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Comparison and evaluation of high resolution precipitation estimation products in Urmia Basin-Iran

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ABSTRACT

This study focuses on the comparison and evaluation of six daily 0.25° × 0.25° high resolution precipitation data sets (PERSIANN, CMORPH-RAW, CMORPH-CRT, TMPA-RT, TMPA-V7 and APHRODITE). The comparison is performed during years 2000 till 2011 in Urmia basin of Iran and the local daily rainfall gauge observations are considered as the reference data set. Several statistical, categorical and graphical evaluation techniques are used to compare and evaluate the product performances and quantify their biases from reference data. APHRODITE and TMPA-V7, by benefiting from gauge observations during their adjustment procedures present better estimations while among near real-time products, PERSIANN is able to remarkably outperform other estimations. Both CMORPH products has shown to have great overestimation (more than 200%) over the observations while PERSIANN and TMPA-RT tend to underestimate rainfall on average about 26% and 78% respectively. TMPA-V7 and APHRODITE also overestimate observations about 26 and 3 percentages. Compared to near real-time version of products, TMPA-V7 has succeeded to significantly improve TMPA-RT performance while CMORPH-CRT has completely unsuccessful in its mission. Although all rainfall estimation products are characterized by considerable biases in comparison to the gauge observations, detailed analysis indicate that some of them have the capability of becoming a valuable source of high resolution precipitation estimation data set, especially over purely gauged areas.

1. Introduction

Precipitation is a vital part of the water cycle, connecting the ocean, land, and atmosphere. Knowing where it rains, how much it rains and moving toward better and more accurately estimate of the precipitation is of a special importance in hydrological modeling and water resources management of the basins. Therefore, measuring rainfall height in rain gauges using traditional measurement instruments had been done from the distant past. Although traditional rainfall observation in rain gauges is still the most accurate way of rainfall measurement, poor spatial and temporal resolution of the gauge networks (especially in developing countries) has led to appearance of alternative estimation methods, mainly based on satellite data. It should be considered that the precision of these alternative estimation methods are still far from the accuracy of in situ observations. Nevertheless, they are capable of representing high spatial and temporal resolution data. Therefore, in this way it will be possible to have rainfall estimations on a wide range of the earth and cover even far and difficult to pass regions or water bodies.

As a result, some High Resolution Precipitation Products (HRPP) has been produced based on remote sensing techniques and satellite data in recent years. On the other hand, some other HRPPs have been introduced based on international precipitation observations and usage of different interpolation techniques. A number of more recent HRPPs which try to present

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real-time or near real-time accurate estimations of precipitation are now freely available, including the Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN; Hsu et al., 1997; Sorooshian et al., 2000), the National Oceanic and Atmospheric Administration (NOAA) Climate Prediction Center (CPC) Morphing technique product (CMORPH; Joyce et al., 2004), the Tropical Rainfall Measuring Mission (TRMM) Multi-satellite Precipitation Analysis (TMPA; Huffman et al., 2007) and Asian Precipitation Highly Resolved Observational Data Integration Towards Evaluation of water resources (APHRODITE; Yatagai et al., 2012). By using complementary aspects of passive microwave (PMW) data from polar-orbiting satellites (LEO, Low Earth Orbiting satellites) and the infrared (IR) data from geostationary satellites (GEO, Geosynchronous Earth Orbiting satellites), satellite based HRPPs provide global estimations of precipitation in different spatial and temporal resolutions such as 0.04, 0.25 and one degrees and 0.5, 3, 6 or 24 h, respectively.

It is worth mentioning that, although everyone may be interested in using HRPPs because of their strength in high spatial and temporal data resolution, the low accuracy of these products in estimating exact rain rates in comparison with ground based observations is their non-negligible weak point. This low accuracy may be caused by the global scale of the calculations or their indirect nature of precipitation estimations. Moreover, due to the usage of satellite data and especially unique climate patterns for many regions of the earth, HRPPs precision in rainfall estimation may vary in different countries and basins. Therefore, evaluation of HRPPs in comparison with in situ observations has been carried out by many researchers in different regions (e. g.: Alder et al., 2001; Ebert et al., 2007; Tian et al., 2007, 2009; Turk et al., 2008; Habib et al., 2009; Javanmard et al., 2010; AghaKouchak et al., 2012; Tang and Hossain, 2012; Jamandre and Narisma, 2013; Katiraie et al., 2013; Moazami et al., 2013; Nastos et al., 2013; Turk and Xian, 2013; Lo Conti et al., 2014; Porcu et al., 2014; Liu, 2015).

Lo Conti et al. (2014) compared the performance of different versions of PERSIANN, TMPA and CMORPH datasets around a pretty large basin in Italy (Sicilia Island). They performed a deep comparison with respect to numerous methods and indexes such as usual statistical indicators and categorical comparison methods. Another similar deep comparison had been done previously by Habib et al. (2009) focusing only on the TMPA satellite based estimation over Louisiana, USA. This study shows that understanding error properties of HRPPs are vital for their fundamental improvement and developing bias reduction methods, as later emphasized by Sorooshian et al. (2011) and AghaKouchak et al. (2012). However, the evaluation activity needs to be considered with reference to a specific geographic region, because performance can be related to spatial and geographic features (Lo Conti et al., 2014).

In this regard, evaluation studies and comparison of HRPPs over Iran (which is the subject of this study) has been previously addressed by some studies. Javanmard et al. (2010) evaluated the TMPA-3B42 V6 with reference to synoptic rain gauges over entire Iran from 1998 to 2006 and presented some annual, seasonal, monthly and daily comparisons. This study shows the large scale and local error patterns of TMPA over Iran by focusing on bias and correlation coefficient measures. Another Evaluation study has been done by Katiraie et al. (2013) over 32 pixels ($0.25° \times 0.25°$) around the entire country of Iran. In that study, daily and monthly datasets of CMORPH, PERSIANN, TMPA-3B42 V6 and adjusted PERSIANN (using monthly GPCC data) from 2003 to 2007 are used to perform the evaluation using statistical and categorical measures. Results of this study confirm the findings of Javanmard et al. (2010) about local patterns of HRPPs precision and totally address better performance of TMPA-3B42 V6 and adjusted PERSIANN over Iran.

In a more recent research, Moazami et al. (2013) also studied the performance of PERSIANN, TMPA-RT and TMPA-V7 over the entire country of Iran, using statistical and categorical comparison methods. They have performed the evaluation using 47 daily rainfall events during the winter and spring seasons from 2003 to 2006. This study shows better performance for TMPA-V7 from the aspects of statistical measures and superiority of PERSIANN associated with the probability of detection of rainfall events. It is worth mentioning that considering both precision of estimation and speed of delivering rain rates will result in a fairer evaluation over performance of different versions of HRPPs. In other words, it is more logical to compare near real-time versions of TMPA and CMORPH with PERSIANN estimates than to compare all near real-time and adjusted versions together. This point will be more important for meteorological or hydrological studies interested in near real-time usage of HRPPs (such as real-time predictions, flood warnings or etc.) than those which only need historical qualified datasets (such as climate change, water planning or management studies).

As mentioned above, all previous studies over Iran have considered the whole country as their case study and as a result, they have more logically addressed large scale patterns than to deeply focus on comparison details. Therefore, in the current study six of the most common and well-known HRPPs (PERSIANN, TMPA-3B42 RT, TMPA-3B42 V7, CMORPH-RAW, CMORPH-CRT and APHRODITE) are evaluated and compared over domestic rain gauge network of Urmia basin, which is one of the most important and noteworthy basins of Iran. The performance analysis of HRPPs is done by using daily precipitation data from 2000 to 2011 (4749 days) in 69 grids ($0.25° \times 0.25°$) each one having at least one gauge station. The evaluation is performed by analyzing different statistical and categorical measures which are all explained in the following sections after description of data used and study area. Then, results of the study are presented and finally all are summarized in the concluding section.

2. Datasets and study area

2.1. Study area

The study area in this research is one of the most important and controversial basins in Iran named, Urmia basin. This basin is located in the north western of Iran and consists of an environmentally valuable lake named Urmia Lake (Fig. 1). Urmia basin is located between 44°–07′ and 47°–53′ eastern latitude and 35°–40′ and 38°–30′ northern longitude, with a surface area of about 51,862 km^2. The morphological structure of the basin consists of about 34,100 km^2 of mountainous area, 13,123 km^2 containing foothills and flat areas and the remaining 4639 km^2 of the basin which belongs to the Urmia Lake.