PRECIPITATION ESTIMATION THROUGH SATELLITE SYSTEM OVER THE MAJOR MEDITERRANEAN ISLANDS

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KEY POINTS

- *Precipitation GPM products were tested against data provided by raingauges over Sardinia and Sicily*
- *Features of rainfall spatial distribution and the influence of the aggregation time scale have been investigated*
- *GPM satellite data slightly overestimates rainfall over the study areas*
- *GPM performances improve as the temporal aggregation increases*

1 INTRODUCTION

Reliable and accurate precipitation measurement or estimation is crucial for disaster monitoring and water resource management. Nowadays the scientific community expects significant improvements in precipitation monitoring by the continuous technological evolution of satellite-rainfall estimate systems which are able to produce data with global coverage and thus can provide low-cost information even in scarcely populated areas or places where for economic reasons ground measures are missing. The most recent satellite mission is the Global Precipitation Measurement (GPM), which is an international constellation of ten partner satellites, and a source of rainfall estimates at high spatial and temporal resolution (Huffman et al., 2017).

In this context, the aim of this study is to test satellite-precipitation GPM-IMERG products against data provided by dense raingauges over the two major islands of Mediterranean Sea, i.e. Sardinia and Sicily. The two islands are characterized by a complex morphology and by small spatial scale and long see-land transition borders. Moreover, they experience different precipitation types, originated by convective and stratiform systems as well as by the interaction of steep orography in the coasts with winds carrying on humid air masses from the Mediterranean Sea. For these reasons, the two islands can be considered as interesting test sites for satellite-precipitation GPM-IMERG product in the European mid-latitude area and in general for complex domains. The GPM-IMERG post real-time “Final” run product (last version V4 released in spring 2017) at 0.1° spatial resolution and half-hour temporal resolution has been selected for the two years period 2015-2016. Evaluation and comparison of the selected product are performed with reference to data provided by the raingauges network of the two islands. Both GPM and raingauges data have been aggregated at hourly time scale, then the raingauges data have been spatially interpolated and resampled at the GPM resolution grid. In order to obtain general information about the performances of estimates related to the entire two islands, features of rainfall spatial distribution and the influence of the aggregation time scale have been investigated using statistical and graphical tools.

2 DATABASE

2.1. Reference raingauges networks

The raingauges dataset of Sicily is provided by the Osservatorio delle Acque-Agenzia Regionale per i Rifiuti e le Acque (OA-ARRA) (http://www.osservatorioacque.it/), which maintains the meteorological informative system of Sicily that collects information and provides a quality-controlled dataset. The dataset includes 195 tipping-bucket raingauges with a rather homogeneous spatial distribution, and an average density equal to about 130 km^2/gauge. Data are retrieved with hourly resolution.

The raingauge data set of Sardinia is provided by the Civil Protection service that collects meteo-climatic information and provides a quality-controlled dataset. The dataset is comprised of 105 tipping-bucket raingauges, with an average density equal to about 228 km^2/gauge. Data are retrieved with high-temporal resolution (1 minute).

For both islands the data collected in the period 2015-2016 (i.e., two years) were aggregated at hourly time scale and then used as reference to evaluate the performance of the GPM satellite data.

A direct quantitative comparison between satellite-product and raingauges data (i.e., a grid-to-point evaluation) can be problematic mainly because the first product provides an estimation of mean precipitation in each grid cell, while the latter relies on point observation. In order to overcome this issue, the nearest neighbor method was adopted to interpolate the raingauge records over a regular grid structure. First, a high-resolution (0.01º, i.e., ~1 km) grid covering the islands was defined. The rainfall value in each pixel of the high-resolution grid was assumed equal to the value observed in the nearest raingauge. The resulting rainfall field was then resampled at the same grid of satellite product (i.e., 0.1º resolution) by averaging the values of the high-resolution grid.

2.2. GPM satellite data

We used precipitation estimates from the latest version V4 of the Global Precipitation Measurement (GPM) mission Integrated Multi-satellitE Retrievals for GPM (IMERG) "Final" product, released in spring 2017 (ftp://arthurhou.pps.eosdis.nasa.gov/gpmallversions/V04/). IMERG provides timely observation of precipitation at 0.1° resolution every 30 minutes. For Sicily only raingauges data at hourly time scale are available, therefore, in this study, the GPM data have been aggregated at least to hourly time scale for both islands.

3 EVALUATION INDEXES

The following set of indexes has been chosen to describe different aspects of satellite-precipitation performances in reproducing interpolated maps and reference raingauges network datasets.

The Correlation Coefficient (CC) is equal to:

$$CC = \frac{\mathrm{cov}(P_{est}, P_{obs})}{\sigma(P_{est}) \cdot \sigma(P_{obs})} \tag{1}$$

where P_{est} and P_{obs} are the precipitation estimation provided by the satellite product for a single pixel and the resampled precipitation value provided by raingauges, respectively, while cov(X,Y) is the empirical covariance between X and Y variables, and σ(X) is the empirical standard deviation of X.

The Standardized Root Mean Square Error, S-RMSE, can be written as:

$$S-RMSE = \sqrt{\frac{\sum_{i=1}^{n}(P_{obs}^{(i)} - P_{est}^{(i)})^2}{n}} \Big/ \left(\frac{\sum_{i=1}^{n} P_{obs}^{(i)}}{n} \right) \tag{2}$$

where n is the number of observations.

The Standardized Mean Bias Error, S-MBE, can be defined as:

$$S-MBE = \frac{\sum_{i=1}^{n}(P_{obs}^{(i)} - P_{est}^{(i)})}{\sum_{i=1}^{n} P_{obs}^{(i)}} \tag{3}$$

The Probability of Detection, POD, sometimes referred to as Hit Score, has been estimated as:

$$POD = \frac{\sum_{i=1}^{n} I(P_{est}^{(i)} > t \,|P_{obs}^{(i)} > t)}{\sum_{i=1}^{n} I(P_{obs}^{(i)} > t)} \tag{4}$$

where n is the sample size, t is the threshold value above which the precipitation occurrences are considered for POD computation, and $I(a|b)$ is a function counting the number of occurrences when conditions a and b are both satisfied. In this study, the threshold value for categorical indexes is set equal to the 5th, 50th and 95th percentiles at each pixel and then is spatially distributed. POD is equal to 1 if the analyzed data set is able to represent all occurrences and 0 if no occurrences are detected.

The False Alarm Ratio, FAR, can be defined as follows:

$$FAR = \frac{\sum_{i=1}^{n} I(P_{est}^{(i)} > t \,|P_{obs}^{(i)} < t)}{\sum_{i=1}^{n} I(P_{est}^{(i)} > t)} \tag{5}$$

FAR indicates the relative number of rainfall occurrences above a threshold t detected by the satellite product when the reference dataset is less than t. FAR is equal to 0 if estimates do not reproduce any false occurrence and 1 if all estimated occurrences do not correspond to observed threshold exceedances.

4 Results

4.1 Spatial analysis

Figure 1 shows the spatial distribution of the correlation coefficient (CC), the standardized root mean square error (S-RMSE), and the standardized mean bias error (S-MBE), obtained comparing hourly time series in each grid cell for Sardinia (Panels a,c,e) and Sicily (Panels b,d,f). The highest values of the CC for Sardinia (Figure 1a) are equal to ~0.55 mainly in the northern part of the island, while for Sicily (Figure 1b) the highest values of the CC, equal to ~0.45, are observed in the south-western part of the island. The lowest values of S-RMSE are ~6.5 in the eastern part of Sardinia, while the highest values are equal to ~16 in the north-west (Figure 1c). In Sicily, S-RMSE ranges from ~7.3 in the north-east and north-west to ~19 in the south-east and north-west (Figure 1d). The S-MBE reaches the best performance (green pixels in Figure 1e,f) in the center of the two islands. This could be due to an issue arising from coastal treatments because retrieval algorithms can suffer from some weaknesses due to different radiative properties of hydrometeors over the land and the ocean respectively.

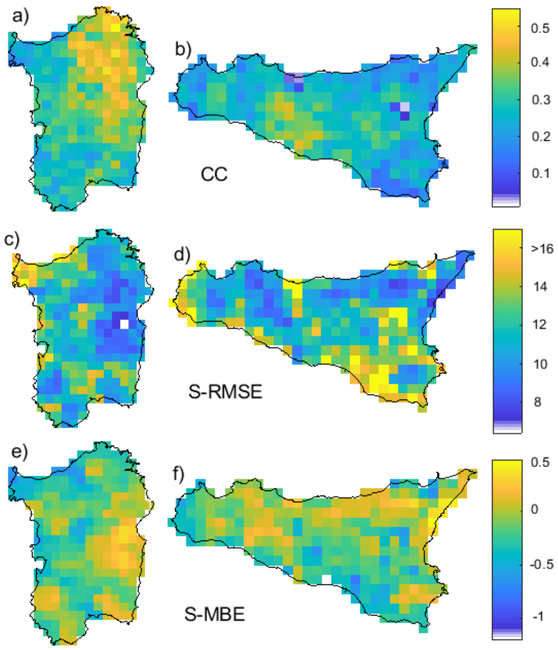

Figure 1. Comparison of hourly GPM satellite precipitation and interpolated-raingauges data for Sardinia (a,c,e) and Sicily (b,d,f) by continuous indexes: CC, correlation coefficient (a,b); S-RMSE, standardized root mean square error (c,d); S-MBE, standardized mean bias error (e,f).

4.2 Analysis of spatially averaged precipitation values

In order to better investigate how GPM product performances vary with the time aggregation scales, several indexes have been evaluated at 1, 3, 6, 12 hours, 1, 2, 3, 4, 5, 10, 15, 20, 30, 60 days. Results of such analysis have been summarized in Figure 2, where spatially averaged indexes for each time aggregation scale are plotted for Sardinia (Figure 2a,c,e,g) and Sicily (Figure 2b,d,f,h). Specifically, we considered: the correlation coefficient CC, the standardized root mean square error S-RMSE, the probability of detection POD, and the false alarm ratio FAR. Figure 2 points out that statistical indexes describe an improvement of performances as time aggregation increases, showing about the same behavior for both islands. The CC (Figure 2a,b) values increase as the time resolution decreases, while the S-RMSE decreases as the time-aggregation interval increases (Figure 2c,d). POD (Figure 2e,f) and FAR (Figure 2g,h) values have been calculated considering again precipitation values higher than 1 mm and then using as threshold the 5th, the 50th and the 95th empirical percentiles for each pixel: POD (FAR) increases (decreases) as the time-aggregation interval increases. Almost all the plotted performances indexes improve in the first time intervals (i.e., from hourly to 5-day intervals) and then tend to stabilize and become constant for time aggregation larger than 10 days.

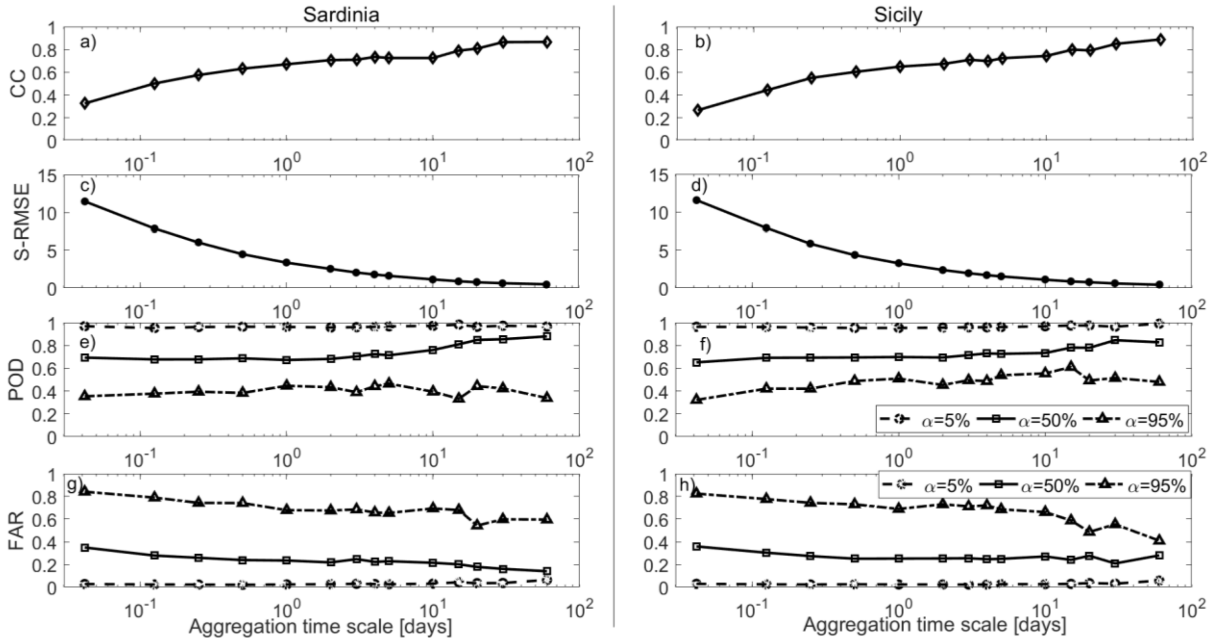

Figure 2. GPM product performances for different aggregation time scales (i.e., 1, 3, 6, 12 hours, 1, 2, 3, 4, 5, 10, 15, 20, 30, 60 days) in Sardinia (a,c,e,g) and Sicily (b,d,f,h): CC, correlation coefficient (a,b); S-RMSE, standardized root mean square error (c,d); POD, probability of detection (e,f); FAR, false alarm ratio (g,h). Last two indexes are computed for thresholds tα with α equal to 5%, 50%, and 95%.

5 CONCLUSIONS

The results of this study showed that correlation among GPM satellite data and interpolated gauges rainfall is rather good. The values of bias confirmed that GPM satellite data slightly overestimates rainfall over the study areas, but they have reasonable agreement with the raingauge data. GPM performances improve as the temporal aggregation increases, reaching a stable performance approximately at 10 days.

Satellite estimates are not yet fully suitable to represent the corresponding climate. The bias characteristic of satellite-precipitation estimates needs further analysis. Since the GPM is a new tool for precipitation measurements, some challenging issues in its accuracy amount in different regions of the world having dissimilar conditions will continue to stay open for researchers.

REFERENCE

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