TEMPORAL AND SPATIAL VARIATIONS OF PRECIPITATION OF LANDFALL TYPHOONS IN THE TAIWAN AREA

Ben Jong-Dao Jou
Department of Atmospheric Sciences, National Taiwan University, Taiwan

1. INTRODUCTION

Heavy rainfall and flash flood produced by landfall typhoons is one of the biggest natural disasters in Taiwan. Not only human lives and personal property were severely demolished, but also the societal stability and sustainability were greatly threatened. To understand and predict heavy rainfall and flash flood caused by landfall typhoons has become the most urgent challenge the meteorological community in Taiwan to face. The island wide Doppler radar network has been completed in 2001 and four NEXRAD type S-band Doppler radars are in operation since then. In this study, the precipitation structure of Typhoon Nari (0116) before and after landfall is investigated using the reflectivity data collected by Wu-Feng-Shan radar (northern Taiwan). Typhoon Nari made landfall at northern Taiwan on Sept. 16, 2001. Its slow movement and associated heavy rainfall and flash flood caused many fatality and more than 10B US$ property damages. In addition to the NEXRAD data, TRMM TMI and PR data were also used to study the precipitation structure changes during landfall period.

2. AZIMUTH-AVERAGED REFLECTIVITY

The space and time variations of precipitation of Nari are examined by restructuring the reflectivity data with radar site as origin into cylindrical coordinate with storm center as origin. The Hovmoller diagram shown in Fig.1 is 18 hours (13 hours before landfall and 5 hours data after landfall) of azimuth-averaged 4 km height reflectivity field. Each bin (~1^0 and 1 km resolution) of reflectivity was calculated by averaging data azimuthally and the time interval of observation was 6 minutes. The figure shows the precipitation area of typhoon Nari extended 200 km in radius. The eye region with echo less than 10dBZ was about 20 km wide. Significant precipitation occupied region from 20 km to 110 km with mean reflectivity value larger than 30 dBZ. No distinguished echo peak was observed when the storm was still far away from the island. Reflectivity larger than 35 dBZ scattered between 40-110 km range in an earlier time and became to concentrate into eyewall region, i.e., 30-60 km range, however, when the storm moved closer to the island. The near center precipitation intensified significantly during landfall period. The eye contracted and filled with precipitation after the storm made landfall.

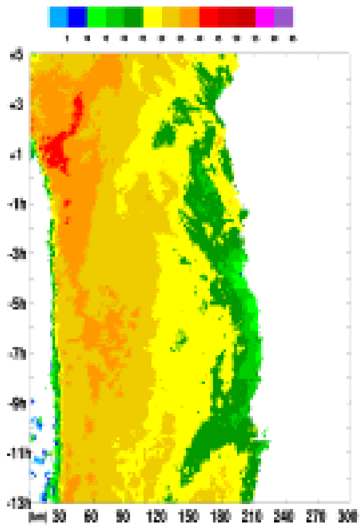

Fig.1. Hovmoller diagram of 4 km height azimuth mean reflectivity (in dBZ) of typhoon Nari. The abscissa is distance in km from the storm center and the vertical coordinate is time in hours before (-) and after (+) the storm made landfall.

We divided the precipitation distribution of Nari into three annular rings (e.g., r<100km, ring A, the inner core region; 100km<r<200km, ring B, the outer region 1; and r>200km, ring C, the outer region 2; respectively), the area-weighted precipitation (using $Z=300R^{1.4}$ to convert mean reflectivity into rainfall rate) can be estimated respectively. The area-weighted precipitation total in the inner core region was almost the same as that in the outer region while the storm was still 12 hours before landfall. It was observed that the precipitation total of the inner core increased gradually and the outer core decreased at about the same rate while the storm approached to the island. At landfall, the area-weighted precipitation total in the inner core possessed more than 75% of rainfall for the whole storm system. Concentration of precipitation into the inner core of the storm is a good indicator for an intensifying storm and this is the case Nari was experienced in this period. However, it is interesting to note that at about one hour before landfall, the inner core precipitation total increased at a rate about four times faster than that previously had. This abrupt increase of precipitation in the inner core of the storm indicates the pronounced influence of topography on enhancing the precipitation of landfall typhoons.

3. ASYMMETRICAL STRUCTURE OF PRECIPITATION

It is interesting to know the changes of the asymmetrical structure of precipitation of Nari during its landfall period. In this study, the quadrant averaged rainfall rate divided according to vertical wind shear vector is calculated. At about 13 hours before landfall, the mean (200-850 hPa) vertical wind shear was directed to NE and the storm moved SW, the maximum rainfall rate occurred in upshear left and right front of movement. The maximum rainfall rate moved to the forefront of movement during landfall.

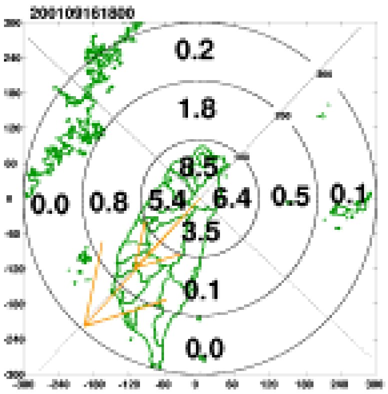

Fig.2. Annular-quadrant display of mean rainfall rates (unit in mmh^{-1}) after typhoon Nari made landfall. The long arrow indicates the movement of the storm and the short arrow indicates the 200-850 hPa mean vertical wind shear direction.

5 hours after landfall, the maximum rainfall rate occurred at the right rear quadrant of movement. It should be pointed out that the 200-850hPa mean vertical shear in Nari case was very weak and was smaller than 1 m/s for the whole period. The asymmetrical structure of precipitation should not be produced by the effect of vertical shear in this case. On the other hand, the moving speed of Nari was less than 3 m/s in average during landfall period, thus, should not alter the precipitation structure significantly. We may conclude that the shift of the maximum rainfall rate quadrant was possibly due to the effect of topography of Taiwan through the processes of slope uplifting and the enhanced low level convergence produced by differential friction between ocean and land.

4. SUMMARY

During the landfall period of Nari, the occurrence of deep convection along the coastal region outside the eyewall was noted. Extremely low brightness temperature (less than 180K) detected by TRMM 85GHz TMI sensor and reflectivity larger than 50 dBZ of PR were also documented. Lightning activity was also reported by ground observer and TRMM lightning mapper. All these observations indicated the existence of deep convection along the coastal region during the period of storm landfall. It is also suggested the convective nature of severe heavy rainfall during Nari made landfall.

Acknowledgement

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