TxBLEND Model Calibration and Validation for the Guadalupe and Mission-Aransas Estuaries

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Bays & Estuaries Program
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Introduction

Senate Bill 137 (1975), House Bill 2 (1985), Senate Bill 683 (1987), and other legislative directives call for the Texas Water Development Board (TWDB) to maintain a data collection and analytical study program focused on determining the freshwater inflows needs which are supportive of economically important and ecologically characteristic fish and shellfish species and the estuarine life upon which they depend. More recent legislative directives, Senate Bill 1 (1997) and Senate Bill 3 (2007), also direct TWDB to provide technical assistance in support of regional water planning and development of environmental flow regime recommendations, which include consideration of coastal ecosystems. In response to these directives, the Bays & Estuaries Program at TWDB has developed TxBLEND, a two-dimensional, depth-averaged hydrodynamic and salinity transport model to simulate water circulation and salinity conditions within the bays. Because TxBLEND produces high-resolution, dynamic simulations of estuarine conditions over long-term periods, the model has been used in a variety of projects including freshwater inflow studies, oil spill response, forecasts of bay conditions, salinity mitigation studies, and environmental impact evaluations.

Presently, TWDB has calibrated TxBLEND models for all seven of the major estuaries in Texas including Sabine Lake, Galveston Bay, Matagorda Bay, San Antonio Bay, Aransas and Copano Bays, Corpus Christi Bay, and the Laguna Madre. In some cases, TWDB has multi-bay models, such as presented in this report. While TxBLEND continues to be the principle hydrodynamic model used by TWDB for estuary analyses, staff is exploring the use of three-dimensional hydrodynamic models for future efforts.

This report is one in a series which documents the calibration and validation of TxBLEND for the major estuarine systems. This report focuses on the calibration and validation of TxBLEND for the Guadalupe and Mission-Aransas estuaries, but is not limited to the San Antonio-Aransas-Copano bays system. Instead, the model includes Matagorda Bay to the northeast and Corpus Christi Bay to the southwest in order to better simulate water circulation and salinity transport within the estuary. TxBLEND was calibrated for velocity, discharge, surface elevation, and salinity for the period 1987-1997. The model subsequently was validated for salinity for the period 1999-2009. Model validation focused on model performance near established long-term monitoring locations. However, additional sites may be validated upon request or as data becomes available. Future updates to model calibration or validation will be documented in later versions of this report.

Study System

The Guadalupe Estuary (or San Antonio Bay system) includes San Antonio Bay, Hynes Bay, Guadalupe Bay, and Mesquite Bay (Figure 1). The Mission-Aransas Estuary includes Aransas Bay, Copano Bay, St. Charles Bay, and Mission Bay. The distinctive feature of the Guadalupe Estuary is the lack of a direct connection to the Gulf of Mexico. Instead, the exchange of Gulf water occurs through the Gulf Intracoastal Waterway (GIWW), Espiritu Santo Bay, Big Bayou, and Saluria Bayou into Matagorda Bay and out through Pass Cavallo or the Matagorda Entrance Channel to the northeast *or* through the GIWW, Ayres Dugout, Cedar Dugout in Aransas Bay and the Lydia Ann Channel and Corpus Christi Entrance Channel to the southwest. The primary source of freshwater is the Guadalupe River and San Antonio River.

Figure 1. Regional map of the Guadalupe and Mission-Aransas estuaries in the coastal bend of Texas. The Guadalupe Estuary (San Antonio Bay) has no direct outlet to the Gulf of Mexico, but rather is hydraulically connected via Espiritu Santo Bay to the north and Aransas Bay to the south. San Antonio Bay receives freshwater from the Guadalupe and San Antonio rivers.

Model Description

TxBLEND is a computer model designed to simulate water circulation and salinity conditions in estuaries. The model is based on the finite-element method, employs triangular elements with linear basis functions, and simulates movements in two horizontal dimensions (hence vertically averaged). TxBLEND is an expanded version of the BLEND model developed by William Gray of Notre Dame University to which additional input routines for tides, river inflows, winds, evaporation, and salinity concentrations were added along with other utility routines to facilitate simulation runs specific to TWDB's needs (Gray 1987, TWDB 1999). The current version of TxBLEND being used for model applications is Version S8HH.f. Important parameters and features of the model are explained in Table 1.

Water circulation (velocity and tidal elevation) is simulated by solving the generalized wave continuity equation and the momentum equation, often jointly called the *shallow water equations* (TWDB 1999). Salinity transport is simulated by solving a mass transport equation known as the advection-diffusion equation.

Several assumptions are inherent to using the shallow water equations to simulate two-dimensional flow in a horizontal plane, specifically:

1. Fluid depth is small relative to the horizontal scale of motion
2. Vertical pressure distribution is hydrostatic
3. Vertical stratification is negligible
4. Fluid density variations are neglected except in the buoyancy term (Boussinesq approximation).

Texas bays are generally very shallow, but wide, bodies of water which are relatively un-stratified, thus satisfying the assumptions above.

Model output includes time-varying depth and vertically-averaged horizontal velocity components of flow and salinity throughout the model domain. TxBLEND thus provides water velocity and direction, surface elevation, and salinity at each node in the model grid (see below for details about the model grid for the Guadalupe and Mission-Aransas estuaries). The model does not provide information about vertical variation within the water column, but rather provides information about horizontal variation, such as salinity zonation patterns throughout the estuary. The model is run in two or three minute time-steps, typically with hourly output. Model simulations may be run to represent brief periods of time, a week or month, or may be run for years.

Table 1. Description of TxBLEND model parameters, features, and inputs.

Feature	*Description*
Generalized Wave Continuity Equation (GWCE)	A special form of the continuity equation designed to avoid spurious oscillation encountered when solving the primitive continuity equation using the finite element method. Solved by an implicit scheme prior to solving the momentum equation. The GWCE is an established equation used to solve mass-balance or flow continuity in 2-D finite element hydrodynamic models (Kinnmark and Gray 1984).
Momentum Equation	2-D, Depth Integrated Momentum Equation is solved for most applications. Non-linear terms are neglected most of the time.
Advection-Diffusion Equation	Used to calculate salinity transport.
BigG	A parameter in the generalized wave continuity equation. Larger values of BigG reduce mass balance errors by increasing the enforcement of the continuity equation at the price of increased numerical difficulty (TWDB 1999). Typically, set at 0.01 – 0.05.
Manning's n Roughness Coefficient	Used to represent bottom friction stress. For TxBLEND, 0.015 to 0.02 is a reasonable default value, but can be increased to 0.03 or higher for a seabed with thick grasses or debris or lowered to 0.01 or less to represent a smooth bay bottom.
Turbulent Diffusion Term	A diffusion factor, representing horizontal diffusion, used to diffuse momentum as a result of the non-linear term in the momentum equation.
Boundary Conditions	Three types of boundaries form the edge of the model domain. (1) *River Boundary* – portion of river entering the bay; (2) *Tidal Boundary* – the limited portion of Gulf of Mexico included where salinity and tidal boundary conditions are set; and, (3) *Shoreline Boundary* – enclosing boundary of the bay.
Wind Stress	Used to impose the effect of wind on circulation.
Dispersion Coefficient	Uses a modified version of the Harleman's equation which contains a dispersion constant (DIFCON) that can be varied depending on expectations for mixing rates and to better simulate salinity conditions. Due to variable velocities, the dispersion coefficient is updated in 30-minute intervals during simulation. For most applications, constant dispersion coefficients are used.
Coriolis Term	Used to impose the Coriolis Effect on the hydrodynamics
Tide Data	Water surface elevations at the ocean boundary are specified by input tides.
River Inflow Data	Daily river inflows are introduced at identified inflow points. The data are obtained from TWDB Coastal Hydrology estimates based on gaged and ungaged inflows.
Meteorological Data	Includes evaporation, precipitation, wind speed, and wind direction. Wind data may be input as daily average, 3-hour average, or as hourly data. Evaporation data is used to reflect the effect of evaporation on salinity (Masch 1971). Evaporation rate is a modification of the Harbeck equation to estimate daily evaporation from estuaries developed by Brandes and Masch (1972). Precipitation is input as daily values.

TxBLEND Model Domain for the Guadalupe and Mission-Aransas Estuary

The TxBLEND computational grid for the Guadalupe and Mission-Aransas estuaries contains 6,486 nodes and 10,669 triangular elements (Figure 2). In addition to the bays of the Guadalupe and Mission-Aransas systems, the model grid also represents Matagorda Bay to the northeast and Corpus Christi Bay to the southwest. These bays were included to yield better simulation results by modeling conditions at the boundary of the estuary, based on conditions in the neighboring bays, rather than prescribing a pre-set boundary condition. The model grid has 16 inflow points (Figure 3), corresponding to flows coming from the: Colorado River, Tres Palacios Creek, Turtle Creek, Carancahua Creek, Cox Creek, Lavaca River, Garcitas Creek, Chocolate Bayou, Powderhorn Creek, Guadalupe River, Salt Creek, Copano Creek, Mission River, Aransas River, Nueces River, and Oso Creek. Bathymetry used to develop the grid was obtained from National Oceanic and Atmospheric Administration (Nautical Chart 11315: Intracoastal Waterway, Espiritu Santo Bay to Carlos Bay, including San Antonio Bay and Victoria Barge Canal). Bathymetry of the Corpus Christi ship channel was obtained from the Port of Corpus Christi Authority.

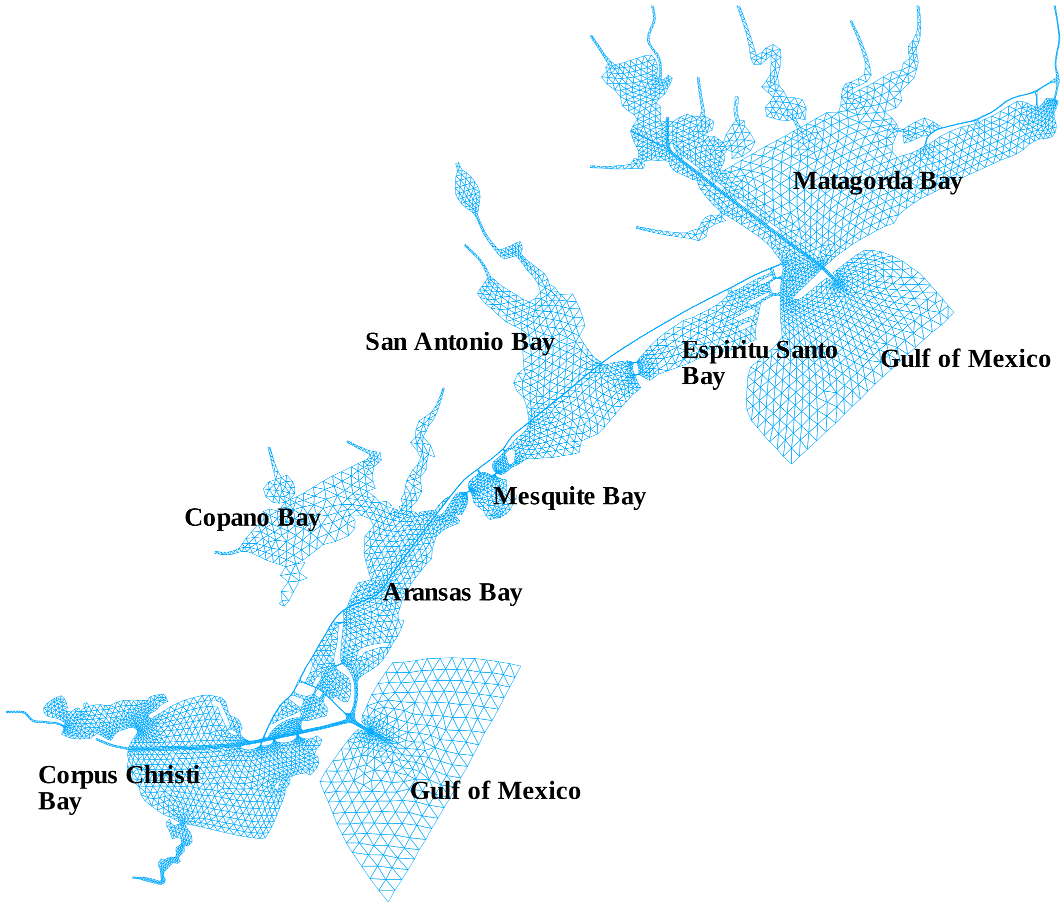

Figure 2. Computational grid for the Guadalupe and Mission-Aransas TxBLEND model. The model grid includes Matagorda and Corpus Christi bays in order to better represent boundary conditions for Espiritu Santo Bay and Aransas Bay, respectively.

Figure 3. Sixteen inflow points for the Guadalupe and Mission-Aransas TxBLEND model.

Inflows

Daily inflow values were taken from the TWDB coastal hydrology dataset for 1987 to 2009. This dataset uses measurements from U.S. Geological Survey (USGS) stream gages along with rainfall-runoff estimates from the Texas Rainfall-Runoff (TxRR) model, adjusted for known diversion and return flows obtained from the Texas Commission on Environmental Quality (TCEQ), the South Texas Water Master, and the TWDB Irrigation Water Use estimates, to develop daily inflows for the estuaries.

Table 2 lists the USGS stream gages used to develop the gaged inflow component of inflows for the 16 inflow control points identified in Figure 3. Approved USGS stream gage data was available through September 2009 and was provisional for the period October to December 2009. Figures 4 and 5 show the watershed boundaries, including the ungaged watersheds modeled with TxRR, during the period of record 1977-2009 for the Guadalupe and Mission-Aransas inflows. Ungaged flows were estimated using precipitation data from the National Weather Service. Precipitation records were complete through May 2009 but were incomplete from June to December 2009. Diversion data was obtained from TCEQ for the period January 1987 to December 2006. Similarly, industrial and municipal return flow data was obtained from TCEQ for the period January 1987 to December 2007. Additional diversion data was obtained from the South Texas Water Master through October 2005, and additional return flow data was obtained from TWDB's agricultural return flow estimates through December 2006.

Table 2. USGS streamflow gages used to develop freshwater inflow estimates for the Guadalupe and Mission-Aransas estuaries model.

Estuary	Gage Station Number	Gage Location
Lavaca-Colorado	8162600	Tres Palacios River near Midfield
	8164000	Lavaca River near Edna
	8164503	West Mustang Creek near Ganado
	8164500	Navidad River above Ganado
	8164600	Garcitas Creek near Inez
	8164800	Placedo Creek near Placedo
	8164525*	Lake Texana near Edna
	8162500	Colorado River near Bay City
Guadalupe	8177500	Coleto Creek near Victoria
	8177000	Coleto Creek near Shroeder
	8176500	Guadalupe River at Victoria
	8188500	San Antonio River at Goliad
Mission-Aransas	8189800	Chiltipin Creek at Sinton
	8189700	Aransas River near Skidmore
	8189500	Mission River at Refugio
	8189200	Copano Creek near Refugio
Nueces	8211520	Oso Creek at Corpus Christi
	8211000	Nueces River near Mathis

*USGS gage #8164525 provides lake level, but TWDB uses release data from Lake Texana provided by the Lavaca-Navidad River Authority.

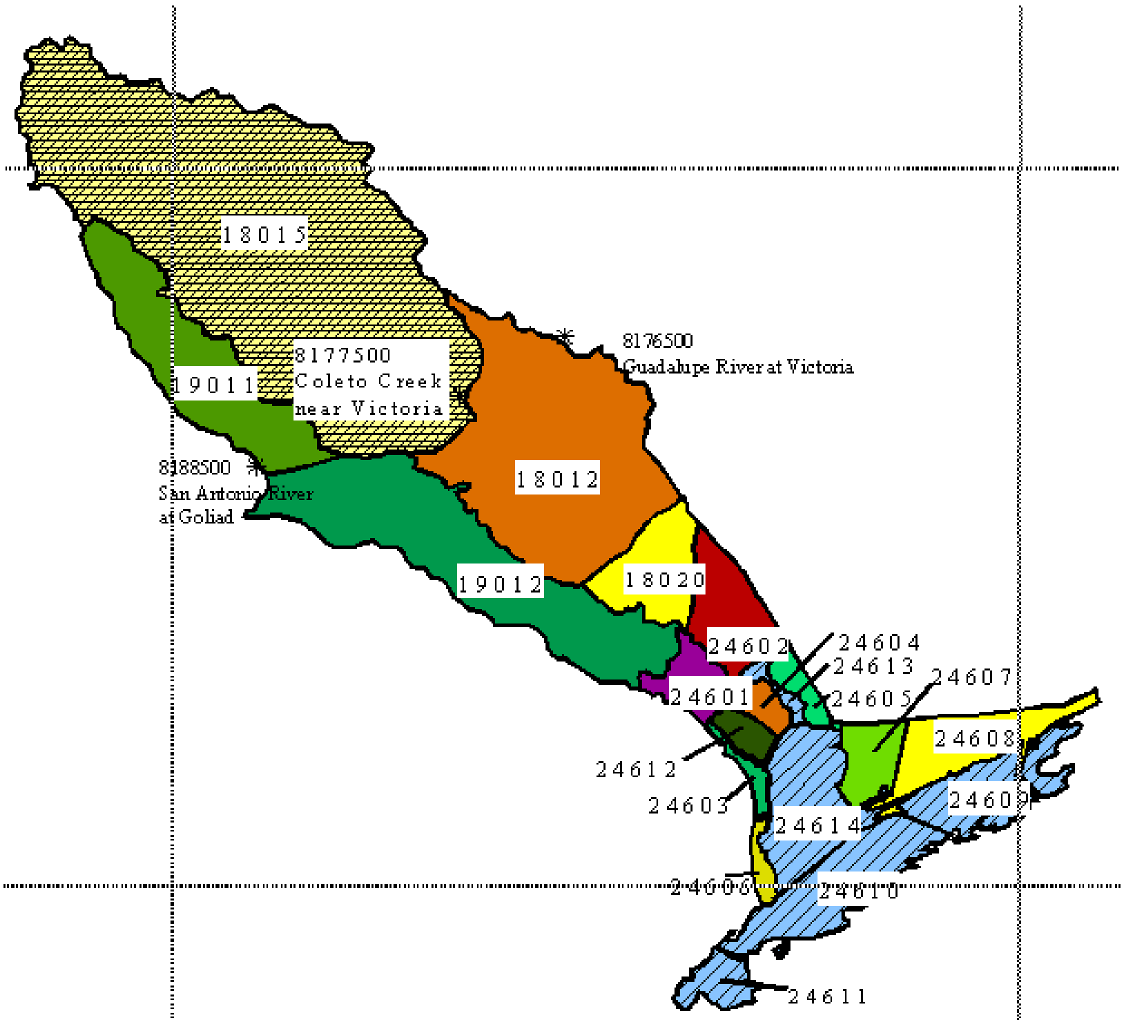

Figure 4. Ungaged watershed delineation used in TxRR from July 1, 1978 to present to determine ungaged flows to San Antonio Bay.

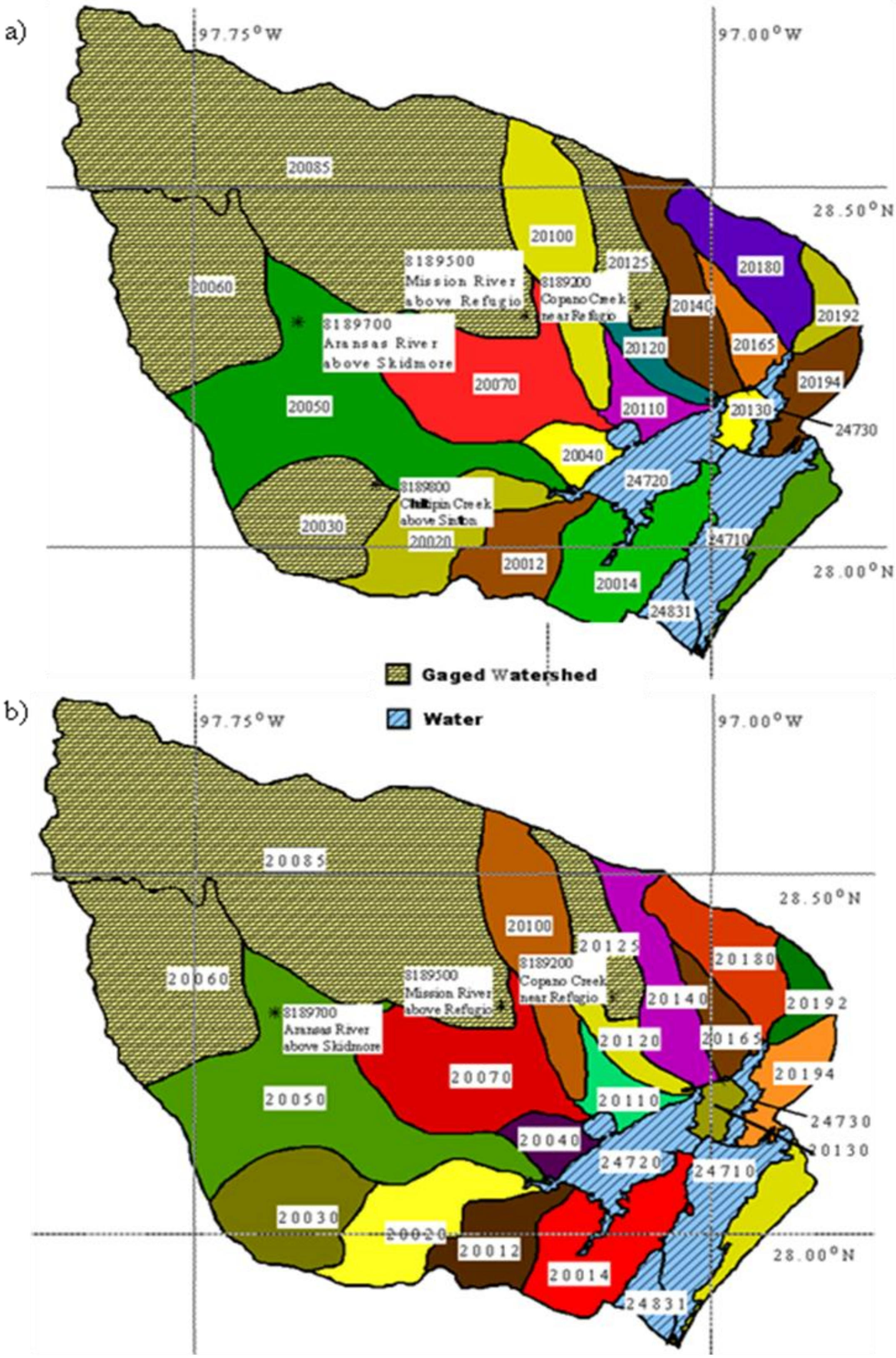

Figure 5. Ungaged watershed delineation used in TxRR from: a) January 1, 1977 to September 30, 1991, and b) October 1, 1991 to present to determine ungaged flows to Copano and Aransas bays.

Tides

Tidal elevations at Bob Hall Pier were obtained from the Texas Coastal Ocean Observation Network (http://lighthouse.tamucc.edu/TCOON/HomePage) and applied at the Gulf open boundary.

Meteorology

Time-varying and spatially uniform meteorology is used to drive the model. The dataset includes wind field, air temperature, precipitation, and evaporation. A large portion of the meteorology data (wind speed and direction and air temperature) used to drive the model was obtained from the National Climatological Data Center (NCDC). Wind data was obtained for Corpus Christi for the period January 1, 1981 to December 31, 2001. Evaporation data for Corpus Christi was calculated based on the Harbeck Equation (Brandes and Masch 1972) using temperature data from the NCDC, providing data for the period January 1, 1970 to December 31, 2001. Precipitation data used for model calibration and validation simulations originally were obtained from the NCDC and subsequently were processed to provide an estimate of precipitation across the San Antonio Bay subwatershed (Figure 4, subwatershed #24614). TWDB archived records of this data provided precipitation for the period January 1, 1977 to November 30, 2009. Wind and evaporation data were obtained for Victoria, Texas for the period January 1, 1980 to December 31, 2009.

Salinity

Time-varying salinity boundary conditions were specified at two locations: the Gulf of Mexico off of Matagorda Bay and off of Port Aransas. Data were obtained from the Texas Parks & Wildlife Department (TPWD) Coastal Fisheries database (V. Swann, TPWD, *pers. comm*.).

Model Calibration

The TxBLEND model was calibrated for both hydrodynamic and salinity transport performance by using water velocity and surface elevation data from intensive field studies to calibrate the hydrodynamic and long-term time-series salinity data for calibration of salinity transport. Model calibration efforts focused on improving model performance by adjusting parameters such as the dispersion coefficient and Manning's *n*.

Velocity and Discharge

For the calibration of this TxBLEND model, two intensive inflow data sets were available. In the Guadalupe Estuary, velocity and discharge measurements were collected at 15 locations in Espiritu Santo Bay, San Antonio Bay, and Mesquite Bay during an intensive inflow study from April 19 - 22, 1988 (Figure 6). In the Mission-Aransas Estuary, velocity and discharge measurements were collected at 12 sites in Mesquite Bay, St. Charles Bay, Copano Bay, Aransas Bay, and Redfish Bay during an intensive inflow study from September 29 - October 2, 1995 (Figure 7). At most locations, velocity measurements were collected at three depths, 2/10th, 5/10th, and 8/10th of water depth.

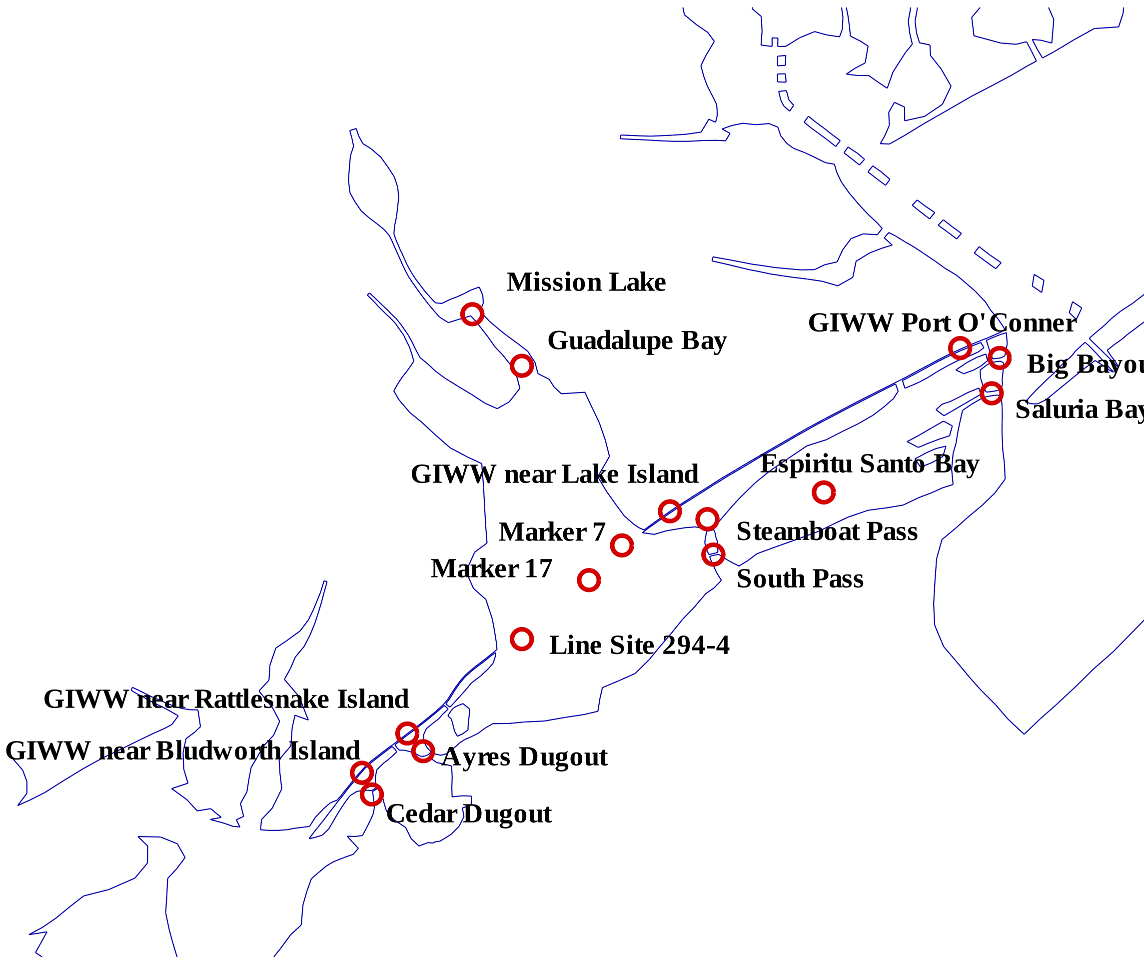

Figure 6. Velocity and discharge measurement sites during an intensive inflow study, April 19-22, 1988, of the Guadalupe Estuary.

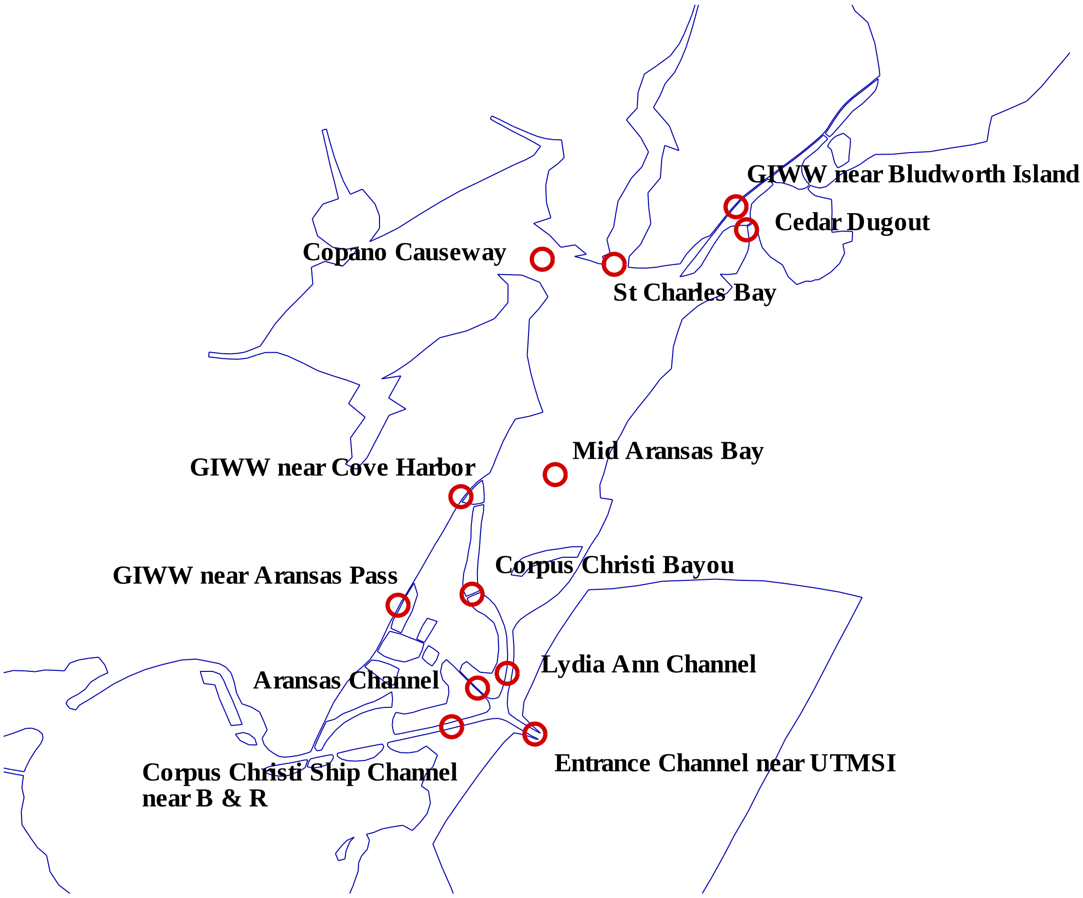

Figure 7. Velocity and discharge measurement sites during an intensive inflow study, September 29 - October 2, 1995, of the Mission-Aransas Estuary.

Salinity

Long-term salinity records collected by the TWDB and TPWD at hourly or more frequent intervals provide important data for calibrating and validating salinity and circulation models in Texas coastal waters. Within-bay salinity data from the TWDB Datasonde Program was used for model calibration and validation for four long-term monitoring sites: San Antonio Bay at Seadrift (1987-1997 and 2001-2010), Mesquite Bay (1987-1989, 1995, 1999), Copano Bay at the Copano Causeway (1987-1989), and Aransas Bay at mid-bay (1987-1989, 1994-2001; Figure 8). Additional information as well as the data itself can be obtained from the TWDB Datasonde Program web site (http://midgewater.twdb.state.tx.us/bays_estuaries/sondpage.html).

To validate TxBLEND, model outputs were compared to TWDB Datasonde data for those sites with salinity data available after 1998 or were compared to point-measurement data obtained from TPWD's Coastal Fisheries database, the Texas Commission on Environmental Quality (TCEQ) Surface Water Quality Monitoring database, or the Texas Department of State Health Services (TDSHS) Shell Fish Safety Program for sites generally located near the four existing datasonde locations. In addition, model validation included a comparison of model results to the Guadalupe-Blanco River Authority GBRA1 station in San Antonio Bay.

Figure 8. Four TWDB long-term monitoring stations which provided time-series salinity data for use in model calibration and validation. The period of record is as follows: San Antonio Bay at Seadrift (1987-1997 and 2001-2010), Mesquite Bay (1987-1989, 1995, 1999), Copano Bay at the Copano Causeway (1987-1989), and mid-Aransas Bay (1987-1989, 1994-2001).

Model Calibration Parameters

Model parameters adjusted during the calibration of the TxBLEND model included BigG, the dispersion coefficient, and Manning's *n*. BigG is a non-physical parameter which ensures mass conservation and was set to 0.03. Another important parameter for hydrodynamic calibration is Manning's *n* which represents bottom roughness, where larger values of *n* slow water movement and smaller values increase water movement. Values used in the calibrated model are shown in Figure 9. Similarly, the dispersion coefficient, which represents physical mixing processes, is the key parameter for salinity calibration. The larger the dispersion coefficient, the more effectively dissolved salt disperses. Figure 10 shows the values used in the calibrated model. Larger values were assigned to the Gulf and major ship channels, and smaller values were assigned to shallow bays.

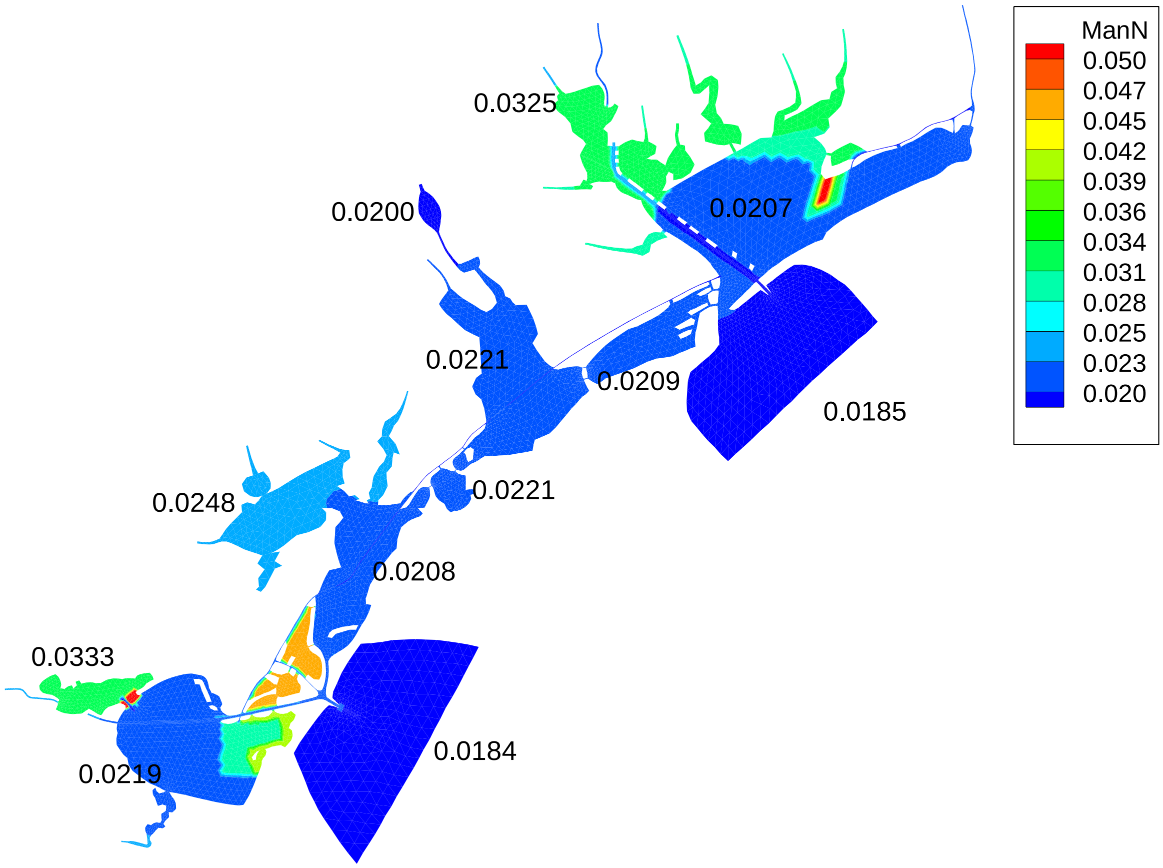

Figure 9. Values of Manning's *n* used in the calibrated TxBLEND model for the Guadalupe and Mission-Aransas estuaries.

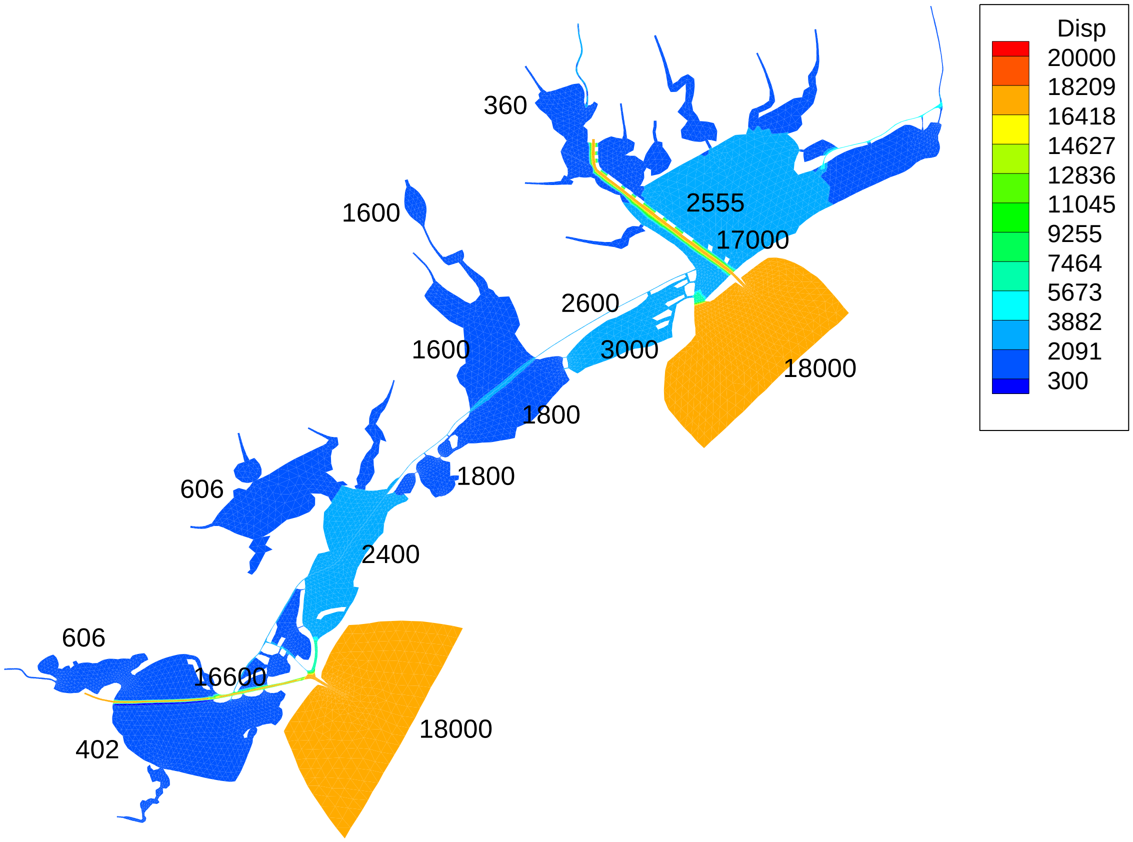

Figure 10. Values of the dispersion factor (ft^2/sec) used in the calibrated TxBLEND model for the Guadalupe and Mission-Aransas estuaries. The Gulf region was set to 18,000 ft^2/sec, ship channels to 16,600 to 17,000 ft^2/sec, and the Gulf Intracoastal Waterway was set at 2,600 ft^2/sec.

Calibration Results

Calibration results for velocity, discharge, surface elevation, and salinity for the period 1987-1997 for the Guadalupe and Mission-Aransas TxBLEND model are presented below.

Velocity & Discharge Results

TxBLEND was calibrated for water velocity and discharge using data obtained from three intensive inflow studies: San Antonio Bay April 1988, Aransas Bay in August 1998 and again in late September 1995. Calibration results are presented in a series of plots showing simulated velocities and discharges as compared to observed field measurements for a number of locations throughout the system. Figures 11- 14 show calibration results for velocity at 16 locations, and Figures 15-17 show results for discharge at nine locations in the Guadalupe Estuary during April 1988. Simulated velocities are representative of observed velocities at 15 locations, but are less representative at Ayer's Dugout. Simulated discharge is representative of observed discharges at all nine locations evaluated for the Guadalupe Estuary.

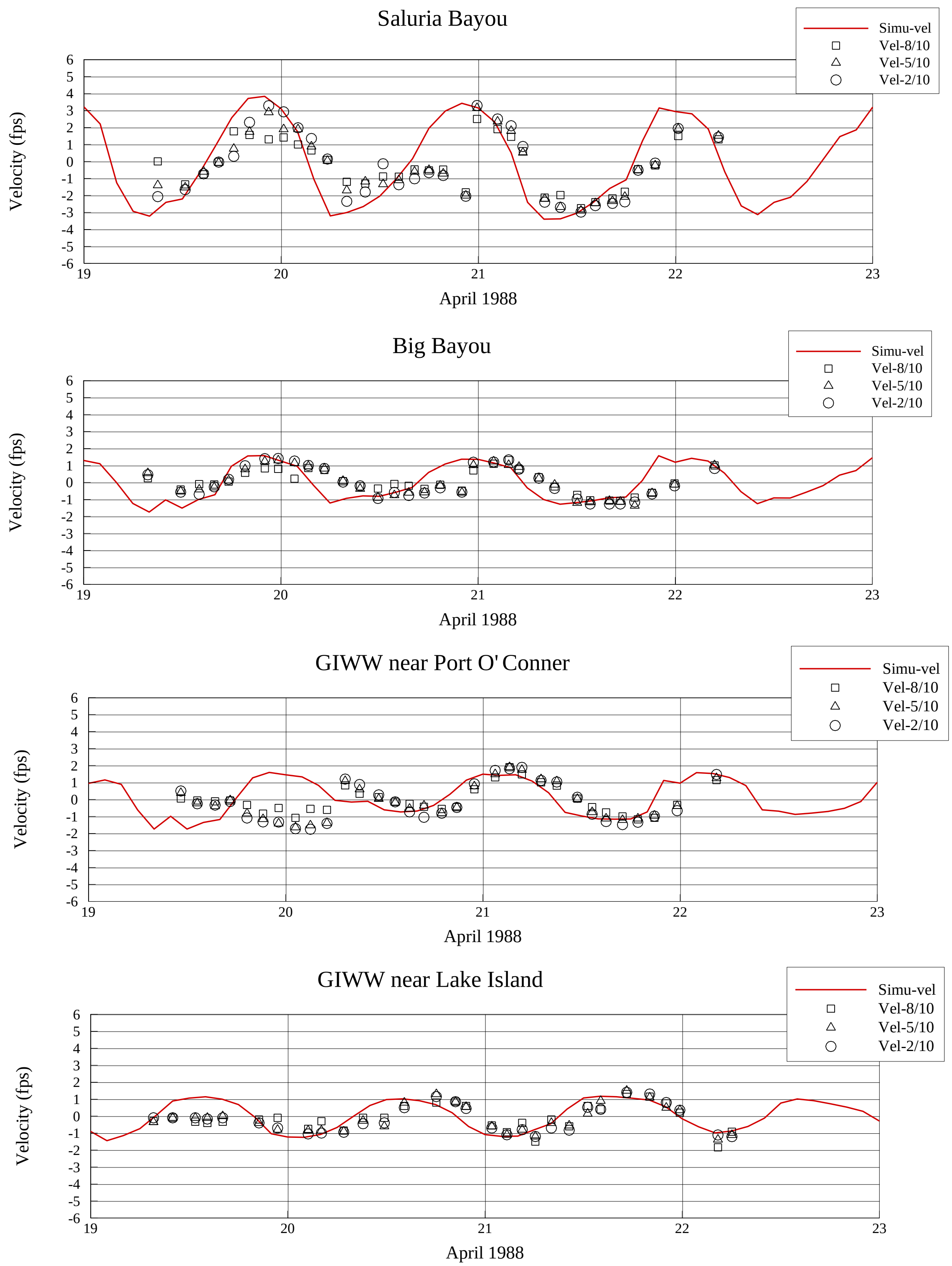

Figure 11. Simulated (red line) and observed (open symbols) velocities for a) Saluria Bayou, b) Big Bayou, c) GIWW near Port O'Connor, and d) GIWW near Lake Island for April 19-23, 1988 in the Guadalupe Estuary. Velocity measurements were collected at three depths, 2/10th (o), 5/10th (△), and 8/10th (□) of water depth.

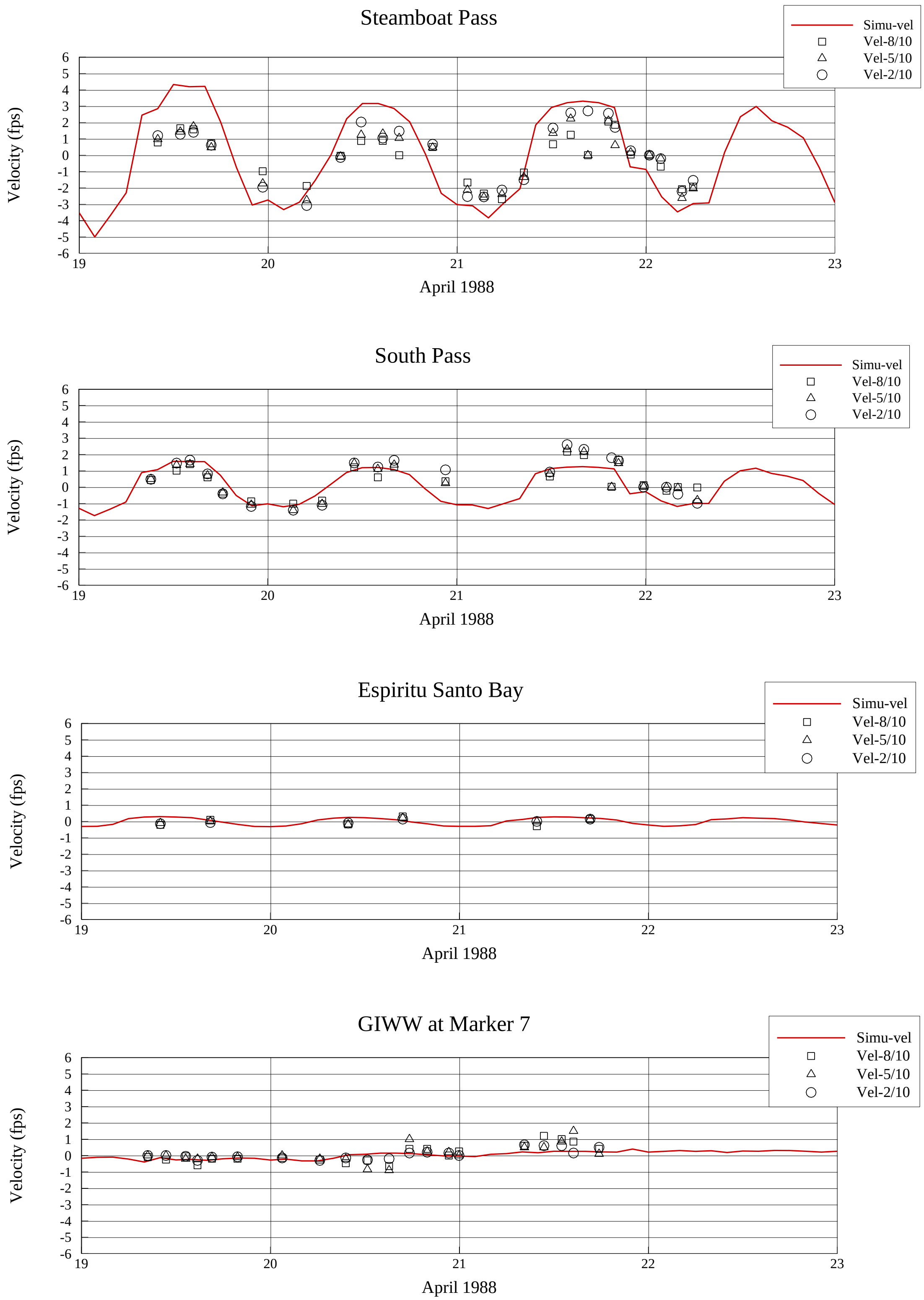

Figure 12. Simulated (red line) and observed velocities (open symbols) for a) Steamboat Pass, b) South Pass, c) Espiritu Santo Bay, and d) GIWW at Marker 7 for April 19-23, 1988 in the Guadalupe Estuary. Velocity measurements were collected at three depths, 2/10th (o), 5/10th (△), and 8/10th (□) of water depth.

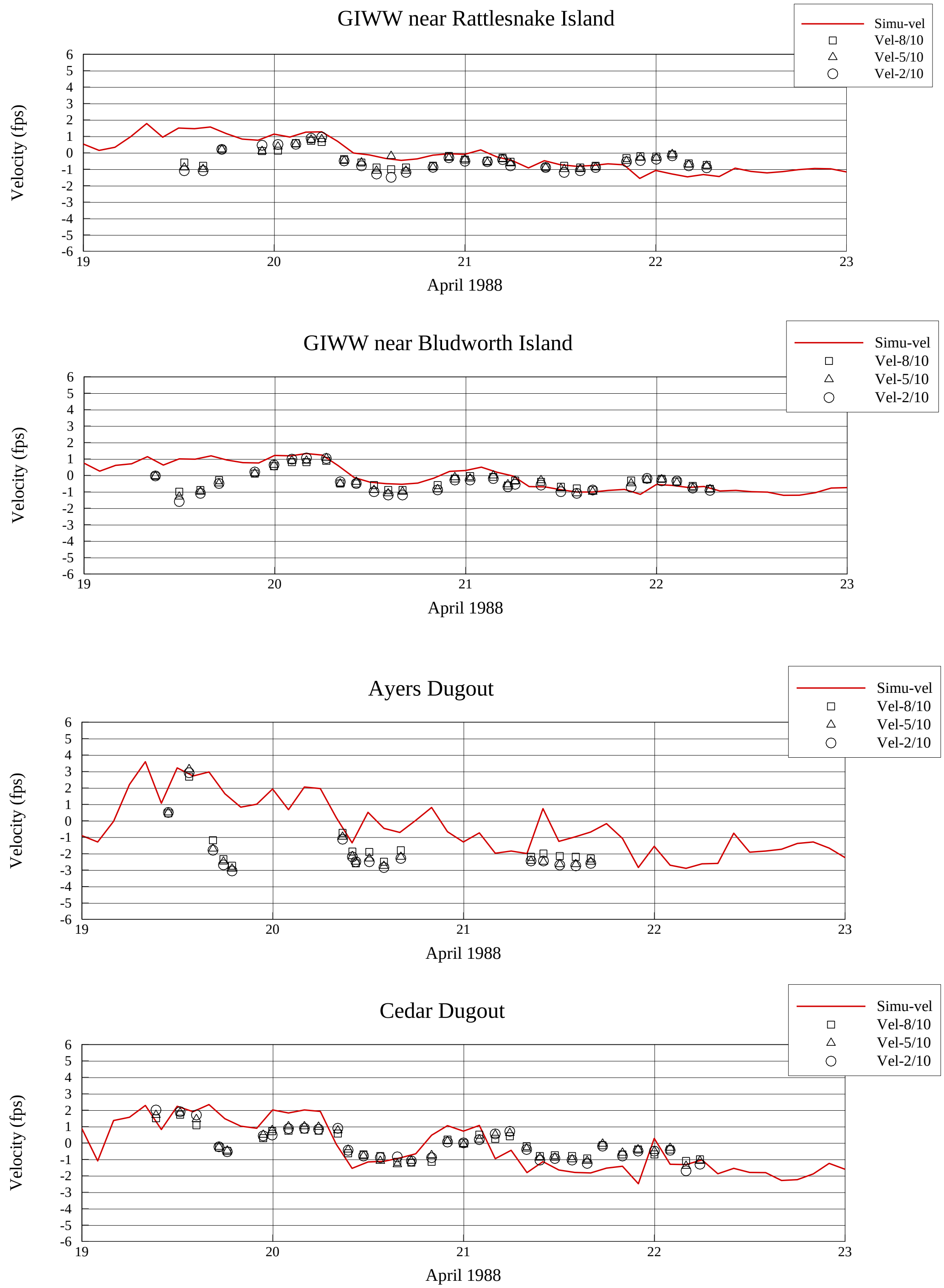

Figure 13. Simulated (red line) and observed velocities (open symbols) for a) GIWW near Rattlesnake Island, b) GIWW near Bludworth Island, c) Ayres Dugout, and d) Cedar Dugout for April 19-23, 1988 in the Guadalupe Estuary. Velocity measurements were collected at three depths, 2/10th (o), 5/10th (△), and 8/10th (□) of water depth.

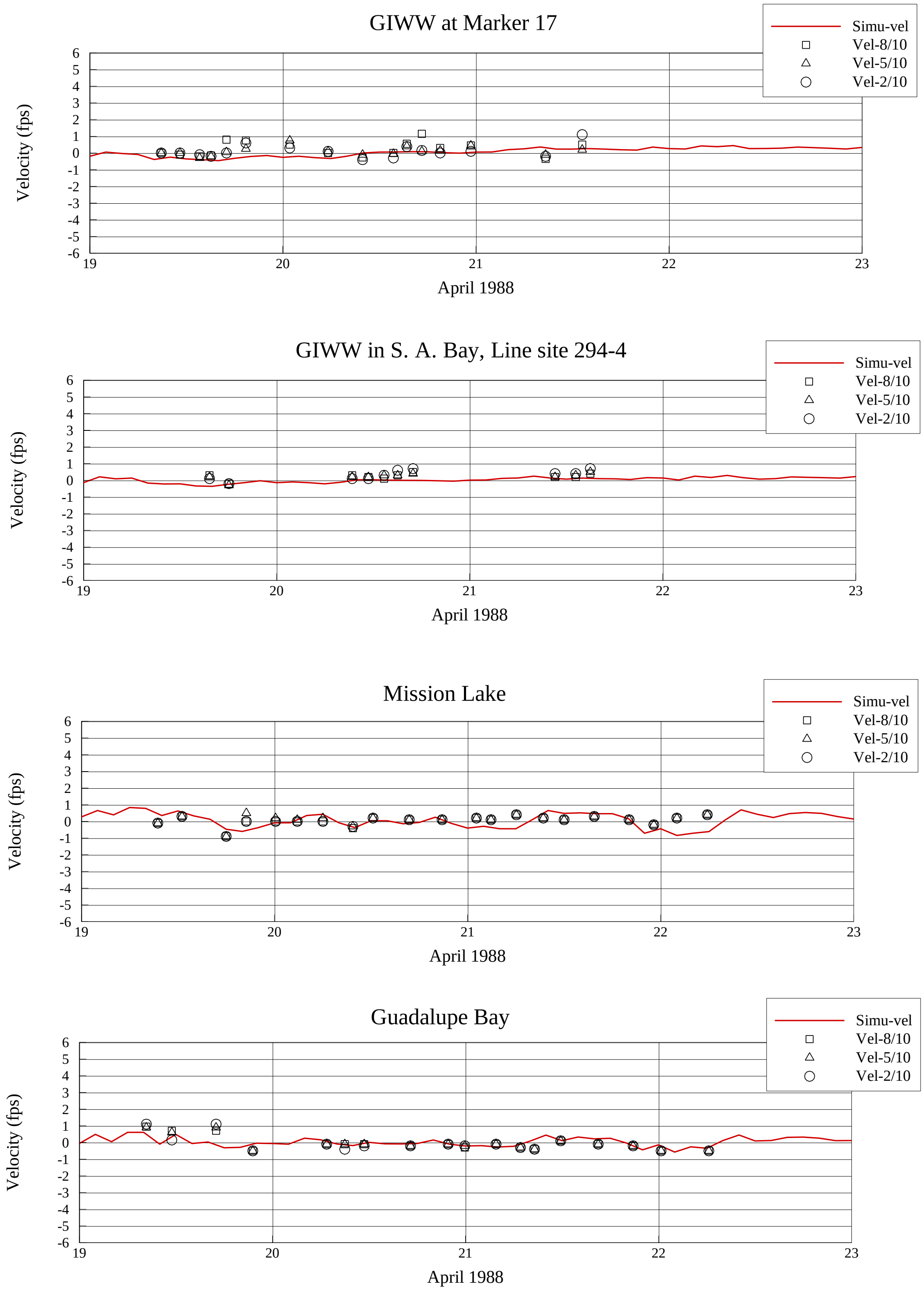

Figure 14. Simulated (red line) and observed velocities (open symbols) for the a) GIWW at Marker 17, b) GIWW in San Antonio Bay, c) Mission Lake, and d) Guadalupe Bay for April 19-23, 1988 in the Guadalupe Estuary. Velocity measurements were collected at three depths, 2/10th (o), 5/10th (△), and 8/10th (□) of water depth.

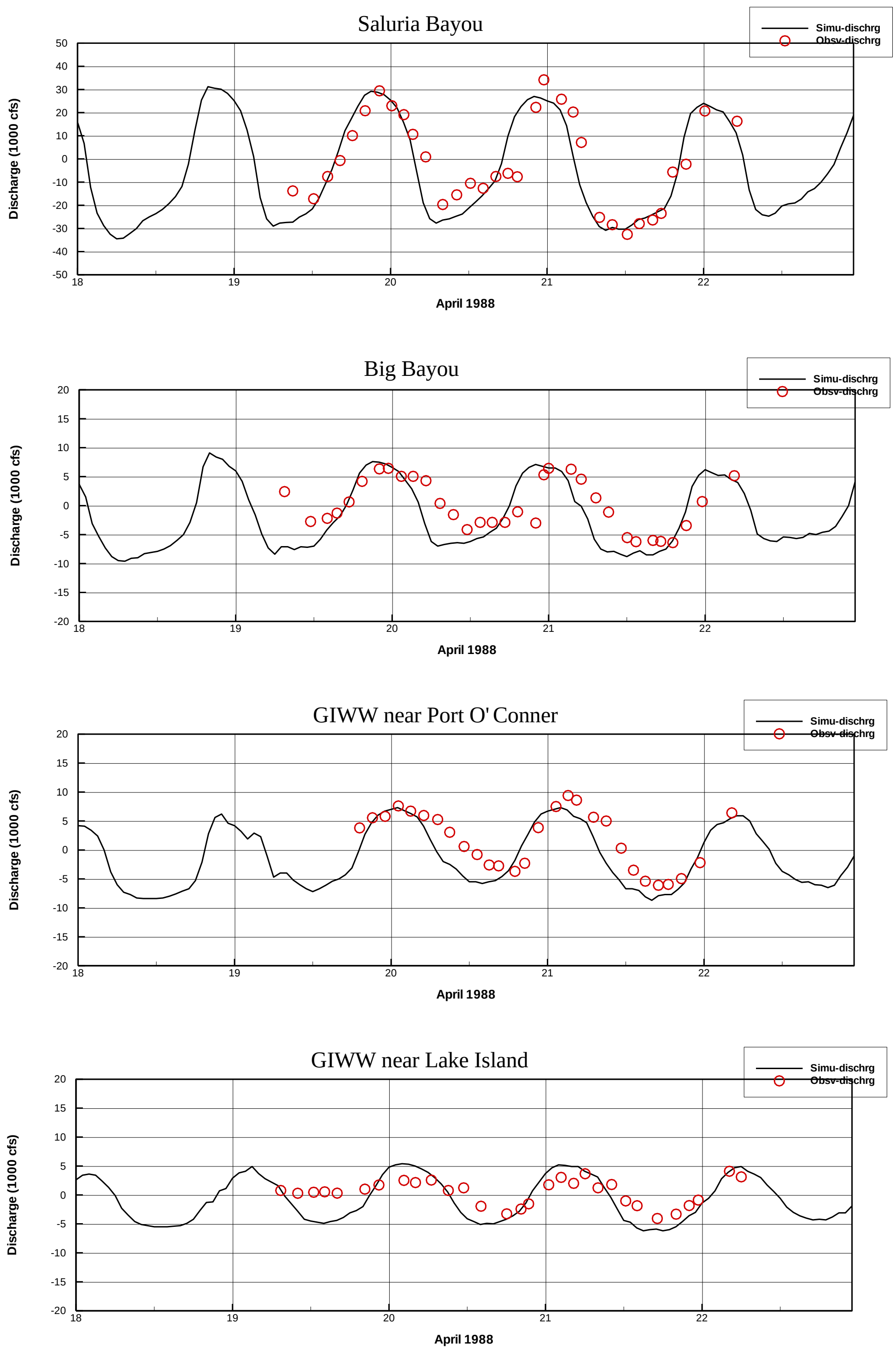

Figure 15. Simulated (red line) and observed (open symbols) discharges for a) Saluria Bayou, b)Big Bayou, c) GIWW near Port O'Connor, and d) GIWW near Lake Island for April 18-23, 1988 in the Guadalupe Estuary.

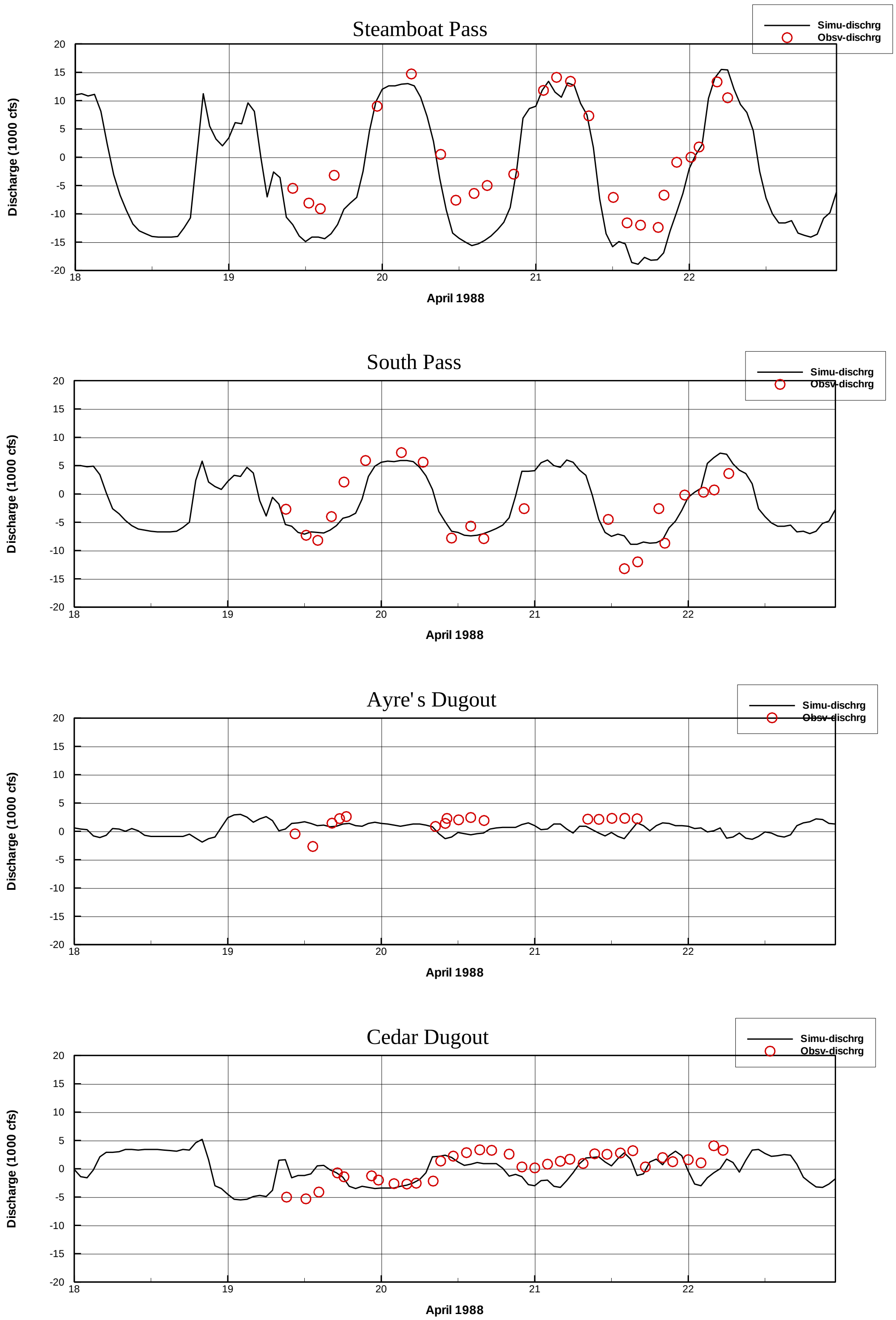

Figure 16. Simulated (red line) and observed (open symbols) discharges for a) Steamboat Pass, b) South Pass, c) Ayre's Dugout, and d) Cedar Dugout for April 18-23, 1988 in the Guadalupe Estuary.

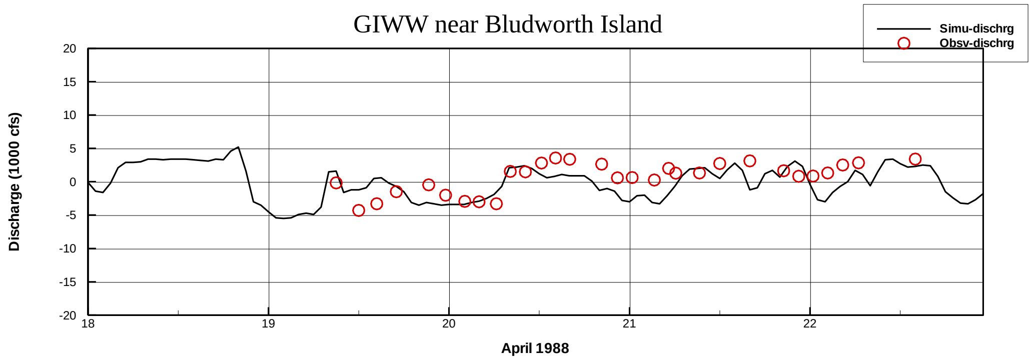

Figure 17. Simulated (red line) and observed (open symbols) discharges for GIWW near Bludworth Island for April 18-23, 1988 in the Guadalupe Estuary.

Figures 18-20 show results for velocity at 11 locations, and Figure 21 shows discharge results at four locations in Aransas Bay during August 1988. Simulated velocities are representative of observed velocities at most locations, except in the GIWW near Bludworth Island and at Cedar Dugout where the model tends to over-predict water velocities. Discharge simulations in the Mission-Aransas Estuary were representative in the Lydia Ann Channel and Cedar Dugout, but were not as representative at the Copano Causeway or in the GIWW near Bludworth Island (Figure 21).

Figures 22 and 23 show results for velocity at eight locations, and Figures 24 and 25 show discharge results for seven locations in Aransas Bay during late September and early October 1995. Velocity simulations for this period of time were well representative of observed measurements at the eight locations in the Mission-Aransas Estuary. Although few observed measurements are available to compare to simulated discharges at several sites, overall the model represents discharges in the system.

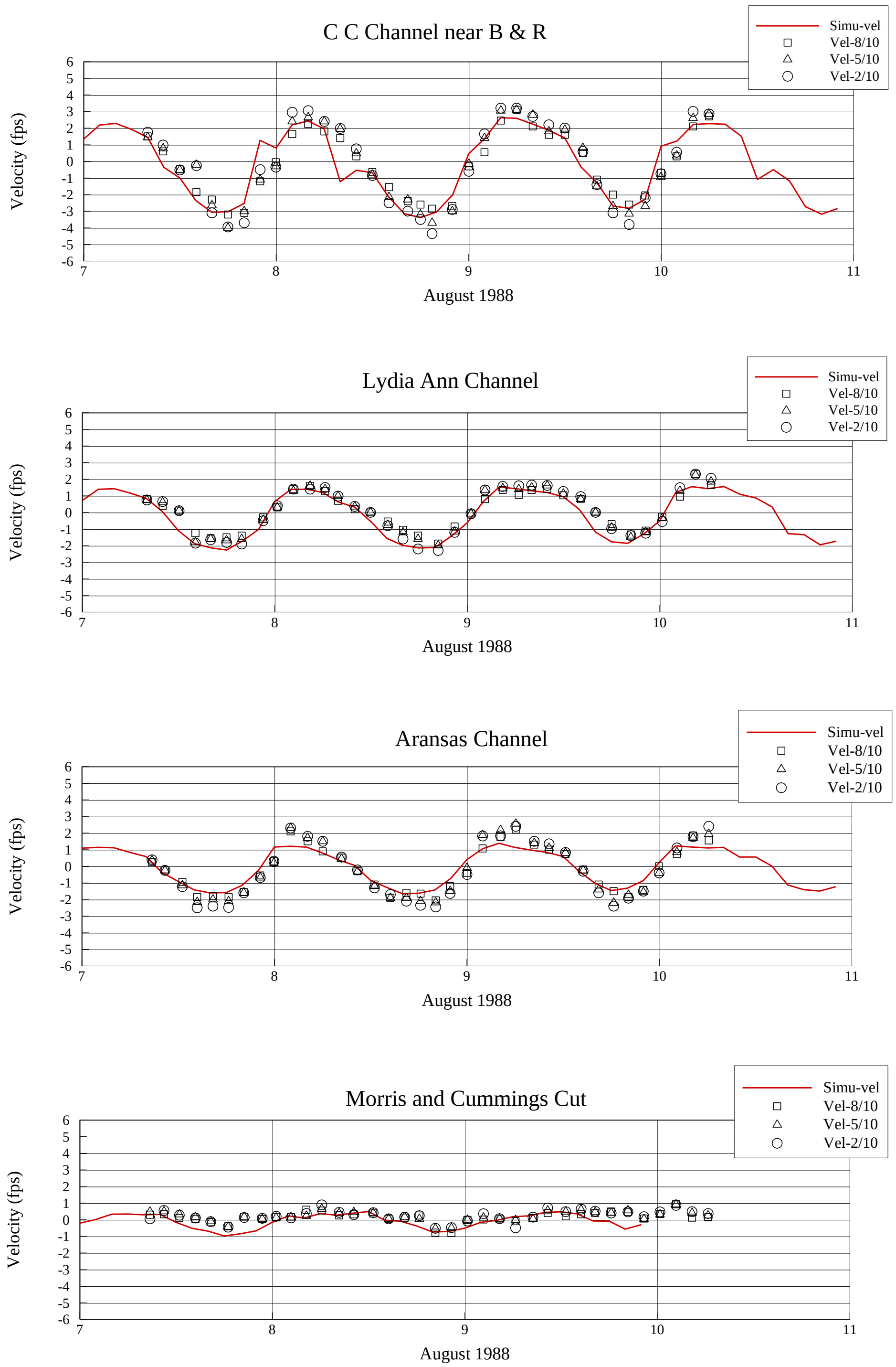

Figure 18. Simulated (red line) and observed (open symbols) velocities for a) Corpus Christi Channel near B&R, b) Lydia Ann Channel, c)Aransas Channel, and d) Morris and Cummings Cut for August 7-11, 1988 in the Mission-Aransas Estuary. Velocity measurements were collected at three depths, 2/10th (o), 5/10th (△), and 8/10th (□) of water depth.

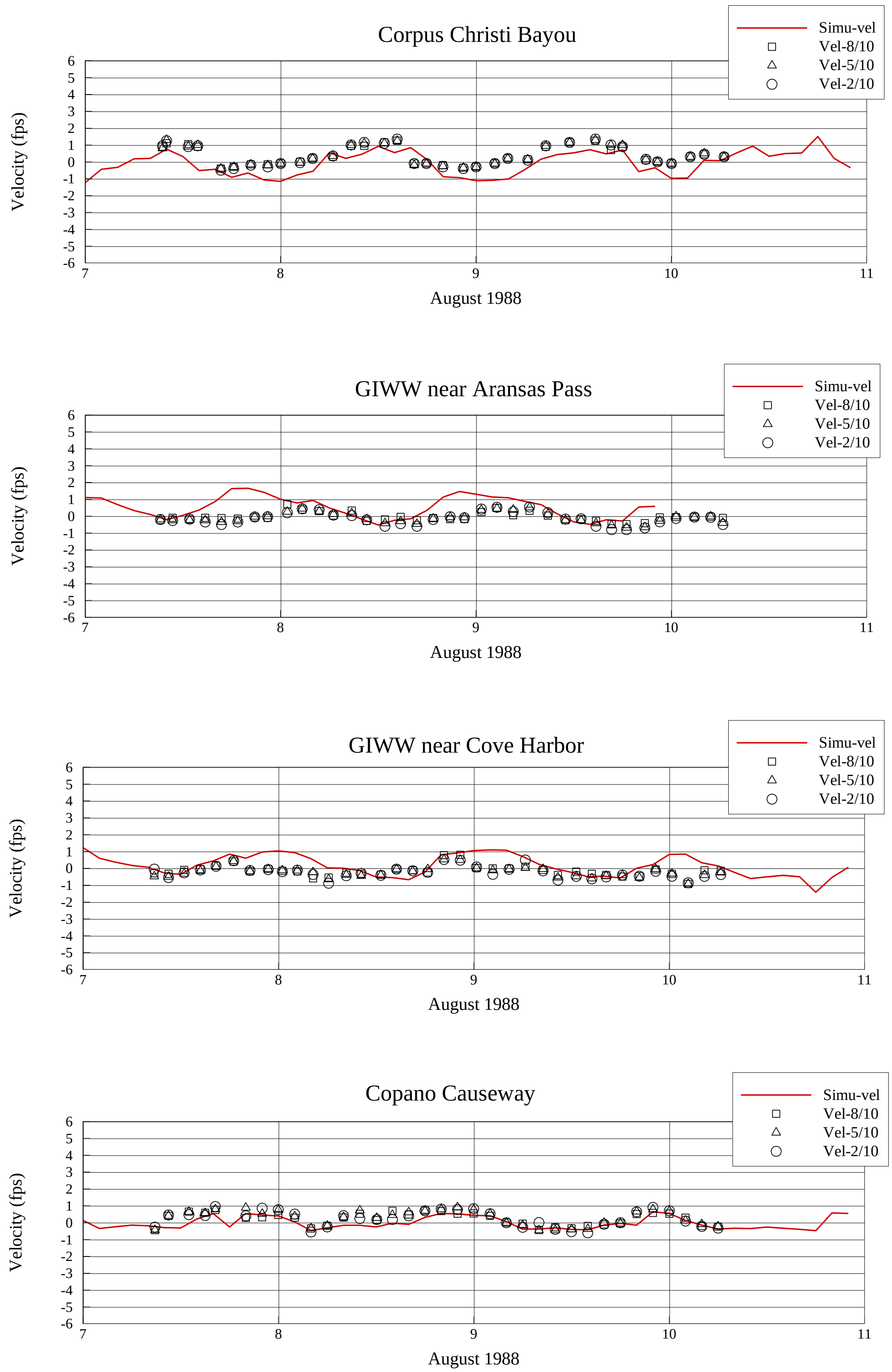

Figure 19. Simulated (red line) and observed (open symbols) velocities for a) Corpus Christi Bayou, b) GIWW near Aransas Pass, c) GIWW near Cove Harbor, and d) Copano Causeway for August 7-11, 1988 in the Mission-Aransas Estuary. Velocity measurements were collected at three depths, $2/10^{th}$ (o), $5/10^{th}$ (△), and $8/10^{th}$ (□) of water depth.

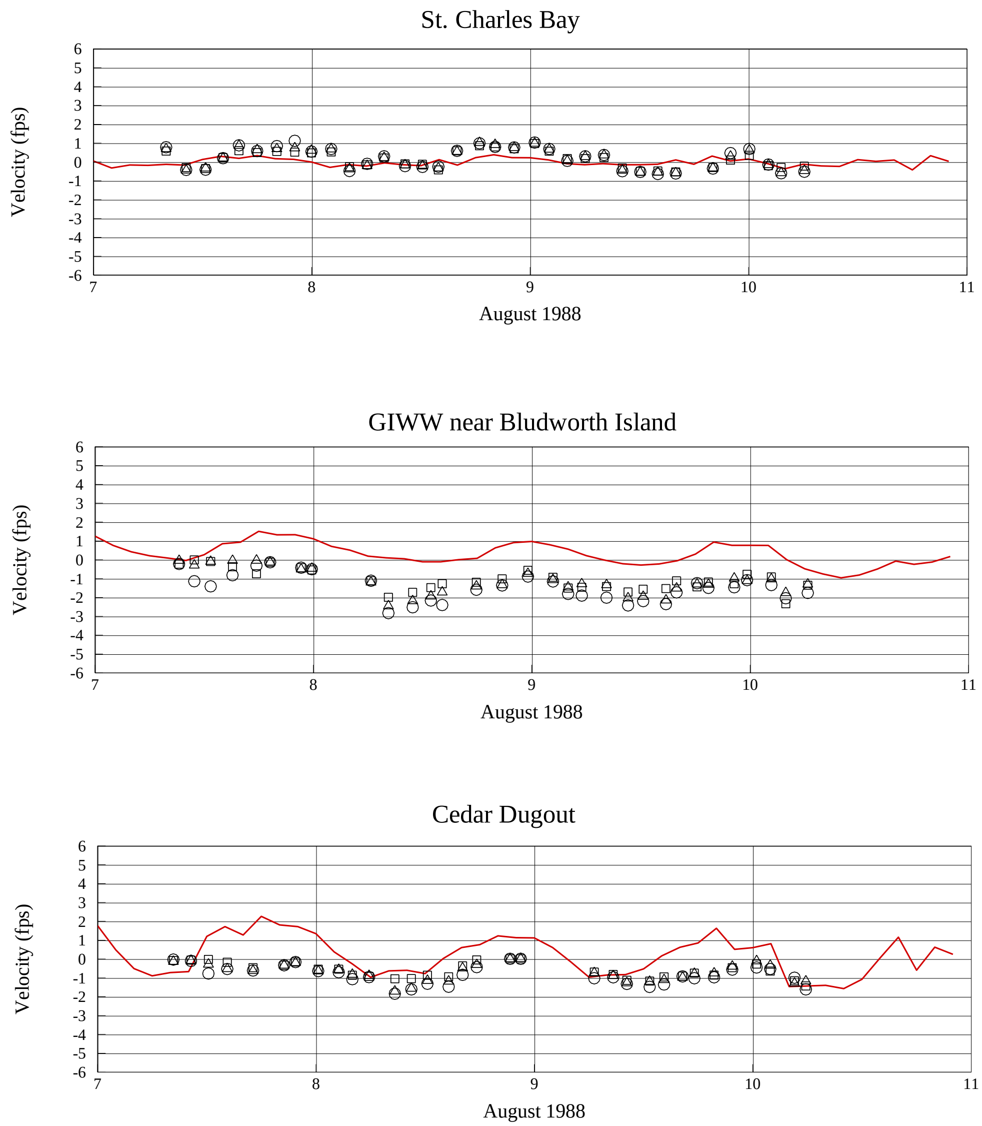

Figure 20. Simulated (red line) and observed (open symbols) velocities for a) St. Charles Bay, b) GIWW near Bludworth Island, and c) Cedar Dugout for August 7-11, 1988 in the Mission-Aransas Estuary. Velocity measurements were collected at three depths, 2/10th (o), 5/10th (△), and 8/10th (□) of water depth.

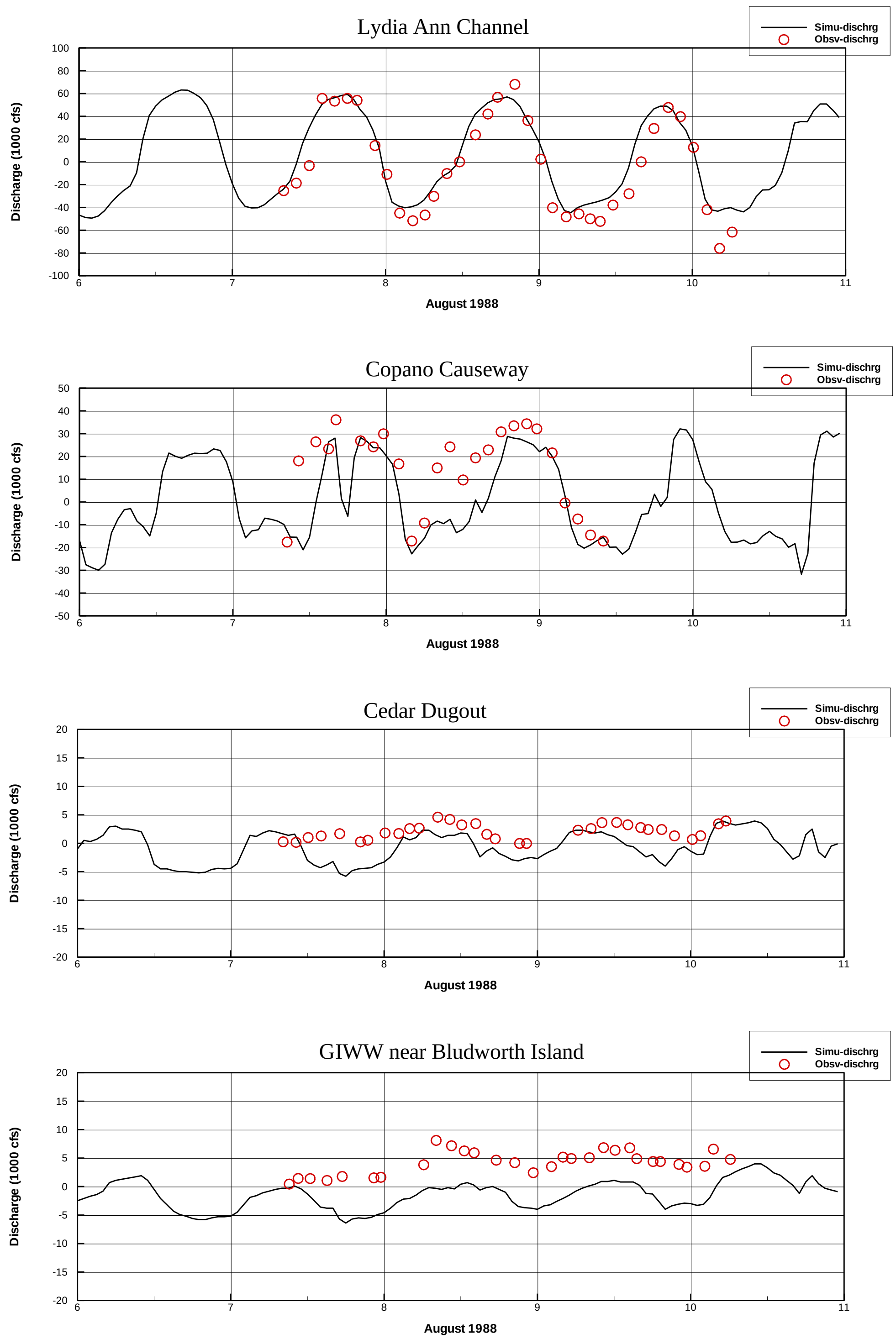

Figure 21. Simulated (red line) and observed (open symbols) discharges for a) Lydia Ann Channel, b) Copano Causeway, c) Cedar Dugout, and d) GIWW near Bludworth Island for August 7-11, 1988 in the Mission-Aransas Estuary.

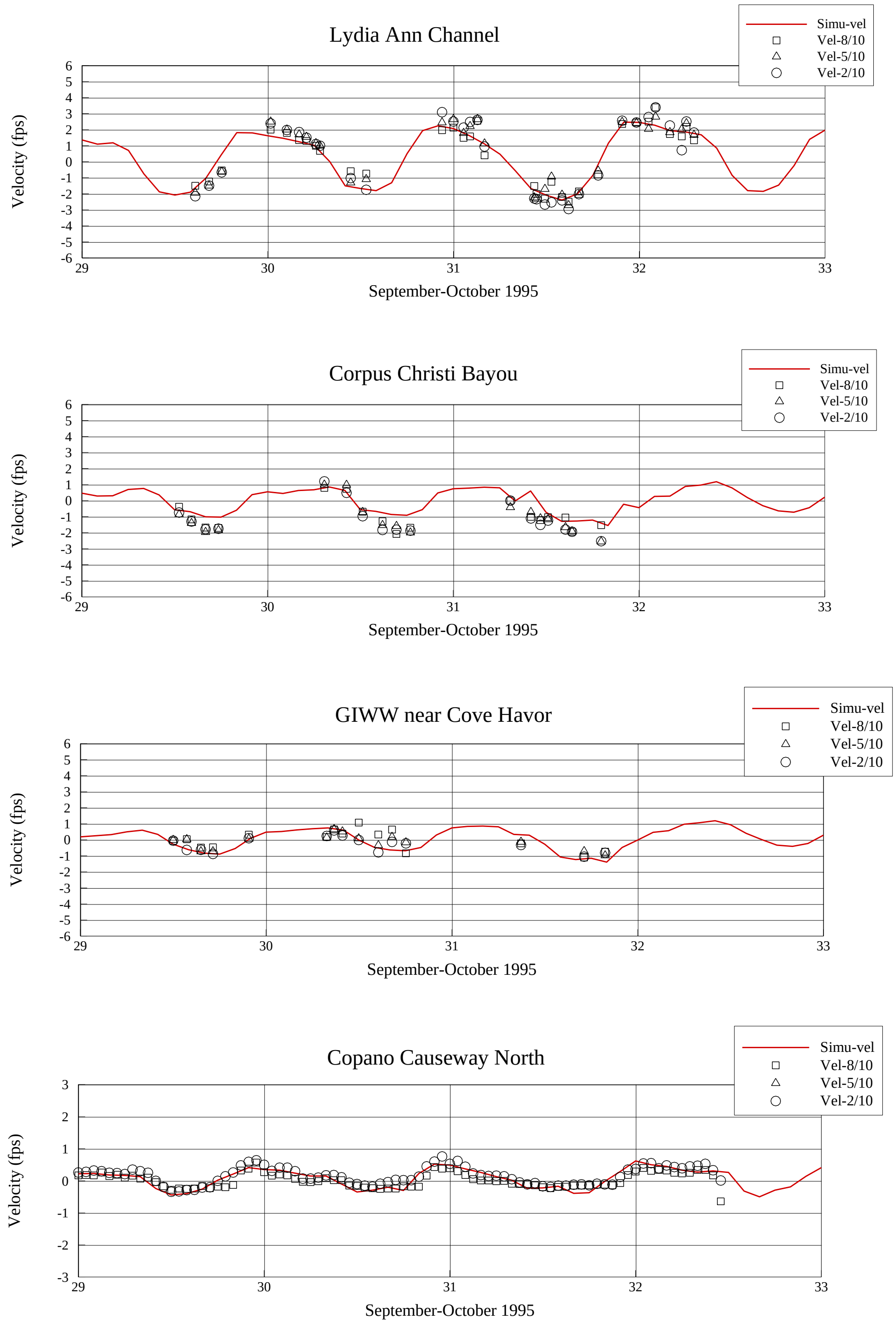

Figure 22. Simulated (red line) and observed (open symbols) velocities for a) Lydia Ann Channel, b) Corpus Christi Bayou, c) GIWW near Cove Harbor, and d) Copano Causeway North for September 29 - October 2, 1995 in the Mission-Aransas Estuary. Velocity measurements were collected at three depths, 2/10th (o), 5/10th (△), and 8/10th (□) of water depth.

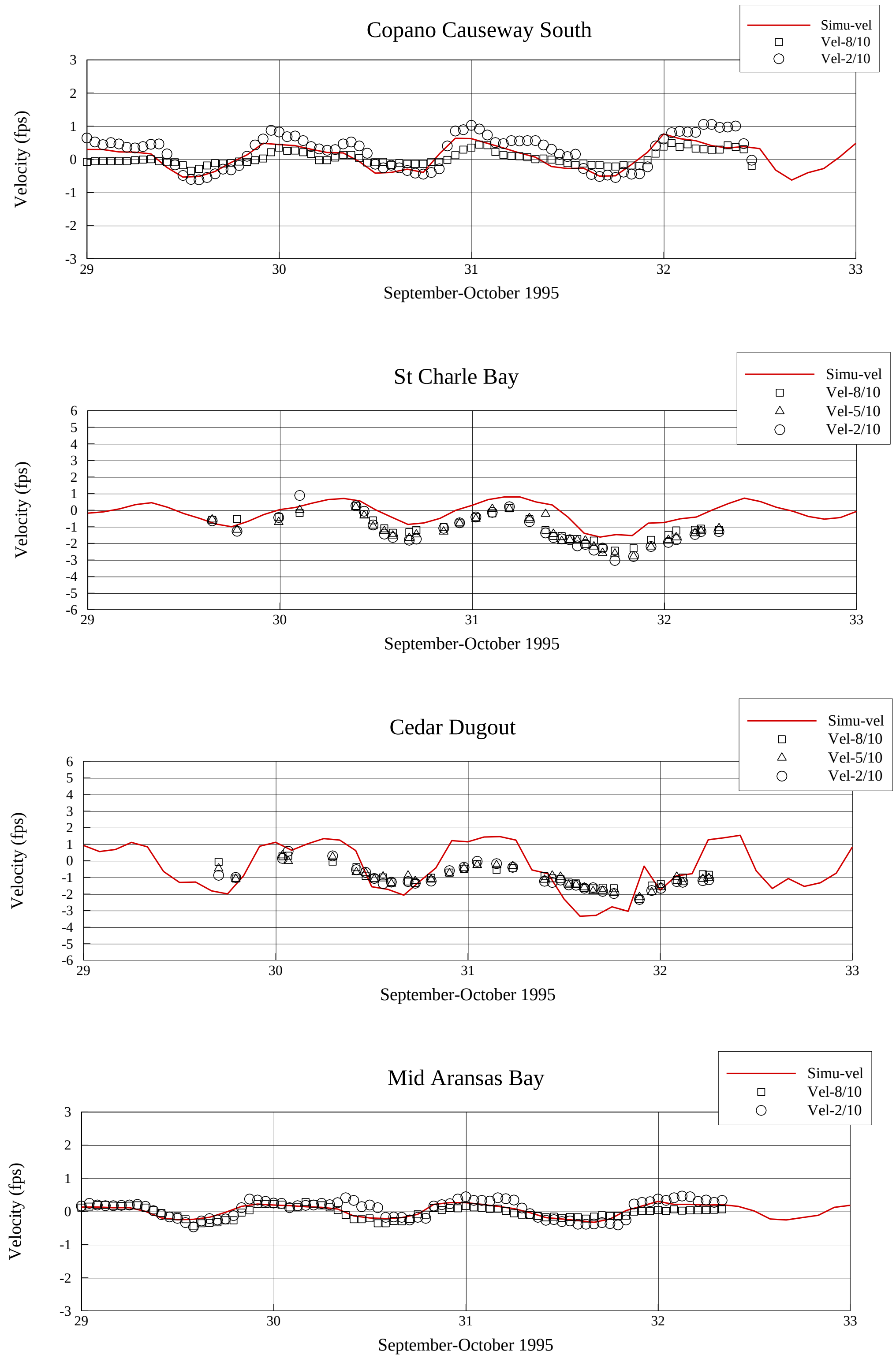

Figure 23. Simulated (red line) and observed (open symbols) velocities for a) Copano Causeway South, b) St. Charles Bay, c) Cedar Dugout, and d) Mid-Aransas Bay for September 29 - October 2, 1995 in the Mission-Aransas Estuary. Velocity measurements were collected at three depths, 2/10th (o), 5/10th (△), and 8/10th (□) of water depth.

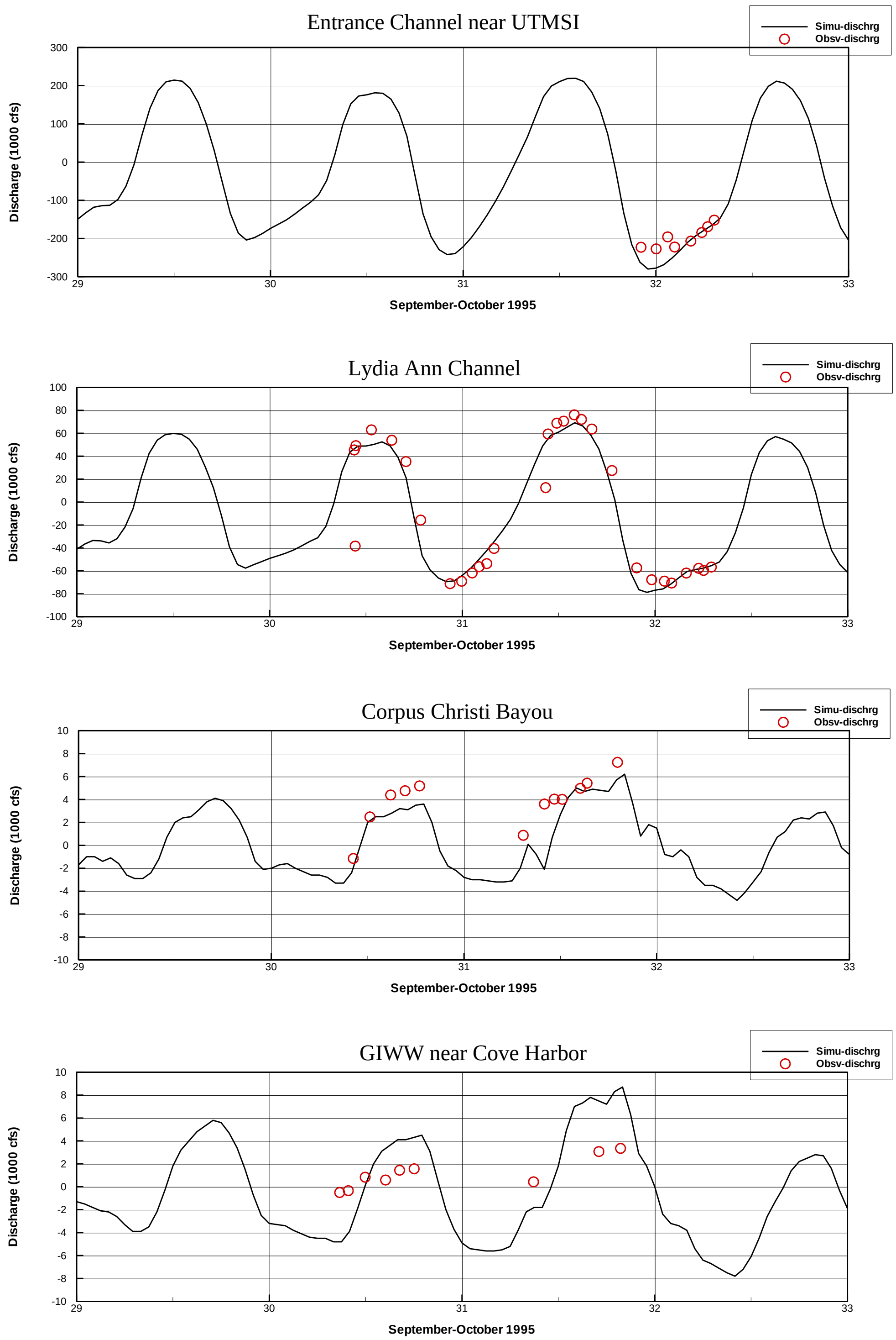

Figure 24. Simulated (red line) and observed (open symbols) discharges for a) Entrance Channel near the University of Texas Marine Science Institute, b) Lydia Ann Channel, c) Corpus Christi Bayou, d) GIWW near Cove Harbor, and d) Copano Causeway North for September 29 - October 2, 1995 in the Mission-Aransas Estuary.

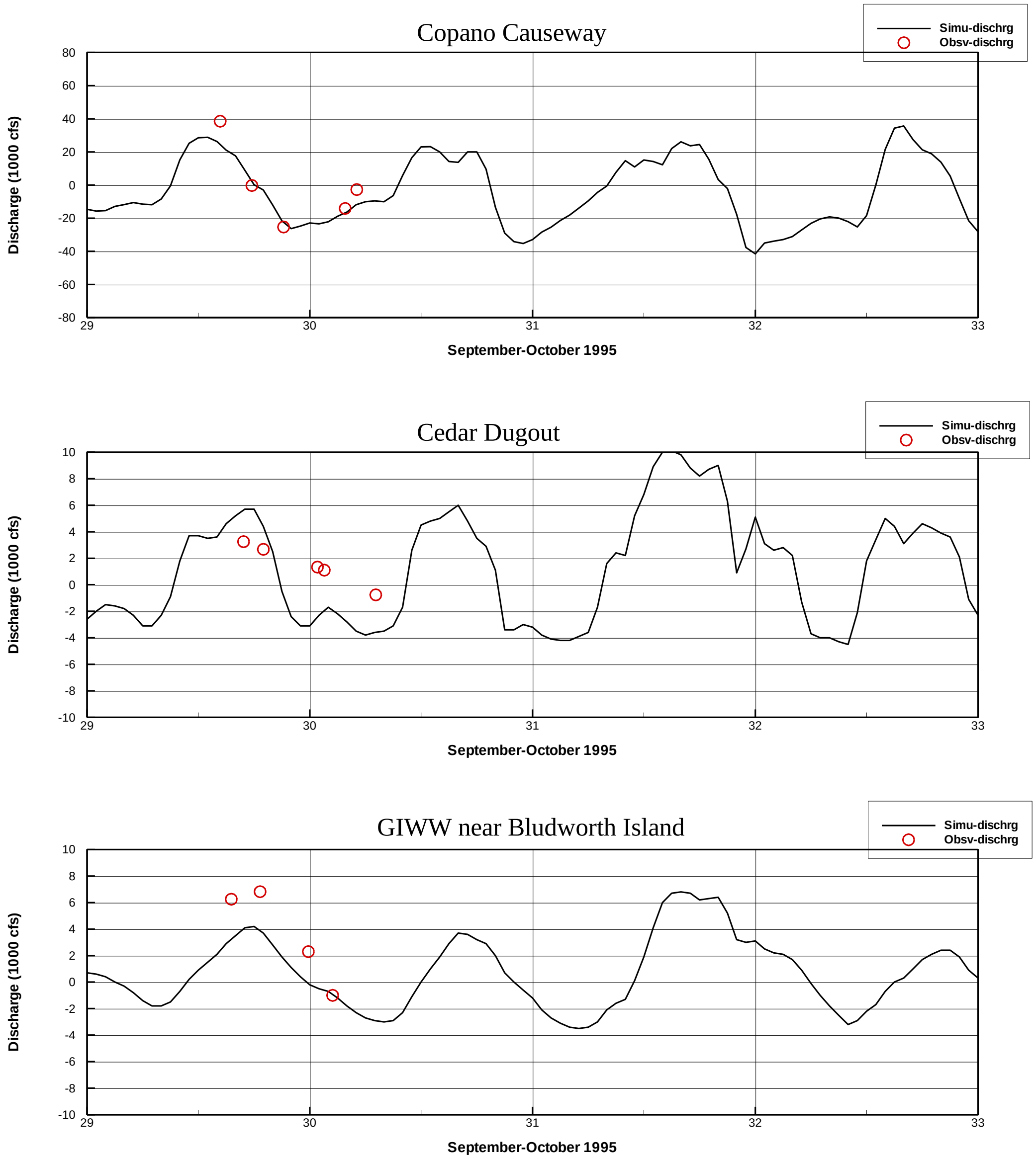

Figure 25. Simulated (red line) and observed (open symbols) discharges for a) Copano Causeway, b) Corpus Christi Bayou, and c) Cedar Dugout for September 29 - October 2, 1995 in the Mission-Aransas Estuary.

Water Surface Elevation Results

Figures 26-28 show generally good agreement between the model simulations for water surface (tidal) elevations and observed data over a three year period from 1997-1999 at the Seadrift and Copano Causeway locations. (Note: For ease of comparison, graphical presentation of observed tides was shifted by +1ft. from the original measurement.)

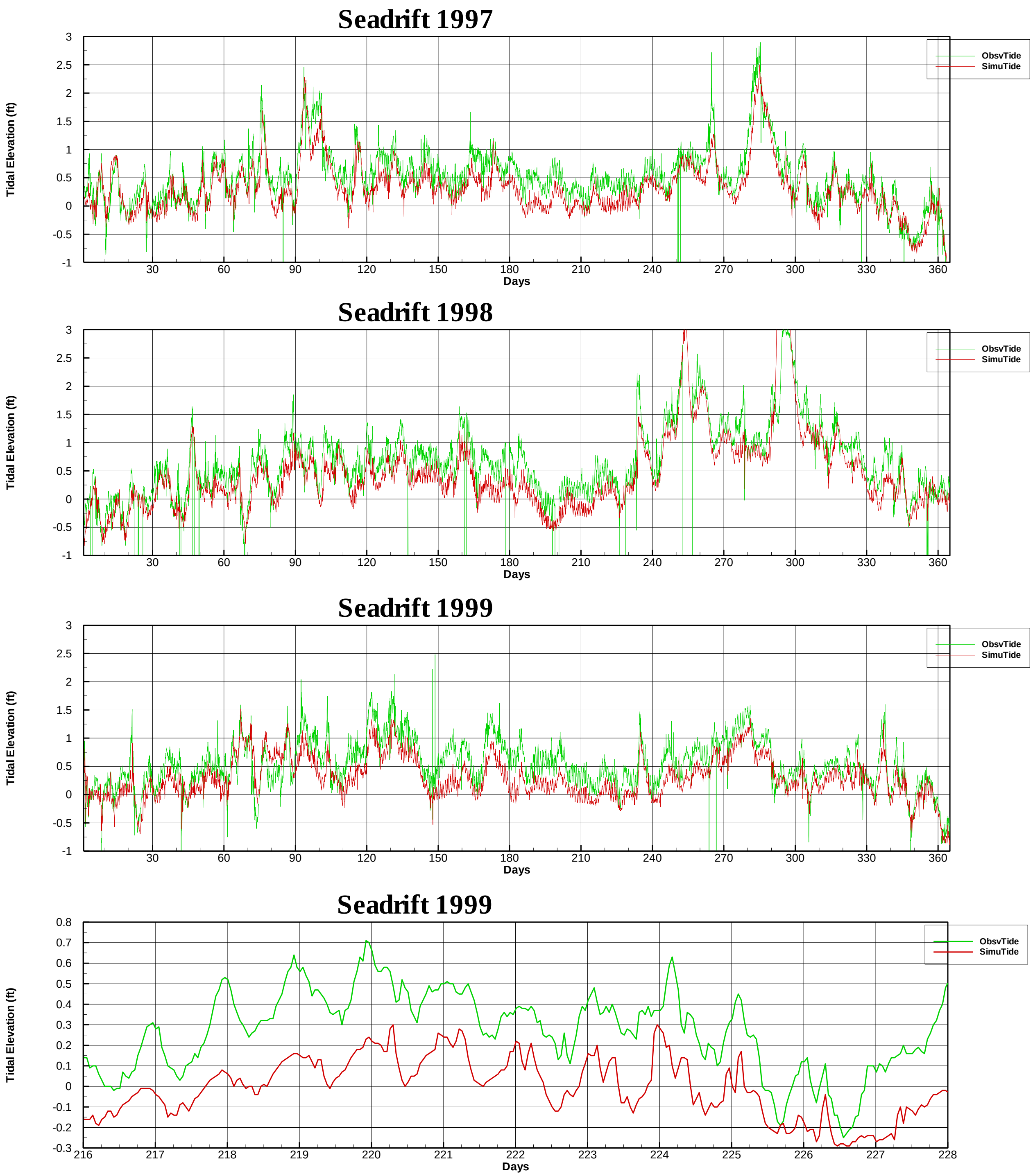

Figure 26. Time-series plots for observed (green) and simulated (red) hourly tide data near Seadrift for three years, 1997, 1998, and 1999. The bottom plot shows a 12-day period during 1999 to better compare the phase (timing) of simulated and observed tidal elevations. *Note*: For ease of comparison, graphical presentation of observed tides was shifted by +1 ft. from the original measurement.

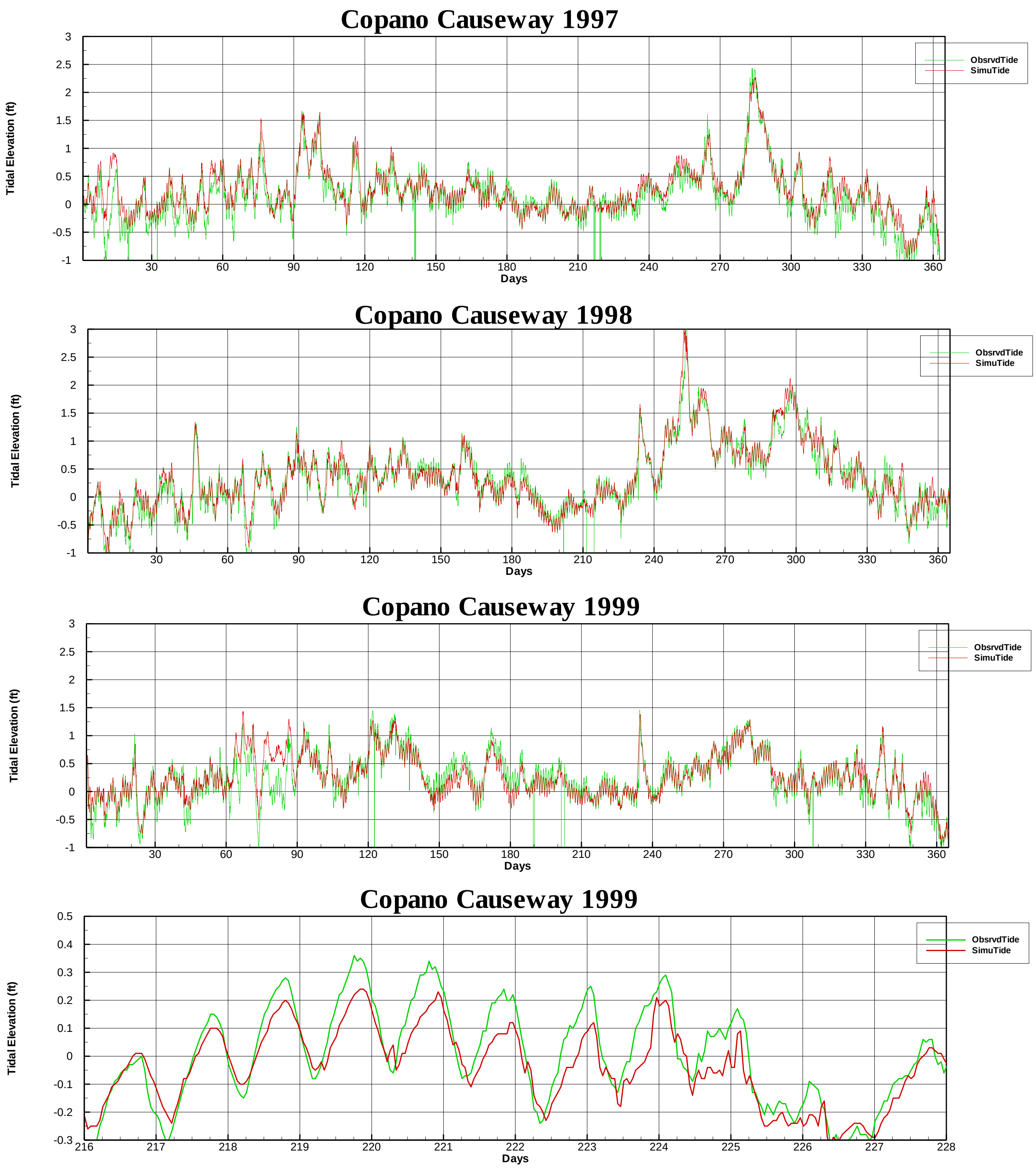

Figure 27. Time-series plots for observed (green) and simulated (red) hourly tide data near the Copano Causeway for three years, 1997, 1998, and 1999. The bottom plot shows a 12-day period during 1999 to better compare the phase (timing) of simulated and observed tidal elevations. *Note*: For ease of comparison, graphical presentation of observed tides was shifted by +1 ft. from the original measurement.

A scatter plot of the above results presents another opportunity to compare observed and simulated tidal elevations (Figure 28). In addition, Table 3 shows summary statistics for hourly tides in each of the three years, showing each year separately; whereas, Table 4 shows summary statistics for the daily tidal elevations across all three years.

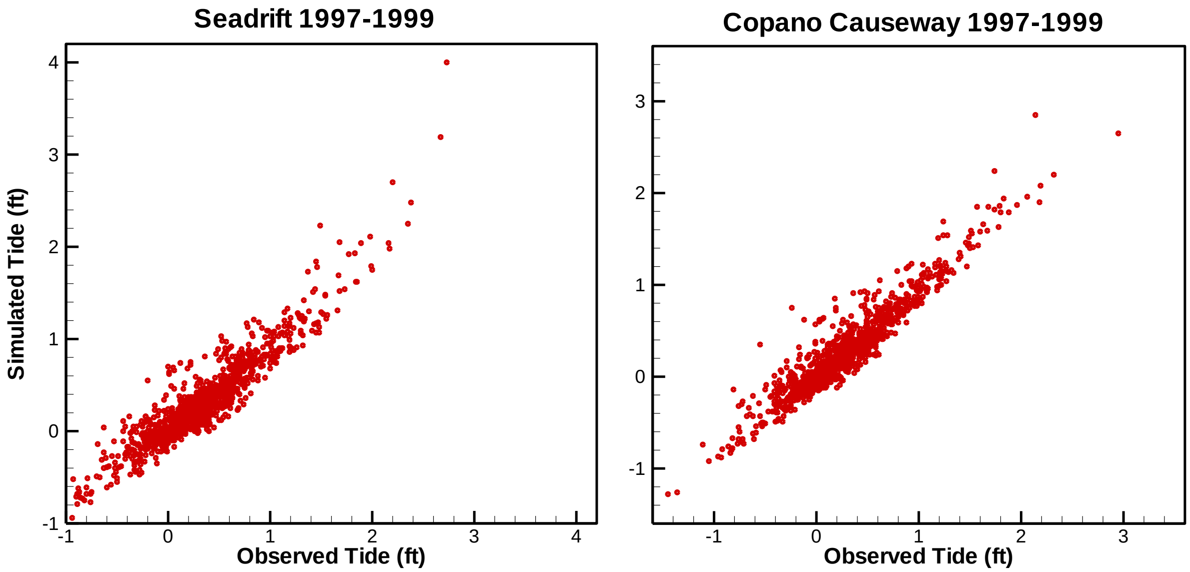

Figure 28. Scatter plots of observed versus simulated daily tidal elevations for a three-year period, 1997-1999, at Seadrift in San Antonio Bay and Copano Causeway in the Mission-Aransas Estuary.

Table 3. Statistics for hourly tidal elevations over three years, 1997-1999.

Location	Year	Days	n	r^2	RMSE(ft)
Seadrift	1997	363	8,701	0.82	0.21
Seadrift	1998	347	8,332	0.70	0.44
Seadrift	1999	365	8,749	0.70	0.24
Copano Causeway	1997	362	8,691	0.84	0.20
Copano Causeway	1998	362	8,683	0.90	0.19
Copano Causeway	1999	363	8,711	0.74	0.22

*RMSE is the root mean square error.

Table 4 Statistics for daily tidal elevations for a three-year period, 1997-1999.

Location	Days	r^2	RMSE(ft)	Nash-Sutcliffe
Seadrift	1,090	0.76	0.28	0.70
Copano Causeway	1,092	0.89	0.15	0.89

*RMSE is the root mean square error.
** Nash-Sutcliffe Efficiency Criterion (*E*) describes model performance, where E=1.0 represents a match between model output and observed data and E<0 suggests the model is a poor predictor.

Salinity Results

Figures 29 to 32 show that the model is able to capture major salinity trends in the system reasonably well. Summary statistics, comparing simulated to observed salinities, are shown in Table 5. Figures 29-36 show that, for most of the system, the model captures salinity trends, though short-term fluxes are less well represented.

Near the Seadrift site in San Antonio Bay the model captures overall salinity trends, as well as important transitions from high to low salinities and vice versa, such as in 1991 and 1992 (Figure 29). Figure 30 shows a scatter plot comparison of these same results. In Mesquite Bay, simulated salinities were compared to four years of datasonde data (Figures 31 and 32). While the model simulates salinity trends in Mesquite Bay, the model is less variable and does not predict the higher salinity fluctuations seen in the observed data.

Table 5. Statistics comparing simulated versus observed daily salinities during the period 1987-1997 at four locations in the Guadalupe and Mission-Aransas estuaries. The quantity of observed data available for comparison varies among sites depending on availability.

Location	Days	r^2	RMSE (ppt)	Nash-Sutcliffe	Average Salinity (ppt)		DiffSal
					Simulated	Observed	
Seadrift	2,976	0.78	4.1	0.77	12.4	12.9	-0.5
Mesquite	916	0.90	3.4	0.89	19.5	20.2	-0.7
Copano Causeway	900	0.68	5.8	0.61	21.8	19.8	1.9
Aransas	1,812	0.75	3.5	0.75	24.3	24.4	-0.1

*RMSE is the root mean square error.
** Nash-Sutcliffe Efficiency Criterion (*E*) describes model performance, where E=1.0 represents a match between model output and observed data and E<0 suggests the model is a poor predictor.

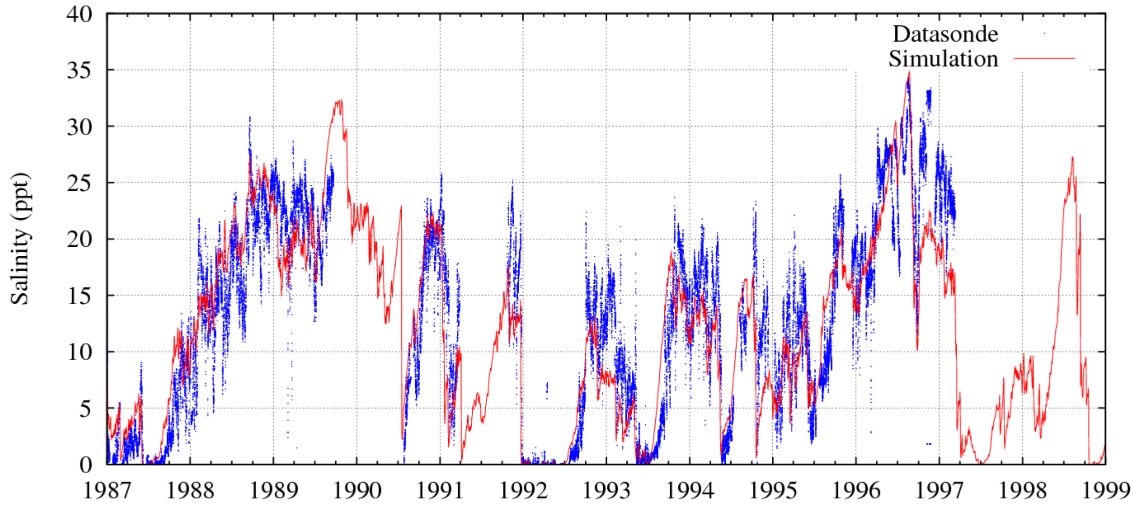

Figure 29. Observed (blue) versus simulated (red) salinities at the Seadrift site in San Antonio Bay for a period including 1987 through 1997, with additional simulated salinities up to 1999.

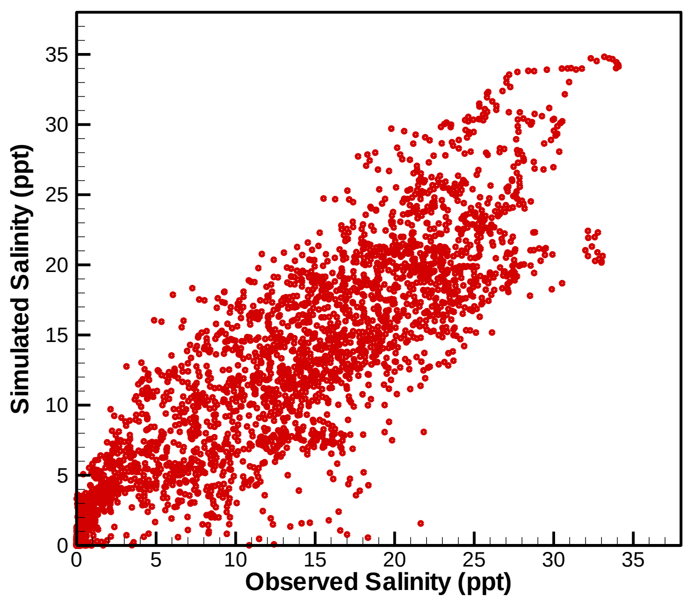

Figure 30. Scatter plot comparing simulated to observed daily salinities at the Seadrift site in San Antonio Bay for the period 1987-1997.

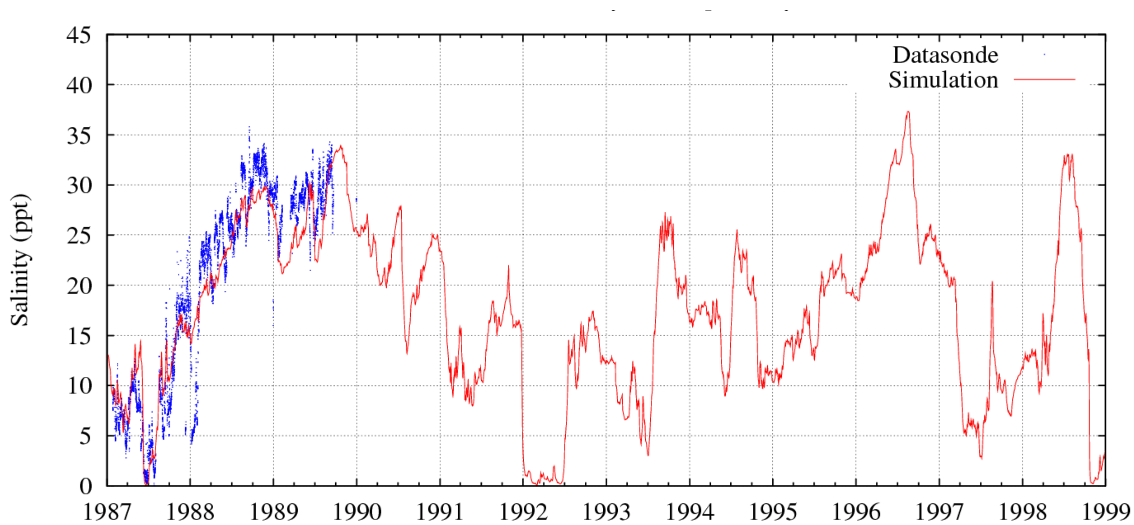

Figure 31. Observed (blue) versus simulated (red) salinities in Mesquite Bay for a period including 1987 to 1990, with additional simulated salinities up to 1999.

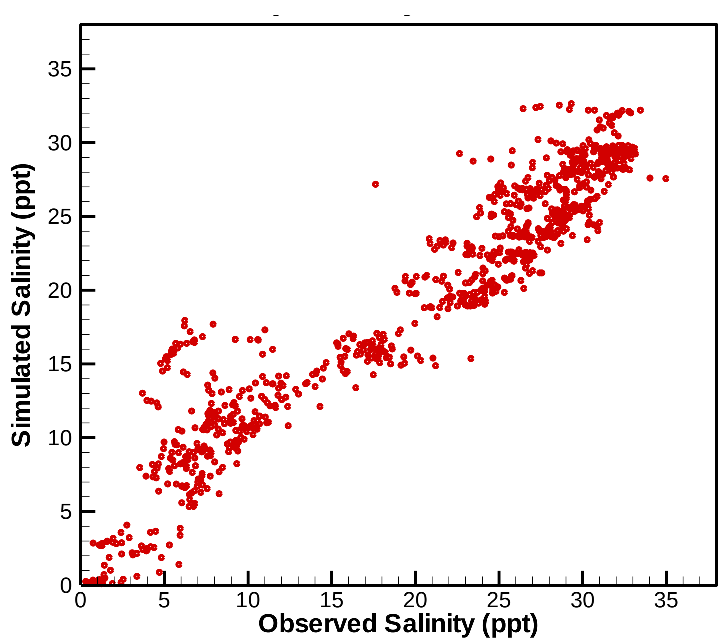

Figure 32. Scatter plot comparing simulated to observed daily salinities in Mesquite Bay for the period 1987-1989.

Salinity simulations for the Copano Causeway location, between Copano and Aransas bays, (Figures 33 and 34) as well in mid-Aransas Bay (Figures 35 and 36), are more representative of observed salinities, in part because salinity is less variable at these sites. Nonetheless, modeled salinities depart from observed salinities in some instances, though longer-term trends are captured.

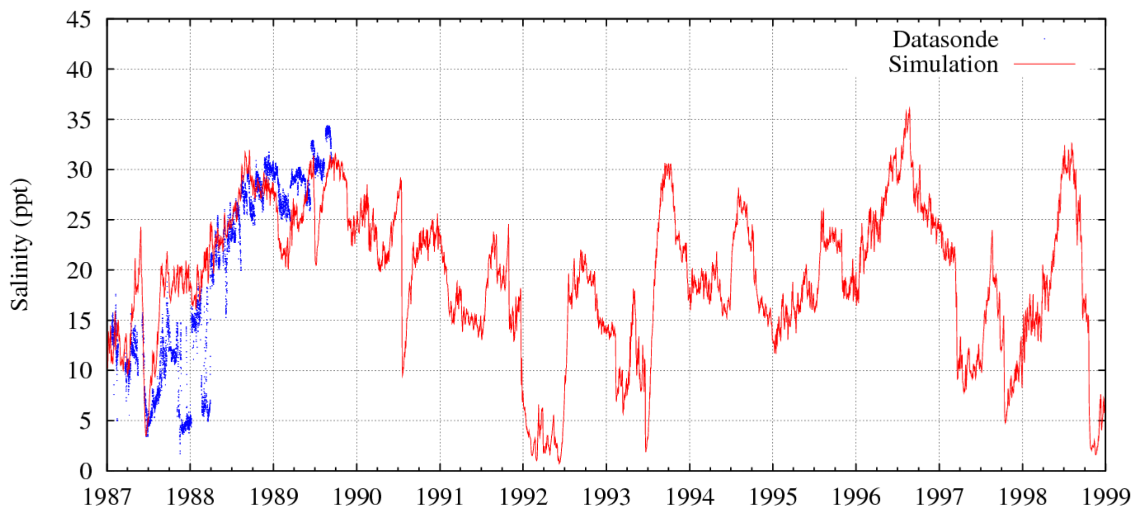

Figure 33. Observed (blue) versus simulated (red) salinities at the Copano Causeway between Copano and Aransas bays for a period including 1987 to 1990, with additional simulated salinities up to 1999.

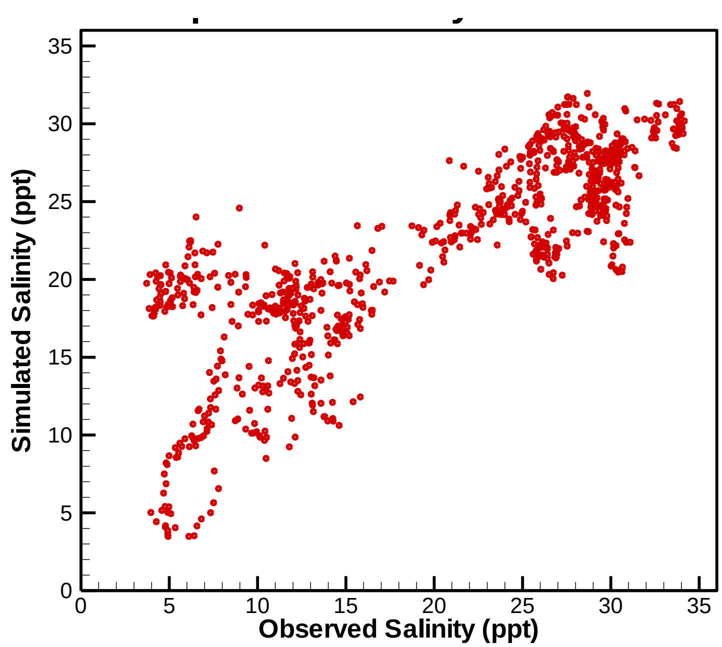

Figure 34. Scatterplot comparing simulated to observed daily salinities at the Copano Causeway for the period 1987-1989.

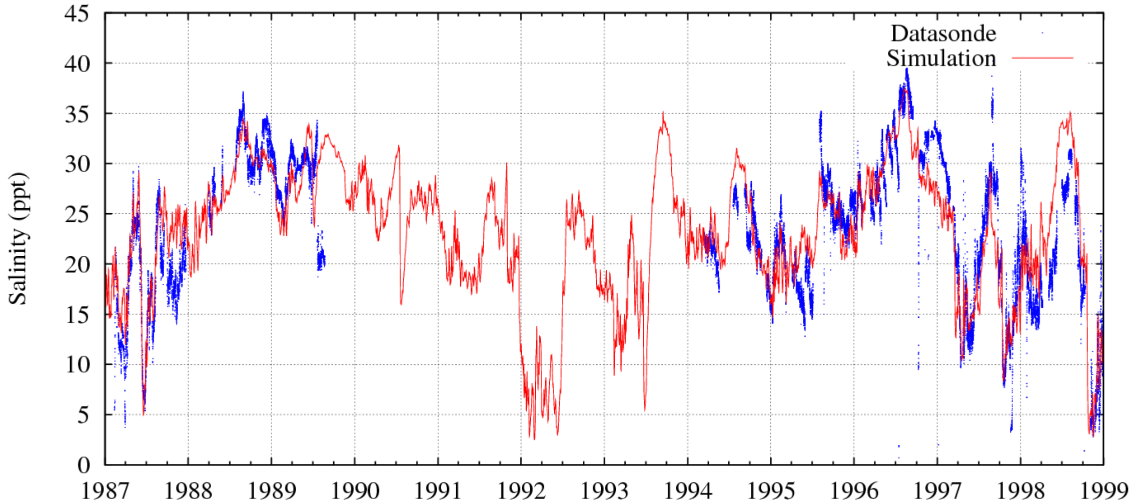

Figure 35. Observed (blue) versus simulated (red) salinities in mid-Aransas Bay for a period including 1987 to 1999, with additional simulated salinities between 1990 and 1994.

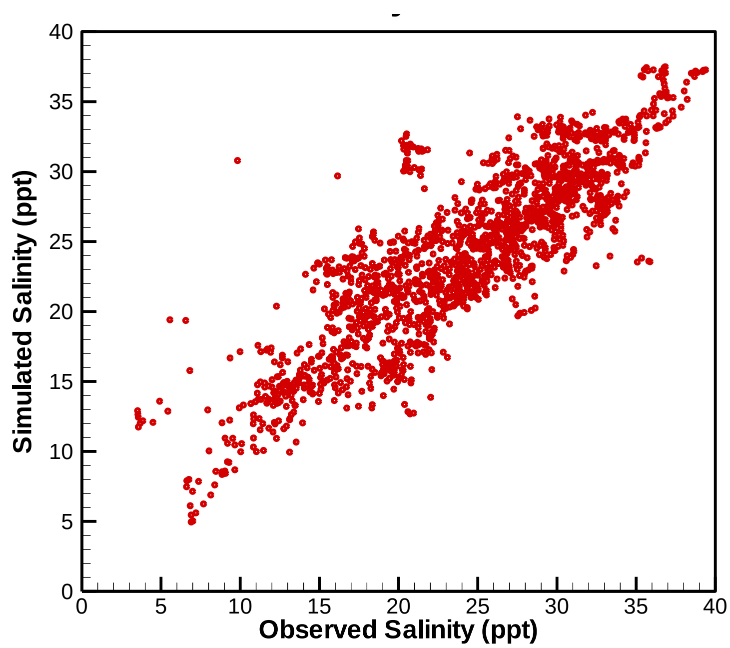

Figure 36. Scatterplot comparing simulated to observed daily salinities in mid-Aransas Bay for the periods, 1987-1989 and 1994-1997.

Model Validation

To verify the validity of the calibrated Guadalupe and Mission-Aransas TxBLEND model for salinity, a second model run was conducted to simulate salinities for the period 1999-2009. These salinity values then were compared to observed salinities obtained from the TWDB Datasonde Program for two monitoring sites: San Antonio Bay at Seadrift (2001-2010) and Aransas Bay at the mid-Aransas location (1999-2001; Figure 8). In addition, data from the Guadalupe-Blanco River Authority monitoring station (GBRA-1), located near Dagger Point in San Antonio Bay and which became operational in 2004, was included in this validation exercise.

TxBLEND model validation results also were compared to point-measurement data obtained from TPWD's Coastal Fisheries database, the TCEQ's Surface Water Quality Monitoring database, or the Texas Department of State Health Services (TDSHS) Shell Fish Safety Program for sites located near to the established monitoring stations presented earlier. For these datasets, data from point measurements collected within the vicinity of the datasonde site were aggregated to represent the local conditions. Their corresponding grid cell or latitude and longitude information is provided within the figures below. Because the TDSHS reports data to the TCEQ, the two databases share many data points. However for some locations, TCEQ contains more data than TDSHS and vice-versa. Therefore, either TCEQ or TDSHS data was selected to represent a site. Sites were chosen based on their closeness to the TWDB Datasondes, as well as based on the number of data points available for the site. For the Mesquite Bay and Copano Causeway locations, point measurement data was the only data available for use in the model validation exercise. Figures 26 through 35 show comparisons of simulated and observed salinities, both as time series plots and as scatter plots, for five sites in the Guadalupe and Mission-Aransas estuaries for the period 1999-2009. Table 4 lists summary statistics for these salinity comparisons.

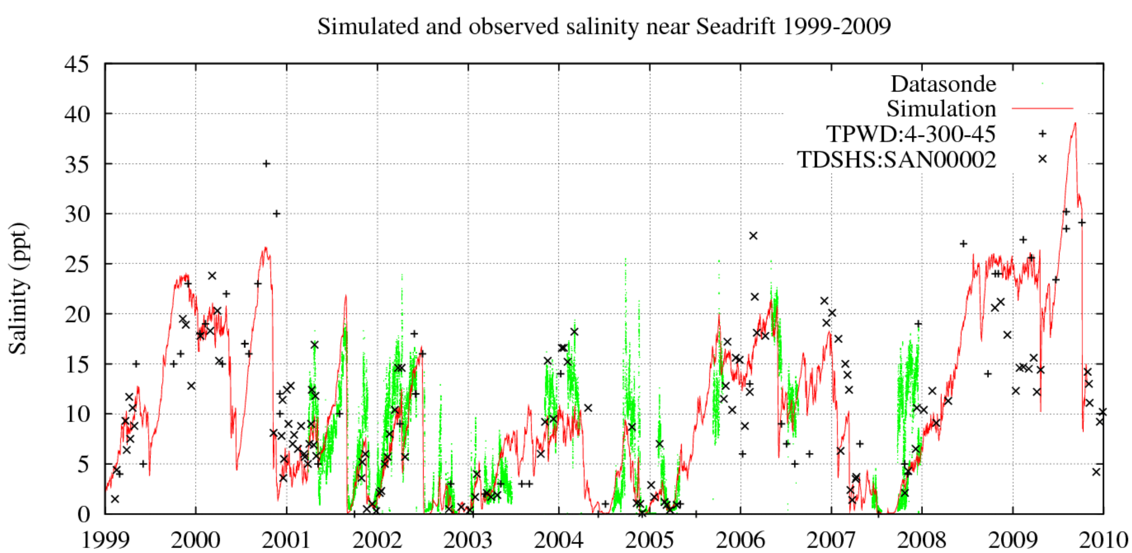

Figure 37. Simulated (red) and observed (green, + or x) salinities near Seadrift for the period 1999-2009. TWDB's Seadrift datasonde (green) is located at 28.3814 N, -96.7425 W. Data collected by TPWD (+) was from grid cell 4-300-45 located at 28.3897 N, -96.7391W. Data collected at the TDSHS (x) SAN00002 site was located at 28.3847N, -96.7283 W.

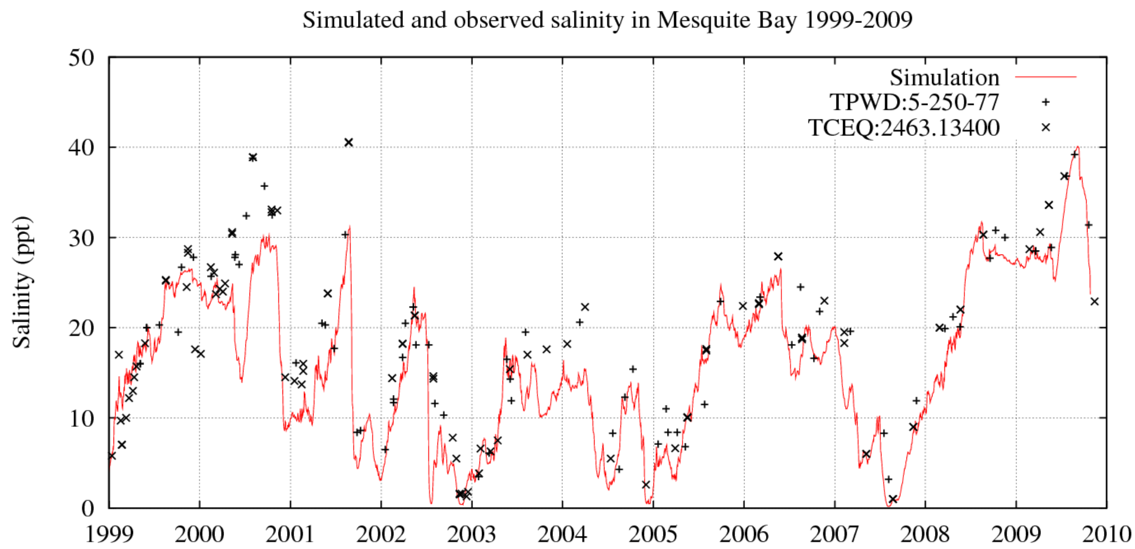

Figure 38. Simulated (red) and observed (green, + or x) salinity in Mesquite Bay for the period 1999-2009. TWDB's Mesquite Bay datasonde was located at 28.16 N, -96.8511 W. Data collected by TPWD (+) was from grid cell 4-300-45 at 5-250-77 located at 28.1571 N,-96.8747 W. Data collected at the TCEQ (x) 2463.13400 site was located at 28.1633N,-96.8617.

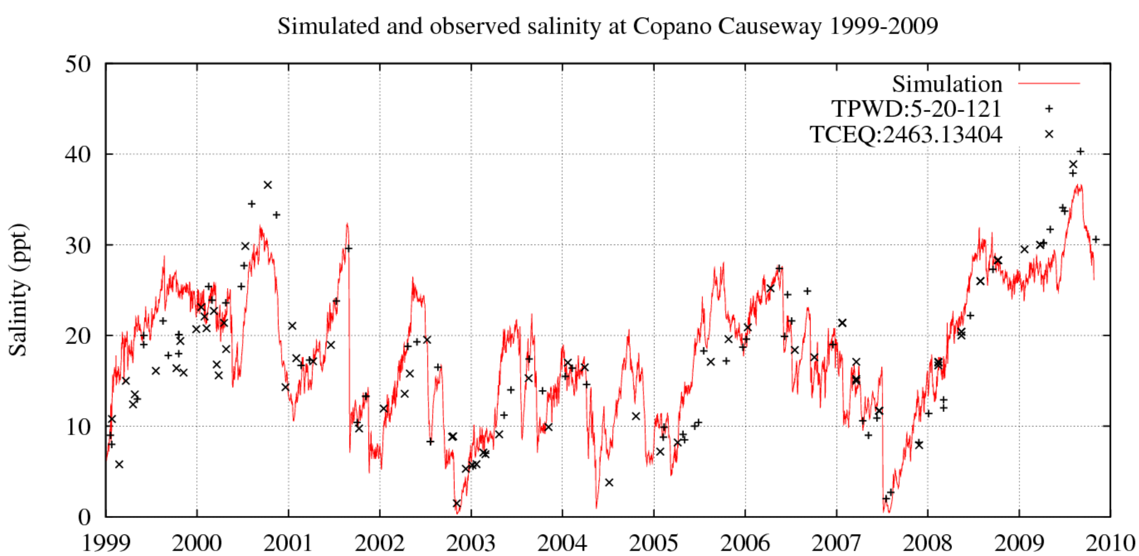

Figure 39. Simulated (red) and observed (+ or x) salinities at the Copano Causeway for the period 1999-2009. The TWDB Copano datasonde was located at 28.1206 N, -97.0233 W but was not active during this period. Data collected by TPWD (+) was from grid cell 5-20-121 located at 28.1256N, -97.0069 W. Data collected at the TCEQ (x) 2472.13404 site was located at 28.1137 N, -97.0259 W.

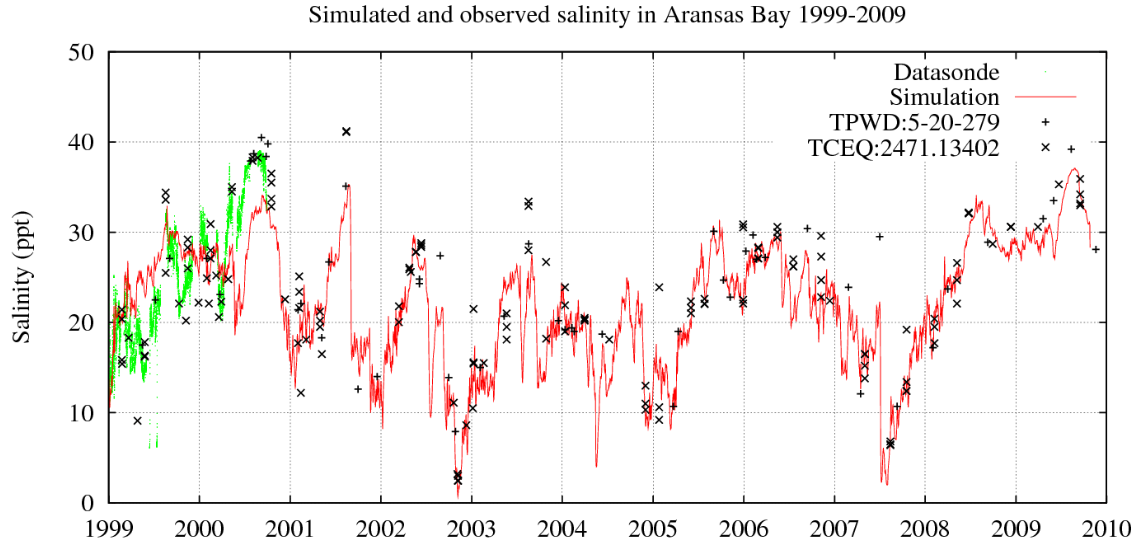

Figure 40. Simulated (red) and observed (green, + or x) salinities at the Aransas Bay for the period 1999-2009. The TWDB Aransas Bay datasonde (green) was located at 27.9892 N, -97.0094 W. Data collected by TPWD (+) was from grid cell 5-20-279 located at 27.9888 N, -96.9889 W. Data collected at TCEQ (x) 2471.13402 site was located at 28.0014 N, -97.0278 W.

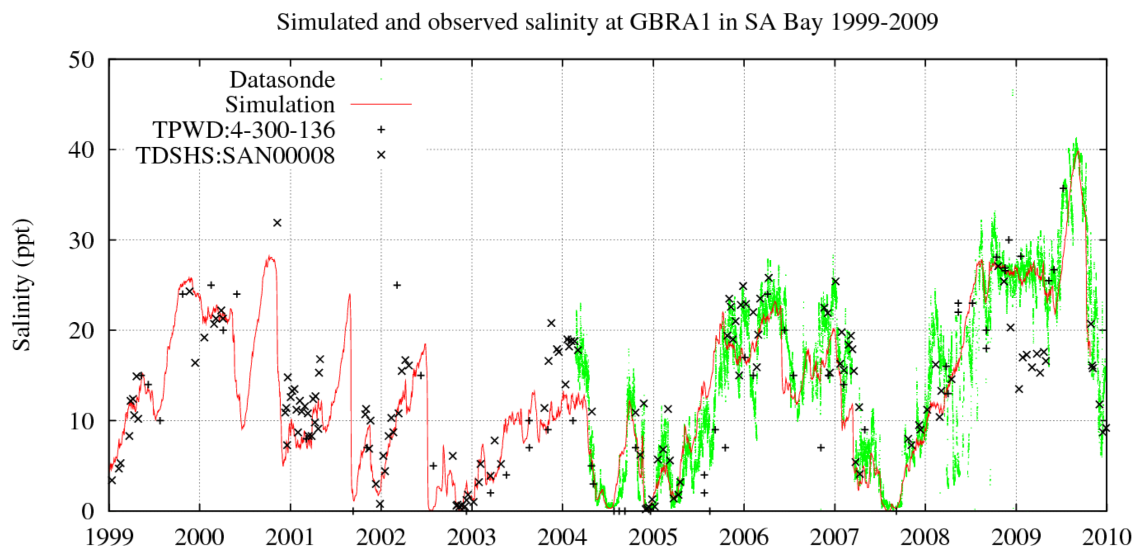

Figure 41. Simulated (red) and observed (green, + or x) salinities at the GBRA-1 site in San Antonio Bay for the period 1999-2009. The GBRA-1 station (green) is located at 28.2597 N, -96.7736 W. Data collected by TPWD (+) was from grid cell 4-300-136 located at 28.2615 N, -96.7771 W. Data collected at TDSHS (x) SAN00008 site was located at 28.2464 N, -96.7692 W.

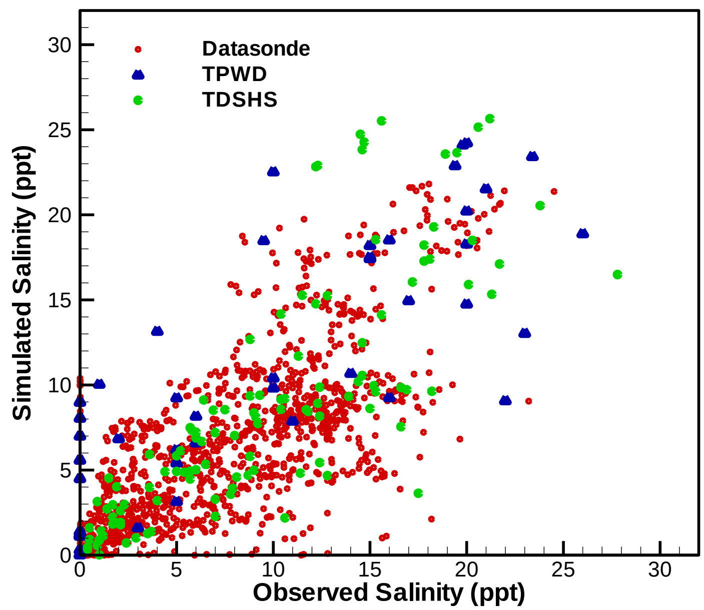

Figure 42. Scatter plot of simulated and observed daily salinity near Seadrift in San Antonio Bay for the period 1999-2009. Observed data are identified according to data source (TWDB-red; TPWD-blue; TDSHS-green).

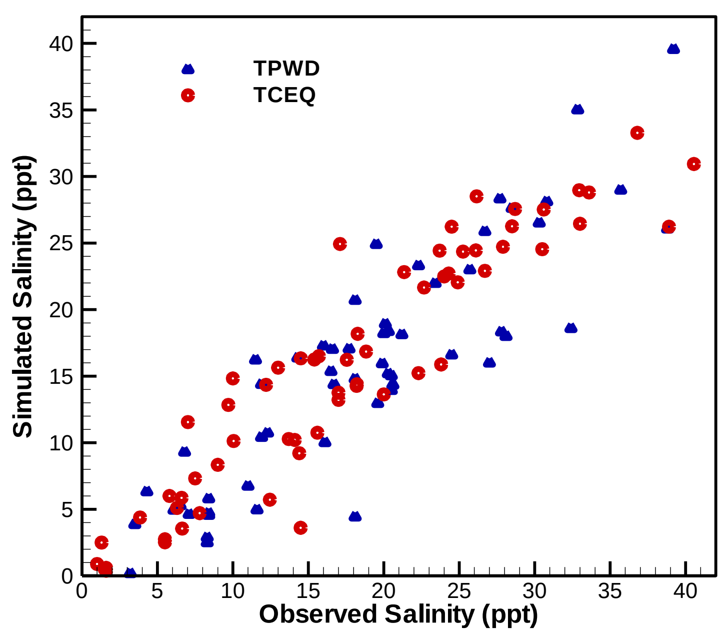

Figure 43. Scatter plot of simulated and observed daily salinity in Mesquite Bay, Guadalupe Estuary, for the period 1999-2009. Observed data are identified according to data source (TCEQ-red; TPWD-blue).

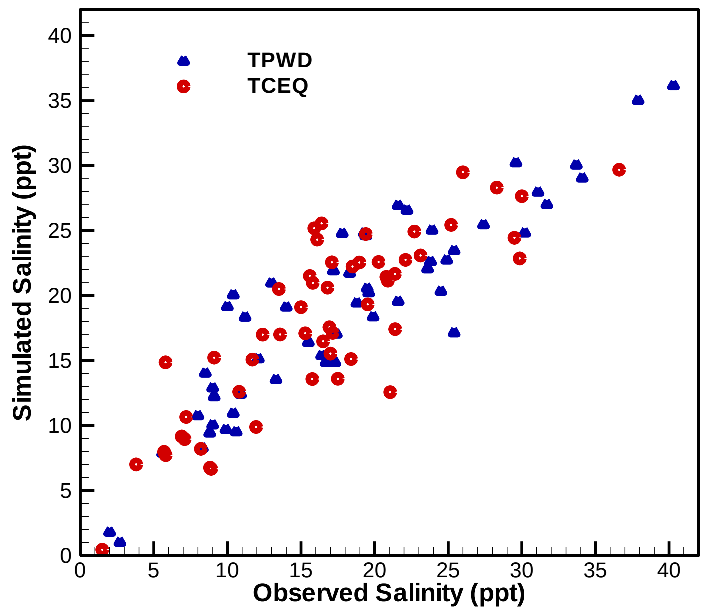

Figure 44. Scatter plot of simulated and observed daily salinity at the Copano Causeway, Mission-Aransas Estuary, for the period 1999-2009. Observed data are identified according to data source (TCEQ-red; TPWD-blue).

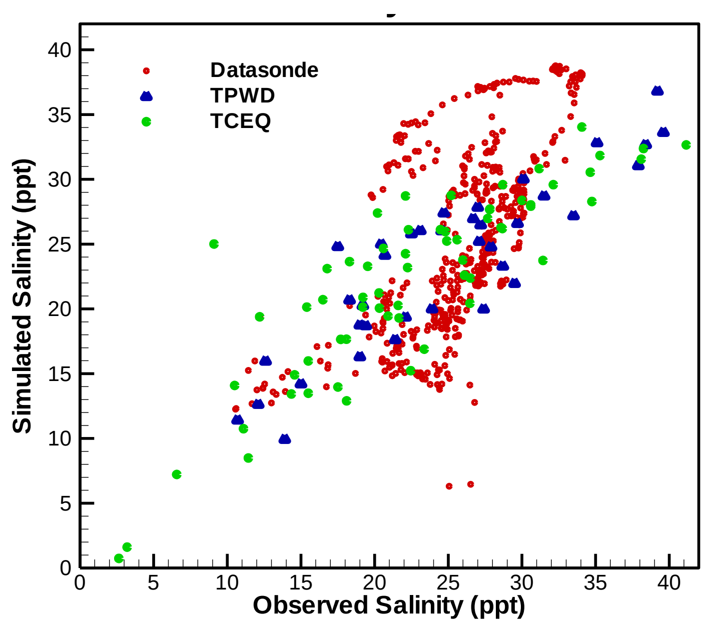

Figure 45. Scatter plot of simulated and observed daily salinity in Aransas Bay for the period 1999-2009. Observed data are identified according to data source (TWDB-red; TPWD-blue; TCEQ-green).

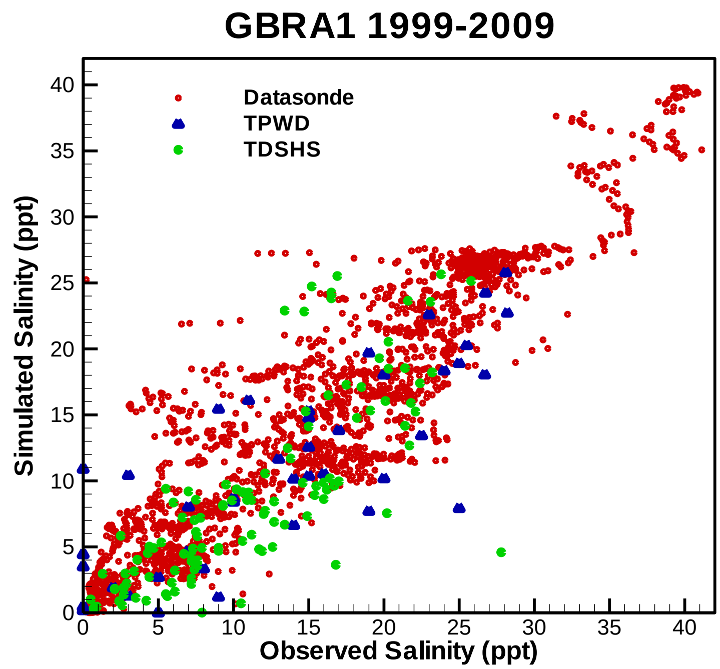

Figure 46. Scatter plot of simulated and observed daily salinity at the GBRA-1 station in San Antonio Bay for the period 1999-2009. Observed data are identified according to data source (TWDB-red; TPWD-blue; TCEQ-green).

Table 6. Summary statistics for comparisons of simulated to observed salinities for five sites in the Guadalupe and Mission-Aransas estuaries during the period 1999-2009. Data is displayed graphically in Figures 26-35.

Location and Data Source	n	r^2	RMSE (ppt)	Nash-Sutcliffe	Average Simulated Salinity	Average Observed Salinity	Difference (Sim – Obs)
Seadrift-Datasonde	1,277	0.59	3.8	0.53	6.0	7.1	-1.1
Seadrift-TDSHS	112	0.64	4.3	0.54	9.0	9.7	-0.7
Seadrift-TPWD	46	0.67	5.1	0.64	10.8	9.5	1.3
Mesquite-TCEQ	63	0.87	4.1	0.83	15.5	17.5	-2.0
Mesquite-TPWD	56	0.78	5.2	0.67	15.6	18.6	-3.0
Copano-TCEQ	54	0.71	4.2	0.66	17.9	16.5	1.4
Copano-TPWD	55	0.82	3.9	0.81	18.8	18.0	0.8
Aransas-Datasonde	475	0.43	5.5	0.43	25.8	25.4	0.4
Aransas-TCEQ	64	0.74	4.2	0.74	22.2	22.6	-0.4
Aransas-TPWD	37	0.78	3.8	0.75	23.6	24.8	-1.2
GBRA1-Datasonde	1,947	0.86	3.9	0.86	14.5	15.1	-0.6
GBRA1-TDSHS	113	0.60	5.1	0.39	8.9	11.4	-2.5
GBRA1-TPWD	41	0.66	5.7	0.58	11.1	13.6	-2.5

*RMSE is the root mean square error.

** Nash-Sutcliffe Efficiency Criterion (*E*) describes model performance, where E=1.0 represents a match between model output and observed data and E<0 suggests the model is a poor predictor.

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