Projection of future changes in extreme precipitation indices over South Korea

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Introduction

- Recently, the intensity and frequency of natural disaster have been increasing due to climate change (Stocker et al., 2014).

- Damages caused by most natural disasters in Korea are related to extreme precipitation (Chang et al., 2009), hence in-depth understanding of changes in extreme precipitation is needed.

- Research on extreme precipitation has been conducted around the world including STARTDEX (Statistical and Regional Dynamic Downscaling of Extremes for European Studies) (Goodess, 2003).

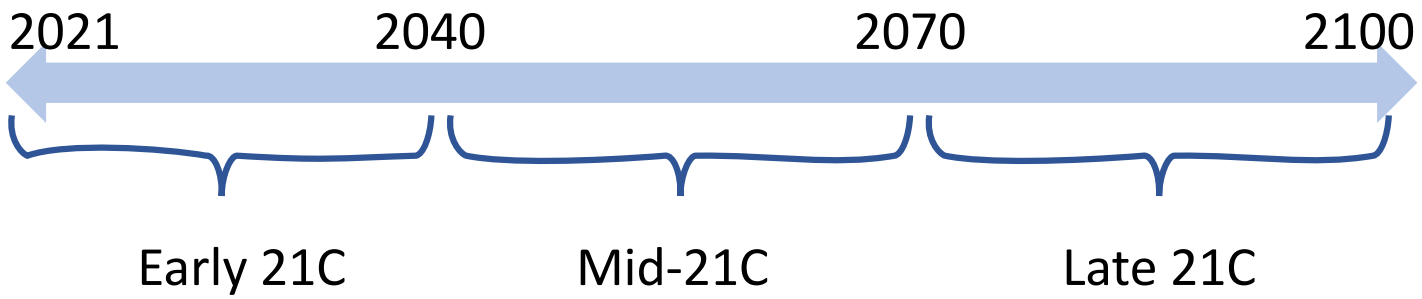
- Although there are some advance research that analyze extreme precipitation indices developed by STARDEX, there have been few studies that analyze STARDEX indices in South Korea using multi-RCMs.

- In this study, STARDEX indices were estimated over South Korea during the present period, and the future changes in STARDEX indices were investigated using high resolution multi-RCMs.

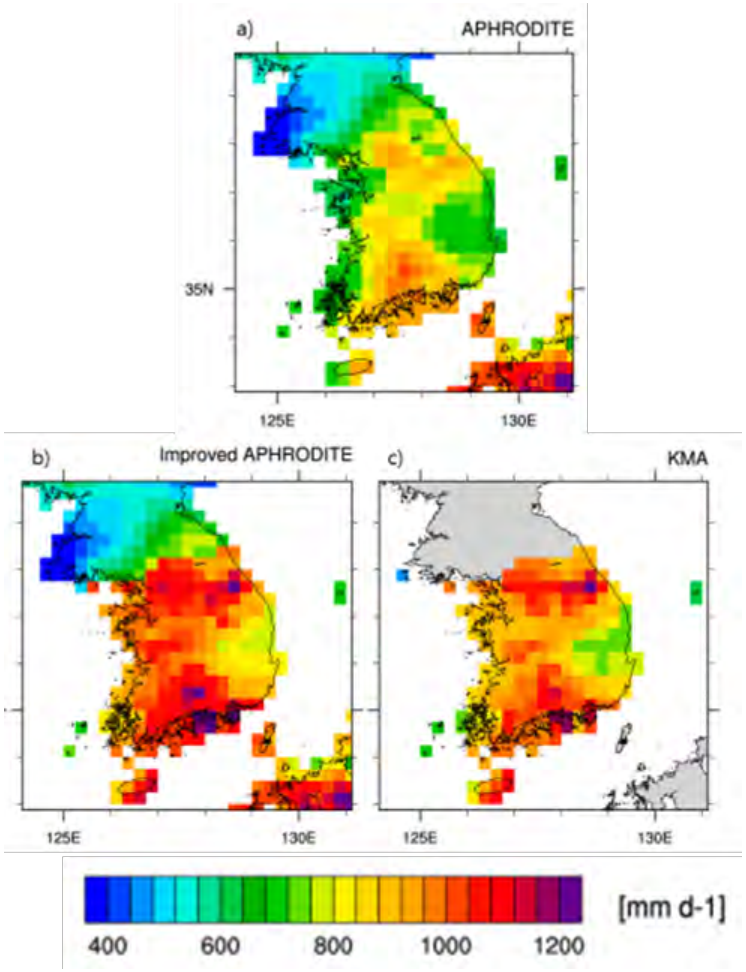
Data and Methods

	HadGEM3-RA	RegCM	SNURCM	WRF	GRIMs
Number of grids (longitude × latitude)	200×180	198×178	199×179	201×180	201×182
Vertical coordination	38 hybrid	23 sigma	24 sigma	27 sigma	28 sigma
Radiation	General 2- stream radiation	NCAR CCM3	CCM2 package	CAM	GSFC
Microphysics	Single moment bulk	SUBEX	Reisner II	WSM3	WSM I
Convection	Revised mass flux	MIT-Emmanual	Kain-Fritch II	Kain-Fritch II	SAS + CMT
Land Surface model	MOSES II	CLM3.5	CLM3.0	NOAH	NOAH
Horizontal resolution	0.11˚ (12.5 km)				

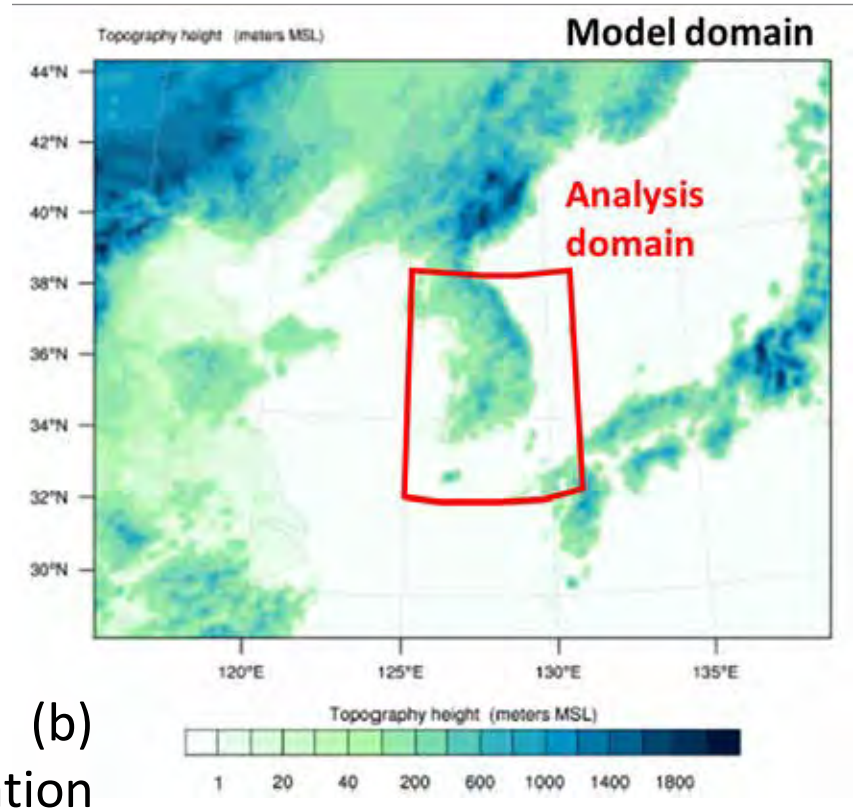
- Forcing data: HadGEM2-AO
- Experiment: Historical (1981-2005), RCP4.5/8.5 (2021-2100)



Data and Methods



- Modified APHRODITE with 0.25 ° resolution is used as observation data (Lee et al., 2017).



Spatial distribution of (a) APHRODITE, (b) improved APHRODITE, (c) ASOS precipitation for JJAS over 25 years (1981-2005)

Data and Methods

STARDEX indices

Acronym	Definition	Unit	Simple description
PINT	Average precipitation on days with > 1 mm precipitation	mm	**Mean precipitation**
PQ90	90^{th} percentile of precipitation on days with > 1 mm precipitation	mm	**Extreme precipitation intensity**
PFL90	Fraction of total precipitation from events > long-term 90^{th} percentile	%	**Fraction of extreme precipitation**
PX5D	Maximum precipitation from any five consecutive days	mm	**Consecutive extreme precipitation**
PXCDD	Maximum number of consecutive days with < 1 mm precipitation	days	**Dry spell lengths**

Data and Methods

- A performance-based ensemble method (**PEA_RAC**) from Suh et al. (2012) was used when indices and seasonal precipitation were analyzed.

$$\mathrm{Pw}_i = \frac{1.0}{(\mathrm{RMSE}_i + 1.0)} \mathrm{Abs}(\mathrm{Corr}_i),$$

→ **Making evaluation parameters**

$$\mathrm{NPw}_i = \frac{\mathrm{Pw}_i}{\sum_{i=1}^{N_M} \mathrm{Pw}_i}.$$

→ **Making normalized weighting of each model**

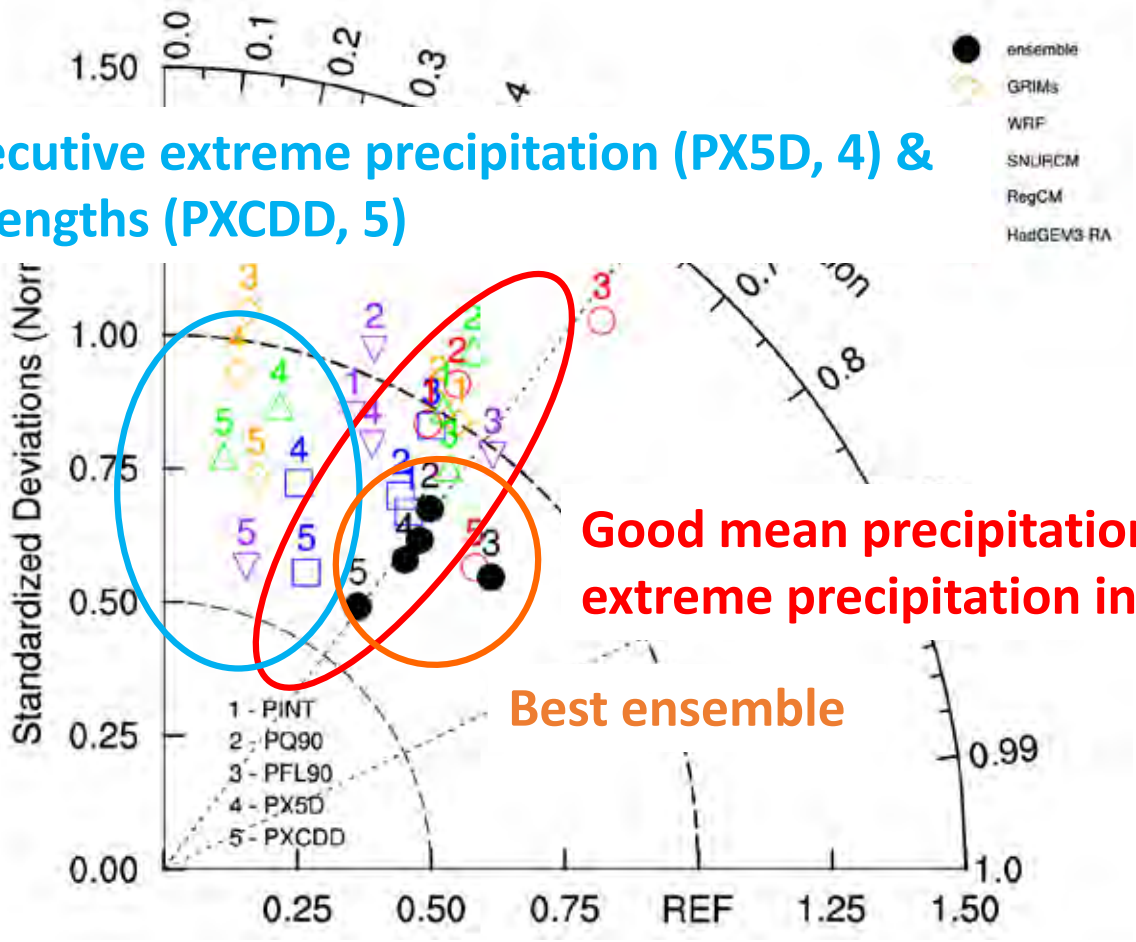
$$\tilde{T} = \sum_{i=1}^{N_M} \mathrm{NPw}_i T_i - \sum_{i=1}^{N_M} \mathrm{NPw}_i \Delta T_i;$$

→ **Simple bias correction**

- Equal-weighted averaging was used when convective precipitation, non-convective precipitation and synoptic field were analyzed.

Results | Evaluation of the model for the present climate in the Historical experiment

Taylor diagram of five RCMs and ensemble mean for the Historical experiment (1981-2005)



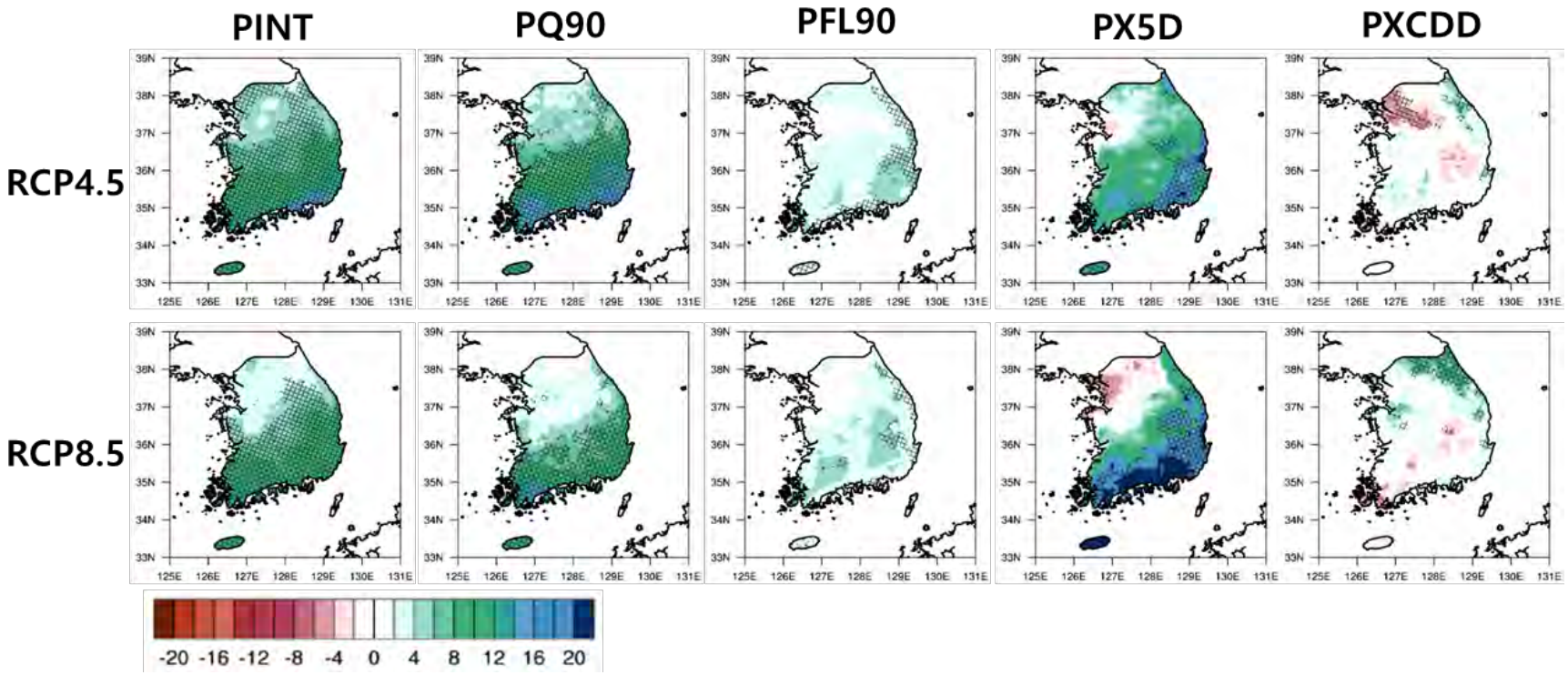
Bad consecutive extreme precipitation (PX5D, 4) & dry spell lengths (PXCDD, 5)

Good mean precipitation (PINT, 1) & extreme precipitation intensity (PQ90, 2)

Best ensemble

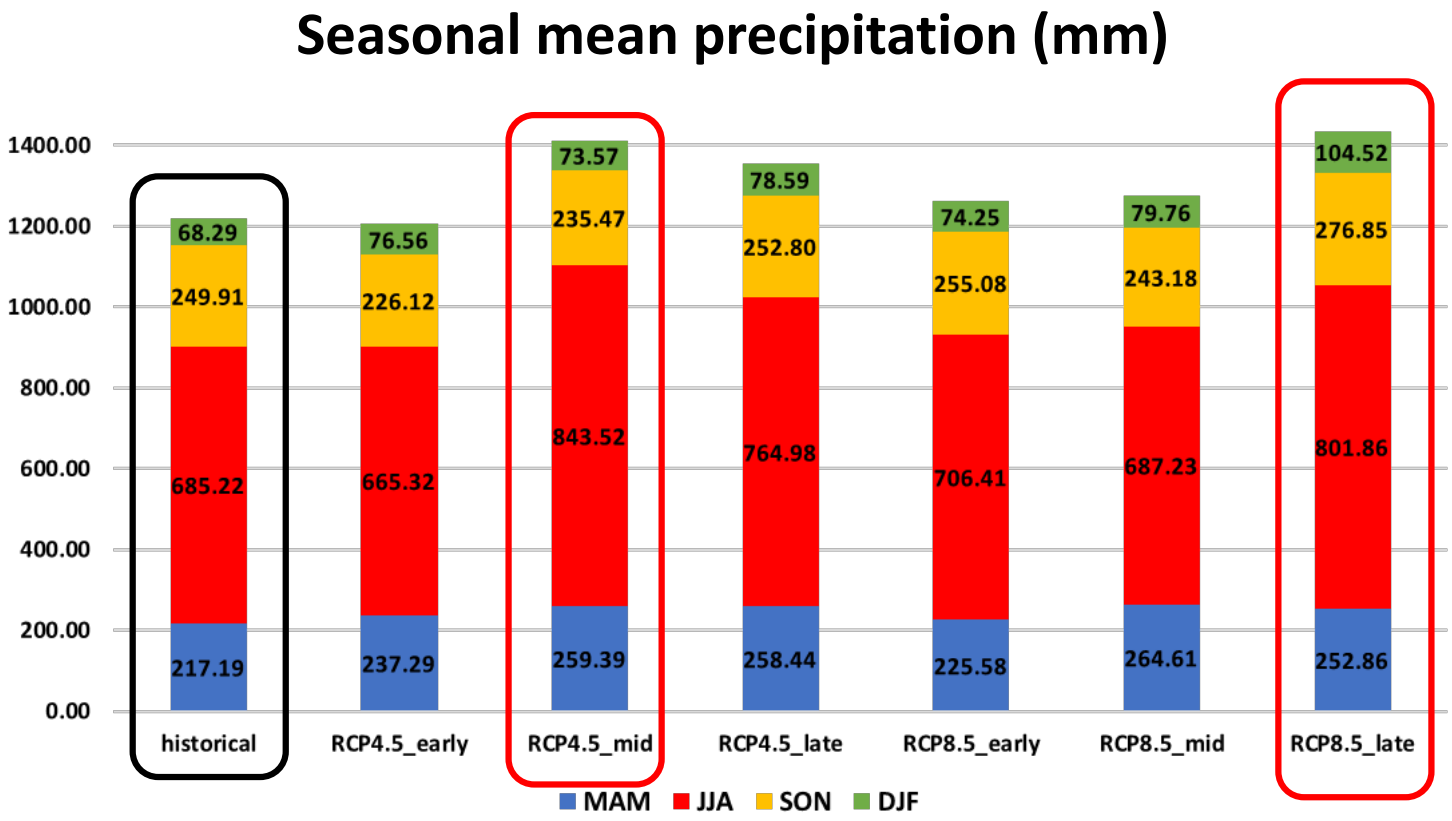
Results | Future change in annual and seasonal extreme precipitation indices

Rate of change in indices between future (2021-2100) and present (1981-2005) runs (%)



- All models simulated increasing mean (**PINT**) & extreme precipitation (**PQ90, PX5D**) over southern region.

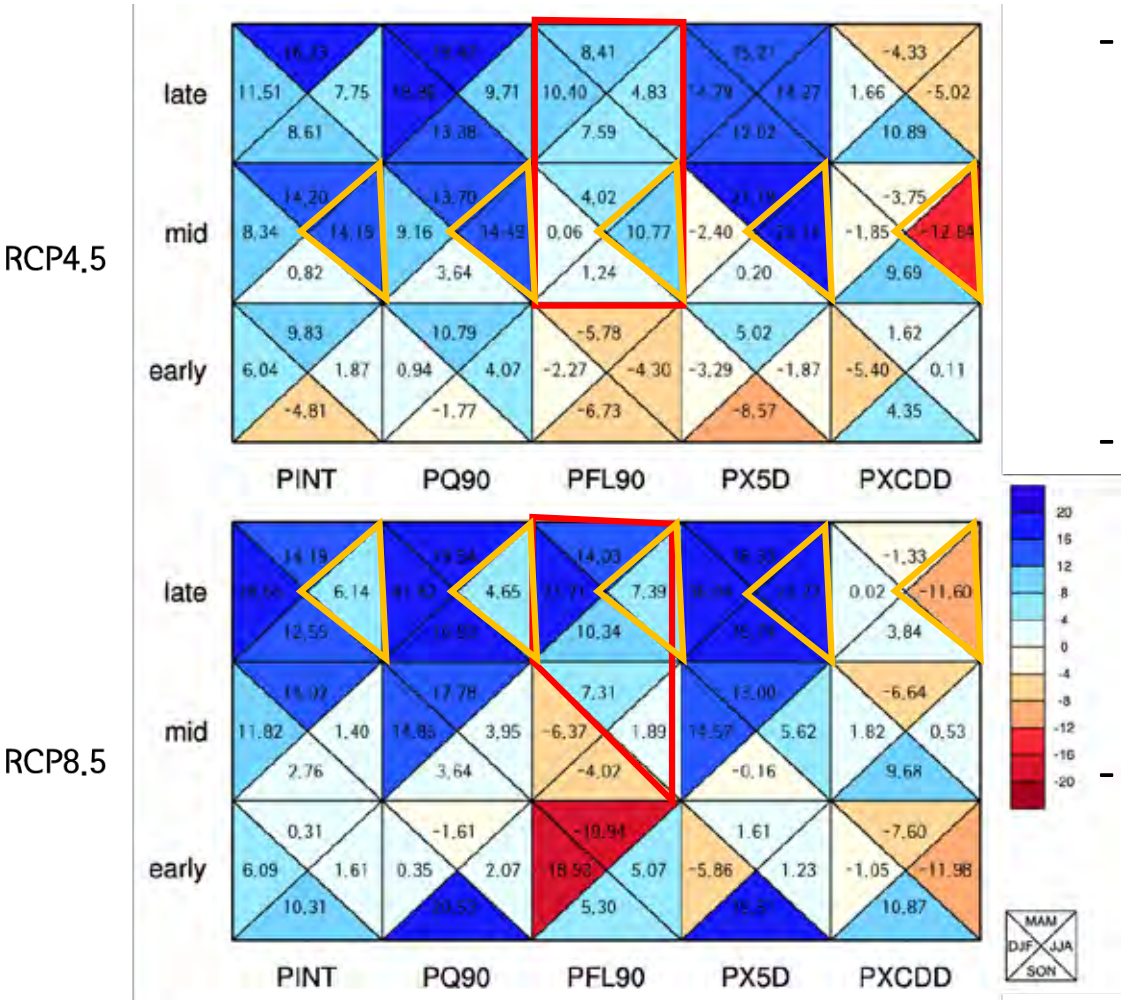
Results | Future change in annual and seasonal extreme precipitation indices



- Annual precipitation was increased significantly during **mid-21C in RCP4.5** and **late 21C in RCP8.5**.

Results | Future change in annual and seasonal extreme precipitation indices

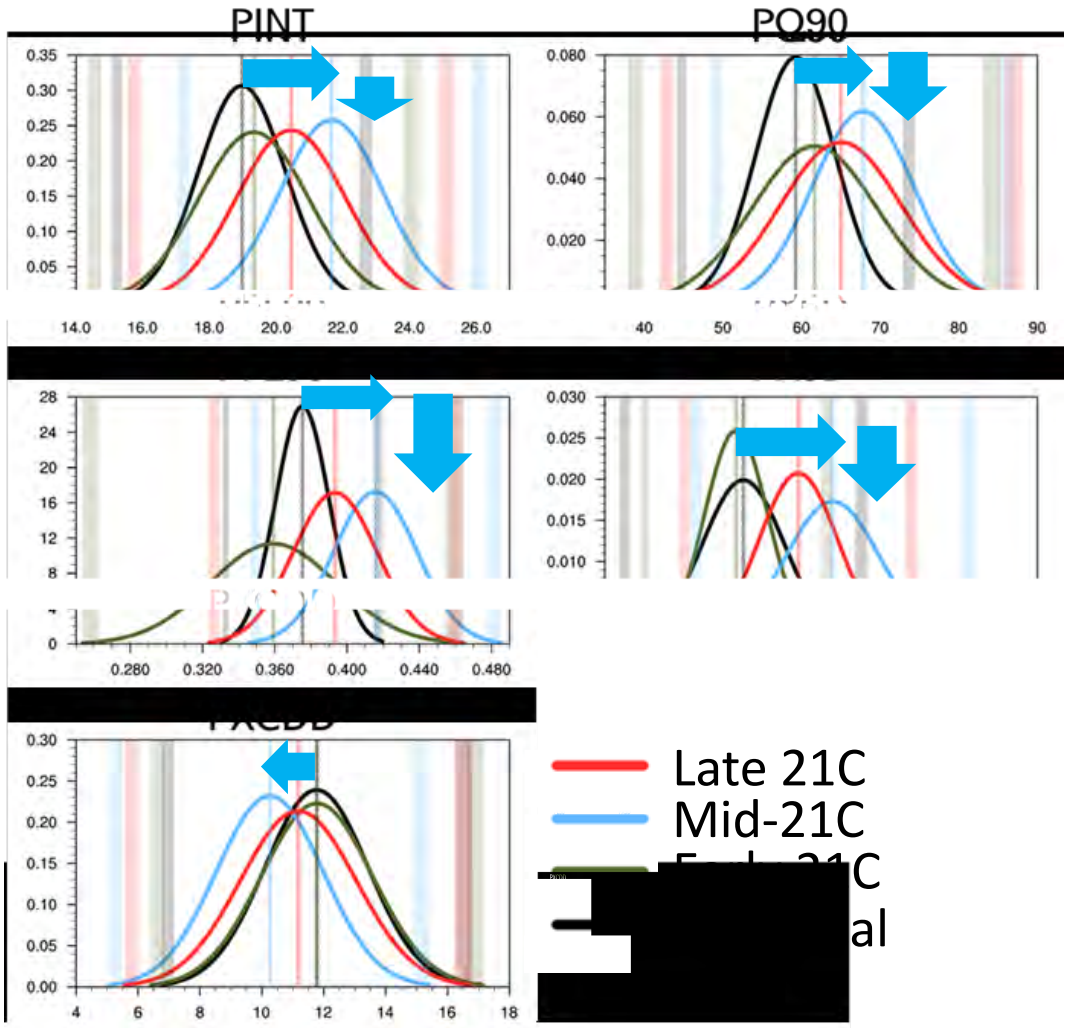
Rate of change for period-mean and area-mean indices (%)



- Generally, mean precipitation (**PINT**) and extreme precipitation (**PQ90**, **PX5D**) were increased while dry spell length (**PXCDD**) was decreased.
- During mid-21C and late 21C, extreme precipitation was more increased than mean precipitation (**PFL90**).
- These features stood out during **mid-21C summer in RCP4.5** and **late-21C summer in RCP8.5**.

Results | Future change in extreme summer precipitation indices

Normal distribution of indices in RCP4.5

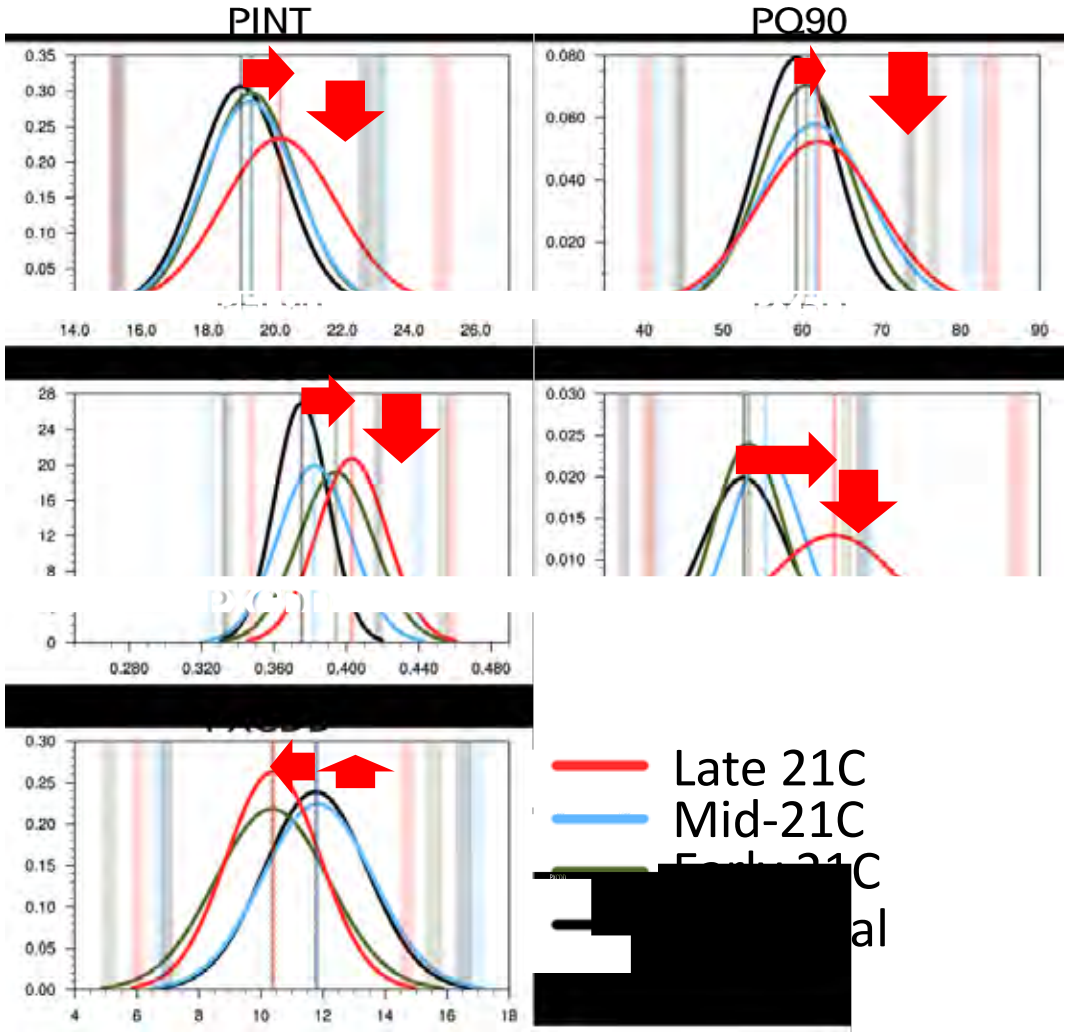


- During **mid-21C in RCP4.5**, upper extreme values of mean (**PINT**) and extreme precipitation (**PQ90, PF90, PX5D**) were increased.

- During **mid-21C in RCP4.5**, lower extreme value of dry spell length (**PXCDD**) was decreased.

Results | Future change in extreme summer precipitation indices

Normal distribution of indices in RCP8.5

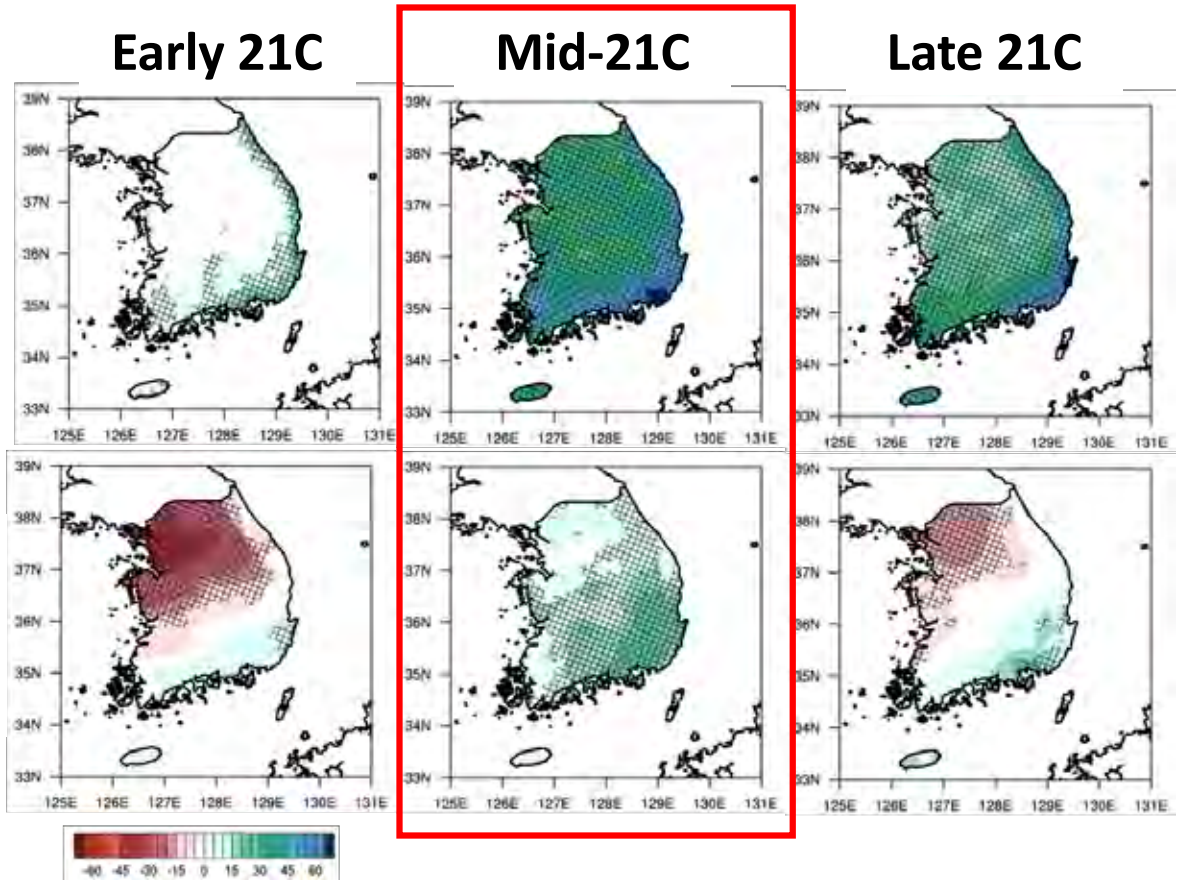


- During **late 21C in RCP8.5**, upper extreme values of mean (**PINT**) and extreme precipitation (**PQ90, PF90, PX5D**) were increased.

- During **late 21C in RCP8.5**, lower extreme value of dry spell length (**PXCDD**) was decreased.

Results | Future change in extreme summer precipitation indices

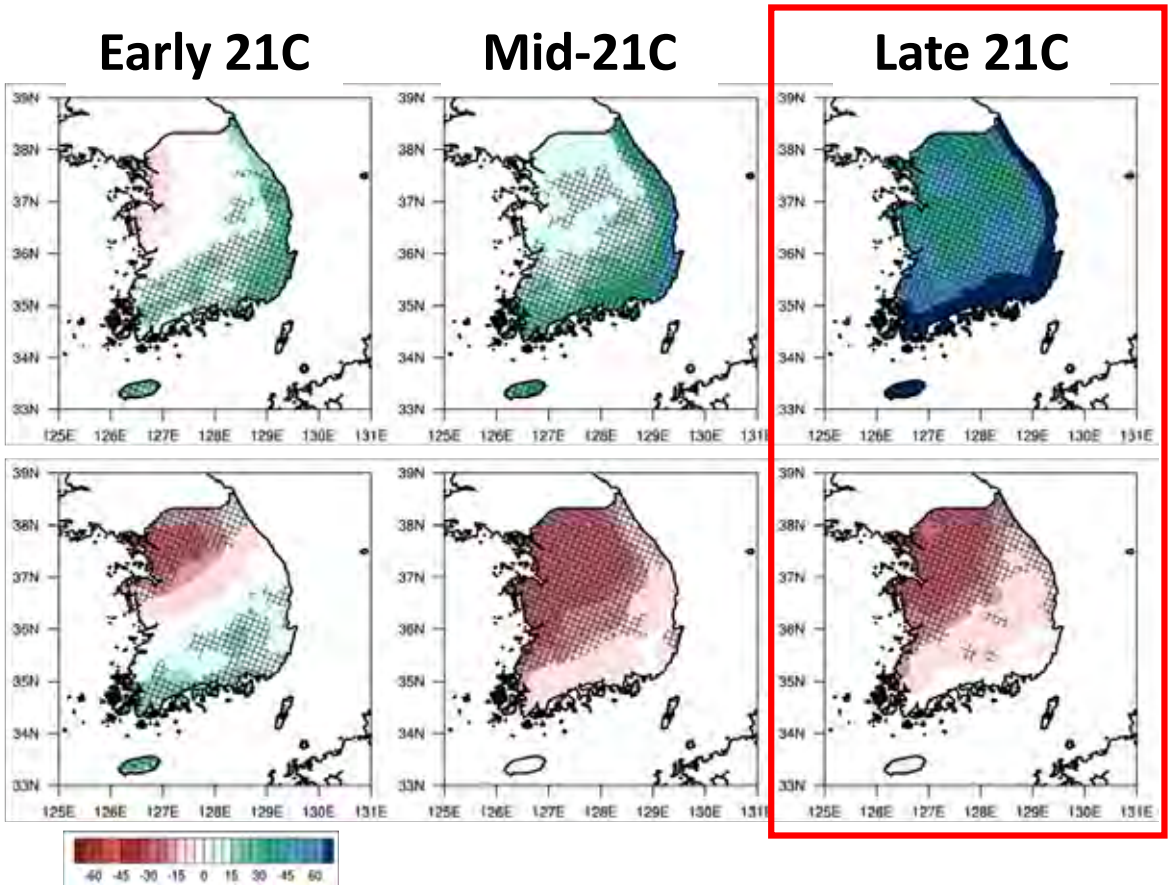
Changing rate of convective/non-convective precipitation in RCP4.5 (%)



- During **mid-21C in RCP4.5**, convective precipitation was significantly increased.

Results | Future change in extreme summer precipitation indices

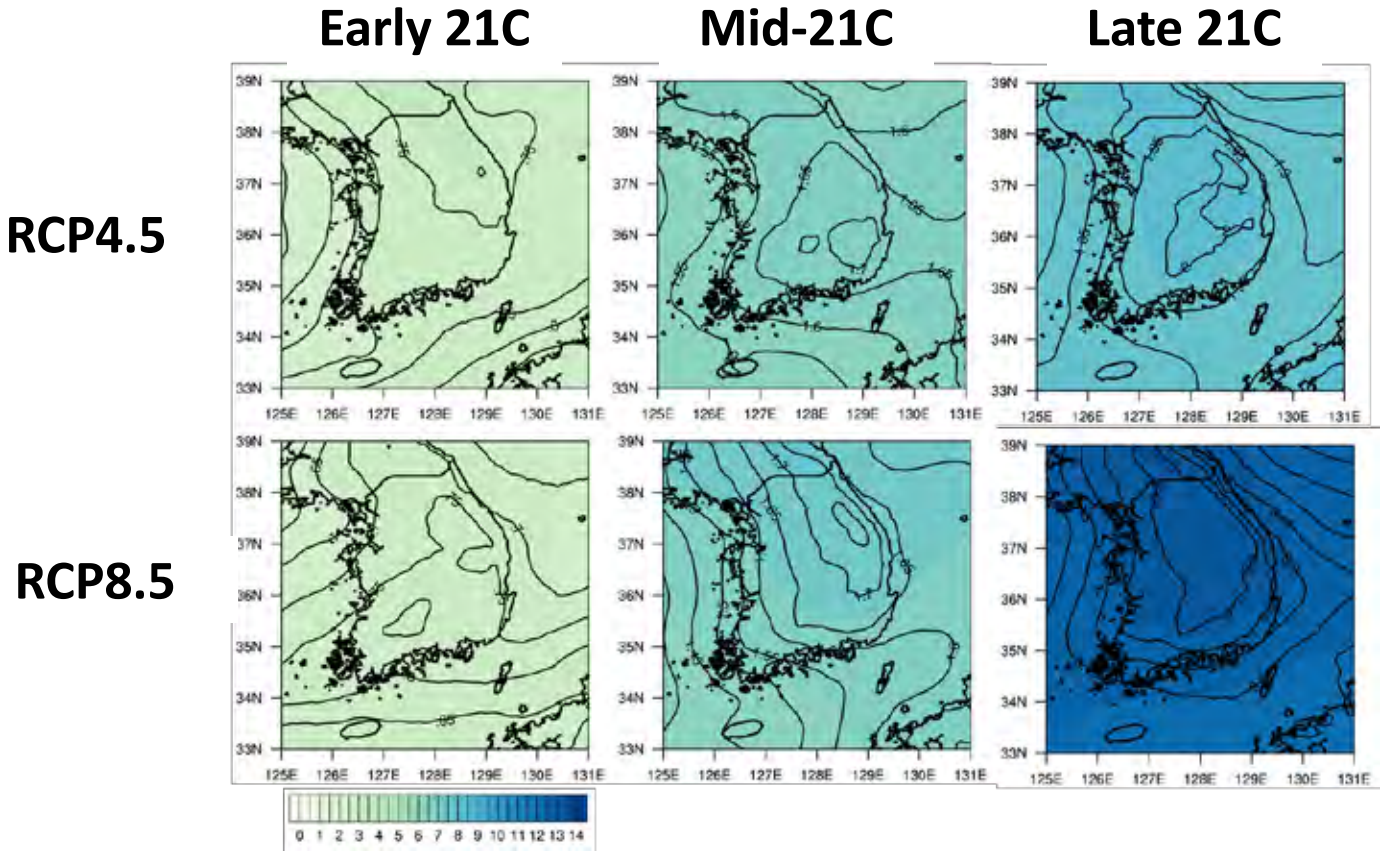
Changing rate of convective/non-convective precipitation in RCP8.5 (%)



- During **late 21C in RCP8.5**, convective precipitation was significantly increased.

Results | Future change in extreme summer precipitation indices

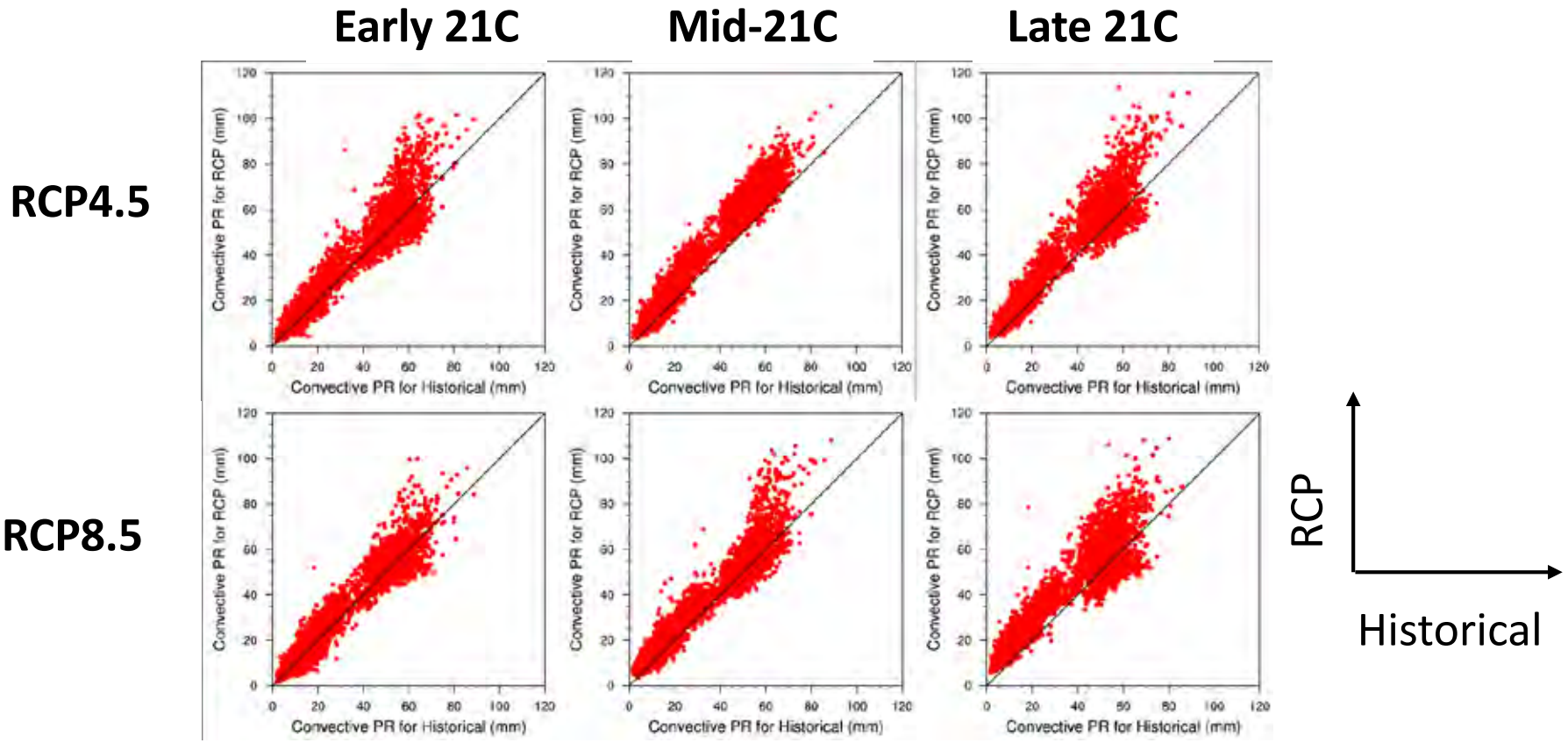
Changes in equivalent potential temperature (shading, K) and specific humidity at 850 hPa (contour, 10^3 kg·kg^{-1})



- Spatial pattern of increasing these two variables were similar with that of **convective precipitation**.

Results | Future change in extreme summer precipitation indices

Changes in convective precipitation when PQ90 events occur (mm)



- Convective precipitation for PQ90 was increased.

Summary and concluding remarks

- In this study, extreme precipitation indices over South Korea were investigated using high-resolution multi-RCMs.

- Ensemble reasonably simulated mean and extreme precipitation intensities during the present period.

- During mid-21C in RCP4.5 and late 21C in RCP8.5, mean and extreme precipitation intensities were significantly increased, and extreme precipitation was more increased than mean precipitation.

- During summer, upper extreme values of mean and extreme precipitation indices were increased while lower extreme value of maximum dry spell length was decreased.

- Convective precipitation was increased while non-convective precipitation was decreased, which means that the increasing extreme precipitation during summer is associated with the increasing atmospheric instability caused by global warming.

Thank you ☺

Kim, G., Cha, D. H., Park, C., Lee, G., Jin, C. S., Lee, D. K., ... & Kang, H. S. (2018). Future changes in extreme precipitation indices over Korea. International Journal of Climatology, 38, e862-e874.