Mapping Cyanobacteria Blooms in Lake Champlain at Multiple Scales: QuickBird and MERIS Satellite Data

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Harmful algal blooms in Lake Champlain (VT-NY-QC) are a serious concern to scientists and the public. Such blooms impact drinking water supplies, recreational use of lake waters, and, if toxic, pose a threat to human health. Remote sensing offers the potential to map and monitor the distribution of blooms and thus greatly augment current point sampling methods. This study assessed the utility of high spatial resolution QuickBird (2.4m, 4 bands at ~100nm) and high spectral resolution MERIS (300m, 15 bands at ~10nm) satellite data to detect and quantify cyanobacteria blooms in Lake Champlain at local and regional scales. Satellite data were acquired coincident with *in situ* water samples and *in-vivo* fluorescence of chlorophyll *a* and phycocyanin during the summers of 2003 and 2004. Cyanobacteria and associated chlorophyll *a* and phycocyanin pigment concentrations were predicted from QuickBird radiance data based on regression analysis. Additionally, the increased spectral information of the MERIS data allowed the use of published optical models to predict pigment concentrations. QuickBird showed great promise for mapping the heterogeneous spatial distribution of algal blooms over small areas while coarse-resolution MERIS was able to detect blooms over the entire lake and accurately predict pigment concentrations over the eutrophic bays.

Introduction: Monitoring lakes for potentially toxic blue-green algae is often difficult due to the patchy and dynamic distribution of blooms. Remote sensing offers promise for mapping and monitoring the spatial distribution and concentration of such blooms.

Objective: This study investigated the utility of two operational satellite sensors (see Table 1) to detect and quantify cyanobacterial (blue-green algae) biomass in Lake Champlain.

Methods: Data from QuickBird and Envisat MERIS multispectral sensors were acquired coincident with *in situ* water samples in the summers of 2003 and 2004. *In-vivo* fluorescence of chlorophyll and phycocyanin were measured along 5-15km transects co-located with GPS. To analyze the QuickBird imagery, regression models were used to link cyanobacteria pigment concentrations to satellite radiance data (band ratios and principal components analysis). Three published optical models[1,2,3] were applied to the MERIS imagery to predict cyanobacteria pigment concentrations. Field pigment data was used to assess the accuracy of these models.

Table 1: Satellite Specifications

	QuickBird	Envisat MERIS
Pixel Size	2.44m	300m
Visible Bands	3 – BGR	8
Near Infrared Bands	1	7
Scene Size (km)	16.5 x 16.5	582 x 650
Revisit Capability	1 – 3.5 days	2-4 days
Acquisition Date(s)	8-17-04	9-26-03, 7-20-04, 8-24-04, 9-3-04, 9-12-04

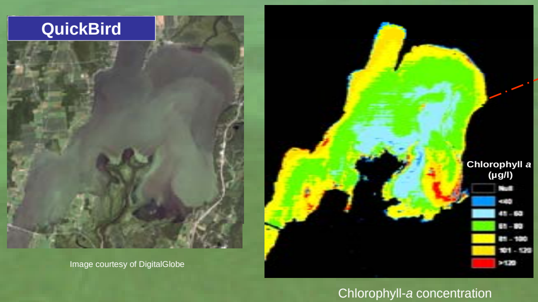

Figure 1. Algal bloom in Missisquoi Bay (USA/CAN) is clearly evident in both the natural color composite (acquired 17 August 2004) and classified QuickBird satellite image based on NIR/Red ratio.

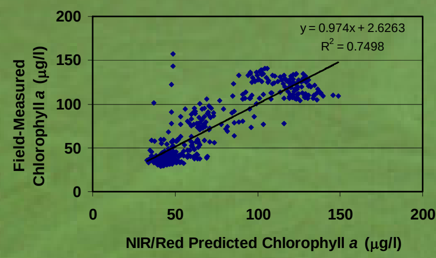

Figure 2. Linear regression plot between QuickBird-derived NIR/Red ratio and field measured chlorophyll *a* (µg/l) concentrations collected on August 17th, 2004 from Missisquoi Bay.

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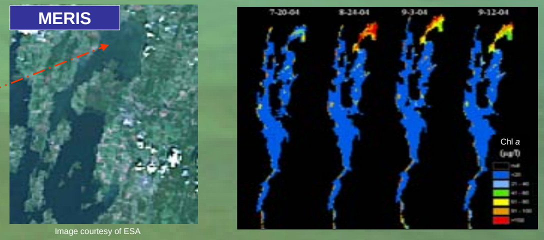

Figure 3. A natural color composite of a MERIS image (acquired on 26 September 2003)(left). Chlorophyll *a* (µg/l) estimations in a time series for Lake Champlain using Envisat MERIS satellite imagery and the Water Processor[3], a free automated model produced by the European Space Agency (right).

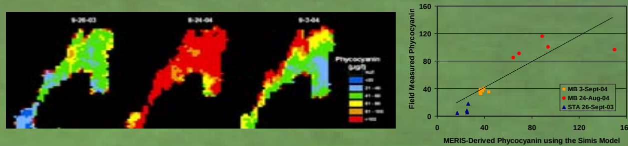

Figure 4. Phycocyanin concentrations for Missisquoi Bay using MERIS imagery with the Simis model[1] (left) and regression results between MERIS predicted phycocyanin and field measured phycocyanin (right).

Conclusions: Although designed for terrestrial applications, QuickBird explained 75% of the variability of cyanobacterial pigments and successfully mapped the heterogeneous spatial distribution of algal blooms. Designed for marine applications, MERIS also proved successful in detecting and monitoring large-scale bloom development without the need for coincident field data. Remote sensing from these and future satellites can provide improved insight to the spatial distribution of cyanobacteria in lakes and therefore should be an integral part of every bloom-monitoring program. In addition, remote sensing in conjunction with field work might advance understanding of the ecology of the bloom-forming algae and thus improve the effectiveness of management and restoration programs.

1. Simis, S. G. H., Peters, S. W. M., Gons, H. J. 2005. Remote sensing of the cyanobacterial pigment phycocyanin in turbid inland water. *Limnology and Oceanography*. 50: 237-245.
2. Gons, H. J., Rijkeboer, M., Ruddick, K. G. 2005. Effect of a Waveband Shift on Chlorophyll Retrievalfrom MERIS Imagery of Inland and Coastal Waters. *J Plankton Res*. 27: 125-127.
3. Thomas Schroeder and Michael Schaale, 2005. The FUB/WeW WATER processor is a plug-in module for the BEAM software developed by Brockmann Consult for ESA. http://scipc3.scicon.gkss.de/services/beam2/software/