Facets of Uncertainty 5th Leonardo EGU Conference

Kos Island, Greece, 17 – 19 October 2013

Spatial and temporal rainfall variability over Greece

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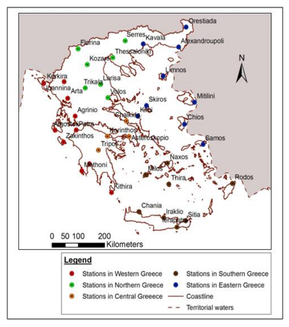
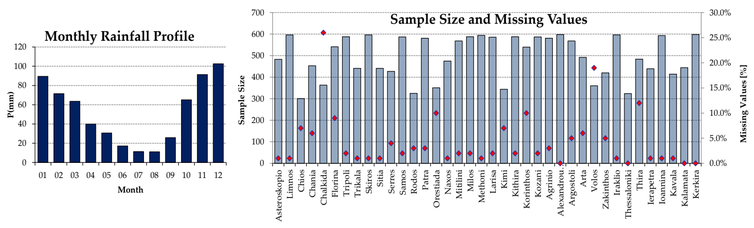
1. Abstract

The main objective of this study is to determine the major statistical properties of rainfall over Greece and analyse their variability through time. To this end, the following properties of rainfall variability were investigated on time series extracted from Hellenic National Meteorological Service records that date back to 1950: (1) the spatial correlation among the stations and the existence of regions which demonstrate homogeneity; (2) the temporal occurrence of maximum rainfall (the month which the daily maximum occurs) and the ratio of the daily maximum to the annual sum; (3) the spatial distribution of the daily maxima, which are observed in a number of stations simultaneously, as well as the rank correlation in space of annual rainfall; (4) the classification of the empirical distributions of daily maxima. The results of our analysis offer an improved overall picture of rainfall variability over Greece and help us clarify whether some attributes have changed over the last 60 years.

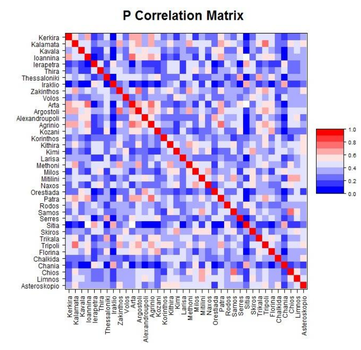
2. Rainfall Data

The software used for our statistical analysis was R software.
We examined daily rainfall data from Hellenic National Meteorological Service dating back to 1950. The data were derived from 38 stations, which were then delimited geographically in five regions based on their cross-correlations (see also the following slide).
All regions exhibit more or less the same inter-annual variability, demonstrated below for all the stations, which in general follows a wet/dry season regime.
The 38 records used had missing values (red points) less than 25% and their sample size (light blue bars) ranged between 300 and 600.

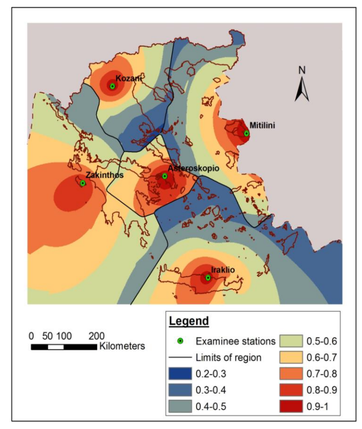




3. Homogenous Regions



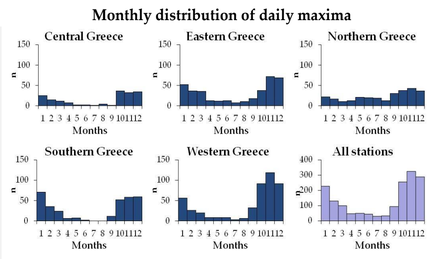
On the map below the correlation between the station closest to the regions center and the rest of the stations is depicted. The kriging method of ArcGIS platform was chosen for the interpolation between data points.



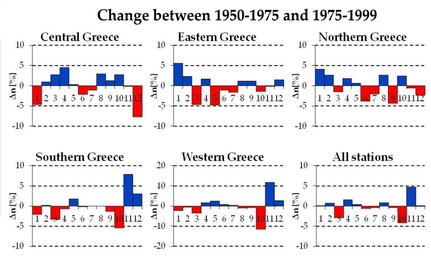
Although the correlation matrix of monthly rainfall may seem quite heterogeneous at a first glance this picture changes when is put at the map. Five regions can be distinguished which share a correlation coefficient above 0.5 and thus can be regarded as homogenous areas. All further analysis presented below was performed both for each region and also for the entire study area.

4. Daily Maxima

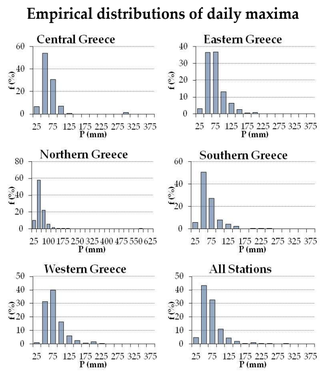
The occurrence of daily maxima follows the distribution of monthly rainfall, with only a single deviation. Thus, the majority of the days with maximum rainfall in each year usually occurs during the wet period. The only exception to this is the region of Northern Greece, where a noteworthy portion of daily maxima also occurs during the period between April and September.



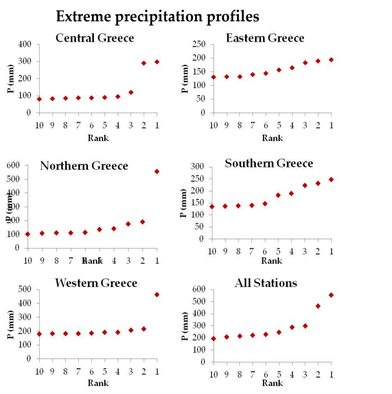
The change (%) in time in the above distributions between 1950-1974 and 1975-1999. Blue bars indicate an increase while red bars indicate a decrease in the number of maxima per month. Again in the Northern Greece the change has a different temporal distribution from the rest of Greece.



5. Daily Maxima (cont.)



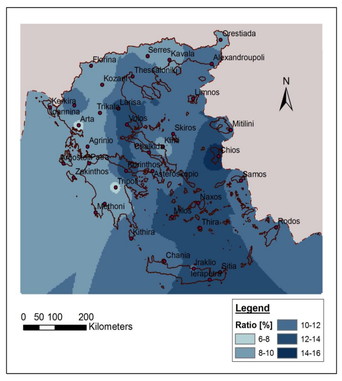
The major frequencies occur in the first six classes at every region and at the entire study area. In these histograms the main corps of the data series is examined while the tails of the maxima data series are analyzed in a different way.

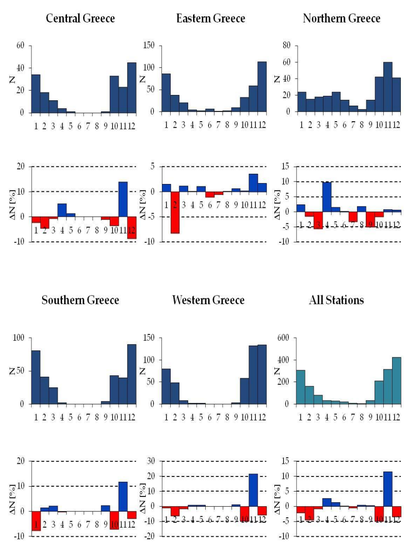


The ten highest daily maxima in Eastern and Southern Greece, are all between 100 and 250 mm with no great differences, whereas in the Central, the Northern and the Western regions the highest value are 2-3 times higher than the rest of the values.

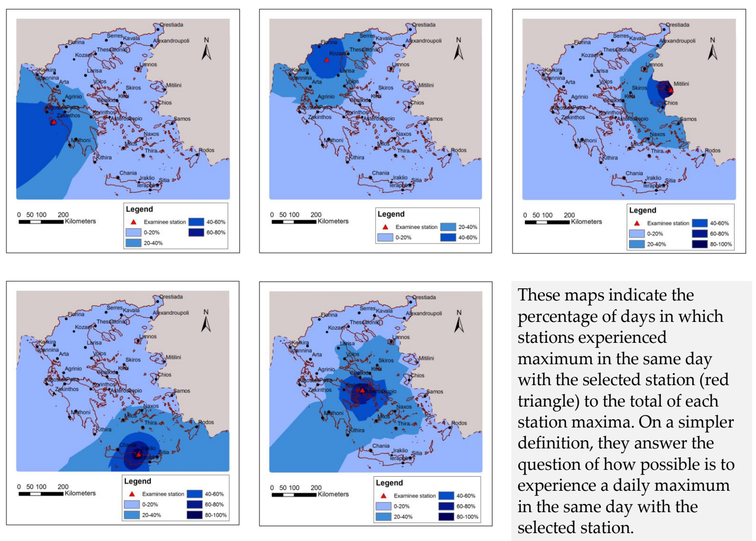
6. Monthly Extremes

A similar approach is followed for the monthly maxima as in the daily maxima with corresponding results. Similar to the daily maxima, in the Northern Greece, monthly extremes show a different temporal distribution than the rest of the regions. Additionally, the ratio of daily maximum to the annual sum is illustrated in the map below.





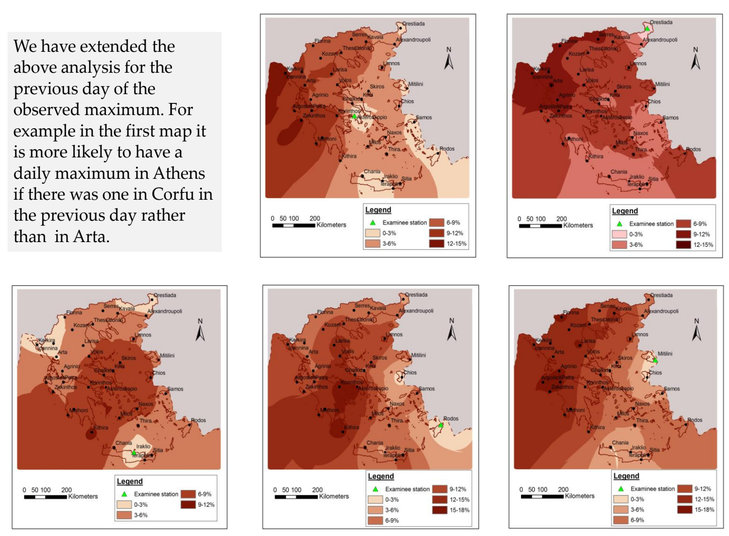
7. Simultaneous occurrence of daily maxima



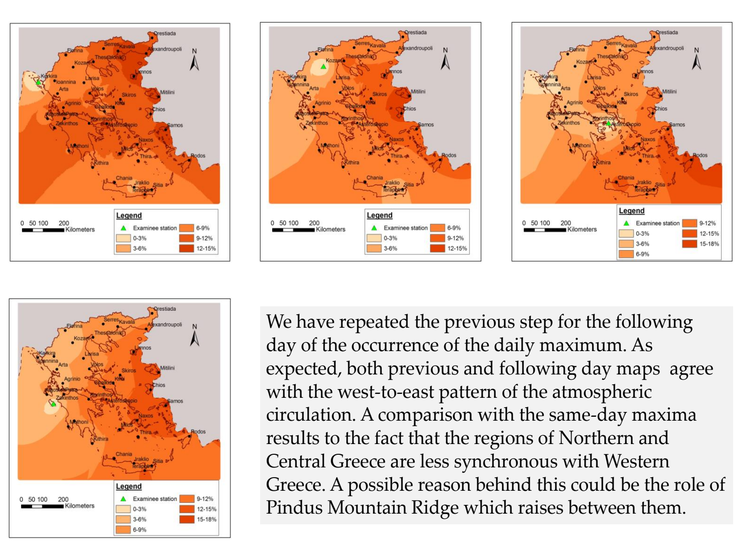
These maps indicate the percentage of days in which stations experienced maximum in the same day with the selected station (red triangle) to the total of each station maxima. On a simpler definition, they answer the question of how possible is to experience a daily maximum in the same day with the selected station.

8. Daily maxima with -1 day lag

We have extended the above analysis for the previous day of the observed maximum. For example in the first map it is more likely to have a daily maximum in Athens if there was one in Corfu in the previous day rather than in Arta.



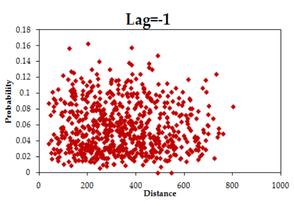
9. Daily maxima with +1 day lag

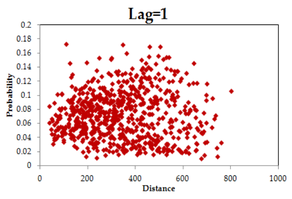


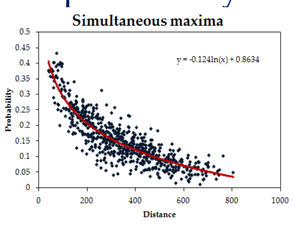
We have repeated the previous step for the following day of the occurrence of the daily maximum. As expected, both previous and following day maps agree with the west-to-east pattern of the atmospheric circulation. A comparison with the same-day maxima results to the fact that the regions of Northern and Central Greece are less synchronous with Western Greece. A possible reason behind this could be the role of Pindus Mountain Ridge which raises between them.

10. Links between distance and probability

Finally, we examined the relationship between the distance (in km) and the probability of simultaneous maximum. To achieve this the distance between each pair of the station was estimated based on their longitude and latitude projections to the surface of the earth.

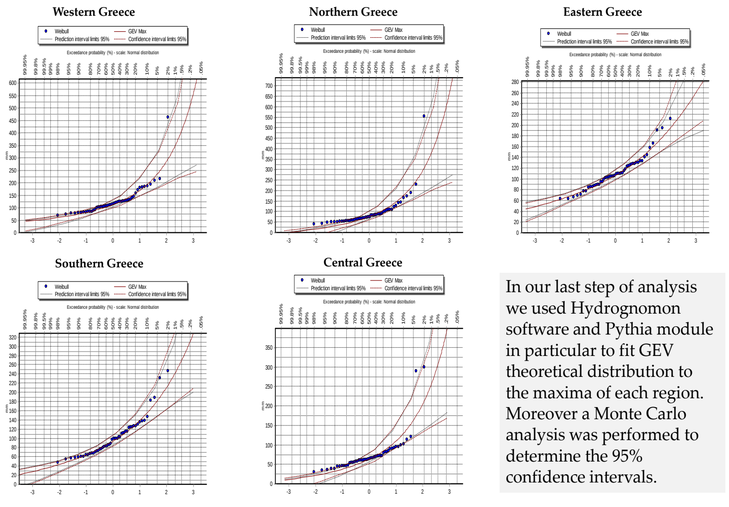






The results show that for the same day of maximum occurrence the probability follows a logarithmic decrease as the distance rises. Further research should clarify the effect of rainfall intensity to this relationship (moving from maxima to lesser episodes of rain). For the previous or the following day no relationship between probability and distance seems to exist.

11. Theoretical distributions and maxima



In our last step of analysis we used Hydrognomon software and Pythia module in particular to fit GEV theoretical distribution to the maxima of each region. Moreover a Monte Carlo analysis was performed to determine the 95% confidence intervals.

12. Conclusions

- As indicated by cross-correlation coefficient of rainfall Greece may be divided in five homogenous regions.
- Daily maxima tend to occur between October and February in most parts of Greece. There are no changes between the first 25-year period of data and the last one.
- The monthly profile of daily maxima at the Northern Greece seems to be slightly different; a significant amount of daily maxima tend to occur also between April and September.
- The analysis of monthly extremes leads to similar results.
- The ratio of the daily maximum to the annual sum varies in space with the lowest values at Western Greece and the highest at the Central Greece and the islands.
- There is a clear relationship between the distance and the probability of same-day daily maximum occurrence.
- No corresponding relationship was found for the next or previous day. The west-to-east movement of the aerial masses and thus rainfall is evident, though.
- The GEV theoretical distribution may be used to describe daily maxima in every region all over Greece.