Intercomparison of satellite and ground-based precipitation in the area of Cyprus

LOULLI E.[1,2,*], BÜHL J.[3], MICHAELIDES S.[1,2], LOUKAS A.[4] and HADJIMITSIS D.G.[1,2]

[1] Cyprus University of Technology, Archiepiskopou Kyprianou 30, Limassol 3036, Cyprus

[2] ERATOSTHENES Centre of Excellence, Limassol 3036, Cyprus

[3] Leibniz Institute for Tropospheric Research (TROPOS), Permoserstraße 15, 04318 Leipzig, Germany

[4] Aristotle University of Thessaloniki, Thessaloniki 541 24, Greece

*corresponding author:
e-mail: eleni.loulli@cut.ac.cy

Abstract Cyprus has an excellent location for studying meteorology, climatology of atmospheric aerosols and aerosol-cloud-precipitation interaction. Aerosol-cloud-precipitation dynamics in the region of Cyprus are responsible for the country's precipitation budget. This study uses observations from the NASA's Global Precipitation Measurement (GPM) Mission and from the two ground-based radars of the Department of Meteorology (DoM) to measure the distribution of precipitation over Cyprus. The DPR (Dual-frequency Precipitation Radar) aboard of GPM is used in order to derive precipitation rate at the ground with a spatial resolution of 5-25km for 120km wide swath. The ground-based radar stations provide raw information with a spatial resolution of 0.1° and a radius of 150km. The two datasets are interpolated on a universal grid in order to enable the calibration of the raw data and their validation with the GPM data. The results will contribute to the development of an automated method for the estimation of the precipitation budget over the area of Cyprus and thus, drought monitoring in the region of the eastern Mediterranean.

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Keywords: remote sensing, precipitation, radar, GPM, eastern Mediterranean

1. Introduction

Drought is reported as a rainfall deficit with regard to its long-term mean that affects a large area for a certain time period (*Hounam et al., 1975*) and is a phenomenon that may trigger or exacerbate desertification (*Paron et al., 2015*).

Contrary to other natural disasters, drought has a variety of unique features. Drought is a multidimensional phenomenon that starts imperceptibly, advances slowly and cumulatively, and its consequences show up gradually (*Kogan et al., 2017*; *NOAA, 2019*). Scientists often apply weather-based parameters and indices to monitor drought, but due to this peculiarity of the phenomenon such methods are inadequate for the estimation of the temporal and spatial drought features. Specifically, the characteristics such as drought start/end, intensity, magnitude, area, season, origination, duration and impact are crucial in drought monitoring and should be taken into account in drought assessment (*Kogan, 2019*).

Several authors (*Katsanos et al., 2018*; *Michaelides and Pashiardis, 2008*; *Papadaskalopoulou et al., 2015*; *Sarailidis et al., 2019*) have analyzed and reviewed the climatic behavior over the Mediterranean region. Their findings underlined the vulnerability of the region to climatic extremes, particularly to precipitation decrease, but to extreme precipitation decrease (*Alpert et al., 2002*). Cyprus is located in the Southeast Mediterranean basin and its climate is described by mild dry-to-hot summers and cool to mild-to-wet winters. The majority of the annual precipitation, ca. 60% comes during the winter months (*Michaelides and Pashiardis, 2008*) and mostly occurs in the western parts of the island, due to the orographic precipitation effect (i.e. west winds that transport moist cloud from the Mediterranean Sea (*Nikolakis, 2008*). The mean annual precipitation fluctuates between 400 – 500 mm, with a decrease tendency in the coming years (*Giannakopoulos et al., 2010*).

Conducted literature review showed that existing research for the evolution of the phenomenon of drought in Cyprus is limited to in-situ monitoring, involving mainly precipitation and temperature parameters from meteorological stations. This presents a substantial risk for decision makers and stakeholders, as potential technical damages or remote areas of interest may lead them to inadequate conclusions or erroneous decisions. Remote sensing data are a key tool in overcoming this risk, as they provide continuous, digital and spatially explicit information on earth's processes around the globe.

2. Methodology

2.1. Data

This study uses observations from the NASA's Global Precipitation Measurement (GPM) Mission and from the two ground-based radars of the Department of Meteorology (DoM) to measure the distribution of precipitation over Cyprus. The two datasets are interpolated on a universal grid in order to be comparable and to enable their accurate calibration and validation.

2.2. Ground-based radars

The ground-based radar data employed in this study is provided by the Department of Meteorology of the Republic of Cyprus. The Department has access to two weather radar stations that are located in Rizoelia (Larnaca district) and Nata (Paphos district). Figure 1 shows the position of the two radar stations on the map with respect to the elevation of the island. Each station is composed of an X-Band, Doppler, dual-polarization radar that provide continuous information on the estimation of rainfall and hydrometeor classification (*Republic of Cyprus - Department of Meteorology, 2020*).

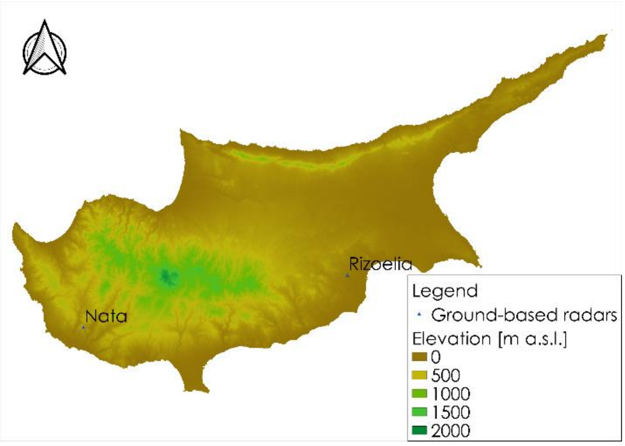

Figure 1. Location of the two ground-based radars of the Department of Meteorology (DoM) with respect to the elevation of the island

The radars scan in Plan Position Indicator (PPI) mode with the radar holding an elevation angle constant and varying its azimuth angle, and provide raw information with a spatial resolution of 0.1° and a radius of 150km. The raw information is provided with a frequency of approximately 10 minutes. The radars rotate through 360 degrees and provide surveillance scans for 8 different elevation angles. Table 1 shows the output data that are provided in each scan. For the present study we employed the Corrected Horizontal Reflectivity (Z_h).
As the radar data are provided in raw format, some initial pre-processing conversion was done. Using the given range, azimuth and elevation of the radar, we estimated the height and the distance of each cell. Additionally, the data are converted to a linear scale.

Table 1. Radar output data

Output	Unit
Corrected Horizontal Reflectivity (Z_h)	dBZ
Corrected Vertical Reflectivity (Z_v)	dBZ
Uncorrected Horizontal Reflectivity (UZ_h)	dBZ
Uncorrected Vertical Reflectivity (UZ_v)	dBZ
Differential Reflectivity (ZDR)	dB
Horizontal Radial Velocity (V_h)	m/s
Horizontal Vertical Velocity (V_v)	m/s
Horizontal Spectral Width (W_h)	m/s
Vertical Spectral Width (W_v)	m/s
Differential Phase (PHIDP)	°
Specific Differential Phase (KDP)	deg/km
Horizontal Signal Noise Ratio (SNR_h)	dB
Vertical Signal Noise Ratio (SNR_v)	dB

2.3. GPM DPR L2A

The DPR (Dual-frequency Precipitation Radar) aboard of GPM is applied in order to derive the reflectivity and the respective precipitation rate at the ground with a spatial resolution of 5-25km for 120km wide swath. The DPR comprises two precipitation radars that are the Ku Precipitation Radar on the Ku-band (13.6 GHz) and the Ka Precipitation Radar on the Ka-band (35.5 GHz). This allows the detection of information about strong rainfall classification (*Japan Aerospace Exploration Agency (JAXA), 2017*).

For the present study, we used the zFactorCorrected of the Matched Scan (MS) that is provided in the solver (SLV) module. The zFactorCorrected is the vertical profile of the reflectivity factor Z with attenuation correction. It is a L2A product, which means that radiometric correction is carried out, missing data is processed based on missing data information, scan time is corrected and geometric calculation of the time, latitude, longitude and height of each cell of scan data in each range bin is calculated (*Iguchi et al., 2018*).

2.4. Universal grid

The most important step for the intercomparison of the two datasets was to bring them together into one grid. To do so, a universal grid is developed, on which both datasets are interpolated. The universal grid is a 3D grid with predefined dimensions. The examples shown in this study are computed on a grid with n_longitude equal to 100, n_latitude equal to 100 and n_height equal to 101 for the ground-based data. Considering the universal grid for the GPM data, its n_longitude and n_latitude are the same to those of the grid for the ground based data, but n_height is equal to 175 which is the number of the range bins. The n_longitude and n_latitude of the universal grid could vary based on how fine or coarse the grid is needed to be, but as the examples shown here are still in an initial phase, the grid is kept coarse in order to avoid artefacts.

The width of each universal grid cell on the longitude axis is calculated by subtracting the $longitude_{min}$ from the $longitude_{max}$ and dividing it to 100. The width of each universal grid cell on the latitude axis is calculated using the same method. The same procedure is done for the two datasets (i.e., ground-based radar dataset and GPM dataset).

Regarding the height of each universal grid cell, for the case of the GPM dataset, the height of each cell is equal to the bin height (i.e., 125m). Thus, the height of each universal grid cell for the case of the ground-based dataset is also set to 125m and should stay constant in case of refining the 2D grid, in order to keep the two datasets comparable. After constructing the universal grid, both datasets are linearly interpolated into the grid.

2.5. Precipitation rate

In order to have a better insight for the comparison of the two datasets, firstly we compare the reflectivity and then, using the reflectivity, we calculate and compare the precipitation rate. The precipitation rate is calculated according to the Marshall-Palmer formula (Marshall and Palmer, 1948):

$$R = \left(\frac{10^{Z/10}}{200}\right)^{5/8},$$

where R is the precipitation rate and Z is the reflectivity.

3. Results

This paper shows the preliminary output of the study. Therefore, the shown figures present results for one specific day, which was used as a reference case to implement the methodology. This is the 12th of December 2019, on which there was intensive rainfall event over the island of Cyprus and an overpass of the GPM satellite. Since the GPM DPR dataset is a L2A processing dataset, it is considered as a reference dataset. Figure 2 shows the precipitation rate derived from (A) the GPM DPR L2A zFactorCorrected, (B) the Rizoelia radar station and (C) the Nata radar station. As observed in the Figures, there is a fair correspondence of the precipitation rate, but there is an offset of around 20-30 mm/h, with an underestimation of the ground-based radars.

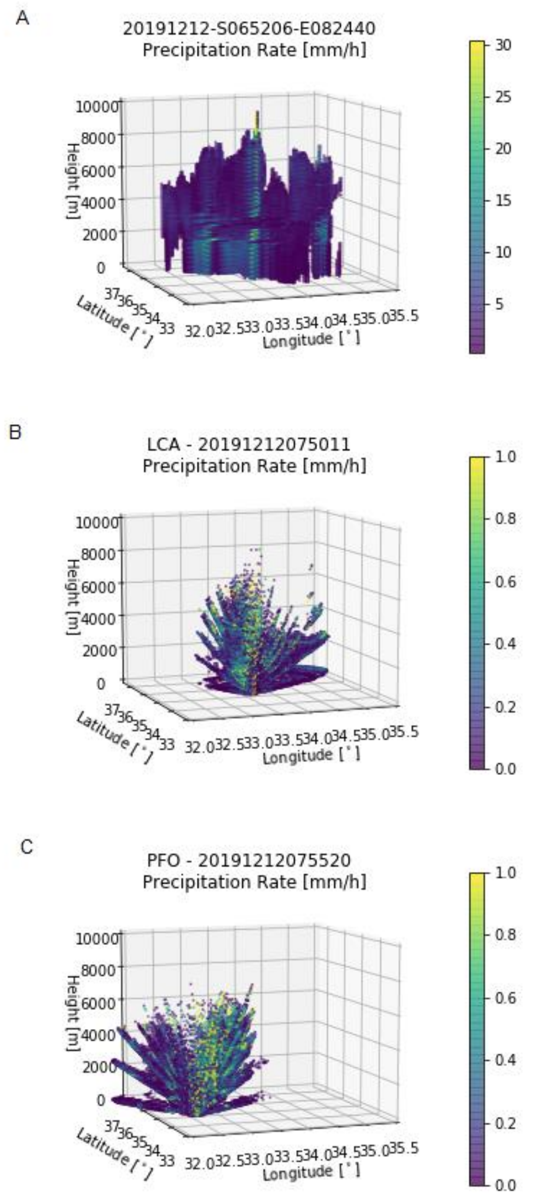

Figure 2. Precipitation rate [mm/h] derived from (A) the GPM DPR L2A zFactorCorrected, (B) the Rizoelia radar station and (C) the Nata radar station.

4. Discussion and future work

This paper shows the basis of the workload for the intercomparison of the ground-based radar data and the GPM DPR data for the estimation of the precipitation and eventually drought over the area of Cyprus. The interpolation of the data on a universal grid poses an important step for the future step. Future work includes the calibration of the ground-based data, using the GPM DPR data as a reference dataset and modifying different parameters in the precipitation rate derivation procedure. The overall outcome is expected to be an accurate and reliable dataset that will contribute to the development of an automated method for the estimation of the precipitation budget over the area of Cyprus.

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