TROPICAL STORM GENESIS IN OPERATIONAL MODEL FORECASTS : PROBLEMS AND CHALLENGES

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1. INTRODUCTION

Up until 1995, the National Centers for Environmental Prediction (NCEP, then known as the National Meteorological Center) Medium-Range Forecast (MRF) model did not generate tropical storms. In order to use the global MRF model to help predict tropical storm tracks, a procedure was implemented in 1989 to add synthetic storm observations based on the observed storm location, intensity, size and motion. In the Global Data Assimilation System (GDAS) running four-times daily analysis using previous cycle 6-hour forecast as first guess, the ingest of the synthetic data helps to define the tropical storm in the initial condition for the MRF model. Since the model was not "active" in the tropics, the storms invariably weaken in the model forecast and forecasters learned to look at open easterly waves in the forecast and imagine the tropical storms they should be.

In an implementation in October 1995, the MRF started to generate and deepen tropical storms. While the predicted storm intensities do not match the stronger storms and the smaller storms are over-estimated in size, the model will maintain closed circulations of the storms through the 7-10 day period running in high resolutions (about 100 km). The model can often take a weak initial circulation and intensify it into circulations with some semblance to tropical storms and hurricanes. While it is gratifying to see the new capability of an operational forecast system running in its routine mode and generating tropical storms, this ability also created problems that made life of hurricane specialists and other forecasters very difficult at times.

2. PROBLEMS

Because there are few vertically coherent observations in the vast tropical ocean region, the analysis of tropical storms in the GDAS is a very difficult task. Just because we can see an easterly wave in the satellite picture does not mean we know how the 3-dimensional motion and thermal fields will be for the storm. As a result, model that can initiate tropical storms will do so when there is instability in the flow but it may not be located where nature puts them. In recent years, the improved usage of satellite observations have led to better initialization of the tropical disturbances but we have a long way to go.

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There are quite a few cases when the model initiate a tropical storm in a disturbed weather region when nature does not. This is especially true in eastern Pacific Ocean. The problem is that once the model initiate a tropical storm, it provides the wrong first guess to the next cycle analysis package. Without data to suppress the storm, the false alarm storm will continue to develop in the GDAS and lead to several bad forecasts in a roll.

In the Atlantic Ocean, the problem is less one of false alarm but one of bad initialization. When the model generate a storm in the first guess, it is often weaker, larger for small-sized storms, and located away from the real storm. Adding in a set of wind observations based on the observed storm will often lead to two vortices in the same region one belonging to the first guess storm and the other the real storm. This often led to a weakening of the storm in the forecast (while the vortices try to combine) and bad storm track forecasts.

3. PARTIAL FIXES

The ultimate solution lies in the improvement of data assimilation system to make intelligent use of the satellite observations. We are currently working on the use of the SSM/I precipitation data and the adjoint of the model physics to improve the definition of tropical storms in the initial condition field. This is a long term research effort that will be reported at a later time. In the mean time, we must try to reduce both problems mentioned above to help forecasters with real time forecast issues. We have worked on two aspects of the system to reduce the problem : a modified convection package and a relocation strategy. I will concentrate on the convection modification and Qingfu Liu will present the relocation strategy in more detail in another talk.

The convection change I will present started as an attempt to improve the model climate. As the MRF model is now also been used to provide 7-14 day forecasts and for monthly and seasonal predictions, the issue of model climate in the tropics becomes more and more important. It is well known that most global forecast models have a deficiency in maintaining tropical convection in western Pacific Ocean where the warmest sea surface temperature can be found. For the MRF, we know that the model maintains good precipitation patterns in the short-range forecast (1-3 days range) but starts to fall as forecast range increases. In addition to this, we also are aware that the MRF has a dry bias in the mid to upper troposphere in the tropics. This problem appears in the initial analysis as well as in the forecasts. We interpreted this dry bias as a result of the design of the Simplified Arakawa-Schubert (SAS) scheme (Pan and Wu, 1995) to choose the deepest possible cloud at each time step. We have long been aware of the work of Moorthi and Suarez (1992) where the choice of cloud is not the deepest but a random selection from the eligible ones. It turns out that this is a fairly easy change and it was added to the current SAS scheme. The change indeed reduced the tropical dry bias but also reduced the precipitation drying trend in longer range model runs. These tests were all performed using a lower resolution version of the model (~200 km).

The challenge is then to test the scheme in the high resolution version (70 - 100 km) since the model is used to make daily forecast for a wide range of purposes. It is important that any change we make will not result in deterioration of precipitation prediction skill over North America nor skills in hurricane track predictions. In order to make these tests, we must run the data assimilation aspect as well as the forecast part. The amount of resource required for both computation and storage is large and expensive. Taking advantage of the new computer NCEP acquired after two years of almost no computer resource, we made a set of T126 runs for the summer of 1999. For North America precipitation skill evaluation, we looked at the forecasts for the month of August and the increase of skill was surprisingly large. This led us to tackle the hurricane problem.

Concurrent with the convection tests, we have also been working on a solution to the initial condition problem for hurricanes in the GDAS. We decided to test a new procedure abandoning the use of the synthetic observations and replacing it with a relocation procedure. In this approach, we recognize that the first guess field will likely have a tropical storm in the vicinity when the Tropical Prediction Center (TPC) announces the formation of a tropical storm. Instead of adding a set of 'observations' based on the real storm, we will move the existing storm to the correct location. The storm size and intensity will be the ones that the model is capable of generating and maintaining and not the real storm. The main advantage is that the storm structure will be coherent and not superimposed with another vortex. The actual coding of the procedure is quite complicated and is done in an iterative manner. The results that will be presented in this talk are derived from one of the iterations. They show sufficient promise to improving the hurricane track forecast for us to continue the development.

For the hurricane track forecast, we reran the GDAS and twice daily 72-hour forecast for the period 23 August to 23 September 1999 to capture as many of the Atlantic storms as we can. The track error for all the storms in this period is shown in Fig. 1 for the control (labeled AVNO), the experiment (labeled sas99), and the standard Climate-Persistence model (CLIPER). It can be seen that there is a significant improvement of the forecasted tracks (by about 50 nm at 72 hours). In addition to the reduction of track errors, we also noted a reduction of the false alarm storms. It should be noted that t hese runs did not use any synthetic observation. The storms are entirely generated by the GDAS. We plan to perform further test and implement the package before the year 2000 hurricane season.

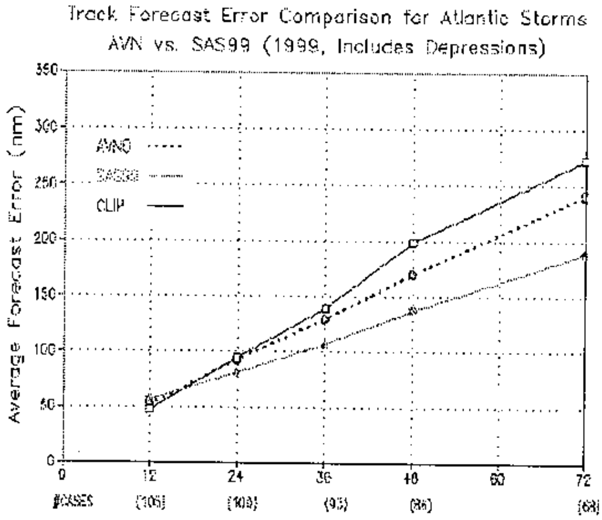

Fig. 1 Track forecast error comparison.

4. CONCLUSION

In summary, tropical storm initialization has become more difficult in recent years due to changes in the model physics. There are also new opportunities to improve the hurricane track forecast and possibilities to make hurricane-genesis forecast.

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