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Study of extreme wet and dry periods in Cyprus using climatic indices

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ABSTRACT

Climate change affects the precipitation regime globally, including its extreme values, as well as the frequency of the corresponding extreme events. Generally, observations and simulations with climate models show that a warming climate typically results in an intensification of precipitation extremes. An analysis of the daily precipitation database for the island of Cyprus is performed, using a period of 50 years. A number of climatic indices for precipitation are calculated, including the Standardized Precipitation Index (SPI), using the dense network of rain gauges of the Cyprus Department of Meteorology. All parameters are calculated for the recent 30-year period 1981–2010 (considered by the World Meteorological Organization as the new current standard period); the results are compared with those of the period 1961–1990 (considered by the World Meteorological Organization as the reference period), with a view to examine the differences in the occurrence of wet and dry periods. The results show an increase in the occurrence of heavy rainfall events and a slight decrease in extreme drought events.

1. Introduction

Precipitation is one of the most important factors of Earth's water cycle, affecting a number of human activities, like agriculture, with significant impacts in the economy. Extreme events like flash floods or prolonged droughts influence the lives of many people on the global and regional scales. The study of the trends in precipitation is crucial in order to decide short-term or long-term measures, regarding water resources management. Hence, the knowledge of the spatio-temporal and physical characteristics of rainfall by all available means is essential (Michaelides et al., 2009a).

The Mediterranean region is characterized by its vulnerability to climatic extremes. Studies over the Mediterranean basin show that even though the amounts of precipitation decrease, the events of extreme rainfall have a tendency to increase (Alpert et al., 2002). Focusing over the Eastern Mediterranean, Nastos and Zerefos (2009) found an increase in the occurrence of consecutive dry days, especially in the Aegean Sea, and a decrease in the incidence of consecutive wet days over the same area. Accordingly, Federico et al. (2009) showed a negative trend in yearly precipitation using the Standardized Precipitation Index (SPI), with local exceptions, for the region of Calabria in Southeastern Italy. Livada and Assimakopoulos (2007) calculated the SPI to detect drought events on a spatial and temporal basis, built on monthly precipitation data from 23 stations in Greece, for the period 1950–2000. They concluded that mild and moderate droughts reduce from north to south and from west to east on the 3- and 6-month time scale, while the frequency of occurrence of severe and extreme drought conditions is very low over the whole Greek territory on the 12-month running time scale. Michaelides and Pashiardis (2008) studied drought in Cyprus by calculating SPI, based on precipitation records of the network of the Cyprus Department of Meteorology, for the hydrological year 2007–2008 for different time scales, quantifying, thus, the precipitation deficit during different months of the year.

The climate of Cyprus is typical Mediterranean, exhibiting hot dry summers from mid-May to mid-September and rainy, rather variable, winters from November to mid-March (Cyprus Department of Meteorology, 2016). With regard to Köppen–Geiger classification codes (see Kottek et al., 2006), Cyprus can be classified as belonging to the two types Csa = Warm temperate (summer dry – hot summer) and Csb = Warm temperate (summer dry – warm summer).

Michaelides et al. (2009b) showed a tendency for reduced probability of large annual rainfall amounts, which reflected in a severe water shortage on the island; this in turn has resulted in an acute problem for the economy, in conjunction with the increasing water demands.

In a study by Anagnostopoulou and Tolika (2012), the authors proposed a value of around 40–45 mm in daily precipitation, in order to characterize an event as extreme, in the island of Cyprus. In the present

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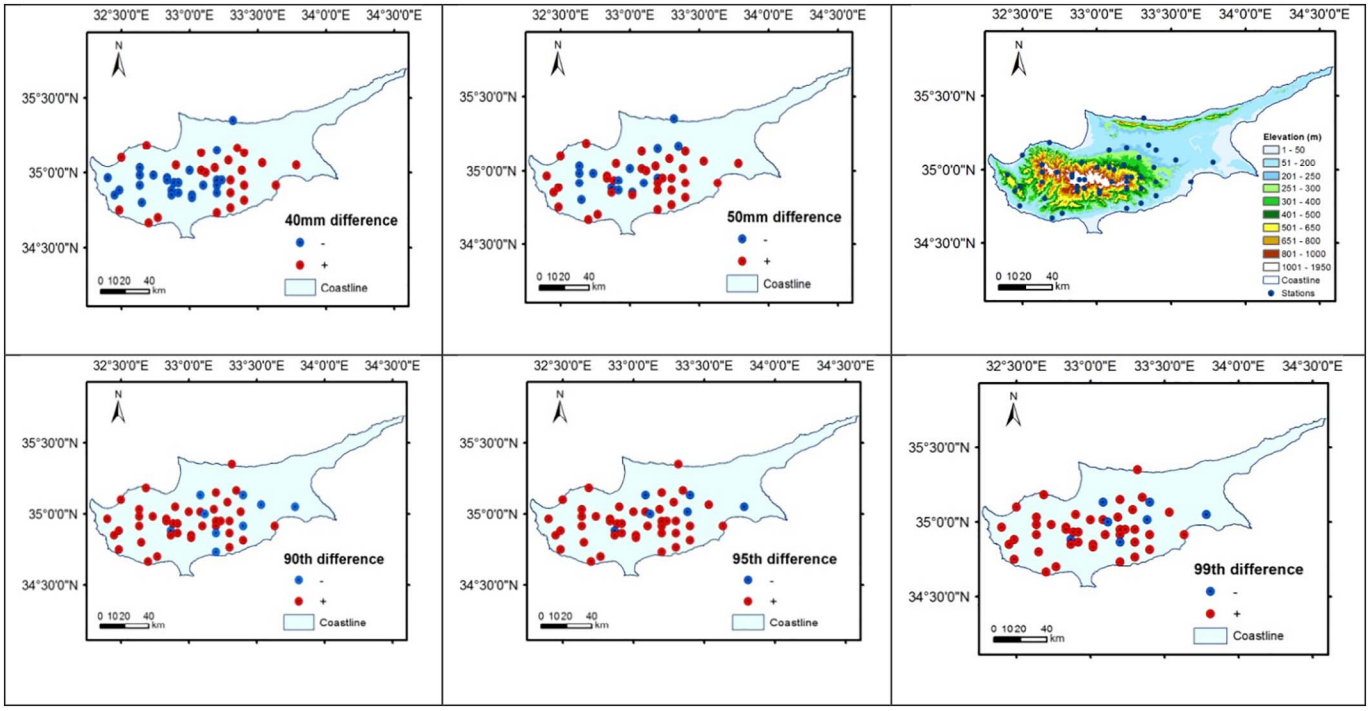

Fig. 1. Trends in the precipitation indices used: R40mm (upper left), R50mm (upper middle), 90th (lower left), 95th (lower middle) and 99th (lower left) percentiles; for positive trends, stations are shown as red; for negative trends stations are shown as blue. The map in the upper right shows the land relief with the positions of the stations used in this study. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 1
Classification of a wet/dry period based on SPI values.

Value	Drought class	Probability
SPI > 2.0	Extremely wet	0.023
1.5 < SPI ≤ 2.0	Very wet	0.044
1.0 < SPI ≤ 1.5	Moderately wet	0.092
−1.0 ≤ SPI ≤ 1.0	Near normal	0.682
−1.5 ≤ SPI < −1.0	Moderate drought	0.092
−2.0 ≤ SPI < −1.5	Severe drought	0.044
SPI < −2.0	Extreme drought	0.023

Table 2
Comparative results for the five indices calculated for the periods p1 (1961–1990) and p2 (1981–2010). The numbers express the number of stations belonging to each class.

Index calculated	Class		
	p1 > p2	p2 > p1	p1 = p2
R40mm	25	22	1
R50mm	15	30	3
R90p	9	39	0
R95p	6	42	0
R99p	7	41	0

Table 3
Extreme wet SPI values for the two 30-year periods (1961–1990 and 1981–2010).

Extreme wet index (SPI > 2.0)	Period	
	1961–1990	1981–2010
SPI-3	271	323
SPI-6	250	262
SPI-12	280	261
SPI-24	167	363

study, the number of days with values over 40 mm and 50 mm were calculated for both periods mentioned above (i.e., p1 and p2), with the aim to quantify the differences in the occurrence of extreme rainfall between the aforementioned periods. Furthermore, the percentage of days with an amount greater than the 90th, 95th and 99th percentiles is calculated in order to identify increase or decrease in the extreme events, after comparing the two periods of study.

Kostopoulou and Jones (2005) studied climate extremes by calculating a number of climate indices emphasising on precipitation and temperature with meteorological data provided by ten countries covering the European side of the eastern Mediterranean Sea, for the period 1958–2000. They found that the eastern Mediterranean region (Balkan Peninsula, western Turkey and Cyprus) reveals, generally, negative trends, indicating tendencies towards a drying climate over time, especially, at the southern coastal and island stations, which present large positive and significant trends in the maximum number of the consecutive dry days (CDD) index.

Giannakopoulos et al. (2010) used a high resolution Regional Climate Model (RCM) to examine future climate changes and variations in precipitation over Cyprus. Two future periods were studied, 2021–2050 and 2071–2100, while results were compared from the recent past (1961–1990) for both mean and extreme parameters. They concluded that a drop in rainfall amounts is foreseen for future simulations. The sharpest decrease was evident seasonally for the 2071–2100 simulation (decrease in winter accompanied with decrease in autumn), whereas, for the 2021–2050 simulation, rainfall showed a decrease in winter, but an increase in autumn. An increase in the dry period with precipitation below 1 mm of about 15 days for 2021–2050 and of about 15 days to 1 month for 2071–2100 was also indicated.

In this study, the focus is over the island of Cyprus, for two 30-year periods, namely 1961–1990 and 1981–2010. Indices regarding extreme daily rainfall together with the SPI, that uses monthly amounts of precipitation, are analyzed and examined.

Section 2 focuses on the presentation of the data used in this study and the methodology adopted. The results are resented and discussed in Section 3. Finally, some concluding remarks are given in Section 4.