7B.7 THE IMPLEMENTATION OF THE GRAPHICAL FORECAST EDITOR FOR A NATIONAL CENTER MARINE DOMAIN

Ariel E. Cohen*[1], E. Christensen[2], C. A. Juckins[2], J. P. Cangialosi[2], C. Lauer[2], H. D. Cobb[2], and M. Nelson[2]

[1]NOAA/National Weather Service Forecast Office, Jackson, Mississippi
[2]NOAA/National Hurricane Center, Miami, Florida

1. Introduction

The Tropical Analysis and Forecast Branch (TAFB) of the National Oceanic and Atmospheric Administration (NOAA) National Hurricane Center (NHC) is responsible for issuing marine weather analyses, forecasts, and warnings for the tropical, and portions of the subtropical, Atlantic and Pacific Oceans, as well as the Caribbean Sea and Gulf of Mexico. These include forecasts of wind velocity and significant wave height out to 48 hours from the present in High Seas Forecasts (HSFs) across much of the TAFB Area of Responsibility (AOR) (see Figure 1), and out to 5 days from the present in Offshore Waters Forecasts (OFFs) for the southwest and portions of the tropical North Atlantic Ocean, Caribbean Sea, and Gulf of Mexico. Additionally, numerous graphical products, including 24-, 48-, and 72-hour wind/wave charts, are manually prepared using NOAA WAVEWATCH III (NWW3) and global Numerical Weather Prediction guidance. TAFB issues over 100 graphical and text products, combined, each day.

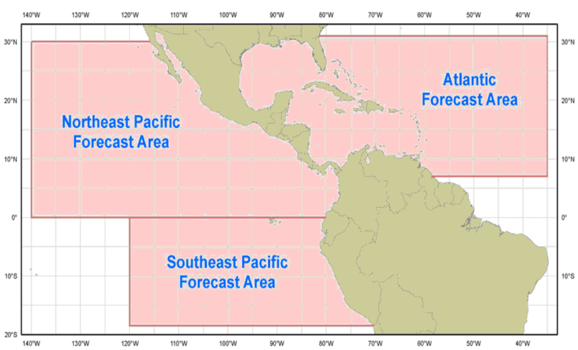

Figure 1: TAFB Area of Responsibility (AOR).

TAFB is currently reconstructing the marine forecast process across its AOR via the use of the Graphical Forecast Editor (GFE) (Ruth 2002). This will provide an opportunity for TAFB to communicate its forecasts at a much finer spatial and temporal resolution than it ever has, add significant detail to forecasts including the inclusion of local effects, collaborate with other national centers and National Weather Service Forecast Offices, and both automate and enforce consistency the process of generating text forecasts.

*_Corresponding Author Address_: Ariel Cohen, National Weather Service, Jackson, MS Weather Forecast Office, 234 Weather Service Dr., Flowood, MS 39232; e-mail: Ariel.Cohen@noaa.gov.

2. Legacy Forecast Preparation

For decades, TAFB has used the National Advanced Weather Interactive Processing System (NAWIPS) for the analysis of current and forecast state of the atmosphere and ocean. Included in this analysis is a large suite of global Numerical Weather Prediction (NWP) guidance, as well as NWP-driven NWW3 output for forecasting sea state variables (e.g., significant wave height and wave period). One of the oft-used tools available from NAWIPS is the Products Generator tool, which forecasters use to generate forecast charts of the wind and wave conditions, wave periods, surface pressures, and many other variables. These charts are converted to radiofax charts that are then broadcast from points across the AOR to a large and diverse customer base, including marine vessels, cruise lines, and recreational marine users. An example of one of these charts is provided in Figure 2.

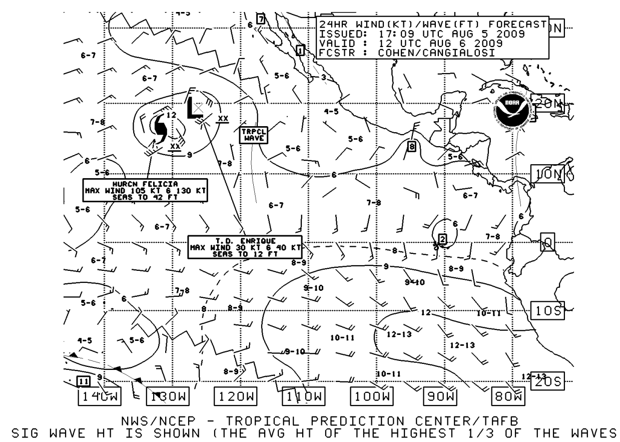

Figure 2: Forecaster-prepared 24-hour Wind/Wave chart over the Pacific AOR, providing 24-hour forecast wind vectors and significant wave height contours, range labels, maxima, and minima. The chart also displays critical meteorological features, including tropical cyclones, fronts, trough and ridge axes, and high and tropical and extratropical high and low centers.

Such charts provide general overviews of the overall forecast state of a particular basin. However, they are also associated with numerous limitations. For example, the spatial and temporal resolution of the charts is very low, and mariners desiring forecast information at a specific point can find themselves at a loss for information from such charts. In particular, there are several locations across the AOR where terrain variations highly modulate wind velocities, and thus wave heights, and these variations can occur over a spatial scale that these charts cannot resolve. Examples include gap wind events in the Gulf of California (Cohen and Cangialosi) and the Gulf of Tehuantepec (Cobb et al. 2002). Additionally, forecasters are commonly forced to provide degraded model NWP and NWW3 output for the benefit of providing a concise and easy-to-read chart, especially given the way in which the product is automatically gridded.

As mentioned earlier, forecasters are responsible for issuing OFFs for the Gulf of Mexico, Caribbean Sea, and southwest and tropical North Atlantic. This area is subdivided into nine subzones, which are issued in two separate forecast packages for five-day periods.

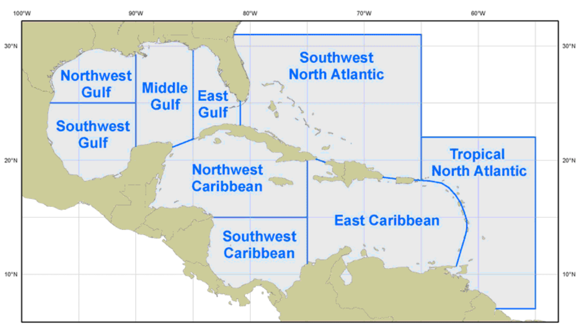

Figure 3: Offshore Waters Forecast (OFF) zones for TAFB.

As is immediately apparent in Figure 3, the large size of these zones reduces forecast precision and can make forecast lengths unwieldy, particularly for complex synoptic regimes. In particular, the southwest North Atlantic zone covers an area about the size of Mississippi, Louisiana, Arkansas, Alabama, and Tennessee combined. Even without fronts in the area, conditions east and west of the Bahamas vary considerably, and it can become impossible to consistently portray these variations in a concise and accurate manner. Below is an example excerpt of only two periods of the OFF for the southwest North Atlantic zone:

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.THIS AFTERNOON AND TONIGHT...N OF 28N N
TO NE WINDS 10 TO 15 KT INCREASING TO NE
15 TO 20 KT...EXCEPT W OF 75W NE TO E
WINDS 10 KT EARLY BECOMING SE TO S 10 TO
15 KT AND S TO SW 15 KT TONIGHT.
SEAS 3 TO 5 FT...EXCEPT 6 TO 8 FT IN NW
SWELL E OF 75W. S OF 28N W OF FRONT TO 76W
NE WINDS 15 TO 20 KT. SEAS 6 TO 8 FT.
ELSEWHERE W OF FRONT NE TO E WINDS 10 TO
15 KT. SEAS 4 TO 6 FT...EXCEPT 2
TO 4 FT SW OF BAHAMAS. E OF FRONT E TO SE
WINDS 10 TO 15 KT... EXCEPT E 15 TO 20 KT
S OF 22N. SEAS 4 TO 6 FT...EXCEPT 6 TO 9
FT IN SUBSIDING N SWELL S OF 22N.
SCATTERED SHOWERS AND ISOLATED TSTMS ALONG
FRONT.
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Not only can such a forecast be confusing to both the reader and the forecaster, but it can also result in inconsistencies with other products (e.g., High Seas Forecasts), as well as typographical errors, given the manual preparation process. Additionally, these forecasts are communicated to mariners via NAVTEX stations, which are operated by the U.S. Coast Guard. Such long and complicated forecasts are often truncated, providing incomplete information to listeners, and are simply difficult to interpret. TAFB is trending toward the use of GFE to solve a number of these problems, which is discussed in the next section.

3. Solution: The Graphical Forecast Editor (GFE)

For the last decade, local National Weather Service Forecast Offices (NWSFOs) have been using and enhancing the GFE as a primary tool for forecast preparation and dissemination. GFE is a software package developed by the Global Systems Division of NOAA's Earth System Research Laboratory and provides a forecaster-editable database of high resolution forecast variables. When using GFE, forecasters can directly load model output, which is downscaled to grids at high spatial and temporal resolutions for a large number of sensible weather elements. Forecasters can then use "Smart Tools" to adjust model output, allowing improvements in resolving local geographic and topographic effects and maintaining intra-forecast consistency, as well as inter-forecast consistency among neighboring NWSFOs. More importantly, these high-resolution forecasts are available to the public via the National Digital Forecast Database (NDFD), which provides individually-tailored forecasts of basic sensible weather elements. GFE also includes the opportunity to automatically generate text forecasts and verification information, providing significant efficiencies in the forecast process.

Since autumn 2008, forecasters and technical staff at NHC have engaged in grassroots efforts to configure GFE for the TAFB AOR. This has opened the door for TAFB to greatly improve both efficiency and consistency in its forecasts, as well as provide a much more valuable product to its customers. In addition to providing higher resolution forecasts of winds and significant wave heights, GFE will allow forecasters to graphically depict hazardous wind and sea grids. Additionally, GFE provides the opportunity to use forecaster-edited wind grids as input for wave height, wave period, and swell forecasts. Numerous text formatters have also been locally developed to automatically generate Offshore Waters Forecasts and other text products derived from the gridded forecasts.

4. Gridded Forecasts at TAFB

Figure 4 provides an example of a mean sea level pressure (MSLP) forecast from the GFE interface. This is the result of loading in direct output from the Global Forecast System NWP model followed by using a smoothing algorithm to populate the field onto a 12.5 km x 12.5 km domain (default horizontal resolution for all TAFB GFE grids). The current TAFB GFE forecast temporal resolution is 6 hours, though other times are being considered. Interpolation allows the time step to be reduced to as low as one hour. Of course, the accuracy of such resolute forecasts is an area of potential improvement, but it is known that customers do desire this information at the highest temporal resolution possible.

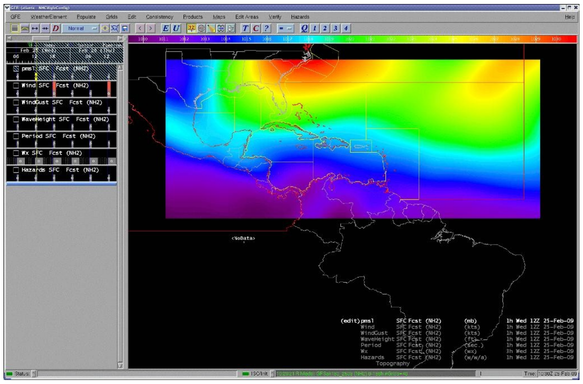

Figure 4: MSLP (mb) forecast in GFE.

In a number of cases, NWP guidance is unable to accurately resolve significant tropical features, including tropical cyclones and tropical waves, and sometimes inaccurately depicts gridscale feedback problems. These problems are corrected via the use of "Smart Tools." For example, if forecasters and analysts were tracking a low pressure center and believe that the guidance pressures are initializing too high in the vicinity of the wave, they can reflect this by adjusting the model output as seen in Figure 5.

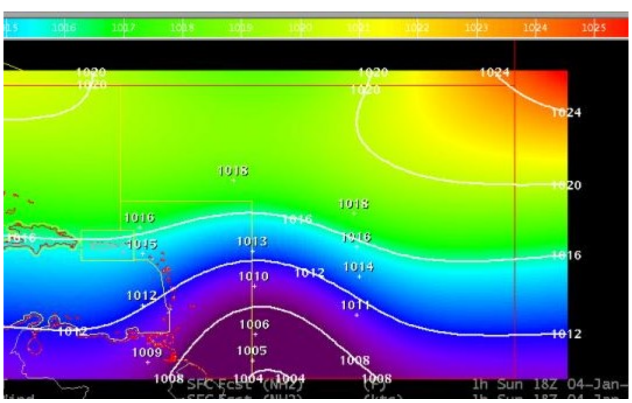

Figure 5: Adjusted and zoomed-in MSLP (mb) forecast to account for a tropical wave approaching the Lesser Antilles.

In addition to using these MSLP forecasts as the basis for surface prognostic charts, they are also used as input for modifications to the wind field. Specifically, using the geostrophic wind balance, which often describes the marine wind field, forecasters can adjust the forecast wind field from model output using the adjusted MSLP as input. A "Smart Tool" has been developed to account for this. Since the Coriolis parameter becomes very small in the deep tropics, an ageostrophic forcing factor is included in the "Smart Tool" to appropriately adjust the wind direction. Figure 6 provides the adjusted wind field based on the pressure field around the tropical wave shown in Figure 5. The cyclonic curvature in the wind field around the wave axis is better depicted in this image, along with the stronger wind speeds due to a steeper pressure gradient on the outer periphery of the wave.

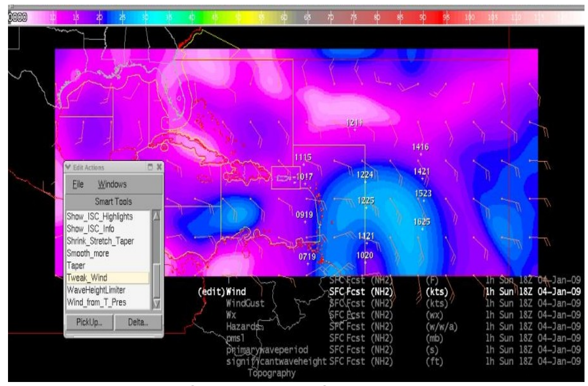

Figure 6: Adjusted forecast wind field, along with a truncated list of "Smart Tools" (wind velocities at selected points are displayed, with the one tenth of the wind direction in degrees as the first two digits, and the wind speed in knots as the final two digits).

Forecasters can adjust the wind field automatically to build in tropical cyclone wind fields directly from tropical cyclone advisory packages issued by the NHC using the "TCMWindTool" procedure. Not only are synoptic enhancements to the wind field made by such tools, but also local effects and gap wind events can also be resolved, including enhancements to the flow near the coast of Colombia, as seen in Figure 6. Forecasters can adjust the wind speeds or directions over selected areas using the "Smart Tools," as well as blend different model output spatially. All of these tools allow for science to better be integrated into the forecast process, alleviating many of the concerns presented by Mass et al. (2003), which identified lack of meteorological consistency to be a significant set-back for the use of GFE.

GFE allows for additional variables, including multiple components of wave period and swell, to be forecast in similar ways. GFE also opens the door to collaboration with NWSFOs and national centers. Grids from these agencies can be overlaid with TAFB grids for any forecast variable and time, allowing for inter-office consistency in the forecasts.

5. Bi-products of Gridded Forecasts

Forecasters can use a number of Smart Tools and formatters to communicate their forecasts to TAFB customers. One example is a locally-developed tool that plots areas of wind speeds and wave heights meeting particular thresholds. Such a graphic could be used for delineating areas of hazardous marine conditions for mariners, and could be used as specific input for GPS-tracking devices to indicate which routes or areas to avoid. Figure 7 provides an example of this grid. Such a grid can be used as direct input for high seas forecasts, which specifies locations of hazardous winds and seas at particular times. The idea of issuing these forecasts in the form of polygons from these grids is being explored.

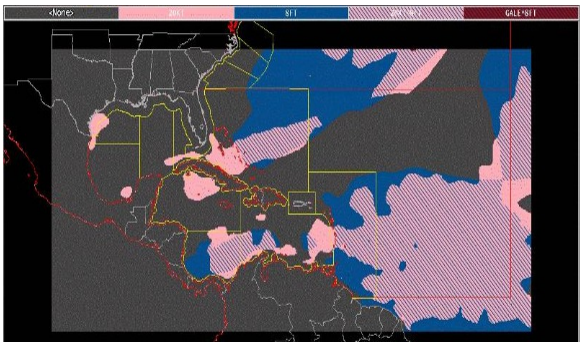

Figure 7: Hazardous winds and seas grid that plots locations where various thresholds of wind speed and wave height have been met, including 20-kt winds, gale force winds, and wave heights at least 8 feet. These areas are coded in the legend at the top of the image.

Additionally, the gridded information can be used as input for automatically-generated text products via text formatters, which compute statistics of gridded variables and report representative forecasts. Such forecasts require little, if any, human post-editing. Formatters are being developed for the OFFs in English, Spanish, and French languages in both English and metric units. This will ultimately diversify our communication ability to the wide customer base that TAFB serves. Figure 8 shows an example of an OFF that has been automatically generated from forecaster-edited grids.

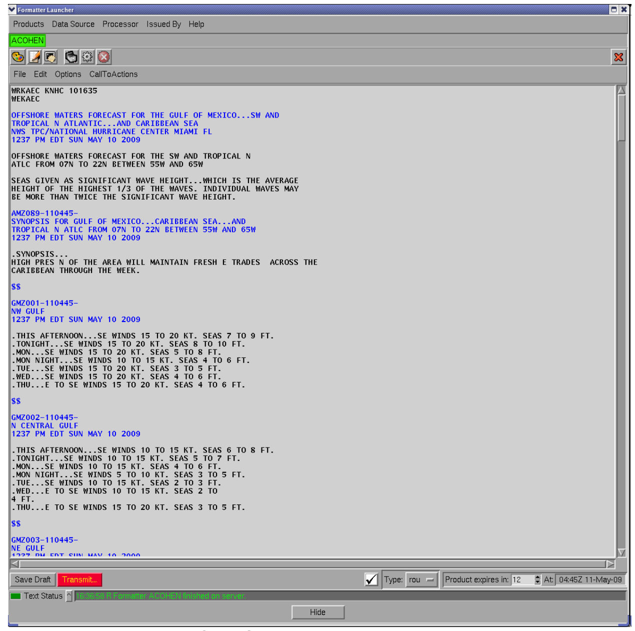

Figure 8: Example of an OFF that was automatically generated from forecast grids.

Given the capabilities of GFE, TAFB is exploring further subdividing its AOR in issuing OFFs to provide forecasts tailored for specific areas. New marine zones are being proposed, and Figure 9 shows an example of subdivisions for the southwest North Atlantic and northeastern portions of the Caribbean Sea. These subdivisions are based on distinct wind regimes identified by annual climatological analysis of ocean wind vectors provided by the U.S. Department of Energy National Renewable Energy Laboratory. An example of these partitions is shown in Figure 8 over the Caribbean Sea, as well as portions of the southwest North Atlantic and southern Gulf of Mexico. The smaller zone sizes will permit substantially more concise information to be communicated in forecasts.

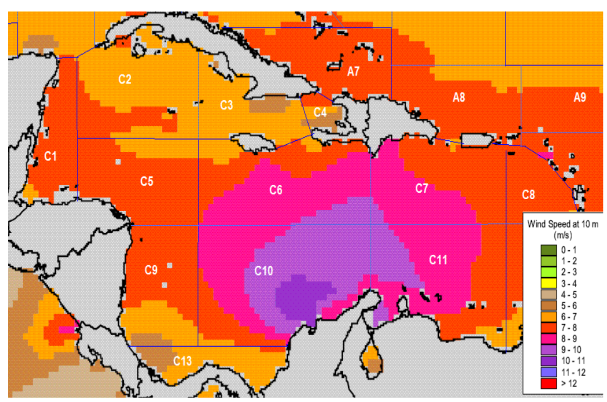

Figure 8: Proposed OFF zone areas overlaid on average annual wind speeds.

Finally, local techniques have been developed to convert the netCDF files generated from the forecast grids to graphical products that can be modified in NAWIPS. This has provided a significantly more efficient method of creating wind/wave and surface prognostic charts.

6. Future Work

TAFB continues to forge ahead with improving its GFE operations. Additional formatters are being developed to permit a more robust verification program, incorporating all area buoys into forecast verification. The integration of forecaster-edited wind grids into NWW3 will provide more consistent wave forecasts, and this issue is currently being explored. Eventually, TAFB envisions merging their grids with those available on the National Digital Forecast Database (NDFD), which provides a one-stop source for accessing NWS forecasts. Likewise, integration into the point-and-click forecast database could be a direct result of issuing gridded forecasts.

TAFB is also sharing its developments with the Ocean Prediction Center (OPC), which provides similar forecasts only for higher latitudes. GFE is expected to provide improvements to coordination efforts between the TAFB and OPC and better synergize the two agencies. Teams are being organized among TAFB, OPC, the Honolulu NWSFO, and Alaska Region of the National Weather Service (NWS) to integrate multiple agencies in GFE development endeavors. Much of the work is being done locally, and joining efforts is intended to work on this project more efficiently.

Acknowledgements

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7. References

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