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Integrated analysis of present and future responses of precipitation over selected Greek areas with different climate conditions

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ABSTRACT

The assessment of future precipitation variations prevailing in an area is essential for the research regarding climate and climate change. The current paper focuses on 3 selected areas in Greece that present different climatic characteristics due to their location and aims to assess and compare the future variation of annual and seasonal precipitation. Future precipitation data from the ENSEMBLES anthropogenic climate-change (ACC) global simulations and the Climate version of the Local Model (CLM) were obtained and analyzed. The climate simulations were performed for the future periods 2021–2050 and 2071–2100 under the A1B and B1 scenarios. Mann–Kendall test was applied to investigate possible trends. Spatial distribution of precipitation was performed using a combination of dynamic and statistical downscaling techniques and Kriging method within ArcGIS 10.2.1. The results indicated that for both scenarios, reference periods and study areas, precipitation is expected to be critically decreased. Additionally, Mann–Kendall test application showed a strong downward trend for every study area. Furthermore, the decrease in precipitation for the Ardas River basin characterized by the continental climate will be tempered, while in the Sperchios River basin it will be smoother due to the influence of some minor climatic variations in the basins' springs in the highlands where milder conditions occur. Precipitation decrease in the Geropotamos River basin which is characterized by Mediterranean climate will be more vigorous. B1 scenario appeared more optimistic for the Ardas and Sperchios River basins, while in the Geropotamos River basin, both applied scenarios brought similar results, in terms of future precipitation response.

1. Introduction

Climate change is the greatest human challenge the world faces, as negative effects, such as flooding phenomena, heat waves, forest fires and droughts have started becoming very severe (Hillel and Rosenzweig, 2002). At continental, regional and ocean basin scales, numerous long-term changes in climate have been observed. These include changes in Arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather including heavy precipitation and the intensity of tropical cyclones (IPCC, 2007).

Although these changes are evident, changes in precipitation are harder to observe and measure with the existing records, both because of the greater difficulty in sampling precipitation and also because it is expected that precipitation will have a smaller fractional change than the water vapor content of air as the climate warms. Some regional precipitation trends appear to be robust, but when virtually all the land area is 'filled in' using a reconstruction method (e.g. GIS-Techniques), the resulting time series of global mean land precipitation has been showing a little change since 1900 (IPCC, 2014).

According to previous IPCC studies, annual precipitation trend in the 20th century, for a number of stations in Europe, exhibits a clear general increase for northern Europe, with the exception of Finland, and a decrease for southern Europe and the Mediterranean (IPCC, 1996; 2001). Furthermore, these uncertainties and changes in the climate have a great impact on water resources, and droughts and floods arise for various reasons such as different scenarios of economic development and greenhouse emissions. Additionally, according to the results of climatic models (SRES A1B) rainfall will shift northwards and south areas of the Mediterranean will show a decrease in rainfall for the period 2080–2099 more than 20% compared with 1980–1999 (IPCC, 2007). Nevertheless, regional differences are relatively high (Nastos and Zerefos, 2008). Especially for the Mediterranean region, it is situated at the southernmost tip of the northern zone of the middle latitudes, which seems to be more vulnerable to changes in global warming with a significant impact on the rainfall parameter (Nastos et al., 2013a). Human activities have been affected by these changes and they will continue influencing in the future (IPCC, 2014).

Many recent studies have also contributed to the assessment of present and future precipitation variability over Greece and generally over

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the Mediterranean region (Repapis, 1986; Metaxas et al., 1999; Brunetti et al., 2004; Goubanova and Li, 2007; Nastos and Zerefos, 2007; 2008; 2009; Nastos et al., 2013a; 2013b; Gocic and Trajkovic, 2013; Hertig and Jacobeit, 2008; 2014). According to the results of these previous studies, the Mediterranean region has tended towards the decrease of the winter precipitation during the last few decades, mostly starting in the 1970s and proceeding to an accumulation of dry years in the 1980s and 1990s (Schönwiese et al., 1994; Piervitali et al., 1997). Especially over the eastern Mediterranean where Greece is located; decreasing precipitation is also evident in large parts of the sea (Feidas et al., 2007). Schönwiese et al. (1994) reported a pronounced significant trend towards a drier winter climate over the eastern Mediterranean area, for the period of 1961–1990. A general drying is also discernible over most of the south-eastern part of Mediterranean and Greece, which is prominent and statistically significant during the second half of the 20th century (Feidas et al., 2007).

Greece belongs to a part of the Mediterranean region, where the accurate knowledge of precipitation variations is mandatory for agriculture. Hence, possible future changes in precipitation amount are more critical for agriculture than the average conditions. Thus, the reason for the selection of the specific study areas lies in the fact that the agriculture is the main production and economic activity. A significant part of the local population is employed fully or partly in the primary sector (agriculture and livestock). Additionally, the climatic conditions in the certain areas vary as the Geropotamos River basin in Crete Island is affected by the Mediterranean climate conditions, while the Sperchios River basin in Central Greece also faces Mediterranean conditions with some minor variations on the rivers' springs in the mountainous area where milder conditions appear. On the other hand, the Ardas River basin in north-eastern Greece is affected by the continental climate and presents different climatic conditions. Due to these facts, most of the local population uses the water from the torrential streams for irrigation. Irrigation plays an important role, due to the reduced amount of water availability from rainfalls and the farmer's inability to “buy” water (Paparrizos et al., 2015a). Farming and manufacturing activities based on the agricultural activity, as well as other activities of the primary and secondary sector productions create a pressing need for a research that will provide information and adapting systems regarding the future response of precipitation over areas that face different climate conditions.

The results of the current study will provide the opportunity to the farmers, residents and all the stakeholders to understand the climate conditions prevailing in their area regarding the future changes and shifts in the amount of precipitation and adjust their systems in order to deal with future conditions. This contributes to the development of the agricultural production for the local population related with agricultural activities or, for those who have in mind being occupied with the agriculture sector. Moreover, the current study will also focus on the role that topography plays in the future variation of precipitation. Finally, the current research will provide a helping hand towards the understanding of the future response of precipitation in relation with the climatic conditions prevailing in each area, in order to plan, implement and manage the available water resources and water availability that will lead to a sustainable development of the agriculture and the environment.

The objective of the current study was to simulate and map through downscaling spatial interpolation techniques, the future response of the precipitation for the periods 2021–2050 and 2071–2100, under the A1B and B1 emission scenarios in relation with the reference periods that were determined for each study area. Future precipitation data from the ENSEMBLES anthropogenic climate-change (ACC) global simulations and the Climate version of the Local Model (CLM) were obtained and analyzed. A combination of dynamical and statistical approaches was performed in order to downscale and perform the spatial interpolation of precipitation through ArcGIS 10.2.1 program. Finally, seasonal analysis was conducted and the Mann–Kendall was performed in order to detect possible trends between the present and the future precipitation responses.

Table 1
Local population related with the primary section.

Study area	Region	Region population	People occupied in the primary section	Percentage (%)
Ardas River basin	Evros	149.354	37.560	25.1
Sperchios River basin	Ftiotida	169.542	52.426	30.9
Geropotamos River basin	Irakleion	304.270	116.251	38.2

2. Study areas & methodology

2.1. Study areas

The study areas are located in Greece. The Ardas River basin (Manolas et al., 2009; Serbis et al., 2013) is located in the north-eastern part of Greece (a big part of the basin belongs to Bulgaria — mostly the mountainous area of the basin) with an area of 5681.3 km^2. The mean annual precipitation is 839.8 mm while the mean annual T_{mean} is 10.5 °C. In the Ardas River basin various climate types exist, but the basin is mainly characterized by humid continental climate conditions (Peel. et al., 2007). Sperchios River basin (Paparrizos et al., 2014; Paparrizos et al., 2015a; Paparrizos et al., 2015b) with an area of 1727.7 km^2 is located in Central Greece and it faces Mediterranean conditions with mean annual precipitation 792.9 mm and mean annual T_{mean} 16.6 °C. The third area is Geropotamos River basin (Stobbelaar, 2000; Matzarakis and Nastos, 2011; Bleta et al., 2014), located in South Greece in Crete Island. It has an area of 651.6 km^2, mean annual precipitation 759.8 mm and mean annual T_{mean} 17.2 °C. Table 1 presents the local population that is employed in the primary section or is related with agricultural activities, while Fig. 1 shows the general location, the meteorological stations and the characteristics of the study areas.

2.2. Climate data

Daily values of precipitation data obtained from stations within or adjacent to the study areas as can be seen in Fig. 1, derived from the Hellenic Meteorological Service (HNMS) and OGIMET[1] were used in the study. The characteristics of the stations can be found in Table 2. Since there were no available common precipitation data series for the study areas, a homogeneity test was performed (Dingman, 1994; 2002) followed by a statistical correlation test, the t-test (Snedecor and Cochran, 1989; Haan, 2002) in order to correlate the existing values and determine the reference periods that will be adopted in the current study. Finally the determined reference periods were 1981–2000 for the Sperchios and the Geropotamos River basins and 1985–2000 for the Ardas River basin.

Future climate change conditions were obtained by the outputs of the ENSEMBLES anthropogenic climate-change (ACC) Stream 1 simulations, using Mathworks (2014a). These anthropogenic climate-change runs simulate anthropogenic and natural forced climate responses for the historical period from 1860 to present and projected response to 2100 for three SRES scenarios: A2, A1B and B1. These centennial predictions have been performed with seven different coupled atmosphere–ocean circulation models (AOGCMs) of the ENSEMBLES partners: BCM2 (NERCS-BCCR), CNRM-CM3 (CNRM), ECHAM5/MPI-OM (MPIMET, DMI), EGMAM (FUB), HadCM3 and HadGEM1 (both METO-HC), and IPSL-CM4 (IPSL). Additionally, the Climate version of the Local Model (CLM) which is based on the COSMO model was also

[1] www.ogimet.com.