Comparison of two methods to implement rivers in Oceanic General Circulation Models

Martial Boutet, Flavien Gouillon, Rémy Baraille, Yves Morel
SHOM
martial.boutet@shom.fr

Building on the work of *Schiller et al.* (2010), this study investigates the impact of two usual methods to implement rivers on the dynamics of the river plume. We perform numerical simulations using the HYbrid Coordinate Ocean Model (hereafter HYCOM) from the NRL (HYCOM-NRL) and the SHOM (HYCOM-SHOM). The main difference between the two experiments presented below is associated with the implementation of rivers. Indeed, the HYCOM-NRL represents the river as a salinity flux (salinity relaxation) and thus does not consider the river debit. The HYCOM-SHOM represents the river as a true mass flux at the boundary (true barotropic river inflow). We expect that adding the velocity terms will change the river plume structure and the local dynamics.

Model configuration

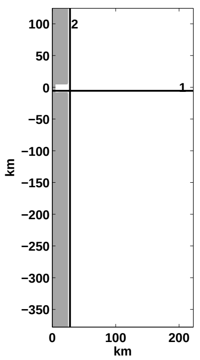
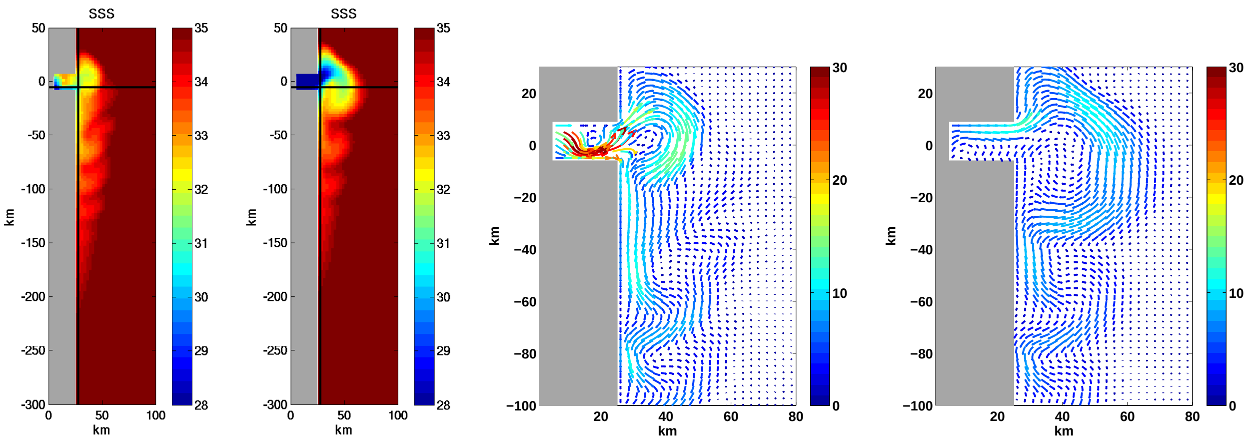


Figure 1: Schematic of the model configuration. Black lines show locations of vertical sections.

We used an idealized coastal basin configuration similar to *Schiller et al.* (2010) (200 km in the across-shore direction and 500 km in the along-shore direction with a model grid resolution of 2.5 km) and an estuary (20 km long and 15 km wide). Depth is uniform and set to 20 m (Figure 1). The initial condition is a barotropic ocean (28°C and 35 PSU) at rest. The vertical mixing scheme used is the K-Profile Parametrization (KPP) and a no-slip condition is imposed at the lateral boundaries. **In the HYCOM-SHOM, the river debit is a freshwater inflow (0 PSU) at 28°C while the HYCOM-NRL uses a salinity relaxation.** For further details, the reader is referred to the flat control experiment in *Schiller et al.* (2010).

Results

Snapshots of surface salinity and surface currents fields are presented below for both configurations at day 60 :



HYCOM-SHOM HYCOM-NRL HYCOM-SHOM HYCOM-NRL

Figure 2: Sea Surface Salinity (PSU) (left panels) and surface velocities in cm.s^{-1} (right panels) for the HYCOM-SHOM and the HYCOM-NRL.

For both simulations, we observe the development of a recirculating bulge and a coastal current flowing southward. Barotropic and baroclinic instabilities develop along this current and the southward extension is more important in the HYCOM-SHOM. Visual inspection of Figure 2 clearly shows that there are different dynamics caused by the introduction of momentum inside the estuary. Indeed, for the HYCOM-SHOM, there is a recirculating zone inside the estuary associated with higher velocities. Furthermore, the estuary dynamics impacts the shape of the plume and velocities inside the bulge. The velocities for the HYCOM-SHOM are stronger but the size of the bulge is smaller. This could be explained by more mixing induced by more shear.

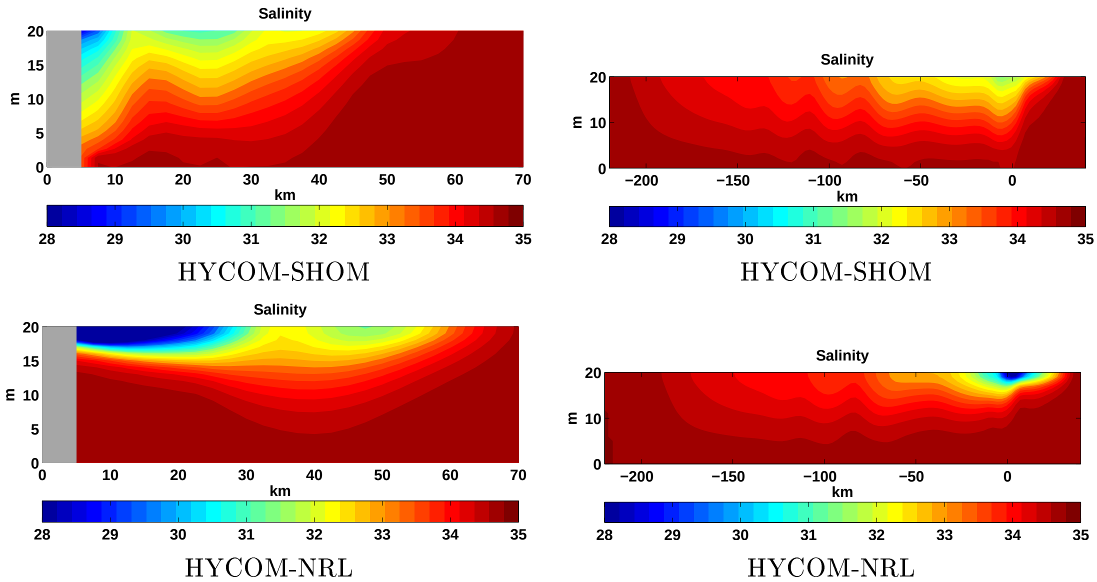


Figure 3: Across-shore salinity (PSU) vertical sections along section 1 (the estuary mouth is located at 25 km) (left panels) and along-shore salinity (PSU) vertical sections along section 2.

It is clear that the vertical mixing is different in both configurations (Figure 3). Indeed, in the HYCOM-SHOM, waters in the estuary and inside the bulge are fresher than for the HYCOM-NRL in which there is a quasi-two-layered flow. The buoyancy circulation has also a more important vertical extension in the HYCOM-SHOM.

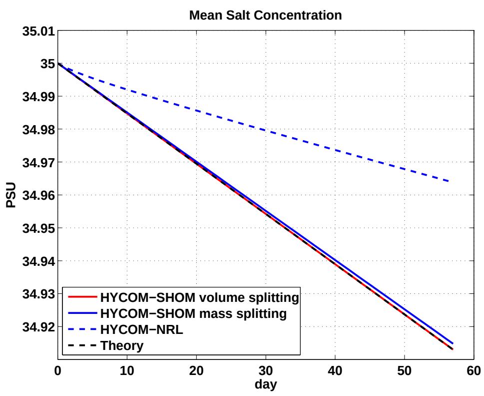


Figure 4: Time evolution of the volume integrated salinity for the HYCOM-SHOM and the HYCOM-NRL.

It is important to note that since the river representation is not the same (mass flux *vs.* relaxation), the volume integrated salinity is not similar. To correct this inconsistency, values of the river debit in the HYCOM-SHOM are changed in order to have the same freshwater introduced volume in the domain. The time evolution of the volume integrated salinity before debit correction is shown in Figure 4. In the HYCOM-SHOM, we prescribed a debit of 1000 $m^3.s^{-1}$ and theoretical evolution is computed assuming an introduction of $8.64x10^7$ m^3 of freshwater per day. The volume splitting calculation uses volume conservation while mass splitting calculation uses mass conservation. The HYCOM-NRL uses only mass splitting and we use volume splitting for HYCOM-SHOM simulations which gives more accurate results when compared to the analytical solution.

Conclusion

The structure and the shape of the river bulge and of the coastal current are highly influenced by the local dynamics in the estuary which is mainly controlled by how the river is represented. The HYCOM-SHOM uses a more physically consistent representation of the river as it includes the momentum. Future studies including other forcing terms such effect of atmospheric pressure, winds and tides are planned in order to study storm surges within the estuary.

References

Schiller, R., Kourafalou, V., 2010. Modeling river plume dynamics with the HYbrid Coordinate Ocean Model.Ocean Modelling 33, 101-117