Changes in Nearshore-Offshore Distributions of Particulate Matter and Nutrients in Southern Lake Michigan in Response to a Recurrent Coastal Sediment Plume

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Overview

Distributions of particulate matter and nutrients were measured along 5 cross-shelf transects throughout the southern basin of Lake Michigan (Fig. 1) to evaluate the impact of an annually recurrent coastal resuspension event. The goals of the project are to: map out spatial and temporal patterns of the plume; estimate the quantities of particles and nutrients that are introduced into the water column as a result of the plume; provide background nutrient concentrations for nutrient cycling studies; and provide nutrient and biological distributions for the coupled physical/biological model.

Sampling along transects was initiated at the 15m depth contour and extended lakeward approximately 20 km. The depth of the outermost station varied from 45m to 110 m depending upon the shelf bathymetry. Sampling was conducted both on a continual basis using a surface pumping system while towing at 4 knots, and with discrete water casts at fixed stations located at depth contours of 15m, 30m, 45m, and 80m (or 110m).

Results are presented from the two field years 1998 and 1999. In each year, survey cruises were conducted before any recognized plume (January or February), immediately after the onset of a major resuspension event (second week of March in both 1998 and 1999), a few weeks after the onset of the plume, and in late spring after the onset of stratification.

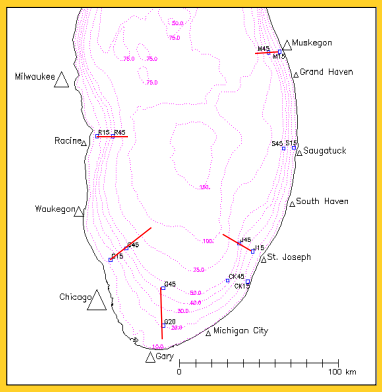

Figure 1. Study Area map of the survey transects for the Episodic Events: Great Lakes Experiment (EEGLE) study.

Methods

A continuous surface pumping system was developed to measure distributions of nutrients and suspended matter along cross-shelf transects. Surface water was pumped through a 5/8" tygon tubing attached to a weighted wire cable suspended down to 2m depth. Water was pumped onboard using a Cole Parmer variable speed peristaltic pump and fed into a 1m section of a 15cm diameter PVC pipe, into which we inserted a 25cm path length transmissometer that was connected to an external SeaBird CTD for data logging. Baffles were placed at end of the transmissometer to minimize bubbles and turbulence along the light path and hold the transmissometer in a fixed position. Flow rates were maintained at 4 L/min for all tows and yielded measured water renewal times of approximately 3.3 min from inflow to outflow. A needle and syringe with a leur lock connection were mounted in-line prior to the pump to pull off water samples for nutrient analyses. Time and ship's position were recorded manually at five minute intervals throughout the tows and were integrated with a continuous record of time and position that was collected from tows of the Plankton Survey System (PSS) that were done concurrently. Beam attenuation data from the transmissometer were regressed against measured concentrations of total suspended matter taken at discrete stations along each transect. The empirical relationship was used to generate modeled distributions of TSM.

Samples for dissolved nutrients were taken at 5 to 10 minute intervals, with the longer intervals applied for the more offshore locations. The withdrawn sample was immediately filtered through a 0.2 uM Nylon syringe filter unit, collected into clean polypropylene test tube, and frozen for later analyses back at the laboratory. Each filter and test tube was rinsed with 5 ml of sample before collection. Nutrient concentrations were determined on an Auto Analyzer II, using standard colorimetric procedures.

TSM and nutrient concentrations are only available for the 1999 continuous tows. A problem occurred in our original design of the flow-through system that allowed bubbles to be trapped against the lens of the transmissometer and nutrient samples were collected from the overflow that year and did not agree well with discrete samples, indicating some contamination occurred within the system.

Future Direction

In the next field year we hope to improve the sampling intensity within the nearshore region of the basin and to focus on regions where offshore transport occurs. Last year we initiated procedures to relay satellite images directly to the ship, and hope to be more responsive to these near-real time observations. In addition, we will deploy three remote sequential water samplers to capture finer resolution of the variability in particle and nutrient concentrations within various regions of the plume.

Results and Discussion

Satellite Imagery

The magnitude and spatial distribution of the resuspension plume varied substantially between the two years in response to the direction and intensities of the wind and wave fields. NOAA AVHRR satellite images reveal that in 1998 the plume covered a much greater region of the southern basin and produced a distinct offshore feature along the eastern shore (Fig. 2). Maximum particle concentrations were observed along the St. Joseph and Gary transects. Unfortunately we did not manage to sample directly within the offshore feature to determine actual concentrations. In 1999, the plume was more limited to the southwestern region of the basin and maximum particle concentrations occurred along the Chicago transect. Ironically, almost no resuspension occurred within the St. Joseph region during this second field year.

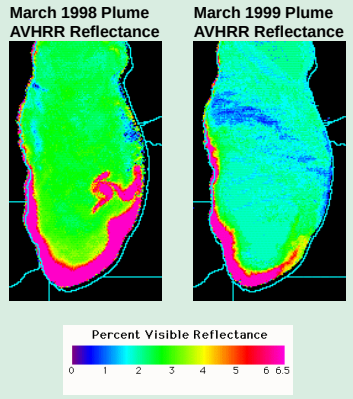

Figure 2. Satellite images of percent visible reflectance captured by NOAA AVHRR satellites during the plume events of March 1998 and March 1999 in southern Lake Michigan.

Continuous Surface Distributions

Continuous distributions of surface TSM concentrations revealed sharp gradients in the nearshore zones of Chicago, Gary, and St. Joseph during both pre- and post-plume conditions (Fig. 3). Following the March 1999 plume event, TSM concentrations increased substantially at Chicago and Gary and these gradients became quite large. In general, elevated concentrations were restricted to water depths less 40m. At Gary, the decline occurs within depths of only 20m, but this corresponds to a similar distance offshore due to the shallower slope within this region. TSM concentrations along the St. Joseph and Muskegon transects were higher during the pre-plume cruise, and probably reflect the influence of nearby rivers in both cases. The different pattern in the offshore gradients between these sites most likely reflects differences in slopes, as well as, in the type of suspended matter. Specifically, the contribution of biological material was much greater at the Muskegon site. In March 1999, a distinct offshore feature of elevated TSM concentrations was observed at the 60m depth contour along the St. Joseph transect. This parcel of water most likely originated from the nearshore region, or was advected from the southern region, because there is not a source of material out at these depths. We do not presently know the rate or path over which this advection may have occurred.

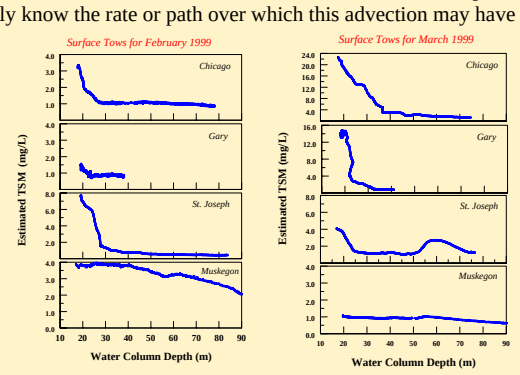

Figure 3. Modeled distributions of total suspended matter along the Chicago, Gary, St. Joseph, and Muskegon transects during February (pre-plume) and March (plume) of 1999.

Offshore gradients in dissolved nutrient differed substantially for St. Joseph and Chicago in 1999 (Fig. 4). For St. Joseph, concentrations of chloride, nitrate, and silica exhibited very steep gradients between the 15 and 30m depth contours and indicate a significant influence from the St. Joseph River, particularly during the March plume cruise. SRP concentrations were only minimally higher during the plume cruise but basically near the limit of detection for all samples. Ammonia concentrations were also similar between cruises but nearshore concentrations were actually higher in February than in March. For Chicago, there were no differences in chloride, nitrate, and silica concentrations between cruises and very minimal offshore gradients suggesting the lack of any direct riverine influence. The greatest differences occurred in pre- and post-concentrations of SRP and ammonia. Following the plume, concentrations were notably higher over most of the transect and exhibited a fairly gradual decline with depth.

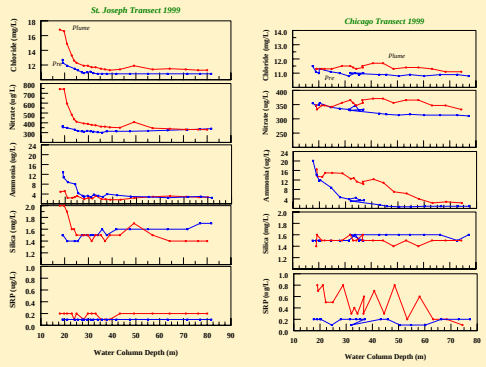

Figure 4. Distributions of dissolved nutrient concentrations along the Chicago, Gary, St. Joseph, and Muskegon transects during February (pre-plume) and March (plume) of 1999.

Discrete Sample Comparisons

Distributions of total suspended matter (TSM) and total phosphorus (TP) were strongly impacted by the resuspension events of 1998 and 1999, and these parameters exhibited similar spatial and temporal patterns (Fig. 5). The resuspended material contained considerable amounts of phosphorus and a regression of TP against TSM was highly significant ($R^2 = 0.70$). For both parameters, elevated concentrations were restricted to water depths less than 45m, and really only at for the St. Joseph transect in 1998 was there still a significant enrichment in out at the 30m station. In general, TSM and TP concentrations were greater in 1998 than in 1999 and elevated concentrations occurred over a broader region of the basin. In 1998, TSM concentrations were over 30 mg/L at stations J15 and G15, compared to pre- and post values of between 1-2 mg/L. The impact of the plume was less in the Chicago region that year and TSM concentrations at C15 reached only around 12 mg/L. In contrast, during 1999 the amount of resuspension was maximum along the Chicago transect and TSM concentrations reached around 21 mg/L. This peak is still considerably less than occurred near St. Joseph in 1998, perhaps reflecting a difference in the amount of material available for resuspension. In 1999, TSM concentrations reached only 8 mg/L at the nearshore Gary site and at St. Joseph TSM concentrations were actually lower during the plume event than for the pre-plume cruise. TP concentrations exhibited a very similar trend going from background levels of between 4-8 ug/L up to levels of 12, 35 and 45 ug/L for C15, G15 and J15 respectively during the 1998 plume. In 1999, concentrations were only 16, 10, and 10 ug/L at these stations respectively and again the enrichment was greatest at Chicago and minimal at St. Joseph. TDP was much more uniform spatially and temporally, and exhibited minimal influence from the plume. The greatest differences were again found within the nearshore region of St. Joseph in 1998, but the increases in concentration were minor compared to those observed for particulate components. In 1999, there were very little differences among sites and among cruises.

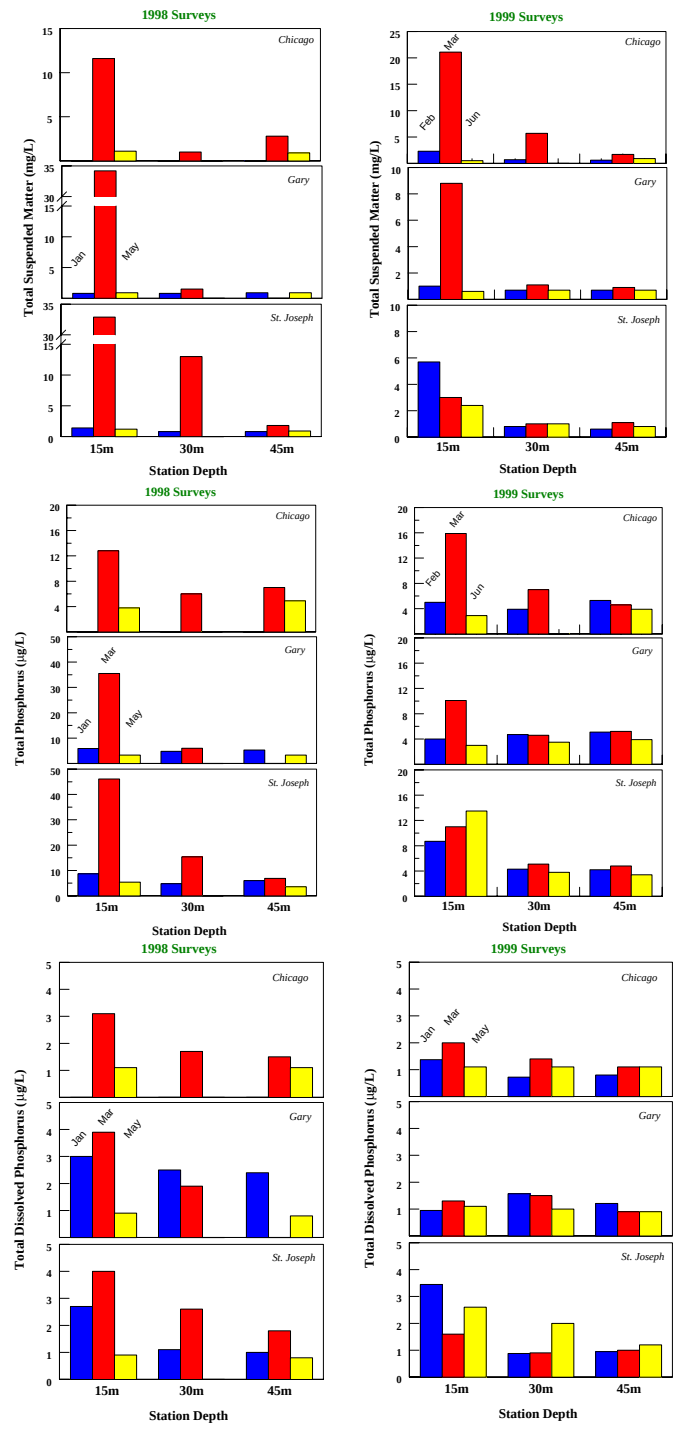

Figure 5. Distributions of total suspended matter (TSM), total phosphorus (TP), and total dissolved phosphorus (TDP) for 15m, 30m, and 45m stations along Chicago, Gary, and St Joseph transects during 1998 and 1999. Results are presented from surveys conducted before the plume (blue), during the plume (red), and approximately 2 months after the plume following the onset of stratification (yellow).