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Comparison of two long-term and high-resolution satellite precipitation datasets in Xinjiang, China

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ABSTRACT

To investigate the long-term characteristics of precipitation in Xinjiang, China, two long-term monthly satellite precipitation datasets called CHIRPS (Climate Hazards Group Infrared Precipitation with Stations data) and PERSIANN-CDR (Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks - Climate Data Record) are evaluated and compared with in situ measurements from 105 meteorological stations for the period 1983–2014. The evaluation is performed at multiple temporal and spatial scales. Results based on comparisons with in situ measurements show that PERSIANN-CDR and CHIRPS have similar correlations. However, both of the BIAS and RMSE, CHIRPS outperformed PERSIANN-CDR with the smaller errors and bias. In terms of the long time-series comparison at temporal scale, CHIRPS is more accurate with gauge observations at monthly and annual scales while PERSIANN-CDR tends to overestimate the precipitation in the rain season (from May to September). Furthermore, compared with PERSIANN-CDR, results show that CHIRPS is more accurate in reflecting the spatial distribution of average monthly and annual precipitation. In summary, the study shows that CHIRPS is a valuable complement to gauge precipitation data and provides useful guidance when choosing satellite precipitation product for hydrometeorological applications in Xinjiang.

1. Introduction

Precipitation is an essential component for global energy and water cycles and is also a vital input for hydrological, meteorological and agricultural applications(Ebert et al., 2007). Precipitation datasets based on spatial interpolation is often subject to large uncertainties, particularly in high elevation zones (Guo et al., 2016). It is challenging in many parts of the world to obtain rainfall data with high accuracy and long-term record for hydrometeorological applications, such as the mitigation of natural hazards and climate change studies (Chiaravalloti et al., 2018; Gao et al., 2018; Zhang et al., 2012). Recently, the increased availability of satellite-based rainfall datasets with relatively long-term historical record provides an unprecedented opportunity for a wide range of hydrometeorological applications.

In the past decades, satellite datasets provide an alternative way to assess spatial-temporal variability of precipitation (Xie and Xiong, 2011; Zambrano et al., 2017a). Products like TRMM(Huffman et al., 2010), CMORPH(Buarque et al., 2011), PERSIANN(Sorooshian et al., 2010), PERSIANN-CCS(Hong et al., 2007) and other products provide precipitation data with the spatial resolution of 0.25° or finer(Maggioni and Massari, 2018). To date, extensive efforts have been devoted to producing high-resolution precipitation datasets in a global or quasi-global scale with different spatial and temporal scales(Chen et al., 2013; Derin and Yilmaz, 2014; Melo et al., 2015; Scheel et al., 2011; Yang and Luo, 2014). A wide range of studies have been conducted to evaluate these products using rain gauge measurements and gridded precipitation products(Chen et al., 2001; Chen et al., 2013; Duan et al., 2016; Gao and Liu, 2013; Jiang et al., 2012; Tang et al., 2016; Zhou et al., 2008). However, the performance of satellite precipitation products could vary from region to region, which is often subject to various factors such as location and altitude. Accurate and long-term precipitation data is essential for drought monitoring, hydrological modelling, agricultural production and water resource management, especially in areas where meteorological stations are sparse(Massari et al.,

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2017). Meanwhile, many climate-related studies often require a historical record of at least 30 years, as recommended by the World Meteorological Organization (WMO). Therefore, it is a pressing need but also a significant challenge to provide accurate precipitation products of long-term record that are suitable for climate changes and drought monitoring studies in many parts of the world.

Among various precipitation products, the PERSIANN-CDR(Ashouri et al., 2014) and CHIRPS(Funk et al., 2015) provide the unprecedented opportunity to explore long-term precipitation patterns with high spatial resolution on a quasi-global scale over the past three decades. PERSIANN-CDR and TRMM-3B42V7 products have been evaluated over Iran and the results indicated low performance in the mountainous and arid parts in the southeast region of the country (Wang et al., 2013). PERSIANN-CDR has been evaluated through the comparison with ground-based gridded China monthly Precipitation Analysis Product (CPAP) over China from 1983 to 2014, in which large differences for drought monitoring have been found over Xinjiang and Qinghai-Tibet Plateau region(Guo et al., 2016). It was also shown that the agreement of the PERSIANN-CDR with the in situ measurements in dry regions in China was not strong(Buarque et al., 2011). Compared with PERSIANN-CDR and TRMM 3B43, it was shown that CHIRPS has the highest agreement with ground measurements over Chile from the spatial variation pattern of correlation coefficients (Zambrano et al., 2017a). CHIRPS, TRMM and CMORPH_BLD have a better performance over Adige Basin in Italy compared with eight high spatial resolution gridded precipitation products(Sorooshian et al., 2010). CHIRPS shows good correlation with record precipitation over Cyprus for a 30-year period (Scheel et al., 2011). Although there are some studies to evaluate PERSIANN-CDR and CHIRPS with dense rain gauges networks(Katsanos et al., 2015; Katsanos et al., 2016; Paredes-Trejo et al., 2017; Zambrano et al., 2017b), the accuracy and spatial-temporal patterns of precipitation over the arid and semi-arid area in China have not been investigated. Meanwhile, in situ measurements is the traditional way to observe precipitation with a limited spatial resolution(Zhang et al., 2016). Unfortunately, the meteorological stations in Xinjiang region are sparse and uneven. It is critical to compare and evaluate the performance and applicability of these satellite precipitation products in this typically arid and semi-arid area. Meanwhile, it is helpful to improve the performance in future versions of CHIRPS and PERSIANN-CDR. Therefore, this study was to: 1) evaluate CHIRPS and PERSIANN-CDR in Xinjiang region with in situ measurements, and 2) reveal the long-term precipitation characteristics at spatial and temporal scales. Section 2 introduces the study area and the datasets, followed by Section 3 focusing the evaluation method. Results and discussions are presented in Section 4, followed by conclusions in Section 5.

2. Study area and data

2.1. Study area

Xinjiang is an arid and semi-arid region which locates between 34°25`-48°10′N and 73°40`-96°18′E in the northwest of China (as shown in Fig.1) and covers an area of 1.6 million km^2. It is a complex terrain with elevation ranging from −158 to 7390 m and a mean elevation of 1000 m. Traditionally, it is divided into northern Xinjiang and southern Xinjiang by Tianshan Mountain. Due to the complex terrain, the climate condition in the study area varies significantly. This area is far from ocean and has a continental arid and semi-arid climate with annual average temperature varying from 4 to 8 °C in northern Xinjiang and a continental dry climate from 10 to 13 °C in southern Xinjiang. The precipitation differs substantially between high mountains and low basins in Xinjiang (Zhang et al., 2012). Normally, the long-term mean annual precipitation is 130 mm while the evaporation is > 1000 mm in this area. The irrigation water is of great importance to agricultural production and ecological development(Tan and Shao, 2016). In the recent decades, the former studies indicated that Xinjiang is changed to be a warm-wet climate. The change of precipitation in the past is significant for future drought prediction and monitoring. Therefore, it is of critical importance to quantitatively investigate the temporal and spatial precipitation patterns in this region.

2.2. Meteorological stations data

A relatively dense network of rain gauges is used in this study including a total of 105 meteorological stations (in Fig.1). Precipitation data from 105 meteorological stations (after quality control) are used in this study within the period of 1983–2014, which can be downloaded for free from the official website of China Meteorological data network (http://data.cma.cn). The meteorological stations with missing data are interpolated by the near stations. A lot of quality control steps are used for each new run of CHIRPS. The stations produced for CHIRPS vary from month to month. The meteorological stations used for validation are contained in CHIRPS. However, > 80% of the 105 meteorological stations are not used in the production of CHIRPS.

2.3. Satellite precipitation datasets

2.3.1. CHIRPS

CHIRPS provides monthly precipitation data at spatial resolution of 0.05° with a quasi-global coverage of 50°S-50°N from 1981 to near present. The latest product is the Version 2.0 product that can be downloaded from the website (http://chg.geog.ucsb.edu/data/chirps/). CHIRPS is developed by the incorporation of satellite imagery with in situ measurements and a high resolution climatology. The high resolution climatology is based on satellite precipitation averages, elevation, latitude, longitude and in situ station normal(Funk et al., 2015). CHIRPS belongs to the "satellite-gauge" category and more details can be found in (Melo et al., 2015). It uses a fairly simple cold-cloud duration Global Precipitation Index analysis of infrared brightness temperatures, tuned with TRMM, and constrained using the high resolution climatology. CHIRPS is performed to monitoring drought and climate change on a global scale. Meanwhile, it has used for long-term trend analysis and supported the United States Agency for International Development Famine Early Warning System Network (FEWS NET). In this study, CHIRPS monthly precipitation data at 0.05° spatial resolution for the period 1983–2014 are used and evaluated.

2.3.2. PERSIANN-CDR

PERSIANN-CDR is developed by the Center for Hydrometeorology and Remote Sensing (CHRS) at the University of California. It provides daily precipitation at a spatial resolution of 0.25° for the quasi-global overage of 60°S-60°N from 1983 to present. More details about this product can be found in the website (http://chrs.web.uci.edu/persiann/). This product is aimed to supply a consistent and long-term precipitation dataset and can be useful for studying the extreme precipitation events caused by the climate change. Whereas the CHIRPS uses a simple CCD-based metric in conjunction with a complex climatology, PERSIANN-CDR uses a much more complicated algorithm based on Artificial Neural Nets (ANN) and classifications of the thermal brightness temperatures(Hsu et al., 1996). PERSIANN-CDR monthly precipitation data at 0.25° spatial resolution for the period 1983–2014 are evaluated by in situ measurements and compared with CHIRPS.

3. Method

It is well recognized that the station rainfall data generally do not match with the satellite precipitation dataset because issues related to discontinuities of scale (Duan et al., 2016). Usually the rain gauges' data are interpolated to the same scale with the satellite precipitation product by different interpolation techniques, such as the inverse distance weighting (IDW), the Thiessen polygon, and the Kriging method. However, each interpolation method has its own advantages and