A High Resolution Near-Shore Wave Model for the Mid-Atlantic Coast

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1 Summary of Project Objectives

Primary goals of the National Oceanic and Atmospheric Administration (NOAA) are to protect life and property while serving society's need for weather and water information, and support the Nation's commerce with safe, efficient, and environmentally sound transportation. Key performance measures for the National Weather Service (NWS) Strategic Plan are to extend and improve the accuracy of marine wind and wave forecasts, and to increase the availability of graphical marine forecasts.

A critical NWS responsibility is to produce nearshore wave forecasts. Waves influence all commercial and recreational uses of the coastal ocean, and furthermore contribute to coastal flooding, surf zone behavior, shore erosion, and hazardous rip currents. Prior to this project, the NWS offices along the East Coast relied solely on deep water wave models that excluded detailed wave behavior in the nearshore coastal waters, sounds, bays, and inlets. Forecasters used techniques that either linearly extrapolated deep water wave models to the coast, or used wind-to-wave nomograms and other ad hoc methods to forecast wave conditions in populated near shore waters. These techniques for forecasting wave conditions are very subjective, and highly dependent on individual forecaster expertise.

As a result of this Cooperative Program for Operational Meteorology, Education and Training (COMET) project, NWS Weather Forecast Offices (WFOs) Wakefield, VA, Newport/Morehead City, NC and Wilmington, NC now have state-of-the-art coastal wave model guidance and tools to help them provide improved coastal water forecasts. The nearshore wave model used for this project is the Simulating Wave Nearshore (SWAN) wave model developed by Delft University (The SWAN team, 2009).

The original objectives of this project were to:

(1) Develop a SWAN model application for the mid-Atlantic shallow-coast environment
(2) Develop an operational wave partitioning capability for providing gridded wind-wave and swell component fields to the Interactive Forecast Preparation System (IFPS)
(3) Conduct a careful calibration and validation of model performance
(4) Implement the model at participating WFOs

These objectives were further refined into the following tasks and their associated completion dates:

(1) Development of east coast SWAN Application (December 2007)
(2) Preparation of wind input products (December 2007)
(3) Calibration and validation at the US Army Corps of Engineers Field Research Facility (USACE-FRF) (June 2008)
(4) Development of operational wave partitioning and spatial tracking technology (September 2008)
(5) Transition of technology to weather offices of Wilmington, Morehead City and Wakefield (May-August 2009)

(6) On-site optimization and customer feedback (September-December 2009)
(7) Project documentation (December 2009)

Project key accomplishments, findings and benefits are described in the following sections.

2 Project Accomplishments and Findings

2.1 East Coast Wave Model Application

2.1.1 Preliminary Model Application Development

An east coast SWAN application has been running at the USACE-FRF since January 2007 to provide experience in running SWAN and using SWAN model products. The model is run in forecast mode forced by waves at the outer boundaries from the deep ocean wave model WAVEWATCH III™ (WW3), winds from the National Digital Forecast Database (NDFD) out to 20 nautical miles offshore, and winds from the North American Mesoscale (NAM) wind model beyond 20 miles offshore. Bathymetry was extracted from an ADCIRC model grid developed as part of the National Flood Insurance Program/North Carolina Floodplain Mapping Program (NCFMP) study. A web-site was developed by UNC/FRF and hosted by USACE-FRF for use by the WFOs while WFO on-site implementation was being developed. This web-site provided preliminary prediction products to forecasters and can be found at: http://140.194.28.33/eve/modeling/modelMainPageFrame.pl. The web-site includes forecast maps, forecast points and model validation. As operational coastal wave forecasting has now transitioned to the WFO forecast centers, it is likely that this web site will transition to support a regional Integrated Ocean Observing System (IOOS) modeling effort in 2010.

2.1.1.1 Forecast Maps

The web-site presents forecast maps of significant wave height, mean period and wave direction, as well as wind speed and direction. The maps are produced for an outer domain extending from South Carolina to north of Chesapeake Bay, and three inner domains detailing wave conditions in each WFO area of responsibility.

2.1.1.2 Forecast Points

Detailed plots of the model output parameters are also provided at forecast points co-located with buoys at specific locations requested by each WFO. Also, a summary table is created for each point with detailed wind and wave information. An example of a wave height forecast plot at the USACE-FRF 17-m depth Waverider buoy is presented in Figure 1. The pink vertical line represents the nowcast or current time. The two first data points are for model initialization.

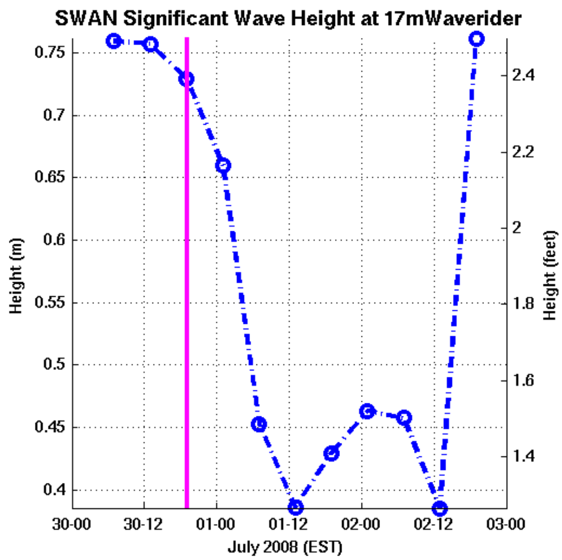

Figure 1: SWAN Wave Height Forecast at the USACE-FRF 17-m depth Waverider Buoy

2.1.1.3 Automated Performance Assessment

The USACE-FRF web-site also features model error statistics produced by the Automated Model Evaluation and Diagnostic System (AutoMEDS). AutoMEDS is the automated version of the Interactive Model Evaluation and Diagnostics System (IMEDS) (Devaliere and. Hanson, 2009; Hanson et al., 2009). AutoMEDS provides updates after each SWAN model run and generates statistics and performance scores by station, month and year. Details and validation results are provided in the following section.

2.1.2 Validation and Tuning

Detailed model evaluations and sensitivity analyses have been conducted by USACE-FRF and UNC-CH using the Carolinas coastal process numerical modeling test bed, developed through collaboration between the USACE MORPHOS program and the NOAA IOOS program (UNC-CH principal investigator Rick Luettich and UNCW principal investigator Lynn Leonard). As illustrated in the concept diagram of Figure 2, the test-bed brings together regional observations and numerical model predictions using state-of-the-art AutoMEDS model evaluation and diagnostics technology. These tools conduct a detailed assessment of model performance based on the evolution of individual wind-sea and swell events (Hanson et. al., 2009). Figure 3 presents the Carolinas Test-Bed domain and available stations. Two different studies have been completed for this investigation: a model sensitivity study (Devaliere et. al., 2007) and a 3-year annual performance analysis. The 2007 annual performance analysis is presented in our first year COMET report (Devaliere et. al, 2008).

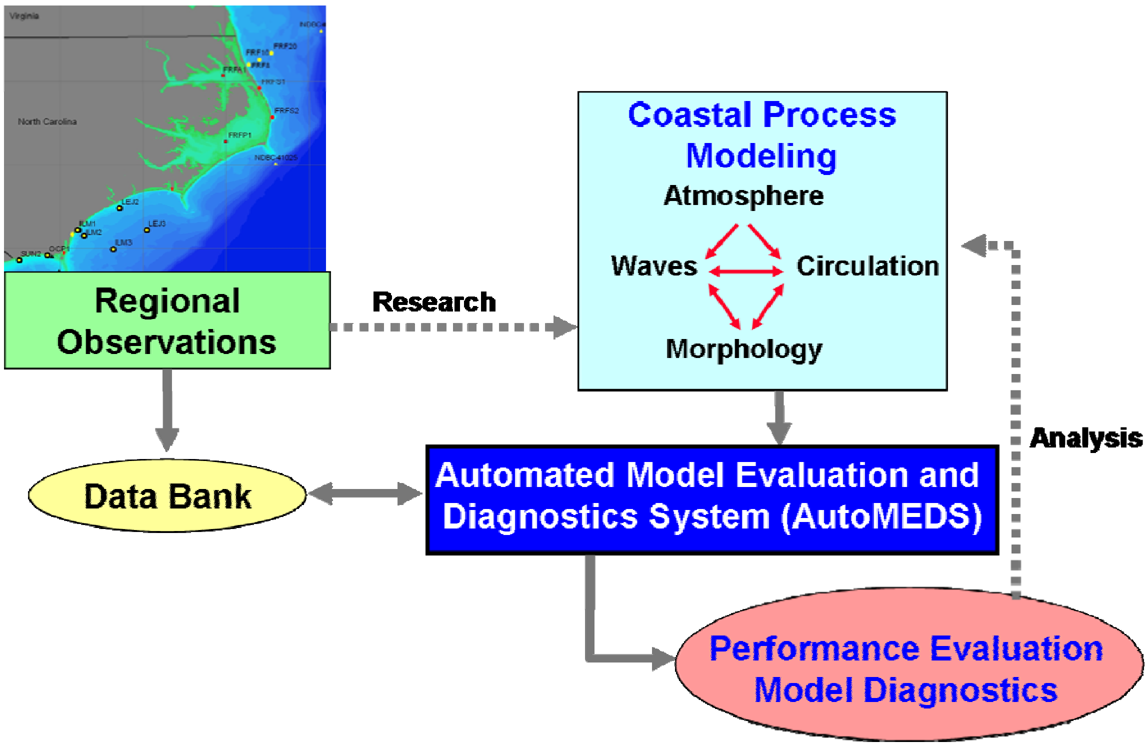

Figure 2: Test Bed Concept Diagram

The sensitivity study was based on four storm events with contrasting wave climates. The key findings were:

- SWAN gives reasonable results with the default settings
- The domain resolution can be reduced from about 7 km to about 14 km
- Instabilities can occur for specific resolutions and wave conditions. (Those instabilities are related to the SWAN model itself, and are likely to be addressed by SWAN developers in future releases.)
- A non-stationary mode could improve SWAN results for the outer grid domain

In stationary mode, the wind input is assumed to have been constant. In non-stationary mode, incremental changes in the wind are used. Tests with non-stationary mode show improvement in some areas however at a cost of extremely long model run times. The non-stationary mode has not been implemented in the NWS operational environment; this is an option in the future if computer resources become available.

As a result of this study, the resolution of the operational grids has been reduced to 14 km.

For the annual performance analysis, AutoMEDS was used to assess model errors at all available stations using nowcasts generated during 2008 and 2009. Model wave height errors during this period appear in Figures 4 and 5. Monthly wave height bias, Root-Mean-Square (RMS) error, scatter index (SI) values and performances scores (Perf) at each station are shown for the full wave spectrum and are then subdivided into wind-sea, young swell, and mature swell wave classes. All error metrics are computed as specified in Hanson et al., (2009). In general the error levels are quite reasonable. Note that, compared to the west coast, mature swell events are rare for the east coast; hence fewer data points are available in this particular wave class. Most of the wind-sea and young swell errors show strong seasonal trends. This is expected since increased winter storm activity results in larger relative errors both in driving winds and resulting wave predictions.

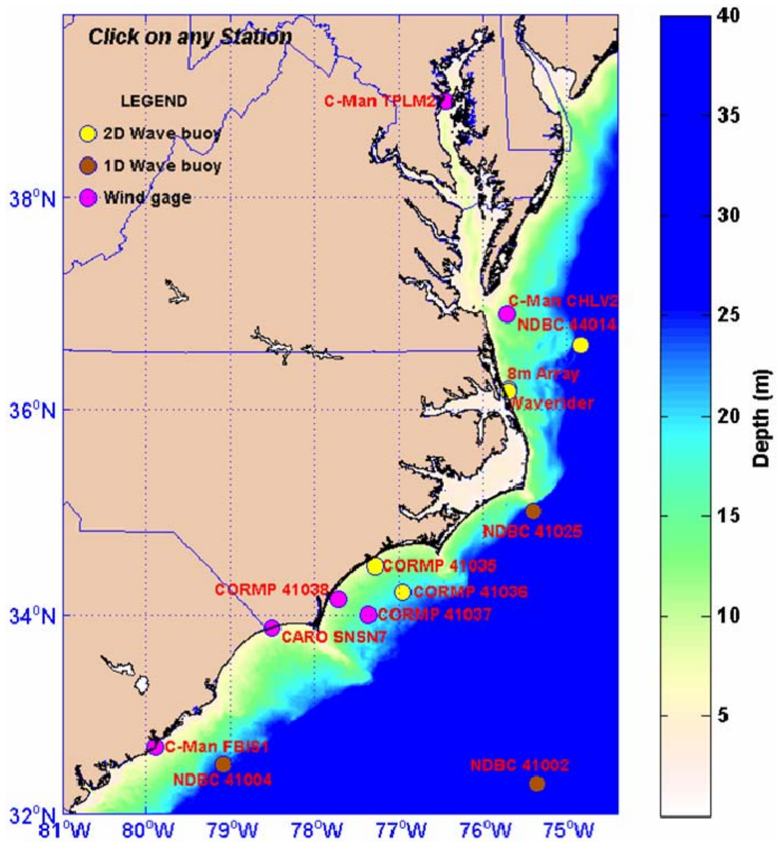

Figure 3: Observation Stations within Carolinas Test Bed

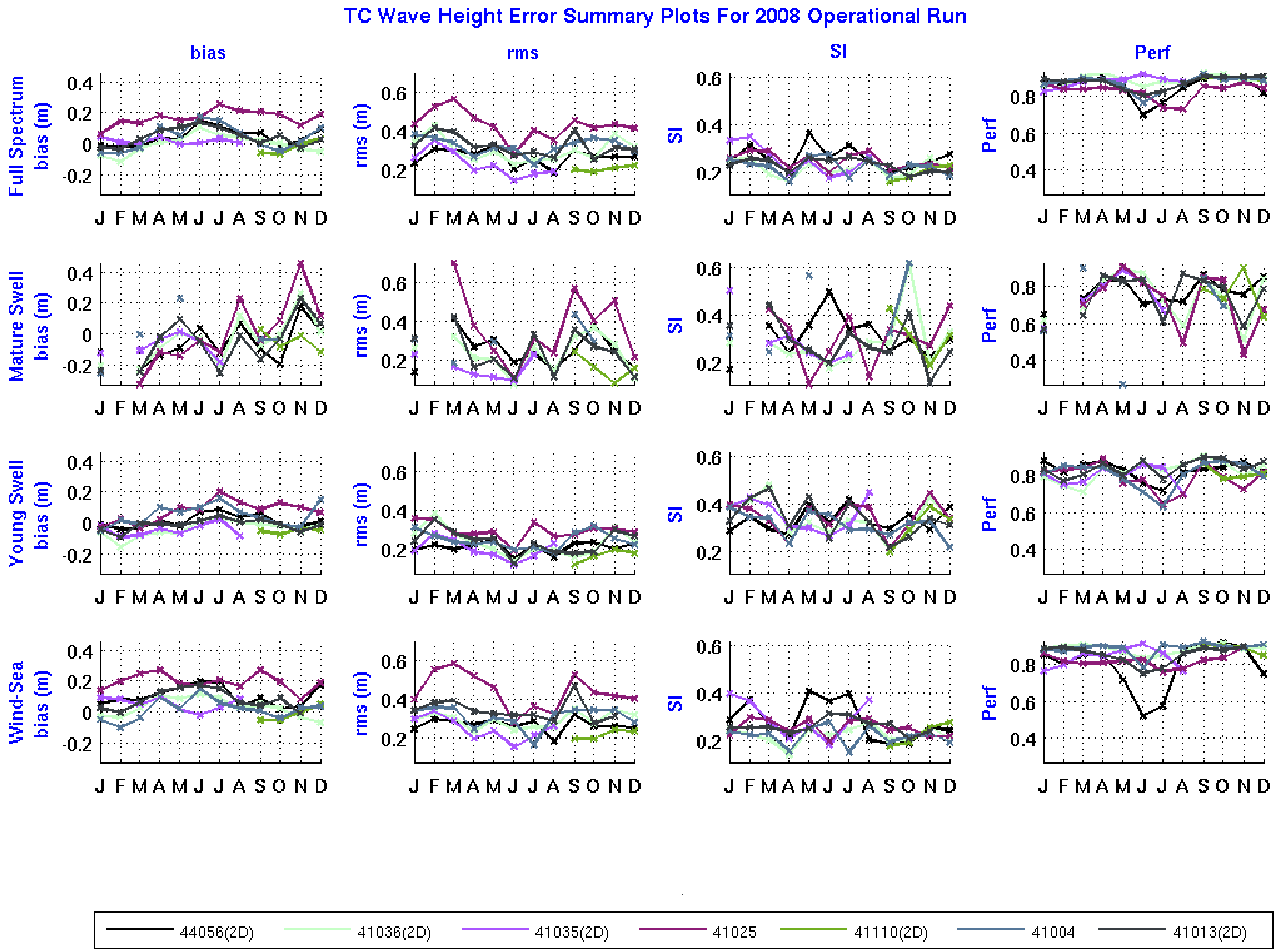

Figure 4: 2008 Annual Wave Height Error Assessments for East Coast SWAN Application

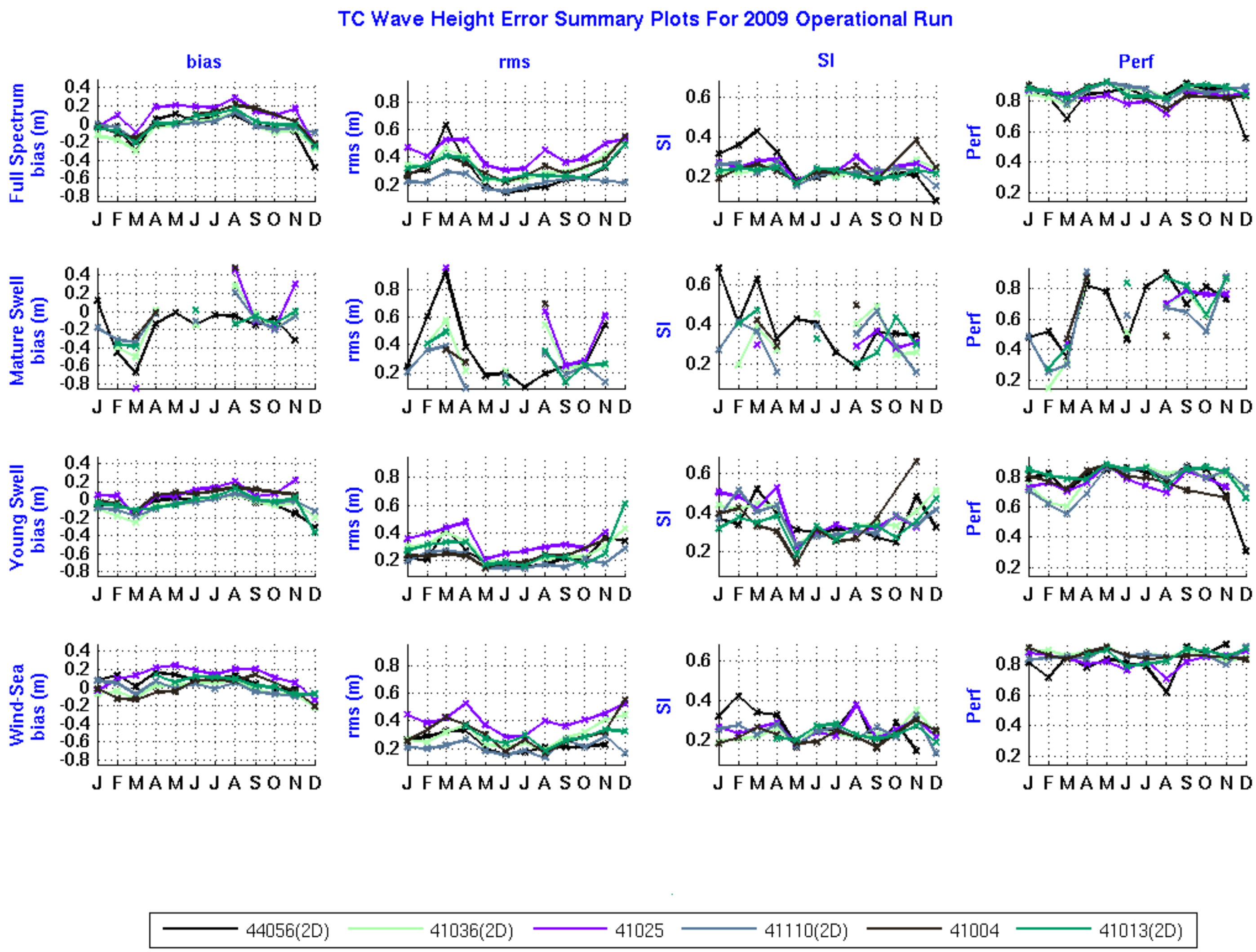

Figure 5: 2009 Annual Wave Height Error Assessments for East Coast SWAN Application

2.1.3 Development of Operational Wave Partitioning and Tracking Technology

Several improvements were made by USACE-FRF and UNC-CH to prepare SWAN output for operational WFO use. These improvements involve both partitioning of the wave-field into wind-sea and swell components, and tracking the evolution of these components over space and time. Specific details are provided below.

2.1.3.1 Wave Partitioning

Separation of the wave spectrum into individual wave components adds value to the wave forecast by providing additional detailed information that can be used to better protect life and property. The partitioning technique developed for the east coast SWAN application is based on the method of Hanson and Phillips (2001), and later modified by USACE-FRF for operational use in WW3 at NCEP and in SWAN at WFO Eureka. It was then further revised during this project. The method partitions the wave spectra produced at each grid point, and for each model output time, into individual wave components. A wave component represents the wave energy resulting from a specific wind event on the ocean surface. Wave components are further separated into wind-sea and swell categories. A component is called wind-sea when the wind is actively transferring energy to the waves. When the wind is not transferring energy to the waves, the wave component is called a swell. There can be only one wind-sea component at each point in space and time, but many swells can co-exist.

The initial partitioning method employed at WFO Eureka separated wind-sea and swell with a wave-age dependant cut-off frequency. Although this technique works well when there is a distinct frequency separation between the wind-sea and swell wave components, it can produce an artificial division in wave fields that do not exhibit this frequency separation. Furthermore, in the original Eureka application, the energy associated with the wind-sea component was not removed from the spectrum prior to identifying the remaining wave systems, thus resulting in a set of wave systems that did not conserve total wave energy.

For this project an improved methodology was developed for the identification of wind-sea. The fraction of the wave energy associated with wind-sea in each component is calculated using a ratio of the wind sea energy (computed using a wave age criteria) to the total component energy. When this energy ratio, known as the wind forcing ratio (*wf*), rises above a threshold value (*wf* >0.33 is used in WW3), the wave component is labeled as wind-sea. All other components are classified as swell. This approach was tested and implemented at WFO Eureka and was found to improve model results, making the output wave systems energy conservative. However, the use of thresholds to separate wind-sea and swell can also be problematic. For mixed wind sea and swell wave systems the separation can be inconsistent across the spatial domain, creating discontinuities in the individual wave component fields and resulting in Graphical Forecast Editor (GFE) grids that are difficult to follow. A solution to this was to keep all the wave systems intact, and not try to determine a numerical separation between wind-sea and swell. In this scenario the forecasters decide which wave system to use for the wind-sea forecast when such a grid is required in the forecast.

2.1.3.2 Wave System Tracking

Once different wave components are identified for each model grid point, they are tracked through space (spatial tracking) and time (temporal tracking) to form evolving wave systems. A significantly improved spatial and temporal tracking algorithm has been developed by USACE-FRF and UNC-CH for this project (Devaliere et al, 2009). An earlier spatial tracking method used a sorting approach that grouped wave partitions depending on their periods and directions. This approach worked reasonably well for local domains with uncomplicated coastline bathymetries (minimal wave refraction). In irregular coastal areas, patchy results were obtained. Given the complex coastline, shallow bathymetry, and large domain of the east coast project, a more robust method was required. The new approach uses a spatial search algorithm that spirals outward from a seed location to match neighboring wave components. The matching decisions are made using wave-period dependant height, period and direction thresholds. The resulting grids are no longer patchy and this method greatly improves the quality of the grid output sent to GFE.

2.2 Technology Transition

2.2.1 SWAN successfully installed at the local WFOs

The SWAN interface is now fully operational at each of the three local WFOs. We first installed a basic interface in WFO Morehead-City. Once this was stable and propagated to the other offices, a UNC representative (Eve Devaliere) spent a couple days at WFO Morehead-City and installed the advanced interface. Once the output was stable, the same approach was documented and used at the Wakefield and Wilmington offices. We were thus able to troubleshoot the main issues in one office before expanding implementation to the others. While this method worked fairly well, and even though each office possessed the same equipment and software, specific challenges emerged from each office. The most significant are mentioned in section 4. Components of the basic and advanced interface are further detailed below:

- Basic interface

  This first step was providing forecasters significant wave height, peak wave period, and primary wave direction grids in GFE. We were thus able to test:
  - The wind procedure ingesting forecast winds over the area of responsibility and the GFS (Global Forecast System) winds for remaining areas outside of the local domains. When the forecasters trigger the SWAN run from GFE, a netCDF wind file is created on a custom SWAN GFE and is copied to the SWAN machine to trigger the model run.
  - All the communication routes between the SWAN machine and the AWIPS systems were correctly setup.
  - Boundary conditions from Wavewatch III were downloaded properly from the NCEP ftp site to the SWAN machine.

- o The SWAN model itself was running appropriately (We compared the results in each office to the data obtained at the FRF)
- o GFE was recognizing new model data and filled the resulting grids properly. Smart initialization tools in GFE also were setup to combine datasets such as height and direction into the same grids, and translating data from meters to feet. An example of a resulting significant wave height (feet) grid from WFO Morehead-City is presented in Figure 6.

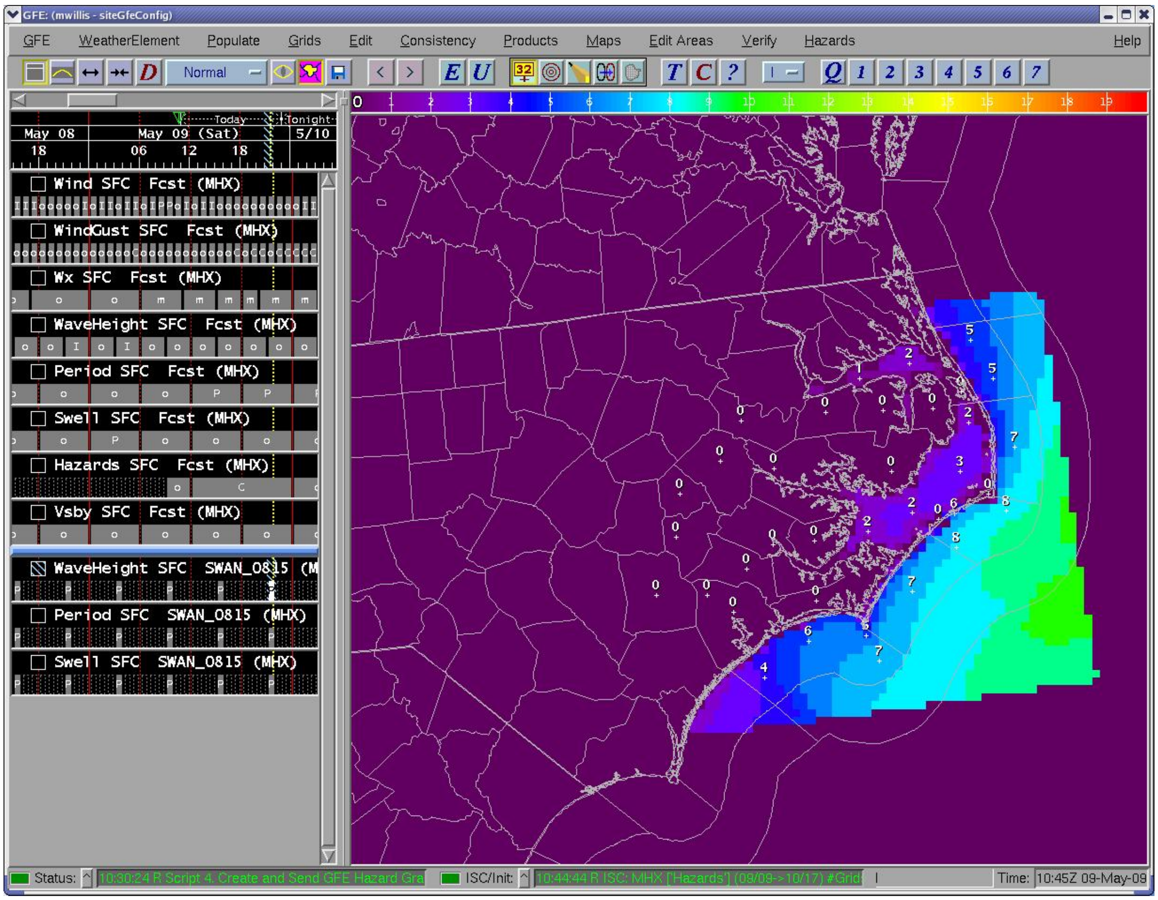

Figure 6: SWAN Significant Wave Height Grid in GFE at WFO Morehead-City for May 9th, 2009

- Advanced interface

  The advanced interface was then set up to handle extra post processing. The advanced interface includes:
  - o Partitioning for each coastal waters grid point.
  - o Spatial tracking of wave components into wave systems with spatial consistency.
  - o Time tracking of wave systems through time.
  - o The output of the three above processes was written to a netCDF file for ingestion by GFE. The forecasters can now access spatially and temporally consistent grids for each wave system present in each of the local WFO coastal waters. A wave system wave height and direction grid from WFO

Wilmington is presented in Figure 7. Other products from the advanced interface were not in the original scope of the proposal and are further described in section 2.2.2.

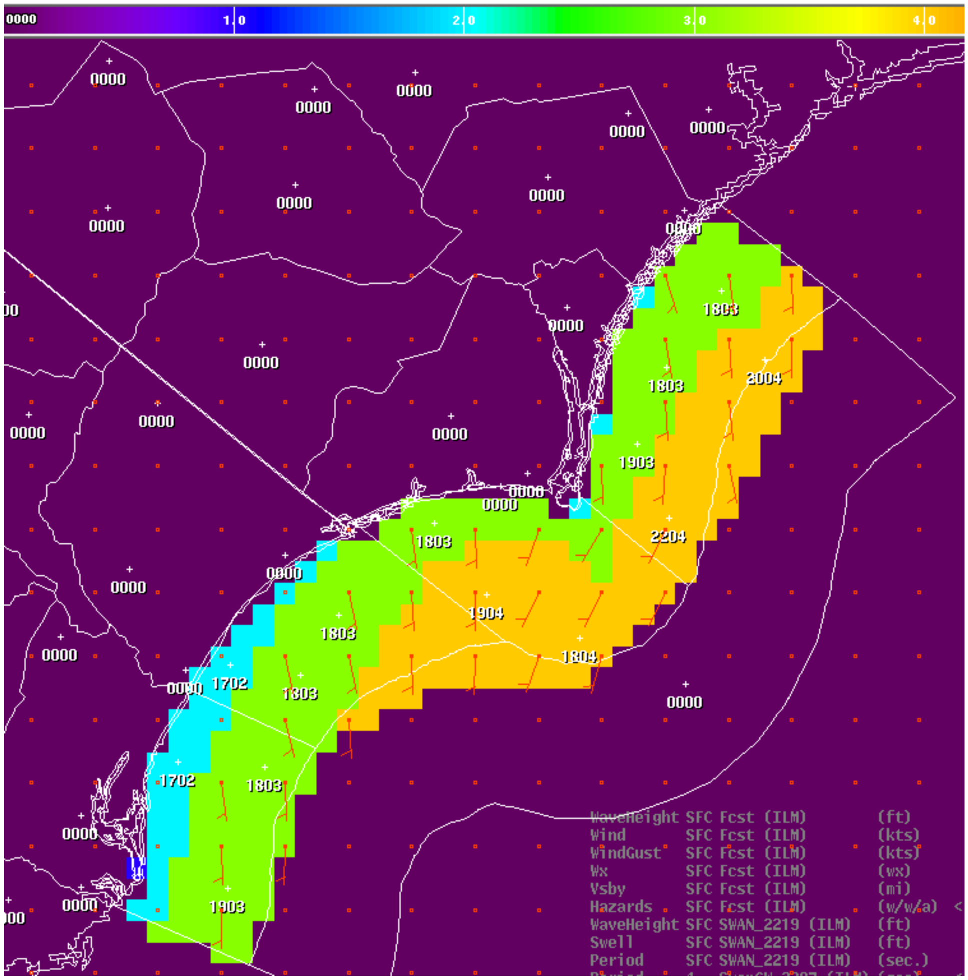

Figure 7: Most Energetic Wave System Height and Direction Grid from WFO Wilmington during Hurricane Bill

2.2.2 Additional Products

The following additional products were developed using funds leveraged from other projects.

2.2.2.1 Wave Vector plots for specific output points

The wave vector plot, referred to by the NWS as the 'Hanson Plot', is useful for both visual validation and forecast guidance through graphical representation of the forecasted wave systems. The wave vector plot displays evolution of wave systems for a particular point in space through the forecast period. If this point coincides with an observation point, the plot starts with a day of observations, allowing the forecaster to see at a glance how well the model matches observed data. Figure 8 is an example of a vector plot for buoy 41036, situated In Onslow Bay, NC. The length of the arrows are proportional to the wave height, the arrow direction indicates the direction of wave propagation (‘toward’ true north), and the base of the arrows identify the wave period. Differing wave systems are coded with different colors. The wind speed is plotted in the lower panel. Observed buoy data is positioned left of the pink vertical line, while model data is located to the right of the line. The ‘TDY’, ‘TNT’, etc. nomenclatures at the top of the plot designates ‘Today’, ‘Tonight’, etc. matching the nomenclatures used in the GFE.

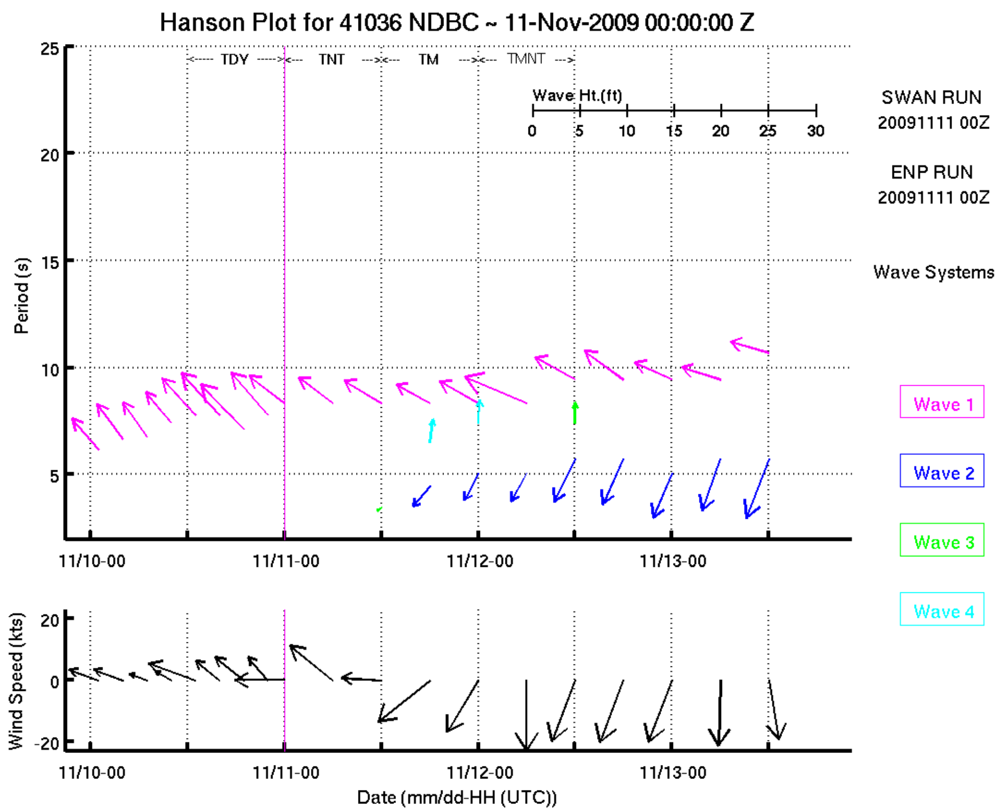

Figure 8: Vector Plot for Observed Data and SWAN Forecast at Buoy 41036 Location

2.2.2.2 Time-series of different wave systems for specific output points

To provide additional graphical wave guidance for the forecasters, a product similar to the vector plots was developed: the wave system time-series plots. The time-series plots show data in a similar fashion as the Wavewatch III text bulletins that the forecasters are familiar with. The observed data however is not available in the time-series plots. An example of a wave system time-series plot is presented in Figure 9 for the same output point as the Figure 8 wave vector plot. The wave system color codes are the same in both products and the wave system numbers correspond to the wave system numbers found in the GFE grids.

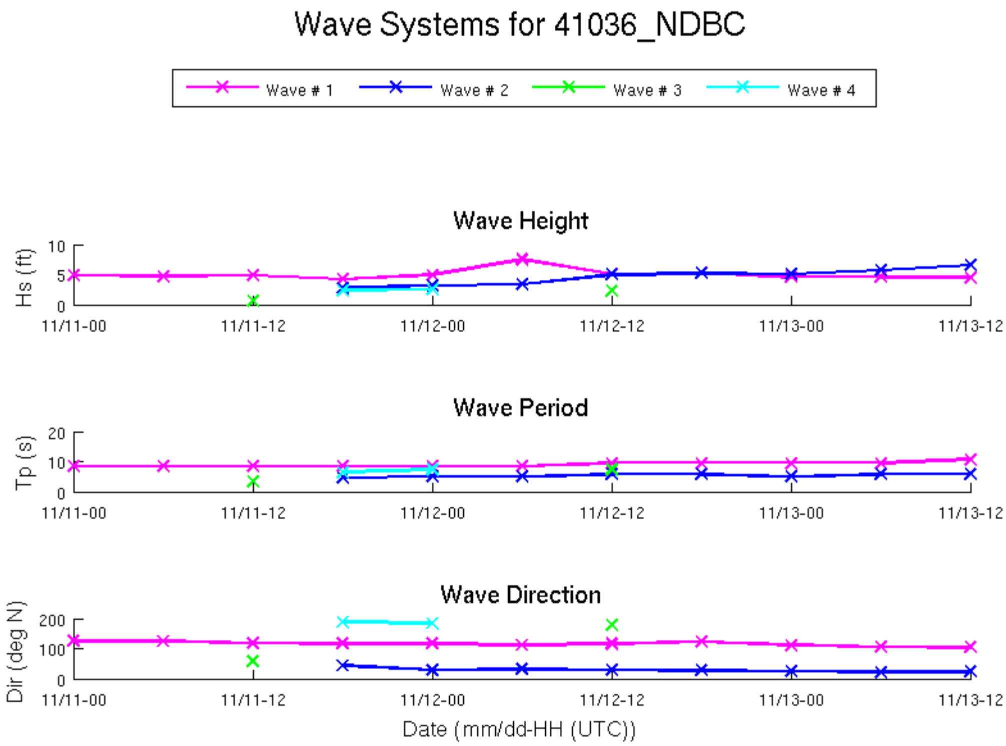

Figure 9: Wave System Time-Series for SWAN Forecast at Buoy 41036 Location

2.2.3 In office validation plots

A simplified version of the AutoMEDS software has been custom developed for the National Weather Service, giving wave height, wave period and wave direction time-series comparison plots between modeled and observed data where available. The forecasters can see directly how well SWAN is resolving wave forecasts. The plots are updated each model run. This set of validation tools represents an additional product, and relies on downloading and archiving data from the National Data Buoy Center (NDBC), on a daily basis. Figure 10 depicts a wave height time-series comparison for buoy 44099, a few miles offshore from Cape Henry, VA and within the WFO Wakefield domain. The buoy data is in red, the SWAN nowcast in blue. Each blue circle represents a model run. In this case, the model wasn't run during approximately 23- 25 September.

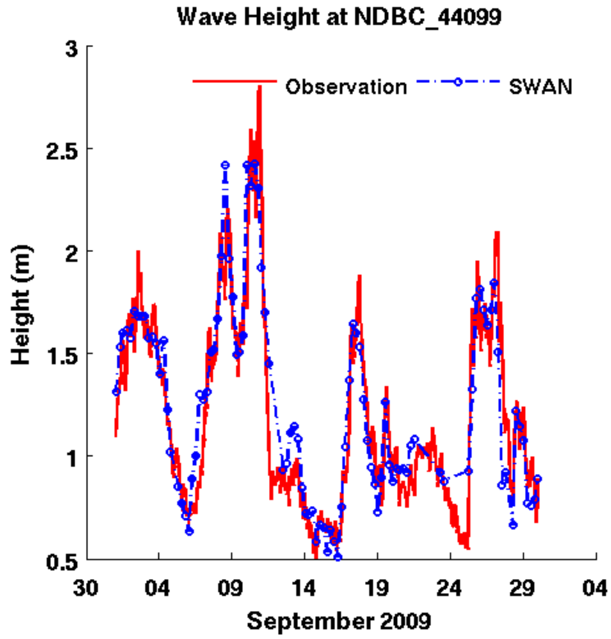

Figure 10: Wave Height Time-Series Comparison for Buoy 44099 from WFO Wakefield

2.2.4 Wiki Help

WFO Morehead-City and WFO Wilmington also developed a Wiki page that can be accessed by any WFO. This Wiki page gives details on each of the available products and is used by the forecasters as a reference point.

2.2.5 Additional users

Since this project began, other WFO offices, particularly Southern Region offices of Tallahassee, Miami and Key-West, have been eager to use this technology, and have been making significant progress on catching up with the east coast sites. The three offices mentioned above are now running SWAN as a result of this project, and the same technology is about to spread to the remaining coastal Southern Region offices. They do not yet possess all of the tools included in the advanced interface, but should be fully operational in a very near future. Documentation detailing how to setup an office was developed by Southern Region WFOs (Gibbs et al., 2009).

2.3 User feedback

A survey was distributed to the WFOs to evaluate how well this project was received by the forecasters. A total of 35 forecasters answered the survey with 16 from Wakefield, 11 from Morehead-City and 8 from Wilmington. The survey was anonymous. Some of the forecasters did not answer all the questions.

On a scale of 1 to 5 with 1 being the least effective and 5 being the most effective, the forecasters were asked to answer the following questions:

1) How would you rate the usefulness of SWAN?
2) How would you rate the accuracy of SWAN?
3) How would you rate the timeliness of SWAN?
4) How would you rate the ease of use of SWAN?

5) How would you rate SWAN's performance over other available wave models such as WW3?
6) How would you rate the usefulness of the wave systems gridded output?
7) How would you rate the accuracy of the wave systems gridded output?
8) How would you rate the usefulness of the Hanson plots?
9) How would you rate the usefulness of the time-series plots?
10) How would you rate the usefulness of the Validation Plots?

Results of this survey are provided by Figure 11. The purple bars provide the mean scores for each question, and the black error bars provide the minimum and maximum scores for the entire set of replies.

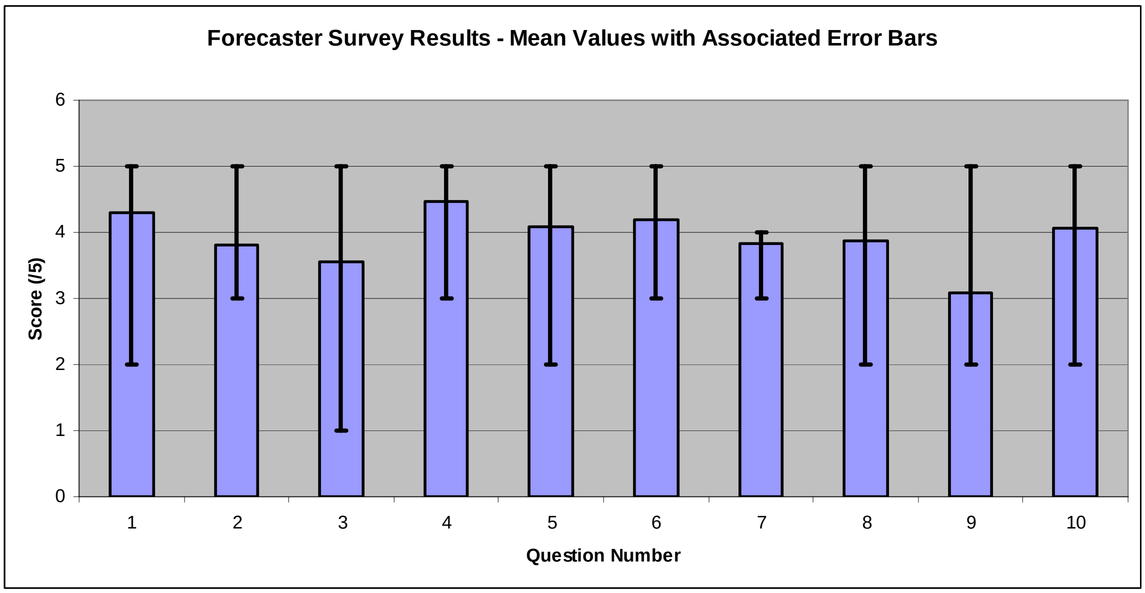

Figure 11: Forecaster Survey Results

The survey also included 2 additional questions. These questions and the various responses are presented below. All the comments received are presented and no editing has been done to the forecasters comments.

- Can you think of any improvements you'd like to see with SWAN?
  - Data for later periods and more increments in short term.
  - Would like to see more flexibility with background winds, more output points or spectra, bulletins comparable to WW3, and validation plots of shorter time frames (one month is too long).
  - Larger domain.
  - I would like to see the validation data and Hanson data more readily available for use in our operations.
  - Much faster run time. I don't like having to wait nearly an hour after my winds are done to use SWAN.
  - A longer time span.
- If you have any comments concerning the 10 above questions, please indicate them below along with the question number it pertains to.

- Don't like having to wait to run it after winds are done but run time has improved (Question 3).
- Great job with this project!

WFO Wakefield summarized their forecasters' habits and comments from the survey: 'Almost all forecasters do run SWAN. They use it as an added piece of guidance just like Wavewatch 3 or a local tool that was developed from climatology. Many of the forecasters will use SWAN or some blended form of SWAN and Wavewatch 3 to create the waves on the coastal waters. The vast majority of forecasters think this gives the best product. All forecasters agree that one of SWANs strengths is building or diminishing waves. They see SWAN as the best model for this.

Over the bay is where things get more interesting. For some reason there still remains a small part of the bay which does not get any values from SWAN so it always shows up with 0 wave heights. This can be worked around by the forecasters however. The main question is the issue of SWAN in small craft or gale conditions gives about one foot lower then the current regression tool the office has been using for years. Without some solid verification in the bay it will be hard to get forecasters to go under the higher tool. SWAN does give a good distinction of higher waves where the fetch is longer which is better then our current tools so that is getting some forecasters to use it some.
On some of the 3 hourly updates we do the SWAN is not rerun. There are two reasons for this. One is the time it takes SWAN to run and the second is that if the wind changes are minimal, most forecasters do not expect any changes to the waves.'

In general, the forecasters are pleased with the SWAN application. As the results slightly differ from previous methods and other models, some forecasters have concerns on the accuracy of the model. The run time is a major concern and many forecasters find it excessive. Even though the wave systems output is new to the majority of the forecasters, the wave system output grids are well received. Some of the forecasters apparently have some concerns about the new graphical products, particularly the time-series.

3 Benefits and Lessons Learned: Operational Partner Perspective

3.1 Benefits

Graphical data output from the SWAN project at the National Weather Service has thus far proved illuminating, insightful, and invaluable. We are seeing firsthand from SWAN data how waves behave when propagating through shallow waters of the continental shelf, refracting around prominent shoals and capes which extend through our coastal water forecast zones.

Specifically, we are observing the extent of wave shadowing in our coastal waters due to the presence of shoals, the degree of bottom friction encountered by wave energies of varying frequencies, and which wave directions are most efficient in producing significant wave heights nearshore where marine traffic is concentrated.

Additionally, we are observing how our local shoals affect wave period distribution in cases of swell shadowing. Wave periods are a critical element in wave forecasting. For a constant wave height, differing wave periods translate to differing wave steepness. As wave steepness increases, so also does the potential hazard to those navigating small craft vessels.

SWAN will allow the NWS forecasters to include more detailed wave information in the first few time periods of the widely disseminated "coastal waters forecast", one of the only routine products still disseminated on the Weather Channel. This detailed information can be gleaned from the partitioning scheme SWAN incorporates. In addition to just saying "seas 2 to 4 feet", we are now capable of providing supplemental wave information. For example consider the following wording: "wave detail – NE waves 2-3 feet every 6 seconds, and SW waves 3 feet every 10 seconds." Additionally we are now capable of providing a "dominant wave period" for a given wave spectrum.

SWAN is showing us things we have not seen before. The combination of shallow water physics that SWAN incorporates, and the ability to ingest a flexible set of forecast winds is resulting in graphical output that is serving not only as a learning tool, but guidance for more accurate wave forecasts. This improved accuracy will enhance our ability to protect life and property at sea by providing mariners advanced notice of potential or developing hazards.

3.2 Problems

As discovered during the preliminary sensitivity study, the stationary mode in SWAN builds up the seas too fast at times. Complimentary tests have been made confirming this behavior. It is likely that switching the outer domain to a non-stationary mode would alleviate this problem. However a full sensitivity study should be conducted to explore all non-stationary options. Such an effort is beyond the scope of the present project.

No other major problems have been noted, only minor configuration adjustments and localized, solvable program bugs.

4 Benefits and Lessons Learned: University Partner Perspective

4.1 Benefits

4.1.1 Development of additional spin-off programs

This project has produced a valuable coastal wave modeling capability for the mid-Atlantic coast. The existence of this capability, and the wave model validation technology implemented to verify the results, has fostered development of the following additional programs.

4.1.1.1. IOOS

IOOS has invested in further development of the Carolinas Test Bed that was used to conduct SWAN sensitivity analysis. Specific goals include adding additional observation stations with an emphasis on coastal waves and currents, and developing a validation capability for ocean circulation and water level modeling efforts. Leveraging of resources with the IOOS project has allowed us to go above and beyond the initial COMET objectives.

4.1.1.2. FEMA North Carolina Floodplain Mapping Program (NCFMP) Study

This is a collaborative project between the RENaissance Computing Institute (RENCI) and the University of North Carolina, using past and simulated hurricane data to assess coastal flooding risks. These two projects (COMET and NCFMP) are similar on the validation aspect but are essentially testing different SWAN features. The NCFMP project needs to know how SWAN is performing in the event of extreme wave scenarios, such as hurricanes, while the COMET project requires continuous forecast performance assessment.

4.1.2 Improved partnership with NWS

UNC/FRF and each WFO communicated extensively during this entire project, specifically during the transition process. This has helped to solidify the existing partnership between UNC, the FRF and the NWS. As other potential partnership projects surface, for example rip-current forecast technologies, existing collaboration with the NWS would greatly improve the execution of such a project. UNC/FRF gained great insights on the difficulties of working on a research project in the operational forecasting world and is now much more aware of the challenges that this involves.

4.2 Problems/Challenges

The majority of challenges associated with this project were due to the nature of the operational forecasting environment. While transitioning, installation and testing were sometimes delayed as the Information Technology Officer (ITO) at the WFOs was required to address other emergencies in operations, or servers could not be rebooted until forecasters completed sending the suite of forecast products. Other challenges were due to technical limitations, some of which are described below.

4.1.3 Issues with rotated domains

The first problem occurred while designing domains specific to each WFO. Along the 3 participating WFO's coastal areas of responsibility, the coastlines are oriented at considerable angles to a north-south orientation. We first tried setting up the domains so they match or follow the coastline, referred to as 'rotated domains'. The use of rotated domains provided a useful reduction in computer time vs north to south oriented domains. One of the resulting 'rotated' netCDF files was tested with GFE after building the first domain. NetCDF is one of the formats used by GFE to display models results. After discussions between UNC, the FRF, the WFOs, the Weather Service Headquarters and the Global Systems Division (GFE developers), we discovered that GFE cannot display netCDF files unless they have a north to south orientation.

Two potential solutions were considered: (1) use a north to south domain orientation for the SWAN runs or (2) keep the rotated domains and interpolate the results into a north to south oriented domain. After a few tests on the run-time, it was decided that although a longer run-time was required by the north to south domains, the run-time was still viable for the chosen 2.5 to 5 km resolution. This solution eliminated the need to interpolate SWAN results between the grids, which would have resulted in some loss of model data and was therefore considered to be unacceptable. It was thus decided to design the domains with a north to south orientation.

4.1.4 Delay in obtaining the WFO computers

There was a significant delay in acquiring the WFO computers. In order to alleviate the impact of this major delay and to start the transitioning to one WFO, UNC lent a computer to WFO Morehead-City. It unquestionably allowed for a faster completion of this project.

4.1.5 Ingesting model data in the GFE

Steps to ingest new and non standardized model data to GFE are various and not well documented. Project investigators found limited resources to help with this critical step. Some valuable knowledge has been gained, however, and the procedure has been documented and is presented as part of the 'Advanced Interface Installation Guide' in Appendix 1.

4.1.6 GFE and SWAN resolution issues

The GFE display is at 5km resolution, and for accuracy purposes, SWAN is run at 2.5km resolution. Interpolation errors occurred in the initial setup, as waves were not propagating to the coast in the display due to the crude GFE resolution. This issue required extensive and meticulous troubleshooting before an understanding of the source of the problem could be determined. Wilmington's ITO developed a methodology that addresses this issue by using a mask and interpolation technique in the very near shore waters.

4.1.7 Clutter in SWAN results display due to a trailing GFE mask

Waves suddenly appeared to be over land in the middle of the transition process for one of the WFOs. After careful debugging, we determined that it was due to a mask that was being applied while ingesting the data. Eliminating this mask solved the issue.

5 Publications and Presentations

Devaliere, E. and J. Hanson, 2009. Interactive Model Evaluation and Diagnostic System (IMEDS) User Guide, US Army Corps of Engineers, Field Research Facility, Duck, NC.

Devaliere, E., J. Hanson and R. Luettich, 2009. Spatial Tracking of Numerical Wave Model Output Using a Spiral Search Algorithm Proceedings 2009 World Congress on Computer Science and Information Engineering, Los-Angeles, CA

Devaliere, E., R. Luettich, M. Willis and J. Hanson, 2008. A High Resolution Near-Shore Wave Model for the Mid-Atlantic Coast, UCAR S07-66810 COMET Project Year 1 Report

Devaliere, E., J. Hanson and R. Luettich, 2007. Evaluation of wave model performance in a North Carolina Test Bed, Proceedings 10th International Wave Hindcasting and Forecasting Workshop, North Shore, HI.

6 Summary of University/Operational Partner Interactions and Roles

6.1 UNC/FRF

- Lead development of application
- Conducted the initial test and evaluation
- Oversee transition to WFOs
- Troubleshoot implementation issues

6.2 AKQ, MHX and ILM WFO's

- Arrange for wind input for SWAN to be created and comply to application needs
- Purchase the computers for the SWAN model
- SWAN GFE setup
- Operational test
- Apply updates as needed
- Forecasters survey

6.3 EKA WFO

- Test bed for SWAN application and new spatial tracking algorithm
- Guidance on installation at local offices

References

Devaliere, E. and J. Hanson, 2009. Interactive Model Evaluation and Diagnostic System (IMEDS) User Guide, US Army Corps of Engineers, Field Research Facility, Duck, NC.

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Gibbs, A., T. Freeman, P. Santos, D. Gaer and D. Van Dyke, 2009. GFESwan/SWAN v1.0 Installation and Configuration Procedures

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Devaliere, E., J. Hanson and R. Luettich, 2007. Evaluation of wave model performance in a North Carolina Test Bed, Proceedings 10th International Wave Hindcasting and Forecasting Workshop, North Shore, HI.