EVALUATION OF NCEP OPERATIONAL MODEL FORECASTS OF SURFACE WIND AND PRESSURE FIELDS OVER THE OCEANS

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1. INTRODUCTION

Ocean surface winds and pressure forecasts are important for coastal and offshore marine weather guidance. In particular, ocean winds are most essential for driving global wave and ocean circulation forecast models. During the last three years, there has been a great increase in the amounts of surface data and area coverages of ocean wind observations from several operational satellites. These surface wind data include DMSP/SSMI wind speeds (since 1987 to present time) , ERS 1-2 scatterometer winds (from 1998 to 2001) , and most recently, QuikSCAT wind data since 2002). Use of these surface wind data in the operational Global Data Assimilation System (GDAS) at the National Centers for Environmental Prediction (NCEP) has been shown to improve short range weather forecasts, with the largest improvement being in the wind and mass fields near the ocean surface (Yu, et al, 1997, and Yu, 2003).

The NCEP global model forecasts of wind and pressure fields are based on the Global Forecast System (GFS). During the last three years, the GFS model has numerous improvements in model resolution and physics. GFS model resolution has changed from a relatively lower resolution of T126, L28 in 2000, to a higher resolution model of T172, L42 in 2001, and to the current operational high resolution forecast model of T254, L64 since October 2002. Similarly, the atmospheric spectral statistical analysis scheme (SSI) has also had numerous improvements, particularly on the use of satellite data. One of the recent improvements is on the calculation of differences between asynoptic satellite observations and exact timeliness of first guess fields. These changes in SSI analysis scheme together with improvements in model resolution and physics have led to great improvements in the overall aspects of numerical weather forecasts. The focus of this study is mainly on the performance of GFS forecasts over the oceans. This paper presents error statistics of wind and pressure fields by comparing model forecasts against buoy observations as one of the objective measures of GFS model performance over oceans from 2000 to 2003. Evaluation based on a set of similar error statistics of the NCEP regional ETA model will be the subject of forthcoming articles.

2. EVALUATION OF GFS MODEL FORECASTS

During the last three years, we have routinely collocated model forecasts of winds and sea level pressures with global buoy observations. Since buoy reports are available on a hourly basis, there is no need for a time interpolation. The collocation procedure requires simply a spatial interpolation of the model forecasts to the buoy locations. The spatial interpolation invokes both horizontal and vertical interpolation. First, the model forecasts are interpolated from a one degree by one degree longitude- latitude grid value to the buoy locations. Then, a simple boundary layer model is employed to extrapolate model forecasts from the lowest sigma level (at about 40 meters above the ocean surface) to the 10 meters height where buoy observations are reported. It is important to note that the two spatial interpolation procedures will undoubtedly add some undetermined errors to the model forecasts. This in turn may lead to a slight overestimate of model forecast errors. Moreover, buoy reports also have their inherent observation and instrument errors, so that winds and pressures measured from the buoy observations are far from being the ground truth. Nevertheless, for this investigation, we have based on wind and pressures taken from the buoy observations as the standard to compare against the model forecasts.

Depending on their platform locations, buoys are classified into deep ocean buoys and near shore buoys, with 50 km from the coastline being the demarcation boundary between the two groups. These buoy locations are further geographically divided into five regions: East Coast of the U. S., West Coast of the U. S., Gulf of Mexico, North Sea, and TOGA regions (see

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Fig. 1). Only deep buoys are used in the calculation of error statistics. For this study, there are 8 deep water buoys over the U.S. East Coast Atlantic ocean, 16 deep water buoys over the U.S. West Coast Pacific ocean, 12 in the Gulf of Mexico, and 8 over the North Sea regions. Over the TOGA region, there are about 80 buoys. However, most of the TOGA buoys only report temperatures and pressures, with only a very small numbers of them reporting both wind and pressures. There are a total of 56 deep ocean buoys for the whole global regions used in the calculation of error statistics reported in this study. It should be noted that there are several deep water buoys over the Hawaii and Canadian ocean areas, which are not included in any of the five regions, but are included among the 56 deep ocean buoys used in the study. Morever, since buoy winds are reported at various heights depending on the types of platforms, they are all adjusted to the standard 10 meters level above the ocean surface using a simple boundary layer model similar to that for the extrapolation of the GFS model forecasts to the 10 meters height level.

Table 1 shows the mean global average of RMS error statistics of wind, and sea level pressures, averaged over the 40 months from May 2000 to August 2003. With exception of wind speed, model biases (numbers inside the bracket) are in general very small for wind direction, and sea level pressures from analysis time (F00) to 72 hors of forecasts (F72). Model wind speed exhibits a very large negative bias of 0.55 m/s at the analysis time (F00), and this wind speed bias becomes positive but very small during the forecasts. Large wind speed biases also appear over the U. S. West Coast Pacific ocean region (Table 3), Gulf of Mexico (Table 4), and TOGA (Table 6) regions at the analysis time. This negative bias in wind speed analyses has been consistently evident from a time series plot (not shown) during the last three years, and certainly requires a careful investigation.

Inspection of bias and RMS wind error statistics for all regions (from Tables 2 to 6) clearly shows model forecast errors are larger over the North Sea region, and smaller over the tropical TOGA and Gulf of Mexico areas. The same is true for the sea level pressure forecasts. On the average, the RMS wind direction errors range from 17 degrees at the analysis time (F00) to 42 degrees for the 72 hour forecasts. RMS model wind speed errors range from less than 1.8 m/sec to less than 3.2 m/sec for the 72 hours of forecasts. RMS sea level pressure errors are generally small, and range from 0.8 mb at the analysis time to about 3.1 mb for the 72 hours of forecasts. RMS vector wind errors range from 2.87 m/s at the analysis time to less than 5.73 m/s for the 72 hours forecast. Because of the very large numbers of collocated data points used in the calculation, these statistics are very robust and representative of GFS model forecast error characteristics for the 40 months period.

Fig. 2 shows time series of the monthly mean model RMS vector wind errors (top panel), and RMS sea level pressure errors (bottom panel) of the NCEP operational GFS model forecasts from May 2000 to August 2003. These statistics clearly show an annual variability, with larger errors being during the winter months, and smaller errors in the summer. A careful inspection of the time series shows that there is a small reduction of forecasts errors of both vector winds and sea level pressures over the last three years, suggesting a small improvement of the GFS forecasts of these two fields over the oceans during the last three years.

3. SUMMARY

This paper evaluates the NCEP GFS model forecasts of winds and sea level pressures fields over the oceans during the last three years period from May 2000 to August 2003. Bias and RMS of the model forecasts errors are calculated using observations of deep water buoys as the comparison standards. GFS model forecast error characteristics are clearly shown to have a regional dependency. Based on bias and RMS forecast errors, GFS seems to perform reasonably well over the U.S. east coast and west coast regions, as well over the Gulf of Mexico area, but not performs as well over the North Sea region. Time series of monthly mean RMS forecast errors of vector winds and sea level pressures are also presented, and they suggest that there is a small improvement in the GFS forecasts of the these two fields over the oceans during the last three years.

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