Collaborative Research (MSM): Coupling Meteorological, Hydrological, and Circulation Models to Understand the Physical Template for Hypoxia

Project Summary

The Problem: Hypoxic events are increasing in coastal waters, causing significant ecological and economic impacts. Coastal hypoxia is caused both by water-column stratification and excess nutrient loads. Hypoxia typically occurs when buoyancy-induced stratification (by fresh water and heat) is of sufficient extent and duration to inhibit oxygen replenishment. Oxygen replenishment may take place by vertical mixing across the density gradient or by lateral advection via wind-generated currents. These interactions vary on synoptic, seasonal, and inter-annual time scales, modulated in some locations by tides. River discharge, the principal buoyancy source, is climate-related, and for large catchments (e.g. the Mississippi River), hydrological responses may be decoupled from coastal processes. Models limited to a single domain cannot capture the complexities of ecosystems affected by hydrological, meteorological, physical, and climate impacts varying over event to seasonal timescales and local to continental river basin spatial scales. Therefore a multi-scale modeling approach, coupling models across small and large (time/space) scale systems, is required to investigate the hydrological and coastal ocean physical interactions underpinning hypoxia.

Goal: The goal of the proposed study is to advance the understanding of the physical forcing functions on hypoxia in shelf and estuarine waters. The objectives of the study are to explore stratification sensitivity to different forcing scenarios within three distinctive regimes and to perturb these under varying climate scenarios as indicators of future hypoxia event potential.

Approach: Multi-scale (time and space), interdisciplinary (hydrology, ecology, physical oceanography, meteorology) numerical model experiments will be conducted for the Chesapeake Bay, the West Florida shelf, the Northern Gulf of Mexico and their respective catchments. Oxygen budget and sensitivities to physical forcing will be examined for present and future scenarios based on observed normal and extreme conditions in each region, including perturbations based on projected climate change. A standards-based data and information management system will provide archive and catalog services and enable interoperability and collaboration among the modelers.

Intellectual Merit: In the context of an oxygen balance, the conservative aspects of hypoxia will be elucidated (conditions of water mass isolation, aging and eventual oxygen depletion) and case study diagnoses will provide inferences on net, non-conservative consumption rates. By diagnosing three regimes, coastal ocean sensitivity to physical forcing as pertains to hypoxia will be established. Inference for future climate scenarios can then be extrapolated through perturbation experiments. Conservative aspect understanding of the problem provides a foundation for biogeochemical process studies.

Broader Impacts: The study will advance understanding of hypoxia, a coastal ocean problem of societal importance. The development of continental-scale hydrological modeling capabilities will improve interdisciplinary linkages between ocean modeling and hydrological modeling communities. The data management and collaboration components will serve both current and future research groups.