Introduction

The need to calculate residence time arises in many studies of estuaries. Specific applications include larval dispersion, chemical species fate, hazardous material cleanup, and changes in residence time owing to fresh water withdrawal from the rivers feeding an estuary. Historically, estuarine residence time has been variously defined, and calculation usually relied on bulk approximations that were either generally invariant in time and space, or based on box models of salinity concentrations. Examples include the mixing length theory of Arons and Stommel (1951), or more recently, the modeling work of Miller and McPherson (1991), Dimou and Adams (1993), and Hagy et al. (2000). These simplifying assumptions tend to ignore the variability inherent in the residence time, both in space and time.

This dissertation compares two distinct methodologies (Eulerian and Lagrangian) for determining spatiotemporal variation in estuarine residence times. It also investigates the relative impact of major forces affecting residence time in general, and is a first step in determining this information for Tampa Bay. The Eulerian method is based on the advection and diffusion of a passive tracer in the model domain, while the Lagrangian method is based on a particle tracking approach, where neutrally buoyant dimensionless particles are advected by the model velocity field. The Eulerian method would seem, at first glance, to be the logical framework for such a study, and indeed is similar to box model approaches in that the reference frame is made up of discrete fixed volumes in model space. The Lagrangian approach however has the advantage of realistic sub-grid scale motion that prevents particle accumulations in model grid cells from artificially diffusing down stream. Residence time is defined as the time (in days) needed for a model grid cell to fall below 1/e of the original normalized daily value, whether concentration of passive tracer or particle accumulation. Here e is the base of the natural logarithm, and either method can be applied to sections of the estuary, or to the estuary as a whole, by normalizing over the appropriate geographical area.

The first step in this study is development and testing of a numerical model. Herein a version of the Princeton Ocean Model (POM) called ECOM-3D (Estuarine and Coastal Ocean Model Three Dimensional) is employed. ECOM-3D is a primitive equation model that has been enhanced at the University of South Florida (USF) to include evaporation and precipitation surface boundary data, now-cast and forecast modes, passive concentration fields, and drifter trajectories. ECOM-3D has also been tuned to the geometry and physics of Tampa Bay, which serves as the testbed for this work. This model, together with several longterm data sets from the Physical Oceanographic Real-Time System (PORTS), the Coastal Ocean Monitoring and Prediction System (COMPS), and the Tampa Oceanographic Project (TOP), allowed for extensive validation for water level, velocity field, and salinity structure in Tampa Bay. The operational now-cast and forecast modes of the model were chosen as the testbed for validation of the particle tracking subroutine. This was accomplished via TRACKER, an on call, interactive, world wide web distributed, hind-cast to forecast drifter tracking application. TRACKER allowed for validation of the particle tracking subroutine, as the modeled drifter positions could be easily validated and verified.

Using the validated model and longterm high resolution (both in space and time) data it was possible to adjust the amplitude of the forcing at the boundaries of the model domain to allow simulations of the effects of extreme events and longterm trends in subtle changes in forcing. Herein, the major components of the forces effecting the residence time were varied over the study period to show their relative contributions to the residence time variability in Tampa Bay.

This dissertation begins with a review of ECOM-3D and its modifications, including the particle tracking subroutine. A description of the study area and the available data are then presented, followed by an explanation of the now-cast forecast model that is the "engine" that drives TRACKER. The validation process for the various model and data set iterations is then presented, along with the method for displaying the deterministic spatial structure of residence time over an estuary. Results of model sensitivity, validation, and residence time model runs are then presented. These results focus on comparing particle tracking based versus concentration based results and the effect of various changes in forcing on these values. The hypothesis that a particle tracking (Lagrangian) approach to modeling residence time can set deterministic spatiotemporal bounds on the variability in residence time is discussed in detail in the discussion section. This section also addresses the limitations of the Lagrangian approach. In the conclusion a short list of recommendations for future direction, as seen by this researcher, is presented.