Oceanic Cyclone Analysis and Forecasting at the NCEP/Ocean Prediction Center: The Role of Observations & Progress in Medium Range Forecasting

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1. Introduction

The Ocean Prediction Center's (OPC) primary responsibility is the issuance of marine warnings, forecasts, and guidance in both text and graphical formats for maritime users over the Northern hemisphere Atlantic and Pacific marine areas extending from 20°N to 67°N for purposes of protection of life and property, safety at sea, and the enhancement of economic opportunity. In addition, these forecast products fulfill the US obligations under the World Meteorological Organization and Safety of Life at Sea Convention. A brief summary of US National Weather Service marine and coastal weather services and OPC forecast operations will be given in section two. This paper emphasizes OPC's handling of atmospheric and oceanographic observations over the data sparse oceans from a forecaster's perspective, specifically, the visualization techniques utilized to rapidly determine model initialization errors, model trends, and global model differences. Examples focusing on the use of observations in the forecast and verification of extreme events will be presented in the third portion. The fourth section of this paper centers on the recent progress made in medium range forecasting at OPC, including warning criteria probabilities through the use of the NCEP Global Ensemble Forecast System and ECMWF Ensemble Prediction System members. In the final part of this paper a summary with upcoming OPC science priorities will be offered.

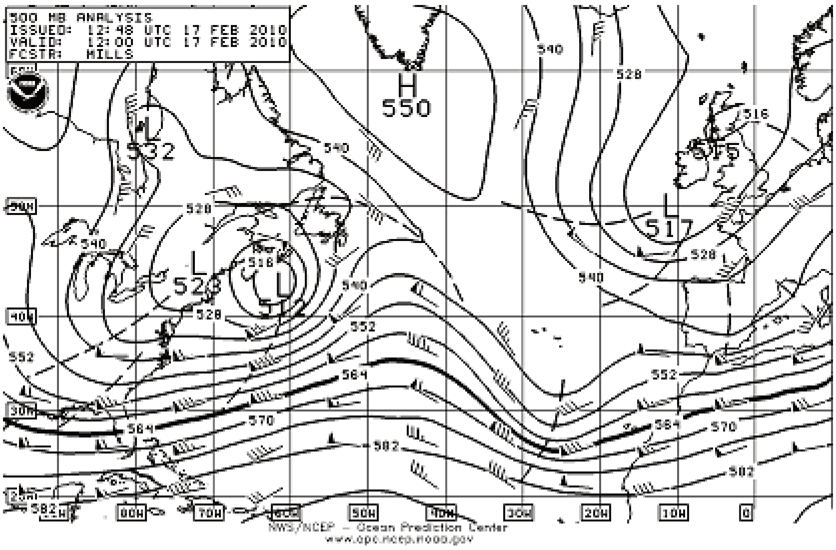

Fig. 1 OPC Atlantic 500 hPa analysis.

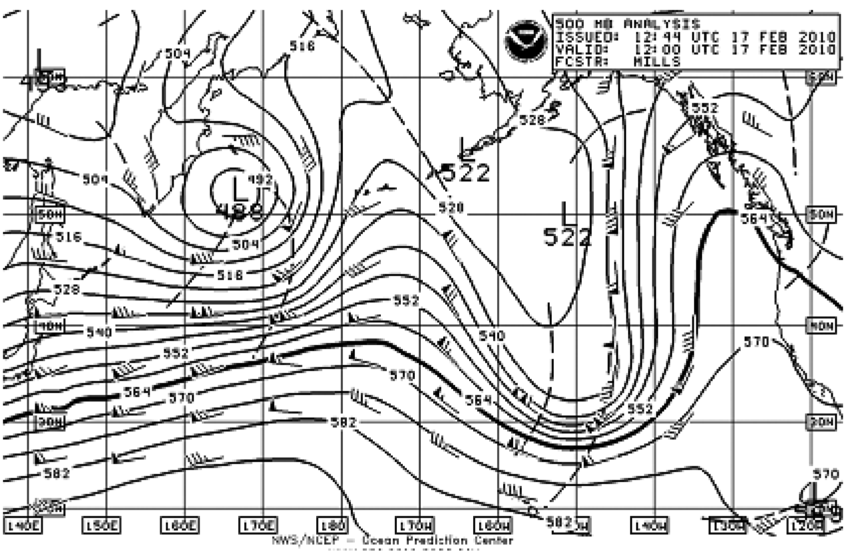

Fig . 2 OPC Pacific 500 hPa analysis.

2. US National Weather Service Marine Services Overview

OPC's forecast areas of responsibility for both the Atlantic and Pacific basins are shown in Figs. 1 and 2, respectively. The examples given are 500 hPa analyses and illustrate the expansive domain encompassed by OPC graphical forecast products. These regions extend over marine areas from Asia (138°E) to the US West coast in the Pacific, and from the US East coast to Western Europe (10°E) in the Atlantic, including the Mediterranean Sea. The US National Weather Service Marine Services include coastal, offshore, and high seas forecast zones. Forty-six coastal and Great Lakes local weather forecast offices provide guidance over coastal zones typically within 20 to 60 nautical miles of shore, while OPC, the National Hurricane Center, and the Anchorage and Honolulu offices are responsible for the offshore and high seas areas. The temporal extent of marine forecast products for weather systems and associated winds and seas is out to day five. In addition to being available on the OPC homepage (www.opc.ncep.noaa.gov), graphical products are transmitted via high frequency short-wave radiofacsimile. Text products are disseminated by various means such as US Coast Guard HF, MF, and VHF voice broadcasts via single side band radio, the Global Maritime Distress and Safety System (GMDSS), and INMARSAT-C SafetyNET via satellite. More information on marine forecast product dissemination is available at (www.weather.gov/om/marine/home.htm)

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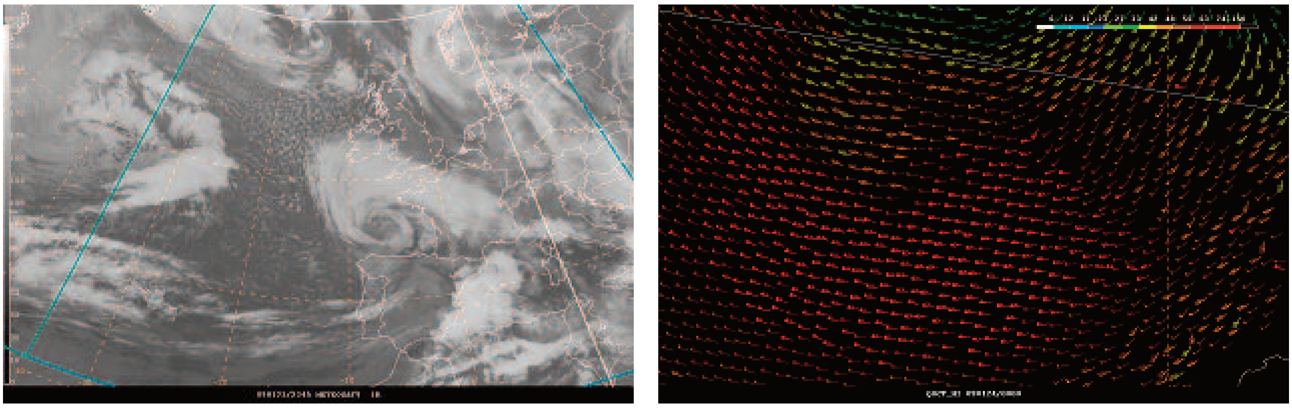

Fig. 3 (A) 2345 UTC 23 Jan 2009 Meteosat IR image of hurricane force extratropical cyclone in Bay of Biscay (Klaus). (B) 0000 UTC 24 Jan 2009 Quikscat pass over South quadrant of Klaus. Bright red shading indicates winds 33 m/s or greater.

3. Use and Visualization of Observations

The lack of in-situ observations over the ocean makes remote sensing data vital to OPC in order to diagnose initial conditions, determine warning criteria, and place synoptic features. The next examples will highlight how remote sensing data, particularly ocean vector wind and radar altimeter, are visualized by OPC forecasters to quickly assess model errors in hurricane force extratropical oceanic cyclones. Fig. 3 shows the importance of ocean vector wind or scatterometer retrievals in solely determining that this oceanic cyclone attained maximum winds of 40 to 45 m/s. The first picture is an infrared satellite image indicating an intense mature cyclone over the Bay of Biscay. Based on this satellite signature, a forecaster would likely infer that the storm possesses marginal hurricane force winds. However, upon close inspection of the Quikscat retrievals, it is revealed that the cyclone was producing winds on order of 25 to 30 percent higher than minimal hurricane force.

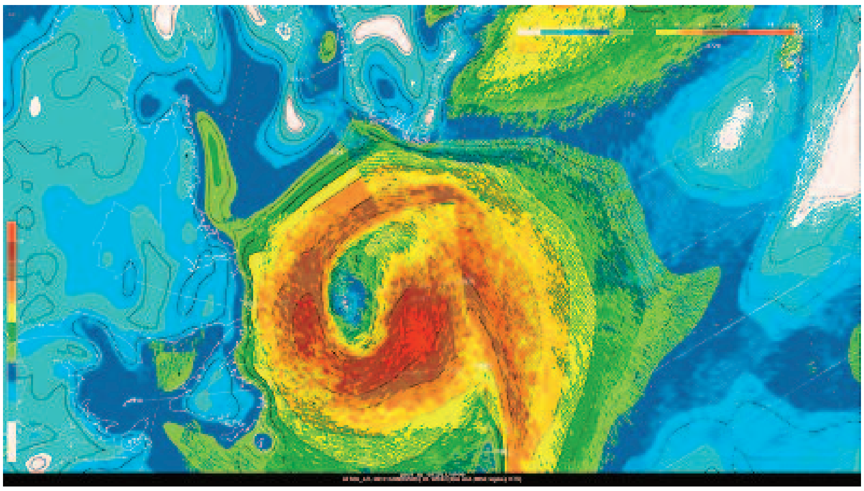

Fig. 4 12.5km resolution Quikscat pass overlaid on corresponding GFS 10m winds for 15 Oct 2009 hurricane force extratropical cyclone near 53N49W in North Atlantic.

Fig. 4 presents a visualization technique used by OPC forecasters to determine model initialization errors within the surface wind field by overlaying ocean vector wind data on the model wind speeds. In this figure, areas where the scatterometer wind barbs appear (being a different color than the underlying model data) depict places where the retrievals differ from the model wind speeds by 2.5 m/s or greater. Within the Southeast quadrant of the cyclone, the broad area of bright red retrievals indicate hurricane force winds (33 m/s or greater) where the model is only indicating storm force winds (~ 30 m/s).

To marine forecasters, as critical as determining model errors within the surface wind field is diagnosing any errors within the NOAA Wavewatch III's significant wave heights. Overlaying radar altimeter data on the model as shown in Fig. 5 is an effective way to do so. Within this hurricane force oceanic cyclone, it is immediately apparent that the ocean swell is outrunning the WaveWatch's representation. Similar to the ocean vector wind retrievals, areas where the numerical altimeter significant wave height values appear, or are a different color from the underlying model field, indicate discrepancies of 1 m or greater between the altimeter and the model wave heights. The altimeter pass revealed maximum significant wave heights in the 14 to 17 m range, while the Wavewatch guidance indicated maximum values of 12 m.

4. Progress in Medium Range Forecasting

As has occurred within the global forecasting community, an effort is taking place at OPC to shift from deterministic to probabilistic forecasts at the medium range through the use ensembles. A first step taken at OPC was the addition of offshore warning forecast confidence levels to the Atlantic and Pacific marine weather discussions. Medium range forecast techniques such as model blending and probabilistic wind forecasts will be discussed here. Using the 51 members of the ECMWF EPS, OPC incorporates probability into it's days 3 through 5 forecasts. Fig. 6 presents the percentage of ECMWF EPS members which meet a warning criteria, in this case, those members whose winds are storm force or greater

(> 24 m/s). The red shading indicates areas where 80% or more of the members possess winds of at least storm force, or subjectively speaking, areas where storm force winds are highly likely. OPC has the ability to combine and intermix ECMWF EPS, NCEP GEFS, and Canadian ensemble members to arrive at such probabilities. The next step will be to validate the ensemble members' winds with historical Quikscat or Ascat data and develop a bias corrected product.

A second tool utilized by OPC forecasters at the medium range is model blending, which is useful when model spread is great and forecast confidence is low. Fig. 7 shows the model blender menu available within the NMAP2 software at NCEP. Forecasters can choose which global models or ensemble means, and which cycles to blend. Forecasters also have the ability to assign the weight that each particular model run contributes to the blend.

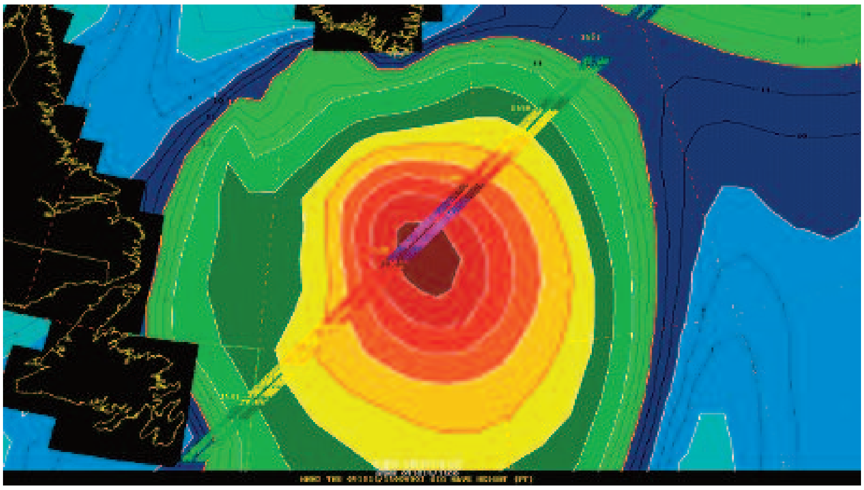

Fig. 5 1500 UTC 15 Oct 2009 Jason altimeter significant wave heights overlaid on corresp-onding NOAA Wavewatch III significant wave height field.

5. Summary

Forecast products and tools used at the OPC with an emphasis on the medium range, and visualization techniques highlighting how OPC monitors observations were discussed above. In the immediate future, OPC is focused, among other science priorities, on the following: improved numerical weather prediction of the marine boundary layer, improved numerical weather prediction of explosive extratropical cyclogenesis, improved numerical weather prediction of hazardous mesoscale marine conditions in the vicinity of the Gulf Stream, and improved techniques for use of ensemble products in the forecast process.

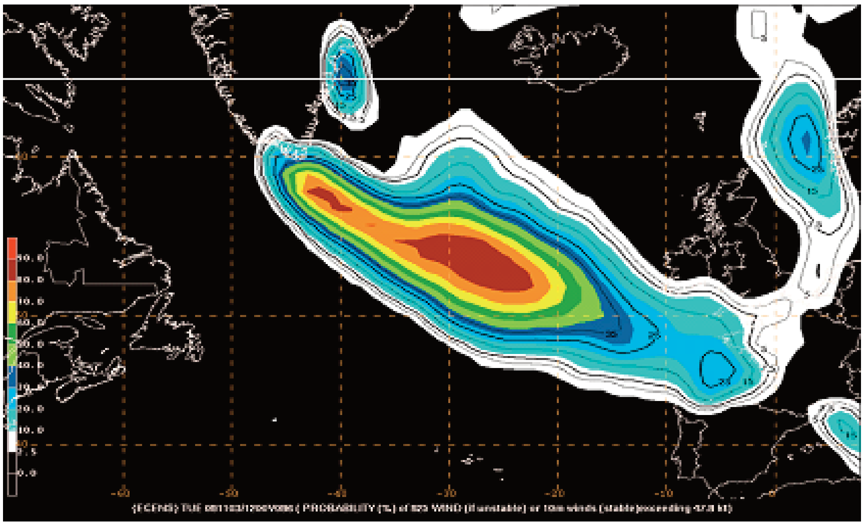

Fig. 6 Percentage of ECMWF Ensemble Forecast System (EFS) meeting following criteria: 925mb winds 48 kt or greater where low level lapse rate less than -1...or 10m winds 48 kt or greater where low level lapse rate greater than -1. Red filled contour indicates 80% or greater.

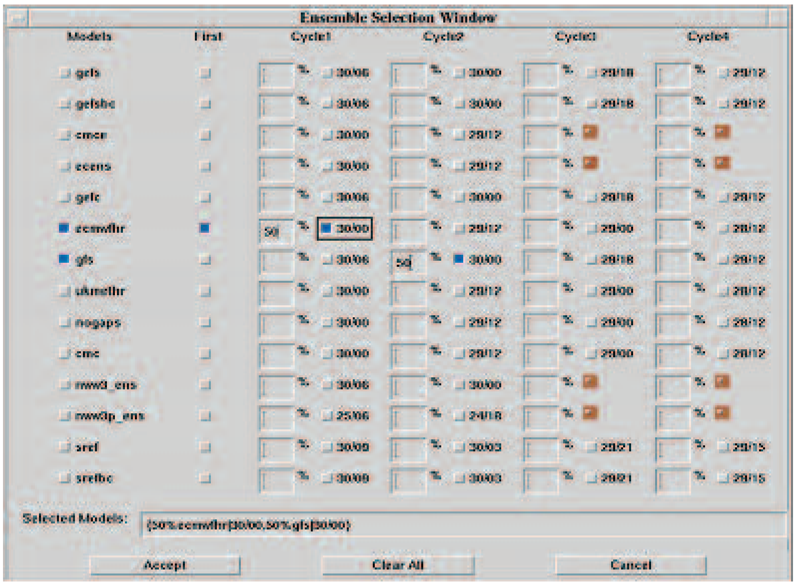

Fig. 7 Model blender menu available at NCEP in the GEMPAK NMAP2 software environment.