Assessing the performance of a coastal carbon model in the Chesapeake Bay

Yang Feng[1], Marjorie A.M. Friedrichs[1], John Wilkin[2]

[1]Virginia Institute of Marine Science, College of William and Mary
[2]Institute of Marine and Coastal Sciences, Rutgers University

Introduction/methods

As a connecting point between land and oceans, estuaries are where inorganic and organic carbon undergoes important biogeochemical processes and transformations, such as photosynthesis, respiration, regeneration, flocculation, and sedimentation, but the net role estuaries play in the coastal carbon cycle is still not well understood. We applied a high resolution, 3-D, coupled biogeochemical model (Fig. 1) to the Chesapeake Bay to study the role of estuaries in coastal carbon cycling. The model is forced by riverine inorganic nutrients, inorganic carbon and organic carbon from USGS. We ran the model for 2004 and compared the model simulated state variables with available observations from the Chesapeake Bay Program (CBP; Fig. 2) using Target Diagrams (Fig. 3).

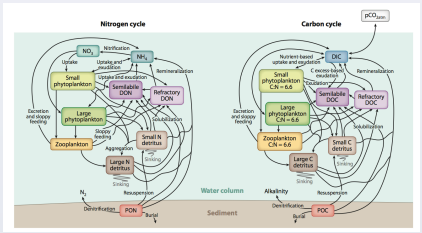


Figure 1. Schematic of the biogeochemical component of the coupled model (Druon et al. 2010; Hofmann et al. 2011). The model includes both carbon and nitrogen cycles, and is embedded within the Regional Ocean Modeling System (ROMS) physical circulation model.

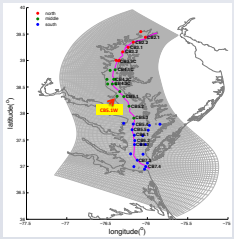
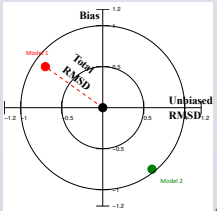


Figure 2: The physical model domain and CBP observation stations. Magenta line shows the position of trench in Figure 4, 5, 7, 9. The CBP stations are grouped into north (red), middle (green) and south (blue) for model skill assessment in Figures 6, 8, and 10. CB5.1W is the only station with DON data (Fig. 8).

Figure 3: Target diagram schematic. The X-axis shows the unbiased RMSD multiplied by the sign of the standard deviation difference between model and observation. X > 0 means the model standard deviation is larger than the observation and vice versa. The Y-axis shows the positive (Y>0) and negative (Y < 0) bias. The distance between the origin and each model symbol is then equal to the total Root-Mean Squared Difference (RMSD). Both X and Y axes are normalized by the observational standard deviation in Figures 6, 8, 10.



Results

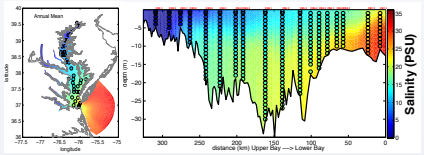


Figure 4: The 2004 annual salinity field from the model (background color) and CBP observations (dots). Left panel is surface salinity; right panel is the salinity vertical distribution along the Bay trench.

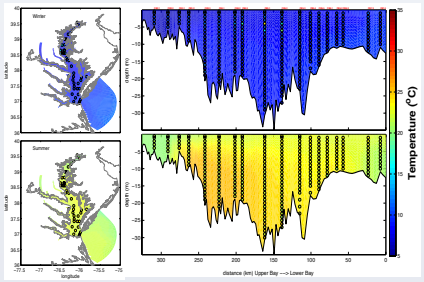


Figure 5: The 2004 half-year average temperature field from the model and observations. Winter is from Dec to May; summer is from June to November. The model successfully captured the seasonal variation in temperature.

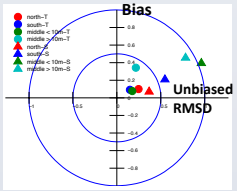


Figure 6: The target diagram of temperature (circle) and salinity (triangle) in the upper (red), middle (shallower than 10m = green; deeper than 10 m = cyan) and lower (blue) Bay. Almost all symbols are close to the origin and within the unit circle, which means that the model has relatively high skill in terms of reproducing the magnitude and variability of the observations.

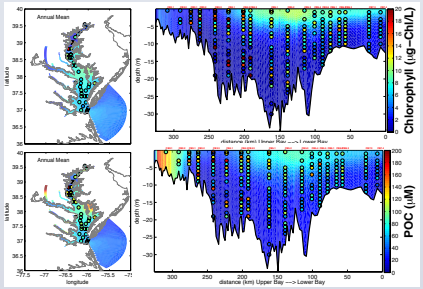
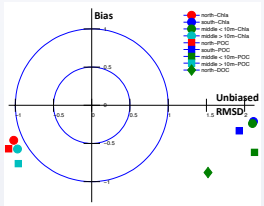


Figure 7: As in Figure 4, except showing annual chlorophyll and particulate organic carbon (POC).

Figure 8: The target diagram of chlorophyll (circle); POC (square) and DOC (diamond) in the upper (red), middle (shallower than 10m = green; deeper than 10 m = cyan) and lower (blue) Bay. The DOC data was only available at 1 station in 2004 (CB 5.1W Figure 2).



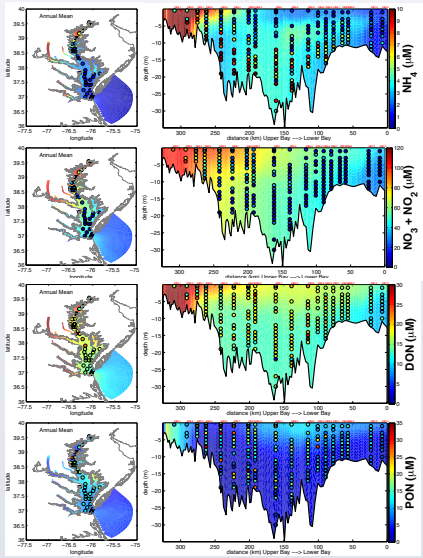


Figure 9: As in Figure 4, except showing annual ammonium (NH_4), nitrate + nitrite ($NO_2 + NO_3$), dissolved organic nitrogen (DON) and particulate organic nitrogen (PON).

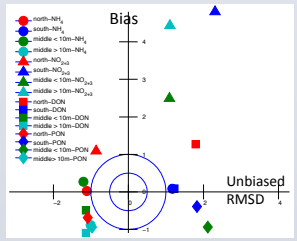


Figure 10: The target diagram of ammonium (circle); nitrate + nitrite (triangle); DON (square) and PON (diamond) in the upper (red), middle (shallower than 10m = green; deeper than 10 m = cyan) and lower (blue) Bay.

Conclusions

Model-data comparisons of physical variables (e.g. salinity and temperature; Fig. 4-6) demonstrate that the model has significant skill in terms of reproducing the hydrodynamics of the estuary. Model-data comparisons of biogeochemical variables (e.g. ammonium, nitrate, chlorophyll, dissolved and particulate organic nitrogen (DON & PON), dissolved and particulate organic carbon (DOC & POC); Fig. 7-10) demonstrate that the model has more difficulty reproducing the biogeochemical fields. Specifically, the model significantly overestimates the nitrate field, particularly in the lower Bay. The model also slightly underestimates chlorophyll, POC, DOC and PON, implying that the model may need to be adjusted such that inorganic nitrogen and carbon are converted more efficiently to organic forms. In general, the biogeochemical model reproduces the magnitude of the observed carbon and chlorophyll distributions better than the seasonal variability.

Future Work

Kemp et al. (1997) estimated carbon fluxes in the mainstem of Chesapeake Bay, including physical input and output fluxes as well as biotic metabolism associated with primary production and respiration (Figure 11). We will use our model to similarly estimate these carbon fluxes and transformations, in order to better understand the role estuaries play in the coastal carbon cycle.

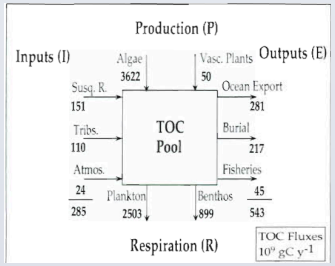


Figure 11: Carbon budgets by Kemp et al. (1997)

Reference

Druon et al. (2010), Modeling the dynamics and export of dissolved organic matter in the northeastern U.S. continental shelf, Estuar. Coast Shelf S., 88(4), 488 – 507

Hofmann et al. (2011), Modeling the dynamics of continental shelf carbon, Annu. Rev. Mar. Sci., 3(1), 93–122

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Acknowledgement

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