SATELLITE PRECIPITATION AND EVAPOTRANSPIRATION ESTIMATION OVER THE SOUTH AMERICAN ANDEAN PLATEAU (ALTIPLANO)

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ABSTRACT

During the last decades, the South American Andean Plateau water resources is facing unprecedented pressure due to the combination of climate variability and agricultural activities increase. However, the available meteorological gauge network is too sparse in time and space to adequately understand and prevent ongoing change. In this context, this study aimed at the validation of newly released CHIRPS rainfall and GLEAM potential evapotranspiration (ETp) products for the 1981-2012 period. by comparing them with in situ data. The results show that CHIRPS and GLEAM provide consistent precipitation and evapotranspiration estimates at the regional. Even if some inconsistencies are highlighted at the local scale (especially for GLEAM) these dataset offer a great opportunity toward a sustainable water use management.

Key words — Evapotranspiration, Rainfall, CHIRPS, GLEAM, ALTIPLANO.

1. INTRODUCTION

Considering an increase in air temperature estimated between 0.15 and 0.25 °C by decades from 1965 to 2012 [1,2] the South American Andean plateau (i.e. South American Andean Plateau), region particularly sensitive to global warming. Actually climate variability is threatening Bolivian water security as illustrated by the example of recent water restrictions of La Paz capital city from November 2016 to March 2017 after the main fresh water reserve drought up. On the same period the agriculture activity drastically increased and contribute to an ongoing desertification processes as illustrated by the totally lake Poopo drought in 2015 (Satgé et al. 2017). Understanding ongoing changes requires consistent meteorological estimates in space and over time. However, because of the regional economic and geographic context, the available gauges network suffer from many gaps in time and space compromising it use in such studies.

Recently, the emergence of remote sensing product offer the opportunity to follow climate variable on regular grids at the near-global scale, representing an unprecedented opportunity to traditional measurement. Among the currently available remote sensing datasets, the Climate Hazards Group InfraRed Precipitation with Station version 2 (CHIRPS) and GLEAM version 3.1 database [3] provide precipitation and potential evapotranspiration (PET) estimates, respectively. With a consistent overlapping time period of 35 years (1981-2016) these products seems particularly suited for the above described context to understand past and ongoing changes.

However, CHIRPS and GLEAM are indirect measurements made from satellite and are subject to uncertainty due to technical limitations. Because of their recent availabilities, few studies report on CHIRPS [4] and GLEAM v3.1 [3], but all studies revealed a great potential for meteorological drought monitoring. In this context, the present study aims at the assessment of CHIRPS and GLEAM monthly estimates over the Altiplano using in situ dataset as references to provide a source of feedback upon their merits and demerits.

2. MATERIAL AND METHODS

2.1. Study Area

The Andean Altiplano plateau is an endorheic region located in the South American high land between latitude 22° S and 14° S and longitude 71° W and 66° W (Figure 1). The regional watershed is delimited at the East and West by oriental and occidental cordilleras, respectively. The region is very flat with a mean slope value of 5° and a mean altitude of 4,000m [5]. It is called TDPS system in relation to the specific system including the Lake Titicaca, the Desaguadero River, the lake Poopó and the two salt deserts of Coipasa and Uyuni with total area of approximately 192 390 km^2 . The climate is semi-arid with wet conditions originating from low land of the Amazon region [6]. Wet conditions from the pacific cannot reach the region because of the coastal topography and the persistent temperature inversion close to 800 m above sea level [7]. Consequently, rainfall decreases from 1,100 mm.year-1 to less than 200 mm.year-1 following a very marked north-south gradient [8] and a light east-west gradient. The rainy season occurs during the austral summer from November to March and contribute up to 70% of the total annual rainfall amount.

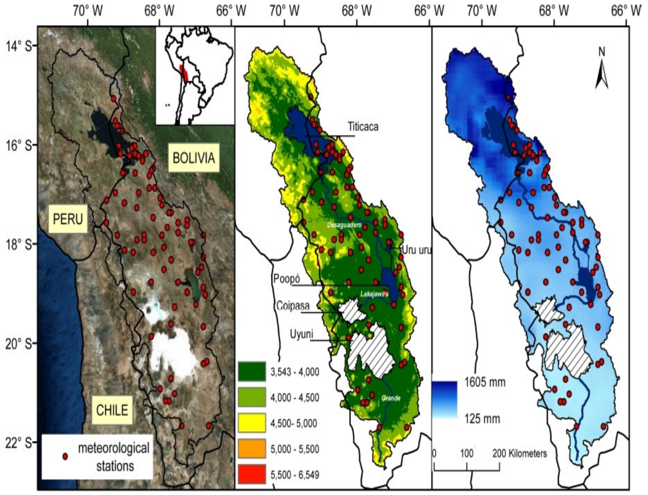

Figure 1. Study area: (a) locations of the meteorological stations (b) elevation derived from the SRTM and (c) mean annual rainfall derived from CHIRPS data for the 1982–2016 period.

2.2. Data Used

2.2.1.Reference meteorological data

The Servicio NAcional de Meteorologia y Hidrologia (SENAMHI) is responsible for the Bolivian national hydro-meteorological network. In this study, data from 154 meteorological stations equipped with a rain gauge and the required climatic sensors (temperature, air humidity and wind) for potential evapotranspiration computation with data for the 1960-2012 period were made available by the Bolivian SENAMHI. Meteorological stations were not available over the Peruvian region due to geopolitical tension on the water management of Lake Titicaca.

2.2.2. CHIRPS

Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) is a product developed by the U.S. Geological Survey (USGS) and the Climate Hazards Group (CHG) [4]. In a first step, rainfall estimates are derived from global Cold Cloud Duration (CDD) retrieved from the Globally Gridded Satellite (GriSat) and NOAA Climate Prediction Center (CPC) thermal infra-red dataset using a fixed threshold of 235 °K. Additionally, CDD estimates are calibrated over the 2000-2013 period using the Tropical Rainfall Measuring Mission (TRMM) Multisatellite Precipitation Analysis 3B42 (TMPA-3B42) gauges adjusted version 7. In a second step, rain gauges data from world meteorological organization's including the Global Historical Climate Network (GHCN), the Global Summary of the Day (GSOD), the Global Telecommunication System (GTS) and Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL) jointly with data from Mexico, Central and South America, and Sub Saharan Africa from national agencies are blended with CDD rainfall estimates, using a modified inverse distance weighting algorithm to enhance rainfall estimates accuracy. For more information, please refer to [9].

2.2.3. GLEAM

The Global Land Evaporation Amsterdam Model (GLEAM) is a set of algorithms to estimates evaporation components from satellite observations. Potential Evapotranspiration (ETp) is retrieved from the Priestley and Taylor equation based on surface net radiation and near-surface air temperature. Then, root-zone soil moisture and Vegetation Optical Depth (VOD) are used to apply a multiplicative evaporative stress factor on ETp to retrieve the Actual Evaporation (Eta). Recently, the third GLEAM version (GLEAM v3.1) was made available with three datasets (GLEAM v3.1a, b and c) [3]. The datasets differ in terms of spatial coverage, spatial resolution and forcing data. According to the study objectives, the dataset GLEAM v3.1a with a global coverage and a 0.25° mesh size is selected as it presents the highest spanning time among the three datasets (37 years from 1980–2016). Data are available on daily time step (https://www.gleam.eu/).

3. RESULTS

3.1. CHIRPS and GLEAM Assessment

Figure 2a shows the comparison between mean regional precipitation estimates derived from CHIRPS and the gauges. Compared to mean regional rainfall derived from the gauges, CHIRPS achieves to represent rainfall pattern with a very high degree of confidence. CC, NRMSE and %B of 0.97, 0.27 and -5.45%, respectively (Figure 2a), correspond to an overall very good performance rating . Therefore, CHIRPS is suitable to represent the mean monthly regional rainfall regimes over the South American Andean plateau.

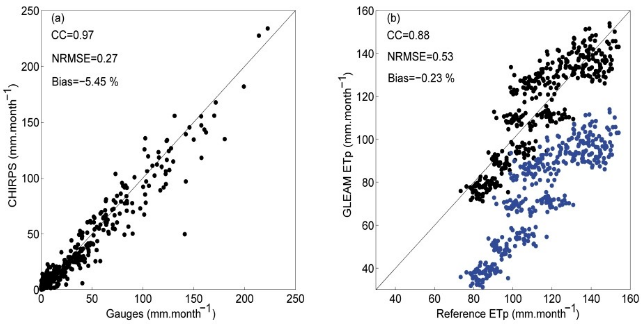

Figure 2. CHIRPS and GLEAM regional consistency against reference rainfall and ETP derived from the meteorological stations: scatter plot with CC, %B and NRMSE comparing mean monthly regional rainfall (a) and ETp (b). Blue and black colors are used for GLEAM estimates before and after the bias correction.

Looking at the spatial distribution of CHIRPS statistical scores (e.g. CC, RMSE and %B), CHIRPS remains well correlated to gauges data all over the region with CC superior to 0.7 excepted for 5 stations with CC around 0.6 (unsatisfactory) (Figure 3). For most of the pixels, %B ranges between -25 to 25% corresponding to good performance rating. It is noteworthy that most of the pixels with absolute %B superior to 50% correspond to pixels compared to rain gauges with less than 15% of the data. Therefore, those results should be considered with caution, as very few data were available for comparisons. The pixels with less than 15% of data correspond to pixels with unsatisfactory NRMSE (>0.7). Pixels located in the extreme south part of the watershed and on the Lake Titicaca shore present unsatisfactory NRMSE. Actually, SREs are known to be less accurate in those specifics regions due to (i) very arid context (southern part) and (ii) emissivity and temperature variability (Lake Titicaca) [10]. However, CHIRPS appears less impacted by Lake Titicaca effect than other SREs (e.g. PERSIANN, CMORPH, GSMaP, TMPA) with higher CC and lower %B values. According to the obtained results, CHIRPS can be used at the regional scale (Figure 2a) to observe rainfall variability with a very good degree of confidence and at the local scale with an overall satisfactory to good degree of confidence (Figure 3).

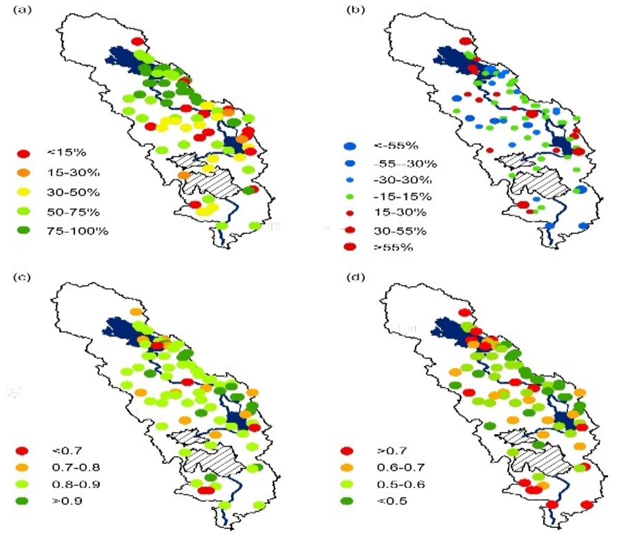

Figure 3. CHIRPS spatial consistency against gauges measurement: (a) available monthly rainfall amounts from gauges for the period 1982–2012, (b) mean %B, (c) CC and (d) NRMSE.

Figure 2b shows the comparison between mean regional ETp estimates derived from GLEAM and the gauges. When comparing GLEAM and reference ETp regional monthly series, a negative bias of approximately 40 mm.month^{-1} due to GLEAM ETp underestimation. This bias was systematically corrected and only results after bias correction are presented (Figure 2b). GLEAM reference ETp agreed well with CC, NRMSE and %B values 0.88, 0.53 and −0.23%, respectively. All statistical scores are into the threshold quality range required for a very good performance rating. Therefore, GLEAM is suitable to represent monthly regional ETp over the Altiplano. Looking at the spatial distribution of GLEAM ETp statistical scores (Figure 4); scores are unsatisfying for many pixels. In many pixels, NRMSE value is very high. According to the results obtained, GLEAM ETp should not be used at the pixel scale in order to limit erroneous local observations. Therefore, in this study, GLEAM ETp was aggregated to the regional scale with average values obtained from all pixels included into the study region to observe monthly regional ETp.

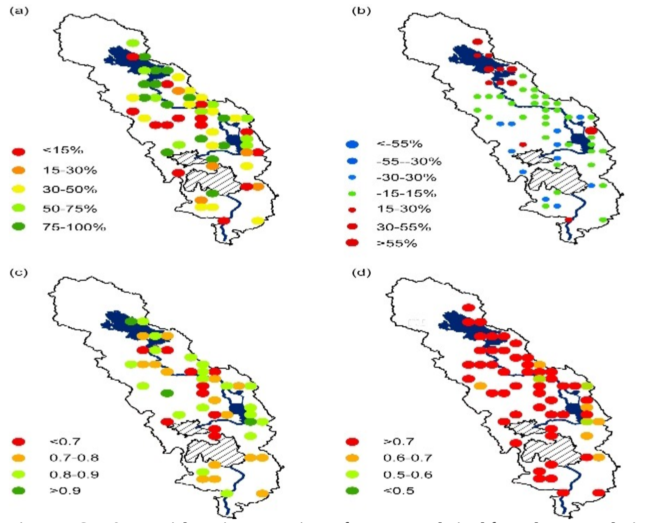

Figure 4. GLEAM spatial consistency against reference ETp derived from the meteorological stations: (a) available monthly ETp amounts from the meteorological station for the period 1982–2012, (b) mean %B, (c) CC and (d) NRMSE.

4. CONCLUSIONS

In this study, the satellite based rainfall and evapotranspiration over Altiplano is assessed. The study is based on remote sensing products involving, CHIRPS, GLEAM Datasets. THE validation of CHIRPS and GLEAM to represent regional rainfall and ETp along space and time is done at monthly scale. Some consistent features emerged from the analyses:

1. CHIRPS is accurate enough to represent monthly rainfall variations at the regional and local pixels scale. With more than 35 complete years data availability, it offers the possibility to follow rainfall spatiotemporal variability with a high degree of confidence.
2. GLEAM-ETp underestimated monthly ETp and bias needs to be corrected before its use. GLEAM ETp is well-suited to represent ETp at the regional scale offering the possibility to describe regional monthly ETp variability with a high degree of confidence over the last 35 years. The inconstancies in GLEAM ETp at the local pixel scale limit its use in the regional scale.

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