Climate trends and climate change scenarios in Ho Chi Minh City

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Abstract. This paper reviews the trends of climate and climate change scenarios in Ho Chi Minh City (HCMC). The linear regression method is used to determine the trend and variation of past climate (1980-2019) at Tan Son Hoa station. The annual average temperature tends to increase about 0.024°C/year ($r^2=0.54$) and the rainfall tends to increase about 6.03 mm/year ($r^2=0.67$). For temperature scenario, by 2030 the annual average temperature in the whole city will increase from 0.80-0.81°C (RCP4.5) and 0.92-0.98°C (RCP8.5). By 2050, it will increase 1.23-1.33°C (RCP4.5) and 1.55-1.68°C (RCP8.5). By 2100, it will increase 1.75-1.88°C (RCP4.5) and 3.20-3.55°C (RCP8.5) compared to the base period. Regarding rainfall scenario, in 2030, the city-wide average rainfall will increase by 12-21% (RCP4.5) and by 12-17% (RCP8.5). By 2050, the average rainfall is likely to increase by 13-15% (RCP4.5) and 15-17% (RCP8.5). By 2100, the average rainfall is likely to increase by 18-22% (RCP4.5) and 20-21% (RCP8.5) compared to the base period.

1. Introduction

HCMC has a tropical monsoon climate. A year is divided into two distinct seasons. The northeast monsoon months (dry season) from December to April and the southwest monsoon months (rainy season) from May through November.

The annual average temperature in HCMC is 27°C–28°C, and the hottest and coldest months of the year differ by just 3°C. In recent years, the annual average temperature has increased. The higher temperature increase in HCMC since the 1990s has coincided with the accelerated urbanization in the area. The urban heat island effect, which is likely to have contributed significantly to observed warming and may intensify further as urbanization continues.

Rainfall during the wet season accounts for 90–95% of the total annual. There is already high variation in rainfall, bringing both localized flooding and droughts. HCMC endures droughts, usually in March or April. In recent decades, there were extreme dry seasons in 1993, 1998, and 2002. Dry season drought in the future is likely more frequent.

This paper reviews the trends of climate and climate change scenarios in HCMC to provide current and future climate information for climate change mitigation and production planning, socio-economic development and disaster prevention in HCMC.
2. **Materials and methods**

2.1. **Methods**

2.1.1. **Climate Trend Analysis Method.**
The linear regression method is used to determine the trend and variation of past temperature and precipitation (1980-2019) at Tan Son Hoa Station in HCMC.

Linear regression attempts to model the relationship between two variables. One variable is considered to be an explanatory variable (times), and the other is considered to be a dependent variable (temperature and precipitation). A linear regression line has an equation of the form \( Y = a + bX \), where \( X \) is the explanatory variable and \( Y \) is the dependent variable. The slope of the line is \( b \), and \( a \) is the intercept (the value of \( Y \) when \( X = 0 \)). A valuable numerical measure of association between two variables is the correlation coefficient \( (R^2) \), which is a value between -1 and 1 indicating the strength of the association of the observed data for the two variables.

2.1.2. **Downscaling Dynamic Method.**
The climate change scenario in HCMC is calculated on four regional climate models (PRECIS, CCAM, RegCM, cIWRF). Thus, there are 12 calculation plans based on results from global climate model.

Based on the evaluation results for 4 climate models, in HCMC, the temperature scenario is calculated according to 8 plans from 3 models (4 plans of CCAM model, 3 plans of PRECIS model and a plan of cIWRF model), the precipitation scenario is calculated according to 3 plans of the PRECIS model.

![High-Resolution dynamical downscaling scheme for Viet Nam](image)

Figure 1. High-Resolution dynamical downscaling scheme for Viet Nam [1]

2.2. **Materials**
The trend and variation of past temperature and precipitation is based on observed data at Tan Son Hoa Station, with a reliable and long enough data series to calculated in the period of 1980-2019.
Global and regional climate models are the main tools used to forecast future climates, especially climate extremes. The following models is used to calculate high-resolution cc scenarios in HCMC: (i) The PRECIS model of Center’s Hadley Meteorology – United Kingdom, (ii) CCAM model of Commonwealth Scientific and Industrial Research Organization (CSIRO), (iii) RegCM model of International Centre for Theoretical Physics (ICTP), and (iv) clWRF model of United States (Table 1).

Table 1. Regional climate models used for updating climate change scenarios [1]

| No. | Regional climate models | Boundary conditions (global model) | Resolution | Data period |
|-----|-------------------------|------------------------------------|------------|-------------|
| 1   | CCAM                    | ACCESS1-0                          | 10km       | 1970-2005   | 2006-2099 | 2006-2099 |
| 2   | CCAM                    | ACCESS1-0                          | 10km       | 1970-2005   | 2006-2099 | 2006-2099 |
| 3   | CCAM                    | ACCESS1-0                          | 20km       | 1980-2000   | 2046-2065 | 2046-2065 |
| 4   | CCAM                    | ACCESS1-0                          | 25km       | 1960-2005   | 2006-2099 | 2006-2099 |
| 5   | CCAM                    | ACCESS1-0                          | 30km       | 1980-2000   | 2006-2099 | 2006-2099 |

3. Results and discussion

3.1. Trend of temperature and rainfall for the period of 1980-2019
The annual average temperature was 27.9°C. In the period from 1980 to 2019, the temperature at Tan Son Hoa station tended to increase by 0.024°C per year ($r^2=0.5416$) (Figure 2). In which, the lowest average temperature was 27.0°C (in 1987) while the highest was 28.5°C (in 1999).
January has the lowest average temperature of the year (27.3°C). The temperature then gradually increases, reaching 30.4°C in April. This is the highest temperature of the year. Then the temperature gradually decreases from April to July (28.1°C) and then increased, peaking in September (28.8°C) and then continuing to decrease until December (Figure 3).

![Figure 3. The monthly average temperature (°C) at Tan Son Hoa Station for the period of 1980-2019.](image)

In the period from 1980 to 2019, the annual rainfall at Tan Son Hoa Station tends to increase by 6.03 mm per year ($r^2=0.669$). The average annual rainfall was 1951 mm. The year with the lowest rainfall (1321mm) was 2002 and the year with the highest rainfall (2662 mm) was 2000 (Figure 4).

![Figure 4. Trend of annual average rainfall (mm) at Tan Son Hoa station for the period of 1980-2019.](image)

The rainy season from May to November gained an average total rainfall of 1798mm, accounting for 92% of the total annual rainfall. The dry season from December to April next year had a total rainfall of 153mm, accounting for only 8% of the total annual rainfall. The month with the highest average rainfall of the year is September (about 310mm) while the month with the lowest average rainfall of the year was February (approximately 10mm) (Figure 5).
3.2. *Climate change scenario in Ho Chi Minh City*

The average temperature in the base period (1986-2005) is around 26.7 - 27.6°C, the central area has a temperature of about 27.2-27.6°C, the suburban area is about 26.7-27.1°C. Thus, the central area has a temperature 0.5°C higher than the suburban area (Figure 6). The average rainfall is about 1500-1900mm, the highest in the northwest region (Cu Chi district) and decreases in the southeast region (Can Gio district) (Figure 7).

According to RCP 4.5 scenario, by 2030, the average temperature in HCMC will increase 0.80-0.81°C compared to the base period, the increase in the northeast region (Thu Duc City, District 12) is higher than the rest, by 2050, it will increase by 1.23-1.33°C, and by 2100, it will increase by 1.75-1.88°C, the increase in Can Gio district area is lower than the rest (Figure 8, Figure 9 and Figure 10).
According to the RCP 8.5 scenario, by 2030, the temperature increase 0.92-0.98°C, by 2050, the temperature increase 1.55-1.68°C and by 2100, the temperature increase 3.20-3.55°C compared to the baseline period, the increase in Can Gio district area is lower than the rest (Figure 11, Figure 12 and Figure 13).
According to the RCP 4.5 scenario, by 2030, the city-wide rainfall increase by 12-21%, by 2050, the rainfall increase by 13-15% and by 2100, the rainfall increase by 18-22% compared to the base period, the highest change in the region. Southeast (Can Gio district area).
According to the RCP 8.5 scenario, by 2030, the city-wide rainfall will increase in the range of 12-17%, by 2050, the rainfall will increase from 15% to 17% and by 2100, the rainfall will increase from 20% to 21% compared to the baseline period in which the highest change will appear in the Southeast region (Can Gio district area).
4. Conclusions
The climate of HCMC has changed in recent years. For the period of 1980-2019, the average annual temperature was 27.9°C and its trend increased by 0.024°C/year. The average temperature of April was the highest, however the temperature of January was the lowest. The annual rainfall was 1951 mm, and
its trend increased by 6.03mm/year. The rainy season between from May to November accounted for 92% while the dry season from December to April next year gained only 8% of the total annual rainfall.

According to the RCP 4.5 scenario, by 2030, the temperature in the whole city will increase from 0.80-0.81°C, by 2050, the temperature will increase from 1.23-1.33°C and by 2100, the temperature will increase from 1.75°C to 1.88°C compared to the base period. The increase in the northern region will be higher than the rest. According to the RCP 8.5 scenario, by 2030, the temperature in HCMC will increase from 0.92°C to 0.98°C, by 2050, the temperature will increase from 1.55°C to 1.68°C and by 2100, the temperature will increase in the range of 3.20-3.55°C compared to the base period.

According to the RCP 4.5 scenario, the city-wide average rainfall will increase by 12-21% in 2030, by 13-15% in 2050 and by 18-22% in 2100 compared to the base period. According to the RCP 8.5 scenario, the average rainfall will increase in the range of 12-17% in 2030, increase from 15-17% in 2050 and increase by 20-21% in 2100 compared to the base period. For both scenarios, the highest change will take place in the Southeast region (Can Gio District).

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