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A perturbation approach for assessing trends in precipitation extremes across Iran

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S U M M A R Y

Extreme precipitation events have attracted a great deal of attention among the scientific community because of their devastating consequences on human livelihood and socio-economic development. To assess changes in precipitation extremes in a given region, it is essential to analyze decadal oscillations in precipitation extremes. This study examines temporal oscillations in precipitation data in several sub-regions of Iran using a novel quantile perturbation method during 1980–2010. Precipitation data from NASA's Modern-Era Retrospective Analysis for Research and Applications-Land (MERRA-Land) are used in this study. The results indicate significant anomalies in precipitation extremes in the northwest and southeast regions of Iran. Analysis of extreme precipitation perturbations reveals that perturbations for the monthly aggregation level are generally lower than the annual perturbations. Furthermore, high-oscillation and low-oscillation periods are found in extreme precipitation quantiles across different seasons. In all selected regions, a significant anomaly (i.e., extreme wet/dry conditions) in precipitation extremes is observed during spring.

1. Introduction

There is a general agreement that the global climate is undergoing a noticeable change, leading to intensified hydrological cycles due to increased atmosphere's moisture holding capacity (Trenberth, 2011). More frequent occurrences of extreme precipitation events over a large part of the land have been highlighted by the Intergovernmental Panel on Climate Change 4th and 5th Assessment Reports (IPCC, 2007, 2013). However, trends and patterns of precipitation vary substantially in different regions, with no clear and uniform trend across the globe (Sheffield et al., 2012; Damberg and AghaKouchak, 2014).

Study of precipitation extremes is of paramount importance for policymakers, as these events can result in devastating floods and droughts. Given the impacts of extreme precipitation events on human society and ecosystems, the variability and change in precipitation extremes have been increasingly studied on local and global scales (Kiktev et al., 2003; New et al., 2006; Di Baldassarre et al., 2006; Endo et al., 2009; Pal and Al-Tabbaa, 2011; AghaKouchak and Nasrollahi, 2010; Nyeko-Ogiramoi et al., 2013; Willems, 2013a, 2013b). At global scale, Frich et al. (2002) showed that heavy precipitation events have become more frequent in some parts of the world (i.e., southern Africa, southeastern Australia, western Russia, parts of Europe and eastern USA) during the second half of the 20th century. In another study, Alexander et al. (2006) found a widespread and significant increase in precipitation extreme and also a much less spatial coherency for precipitation changes compared with temperature changes. Zhang et al. (2005) showed that the trends in precipitation indices, including annual total precipitation, number of days with precipitation, and maximum daily precipitation, are generally weak and insignificant for the Middle East region, and there is no spatial coherence in the trends. Damberg and AghaKouchak (2014) analyzed wetting and drying trends across the globe and showed significant regional wetting and drying trends, but no significant trend in the average global precipitation.

Most previous studies on precipitation trends in Iran indicate insignificant trends across a wide range of spatial and temporal scales (Soltani et al., 2011; Tabari et al., 2011, 2012; Tabari and Aghajanloo, 2013; Fathian et al., 2014; Dhorde et al., 2014), though Rahimzadeh et al. (2009) reported both negative and positive trends for precipitation-based indicators. Nevertheless, there is an evidence of a significant decreasing trend in precipitation over the northwestern regions of Iran (Tabari and Hosseinzadeh

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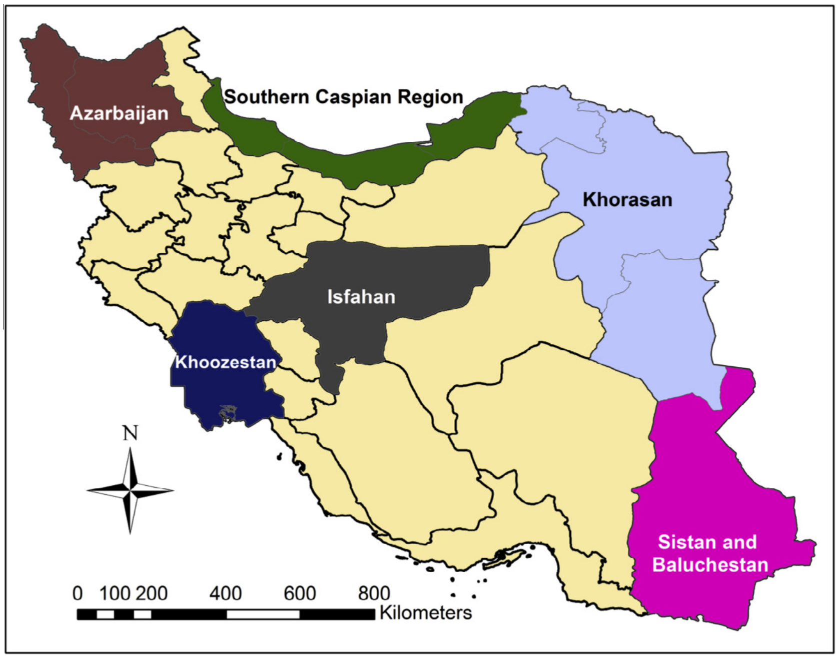

Fig. 1. Study areas in Iran Map.

Talaee, 2011; Shifteh Some'e et al., 2012; Golian et al., 2014). In a recent study, Madani (2014) highlights Iran's water crises including depleting groundwater levels, drying lakes, water supply, and extreme events. With nearly 85% of the country being in semi-arid and arid climates, the country faces both prolonged droughts, as well as floods. In the past two decades, floods have affected 11 million people in Iran and caused over 2600 fatal casualties (Madani, 2014; DOE, 2010). This highlights the importance of monitoring and assessing extreme precipitation across Iran.

Precipitation estimates over land areas are typically derived from surface rain gauge observations at automated or human-operated sites (Lockhoff et al., 2013). Rain gauges, although they provide longer records (Yatagai et al., 2009), are limited in sampling precipitation for continental and global applications (Nastos et al., 2013). In most regions of the world, rain gauges do not provide a reliable spatial representation of precipitation (Gruber and Levizzani, 2008), especially over oceans, deserts and mountainous areas. In addition, surface rain gauge observations are very inhomogeneously distributed in space and often suffer from substantial missing data, resulting in inadequate temporal and spatial sampling (Lockhoff et al., 2013) especially in developing countries. One of the main limitations of gauge-based trend analysis over Iran is that large areas of the country do not have sufficient observations (eastern, and southeastern Iran) in temporal and spatial scales.

On the other hand, global land-surface, land–atmosphere models, and satellite observations provide spatially and temporally homogeneous precipitation information at a quasi-global to global scale. In this study, precipitation data are obtained from NASA's Modern-Era Retrospective Analysis for Research and Applications-Land (MERRA-Land; Reichle et al., 2011), which is based on a fully coupled land–atmosphere that integrates satellite observations. Following the Intergovernmental Panel on Climate Change (IPCC, 2001) decadal analysis for climate change assessment, this study investigates decadal anomalies in extreme precipitation quantiles in several sub-regions of Iran during 1980–2010.

Previous studies for the trend analysis of hydrological variables have used mostly non-parametric tests such as Mann–Kendall and Spearman. These statistical tests are rank-based methods which take the ranks of measurements into consideration rather than their actual values, and hence they are effective for hydrological records which are usually positively or negatively skewed (non-normally distributed). However, a limitation associated with these statistical tests is that their results are often influenced by serial correlation in the time series. Specifically, a positive serial correlation, that is likely the case for most hydroclimatological data, would increase the chance of incorrectly rejecting the null hypothesis of no trend or vice versa. Albeit several methods have been developed for removal of significant serial correlation from time series, it is helpful to use a method which does not depend on such restrictive assumptions. Thus, in this study, a rather novel approach named quantile perturbation method (QPM; Ntegeka and Willems, 2008; Willems, 2013a) which is not dependent on the above-mentioned assumptions is utilized for analyzing the anomalies. This approach is analogous to the frequency-perturbation method which has been applied in several climate change studies (e.g., Harrold et al., 2005; Chiew, 2006; Mpelasoka and Chiew, 2009; Willems and Vrac, 2011; Ntegeka et al., 2014) for construction of future climate change scenarios from climate models.

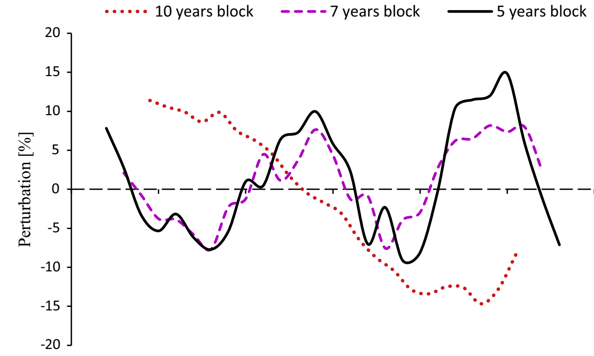

Fig. 2. Comparison between extreme precipitation perturbations of different block lengths in Azarbaijan region.