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Initial Tests of an Automated Operational Storm Surge Prediction System for the National Hurricane Center

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1. Introduction

An automated real-time operational storm surge prediction system has been developed for the National Hurricane Center (NHC). The system uses the National Weather Service Sea Lake and Overland Surges from Hurricanes (SLOSH) model which is run operationally during tropical cyclone events.

AutoSurge automates and accelerates operational workflows, computes storm track input parameters with greater accuracy, prevents human input error and eliminates labor-intensive tasks, giving storm surge forecasters additional time to conduct model analyses, generate forecast guidance products, calculate model output statistics, and assess model results.

2. Methodology

Shortly after synoptic times, the input wind parameters for SLOSH are extracted from the NHC's best track, official track and intensity forecasts, and the NHC track and intensity models, enabling AutoSurge to run off any and all of the guidance available within the Automated Tropical Cyclone Forecast (ATCF) system.

Implementing the SLOSH wind model directly into the operational workflow ensures that the computed wind parameters are consistent with the SLOSH wind formulation.

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The grid basins for the ensuing SLOSH simulation are selected by the Storm Surge Specialist or automatically by AutoSurge.

The basins can also be prioritized according to the distribution of the probabilistic P-Surge (Taylor and Glahn 2008) product's ensemble tracks, created from past performance statistics of the forecast advisories.

The closest point of approach is estimated from the selected basins' coastline locations and the tropical cyclone track. A cubic spline interpolation algorithm is applied to the storm track to provide the temporal resolution required to run SLOSH.

The system automatically generates a vast array of guidance products from SLOSH model output, including the maximum envelope of water and the temporal evolution of surge in areas that could be impacted by the storm.

In the present study, we build upon previous SLOSH verification analyses by developing an objective methodology for configuring, running and assessing the SLOSH forecast and hindcast simulations that can be replicated over multiple storms and for different forecast times and areas.

3. Forecast and Hindcast Simulations

The AutoSurge system's capabilities were demonstrated by conducting real-time forecast simulations of Hurricane Irene (2011) and including a temporal analysis through the use of NOAA tide station time series. Such efforts are essential to evaluate current and future SLOSH and basin upgrades, as well as to allow robust comparisons with other hydrodynamic modeling systems.

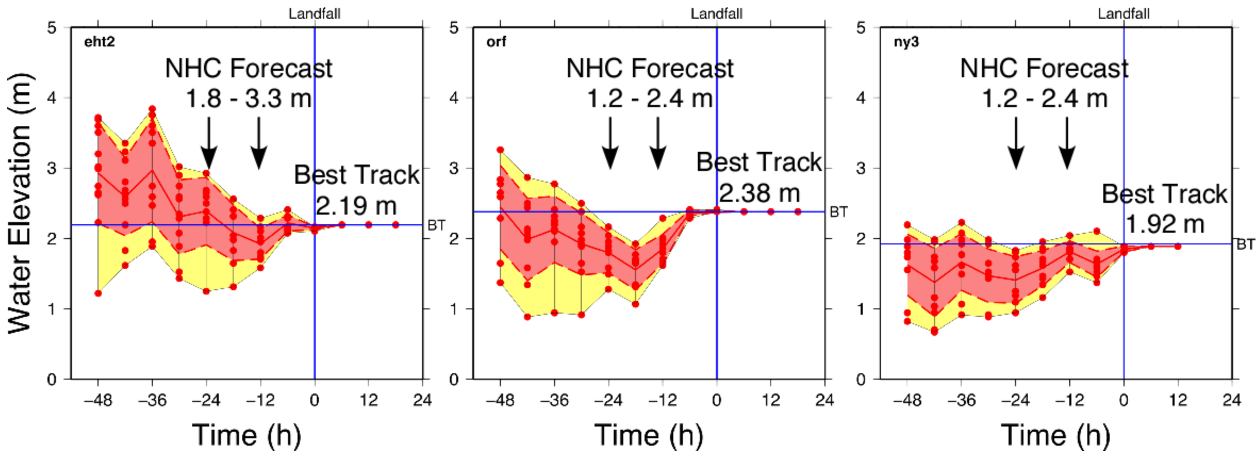

FIG. 1. Evolution of the ensemble water levels generated by AutoSurge from different ATCF models/aids over time in the eht2, eorf, and ny3 basins during Hurricane Irene (2011).

3.1 Forecast Simulations

An example of the forecast guidance provided by AutoSurge for three different SLOSH basins (eht2 – Cape Hatteras, NC; eorf – Norfolk, VA; and ny3 – New York, NY) is shown in Fig. 1.

The ensemble members' (red dots) predicted maximum and minimum (yellow shade) water level spread, average (red middle line) and standard deviation (or 68% confidence interval assuming a normal distribution, pink shade) from various ATCF trackers are displayed.

The average value and the standard deviation are highest for the eht2 basin and smallest for the ny3 basin. The NHC storm surge predictions from the forecast advisories at 24 and 12 hours before landfall are shown as well. The forecast surge range is consistent with the results from the best track simulations.

3.2 Hindcast Simulations

As part of the storm validation procedure, hindcast simulations of Hurricane Irene (Avila and Cangialosi 2011) were run with the AutoSurge hindcast option selected. This mode of operation uses best track information exclusively. The simulations were run after the storm had passed through all available basins as part of a post-storm analysis. The maximum simulated water levels using the best track are also shown (horizontal blue line) in Fig. 1.

Comparisons between observed and modeled water levels and their evolution in time for the three different SLOSH basins in Section 3.1 have been described by Forbes and Rhome (2012). Fig. 2 shows examples of observed vs. modeled water levels in the ny3 (Figs. 2a and 2b) and eht2 basins (Fig. 2c) during Hurricane Irene (2012).

The performance of the simulations were quantified by calculating the root mean square error (RMSE) and correlations from time series of the observed and SLOSH-simulated surface water surface elevations at 16 locations. Thirteen stations have RMSE less or equal to 0.42 m and 12 stations correlations greater than 0.80.

Overall, the eorf (green line in Fig. 3) and ny3 basin (Figs. 2a and 2b) simulations produce high correlations and low RMSE at most of the stations (Forbes and Rhome 2012).

Time series of water surface elevation at a few stations (not shown here) in the eht2 basin located on the sound side were out of phase and exhibited large negative correlations. More grid refinement needs to be done along the sound side of the eht2 basin to better simulate the flow through the outer banks and capture the arrival time and magnitude of the peak with better fidelity.

In addition, excessive drawdown at the Beaufort station produced in the eht2 basin is apparent in Fig. 2c.

Anomalously high wind speeds generated in some areas by the SLOSH parametric wind model, identified through comparisons with real surface wind measurements, revealed that some of the land cover categories need to be reclassified to

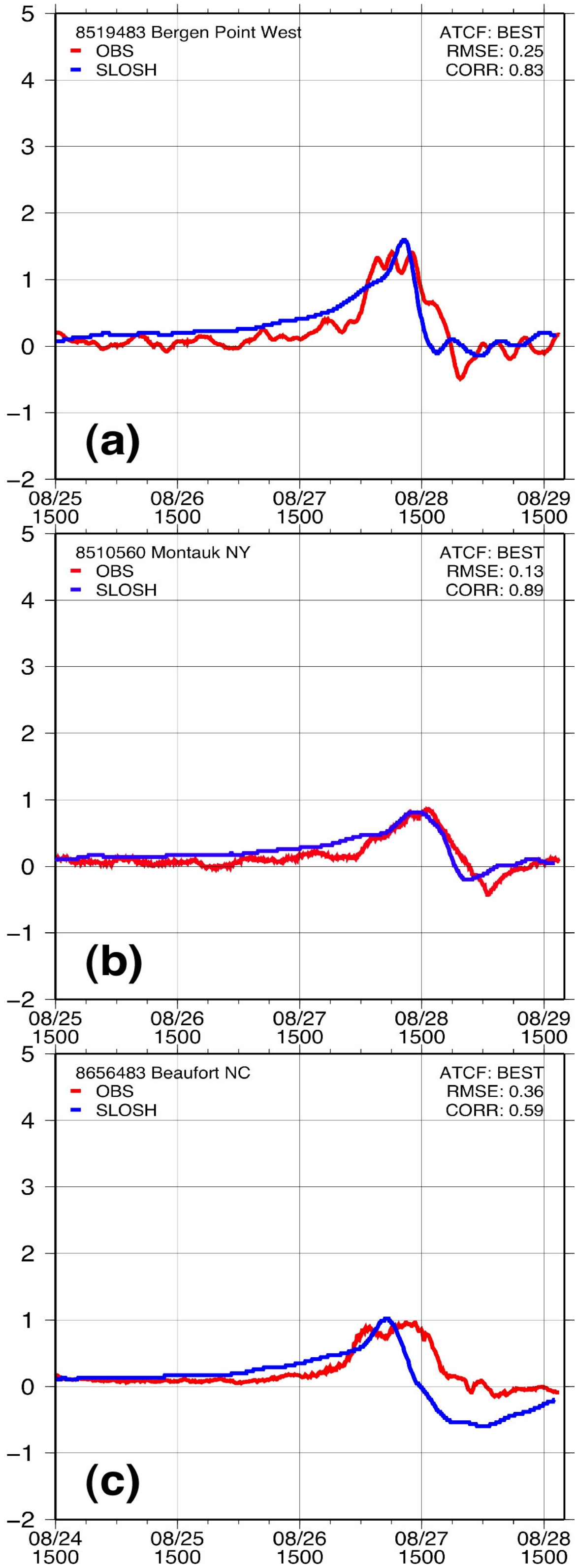

FIG. 2. Evolution of the water levels generated by AutoSurge at stations in the ny3 and eht2 basins.

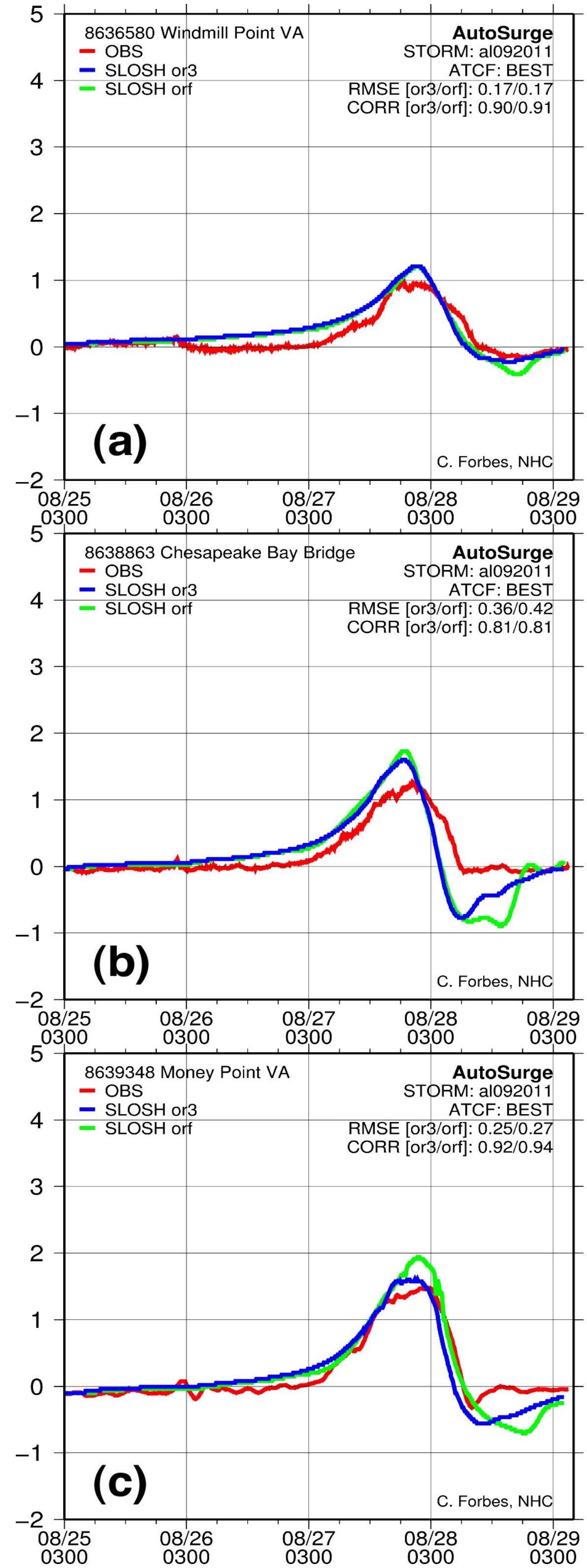

FIG. 3. Comparison of the evolution of the water levels generated by AutoSurge at stations in the eorf basin and in a preliminary version of the new high-resolution hor3 basin.

produce more realistic values of surface drag and wind speed (Forbes and Rhome 2012).

3.3 New Basin Testing

A new generation of high-resolution SLOSH basins is currently being built from detailed geospatial data sets to better determine and incorporate representative land cover classifications.

A new Cape Hatteras basin is being planned and a larger higher resolution Norfolk basin (hor3) is being developed and is undergoing testing. A comparison of the attributes for the old and new versions of the Norfolk basins is shown in Table 1.

Table 1. Comparison between the eorf basin and the new preliminary high resolution basin.

SLOSH Basin Name	Minimum Resolution (km)	Number of Grid Points	Total Number of Grid Points
eorf	836	110x110	11,000
hor3	165	319x429	136,851

AutoSurge is being used to test and assess the new hor3 basin. An example of the performance at stations in the current eorf basin vs. in a preliminary version of the hor3 basin is shown in Fig. 3. Some of the land use classifications were changed to produce a more realistic impact of the land cover on the winds. These preliminary results from simulations with the new hor3 basin show improvement. The peak surge at the Money Point NOAA station (Fig. 3a) has been diminished, more in accordance to the observed maximum water levels. The excessive drawdown has decreased due to lower wind speeds blowing from land offshore (Figs. 3b and 3c).

4. Conclusions

AutoSurge has been proven to be efficient, accurate, and consistent in configuring and running the SLOSH numerical model and assessing model results in hurricane validation studies, post-storm analyses, basin development testing, and for operational storm surge forecasts.

AutoSurge underwent rigorous testing in NHC's Storm Surge Unit during the 2011 hurricane season and will be deployed for operational use during the 2012 hurricane season.

Forecast and hindcast simulations will be able to be configured and run automatically and the predicted modeled results and statistics calculated, viewed and analyzed in a more expeditious consistent manner.

5. References

Forbes, C. and Rhome, J. 2012: An Automated Operational Storm Surge Prediction System for the National Hurricane Center, *Estuarine and Coastal Modeling XII*, M. L. Spaulding [ed], ASCE, in press.

Taylor, A. A. and B. Glahn, 2008: Probabilistic guidance for hurricane storm surge, 88th Annual Meeting of the American Meteorological Society (20-24 January 2008), New Orleans, LA, 7.4, 8 pp.

Avila L and J. Cangialosi, 2011: Tropical Cyclone Report Hurricane Irene (AL0920011), 21-28 August 2011. http://www.nhc.noaa.gov/data/tcr/AL092011_Irene.pdf