Improvements in Hurricane Initialization and Forecasting at NCEP with Global and Regional (GFDL) models

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1. Introduction

A new relocation procedure to initialize hurricanes has been tested successfully at NCEP (National Centers for Environmental Prediction). The procedure has yielded dramatic improvement in hurricane track forecasts not only in the global model suites(MRF and AVN), but also in the GFDL model, which uses initial conditions from the global suite.

In retrospective forecasts made from 1999 cases, the average track forecasts in the AVN suite improved by 31% compared to that of the 1999 operational AVN forecast. The track forecast skill has surpassed 1999 operational GFDL forecast skill and is comparable to that of the global models of other major centers. The improvement in AVN initial field, in turn, improves the GFDL hurricane initialization and forecasts significantly. The average track forecast in the GFDL model improved by 25% compared to that of the 1999 operational GFDL model. The relocation is expected to be fully operational by 5 July, 2000.

The MRF and AVN forecasts are initialized using the Global Data Assimilation System (GDAS) in which the model 6-hour forecasts are used as a first guess by the Spectral Statistical Interpolation (SSI) analysis package (Derber, et. al., 1991). The SSI analysis uses the guess field and all of the available observational data. The relocation procedure takes the guess field and moves the hurricane vortex to the correct location before the SSI updates the analysis. The steps can be briefly summarized as: 1) locate the hurricane vortex center in the guess field, 2) separate hurricane model's vortex from its environmental field, 3) move the hurricane vortex to the TPC's official position), and 4) if the vortex is too weak in the guess field, add a bogus vortex in the SSI analysis.

In the following paragraphs we will describe the hurricane relocation procedure in the GDAS and show some of our test results from AVN and GFDL forecasts.

2. Procedures to isolate and relocate the hurricane component from global model forecast fields.

The procedure to isolate the hurricane component from the environment field is basically drawn from the GFDL model suite

(Kurihara et. al., 1992, 1995). The difference is in the determination of the hurricane center in the guess field instead of in the analysis field. The location of the vortex center in the guess field may not be important in the GFDL model, but it affects the accuracy of the relocation procedure in the AVN forecast. The steps to relocate the hurricane vortex in the guess field are listed below:

1) Convert the global spectral data to global grid data on the Gaussian grid, then create regional grid data which completely contain the hurricane vortex (we use 41x41 horizontal grids, with grid intervals of 1 degree by 1 degree).

2) Split the forecast field into basic and disturbance fields by repeated use of a local filtering operator:

(Total field)=(basic field)+(disturbance field)

The local filtering operator is done with a three-point smoothing operator which is used first in the zonal direction, then in the meridional direction with a varying filter coefficient. If the filter is applied to a field of sinusoidal waves, components with less than 9^0 wavelength will be completely filtered out and the amplitude of those with 10^0, 20^0 and 30^0 wavelength will be reduced by 82%, 60%, and 32%, respectively.

3) Locate the hurricane center from the guess field.

The center location is obtained from a tracker program written by Tim Marchok. The program gives vertically weighted average of the max or min of several parameters within 275 km of an input observation position of a vortex. It uses these parameters to estimate the vortex forecast position in the NCEP global model. For the levels 700 and 850 mb, the tracked parameters are relative vorticity (max), wind magnitude (min), and geopotential height (min). Also tracked is the minimum in the mean sea level pressure. Those parameters are tracked in order to provide more accurate position estimates for weaker storms, which often have poorly defined structures/centers.

4) Define a filtered domain within the regional grid which completely contains the hurricane vortex.

The extent of the filtered domain is determined by testing the radial profiles of the tangential component of the disturbance wind in 24 directions originating from the vortex center. Some empirical criteria are used to seek the limits of the region of steep gradient in the tangential wind component. The maximum radius is set to be 1200 km.

5) Construct the non-hurricane component inside the filtered domain using optimum interpolation of the disturbance field from the non-hurricane values along the boundary of the filtered domain. A first-guess value of zero is used within the filtered domain. The optimum interpolation scheme generates the non-hurricane components which vary smoothly within the filtered domain and continuously connect across the domain boundary to the

outside non-hurricane field, that is, the basic field.

6) Create the environment field by adding the non-hurricane component to the basic field:

(environment field)=(basic field)
+(non-hurricane component)

7) The hurricane component is obtained by subtracting the environment field from the total field:

(Hurricane component)=(total field)-(environment field)

8) Move the hurricane component to the observed location and interpolate back to the Gaussian grid using cubic splines. Finally convert the Gaussian grid data back to global spectral data.

The hurricane vortex is not relocated if the hurricane center is over a major land mass (less that 250 km), or if the topography is higher than 500 m in the filtered domain.

3. Global model results

The results shown in Fig.1 and Fig. 2 are obtained from a T126L28 version of the GDAS system (T126 horizontal spectral truncation with 28 layers). The model version used for the tests included a modification of the convective scheme, but we expect the influence of the convective scheme on the hurricane track statistics to be small. The experimental runs cover the period from 08/23/99 to 09/23/99 and includes the storms Dennis, Floyd and Gert. In Fig. 1, comparison is made with the operational AVN forecast tracks(AVNO) and an earlier test(EXP1) as a function of forecast hour. The difference between EXP1 and EXP2 is in the relocation accuracy. In EXP1, the relocation is accurate to only within 100 km of the TPC reported center location while the accuracy of the relocation in EXP2 is within 15 km. The top panel of Fig.1 provides the track errors in nautical miles together with CLIPER forecasts(the standard forecast used by TPC to compare track errors). The number of cases included in the track errors is given below the x-axis. It can be seen that the average track error for the 50-80 cases for EXP2 was uniformly better than that of EXP1 and the AVN forecasts. The lower panel of Fig. 1 is a display of the normalized error. The track errors are normalized based on the CLIPER track errors. A negative number indicates that the error is smaller than that of CLIPER. Since all track errors grow with forecast lead time, the relative error diagram is a way to see the improvements for all lead times without the bias of the expected deterioration of forecast tracks.We can see that the initial track error for EXP1 led to worse 12-hour track forecasts. In the longer lead-time forecasts, both EXP1 and EXP2 were better than the operational AVN forecasts. In Fig. 2, the comparisons are made against the other major operational centers' hurricane track forecasts. It can be seen that the track errors of the new relocation package(EXP2) bring NCEP forecast skill up to that of the U.K. Met Office and the Navy NOGAPS models. In the last few years, the AVN forecast tropical storm tracks have been significantly worse than these two centers' forecasts. The relocation algorithm should make the NCEP model forecasts significantly more useful for hurricane forecasters.

4. GFDL hurricane model forecast results

In Fig. 3, we present the GFDL reruns made from the reruns of the current operational GDAS system with the relocation algorithm added. The current operational GDAS system runs with a T170L42 configuration (T170 horizonal spectral truncation with 42 vertical layers). The runs were made for the same period as those of the previous section (8/23 - 9/23 1999). The comparison of the relative errors is made for the GFDL forecasts initialized from the operational AVN analyses(GFDO), the T126 version of the GDAS discussed in section 3 as the EXP2 run(GFDW), the T170 version of the current operational GDAS with relocation(GFDS) and the U. K. Met. Office analysis(GFDU). It can be seen that the T170 GDAS system(GFDS) has the lowest track error for all forecast lengths when averaged over the 60-70 cases rerun.

5. Conclusion

Based on the test results for the Global model tropical storm track improvement and the significant improvement from the GFDL hurricane model forecast tracks, we recommend that the relocation package should be run regularly in the NCEP operational GDAS family.

References

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Fig. 1 The absolute and relative forecast errors of hurricane tracks of the NCEP global model run in the operational (AVNO) and with the relocation package (EXP1 and EXP2). All runs were done at T126L28 model resolution.

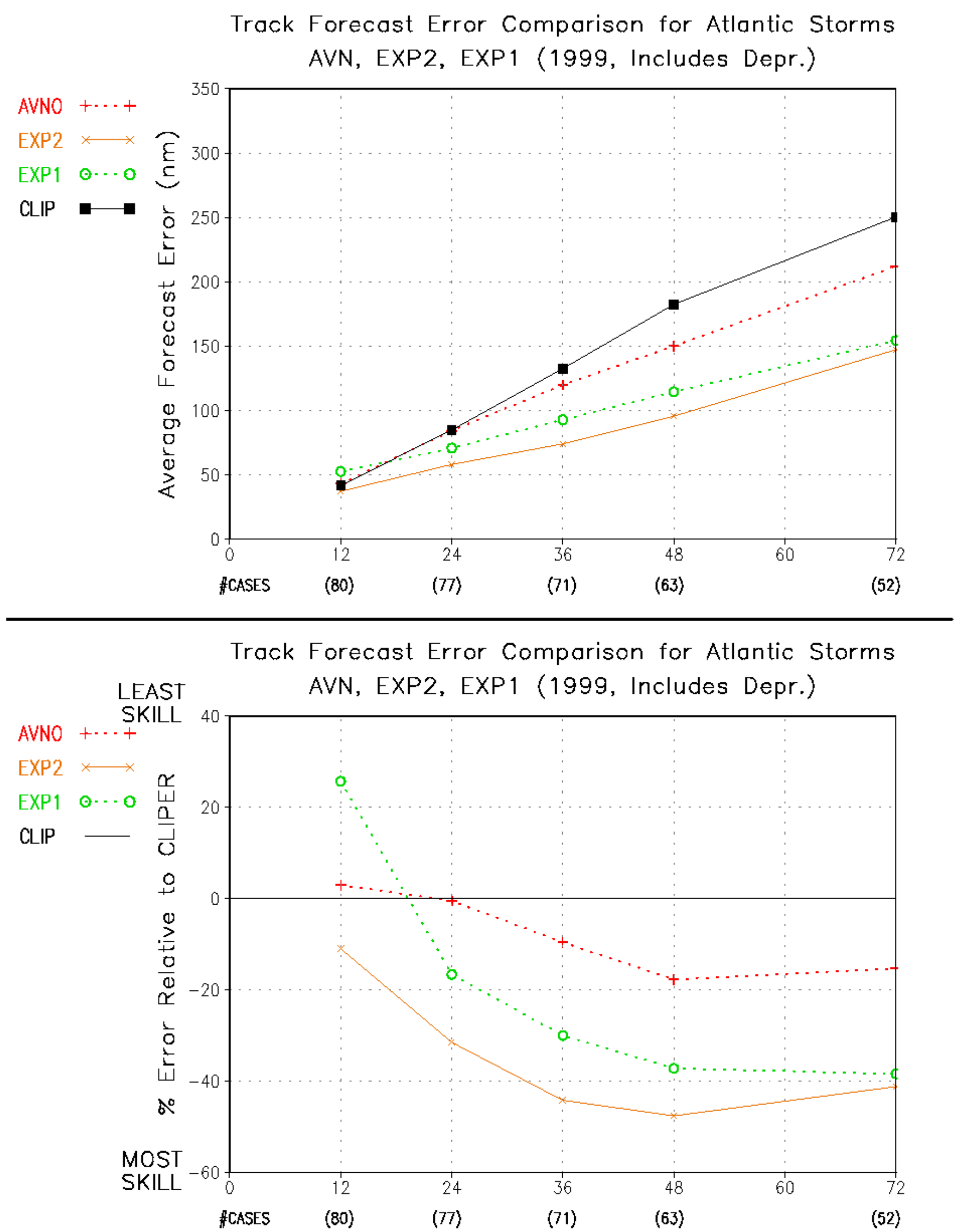
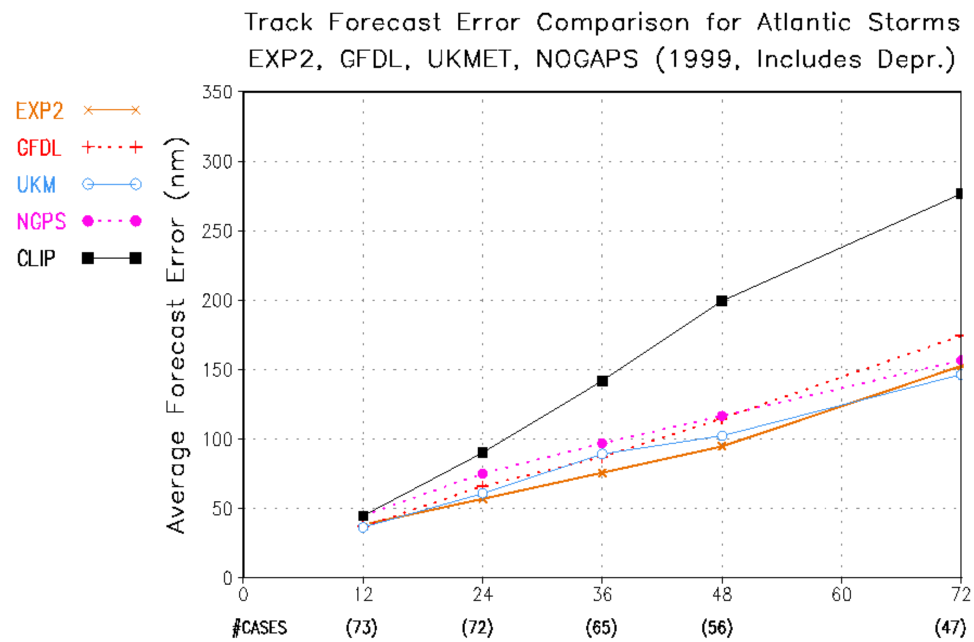


Fig. 2 The absolute and relative forecast errors of hurricane tracks of the NCEP global model(EXP2) compared to the track errors of the GFDL hurricane model forecast(GFDL), the U. K. Met. Office(UKMO) global model forecast and the U. S. Navy global model(NOGAPS) forecast.



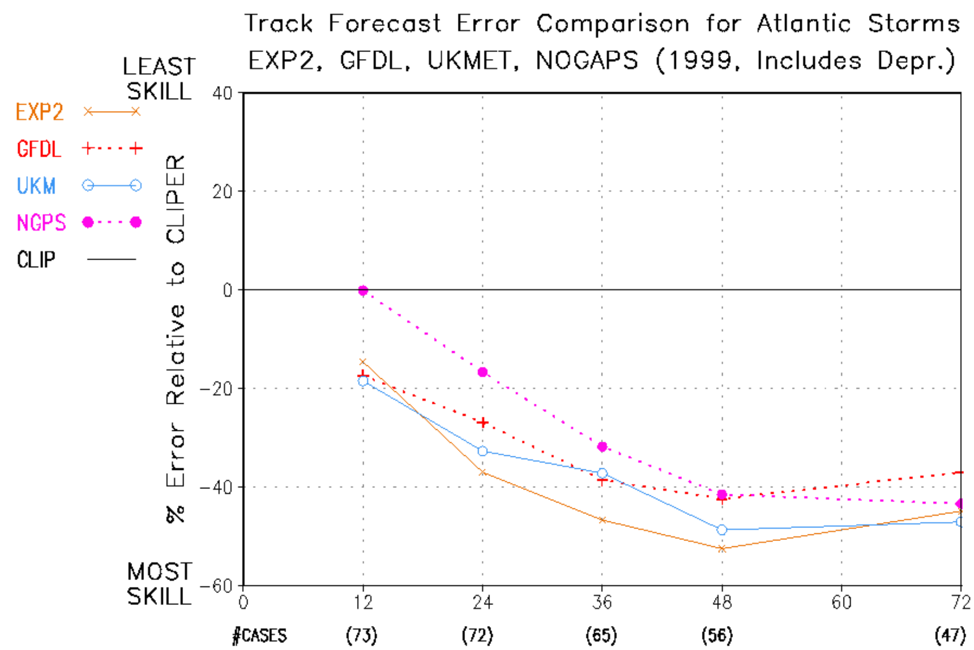


Fig. 3 The relative forecast errors of hurricane tracks of the GFDL hurricane model runs from initial conditions from the NCEP operational GDAS(GFDL), the T126L28 version of the NCEP GDAS with relocation and some convection changes(GFDW), the NCEP operational GDAS with tropical storm relocation(GFDS), and the U. K. Met. Office analysis(GFDU).