A climatic study at a vulnerable touristic region of Southwestern Greece – Observations and simulations

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Abstract In the framework of the XENIOS project (http://www.xenios-net.gr/en/), Messinia, one of the most popular touristic destinations of Greece, was selected to assess the impacts of climate change on tourism in vulnerable areas. Historical observations were used to detect mean climatic features at this region as well as climatic variability and trends. A significant increase of the maximum air temperature was detected after mid 1970's in accordance with the general trend for the eastern Mediterranean. This increase approximates 1^0 C/ decade at the continental sites. The annual precipitation amount does not reveal any statistically significant change over the studied period. However, the annual number of rainy days was found to decrease by 4 days/decade, in contrast to the increasing trend in the annual number of heavy rain days. A set of Regional Climate Models from EU projects ENSEMBLES (www.ensembles-eu.org) and CIRCE (www.circeproject.eu) was also validated using observational data at Messinia . The use of an 'average' model improved the performance of individual models for all climatic indices. The 'average' model simulated successfully temperature and precipitation indices in the area, such as total precipitation and number of days above certain thresholds and hence can be used for future climate change projections.

1 Introduction

Climate change is a global phenomenon but its effects concern local scales and have a direct impact on local economies. One of the economic activities which is particularly affected by weather and climate is tourism.

The tourism industry is very important for local economies, providing employment and generating income. In Greece, tourism industry is a main pillar of the country's economy corresponding to a high proportion (> 20%) of employment. Nevertheless, this industry is interlinked with climate change in various and different ways. It is imperative to reduce vulnerability (related to exposure/sensitivity and adaptive capacity) of touristic areas and implement measures of adaptation to climate change. First, vulnerable areas that face with problems must be recognized.

As regards climate change in the country, recent studies report a general warming over the past three decades, characterized by large spatial and seasonal variability (e.g. Feidas et al. 2004, Philandras et al. 2008). According to these studies, warming is more important and statistically significant during the warm season of the year, while in winter some areas present a cooling trend and others a warming trend (the latter not statistically significant). Moreover, extreme events and particularly heat waves have increased in terms of frequency, intensity and duration and are expected to be more frequent in the future (Founda and Giannakopoulos 2009).

Assessing vulnerability of tourism industry to climate change in Greece will allow mitigation and adaptation measures. In the framework of the XENIOS project (http://www.xenios-net.gr/en/), Messinia was selected to assess the impacts of climate change on tourism in vulnerable areas. A climatic study for Messinia was conducted, aiming at the detection of climatic changes in the area from long term observations, while a set of Regional Climate Models was validated to allow their application for future projections at Messinia.

2 Data and Methodology

Historic weather data from the network of meteorological stations of the Hellenic National Meteorological Service (HNMS) at Messinia, covering a period of at least three decades were used to demonstrate the spatial and temporal climate variability and detect possible significant trends. The stations of Methoni (coastal), Kalamata (airport) and Diavolitsi (continental) were used for the analysis. A number of climatic indices for air temperature and precipitation (concerning average and extreme values) as defined by the Expert Team of Climate Change, Detection and Monitoring Indices (ETCCDMI) was also calculated from daily historic data. Air temperature indices include daily maximum (Tmax) and minimum (Tmin) temperature, while extreme temperature indicators are based on percentiles and absolute temperature threshold values (e.g. number of days/nights with temperature above/below certain threshold values indicating summer days/nights or tropical days/nights or frost days etc). As regards precipitation, total precipitation amount, number of rainy days (>1mm) and number of days with light, moderate, heavy and extreme precipitation were also calculated.

Historic climatic data at Messinia for the control period 1975-2004 were also used for the validation of Regional Climate Models (RCMs) to be applied in the area for future projections. A set of RCMs simulations was carried out in the framework of the European Projects ENSEMBLES (www.ensembles-eu.org) and CIRCE (www.circeproject.eu) was used, at 25 Km horizontal resolution. Observations were compared with simulations of each RCM but also with an 'average' model produced by averaging the simulations of the individual models. In addition, daily reanalysis data (E-Obs) developed for Europe by Haylock et al. (2008) in the framework of the ENSEBLES Project were also compared to observations and simulations for the control period.

3 Results

3.1 Air temperature variability

As regards the temporal variability of the air temperature at Messinia, the analysis of the historical records revealed significant positive trends in the summer maximum and minimum temperatures since mid 1970s at all stations, but lack of any significant trend in winter temperature.

Figure 1 displays the interannual variability of the daily maximum temperature in summer (June to August) at the coastal station of Methoni, at the west side of Messinia, from 1956 to 2010. A cooling from 1956 to 1975 is observed, followed by a crystal clear warming from 1975 onwards. The overall long-term trend is positive and statistically significant (at 0.05 confidence level) according to the Mann Kendall test, amounting to +0.2 ^{0} C /decade. However, the trend for the period after mid 1970's is much larger, amounting to +0.6^{0} C, and statistically significant at 0.01 confidence level. Warming trends in summer were also found at Kalamata station, while an outstanding positive trend in the summer maximum temperature, amounting to +0.9 °C/decade after mid 1970's, was observed at the continental station of Diavolitsi (not shown). The findings for Messinia are in full agreement qualitatively and quantitatively with the findings at other parts of Central and Southern Greece, for instance Athens, where a pronounced warming in the summer maximum temperature has been observed during the last three decades (Philandras et al. 2008, Founda 2011).

The frequency of cold extremes at Messinia is very low. It was calculated that the frequency of days/year with Tmin<0 °C is less than 1% at the coast (Methoni) but reaches up to 5% at other sites (e.g. Kalamata). The lowest temperature ever recorded at Methoni was -5.6 °C (14/02/2004).

Hot extremes are more important for the area of Messinia as they can have a great impact on a number of sectors. The highest temperature ever recorded at Methoni was 41 °C, however, the values of 43 °C or even 45 °C have been recorded at nearby stations of the area.

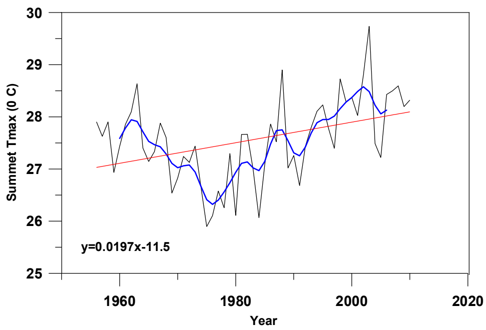

Fig. 1. Summer Tmax at Methoni from 1956-2010, along with 9-points weighted moving average and linear trend.

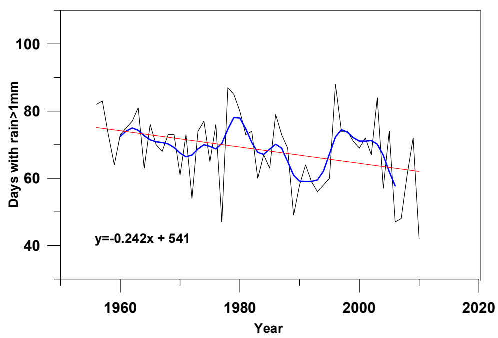

Fig. 2. Number of rainy days (>1mm) at Methoni from 1956-2010 along with 9-points weighted moving average and linear trend.

The frequency of summer days (Tmax >25 °C)/year is very high, amounting to 30-40% of the total days of the year, while the number of consecutive summer days per year was found to be on average 73 at Methoni and 107 at the station of Kalamata. As regards the frequency of occurrence of tropical days (Tmax >30 ^{0}C) from 1956 to 2010 at Methoni, a statistically significant increase (at 0.01 confidence level) in the number of tropical days/year is detected after mid 1970's , amounting to 6 days/decade .

3.2 Precipitation variability

The analysis of the interannual variability of precipitation at Messinia suggested the lack of any significant long term trend, as regards the total rainfall amounts. Nevertheless, as regards the number of rainy days/year, the analysis revealed an ongoing decreasing trend, particularly pronounced at Methoni station. Figure 2 displays the interannual variability of the number of rainy days (daily rainfall >1mm) at Methoni for the period 1956-2010. The observed negative trend is equal to approximately 2.5 days/decade. It is worthy however to note that, the trend becomes much larger (approximately 4 days/decade) when rainy days are assigned as days with rainfall amount >0mm. Despite the decrease in the number of rainy days/year, a positive trend in the number of days/year with heavy rain (30mm/day) was observed at all stations.

3.3 Validation of RCMS

Figure 3 shows the intra annual variability (average monthly values) of the maximum air temperature at Methoni from simulations, observations and E-Obs.

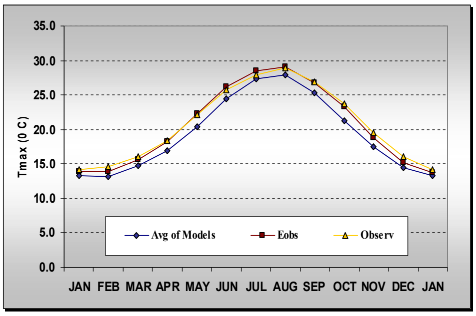

Fig.3. Mean monthly values of Tmax at Methoni from observations, 'average' model and E-Obs, for the control period.

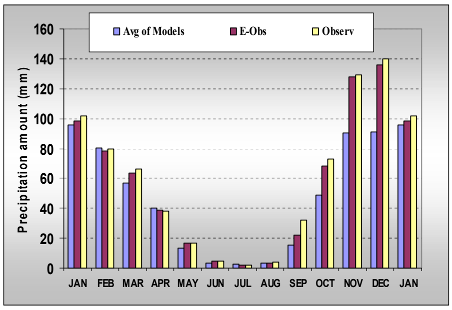

Fig. 4. Monthly values of precipitation at Methoni from observations, 'average' model and E-Obs, for the control period.

All models reproduce successfully the intra annual variability of the maximum and minimum air temperature, however with different scores. The accuracy of each model was sensitive to the particular climatic index (better performance was found in the maximum than minimum temperature) but also to the particular features of each site (coastal or continental). The performance of the 'average' model was much better, as it compensated overestimations or underestimations of individual models. However, even the 'average model' has a cold bias which ranges from 0.5^0 C in January to 1.9^0 C in May. An excellent agreement between observations and E-Obs is also found.

The inter annual variability and trends of Tmax at Methoni from observations was found to agree very well with E-Obs (for instance, $+0.6^0$ C and $+0.7\ ^0$ C/decade in summer from observations and E-Obs respectively for summer), however, the simulated trend from the 'average model', though positive, was smaller by approximately 50%.

As regards extreme indices, the average model and E-Obs simulated successfully the upper percentiles (90^{th} and 95^{th}) of the maximum and minimum air temperatures at all stations, however, the model overestimated the number of very hot days (Tmax> 30^0 and 35^0 C) at coastal stations and underestimated it at continental stations.

Figure 4 shows the mean monthly precipitation amounts at Methoni for the control period from observational data, 'average' model and E-Obs. E-Obs are in full agreement with observations, while the average model reproduces satisfactorily the precipitation amount for each month except for November and December, where an underestimation of almost 30% is found. The performance of all models was found to be quite successful in terms of the number of rainy days/year as well as the number of days corresponding to all categories of precipitation (light, moderate, heavy and extreme).

4 Conclusions

A climatic study for Messinia was conducted, to assess exposure and vulnerability to climate change effects that could have an impact on tourism activities in this area. A significant warming in the summer maximum air temperature after mid 1970's was detected, in accordance to the findings in other areas of Greece. Warming is more pronounced at continental sites, accompanied with increased frequency of very hot (tropical) days.

A decrease in the number of rainy days/year is also detected, which in combination with hotter conditions could stress tourism activity at Messinia.

The comparison of RCMs output with observations and E-Obs for the control period 1975-2004, showed satisfactory performance of the 'average' model for almost all examined climatic indices except for the frequency of very hot days which was very sensitive to the location and characteristics of the stations site and mean precipitation amounts of November and December. In general, the use of an 'average' model improved the performance of individual models and can be used for future climate projections at Messinia.

Acknowledgements

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