Research Paper

# INDICATORS OF CLIMATE CHANGE ACROSS THE SOUTH-CENTRAL REGION

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**ABSTRACT**

*In this study, we focus on the findings of the indicators of climate change across the South-Central region based on assessing the trends of temperature (mean, maximum and minimum) and rainfall as well as drought conditions. The change trends of climatic variables are tested by the simple linear method at significance level of 0.05 (corresponding to the 95% confidence level). The observation data is updated up to 2017. The results show that the annual mean temperature tends to increase at 15 stations, where, the increase in temperature in the dry season is greater than that in rainy season. The increases in annual temperature are mostly from 0.01 to 0.03 per year and accepted by the 90% confidence level. The increase trends of annual rainfall are mostly from 0.1 to 1.35% per year. The A index is mostly found by increase trend that the wet condition is found at most station. In addition, the increase trend of the drought condition defined by the decrease trend of the A index at some southern stations in the South-Central region. However, the trends of both rainfall and A index are not mostly at significance level of 0.05.*

**Keywords**: *Indicators of climate change, Rainfall, temperature, South-Central region.*

## 1. Introduction

Defining the indicators of climate change plays an important role in providing information and scientific basis for the response to climate change. Thus, the climate change assessment is one of the important topics of climate change studies. In reports of IPCC, the global climate change indicators are clearly defined by the increase in temperature, sea level rise and changes in rainfall as well as the decrease in global ice mass (IPCC, 2007, 2013). In Vietnam, climate change assessment has been considered in many studies since 1990s (Ngu and Hieu, 1991, 1999; Hieu, and Tuan, 1991, Lien, 2000). Over the past 10 years, studies on climate change assessment have been strongly developed. Indicators of climate change defined by assessing the changing trends of climatic variables has been clearly indicated (Ha and Tan, 2009; Thanh and Tan 2012; Ngu, 2008; Thang et al., 2010; Thang et al., 2016; Thang et al., 2017; Thang et al., 2013; Tan et al., 2010; Lien, 2000; Lien et al., 2007; Hang et al., 2009; Tuyen, 2007). Compiled from research results, adequate assessments on climate change indicators across Vietnam have been presented in reports of MONRE (MONRE, 2009, 2012, 2016).

However, the previous studies were mainly based on the data that updated up to 2010 or 2014. These studies mostly focused on the gen-

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eral climate variables and some of its extreme events. But, the drought/wet conditions are not considered, particularly for areas strongly impacted by droughts such as the South - Central region. In reality, the South-Central region has the lower annual rainfall than other climatic regions and has a long dry season, up to nine months of dry season (Ngu and Hieu, 2004). Thus, the issues of water shortage and drought seriously effect on socio-economic development and human's activities. In recent years, there have been many serious drought events in the South-Central region, such as the drought events in 1983, 1993 and 1998 (Thang et al., 2015) and in the 2015 - 2016 (DWR, 2016). In addition, the significance level of the trend was not tested.

From these above issues mentioned, we focus on defining the climate change indicators in the South-Central region through analyzing the trends of general variables (temperature and rainfall) and drought/wet conditions based on the observation data updated up to 2017.

## 2. Data and method

### *2.1. Data used*

In this study, we use observation data of temperature (T2m), maximum temperature (Tx), minimum temperature (Tn), rainfall (R) and evaporation (E). These data are updated up to 2017 from 15 stations in the South-Central region (Table 1).

**Table 1**. The information of 15 stations used in the study

| No | Name of stations | longitude | latitude | Variables |
|---|---|---|---|---|
| 1 | Da Nang | 108.18 | 16.03 | T2m, Tx, Tn, E, R |
| 2 | Tam Ky | 108.50 | 15.55 | T2m, Tx, Tn, E, R |
| 3 | Tra My | 108.22 | 15.35 | T2m, Tx, Tn, E, R |
| 4 | Ba To | 108.72 | 14.77 | T2m, Tx, Tn, E, R |
| 5 | Quang Ngai | 108.78 | 15.13 | T2m, Tx, Tn, E, R |
| 6 | Hoai Nhon | 109.02 | 14.53 | T2m, Tx, Tn, E, R |
| 7 | Quy Nhon | 109.22 | 13.77 | T2m, Tx, Tn, E, R |
| 8 | Son Hoa | 108.98 | 13.05 | T2m, Tx, Tn, E, R |
| 9 | Tuy Hoa | 109.28 | 13.08 | T2m, Tx, Tn, E, R |
| 10 | Nha Trang | 109.20 | 12.25 | T2m, Tx, Tn, E, R |
| 11 | Cam Ranh | 109.17 | 11.95 | T2m, Tx, Tn, E, R |
| 12 | Truong Sa | 111.92 | 8.65 | T2m, Tx, Tn, E, R |
| 13 | Phan Thiet | 108.10 | 10.93 | T2m, Tx, Tn, E, R |
| 14 | Ham Tan | 107.75 | 10.68 | T2m, Tx, Tn, E, R |
| 15 | Phu Quy | 108.93 | 10.52 | T2m, Tx, Tn, E, R |

### *2.2 Methods used*

*2.2.1 Wet/drought conditions defined*

Wet/drought conditions cannot be observed by measuring instruments at meteorological and hydrological stations. Thus, the question is how can drought be identified? Many authors show that it is possible to identify wet/drought conditions through indices such as Standardized Precipitation Index (SPI) and accumulated rainfall, etc.

As mentioned in many studies (Ngu and Hieu, 2004; Tri, 2015; Mau, 2015; Thang, 2015; Thang et al., 2015) the A (or K) index is the suitable index for identifying the wet/drought con-

ditions in Vietnam because this index is a type of water balance equation between the water in (via rainfall) and water out (via evaporation). Basically, a water balance equation can be used to describe the flow of water in and out of a system. A system can be one of several hydrological domains, such as a column of soil or a drainage basin.

In this study, the A index is defined as follows:

$$A = \frac{R}{E} \quad (1)$$

Where R is the rainfall; E is the evaporation.

According to this method, the drought condition occurs when the A index<1.That is, the amount of evaporation is greater than the amount of rainfall. The stronger drought condition is found when the A index is smaller. The wet condition occurs when the A index>1.

*2.2.2 Assessment of climate change*

**Climate trend defined:**

For identifying climate change trend in the South-Central, we use the simple linear regression equation as used in many studies (IPCC, 2007, 2013; MONRE, 2009, 2012, 2016; Thang et al., 2015). In statistics, simple linear regression is a linear regression model with a single explanatory variable. That is, it concerns two - dimensional sample points with one independent variable and one dependent variable (conventionally, the x and y coordinates in a Cartesian coordinate system) and finds a linear function (a non-vertical straight line) that, as accurate as possible, predicts the dependent variable values as a function of the independent variables. The adjective simple refers to the fact that the outcome variable is related to a single predictor.

Given a data set X: $x_1, x_2, x_3, \ldots, x_n$ of n statistical units. The remainder of the article assumes an ordinary least squares regression. In this case, the slope of the fitted line is equal to the correlation between y and x corrected by the ratio of standard deviations of these variables. The intercept of the fitted line is such that the line passes through the center of mass of the data points.

Considering the simple linear equation:

$$x_t = b_0 + b_1 t \quad (2)$$

where

$$b_1 = \frac{\sum_{t=1}^{n}(x_t - \bar{x})(t - \bar{t})}{\sum_{t=1}^{n}(t - \bar{t})^2}$$

$$b_0 = \bar{x} - b_1 \bar{t}$$

We can find:

- $b_1$: the slope of the fitted line (linear changing rate)

- $b_o$: mean value mass of the data points

From that, we can find the increase/decrease rates during the study period (D) as:

$$D = b_1 n \quad (3)$$

Where: n is sample sizes

We can define the correlation coefficient ($r_{xt}$):

$$r_{xt} = \frac{\sum_{t=1}^{n}(x_t - \bar{x})(t - \bar{t})}{\left[\sum_{t=1}^{n}(x_t - \bar{x})^2 \sum_{t=1}^{n}(t - \bar{t})^2\right]^{\frac{1}{2}}} \quad (4)$$

Testing the trend:

The rxt and sample sizes (n) are the criteria for deciding the confidence of the trend. In this study, we test the significance level at 0.05 (corresponding to the confidence of 95%) for the trends.

Assume that: H0 is corresponding to r=0 (*)

The first criteria tested (*) is:

r - 0≥ dα : r is significance level

r – 0< dα : r is not significance lvel

dα has been sure to:

$H_0$ is true : $P\{|r-0| \geq d\alpha\} = \varepsilon$

The t is defined by the below equation:

$$t = \frac{r}{\sqrt{1-r^2}/\sqrt{n-2}} \quad (5)$$

In statistics, the t has the Student probability, then we have:

$|t| \geq t\alpha$ : r is significance level

$|t| < t\alpha$ : r is not significance level

If $H_0$ is true, we have $P\{|t| \geq t\alpha\} = \alpha$

Following the above theory, based on the rxt and sample sizes (n), we can identify the trend of climate variable that is accepted at the 0.5 significance level (or at the 95% confidence level) as listed in the Table 2.

**Table 2.** The correlation coefficients corresponding to sample sizes (n) at the 95% confidence level for defining the significance level of 0.05

| n-2 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|
| α = 0.05 | 0.576 | 0.423 | 0.349 | 0.304 | 0.273 | 0.250 | 0.232 | 0.217 | 0.205 | 0.195 |

Climate variability defined:

For defining the annual variability, we use the coefficient of variation (Cv). The Cv (%) is defined by the below equation:

$$C_v = \frac{S_x}{\bar{x}}.100 \quad (6)$$

Where $S_X$ is the standard deviation; $\bar{x}$ is the mean value.

## 3. Results

### *3.1 Changes in temperature*

Table 3 presents the rates of temperature change (T2m, Tx, Tn) (°C per year) at 15 stations. In Table 3, the values are bold and shaded in follow that reflect the trend of change that satisfies the 0.05 significance level under the r test. These results show that the trends of temperature are increasing at stations in the South-Central region. These increase trends are at the significance level of 0.05 at most stations. However, some trends are not at the significance level of 0.05; for example at the Da Nang, Son Hoa, Hoai Nhon and Phu Quy stations (Table 3).

**Changes in average temperature (T2m):**

During 1961 - 2017, the annual T2m has the increase trend at 15 stations. Across the South - Central region, the annual T2m rose from 0.01 to 0.03°C/year, corresponding to the rate of 0.57 to 1.7°C between 1961-2017. However, the maximum increase rate is only found at Cam Ranh station. In fact, the increase in temperature is around from 0.01 to 0.02°C/year, corresponding to the rate of 0.57 to 1.14°C between 1961-2017. Excluding Cam Ranh station, the most significant increases of annual T2m are found at the stations: Tra My, Ba To and Truong Sa. In contrast, the lower increases of annual T2m are found most stations in the South-Central region. The increase trend of annual T2m is found as the significance level of 0.05; Particularly, the trend of Son Hoa station does not reach the significance level of 0.05 (Table 3).

Interestingly, the T2m in the dry season has more increase rate than that in the rainy season. During dry months, the annual T2m has a typical increase from 0.01 to 0.03°C/year. In contrast, the T2m trend in the rainy season is slight from 0.0°C/year to 0.01°C/year at most stations. In addition, the trend in the dry season has the significance level of 0.05 at most stations, particularly in Da Nang and Son Hoa stations, which does not reach the significance level of 0.05. In the rainy season, the T2m trend does not reach the significance level of 0.05 at more stations, for example at Tam Ky, Hoai Nhon, Son Hoa, Ham Tan and Phu Quy stations (Table 3).

**Changes in maximum temperature (Tx):**

The increase trend of annual Tx during 1961-2017 is found at most stations. Where, the increase rates are mostly from 0.01 to 0.04°C/year, corresponding to the increase rate of 0.57 to over 2.0°C between 1961 and 2017. In particular, the greatest increase rate is found at the Cam Ranh and Truong Sa stations. However, the trend of annual Tx is not found at the Nha Trang station. Remarkably, the increase trends of annual Tx do not reach the significance level of 0.05 at

most stations. The increase trends at Ba To, Son Hoa and Nha Trang stations do not reach the significance level of 0.05 (Table 3).

The increasing trend of Tx is relatively different between the rainy season and the dry season. The Tx in the dry season experiences the increase trend at 15 stations, with increases in 0.01 to 0.05°C/year. In particular, the greatest increase rates are also found at the Cam Ranh and Truong Sa stations. Additionally, the increase trend at Nha Trang station is not found at Nha Trang station. For the dry season, the increase trend of Tx satisfies the significance level of 0.05 at most stations. In contrast, the trend does not reach the significance level of 0.05 at Quy Nhon, Son Hoa and Nha Trang stations (Table 3). For the rainy season, the change of Tx is found from -0.01 to 0.04°C/year. The greatest increase rates are from 0.03 to 0.04°C/year found at Cam Ranh and Truong Sa stations, respectively. However, the decrease rate of Tx is found at Son Hoa station, with the rate of -0.01°C/year. In addition, the change trend is not clearly found at Da Nang, Tra My, Ba To, Quang Ngai, Nha Trang and Phu Quy stations. The trend of Tx in the rainy season reaches the significance level of 0.05 found at 7/15 stations (Tam Ky, Hoai Nhon, Quy Nhon, Tuy Hoa, Cam Ranh, Truong Sa and Phan Thiet stations) (Table 3).

From these above analyses, the annual and dry season Tx are likely to increase at most stations in the South-Central region. In addition, the increase trend of the annual and dry season Tx reaches the significance level of 0.05 at most stations. However, the increase trend in the rainy season Tx is not clearly found at 6 stations. Remarkably, the decrease trend is found at the Son Hoa station, with the decrease rate of 0.01°C/year.

**Changes in minimum temperature (Tn):**

The results show that the increase trends of the annual and both two seasons are found at most stations. Moreover, the trend of Tn is not much variable among 15 stations. Additionally, the significance level of 0.05 is found at most trends of Tn. During 1961-2017, Tn tends to increase, with a typical increase from 0.01 to 0.03°C/year. In particular, the increase trend of dry Tn is greater than the increase trend of the rainy Tn. In terms of the significance level of 0.05, the increase trend of Tn satisfies this significance level at most stations. In contrast, the trend did not meet the significance level of 0.05 at Son Hoa station (dry season), Hoai Nhon and Truong Sa (rainy season) and Hoai Nhon (annual) (Table 3).

The Table 3 shows the greatest increase trend of annual Tn (0.03°C/year) at Da Nang, Ba To, Nha Trang and Phan Thiet stations. In the dry season, the greatest increase trend (0.03°C/year) is found at Da Nang, Tra My, Ba To, Quang Ngai, Cam Ranh and Ham Tan stations. In the rainy season, the greatest increase trend is found at Da Nang, Ba To, Nha Trang and Phan Thiet stations. In contrast, the increase trend of Tn is not clearly determined at some stations such as Hoai Nhon (rainy season and annual) and Truong Sa (rainy season) stations.

In general, the trend of Tn is more clearly found than the of T2m and Tx. The trend of Tx is much variable among stations than those of T2m and Tn. Averaging values from 15 stations in the South-Central region, the increase rate is from 0.01 to 0.02 found by T2m, Tx and Tm. However, the increase rate of rainy season Tn is greater than that of T2m and Tx. Referring the contributing to the increase rate in T2m at each station, the contribution of Tn is more than that of Tx.

**Table 3**. Changing rate of T2m, Tx and Tn (°C/year) (the trend is at significance level of 0.05 is bold and shaded by yellow color)

| Station | T2m | | | Tx | | | Tn | | |
|---|---|---|---|---|---|---|---|---|---|
| | Dry season | Rainy season | Annual | Dry season | Rainy season | Annual | Dry season | Rainy season | Annual |
| Da Nang | 0.01 | 0.01 | 0.01 | 0.02 | 0.00 | 0.01 | 0.03 | 0.03 | 0.03 |
| Tam Ky | 0.02 | 0.01 | 0.01 | 0.03 | 0.02 | 0.03 | 0.02 | 0.01 | 0.02 |
| Tra My | 0.03 | 0.01 | 0.02 | 0.02 | 0.00 | 0.01 | 0.03 | 0.01 | 0.02 |
| Ba To | 0.02 | 0.01 | 0.02 | 0.02 | 0.00 | 0.01 | 0.03 | 0.03 | 0.03 |
| Quang Ngai | 0.01 | 0.01 | 0.01 | 0.02 | 0.00 | 0.02 | 0.03 | 0.02 | 0.03 |
| Hoai Nhon | 0.01 | 0.00 | 0.01 | 0.02 | 0.02 | 0.02 | 0.01 | 0.00 | 0.00 |
| Quy Nhon | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 |
| Son Hoa | 0.01 | 0.00 | 0.01 | 0.01 | -0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Tuy Hoa | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Nha Trang | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.02 | 0.03 | 0.03 |
| Cam Ranh | 0.03 | 0.02 | 0.03 | 0.05 | 0.03 | 0.04 | 0.03 | 0.02 | 0.02 |
| Truong Sa | 0.03 | 0.01 | 0.02 | 0.04 | 0.04 | 0.04 | 0.02 | 0.00 | 0.01 |
| Phan Thiet | 0.01 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 |
| Ham Tan | 0.03 | 0.00 | 0.01 | 0.03 | 0.01 | 0.02 | 0.03 | 0.01 | 0.02 |
| Phu Quy | 0.02 | 0.00 | 0.01 | 0.02 | 0.00 | 0.01 | 0.02 | 0.01 | 0.02 |
| **South-Central region** | 0.02 | 0.01 | 0.01 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 |

***3.2. Changes in rainfall and wet/drought conditions***

The results of calculating the changes in precipitation and A index as well as determining the trend at the significance level of 0.05 are presented in Table 4. In general, the rainfall trend tends to increase across most stations in the South-Central region, with the greatest increase rate of up to 2.89%/year of dry season at Tuy Hoa station, corresponding to the increase rate of 164.7% between 1961 and 2017. However, the trend of rainfall does not have the significance level of 0.05 at most stations. According to the increase in rainfall, index A also tends to increase at most stations, with the greatest increase rate of 0.3%/year of dry season at Tra My station, corresponding to the increase rate of 17% between 1961 and 2017. The increase in A index also does not have the significance level of 0.05 at around half the number of stations. On averaging values of 15 stations in the South-Central region, the annual rainfall has an increase rate of 0.71%/year, corresponding to the increase rate of 40.47% between 1961 and 2017. In particular, the increase rate of rainfall is found by greater values in the dry season than in the rainy season. Where, the increase rates are found by 1.46%/year and 0.25%/year for dry and rainy seasons, respectively. The A index has an increase rate from 0.01%/year (rainy season) to

0.07%/year (dry season) and 0.04% of increase rate of annual A index.

**Changes in rainfall:**

During 1961-2017, the increase trend of dry and rainy seasons as well as annual is found at most stations. In contrast, the slight decrease in the rainfall trend is found at Ham Tam (dry season, rainy season and annual) and Phu Quy (dry season and annual). The significance level of 0.05 testing shows that trend of rainfall is not significance level found at most stations.

During 1961-2017, the rainfall of dry season has an increase trend at most stations in South-Central region, with the increase rate of value ranges from 0.4%/year (Phan Thiet) to 2.89%/year (Tuy Hoa). In contrast, the decrease trend with slightly rate is found at Ham Tan (-0.97%/year) and Phan Thiet (-0.13%/year) stations. The trend of rainfall has the significance level of 0.05 that is found at the Da Nang, Tuy Hoa, Nha Trang, Truong Sa, Phan Thiet and Ham Tan stations, in which, the decrease trend at Ham Tan has the significance level of 0.05 (Table 4). It is noteworthy that the total amount of rainfall in the dry season in the South-Central is very small. In fact, the contribution to total amount of rainfall in the dry season is not much. For that, just an unseasonal heavy rain event in the dry season also significantly changes the total amount of rainfall in the dry season and leads to a change in trend of time-series data.

The Table 4 also shows the increase trend of rainfall in the rainy season with a slightly increase rate from 0.17%/year (Nha Trang) to 1.02%/year (Truong Sa). In addition, we also find the decrease trend of rainfall in the rainy season at Da Nang, Tra My, Quang Ngai and Ham Tan stations. However, the decrease rate in rainfall at these stations is very low. The significance level of 0.05 is only found at 4 stations (Son Hoa, Tuy Hoa, Nha Trang and Phan Thiet). These stations have the 95% of confidence that are located in the southern areas of the South-Central (Table 4). It is very important that the amount of rainfall in the South-Central is very huge. Thus, the contribution in the total value in the rainy season is relatively large.

The annual rainfall has the increase trend at most stations in the South-Central region. The increase rate is found as from 0.1 %/year (Phu Quy) to 1.41%/year (Ba To), corresponding to the increase rate from 5.7% to 80.37% between 1981-2017, respectively. The decrease trend of annual rainfall is found at Ham Tan station, with the decrease rate of 0.72%/year, corresponding to the rate of 41.04%. The significance level of 0.05 in the annual rainfall trend is found at Tuy Hoa, Ha Trang, Phan Thiet and Ham Tan stations (Table 4).

From these above analyses, we find that the increase trend of rainfall at most stations found in annual and both two seasons. However, we also find the decrease trend of rainfall in dry season at Ham Tan and Phu Quy stations which are located in the southern areas of the South-Central region. These decrease trends show the increase in intensity of drought in the southern areas of South-Central region.

**Changes in A index:**

According to the increase trend of rainfall, the A index also has the increase trend at most stations. The increase trend of the A index is found in both dry and rainy seasons. The number of stations has the trend of A index at the significance level of 0.05 that is more than the trend of rainfall. In Averaging from 15 stations in the South-Central region, the annual A index has an increase trend with the trend rate of 0.04%/year. In which, the increase rate of rainy season is smaller than the annual trend. However, the increase rate of dry season is bigger than the annual trend. The trend of the A index is not clearly found at Phan Thiet station for annual and both two seasons. Especially, the decrease trend of the A index is found at the Ham Tan and Phu Quy stations (Table 4).

For the dry season, the increase rate of the A index is mostly from 0.01%/year to 0.3%/year. In which, the greatest increase rates are found at the northern stations of the South-Central region.

The very small increase rates mostly found from Hoai Nhon station to Nha Trang station. The trend of dry season A index is not clearly found at Phan Thiet station. The increase in the intensity of drought condition is found by the decrease rate of the A index at Ham Tan and Phu Quy stations. In dry season, the trend of A index has the significance level of 0.05 at most stations (Table 4).

For the rainy season, the results in the Table 4 show that the A index has the increase trend at many stations (Tam Ky, Tra My, Ba To, Son Hoa, Hoai Nhon, Cam Ranh and Truong Sa). The increase rate of A index is found from 0.01%/year to 0.03%/year. However, the change trend is not clearly found at 7 stations (Da Nang, Quang Ngai, Quy Nhon, Nha Trang, Phan Thiet, Ham Tan and Phu Quy). The trend of A index in the rainy season has the significance level of 0.05 that is found at some stations (Tam Ky, Tra My, Ba To, Son Hoa, Cam Ranh and Truong Sa) (Table 4). As can be seen, in the period 1961-2017, wet conditions in the rainy season in the South -Central region has an increase trend at many stations that having the increase trend of A index. However, the changing trend of wet condition in the rainy season is not clearly found at many stations that the trend of A index is not found (Table 4).

**Table 4.** Rate of changes in rainfall and drought index (A index) (% per year) (the trend is at significance level of 0.05 is bold and shaded by yellow color)

| Station | R | | | A | | |
|---|---|---|---|---|---|---|
| | Dry season | Rainy season | Annual | Dry season | Rainy season | Annual |
| Da Nang | 1.89 | -0.04 | 0.72 | 0.05 | 0.00 | 0.02 |
| Tam Ky | 2.46 | 0.44 | 1.28 | 0.22 | 0.03 | 0.11 |
| Tra My | 2.64 | -0.04 | 1.08 | 0.30 | 0.03 | 0.15 |
| Ba Tơ | 2.26 | 0.94 | 1.41 | 0.21 | 0.03 | 0.11 |
| Quang Ngai | 1.09 | -0.32 | 0.19 | 0.07 | 0.00 | 0.03 |
| Hoai Nhon | 1.86 | 0.24 | 0.86 | 0.05 | 0.01 | 0.02 |
| Quy Nhon | 1.03 | 0.25 | 0.57 | 0.01 | 0.00 | 0.01 |
| Son Hoa | 1.34 | 0.39 | 0.33 | 0.05 | 0.01 | 0.02 |
| Tuy Hoa | 2.89 | 0.39 | 1.35 | 0.03 | 0.01 | 0.01 |
| Nha Trang | 1.30 | 0.17 | 0.70 | 0.01 | 0.00 | 0.00 |
| Cam Ranh | 1.77 | 0.37 | 0.94 | 0.04 | 0.01 | 0.02 |
| Trường Sa | 2.05 | 1.02 | 1.42 | 0.12 | 0.04 | 0.07 |
| Phan Thiet | 0.40 | 0.36 | 0.37 | 0.00 | 0.00 | 0.00 |
| Ham Tan | -0.97 | -0.59 | -0.72 | -0.02 | 0.00 | -0.01 |
| Phu Quy | -0.13 | 0.17 | 0.10 | -0.02 | 0.00 | -0.01 |
| **South-Central region** | **1.46** | **0.25** | **0.71** | **0.07** | **0.01** | **0.04** |

## 4. Conclusion and discussion

From the above results of the calculation and analysis, some indicators of climate change in the South-Central region can be found as:

**Changes in temperature:**

It can be seen that the clearest indicator of temperature (T2m, Tx and Tn) is the increase trends during 1961-2017 in the South-Central region, having the significance level of 0.05 at most stations

- Average temperature (T2m): The increase

rate of T2m is mostly found from 0.01°C/year to 0.03°C/year. In which, the increase rate of T2m in the dry season is greater than in the rainy season. Averaging from 15 stations across the South-Central region, the T2m has the increase rates that are 0.02, 0.01 and 0.01°C/year corresponding to the dry season, rainy season and annual, respectively.

- Maximum temperature (Tx): The Tx has an increase trend at most stations in the South-Central region. However, the increase rate is much variable among stations, with the rate defined from 0.0°C/year (mostly in the rainy season) to 0.05°C/year (mostly in the dry season). Thus, the annual Tx also has the huge range of increase rate, from 0.01°C/year to 0.04°C/year. On average from 15 stations, the increase rate in the dry season, rainy season and annual is 0.02, 0.01 and 0.02°C/year, respectively.

- Minimum temperature (Tn): The increase rate of the Tn is found from 0.0 to 0.03°C/year at stations in the South-Central region. However, the increase rate is mostly ranged from 0.02 to 0.03°C. Averaging in South-Central region, the increase rate of the Tn is similar in the dry season, the rainy season and annual, with the increase rate that is 0.02°C/year. In general, the increase rate of Tn is slightly higher than increase rate of the Tx.

Changes in rainfall and wet/drought conditions:

- Rainfall (R): Rainfall has the increase trend in both dry and rainy seasons at most stations in the South-Central region. The decrease trend is only found at southern stations of region (Ham Tan, Phu Quy). The significance level of 0.05 is not found at most stations. On average from 15 stations, the increase rate in the dry season, rainy season and annual is 1.46, 0.25 and 0.71%/year, respectively.

- Wet/drought conditions: During 1961-2017, drought condition in the dry season in the South-Central region does not clearly change or slightly decrease at many stations. In particular, the increase in intensity of drought is found at stations in the south of the South-Central region. In the rainy season, the increase in the wet condition is found at most stations. However, the changing trend of the wet condition is not found at many stations in the center and south of the South-Central region.

**Discussion:**

In this study, the A index is only calculated for data at the 6-month scale (for dry and rainy seasons). Thus, the A index at the season scale does not reflect the extremes of the wet/drought conditions in the South-Central region.

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