# Modeling Global Water-leaving Radiances

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Abstract. Water-leaving radiances are the next challenge in global biological data assimilation. The radiances are important because they are indicators of ocean optical properties, which:

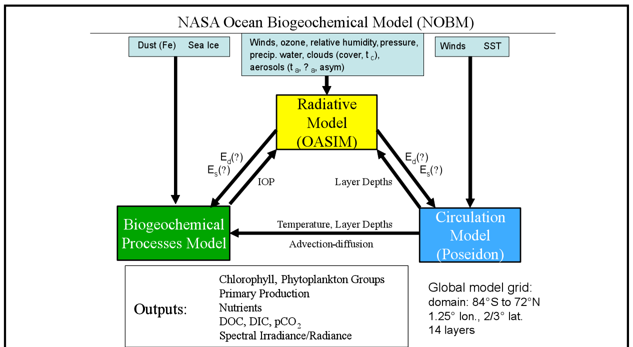
1) determine the radiative transfer of irradiance in the oceans, and thus affect the simulation of photosynthesis and heat transfer
2) provide information on the distributions of optically important constituents

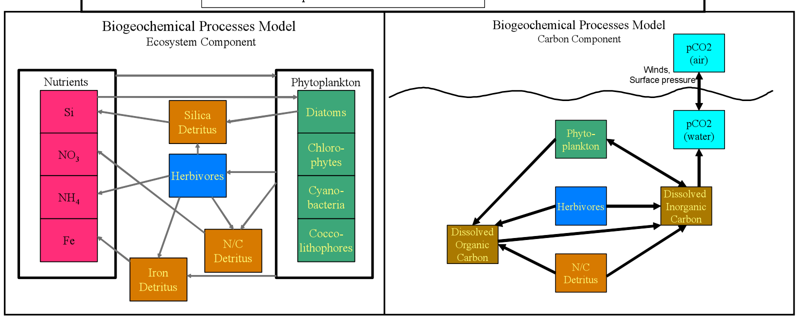
Initial results indicate good agreement of the model with MODIS-Aqua but show departures representing anomalous absorption and scattering.


**Coupled General Circulation/Biogeochemical/Radiative Model of the Global Oceans**

A schematic of a fully coupled general circulation/ biogeochemical/radiative model illustrates the complex interactions among the three major components (Gregg et al., 2003; Gregg and Casey 2007). The Ocean General Circulation Model (OGCM) is a reduced gravity representation of circulation fields, extending from near the South Pole to 72° N, in increments of 2/3° latitude and 1 1/4° longitude (Fig. 1). The model contains 14 vertical layers, in quasi-isopycnal coordinates.

The biogeochemical model utilizes the circulation fields and the vertical mixing processes to produce horizontal and vertical distributions of constituents. The model contains 4 phytoplankton groups, which differ in maximum growth rates, sinking rates, nutrient requirements, and optical properties to help represent the extreme variety of environments encountered in a global model (Fig 2). Phytoplankton are ingested by a separate herbivore component, which also contributes to the ammonium field through excretion. Carbon components are shown in Fig 2.




Oceanic properties in the Ocean-Atmosphere Spectral Irradiance Model (OASIM -- Gregg and Casey, 2009) are driven by water absorption and scattering, CDOM absorption, and the optical properties of the phytoplankton groups (Figure 7). Three irradiance paths are enabled: a downwelling direct path, a downwelling diffuse (scattered) path, and an upwelling diffuse path All oceanic radiative calculations include the spectral nature of the irradiance. Phytoplankton group-specific optical properties are derived from a variety of carefully controlled laboratory observations (Ahn et al. 1992; Bricaud et al., 1983; 1988; Morel, 1988; Morel and Bricaud, 1981; Sathyendranath et al., 1987). These characterizations are very similar to the compilation by Stramski et al. (2001) with different phytoplankton classification.

We have implemented a "three-stream" ocean radiative transfer model which is based on the Aas (1987) two stream approximation, modified for an explicit direct downwelling component by Ackleson et al. (1994).

Optical properties are defined by

$$a(\lambda) = a_w(\lambda) + a_{CDOM}(\lambda) + \sum chl_n a^*_{pn}(\lambda) + a_d(\lambda)$$

$$b_b(\lambda) = b'_{bw} b_w(\lambda) + \sum chl_n b'_{bpn} b^*_{pn}(\lambda) + b'_{bd} b_d(\lambda)$$

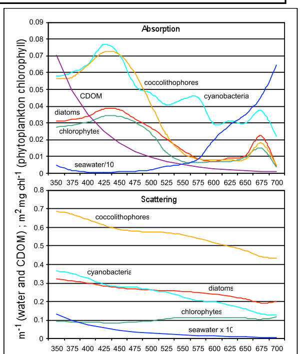



Figure 7. Spectral absorption and scattering coefficients of phyto-plankton groups, CDOM, and water in OASIM.

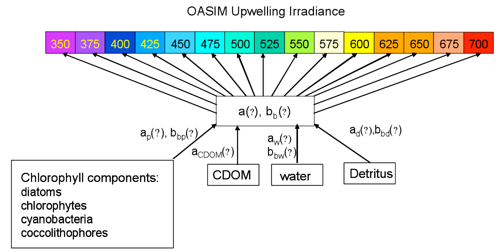
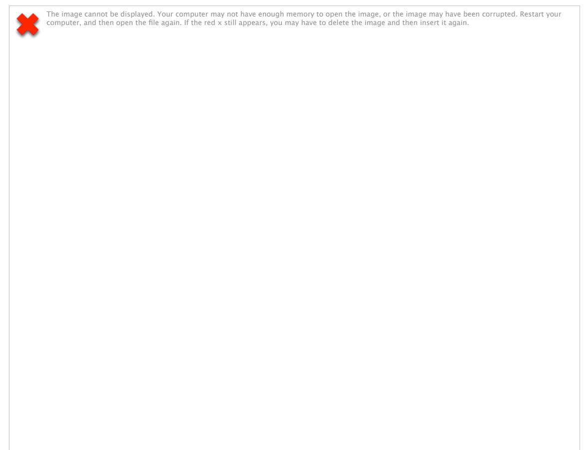



Figure 4. OASIM spectral upwelling irradiance and dependencies in the ocean. Shown are the visible bands. There are 2 additional bands in the UV and 16 additional bands in the NIR. Inherent optical properties are derived from pre-determined spectral characteristics of phytoplankton groups, CDOM, detritus, and water, and converted to apparent optical properties based on solar angles and relative abundances of phytoplankton groups. The optical properties known in the model, irradiance in the water column and backscattered upwelling radiance is computed from a "three-stream" model.




Modeled and observed water-leaving radiances for 443nm and 551nm. OASIM-centered radiances have been adjusted to MODIS-Aqua centers for a clearer comparison. Note that the underlying chlorophyll for the model has been assimilated using MODIS. There leads to overall agreement in spatial distributions, but the 443nm data shows the absence of a source of absorbing substances from tropical rivers, namely the Amazon and Congo. The radiances in th ecenter of the South Pacicfc gyre are not as bright as observed.

Radiances for 551nm also show overall agreement. Brightening in the northern high latitudes is due to coccolithophores and detritus in the model, and the correspondence with observations is noticeable. The model more clearly delineates mid-ocean gyres than MODIS does.


Modeled and observed water-leaving radiances for 412nm and 531nm. OASIM-centered radiances have been adjusted to MODIS-Aqua centers for a clearer comparison. The results are similar to the 443nm and 551nm comparison, but the departures are enhanced. This is especially true for the anomalous absorbing features related to tropical river discharges in 412nm.