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Monthly rainfall trends in Greece (1950 – 2012)

Yiannis Dimakos, Efie Christina Moschou, Stamatis Christos Batelis, Yiannis Markonis, and Demetris Koutsoyiannis Department of Water Resources and Environmental Engineering National Technical University of Athens

Abstract

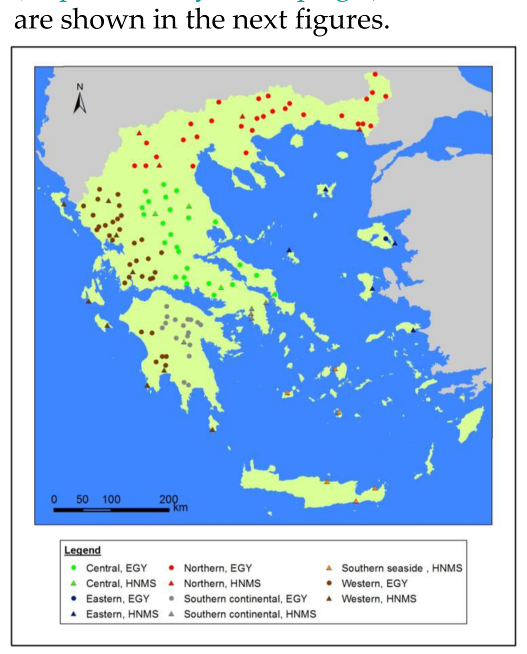
Trends in monthly rainfall during the period from 1950 to 2012 and the variability thereof in space and time are investigated. The time series analysed are from 120 stations and cover mainly the continental part of Greece. To estimate their trends, linear regression is used for each time series separately for: (a) the entire record length (1950 - 2012) and (b) for each half of the period (1950 - 1981 and 1982 - 2012). A spatially aggregated time series of rainfall over Greece is also produced and its correlations with climatic features of the northern hemisphere are explored.

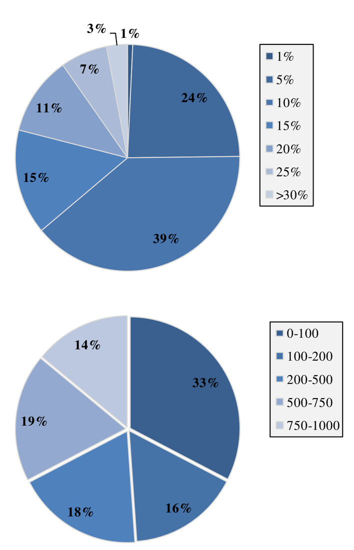
1. Introduction - motivation

Monthly rainfall slopes, at the period (1950 - 2010) depict the spatial and temporal variability of the examined variable. The entire period was divided in various subperiods (1950-1980, 1981-2010), in order to examine whether the behaviour of the time series in a longer period follows the slopes of the shorter ones. Additionally, the seasonality of slopes and long time series (70-150 years) were analysed to further explore the variability of annual rainfall. Furthermore, their correlation to the entire northern hemisphere sea-level pressure gradient was processed, as well as the air and sea surface temperature in order to disclose any relevant relationships among them. The above mentioned data analysis is motivated by the need to assess the uncertainty in temporal and spatial rainfall variability. The overall conclusions show that the changes in the rainfall are small and depend on the time scale.

2. Study area and data

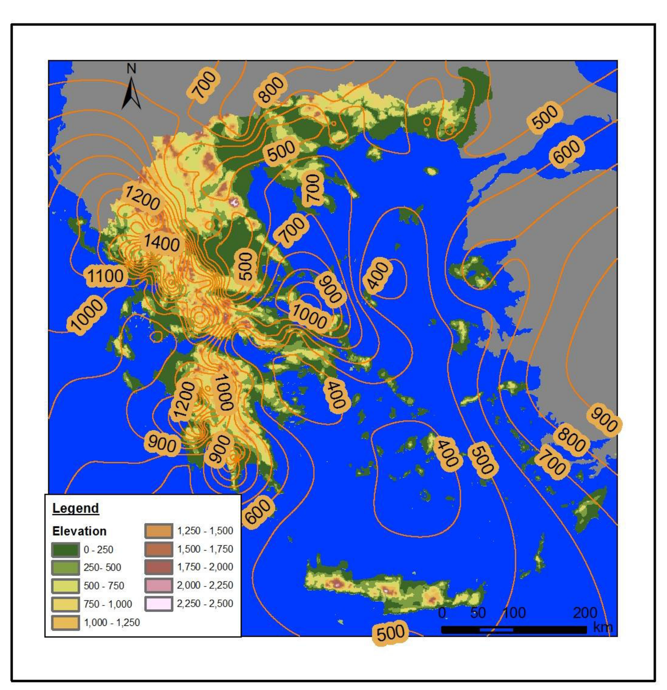
R software was used for our statistical analysis. 136 stations of monthly rainfall were derived from Hellenic National Meteorological service (HNMS) and from Special Secretariat of Water (SSW), numbered 29 and 107, respectively (http://www.hydroscope.gr/). Stations, elevation clustering and missing values are shown in the next figures.





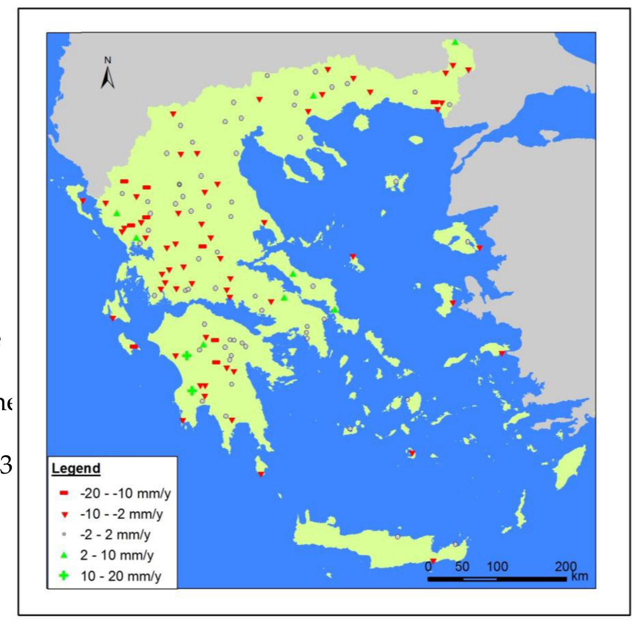
3. Spatial variability of rainfall over Greece

Rainfall observed values were spatially integrated in order to disclose grouped areas, with similar rainfall characteristics. The most rainy areas, are located at the western part of Greece. This agrees with the general atmospheric circulation pattern, where the fronts move eastwards above the Mediterranean Sea. Moving further across the mainland, the humid air masses are blocked by the Pindus ridge, and hence central and northern Greece experiences less rainfall. Rainfall rises again at the easternmost part of Greece, and the islands of the south, due to the effect of convective storms and the cyclonic centers in the eastern Mediterranean (between Cyprus and Turkey).



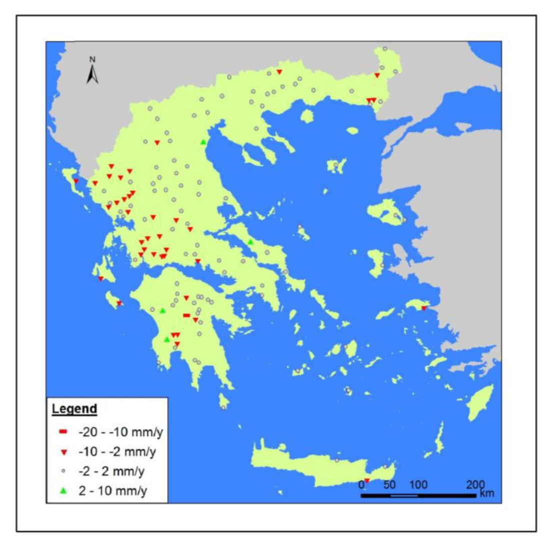
4.Slopes of rainfall during the period 1950 - 2010

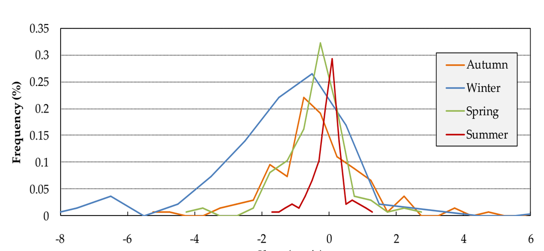
Rainfall slopes were estimated for the overall observed period (1950-2010) at monthly time scale, following linear regression of the stations' data. Results of the above mentioned process revealed areas with positive and negative tendencies. In the majority of the reporting area were captured negative slopes at the range of (-20 to -2 mm/y). A few exceptions were found in the south-western continental Greece (3 stations), in the north-northeastern Greece (2 stations) and in the central Greece (3 stations), where the positive slopes were ranged from (2 to 20 mm/y). Finally, at many stations at the central and northern Greece, both positive and negative slopes were found at the range of (-2 to 2 mm/y).



5. Seasonality of slopes

Slopes were also estimated at seasonal basis due to the high variability of rainfall through out the year. Each and every season has different estimation slope ranges (see figure below), with the greater ones to be occurred during the winter season (-8 to 4 mm/y) and the smaller in the summer season (-2 to 2 mm/y), as expected. Thus, we see that the over decrease of rainfall during the last 60 years can be linked to the decrease of the winter rainfall.

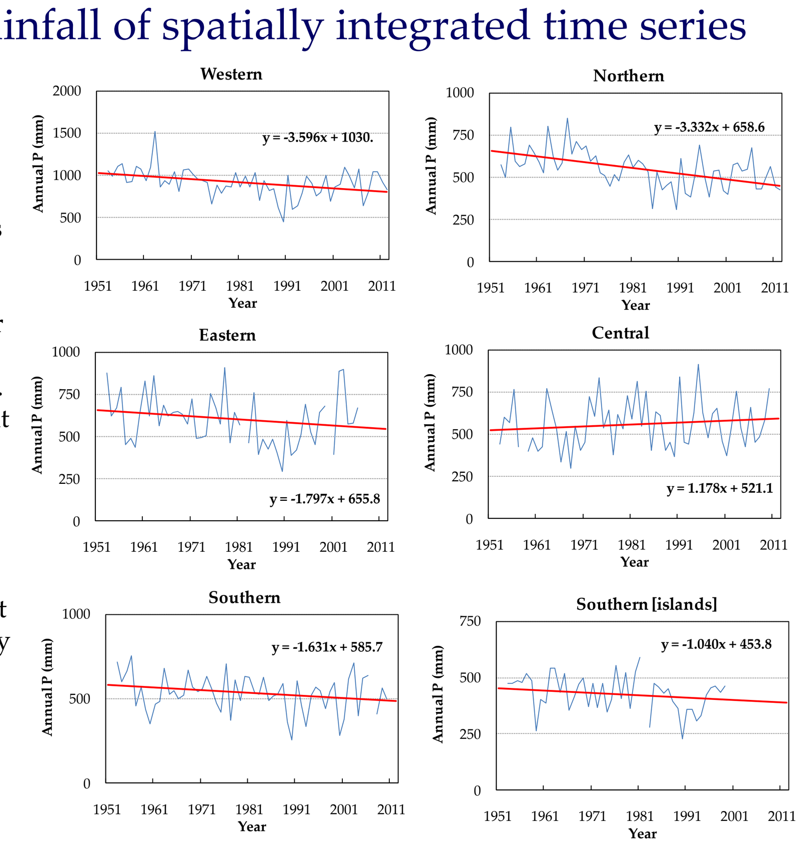




Again, the largest slope are located at the western part of Greece, depicted at the map above.

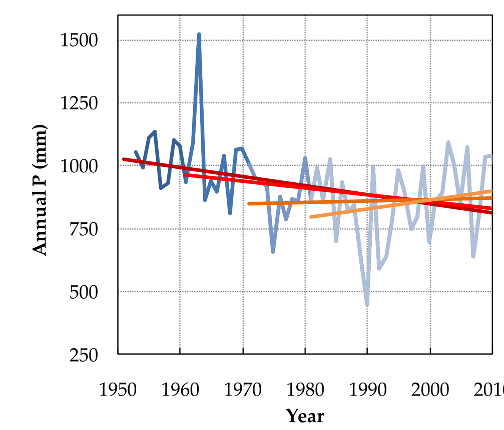
6. Slopes of rainfall of spatially integrated time series

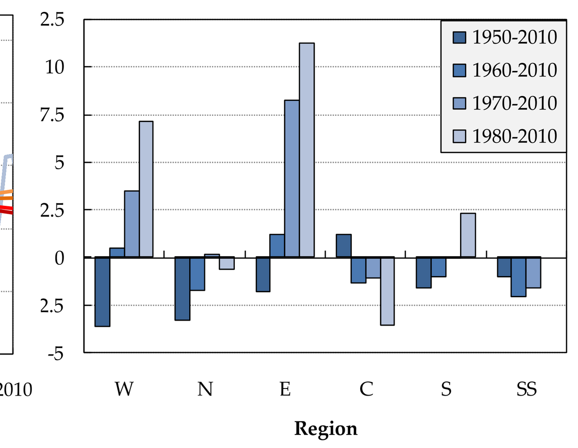
The estimation of the slopes was also implemented at the spatially integrated time series of 6 regions with high rainfall corellations, which where aggregated over hydrological year (October – September). The figures on the right show the slopes of the annual precipitation (mm) at different regions of Greece, where all the results show a decrease except the central area (mainly Thessalia region). The highest negative slopes are found in western and northern Greece.



7. The effect of time window in the estimation of slopes

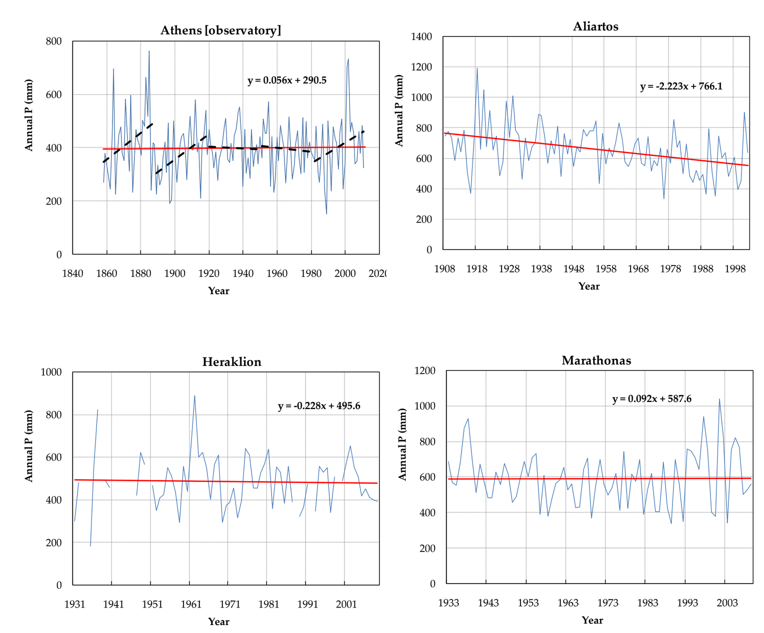
The rainfall slopes were also estimated at different time intervals of 60, 50, 40 and 30 years. The results show that slopes are highly sensitive to the time period taken, which is shown in the figures below. On the left, the integrated time series of western Greece is taken and the change in the slope (from negative to positive) as the time interval decreases is evident. On the right, we can see that these changes are different and come with varying patterns for each region, i.e. they are monotonous for western, eastern and southern Greece, but not for the other parts of Greece. the show different behaviour of rainfall slopes, estimated for different regions.





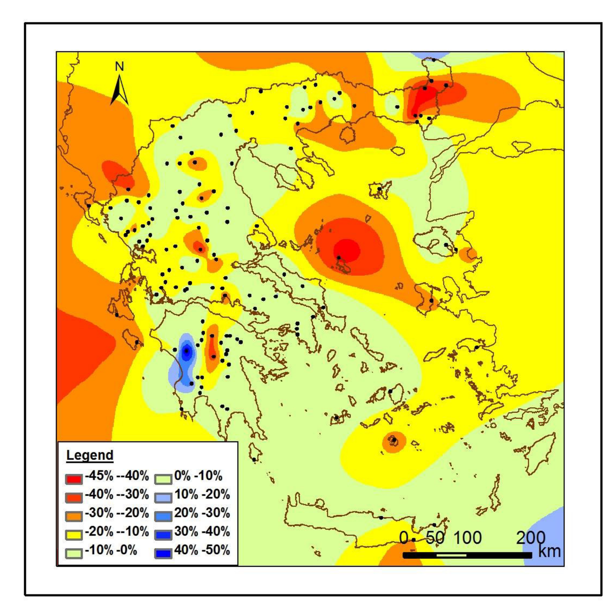
8.Estimation of slopes in larger scales

Four stations with longer records (70-150 y) were also examined to further investigate the effect of time window in the estimation of the slopes. Although the sample size is extremely small the analysis was conducted for exemplary purposes, as at these scales the overall slopes become milder or zero. Furthermore, if we split the Athens (observatory), which is the largest instrumental time series available in Greece, time series in 30-year intervals and estimate the individual slopes, we see that there are three periods with strongly positive slopes. However, the overall slope is very close to zero!

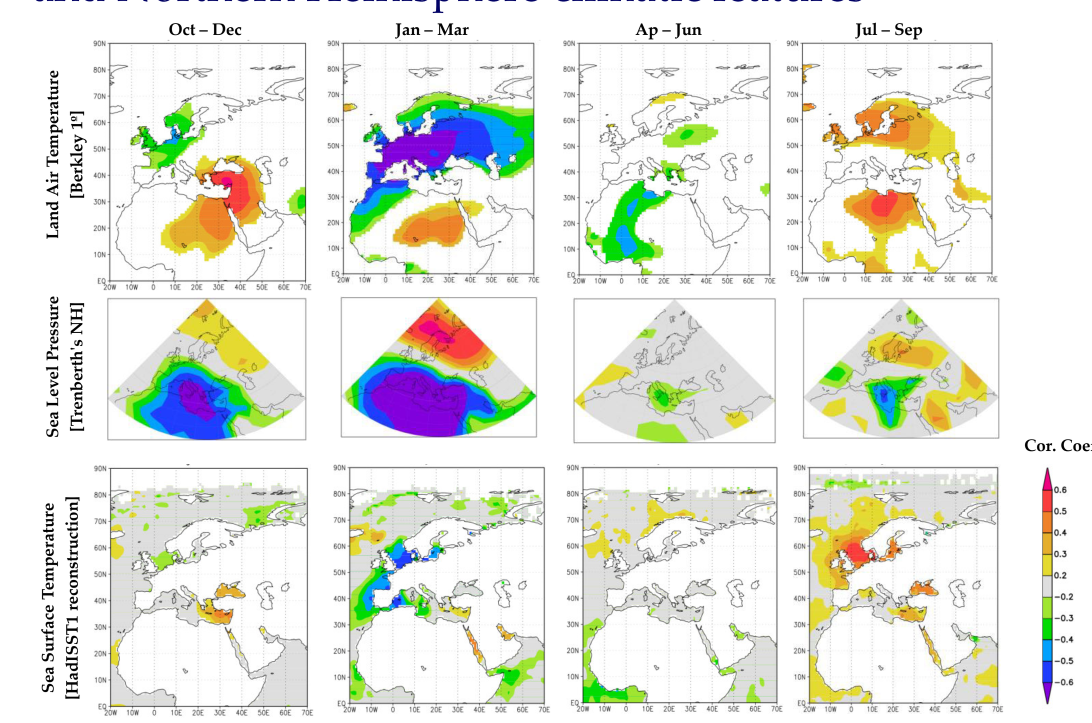


9. Mean differences of rainfall between the periods of 1950 – 1980 and 1981 – 2010

The overall picture that the slopes give suggest that there was a humid period in the first 30 years of our records with a succeeding dry one in the last 30. To validate this we estimated the difference of the means between the two periods for each station as a percentage of the means of the 1950 – 1980 period. As expected the majority of the examined area were negative (map on the right). The largest differences were found at a) westernmost regions, b) easternmost regions and c) high elevation stations (i.e. Pindus ridge). This implies that there could be some links with the general atmospheric circulation, especially for a), as suggested also by Moschou et al. (2013).

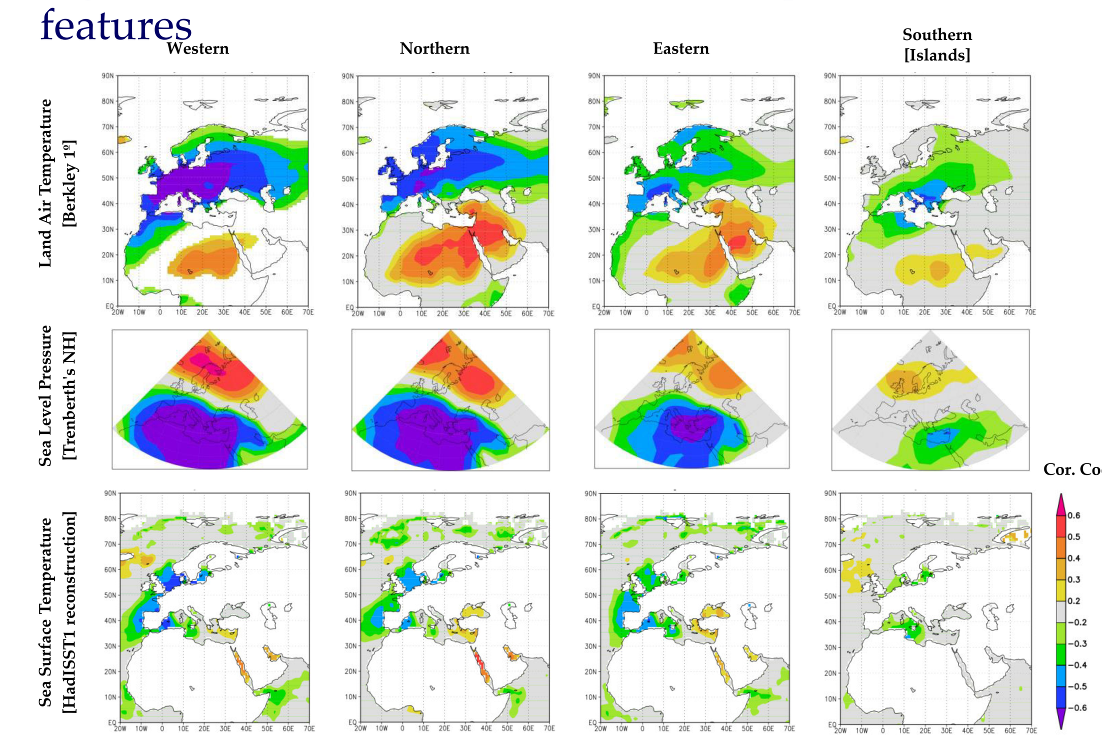


10. Seasonal correlations between rainfall at W. Greece and Northern Hemisphere climatic features



KNMI explorer (http://climexp.knmi.nl/s) was used for the analysis and the field data sets.

11. Correlations between Jan-Mar rainfall at different regions of Greece and Northern Hemisphere climatic features



KNMI explorer (http://climexp.knmi.nl/s) was used for the analysis and the field data sets.

12. Conclusions

- There is a decrease in rainfall in most regions of Greece, near 2.5 mm/y for the overall estimated period, 1950-2010, which is in good agreement with the results of other works for smaller rainfall records (Feidas et al., 2006) or adjacent regions (Türkeş et al, 2008).
- The rainfall slope's decrease is observed mainly during the winter and is higher in western Greece. Central Greece is the only region presenting a positive slope.
- Examining the slopes in the 30-year intervals, we observe that 1950-1980 was a wetter period than 1980-2010 showing a negative trend. On the contrary, during the last 30 years there was a rise in rainfall in all regions except central Greece and the islands at the south.
- The slopes of longer records (70-150 years) show milder, nearly neutral slopes .
- Notably, splitting the slopes in 30 year intervals may create the impression of steeper slopes, which can be misleading.
- Significant correlations were found between regional rainfall (especially for western Greece) with land air temperature, sea level pressure, and sea surface temperature. These patterns show seasonal variability with highest correlations during winter and nearly non-existent in spring.

References

Feidas, H., Ch. Noulopoulou, T. Makrogiannis, E. Bora-Senta, Trend analysis of precipitation time series in Greece and their relationship with circulation using surface and satellite data: 1955–2001, Theoretical and Applied Climatology, 87: 155-177.

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Türkeş, M., Koç, T. and Sariş, F. (2009), Spatiotemporal variability of precipitation total series over Turkey. Int. J. Climatol., 29: 1056–1074.