Challenges in Atmospheric Correction for Ocean Color Retrievals from OES

Zia Ahmad
NASA/GSFC/Ocean Ecology Lab.

Acknowledgements
Bryan Franz, Chuck McClain and OBPG
NASA/GSFC/Ocean Ecology Lab.

Overview

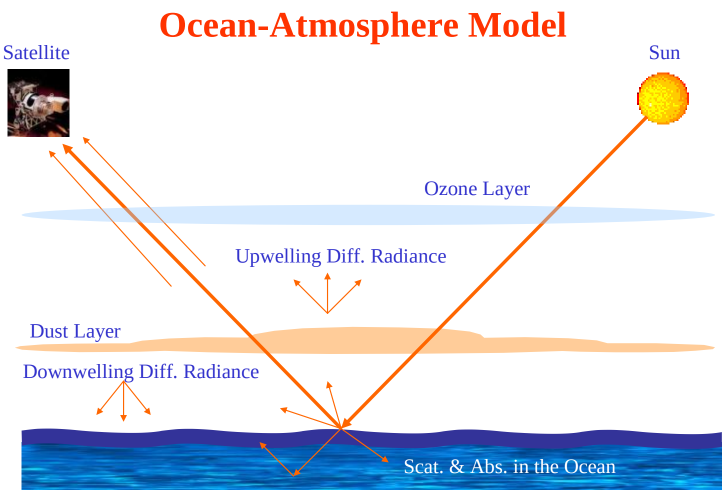
- Background
- Atmospheric Correction
  - Trace gases
  - Oceanic aerosols
- Challenges
  Spectral dependence of TOA reflectances
  - Coastal regions
  - Absorbing aerosols
- Cooperative retrievals
- Summary and Conclusions

Atmospheric Correction -1

TOA Radiance (in the absence of trace gases)

$$L_{tot}(\lambda) = L_{atm}(\lambda) + t_1 L_g(\lambda) + t_2 L_{wc}(\lambda) + t_3 L_{WL}(\lambda)$$

$L_{Rayl} + L_{aer}$



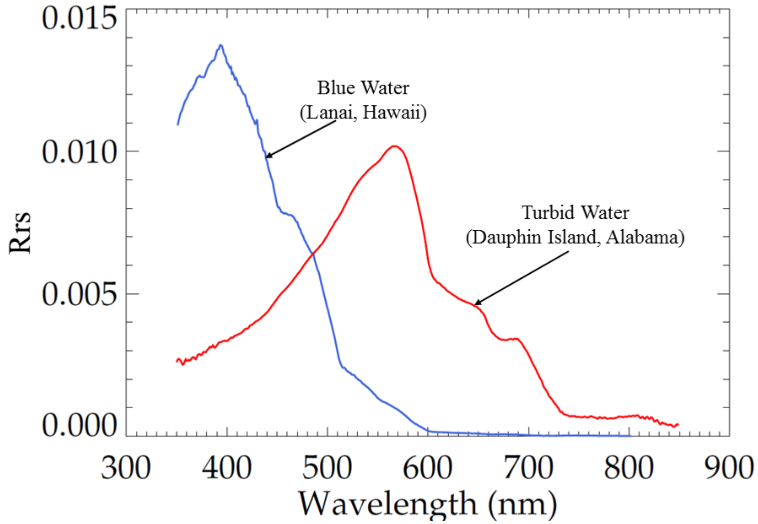
Goal: $L_{WL}(\lambda)$

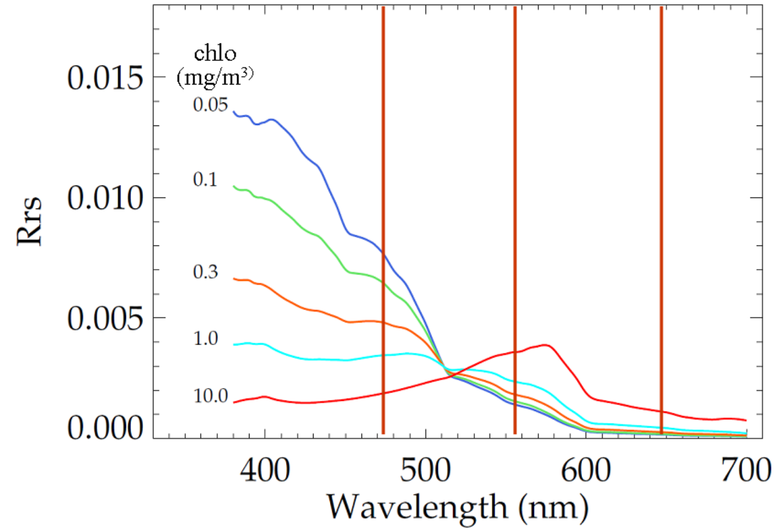
- Note: L_{Rayl} varies as λ^{-4}, whereas L_{aer} varies as λ^{-n}
  n generally lies between 0 and 2

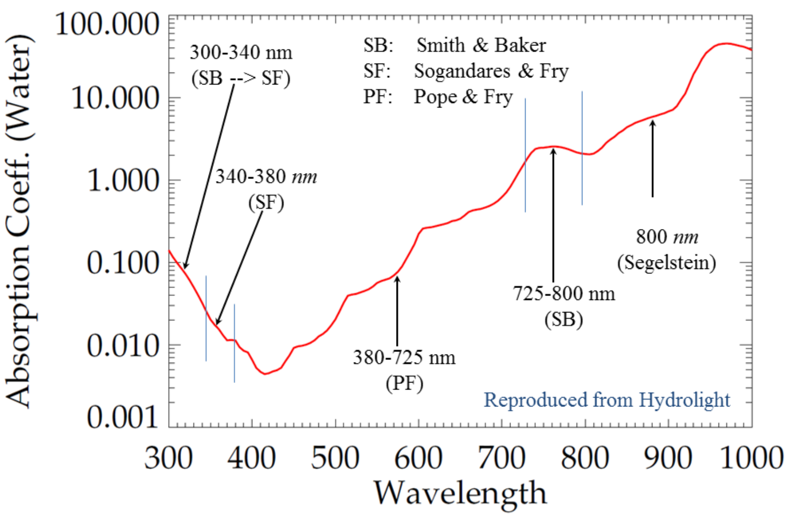
Remote Sensing Reflectance Rrs

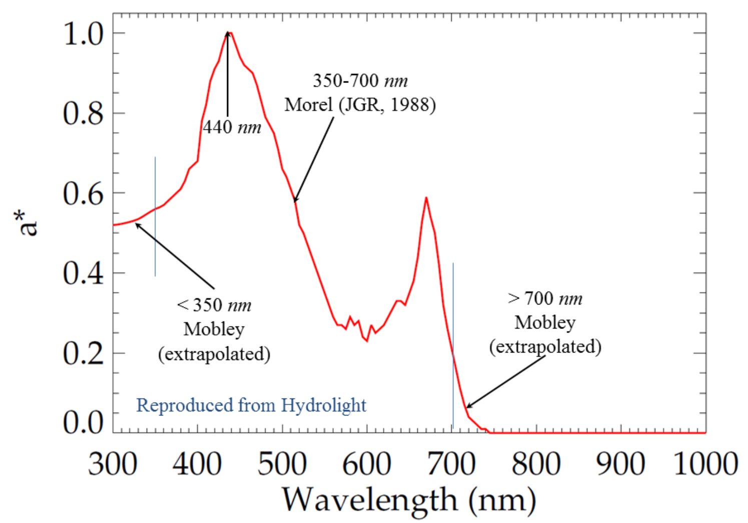
$$Rrs(\lambda)=L_{WL}(\lambda)/E_d^{(0+)}(\lambda)$$

Effect of Phytoplankton, CDM & Particulate Matter

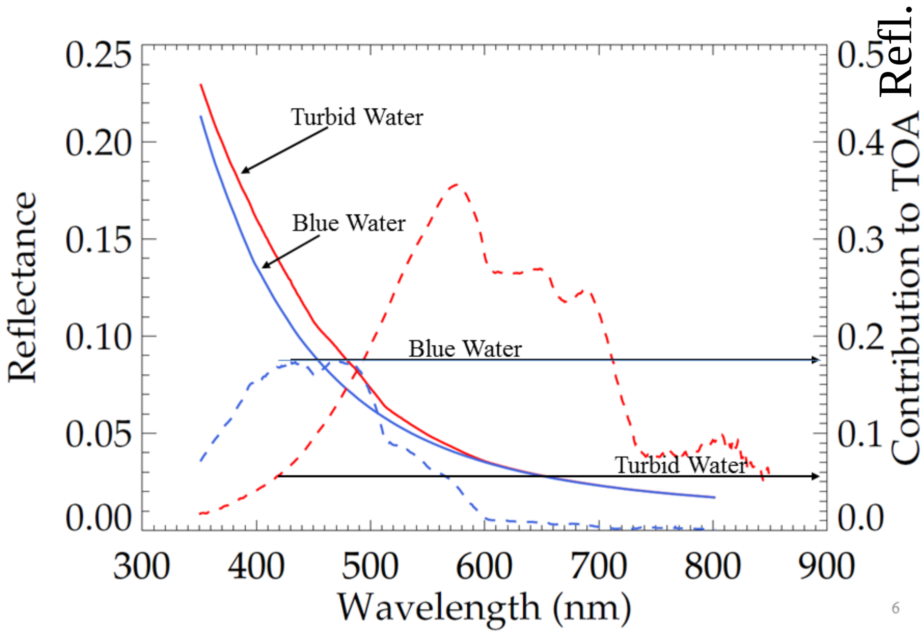


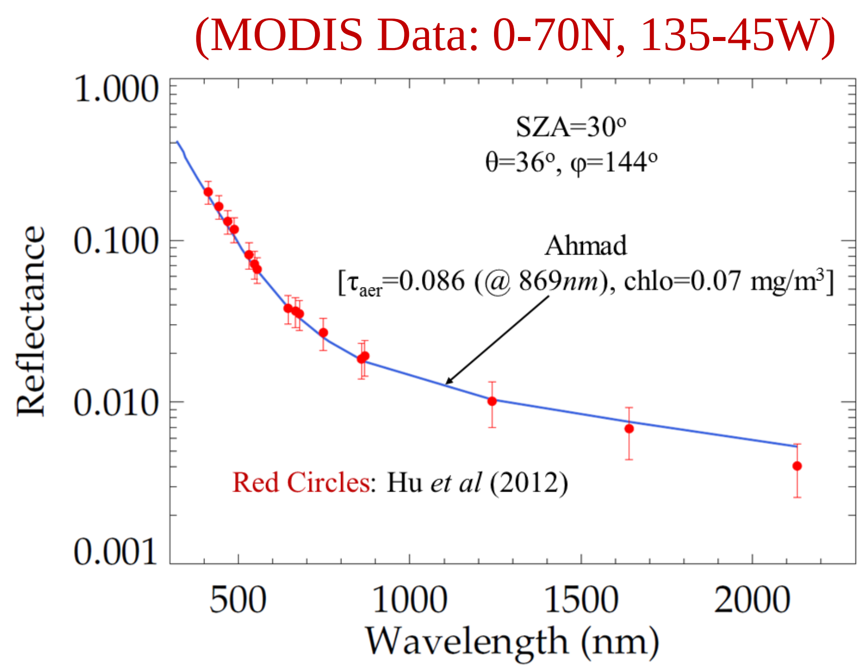






TOA Reflectance





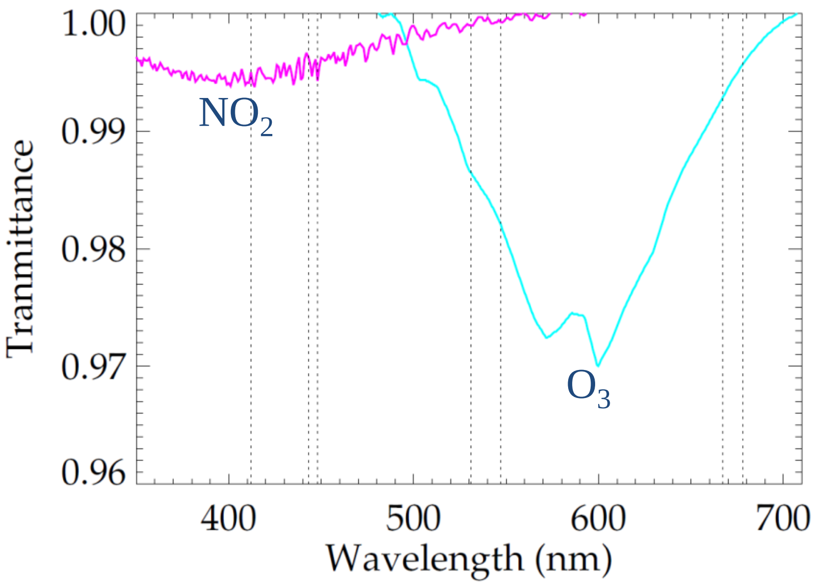
- Contribution from water-leaving radiance ($t_3 L_{WL}$) to the TOA reflectance (L_{tot}) @ 412 *nm* is ~ 17% for blue water and ~5% for turbid water.
- The RT simulation clearly captures the spectral dependence of TOA reflectance measured by MODIS aqua.

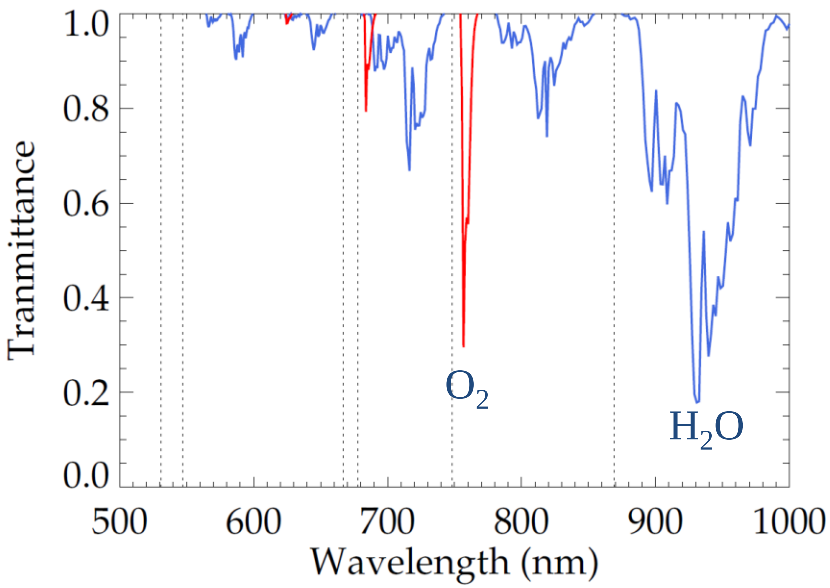
OES Multispectral Bands and Spectral Transmittances

λ	Δλ	Ltyp	Lmax	PACE OES SNR-spec (1 km)	SeaWiFS SNR	MODIS SNR
350	15	7.46	35.6	300		
360	15	7.22	37.6	1000		
385	15	6.11	38.1	1000		
412	15	7.86	60.2	1000	897	1861
425	15	6.95	58.5	1000		
443	15	7.02	66.4	1000	967	2487
460	15	6.83	72.4	1000		
475	15	6.19	72.2	1000		
490	15	5.31	68.6	1000	1010	2672
510	15	4.58	66.3	1000	1000	
532	15	3.92	65.1	1000		2155
555	15	3.39	64.3	1000	870	2271
583	15	2.81	62.4	1000		
617	15	2.19	58.2	1000		
640	10	1.90	56.4	1000		
655	15	1.67	53.5	1000		
665	10	1.60	53.6	1000	570	1839
678	10	1.45	51.9	2000 @ 4km		2070
710	15	1.19	48.9	1000		
748	10	0.93	44.7	600		1311
765	40	0.83	43.0	600	522	
820	15	0.59	39.3	600		
865	40	0.45	33.3	600	364	1285
940	**25**	**0.78**	**21.0**	**150**		
1245	20	0.088	15.8	250		51
1378	**10**	**0.35**	**9.5**	**100**		
1640	40	0.029	8.2	250		39
2130	**15**	**0.008**	**2.2**	**100**		
2250	**50**	**0.07**	**2.1**	**150**		

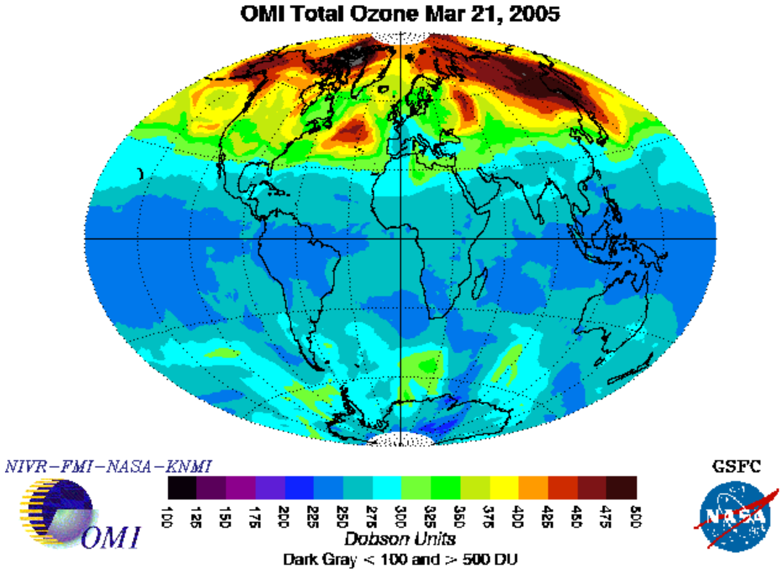
Units: mW/cm² μm str

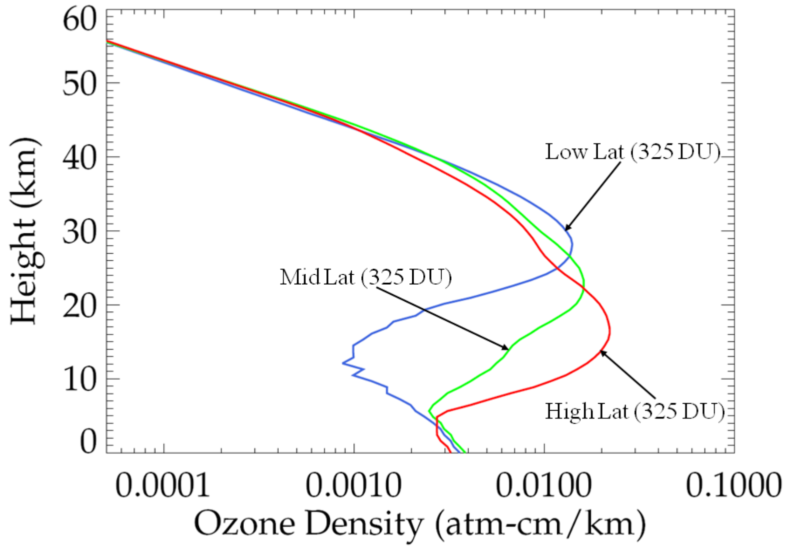
Cloud & Aerosol augmentations to Ocean band set

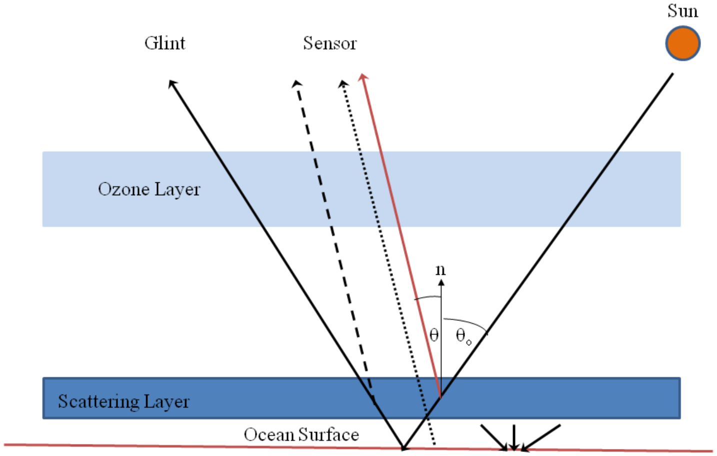




Ozone Correction





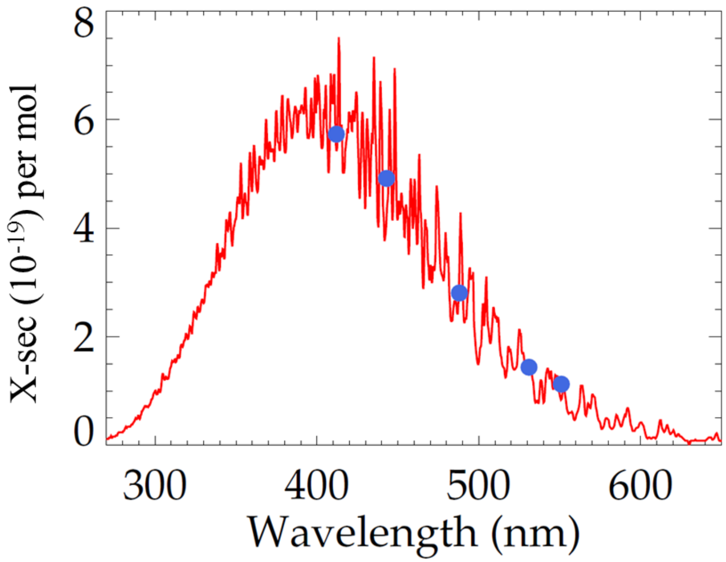


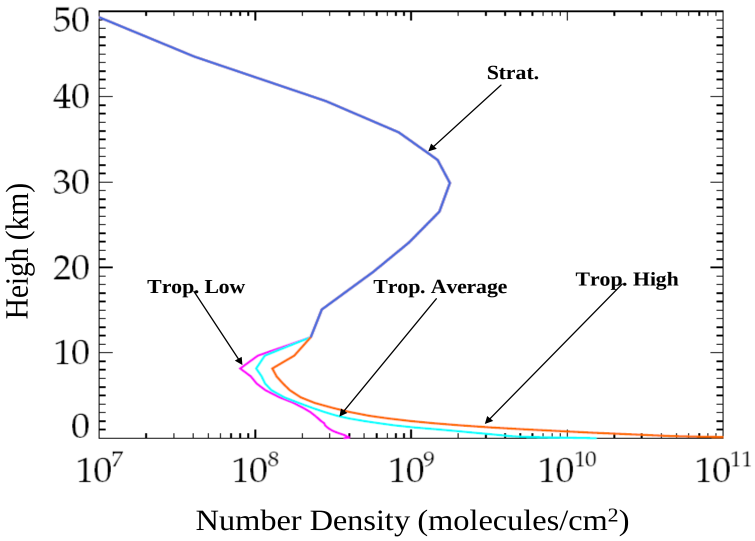
$$L = L_o \exp\left[-\tau_{o3}\left(\frac{1}{\mu_0} + \frac{1}{\mu}\right)\right]$$

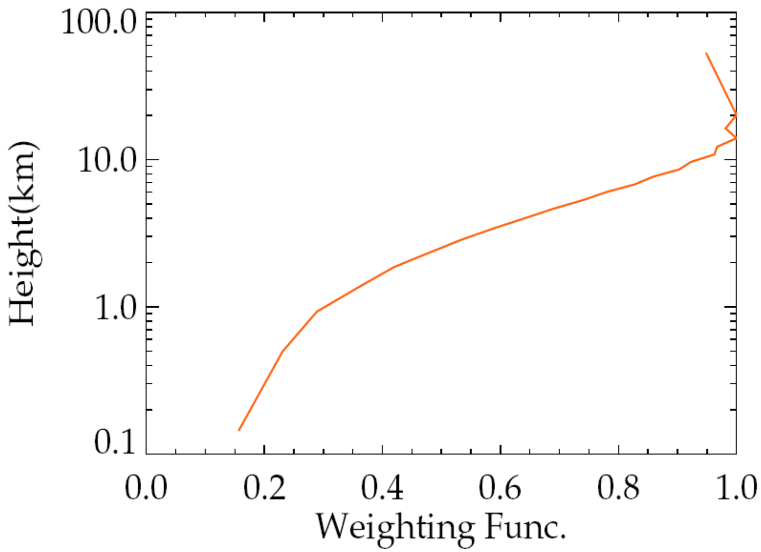
$$\mu_o = \cos(\theta_o)$$

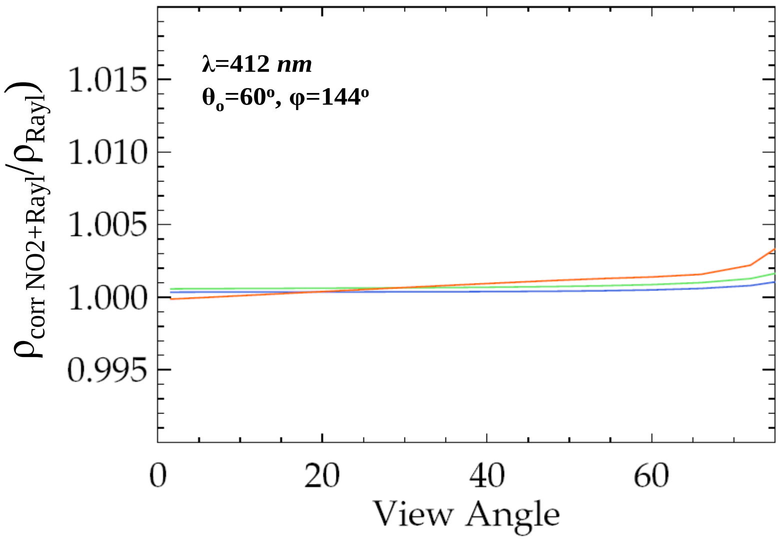
$$\mu = \cos(\theta)$$

NO_2 Correction



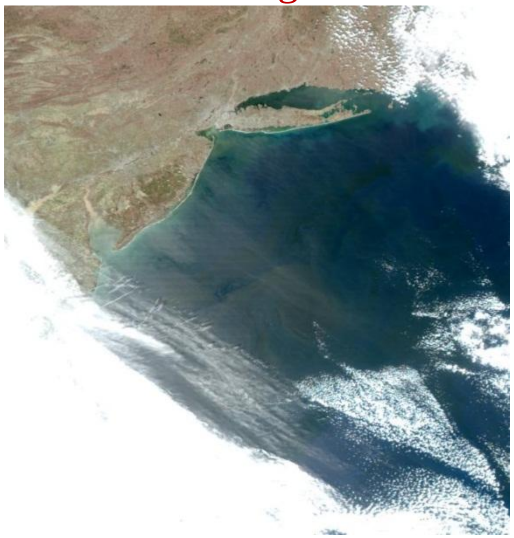




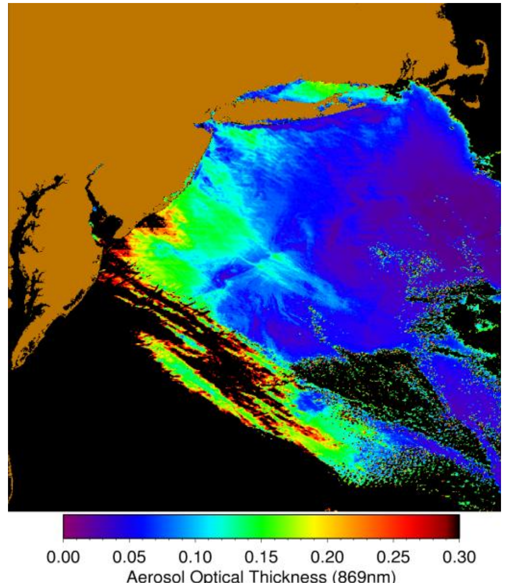


An Example of NO_2 Correction

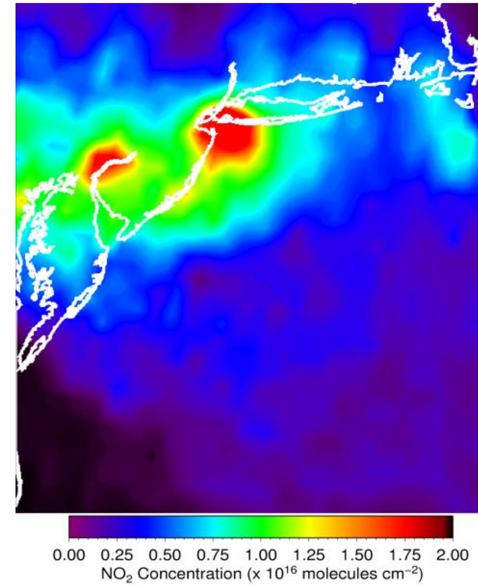
RGB Image



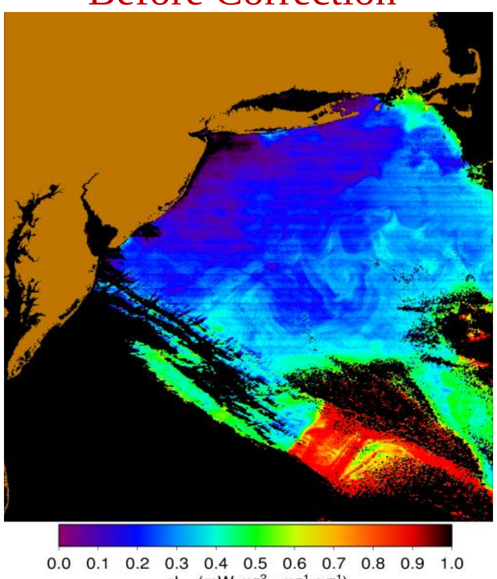
τ_A



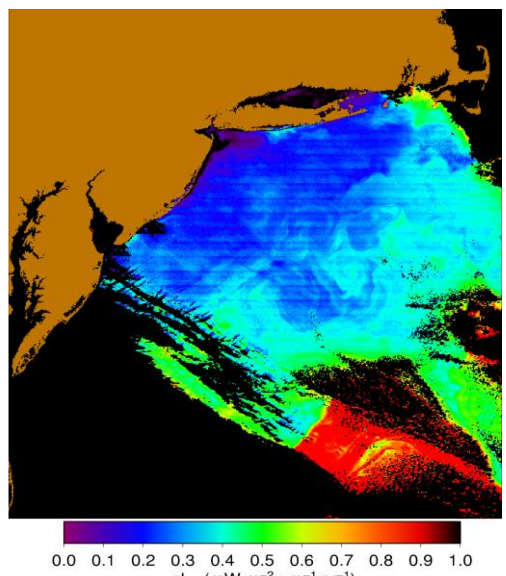
NO_2



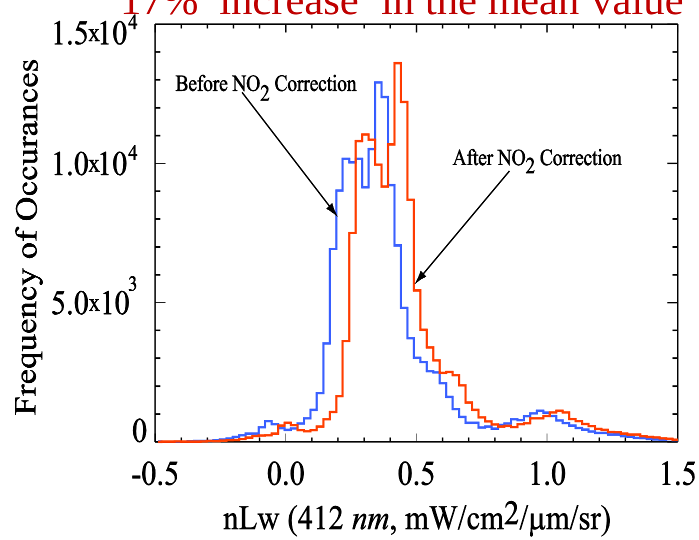
Before Correction



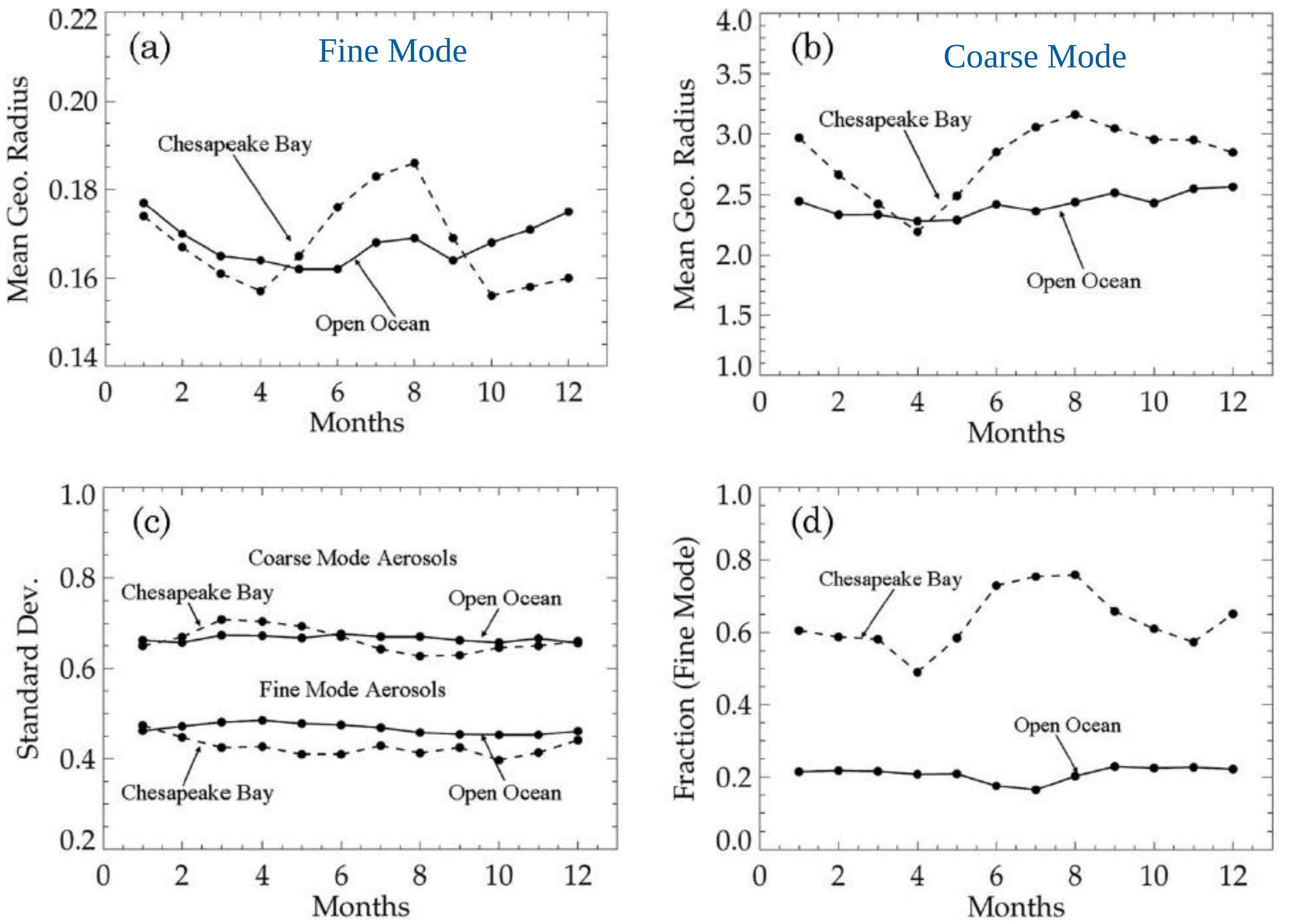
After Correction



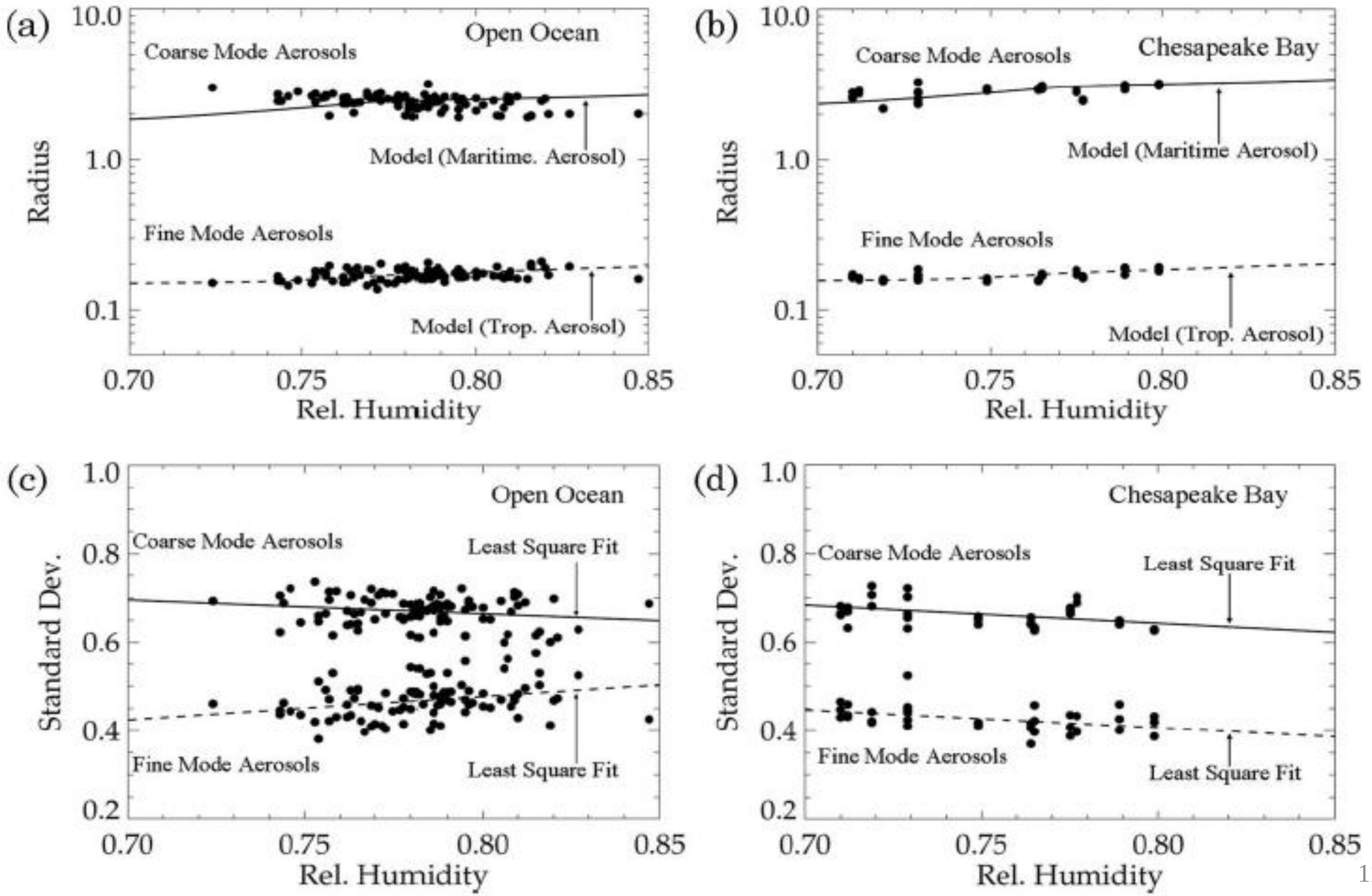
17% increase in the mean value



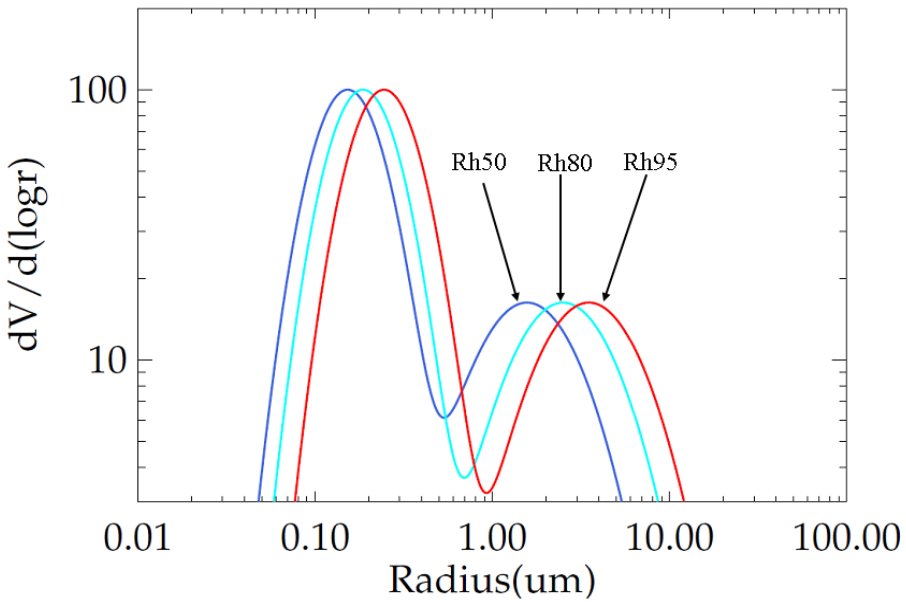
Characteristics of Aerosols over Chesapeake Bay and Open Ocean

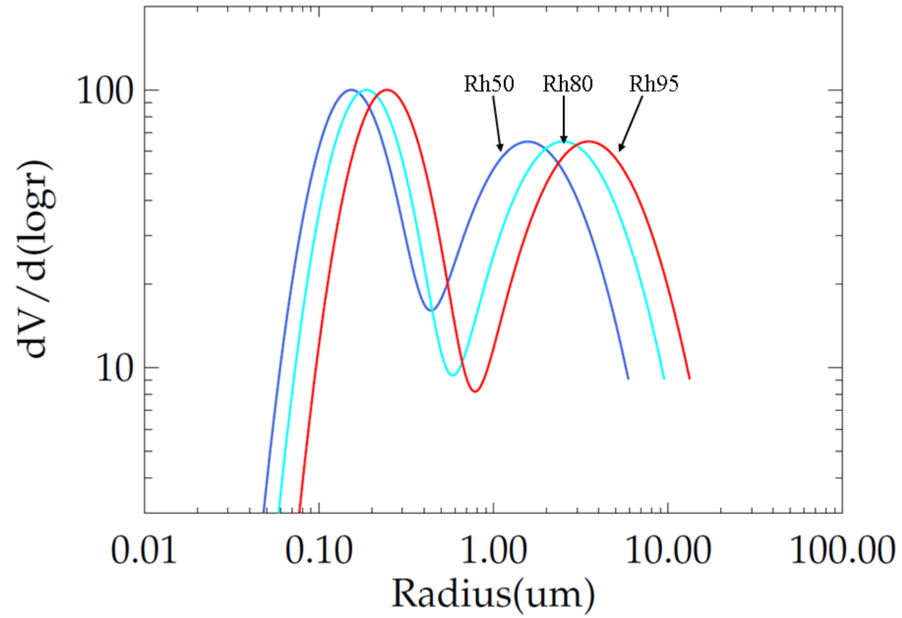


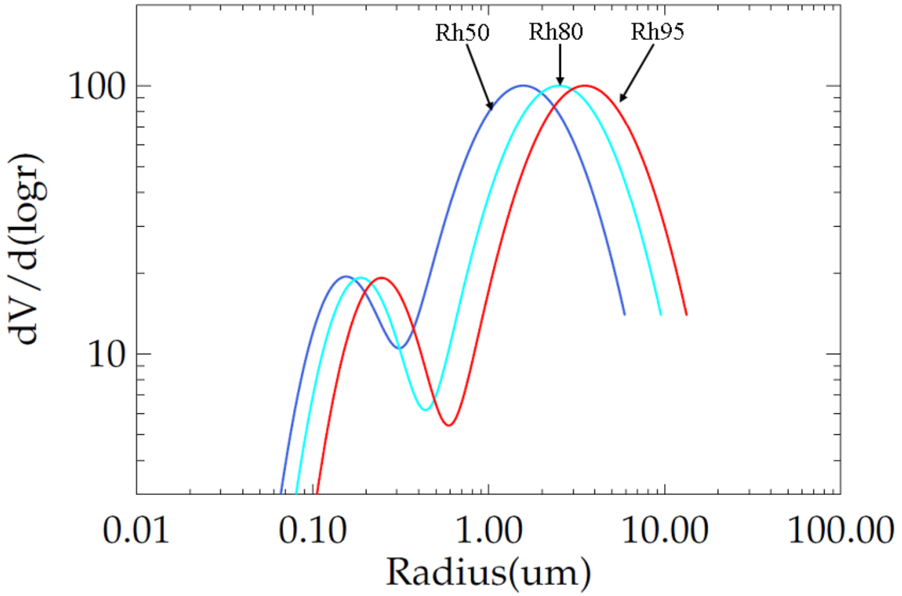
Modal Radius and Std. Dev. (Fine and Coarse Modes)



Examples of the New Aerosol Models

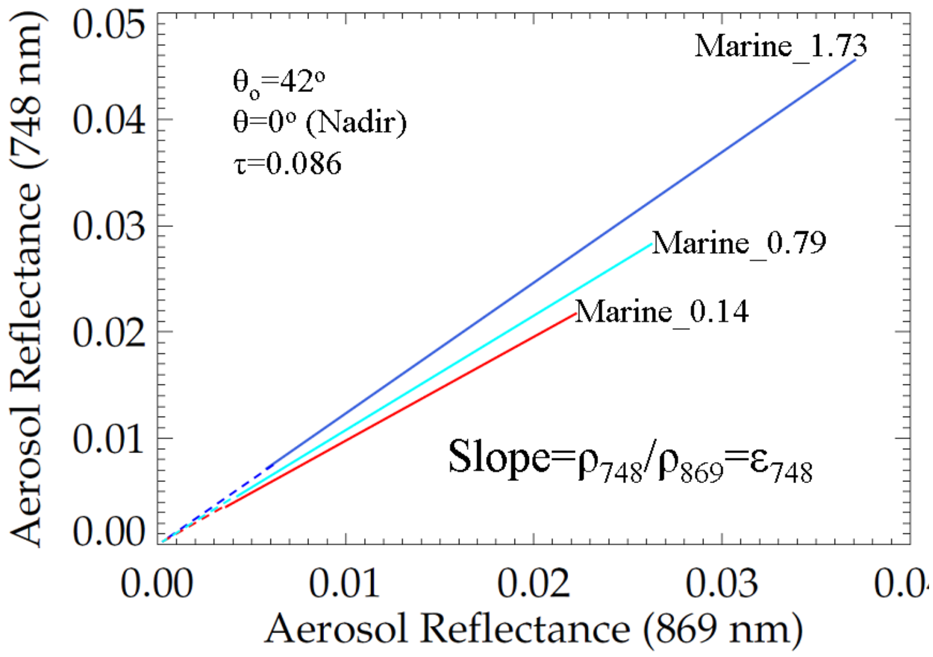


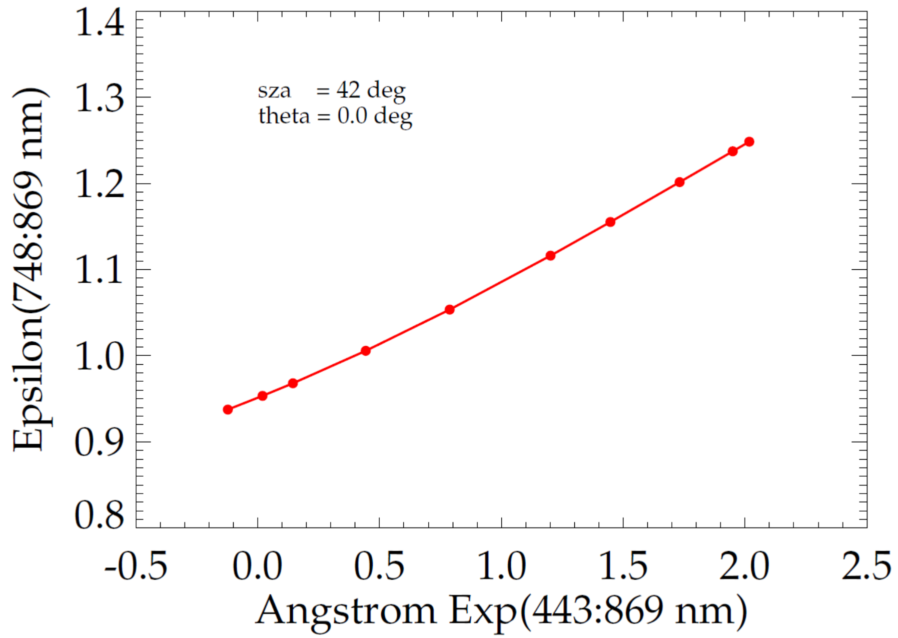




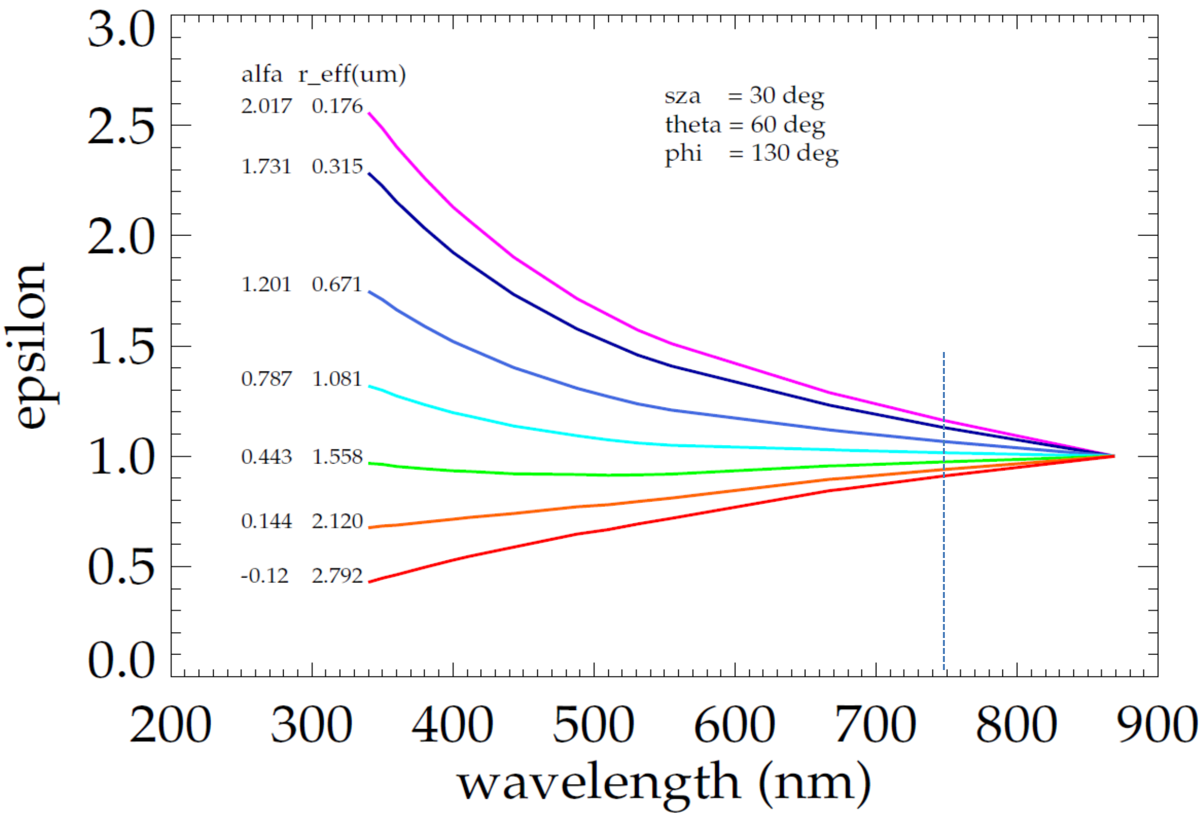
- Aerosol Models are selected based on:
  - Relative humidity (NCEP)
  - Scaled reflectance ($\varepsilon_{\lambda}=\rho_{\lambda}/\rho_{\lambda o}$)

Scaled Reflectance (ε) and Angstrom Exponent



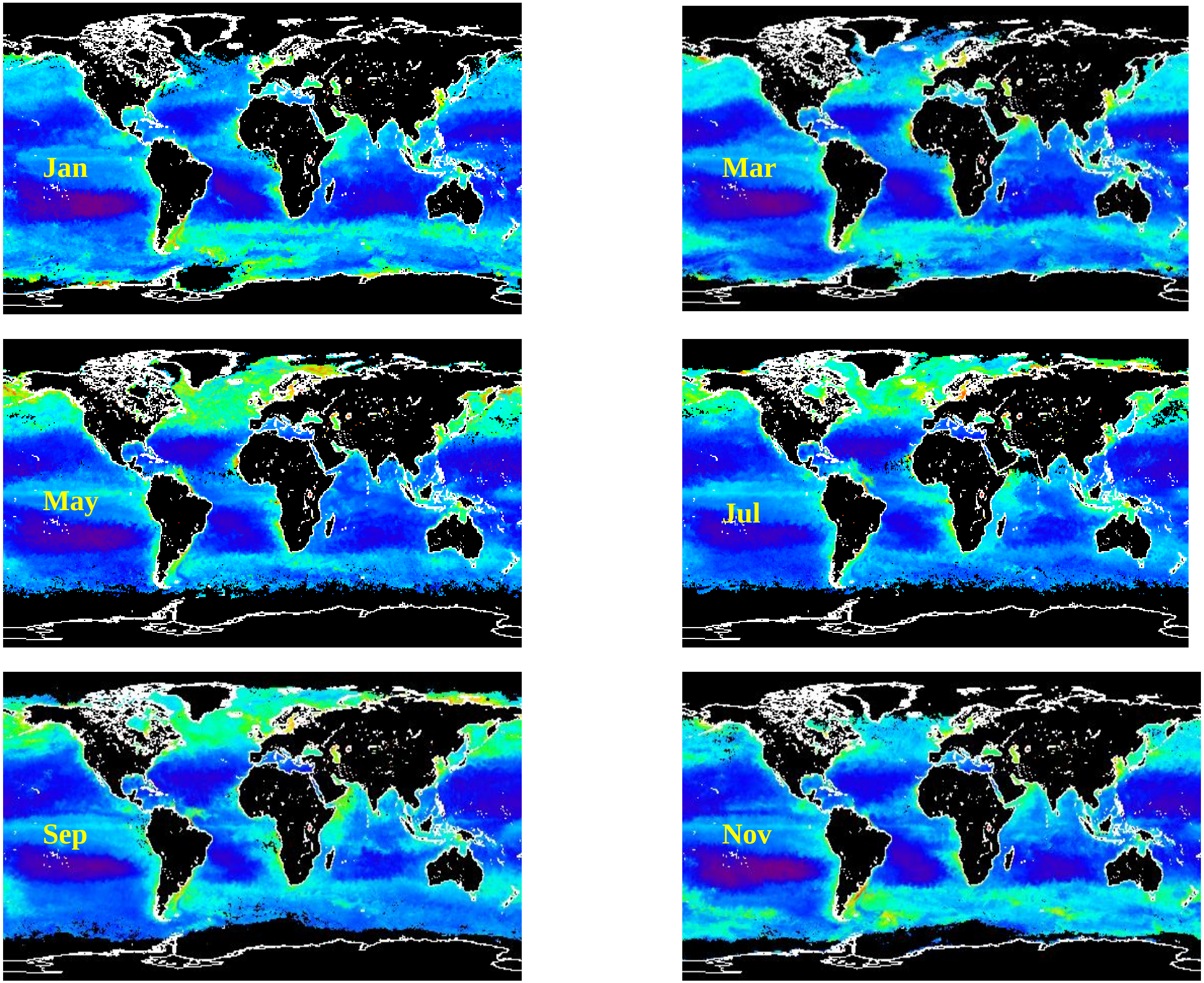


Epsilon (ss) vs. Wavelength

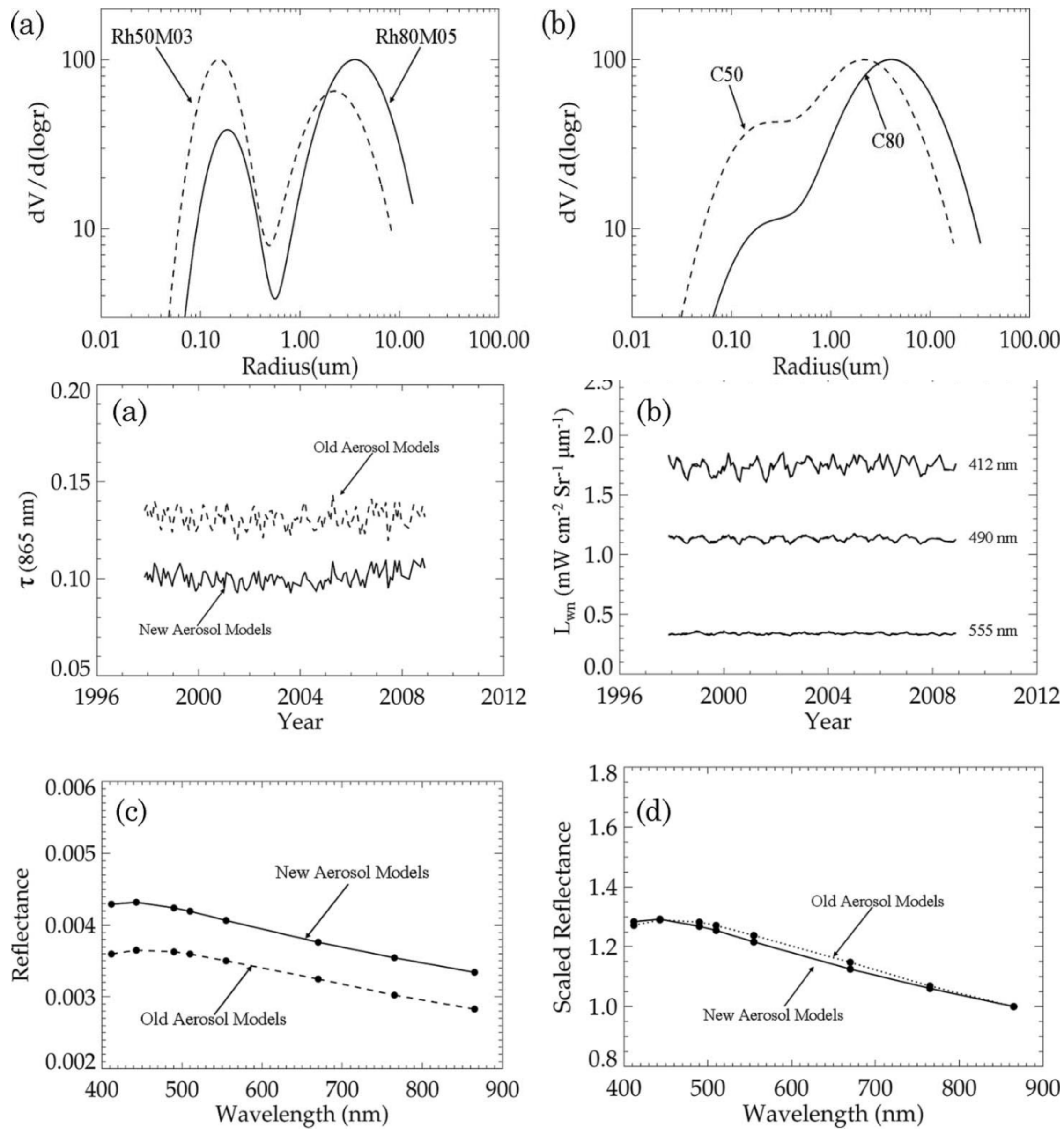


$$\varepsilon_\lambda^{model} = \frac{\rho_\lambda^{model}}{\rho_{869}^{model}} = \frac{\rho_\lambda^{obs}}{\rho_{869}^{obs}} \longrightarrow \rho_\lambda^{obs} = \varepsilon_\lambda \rho_{869}^{obs}$$

Chlorophyll (SeaWiFS, 2003)



Spectral Dependence of TOA Reflectance

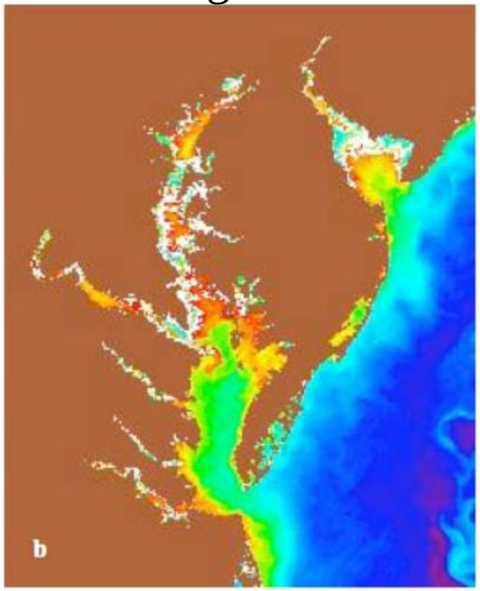


Use of SWIR Bands in Retrieving Chlorophyll Over the Chesapeake Bay Area

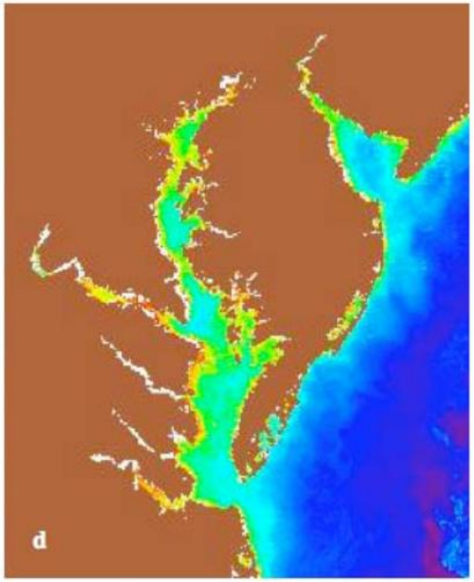
- Wang and Shi's Algorithm for Coastal Areas

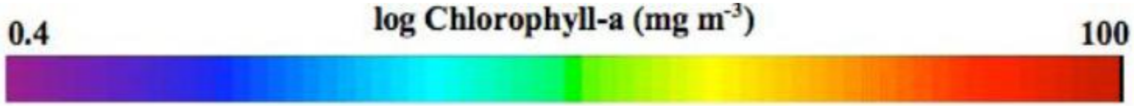
RGB Image

Chlo. using NIR Bands

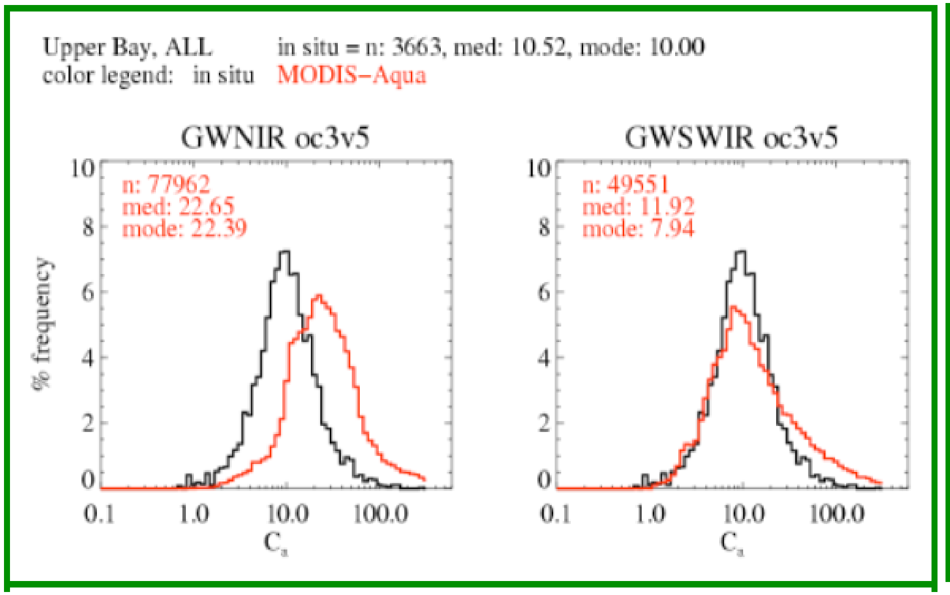


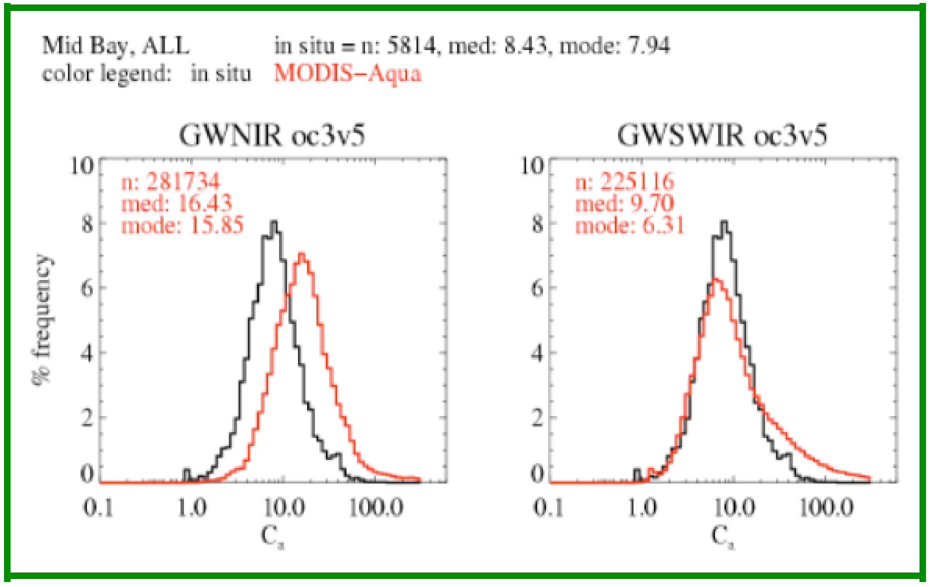
Chlo. using SWIR Bands

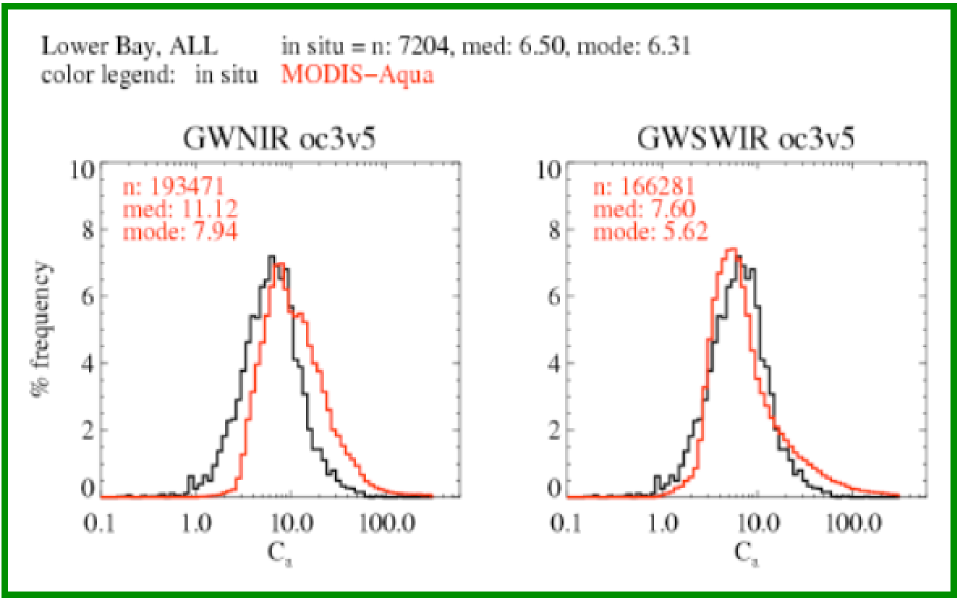




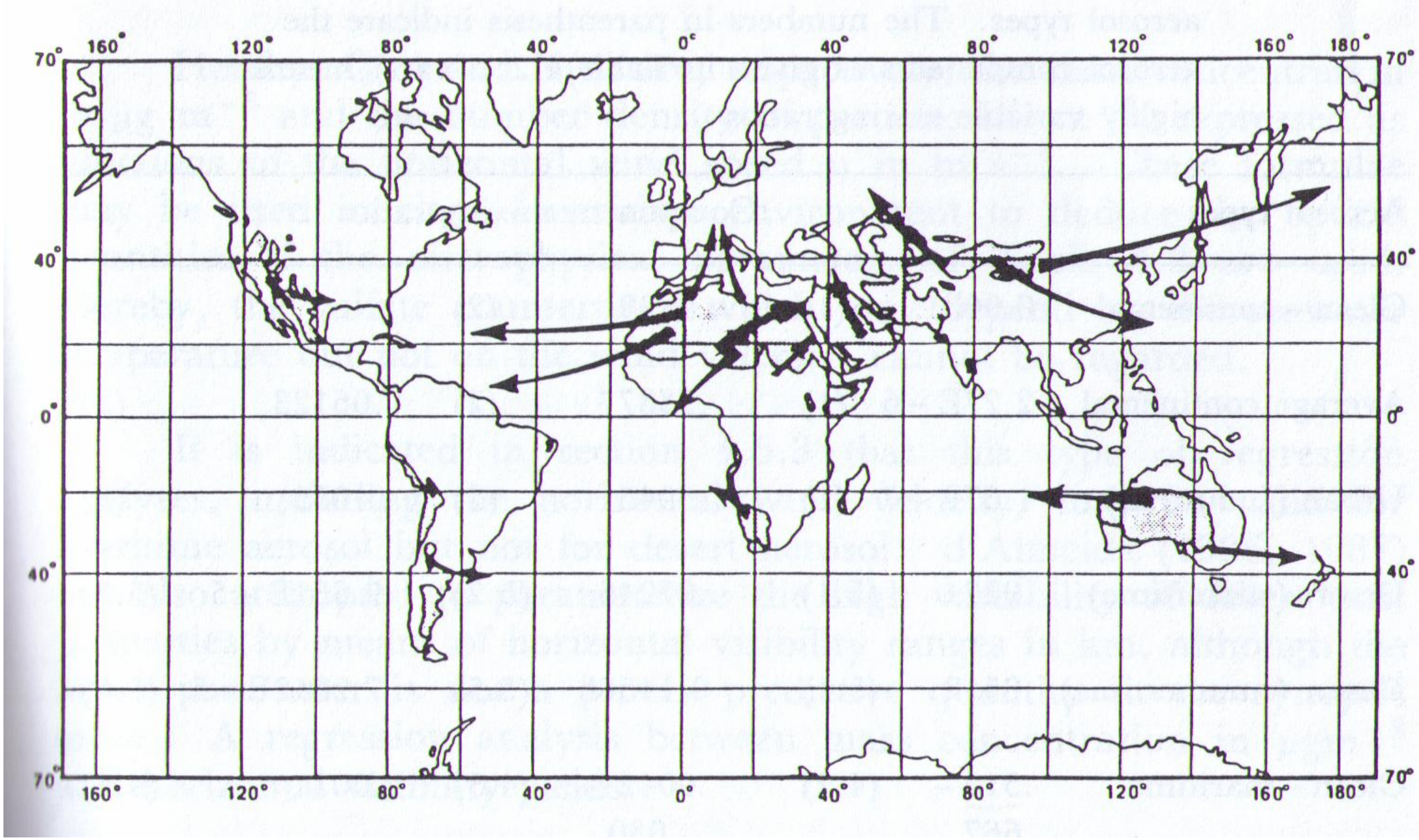
Comparison of NIR and SWIR Based Retrievals over the Chesapeake Bay Area







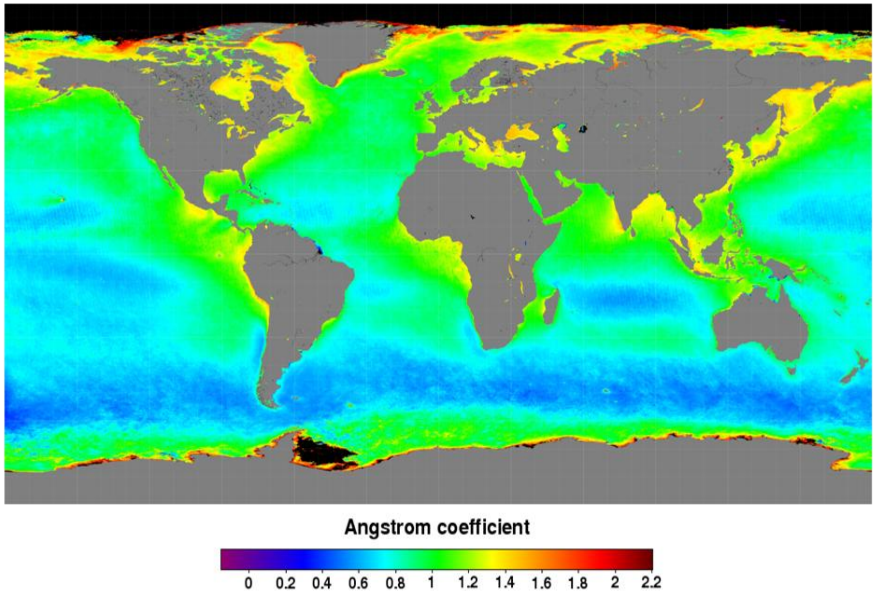
Sources and Transport of Mineral Dust



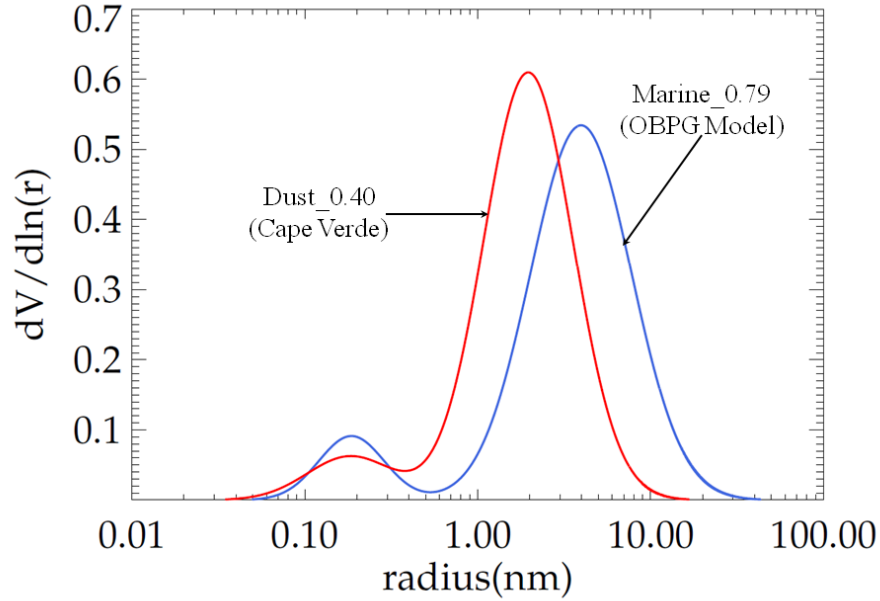
Reproduced from D’Almeida et al (1991)

Aerosol Properties

Angstrom Coefficient

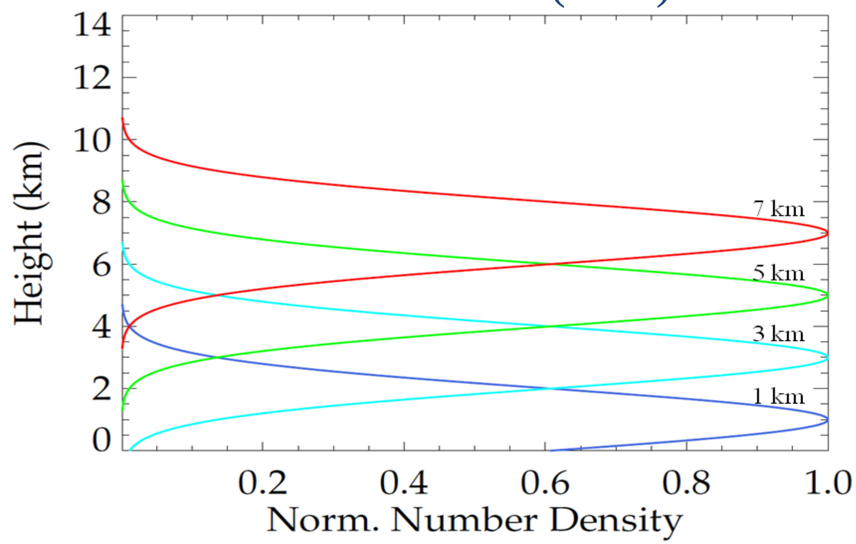


Aerosol Models



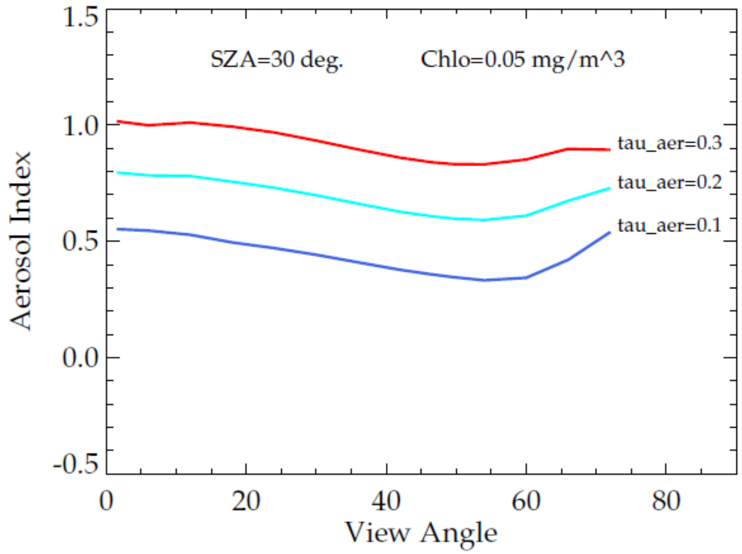
Parameters	Dust	Marine
r_f	0.184	0.187
σ_f	0.574	0.437
R_c	1.965	3.966
σ_c	0.595	0.672
V_f	0.090	0.100
V_c	0.910	0.900

vertical Profile (Dust)

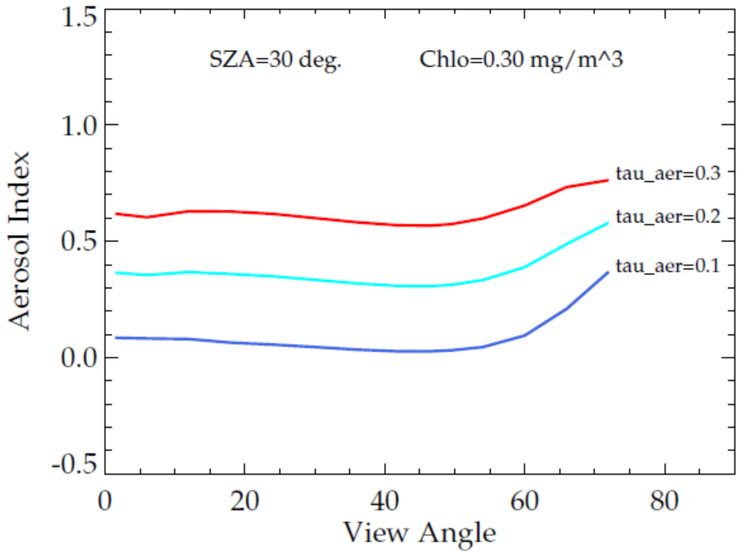


Aerosol Index (SZA=30°, Ht=3 km)

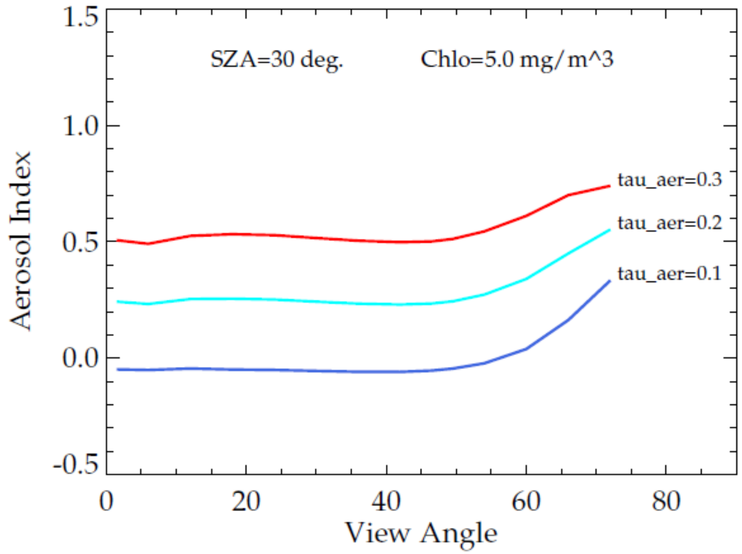
Chlo=0.05 mg/m^3



Chlo=0.30 mg/m^3

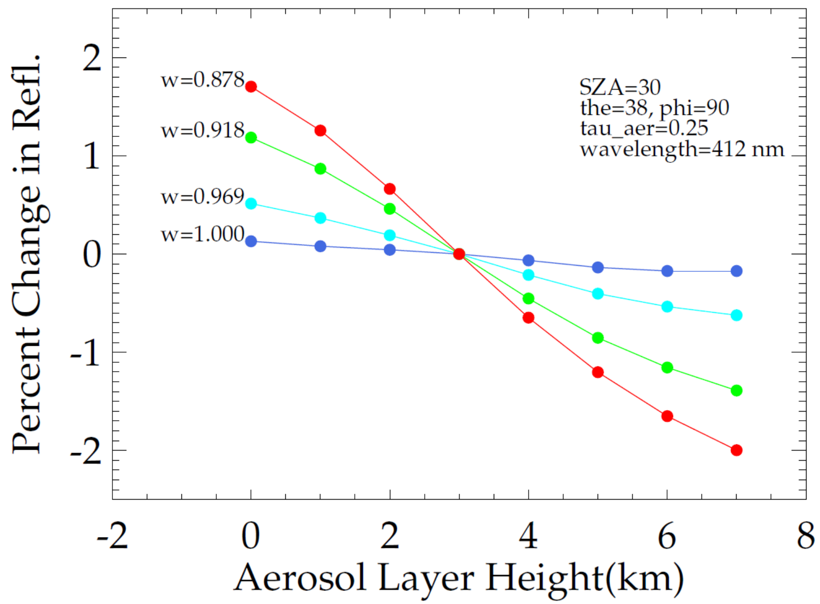


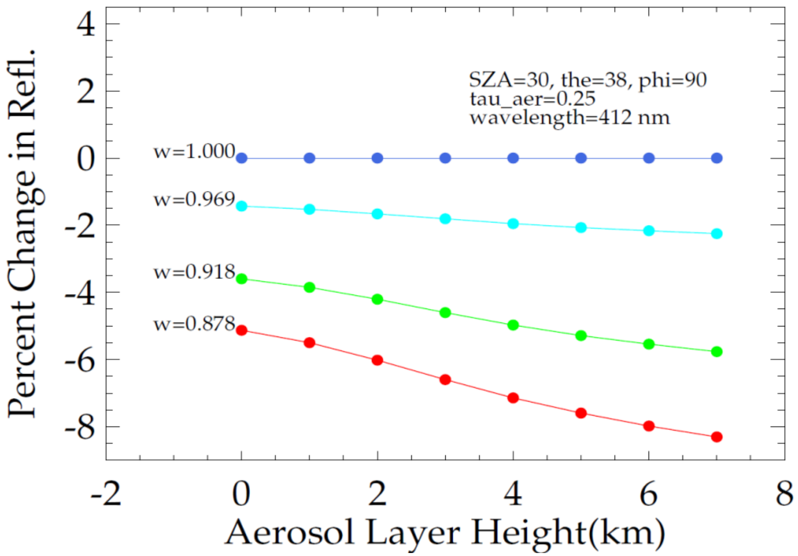
Chlo=5.0 mg/m^3



- •AI shows very weak dependence on view angle (< 60°)
- •AI increases with dust optical thickness (τ_A)
- • Over open ocean where chlorophyll value is very small, AI ≈ 0.5. As chlorophyll value increases to 5.0 mg/m^3, AI ≈ zero for τ=0.1

Change in TOA Reflectance with Aerosol Layer Height and Refractive Index

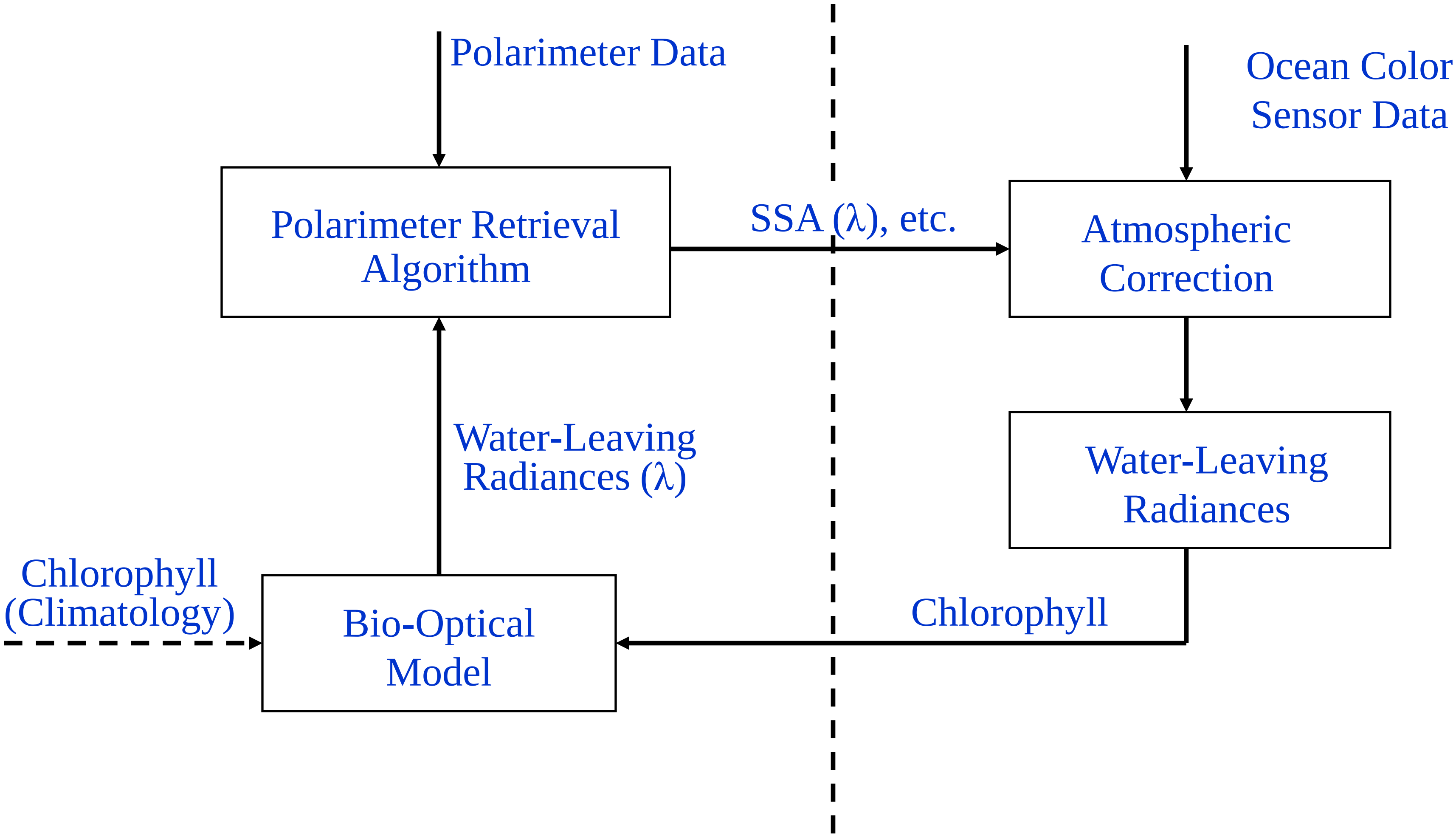




• Note: Based on the dust model used in the simulations, the SSA at 412nm is ~ 0.89. For τ_A=0.25, an error of 1 km in aerosol layer height would change the TOA reflectance by ~ 0.7%. This will result in ~7% change in water-leaving radiance. The error will increase with an increase in τ_A.

• These graphs show the effect of assigning wrong SSA to aerosols, although the aerosol layer-height is exactly known. Here, TOA reflectance for each aerosol model is normalized by the TOA reflectance of a **non-absorbing aerosol** model at exactly the same height. For example, for an aerosol layer at 3 km, and τ_A=0.25, a change in SSA value from 0.878 to 0.918 would result in a change of ~2% in TOA reflectance . This would be equivalent to a change of ~20% in water-leaving reflectance.

Cooperative Retrieval Methodology Using Polarimeter and Ocean Color Sensor Data



Summary and Conclusions

- An over view of the atmospheric correction is presented and some of the major challenges for ocean color retrieval from OES are identified.
- Over turbid waters, it has not been established that an aerosol model selected on the basis of measurements in SWIR bands could correctly represent the spectral dependence of TOA reflectances in the blue and near UV parts of the spectrum.
- Absorbing aerosols are a serious problem. Presently, there is no working algorithm to detect these aerosols when the aerosol concentration is low ($\tau < 0.2$)
- A high level cooperative retrieval scheme is presented to use polarimeter data for ocean color retrievals. It should be tested using RT simulated and actual data.