represent the day and time of the image in (a). The subscript "pg" denotes particulate plus gelbstoff. Remote sensing data provides a means to resolve spatial variability and infer important bio-optical parameters. MODIS imagery and derived bio-optical products were provided by Richard Gould and Robert Arnone, Naval Research Laboratory, Stennis Space Center.

Ocean color data obtained from satellite sensors [e.g., SeaWiFS, Moderate Resolution Imaging Spectroradiometer (MODIS), and several others; see IOCCG Reports 1-3, 1999, 2000, and 2001, respectively] are most often used to infer concentrations of biological quantities (e.g., chlorophyll; O'Reilly et al., 1998; Yoder et al., 2001) and other optical information (absorption and scattering coefficients; Figure X.8). Empirical ocean color algorithms are developed to quantify constituents in the water column using wavelength or waveband ratios. Different ratios are employed for different optical parameters, e.g., normalized water-leaving radiance at 490 to 555 nm ($L_{WN}(490)/ L_{wn}(555)$) for chlorophyll-*a* concentration and $L_{WN}(443)/L_{WN}(510)$ for dissolved matter or gelbstoff (Kahru and Mitchell, 2001). Several different chlorophyll-*a* algorithms exist, applying different wavelengths ratios depending on the water column characteristics (O'Reilly et al., 1998). Analytical or semi-analytical algorithms employ the relationship between remote sensing reflectance and the ratio of backscattering to absorption (or absorption plus backscattering), i.e. radiative transfer (Lee et al., 2002). Algorithms using ocean color measurements of sun-induced fluorescence at wavelengths near 685 nm are proving to be valuable for estimating chlorophyll-*a*, especially in coastal waters (IOCCG Report 3, 2001). In addition, remotely sensed optical data can be utilized to estimate primary productivity (Behrenfeld and Falkowski, 1997; Behrenfeld et al., 2004) and beam attenuation and particle size distribution (Roesler and Boss, 2003).

With the advent of hyperspectral sensors (defined in Section X.3.1), a single instrument can provide a multitude of wavelengths and wavelength ratios to more accurately resolve a variety of water column constituents. Potentially, hyperspectral technology provides a means for oceanographers to remotely and synoptically classify and quantify complex oceanic environments with respect to particle characteristics, including phytoplankton identification at least by group, and specific chemical compounds (Chang et al., 2004). Recently, hyperspectral remote sensing systems have been used for the identification of red tides and other HABs (Stumpf, 2001), and the characterization of river plumes and fronts in the coastal ocean (Figure X.8).

It is important to keep in mind that remote sensing, although the only available platform for synoptic measurements and extremely powerful, can be limited. Cloud cover and coastal fog often obscure remote sensors, making images and data useless for analyses. Importantly, remote sensors measure radiances emitted only over the upper optical depth (Gordon and McCluney, 1975), typically ranging from about < 1 m in coastal waters to a maximum of ~35 m in the clearest, open ocean regions. Therefore, only surface HAB species may be detected in remotely sensed images. Due to sensor resolutions, satellite ocean color data is oftentimes contaminated by land; data are not available within about 5 km of coasts. Also, the nature of satellite orbital mechanics imposes restrictions on revisit frequencies, thus ocean color data are restricted in terms of temporal coverage. Thus, remote sensing information must be complemented with *in situ* observations (described below) to calibrate remote sensors (Barnes et al., 2001;