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1. INTRODUCTION

Forecasts over oceans have traditionally been difficult to perform due to sparse data sources. In the past decade, scatterometer observations of oceanic winds have improved this data gap, but have not been used routinely in operational models. This paper describes the implementation of a numerical model which has been performing this task twice a day since June 1997. This model, called the Harris Quasi-Lagrangian Model (HQLM), is a hydrostatic primitive equation model developed at Harris Corporation based on the formulation described in Mathur (1983; 1991). The version which assimilates scatterometer data during the model spin-up period is currently being run at User Systems Enterprises, Inc. (USEI). A description of this model now follows.

2. DESCRIPTION OF HQLM MODEL

The HQLM model includes standard convection, radiation, and convective parameterization schemes, and forecasts typical meteorological parameters (wind, temperature, moisture, etc.). A unique aspect of this model is that it runs on a Windows NT pentium computer, and produces forecasts quickly (about 40 minutes on a 200 MHz Gateway 2000 machine) in a combined UNIX/Windows data assimilation environment. Data through a Family of Services ingest is downloaded from a satellite link onto the NT, although automated tasks and the satellite data assimilation are performed on an SGI networked to the NT. Should the satellite link fail (rare), data is downloaded through an automated modem system.

However, what makes USEI's HQLM version unique is its use of a *nudging methodology* which incorporates wind information from three satellites, as well as all available buoy, ship, and land observations. The nudging methodology has the following form in the equations of motion:

$$\frac{\partial u}{\partial t} = \text{other terms} + \varepsilon(u_{sat} - u_{mod})$$

$$\frac{\partial v}{\partial t} = \text{other terms} + \varepsilon(v_{sat} - v_{mod})$$

where u is the zonal wind and v is the meridional wind. "Other terms" include advection processes, the pressure gradient force, the Coriolis force, and friction. The last term is the expression for nudging, where ε is the nudging coefficient, u_{sat} and v_{sat} are the interpolated satellite winds at each grid point using a Barnes analysis, and u_{mod} and v_{mod} are the model predicted winds before the nudging procedure.

Nudging of the surface wind field is performed by first incrementing the model each hour using a 3-min time step, then rerunning the 1-h prediction using a large nudging value of $\varepsilon = 0.01 s^{-1}$. The satellite winds are obtained from three sources: the ERS-2 scatterometer, which gives 10-m wind speed and direction; the SSM/I microwave radiometer, which gives 19.5-m wind speed; and the TOPEX altimeter, which gives 10-m wind speed. Since 19.5-m winds will create a positive surface wind bias, SSM/I winds are reduced to 10-m heights using a standard logarithmic bulk formula (Liu et al. 1979). Quality control is performed by removing any erroneously large wind speeds (an occasional situation usually associated with rawinsonde and ship reports). In general, nudging improves model initialization, with the added benefit of generating dynamically consistent wind fields in nearby data-void regions, and producing temporally correct winds between satellite passes.

Currently scatterometer data is downloaded from the three satellites between 12-20Z and 00-08Z. At

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08Z and 20Z, the QLM is initialized using 00Z or 12Z data, and then nudged with additional land and scatterometer data during the next 8 hour period. Once the nudging is complete, the model continues forecasting an additional 16 hours.

Forecasts are typically completed within one hour after model start, and are downloaded to the web site <http://www.usersystems.com>. Currently operational forecasts are performed for the CONUS region with a grid spacing of 80 km and lateral boundary conditions based on AVN, NGM, or ETA fields. However, it is straightforward to use different nudging timescales, different forecast times, and smaller grid spacing. The model is also portable and flexible--- capable of being run anywhere in the world for a variety of domain sizes.

3. COMPARISONS OF HQLM WITH AND WITHOUT NUDGING

To assess the impact of the satellite nudging, comparisons of the HQLM forecasts were performed with and without nudging. Due to AMS expenses regarding color graphics, we will not be able to show these examples in this manuscript, but examples will be shown at the conference. A verbal description now follows of a case study.

A model run was initialized at 00Z on 12 December 1997 without satellite nudging. A strong cold front in the Gulf of Mexico was forecast with a homogenous wind field of 10 kts ahead of the front with a narrow band of 15-20 kts winds behind. In contrast, the satellite-nudged prediction using 00-08Z satellite data, predicted weak winds near the Yucatan peninsula ahead of a front that increased towards Florida and broadly distributed 20-25 kts winds behind the front, which more accurately represented the buoy observations (not shown). This improved forecast resulted from SSM/I and ERS-2 satellite-derived wind observations in the Gulf of Mexico between 00 and 08Z that were nudged into the HQLM model. This and other case studies will be presented at the conference.

4. COMPARISONS OF HQLM AGAINST NSCAT

During its short lifetime in the spring of 1997, NSCAT provided the most accurate scatterometer winds before its demise in June 1997. To assess how well HQLM could serve as a substitute for the lost NSCAT data source, USEI is currently running 12-h Spring 1997 simulations with nudging from ERS-2, TOPEX, and SSM/I throughout the modeling period, and the output is being compared against the NSCAT observations. Table 1 shows a comparison for 03Z 10 March 1997 in the Atlantic Ocean Basin of HQLM output against interpolated NSCAT data. Additional comparisons will be presented at the conference.

Table 1. Mean error comparisons of interpolated NSCAT data against HQLM for 03Z 10 March 1997 for the Atlantic Ocean.

Root mean square error in speed (m/s)	3.1
Root mean square error in direction (deg)	24.1
Mean absolute error (m/s)	2.7
Mean relative error (m/s)	-2.7
Mean absolute direction (deg)	17.1

5. MM5 MODEL RUNS

Since August 1998, the MM5 model has been run quasi-operationally at Jackson State University on a Cray C98 supercomputer. The model domain is centered over the Gulf of Mexico with a 40-km grid spacing, and 48-h predictions initialized at 00Z and 12Z may be viewed at <http://santa.jsums.edu>. During Fall 1998, we plan to perform the following tasks: 1) implement a nested grid; 2) port a massively parallel version of the MM5 to an IBM SP2 located at Jackson State University's Army High Performance Computing Research Center; 3) port a workstation version of MM5 to an SGI workstation located at USEI; and 4) assimilate the three satellite data sources into the MM5 using Four Dimensional Data Assimilation. These efforts will be discussed in more detail at the conference.

6. ACKNOWLEDGMENTS

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