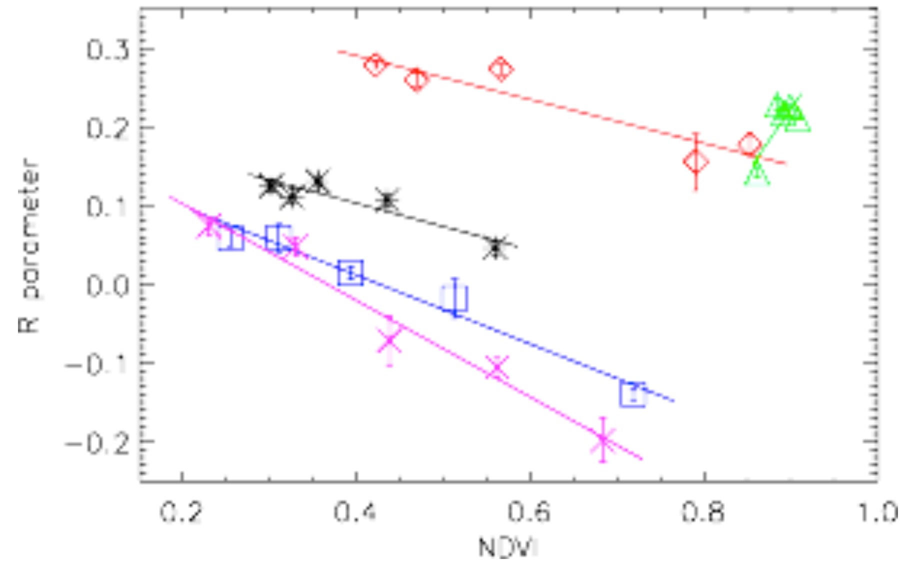


NDVI computed from new BRDF inversion (V and R varies linearly with NDVI)



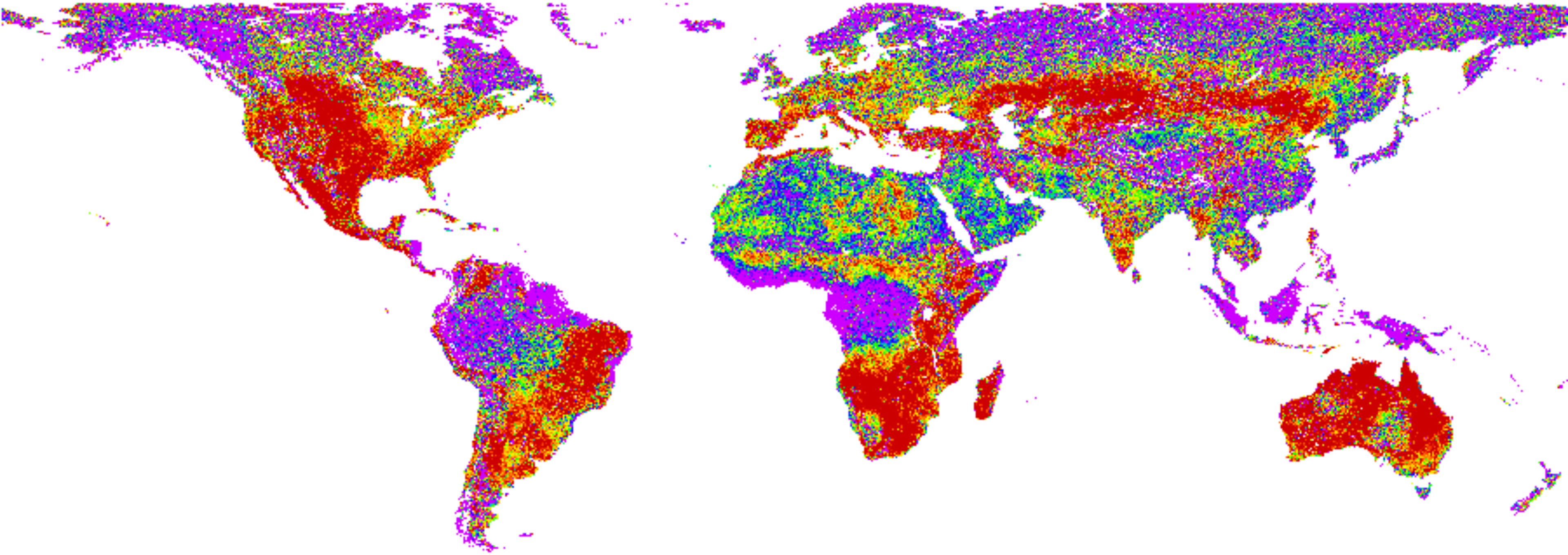
Results for various land covers





		Savanna	Evergreen forest	Deciduous forest	Broadleaf crops	Broadleaf crops
Channel 1	Raw data noise	0.019 (18.8%)	0.006 (33.6%)	0.011 (23.0%)	0.011 (12.6%)	0.016 (16.3%)
	Cor. Data noise	0.004 (3.4%)	0.002 (13.0%)	0.004 (10.0%)	0.005 (6.2%)	0.006 (7.3%)
Channel 2	Raw data noise	0.040 (16.4%)	0.063 (20.6%)	0.043 (19.7%)	0.024 (9.4%)	0.043 (16.5%)
	Cor. Data noise	0.005 (2.4%)	0.007 (2.5%)	0.010 (4.5%)	0.011 (4.5%)	0.011 (4.6%)
NDVI	Raw data noise	0.019 (4.6%)	0.016 (1.8%)	0.017 (3.0%)	0.027 (5.6%)	0.026 (5.7%)
	Cor. Data noise	0.008 (2.3%)	0.012 (1.4%)	0.013 (2.3%)	0.012 (2.8%)	0.023 (5.3%)

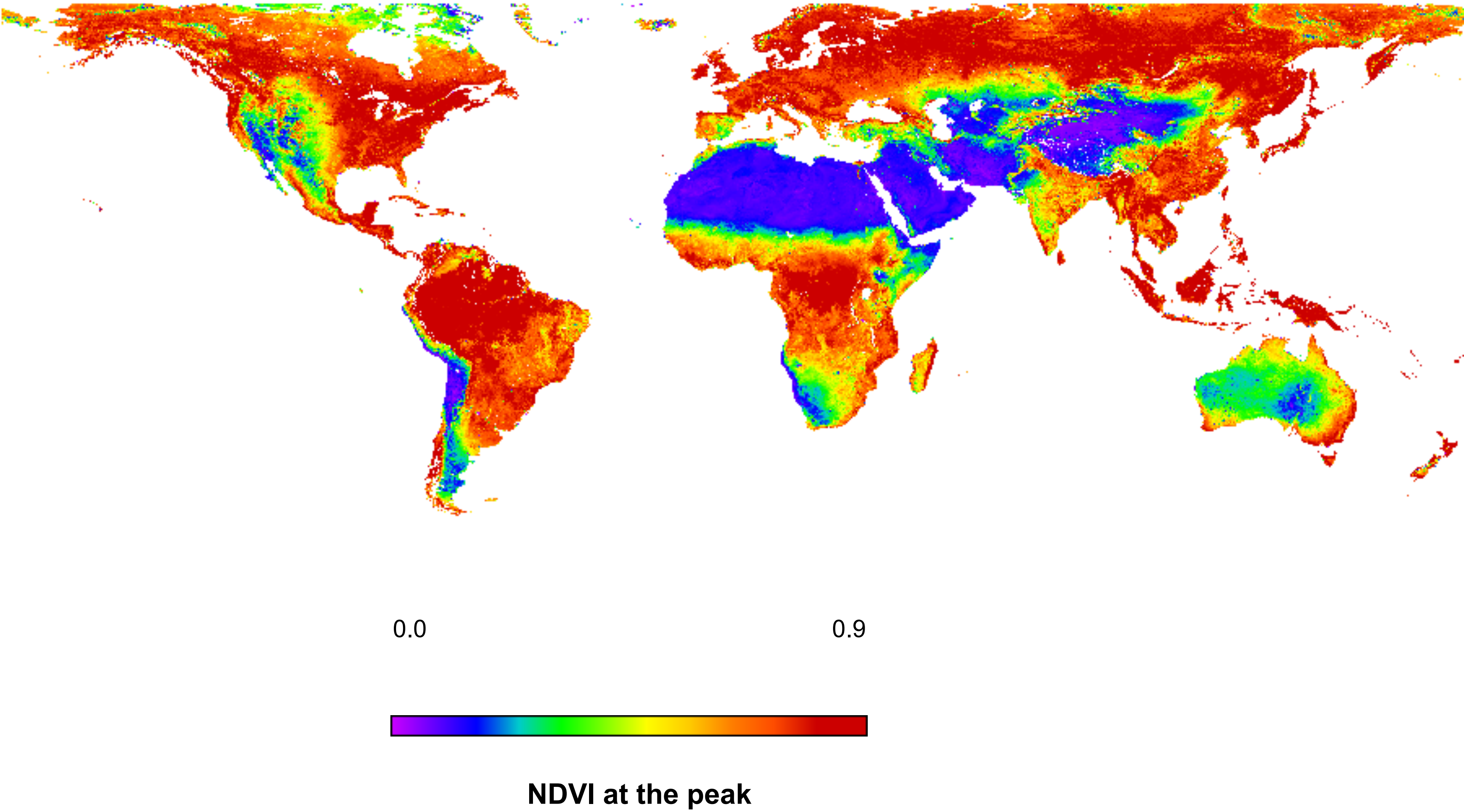
Global reduction in NDVI noise



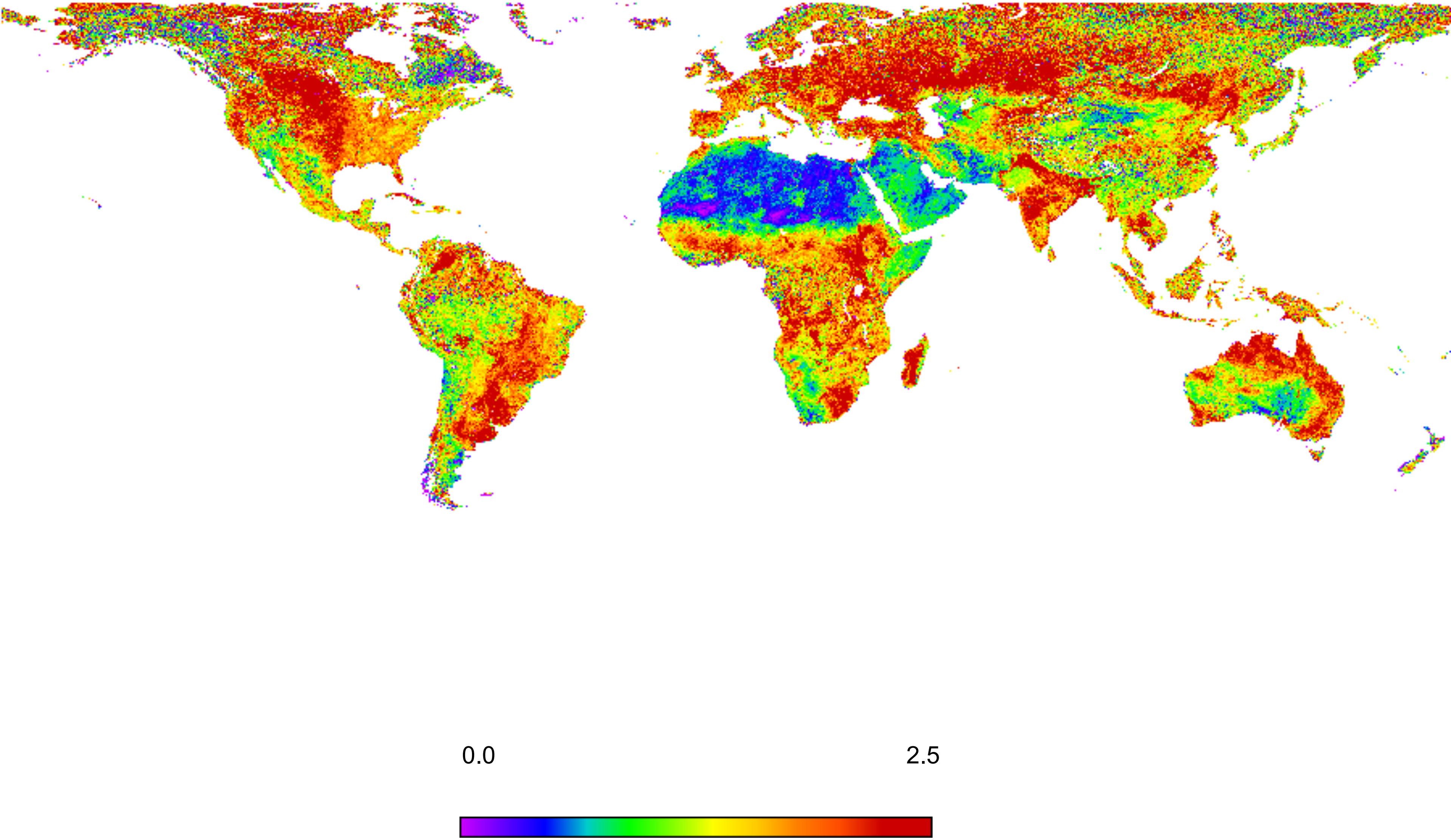
0.0 50%

NDVI Noise reduction in %.

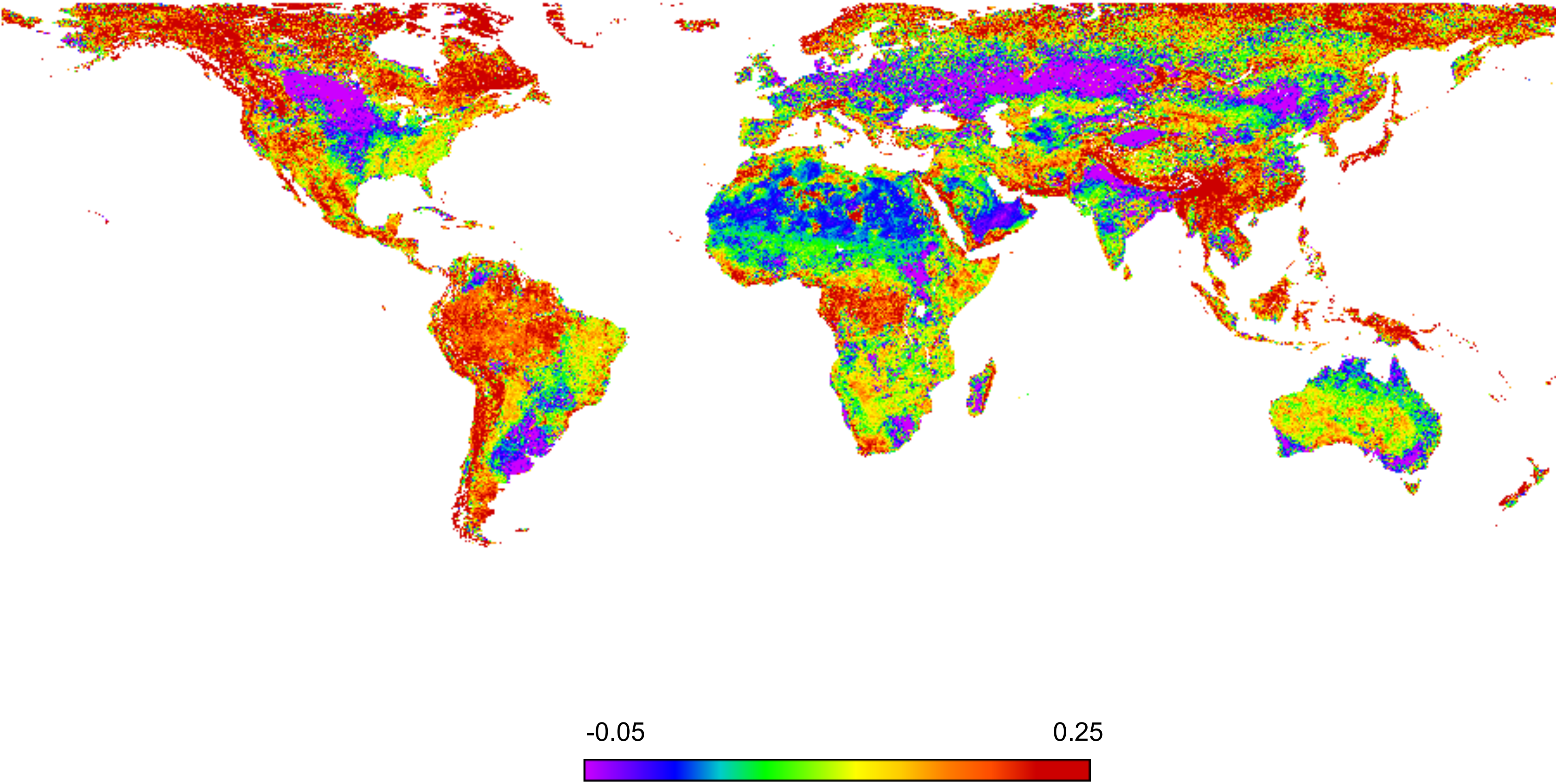
Global map of R and V parameters at the peak NDVI



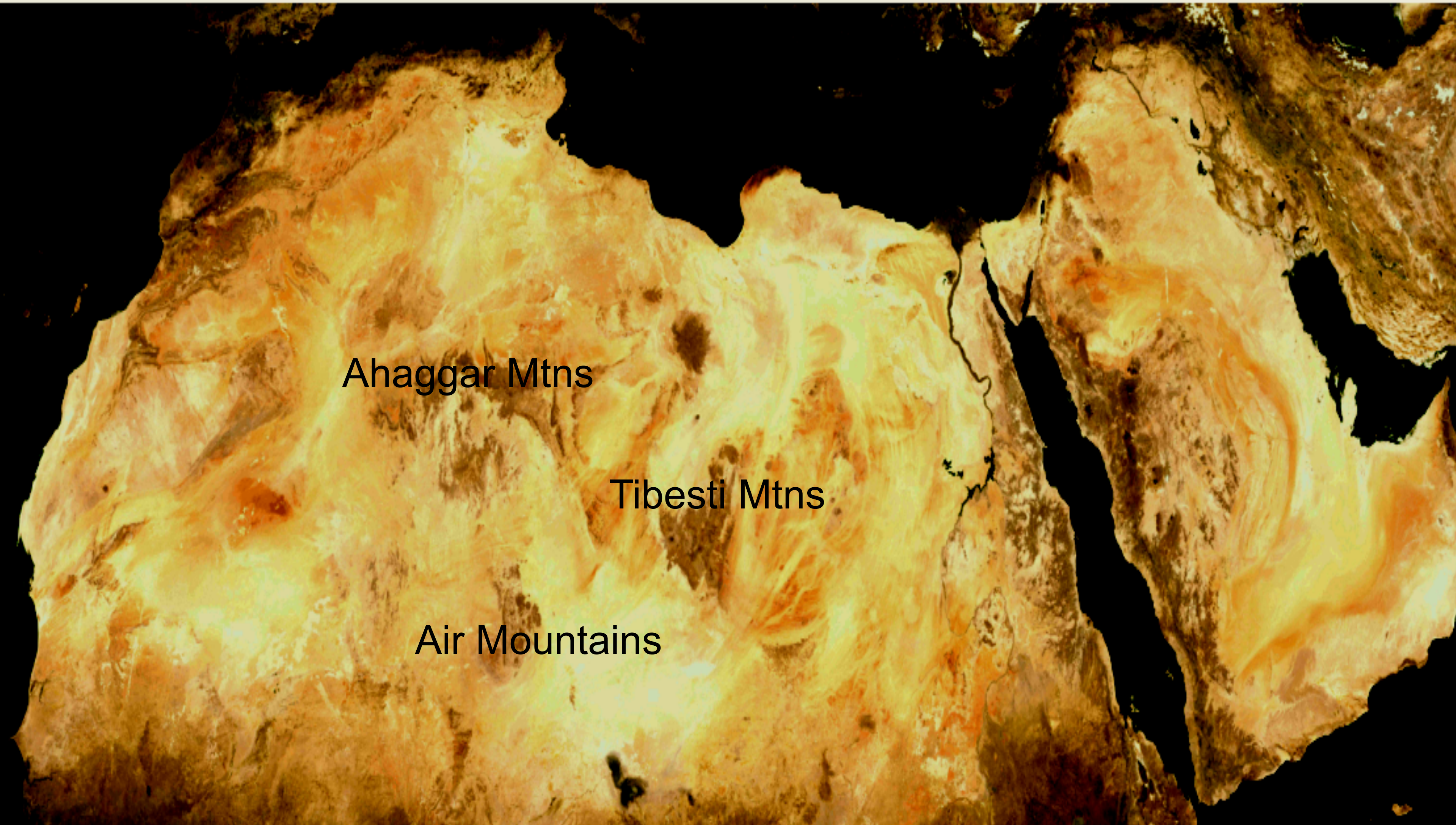
V parameter at the peak NDVI



R parameter at the peak NDVI

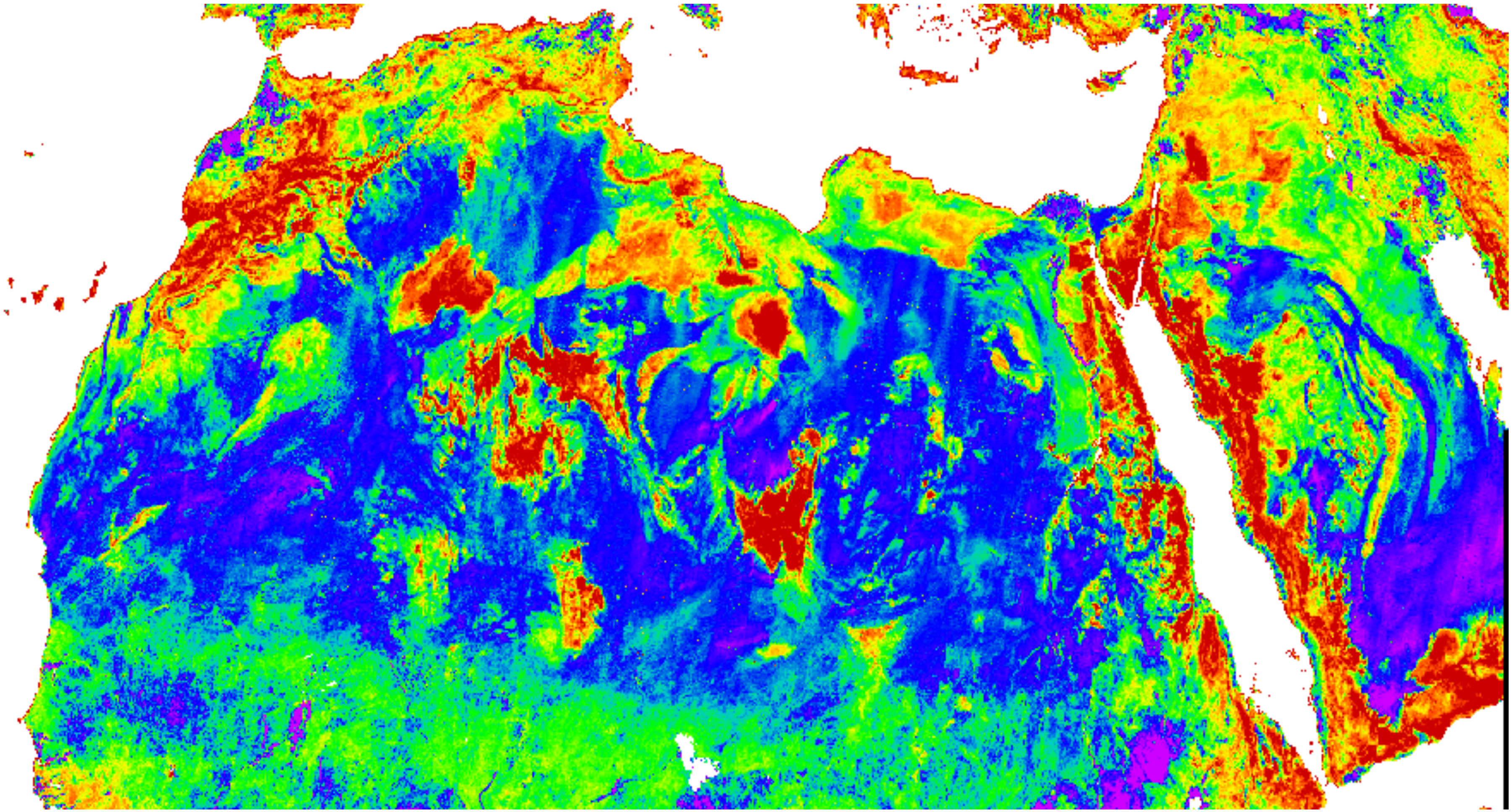


Sahara Desert Detail

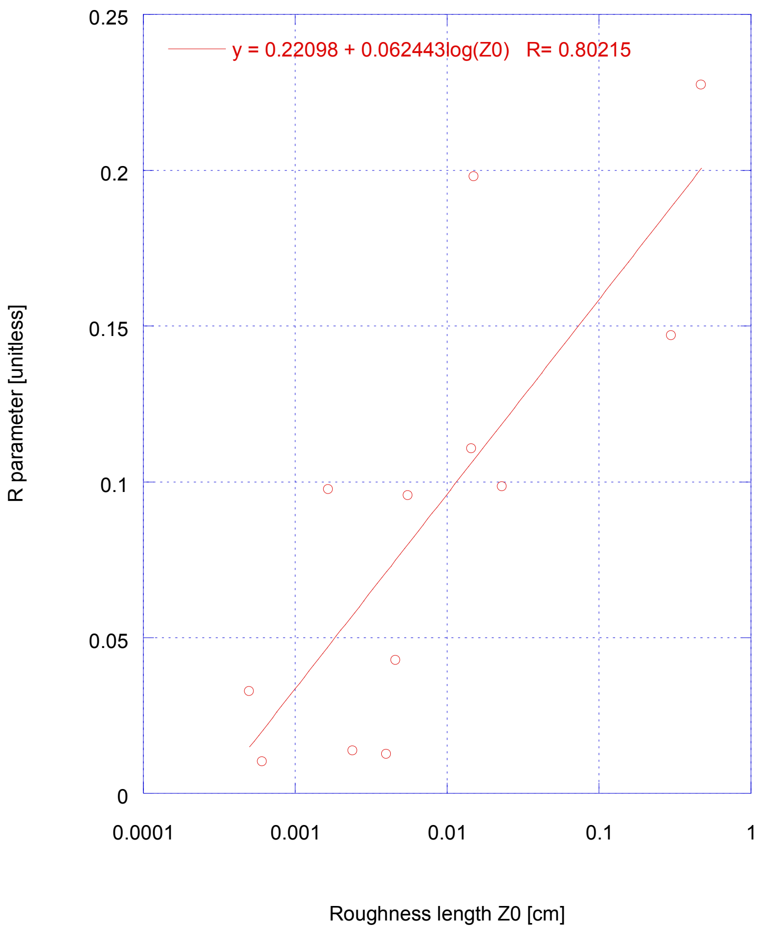


Surface Reflectance (RGB)

Details over Sahara (Roughness)



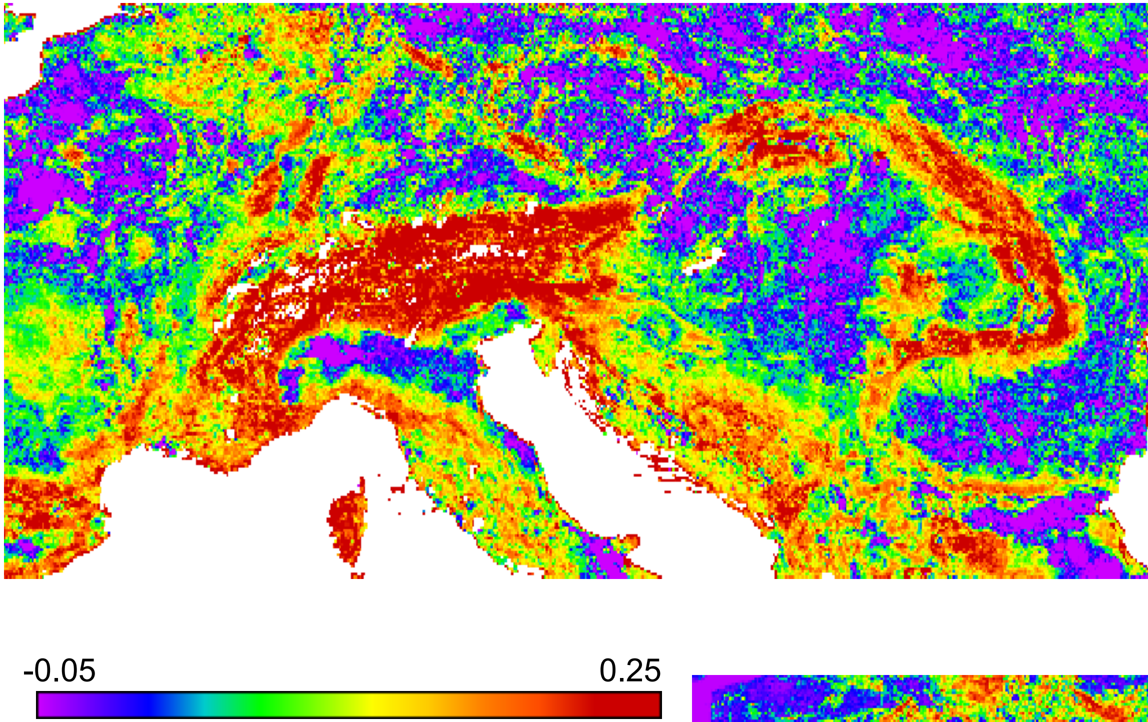
The R parameter is related to aerodynamic surface roughness length (Marticonera et al. POLDER data)



We used the dataset of roughness length collected by Greeley et al. for Namibia, Death Valley and Lunar Lake U.S.A. and the dataset collected by Marticorena et al.
for an arid surface in southern Tunisia.

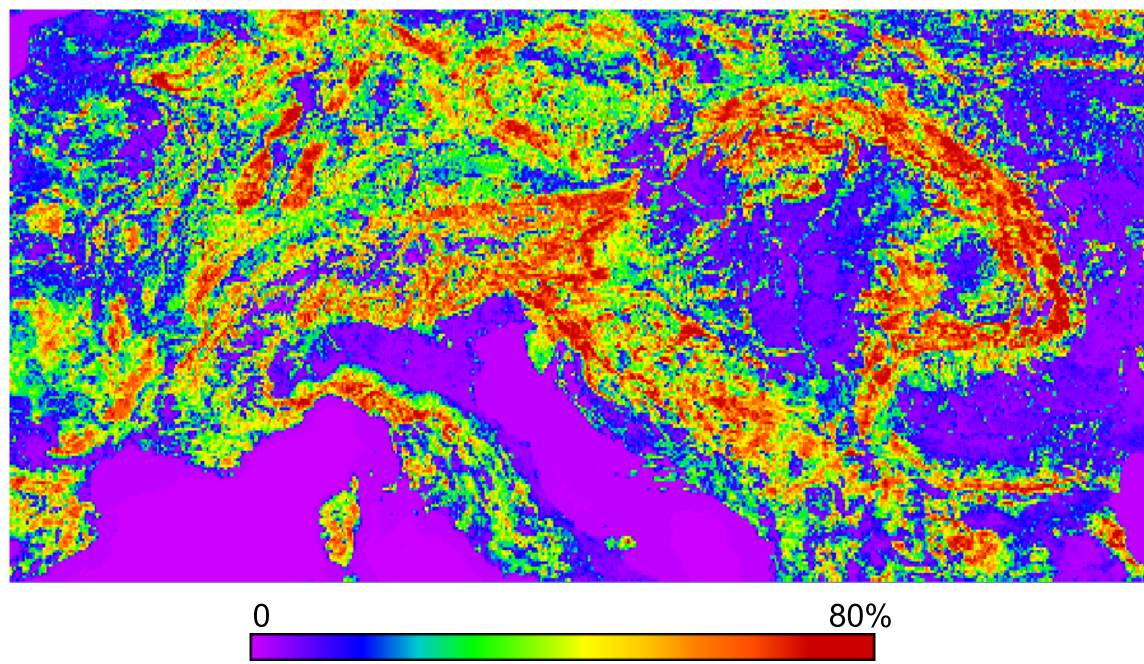
Excluding sites with substantial vegetation cover, we compared the R parameter derived from this study to the aerodynamic roughness length Z0. The relationship derived is close to the one derived by Marticorena et al. i.e. (0.277+0.052log(Z0))

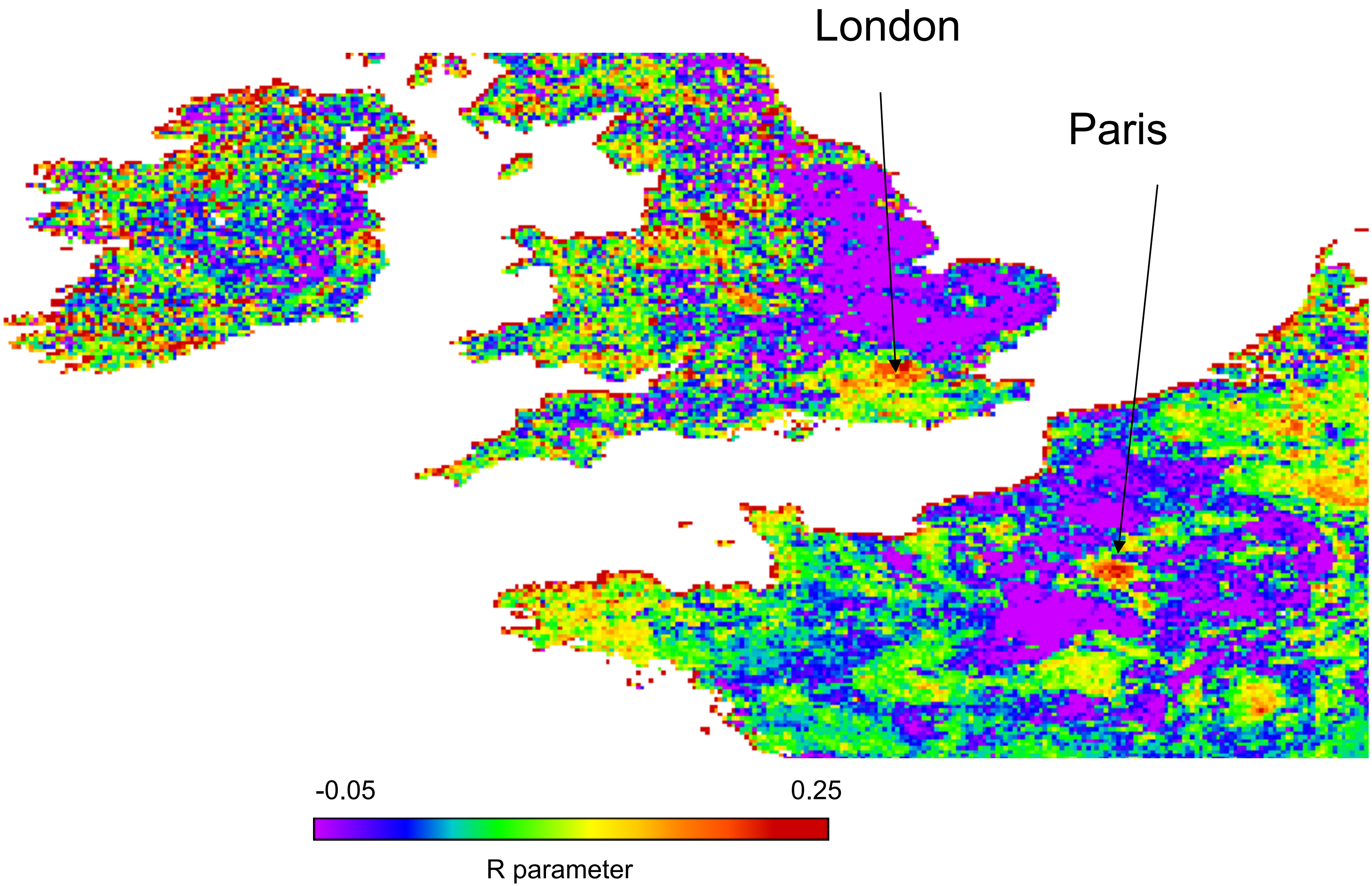
Details over Europe (Roughness)



R parameter

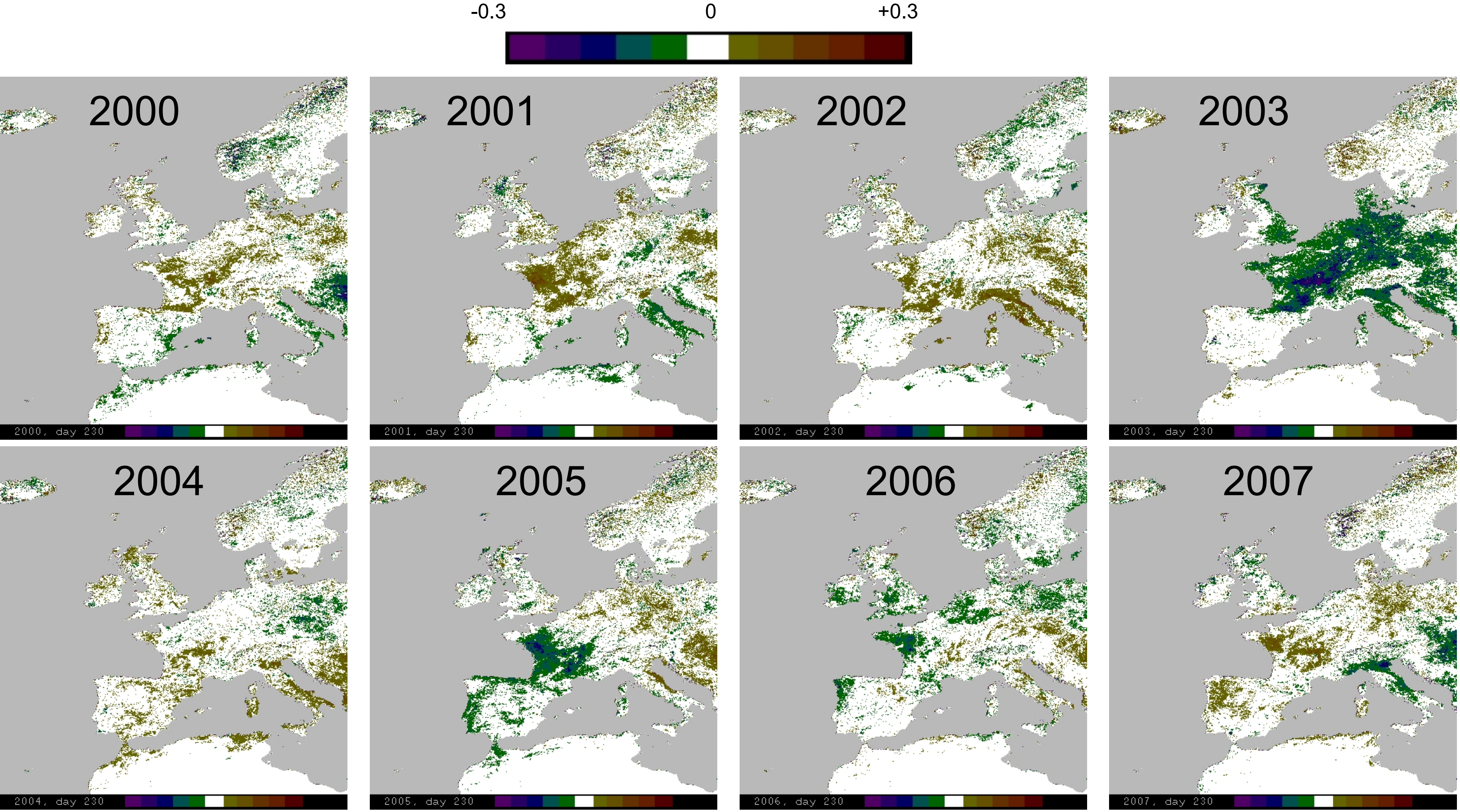
% Tree cover
Hansen et al. (2002)





High Roughness Associated with Major Cities

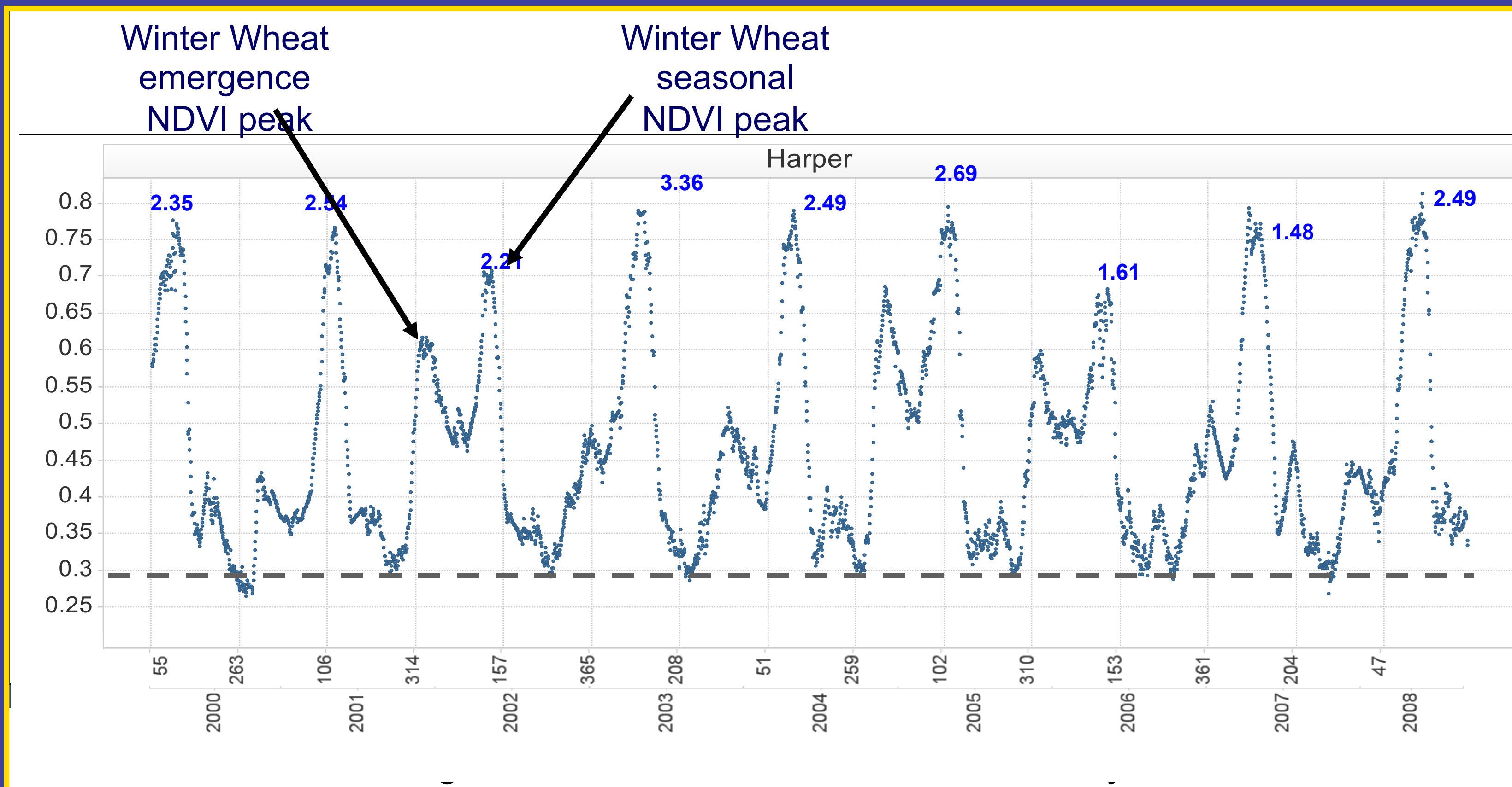
Enhanced Monitoring of vegetation MODIS- Julian Day 230- NDVI Anomaly



Extreme heat and drought in 2003 over Europe (30% reduction in GPP) resulting in a net source of Carbon Dioxide of 0.5 PgC/year (Ciais et al., Nature, 2005)

Kansas Harper County daily 0.05 degree NDVI Time Series for Winter Wheat Pixels

Blue numbers: yield in T/ha

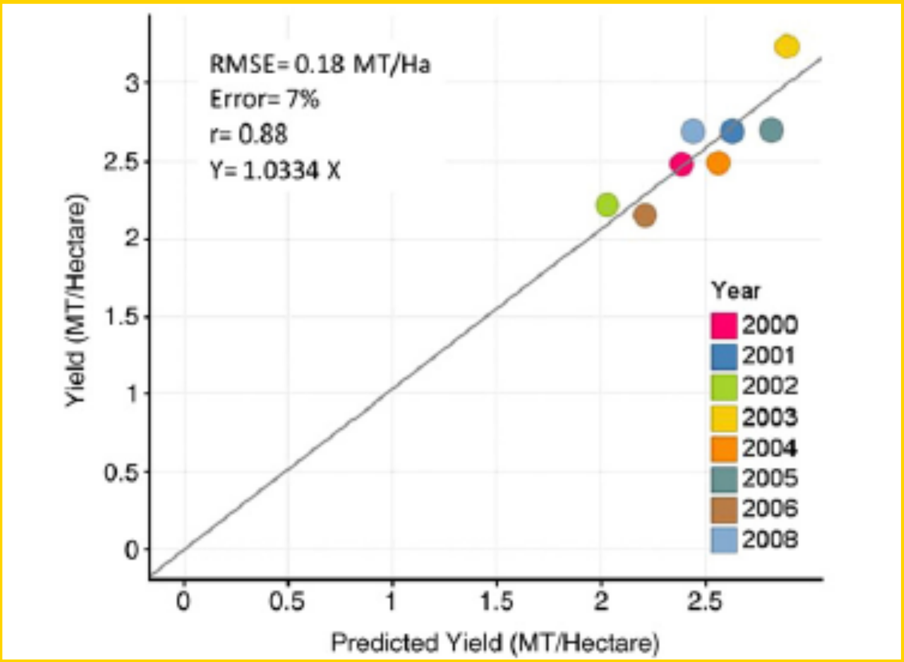


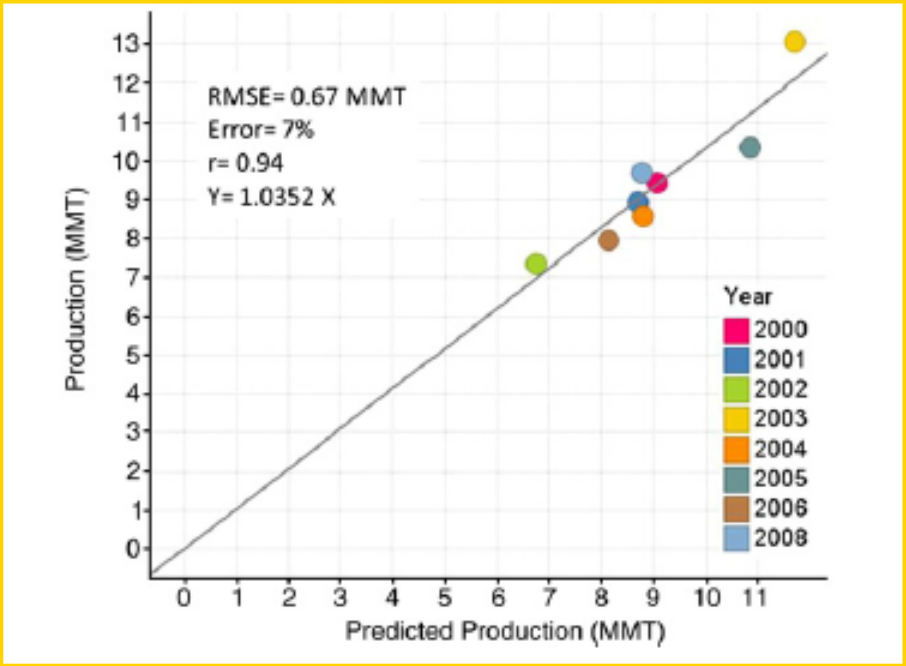
Maximum Adjusted NDVI

$$MA\_NDVI_y = VI_{max95,y} - \frac{1}{N}\left[\sum_{y=1}^{N} VI_{min5,y}\right]$$

Kansas Results:

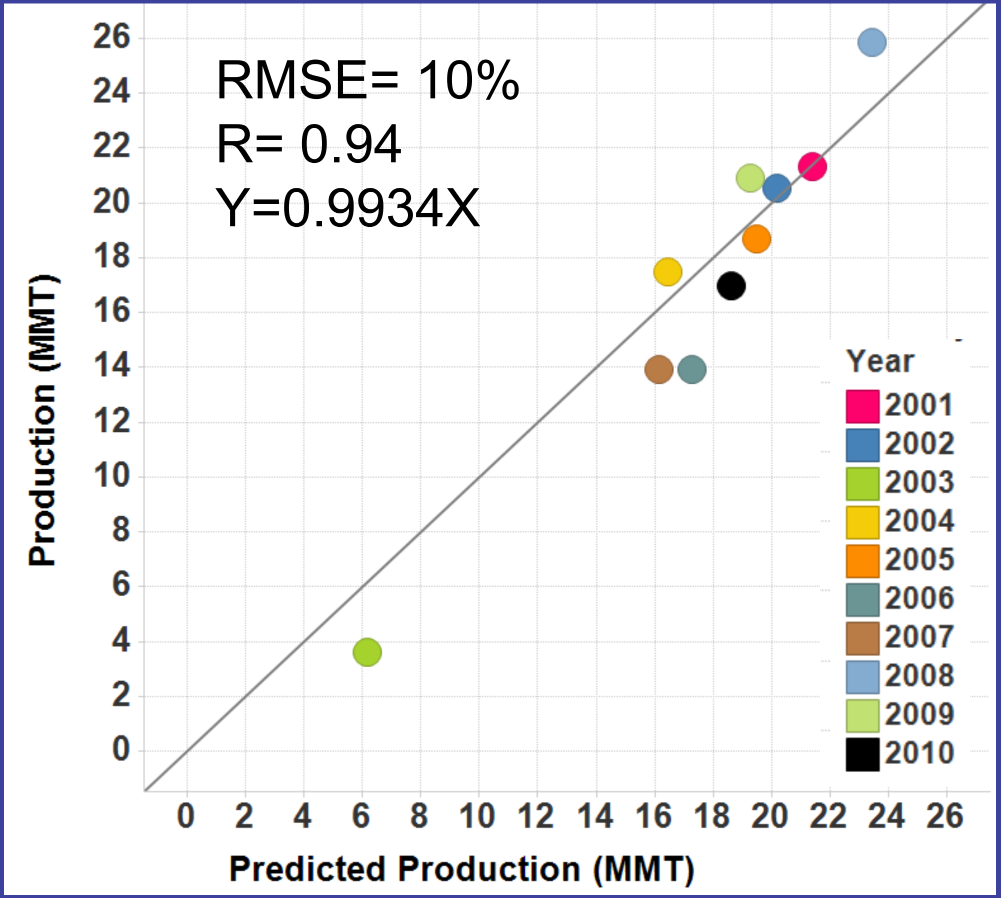
Kansas Model Estimates vs. USDA NASS Crop Statistics





Model Results in Ukraine:

Model estimated production vs. Ukrainian State Statistical Committee Crop Statistics



The model forecast 6 weeks prior to beginning of harvest was within 10% of final reported production.

Application to AVHRR

Assessing CLAVR using MODIS shows the need of an improved cloud mask (1/2)

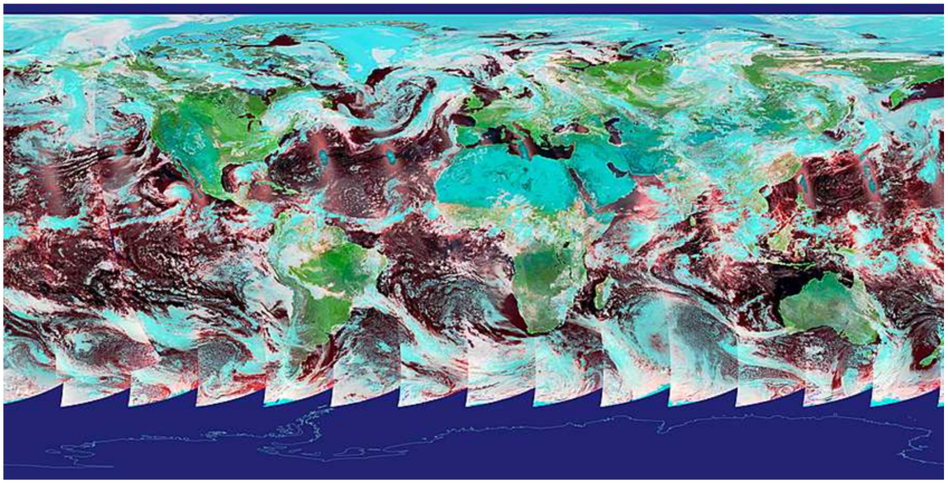


Figure 5a: *AVHRR (NOAA16) LTDR surface reflectance product (B:0.67µm G:0.87µm,R:3.75µm) for day 193 of 2003.*

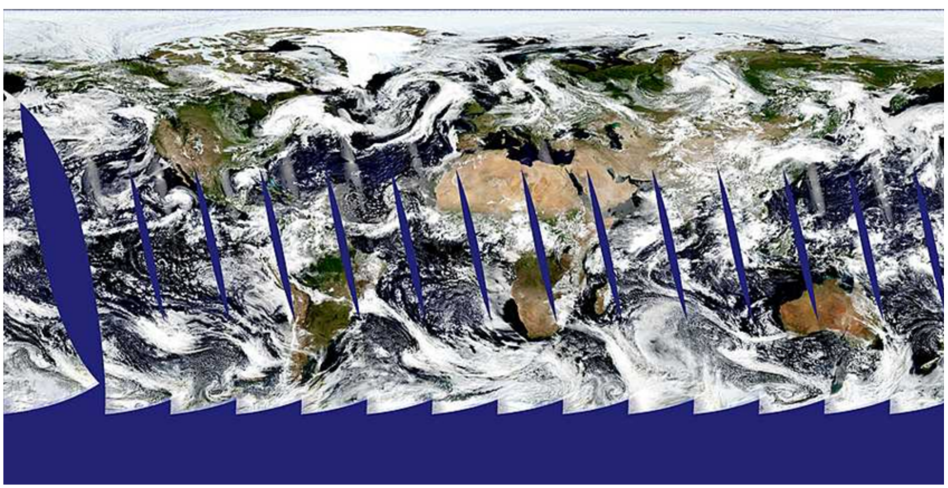


Figure 5b: *MODIS Aqua LTDR surface reflectance product (B:0.47µm, G:0.55µm,R:0.67µm) for day 193 of 2003 near coincident with the AVHRR data.*

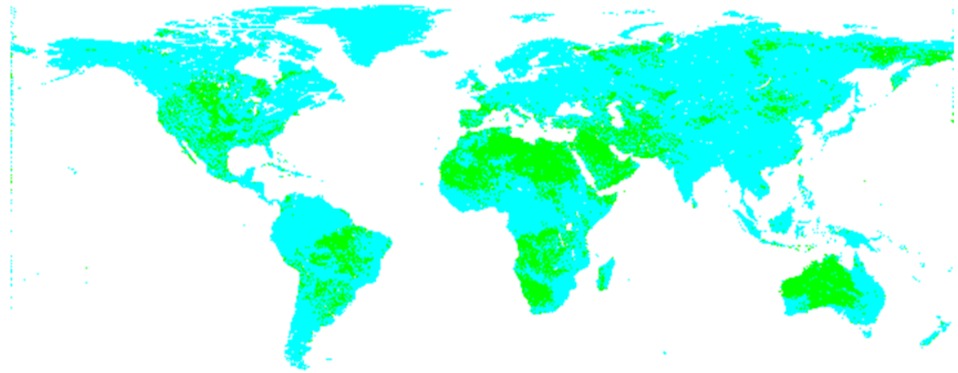


Figure 5c *:Results of the CLAVR cloud mask over land (mixed and cloudy) for NOAA16 AVHRR Day 193 year 2003, cloud are in blue and clear pixels are in green*

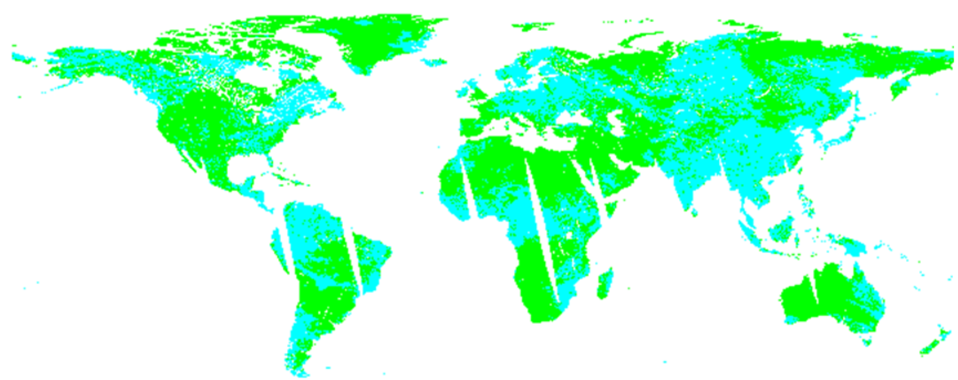
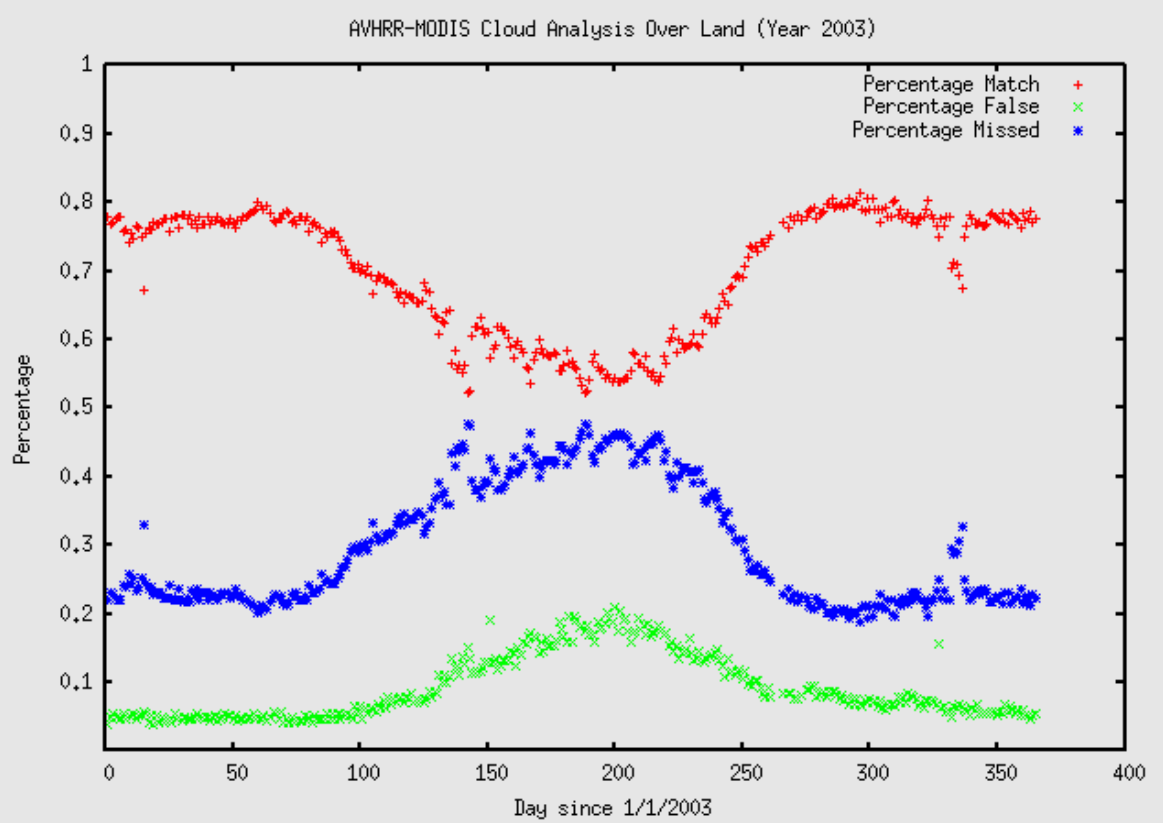


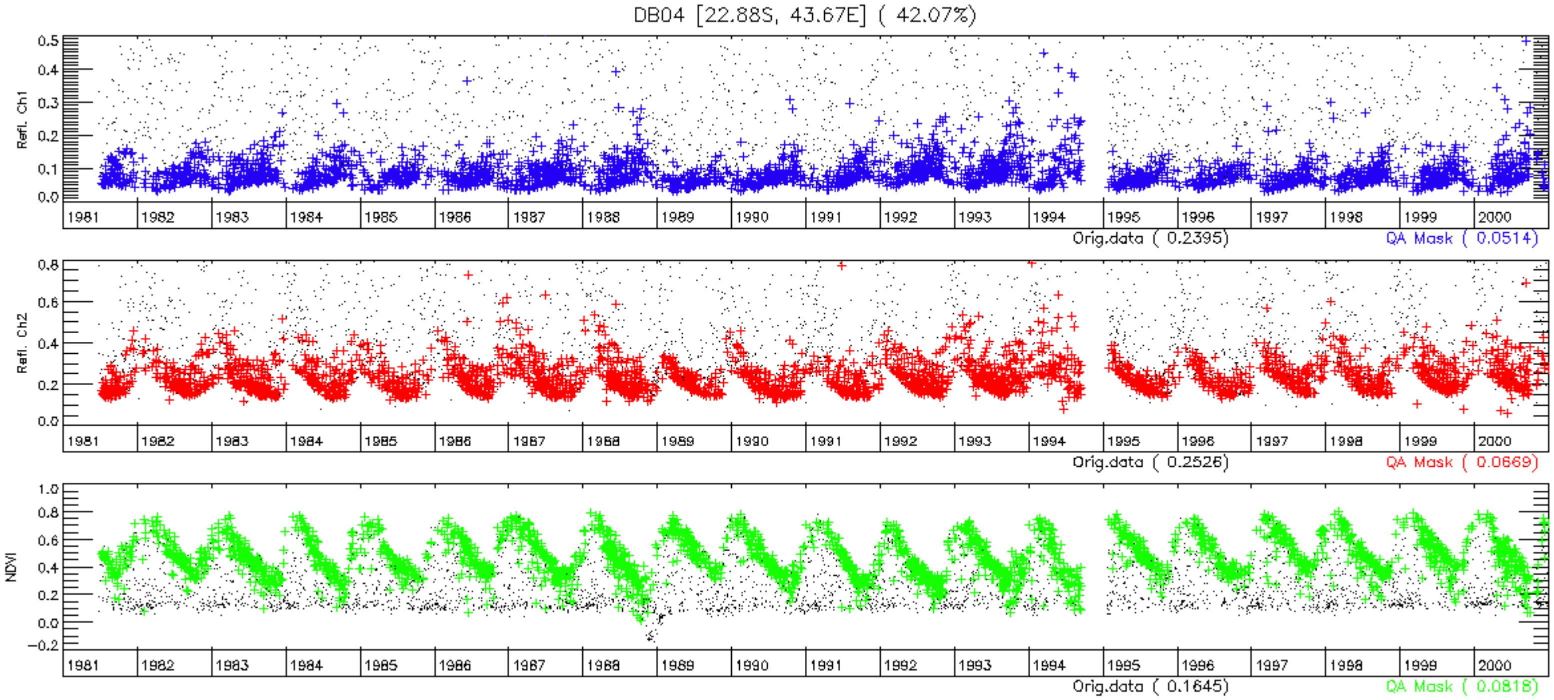
Figure 5d: *Result of the MODIS internal cloud mask over land for Aqua Day 193 year 2003 cloud are in blue and clear pixels are in green*

Assessing CLAVR using MODIS shows the need of an improved cloud mask (2/2)

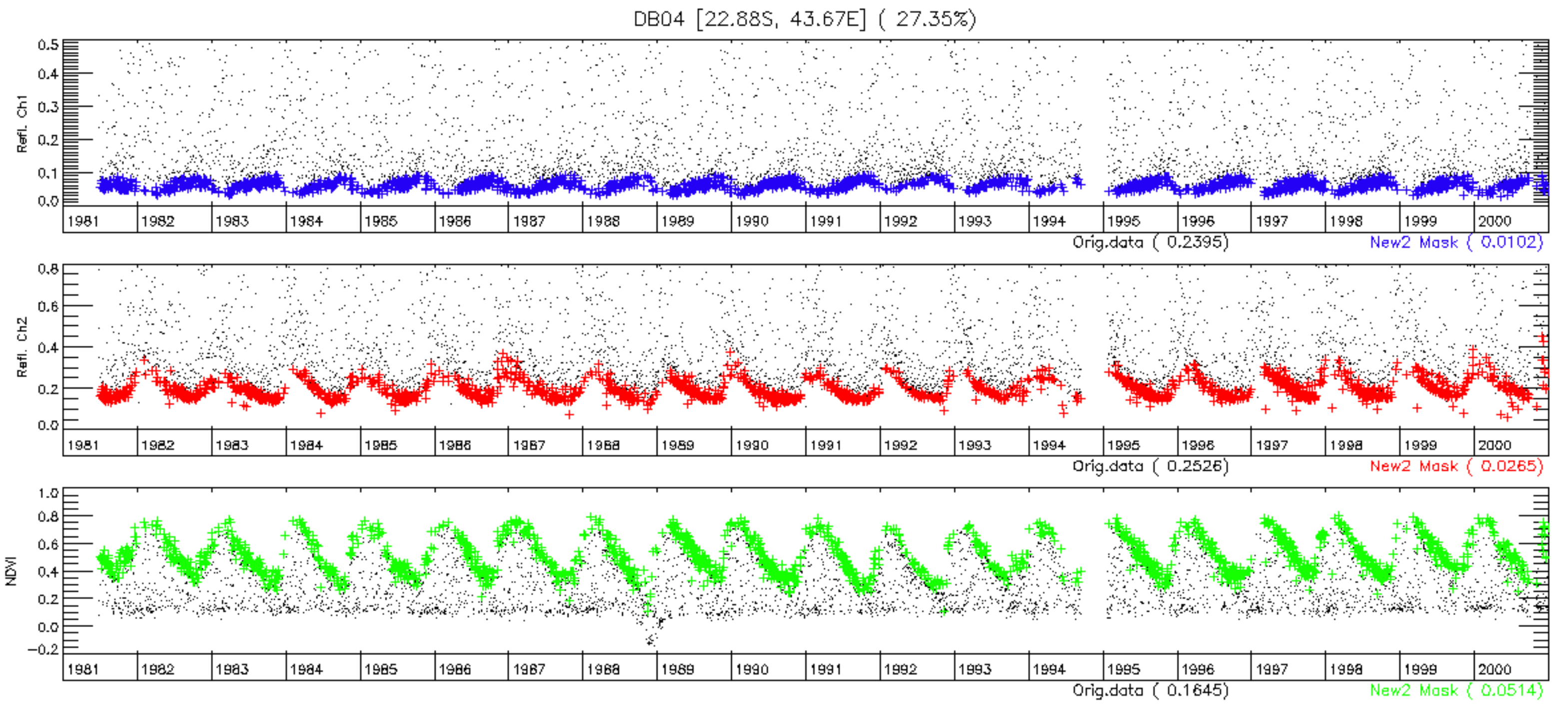


Evaluation of the global performance of the CLAVR Algorithm reported as percentage. Overall CLAVR identified only 2/3 of the cloud flagged by MODIS (red points), and labeled about 1/3 of the observation flagged as clear by MODIS as cloudy (blue points).

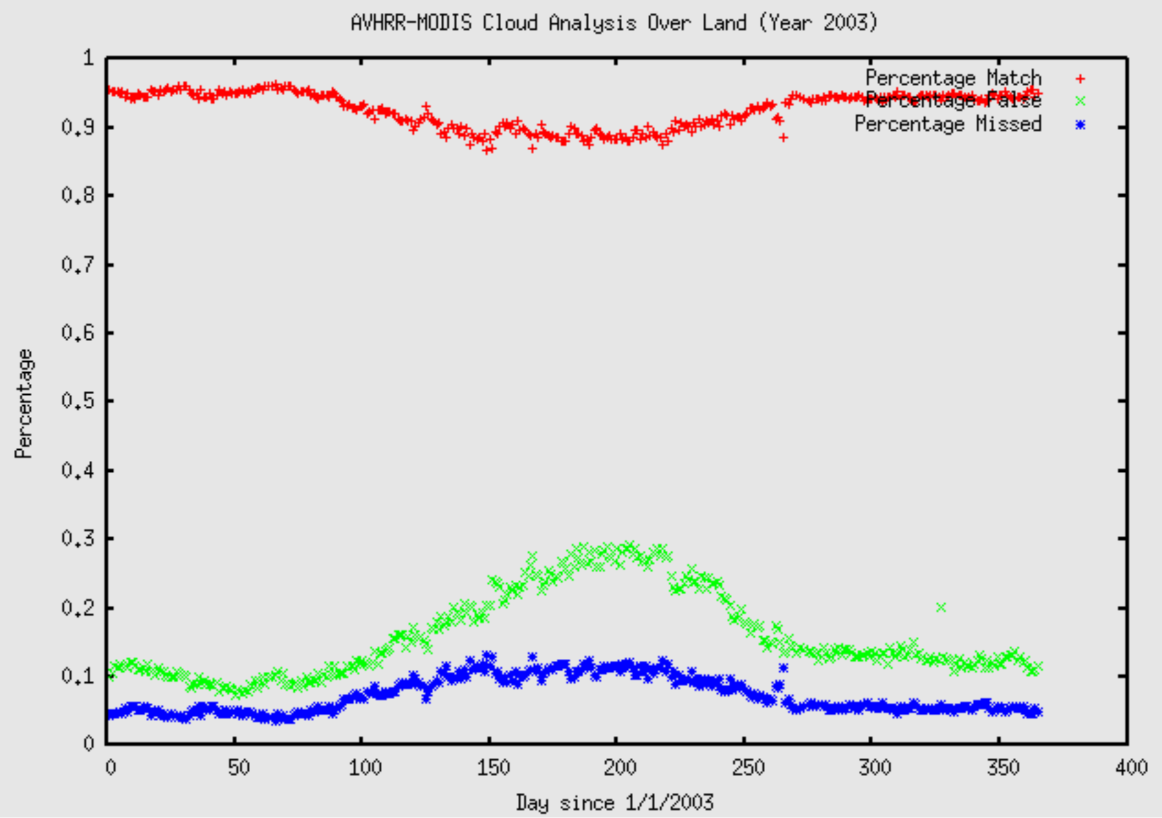
AVHRR Time series CLAVR mask



AVHRR Time series LTDR cloud mask



New improved cloud mask for AVHRR



Evaluation of the global performance of the LTDR v3 cloud mask Algorithm reported as percentage.

Applying MODIS BRDF correction and atmospheric correction to account for AVHRR orbital drift

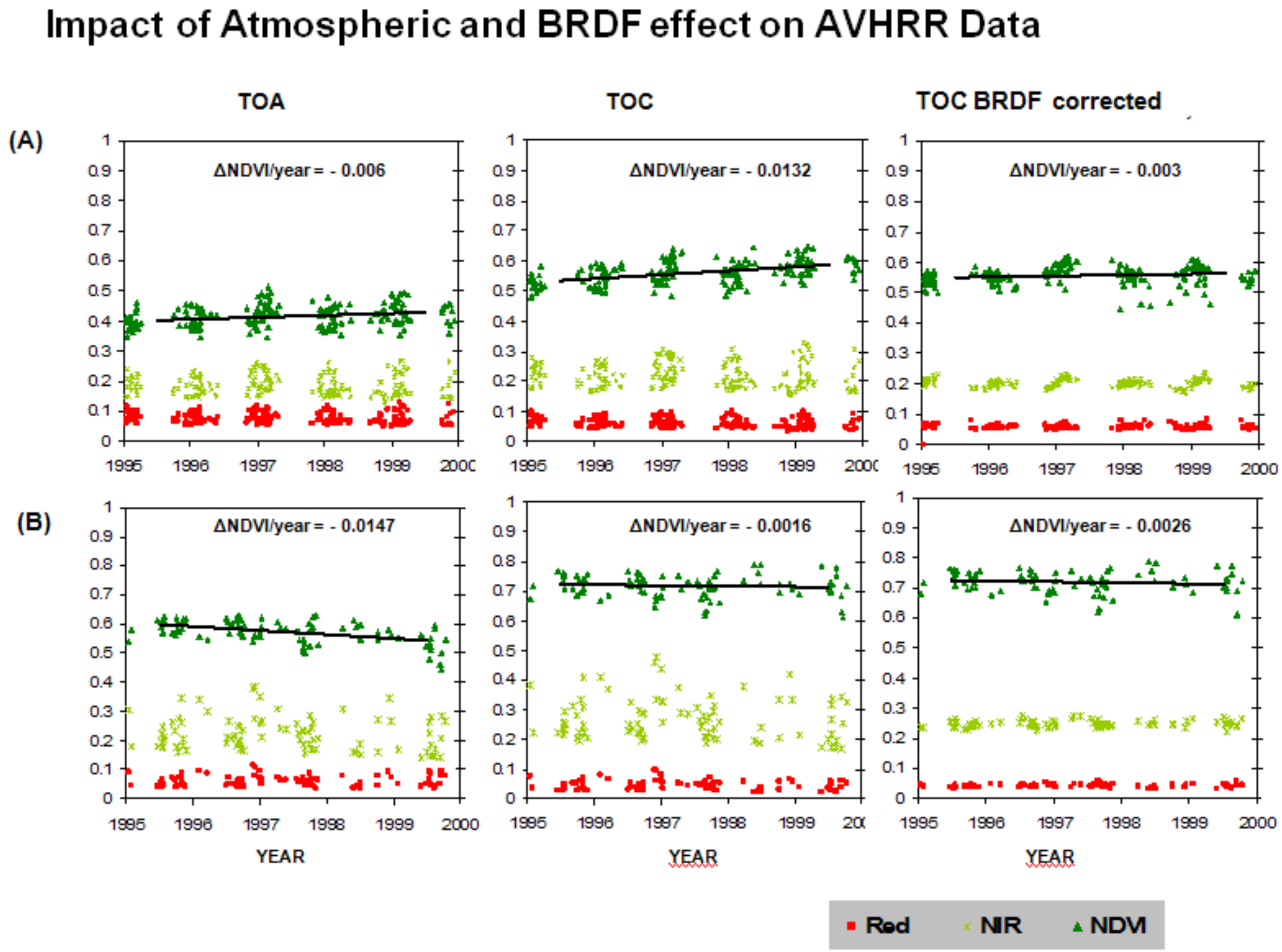


Figure 2a: Impact of the orbital drift on NOAA14 (1995-1999) data for two evergreen forest sites in Australia, (A) with 50% tree cover, (B) with 95% tree cover. TOA is top of the atmosphere, TOC is the Top of the canopy, BRDF corrected uses the correction described in 2.3.5.

MERCI !