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Research papers

Dry and wet spell variability during monsoon in gauge-based gridded daily precipitation datasets over India

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ABSTRACT

Accurate estimates of monsoonal rainfall at daily time scales are essential inputs for various water-related sectors such as drought and flood forecasting, crop and water management for agriculture. To serve this purpose, a variety of rainfall products, especially the gauge based products which serve as the ground-truth for other derived rainfall products, are available over India. In this study, three different daily gauge based gridded rainfall datasets, namely Indian Meteorological Department (IMD), Asian Precipitation Highly Resolved Observational Data Integration Towards Evaluation of water resources (APHRODITE) and Climate Prediction Center (CPC) unified rain gauge data are compared over India for the monsoon season of 1979–2007. The comparison among the datasets is based on the duration, frequency and intensity of three different spell characteristics, namely dry, wet and extreme wet spells, and their associated trends. Wet (dry) spells are defined as the consecutive period of wet (dry) days, where a wet (dry) day is defined using rainfall threshold of 1 mm. Extreme wet spells are defined using the 90th percentile of rainfall above the depth of wet day. All datasets capture the spatial distribution of precipitation characteristics, albeit with pronounced differences at heavy rainfall regions. CPC and IMD show a close match in spell characteristics while APHRODITE significantly deviates. APHRODITE shows increased intensity of rainfall during dry periods, leading to over-estimation of wet days and under-estimation of dry days. Northern extreme of India (Jammu and Kashmir) show major differences in replicating the spell characteristics. Trend patterns are also not consistent between the three datasets. The present study will provide information on the spatio-temporal pattern of dry, wet and extreme wet spell characteristics over India and aid in selecting appropriate datasets for studying the Indian monsoon rainfall depending on their scope and application of research.

1. Introduction

Reliable and accurate rainfall estimates of fine spatio-temporal resolution are needed to understand the catastrophic impacts of extreme rainfall events and enhance our preparedness to floods and droughts. While in-situ rain-gauge measurements provide highly accurate and precise information of rainfall over any local region, these datasets are usually converted into gridded form using a suitable interpolation algorithm for widespread application in hydrological and climate modeling (Pai et al., 2014; Tustison et al., 2001). Often, such gridded datasets are not consistent with each other, primarily due to the differences in observation data sources, its temporal resolution, interpolation algorithm and assimilation technique deployed. This demands a critical evaluation of these datasets, before their usage in modeling and management applications. Such evaluation is, in particular, necessary for monsoon-dominated regions like India, where almost 70% of the population rely on the summer monsoon rainfall for their sustenance, either in the form of food, occupation or energy. Indian Summer Monsoon Rainfall (ISMR) occurring between June and September, plays a very crucial role in the sectors of agriculture, hydrology and economy of India. However, the increasing variability of the monsoonal rainfall (Rajeevan et al., 2012) and considerable fluctuations in the duration, intensity and frequency of heavy rainfall (wet spells) and low rainfall (dry spells) periods have raised concern (Singh and Ranade, 2010; Singh et al., 2014; Vinnarasi and Dhanya, 2016). Changes in the monsoonal rainfall characteristics, especially the occurrences of frequent extremes - floods and droughts (Guhathakurta et al., 2011; Mohapatra and Singh, 2003) and its adverse effects on agriculture (Revadekar and Preethi, 2012; Zeppel et al., 2014) have also gained attention.

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Therefore, the analysis of Indian monsoonal rainfall characteristics using different precipitation datasets is of greater interest.

The India Meteorological Department (IMD) has established a large network of rain-gauge stations spread all over India, and gridded rainfall data at different spatial resolutions of $1^\circ \times 1^\circ$ (Hartmann and Michelsen, 1989; Rajeevan et al., 2006), $0.5^\circ \times 0.5^\circ$ (Rajeevan and Bhate, 2009), and $0.25^\circ \times 0.25^\circ$ (Pai et al., 2014) are made available. The $0.25^\circ \times 0.25^\circ$ gridded daily rainfall dataset is constructed using a large number of rain gauge stations and is widely used for different applications (Bharti and Singh, 2015; Prakash et al., 2016,in press; Vinnarasi and Dhanya, 2016). Apart from the IMD datasets, different gauge based gridded datasets like Asian Precipitation Highly Resolved Observational Data Integration Towards Evaluation of Water Resources (APHRODITE) and Climate Prediction Center (CPC) unified rain gauge data, which are freely available are frequently being used. IMD dataset covers only India whereas APHRODITE and CPC have a wider coverage of entire Asia and whole globe respectively. These three gridded datasets vary in the interpolation technique deployed, gauge density and configuration, objective function, etc.

Recent advances have shown an increase in the usage of these gauge-based rainfall datasets as "ground truth" for validating rainfall estimates from different satellite products, reanalysis datasets and climate models. For example, Rahman et al. (2009) used IMD dataset for comparison of two satellite datasets - Global Precipitation Climatology Project (GPCP) and Tropical Rainfall Measurement Mission (TRMM). Wei et al. (2013) used CPC data to validate the Modern-Era Retrospective Analysis for Research and Applications (MERRA) land dataset over northern India. Rana et al. (2015) used APHRODITE as the reference data to evaluate CPC, GPCP, TRMM, Climate Forecast System Reanalysis (CFSR) and European Centre for Medium-Range Weather Forecasts interim reanalysis (ERA-Interim) rainfall product over India. Prakash et al. (2016a,in press) used IMD as the base data for comparison of different satellites based rainfall products like TRMM, Global Satellite Mapping of Precipitation (GSMaP) and Global Precipitation Mission (GPM). Considering such diverse usage of multiple gauge-based datasets as a reference over India, it is necessary to carefully examine and compare the characteristics and pattern of the monsoonal rainfall inhibited by them. Such an inter-comparison should analyse the prominent spell characteristics (dry, wet and extreme spells) among the different gauge datasets, since any drastic difference in the precipitation characteristics, especially the frequency, length and intensity of dry and wet spells may often lead to faulty agricultural decisions like improper selection of crops, misjudgement of sowing and harvesting time, etc. (Revadekar and Preethi, 2012). Dry (wet) spells are prolonged period of dry (wet) days and serve as an indicator of drought (flood) conditions. Extreme wet spells are extended period of heavy wet days and are mostly short-lived, occasionally causing flash floods. The information about the dry, wet and extreme wet spell characteristics is of prime importance to the agronomist, hydrologists, ecologists and water-resources engineers (Ratan and Venugopal, 2013; Singh and Ranade, 2010; Singh et al., 2014; Sivakumar, 1992; Sushama et al., 2014; Vinnarasi and Dhanya, 2016).

Previous studies on inter-comparison of gauge-based precipitation datasets over India focused on basic statistical measures for comparison. Often, IMD precipitation dataset is compared with APHRODITE, CPC, etc. using statistical measures like standard deviation, correlation, bias and Root Mean Square Error (RMSE) (for e.g., Kishore et al., 2016; Pai et al., 2014; Prakash et al., 2015). Few studies have also analyzed the spatio-temporal variability in the gauge datasets using Empirical Orthogonal functions (EOF) (e.g. Rana et al., 2015). However, limited studies have compared the spell characteristics of monsoonal rainfall pattern of different gauge datasets. Sushama et al. (2014) compared the selected dry spell characteristics over India by IMD and APHRODITE datasets using coarser resolution gauge datasets ($1^\circ \times 1^\circ$ IMD and $0.5^\circ \times 0.5^\circ$ APHRODITE). A detailed investigation incorporating different dry and wet spell characteristics, should be carried out to analyze different gauge based datasets like IMD, APHRODITE and CPC.

In the view of the above shortcomings, the present study aims to (i) identify the basic differences between the three gauge based gridded datasets of IMD, CPC and APHRODITE over India, (ii) analyse different monsoonal spell characteristics over India and identify prominent differences in the spells of the datasets, and (iii) compare the natural trend of extreme spell characteristics exhibited by these three datasets. The present study will aid practitioners in selecting the appropriate precipitation dataset for studying the Indian summer monsoon rainfall depending upon the scope and application of their study. In addition, this study will also provide insights into the spatio-temporal behavior of these three datasets over different regions, which in turn will benefit hydrological applications over any un-gauged or sparsely gauged regions.

2. Gauge based precipitation datasets

Three gauge-based daily precipitation datasets of IMD, CPC and APHRODITE from 1979 to 2007 (29 years) are considered in this study, based on overlapping data period. These datasets are extracted for the region covering the Indian subcontinent from 66°E to 100°E and 6°N to 39°N. The digital elevation map of the study region is shown in Fig. 1 in which prominent topographic features such as Himalayas, Western Ghats and Thar Desert are indicated. For the present study, precipitation occurring during the monsoon months of June, July, August and September (JJAS) over the land region of India are only considered. Details of the three datasets are shown in Table 1 and a brief description of these datasets are provided below.

2.1. APHRODITE

APHRODITE (Asian Precipitation Highly Resolved Observational Data Integration Towards Evaluation of Water Resources) dataset

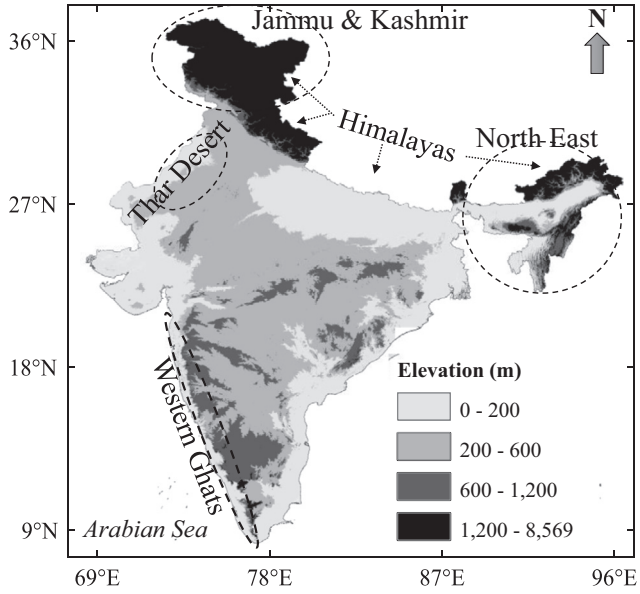

Fig. 1. Digital elevation map of the study region (India) prepared using the Shuttle Radar Topography Mission (SRTM) 90 m version 4 data. Elevation is expressed in meters above the mean sea level. Prominent topographical features are indicated by dotted lines.