Investigation of drought characteristics in different temporal and spatial scales: a case study in the Mediterranean region

Y. Markonis, A. Efstratiadis, A. Koukouvinos, N. Mamassis and D. Koutsoyiannis, Department of Water Resources and Environmental Engineering National Technical University of Athens

Facets of Uncertainty
Kos Island, Greece, 17–19 October 2013

Investigation of drought characteristics in different temporal and spatial scales: a case study in the Mediterranean region

Y. Markonis, A. Efstratiadis, A. Koukouvinos, N. Mamassis and D. Koutsoyiannis

Department of Water Resources and Environmental Engineering
National Technical University of Athens
(www.itia.ntua.gr)

1. Abstract

In 1988-1995 Greece experienced a drought, one of the most extended (both in space and time) and intense since the beginning of hydro-meteorological instrumental measurements. The aim of this study is to describe the phenomenon in different temporal and spatial scales in order to (a) identify possible links with Mediterranean/global climatic regime and (b) to demonstrate the role of the marginal distribution function in estimating the return period of the drought and its impact. Three spatial scales were examined: the local scale (Macedonia in the northern part of Greece; ≈2×2° each), the national scale (≈ 8×8°) and the Mediterranean scale (≈ 15×45°). In the time domain the monthly, annual and inter-annual time steps were taken, while the time horizon is that of the instrumental record as well as a broader time window obtained by introducing qualitative evidence from paleoclimatic studies. Our findings show both strong temporal variability and spatial heterogeneity, which imply enhanced uncertainty.

2. Data set

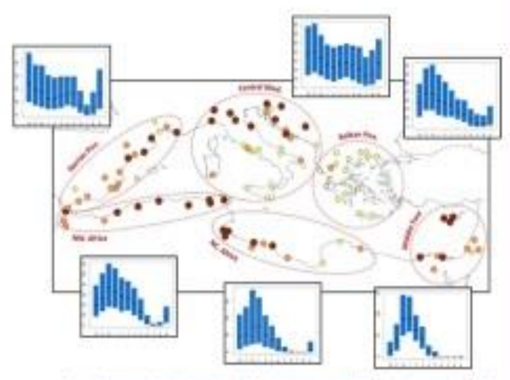
Three different data sets of observational data were used; one for each scale:

- Data from the Drought Management Plans for the water districts of western and central Macedonia; 68 record with length between 30 and 60 years (processed by Efstratiadis et al. 2013; Koukouvinos et al. 2013).
- National Meteorological Service monthly data from the National Meteorological Service; 35 records with length of 50 years (processed by Moschou et al. 2013).
- World Meteorological Organization time series, available through KNMI explorer for the Mediterranean region; 120 stations with length between 30 and 200 years (processed by Markonis et al. 2013).

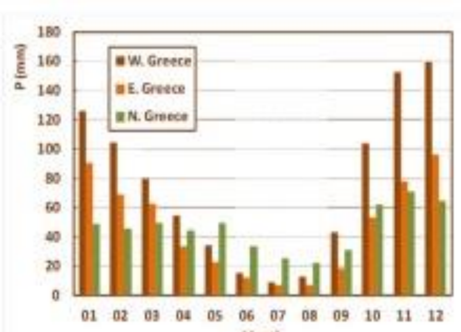
3. Precipitation heterogeneity of the study area

The spatial variability in precipitation is evident in all three scales:

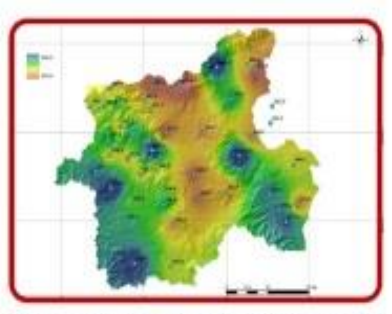
- In the Mediterranean scale 6 different patterns can be found.
- Western Greece experiences higher precipitation, due to the Pindos Mountain Ridge, while northern Greece demonstrates milder seasonal variability.
- Even at the local scale, the precipitation varies strongly due to the sharp topographic features .



Monthly precipitation at the Mediterranean (Markonis et. al 2013)



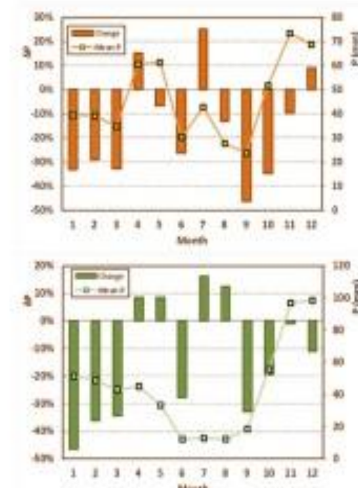
Monthly precipitation in Greece

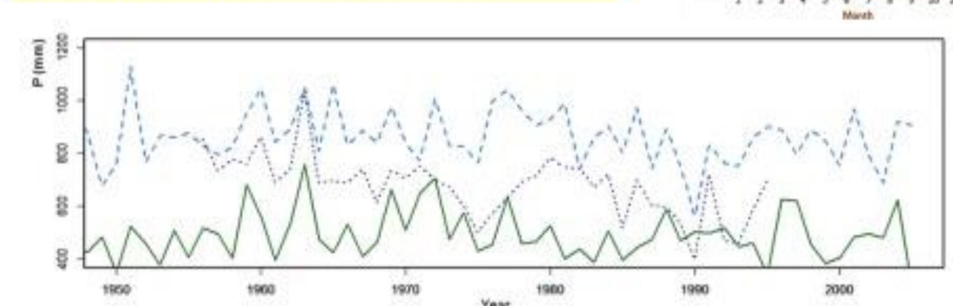


Annual precipitation at W. Macedonia district. The brown color corresponds to 450mm while deep blue tp 950 mm (Koukouvinos et. al 2013)

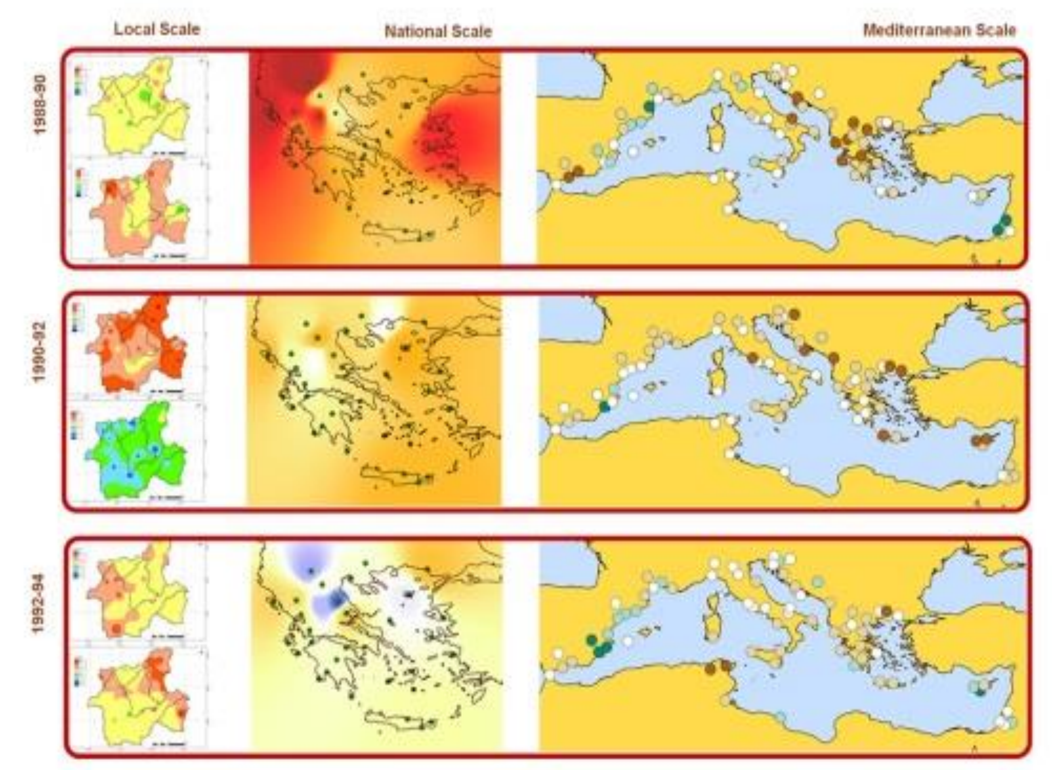
4. The drought of 1988-1995 – Temporal characteristics

- During the drought, the monthly rainfall profile is roughly the same for both regional and national scale.
- January, February, March, September and October are the months with the highest decreases in rainfall.
- Surprisingly, the months with the largest portion of the rainfall (November and December) demonstrate slight deviations from their mean.
- However, during January and February the potential evapotranspiration is minimal in Greece (Tegos et al. 2013), which amplifies the enrichment of the water resources.
- The spatially averaged precipitation for Spain (solid green line on the figure below), Italy (dashed blue line) and Greece (dotted dark blue line), indicate that the drought was located mainly in the eastern part of the Mediterranean.



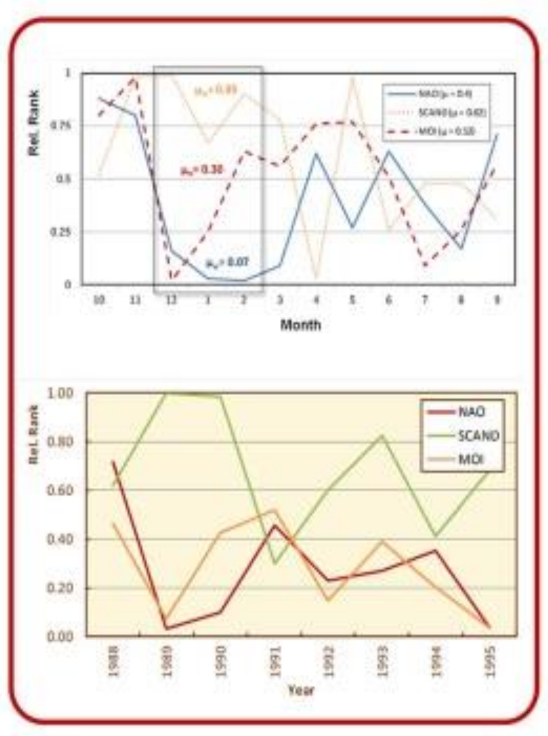


5. The drought of 1988-1995 – Spatial characteristics



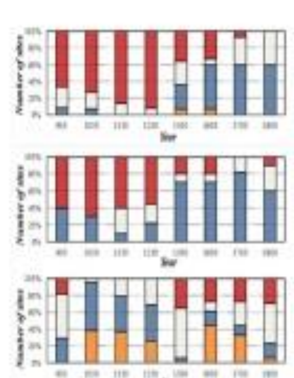
6. Links to Northern Hemisphere atmospheric circulation

Atmospheric circulation is often described by climatic indices such as North Atlantic Oscillation (NAO). The later represents the pressure difference between the Icelandic low and the Azores High and is known to be connected with rainfall variability of the Mediterranean (Trigo et al., 2002), explaining 30% of the variability during the winter (Mariotti and Dell'Aquila 2012). In our analysis we also examined the rest of the northern hemisphere climatic indices and here we show the results for the three which may be linked to the drought. Although, they do not seem to correlate strongly in monthly scale, if we examine only the winter months (when the largest portion of rainfall is connected to the cyclonic activity) then the results are quite different. As it can be seen in the first figure the NAO/MOI (Mediterranean Oscillation Index) have successive low relative ranks (e.g. averaged within the 7% of the highest values of NAO index) , while SCAND (Scandinavian pattern) stays high. The physical basis behind this outcome is the persistent blocking of aerial humid masses towards the Mediterranean due to the Azores high. If we examine the mean value of each index during the winter, we see that the same pattern remains for the following years. It must be noted that **Hurst-Kolmogorov behaviour (long-term persistence) has been already identified in the NAO pattern (Stefenson et al. 2000).**



7. Going back in time – Proxy data

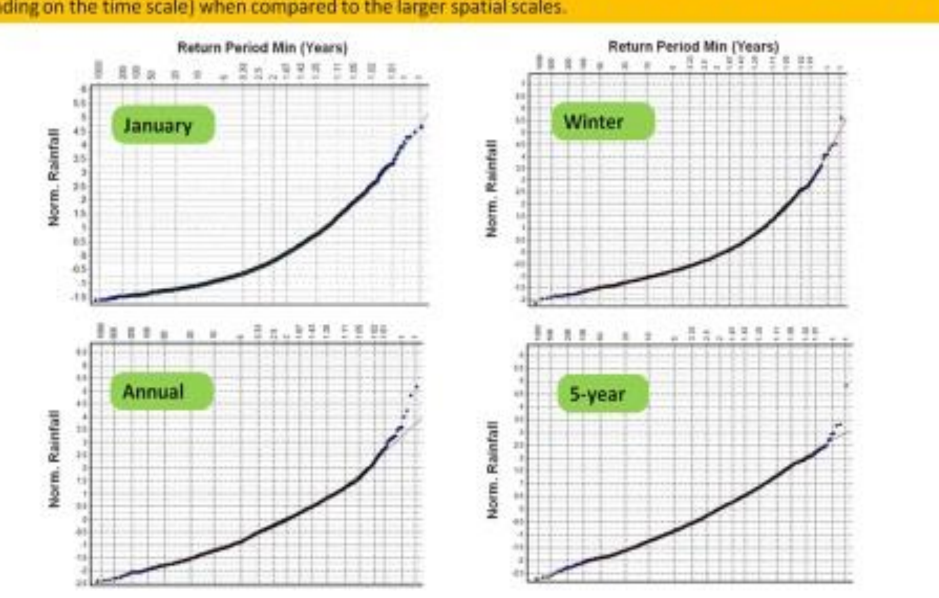
During the beginning of the second millennium dry conditions prevailed for approximately 200 years at the western part of the Mediterranean. Below on the right, there is a comparison of the number of climatic reconstructions which indicate dry (red bars), wet (blue bars), similar to today(white), or variable (orange) conditions at western, central and eastern Mediterranean respectively (Markonis et al., in preparation). Two periods have been examined, Medieval Warm Period and Little Ice Age, both showing a **dipole of opposing conditions between western and eastern Mediterranean**, identified by other researchers as well (Roberts et al., 2011). This can be also seen on the map, in which circles represent temperature (50 year mean, starting at 950 AD) and squares rainfall.



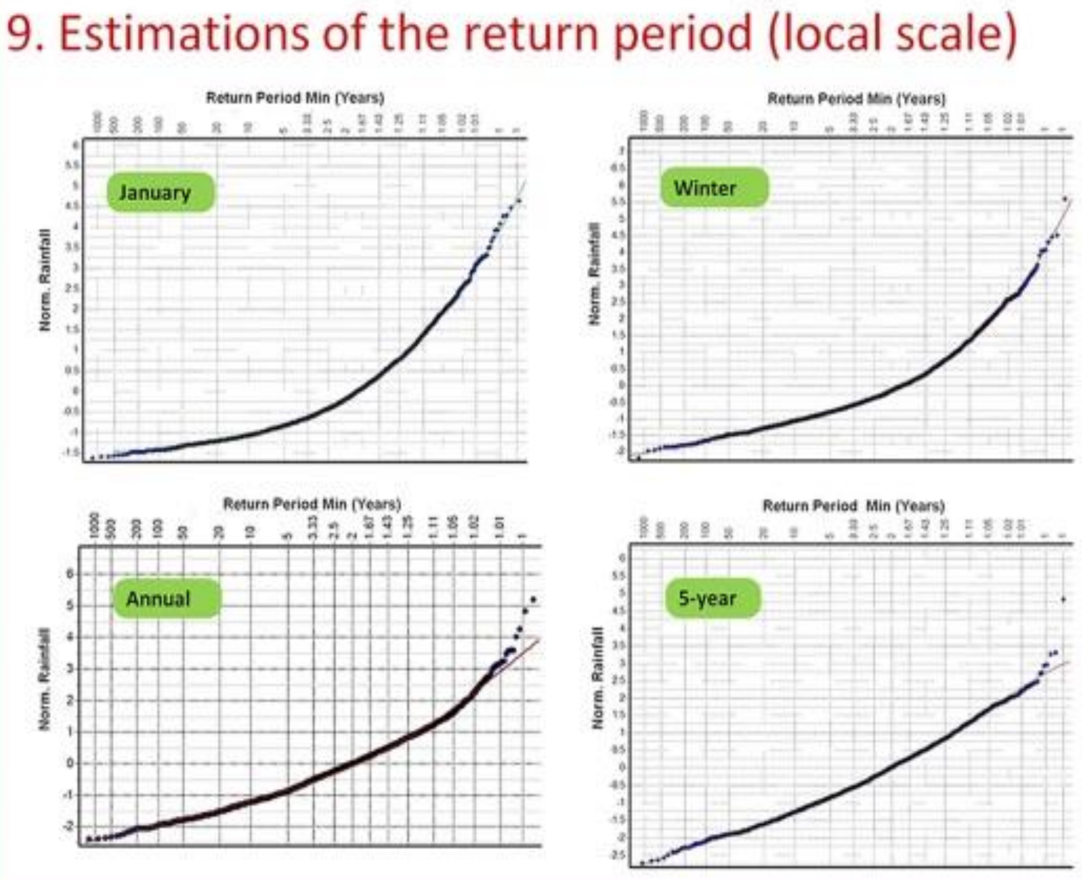
Rainfall during the Medieval Warm Period (Markonis et. al, in preparation)

8. Estimation of the return period

We have used Hydrognomon hydrological time series analysis software application to demonstrate the role of the marginal distribution in the estimation of the return period in different scales. To this end GEV distribution was fitted to the normalized time series of rainfall of each data set (green lines for GEV-min and red lines for GEV-max in the figures below), and the return periods were estimated. Four time scales were used: monthly (January), seasonal (winter), annual (hydrologic year; i.e. October to September) and 5-year (moving average of hydrological years). As it can be seen below, the general rule is that as scale grows larger the return period decreases. For comparison purposes, the return period for a single station was used (figures below). Notably, the return period for the minima is ≈ 15 to 100 hundred times larger (depending on the time scale) when compared to the larger spatial scales.

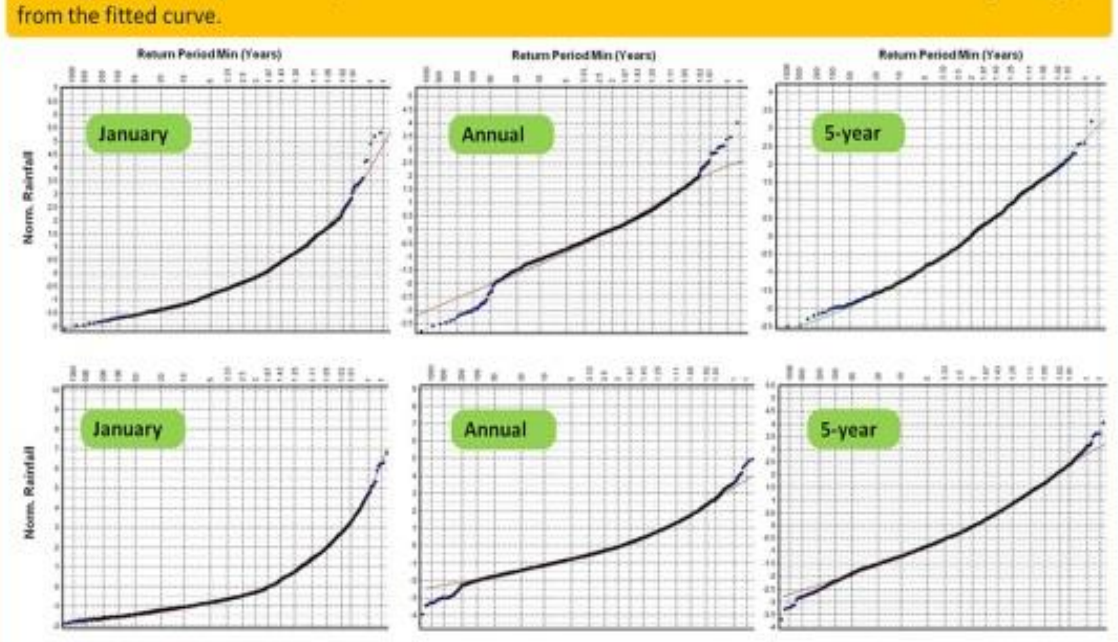


9. Estimations of the return period (local scale)



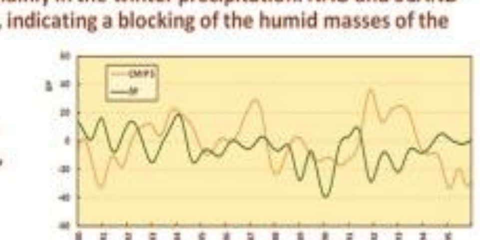
10. Estimations of the return period (Greece and the Mediterranean)

Winter scale was omitted as it was quite similar with monthly (both in shape and goodness-of-fit). On the upper row the figures correspond to Greek area, while the second row corresponds to the Mediterranean region. Although, they are represented by different data sets, their minima have the same behaviour deviating strongly from the fitted curve.



11. Conclusions

- **We have demonstrated that meteorological drought in the Mediterranean varies strongly in different scales both in space and in time.**
- **The temporal and spatial scale affects strongly the determination of the return period of the drought.**
- **There is evidence showing that the inter-annual rainfall variability plays a crucial role to the development of dry conditions. During winter evapotranspiration is minimal and thus more water reaches the water resources.**
- **Large-scale atmospheric circulation is linked to rainfall variability at the Mediterranean, especially in the winter.**
- **During the drought of 1988-95, there has been a decrease mainly in the winter precipitation. NAO and SCAND index showed persistently high and low values respectively, indicating a blocking of the humid masses of the Atlantic Ocean towards the Mediterranean.**
- **Till today, numerical climatic models fail to reproduce the NAO pattern. Thus, they fail to describe the precipitation correctly. This can be also seen if we compare the averaged rainfall difference from the monthly mean over Greece (δP), with the latest model results of the Coupled Model Intercomparison Project Phase 5 (CMIP5).**



References

Efstratiadis, A., A. Koukouvinos, N. Mamassis, S. Baki, Y. Markonis, and D. Koutsoyiannis, Drought Management Plans for the water districts of Western Macedonia (in Greek), Ministry of Environment, Energy and Climate Change, 205 pp, February 2013.
Koukouvinos, A., A. Efstratiadis, N. Mamassis, Y. Markonis, S. Baki, and D. Koutsoyiannis, Drought Management Plans for the water districts Central Macedonia (in Greek), Ministry of Environment, Energy and Climate Change, 144 pp, February 2013.
Mariotti, A., & Dell'Aquila, A. (2011). Decadal climate variability in the Mediterranean region: roles of large-scale forcings and regional processes. Climate Dynamics, 38(5-6), 1129–1145. doi:10.1007/s00382-011-1056-7
Markonis, Y., S.M. Papalexiou, and D. Koutsoyiannis, The role of teleconnections in extreme (high and low) precipitation events: The case of the Mediterranean region, European Geosciences Union General Assembly 2013, Geophysical Research Abstracts, Vol. 15, Vienna, EGU2013-5368, European Geosciences Union, 2013.
Mosxou, E., S. Batelis, J. Dimakos, I. Fountoulakis, Y. Markonis, S.M. Papalexiou, N. Mamassis, and D. Koutsoyiannis, Spatial and temporal rainfall variability over Greece, 5th EGU Leonardo Conference – Hydrofractals 2013 – STAHY '13, Kos Island, Greece, European Geosciences Union, International Association of Hydrological Sciences, International Union of Geodesy and Geophysics, 2013.
Stephenson, Pavan, Bojariu, 2000. Is the North Atlantic Oscillation a random walk? International Journal of Climatology, 20:1–18.
Tegos, A., Efstratiadis, A. and Koutsoyiannis, D. A parametric model for potential evapotranspiration estimation based on a simplified formulation of the Penman-Monteith equation, Evapotranspiration-An Overview, edited by S. Alexandris, 143–165, doi:10.5772/52927, InTech, 2013 (dx.doi.org/10.5772/52927)
Trigo RM, Osborn TJ and CorteReal JM. (2002) The North Atlantic Oscillation influence on Europe: climate impacts and associated physical mechanisms. Climate Research 20: 9-17.
Roberts N, Moreno A, Valero-Garcés BL, et al. (2011) Palaeolimnological evidence for an east–west climate see-saw in the Mediterranean since AD 900. Global and Planetary Change.