8C.4 **NUMERICAL SIMULATIONS OF THE FORMATION OF TYPHOON ROBYN (1993)**

Kevin K. W. Cheung *

Department of Meteorology, Naval Postgraduate School, Monterey, California

1. Introduction

It has been observed that formation of tropical cyclones (TCs) is often associated with the activities of one or more mesoscale convective system (MCS). Sometimes, a midlevel mesoscale convective vortex (MCV) can be formed in the rear stratiform rain region associated with the outflow from the convective rain region of a MCS. Since vertical velocity is in general upward in this stratiform area, and a mesoscale downdraft is induced by evaporation of precipitation in the lower troposphere, a vortex stretching mechanism exists to create a MCV. If a mechanism exists to intensify the MCV so that it penetrates toward the surface, this mesoscale circulation may then be the locus for a TC formation if it is embedded in favorable environmental conditions.

Few previous studies performed explicit modeling of MCV in relation to TC formation. Chen and Frank (1993) used a modified version of the PSU-NCAR hydrostatic MM5 model to simulate mesovortex genesis in analytically generated pre-MCS large-scale environments. The evolution and structure of the simulated MCV are similar to those of the observed MCVs associated with midlatitude MCSs. Chen and Frank's results also showed that the mesovortex is produced by localized warming in a region of locally reduced Rossby radius, which induces convergence and creates vorticity via geostrophic adjustment. Bister and Emanuel (1997) used an axisymmetric model to explore the evolution of an initial cold-core, midlevel vortex into a tropical cyclone. Their focus was placed on the cooling effect of evaporation of the falling rain shower on the lower troposphere, and how this leads to the spinup of a mid-level vortex. Bister and Emanuel's analysis results also showed that the stratiform rain must last long enough to drive the mid-level vortex down to the boundary layer, and for warm-core development to occur.

In this study, numerical simulations are performed on the formation of Typhoon Robyn (1993) in the western North Pacific (WNP) during the Tropical Cyclone Motion (TCM-93) field experiment. One of hypotheses of the experiment addresses the role of tropical MCSs in the development of TCs. This TCM-93 case is chosen because additional in-situ and aircraft data are available to define the structure of several MCSs associated with the formation process (Harr et al. 1996). This modeling study identifies the physical processes responsible for TC formation in the WNP where the background vorticity associated with the monsoon trough and passages of tropical disturbances are both essential factors.

* *Corresponding author address:* Kevin K. W. Cheung, Department of Meteorology, Naval Postgraduate School, Monterey, CA 93943; email: kwcheung@nps.navy.mil

2. Formation of Typhoon Robyn (1993)

Typhoon Robyn formed at the end of July 1993 in the monsoon depression between 150°E and 160°E. The 850-hPa large-scale flow obtained from the Navy Operational Global Atmospheric Prediction System (NOGAPS) analyses at 1200 UTC 31 July 1993 [hereafter 93073112, one hour before a TC formation alert (TCFA) was released (ATCR, 1993)] indicates a cyclonic area north of the equator between these longitudes formed by the cross-equatorial southwesterlies and easterlies south of the subtropical high (Fig. 1a). This confluence monsoon region is actually one of the common large-scale patterns for TC formation in the WNP (Ritchie and Holland 1999). At 200 hPa, divergence flows that favor development of deep convection are found in the area where pre-Robyn occurred (Fig. 1b).

During the TCFA and the first warning of Robyn at 93080112 (ATCR 1993), two MCSs developed in the monsoon depression (not shown). One of them was at the southern portion of the monsoon depression that had been a region of convergence between the circulation and the cross-equatorial southwesterlies. Due to this favorable low-level environment, it was expected to develop further and likely to intensify into a tropical depression. However, it elongated in the following hours and dissipated into smaller cells. At about the same time, another MCS persisted at the northern portion of the monsoon depression where easterlies dominated. It rotated westward along the circulation during the following ten hours. Eventually, the circulation of the monsoon depression began to be centered around the MCS, and the MCS was upgraded to a tropical depression by the Joint Typhoon Warning Center.

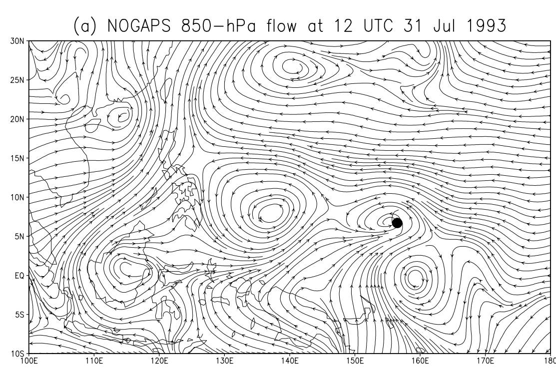

Fig. 1 (see caption on next page)

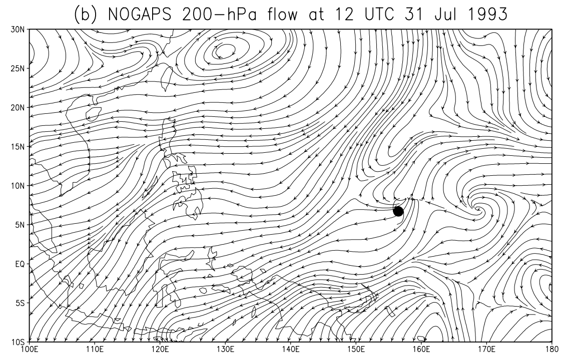

Fig. 1 (a) 850-hPa and (b) 200-hPa streamline from NOGAPS analyses at 1200 UTC 31 July 1993. The typhoon symbol indicates the position where typhoon Robyn started to develop.

3. Experiments on the MM5

The PSU-NCAR mesoscale model MM5 with nested grids is used for the simulations. The boundary layer scheme is the same as in the NCEP MRF model. The Reisner mixed-phase explicit moisture scheme with graupel is used. The Kain-Fritsch cumulus parameterization is activated on both the coarse grid with 81-km resolution and the fine grid with 27-km resolution (D01 and D02 in Fig. 2)

The model is initialized with large-scale analyses from NOGAPS. Model integration is from 93073112, and lasts for 60 hours until 93080300. During the simulation, observations from the two aircraft observation periods (AOPs) during TCM-93 are nudged into the model fields. The first period (AOP3A) was from about 93080100 to 93080106 when some MCS started to develop in the monsoon depression, and consisted of 17 Omega dropwindsondes (ODWs). There were also some individual soundings from islands in the vicinity of the field experiment area. The second AOP (AOP3B) was from about 93080200 to 93080210, and there were 25 ODWs. These observations define the mature structure of the MCS that eventually developed into Typhoon Robyn.

Basically the deepening process of the pre-Robyn disturbance in a monsoon depression can be simulated in the MM5. After 48 hours of model integration (valid at 93080212), a tropical depression with a minimum central pressure of about 1004 hPa forms (Fig. 3). The rate of intensification, however, is slower than that observed. Detailed structure of the simulated cyclone and other diagnostics will be presented in the conference. Sensitivity experiments will also be performed on the choice of cumulus parameterization, and the addition of a finer grid (D03 in Fig. 2) in which an explicit depiction of the convective clouds associated with the pre-Robyn MCSs, and their potential vorticity structures, can be carried out based on guidance from satellite imagery.

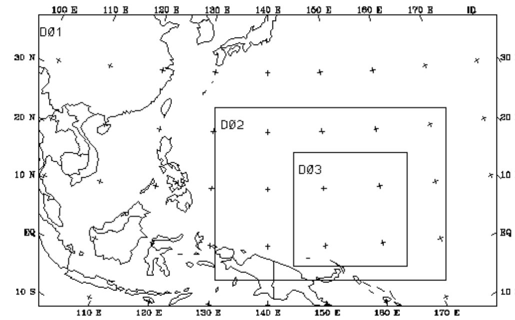

Fig. 2 Model domains used in the MM5

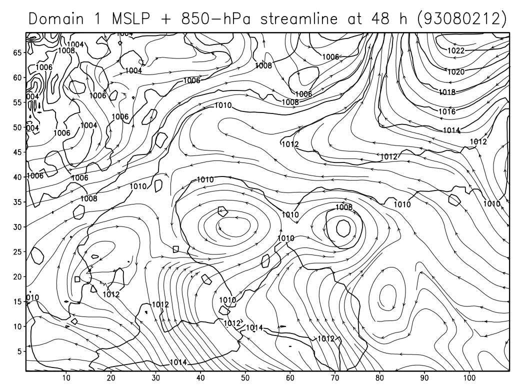

Fig. 3 Mean-sea-level pressure and 850-hPa streamline from domain 1 after 48-h simulation of the MM5 model. Validation time is 98030212.

Acknowledgements

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