Analysis of changes in daily temperature and precipitation extreme in Jakarta on period of 1986-2014

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Abstract. Climate change due to an increase in greenhouse gas concentrations has led to changes in extreme climate events. IPCC 2007 already predicted that average global temperatures would reach 0.74° C in the last 100 years (1906-2005). A study on the temperature index trends and extreme precipitation in the period of 1986-2014 in Jakarta are represented by 5 weather stations. Daily of maximum temperature, minimum temperature, and precipitation data are calculated using RCLimDex Software so that temperature and rainfall index data are obtained. The indexes are extreme climate indexes defined by ETCCDMI (Expert Team for Climate Change Detection Monitoring and Indices). The indexes consist of TN10p, TN90p, TX10p, TX90p, TNn, TNx, TXn, TXx, DTR, RX1day, RX5day, RCPTOT, CDD, CWD, and R95p. The purpose of this research is to know the change of temperature and precipitation characteristics from observation result in Jakarta by using index calculation. The results show that Jakarta has number of hot days according to the trends which are generally increasing. It can cause the temperature in Jakarta to get hotter. However, for the rainfall, the upward or downward trend is not significant, so it can be said there is no change in precipitation in Jakarta during 1986-2014.

1 Introduction

In the recent years, climate change has become a significant highlight among researchers in the field of atmospheric science. It is known that there is an increase in average global air temperatures predicted to reach 0.74° C in the last 100 years (1906-2005) [1]. The increase in global air temperature has an impact on the increasing frequency of extreme weather events, especially extreme temperatures. Solomon et al. (2008) suggested that climate change can extend the frequency of occurrence and duration of extreme temperatures [2]. It is also stated that global warming encourages a change in the climate system [3]. Therefore, it is necessary to observe the events of climate change by defining the climate index for extreme climate analysis.

The increase in global temperature is expected to cause other changes such as rising sea levels, increased intensity of extreme weather phenomena, and changes in the number and pattern of precipitation. It is similar to the phenomena which occur in Indonesia. The increase in global temperatures impacts rainfall with high intensity is more common, and the amount of rainfall is slightly higher [4].

Climate change and global warming are a phenomenon that is clearly observed on a global scale [5]. Therefore, research is needed to know the changes that are happening and the possibility of future changes.

In this study, analysis of extreme climate index uses RCLimindex. RCLimindex is an R-developed application developed by the Climate Research Branch of the Meteorological Service of Canada to detect and monitor climate change with a primary focus on extreme events [6]. RCLimindex has 27 climate indexes consisting of 16 temperature indexes and 11 precipitation indexes.

The purpose of this research is to know the change of temperature and rainfall characteristics from observation result in Jakarta by using index calculation. Extreme climate analysis needs to be done especially in susceptible areas of disasters due to extreme events [7].

The results obtained in this study are expected to be useful to anticipate the possibility of climate change due to global warming and local factors that can have a negative impact on the development of various sectors, environmental, development, social and political.

2 Material and method

The data used in this study are daily minimum temperature data, daily maximum temperature, and daily rainfall data on period 1986 to 2014 from the 5 weather stations spread in Jakarta which is assumed to represent Jakarta. The weather stations are Tangerang Selatan (06°15'20.8" S and 106°45'00" E), Curug (6°14'00" S and 106°39'00" E), Tanjung Priok (6°6'28.2" S and 106°52'49.6" E), Kemayoran (6°11'00" S and

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106°50'00" E), and Cengkareng 6°7'32.65" S and 106°39'28.29" E).

Data that has been obtained are conducted quality control, where the empty data is replaced by value -99.9 and outlier data which are suspected as error input are not used. But the outlier data which due to extreme weather remains and are included in the analysis.

The period used as the baseline is the 1986 – 2010. Data is processed using the RclimDex software. The calculated index is the index set by the ETCCDMI (Expert Team for Climate Change Detection Monitoring and Indices) with specific user-specified value (Table.1). In this research, 9 indexes of temperature and 6 indexes of rainfall are used. Research using CLIMDEX has been done on the previous researches [7],[8],[9]. The specific indexes which are used in this research are:

Table 1. ETCCDMI Indexes used in the study.

ID	Indicator name	Definitions	Units
TXx	Max Tmax	Monthly maximum value of daily maximum temp	°C
TNx	Max Tmin	Monthly maximum value of daily minimum temp	°C
TXn	Min Tmax	Monthly minimum value of daily maximum temp	°C
TNn	Min Tmin	Monthly minimum value of daily minimum temp	°C
TN10p	Cool nights	Percentage of days when TN<10th percentile	Days
TN90p	Warm nights	Percentage of days when TN>90th percentile	Days
TX10p	Cool days	Percentage of days when TX<10th percentile	Days
TX90p	Warm days	Percentage of days when TX>90th percentile	Days
DTR	Diurnal temp range	Monthly mean difference between TX and TN	°C

RX1day	Max 1-day precipitation amount	Monthly maximum 1-day precipitation	Mm
RX5day	Max 5-day precipitation amount	Monthly maximum consecutive 5-day precipitation	Mm
CDD	Consecutive dry days	Maximum number of consecutive days with RR<1mm	Days
CWD	Consecutive wet days	Maximum number of consecutive days with RR>=1mm	Days
PRCPTOT	Annual total wet-day precipitation	Annual total PRCP in wet days (RR>=1mm)	mm
R95p	Very wet days	Annual total PRCP when RR>95 th percentile	Mm

3 Result and discussion

The changes that occur as a result of the calculation of RCLimdex are checked for its significance. Its significance is tested with p-value and comparison of estimate slope and error slope. Significant changes will be recognized if the p-value is less than 0.05 and estimate slope is larger than the slope error value [10].

3.1 Maximum temperature

Percentage number of days where the maximum temperature is less than the 10th percentiles determined with the TX10P index or called cool days. Fig. 1 (a) shows that TX10P on Tangerang Selatan, Kemayoran, and Cengkareng weather stations significantly decrease from 1986 to 2014 with slope value on Tangerang Selatan weather station is -0.448, Kemayoran weather station is -0.24, and Cengkareng weather station is -0.31. While on the other weather stations have no significant changes. In figure 1 (b) shows the TX90P index. The TX90P index is a hot day or called warm days which is defined as a percentage number of days where the maximum temperature is more than the 90th percentiles. From the picture show that TX90P on Tangerang Selatan weather station experiences the significant decrease in slope value -0.709. While on Kemayoran and Cengkareng weather station experience significant increase with the slope value of 0.591 and 0.438. And on the other weather stations have no significant changes.

TXN index is an index which represents a minimum value of maximum temperature, and TXX index represents the maximum value of maximum temperature (Fig. 1 (c). and (d).). TXN is the coldest temperature on the day or called most cooling days, and

Fig. 1. Extreme of Maximum Temperature Indexes including (a) TX10p (b)TX90p, (c) TXn, and (d) TXx on CGK (Cengkareng weather station), CRG (Curug weather station), KMY (Kemayoran weather station), PBT (Tangerang Selatan weather station), and PRK (Priok weather station).

TXx is the warmest temperature on the day or called warmest days [11]. The figure shows that no weather station has significant changes of TXN index, whereas there are significant changes on Tangerang Selatan and Kemayoran weather station with the slope value of 0.063 and 0.057.

3.2 Minimum temperature

Fig. 3 (a). shows TN10P index or called cool night, where the percentage of the number of nights for the minimum temperature is smaller than the 10th percentile in a year. The tendency of the TN10P index to decline significantly in the period 1986-2014 is seen in all weather station. The slope value of Tangerang Selatan weather station is -0.633, Curug weather station is -0.255, Priok weather station is -0.726, Kemayoran weather station is -0.92 and Cengkareng weather station is -0.639.

TN90P index states a warm night, defined as the percentage of the number of nights in a year with a maximum temperature value more than the 90th percentile (Fig. 3 (b).). The picture of the TN90P index shows the significant increase on all weather stations. The slope value of Tangerang Selatan weather station is 1.149, Curug weather station is 0.473, Priok weather station is 1.461, Kemayoran weather station is 0.935, and Cengkareng weather station is 1.188.

Beside TN90P, there are TNN and TNX indexes which each one shows the minimum and maximum of minimum temperature (Fig. 3 (c). and (d).). The TNN

index pattern shows there is increasing changes in all weather stations, but only Tangerang Selatan, Priok, and Kemayoran that have significant value. The slope value of Tangerang Selatan is 0.076, Priok is 0.065, and Kemayoran is 0.07. This indicates that on those stations region experiences a minimum temperature shift towards 2014 getting warmer.

Then for TNX index is seen the significant increase in all weather stations with slope value on Tangerang Selatan weather station is 0.082, Curug weather station is 0.027, Priok weather station 0.057, Kemayoran weather station is 0.061, and Cengkareng weather station 0.052.

Fig. 2. Series of diurnal temperature range on CGK (Cengkareng weather station), CRG (Curug weather station), KMY (Kemayoran weather station), PBT (Tangerang Selatan weather station), and PRK (Priok weather station).

Fig. 3. Extreme of Minimum Temperature Indexes including (a) TN10p (b)TN90p, (c) TNn, and (d) TNx on CGK (Cengkareng weather station), CRG (Curug weather station), KMY (Kemayoran weather station), PBT (Tangerang Selatan weather station), and PRK (Priok weather station)

Diurnal Temperature Range (DTR) is the monthly average difference between maximum temperature and minimum temperature. DTR tends to decline during the period 1986-2014 (Fig. 2.) in all weather stations except on Tangerang Selatan. The changes on Tangerang Selatan weather station tends to increase with a slope of 0.004 but not significant. While Priok weather station decreases with slope -0.076 and Cengkareng weather station also decreases with slope value 0,021 significantly. The changes on Kemayoran and Curug weather station also decrease but not significant.

3.3 Rainfall

The maximum amount of rainfall in a day is expressed by the RX1day index as shown in fig. 4 (a). In the period of 1986-2014, the largest rainfall in a single day tends to rise significantly only in Kemayoran weather station with slope value 2.589, other weather stations do not have significant changes.

The RX5day index (Fig. 4 (b).) represents the highest amount of rainfall measured in five consecutive days. This index also has a significant increasing trend during the period 1986-2014 only on Kemayoran weather station with slope 6.688, while others have no significant changes.

Fig. 4. Precipitation Indexes including (a) RX1day, (b) RX5day, (c) CDD, and (d) CWD on CGK (Cengkareng weather station), CRG (Curug weather station), KMY (Kemayoran weather station), PBT (Tangerang Selatan weather station), and PRK (priok weather station).

Fig. 5. shows the amount of rainfall in a year represented by the Annual Index of Total Wet Day Precipitation (PRCPTOT). The amount of annual rainfall in Jakarta from 1986 to 2014 is only significant on Tangerang Selatan weather station with a decrease trend with a slope of -12.868 according to its p-value.

Fig. 5. Precipitation Total in a year (1986-2014) on CGK (Cengkareng weather station), CRG (Curug weather station), KMY (Kemayoran weather station), PBT (Tangerang Selatan weather station), and PRK (Priok weather station).

Consecutive Dry Days (CDD) is the index of the most number of days in a year with the amount of rainfall < 1 mm in a row [12]. CDD is also referred to as a day without rain in a row. Based on Fig. 4 (c). the CDD index in the period 1986-2014 on Tangerang Selatan, Curug, Kemayoran, and Cengkareng wether station have an upward changes trend and on Priok, weather station has a downward changes trend, but none is significant.

The maximum number of days in a year with a rainfall > 1 mm is expressed by the Consecutive Wet Days (CWD) index as shown in Figure 4 (d). The CWD index is also called a consecutive rainy day. Only Curug weather station which has a significant decrease with the slope of -0.269, while the other areas have no significant changes according to its p-value.

Very wet days or annual rainfall in which rainfall is greater than the 95th percentile is represented by the R95p index (Fig. 6.). R95p index in the period of 1986-

2014 tends to increase significantly with slope 15.074 only on Kemayoran, while others have no significant changes.

Fig. 6. Annual precipitation when $RR > 95^{\text{th}}$ percentile.

3.4 Temperature and precipitation changes

Based on extreme data from some indexes, that include TX10p, TX90p, TN10p, and TN90p, it is found that there has been a change in extreme temperatures related to minimum and maximum temperatures.

From five weather stations, most of its TX10P index declines, indicating that the number of days with maximum temperatures lower than 10th percentile decreases in most parts of Jakarta. The decline of the high-temperature index (TX10P) coupled with an increase in the TX90P index, indicating that the highest maximum temperature is increasing and increasing the temperature in Jakarta.

Then for the TN10P index itself decreases in all weather stations. The decrease of the slope of TN10P cold temperature index resulted in the increase of slope at TN90P heat temperature index. The decrease in the TN10P cold temperature index slope indicates fewer minimum temperatures within the 10th percentile range of data and indicates an increase in the number of days with a minimum air temperature of the 90th percentile, which may indicate a minimum temperature increase occurring in the Jakarta.

The index which shows the highest and lowest maximum extreme temperatures seen from its TXX and TXN. But most of the Jakarta area does not experience significant changes for TXX and TXN index. This indicates that no increase or decrease in the highest and lowest maximum extreme temperatures.

Then, for the highest and lowest extreme minimum temperatures can be seen from TNN and TNX indexes. It can be seen that most of Jakarta experience significant increase changes for TNN, indicating that there is a change of the lowest minimum temperature value to be hotter. And for the TNX index in all areas of Jakarta also experienced an increase that shows the temperature becomes hotter.

Changes that occur in the minimum and maximum temperatures affect the Diurnal Temperature Range (DTR), defined as the difference between the maximum temperature in the day and the minimum temperature at night. DTR values tend to decline during the period 1986-2014 in Jakarta but only a small part of the territory. The decrease in DTR values is mainly due to a rise in the minimum temperature or increased frequency of warmer temperatures at night. The decreasing trend in DTR is one indication of climate change [11].

Then, from the RX1day index which shows the highest rainfall in 1 day and RX5day which shows the maximum rainfall for five consecutive days, are seen not having significant changes in Jakarta. Similarly, PRCPTOT, showing no significant change in Jakarta, illustrates that the amount of annual rainfall is unchanged.

Based on the CWD and CDD indices, there are no significant changes in Jakarta, indicating that during the years 1986-2014 the number of days with rain ≥ 1 mm in a row and the number of days without successive rain did not change. CDD and CWD indices are often associated with potential droughts and floods. Then from the R95 index which also does not reflect any significant changes, it shows that the annual extreme rainfall does not change in number.

4 Conclusions

From 15 indexes that are used, there are 13 indexes which have significant changes according to its p-value, including TN10p, TN90p, TX10p, TX90p, TNn, TNx, TXX, DTR, RX1day, RX5day, RCPTOT, CWD, and R95p. Two indexes that are not significant are TXn which shows the monthly minimum value of daily maximum temperature and CDD which shows the maximum number of consecutive days with $RR < 1$ mm.

Indexes which have significant changes in Jakarta (on all weather stations) are TN10p, TN90p, and TNx. TN10p tends to decrease and TN90p tends to increase, means that it indicates fewer minimum temperatures within the 10th percentile range of data and indicates an increase in the number of days with a minimum air temperature of the 90th percentile, which may indicate the temperature in Jakarta is getting hotter during 1986-2014.

The indexes which have significant changes in most part of Jakarta, seen from 3 or more than 3 weather stations have significant change, are TX10p, TX90p, and TNn. The decrease of TX10p and TX90p indicate that the number of days with maximum temperatures lower than the 10th percentile and 90th percentile decrease. And the increase of TX90p means that the number of days with maximum temperatures more than 90th percentile increases. Which means it coupled with the significant indexes before and make Jakarta feel high temperature more often during 1986-2014. It is not impossible that the hotter temperature will continue to happen more often if there is no action to reduce the temperature rise.

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