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Phosphorus limitation reduces hypoxia in the northern Gulf of Mexico: results from a physical-biogeochemical model

Arnaud Laurent and Katja Fennel
Dalhousie University, Oceanography Department, Halifax, Canada (arnaud.laurent@dal.ca)

In the northern Gulf of Mexico, excess dissolved inorganic nitrogen and phosphorus loads from the Mississippi-Atchafalaya River system promote high primary production and contribute to the seasonal development of hypoxic bottom waters on the Louisiana Shelf. While phytoplankton growth is considered to be typically nitrogen-limited in marine waters, phosphorus limitation has been observed in this region during peak river discharge in spring and early summer. Here we present a synthesis of recent investigations that quantitatively assessed, using a realistic physical-biogeochemical model, the effect of phosphorus limitation on primary production and hypoxia development in the Mississippi-Atchafalaya River plume. Our model simulations indicate that phosphorus limitation delays and displaces westward a portion of river-stimulated primary production and depositional fluxes, resulting in a redistribution of respiration processes toward the western Louisiana Shelf. Despite this redistribution, phosphorus limitation did not promote a westward expansion or relocation of hypoxia, as some had previously speculated. Rather, the onset of hypoxia was delayed and the size of the hypoxic zone reduced. In other words, P limitation diluted the effects of eutrophication on the Louisiana shelf. Simulations with altered nutrient river loads show that despite phosphorus limitation, the co-reduction of nitrogen and phosphorus remains the best strategy to reduce hypoxia. Yet, a 50% reduction in both nutrients was not sufficient to meet the Gulf Hypoxia action plan goal of a $5 \cdot 10^3$ km^2 hypoxic area in our model simulations. This result emphasizes the need for a drastic co-reduction of N and P loads from the Mississippi-Atchafalaya River system to significantly reduce hypoxia in this region.