Introduction to special section: Transport and transformation of biogeochemically important materials in coastal waters

Sarah A. Green
Department of Chemistry, Michigan Technological University, Houghton, Michigan, USA

Brian J. Eadie
NOAA Great Lakes Environmental Research Laboratory, Ann Arbor, Michigan, USA

Received 2 September 2004; accepted 8 September 2004; published 15 October 2004.

[1] Two projects in the Laurentian Great Lakes were funded under the Coastal Ocean Processes Program. In Lake Superior the Keweenaw Interdisciplinary Transport Experiment in Superior (KITES) focused on a region dominated by a strong coastal jet, and a sister project in Lake Michigan, Episodic Events—Great Lakes Experiment (EEGLE), concentrated on the biogeochemical effects of a major plume of resuspended sediment that occurs annually in the southern portion of the lake. *INDEX TERMS:* 4239 Oceanography: General: Limnology; 4528 Oceanography: Physical: Fronts and jets; 4558 Oceanography: Physical: Sediment transport; 4808 Oceanography: Biological and Chemical: Chemical tracers; 4599 Oceanography: Physical: General or miscellaneous; *KEYWORDS:* Keweenaw Current, Lake Superior, Lake Michigan

Citation: Green, S. A., and B. J. Eadie (2004), Introduction to special section: Transport and transformation of biogeochemically important materials in coastal waters, *J. Geophys. Res.*, *109*, C10S01, doi:10.1029/2004JC002697.

[2] The Coastal Ocean Processes (CoOP) program is an interagency effort to support interdisciplinary studies of coastal margins, with a particular emphasis on the interactions of physical, chemical and biological processes within these dynamic systems. CoOP is supported by the National Science Foundation (NSF) and the National Oceanic and Atmospheric Administration (NOAA) Coastal Ocean Program (COP). Five major studies have been funded since the establishment of CoOP: Distribution and Transport of Larvae of Inner-Shelf Benthic Invertebrates (1992); Coastal Air-Sea Chemical Fluxes (1995); Cross-Margin Transport Processes in the Great Lakes (1997); Wind-Driven Transport Processes (2000); and Buoyancy-Driven Transport Processes (2003).

[3] The focus of the third major CoOP effort was cross-margin processes in the Great Lakes. The motivations for these Great Lakes studies were laid out in the report [*Klump et al.*, 1995] from the workshop, "Coastal ocean processes: Cross-margin transport in the Great Lakes," held in Milwaukee in October 1994. Research questions were broadly directed toward understanding the effects of vertical stratification, coastal jets, storm events, and the thermal bar on the distribution and transport of chemically, geologically, and biologically important constituents in coastal environments of the Great Lakes. As with all CoOP sponsored programs, the goal was studies that elucidate processes common to many coastal regions though intensive investigation of particular systems.

0148-0227/04/2004JC002697$09.00

[4] Two projects were funded under the cross-margin transport CoOP announcement: the Keweenaw Interdisciplinary Transport Experiment in Superior (KITES) and Episodic Events—Great Lakes Experiment (EEGLE). KITES focused on the dynamics of a strong coastal jet in Lake Superior, while EEGLE investigators characterized the behavior and consequences of a recurring spring plume of suspended sediments in Lake Michigan. The KITES project was coordinated by Sarah A. Green at Michigan Technological University and Elise A. Ralph at the University of Minnesota, Duluth. Fifteen Principle Investigators from 9 institutions participated in the KITES project, with more than 20 graduate students and numerous undergraduates contributing to the effort. EEGLE's management team of Brian Eadie and David Schwab (NOAA/GLERL), along with Val Klump (U WI-Milwaukee) and Wayne Gardner (U TX-Marine Science Institute) coordinated the overall efforts of 41 Principle Investigators at 17 institutions.

[5] The KITES research area extends 170 km along the northwest side of the Keweenaw Peninsula in Lake Superior from the mouth of the Ontonagon River to Copper Harbor at the tip of the peninsula. This region is characterized by a northeastward flowing coastal jet coupled with alternate upwelling and downwelling events, which are primarily wind driven. The bathymetry varies from a shallow slope at the southwestern edge of the study region to a sharp drop-off at Eagle Harbor, where the depth reaches 200 m only 1.5 km offshore. In spring and early summer a nearshore zone can be defined by a thermal bar dividing warm coastal water from offshore water below 4°C, the temperature of maximum density for freshwater; the bar moves gradually

offshore until the lake surface warms and stratifies in midsummer. An important focus of KITES was to examine to what degree the thermal bar inhibits cross-margin transport of sediments and nutrients from the nearshore zone and what other mechanisms can facilitate such transport. Thus shipboard sampling was conducted along three primary and 4 secondary transects perpendicular to shore. Moored water column and near-bottom sediment traps, current meters, and thermister arrays were also deployed.

[6] Lake Superior is the largest and most oligotrophic of the Laurentian Great Lakes. Despite the vast extent of the lake, spatial variability is relatively subtle, with strong biogeochemical gradients confined primarily to the nearshore, river outlets, bays, and inlets. However, with the acquisition of multiyear data sets, such as KITES results, significant interannual variability is becoming apparent in chlorophyll, dissolved phosphorous, bacterial production, and other parameters. These fluctuations are presumably related to meteorological factors that control the timing and extent of lakewide stratification and terrestrial runoff. Long-term human impacts due to land use changes, importation of exotic species, and atmospheric inputs undoubtedly provide additional perturbations to the system. Significant KITES results reported here include (1) the Keweenaw current is can be reasonably well modeled with forcing by surface heat flux and winds, but the intensity of the current fluctuations is not well simulated using the available measurements of mesoscale winds; (2) sediment resuspension plays a significant role in cross margin transport, and resuspension is greatly enhanced during late fall and winter storms; (3) multiple lines of evidence indicate that Lake Superior is net heterotorophic, despite considerable uncertainties in individual carbon budgets.

[7] Additional KITES results are appearing in a dedicated volume of the Journal of Great Lakes Research, a series of graduate dissertations and theses, and in several other venues. A full listing of personnel, publications, and data is available via http://kites.chemistry.mtu.edu/.

[8] The EEGLE program was designed to quantify the impacts of major late winter–early spring storms on sediment-water exchange, nearshore-offshore transport and subsequent influence on the lakes' productivity in southern Lake Michigan. The observation strategy consisted of three components: (1) moored arrays of current meters, thermistors and sequencing traps, (2) interdisciplinary Lagrangian measurements, and (3) shipboard surveys. In addition, survey and process measurement cruises were conducted along with special cruises for ROV sediment-water interface sampling, particle transformation measurements, and collection of sediments. The time series and survey data were supplemented by synoptic coverage from satellite imagery and multifrequency HF radar observations.

[9] A lake-scale hydrodynamic circulation model (the Great Lakes version of the Princeton Ocean Model) was coupled with a wave model and has been used to explore sediment transport observations and lower food web models were incorporated in order to assess the impact of internal nutrient recycling and nearshore-offshore transport on sedimentary and biological processes. A summary of conclusions to date include: 1) the magnitude of resuspended sediments from a major storm is 1–5 Mt, larger than annual external input of fine-grained materials to the southern basin, 2) resuspension surrogates covering 50 years show an interannual variability in major storm events that ranges over an order of magnitude, 3) resuspended total phosphorus is several times the annual external input, but only a small fraction appears to be available for primary production, 4) the reduction of light in the plume counteracts the increased nutrients and results in somewhat reduced primary productivity, 5) the events result in greatly increased heterotrophy which appear to be localized to the region near the plume, and 6) the events appear to be primarily responsible for the complicated sediment accumulation patterns in the southern basin of Lake Michigan.

[10] Further information on program participants, hypotheses, results, and data are available at http://www.glerl.noaa.gov/eegle.

References

Klump, J. V., K. W. Bedford, M. A. Donelan, B. J. Eadie, G. L. Fahnenstiel, and M. R. Roman (1995), Coastal ocean processes: Cross-margin transport in the Great Lakes, *Univ. Md. Tech. Rep. UMCES TS-148-95*, 133 pp., College Park.

B. J. Eadie, NOAA Great Lakes Environmental Research Laboratory, 2205 Commonwealth Blvd., Ann Arbor, MI 48105, USA.

S. A. Green, Department of Chemistry, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931, USA. (sgreen@mtu.edu)