

Resuspension and sediment bed oxygen consumption: developing and testing a coupled model

Moriarty Julia¹, Courtney Harris¹, Christophe Rabouille² and Flora Toussaint²

¹ the College of William & Mary, Virginia Institute of Marine Science
PO Box 1346 Gloucester Point, Virginia 23062, USA
E-mail: moriarty@vims.edu

² Laboratoire des Sciences du Climat et de l'Environnement, CEA-CNRS-UVSQ, Bât. 12, Avenue de la Terrasse, F-91198 Gif-sur-Yvette Cedex, France

Sediment resuspension in coastal environments is classically seen as a process which entrains deposited organic material and porewater into the overlying water. The alteration of sediment diagenesis due to this transfer is largely understudied. Models representing water column oxygen budgets have usually relied on simplifying assumptions for sediment oxygen demand such as instant remineralization of detritus at the seabed. Model estimates of oxygen concentrations in the Gulf of Mexico, however, have been shown to be very sensitive to parameterizations of sediment oxygen demand. Meanwhile, diagenetic models tend to calculate sediment oxygen demand under an assumption of steady accumulation of organic matter and sediment. Though most diagenetic models neglect resuspension, observations from the Rhone River subaqueous delta indicate that oxygen fluxes increased during resuspension events. To the best of our knowledge, however, no model exists that directly couples diagenetic processes, water column biogeochemistry, and sediment erosion and deposition, and therefore tools for comparing the significance of these processes are lacking.

To evaluate the role of resuspension on sediment oxygen consumption, we implemented a version of the Regional Ocean Modelling System (ROMS) that couples hydrodynamic, sediment transport, and biogeochemical processes. To link the resuspension and biogeochemical modules, a diagenetic model was added to the seabed (Fig. 1). Here, we present a one-dimensional (vertical) version of the coupled model and apply it to the Rhone River subaqueous delta. Preliminary results indicate that resuspension of organic material and reduced porewater constituents produce pulses of oxygen consumption and increase overall sediment oxygen demand.

Model description

The coupled model was developed within the ROMS hydrodynamic model (Haidvogel *et al.*, 2000) and utilized the Community Sediment Transport Modeling System (CSTMS; Warner *et al.*, 2008) and a water column NPZD (nutrient-phytoplankton-zooplankton-detritus) biogeochemical module (Fennel *et al.*, 2006) because this framework is community-based and well-utilized. This study adapted the ROMS-CSTMS-Fennel model by coupling it to a diagenetic model based on Soetaert *et al.* (1996). We also adapted the ROMS-CSTMS seabed layering scheme to resolve millimetre scale features near the seabed surface while maintaining computational efficiency.

This coupled model accounts for processes including diffusive vertical mixing, resuspension, deposition, and burial of particles and dissolved species. Detrital material, created by the water column biogeochemical model, becomes associated and transported with suspended sediment classes, undergoing advection, diffusion, deposition, and erosion. Dissolved constituents (O_2 , NO_3^- , NH_4^+ , etc.) from the biogeochemical model may be exchanged with the seabed through deposition, erosion, and diffusion across the sediment – water interface. Seabed organic material and porewater constituents are subject to diagenetic processes including aerobic, nitrate and anoxic mineralization, and biodiffusion may mix sediment, organic material, and porewater in the seabed.

Implementation for the Rhone River sub-aqueous delta and future work

This coupled one-dimensional vertical model is being implemented for a high-depositional, organic-rich, sub-aqueous delta offshore of the Rhone River (Fig. 2). Model results are being validated using a time series of water column and seabed oxygen profiles described in Toussaint *et al.* (2014). These observations were collected from an *in-situ* benthic station and indicate that increased oxygen consumption in the seabed by a factor of 3 occurs during wave resuspension events compared to quiescent periods. Preliminary results indicate that resuspension events increase oxygen consumption by re-introducing organic matter and reduced porewater species into the water column. Resuspension also erodes the more oxygenated surface sediment from the seabed, exposing the typically-anoxic subsurface to oxygen. Ongoing work includes evaluating the response of seabed-water column fluxes to resuspension events (e.g., frequency and duration), and to less-constrained model parameters (e.g. diffusion and remineralization rates).

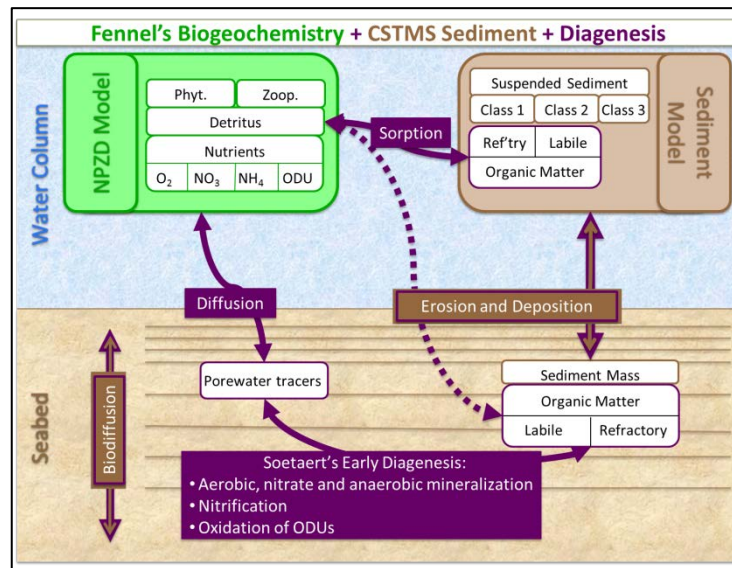


Fig. 1. Schematic illustrating links between the diagenetic, biogeochemistry, and sediment transport modules. Green, brown, and purple outlines indicate for which module (biogeochemistry, sediment transport, and/or the diagenetic model) the process or variable is used. White boxes indicate variables, and coloured boxes indicate processes.

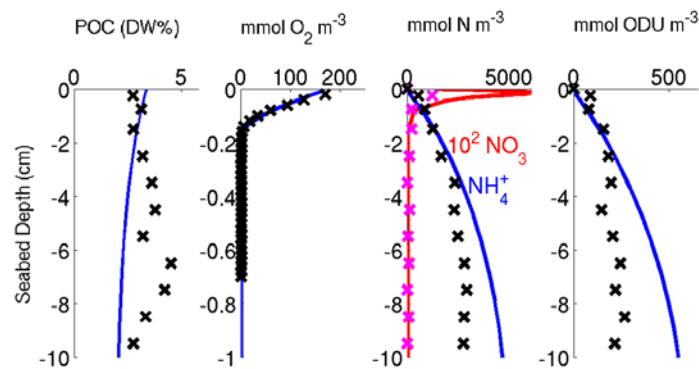


Fig. 2. Profiles of (a) particulate organic material (dry weight, DW), (b) oxygen, (c) nitrate and ammonium, and (d) oxygen demand units (ODUs) for the Rhone River shelf. Lines are preliminary results from a model that neglected resuspension; 'X' shows observations from Pastor *et al.* (2011).

References

- Fennel K., J. Wilkin, J. Levin, J. Moisan, J. O'Reilly and D. Haidvogel. 2006. Nitrogen cycling in the Middle Atlantic Bight: results from a three-dimensional model and implications for the North Atlantic nitrogen budget. *Global Biogeochemical Cycles* 20(3):GB3007.
- Haidvogel D., H. Arango, K. Hedstrom, A. Beckmann, P. Malanotte-Rizzoli and A. Shchepetkin. 2000. Model evaluation experiments in the North Atlantic basin: simulations in nonlinear terrain-following coordinates. *Dynamics of Atmospheres and Oceans* 32(3-4):239-281.
- Pastor L., C. Cathalot, B. Deflandre, E. Viollier, F.J.R. Meysman, C. Ulses, E. Metzger and C. Rabouille. 2011. Modelling biogeochemical processes in sediments from the Rhone River prodelta area (NW Mediterranean Sea). *Biogeosciences* 8:1351-1366.
- Soetaert K., P. Herman and J. Middelburg. 1996. A model of early diagenetic processes from the shelf to abyssal depths. *Geochimica et Cosmochimica Acta* 60(6):1019-1040.
- Toussaint F., C. Rabouille, C. Cathalot, B. Bombled, A. Abchiche, O. Aouji, G. Buchholtz, A. Clemençon, N. Geyskens, M. Repecaud, I. Pairaud, R. Verney and N. Tisnerat-Laborde. 2014. A new device to follow temporal variations of oxygen demand in deltaic sediments: the LSCE benthic station. *Limnology and Oceanography: Methods*. Accepted.
- Warner J., C.R. Sherwood, C.K. Harris and H. Arango. 2008. Development of a three-dimensional, regional, coupled wave, current, and sediment-transport model. *Comput. Geosci.* 34:1284-1306.