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## Chapter 7

# Bio-Optical Characteristics and Remote Sensing in the Mid Chesapeake Bay Through Integration of Observations and Radiative Transfer Closure

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Remotely sensed ocean color is an essential tool for studying water quality and biogeochemical processes, and applying results for coastal ecosystem assessment and management. Successful interpretation and application of remote sensing data depends to a large extent on the accuracy of, and consistency among, the in-situ data used in the calibration and validation of satellite measurements and in algorithm development. Thus, the degree of closure among bio-optical quantities independently measured in the field becomes critical for remote sensing applications. Optical closure results can be used to identify sources of errors associated with different measurement methodologies, investigate uncertainties in relations between inherent and apparent optical properties used in bio-optical models, and examine the relative importance of certain processes in determining ocean color. Here, we discuss how remote sensing of water quality in optically complex environments can be improved by integrating optical measurements and radiative-transfer model calculations. This approach is illustrated with recent findings on the bio-optical characteristics of Chesapeake Bay waters, including measurements of the magnitude and spectral characteristics of particulate backscattering. We then discuss progress on optical closure studies in coastal regions and propose bio-optical relations for remote sensing retrieval of water quality indicators in the Chesapeake Bay ecosystem.

## 7.1 Remote Sensing of Ocean Color in the Chesapeake Bay: Progress and Challenges

The Chesapeake Bay is the largest estuary in the U.S. with about 150 rivers and streams draining into the Bay. Its drainage basin is 166,000 km<sup>2</sup> in area, supports more than 3,000 species of plants, fish and animals, and has over 15 million people living nearby. In addition to its great socio-economic significance, Chesapeake

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Bay has significant commercial, recreational, and national security value directly related to the productivity and quality of its water. In recent years the water quality of the Chesapeake Bay has suffered as a consequence of growing human activity on the surrounding land and from excessive fishing in the bay. Nutrients entering the bay from agricultural runoff and inadequate sewage treatment often cause extensive phytoplankton blooms, leading to increased biological oxygen demand and reduced light penetration into the water column. Depleted fisheries, resulting from excess removals, increased pollution, and loss of submerged aquatic vegetation (SAV), associated with reduced water clarity, are major problems in these waters (e.g. Boesch 2000).

Improving the Bay's water quality has been a primary objective of management agencies for several decades. Because the composition and concentrations of water constituents (e.g. dissolved organic matter, phytoplankton and suspended sediments) influence the water optical characteristics, optical measurements can be applied to monitor changes in water quality in the Bay (e.g. Glibert et al. 1995, Harding et al. 2004, Gallegos and Bergstrom 2005). Monitoring methods that include aircraft, satellite, and in situ optical instruments are being used to assess ecosystem state and detect changes in response to management actions (Harding et al. 2004). Recently, our ability to detect these changes has been augmented by technological advances in optical sensors and radiative transfer modeling techniques. Here, we discuss how remote sensing of water quality in this optically complex environment can be improved by integrating optical measurements and radiative transfer calculations. This approach is illustrated with recent findings on the bio-optical characteristics of the middle region of the Chesapeake Bay.

Incorporating new techniques with in situ and remotely-sensed measurements into the Chesapeake Bay monitoring activities is challenging, but also a critical step for taking advantage of the strengths offered by the different approaches (e.g. Boesch 2000, Harding et al. 2004). In situ measurements of optical properties, as well as physical, chemical, and biological indicators of the Bay's health, have been performed by several ship-based programs during the last decades. By providing observations at high spatial resolution and information on diurnal changes or vertical distribution of water constituents, these field efforts have resulted in an extensive monitoring network that has evolved to provide important information for sustainable management of the Chesapeake Bay natural resources. Yet, the spatial and temporal coverage of in situ measurements is often insufficient for resolving important estuarine processes. Because in situ measurements are essentially point observations, tides and advection can further complicate their interpretation.

Remote sensing of ocean color, using airborne or satellite sensors, offers the capability of extending field observations beyond the restricted in situ sampling domain. Aircraft surveys provide surface maps at high spatial (less than 1 m) and spectral (up to 256 channels in the visible) resolution. Since aircrafts can be flown under clouds, they can provide data even on cloudy days. The Chesapeake Bay is probably the best-studied water body in the world using aircraft remote sensing, with over 300 flights flown between 1989 and 2002 (e.g. Hoge and Swift 1981, Harding et al. 1994, Lobitz et al. 1998). However, aircraft surveys, similar to shipboard surveys,