# PRECIPITATION OVER THESSALY PLAIN, GREECE. PRESENT AND FUTURE CHANGES

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## ABSTRACT

Precipitation variability and extremes are of high scientific concern, due to their economic, social and ecological impacts. Large changes in the wintertime atmospheric circulation along with local factors such as orography and continentality have had a profound effect on regional distributions of precipitation in the Mediterranean basin. Precipitation studies have been carried out either by the analysis of rain gauge data from individual stations or by gridded precipitation data, in order to smooth the spatial discontinuities.

The objective of this study is to analyze on one hand, the spatiotemporal variability of high resolution gridded daily precipitation datasets (0.25º x 0.25º), based on the E-OBS project, over Thessaly plain, Greece. Thessaly is the largest plain and granary of Greece including a total area of 14,036 km$^2$, which represents almost 11% of the Greek territory. Regarding the geomorphology, the ground is 50% mountainous-hilly and 50% flat, irrigated by Peneus, the third largest river in the country, which flows through the axis east-west.

The E-OBS is a European land-only gridded dataset of daily minimum, maximum and mean temperature and precipitation. In total, data from 2316 stations were used, for most of which precipitation data were available. The E-OBS data set was designed to provide best estimates of grid box averages rather than point values to enable direct comparison with Regional Climate Models (RCMs). The daily station data were interpolated into 0.25º and 0.5º regular grids.

On the other hand, despite the present precipitation conditions over Thessaly plain, based on E-OBS datasets, the future projected changes of precipitation between the period 1961-1990 (reference period) and the periods 2021-2050 (near future) and 2071-2100 (far future), along with the inter-model standard deviations derived by a number of six Regional Climate Models (RCMs), within the ENSEMBLE European Project, are presented under A1B emissions scenario.

The findings of the analysis revealed significant spatiotemporal changes of precipitation over Thessaly plain, which should be taken into account by stake holders in order to mitigate the impacts of the oncoming climate change.

**Keywords:** Precipitation, E-OBS project, Regional Climate Models, Ensemble project, Thessaly

## 1. Introduction

Cyclone activity presents large seasonal and spatial variability, with large differences from western to eastern Mediterranean and between cold and warm season (Lionello et al., 2006). Besides, according to the results of climatic models (SRES A1B) it is very likely that during the period 2080-2099, precipitation will shift northwards while decreases of more than 20% over the reference period 1980-1999 will appear (IPCC, 2007) at southern Mediterranean regions. Precipitation trends and variability within Greece have been studied by many researchers (Repapis, 1986; Maheras and Kolyva-Mahera, 1990; Metaxas et al., 1999, Paliatsos et al., 2005; Feidas et.al., 2007; Nastos and Zerefos, 2008; Nastos, 2008). Precipitation assessment has been conducted either by the analysis of rain gauge data from individual stations or by gridded precipitation data, in order to smooth the spatial discontinuities. Recently, a European land-only daily high-resolution gridded data set for precipitation and minimum, maximum, and mean surface temperature (E-OBS gridded data set) has been constructed (Haylock et al., 2008). Gridded precipitation data sets are identical for studies in regional scale due to scarce precipitation network, especially in areas with a complex relief, where the plains are interrupted abruptly by high mountains; this is the case of Thessaly region, Greece, where the elevation ranges from 0 m to 2800 m, with mean elevation being about 500 m. The objective of the study is to analyse the present precipitation conditions over Thessaly plain, Greece, based on E-OBS data sets as well as the future projected changes by an ensemble of six Regional Climate Models simulations, under A1B emissions scenario.

## 2. Data and methodology

The study area concerns Thessaly plain, which is the largest plain and granary of Greece including a total area of 14,036 km$^2$, which represents almost 11% of the Greek territory (Figure 1). The climate is continental with cold winters and hot summers, while summer rainstorms are frequent over the region. Mean annual precipitation ranges from 400 mm to 1850 mm. The mountain areas receive significant snow during the winter months.

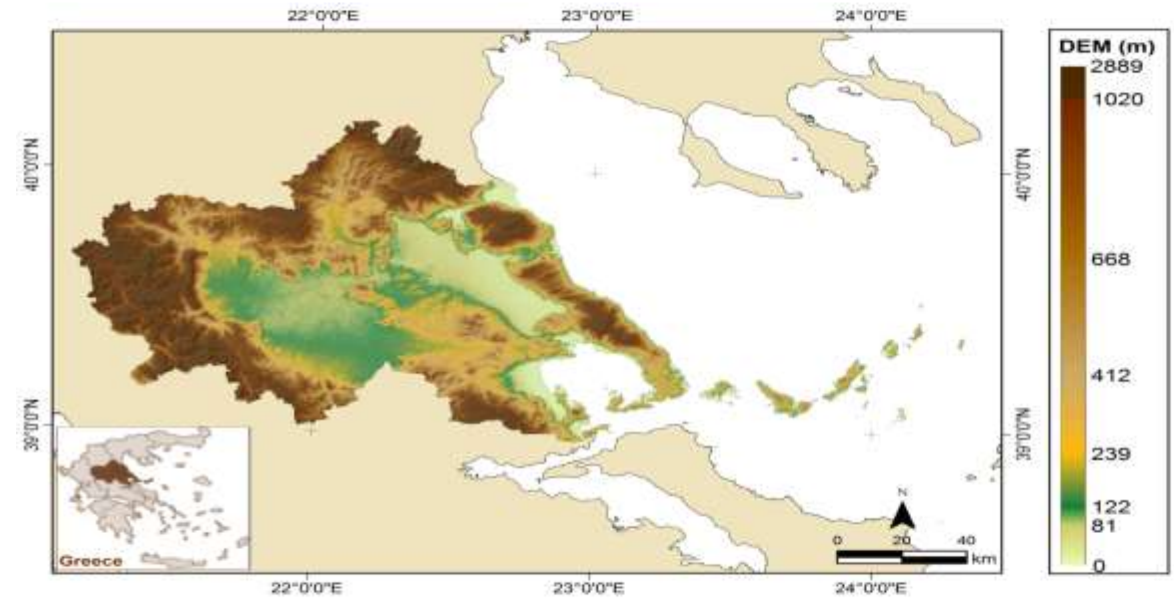



**Figure 1:** The Thessaly plain, Greece

The present precipitation conditions over Thessaly were estimated by the use of E-OBS daily precipitation data sets, within the period 1961-1990. The E-OBS (Haylock et al., 2008) is a European land-only gridded dataset of daily minimum, maximum and mean temperature and precipitation. It spans the area of 25º-75ºN x 40ºW-75ºE over land for the years 1950-2011. In total data from 2316 stations were used, for most of which precipitation data were available. The E-OBS data set was designed to provide best estimates of grid box averages rather than point values to enable direct comparison with RCMs (Kyselý and Plavcová, 2010). The daily station data were interpolated into 0.25º and 0.5º regular grids. The interpolation methods used were chosen after careful evaluation of a number of alternatives.

The future precipitation projections were assessed by the simulations of an ensemble of six Regional Climate Models (RCMs) within the European project “ENSEMBLES” (http://ensemblesrt3.dmi.dk/). Thus, the daily precipitation data sets were used from the following six RCMs: CNRM-RM5.1 [ARPEGE], DMI-HIRHAM5 [ARPEGE], ETHZ-CLM [HadCM3Q0], METO-HC_HadRM3Q0 [HadCM3Q0], KNMI-RACMO2 [ECHAM5], MPI-M-REMO [ECHAM5]. The models’ simulations used as initial and boundary conditions the output data of various

General Circulation Models (GCMs), which are presented in the above brackets after each RCM. All six RCMs have spatial resolution 0.22° x 0.22° (approximately 25km x 25km). The simulations of the six RCMs for the near future (2021-2050) and the far future (2071-2100) were made under the A1B emissions scenario, while the simulations for the reference period (1961-1990) were made under the 20C3M emissions scenario, which represents a 20th century simulation using historical GHG concentrations (note this is actually 1871-2000).

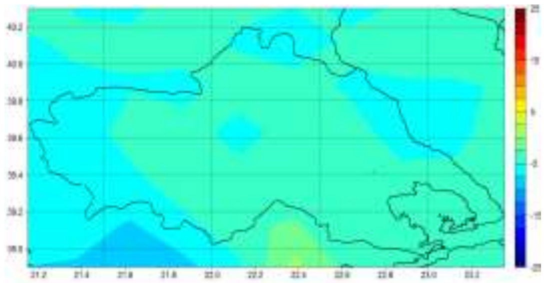
The processing of the climatic data was carried out by using the statistical package R-project, resulting in the seasonal and annual ensemble mean precipitation changes for the near and far future, along with the Inter Model Standard Deviations (IMSD).

## 3. Results and discussion

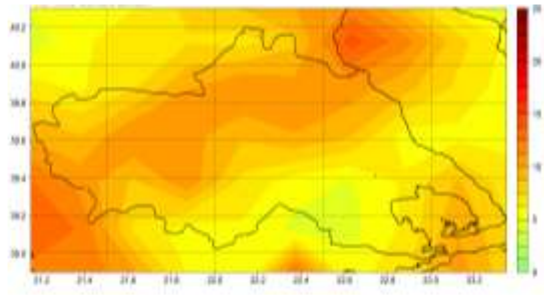
The precipitation totals over Thessaly plain within the reference period 1961-1990 are based on the high resolution gridded E-OBS data sets. We estimated the mean annual and seasonal precipitation patterns (not shown) and compared them with the respective simulations, derived by the ensemble of six RCMs, within the ENSEMBLE European Project (not shown). The annual mean E-OBS precipitation accounts for 400-800 mm, against 350–1050mm derived by the ensemble mean of the six RCMs. Thus, there is a small underestimation (almost -10%) over the central plain, against a moderate overestimation (+30%) by RCMs with respect to highlands and mountainous regions surrounding the plain. This could be attributed to some extend to the lack of adequate rain gauges over the mountainous regions of Thessaly.

The findings of the analysis revealed significant seasonal changes for the future periods examined, which along with the Inter Model Standard Deviations (IMSD) are depicted in Figures 2 and 3 for the near and far future, respectively. More specifically, regarding simulations for the near future in winter, precipitation decreases from 5% over mountainous areas towards 2.5% at the plain, with IMSD ranging from 5 to 10%. Accordingly, the near future decreases for mean precipitation in spring range from -7.5 to -2.5% (IMSD: 5-11%), in summer from -25 to -7.5% (IMSD: 7.5-22.5%), in autumn from -2.5 to +5% (IMSD: 7.5-14%) and finally the mean annual precipitation is likely to decrease from -7.5 to -5% (IMSD: 5-9%).

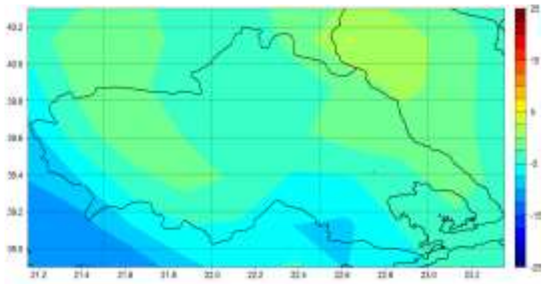
Regarding the far future projections, we estimated almost twofold precipitation decreases due to global warming. The highest projected changes are likely to appear in summer (-45 to -15%; IMSD: 10-30%) against winter with lower decreases of -10% (IMSD: 10-17.5%).



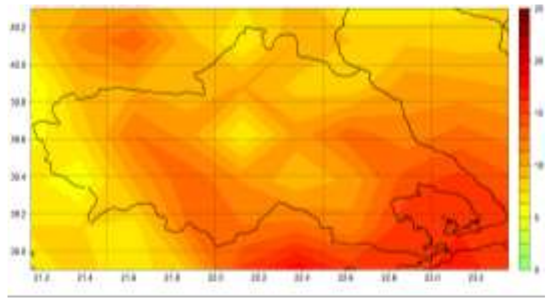
(a) Mean winter precipitation change



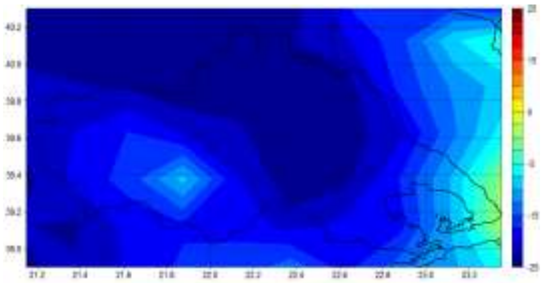
(b) IMSD winter precipitation change



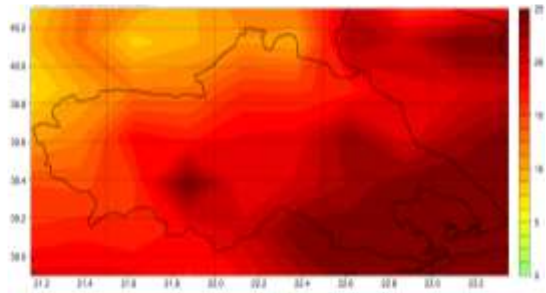
(c) Mean spring precipitation change



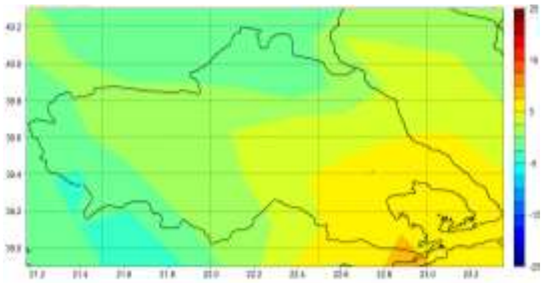
(d) IMSD spring precipitation change



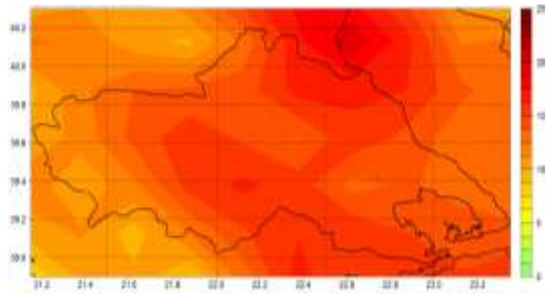
(e) Mean summer precipitation change



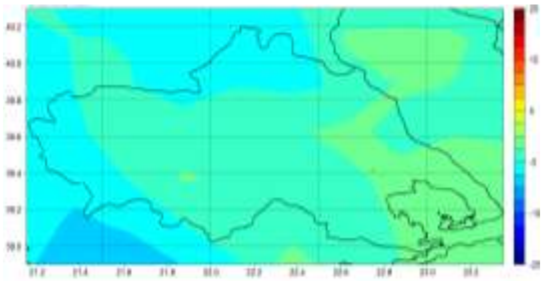
(f) IMSD summer precipitation change



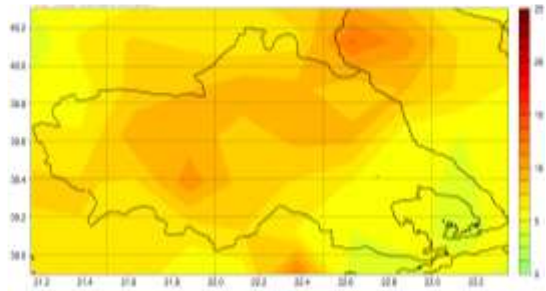
(g) Mean autumn precipitation change



(h) IMSD autumn precipitation change

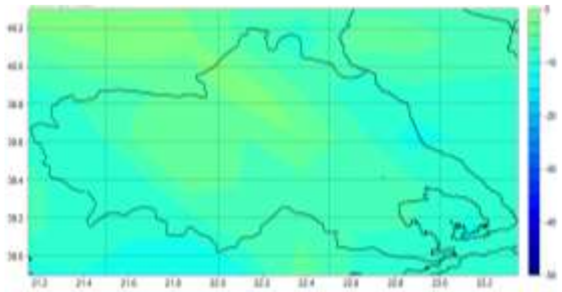


(i) Mean annual precipitation change

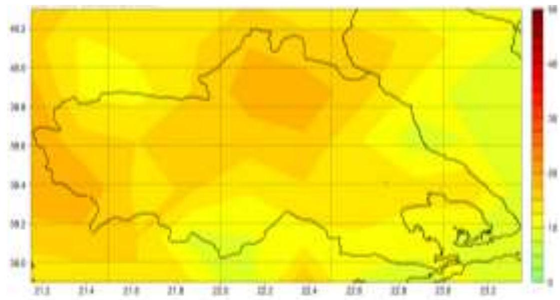


(j) IMSD annual precipitation change

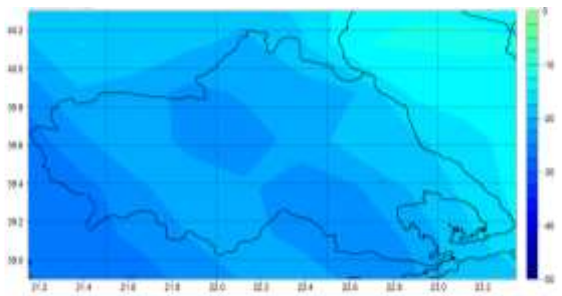
**Figure 2:** Spatial distribution of ensemble mean precipitation for winter (A), spring (C), summer (E), autumn (G) and year (I) along with the respective inter model standard deviations (B, D, F, H, J), for the near future 2021-2050, under SRES A1B.



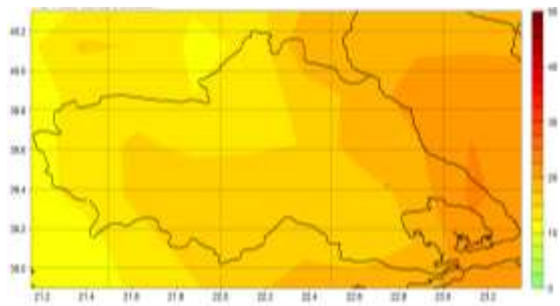
(a) Mean winter precipitation change



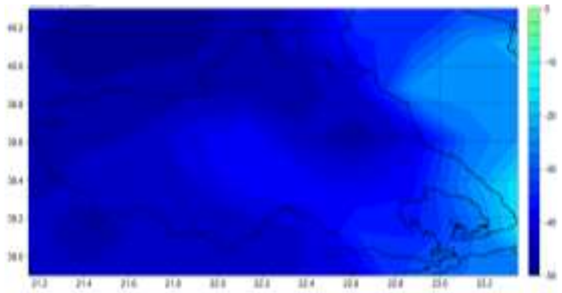
(b) IMSD winter precipitation change



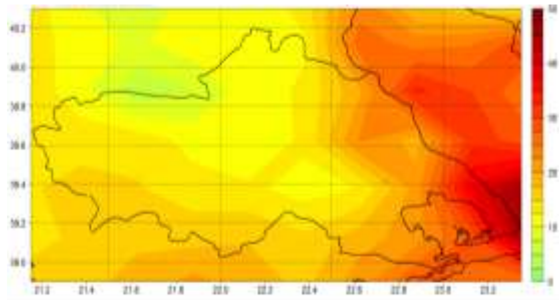
(c) Mean spring precipitation change



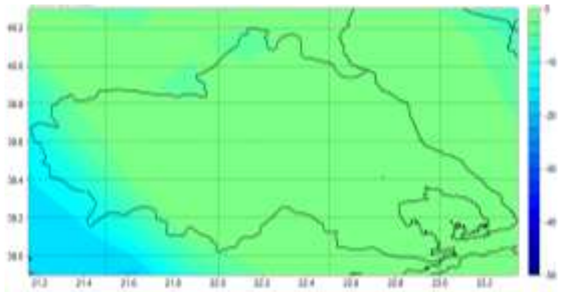
(d) IMSD spring precipitation change



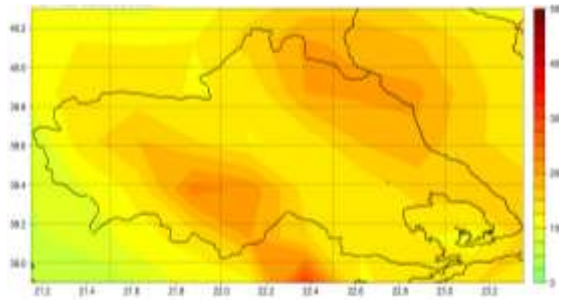
(e) Mean summer precipitation change



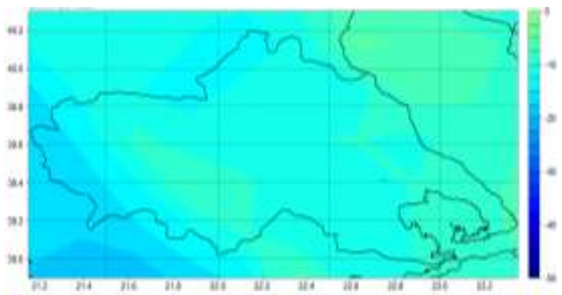
(f) IMSD summer precipitation change



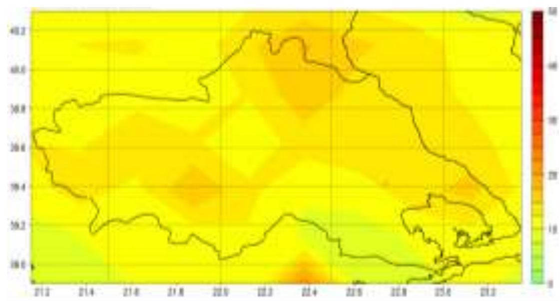
(g) Mean autumn precipitation change



(h) IMSD autumn precipitation change



(i) Annual Mean precipitation change



(j) IMSD annual precipitation change

**Figure 3:** Spatial distribution of ensemble mean precipitation for winter (A), spring (C), summer (E), autumn (G) and year (I) along with the respective inter model standard deviations (B, D, F, H, J), for the far future 2071-2100, under SRES A1B..

According to the projected simulations, it is likely that the mean annual and seasonal precipitation will decrease more over highlands and mountainous regions against lowlands and coastal areas of Thessaly plain.

## 4. Conclusions

In this work, the present precipitation conditions (reference period 1961-1990) over Thessaly plain, based on E-OBS datasets, as the future precipitation projections by an ensemble of six Regional Climate Models (RCMs) within the European project “ENSEMBLES”, for the near (2021-2050) and far (2071-2100) future, along with the inter-model standard deviations, are assessed under A1B emissions scenario. The ensemble mean precipitation by the RCMs seems to overestimate in some extend the mean annual E-OBS precipitation; the overestimation is higher over highlands where insufficient number of rain gauges exist. Based on the projected simulations, the future shortage of precipitation is likely to appear higher over mountainous regions against lowlands. Besides, almost twofold precipitation decreases due to global warming, is likely to prevail in the far against near future.

## ACKNOWLEDGEMENTS

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