Towards Water-Type-Invariant Chlorophyll-a Estimation Using Normalized Relative Arc Length

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Satellite-based Earth observation has emerged as an important technology for understanding how aquatic systems are affected by global climate change and local anthropogenic forcings. Phytoplankton dynamics are the primary indicators of this response. Phytoplankton are microscopic plant-like organisms that live in natural water bodies and chlorophyll-a is their dominant pigment along with various accessory pigments. Because these pigments absorb a significant amount of the incident light, their absorption features are visible in the spectral reflectances. However, the phytoplankton signal is mixed with that of other optically active constituents such as non-algal particles (NAP) and colored dissolved organic matter (CDOM) and in shallow waters, the measured spectral reflectance is further influenced by bottom reflectance from substrates such as sand or sediment. Estimating pigment concentrations from reflectance is therefore an ill-posed inverse problem [1], and the absorption features of phytoplankton are difficult to resolve from hyperspectral satellite data of natural waters with varying optical backgrounds.

The relative importance of these constituents varies strongly between water types [2]. In the open ocean, the phytoplankton is the dominant contributor to the measured signal, whereas in optically complex waters such as lakes, rivers and estuaries, it is one of several contributors, and its magnitude varies relative to CDOM, NAP, and bottom reflectance. Because the dominant contributor changes across water types, regression methods calibrated for one optical regime do not reliably transfer to another.

To accurately estimate the concentration of pigments such as chlorophyll-a from measured spectral data, it is necessary to determine a unique representation of chlorophyll-a that is invariant across different water types. Since chlorophyll-a is one of the dominant factors influencing spectral reflectance in the visible wavelength region, the data manifold sampled by a set of spectra can be approximated by a curve whose endpoints are defined by spectra of phytoplankton with maximum and minimum chlorophyll-a content. Estimating the chlorophyll-a content of a test sample then reduces to determining its relative position along this curve. To efficiently determine the relative position of a sample along the curve, the Normalized Relative Arc Length (NRAL) was proposed in [3] for soil moisture estimation. In this work, we investigate the applicability of NRAL for estimating chlorophyll-a from spectral reflectance measurements acquired from different water types. The initial results indicate that NRAL is also applicable to chlorophyll-a estimation. On a dataset constructed using the GLORIA[4] and BRAZA[5], NRAL reduced the RMSE from 20.73 μg/l for a two-band ratio algorithm baseline to 13.43 μg/l, a 35% improvement.

References

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