Evaluation of probable maximum precipitation and extreme daily rainfall at high temperature in Northeast Vietnam in the context of climate change

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1. Introduction

Lying within the southeast Asian typhoon belt, Vietnam experiences high frequencies of storms and heavy rainfall. Two obvious consequences from such rainfall-related problem are floods and landslides occurrences. Northeast Vietnam is one of the most prone area to such disasters. Climate change would obtain the great influences on the extreme precipitation[1)] . The increase in water holding capacity of the atmosphere is associated with the rise in air temperature as described in the Clausius-Clapeyron (CC) relation[2)] . With the purpose of obtaining better understanding of precipitation characteristics in Northeast area, we first analyzed the relationship between temperature and extreme rainfall. The Probable Maximum Precipitation (PMP) is then estimated using historical meteorological data. We also considered the changes of dew point temperature regarding to project temperature and relative humidity in order to evaluate the extent of changes in PMP in the context of climate change.

2. Study area

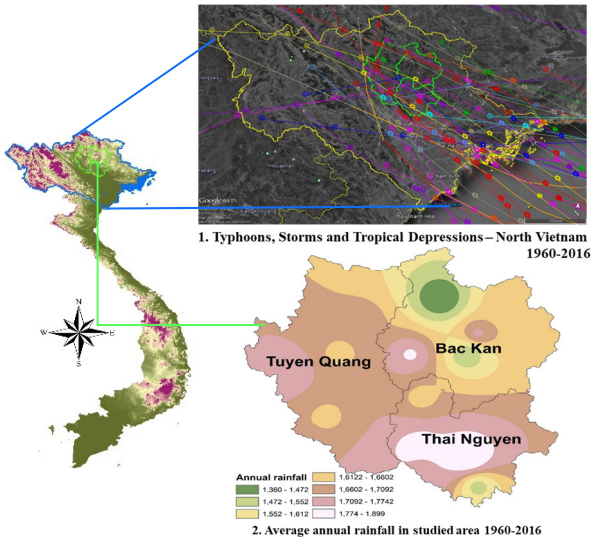

Fig. 1 Studied area

In this paper, we examined the precipitation characteristic in three provinces in Northeast Vietnam – Bac Kan(BK), Thai Nguyen(TN) and Tuyen Quang(TQ). This area is a mixture of mountainous and hilly terrain conditions. According to the historical typhoon data from NOAA [3)] , about 68 tropical cyclones hit the North Vietnam from 1960 to 2016. Heavy rainfall in this area is not only a result of tropical concentration line across the delta, trough, but typhoon-related events, which hit inland of Vietnam and South China area, as well. During the period from 1960 to 2016, the average annual rainfall in this area is 1380-1900 mm, and rainy season often lasts from late April to early October with average monthly rainfall and average temperature of 108-317 mm and 23.5-27.9°C, respectively. The highest daily precipitation at 15 out of 18 rain stations occurred in accordance with typhoon-related events.

3. Methodology

To determine the behavior of extreme precipitation, we first set up the relationship between heavy-daily-rainfall and average daily air surface temperature in the studied site. The analysis was implemented by binning method [2)] . The temperature-rainfall pairs are allocated to compute the average and 99.9th percentiles of rainfall intensities ($P_{99.9}$) in each bin. The CC scaling is then used to examine the possible changes in precipitation regarding to the changes in temperature. With regards to PMP estimation, statistical and moisture maximization methods are widely applied. The former approach applies Hershfield method (1961) to estimate PMP by statistical analysis (eq.1).

$$PMP = \bar{X}_n + S_n \frac{X_{max} - \bar{X}_{n-1}}{S_{n-1}} \quad \text{(eq.1)}$$

In where $\bar{X}$ and S denote mean and standard deviation; sub-index (n) and (n-1) refer to annual extreme series and annual extreme series excluding the maximum value, respectively; X_{max} is the maximum rainfall. The latter method considers the maximization ratio between maximum precipitable water (W_{max}) at certain time period of a year and actual precipitable water (W_s) of the storm event regarding to precipitation P (eq.2).

$$PMP = P \frac{W_{max}}{W_s} \quad \text{(eq.2)}$$

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After selection of extreme rainfall events, we determined W_{max} and W_s by applying the relationship between precipitable water and surface dew point temperature (t_d). In this study, t_d is calculated from relative humidity (RH) and surface temperature. W_{max} is estimated based on maximum dew point temperature(t_d^{max}), which can be either the maximum of t_d within 15 days after the storm event [4], or corresponding of 100-year-return period of maximum t_d in a month of storm event or over 30-day window data (15 days before and after the event) [5) 1)].

4. Results

According to the Vietnamese government standard, the 24hour-rainfall-intensity that from 51 mm and above is considered as a rain-induced-waterlogging event. In this study, we therefore set up the relationship between temperature and daily precipitation of heavy-rain-days with the threshold of 51 mm. The results illustrate that the CC-like relations (6-7%/°C) almost fit the rise in $P_{99.9}$ up to the temperature of 23°C while a super CC scaling up to 10.25 %/°C is shown when the temperature reaches the peak point of about 26°C. Higher temperatures demonstrate a decrease trend as a result (Fig. 2).

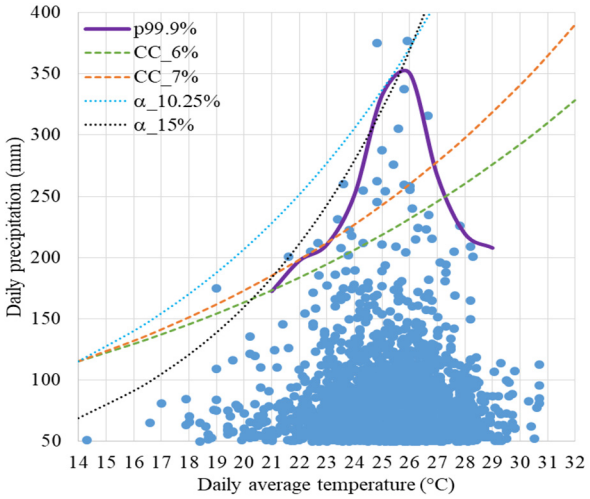

Fig. 2 P_{99_9} in each temperature bin in rainy season

Regarding to PMP determination, annual maximum daily rainfall in 55 years at 8 meteorological stations are used in statistic method. This approach obtains PMP results from 232 mm to 517 mm (Fig. 3). We selected 6-extreme precipitation events at each stations to calculate PMP by maximization method. The t_d^{max} is computed by various options as described in section 3. Among above options, $PMP_{\_td\_100yr}$, which is calculated based on 100-year-return period dew point temperature for W_{max} estimation, provides the highest values of 301 – 568 mm. Additionally, seven GCMs from WorldClim are also used to obtain future temperature regarding to RCP2.6 and RCP8.5 with projected rise of 2.69–3.32 degree in rainy-season-

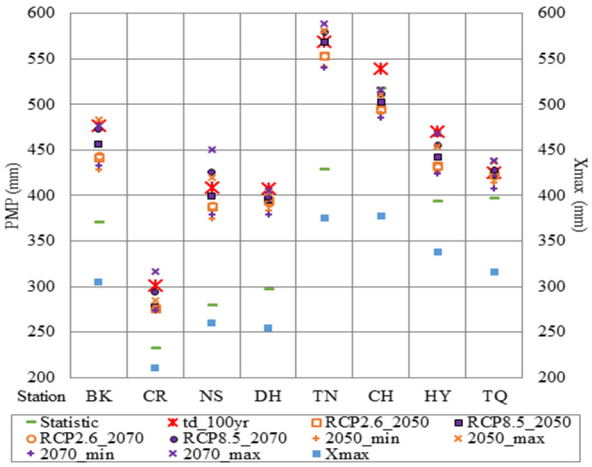

Fig. 3 PMP estimation regarding to historical data and RCP scenarios at 8 meteorological stations

temperature (April-October). Relative humidity at high temperature is predicted to reach critical value (based on maximum record of RH at the temperature above 26°C). Considering changes in air temperature and RH in the future, scenarios in 2050 almost agree with $PMP_{\_td\_100yr}$, while higher values are predicted at some stations in 2070.

5. Discussion and conclusions

The peak-like structure of $P_{99.9}$ in this area (21°N - 22°N) agrees with Utsumi et al. [2] for trend in changes of extreme precipitation at mid-latitude-stations globally. When relative humidity is predicted to reach the critical value at high temperature, dew point temperature can be therefore higher than historical data. It also note that there would be a possible increase in PMP in case of higher air temperature. This study provides important output for our further consideration about impact of extreme precipitation on landslide issue under climate change.

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