12.6 MID-LEVEL FRONT INDUCED BY INTERACTION OF THE TYPHOON AND MIDDLE-LATITUDE TROUGH : A CASE OF TYPHOON RUSA IN AUGUST 2002

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1. Introduction

On 30-31 August 2002, a modest mid-latitude trough system moved over the north of Korean peninsula and a typhoon came from the south of the peninsula. The east coast of the middle part of the peninsula in latitude was devastated by the typhoon, mainly due to the unexpected heavy rainfall. Especially in Gangneung area, a daily precipitation reached 870.5 mm/day in 31 August (Fig. 1)

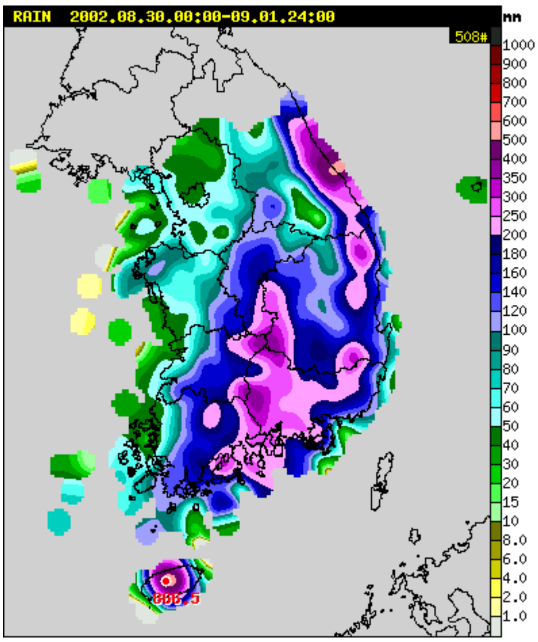

Fig.1 Precipitation from 30 Aug. to 1 Sep. in 2002 (data from KMA)

Previous Korean researchers tried to found the mechanism of this case. Kim et al. (2003) found that strong easterly flow at the northern part of Rusa resulted in topographically-induced convective rainfall and greatly increased the amount of rainfall that would have occurred over the flat terrain. Kang et al, (2003), however, suggested that terrain effect can not explains a plenty of heavy rainfall by typhoon 'Rusa' through calculating a quantity of topographic precipitation supposed by Lin at al. (2002). When considering previous results on this heavy rainfall system and very localized distribution of rainfall in contrast with north-south oriented mountain range, we think that both topography and Synoptic dynamical effect seemed to be important in the development of this heavy rainfall event.

We have found that this heavy rainfall was occurred by not only terrain effect but also mid-level frontogenesis developed between the typhoon and mid-latitude trough. In this study, the frontogenetical forcing together with secondary circulation is discussed to cause the intense precipitation over that region.

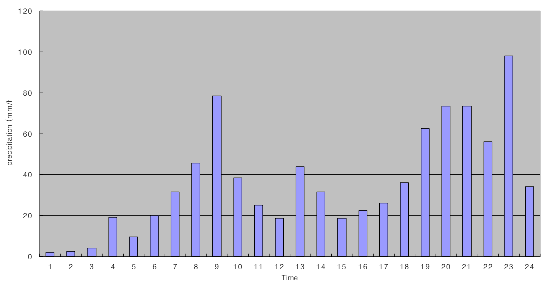

Fig.2 hourly precipitation in Gangneung area

2. Synoptic Background

Typhoon Rusa (2002) made landfall on the south coast of the Korean Peninsula around 0600 UTC (1500 LST) on 31 August, with a maximum wind speed of 38 m/s and a minimum pressure of 960hPa. At this rainfall episode, there were two precipitation peaks in Gangneung area where the worst rainfall was recorded in Korea (Fig. 2). It means that there are two precipitation mechanisms in this case. The first peak time is 00UTC 31 Aug. 2002 and the second peak time is 14UTC 31 Aug. 2002. For the two peaks of hourly amounts of rainfall, it was obvious that the second peak was caused by directly typhoon effect but the first peak was not considering the typhoon path and radius with time.

In order to find the mechanism of the first precipitation episode, we analyzed 500hPa and 850hPa weather charts at 12UTC, 30, Aug. when the first rainfall event was started. At 850hPa level, the center of typhoon located on the south of Korean peninsula, the west of Kagoshima, Japan and it make on influence on the middle part of peninsula. There are high pressures both sides of the peninsula and no low pressure on the north of peninsula (Fig. 3b). At 500hPa level, however, the typhoon stood against a low pressure system which located at the north of peninsula. Then a confluent deformation was formed at the middle part of peninsula on latitude 38°N, and so strong vertical wind shear was occurred existing a easterly at lower level and a westerly at upper level in this region.

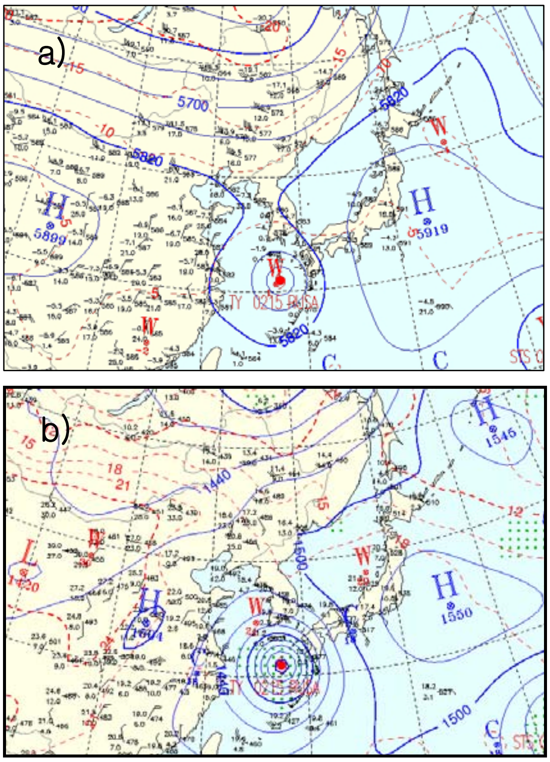

Fig.3 Synoptic weather charts at a) 500hPa and b) 850hPa

There are line shaped clouds from the southwest to the northeast of peninsula in satellite image at 12UTC 30, Aug. when the first rainfall event began. It also indicated that the north (the south) of that clouds was dry (wet), that is, a steep humidity gradient was appeared in the middle part of Korean peninsula. Then there is a temperature inversion level and strong vertical wind shear at about 500hPa analyzing skew-T diagram in Sokcho station located approximately 60-km northward from Gangneung at same time. It means that a upper-level front was formed at the level.

3. Frontogenesis

Analyzing the synoptic background we found some evidences that a upper-level front was generated between the typhoon and upper-level trough, though not in mature phase. For the purpose of a structure of this frontogenesis, we conducted a numerical simulation of this case using WRF model (version 2.2) that was initialized at 12UTC on 29 August 2002 using the NCEP final analysis data. The model integrated up to 60hrs.

We calculated the horizontal frontogenesis function formula for the sake of searching out the main forcing in this case. Each frontogenetical forcing was analyzed both at the 500-hpa level at which frontogenesis was the most intensified. First of all in fig.4 a) means total frontogenesis forcing, which was positively distributed from the southwest to the northeast centering Gangneung area. And b), c), and d) means each horizontal deformation forcing, diabatic forcing, and tilting forcing. The horizontal deformation forcing was strong positive values over the frontal region, while the diabatic forcing and tilting forcing was compensated each other in point of their spatial distribution and values, so they didn't contribute much frontogenesis. This front was generated mainly due to horizontal deformation as a consequence. It was consistent result with the previous synoptic background.

We also calculated the Sawyer-Elliassen equation using RIP tool with the model result data to evaluate how influence the frontogentical forcing made on this heavy rainfall case. Frontogenetical forcing is formed at the northeastern part of heavy rainfall area on about 400hPa level at 15UTC 30 Aug. The

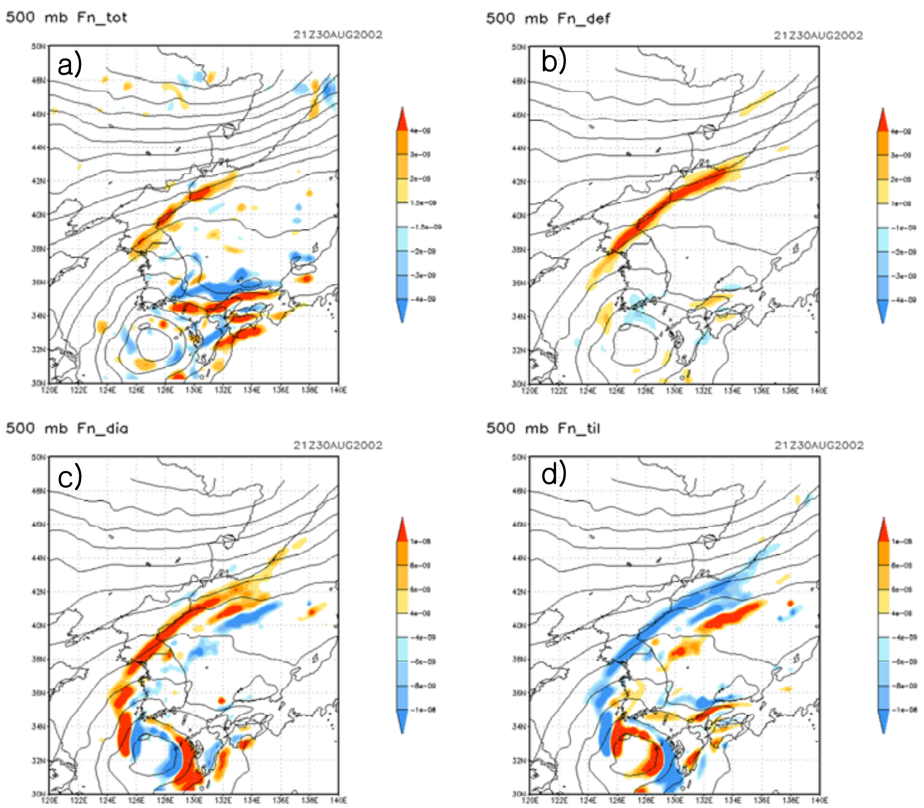

Fig.4 Frontogenetical forcing terms; a) Total forcing, b) Deformation forcing, c) Diabatic forcing, d) Tilting forcing. The red(blue) means positive(negative) value. Unit is $K \cdot m^{-1} \cdot s^{-1}$.

streamfunction value is -1013($Pa \cdot m \cdot s^{-1}$). The forcing is intensified and extends lower level at the first peak time, 00UTC 31 Aug. The value is -1216($Pa \cdot m \cdot s^{-1}$) (Fig.5). Applying Sawyer-Elliassen equation to the simulated frontal zone, we confirmed that the front was key mechanism in bring out strong convection causing heavy rainfall.

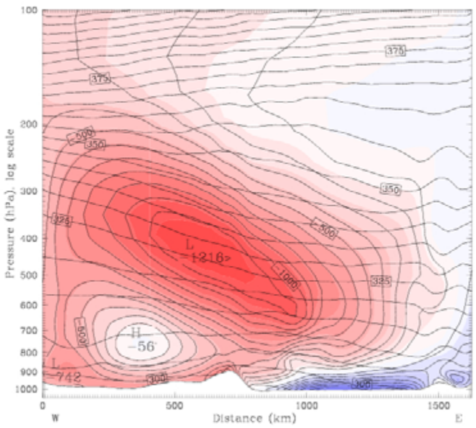

Fig.5 Cross-section of Streamfunction across the frontal region with calculating Sawyer-Elliassen eq. at 00UTC 31, Aug. in 2002

4. Concluding Remarks

WRF (27km run) model simulated the RUSA case reasonably well. In particular, heavy rainfall localized near Gangneung area has been captured in the simulation. When the upper-level baroclinic wave and typhoon are arranged on the north and south each other, frontogenesis was occurred at the mid-level in this region between the mid-level trough and a typhoon. As the frontogenesis was intensified, frontal zone extended toward the surface.

We calculated the individual forcing terms of the 3-D Frontogenesis function. In this case, deformation forcing produced by the proper configuration of the Mid-level trough and typhoon is the most important. Secondary circulation calculated with geostrophic frontogenetical forcing using Sawyer-Elliassen eq. explained the structure of this front well. But the intensity was rather weak.

In conclusion, the interaction between typhoon vortex and mid-latitude mobile trough generated horizontal deformation field at mid level, which causes strong temperature gradient at the same level at the slightly north of Gangneung area. The intense heavy rainfall, consequently, existed at the ascent region of secondary circulation forced by the front.

5. References

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