Determining Aerosol Composition from the Spectral Dependence of Aerosol Absorption in the UV and Blue Wavelengths

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Effect of Aerosols on UV reflectance

Non-absorbing Aerosols

$$\rho_m = \rho_{atm} + T\rho_{sfc} + \rho_{aer} + \ldots.$$

Typical Values at 340 nm:

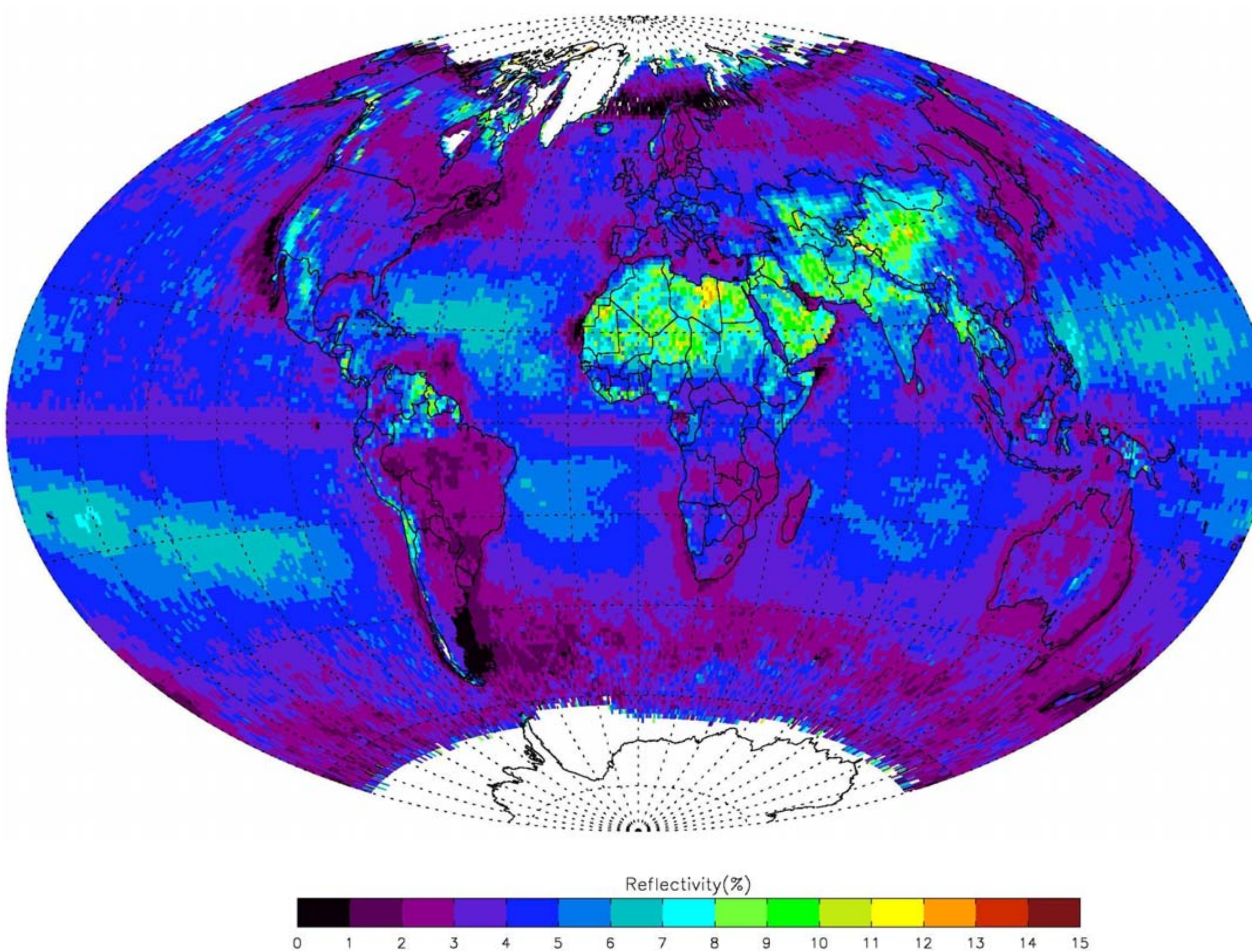
ρ_{atm} ≈0.25 (±0.001)
T ≈0.50
ρ_{sfc} =0.005-0.08 (±0.005)
ρ_{aer} =0.005-0.05 (±0.003)

Three advantages of going to the UV:

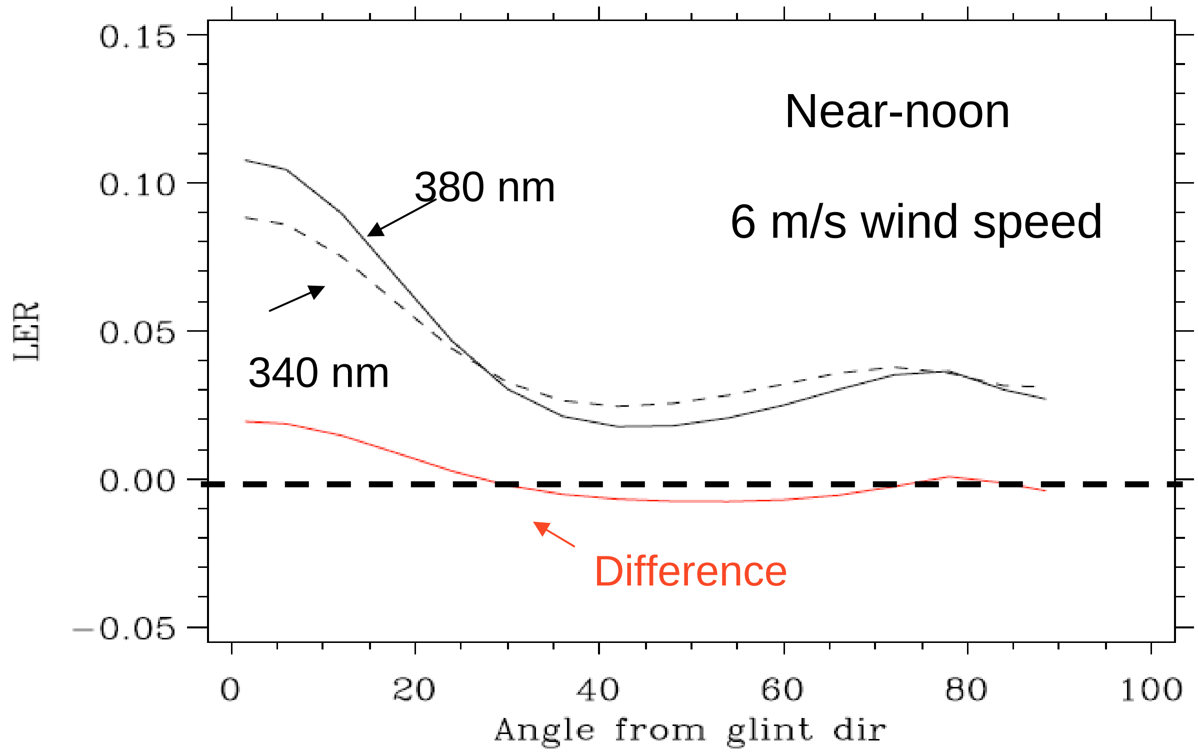
✓T reduces the effect of surface reflectance by half.
✓Diffuse atm radiation reduces the effect of surface BRDF.
✓Land/coastal ocean reflectivity is smaller and less variable than in the visible.

Reflectance of Earth at 380 nm

June, near-noon LST, w/o Fresnel reflection from water

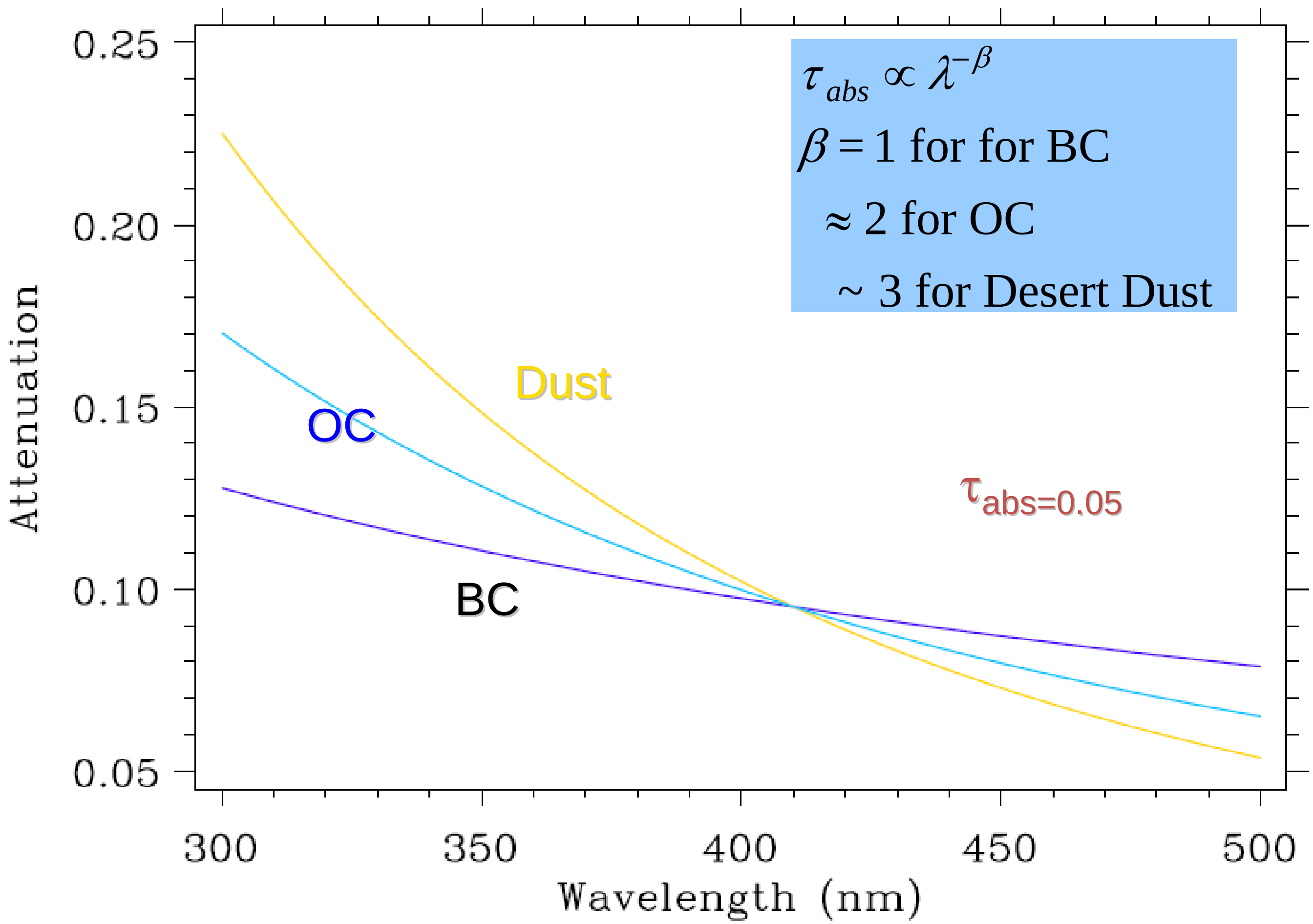


Effect of Fresnel Reflection on UV Reflectance



From Cox-Munk Model
Courtesy Zia Ahmad, NASA GSFC

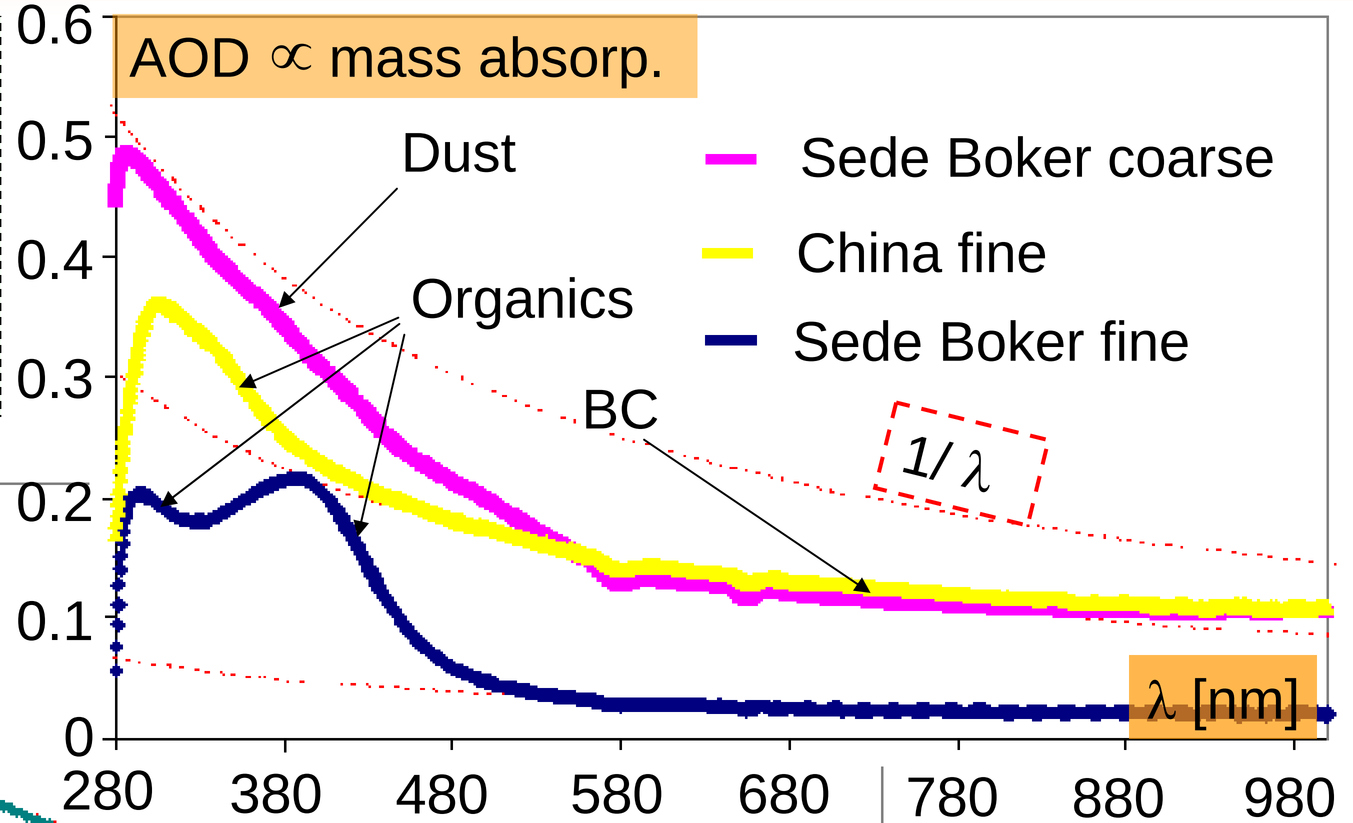
How do aerosols absorb in the UV?

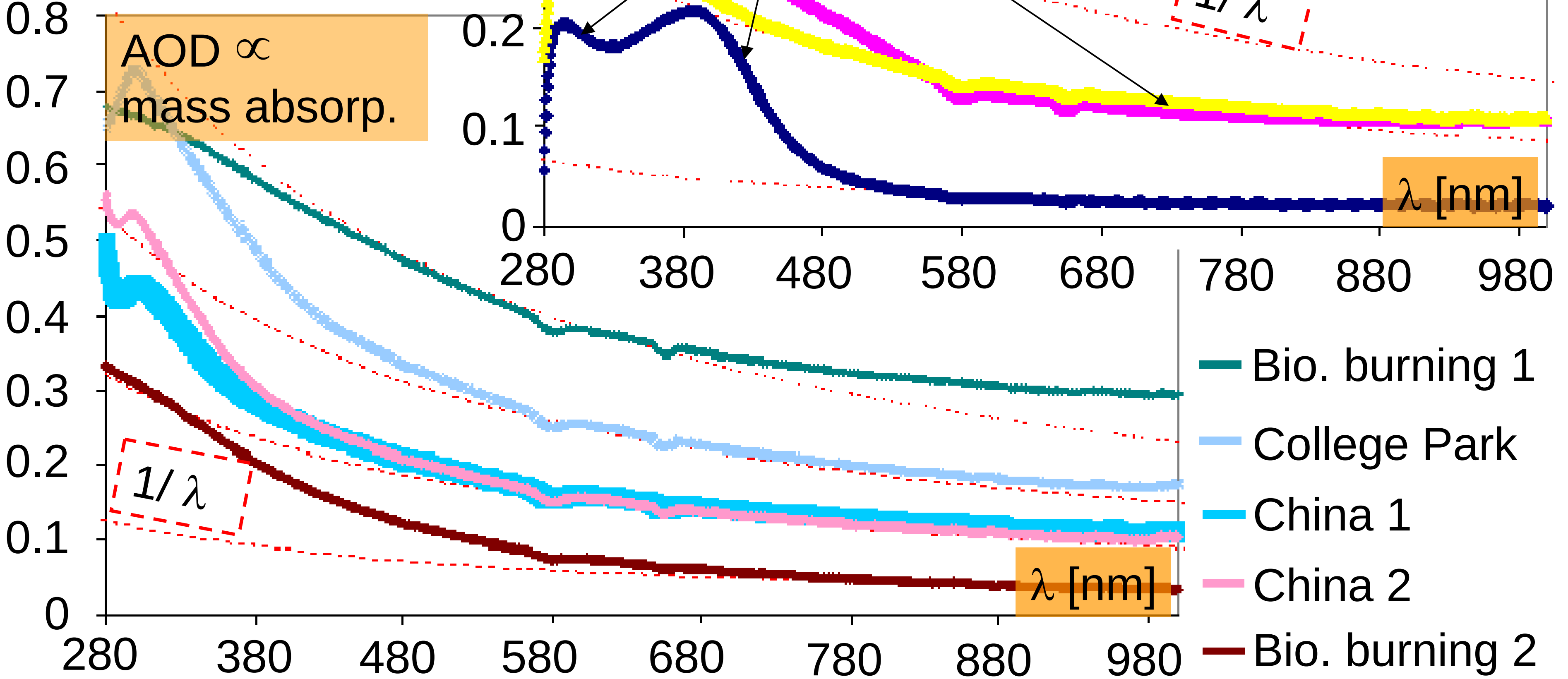


Absorption: dust, urban, biomass (Martin et al.)

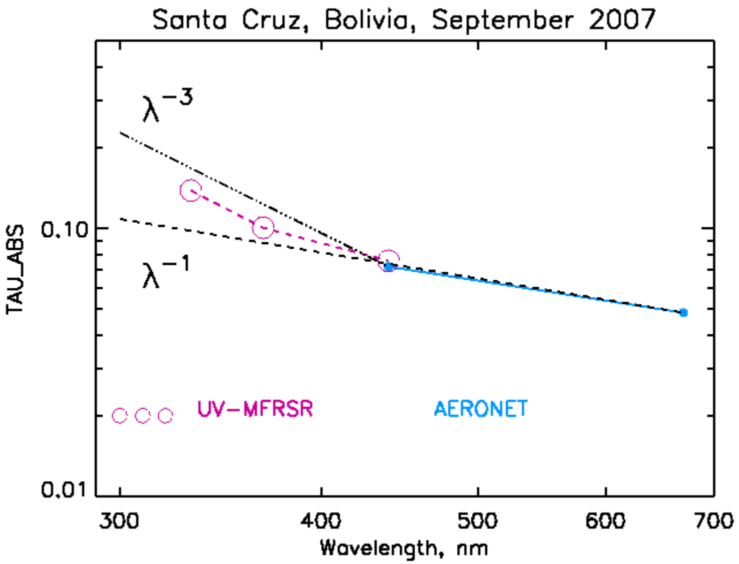
AOD vs. λ differs from 1/ λ shape

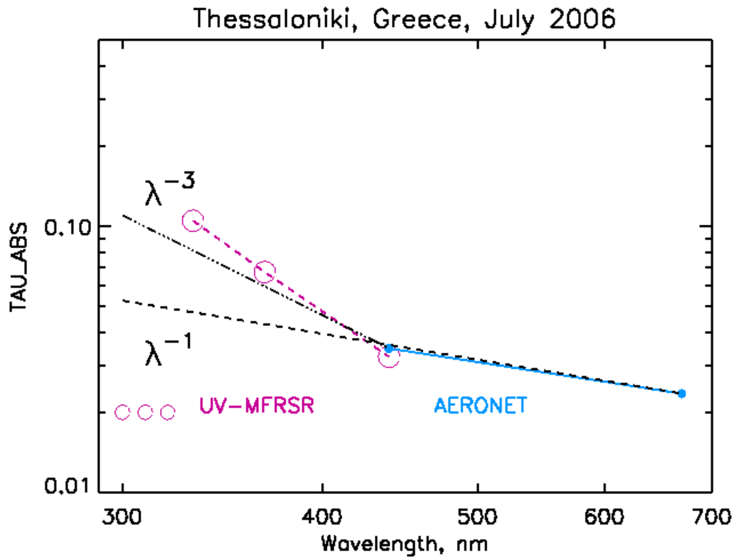
significant imaginary refractive index





Shadow-band Measured Spectral dep of τ_{abs}





Source: Krotkov et al.

Effect of Aerosol Absorption

Plume model

$$\rho_m = \rho_{above} + \left(T\rho_{sfc} + \rho_{below}\right)e^{-m\tau_{abs}} + \varpi\rho_{aer} + ...$$

$$m \approx \sec\theta + \sec\theta_0$$

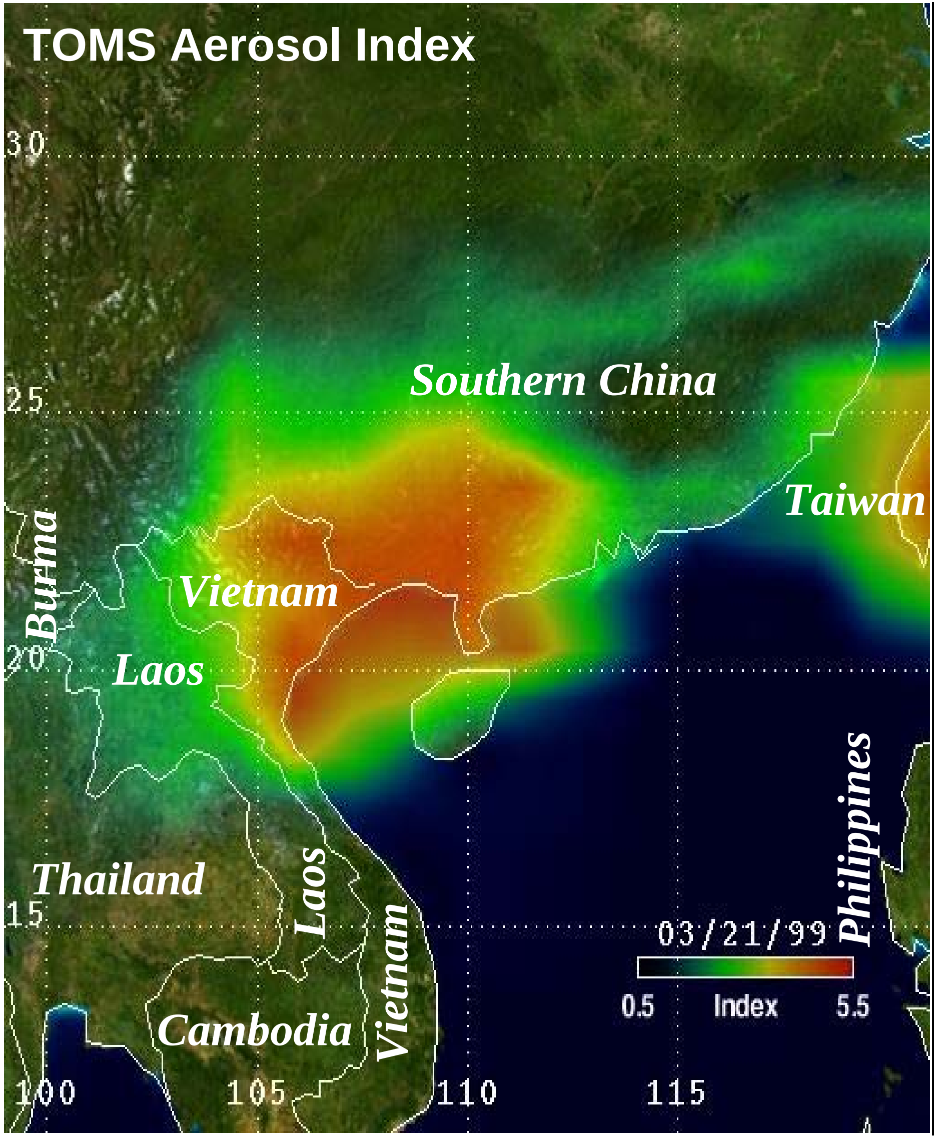
for small τ_{abs} ,

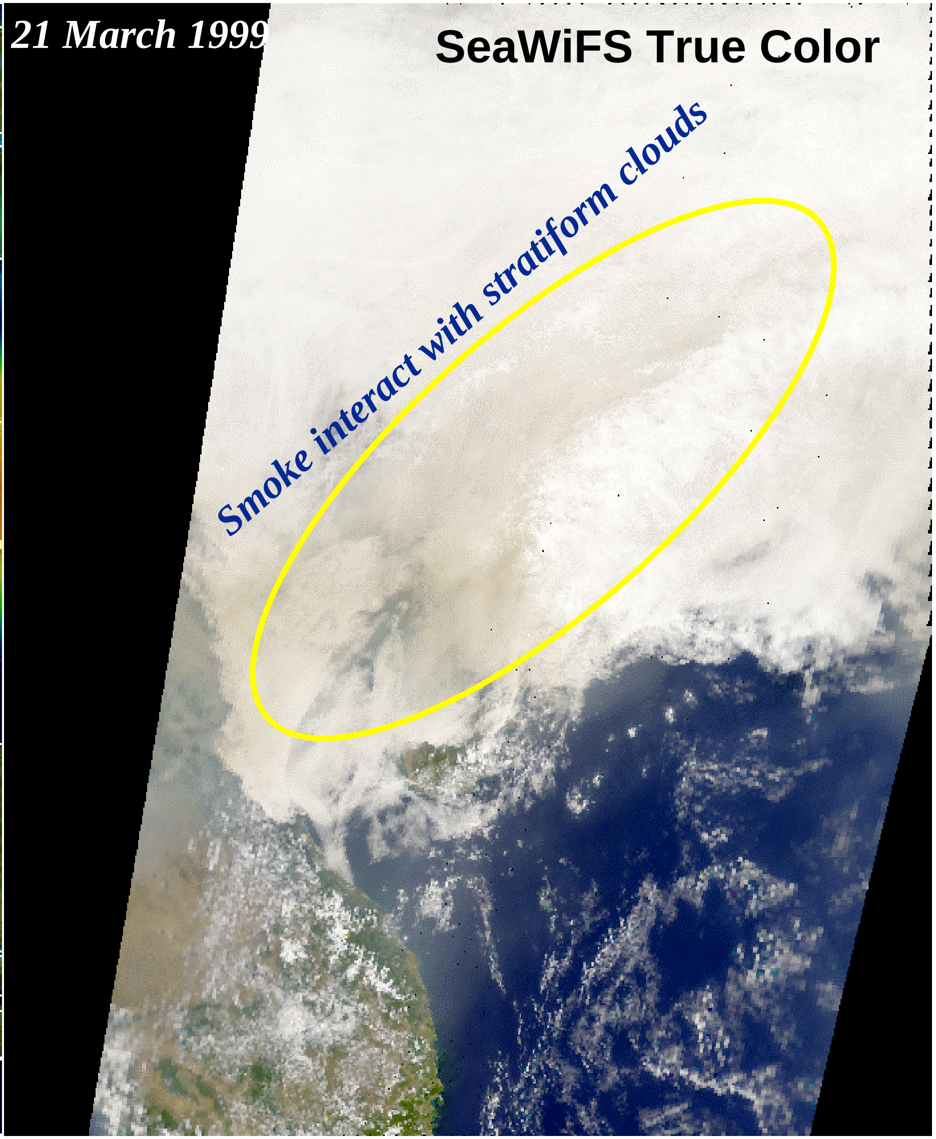
$$\Delta\rho = \rho_{abs\_aer} - \rho_{non\_abs\_aer} \approx -\left(T\rho_{sfc} + \rho_{below}\right)m\tau_{abs} + ...$$

where, $\rho_{below} \propto \left(1 - p_{aer}/p_{sfc}\right)$

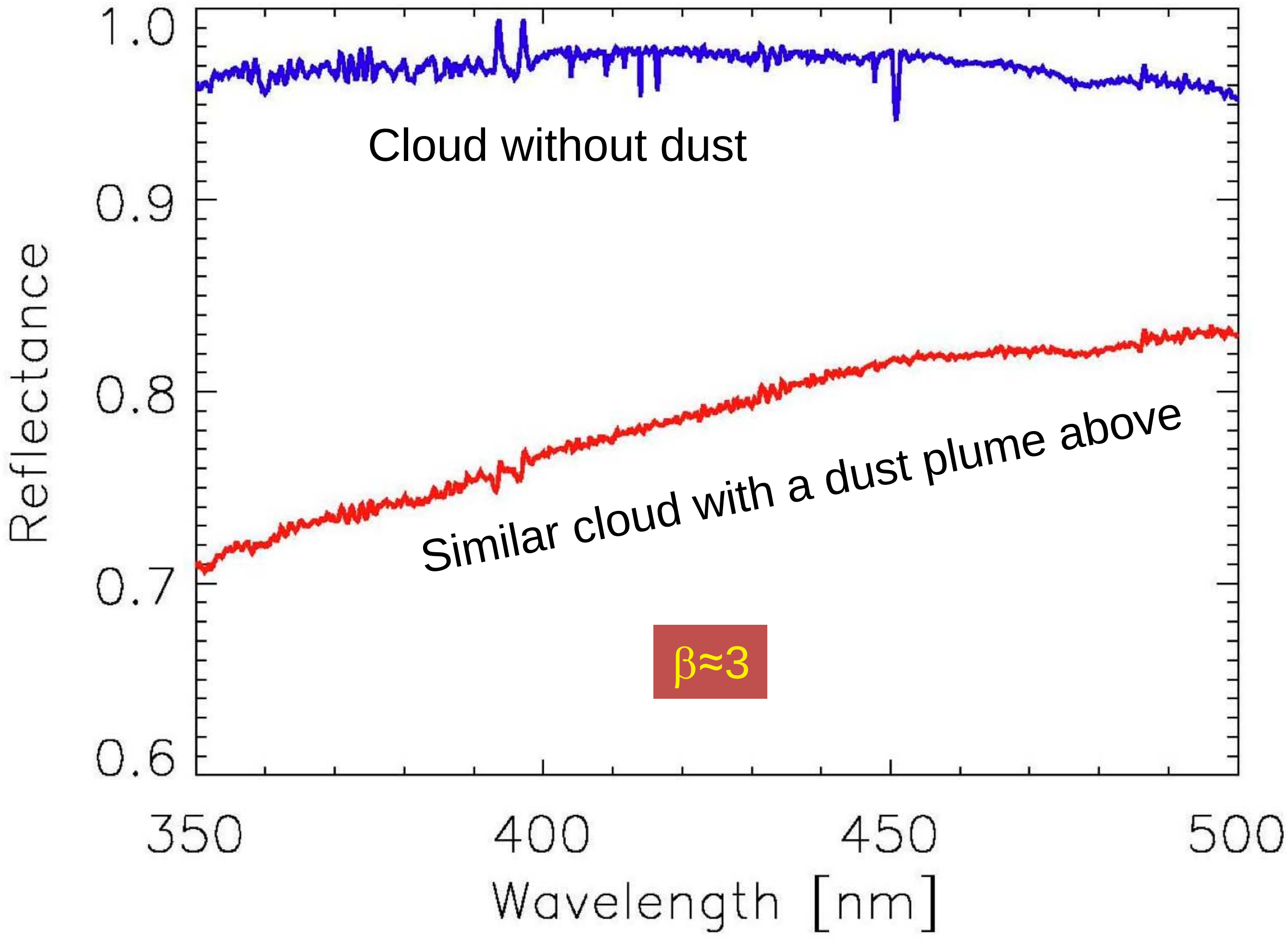
✓ $\Delta\rho$ is proportional to τ_{abs} over both dark and bright surfaces.
✓Over dark surfaces sensitivity to τ_{abs} increases with plume height.
✓In principle, λ dep of $\Delta\rho$ can provide the spectral exponent β of τ_{abs}, which contains information about OC/BC or BC/Dust fraction.

Detection of Smoke Over Clouds using TOMS





An example: Dust plume over very bright cloud- from Aura OMI



TOMS UV Aerosol Index (UV-AI) Method

$$-\frac{\partial \Delta\rho}{\partial\lambda} = \left(\frac{\partial T\rho_{sfc}}{\partial\lambda} + \frac{\partial\rho_b}{\partial\lambda} \right) m\tau_{abs} + \left(T\rho_{sfc} + \rho_b\right) m \frac{\partial\tau_{abs}}{\partial\lambda} + \ldots$$

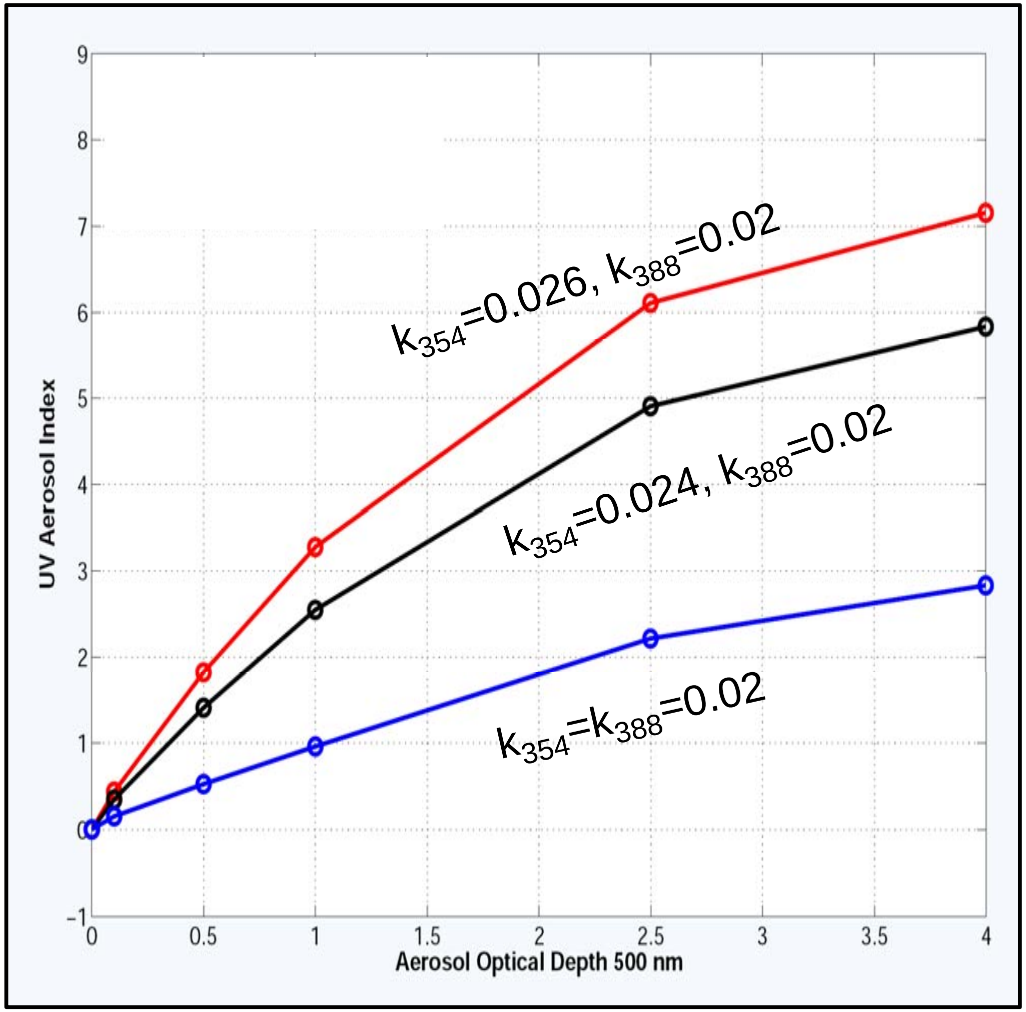
Ignoring λ - dep of the surface term,

$$-\frac{\partial \Delta\rho}{\partial\lambda} \approx \frac{\partial\rho_b}{\partial\lambda} m\tau_{abs} + \left(T\rho_{sfc} + \rho_b\right) m \frac{\partial\tau_{abs}}{\partial\lambda} + \ldots$$

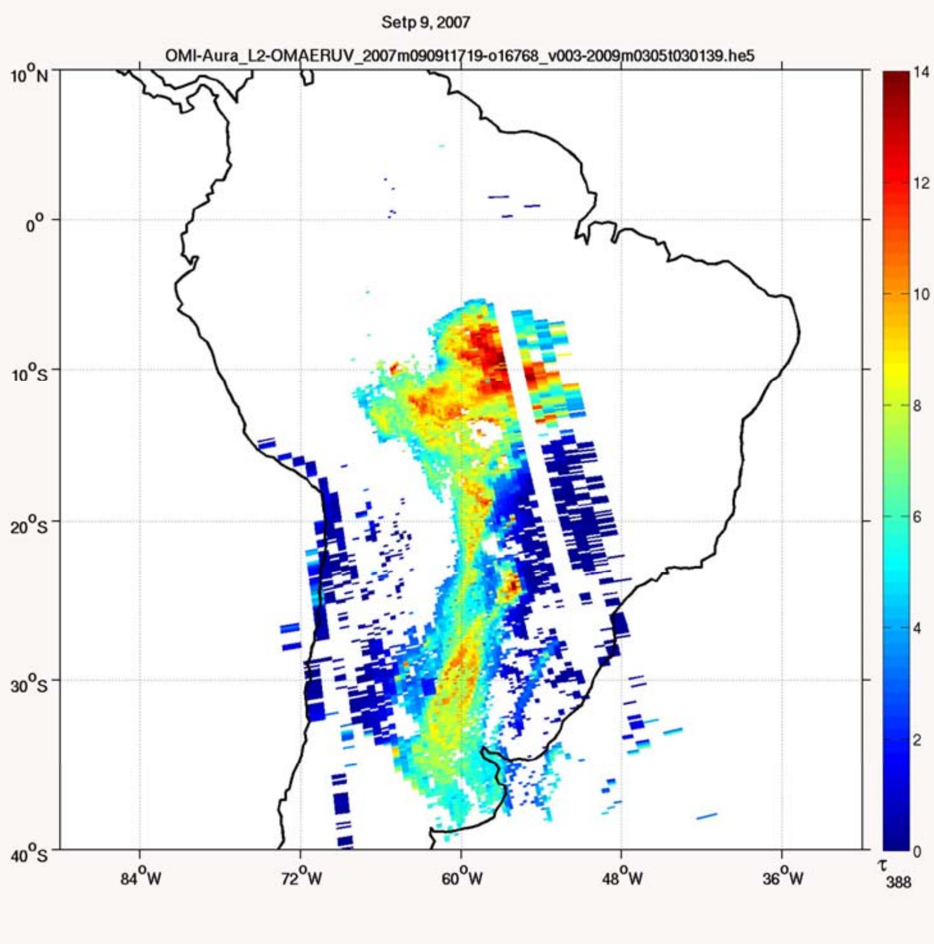
$$AI \propto -\frac{\partial \Delta\rho}{\partial\lambda}$$

✓ UV-AI is sensitive to both aerosol absorption OT and its slope with λ.

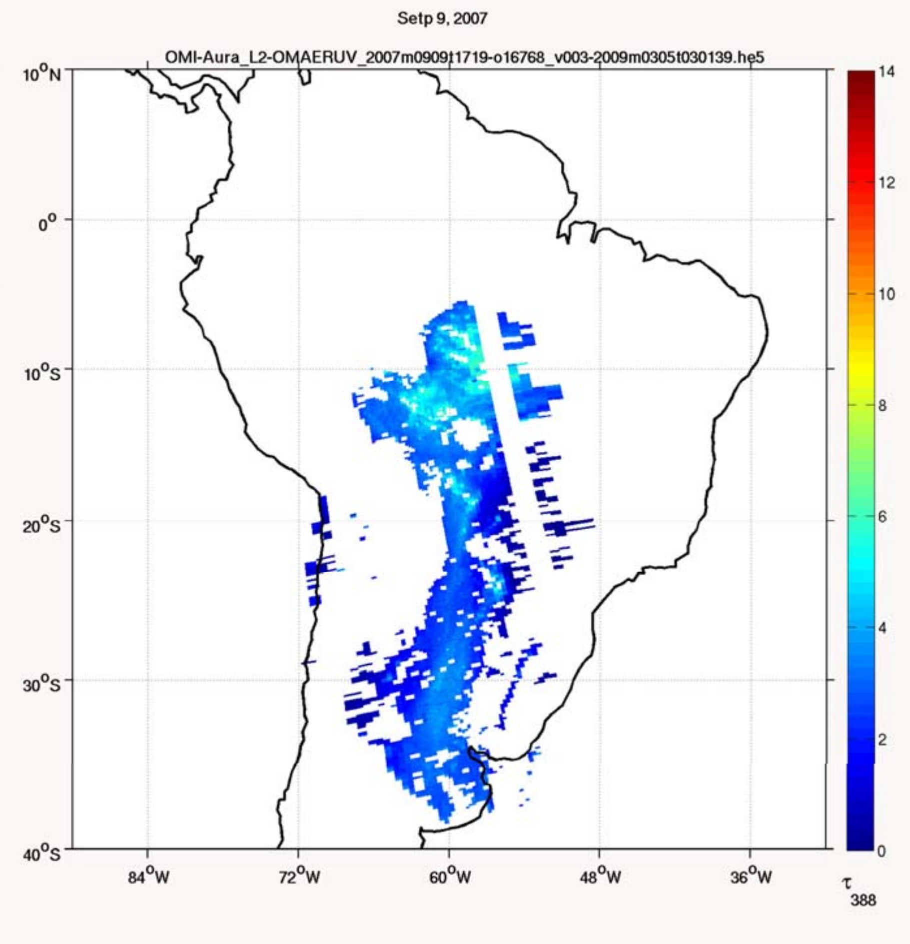
Sensitivity of AI to λ-dep of imaginary refractive index (k)



OMI Retrieved Aerosol Optical Depth on September 09, 2007



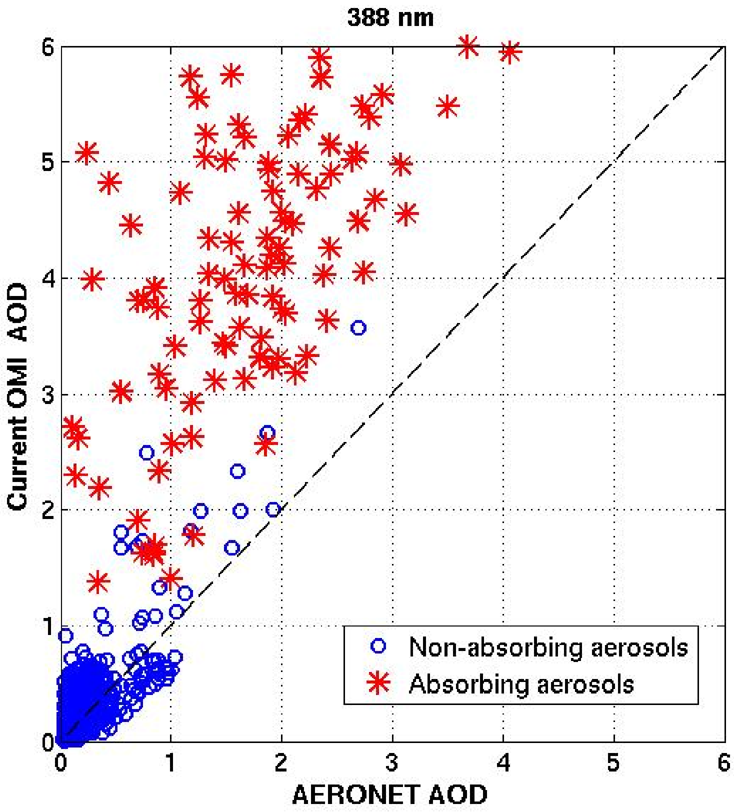
Black Carbon Assumption

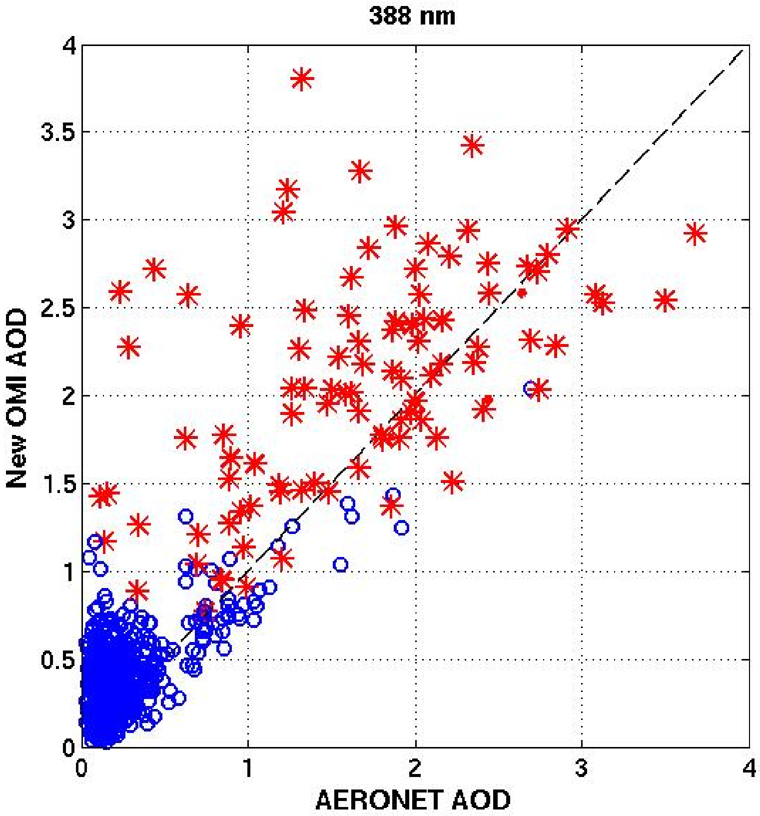


Organic Carbon Assumption

The BC assumption yields AOD twice as large as those under the OC assumption

Validation of Retrieved AOD (388 nm) using AERONET observations
(Seven sites, 2005-2007)





'Gray-aerosol' (black carbon) assumption.

'Colored aerosol' (organic carbon) assumption

The BC assumption results in a large overestimation of AOD (a factor or 2 or larger)

Summary

- Spectral exponent (β) of τ_{abs} contains useful aerosol composition information.
- It may be possible to estimate β from satellite measurements.
  - Need aerosol center of mass altitude over dark surfaces.
  - Retrieval of β may be easier if aerosols are over snow/ice or clouds.
- Continued in-situ and remote-sensing (using shadow-band and almucantar) measurements of β are necessary to interpret satellite data.