The Light and Radiometry chapter explains how to describe light quantitatively. This chapter now explains how to describe and measure the optical properties of the medium through which the light propagates. We start with basic definitions and then discuss various schemes used to classify the optical properties of water bodies. The radiative transfer equation, which connects the optical properties of the water body and the light within the water, is developed in the chapter on Radiative Transfer Theory.

Natural waters, both fresh and saline, are a witch's brew of dissolved and particulate matter. These solutes and particles are both optically significant and highly variable in kind and concentration. Consequently, the optical properties of natural waters show large temporal and spatial variations and seldom resemble those of pure water.

The great variability in the optical properties of natural waters is the bane of those who desire precise and easily tabulated data. However, the coupling between constituent properties and optical properties implies that optical measurements can be used to deduce information about aquatic ecosystems. Indeed, it is the connections between the optical properties and the biological, chemical and geological constituents of natural waters that define the critical role of optics in aquatic research. For just as optical oceanography utilizes results from the biological, chemical, geological and physical subdisciplines of limnology and oceanography, so do those subdisciplines incorporate optics. This synergism is seen in such areas as bio-geo-optical oceanography, marine photochemistry, mixed-layer thermodynamics, lidar bathymetry, and "ocean color" remote sensing of biological productivity, sediment load, pollutants, or bathymetry and bottom type.

The bulk, or large-scale, optical properties of water are conveniently divided into two mutually exclusive classes: inherent and apparent. Inherent optical properties (IOPs) are those properties that depend only upon the medium, and therefore are independent of the ambient light field within the medium. The two fundamental IOPs are the absorption coefficient and the volume scattering function. Apparent optical properties (AOPs) are those properties that depend both on the medium (the IOPs) and on the geometric (directional) structure of the ambient light field, and that display enough regular features and stability to be useful descriptors of the water body. Commonly used AOPs are the various reflectances, average cosines, and diffuse attenuation coefficients. All of these quantities are defined and illustrated in this chapter.

Note that radiometric variables such as the radiance and various irradiances are not AOPs. They certainly depend on the radiance and on the IOPs, but they fail the requirement of being stable enough to be useful descriptions of the water body. For example, if the sun goes behind a cloud, the irradiances E_u and E_d can change by an order of magnitude within seconds, but the water body itself remains the same. However, the ratio E_u/E_d remains almost unchanged. As we will see, E_u/E_d does contain useful information about the water body itself, regardless of the ambient lighting conditions. E_u/E_d is thus a good candidate to be called an AOP.

Radiative transfer theory provides the connection between the IOPs and the AOPs. The physical environment of a water body—the waves on its surface, the depth and character of its bottom, the incident radiance from the sky—enters the theory via the boundary conditions necessary for solution of the equations arising from the theory.

The goal of this chapter is to survey the bulk optical properties of natural waters. Our discussion of these properties is tailored to meet the needs of radiative transfer theory as applied to optical oceanography, and we shall draw upon this information elsewhere in the web site. The reasons why the various optical properties have their observed values are discussed in other chapters. However, the unseverable connections between optics and biology, chemistry, and geology will still be obvious.