SPECTRAL BIOMASS ALGORITHMS Vs. PRINCIPAL COMPONENT ANALYSIS IN WATER QUALITY MAPPING

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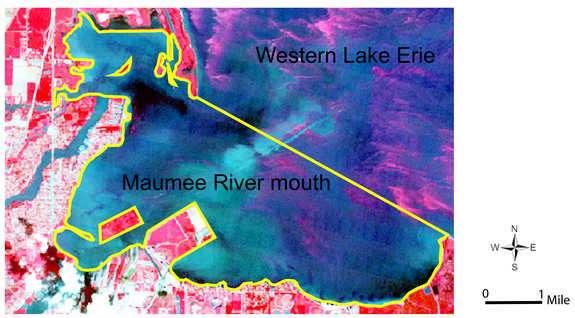
ABSTRACT

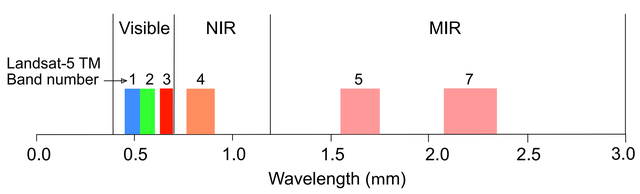
The study compared the effectiveness of spectral biomass algorithms and principal component analysis for mapping the spatial extents of suspended particulates and *Microcystis* bloom in Maumee River mouth of western Lake Erie. We processed Landsat-5 TM imagery acquired on 19 August 2003 as many literature sources identified and confirmed the occurrence of a *Microcystis* harmful algal bloom (HAB) over the investigated area during that period. Comparisons were made between spectral biomass indices and the meaningful latent water quality parameters resulted from principal component analysis (PCA) focusing on each pixel of the study area in order to identify even minor localized water quality variations. Microcystis is a cyanobacteria and it has been shown that the measurements of the pigment phycocyanin can be used to estimate their concentration and distribution using Landsat TM imagery (Vincent et al., 2004). For spectral biomass algorithms, we used normalized difference vegetation index (NDVI) and phycocyanin quantification algorithms proposed by Vincent et al., 2004. The first two meaningful components resulted from PCA accounted 42% and 17% of variance in the entire data set and reported correlations of 0.64 and 0.93 with single band phycocyanin algorithm and NDVI respectively. The presence ofphycocyanin in the areas identified by the algorithms in Vincent et al., 2004 remained uncertain because the spatial pattern of high positive factor scores of component-1 which coincided with that of single-band phycocyanin algorithm seemed to represent the particulate input from Maumee River as mentioned in the Vincent et al. The remarkable green slick of *Microcystis* bloom was detected through NDVI as well as component-2.

MAUMEE RIVER MOUTH



The color composite of bands 432 of Maumee River mouth on August 19, 2003 was clipped from path 20 row 31 Landsat-5 TM satellite imagery. The spatial resolution of a pixel is 30 m. The yellow outline is the boundary of the water bearing pixels considered. Reddish color localized patches on Lake Erie water is the slimy green surface scum of the *Microcystis* bloom (Rinta-Kanto et al., 2005).

LANDSAT-5 TM IMAGERY



Thematic Mapper (TM) sensor collects reflectance data through six spectral bands located within visible, near infrared (NIR), and mid infrared (MIR)wavelengths of electromagnetic (EM) spectrum.

SPECTRAL BIOMASS INDICES

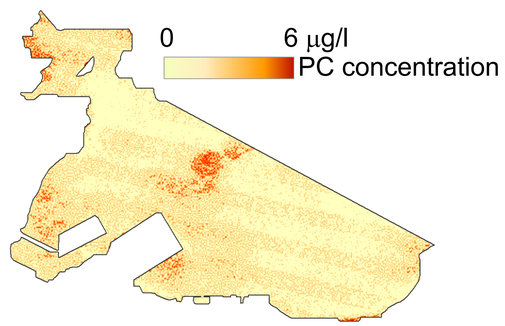
We used two specrtal biomass indices derived by previous reseachers to identify the spatial extents of the HAB reported during the day of the imagery.

(1) Relative phycocyanin content (PC) algorithm (Vincent et al., 2004)

$$PC = 0.78 - 0.0539(B1) + 0.176(B3) - 0.216(B5) + 0.117(B7)$$

B1, B2, B3, and B7 stand for dark-object-subtracted digital numbers of Landsat TM band 1, band 2, band 3, and band 7 respectively.

Relative phycocyanin spatial pattern



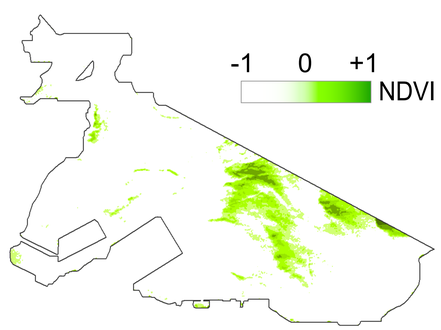
(2) Normalized Difference Vegetation Index (NDVI)

$$NDVI = \frac{(R_{Band4} - R_{Band3})}{(R_{Band4} + R_{Band3})}$$

R = % Reflectance

NDVI provides an estimate of live green macro or microphyte communities in a range from 0 to +1.

NDVI spatial pattern



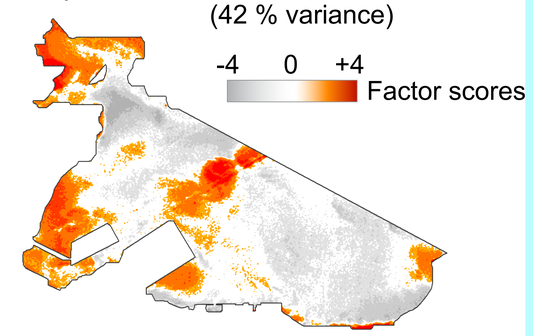
PRINCIPAL COMPONENT ANALYSIS (PCA)

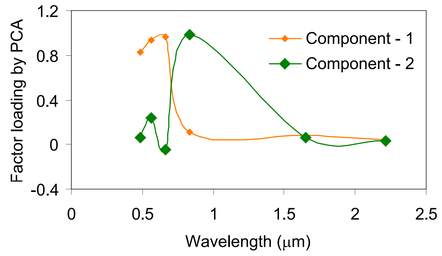
Varimax-rotated principal component analysis was applied to mazimize the variance between resulting components to make them as distinctive as possible.

Factor loading values are the correlation matrix between original variables (six reflective bands) and the newly derived components. We generated the spectral patterns of the resulted components by plotting the factor loading values against the mid point of the of specific Landsat-5 TM band.

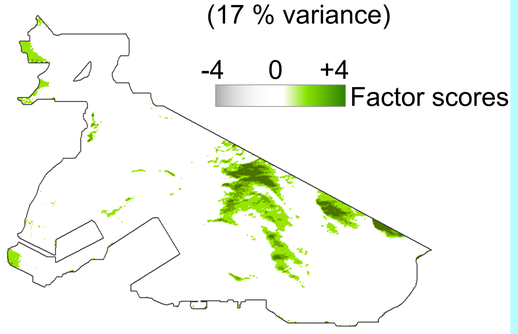
Factor scores are the projected values of factor loadings onto each pixel and used to generate raster images by spatial interpolation using ArcGIS 9.2.

Component-1 (Suspended particulates) (42 % variance)





Component -2 (*Microcystis* bloom) (17 % variance)



DISCUSSION

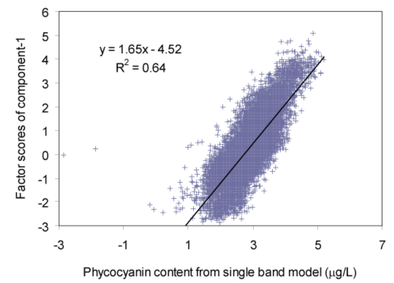
The relative importance of each dominant water quality parameter could be quantified by PCA based on % variance which was not reported by the spectral biomass algorithms. The single-band and band-ratio spectral algorithms discussed in Vincent et al., 2004 were applied to the Maumee River mouth area, though only the results from single-band algorithm is reported here.

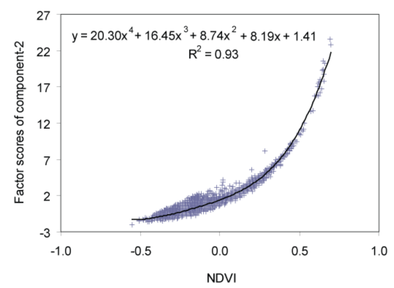
The spatial phycocyanin distribution pattern of band-ratio algorithm displayed absence of phycocyanin for this imagery which was a contrasting result to the other literature sources which identified and confirmed the occurrence of a *Microcystis* bloom on 19 August 2003.

Although the single-band algorithm reported quantitative values for phycocyanin distribution ranging from 0 to 6 µg/L, its spatial pattern seemed to be coincided with that of component-1 which we believed the particulate input from the Maumee River. Consequently, the capability to map phycocyanin content from Landsat TM data in Lake Erie using the single-band and band-ratio algorithms seemed controversial and also it did not address the striping problem in Landsat-5 TM imagery.

In contrast, PCA was able to detect the noise appeared due to stripping problem in Landsat-5 TM imagery as it was extracted as a seperate component. Hence, the spatial distribution patterns of the meaningful components were not interupted with the dark and light strips of the imagery.

Comparison of spectral properties





HARMFUL ALGAL BLOOMS (HABs)

HAB is a term for blooms of autotrophic algae and some heterotrophic protists in coastal waters around the world. Microcystis is a common toxic form of blue-green algae that has appeared in western Lake Erie almost every summer since 1995. Normally, the Maumee bay area is the first place microcystis shows up as western Lake Erie is the shallowest and the warmest part of the Great Lakes.

Source:http://toledoblade.com/apps/pbcs.dll

Microcystis bloom in Western Lake Erie, August 2003

REFERENCES

Rinta-Kanto, J. M., Ouellette, A. J. A., Twiss, M. R., Boyer, G. L., Bridgeman, T., and Wilhelm, S. W. (2005) Quantification of toxic Microcystis spp.during the 2003 and 2004 blooms in western Lake Erie using quantitative real-time PCR. *Environ.Sci. Technol.* 39:4198-4205

Boyer, G.L. (2006) Toxic Cyanobacteria in the Great Lakes: More than just the Western Basin of Lake Erie. *Great Lakes Research Review* 7: 2-7

Vincent, R. K., Qin, X., McKay, R. M. L., Miner, J., Czajkowski, K., Savino, J., and Bridgeman, T. (2004) Phycocyanin detection from Landsat TM data for mapping cyanobacterial blooms in Lake Erie. *Remote Sensing of Environment* 89:381-392