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Long-term trends and variability of rainfall extremes in the Philippines

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ABSTRACT

Owing to the increasing concerns about climate change due to the recent extreme rainfall events in the Philippines, long-term trends and variability in rainfall extremes in the country are investigated using 60-year (1951–2010) daily rainfall data from 35 meteorological stations. Rainfall extremes are described using seven extreme precipitation indices (EPI) that characterize daily rainfall in terms of intensity, accumulation, and duration on a seasonal perspective. The nonparametric Mann–Kendall test is employed in combination with the moving blocks bootstrapping technique to detect significant trends in EPI. The results suggest a tendency toward a drying condition for the dry season, January–March (JFM), as indicated by statistically significant decreasing trends in seasonal wet days total rainfall (PCPTOT) associated with increasing trends in maximum length of dry spell (LDS). In contrast, statistically significant increasing trends in maximum 5-day rainfall (RX5day) and decreasing trends in LDS denote a wetting condition during the July–September (JAS) season, particularly at stations located in the northwest and central Philippines. The trends obtained are further assessed by examining the longer time series of EPI at four meteorological stations (Aparri, Dagupan, Iloilo, and Masbate) that have rainfall data from 1911 to 2010. The longer historical data revealed that the trends obtained in the shorter period (1951–2010) could either be consistent with the continuous long-term trends, as observed in RX5day during JAS at Aparri and Masbate, or represent interdecadal variability as was observed at Dagupan and Iloilo. The long-term (1911–2010) southwestward extension of the western North Pacific subtropical high associated with a weakening of the 850-hPa westerly wind over the South China Sea partly provides a possible cause of the trends in EPI during JAS, whereas the weakening of the East Asian winter monsoon contributed somewhat to the trends obtained during JFM. Furthermore, interannual variations in EPI are found to be influenced greatly by the El Niño–Southern Oscillation (ENSO). Composite analyses suggest that El Niño (La Niña) events are associated with statistically significant drier (wetter) conditions over the Philippines, especially during the seasons close to ENSO mature stage.

1. Introduction

Trends and changes in precipitation and temperature extremes have been a focus of research over the past decade. Consistent with this focus, a suite of extreme precipitation and temperature indices was defined by the Expert Team on Climate Change Detection and Indices (ETCCDI) to enable

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uniformity in analysis of climate extremes in different regions around the world (e.g., Klein Tank et al., 2006; New et al., 2006; Zhang et al., 2005). Consequently, Alexander et al. (2006) were able to incorporate studies across different regions to obtain a global picture of trends in extreme precipitation and temperature. Unlike those of extreme temperature, trends in extreme precipitation were commonly found to be spatially incoherent. In this regard, more recent studies have maximized the spatial availability of observations to examine trends in precipitation extremes. For instance, Endo et al. (2009) investigated trends in extreme precipitation using almost the entire network of stations in Southeast Asia. They were able to provide a clearer picture of trends across the neighboring countries in the region. However, Endo et al. (2009) analyzed trends using annually computed extreme precipitation indices (EPI), whereas, Klein Tank et al. (2006) emphasized that trends obtained from annually analyzed EPI, specifically in monsoon regions, may be dominated by wet or dry seasons. Thus, further analysis of trends in EPI in the Southeast Asian region, including the Philippines, where rainfall is influenced by monsoons, is needed.

The prevailing surface winds brought by the monsoons and the topographic effect are the main causes of rainfall seasonality over Southeast Asia (Chang et al., 2005). In the Philippines, mountain ranges are mostly stretched with a north–south orientation along the east and west coasts and reach elevations higher than 1000 m (see Fig. 1). Thus, rainfall in the Philippines shows seasonally and spatially contrasting characteristics. The rainy season in the country generally begins around mid-May, when the western North Pacific subtropical high (WNPSH) moves northeastward, enabling the southwesterly wind brought by the Asian summer monsoon to propagate over the Philippines (Akasaka, 2010). Subsequently, the East Asian winter monsoon is established around November (Ding, 1994) and brings northeasterly surface winds that cause the wetness (dryness) of the windward (leeward) eastern (western) coasts of the Philippines. Hence, agricultural activities throughout the country are patterned according to this rainfall seasonality. However, the eventualities of heavy rainfall events leading to floods, on the one hand, and rainfall deficits causing droughts, on the other hand, are embedded during these seasons. Such eventualities of heavy rain and drought were experienced during a recent five-year period (2004–2008), which directly affected the agricultural and energy sectors of the country as well as the Philippine economy (Yumul et al., 2011).

Droughts in the Philippines generally coincide with strong El Niño (EN) events (Jaranilla-Sanchez et al., 2011; Jose and Cruz, 1999); whereas, excessive rains in the country often occur during La Niña (LN) conditions (Hilario et al., 2009; Yumul et al., 2008). Because LN events are generally associated with excessive rains in the Philippines, the country was expecting a wet condition in 2007, a strong LN year, but drought was instead experienced from June to July of that year (Yumul et al., 2011). However, this seasonally opposite rainfall response with El Niño–Southern Oscillation (ENSO) in the country had been noted initially by Lyon et al. (2006), who showed that the seasonal total precipitation in the Philippines during July–September tends toward a wetter (drier) condition during EN (LN), while an exactly opposite behavior occurs during October–December. Nevertheless, these studies did not directly investigate ENSO-extreme rainfall relationships on a seasonal perspective over the entire region of the Philippines; therefore, this study focuses on this aspect.

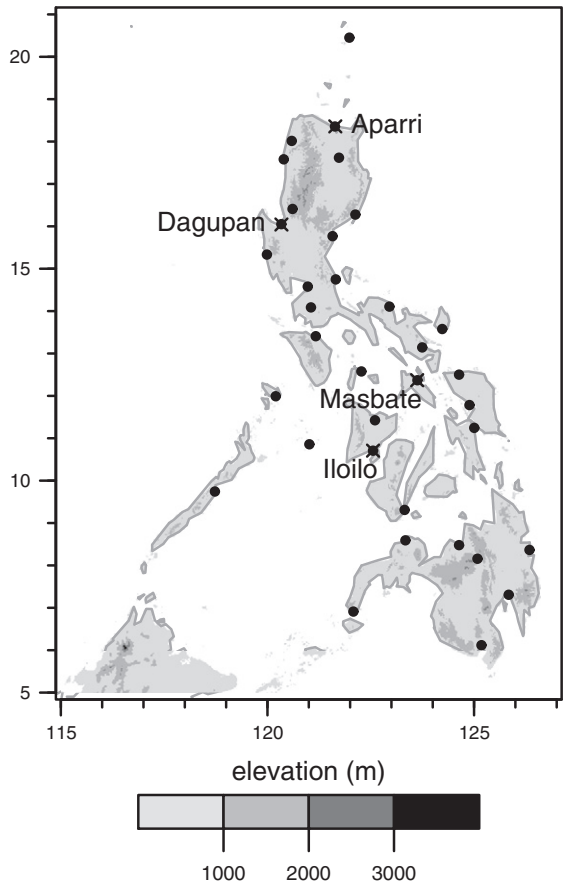

Fig. 1. Topographical map of the Philippines showing the geographical distribution of the 35 meteorological stations (black dots) considered in this study. The four stations marked with crosses have nearly complete data in the earlier 30-year period (1911–1940) and are used in Fig. 6.

On a multidecadal timescale, the Pacific Decadal Oscillation (PDO) has been shown to influence global precipitation anomalies that are well-pronounced over extratropical regions (Mantua and Hare, 2002). As the influence of PDO is only secondary in tropical regions, less attention has been given to its impact on rainfall over the Tropics. Studies that have examined the influence of PDO include Sen Roy et al. (2003) and, just recently, Krishnamurthy and Krishnamurthy (2013), both of which showed that the positive (negative) phases of the PDO are associated with rainfall shortages (excesses) over India. In the Philippines, decadal variability in rainfall needs to be further investigated. For instance, Jose et al. (1996) showed an increasing trend in both seasonal and annual total rainfall during 1951–1992 in the northwestern section of the Philippines, whereas Cruz et al. (2013), who used rainfall data from 1961–2010, showed a drying trend over the same region. Moreover, remarkable floods were experienced in the Philippines in the 1960s, 1970s, and 2000s, whereas several droughts were recorded in the 1980s and 1990s (Hilario et al., 2009). To determine whether these extreme rainfall events in the country are associated with PDO remain to be confirmed.