CLIMATE CHANGE INTENSIFIED RAINFALL EXTREMES IN CENTRAL VIETNAM: A CASE STUDY OF DA NANG CITY

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Abstract: *Climate change has intensified rainfall extremes. It was well demonstrated during the invasion of Storm Son Ca over Central Vietnam in mid-October 2022. This paper presents the analysis of rainfall extremes in Da Nang City based on climatological observation in the present climate (1983-2022). Conventional trend and frequency analyses were employed to detect the pattern of changes. Results show that rainfall extremes tend to be increasing over the entire period, but they have been further intensified in the last decades in line with the simulation by climate models. These research results are good references to support water engineers and policy-makers in urban planning and development for the promotion of climate resilient infrastructure.*

Keywords: *Climate Change, Rainfall Extreme, Frequency, Da Nang*

1. INTRODUCTION

Climate change has been considered as one of the biggest environmental challenges in the 21st century. Changes in future weather extremes have been projected and recently re-emphasized in the 6th Assessment Report of the Intergovernmental Panel on Climate Change [1]. In the early 2000s, scientists at the Meteorological Research Institute of Japan implemented advanced experiments to diagnose the future characteristics of tropical cyclones [2]. Results from this research are important to inform decision-makers and water infrastructure engineers. It is very likely that the number of tropical cyclones in the future climate will be less than that in the present climate (in the same time slice, e.g., 25 years).

But there will be a 40-60% increase in precipitation within a 100 km radius of the tropical cyclone center. Figure 1 illustrates the ensemble mean of the rainfall profile around all simulated tropical cyclones.

With respect to current practices on engineering design, the scales of most water infrastructure have been determined under the consideration of rainfall variability, but variation properties are stationary with time (neglecting future impacts). Design rainfall intensity duration frequency (IDF) curves have been established based on variations of the rainfall recorded in the past. They are perhaps no longer valid under a changing climate; as it has been found that most extreme events occurred in the last several decades were distributed beyond the margins of those observed in the past.

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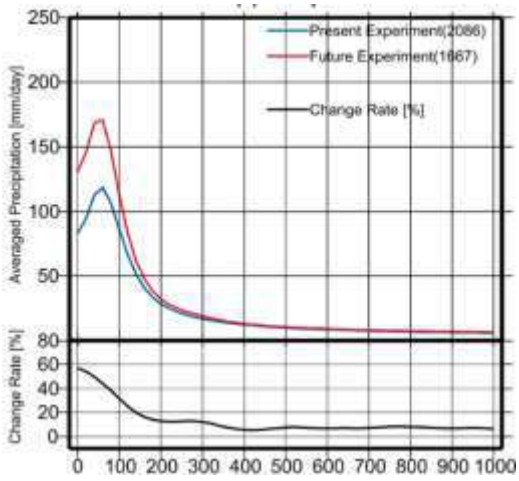

Figure 1: The radial profile of rainfall around all simulated tropical cyclones in the present (1979-2003) and future (2975-2099) experiments. The four digits in parentheses show the number of tropical cyclones. (Adopted from [2])

Increased rainfall extremes pose threats to flood defense infrastructure, especially the urban drainage system. This was well elaborated recently in Da Nang City which was severely influenced by the Storm Son Ca during October 14-15th 2022 (Figure 2). Torrential rains induced severe widespread urban inundation causing heavy damage to citizens' properties, public transport infrastructure, warehouses and electricity substations, directly affecting daily life and production activities (Figure 3).

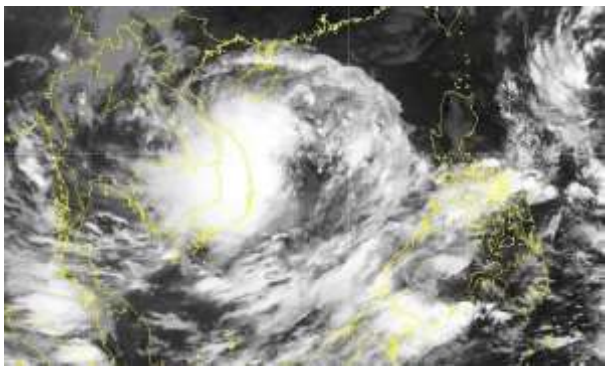

Figure 2: A satellite image of the Storm Son Ca off central Vietnam on October 14, 2022 (Photo source: National Center for Hydrometeor logical Forecasting).

In terms of damages, Storm Son Ca has caused the worst flood in Da Nang City in a decade. Serious inundation was seen in all districts and wards. Most streets and low-lying houses were submerged. There hasn't been an official report on losses, but they were estimated about 60 million USD.

Figure 3: An inundated street in center Da Nang City on Oct. 14th 2022

This paper addresses the trend of rainfall extremes in Da Nang City based on a climatological analysis of the present climate (1983-2022). The study results are considered to be fundamental information in supporting urban planning and development, an urgent adaptation requirement to tackle climate change.

2. DATA AND METHOD

2.1. Data

Climatological data was derived from a daily observation dataset in period 1983-2022 at Da Nang meteorological station. Additional monitoring rainfall data observed by automatic rain gauges around Da Nang City on October 14-15th 2022 were employed for spatial analysis.

2.2. Method

- Trend analysis

The estimation and prediction of trends and associated statistical and physical significance are conventional methods of climate and

meteorological studies. With a time-series of rainfall, the trend is defined as the rate at which rainfall changes over a certain time period (time slice). The trend is formulated using either linear or non-linear relationships between predictors and predictands. However, this study adopted a simple linear regression which is most commonly used to estimate the linear trend (slope).

- Frequency analysis

Frequency analysis of extreme rainfall events is useful for determining the scale of water engineering infrastructure and flood risk assessment. This study employed a conventional method presented in the literature [3] and [4] for defining rainfall extremes with chosen return periods (Tr) for the baseline climate. The method employs the Gumbel extreme value distribution fitting of the annual maximum discharge using the L-moments approach [5], as expressed in Equation (1).

$$Q(Tr) = \xi - \alpha\, ln(-ln(1-\frac{1}{Tr})) \quad (1)$$

where α and ξ are the scale and location parameters of the analytical Gumbel distributions.

3. RESULTS AND DISCUSSION

- Maximal daily rainfall trend

The study area has been recognized as the region that receives the most severe landfalls in Central Vietnam, which is a result of cyclone invasion and topographical effects. This type of rainstorm usually causes rainfall extremes of the year [6]. The daily rainfall data of 40-year (1983-2022) were analyzed to determine the annual one-day maximum rainfall of Da Nang City. Rainfall extreme trend analysis was first performed for the entire dataset. This helps detect a long-term trend of rainfall extremes. Results show that there is an obvious increase in rainfall extremes (Figure 4). The dataset is further divided into 20-year time slices (1983-2002 and 2003-2022). It is found that the trend of rainfall extremes in the former time slice is quite consistent with the trend detected for the last 40-year. However, in the later time slice the trend is found increasing significantly. The recent two largest events are set beyond the historical observation. These imply increases in rainfall extremes recently, both frequency and intensity.

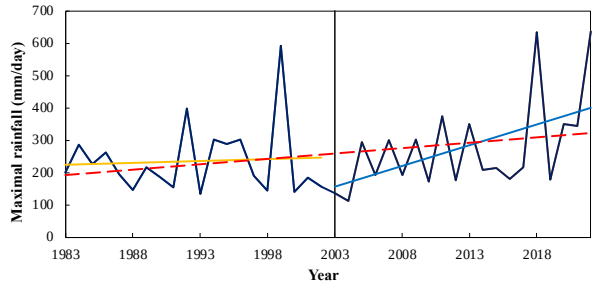

Figure 4: Maximal daily rainfall trend in period 1983-2022 (the red line represents a 40-year time slice; the green line denotes the first 20-year time slice and the blue line denotes the last 20-year time slice)

- Frequency of rainfall extremes

The frequencies of rainfall extremes in the present study were derived based on three time slices, including: the first half (1983-2002), second half (2003-2022), and entire dataset (1983-2022). Rainfall extremes were defined with 2-, 5-, 10-, 25-, 50-, and 100-year return periods. Figure 5 presents a comparison of frequency curves derived from the maximal daily rainfall in different time slices. If the time slice 1983-2022 is selected as reference baseline climate, the results show that the frequency curve derived from the first 20-year of the dataset tends to underestimate rainfall extremes; on the other hand, the frequency curve derived from the last 20-year overestimates the rainfall extremes. These indicates significant increases in the frequencies of extreme precipitation events in the late decades. Table 1 presents the statistics of frequency changes. It can be interpreted as follows. If the rainfall dataset in period 1983-2002 was used to design a drainage system

(usually designed with 10-year return period), the design might underestimate approximately 10% of rainfall extremes. In case the rainfall dataset in period 2003-2022 was employed, the design tends to be oversized (approximately 10%); however, under the context of climate change, the rainfall extremes are expected to be further intensified. Thus, additional inputs from climate model projections are critical to inform engineers in designing urban infrastructure.

With regard to serious inundation situation in Da Nang City recently, the Storm Son Ca triggered widespread heavy rainfall in a short-duration (Figure. 6). Many places experienced more than 300 mm of rainfall in 6-hour that exceptionally exceeds the capacity of the existing urban drainage system. As previously mentioned, the system was designed to drain out local rainfall with the frequency of 10- or 20-year return period.

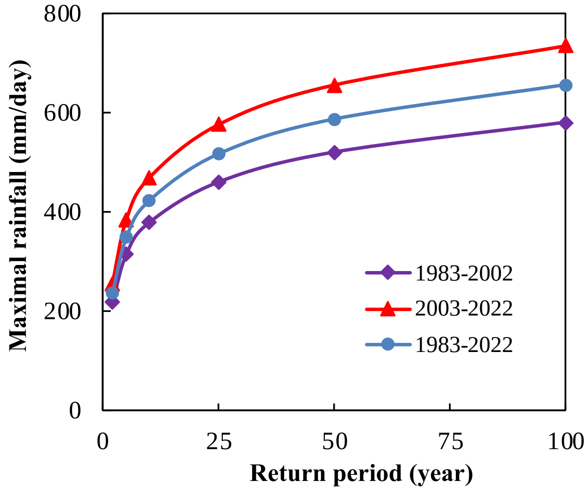

Figure 5: Frequency of rainfall extremes: the blue line was derived from the entire dataset; the purple and red lines were derived from 1983-2002 and 2003-2022 time slices, respectively.

Table 1: Statistics of changes (%) in estimates of rainfall extremes as compared to reference baseline climate (1983-2022)

	Return period (year)					
Time slices	**100**	**50**	**25**	**10**	**5**	**2**
1983-2002	-11.5	-11.2	-10.9	-10.3	-9.6	-7.6
2003-2022	12.1	11.8	11.5	10.9	10.2	8.3

Figure 6: Accumulated rainfall measured by automatic rain gauges around Da Nang City on October 14th, 2022

4. CONCLUSION

Vietnam has been classified among the six countries that most affected by climate change. Meteorological data demonstrates that recent extreme events are beyond the historical observation. Consequences were observed during the influence of Storm Son Ca when the urban drainage system in Da Nang City was completely defeated by the intensified flood. Other urban areas across Vietnam have been experiencing similar inundation problems. Understanding increases in rainfall extremes are crucial to inform adaptation options, including

engineering and non-engineering interventions. The former requires physical investment for prioritized infrastructure. Especially, the later urges updates on technical standards to promote climate resilient urban planning and infrastructure which will be further addressed in the next publication of this on-going research.

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