concerns the modulation of the spectral light field and radiant heating at depth as phytoplankton concentrations and communities wax and wane (Dickey and Falkowski, 2002). Some of the driving mechanisms, processes, and feedbacks for phytoplankton production are illustrated in a conceptual physical/biogeochemical model (Figure 2), which includes a basic nutrient-phytoplankton-zooplankton-detrital model component.

A major biological research effort has involved the estimation and modeling of primary production. This has been driven in part by a host of new technologies involving *in situ*-, satellite- and aircraft-based optical (color) sensors capable of measuring key parameters (with varying spectral resolution; often 7 and recently up to 100 wavelength bands in the visible) on unprecedented time and space scales. Primary productivity, P(z), as a function of depth, z, has also been estimated with relatively simple models using chlorophyll *a*, Chl(z), and PAR(z) data. Best estimates or measurements of the chlorophyll *a* specific light absorption coefficient for phytoplankton, a*, and the quantum yield for carbon fixation, $\phi(z)$, have been utilized as in the following empirical formulation

$$P(z) = a^* \, \phi(z) \, Chl(z) \, PAR(z) \tag{1}$$

Some of examples presented in this chapter utilize this type of relationship (see (e.g., see Bidigare et al., 1990, and Behrenfeld and Falkowski, 1997a,b, for more detailed information). Importantly, neither a* nor ϕ is constant because of community structure changes and varying light and nutrient stresses.

Another of our major remaining research questions concerns the relationship of upper ocean primary production and the flux of biogeochemical materials, especially carbon, to the deep sea. This is a complicated problem that again involves physical, chemical, and biological interactions and transformations. Some of the examples presented in this chapter outline recent work in this important study area.

The present chapter is intended to provide an introduction to our current understanding of biogeochemical processes, their observation, and their relationships with ocean physics. Our focus is primarily on the time domain, with consideration of processes that have time scales from minutes to the interannual (see Levy, this volume, concerning small time and space scale processes). Long-term, high frequency time series studies are ideal, and likely crucial, if we are to begin to understand subtle changes in the ocean habitat which are likely greatly affected by periodic forcing as well as episodic events that perturb the ocean's ecosystem and thus biogeochemical variability (e.g., Karl et al., 2001). Likewise, such studies are needed to help us to begin to unravel vexing biogeochemical questions related to presently unpredictable, large-scale climate variations such as El Niño-Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), the North Atlantic