3-D Sarasota Bay Modeling to Support Restoration of Bay Scallop Populations

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Executive Summary

Funded by Florida Fish and Wildlife Commission, this study in undertaken to support the restoration of bay scallop population in the Sarasota Bay estuarine system. After reviewing the historical wind and precipitation data in the region, it was decided that 2001 represents a "typical" year. Using a 3-dimensional circulation model CH3D, one-year simulation of the Sarasota Bay system in 2001 was conducted. Results of the one-year simulation, including simulated vs. measured water level and simulated residual flow and salinity fields for each month of 2001, are first presented in this report. The CH3D model was then coupled to a 3-dimensional particle tracking model to simulate the fate and dispersion of particles released from three locations in Sarasota Bay during November 1 to November 14, 2004. Based on detailed comparison of model results, release site #3 is found to be the best since most of the particles remained in the estuary after 14 days. Digital results of the model runs will be provided to Florida Fish and Wildlife Commission soon.

Introduction

The Sarasota Bay System is a barrier island-lagoon located along the Southwest coast of Florida. Circulation in the Sarasota Bay is primarily driven by tide, and to a lesser extent by wind. river discharges, and precipitation. Sheng and Peene (1995) previously conducted a modeling and monitoring study to quantify the three-dimensional circulation in the Sarasota Bay estuarine system. CH3D, developed originally by Sheng (1986, 1989) was used in that study. This study uses an enhanced version of CH3D with a larger model domain and a finer model grid to conduct long-term simulations of Sarasota Bay circulation. In addition, to support Florida Fish and Wildlife Commission's effort to restore bay scallop population in the Sarasota Bay, we conducted three-dimensional particle tracking modeling to simulate the trajectories of particles (which are supposed to represent scallop larvae) released from three candidate sites within the Sarasota Bay. The purpose of the simulation is to determine the best release site (among the three sites) and the best release time (flood tide, high tide, ebb tide, and low tide), based on comparison of model results to one another.

Measured data used in the simulation.

Measured data used in the simulation include water level, wind, river discharge, precipitation and evaporation. Plots of measured data can be found in Appendix 1.

Sarasota Bay numerical grid and simulation setup

The simulation was made using a newly developed 230x64 grid in UTM coordinate system as shown in Figure 1. A zoom-in plot of the Sarasota Bay grid is shown in Figure 2. In order to minimize the open boundary effect on model results, the open boundaries along north, west and south were extended at least 10 km away from the coastline. Bathymetry data from GEODAS were

interpolated onto the entire grid. Locations of data measurement stations are shown in Figure 3.

The water level along the open boundaries were generated by combining harmonic tidal constituents (obtained from the ADCIRC model) with long-period (longer than tidal period) water level generated by a filtering process which removes tidal signals from measured water level in the region. The procedures for generating the open boundary condition is explained next.

(A) Tidal constituents from ADCIRC tidal databases were extracted to produce the water level along the open boundaries. A total of seven constituents were considered using version ec2001_v2d database, which includes: M2, S2, N2, K2, O1, K1 and Q1. Details of the ADCIRC tidal database can be found at http://www.marine.unc.edu/C_CATS/tides/tides.htm.

(B) Measured water level at the NOAA St. Petersburg station within Tampa Bay was processed with the Doodson and Warburg 39-hourly weighted average tidal filter to obtain the long term filtered water level during 2001 (Figure 4), which was then used at all three open boundaries.

(C) Mean water level at the open sea was then adjusted to account for the local vertical datum. Since vertical datum NAVD88 is used for the bathymetry and water level data, the Mean Sea Level (MSL) used in the ADCIRC tidal databases needs to be adjusted first before applied to CH3D simulation. Although there is no known datum information available for the open boundaries of this study, a few isolated stations in the vicinity were found with MSL to NAVD88 datum adjustment. These stations include Clear Water station & Port Manatee station from National Ocean Survey and AG7424 station & AG5037 station from Nation Geodetic Survey (http://www.ngs.noaa.gov/cgi-bin/ngs_opsd.prl). As shown in Figure 5, the vertical datum difference between NAVD88 and MSL can be approximately represented by a linear function along the western open boundary. Along the northern and southern open boundaries, constant datum adjustment is used.

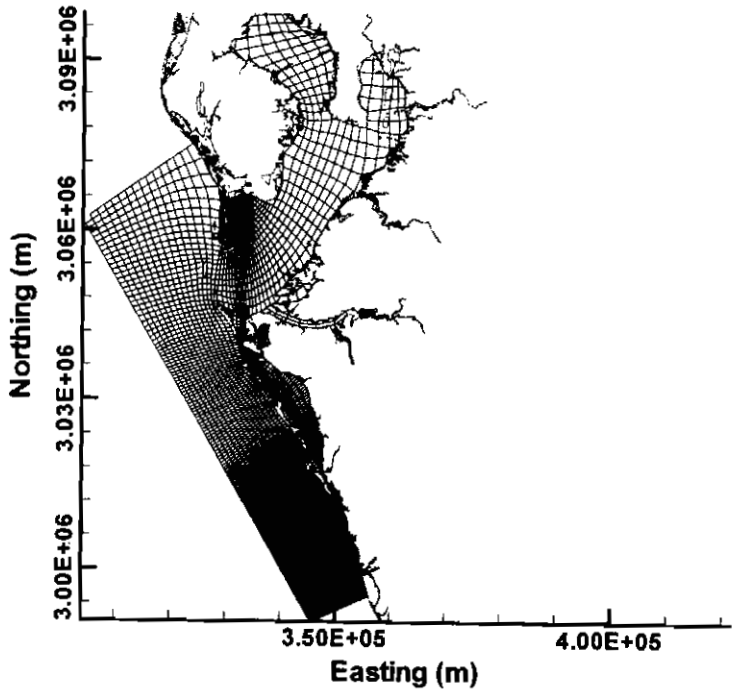

Figure 1 The Sarasota Bay 230x64 grid system in UTM coordinate system.

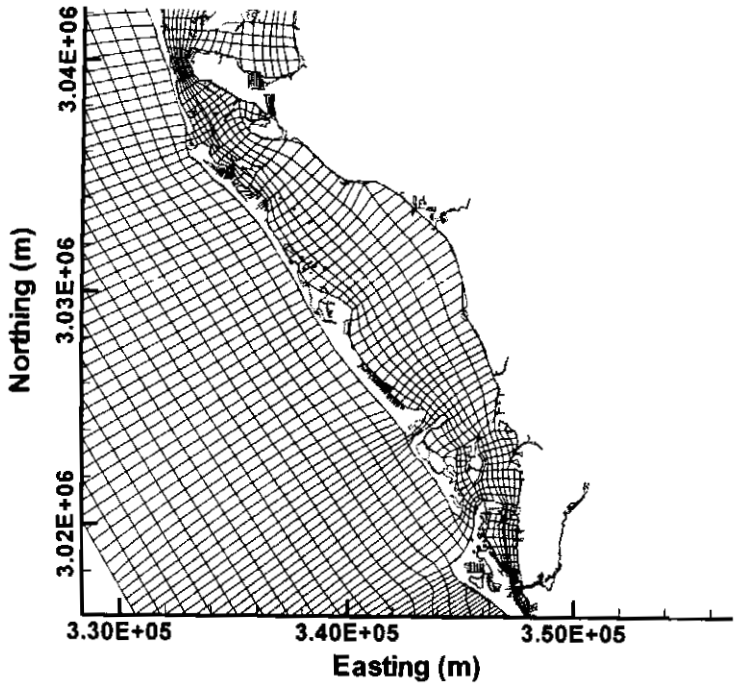

Figure 2 A zoom-in plot of the Sarasota Bay grid system in UTM coordinate system..

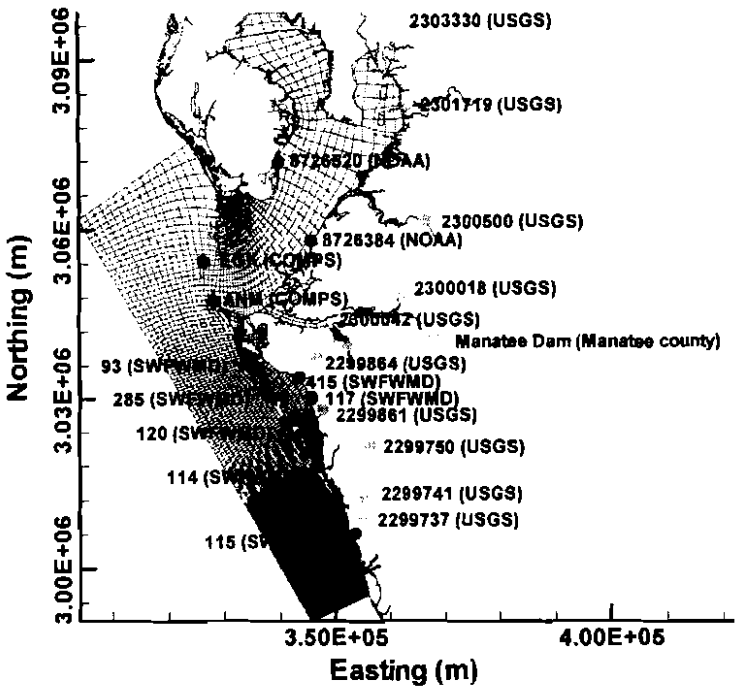

Figure 3. Locations of the data measurement stations within the Sarasota Bay grid system.

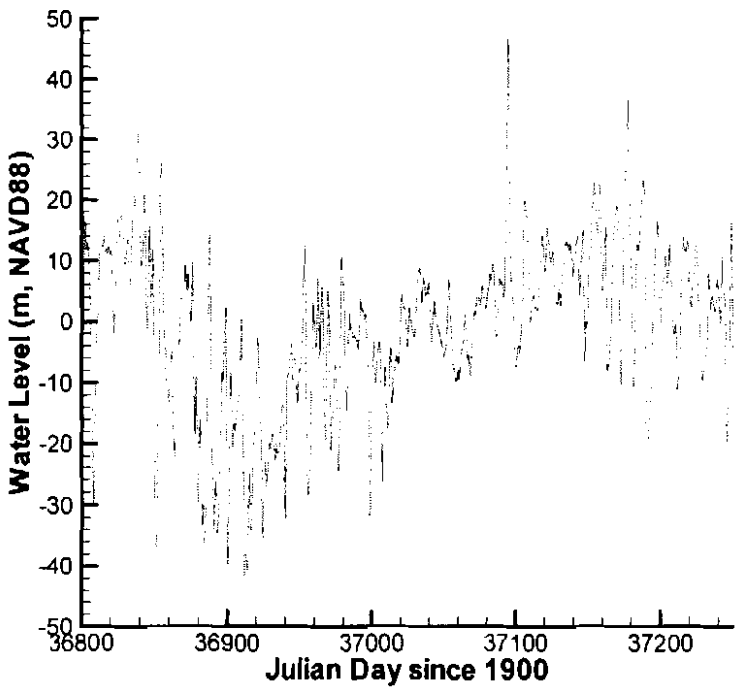

Figure 4. Filtered water level at St. Petersburg during year 2001. The filter removes signals with periods od 39 hours or less.

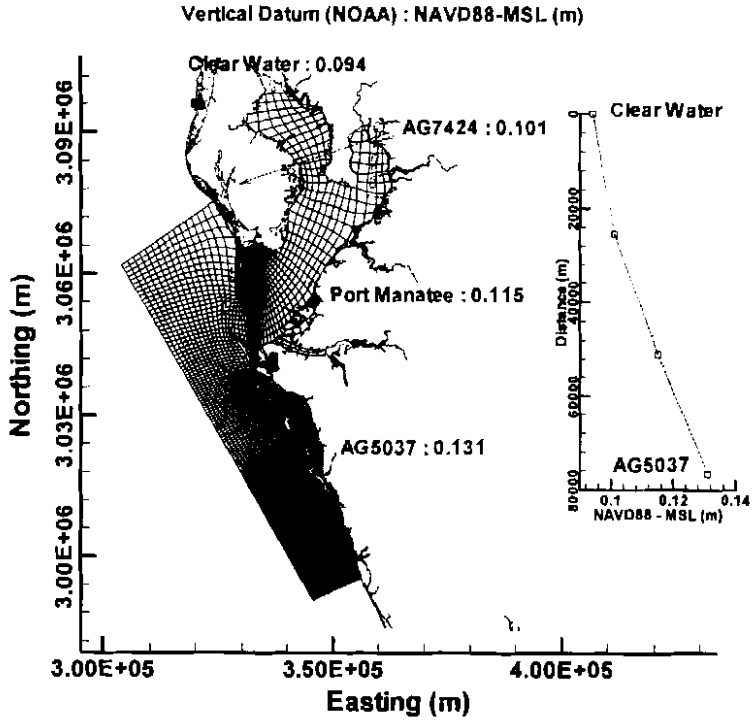

Figure 5 Datum adjustment for Sarasota Bay simulation.

Simulation results.

First a three-month from Oct.2000 to Dec.2000 was carried out to allow the model to spin up, i.e., to eliminate the transient effect. Then a one-year simulation of 2001 was made using the initial condition generated by the spin up simulation. The model output includes water level and residual flow and salinity fields for each month. The projection used in the output is UTM NAD83.

Water level

The water levels at four monitoring stations during 2001 are shown in Figure 6. Good agreement with data are achieved for all stations,as evidenced by the error analysis of simulated water level shown in Table 1. The overall Root Mean Square (RMS) error for all stations is 6.716 cm, which corresponds to a 4% normalized error after normalization by the range of water

level. The overall relative error (absolute difference) is 5.41 cm. A detailed time series comparison of water level during January, 2001 is shown in Figure 7.

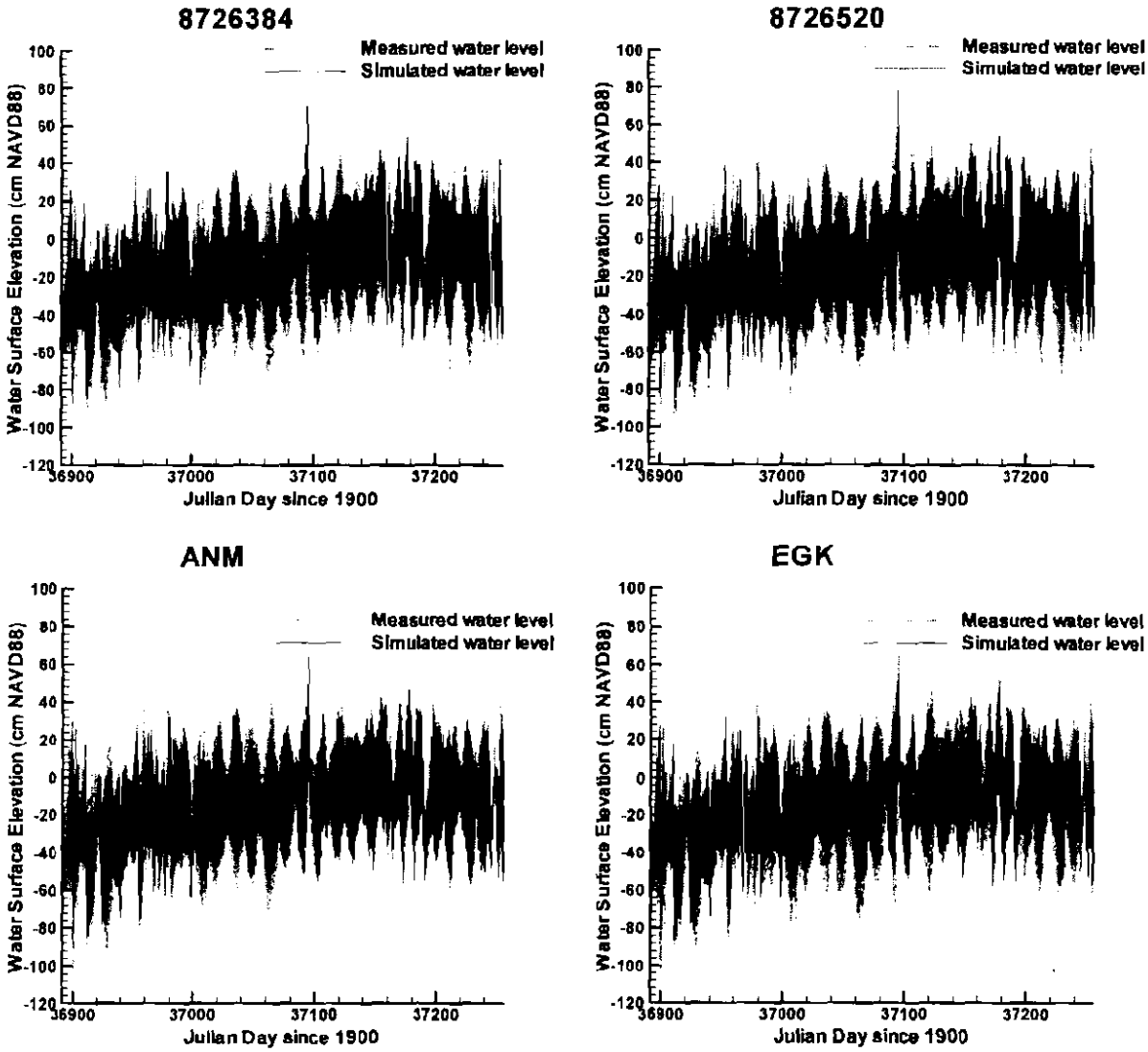

Figure 6 Simulated vs. measured water levels at four monitoring stations during 2001

Table 1 Error analysis of simulated water levels of Sarasota Bay 2001 simulation

Station Name	RMS error (cm)	Normalized RMS	Relative Error (cm)
COMPS-EGK	6.862	0.043	5.488
COMPS-ANM	7.199	0.049	5.901
NOAA-8726520	6.248	0.033	4.993
NOAA-8726384	6.556	0.036	5.257
Overall	6.716	0.04	5.410

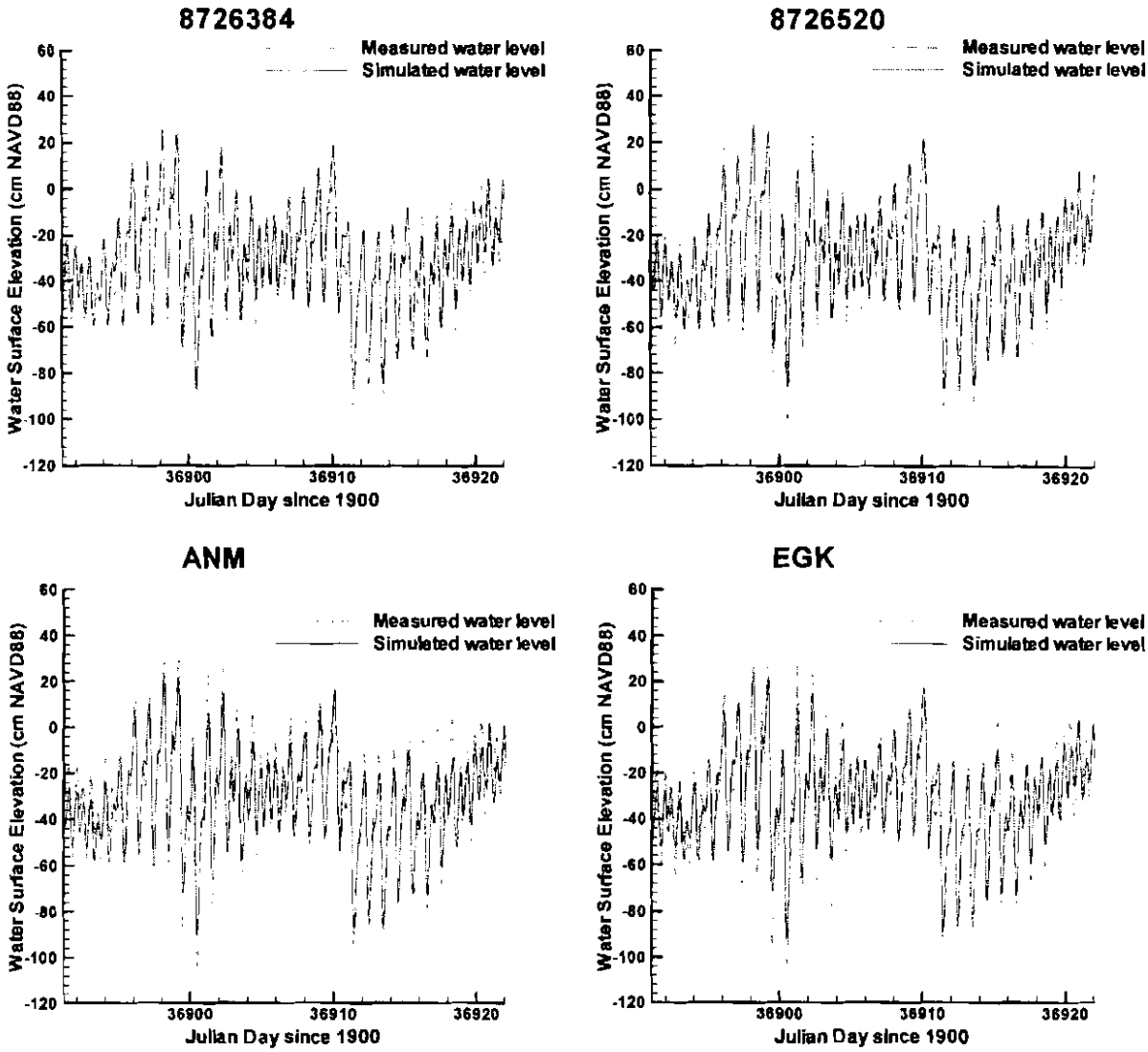

Figure 7. Simulated vs. measured water levels at four monitoring stations in Sarasota Bay during January, 2001.

Residual flow

The monthly residual flow within Sarasota Bay is shown from Figures 8 through 19. The monthly variation in mean water level is primarily caused by the seasonal water level variation along the offshore open boundary, and to a lesser extent the variation in the mean wind field.

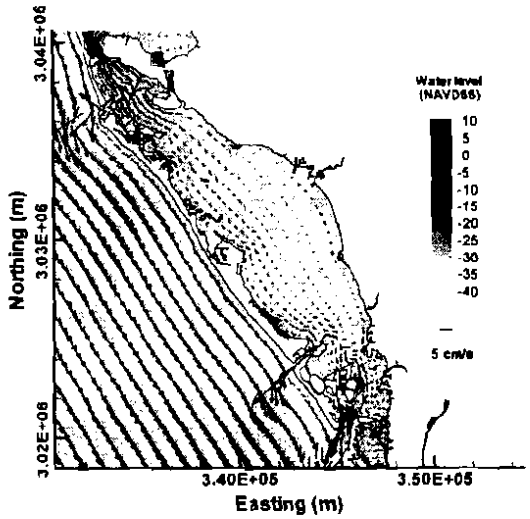

Figure 8 Sarasota Bay residual flow during January, 2001

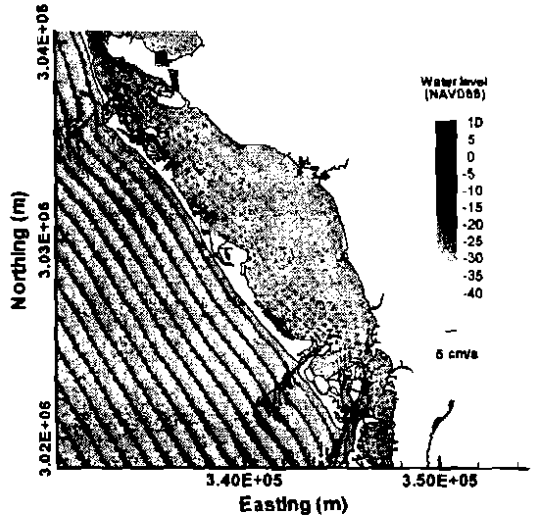

Figure 9 Sarasota Bay residual flow during February, 2001

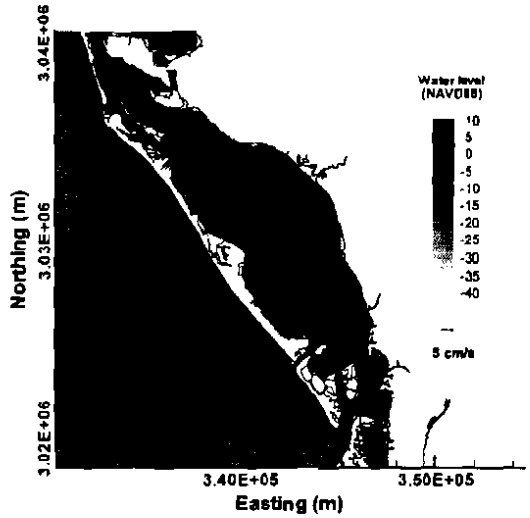

Figure 10 Sarasota Bay residual flow during March, 2001

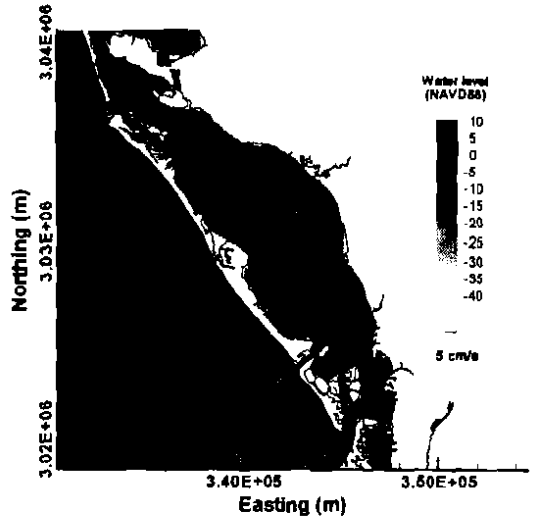

Figure 11 Sarasota Bay residual flow during April, 2001

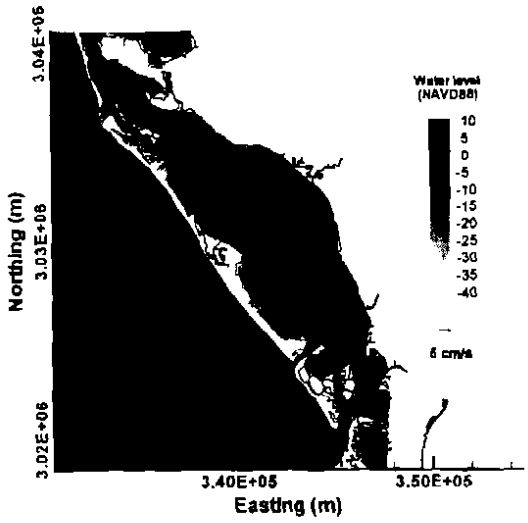

Figure 12 Sarasota Bay residual flow during May, 2001

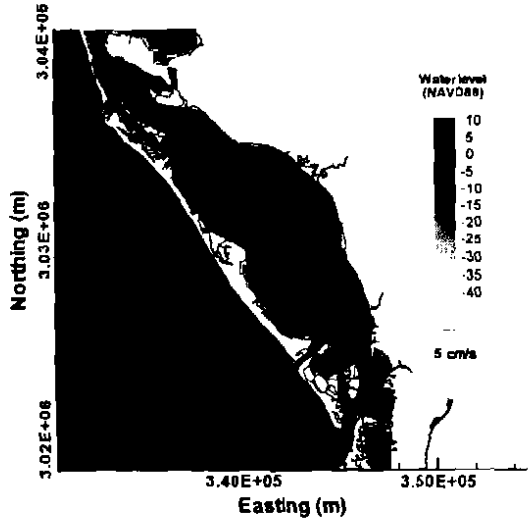

Figure 13 Sarasota Bay residual flow during June, 2001

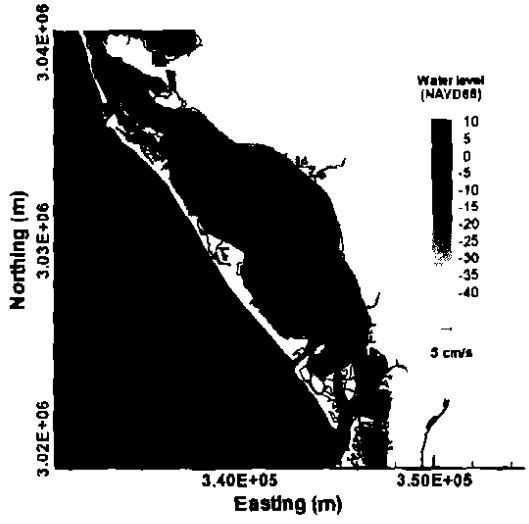

Figure 14 Sarasota Bay residual flow during July, 2001

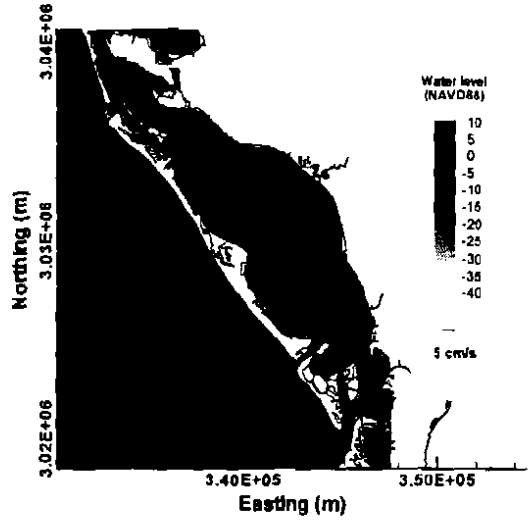

Figure 15 Sarasota Bay residual flow during August, 2001

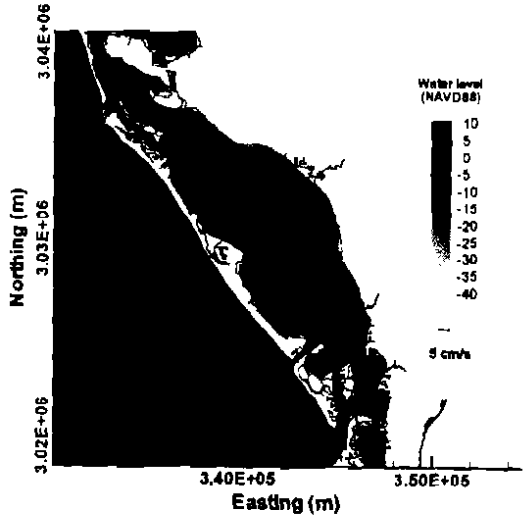

Figure 16 Sarasota Bay residual flow during September, 2001

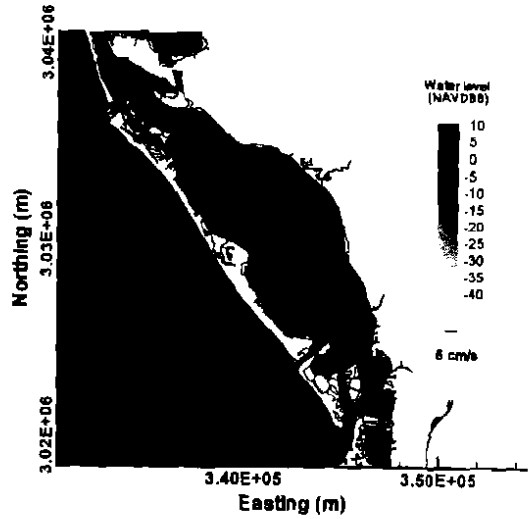

Figure 17 Sarasota Bay residual flow during October, 2001

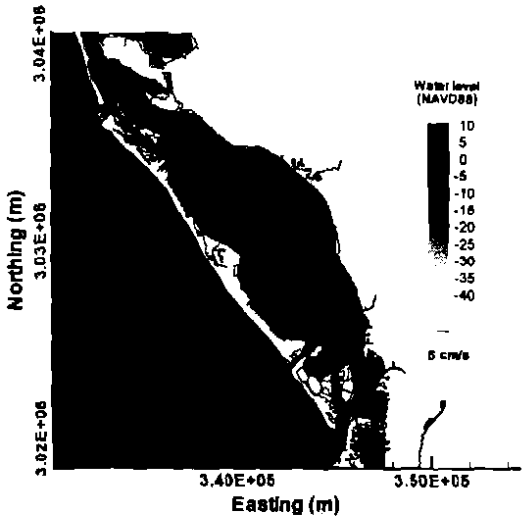

Figure 18 Sarasota Bay residual flow during November, 2001

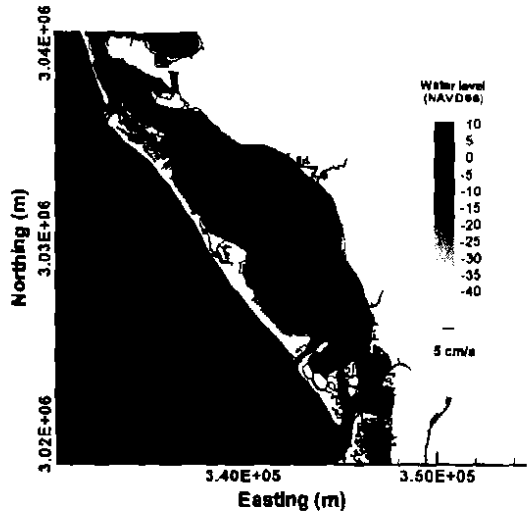

Figure 19 Sarasota Bay residual flow during December, 2001

Residual Salinity field

The monthly averaged salinity plots of Sarasota Bay for 2001 are shown in Figures 20 through 31. During the dry season (November to April), the salinity field remains approximately constant with some slight variation between 34 to 36 ppt. During the wet season, however, salinity drops more noticeably with increased precipitation and discharge from rivers and creeks.

The highest monthly salinity of 36 ppt occurs in June, in contrast to the lowest monthly salinity of 32 ppt in September. Within Sarasota Bay, the salinity concentration is approximately uniform.

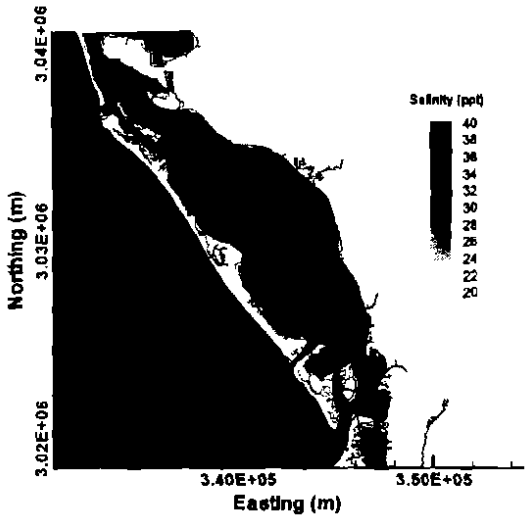

Figure 20 Sarasota Bay salinity field during January, 2001

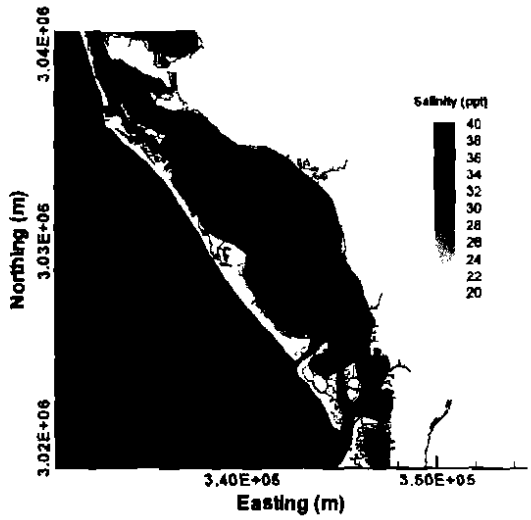

Figure 21 Sarasota Bay salinity field during February, 2001

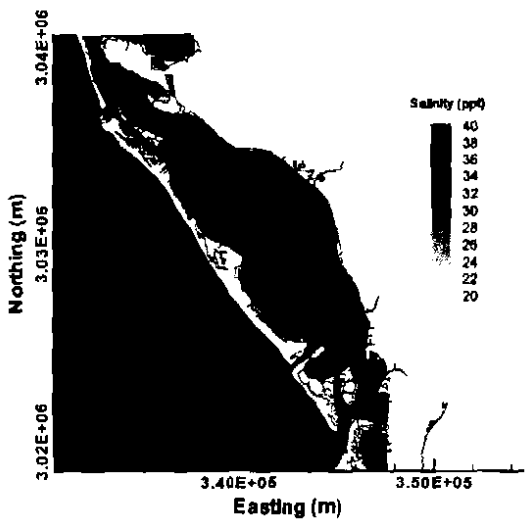

Figure 22 Sarasota Bay salinity field during March, 2001

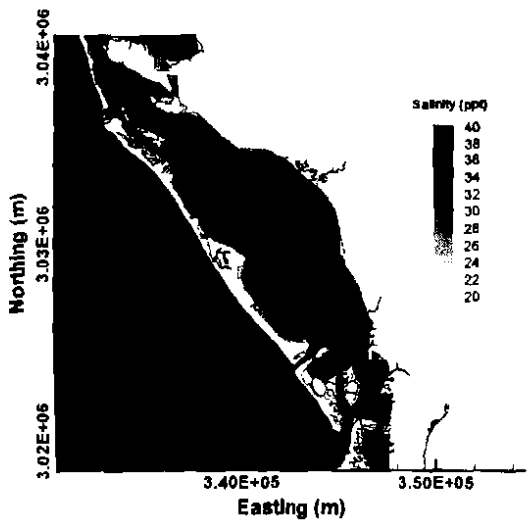

Figure 23 Sarasota Bay salinity field during April, 2001

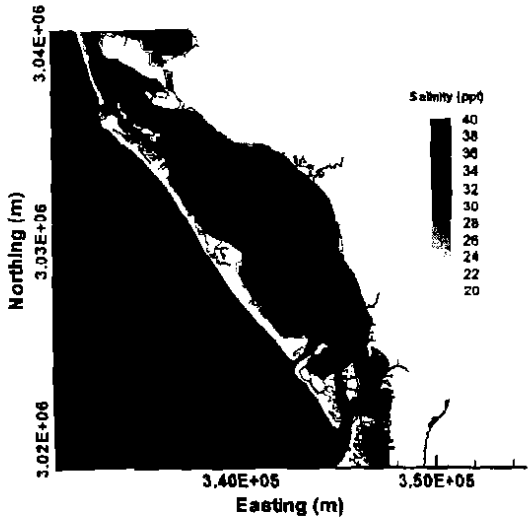

Figure 24 Sarasota Bay salinity field during May, 2001

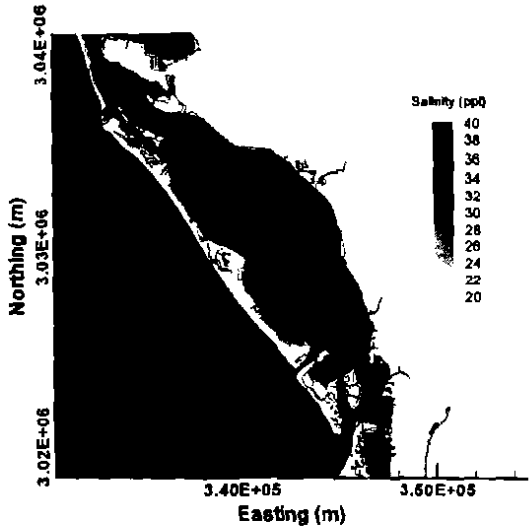

Figure 25 Sarasota Bay salinity field during June, 2001

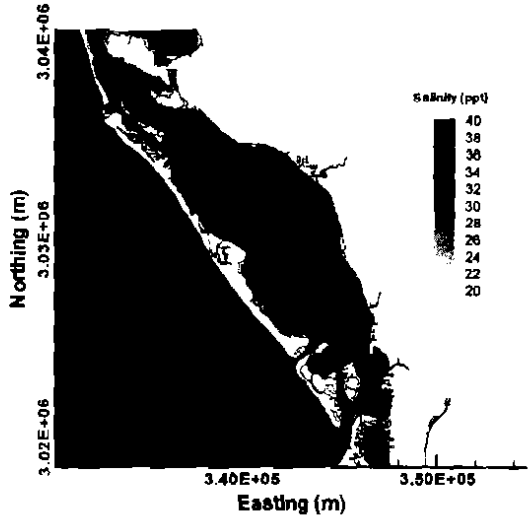

Figure 26 Sarasota Bay salinity field during July, 2001

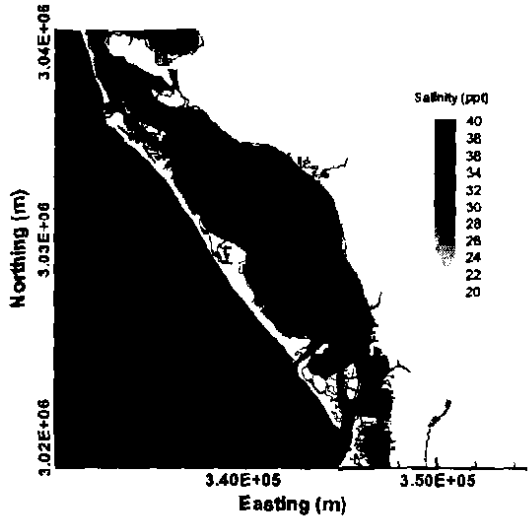

Figure 27 Sarasota Bay salinity field during August, 2001

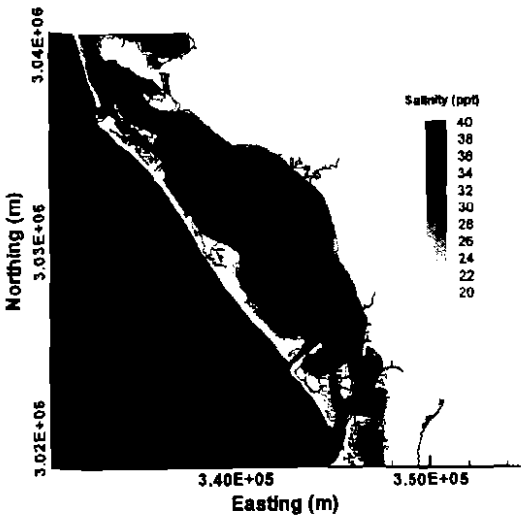

Figure 28 Sarasota Bay salinity field during September, 2001

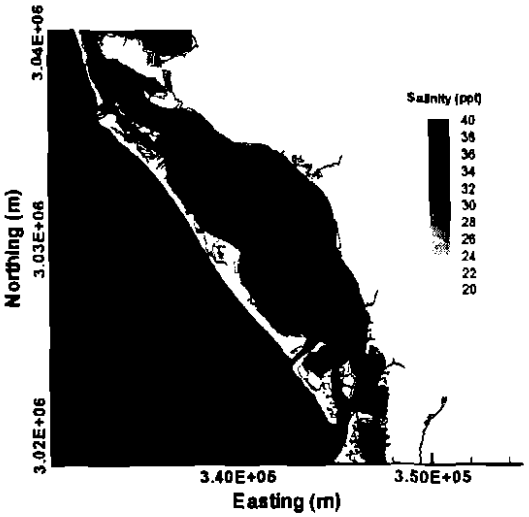

Figure 29 Sarasota Bay salinity field during October, 2001

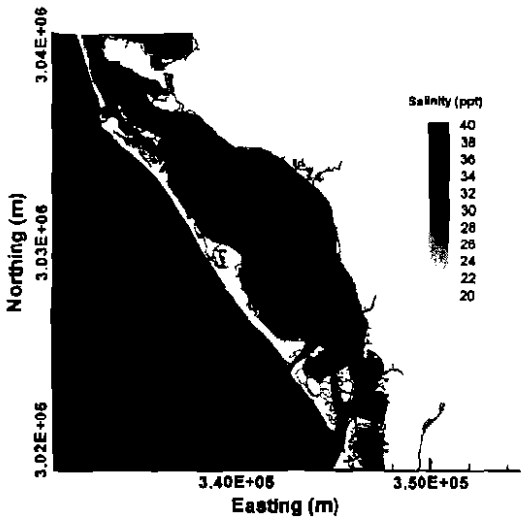

Figure 30 Sarasota Bay salinity field during November, 2001

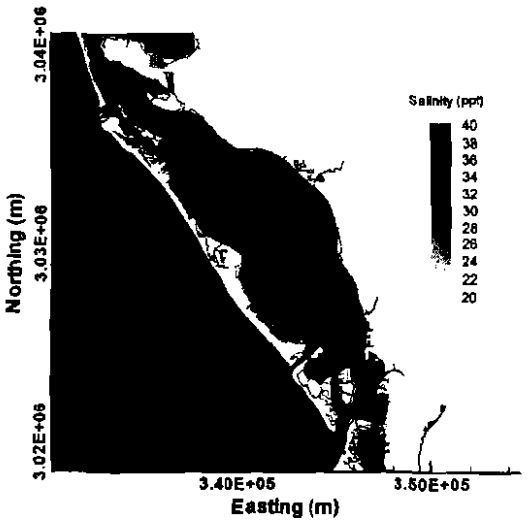

Figure 31 Sarasota Bay salinity field during December, 2001

Particle tracking simulation - which release site and what release time are the best

Using a 3-D particle tracking model, a 14-day particle tracking simulation was conducted and results are presented in this section. The primary purpose of this simulation is to compare the trajectories of particles released from three candidate release sites (see Figure 32). The simulation time covers from Nov 1st, 2004 to Nov 14th, 2004. First, a set of selected simulations

are made with particles released from three candidate release sites (#1, #2, #3 in Figure 32) and four particle release times - flood tide, high tide, ebb tide and low tide (see Figure 33). Model simulated percents of particles remaining within the Sarasota Bay are summarized in Table 2. Generally only small variations were found among the results for varying horizontal diffusion coefficients and number of particles used in the simulation (1,000 and 10,000 in the tests).

At Site #1, the result is very sensitive to the release time. With a release time at high tide, particles are quickly carried out into the Gulf of Mexico and there is no particle left within Sarasota Bay at the end of 14 days. For the other release times, approximately 70-80 percent of the total particles remain in the bay. Site#1 appears to be the worst release site.

This is quite different for Site #3, however, since it is far away from the inlet, hence the release time has little effect. On the average, the low tide release time appears to be the best since the highest percent of particles remain within the bay. In fact, low tide release time is the best for all release sites.

Site #2 appears to be an intermediate release site, since the model results show that particles remaining in the bay are somewhere in between those for Site #1 and Site #3.

With particles released from Site #3 at low tide (Nov 1st, 14:20, 2004), a final 14-day particle tracking simulation was made with hourly interval output. The Smagorinsky diffusion formula was applied in the simulation. Initially 1000 particles were released and transported by mean current and turbulent diffusion. Even though the particles' positions were saved every hour, only daily-updated locations were shown in Figures 34 through 47. At the end of 14 days, over 90% of the particles remain within the Sarasota Bay with distributed locations around central eastern part of the Bay. The other particles were flushed out of the Bay through the inlets. Figures 48 to 50 show three representative particle tracks with different final locations including north,

center and south of the particle cloud.

Table 2 Percent of particles left within Sarasota Bay

	Location 1				Location 2				Location 3			
	a	b	c	d	a	b	c	d	a	b	c	d
Time 1	76.2	78.9	65.1	76.4	86.6	88.4	86.2	86.3	90.1	94.4	88.0	90.0
Time 2	0.0	0.0	0.0	0.0	5.2	11.0	52.4	5.2	90.5	84.8	94.6	90.8
Time 3	72.8	58.6	79.8	70.7	75.9	77.8	88.0	80.0	89.0	86.1	85.5	89.3
Time 4	89.1	87.9	81.2	89.0	92.5	89.1	89.4	92.7	92.7	91.1	92.0	93.0

a: Ah = 1,000 cm^2/s; 1,000 particles
b: Ah = Variable (Smagorinsky formula) ; 1,000 particles
c: Ah = 1,00 cm^2/s; 1,000 particles
d: Ah = 1,000 cm^2/s; 10,000 particles

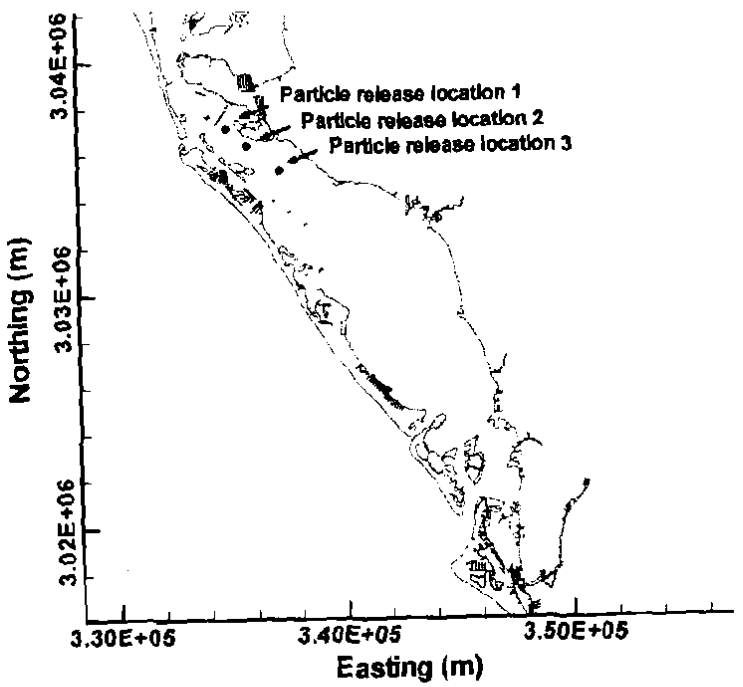

Figure 32. Locations of the three release sites (#1, #2, and #3).

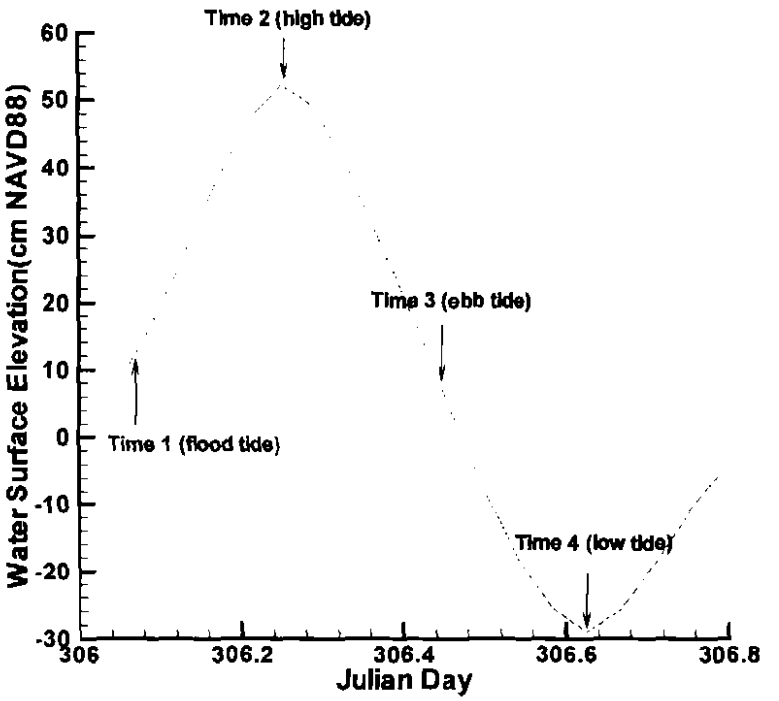

Figure 33 Four different release times for particle tracking.

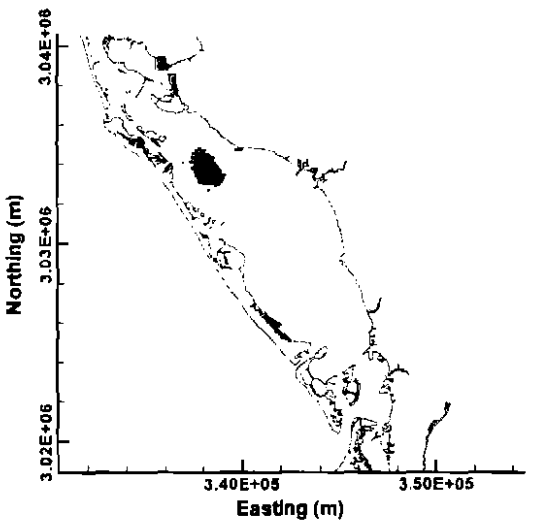

Figure 34 The particle locations after one day simulation

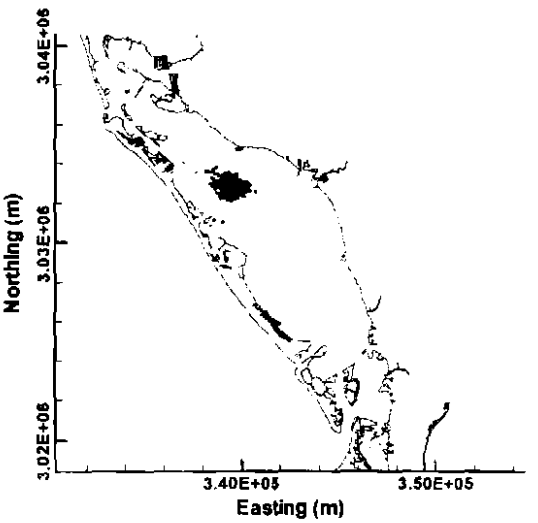

Figure 35 The particle locations after two day simulation

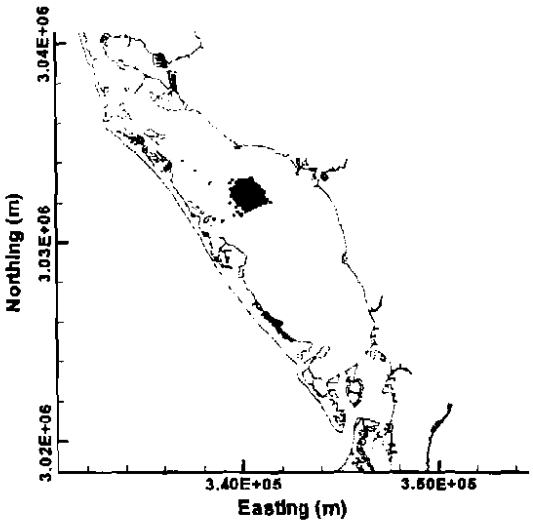

Figure 36 The particle locations after three day simulation

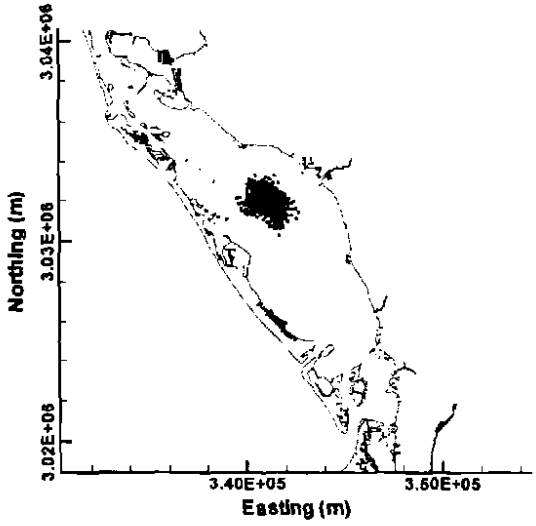

Figure 37 The particle locations after four day simulation

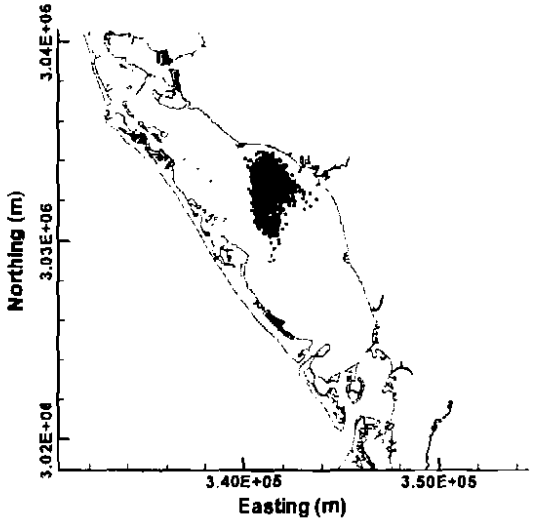

Figure 38 The particle locations after five day simulation

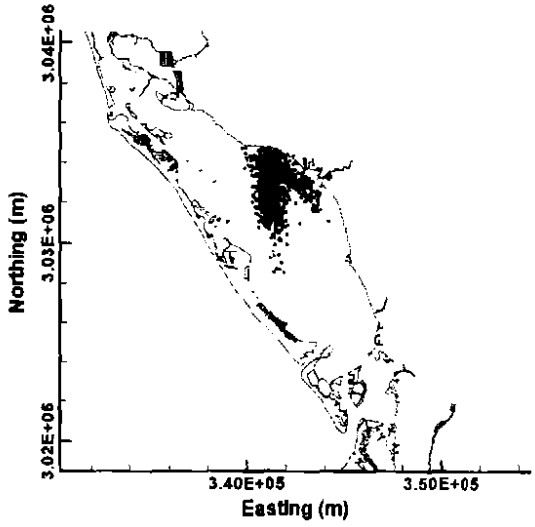

Figure 39 The particle locations after six day simulation

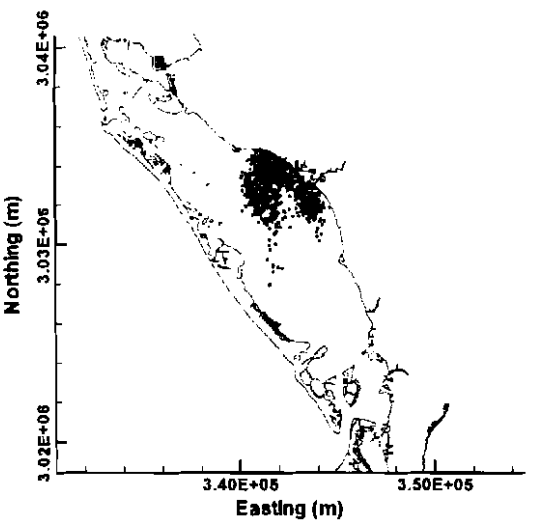

Figure 40 The particle locations after seven day simulation

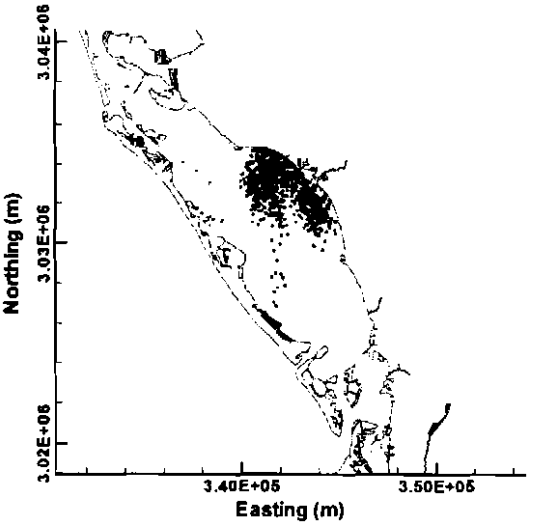

Figure 41 The particle locations after eight day simulation

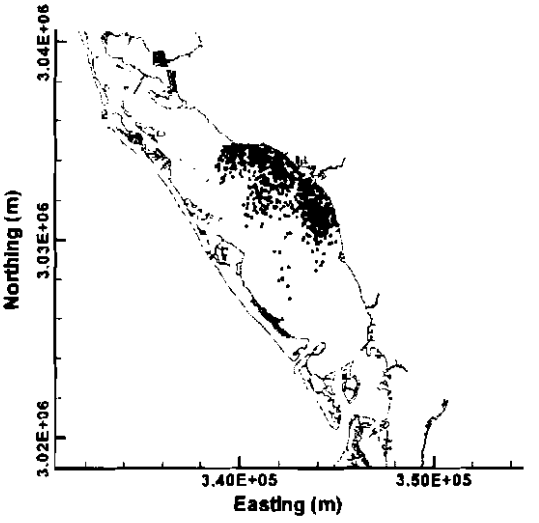

Figure 42 The particle locations after nine day simulation

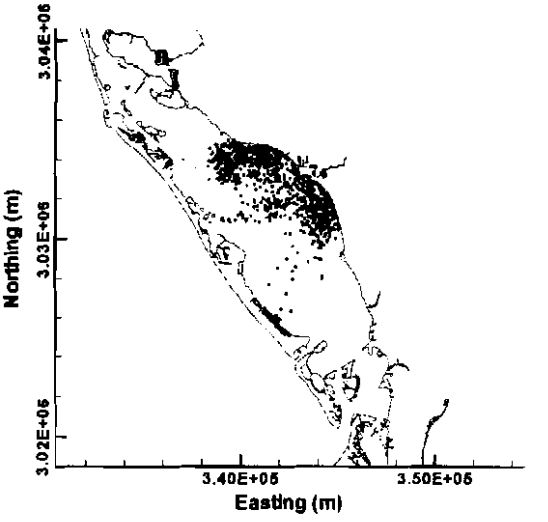

Figure 43 The particle locations after ten day simulation

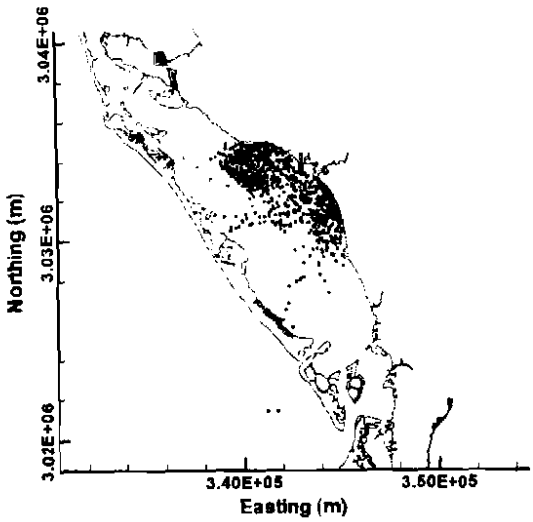

Figure 44 The particle locations after eleven day simulation

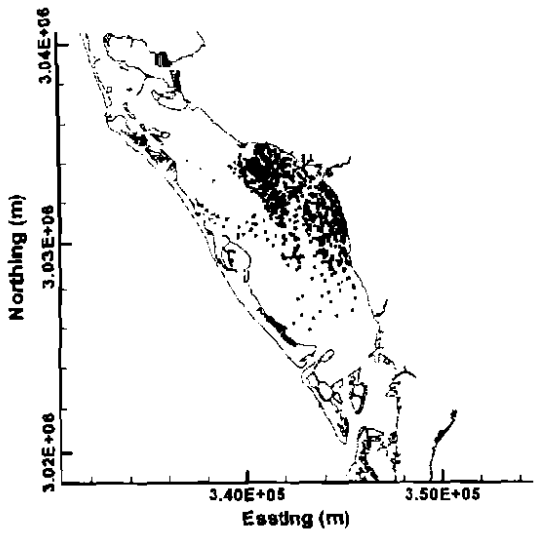

Figure 45 The particle locations after twelve day simulation

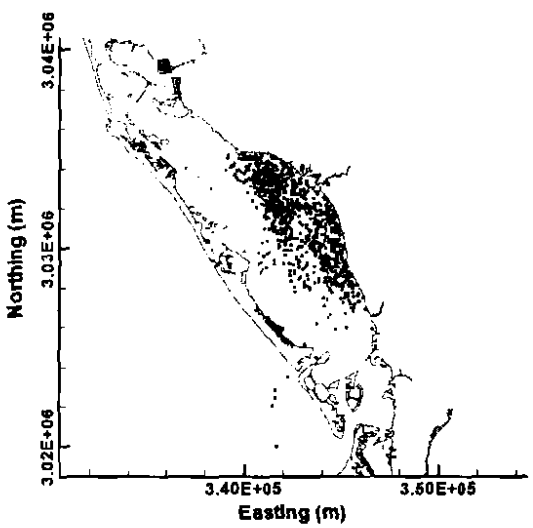

Figure 46 The particle locations after thirteen day simulation

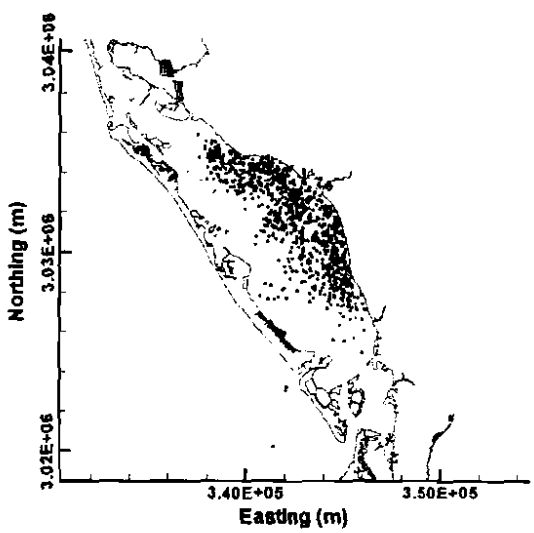

Figure 47 The particle locations after fourteen day simulation

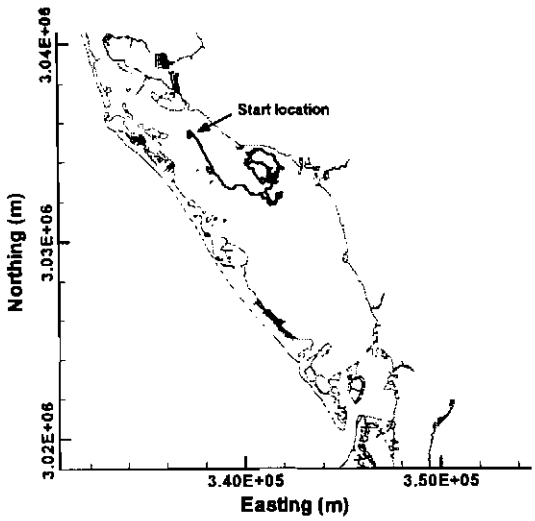

Figure 48 The representative track one of the 14-day particle tracking

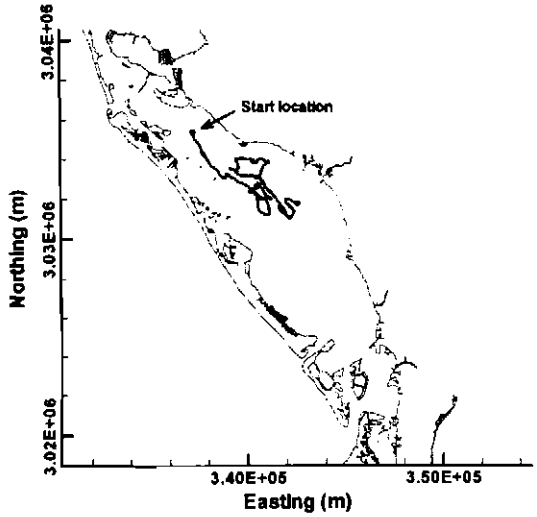

Figure 49 The representative track two of the 14-day particle tracking

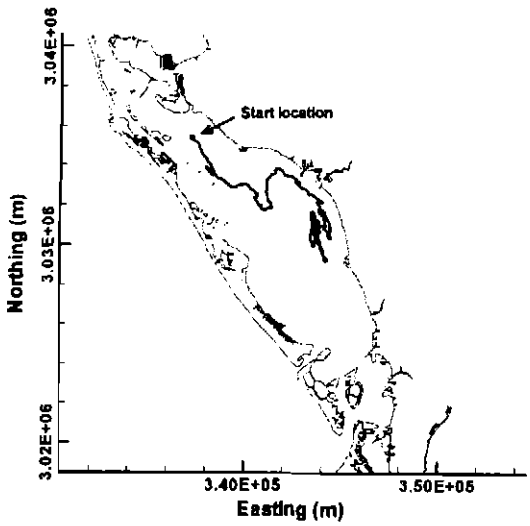

Figure 50 The representative track three of the 14-day particle tracking

Appendix 1 Measured data for Sarasota Bay simulation

Discharge

The daily discharge data at Alpha River, Little Manatee River and Hillsborough River were obtained from USGS. The daily discharge of Manatee River at Manatee dam was provided by Manatee County. Their time series discharges are shown in Figure A.1. As there is no measured discharge data during 2000 and 2001 period for South Creek, Catfish Creek, Walker Creek, Whitake Creek and Phillippee Creek, the historic monthly discharge for each Creek was obtained from USGS and was applied in the model (Figure A.2).

Precipitation and evaporation

The precipitation data was obtained from South West Florida Water Management District (SWFWMD) online database. The locations of the seven stations (station 114, 115, 117, 120, 285, 415 and 93) were shown in Figure 1. As to evaporation, there is only one set of data available during the simulation period at station BCBNAPLES from South Florida Water Management District (SFWMD) DBHydro database. The time series of precipitation and evaporation were shown in Figure A.2.

Wind

There were three wind stations with data used in the simulation. Two of them were from NOAA stations: St. Petersburg (8726520) and Port Manatee (8726384) and one from University of South Florida Coastal Ocean Monitoring and Prediction System (COMPS) station EGK. The time series of wind vector plots at these three stations were in Figure A4.

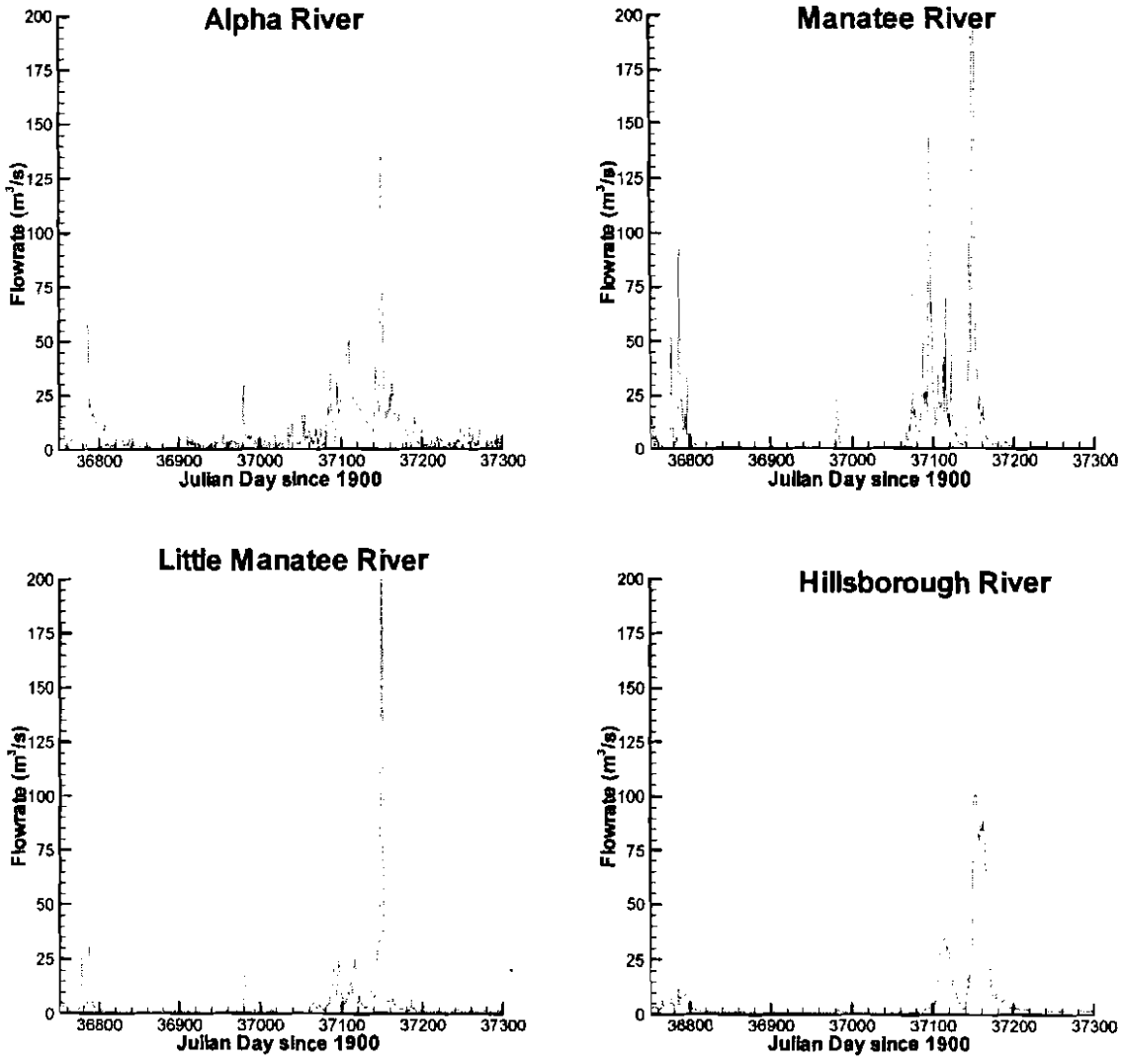

Figure A1 Measured discharge for Sarasota Bay simulation (part 1)

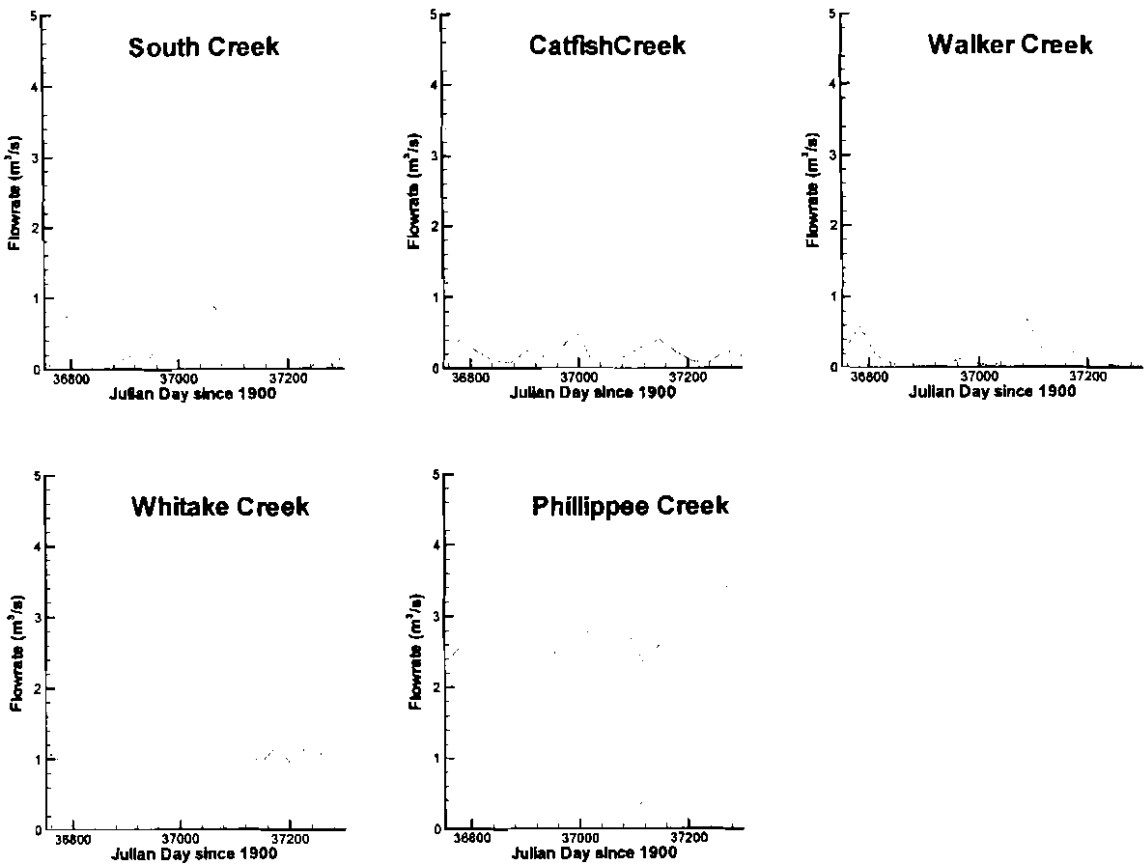

Figure A2 Measured discharge for Sarasota Bay simulation (part 2)

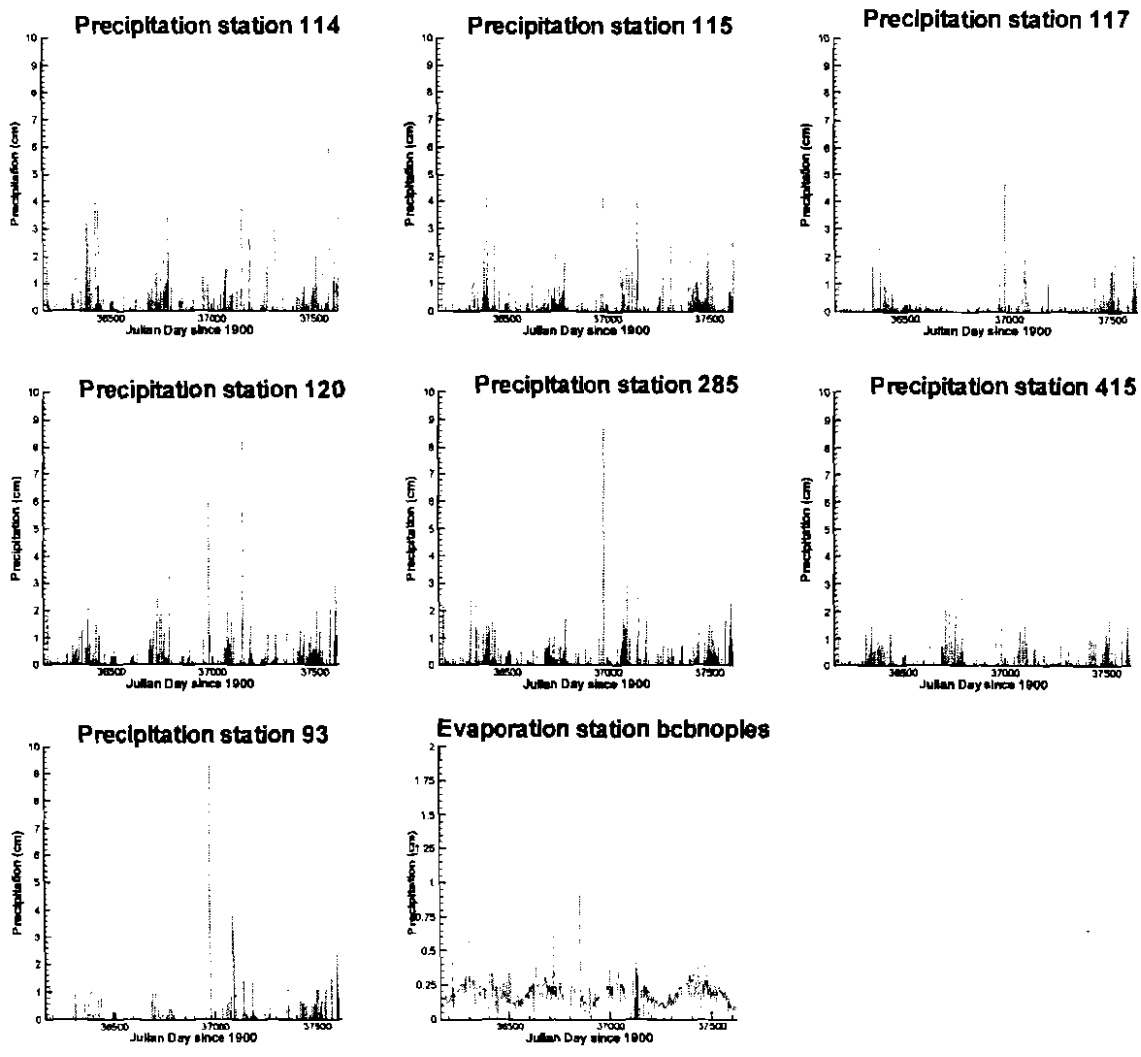

Figure A3 Measured precipitation and evaporation for Sarasota Bay simulation

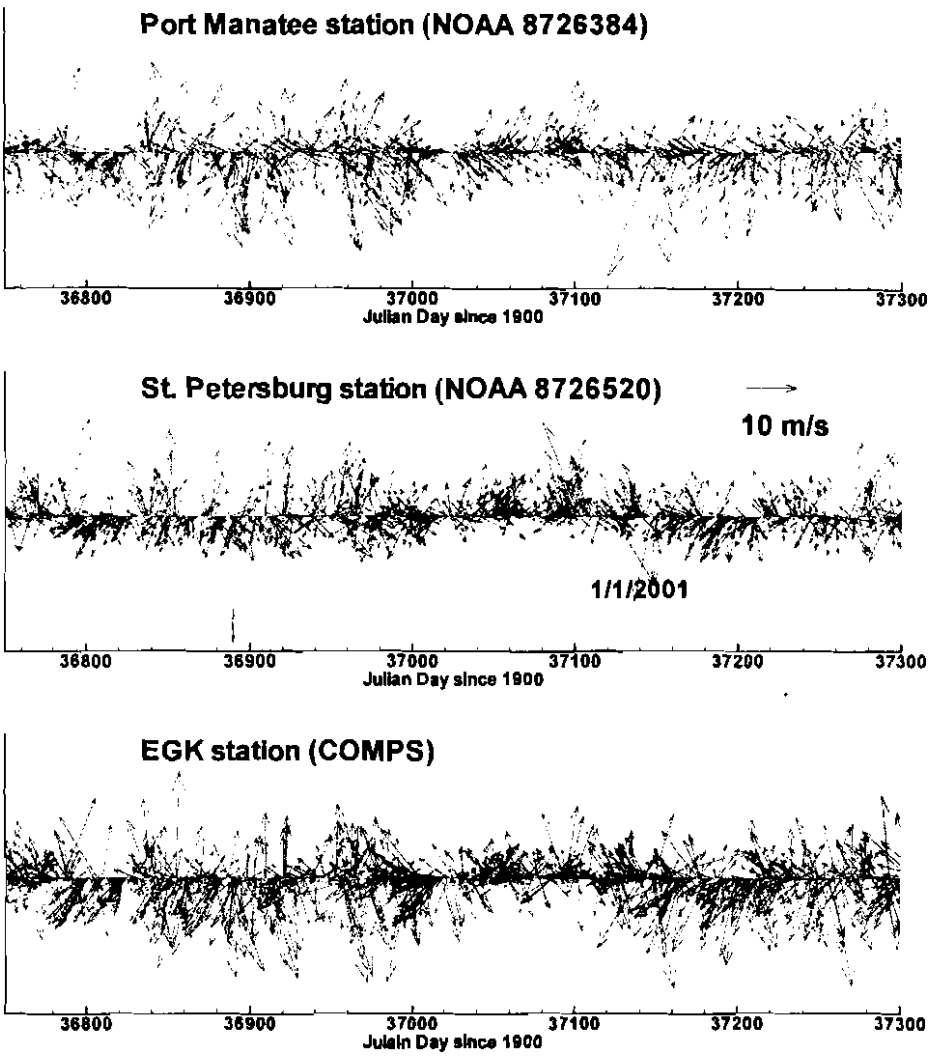

Figure A4 Measured wind data for Sarasota Bay simulation