Multi-Angle Implementation of Atmospheric Correction for MODIS: Algorithm MAIAC

MODIS Science Team Meeting

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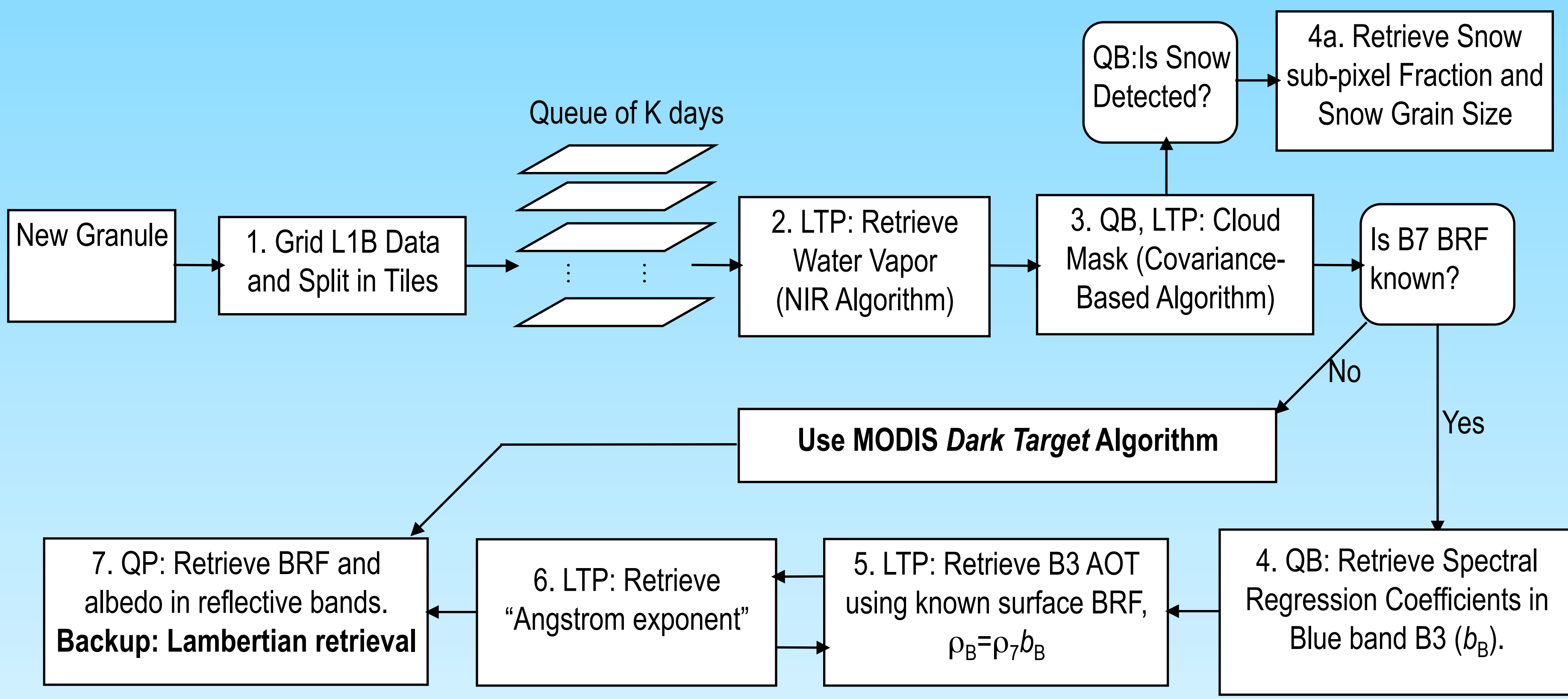
Block-diagram of Processing

(Backup: Standard Algorithm)



***MAIAC Products** (1 km, gridded)*

***Atmosphere**:*

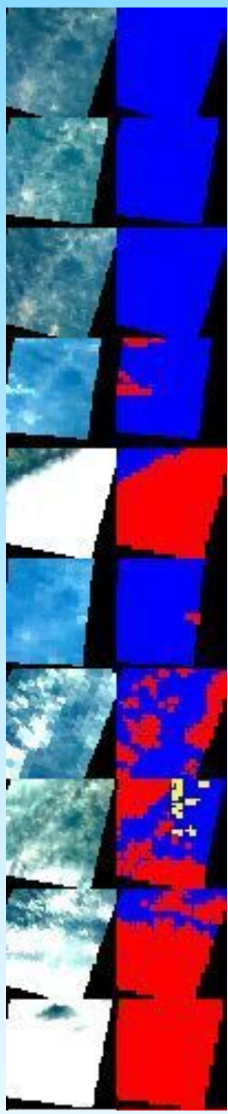
- *Cloud Mask;*
- *Water Vapor;*
- *AOT & fine mode fraction;*

***Surface**:*

Parameters of RTLS BRF model;
Surface Reflectance (BRF)/ Albedo;
Dynamic Land-Water-Snow Mask.

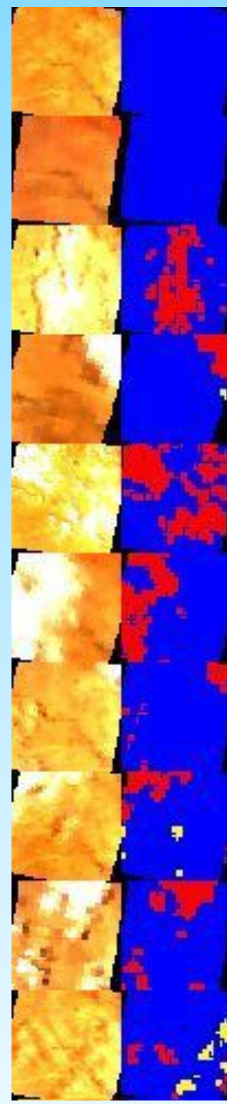
Cloud Mask

Left – MODIS TERRA RGB, 2003 (50×50km²), Right – MAIAC CM



DOY 187
GSFC, USA

DOY 116
Mongu, Zambia



DOY 139
Solar Village

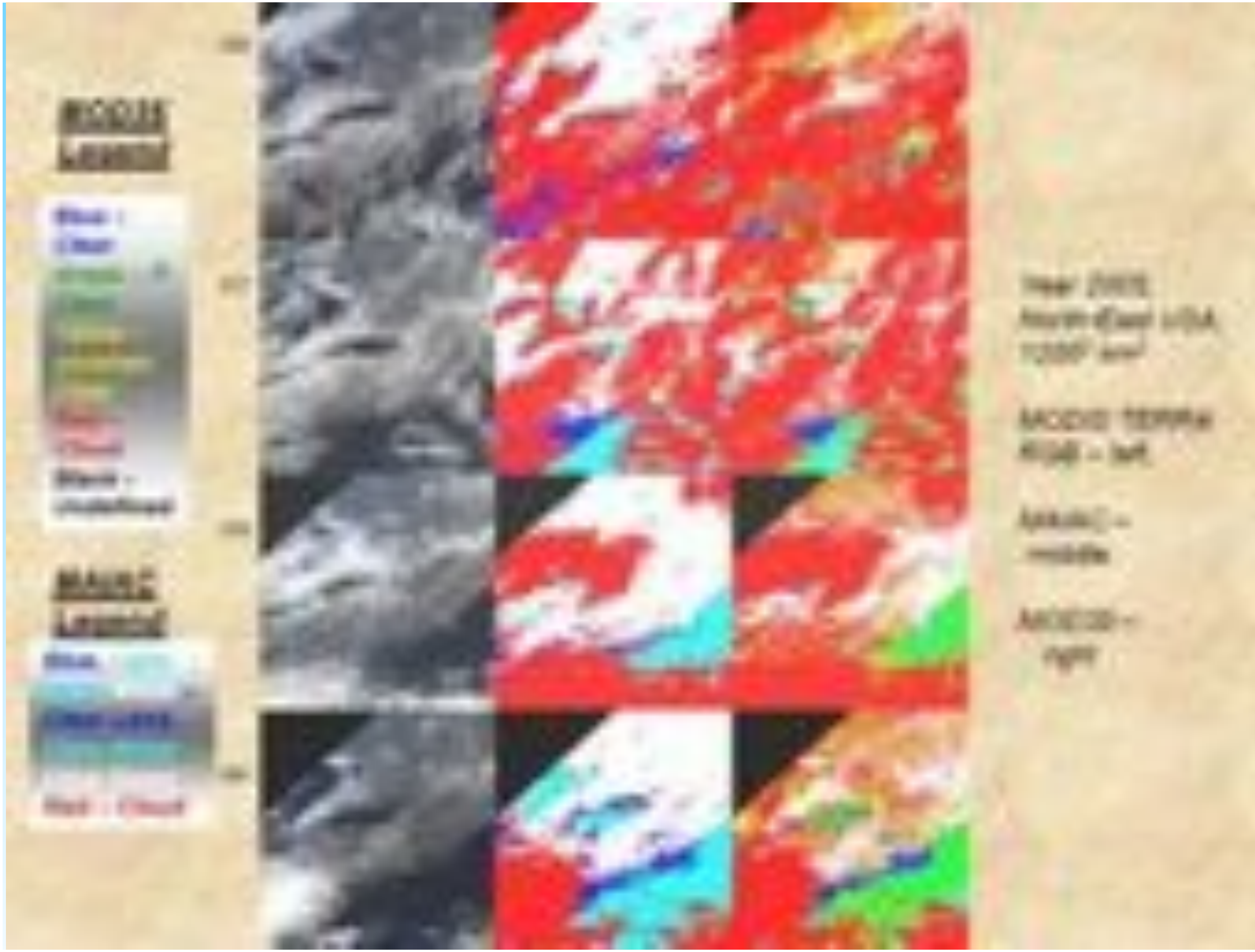
- ***Basis*** *- covariance analysis (identifies reproducible surface pattern in the time series) & reference clear-sky image of surface (B. Rossow)*
- ***High covariance - CLEAR****. Ephemeral clouds disturb the pattern and reduce covariance.*
- *Because covariance removes the average component of signal and uses variation, it* ***works well****:*
  1) for ***bright surfaces and snow****, 2) in* ***high AOT*** *conditions if the surface variability is still detectable.*
- *Algorithm maintains a dynamic clear-skies reference surface image (refcm), used as a comparison target in cloud masking.*
- *Internal Land-Water-Snow surface classification.*

Bright-Cold Cloud Test (@Pixel)

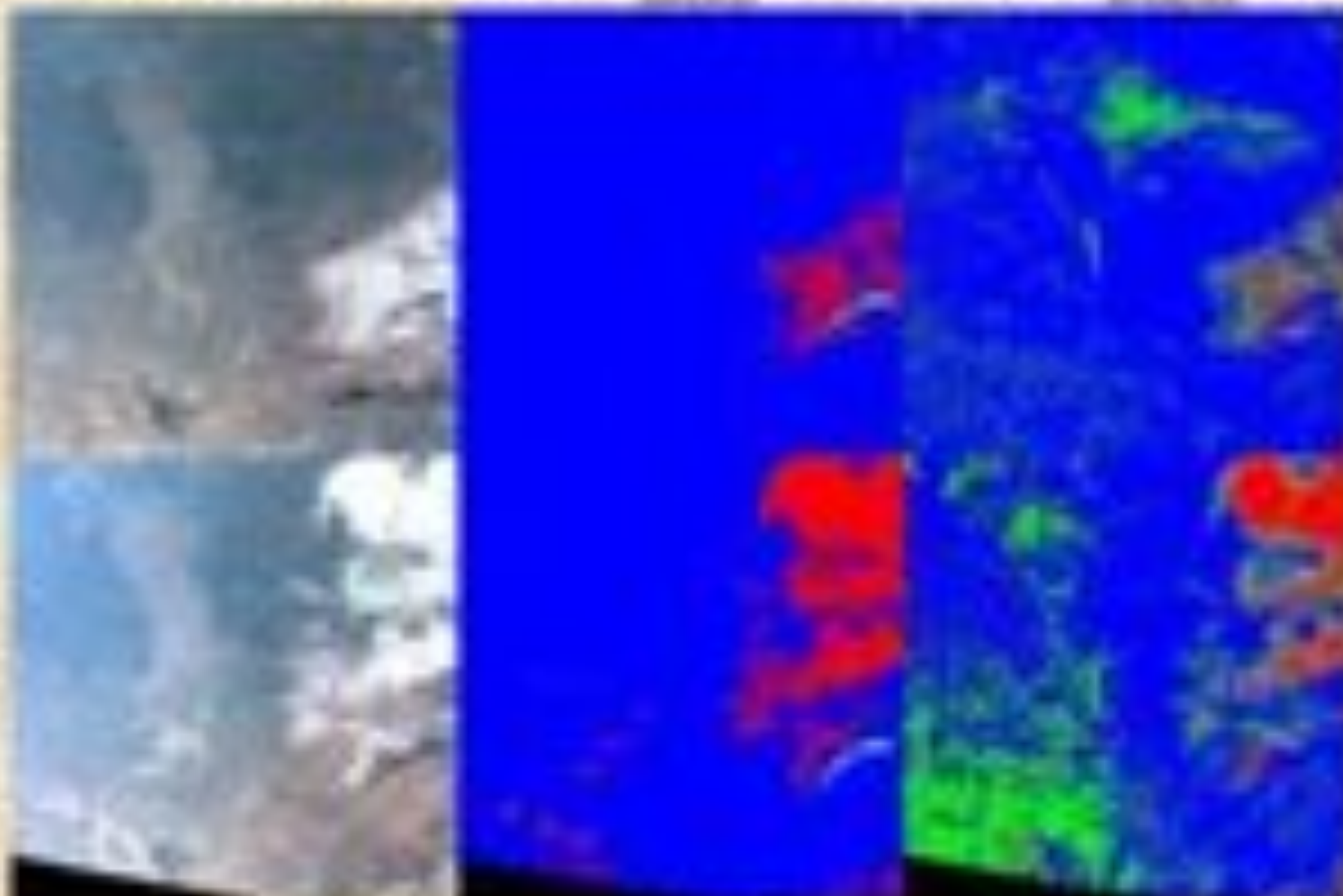
$$(BT_{ij} < BT_G - 4) \text{ AND } (r1_{ij} > refcm.r1_{ij} + 0.05) \Rightarrow \text{PCLOUD}$$

CM Legend:

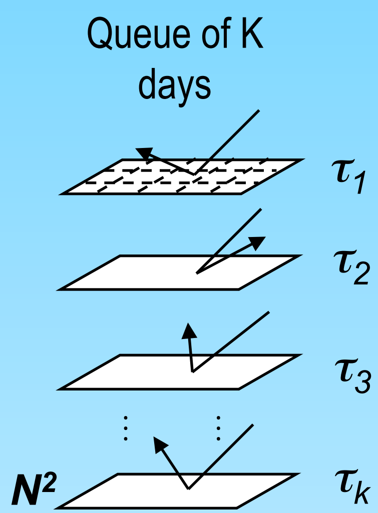
Blue *(Clear),* ***Red & Yellow*** *(Cloudy).*



Cloud Mask: Zambia, Africa (1200 km)



Generic Retrieval of SRC



$$\{\rho_{ij}^{\lambda} \propto (k_L, k_{go}, k_v)_{ij}^{\lambda} \propto b_{ij}^{\lambda}\}$$

Basis:

- surface is spatially variable and stable in short time intervals;

- aerosols are variable in time and have a mesoscale (60-100 km) range of global variability.

Approach:

- Accumulate gridded MODIS L1B data for K days;

- Process K days for area N×N pixels simultaneously:

$$KN^2 \text{ (measurements)} > K + 3N^2 \text{ (unknowns)}, \text{ if } K>3$$

- Derive shape of BRF from 2.1 μm, and use spectral scaling to reduce DIM:

$$\rho_{ij}^{Blue} = b_{ij}\rho_{ij}^{B7} \Longrightarrow KN^2 > K_{\{\tau_k\}} + N^2_{\{b_{ij}\}}$$

MISR heritage:

-Using spatial and angular structure of imagery for aerosol retrievals (Martonchik et al., IEEE TGARS 1998);

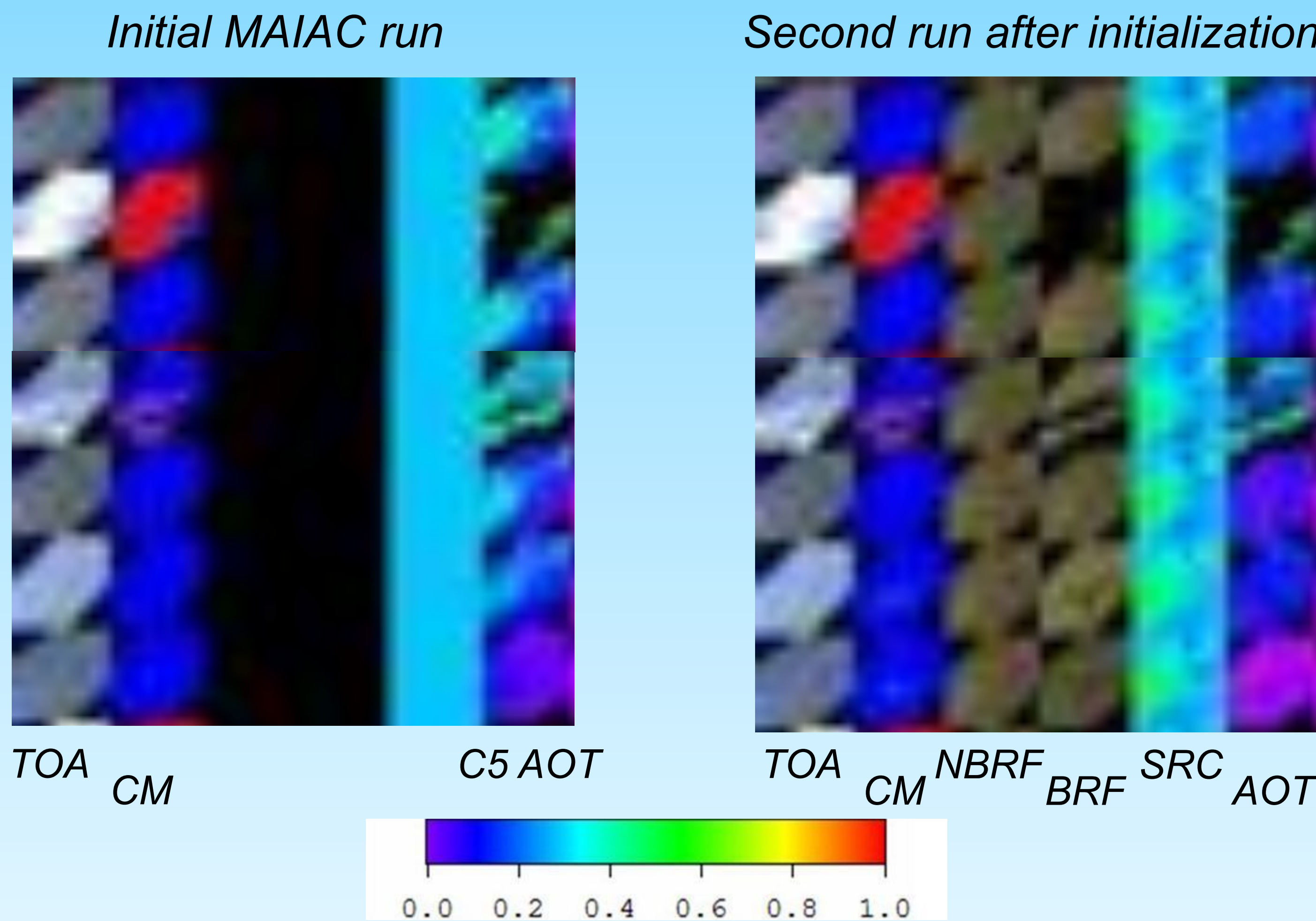
-Using angular and spectral shape similarity constraints in aerosol retrievals over land (Diner et al., *RSE*, 2004).

MODIS heritage:

- RTLS BRF retrieval algorithm (Schaaf et al., 2002)
- Gridding algorithm (Wolfe et al., 1998)
- Cloud Mask (Ackerman et al., 1998)

Prescribed vs Retrieved SRC

(Example for Goddard Space Flight Center, 2000, DOY 84-93)

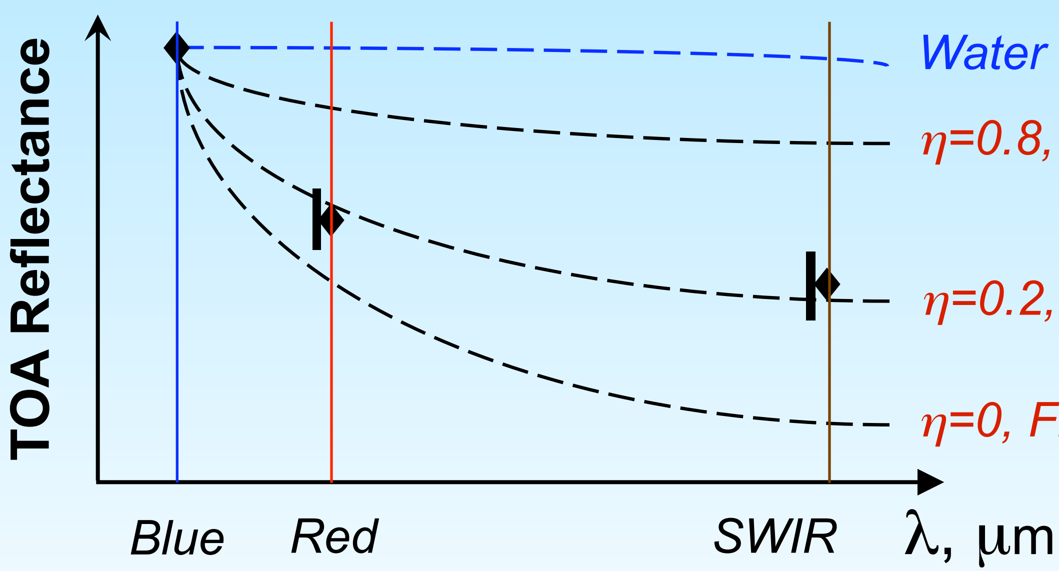


1. *In standard retrievals, AOT correlates with surface brightness (left).*
2. *MAIAC removes artificial correlation by means of SRC retrieval (right).*

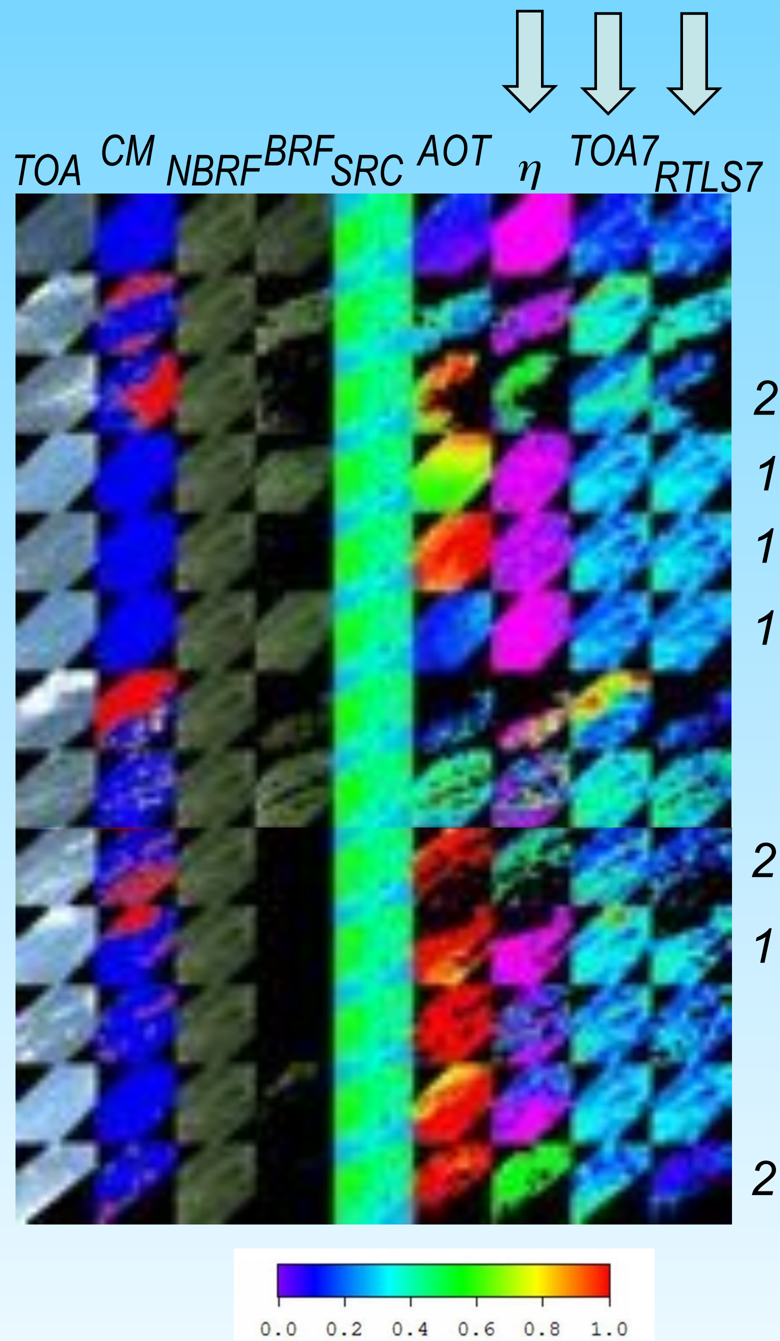
Aerosol Retrieval Algorithm

- Compute AOT_B and weight of coarse mode η using Blue (B3), Red (B1), SWIR (B7) bands.
- Surface BRF: use SRC in blue band, $\rho_{ij}^{Blue} = b_{ij}\rho_{ij}^{B7}$. BRF in B1 and B7 is known from previous retrieval with uncertainty $\sigma_{ij}(\lambda)$ at TOA.
- Algorithm: Fit Blue band to find AOT_B for given η, and find η by minimizing

$$rmse = \sum \left\{ \frac{R_\lambda^{Meas} - R_\lambda^{Theor}(AOT_B, \eta)}{\sigma_\lambda} \right\}^2$$



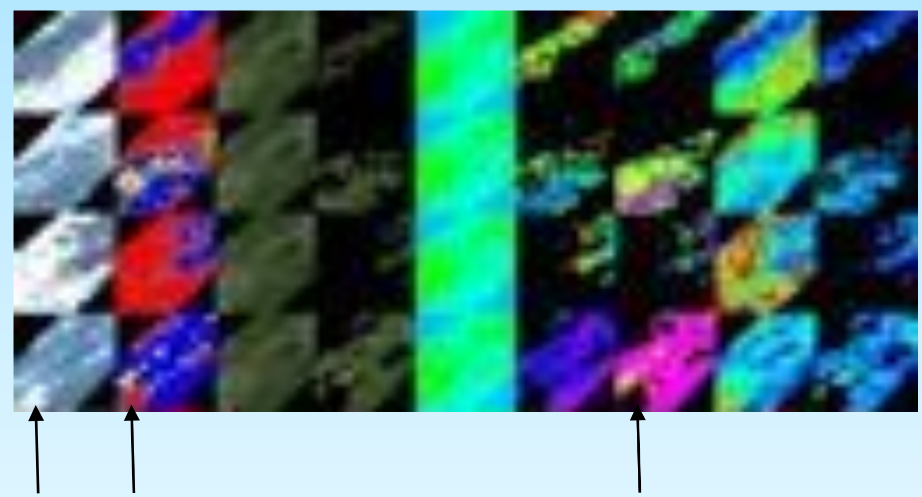
… examples



η classification: Fine – Coarse - Cloud

Illustration of AOT and coarse mode fraction for GSFC in June 2002:

1. *Fine mode aerosol does not affect B7 (measured and modeled reflectance agree).*
2. *Coarse mode aerosol affects B7 (measured reflectance is higher than modeled reflectance)*



Resolving thin clouds using Cloud Model (yellow color)

Surface Retrieval Algorithm

- *Compute 3 parameters of Ross-Thick Li-Sparse (RTLS) model by fitting 4-16 days of MODIS data at TOA:*

$$R(\mu_0,\mu,\varphi) = R^D(\mu_0,\mu,\varphi) + k^L F^L(\mu_0,\mu) + k^V F^V(\mu_0,\mu,\varphi) + k^G F^G(\mu_0,\mu,\varphi) + R^{nl}(\mu_0,\mu)$$

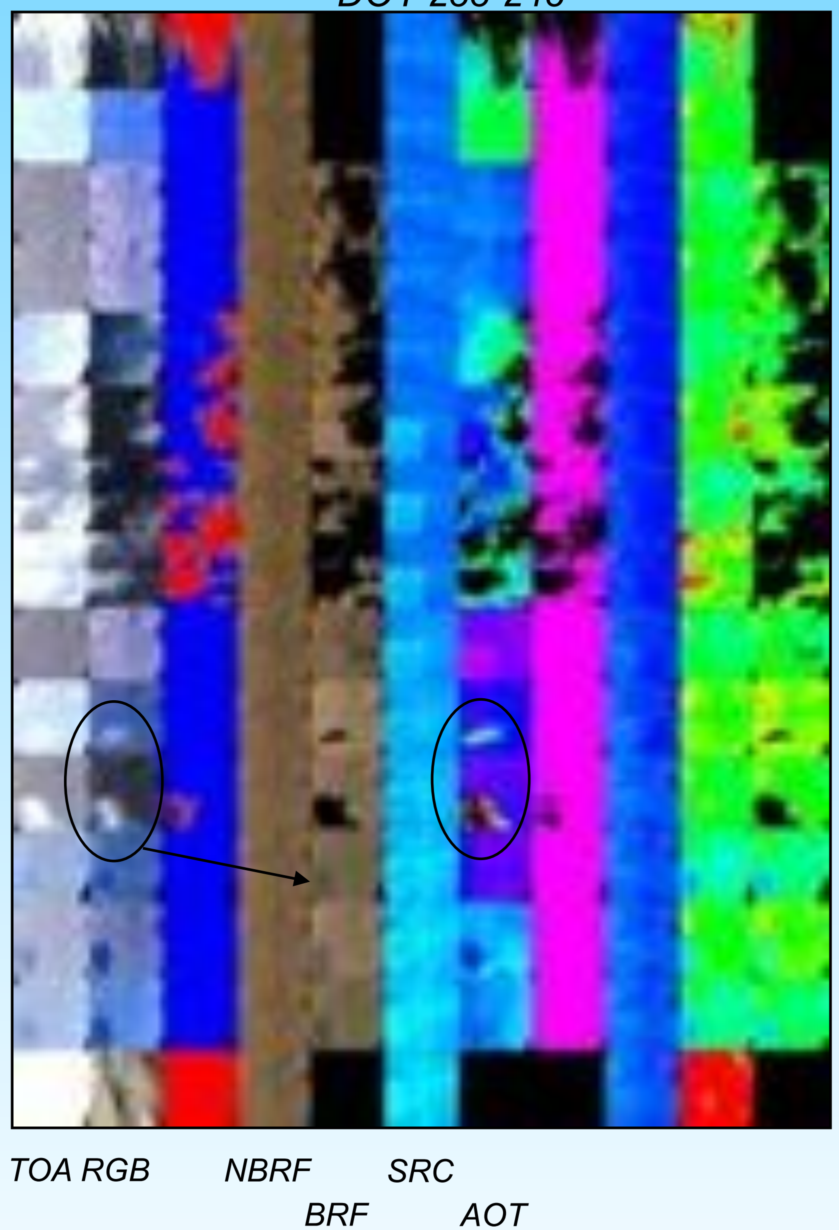
Quality Control

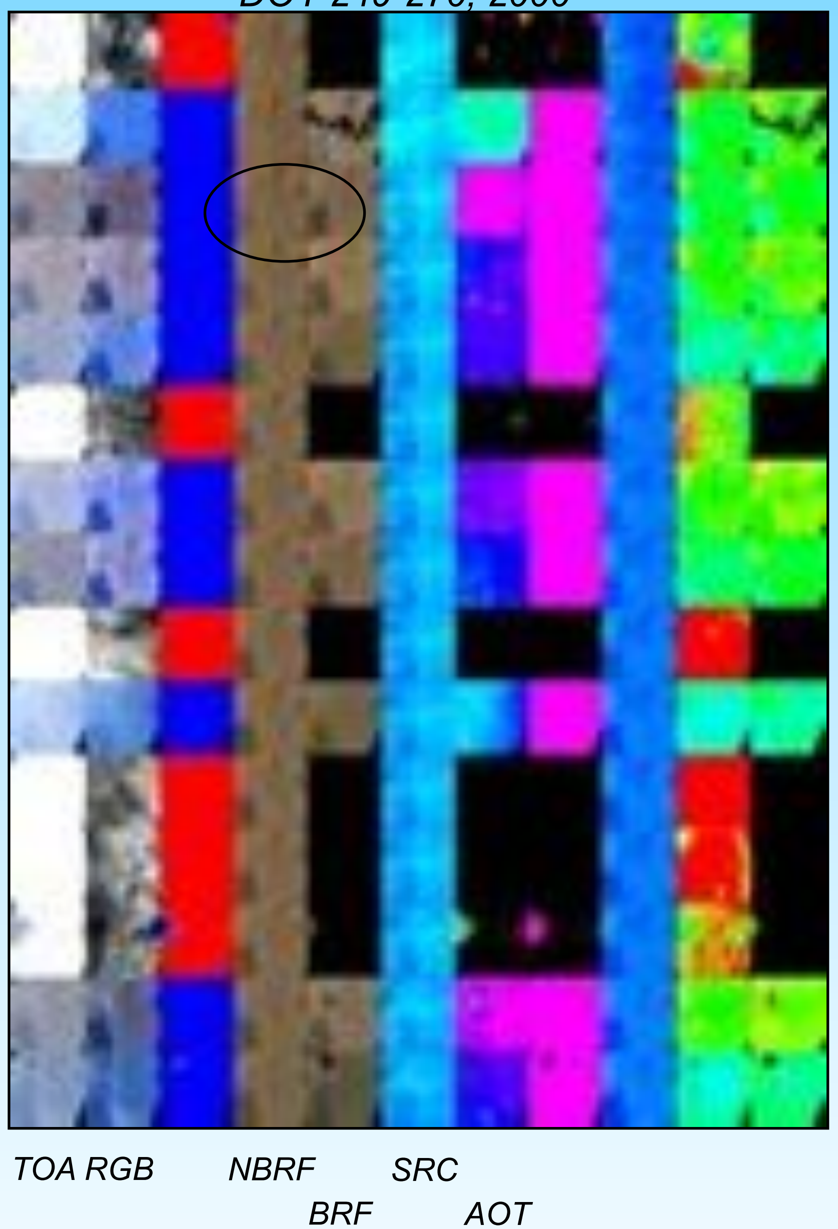
- *Detect seasonal and rapid surface change from measurements (green-up or senescence shows as large-scale correlated changes in NDVI and NIR and SWIR reflectance as compared to theoretical RTLS values). If surface is stable, use 16-day Queue. If change is detected, use last 4 days for faster response.*

- *In stable conditions, require consistency with previous solution.*

- *Check shape of BRDF, rmse etc. (including sufficient angular sampling, filtering of high AOT …).*

Response to Rapid Surface Change

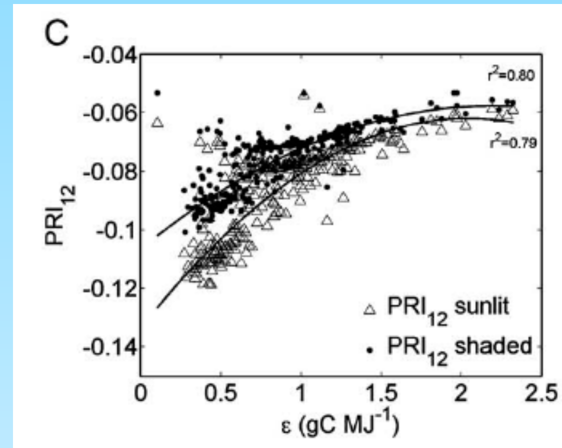




Example: MODIS PRI analysis

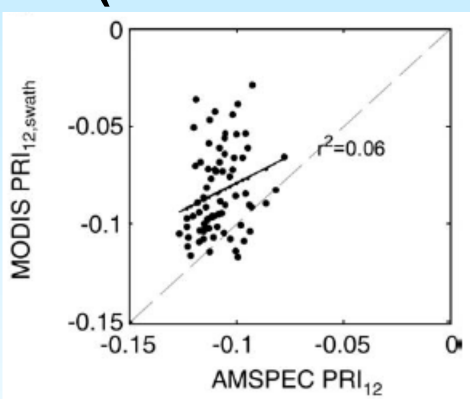
Hilker, T. et al. (2009). An assessment of photosynthetic light use efficiency from space: Modeling the atmospheric and directional impacts on PRI reflectance. *RSE,* doi:10.1016/j.rse.2009.07.012.

Photochemical Reflectance Index (PRI): $$\frac{\rho_{531} - \rho_{554}}{\rho_{531} + \rho_{554}}$$

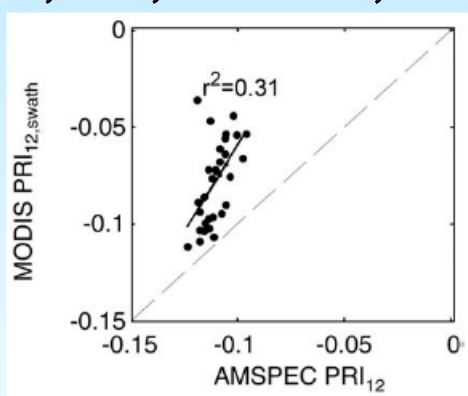


The “ocean fluorescence” band 531 nm is sensitive to down-regulation of plant photosynthesis changing by several tenths of 1%, while reference band is stable. The ground measurements showed a good correlation of PRI with light use efficiency (ε).

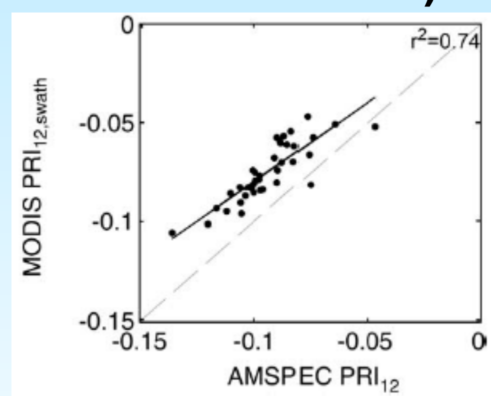
Ground PRI (AMSPEC) vs MODIS PRI generated with 6S and MAIAC (Vancouver Island, BC, Canada, March-October 2006)



6S, all angles

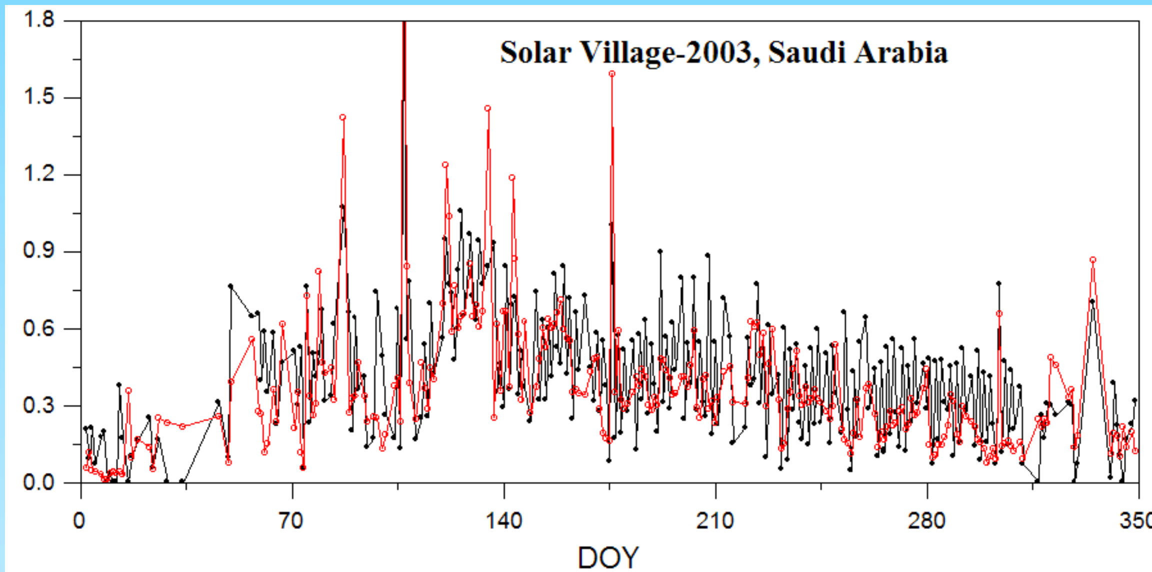


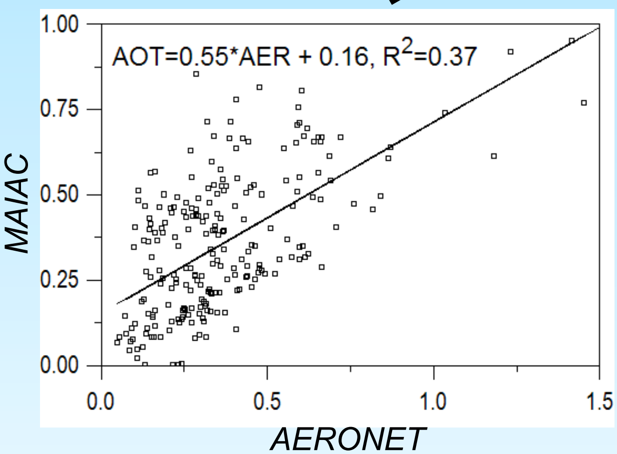
6S, backscattering angles



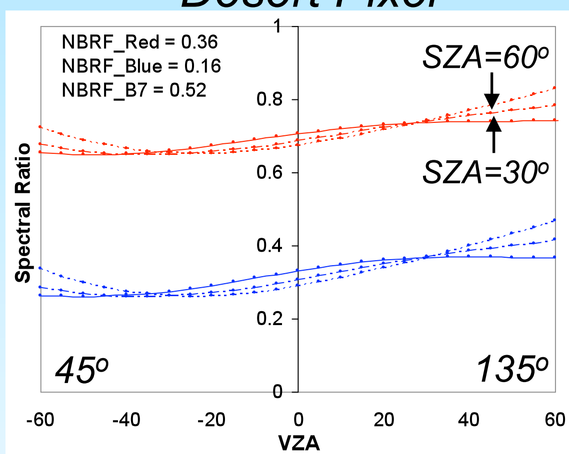
MAIAC

Problem of Brighter Surfaces





Desert Pixel



- *MAIAC overestimates AOT in the backscattering directions, and underestimates it at forward scattering angles.*
- ***Reason**: spectral invariance assumption*

$$\rho_{ij}^{\lambda} = b_{ij}^{\lambda}\rho_{ij}^{B7}$$

is not very accurate for soils and sands when difference in brightness is significant.

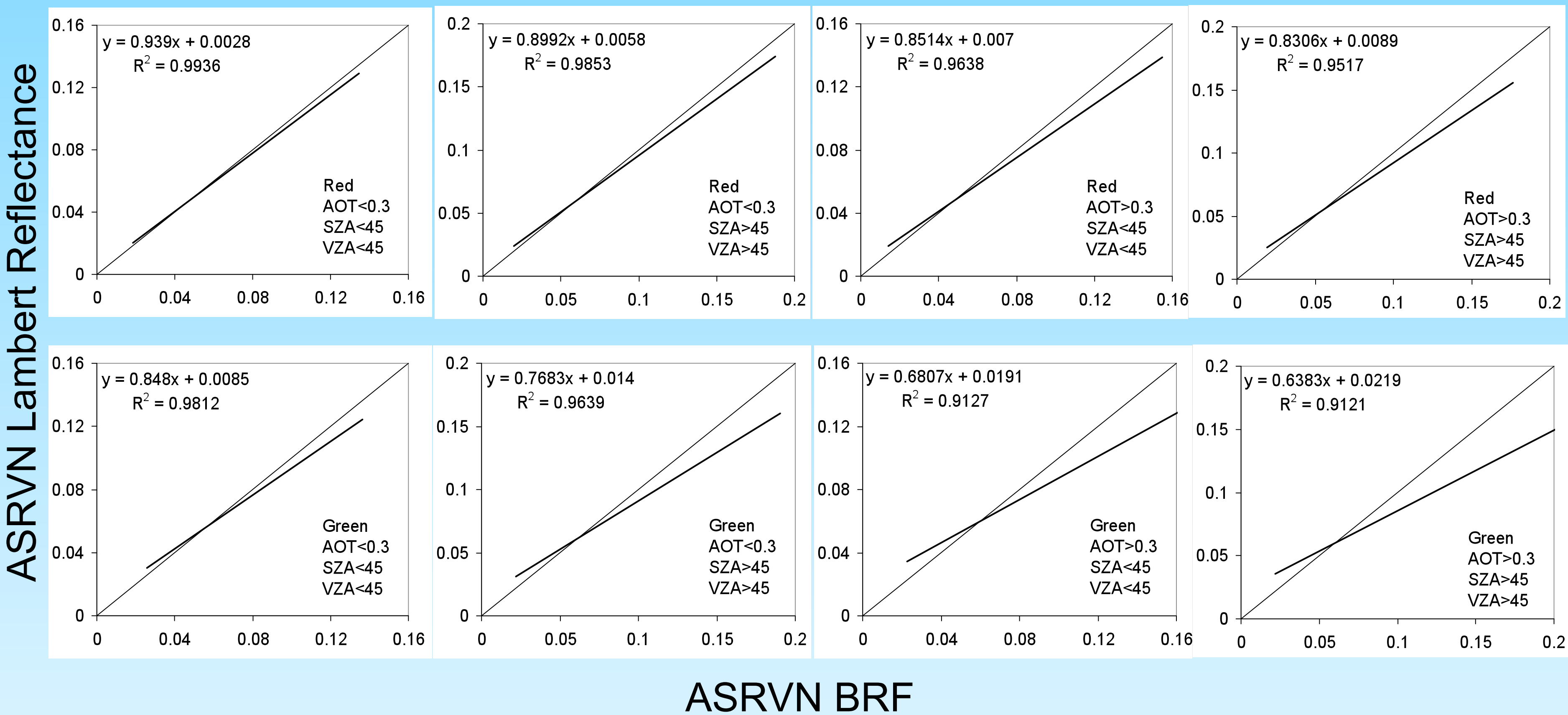
- *Analysis shows that*

the Blue band BRF is more anisotropic than at 2.1 μm.

The bottom Figure shows Spectral Ratio for the blue (ρ_{B3}/ρ_{B7}) and red (ρ_{B1}/ρ_{B7}). The BRF was computed using LSRT parameters of ASRVN.

Wang, Y., A. Lyapustin, J. L. Privette, J. T. Morisette, B. Holben, Atmospheric Correction at AERONET Locations: A New Science and Validation Data Set, . IEEE Trans. Geosci. Remote Sens., in press.

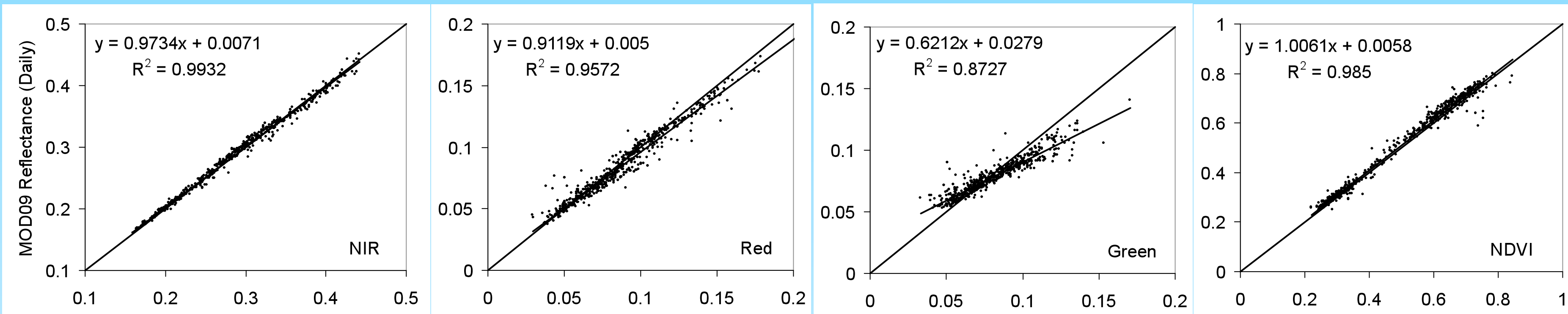
Assessment of Lambertian Biases from ASRVN Data (GSFC site)



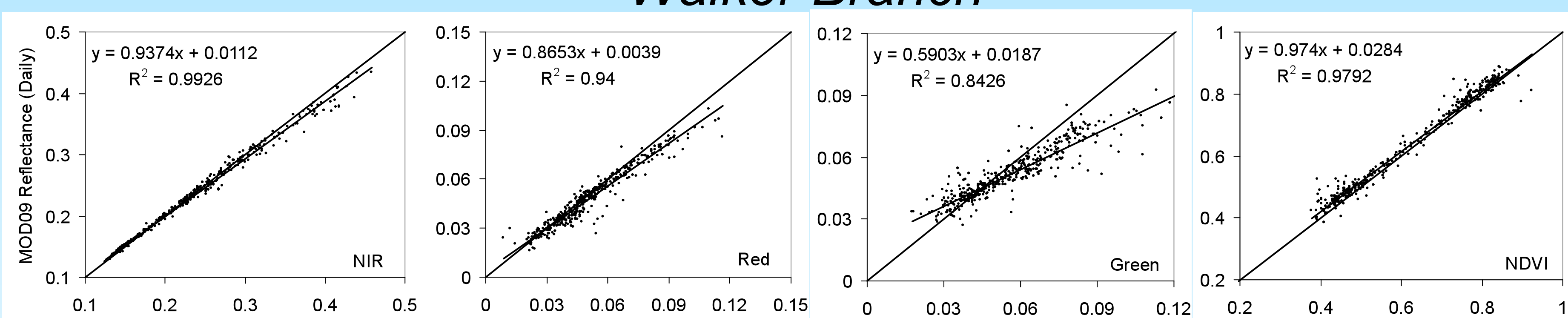
Slope of regression decreases by up to ~15% in red and 35% in green from consistent comparison of ASRVN-based BRF and R_L (*Wang, Lyapustin, Privette, Vermote, Schaaf, Wolfe, R. Cook et al*.)

Assessment of Lambertian Biases from MODIS Data

Konza EDC



Walker Branch



ASRVN BRF   ASRVN BRF   ASRVN BRF   ASRVN NDVI

Observed biases over vegetated sites are similar to results of ASRVN-based comparison of BRF and R_L which indicates that they are mostly due to Lambertian assumption.

AERONET Validation, 7+ yrs. (old Version)