Role of Particulate Resuspension on Organic Matter, Nitrogen, and Oxygen Dynamics: Preliminary Results from a Coupled Model for Chesapeake Bay

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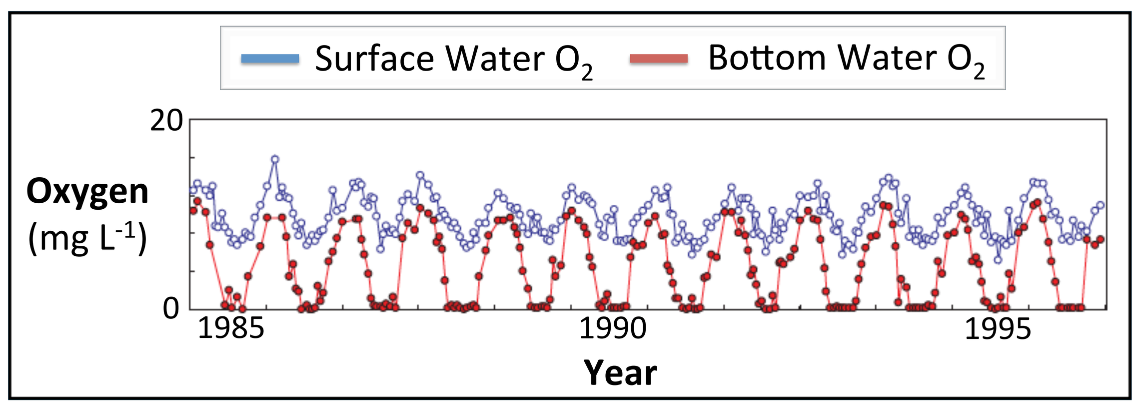
1. Motivation

Hypoxia, or the occurrence of low oxygen levels, occurs in many coastal water bodies and can harm fish and other marine species. In the Chesapeake Bay, summertime hypoxia develops as stratification and biological oxygen consumption increase, and oxygen solubility decreases (Fig. 1).



Resuspension may affect water column biogeochemistry, including oxygen concentrations, through multiple mechanisms. For example, resuspension of particulates may increase light attenuation, or facilitate near-bed remineralization of organic matter. Additionally, currents may redistribute resuspended material, including organic matter, around the estuary.

Figure 1 (left): Oxygen observations from the mesohaline Chesapeake Bay (Ches. Bay Program station CB4.3C ; Testa and Kemp, 2011).

Conclusions

1. A coupled hydrodynamic–sediment transport–biogeochemical model was implemented for Chesapeake Bay.
2. In the Upper Bay, resuspension of sediment increased light attenuation, limiting photosynthesis, and reducing oxygen production, uptake of ammonium, and organic matter remineralization.
3. In the Mid- to Lower- Bay, resuspension increased remineralization of organic matter, increasing oxygen consumption and ammonium production.
4. Together, these resuspension-induced changes in remineralization rate and primary productivity lowered oxygen concentrations and increased ammonium concentrations.

2. Objective

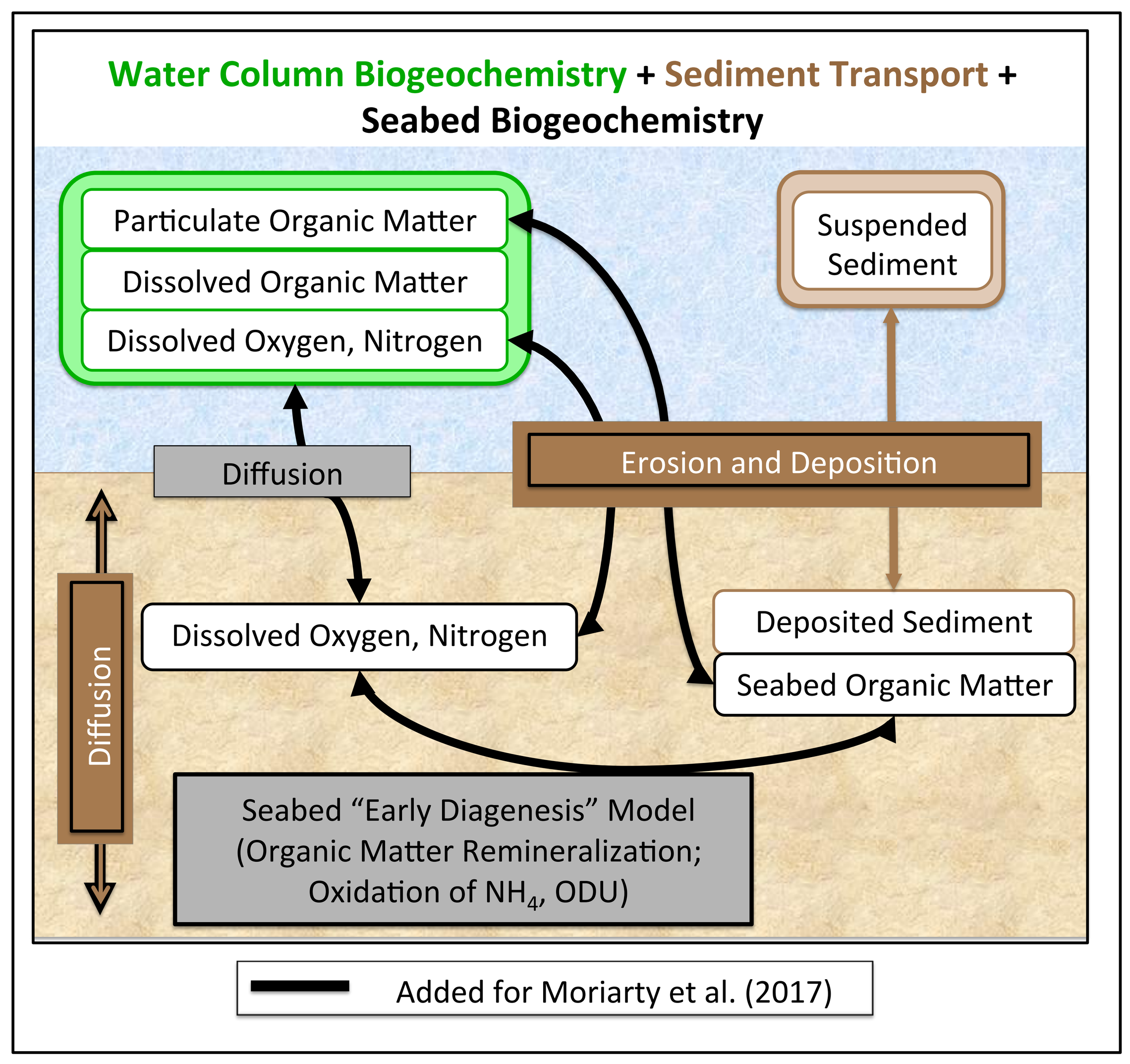
Explore the effects of resuspension, and subsequent redistribution, of sediment and particulate organic matter on oxygen and ammonium dynamics in Chesapeake Bay.

3. Implementation of a Coupled Hydrodynamic-Sediment Transport-Biogeochemical Model for Chesapeake Bay

We implemented a process-based numerical model that couples hydrodynamics, sediment transport and biogeochemical processes (Fig. 2; Moriarty et al., 2017) for the Chesapeake Bay by building on a previous model (ChesROMS-ECB; Feng et al. 2015).

Numerical experiments included:

1. Standard model run with resuspension (Jan. – Dec. 2000)
2. No-resuspension model run (July 2000)



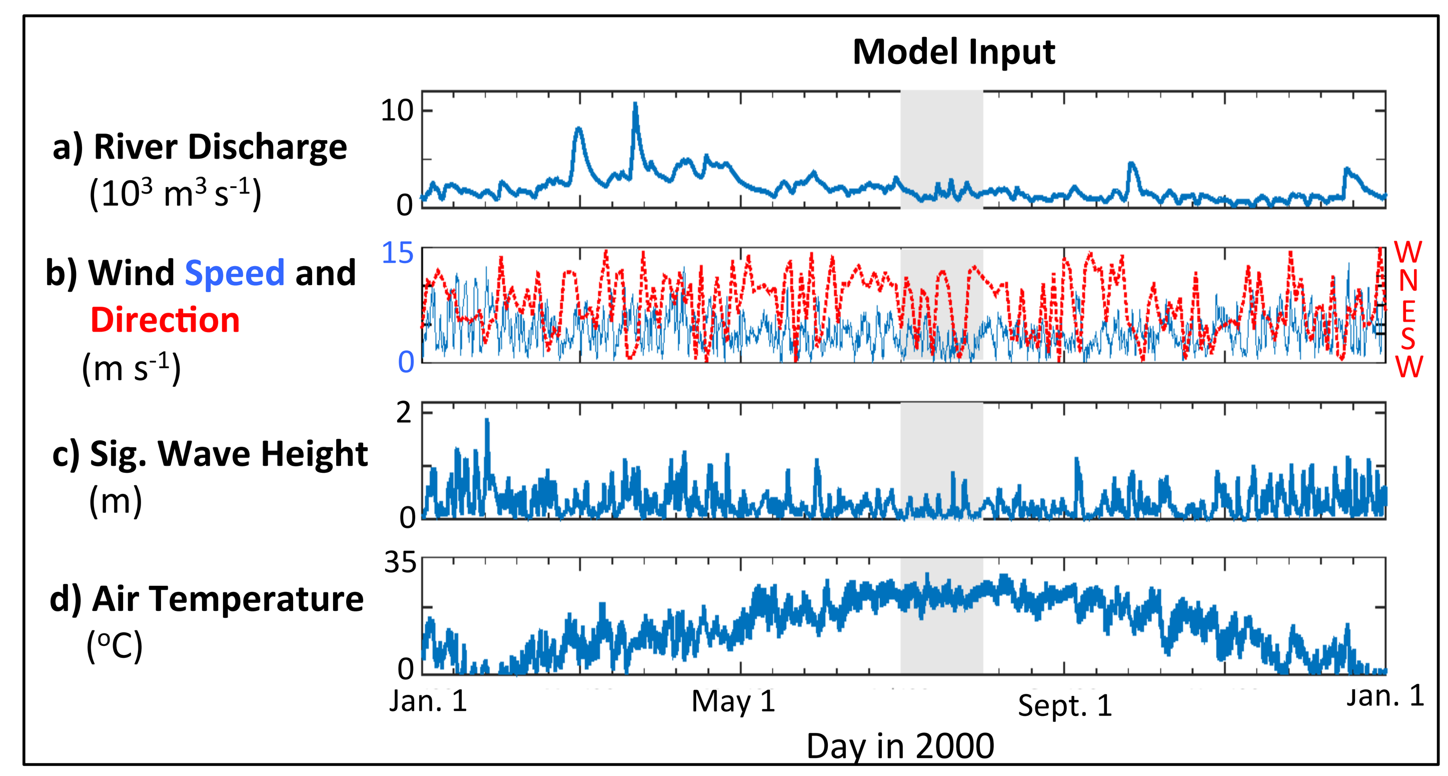


Figure 2 (left): Schematic of the coupled model, developed within the ROMS hydrodynamic modeling framework.

Figure 3 (above): Model input included (a) river discharge from EPA's watershed model; (b) winds and (d) air temperature from NOAA's North American Regional Reanalysis (NARR) dataset; and (c) waves estimated by the SWAN model.

Movie Goes Here!

Figure 4: Movie of standard model run estimates.

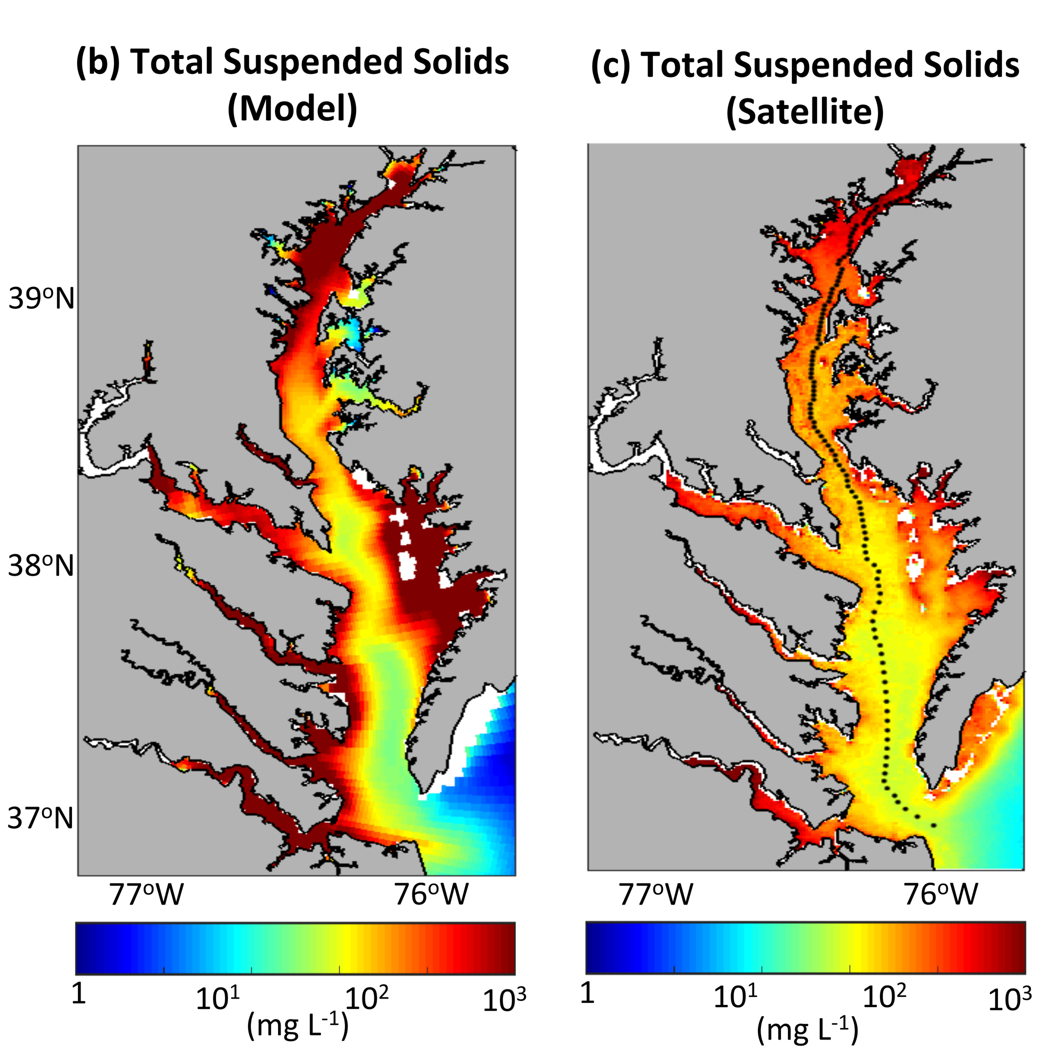


Figure 5: Total suspended solids (TSS; includes inorganic and organic components) from the (a) model and (b) MODIS satellite (Wang et al., 2009). Data was averaged over July 2000 (model) and all Julys in 2002-2012 (satellite). Black dots in (b) indicate location of transect for Fig. 6.

4. Preliminary Results: Effect of Resuspension on Oxygen & Nitrogen Dynamics

- Resuspension increased light attenuation and decreased primary productivity in the Upper Bay. This decreased uptake of dissolved inorganic nitrogen by phytoplankton in the Upper Bay, allowing more nutrients to reach the Mid- and Lower- Bay and increasing primary productivity there.
- Resuspension of seabed organic matter, as well as enhanced organic matter availability due to increased primary productivity, increased remineralization rates in the Mid- to Lower- Bay. In the Upper Bay, remineralization rates decreased due reduced organic matter production.
- On the timescale of a month, these changes in biogeochemical processes reduced oxygen concentrations and increased ammonium concentrations.

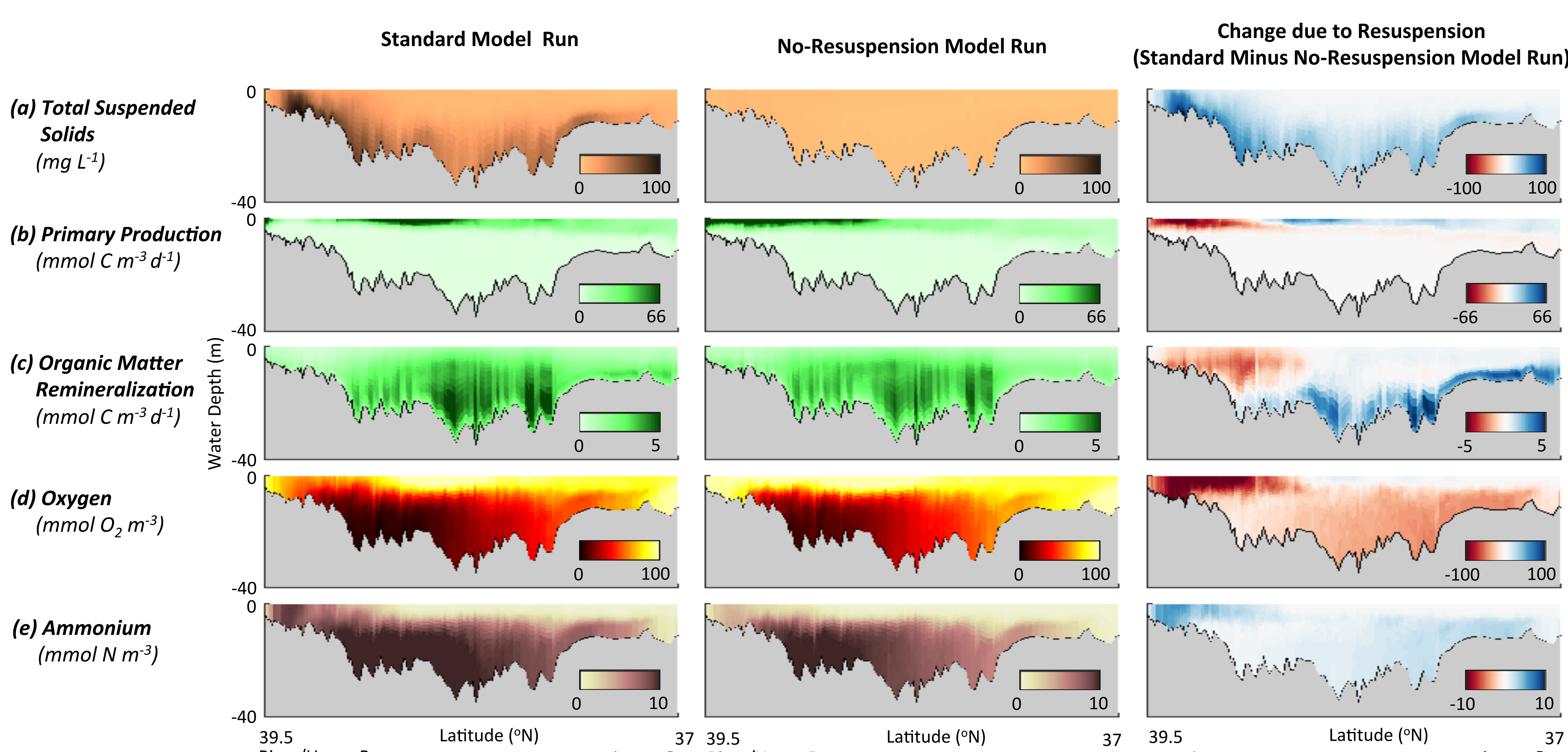


Figure 6: Model estimates along the main channel averaged over July 2000.

References

Feng, Y., et al. (2015). Journal of Geophysical Research: Biogeosciences, 120: 1666-1695. ***Moriarty***, J., et al. (2017). Biogeosciences, 14: 1919-1946. ***Testa***, J. and Kemp,W. (2011). In: Wolanski and McLusky (eds). Treatise on Estuarine and Coastal Science, 5: 163-199. ***Wang***, M., et al. (2009). Journal of Geophysical Research, 114, C10011.

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