Adapting MAIAC to Geostationary Observations: Current Limitations and What's Possible

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July 23, 2019

MAIAC: General Information

Lyapustin, A., et al..: MODIS Collection 6 MAIAC Algorithm, AMT, 2018

Status:

- ***C6 MAIAC MODIS was released in May 2018 (MCD19)***
- *MAIAC VIIRS expected this summer-fall;*

Products (gridded):

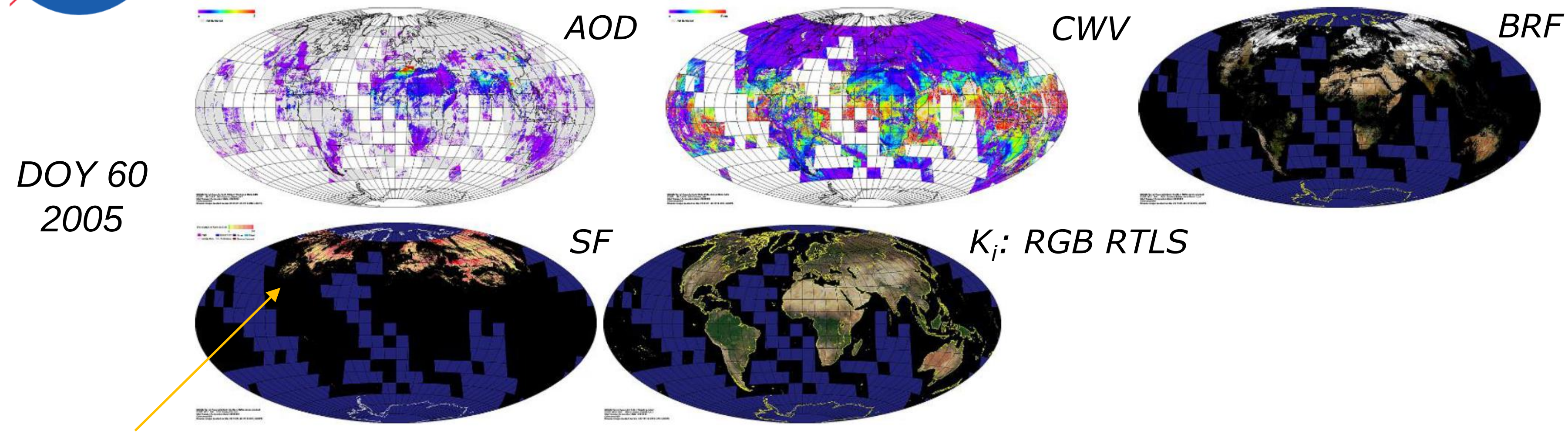
- ***Atmosphere (MCD19A2 - daily)****: CWV, CM, AOD, aerosol type (background/smoke/dust), Smoke Plume Height @1km resolution;*
- ***Land Surface (MCD19A1 – daily; MCD19A3 – 8-day)****:*

  - (MCD19A1): spectral BRF (surface reflectance) @1km (B1-B13) and 500m (B1-B7); SigBRFn_B1,B2. Will add 250m in C6.1;

  - (MCD19A3 – 8-day): BRDF (RTLS model, naturally gap-filled), instantaneous albedo (B1-B8);
- ***Detected Snow (MCD19A1)****: snow grain size, and sub-pixel snow fraction (1km);*

MAIAC Global Products

https://landweb.modaps.eosdis.nasa.gov/cgi-bin/browse/browseMODIS.cgi



A factor of ~2 increase in accuracy of snow detection: *Cooper, M. J., Martin, R. V., Lyapustin, A. I., and McLinden, C. A.: Assessing snow extent data sets over North America to inform and improve trace gas retrievals from solar backscatter, AMT, 11, 2983-2994, 2018.*

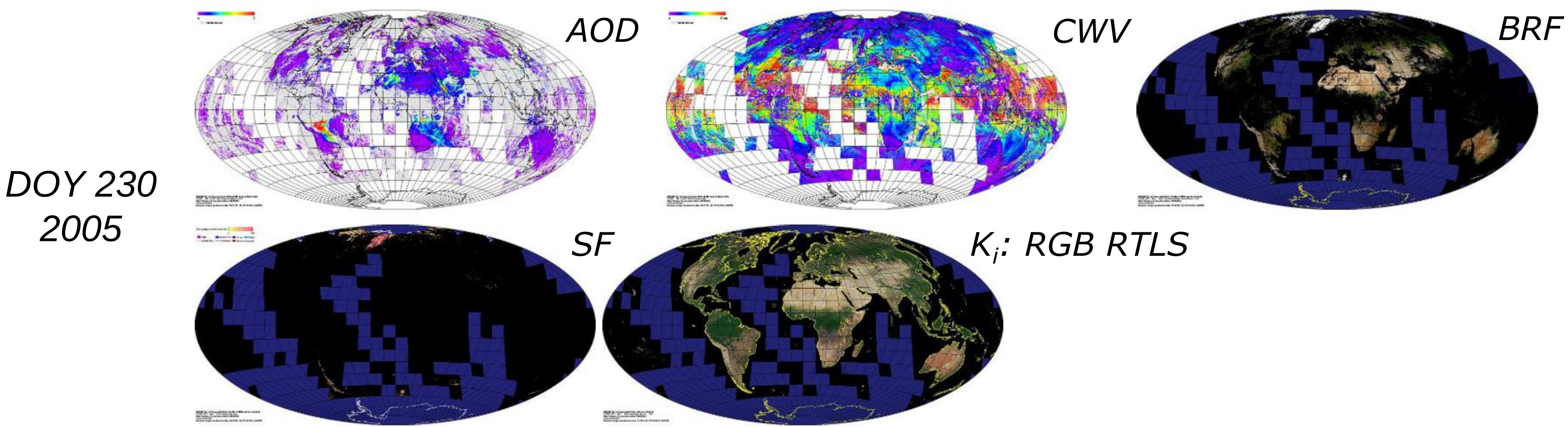


Figure 6. Global browse images showing MAIAC AOD (scale 0-2), column water vapor (scale 0-5cm), RGB BRF, snow fraction (scale 0-1) and RGB of the isotropic parameter (k^L) of the RTLS model for days 60 (top row) and 230 (bottom row) of 2005.

MAIAC: Main Features

1. *Sliding window algorithm – store up to 2 days of measurements in memory → BRDF;*
2. *Dynamic characterization of SR spectral ratios using MRM*
3. *Detailed surface characterization for each grid cell (spectral BRDF; spatial variation from 500m band; BT-contrasts etc.) → high quality cloud, snow, cloud shadow detection;*
4. *Smoke/Dust Absorbing aerosol Test*

MAIAC Aerosol Type (Smoke/Dust)

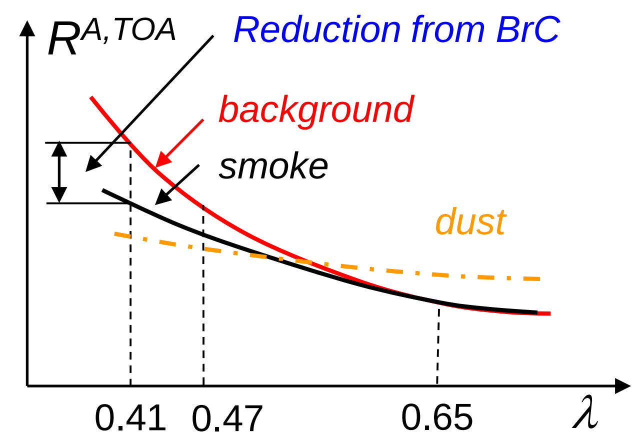
*Lyapustin, A. et al., 2012: Discrimination of biomass burning smoke and clouds in MAIAC algorithm, **ACP**, 12, 9679–9686.*

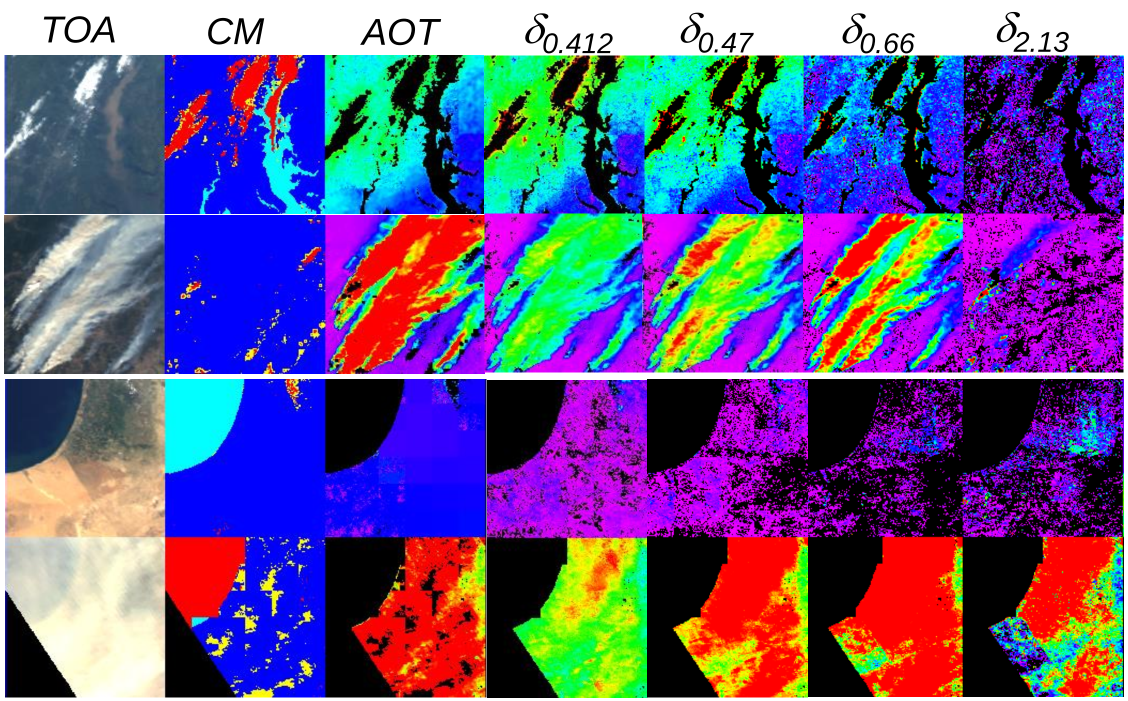
*Phys. principles (~OMI) – **enhanced shortwave absorption** (Red →Blue →DB)*

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

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

2) Multiple scattering, for absorbing aerosols.





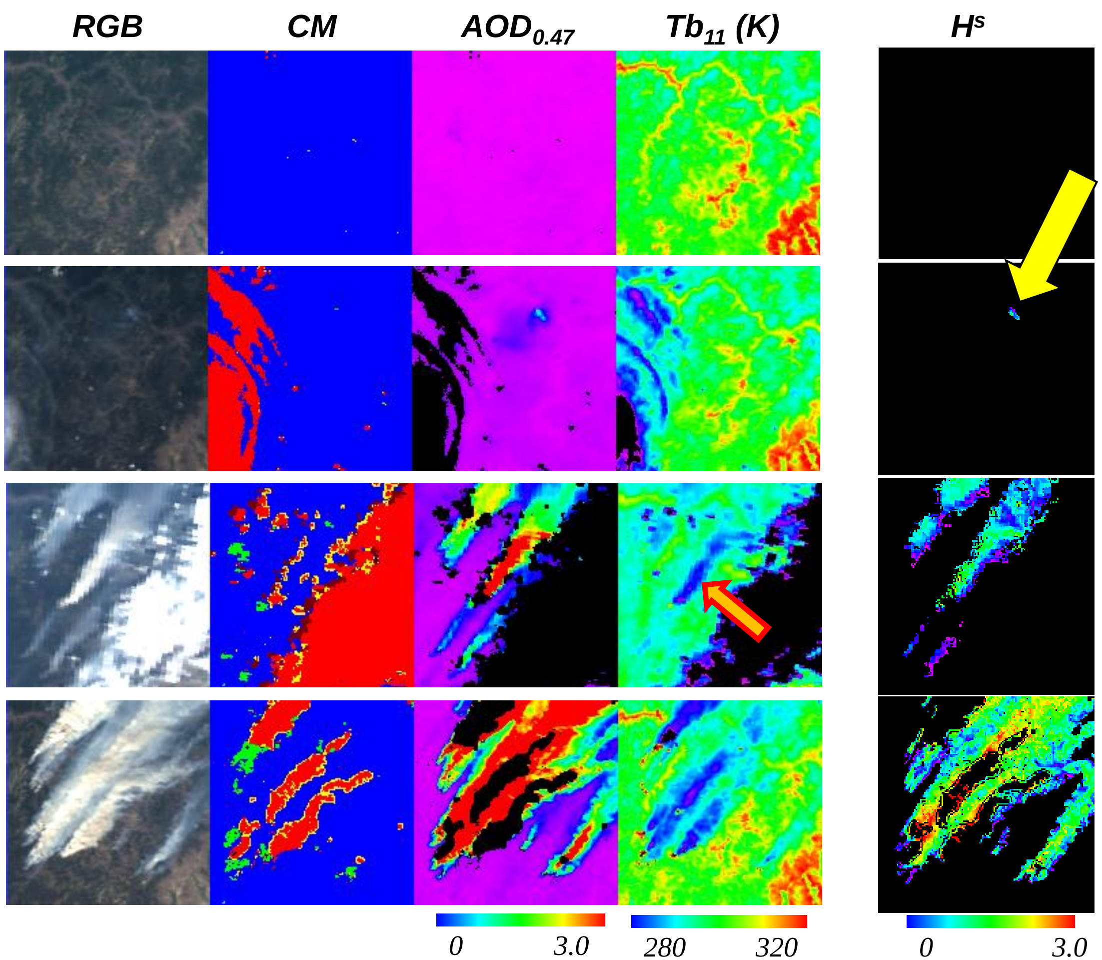
Backgr./Smoke/Dust

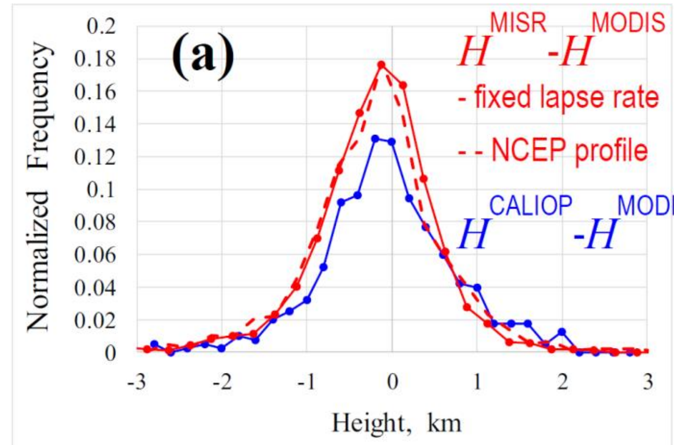
$$\delta_\lambda = R_\lambda^M - R_\lambda^T(\tau_{0.47}^a = 0.05)$$

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

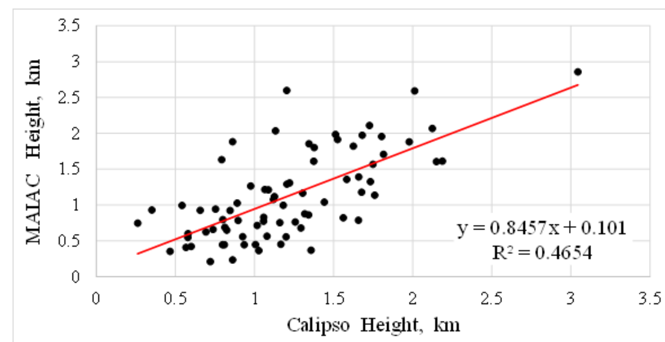
New: Aerosol Plume Height

Lyapustin, A., Y. Wang, S. Korkin, R. Kahn and D. Winker, MAIAC Thermal Technique for Smoke Injection Height from MODIS, TGRL, in review.





a) *Histogram of MODIS-MISR MINX plume height difference (2000-2008);*

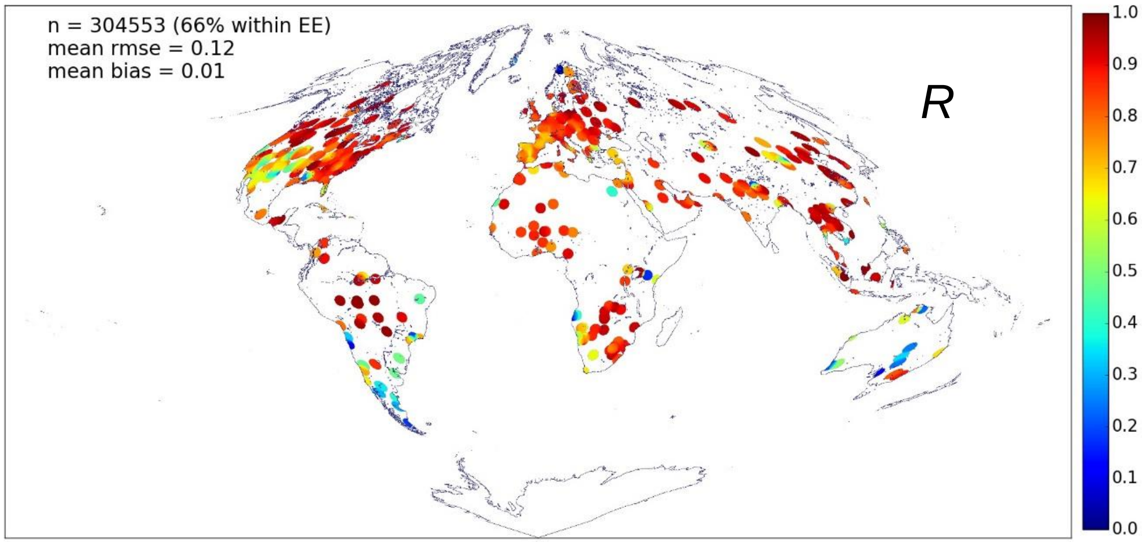


b) *Validation against CALIOP CALIPSO plume heights over N. America.*

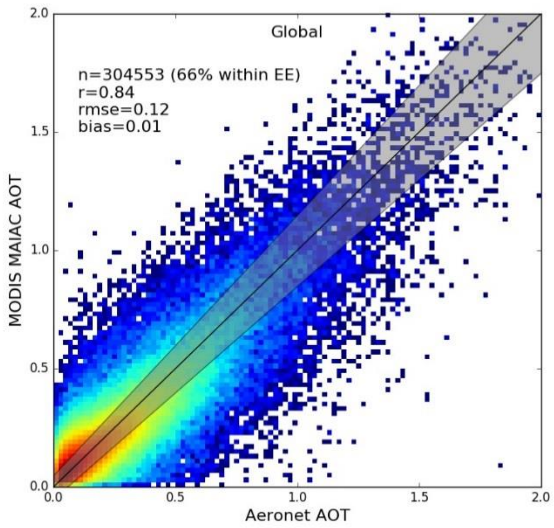
1. *MAIAC agrees to both MISR MINX and CALIOP CALIPSO to about ±500m.*
2. *On average, thermal height is 220-450m lower than lidar and stereoscopic data.*

Aerosol Validation (2000-2016)

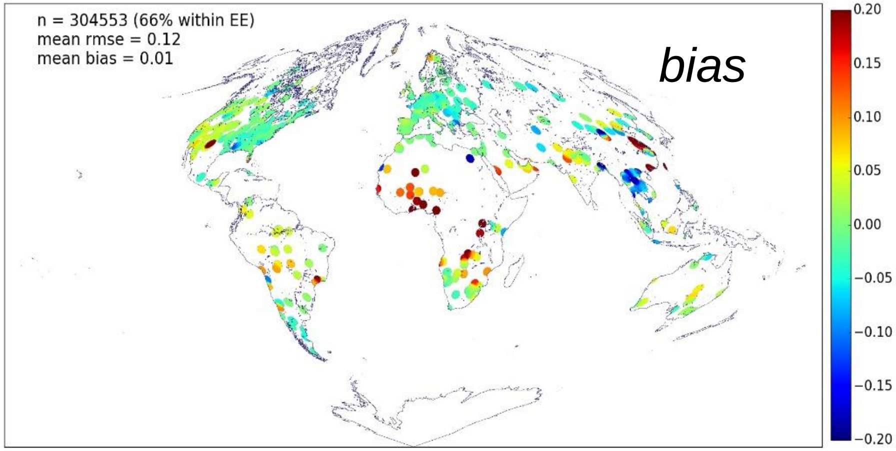
Lyapustin, A., et al..: MODIS Collection 6 MAIAC Algorithm, AMT, 2018

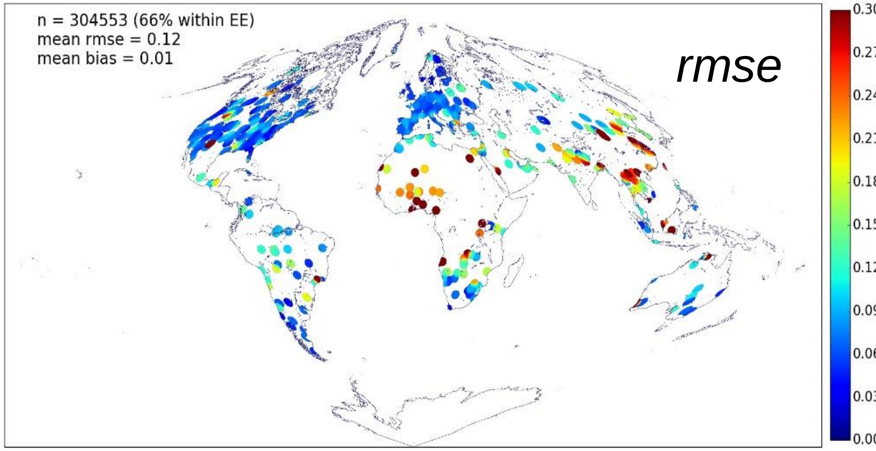


EE = ±0.05 ±0.1AOD



Bias is regionally clustered. Will be fixed in C6.1.

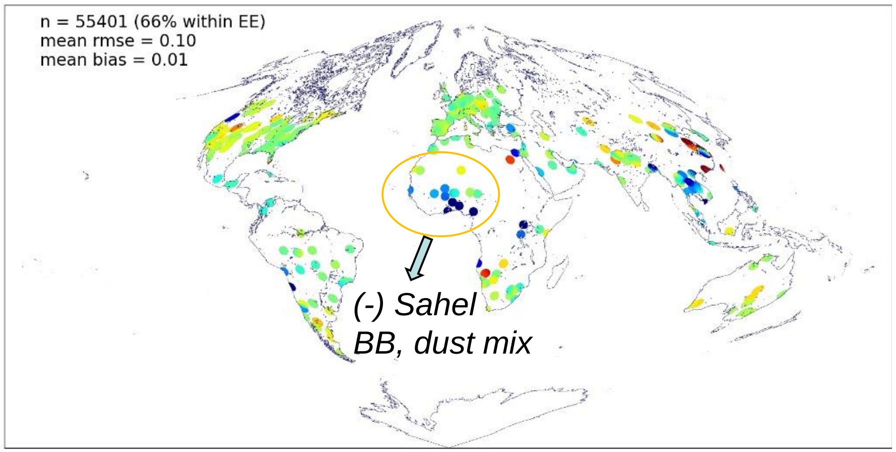




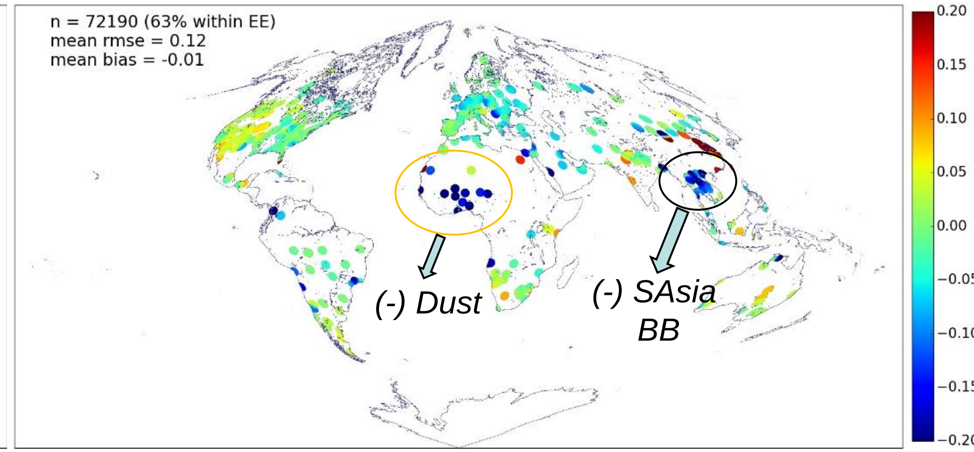
Seasonal Bias Analysis (2000-2016)

(planned improvements for C6.1)

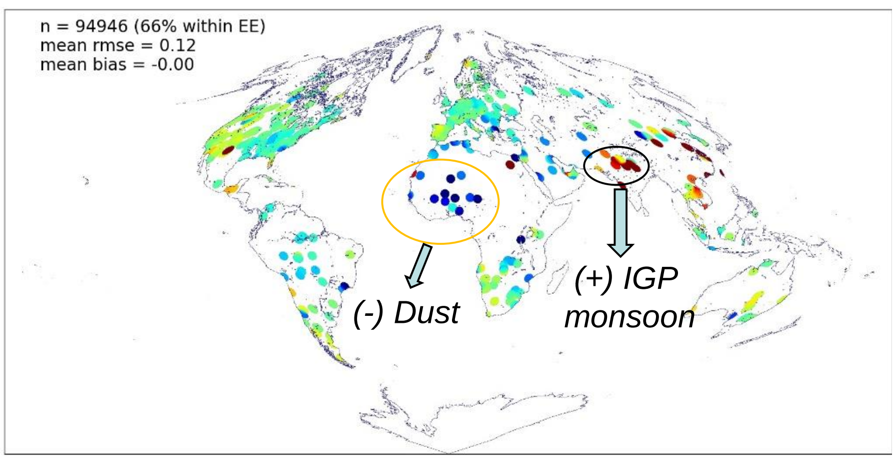
DJF



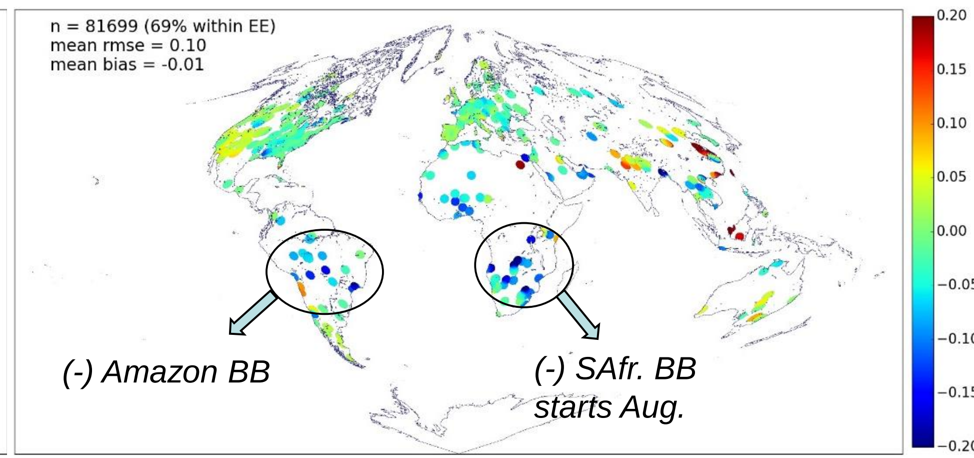
MAM



JJA

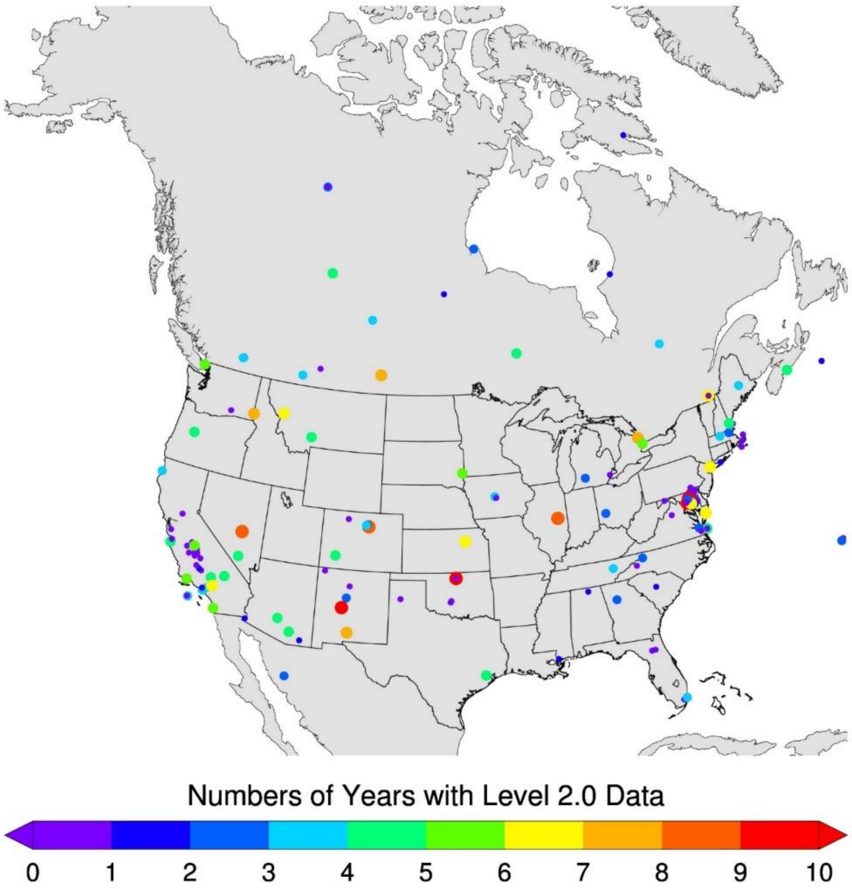


SON

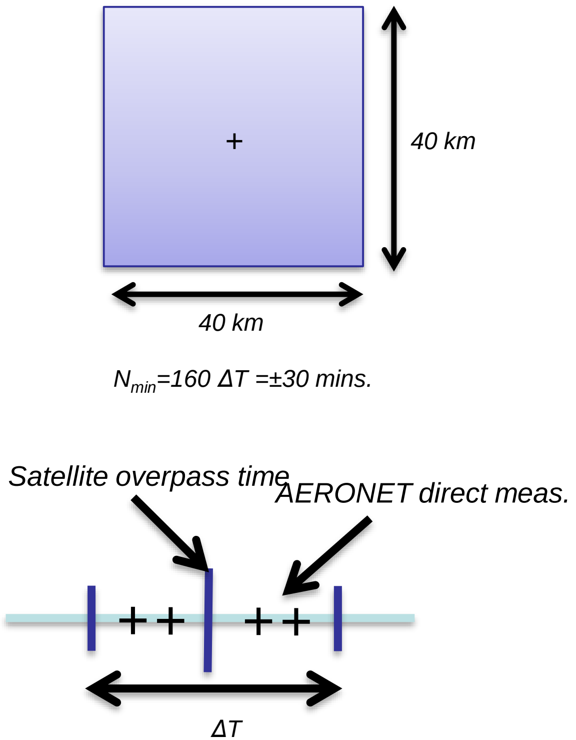


Ground-Satellite Collocation Criteria

Geographical Distribution of AERONET Sites over North America



Spatio-Temporal Approach



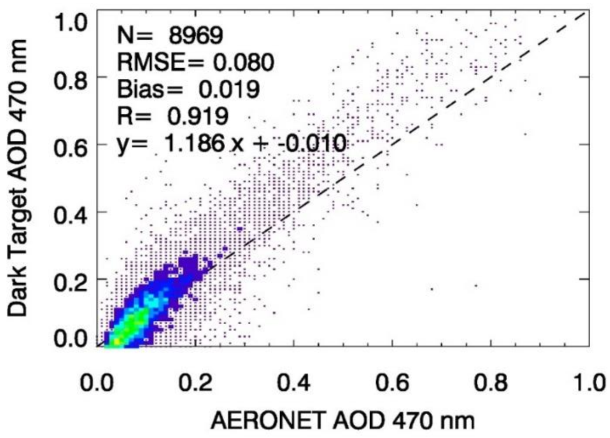
Only best quality satellite AOD retrievals are considered in this analysis.

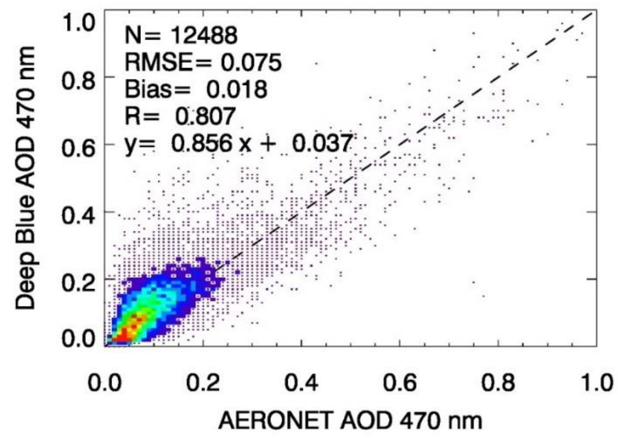
Jethva, Torres, Yoshida, *Accuracy Assessment of MODIS Land Aerosol Optical Thickness Algorithms using AERONET Measurements*, AMTD, 2019

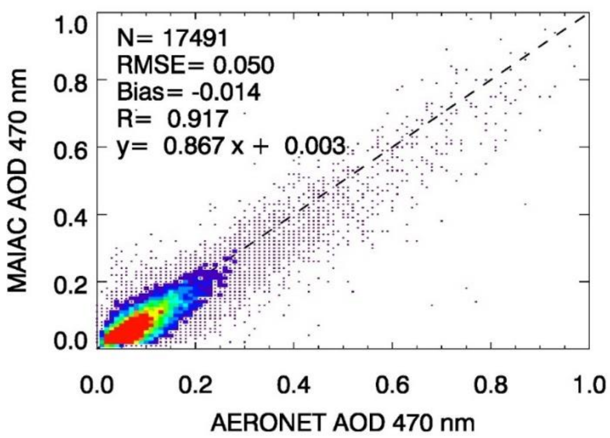
Eastern NA Composite

Independent comparison

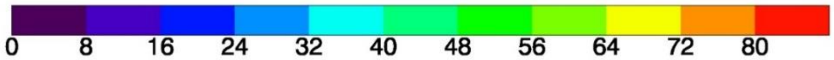
eUS 0.4x0.4_30min







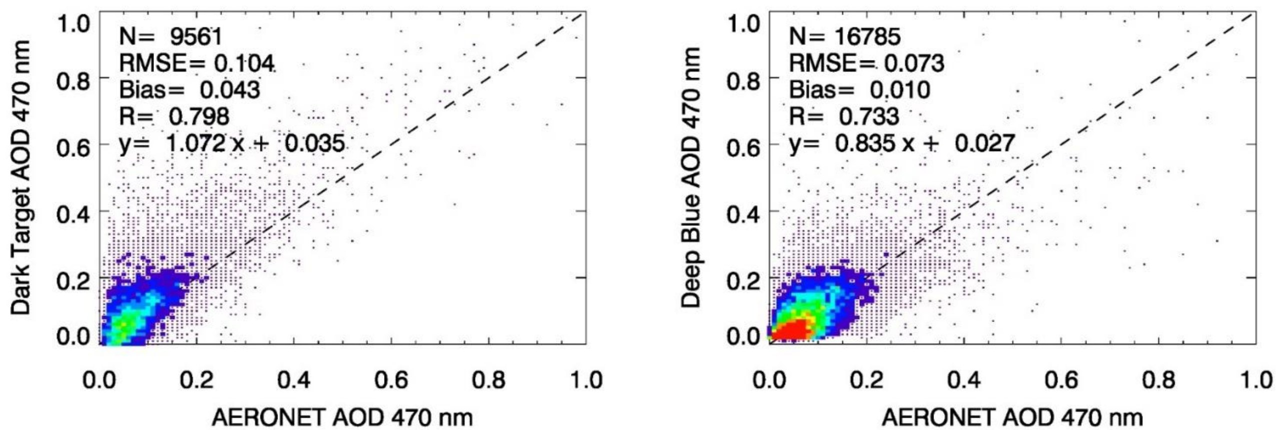
	DT	DB	MAIAC
N	8969	12488	17491
Corr.	0.919	0.807	0.917
Slope	1.186	0.856	0.867
Y-int	-0.010	0.037	0.003
RMSE	0.080	0.075	0.050
Bias	0.019	0.018	-0.014

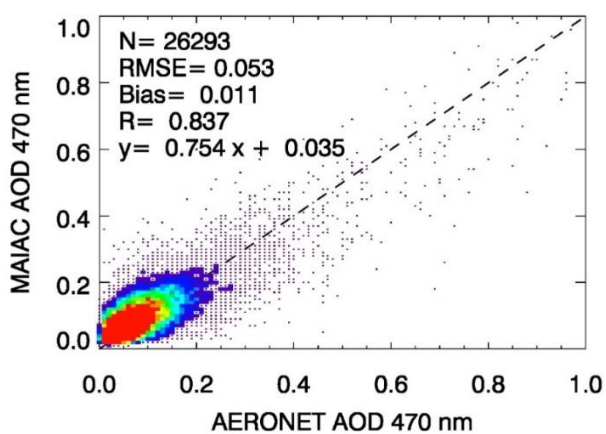


Western NA Composite

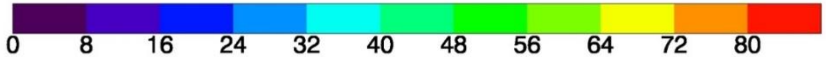
Independent comparison

wUS 0.4x0.4_30min



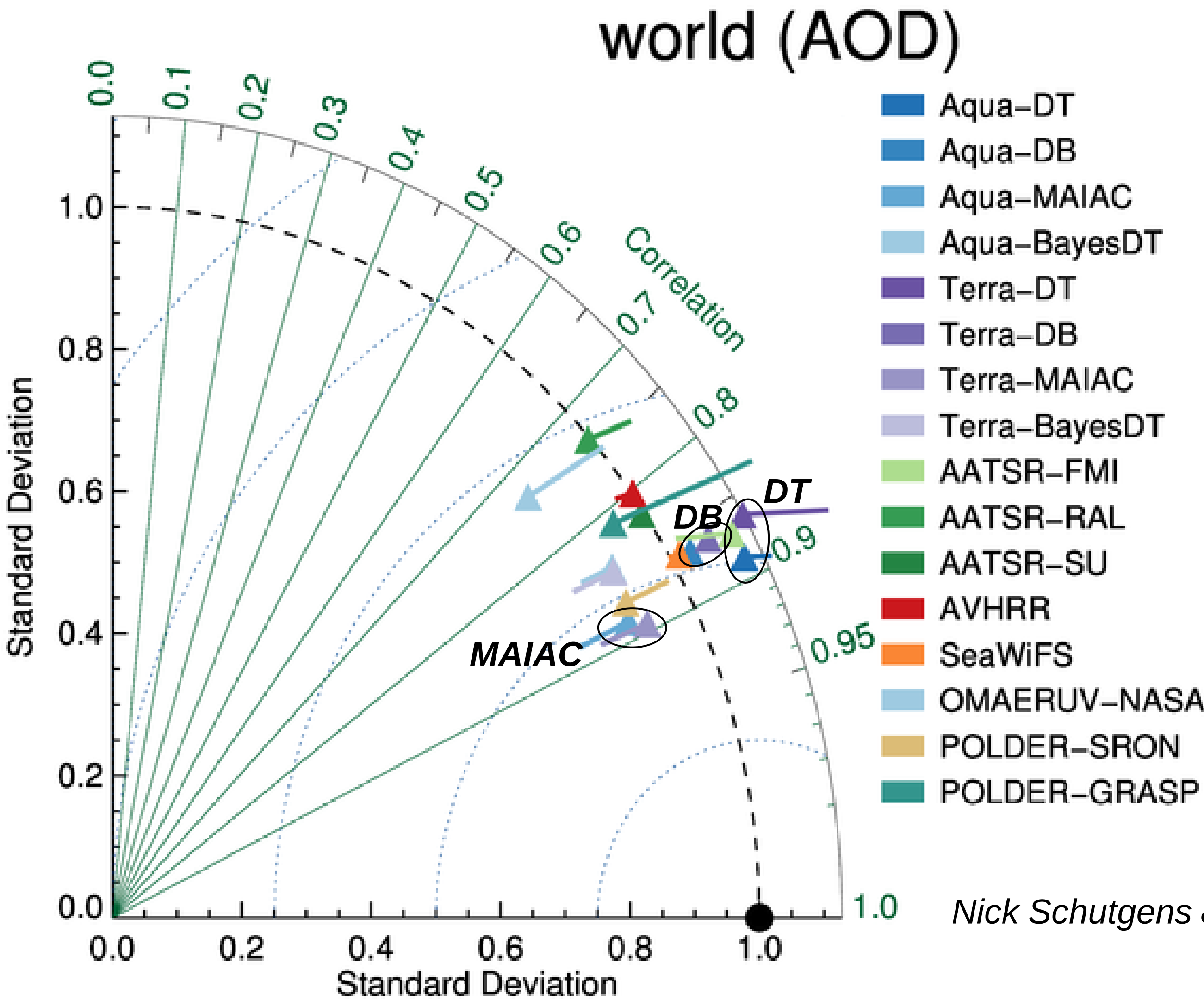


	DT	DB	MAIAC
N	9561	16785	26293
Corr.	0.798	0.733	0.837
Slope	1.072	0.835	0.754
Y-int	0.035	0.027	0.035
RMSE	0.104	0.073	0.053
Bias	0.043	0.010	0.011



Global Over Land Inter-Comparison

1×1°, time-resolved



Nick Schutgens & AEROSAT team

Geostationary Observations

1. ***Geostationary Observations (10-15min):***

   - Provide dynamics to study Aerosols, Clouds and their interactions;

   - Diurnal Cycle of Aerosol $\rightarrow$ Air Quality;

   - Dynamics of fires and dust storms;

   - Unprecedented angular resolution (in SZA, AZ) for land BRDF studies and vegetation structure;

   - Improved vegetation phenology and productivity (e.g., timing of northern spring green-up);

   - Improved GPP modeling from diurnally-resolved PAR;

   - Rapid disturbance characterization at scales 500m-1km, etc.

2. ***Adapting MAIAC to AHI-8 HIMAWARI**:*

   Bands: 0.47, 0.51, 0.64, 0.86, 1.61, 2.25, 3.9, …, 10.4, 11.2, 12.4μm

3. ***Adapting MAIAC to ABI GOES-16**:*

   Bands: 0.47, 0.64, 0.86, 1.38, 1.61, 2.25, 3.9, …, 10.4, 11.2, 12.4μm

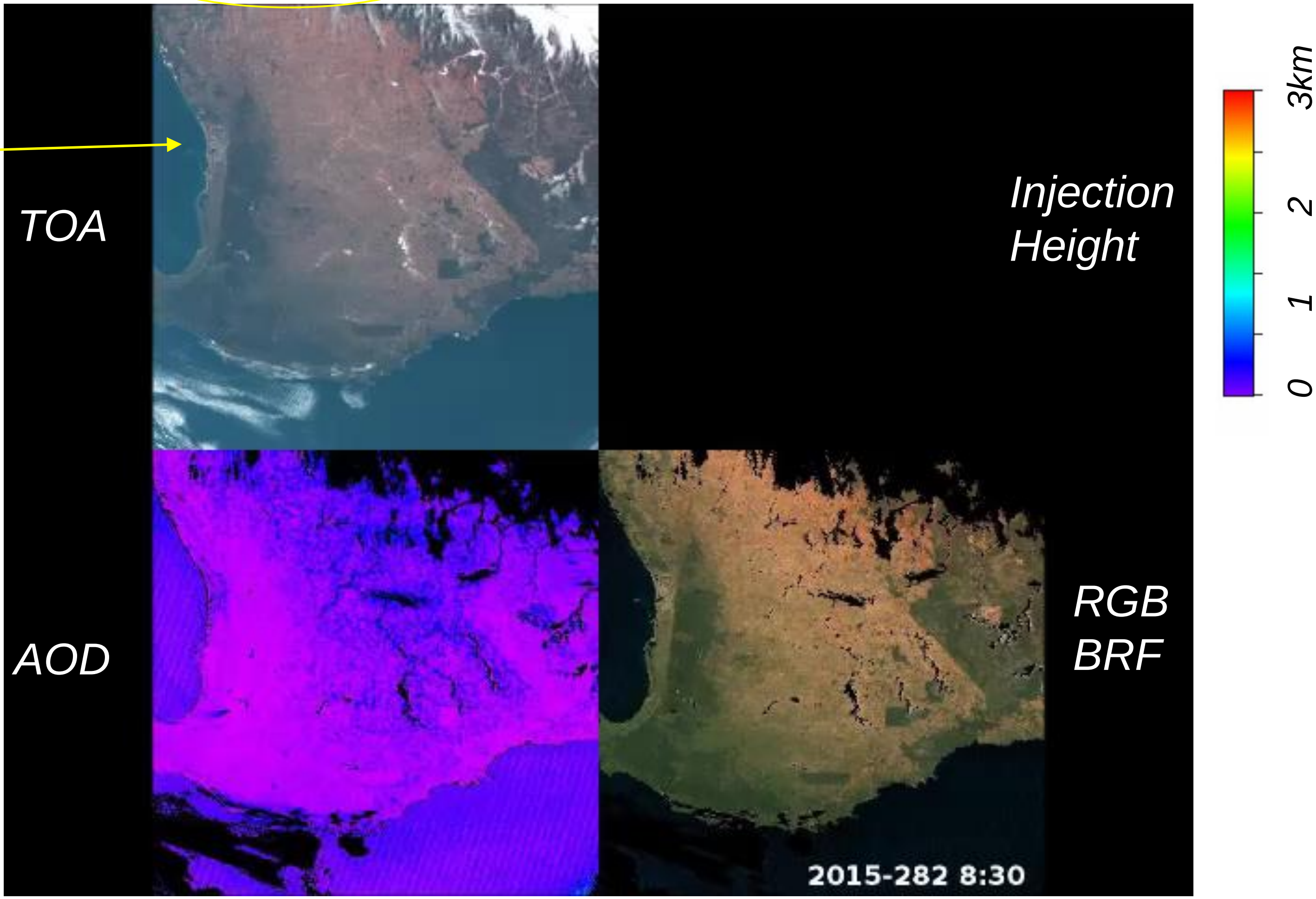
MAIAC for HIMAWARI AHI-8

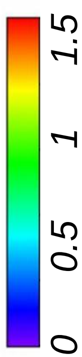
(*Australian Bureau of Meteorology*: controlled burns)

Parked at 142°E; → *Smoke detection bands: sub-optimal*

Bands: 0.47, 0.51, 0.64, 0.86, 1.6, 2.3, 3.9, …, 10.4, 11.2, 12.4μm

South-West Australia: Perth





7-10 day Synoptic Cycle,
Northern China

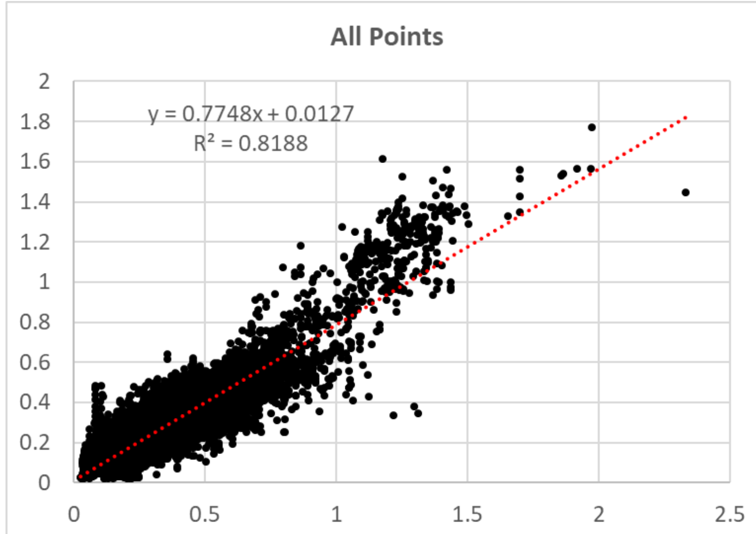
High AOD Over Korea

October 13, 2016

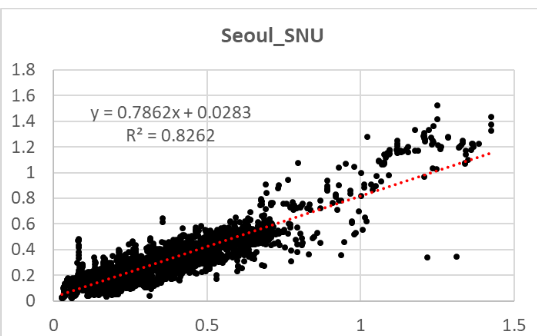
Siberian Fire Smoke Over Japan

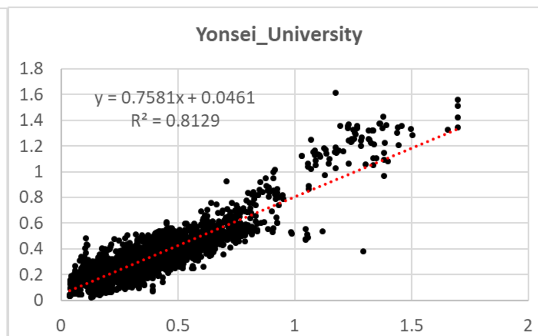
May 17-23, 2016

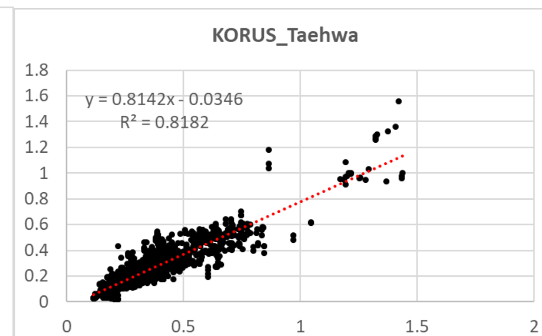
Validation for KORUS-AQ Campaign

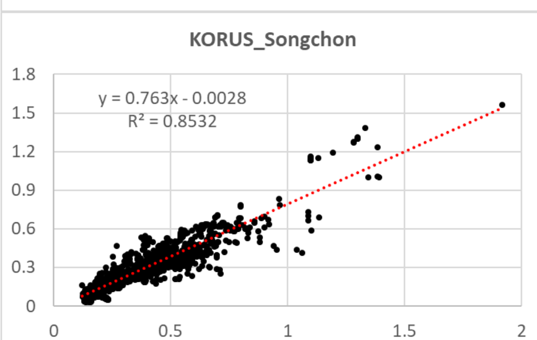


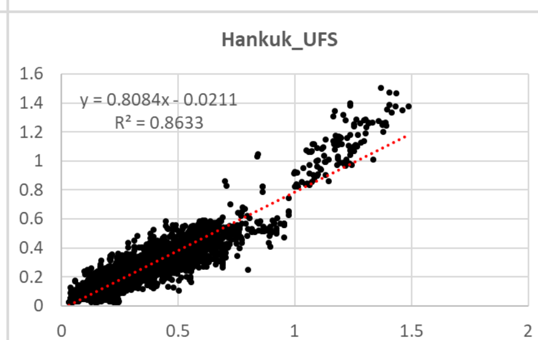
MAIAC data are averaged over 11km^2

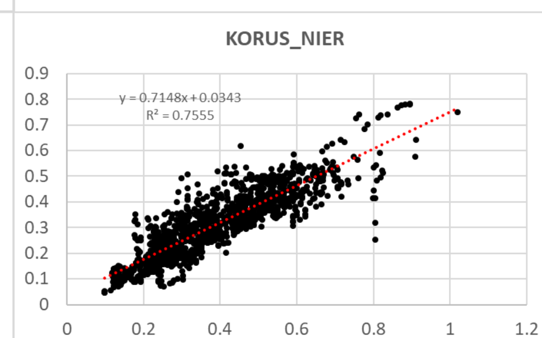






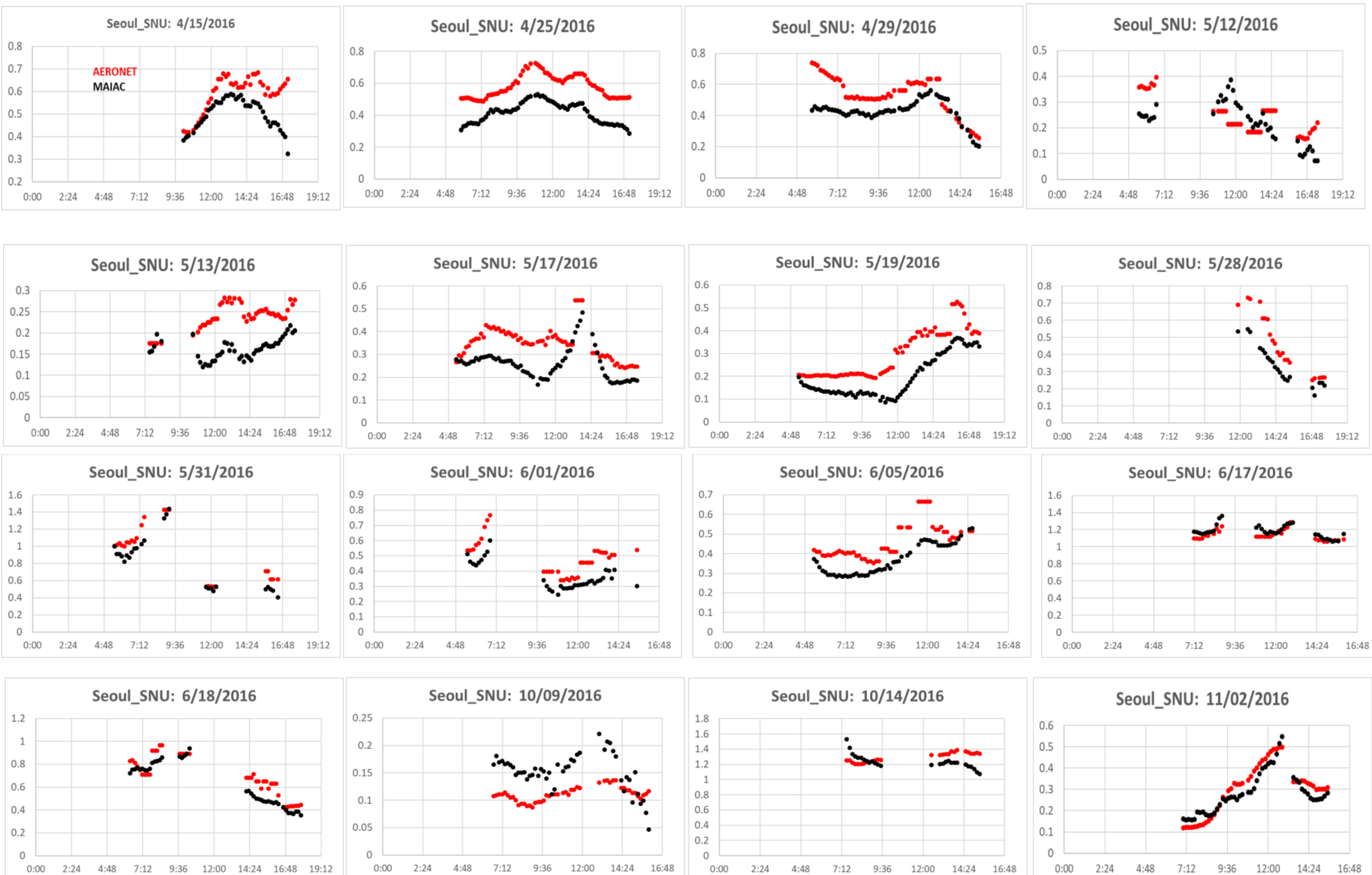




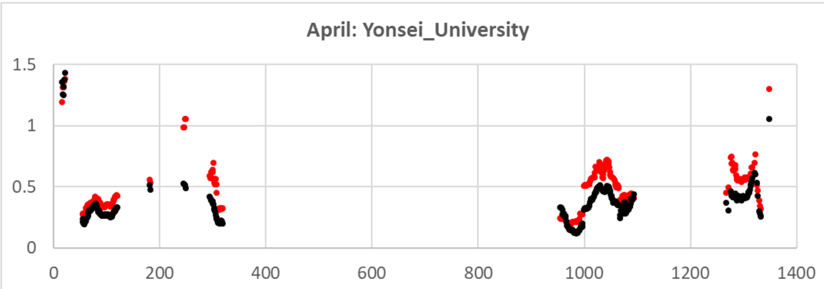


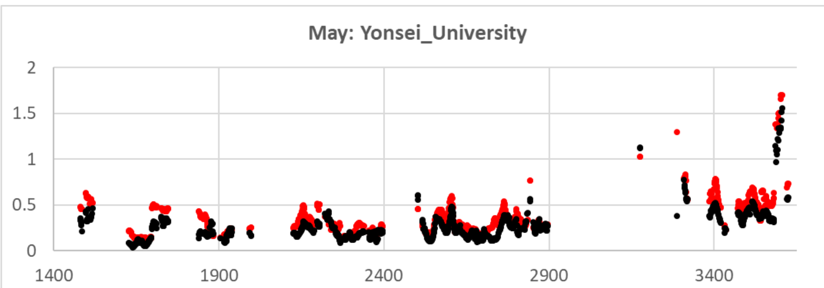
Diurnal Cycle

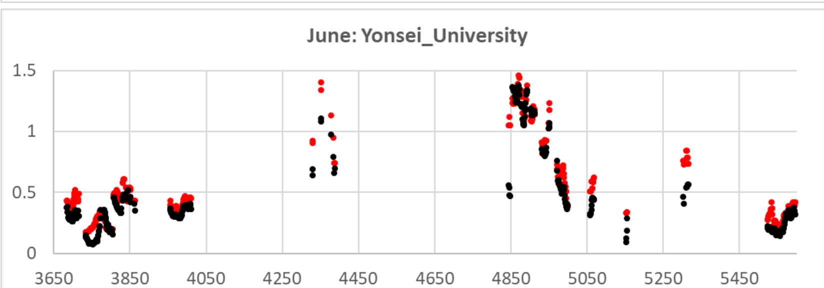
MAIAC data are averaged over 11km^2

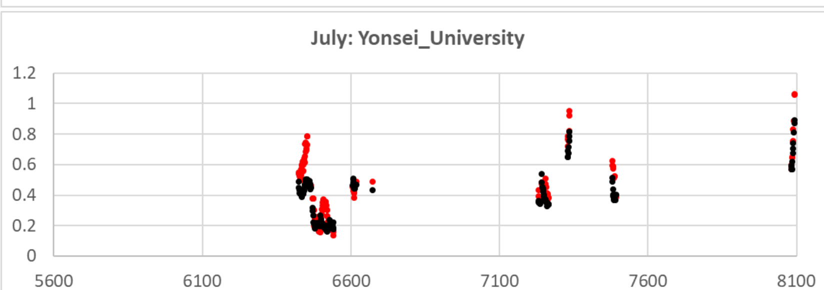


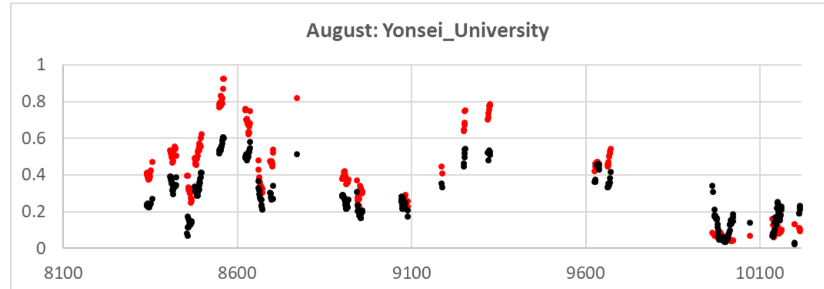
Diurnal Cycle

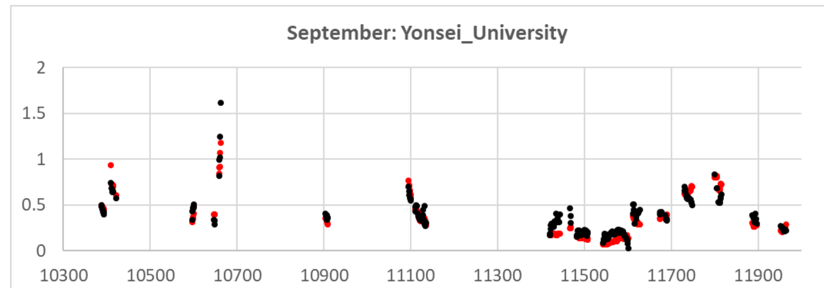


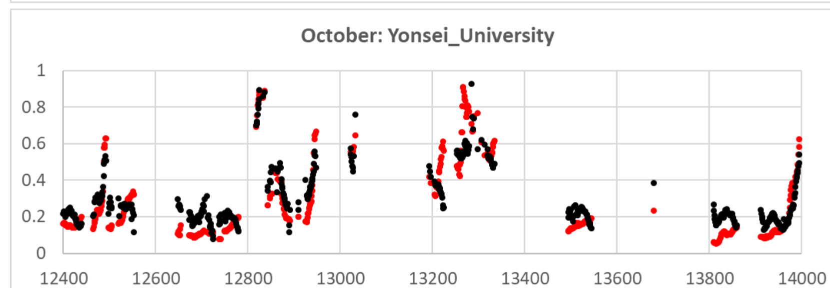


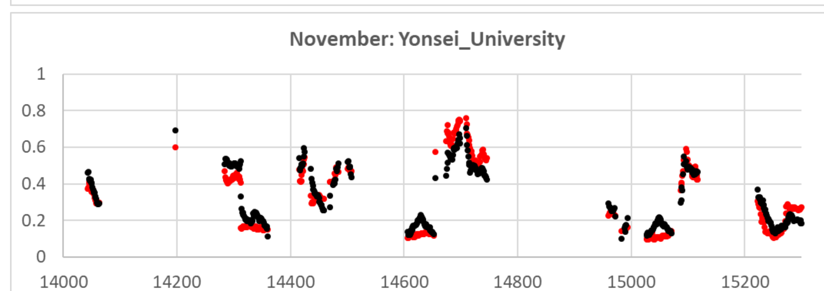












Current Issues

1. ***BRDF***
   - *Geo's do not give BRDF in a sense of RT (to integrate downward sky irradiance, in VZA, AZ);*
   - *BRDF is not reciprocal:*

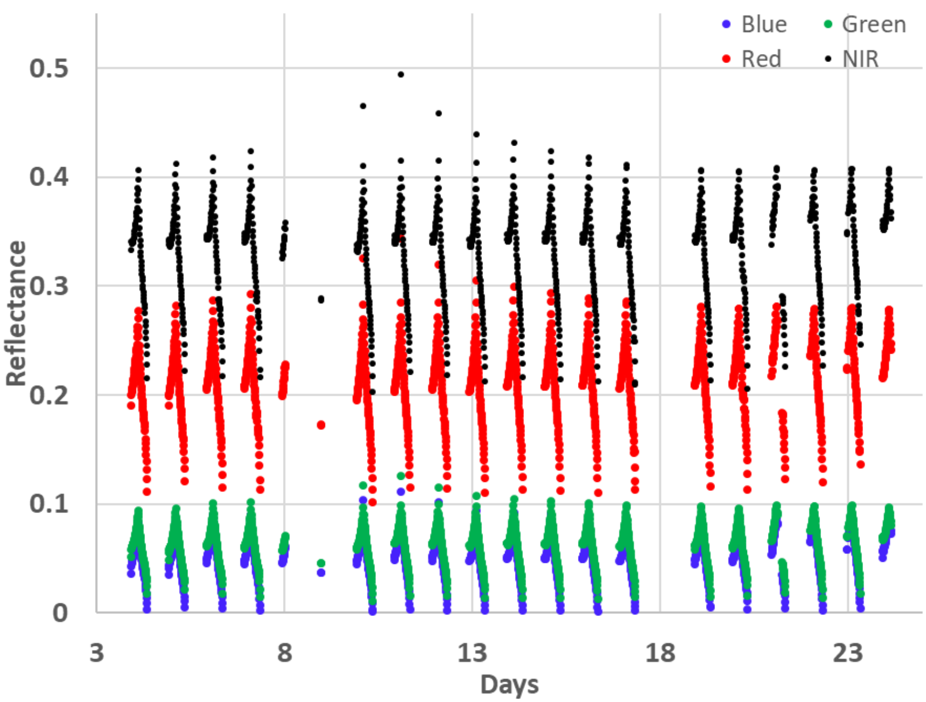
     $$\rho(\mu_0,\ \mu)/\mu_0 \neq \rho(\mu,\ \mu_0)/\mu$$

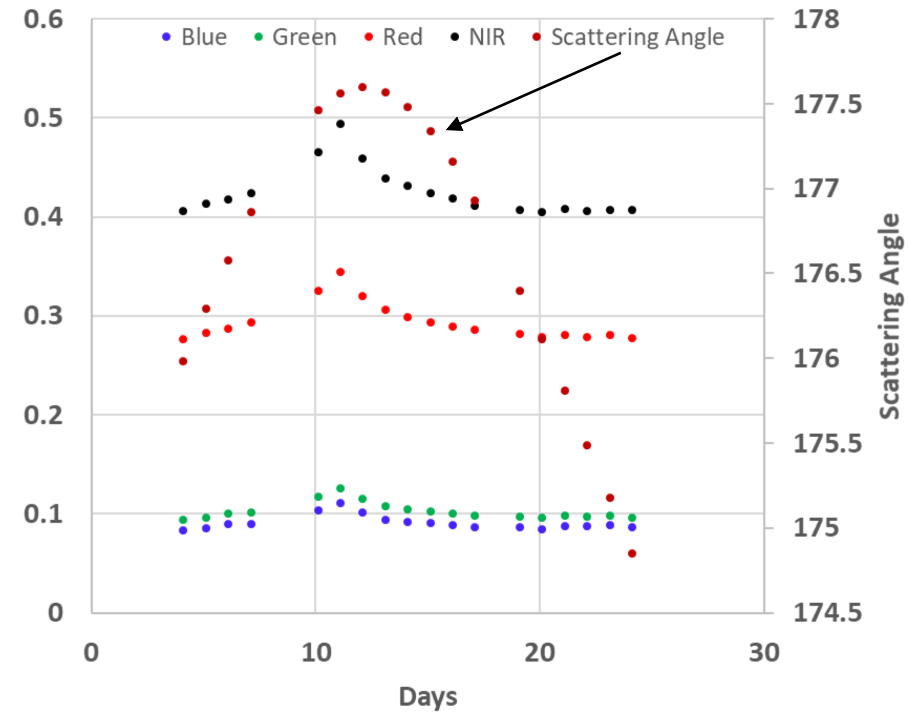
     Physical reason - different shadows at changing SZA, while shadows are the same at fixed SZA and changing VZA (LEOs);
   - *RTLS model does not work for the whole range of SZA. In MAIAC, it is important to detect clouds, shadows and surface change. Perhaps, 2 models, μ_0 <60°, and ≥60°.*

2. ***Noise in AHI data** (in particular over ocean, when switching from NIR-based to 1.6um-based).*

3. ***BRDF – Hot Spot – Artificial Diurnal Cycle***

BRDF and Hot-Spot from AHI-8

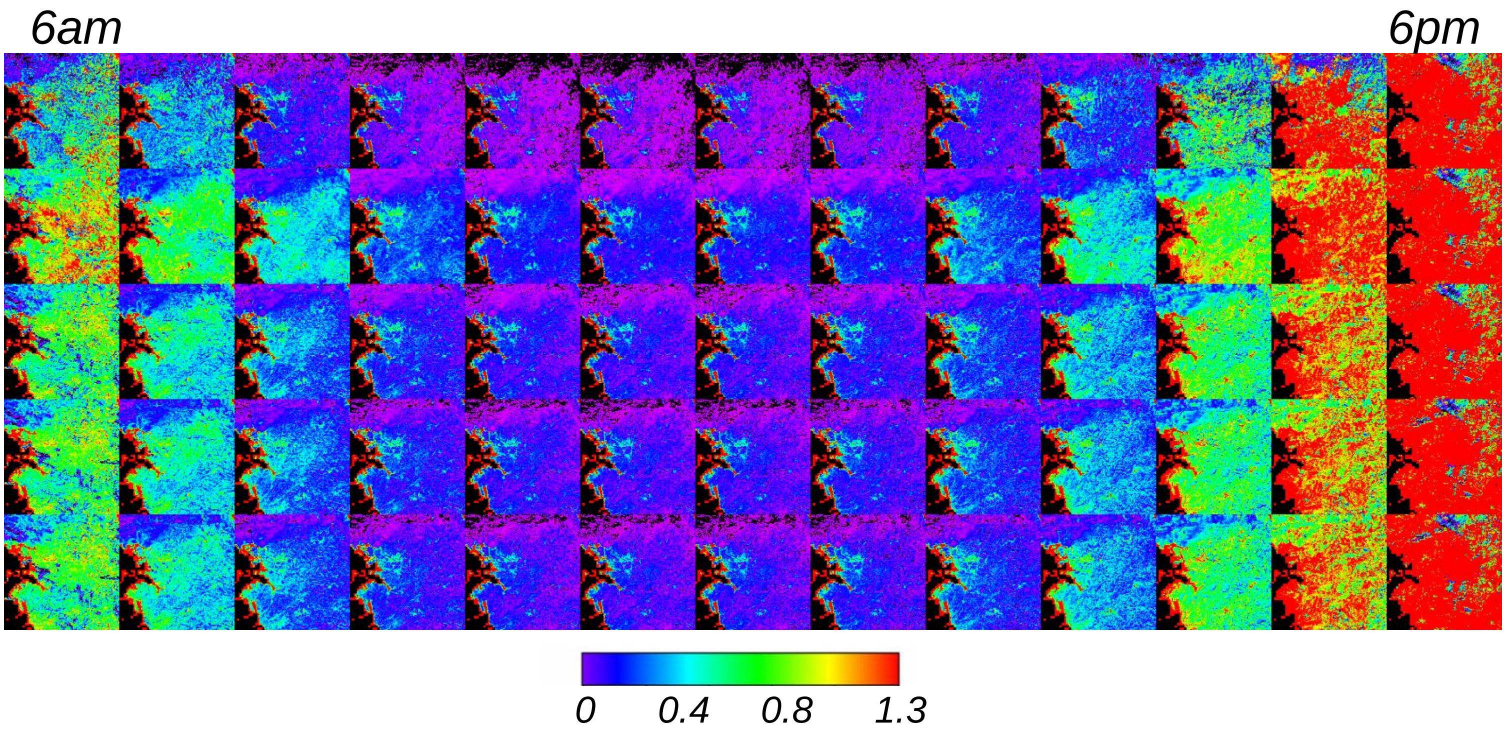




1. *High quality; well-reproducible daily BRDF pattern;*
2. *Hot-spot: dramatic, ~20% increase in reflectance for 2° change in scattering angle*
3. *Every pixel goes through the HS in the course of the year*

Current Issues

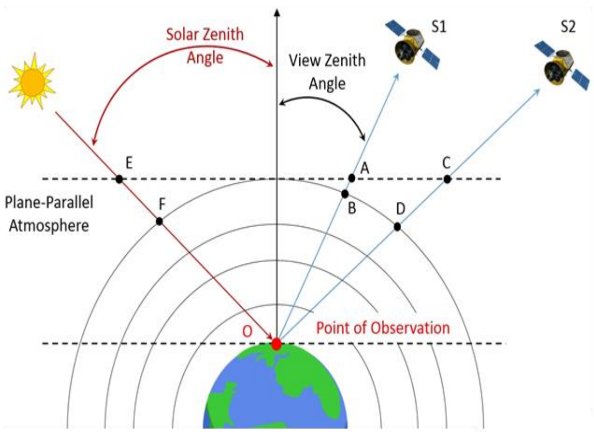
4. ***Distortions at high SZA*** *(>65-70°): underestimation of AOD → errors in AC*
    - *Tried pseudo-spherical RT – does not work*
    - *Tried fully anisotropic RT for SRC and aerosol retrievals – does not work;*
    - *SRC=$\rho_{0.47}/\rho_{2.25}$ >1 in low and high bins which does not happen over land. For reasonable results, limit SRC to 0.9 (artificial solution).*

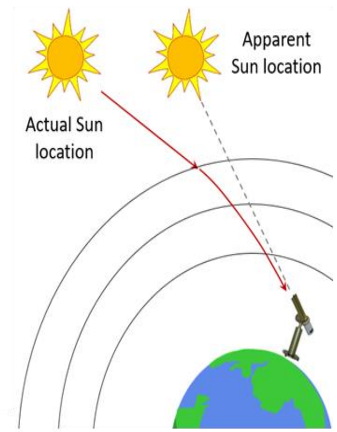


SRC in 13 hourly bins for the Seoul area 250×250km^2 (April-May)

II vs O Difference: 2 Main Reasons

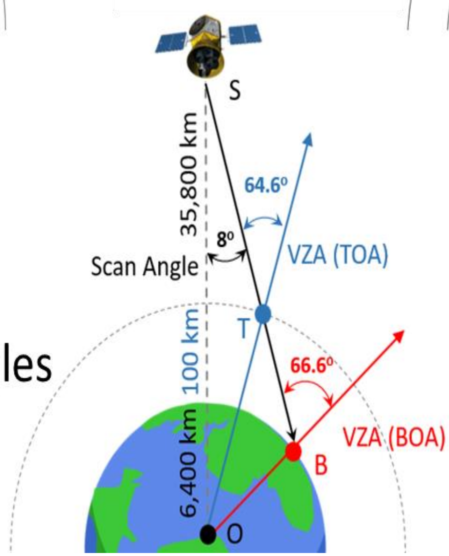
1. Difference in view (AB vs CD) and solar (EF) paths: $\exp(-\tau/\mu_0) \rightarrow \exp(-ChF) = \exp(-\sum \tau^{(i)}/\mu^{(i)}_0)$

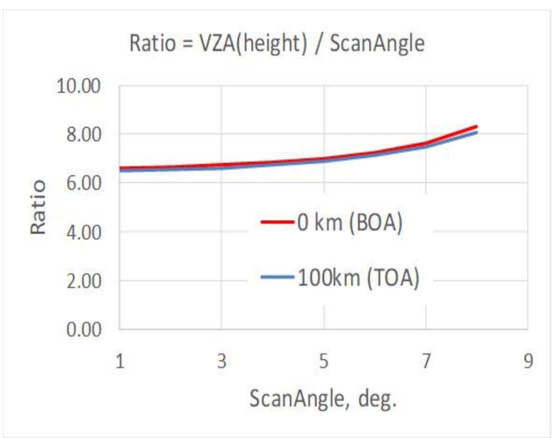




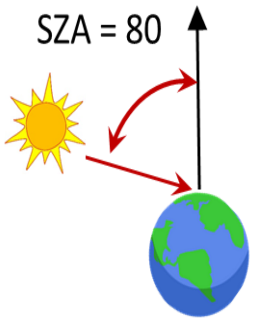
Chapman function:
Dahlback and Stmanes, 1991:
Planet. Space. Sci, 39(5), App. A

2. Difference in solar & view zenith angles

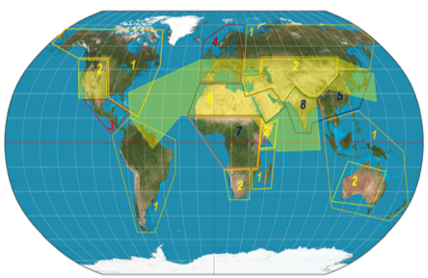




Plane-Parallel vs Spherical: Simulations

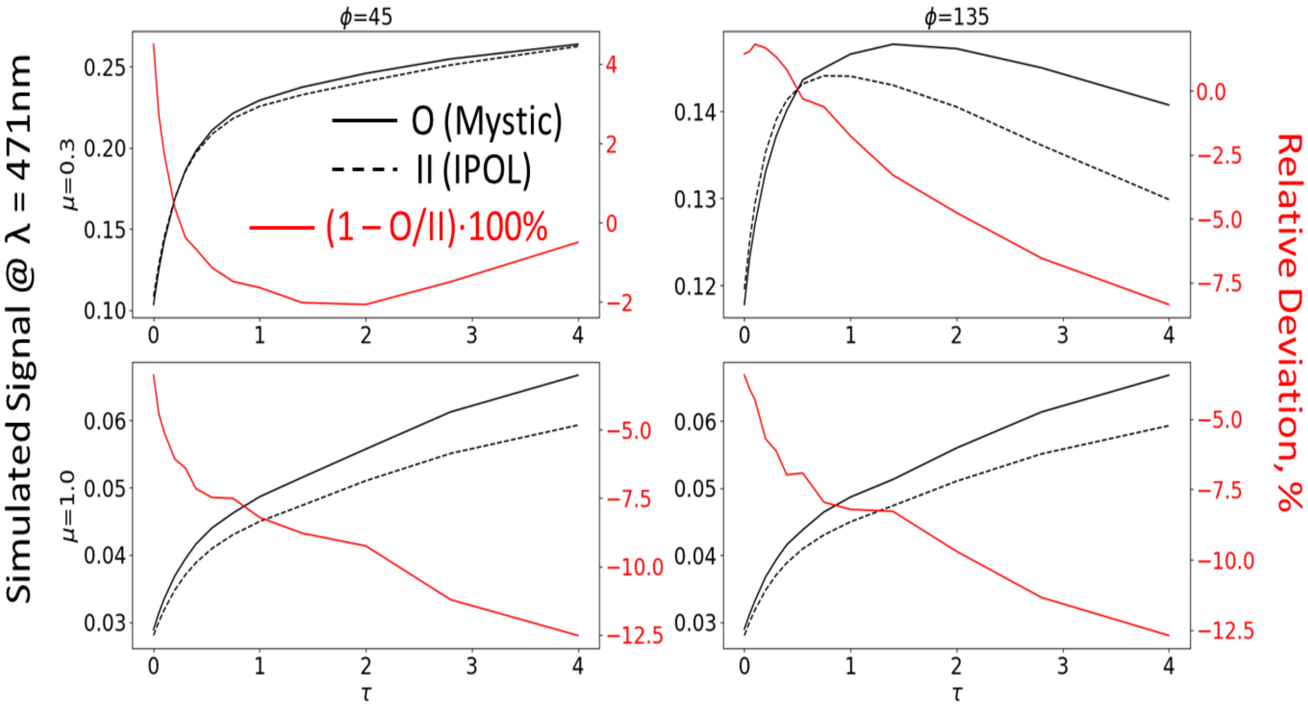


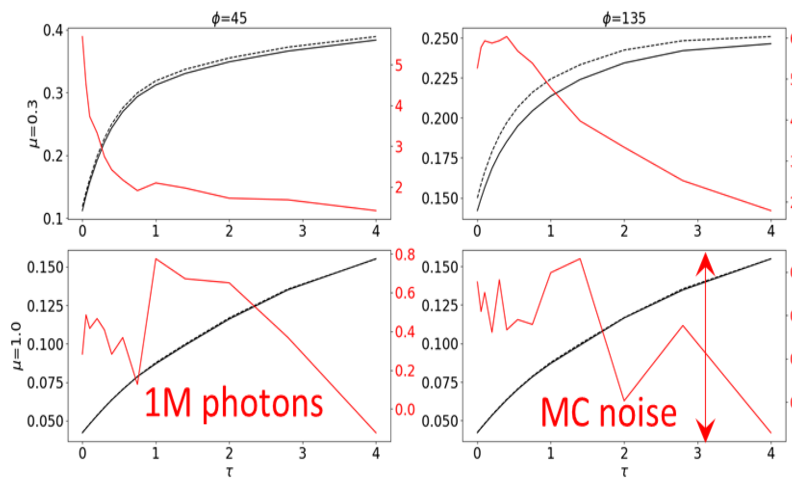
MAIAC aerosol model 1:

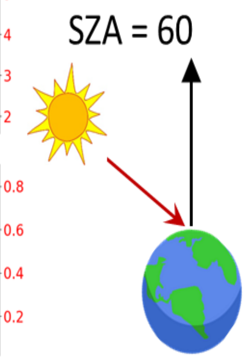


Spherical Solution: MC RT code Mystic (*B. Mayer, C. Emde et al.*) from libRadtran

www.libradtran.org

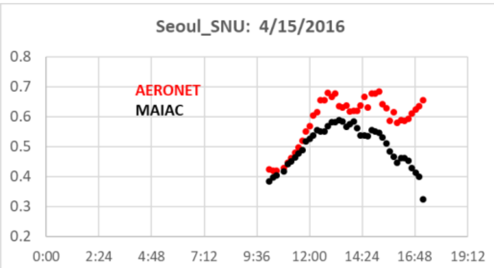


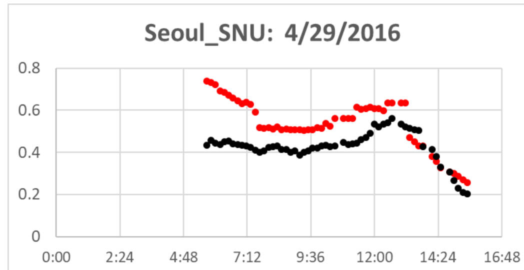


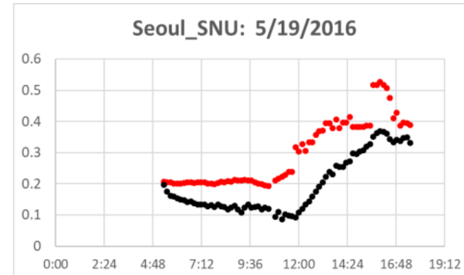


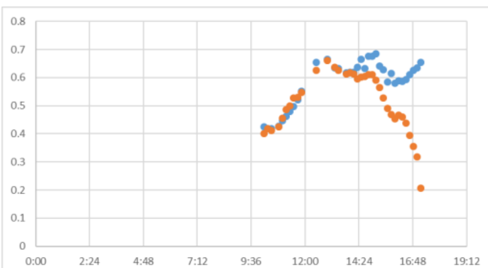
Diurnal Cycle

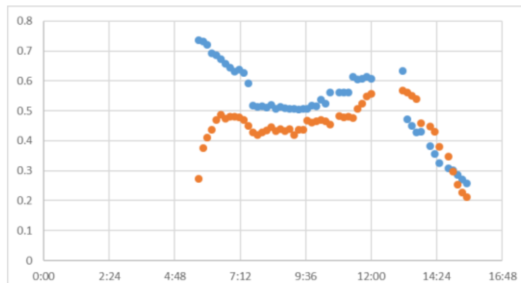
Using Spherical Model

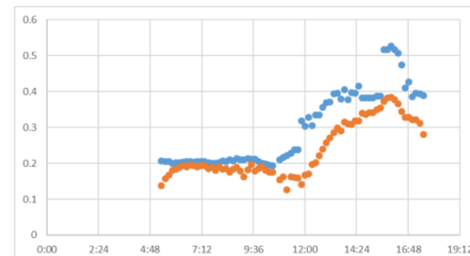


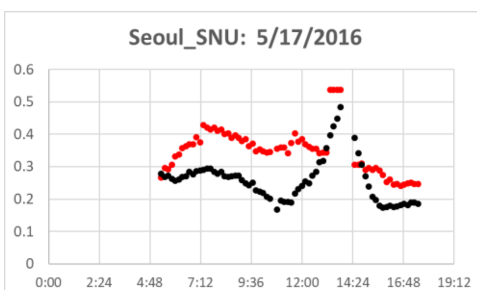


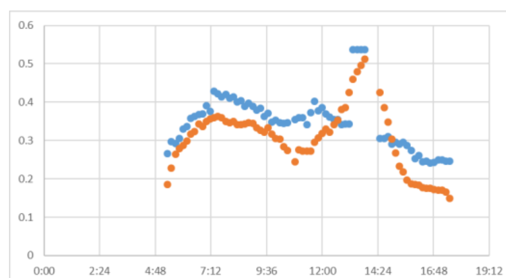












Conclusions

1. *Currently, MAIAC is ~70% adapted for AHI-8 HIMAWARI;*

2. *Correlation with AERONET is good,* $R^2>0.8$*;*

3. *Reproduce the AERONET diurnal pattern with some exceptions;*

4. *Geostationary helps distinguish local sources vs long-range transport;*

5. *Issues to be addressed:*
   - *Dust Detection;*
   - *CM & snow detection optimization;*
   - *Systematic low biases in both AOD and SR at cSZA<0.4*