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Analysis of Rainfall Generation Process in East Asia by Summer Cold Wave

Kwang-Hee Han[1)], Ho-Young Ku[1)], Hayeon Noh[1)], Jee-Hoon Jeong[2)], and Baek-Min Kim[1)*]

[1)]Division of Earth Environmental System Science Major of Environmental Atmospheric Sciences, Pukyong National University, Busan, South Korea. Email: **arthurhan90@gmail.com**

[2)]Faculty of Earth and Environmental Sciences, Chonnam National University, Gwangju, South Korea.

Introduction and Purpose

- In 08. Aug. 2022. Severe rainfall strengthened the Korean Peninsula. On August 8, Seoul received **381.5 mm** of rain, the most in 115 years.
- The synoptic pressure **pattern** that caused **heavy rain** in August 2022 **differed** from the **rainfall pattern studied in general**.
- The **pressure system** around the Korean Peninsula also showed a **different pattern** from **the typical summer** pressure systems.

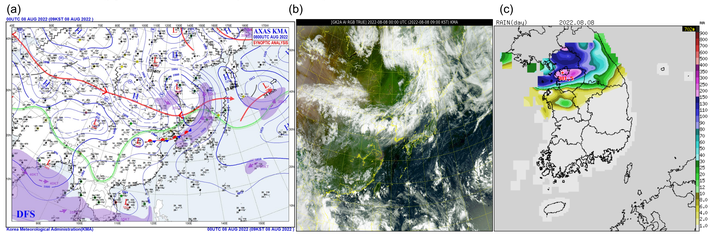

Fig 1. (a) The analysis weather chart for 00 UTC on August 8, 2022. (b) The true color image obtained on August 8, 2022. at 00:00 UTC using the GEO-KOMPSAT-2A satellite. (c) The accumulated precipitation on August 8, 2022. as observed by AWS

A stationary front developed between the North Pacific high (mT) and the high pressure located to the northwest of the Korean Peninsula and lay across the Korean Peninsula from east to west.

- **Research purpose**
  1. **Analyze the process of rainfall generation in East Asia on August 8, 2022.**
  2. **Define, generalize, and analyze the characteristics of this phenomenon.**

Data and Method

- We used ERA5 reanalysis data(table 1) from European Centre for Medium-Range Weather Forecasts(ECMWF) and GPM precipitation data(table2) from National Aeronautics and Space Administration (NASA) to analyze meteorological singularities and phenomena.

Table1. Information of ERA5 reanalysis data

Data description	
Data type	Gridded
Projection	Regular latitude-longitude grid
Horizontal coverage	Global
Horizontal resolution	Reanalysis: 0.25° x 0.25°
Vertical coverage	1000 hPa to 1 hPa
Vertical resolution	37 pressure levels
Temporal resolution	Hourly

Table2. Information of GPM precipitation data

Data description	
Data type	The Integrated Multi-satellite Retrievals for GPM
Spatial Coverage	Global
Horizontal resolution	0.1° x 0.1°
Precipitation	Daily accumulation (mm)
Temporal resolution	1 day

- Blocking detection methods including Tibaldi and Molteni's method(TM; Tibaldi and Molteni's, 1990), Hybrid method(HYB; Dunn-Sigouinet al., 2013) and Large-scale reversal method(LAR; Masato et al., 2012) were used.

2022 summer cold wave

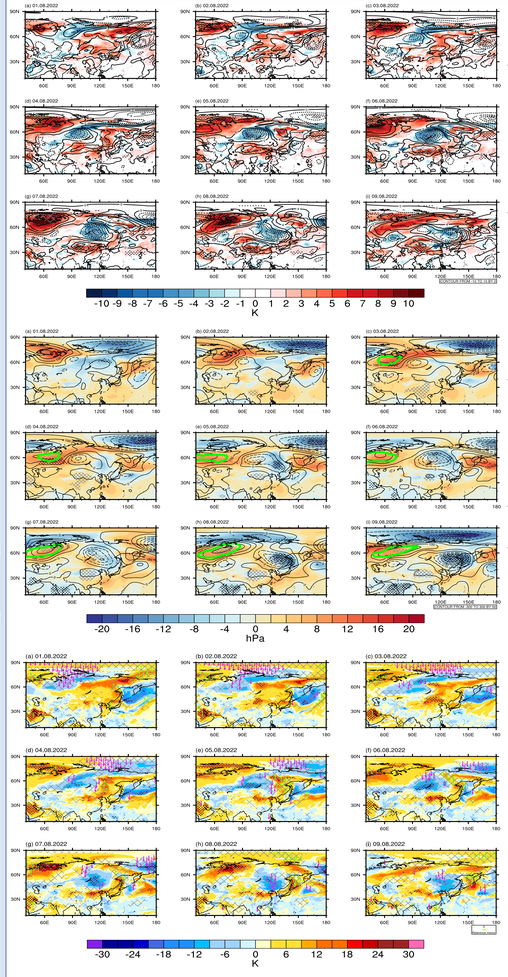

Fig 2. (a) The daily mean temperature anomalies for the period from August 1 to 9, 2022. shading is surface and contour is 500 hPa.

- **Cold air** moved from **Siberia towards the Korean Peninsula**, strengthening its intensity over Lake Baikal. As a result, the **northwestern region of the Korean Peninsula** experienced a **sharp drop in temperature**.
- The **500 hPa temperature anomalies** also showed **strong negative values**, indicating that cold air had been infiltrating even to the **upper levels** of the atmosphere.

Fig 3. (a) The daily mean MSLP anomalies for the period from August 1 to 9, 2022. shading is surface pressure and contour is 500 hPa GPH.

- A **high-pressure** system strengthened around the **Ural Mountains**, and the intensified system moved through **Siberia toward the northwestern region of the Korean Peninsula**.
- **Blocking** was detected near the **Ural Mountains** at the 500 hPa level.
- **500 hPa low-pressure** system developed north of the Korean Peninsula, indicating the presence of **cold advection in the lower atmosphere**.

Fig 4. The daily mean 850 hPa ept and v wind anomalies for the period from August 1 to 9, 2022. shading is 850 hPa ept and vector is v wind.

- **Like** the movement of **cold air** and **high pressure** at the **surface**, **dry and cold air** (with lowe ept) is **transported at 850 hPa**, mainly observed in areas where the **northerly winds are strengthened**.
- **Summarizing the analysis that during the summer season, the strengthening of the northerly winds and the intrusion of cold air from high latitudes into the vicinity of the Korean Peninsula, combined with the edge of the North Pacific high, has led to the occurrence of heavy rainfall.**

We call this phenomenon Summer Cold Wave(SCW)

Generalization of Summer Cold Wave

Table3. list of past Summer Cold Wave cases

Case	Year	A area cold			B area cold			Blocking detection
		Month	Day	Anomaly	Month	Day	Anomaly	
1	1979	8	26	-5.7	8	28	-3	LAR
2	1984	8	8	-4.6	8	14	-1.7	LAR/LOC
3	1989	7	24	-3.6	7	27	-2.5	LOC
4	1989	8	18	-4.7	8	20	-2.1	LAR/LOC
5	1993	8	8	-3.4	8	11	-1.7	-
6	1995	7	4	-2.7	7	25	-1.8	-
7	1996	8	19	-5.6	8	25	-3.6	-
8	2001	7	25	-2.8	7	27	-1.9	LOC
9	2002	8	5	-3.8	8	10	-3.4	LOC
10	2003	8	10	-3.6	8	15	-3.1	LOC
11	2003	8	27	-3.6	8	30	-4	-
12	2004	7	28	-6.3	7	30	-1.9	-
13	2004	8	10	-4.3	8	16	-3	-
14	2005	8	15	-5.5	8	19	-2.4	-
15	2006	7	21	-3.3	7	25	-2.9	LOC
16	2008	8	30	-4.1	8	31	-2.1	-
17	2009	8	27	-5	8	29	-3.7	HYB
18	2011	7	27	-3.2	8	2	-2.8	LOC
19	2012	8	10	-3	8	14	-3.1	LOC
20	2012	8	20	-6.8	8	22	-2.5	-
21	2014	8	4	-3.5	8	6	-3	LOC
22	2016	8	24	-3.4	8	26	-1.9	HYB/LOC
23	2017	8	27	-8.1	8	29	-3.1	LOC
24	2020	8	18	-3.5	8	21	-1.7	-
25	2022	8	7	-4.5	8	9	-3	LOC
26	2022	8	25	-5.1	8	28	-4	LOC

- **Cases of SCW** occurrence during the period of **July 24 to August 31** when the Korean summer monsoon ends from **1979 to 2022.**
- Cases were recorded where a cold case in the **lower 10%** occurred in **Area A** (red box in Fig. 6) **followed** by a cold case in **Area B** (purple box in Fig. 6).
- A **total of 26** cases were recorded, and **16 of them were detected with blocking** before the occurrence. The frequency of occurrence **has been increasing since 2000.**

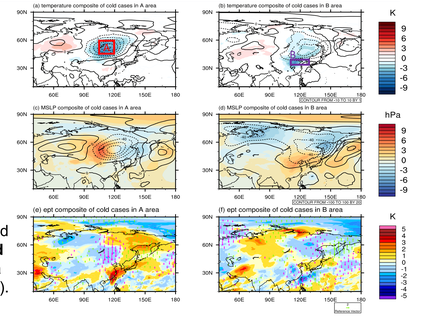

Fig 5. Summer Cold Wave case composite. (a) and (b) As in fig.2, (c) and (d) As in fig.3, (e),(f) As in fig.4. but (a),(c) and (e) are area A cold case, the others are area B cold case.

- **SCW cases** are analyzed in a **composite**. **In Area A** (near Lake Baikal), a strengthening of **cold /high pressure/low ept** occurs, followed by **in Area B** (near the northwestern part of the Korean Peninsula).

Correlation between Summer Cold Wave and Heavy Rain

- When the SCW occurs, a **Stationary front** forms in an east-west direction across the **East Asian region**, including the Korean Peninsula, and precipitation occurs in that area. This is called the **Summer Cold Front (SCF)**

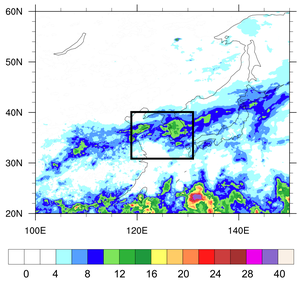

Fig 6. (a) The average daily accumulate precipitation in Northeast Asia from 2 days before to 2 days after the onset of cold in region B for the cases of SCW(after 2001)

Table4. Precipitation in the Korean region (Fig. 6, Black Box) for SCW Cases after 2001.

Case	Korea	
	Maximum rain day	Precipitation(mm)
8	2001-07-29	119,652
9	2002-08-10	177,916
10	2003-08-17	140,455
11	2003-08-29	112,625
12	2004-07-31	14,593
13	2004-08-17	281,851
14	2005-08-19	168,173
15	2006-07-27	163,314
16	2008-08-31	119,463
17	2009-08-27	77,672
18	2011-08-03	100,746
19	2012-08-14	192,807
20	2012-08-23	303,114
21	2014-08-07	127,486
22	2016-08-25	87,302
23	2017-08-28	49,043
24	2020-08-22	38,254
25	2022-08-09	195,834
26	2022-08-30	128,107

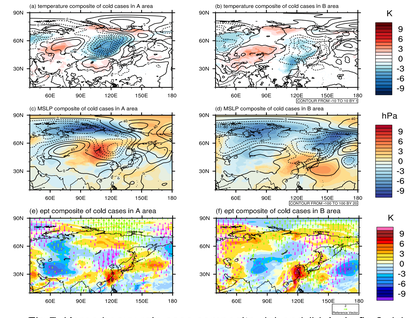

Fig 7. Korea heavy rain case composite. (a) and (b) As in fig.2, (c) and (d) As in fig.3, (e),(f) As in fig.4. but (a),(c) and (e) are area A cold case, the others are area B cold case.

- Synthesizing **cases with heavy precipitation in Korea(Table 4. blue cases)** show a similar pattern to SCW cases but with a stronger cold. Additionally, it demonstrates that **precipitation increases** when the **North Pacific High** develops **more strongly**

Summary and Conclusion

- **This study analyzed the heavy rainfall event that occurred in Seoul in August 2022 and identified its causes through the daily temperature and pressure distributions in the Eurasian region. Additionally, the specificity of the Summer Cold Wave (SCW) was analyzed by synthesizing past cases.**
- **Future research will consider the potential for climate change to increase the frequency of blocking and SCW occurrence.**

Acknowledgements

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