Report for 2002VT5B: Detection of cyanobacterial blooms using remote sensing

- Other Publications:
    - Wheeler, S., L. Morrissey, S. Levine, and W. Vincent, 2005, Mapping Cyanobacteria Blooms in Lake Champlain at Multiple Scales: A Comparison of Three Satellites, Ecological Society of American 90th Annual Meeting, August 7 – 12, Montreal, Canada. Morrissey to present.
    - Wheeler, S., S. Levine, L. Morrissey, and W. Vincent, 2005, A Comparison of Satellite Sensors for Mapping Cyanobacteria in Lake Champlain, USA/CAN, American Society of Limnology and Oceanography Annual Summer Meeting, June 19-24, Santiago de Compostela, Spain.
    - Wheeler, S.M, S.N. Levine, L.A. Morrissey, and W.F. Vincent. 2005. A COMPARISON OF SATELLITE SENSORS FOR MAPPING CYANOBACTERIA IN LAKE CHAMPLAIN. ASLO Meeting, June 19-24, Santiago de Compostela, Spain
    - Wheeler, S.M, L.A. Morrissey, S.N. Levine and W.F. Vincent. 2005. Mapping cyanobacteria blooms in Lake Champlain at multiple scales: A comparision of three satellites. Abstracts. ESA INTECOL Joint Meeting, August 7-12, Montreal, Canada.

Report Follows

Detection of cyanobacterial blooms using remote sensing

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The goal of this two-year study is to assess the feasibility of tracking and quantifying cyanobacterial blooms in Lake Champlain using remote sensing. Throughout this study, the specific project objectives included: 1) investigation of the spectral and spatial capabilities of existing satellites (literature research and consultation); 2) development of "groundtruthing" methodology (means of describing bloom pattern and intensity across image pixels); 3) simultaneous satellite image acquisition and field assessment of blooms in Lake Champlain; and 4) develop a local bio-optical model that relates spectral parameters measured by the satellites to cyanobacteria biomass in the lake, (assessed by pigment analysis and transmissivity data, the latter an indicator of particle concentration). We investigated the usefulness of three operational satellites for mapping and quantifying cyanbacterial biomass in Lake Champlain. The three satellite sensors examined included SPOT, Envisat MERIS and QuickBird. The spatial and spectral resolution of each satellite along with the cost and frequency of image acquisition were considered while evaluating the utility of each system.

In the summer of 2003, we acquired two images from the commercial European satellite SPOT. SPOT has a spatial resolution of 10 m that allows for examination of spatial detail within lakes and bays. However, this sensor also has broad spectral bands that can lead to sediment interference with chlorophyll assessment. This interference does not seem to be a serious problem in waters with high biomass levels such as those present in the bays of Lake Champlain. One scene was acquired (Aug 18th, 2003) coincident with field data collection.

Two cloudless MERIS images were acquired in September of 2003, in addition to 4 images in the summer of 2004. Groundtruthing was conducted for four of the dates of image collection (in either St. Albans or Missisquoi Bays during MERIS flyovers). MERIS is a sensor on the European satellite Envisat and has a return time of about 3 days. Although its spatial resolution is coarse (300 m pixel width), spectral band positioning is optimized for examining phytoplankton. The 15 spectral bands of this satellite allow for bio-optical modeling which is not possible with the other two satellites examined for this study. MERIS might be used to flag small lakes or bays of Lake Champlain with algal problems that might subsequently be analyzed through use of satellites with greater spectral resolution or field sampling. ENVISAT is considered an experimental satellite; only principal investigators on approved projects may order images. We obtained images through a Canadian collaborator, Warwick Vincent (Laval University, Quebec City). Dr. Vincent is tracking North American lakes between 70 and 75° W longitude, including Lake Champlain, to detect possible responses to climate change.

A single QuickBird image was collected in August of 2004. QuickBird is a commercial satellite launched by the company, DigitalGlobe, based out of Colorado. This satellite has 2.4-meter spatial resolution and spectral resolution similar to SPOT. Although QuickBird imagery is not practical from a monitoring perspective due to high cost, the high resolution imagery provides an excellent opportunity to study spatial detail of phytoplankton distributions.

For field assessment, water was pumped through a train of probes that measured fluorescence of phycocyanin and chlorophyll *a* along with transmissivity (a proxy for particle content). Water was collected from the front of the boat from a depth of approximately 10 cm and continuous measurements were made as our boat traversed a long transect at each field site. Transects were defined based on collecting the greatest variation of algae concentration. Transects usually began in deep, clear waters and ended in shallow areas within the bay with high concentrations of cyanobacteria. A Garmin GPS unit was used to track the exact time and location of the boat along each transect at 1-second intervals. Water samples were collected at several points along transects to permit analysis of extracted phycocyanin and chlorophyll, and thus calibration of the fluorescence data to pigment concentrations. In addition, phytoplankton samples were taken to determine species composition and cyanobacterial biomass.

Algorithm development for the satellite imagery continues. Initial processing techniques for our SPOT image were conducted based on research published by Chacon-Torres et al. (1992). Principal components analysis (PCA) was performed on the SPOT image and a correlation was made between SPOT PCA band 1 and field chlorophyll data (r^2=0.57; n=415). Based on the derived algorithm, a map of chlorophyll *a* concentrations in St. Albans Bay on August 18 was produced (Figure 1). Wind piling of algae along shorelines is apparent. Clearly this image better represents conditions in the Bay much better than the single site sampling normally carried out by the Vermont Department of Environmental Conservation.

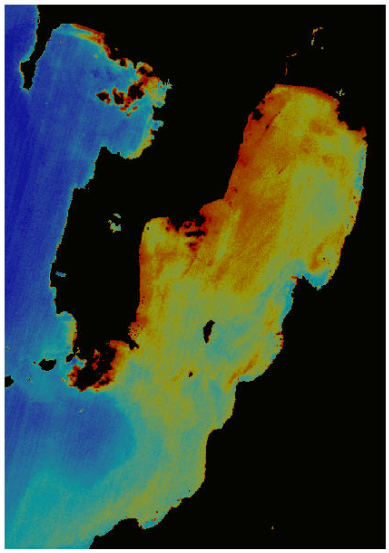

Figure 1. Relative chlorophyll content displayed from red (high concentrations) to blue (low concentrations). Predictions are based on principal components analysis of SPOT satellite imagery collected over St. Alban's Bay on August 18th, 2003.

The positioning of QuickBird spectral bands are similar to those of SPOT and therefore, PCA analysis is also being conducted on the QuickBird image. The derived algorithm from the analyses will be used to extrapolate chlorophyll *a* and phycocyanin concentrations for all of Missisquoi Bay. The high resolution imagery should allow for detailed examination of cyanobacteria distribution in the Northern portions of Lake Champlain.

For the MERIS images we have begun initial digital processing; however, we have not yet formulated algorithms. Analysis will focus on the relationship between band ratios and pigment concentrations. Figure 2a shows the large size of the MERIS frames; not only the entire lake but also many small lakes in Vermont and the Adirondack are covered by a single image. Figure 2b is a close-up of the north end of Lake Champlain. The green color in Missisquoi and St. Albans Bays represents algal presence at bloom densities.

Results to date will be presented this June at the American Society for Limnology and Oceanography (ASLO) conference in Santiago de Compostela, Spain as well as at the Ecological Society of America conference this August in Montreal.

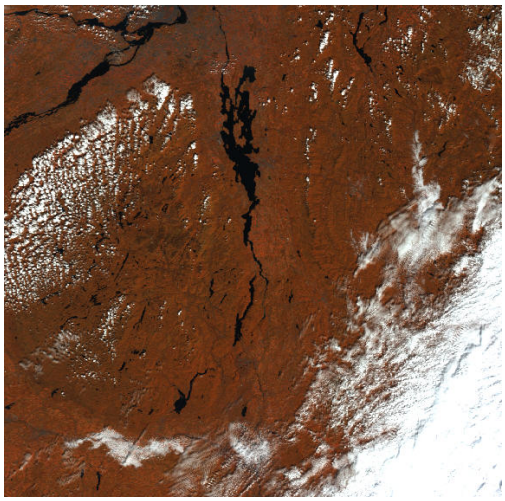

Figure 2a. Full scene of Lake Champlain taken from ENVISAT Meris on September 26th, 2003.

Figure 2b. ENVISAT Meris image of Mississquoi Bay and St. Albans Bay collected on September 26th, 2003.

Conference Abstracts

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References

Chacon-Torres, A., Ross, L.G., Beveridge, M.C.M., Watson, A.I. (1992). The application of SPOT multispectral imagery for the assessment of water quality in Lake Patzcuaro, Mexico. *International Journal of Remote Sensing*, **13**, 587-603.