SEASONAL AND SPATIAL VARIATIONS IN PHYTOPLANKTONIC CHLOROPHYLL IN EUTROPHIC MONO LAKE, CALIFORNIA, MEASURED WITH THE AIRBORNE VISIBLE AND INFRARED IMAGING SPECTROMETER (AVIRIS)

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1. INTRODUCTION

The principal problem with application of airborne imaging spectrometers to lakes is the weak upwelling signal, especially when narrow spectral bands with high spatial resolution are sought. Furthermore, atmospheric path radiance dominates the signal received from dark targets such as lakes. Once atmospheric effects have been removed from the radiance received at the sensor, semi-empirical relationships can be developed to extract information about phytoplankton pigment concentrations for different underwater optical conditions (Carder, *et al.* 1986). In lakes where concentrations of dissolved organics and suspended detritus may not co-vary with phytoplankton pigments, the many spectral channels of an imaging spectrometer such a AVIRIS are likely to be required to distinguish the various aquasols.

The objectives of our study are two-fold: (1) We estimate the chlorophyll content of a lake with hundred-fold seasonal ranges in chlorophyll concentration using atmospherically corrected upwelling radiances derived from AVIRIS imagery. (2) After reduction of the coherent noise in the imagery by filtering techniques, we examine spatial patterns in chlorophyll.

2. STUDY SITE

Mono Lake is a large (150 km^2), moderately deep (mean depth, 17 m), hypersaline (total dissolved solids, ca. 90 g L^{-1}) lake lying in the North American Great Basin just east of the Sierra Nevada, California (38°N, 119°W; elevation ca. 1942 m above sea level) (Melack 1983). A decade-long, ongoing limnological study has included examination of spatial variability of the plankton (Lenz 1986) and primary productivity (Jellison and Melack 1988). The phytoplankton is dominated by very small (2-3 μm diameter) coccoid cells that vary in abundance from <1 to ca. 90 mg chlorophyll a m^{-3}. The offshore waters are largely uncontaminated by suspended particles from inflows but contain considerable dissolved organic matter.

3. METHODS

AVIRIS imagery of western and southern regions of Mono Lake was acquired on four dates: 26 May 1989, 27 March 1990, 10 August 1990 and 30 September 1991. On each date samples were collected at multiple stations for analysis of chlorophyll a and other photosynthetic pigments. Filtered water was obtained for laboratory absorption spectra. Up and downwelling photosynthetically available irradiance (PAR, 400 - 800 nm) was measured on each date.

The radiometrically corrected AVIRIS images were obtained from the AVIRIS project at the Jet Propulsion Laboratory (JPL). Atmospheric corrections were performed with LOWTRAN 7 using a multiple-scattering, mid-latitude, rural model. The atmospheric path radiance spectra, binned to the midpoints of the AVIRIS wavelengths, were subtracted band by band from radiance spectra averaged over subsets of the image containing only water to yield atmospherically corrected radiance spectra.

Chlorophyll a concentrations were estimated using a CZCS-type algorithm developed for coastal waters. To identify and reduce coherent noise, along-track and across-track power spectra were calculated for selected bands.

4. RESULTS

In-situ measurements of chlorophyll a concentrations ranged widely among dates and within the lake on individual days: 26 May 1989, 13 - 31 mg m^{-3}; 23 March 1990, 28 - 91 mg m^{-3}; 10 August 1990, 1 - 4 mg m^{-3}; 30 September 1991, 3 - 7 mg m^{-3}. Application of CZCS-type algorithms underestimated chlorophyll concentrations by a factor of about 2 for concentrations above 20 mg m^{-3}. Further research in progress will utilize more spectral information to develop new algorithms appropriate for eutrophic lakes.

Atmospherically corrected reflectance spectra have a signature for chlorophyll a when concentrations are above about 20 mg m^{-3}. However, the conspicuous reflectance maximum at about 570 nm and distinct minima at about 680 nm and 480 nm reported by Melack and Pilorz (1990) were less well defined for the other scenes.

Radiances from the surface as measured at the sensor, for bands near 570nm, were low (1 - 3 $\mu W\ cm^{-2}nm^{-1}sr^{-1}$) as expected for inland waters. Coherent noise in the form of 0.1 to 0.2 $\mu W\ cm^{-2}nm^{-1}sr^{-1}$ undulations oriented diagonally to the flight line were present in the 26 May 1989 image. Removal of most of the coherent noise by a simple ratio of two spectral bands revealed regional variation in brightness possibly related to differences in chlorophyll content. Coherent noise was detected in the other images and removal by ratioing and filtering is progressing. Hence, measurements of spatial patterns of chlorophyll concentrations are most likely obtainable.

5. REFERENCES

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