

Advanced Numerical Methods for Realistic River Plume Modeling in Coastal-Scale Domains

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LONG-TERM GOAL

The long-term goal of this research is to realize the potential for realistic-domain numerical models as tools for prediction and understanding of the dynamics and transport processes in the coastal ocean.

OBJECTIVES

The overall objective of this research program is to improve the robustness and fidelity of three-dimensional models of river plumes. This involves several steps, including 1) the development of idealized and realistic “test problems” involving the dynamics of river plumes; 2) the application of a particular model, ROMS, to these test problems, using it to investigate sensitivity to forcing, boundary conditions, resolution, and model algorithms (e.g., turbulence closure, advection schemes); 3) the comparison of the model with specific data sets (e.g., the Eel River outflow, the Gulf of Maine Coastal Current).

APPROACH

This project is a cooperative effort between Rob Hetland at Texas A&M and me. I am providing overall guidance and access to observational data. Rob is performing the numerical simulations and developing model algorithms.

The initial modeling involves an idealized domain, performing a set of tests to define the appropriate input conditions for a river plume. It was not known a priori how much detail in the estuary was required to provide a realistic specification of the river-mouth flow and salinity. The next step is to determine the sensitivity to horizontal grid resolution and numerical advection scheme, and to determine the requirements for a 'grid-converged' solution.

After the model configuration has been established, we address specific components that lead to realistic simulations. These include wind stress forcing, tides, ambient flow in the coastal ocean, and time-variation of river flow.

The final step is to perform realistic simulations, using data sets from the Gulf of Maine and the Eel River shelf.

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WORK COMPLETED

The exploration of the input conditions for the river plume have been completed. The sensitivity to horizontal grid resolution and advection scheme are essentially complete, yielding “grid converged” solutions. We have started exploring the influence of tides and wind-forcing on the plume results.

RESULTS

The investigations of the model boundary conditions have yielded important information about estuarine dynamics and their impact on plumes. These are important both for the understanding of how estuaries work and for the implementation of boundary conditions for river plume models. The key finding is that the exchange condition at the mouth of an estuary is very insensitive to the amount of mixing in the estuary. This result is reminiscent of the venerable paper by Stommel and Farmer (1952) on “overmixing”, in which they note that there is a certain level of mixing above which the exchange flow at the mouth will remain constant. Our model simulations indicate that the “overmixed” condition is not exactly obtained, but the exchange flow is very insensitive to the amount of mixing in the estuary. This means that the details of the estuarine regime do not need to be included in a model in order to obtain a realistic representation of the boundary conditions at the mouth. The magnitude of the exchange flow does have to be properly specified, which is set by the buoyancy flux from the river and the depth at the river mouth.

IMPACT/APPLICATION

Our improved understanding of the boundary conditions for river plumes will provide significant improvements in the realistic modeling of river plumes. Previous simulations of plumes have inadequately treated the estuarine boundary condition, however the constraints for accurate specification of this condition were not fully understood. Our new results allow a realistic estuarine boundary condition to be applied to plume models without the computational burden of including an extensive estuarine reach into the model domain.

TRANSITIONS

Rob Hetland has developed numerical algorithms for implementing fresh water sources (i.e., rivers) and tides, both of which have become part of the standard ROMS releases. He has also developed new boundary conditions for estuarine simulations, which will become part of the ROMS distribution.

RELATED PROJECTS

Geyer is working with Peter Traykovski and Courtney Harris on a three-dimensional model of sediment transport on the Eel River shelf as part of ONR’s STRATAFORM Program. Geyer was lead author and PI on an ONR-funded review of buoyancy-driven sediment transport processes, which has resulted in a review paper that will be submitted for publication in 2001. Geyer is also funded by the by the ONR Harbor Processes Program and the Hudson River Foundation for studies of sediment and contaminant transport in the Hudson River estuary.

REFERENCES

Stommel, H., and H. G. Farmer, 1952. Control of salinity in an estuary by a transition. J. Mar. Res., 12, 13-20.