Convective Asymmetries Associated with Tropical Cyclone Landfall
Part I: F-Plane Simulations

Xudong Liang*[1 2] and Johnny C L Chan [2]

[1] Shanghai Typhoon Institute, China Meteorological Administration
[2]Laboratory for Atmospheric Research, Department of Physics and Materials Science
City University of Hong Kong
*Email: liangxd@mail.typhoon.gov.cn

1. Introduction

The problem of tropical cyclone (TC) landfall has received more attention in recent years especially after it has been listed as one of the foci of the US Weather Research Program. The earlier modeling efforts by Ooyama (1969), Rosenthal (1971), Tuleya and Kurihara (1978) and Tuleya et al. (1984) have given some characters of the landfall TC. This study therefore represents an attempt to investigate the physical processes that, under idealized conditions, lead to changes in the rainfall distribution in a TC prior to, during and after landfall using the mesoscale model MM5. The following experiments on *f* plane and without mean-flow are performed: turning off the sensible heat flux over land (Expt. 2), turning off the moisture flux over land (Expt. 3), and setting the roughness length to be 0.25 m over land (Expt. 4). The coastline is moved to represent the movement TCs In all of the experiments.

2. Results

The results of the experiments suggested that cutting off the moisture flux over land should have a profound effect on the TC characteristics while changing the sensible heat flux has very little impact. In Expt.3, before and during TC landfall, the maximum rainfall primarily occurs in upper and upper left quadrants (Fig. 1), which are very similar to that in Expt.4. Because the change in the roughness length of the underlying surface in Expt.4 causes a change in the wind speed in the PBL, which will then reduce the moisture flux. Therefore, both in Expt.3 and 4, the moisture flux on the land surface is smaller than that on the sea surface. These results also suggest that the moisture flux is very important to determine the rainfall pattern before and during TC landfall, and the convergence/divergence in the onshore/offshore areas may not play the key role in determining the distribution of precipitation.

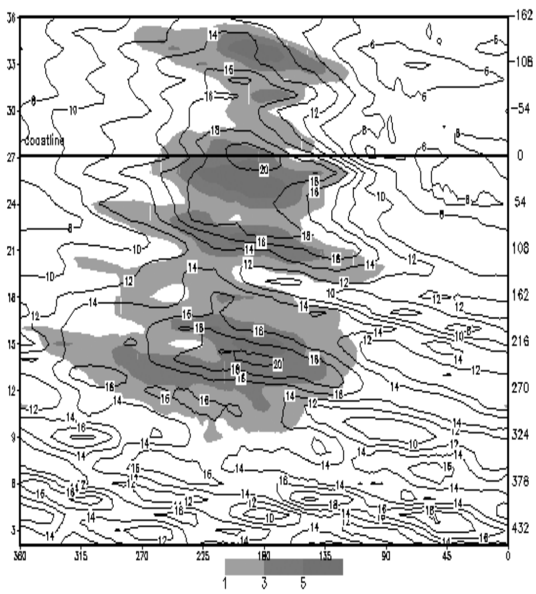

Fig. 1 Azimuthally-summed 1-h rainfall (cm) from 1 to 36 h in Expt. 3. Shaded is the increased rainfall compared with the control run. The 1-h rainfall is obtained by radially summing the hourly rainfall within each 15-km, 1 degree azimuth box (centered on the TC center) out to 300 km at each degree from east. The x-axis is the degree relative to east (anti-clockwise, 1^{o}), left ordinate is the integrating time and right ordinate is the distance of the TC center relative to the coastline in km.

3. Effect of moisture flux

During TC landfall, moisture flux over land is less than that on the sea, but it is not always favorable to reduce the rainfall. In fact, it usually increases the rainfall in upper and upper left quadrants related to the TC and reduces it behind. The reason is that the dry air over land and moist air over the sea are advected into the inner area of the TC and raised by rising motion. As a result, the instability should be decreased/increased by the inflow of dry/moist air in lower levels with moist/dry air in upper levels. The asymmetric distributions of $\partial\theta_{se}/\partial z$ in Expt. 3 (Fig. 2) indicate that the lower levels in inner areas to the east and north of TC center are more unstable than those to the west and south while to the east and north are more stable in the higher levels before landfall. The increased/decreased instability will lead to increase/decrease of upward motion. Therefore, the anomalous upward motion begins to the east and north of TC at lower levels and increases to the west and south at high levels before and during landfall. The rainfall anomaly caused by upward motion does not directly occur in the east and north, because the rainfall occurs only after the air is raised up to a certain height. For a TC, the average horizontal wind speed is very large; when the air is rising, it is cyclonically advected to the downstream areas so that enhanced rainfall exists from northwest to southwest of the TC due to the anomalous upward motion.

References

Tuleya R. E. and Y. Kurihara, 1978: A numerical simulation of tropical cyclones. *J. Atmos. Sci.*, **35,** 242-257.

Tuleya R. E., M. A. Bender and Y. Kurihara, 1984: A simulation study of the landfall of tropical cyclones using a movable nested-mesh model. *Mon. Wea. Rev,* **112,** 124-136.

Ooyama, K., 1969: Numerical simulation of the life cycle of tropical cyclones. *J. Atmos. Sci.*, **26,** 3-40.

Rosenthal, S., 1971: The response of a tropical cyclone model to variations in boundary layer parameters, initial conditions, lateral boundary conditions and domain size. *Mon. Wea. Rev*, **99,** 767-777.

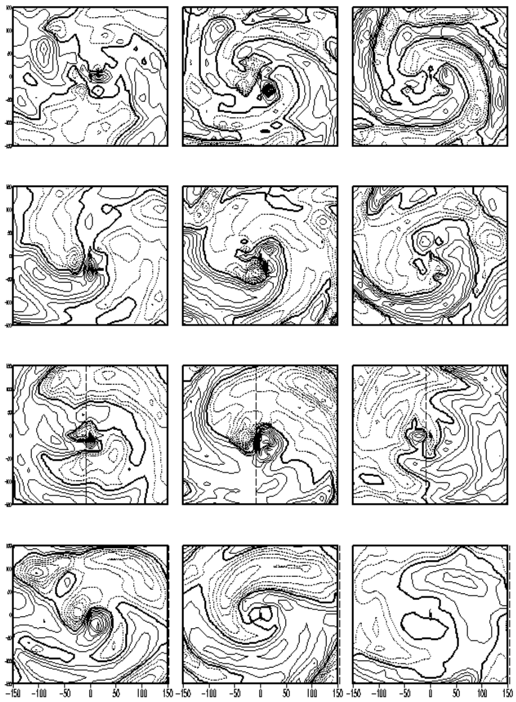

Fig. 2. Anomalies of $\partial\theta_{se}/\partial z$ (unit: K km^{-1}) at σ levels 3 (~ 920 hPa), 5 (~ 850 hPa) and 7 (~ 750 hPa) (from left column to right) in Expt. 3 at 9, 18, 27 and 36 h (from top row to bottom). The abscissa and ordinate are respectively the zonal and meridional distances (km) relative to the TC center, which is represented by the typhoon symbol. The straight long dashed line indicates the coastline.