Relationships between heavy rainfall over the Korean peninsula and remote tropical cyclones

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❖ INTRODUCTION

- Tropical cyclones (TCs) result in tremendous damage along with heavy rainfall and strong winds. One of the primary hazards caused by TCs is heavy rains and their associated freshwater flooding (AMS 2007).
- A TC can produce tremendous rainfall in its eyewall and its surrounding rainbands directly. This is generally referred to as direct effect of a TC on precipitation, or precipitation induced by the TC itself (Wang et al. 2009).
- On the other hand, when a strong interaction with other synoptic systems occurs, a TC can induce heavy rainfall far away (Wang et al. 2009). Such an effect of a TC on precipitation in a remote area is generally referred to as indirect or remote effect of a TC on precipitation.
- According to previous studies, the role of TC in southern China is generally known as one of the important factors which contribute to the formation of heavy rainfall over the Korean peninsula.
- Previous studies

Wang et al. (2009) - Western North Pacific TC Songda (2004) case
Galarneau et al. (2010) - Environments associated with predecessor rain events of TCs

- However, statistical analysis and a composite study of heavy rainfall over Korea induced by remote TCs have not been conducted until the present time.

What are the questions to answer?

- Are there relationships between heavy rainfall over the Korean peninsula and remote tropical cyclones?
- How do remote tropical cyclones affect heavy rainfall over the Korean peninsula?

❖ PURPOSE

- to understand the relationships between heavy rainfall over the Korean peninsula and the location of remote TCs through statistical and composite analysis.
- to examine the climatology and the typical environments associated with heavy precipitation over the Korean peninsula induced by remote TCs.

❖ DATA and METHODS

Data (29 yrs, 1981-2009)
- RSMC (Regional Specialized Meteorological Center) best track data
- 1.25°×1.25° gridded Japanese 25-year reanalysis (JRA-25) data
- observed precipitation data from about 70 manned stations of the KMA

Statistical analysis (Waylen and Harrison 2005, Ho et al. 2004)
- Heavy rainfall : ≥ 40 mm (6 h)$^{-1}$ for at least one station
  ≥ 5 mm (6 h)$^{-1}$ for the average amount of total stations
- 6-hourly typhoon position is binned into the corresponding a 2.5 degree latitude–longitude grid box.
- Critical radius: L30(longest radius of 30kt winds)+100 km(>50-75km)+1.75° (TC moving for 6 hours)

Composite analysis (Hanley et al. 2001)
- Compositing loses potentially important characteristics of individual storms, but it retains signatures that appear repeatedly.
- It is a useful method for examining the similarities and differences in synoptic structure between heavy rainfall (HR) and no rainfall (NR) environments, although TCs are in the same location.

❖ RESULTS

Climatology and statistical analysis

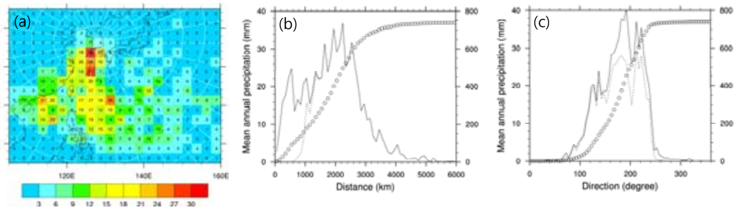

Fig. 1. (a) Geographical distributions of heavy rainfall frequency in the Korean peninsula, when the nearest TCs are located in an each grid box for 1981-2009. Mean annual precipitation (black lines), mean annual precipitation except in the direct rainfall cases by TCs (dash lines), and accumulated mean annual precipitation (open circles) associated with location of the nearest TCs within varying (b) distances (every 100 km), (c) directions (every 5 degree) from the median station for surface observations of South Korea.

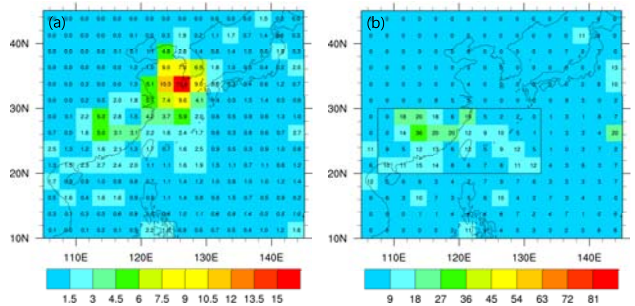

Fig. 2. Geographical distributions of (a) averaged 6-hourly precipitation over the Korean peninsula, and (b) the rate of heavy rainfall events except for the grid box under direct effects of TCs, after TCs are located in an each grid.

Synoptic environments

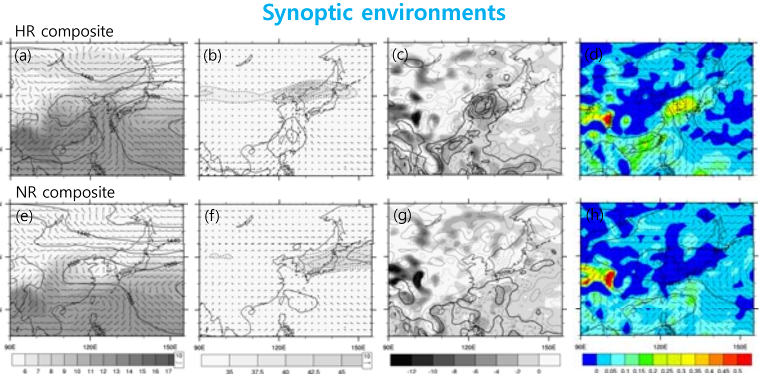

Fig. 3. Composite maps for 69 HR cases (upper) and 103 NR cases (lower) of (a), (e) wind fields (wind barb), geopotential height (solid), and specific humidity (shaded) at 850 hPa (b), (f) wind fields at 850 hPa, isotachs for 200 hPa (every 2.5 from 40 m s^{-1}, dashed and shaded) and 850 hPa (every 2.5 from 10 m s^{-1}, solid black lines), (c), (g) horizontal divergence at 850 hPa (every 10^{-6} s^{-1}, shaded), 200 hPa [every 10^{-6} s^{-1}, dashed (+) and dotted (-) gray lines] and vertical motion at 500 hPa (every 0.05 from -0.05 Pa s^{-1}, solid black lines), and (d), (h) SLP (every 4 hPa, solid black lines), wind fields at 1000 hPa (wind barb), and column-integrated MFC (every 0.05×10^{-4} from 0 g kg^{-1} s^{-1}, shaded)

QG forcing and frontogenesis

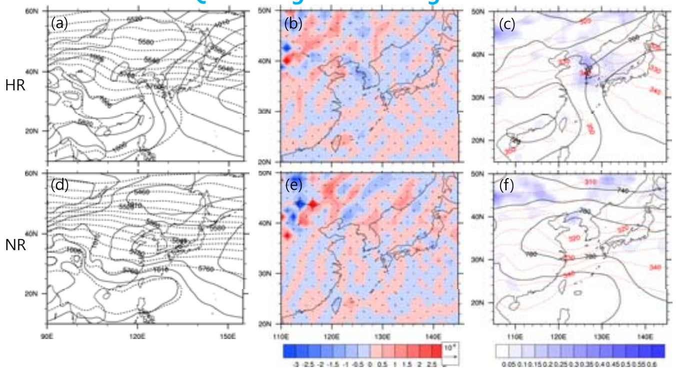

Fig. 4. Composite maps for HR (upper) and NR (lower) of (a), (d) SLP (solid) & 1000-500 hPa thickness (dashed), (b), (e) Q-vector (arrows) & div. of Q-vector (shaded), (c), (f) geopotential height (solid black), θ_e(dashed red), & frontogenesis (shaded) at 925 hPa

❖ SUMMARY

The statistical analysis of the period from 1981 to 2009 shows that landfalling TCs over southern and southeastern China and TCs over southern East China Sea can induce heavy rainfall over the Korean peninsula with higher probability.
Large-scale environments and the moisture transport into the Korean peninsula by remote TC's outer circulation affect heavy rainfall over the Korean Peninsula.
Important mechanisms in driving the ascent in the Korean peninsula
- QG forcing by warm advection (LLJ, TC, western Pacific high)
- Frontogenesis is in agreement with the deep-layer warm air advection and moisture convergence.
- Associated with large-scale low-level convergence (low-level trough, WPSH, TC) and upper-level divergence (ULJ)

FUTURE WORKS

- To investigate moisture source regions using a backward trajectory model
- Detailed case studies (a multiscale case analysis)
- Topographic effects

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