



Regional variation of the Relationship between Extreme Precipitation and Temperature over Japan

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Regional variation of the Relationship between Extreme Precipitation and Temperature over Japan

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Abstract: This study explores the relationship between extreme precipitation events and temperature over Japan and its connection with Clausius-Clapeyron relationship and the regional variation of the relationship over different sub-regions of Japan by using during APHRODITE observations for the period 1961-2007 and d4PDF dataset for the period 1951-2010.

Keywords: Clausius-Clapeyron relationship, extreme precipitation events, d4PDF

1. Introduction

The frequencies of extreme precipitation events are now of serious concern which are expected to increase more in future warming climate (IPCC 2012). This is because atmosphere can hold more moisture in warmer air temperature according to the Clausius-Clapeyron (CC) equation ($\sim 7\%$ per $^{\circ}\text{C}$ of warming). According to the studies that are conducted over Japan, it is expected that the extreme precipitation events linked to temperature will increase at $\sim 7\%/^{\circ}\text{C}$ (Utsumi et al., 2011; Yamada et al., 2014; Nayak and Dairaku, 2016; Nayak et al., 2017). Consequently, more extreme precipitation events may occur under future warming climate and have societal impacts such as on the human health, the environment, and also the economy.

Previous researches indicate that the relationship between extreme precipitation events and temperature is not uniform and different at various regions (e.g., Linderinck and Van Meijigaard, 2008; Berg et al., 2009; Hardwick et al., 2010; Nayak, 2018; Nayak and Takemi, 2019) because of the topography and physical mechanisms of the precipitation. However, no sufficiently comprehensive studies have yet been conducted to examine whether if the relationship between extreme precipitation events and temperature follows CC relationship over different sub-regions of Japan. If so, then to what extent? This study attempts to focus on this issue to discuss the regional variation of the relationship between extreme precipitation and temperature over Japan and its seven sub-regions: Sea of Japan side of North Japan (NS); Sea of Japan side of East Japan (ES); Sea of Japan side of West Japan (WS); Pacific Ocean side of North Japan (NP); Pacific Ocean side of East Japan (EP); Pacific Ocean side of West Japan (WP); and Okinawa (OK).

2. Methods and Dataset

We use Asian Precipitation-Highly-Resolved Observational Data Integration Towards Evaluation (APHRODITE) daily datasets at 0.25 degree for the period 1961-2007 and database for Policy Decision making for Future climate change (d4PDF) dataset at 20 km for the period 1951-2010. We first identified the wet events with a threshold of more than 1 mm/day over different sub-regions of Japan and paired them with their corresponding day's mean temperature. Then we formed different temperature bins with 1°C interval and put the precipitation intensities in to different bins according to their associated temperature values. The extreme precipitation events (99th percentile) are finally calculated from each temperature bin. The rate of change of extreme precipitation events (CC scaling) are computed by using the equation:

$$P_2 = P_1(1 + \alpha)^{\Delta T} \quad Eq(1)$$

Where P_1 and P_2 are precipitation values at two temperatures T_1 and T_2 , respectively; $\Delta T = T_2 - T_1$ is the change in temperature, and α is the rate of change of extreme precipitation events, which is equivalent to ~ 0.07 in case of CC scaling. This rate can be obtained from August-Roche-Magnus approximation for saturated vapor pressure, e_s from

the equation:

$$e_s = 6.11 \times \exp\left(\frac{17.62 \times T}{243.04 + T}\right) \quad Eq(2)$$

3. Results

3.1 Relationship between extreme precipitation events and temperature

Figure 1 shows the relationship between extreme precipitation events and temperature over Japan and its seven sub-regions from APHRODITE and d4PDF datasets. We find that the relationship between extreme precipitation events (99th percentile) and temperature follows CC relationship over Japan as well as its sub-regions up to a certain temperature and then starts decreasing. This characteristic of extreme precipitation events and temperature relationship is noticed to be qualitatively similar over each sub-region of Japan, however, quantitatively they are found to be different. Over Northern part of Japan, the extreme precipitation increase with temperature up to 21-degree, while over Okinawa, the extreme precipitations increase up to 24-degree. The peak intensities of relationship over western regions of Japan including Pacific Ocean side of eastern Japan and Okinawa are found to be about 100 mm/day and more, while the peak intensities over northern regions of Japan are found to be below 60 mm/day.

3.2 Rate of change of extreme precipitation events linked to temperature

In this section we discussed the rate of change of extreme precipitation events linked to temperature over Japan and its seven sub-regions from APHRODITE and d4PDF datasets. We computed the rates with consideration of all temperatures (shown as black color in Figure 2) and with consideration of the temperatures where precipitation has a peak (shown as white color in Figure 2). We find that the rates of change of extreme precipitation events over all regions of Japan follows nearly CC scaling over Japan, Okinawa, western and northern Japan when considered all the temperatures. Eastern regions show sub-CC scaling. However, the rate is significant when considered the peak values. This study is conducted with APHRODITE and d4PDF data (one member). We would like to further analyze more ensemble members of d4PDF datasets in present and future climate.

4. Summary

In this study, we investigate the regional variation of the relationship between extreme precipitation events and temperature over Japan and its connection with Clausius-Clapeyron relationship by using during APHRODITE observations for the period 1961-2007 and d4PDF dataset for the period 1951-2010. We find that the relationship between extreme precipitation events and temperature follows CC relationship over Japan as well as its sub-regions up to a certain temperature and then starts decreasing. Over Northern part of Japan, the extreme precipitation increase with temperature up to 21-degree, while over Okinawa, the extreme precipitations increase up to 24-degree. The rates

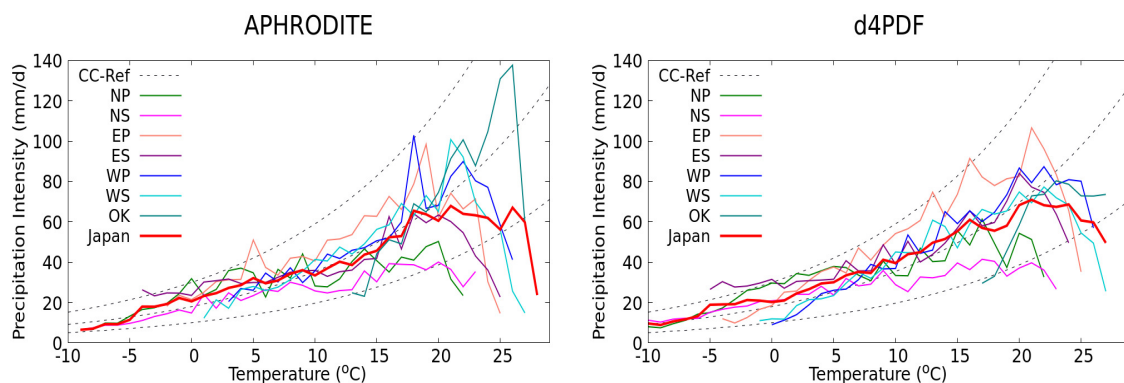


Figure 1. The relationship between extreme precipitation events and temperature over Japan and its seven sub-regions derived from APHRODITE datasets for the period 1961-2007.

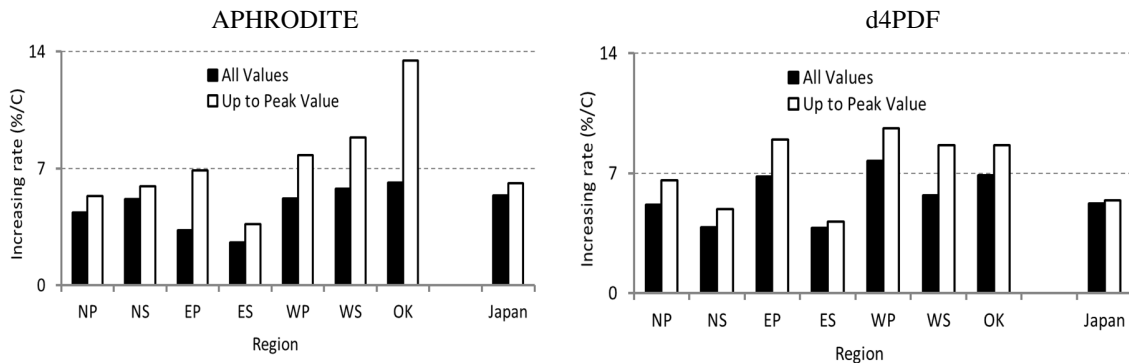


Figure 2. The rate of change of extreme precipitation intensities linked to temperature.

of change of extreme precipitation events over all regions of Japan follows nearly CC scaling over Japan, Okinawa, western and northern Japan when considered all the temperatures. Eastern regions show sub-CC scaling. However, the rate is significant when considered the peak values. We would like to further analyze more ensemble members of d4PDF datasets in present and future climate.

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