Atmospheric Research 169 (2016) 301–317

Contents lists available at ScienceDirect

Atmospheric Research

journal homepage: www.elsevier.com/locate/atmos

Long-term trends and variability of total and extreme precipitation in Thailand

Atsamon Limsakul [a,*], Patama Singhruck [b]

[a] *Environmental Research and Training Center, Technopolis, Klong 5, Klong Luang, Pathumthani 12120, Thailand*
[b] *Department of Marine Science, Faculty of Science, Chulalongkorn University, Phayathai Road, Pathumwan, Bangkok 10330, Thailand*

ARTICLE INFO

Article history:
Received 20 September 2014
Received in revised form 30 September 2015
Accepted 19 October 2015
Available online 27 October 2015

Keywords:
Thailand
Trend
Precipitation
Extreme indices

ABSTRACT

Based on quality-controlled daily station data, long-term trends and variability of total and extreme precipitation indices during 1955–2014 were examined for Thailand. An analysis showed that while precipitation events have been less frequent across most of Thailand, they have become more intense. Moreover, the indices measuring the magnitude of intense precipitation events indicate a trend toward wetter conditions, with heavy precipitation contributing a greater fraction to annual totals. One consequence of this change is the increased frequency and severity of flash floods as recently evidenced in many parts of Thailand. On interannual-to-interdecadal time scales, significant relationships between variability of precipitation indices and the indices for the state of El Niño–Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO) were found. These results provide additional evidence that large-scale climate phenomena in the Pacific Ocean are remote drivers of variability in Thailand's total and extreme precipitation. Thailand tended to have greater amounts of precipitation and more extreme events during La Niña years and the PDO cool phase, and vice versa during El Niño years and the PDO warm phase. Another noteworthy finding is that in 2011 Thailand experienced extensive flooding in a year characterized by exceptionally extreme precipitation events. Our results are consistent with the regional studies for the Asia-Pacific Network. However, this study provides a more detailed picture of coherent trends at a station scale and documents changes that have occurred in the twenty-first century, both of which help to inform decisions concerning effective management strategies.

1. Introduction

Precipitation is a key component of the hydrological cycle and a defining feature of Earth's changing climate. Of all meteorological variables, precipitation most likely affects life and civilization most directly and significantly because variations in precipitation often cause significant impacts on both human society and the natural environment (e.g., Barretta and Santos, 2014; Pielke and Downton, 2000; Guan et al., 2014; Trenberth et al., 2003). Over the last few decades, it has become increasingly evident that the frequency and intensity of extreme precipitation events have been changing especially under the anthropogenically induced climate warming (e.g., Allan and Soden, 2008; Coumou and Rahmstorf, 2012; Donat et al., 2013; Min et al., 2011). For the tropics and subtropics, the amount of research focused on extreme precipitation events has recently progressed enormously. Based on a daily rainfall dataset of 1803 stations, for example, Goswami et al. (2006) discovered significant trends for increases in the frequency and magnitude of extreme rain events occurring over central India during the monsoon seasons from 1951 to 2000. Endo et al. (2009) examined trends in precipitation extremes over Southeast Asia, and demonstrated that the average precipitation intensity of wet days exhibited an increasing trend at many stations. Analysis of daily data in the Philippines for the period of 1951–2010 showed significant increases in both frequency and intensity of extreme daily rainfall events at some stations (Cinco et al., 2014). In addition, the results based on a series of regional workshops have revealed that trends in precipitation extremes were less spatially consistent across the Indo-Pacific, Asia-Pacific and Arab regions (Caesar et al., 2011; Choi et al., 2009; Donat et al., 2014).

It is recognized that a key aspect of the analysis of precipitation extremes is to distinguish the difference between the detection of a change and the attribution of a change to some identifiable climate forcing factor (Griffiths and Bradley, 2007; Hoerling et al., 2010). Several studies have demonstrated that changes in extreme precipitation events are related to atmospheric circulation patterns (e.g., Kenyon and Hegerl, 2010; Caesar et al., 2011; Donat et al., 2014; McGree et al., 2014; Queralt et al., 2009; Zhang et al., 2010). Kenyon and Hegerl (2010) demonstrated that variations in global precipitation extremes are significantly affected by ENSO and that these effects are most evident around the Pacific Rim.

Given the potentially significant social, economic and ecological impacts of precipitation extremes, an up-to-date assessment at a local scale is required to support the decision-making processes associated

---

* Corresponding author. Tel.: +66 2 577 1136; fax: +66 2 577 1138.
E-mail address: atsamon@deqp.go.th (A. Limsakul).

http://dx.doi.org/10.1016/j.atmosres.2015.10.015
0169-8095/© 2015 Elsevier B.V. All rights reserved.

with the development of effective management strategies for agriculture, water resources and disasters. In this study, particular attention is paid to Thailand, a country for which the number of studies of changes in extreme precipitation events is still limited. To the best of our knowledge, only the works of Limjirakan et al. (2010) and Limsakul et al. (2010) who examined the changes in daily precipitation extreme events in the Bangkok Metropolitan area and along Thailand's coastal zones for the period of 1965–2006 are found in the literature. In this study, precipitation indices mostly focused on extreme events that are recommended by the World Meteorological Organization–Commission for Climatology (WMO–CCI)/World Climate Research Program (WCRP)/Climate Variability and Predictability (CLIVAR) project's Expert Team on Climate Change Detection and Indices (ETCCDI) were calculated. The long-term trends for these indices in Thailand during the period from 1955 to 2014 were then examined, using quality-controlled daily station data. The relationships between the calculated precipitation indices and the indices for the state of ENSO and PDO on interannual-to-interdecadal time scales were further investigated.

2. Data and analytical methods

2.1. Daily precipitation data

Daily precipitation data from surface weather stations of the Thai Meteorological Department (TMD) covering the period from 1955 to 2014 provided the basis for this study. To analyze extreme climatic indices, rather strict criteria were applied in selecting station data. These criteria include the following: (i) a month is considered as having sufficiently complete data if there are less than or equal to 5 missing days; (ii) a year is considered complete if all months are complete according to item (i); (iii) a station is considered to have complete data if the entire record has less than or equal to 5 missing years according to (ii) (Griffiths and Bradley, 2007; Moberg and Jones, 2005; Chu et al., 2010). Based on these criteria, a total of 44 stations were selected for the subsequent quality control and homogeneity tests. Overall, the percentage of missing data ranged from 0% to 1.9%, with 15 stations that did not have any missing values.

2.2. Quality control and homogeneity checks

All selected records were subjected to a further statistical quality control (QC) algorithm following the method outlined in Klein Tank et al. (2009) and using the ETCCDI RClimDex software. Outliers identified by the QC check were then evaluated by comparing their values to adjacent days, to the same day at nearby stations and to the expert knowledge of local climate conditions before being validated, edited or removed. As a second step, the quality-controlled records were assessed for homogeneity, based on the penalized t-test (Wang et al., 2007) and the penalized maximal F-test (Wang, 2008) using the ETCCDI RHtestsV4 software. This method is capable of identifying multiple step changes in time series by comparing the goodness of fit of a two-phase regression model with that of a linear trend for the entire base series (Wang, 2008). In this study, homogeneity analyses were performed on the monthly total precipitation series using a relative test in which the candidate series was examined in relation to a reference series (e.g., Cao and Yan, 2012; Aguilar et al., 2003; Peterson et al., 1998). A set of homogeneous neighboring stations that were well correlated with the candidate station was used as the reference series (Aguilar et al., 2003). Most of the neighbors (90%) used to construct the reference series had high correlations (correlation coefficients > 0.7) with the candidate series.

Homogeneity testing identified 3 stations with significant step changes in their monthly total precipitation series. Based on information available from station history metadata, possible explanations for the causes of these step changes were unclear. No further attempt was made to adjust the data because the adjustment of inhomogeneous daily precipitation data is a complex problem with a number of uncertainties (Domonkos, 2011; Aguilar et al., 2003), and a conservative approach was taken to exclude inhomogeneous data. On the basis of the quality control and homogeneity tests, the daily precipitation data for a set of 41 high-quality records spanning from 1955 to 2014 were prepared for the calculation of precipitation indices (Fig. 1). Detailed information of the stations is provided in Table 1.

2.3. Precipitation indices

Eleven extreme precipitation indices, including precipitation totals (PRCPTOT) and the number of rainy days (RD; days with precipitation ≥ 1 mm), as recommended by the WMO–CCI/WCRP/CLIVAR project's ETCCDI, were computed for each of the stations (Zhang et al., 2011). Data were processed using the ETCCDI RClimDex software. For the percentile-based indices of very wet days (R95p) and extremely wet days (R99p), the methodology uses bootstrapping to calculate the values for the base period so that there is no discontinuity in the time series of the indices at the beginning or end of the base period (Klein Tank et al., 2009; Zhang et al., 2011). For comparative purpose with the previous studies, a base period of 1971–2000 was used when computing percentile-based indicators.

Table 2 provides a description of the eleven ETCCDI precipitation indices. The R95p, R99p and maximum 1-day and 5-day precipitation amount (RX1day and RX5day) indices characterize the magnitude of intense rainfall events, whereas, simple daily intensity index (SDII) is a measure of the mean total precipitation that falls on a wet day in a given year. R95pT represents the contribution from the very wet days to the annual precipitation totals. In this study, R20 (number of days with precipitation ≥ 20 mm) is applied to assess the frequency of heavy precipitation events because this threshold is more applicable to tropical climates, which obviously have greater daily precipitation totals than mid- and high-latitude regions. Finally, consecutive dry

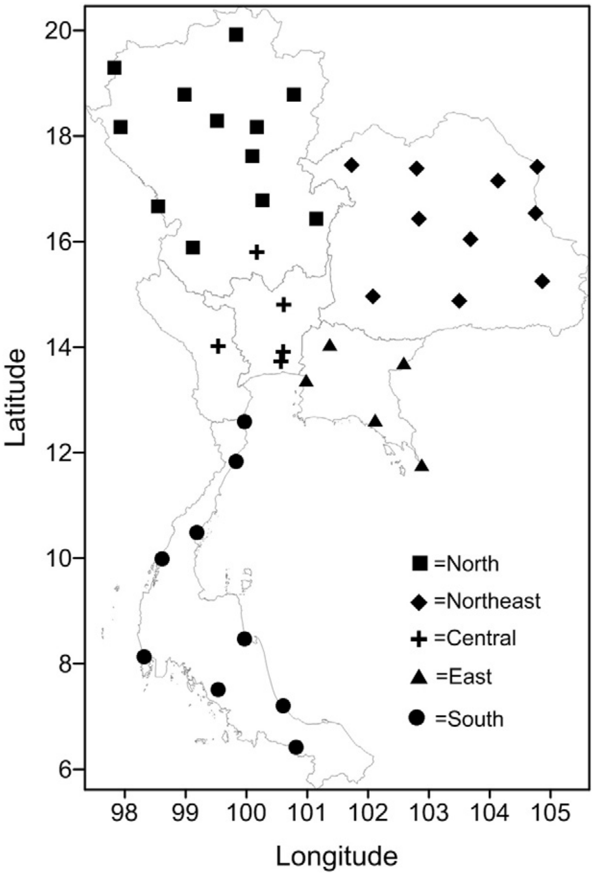

Fig. 1. Geographical distribution of the TMD's surface weather stations with long-running quality controlled daily precipitation records for the period from 1955 to 2014. Locations of the stations are basically divided into five topographic regions: 1) North, 2) Northeast, 3) Central, 4) East and 5) South, respectively.