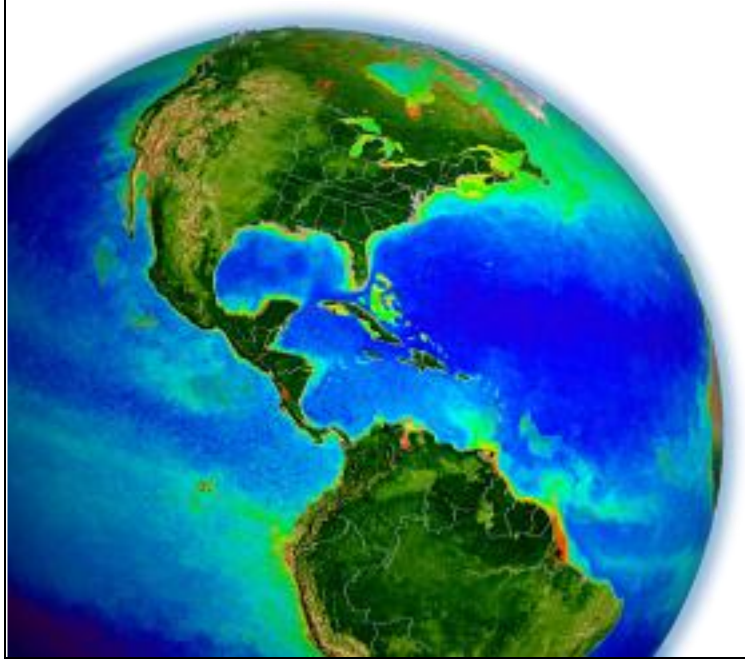
Aerosol Determination



Sean Bailey

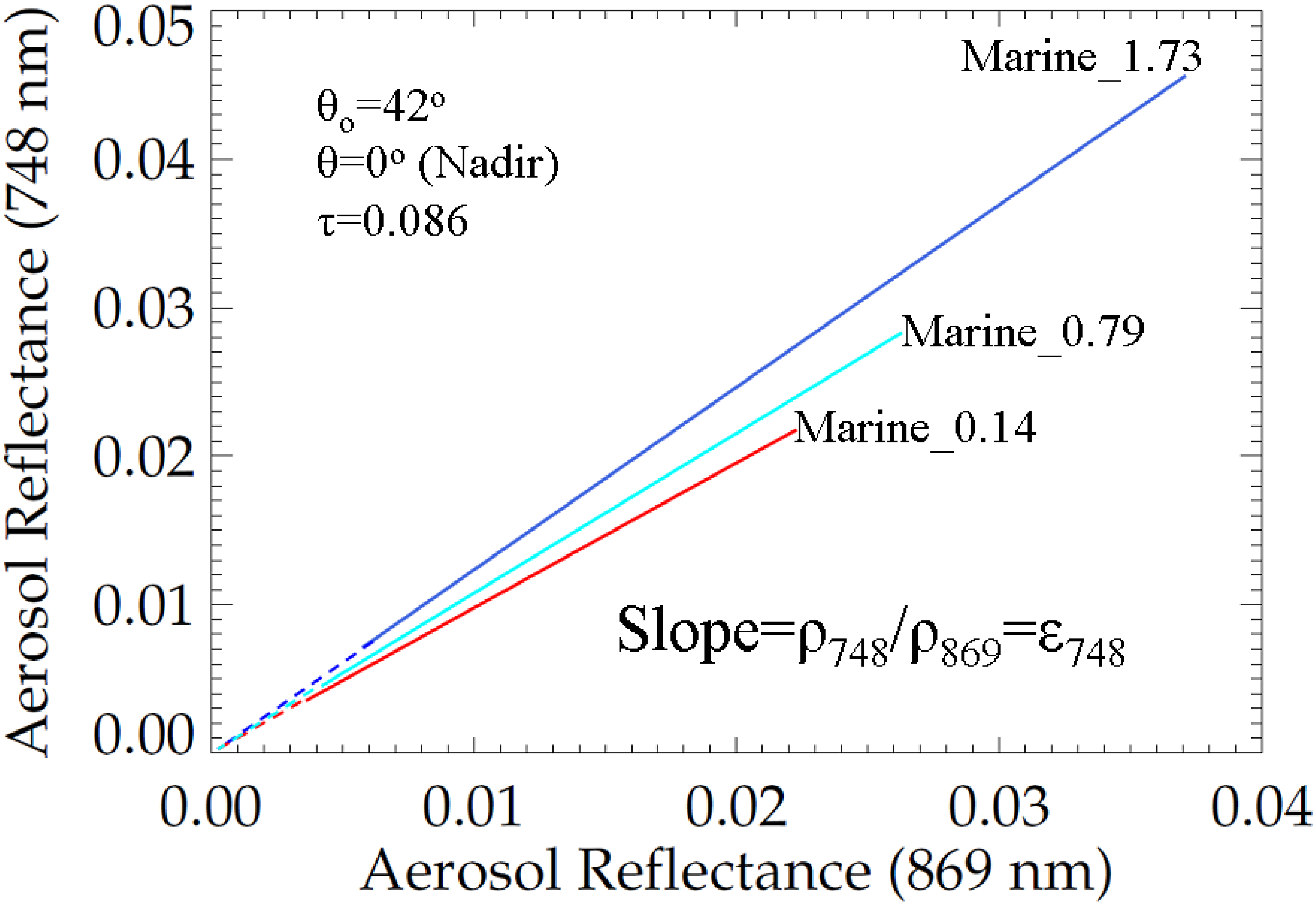
NASA Goddard Space Flight Center

06 May 2013

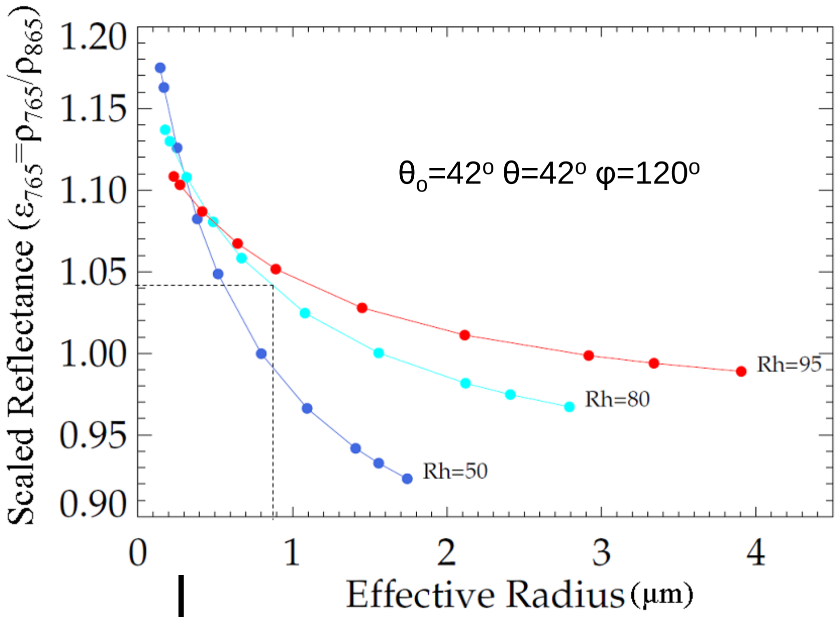
International Ocean Color Science Meeting

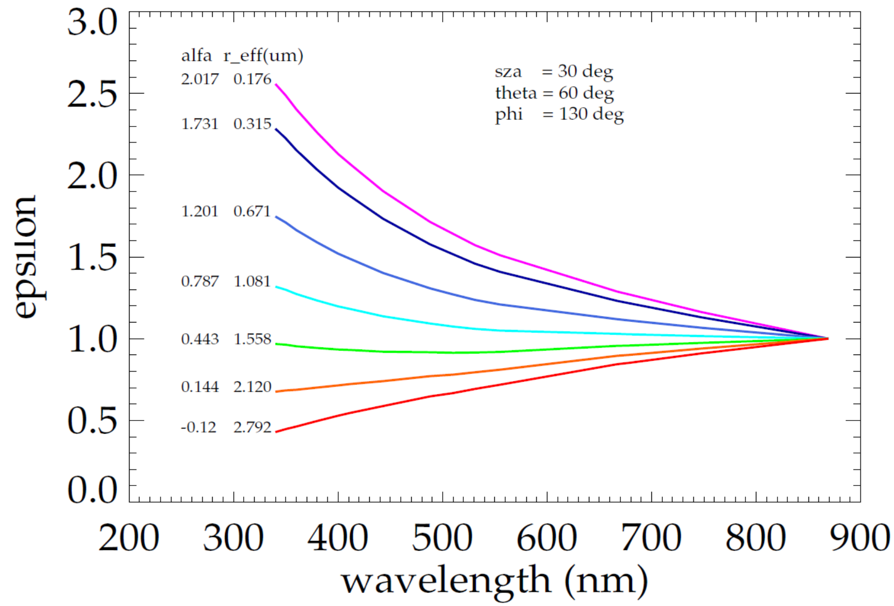
Darmstadt, Germany

Scaled Reflectance (ε)



Computation of Aerosol Correction





$$\frac{\rho_{748}^{\mathrm{mod}}}{\rho_{869}^{\mathrm{mod}}} = \frac{\rho_{748}^{obs}}{\rho_{869}^{obs}}$$

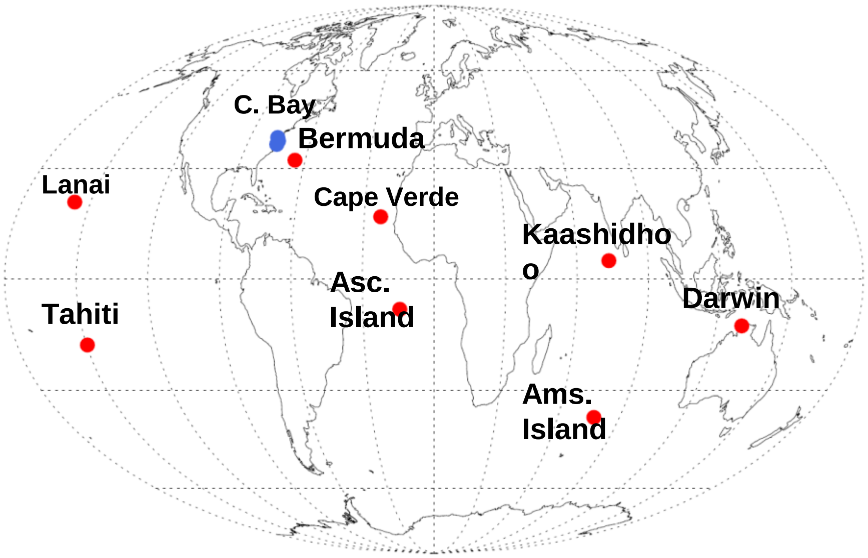
$$\varepsilon_{\lambda}^{\mathrm{mod}} = \frac{\rho_{\lambda}^{\mathrm{mod}}}{\rho_{869}^{\mathrm{mod}}} = \frac{\rho_{\lambda}^{obs}}{\rho_{869}^{obs}}$$

$$\rho_{\lambda}^{obs} = \varepsilon_{\lambda}\rho_{869}^{obs}$$

AERONET Data

- Open Ocean
  - No. of Sites: 8
  - No. of Daily Obs. 2543

- Chesapeake Bay
  - No. of Sites: 3
  - No. of Daily Obs. 2193

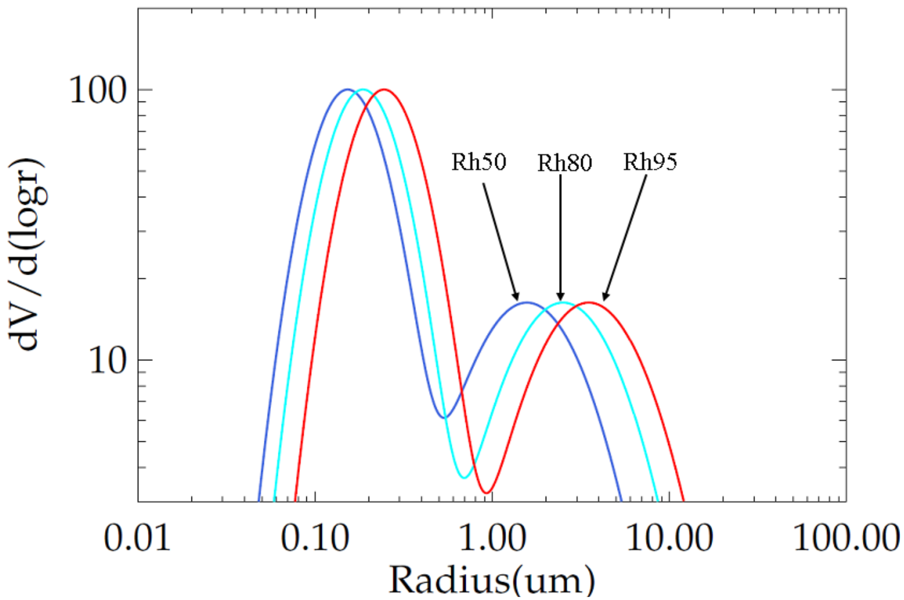


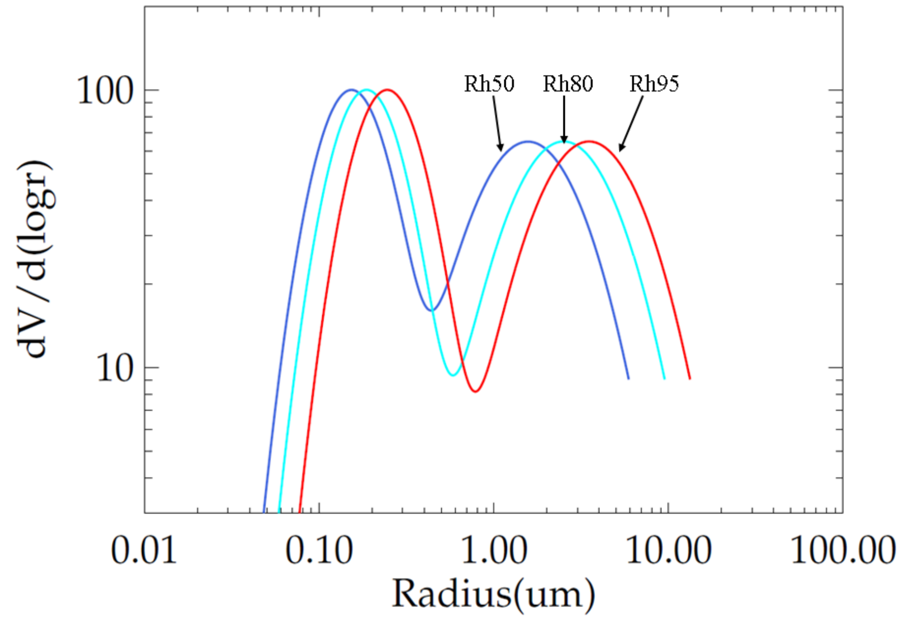
- Each site had 150 or more daily observations
- Only observations with $\tau_{aer} \leq 0.3$ were considered

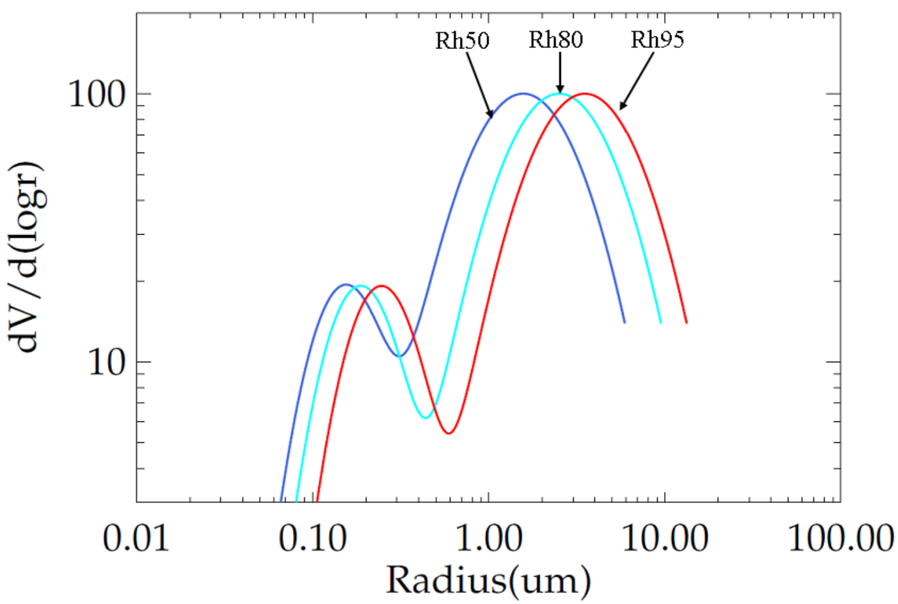
Details of the Ahmad Aerosol Models

- Type of distribution:	Lognormal bimodal
- Fine mode:	Similar to coastal region aerosols
- Coarse mode:	Similar to open ocean aerosols
- Modal radii:	Vary with RH
- Std. dev.:	Constant with RH
- Refractive Index:	Vary with RH
- Absorption:	All absorptions due to fine mode aerosols.
- No. of RH :	Eight (30, 50, 70, 75, 80, 85, 90 and 95)
- No. of aerosol models/RH:	10 (constructed by varying fine mode fraction from zero to one)
- Total no. of aerosol models:	80 (8RH x 10 models/RH)

Ahmad Aerosol Models Examples



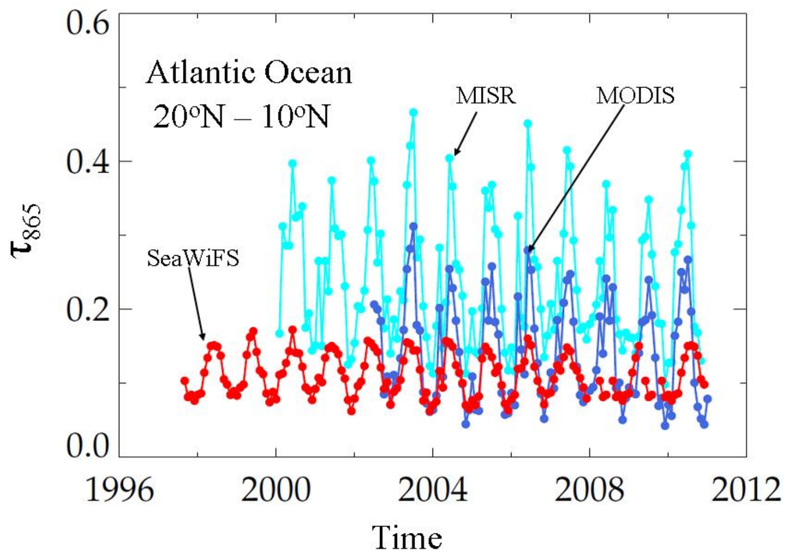


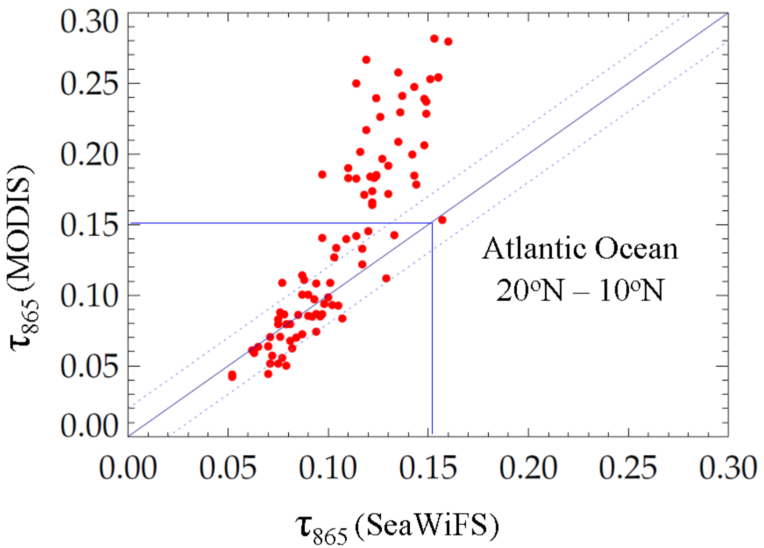


- Model selection is based on:
  - Relative humidity (NCEP)
  - Scaled reflectance ($\varepsilon_\lambda = \rho_\lambda / \rho_{\lambda o}$)

Comparison of τ_{865} (SeaWiFS vs. MODIS(Atmos) vs. MISR)

Atlantic Ocean (10°N – 20°N Dust Belt)



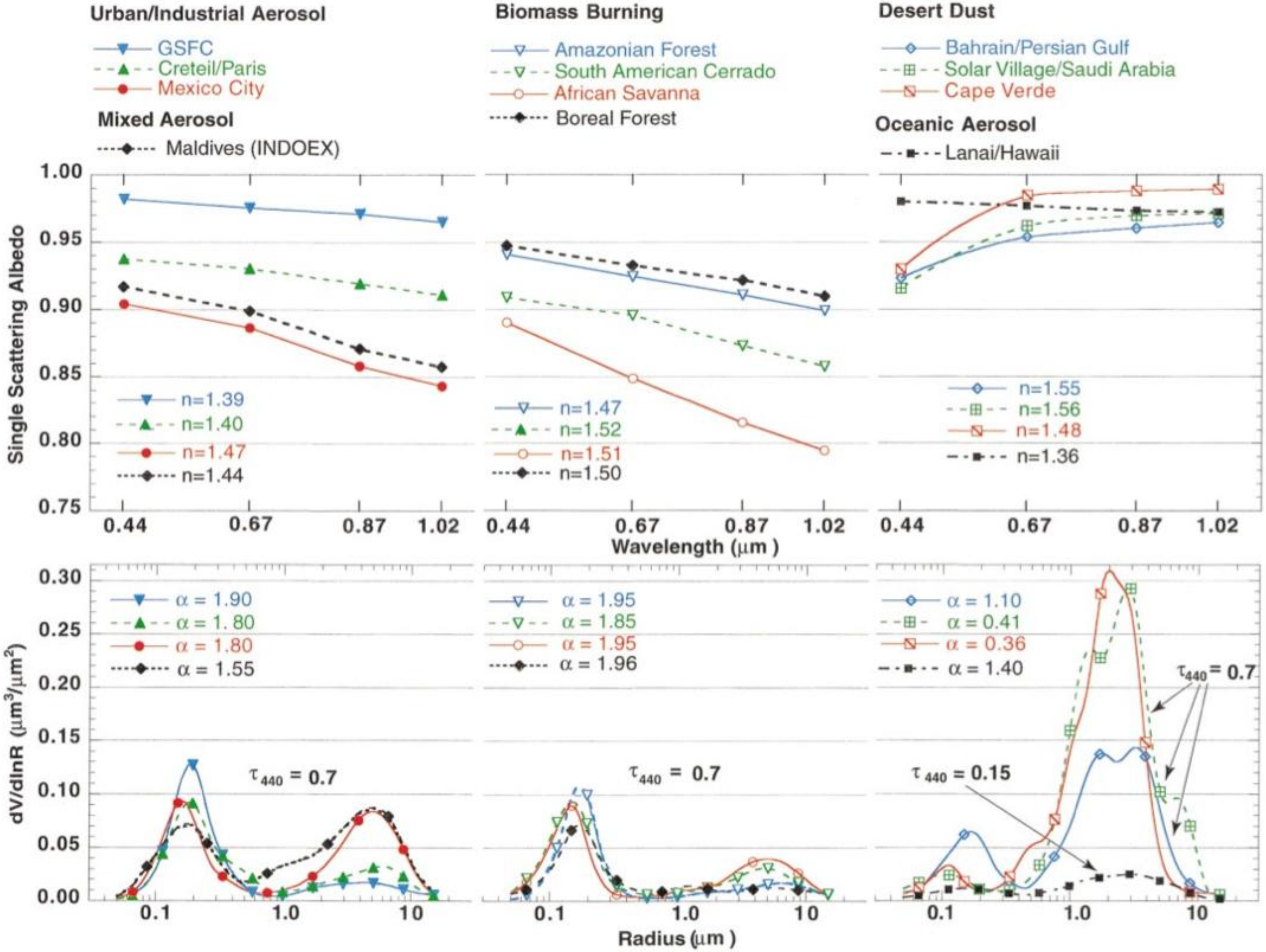


- For small τ_{865} (< 0.15) SeaWiFS and MODIS values agree very well one another over the entire overlapping time period.

- Since ocean color retrievals are made under low to moderate aerosol loads, SeaWiFS effectively screens out large values of τ_{865}. This results in large bias when τ_{865} exceeds 0.15

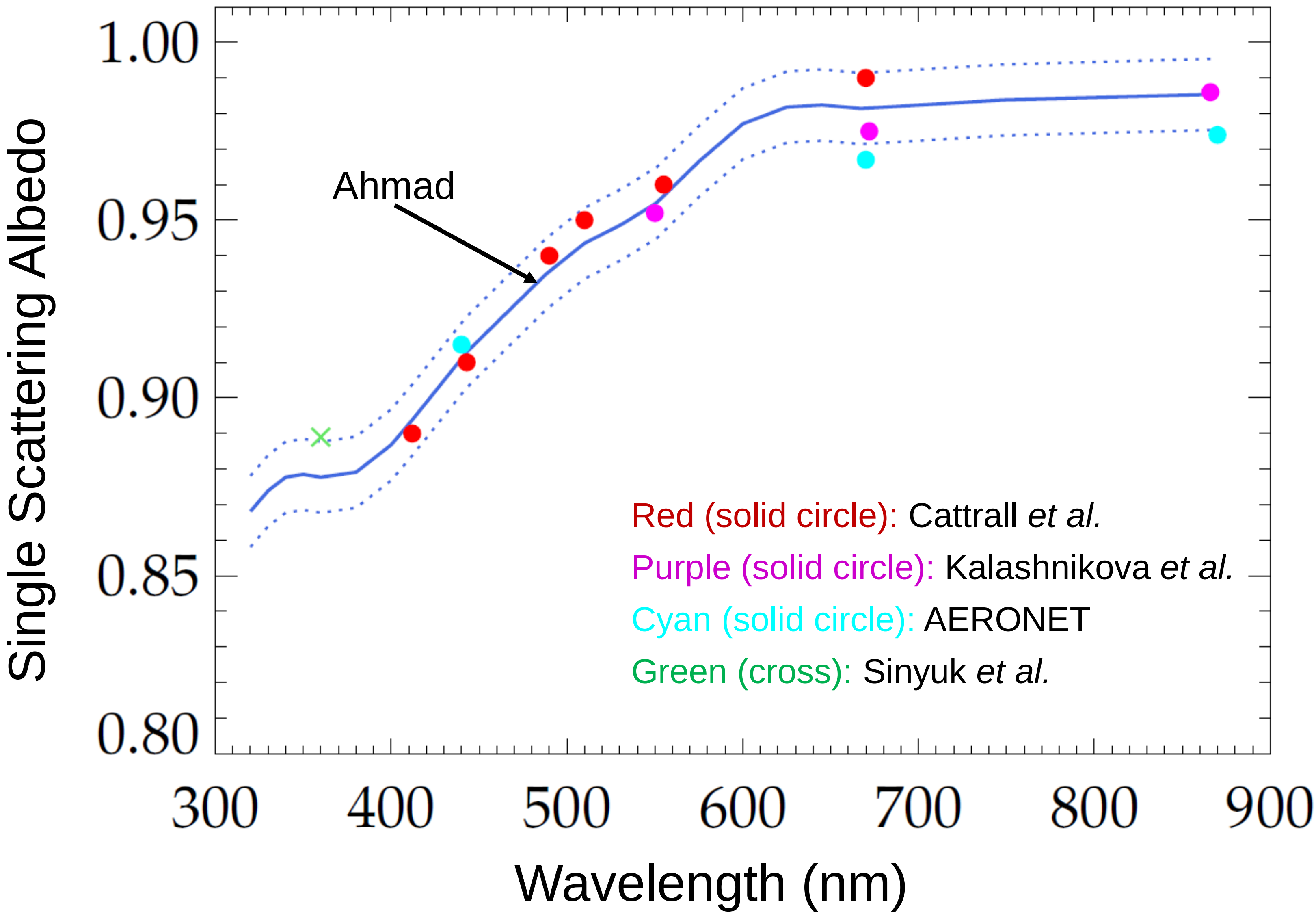
Absorbing Aerosols

- Dust
- Black Carbon
  - incomplete combustion
    - fossil fuels, bio-fuels, biomass
  - emitted in both anthropogenic and naturally occurring soot
- Urban/Industrial Pollution

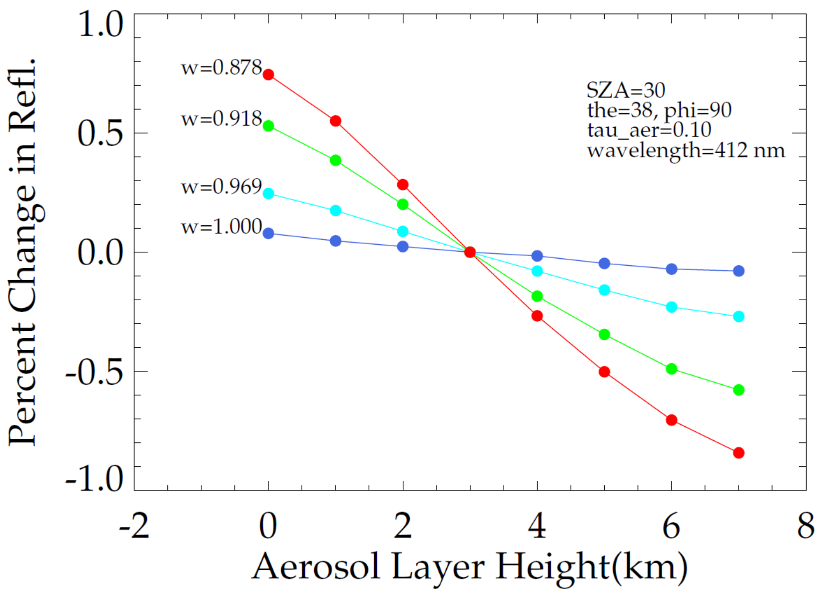


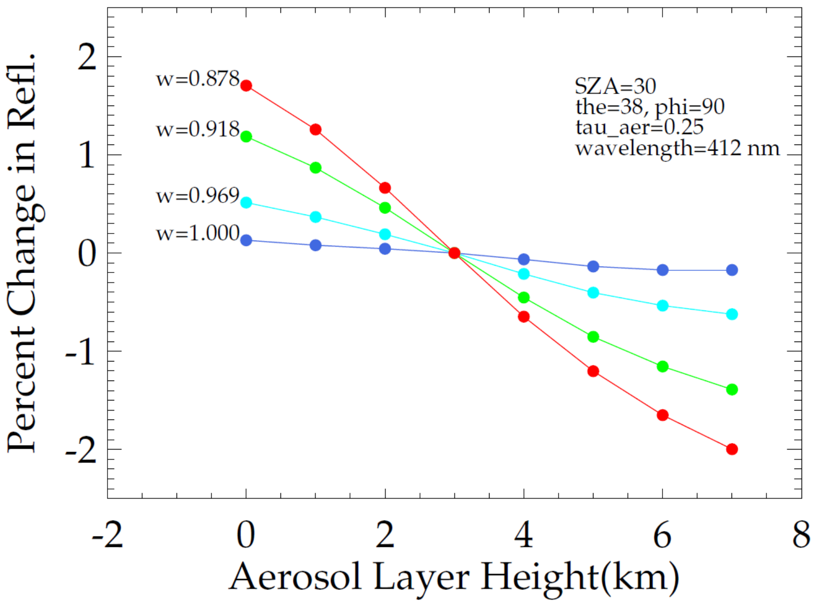
Dubovik, O., B. Holben, T. F. Eck, A. Smirnov, Y. J. Kaufman, M. D. King, D. Tanré, and I. Slutsker (2002), Variability of absorption and optical properties of key aerosol types observed in worldwide locations, *J. Atmos. Sci., 59*, 590-608.

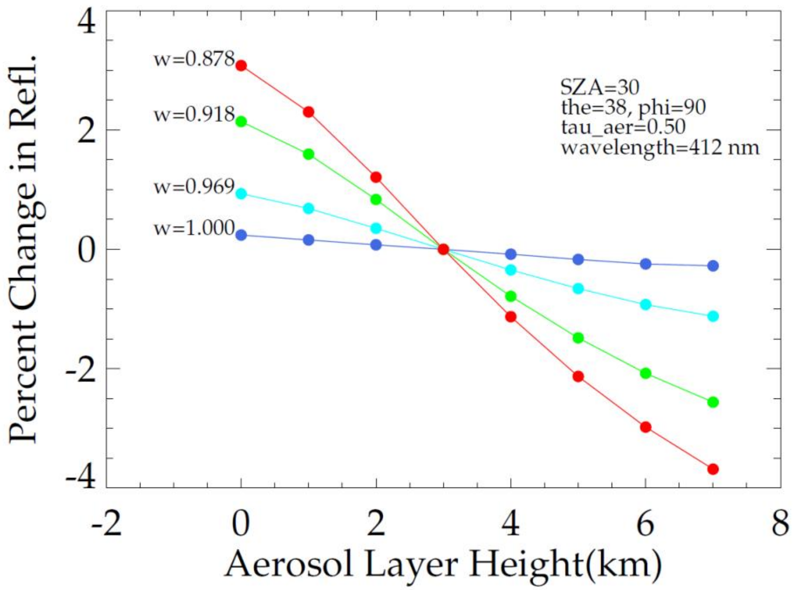
Dust Spectral Dependence



TOA Reflectance - Aerosol Layer Height

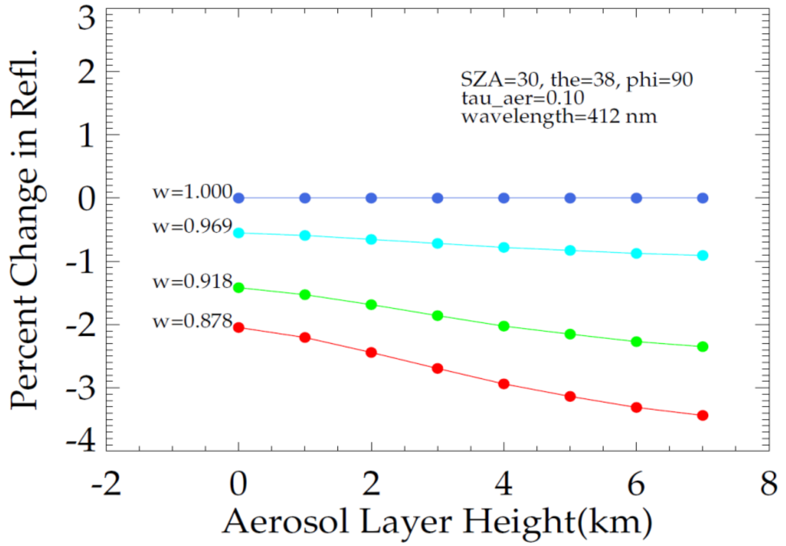


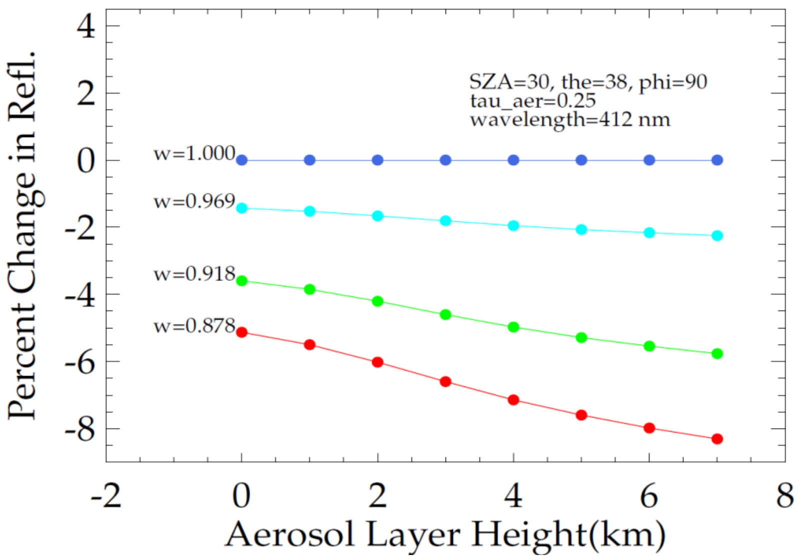


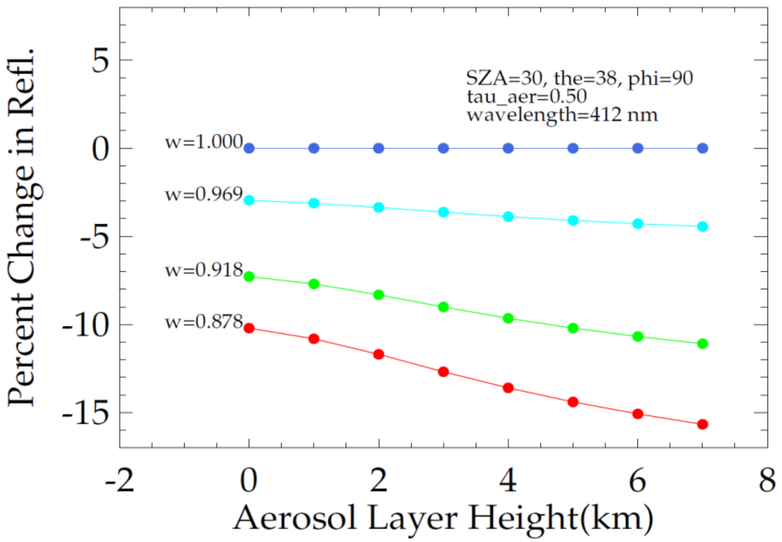


- Note: Based on our latest dust model, the SSA at 412nm is ~ 0.89. For τ_{aer}=0.25, an error of 1 km in aerosol layer height would change the TOA reflectance by ~ 0.7%. This will result in 7% change in water-leaving radiance. The error will increase with an increase in τ_{aer}

TOA Reflectance - Aerosol Layer Height







The effect of assigning wrong SSA to aerosols…even if the aerosol layer-height is exactly known…

TOA reflectance for each aerosol model has been normalized by the TOA reflectance of a **non-absorbing aerosol** model at exactly the same height.

i.e. for an aerosol layer at 3 km, and τ_{aer}=0.25, a change in SSA value from 0.878 to 0.918 would result in a change of ~2% in TOA reflectance . This is equivalent to a change of 20% in water-leaving reflectance

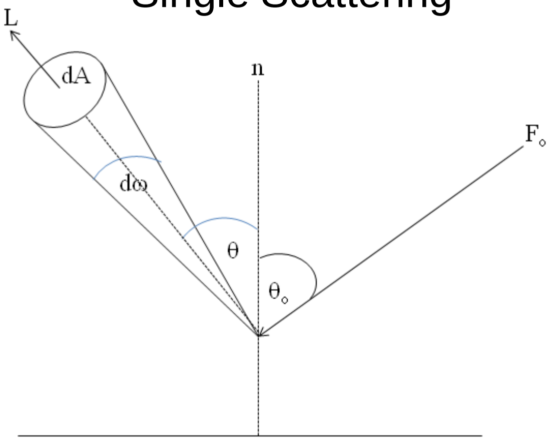
One Small Step…

Some Basic Definitions

$$\rho_\lambda^s = \frac{\pi L^s}{\mu_o F_o}$$

$$\varepsilon_{\lambda_o \lambda}^s = \frac{\rho_\lambda^s}{\rho_{\lambda_o}^s}$$

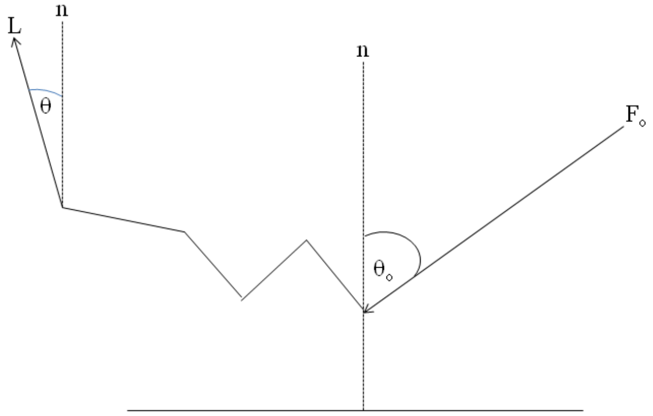
Single Scattering



$$\rho_\lambda^m = \frac{\pi L^m}{\mu_o F_o}$$

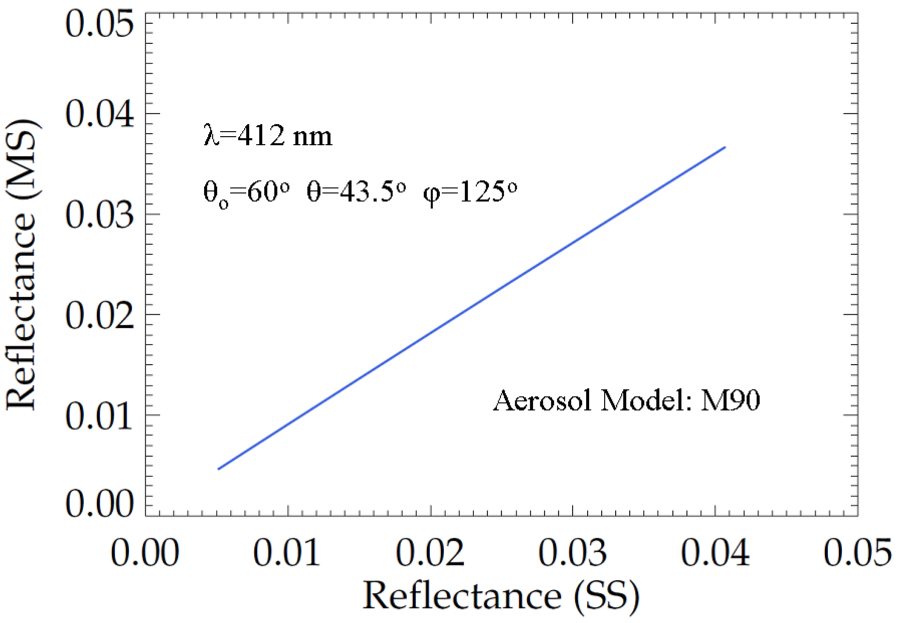
$$\varepsilon_{\lambda_o \lambda}^m = \frac{\rho_\lambda^m}{\rho_{\lambda_o}^m}$$

Multiple Scattering



Relationship Between Single & Multiple Scattered Reflectances

• In atmospheric correction algorithm the relationship between single and multiple scattered reflectances is defined as:



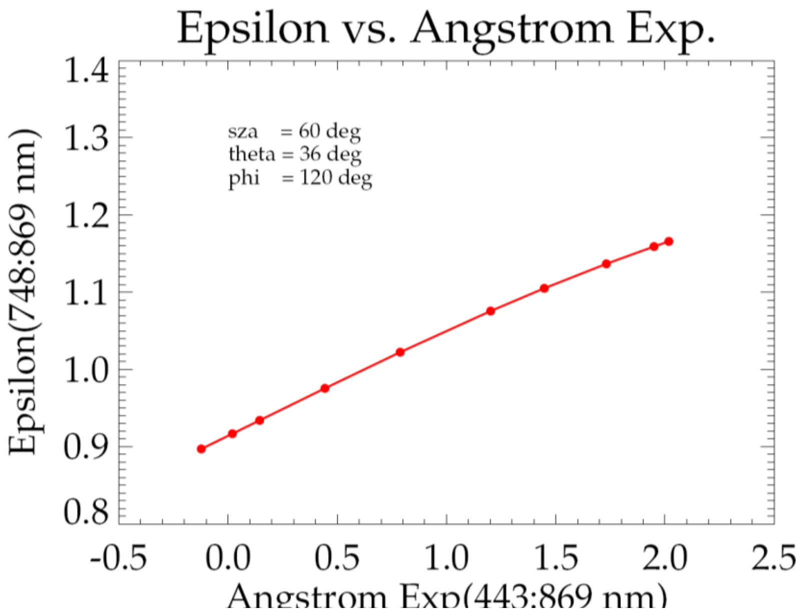
$$ln(\rho_{ms}) = a_0 + a_1\, ln(\rho_{ss}) + a_2[ln(\rho_{ss})]^2$$

Computation of ε_{ss}(obs.) from ε_{ms}(obs.)

- GW94 Algorithm

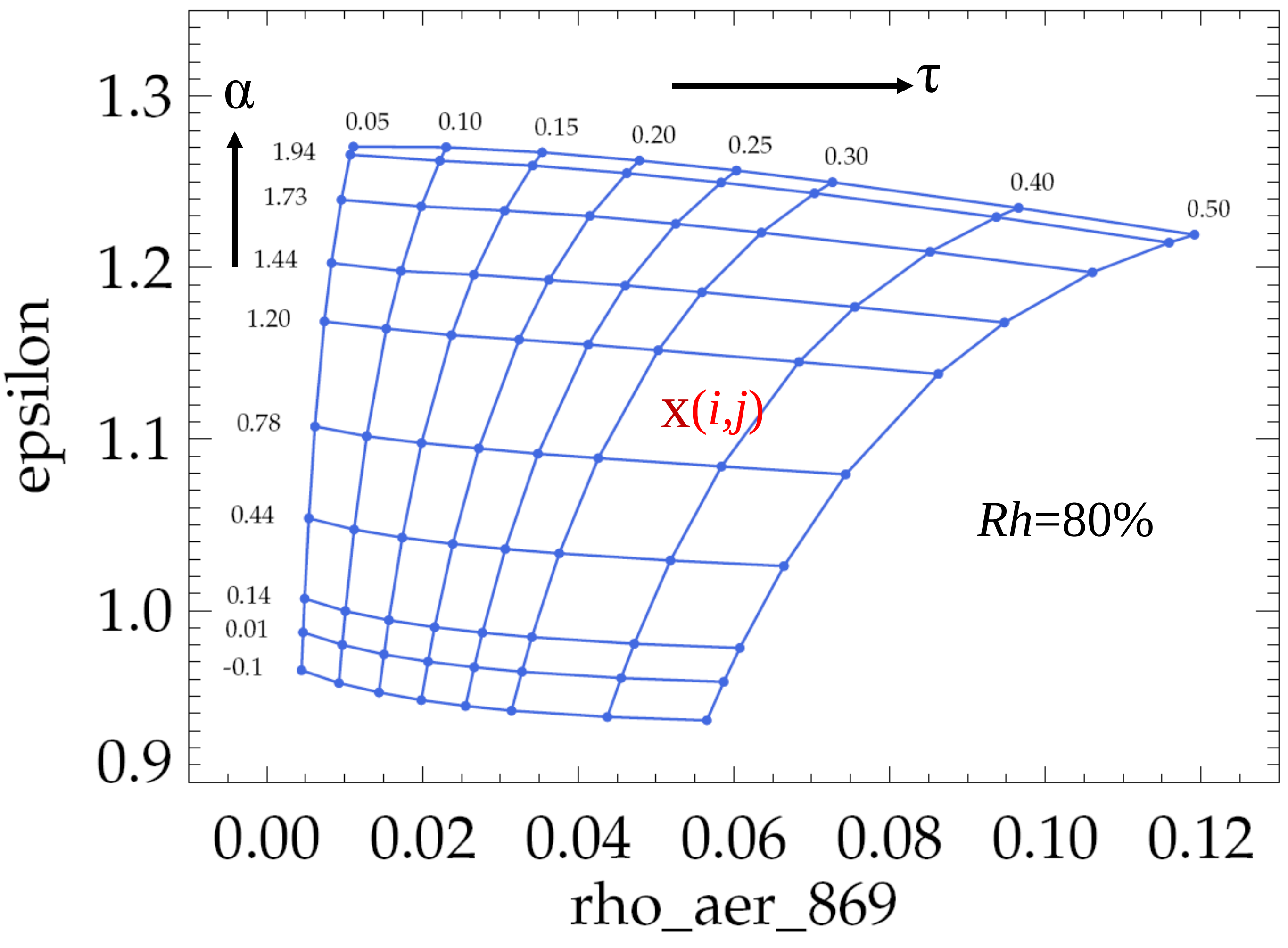
$$ln(\rho_{ms}) = a_0 + a_1\, ln(\rho_{ss}) + a_2[ln(\rho_{ss})]^2$$

- Using the observed multiple scattered $\rho_{ms}(\lambda_{748}, \lambda_{869})$ values, compute the single scattering $\rho_{ss}(\lambda_{748}, \lambda_{869})$ values for each aerosol model of the selected Rh suite.



- Compute the single scattering epsilon values ($\varepsilon_{ss}=\rho_{748}/\rho_{969}$).
- Determine the mean ε_{ss} value.
- Next, throw away the two extreme ε_{ss} values and re-compute the mean ε_{ss} value
- Continue this process until only four ε_{ss} values are left.
- Mean of the four ε_{ss} values is then considered as the single scattering ε_{ss} value for the observed ε_{ms} value.

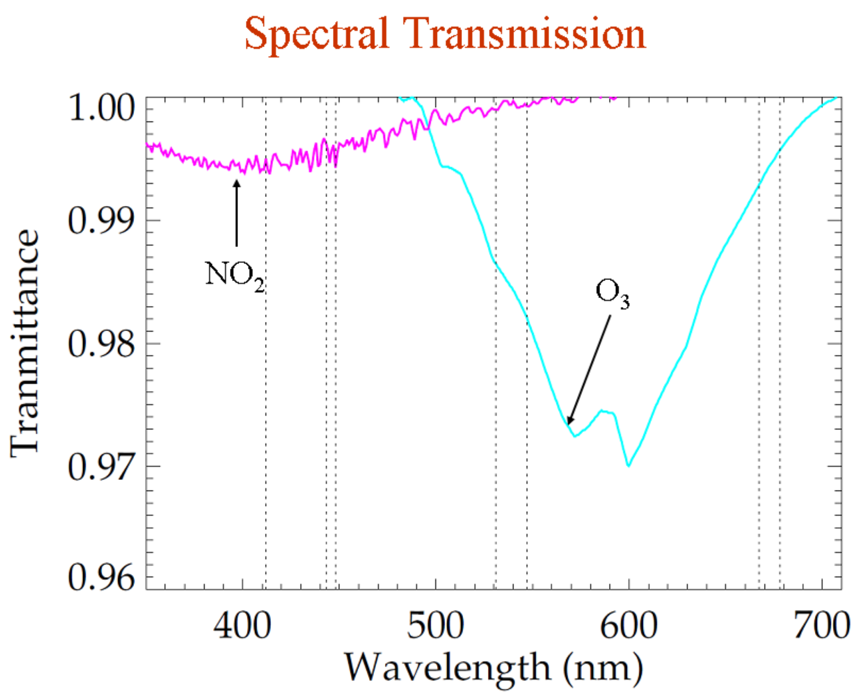
ε vs. ρ_{869}

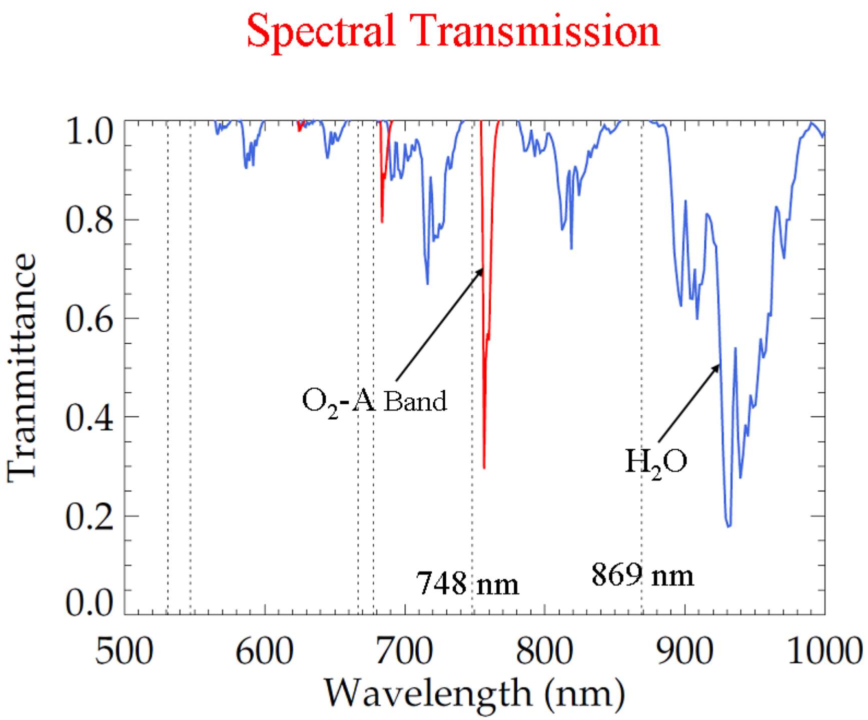


α
τ
0.05
0.10
0.15
0.20
0.25
0.30
0.40
0.50
1.94
1.73
1.44
1.20
0.78
0.44
0.14
0.01
-0.1
x(i,j)
Rh=80%
1.3
1.2
1.1
1.0
0.9
epsilon
0.00
0.02
0.04
0.06
0.08
0.10
0.12
rho_aer_869

It's not all Aerosols…

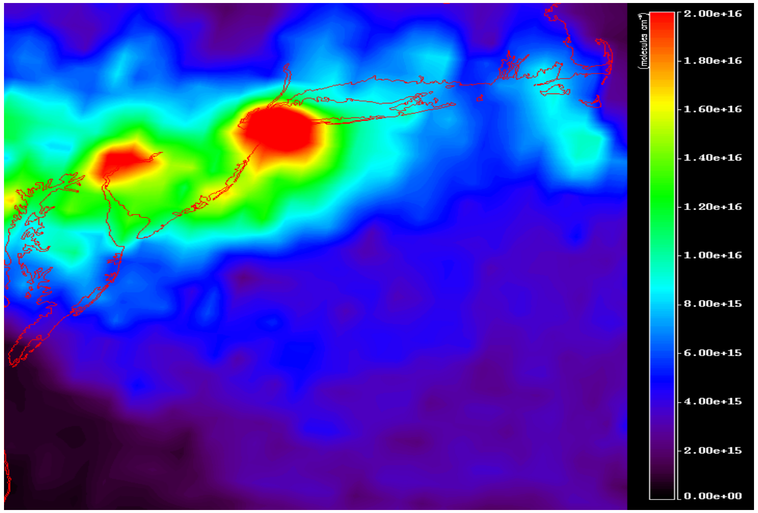
Spectral Transmission



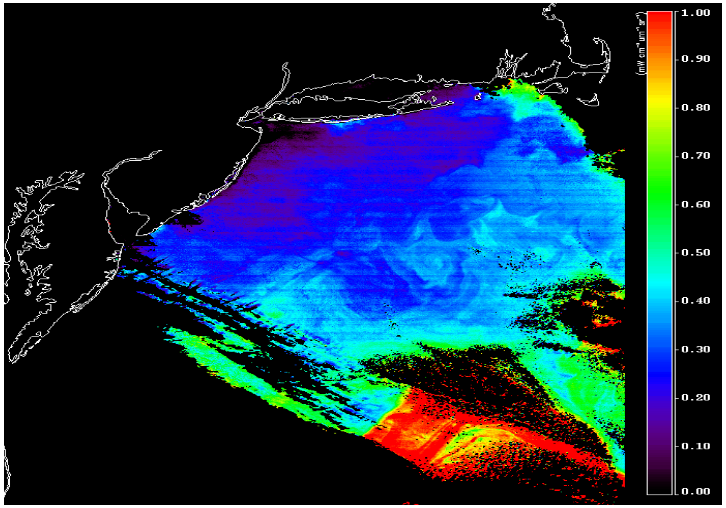


An Example of NO_2 Correction

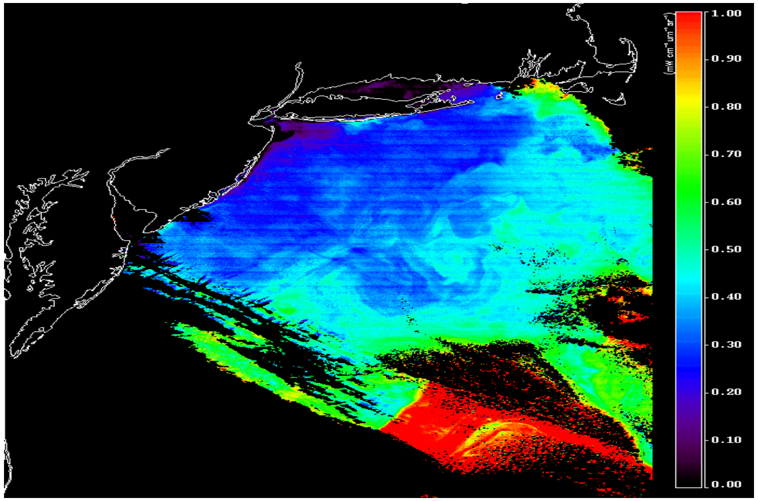
MODIS RGB Image (April 11 2005)



NO_2 (OMI, April 11 2005)



Before NO_2 Correction



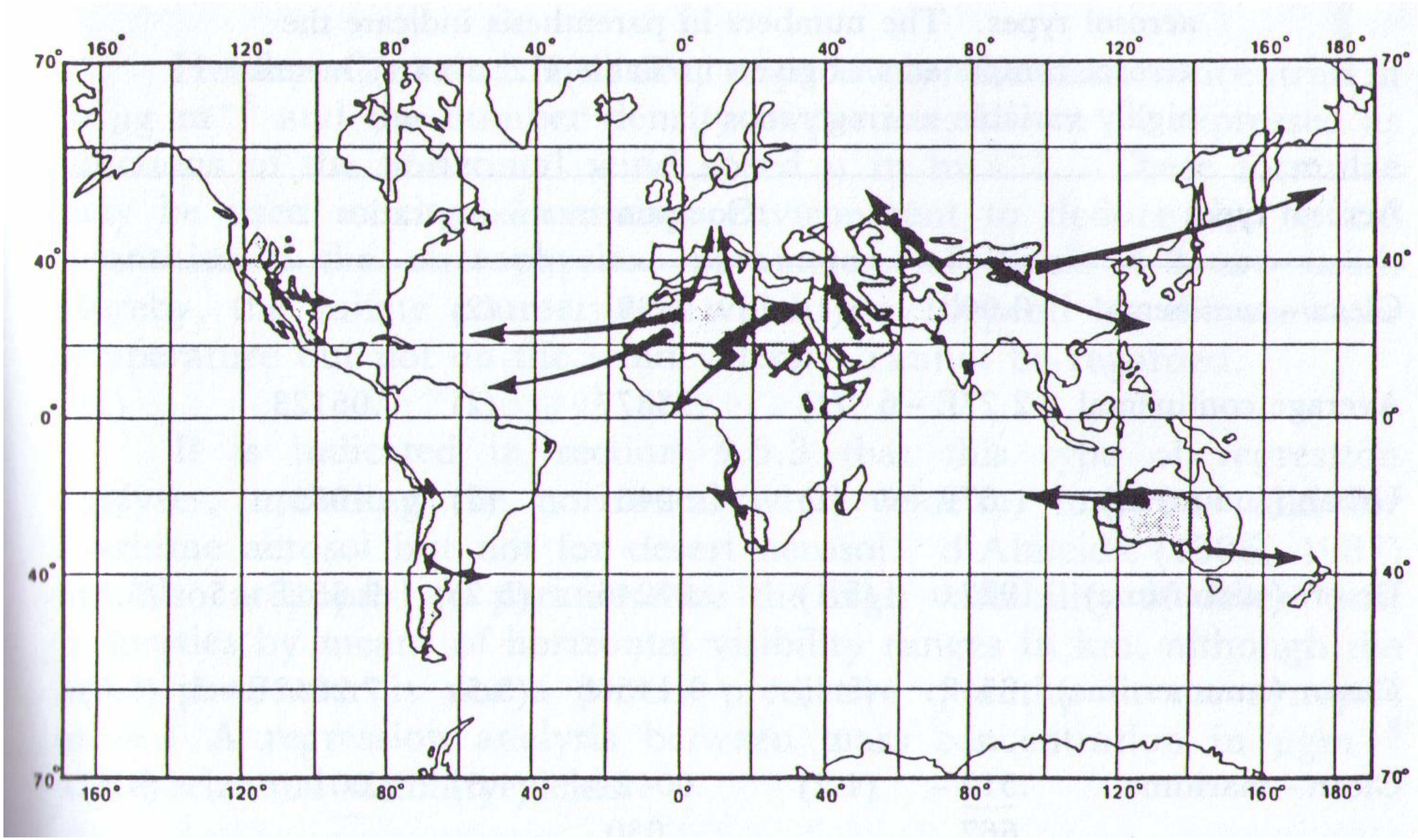
After NO_2 Correction

The Tall Poles

- Absorbing Aerosols
  - Three flavors – perhaps no single solution
- Single/Multiple Scattering
- Non-conservative gaseous absorption

Additional Resource Slides

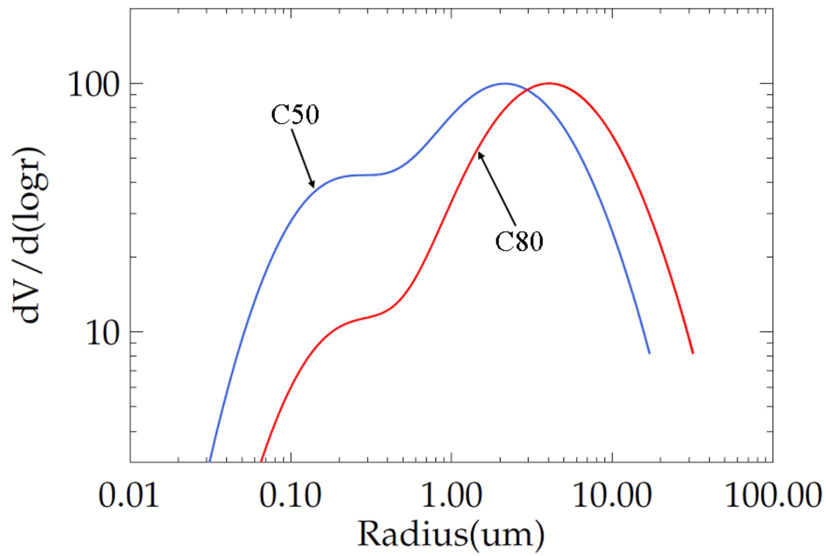
Transport of Mineral Dust



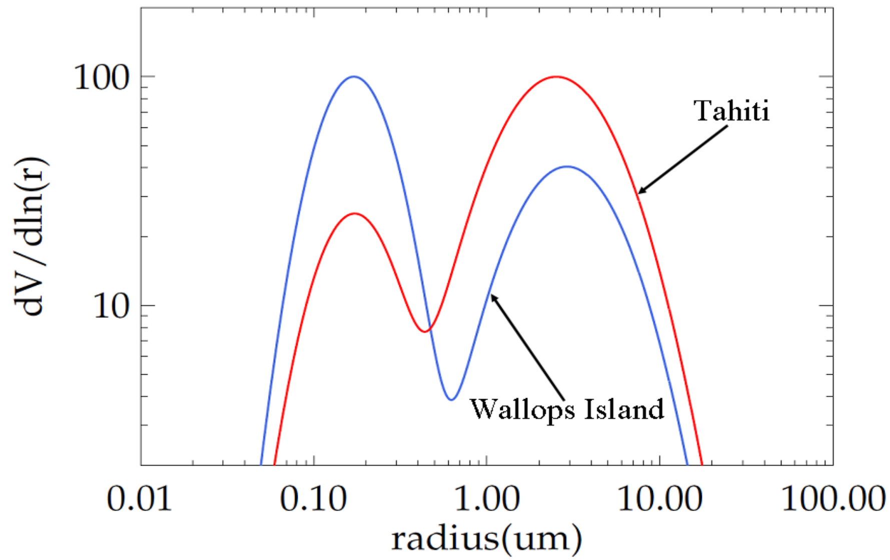
Reproduced from D'Almeida et al (1991)

Aerosol Models

Gordon-Wang Models



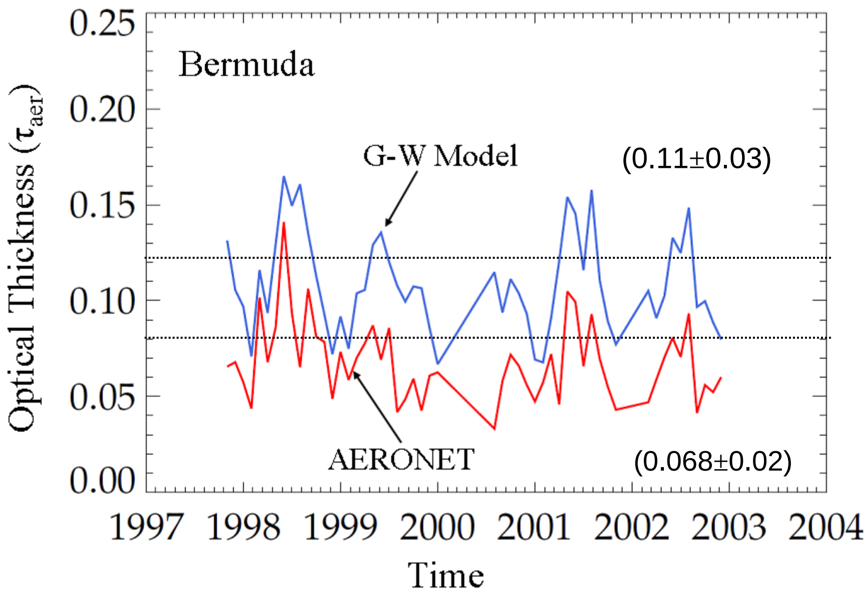
AERONET Models



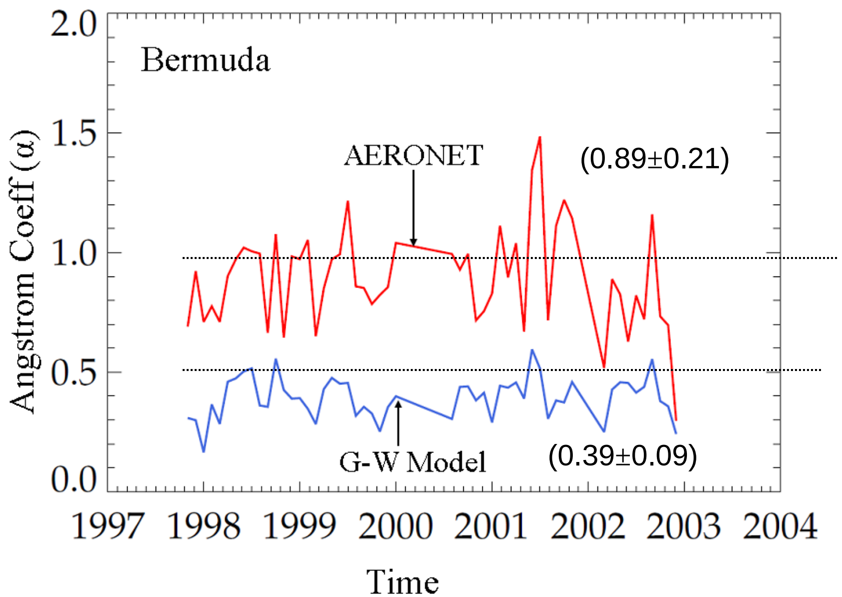
- Gordon-Wang models are based on Shettle-Fenn's models proposed for climate and radiation studies in 70s
- Width of Gordon-Wang models are much broader than AERONET models. For example, Fine mode: 0.806 vs. 0.437; Coarse mode: 0.921 vs. 0.672

Gordon-Wang Model vs. AERONET

Aerosol Optical Thickness (τ_{aer})



Angstrom Coefficient (α)

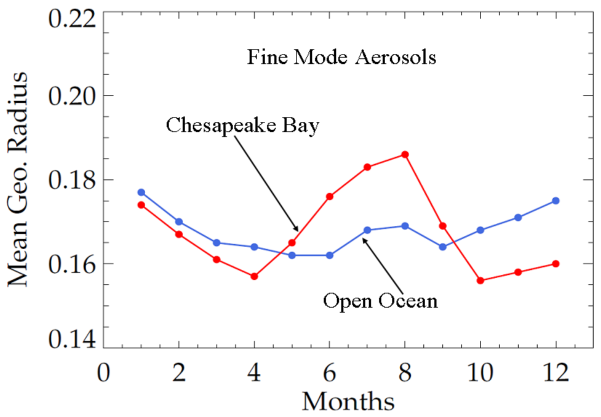


- <τ> retrieved from Gordon-Wang (G-W) models is almost 1.6 time as large as retrieved from AERONET

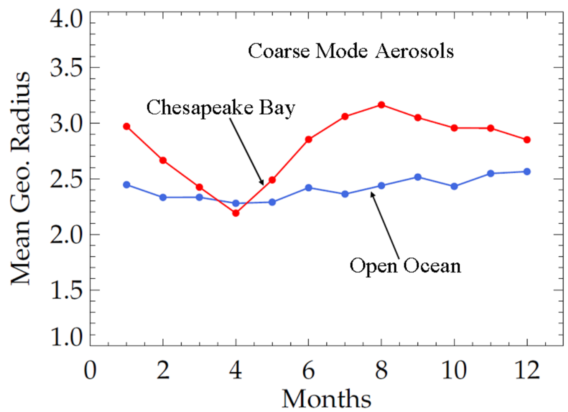
- <α> (443:865 nm) retrieved from Gordon-Wang (G-W) models is less than half (0.44) as retrieved from AERONET

Seasonal Characteristics of Aerosol Size Distributions (AERONET)

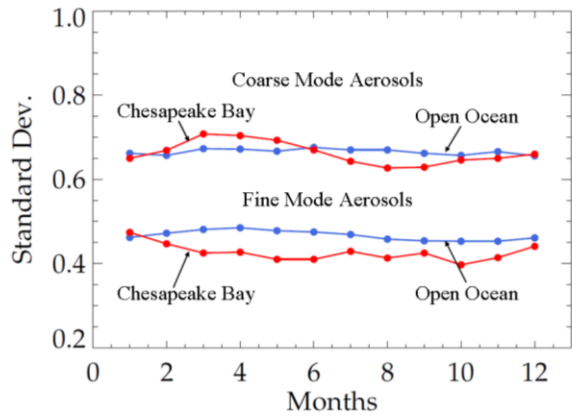
Fine Mode



Coarse Mode



Standard Dev.



- Over the Chesapeake Bay region, mean geometric radius of fine and coarse mode aerosols show strong seasonal dependence.
- Over open ocean, fine mode radius show a weak seasonal dependence, whereas, coarse mode radius is practically constant.
- Std. dev. of fine and coarse mode distributions are practically constant throughout the year. ($\langle\sigma_f\rangle=0.44$ and $\langle\sigma_c\rangle=0.67$)