10C.5 RECENT IMPROVEMENTS TO COUPLED OCEAN/ATMOSPHERE MESOSCALE PREDICTION SYSTEM FOR TROPICAL CYCLONE INTENSITY FORECAST

Chi-Sann Liou[1*] and Yi Jin[2]
[1]Naval Research Laboratory, Monterey, California[*]
[2]Science Applications International Corporation, Monterey, California

1. INTRODUCTION

The Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS[TM+]) is a globally relocatable, nonhydrostatic, nested-grid forecast system that is designed to predict mesoscale atmospheric phenomena down to the meso-β scale (Hodur, 1997). In the last three years, we have devoted efforts to extend COAMPS[TM] applications for tropical cyclone (TC) forecast with emphases on structure and intensity forecast. The improvements made in the late years includes (1) development of a TC initialization system for high resolution COAMPS[TM] (Liou 2002), (2) upgrade to microphysics parameterization (J. Schmidt personal communication; Chen et al. 2003), (3) upgrade to movable inner mesh capability for operational TC forecast, and (4) development of a dynamical internal TC tracker for outputting TC track, structure and intensity forecast. The first two improvements have been operational and the last two improvements are under operational checkout pending to be operational soon. The 3-year (2001-2003) statistics of track forecast errors for West Pacific TCs indicates that COAMPS[TM] is a very competitive model for TC track forecast (Fig. 1), although there still are rooms for the improvement. Following sections briefly describe the upgrades to COAMPS[TM] model physics and numerics specifically for high resolution TC structure and intensity forecast.

2. MICROPHYSICS PARAMETERIZATION UPGRADE

The original microphysics parameterization used in COAMPS[TM] before summer 2002 includes only cloud water, cloud ice, and rain water predictions in the parameterization. The upgrade to the microphysics parameterization adds predictions for grauple, drizzle, and aggregates so that the microphysics processes are more completed. Furthermore, the calculation for the saturation adjustment is modified using the implicit solution described by Soong and Ogura (1973), and a nonzero fall speed is assigned to the cloud ice. The upgrade basically cures the original problem in COAMPS[TM] that a high-resolution mesh without cumulus parameterization predicts much weaker TC intensity than those coarser meshes with cumulus parameterization.

3. AUTOMATED MOVEABLE INNER MESHES

To efficiently apply high-resolution grids following a specific target requiring high resolutions, COAMPS[TM] has included a capability to move the inner mesh during a forecast run. However, this application requires the pre-knowledge of where the high-resolution mesh should be moved to before the forecast run start. For operational TC forecast, we have to overcome this limitation by developing an automated tracking method to identify the position of a selected TC during the forecast period. In order to define a smooth TC movement and better represent the center of areas covered by TC circulation, we use the "mass center" to position a selected cyclone, similar to the method used in the GFDL tropical cyclone model. The mass center (x_m, y_m) is defined as the gravity center of pressure deficits with respect to a reference pressure, $x_m = \frac{\sum \delta P_i x_i}{\sum \delta P_i}$, $y_m = \frac{\sum \delta P_i y_i}{\sum \delta P_i}$, where δP is the pressure deficit. The reference pressure is computed as the average of minimum and maximum sea level pressure within a 300 km by 300 km grid box centered at the previous cyclone position. When a high-resolution inner mesh is assigned to follow a selected TC, the center of the inner mesh is initially set at the TC position. The position is tracked at every time step in the forecast. When the cyclone moves away from the inner mesh center more then one grid distance of the mother mesh, the inner mesh is moved to a new location where the cyclone position will be at the mesh center again. For data assimilation runs, the inner mesh center is initially set at the cyclone first guess position predicted from previous model forecast. The difference between this initial position and the current observed TC position is added to the inner mesh movement so that the moveable inner mesh center will match the TC position within 6 hours. Comparison of forecast from moving grids and fixed grids reveals that the grid movement introduces very minimal errors (not shown).

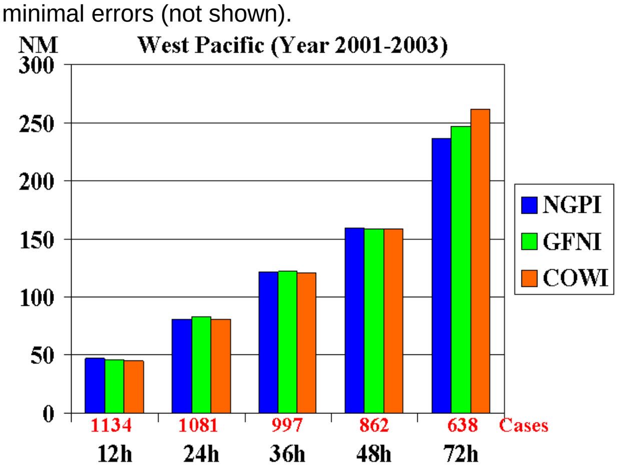

Fig.1. Homogenous comparison of 3-year (2001-2003) TC track forecast errors over West Pacific from 3 Navy operational models.

* *Corresponding author address:* Chi-Sann Liou, 7 Grace Hopper Ave., Monterey, CA; e-mail: liou@nrlmry.navy.mil
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The high-resolution forecast from the moving inner mesh can provide much more detailed TC structure forecast to forecasters, especially when the TC interact with complex terrain (Fig. 2). The high-resolution moving inner mesh also improves TC track forecast over the coarser mother mesh in our test runs for evaluation.

4. INTERNAL TROPICAL CYCLONE TRACKER

Tropical cyclone centers from a model forecast are typically tracked offline from forecast fields after the forecast run has been completed. Since those forecast fields are required to be outputted, the frequency of the offline tracking may be limited by the affordable amount of output and the accuracy may be contaminated by interpolation errors introduced during the output. Furthermore, coordinate adjustment is needed when the offline tracker is used to track TC forecast of a moving mesh. We have developed an internal TC tracker for COAMPS™ to dynamically track TC centers with user selected time interval during the forecast run. The internal tracker will track all TC circulation centers within all COAMPS™ nested grid domains. The reason of tracking the circulation centers rather than minimum sea-level pressure centers or maximum vorticity centers is because the TC centers will then be used to determine the cyclone wind structure, 34 and 50 knot wind radii, and the cyclone intensity, maximum wind speed, at that time of the forecast. The internal tracker needs no first guesses in tracking so that it can detect TC genesis when it occurs during the forecast period.

The internal TC tracker is designed according to the two characters of a TC center: (1) the center is located nearby a local sea-level pressure minimum and a local low-level vorticity maximum, and (2) the circulation at the TC center is either calm or circularly cyclonic. Layer averaged wind between 100 m to 1500 m above the surface is used in the low-level vorticity calculation and tracing for the circulation center. To avoid the tracker picks up small-scale centers, a 9-pont smoother is applied to the sea-level pressure and low-level vorticity before the minimum and maximum centers are searched. To avoid the tracker picks up short-live weak centers, threshold values are set for the sea-level pressure minimum and low-level vorticity maximum. A restriction that TC genesis can only occur over oceans between 30°N and 30°S is applied to avoid mistreating an extratropical cyclone center to be a TC. Once the TC circulation center has been identified, maximum wind speed of the bottom model level is searched within 250 km from the center. The maximum wind speed is then adjusted by a factor obtained from fitting the model statistics to the observed statistics for the relationship between maximum wind speed and minimum sea-level pressure. From the cyclone circulation center, radially averaged bottom level wind speed is computed at 4 quadrants and then used to search for 34 and 50 knot wind radii at each quadrant. Therefore, with the internal tropical cyclone tracker, COAMPS™ can produce TC track, wind structure, intensity, as well as cyclone genesis forecast in a user specified time interval like 1 h.

5. SUMMARY

Developing a skillful dynamic forecast model for TC structure and intensity forecast remains as a challenge to TC modelers. We have upgraded COAMPS™ in last 3 years toward that goal. Currently, we are testing and evaluating different physical parameterization schemes to look for the best combination of all available schemes for COAMPS™ TC structure and intensity forecast. We are also working on improvement to the COAMPS™ TC initialization for the intensity forecast. The initialization system may work well for the track forecast, but too weak and not balanced initial TC circulation is often shown in the COAMPS™ TC initial conditions.

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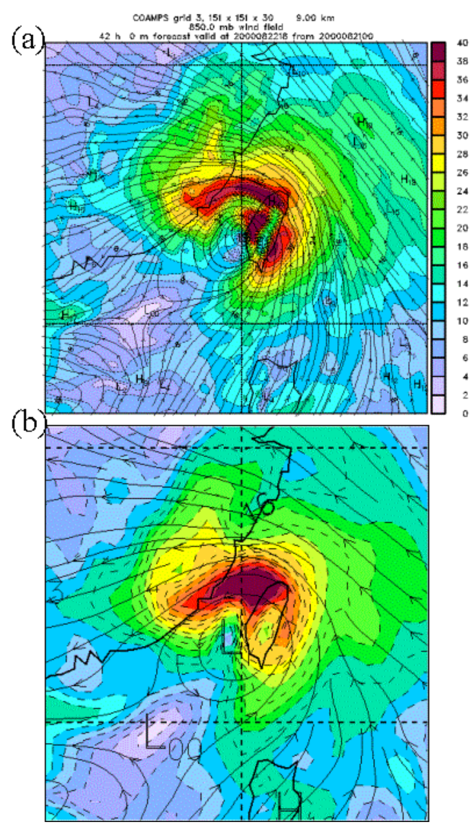

Fig.2. Comparison of 850 hPa wind speed (shaded contours) and streamlines forecast from (a) 9-km moving mesh, (b) 27-km mother mesh for TC Bill near Taiwan.