Advanced Aerosol Retrieval and Atmospheric Correction in v2/2.1 MAIAC EPIC Algorithm

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DSCOVR STM

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Overview

- ***MAIAC v2/2.1 includes****:*

  i) standard processing (aerosol retrieval with climatological regional aerosol models and atmospheric correction),

  ii) advanced aerosol retrieval and speciation algorithm

- ***MAIAC v2.1 re-processing 2015 – 2019 … two more days***
- ***Reported products (standard algorithm):***
  - *CM, QA, $AOD_{0.44}$, spectral BRF, and BRDF model parameters over land;*
  - *AOD-FMF, water leaving reflectance over ocean;*
- ***Reported products (advanced retrievals based on UV-Vis):***
  - *AOD, refIM(λ), SSA (for H^{a}=1km and 4km)*
  - *Speciation information on main absorbers for smoke (Bc/BrC) and dust (Hematite/Goethite)*

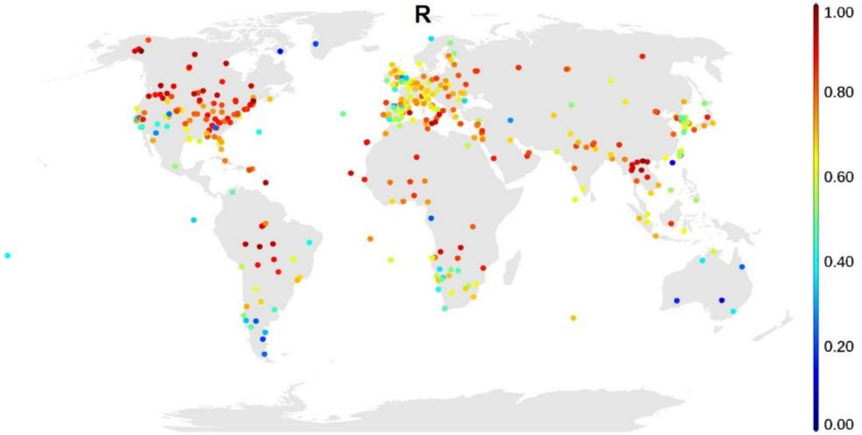
1. Lyapustin A, Wang Y, Go S, Choi M, Korkin S, Huang D, Knyazikhin Y, Blank K and Marshak A (2021) Atmospheric Correction of DSCOVR EPIC: Version 2 MAIAC Algorithm. Front. Remote Sens. 2:748362. doi: 10.3389/frsen.2021.748362.

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.

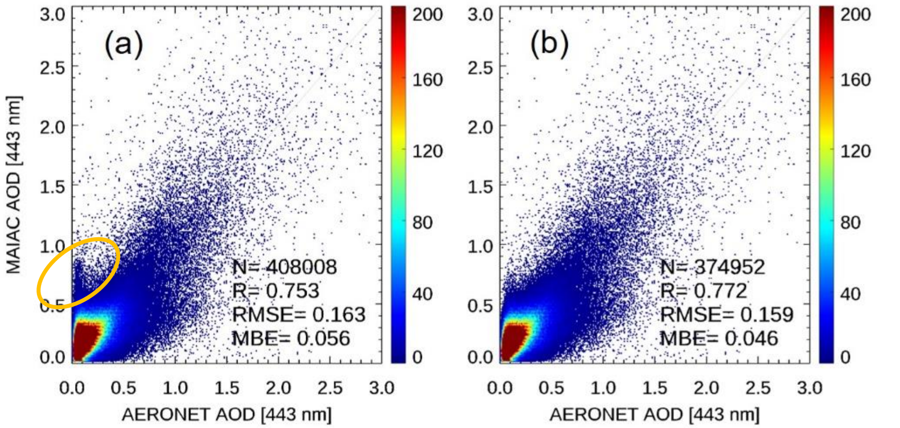
3. Go, S., Lyapustin, A., Schuster, G. L., Choi, M., Ginoux, P., Chin, M., Kalashnikova, O., Dubovik, O., Kim, J., Silva, A. D., Holben, B., and Reid, J. S.: Inferring iron oxides species content in atmospheric mineral dust from DSCOVR EPIC observations, Atmos. Chem. Phys. Discuss. https://doi.org/10.5194/acp-2021-599, in review, 2021.

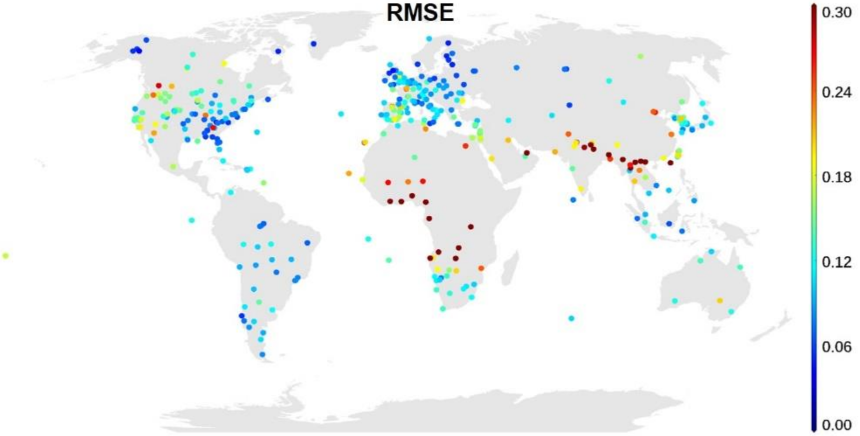
4. Choi, M., A. Lyapustin, G. Schuster, S. Go, et al. Retrieval of BC and BrC smoke aerosol components from DSCOVR EPIC, Atmos. Chem. Phys. (to be submitted, 2021).

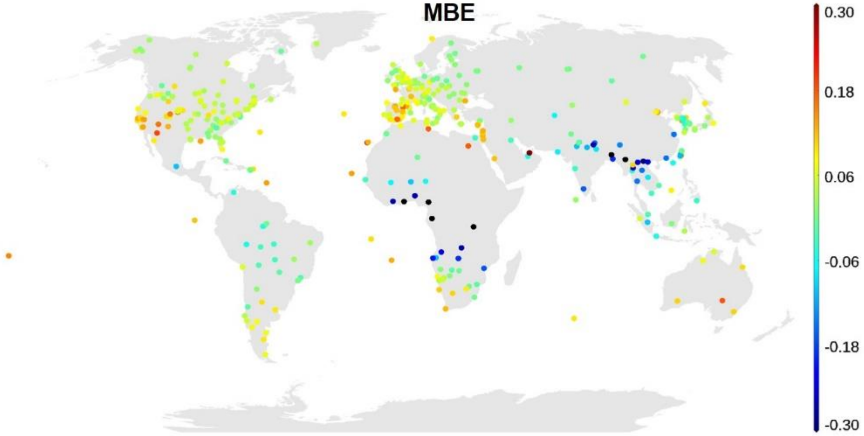
MAIAC v2: Aerosol Retrieval (standard)



All AERONET sites ***12 Bright Sites Excluded***



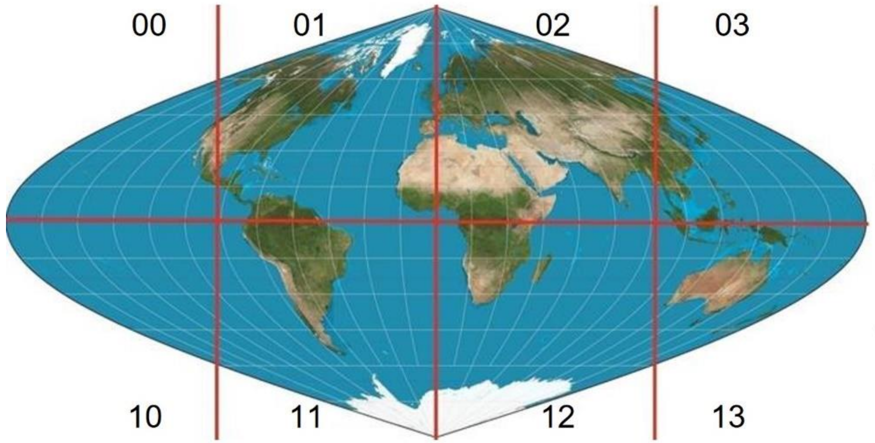




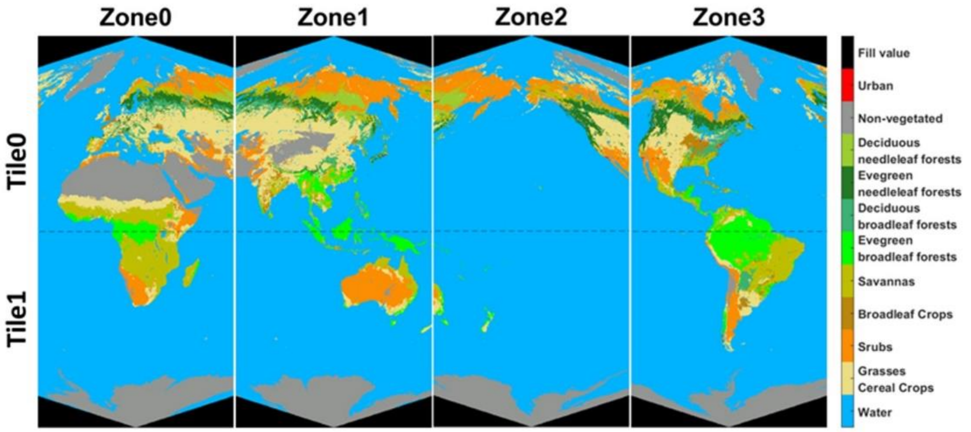
MAIAC	EPIC v1	EPIC v2	MODIS (1km)
R	0.69	0.77	0.82
RMSE	0.17	0.159	0.12
Bias	0.03	0.046	0.01

v2 is a significant improvement over v1, approaching MAIAC MODIS.

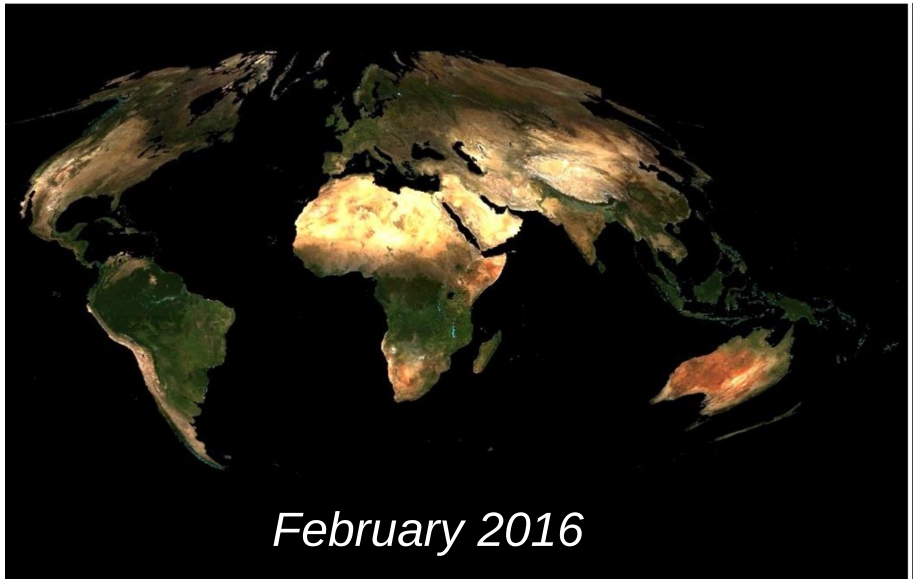
MAIAC v2/2.1: Atmospheric Correction

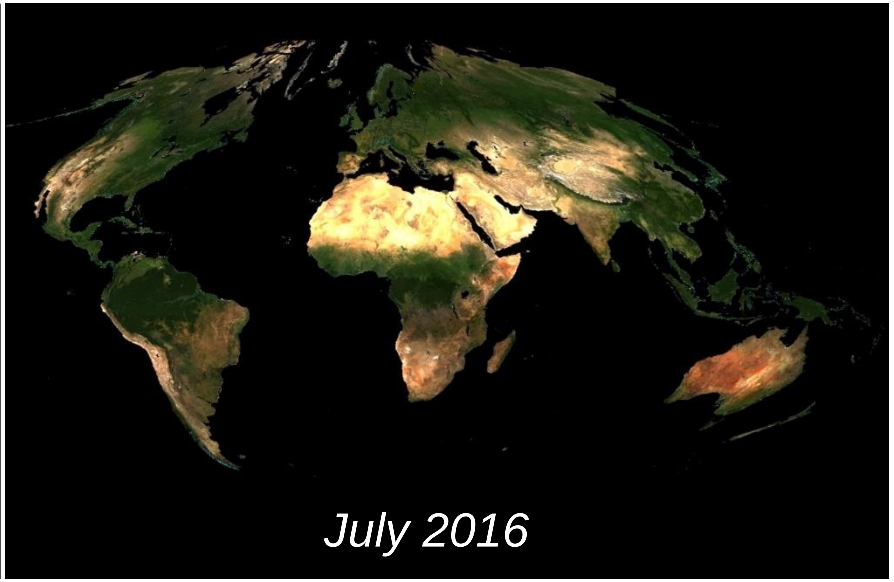


v1: Global Sinusoidal Projection



v2: Rotated Sinusoidal Projection


February 2016


July 2016

Ancillary: Monthly average surface BRDF in RGB and NIR from MAIAC MODIS MCD19A3 product

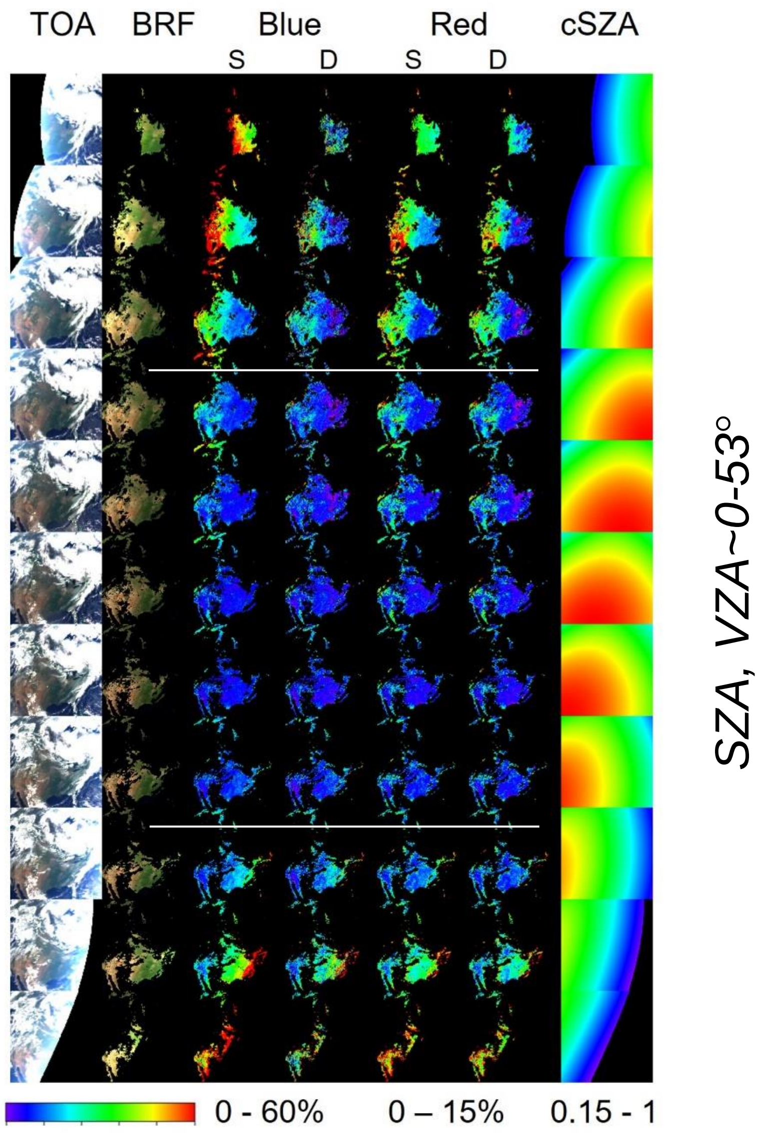
v2/2.1 - Atmospheric Correction

- *Because MODIS and EPIC view geometries are very different, the use of ancillary MODIS BRDF for EPIC AC requires investigation.*
- *We analyzed and compared:*
  - ***Lambertian** (underestimates BRF)*
  - ***MAIAC Scaling Method (S)***
  - ***Method of separation of Direct and Diffuse Reflectance (D)***
- ***S-method**: Ratio=BRF/Lamb is too high at high SZA (over 80-100%)*
- ***D-method**: more constrained, and Ratio nearly constant at SZA~ 0-53°.*
- Selected ***Hybrid method*** for AC:
  - characterize ***Anisotropic Conversion Factor(ACF)***

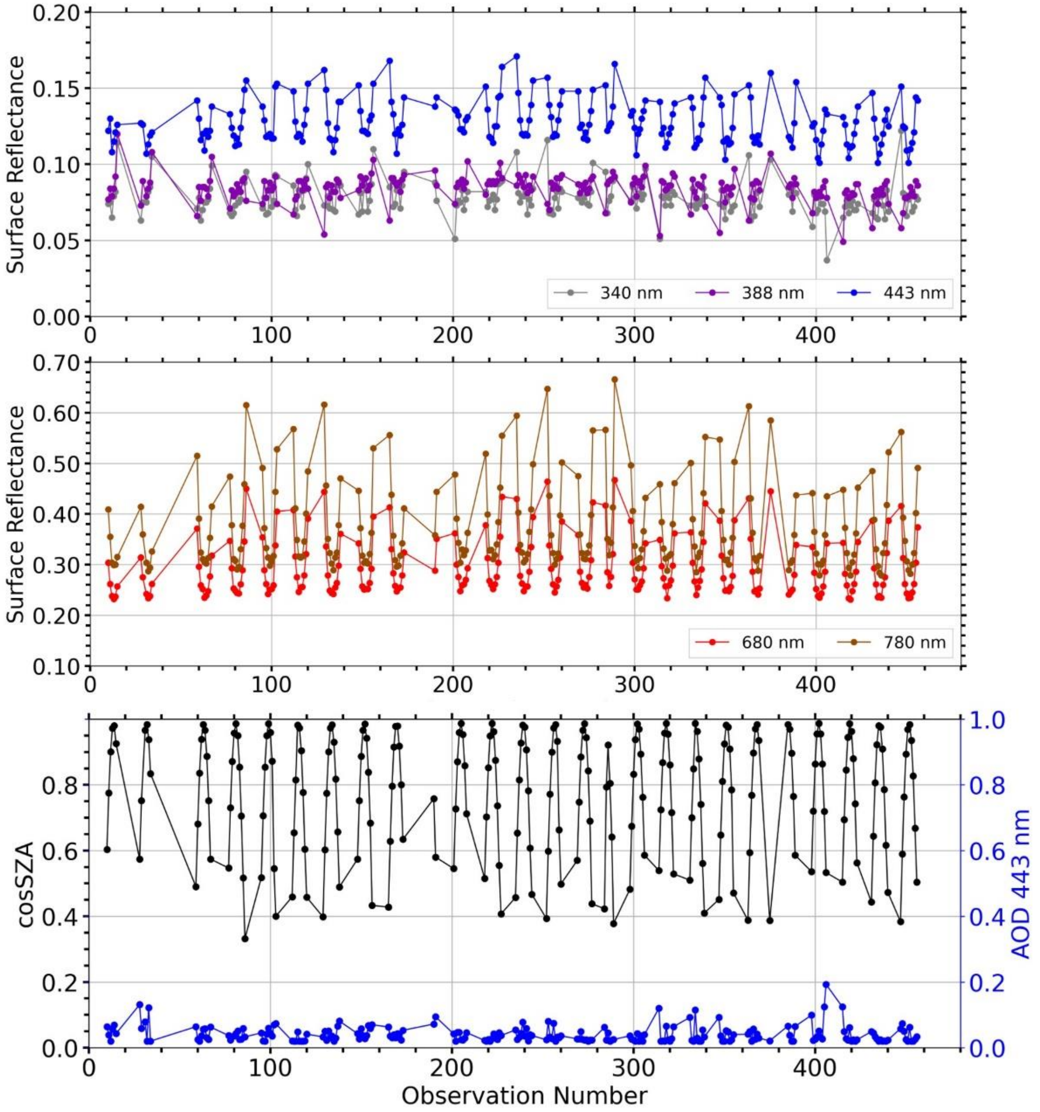
    ACF=BRF/Lamb

    from EPIC's observations near local noon;
  - Compute Lamb reflectance factor;
  - Compute BRF=ACF × Lamb.
- ACF – 1 is: 1-2% in NIR, and 8-15% in Blue
- We plan more analysis using geostationary data

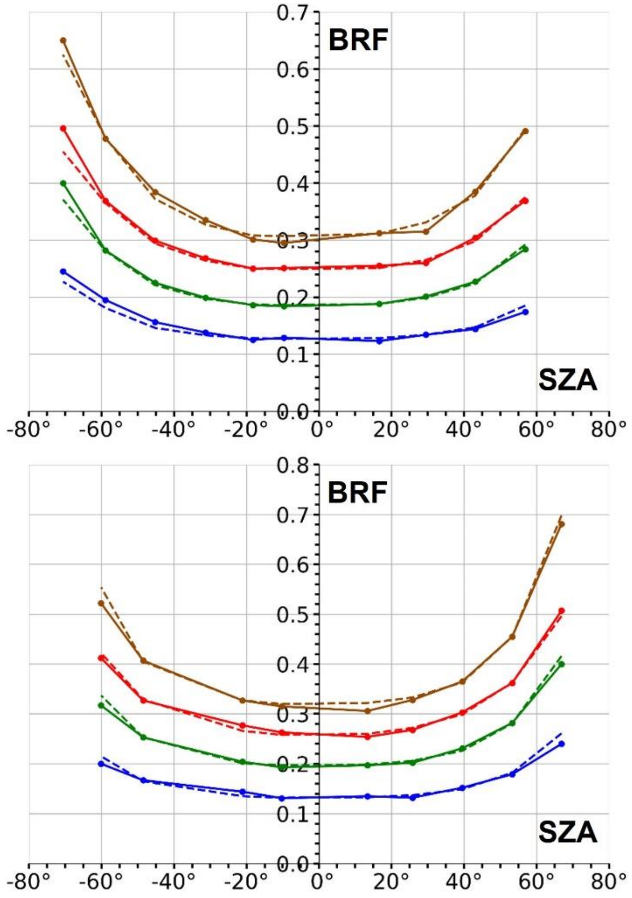
Anisotropic vs Lambertian: Relative Difference (June 3, 2018)



v2/2.1: Example of Atmospheric Correction



Time series of EPIC's SR over the bright pixel in Arizona, USA, in June – early July of 2020.



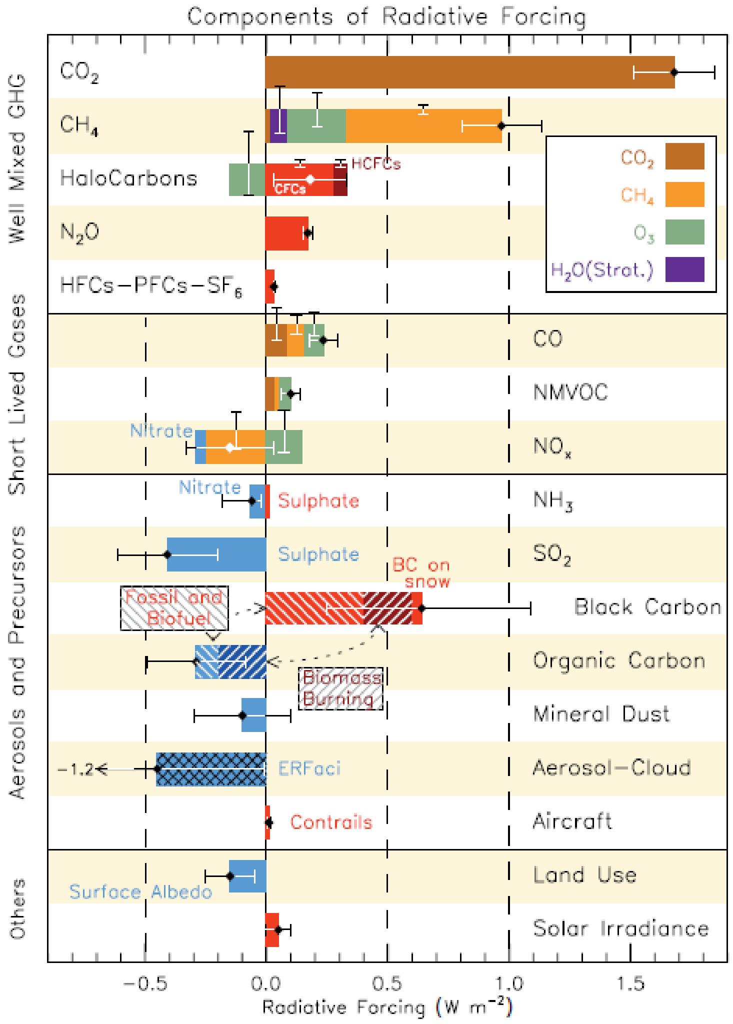
Retrieved BRF (dots connected by solid lines) and the best-fit BRDF model (dashed lines) for 2 different days

Advanced Aerosol Retrievals:

- AOD and Spectral Absorption

- Aerosol Speciation (next talk)

Aerosol Absorption

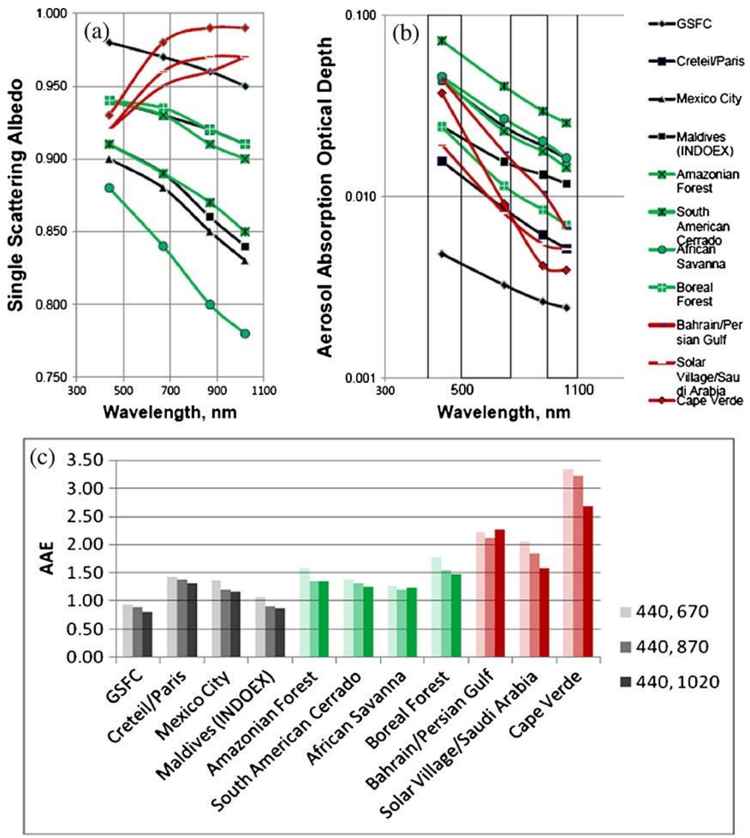


from IPCC AR5

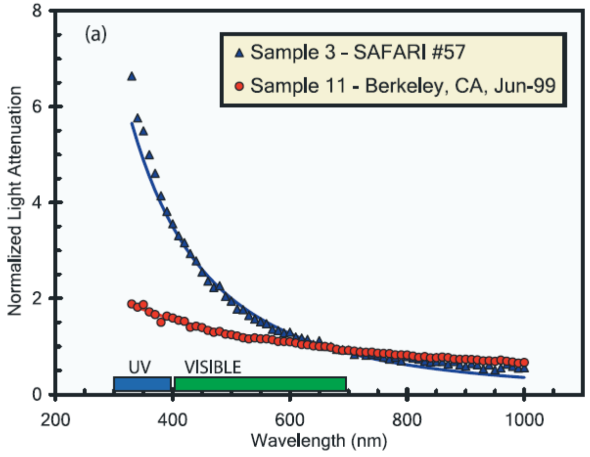
- *Aerosol absorption is a very important property for both direct and indirect (semidirect) aerosol effects. Absorbing aerosols have the largest associated uncertainty in climate projections (IPCC 2013).*
- *Knowledge of spectral aerosol absorption is a path to aerosol speciation. For instance, black-organic carbon partitioning for smoke is an essential information for the climate/RB models and for the air quality – epidemiology (health associations) studies.*
- *Composition analysis of aerosol particles and investigation of toxicity and adverse health effects of different components is a central goal of the future NASA MAIA (Multi-Angle Imager for Aerosols) mission (Diner et al., 2018).*
- *Absorption from Current/Future Satellites*
  - *OMAERUV Algorithm on Aura/OMI, DSCOVR EPIC, OMPS on SNPP, S5p/TropOMI (Torres et al., 2020) and GEMS (Kim et al., 2020);*
  - *MISR (+ AOD, size, shape)* (*Kahn et al., 2010; Kahn and Gaitley, 2015*);
  - *MODIS/VIIRS DB (Hsu et al., 2013) provides AOD and SSA;*
  - *GRASP from POLDER (e.g., Dubovik et al., 2011; Chen et al., 2020*);
  - *Expected multi-angle spectro-polarimetry (MAIA; EUMETSAT EPS-SG/3MI; PACE SPEXone and HARP2 etc.*);

UV Aerosol Absorption

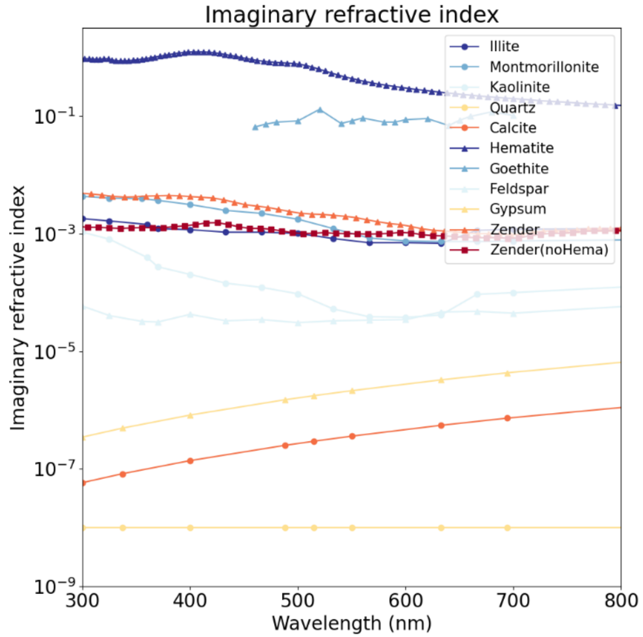
- *TOMS, OMI were the first instruments providing initially qualitative (AI) and later quantitative (SSA) information on aerosol absorption from pioneering works of Torres et al (Herman et al., 1997; Torres et al., 1998, 2002, 2018; Jethva et al., 2014). UV channels are key.*
- *The baseline OMAERUV algorithm (Torres et al., 2007) retrieves AOD-SSA from 2 channels 354-388nm* ***assuming spectral dependence of absorption****. Because of aerosol height sensitivity, it is reported for several heights (0, 1.5, 3, 6, 10 km). Later versions use ancillary information on spectral absorption (AERONET) and regional-seasonal height (CALIOP CALLIPSO) (Torres et al., 2013).*



Russell et al., 2014, JGR, 119, *doi:10.1002/2013JD021411*



Kirchstetter, Novakov, JGR, 2004

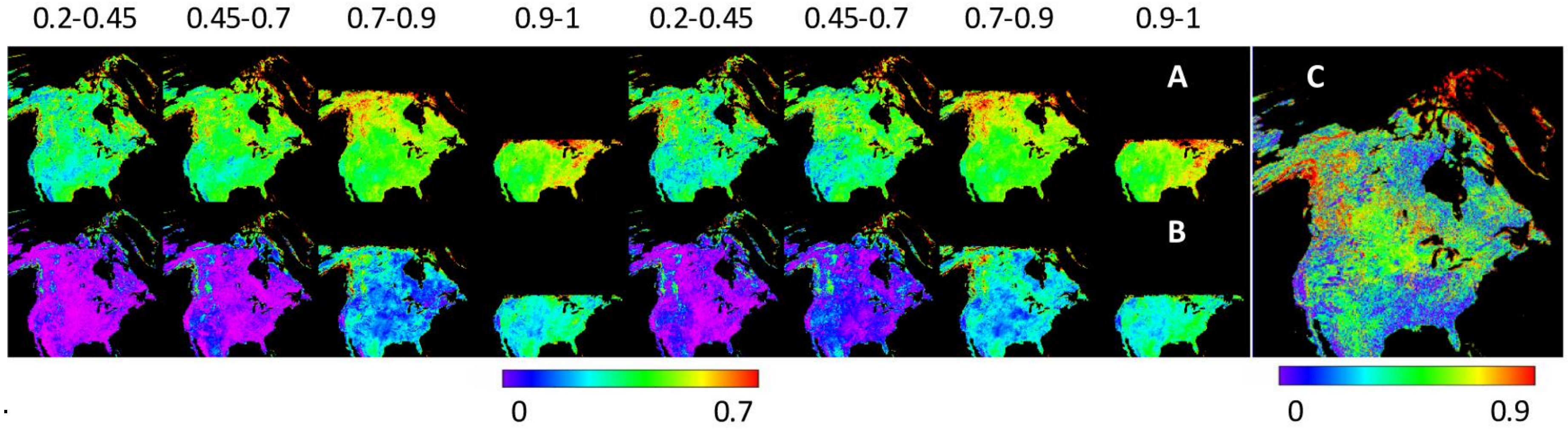


Scanza et al., 2015

Eck et al., JGR, 2013 – Increase of SSA through the dry season (July to Nov) in Southern Africa

MAIAC EPIC AOD – refIM Algorithm

- Minimum Reflectance Method to characterize spectral SR ratio at 340, 388, 443 and 680nm in 4 SZA bins



Example for NA:
(A) 443/680
(B) 388/680
(C) 340/388

- Absorption model: $k_\lambda = k_0 (\lambda/\lambda_0)^{-b}$ for $\lambda < \lambda_0$, where λ_0 = 680nm
  (*in the limit of small particles, AAE~b+1, where Absorption Ångström Exponent AAE is defined for the AAOD*).

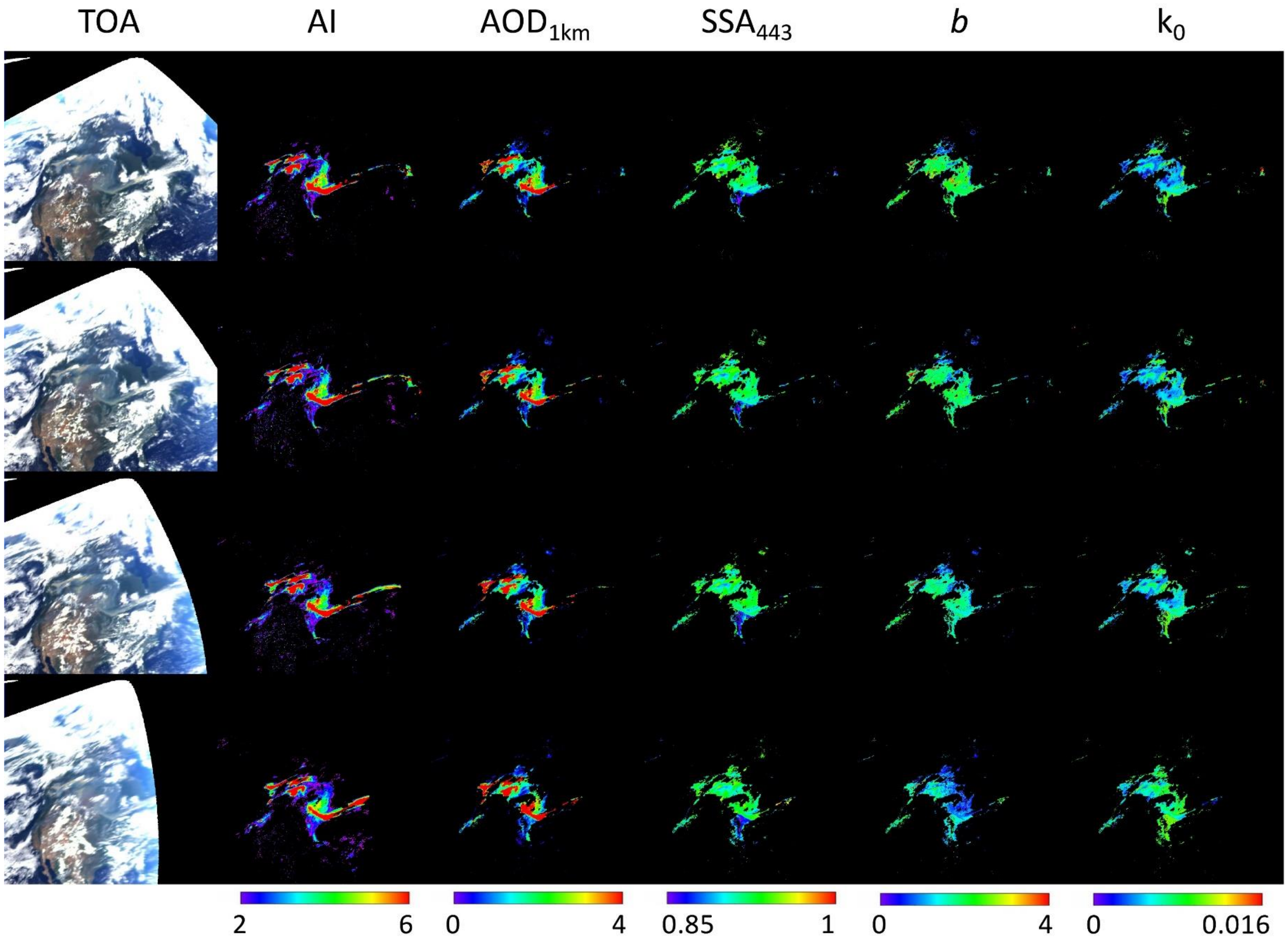
- Real *refIM* and size distribution are fixed. The results are reported for H^a=1 and 4km for smoke and dust.

- AOD-k_0-b retrieval using ***Levenberg-Marquart optimal fit*** of 340, 388, 443 and 680nm:

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

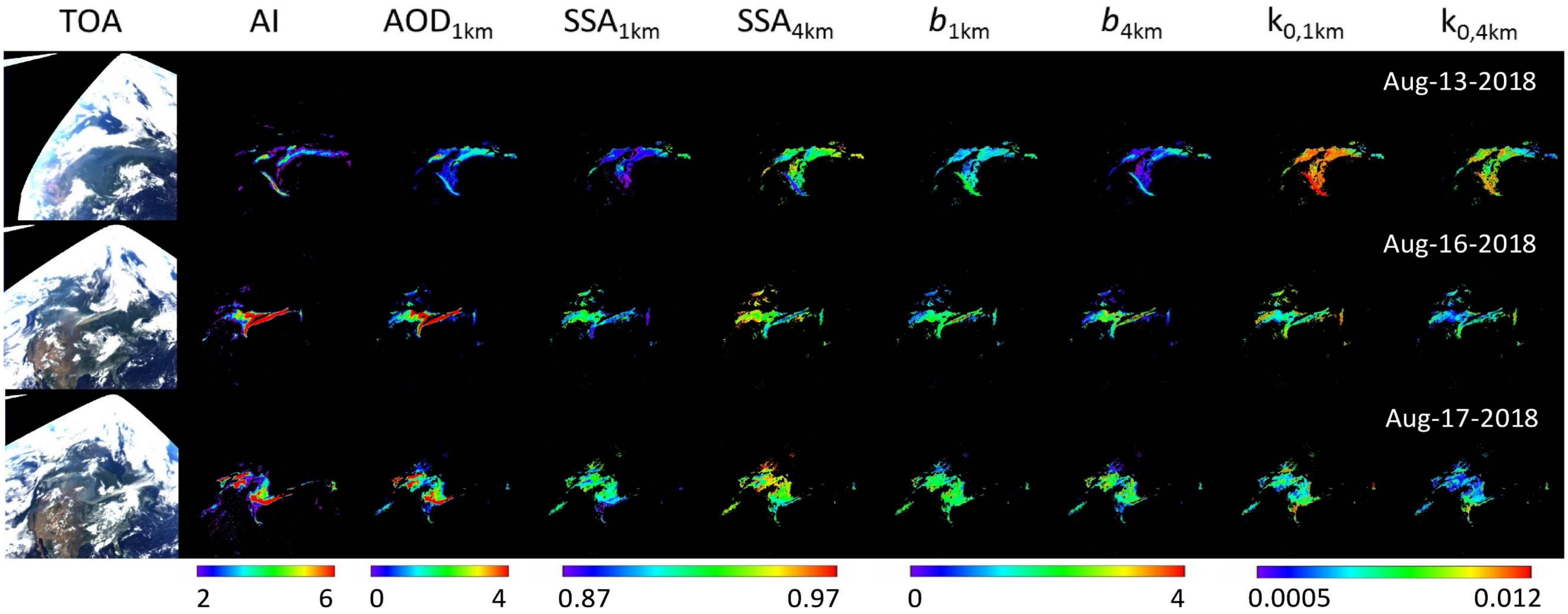
- LUT-based retrievals on a 4x4 matrix of b={0.1, 1.5, 3, 4} and k_0 ={0.001, 0.006, 0.011, 0.016} - smoke
  {0.0006, 0.0014, 0.0022, 0.003} - dust.

Retrieval Example (August 17, 2018) for H^a=1km



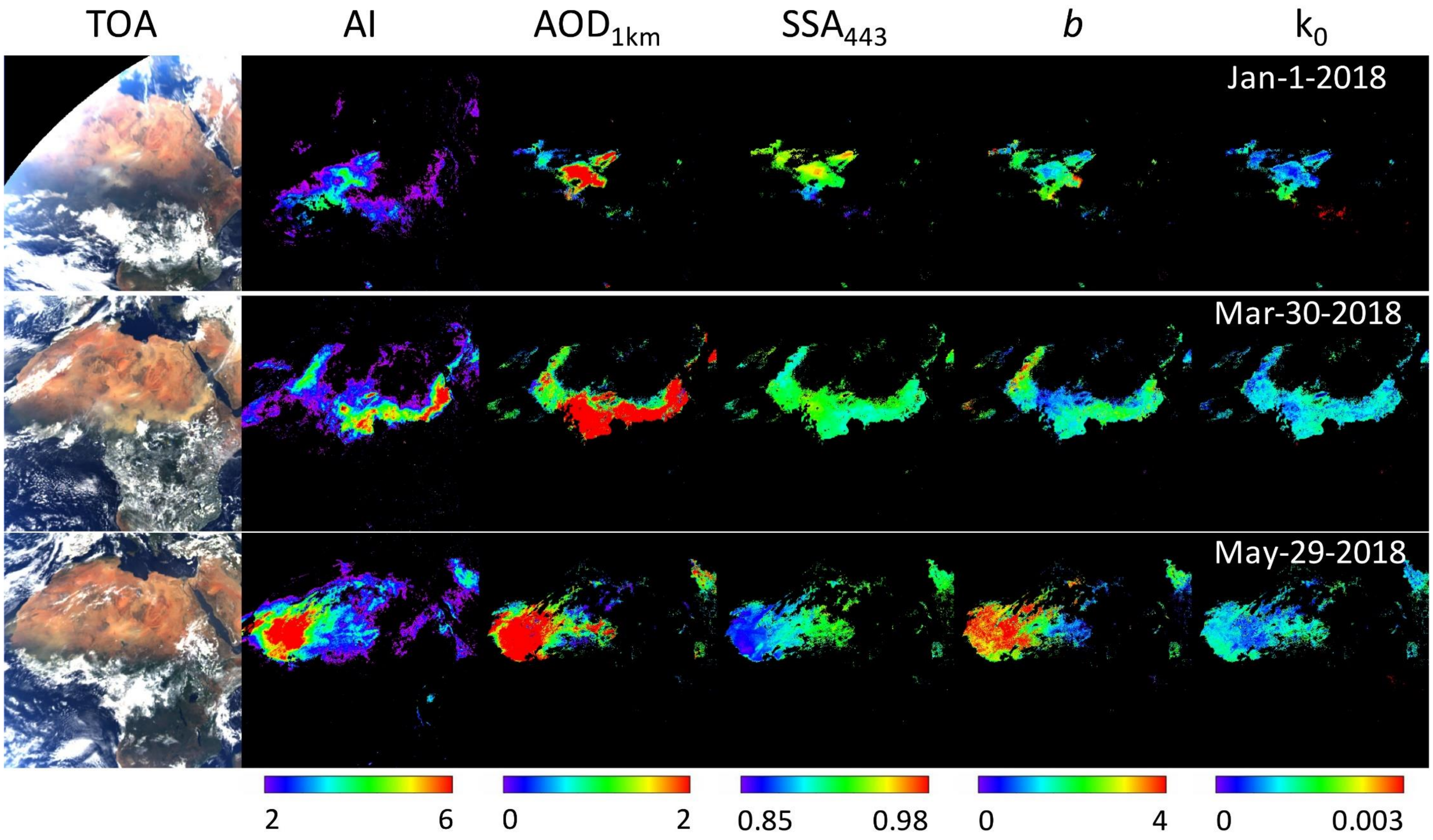
Good stability of retrievals vs SZA

Effect of Aerosol Height (H^a=1km vs 4km)



1. Retrieved aerosol absorption is lower for elevated aerosols (as it should be).
2. Knowledge of height is important for interpretation: an apparent increase of SAE (b) and decrease of refIM (k_0) for elevated layer would point to more organic carbon and less black carbon in aerosol particles and vv.

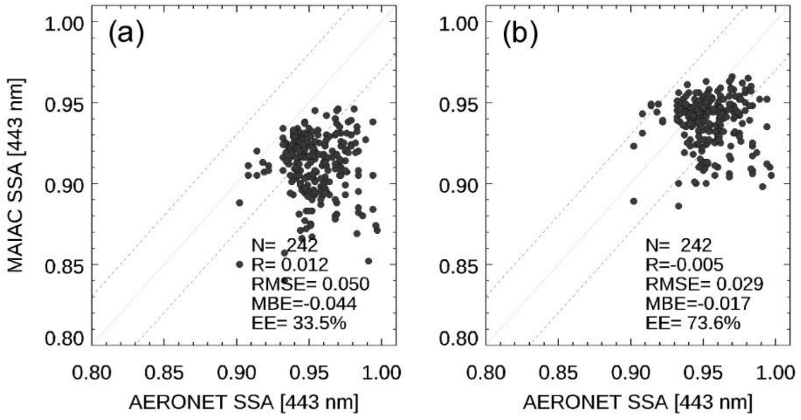
Mineral Dust: Different Sources - Different Absorption



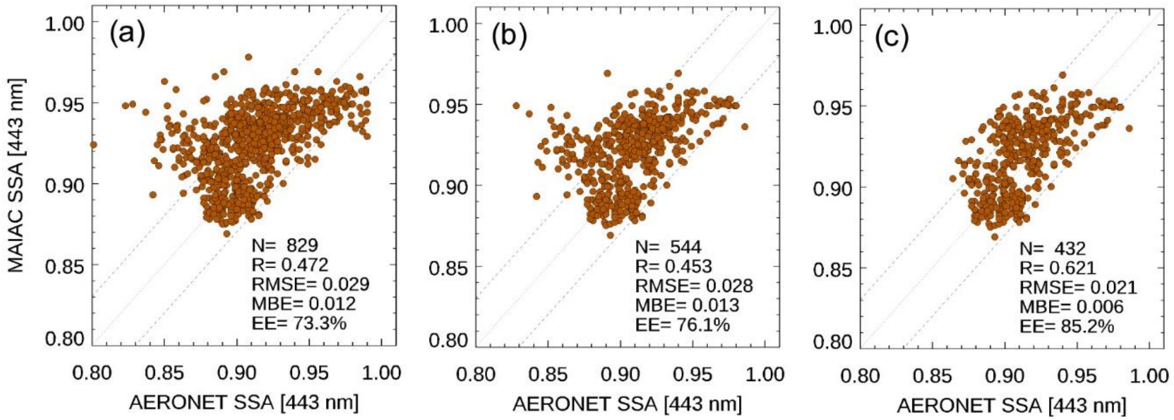
Summary SSA_{443} Validation: 2018

North America Smoke

H^a=1km H^a=4km



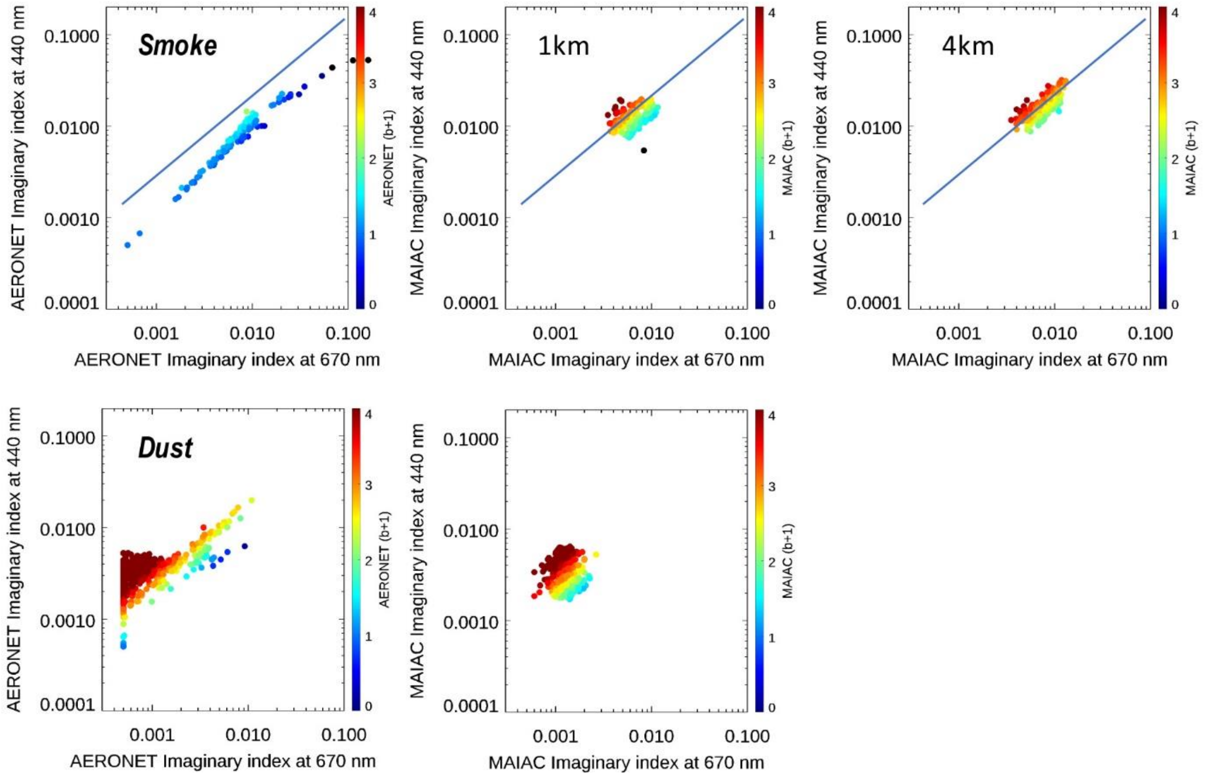
Dust: North Africa/Middle East



(A,B) 17 sites, AERONET AOD_{440} > 0.4 and > 0.6.
(C) 15 sites (AOD_{440} > 0.6), with Cairo_ENM_2 and Ilorin excluded.

Spectral Dependence of Absorption

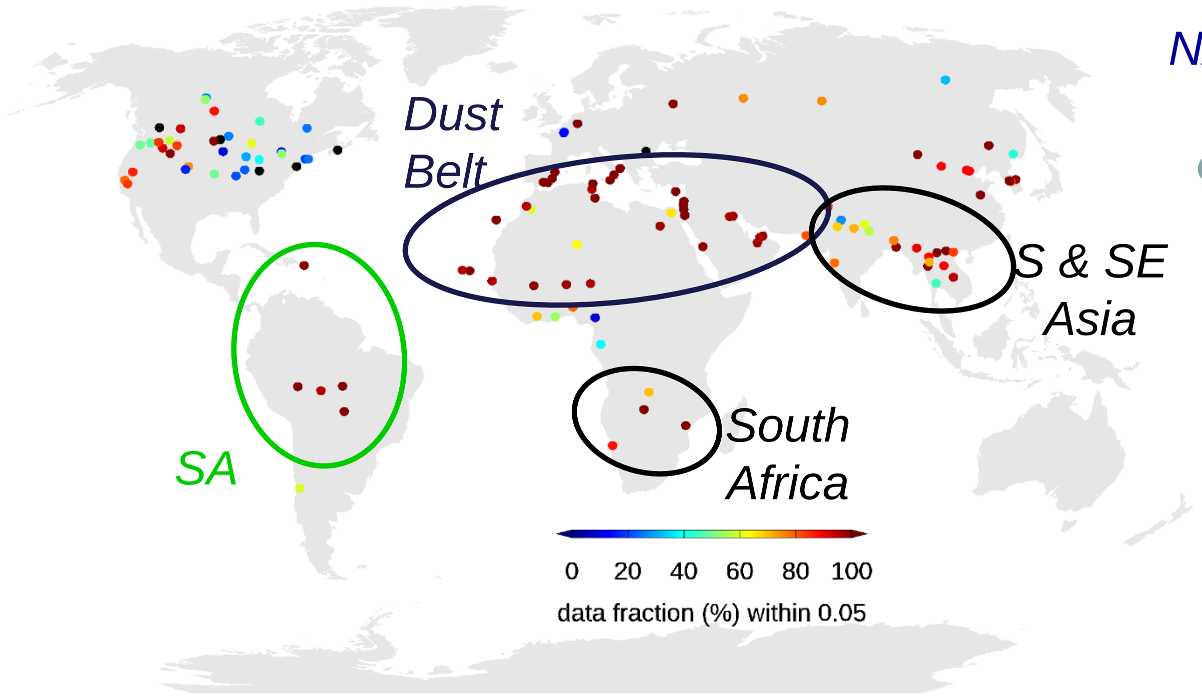
Following Figure 3 and Figure 4 of Schuster et al (2016)



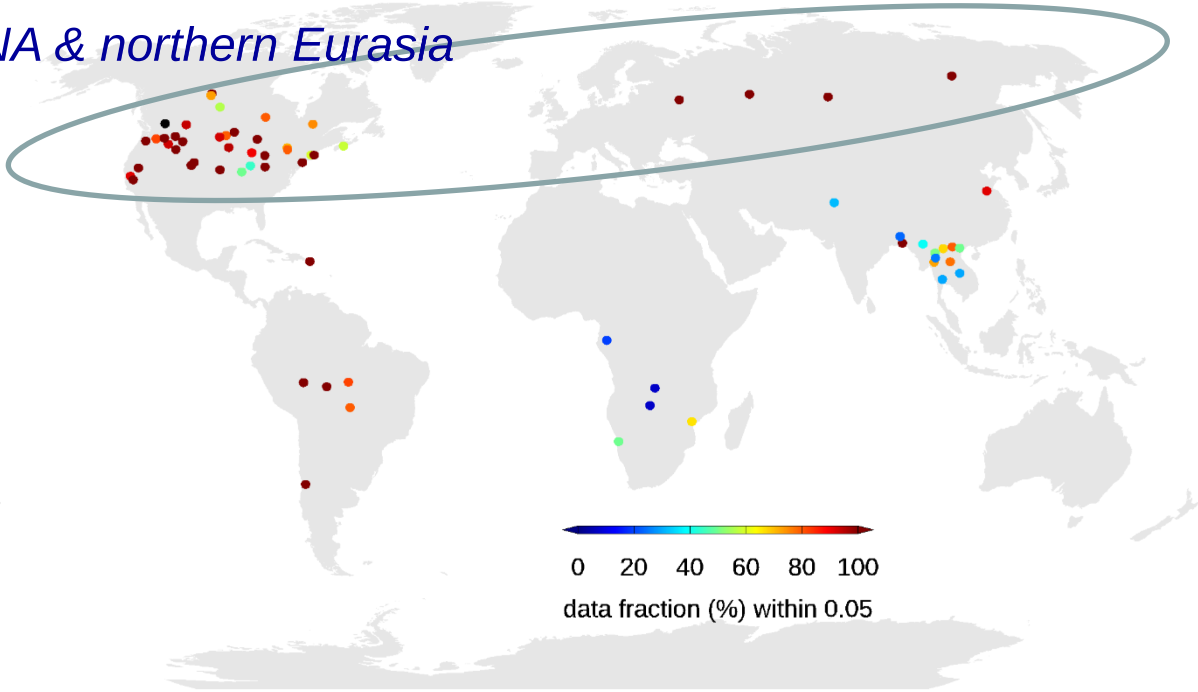
Smoke: MAIAC EPIC shows higher SAE (b) than AERONET *(expected from UV compared to AERONET's Blue-1020nm)*
Dust: EPIC and AERONET SAE are similar

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

H^a= 1km (smoke, <u>dust</u>)



H^a = 4km (smoke only)



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)*

Conclusions

- ***MAIAC v2/2.1 features:***
  - *Improved aerosol retrievals vis-a-vis v1*
  - *Anisotropic atmospheric correction which is important in the EPIC's backscattering sun-view geometry;*
  - *New joint retrieval of AOD and spectral absorption*
  - *Good SSA accuracy, e.g. R~0.62, rmse~0.02, bias ~0.006 for dust and rmse~0.029, EE=73.6% for smoke (AERONET SSA uncertainty ±0.03)*

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.

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- ***Next:***
  - *A clear need to simultaneously retrieve H^a using EPIC A,B – O2 bands*