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Oregon, USA Shelf Hypoxia: What are the driving processes of hypoxia in the Northern California Current?

Andrey O. Koch (1), Yvette H. Spitz (2), and Harold P. Batchelder (2)

(1) University of Southern Mississippi, Department of Marine Science, Stennis Space Center, MS, United States, (2) College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, OR, United States

During the last decade frequent summertime episodes of hypoxic (< 1.43 ml DO/l; DO - dissolved oxygen) waters occupying significant areas of the Oregon coastal shelf have been observed. The spatial extent and severity of low oxygen conditions on the shelf vary interannually and are the cumulative results of both physical and biological processes. Among the most important factors are the amount of total primary production, the retention (or residence) time of water before it is flushed from a local region and DO and nitrate (NO_3) concentration of the source waters that are transported onto the shelf. In order to examine the importance of these physical and biological processes as well as their interaction, a 6-component (nitrate, ammonium, phytoplankton, zooplankton, detritus, dissolved oxygen) ecosystem model has been coupled to a ROMS (Regional Ocean Modeling System) circulation model. We analyzed model hindcasts for three years: 2002, with strong hypoxia record; 2006, when hypoxia was severe (even approaching anoxia), spatially extensive and lasted for several months; and 2008, when hypoxic events were shorter and not as widespread on the shelf. The sensitivity analysis of 2002 and 2006 summer hypoxia on the Oregon shelf to variable initial and open boundary NO_3 and DO conditions showed that: (i) for accurate forecasting of summer-autumn oxygen on the Oregon shelf, it is crucial to have accurate ecosystem boundary and late-spring initial conditions (especially for NO_3 and DO); (ii) initial DO and NO_3 conditions formed from climatology fields could substitute for missing in situ observations for initial conditions and reasonably simulate summer hypoxia on the Oregon shelf in most years (2002 was exceptional in having springtime DO and NO_3 values that were extreme compared to "climatological" values), and (iii) offshore and especially northern DO and NO_3 boundary conditions are important to simulating hypoxia on the Oregon Shelf. Although DO production due to biological processes is large, physical processes, mostly horizontal advection and diffusion of DO and nitrate, are responsible for net DO reduction in spring-summer and bottom hypoxia in summer on the Oregon shelf. We also showed that the physical mechanism most responsible for Oregon shelf hypoxia is the coastal upwelling. In 2006, about two thirds of the April to August decline in DO occurred in April-May during a strong and long-lasting upwelling event.