AGU BOOKSHELF

Indian Ocean Biogeochemical Processes and Ecological Variability

The Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER) conference was held in 2006 in Goa, India. The goals of the workshop were to assess the known facts about basin-wide biogeochemical and ecological dynamics of the Indian Ocean, to answer major questions, and to draw a road map for future research. The AGU monograph *Indian Ocean Biogeochemical Processes and Ecological Variability,* edited by Jerry D. Wiggert, Raleigh R. Hood, S. Wajih A. Naqvi, Kenneth H. Brink, and Sharon L. Smith, synthesizes the talks that were presented at this conference. In this interview, *Eos* talks with Jerry Wiggert, assistant professor of marine science at University of Southern Mississippi, Hattiesburg.

Eos: *What is the long-term goal of Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER)?*

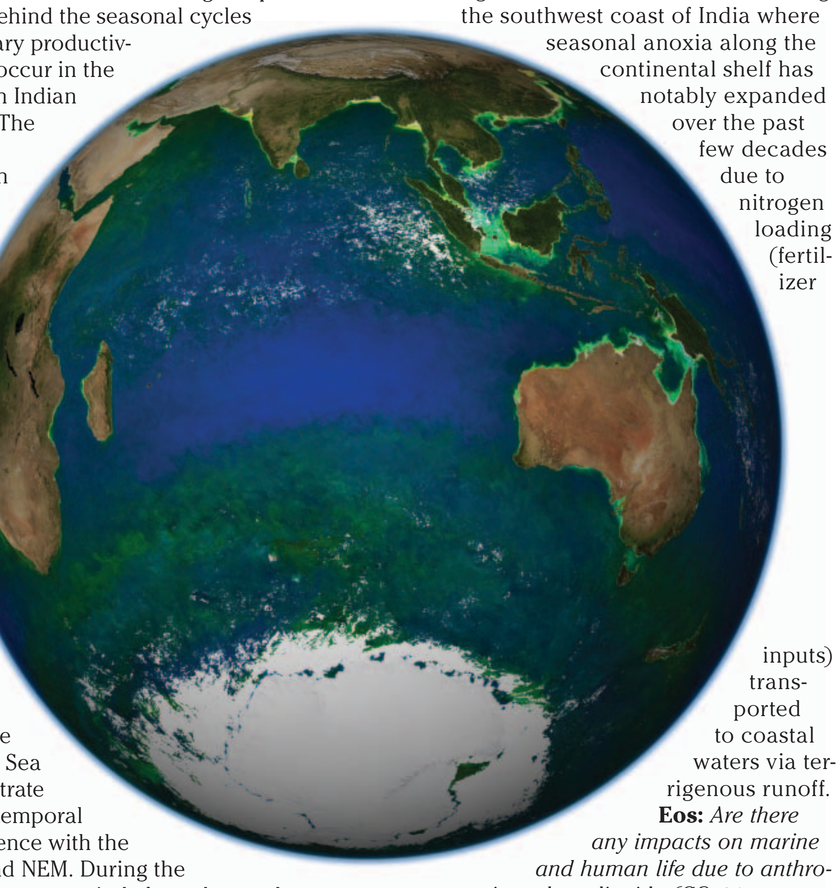
Wiggert: The long-term goal of SIBER is to understand the role of the Indian Ocean in global biogeochemical cycles and the interaction between these cycles and marine ecosystem dynamics. This understanding will be required to predict the impacts of climate change, eutrophication, and harvesting on the global oceans and the Earth system. It is fundamental to policy makers in the development of management strategies for the Indian Ocean. To address this goal, emphasis will be given to the analysis required to predict and evaluate the impacts of physical and anthropogenic forcing on biogeochemical cycles and ecosystem dynamics in the Indian Ocean. SIBER will leverage the sampling and monitoring activities of several coastal and open-ocean observing systems that are being planned and deployed in the Indian Ocean and will provide the basin-wide scientific coordination and communication.

Eos: *Why is it important to understand the dynamics of the Indian Ocean?*

Wiggert: As for any ocean, understanding the dynamics is vital for studies of biogeochemical and ecological processes because the physical environment will be the primary determinant of the spatiotemporal availability of nutrients within the euphotic zone. For the Indian Ocean the proximity of the Eurasian landmass results in seasonally reversing monsoonal winds that are unique among the tropical oceans. The monsoon seasons consist of the summer Southwest Monsoon (SWM), which features strong winds (>0.6 newton per square meter) that travel from the southwest to northeast that drive ocean upwelling; and the winter Northeast Monsoon (NEM), which features more moderate, oppositely directed winds (~0.15 newton per square meter) and cool, dry air that drive convective mixing. As a result of this monsoonal forcing, the Somali Current also reverses seasonally. Considering that this is the Indian Ocean's western boundary current, some perspective can be gained by realizing this would be equivalent to the Gulf Stream or the Kuroshio reversing direction.

Eos: *How does the monsoon season affect the ecosystem of the ocean?*

Wiggert: Monsoon forcing is a prominent factor behind the seasonal cycles of primary productivity that occur in the northern Indian Ocean. The phytoplankton bloom dynamics of the Arabian Sea demonstrate a clear temporal coincidence with the SWM and NEM. During the summer, strong winds from the southwest drive coastal upwelling and offshore transport of entrained nutrients that support the observed phytoplankton blooms of the Arabian Sea. During the winter, moderate northeasterly winds bring cool, dry air that originates from the Tibetan Plateau over the northern Arabian Sea. Through their cooling of surface waters, convection (i.e., vertical mixing) results that entrains nutrients and stimulates the winter bloom. Despite being subject to similar monsoon forcing, the Bay of Bengal's bloom dynamics do not exhibit a similarly clear temporal coincidence due to the profound freshwater inputs it receives from rivers and direct precipitation that significantly affect surface stratification.



Eos: *What are the impacts of human activity on the aquatic biogeochemical processes?*

Wiggert: There are a number of ways that human activities can affect the biogeochemical processes of the Indian Ocean. These include (1) coastal development as populations in southern Asia increase, with associated urbanization and industrial development; (2) modifications in agricultural methods as the transition toward more modern practices with expanded use of fertilizers occurs; and (3) rerouting of water supplies for urban and agricultural purposes. These activities all are likely to significantly modify the timing and makeup of dissolved nutrients, elemental ratios, and particulate species within freshwater inputs to the coastal watersheds of the Indian Ocean. A documented example of human influences affecting the marine environment is along the southwest coast of India where seasonal anoxia along the continental shelf has notably expanded over the past few decades due to nitrogen loading (fertilizer inputs) transported to coastal waters via terrigenous runoff.

Eos: *Are there any impacts on marine and human life due to anthropogenic carbon dioxide (CO_2)?*

Wiggert: The anthropogenic CO_2 inputs to the global biosphere have profound impacts on all life forms. The warming that it engenders will promote retreat of ice caps and sea level rise. In the marine environment a persistent change in temperature range and/or levels of atmospheric CO_2 is likely to result in speciation shifts, or adjustments by a given species, that will alter biogeochemical cycling. Another critical aspect of anthropogenic CO_2 is its promotion of ocean acidification (OA). Identifying the consequences of OA is a recent focal point of the research community, and understanding the full extent of its implications to the health of the world's marine systems has yet to be attained. However, with the decreasing pH of seawater, it is expected that organisms that depend on shell building (e.g., corals, coccolithophores, crustaceans) will need to expend significantly more energy to fulfill that need, which will detract from reproduction and other critical life functions.

Eos: *What is the influence of the Indian Ocean Dipole?*

Wiggert: The Indian Ocean Dipole (IOD) is a climate mode intrinsic to the Indian Ocean that manifests as anomalous surface temperature distributions that significantly modify weather patterns of the basin's rim nations and the phytoplankton bloom dynamics of its marine system. During the 1997–1998 IOD the shift in phytoplankton accumulations that accompanied the altered state of oceanic upwelling had a profound influence on tuna fisheries, with the purse seine catches shifting eastward to fully encompass the equatorial Indian Ocean. Thus, the ecological impact of the IOD extends to the highest trophic levels as they respond to the anomalous forage distribution.

Eos: *How important are the large dust and aerosol inputs that occur year-round?*

Wiggert: There are a number of arid terrestrial regions around the Indian Ocean that are prominent sources of windblown mineral dust that gets deposited over the surface ocean. A portion of the deposited dust's ferrous component is solubilized and becomes part of the oceanic pool of dissolved iron, which is an essential micronutrient for phytoplankton photosynthesis. Anthropogenically derived aerosols are also prevalent, particularly the persistent brown haze over the Arabian Sea, Bay of Bengal, and southern tropical Indian Ocean that derives from industrial pollution and biomass burning with myriad sources across South and Southeast Asia.

The dust and aerosols have several impacts on the marine ecosystem. One is to modulate the intensity and spectral quality of the solar radiation that reaches the sea surface and is then harvested by the photosynthetic pigments of phytoplankton in the euphotic zone. Such shifts in the character of downwelling radiance can influence which autotrophic species will be best suited to being in the water light field. Another profound impact of the mineral dust, as noted, is its augmentation of the mixed layer concentration of dissolved iron that is fundamental for photosynthesis. With its principal dust source regions in northwestern Australia and around the Arabian Sea, the Indian Ocean experiences broad spatial gradients in eolian iron fluxes that are a leading-order influence on the distribution of iron-stressed phytoplankton populations.

Eos: *What are the future goals of Indian Ocean biogeochemical and ecological research?*

Wiggert: The future goals of Indian Ocean research are varied and numerous, and range from very specific questions to much broader basic informational gaps. An example of the former is the question that has emerged since the Joint Global Ocean Flux Study (JGOFS) Arabian Sea campaigns in the 1990s regarding the relative roles of zooplankton grazing and iron availability in limiting phytoplankton production in the Arabian Sea during the SWM. Addressing this very topic was the focus of a funded project that was subsequently relocated to the eastern Pacific because of the threat that piracy posed to the safety of University-National Oceanographic Laboratory System (UNOLS) research vessels in the northern Arabian Sea. Thus, investigators with an interest in pursuing research activities in the Indian Ocean have unique challenges to face beyond solely competing with their peers for the available funding dollars.

In terms of addressing the broader informational gaps that exist, a partial list includes (1) better understanding of the fundamental contrasts that exist between the Arabian Sea and the Bay of Bengal ecosystems despite the similar monsoon forcings they are subject to; (2) comprehensive cross-basin characterization of biogeochemical distributions of the equatorial and southern tropical Indian Ocean, including the influence of the Indonesian Throughflow; and (3) establishing a more complete database for the purposes of determining the Indian Ocean's role in the global carbon cycle, where an accurate baseline is critical for identifying how its contribution evolves going forward.

These are all foundational goals that motivated the initial SIBER conference from which the contributions to this monograph are derived. From an even broader perspective, a profound potential exists for the SIBER program to stimulate the building of scientific research capacity in the Indian Ocean rim nations and to foster international cooperation through joint research efforts in the Indian Ocean.

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—LESLIE OFORI, Staff Writer