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# EVALUATION OF A TROPICAL CYCLONE TRACKER FOR OPERATIONAL USE WITH THE COAMPS™ REGIONAL MODEL

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## 1. INTRODUCTION

From 1996-2005, Fleet Numerical Meteorology and Oceanography Center's (FNMOC) operational tropical cyclone tracker for the Coupled Ocean Atmosphere Mesoscale Prediction System (COAMPS) was a variation of the vortex tracker developed by Marchok (2002). The tracker locates a cyclone circulation based upon finding an isogon in the 850 millibar vorticity fields. A newer algorithm is tested whereby native sigma level data is utilized in locating a low level cyclone. The newer tracker is referred to as an *internal* tracker as the tracker job runs during the COAMPS forecast. The older operational version is referred to as an *external* tracker as it is run at the conclusion of the COAMPS forecast job (i.e., external to COAMPS).

The internal tracker computes a mean layer wind in the 100-1500 meter layer above the surface in terrain-following sigma level coordinates to track the tropical cyclone (Liou 2004). This has advantages over rough terrain, and for developing and dissipating storms in which fixed pressure-level data becomes less reliable than using a layer to track a circulation. Thus, it is hypothesized that the internal COAMPS tracker will perform as good or better than the operational tracker in regards to both track, intensity, and hit rate errors.

## 2. METHODOLOGY

Beginning 01 June 2005, the COAMPS internal tracker was run in a beta environment to closely parallel the COAMPS West Pacific operational (OPS) run. The real-time OPS run is nominally set to start at +3:45 hours into the 0000 and 1200 GMT watch cycles and complete the 84-hour forecast run at +5:00 hours. A 12-hour forecast is run at the offtimes of 0600 and 1800 GMT to provide continuous and updated background conditions for the subsequent real-time runs.

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The Navy Operational Global Atmospheric Prediction System (NOGAPS) boundary conditions are provided every three hours during the COAMPS forecast.

The COAMPS beta run takes advantage of the same data cut-off time as the OPS run. Thus, there should be no appreciable difference in the output of the OPS and beta runs. To quantify subtle differences between the beta and operational runs, the operational tracker was run on the output of the beta run. By obtaining two nearly identical operational tracker output files, we can draw conclusions about relative impact on the operational performance of the beta tracker. Thus, there are two operational, *external*, tracker jobs and an *internal* tracker running for each watch when there is an active storm in the West Pacific COAMPS domain. They are:

**COWP** – The COAMPS operational run with the external tropical cyclone tracker
**CWP2** – The COAMPS beta run with the external tropical cyclone tracker
**COW2** – The COAMPS beta run with the internal tropical cyclone tracker

The conclusions made in this paper will be drawn from results comparing COW2 against CWP2 since this comparison most closely represents deviations from the operational tracker. For ease of computing track and intensity error statistics, each tracker program outputs an ascii text file written in the Automated Tropical Cyclone Forecast (ATCF) "a-deck" file format (see http://www.nrlmry.navy.mil/atcf_web/docs/database/new/abrdeck.html for a detailed format description or Sampson and Shrader, 2000).

Tropical cyclone errors are calculated for: direct positional (or track) (nm) and mean sea-level pressure (MSLP) error (hPa). The track error computes the great circle distance between the forecast tropical cyclone center position and the verifying best estimate provided by the Joint Typhoon Warning Center (JTWC). Even though MSLP does not represent the track error directly, MSLP error measures performance when we assume that the lower MSLP error implies that we're tracking the feature that better defines a storm center.

Another important verification parameter for determining superior tracker performance is the hit rate of the two trackers. That is, the objective storm tracker will not always detect a storm center in the model forecast output fields. Conversely, the objective storm tracker may be tracking a storm center that does not verify in observations.

## 3. RESULTS

The beta tracker was run on a total of 14 tropical cyclones in the Western Pacific domain. An inventory of the storms is listed in Table 1. Eleven out of 14 storms (80%) reached Typhoon strength ($V_{max} \geq 64$ knots). Of those, 4 (36% of sample) reached super Typhoon intensity ($V_{max} \geq 130$ knots). A total of 175 separate forecasts were made for the experiment.

### *3.1 Track Errors*

The homogeneous forecast track errors for the experiment sample show very little difference between CWP2 and COW2 (Figure 1). For reference, track errors for NOGAPS (NGPS) and the Geophysical Fluid Dynamics Laboratory – Navy (GFDN) models are shown. The relative differences are all less than 1% between the OPS and beta trackers. At forecast hour 36 and greater, NOGAPS and GFDN outperform the COAMPS West Pacific track error, on average.

The individual non-homogeneous model tracker errors (not shown) are nearly identical to what is shown in Figure 1.

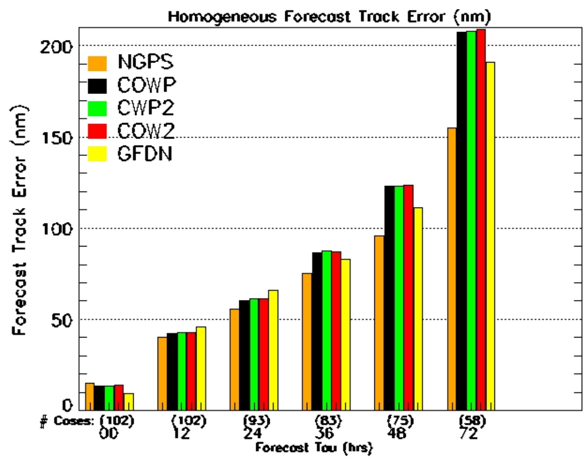



Figure 1: Tropical cyclone track error (nm) and number of cases in homogeneous sample as a function of forecast length (hours) for the experiment period 01 June – 31 October 2005.

Table 1: Inventory of 01 June – 31 October 2005 experiment sample: Storm longevity is indicated by both the start/stop dates and the number of forecasts in which the experiment was run for each storm.

| Storm Name | Storm Number | Start date | End date | Number of Forecasts | Peak Intensity ($V_{max}$, Knots) |
|---|---|---|---|---|---|
| NESAT | 04 | 2005052712 | 2005061000 | 19 | 125 |
| HAITANG | 05 | 2005071012 | 2005071912 | 16 | 140 |
| NALGAE | 06 | 2005071700 | 2005072312 | 4 | 50 |
| BANYAN | 07 | 2005071900 | 2005072918 | 11 | 60 |
| MATSA | 09 | 2005072918 | 2005080606 | 12 | 90 |
| SANVU | 10 | 2005080800 | 2005081306 | 5 | 65 |
| MAWAR | 11 | 2005081800 | 2005082706 | 16 | 130 |
| TALIM | 13 | 2005082218 | 2005090112 | 12 | 125 |
| NABI | 14 | 2005082806 | 2005090618 | 17 | 140 |
| KHANUN | 15 | 2005090400 | 2005091118 | 12 | 115 |
| VICENTE | 16 | 2005091318 | 2005091700 | 5 | 45 |
| DAMREY | 17 | 2005091812 | 2005092912 | 14 | 90 |
| LONGWANG | 19 | 2005092318 | 2005100300 | 14 | 130 |
| KIROGI | 21 | 2005100900 | 2005101900 | 18 | 125 |

### *3.2 Intensity Errors*

Each forecast tropical cyclone minimum mean sea level pressure (MSLP) was compared to the verifying best track estimated pressure. Typically, the best track minimum central pressure of the storm is deeper (lower value) than the forecasted value from the dynamical model for a number of reasons including coarse horizontal resolution, poor understanding of inner-core dynamics, parameterized microphysics, and poor understanding of important air-sea interactions. The verifying (best estimate) intensity produced by JTWC is primarily derived using the Dvorak technique (Dvorak 1975) on infrared and visible satellite imagery. Results of computing the average central pressure error (ACPE) are displayed in Figure 2. Relative differences among the two trackers indicate slightly smaller error with the internal tracker, COW2 (i.e., the internal tracker is on the order of 0-3 hectopascals more intense than the external tracker). These average differences are more evident at the beginning and end of the forecast cycle.

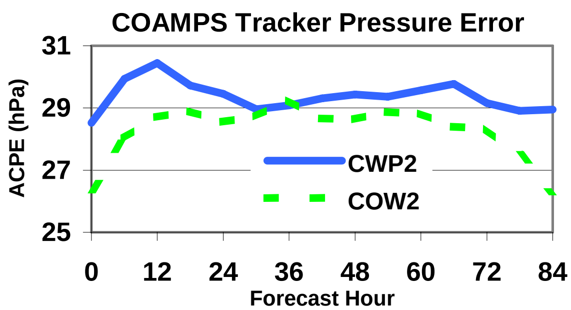



Figure 2: Average central pressure error (ACPE) in hectopascals comparing the operational COAMPS tracker (CWP2) and the *internal* beta tracker (COW2). Errors are computed on homogeneous sample used in Figure 1.

### *3.3 Cyclone Detection*

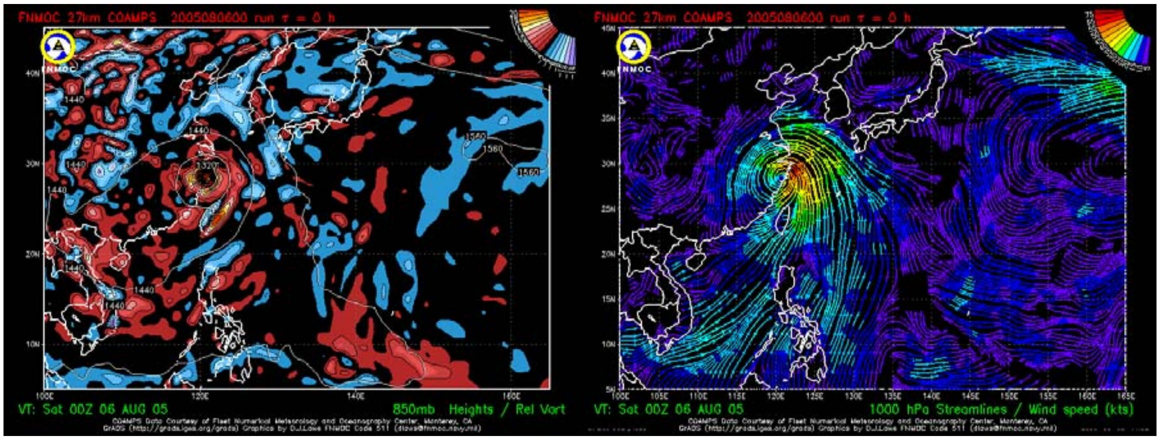
The hit rate is a metric that tests the ability of the storm tracker to detect a storm in the event that the storm was observed. By computing the hit rate for each storm of the sample, we are able to determine where one tracker succeeds and the other fails in detecting a vortex center from the model output fields.

The best track estimate file (also known as the ATCF *b-deck*) contains all analyzed positions for each storm, which we will term “observed.” For the 14-storm sample, the total number of possibilities of a storm being observed or forecast, n=4755. Of this total, there were 1510 (31.7%) and 1651 (34.7%) forecasts that were both observed and forecast for the operational and beta tracker CWP2 and COW2, respectively. Thus, the beta tracker detected a cyclone 141 more times than the operational tracker (or about 3% more often). The magnitude of the hit rate might seem rather low which is due to a couple of reasons: 1) the model in many instances would not have forecast a circulation before the warning and corresponding bogus message that, in many cases, initiates the circulation, and 2) a concurrent moving nest experiment was being run in parallel with the constraint that the tracker runs on one storm at a time.

Individual forecasts from each storm were compared to see where COW2 forecasts a storm and CWP2 does not to determine why the beta tracker was more successful. This occurs most frequently for landfalling storms such as storm 09W (Matsa). What occurred during these situations is that the feature at 850 mb was not well defined on the pressure-level surface (which will sometimes intersect the terrain) and thus the requirements for a trackable feature were not met. In the case of the beta tracker, a circulation is much more likely to be identified in the terrain-following lowest layer of winds. Figure 3 is an example of when this type of scenario occurred. For this particular date, time and analysis, COW2 was identifying Matsa’s center while CWP2 was not.

## 4. SUMMARY

Two objective tropical cyclone trackers were run in parallel on the COAMPS West Pacific model from 01 June - 31 October 2005 to determine which algorithm delivers superior performance in terms of standard track and pressure errors and hit-rate statistics. An objective tracker which tracks cyclone features on fixed pressure-level data (*external* tracker) was compared against a newer, terrain-following, layer tracking algorithm (*internal* tracker). While there was no appreciable improvement in the track error results and only slight improvement in average central pressure errors, superior detection success was obtained for the internal tracker particularly for storms interacting with terrain. Based on the results obtained in this experiment, FNMOC will begin using the internal tracker operationally with the COAMPS model beginning in the 2006 tropical cyclone season.




(a) (b)

Figure 3: COAMPS West Pacific depictions of Tropical Cyclone 09W (Matsa) on 06 August 2005 0000 GMT. Panel (a) shows the 850 mb geopotential height contours (meters) overlaying the 850 mb relative vorticity (*$10^{-5}$ $s^{-1}$). Panel (b) depicts the 1000 mb wind streamlines color coded by the corresponding wind speed (knots).

## 5. REFERENCES

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