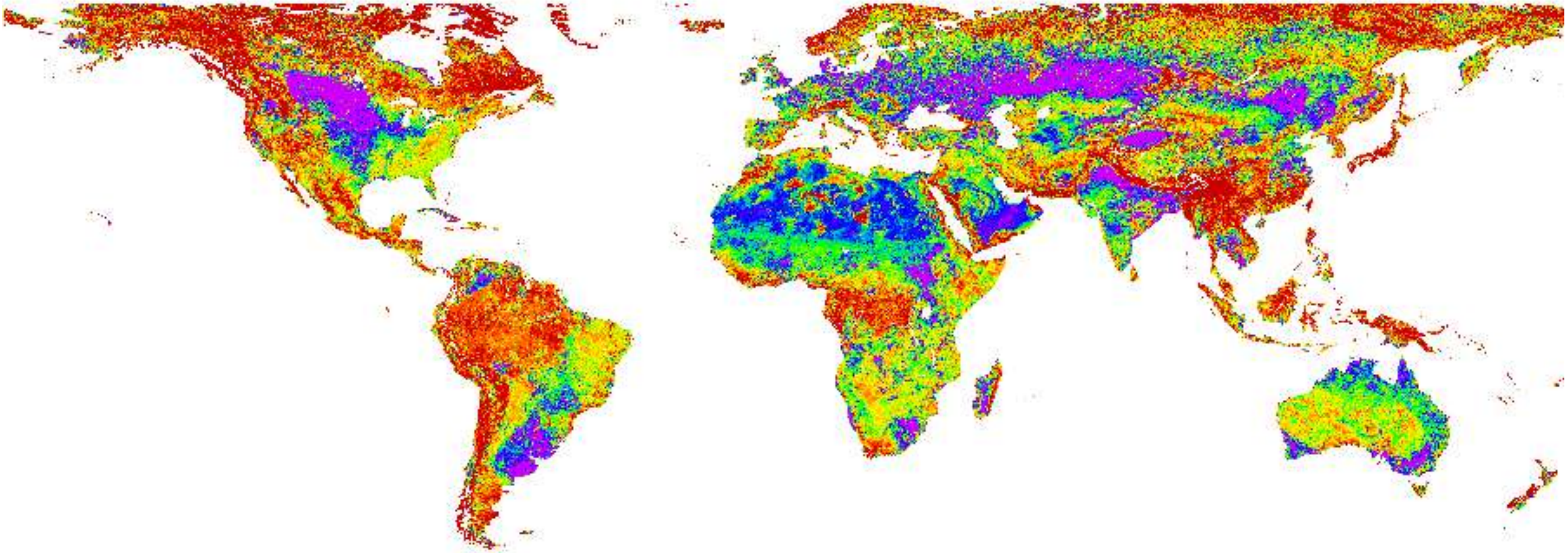
“Using MODIS and POLDER data to develop a generalized approach for correction of the BRDF effect”



Eric F. Vermote, Christopher O. Justice
Dept of Geography, UMCP
Francois-Marie Breon
Laboratoire des Sciences du Climat et de l’Environnement,
Unité Mixte de Recherche CEA-CNRS-UVSQ
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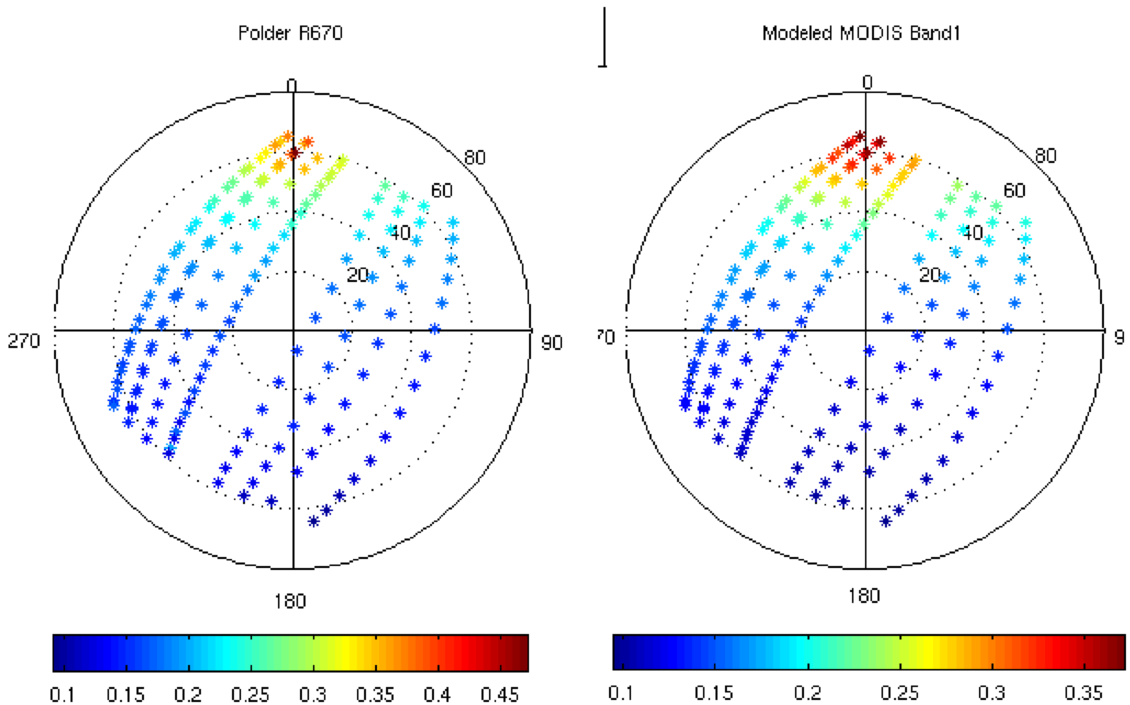
Introduction

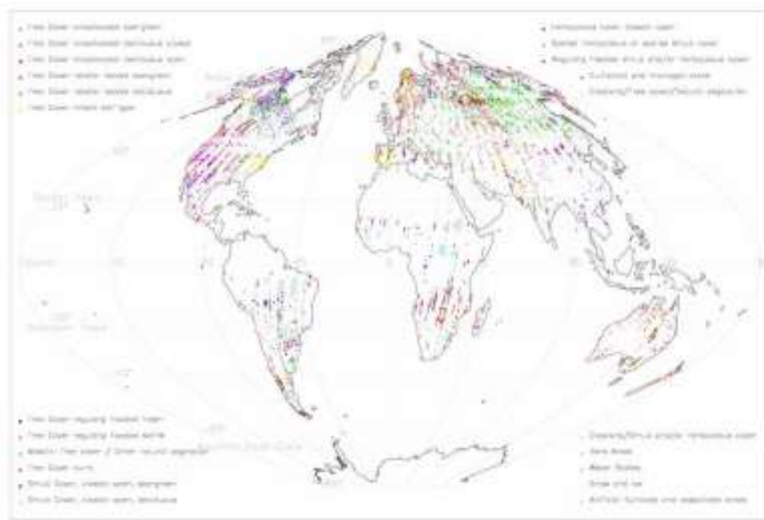
- The effect of surface anisotropy on remotely sensed satellite data has been the subject of intensive research over the past 20 years The surface reflectance is described by the Bidirectional Reflectance Distribution Function (BRDF), which is a function of the sun zenith angle θ_s, the view zenith angle θ_v, and both azimuths ϕ_s and ϕ_v with respect to a reference direction. In practice, for most applications, the azimuth variations only depend on the relative azimuth $\phi=\phi_s-\phi_v$.



Directional reflectance observed for an evergreen needle leaf forest from Schaaf et al.

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

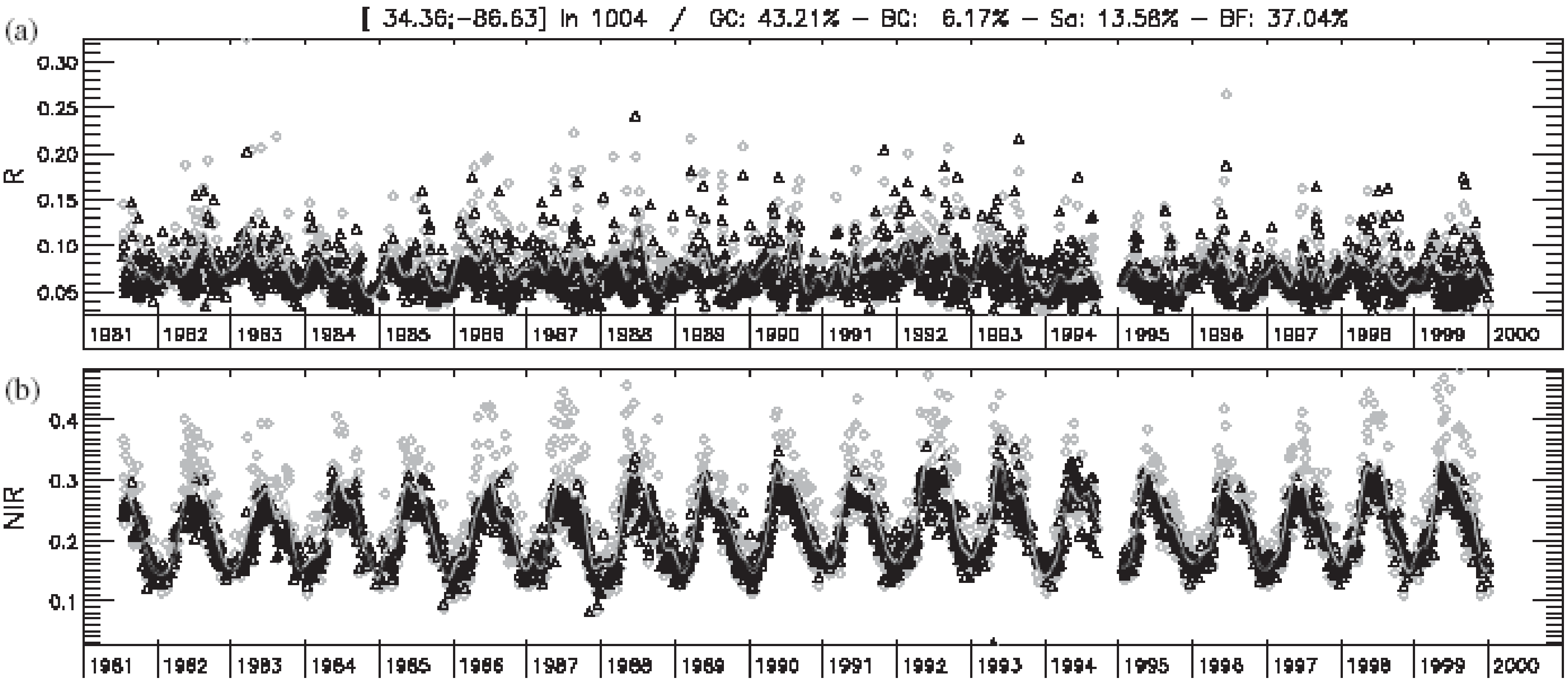


$$\rho(\theta_s,\theta_v,\phi) = k_0 + k_1\, F_1(\theta_s,\theta_v,\phi) + k_2\, F_2(\theta_s,\theta_v,\phi)$$
$$= k_0\left[1 + \frac{k_1}{k_0}\, F_1(\theta_s,\theta_v,\phi) + \frac{k_2}{k_0}\, F_2(\theta_s,\theta_v,\phi)\right]$$

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.

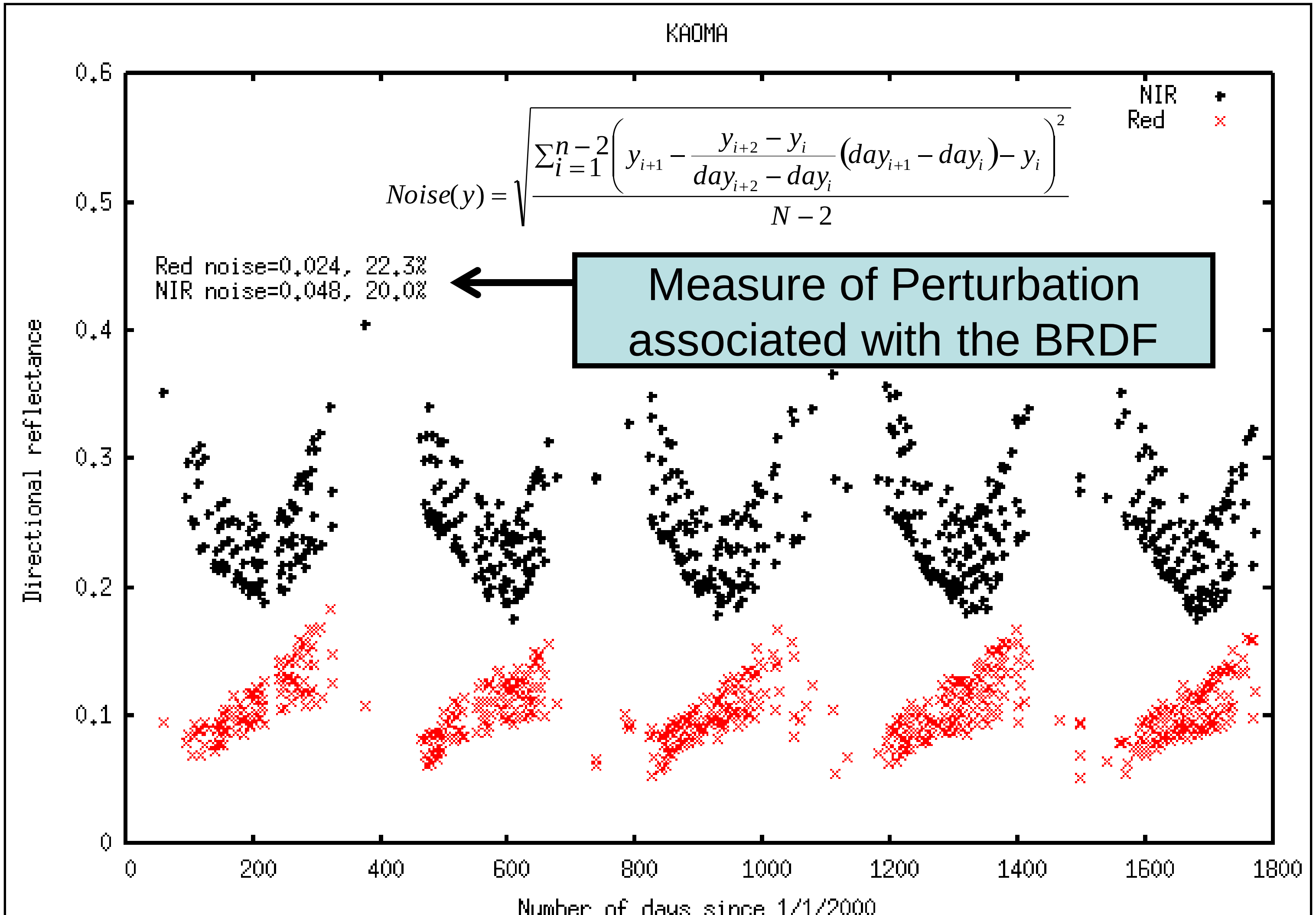
The POLDER results toward a generic BRDF

- 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



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

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

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

The equation to be solved is still linear

$$\begin{pmatrix} \sum_{i=1}^{N-1} \Delta^i \rho F_1 \, \Delta^i \rho F_1 & \sum_{i=1}^{N-1} \Delta^i \rho F_1 \, \Delta^i \rho F_2 \\ \sum_{i=1}^{N-1} \Delta^i \rho F_1 \, \Delta^i \rho F_2 & \sum_{i=1}^{N-1} \Delta^i \rho F_2 \, \Delta^i \rho F_2 \end{pmatrix} \otimes \begin{pmatrix} V \\ R \end{pmatrix} = \begin{pmatrix} -\sum_{i=1}^{N-1} \Delta^i \rho \, \Delta^i \rho F_1 \\ -\sum_{i=1}^{N-1} \Delta^i \rho \, \Delta^i \rho F_2 \end{pmatrix}$$

with

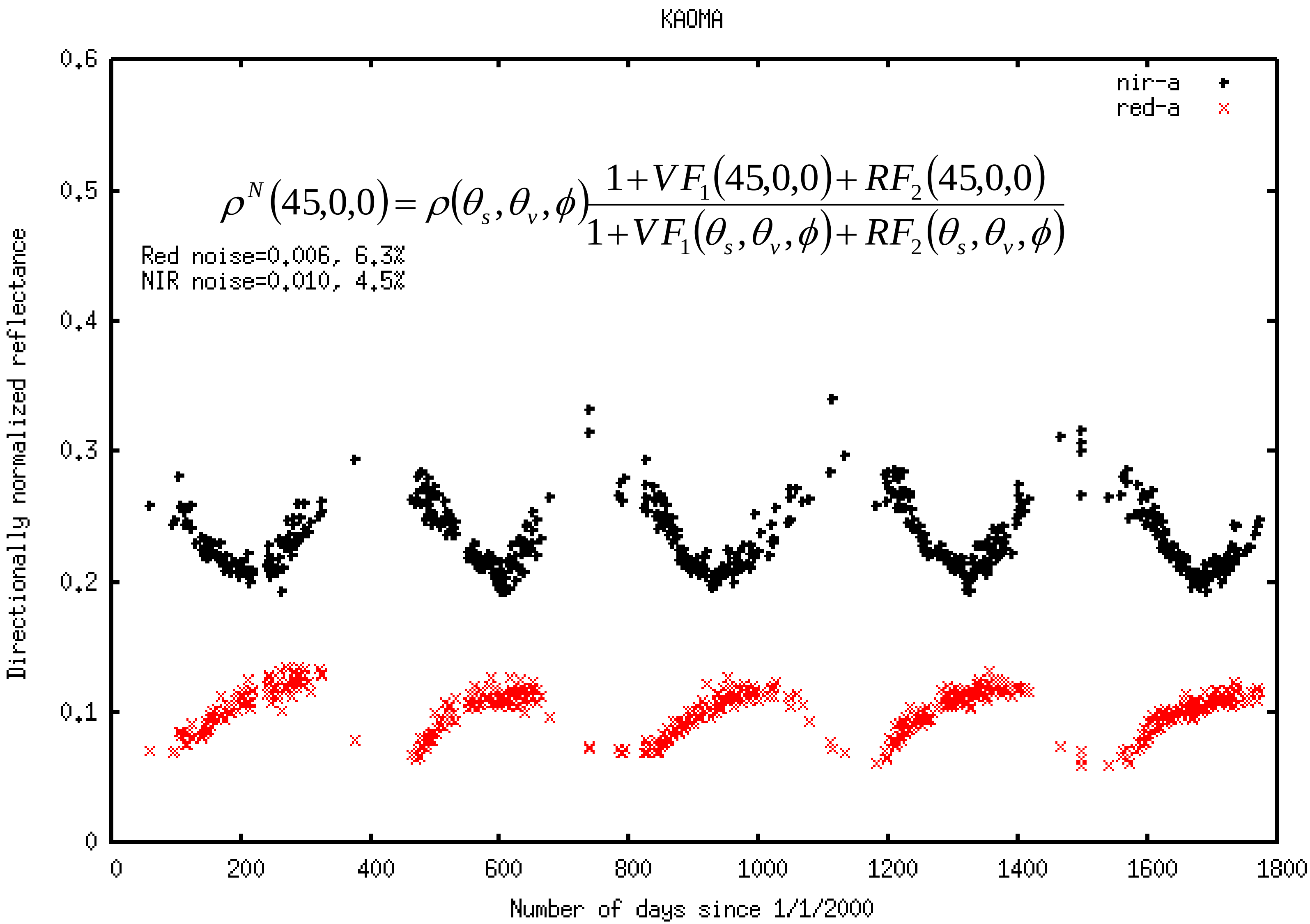
$$\Delta^i d = day_{i+1} - day_i + 1$$

$$\Delta^i \rho = (\rho_{i+1} - \rho_i) / \sqrt{\Delta^i d}$$

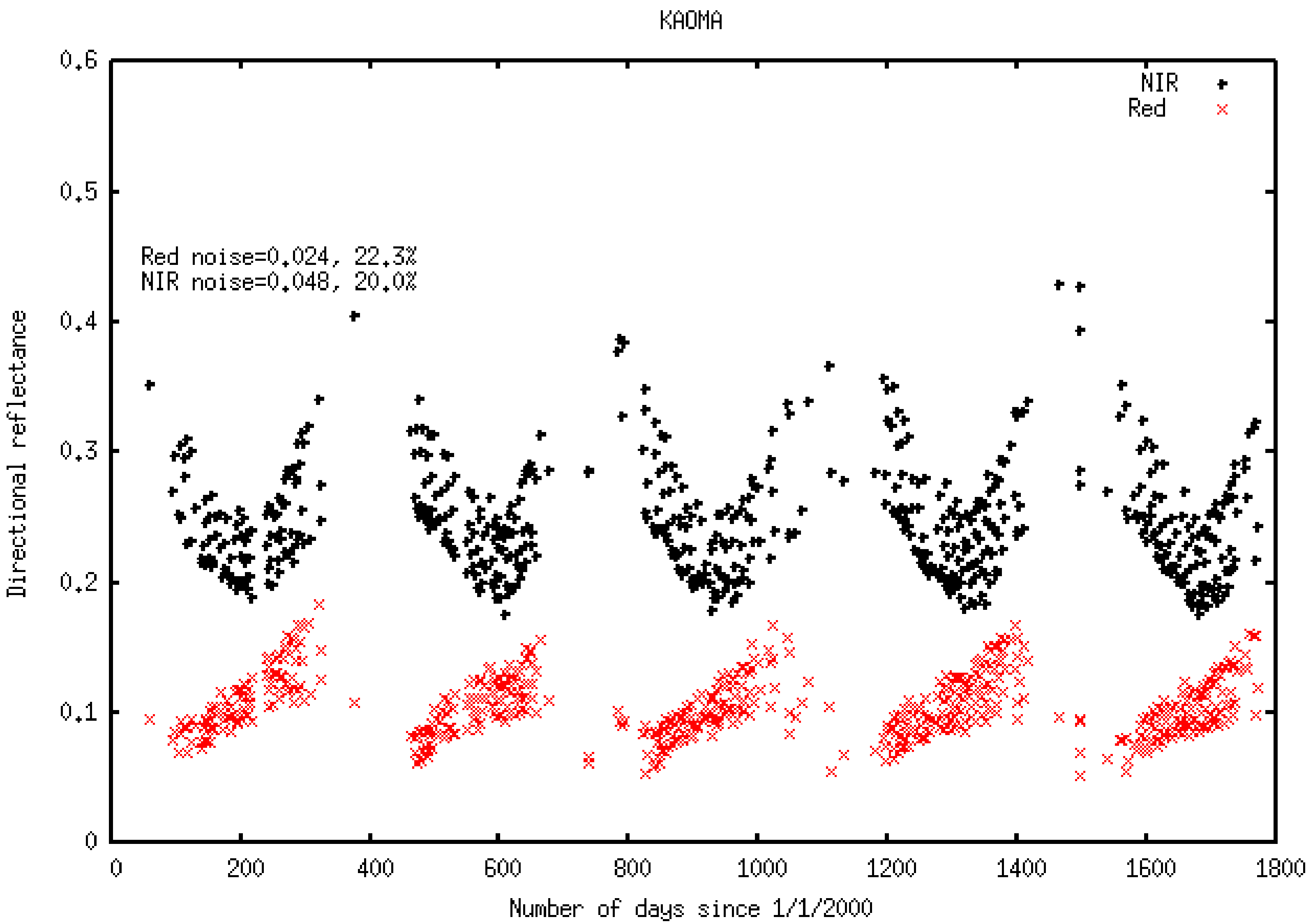
$$\Delta^i \rho F_1 = \left(\rho_{i+1} F_1^i - \rho_i F_1^{i+1} \right) / \sqrt{\Delta^i d}$$

$$\Delta^i \rho F_2 = \left(\rho_{i+1} F_2^i - \rho_i F_2^{i+1} \right) / \sqrt{\Delta^i d}$$

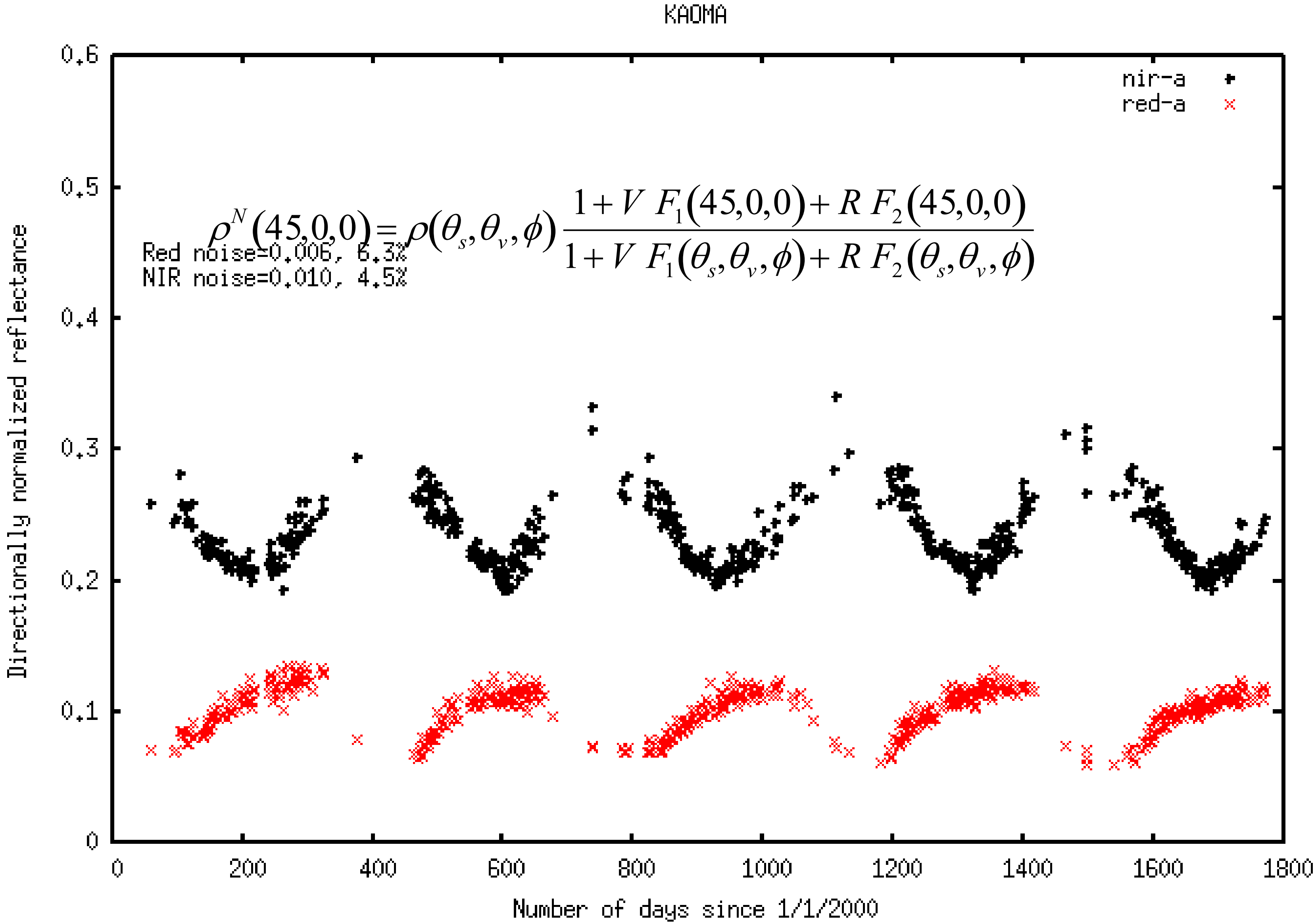
Time series of normalized reflectance using the classical approach (tropical savanna)



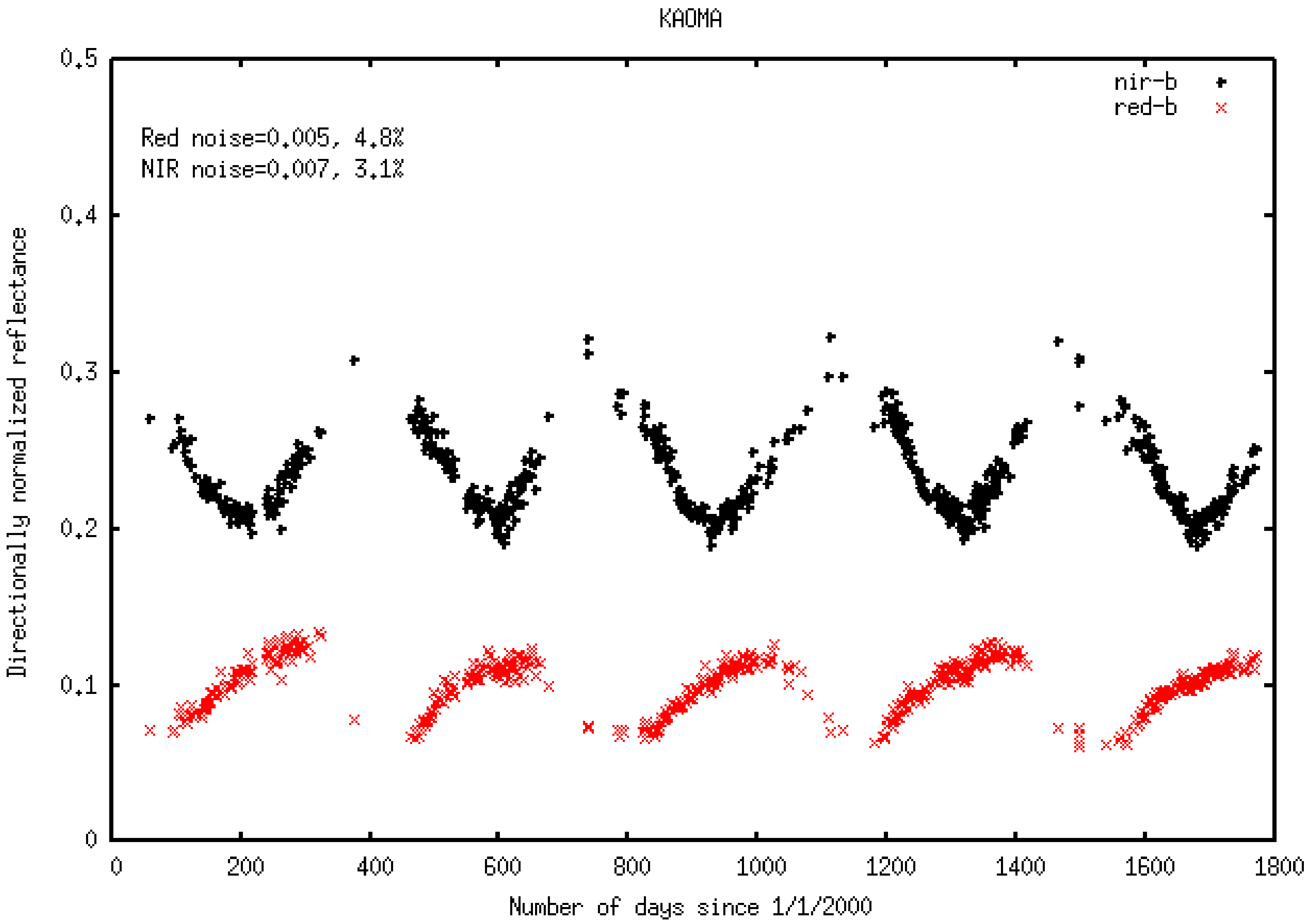
Uncorrected Reflectance Data



Time series of normalized reflectance using the classical approach

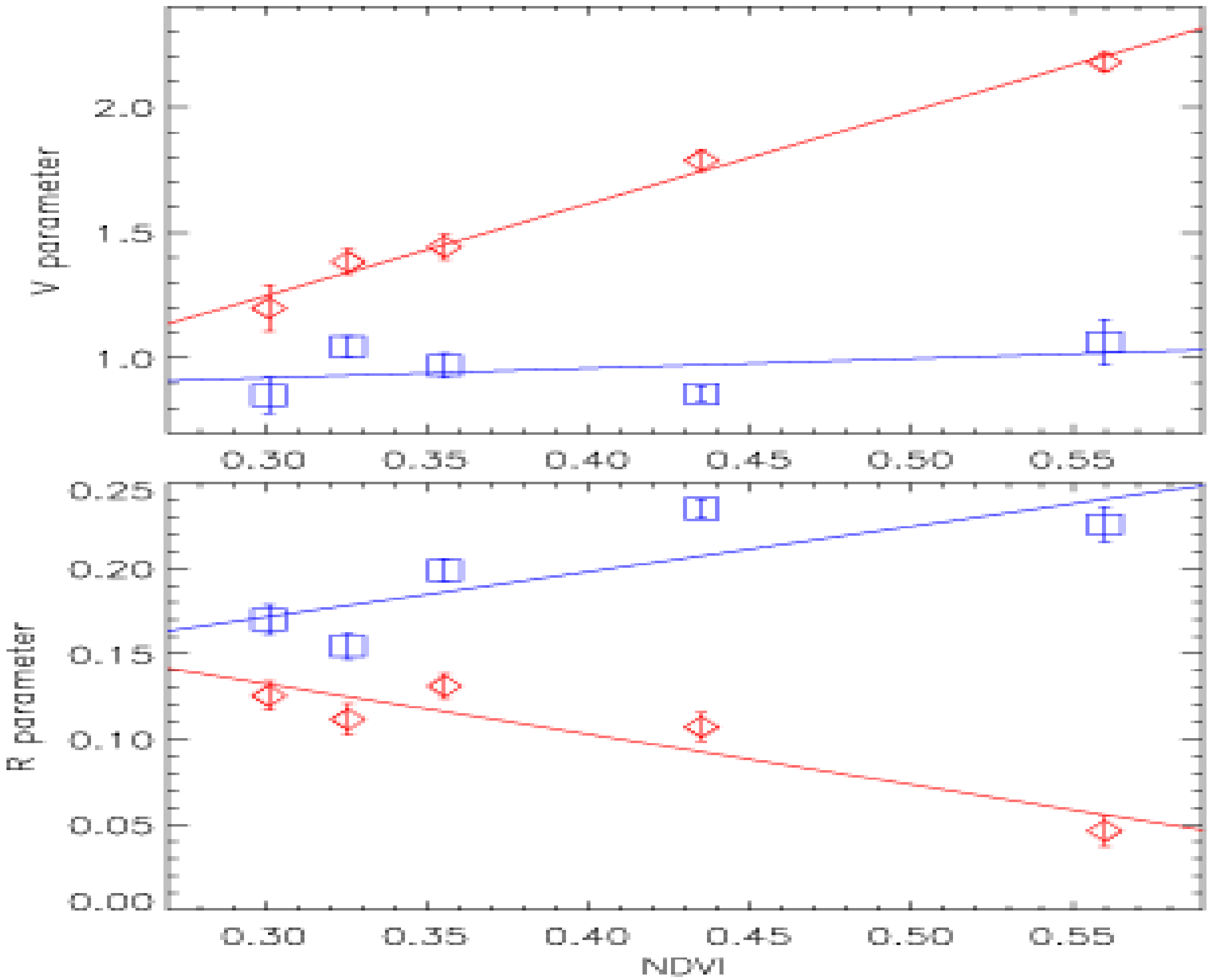


Time-series of normalized reflectance using the new approach



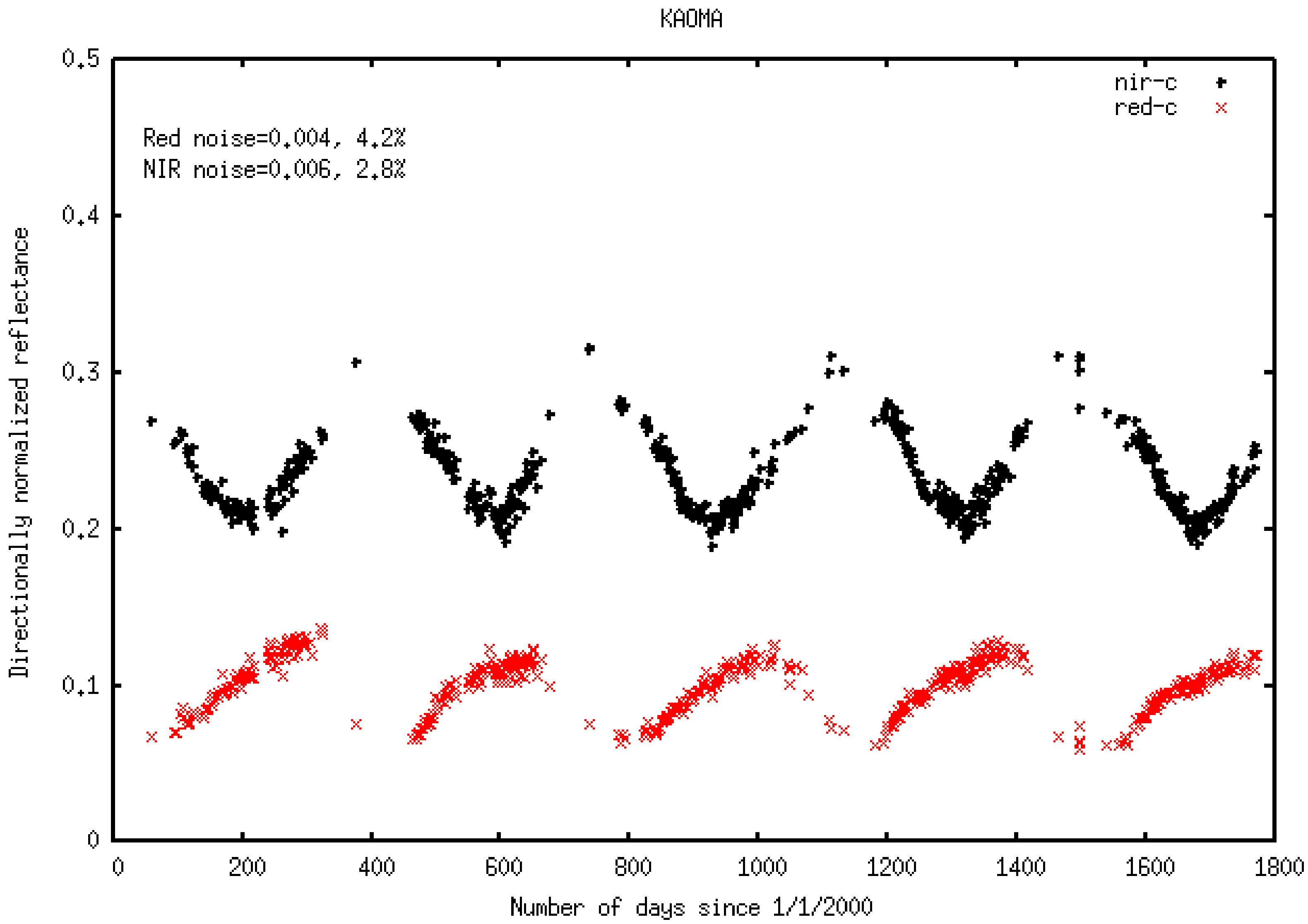
Further improvements allow the V (volume parameter) and R (roughness parameter) to vary as a function of NDVI

Red: band 2
Blue: band 1

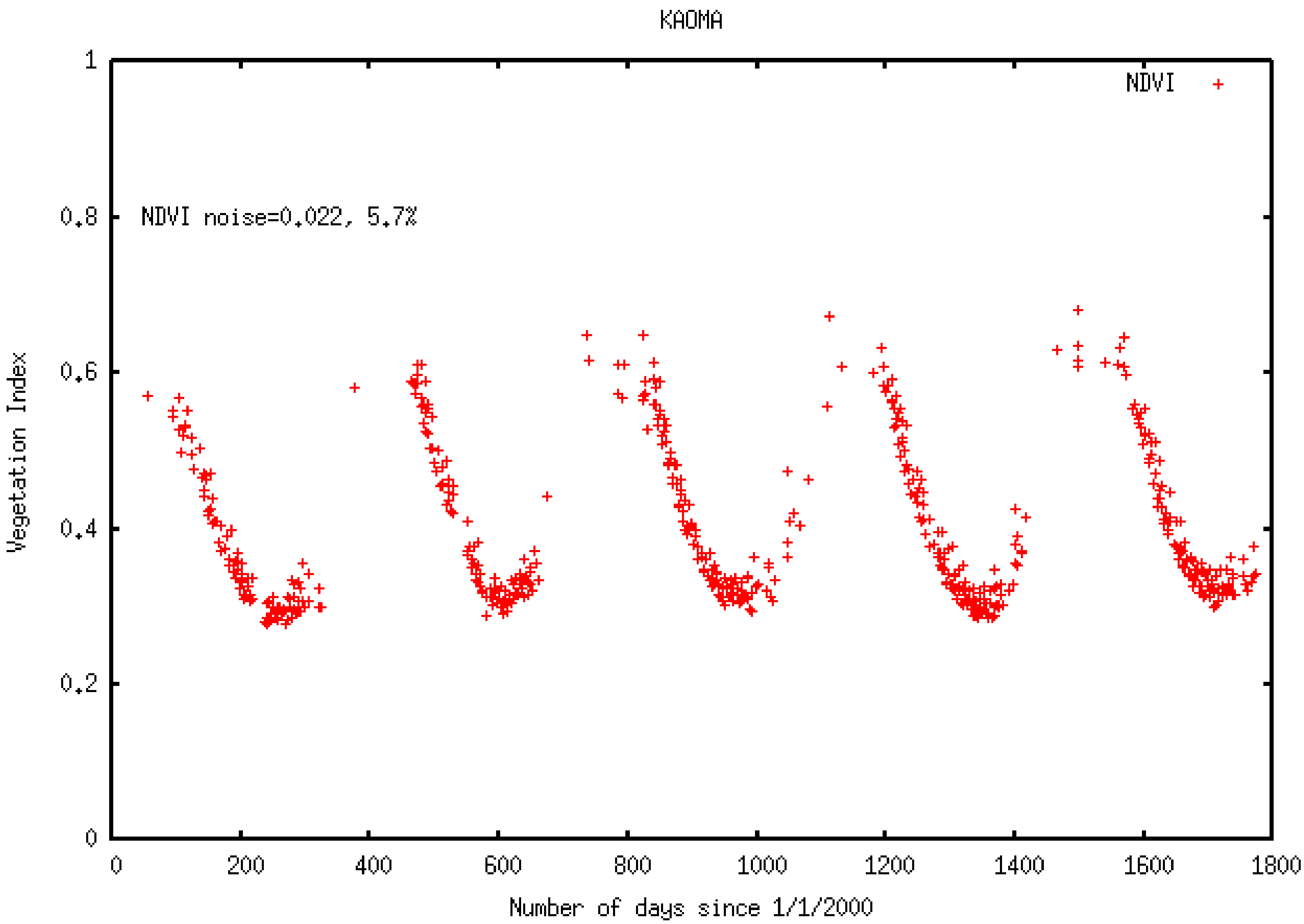


Improving Correction by Stratifying by Vegetation ‘Amount’ over Time

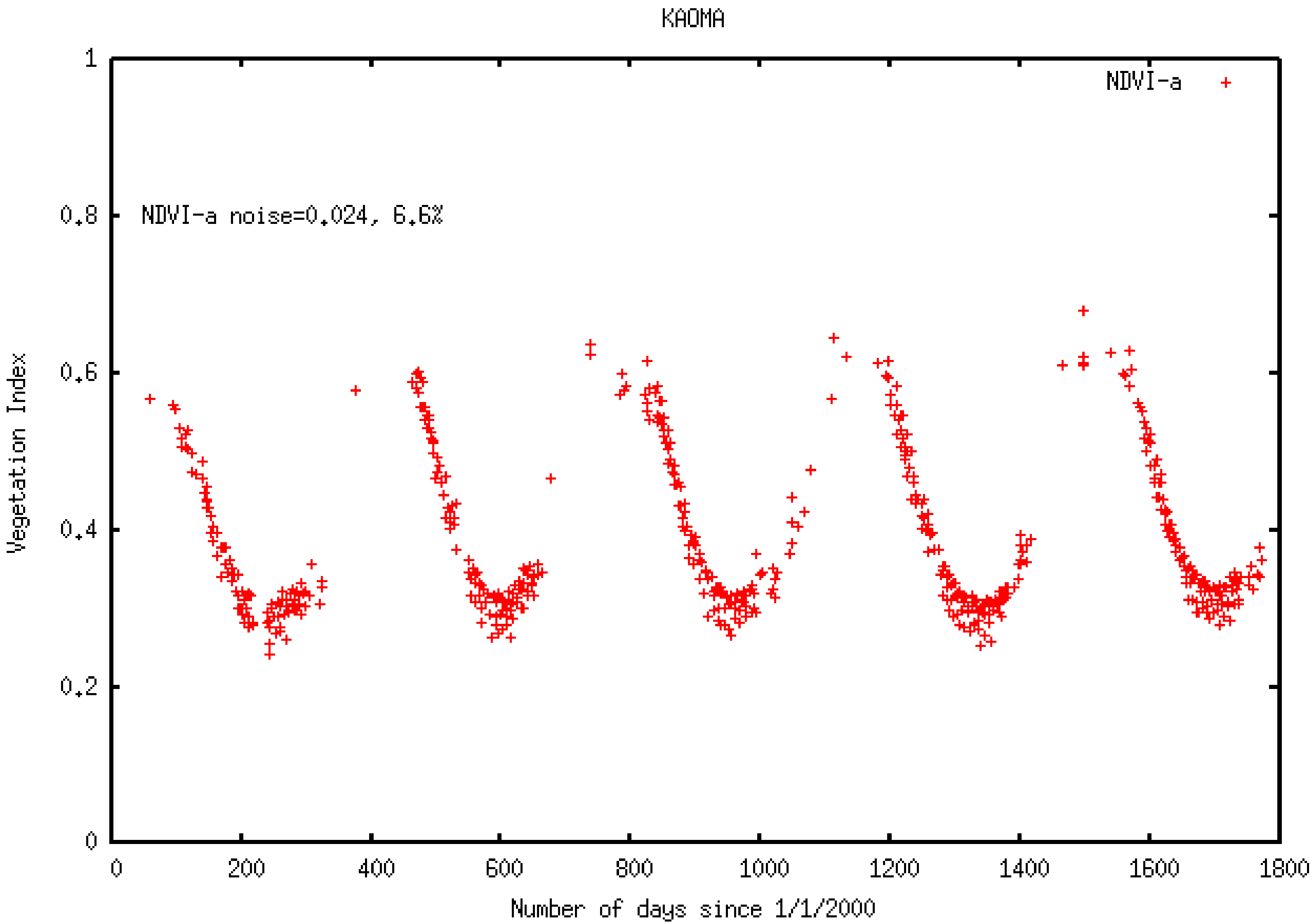
Results of final BRDF Correction



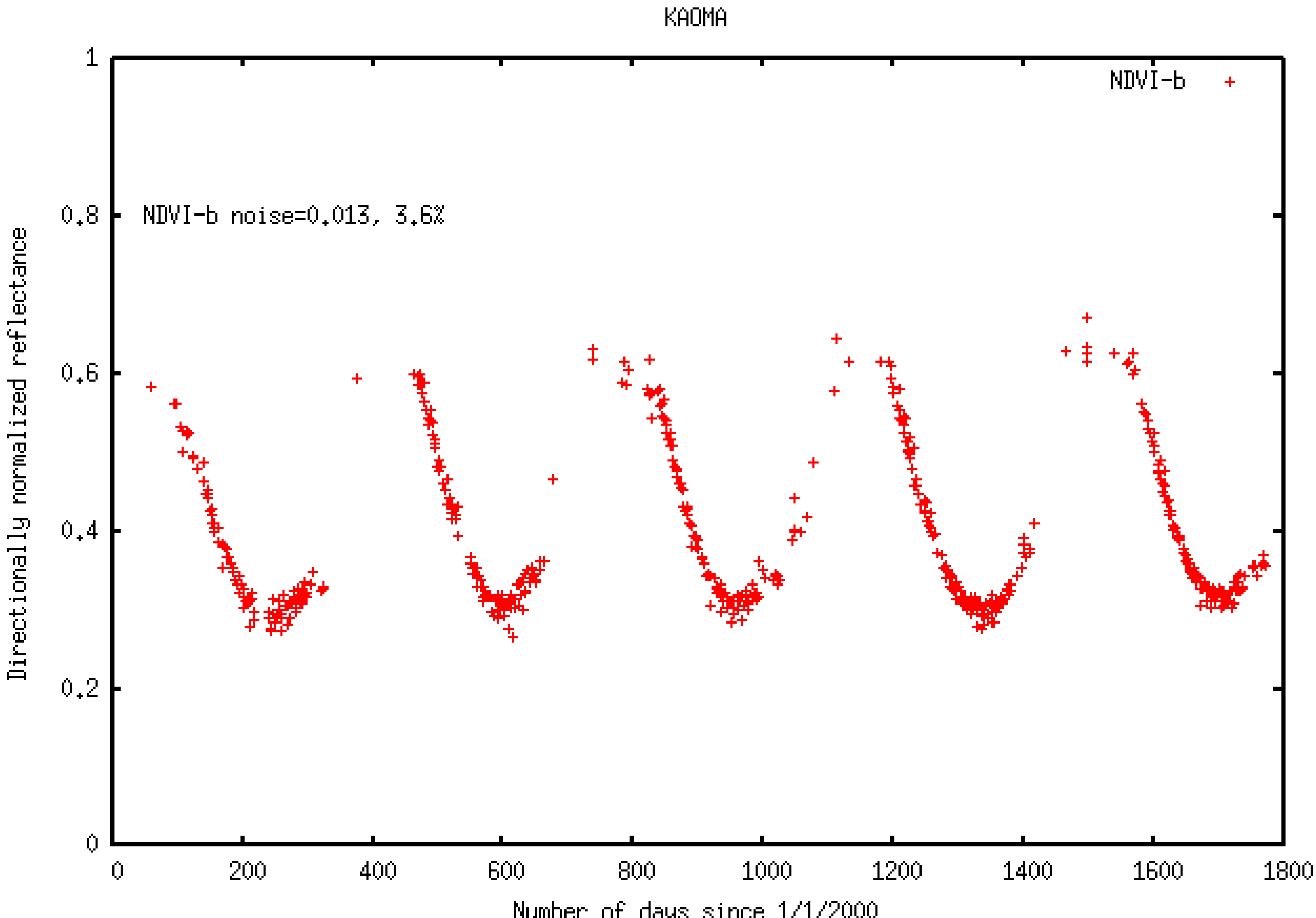
Original NDVI



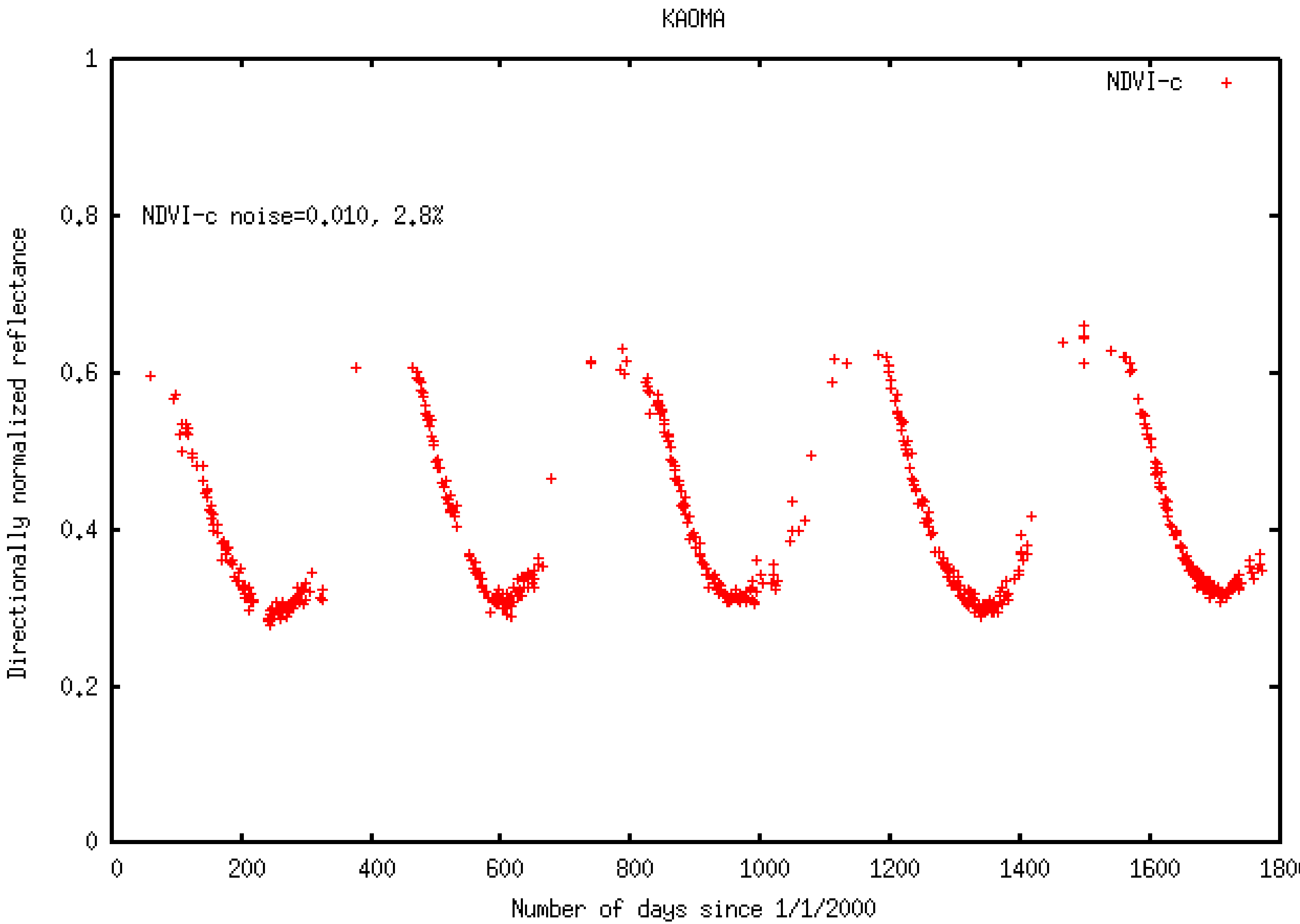
NDVI computed from classical BRDF approach



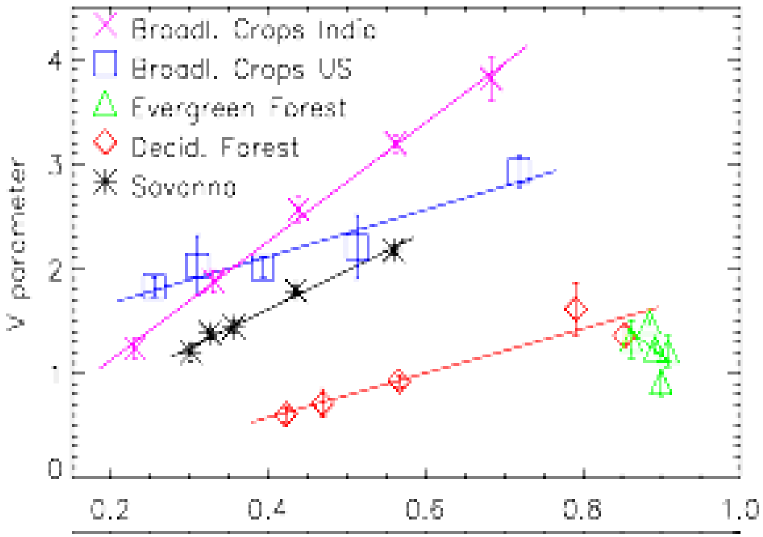
NDVI computed from new BRDF inversion (V and R fixed)

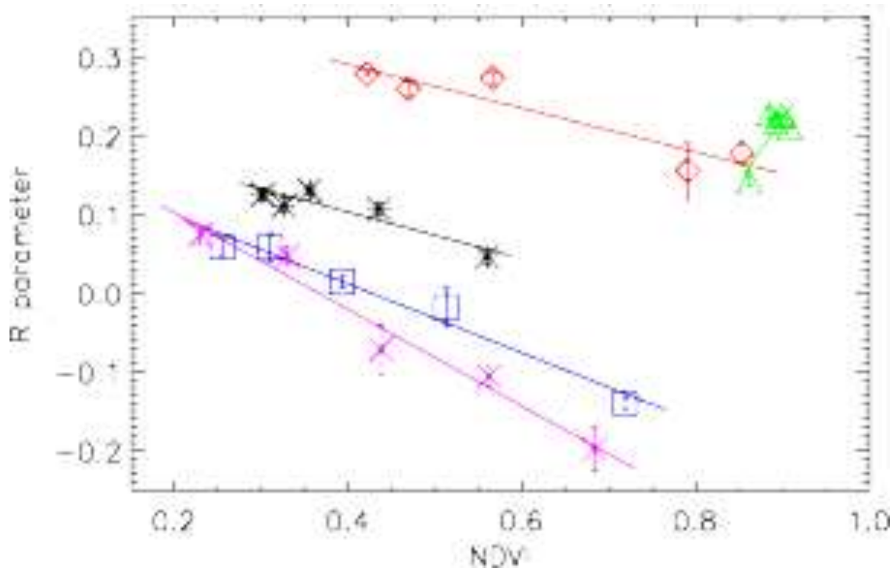


NDVI computed from new BRDF inversion (V and R varies linearly with NDVI)



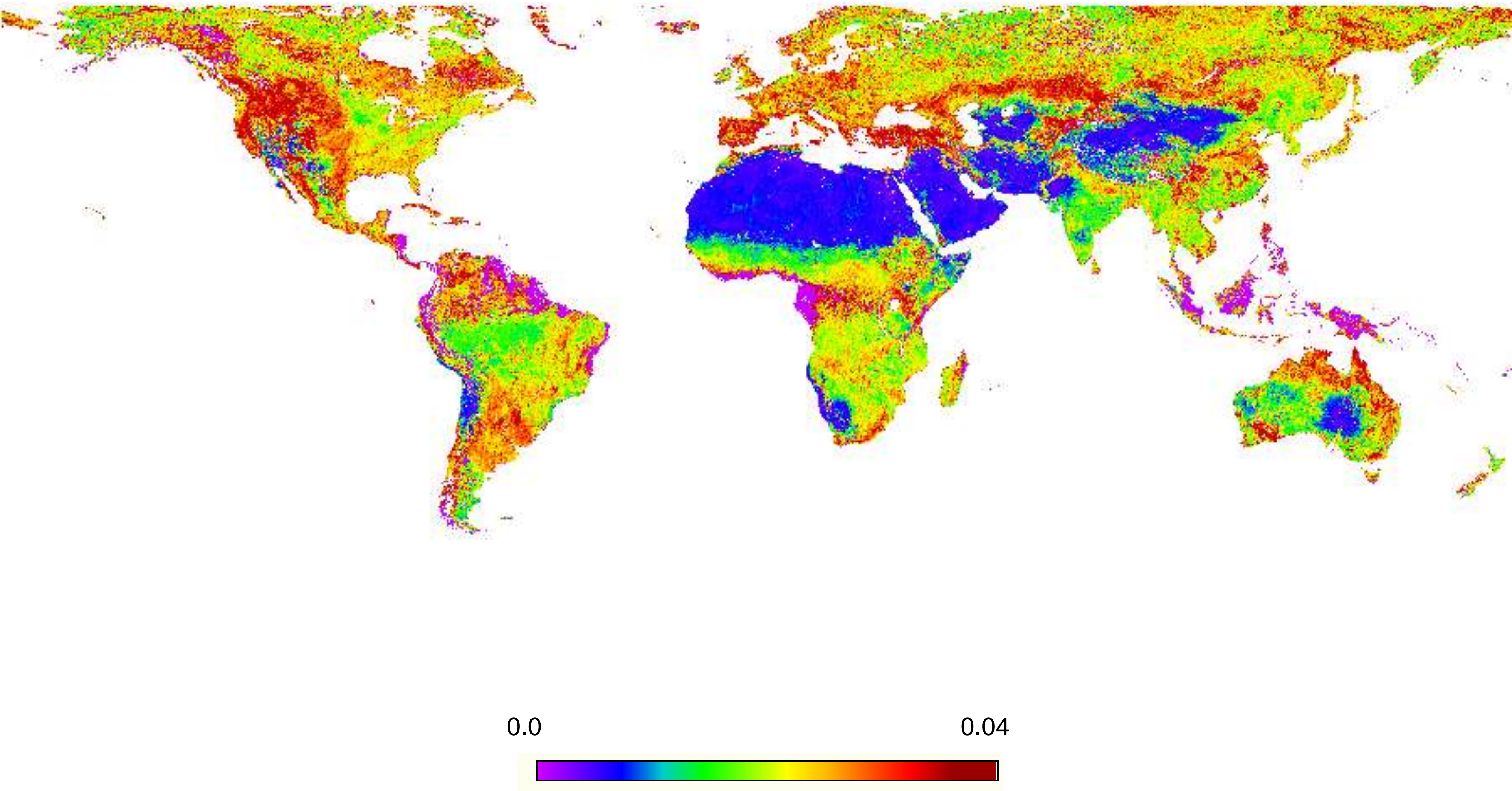
Results for various land covers





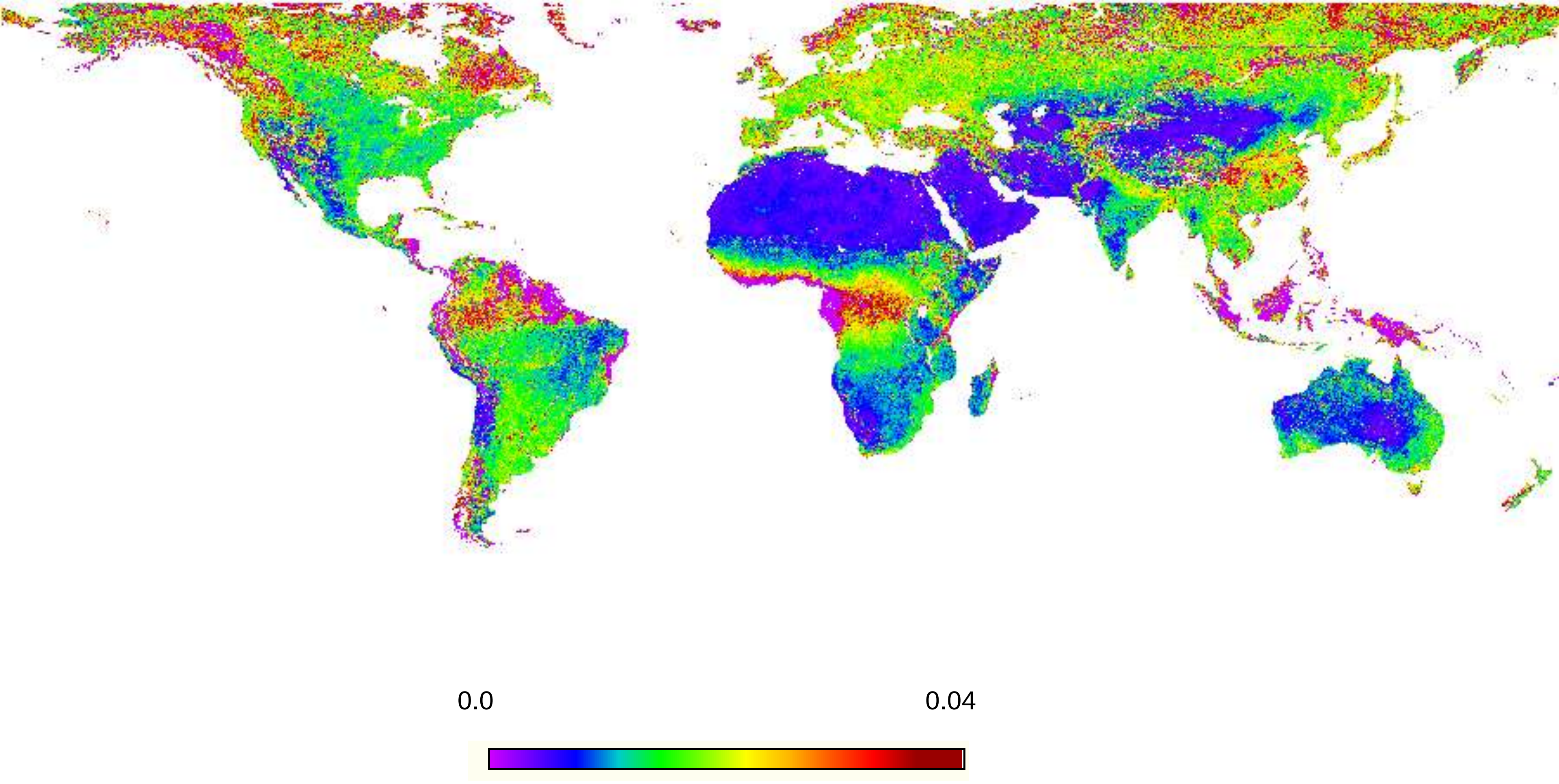
		Savanna	Evergreen forest	Deciduous forest	Broadleaf crops	Broadleaf crops
Channel 1	Raw data noise	0.019 (18.8%)	0.006 (33.6%)	0.011 (23.0%)	0.011 (12.6%)	0.016 (16.3%)
	Cor. Data noise	0.004 (3.4%)	0.002 (13.0%)	0.004 (10.0%)	0.005 (6.2%)	0.006 (7.3%)
Channel 2	Raw data noise	0.040 (16.4%)	0.063 (20.6%)	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 NDVI (without BRDF correction)



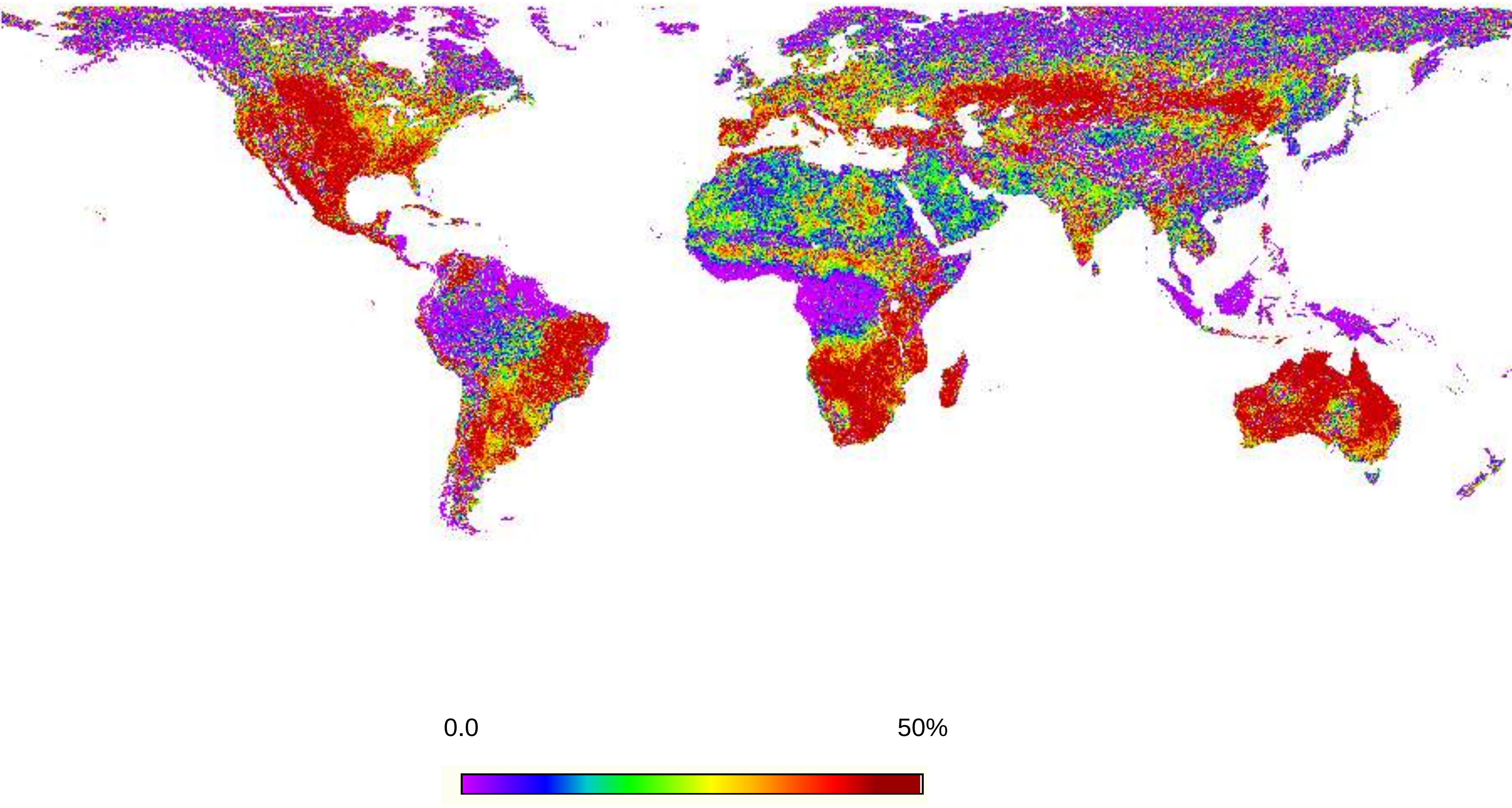
Noise on the NDVI computed using the directional reflectance from MODIS band 1 and 2.

Global NDVI (with new BRDF correction)



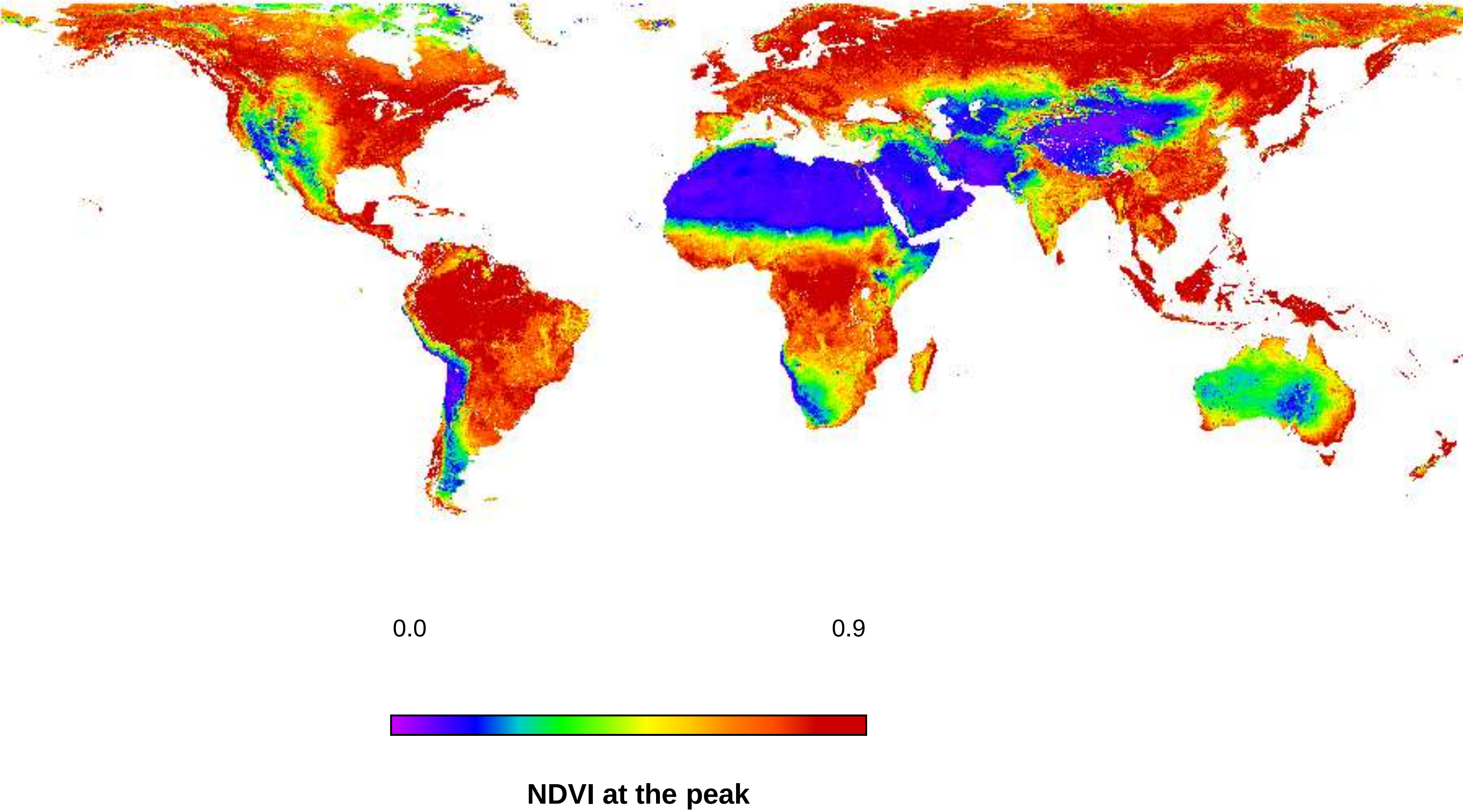
Noise on the NDVI computed using the reflectance corrected for BRDF effect from MODIS band 1 and 2

Global reduction in NDVI noise

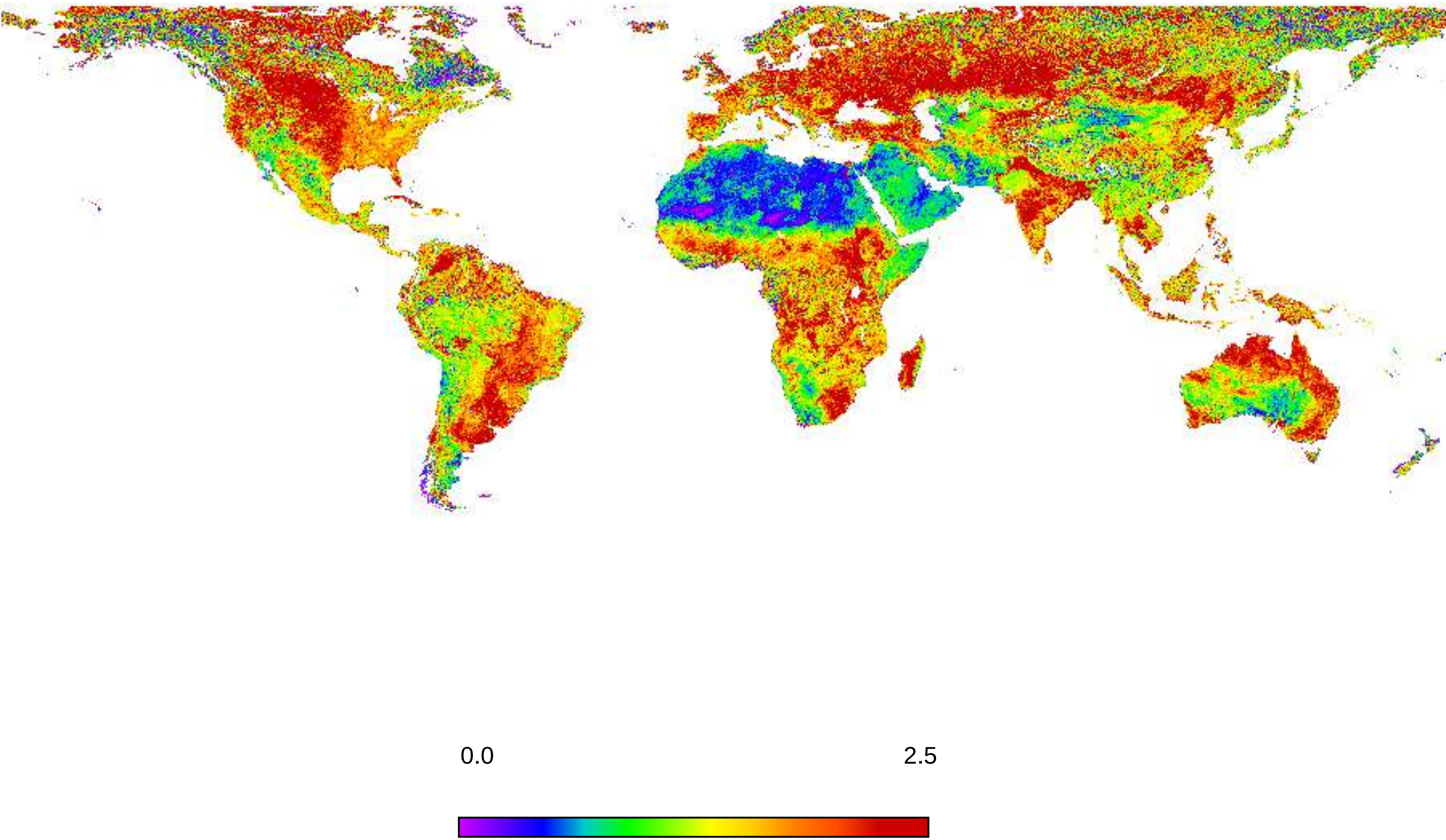


NDVI Noise reduction in %.

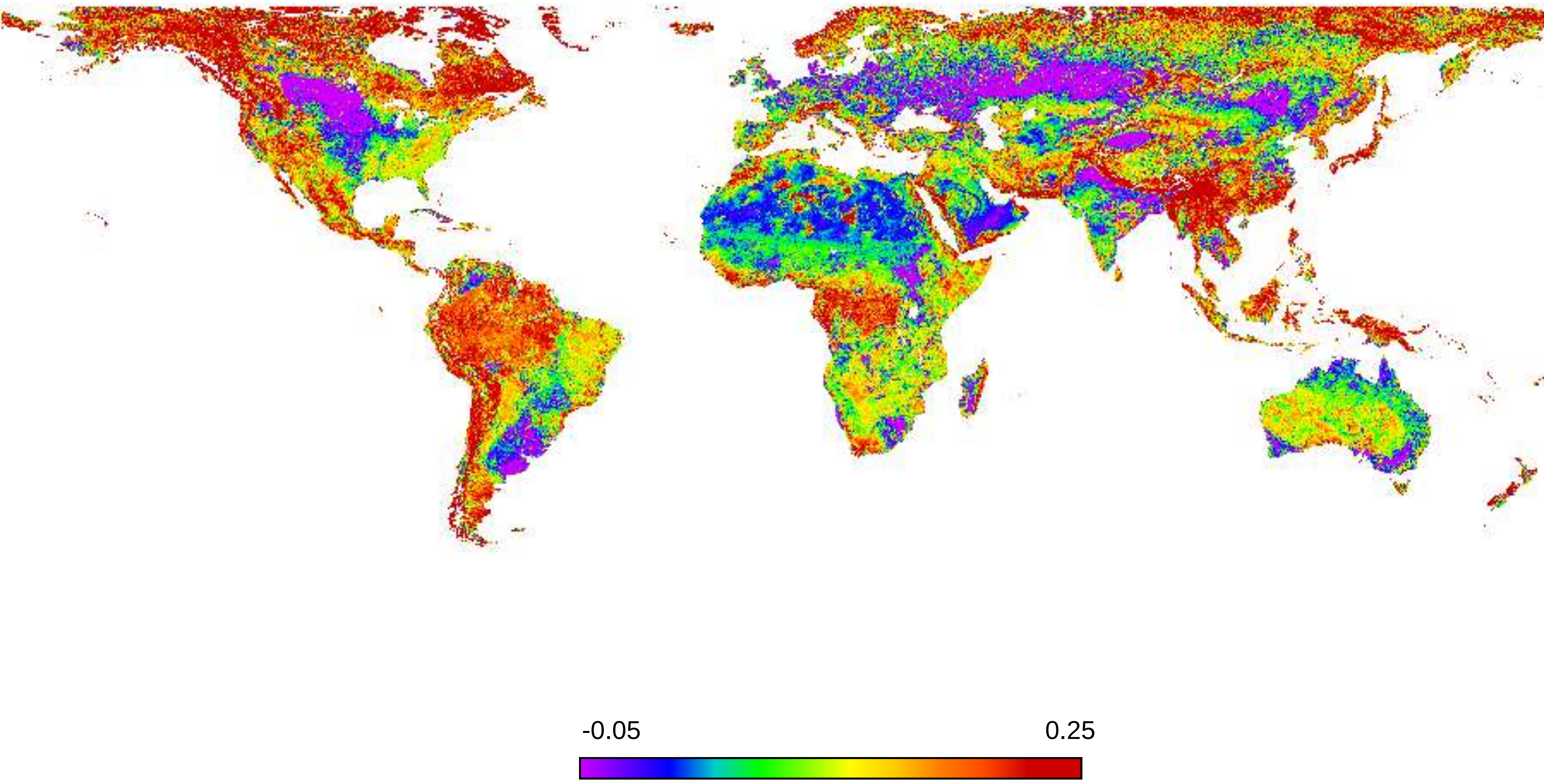
Global map of R and V parameters at the peak NDVI



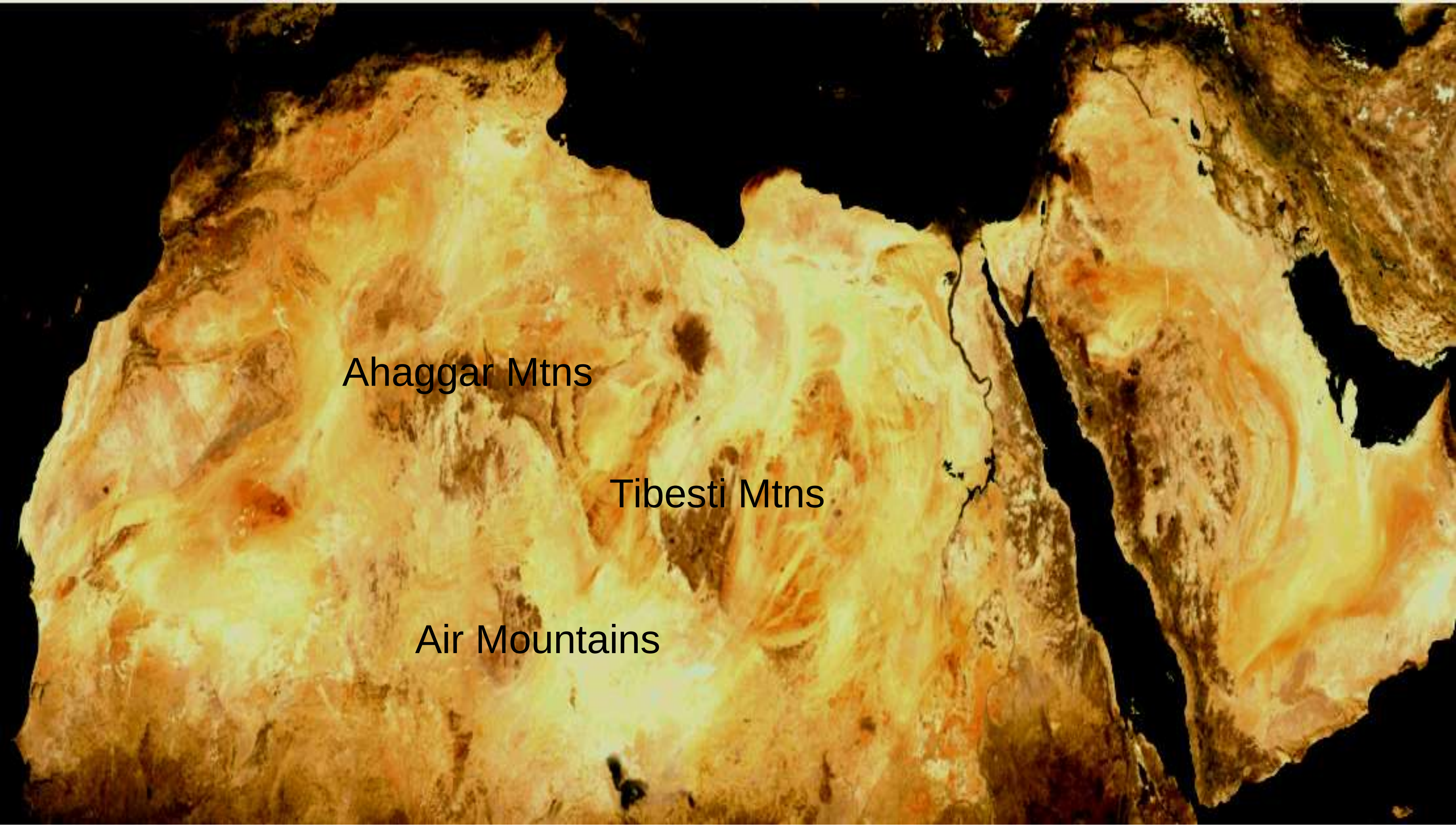
V parameter at the peak NDVI



R parameter at the peak NDVI

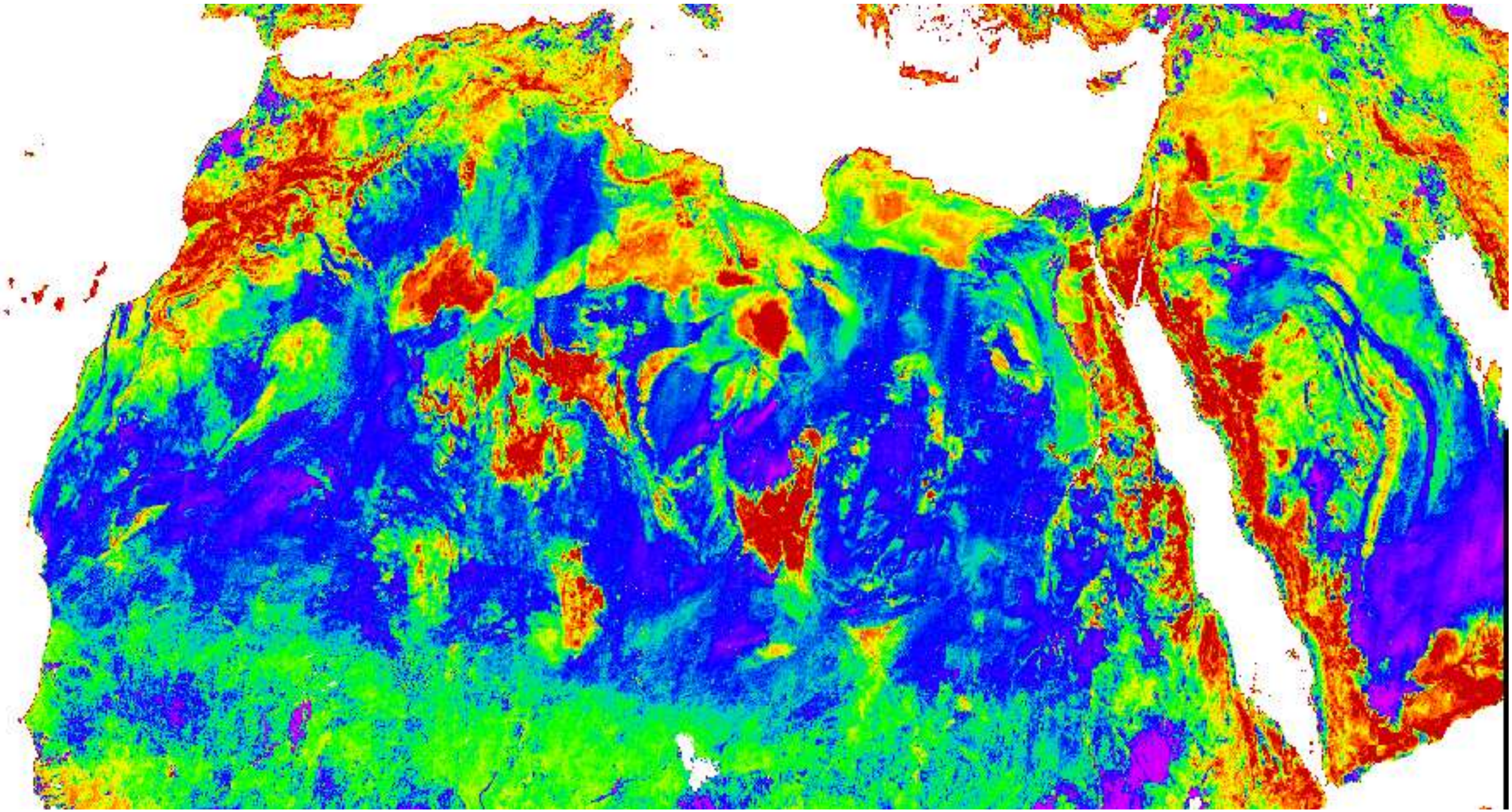


Sahara Desert Detail

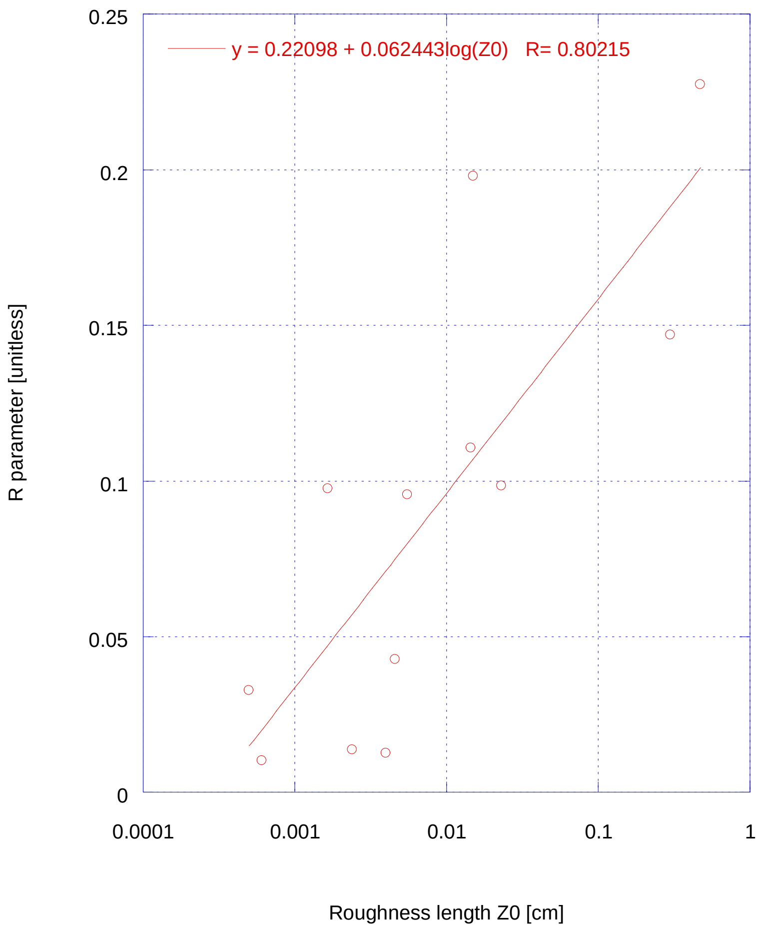


Surface Reflectance (RGB)

Details over Sahara (Roughness)



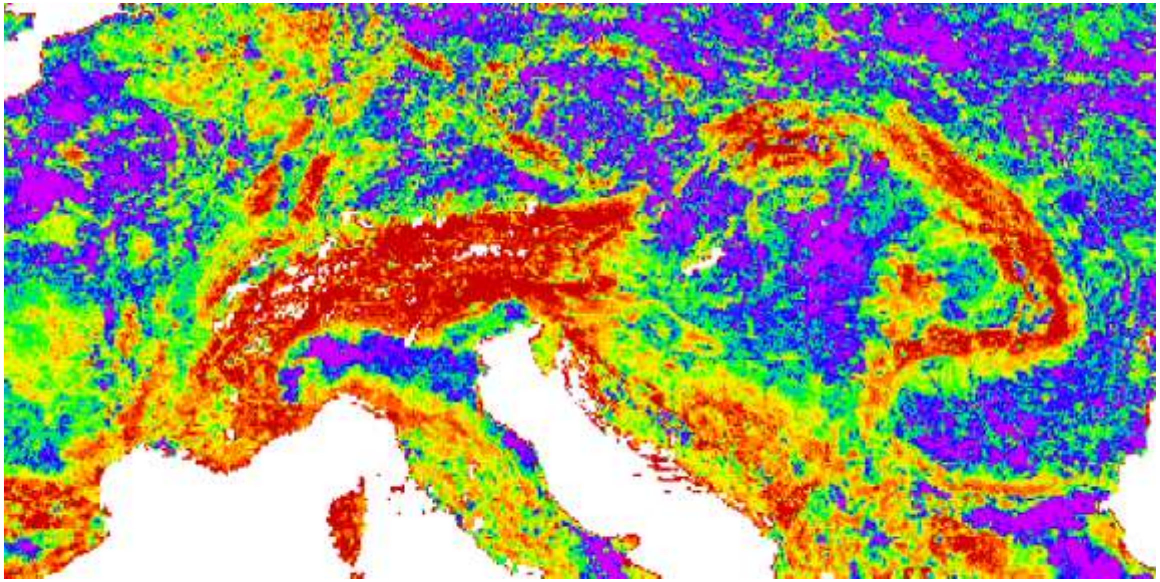
The R parameter is related to aerodynamic surface roughness length (Marticonera et al. POLDER data)



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.

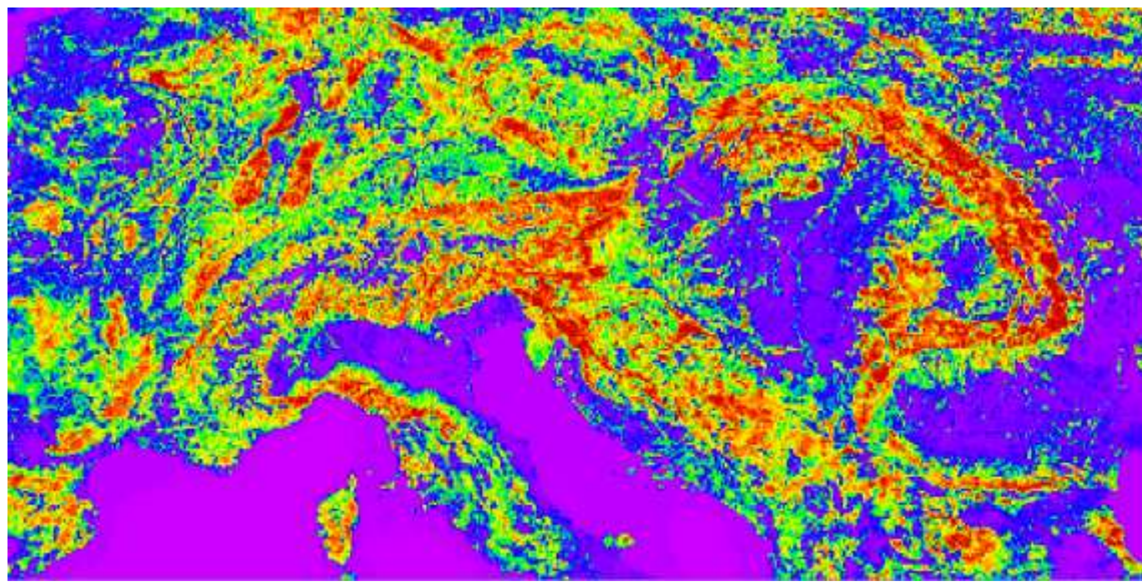
Excluding sites with substantial vegetation cover, we compared the R parameter derived from this study to the aerodynamic roughness length Z0. The relationship derived is close to the one derived by Marticorena et al. i.e. (0.277+0.052log(Z0))

Details over Europe (Roughness)

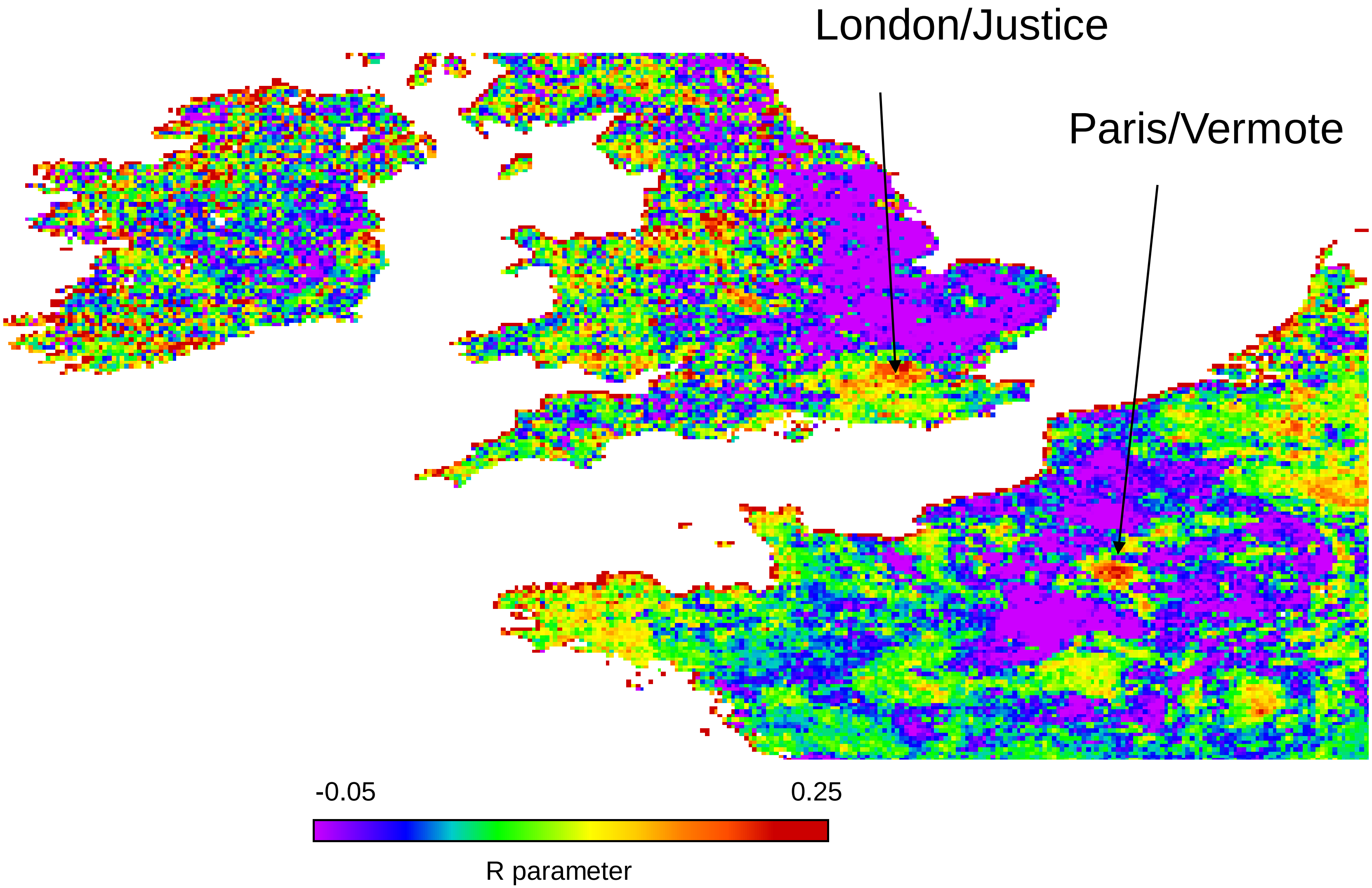


R parameter

% Tree cover
Hansen et al. (2002)



A Tale of Two Cities



High Roughness Associated with Major Cities

Conclusions

- A new approach has been developed and tested to correct daily time-series of reflectance data for the BRDF effect (using a database of coefficient V and R that only depend on NDVI) (*paper in preparation*)
- The NDVI after the new BDRF correction is greatly improved (factor 2 reduction) for a large percentage of the land cover types as compared to non-corrected data
- Once the database (effectively a time varying map of R an V) is developed - the correction could be applied to other similar time-series data sets without deriving the BRDF
- The V and R coefficients themselves also could be used in other applications e.g. R could be used for Aerodynamic roughness and land cover characterization
- We intend to use the approach in the LTDR project to correct AVHRR and MODIS Surface Reflectance time series for the BRDF effect.