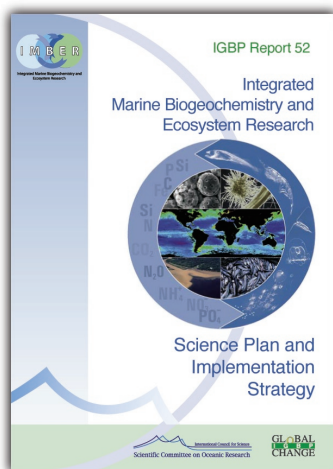


# Integrated Marine Biogeochemistry & Ecosystem Research

## Science Plan and Implementation Strategy



IMBER (Integrated Marine Biogeochemistry and Ecosystem Research) is a new IGBP-SCOR project focussing on ocean biogeochemical cycles and ecosystems. IMBER will build on the successes of the now-complete JGOFS and the ongoing GLOBEC project. The IMBER vision is *to provide a comprehensive understanding of, and accurate predictive capacity for, ocean responses to accelerating global change and the consequent effects on the Earth System and human society*. The IMBER Science Plan and Implementation Strategy can now be ordered or downloaded from [www.imber.info](http://www.imber.info). Here, an overview of the scope of the IMBER science agenda is provided.

Human activities are rapidly altering Earth System processes that directly and indirectly influence society. Informed decisions require an understanding of which parts of the Earth System are most sensitive to change, and the nature and extent of anticipated impacts. This requirement underlies the IMBER goal: *to investigate the sensitivity of marine biogeochemical cycles and ecosystems to global change, on time scales ranging from years to decades*.

To achieve this IMBER will identify key interactions between marine biogeochemical cycles and ecosystems, and assess how these interactions respond to complex natural and anthropogenic forcings. Important forcings include large-scale climate variations, changing physical and biological dynamics, changing carbon cycle chemistry and nutrient fluxes, and widespread marine har-

vesting. The major drivers of change considered are physical dynamics, seawater CO<sub>2</sub> (controlling ocean pH), nutrients (with changing inputs to the euphotic zone from the subsurface waters, sediments and land), and intensive fish harvesting. This research will fill the critical gap between short-term climate events (seasonal scale) and anthropogenic global change (century scale). To address its goal IMBER is structuring its research around four themes as follows:

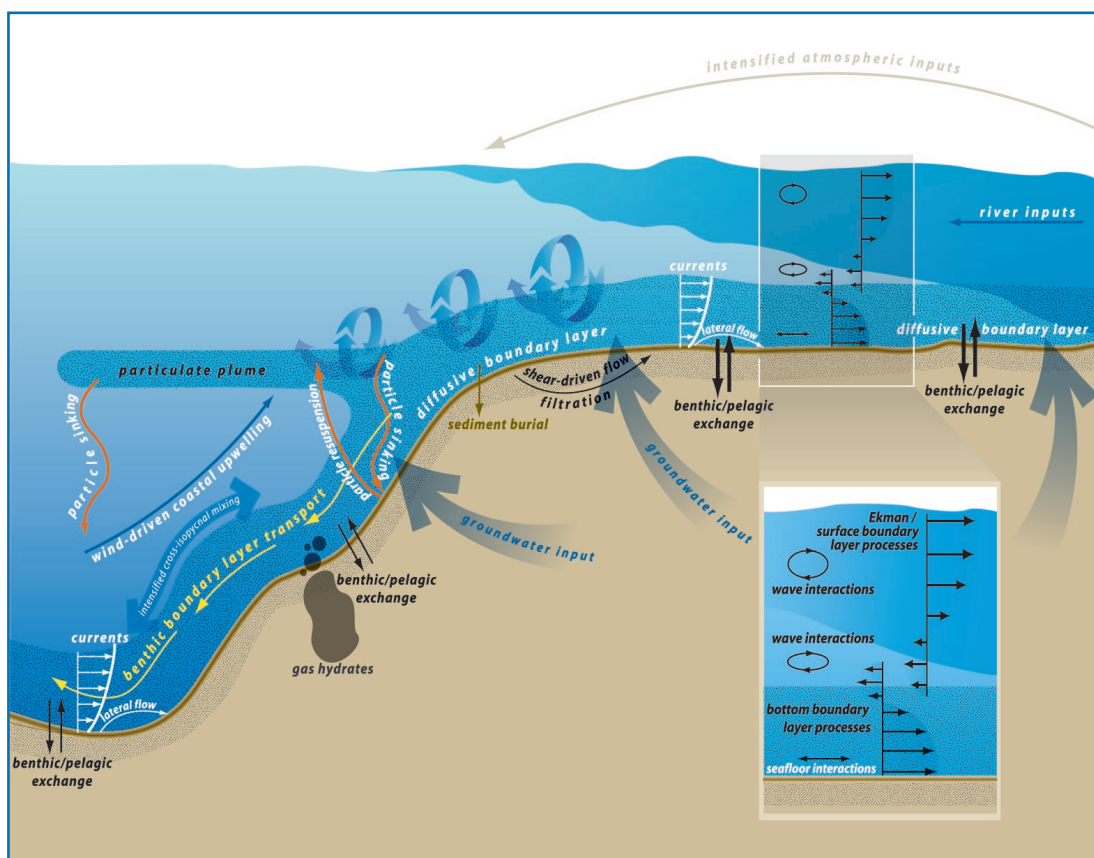


Figure 1. Depiction of processes that are unique to, or intensified at, ocean-continental boundaries. Many of these processes are sensitive to global change, with both local- and global-scale consequences for biogeochemical cycles and foods webs.

## Theme 1: Interactions Between Biogeochemical Cycles and Marine Food Webs

Key issues: (i) the transformation of organic matter in food webs, (ii) transfers of matter across ocean interfaces, and (iii) material flows in end-to-end food webs. Interactions between biogeochemical cycles and food webs are expected to differ between environments such as continental margins associated with coastal upwelling (Fig.1), high latitude and polar regions, and tropical and subtropical oligotrophic gyres. Comparison of different systems will provide new insights for identifying and understanding fundamental interactions between marine biogeochemical cycles and ecosystems.

## Theme 2: Sensitivity to Global Change

This theme will advance understanding of how marine biogeochemical cycles and ecosystems respond to the complex suite of forcings associated with global change. Identifying components that respond directly to global change is a primary concern. In this theme responses are partitioned into four major issues: (i) effects of climate-induced changes in the physical dynamics of the ocean, (ii) effects of increasing CO<sub>2</sub> levels and decreasing pH, (iii) effects of changes in macro- and micronutrient inputs to the ocean, and (iv) impacts of marine harvesting. For example, decadal climate modes and related teleconnections are likely to introduce signals into the ocean system, such as variations in heat content (Fig. 2).

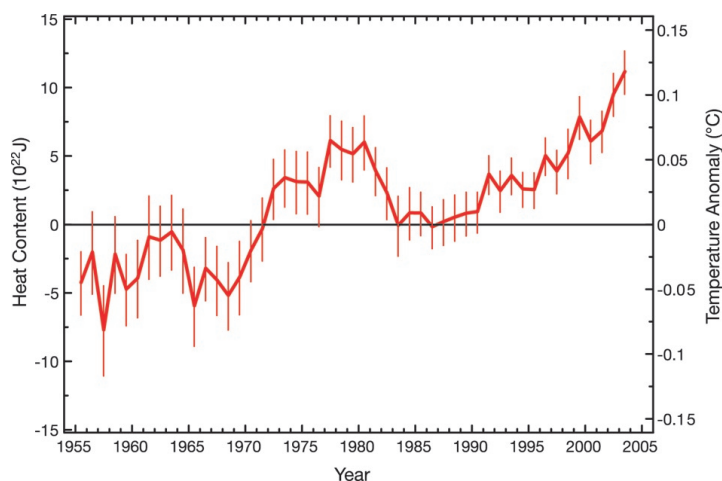


Figure 2. Time series of yearly ocean heat content for the 0–700 m layer. From Levitus et al. (2005). *Science* 287(5,461), 2,225–2,229.

## Theme 3: Feedbacks to the Earth System

This theme will consider the present and future capacity of the ocean to affect the climate system via ocean effects on atmospheric composition and ocean heat storage. Key issues: (i) the varying capacity of the ocean to store anthropogenic CO<sub>2</sub>, (ii) ecosystem feedbacks on ocean physics and climate, and (iii) how changes in low-oxygen zones affect the nitrogen cycle, especially transformations involving N<sub>2</sub>O. For example, N<sub>2</sub>O emissions are not uniformly distributed over the sea surface: the tropical upwelling zones containing O<sub>2</sub>-deficient mesopelagic waters make a disproportionately large contribution (Fig. 3). Modelling the potential feedbacks from marine biogeochemical cycles and ecosystems to the Earth System will require detailed understanding of local and regional manifestations of global change in the ocean, and their interactions with other parts of the Earth System.

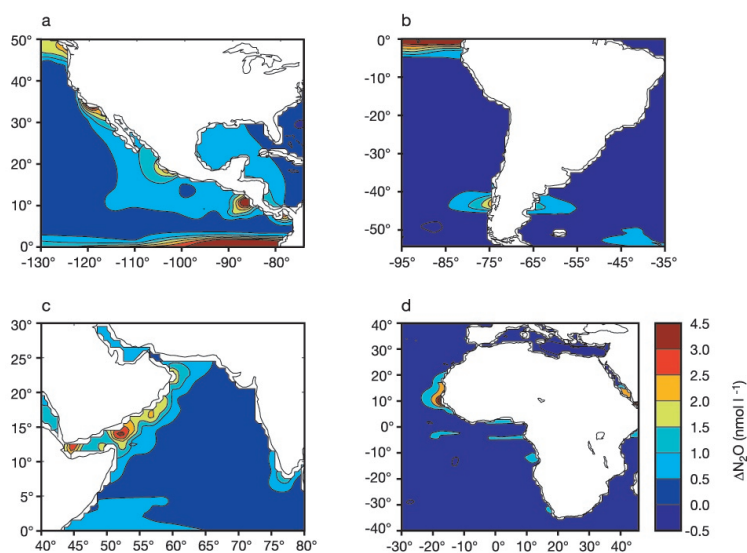


Figure 3. Annual composite maps of  $\Delta\text{N}_2\text{O}$  at the sea surface ( $\text{nmol l}^{-1}$ ). (a) Pacific Northwest and Central American coast, (b) western coast of South America, (c) perimeter of the Arabian Sea, and (d) west coast of Africa. From Nevison et al. (2004). *Global Biogeochemical Cycles* 18, GB1018.

## Theme 4: Responses of Society

This theme will focus on interactions between human and ocean systems. Its motivation stems from recognition that humans not only influence ocean systems, but that humans also depend on ocean systems for goods and services. The theme goal is to promote an understanding of the multiple feedbacks between human and ocean systems, and to clarify what human institutions can do, either to mitigate anthropogenic perturbations of the ocean system, or to adapt to such changes. A major challenge of this theme will be to bring together scientists from a wide range of disciplines, to identify areas of joint concern and interest, and to create an ongoing natural-social science marine research community.

### Implementation

IMBER will take advantage of new and innovative approaches to marine research ranging from new molecular techniques to sustained *in situ* and remotely sensed observations. The development of new sustained observation sites will be an important part of the implementation strategy complemented by targeted field-based process studies, *in situ* mesocosm studies, and field and laboratory experiments. A suite of hierarchical models will be developed to test hypotheses, analyse data and extrapolate in space and time, and identify crucial knowledge gaps that require new observations. Extrapolation to the global scale will require integration and assimilation of data from basin-wide surveys. To support modelling and synthesis, interconnected biological, geochemical and physical databases will be built, extended, and updated in near real-time.

Answering the broad interdisciplinary questions will require an effort much larger than any single nation can mobilise. Multiple investigators spanning disciplines, and intercomparisons of data across a range of systems will be needed. Interfacing the natural and social science communities to study the key impacts and feedbacks between marine and human systems will be a major challenge. IMBER will encourage collaborative activities that will draw on the expertise of other international research projects and programmes, including the Global Ocean Observing System, to avoid duplication and to ensure a truly interdisciplinary approach.