A New High Resolution Aerosol Dataset from Algorithm MAIAC

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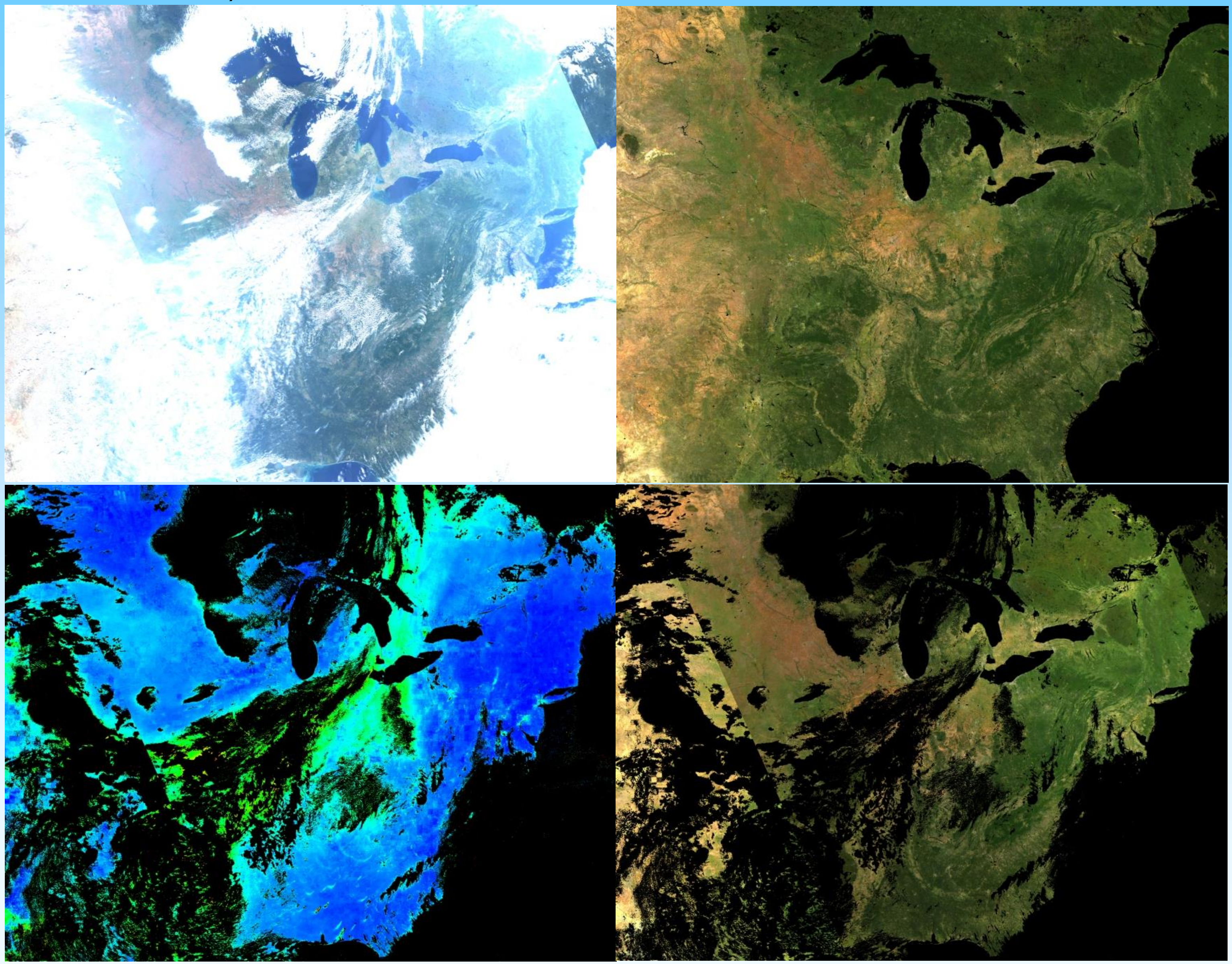
MAIAC *= Time Series + Spatial Analysis*

MODIS, TOA RGB *NBRF*



AOT *BRF*

MAIAC: Standard and New Features

- Anisotropic surface model;

- Retrieval of Spectral Regression Coefficient;

- Detection and accommodation of seasonal and rapid surface change;

- Storing "static" (surface) information;

- Products: WV, CM, AOT, AE (over dark surfaces) and aerosol type (background/smoke/dust – in progress) @1km resolution and surface suite (spectral BRDF model, BRF (SR), albedo).

New Features

- *Removed blockiness (25km) of AOT and SR images;*
- *Provide uncertainty of AOT;*
- *Aerosol type classification (background/smoke/dust);*
- *Improvements in cloud detection.*

Retrieval of SRC

Old: Multi-day minimization over 25x25km² blocks

New: Minimum Reflectance Method:

- We can express measured B3 radiance as a function of 2.1μm BRDF:

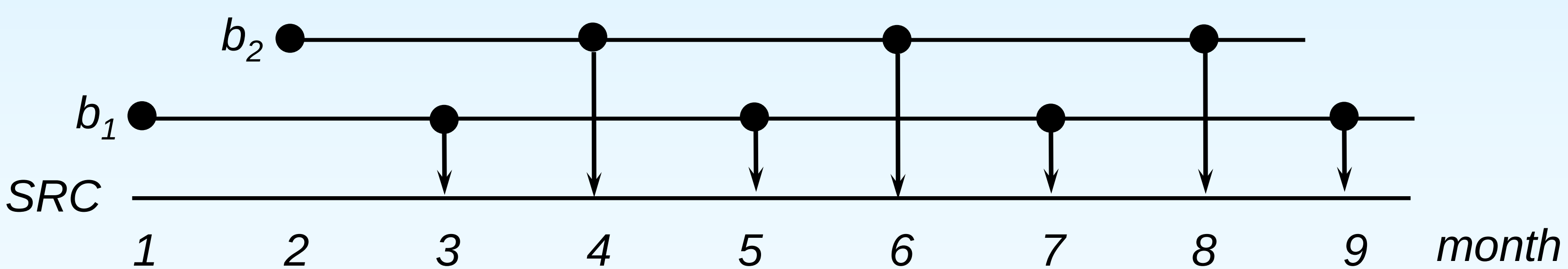
$$L^{B3} \cong D + L_s(b\rho^{B7})$$

-Compute b for the background aerosol (AOT~0.05);

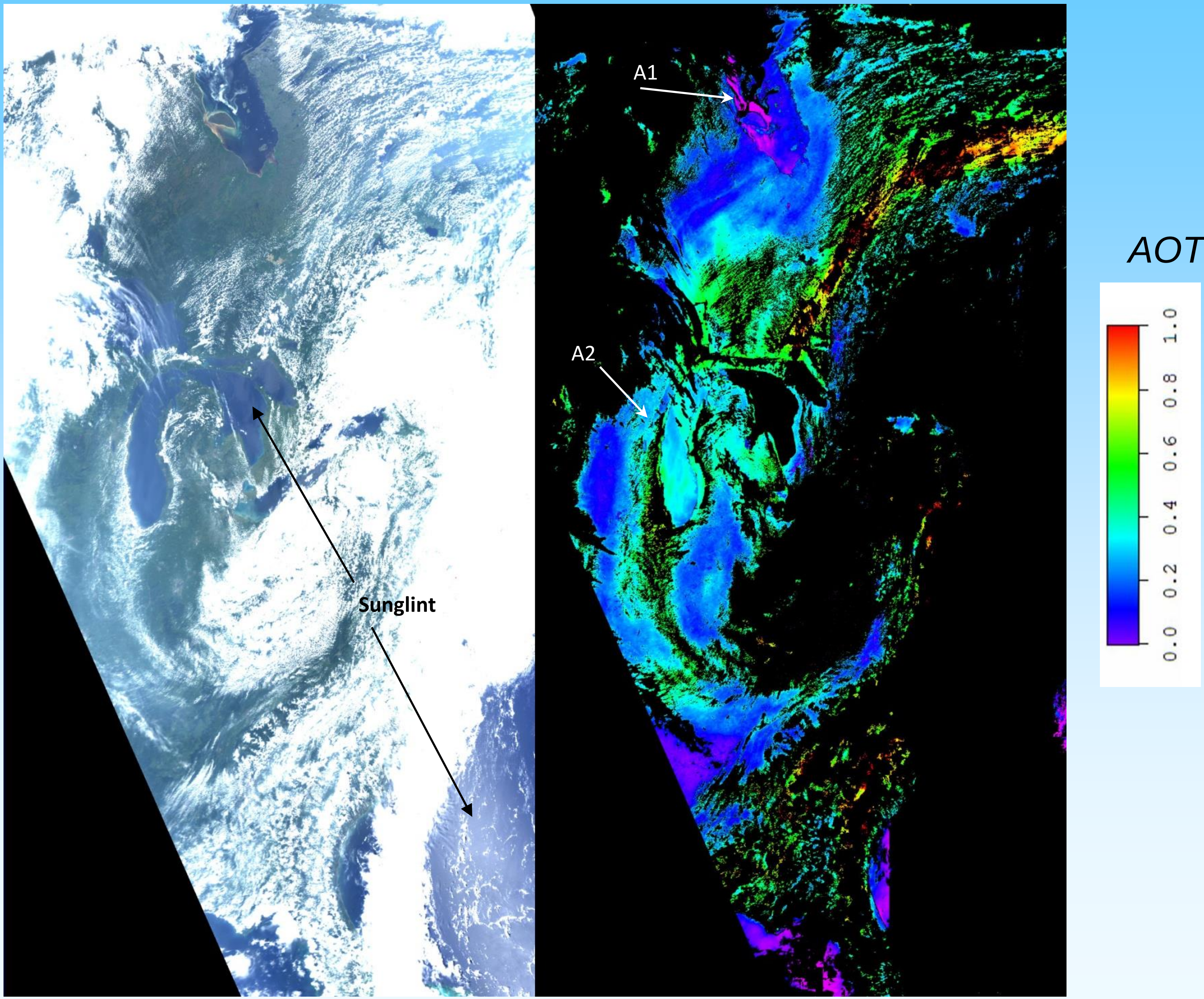
- Blue band is "dark", aerosols increase SRC (b);

- Select SRC as min over ΔT;

- Run 2 lines of SRC update: each line initializes over 2 months, and SRC is updated monthly



Example, incl. coastal and inland water



Aerosol Type Discrimination (Smoke/Dust)

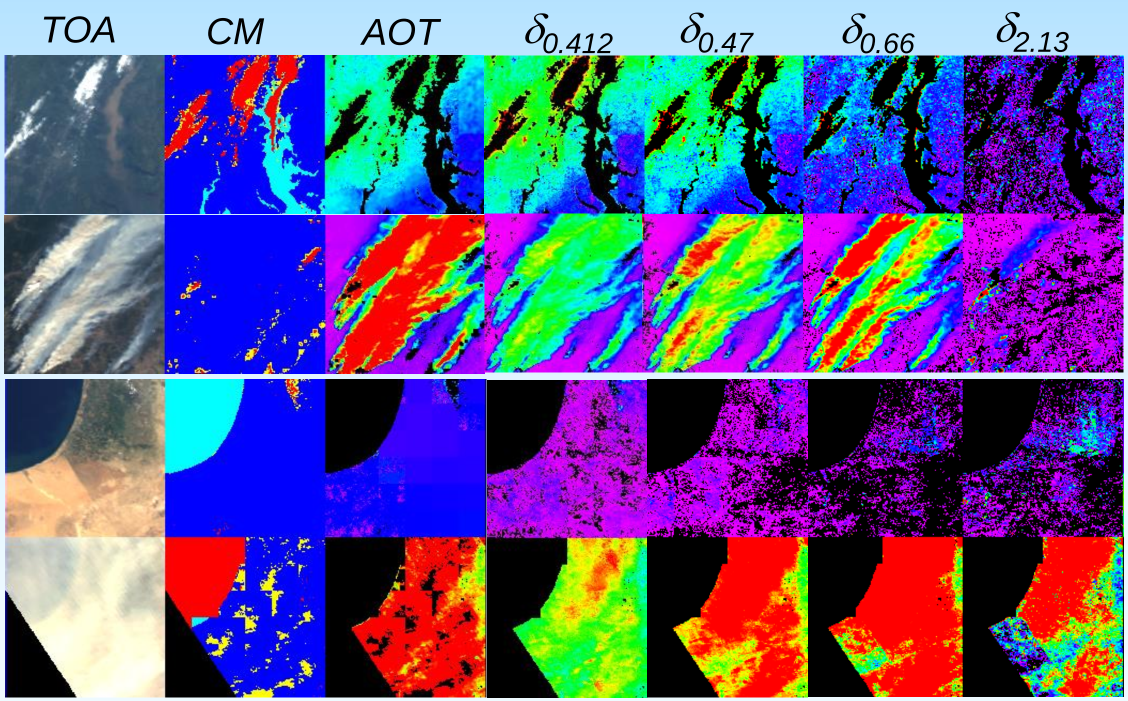
*Lyapustin, A. et al., 2012: Discrimination of biomass burning smoke and clouds in MAIAC algorithm, **ACP**, 12, 9679–9686.*

*Phys. principles (~OMI) – **enhanced shortwave absorption** (Red →Blue →DB)*

$$R_\lambda^{Aer} = R_\lambda^{Meas} - R_\lambda^{Molec} - R_\lambda^{Surf}(\tau^a)$$ *- proxy of aerosol reflectance*

1) n_i increases R→DB for OC (smoke) and dust;

2) Multiple scattering, and absorption, increase R→DB, for absorbing aerosols.

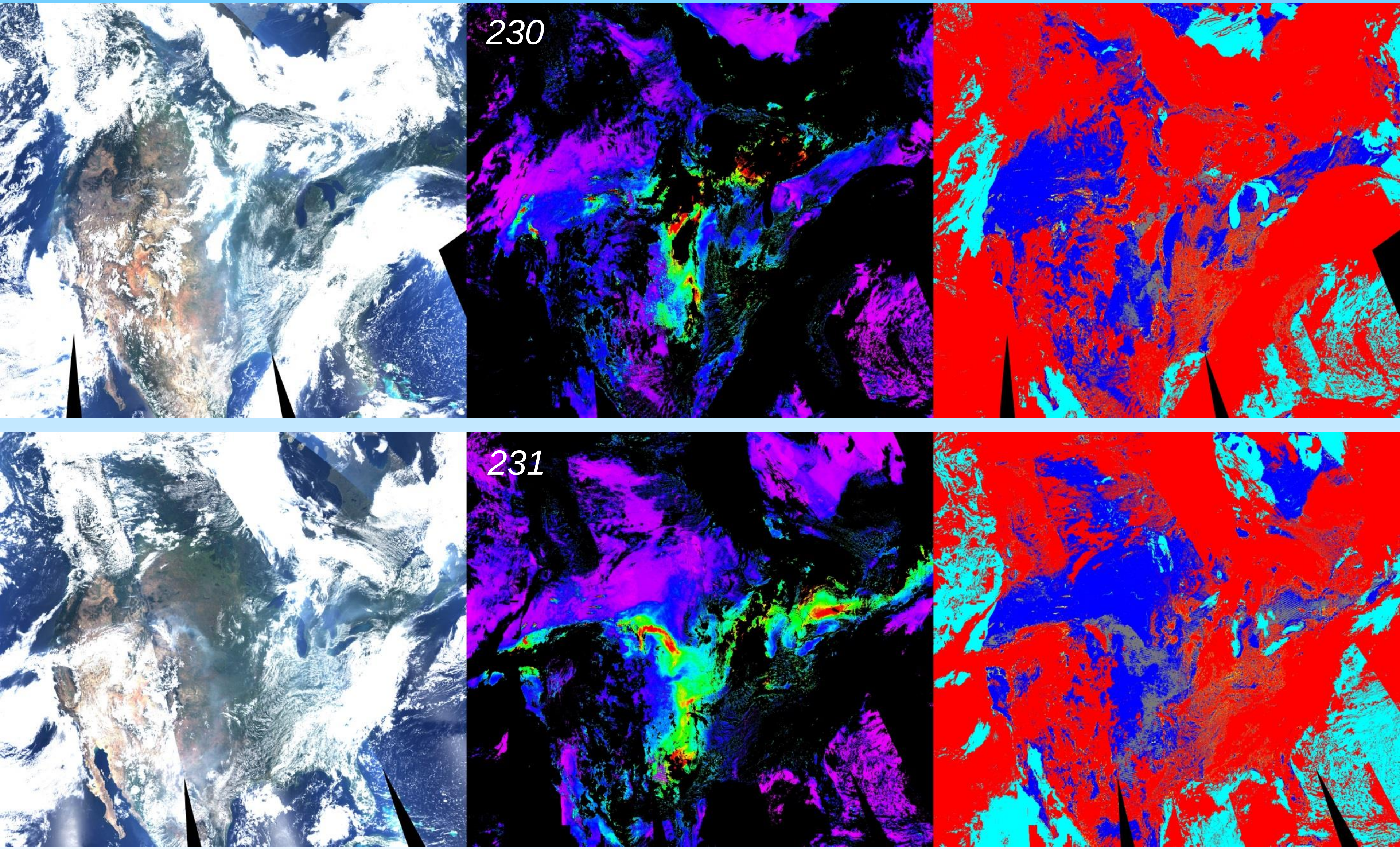


Backgr./Smoke/Dust

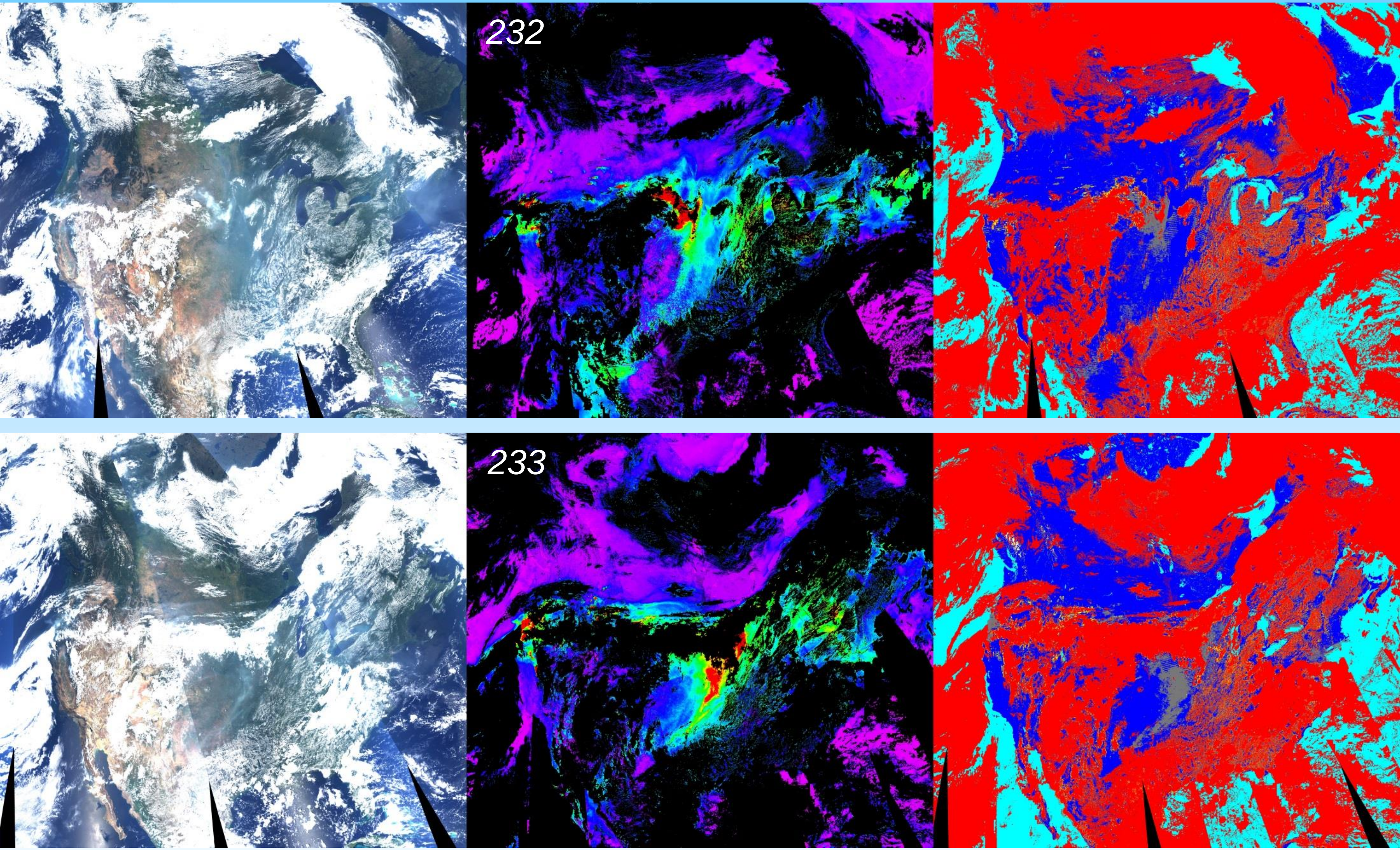
$$\delta_\lambda = R_\lambda^M - R_\lambda^T(\tau_{0.47}^a = 0.05)$$

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

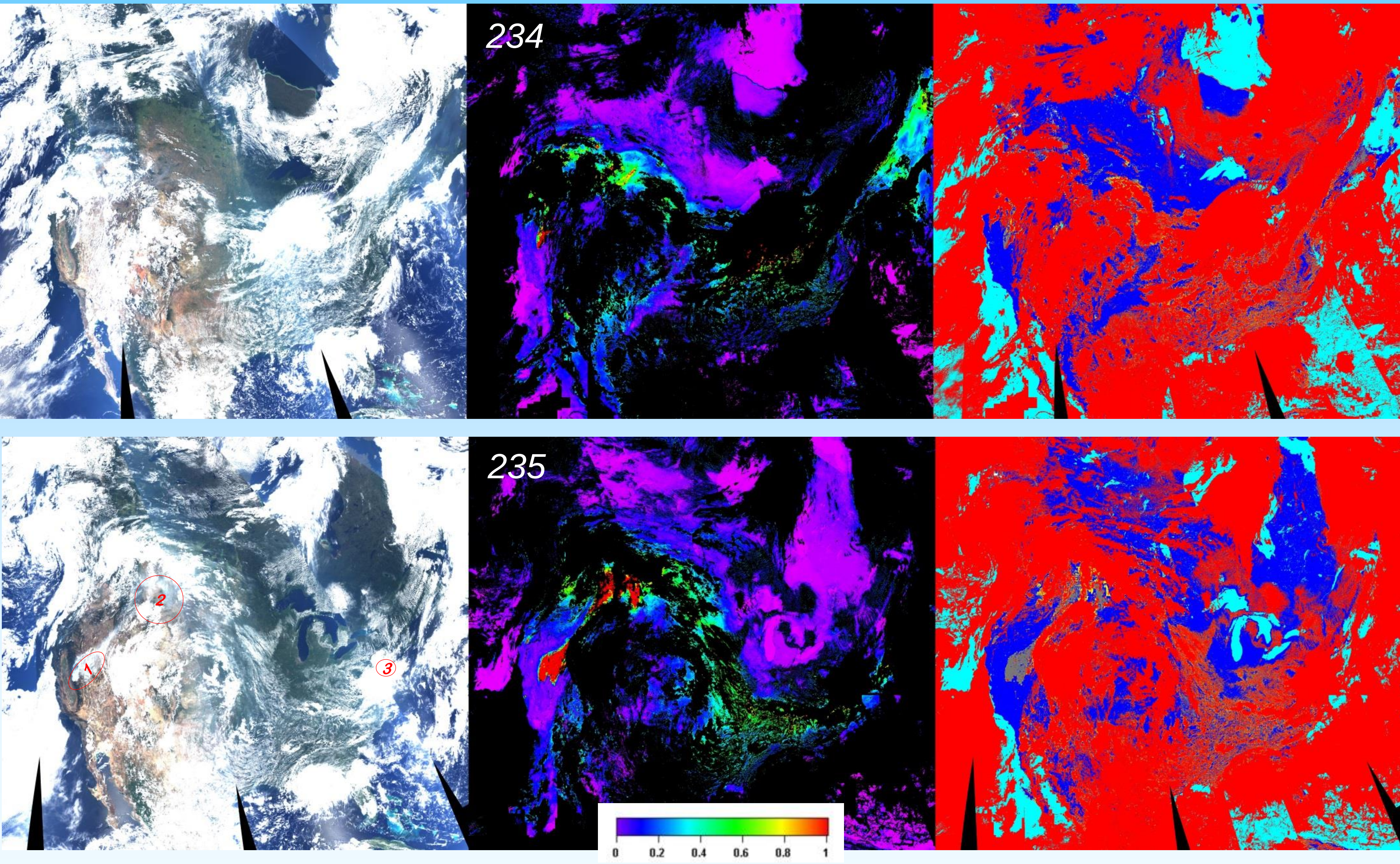
Idaho/Wyoming – Yosemite Fires (08-2013)



Idaho/Wyoming – Yosemite Fires (08-2013)



Idaho/Wyoming – Yosemite Fires (08-2013)



On Spectral Invariance Assumption

SRC algorithm assumes the BRDF shapes in Blue and SWIR are the same:

$\rho_{ij}^{Blue} = b_{ij}\rho_{ij}^{B7}$. *Are they?*

- The 1st order of scattering must be the same as 3D structure of surface is the governing property:

$$\rho_{B3}^{(1)} = b\rho_{B7}^{(1)}$$

- The total reflectance:

$$\rho_{\lambda} = \rho^{(1)} + \rho^{(2)} + \rho^{(3)} \ldots \cong \rho^{(1)} + \frac{\eta^2}{1-\eta}$$

where $\eta \approx \int_{\Omega^+}\int_{\Omega^-} \rho^{(1)}(s,s')ds\,ds'$ *is "spherical" albedo.*

-With linear RTLS model, $\eta = k_L^{(1)} + k_v\nu_v + k_g\nu_g$.

-Further, the RTLS parameters become: $\{k_L^{(1)} + \frac{\eta^2}{1-\eta}, k_v, k_g\}$

Implications:

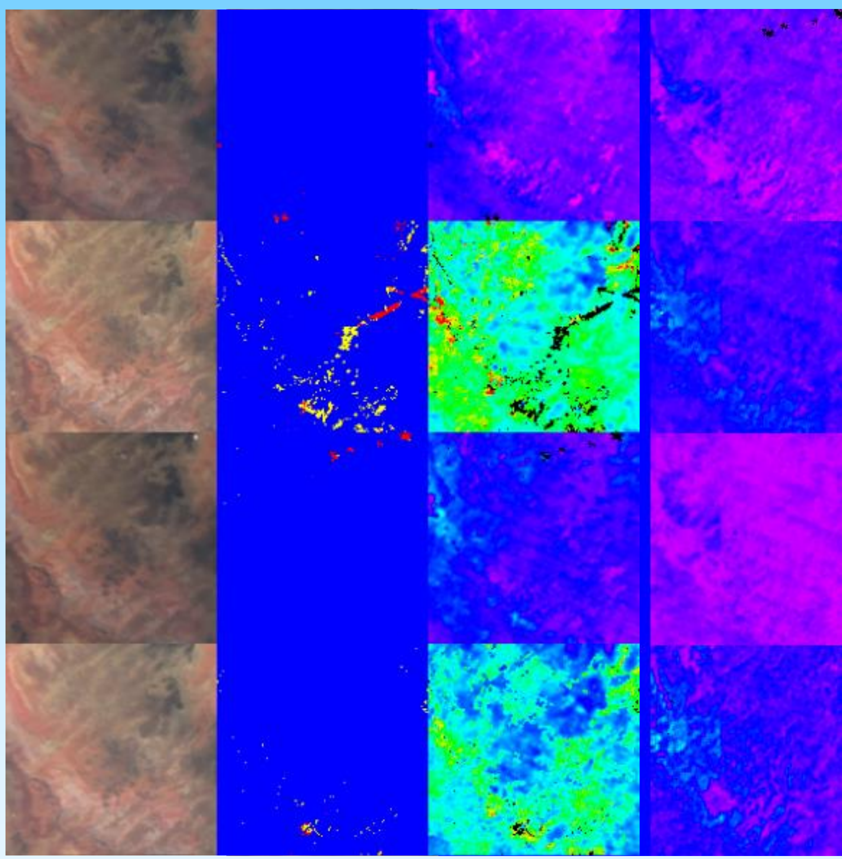
- Improve BRDF shape for aerosol retrievals;

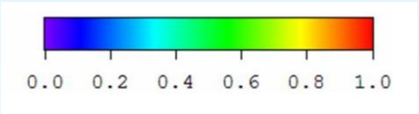
- Full AC (RTLS inversion) only needed in B7 (pure LC types – e.g. deserts)

Example: Flagstaff, AZ

DOY 129-133, 2009

RGB *CM* *AOT* *AOT*[(1)]





AOT

What is Dark/Bright Surface?

$$\delta R^{TOA} = R'_\tau \delta\tau + R'_\rho \delta\rho$$

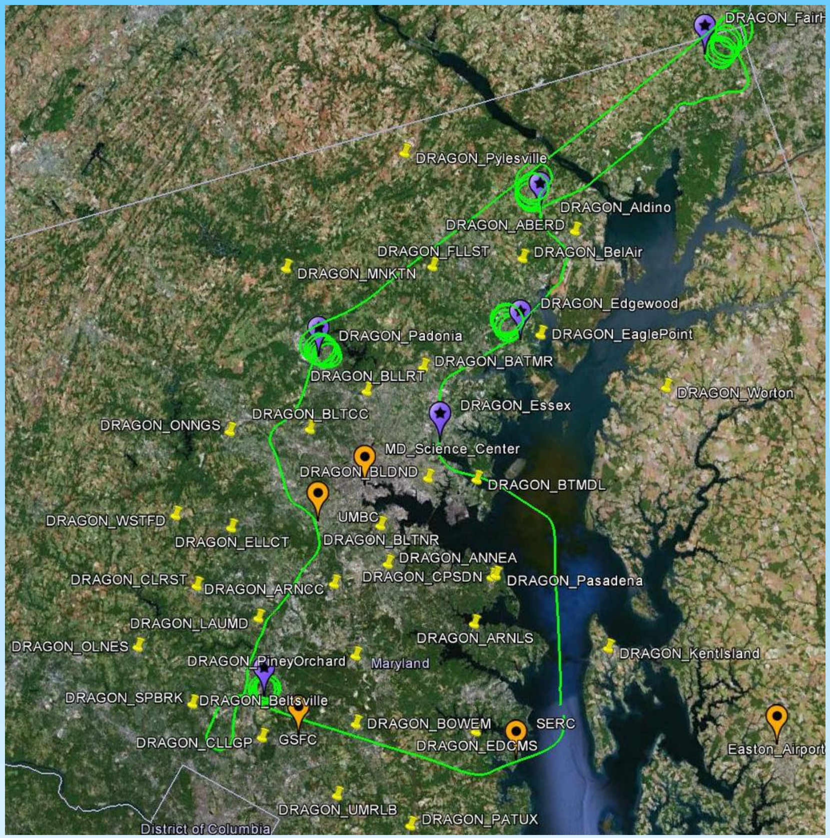
$$\delta R^{AOT} \qquad \delta R^{\rho}$$

We can assess SR uncertainty
(from TMS analysis for stable surface):

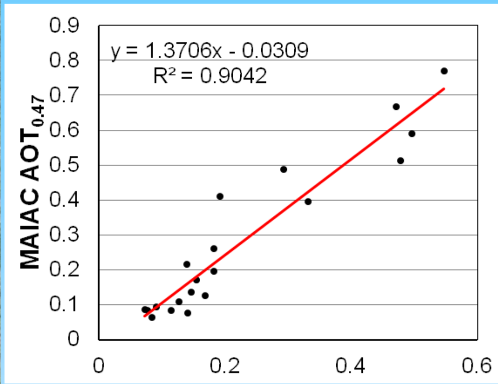
$$\delta\rho \sim 0.002 - 0.005$$

$$\delta\tau = R'_\rho \delta\rho / R'_\tau$$

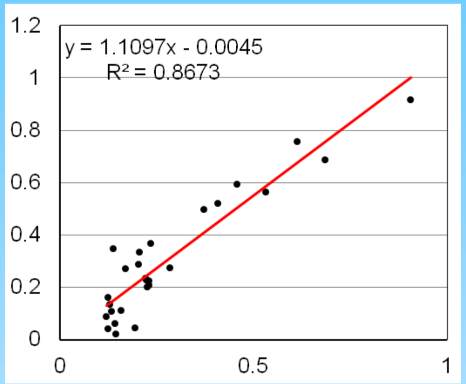
DRAGON, USA: Balt. – Washington, 2011



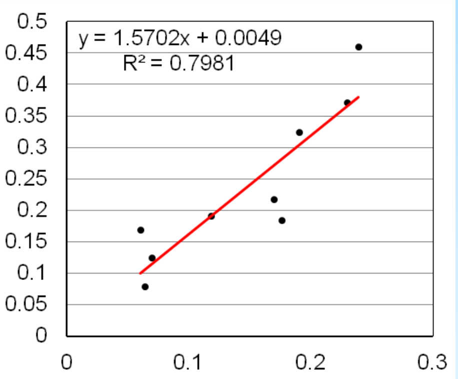
BATMR



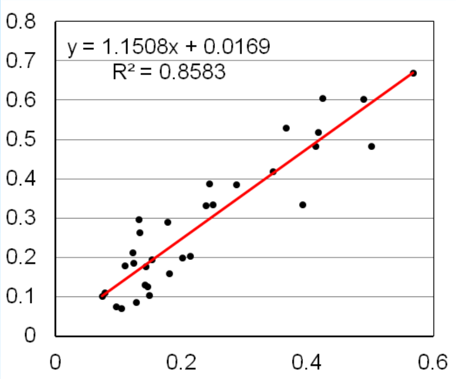
UMBC

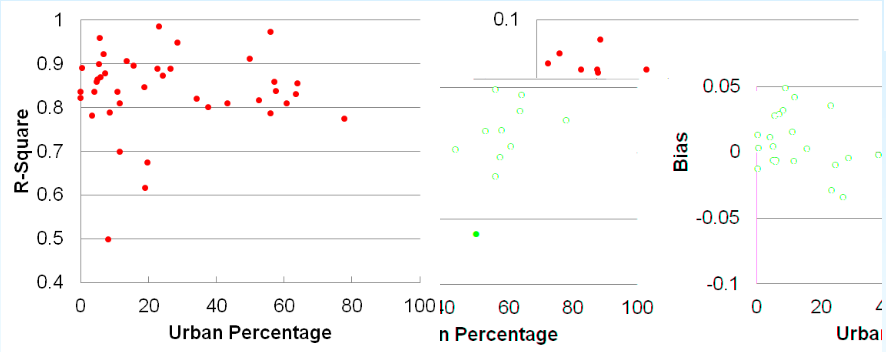


MD_SC_CENTER



ESSEX

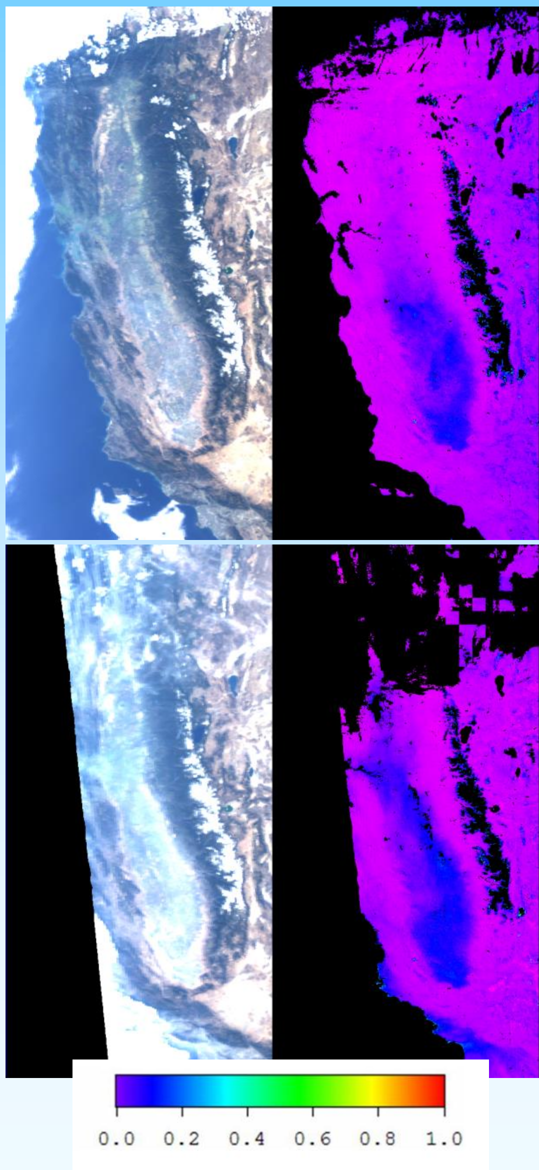




MAIAC did not show decreased performance over urban surfaces over B-W area.

San Joaquin Valley 2012-2013

DOY: 329, 331, 2012



Yosemite Fires, Aug. 2013

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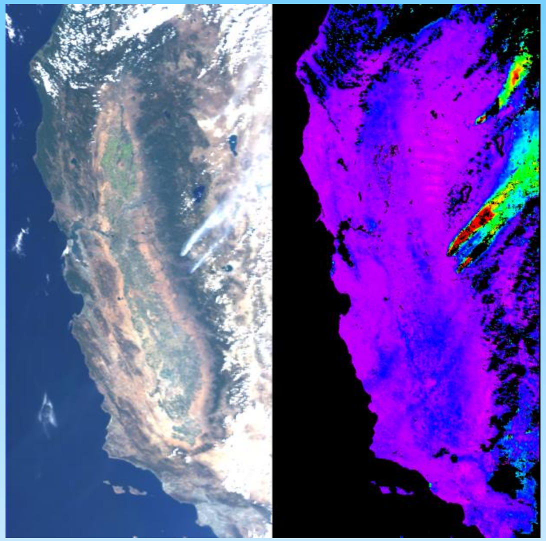

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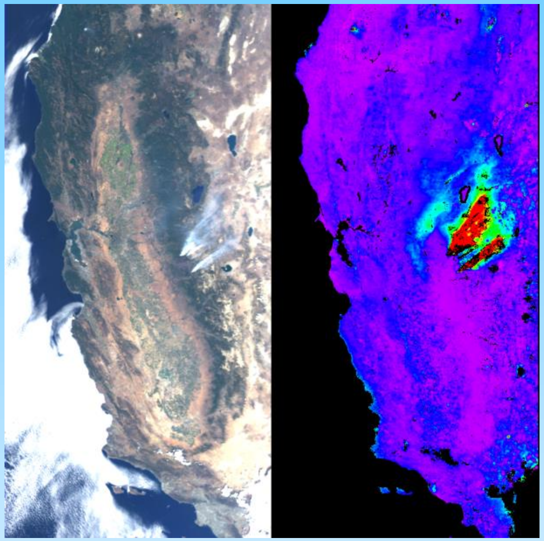

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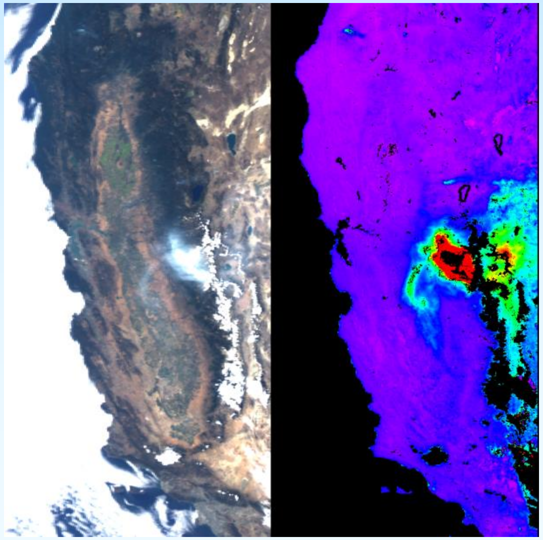

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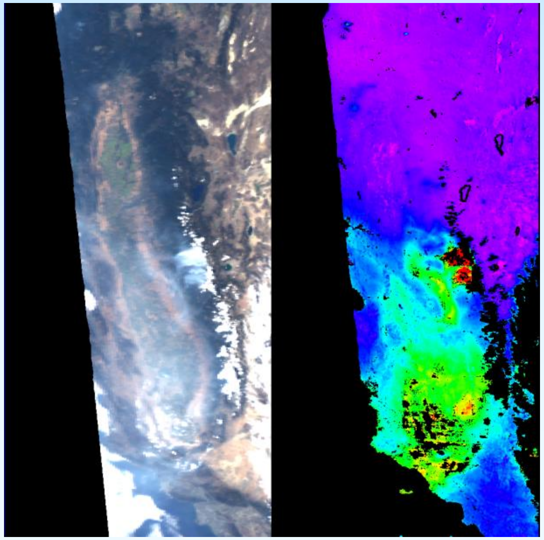
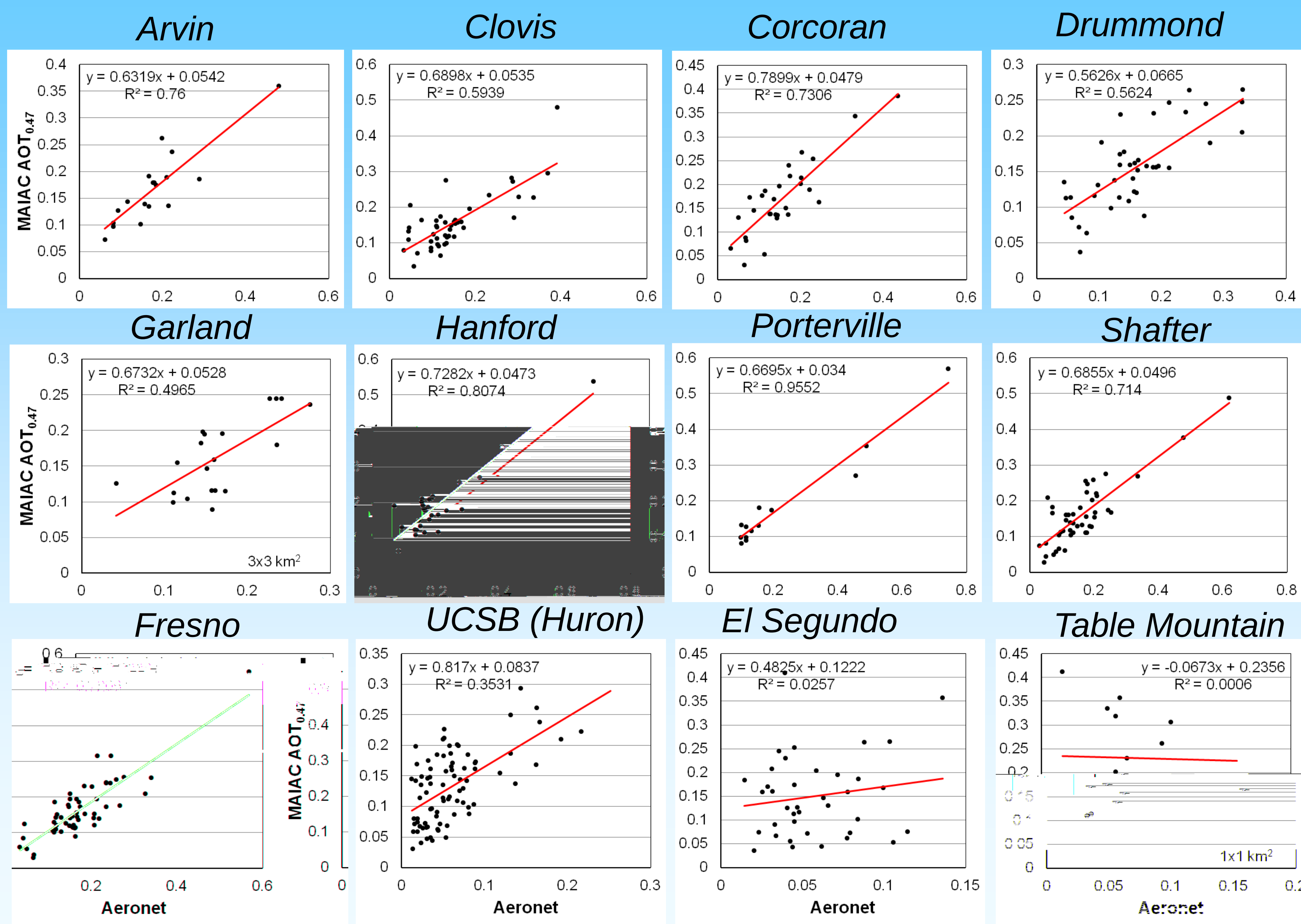
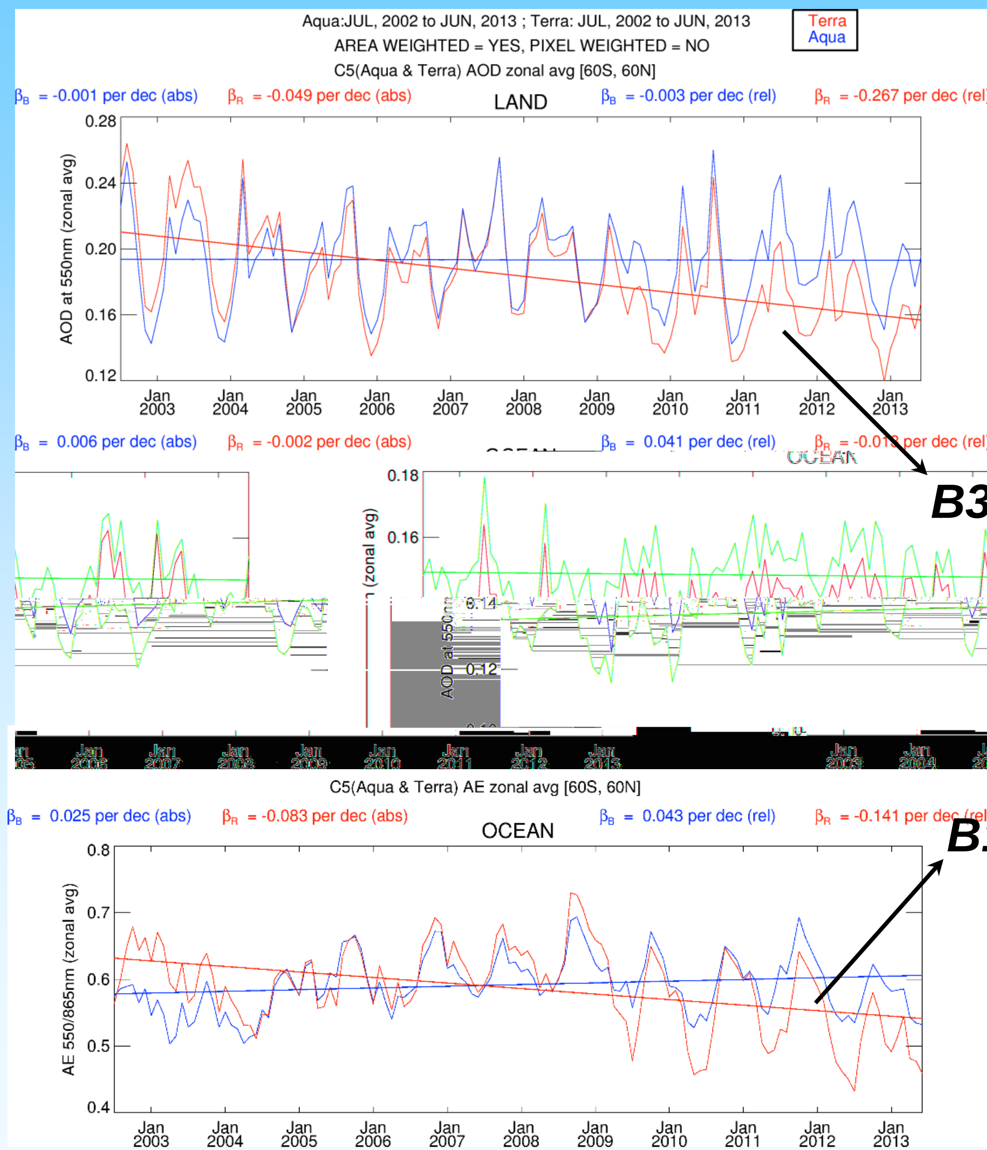


San Joaquin Valley 2012-2013

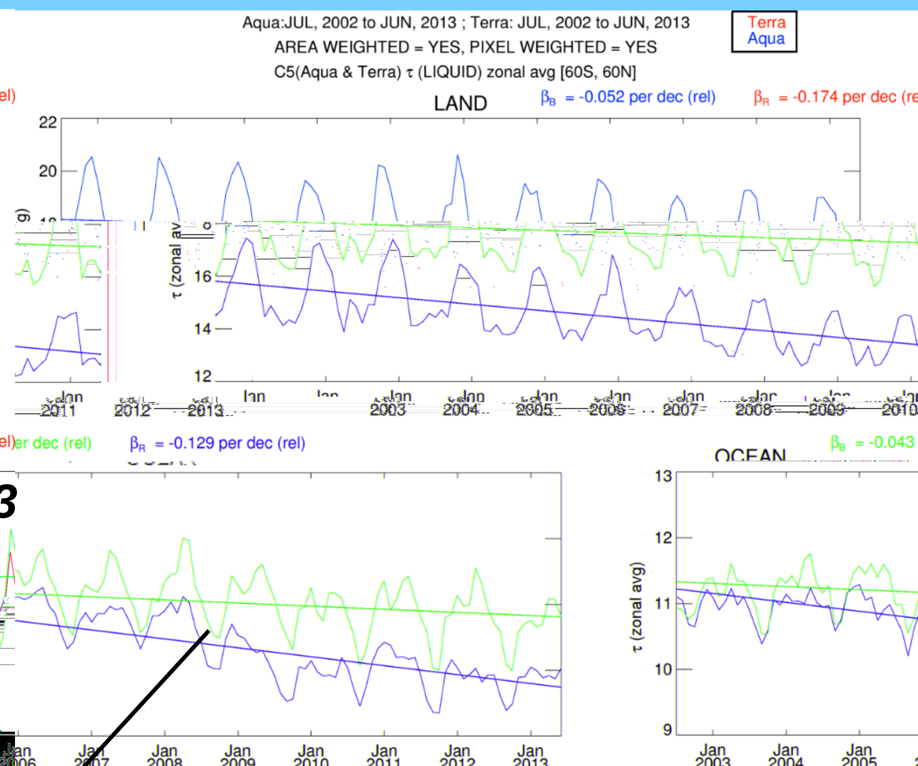


C5 Trends: Aerosol and Clouds

DT Aerosol: AOD and AE (R. Levy)



Cloud Opt. Properties: COT (S. Platnick)

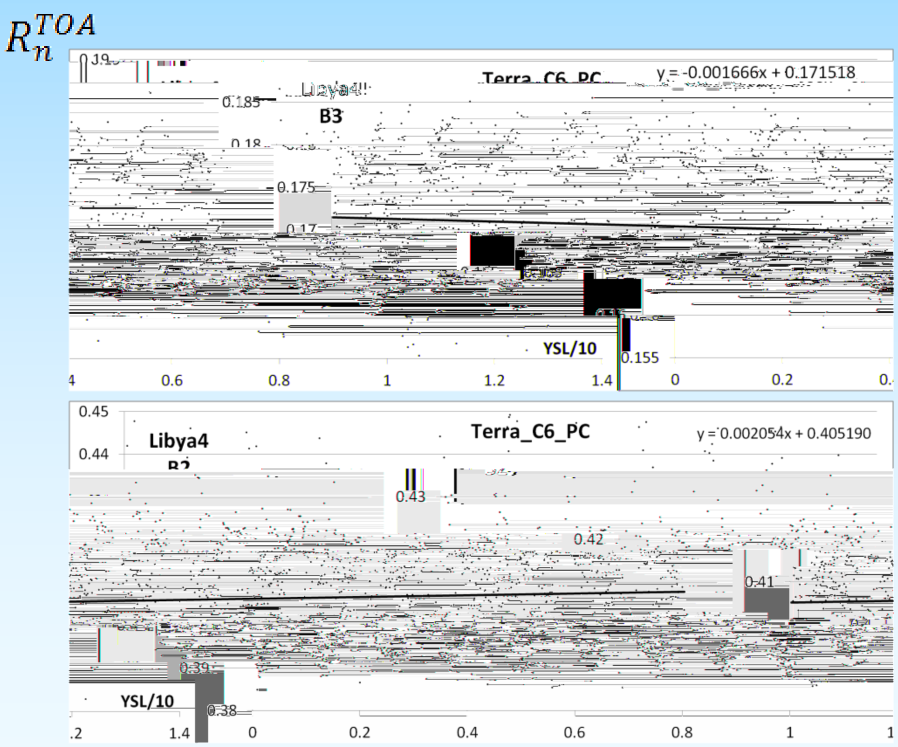


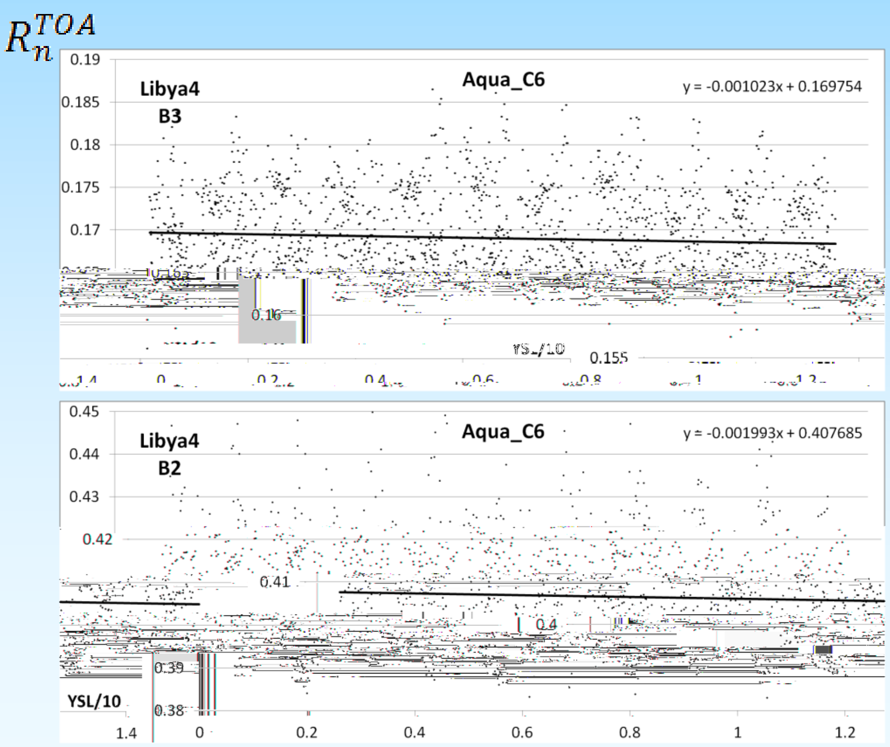
Levy et al. (2010), Global evaluation of the Collection 5 MODIS dark-target aerosol products over land, ACP.

Koukouli et al. (2010), Signs of a negative trend in the MODIS aerosol optical depth over the Southern Balkans, Atm. Environ.

C6+: MODIS de-trending and X-calibration

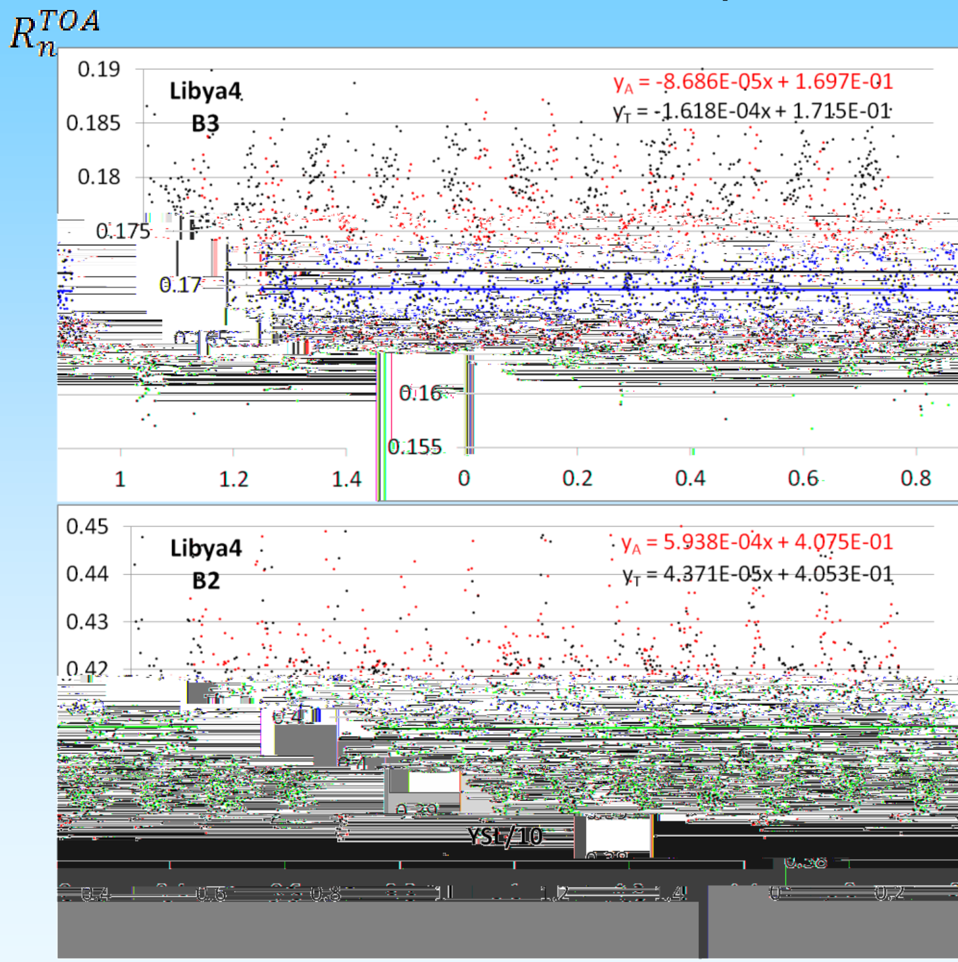
- *MODIS C6 L1 removed major calibration trends of Terra;*
- *Remained: Terra polarization sensitivity (PC); Applied PC algorithm developed by GSFC OBPG => found residual trends of T&A;*
- *Used CEOS desert cal. sites => TOA reflectances (R_n) for fixed geometry (VZA=0°, SZA=45°);*





C6+: MODIS de-trending and X-calibration

- *Use of R_n allows us to X-calibrate Terra vs Aqua!*
- *Based on C6+, MAIAC processes Terra & Aqua jointly.*



Average trend/decade/unit_refl.

Bands	Δ_T	σ	Δ_A	σ
B1	0.0048	0.0020	-0.0046	0.0022
B2	0.0035	0.0019	-0.0062	0.0027
B3	-0.0082	0.0015	-0.0048	0.0016
B4	0.0049	0.0022	-0.0021	0.0023
B8	0.0094	0.0015	-0.0015	0.0013

Average X-gain for Terra

Bands	Egypt1	Libya1	Libya2	Libya4	Xcal gain	σ
B1	1.017	1.023	1.021	1.019	1.020	0.0024
B2	1.004	1.008	1.007	1.006	1.006	0.0016
B3	0.989	0.992	0.992	0.990	0.991	0.0013
B4	1.006	1.013	1.010	1.009	1.009	0.0031
B8	0.997	0.996	0.998	0.994	0.996	0.0015

Lyapustin, A., Y. Wang, X. Xiong, G. Meister, S. Platnick, R. Levy, B. Franz, S. Korkin, T. Hilker, J. Tucker, F. Hall, P. Sellers, A. Wu, A. Angal, Science Impact of MODIS C5 Calibration Degradation and C6+ Improvements, AMTD, 7, 7281-7319, 2014.

Data Structure

AOT_QA definition
(16-bit unsigned integer)

Bits	Definition
0-2	Cloud Mask 000 --- Undefined 001--- Clear 010 --- Possibly Cloudy (detected by AOT filter) 011 --- Cloudy (detected by cloud mask algorithm) 101 -- - Cloud Shadow
3-4	Land Water Snow/ice Mask 00 --- undefined 01 --- Land 10--- Water 11 --- Snow/ice
5-7	Adjacency Mask 000 --- Normal condition 001 --- Adjacent to cloud 010 --- Surrounded by more than 8 cloudy pixels 011 --- Single cloudy pixel 100 --- Adjacent to snow 101 --- snow was previously detected on this pixel
8-11	Cloud Detection Path 0000 --- CM test clear 0001 --- CM test bright 0010 --- CM test high 0011 --- CM test CldBT 0100 --- CM test SIG500 0101 --- CM test Band Ratio test 0110 --- CM test REFCM 0111 --- AOT B1B3 1000 --- CM test bluing 1001 --- CM test SIG3x3
12	Glint Mask 0 --- glint is not detected 1 --- glint is detected
13-14	Aerosol Model 00 --- Background model 01 --- Smoke model 10 --- Dust model
15	Reserved

Aerosol Optical Thickness
(MAIACAOT)

SDS name	Data Type	Scale	Description
Optical_Depth_Land	INT16	0.001	Blue band aerosol optical depth
AOT_Uncertainty	INT16	0.0001	AOT uncertainties
Angstrom_Para	INT16	0.001	Angstrom parameter
SSA	INT16	0.001	Single Scattering Albedo
Column_WV	INT16	0.001	Column Water Vapor
AOT_QA	UINT16	n/a	AOT QA

1. *Finishing science development;*
2. *Plan is to re-process MODIS Terra-Aqua by the end of this year on MODAPS;*
3. *Operational code – early next year;*
4. *In 1-4 weeks: North and South Americas and Europe on NCCS (free access)*