Deliverable C.2: Report on historical data trends and climate change projections for the greater urban areas of interest

LIFE URBANPROOF
CLIMATE PROOFING URBAN MUNICIPALITIES

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The project is being implemented by the following partners:

Coordinator Beneficiary	
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Associated beneficiaries	
	National Technical University of Athens *(Greece)*
	National Observatory of Athens *(Greece)*
	University of Venezia*(Italy)*
	Municipality of Reggio Emilia *(Italy)*
	Municipality of Strovolos*(Cyprus)*
	Municipality of Lakatamia *(Cyprus)*
	Municipality of Peristeri*(Greece)*

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EXECUTIVE SUMMARY

In this report the current climatological conditions in the partner municipalities as well as the impacts of future climate change under two different future emission scenarios are presented. For the current situation, observations gathered by the partner municipalities are analysed. More specifically, daily observations of temperature (daily maximum (Tmax), daily minimum (Tmin) and daily mean (Tmean) as well as daily precipitation are analysed for the partner municipalities of Strovolos-Lakatamia, Peristeri and Reggio Emilia. Apart from the seasonal trends of the mean annual values for the aforementioned variables a number of absolute, threshold and duration indices are also considered. For the common period, 1985-2014, used in all partner municipalities the analysis reveals that in all seasons an increasing trend for temperature is calculated. For instance, the increase over the 30 yr period for the daily maximum temperatures, depending on the season and the municipality varies from 0.5 to 1.5 °C. It should be mentioned that the highest increases, reaching in some cases over 3°C by the end of the 30 yr period are calculated for the Tmin. In particular, the Tmin summer trend for Reggio Emilia indicate the highest warming rates (1.3°C/decade) leading to an increase of about 3.9°C over the 30yr period. Tmean and Tmax are calculated to increase by 2.2°C and 0.7°C, respectively. As far as the extreme temperature related indices the analysis reveals that all municipalities are facing a high annual number of days with Tmax> 30° and 35° C and Tmin>20°C.

Regarding the precipitation results, increasing trends of about 16, 48 and 38 mm/decade are calculated for the annual total precipitation for Strovolos-Lakatamia, Peristeri and Reggio Emilia, respectively. However, the increase is not uniform for all seasons. In particular, winter precipitation increases are shown for all municipalities while for the rest of the seasons, increases or decreases are calculated. For Strovolos-Lakatamia the highest increase is calculated for the spring period (about 25 mm over the 30 yr period) whereas for Peristeri and Reggio Emilia the highest increases over the 30 yr period are calculated for the winter season, about 75 and 53 mm for Peristeri and Reggio Emilia, respectively. In addition, these increases are accompanied with increases in the 1 and 5 days maximum precipitation as well as with decreases in the maximum number of consecutive days with precipitation less than 1mm. Regarding the indices describing heavy and very heavy precipitation, no statistical significant trends are found.

To examine the future climate changes under the RCP4.5 and RCP8.5 future emission scenarios initially four Regional Climate Models from the EURO CORDEX framework were considered. However, the evaluation analysis against gridded observational data as well as the station observations revealed considerable biases. Therefore bias correction techniques for temperature and precipitation are applied to the data of one of the models and more specifically the MPI-RCA4. Regarding the Tmax the analysis reveals that in Strovolos-Lakatamia increases by 0.16°C and 0.58°C/decade under RCP4.5 and RCP8.5 scenarios, respectively are projected. The RCP8.5 indicates a more intense increase for the period 2045-2100 compared to the near future. The projected maximum temperature in Peristeri presents an increasing trend of 0.14°C/decade, resulting in an increase of 1.1°C until 2100, under the RCP4.5 scenario. Following the RCP8.5 scenario, the maximum temperature increases by 0.51°C/decade. The maximum temperature in Reggio Emilia seems to increase under both scenarios. The simulated trend is 0.2°C and 0.5°C/decade under RCP4.5 and RCP8.5, respectively. For the first 30 years (until 2045) the trend is almost the same in both cases, while thereafter the slope is sharper for RCP8.5 indicating a more intense increase (0.7°C/decade, from 2045 until 2100). The projections for the minimum temperature at the study area in Cyprus present an increasing trend. More specifically, increases by 1.2°C until 2100 according to RCP4.5 (0.14°C/decade) and by 4.4°C according to RCP8.5 (0.52°C/decade) are calculated. In Peristeri under the RCP4.5 scenario an increasing trend of 0.13°C/decade, resulting in an increase of 1.0°C until 2100 is found. The RCP8.5 scenario seems to result in an increase of 0.48°C/decade). Finally, an increasing trend of the minimum temperature is simulated for Reggio Emilia. The rates are 0.2°C/decade and 0.51°C/decade under the RCP4.5 and the RCP 8.5 scenario, respectively. The trend is more intense under RCP8.5 scenario for the period 2045-2100. These increases in Tmax and Tmin are accompanied by increasing trends in the annual number of days with Tmax> 30°, 35° and 40 ° C and Tmin>20°C.

As far as the precipitation results are considered for Strovolos-Lakatamia a decreasing trend under both scenarios is calculated. The rates of reduction are -2.0 mm/decade and -7.9 mm/decade under RCP4.5 and RCP8.5 scenarios, respectively. Both scenarios show a decreasing trend of precipitation Peristeri. The low-medium RCP4.5 scenario indicates a decrease of 6.5 mm/decade, while the RCP8.5 the decrease is 4.5 mm/decade. These rates result in an annual decrease of about 55 mm and 40 mm over the 85-year period, until 2100. Under the RCP4.5 scenario a significant decrease of precipitation at the Reggio Emilia is shown. The reduction rate is 7.9 mm per decade, meaning 70 mm decrease until 2100. The corresponding reduction rate simulated by the RCP8.5 is 4.5 mm per decade, namely 40 mm until 2100.

1 INTRODUCTION

Global climate change is now considered undisputable as average temperature is increasing, precipitation patterns are shifting, snow and glaciers are melting, sea level is rising and extreme weather events, such as floods, droughts and heat waves are becoming more frequent and intense. Independently of the future climate change scenarios and of the efforts for mitigating GHG emissions, it is believed that climate will continue changing in the coming decades due to the previous and current GHG emissions.

Though climate change is a global problem often discussed at a national scale, urban areas are increasingly seen as having a distinct role in the climate agenda in terms of both mitigation and adaptation. In addition to global disasters, urban areas have unique climate risks (e.g., urban heat island, impervious surfaces exacerbating flooding, coastal development threatened by sea level rise, etc.) (Carter et al., 2015; Gill et al., 2007; Smith et al., 2009). In addition, urban areas also house a majority of the world’s population (UN, Department of Economic and Social Affairs, Population Division, 2014) and are global economic hubs, thus exposing many assets to climate change hazards (Satterthwaite, 2007).

Regarding Europe, previous climate change assessments have shown that the number of heat-waves in Europe is projected to increase, with greater increases expected in southern Europe. Jacob et al (2013) showed that these increases are mostly robust and significant throughout the EURO-CORDEX RCP8.5 model ensemble, but they depend on the definition of heat-wave (ranging from an increase of nine to 45 heat-waves). Fischer and Schär (2010), estimated that Iberia and the Mediterranean region will see the biggest changes in number of heat-wave days (from 2 days to 27–67 days). However, the biggest increases in heat-wave amplitude, will be over south-central Europe where extreme temperatures are expected to rise much more (up to 7 K) than mean summer temperature.

Assessment of changes in drought depends on the type of drought being studied (meteorological, agricultural, hydrological, etc.) and on the drought index chosen. Nevertheless, droughts are projected to become longer/more frequent in central Europe and the Mediterranean region (Cisneros et al 2014) and in the Iberian peninsula (Guerreiro et al 2017b). Forzieriet al (2014) concluded that future discharge decreases in the South of Europe and increases in the North of Europe were significant, but in between (the transition zone) the projections were discordant.

In a recent study, Guerreiro et al. (2018) studied the impact of climate change in droughts, heat-waves and floods in 571 European cities using all projections from CMIP5 –wide range of climate change impact scenarios-for the RCP8.5 emissions scenario, and comparable methods for each hazard. The analysis revealed that heatwave days are projected to increase across all cities, and especially in southern Europe, while the greatest heatwave temperature increases are expected in central European cities. For the low impact scenario, drought conditions intensify in southern European cities while river flooding worsens in northern European cities. However, the high impact scenario projects that most European cities will see increases in both drought and river flood risks.

Higher temperatures and heatwaves under global warming are also associated with population discomfort, increased energy consumption, peri-urban fires and ozone exceedances. For instance, Giannakopoulos et al (2011) examining the climate change impacts in Greece in the mid-twenty-first century (2021–2050) found that in urban areas, unpleasantly high temperatures during day and night will increase the feeling of discomfort in the citizens. Another impact of climate change in urban regions was the increasing energy demand for cooling in summer. Increases in energy demand during the warm period were also found in a study examining the climate change impacts in Cyprus for the period 2021-2050 (Giannakopoulos et al., 2016). Karali et al (2014) examining the impact of climate change on fire risk in Greece under the A1B future emissions scenario, found that the number of days with critical fire risk are expected to increase by as many as 50 days per year by the end of the century. Varotsos et al. (2011) examining the impact of climate change on ozone exceedances in the greater Athens area using a statistical model based on the historical relationship of temperature and ozone, found that a probable increase in the higher centiles of temperature less than 0.65 ◦C in the 2021–2050 and less than 2.86 ◦C in the 2071–2100 period compared to the observed could lead to an increase in the ozone exceedance days of about 8 and 30 days per year, respectively.

A number of finalized and ongoing projects assess the climate change impacts and adaptation options in urban environments among other sectors.These are the EU-funded projects HELIX, IMPRESSIONS and RISES-AM, the RAMSES project, the RESIN project and the CORFU project.

In this report, we examine both the current climate and the impact of climate change in four municipalities located in three different countries of the Mediterranean: The municipalities of Strovolos and Lakatamia located in Cyrpus, the municipality of Peristeri located in Athens, Greece and the Reggio Emilia located in northern Italy. The partner municipalities exhibit different characteristics and climate change vulnerabilities, which are at the same time typical for the Mediterranean, South and Central Europe.

It should be noted that due to the proximity of the two selected municipalities located in Cyprus, Strovolos and Lakatamia, in this climatological report the results of the analysis for the two municipalities are presented as one (hereafter Strovolos-Lakatamia).

2 DATA AND METHODS

2.1 Observational Data

Available temperature and precipitation observational data for the partner municipalities were collected for the purposes of the project. For temperature daily maximum and daily minimum as well as daily mean were available whereas for precipitation daily values were obtained. For the Reggio Emilia and Peristeri the available observations cover the period 1961-2014 while for Strovolos-Lakatamia the data cover the period 1983-2016.

2.2 Regional Climate Models (RCMs) used

In the framework of the project a set of four RCM simulations carried out in the frame of **EURO-CORDEX**(Coordinated Regional Climate Downscaling Experiment) were used. The four regional climate model experiments with horizontal resolution of about 12km (0.11^{o}) are:

- the RCA4 regional climate model of the Swedish Meteorological and Hydrological Institute (SMHI) (Stranberg et al., 2014 and references therein) driven by 3 different global climate models: the CNRM-CM5 (Voldoire et al., 2012) hereafter CNRM-RCA4, the Hadley Centre Global Environmental Model version 2 Earth System called HadGEM-ES (HadGEM) (Collins et al., 2011; Martin et al., 2011) of the Met Office Hadley Centre (MOHC), hereafter **MOHC-RCA4** and the Max Planck Institute for Meteorology model MPI-ESM-LR (Popke et al., 2013), hereafter **MPI-RCA4**.
- the ALADIN RCM version 5.2 of the Météo France Institute (CNRM) (Herrmann et al., 2011) driven by the CNRM-CM5 (Voldoire et al., 2012), hereafter **CNRM-ALADIN**.

The three first simulations are basically the SMHI regional climate model with boundary conditions from three different global models (CNRM, MOHC, and MPI), which makes the combined modeling systems substantially diverse so as to be considered as different models.

All models provide daily data for the period 1970-2100 with the present day simulations covering the period 1970-2005 while the new IPCC RCP4.5 and RCP8.5 future emissions scenarios are implemented in the simulations after 2005 covering the period 2006-2100. *(refer to paragraph* 2.3 *for more information)*.

2.2.1 RCM evaluation

2.2.1.1 Gridded data for model evaluation

As observational reference for evaluating simulated temperature and precipitation we use version 13 of the daily gridded E-OBS data set (Haylock et al., 2008). E-OBS covers the entire European land surface and is based on the ECA&D (European Climate Assessment and Dataset) station data set plus more than 2000 further stations from different archives. It is available at four different resolutions; we here use the rotated 0.22° version, which applies the same grid rotation of the EURO-CORDEX experiments. The E-OBS 0.22° grid corresponds to a horizontal resolution of about 25 km. Each E-OBS 0.22° grid cell contains four cells of the rotated 0.11° EURO-CORDEX grid. According to Kotlarski et al., (2014) several previous studies have questioned the quality of E-OBS in regions of sparse station density and particularly regarding daily extremes (Bellprat et al., 2012a; Herrera et al., 2012; Hofstra et al., 2009, 2010; Kyselý and Plavcová, 2010; Maraun et al., 2012; Rajczak et al., 2013) and its effective spatial resolution (e.g., Hanel and Buishand, 2011; Kyselý and Plavcová, 2010). Higher deviations were found in areas with low density of stations and in areas with complex terrain where interpolation usually degrades. However, the clear advantage of E-OBS is its spatial (entire European land surface) and temporal (1950–2012) coverage, which makes it ideal for an approximate evaluation of RCM-simulated temperature and precipitation characteristics over Europe.

In addition the observational data collected, temperature and precipitation, from the partner municipalities in the early stages of the project are also implemented in the analysis

2.2.1.2 Methods and metrics for model evaluation

We apply one evaluation metric, to seasonal (winter: DJF, summer: JJA) and annual mean values of temperature (daily maximum (TX) and precipitation for all experiments. This metric has been used in previous studies (Kotlarski et al., 2014) and is a well-established distance measure that assesses the quality of regional climate simulations by comparison against a gridded observational reference. It represents spatial and temporal bias characteristics and demonstrates the unavoidable spread of model performances in the reproduction of present-day regional climate. The following metric is used for the period 1971-2005:

- **BIAS:** the difference (model – reference) of spatially averaged climatological annual or seasonal mean values for Sicily, Crete and Cyprus (relative difference for precipitation).

In order to capture the spatial variability of the models performance over the Mediterranean the evaluation of the model experiments ensemble was carried out on the coarser 0.22° E-OBS grid. The regridding procedure followed can be found in detail in Kotlarski et al., (2014). The remapping of the

EURO-CORDEX RCM output to the E-OBS reference grid was selected due to the fact that each E-OBS 0.22° grid cell contains four cells of the rotated 0.11° EURO-CORDEX grid. Thus the new model projection results from a simple arithmetic four-point average of the finer grid.

2.3 IPCC's Representative Concentration Pathways

For the Fifth Assessment Report of IPCC, the scientific community has defined a set of four new scenarios, denoted Representative Concentration Pathways (RCPs). Those new scenarios include four pathways: RCP8.5, RCP6, RCP4.5 and RCP2.6. Together they reflect the range of radiative forcing values for the year 2100 relative to 1750, ranging from 2.6 to 8.5 W/m^2.

These four RCPs include one mitigation scenario leading to a very low forcing level (RCP2.6), two stabilization scenarios (RCP4.5 and RCP6), and one scenario with very high greenhouse gas emissions (RCP8.5). The RCPs can thus represent a range of 21st century climate policies, as compared with the no-climate policy of the Special Report on Emissions Scenarios (SRES) used in the Third Assessment Report and the Fourth Assessment Report. For RCP6.0 and RCP8.5, radiative forcing does not peak by year 2100; for RCP2.6 it peaks and declines; and for RCP4.5 it stabilizes by 2100. Each RCP provides spatially resolved data sets of land use change and sector-based emissions of air pollutants, and it specifies annual greenhouse gas concentrations and anthropogenic emissions up to 2100. RCPs are based on a combination of integrated assessment models, simple climate models, atmospheric chemistry and global carbon cycle models.

In the framework of the project future RCM projections were based on the intermediate mitigation scenario (RCP4.5) and the high emission scenario (RCP8.5). More information for each RCP is given below:

The **RCP4.5** was developed by the GCAM modeling team at the Pacific Northwest National Laboratory's Joint Global Change Research Institute (JGCRI) in the United States. It is a stabilization scenario in which total radiative forcing is stabilized shortly after 2100, without overshooting the long-run radiative forcing target level (Clarke et al. 2007; Smith and Wigley 2006; Wise et al. 2009). This scenario also suggests that various climate policies are implemented (Thomson et al., 2011). It suggests the implementation of strong reforestation programs, the use of cropland and grassland decreases, following considerable yield increases and dietary changes (van Vuuren et al., 2011). In addition, CH_4 emissions are expected to remain stable, while CO_2 emissions are allowed to increase slowly until 2040, when a decline starts taking place. RCP4.5 depicts declines in overall energy use, as well as declines in fossil fuel use compared to the reference case, while substantial increases in renewable energy forms and nuclear energy both occur (Thomson et al., 2011).

The **RCP8.5** was developed using the MESSAGE model and the IIASA Integrated Assessment Framework by the International Institute for Applied Systems Analysis (IIASA), Austria. This RCP is characterized by increasing greenhouse gas emissions over time, representative of scenarios in the literature that lead to high greenhouse gas concentration levels (Riahi et al. 2007). It represents a future state where no climate policies aiming at the reduction of GHG emissions are implemented (van Vuuren et al., 2011). CH_4 and N_2O emissions are expected to grow rapidly by the end of the century too (van Vuuren et al., 2011). The use of cropland and grasslands increases, mostly driven by an increasing global population. Given the overall slow rate of technological improvements in low-carbon technologies, the future energy system moves toward coal-intensive technology choices with high GHG emissions. Coal use in particular increases almost 10 fold by 2100 and there is a continued reliance on oil in the transportation sector (Riahi et al., 2011).

2.4 Methodology

In the framework of this action, climatic indices mainly related to temperature and precipitation with particular relevance to urban areas, were constructed. These indices can be divided into two main categories:

Absolute indices (such as: mean annual and seasonal temperature and annual total precipitation)

Threshold indices (such as: number of days with maximum/minimum temperature and precipitation greater/less than specific thresholds)

Table 1 Climatic indices relevant to urban areas used in this action

Mean Seasonal Temperatures (absolute indice)	For daily maximum, daily minimum and daily mean temperatures
Number of days Tmax> 30 °C (threshold indice)	For daily maximum temperature
Number of days Tmax> 35 °C (threshold indice)	For daily maximum temperature
Number of days Tmax> 40 °C (threshold indice)	For daily maximum temperature
Number of days Tmin> 20 °C (threshold indice)	For daily minimum temperature
Total Precipitation (absolute indice)	Seasonal and annual sums
Highest 1-day precipitation amount (absolute indice)	Maximum (annual/seasonal) precipitation sums for 1-day intervals
Highest 5-day precipitation amount (absolute indice)	Maximum (annual/seasonal) precipitation sums for 5-day intervals.
Heavy precipitation days (threshold indice)	Number of days (per year/season) with precipitation amount greater than 10 mm

Very heavy precipitation days (threshold indice)	Number of days (per year/season) with precipitation amount greater than 20 mm

3 EVALUATION RESULTS

3.1 Spatial and Temporal mean

Figure 1to Figure 4, provide an overview of the spatial distribution of the 35-year mean winter and summer model biases for maximum temperature and precipitation. In wintertime (Figure 1), temperatures are typically underestimated over large parts of the domain. The negative biases are in the range of -1 to -3 ◦ C, with the highest negative values found along the Alpine ridge and some parts of the Iberian Peninsula. Regarding the areas of interest, in northern Italy (Reggio Emilia) two of the experiments (CNRM-ALDIN and CNRM-RCA4) indicate a cold bias of about 1 ◦ C, while for the other two experiments (MPI-RCA4 and MOHC-RCA4) a warm bias of the same magnitude is shown. For Athens (Peristeri) the majority of the models (CNRM-ALDIN, CNRM-RCA4 and MPI-RCA4) indicate a warm bias of about 1 ◦ C with the exception of MOHC-RCA4 where the cold bias shown is less than 1 ◦ C. Regarding Cyprus (Strovolos-Lakatamia), all models indicate a cold bias of less than 1 ◦ C. For the CNRM driven RCMs the cold temperature bias, which is found in winter, is also evident in summer in most parts of the Mediterranean (Figure 2). In addition, these cold biases are more pronounced than in winter (e.g Spain) and both models have a tendency to overestimate summer temperature in the central and eastern Mediterranean. The other two models (MPI-RCA4 and MOHC-RCA4) have a tendency to overestimate summer temperature in most parts of Mediterranean. Regarding the areas of interest, in northern Italy (Reggio Emilia) two of the experiments (CNRM-ALDIN and CNRM-RCA4) indicate a cold bias of about 1 ◦ C while for the other two experiments (MPI-RCA4 and MOHC-RCA4) a warm bias about 1 to 3 ◦ C is shown. For Athens (Peristeri) all of the models indicate low deviations from the E-OBS in the range of -0.5 to 0.5 ◦ C depending on the model. As far as Cyprus (Strovolos-Lakatamia) is concerned, all models indicate a cold bias of less than 1 ◦ C.

Concerning mean seasonal precipitation, the evaluation indicates a wet wintertime bias of most models over most parts of Europe (Figure 3). Biases of more than 50 % are obtained over the Iberian Peninsula and the Balkans. In contrast, winter precipitation amounts over parts of northern Italy and southern France are underestimated in most cases. Regarding northern Italy (Reggio Emilia), three of the experiments (CNRM-ALDIN, CNRM-RCA4 and MPI-RCA4) indicate a wet bias of about 25% while for the MOHC-RCA4) a dry bias of the same magnitude is shown. For Athens and Cyprus all models indicate a wet bias of about 25%. Regarding the mean summertime precipitation (Figure 4) both CNRM driven experiments indicate a wet bias (is some case higher than 75%) is most parts of the Mediterranean. The other two models (MPI-RCA4 and MOHC-RCA4) indicate similar results with the dry and wet bias in the range of -50 to 75 % respectively.

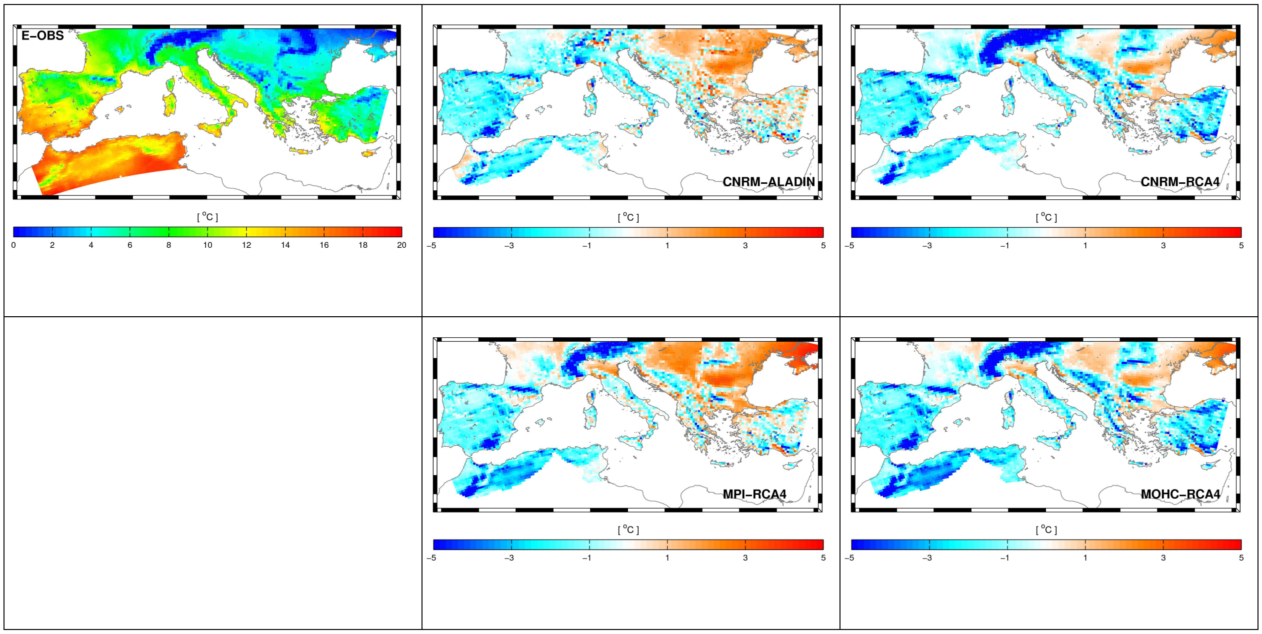


Figure 1 Mean winter maximum temperature bias (oC) for all model experiments and the period 1971–2005. The upper-left panel of the section shows the horizontal pattern of mean seasonal temperature as provided by the E-OBS reference (oC).

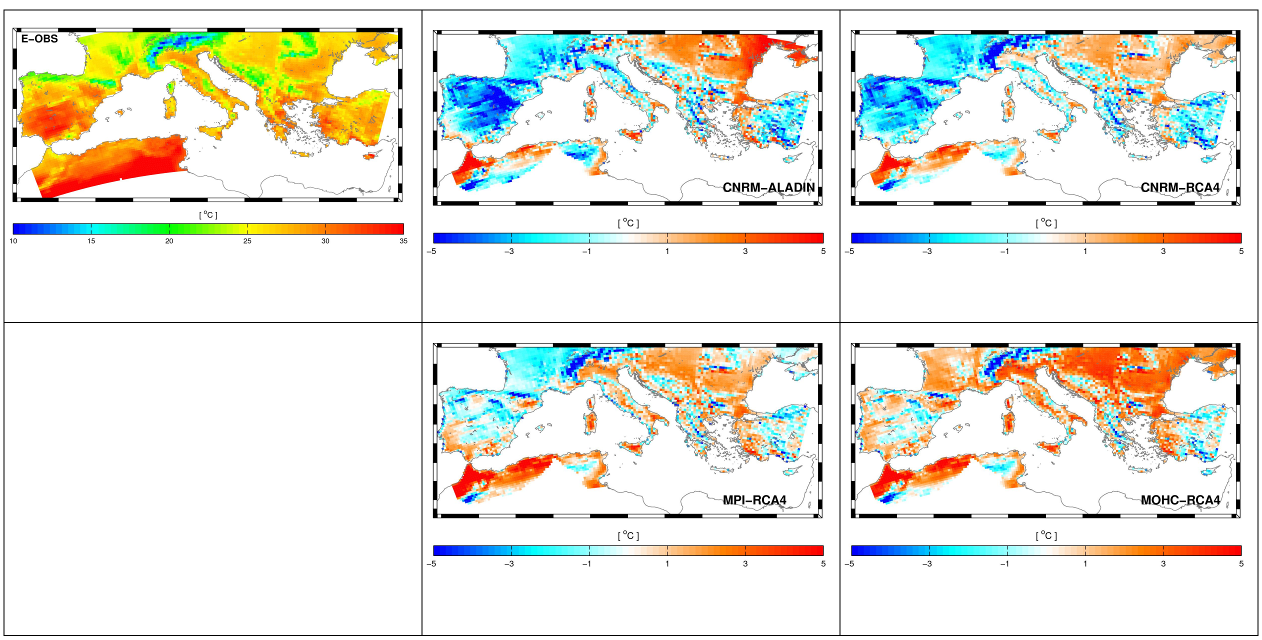


Figure 2 As in Figure 1 but for the mean summer maximum temperature.

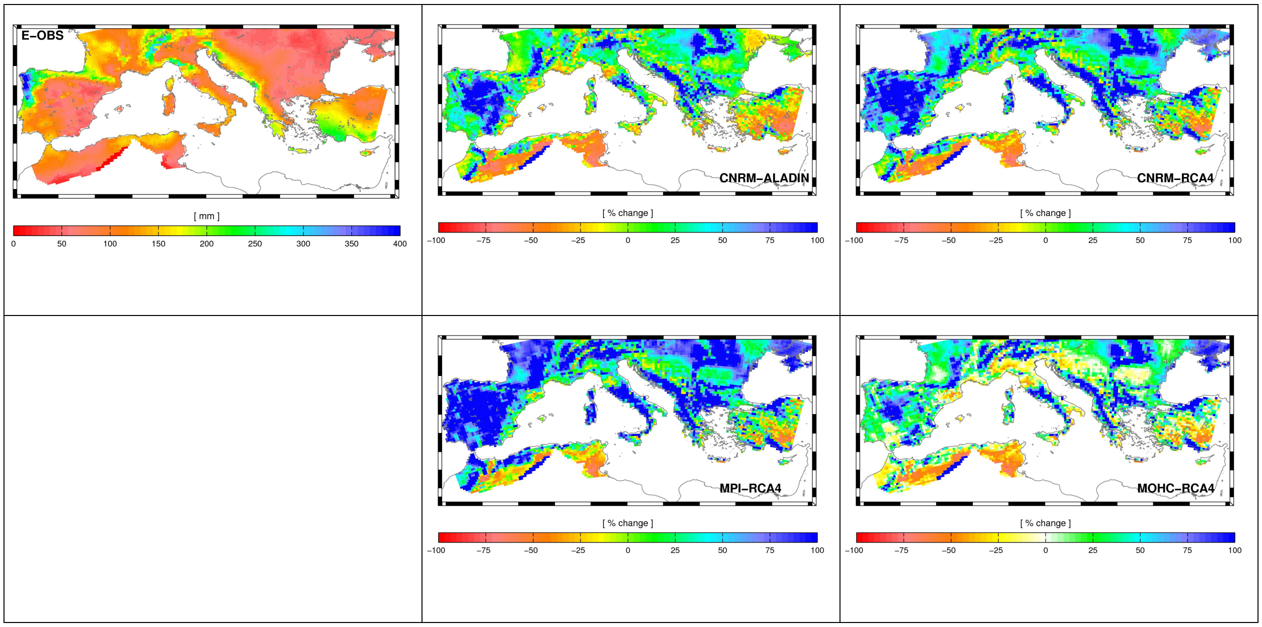


Figure 3 As Figure 2 but for the mean relative winter precipitation bias (%). The upper-left panel of the section shows the horizontal pattern of mean winter precipitation as provided by the E-OBS reference (mm).

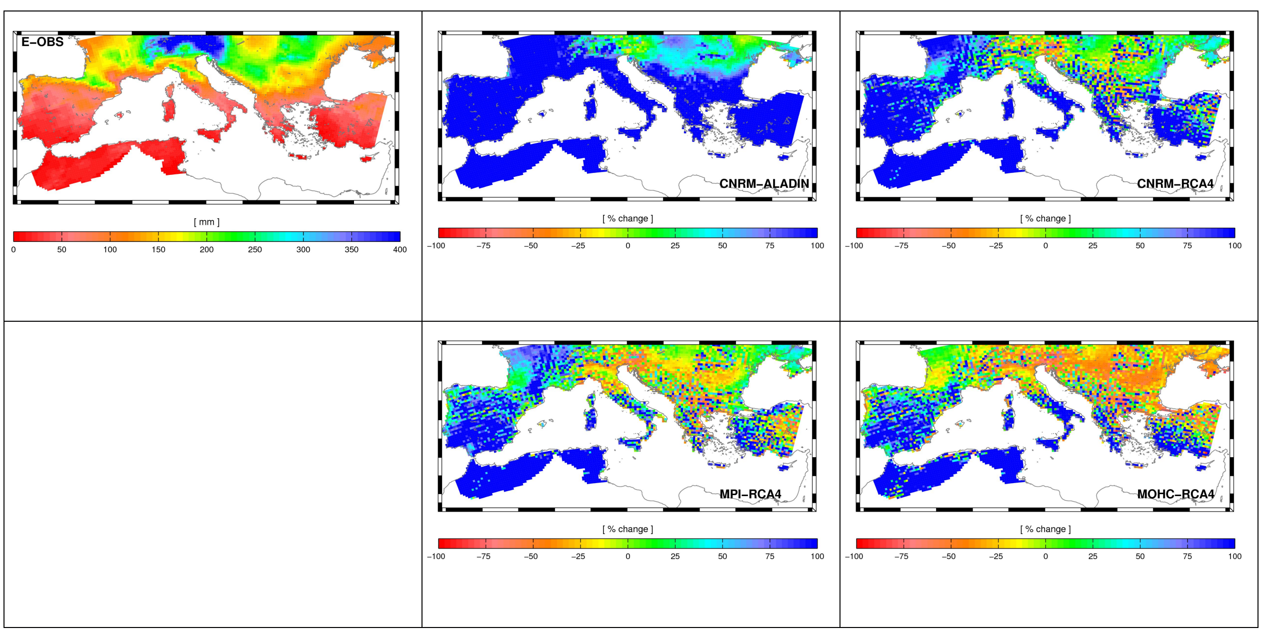


Figure 4 As in Figure 3 but for the mean relative summer precipitation

In Figure 5 and Figure 6 the averaged biases in mean seasonal and annual temperatures and precipitation for the partner municipalities are summarized. It should be noted here that in the two figures the biases between the observational data, collected from the partner municipalities, and the model data from the closest grid point to the corresponding station are shown. For Reggio Emilia and Peristeri we used the period 1970-2005 while for Strovolos-Lakatamia due to the shorter available observational timeseries we used the period 1983-2005. Regarding the results, for the daily maximum temperature (TX, top row Figure) the analysis reveals that the averaged biases vary depending on the municipality. More specifically, for Reggio Emilia two of the models indicate a warm bias of less than 2°C (MPI-RCA4 and MOHC-RCA4) while the other two (CNRM-RCA4 and CNRM-ALADIN) indicate a cold bias of about less than 3°C. For Peristeri all models indicate a cold bias of less than 2°C while for Strovolos-Lakatamia the cold bias foe all models is in the range of -1 to -4 °C. A similar pattern in the biases is also revealed for daily mean and daily minimum temperatures (TM middle row and TN bottom row respectively in Figure 5). However the colder bias especially for the CNRM-ALADIN model in all municipalities are higher than TX, about 1°C .Moreover, the MPI-RCA4 and MOHC-RCA4 models indicate the lowest warm and cold biases with similar results to each other.

Regarding the average precipitation biases (Figure 6), it should be highlighted that the CNRM-ALDIN model indicates a very high summer wet bias mostly in Peristeri and Strovolos-Lakatamia while the results for the rest of the models indicate both wet and dry biases depending on the season and the municipality which are comparable to results from previous studies (e.gKotlarski et al., 2014).

Based on the analysis presented in this section we conclude that the MOHC-RCA4 and the MPI-RCA4 models are the ones that better capture the observed seasonal patterns of the temperatures and precipitation in the municipalities of interest. However as shown in Figure 5 and Figure 6, high biases on the municipalities' scales are persistent for both of the models, therefore we opt to apply bias correction techniques for temperature and precipitation in the data of one of the models and more specifically the MPI-RCA4. More specifically, the local intensity scaling (LOCI) method (Schmidli et al., 2006) was applied to precipitation data and the variance scaling (Chen et al., 2011) to temperature data. In brief, the LOCI method adjusts the mean values as well as both wet-day frequencies and wet-day intensities of precipitation time series. The variance scaling method corrects both the mean values and the variance of temperature time series.

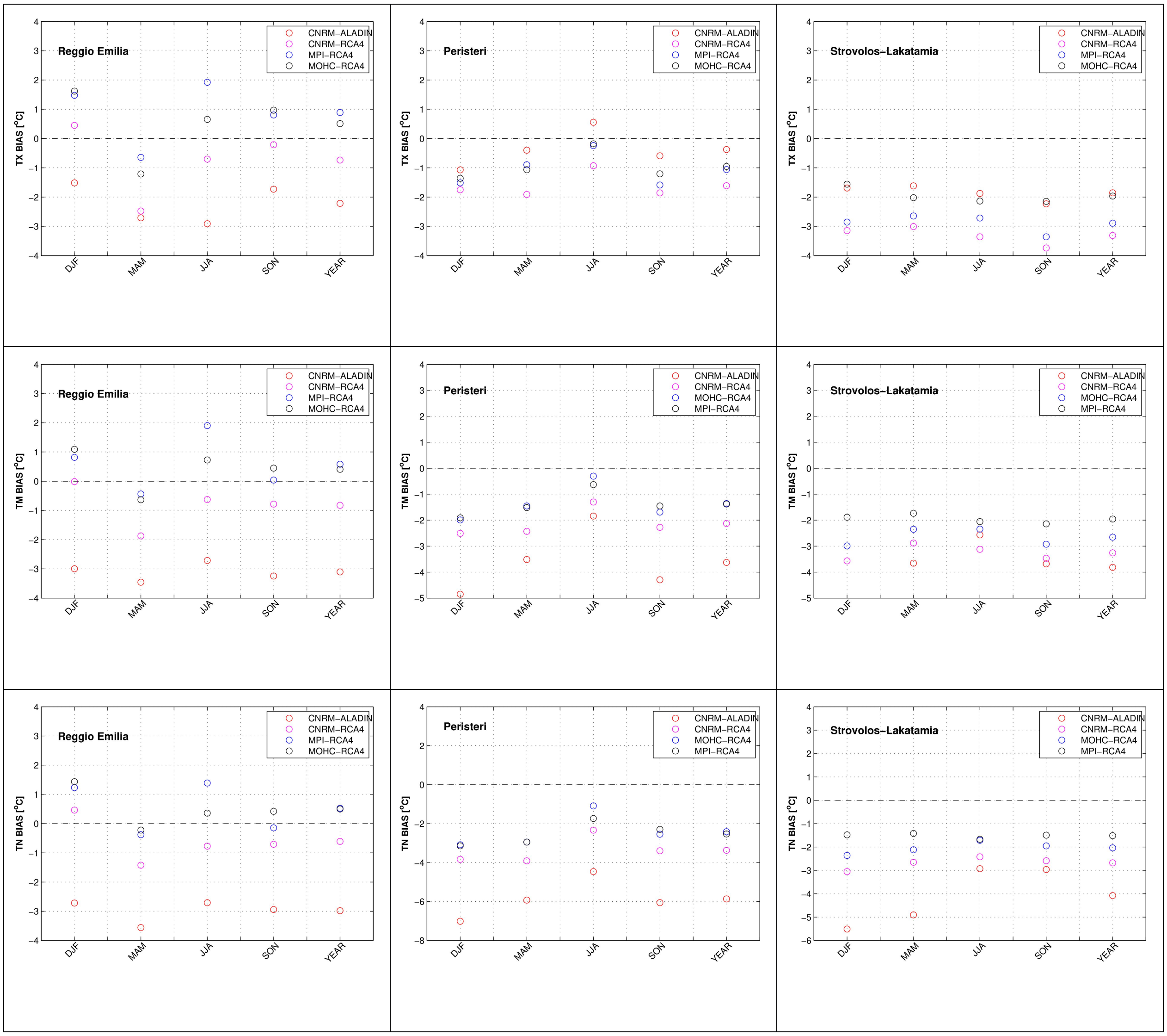


Figure 5 Mean seasonal and annual bias (°C) for daily maximum (TX, top row), daily mean (TM, middle row) and daily minimum (TN, bottom row) temperatures for the EURO-CORDEX models for the partner municipalities.

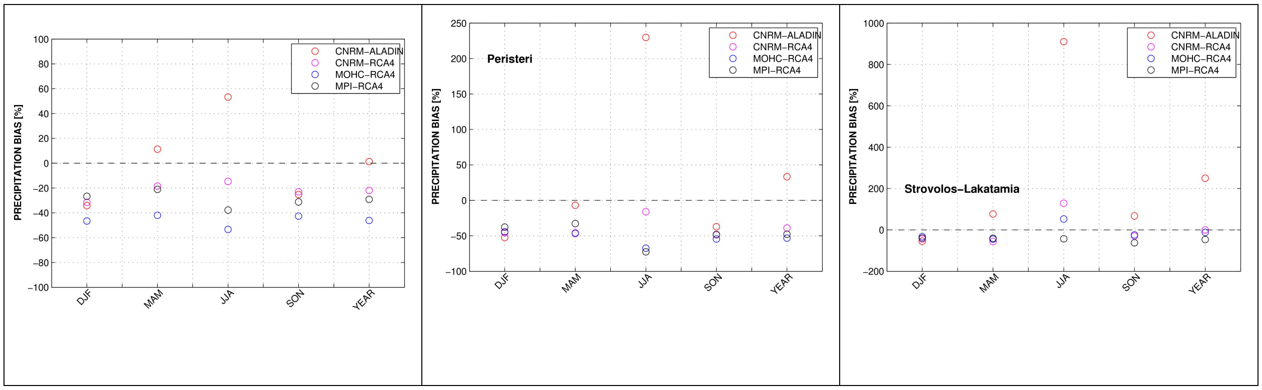


Figure 6 : As in Figure 5 but for the mean seasonal and annual relative precipitation bias (BIAS; %)

4 ANALYSIS OF THE HISTORICAL CLIMATE CONDITIONS

The historical climate conditions of the study areas, in terms of temperature and precipitation, are important in order to draw safe conclusions about their vulnerability to climate change. All the three locations of interest are classified as Mediterranean climate, which is considered especially sensitive to global change (Diffenbaugh and Giorgi, 2012).

The selected meteorological stations are located near or at the partner municipalities and are considered as representative of each area, providing continuous and reliable temperature and precipitation time series. Daily climatic records are analysed for all stations for the period from 1985 to 2014.

4.1 Temperature Results

4.1.1 Mean Annual Cycle

The following figures present the mean annual cycle of the daily average air temperature (minimum, mean and maximum), over the 30-year period, for the closest stations to the three partner municipalities. A clear seasonal cycle, typical of the Mediterranean climate, is observed in all cases with winter minima (December to February) and summertime maxima during July and August.

In the study area of Cyprus the monthly average maximum temperature (Tmax) (Figure 7, left panel) is the highest compared to the other two stations all year-long. It is particularly high, reaching 37°C during summer and 17°C during winter. The monthly average of the mean temperature ranges between 11°C and 30°C throughout the year. Accordingly, the minimum temperature (Tmin) ranges between 6 and 22°C.

The mean climatic summer values of Tmax in Athens (Figure 7, central panel) is 34°C (lower compared to the Lakatamia station), but the observed average summer Tmin is the highest of all three stations, reaching 24°C. During winter months the mean air temperature is about 10°C, the minimum is about 7°C and the maximum about 14°C.

The observed Tmin in the Reggio Emilia station (Figure 7, right panel) is the lowest of all three stations, ranging between -1°C (during winter) and 18°C (during summer). The Tmax during August is 32°C and 7°C during January

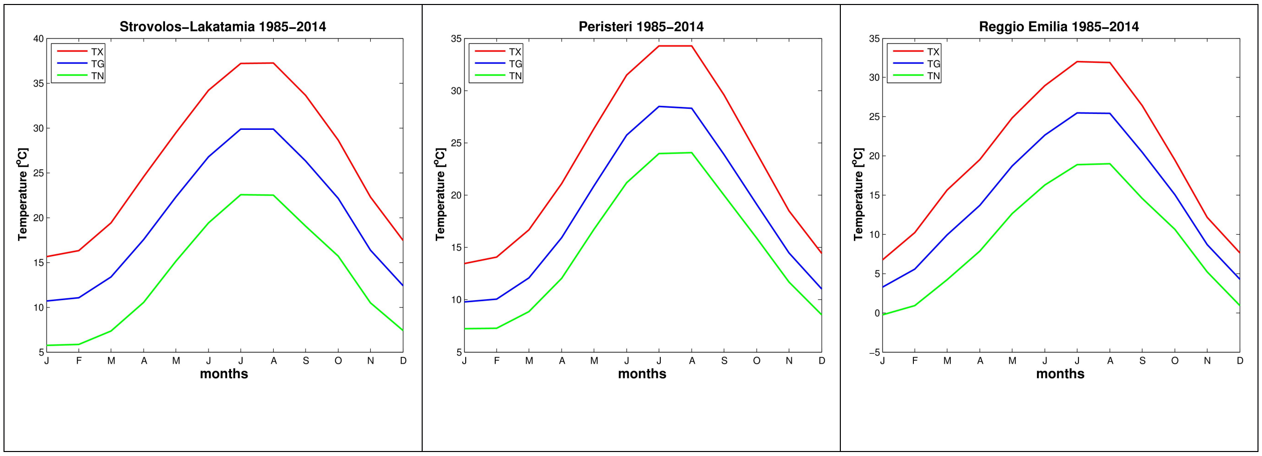


Figure 7 Observed monthly average air temperatures in Strovolos-Lakatamia station (left panel), Peristeri station (central panel) and Reggio Emilia station (right panel) for the period 1985-2014. Red, blue and green curves depict the maximum, mean and minimum temperature, respectively.

4.1.2 Seasonal Trends

In order to evaluate the climate change and draw conclusions about global or regional warming, it is important to know the long term variability and trends for each study area. The following figures display the annual trend of temperature for each season separately, using the observational data from the past 30 years. An increasing trend is observed in all cases, with Tmin exhibiting the largest warming rates in all seasons. Tmin is of special interest as it reflects the impact of the urban effect in the cities.

4.1.2.1 Winter results

The winter temperatures in the Cyprus area (Figure 8, left panel) seem to have increased over the years. Minimum (Tmin), mean (Tmean) and maximum (Tmax) temperatures present similar increasing rate (0.46-0.52°C/decade) meaning that over the 30 years study period the average winter temperature has increased by about 1.5°C.

An increasing trend in winter temperature is also observed in the Athens' station (Figure 8, central panel), with Tmin and Tmean being more affected (increased by 0.53°C and 0.42°C per decade, respectively) than the Tmax (increased by 0.22°C/decade). Over the 30 years study period the average maximum temperature increased by 0.7°C, while the mean and the minimum by almost 1.5°C.

Reggio Emilia observations (Figure 8, right panel) show the most notable increase in mean and minimum winter temperature over the years (2.2°C and 3.3°C, respectively, over the 30 years period). The corresponding increasing rate for Tmax is 0.34°C/decade, resulting in an increase by 1°C over the study period

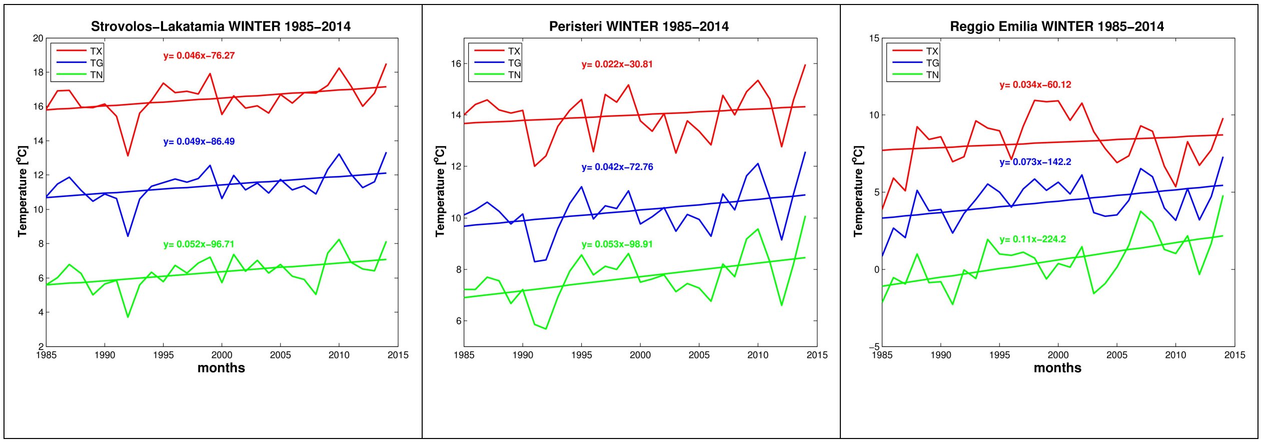


Figure 8 Average annual winter temperatures at Strovolos-Lakatamia station (left panel), Peristeri station (central panel) and Reggio Emilia station (right panel), during the period 1985-2014. Red, blue and green curves depict the maximum, mean and minimum temperature, respectively.

4.1.2.2 Spring Results

The spring warming rates observed at the Cyprus study area during 1985-2014 (Figure 9, left panel) are 0.3°C, 0.5°C and 0.7°C per decade for Tmax, Tmean and Tmin, respectively. The highest rate corresponds to the minimum temperature, leading to an increase by 2.1°C over the study period.

The warming rates in Athens (Figure 9, central panel) are similar to the corresponding rates in Cyprus, resulting in an increase by 1.1°C, 1.7°C and 2.2°C over the 30 year period for Tmax, Tmean and Tmin, respectively.

Reggio Emilia station presents a significant increase of the minimum spring temperature (Figure 9, right panel), which has increased by 4.2°C during the study period. Accordingly,Tmax and Tmin have increased by 1.1°C and 2.7°C, respectively

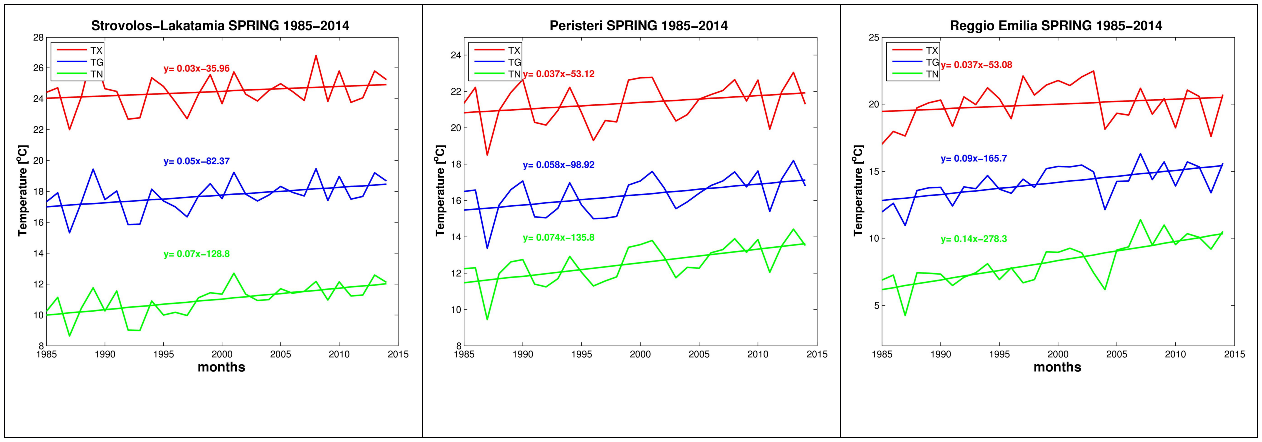


Figure 9 Average annual spring temperatures at Strovolos-Lakatamia station (left panel), Peristeri station (central panel) and Reggio Emilia station (right panel), during the period 1985-2014. Red, blue and green curves depict the maximum, mean and minimum temperature, respectively.

4.1.2.3 Summer Results

A warming trend is also present during summer in Lakatamia station (Figure 10, left panel), with greater rate of increase observed at low temperatures (0.75°C/decade - 2.2°C over the whole period). The corresponding values for Tmean and Tmax are 0.51°C - 1.6°C and 0.26°C - 0.8°C, respectively.

A significant increase of the annual summer temperatures is found for Athens (Figure 10, central panel), with warming rate reaching 1°C/decade when the Tmin is considered. The corresponding rates for Tmean and Tmax are 0.74°C and 0.53°C, respectively.

The observations at the Regio Emilia station (Figure 10, right panel) show that the minimum summer temperature is highly affected by both the warming and the urban effect, presenting the highest warming rates (1.3°C/decade), and it is increased by 3.9°C over the whole period. Tmean and Tmax are increased by 2.2°C and 0.7°C, respectively.

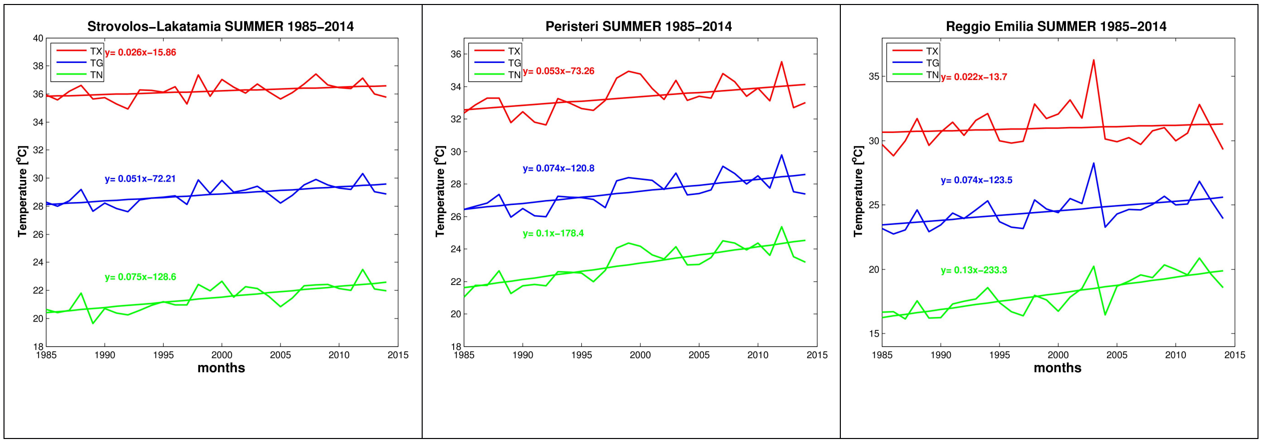


Figure 10 Average annual summer temperatures atStrovolos-Lakatamia station (left panel), Peristeri station (central panel) and Reggio Emilia station (right panel), during the period 1985-2014. Red, blue and green curves depict the maximum, mean and minimum temperature, respectively.

4.1.2.4 Autumn Results

Tmax, Tmean and Tmin at the study area in Cyprus (Figure 11, left panel) seem to have increased by 0.8°C, 1.2°C and 1.7°C, respectively, over the 30 years period, during autumn. The positive trend of Tmax (0.28°C/decade) is less significant than in other seasons.

The warming trend during autumn for the study period at the station in Athens (Figure 11, central panel) ranges between 0.31°C (Tmax) and 0.73°C (Tmin) per decade. The higher rate corresponds to the minimum temperature and has led to an increase by 2.2°C during the whole study period.

The Regio Emilia station (Figure 11, right panel) presents the higher warming rates of all three study areas. Tmax, Tmean and Tmin have increased by 0.5°C, 1.9°C and 3.3°C, respectively, over the study period. The increase of Tmax is the less pronounced in autumn when compared to other seasons.

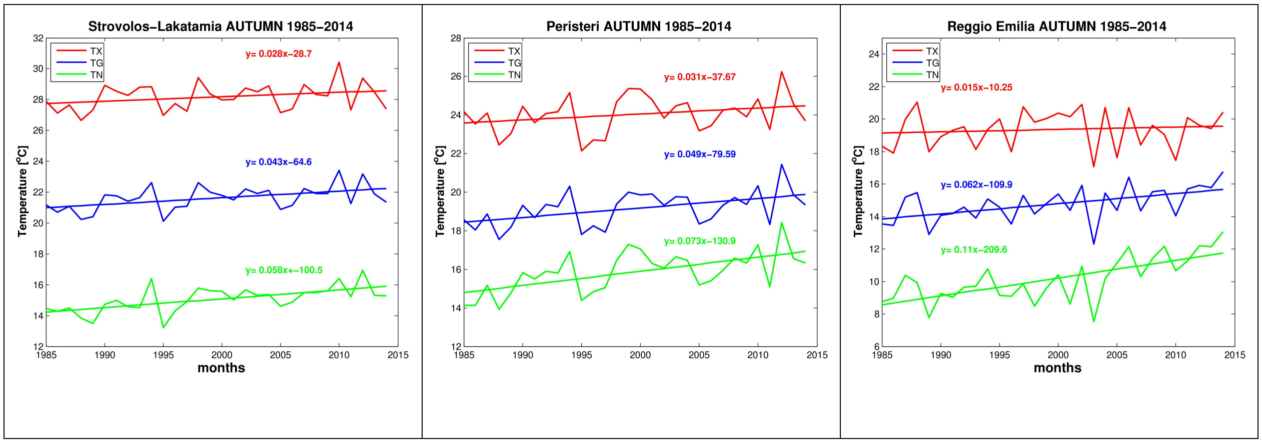


Figure 11 Average annual autumn temperatures at Strovolos-Lakatamia station (left panel), Peristeri station (central panel) and Reggio Emilia station (right panel), during the period 1985-2014. Red, blue and green curves depict the maximum, mean and minimum temperature, respectively.

4.1.3 Extreme Temperatures

It is well known that high ambient temperatures are associated with increased mortality even in temperate climates (e.g. Hajat et al., 2006; Armstrong et al., 2011).The following figures present the annual number of daily maximum temperature threshold exceedances between 1985-2014. An interesting trend towards Tmaxexceedances can be noticed when the threshold is set to 35°C at the study areas in Greece and Italy.

The annual number of daily Tmax exceeding 30°C at the Cyprus study area (Figure 12, left panel) range between 127 and 162 for the years 1985-2014. The corresponding numbers for days exceeding 35°C and 40°C are 53-95 and 0-15, respectively. No specific trend is observed throughout the years.

The annual number of daily Tmax exceeding the thresholds of 30°C, 35°C and 40°C in Athens (Figure 12, central panel) range between 72 and 158, 6-54 and 0-8, respectively. It seems that there is an increasing trend in the number of days with temperatures exceeding 35°C.

At the study area in Italy, the annual number of daily Tmax exceeding 30°C and 35°C ranges between 30-95 and 0-56, respectively (Figure 12, right panel). During the study period, temperatures exceeding 40°C were recorded only in 2003.

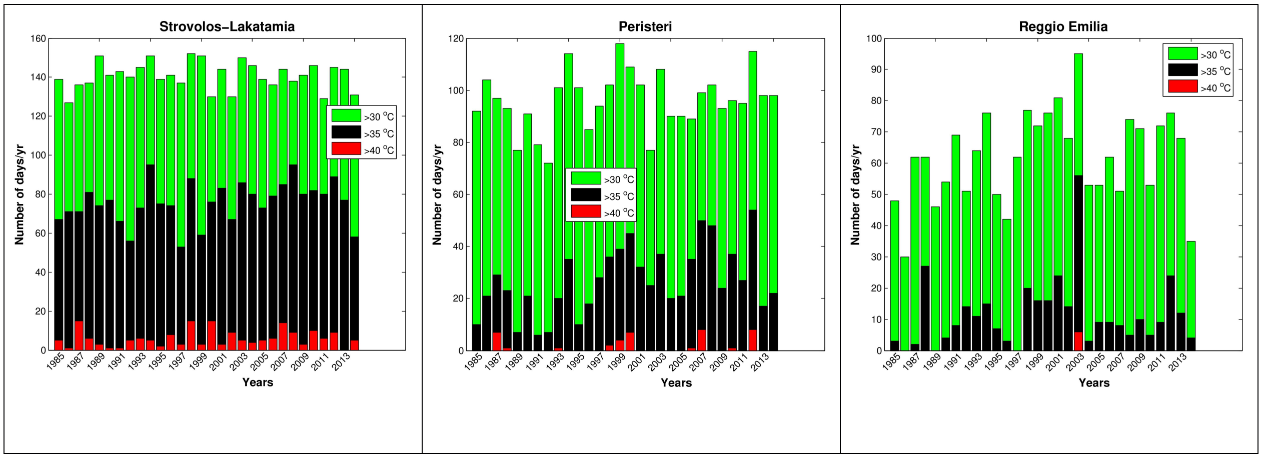


Figure 12 Annual number of daily maximum temperatures greater than 30ºC (green bars), 35ºC (black bars) and 40ºC (red bars), at Strovolos-Lakatamia station (left panel), Peristeri station (central panel) and Reggio Emilia station (right panel), during the period 1985-2014.

In Figure 13, the annual number of daily Tmin exceeding 20°C is shown. For Strovolos-Lakatamia the indice ranges between 47 and 97 days for the years 1985-2014. For Peristeri the range is from 66 to 128 days for the same period while for Reggio Emilia the indicevaries from 2 to 66 days. In all three municipalities the trend is about 1.3 days/yr indicating an increase of about 40 days at the end of the 30 yr period.

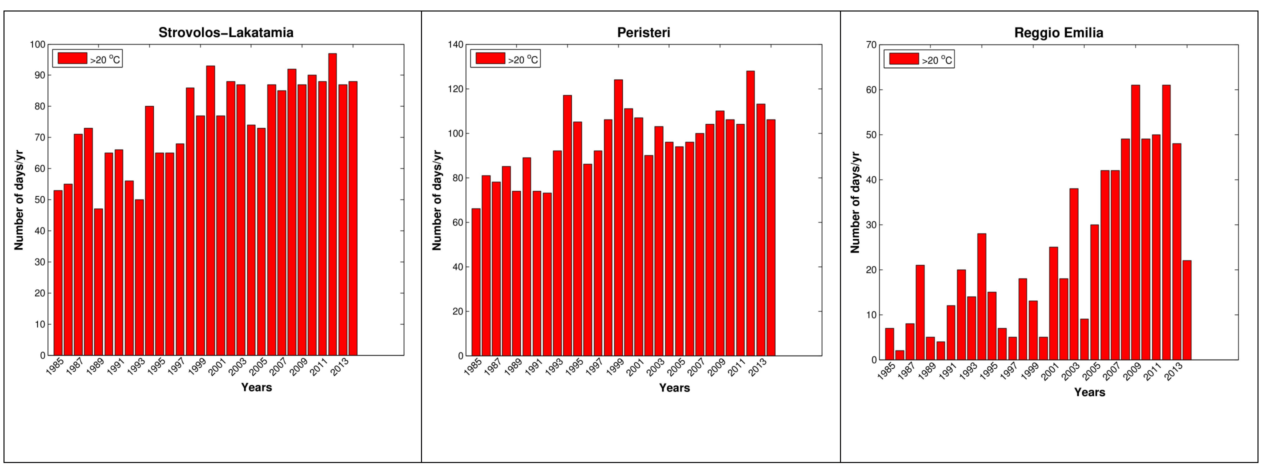


Figure 13 Annual number of daily minimum temperatures greater than 20ºC , at Strovolos-Lakatamia station (left panel), Peristeri station (central panel) and Reggio Emilia station (right panel), during the period 1985-2014.

4.2 Precipitation Results

4.2.1 Mean Annual Cycle

At the study area in Cyprus the precipitation presents a clear seasonal cycle, with low summer and high winter levels (Figure 14, left panel). It is significantly reduced during summer months, with zero wet days in July and August. High precipitation levels have been monitored from November until March, with monthly precipitation reaching almost 60mm in December.

The monthly precipitation levels are low, less than 10mm, from May until September in Athens (Figure 14, central panel), with zero wet days during the whole summer. The rainy period actually starts in October and ends in April, reaching high levels (almost 40mm in November).

The observations at the Reggio Emilia station (Figure 14, right panel) show that the precipitation is higher during autumn and spring. October and November are the more rainy months of the year, exceeding 70mm. The lowest precipitation levels are observed during January, July and August, with monthly values ranging between 30 and 40mm.

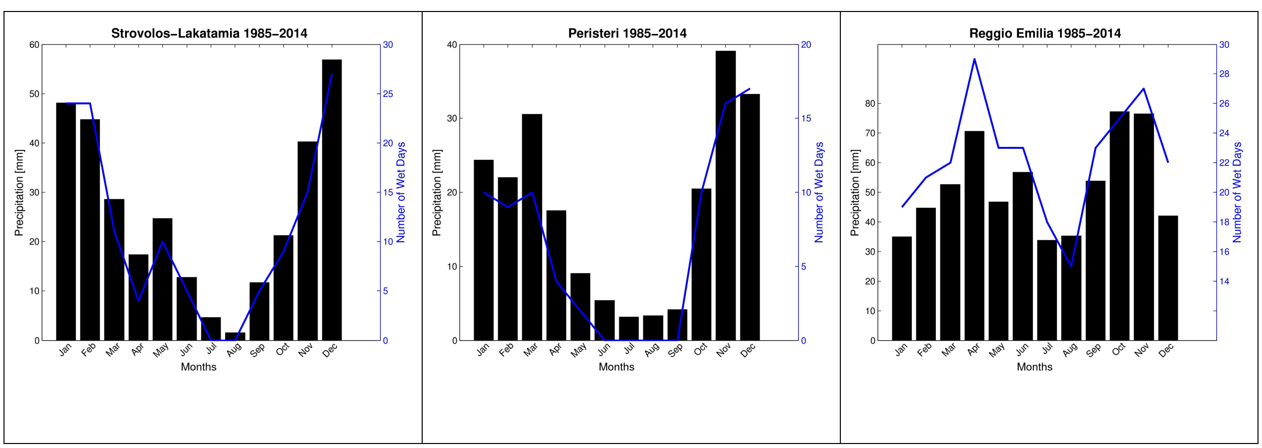


Figure 14 . Monthly distribution of precipitation for the period 1985-2014 (black bars) and number of wet days per month (number of days greater than 1mm) (blue curve) for the monitoring stations at Strovolos-Lakatamia (left panel), Peristeri (central panel) and Reggio Emilia (right panel)

4.2.2 Seasonal Trends

In Figure 15 the seasonal trends for the annual total precipitation during the period 1985-2014 are shown. From the figure it is evident that the winter total precipitation has increased over the 30-yr period by 17.7 mm in Strovolos-Lakatamia, by 75 mm in Peristeri and by 53.7 mm in Reggio Emilia. In spring an increase is calculated for Strovolos-Lakatamia and Reggio Emilia (about 25.2 and 31.8 mm respectively) while for Peristeri a decrease of about 35 mm is calculated by the end of the 30 yr period. In summer in Strovolos-Lakatamia increases of about 10.5 mm are calculated, while for Reggio Emilia decreases of about 22.5 mm are shown. In Peristeri no statistical significant summer trend is calculated. Finally for the autumn season increases of about 55.2 and 33.6 mm are calculated for Peristeri and Reggio Emilia respectively, while for Strovolos-Lakatamia no statistically significant trend is calculated.

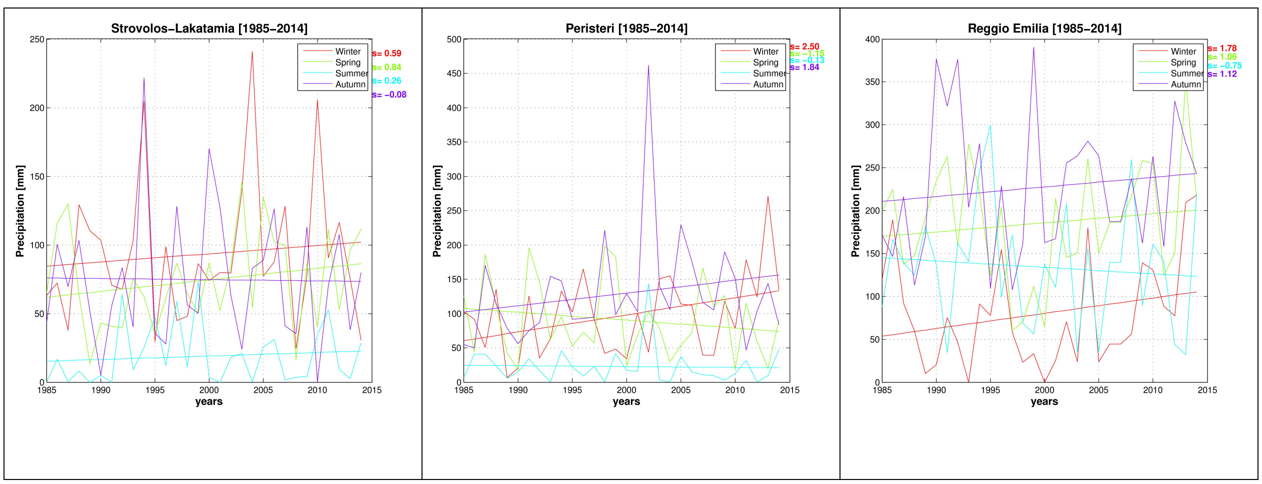


Figure 15 Seasonal trend for the total precipitation over the period 1985-2014 for StrovolosLakatamia (left panel), Persiteri (middle panel), and Reggio Emilia (right panel). The colored numbers on the right side indicate the calculated slopes for each one of the seasons.

4.2.3 Extreme precipitation

In Figure 16 to Figure 18 the seasonal results regarding the extreme precipitation indices are shown for the three municipalities during the periods 1985-2014.

In Figure 16 the annual maximum seasonal precipitation over 1-day is shown. From the figure it is evident that depending on the season the indice exhibits both increasing and decreasing trends over the 30 yr-period. More specifically, in Strovolos-Lakatamia the highest slopes are shown for the spring and the summer seasons, 0.44 and 0.24 respectively, indicating an increase of about 13.2 mm and 7.2 mm for these two seasons respectively at the end of the 30 yr period. For the winter and the autumn seasons the trends do not exhibit significant changes. For Peristeri the highest slope is shown for the winter, 0.7, indicating an increase of about 21 mm at the end of the 30 yr period. Moreover, for spring and autumn opposite trends of the same magnitude are calculated. In particular a trend decrease is shown for spring (-0.31) whereas an increasing trend is shown for autumn. The change in both seasons is about 9.3 mm at the end of the studied period. For Reggio-Emilia an increasing trend is shown for winter (0.5) while little changes or no changes are shown for the rest of the seasons. For winter the increasing slope indicates an increase of about 15 mm at the end of the 30 yr period.

In Figure the results regarding the annual maximum seasonal precipitation over 5-days are shown. For Strovolos-Lakatamia increasing trends are calculated for the spring and the summer seasons, 0.48 and 0.23 respectively while little changes or no changes are shown for the rest of the seasons. The increasing trends indicate an increase of about 14 and 7 mm at the end of the 30yr period. For Peristeri the highest slope is shown for the winter season, 1.38, indicating an increase of about 41 mm at the end of the 30 yr period. Moreover, a lower slope, about 0.28 is shown for autumn (about 8 mm) while little changes or no changes are shown for the rest of the seasons. Finally, for Reggio-Emilia decreasing slopes -0.46 and -0.28 are calculated for autumn and winter respectively while an increasing one (0.20) is calculated for summer.

In Figure 18 the results regarding the annual maximum length with precipitation lower than 1mm (dry spells) are shown. In particular, for Strovolos-Lakatamia decreasing trends are calculated for the spring and the summer seasons, -0.37 and -0.71 respectively while little changes or no changes are shown for the rest of the seasons. The negative slopes indicate a decrease in the dry spells of about 11 and 21 days at the end of the 30yr period for the spring and the summer period respectively. For Peristeri a positive slope of about 0.60 (increase of about 18 days by the end of the 30yr period) is calculated for the spring season, whereas negative slopes of about -0.25 (-7.5 days by the end of the 30yr period) and -0.4 (-12 days by the end of the 30yr period) are calculated for winter and autumn respectively.

Finally, regarding the heavy and the very heavy rain precipitations indices, number of days (per season) with precipitation amount greater than 10 and 20 mm respectively no statistical significant trends are calculated (not shown)

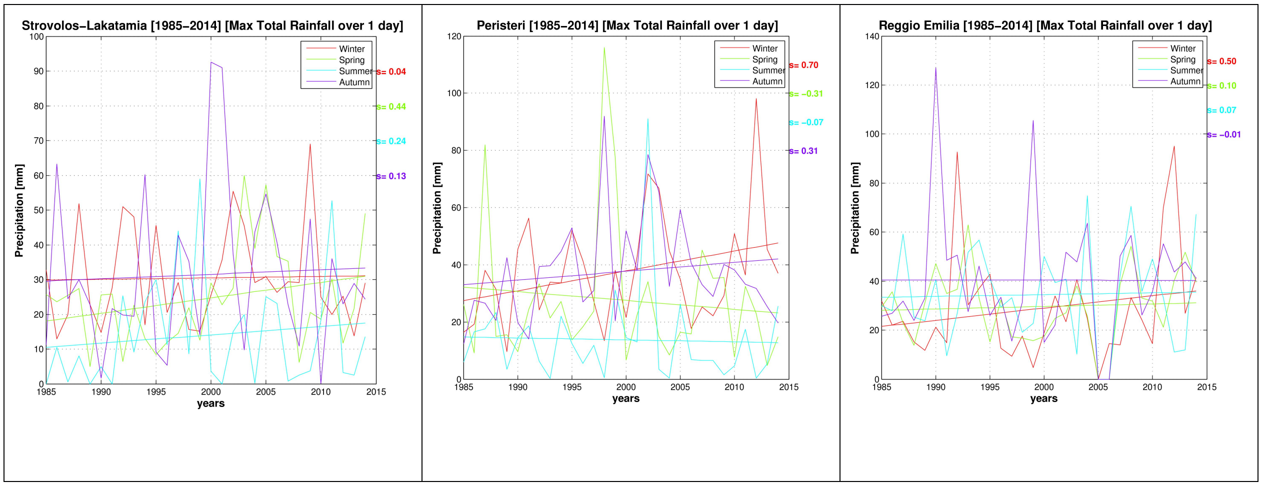


Figure 16Sesonal trends for the annual maximum total precipitation over 1 day for Strovolos-Lakatamia (left panel), Peristeri (middle panel) and Reggio Emilia (right panel) for the period 1985-2014. The colored numbers on the right side indicate the calculated slopes for each one of the seasons.

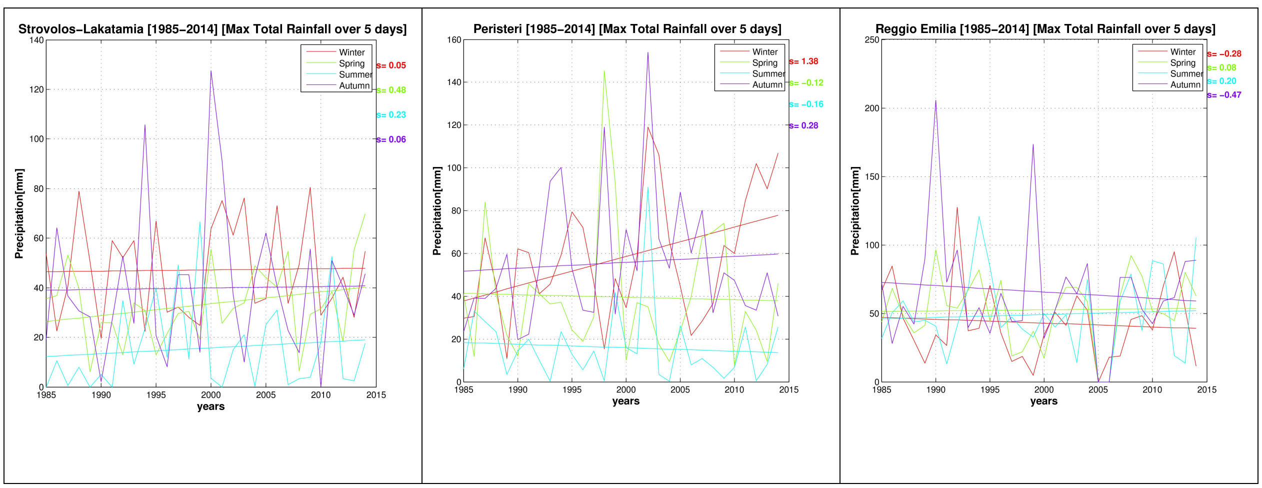


Figure 17 As in Figure 16but for the annual maximum total precipitation over 5 days

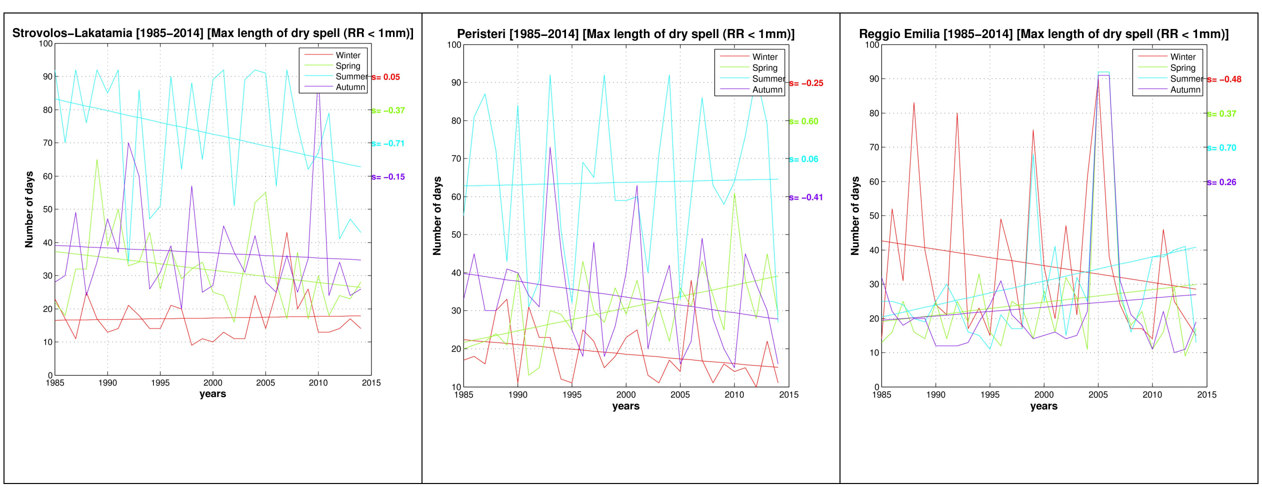


Figure 18 As in Figure 16 but for the annual maximum length of days with precipitation < 1mm

5 FUTURE PROJECTIONS

In this section the results for both future emission scenarios,RCP45 and RCp85 are shown. It should be noted that the results are based on the bias correction methods applied on temperatures and precipitation model data as mentioned is section 3.1.

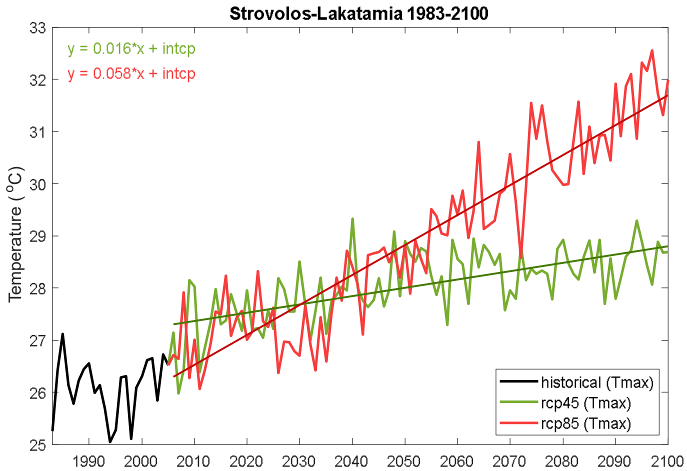
5.1 Temperature Results

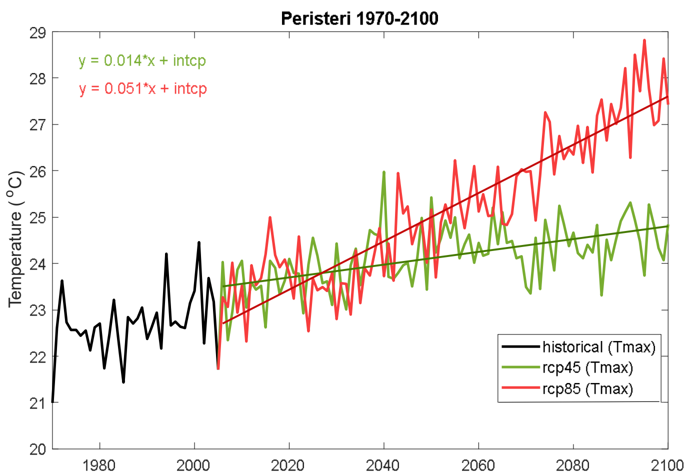
5.1.1 Mean Annual Maximum Temperatures

In the Figure 19 the results regarding the daily maximum temperatures are shown. The results indicate that the maximum temperature at the study area in Cyprus increases by 0.16°C and 0.58°C/decade under RCP4.5 and RCP8.5 scenarios, respectively. The RCP8.5 predicts a more intense increase for the period 2045-2100 compared to the near future.

The predicted maximum temperature in Athens presents an increasing trend of 0.14°C/decade, resulting in an increase of 1.1°C until 2100, under the RCP4.5 scenario. Following the RCP8.5 scenario, the maximum temperature increases by 0.51°C/decade.

The maximum temperature in Reggio Emilia seems to increase under both scenarios. The simulated trend is 0.2°C and 0.5°C/decade under RCP4.5 and RCP8.5, respectively. For the first 30 years (until 2045) the trend is almost the same in both cases, while thereafter the slope is sharper for RCP8.5 indicating a more intense increase (0.7°C/decade, from 2045 until 2100).


Strovolos-Lakatamia 1983-2100
y = 0.016*x + intcp
y = 0.058*x + intcp
Temperature (°C)
historical (Tmax)
rcp45 (Tmax)
rcp85 (Tmax)


Peristeri 1970-2100
y = 0.014*x + intcp
y = 0.051*x + intcp
Temperature (°C)
historical (Tmax)
rcp45 (Tmax)
rcp85 (Tmax)

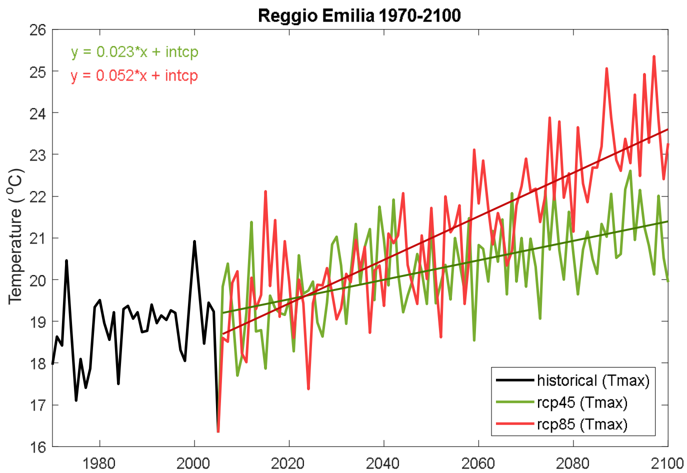


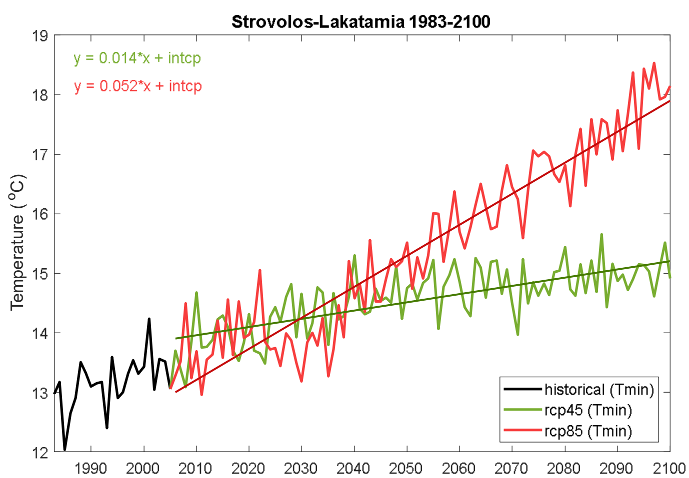
Figure 19 .Maximum temperature predictions for Strovolos-Lakatamia (top panel), Peristeri (middle panel) and Reggio Emilia (bottom panel) under the future scenarios RCP4.5 (green line) and RCP8.5 (red line). The black line represents the historical period.

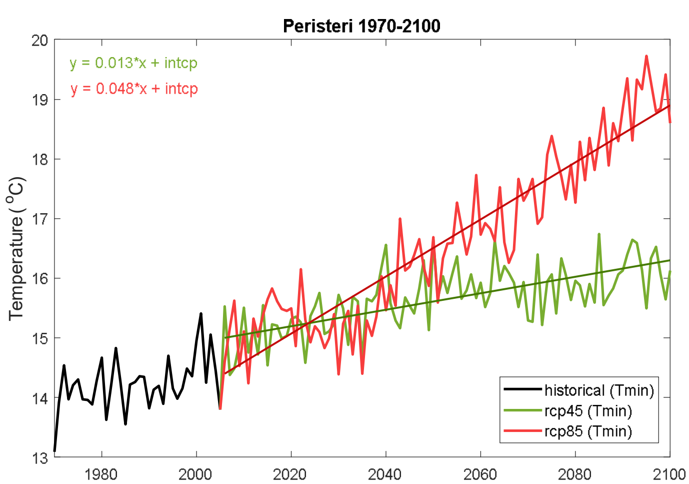
5.1.2 Mean Annual Minimum Temperatures

The predictions for the minimum temperature (Figure 20, top row) at the study area in Cyprus present an increasing trend. More specifically, the minimum temperature will have been increased by 1.2°C until 2100 according to RCP4.5 (0.14°C/decade) and by 4.4°C according to RCP8.5 (0.52°C/decade).

The simulated minimum temperature in Peristeri (Figure 20, middle row) under the RCP4.5 scenario presents an increasing trend of 0.13°C/decade, resulting in an increase of 1.0°C until 2100. The RCP8.5 scenario seems to result in an increase of 0.48°C/decade)

An increasing trend of the minimum temperature is simulated for Reggio Emilia (Figure 20, bottom row). The rates are 0.2°C/decade and 0.51°C/decade under the RCP4.5 and the RCP 8.5 scenario, respectively. The trend is more intense under RCP8.5 scenario for the period 2045-2100.


Strovolos-Lakatamia 1983-2100
y = 0.014*x + intcp
y = 0.052*x + intcp
Temperature (°C)
historical (Tmin)
rcp45 (Tmin)
rcp85 (Tmin)


Peristeri 1970-2100
y = 0.013*x + intcp
y = 0.048*x + intcp
Temperature (°C)
historical (Tmin)
rcp45 (Tmin)
rcp85 (Tmin)

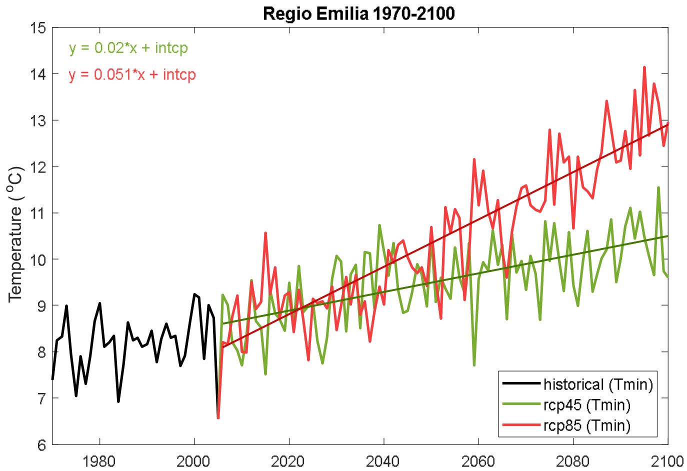


Figure 20 Minimum temperature predictions for Strovolos-Lakatamia (top panel), Peristeri (middle panel) and Reggio Emilia (bottom panel) under the future scenarios RCP4.5 (green line) and RCP8.5 (red line). The black line represents the historical period.

5.1.3 Extreme Temperatures Trends

In Figure 21 to Figure 24 the results for the average annual number of days with maximum temperature higher than 30°, 35° and 40°C as well as the average annual number of days with minimum temperature higher than 20° under both future emission scenarios are shown.

Regarding the first indice, the results indicate similar slopes for the three municipalities under RCP4.5 (Figure 21, left panel) ranging from 0.23 number of days/ year (Reggio Emilia) to 0.26 number of days/ year (Peristeri). For Reggio Emillia and Peristeri this leads to about 34 extra more days at the end of the century, while for Strovolos-Lakatamia the slope indicates about 28 extra more days for the same period. Under RCP8.5 the slopes for all three municipalities become steeper (Figure 21, right panel). The lowest slope is calculated for Reggio Emilia (0.42) while for Peristeri and Strovolos-Lakatamia the slope reaches 0.56 and 0.57 respectively. The slopes indicate about 55, 70 and 65 extra more days by the end of the century for Reggio Emilia, Peristeri and Strovolos-Lakatamia, respectively.

For the average annual number of days with maximum temperature higher than 35° C, under RCP 4.5 (Figure 22, left panel) for both the Reggio Emilia and Peristeri a slope of about 0.25 is shown indicating about 32 extra more days by the end of the century. For Strovolos-Lakatamia the slope reaches 0.43 leading to about 48 extra more days by the end of the century. Under RCP8.5 (Figure 22, right panel) the slopes range from 0.43 to 0.79 for Reggio Emilia and Strovolos-Lakatamiarespectively. This leads to about 56, 70 and 89 extra more days by the end of the century for Reggio Emilia, Peristeri and Strovolos-Lakatamia respectively.

For the average annual number of days with maximum temperature higher than 40° C, under RCP 4.5 (Figure 23, left panel) for both the Reggio Emilia and Peristeri a slope under 0.1 is calculated indicating about 11 and 6 extra more days by the end of the century respectively. For Strovolos-Lakatamia the slope reaches 0.27 leading to about 30 extra more days by the end of the century. Under RCP8.5 (Figure 23, right panel) the slopes range from 0.22 to 0.77 for Peristeri and Strovolos-Lakatamia respectively. This leads to about 28, 32 and 87 extra more days by the end of the century for Peristeri, Reggio Emilia and Strovolos-Lakatamia respectively.

Finally regarding the average annual number of days with minimum temperature higher than 20° C, under RCP 4.5 (Figure 24, left panel) for both the Reggio Emilia and Peristeri a slope about 0.3 is calculated indicating about 40 extra more days by the end of the century respectively. However the impact is higher for Peristeri due to the historical increased number of days (Figure 13). For Strovolos-Lakatamia the slope reaches 0.45 indicating about 40 extra more days by the end of the century. Under RCP8.5 the slopes for all three municipalities become steeper (Figure 24, right panel). The lowest slope is calculated for Reggio Emilia and Peristeri, 0.6 for both municipalities respectively, while for Strovolos-Lakatamia the slope reaches 0.89. The slopes indicate about 79 extra more days by the end of the century for Reggio Emilia and Peristeri and about 100 extra days for Strovolos-Lakatamia.

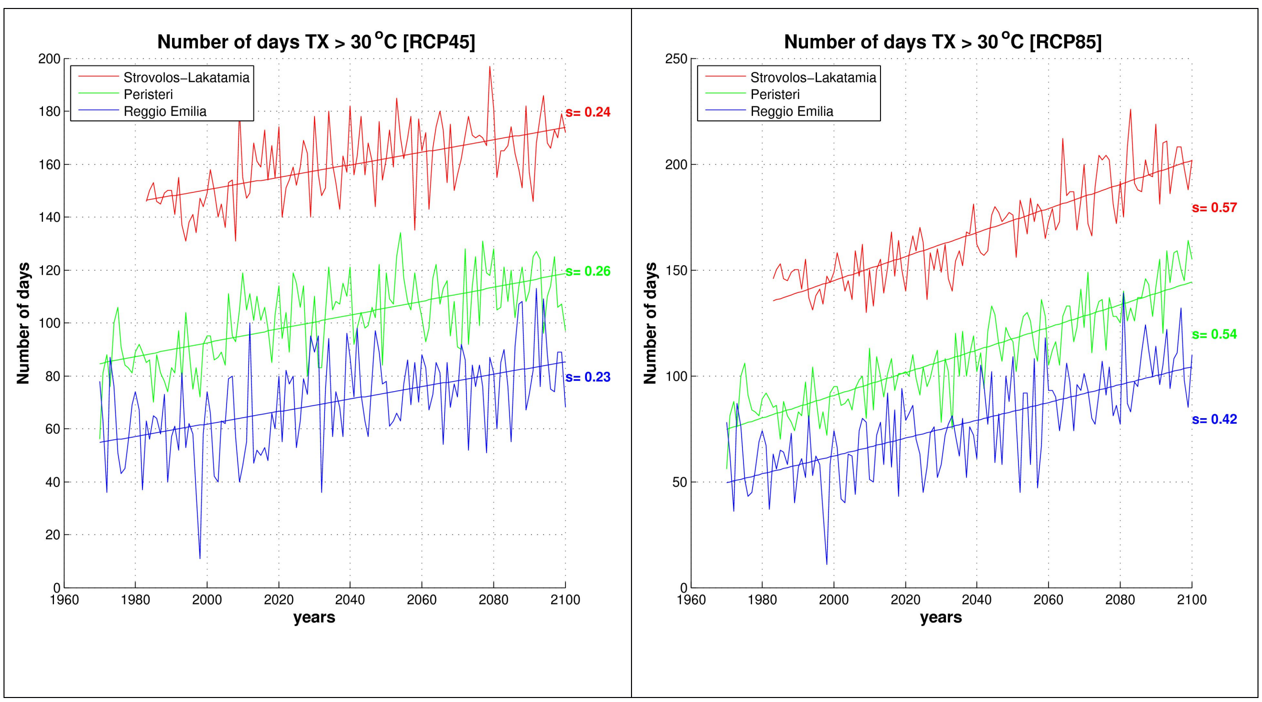


Figure 21.Average annual number of days with maximum temeparature higher than 30oC for Reggio Emilia (blue line), Perister (green line) and Strovolos-Lakatamia (red line) under RCP4.5 (left panel) and RCP8.5 (right panel). The colored numbers on the right side indicate the calculated slopes for each one of the municipalities.

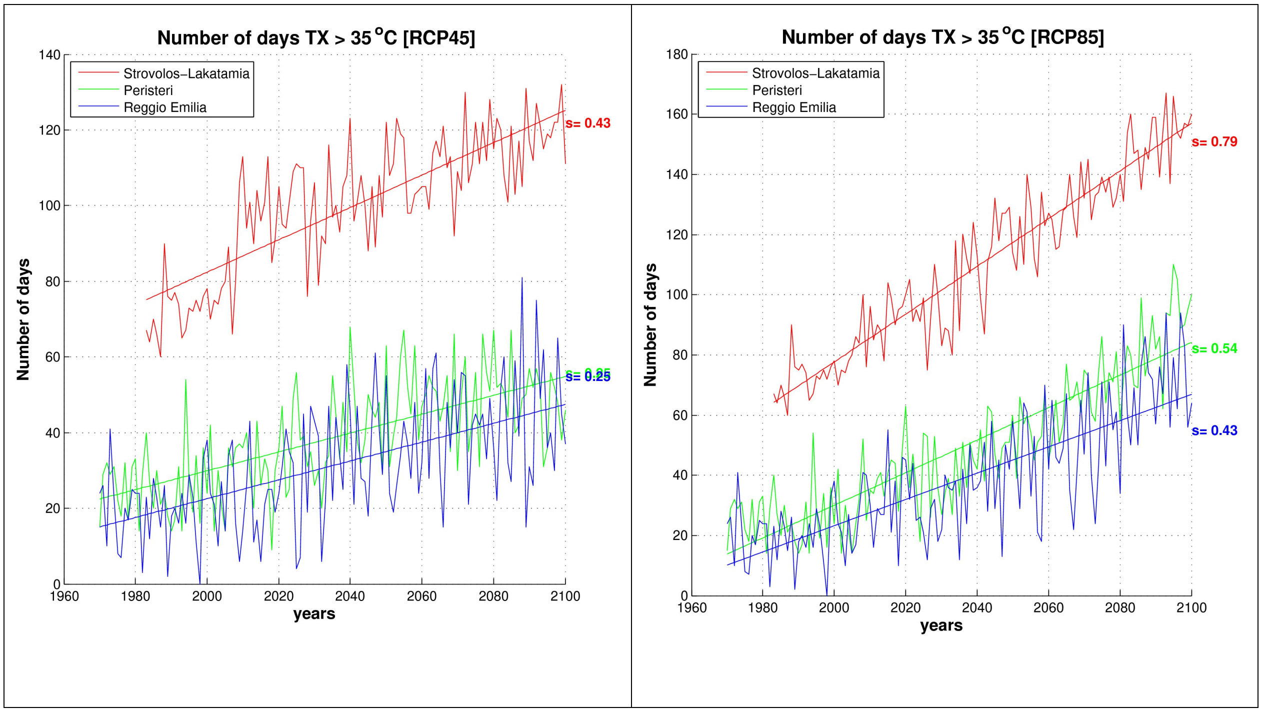


Figure 22 Average annual number of days with maximum temperature higher than 35°C for Reggio Emilia (blue line), Peristeri (green line) and Strovolos-Lakatamia (red line) under RCP4.5 (left panel) and RCP8.5 (right panel). The colored numbers on the right side indicate the calculated slopes for each one of the municipalities.

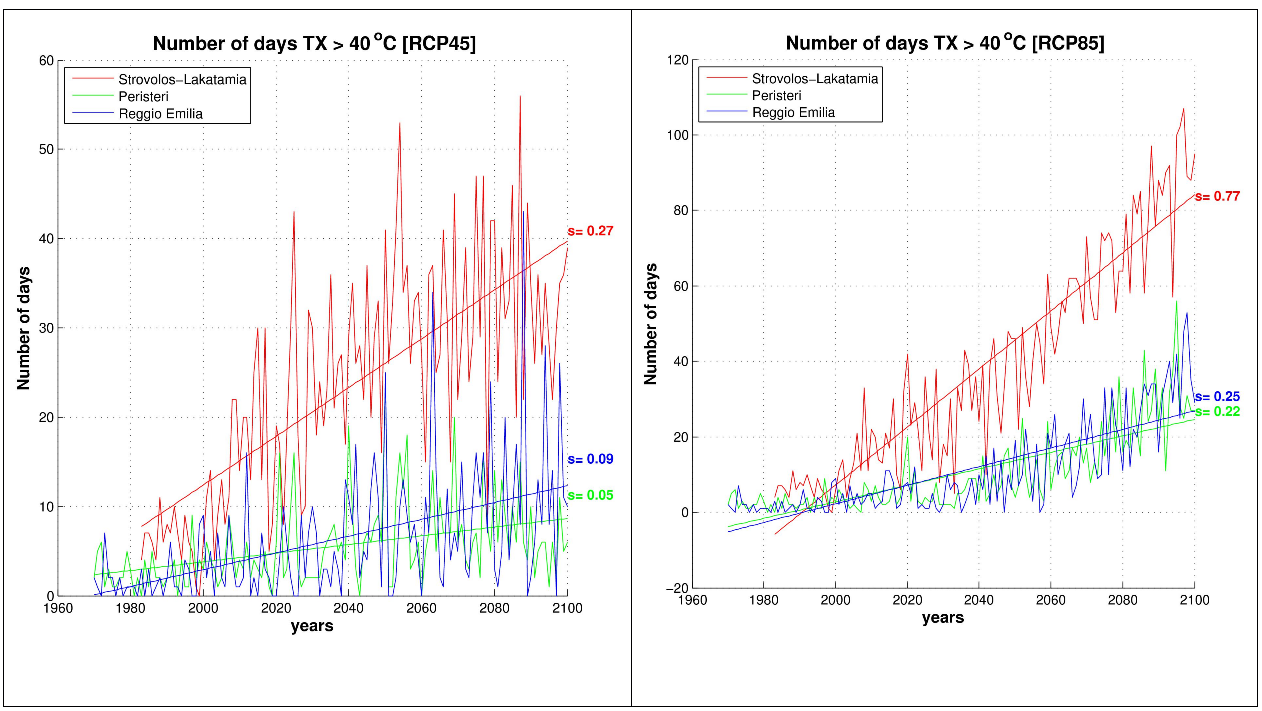


Figure 23 Average annual number of days with maximum temeparture higher than 40°C for Reggio Emilia (blue line), Perister (green line) and Strovolos-Lakatamia (red line) under RCP4.5 (left panel) and RCP8.5 (right panel). The colored numbers on the right side indicate the calculated slopes for each one of the municipalities.

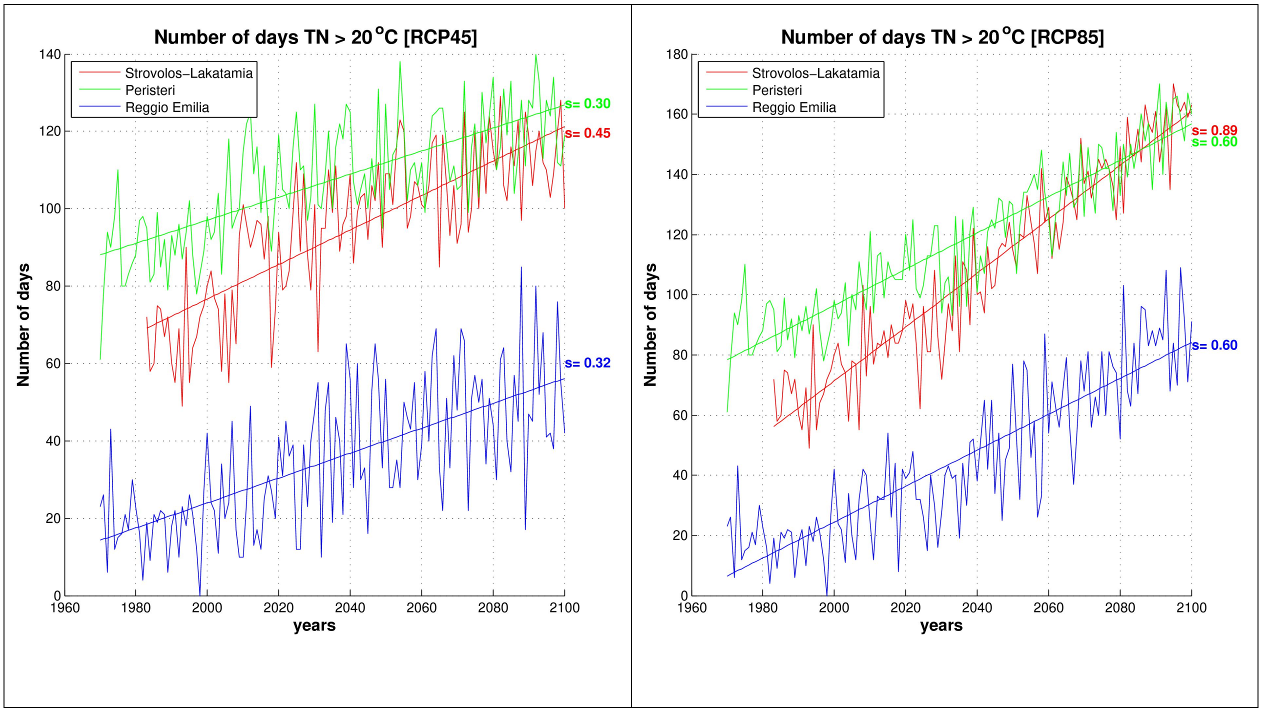


Figure 24 Average annual number of days with minimum temperature higher than 20oC for Reggio Emilia (blue line), Peristeri (green line) and Strovolos-Lakatamia (red line) under RCP4.5 (left panel) and RCP8.5 (right panel). The colored numbers on the right side indicate the calculated slopes for each one of the municipalities.

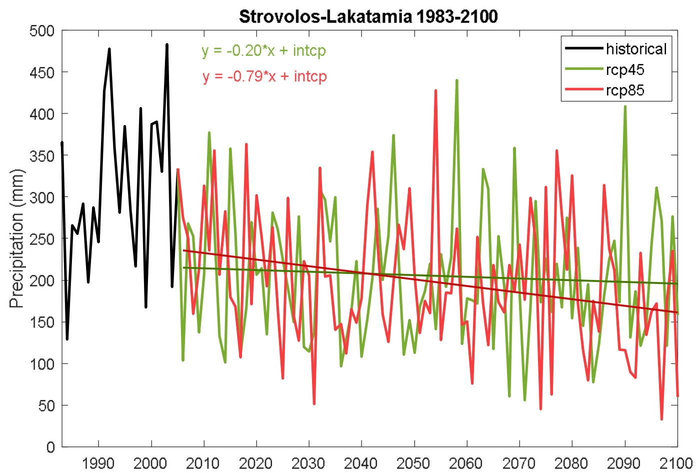
5.2 Precipitation Results

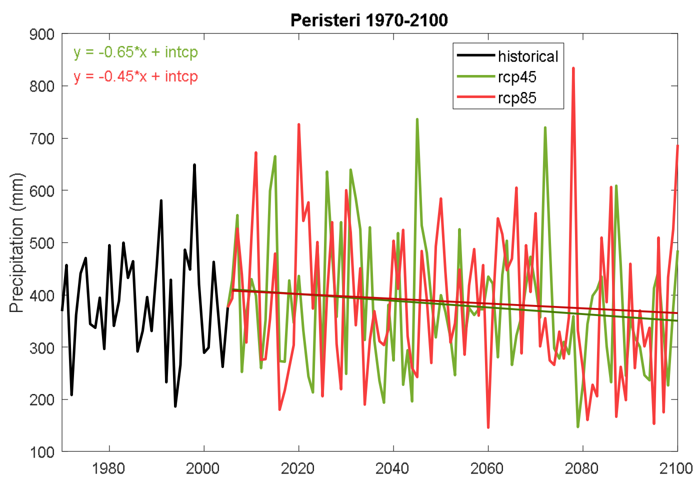
5.2.1 Total Annual Precipitation

In Figure 25 the future projections for the total annual precipitation are shown. For Cyprus a decreasing trend under both scenarios is calculated. The rates of reduction are -2.0 mm/decade and -7.9 mm/decade under RCP4.5 and RCP8.5 scenarios, respectively.

Both scenarios show a decreasing trend of precipitation for the study area in Athens, Greece. The low-medium RCP4.5 scenario indicates a decrease of 6.5 mm/decade, while the RCP8.5 the decrease is 4.5 mm/decade. These rates result in an annual decrease of about 55 mm and 40 mm over the 85-year period, until 2100.

Under the RCP4.5 scenario a significant decrease of precipitation at the Reggio Emilia is shown. The reduction rate is 7.9 mm per decade, meaning 70 mm decrease until 2100. The corresponding reduction rate simulated by the RCP8.5 is 4.5 mm per decade, namely 40 mm until 2100.


Strovolos-Lakatamia 1983-2100
y = -0.20*x + intcp
y = -0.79*x + intcp
historical
rcp45
rcp85
Precipitation (mm)


Peristeri 1970-2100
y = -0.65*x + intcp
y = -0.45*x + intcp
historical
rcp45
rcp85
Precipitation (mm)

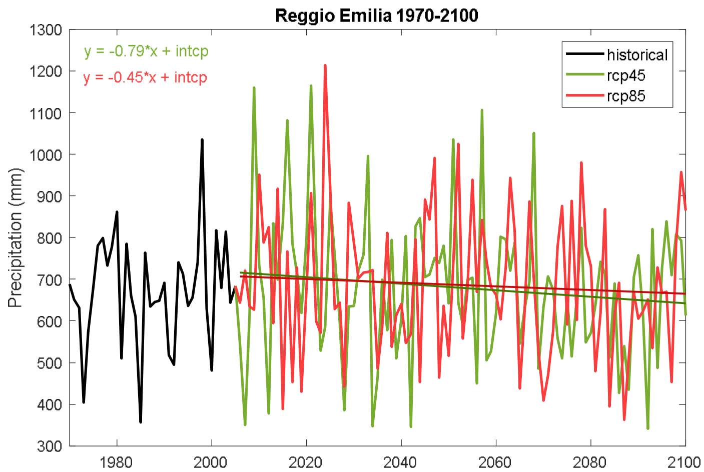


Figure 25 Total annual precipitation results for Strovolos-Lakatamia (top panel), Peristeri (middle panel) and Reggio Emilia (bottom panel) under the future scenarios RCP4.5 (green line) and RCP8.5 (red line). The black line represents the historical period.

5.2.2 Extreme Precipitation

Regarding the indices related to extreme precipitation the analysis reveals that statistically significant results are obtained only for the annual maximum consecutive days with precipitation less than 1mm (Figure 26). More specifically, from Figure 26 it is evident that for the specific indice only in Strovolos-Lakatamia a statistically significant slope is calculated under RCP4.5: the slope reaches 0.15 leading to about 19.5 extra days with no precipitation towards the end of the century. Under RCP8.5 statistically significant trends are found for Strovolos-Lakatamiaand Peristeri. The calculated slopes are 0.46 and 0.22 for the two municipalities, respectively. The results indicate an increase in the maximum consecutive days with precipitation less than 1 mm of about 60 and 29 extra days for Strovolos-Lakatamia and Peristeri, respectively.

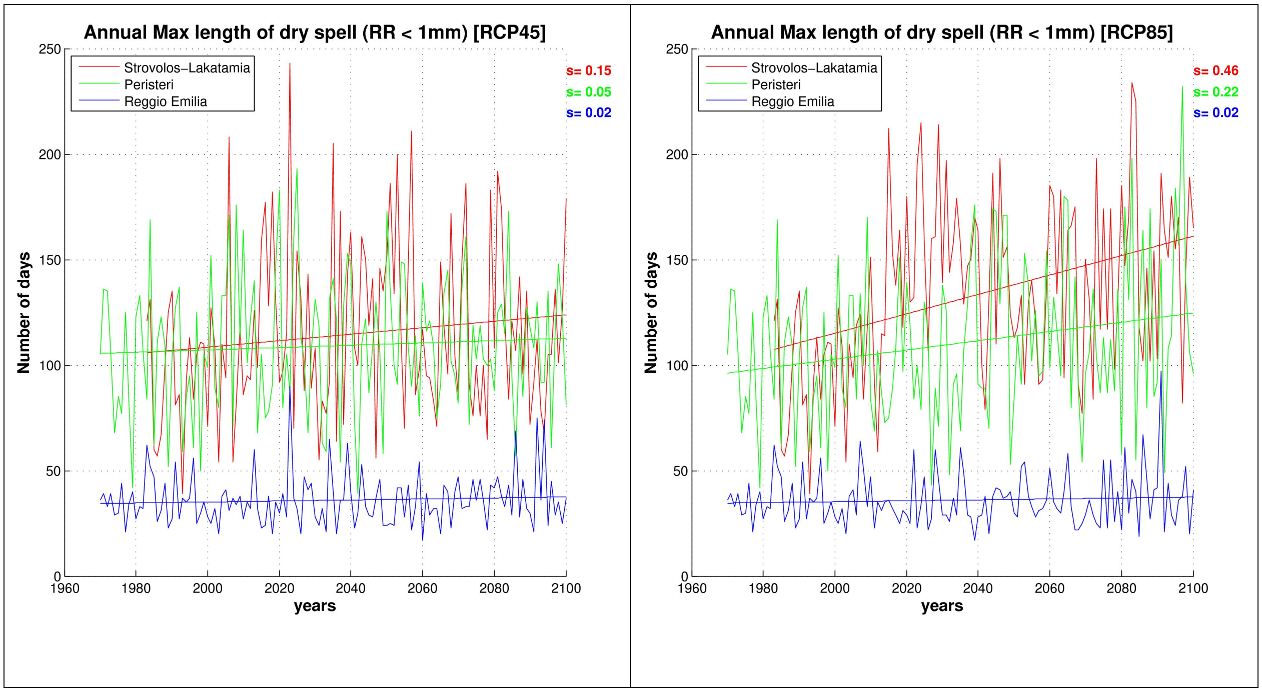


Figure 26 Annual maximum length of days with precipitation <1mm for Reggio Emilia (blue line), Peristeri (green line) and Strovolos-Lakatamia (red line) under RCP4.5 (left panel) and RCP8.5 (right panel). The colored numbers on the right side indicate the calculated slopes for each one of the municipalities.

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