The objectives of our Sea Grant project entitled "Modeling Transport and Ocean-Estuary Exchange Processes in the Great Bay Estuary" were to implement a finite-element numerical circulation model of the Great Bay system that was coupled to the coastal ocean. Further, this model was to be augmented with a Lagrangian particle tracking component so that one could address questions pertaining to ocean-estuary exchange. The basic objectives were accomplished during the one year project.

One focus under this project was to develop methods that could be used to increase our understanding of the processes controlling the flushing, residence time and exchange with the coastal ocean. We completed a study looking at these with a Lagrangian particle method that nicely displays the interconnectedness of the various portions of the Great Bay system and how they are flushed through tidal action and river inputs. The results for a series of massive [$O(500,000)$] particle releases allowed us to confirm that the various intra-estuary and ocean-estuary exchanges can be reasonably addressed as a first-order Markov process through the concept of transition probabilities similar to the work of Thompson et al. (2002). The importance of this result is that it implies that one can justifiably apply box models to this estuary to gain a conceptual look at problems of transport and fate of pollutants in this system. This has allowed us to design research efforts addressing the cycling of heavy metals (e.g. mercury) in the Great Bay system.

To study questions of estuarine residence time of importance to water quality managers, we considered three different but complementary methods to try to characterize the residence times:

1) The time it takes for the number of particles initially within a particular sub-domain to decrease by a factor of e (i.e. particle count e-folding time).
2) Maps of the time in residence within a particular sub-domain depending upon particle release location.
3) The average time a particle from a particular sub-domain takes before first crossing the ocean-estuary boundary.

The latter being the most physically comparable to residence time calculation of Brown and Arellano (1979). We found the first ocean-estuary crossing time, averaged over all of the particles initially in Great Bay proper, to be just over 40 tidal cycles. This is in keeping with their estimate of 49 and 58 tidal cycles for particles released at the head of
Great Bay under high and low flow conditions. The particle method, however, allowed us to look at transport pathways and intra-estuary connections that would be difficult or impossible from other approaches. For example, we found that through tidal action combined with channel asymmetry, a non-negligible fraction of the water from the Upper Piscataqua is pumped into Great Bay proper. However, the converse (i.e., Great Bay water moving into the Upper Piscataqua) doesn’t occur to a significant degree. This method also allows one to cleanly quantify the exchange times. We found that a small fraction of the water in Great Bay proper reaches the ocean/estuary boundary in as little as 3 tidal cycles. Further, some Portsmouth harbor water makes it into Great Bay in just over 2 tidal cycles. These results were summarized in two papers (Proehl et al., 2004; Bilgili, et al., 2004)

For this work, the hydrodynamic model was updated with several improvements. These include the capability of handling river discharge input (salinity effects are ignored), the addition of the earth’s rotation, the parallelization (MPI) of the particle tracking code for launching a large number of particles (up to 1 million) and the addition of the random walk diffusion. The previous land boundary handling of the particle tracking code was also updated to include the flooding and drying of tidal flats. These advances have added to the maturity of the Lagrangian method for addressing problems of ocean-estuary exchange and estuary flushing and residence time.

The difficulties that we encountered on this project were not severe. We uncovered early on that a more resolved grid and shorter time step were needed to accurately predict the Lagrangian particle motions. The most significant problem was that the number of parameter variations to consider to fully investigate the nature of ocean-estuary exchange was quite large. While we addressed the most important scenarios during this project, some interesting cases were left for future work. For example: investigating the effects of the seasonal variability in the Maine Coastal Current, the effects of varying river flow (more than on/off), the temporal dependence of release location on the particle exchange, and the effect of spatially varying diffusivity. Overall, these lingering questions did not compromise the results that were obtained.

As a result of this one year project we presented posters at the biannual Gordon Research Conference on Coastal Ocean Modeling in June, 2003 (necessarily not published due to GRC rules) and at the celebration of UNH becoming a Sea Grant College. We will present a talk at the Computational Methods in Water Research Conference in mid June, 2004 and have a publication in press in the Proceedings of this
conference. Further, we have a manuscript summarizing this work submitted to the Journal of Estuarine, Coastal and Shelf Science (attached). In addition, this research was leveraged to obtain approval from CICEET to transfer the model technology to the Sea Coast Science Center and resource managers at NH-DES working on water quality questions in Great Bay and into proposals to NSF and NOAA to look at mercury cycling in the Great Bay estuary.

References:


Sea Grant Sponsored Publications:
