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A climatological analysis of the southwest monsoon rainfall in the Philippines

F. T. Cruz [a,*], G. T. Narisma [a,b], M. Q. Villafuerte II [b,1], K. U. Cheng Chua [a], L. M. Olaguera [b]

[a] *Regional Climate Systems, Manila Observatory, Quezon City, Philippines*
[b] *Atmospheric Science Program, Physics Department, Ateneo de Manila University, Quezon City, Philippines*

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ABSTRACT

The historical behavior of the southwest monsoon (SWM) rainfall in the Philippines is described using observed rainfall during the months of June to September from 1961 to 2010. Data are obtained from meteorological stations situated in the western half of the country where the impact of SWM is well pronounced. Time series analysis indicates significant decreasing trends from 0.026% to 0.075% per decade in the total SWM rainfall in six of the nine stations (Ambulong, Baguio, Coron, Dagupan, Iba and Vigan) in the past 50 years. A rainfall anomaly index is derived to characterize the inter-annual variability and the influence of the El Niño Southern Oscillation on the SWM rainfall. Results show no above normal rainfall events associated with La Niña years and few occurrences of below normal rainfall associated with El Niño events. Years where the SWM rainfall significantly deviates from its climate mean are also identified. Furthermore, an examination of the rainfall extremes indicate an increasing trend in the number of days without rain, which can be detected with statistical confidence in Ambulong (2.9% per decade), Baguio (5.9% per decade) and Dagupan (4.0% per decade), as well as a decreasing trend in the heavy rainfall days. These findings suggest a climatic change towards a prolonged dry period and an overall decreasing trend in rainfall during the SWM season over western Philippines in the recent decades, which can have serious implications on the country's agricultural sector.

1. Introduction

Rainfall is a major driver of climate variability in the Philippines, influenced by synoptic systems such as monsoons and the El Niño Southern Oscillation (ENSO), and mesoscale systems (De las Alas and Buan, 1986; Francisco et al., 2006; Jose et al., 1996). In particular, the Southwest Monsoon (SWM) during the boreal summer affects rainfall in most areas located in the western side of the country. The SWM originates as trades from the Indian Ocean anticyclone and generally reach the Philippines as a southwesterly stream. This equatorial air mass is warm, very humid and characterized by frequent convective activity. It can appear as early as April but it usually begins in early May with a peak in August and ends in October, occasionally lasting until December (Flores and Balagot, 1969). However, the onset of a monsoon season can vary every year (Lau and Yang, 1997; Moron et al., 2009). At the station scale over the Philippines, the onset date can also depend on the geographical location and elevation of the meteorological station, wherein stations located along the western coast and in the islands in central Philippines with flat terrain exhibit the latest onset dates (Moron et al., 2009).

This observational study aims to examine the historical behavior of the SWM rainfall in the Philippines, particularly in the western region. Locally, the rainfall brought by the SWM is important. According to Asuncion and Jose (1980), the SWM accounts for 43% of the mean annual rainfall in the Philippines

* Corresponding author at: Manila Observatory, Ateneo de Manila University Campus, Loyola Heights, Quezon City, 1108, Philippines. Tel.: +63 2 426 5921; fax: +63 2 426 0847.
E-mail address: faye.cruz@gmail.com (F.T. Cruz).
[1] Present affiliation: Philippine Atmospheric Geophysical and Astronomical Services Administration, Quezon City, Philippines.

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(Cayanan et al., 2011). SWM rainfall contributes to the supply of water for agriculture, electricity through hydroelectric power plants, and domestic use. Changes in the timing and intensity of rainfall have vital impacts on livelihood, food security and economic stability. The Philippines is highly vulnerable to climatic changes and variability in rainfall. The country ranks high in terms of vulnerability to floods and droughts (Yusuf and Francisco, 2009). For example, historical analysis shows noticeable declines in rice production during El Niño events, when the country experiences prolonged dry conditions (Villarin and Narisma, 2011). Therefore, it is important to understand how rainfall, especially during the SWM season, has changed in the recent decades, particularly its extremes.

While there are numerous studies on the East Asian monsoon and the South China Sea monsoon (Yihui and Chan, 2005) and its associated rainfall (e.g. Karev et al., 2010), to our knowledge, only a number focus on the SWM. Some of these works have examined trends (Jose et al., 1996), the temporal and spatial variability of the SWM onset (Moron et al., 2009), and the interaction of SWM with other systems, such as tropical cyclones (Cayanan et al., 2011) and ENSO (Lyon and Camargo, 2009; Lyon et al., 2006). This study focuses on characterizing and analyzing long-term trends, inter-annual variability and change in rainfall in the Philippines during the SWM season.

The next section describes the methodology used in the data analysis for selected observation stations. The historical behavior of rainfall during the SWM season is discussed in Section 3, which also explores the relationship of ENSO with SWM rainfall. Finally, Section 4 presents a summary of the important findings.

2. Methodology

2.1. Data

Monthly accumulated rainfall from 1961 to 2010 are obtained from selected meteorological stations (see Fig. 1) from the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA). Note that data from Iloilo station is only until 2009 because operations at this site have been discontinued. To treat the missing data and trace amounts present in the station data, months with missing data are replaced with the climatological mean monthly total rainfall, while trace amounts are replaced with zeros. In this study, the reference period for the baseline climate is from 1961 to 1990.

In order to identify the stations to be used, rainfall data from 1961 to 1990 are obtained from the high resolution (0.25°× 0.25°) gridded dataset from the Asian Precipitation—Highly-Resolved Observational Data Integration Towards Evaluation of the Water Resources (APHRODITE) project. The APHRODITE V1003R1 dataset is an updated version of V0902, described in Yatagai et al. (2009), which used rain gauge observations across Asia with improved quality control and interpolation methods (see http://www.chikyu.ac.jp/precip, last accessed June 2012).

Fig. 1 shows the average June to September total rainfall as a fraction of the mean annual total rainfall from 1961 to 1990. This figure indicates the strong influence of the SWM over the western part of the country. In the northwest regions, up to 80–90% of the 30-year mean annual total rainfall occurs during the SWM season from June to September. Hence, nine stations situated in these areas (Ambulong, Baguio, Coron, Dagupan, Iba, Iloilo, Laoag, Science Garden and Vigan) are selected for this study.

2.2. Southwest monsoon rainfall trends and variability

While there are different ways to define the onset of a monsoon season (Moron et al., 2009; Wang et al., 2004), the SWM season is defined here as the months from June to September based on the prevailing flow at the surface from the ERA-40 reanalysis dataset (Kallberg et al., 2007) from 1961 to 1990. October is a month of transition from the southwest monsoon to the northeast monsoon season. The months of the SWM season are also consistent with Cayanan et al. (2011). The historical trend and variability of the SWM rainfall are investigated using several methods.

The annual accumulated rainfall for the SWM season is derived for each station. Because many factors can affect the detection of trends, such as temporal coverage of data, variability and autocorrelation of the noise in the data, the formulae from Weatherhead et al. (1998) is used to estimate the number of years required to detect a certain trend. This formula for the trend detection takes into account the inter-annual variability and autocorrelation in the time series of the data. Although 50 years of data are used in the analysis here, it is possible that this length of time may be enough to detect a particular trend at a site, but not for another site. Thus, this method also identifies the stations that show reliable estimates of the linear trend in the SWM rainfall given the amount of data used in this study.

The annual variation of rainfall brought by the SWM is determined using a rainfall index. Monthly rainfall data from PAGASA is expressed as a standardized anomaly to allow a direct comparison of the rainfall at different locations by removing the bias from local conditions such as elevation and land use. Using a formula adapted from Wilks (1995), the standardized anomalies, Z_i, are expressed in each station as:

$$Z_i = \frac{x_i - \bar{x}_i}{s_{xi}} \quad (1)$$

where x_i is the SWM rainfall value at station i for a particular year, $\bar{x}_i$ and s_{xi} are the mean SWM rainfall and standard deviation at station i for 1961 to 1990, respectively. Similar to earlier studies (Katz, 1978; Kraus, 1977; Lamb, 1982, 1983; Nicholson, 1983), the spatial average of the standardized rainfall anomaly (Eq. (1)) at each station is derived to obtain a single index, called the SWM Rainfall Anomaly Index (SWMRAI). Thus for each year, t, SWMRAI is expressed as:

$$\mathrm{SWMRAI}_t = \frac{1}{N}\sum_{i=1}^{N} Z_{it} \quad (2)$$

where N is the total number of stations and Z_{it} is the standardized rainfall anomaly at year t. The standard deviation of annual SWMRAI is also obtained to define a threshold for identifying years with above normal, normal and below normal rainfall. The statistical significance of the deviation of the annual SWM rainfall from the baseline is also determined for