Characterization of aerosols spectral absorption properties using satellite observations

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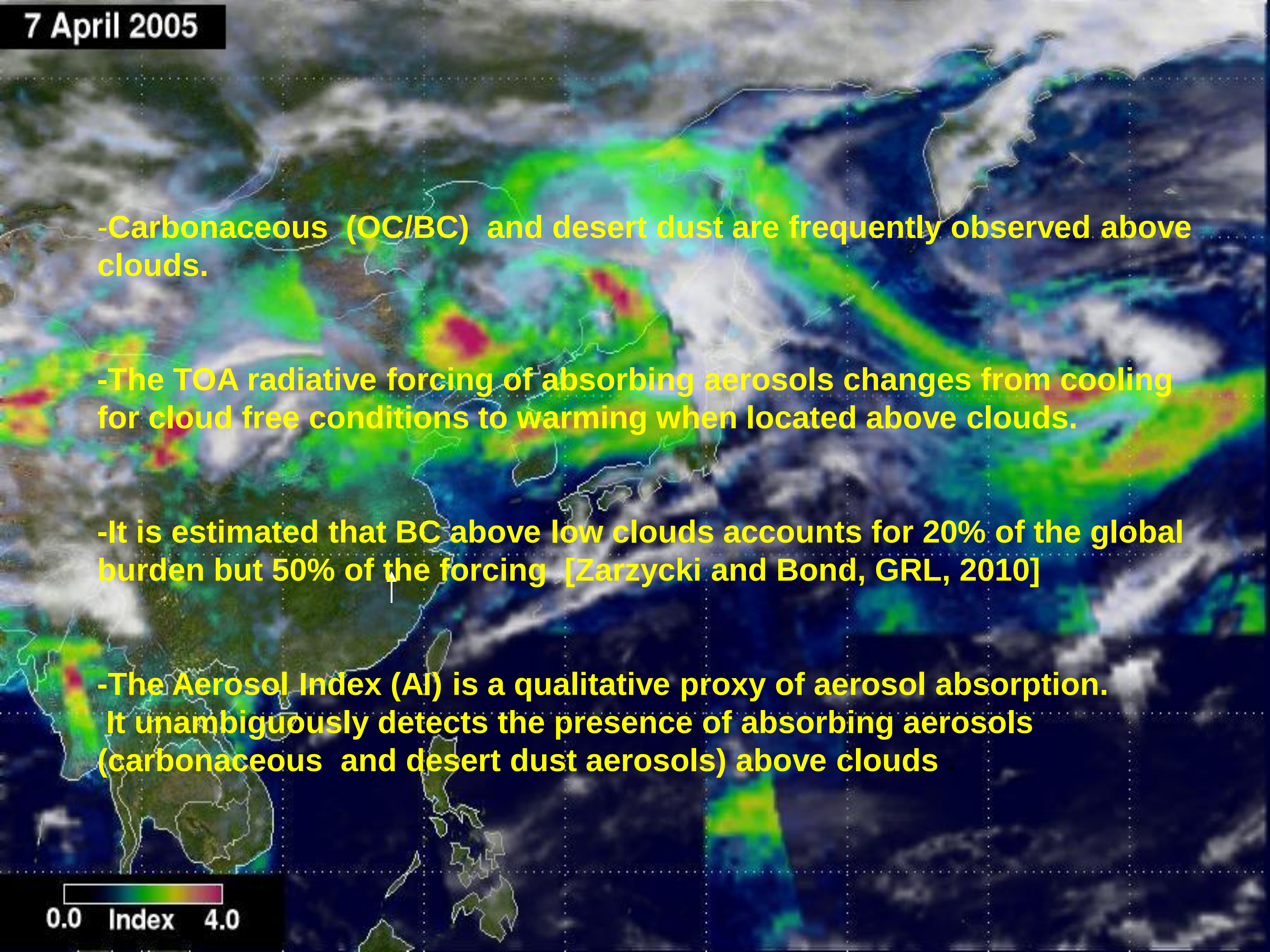


-Carbonaceous (OC/BC) and desert dust are frequently observed above clouds.

-The TOA radiative forcing of absorbing aerosols changes from cooling for cloud free conditions to warming when located above clouds.

-It is estimated that BC above low clouds accounts for 20% of the global burden but 50% of the forcing [Zarzycki and Bond, GRL, 2010]

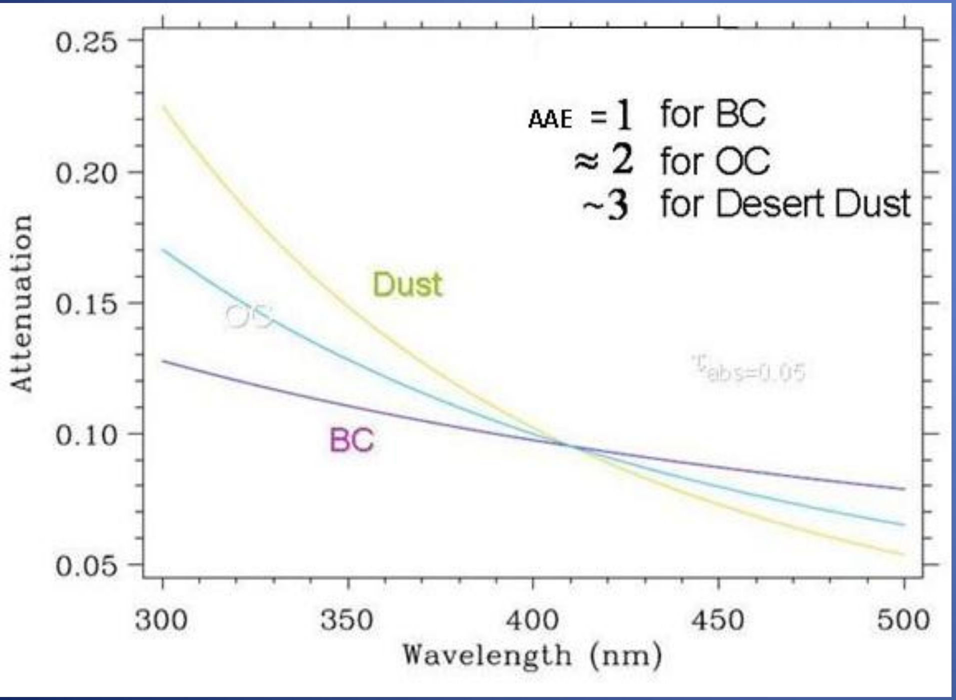
-The Aerosol Index (AI) is a qualitative proxy of aerosol absorption. It unambiguously detects the presence of absorbing aerosols (carbonaceous and desert dust aerosols) above clouds.

Wavelength Dependence of Aerosol Absorption Optical Depth

The AAOD spectral dependence can be described by a simple exponential function of the form

$$AAOD = K\lambda^{-AAE}$$

where AAE is referred to as the Absorption Angstrom exponent.



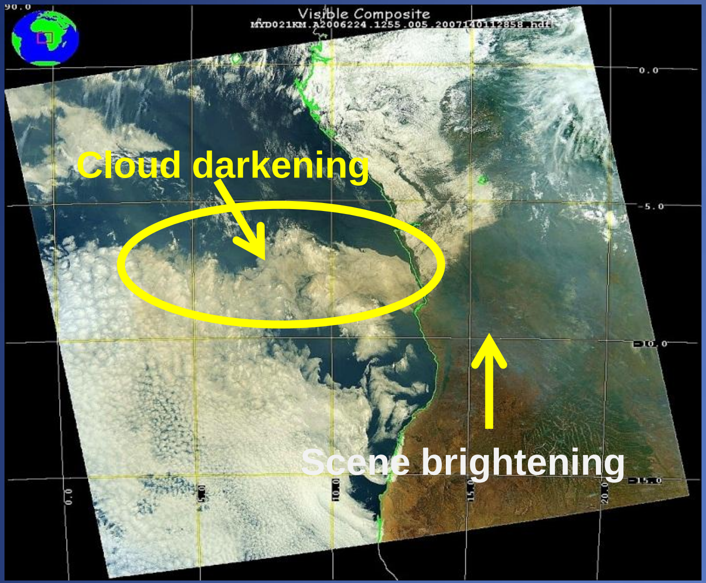
Observational analyses indicate that typically

AAE ~ 1 for black carbon aerosols
AAE ~ 2 for organic carbon aerosols
AAE ~ 3 for desert dust

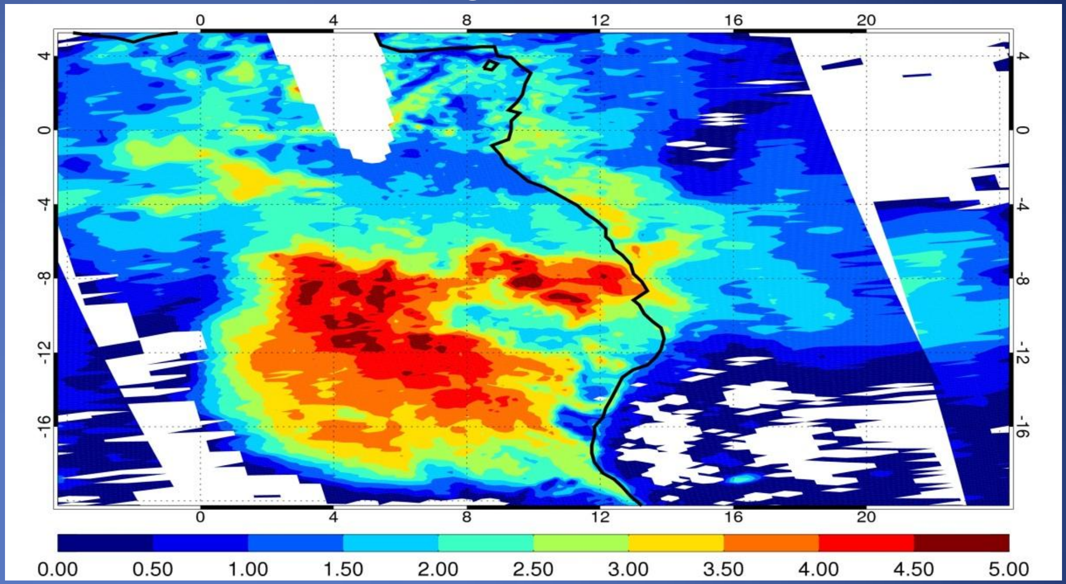
The magnitude of AAE is associated with aerosol composition.

Above-cloud Absorbing Aerosols seen by A-train Sensors

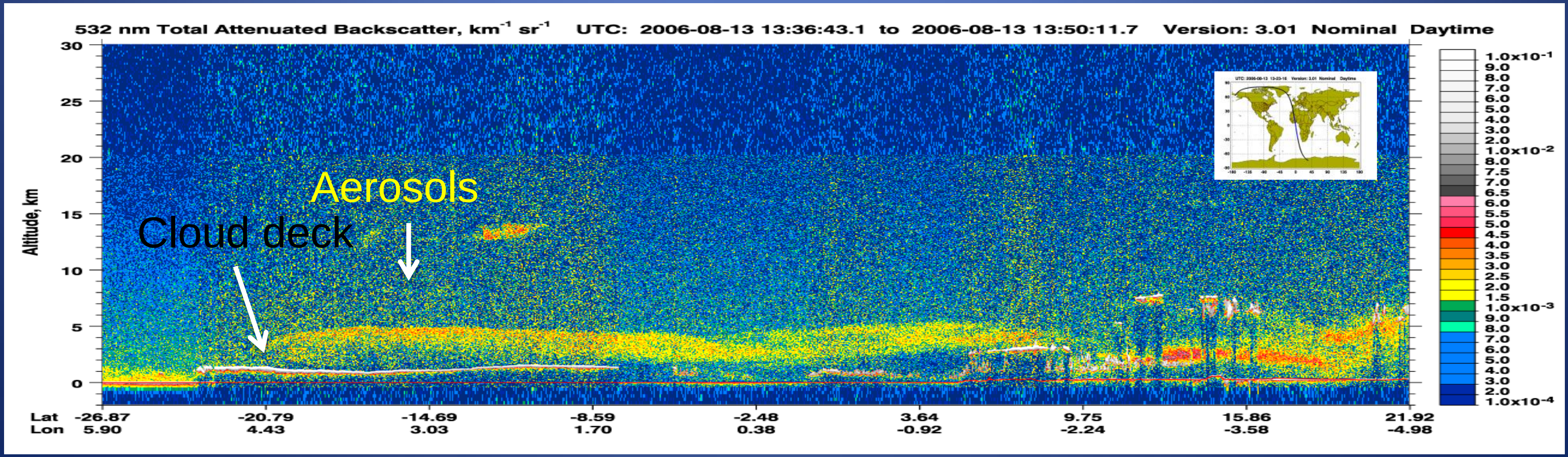
MODIS RGB Composite
Aug 12, 2006



OMI UVAI
Aug 12, 2006

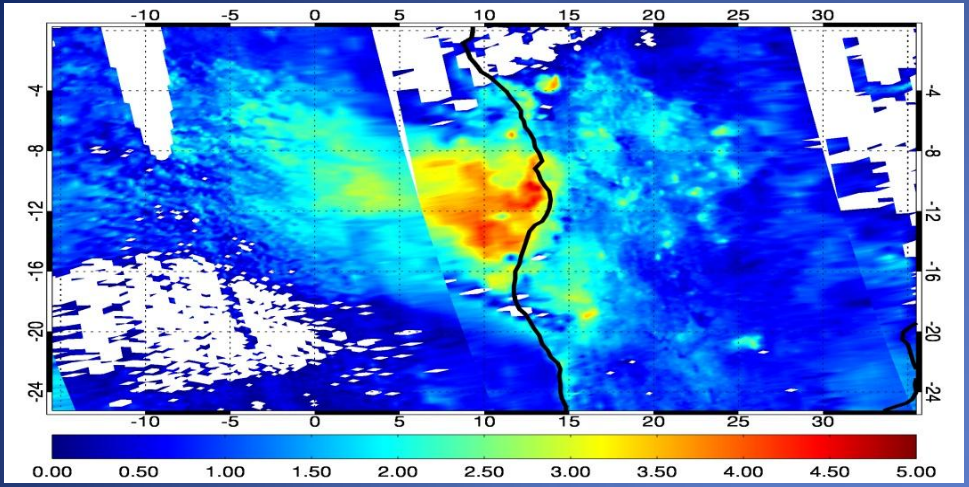


CALIOP/CALIPSO Vertical Back-scatter
Aug 13, 2006



Simultaneous Retrieval of Aerosol and Cloud Optical Depth

OMI UVAI (Aug. 31 2005)



Torres et al. (JAS, 2012)

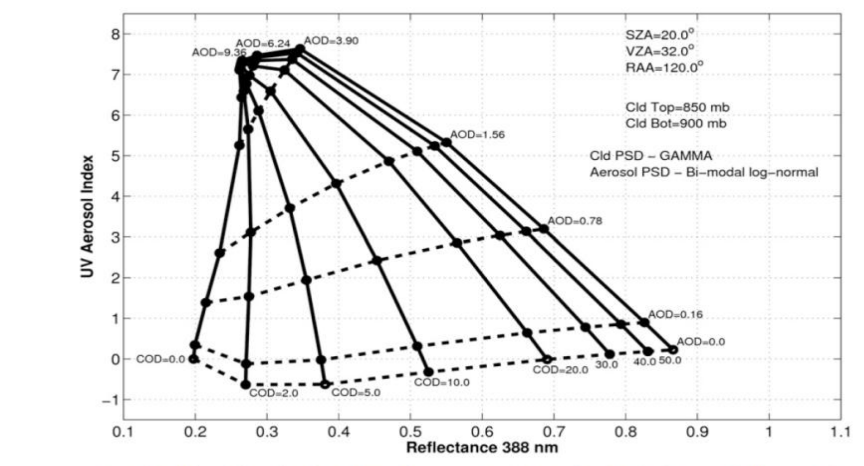


FIG. 5. Retrieval domain of AAI vs reflectance at 388 nm simulated using a radiative transfer model for several values of AOD at 388 nm (0.0, 0.156, 0.780, 1.56, 3.9, 6.24, and 9.36) and COD (0.0, 2, 5, 10, 20, 30, 40, and 50).

Assuming aerosol and cloud PSD's and aerosol SSA, the UVAI and reflectance at 388 nm are related to a set of ***AOD and COD values***

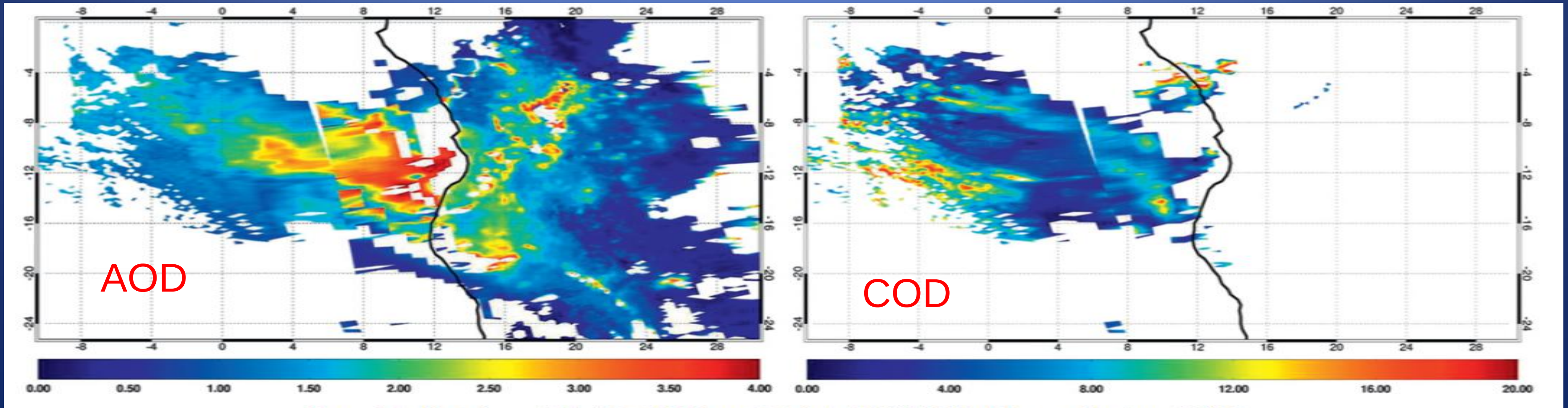
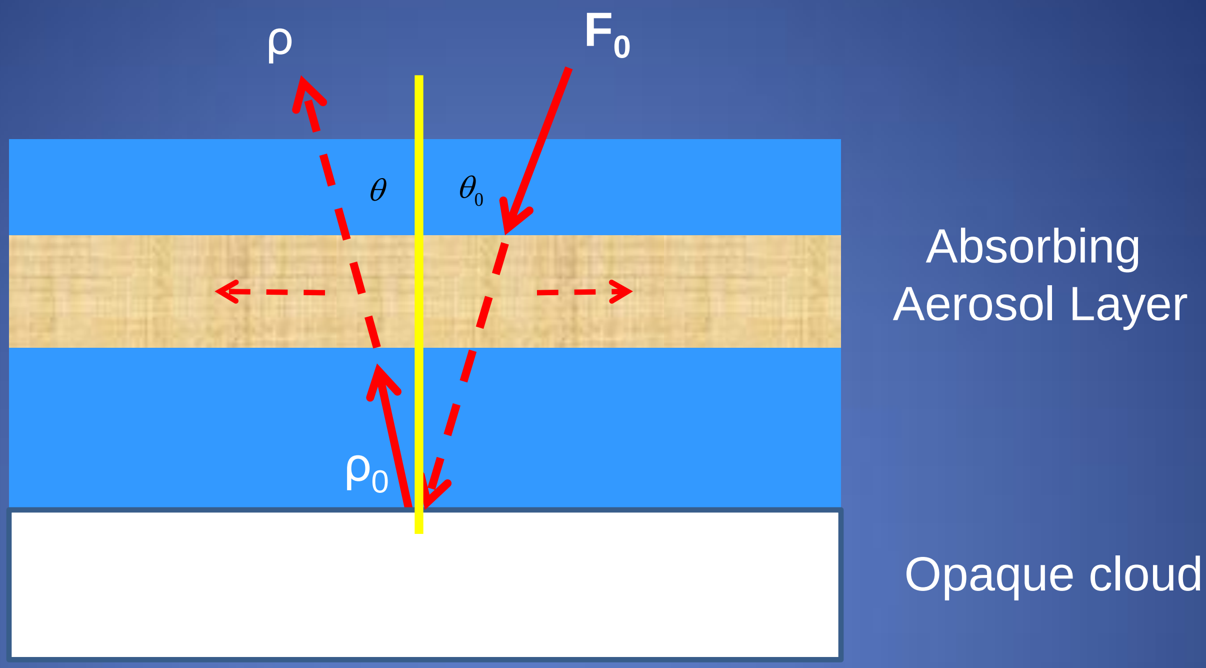


FIG. 11. Retrieved (left) AOD and (right) COD fields on 31 Aug 2005.

This approach can also be applied to visible observations (Jethva et al, IEEE, 2012)

Retrieving AAOD using satellite observations of aerosols above clouds



The bright background provided by optically thick clouds can be used to infer the AAOD spectral dependence making use of a Beer's law approximation:

$$\rho_\lambda = \rho_{c_\lambda} e^{-mAAOD_\lambda}$$

Only aerosol absorption effects are considered. A correction for scattering effects is required.

To solve for $AAOD_\lambda$ in this approximation, the term ρ_{c_λ} (a function of cloud optical depth) must be known.

Determining Cloud Optical Depth (COD)

- COD is wavelength independent.

Standard COD retrievals at 0.865 nm are affected by aerosol absorption effects (Wilcox, 2008).

Several approaches can be used retrieve COD

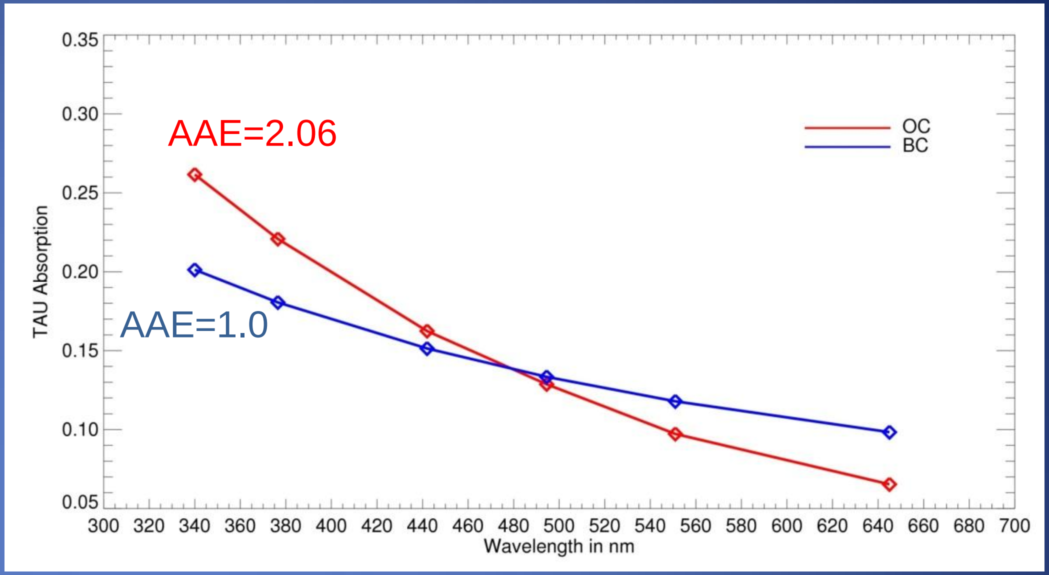
-Use color ratio in the near UV (Torres et al, JAS 2012) or in the visible (Jethva et al, IEEE, 2012, submitted) to simultaneously derive COD and AOD of the above-cloud aerosol layer.

-Use SWIR wavelengths where aerosol absorption effects are very small (DeGraaf et al., JGR,2012)

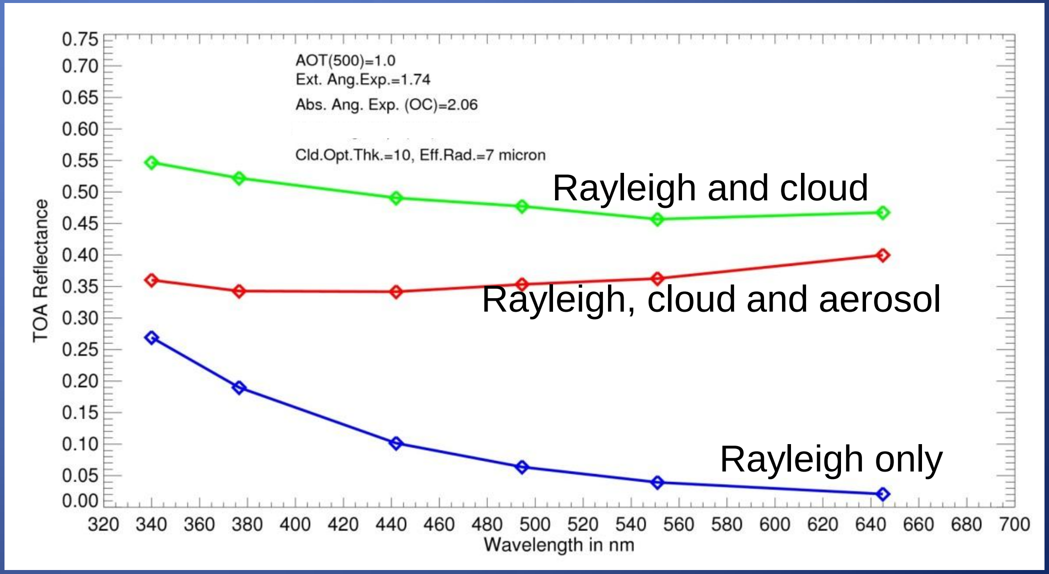
In this application using OMI data we make use of the OMI near-UV method

Spectral AAOD retrieval: Sensitivity Analysis (1)

SMOKE:
Log-normal Distribution
Mean radius = 0.08 µm; stddev=1.492 µm
SSA (388)=0.89; SSA(354)=0.88
Aerosol peak height=3.0 km
Half-width=1.0 km

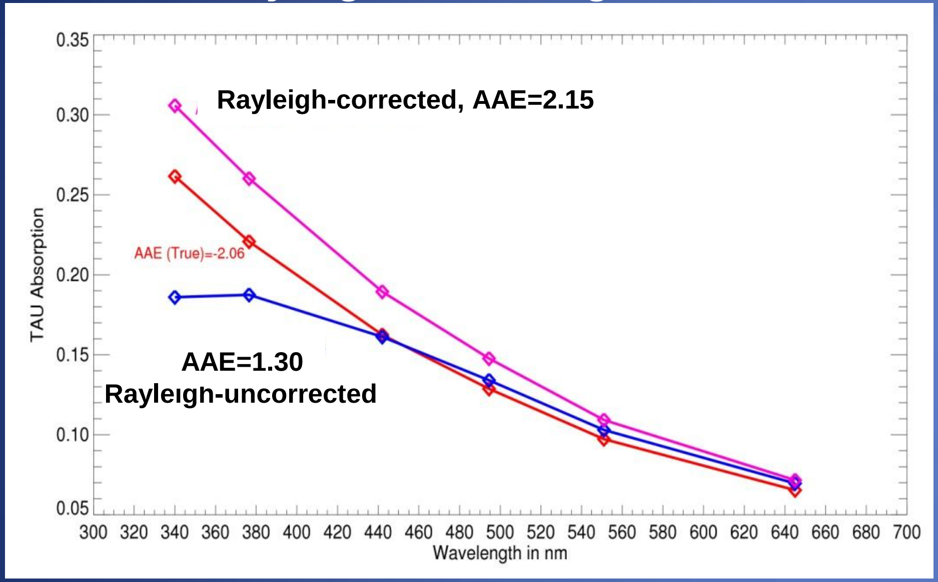


CLOUD:
Modified GAMMA distribution
Effective Radius = 7.0 µm
Cloud top = 850 mb
Cloud bottom = 900 mb
Real refractive index=1.35
Imaginary index=0.0

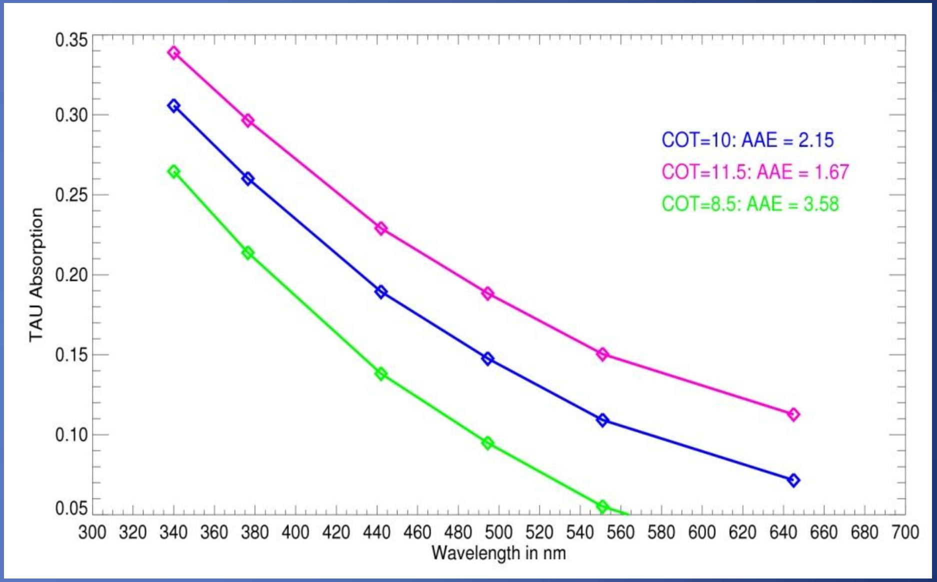


Sensitivity Analysis: Retrieved AAOD and AAE

Rayleigh Scattering Effects



Effect of COD uncertainty on derived AAE



15% COD underestimate results in 66% AAE error
15% COD overestimate results in -22% AAE error

Spectral AAOD Retrieval Procedure

1. Identify Absorbing Aerosols above clouds (UVAI)

2. Derive COD (and AOD) using near UV color ratio (354 and 388 nm)

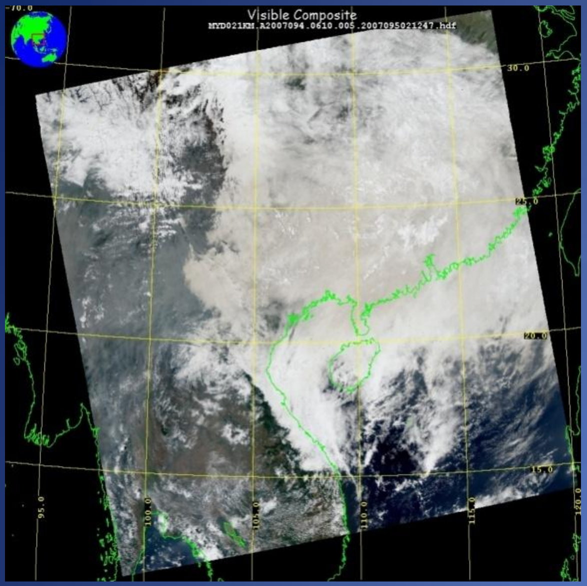
3. Use derived COD to calculate Cloud Reflectance at a few wavelengths in the 350-500 nm range (used 17 in this application)

1. Apply Rayleigh scattering correction to calculated cloud reflectance and OMI observed TOA reflectance

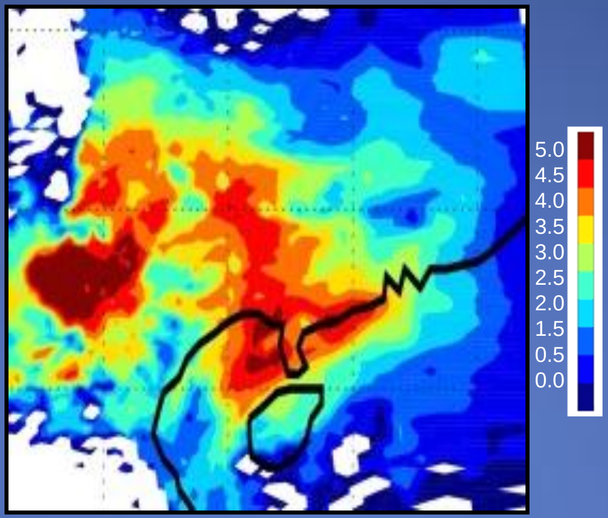
5. Obtain spectral AAOD in the 350-500 nm range using Beer’s law approximation

6. Calculate Angstrom Absorption Exponent

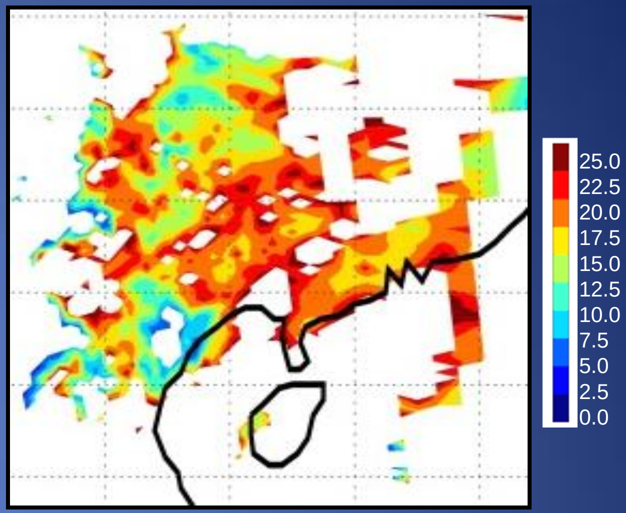
Case 1: April 4 2007; 100E to 120E, 20N to 25N



UV Aerosol Index

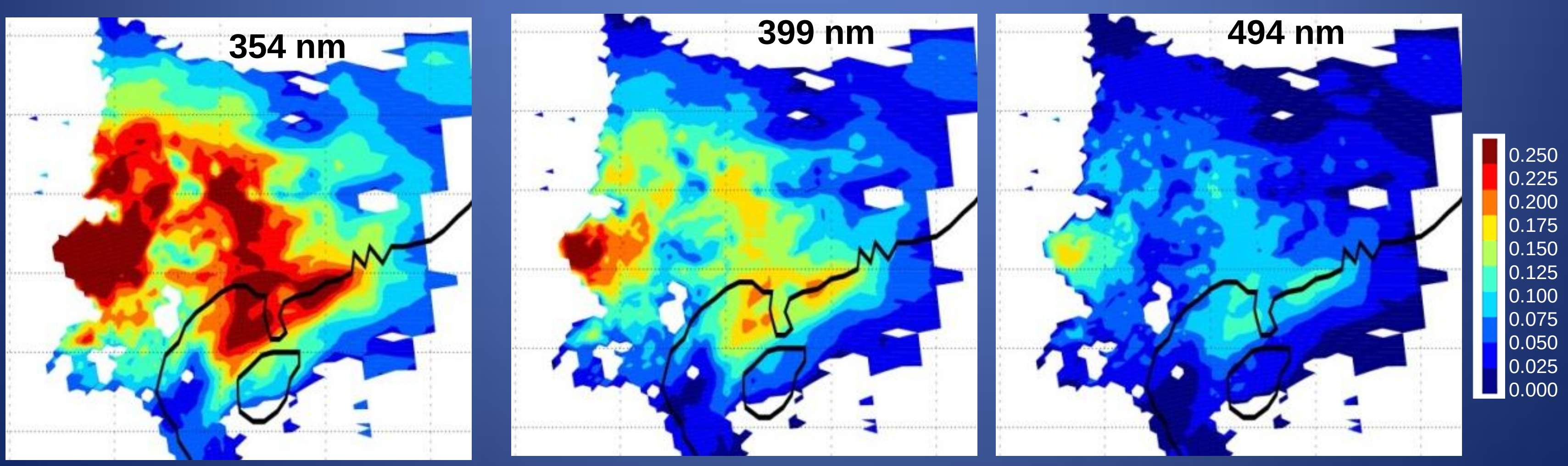


Cloud Optical Depth



COD=8, AI=1.5

AAOD:



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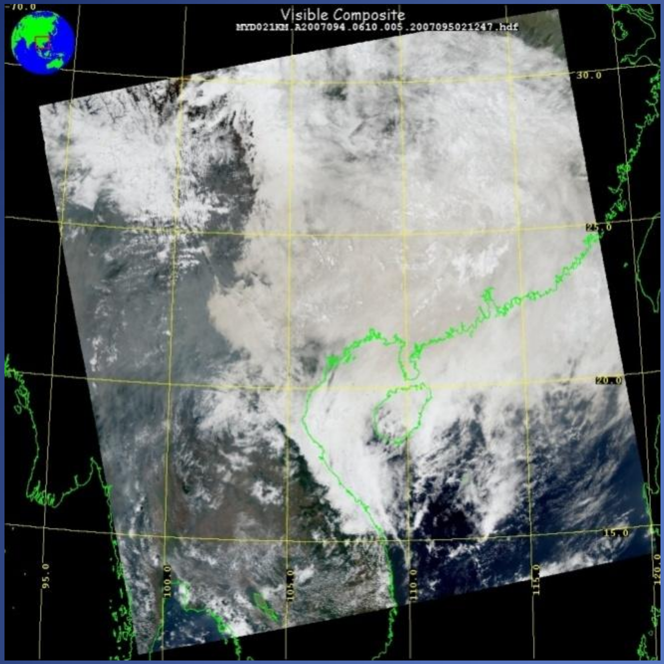
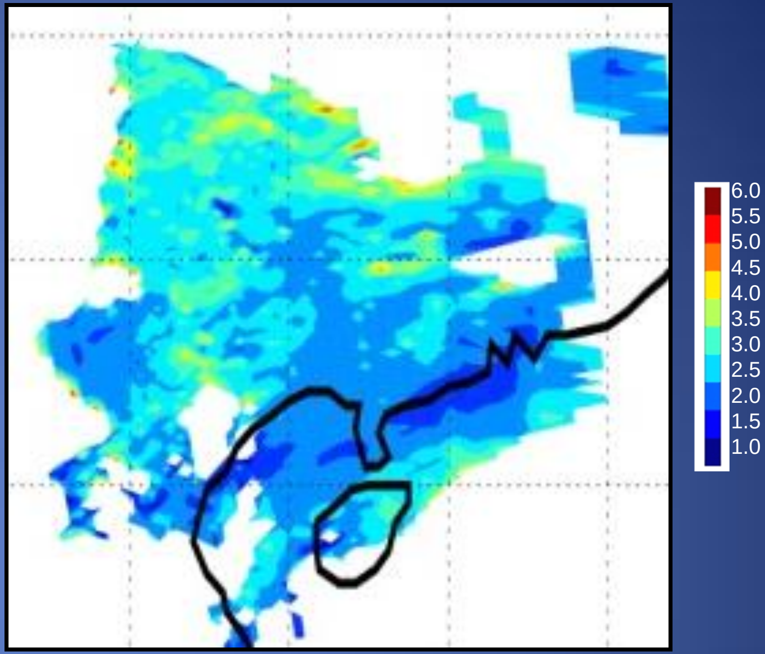
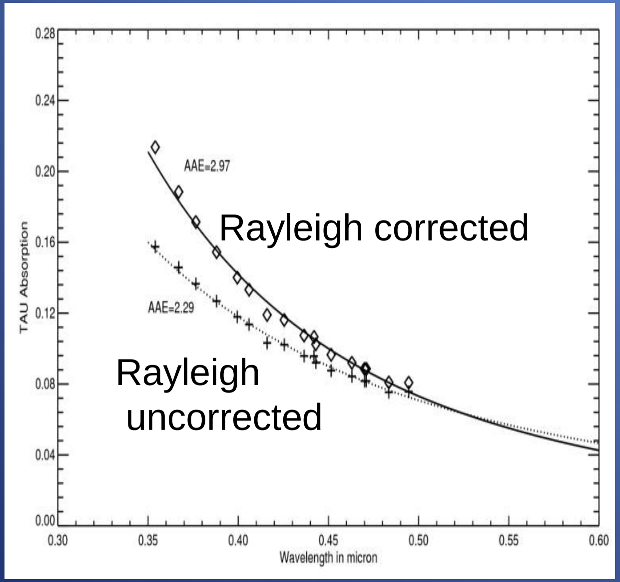




Absorption Angstrom Exponent



$$AAOD = K\lambda^{-AAE}$$

Summary

-A retrieval approach to simultaneously derive aerosol and cloud optical depth for ACA's events has been developed.

-The OMI-derived spectrally independent COD is used to characterize cloud reflective properties.

-A Beer's Law approximation is applied to derive the spectral aerosol Absorption optical depth and associated Angstrom Absorption Exponent.

-The obtained AAOD and AAE yields information on Aerosol composition and facilitates the quantification of the direct radiative forcing of above-cloud aerosols.