

ANALYSIS OF HYPERSPECTRAL COASTAL OCEAN COLOR DATA

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LONG-TERM GOALS

The goal of this project is to develop spectral analysis techniques for ocean color analysis that are explicitly designed for use with hyperspectral data.

OBJECTIVES

The CoBOP program offers a rare opportunity to test any spectral analysis techniques with a wealth of remote sensing and in situ spectral data. Our objective is to develop a set of spectral analysis methods that are appropriate for remote sensing and to adapt them to remote sensing of ocean color. The procedures will be tested and evaluated using data collected during the CoBOP field program.

APPROACH

Since spectral analysis methods for laboratory applications have been well developed and documented, the general approach is to adapt methods used in analytical spectroscopy to remote sensing of ocean on coastal waters. Clearly, not all methods used in spectroscopy can be directly adopted to remote sensing analysis because there are issues that are unique to remote sensing (e.g., variable illumination, atmospheric transmission, lack of reflectance standards, etc.). Thus, to the extent that standard methods cannot be directly applied, we will either modify them or attempt to develop appropriate solutions.

Three general analytical procedures were identified as promising:

- 1) Multi-component analysis. This nonlinear optimization of reflectance spectra uses absorption and backscattering cross-section spectra to solve for the concentration of each component using any kind of known nonlinear relationship, (e.g. $R \propto bB/a$).
- 2) Spectral Feature Analysis: This is a nonlinear optimization procedure based on reflectance or absorption spectra, or even on derivative spectra. This method uses a Gaussian or Lorentzian elemental

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function to fit the whole spectrum and reduces the whole spectrum into a few spectral signatures (magnitude, FWHM, peak positions).

- 3) Self modeling, which estimates endmembers using only the remote sensing data and computes the portions of all endmember components simultaneously. Craig (1990) and Boardman (1993) introduced this method. The key point is to find a convenient way to estimate endmembers from a hyperdimensional space. Our approach is to develop a self modeling algorithm using classification and various hyperplane estimation techniques to the data points. Since water components contribute to the water leaving radiance nonlinearly, the result will not usually show the pure component spectra of water constituents, such as Chl, DOM, SM etc. Unless the nature of the spectral mixing can be specified *a priori* it may be necessary to limit this application to scenes consisting of only a few, relatively distinct components

WORK COMPLETED

Preliminary versions of software have been written and tested on synthetic data for each of the techniques described above. The programs are now being adapted to operate with image data. In addition, a program has been written to search for significant spectral features that correlate with in situ observations. The program uses the original spectra or derivative spectra

RESULTS

All of these analysis methods are based on an assumption of the linear additivity of individual component information. All are generally worthwhile approaches for land remote sensing where it is not unreasonable to assume that radiance from the surface is the sum of different spectral signals whose weightings are equivalent to the areal portion occupied in the pixel. This is not a very good assumption for water. The water-leaving radiance results from absorption and multiple scattering events over the optical depth of the water. Each component contributes to the signal in a non-linear fashion. Thus, of the three methods described above, only the multi-component analysis (method 1) is really appropriate. However, this method is also problematic since it requires prior knowledge of all the absorption and backscattering cross section spectra for all individual components. This idea is not a new one, having been proposed by Bukata et al. (1995), and perhaps others.

In spite of its drawbacks, we expect that nonlinear optimization will be an important technique and we expect to devote a significant portion of our development effort to it. There are two major reasons for taking this approach: 1) other conventional methods are not quite appropriate, and 2) there are now efforts to measure the spectral absorption and scattering cross

section of different water types and components (e.g. Stramski and Mobley, 1997). Hopefully, these efforts, including the measurements to be made as part of the CoBOP field program, will result in a sizable library of optical cross-section spectra which can be used to expand the utility of the nonlinear optimization approach.

Nonlinear optimization is computationally intensive for hyperspectral imagery since many computations are required for each pixel. For example, 5 components at 50 wavelength bands data requires $10^4 - 10^6$ FLOP counts according to the methods and iterations. One of our major concerns will be finding very efficient computational techniques.

Methods 2 and 3 are still likely to be useful although it is not yet clear to what extent. What these methods lack in their ability to track the true optical interactions in water they may make up for in providing practical tools.

IMPACT/APPLICATIONS

The non-linear nature of in-water optical interactions complicate the analysis of hyperspectral remote sensing data. It will be important to understand the practical limitations of methods that rely on the assumption of linear additivity while developing non-linear approaches.

TRANSITIONS

The intent is to apply our techniques to data collected by other investigators in the CoBOP program and to facilitate the data analysis. Thus far we have received reflectance spectra collected by Dr. Mazel and examined the relationship with concurrent chlorophyll observations.

RELATED PROJECTS

AASERT Project, N000149710721. This project is geared toward a more traditional remote sensing approach to multispectral analysis. It will provide a point of comparison to the more elaborate methods being developed here.

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