Atmospheric Contributions to PACE Observations

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Outline

Focus on the atmospheric contributions to PACE measurements

Discuss calculations of aerosol effects

Absorptive vs scattering aerosol is a key point to consider

Comments are presented

Personal Viewpoint

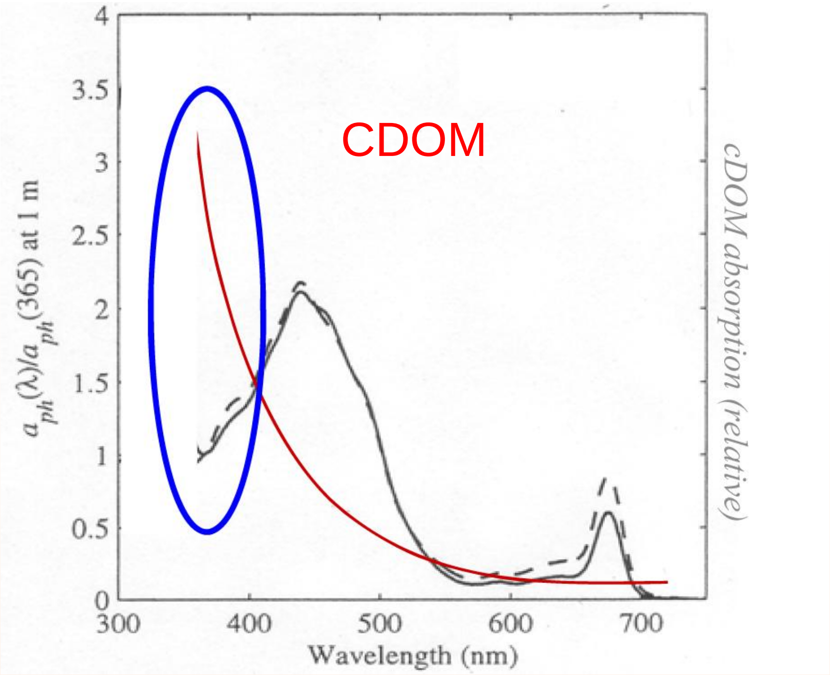
Priorities

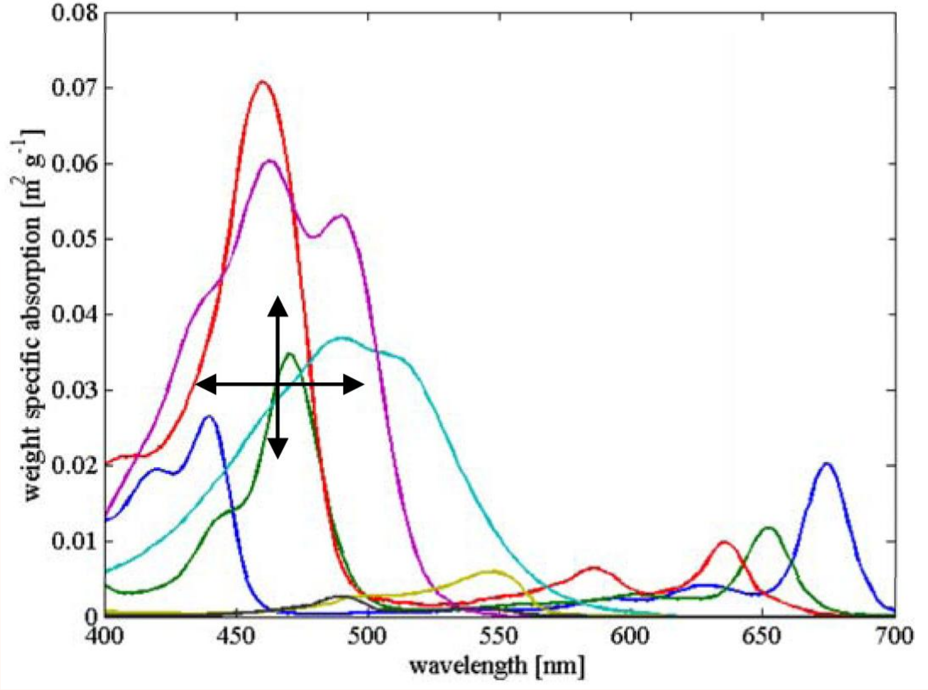
Multi-spectral (λ) resolution of the taxonomy

Sub -1 km (spatial) resolution of the coastal shore

Multi-spectral (λ) range is needed for better aerosol correction

The Biological Taxonomy is diverse





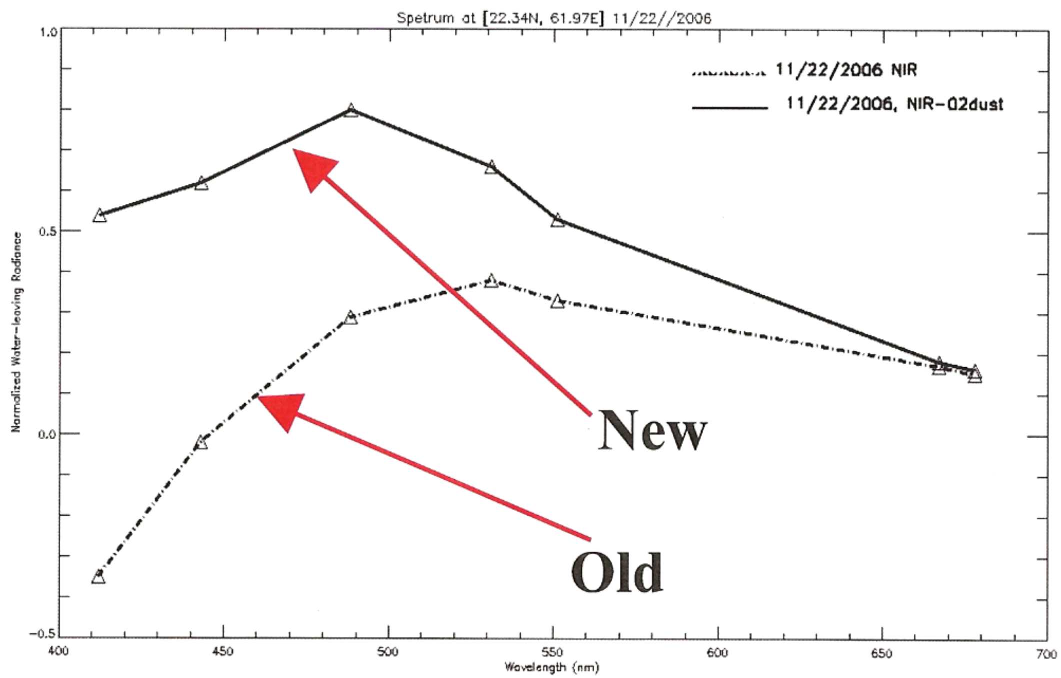
Wavelength region λ< 400 nm is not "dark" (subsurface reflectance $\neq$ 0)

Figures courtesy of Mike Behrenfeld

Absorptive Aerosol

Spectral Comparison at [22.34°N, 61.97°E]

Normalized Water Leaving Radiance (Lwn)



1.0

positive

0

negative

-0.5

400

700 nm

Some previous retrievals have produced negative Lwn values due to aerosol characterization difficulties

Figure courtesy of Menghua Wang

Atmospheric Fundamentals

Atmospheric Transmission

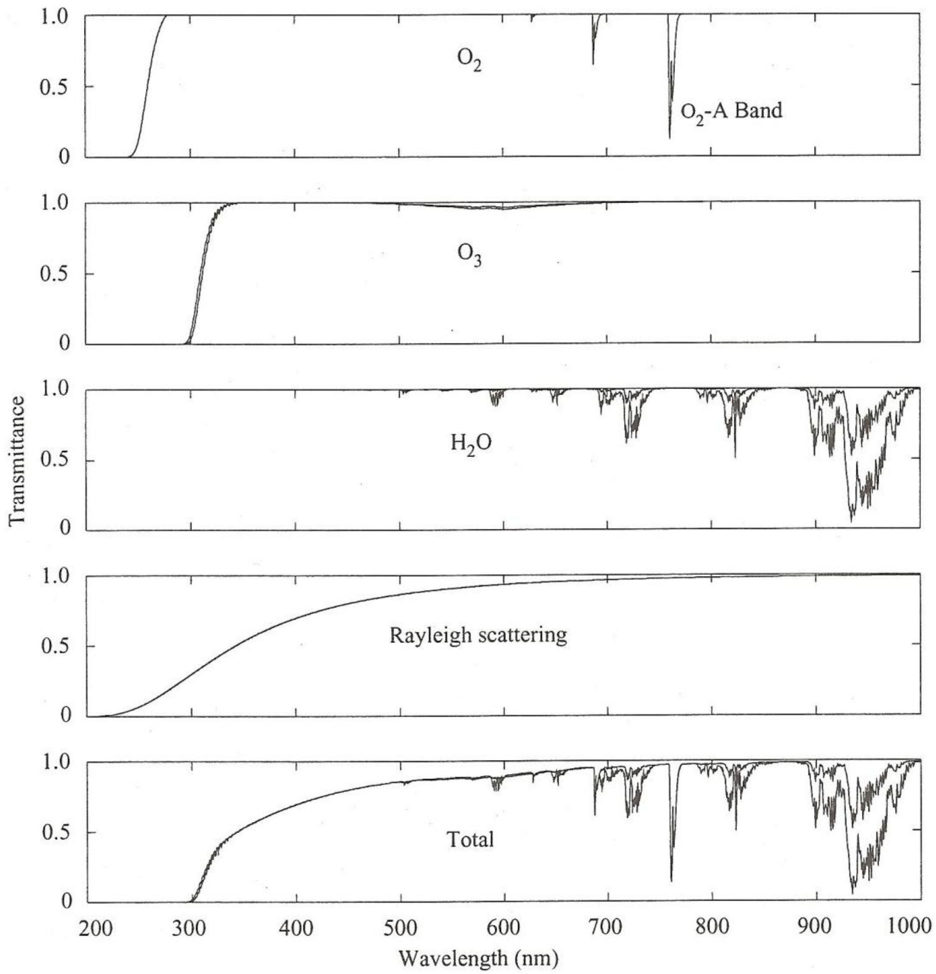


Figure 4.10. The wavelength dependence of the atmospheric transmittance for oxygen, ozone, water vapor, and Rayleigh scattering, for the two extreme MODTRAN cases of Tropical and Sub-arctic winter. For water vapor, the lower curve corresponds to the winter case.

O_3 absorption and Rayleigh scattering are strong at λ < 400 nm

Martin

Influence of Changes in Ozone

90 *Atmospheric properties and radiative transfer*

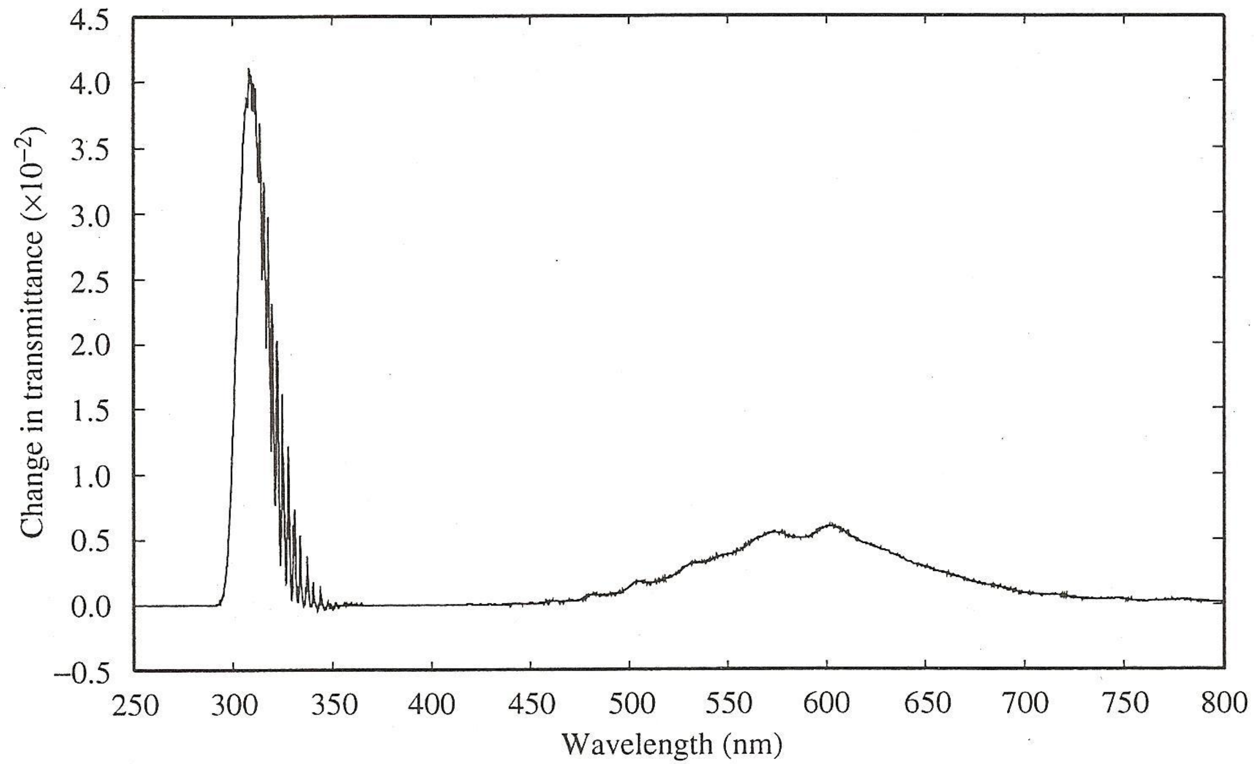


Figure 4.11. The difference between the MODTRAN Mid-latitude summer and winter transmittance associated with the decrease in summer ozone.

O_3 effects are small 350 – 450 nm

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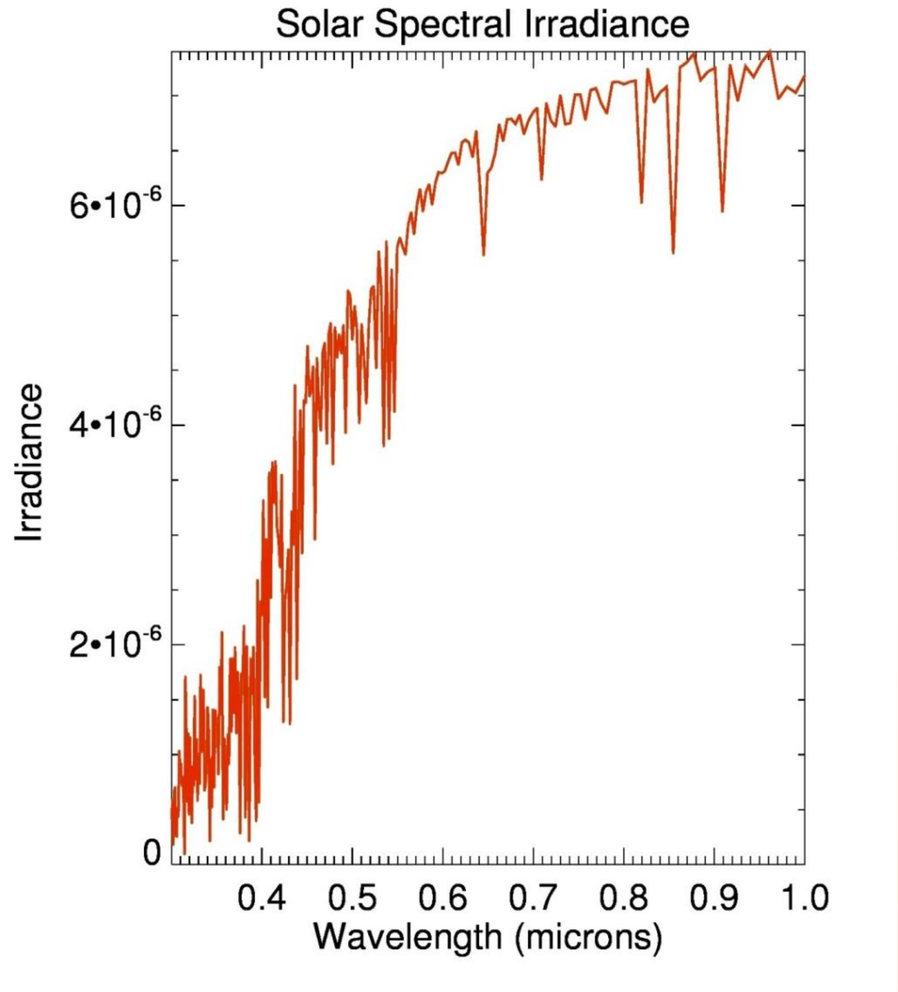
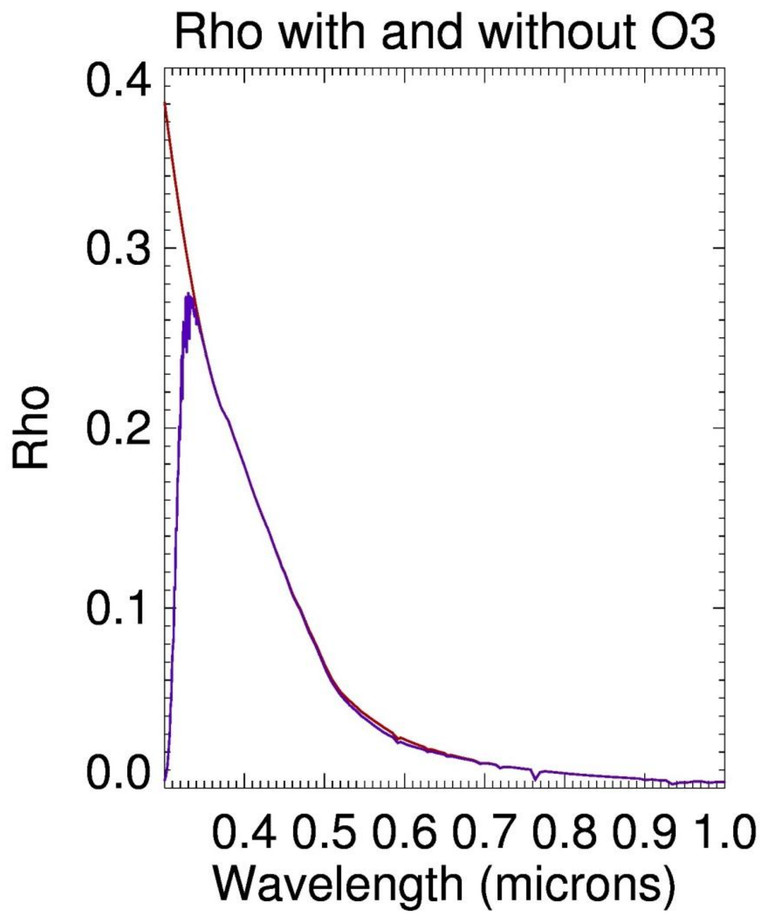
Solar Spectral Irradiance



The solar input becomes low at shorter wavelengths

Ozone effects



Rho – normalized radiance

Red
no O3

Purple
O3 included

Ozone effects become strong at $\lambda < 350$ nm

Calculations

Inputs to Modtran3 Program

Baseline is Robert Frouin's Maritime aerosol case

Solar zenith angle 29.4

Viewing angle 20.1

Ps=1013 (surface pressure)

Relative azimuth angle = 180

Appreciation is expressed to Oleg Dubovik and Arlindo da Silva for aerosol calculations that are applied in the Modtran calculations

Focus here is on aerosol effects

Will also present perturbation calculations (e.g. effects of Pressure, etc)

Ocean Color Definitions

Normalized Radiance (Rho, ρ)

Rho = π E / L (L Solar Spectral Irradiance)

Top of atmosphere E from Modtran3 is watts / (cm^2 (cm^{-1}) ster)

L is in watts / (cm^2 (cm^{-1})

Divide L by π to get spectral radiance units

Ocean Color Definitions

Seelye Martin (An Introduction to Ocean Remote Sensing) discusses the normalized water leaving radiance

$$Lwn(\lambda) = T^2\, Refl(\lambda)\, Solar(\lambda) / n^2 Q \qquad T=0.98,\ n=1.34,\ Q \text{ from 3 to 6}$$

and remote sensing reflectance R_{rs}

$$R_{rs}(\lambda) = T^2\, Refl(\lambda) / n^2 Q$$

Normalized reflectance

$$\rho(\lambda) = \pi\, R_{rs}(\lambda)$$

Cases considered

Aerosol optical depth (AOD) = 0.15 at 550 nm

Cases	Comments
Robert's Marine	View = 20.1, SZA = 29.4, Azimuth=180
Dubovik Cape Verde	Dust
Arlindo's case #4	"Dust 1" case
Marine + Cape Verde	Dust from 3 - 5 km, Marine 0 – 2 km
Marine + Cape Verde	Dust from 4 - 6 km, Marine 0 – 2 km No dust from 3 to 4 km This case is the "DZ+1km" case

Robert's Aerosol Types

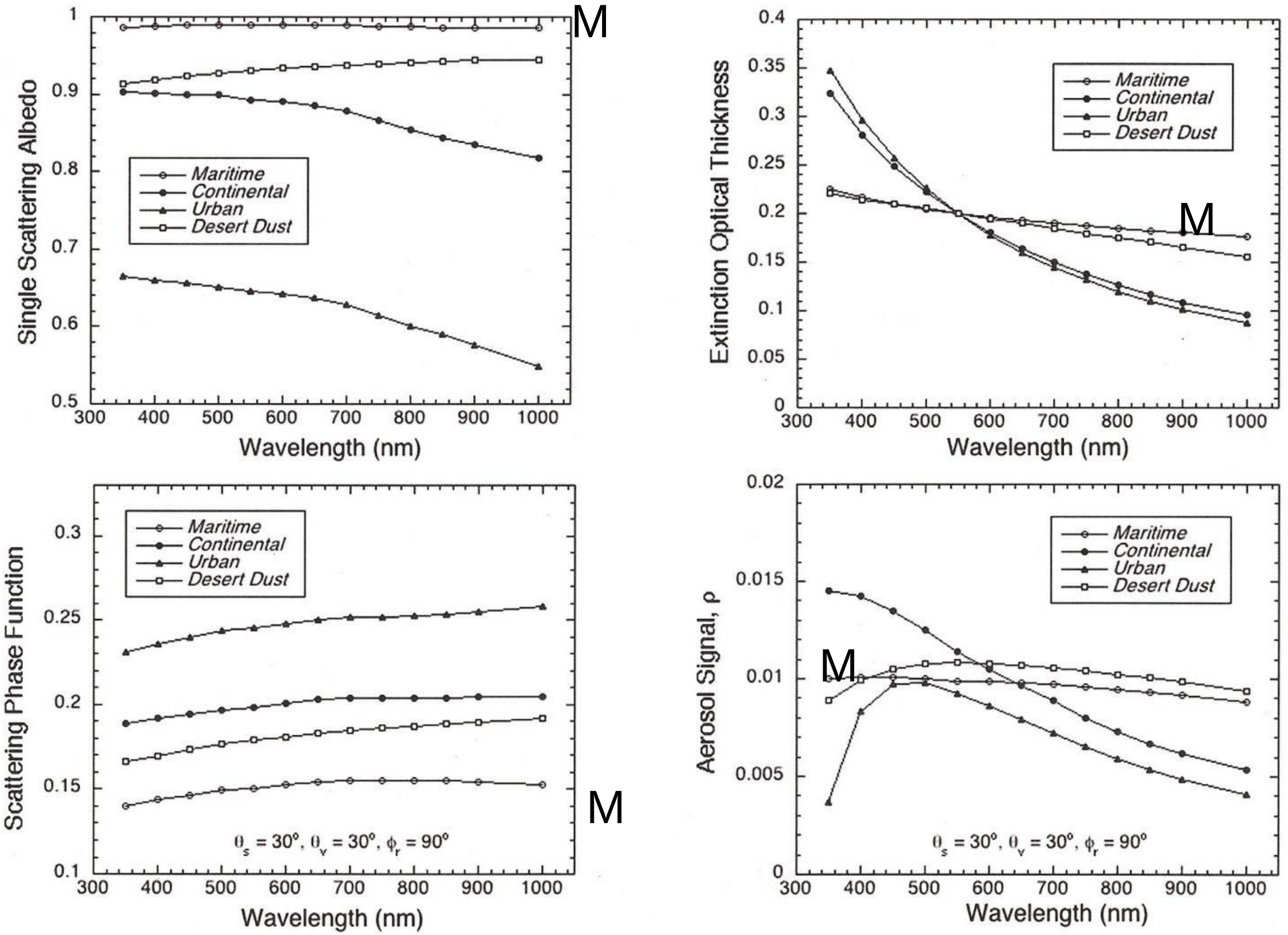


Figure 1: Aerosol single scattering albedo (top left), optical thickness (top right), and phase function (bottom left) for the selected geometry and aerosol conditions (see previous slide). Resulting aerosol signal, ρ (bottom right).

M – Maritime (strong Scattering)

AOD=0.2 at 550 nm

SZA=30
View=30
Azimuth=90

Notice that absorptive aerosol (desert dust and urban) ρ falls off at shortest λ

Figure courtesy of Robert Frouin

Robert’s Calculations

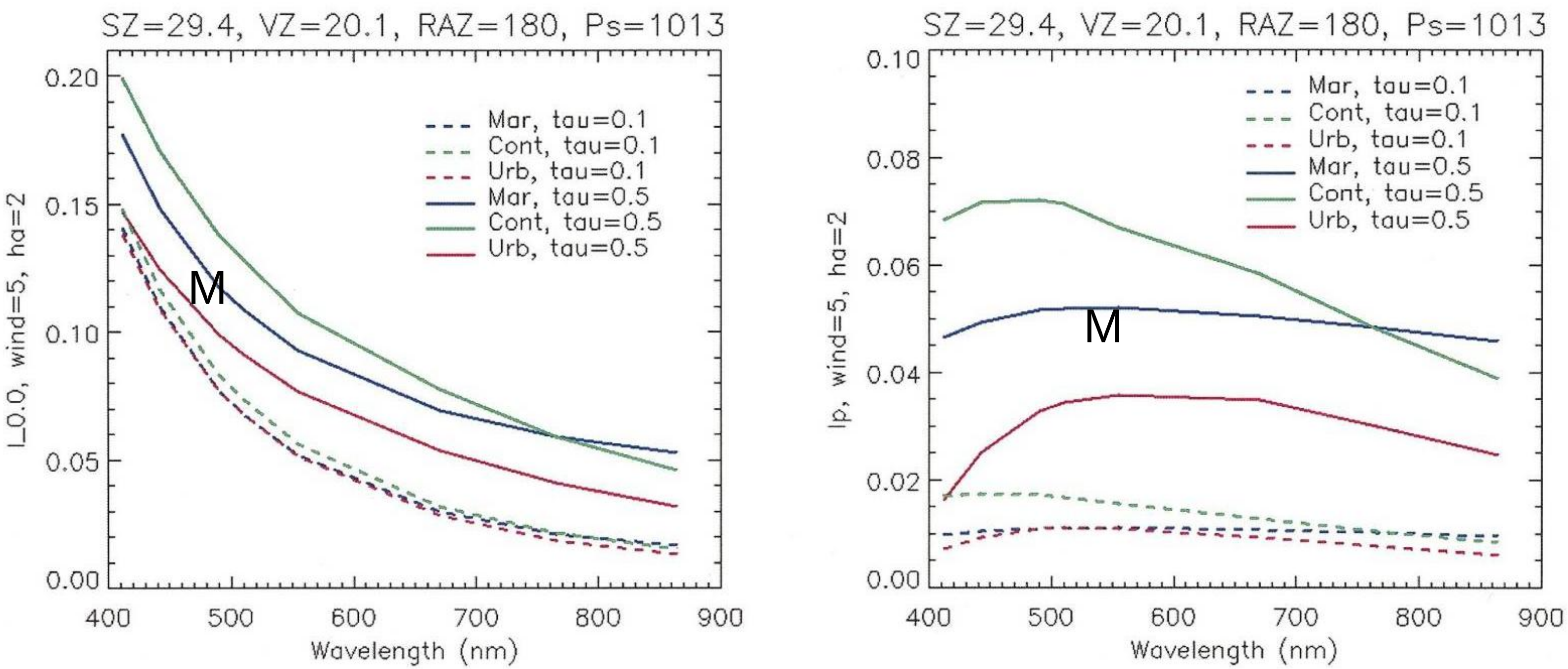
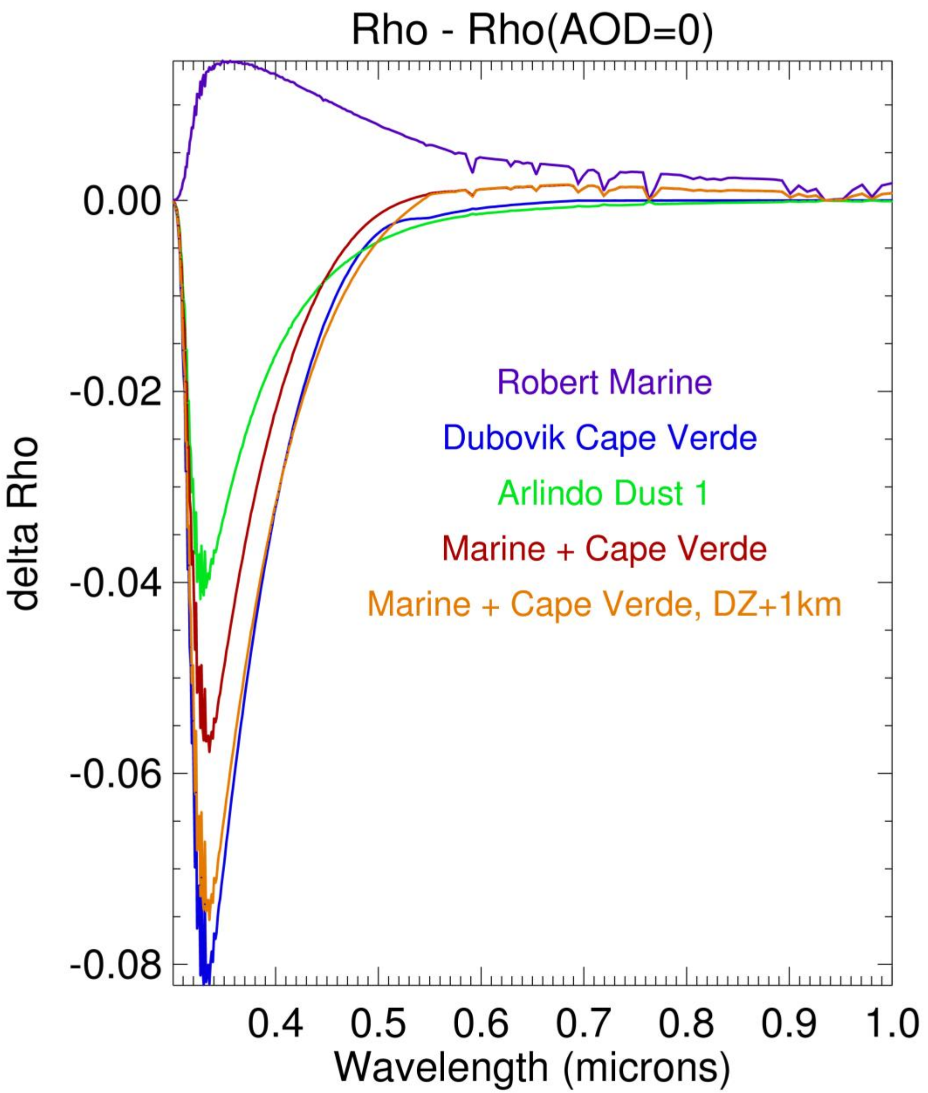


***Figure 1 a**: Simulations of the top-of-atmosphere normalized radiance ($\pi L/E$) by a vector radiation transfer code based on the successive-orders-of-scattering method. The atmosphere contains molecules and aerosols and is bounded by a wavy surface. Backscattering by the water body is null. Sun zenith angle is 29.4 deg., view zenith angle is 20.1 deg., relative azimuth angle is 180 deg. (backscattering), wind speed is 5 m/s, and surface pressure is 1013 hPa. Three types of aerosols are considered, maritime, continental, and urban, and aerosol optical thickness is 0.1 and 0.5 at 865 nm. Aerosol scale height is 2 km. (Left) Total signal. (Right) Signal after subtraction of the molecular signal (calculated assuming no aerosols).*

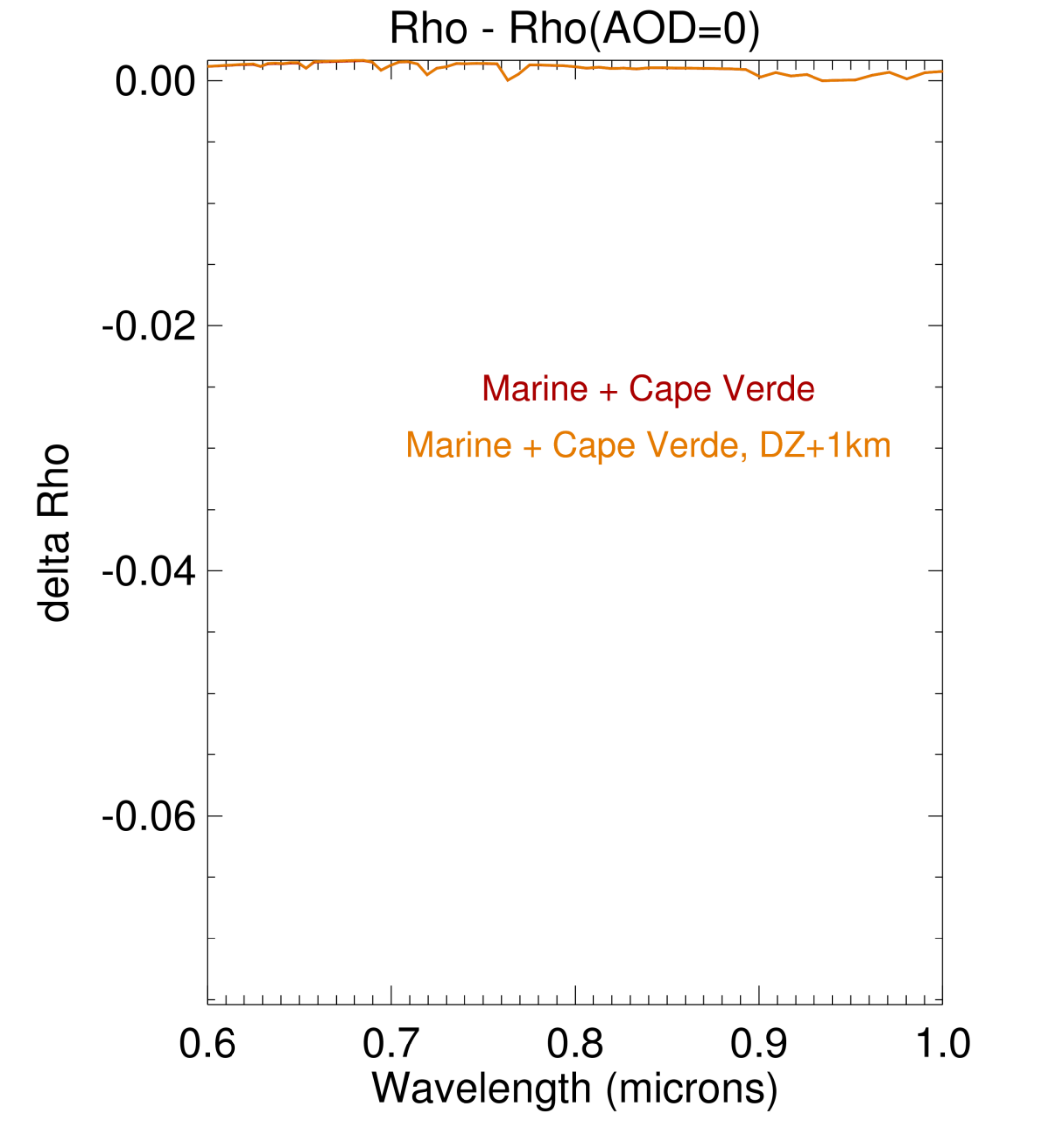
M - Maritime

Figure courtesy of Robert Frouin

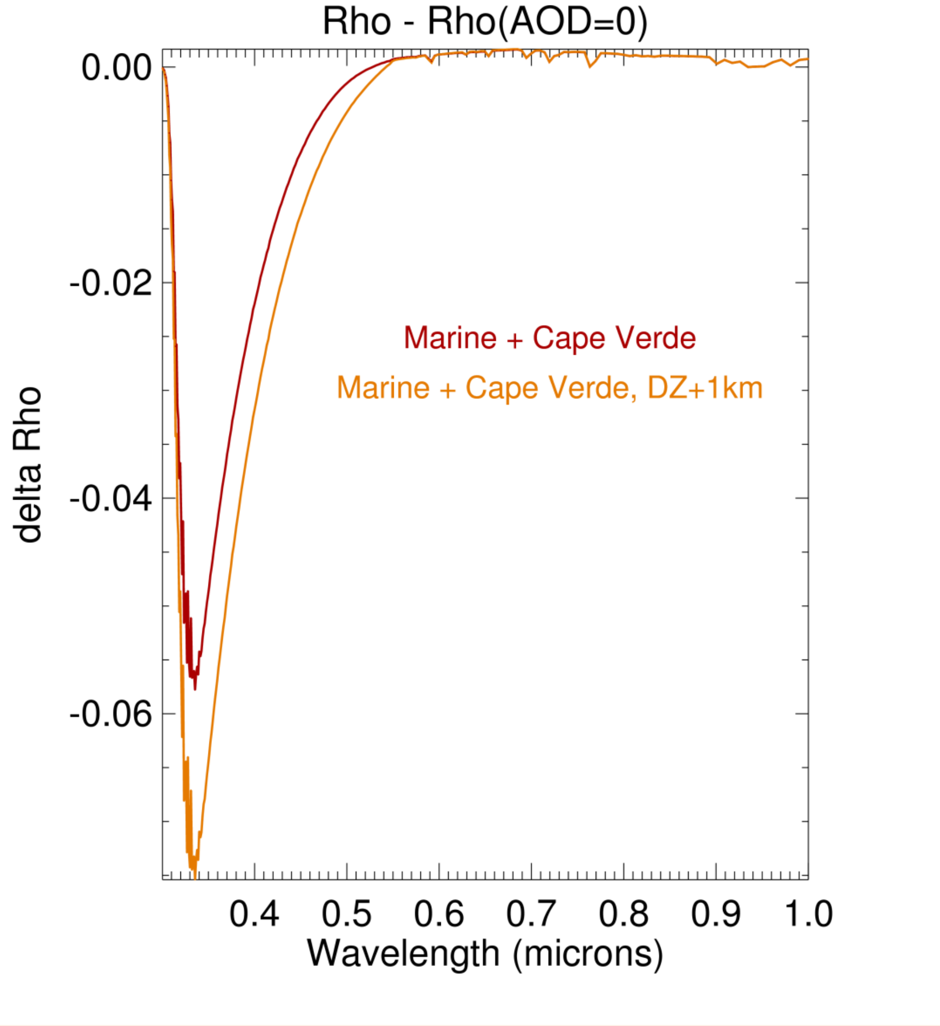


Aerosol scattering increases normalized radiances for Robert's marine case

Aerosol absorption decreases normalized radiances



It is not possible to distinguish between the two curves if only Information from λ > 600 nm is used.



Absorptive-aerosol altitude effects are important.

Information from the full wavelength range (λ > 340 nm) is needed to discern the details of the aerosol effects.

The two curves do differ at wavelengths less than 600 nm.
The two curves differ by $\Delta\rho$ ~ 0.006 near 450 nm

Subsurface Reflectivity

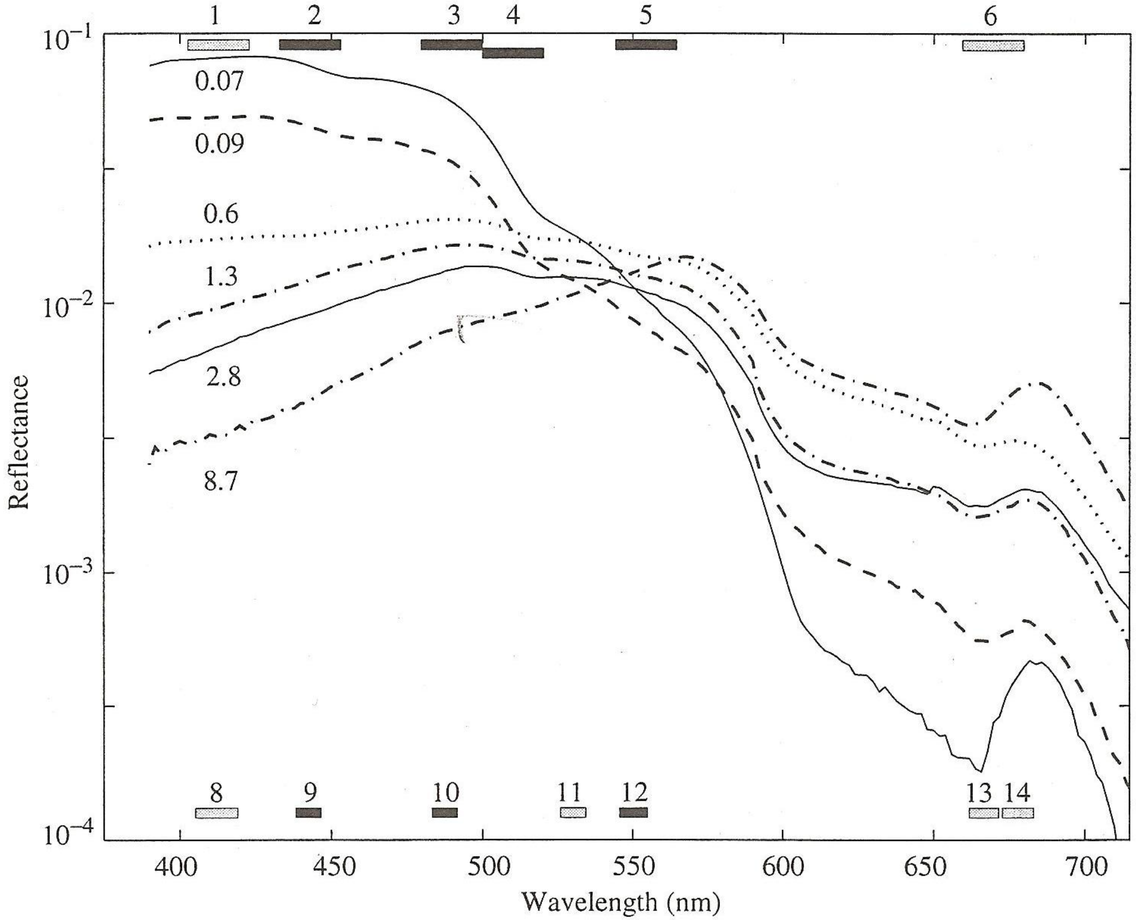


Figure 6.14. The subsurface reflectance $R(\lambda)$ plotted versus wavelength, for several values of C_a shown to the left and adjacent to each curve in units of mg m^{-3}. The lower horizontal bars show the MODIS bands; the upper, the SeaWiFS bands. SeaWiFS band 4 is offset vertically for clarity. For each set of bands, the black bars identify those used in the SeaWiFS and MODIS empirical Chl-*a* algorithms discussed in Section 6.6 (Data from Roesler and Perry, 1995, courtesy Collin Roesler).

0.10

0.01

0.001

0.0001

Refl

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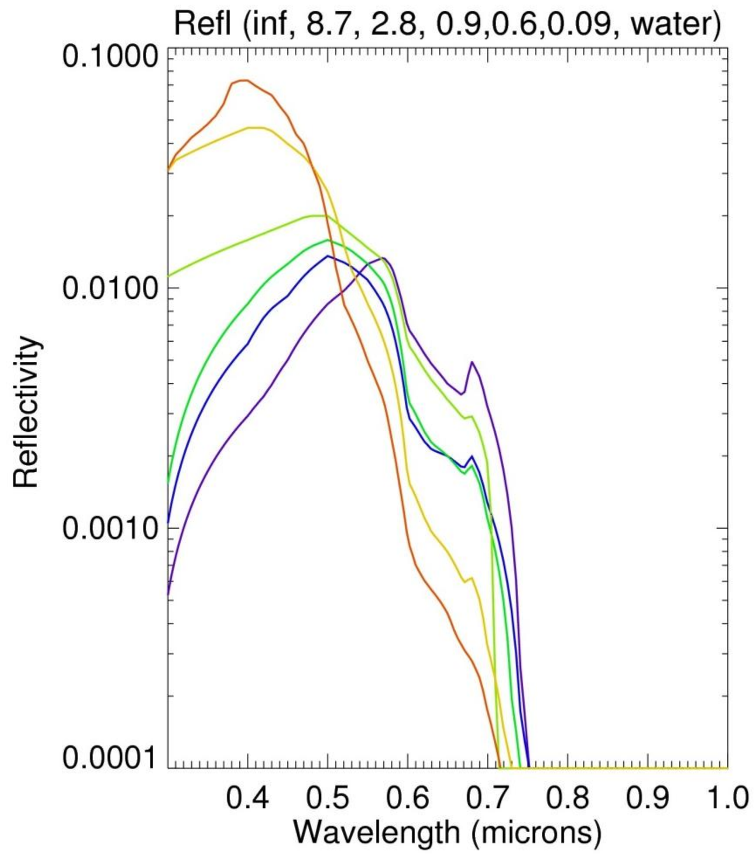
Changes in Refl are small as Chlor-a > 1.3 mg/m3

Subsurface Reflectivity used in Modtran calculations



Orange
Sea Water
(refl max near 7%)

Yellow
Chlor =0.09 mg/m3

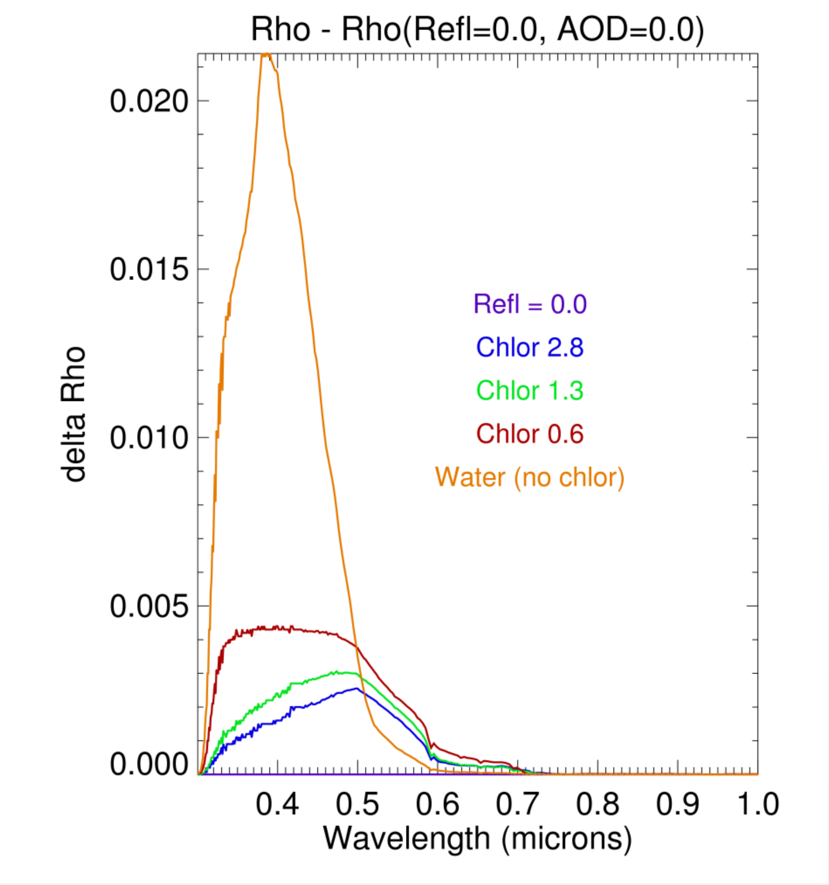
Light green
0.6

Green
0.9

Blue
2.8

Purple
8.7

Extrapolation used from 400 to 300 nm – need to revise !



Chlor in mg /m^3

Gordon and Wang
(Appl Opt, v33, p443, 1994)
SeaWifs accuracy spec $\Delta\rho_w$ ~ 0.001 at 443 nm

Difference in 2.8 and 1.3 mg/m^3 curves is ~0.0007

Representative Sensitivities

Variable	Derivative	Perturb	Δ Rho
AOD	0.08 (Rho/ AOD)	0.1 AOD	0.008
Chlor-a (2.8 mg/m^3)		see note	0.0007
ω (scattering)	0.08 (Rho/ω)	0.05 ω	0.004
Pressure	8×10^{-5} (Rho/hPa)	25 hPa	0.002

ΔRho for Chlor-a are the differences in the Rho(chlor-a) curves for the 2.8 and 1.3 mg/m^3 curves in the previous graph

All ΔRho's (<u>all variables</u>) are important

Comments

PACE multi-spectral (λ) measurements are needed to obtain better resolution of the taxonomy

Sub-1km resolution is needed to resolve features near the coastal shore

It is important to download from space the full set of spectra (full λ range at sub-1 km resolution, full latitude-longitude raster)

The full spectra are needed to account for the atmospheric contributions to the measured radiances

To improve upon the aerosol correction, one needs to use aerosol information in the full λ range from 350 nm to 1000 nm.

Thank You

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To provide facility support to the wider community; and,
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