# A COMPARISON OF RAINFALL HISTORICAL MEASURES AND CLIMATE DATA IN THE MYGDONIA WATER BASIN

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## ABSTRACT

Weather stations provide temporal information of rainfall at a limited area and consequently there is a need for implementing a spatial interpolation method to represent the spatial variability of rainfall. In this paper we spatially interpolate the rainfall data in the Mygdonia water basin by using the ordinary kriging method with the surface elevation as an external drift. The analysis is based on a monthly time scale for the period 1970-1999. In addition, rainfall data from the ETHZ-CLM Regional Climate Model under the special report on emission scenarios A1B were collected at twelve grid points which cover the water basin. These points form a matrix of point-estimated values with a spatial resolution of 25 x 25 km. The spatial distribution of the mean annual rainfall is graphically presented for the observed and the climatic data. Results highlight the spatial discrepancies between the climate model and the observations. Although the spatial rainfall patterns depend on the spatial interpolation method, results further highlight the need for bias correction when investigating the impact of climate change on hydrology using climate models.

**Keywords**: rainfall, kriging, climate modelling, Mygdonia water basin, semi-variogram.

## 1. Introduction

Geostatistical methods have been used to spatially interpolate rainfall from weather stations, whilst they are capable of evaluating the uncertainty of the predictions. Among the geostatistical methods, kriging is considered to be the most accurate and widespread (Yimit *et al*., 2011: Peng *et al*., 2014). In general rainfall increases with increased altitude and therefore the surface elevation parameter within kriging is an essential part of the rainfall distribution. The importance of using the surface elevation in the kriging method has been highlighted in Sanchez-Moreno *et al*. (2014), who studied the rainfall distribution (at daily and monthly temporal scales) in the Santiago Island. In addition, Tobin *et al*. (2011) concluded the importance of the elevation parameter especially in the case of extreme rainfall events in the Swiss Alps.

Climate change seems to affect the rainfall spatiotemporal distribution around the globe. A declining trend in the total rainfall amounts has already been observed in various regions due to climate change (Randall *et al*., 2007). Kostopoulou and Jones (2005) reported changes in rainfall volumes over the eastern and southern Mediterranean, while Feidas *et al*. (2007) concluded declining trends in rainfall over the entire Greek domain. Climatic models have the potential to project rainfall till the end of the century. However, data information is usually extracted at 30-year time scales to represent future climatology. Christensen *et al*. (2010) studied the accuracy of several Regional Climate Models (RCMs) in the pan-European domain based on six climate indicators. Results showed that the ETHZ-CLM RCM was the second most accurate RCM.

In here, in an effort to contribute to the ongoing analysis of rainfall trends in Greece, we spatially interpolate monthly rainfall estimated in the Mygdonia water basin, Greece, using both ground observations and projections from the ETHZ-CLM RCM.

## 2. Study area

The water basin (WB) of Mygdonia is located in Northern Greece, about 11.5 km NE of the city of Thessaloniki (Figure 1). The coordinates of the “gravity point” of the under study WB are 23˚ 19’ 49’’ 19 latitude and 40˚ 41’ 27’’ 16 longitude according to the World Geodetic System (WGS 84).

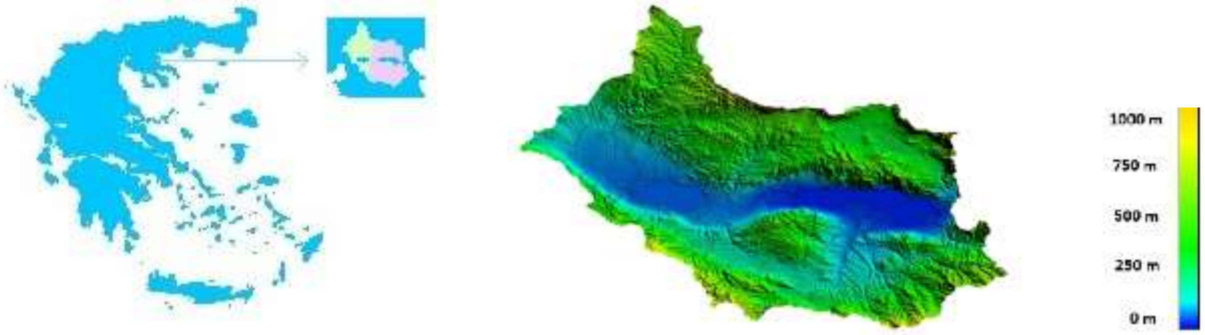


**Figure 1:** The Mygdonia WB (green: WB of Koronia, pink: WB of Volvi) and the DEM of the study area.

The area of the Mygdonia WB is 2100 km$^2$ and it consists of the WBs of the lakes Koronia and Volvi, which further form an extended wetland. The study area is protected by a number of binding actions, including the Ramsar Convention since 1975, the Natura 2000 network and a Common Ministerial Decision that designates the region as a national park. The extensive agricultural activities along with those from the industrial sector have gradually led to the rapid degradation of water quality and quantity in the WB of Mygdonia. Lakes Koronia and Volvi play a significant role to the climate configuration in the study area because they act as heat “stores” affecting the climate conditions of the wider area. In particular, the climate of the wider area is characterized by mild winters and, dry and hot summers while the average temperature is about 15 $^o$C.

## 3. Material and methods

### 3.1. Historical data

The spatial distribution of the rainfall data was performed on a monthly basis from October 1970 to September 2000 by using the ArcGIS v.10.2 software. Firstly, the water basins of Lakes Koronia and Volvi are imported to the software and they are georeferenced to the Greek Geodetic Reference System 1987 (GGRS87) while the rainfall stations (Laxanas, Nikopoli, Lagadas, Agios Vasileios, AUTH, Mikra, Sedes, Loutra Thermis, Arethousa, Nea Apollonia, Zagliveri, Agios Prodromos, Rizes, Taksiarxis, Arnaia) and twelve grid points (17, 18, 19, 20, 24, 25, 26, 27, 31, 32, 33, 34) were also added to the model (Figure 2). The above grid points were selected in order to cover the entire study area.

The ordinary kriging method with the elevation as the external drift (KED) was chosen among several kriging types (ordinary, simple, universal, indicator, probability and disjunctive) as the most accurate one. The surface elevation variable was taken into account by using the ASTER GDEM v.2 file which has a spatial resolution of 30 m and a vertical precision of 7-14 m and it is available at the Jet Propulsion Laboratory of the National Aeronautics and Space Administration (NASA). Afterwards, the DEM file was cut in order to cover the whole Water Basin of Mygdonia and it was georeferenced in the Greek Geodetic Reference System 1987 (GGRS87).

The selection of the most appropriate semi-variogram type (circular, spherical, tetraspherical, pentaspherical, exponential, Gaussian, rational quadratic, hole effect, K-Bessel, J-Bessel and stable) for each month was relied on meeting the following restrictions: (i) the Mean Error between observations and interpolated data to be equal to zero, (ii) minimization of the Root Mean Square Error, (iii) the Mean Standardized Error to be equal to zero, (iv) the Root Mean Square Standardized Error to be equal to 1 and finally, (v) the Average Standard Error to be equal to RMSE. The selection of the best-fit semi-variogram type was sequentially repeated for 30 years in total.

**Figure 2:** Rainfall stations and grid points in the study area (green: WB of Koronia, pink: WB of Volvi).

### 3.2. Climatic data

Climate data were collected via the online database of the European program "ENSEMBLES". In particular, monthly rainfall data were downloaded from the ETHZ-CLM RCM under the SRES (Special Report on Emissions Scenarios) A1B which was produced by the Institute of Atmospheric and Climate Science of Zurich (ETHZ) (Bohm *et al*., 2006). The collected climate data were exported to twelve grid points (17, 18, 19, 20, 24, 25, 26, 27, 31, 32, 33, 34) forming a matrix with a spatial resolution of 25 x 25 km (Figure 2).

## 4. Results

In the study region, rainfall is highly variable both in space and time. The temporal variability during the historical period is presented in Figure 3.

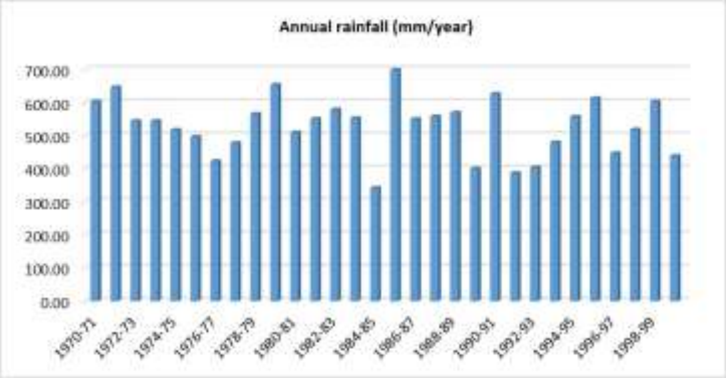
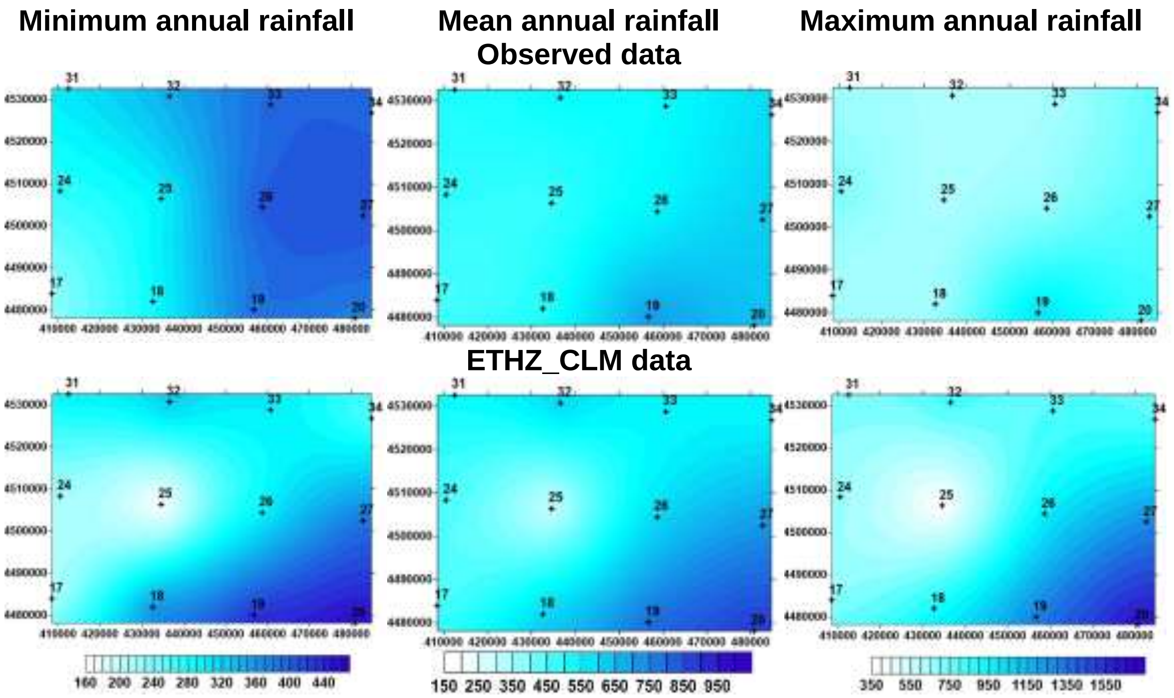


**Figure 3:** Mean annual basin rainfall for the period 1970-1999.

The minimum, mean and maximum annual rainfall estimated based on the ETHZ-CLM RCM climate model were calculated at 312.91 mm, 570.42 mm and 922.30 mm respectively. Also, by observing the output data of the ordinary kriging method it was found that the annual rainfall during 1970-1999 ranges between 342.05 and 699.80 mm, with mean annual rainfall being 528.81 mm. These statistical properties of annual rainfall are spatially interpolated using kriging. Their spatial distribution for the entire hydrological period 1970-1999 is presented in Figure 4 for the observed data and the climatic data from ETHZ-CLM RCM.


Minimum annual rainfall

Mean annual rainfall
Observed data

Maximum annual rainfall

ETHZ_CLM data

**Figure 4:** Comparison of rainfall statistical properties between observations and climate model.

In general, as expected a strong positive correlation between rainfall volumes and elevation is observed; the lowest rainfall occurs in the western part of the Mygdonia WB and the highest rainfall occurs in the southeastern parts (WB of Lake Volvi). Finally, results show the spatial discrepancies in representing the main rainfall statistical parameters between the ETHZ-CLM Regional Climate Model and the observations; particularly in the relative difference in the minimum and maximum annual rainfall.

## 5. Discussion and conclusions

In this study, ordinary kriging using the elevation as an external drift, was applied to map the spatial variability of the annual rainfall. Although the method showed high potential in the region, representation of rainfall's spatial distribution depends on the density of the raingauge network. In addition, the observation record and the inconsistency in data recordings could also influence rainfall's predictability making the use of exploratory data analysis techniques a mandatory task before using the data for geostatistical modeling. In here, a correlation and homogeneity analysis was primarily performed at 15 rain gauge stations spread across the WB of Mygdonia. The adequate performance of the applied geostatistical method can be attributed on the large number of the rainfall stations that are used in the kriging method and on the evenly spatially distributed rainfall stations. It is also important to note that the accuracy of the spatial distribution of the observed rainfall data is due to the use of the 6 rainfall stations that were nearly outside of the Mygdonia WB boundaries and on whose data a correlation and homogeneity analysis was also primarily performed. Rainfall estimates (minimum, mean and maximum) from the ETHZ-CLM climate model did not show high consistency with the observations. This highlights the need for bias correction prior to using climate model results to assess the impact of climate change on water resources in the region.

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