Exposure time and connectivity in the Baía de Todos os Santos, Brazil

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Exposure time and connectivity in the Baía de Todos os Santos, Brazil

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SUMMARY

We applied the Regional Ocean Modeling System (ROMS) to simulate the circulation within Baía de Todos os Santos (BTS). Using lagrangian particle tracking, we performed sensitive studies to compare the importance of the winds (W), tides (T) and fresh water and heat fluxes (FWHF) to the exposure time and connectivity in BTS. We added tracking particles to three sectors of the bay (upper, middle and entrance) and tracked the trajectories for 330 days. The circulation forced exclusively by tides (T) or by winds (W) did not flush all particles from the bay after 330 days. The simultaneous effect of tides and winds (T+W) resulted in an exposure time of 210 days, with particles from the entrance, the middle and the upper sections leaving the bay after 30, 60 and 110 days, respectively. When we added fresh water and heat fluxes plus the riverine discharge to the model (W+T+FW+HF+RV) the exposure time was reduced to 115 days. The interconnection between the entrance and the bay head is small, with less than 10% of the particles released from the entrance reaching the upper bay. Most of the particles released within the bay are advected to the continental shelf southwest of the BTS. Our results show that, differently from what has been previously described, the baroclinic circulation is important for reducing the exposure time. It is expected that the insights gained from this simulation will also be applicable to transport studies of inorganic and organic loads from small bays and river discharges within the BTS.

1. INTRODUCTION

The Baía de Todos os Santos (BTS) is located in the northeastern region of Brazil (12°50' S) and is the second largest bay of the eastern coast of South America. The discharge from several industrial plants and by the third biggest metropolitan region of the country can affect the water quality of bay, its tributary streams, and the coastal region adjacent to it. Consequently, is important to quantify the rate at which pollutants are removed from the bay by hydrodynamic processes and to understand the connection between the different regions of the bay.

Lagrangian particle tracking, on the top of hydrodynamic numerical models, is used to track the fate of the pollutants and the connectivity within the bays and estuaries. This methodology is also used to calculate the exposure time, which is an indicator of how long a substance or an organism will spent in an enclosed system before being definitively exported. Only A few short-term monitoring programs and a barotropic model have been used to study the circulation within the BTS. Cirano & Lessa (2007), using observational data, showed that a typical estuarine gravitational circulation is presented in BTS. Pereira & Lessa (2009) indicated that an inverse estuarine circulation can ALSO be developed in the dry summer months in a restrict sector of the bay (Baía de Aratu). Xavier (2002), using a barotropic numerical model, showed that the residence time in the BTS varies from from 0 days, at the bay entrance, to 30 days at the inner most section.

The importance of each forcing of the circulation within the BTS and its likely effect on the water quality remains, however, to be determined. In order to fill this gap, we aim to compare the importance of the winds (W), tides (T) and fresh water and heat fluxes (FWHF) to the exposure time (the total time spent by a particle in an area of interest, including eventual returns, before being definitely flushed out) and connectivity within BTS.

2. METHODS

We applied the Regional Ocean Modeling System (ROMS) to perform sensitive studies of the circulation within the BTS. Using lagrangian particle tracking, we compared the importance of the winds (W), tides (T) and surface fresh water and heat fluxes plus riverine discharge (FW+HF+R) to the exposure time and connectivity of different regions of the BTS. We forced the model in the boundaries with tidal elevations and currents from the global tidal model tpx07.2. We also used monthly climatological means of water current velocities, and water temperature, salinity and elevation calculated from HYCOM/NCODA. At the surface, we forced the model with climatological monthly values of wind stresses, fresh water and heat fluxes from a combination of NCEP/REANALISES and data from local weather stations. Climatological discharges of the three largest rivers that flow into the BTS were also set as model input. A rectilinear grid with spatial resolution of 500 x 500 m and 20 sigma layers is used. The grid covers the entire BTS area, the adjacent shelf and slope down to 1400 m.

We ran cyclic simulations for four years and added tracking particles at mid-depth to each grid point at the first day of the fifth year. The bay was divided in three sectors - upper, middle and entrance (figure 1a) - and the particle trajectories were tracked for 330 days.

3. RESULTS

The results of tidal-only simulations compared well with the observations at the entrance and at the central region of the BTS, with the model under-estimating the M2 and S2 amplitudes in less than 10%. Depth-averaged currents, from the experiment with all forcing agents (T+W+ FW+HF+R), agree well with observations collected with an ADCP in January 1999 at the bay entrance. A small overestimation of the flood currents during spring tides occur. Details about the model validation and the residual circulation can be found in Santana *et al*, this volume.

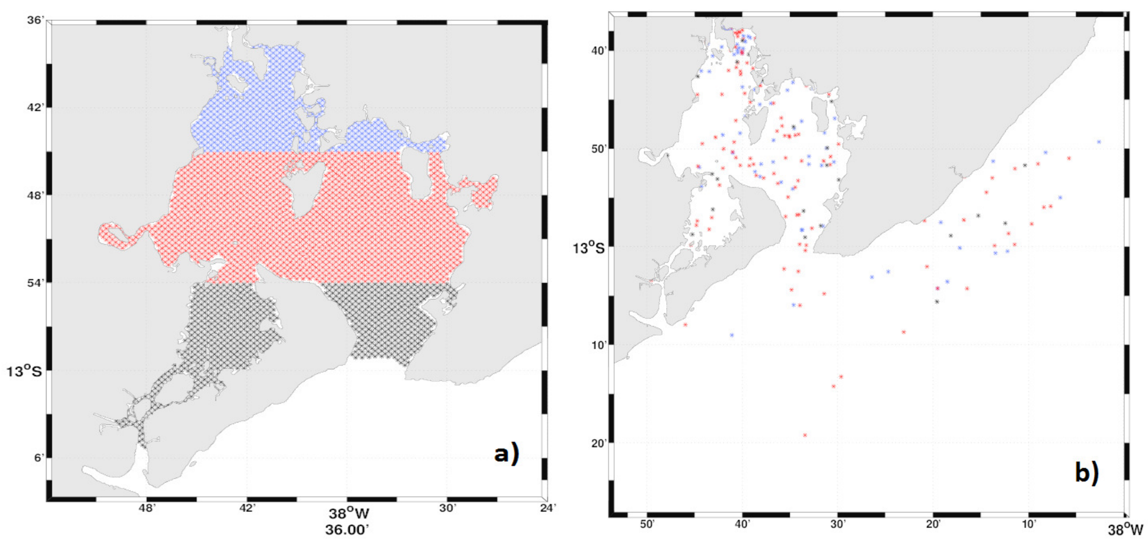

Figure 1: a) Initial position of the particles in each sector of the BTS: upper (blue), middle (red) and lower (black). b) Final position of the particle after 330 days of simulation using all forcing (T+W+ FW+HF+R).

The circulation forced exclusively by tides or by winds did not flush all particles from the bay after 330 days of simulation (Fig 2). The simultaneous effect of tides and winds flushed the particles after 210 days. When the baroclinic effects of the heat and fresh water flushes plus the riverine discharge are included in the simulations, the exposure time of the BTS decreases to 115 days. This difference can be ascribed to the effects of the gravitational estuarine circulation within the BTS. Santana *et al* (this volume) shows that when the river discharge is included to the simulation, a vertically-sheared flow is observed, with water entering the BTS at the bottom and leaving at the surface. This two layer circulation is responsible for increasing the exchange of water from the BTS with the shelf. Most of the particles released within the bay are advected to the continental shelf southwest of the BTS (Figure 1b).

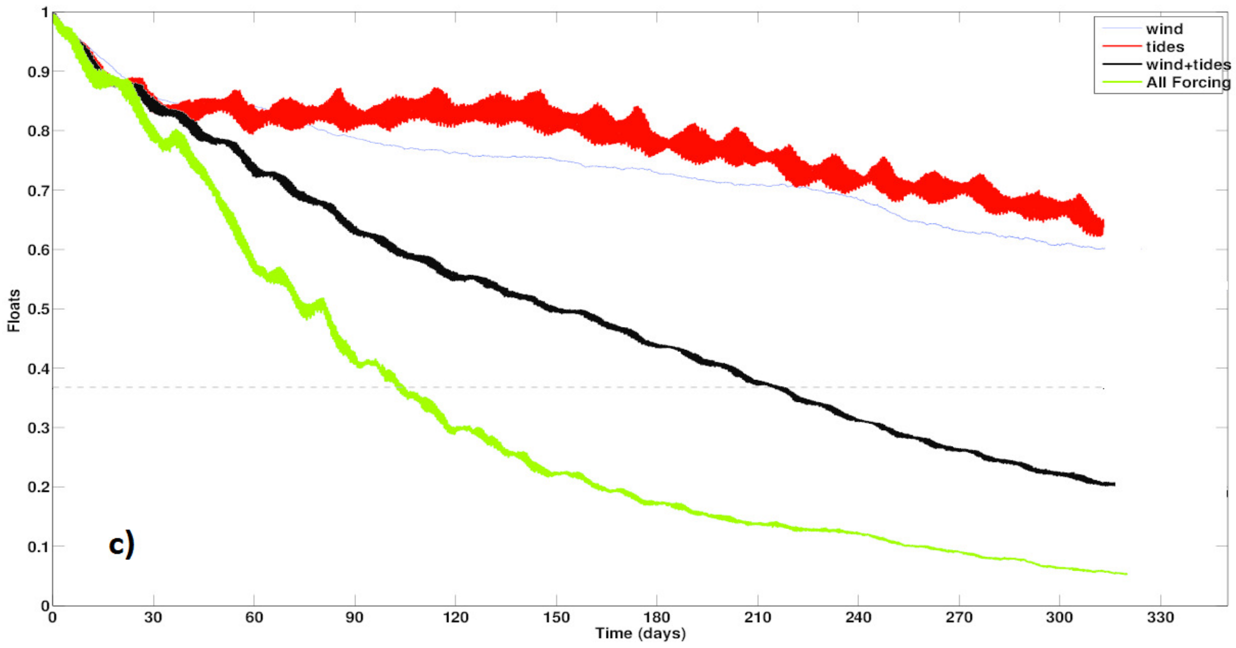

Figure 2*) Particle concentration within the BTS for each simulation.*

In Figure 3 we present the exposure times for each section of the bay for the simulation with all forcing agents *(T+W+ FW+HF+R).* The particles from the lower (Figure 3c), the medium (Figure 3b), and the upper (Figure 3a), sections leave the bay after 30, 60 and 110 days, respectively. The interconnection between the entrance and the bay head is small, with less than 10% of the particles released from the entrance reaching the upper bay (Figure 3c).

Xavier (2002) showed that the residence time in the BTS varies from 0 days, at the bay entrance, to 30 days at the inner most section, however, since the tides produce the largest currents within the bay most of the water that has left the bay (or each individual segment) during the ebb will return during the flood. The concentration of particles within the different sectors or within the BTS (Figure 3) increased a few times during the simulation, showing that particles re-enter the domain several times. These results show that the exposure time can more properly assess the fate of the pollutants within the BTS than the residence time (i.e. the time spent in the domain of interest until the particles cross the boundary for the first time). Moreover, it is shown that the baroclinic circulation is important to the renewal of the bay waters. Simulation efforts underway will provide insights to the transport of inorganic and organic loads brought into the BTS and its smaller segments by river discharges.

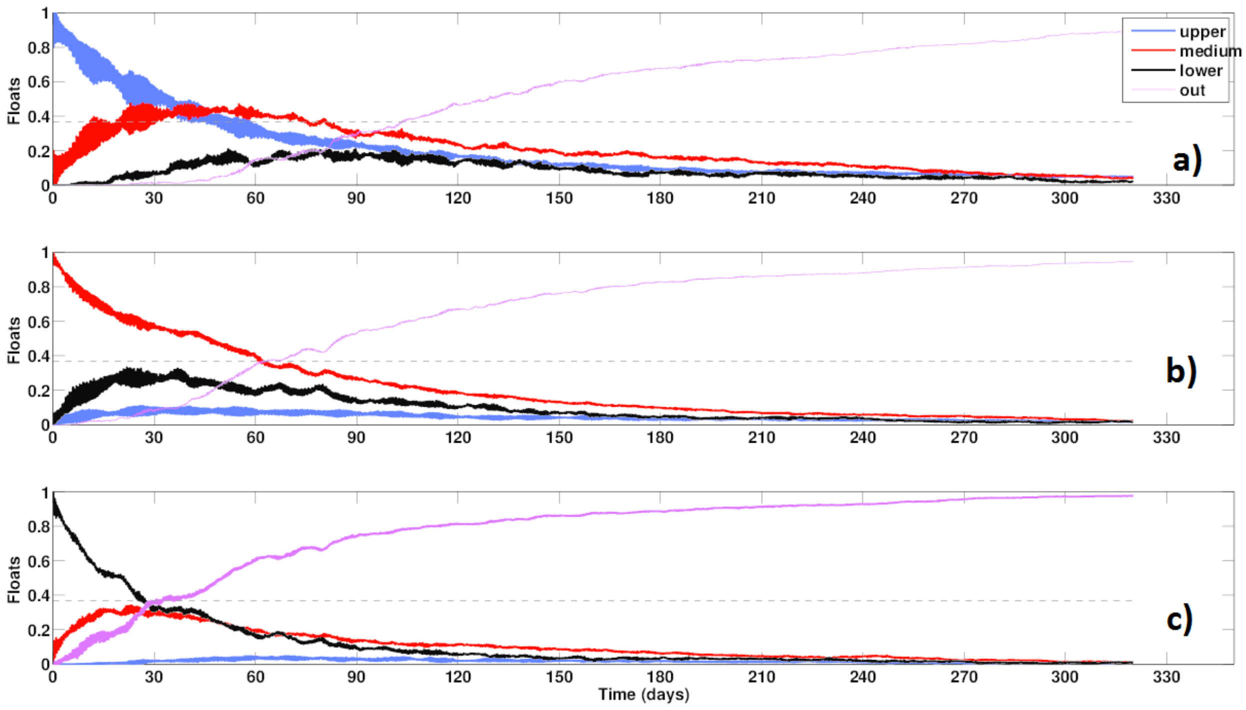

Figure 3: Particle concentration within each sector of the BTS for the simulation using all forcing (T+W+ FW+HF+R). Figure 3a) Particle concentration released at the upper BTS. Figure 3b) Particle concentration released at the medium BTS. Figure 3c) Particle concentration released at the lower BTS.

5. ACKNOWLEDGEMENT

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