P1.13

HOW THE NCEP TROPICAL CYCLONE TRACKER WORKS

Timothy P. Marchok
SAIC at NCEP/GFDL
Geophysical Fluid Dynamics Laboratory, Princeton, New Jersey

1. INTRODUCTION

The Environmental Modeling Center (EMC) at the National Centers for Environmental Prediction (NCEP) runs a daily suite of global and regional models and has the responsibility of providing tropical cyclone guidance based on these model forecasts to the Tropical Prediction Center (TPC) on an operational basis. In 1998, a new tropical cyclone tracking system for extracting track and intensity forecast information from these forecasts was implemented at NCEP. The purpose of this paper is to describe this new tracking system, including its core algorithm and other related features.

2. DATA REQUIREMENTS

The tracker processes data that are in GRIB format on any standard, cylindrical equidistant (lat/lon) grid, whether the grid is global or regional. Grids from other models which are not already on a lat/lon grid, such as the NCEP Eta model, are first interpolated to a lat/lon grid before the tracker is run. While the system can produce a track based on the position of just one parameter center, it is designed to produce a track based on an average of the positions of 5 different primary parameters (mslp, 700 and 850 mb relative vorticity, 700 and 850 mb geopotential height) and 2 secondary parameters (minimum in $\overline{V}$ at 700 and 850 mb).

3. ALGORITHM

To locate a center, the system uses a single-pass Barnes analysis of each parameter at grid points in an array centered initially around the TPC-observed position of the storm. For a variable F, the Barnes analysis B, at a given point g, is given as:

$$B_g = \frac{\sum_{n=1}^{N} w_n F(n)}{\sum_{n=1}^{N} w_n}$$

where w is the weighting function defined as $w = e^{-(d_n^2 / r_e^2)}$, d_n is the distance from a data point n to the grid point g, and r_e is the e-folding radius. We typically use an r_e value of 75 km for models with a grid resolution finer than 1.25^o and 150 km for those with coarser resolution.

The center is defined as the point at which this function is a maximum or a minimum, depending on the parameter being analyzed. After a parameter center is obtained at the grid's original resolution, four subsequent Barnes analyses are performed, each done over a restricted area smaller than that of the original analysis and centered on the position obtained from each previous analysis, with each successive analysis done on a grid with half the grid-spacing of the previous iteration. In this way, for example, the position for a storm from a model dataset with 1-degree resolution can be refined to within 1/16 of a degree.

This method is used for the 5 primary parameters, but for the minima in wind speed at 700 and 850 mb, a smaller area within 120 km of the center guess position is first interpolated to a fine mesh and then a Barnes analysis is done on that smaller grid. The reason the larger area is not searched in this case is to avoid the mistake of identifying a calm area well outside the storm as the calm area near the center of the storm. The centers obtained from these wind speed minima are used only to refine the center estimate obtained from the average center position of the 5 primary parameters. If center fixes were unable to be made for all 5 of the primary parameters, then the tracker quits without attempting to find the wind speed minima.

The center guess position for subsequent forecast hours is obtained through an average of 2 different methods. The first is a simple linear extrapolation of the 2 most recent center fixes. The second is through the advection of the current storm according to the mean wind obtained from Barnes analyses of the winds at 850, 700 and 500 mb, centered on the storm.

4. RESTRICTION CRITERIA

Since this Barnes algorithm will always return a max or min position, care must be taken to ensure that the center that is found not only resembles a storm, but is also likely the storm that is being targeted and not just another, passing vortex. This is especially critical in cases with weak or poorly-defined vortices, such as for weak depressions or for storms that are weakening as they recurve into poleward latitudes.

The first check that is done it to make sure that a parameter center that has been found is within a specified distance of the guess position for that forecast hour. This allowable error distance can change throughout a forecast, based on the spread of position estimates in the 3 preceding forecast hours, but can never be less than a hard minimum limit that is specified for a model based on its resolution (275 km for the AVN).

The second set of checks examines the intensity of the found storm, specifically the pressure field and the 850 mb winds. A minimum critical mslp gradient, extending in any direction from the center mslp position, must be found. For the AVN, this pressure gradient is 1 mb / 333 km. By comparison, the higher resolution GFDL hurricane model uses a more stringent mslp gradient constraint of 1 mb / 100 km (Morris Bender, personal

* Corresponding author address: Timothy Marchok, NOAA/GFDL, P.O. Box 308, Princeton, NJ, 08542.
email: timothy.marchok@noaa.gov

communication, 2001). For the 850 mb winds, the average tangential winds within 225 km of the 850 mb wind minimum center position must be cyclonic and, for the AVN, at least 3 ms $^{-1}$.

Two final gross error checks are done to make sure that (a) the distance between the mslp center position and the 850 mb relative vorticity center position does not exceed a specified distance (325 km), and (b) the average speed that the storm would have had to travel from the last forecast position to the current one does not exceed a maximum threshold (60 kts).

5. EXAMPLES

Figure 1 illustrates some of the main features of the tracker described above. Positions for 3 of the 7 tracker parameters are marked near the center of the storm, and a "T" marks the average position that the tracker fixed at this time. Text output on the figure indicates that the checks for the mslp gradient and 850 mb winds found acceptable values, and the tracker continued running.

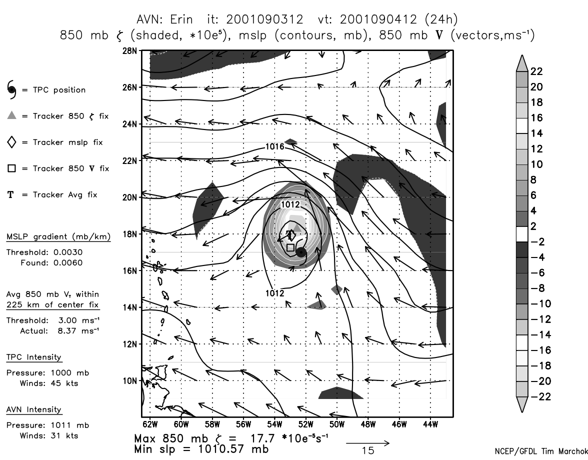

Fig. 1) 24h AVN forecast for Erin from 12 UTC 03 Sep 2001, showing 850 mb zeta (shaded), mslp, 850 mb winds, and related tracker output info (see text).

Figure 2 shows another case of Erin, initialized only 12 hours earlier than the case in Fig.1, but in this case the restriction criteria were not satisfied and the tracker stopped tracking. Although center positions were able to be found for several of the parameters and a moderate 850 mb relative vorticity signature was evident, the model storm resembled more of an open easterly wave than it did a well-formed tropical cyclone. As the text on the figure indicates, the mslp gradient was too weak, the 850 mb winds were too weak, and so the tracker quit at this point.

6. PERFORMANCE

In order to assess the relative performance of the NCEP tracker, tracks obtained from the NCEP tracker using GFDL, NOGAPS and UKMET GRIB data were compared against those tracks provided to NHC by each of those respective modeling groups. The comparison in Table 1 indicates that the NCEP tracker produced tracks at least as skillful as those from the respective centers.

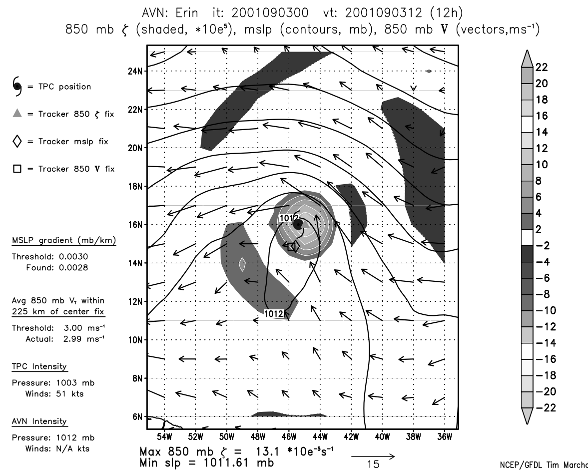

Fig. 2) As in Fig. 1, but for 12h forecast from 00 UTC 03 Sep 2001

7. INTENSITY PARAMETERS

At each forecast hour, the NCEP tracker reports intensity information, including minimum sea level pressure and maximum surface or near-surface winds. In addition, the tracker also analyzes the surface winds in each storm quadrant in order to determine the forecasted radii of 34-, 50- and 64-knot winds in each quadrant at each forecast hour.

8. REMARKS

Over the past 4 hurricane seasons, the NCEP tracker has proven to be a reliable research and forecasting aid. We continue to make improvements to it, including upgrading it to be able to automatically monitor for tropical cyclogenesis and to extend its utility to tracking mid-latitude storms.

Table 1: Homogeneous comparison of mean track error (nm) of NCEP tracks (each ends in "X") vs. those from respective centers for 2001 Atlantic storms.

	00	12	24	36	48	72	96	120
GFDL	9	39	70	102	137	201	313	380
GFDX	12	36	66	98	132	195	308	376
#Cases	188	183	155	132	115	82	29	19
NGPS	27	53	80	121	168	266	353	409
NGX	19	44	76	118	164	263	345	402
#Cases	84	81	68	60	51	35	23	17
UKM	17	44	69	104	144	213	0	0
UKX	24	45	68	99	133	211	0	0
#Cases	92	90	78	67	54	37	0	0

ACKNOWLEDGEMENTS:

Many thanks to Mark DeMaria, who originally suggested to me the use of the Barnes analysis for the center-fixing scheme in the tracker.