4.3 A NOWCAST/FORECAST MODEL OF THE ST. JOHNS RIVER AND ITS PERFORMANCE ASSESSMENT

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1. INTRODUCTION

As part of the Coastal Storms Initiative (CSI), an interdisciplinary NOAA project aimed at providing local communities with enhanced tools and resources to help mitigate the hazards of coastal storms, an experimental circulation model-based nowcast/forecast system of the St. Johns River, Florida has been implemented. The hydrodynamic model of the river and estuary makes nowcasts and forecasts of water levels, currents, salinity, and temperature and provides a means for the community to view the results. Two circulation model applications have been implemented and evaluated in the development stage of the nowcast/forecast system. The first of these model applications uses the Environmental Fluid Dynamics Code (EFDC; Hamrick, 1992a,b) to perform operational hourly nowcasts and 36-hour forecasts. This model application was originally developed by the St. Johns River Water Management District (SJRWMD) and calibrated for 1995-1998. The SJRWMD provided the calibrated model to NOAA's Coast Survey Development Laboratory (CSDL) for its implementation as a real-time nowcast-forecast system. The other model being examined for use in the St. Johns River is ELCIRC (Eulerian-Lagrangian CIRCulation model), a finite volume/finite difference baroclinic model for unstructured grids (Myers and Baptista, 2001).

In order to quality assess the performance of the model applications, software tools were developed to compute a standard suite of NOS skill assessment statistics. As part of the Coastal Ocean Modeling Framework that the National Ocean Service (NOS) is implementing, all models are first adjusted to output in standardized netCDF formats. The skill assessment software is then designed to read such output from any model and compute statistics using modeled and observed water levels, currents, salinities and temperatures. The statistics address the performance of the models under several types of simulation scenarios in both a hindcast and a forecast framework. The St. Johns River model applications are evaluated using this software, and these statistical results will help guide the best approach for transitioning the models to an operational environment.

2. MODEL SETUP

As part of a program to examine water quality in the St. Johns River, the St. Johns River Water Management District (SJRWMD) developed a hydrodynamic model that could be linked to a water quality model. Sucsy and Morris (2001) developed an application of EFDC to the lower St. Johns River to simulate the period of 1/1/1995 – 11/30/1998. For optimal results, the SJRWMD calibrated the model by adjusting parameters such as bathymetry, friction, open ocean tides, ocean salinity, the number of vertical layers, and specification of a non-reflective upstream boundary condition. Their comparisons with data showed that water levels, currents, and salinity were represented well by the numerical model. To facilitate the development of a nowcast/forecast system for the Coastal Storms Initiative, the SJRWMD model was transferred to the Coast Survey Development Laboratory for adjustments so that operational nowcasts and forecasts could be made.

2.1 Hindcast Model Setup

The EFDC grid developed by the SJRWMD is an orthogonal, boundary-fitted, structured grid that extends from the Atlantic Ocean to the upstream boundary at Buffalo Bluff (Figure 1). There are 2,210 water cells that are embedded within a transformed 188 x 105 rectangular computational grid. Cell length sizes range from 2,040 m to 81 m. there are six stretched, sigma vertical layers.

The ocean boundary of the grid is forced with a superposition of the observed subtidal water levels at Mayport (shown in Figure 1) and

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predicted tides. The former are determined using a low-pass filter, and the latter are based on tidal harmonics available at Mayport with a slight adjustment (approximately 5% increase in tidal amplitudes) for matching the model with observations. Salinity is also specified along the ocean boundary to linearly transition from 35 psu at the surface to 36 psu at the bottom.

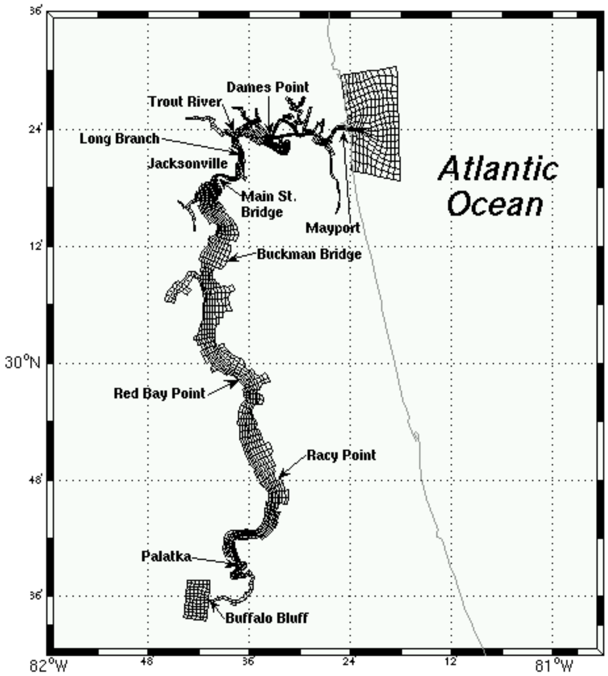

Figure 1. Orthogonal grid used by EFDC.

At the upstream boundary, the SJRWMD used a sponge condition (as seen in Figure 1 by the rectangular region at the upstream end) to control reflection of the tides back into the model domain. The main flow of the St. Johns River was forced at the upstream boundary using data collected by the USGS gauge at Buffalo Bluff. Salinity is also specified at Buffalo Bluff using conductivity data collected by the USGS gauge. Freshwater discharge from 61 other tributaries was specified in the SJRWMD model. These values were estimated from a GIS-based hydrologic model that uses rainfall-runoff ratios that are dependent on land-use and soil types.

Wind forcing was provided from a Jacksonville Naval Air Station wind sensor and was specified throughout the grid as spatially constant and temporally varying. A spatially constant rainfall was likewise applied throughout the domain using a composite of 8 rainfall stations. River evaporation was determined based on daily pan evaporation data in Gainesville multiplied by a pan correction factor.

2.2 Experimental Nowcast/Forecast Setup

For the nowcasts, water levels along the open ocean boundary are determined using a slight correction factor of 1.05 applied to data from the Mayport, Florida NOAA water level gauge. Salinity along the open ocean boundary is set equal to the hindcast values of 35 psu at the surface and 36 psu at the bottom. Wind data available from the NOAA Mayport station is applied to all the grid cells in the model. Finally, real-time river discharges along six of the main tributaries entering the St. Johns River are downloaded from the USGS as lateral inflows. The nowcasts are run every hour, and results are made available on a web page.

Thirty-six hour forecasts are made with the model four times a day. Along the open ocean boundary, water levels are specified as a superposition of the tide predictions from Mayport and the subtidal water level forecasts at Fernandina Beach, Florida. The latter are made available by the National Weather Service (NWS) as output from their Extratropical Storm Surge Model. While river discharge is currently persisted from the latest observations, NOS and NWS are coordinating to develop hydrologic forecasts at locations where real-time observations are currently available. Forecasts of atmospheric variables from the Eta-12 model are currently used as input to the circulation model. As part of the CSI, NWS is developing a high resolution atmospheric model that will supplant the Eta-12 forecasts used by the hydrodynamic model.

3. SKILL ASSESSMENT OF THE MODEL

3.1 Method

Skill assessment is an objective measurement of the performance of model simulations (including hindcasts, nowcasts or forecasts) compared with observations. NOS has developed a suite of standard statistics for evaluating hydrodynamic model systems (Hess et al., 2003). A software package (Zhang et al., 2004) has been implemented that computes the skill assessment scores automatically using data files containing observed as well as modeled variables.

The skill assessment for each location requires three basic types of time series data: observed, tidally predicted (for tidal regions), and model simulated. A uniform time interval of 6 minutes is required for each series, but hourly

Table 1. Skill Assessment Statistics

Variable	*Explanation*
Error	The error is defined as the predicted value, p, minus the reference (observed or astronomical tide value, r : $e_i = p_i - r_i$.
SM	Series Mean. The mean value of a series. Calculated as $\bar{y} = \frac{1}{N}\sum_{i=1}^{N} y_i$.
RMSE	Root Mean Square Error. Calculated as $RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N} e_i^2}$.
SD	Standard Deviation. Calculated as $SD = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N} (e_i - \bar{e})^2}$
CF(X)	Central Frequency. Fraction (percentage) of errors that lie within the limits ±X.
POF(X)	Positive Outlier Frequency. Fraction (percentage) of errors that are greater than X.
NOF(X)	Negative Outlier Frequency. Fraction (percentage) of errors that are less than -X.
MDPO(X)	Maximum Duration of Positive Outliers. A positive outlier event is two or more consecutive occurrences of an error greater than X. MDPO is the length of time (based on the number of consecutive occurrences) of the longest event.
MDNO(X)	Maximum Duration of Negative Outliers. A negative outlier event is two or more consecutive occurrences of an error less than -X. MDNO is the length of time (based on the number of consecutive occurrences) of the longest event.
WOF(X)	Worst Case Outlier Frequency. Fraction (percentage) of errors that, given an error of magnitude exceeding X, either (1) the simulated value of water level is greater than the astronomical tide and the observed value is less than the astronomical tide, or (2) the simulated value of water level is less than the astronomical tide and the observed value is greater than the astronomical tide.

intervals are suitable for water levels. The length of each time series is ideally 365 days, in order to capture all expected seasonal conditions. Since it is often difficult to obtain time series of this length, the minimum required length of time is at least several months for water levels and 29 days for currents. The statistical variables used in the skill assessment are defined in Table 1.

Most of the statistical variables in Table 1 have an associated target frequency of occurrence, for example,

$$S(X) \leq P$$

where S is the statistic, X is the acceptable error magnitude (defined by the user), and P is the target frequency (or percentage). Some examples include:

$$CF(X) \geq 90\% \qquad POF(2X) \leq 1 \qquad NOF(2X) \leq 1$$

Other statistical variables are expressed as limits on the duration of errors, such as

$$S(X) \leq L$$

where L is the time limit or maximum allowable duration. For example,

$$MDPO(2X) \leq L \qquad MDNO(2X) \leq L$$

The standard criteria for skill assessment are listed in Table 2.

Table 2. Standard Suite of Statistics and Standard Criteria

Variable	*Criterion*
SM	none
RMSE	none
SD	none
NOF(2x)	≤1%
CF(X)	≥90%
POF(2X)	≤1%
MDPO(2X)	≤L
MDNO(2X)	≤L
WOF(2X)	≤0.5%

3.2 Skill Assessment for the St. Johns River

For the St. Johns River models, skill assessment is being made at 8 stations for water levels (Table 3) and 3 stations for currents (Table 4).

Table 3. Stations used in water level skill assessment

Name	*Latitude*	*Longitude*
Mayport	30.395	-81.465
Dames Point	30.392	-81.565
Long Branch	30.360	-81.620
Main Steet	30.320	-81.658
Buckman Bridge	30.192	-81.692
Red Bay Point	29.968	-81.618
Racy Point	29.800	-81.536
Palatka	29.635	-81.619
Buffalo Bluff	29.585	-81.669

Table 4. Stations used in skill assessment of currents

Name	*Latitude*	*Longitude*
Mayport	30.397	-81.399
Dames Point	30.385	-81.555
Trout River	30.384	-81.628

The EFDC hindcast model application in the St. Johns River had been well calibrated by the SJRWMD for the years 1995-1998. Their hindcast simulation for 1998 was reproduced at CSDL using the same input files. The hindcast model results were then analyzed with the skill assessment software using verified 6-min water level and ADCP observations from CO-OPS. As documented by Sucsy and Morris (2001), the hindcast results for 1998 agreed well with the observations of water levels and currents. This has been validated with the skill assessment software, as most of the standard criteria for water level are reached at the 8 stations. The amplitudes of flood and ebb currents in the hindcast simulation also passed standard criteria at the three stations.

The skill assessment is currently being made for the nowcast and forecast simulations of 2003, since more data is available during this year. Preliminary results show that the water levels at the eight locations pass the standard criteria. Further analysis is under development, though, for the skill assessment of the currents during this time.

5. FUTURE WORK

Skill assessment is also planned for hindcast simulations using the ELCIRC model. The ELCIRC model application will help assist in simulating the inundation associated with storm surge events. NOS and NWS are also collaborating to further improve the flood forecasting capabilities in the St. Johns River by evaluating the EFDC/ELCIRC models with the NWS river forecast models. As the model evaluation evolves, products for dissemination to the public will be further improved upon through meetings with local constituents in the northeast Florida communities. It is expected that an operational version of the St. Johns River nowcast/forecast system will be implemented in 2005 in the NOS' Center for Operational Oceanographic Products and Services.

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