UV-VIS Spectral Aerosol Absorption Models Derived from AERONET-OMI-MODIS Synergy and its Applications

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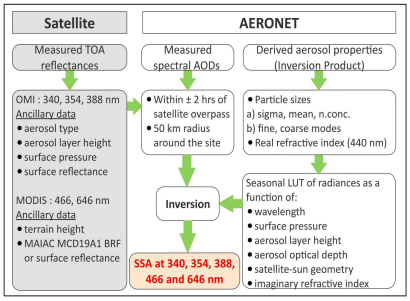
Highlights

- 12 years (2005 – 2016) of *satellite + ground* measurements are used in a synergy algorithm to independently derive aerosol spectral single scattering albedo at 340, 354, 388, 466 and 646 nm.
- For observations with $\tau_{440} \geqslant 0.4$, our theoretical estimates show that $\Delta\omega_o$ can be retrieved within the accuracy of ±0.03 at 340 nm due to errors in aerosol layer height and ±0.05 at 646 nm due to errors in surface characterization.
- Our analysis shows spectral dependence of aerosol absorption in the UV-VIS spectrum varies considerably for all aerosol types other than black carbon.
- **Dataset available at: Kayetha et al. 2022, AMT, https://doi.org/10.5194/amt-2021-8.**

Our approach

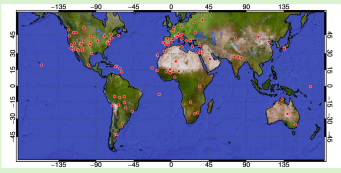
Explain satellite-measured TOA radiances(λ) by constraining the collocated ground measurements of $\tau_{ext}(\lambda)$ and derived columnar $\omega_o(\lambda)$ using RT.



Flowchart showing the methodology adopted in this work.

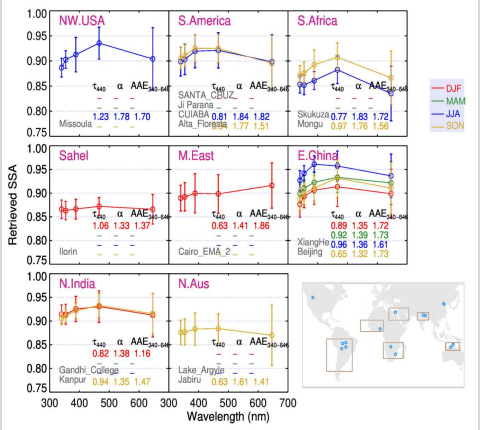
Methodology

- Developed seasonal LUT of radiances
  - Site-specific: *Spheres for fine-mode particles*
  - Dust Model: *Spheroidal distribution of coarse-mode aerosols.*
- Trace gas correction
  - Ozone – assumes 275 DU (static)
  - NO_2 – applied correction using spectral τ_{NO2} (Krotkov et al., 2005).
- Aerosol layer height: CALIPSO climatology.
- Aerosol type identification for analysis
  - Carbonaceous: $\alpha_{440\text{-}870} \geq 1.2$ and UVAI ≥ 0.8,
  - Dust: coarse mode ($\alpha_{440\text{-}870} < 0.2$),
  - Urban: $\alpha_{440\text{-}870} \geq 1.2$ and UVAI < 0.8.



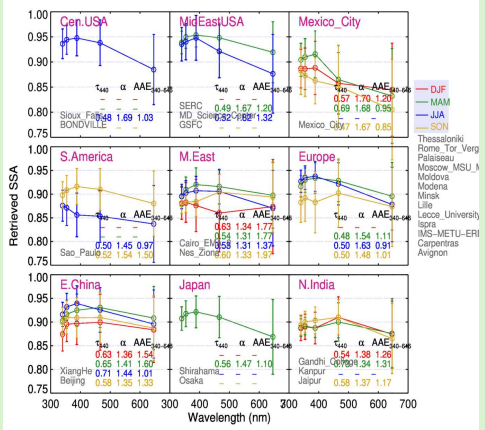
Geographical location of AERONET sites used in this work.

Carbonaceous



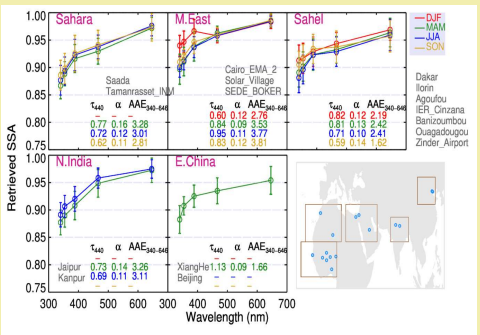
Seasonal average of SSA(λ) for carbonaceous type aerosols with $\tau_{440} \geq 0.4$.

Urban



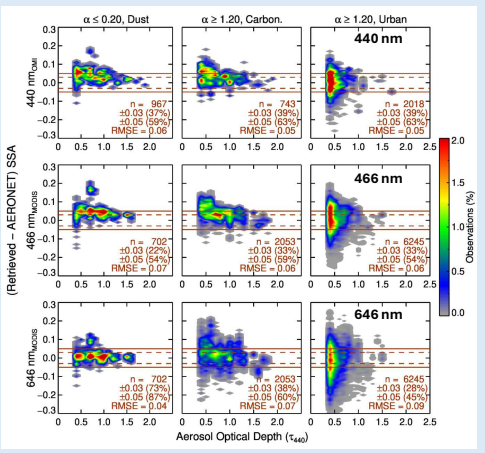
Seasonal average of SSA(λ) for urban type aerosols with $\tau_{440} \geq 0.4$.

Dust



Seasonal average of SSA(λ) for dust type aerosols with $\tau_{440} \geq 0.4$.

Retrieved SSA vs AERONET



- Coarse-mode SSA has better agreement then fine-mode.
- Spectrally, near-UV SSA has better agreement than Vis.
- Overall agreement: 38% and 62% observations within ±0.03 and ±0.05.

Theoretical Uncertainty in SSA Retrieval

	Input Uncertainty	Theoretical SSA Uncertainty ($\Delta\omega_0$) for τ_{440} = 0.4					
		λ = 340 nm			λ = 646 nm		
		Carb.	Dust	Urban	Carb.	Dust	Urban
Extinction AOD	λ < 400 nm, $\Delta\tau$ = ±0.02 λ > 400 nm, $\Delta\tau$ = ±0.01	0.002	0.001	0.002	0.009	0.007	0.011
Particle sizes	ΔVMR = ±20%	0.018	0.003	0.014	0.044	0.0006	0.040
Real part of RI.	ΔRRI = ±0.04	0.007	0.007	0.009	0.001	0.002	0.002
Calibration of TOA measurements	OMI = ±1.8% MODIS = ±1.9%	0.026	0.021	0.027	0.020	0.027	0.037
Surface reflectance	$\Delta\rho_{surf}$ = ±0.01	0.006	0.011	0.006	0.032	0.022	0.050
Aerosol layer hgt.	ΔALH = ±1 km	0.021	0.028	0.006	0.001	0.001	0.0006
Presence of cloud	τ_{cloud} = 0.5	0.016	0.020	0.017	0.042	0.041	0.056
Surface pressure	±12 mb/hPa	0.011	0.011	0.011	0.004	0.0004	0.006
Variability in AOD	λ < 400 nm, $\Delta\tau$ = ±0.2 λ > 400 nm, $\Delta\tau$ = ±0.1	0.022	0.014	0.012	0.006	0.001	0.053
O_3 absorption	±50 DU	0.003	0.005	0.003	0.008	0.007	0.011
NO_2 absorption	±1 DU	0.016	0.023	0.014	0.001	0.0007	0.001
Max. combined theoretical uncertainty		**0.051**	**0.047**	**0.043**	**0.073**	**0.055**	**0.108**

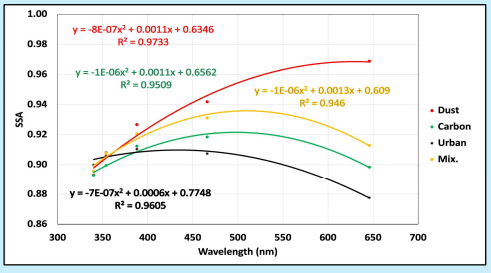
Our sensitivity tests indicate $\Delta\omega$ is:

- Spectrally dependent due to multiple-variables,
- Decreases with increasing AOD, and
- Varies with absorbing nature of aerosols.

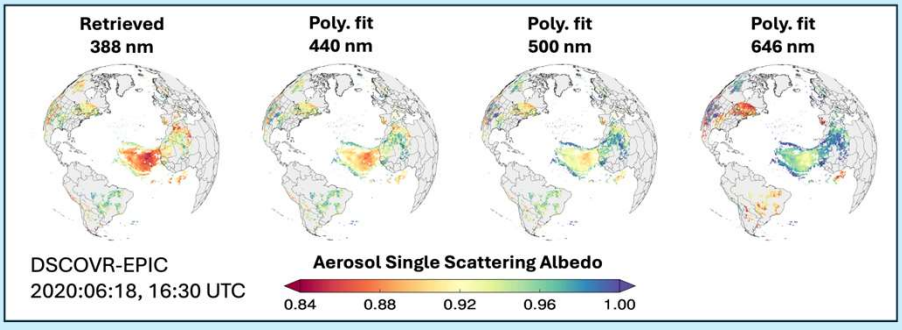
NOTE: For the scenarios where errors stemming from individual sources are in opposite direction, the overall error in derived SSA will be less than the max. combined error (shown in the Table).

Application: Extending the spectral domain of SSA reporting in UV Aerosol Products

Regional and seasonal absorption models derived here can be used in a polynomial fitting to derive spectral SSAs if any one reference wavelength SSA can be retrieved from the satellite measurements.



Polynomial fitting derived for the Sahara region for four distinct aerosol types. Note: For any region if any aerosol type is not available we use globally averaged spectral SSA.



Retrieved SSA (388 nm) from EPIC near-UV aerosol algorithm on 18 June 2020 (16:30 UTC) and reported spectral SSA at 440, 500 and 646 nm using polynomial fitting referenced to 388 nm.