The Enhanced FNMOC TC Tracking Scheme

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1.0 Introduction

Objective schemes for locating tropical cyclone (TC) vortices in model output are fundamental to the diagnosis of model TC forecast skill. The schemes can be classified as being either *meteorological* or *operational*. Meteorological trackers output parameters strongly related to observed TC structure, such as positive temperature anomalies above low surface pressure (e.g., vertically stacked and warm core). In contrast, operationally orientated trackers seek significant features in weather maps that can be used for track forecasting. These later trackers typically depend only on relative vorticity maxima and/or surface pressure minima.

The TC diagnostic system implemented for ERA-40 and used operationally at the Joint Typhoon Warning Center to aid TC warnings features both types of trackers, but in this report only the operational tracker is described. The scheme is an enhancement of that used at Fleet Numerical Meteorology and Oceanography Center (FNMOC, http://www.fnmoc.navy.mil) to produce tracks from their global (NOGAPS) and limited-area models (GFDN). The documentation is based on the FORTRAN source code.

2.0 FNMOC Operational Tracker

The original tracker, developed circa 1995, used the 1000 mb winds, but later switched to surface or 10 m winds as the surface wind field has operational significance to the military users of JTWC warnings (winds > 30 kts affects naval flight operations and 15 kts of cross wind air force). The basic idea is to locate centers of cyclonic wind shifts.

The scheme starts with an observed TC initial position and motion, typically coming from the "bogus" message sent from JTWC used in creating TC dropwindsonde retrievals for vortex initialization in the NOGAPS model. The input model data is the surface winds (u,v components) on a global 1° latitude grid.

The scheme sets a window of 5-9 grid points square around the TC position and then two passes are made to locate cyclone wind shifts. The search window is based on the motion of the storm and increases with increasing speed.

The first is 1x1 4-point grid (Figure 2) and the second 3x3 4-point grid (Figure 1). The idea is to first look for small-scale cyclonic circulations (1 grid box or ~1°), and then look for larger scale cyclones (3 grid-point box or ~3°).

If the four corners contain a wind direction in range, then a potential position is saved. After these two passes, between 1 and 8 candidates can exist. For a well-defined cyclone there would be 8 candidates and number of candidates indicates quality. The final position is the "best" center from an "isogon" analysis of the wind fields around the candidate positions.

The details of the isogon analysis are not described as the output is a position between the grid points defined by candidate square.

These candidate positions are further culled by comparison of the maximum wind speed and nearness of the candidate to the initial position. The final output is a "best" position with the highest score based on three quality factors:

1) surface wind circulation confidence = 1-4, where 1 is highest/best and 4 is lowest/poor);

2) cyclonic wind shift support factor = 3 or 4 points with shifts, 4 is highest/best;

3) intersection support = 2-8, where 8 is highest/best.

The system starts with the observed TC position and motion at t=0. If a model position is found at t=0, then the observed motion is used to make an estimated position for the next forecast time. For application to global model output¸ we use a 12-h forecast time increment.

The 12-h forecast position search is initialized with a position from a 12-h rhumb-line extrapolation from the initial model position and the observed heading and speed of motion. For the next forecast time (e.g., 24 h), the motion from the current (e.g., 12 h) and 12-h old position (e.g., 0 h) is used for the rhumb-line extrapolation.

The scheme was originally verified by visual comparison with surface wind field, surface pressure and other plots such as 700 and 500 mb heights and temperature. It was found that the scheme produced positions consistent with those from a tropical meteorologist's interpretation of the plots and was thus considered meteorologically sensible, under most conditions. While the objective tracker was not intended to completely replace field inspection, it was found to correctly handle at least 95+ % of the model cases.

During application to ERA-40 (T159L60) and the ECMWF (T319L60 – T511L60) operational model, it was found that the tracker failed for cases with a clear TC-circulation signal in the 850 mb relative vorticity field. An additional tracker was added based on scheme of Fiorino and Elsberry (1989) and this is why the scheme is referred to as the enhanced FNMOC operational tracker

When the surface wind field scheme fails, an 850-mb relative vorticity maximum (northern Hemisphere) > $5x10^{-5}$ s^{-1} (a settable threshold) within the search window is sought. The local vorticity extrema with the greatest cyclonic vorticity nearest the initial (estimated from motion) position is selected. The location between grid points is based on Stirling's formula and the position and the maximum vorticity is output in place of the support factors in the wind scheme.

3. Application and Summary

The enhanced FNMOC operational TC tracker has been applied to the operational global model output from: 1) ECMWF (T511L60); 2) FNMOC (T159L28) and 3) NCEP (T172L43) since 1998 (e.g., Goerss 2000). Verification statistics and plots of the forecast tracks have shown no obvious errors (e.g., huge jumps). Thus, we have good confidence that the scheme is aggressively detecting TC-like features and "making forecasts." However, the scheme cannot be considered perfect as some of the forecasts may not be meteorologically reasonable, but in application to warning process, errors on the side of overforecasting are preferred.

The scheme is currently being used at ECMWF for TC tracking in ERA-40 and at JTWC for local tracking of model global model output from NCEP and FNMOC. In addition, the scheme is being run on 12 UTC deterministic forecast (T511L60) of the ECMWF operational model for internal verification purposes. The original FNMOC scheme uses the 1000 mb vice surface winds with 6-h time increment.

Finally, we believe that the scheme is well-tested, robust and appropriate for global model application at both climate (low) and weather (high) resolutions; source code is available on request.

References

Goerss, James S., 2000: **Tropical Cyclone Track Forecasts Using an Ensemble of Dynamical Models.** *Monthly Weather Review*: Vol. 128, No. 4, pp. 1187–1193.

Fiorino, Michael, Russell L. Elsberry, 1989: **Some Aspects of Vortex Structure Related to Tropical Cyclone Motion.** *Journal of the Atmospheric Sciences*: Vol. 46, No. 7, pp. 975–990.

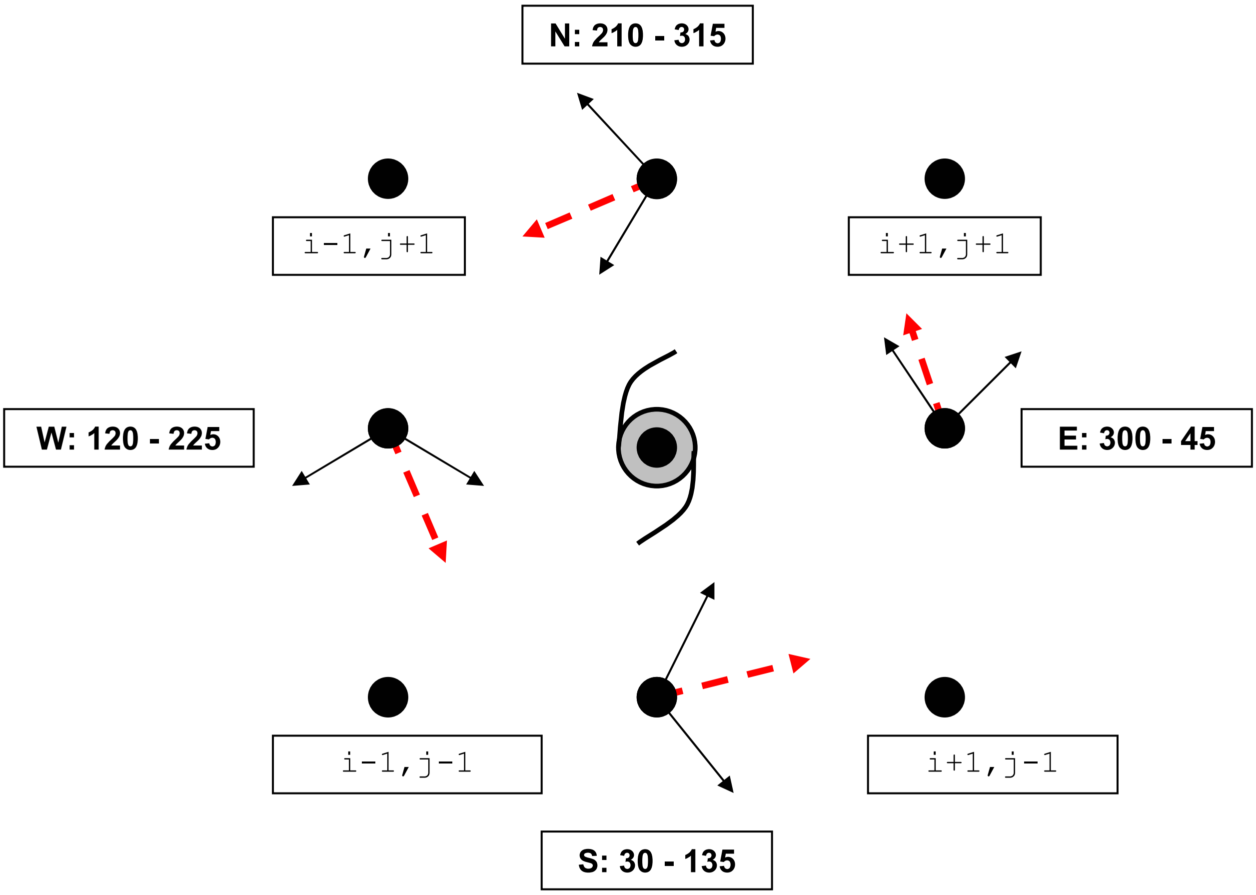

Figure 1. Second pass of wind shift check using the 9-point square. The black dots are grid points with relative i,j indices show in the box below. Boxes with N, E, S, W contain the wind heading range used to classify the surface wind direction (dashed vector) as cyclonic (northern Hemisphere). If the wind direction are within range at 3 of the 4 points then the grid point (i,j) is considered as having a TC in the vicinity.

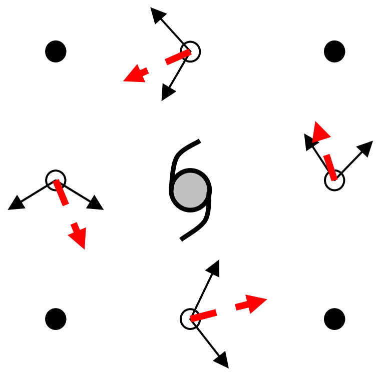

Figure 2. First pass using the 4-point box scaled to grid stencil in Figure 1. Demonstration of the small-scale (within a grid box) search, otherwise as in Figure 1.