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THE NAVY OPERATIONAL GLOBAL ATMOSPHERIC PREDICTION SYSTEM (NOGAPS)

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Introduction

The U.S. Navy has been running a global numerical weather prediction model since the early-1980s. This model is called NOGAPS (Navy Operational Global Atmospheric Prediction System). It is a global, spectral model, comparable to the other operational models being run at other national centers. It is run every 12 hours out through 10 days. Recently, forecast fields for this model have become available on the Internet, allowing Western Region forecasters to begin to use this model as another forecasting tool. This paper will briefly discuss some of the history of the model, the main points of the model physics, some model tendencies, and where the model fields can be found on the Internet.

History

The U.S. Navy began development of a global numerical weather prediction model in the mid-1970s. By the early-1980s, the NOGAPS 2 system was developed and became operational. By the mid-1980's, it became clear that this first model was being outperformed by newer global models implemented at both the European Centre for Medium-Range Weather Forecasts (ECMWF) and the National Meteorological Center (NMC), now known as NCEP. Both of these newer models proved that spectral models were superior when horizonal advection was important, such as in the prediction of Rossby short waves. Additionally, spectral models easily incorporate computationally efficient semi-implicit time-integration schemes that are essential for high model resolution (Rosmond, 1992). Also at this time, optimum interpolation (OI) analysis and nonlinear normal model (NLNM) initialization also became popular. At that time, OI and NLNM made it possible to do quite sophisticated four-dimensional data-assimilation schemes that would allow exploitation of nonconventional data sources such as surface wind speeds from SSMI data and precipitable water estimates.

Because of these rapid changes to global numerical modeling, the NOGAPS 2 model needed to be improved if it was to remain competitive. Instead of a piecemeal replacement of the system, the model was abandoned and a totally new system was developed. This model was known as the NOGAPS 3. Originally, this model's resolution was 47 wave triangular truncation (T47), in the horizontal, and 18 levels in the vertical. Since then, several fixes have been made to some of the various parameterizations, resulting in version 3.1 in early 1989. In late 1989, the horizontal resolution of the model was increased to 79 wave triangular truncation (T79), keeping 18 levels in the vertical. This version of NOGAPS was designated 3.2. Additional revisions to the code were completed through 1991. In January 1992, a new set of parameterizations were added to the model, resulting in NOGAPS 3.3. With the purchase of a CRAY computer in 1993, the Navy optimized some of the code, added a new set of radiation parameterizations, and at the same time increased the horizontal resolution of the model to T159, or approximately 80 km horizontal resolution in the mid-latitudes. This version, NOGAPS 3.4 is the current version of the model running, although, as with all numerical models, slight modifications continue to be made to improve the model. Currently, the model is run at T159 resolution through day five, with reduced resolution to T79 out to day ten.

Description of the Model

A detailed description of the NOGAPS initialization and forecast model can be found in Hogan and Rosmond (1991). In this section, a brief description of the main portions of the model will be discussed.

The model equations are formulated in spherical coordinates and a hybrid vertical coordinate. This system uses the same coordinate system as the ECMWF's forecast model. The horizontal coordinates are longitude and latitude, while the vertical coordinate is represented by a variation of the sigma coordinate, which follows topography. Figure 1 is a diagram showing the vertical coordinate and the placement of the 18 levels in the vertical. More information regarding the spherical harmonic transforms and other details of the NOGAPS model equations can be found in Haltiner and Williams (1980). Triangular truncation of the spherical harmonic series is used in the model, which is the most popular form for all spectral models run at major operational and research centers around the world.

Many of the computational processes in the model are similar to those used in other global spectral models. Gravity-wave propagation is handled by a semi-implicit time-integration scheme. To explicitly handle them, a longer time step would be needed than what is possible with a T159 truncation. The zonal advection of vorticity and moisture are treated in an implicit manner. Advective processes are handled explicitly.

The model includes parameterizations for such things as gravity-wave drag, vertical diffusion, shallow and deep convection, longwave radiation, and shortwave radiation. Particular requirements have been placed on this model by the Navy, with emphasis on the way it handles heat, moisture, and momentum fluxes over the ocean. Thus, much of the NOGAPS research effort has concentrated on reducing biases associated with these fluxes. The design of the NOGAPS diabatic processes emphasize the interactions between surface heat and momentum fluxes with clouds and radiation. To aid in this and with forecasting along ship routes, the model has also been required to perform well in cases of oceanic midlatitude cyclogenesis. Special efforts have been taken to do sea-level pressure bogusing in the NOGAPS data-assimilation system. This has acted to improve cyclogenesis prediction (Goerss and Phoebus, 1991).

Model Tendencies

This section will discuss some of the model tendencies which have been noted by Navy forecasters and other investigators of the model. Please note that many of the other global numerical models suffer from similar tendencies.

1. Developing surface low pressure systems tend to develop slower in the model than in reality. Filling low-pressure systems also tend to be slower to fill then in reality. Secondary lows are also slow to develop, deepen, and move.

2. Low-pressure systems north of the polar jet tend to deepen too much, while lows developing south of the polar jet are typically too weak and slow to deepen. Lows which develop in the lower-levels and build upward into the atmosphere are also slow to develop/deepen.

3. Surface low-pressure systems over land have a tendency to be slightly too deep.

4. The formation of upper-level cutoff lows is well forecasted by the model, although minimally weak throughout their life-cycle. Surface low-pressure systems associated with the formation of upper-level cutoff lows tend to be too weak and slow to deepen, remaining about 3-4 mb weak throughout their life cycle.

5. Complex lows are usually merged into one elongated low-pressure system. In this situation the mature low-pressure system tends to be too deep and slow to fill, while the developing low is weak, too slow to weaken, and too slow to move.

6. Extra-tropical lows associated with former tropical cyclones are significantly underforecast, slow to re-deepen, and slow to move.

7. Upper-level shortwave troughs embedded in either zonal flow or a broad trough are poorly forecast and difficult to follow.

8. Upper-level lows north of the polar jet are too deep. Upper-level highs south of the polar jet are typically too strong.

9. Western ocean high pressure cells and eastward ridging off the east coast of continents are slightly weak, and slightly slow to move offshore.

10. Mid-ocean high pressure cells are typically 1-2 mb too weak.

11. Ridging into the west coast of continents tends to be too strong. The offshore cell is usually 2-3 mb under forecast, especially in the Eastern Pacific.

12. The subtropical jet tends to be weaker than reality and slightly poleward of its real position.

13. The forecast has a tendency to become more zonal toward the end of the integration.

14. There tends to be an over prediction of the upper-level tropical easterlies.

15. The bogusing technique used on Pacific typhoons has improved their storm track immensely, so that the NOGAPS-predicted typhoon tracks have been considered the best guidance available by the Joint Typhoon Warning Center in Guam (Rosmond, 1992).

16. The model tends to over-produce precipitation after day 4.

Overall, the model seems to perform well over the oceans and in the tropics. The model has been tailored to meet the needs of the Navy, with much of the model development focused on these areas. Little verification has been done inland, however over the ocean, the model is very competitive with other national global models.

Accessing the Data

Using the Internet, the forecast fields from the model can be viewed easily. The URL for the data is

http://www-pcmdi.llnl.gov/fiorino/wxmap/wx.conus.htm

You will then need to click on the icon which says NGP Home. There are also buttons for the AVN and MRF models. Once you click on the NGP Home icon, your browser will take you to another page, where various fields for the NOGAPS model can be accessed. The fields available for viewing are 500 mb heights/relative vorticity, 850 mb temps/winds/relative humidity, 6 hour precipitation accumulation/sea level pressure, and 700 mb vertical velocity/mean sea level pressure/500-100 mb thickness. You can access each field and forecast time separately by clicking on the green button relating to that model field/time, or you can load all the forecast times for a particular field by clicking on the All Times icon. If you want to look at all the fields for a particular time, click on the All Maps icon for that particular time period. If a particular button is red, that indicates the field for that time frame is not available. Also, occasionally the NGP Home button is not available as an option on the first page mentioned above. This indicates that there is no current model data. Output from the model in this format is available through 144 hours.

Conclusion

The U.S. Navy has been running a global numerical model since the early-1980s. As stated before, the model is run twice a day, at 0000 UTC and at 1200 UTC, giving forecasters two views of the extended forecast period, as opposed to just one with the other national global models. This in itself makes this model worth investigating. NWS offices at both Sacramento and Monterey have been able to view NOGAPS data for the past few years, and have found the model to be of value in the forecast process. It has become a routine forecast product to look at during the development of the 3-5 day forecast package. Hopefully other NWS offices will also find this model to be of use, and integrate it into their current methods of extended-range forecasting.

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References

Goerss, J.S., and P.A. Phoebus, 1991: The Navy's operational atmospheric analysis. *Wea. Forecasting*, **7**, 232-249.

Haltiner, G.J., and R.T. Williams, 1980: *Numerical Prediction and Dynamic Meteorology.* 2nd ed., John Wiley and Sons, 477 pp.

Hogan T.F., and L.R. Brody, 1993: Sensitivity studies of the Navy's Global Forecast Model parameterizations and evaluation of improvements to NOGAPS. *Mon. Wea. Rev.*, **121**, 2373-2395.

Rosmond, T.E., 1992: The design and testing of the Navy Operational Global Atmospheric Prediction System. *Wea. Forecasting*, **7**, 262-272.

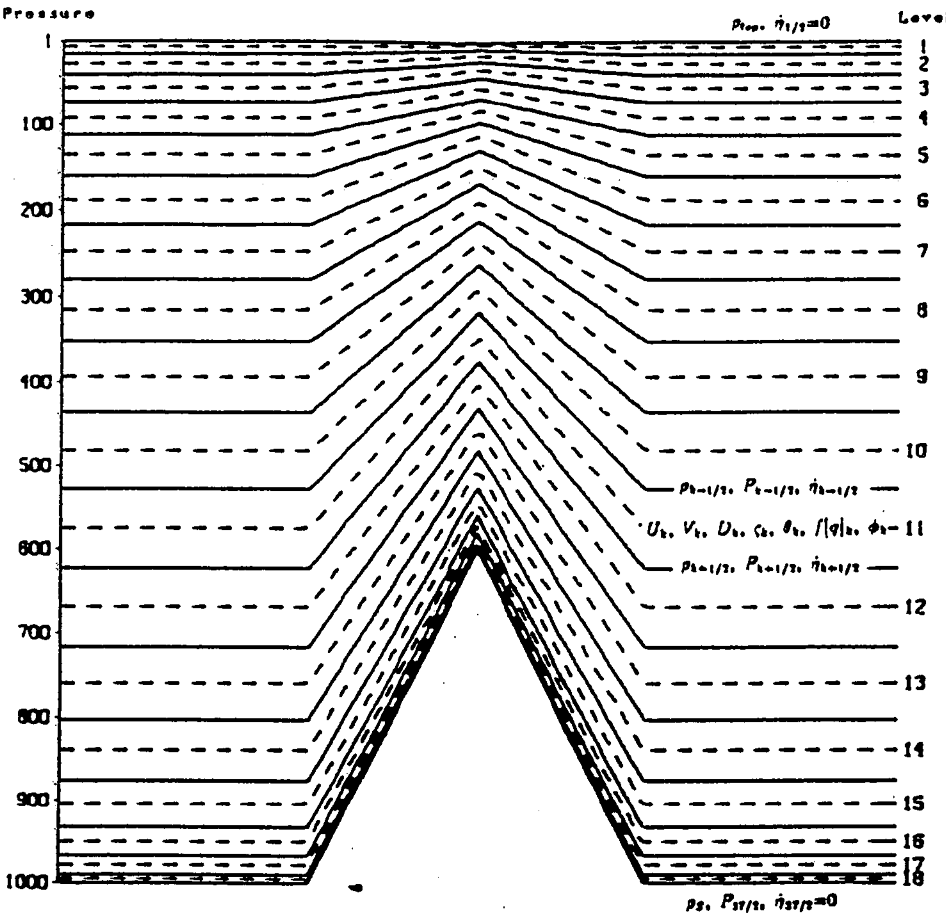

FIG. 1. The vertical structure of the forecast model. The 11th level is used to illustrate the assignment of variables.