MAIAC Update

Alexei Lyapustin, GSFC, code 613
Yujie Wang, Sergei Korkin

MODIS Science Team Meeting

April 16, 2013

MAIAC = *Time Series + Spatial Analysis*

Complete Physical Model of RT (Deterministic):

- *Anisotropic surface;*
- *Retrieval of Spectral Regression Coefficient:* $\rho^{\lambda} = b^{\lambda}\rho^{2.1}$
- *Detection and accommodation of seasonal and rapid surface change;*
- *Storing "static" (surface) information;*
- *Synergy among WV, CM, aerosol and AC algorithms.*

Explicit representation of BRF in RT*:*

$$\rho(\mu_0,\mu,\varphi) = k_L + k_G f_G(\mu_0,\mu,\varphi) + k_V f_V(\mu_0,\mu,\varphi)$$ *- RTLS BRF model*

$$R^{TOA} = R^{D} + k^{L}F^{L}(\mu_0,\mu) + k^{G}F^{G}(\mu_0,\mu,\varphi) + k^{V}F^{V}(\mu_0,\mu,\varphi) + R^{nl}(\mu_0,\mu,\varphi),\quad R^{nl} \propto qc_0$$

Lyapustin, A., and Yu. Knyazikhin, Green's function method in the radiative transfer problem. I: Homogeneous non-Lambertian surface, *Appl. Optics*, **40**, 3495-3501, 2001.

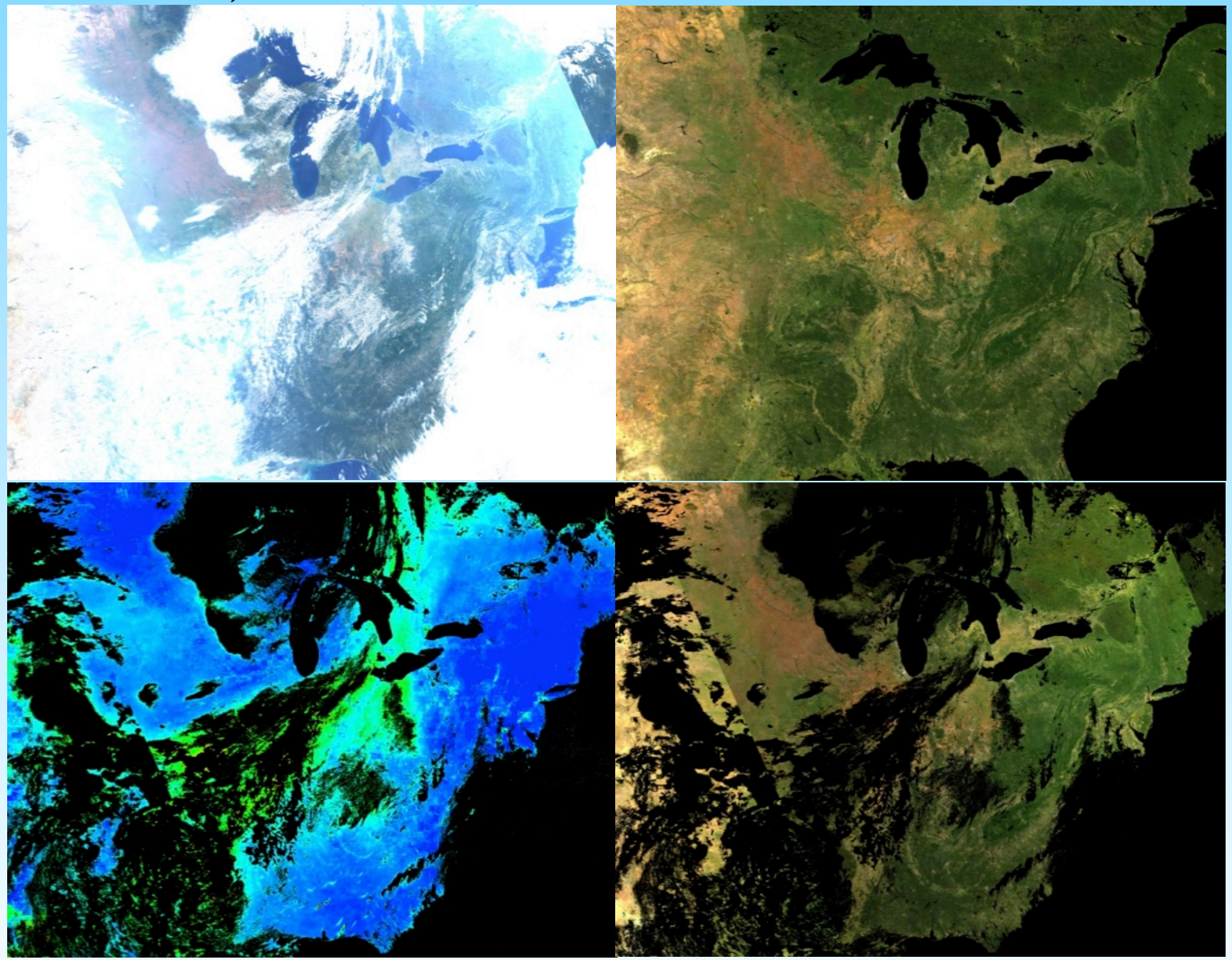
Plan

- *Brief Overview of MAIAC*
- *Algorithm Developments (Aerosol Type Discrimination and Cloud Filtering)*

Learning and Retaining "Static" Information

MODIS, TOA RGB

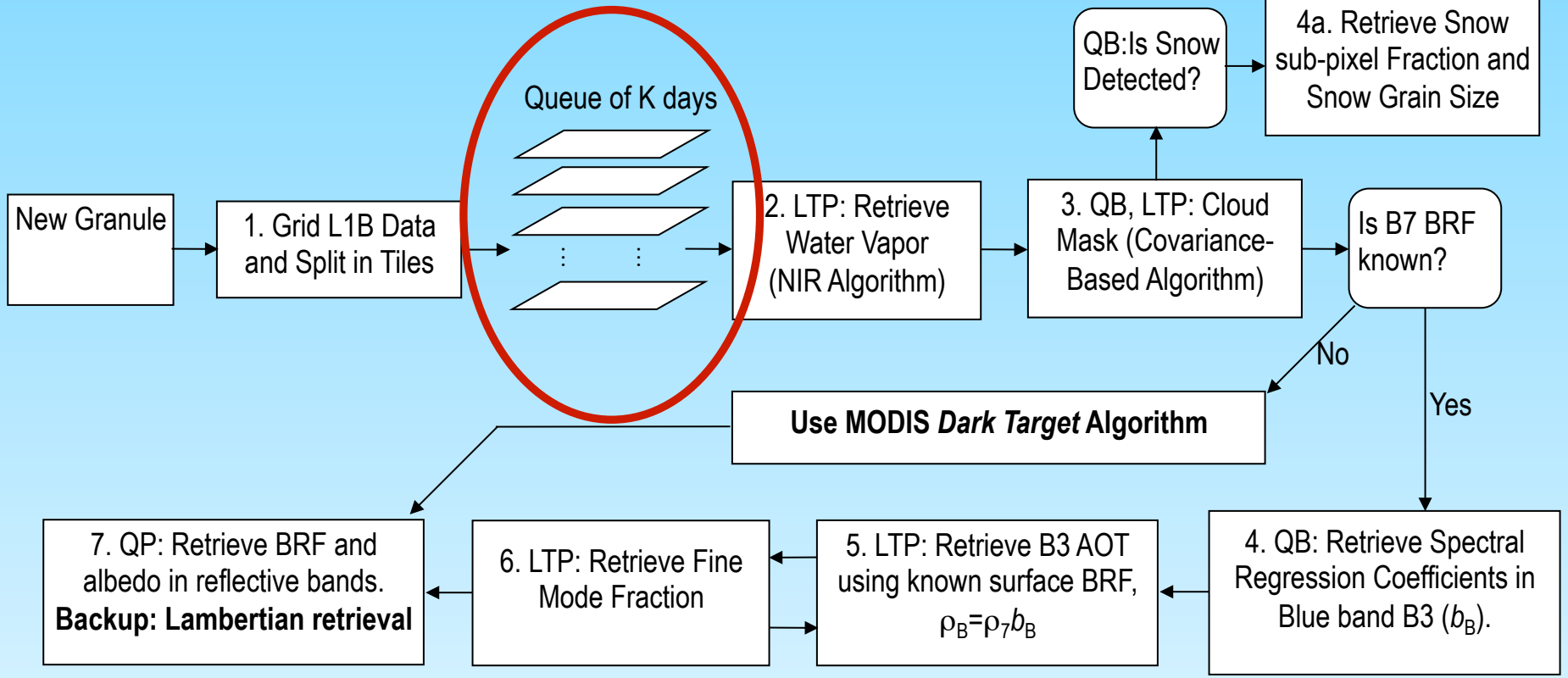
NBRF



AOT

BRF

Multi-Angle Implementation of Atmospheric Correction (MAIAC)



MAIAC Products (1 km, gridded)

Atmosphere:

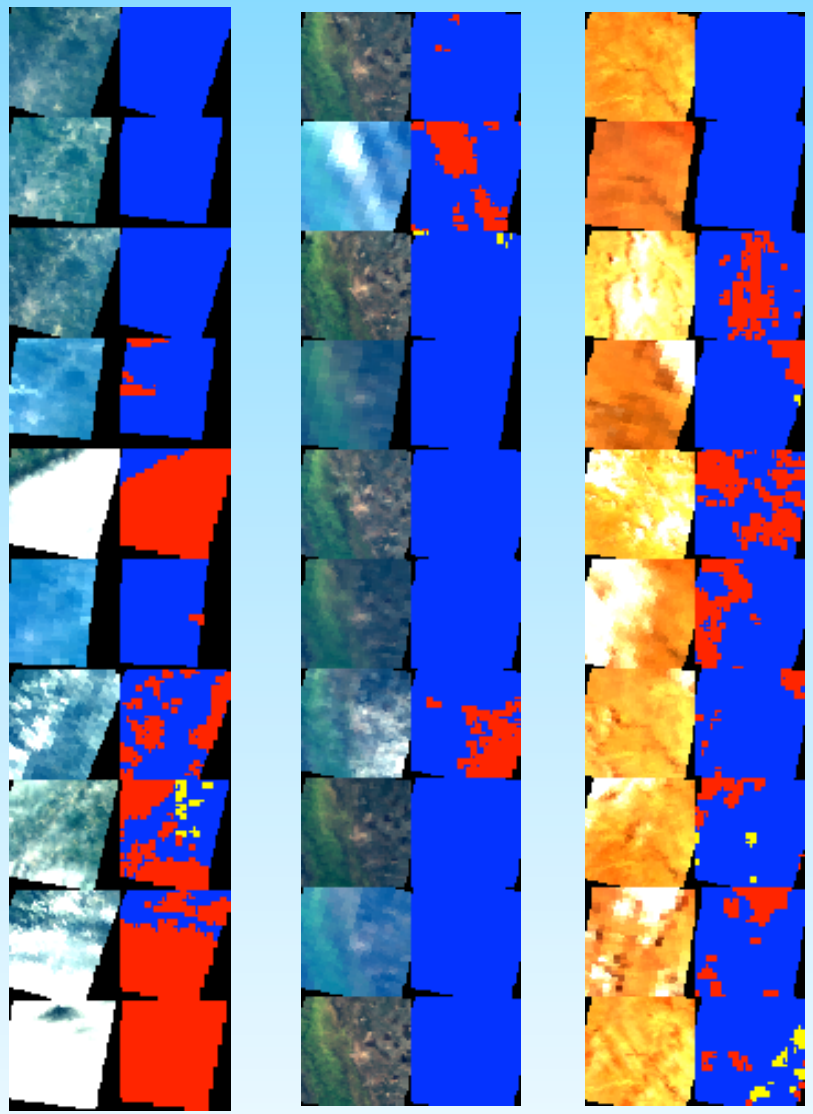
- *Cloud Mask;*
- *Water Vapor;*
- *AOT & aerosol type;*

Surface:

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

Cloud Mask

Left – MODIS TERRA RGB, 2003 (50×50km^2), Right – MAIAC CM



GSFC, USA | Mongu, Zambia | Solar Village

- ***Basis*** - *covariance analysis (identifies stable pattern in the time series) & reference clear-sky image of surface*
- ***High covariance - CLEAR**. Ephemeral clouds disturb the pattern and reduce covariance.*
- *Algorithm maintains a **dynamic clear-sky reference surface image** in B1, B7, used as a comparison target in cloud masking.*
- ***Approach**:*

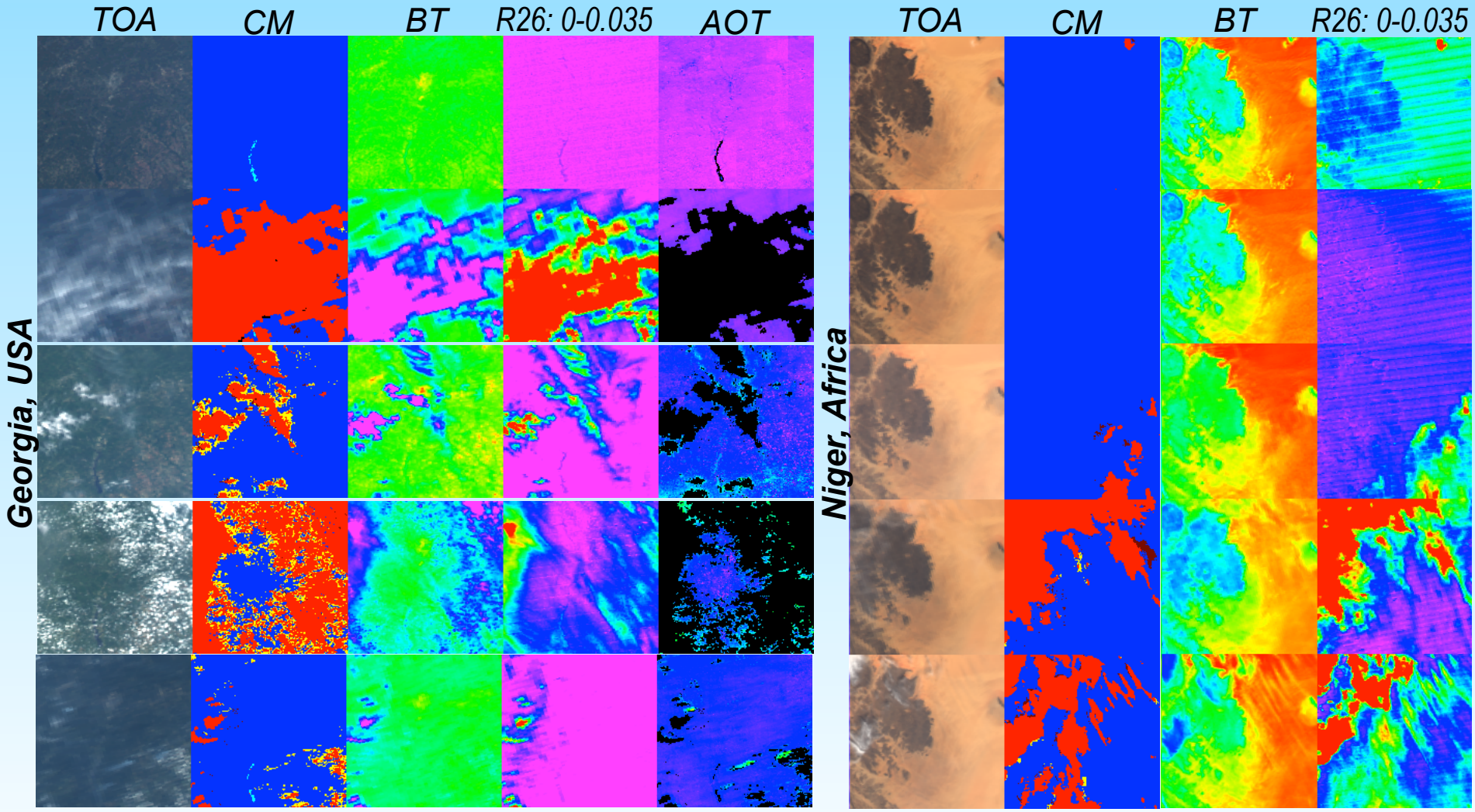
  High_cov – search for clouds
  Low_cov – search for clear-sky

CM Legend:

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

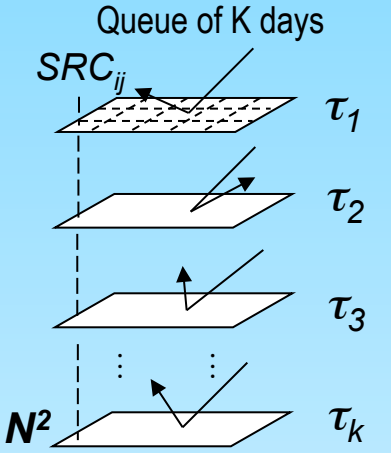
Enhanced Cirrus Detection using WV

- *MOD35: $R_{1.38}$ > 0.035, not used if H>2km*
- *MAIAC: a) Threshold is f(WV): 0.01 (WV>1cm), and 0.035 (WV>0.3 cm)*
  b) Detect Clear Snow: cov(1.38,1.24)>High, cov(B1,refcm)>High



Spectral Regression Coefficient

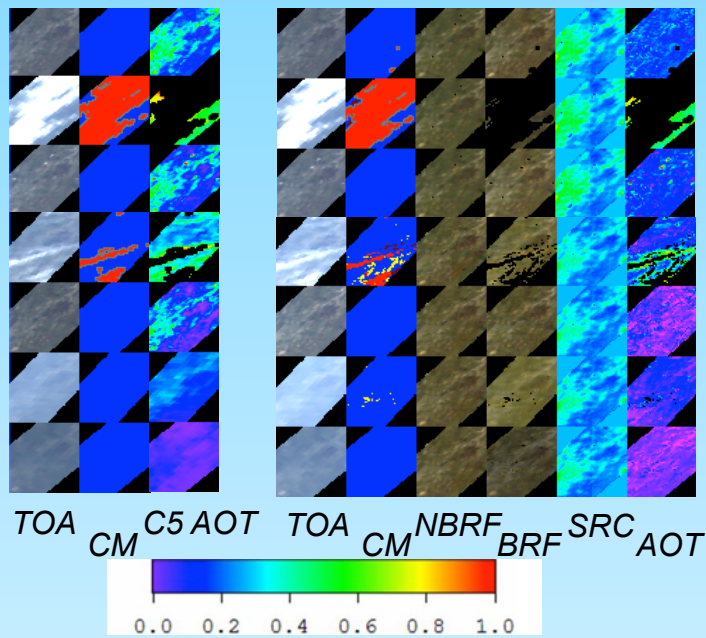
$$\rho_{ij}^{Blue} = SRC_{ij}\,\rho_{ij}^{RED}$$



Accumulate K>3 days and solve for N^2 SRC

Initial run using Levy et al., 2007

Second run after initialization

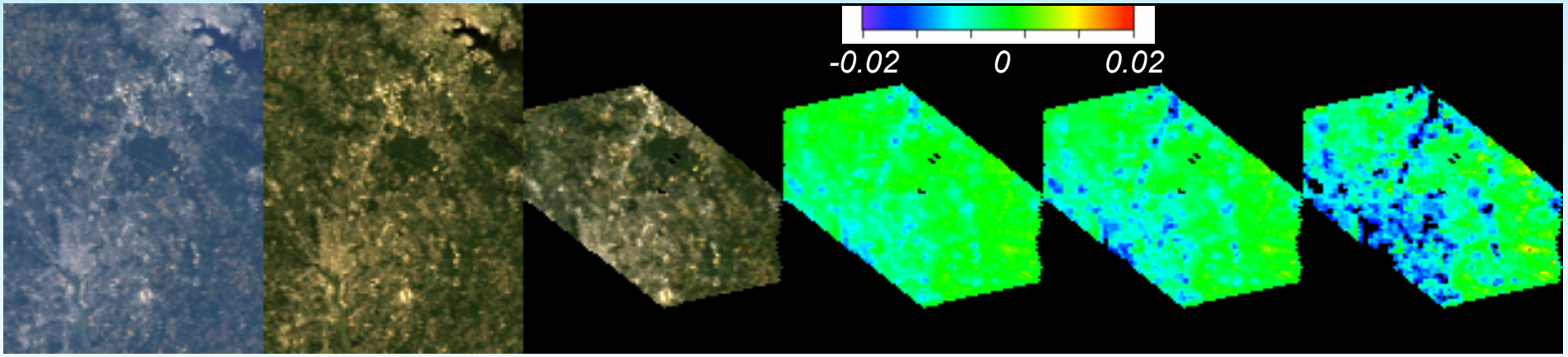


GSFC, 2000, DOY 84-93

1. *In standard retrievals, AOT correlates with surface brightness (left).*
2. *SRC retrieval helps avoid surface artifacts (right).*

*Difference Image: **MOD09-ASRVN** (GSFC, 2005, day 264)*

Blue/Black-Underestimation
Green – Agree
Yellow/Red - Overestimation

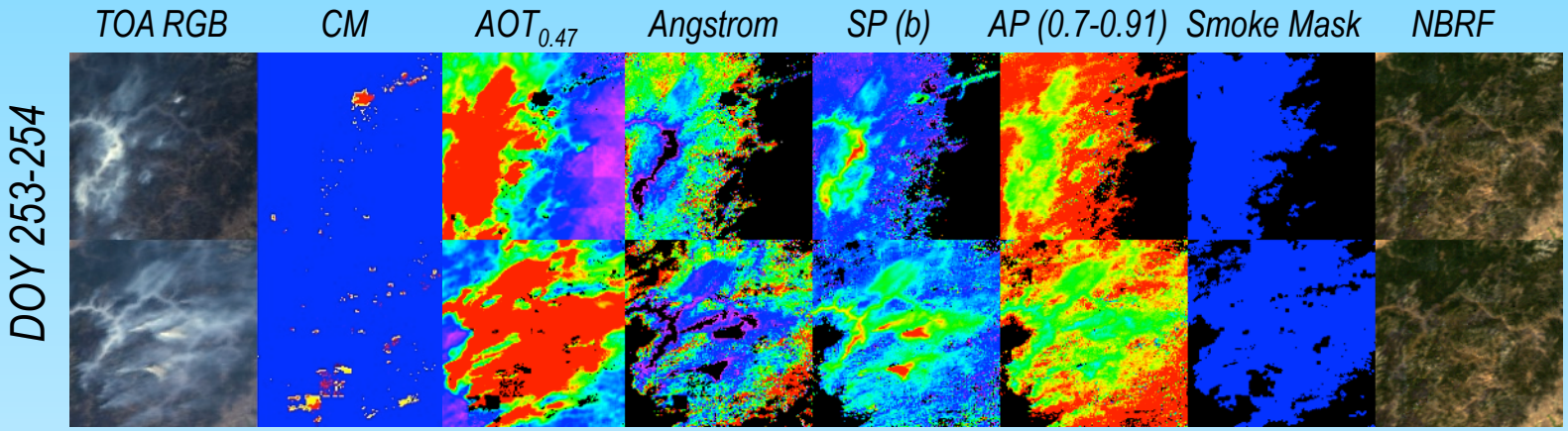


TOA *MOD09* *ASRVN* *diff-Red* *diff-Green* *diff-Blue.*

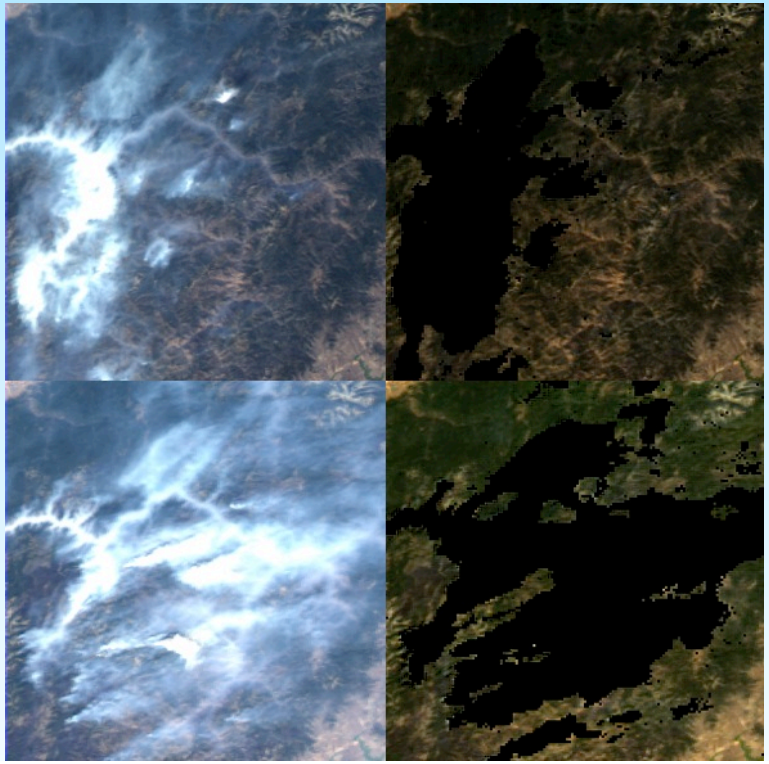
Aerosol Algorithm: Smoke Test

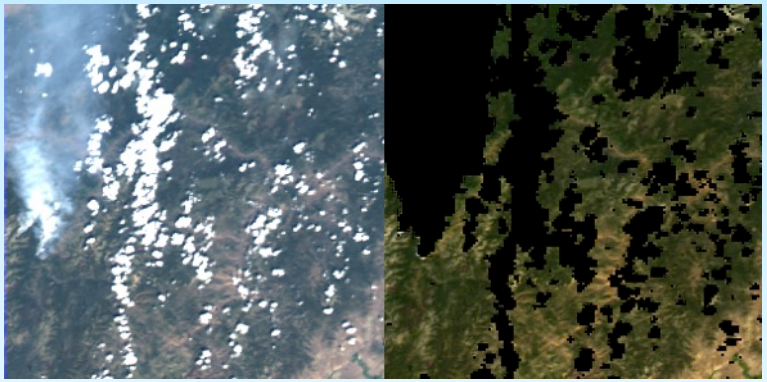
*Lyapustin, A. et al., 2012: Discrimination of biomass burning smoke and clouds in MAIAC algorithm, **ACP**, 12, 9679–9686.*

Phys. principles (~OMI): 1) n_i increases R→DB; 2) Multiple scattering, and absorption, increase R→DB, for absorbing aerosols.

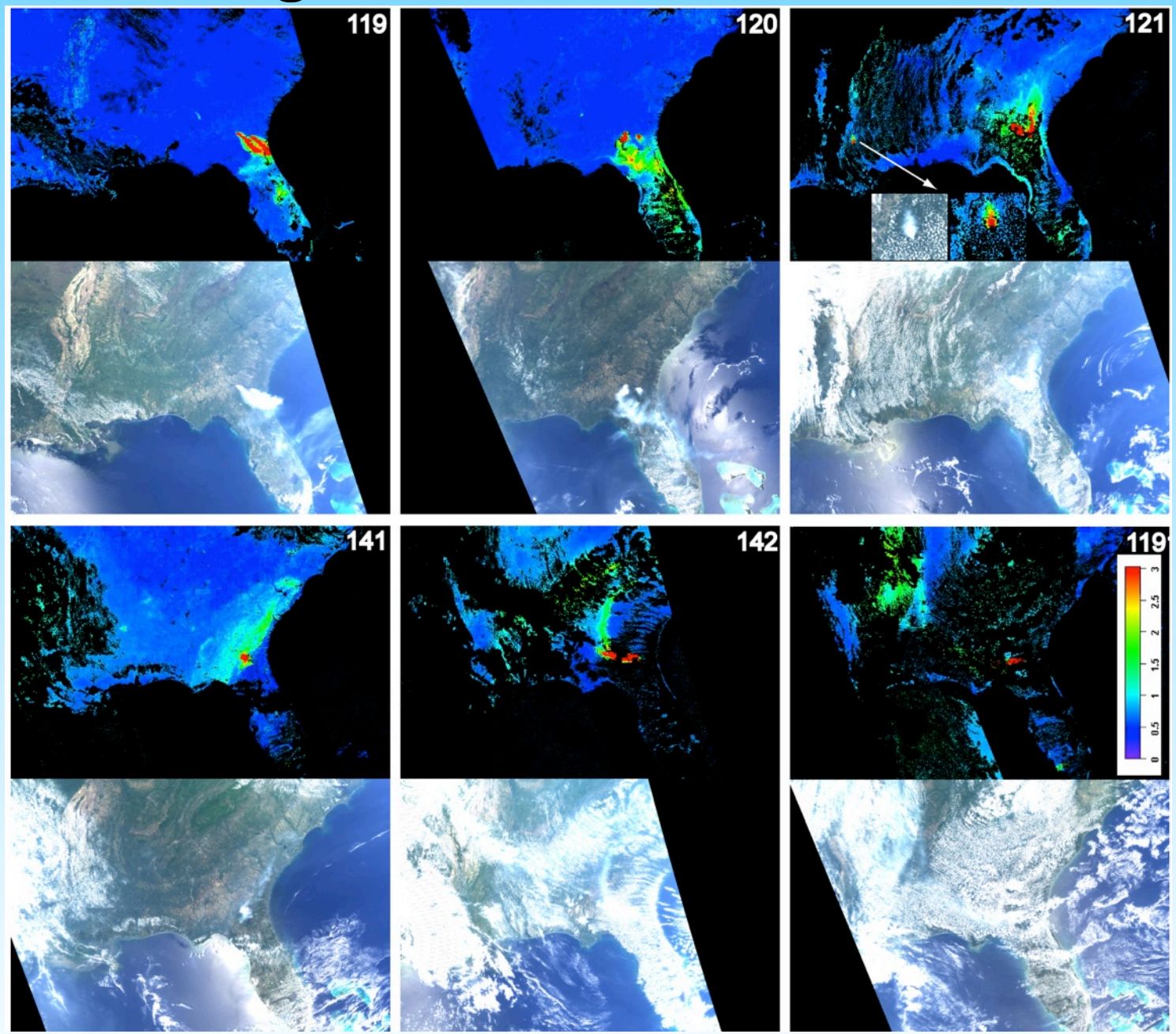


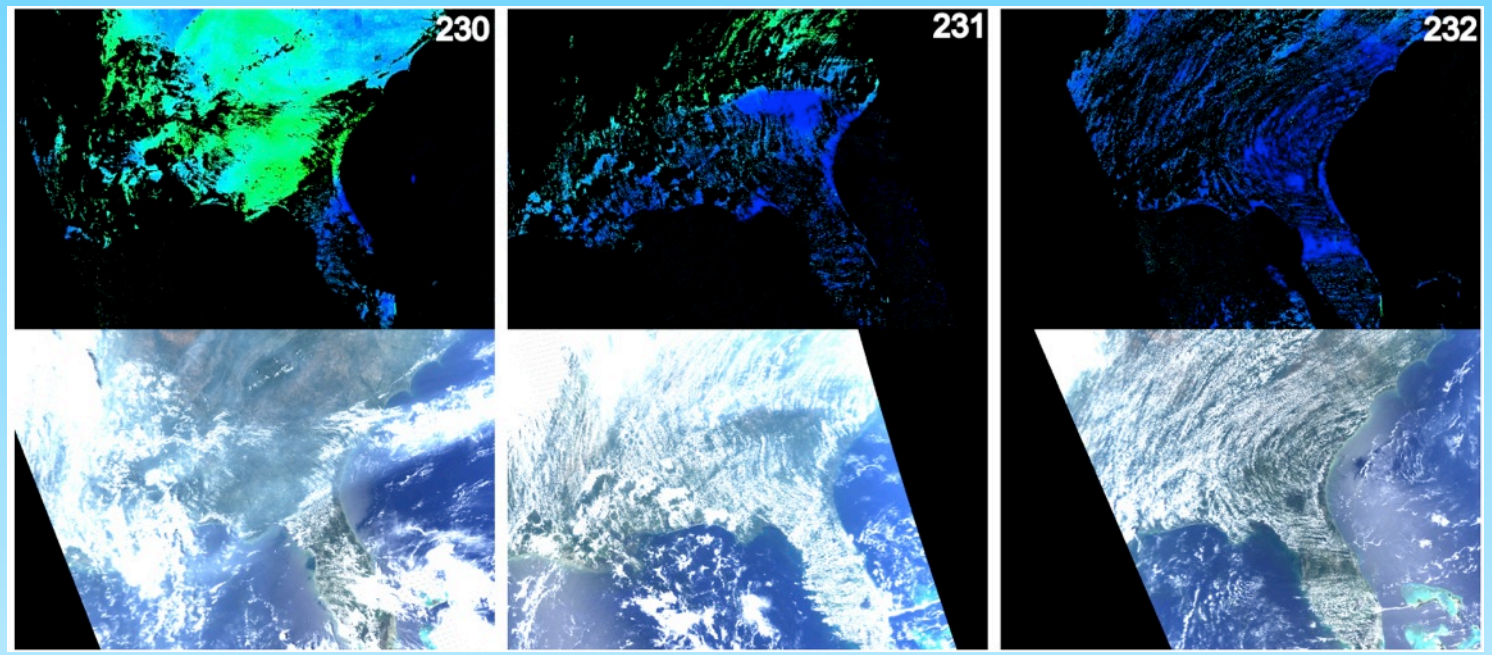
$$R_\lambda^{Aer} = R_\lambda^{Meas} - R_\lambda^{Molec} - R_\lambda^{Surf}(\tau^a)$$



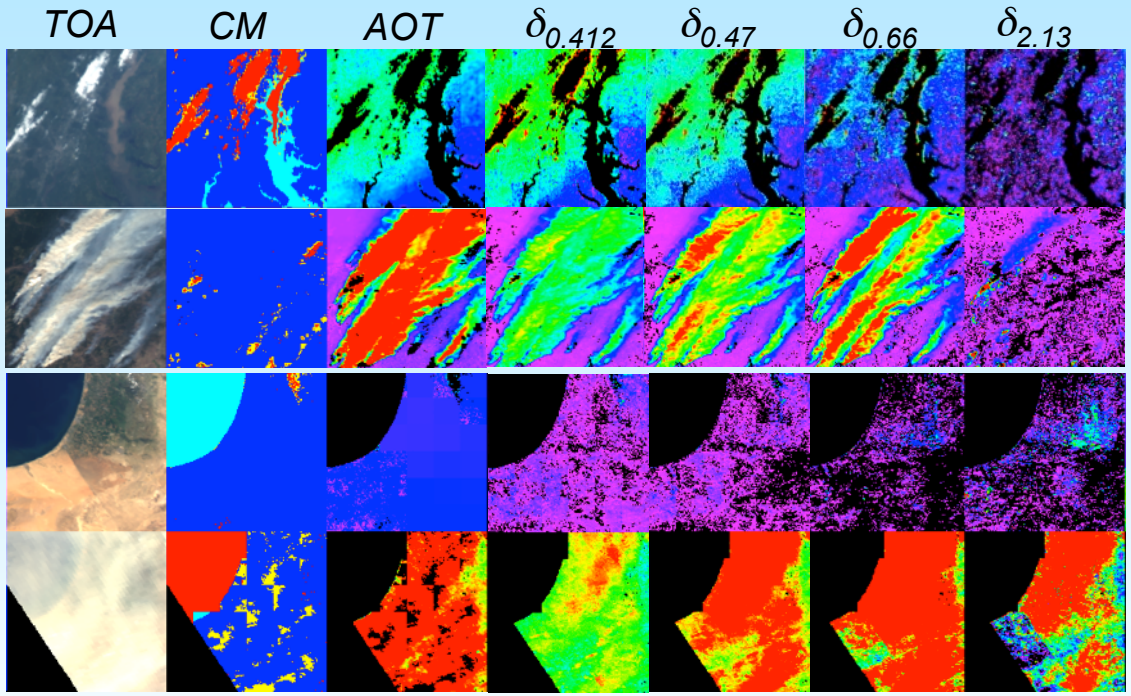


Georgia/Florida Fires of 2007





Removal of polluted air by weather system [Lyapustin et al., 2012, ACP].

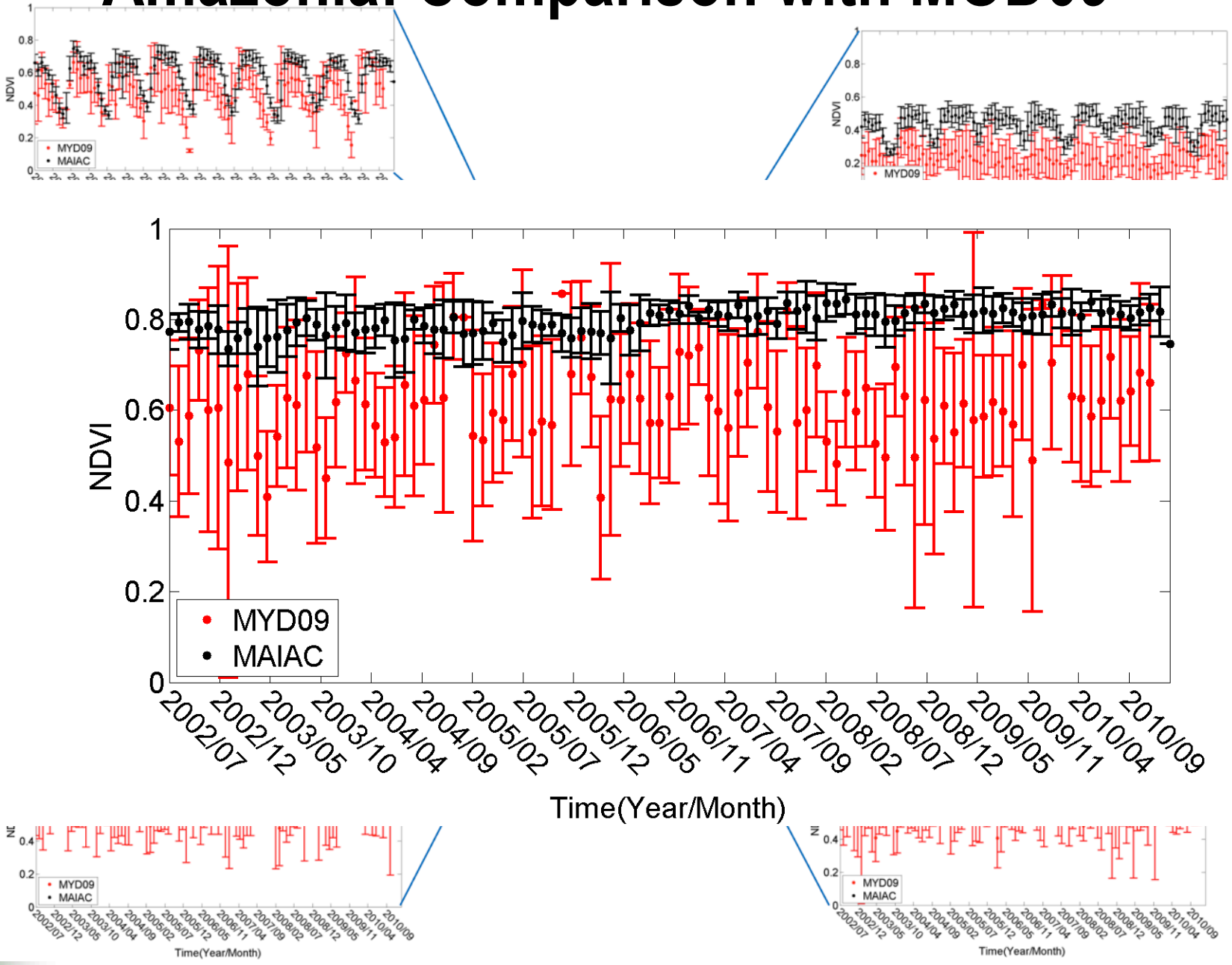


Backgr./Smoke/Dust

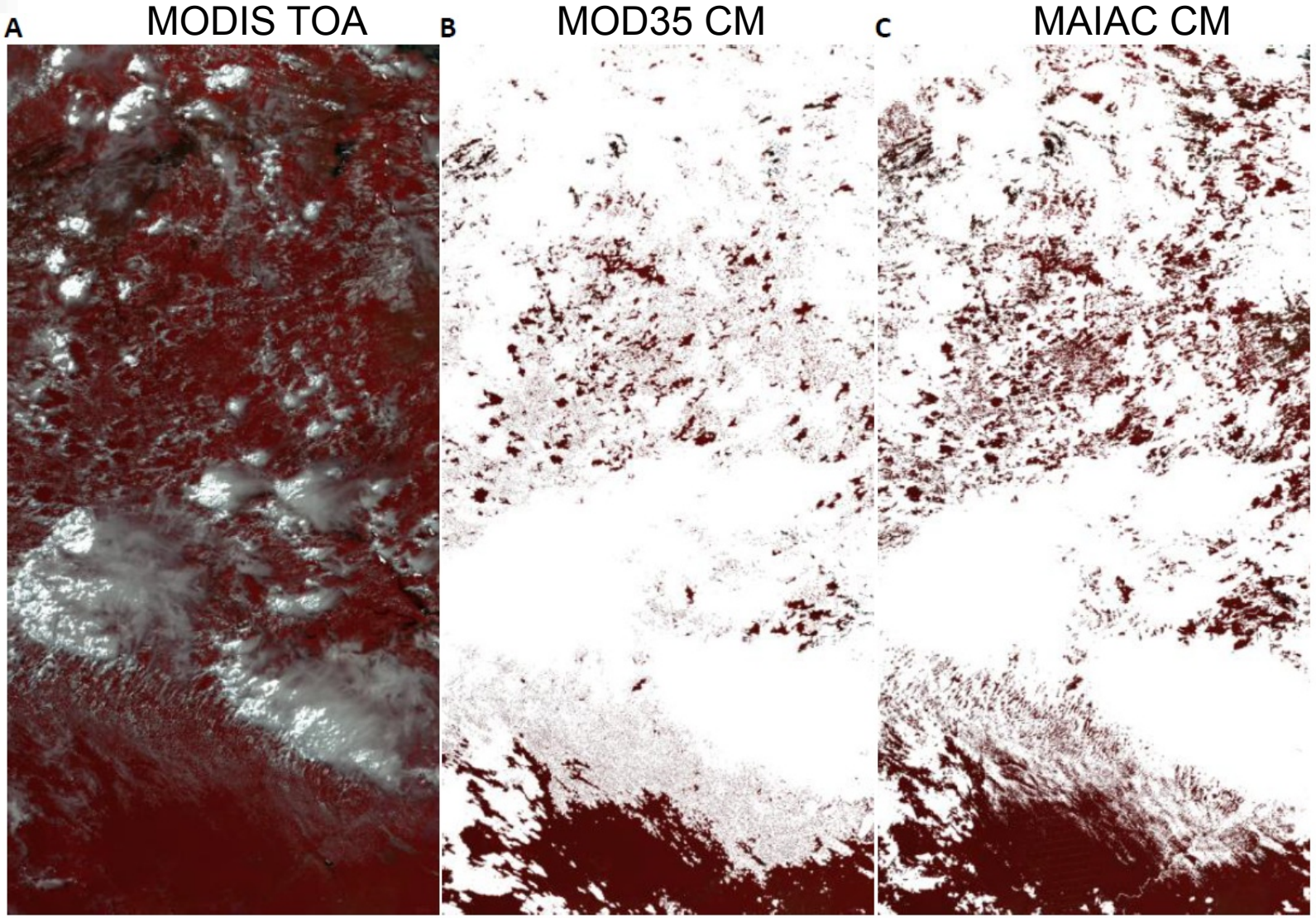
$$\delta_\lambda = R_\lambda^M - R_\lambda^T(\tau_{0.47}^a = 0.05)$$

Model	Abs.	Size
Backgr.	No	Small
Smoke	Yes	Small
Dust	Yes	Large

Amazonia: Comparison with MOD09



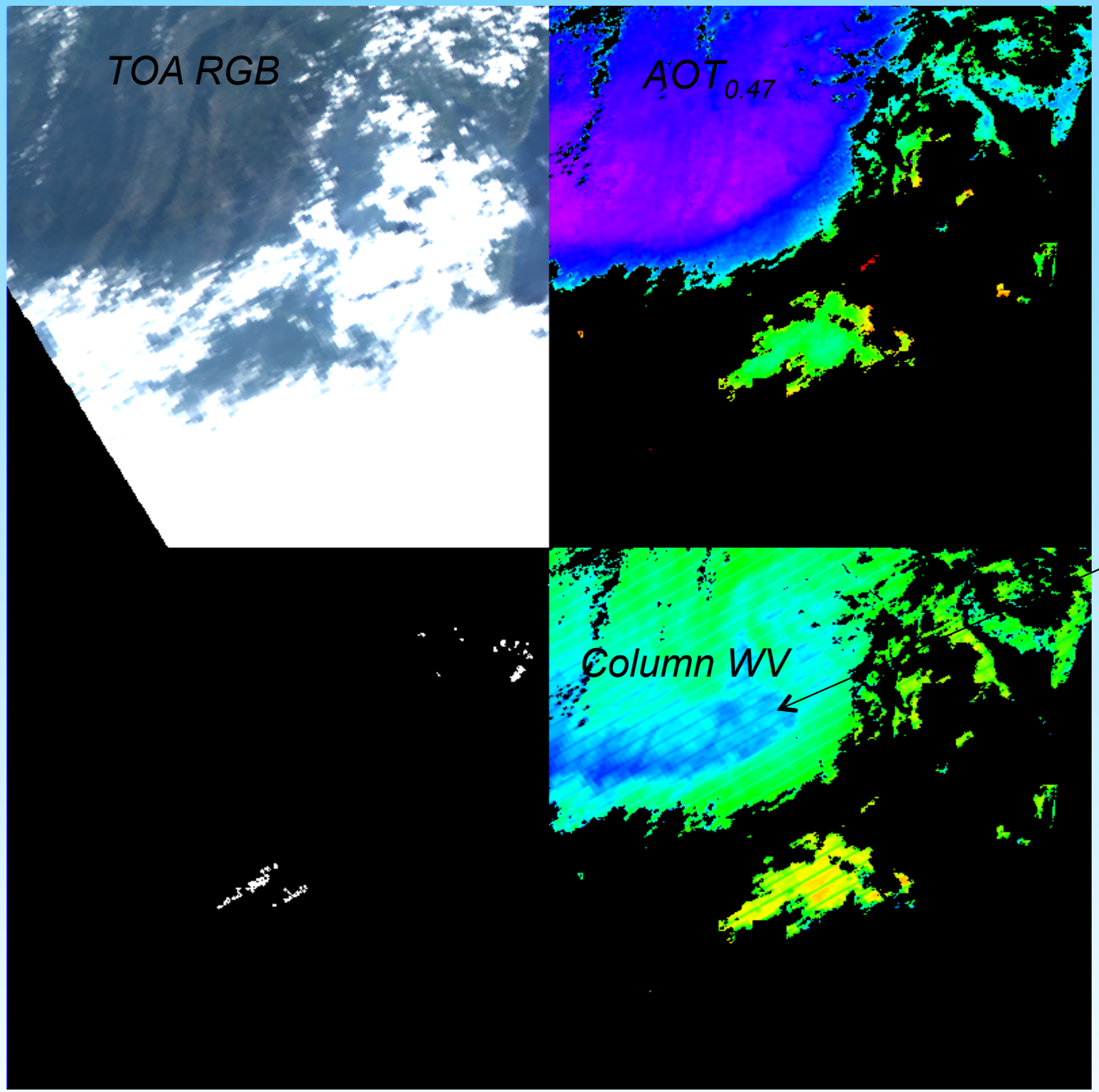
Cloud mask



Hilker, T., A. I. **Lyapustin**, C. J. Tucker, P. J. Sellers, F. G. Hall, Y. Wang, 2012: Remote Sensing of Tropical Ecosystems: Atmospheric Correction and Cloud Masking Matter. *RSE*, http://dx.doi.org/10.1016/j.rse.2012.08.035.

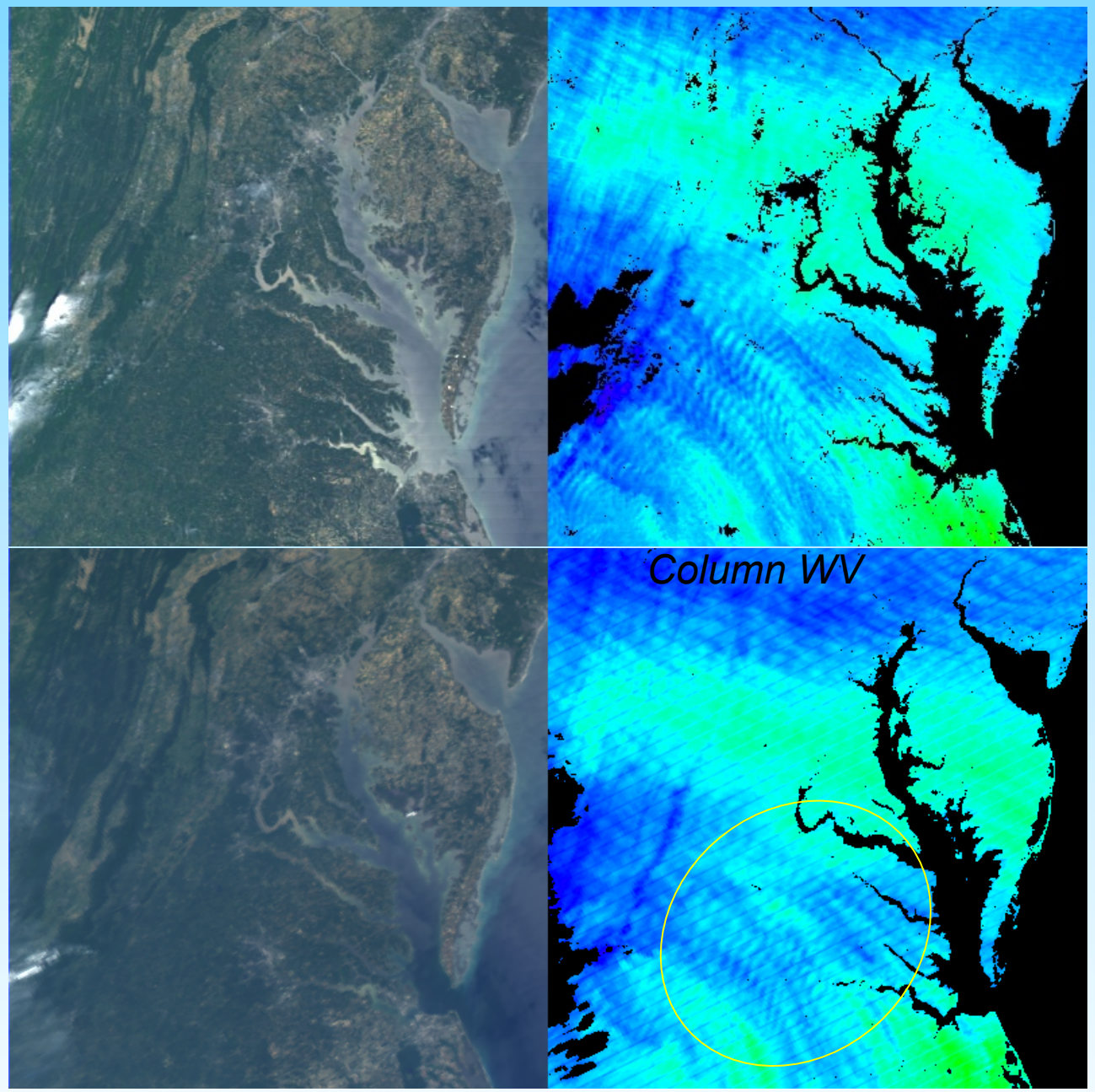
MAIAC Terra&Aqua Amazon dataset is available *on the LAADS FTP site* ftp://ladsweb.nascom.nasa.gov/MAIAC/

WV-AOT-Clouds …

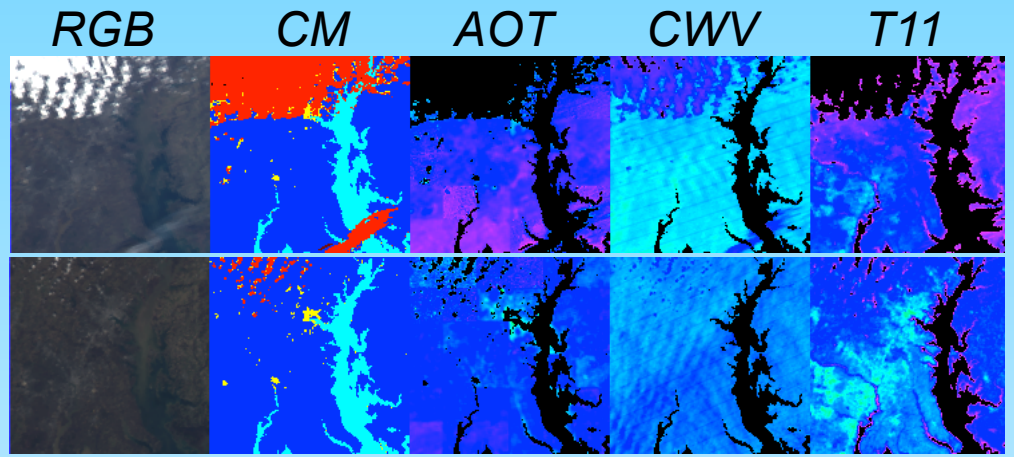


Aqua: 2011, DOY 212, 17:30

Mountain Waves in MODIS NIR WV

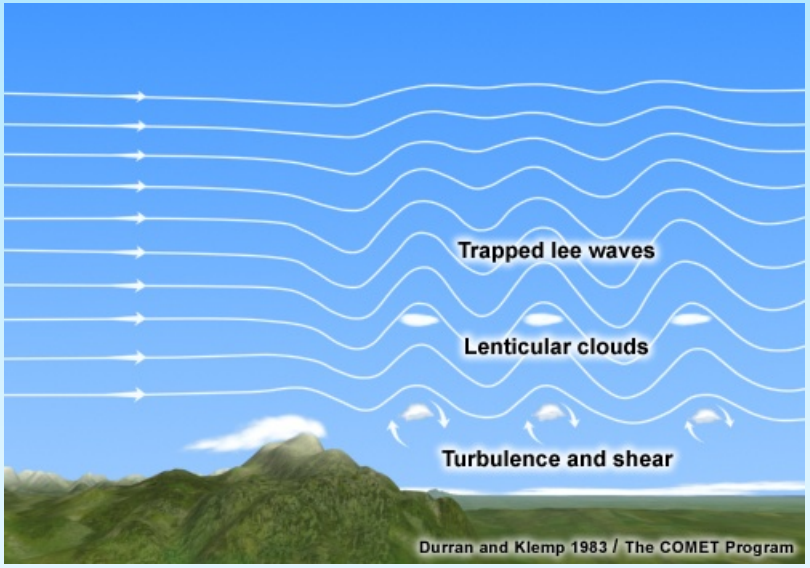


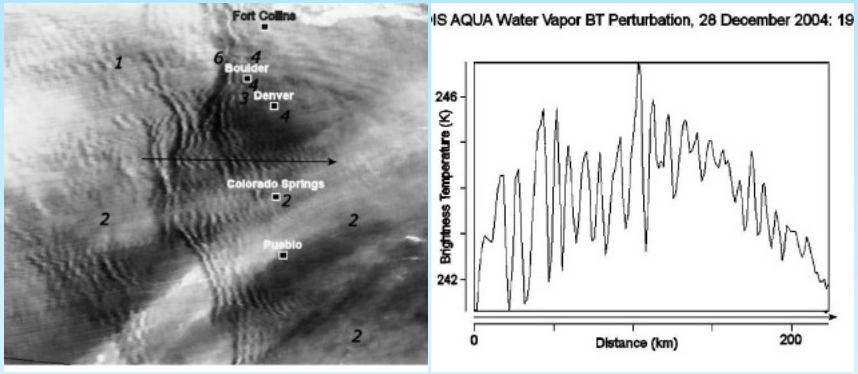
Mountain Waves in Water Vapor



Aqua: 2011
DOY 77

Aqua: 2011
DOY 79





MODIS Aqua WV BT (6.7μm), 12-28-04, from Uhlenbrock et al., Weather and forecasting, 22, 662-670, 2007.

CWV can provide wave period and drag (dissipation) distance. How can this information be used?

What is Bright Surface?

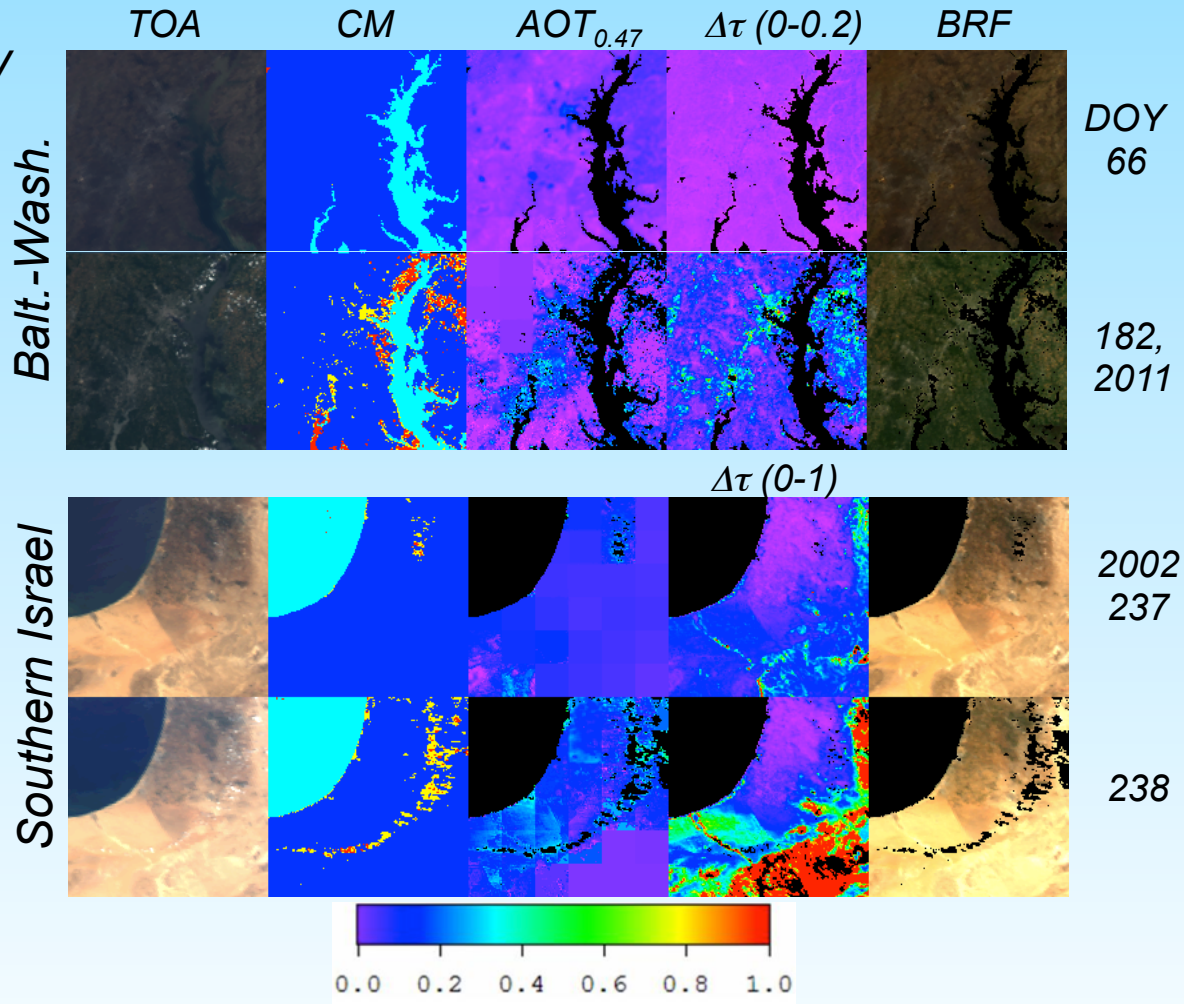
1. *Sensitivity of measurements to AOT variations* $L'_\lambda \approx \frac{L^{Th}_\lambda(0.1) - L^{Th}_\lambda(0.05)}{0.05};$

2. *AOT uncertainty relates to surface BRDF uncertainty:* $\Delta\tau_{\lambda;i,j} = \frac{\mu_0 \sigma_{\lambda;i,j}}{L'_{\lambda;i,j}};$

3. *Over land, uncertainty of AE(Blue, Red) is defined by the Red band retrieval:*

$$\alpha = \ln\left(\frac{\lambda_B}{\lambda_R}\right)(\ln\tau_R - \ln\tau_B);$$

$$\Delta\alpha = c\left(\frac{\Delta\tau_R}{\tau_R} - \frac{\Delta\tau_B}{\tau_B}\right) \sim c\frac{\Delta\tau_R}{\tau_R};$$



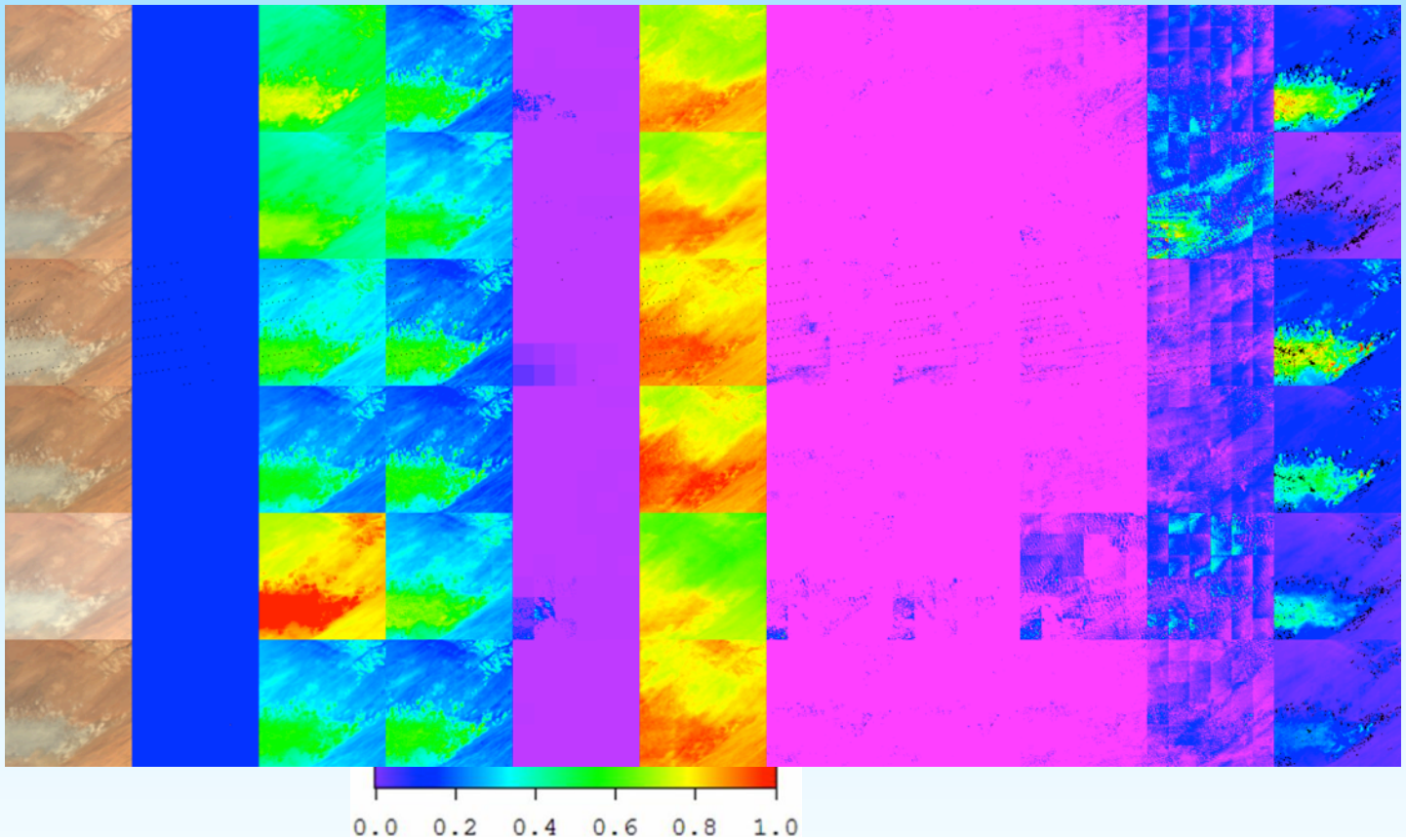
Bright-I: Surface Characterization

Analysis for 25×25 km² blocks (includes both magnitude and contrast)

$$\delta_{\lambda;i,j} = \frac{R^{M}_{\lambda;i,j} - R^{T}_{\lambda;i,j}}{\sigma_{\lambda;i,j}}; \quad \chi_{i.j} = \sum_{\lambda} \delta^{2}_{\lambda;i,j}; \quad rmse = \sum_{i,j} \chi^{2}_{i,j} = \min_{\tau<0.3}\{\tau\}$$

⇒ *Accept if* ***Cov***>*HIGH* & ***rmse***<*1*

Example for Bodele Depression (150×150 km²: DOY 344-351, 2007)



$$\Delta\tau_{\lambda;i,j} = \frac{\mu_0 \sigma_{\lambda;i,j}}{L'_{\lambda;i,j}};$$

- AOT uncertainty

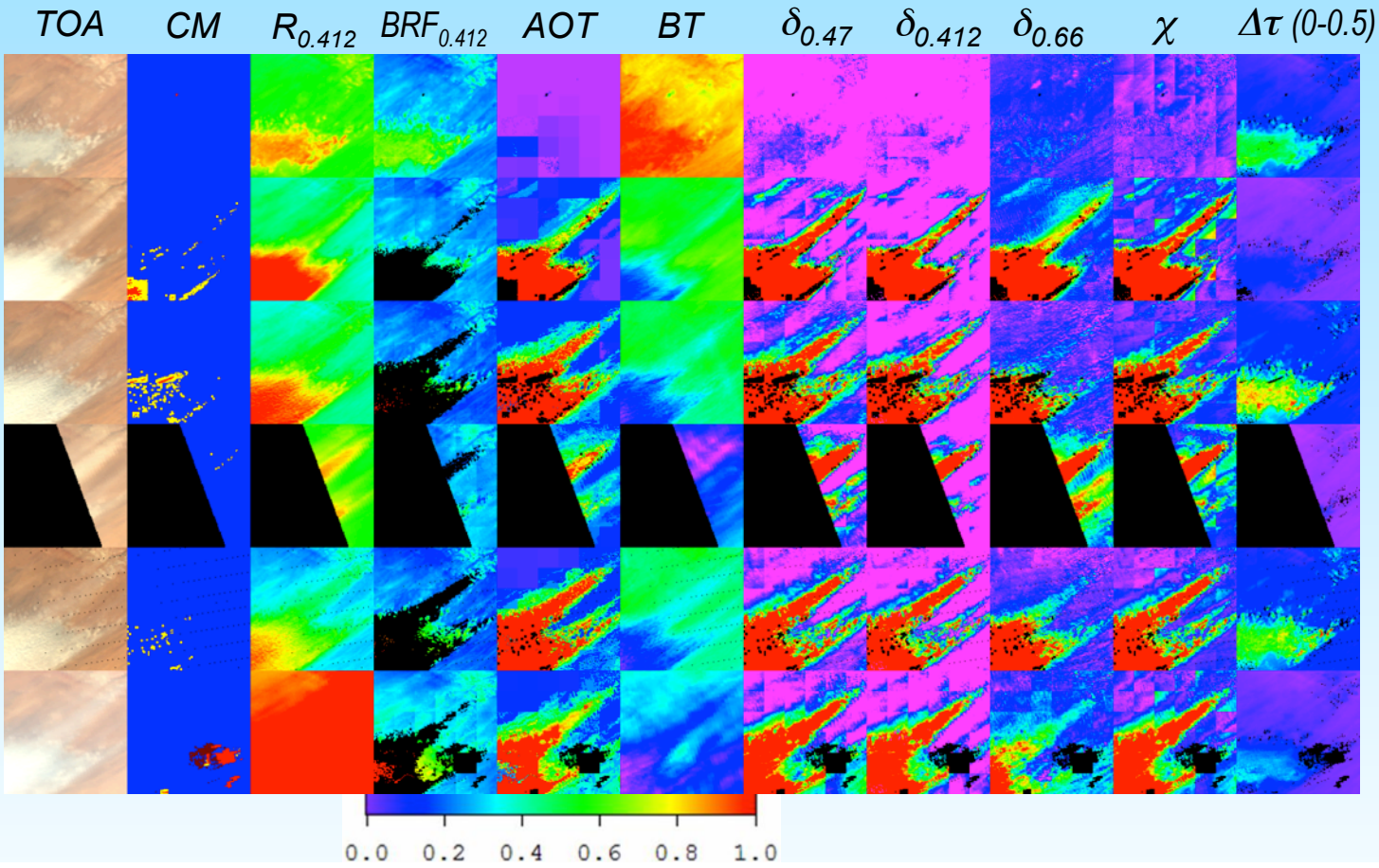
Bright-II: Aerosol Retrieval

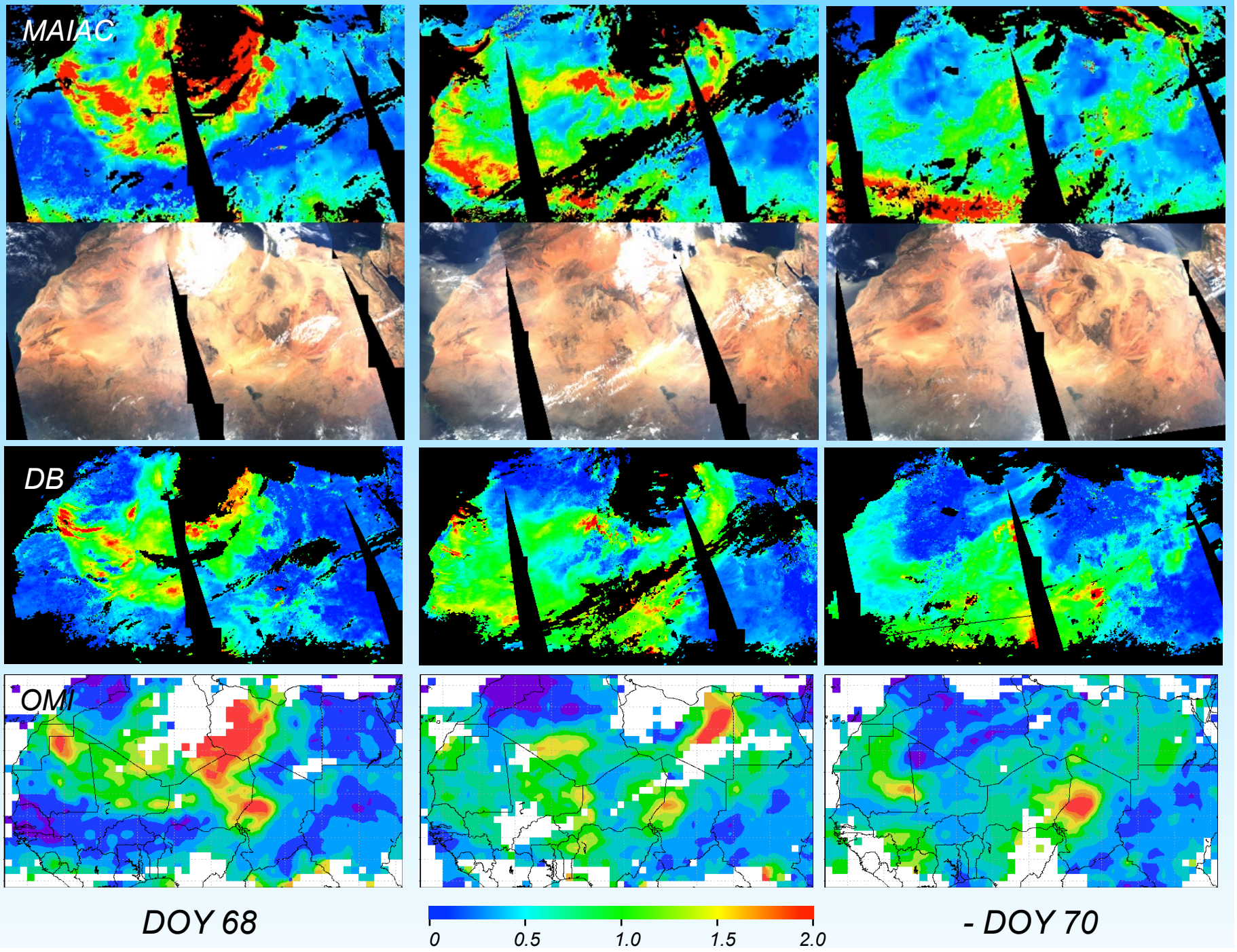
Pixel Analysis

$$\delta_{\lambda;i,j} = \frac{R^{M}_{\lambda;i,j} - R^{T}_{\lambda;i,j}}{\sigma_{\lambda;i,j}}; \qquad \chi_{i,j} = \sum_{\lambda} \delta^{2}_{\lambda;i,j} = \min\{\tau; Model\}$$

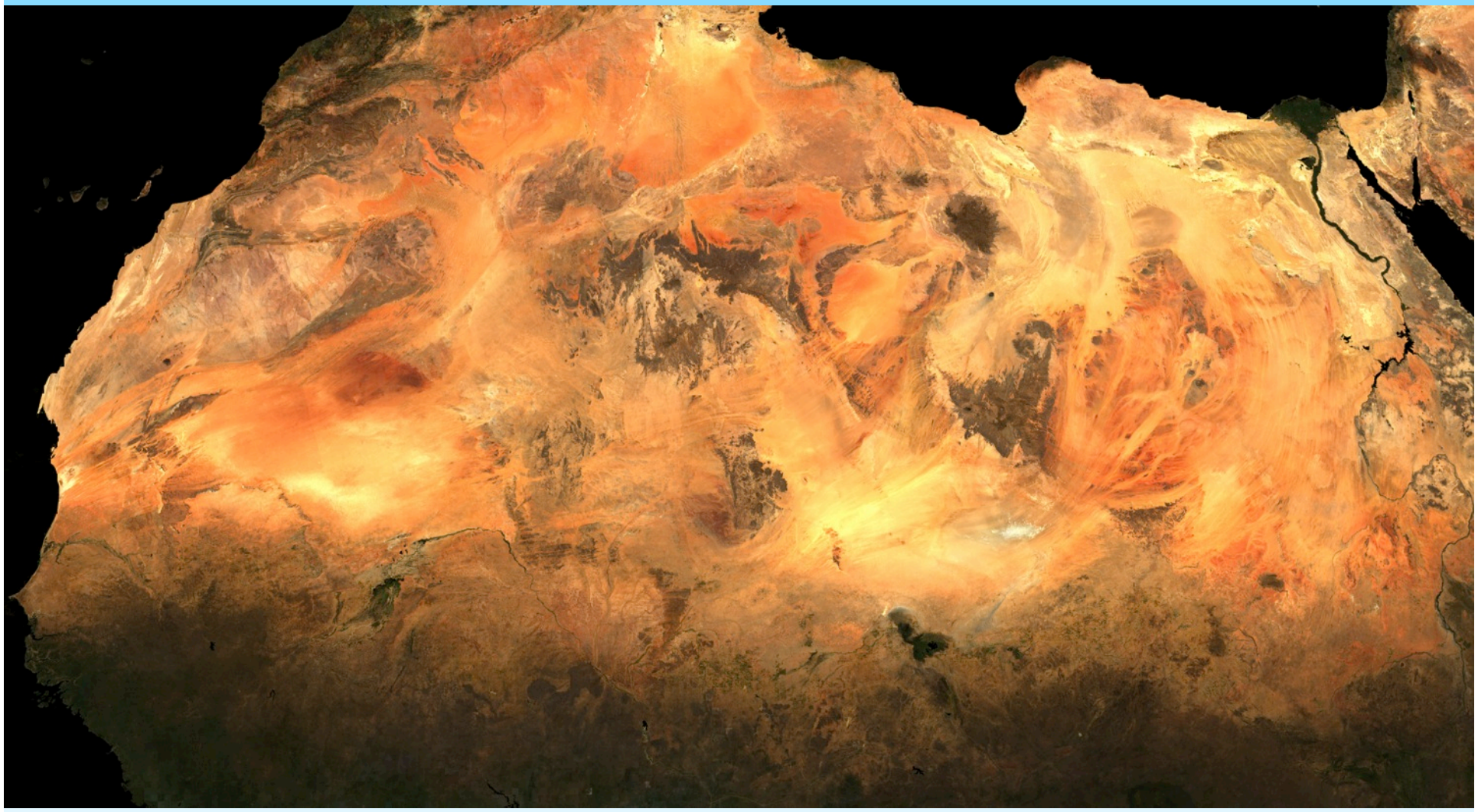
for every pixel with χ>0.5

… Bodele Depression (DOY 352-358, 2007 – Dust Storm)




MAIAC
DB
OMI
DOY 68
0
0.5
1.0
1.5
2.0
- DOY 70

RGB NBRF, 5500×3000 km^2, 2007



MAIAC NBRF (SZA=45°, VZA=0°), end of 2007