Final Report for Project

Technical support - TWDB #0704830669

Feb 2008

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Summary

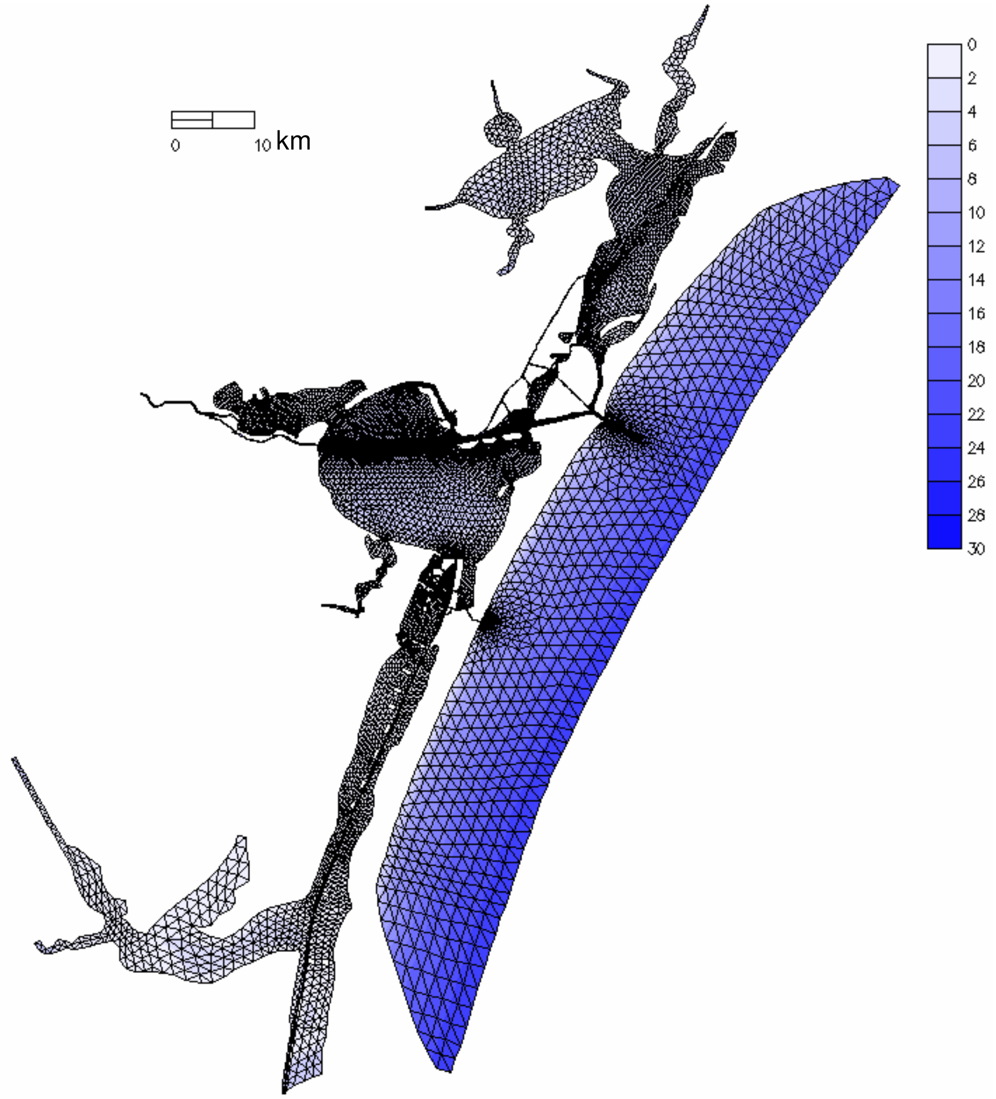
As a continued effort to benchmark two 3D baroclinic circulation models, ELCIRC (Eulerian-Lagrangian Circulation) and SELFE (Semi-implicit Eulerian-Lagrangian Finite Elements), we have applied SELFE to the study of long-term salinity trend in Corpus Christi Bay region in Texas; TWDB is applying ELCIRC to the same problem with help from OHSU. Several two-year simulations have been done and results suggest that SELFE is able to capture the overall variation of salinity and temperature. A real-time forecasting system based on the model presented here was brought up at OHSU in March 2008 (http://nefs.ccalmr.ogi.edu/nefs/rover.php?fcastid=corpus), and will be transferred to TWDB in the future upon mutual agreement.

Corpus Christi Bay testbed

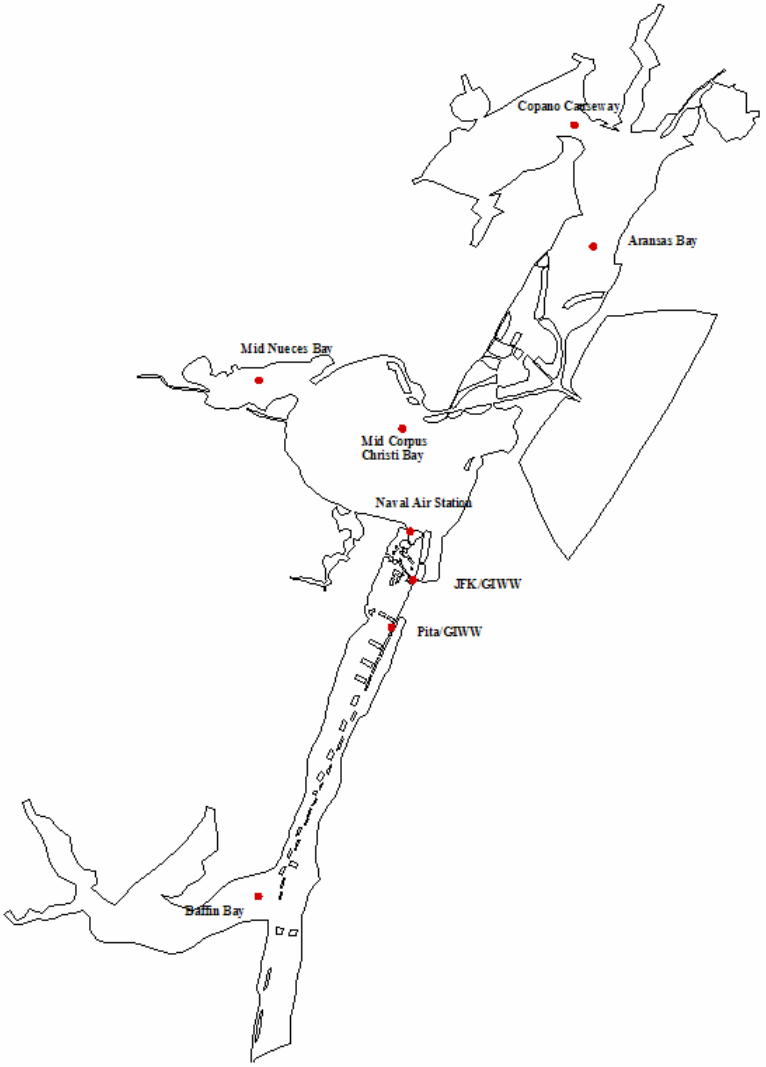
1. Model domain

The model domain extends from Aransas Bay to the north, including a small part of Gulf of Mexico (GoM), Nueces Bay, Corpus Christi Bay, the upper Laguna Madre, and to just below Baffin Bay to the south (Fig. 1a). The bathymetry is shallow in the bays, generally below 5m, and thus the effects of evaporation and precipitation are expected to be significant.

The main goal of the exercise is to study the long-term salinity trend in the bays, as a part of effort to test and calibrate the model for all physical variables (elevation, velocity, salinity, temperature etc).



(a)



(b)

Fig. 1 (a) Model grid, and (b) station locations used for salinity calibration.

2. Model forcings

At the rivers, powerplant intake and outflow and GoM boundaries, discharges or elevations are imposed. In addition, salinity values are also specified at rivers, Intracoastal Water Way (ICWW) at Cabal, and the GoM boundary. At the air-water interface, evaporation and precipitation rates are applied, in addition to wind, air pressure, solar radiation, humidity, and longwave radiation. All time series boundary inputs and initial conditions were supplied by TWDB group, except for the air pressure, solar radiation, humidity, and longwave radiation, which were instead taken from NCEP NARR (National Centers for Environmental Prediction's Regional Reanalysis product; http://www.cdc.noaa.gov/cdc/data.narr.html). The SELFE source was modified to read in the time series for wind, evaporation and precipitation rates from the files supplied by TWDB. Also the salinity and temperature conditions at power plant outflow points are set to the values at corresponding intake points inside the code.

3. Observational data

The long-term data we have received from TWDB so far is the salinity and temperature records at several stations in various bays (Corpus Christi, Nueces, Aransas, Copano and Baffin; Fig. 1b). In addition, elevation and velocity data from two 3-day field surveys in August 1987 and 1988 is also used in calibration effort. Note that some of the data has not been quality controlled and may have some outliers (see, e.g., Fig. 5a).

4. Model calibration

We have carried out model calibrations for years 1987 and 1988. SELFE version 1.5k2 was used in this exercise (with changes mentioned in Section 2). The horizontal grid consists of 10877 nodes and 18862 triangular elements, with the finest resolution of ~30m in some channels (Fig. 1a). A total of 5 terrain-following *S* layers were used in the vertical. A large time step of 60s was used, thanks to the superior stability for this semi-implicit model. A generic length-scale turbulence closure of *k-kl* (Umlauf and Burchard 2003), which is a modified Mellor-Yamada scheme was used to compute the viscosity and diffusivity. The model, running on a single 2.2 GHz AMD Opteron processor, is efficient as a 3D baroclinic model; a 1-year run took about 11 days. Significant speed-up is expected with parallel version of SELFE becoming available recently.

Main model uncertainties include (1) the external forcings; (2) reference times used in various forcing files (e.g., Central Standard Time vs. GMT). We have used alternative evaporation/precipitation rates from either TWDB or NARR sources, and found comparable results (although results from TWDB sources seem to be slightly better). One major technical difficulty we found is associated with the southern part of the ICWW near Baffin Bay. We found that the wind there had set up some small residual currents that carry very high salinity water from Cabal up to other bays and would eventually make salinity too high everywhere. Note that the wind record from TWDB was taken at one station and applied to the entire domain, and this may have some errors. Therefore we decided to ramp down the wind near the Cabal boundary in order to shut down the residual transport there.

5. Elevation and velocity comparisons

The primary source of field data is from the 3-day field surveys in August 1987 and 1988. Due to the ambiguity in the reference times used in various forcing and data files, validation of modeled elevation and velocity is very difficult. The mismatches between reference times would affect not only the phases but also amplitude due to nonlinear interactions. The model results shown in this section are from the "new" cold-start runs (cf. Section 6).

Preliminary comparison for elevations at two gages in 1987 is shown in Fig. 2. The vertical datum is unknown and therefore only the amplitudes and phases can be compared. The time series is not long enough for a comprehensive harmonic analysis. While there is overall agreement in amplitudes and phases at the two gages, the errors are significant.

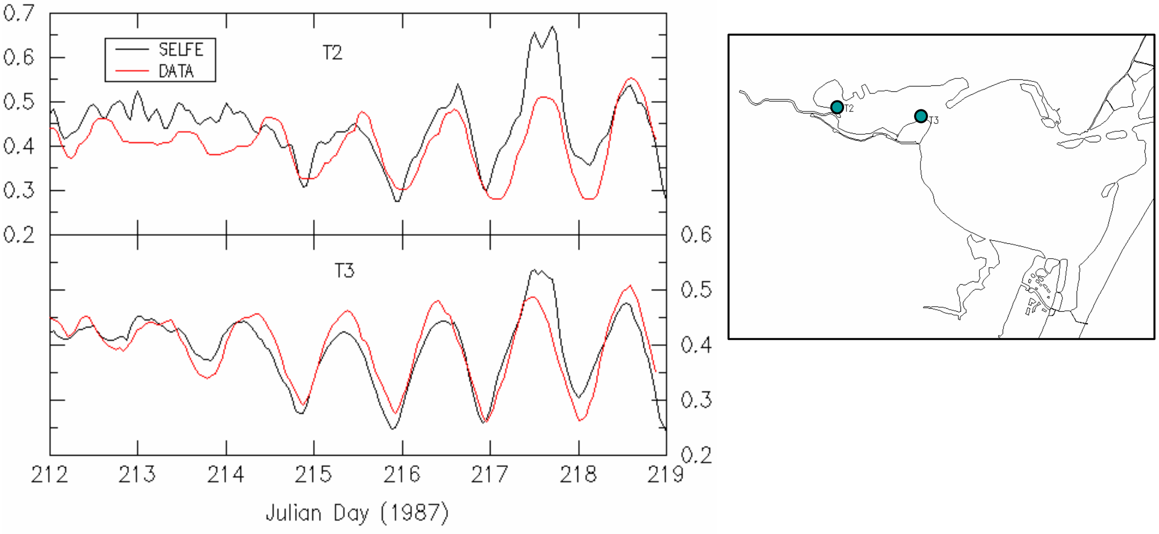


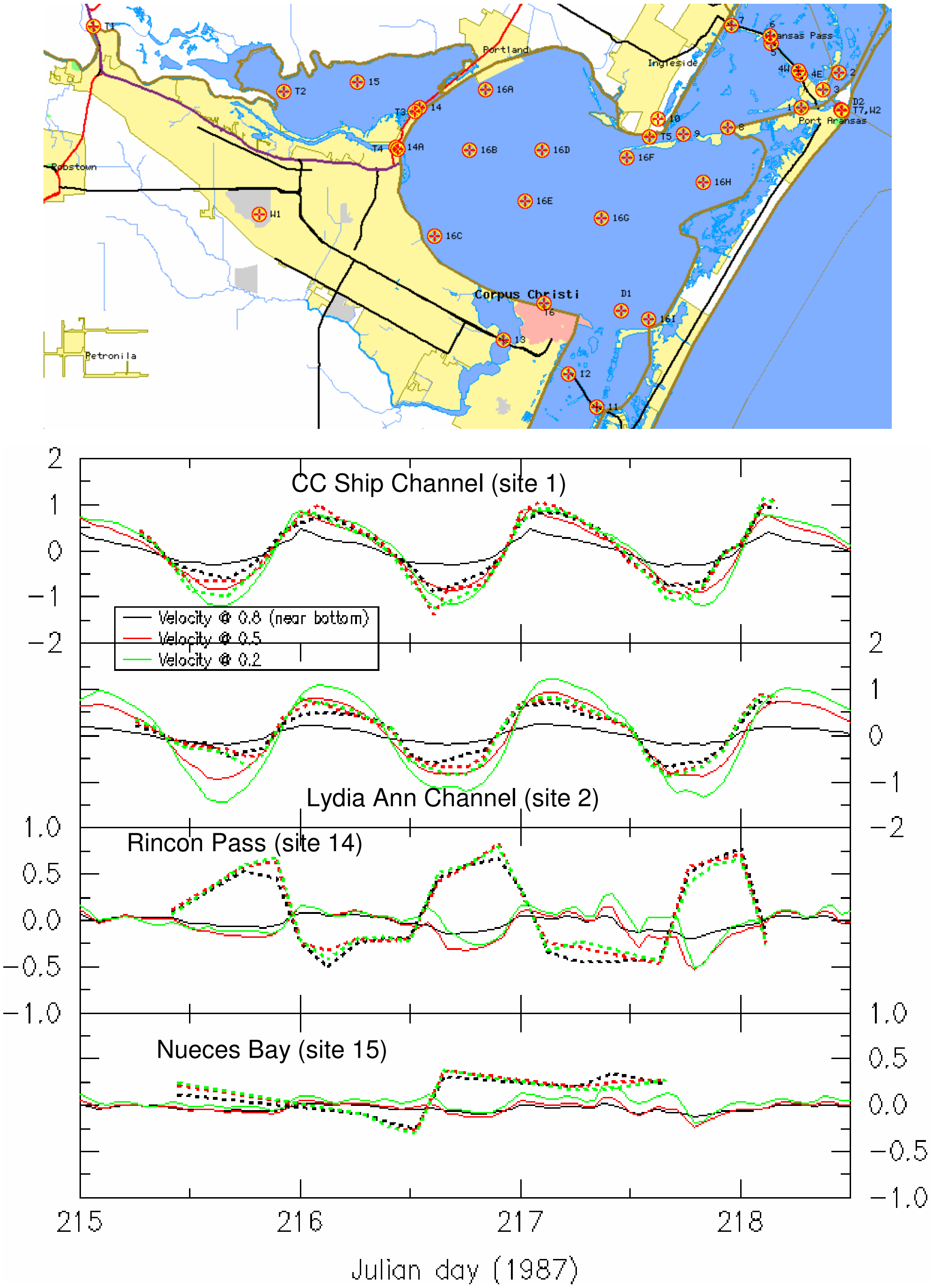
Fig. 2 Comparison of elevations at 2 tide gages (the insert shows their locations). The data was vertically shifted down 0.4 and 0.55 m for T2 and T3 respectively.

The velocities are compared at 3 depths (near bottom, middle, and near surface) at multiple stations (Fig. 3). Besides uncertainties in the reference times in inputs, our experiences are that velocity is also highly sensitive to the local bathymetry. The comparison between the actual water depths and those represented in the grid indicates that the difference can be up to 1m. Therefore a much more careful calibration exercise is needed for velocity.

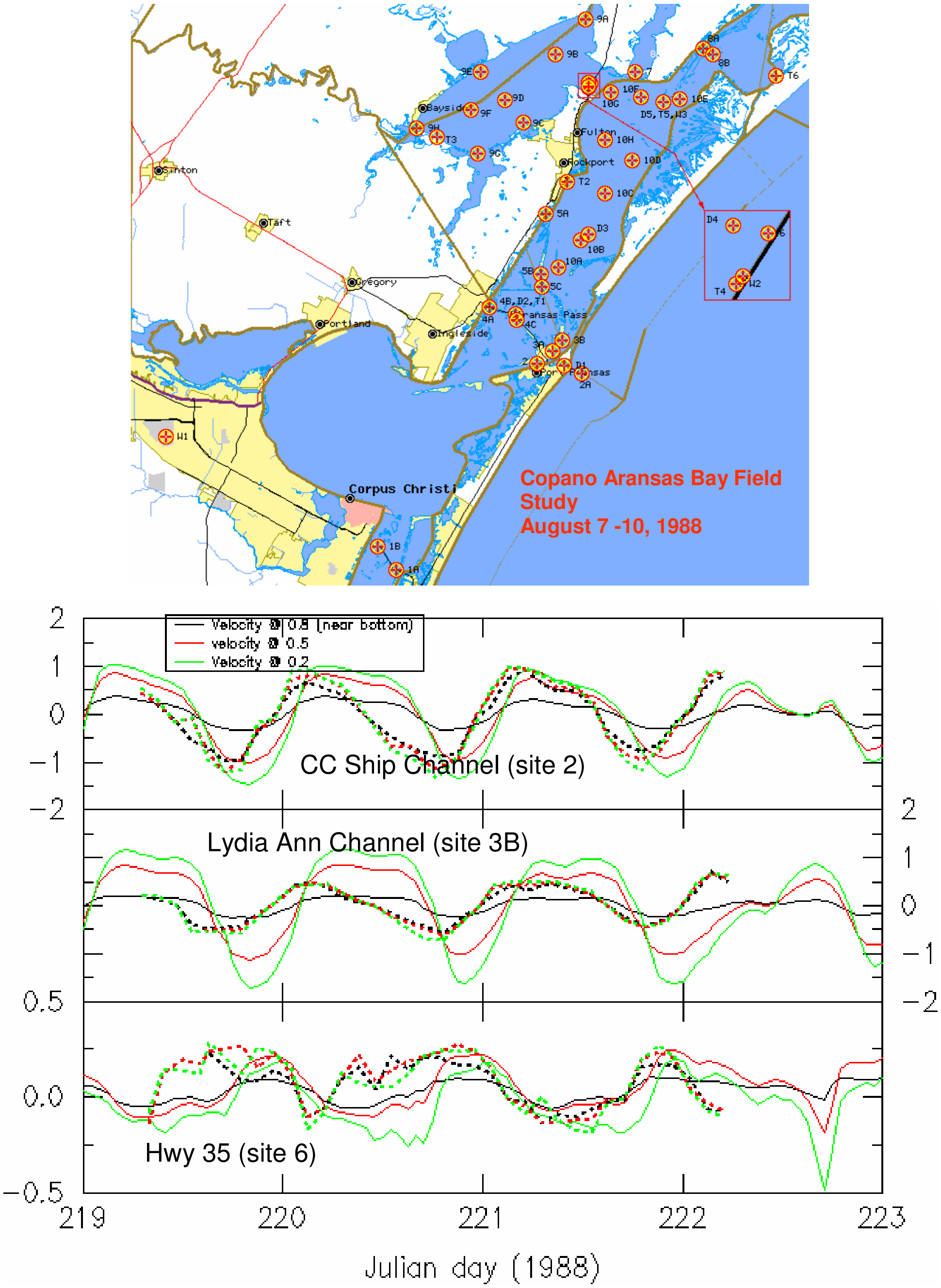
The amplitudes of modeled surface and mid-depth velocities are generally reasonable, except at Rincon Pass (Fig. 3a), where they are substantially under-estimated. A comparison at a nearby site 15, however, is better (Fig. 3a). The difference implies that the representation of local bathymetry may be important; the difference between model grid and actual depths is estimated to be over 1m at Rincon Pass. The near-bottom velocities are generally under-estimated, which may be due to the erroneous bottom drag coefficient used (currently a constant of 0.0025).

The large errors in elevations and velocities are not consistent with our experiences with Columbia River and other systems. More effort is clearly needed to resolve these issues in the future.

Corpus Christi Field Study
August 4 - 7, 1987



(a)



(b)

Fig. 3 Comparison of velocity along specific directions (given by TWDB) for (a) 1987 and (b) 1988, at multiple stations and depths. The solid lines are from SELFE, and dash lines from field survey. The numbers “0.8”, “0.5”, “0.2” in the legend refer to the fraction of the total depth where the velocity is measured.

6. Salinity comparisons

The evaporation and precipitation rates from TWDB are plotted in Fig. 4. Years 1987-8 are classified as "dry" year, where precipitation was sporadic and only occasionally significant. The evaporation rate, on the other hand, seems to be consistent throughout this period.

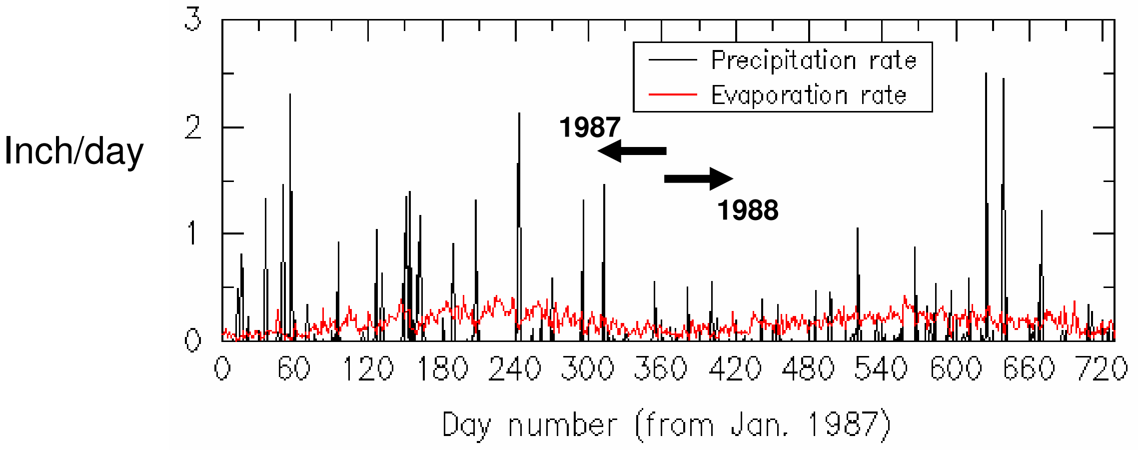


Fig.4 Evaporation and precipitation rates for 1987-8.

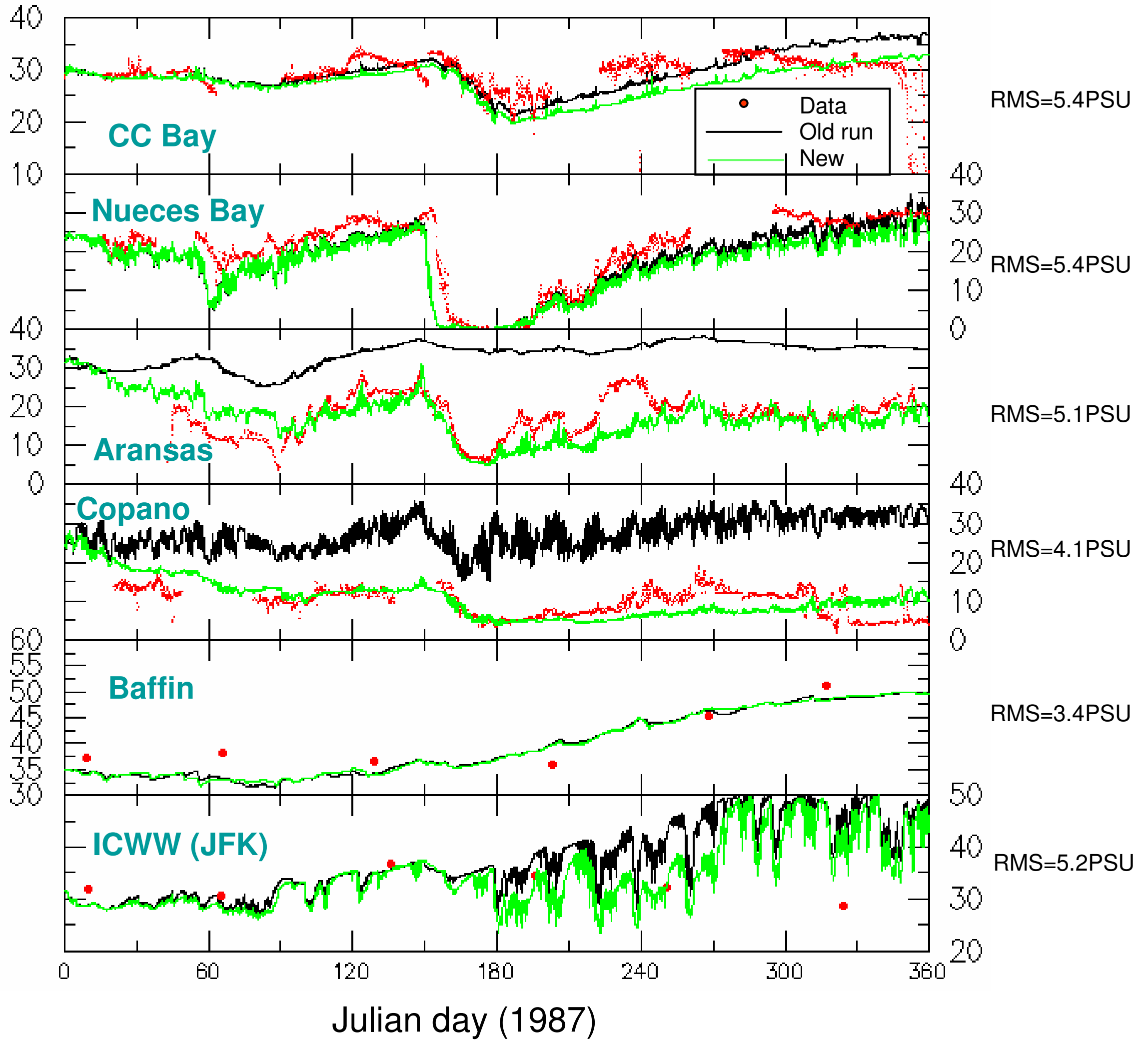
Several iterations of calibration were carried out. Initially we did one cold-start run each for 1987 and 1988, plus a hot-start run for 1988. The results from the two runs for 1988 converge in the second half of the year (Fig. 5b). However, there are large errors at Aransas and Copano stations; in addition, the “hot” run in 1988 also has large errors at the Corpus Christi and Nueces Bay stations for the first half of the year (Fig. 5b). Salinities are generally over-estimated at most stations.

The problem was traced to the lack of flow boundary conditions at the Cedar Bayou and Bludworth boundaries near Aransas Bay. Radiation boundary condition was imposed there, which had distorted the net inflow over time. The close proximity of these two boundaries means that the two stations in Aransas and Copano Bays are affected most.

To rectify this problem, we did a new run with flow information (from TWDB) imposed at the two boundaries. Due to time constraint, we did not redo the “hot” run for 1988. The improvement in the model results is quite obvious, not only for the two stations in

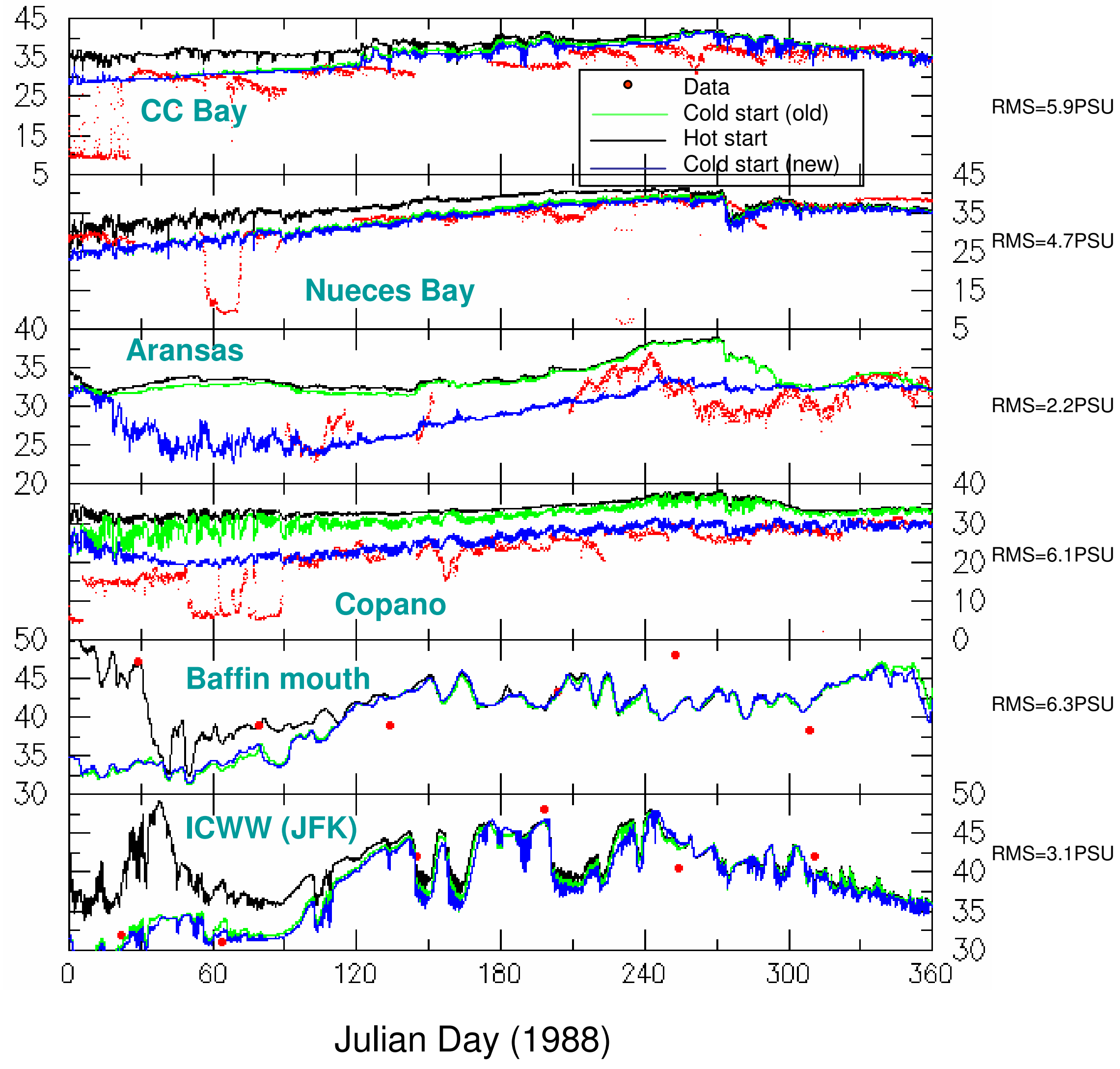
Aransas and Copano Bays, but also, to a lesser extent, for other stations as well (Fig. 5). More importantly, the new run also seems to have corrected the over-estimation of salinity at Corpus Chrisiti Bay near the end of 1987, and we speculate that a continuing hot-start run from 1987 into 1988 will lead to better results than the old “hot” run.

Further away from the Aransas Bay, the results at Baffin Bay agree reasonably well with data in 1987. However, the two cold-start runs (“old” and “new”) under-estimate salinity in the first two months of 1988, while the hot-start run does a better job. There is a clear discontinuity between the salinity values at the end of 1987 (~50 PSU) and beginning of 1988 (~35 PSU) in the two cold-start runs, suggesting that the initial conditions in the cold-start runs are responsible for the errors. As mentioned before, we had to ramp down the wind towards Baffin Bay to prevent some small residual currents from carrying very high salinity water from Cabal (from boundary conditions) to other bays.



CC Bay
Nueces Bay
Aransas
Copano
Baffin
ICWW (JFK)
Data
Old run
New
RMS=5.4PSU
RMS=5.4PSU
RMS=5.1PSU
RMS=4.1PSU
RMS=3.4PSU
RMS=5.2PSU
40
30
20
10
0
60
55
50
45
35
0
60
120
180
240
300
360
Julian day (1987)

(a)

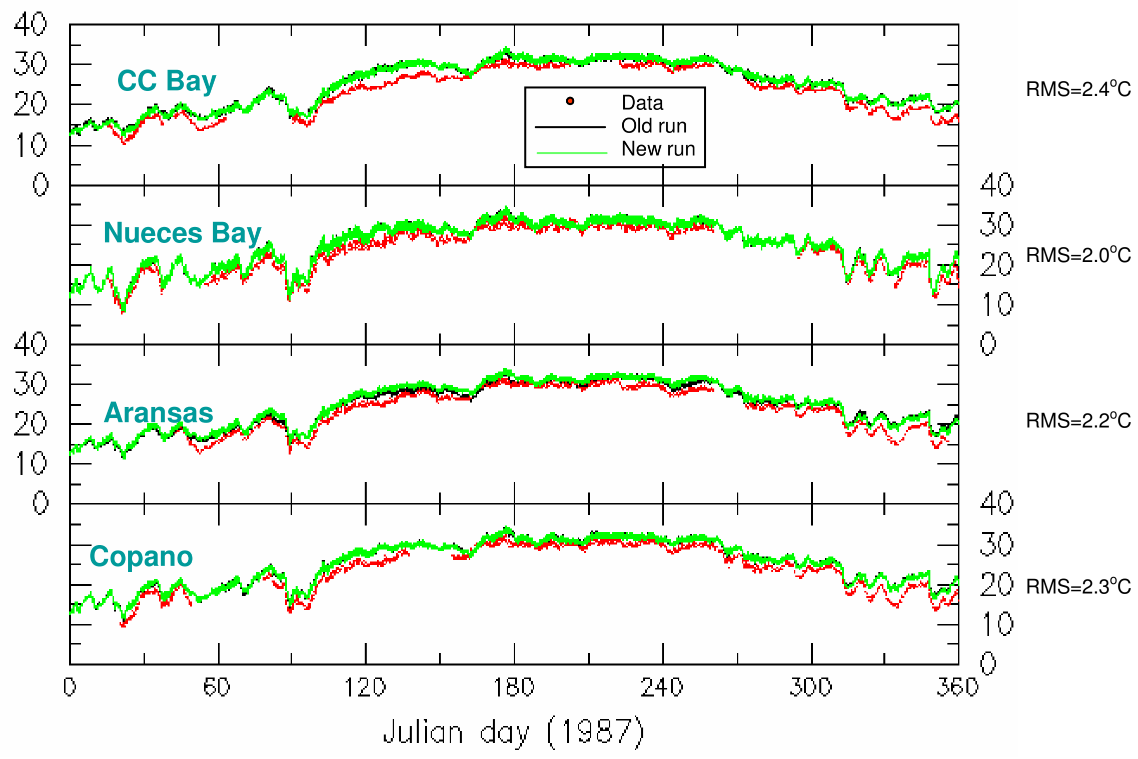


(b)

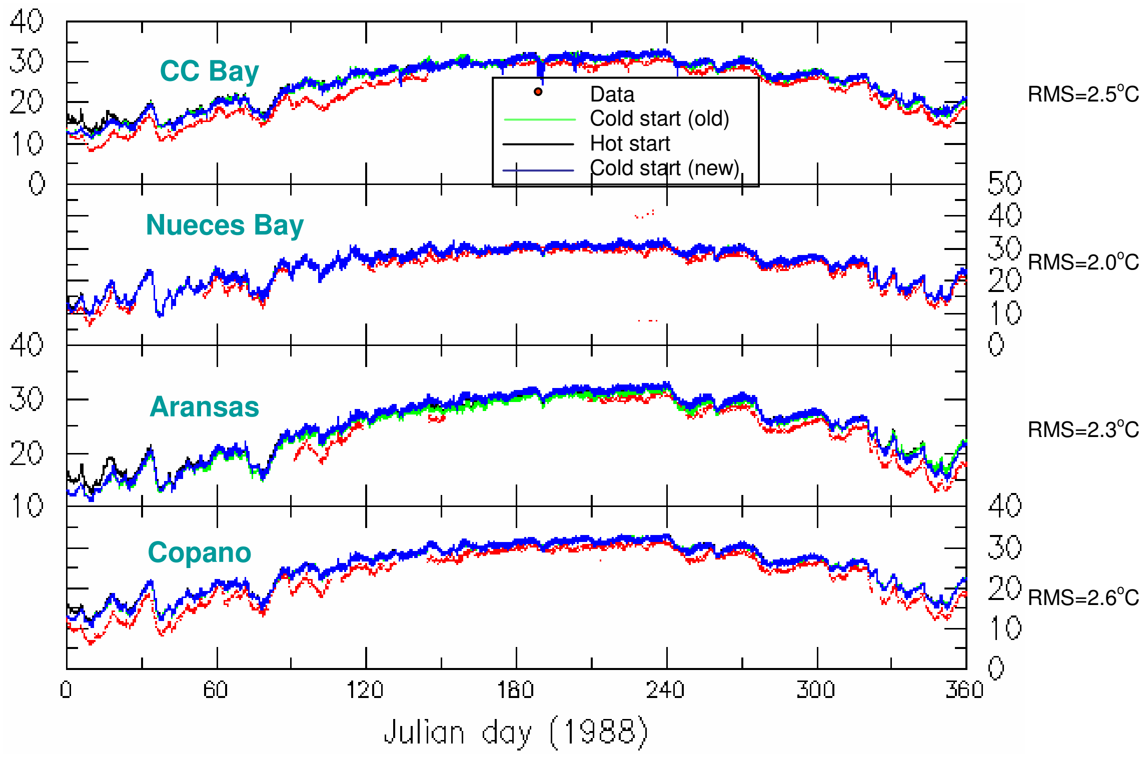
Fig. 5 (a) Comparison of surface salinity at multiple stations for (a) 1987 and (b) 1988. The station locations can be found in Fig. 1b. Note that the data shows very large oscillations near end of 1987 and beginning part of 1988 at CC Bay. For 1987, two cold-start runs were done from initial T,S on Jan. 01, 1987 (from TWDB); the "new" run incorporates the flow information at Cedar Bayou and Bludworth. For 1988, three runs were done; two runs are cold started, with the "new" run again incorporating the flow information at Cedar Bayou and Bludworth. The 3rd run was hot started from the "old" cold start run of 1987. The Root-Mean-Square errors for the “new” runs are shown on the right.

7. Temperature comparisons

The temperature variation is generally captured for both years (Fig. 6). There are no substantial differences between various runs, and there is over-estimation in all runs.



(a)



(b)

Fig. 6 Comparison of temperature for (a) 1987 and (b) 1988. See Fig. 5 for explanation of runs. The Root-Mean-Square errors for the “new” runs are shown on the right.

Conclusion

Salinity and temperature trends in the Corpus Christi Bay region have been studied using SELFE for two years 1987-8. Overall, the study suggests that SELFE is able to capture the long-term variation of salinity and temperature, subject to uncertainties in external forcings and boundary conditions. Validation of the model for other years would be a good way to confirm this finding and further test the model's capability under other types of conditions (e.g., very wet years).

Technology transfer to TWDB

Upon completion of this project, OHSU has transferred the following documents to TWDB:

1. This final report;
2. All input files and source code used in all runs in electronic form.

In addition, a real-time forecast for the Corpus Christi Bay based on the hindcast study detailed in this report has been brought up at OHSU, and will be transferred to TWDB upon mutual agreement.

References

Umlauf, L. and H. Burchard (2003) A generic length-scale equation for geophysical turbulence models. *J. Mar. Res.*, 6, pp. 235-265