Aerosol Properties over "*Bright-Reflecting Source Regions*": *The Deep Blue Algorithm and its Applicability to MODIS*

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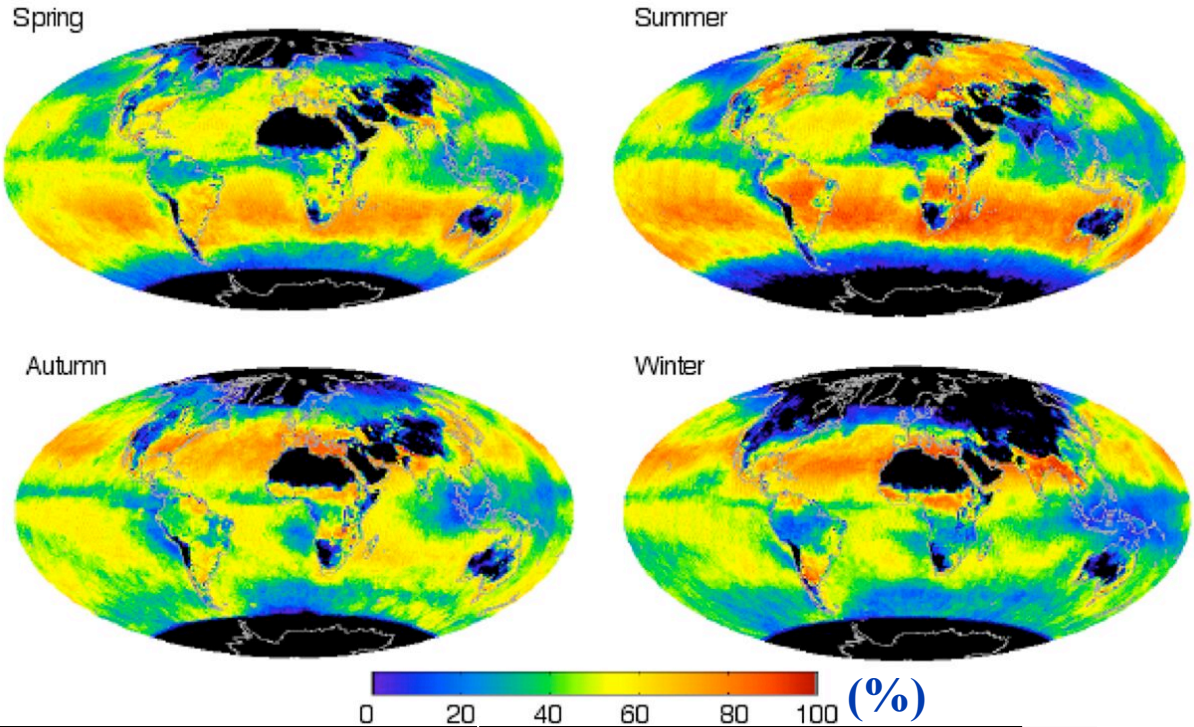
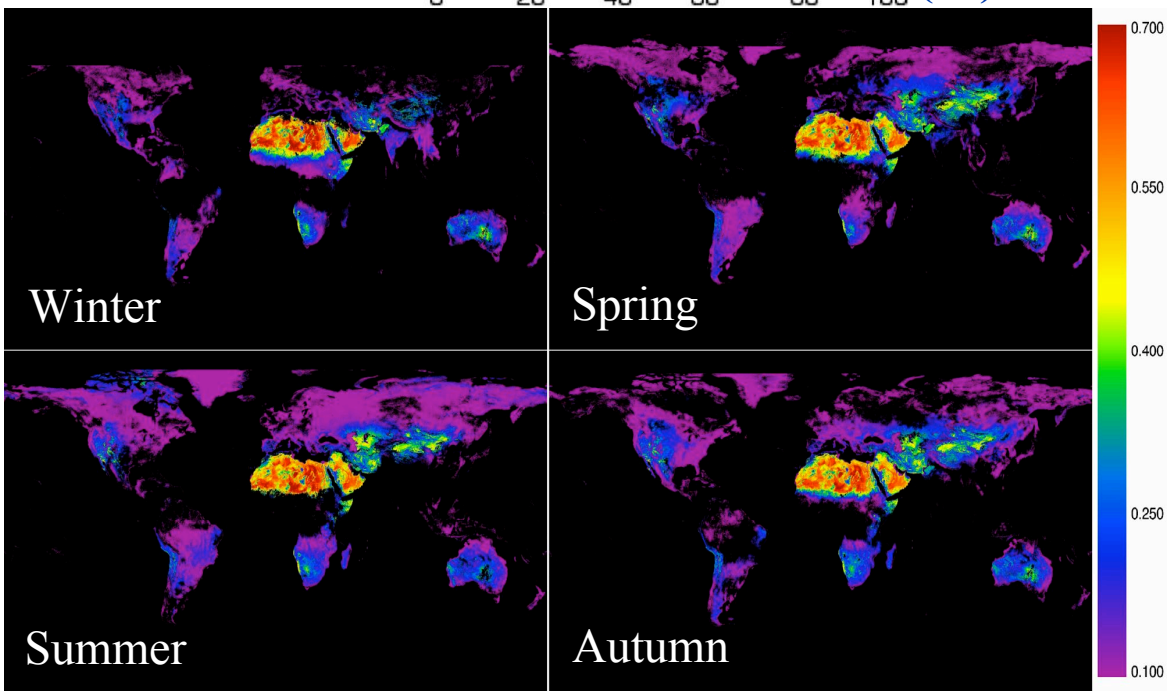
Rationale

- ***Climate Forcing****: requires* ***aerosol properties near source regions*** *to achieve a complete picture of aerosol information from source to sink;*
- ***Carbon Cycle****: tracks* ***iron sources*** *from windblown dust for stimulating* ***plankton*** *growth in the open ocean;*
- ***Aerosol Transport Modeling****: needs accurate and realistic* ***dust source*** *locations; and*
- ***Visibility and Adverse Health Effects****: demands timely* ***atmospheric turbidity*** *information over affected regions.*



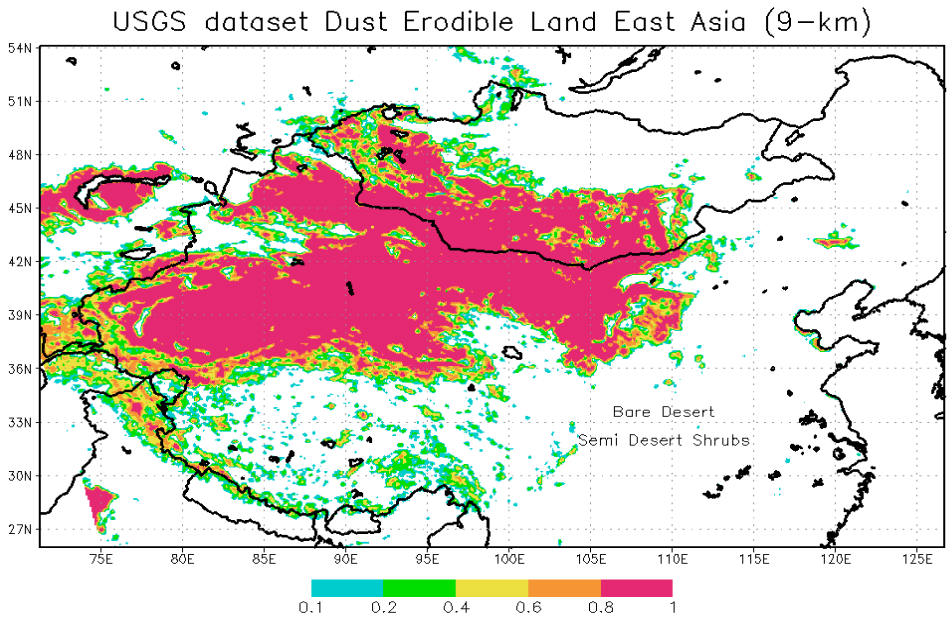
Percentage of Area Retrieved by Current MODIS Aerosol Algorithm

[Chu et al., JGR, 2003]

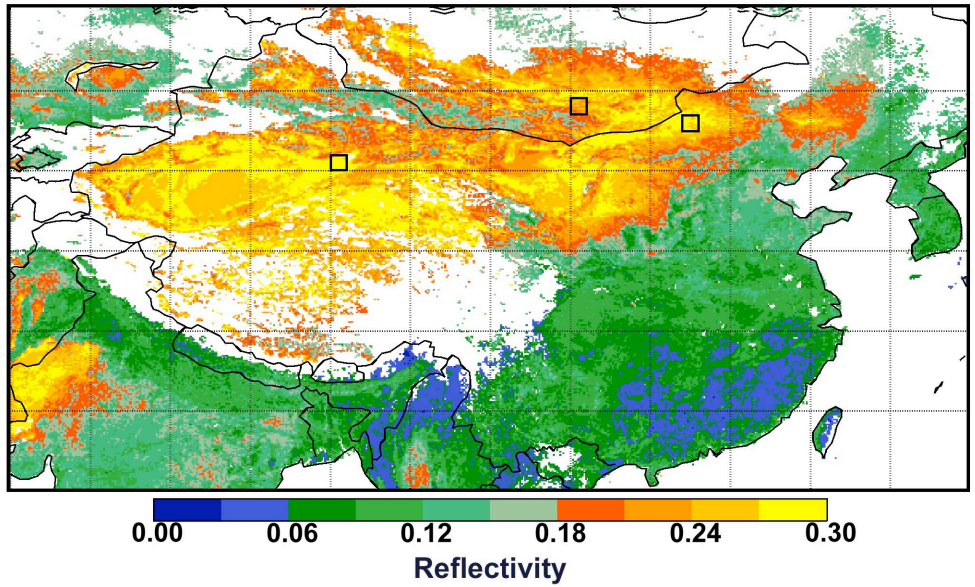


Global Coverage for
Surface Reflectance (2.1μm) >0.25
~15% ≤ f(season) ≤ ~25%

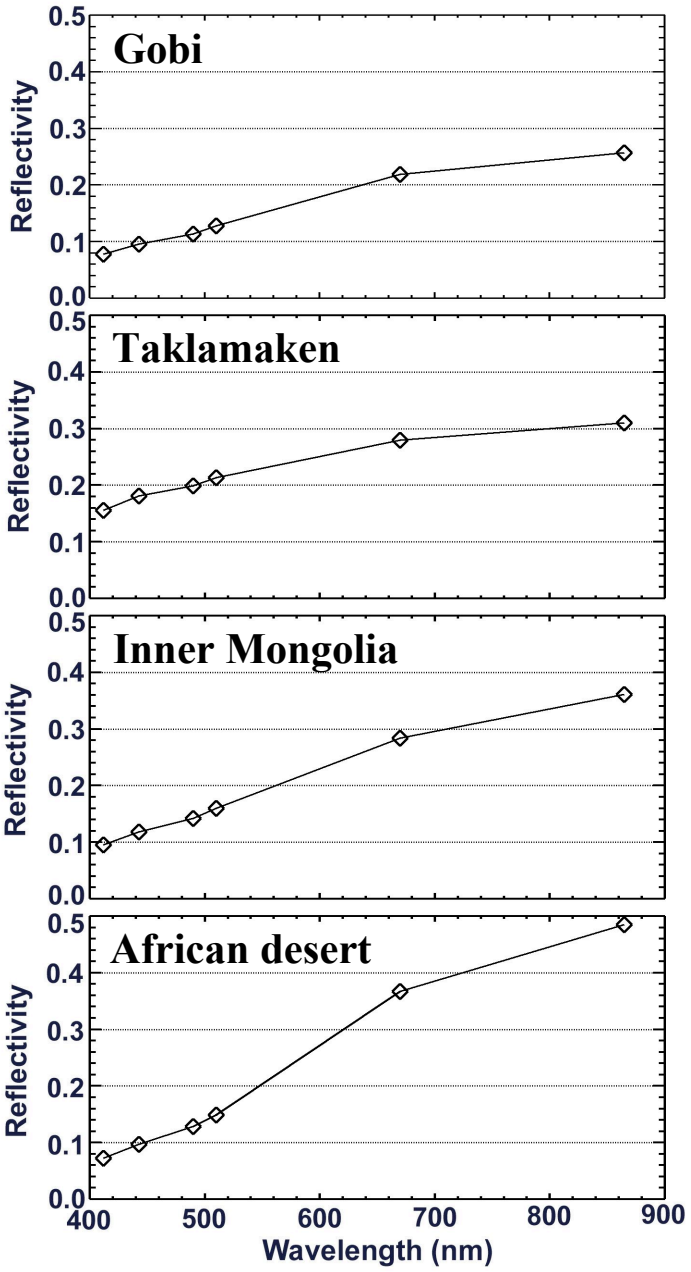
[Moody et al., 2004, in press, IEEE TGRS]



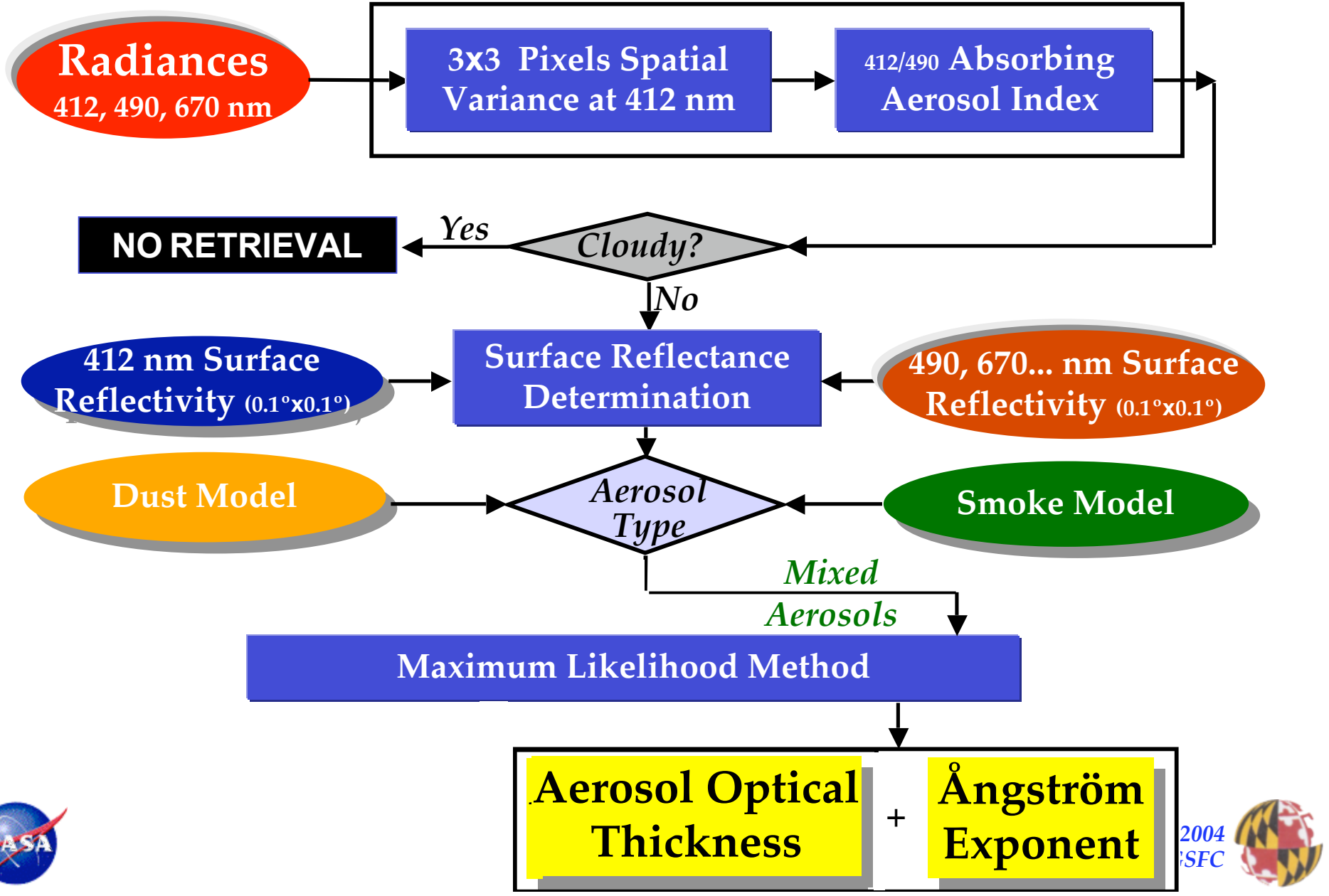
b) Reflectivity (670 nm)



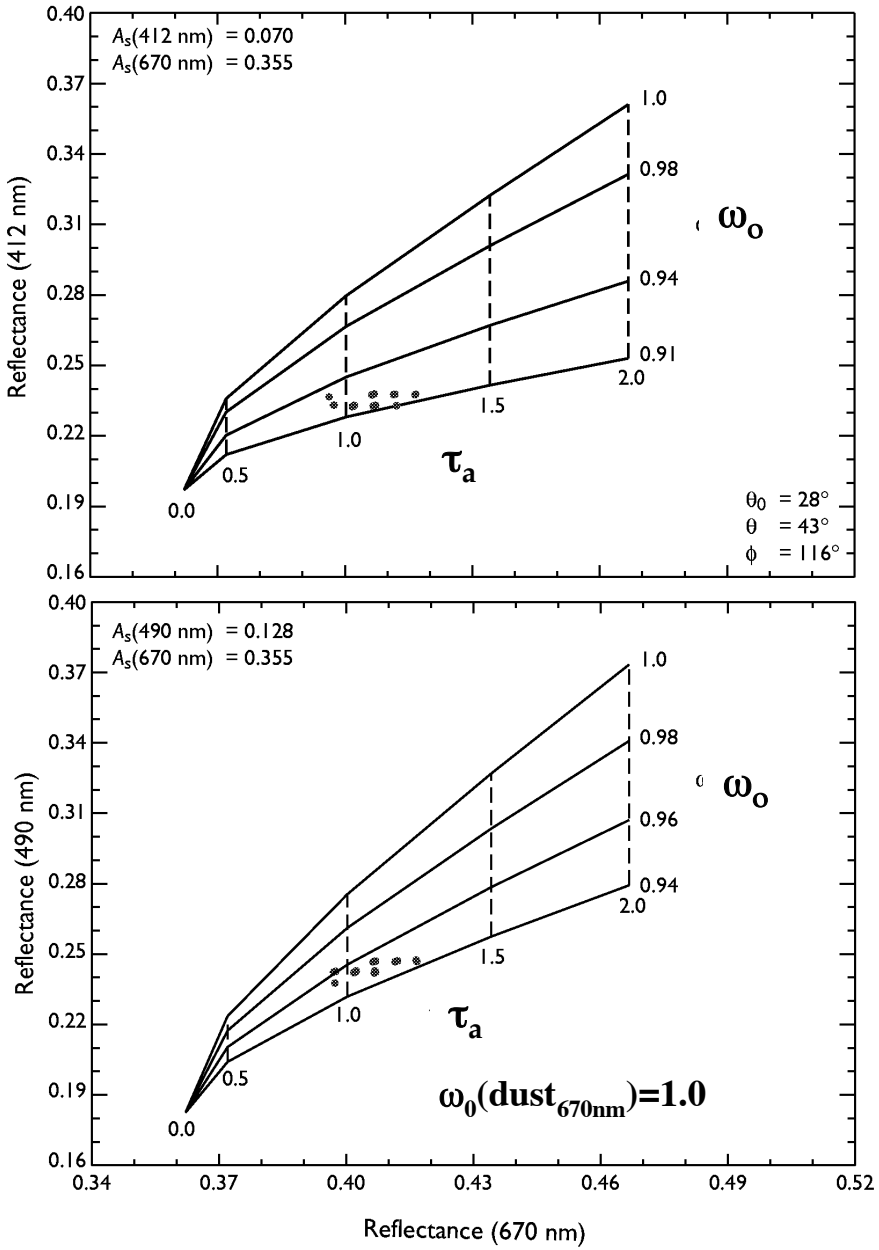
c) Spectral Reflectivity



Flowchart for Deep Blue Algorithm

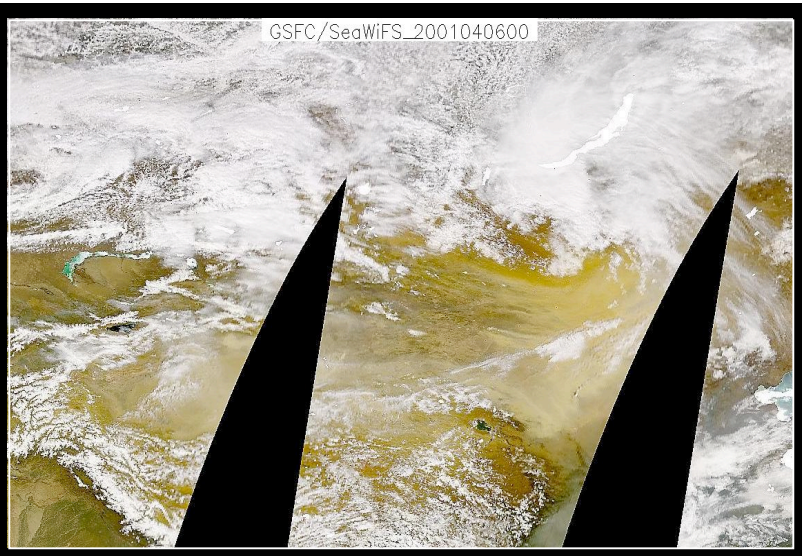


Deep Blue Algorithm for SeaWiFS/MODIS



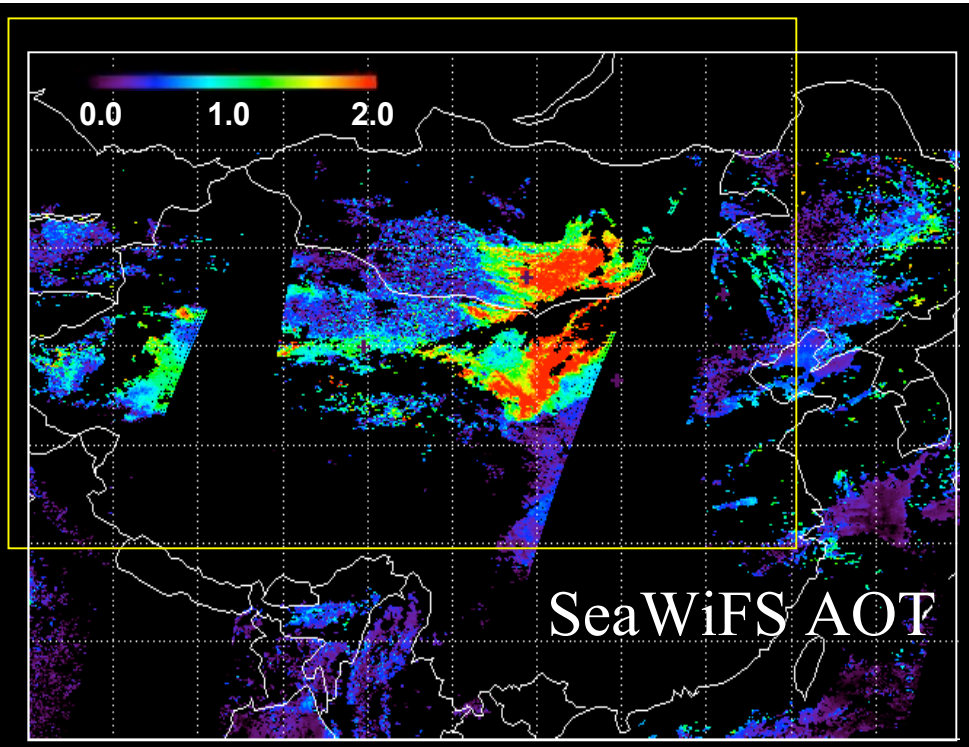
- **Utilize solar reflectance at λ = 412, 490, and 670 nm to retrieve aerosol optical thickness (τ_a) and single scattering albedo (ω_o).**
- **Less sensitive to aerosol height, compared to UV methods.**
- **Works well on retrieving aerosol properties over various types of surfaces, including very bright desert.**

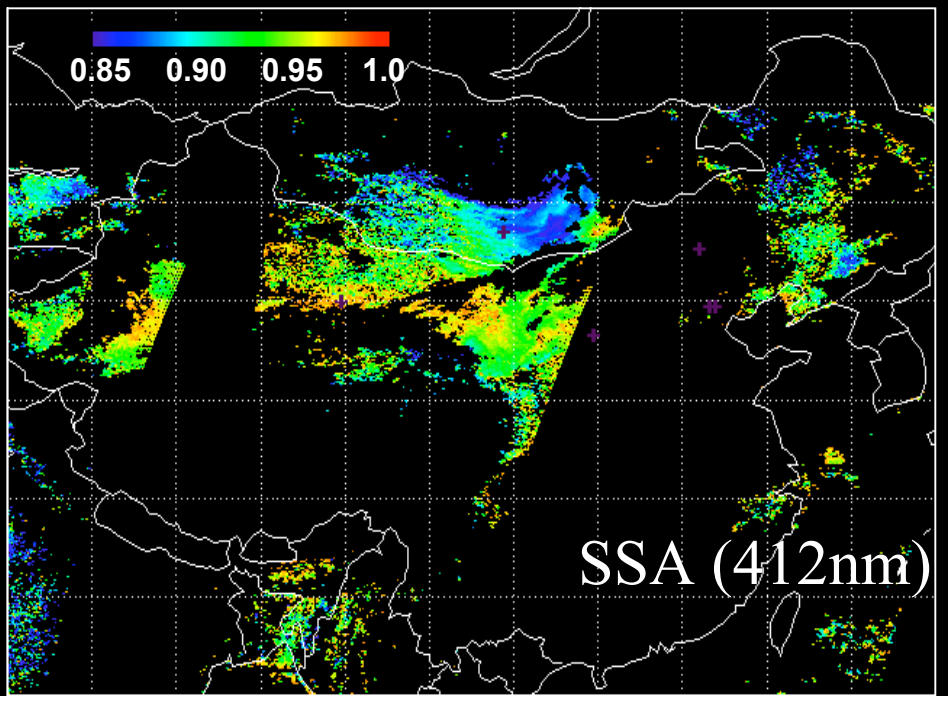
**Hsu, Tsay, King, and Herman, 2004: Aerosol properties over bright-reflecting source regions, IEEE TGRS, 42, 557-569.*



SeaWiFS RGB - Rayleigh

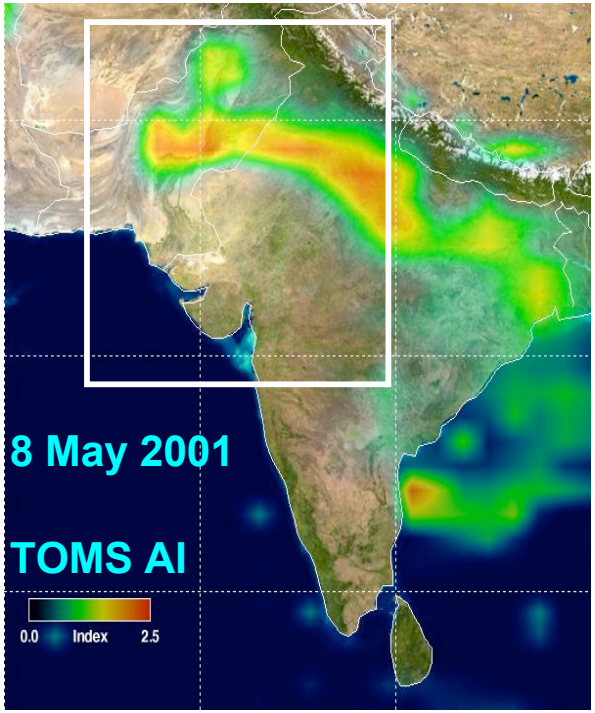
Asian Dust Outbreak
6 April 2001

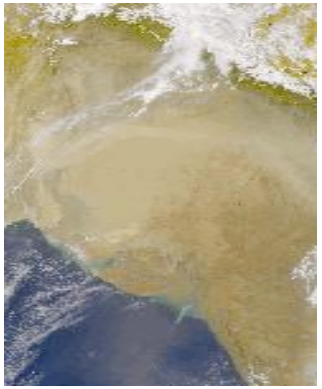




➪ *Deep Blue Algorithm:*

- *Cloud mask works very well*
- *Aerosol retrievals indicate dust storms originated from Gobi and Inner Mongolia regions*
- *Single scattering albedos are quite different between these two regions*

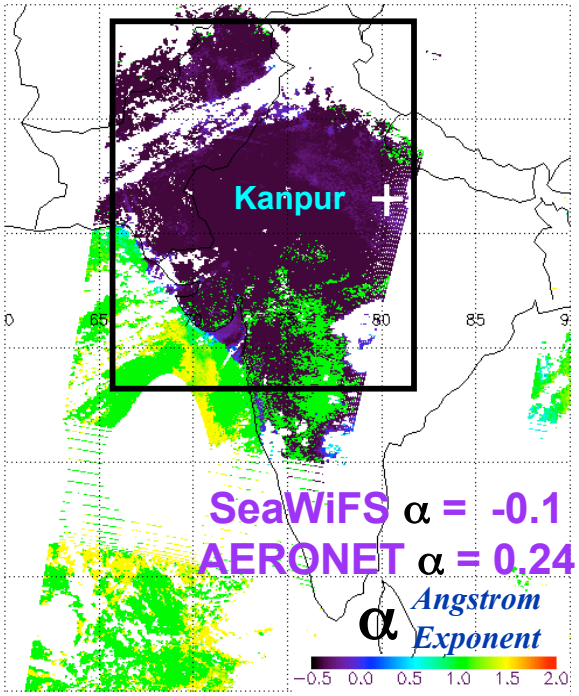


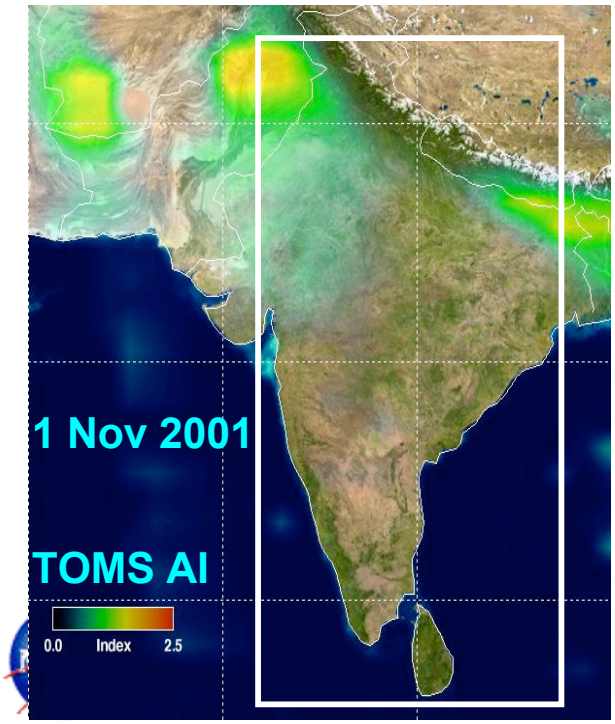


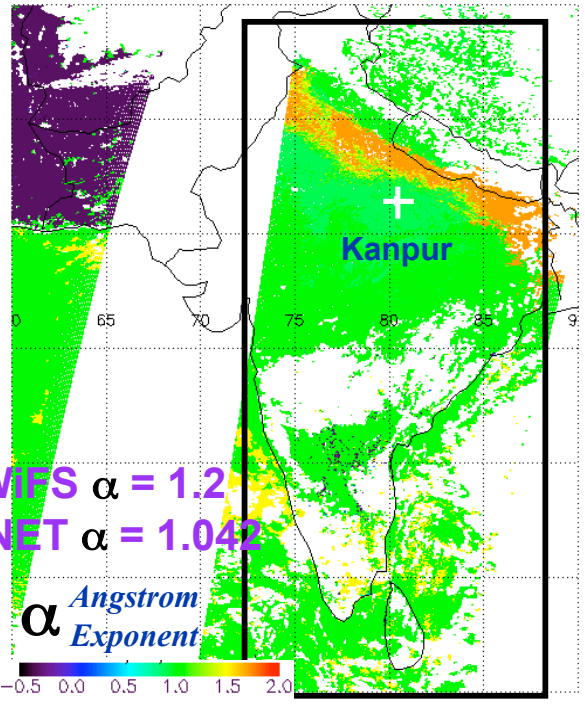
SeaWiFS RGB

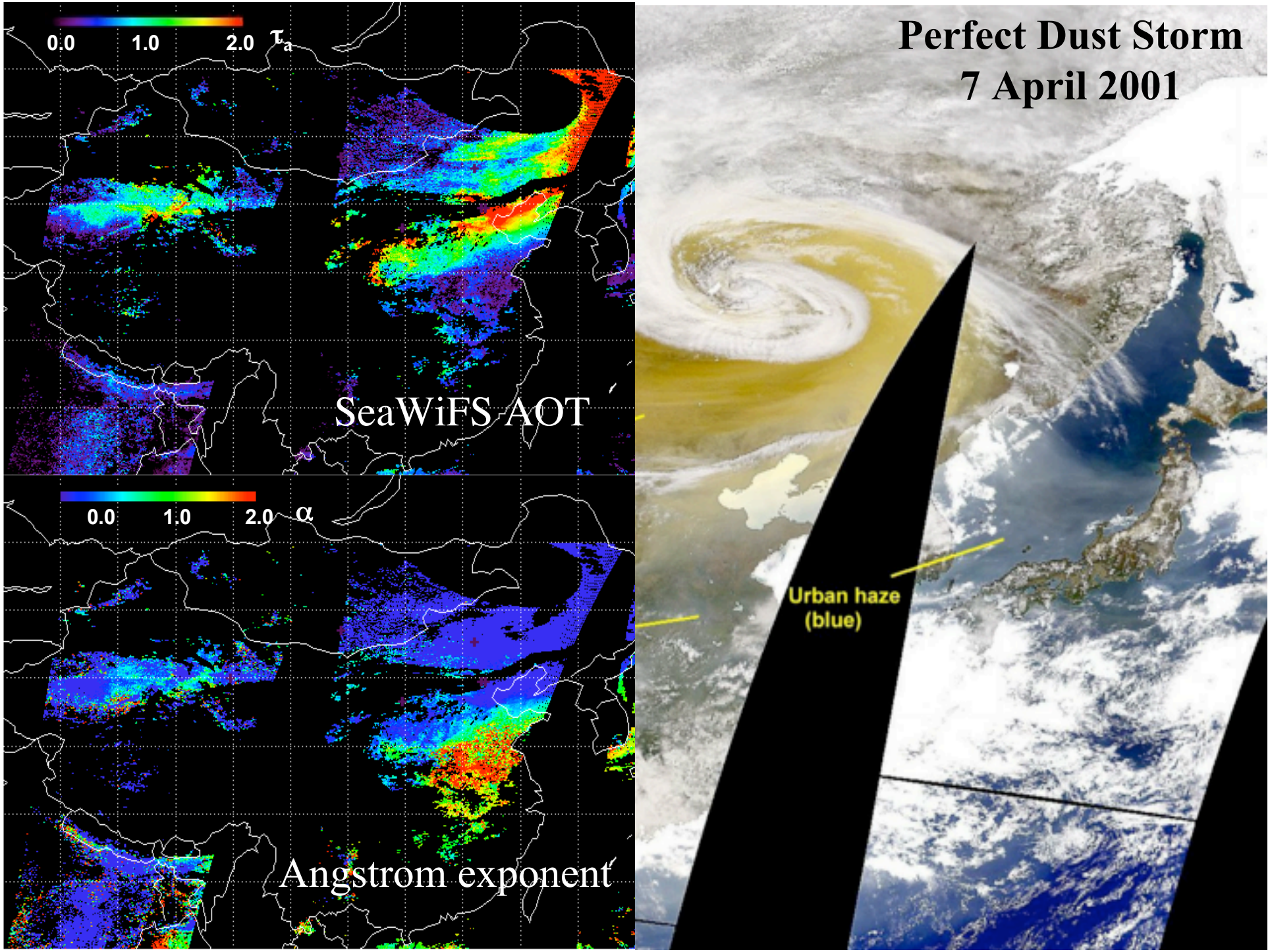
$$\tau_\lambda \propto \lambda^{-\alpha}, \text{(Ångström 1961)}$$

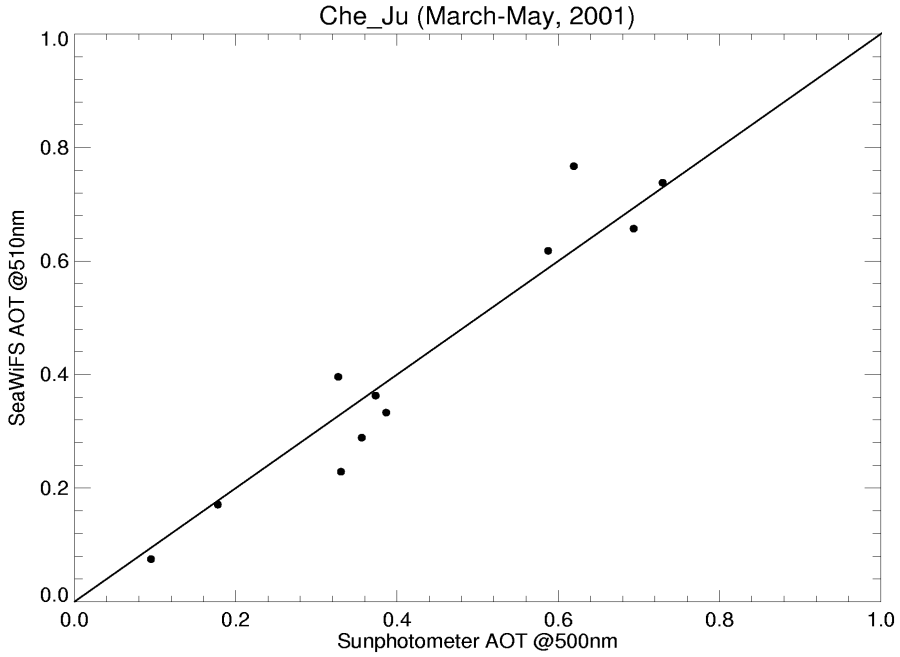
$$\alpha = \ln\left[\frac{\tau_1}{\tau_2}\right] \Big/ \ln\left[\frac{\lambda_2}{\lambda_1}\right]$$

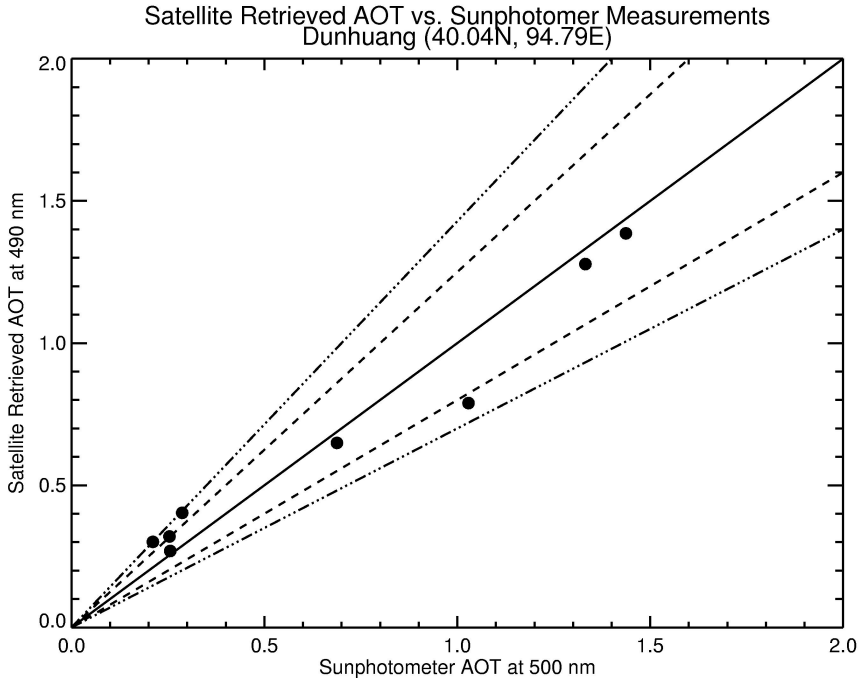


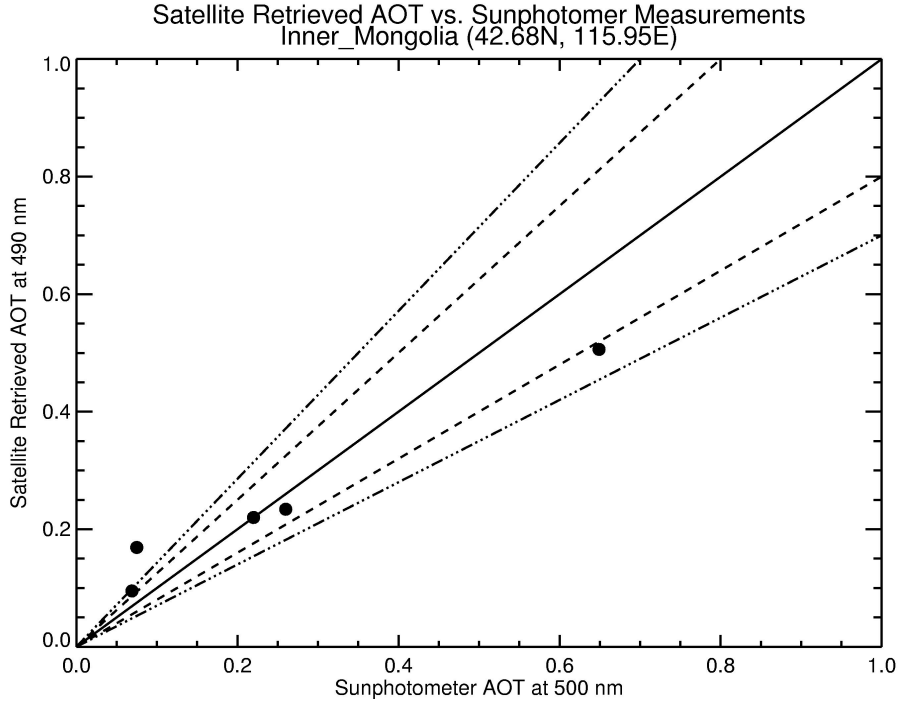


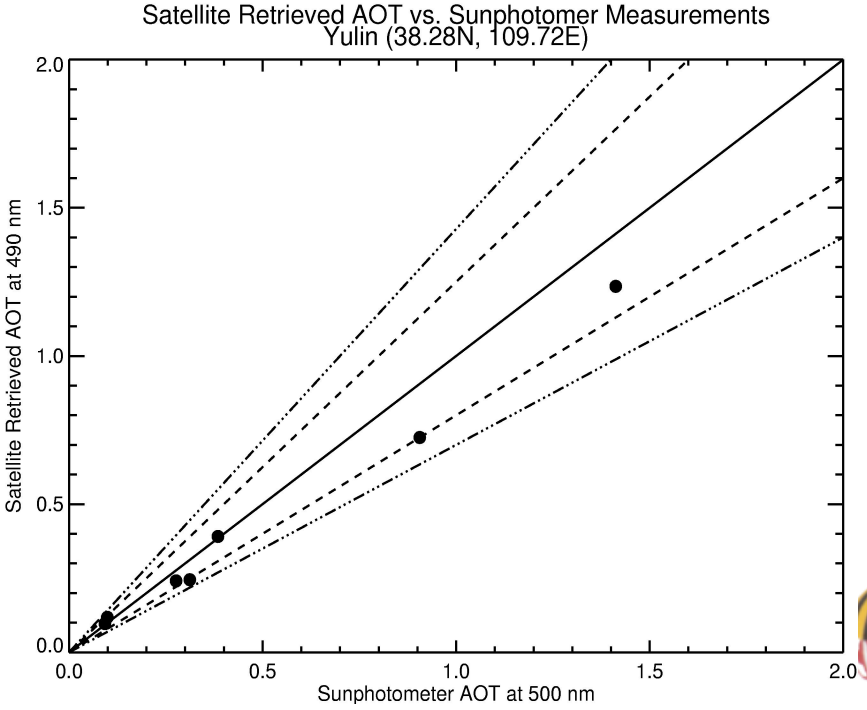



0.0
1.0
2.0
τ_a
SeaWiFS AOT
0.0
1.0
2.0
α
Angstrom exponent
Perfect Dust Storm
7 April 2001
Urban haze
(blue)


Che_Ju (March-May, 2001)
SeaWiFS AOT @510nm
Sunphotometer AOT @500nm
0.0
0.2
0.4
0.6
0.8
1.0

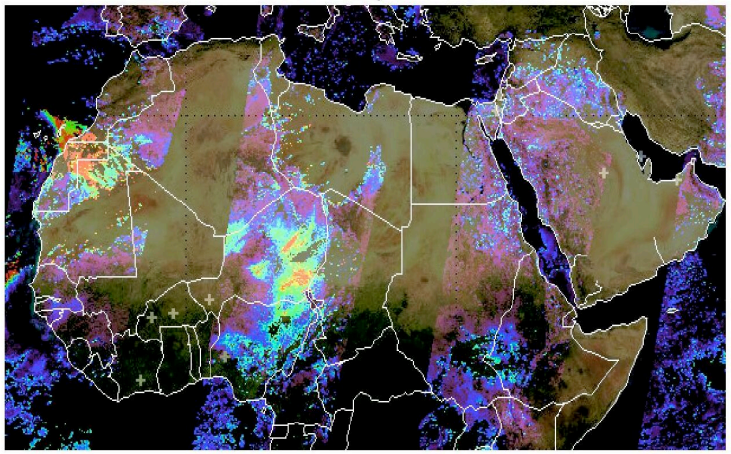

Satellite Retrieved AOT vs. Sunphotomer Measurements
Dunhuang (40.04N, 94.79E)
Satellite Retrieved AOT at 490 nm
Sunphotometer AOT at 500 nm
0.0
0.5
1.0
1.5
2.0


Satellite Retrieved AOT vs. Sunphotomer Measurements
Inner_Mongolia (42.68N, 115.95E)
Satellite Retrieved AOT at 490 nm
Sunphotometer AOT at 500 nm
0.0
0.2
0.4
0.6
0.8
1.0

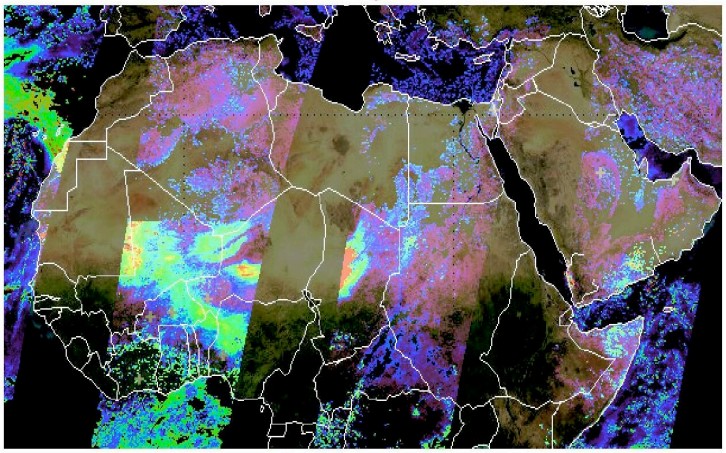

Satellite Retrieved AOT vs. Sunphotomer Measurements
Yulin (38.28N, 109.72E)
Satellite Retrieved AOT at 490 nm
Sunphotometer AOT at 500 nm
0.0
0.5
1.0
1.5
2.0

Aerosol Optical Thickness Retrieved from Deep Blue Algorithm: Dust plumes in Africa

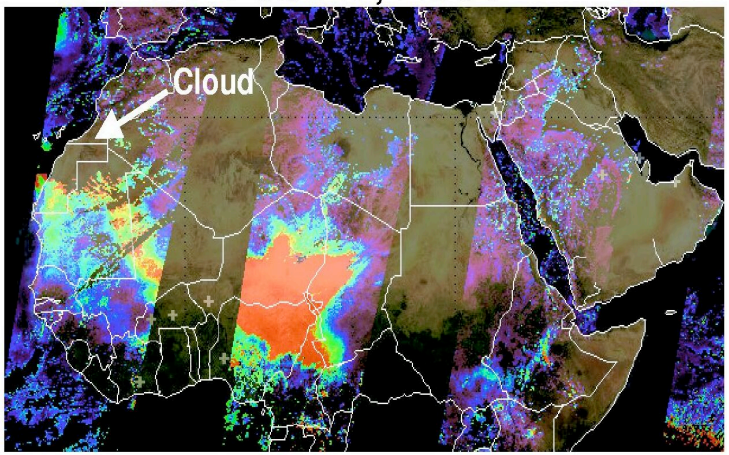
Feb 25, 2000

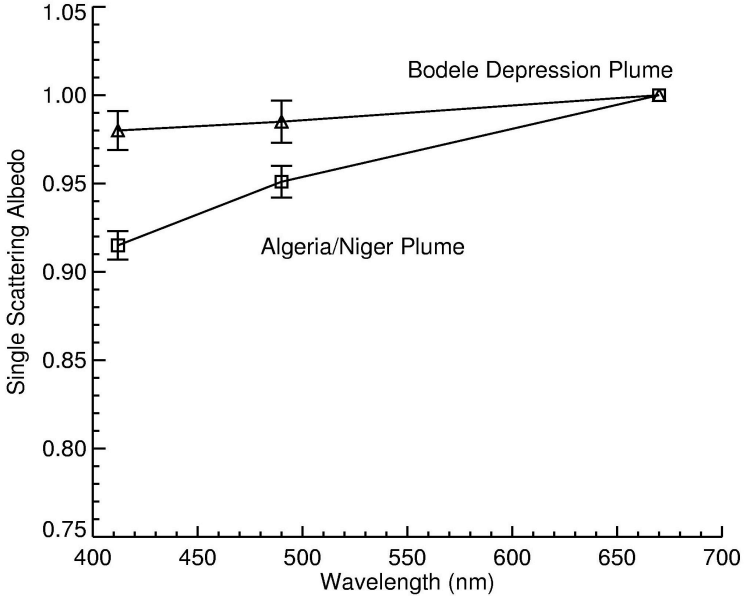


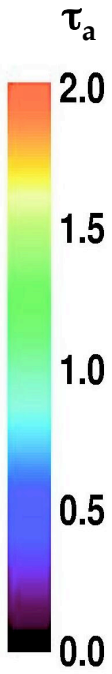
Feb 26, 2000



Feb 27, 2000

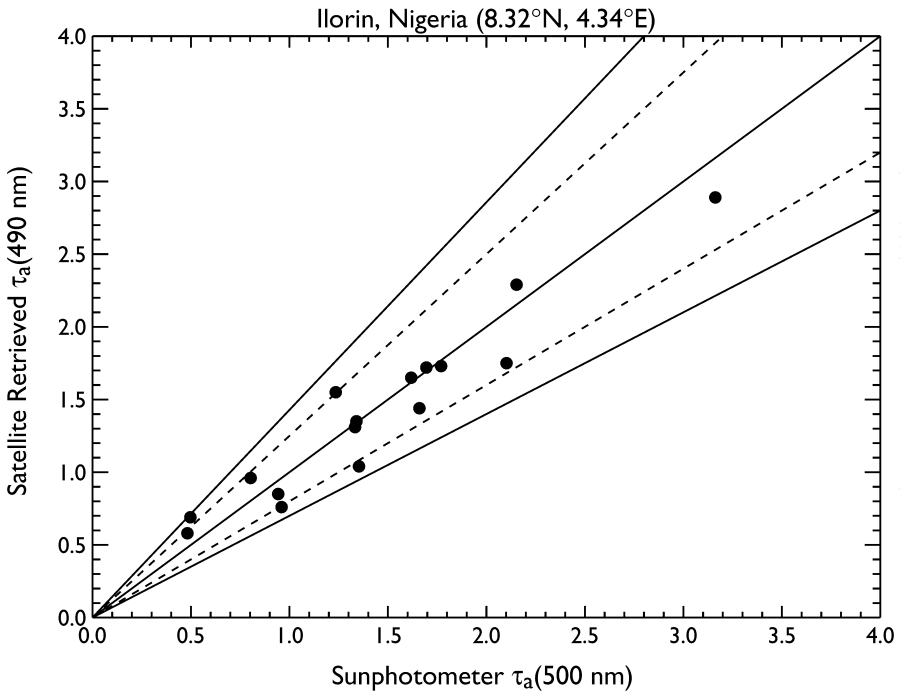




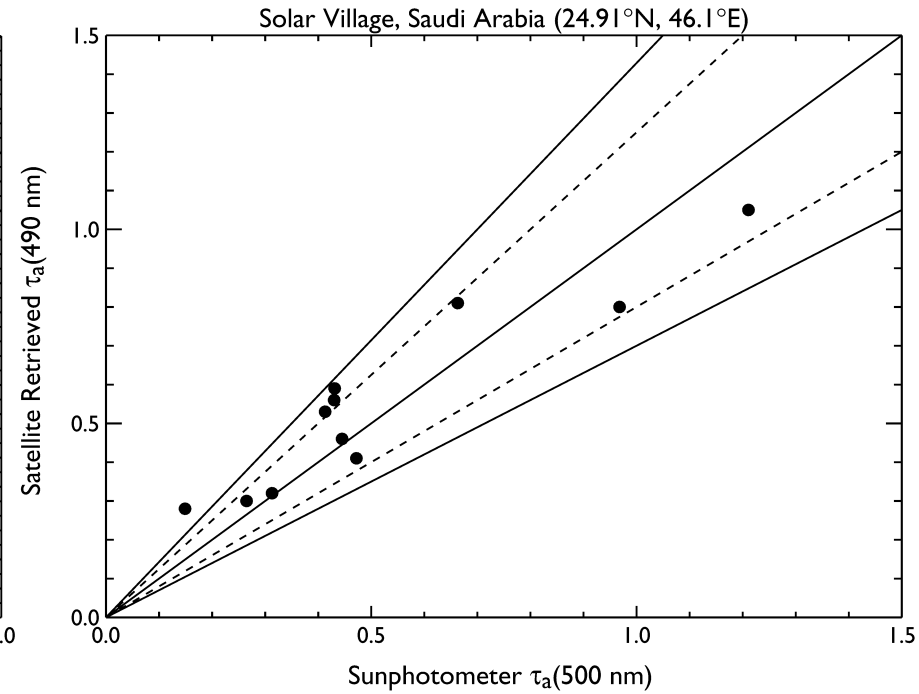


Validation: Comparisons with AERONET Aerosol Optical Thickness

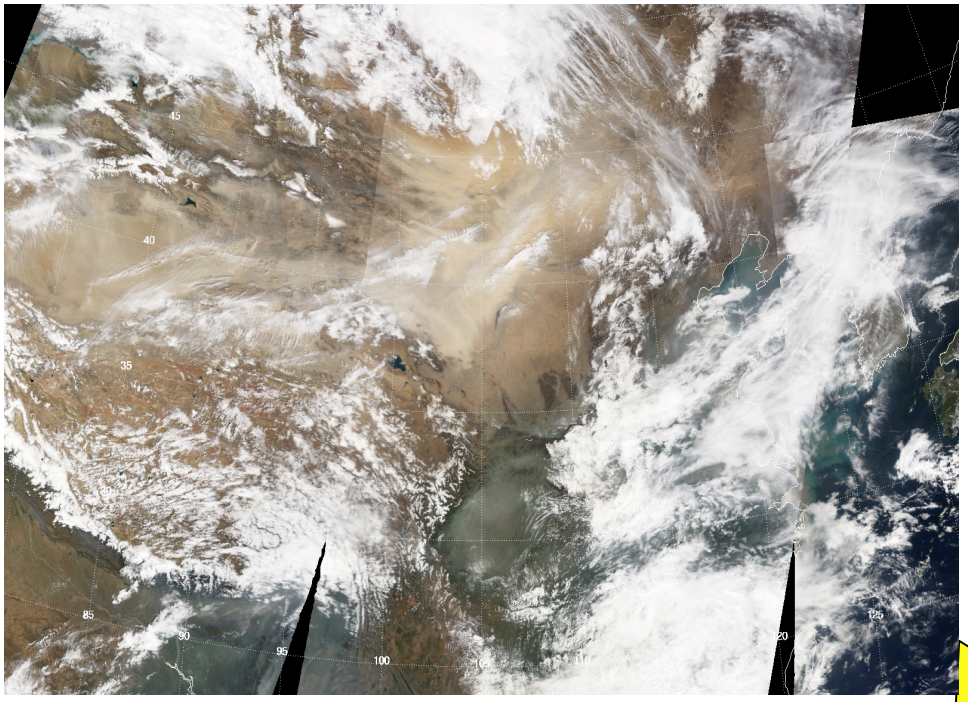
North Africa
February 2000



Arabian Peninsula
June - July 2000

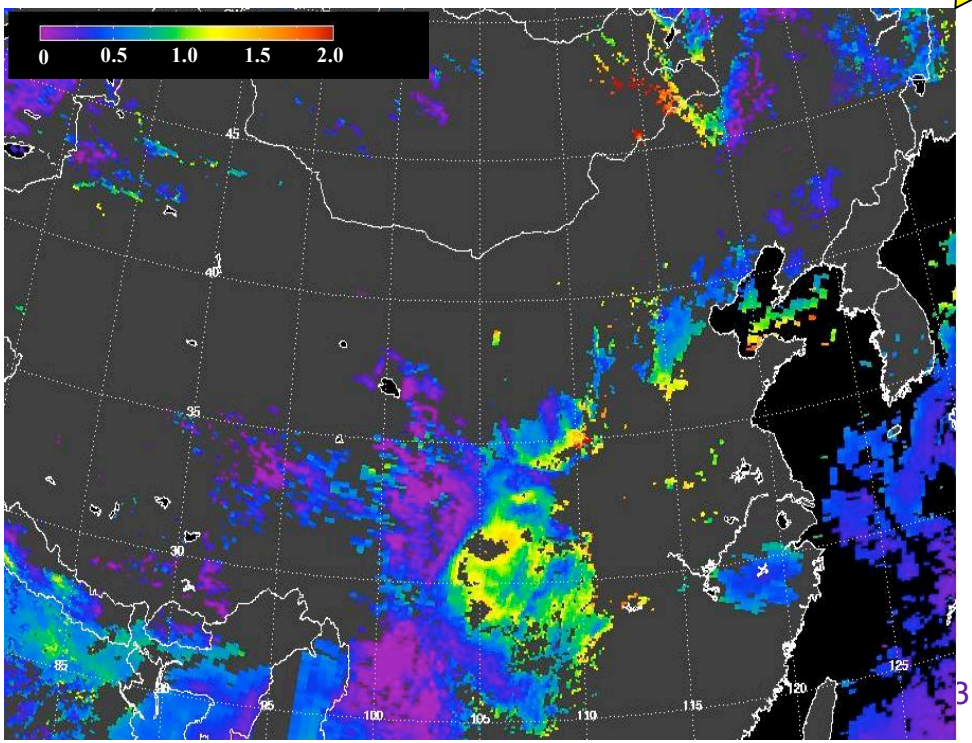


1st Case: 6 April 2001

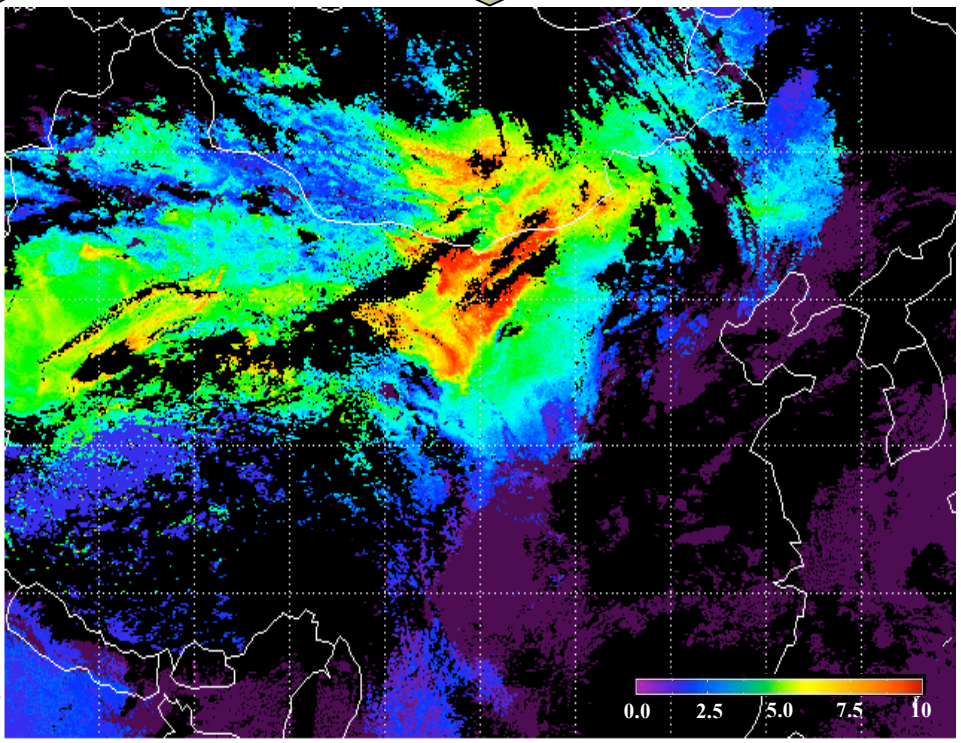


MODIS *Red*-*Green*-*Blue* with Rayleigh scattering removed

Current MODIS *Aerosol Optical Thickness*



MODIS *Deep Blue* *Aerosol Index*



Summary

- *It works!*
  - *Deep-Blue Algorithm well* for SeaWiFS measurements
  - Compared *well* with surface/aircraft products
  - Separate dust *well* from other anthropogenic sources

- *We expect:*
  - Implement *Deep-Blue Algorithm soon* for MODIS
  - Produce new MODIS products over bright-reflecting surfaces, and integrate into operational MODIS products

Backup Slides

Aerosol retrievals use an Aerosol Index:

Defined in a manner similar to the aerosol index for TOMS to distinguish between absorbing and non-absorbing aerosols:

$$AI = -100 \cdot \left[\log_{10}\left(\frac{I_{412}}{I_{490}}\right)_{meas} - \log_{10}\left(\frac{I_{412}}{I_{490}}\right)_{calc} \right]$$

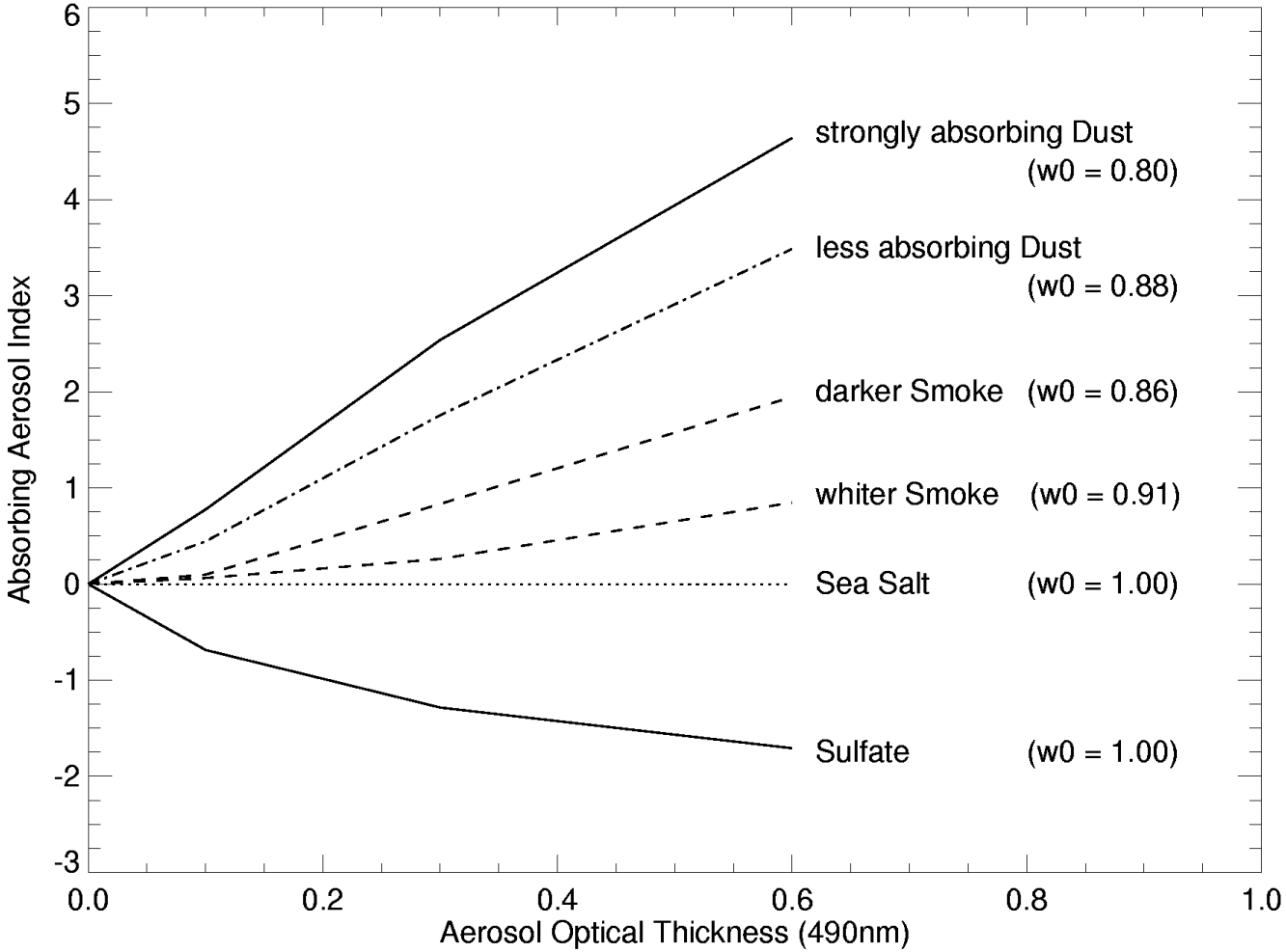
I_{meas} = Radiance measured by the satellite at 412 or 490 nm

I_{calc} = Radiance calculated using a radiative transfer model

Large AI's are caused by high AOT or by highly absorbing aerosols. As with UV wavelengths, the visible AI is also a function of altitude.

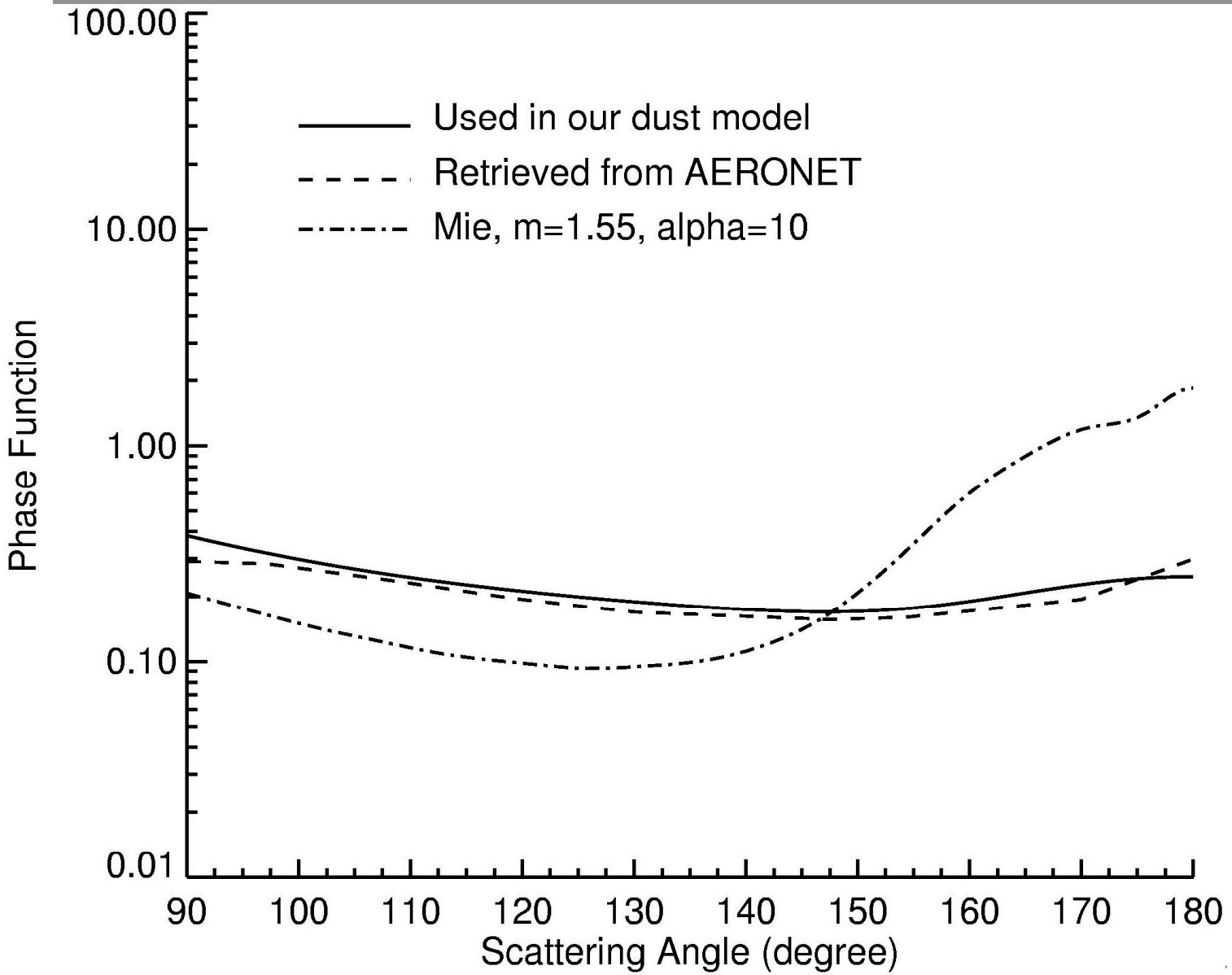
*Properties of Aerosol Index**

The dependence of AI with both AOT and absorption is confirmed by simulations we performed using aerosols of different types

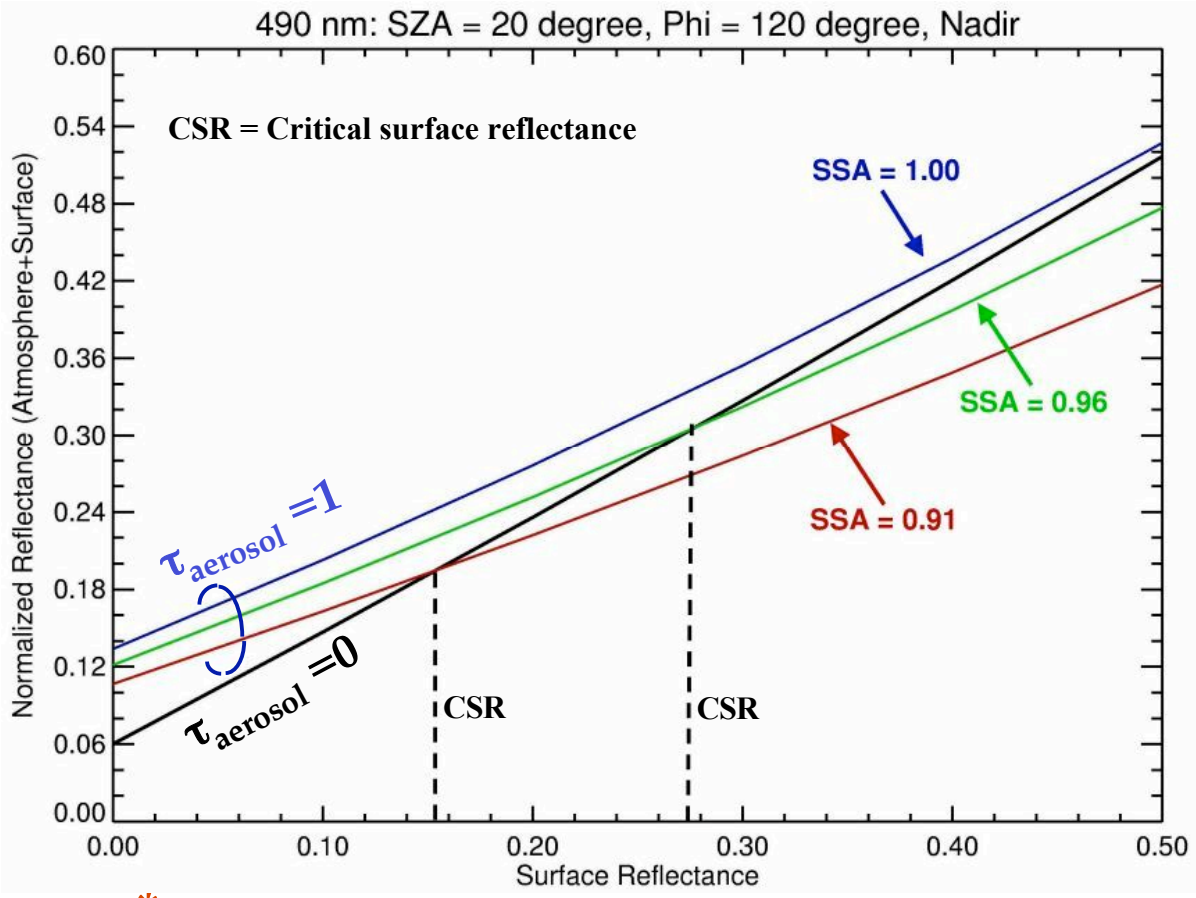


***The properties of blue water were assumed in this simulation**

Phase Function for Dust Model



Principle of Aerosol Retrievals*

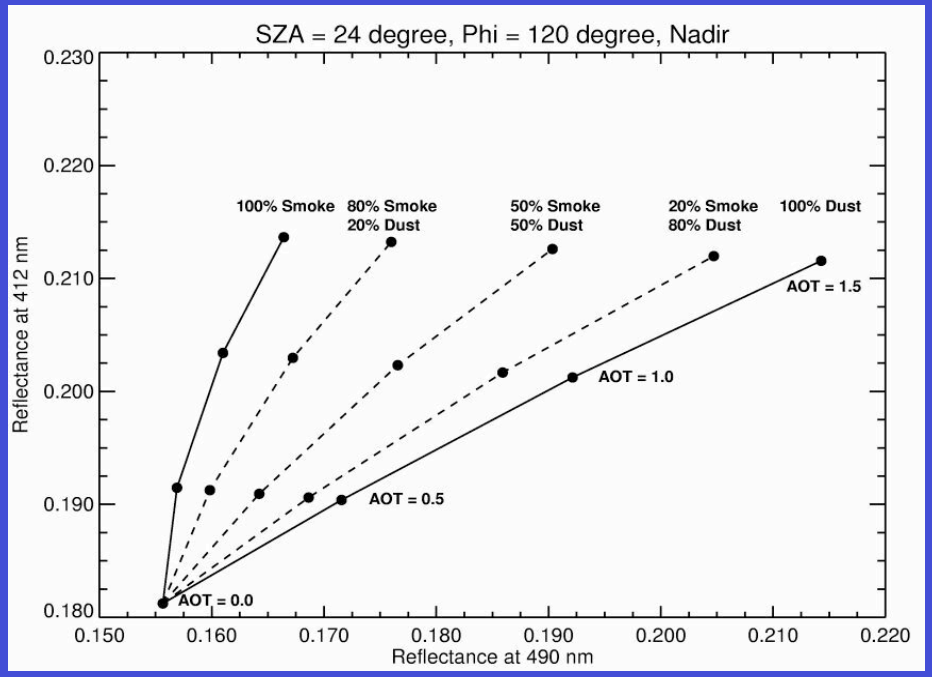


- *Simulated apparent 490 nm reflectance (atmosphere + $\tau_{aerosol}$ =1 + surface) at the top of the atmosphere, as a function of surface reflectance.*
- *Non-absorbing aerosols make contrast apparent reflectance diminished faster for brighter surface.*
- *Absorbing aerosols make apparent reflectance brighter (or darker) for darker (or brighter) surface.*
- *The dashed lines denote the critical values of surface reflectance where the presence of aerosol CANNOT be detected by that particular spectral wavelength.*

*Hsu, Tsay, King, and Herman, 2004: Aerosol properties over bright-reflecting source regions, IEEE TGRS, 42, 557-569.

The aerosol characteristics used to generate the simulated radiances in these two figures are shown below

Aerosol Model	τ_{412}/τ_{470}	τ_{490}/τ_{470}	Refractive Index 412 nm	Refractive Index 490 nm	ω_0 412 nm	ω_0 490 nm
Dust	1.00	1.00	1.55 – 0.020i	1.55 – 0.008i	0.91	0.96
Smoke	1.30	0.92	1.55 – 0.022i	1.55 – 0.026i	0.90	0.89



In areas of mixed aerosol types, we linearly mix radiances from the dust aerosol model, R^{dust}, with those from the smoke aerosol model, R^{smoke} $= aR^{dust} + (1-a)R^{smoke}$

Gaussian distribution with a peak at 3 km and a width of 1 km was assumed