Overview of MAIAC Aerosol Retrieval Capabilities from Polar, Geostationary and L1 Orbits

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ICAP Meeting,

Monterey CA, October 18-20, 2022

MAIAC MODIS/VIIRS Update

Status

MAIAC MODIS C6 available since 2018

MAIAC MODIS C6.1 re-processing ongoing (2008 …):

- New regional aerosol models (removes low AOD bias)
- Improved over-ocean algorithm (case I, II waters);
- New alg. over high-sediment (brown) waters;
- Added 0.05° (CMG) operational daily product;

MAIAC VIIRS C2 is in integration and testing at MODAPS:

- We de-trended and cross-calibrated SNPP and N20 VIIRS to MODIS Aqua (continuity of CDRs);
- New Rotated Sin Projection (in MAIAC MODIS C7);
- 0.75km spatial resolution (vs 1km MODIS);

MAIAC VIIRS Products

Atmospheric:

- Cloud/Shadow/Snow Mask,
- AOD, FMF (over water),
- Smoke Plume Injection Height (thermal)

Surface:

- BRF (surface reflectance) at 0.375 and 0.75km;

Surf. Daily Gap-Filled:

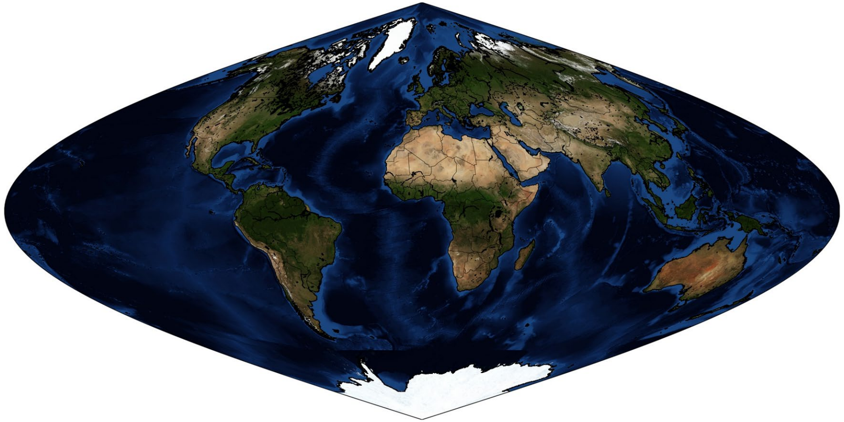
- BRDF;
- NDVI (0.75km);
- Snow grain size and snow fraction (0.75km);

CMG Daily:

- most of the above + additional VIs

MAIAC Update (VIIRS C2, and MODIS C7)

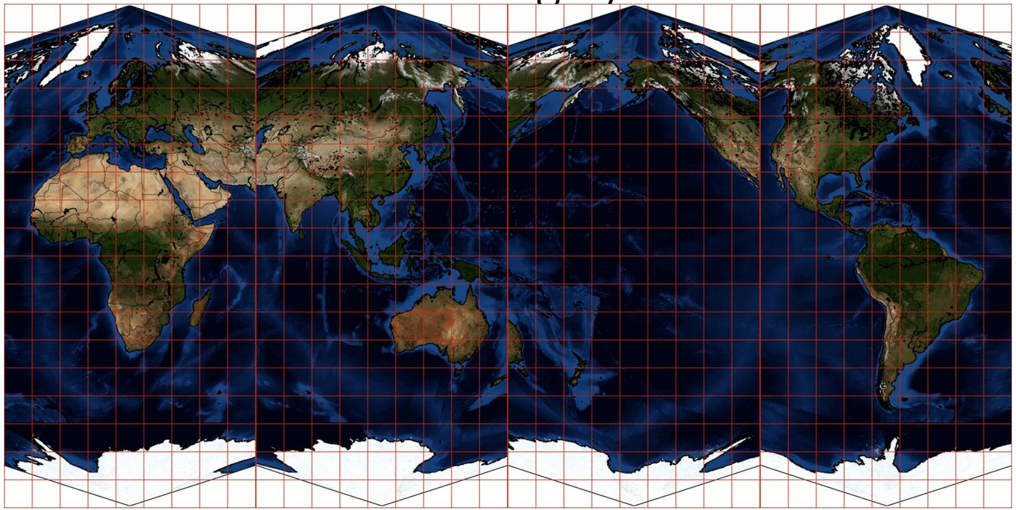
Standard Global Sin



We will provide re-projection tools for users.

Rotated Sin Projection

New Tiling System



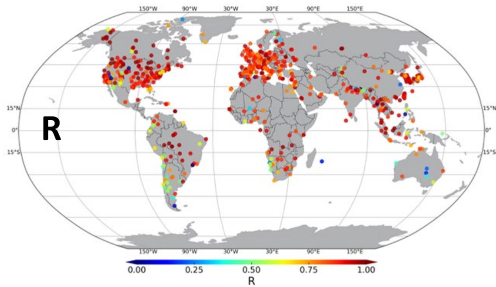
Zone 0 Zone 1 Zone 2 Zone 3

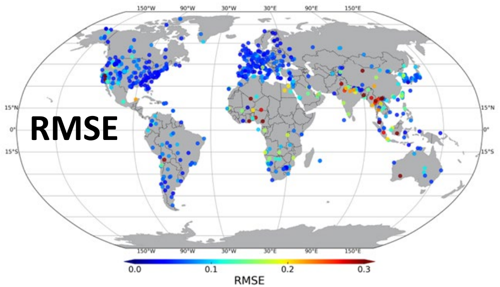
In each zone, there are 9x18 tiles, the total number of tiles is the same as that in standard MODIS tiling system (36 by 18)

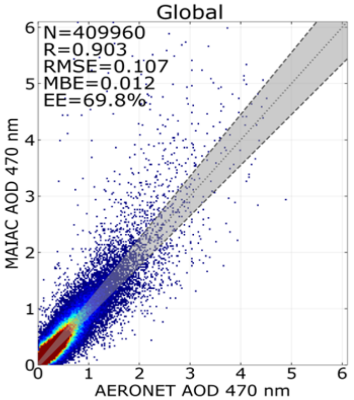
MAIAC MODIS C6.1 Updates

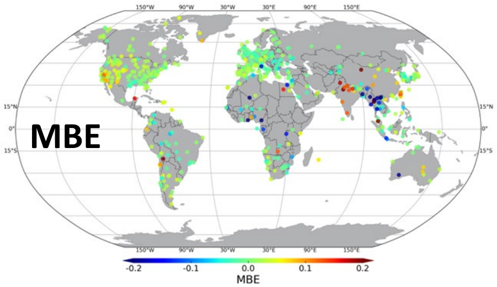
- Developed new regional aerosol models based on AERONET climatology → improves AOD and AC under smoke and dust conditions;

21x21 km² (50% coverage), 0.47µm



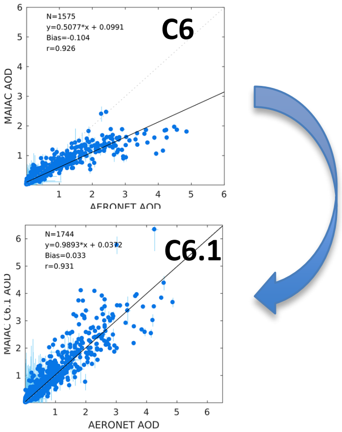






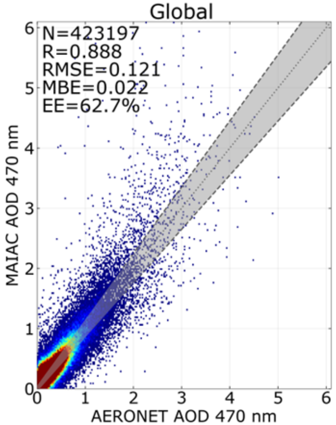
$$\text{C6 EE} = \pm 0.05 \pm 0.1\tau_{0.47}$$

Sept. 2020, Western USA



Courtesy: X. Ye, P. Saide (UCLA)

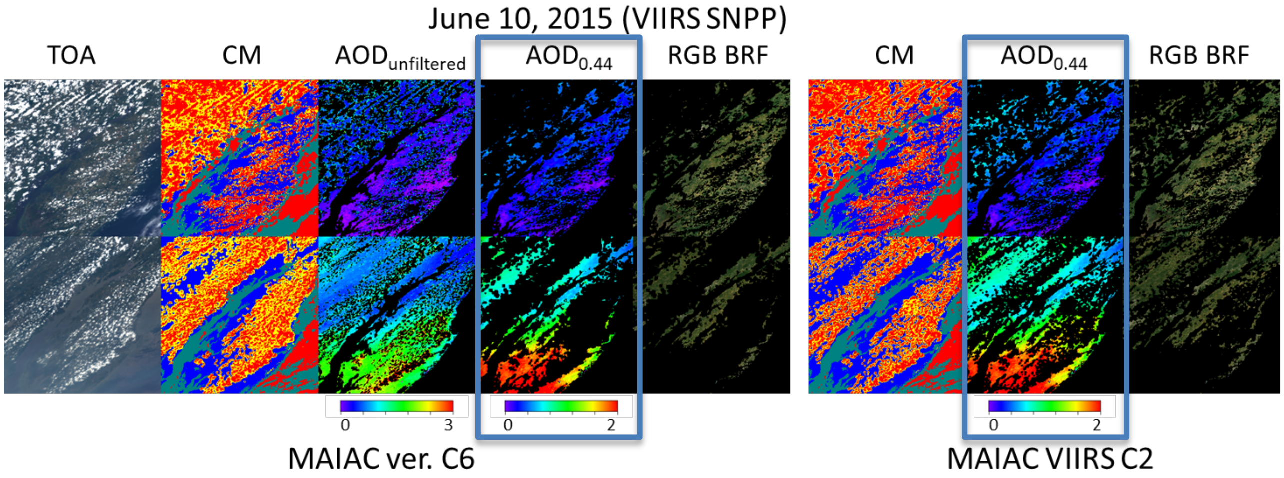
A single 1km pixel



	MAIAC C6	C6.1	C6.1 1km
N	304553	409960	423197
%EE	66%	69.8%	62.7%
R	0.84	0.903	0.888
RMSE	0.12	0.107	0.121
MBE	0.01	0.012	0.022

MAIAC C6.1 Updates

- Relaxed cloud adjacency analysis → increase in AOD and SR coverage
- *From Lyapustin et al. (2021)*: MAIAC C6 has 5-25% more high-quality data than MOD09 annually. This difference will further increase in MAIAC MODIS C6.1 and VIIRS C2;



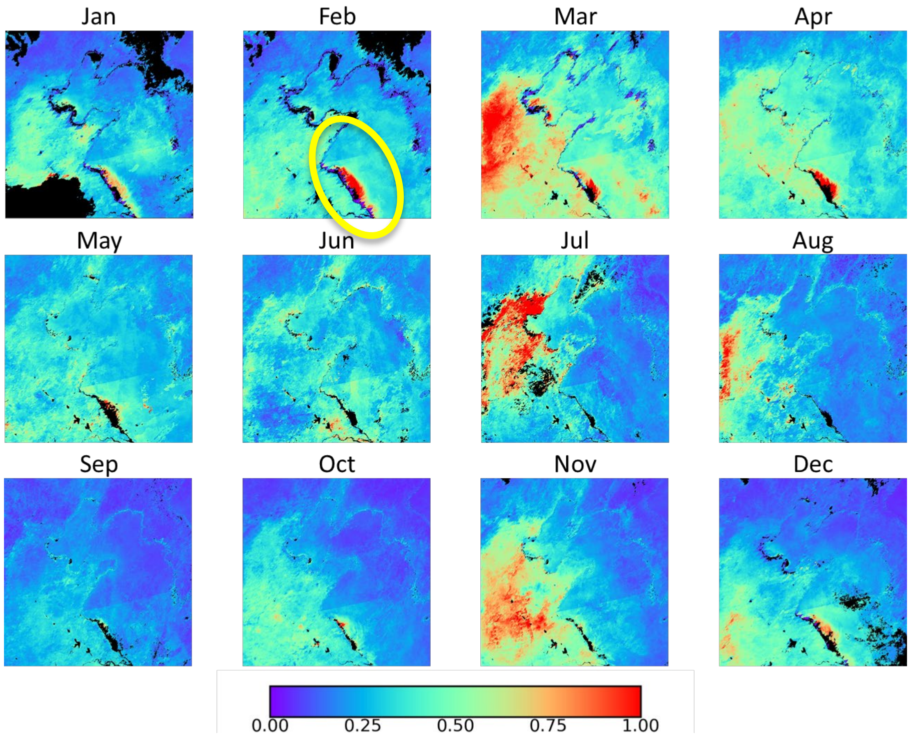
- Improved snow detection;
- Aerosol retrievals and AC over high sediment (brown) waters;
- Amended RTLS BRDF model to work at high SZA, VZA>60° - important for VIIRS, EPIC, geo … and at high latitudes (*in preparation*)

Lyapustin A, Zhao F and Wang Y (2021) A Comparison of Multi-Angle Implementation of Atmospheric Correction and MOD09 Daily Surface Reflectance Products From MODIS. Front. Remote Sens. 2:712093. doi: 10.3389/frsen.2021.712093

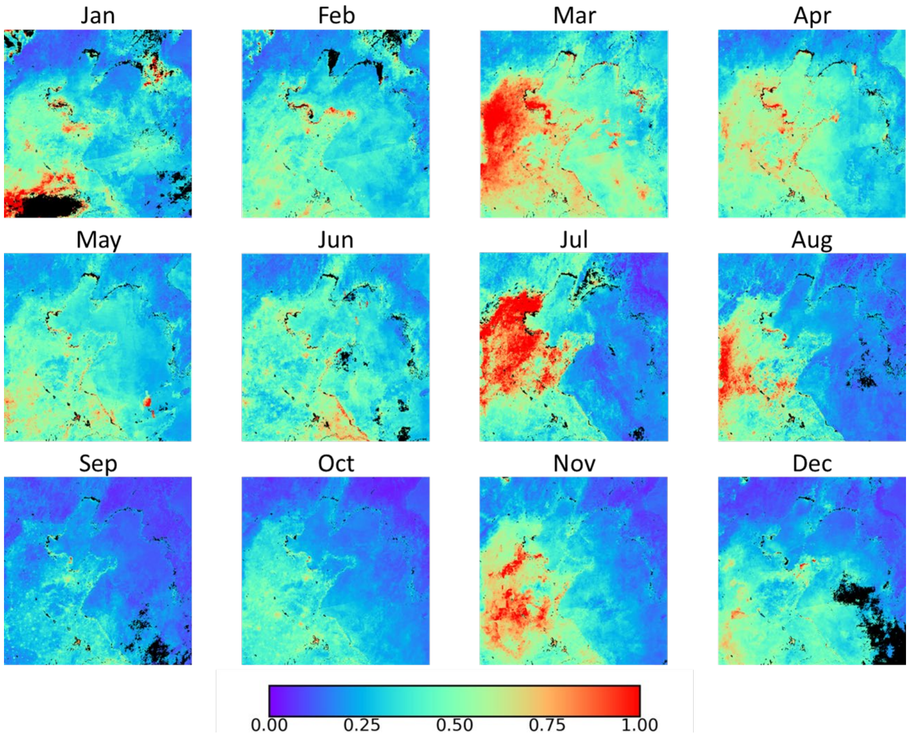
MAIAC C6.1 Updates

- Aerosol retrievals and AC over high sediment (brown) waters (example for Yellow Sea in north-eastern China)

C6



C6.1



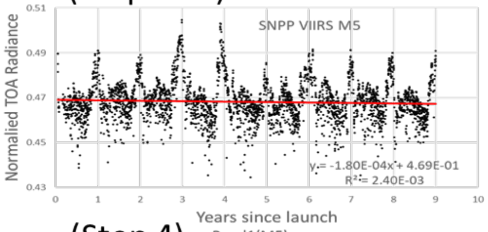
VIIRS Cross-Calibration to MODIS Aqua

MAIAC VIIRS Calibration (Libya 4)

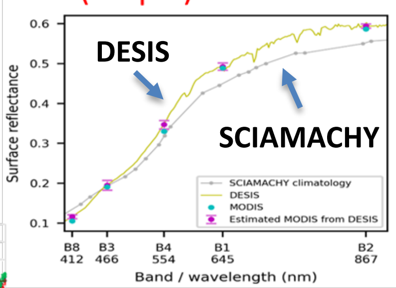
(based on Lyapustin et al., AMT, 2014)

1. Perform MAIAC retrievals (CM, AOD, WV, BRDF etc.);
2. Compute TOA reflectance (R_n) for a fixed view geometry (VZA=0°, SZA=30°) and evaluate trends in both MODIS Aqua and VIIRS SNPP and N20;
3. Applied spectral conversion factor based on DESIS to account for RSR difference;
4. Apply de-trending and compute VIIRS-MODIS Aqua X-calibration factors
5. Good overall agreement with MCST/VCST and NASA LaRC but more reliable in VIIRS X-calibration to MODIS Aqua (Lyapustin et al. (in preparation))
6. Continuity of MAIAC MODIS and VIIRS Aerosol, surface reflectance (BRF), BRDF, NDVI records.

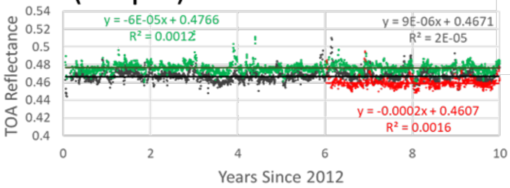
(Steps 1-2)



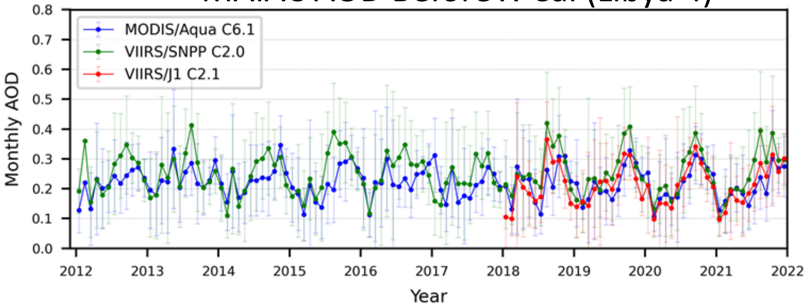
(Step 3) - Novel



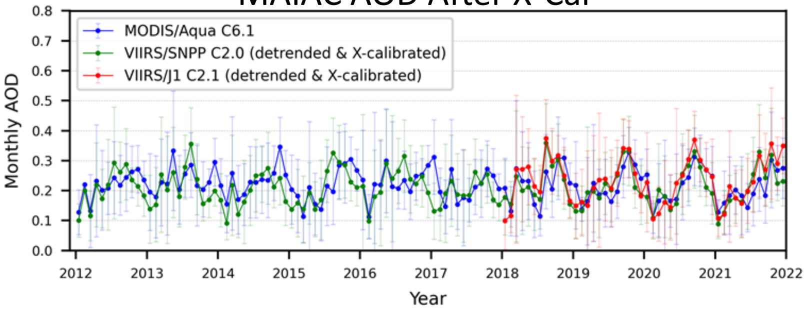
(Step 4)



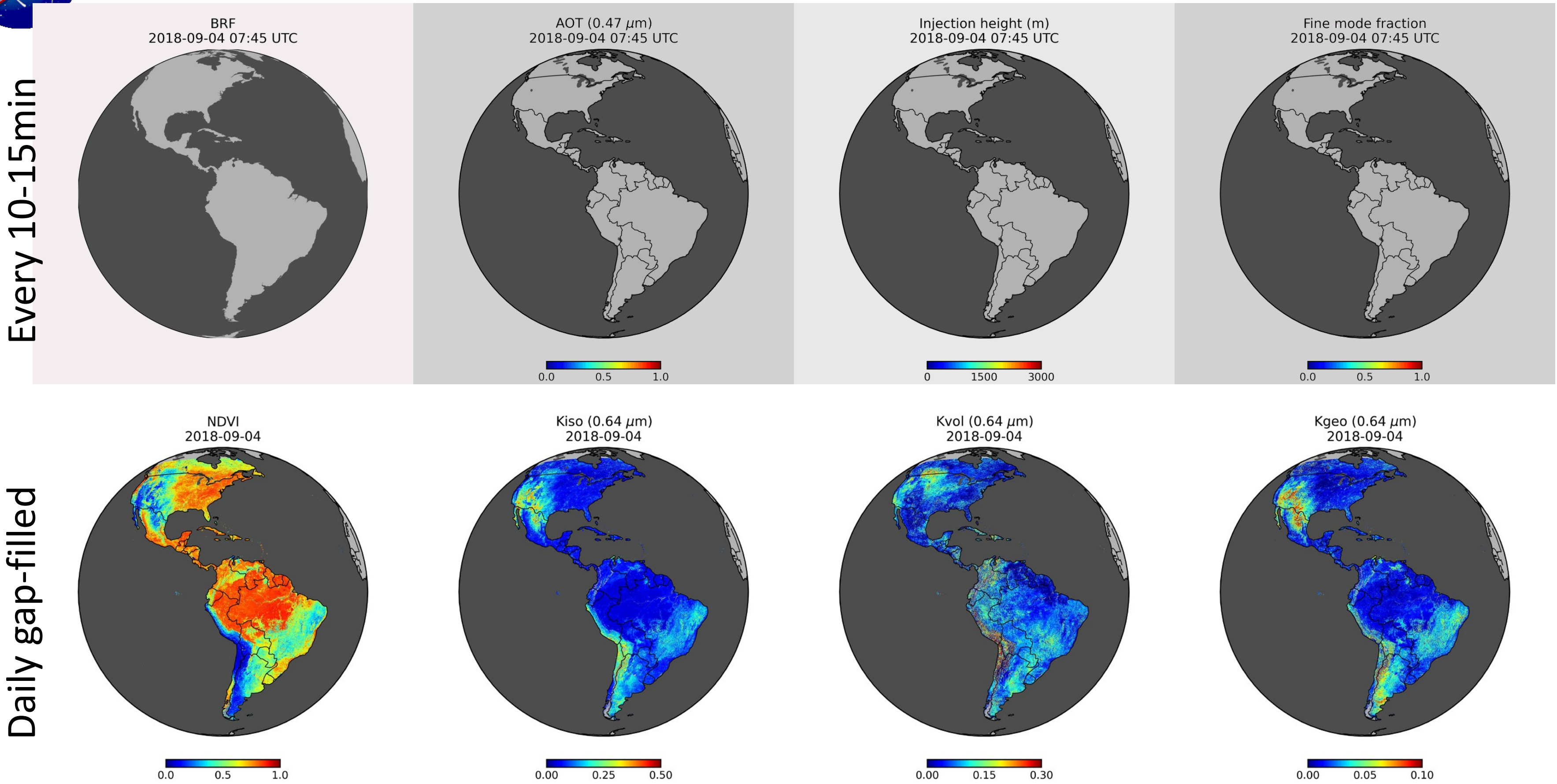
MAIAC AOD Before X-Cal (Libya 4)



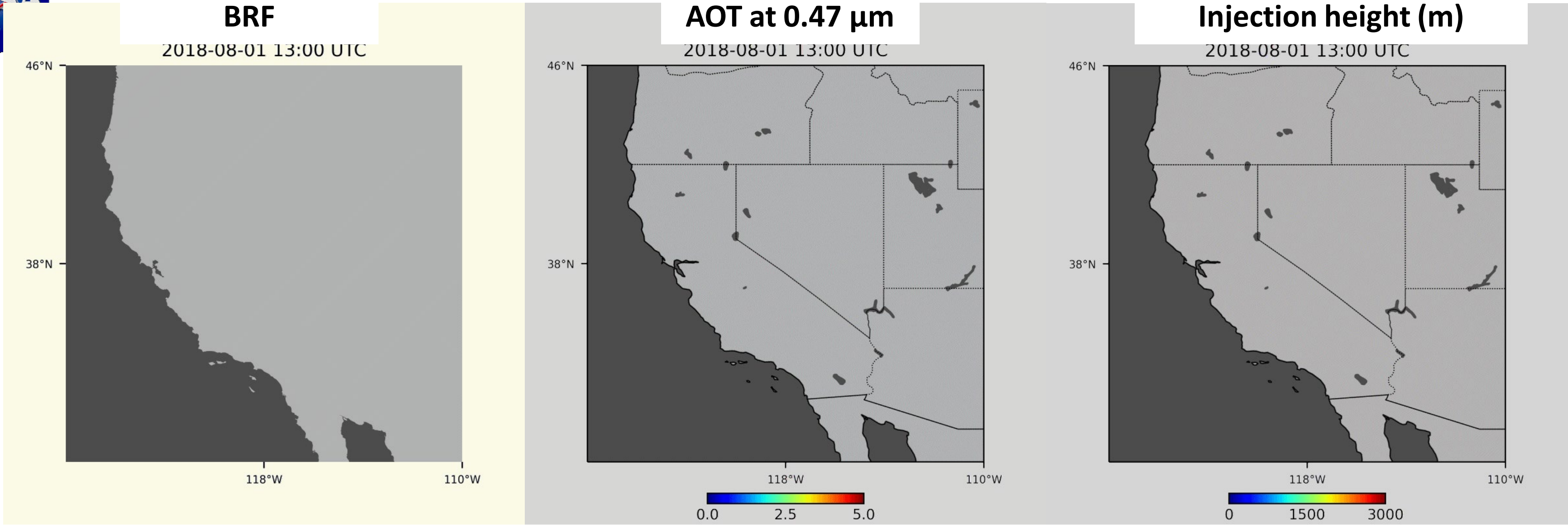
MAIAC AOD After X-Cal



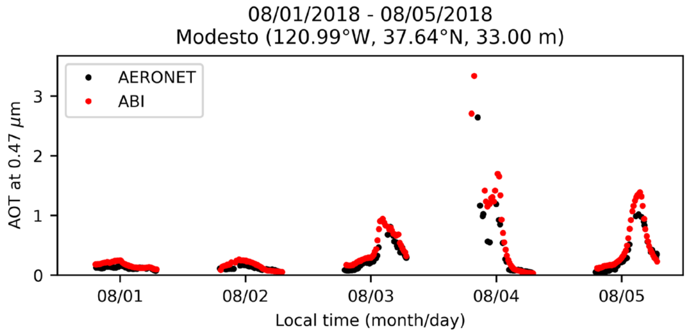
ABI MAIAC products, 2018-09-04

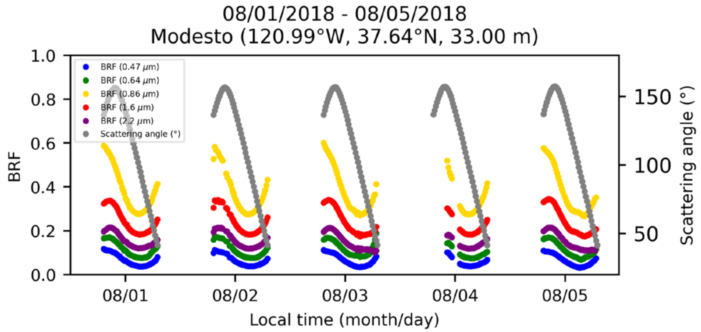


California fires (2018-08-01 to 2018-08-05)

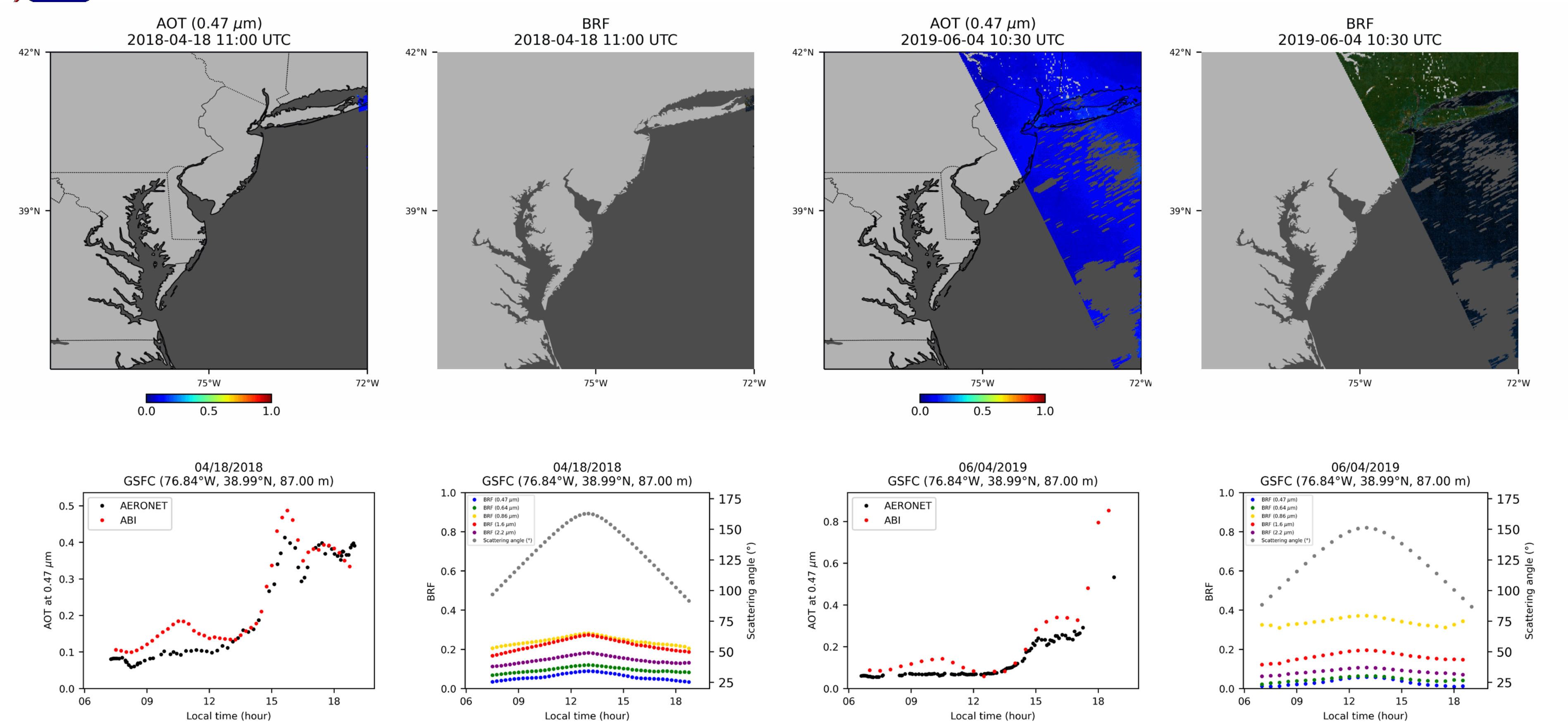


AERONET AOD at 0.47 µm **MAIAC AOT at 0.47 µm** **Scattering angle (°)** **BRF at (0.47, 0.64, 0.86, 1.6, 2.2 µm)**





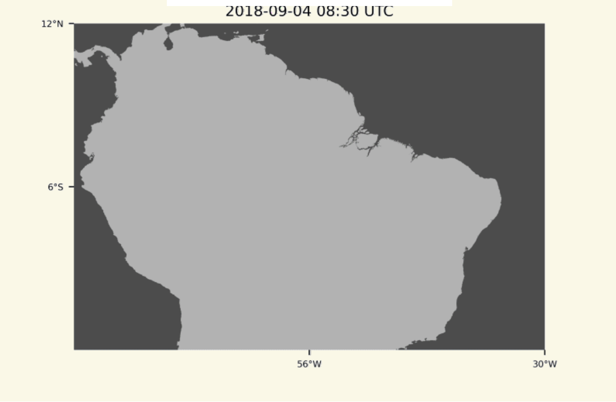
Tile h17v03 (DC/MD/VA/NC/DE/PA/NJ/NY areas)



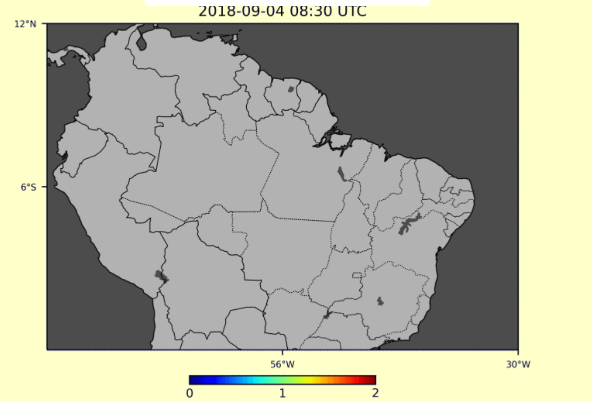
AERONET AOD at 0.47 µm **MAIAC AOT at 0.47 µm** **Scattering angle (°)** **BRF at (0.47, 0.64, 0.86, 1.6, 2.2 µm)**

Amazonian fires (2018-09-04 to 2018-09-06)

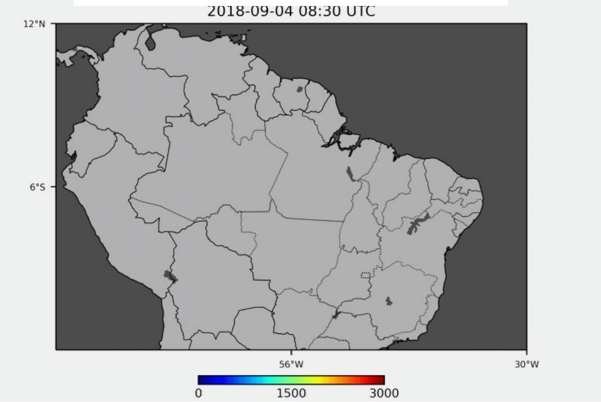
BRF

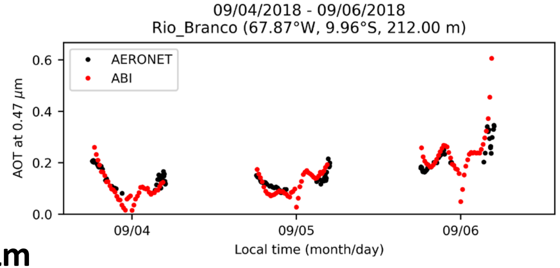


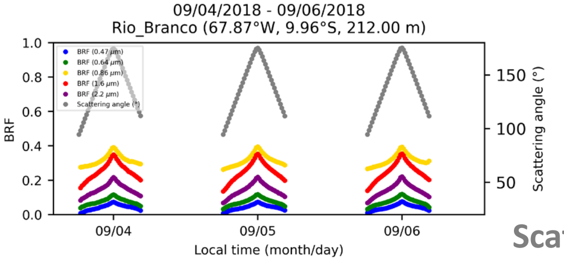
AOT at 0.47 µm



Injection height (m)





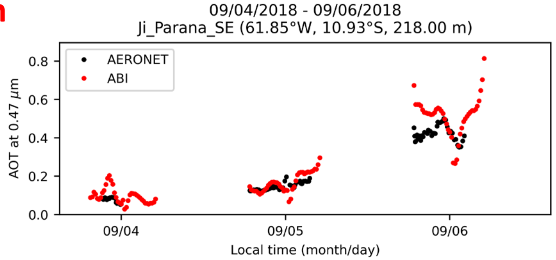


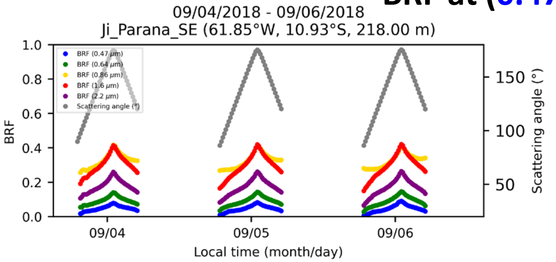
AERONET AOD at 0.47 µm

MAIAC AOD at 0.47 µm

Scattering angle (°)

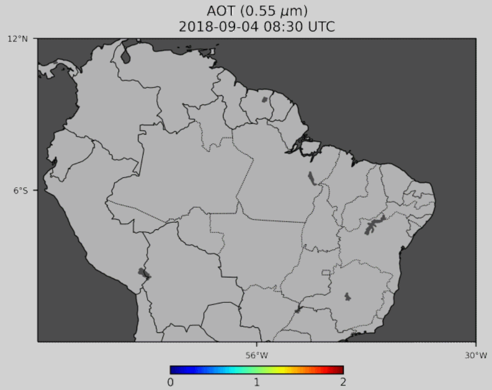
BRF at (0.47, 0.64, 0.86, 1.6, 2.2 µm)



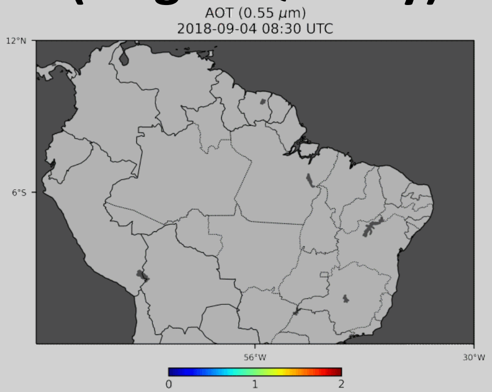


Amazonian fires (2018-09-04 to 2018-09-06)

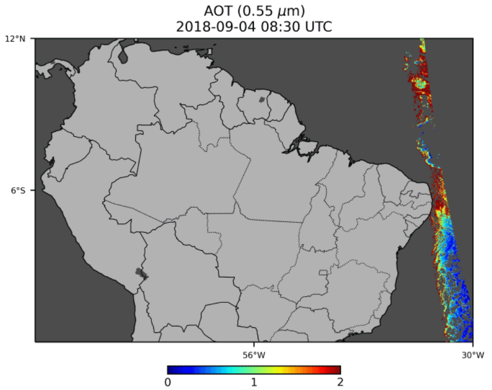
MAIAC



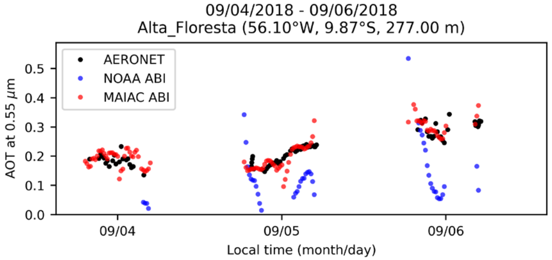
NOAA
(“high” QF only)



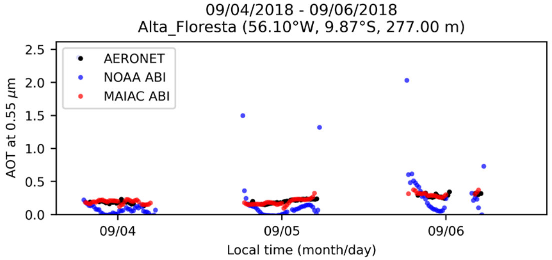
NOAA
(all retrievals)



AERONET, MAIAC,
NOAA (“high” QF)



AERONET, MAIAC,
NOAA (all retrievals)



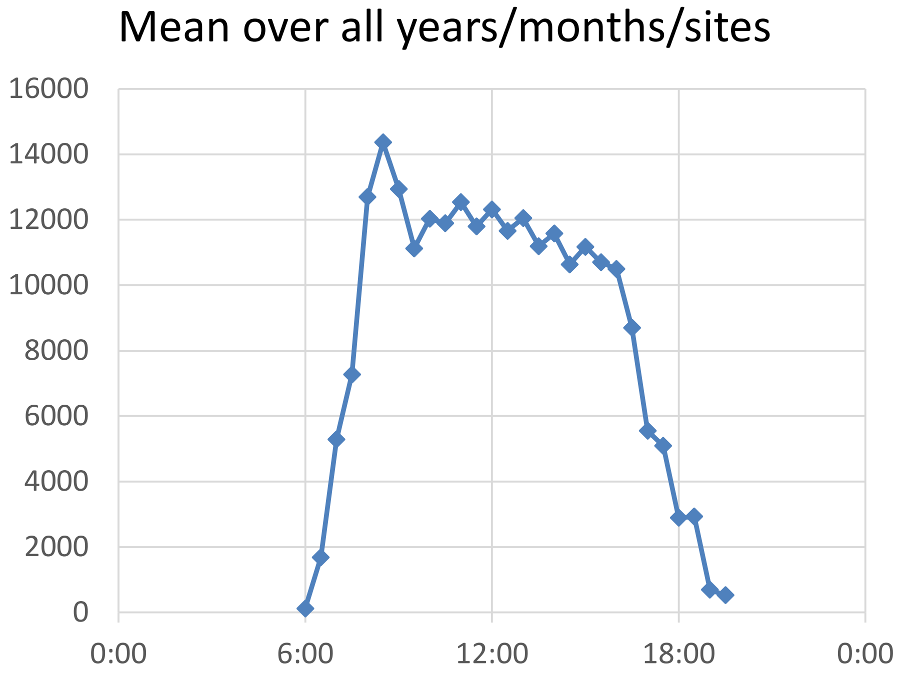
Data

- **GOES ABI MAIAC AOD 550nm**
  - 2018-2020
  - Every 10-15min
  - Conus
  - **1KM**

- **GOES ABI NOAA AOD 550nm**
  - 2018-2020
  - Every 10-15min
  - Conus
  - **2KM**

- **AERONET AOD 550nm** (interpolated)
  - 2018-2020
  - Every 10-15min
  - >100 sites, USA

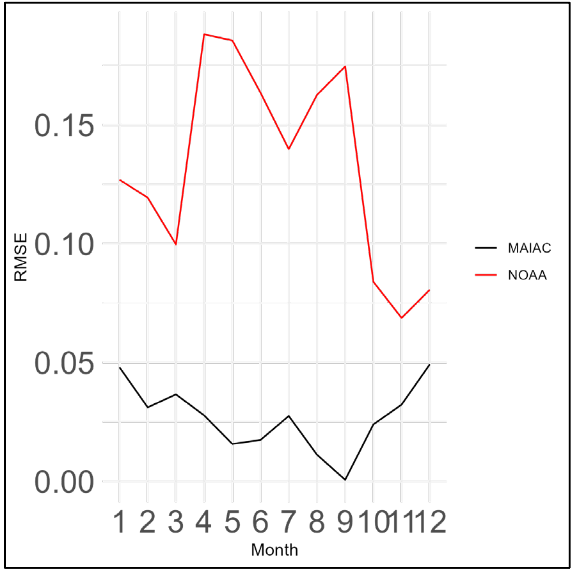
MAIAC Availability by Hour (30min increments)



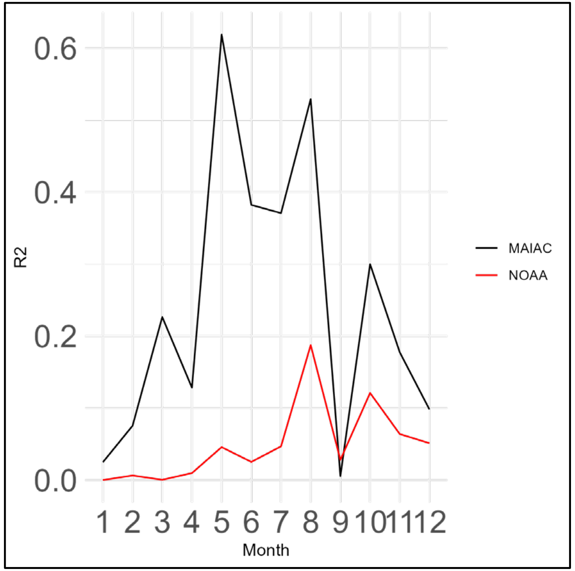
Courtesy of: Meytar Sorek-Hamer, Weile Wang, Ian Brosnan (**NASA Ames**)
Allan Just (**Mt. Sinai Icahn school of Medicine, New York, NY)**

MAIAC/NOAA - AERONET AOD Monthly Stats (CONUS)

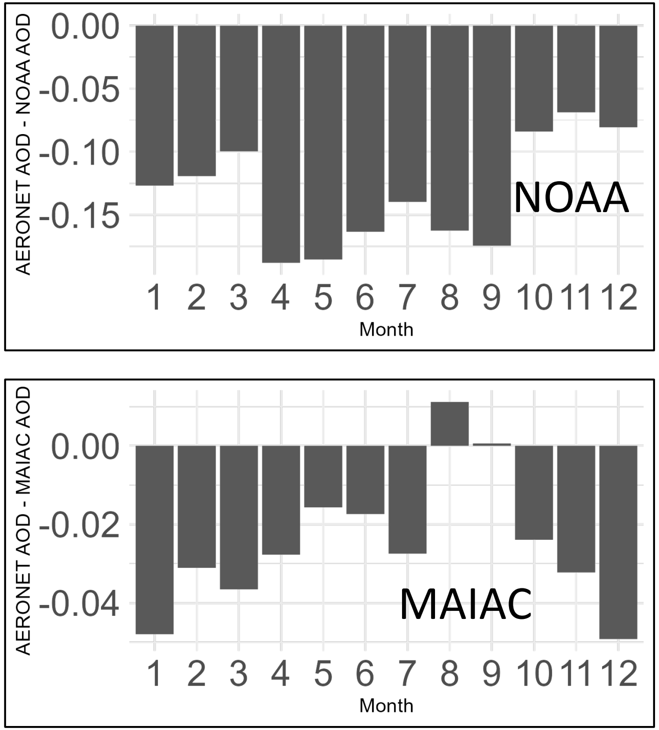
RMSE



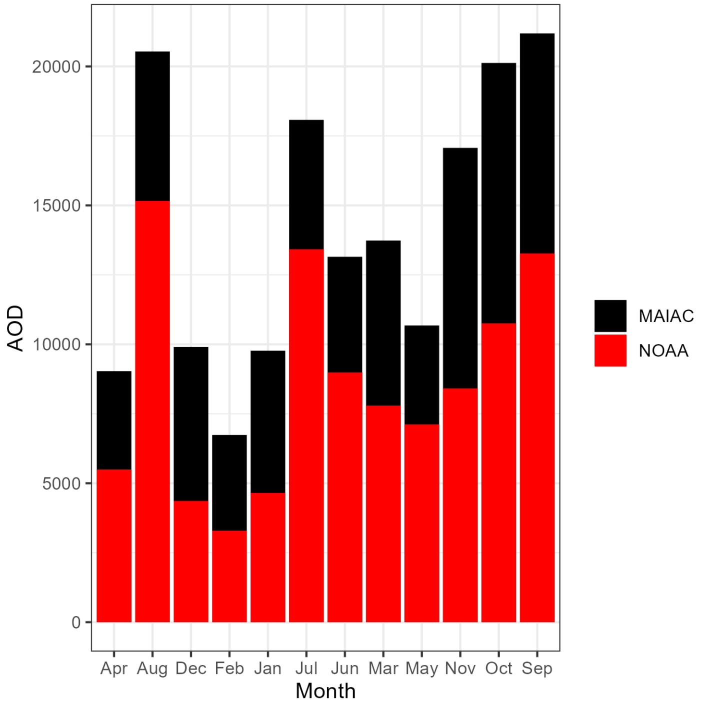
R^2



BIAS (all years)



Data Availability (single pixel) all 3 datasets are available and collocated (AERONET, NOAA AOD, MAIAC AOD)



30-50% more data from MAIAC compared to NOAA

Spectral Aerosol Absorption and Height

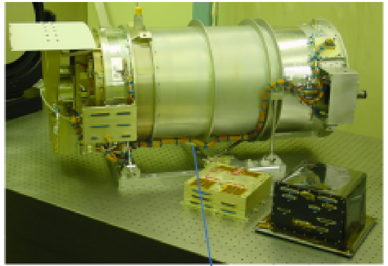
Earth Polychromatic Imaging Camera (EPIC)

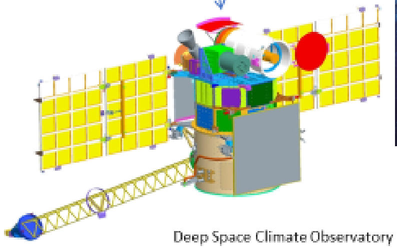
on DSCOVR

- 2048 x 2048 pixel CCD;
- 8 km pixel; 2x2 onboard aggr.
- Number of daytime images
  6 in winter (same area)
  Up to 12 in summer

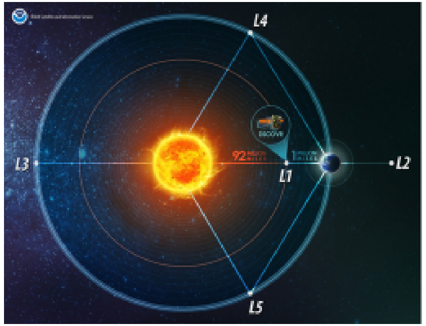
Wavelength (nm)	Full width (nm)	Primary Applications
317.5 ±0.1	1 ±0.2	Ozone, SO_2
325 ±0.1	2 ±0.2	Ozone
340 ±0.3	3 ±0.6	Ozone, Aerosols
388 ±0.3	3 ±0.6	Aerosols, Clouds
443 ±1	3 ±0.6	Aerosols
551 ±1	3 ±0.6	Aerosols, Vegetation
680 ±0.2	2 ±0.4	Aerosol, Vegetation, Clouds
687.75 ±0.2	0.8 ±0.2	Cloud Height
764.0 ±0.2	1 ±0.2	Cloud Height
779.5 ±0.3	2 ±0.4	Clouds, Vegetation

Aerosol Retrieval
Atmospheric Correction

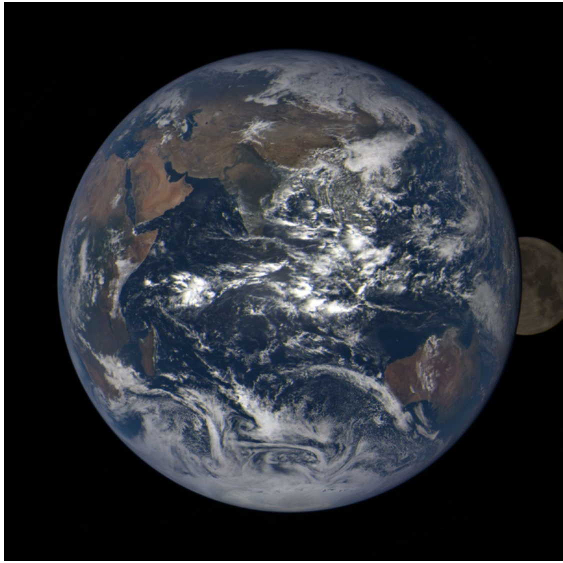




Deep Space Climate Observatory (DSCOVR)



2



340, 388, 443, 551, 680, 685, 764, 780nm

MAIAC EPIC AOD – refIM Algorithm (3D)

- Absorbing dust aerosols detection using AI (340-388) and AOD_{388}/AOD_{443}, AOD_{340}/AOD_{443}
- Absorption model (refIM): $\mathbf{k_\lambda = k_0 (\lambda/ \lambda_0)^{-b}}$ where λ_0 = 680nm
  (*in the limit of small particles, AAE~b+1, where Absorption Ångström Exponent AAE is defined for the AAOD*).
- Real *refIM* and size distribution are fixed. The results are reported for H^a=1 and 4km for smoke and dust.
- AOD-k_0-b retrieval using **Levenberg-Marquart optimal fit** of 340, 388, 443 and 680nm:

$$F^2 = 1/N \sum\left(\frac{L_\lambda^m - L_\lambda^t}{L_\lambda^m}\right)^2 = \min\{AOD_{443}, k_0, b\}$$

- LUT-based retrievals on a 4x4 matrix of b={0.1, 1.5, 3, 4} and k_0 ={0.001, 0.006, 0.011, 0.016} - smoke
  {0.0006, 0.0014, 0.0022, 0.003} - dust.

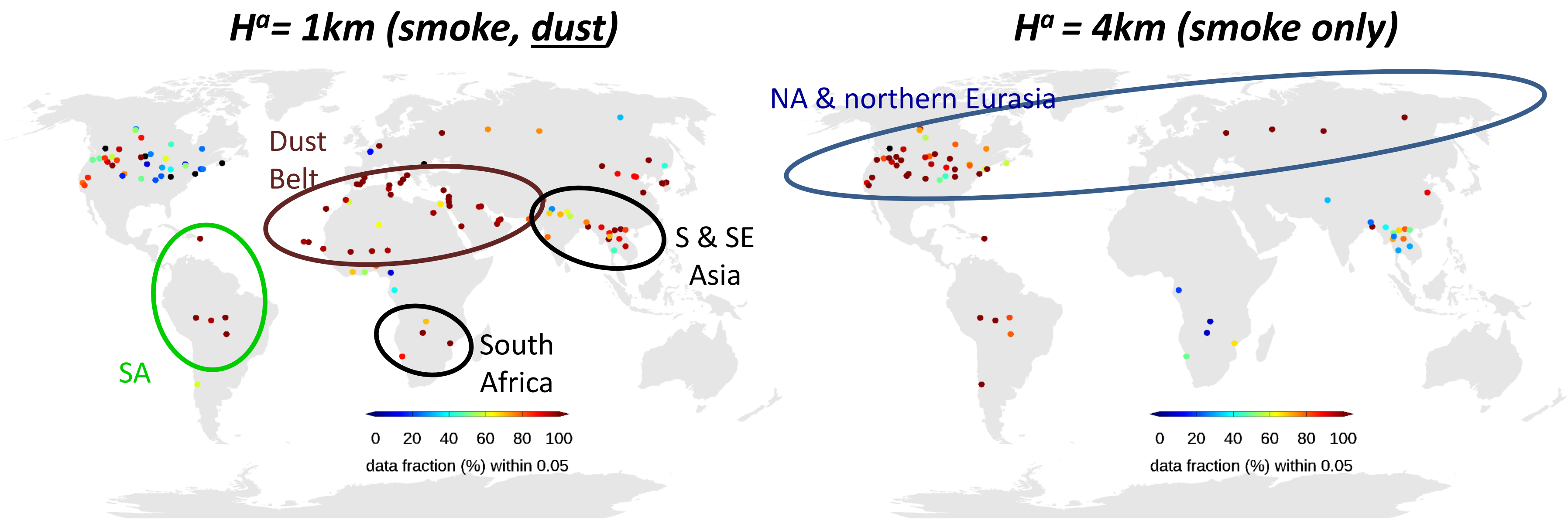
1. Lyapustin A, Wang Y, Go S, Choi M, Korkin S, Huang D, Knyazikhin Y, Blank K and Marshak A (2021) Atmospheric Correction of DSCOVR EPIC: Version 2 MAIAC Algorithm. Front. Remote Sens. 2:748362. doi: 10.3389/frsen.2021.748362.

2. Lyapustin A., Go S., Korkin S., Wang Y., Torres O., Jethva H. and Marshak A. (2021) Retrievals of Aerosol Optical Depth and Spectral Absorption From DSCOVR EPIC. Front. Remote Sens. 2:645794. doi: 10.3389/frsen.2021.645794.

3. Go, S., Lyapustin, A., Schuster, G. L., Choi, M., Ginoux, P., Chin, M., Kalashnikova, O., Dubovik, O., Kim, J., Silva, A. D., Holben, B., and Reid, J. S.: Inferring iron oxides species content in atmospheric mineral dust from DSCOVR EPIC observations, ACP, 22, 1395–1423, https://doi.org/10.5194/acp-22-1395-2022, 2022.

4. Choi, M., A. Lyapustin, G. Schuster, S. Go, et al. Retrieval of BC and BrC smoke aerosol components from DSCOVR EPIC, Atmos. Chem. Phys. (to be submitted, 2022).

v2: SSA_{443} AERONET Validation (2015-2020)

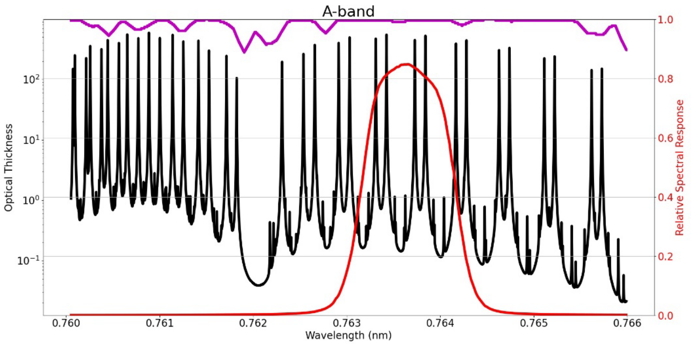


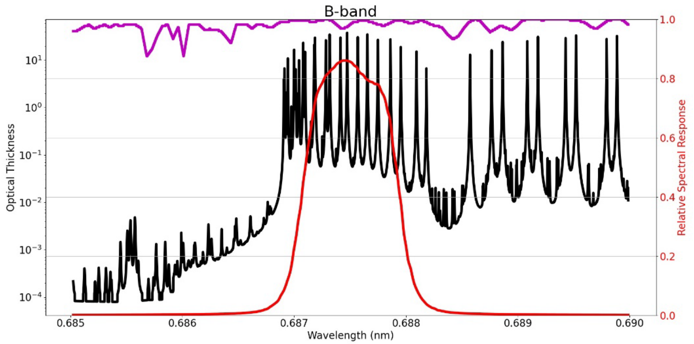
1. For most sites, SSA_{443} is within ±0.05 of AERONET for >80% of retrievals (AOD>0.6)
2. Indirectly assessed H^a qualitatively agrees with known aerosol plume height datasets (e.g., Val Martin et al., 2018)

AOD – k_0 – SAE - ALH Algorithm (4D)

- Absorption model: $k_\lambda = k_0 (\lambda / \lambda_0)^{-b}$ where λ_0 = 680nm.
- LUT(k_0,b): 4x4 matrix for non-absorbing channels, and LUT_{O2}(k_0,b) for O2 A and B-bands. All LUTs are generated for 4 ALH=0.5, 1, 4, 7km, 2 P_s=1 & 0.7. LUT_{O2} are generated with SHARM-IPC code (accuracy ~0.1% vs LBL but ~100 times faster).
- The algorithm uses 8-dim linear interpolation in (geom, P, AOD, k_0, b, H) - fast.
- AOD-k_0-b-H retrieval using **Levenberg-Marquart optimal fit** of 340, 388, 443, **688, 764** and 680, 780nm:

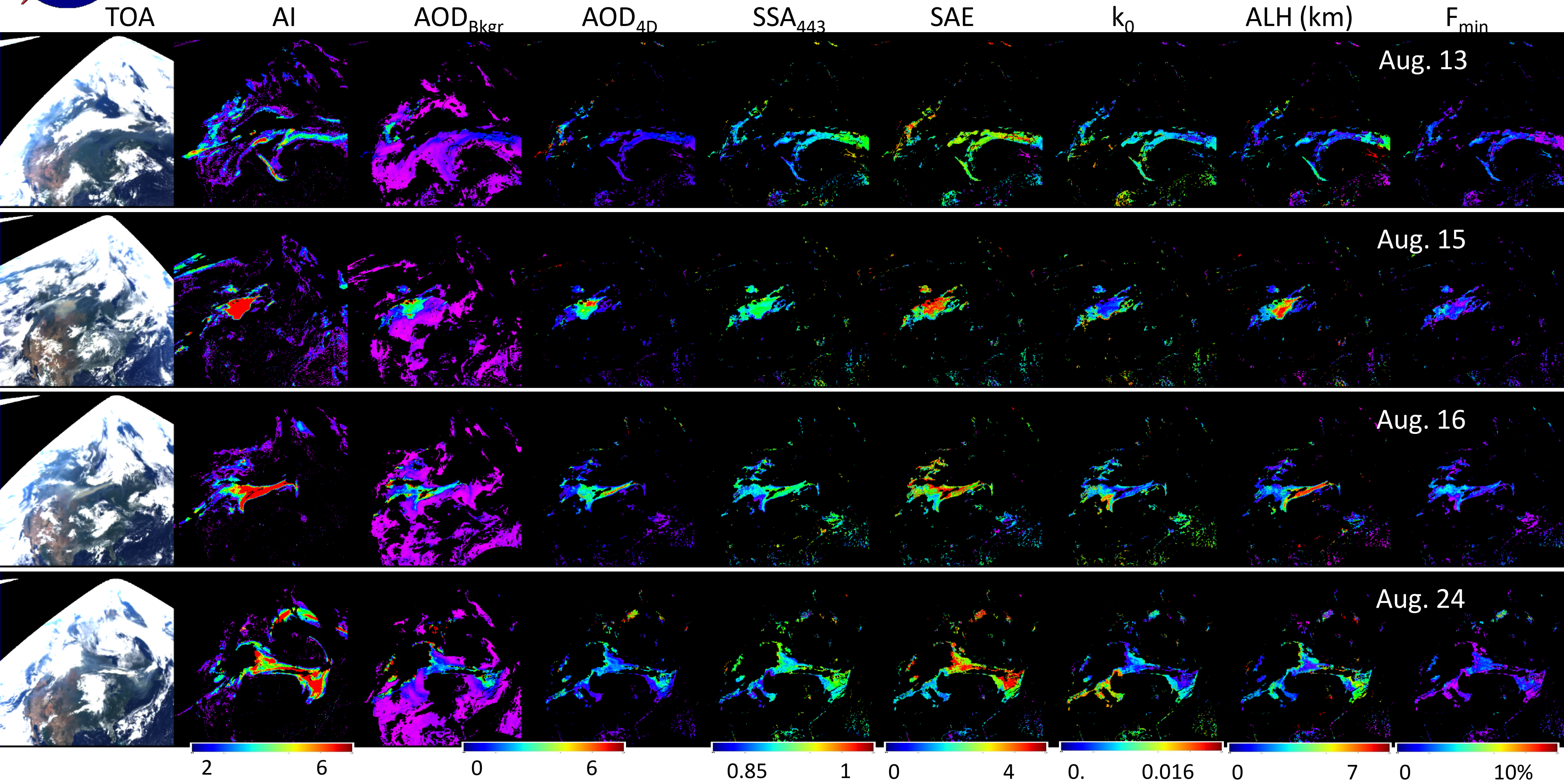
$$F^2 = 1/N \sum \left(\frac{L^m_\lambda - L^t_\lambda}{\sigma_\lambda L^m_\lambda}\right)^2 = \min\{AOD_{443}, k_0, b, H\}$$





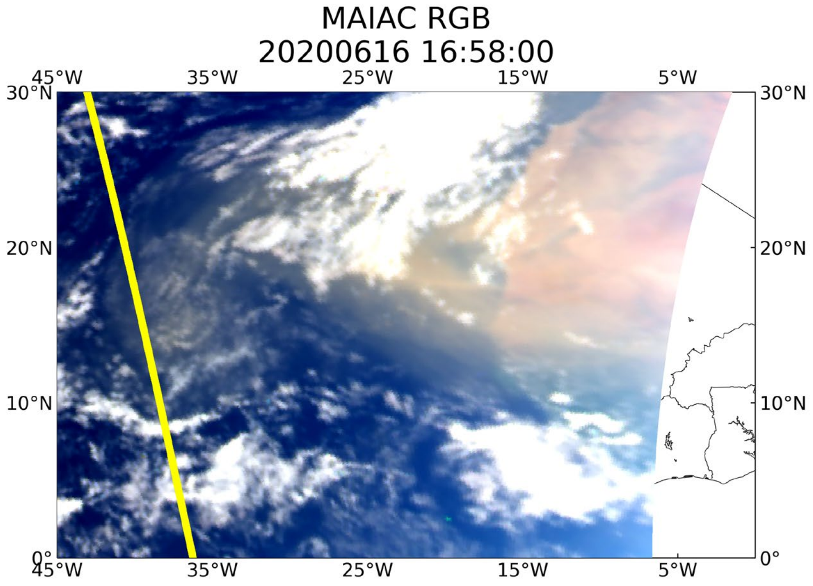
Lyapustin, A., 2003: Interpolation and Profile Correction (IPC) method for shortwave radiative transfer in spectral intervals of gaseous absorption. J. Atmos. Sci., 60, 865-871

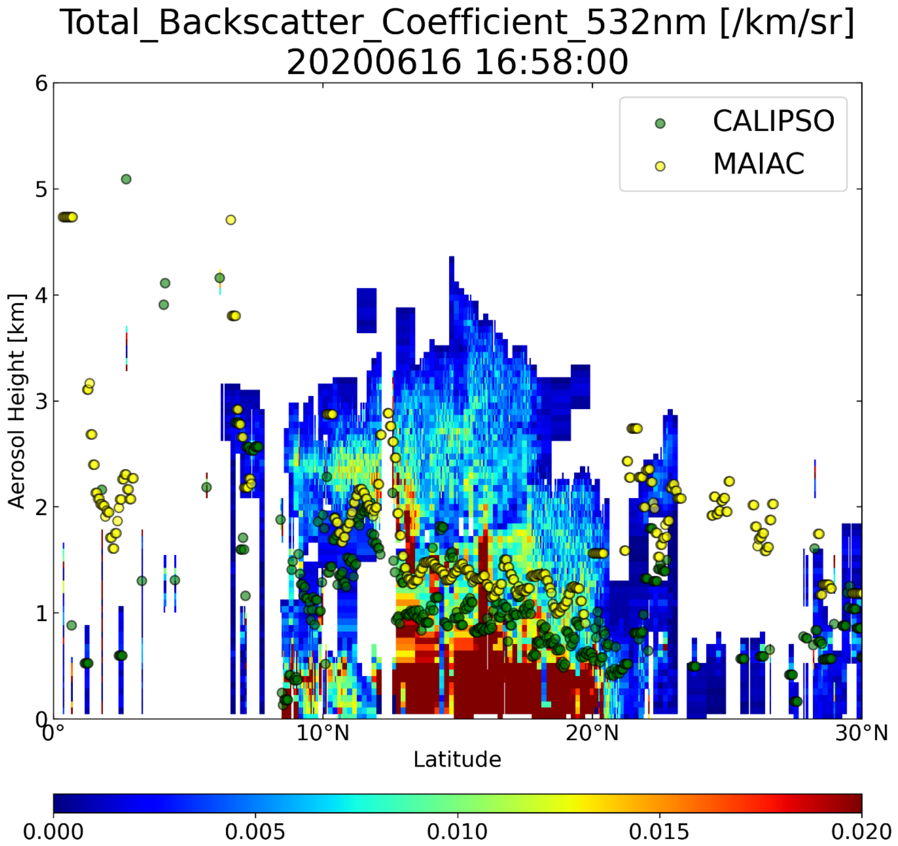
Example: US Fires in August 2018

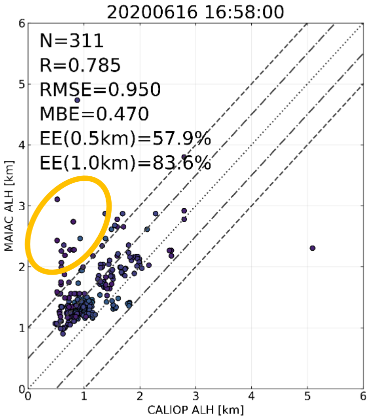


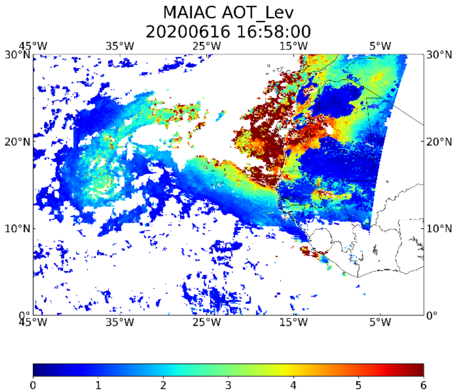
Atlantics_20201681658_MAIAC_RGB_2020-06-16T16-08-22ZD.png

CALIOP ALH Evaluation



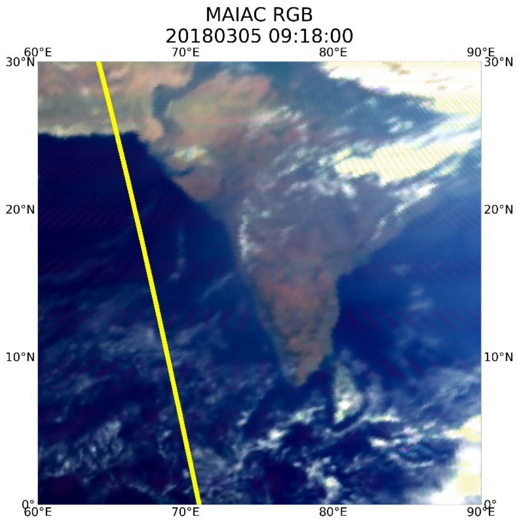


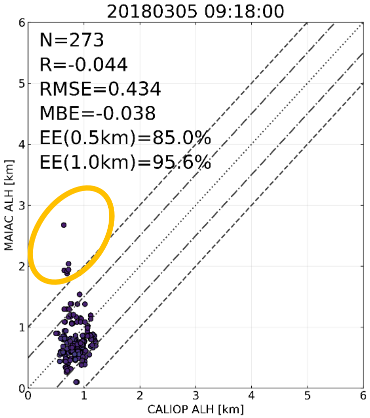


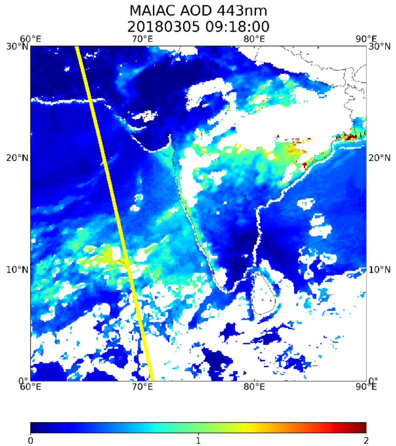


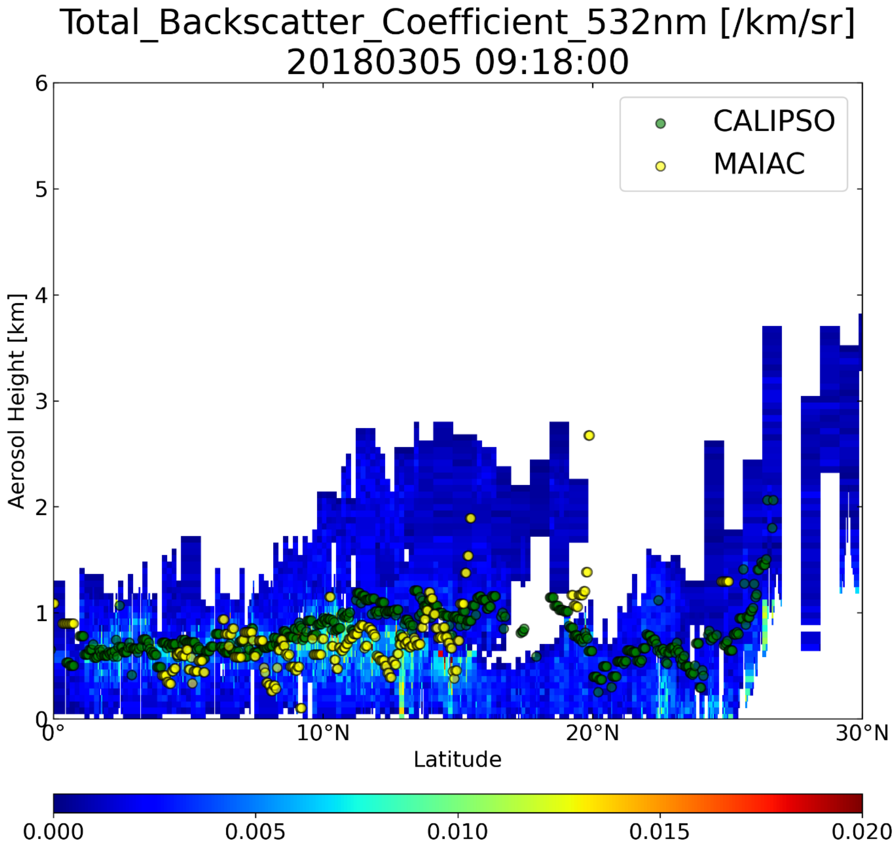
India_20180640918_MAIAC_ALH_Validation_2018-03-05T08-34-22ZD.png

CALIOP ALH Evaluation



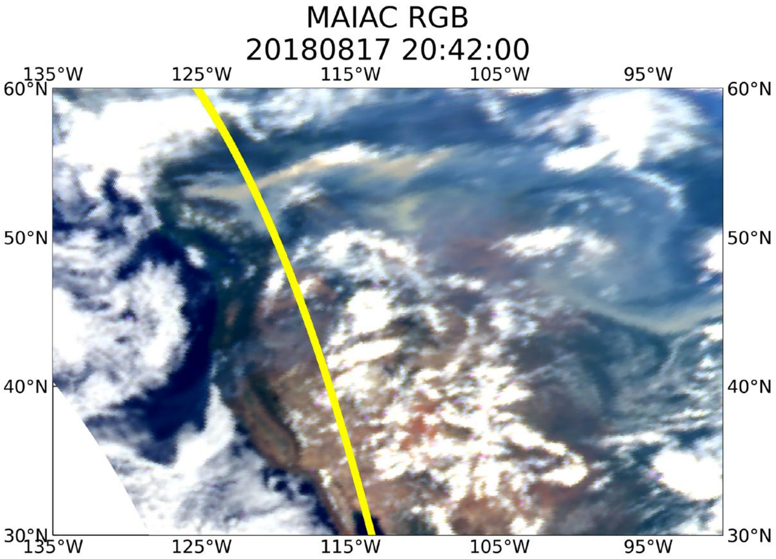


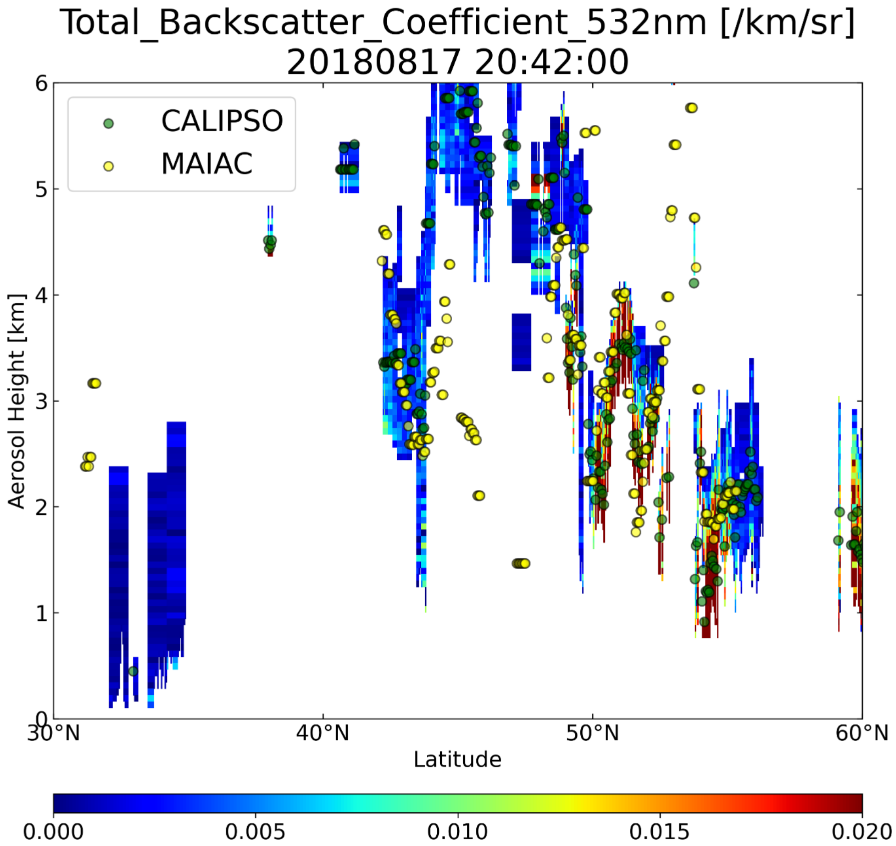


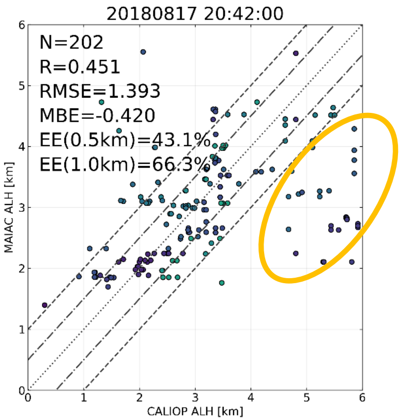


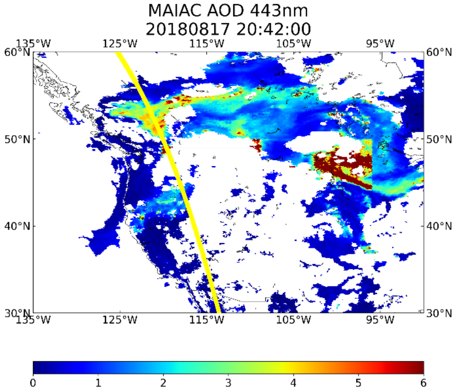
Conus_20182292042_MAIAC_RGB_2018-08-17T20-30-33ZD.png

CALIOP ALH Evaluation









Conclusions

- **MAIAC MODIS C6.1 should be available in 2-4 months:**
    - Removed low AOD bias at high AOD;
    - New CMG data;
- **MAIAC VIIRS C2** (expect MODAPS to start re-processing in several months)
    - Compatible with MAIAC MODIS (Detrended and X-calibrated to MODIS Aqua)
- **MAIAC DSCOVR EPIC**
    - Joint retrieval of AOD, spectral absorption and ALH using UV-Vis-O2 A,B-bands
    - Retrieval of speciation for dust (hematite/goethite) and smoke (BC/BrC) based on AOD and k_{λ};
    - Finalizing the algorithm and assessing global and regional accuracy
- **Next:**
    - Implementing full MAIAC processing including (SSA_{λ}, ALH) and hyperspectral AC on TropOMI;
    - Finalizing MAIAC algorithm for PACE OCI.