Forecasting Typhoon Herb in 1996 Using the U.S. Navy Nonhydrostatic Model

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1. INTRODUCTION

The Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS) developed in the Marine Meteorology Division at the Naval Research Laboratory, is currently being evaluated as the next generation mesoscale forecast model for the U. S. Navy. The system allows multi-level grid nesting and has explicit treatment of precipitation and boundary layer effects to provide forecast of mese-alpha and mese-beta scale phenomena. The configuration of the system can cover a large domain in the outer coarse grid and high resolution in the central region that is suitable for tropical cyclone forecasting such as the case presented here for Supertyphoon Herb that hit Taiwan island and caused severe damage. Performance of the COAMPS on the track forecast, wind and precipitation forecast, and interaction of the typhoon with topography is evaluated and analyzed.

2. SUPERTYPHOON HERB

Supertyphoon Herb had a history of 14 days from 21 July to 3 August, 1996 with a predominate movement to the west and northwest (Fig. 1). A maximum wind of 140 knots was estimated on 1800 UTC 30 July. The landfall of Herb over the northern part of Taiwan between 1200 UTC July 31 and 0000 1 August caused severe damage and took more than 50 lives. The 24h accumulated precipitation measured close to 1200 mm which broke the record. During that time, even though most forecast centers issued official forecasts fairly close to the best track, the objective aids provided rather diversified forecasts (Fig. 1). To study the forecast skill of COAMPS on tropical cyclone motion as well as its capability of a detailed forecast on the associated local wind and precipitation, the date on 0000 UTC 30 July is chosen for our experiment. After this initial time, Herb changed its course from northwest to west by northwest. Had it kept its northwest direction straight, it would have missed Taiwan.

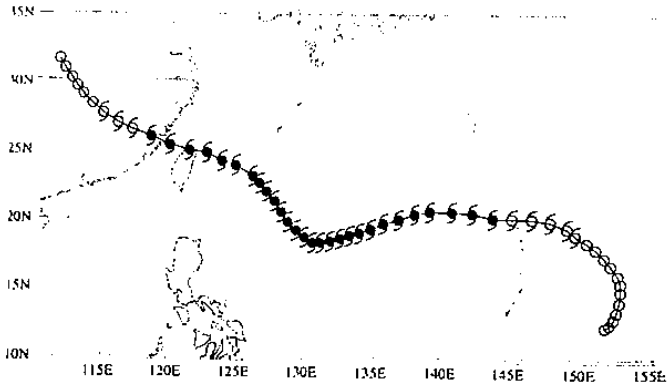


Figure 1. Best track for Typhoon Herb determined at the JTWC.

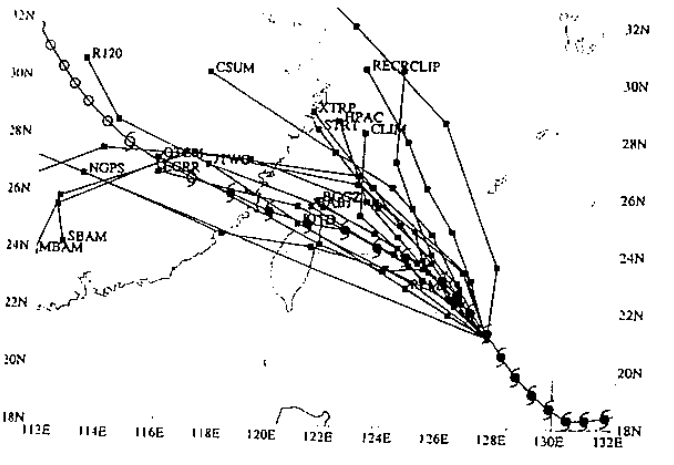


Figure 2. Best track and forecast tracks for 30 July 1990 from some

objective aids available at the JTWC.

3. MODEL DESCRIPTION AND CONFIGURATION

The COAMPS is a non-hydrostatic limited-area primitive equation system that contains quality control, multi-variant optimal interpolation analysis and forecast integration (Hodur 1997). For the present study, only the atmospheric part is used with fixed SST. The model adopts the nonhydrostatic, compressible form of the dynamics (Klemp and Wilhelmson 1978). Physical processes include subgrid-scale mixing (Deardorff 1980), surface fluxes (Louis et al. 1982), cumuls convective parameterization (Kain and Fritsch 1990, 1993), and radaition (Harshvardan et al. 1987). When the grid size is smaller than 10 km, explicit moist physics following Rutledge and Hobbs (1983) is activated instead of cumulus parameterization. All these references can be found in Hodur (1997).

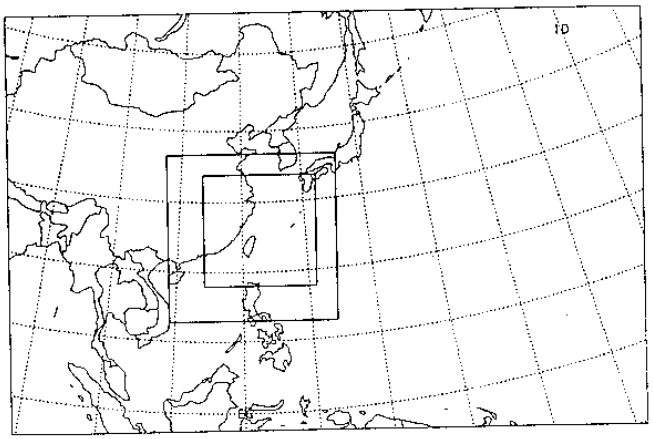


Figure 3. Domain of the COAMPS for the three nested grids.

The forecast of Herb uses a three-level nested grid with the outer grid size equals 81km, the middle grid size equals 27km and the inner grid size equals 9 km. The array size for the outer domain is 121 by 87, 97 by 97 for the medium mesh and 166 by 166 for the inner most fine mesh domain. Their respective domains are shown in Fig. 3. The outer domain covers a large area to capture the synoptic features while the inner domain covers Taiwan and its vicinity to allow proper interaction between the storm and Taiwan's steep topography. The highest mountain in the fine mesh is around 3000m, as oppose to 4000m in reality. A total of 30 sigma levels are used in each mesh.

COAMPS uses the Navy Operational Global Atmospheric prediction System (NOGAPS) analysis field as the first guess and then carries out its own optimal interpolation analysis on all grids. Since the NOGAPS contains a bogussing procedure for tropical cyclone (Goerss and Jeffries 1994), the initial wind field of COAMPS will have the bogus vortex built in already, but the observational data set also include synthesis data used in the NOGAPS so that reanalysis in the COAMPS will further enhance the vortex. However, the synthesis data was designed for the NOGAPS analysis with two-degree resolution, the data resolutions are too coarse for the current use. We interpolate the inner most four points of data at 200km away from the center to be at 120 km from the center in order to have a smaller radius of maximum wind. In the future, the procedure of generating synthesis data for COAMPS will be carried out. The forecast is carried out to 48 h with the boundary conditions updated every 12 h from the NOGAPS forecast.

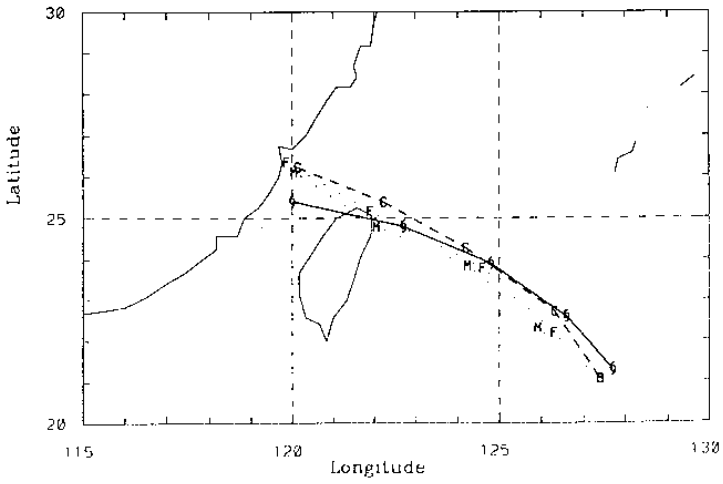


Figure 4. Best track (solid line) and forecast track of the COAMPS for Herb on 0000 UTC 30 July.

4. FORECAST VERIFICATION

Figure 4 depicts the 48 h track forecast from all three grids along with the best track. The forecast track of the three meshes are similar, suggesting that increasing resolution locally may not provide a significant difference on the track forecast because tropical cyclone motion relies heavily on the large-scale environmental flow. In our sensitivity tests, the domain of each mesh is proven to be an important parameter that determines the track. For example, when the domain of the inner mesh is reduced by a third, the forecast track is deflected to the north, increasing the 48 h forecast distance error more than 100km. But more detailed terrain profile and higher mountain in the fine mesh allows better interaction between the flow associated with the storm and the terrain, and provides better forecast of local wind distribution and precipitation. The overall track forecast of Herb is very good, with an average 48h forecast distance error from the three grids equals 112km.

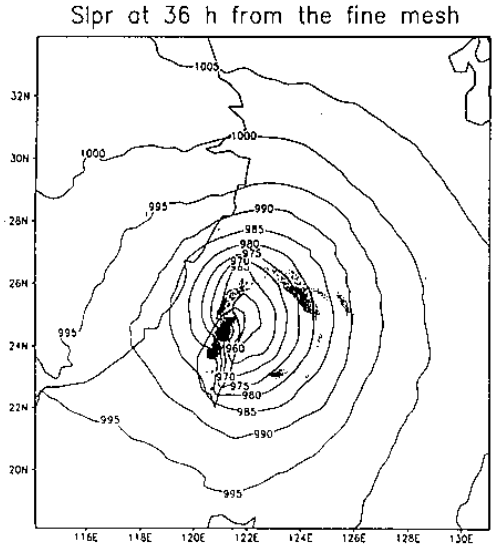


Figure 5. Sea-level pressure and 12 accumulated precipitation (shaded) at 36 h from the fine mesh.

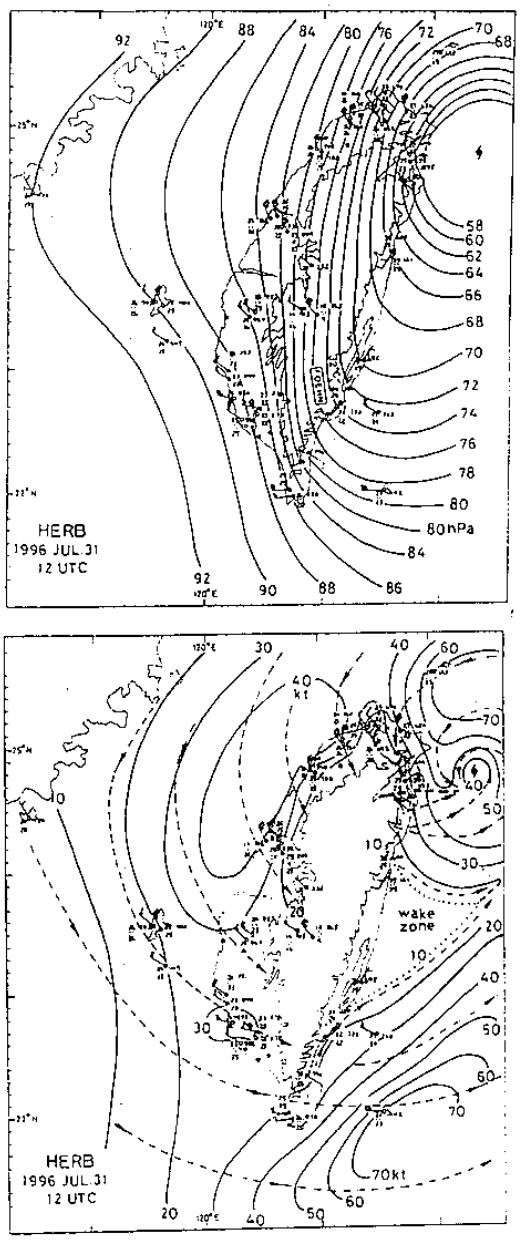


Figure 6. The subjective analysis in CWB at 12 UTC 31 JULY; a) sea-level pressure, b) streamline and isotachs.

At 36h (12 UTC 31 July 1996), when the forecast was most crucial for Taiwan island, prediction of Herb's position is slightly faster and to the north of the storm (Fig. 5). The subjective analysis of the Central Weather Bureau (CWB) in Taiwan using their dense observation network data on the island and surrounding small islands is given in Fig. 6. The wind

field distribution is well predicted by both the medium and fine meshes (Fig. 7). Since the predicted storm is to the north and west of actual typhoon position, the wake zone off eastern Taiwan is not well captured. To illustrate the importance of relative position of the storm to the terrain in determining the wind field, the forecast from the medium mesh at 33h is depicted in Fig. 8. The position of the storm at 33h forecast is time is very close to actual typhoon position valid at 36h forecast time. Therefore, the forecast wind compares favorable with the verification three hours later.

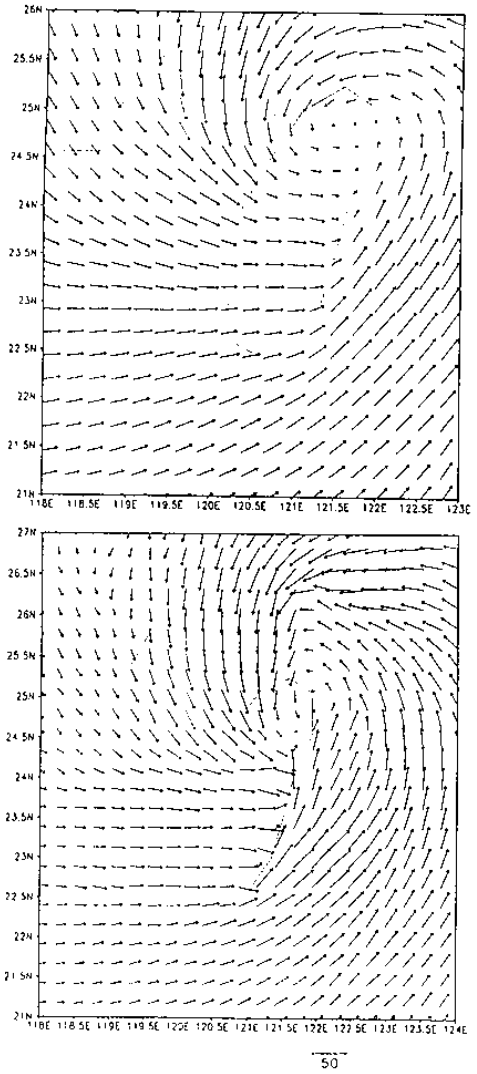


Figure 7. Wind field at 100 m height at 36h (valid for 12 UTC July) from a) the medium mesh and b) the fine mesh.

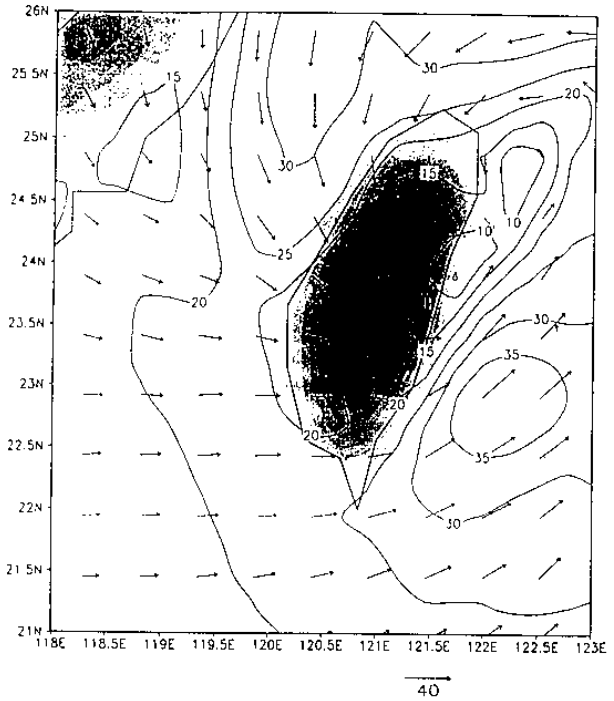


Figure 8. Wind field at 100m from the medium at 33h.

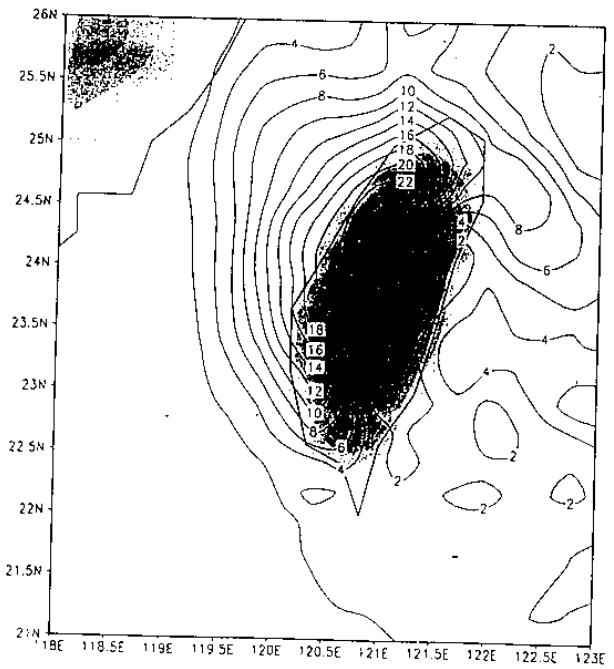


Figure 9. The 12h accumulated total precipitation at 36 h from; a) the medium mesh.

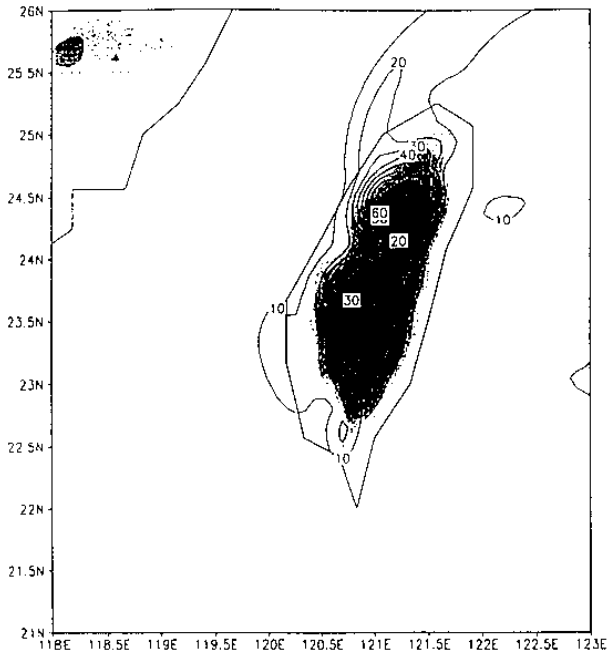
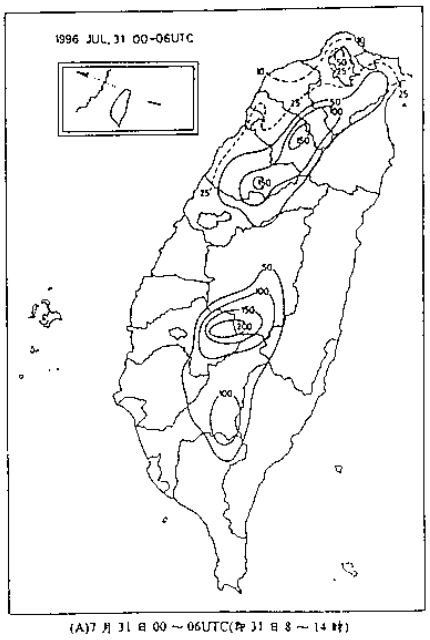
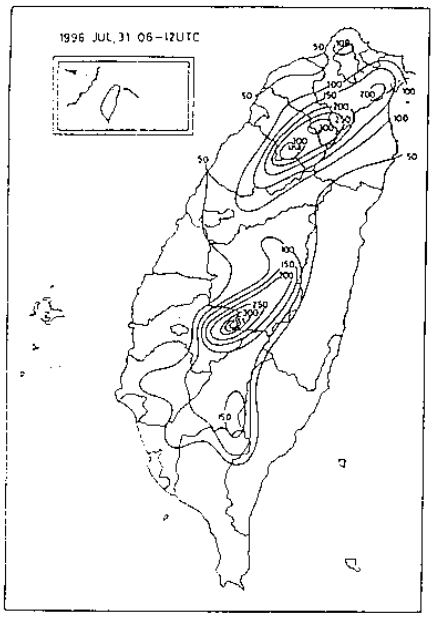


Figure 9. The 12h accumulated total precipitation at 36 h from; b) the fine mesh.

Thee 12h accumulated precipitation at 36h from the medium mesh and the fine mesh is shown in Fig. 9. Comparing Fig. 7 with the observation in Fig. 10 indicates that more detailed terrain profile in the fine mesh provided much superior forecast of the precipitation. Comparing with the observation, the prediction from the COAMPS is slightly to the west of the Central Mountain.



(A)7 月 31 日 00 ～ 06UTC(年 31 日 8 ～ 14 時)



(B)7 月 31 日 06 ～ 12UTC(年 31 日 14 ～ 20 時)

Figure 10. The observed 6h accumulated precipitation analyzed in the CWB at; a) 06 UTC 31 July and b) 12 UTC 31 July.

5. CONCLUSION

The new U. S. Navy limited-area nonhydrostatic model (the COAMPS) provided a satisfactory forecast of Herb in 1997 during critical time that Herb hit Taiwan. Sensetivity experiments indicate that the domain of each grid is very important to generate a good track forecast. The track forecasts from three grids are similar. The distribution of local wind is determined by the track forecast because it is the relative position of the storm with respect to the mountain that warrants a good forecast. The medium mesh provides similar overall forecast as the fine mesh but the fine mesh generated much superior prediction of the precipitation due to its detailed terrain profile.

References

Goerss, J. S. and R. A. Jeffries, 1994: Assimilation of synthetic tropical cyclone observations into the Navy Operational Atmospheric Prediction

System. Wea. And Forecasting, 9, 557-576.

Hodur, R., 1997: The Naval Research Laboratory's Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS). Mon. Wea. Rev.