Executive Summary

Coastal Ocean Processes (CoOP) is a program that seeks to plan and implement multi-investigator, interdisciplinary research in the coastal ocean. The CoOP Buoyancy-Driven Transport Processes Workshop was held from October 6-8, 1998, in Salt Lake City, Utah. As requested by the workshop participants, the title of the workshop report was changed to "Transport and Transformation Processes over Continental Shelves with Substantial Freshwater Inflows", since even in coastal regions with large freshwater inflows, much of the transport can be due to other processes, such as wind. The overall question addressed by the workshop was: How do processes on shelves with large freshwater inflows affect cross-margin transport of biologically, geologically, and chemically important materials? This question is important because coastal ocean regions with large freshwater inflows are major gateways for the transfer of materials from continents to oceans. In part due to nutrients supplied with the freshwater, these areas tend to be highly productive and to support major fisheries. Shelves with large freshwater inflows are among those most affected by human activities, with impacts including eutrophication and accumulation of toxic metals in sediments and biota. Climatic warming due to anthropogenic greenhouse gases could lead to marked alteration in freshwater discharge and material transport in these shelf regions.

The workshop was open to all interested scientists. The 40 attendees represented all oceanographic disciplines, but were mainly drawn from the field of physical oceanography. This report includes summaries of the five keynote addresses to the workshop participants, reports of the five Working Groups, and a Science Prospectus prepared by the Workshop Committee. The Science Prospectus has been reviewed by the CoOP Scientific Steering Committee and by an interdisciplinary group of scientists who did not participate in the Workshop.

Workshop participants drafted three broad questions:

1. **How does freshwater inflow interact with winds, topography, and tides to produce across-margin transport of materials?**
2. **How are primary and secondary production influenced by freshwater inputs?**
3. **How are transport and transformation of dissolved and particulate materials affected by freshwater inflows?**

Within these, more specific questions were developed, as described in the Science Prospectus section of this report.

Workshop participants did not reach a consensus on the optimal study region for the investigation of processes related to freshwater inflows. It was agreed that several criteria should guide the selection of a study site, including: buoyancy-influenced flow should be a major component of the coastal current; the

quantity of dissolved and particulate material delivered by the river(s) in the study region should be sufficiently large to make detection and quantification of cross-margin transport possible; and there should be evidence that biological communities are influenced by the freshwater inflow. Further, the study will necessarily be constrained by the resources available, and a site or sites appropriate to those constraints should be chosen. Limited resources can be augmented by collaboration with other ongoing or planned programs.

Certain topics should be considered for funding before a major process study is initiated. Retrospective syntheses of existing knowledge of buoyancy-influenced systems are needed to help identify critical regions and processes for further study of cross-margin transport. Targeted modeling studies should examine the relative influences of buoyancy inflows, winds, and tides in several different systems. Models of the interactions of plumes with the surrounding ocean need improvement. Analyses of sediment cores or other long-term records could better define the location and temporal variation of terrestrial materials in continental margin sediments or changes in precipitation or winds. A synthesis of satellite data, to gain a better understanding of plume dynamics, would be helpful.

The components of a study of transport and transformation processes over continental shelves with substantial freshwater inflows will vary with the specific questions and regions being investigated. However, the following were identified as likely elements: characterization of the boundary conditions, including the freshwater inflow and wind forcing; characterization of the buoyant water and its biological communities with a variety of approaches suited to a range of spatial and temporal scales, including moored instruments, shipboard observations and experiments, drifters, and remote sensing; studies of the benthic boundary layer and sea bed; tracer studies of cross-margin transport; and interdisciplinary modeling.

I. Introduction

A. CoOP Background

The coastal ocean is a complex zone where biological, chemical, geological and physical processes are strongly influenced by the land, bottom sediment, and atmosphere boundaries, as well as interactions with the open sea. While coastal ocean studies from the perspectives of single disciplines have yielded a valuable body of knowledge, essential for the design of future research, they have also revealed that many important questions must be addressed using an interdisciplinary approach. The need for improved understanding of the coastal ocean is urgent, since this ocean region has special importance to society. For example, we need to make wise use of coastal ocean fishery and petroleum resources, while coping with the hazards the ocean can pose to the 50% of the U.S. population that lives near the coast. Understanding the coastal ocean can help to minimize adverse impacts of coastal engineering projects, changes in freshwater drainage, pollution, and introduction of exotic species.

Coastal Ocean Processes (CoOP) is a program that seeks to plan and implement multi-investigator,

interdisciplinary research in the coastal ocean. CoOP planning and research activities have included scientists from the disciplines of Biological, Chemical, Geological, and Physical Oceanography and Marine Meteorology. CoOP defines the coastal ocean as extending from the surf zone to the continental rise. CoOP also includes large, inland bodies of water, such as the Great Lakes, that exhibit processes similar to those in the oceans. **The overall CoOP goal is to "obtain a new level of quantitative understanding of the processes that dominate the transports, transformations, and fates of biological, chemical, and geologically important matter on the continental margins"** (Brink et al., 1992).

The coastal ocean is too diverse and vast to allow comprehensive study of all regions. The original CoOP Steering Committee decided that the most cost-effective and fruitful approach would be to intensively study coastal regions where one physical process dominates cross-margin transport, so that the effects of that process could be identified and quantified in relative isolation. CoOP-sponsored research includes process studies and well-integrated modeling that aim to produce an interdisciplinary synthesis of the results of each regional study and a means of generalizing those results to other areas. The CoOP Science Prospectus (Brink et al., 1992) originally proposed five shelf types for study:

1. Wind-driven shelf regions: Currents and current variability are primarily caused by winds, either local or remote, on time scales longer than one day. Seasonal upwelling is found over many of these shelves, including those off Washington and Oregon, Portugal, Southwest Africa, and western South America.
2. Tidally driven shelf regions: Over these shelves, strong tides can determine mixing processes and mean flows. Examples include Georges Bank and the Bering Sea.
3. Buoyancy-driven shelf regions: Freshwater discharge from rivers creates an alongshore flow. In areas where the freshwater influx is large, such as the coastal Gulf of Alaska or the northeastern Gulf of Mexico, the effects can dominate the entire shelf.
4. Western boundary current shelves: Transport over these shelves is influenced by strong offshore ocean currents, such as the Kuroshio or the Gulf Stream, and by eddies that originate from these currents. The Atlantic coast of the U.S. is a prime example.
5. Ice-covered shelves: The Great Lakes and the Bering, Chukchi, and Beaufort Sea coasts of Alaska are seasonally ice-covered. Ice strongly affects air-sea exchange of heat and momentum. Sea ice formation results in formation of dense water masses with elevated salinities due to brine rejection.

Although the ideal study region would be dominated by one of these physical processes, in reality winds and tides are present to some degree everywhere. Therefore, CoOP has attempted to select areas where other influences are minimized compared to the target process of a particular study. To date, CoOP has initiated major process studies of cross-margin transport processes in the Great Lakes and in the northeastern Pacific. Both of these studies were initiated with a community workshop, open to all interested

scientists. Based on input received at these workshops, plus reviewer comments, reports describing the important scientific questions and possible research approaches to those questions were prepared by committees selected by the CoOP Steering Committee (Smith and Brink, 1994; Klump et al., 1995).

The CoOP Steering Committee selected buoyancy-driven shelf regions as an important topic for a community workshop. The Buoyancy-Driven Transport Processes Workshop was held in Salt Lake City, Utah, October 6-8, 1998. This report includes synopses of five keynote presentations; summaries of working group discussions at the workshop; and a science prospectus. The prospectus was written by the Workshop Committee, based on working group and plenary discussions and modified in response to reviewer and community comments on a draft version of this document.

B. The Workshop Goal and Charge

The overall question addressed by the workshop was: **How do processes on shelves with large freshwater inflows affect cross-margin transport of biologically, geologically, and chemically important materials?** The Working Groups were originally organized around themes related to boundaries and processes, and the reports they generated were titled: "Benthic-Pelagic Coupling", "Biogeochemical Transformations", "Freshwater Input", "Fronts and Eddies", and "Wind Effects on Freshwater Outflow Plumes". In addition to addressing the overall question of buoyancy effects on cross-margin transport, the Working Groups were asked to explicitly address the following in their discussions and eventual report:

1. Identify and prioritize (and provide justification for the ranking) of the most important science issues.
2. Identify appropriate locations for studying the questions you identify as important. What are the generic characteristics of the "ideal" site. Which real-world sites approach this ideal?
3. What data are essential? What will data gathering require in terms of platforms and instruments (especially if the requirements are unusual)? What frequency and duration of data gathering are necessary to characterize key processes?
4. What needs to be done to develop appropriate physical models of buoyancy-driven transport? Can current models adequately describe key biogeochemical and biological processes, and can these models be incorporated into appropriate physical models?

C. The Workshop Structure

The workshop was open to all interested scientists; an invitation was widely distributed via the CoOP Newsletter and website (http://www.skio.peachnet.edu/coop). About 40 scientists attended. Most attendees (see Appendix 1) were from the field of physical oceanography, but all disciplines were represented.

A plenary session was held the first day. It included a brief welcome and introduction to CoOP, the five keynote talks (see Appendix 2 of this report), and the charge to the Working Groups. The Working

Groups met that afternoon to identify the most important scientific issues that should be addressed by an interdisciplinary research program in a coastal region with substantial freshwater inflow. The Working Group chairs or Rapporteurs briefly reported their discussions at a plenary session beginning the second day. Then, participants adjourned to the Working Groups for more specific discussions on prioritization of research questions, likely study locations, data needs, and modeling requirements. All participants except the Chairs and Rapporteurs were free to attend a new working group the second day. The Working Group reports are in Appendix 3. The discussions were reported at a plenary session beginning the third day, followed by a general discussion that reached substantial agreement on an outline of key elements of the workshop report. No agreement was reached on the optimal study site or sites. The workshop recommendation, followed in the Science Prospectus, was to include criteria that should guide site selection and examples of potential process study locations, without indicating a preferred site.

The Workshop Committee prepared a draft Science Prospectus and submitted it to the CoOP Steering Committee for review, along with the Working Group Reports. After revision in response to comments of the Steering Committee, the draft Science Prospectus was sent to reviewers selected to represent a broad cross-section of the coastal marine science community. This final version incorporates, as much as possible, all input that the Workshop Committee deemed relevant to this report.