Episodic Events: Great Lakes Experiment

The Impact of Episodic Events on the Nearshore-Offshore Transport and Transformation of Biogeochemically Important Materials in the Great Lakes

Background

The EEGLE study provides a unique opportunity to combine the talents of many scientists with a broad range of expertise in Great Lakes and coastal ocean research (Table 1) in a comprehensive program directed toward fulfilling the goals of both NSF/OCE and NOAA/COP.

Table 1. List of EEGLE participants and affiliations.

Administrators	Affiliation	Program Managers	Affiliation
H. Lawrence Clark	Natl. Sci. Found.	Brian Eadie	NOAA/GLERL
John Wickham	NOAA COP	David Schwab	NOAA/GLERL
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		Wayne Gardner	Univ. of Texas
Co-Principal Investigators			
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Judy Budd	Mich. Tech. Univ.	Gerald Miller	NOAA/GLERL
Marie Bundy	Acad.Nat. Sciences	David Millie	USDA Ag. Res. Svc.
Joann Cavaletto	NOAA/GLERL	Kenneth Nealson	Univ. of Wisc.-Milw.
Changsheng Chen	Univ. of Georgia	John Robbins	NOAA/GLERL
James Cotner	Univ. of Minnesota	Paul Roebber	Univ. of Wisc.-Milw.
David Edgington	Univ. of Wisc.-Milw.	James Saylor	NOAA/GLERL
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W. Charles Kerfoot	Mich. Tech. Univ.	John Vesecky	Univ. of Mich.
Margaret Lansing	NOAA/GLERL	Jim Waples	Univ. of Wisc.-Milw.
Peter Lavrentyev	Univ. of Akron	**Data/Web Manager**	
Barry Lesht	Argonne Natl. Lab	Greg Lang	NOAA/GLERL

The overall goals of EEGLE are to:

1) create an integrated observational program and numerical modeling effort to identify, quantify, and develop prediction tools for the winter-spring resuspension event.
2) assess the impact of the resuspension event on the transport and transformations of biogeochemically important materials (BIMS) on the lake's ecology.

The program is focused along three fundamental hypotheses:

1) The plume develops as a result of the first winter-spring storm and represents the resuspension of particulate materials that have been stored in the lake as sediment floc for a distribution of times, during which they have undergone differential diagenesis.
2) The forced two-gyre vorticity wave response of the lake to episodic wind events is a major mechanism for offshore transport of BIMS.
3) Physical processes associated with the development of the plume are important in determining nutrient and light fields, and in structuring the distribution and composition of biological communities throughout the spring isothermal period and in setting conditions for the critical spring bloom period.

The EEGLE project is designed as a 5-year study, with year 1 as a pilot field year, years 2-3 as field intensive years, and years 4-5 for data synthesis and model development. This poster describes preliminary results from a small subset of the first year field activities. Additional information can be obtained from the project's WEB site at: www.glerl.noaa.gov/eegle.

Preliminary Results

The resuspension plume of March 1998 was one of the largest events of record. Satellite observations reveal a well developed plume extending over 300 km of coastline from Milwaukee, WI to Muskegon, MI with several dominant offshore features originating from the southeastern shoreline (Figure 1). The plume originated around March 10 following several days of intense storms that produced 50 mph northerly winds and generated waves in the basin over 20 ft high. Remnants of the plume feature were still observable by satellite 6 weeks later.

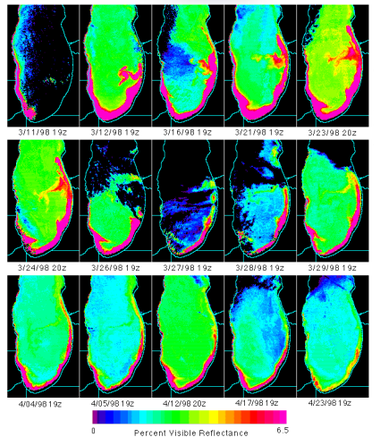

Figure 1. A composite of satellite images of the winter-spring resuspension event of 1998. Images were generated through the Great Lakes CoastWatch program and show reflectance data (channel 1–channel 2) from the NOAA 14 AVHRR satellite.

A series of sequential sediment traps were deployed throughout the basin to quantify the mass fluxes associated with the resuspension event (Figure 2). Fluxes were recorded at 9 day sampling intervals and are compared against turbidity data taken from the St. Joseph Water Intake (Figure 3). Results show an earlier event in December 1997 that produced elevated fluxes throughout the basin. However, fluxes at Racine and Gary are 6–8 times greater following the March plume event than for the previous peaks. Fluxes were also elevated at other sites during the March plume. Fluxes declined sharply after the first 9-day sampling interval indicating fairly rapid settling of much of the resuspended material. Fluxes remained somewhat elevated for 4, 5, and 7 weeks at the Gary, Grand Haven, and Racine sites respectively.

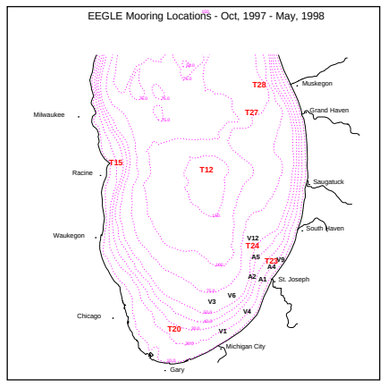

Figure 2. Ten sequencing sediment traps were deployed at seven stations identified with red symbols. Four acoustic doppler current meters, which provide vertical profiles of currents, were deployed at stations labelled A1-A4 along with 12 single point current meters labelled V1-V12.

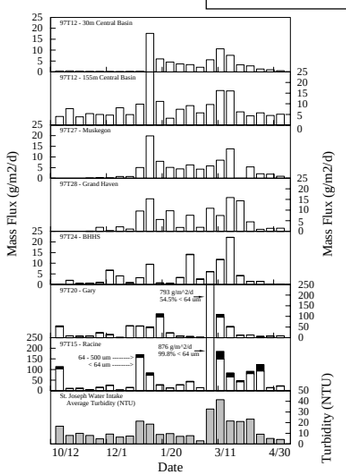

Figure 3. Mass flux extimates for six sites in southern Lake Michigan and averaged turbidity at the St. Joseph water intake for October 1997-May 1998. Twenty three discrete samples were collected with each sequencing trap at 9-day sampling intervals.

Studies using GPS satellite-tracked drifters were conducted to examine large-scale circulation patterns within the southern basin (Figure 4). Results indicate counter-clockwise flow around the basin during the first day after deployment. After day 1, a flow reversal occurred and strong southernly flow was observed along the eastern shoreline (drifters 7 and 8). The flow reversal appears to have set up a convergence zone within the region between Gary and South Haven and generated offshore currents as denoted by the westward movement of drifters 5, 7, and 8 on days 5-7. These observations fit well with the hypothesized circulation pattern necessary to generate offshore transport of materials in this region and the known pattern of maximum sediment accumulation offshore of St. Joseph.

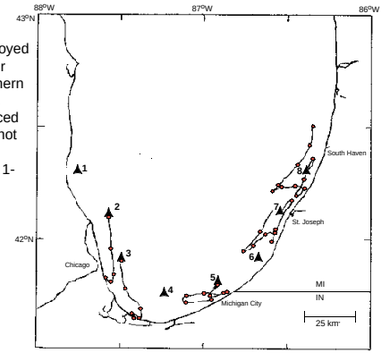

Figure 4. Results of GPS satellite-tracked drifters deployed along the 20 m depth contour around the coastline of southern Lake Michigan April 2, 1998. Drifters 1, 4, and 6 experienced technical difficulties and did not report their position. Circles designate drifter positions at 1-day intervals.

Tow-yows with a Plankton Survey System (PSS) (Figure 6) were conducted to determine the vertical structure of plankton and related physical variables in offshore transects through the plume at various sites around the southern basin. Example results for the St. Joseph transect on March 16, 1998 are presented in Figure 5. The contour plot of light attenuation shows that resuspended material was evenly distributed throughout the water column and that the plume extended approximately 13 km offshore, into 35 m deep water. Fluorescence data revealed only a slight offshore gradient within the first 5 km, and concentrations were again uniform throughout the water column. The temperature gradient along the transect was only 1.2 °C and the nearly vertical isotherms indicate strongly mixed conditions. Results from the PSS will be correlated to plankton abundances and total suspended material (TSM) concentrations determined on discrete samples collected at multiple sites along the transects. These relationships will provide a better quantitative measure of the inventory of particles and plankton associated with the plume.

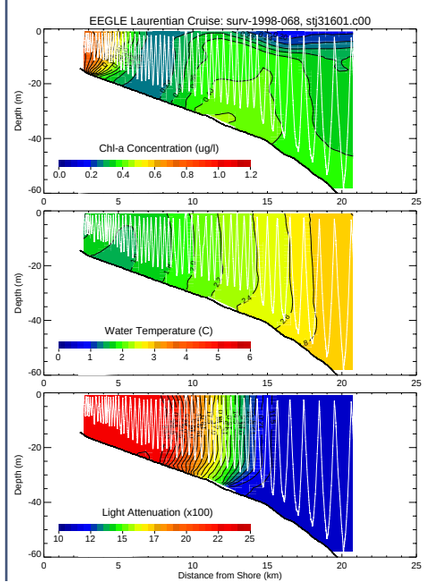

Figure 5. Contour plots of derived chlorophyll *a* concentrations (from in situ fluorescence) water temperature and light attenuation for the St Joseph transect on March 16, 1998. Data were obtained by tow-yows with the PSS along an offshore transect between 15 and 60m depths, as denoted by the white undulating line.

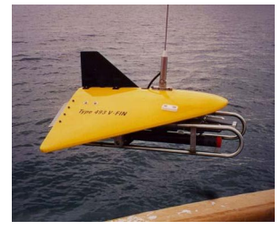

Figure 6. The Plankton Survey System (PSS) is used to determine vertical structure of plankton and related physical variables along the ship's path. PSS underwater assembly includes the Focal Technologies Mini-Optical Plankton Counter (OPC), the Ocean Sciences OS-200 CTD with X-Y tilt sensor, and a Chelsea Aquatracka III fluorometer mounted on an Endeco/YSI V-fin. The system also includes a differential GPS and depth sounder. The PSS is towed in a vertically undulating (tow-yowed) mode as the ship travels at about 2.5 m/s.

Biological and chemical distributions were determined from shipboard surveys before, during, and after the plume event. Total phosphorus (TP) concentrations were significantly elevated within the plume (Figure 7). TP concentrations increased approximately 7x at the shallowest station, 3x at the 30 m station, and only slightly at the 45m station. TP concentrations track closely with TSM concentrations and approximately 90% of the P was associated with particles. Elevated concentrations of dissolved phosphorus and silica were also observed within the plume. A comparison of TP concentrations at various sites around the basin indicates that the coastal region between Gary and St Joseph shows the largest response for this resuspension event (Figure 8). Although TP analyses were not done at shallow stations off Muskegon, PSS surveys revealed that particle concentrations were only a few percent higher at station depths of 10 and 30 m than at 45 m during the plume.

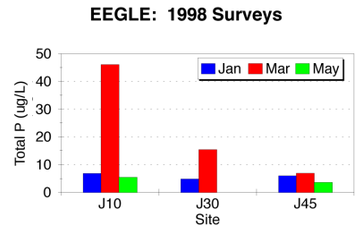

Figure 7. Total phosphorus (TP) depth averaged concentrations at three sites along the St. Joseph transect before, during, and after the major plume event in March 1998. Station names refer to the water column depth.

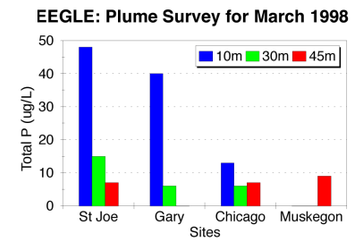

Figure 8. Comparison of TP depth averaged concentrations along transects at St. Joseph, Gary, Chicago, and Muskegon during the March 1998 plume survey.

Results of bacterial production studies closely mirror those for TSM and TP concentrations. Production rates were significantly elevated for sites within the plume, and the increase was greatest at St. Joseph, then Gary, and then Chicago (Figure 9). At Muskegon, TSM and TP concentrations in the nearshore "plume" sample were similar to those in the non-plume sample, thus the similarity in bacterial production at this site was expected. Previous studies in Lake Michigan reported typical summertime rates of 28 µgC/L/d, thus the rates for the St. Joseph plume site are exceptionally high given the 3 °C water temperatures. Elevated production rates most likely resulted from both the increased abundance of bacteria associated with particles and the increased abundance of phosphorus, which is frequently the most limiting element for bacterial and phytoplankton growth.

Figure 9. Bacterial production rates, determined by ^{3}H-Thymidine incorporation, for water samples collected within and outside the plume along 4 transects during the March 1998 survey.