4.1 Climate and climate change database for Adriatic area

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DRINK ADRIA

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CONTENT

1. Introduction

There is a growing evidence for changes in the global hydrological cycle over the past 50 years that may be linked to climate changes (CC). To be able to analyse the available water resources in Adriatic area in DRINKADRIA project it is important to prepare the database of climate and climate change observed characteristics and simulated climate change data for the future (until 2050). Such a database will be useful to develop a common platform to exchange and compare data related to water resources availability and use in trans-boundary context.

According to international and national studies and publications the Mediterranean region is expected to undergo particularly negative climate change impacts over the next decades, which, combined with the effects of anthropogenic stress of natural resources, make this region one of the most vulnerable areas in Europe. The anticipated negative impacts are mainly related to possible extraordinary heat spells (especially in summer), increased frequency of extreme weather events (heat waves, droughts and severe rainfalls) and reduced annual precipitation.

To give an insight in the climate characteristics of the Adriatic area for all Adriatic countries it was necessary to collect data about observed climate and climate change trends and data regarding the simulation of climate changes in the future on the national or regional level.

On the level of selected test areas there was the need to make more detailed evaluation of climate characteristics changes in the future period until 2050 as input data for analysis of CC impact on water resources availability and quality. Temperature and precipitations were the most important characteristics that had to be analyzed.

The database is formed by:

- Joint report, that consists of the overview and most important conclusions regarding climate and climate change characteristics on national level (Italy, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Serbia, Albania and Greece), regional level (FVG Region, Marche and Apulia in Italy, and the Adriatic part of Croatia) and test area level (test area Isonzo Plain in Friuli Venezia Giulia Region, ATO3 Marche test area, Ostuni test area in Apulia, Slovenian test areas, test areas in Croatia, test area in Montenegro, test area in Albania and test area in Greece) prepared by PPs in their reports. Climate and climate change reports from project partners are collected and added as annexes forming a database for the Adriatic region. The joint report text and data are referenced to reports prepared by PPs in which all data used for preparing those reports are referenced in detail.
- Web page, where most important information will be published.

Figure 1.1 shows countries involved in DRINKADRIA project with test areas. Test areas are selected to be the base for more detailed analysis about water resources management aspects in transboundary context (between countries and between regions).

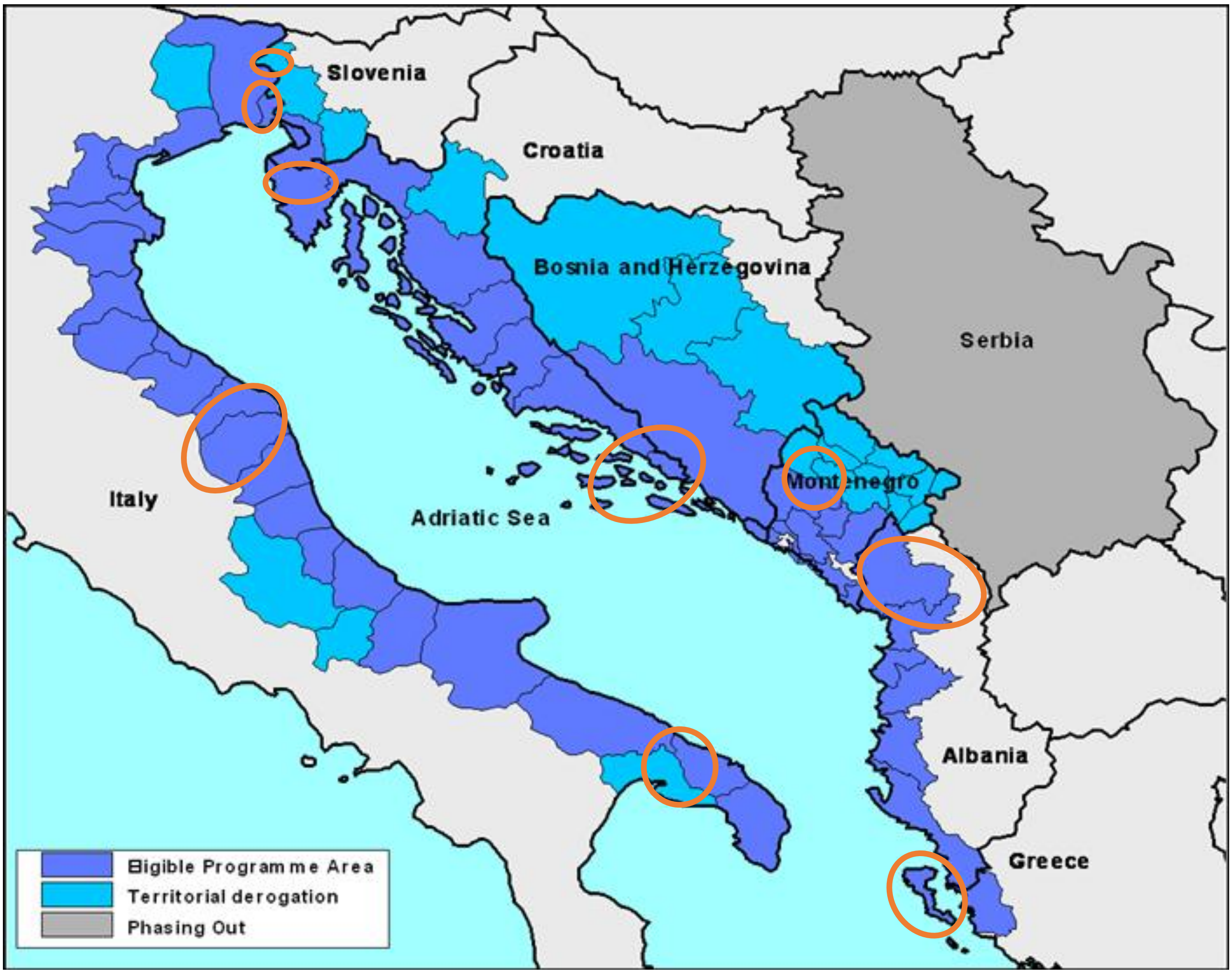

Figure 1.1 Countries that participate in DRINKADRIA project and test areas in WP4

Reports about climate and climate change data on national level, regional level and test area level were prepared regarding following countries and by following project partners:

1. Italy
- Report on national level prepared by FB3
- Reports on regional level: Friuli Venezia Giulia Region prepared by LP
  Marche Region prepared by FB2
  Apulia Region prepared by FB3

- Reports on test area level: Isonzo Plain (in FVG Region) prepared by LP
  ATO3 Marche prepared by FB2
  Ostuni prepared by FB3

2. Slovenia
- Report on national level prepared by FB5
- Report on test areas level prepared by FB5
3. Croatia
- Report on national level prepared by FB8 (FB8 was responsible for report preparation on behalf of FB6 and FB9)
- Report on test areas level prepared by FB8 (part of data prepared by FB12)
4. Bosnia and Herzegovina
- Report on national level prepared by FB12
5. Montenegro
- Report on national level prepared by FB14
- Report on test area level prepared by FB10
6. Serbia
- Report on national level prepared by FB10
7. Albania
- Report on national level prepared by FB11
- Report on test area level prepared by FB11
8. Greece
- Report on national level prepared by FB16 (on behalf of FB15)
- Report on test area level prepared by FB16

2. Climate and climate change data in Adriatic region (national/regional level)

2.1. Methodology

Data regarding climate and climate change are collected and sumarised by PP in individual reports done on national or regional level. Reports are prepared for all countries involved in the Project: Italy, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Serbia, Albania and Greece.
For Italy since the wide area and diversity for each region, a separate report has been prepared on regional level for regions Friuli Venezia Giulia, Marche and Apulia. For Croatia the report covers the national level but also the regional level - Adriatic part of Croatia.
First, observed climate and climate change data are explained and after that, climate change in the future period(s) using different climate simulation models and scenarios is explained.
Based on reports prepared by PPs, collected in Annex I, in following sections the most important parts of reports and conclusions are summarized.
Reports on national level for most countries are based on National Communications under the United Nations Framework Convention on Climate Change (UNFCCC) with additional information from other national studies, documents and published papers (all references are given in national reports – Annex I).
For future climate simulations SRES (Special Report on Emissions Scenarios) scenarios are used in most of the collected reports. The IPCC (Intergovernmental Panel on Climate Change) published a new set of SRES scenarios in 2000 for use in the Third Assessment Report. The SRES scenarios were constructed to explore future developments in the global environment with special reference to the production of greenhouse gases and aerosol precursor emissions.

- A1 storyline and scenario family: a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and rapid introduction of new and more efficient technologies. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B).
- A2 storyline and scenario family: a very heterogeneous world with continuously increasing global population and regionally oriented economic growth that is more fragmented and slower than in other storylines.
- B1 storyline and scenario family: a convergent world with the same global population as in the A1 storyline but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies.

- B2 storyline and scenario family: a world in which the emphasis is on local solutions to economic, social, and environmental sustainability, with continuously increasing population (lower than A2) and intermediate economic development[1].

In some reports the impact of climate change on water resources is already stressesed. These parts of reports will be used in further acitivities in WP4 (analysis regarding water resources quantity and quality vulnerability).

[1] *http://sedac.ipcc-data.org/ddc/sres/*

2.2. Italy

From Annex 1 Report 1.1.:

Climate and climate change characteristics based on observed data

The Italian monthly temperature (mean, maximum and minimum) and precipitation secular data set was updated and completely revised by Brunetti et al. (2006[2]). Station density and metadata availability were greatly improved compared to previous studies and the series were subjected to a detailed quality control and homogenisation procedure. The bias affecting original data is quantified by studying the temporal evolution of the mean adjustments applied to the series and examined in the light of the stations history. The results stress the importance of homogenisation in climate change studies. The final data set was clustered into climatically homogeneous regions by means of a Principal Component Analysis and allowed to achieve the following results in terms of observed climatic trends.

Yearly and seasonal trend analyses were performed both on regional average series and on the mean Italian series. Quite a uniform temperature trend was observed in the different regions, with a trend of 1 K per century all over Italy on a yearly basis. Also on a seasonal basis the situation is quite uniform and no significant differences are evident, either for the different regions or for the different seasons. The trend is generally higher for minimum temperature than for maximum temperature for all the seasons and the year, the only exception being the Pianura Padana region, whose trend is always higher for maximum temperature.

Precipitation trend analysis showed a decreasing tendency, even if the decreases are very low and rarely significant. Considering the average all over Italy, there is a 5% decrease per century in the annual precipitation amount, mainly due to the spring season (−9% per century).

A progressive trend analysis revealed that, both for temperature and precipitation, the significance and the slope of the trends strictly depended on the selected period. In particular, for minimum and maximum temperatures, a turning in the relative behavior was highlighted, minimum temperature trend over the whole series length being higher than that of maximum temperature, and lower if the last 50 years are considered. This suggested that we investigate DTR progressive trends too. The results showed that, considering the whole series length 1865–2003, there was a significant negative trend in the DTR that, in the last 50 years, became positive and significant, the only exception being autumn.

[2] Brunetti M., Maugeri M., Monti F. and Nanni T. Temperature and precipitation variability in Italy in the last two centuries from homogenised instrumental time series. Int. J. Climatol.26: 345–381 (2006).

Climate and climate change simulations for future

As far as concern the future climate projections, the Italy as part of the Mediterranean region is expected to undergo particularly negative climate change impacts over the next decades, which, combined with the effects of anthropogenic stress on natural resources, make this region one of the most vulnerable areas in Europe. The anticipated negative impacts are mainly related to possible extraordinary heat spells (especially in summer), increased frequency of extreme weather events (heat waves, droughts and severe rainfalls) and reduced annual precipitation and river flow.

Most of the climate-related threats reported here are taken from the "Sixth National Communication under the UN Framework Convention on Climate Change" developed by the Italian Ministry for the Environment, Land and Sea in December 2013. In this context, Italy may undergo some expected climate change impacts that would critically affect the following national circumstances, including:

- water resources and areas at risk of desertification;
- coastal areas prone to erosion and flooding and susceptible to alterations of marine ecosystems;
- Alpine regions and mountain ecosystems experiencing glacial loss and snow cover loss;
- Areas prone to flood and landslide risk (i.e. hydro-geological risks including the risk of flash floods,flash mud/debris flows, rock falls and other mass movements related to soil and land management) and, in particular, the hydrographical basin of the Po River.

Climate change is likely to magnify the regional differences in terms of quality and availability of natural resources and ecosystems in Europe and also in Italy.

Water resources (in terms of annual precipitation and river discharge) are projected to decrease over Southern Europe, and this regional pattern could intensify in the last decades of this century. The existing conditions of high stress on water resources and of hydro-geologic disturbance in some Italian regions could be exacerbated by projected climate change including: reduced water availability and quality, increases in frequency and intensity of droughts especially in summer, increases in frequency and severity of river summer flows reductions and annual river flow decline and limited groundwater recharge.

Water quantity/availability and quality in Italy could be particularly affected by:

- reduced water availability, especially in summer;
- increased water stress;
- severe negative impacts in the South, where vegetation and territory are already experiencing a marginal water supply regime;
- increased seasonal water deficit due to significant pressures of summer tourism peaks in small Italian islands;
- potential increased conflicts among multiple uses of water resources.

2.3. Friuli Venezia Giulia Region

From Annex 1 Report 1.2.:

Climate and climate change characteristics based on observed data

To define the climate change characteristics of the Friuli Venezia Giulia Region, were used data partially elaborated by OSMER FVG and data delivered by the Servizio Idrografico per la montagna, Regione FVG for the reference period 1961-1990. Variations in temperatures and precipitations were later commented.

According to Koppen classification the area belongs to the climate type Cfa, a warm temperate rainy (humid mesothermal), humid all year round, with very hot summer. The region has a great variety of climates and landscapes: 42.5% of its surface is made up of mountains, 19.3% of hills and the remaining 38.2% of the plains located in the central areas and along the coast.

Friuli Venezia Giulia has a humid, temperate climate which varies considerably from one area to another. The Alpine System protects the Region from the direct impact of the rigid northerly winds. The opening toward the Po Valley influences the general circulation of air masses from the west to the east. Along this direction, the low pressure canters develop and move, bringing with them thunderstorms and hailstorms, especially in the summer times. Being open to the Adriatic Sea, the territory also receives Sirocco winds, that brings with him heavy rainfalls.

For a first assessing of possible climate change effects in the last decades at regional level, OSMER (ARPA FVG Department) started to collect historical data series on temperatures and precipitations. The longest historical termometric and pluviometric series in Friuli-Venezia Giulia belong to the former National Hydrographic and Mareographic Service stations (now inherited by the Hydrographic Operational Unit of the Friuli-Venezia Giulia Region). The collected data allow defining the evolution through the years of the precipitations and temperatures in the FVG Region. From a general point of view, the Assessment Report realized by IPCC (2007a, b, c), reports that the global warming is unequivocal. There has been an increasing in the temperatures of 0,74°C in the period between 1906-2005 with an important acceleration within the last fifty years (0,13°C/10 years).

In the Alpine region, the ZAMG (Austrian Meteorological Service), in the framework of CLIVALP and HISTALP projects (2006 and 2011), elaborated and homogenized the historical temperatures time series. In particular, in the sub-region of the southern east Alps, which also includes the Friuli Venezia Giulia, is noticed a temperature increase of about 1 °C in the last thirty years. Analyzing more in details the results of the European HISTALP project elaborated by ZAMG for the stations of Udine and Trieste, emerges an increase in the temperatures.

The present report, based on data collected and available at the web site www.meteofvg.it, focused on the analyses of the historical dataset, part of the climate atlas of the entire FVG Region, containing daily rainfalls and temperatures data validated and elaborated by OSMER for the period in the range 1961 and 2000.

Friuli Venezia Giulia Region is famous to be a rainy place, at least when compared to other Italian and European regions. The city of Udine contends, with a few other provincial capitals, the scepter of the rainiest with over 1450 mm of rain per year. To reinforce the image of very "wet", we must always remember that, about 25 km in the NE of Udine, on the Julian Pre-Alps (Mt. Canin area), the average annual rainfall exceeds 3 meters, a value which is among the highest registered in Europe. In the collective imagination while thinking to another city in the region, Trieste, the first weather element that comes to mind is the bora wind and not the rain. In fact, with its 1000 mm of annual rainfall (which, however, at least in Italy, are few) the town has certainly not the reputation of being a rainy city. If we add to these considerations the fact that going from Trieste to Tarvisio, the alpine town located further to the NE of the Region, the average rainfall per year, after having raised till the record values of the Julian Pre-Alps, go back down to levels that almost coincide with those of Udine. So one realizes that precipitation in Friuli Venezia Giulia are actually quite complex.

The rain in the Friuli Venezia Giulia Region is due mainly to: 1) Fronts/depressions; 2) the orographic interactions-wet flows: Stau/Foehn; 3) the instability/storms. These mechanisms interact with the geographic position and with the site-specific orography of the Region that influence a lot, at local scale, the precipitations.

In the Northern emisphere, at 46°N of Lat, where FVG Region is, blow the westerly, wide air masses that guided by the polar front, move from west to east. In them are sited the fronts causing rainfalls and snowfalls. Indeed, is at higher Latitudes (between 50 and 60°N) that the perturbed belt reaches their maximum. Usually also the zones between 40° and 50° parallel are affected by perturbations. To this main „weather engine" are added depressions that originate over Mediterranean, especially during winter times, and that are concentrated on the Genova Gulf or on the middle Adriatic sea (Cicogna et al., 2012)[3].

Regarding the geography and the orography of the study area, is necessary to remember that the Region is located between the Adriatic sea and the Alps in a S-N direction, while at W, there is the Po Plain and the Dolomites; to the E instead, some alpine reliefs and the first Balcans. It is important to note as the main range of the Eastern Alps are the Tauri, in Austria, while the Carnian and the Julian Alps are of lesser height and vastness. This implies a complete protection of the Region by the cold airflows and usually humid, coming from N-W and N-E. Conversely, the exposure of the Region is to the southern flows between E and W. At the exception of eastern flows, less humid, but during wintertime, particularly cold, from the other sectors arrive high humid and quite warm air masses coming from the Mediterranean basin. The regional orography, with the pre-Alps before

[3] Cicogna A., Giani M., Micheletti S. (2012) Cambiamenti climatici, Rapporto Sullo Stato dell'Ambiente, ARPA FVG, Forum Editrice Universitaria, Udine.

and the Alps after (Carnian and Julian) amplify the effects of the Mediterranean humid flows while uplifting them during the southern blowing winds (Stau). In the summertime, the Adriatic Sea as the Po plain are warm and humid. Here the Alps are not enough high comparing with the western sector (4000 m), so often, cold air, at high altitude (since 3000 m) can take over the region and provoke thunderstorms. All these elements explain why the Region is quite rainy not only as frequency, but also as quantity, why the most rainy area are the Prealps, in particular the Julian ones, while close to the sea and in the northern alpine zones the rain decrease, and finally why during summertime, thunderstorms are quite frequent.

In the Friuli Venezia Giulia Region, several meteorological stations are active; some of them are recording since tens of years.

The longest historical time-series in the FVG Region are the ones of the ex-Servizio Idrografico e Mareografico Nazionale (now Unità Operativa Idrografica del FVG). The daily data recorded in the period ranging within 1971-2008 in 109 rainfall stations and in 46 temperature stations was used, all of them managed by the Unità Idrografica Regionale and by OSMER. Missing data were updated using linear regression techniques Stepwise or multiregressions, already used in the updating of the Climatic Atlas of the Friuli Venezia Giulia Region. Natural Neighbor algorithm allowed to elaborate precipitation maps. For the temperatures instead, were used the altimetric experimental gradients obtained through the correlation between the temperature daily data and the elevation of each single station. In the mountain basins, the snow process has been described as follow: all the precipitations fallen at low temperature were considered snow.

Using a wider dataset (1961-2000), the researchers of the OSMER prepared a series of maps available on the web site (www.osmer.fvg.it). From the maps analysis emerges, that the lower mean annual precipitations occur along the coastal area where rains about 1000 mm. In the plain area, the mean values oscillates between 1000 mm in the Low Plain and 1500 mm in the High Plain or in the pedimont zone. Between the pedimont and the pre-alpine belt, the mean annual rainfall value increase up to 1500-2000 mm. Over the Pre-Alps, it reaches values that exceeds 2000 mm with peaks of 2400 mm in the Carnian Pre-Alps and 3100 mm in the Julian Pre-Alps. In the Carnian Alps mountain range, and in the area around Tarvisio, rainfall values can reach 1500-1700 mm. Analyzing the percentiles, every 10 years, in the less rainy year, can fall from 750-800 mm of rain on the coast and 2500-2600 mm over the Pre-Alps. In the rainier year, instead, precipitations can vary from 1200 mm over the coast until 3600-3700 over the Pre-Alps (Mt. Canin area). Within the period 1961-2000, the highest recorded values of rain has been of 4256 mm in the 1965 and 6100 mm in 1960 at Uccea, in Val Resia (UD), close to the Slovenian border.

If we consider the rainy days, that mean the days during which rained at least 1 mm, at year level, the value vary from 90 for the coast are until 120 of the pedimont and mountain areas. With a return time of approximately 10 years, these values rise reaching 100-110

days over the coast and 140 days on the pedimont and mountain. During the dryer years instead, over the coast there can be only 70-80 rainy days and 100-110 over the mountains. In the analyzed period, during 1966, at Uccea was recorded a value of 146 rainy days. In the winter times (DJF), the average number of rainy days is almost the same on the whole region with a value of 6-7. During March, November and October, this value increase with differences over the areas. The inhomogeneity is maxima during June when on the coast there can be 9 days of rain, while over the mountain these count could reach the value of 15.
For the temperatures, analyzed data come from 47 meteorological stations within the period 1993-2012. Data were used to create annual and monthly maps. Some stations in the region are historical, as the one in Trieste and the other in Udine. This means that they hold long time-series, more than 30 years (Histalp, 2014)[4].
To highlight better the annual variations, OSMER evaluated the differences from the mean annual temperatures in four different meteorological stations having the data availability since 1961. Using data made available by the Friuli Venezia Giulia Region - Direzione centrale ambiente, energia e politiche per la montagna - Servizio idraulica, it has been possible to extend the time series within the period 1961-2010. The data analysis highlighted that during the last 20 years, mean annual temperatures increased with years having more often values higher than 13°C. In the past two decades has been calculated an average increase of temperature of 0.7°C. In particular, two stations were analyzed: Trieste and Udine.
The time series of the mean annual temperatures at Trieste station (data available from 1840 to 2005 granted by HISTALP archive as result of different European projects) show an uncertain trend. Analyzing the mobile mean temperatures over a period of 10 years, the value clearly attests around 13,5°C till the 1920. After that date, it increases reaching the 14°C, value that was overcome for the first time in the 1940. During the last 20 years, a rapid increase took the temperature to reach average values of 15°C (after the 2000).
If we observe Udine's dataset, also obtained from the historical series of the HISTALP database, the trend is similar to the one from Trieste. The mobile mean is oscillating between 12 and 13°C for all nineteenth century. In the first half of the 20th century, the temperature values starts to rise reaching the 13° in the 1940. It slightly decrease a little bit and remain constant until the 1985. Finally, it increases again going permanently over the 13° C.
If we analyze all the other available stations, 22 has 50-years series. Among these, the mean minimum temperatures remained almost stable in the period between 1950 and 1985, while during the second half of the 80s, they started to increase fairly gradually and steadily. The overall increase, in a 20-year period, varies between a few tenths of a degree and 2°C.
For the maximum temperatures, also in this case, after 30 years of stability, is possible to note an abrupt jump upwards in the 1985 followed by 10 years of increasing temperatures.

[4] HISTALP (2014) Historical Instrumental Climatological Surface Time Series of the Greater Alpine Region. http://www.zamg.ac.at/histalp/, last access 10.08.2014.

During the last ten years, the trend seems to have a lower growth. Overall, the increase, during the last 20 years varies between 0.5 °C and 2.5°C.
From the same archive (the HISTALP database) were obtained the deviations of the min and max temperatures from the mean seasonal values on the standard period 1961-1990. Analyzing the data, in wintertime, most for maximum than for minimum temperatures, the values showed a meaningful and rapid increase in the second half of the 80s, reaching the maximum values over 50-years period as had happened during a peak in the mid-70s. Over the past 20 years, the situation seems to be stabilized at these high values (roughly about 1°C over the historical mean). In springtime, after a stable 30-year period, with a sharp deviation from the mid-80s, temperatures have risen steadily, reaching values between 1°C and 3°C above the historical average (less than the min). During summer times, the temperatures increase started already from the early 70s for the maximum values and from the 1980 from the minimum ones. They reached 1°C to 3°C in the max and 0.5°C and 2°C in the min. In autumn, the mean maximum temperatures, while periodically oscillating, do not show clear signs of changes.
In a nutshell, despite all the uncertainties, in the Friuli Venezia Giulia Region, the temperatures during the last 20 years seems to be highly increased almost everywhere, especially concerning the maximum spring and summer values. Seems very likely that the values recorded in recent years are the highest for many decades, if not centuries.
Regarding precipitations, on yearly basis, it is difficult to draw conclusions on possible increasing or decreasing trends, beyond some temporary or local signs. For some stations there is a trend indicating a decreasing in the precipitations of about 20% in correspondence of the summer seasons. During the winter times instead, it is expected a slight increase in the precipitation amount taking to a year almost unchanged balance. Unlike the case of temperatures, the wide and frequent oscillations of the pluviometric regime mean that a lot depends from the length of the considered time series. The results obtained by the different projects over the period 1961-1990 show clear signals even if sometimes conflicting, of climate changes.

Climate and climate change simulations for future

All the analysis indicates a rapid increase in the temperatures of about 2/4°C within 2100 with a more pronounced increase during the summer season.

2.4. Marche Region

From Annex 1 Report 1.3.:

Climate and climate change characteristics based on observed data

Temperatures in Marche Region are increasing. The observed trend is characterized by increases ranging between 0,5 and 1,3 °C every 50 years, in maximum temperature series, according to the data recorded in the period 1950 - 2000. Concerning the minimum temperature series the annual trend is similar, although higher (between 0,8 and 1,7 °C/50 years). The minimum temperature shows an increasing trend more pronounced compared to that of the maximum temperature. To better quantify this phenomenon, the increase in temperature has been reported as percentage calculated in relation to the corresponding average values for the period under study.

Being affected by both atmospheric flow and local orography, rainfall is not in direct relationship with soil elevation. It should be noted that autumn is the wettest season, except for a wider range of winter rainfall for the high hill/mountains area, with the upper limit higher than the corresponding autumn one.

Concerning temperatures, annual increase has been observed in most of the stations over the whole period. Such increase is around 5-6% for the maximum temperature values and 10-12% for the minimum values. The increase is evident in all seasons for minimum temperature, with average growth of 1,1 °C every 50 years in Spring, 1,4 °C in Summer, 1,0 °C in Autumn, 1,3 °C in Winter in the period under study. Positive trend (growth) in maximum temperature is especially evident in spring and winter (1,1 °C and 1,2 °C/50 years, respectively). Screening in elevation bands suggests that temperature is increasing with greater intensity in mountain and high hills areas, rather than in coastal zones and lower hills.

Results concerning rainfall analyses reveal a significant decreasing trend in annual precipitation in the period 1950 to 1989 for 59 stations. Maps referred to those stations whose data are updated until 2000 show a decline of rainfall compared to the 40 year long data set for the same area, except for autumn, when there is an increase in precipitation.

Further researches and studies about the probability distribution of monthly precipitation and trend in annual precipitation should update the data set to be taken into account up to present days. If the trend of annual precipitation would prove negative, as shown in the present work, it would be important studying the intensity of rainfall considering the trend of the number of rainy days in the month: if the latter showed a significant negative trend, steeper than the one corresponding to the quantity of rainfall, this would result in a growing intensity trend. Monitoring of the precipitation intensity parameter, correlated to other factors, it is of utmost importance in the prevention of disasters, such as flooding, flash floods, etc.

The results of the investigation on the variability of typical weather indicators, such as precipitation and air temperature near the ground (T2m), made in the recent years in order to study potential climate change on a regional basis, can be summarized as follows:

- detection of a decreasing trend of annual precipitation, even with its natural oscillations, and determination of a reduction, for the most part of the cases, more than 10% and less than or equal to 30%, compared to the average value of the period from 1950 to 1989, which means a reduction of the average annual rainfall of about 5 mm per year, during the time interval in the study;
- determination of a growing trend in the mean maximum and mean minimum temperature. More precisely, based on the analysis of the annual maximum temperature, a positive trend of 0.5 to 1.3 °C every 50 years is evident, to be compared to a different trend of 0.8 to 1.7 °C every 50 years for the minimum, referring to the range from 1950 to 2000.

Climate and climate change simulations for future

These results outline a framework of possible climate change on Marche Region, identifiable in a decrease in total annual rainfall and increase in temperatures.

2.5. Apulia Region

From Annex 1 Report 1.4.:

Climate and climate change characteristics based on observed data

Trends are computed from 1970. Reference stands for observation. Daily minimum temperature reference trend (°C/yr): +0.055. Daily maximum temperature reference trend (°C/yr): +0.047. Cumulated precipitation reference trend (mm/yr): -0.277.

Climate and climate change simulations for future

In the report results of local assessment and bias correction of climate simulations obtained from a state of the art RCM (Regional Climate Model) against ground based observation of climate variables are presented with regard to the Apulia region.
The methodology used for the local projection of RCM control simulations and scenarios is based on a quantile variable correction supported by an incremental assessment. This methodology was applied to both dynamical (temperature) and non-dynamical fields (precipitation) of climatic variables supplied by the PROTHEUS RCM adopting a spatial scale which is consistent with that of a mesoscale hydrological basin (of the order of 10^3 km^2).
Monthly point observations from 1951 to 2001 are used as reference data set. The distribution of temperature and precipitation in a pair of RCM PROTHEUS simulations covering the end of 20th (past scenario) and first half of the 21st (future scenario) centuries were examined.
From the RCM simulation 37 nodes were selected as representative of the entire region. Monthly means of daily maximum and minimum temperature as well as monthly rainfall totals were considered from a sub-set of the available gauge stations characterized by a low amount of missing data. Concerning the reference period corresponding to the second half of the 20th Century, 82 temperature stations and 111 rainfall gauge stations were selected in the available data set. The data coverage was slightly different between the chosen atmospheric variables with maximum and minimum temperature covering the period 1951-1994 while rainfall records were considered for the period 1951-2001. Monthly observations were used here to determine month-by-month quantiles of the reference period. In study case, all weather stations with less than 20% of missing data were retained.
The statistical downscaling was done through the comparison of land control measurements (REF) and dynamical downscaled control simulations (PROTHEUS RCM forced by the ERA-40).

Changes in daily minimum temperature were analysed by differences of monthly means between future and past scenarios over the whole period (1953-2000 and 2001-2050, respectively). Temperature increasing concerned mostly the period ranged between early spring and late autumn (from April to October) with a maximum in October. The maximum of spatial heterogeneity was found on the same period, with value ranging from 0.5 to 2.6°C. From November to March, a homogeneous increasing (below 1°C) of minimum temperature over the whole region were resulted.
Similar results for monthly means of daily maximum temperature were found. A temperature increasing concerned mostly the period comprise between early spring and late autumn (from April to November) with a maximum in September. The maximum of spatial heterogeneity occurs on the same period, with value ranging from 0.5 to 2.1°C (maximum in August). From December to March, an homogeneous increasing (below 1°C) of minimum temperature over the whole region was found.
Based on mean differences of the monthly cumulated precipitation, precipitation presents heterogeneity globally higher than temperature. Contrarily to minimum and maximum temperature which globally continues to increase during the future scenario even if associated trends globally decrease, the global trend of decreasing precipitation is not confirmed over the whole case study. In fact, in October, precipitation increases between 10 and 20 mm/month at the south of the region and between 5 and 10 mm/month at north, meanwhile oppositely in December maximum increase is concentrated at the north of the region with a maximum of 36 mm/month. During January, February, March, May, June and August precipitation are stable in confront with the past scenario, with value ranging between -5 and + 5 mm/month over mostly the whole case study. In January, March and June, a minority of stations present a major decreases, with value ranging from -5 to -10 mm/month. Finally, April, July and September at north and November at south presents a global decrease of precipitation, with a maximum of -21 mm/month in July. Yearly mean values of daily minimum and maximum temperature were also assessed.
The adopted downscaling methodology is explained in detail in the report. The application of the described methodology on the monthly mean values leads to the conclusion that during the next 50 years, temperature increase will be limited to about 1°C from December to June but may exceed 2° C from July to October, that minimum temperature may be more affect than maximum temperature, and that precipitation may decrease in April, July and September while increase in October and December, which are critical information for hydrological modelling studies.

2.6. Slovenia

From Annex 1 Report 1.5.:

Climate and climate change characteristics based on observed data

The climate of Slovenia is determined by numerous factors such as geographic location, relief diversity, orientation of mountain ridges and proximity to the sea. Consequently, diversity and combinations and of number of factors are reflected in a very diverse climate. There are three dominant types of climate, but in certain areas their effects are intertwined: the east Slovenia has a temperate continental climate, in central Slovenia subalpine climate (in mountain alpine climate), and in west of Alpine-Dinaric barrier sub-Mediterranean climate. Climatic diversity of Slovenia is reflected in the differences between the values climate variables and their daily, seasonal and multi-annual variability.

Temperature characteristics in Slovenia are heavily dependent on the type of climate and relief in a given area. The most obvious is the dependence of the temperature conditions of the altitude, where the temperature usually decreases with height. The average annual temperature in Slovenia decreases for 5.3 °C every 1000 m. Besides the altitude, also exposure has a significant impact on the temperature conditions.

The spatial distribution of mean annual temperature is in accordance with relief of Slovenia. The warmest is on the coast and some other valleys on the west, where the average annual temperature exceeds 12 °C. Temperatures between 10 and 12 °C are also found in the rest of the Primorska region (west Slovenia) and in the lowlands of eastern Slovenia, while in the lower parts of central Slovenia the average annual temperatures are between 8 and 10 °C. Lower temperatures are characteristic for mountains, where on the highest peaks average annual temperatures not exceed 0 °C.

For temperature in Slovenia daily and seasonal variations are characterized. Maximum daily temperatures are usually recorded at about 2 pm and the lowest just before sunrise. The warmest month is usually July and August in the mountains while the coldest month everywhere is January. The highest daily and seasonally fluctuations in temperatures are typical for areas with continental climate (eastern Slovenia). On the contrary, the lowest differences are characterized in Primorska region (western Slovenia) due to influence of the sea as well as in the mountains due to open atmosphere.

Based on measured meteorological parameters (temperature, precipitation) general trend of rising temperatures across the country as well as more frequent warm years in last two decades are observed. Changes in precipitation are especially seasonal noticeable with general peak of rainfall in autumn and less rainfall in spring and especially in summer.

The climatic conditions in Slovenia are presented for 30 year period 1971-2000 due to more complete meteorological data for this period. In determining the long-term trends in climate variables in some cases also a longer period is covered.

Temperature conditions during the reference period 1971-2000 show on average increasing across the whole country. In average the coldest temperatures were determined at the beginning of period and the warmest in last years of the period. The temperature increasing was also observed positive deviations of annual average temperature during the last 50 years. The results show that positive deviations of temperature (warmer than the reference period) increase with decades, while negative deviation decrease. In 60's and 70's three positive and seven negative deviations were observed. The following decades show siginifcantly more warmer years with higher temperatures, such as five in 80's, eight in 90's and nine in the last decade. Besides, the last three years show also highly positive deviations.

The spatial distribution of precipitation in Slovenia is strongly associated with its relief diversity. Due to the orographic effect the rainfall (amount of precipitation) increases with the distances from the sea towards the interior of Slovenia and reaches its maximum at the Dinaric-Alpine barrier. Slightly lower, but noticeable maximum rainfall also occurs in the Kamnik-Savinian Alps due to the effect of rising of air masses. On the other side of the Dinaric barrier to the northeast the rainfall rapidly decreases. The northeast of the country has a strong influence of the continental climate and the annual rainfall does not exceed 900 mm. Along the coastline the annual rainfall ranges between 1100 and 1200 mm. Such spatial distribution of rainfall is due to the fact that in Slovenia the most precipitation falls in the weather situations when moist and relatively warm air mass are moving across the country with south-westerly wind. The direction of air masses movement is perpendicular to orographic barrier, causing the rising of air masses, cooling of the air and consequently, the formation of precipitation. Therefore, the maximum of annual precipitation is in the Julian Alps, where falls annually over 3200 mm of precipitation. This area also belongs to the wetter areas in the Alps and in Europe.

Precipitation regime determines the distribution of rainfall throughout the year. In Slovenia, dry or wet part of the year is not evident, but significant differences are observed during the months and seasons. The annual precipitation cycle is dependent on main climate type of certain region. For the sub-Mediterranean climate two precipitation maxima are characterized: the first occurs at the end of spring and the second in autumn. Alpine climate is characterized by main precipitation maximum in autumn and slightly less pronounced maximum in late spring and early summer. East part of the country, where the effect of continental climate occurs, is characterised by most precipitation during the summer showers and thunderstorms, while the winter months are the driest.

Although the global climate changes foresee changes in precipitation, on an annual basis not significant trends are observed in the past. But more obvious variability is shown within individual seasons. The autumn rainfall increases almost across the all country with just some exception of small areas. During the winter the amount of precipitation is decreasing across western Slovenia, while in eastern Slovenia no changes are observed. In spring fairly uniform trend of decreasing rainfall throughout the country is observed with the

exception in eastern Slovenia. In summer the situation is different with less precipitation practically everywhere except in higher elevations of the Alps.
On the basis of the cumulative meteorological water balance the distribution and intensity of agriculture droughts in 10 selected locations in Slovenia has been studied. It was found out that during the summer period (June to end of August) in the last fifty years (1963-2013) water deficit for agricultural plants 17-times caused problems with agricultural drought. Drought on national scale has emerged 7-times since 1990, 5-times since 2000. All of these droughts have reached the dimensions of a natural disaster.

Climate and climate change simulations for future

General circulation models constitute a good basis for assessing the impact and prepare adaptation strategies climate change in Slovenia by individual regions. By the end of this century Slovenia and its wider surroundings is expected to have warmer summers more than winters. In winter we can expect a slightly more precipitation and in summer less.
For the assessment of climate change in Slovenia in the future, the simulation results with 4 MSC methods with incorporated SRES emissions scenarios were used. Changes are analysed in relation to the comparative period 1961-1990 as a 30-year average with a step of 10 years.
The results show that the temperature of the air will increase in the entire area Slovenia with no significant differences between areas of Slovenia were observed. Size of the projected changes in temperature is largely dependent on the selected emission scenarios. In the period from 2001 to 2030 air temperature is expected to rise by 0.5 °C to 2.5 °C, over a period of 2031 to 2060 from 1°C to 3.5 °C, and in the period 2061 to 2090 for 1.5 °C to 6.5 °C.
The predictions of changes in annual precipitation in Slovenia are less reliable and the quality of models is usable for most meteorological stations only for the months of cold half year. One of the reasons is diversity of climate conditions on a small area that locally impact on precipitation variables, especially in the warm half of the year. Therefore the empirical models for assessing precipitation variables produce no high-quality results. Some projections (as a predictor used air pressure at sea level as a temperature of the air) show the trend towards less rainfall, while the others (as a predictor used only air pressure at sea level as a temperature of the air) the trend to a reduction in precipitation projections of results is not observed. Therefore, projections of changes in precipitation are used only as a rough estimate in the elaboration of climate change scenarios. The projected changes in annual precipitation in the future range from +10% to -30%. The precipitation in summer is likely lowered up to 20% .
Climate change characteristics of South East Europe with a higher spatial resolution were observed within CC-WaterS project. The main focus was on the climate variables of

temperature and precipitation. The dynamical downscaling and statistical downscaling were applied to obtain high-resolution climate change scenarios. Dynamical downscaling leads to Regional Climate Models (RCMs), which are limited to a smaller modeling domain, but resolved at a higher spatial resolution. With statistical downscaling models (SDMs), GCM variables (predictors) are linked with local and regional variables (predictands). Three selected RCMs were used to simulate the future climate: RCM Aladin driven by GCM ARPEGE (run by the Centre Nationale de Recherches Météorologique, CNRM), RCM PROMES driven by GCM HadCM3Q0 (Universidad de Castilla-La Mancha, UCLM) and RCM RegCM driven by GCM ECHAM5-r3 (International Centre for Theoretical Physics, ICTP). Besides, regarding the green house emission scenario, the A1B scenario was selected as the common scenario for all analyses. Three meteorological stations with different altitudes were included in calculation. For Slovenia analysis was performed for three meteorological stations: Kredarica in the Alps, Ljubljana (the capital) and Murska Sobota (in SE Panonian basin flat area). RCMs were bias corrected with EOBS data base. By comparing observation data (OBS) to EOBS data sets we came to conclusion that EOBS is a good approximation for locations with flat relief, but not for the high alpine terrain due to underestimation of altitude, which results in underestimation of both air temperature as well as precipitation. Also, there is a considerable difference between OBS and EOBS distributions of rainfall amounts, since EOBS underestimates the frequency of rain events with less than 5 mm rainfall amount as well as the frequency of events with 25 mm or more rainfall. Similarly to EOBS, model data significantly overestimates air temperature in high alpine terrain. Apart from the high altitude location of Kredarica the model to model differences are slim in case of temperature. On the other hand, the precipitation differences among models have a high level of dissimilarity. By applying statistical downscaling (quantile method approach) temperature biases can be successfully removed from RCMcorr data. Also, this approach adjusts the distribution of rainfall amounts.

The future model simulations showed the increase in air temperature on average more than 3 °C at all observed locations. The strongest increase was identified in the warm part of the year, particularly in the summer, and least strong in the cold part of the year. Precipitation data manifests a high degree of ambiguity in the future periods, but the model simulations agree on a general trend pointing to less precipitation in the summer. All models predict an increase of percipitation in autumn. Model data also indicates trends in the direction of longer duration of dry spell and greater maximum daily rainfall. By studying future model simulations we observe the increase in air temperature is the strongest in the warm part of the year, particularly in the summer. Precipitation data manifests a high degree of ambiguity in the future periods, but the model simulations agree on a general trend pointing to less precipitation in the summer. Model data also indicates trends in the direction of longer duration of dry spell and greater maximum daily rainfall.

2.7. Croatia

From Annex 1 Report 1.6.:

Climate and climate change characteristics based on observed data on national level

According to Köppen classification for a standard period 1961-1990, the largest part of Croatia belongs to the climate type C, a moderately warm rainy climate. The southernmost part of the island of Lošinj, the Dalmatian coast and islands have the Mediterranean climate with dry and hot summers, whereas the coastal areas of Istria, the Kvarner littoral and the Dalmatia's interior have a moderately warm and humid climate with hot summers. The moderately warm and humid climate with warm summers prevails in the major part of Croatia, in the continental Pannonian region and the interior of Istria. Only the regions of Gorski kotar, Lika and the Dinaric Alps above altitude of 1200 m belong to the climate type D, subtype Df, a humid snowy forest climate.

The annual mean air temperature in the lowland area of northern Croatia is 10-12 ºC, at altitudes above 400 m it is under 10 ºC and in the mountains it is 3-4 ºC. In the coastal area it is 12-17 ºC. January is the coldest month on average, with the temperature in the Pannonian region ranging from 0 to -2 ºC. Along the Adriatic coast winters are milder; January temperatures are 4-6 ºC. In the north and east of Croatia average July temperatures are 20-22 ºC and on the Adriatic coast 23-26 ºC.

The least precipitation in Croatia is recorded in the open part of the central Adriatic (Palagruža, 304 mm) and in the eastern Slavonia and Baranja (Osijek, 650 mm). Central Croatia and the coastal zone have annual precipitation between 800 and 1,200 mm. The amount of precipitation in the Pannonian region decreases from the west towards the east. From the coast towards the inland the precipitation increases. Most of the precipitation is recorded on the coastal slopes and peaks of the Dinarides (Risnjak, 3,470 m), from Gorski Kotar in the northwest to the southern Velebit in the southeast.

Climate change in Croatia over the period 1961-2010 has been determined by trends in annual and seasonal mean air temperature, mean minimum and mean maximum temperature; in indices of temperature extremes; then in precipitation amounts and precipitation indices, as well as in dry and wet spells.

Temperature trends were calculated for the temperature deviations from the associated 1961-1990 means, and expressed in ºC per decade, while trends in indices of temperature extremes are expressed by number of days per decade. Trends in air temperature (mean, mean minimum and mean maximum temperature) in the last 50 years (1961-2010) show warming all over Croatia. Annual temperature trends are positive and significant, and the changes are higher on the mainland than at the coast and the Dalmatian hinterland. The maximum temperature values were exposed to the greatest changes with the highest frequency of trends in the class of 0.3-0.4 ºC per decade, while trends in the mean and the mean minimum air temperatures mostly range between 0.2 and 0.3 ºC per decade. The overall positive trend in the annual air temperatures comes are mainly caused by the significant positive summer trends, while the trends for the winter and spring gave almost equal contribution to the increasing trends of mean maximum temperature. Autumn temperatures are subjected to small changes and they are mostly positive. Observed warming can be seen in all indices of temperature extremes, with positive trends of warm temperature indices (warm days and nights as well as warm spell duration index) and with the negative trends of cold temperature indices (cold days and nights and cold spell duration index). At most stations, the increase of the number of summer days ranges between 2 and 8 days per decade. Increase in the number of warm days most often accounted 6-10 days and warm nights even 8-12 days per decade. The duration of warm spells at most stations has increased for 4-6 days. Cold days and cold nights have the most significant trends, and their number at most stations is reduced for up to 4 days per decade. The positive temperature trends in the continental part of Croatia is mostly due to winter trends, while on the Adriatic to summer trends.

Annual amounts of precipitation show a downward trend in five parts of Croatia. It is more expressed over the Adriatic, than in the inland. During the recent 50-year period (1961-2010) the annual precipitation amounts experienced prevailing insignificant trends that are increasing in the eastern lowland and decreasing elsewhere. The statistically significant decreases are found for the stations in the mountainous region of Gorski kotar and in the Istria peninsula (northern Adriatic) as well as in the southern coastal region. Expressed per decade as percentages of the respective average values, these decreases range between -7% and -2%. Annual negative trends are mainly caused by decreasing trends in summer amounts, which are found to be statistically significant at most stations in the mountainous region and at some stations along the Adriatic and its hinterland. The statistical significance of the annual negative trend in Istria and Gorski kotar is also influenced by spring negative tendencies (from -8% to -5%). Positive annual trends in eastern lowland are primarily caused by the significant increasing trends in autumn and to a less extent in spring and summer. Summer precipitation shows a clear prominence of negative trend estimates all over the country and there is a number of stations for which this decrease is statistically significant, with the relative change between -11% and -6% per decade. In autumn, the trends are weak and mixed in sign, except in the eastern lowland where some locations show significant increasing trend in precipitation (8% to 11%). In spring results suggest no signal in the southern and eastern part of the country, while a negative tendency seems to affect the rest of the country, significantly only in Istria and Gorski kotar (-5% to -7%). During winter season, precipitation trends are not significant and they range between -11% and 8%. They are mostly negative at the southern and eastern parts as well as at Istria peninsula. Regional distribution of trends in precipitation indices, that define magnitude and frequency of precipitation extremes, shows complex structure.

Climate and climate change simulations for future on national level

Climate changes in Croatia are based on analysis done with model RegCM for two 30-year periods 2011 to 2040 and 2041 to 2070 for the IPCC A2 scenario. It is a regional climate model which, for climate change simulations, takes initial and boundary conditions from joint global climate model ECHAM5/MPI-OM. As reference climate period 1961-1990 was taken.

In the first period of future climate (2011-2040) in Croatia during winter a temperature increase of 0.6 °C is expected, and 1 °C during summer. In the second period of future climate (2041-2070) the expected increase amplitude in Croatia during winter is up to 2 °C in continental part and up to 1.6 °C in the south, and during summer up to 2.4 °C in the continental Croatia, and up to 3 °C in the coastal zone.

Changes in precipitation amounts in the near future (2011-2040) are very small and limited to smaller areas, and they vary in the sign depending of the season. The biggest change in precipitation, according to A2 scenario, can be expected in the Adriatic in autumn when RegCM indicates a decrease of precipitation with a maximum of approximately 45-50 mm in the southern Adriatic. However, this reduction of autumn precipitation amount is not statistically significant. In the second period of future climate (2041-2070) precipitation changes in Croatia are somewhat more expressed. During summer in the mountainous Croatia and in the coastal area a decrease in precipitation is expected. Reductions reach value of 45-50 mm and they are statistically significant. During winter an increase in precipitation in north-western Croatia and on the Adriatic can be expected, however that increase is not statistically significant.

For climate change assessment for the period up to the year 2100 in the framework of project CCWaterS, with mentioned RegCM, model Aladin was also used and model Promes where climate change projections are made until the year 2050.

Climate and climate change over the Croatian Adriatic

The average climate conditions shown and discussed here for the Croatian Adriatic in the reference climate period 1961-1990 are based on the data from the Climate Atlas of Croatia and on an analysis of the climate conditions over the Adriatic catchments regions. In this overview the average annual cycle of air temperature and precipitation is discussed and their seasonality, that would be used to calculate the water balance components, is emphasised. The data series are obtained from the Croatian Meteorological and Hydrological Service (DHMZ), where a routine operational quality control is carried out. The long-term changes in the observed annual and seasonal air temperature and precipitation are analysed for the 1961-2010 period. Trends are estimated by the Kendall's tau method and the non-parametric Mann-Kendall test was applied to determine statistical significance of trends at the 95% confidence level.

The analysed projections of the 21st century air temperature and precipitation are obtained from various RCMs that participated in the EU FP6 project ENSEMBLES using the IPCC A1B scenario of the greenhouse gases concentrations.
From the ENSEMBLES database, 18 combinations of various RCMs, all available at a 25-km horizontal resolution, and forced by various GCMs are analysed. The RCMs results of the future climate are discussed only for the period 2011-2040 (denoted as P1). The climate change in the future period is computed as the differences between the 30-year means of the P1 and P0 periods. Additionally, the agreement in the sign of the projected changes among different RCMs is determined.

Climate and climate change characteristics based on observed data for Croatian Adriatic

Climate of the Croatian Adriatic is primarily determined by circulation of the northern mid-latitudes weather systems with frequent and often intense changes of the local weather during the most part of the year. In the summer, this area is influenced by the ridge of the Azorean high with prevailing dry and warm weather and with regular daily wind circulation from the sea and the night circulation down the hill slopes towards the sea. Local factors - the land/sea contrast and high and steep orography of the Dinarides - together with the north-Adriatic cyclogenetic effect, strongly affect climate of the Croatian Adriatic. In calm weather, which normally prevails during the cold part of the year and at night, the local geophysical conditions are dominant and relatively large differences in the values of meteorological parameters can occur even at nearby stations. Cyclonic activity, typical for winter, early spring and late autumn, affects cloudiness and precipitation regime of both coastal areas and the hinterland.
The Croatian Adriatic river catchments cover the coastal area and its hinterland, including the mountainous regions of Gorski kotar and Lika, where the mountainous climate is present. Over the Croatian Adriatic catchments, July is the hottest and January is the coldest month in the annual cycle of the mean monthly air temperature. Such annual cycle is under a strong influence of the sea and has typically maritime characteristics with the autumn season being warmer than the spring. The effect of the sea on the climate of the Adriatic islands and in a wider coastal zone of Istria is manifested as a moderation of the minimum air temperature. However, in the mountainous areas of the coastal basin, due to strong winter radiative cooling, the minimum temperatures attain their lowest values, especially at the Lika plateau (-28.9ºC in Gospić) as well as in the interior of the Istrian peninsula (-18.7ºC in Pazin). The influence of the sea is also manifested in a reduction of the amplitude of the extreme temperatures on the Dalmatian islands (Lastovo: tmax=36.2ºC, tmin=-6.8ºC) and at the coast (Zadar: tmax=35.7ºC, tmin=-9.1ºC).

Away from the coast, in the karst fields of the Dalmatian hinterland, the impacts of winter cooling and of summer warming are, on the other hand, enhanced, resulting in higher absolute maxima and lower absolute minima (e.g. Sinj: tmax=39.3ºC, tmin=-22.2ºC) than at the coast.

The entire area has a maritime precipitation regime with larger amounts of precipitation in the cold (October to March) than in the warm part (April to September) of the year, and with the minimum in summer. The maximum in the precipitation annual cycle occurs in November (on the Dalmatian islands in December), but with different amplitudes at different locations (Pazin: 134 mm, Opuzen: 180 mm, Hvar: 91 mm). The monthly minimum appears in July (Pazin: 72 mm, Opuzen: 36 mm, Hvar: 25 mm). Interannual variability of monthly amounts is largest in October in Primorje-Istrian basin (70-90% of the total precipitation for that month) and in the Dalmatian hinterland (about 80%), and in July in the southern part of the Croatian Adriatic - on the Dalmatian islands and in the Neretva River valley (120%) and in the Dubrovnik area (100%). The least variable (most stable) on the year-to-year basis are the precipitation amounts in April (31-62%) over the whole area of the Adriatic catchments. The annual precipitation totals are highest in the Primorje-Istrian catchments. The amounts decrease from the coast towards the outer islands and from the interior of the Istrian Peninsula. Over the Dalmatian basin, the largest annual amounts are found in the hinterland and increasing from the northwest to the southeast. The lowest amounts are at the Dalmatian islands and they increase from the outer islands towards the coast. Interannual variability of the annual precipitation amounts is smaller than that for monthly amounts.

Observed trends in the annual and seasonal quantities of climate parameters indicate their temporal change over the area of interest. Temperature trends are calculated for deviations (anomalies) of air temperature from the 1961-1990 mean and expressed in °C per decade. In three seasons, summer, spring and winter, trends in the mean air temperature show warming all over Croatian Adriatic while trends in autumn are of the mixed sign. The annual temperature trends are all positive and significant, and they range mostly between 0.2°C and 0.3°C per decade.

During the recent 50-year period (1961-2010) the prevailing trends in the annual precipitation amounts indicate a decrease in precipitation which, at most stations, is statistically insignificant. The trend values go down to the 7% of the respective climate means. Generally, when negative trends are observed for the whole year, they are mainly caused by decreasing trends (drying) in the summer; the summer trends, in turn, are found to be statistically significant at most stations in the mountainous region and at some stations along the Adriatic and its hinterland. Annual and seasonal long-term precipitation trends for the period 1961-2010, expressed as absolute changes (in mm/decade), are calculated for five regions which belong to the Croatian Adriatic catchments. During the recent 50-year period, trends in the annual precipitation amounts are negative (indicating a reduction in precipitation) in all regions; only in Gorski kotar this trend is statistically significant (-50.6 mm/10yrs). In spring and summer, drying occurred in all regions, but it is statistically significant only during summer in three regions. In other seasons a decreasing trend prevails but it is not statistically significant.

Climate and climate change simulations for future for Croatian Adriatic

The RCM simulations from the ENSEMBLES project indicate for the P1 period an increase of 2m air temperature (*T2m*) in all seasons with the amplitude typically between 1°C and 1.5°C. A somewhat higher warming, between 1.5°C and 1.75°C, is projected over central and southern Dalmatia during the summer. For the P1 period, more than the two-thirds of all ENSEMBLES models agree in the sign of projected changes (warming) when compared to the P0 period. A weak decrease of the mean *T2m* amounting to -0.5°C may be possible in some months during P1, mostly as the consequence of internal variability of the climate system. However, in the rest of the 21st century and for the IPCC A1B scenario all ENSEMBLES simulations indicate only warming, on both seasonal and monthly timescales.

In the first part of the 21st century (P1), the total precipitation amount during winter is projected to increase over parts of the Kvarner region with the amplitude between approximately 5% and 15% relative to the reference period P0, 1961-1990. The sign of these changes agrees in at least the two thirds of all models. For the summer season in the same period P1, the total precipitation amount is projected to decrease from approximately -5% down to -15% over large parts of the Dalmatian hinterland, the mountainous region of Gorski kotar and the Lika highlands. This decrease in precipitation is also found in at least the two-thirds of the models. A reduction of precipitation of the same amplitude is projected for the southern Croatia during spring while during autumn the projected changes are almost negligible, between approximately -5% and +5%.

2.8. Bosnia and Herzegovina

From Annex 1 Report 1.7.:

Climate and climate change characteristics based on observed data

Bosnia and Herzegovina has several climate types: the temperate continental climate type, which is represented mostly in the northern and central parts of BiH; the sub-mountainous and mountainous type (over 1000 m); and the Adriatic (Mediterranean) and modified Adriatic climate type, which represented in coastal area of Neum and includes the Herzegovinian lowlands. The climate of Bosnia and Herzegovina therefore varies from a temperate continental climate in the northern Pannonia lowlands along the Sava River and in the foothill zone, to an alpine climate in the mountain regions, and a Mediterranean climate in the coastal and lowland areas of the Herzegovina region in the south and southeast. In the northern part of the country, air temperature generally ranges between -1 and -2°C in January and between 18 and 20°C in July. In highlands with the altitude above 1000 m, the average temperature ranges from -4 to -7°C in January to 9 to to 14°C in July. On the Adriatic coast and in the lowland regions of Herzegovina, air temperature ranges from 3 to 9°C in January to 22 to 25°C in July (for the period 1961-1990). Extremes of -41.8°C (low) and 42.2°C (high) have been recorded.

The lowland area of northern BiH has a mean annual temperature of between 10°C and 12°C, and in areas above 500 m the temperature is below 10°C. Mean annual air temperature in the coastal area ranges between 12°C and 17°C. In the period 1981-2010, an increase in air temperature was recorded in the entire territory of Bosnia and Herzegovina. The highest increase of approximately 1°C is recorded during summer and winter period.

Annual precipitation amounts range from 800 mm in the north along the Sava River to 2000 mm in the central and south-eastern mountainous regions of the country (period 1961-1990). In the continental part of BiH belonging to the Danube River catchment area, a major part of annual precipitation occurs in the warmer half of the year, reaching its maximum in June. The central and southern part of the country with numerous mountains and narrow coastal regions is characterized by a maritime pluviometric regime under the influence of the Mediterranean Sea, so the monthly maximum amounts of precipitation are reached in late autumn and at the beginning of the winter, mostly in November and December. During the period 1981-2010, major parts of the Herzegovinian lowlands saw a decrease in annual precipitation, whereas the majority of mountainous meteorological stations recorded an increase in precipitation. Compared to 1961-1990, this period had a more uneven distribution of precipitation throughout, which was one of the main factors causing more frequent droughts and flooding.

The duration of sunshine decreases from the sea towards the mainland and at higher altitudes. Annual duration of sunshine in the central mountainous area is 1700-1900 hours, as a consequence of the above average cloudiest conditions (60-70%). Due to frequent fogs during the cold part of the year, solar irradiation inland is lower than at the same altitudes in the coastal area. In southern regions, there are 1900-2300 hours of sunshine (Mostar = 2285 hours). In northern Bosnia and Herzegovina, there are 1800-2000 hours of sunshine, more in the eastern part than in the western part. Cloudiness declines from the west to the east.

Average annual precipitation in BiH is about 1,250 mm, which given that the surface area of BiH is 51,209 km^2 amounts to 64 x 109 m^3 of water, or 2,030 m^3/s. The outflow from the territory of BiH is 1,155 m^3/s, or 57% of total precipitation. However, these volumes of water are not evenly distributed, either spatially or temporally. For example, the average annual outflow from the Sava River basin, which has a surface area of 38,719 km^2 (75.7%) in BiH, amounts to 722 m^3/s, or 62.5%, while the outflow from the Adriatic Sea basin, which has a surface area of 12,410 km^2 (24.3%) in BiH, is 433 m^3/s, or 37.5%.

Observed climate changes are estimated by analyses of available data from Hydrometorogical Institute of FBiH and Republic Hydrometeorogical Institute of RS. The data was colected from 22 difrent meteorological stations from period 1961-1990 and 1981-2010.

Studies of temperature change for the period 1961-2010 indicate that temperatures have increased in all areas of the country. A comparative seasonal analysis for 1981-2010 and 1961- 1990 showed that the largest increases in average temperature during the summer months were observed in southern (1.2°C) and in central areas (0.8°C), while the largest increase in spring and winter temperatures was recorded in north-central areas (0.7°C). The lowest increase in autumn temperatures ranges from 0.1 to 0.3°C. The increase in annual air temperature ranges from 0.4 to 0.8°C, while the increase in air temperature during the growing season (April – September) even reaches 1.0°C. However, increases in air temperature during the last decade are even more pronounced.

During 1961–2010, much of the territory of Bosnia and Herzegovina showed a slightly increasing trend in annual precipitation. The largest increase in annual precipitation occurred in the central mountain areas (Bjelašnica and Sokolac) and near Doboj, while the largest deficit was recorded in the south (Mostar and Bileća). The largest decrease in precipitation was during the spring and summer seasons, in the region of Herzegovina (up to 20%). The autumn season saw the largest increase in precipitation, particularly in northern and central areas. Although the level of annual precipitation has not significantly changed, the pluviometric regime, i.e. annual distribution, has been greatly altered. The number of days with rainfall above 1 mm decreased across the entire country, while the percentage of annual precipitation due to rainfall above 95^{th} percentile during 1961-2010 was increasing. In other words, although the level of annual precipitation has not significantly changed, a decrease in number of days with rainfall above 1.0 mm and an increase in the number of days with intense rain events has significantly distorted the pluviometric regime. Pronounced variability in the annual rainfall regime and temperature increases are key factors in the occurrence of more frequent and intense droughts in Bosnia and Herzegovina.

There is an evident increasing trend in number of “hot” days (tropical days with a maximum daily air temperature above 30°C) across almost the entire territory. Most of these days are recorded in the north (Posavina), central parts and in Podrinje (Višegrad). In the lowland area of the Herzegovina region (Mostar), there is a slight increase of a number of tropical days. However, during the last 5 years (2007 – 2012), there is an increased occurrence of extremely high temperatures (over 40 °C). In other words, although there is no significant increase in number of tropical days, there is an increased number of days with temperatures over 40 °C.

Maximum daily precipitation during 1961-2011 was as follows: Banja Luka - 156 mm, Mostar 127 mm, and Sarajevo - 118 mm. Average maximum precipitation for the same period was: Banja Luka - 54 mm, Mostar - 79 mm, and Sarajevo - 50 mm. The return period for these values is approximately 1000 years. Even though the probability of increasing the absolute maximum daily precipitation is low, the increase in the number of days with rainfall above 10.0 mm speaks to the seriousness of the problem.

Recent drastical climate changes showed some extreme weather conditions in teritory of Bosnia and Herzegovina. These conditions were mostly extreme dry periods and extreme periods of flooding. Extreme dry periods were recorded mostly in southern part of the Bosnia and Herzegovina where the test areas of project DRINKADRIA are situated.

Climate and climate change simulations for future

Bosnia and Herzegovina developed climate models and a selection of adequate future climate change scenarios. Results of the coupled regional climate was made in model EBU-POM from future climate change experiments, received by the method of dynamic downscaling of results from two global climate change models of atmosphere and ocean, SINTEX-G and ECHAM5. The focus was on results from two IPCC scenarios on climate change: the SRES A1 B and A2 scenarios. Model results were analyzed for the time series 2001- 2030 and 2071-2100. Changes in two basic ground meteorological parameters: air temperature at 2 meters and accumulated precipitation are analysed in reference to mean values from the so-called base (standard) period of 1961-1990.

According to climate model A1 B Scenario for period 2001-2030 the mean seasonal temperature changes for the thirty-year period is expected to range from +0,6 to +1,4 °C. This depends from the region of BiH and the biggest temperature changes during summer months will be +1,4 °C in northern parts and +1,1 °C in souther parts of BiH where the project test areas are situated. During the spring months temperatures will rise for approximettly +0,8 to +0,9 °C, during the autumn months range of average temperatures will rise from +0,6 to +0,9 °C. Increasing of temperatures will affect the precipitation changes for wich model showed positive and negative variations. Positive changes of precipitations will be seen during spring months from +5% and during summer months even up to +15%. This is just for the north-east part of the BiH while in the other parts of the BiH with ephasis on southern parts where the project test areas is situated showed the biggest deficit in precipitation raging even up to -20%.

Results in A1 B scenario during the period from 2071 to 2100 showed that distribution of temperature parameter remains the same as in observed period 2001-2030 but with greater magnitudes in changes. Temperature changes in this period ranges from +1,8 to +3,6 °C with biggest values in summer months. During the winter and autumn months temperature will rise up to +2,4 °C and during the spring months up to +2,6 °C. Increasing of temperatures will take affect the precipitation changes in this period which will be characterized in positive percipitation anomaly. Larger negative anomalies are predicted in winter and autumn months with changes from -10% to -50%. Spring months are characterized with value up to -10% while the precipitation defficit in summer months will be greather in southern parts of the country raging up to –30%.

In the A2 scenario for the period 2071-2100, the expected increase in temperature in the entire territory of BiH ranges from +2.4 to +4.8°C. The biggest increase will be during the summer months with values above +4.8°C. During the winter months, the maximum predicted change is approximately +3.6°C. For the spring months period it is predicted values ranging from +3.4 to +3.6°C while during the autumn months the changes are again bigger in the western part of the country, ranging from +2.8 to +3°C.

The A2 scenario has a negative anomaly in terms of accumulated precipitation across the entire territory, with the exception of the southeastern regions, the winter months season has a positive anomaly across almost the entire territory, ranging from 0 to +30%. The biggest changes in this scenario are predicted during the summer season, with values of -50%. During the spring and autumn season, anomalies range from -30 to 0%.

The climate change models show that mean seasonal temperature increasing averaging +1°C by 2030 compared to the period of 1961-1990 over the whole territory of BiH. Largest temperature rising will take up to +1,4 °C during summer season. A2 scenario showed rapid temperature increasing up to +4°C yearly with maximum during summer season +4,8°C. Model show unequal precipitation changes but negative precipitation is expected in whole territory of BiH even up to 50% comparing to the period from 1961 to 1990 during summer season.

2.9. Montenegro

From Annex 1 Report 1.8.:

Climate and climate change characteristics based on observed data

Besides latitude and altitude, the climate in Montenegro is determined by the presence of large bodies of water (the Adriatic Sea, Lake Skadar), the sea entering deeply into the land (the Bay of Kotor), moderately high mountainous hinterland near the coast (Orjen, Lovćen, Rumija), Ulcinj field in the far southeast and the mountainous massif of Durmitor, Bjelasica and Prokletije.

Montenegro is located in the central part of the warm temperate zone of the northern latitudes. Large bodies of water, height and direction of the coastal mountains and the relief influence both locally and regionally on the climate, creating at a small space big differences between coastal climate and climate of high mountainous region with numerous transitional forms of local climate.

The southern part of Montenegro and Zeta-Bjelopavlići plain have Mediterranean climate with long, hot and dry summers and relatively mild and rainy winters. The central and northern parts of Montenegro have some characteristics of mountain climate, but the influence of the Mediterranean Sea is also evident. The far north of Montenegro has a continental climate characterized by low annual precipitation evenly distributed over all months. In the mountainous areas in the north summers are relatively cool and humid, and winters are with low temperatures, which rapidly decrease with elevation. Characteristic winds of Montenegro are the bora and sirocco.

The last decade of the twentieth century was warmer in relation to a multi-year series of measurements (since 1949 until the present day). The average annual air temperature ranges from 4.6 °C in the north (Žabljak) to 15.8 °C in the south.

The year 2003 was the warmest year in Montenegro, when a tropical period of 100 tropical days (with maximum daily temperature greater than or equal to 30 °C) was recorded in Podgorica. The highest daily temperature of 44.8 °C was recorded in August 2007 in Podgorica, while the lowest daily temperature of -32 °C was measured in Rožaje, in the eastern part of Montenegro, in January 1985.

Average, annual number of days with precipitation is about 115-130 on the coast or up to 172 in the north. The rainiest months on average have 13-17 days, and the driest ones 4-10 rainy days. The number of days with more abundant daily rainfall (over 10 mm) ranges from 25 (Pljevlja) to 59 (Kolašin). However, the largest number of days with heavy precipitation is recorded in Cetinje – 74 days. On the slopes Orjen, in the village Crkvice precipitation may even reach 7,000 mm in record years, which makes it the rainiest place in Europe. The snow cover is formed at the altitudes above 400 meters. A snow cover deeper than 30 cm can be found at the altitudes above 600 m, and even deeper than 50 cm at those above 800 m. An average number of days with a snow cover deeper than 50 cm is 76 days (Žabljak).

Monitoring and evaluation of climate shows that the climate is changing in Montenegro as a result of global climate changes as well as variability. The clearest indicators are: a significant increase in air temperature, an increase in sea surface temperature and medium sea level, changes in extreme weather and climate events. Given that climate changes are related to long-term sequential changes (increase or decrease) in mean state of the atmosphere, that is one of the clearest signals of climate changes in air temperature: changes in annual temperatures from 1951 to 2012; mean decade values of annual air temperature, mean values for the period 1961-1990, decade deviation (Δ) of climate normal.

On the basis of belonging to a certain type of climate, four representative municipalities in Montenegro (Žabljak, Pljevlja, Podgorica and Bar) were chosen also taking into consideration the quality of the data. It can be concluded that there was slightly colder weather during the decade of '71-'80;

- Changes to the warmer climate of the 90s (especially pronounced in the northern mountain region);
- 2001-2010 the warmest decade since the measurements began ('49 / '51)
- The biggest changes in the northern mountainous region of +1.4 °C and coastal region of +1.3 °C in period 2001-2010.

This part of the northern mountainous region at an altitude of about 1450 meters above sea level was interesting for the selection and overview of climate change due to major changes in annual temperature and the existence of Debeli namet i.e. a glacier located in Durmitor National Park whose research as a possible endangered system has been in the course. The variability has been more pronounced since the beginning of the 90s.

In the period 1991-2005, there was a statistically significant increase in mean precipitation in September compared to the climate normal (Podgorica, Kolašin). Exceptions are the mountainous areas above 1,000 m, where there is a weak trend of precipitation (Žabljak).

Generally, these changes indicate a change in precipitation regime that takes extreme character:

- decade 2001-2010 was at a record one by mean annual amount of rainfall after twenty years of continuous deficits;
- slightly higher amounts of rainfall were registered in 1971-1980 in the north mountainous region up to 1000 m above sea level and in the coastal region;
- 2010 was a record year by an annual amount of precipitation in the northern mountainous region of over 1000 meters above sea level and Zeta-Bjelopavlici region.

The annual amount of precipitation fluctuates around the normal and generally shows no tendency to increase or decrease. Exceptions are the north-eastern regions of Montenegro (Bijelo Polje) and the coast. In the northeast of the state, precipitation has been increased since 1949 (the correlation is good), while on the coast there is a trend of slight reductions in precipitation (correlation is small, i.e. 0.3).

Climate and climate change simulations for future

The scenario of climate change for the area of Montenegro was made with the assistance of the EBU-POM (Eta Belgrade University – The Princeton Ocean Model) climate models. It is a linked regional climate model, which is a system of two regional models, one for the atmosphere and one of the oceans.
The results of the regional climate model EBU-POM from the experiments of future climate change for Montenegrin territory are focused on the results of scenario A1B for the period 2001-2030 and 2071-2100 and scenario A2 for the period 2071-2010. The values of CO_2 concentration at the end of the twenty-first century for the A1B scenario are around 690 ppm, and for A2 scenario about 850 ppm, which represents approximately twice, i.e. 2.2 times higher value compared to the current observed value of 385 ppm.
The report focuses on two fundamental changes: surface meteorological parameters, temperature at 2 meters and accumulated rainfall. Changes in these parameters are shown in comparison to the average baseline period 1961-1990.
A model with four defined seasons (DJF - December, January, February, MAM - March, April, May, JJA - June, July, August, and SON - September, October, November) was made for the SRES A1B scenario for the change in temperature at 2 meters above the ground and accumulated precipitation. Mean anomalies were calculated for the period 2001-2030.
According to the results of the model seasonal changes in mean temperature during the observed period, 2001-2030, are moving in the range of 0.60°C to 1.3°C, depending on the season and the area of Montenegro. Except for the SON season, it is evident that the temperature changes are significantly greater in the northern, mountainous part of Montenegro, compared with smaller changes in the area near the Adriatic Sea. The biggest change is during the season JJA, with values of 1.3°C in the north and 1°C in coastal areas. For the season DJF changes in the coastal part are about 0.5°C, while in the northern part the temperature increases by 0.9°C. For the season MAM, changes are a bit larger than in DJF with a value of 0.8°C in the south to 1.1°C in the north. The SON season was characterized by almost the absence of differences in temperature change, going from south to north, with more or less steady change in the entire territory of about 0.7°C. Model results show negative and positive changes in precipitation, depending on the part of Montenegro and the season. Positive changes in precipitation and their increase can be seen for the season JJA, for the central area of Montenegro, and for the MAM season in parts bordering Bosnia and Herzegovina. These positive changes are very small, ranging up to 5%, compared to the value of the baseline period, 1961-1990. In other areas of Montenegro during the two seasons, DJF and MAM, model results show a

decrease in precipitation from -10% to 0%. The MAM season is characterized by deficient rainfall and the highest values of -20%, almost over the whole territory of Montenegro.

Results for scenario A1B for the period 2071-2100 for the past 30 years of the twenty-first century show that the spatial structure of changes of relevant parameters has been similar to the previously observed period 2001-2030, but with a greater magnitude of change. Again, the area along the Adriatic Sea has minor temperature changes compared to those in the northern mountainous region. This time temperature changes 2 meters above the ground range between 1.6°C and 3.4°C. The biggest changes are again recorded in the season JJA. Along the coastal area the temperature has increased by approximately 2.4°C, and in the northern mountainous region of the country these values are 3.4°C. During the winter season (DJF), there is a noticeable gradient from the south towards the north of the country, with a temperature increase of 1.6°C in the coastal area, and 2.6°C in the north. For the MAM season, these changes vary from 1.6°C to 2.6°C, though the area with a change of 2.6°C is much wider than in the previous period. Finally, for the SON season changes in the coastal region are about 1.6°C, and 2.4°C in the northern area along the border with Serbia.

During this period there is no season or area in Montenegro which is characterized by a positive anomaly of precipitation. For the DJF season in the central parts of Montenegro there is a negative anomaly of precipitation of -30%, while the northern and coastal parts have also a negative change but with values of up to -30%. The MAM season was characterized by a far more uniform deficit and values of about -10% in the whole territory. A significant deficit during the season JJA is evident in coastal areas, while in the central and northern parts negative anomalies are in the range of -20 to -15%. For the season SON, model results also show a significant decrease in precipitation from -30 to -50%.

The most significant changes in temperature according to the applied model were recorded for A2 scenario for the period 2071-2100, for the northern part of the country during summer period and they are 4.8°C. The greatest increase is during the JJA season in the mountainous region in the north, with values over 4.8° C. For this season, an increase in temperature of 3.4°C is foreseen in the coastal area. For the DJF season, temperature increase along the Adriatic coast is about 2.6°C, while this value in the northern parts is about 3.4°C. These values are a little higher during the MAM season, from 2.8°C to 3.6°C. Spatial distribution of changes is far more uniform during the SON season, in relation to other seasons, in the range of 2.6°C to 3°C. For this scenario, the south-north gradient in the amplitude of temperature change is again present.

During all seasons, except for DJF, a negative anomaly of accumulated rainfall over the entire territory of Montenegro is predicted for the A2 scenario. A positive anomaly in the range 5-10% will be recorded only in the north-western parts during the season DJF, while during the same season changes in other parts of the country will vary from -5% to -10%. The biggest changes according to this scenario are along the coast and during the JJA season, with a value of -50%. During this season an anomaly of -10% will occur in the northern parts. During the seasons of MAM and SON, the spatial distribution of anomalies is more uniform with a mean value of -20%.

The effect of a long-term climate changes was considered for the sensitive sectors such as: water resources, coastal areas, agriculture, forestry, biodiversity and public health. Predictions are made on the basis of climate scenarios A1B and A2 for Montenegro.

The analyses have shown that at about 90% of the country there is a deficit-reduction of annual precipitation that ranges up to 20% in certain areas. As water resources have a high degree of correlation with rainfall volumes and regime, the decrease in precipitation will generate changes in water resources. Changes in water resources are reflected in the significant amplitude and fluctuations, reduced capacity, a sudden increase in flood waters, and longer periods with reduced capacity.

According to the model of correlation between rainfall and the amount of flow, during the climate period 2071-2100, the trend of change in flow quantity on the example of the water resource of the Morača River through Podgorica will be reduced by 31% compared to the climatic normal for the period 1961-1990.

Considering the scenario for the changes in precipitation and temperature, a strong disturbance in the balance of water resources is expected to occur until 2100. Given that there is a high degree of correlation among the rainfall, flow volumes and yield, and in accordance with the expected climate scenarios envisaging different percentages of reduction in rainfall, ranging even up to 50% in some periods (scenario A2 for the period 2071-2100), it can be expected that an overall water balance (water potential) in certain areas will be reduced by as much as 50%. The changes in water resources will be determined by climate change, especially in the regime of precipitation, as follows: first, a reduction of overall water balance and secondly an increase in the amplitude of the hydrological cycles. Accordingly, in years with low overall water balance and with pronounced oscillations there will also be periods of severe deficits and those with an intensive surplus in rainfall. In this new situation, there will be pronounced dry and rainy periods. Flood waves will become more frequent due to an increased intensity of rainfall (not of the volumes, since for example the volumes shall remain within average monthly limits but the number of rainy days will be lower than it is normally the case) and a change in the type of precipitation. Specifically, during the cold months of the year, when precipitation is the largest in major river upper flows (which are mostly mountainous), rainfall usually occurs in the form of snow. Over the past twenty years, due to global warming and higher temperatures, there has been an absence of snow and rainfall, so that it happens that with the same volume of precipitation there is a lot more water in the lower courses of rivers, and an increased risk of flooding, only because a part of this water used to be deposited in the form of snow with a delayed discharge over a longer period of time, which is no longer the case. In accordance with the scenario A1B and a little more pessimistic scenario A2, which envisage an increase in temperature, it can be expected that the lack of snow, and thus the flood waves as well, will be more frequent and stronger.

2.10. Serbia

From Annex 1 Report 1.9.:

In the report, the selected general data for Republic of Serbia are presented. Since there is no test location in Republic of Serbia, all data and information presented apply to the whole territory.

Climate and climate change characteristics based on observed data

Serbia is landlocked country with diverse topography. The climate of Serbia is under the influences of the landmass of Eurasia and Atlantic Ocean and Mediterranean Sea. With mean January temperatures around 0 °C, and mean July temperatures around 22 °C In the northern part of the country, the climate is more continental, with cold winters, and hot, humid summers. In the south, summers and autumns are drier, and winters are relatively cold, with heavy inland snowfall in the mountains. Differences in elevation, proximity to the Adriatic Sea and large river basins, as well as exposure to the winds results in climate variations. Southern Serbia is subject to Mediterranean influences. However, the Dinaric Alps and other mountain ranges contribute to the cooling of most of the warm air masses. Winters are quite harsh in the Pešter plateau, because of the mountains, which encircle it. One of the climatic features of Serbia is Košava, a cold and very squally southeastern wind which starts in the Carpathian Mountains and follows the Danube northwest through the Iron Gate where it gains a jet effect and continues to Belgrade and can spread as far south as Niš. Generally speaking, mean annual air temperatures are more uniform than mean temperatures in singular months. Annual mean air temperatures in the North part of the Republic vary between 10 and 11.8 °C, in lower areas in the Central and South parts between 10 and 12 °C. Lower temperatures occur in hilly and mountainous regions. Mean annual temperatures linearly decline with increase of terrain elevation. Mean annual temperatures for the Republic are approximately as follows: on elevation of 300 m 11,4 °C; on 1000 m 7.3 °C and on 1700 m 3.3 °C. Therefore, vertical mean temperature gradient is approximately –0.6 °C / 100 m.
Precipitation is one of the most important climatological components. Average depth of precipitation on the territory of Republic of Serbia is 734 mm/year. Precipitation regime is very heterogeneous with respect to time and space due to the atmospheric processes and topographic characteristics. The Southwest parts of Kosovo belong to the Maritime precipitation regime (precipitation that occurs during cold half of a year (October-March) presents more than 50% of total annual rainfall). Other parts of the Republic have Continental regime (more that 50% of total annual rainfall occurs in warmer half of a year). Central and Eastern part of Kosovo belong to the transition zone that is characterized with influence of both mentioned regimes.

Total annual precipitation in the River Beli Drim watershed and particularly in its right tributaries (Pećka Bistrica, Erenik and others) is 1500 mm/year. Something smaller but also substantial precipitations occur in the watersheds of upper Ibar River, Plavska River and Lepenica River (more than 900 mm/year). In the central part of the Republic, total annual precipitation depths vary from 1000 mm/year (in mountainous regions) to 600 mm/year. There is a tendency toward decreasing of precipitation depths from the West to the East in the plain areas.

The majority of surface water in Serbia originates out of its territory, approximately 92% (162,5 billion m^3 /year) entering the country from the upstream countries. Domicile surface water resources are approximately 16 billion m^3 /year, e.g., 8%.

Groundwater is significant source for drinking water supply in Serbia, more precisely; over 70% of population and industry use it. More than half of groundwater is from alluvial aquifers, with 80-90% being infiltrated river water.

The period selected for observed data analysis in this report is from 1949 to 2006. This period is convenient because it is relatively long (58 years), data are available from numerous monitoring stations, and they exhibit a close similarity to estimated longterm temperature and precipitation trends.

To assess past temperature trend, 26 temperature stations were selected. It is observed based on analysis that the annual average temperature trend in Serbia was found to be about 0.6°C/100 years. The greatest increase was noted in mountainous regions and in the north of the country, and the smallest increase in the southeast of the country. The greatest increase has been recorded in the spring (some 1.5°C/100yrs), followed by the summer (1.0°C/100yrs) and winter (0.5°C/100yrs), while the autumn exhibited a negative trend of about -0.7°C/100yrs. If the seasons were assessed by calendar instead of groups of three months, the claim about the greatest T increase over the summer months would become quite questionable in Serbia. While all stations reported a significant temperature increase (trend) for daily maxima, the daily minima exhibited from no distinct trend to a negative trend in the southeastern part of the country (consistent with annual trends); in the remainder of the country it was positive but much lower than that of the daily maxima. Nearly all stations recorded a downward stochastic trend, indicating relative consistency of the described temperature trends.

To assess past precipitation trend, 34 precipitation stations were selected. The annual average precipitation trend in Serbia was found to be slightly negative. Findings from majority of GCM and RCM demonstrate decrease in average precipitation in Serbia, with more significant trend in eastern part of the country. According to results of trend evaluation in average precipitation data the lowest negative trend is from -5% to 0% /100 yrs in Central Serbia with gradual trend decrease in average precipitation in Eastern Serbia. These trend projections agree very well with observed data. To a large extent in line with the annual distribution of the precipitation trend, daily maxima exhibited an upward trend in the western and northern parts of the country (albeit with an upward stochastic trend, suggesting increasing unpredictability), while there was a downward trend of daily maxima in the southeastern part of the country, in parallel with a declining stochastic component.

Climate and climate change simulations for future

All global and regional climate models (RCMs) predict an increase in temperature and a decrease in precipitation in Serbia, with expected range from 1°C to 6°C/100 years, largely depending on the selected scenario and to a much lesser extent on the analyst. Annual precipitation predictions range from current levels (trend=0) to -25%/100 years. However, only a few of these models offer spatial (within Serbia) and temporal (yearlong) distributions. Each prediction is sensitive to assumption uncertainties and calculation imperfections. The quality of a prediction grows with increasing validation by recorded long-term trends. Since the first GCM the improvement of resolution is significant by the development of Regional Climate Models (RCM). Different RCM models are developed in Serbia .The most significant improvement is accomplished in last years within the Climate change centre of Hydrometeorological Service of Serbia in cooperation with the Faculty of Physics at the University of Belgrade. Climate change predictions developed by this centre, based on scenario A1B i A2, for near future 2001-2030 (referent period 1961-1990) show that the average temperature change at the anual basis is around +1°C, e.g., while changes in precipitation are between - 5% to ±5%.
For the long term predictions (2071-2100), based on both scenarios (A1B and A2) by the end of the 21st century change in the annual averege precipitation values are expected to be aproximatelly -15%, while for the temperatures there are differences in the predicted changes in average temperatures +2.5°C and +3.7°C, for A1B and A2, respectively.

2.11. Albania

From Annex 1 Report 1.10.:

Climate and climate change characteristics based on observed data

The Republic of Albania is located in southeastern Europe, in the western part of Balkan Peninsula facing the Adriatic Sea and the Ionian Sea. Its terrain is mountainous, where hilly and mountainous areas represent 77% of the country's territory. Climate of Albania is typically Mediterranean. It is characterized by mild winters with abundant precipitation and hot summers. Temperature values vary from 7 °C over the highest zones up to 15 °C on the coastal zone; in the south-west the temperatures even reach up to 16 °C. Annual mean maximum of the temperature varies from 11.3 °C in the mountainous areas up to 21.8 °C in the low and coastal zones while annual mean minimum temperature varies from 0.1 °C - 14.6 °C. The mean annual precipitation total over Albania is about 1485 mm/year. The highest precipitation is recorded in the Albanian Alps (2800-3000 mm/year), while the southeast part has lower precipitation (about 1000 mm/year). According to world bank report on "Adapting to Climate Change in Europe and Central Asia", in a regional context Albania is considered as one of the most risky countries in East Europe and Central Asia. This is because of the high exposure to extreme weather, high sensitivity combined with low adaptive capacity.

Considering the complexity of the different physical and geographical factors, the country is divided in four main climate areas (Field Mediterranean, Hilly Mediteranean, Pre-mountainos and Mountainous Area).

The mean annual precipitation total over Albania is about 1485 mm/year. However, the spatial distribution of precipitation varies a lot, depending on the physical and geographical features of the area. The Alps and the north-western part of the country are the areas that receive more precipitation compared to other parts of the country, and in the same time they represent one of the areas with high precipitation in Europe. The mean annual precipitation in the Alps is roughly 2000 mm/year, and due to the high altitude, a major part of precipitation in this area is in the form of snow. The Alps have recorded also the highest precipitation total with the annual values reach up to 3000 mm/year. The southeast mountainous zone is also one of the areas with high precipitation, where the annual values reach up to 2200 mm. The north-eastern part of the territory is characterized by low precipitation due to the continental climate. The average annual precipitation in the area is between 700 and 900 mm. The eastern part of the central region represents one of the regions with the least amount of precipitation, and the annual average values of precipitation range between 600 and 700 mm. The southeast part of the country receives the smaller amount of precipitation with the annual value up to 600 mm. The temperature values for the country range between 7°C in the highest altitudes up to 15°C in the coastal

zone. The Albanian Alps together with the eastern central mountainous area represent one of the coldest zones. The mean annual temperature in this area is around 7°C. Annual mean maximum air temperature varies from 11.3 °C in the mountainous areas up to 21.8 °C in the low and coastal zones. The annual mean minimum varies from –0.1°C in the mountainous areas up to 14.6°C in the low and coastal zones.
The central mountainous area is influenced by the cold continental air masses coming from the east as well as the cold air masses coming from the sea. As a result, the highest temperatures in this area are in the river valley of Shkumbin (14-15°C), Mat (12-14°C), Drini i Bardhe (12-13°C), Drini i Zi (11-12°C), etc. In the southern mountainous area, the warm air masses coming from the Mediterranean brings high annual temperatures. The Ionian coastal zone of this region is characterized generally speaking by high annual temperatures, varying from 7 to 18°C. The lowland coastal zone, is under the direct effect of the warm air masses coming from the sea, and in the same time is influenced by the latitude of Albania. As a result, despite of the high average annual temperature, the temperature varies a lot from 17°C in the south, up to 14°C in the north. The same temperature regime is present in the north-eastern part of the country, with the only difference that this area is affected also by the mountainous features of the area. The air temperature records measured in the meteorological stations of Shkoder and Tirana for the period 1931 - 2000 show an increase in the temperature by 1°C during the end of the first half of the 20th century. The third quarter of the 20th century is characterized by cooling of 0.6°C, while the rest of that period up to today, the climate has demonstrated an increase in temperature by 1.2°C.

Drini River Basin

The variability of climate can be also noticed in Drini River Basin. In general the annual mean temperature has increased by approximately 1.0°C for the entire zone. The precipitation in the Drini River Basin varies widely also from 910 mm in the eastern part (Kukës) to 2260 mm in Iballe, and the average precipitation is 1634 mm per year.
The data on precipitation for the period 1961-2000 show a slightly decreasing trend in the total precipitation. The highest amount of precipitation (66% of the total), is recorded during the cold months (October-March). The wettest months are November–December, and the driest are July-August.

Climate and climate change simulations for future

According to the climate scenarios for Albania, hotter and drier summers and drier autumns are likely to be expected. A dramatic increase in temperature (+4.0°C to +7.3°C) is projected for summer according to the high-resolution regional climate projections SRES A2. The projections show a decrease in annual precipitation and a drastic decrease in summer precipitation (~40%). Sea level rise of between 30–45 cm is projected by 2100 for the Adriatic Sea. The projected change in climate extremes shows more hot days and heat waves are very likely in almost the entire territory of Albania. There are likely to be more frequent and severe droughts with greater fire risk. An increase in the wind speed is expected for the 2080s. A decreased number of frost days (temperatures ≤ –5°C) in high altitudes is likely to occur. Owing to higher average temperatures in winter more precipitation is likely to fall in the form of rain rather than snow, and this will increase both soil moisture and run-off. Although total precipitation is expected to decrease, the number of days with heavy precipitation is likely to increase.

Temperature is expected to increase and precipitation to decrease, giving milder winters, warmer springs, hotter and drier summer and drier autumn.

The most common climate model RegCM which was used for climate predictions for the period 2011-2050. RegCM is a global climate model which, for climate change simulations, takes initial and boundary conditions from joint global climate model ECHAM5/MPI-OM. For climate change assessment for the period up to the year 2100 in the framework of project CCWaterS with mentioned RegCM model where climate change projections are made until the year 2100.

In the first period of future climate (2025-2049 vs 1980-2004) in Albania during winter a temperature increase of 3 °C is expected, and 4 °C during summer. In the second period of future climate (2050-2074 vs 1980-2004) the expected increase amplitude in Albania during winter is up to 4 °C and during summer up to 4.5 °C. In the third period of future climate (2071-2095 vs 1980-2004) the expected increase amplitude in Albania during winter is up to 6 °C and during summer up to 6.4 °C. In addition to a long term scenario there is a significiant increase of temperature specially in coming years.

Changes in precipitation amounts in the near future (2025-2049) are significiant small but they vary in the sign depending of the season. The biggest change in precipitation, according to first scenario, can be expected in the Adriatic in autumn, with a decrease of precipitation with a maximum of approximately 5-6 mm in the southern Adriatic. However, this reduction of autumn precipitation amount is not statistically significant. In the second period of future climate (2041-2070) precipitation changes in Albania are somewhat more expressed. During summer in the mountainous Albania and in the coastal area a decrease in precipitation is expected. Reductions reach value of 5-6 mm and they are statistically significant. During winter an increase in precipitation in north-western Albania and on the Adriatic can be expected, however that increase is not statistically significant. In the third period of future climate (2071-2095) precipitation changes in Albania are somewhat more expressed. In addition to long term scenario there is a significant decrease of precipitation specially in coming years.

Drought is expected during summer due to increased temperature (likely increase up to 5.6°C) and potential evaporation, not balanced by precipitation (reduction by 41%). Increasing temperatures will raise the probability of extreme events and higher intra-annual variability of minimum temperatures. Higher increase of daily minimum than maximum temperatures is likely to occur. More frequent and severe droughts with greater fire risk are likely. Decreased number of frost days (temperatures ≤ –5°C) in high altitudes is likely to occur. Expected decrease is 4–5 days, 9 days and 15 days by 2025, 2050 and 2100 respectively. Owing to higher average temperatures in winter more precipitation is likely to fall in the form of rain rather than snow, that will increase both soil moisture and run-off. Increase in total precipitation rate may induce greater risks of soil erosion, depending on the intensity of rain episodes. Increase in summer temperature is likely to result in increase in frequency and intensity of extreme weather events (heat waves). The number of days with the temperature ≥ 35°C is likely to increase by 1–2 days by 2025 and by 3–4 days by 2050 compared to 1951–2000 average.

2.12. Greece

From Annex 1 Report 1.11.:

Climate and climate change characteristics based on observed data on national level

Greece has a total surface area of 131,957 km^2 occupying the southernmost extension of the Balkan Peninsula.The mainland accounts for 80% of the land area, with the remaining 20% divided among nearly 3,000 islands. Greece has a Mediterranean climate, with mild and wet winters in the southern lowland and island regions and cold winters with strong snowfalls in the mountainous areas in the central and northern regions, and hot, dry summers. The mean temperature during summer (April to September) is approximately 24°C in Athens and southern Greece, while lower in the north. Generally, temperatures are higher in the southern part of the country. Except for a few thunderstorms, rainfall is rare from June to August, where sunny and dry days are mainly observed. The dry, hot weather is often relieved by a system of seasonal breezes. The mean annual temperature for the period 2001 – 2013, as measured at selected meteorological stations of the country, is higher in most of the stations compared to the mean annual temperature of the period 1991 – 2000 while the mean annual temperature for the period 1991 – 2000 is higher compared to these of the period 1961 – 1990.

Since the ‘90s Greece is experiencing an annual increase of temperature of about 0.4-0.6ºC, as to the mean values of 1961-1990. This increase is mostly due to a steady rise of temperature during summer period (from April to September). Winter temperatures seem to overcome the declining trend that has been observed in the past, showing a lot of fluctuations in the recent years. Various studies converge that in the recent years there is a significant reduction of the precipitation in the Greek Territory, especially during the 2nd half of the 20th century. This trend seems to be confirmed also in the recent years. Precipitation is decreasing more abruptly in the islands of the Ionian and Aegean Sea (Corfu, Rhodes, Mytilini, Irakleio) as well as in the Peloponnese (Kalamata). However, this trend becomes smoother in the cities of the mainland (Athens, Thessaloniki, Aleksandroupoli) and the decrease could be even characterised as insignificant in Larissa, where the precipitation height shows a lot of fluctuations in the period under examination. As regards to the sea level increase in some stations the sea level shows intense fluctuations (Irakleio, Pireus, Rhodes), in a way that no safe conclusion could be conducted. On the contrary, the trend of the time series in Thessaloniki, Aleksandroupoli and Kalamata is much smoother, indicating an overall rise of the sea level in the recent years. The frequency of extreme events has significantly increased in the last two decades. Heat waves are happening every single year since 1997, although duration days are not as high as in the years 1997-2001. In particular in summer of 2007 Greece experienced an all record hot summer which, in combination with a prolonged dry period, led to the catastrophic forest fires causing the death of 70 people and the destruction of properties. Almost quite as interesting is the trend of the cold waves duration index: although there has been a period of almost 30 years from the mid ‘50s, since 1987 extreme cold waves seem to be more frequent than in the beginning of the century, causing problems in transportation, communication and electric power provision.

The climate in Greece is typical of the Mediterranean climate: mild and rainy winters, relatively warm and dry summers with, generally, long sunshine duration almost all the year. A great variety of climate subtypes, always in the Mediterranean climate frame, are encountered in several regions, due to the influence of topography (great mountain chains along the central part and other mountainous bodies) on the air coming from the moisture sources of the central Mediterranean Sea. As a result, the dry climate of Attiki (the great area of capital, Athens) and of the east part of Greece in general, changes significantly towards a wet one in North and West Greece.

In terms of climatology, the year can be broadly divided mainly into two seasons. The cold and rainy period lasting from the mid of October until the end of March, and the warm and non-rain season lasting from April until September. During the first period the coldest months are January and February, with a mean minimum temperature ranging between 5 to 10 ºC near the coasts and 0–5 ºC over mainland areas, with lower values (generally below freezing) over the northern part of the country. As regards to the summer period, the warmest days usually include the last days of July up to the first week of August, when the typical mean maximum temperature lies in the range of 29 and 35 ºC. During the warm period the high temperatures are dampened from the fresh sea breezes in the coastal areas of the country and from the north winds blowing mainly in Aegean, well known as ‘Etesian’.

Various studies converge that in the recent years there is a significant reduction of the precipitation in the Greek Territory, especially during the 2nd half of the 20th century. This trend seems to be confirmed also in the recent years. It is found that precipitation is decreasing more abruptly in the islands of the Ionian and Aegean Sea (Corfu, Rhodes, Mytilini, Irakleio).

The frequency of extreme events has significantly increased in the last two decades. Also, according to extreme events reports of the Hellenic National Meteorological Service, floods have been reported (due to heavy storms) in many cities of the mainland and the islands, having destructive effects on agriculture, infrastructure and transportation.

In Ionian Islands region

The region of Ionian Islands is situated in the Western part of Greece and constitutes one of the 13 Greek regions. The Ionian Islands include the following main islands: Corfu, Kefallonia, Zakynthos, Lefkada. As Greece implements the Water Framework Directive 2000/60/EC, the country is divided in 14 Water Districts. The Ionian Islands belong to

different Water Districts. The island of Corfu belongs to the Water District of Ipiros.
The climate in Corfu is the maritime Mediterranean one. The average annual temperature ranges from 10 to 18 °C (in the coastal and island areas). The warmest month is August and the coldest ones are January and February. The average precipitation level of the water district ranges from 1,000 to 1,200 mm in the coastal areas. The number of rainy days annualy range from 70 to 120 and it gets greater in the coastal areas compared to the water district continental areas. During 20 years (1980-2001) the precipitation shows an unstable fluctuation and there is an increase during 1985-86, 1990-91, 1994-95 and 1997-99.
Data for Kefalonia are provided by the meteorological station in Argostoli for 1955-1997. According to the RBMP of Northern Peloponnisos the precipitation in the basin is almost 800 mm annualy in Kefalonia.
The precipitation in the basin is 700 mm in Zakynthos. The more wet period is October to March and the most wet month is December. The most dry month is June. The average annual evapotranspiration is estimated in 489 mm.

Climate and climate change simulations for future

Current climate change has been estimated to account for a temperature increase of about 1ºC (ground surface temperature) in the last 500 years and of 0.76ºC in the last 100 years. Temperatures in the second half of the 20th century were, as estimated, very likely to have been higher than during any other 50-year period in the last 500 years, and likely the highest in the past 1300 years. The regional warming will be gradual, both of daytime maximum (TX) and nighttime maximum (TN), ranging from 1°C to 3°C in the near-future (2010–2039), to 3–5°C in the mid-century period (2040–2069) and 3.5–7°C by the end of the century (2070–2099). In each period, this warming is more spatially uniform for winter TN, while for TX it is most pronounced at latitudes north of 36°–38°N (reaching 6–7°C in the Balkans, Turkey and the Caucasus by 2070–2099) and weaker in the southern EMME (~3.5°C).
The severity of the climate change impact is more likely to be associated with changes in the frequency of extreme weather events than with a drawn-out ‘average’ climate evolution, given that, in the case of extreme events, a simple change in mean value above a critical threshold can bring about a disproportionate, non-linear impact.
The climate model RACMO2, developed by the Royal Meteorological Institute of the Netherlands (KNMI), was used with a horizontal resolution of 0.25° (~25 km). These datasets cover a 30-year reference period, 1961-1990, for the current climate, and two future periods, 2021-2050 and 2071-2100, for the study of climate change using Scenario A1B of the IPCC. For each of Greece’s 13 climate zones, the change in the relevant climate indices was computed between each future period (2021-2050 and 2071-2100) and the reference period (1961-1990). Scenario A1B is a mid-line scenario in terms of

carbon dioxide emissions and economic growth. The first future period, 2021-2050, was chosen with the specific needs of policy-makers in mind, in order to assist them with nearer-term planning, whereas the second period, 2071-2100, serves to underscore the extent of the changes toward the end of the 21st century. Using the data from this model, it was possible to study the variation in climate parameters and indices between the reference period and each one of the two future periods, and to determine climate change for each of Greece's 13 climate zones.

Minimum winter temperatures in all of Greece's regions will be ~1.5ºC higher in 2021-2050 and ~3.5ºC higher in 2071-2100, than in the reference period 1961-1990. These results concur with large-scale findings, which have recorded a significant upward trend in minimum temperatures over the past few decades. The warming trend will be more pronounced in the more mountainous areas, especially in the mountain ranges of Pindos and of Northern Greece, where it is projected to reach 2ºC in 2021-2050 and 4ºC in 2071-2100). The increase in this parameter is likely to have an impact on forests, presently adapted to colder weather conditions. If the conditions become prohibitive, certain categories of forests (e.g. fir) would have to shift to higher altitudes. The increase in mean maximum summer temperatures in the period 2021-2050 will be greater than that of the winter minimums and will exceed 1.5ºC and in some cases reach as much as 2.5ºC. In the period 2071-2100, the increase in mean maximum summer temperatures may be as much as 5ºC. Most affected will be the continental inland regions, situated far from the cooling effects of the sea, whereas regions with strong sea breezes (Crete, Aegean islands) will experience a significantly smaller variation in maximum summer temperatures. The projected variation in the number of days with maximum temperatures above 35ºC is expected to have a significant impact on human discomfort, especially in urban areas, as the number of hot days countrywide is clearly projected to increase.

The most noticeable changes are projected for the low-lying inland regions of Central Greece, Thessaly, the Southern Peloponnese as well as Central Macedonia, where up to 20 additional very warm days are expected per year in 2021-2050 and up to 40 in 2071-2100, relative to the reference period 1961-1990. The change is expected to be somewhat milder in Crete and Attica, where the number of additional very warm days per year should not exceed 15 in 2021-2050 and 30 in 2071-2100, and milder yet in the Aegean and the Ionian islands, which will count 10 additional very warm days per year in 2021-2050 and 15 additional ones in 2071-2100, due to the proximity of the sea and the tempering effect of sea breezes. Another temperature-related and significant parameter is the change in the annual number of warm nights. Nights are defined as warm (or tropical) when the minimum temperature does not fall below 20ºC. This parameter is closely associated with human health, as a tropical night following an extremely hot day can increase human discomfort. The annual number of tropical nights is projected to increase almost everywhere in Greece, but substantially more so in the coastal and island regions than in the continental mainland regions. Crete, the coastal regions of Eastern Greece and the

Aegean islands are expected to have 40 additional warm nights per year in 2021-2050 and 80 additional warm nights per year in 2071-2100. In Western Greece and Eastern Macedonia-Thrace, however, the increase in the annual number of warm nights will be less than 30 in 2021-2050 and 70 in 2071-2100, with even smaller increases projected for Western Macedonia (15 or less additional warm nights per year in 2021-2050 and 30 or less in 2071-2100).

Together with the projected decrease in total annual rainfall extreme precipitation events will increase in intensity, thereby raising the flood risk. Maximum consecutive 3-day precipitation period during 2021-2050 will remain essentially unchanged, relative to the reference period 1961-1990, in regions like Western Greece, Eastern Macedonia-Thrace and Crete, but will increase significantly in others. In the eastern continental regions, in particular, maximum consecutive 3-day precipitation is projected to increase by 20%. These contrasts become even more pronounced toward the end of the 21st century, with the amount of extreme rainfall projected to decrease by 10-20% in regions of Western Greece and Thrace, but to increase by 30% in the Eastern Central Greece and the NW Macedonia. Small variations are projected for the rest of the country.

Projections regarding the variation in the maximum duration of dry spells, i.e. consecutive dry days, defined as days with no or less than 1 mm precipitation show that the length of dry spells will clearly increase. The smallest variations in dry spell length are projected for Greece's western regions in 2021-2050 (less than 10 more consecutive dry days) and for Western and Northern Greece in 2071-2100 (less than 20 more consecutive dry days). The largest increases in dry spell length are projected for the eastern continental regions (Eastern Central Greece, the Eastern Peloponnese and Euboia) and Northern Crete, which will have more than 20 additional consecutive dry days in 2021-2050 and as many as 40 more consecutive dry days in 2071-2100.

The number of frost days per year is an important parameter for agricultural regions, especially those where frost-sensitive crops, like citrus fruit, are grown. The number of frost days per year is projected to decrease in Macedonia and Thrace by 15 in 2021-2050 and by 40 in 2071-2100, and in the continental regions of Thessaly and the Peloponnese by 10 to 15 in 2021-2050 and by 25 in 2071-2100. Smaller decreases are projected for the rest of Greece, mainly because of the small number of frost days that these regions have even today.

In addition to the number of frost days, the length of the growing season was also examined, defined as the period favorable to plant and crop growth between the last spring frost and the first autumn frost. The observable lengthening can be attributed to the earlier occurrence of the last spring frost and to the later occurrence of the first autumn frost. The largest increases in growth season length (in the order of 25 days for 2021-2050 and 45 days for 2071-2100) are projected for the country's continental mountain regions. Length increases of 10-15 days for 2021-2050 and 15-25 days for 2071-2100 are projected for the rest of the country.

For the purpose of project CCWaterS two test areas in Greece are examined: one in Northern Greece and the other one in Peloponnisos. From the analysis of the results of the three regional climate models under study it was found that generally all models agree that the domain of study would exhibit a general reduction of precipitation mainly during the second future period. So the models indicate generally dryer conditions in the test sites especially by the end of the 21st century.

2.13. Conclusion

Climate and climate change characteristics based on observed data

Based on data about observed climate and climate change characteristics on national and regional level presented in project partners reports it can be concluded that the increase in temperature has been observed in the countries which participate in DRINK ADRIA project. Only in Serbia and Albania negative trends are mentioned in certain periods.

Observed changes in precipitation amount differ from country to country. Italy - Marche Region, Serbia and Greece have observed only the reduction in precipitation. Some countries (Slovenia, Croatia, Bosnia and Herzegovina, and Montenegro) have various data regarding observed precipitation, which means that both decrease and increase of precipitation was observed, depending on the season and part of the country. It was difficult to make conclusions on trends in Friuli Venezia Giulia Region, where frequent oscillations of the pluviometric regime mean that a lot depends from the length of the considered time series.

Most important data about climate characteristics based on observed temperature and precipitation are shown in Table 2.13-1.

Climate and climate change simulations for future

Based on data about climate and climate change simulations for future scenarios on national and regional level presented in project partners reports and sumarised in this joint report, it can be concluded that the increase of temperature is predicted in all countries which participate in DRINK ADRIA project. The predicted temperature rise varies by countries depending on the analyzed period, SRES scenario, season of the year, part of the country, etc.

Regarding the precipitation, changes vary in the sign depending on the season, and depending on the part of the country. Changes also depend on the analyzed period, and the months of the year. It is stressed that those predictions are less reliable. Albania, Serbia and Greece have scenarios in which precipitation generally decreases. It is important to mention that there are cases (Albania) where total precipitation decreases, but the number of days with heavy precipitation increases. In Greece for example, extreme precipitation events will increase in intensity. It is predicted that water resources (in terms of annual precipitation and river discharge) will decrease over Southern Europe, and it could intensify in the last decades of this century.

For climate change simulations different SRES scenarios and different climate simulation models are used. In Slovenian report, SRES scenarios A1T, A1FI, A1B, A2, B1 and B2 are specified. In reports from Croatia, Serbia, Bosnia and Herzegovina, and Montenegro scenarios A1B and A2 are mentioned. In Greek report, scenario A1B is specified. In Albanian report, scenario is not specified for the three analyzed periods. In Italian reports (national and regional) scenarios are not specified.
Models that are used for climate simulations in Adriatic area on national and regional level and that are mentioned in PPs reports are: PROTHEUS RCM, Aladin, PROMES, RegCM, EBU-POM, GFDL-ESM2M and RACMO2.

Most important data about climate and climate change simulations for future scenarios regarding temperature and precipitation are shown in Table 2.13-2.

Table 2.13-1. Climate change characteristics based on observed data in Adriatic region (national/regional level)

	Period	Temperature	Precipitation
ITALY (national level)	1865–2003 (DTR trend)	Yearly and seasonal trend analyses were performed both on regional average series and on the mean Italian series. Quite a uniform temperature trend was observed in the different regions, with a trend of 1 K per century all over Italy on a yearly basis. Also on a seasonal basis the situation is quite uniform and no significant differences are evident, either for the different regions or for the different seasons. The trend is generally higher for minimum temperature than for maximum temperature for all the seasons and the year, the only exception being the Pianura Padana region, whose trend is always higher for maximum temperature. The significance and the slope of the trends strictly depended on the selected period. In particular, minimum temperature trend over the whole series length being higher than that of maximum temperature, and lower if the last 50 years are considered. This suggested the investigation of DTR progressive trends too. Considering the whole series length 1865–2003, there was a significant negative trend in the DTR that, in the last 50 years, became positive and significant, the only exception being autumn.	Precipitation trend analysis showed a decreasing tendency, even if the decreases are very low and rarely significant. Considering the average all over Italy, there is a 5% decrease per century in the annual precipitation amount, mainly due to the spring season (−9% per century). The significance and the slope of the trends strictly depended on the selected period.
ITALY (Region Friuli Venezia Giulia)	Trieste station: 1840 - 2005 (T) 1961-2000 (P)	Two stations were analyzed: Trieste and Udine. The time series of the mean annual temperatures at Trieste station (data available from 1840 to 2005) show an uncertain trend. Analyzing the mobile mean temperatures over a period of 10 years, the value clearly attests around 13,5°C till the 1920. After that date, it increases reaching the 14°C, value that was overcome for the first time in the 1940. During the last 20 years, a rapid increase took the temperature to reach average values of 15°C (after the 2000). If we observe Udine's dataset, the trend is similar to the one from Trieste. The mobile mean is oscillating between 12 and 13°C for all 19th century. In the first half of the 20th century, the temperature values starts to rise reaching the 13°C in the 1940. It slightly decrease a little bit and remain constant until the 1985. Finally, it increases again going permanently over the 13°C. If we analyze all the other available stations, the mean minimum temperatures remained almost stable in the period between 1950 and 1985, while during the second half of the 80s, they started to increase fairly gradually and steadily. The overall increase, in a 20-year period, varies between a few tenths of a degree and 2°C. For the maximum temperatures, also in this case, after 30 years of stability, is possible to note an abrupt jump upwards in the 1985 followed by 10 years of increasing temperatures. Overall, the increase, during the last 20 years varies between 0.5 °C and 2.5°C. In the FVG Region, the temperatures during the last 20 years seems to be highly increased almost everywhere, especially concerning the maximum spring and summer values.	Using a wider dataset (1961-2000): The lower mean annual precipitations occur along the coastal area where rain about 1000 mm. In the plain area, the mean values oscillates between 1000 mm in the Low Plain and 1500 mm in the High Plain or in the pedimont zone. Between the pedimont and the pre-alpine belt, the mean annual rainfall value increase up to 1500-2000 mm. Over the Pre-Alps, it reaches values that exceeds 2000 mm with peaks of 2400 mm in the Carnian Pre-Alps and 3100 mm in the Julian Pre-Alps. In the Carnian Alps mountain range, and in the area around Tarvisio, rainfall values can reach 1500-1700 mm. Within the period 1961-2000, the highest recorded values of rain has been of 4256 mm in the 1965 and 6100 mm in 1960 at Uccea, in Val Resia (UD). It is difficult to draw conclusions on possible increasing or decreasing trends, beyond some temporary or local signs. The wide and frequent oscillations of the pluviometric regime mean that a lot depends from the length of the considered time series.
ITALY (Marche Region)	Observed data:1950-2000	Temperatures are increasing. The observed trend is characterized by increases ranging between 0,5 and 1,3 °C every 50 year, in maximum temperature series, according to the data recorded in the period 1950 - 2000. Concerning the minimum temperature series the annual trend is similar, although higher (between 0,8 and 1,7 °C/50 years).	Detection of a decreasing trend of annual precipitation, and determination of a reduction, for the most part of the cases, more than 10% and less than or equal to 30%, compared to the average value of the period from 1950 to 1989, which means a reduction of the average annual rainfall of about 5 mm per year, during the time interval in the study.
ITALY (Apulia Region)	Trends are computed from 1970	Trends are computed from 1970. Reference stands for observation: Daily minimum temperature reference trend (°C/yr): +0.055. Daily maximum temperature reference trend (°C/yr): +0.047.	Trends are computed from 1970. Reference stands for observation: Cumulated precipitation reference trend (mm/yr): -0.277.
SLOVENIA	Reference period: 1971-2000	Temperature conditions during the reference period show average increasing across the whole country.	Although the global climate changes foresee changes in precipitation, on an annual basis not significant trends are observed in the past. But more obvious variability is shown within individual seasons. The autumn rainfall increases almost across the all country. During the winter the amount of precipitation is decreasing across western Slovenia, while in eastern Slovenia no changes are observed. In spring fairly uniform trend of decreasing rainfall is observed with the exception in eastern Slovenia. In summer the situation is different with less precipitation practically everywhere except in higher elevations of the Alps.

CROATIA	Observed data: 1961-2010 Trends analysed regarding reference period: 1961-1990	Trends in air temperature during the last 50 years show warming all over Croatia. The maximum temperature values were exposed to the greatest changes with the highest frequency of trends in the class of 0.3-0.4 ℃ per decade, while trends in the mean and the mean minimum air temperatures mostly range between 0.2 and 0.3 ℃ per decade. Observed warming can be seen in all indices of temperature extremes, with positive trends of warm temperature indices and with the negative trends of cold temperature indices.	During the recent 50-year period the annual precipitation amounts experienced prevailing insignificant trends that are increasing in the eastern lowland and decreasing elsewhere. Expressed per decade as percentages of the respective average values, these decreases range between -7% and -2%. In autumn, the trends are weak and mixed in sign, except in the eastern lowland where some locations show significant increasing trend in precipitation (8% to 11%). Generally, when negative trends are observed for the whole year, they are mainly caused by decreasing trends (drying) in the summer; the summer trends, in turn, are found to be statistically significant at most stations in the mountainous region and at some stations along the Adriatic and its hinterland.
		On the Croatian Adriatic: In three seasons, JJA, MAM and DJF, trends in the mean air temperature show warming all over Croatian Adriatic while trends in SON are of the mixed sign. The annual temperature trends are all positive and significant, and they range mostly between 0.2°C and 0.3°C per decade.	On the Croatian Adriatic: During the recent 50-year period (1961-2010) the prevailing trends in the annual precipitation amounts indicate a decrease in precipitation which, at most stations, is statistically insignificant. The trend values go down to the 7% of the respective climate means.
BOSNIA AND HERZEGOVINA	Observed data: 1981-2010 Trends analysed regarding reference period: 1961-1990	Temperatures have increased in all areas of the country. The increase in annual air temperature ranges from 0.4 to 0.8°C, while the increase in air temperature during the growing season (April – September) even reaches 1.0°C. However, increases in air temperature during the last decade are even more pronounced.There is an evident increasing trend in number of "hot" days (tropical days with a maximum daily air temperature above 30°C) across almost the entire territory.	Slightly increasing trend in annual precipitation. The largest decrease in precipitation was during the spring and summer seasons, in the region of Herzegovina (up to 20%). The autumn season saw the largest increase in precipitation, particularly in northern and central areas. Although the level of annual precipitation has not significantly changed, annual distribution has been greatly altered.
MONTENEGRO	Observed data: 1949 - present	The last decade of the twentieth century was warmer in relation to a multi-year series of measurements (since 1949 until the present day). Monitoring and evaluation of climate shows that the climate is changing in Montenegro. The clearest indicators are: a significant increase in air temperature, an increase in sea surface temperature and medium sea level, changes in extreme weather and climate events.	The annual amount of precipitation fluctuates around the normal and generally shows no tendency to increase or decrease. Exceptions are the north-eastern regions of Montenegro (Bijelo Polje) and the coast. In the northeast of the state, precipitation has been increased since 1949, while on the coast there is a trend of slight reductions in precipitation.
SERBIA	Observed data: 1949-2006	The annual average temperature trend in was found to be about 0.6°C/100 years. The greatest increase has been recorded in the spring (some 1.5°C/100yrs), followed by the summer (1.0°C/100yrs) and winter (0.5°C/100yrs), while the autumn exhibited a negative trend of about -0.7°C/100yrs.	Precipitation regime is very heterogeneous with respect to time and space. There is a tendency toward decreasing of precipitation depths from the West to the East in the plain areas.The annual average precipitation trend in Serbia was found to be slightly negative. The findings from majority of GCM and RCM demonstrate decrease in average precipitation in Serbia, with more significant trend in eastern part of the country.
ALBANIA	Observed data:1931 - 2000	The air temperature records measured in the meteorological stations of Shkoder and Tirana for the period 1931 - 2000 show an increase in the temperature by 1°C during the end of the first half of the 20th century. The third quarter of the 20th century is characterized by cooling of 0.6°C, while the rest of that period up to today, the climate has demonstrated an increase in temperature by 1.2°C. In the study area (Drini River Basin), the annual mean temperature has increased by approximately 1°C for the entire zone.	The spatial distribution of precipitation varies a lot. The changes in the air temperature are associated with changes in the amount of precipitation. In the study area (Drini River Basin), the data on precipitation for the period 1961-2000 show a slightly decreasing trend in the total precipitation.
GREECE	Observed data: 1961-2013 Trends analysed regarding reference periods: 1961-1990, 1991-2000 and 2001-2013	The mean annual temperature for the period 2001 – 2013, as measured at selected meteorological stations of the country, is higher in most of the stations compared to the mean annual temperature of the period 1991 – 2000 while the mean annual temperature for the period 1991 – 2000 is higher compared to these of the period 1961 – 1990. Since the '90s is experiencing an annual increase of temperature of about 0.4-0.6°C, as to the mean values of 1961-1990. Heat waves are happening every single year since 1997, although duration days are not as high as in the years 1997-2001.	In the recent years there is a significant reduction of the precipitation in the Greek Territory, especially during the 2nd half of the 20th century. It is found that precipitation is decreasing more abruptly in the islands of the Ionian and Aegean Sea. In Corfu (one of the Ionian Islands): during 20 years (1980-2001) the precipitation shows an unstable fluctuation and there is an increase during 1985-86, 1990-91, 1994-95 and 1997-99.

Table 2.13-2. Climate and climate change simulations for future scenarios in Adriatic region (national/regional level)

	Model	SRES scenario	Reference period	Time period	Temperature	Precipitation
ITALY (national level)					The anticipated negative impacts are mainly related to possible extraordinary heat spells (especially in summer) and increased frequency of extreme weather events (heat waves, droughts).	The anticipated negative impacts are mainly related to increased frequency of extreme weather events (severe rainfalls) and reduced annual precipitation and river flow. Water resources (in terms of annual precipitation and river discharge) are projected to decrease over Southern Europe, and this regional pattern could intensify in the last decades of this century. The existing conditions of high stress on water resources and of hydro-geologic disturbance in some Italian regions could be exacerbated by projected climate change including: reduced water availability and quality, increases in frequency and intensity of droughts especially in summer, increases in frequency and severity of river summer flows reductions and annual river flow decline and limited groundwater recharge.
ITALY (Region Friuli Venezia Giulia)					All the analysis indicates a rapid increase in the temperatures of about 2/4°C within 2100 with a more pronounced increase during the summer season.	/
ITALY (Marche Region)					Results from observed climate and climate change outline a framework of possible climate change in future on Marche Region, identifiable in increase in temperatures.	Results from observed climate and climate change outline a framework of possible climate change in future on Marche Region, identifiable in a decrease in total annual rainfall.
ITALY (Apulia Region)	PROTHEUS RCM		1953-2000	2001-2050	Daily minimum temperature: Differences of monthly means between future and past scenarios over the whole period (1953-2000 and 2001-2050) were considered. Temperature increasing concerned mostly the period between early spring and late autumn (from April to October) with a maximum in October. The maximum of spatial heterogeneity was found on the same period, with value ranging from 0.5 to 2.6°C. From November to March, a homogeneous increasing (below 1°C) of minimum temperature over the whole region were resulted. Daily maximum temperature: A temperature increasing concerned mostly the period between early spring and late autumn (from April to November) with a maximum in September. The maximum of spatial heterogeneity occurs on the same period, with value ranging from 0.5 to 2.1°C (maximum in August). From December to March, an homogeneous increasing (below 1°C) of minimum temperature over the whole region was found.	The mean differences of the monthly cumulated precipitation (between future and past scenarios): The global trend of decreasing precipitation is not confirmed over the whole case study. In fact, in October, precipitation increases between 10 and 20 mm/month at the south of the region and between 5 and 10 mm/month at north, meanwhile oppositely in December maximum increase is concentrated at the north of the region with a maximum of 36 mm/month. During January, February, March, May, June and August precipitation are stable in confront with the past scenario, with value ranging between -5 and + 5 mm/month over mostly the whole case study. In January, March and June, a minority of stations present a major decreases, with value ranging from -5 to -10 mm/month. Finally, April, July and September at north and November at south presents a global decrease of precipitation, with a maximum of -21 mm/month in July.
SLOVENIA	a) the simulation results with 4 MSC methods were used	A1T, A1FI, A1B, A2, B1, B2	1961-1990	2001-2090	The results show that the temperature of the air will increase in the entire area. Size of the projected changes in temperature is largely dependent on the selected emission scenarios. In the period from 2001 to 2030 air temperature is expected to rise by 0.5 °C to 2.5 °C, over a period of 2031 to 2060 from 1 °C to 3.5 °C, and in the period 2061 to 2090 for 1.5 °C to 6.5 °C. (*for Ljubljana*)	The predictions of changes in annual precipitation are less reliable. Some projections show the trend towards less rainfall, while the others the trend to a reduction in precipitation projections of results is not observed. The projected changes in annual precipitation in the future range from +10% to -30%. The precipitation in summer is likely lowered up to 20%. (*for Ljubljana*)
	b) CC-waterS: three RCMs were used (Aladin, PROMES and RegCM).	A1B	1961-1990	Aladin and RegCM: 2021-2050, 2071-2100. PROMES: 2021-2050	The future model simulations showed the increase in air temperature on average more than 3 °C at all observed locations. The strongest increase was identified in the summer, and least strong in the cold part of the year (at location Kredarica).	Precipitation data manifests a high degree of ambiguity in the future periods, but the model simulations agree on a general trend pointing to less precipitation in the summer. All models predict an increase of percipitation in autumn (at location Ljubljana). Model data also indicates trends in the direction of longer duration of dry spell and greater maximum daily rainfall.

CROATIA	a) model RegCM	A2	1961-1990	2011-2040	winter: temperature increase of 0.6 °C; summer: 1°C	Changes are very small and limited to smaller areas, they vary in the sign depending of the season. The biggest change, can be expected in the Adriatic in autumn when RegCM indicates a decrease of precipitation with a maximum of approximately 45-50 mm in the southern Adriatic (not statistically significant).
	a) model RegCM	A2	1961-1990	2041-2070	winter: increase amplitude is up to 2 °C in continental part and up to 1.6 °C in the south; summer: up to 2.4 °C in the continental Croatia, and up to 3 °C in the coastal zone	During summer in the mountainous Croatia and in the coastal area a decrease in precipitation is expected. Reductions reach value of 45-50 mm and they are statistically significant. During winter an increase in precipitation in north-western Croatia and on the Adriatic can be expected, but it is not statistically significant.
	b) Various RCMs (18 combinations) that participated in the project ENSEMBLES (*in the analysis of Croatian Adriatic*)	A1B	1961-1990 (P0)	2011-2040 (P1)	Projected differences between P1 and P0: an increase of 2m air temperature (T2m) in all seasons with the amplitude typically between 1°C and 1.5°C. Higher warming, between 1.5°C and 1.75°C, is projected over central and southern Dalmatia during the summer. A weak decrease of the mean T2m amounting to -0.5°C may be possible in some months during P1, mostly as the consequence of internal variability of the climate system.	The total precipitation amount R during winter is projected to increase over parts of the Kvarner region with the amplitude between 5% and 15% relative to the reference period P0, 1961-1990. For the summer, R is projected to decrease from -5% down to -15% over large parts of the Dalmatian hinterland, the mountainous region of Gorski kotar and the Lika highlands. A reduction of precipitation of the same amplitude is projected for the southern Croatia during spring, while during autumn the projected changes are almost negligible, between -5% and +5%.
BOSNIA AND HERZEGOVINA	Results of the coupled regional climate was made in model EBU-POM, received by the method of dynamic downscaling of results from two global climate change models, SINTEX-G and ECHAM5.	A1B	1961-1990	2001-2030	The mean seasonal temperature change is expected to range from +0,6 to +1,4 °C. This depends from the region of BiH, and the biggest temperature changes during summer months will be +1,4 °C in northern parts and +1,1 °C in southern parts of BiH. During the spring temperatures will rise for approximately +0,8 to +0,9 °C, during the autumn average temperatures will rise from +0,6 to +0,9 °C.	For precipitation model showed positive and negative variations. Positive changes of precipitation will be seen during spring from +5% and during summer even up to +15%. This is just for the north-east part of the BiH, while in the other parts of the BiH, with emphasis on southern parts showed the biggest deficit in precipitation, even up to -20%.
	Results of the coupled regional climate was made in model EBU-POM, received by the method of dynamic downscaling of results from two global climate change models, SINTEX-G and ECHAM5.	A1B	1961-1990	2071-2100	Temperature changes in this period range from +1,8 to +3,6 °C with biggest values in summer months. During the winter and autumn temperature will rise up to +2,4 °C and during the spring up to +2,6 °C.	Larger negative anomalies are predicted in winter and autumn with changes from -10% to -50%. Spring is characterized with value up to -10%, while the precipitation deficit in summer will be greater in southern parts of the country ranging up to -30%.
	Results of the coupled regional climate was made in model EBU-POM, received by the method of dynamic downscaling of results from two global climate change models, SINTEX-G and ECHAM5.	A2	1961-1990	2071-2100	The expected increase in temperature in the entire territory of BiH ranges from +2.4 to +4.8°C. The biggest increase will be during the summer with values above +4.8°C. During the winter, the maximum predicted change is approximately +3.6°C. For the spring months predicted values are ranging from +3.4 to +3.6°C, while during the autumn the changes are again bigger in the western part of the country, ranging from +2.8 to +3°C.	There is a negative anomaly in terms of accumulated precipitation across the entire territory, with the exception of the southeastern regions, the winter season has a positive anomaly across almost the entire territory, ranging from 0 to +30%. The biggest changes are predicted during the summer, with values of -50%. During the spring and autumn, anomalies range from -30 to 0%.

MONTENEGRO	EBU-POM (It is a linked regional climate model, which is a system of two regional models.)	A1B	1961-1990	2001-2030	Seasonal changes in mean temperature are moving in the range of 0.6°C to 1.3°C, depending on the season and the area of Montenegro. Except for the SON season, it is evident that the temperature changes are significantly greater in the northern, mountainous part of Montenegro, compared with smaller changes in the area near the Adriatic Sea. The biggest change is during the season JJA, with values of 1.3°C in the north and 1° C in coastal areas. For the season DJF changes in the coastal part are about 0.5°C, while in the northern part the temperature increases by 0.9°C. For the season MAM, changes are 0.8°C in the south and 1.1°C in the north. The SON season was characterized by almost the absence of differences in temperature change, with more or less steady change in the entire territory of about 0.7°C.	Model results show negative and positive changes in precipitation, depending on the part of Montenegro and the season. Positive changes in precipitation and their increase can be seen for the season JJA, for the central area of Montenegro, and for the MAM season in parts bordering Bosnia and Herzegovina. These positive changes are very small, ranging up to 5%, compared to the value of the baseline period, 1961-1990. In other areas of Montenegro during the two seasons, DJF and MAM, model results show a decrease in precipitation from -10% to 0%. The MAM season is characterized by deficient rainfall and the highest values of -20%, almost over the whole territory.
	EBU-POM (It is a linked regional climate model, which is a system of two regional models.)	A1B	1961-1990	2071-2100	The area along the Adriatic Sea has minor temperature changes compared to those in the northern mountainous region. This time temperature changes range between 1.6°C and 3.4°C. The biggest changes are again recorded in the season JJA. Along the coastal area the temperature has increased by approximately 2.4°C, and in the northern mountainous region of the country these values are 3.4 °C. During the winter (DJF), there is a noticeable gradient from the south towards the north of the country, with a temperature increase of 1.6°C in the coastal area, and 2.6°C in the north. For the MAM season, these changes vary from 1.6°C to 2.6°C. For the SON season changes in the coastal region are about 1.6°C, and 2.4°C in the northern area along the border with Serbia.	During this period there is no season or area in Montenegro which is characterized by a positive anomaly of precipitation. For the DJF season in the central parts of Montenegro there is a negative anomaly of -30%, while the northern and coastal parts have also a negative change but with values of up to -30%. The MAM season was characterized by values of about -10% in the whole territory. A significant deficit during the season JJA is evident in coastal areas, while in the central and northern parts negative anomalies are in the range of -20 to -15%. For the season SON, model results also show a significant decrease in precipitation from -30 to -50%.
	EBU-POM (It is a linked regional climate model, which is a system of two regional models.)	A2	1961-1990	2071-2100	The most significant changes in temperature were recorded for A2 scenario, for the northern part of the country during summer period, and they are 4.8°C. The greatest increase is during the JJA season in the mountainous region in the north, with values over 4.8° C. For this season, an increase in temperature of 3.4°C is foreseen in the coastal area. For the DJF season, temperature increase along the Adriatic coast is about 2.6°C, while this value in the northern parts is about 3.4°C. These values are a little higher during the MAM season, from 2.8°C to 3.6°C. Spatial distribution of changes is more uniform during the SON season, in the range of 2.6°C to 3°C.	During all seasons, except for DJF, a negative anomaly of accumulated rainfall over the entire territory is predicted. A positive anomaly in the range 5-10% will be recorded only in the north-western parts during the season DJF, while during the same season changes in other parts of the country will vary from -5% to -10%. The biggest changes are along the coast and during the JJA season, with a value of -50%. During this season an anomaly of -10% will occur in the northern parts. During the seasons of MAM and SON the mean value of anomalies is -20%.
SERBIA		A1B	1961-1990	2001-2030	The average temperature change on the anual basis is around +1°C.	Change in precipitation is between -5% to +5%.
		A1B, A2	1961-1990	2071-2100	Changes in the average temperature are expected to be +2.5°C and +3.7°C, for A1B and A2, respectively.	Change in the annual average precipitation values is expected to be approximately -15%.
ALBANIA	GFDL-ESM2M		1980-2004	2025-2049	During winter a temperature increase of 3 °C is expected, and 4°C during summer.	There is a significiant decrease of precipitation.
	GFDL-ESM2M		1980-2004	2050-2074	The expected increase amplitude during winter is up to 4 °C, and during summer up to 4.5 °C.	Although total precipitation is expected to decrease, the number of days with heavy precipitation is likely to increase.
	GFDL-ESM2M		1980-2004	2071-2095	The expected increase amplitude during winter is up to 6 °C, and during summer up to 6.4 °C.	
GREECE	RACMO2	A1B	1961-1990	2021-2050	Mean minimum winter temperatures will be ~1.5ºC higher in 2021-2050. The warming trend will be more pronounced in the more mountainous areas, where it is projected to reach 2ºC. The increase in mean maximum summer temperatures will exceed 1.5ºC and in some cases reach 2.5ºC.	Maximum consecutive 3-day precipitation during 2021-2050 will remain essentially unchanged in regions like Western Greece, Eastern Macedonia-Thrace and Crete, but will increase significantly in others.
	RACMO2	A1B	1961-1990	2071-2100	Mean minimum winter temperatures will be ~3.5ºC higher in 2071-2100. The warming trend will be more pronounced in the more mountainous areas, where it is projected to reach 4ºC. The increase in mean maximum summer temperatures may be 5ºC. Most affected will be the continental inland regions, situated far from the cooling effects of the sea, whereas regions with strong sea breezes will experience a significantly smaller variation in maximum summer temperatures.	The amount of extreme rainfall (maximum consecutive 3-day precipitation) is projected to decrease by 10-20% in regions of Western Greece and Thrace, but to increase by 30% in the Eastern Central Greece.

3. Climate and climate change data on test areas

3.1. Methodology

Data regarding climate and climate change on test areas are collected by PP in individual reports. Reports are prepared for the following test areas: test area Isonzo Plain (Friuli Venezia Giulia Region, Italy), test area ATO3 (Marche Region, Italy), test area Ostuni (Apulia Region, Italy), test areas in Slovenia, test areas in Croatia, test area in Montenegro, test area in Albania and test area in Greece. Based on the reports prepared by PPs, collected in Annex II, in following sections the most important parts of reports and conclusions are summarized.

General climate characteristics are analysed from the available climatological data, which includes measurements of air temperature and precipitation amounts from the reference climate period 1961-1990 (except for the Greek test area, as indicated in the table 3.8-1). Period 1961-1990 is recommended by the World Meteorological Organization as the referent period for the present climate conditions.
Climate change simulations for future are shown in most of the reports for the period 1951-2050.

Present and future climate is assessed based on the results from numerical simulations of the three regional climate models (RCMs) - Aladin, Promes and RegCM3. Those models were also analysed in the CC-WaterS[5] project, and they participated in the ENSEMBLES[6] project. The following two abbreviations are used in the report:

1. RCMcorr: the RCMs' output was bias corrected by EOBS data.
2. RCMcorr_adj: this is further adjusted model time series due to the differences between EOBS data and local observations.

The mentioned RCMs are not used in the report for test area in Albania, and in the same report simulations for future are shown for years 2030, 2050, 2080 and 2100. The mentioned RCMs are also not used in the report for test area in Greece. In the report for test area Isonzo Plain a different definition of RCMcorr is given, compared to the above mentioned definition (as indicated in the table 3.8-2).

In the report for Croatian test areas, the limitations of the methodology are explained, and a short description is given here:

1. At the used spatial resolution of the RCM simulations (25 km) local characteristics for specific station or catchment may not be fully resolved.
2. When using the IPCC scenarios it should be taken into consideration that the higher GHGs emission scenarios are usually associated with the higher temperature increase.
3. The three RCMs models used here account only for a part of possible modelling uncertainties. The use of the multi-model ensemble approach in climate projection studies is strongly recommended.

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[5] www.ccwaters.eu

[6] www.ensembles-eu.org

4. In the analysed RCM simulations of the reference climate, the RCMs are not reproducing the actual variability observed in the real climate system. Specific values indicated in the time series presented in the report do not signify a specific prediction for a specific year.

   Models simulations of the future climate should be interpreted as projections of possible state(s) of the climate system which is sensitive to applied initial and boundary conditions, GHGs scenarios and a model internal configuration.

3.2. Italian test areas

3.2.1. Test area Isonzo/Soca Plain (Friuli Venezia Giulia Region, Italy)

From Annex 2 Report 2.1.:

The test area corresponds to the Isonzo Plain located in the northeastern side of the Friuli Venezia Giulia Region at the border with Slovenia. Its extend approximately between latitude 45° 58’ 00” and 45° 49’ 00” and longitude 13° 20’ 00” and 13° 40’ 00”, WGS1984, UTM ZONE 33N. The elevation ranges between 10 and 131 m a.s.l., with an average altitude of 35 m a.s.l.

Figure 3.2.1-1. The test area “Isonzo Plain” (in red).

Climate and climate change characteristics based on observed data

The local climate characteristics are described here for the 1961-1990 period, recommended by the World Meteorological Organization as the reference time-period for the present climate conditions and for the DRINKADRIA Project. Seasonality is described in terms of annual cycle of the mean annual precipitation and temperature, their standard deviation (of monthly mean) and the coefficient of variations.
Trends are calculated for the whole span of available data, i.e. 1941 – 2011 for temperature and 1919 – 2012 for precipitation. Data is presented on monthly, seasonal and annual average basis.

The discussion of the extremes is based on percentiles calculated starting from the empirical values expressed as cumulative distribution function (CFD). We analyzed, for the present research, good quality rainfall and temperature time-series.

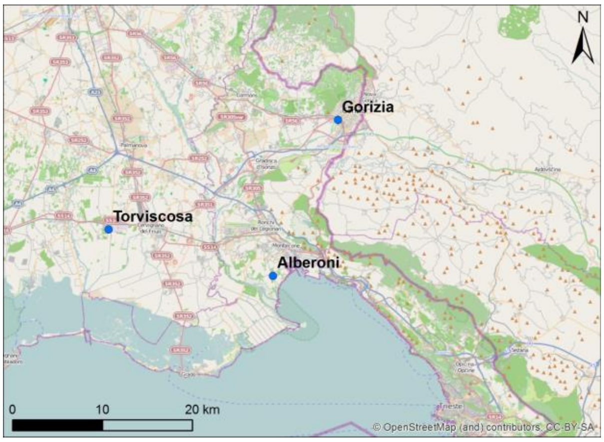


Figure 3.2.1-2. Spatial distribution of the hydro-meteorological monitoring stations with good quality time-series in the surrounding of the test area.

Table 3.2.1-1. Stations data and available measurement time periods for temperature (T) and precipitation (P) data within the study area.

ID Station	Place	P data [mm]	P period	T data [°C]	T period
P005	Monfalcone - Piscina comunale	daily	31/07/2009 - 02/01/2012	daily	2010 - 2012
P001	Monfalcone	daily	01/01/1919 - 31/12/1991	daily	1972 - 1991
P002	Alberoni, Idrovora Sacchetti	daily	01/01/1925 - 02/01/2012		
J209	Torviscosa	daily	01/01/1951 - 02/01/2012	daily	1942 - 2010
J211	Belvat	daily	01/01/1969 - 30/09/1996		
J212	Cervignano	daily	01/01/1917 - 02/01/2012		
N022	Gorizia, Presa C.B.P.I.	daily	01/10/1919 - 02/01/2012	daily	1941 - 2011
N701	Gorizia, Aeroporto di Merna	daily	01/01/1995 - 02/01/2012	daily	2001 - 2011
N024	Farra d'Isonzo, M.Fortin	daily	01/01/1994 - 02/01/2012		
N025	Farra d'Isonzo, Acquedotto IRIS	daily	15/10/1991 - 15/12/2002		
N026	Gradisca d'Isonzo	daily	01/01/1919 - 31/07/1991		
P003	Ronchi dei Legionari	daily	01/05/1925 - 31/12/1934		

Temperature

Temperatures were analyzed in three meteorological stations: Gorizia prese CBPI, Torviscosa and Alberoni (Monfalcone).

In this joint report, figure for station Gorizia prese CBPI is extracted. In the report made by LP, figures are shown for all three stations.

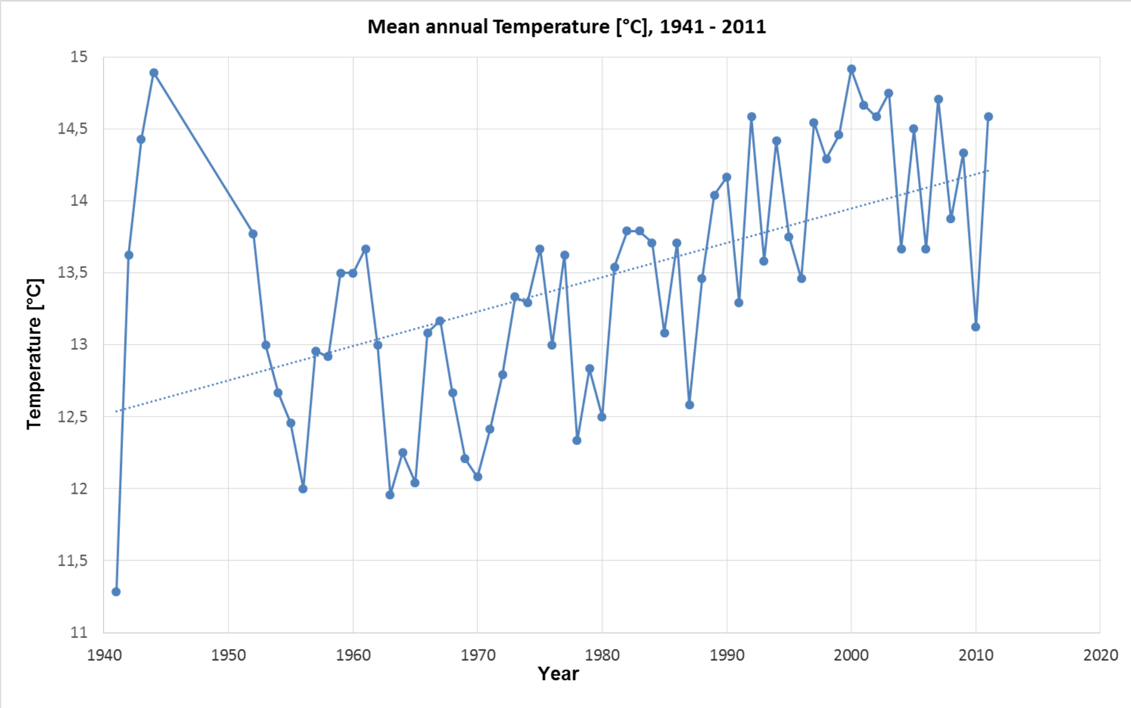


Figure 3.2.1-3. Time series of mean annual air temperature with the fitted trend for the period 1941-2011 for the meteorological station of Gorizia (prese CBPI). Trend=0,2°C/10y, t(1941-2011)=13,4°C.

Temperatures in the catchment area of the Isonzo River vary greatly. Three meteorological stations were analyzed: Gorizia prese, Torviscosa and Alberoni, close to Monfalcone.
For all the three stations, the annual cycle of air temperatures is well defined, with a maximum of 36°-39°C and a minimum of -10,6 – -12°C indicating a passage by a temperate marine climate to a continental alpine ones, but with a maritime prevalence where autumn (SON) are slightly warmer than springs (MAM).
The standard deviation of mean monthly air temperatures indicate the highest variability in autumn for two of the three stations. The situation is different for Alberoni where the marine influence is higher and the variability for a 0,3°C is wider during springtime than in autumn (10,1).

The monthly values of the Sdev range between 1.7 and 4.6 for Gorizia station, 8.6 and 10.4 at Alberoni and 2.2 and 4.6 at Torviscosa indicating a quite high inter-annual variability with a higher variability while leaving the sea.
The calculated percentiles represent the extreme values of annual and seasonal mean temperatures. In the annual cycle of the percentiles of the mean daily air temperature, the difference between the 98th percentile and the 2nd, for the Gorizia station, is highest in spring and autumn due to the highest variability of the temperature values. At Torviscosa and Alberoni stations, even if with different values, the situation is similar, with higher variability in springtime and autumn.

Temperature trends are similar for the analyzed stations: Gorizia is clearly indicating a positive trend with increasing temperatures from 12,5°C recorded during the 40s, till the 14,3°C of the actual measures. Torviscosa is going from 12,2 to 14,3°C even if data are affected by a not so good quality time-series (some annual values are interpreted due to the data scarcity). Also Alberoni station indicates an increase in the temperature during the last period, with values that goes from 14,2°C to 15,1°C. Here temperatures are always higher than the other examined stations due to the sea influence. As consequence, for Gorizia the Trend is of 0,2°C/10y, with a mean temperature value in the analyze period (1941-2011) of 13,4°C; for Torviscosa the Trend is of 0,6°C/10y, with a mean temperature value in the analyze period (1941-2011) of 13,5°C. For Alberoni station the Trend is of 0,4°C/10y, with a mean temperature value in the analyze period (1972-2011) of 14,4°C.

Precipitation

For the test site area, precipitations recorded by three different stations were analyzed. Below are presented the analyzed data for Gorizia prese (CBPI), Torviscosa and Alberoni (Monfalcone) stations.

In this joint report, figure for station Gorizia prese CBPI is extracted. In the report made by LP, figures are shown for all three stations.

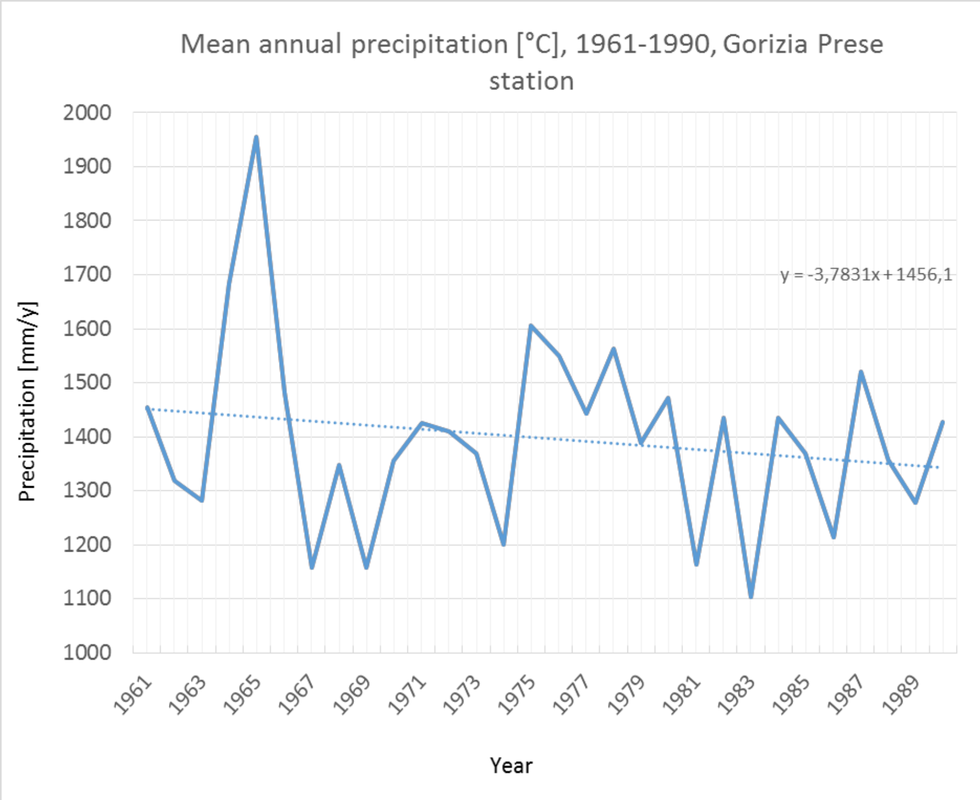


Figure 3.2.1-4. Time series of mean annual precipitations with the fitted trend for the period 1961-1990 for the meteorological station of Gorizia (prese CBPI). Trend=-38mm/10y; R(1961-1990)=1397,5 mm.

At Gorizia, the highest precipitation amount usually occur during autumn with maximum recorded values of 430 mm and min values of 0 mm. This generate a high variability and a std of 50.5. DJF, MAM and JJA have very similar values: the maximum ranges between 255 and 286 mm and the min values are between 1 and 12 mm.
Also at Torviscosa the highest precipitations are recorded in autumn with average values of 118.9 mm and maximum values up to 317 mm. Also the minimum precipitations recorded in autumn are higher (8.6 mm) than during the other periods.
The same trend is visible for the Alberoni station where the higher mean values belong to autumn with values of 112.8 mm. Here the max recorded values are of 422.8 mm and the min values are of 12 mm.

Regarding the precipitation trends, looking at the stations, the situation is completely different. There is no homogeneity in the behavior.
At Gorizia station, the total amount has a decreasing trend. What is also changing is the fluctuation and distribution within the months, with the increasing in June and September and decreasing in January and April. If we look at the trimester SON, the decreasing trend

over 10y is important. The calculated Trend is of -38mm/10y with a mean value of 1397,5 mm computed for the reference period 1961-1990 (R).
At Torviscosa the general trend is negative, with a decreasing of the precipitations since 1950. The only positive time of the year is the autumn. The calculated Trend is of -1,2 mm/10y with a R value (1961-1990) of 1194,0 mm.
At Alberoni station, due to the inconsistency of the recorded min data, it is not always possible to define the min precipitation values that seems to show a very small amount in the winter times. The Trend is of 1,4 mm/10y with a R value (1961-1990) of 1108,23 mm.

Climate and climate change simulations for future

The regional climate models (RCMs) used are the Aladin, Promes and RegCM3 models. The initial and boundary data for each RCM were provided from different global climate models (GCMs): the ECHAM5 GCM data were used to force RegCM3, Aladin was forced by the Arpege GCM and Promes was forced by the HadCM3Q GCM. For the present climate, models are compared with the local observations (Observations -obs). RCM corr is further adjusted model time series due to the differences between the CCmodels data and local observations.

Gorizia CBPI station

Data recorded by the Gorizia CBPI prese meteorological station initially refers to the reference period 1961-1990. For this period were evaluated, not only the observed data temperatures, but also the three RCM bias corrected models available thanks to the CCWATER project.
To define the future scenarios it is important to correct the model data on the observed ones.

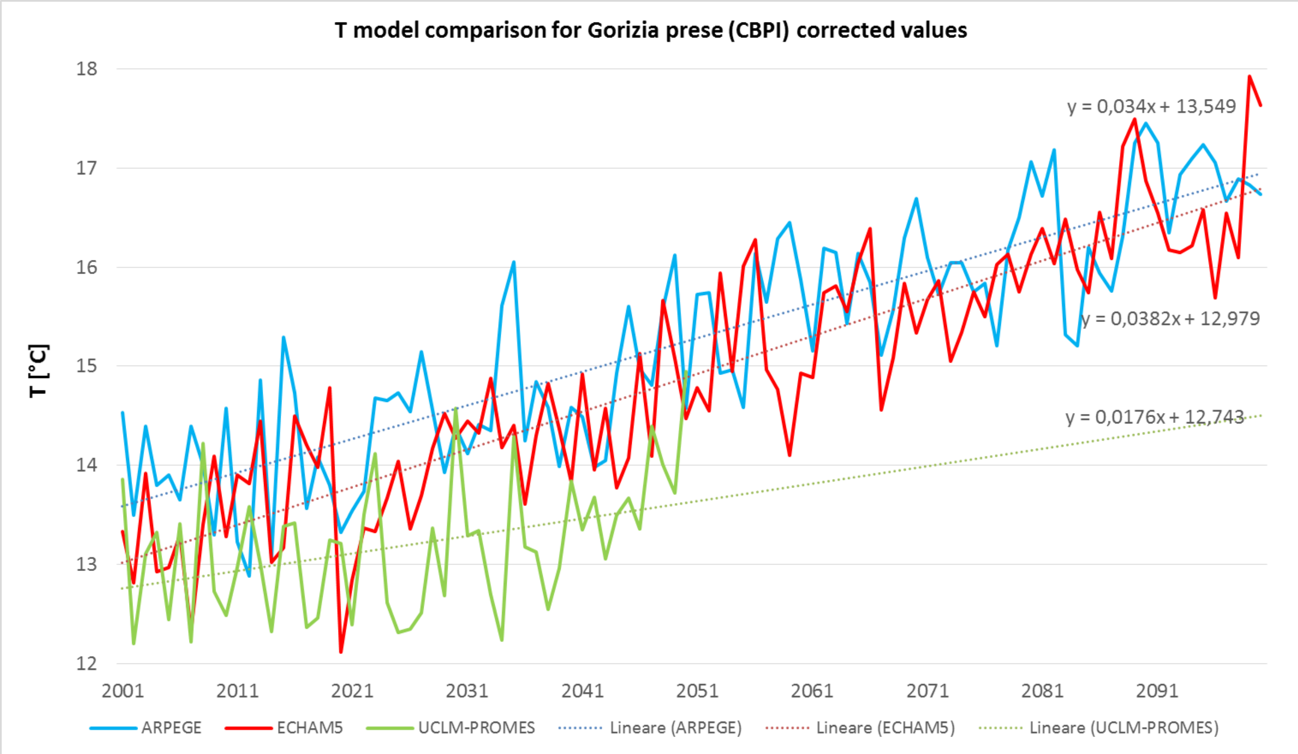


Figure 3.2.1-5. Annual mean temperature and the relative fitted linear trend of Gorizia prese (CBPI) comparison between the three available models. The models have been corrected. All the three models are showing a huge increase of about 0.34°C/10y (ARPEGE), 0.38°C/10y (ECHAM5) and 0.17°C/10y (Promes) respectively.

(models: CNRM-RM5.1 (or ALADIN) forced by ARPEGE, ICTP-REGCM forced by ECHAM5 and UCLM-PROMES forced by HadCM3Q0)

For Gorizia prese (CBPI) station, the available observed precipitation time series were firstly analyzed and later compared with the three model time series CNRM-RM5.1 (or ALADIN) forced by ARPEGE, ICTP-REGCM forced by ECHAM5 and UCLM-PROMES forced by HadCM3Q0 for the period 1951-2000. The observed precipitation dataset has a decreasing constant behavior while the three models are not in agreement one with the other highlighting a slight decrease (ECHAM5) or increase (ARPEGE and PROMES) in the total annual cycle precipitation amount.

Applying the corrections to the future scenarios, it emerges that there is a difference between the 50years (1951-2000) scenarios and the 100years. This can be seen in figure 3.2.1-6, where, for the Gorizia prese CBPI station, it emerges that there is a clear decreasing trend in the precipitation amount.

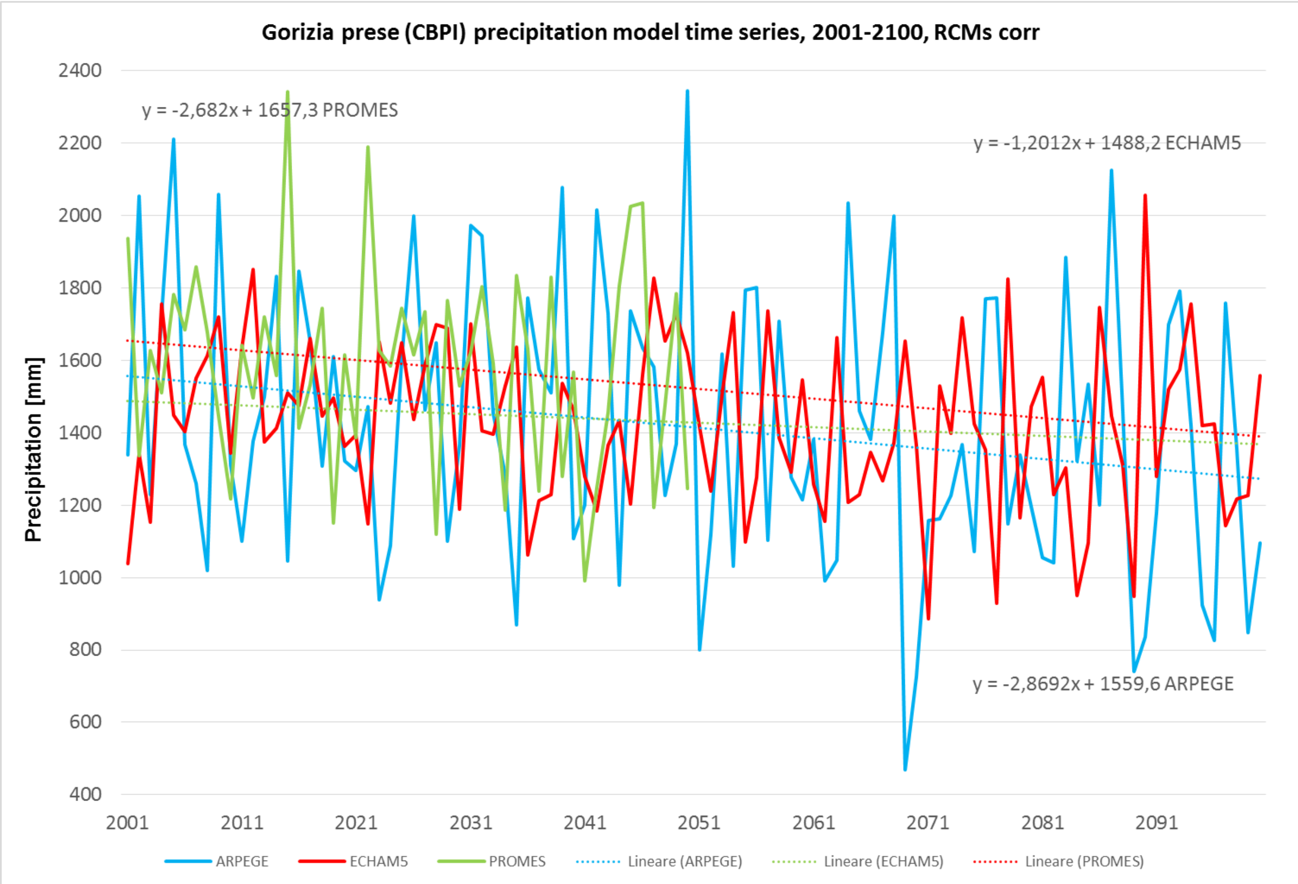


Figure 3.2.1-6. Gorizia prese (CBPI) station time series 2001-2100, annual precipitation amount corrected. The trend for the ARPEGE values is of -28 mm/10y, for PROMES is of -12 mm/10y and for ECHAM5 is of -26 mm/10y. All the three models are indicating a decreasing trend.

Table 3.2.1-2. Summary of the results calculated for the Gorizia prese CBPI station.

Gorizia prese CBPI	ARPEGE	PROMES	ECHAM5	Observed
Temperature [°C/10y] 50y	0.18	0,19	0,14	0,28
Temperature [°C/10y] 100y	0,34	0,17	0,38	
P (50y) [mm/10y]	25	9	-19	-20
P (100y) [mm/10y]	-28	-12	-26	

Torviscosa station

Data time series for Torviscosa station were analyzed for two different period: the first one considering the data from 1951 until 2000 and comparing the observed time series with the three different model available after the end of the CC Water Project; the second one is between 2001 and 2100 proposing a prediction within the following 90 years of the temperature changes.

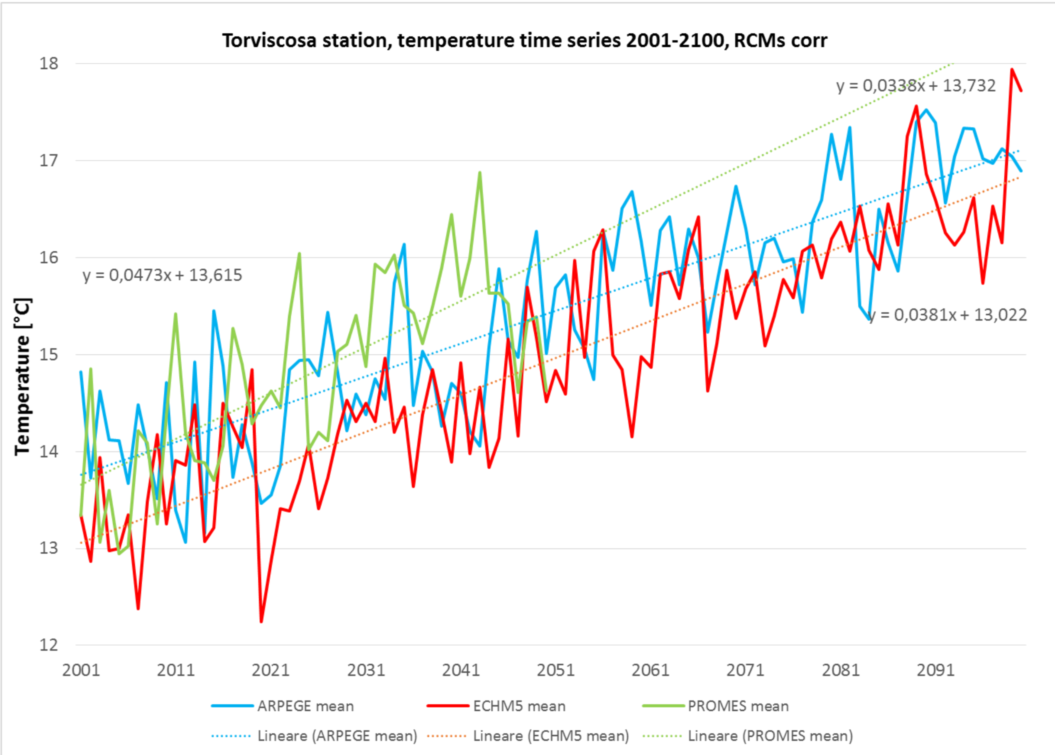


Figure 3.2.1-7. Torviscosa station time series 2001-2100. The temperature value is slighting increasing with a trend for the ARPEGE model of 0.3°C/10y, for PROMES of 0.5°C/10y, for ECHAM5 with values of 0.4°C/10y.

For Torviscosa station, the available observed precipitation time series were firstly analyzed and later compared with the three model time series CNRM-RM5.1 (or ALADIN) forced by ARPEGE, ICTP-REGCM forced by ECHAM5 and UCLM-PROMES forced by HadCM3Q0 for the period 1951-2000. The observed precipitation dataset has a linear decreasing behavior while the three models are not in agreement one with the other highlighting a slight decrease (ECHAM5) or increase (ARPEGE and PROMES) in the total annual cycle precipitation amount, as for the Gorizia prese (CBPI) station. If we have a look at the future projection (Figure 3.2.1-8), using the three model time series CNRM-RM5.1 (or ALADIN) forced by ARPEGE, ICTP-REGCM forced by ECHAM5 and

UCLM-PROMES forced by HadCM3Q0 for the period 2001-2100, it is possible to realize that, all the models evidence a slight decrease in the annual precipitation amount passing from value of 1300 mm to values of 1100, with a decreasing of 2 mm/1y.

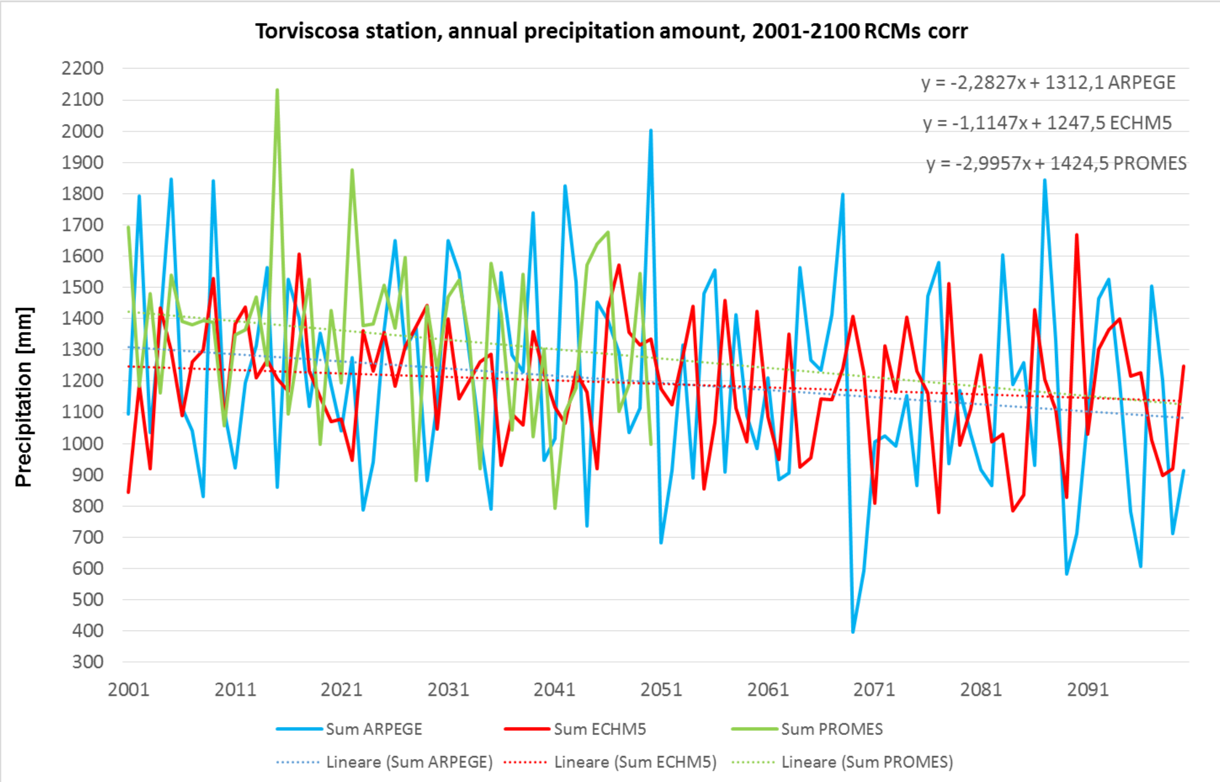


Figure 3.2.1-8. Torviscosa station time series 2001-2100, annual precipitation amount corrected. The trend for the ARPEGE values is of -22 mm/10y, for PROMES is of -30 mm/10y and for ECHAM5 is of -11 mm/10y. All the three models are indicating a decreasing trend.

Table 3.2.1-3. Summary of the results calculated for the Torviscosa station.

Torviscosa	ARPEGE	PROMES	ECHAM5	Observed
Temperature [°C/10y] 50y	0,06	0,11	0,06	0,9
Temperature [°C/10y] 100y	0,34	0,47	0,38	
P (50y) [mm/10y]	47	4	-30	-36
P (100y) [mm/10y]	-22	-30	-11	

Alberoni station

Data time series for Alberoni station were analyzed for two different periods: the first one considering the data from 1951 till 2000 later comparing the observed time series with the three different model available after the end of the CC Water Project; the second one is between 2001 and 2100 proposing a prediction within the following 100 years of the temperature changes.

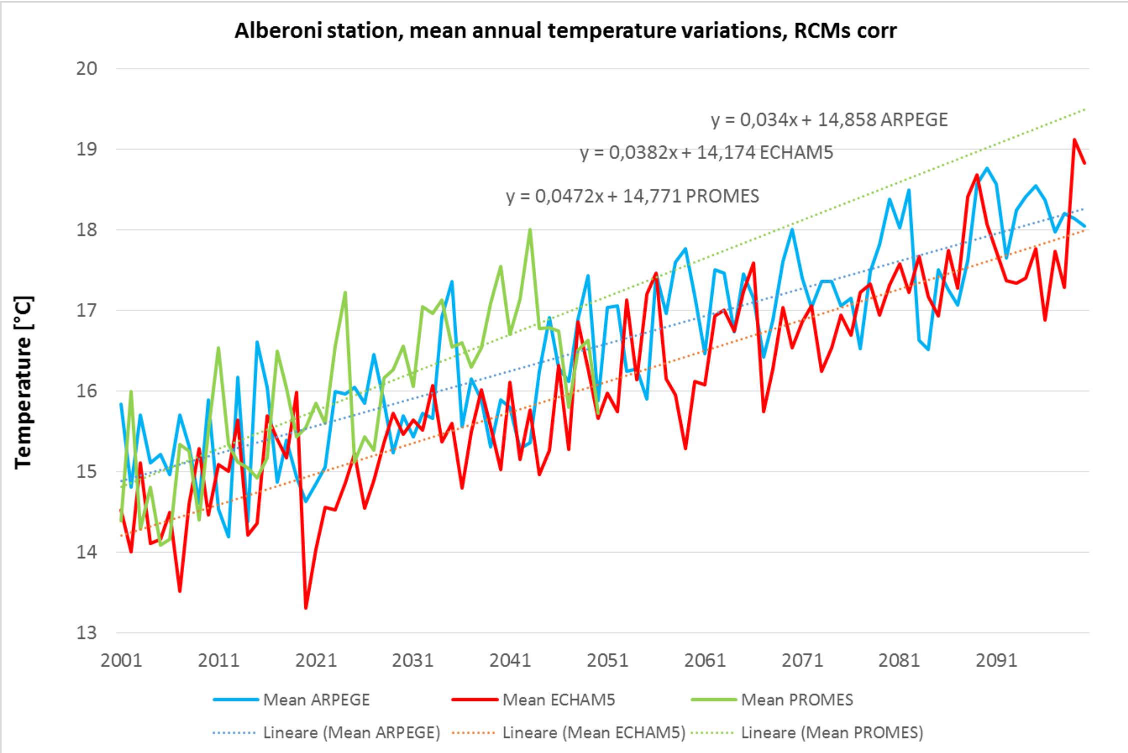


Figure 3.2.1-9. Alberoni station time series 2001-2100. The temperature value is slighting increasing with a trend for the ARPEGE model of 0.3°C/10y, for PROMES of 0.5°C/10y, for ECHAM5 with values of 0.4°C/10y.

For Alberoni station, the available observed precipitation time series were firstly analyzed and later compared with the three model time series CNRM-RM5.1 (or ALADIN) forced by ARPEGE, ICTP-REGCM forced by ECHAM5 and UCLM-PROMES forced by HadCM3Q0 for the period 1951-2000. Also for this station the three models are not in agreement one with the other highlighting a slight decrease (ECHAM5) or increase (ARPEGE and PROMES) in the total annual cycle precipitation amount. If we have a look at the future projection (Figure 3.2.1-10), using the three model time series CNRM-RM5.1 (or ALADIN) forced by ARPEGE, ICTP-REGCM forced by ECHAM5 and UCLM-PROMES forced by HadCM3Q0 for the period 2001-2100, it is possible to realize that, all the models evidence a slight decrease in the annual precipitation amount.

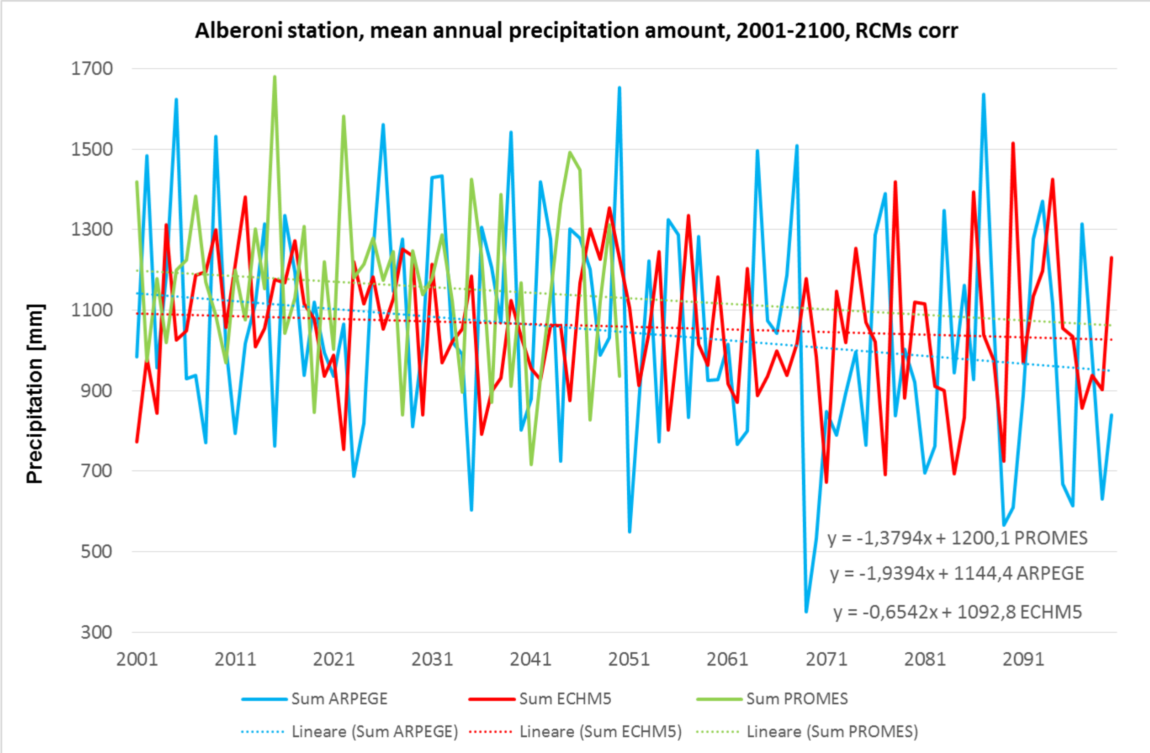


Figure 3.2.1-10. Alberoni station time series 2001-2100, annual precipitation amount corrected. The trend for the ARPEGE values is of -19 mm/10y, for PROMES is of -13 mm/10y and for ECHAM5 is of -6 mm/10y. All the three models are indicating a decreasing trend.

Table 3.2.1-4. Summary of the results calculated for the Alberoni station.

Alberoni	ARPEGE	PROMES	ECHAM5	Observed
Temperature [°C/10y] 50y	0,13	0,13	0,17	0,37
Temperature [°C/10y] 100y	0,34	0,47	0,38	
P (50y) [mm/10y]	38	6,6	-22	-9
P (100y) [mm/10y]	-19	-13	-6	

3.2.2. ATO 3 Marche Test Area (Italy)

From Annex 2 Report 2.2.:

General climate characteristics, climate variability and trends in ATO 3 Test Area are analysed based on available climatological data. They include measurements of air temperature and precipitation amounts from the reference climate period 1961-1990. Observed trends are estimated from a longer period: 1951-2008 as far as concerns precipitations and 1957-2008 for temperatures, with only few data missing.

An assessment of the present and future climate is based on the results from numerical simulations of the three regional climate models that were also analysed for the purpose of the CC-WaterS project. These models also participated in the ENSEMBLES project.

The regional climate models (RCMs) used are the Aladin, Promes and RegCM3 models. The RCMs were forced by the observed concentrations of the greenhouse gases (GHGs) from 1951 to 2000; from 2001 onwards the IPCC A1B scenario of the GHGs emissions is applied. The initial and boundary data for each RCM were provided from different global climate models (GCMs): the ECHAM5 GCM data were used to force RegCM3, Aladin was forced by the Arpege GCM and Promes was forced by the HadCM3Q GCM.

The following two abbreviations are used in the report:

1. RCMcorr: the RCMs' output was bias corrected by EOBS data.
2. RCMcorr_adj: this is further adjusted model time series due to the differences between EOBS data and local stations observations.

Climate and climate change characteristics based on observed data

This chapter provides an overview of climate characteristics of the observed climate variability and trends for ATO 3 Test Area in Marche Region. The catchment includes several climatological stations providing both temperature and precipitation data concerning the period 1951-2008.

Table 3.2.2-1. Geographical station data (elevation h, longitude l, latitude f) and the available measurement time periods for temperature (t) and precipitation (P) data for 2 stations in ATO 3 Test Area.

	Station	*h* (m	f	l	t	P
1.	Lornano	232	43° 17'	13° 25'	1957-2008 (1)	1951-2008 (2)
2.	Montemonaco	987	42° 53'	13° 19'	1957-2007	1951-2007 (3)

(1) the whole year 1977 is missing.
(2) some data of 1989 are missing.
(3) the whole years 1988 and 1989 are missing.

The annual cycle of air temperature monthly averages in ATO 3 Test Area is well defined: the maximum occurs in summer (JJA) and the minimum in winter (DJF), with significant differences between the mountains (Appennines), internal area and the medium-low hill area, but generally indicating a typical maritime annual cycle with autumn (SON) being warmer than spring (MAM).

The annual course of standard deviations of mean monthly air temperatures indicates a higher variability in the central, medium-low hill area, especially in autumn (SON), while the monthly values of stdev, for the mountain meteorological station taken into account range between 0.9°C (JJA) and 1.8°C (DJF) indicating that interannual variability is generally small.

The ATO 3 Test Area has a mix of the maritime and continental types of annual precipitation cycle. In some years there is a significant deviation in monthly amounts from the average precipitation conditions. Coefficient of variation indicates a high interannual variation in mean monthly precipitation, especially on the Appennines. The differences in the CDFs across a small region such as the ATO 3 Test Area reveal the overall large spatial variability of precipitation amounts.

Trends in seasonal and annual mean monthly air temperature and precipitation amounts have been estimated by the Kendall's tau method (or Sen's slope). However, a linear trend is also calculated and given for comparison. The trends are expressed as decadal values for both variables. Additionally, the trends in precipitation amounts are given as the percentage of the corresponding seasonal and annual means from 1961-1990 period.

The trend results reveal the statistically significant increase in annual mean air temperature (0.3°C/10yrs) since 1961 in the ATO 3 Test Area (see Table 3.2.2-2). The annual mean temperature increase is predominantly due to the significant increase in spring (0.2-0.4°C/10yrs) and summer (0.2-0.5°C/10yrs) mean air temperature. Changes observed in the cold half-year are very weak.

Table 3.2.2-2. Decadal air temperature trends (°C/10 yrs) for Lornano and Montemonaco climatological stations based on the 1957-2007 (or 2008) data series.

°C/10yrs	DJF	MAM	JJA	SON	Year
Lornano	0,10	0,20	0,20	0,06	0,30
Montemonac	0,28	0,41	0,49	0,16	0,33

The trends in precipitaiton amounts show the significant decrease in annual totals (2-5%/10yrs) over the ATO 3 Test Area. There is a consistent decrease of precipitation amounts in all seasons (see Table 3.2.2-3).

Table 3.2.2-3. Decadal precipitation trends (mm/10 yrs and %/10 yrs) for Lornano and Montemonaco climatological stations based on the 1951-2007 (or 2008) data series.

	DJF	MAM	JJA	SON	Year
Lornano					
mm/10yrs	-11,2	-4,8	-14,9	-10,9	-36,3
%/10yrs	-6,3	-2,7	-8,0	-5,2	-4,8
Montemonaco					
mm/10yrs	-8,0	-7,3	-0,7	-10,6	-26,6
%/10yrs	-2,4	-2,4	-0,3	-3,1	-2,2

Climate and climate change simulations for future

Lornano station

For the period 1951-2050, all three bias corrected models simulate statistically significant increasing trends in the mean annual temperature from 0.16 °C/10yr in RegCM to 0.30 °C/10yr in Promes (Fig. 3.2.2-1). It should be emphasised here that, in the model simulations for the period 1951-2000, the observed concentrations of the greenhouse gases (GHGs) is used, and in the period 2001-2050, the models were forced by the GHGs concentrations for the IPCC A1B scenario. In the period 1961-2007, when the local observations were available, all three models agree with the observations in the simulated sign of trend, with a magnitude of trend similar to that of the local observations (0.3 °C/10yr; Table 3.2.2-2).

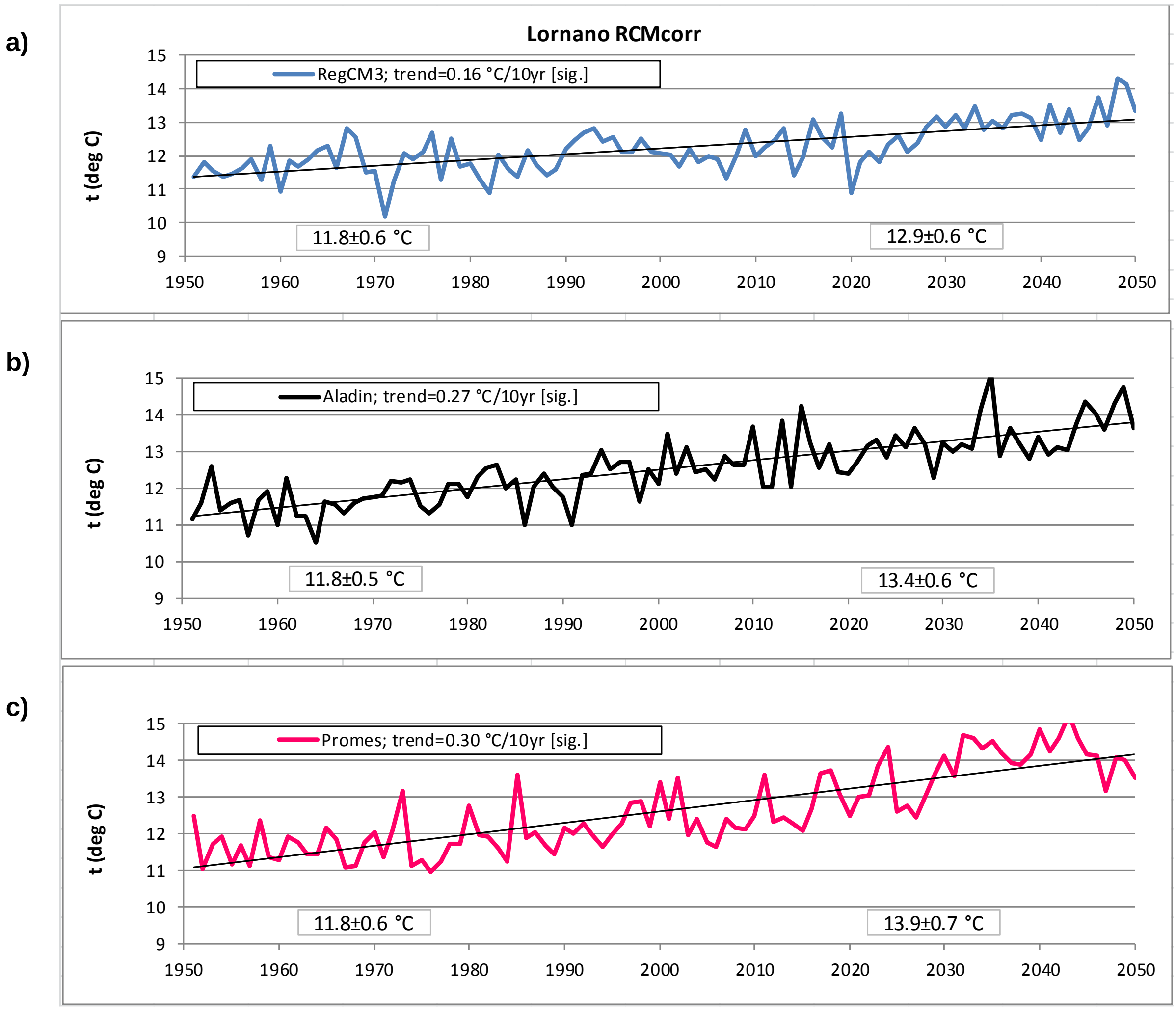


Figure 3.2.2-1. Lornano station: annual mean temperature and associated linear trend in a) RegCM3, b) Aladin, c) Promes. Decadal trend based on the entire time series is shown in panel legends. The statistical significance of the trend is assessed using the Mann-Kendall test and 5% significance level. Additional numbers at the bottom of each panel are mean values and standard deviations during P0 (1961-1990) and P1 (2021-2050). Model time series are RCMcorr.

Two of the three bias-corrected models (RegCM3, Aladin) simulate decreasing trend in the annual precipitation amount for the period 1951-2050 (Fig. 3.2.2-2), while the third one (Promes) simulates opposite sign of the trend. However, in all the models, these trends are not statistically significant. For the period 1951-2008, when local observations at the Lornano station show decreasing trend in annual precipitation amount (-36.3mm/10yr; Table 3.2.2-3), RegCM3 and Aladin simulates the same sign of the trend as observed, but with greatly reduced amplitude and no statistical significance. This implies that, according to the CC-WaterS bias corrected RCMcorr simulations presented here, no robust estimates of significant precipitation change could be made for the first part of the 21st century.

a)

b)

c)

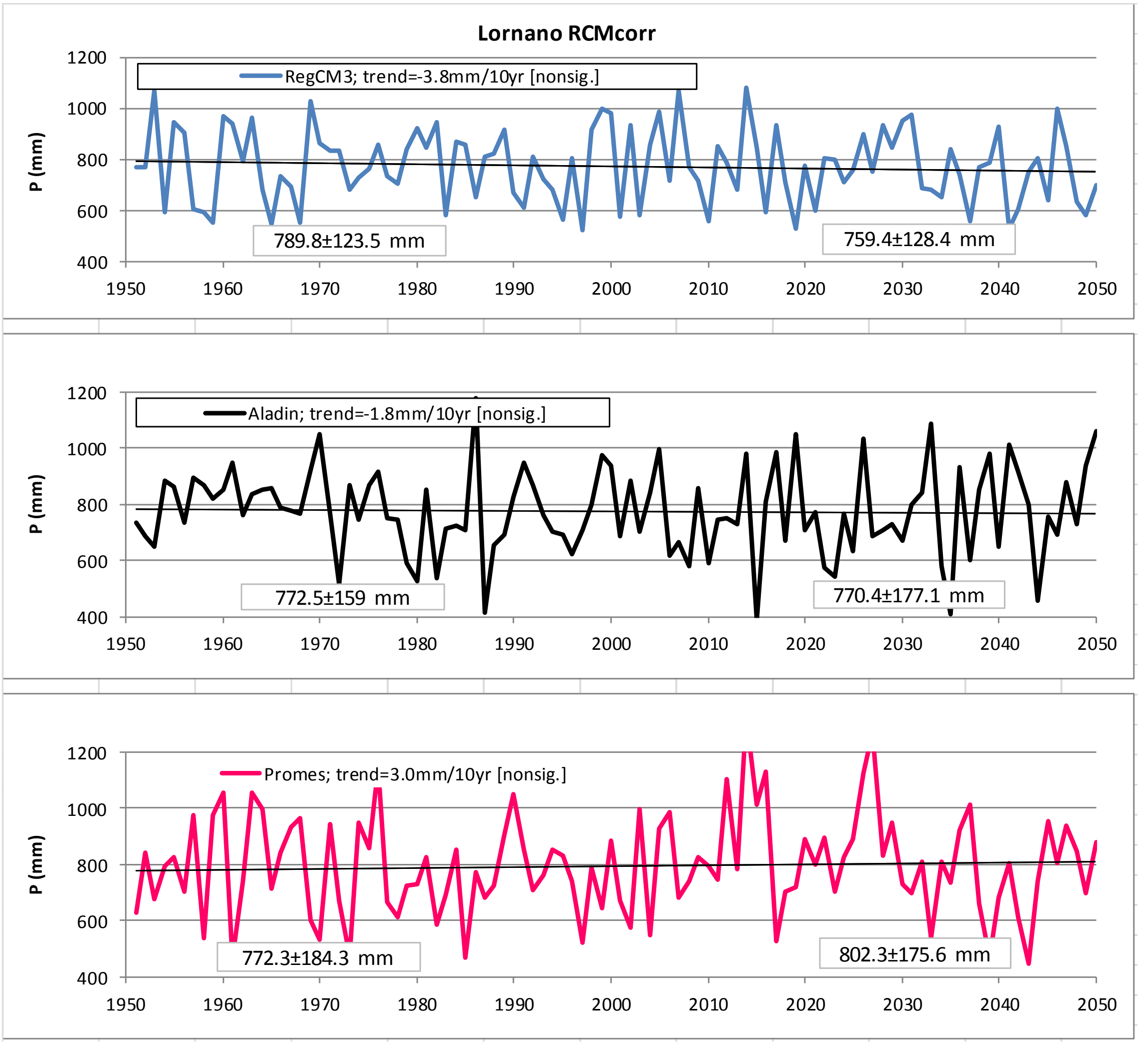


Figure 3.2.2-2. Lornano station: annual precipitation amount and associated linear trend in a) RegCM3, b) Aladin, c) Promes. Decadal trend based on the entire time series is shown in panel legends. The statistical significance of the trend is assessed using the Mann-Kendall test and 5% significance level. Additional numbers at the bottom of each panel are mean values and standard deviations during P0 (1961-1990) and P1 (2021-2050). Model time series are RCMcorr.

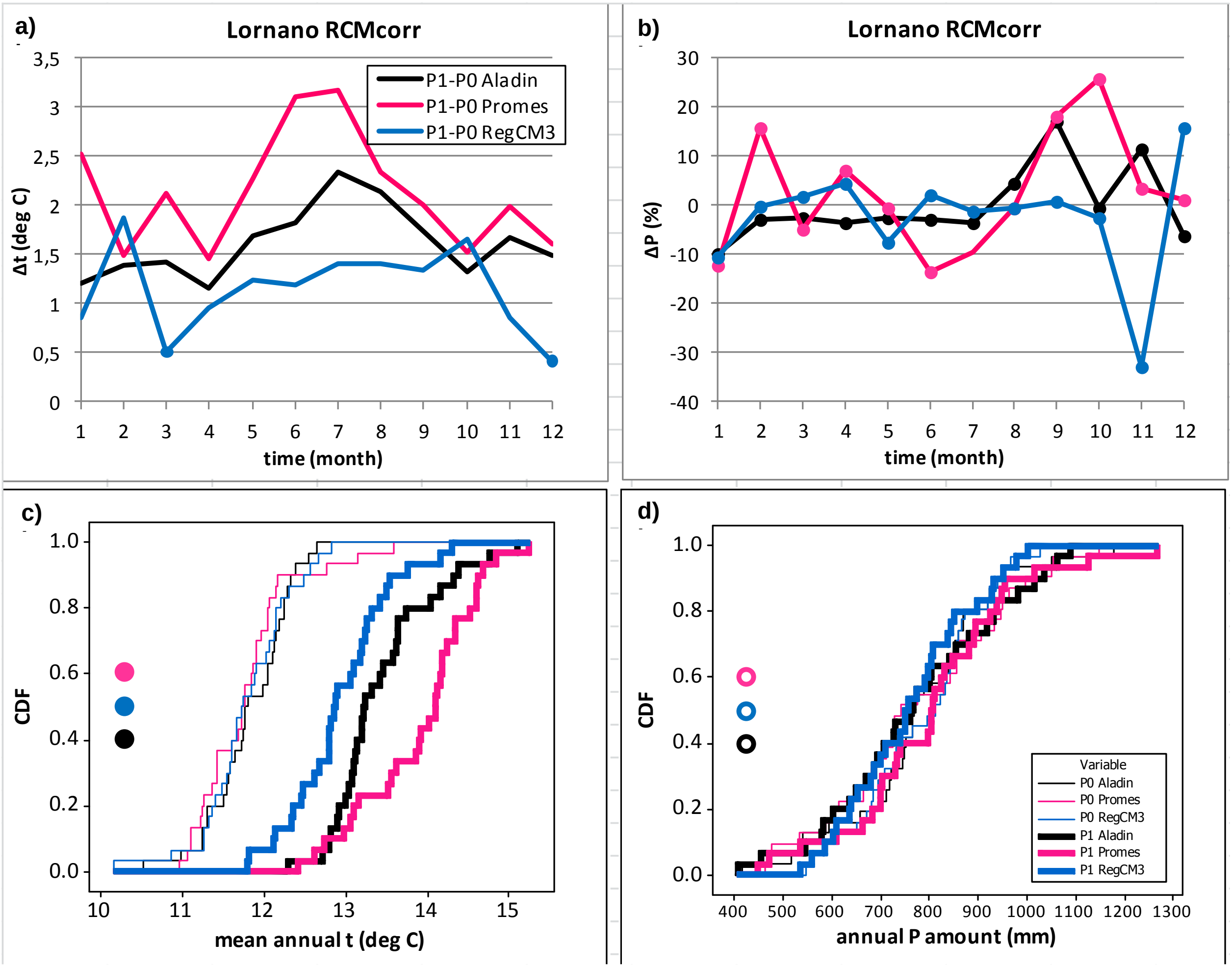


Figure 3.2.2-3. Lornano station: a) monthly mean temperature P1 vs. P0 change; b) relative monthly precipitation P1 vs. P0 change; c) empirical cumulative distribution functions CDFs of mean annual temperature in P0 and P1; d) same as c) but for annual precipitation amount. Time periods are: P0 1961-1990 and P1 2021-2050. Statistically significant differences in a) and b) according to the Wilcoxon-Mann-Whitney nonparameteric rank-sum test and 5% significance level are marked by the filled circles. Statistically significant differences according to the Kolmogorov-Smirnov test and 5% significance level between CDFs in two periods for every model in panels c) and d) are marked by the filled circles. Model time series are RCMcorr.

<u>Montemonaco station</u>

For the period 1951-2050, all three bias corrected models simulate statistically significant increasing trends in the mean annual temperature from 0.17 °C/10yr in RegCM3 to 0.32 °C/10yr in Promes (Fig. 3.2.2-4). It should be emphasised here that, in the model simulations for the period 1951-2000, the observed concentrations of the greenhouse gases (GHGs) is used, and in the period 2001-2050, the models were forced by the GHGs concentrations for the IPCC A1B scenario. In the period 1961-2008, when the local observations were available, all three models agree with the observations in the simulated sign of trend, with a magnitude of trend similar to that of the local observations (0.33 °C/10yr; Table 3.2.2-2).

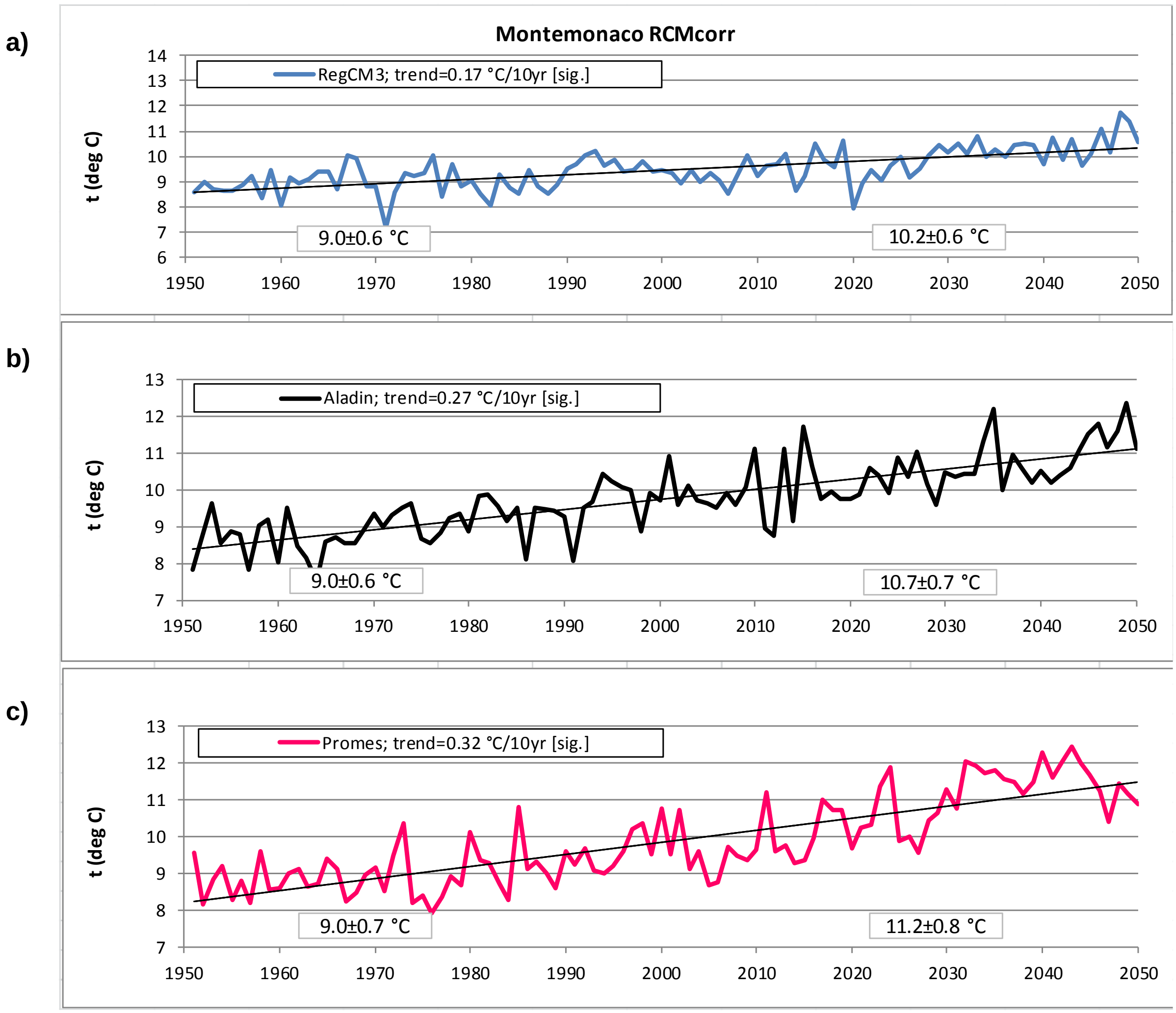


Figure 3.2.2-4. Montemonaco station: annual mean temperature and associated linear trend in a) RegCM3, b) Aladin, c) Promes. Decadal trend based on the entire time series is shown in panel legends. The statistical significance of the trend is assessed using the Mann-Kendall test and 5% significance level. Additional numbers at the bottom of each panel are mean values and standard deviations during P0 (1961-1990) and P1 (2021-2050). Model time series are RCMcorr.

All three bias-corrected models simulate decreasing trend in the annual precipitation amount for the period 1951-2050 (Fig. 3.2.2-5), even if, for all the models, these trends are not statistically significant. For the period 1951-2008, when local observations at the Montemonaco station show decreasing trend in annual precipitation amount (-26.6mm/10yr; Table 3.2.2-3), the models simulates the same sign of the trend as observed, but with greatly reduced amplitude and no statistical significance. This implies that, according to the CC-WaterS bias corrected RCMcorr simulations presented here, no robust estimates of significant precipitation change could be made for the first part of the 21st century.

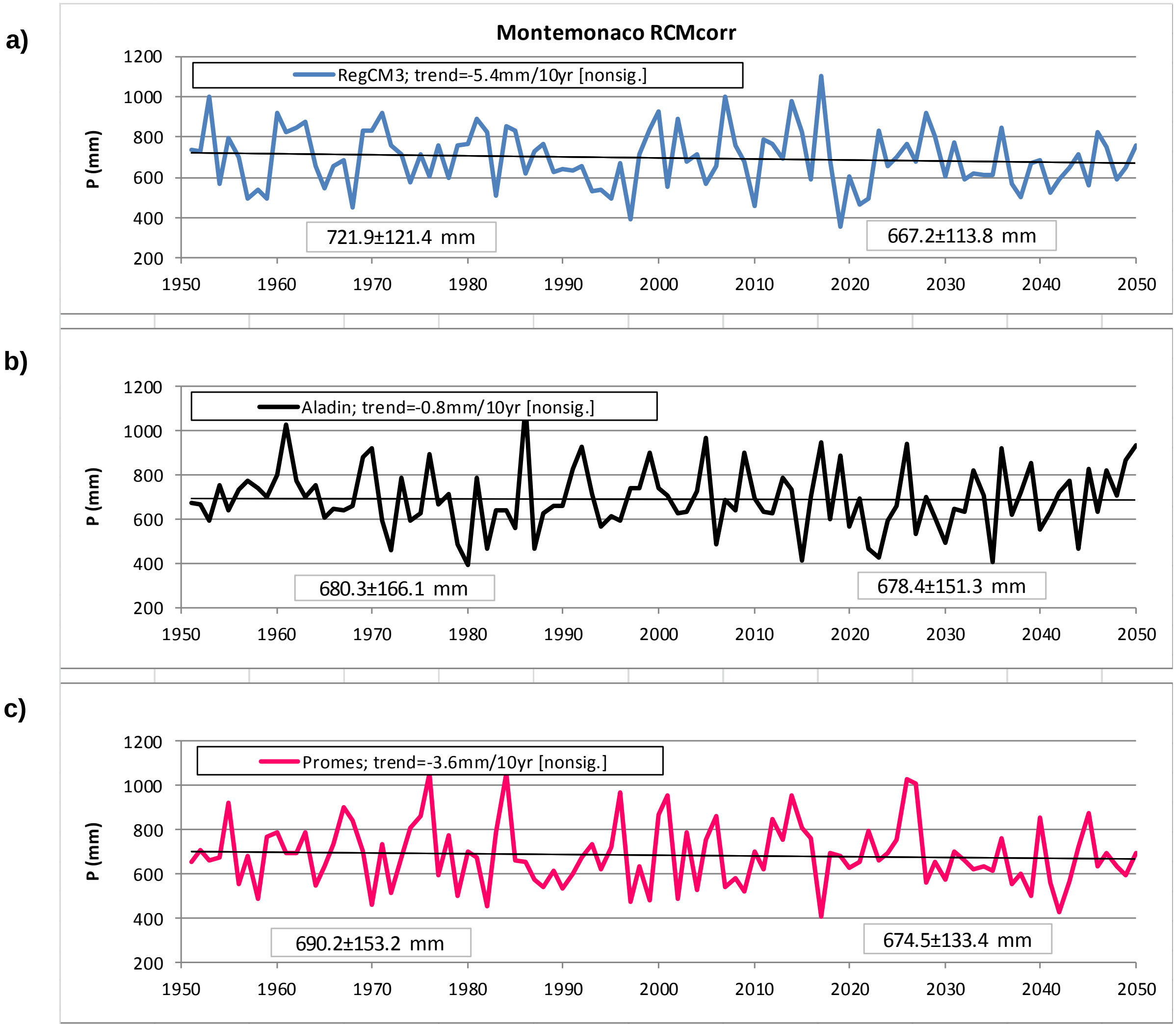


Figure 3.2.2-5. Montemonaco station: annual precipitation amount and associated linear trend in a) RegCM3, b) Aladin, c) Promes. Decadal trend based on the entire time series is shown in panel legends. The statistical significance of the trend is assessed using the Mann-Kendall test and 5% significance level. Additional numbers at the bottom of each panel are mean values and standard deviations during P0 (1961-1990) and P1 (2021-2050). Model time series are RCMcorr.

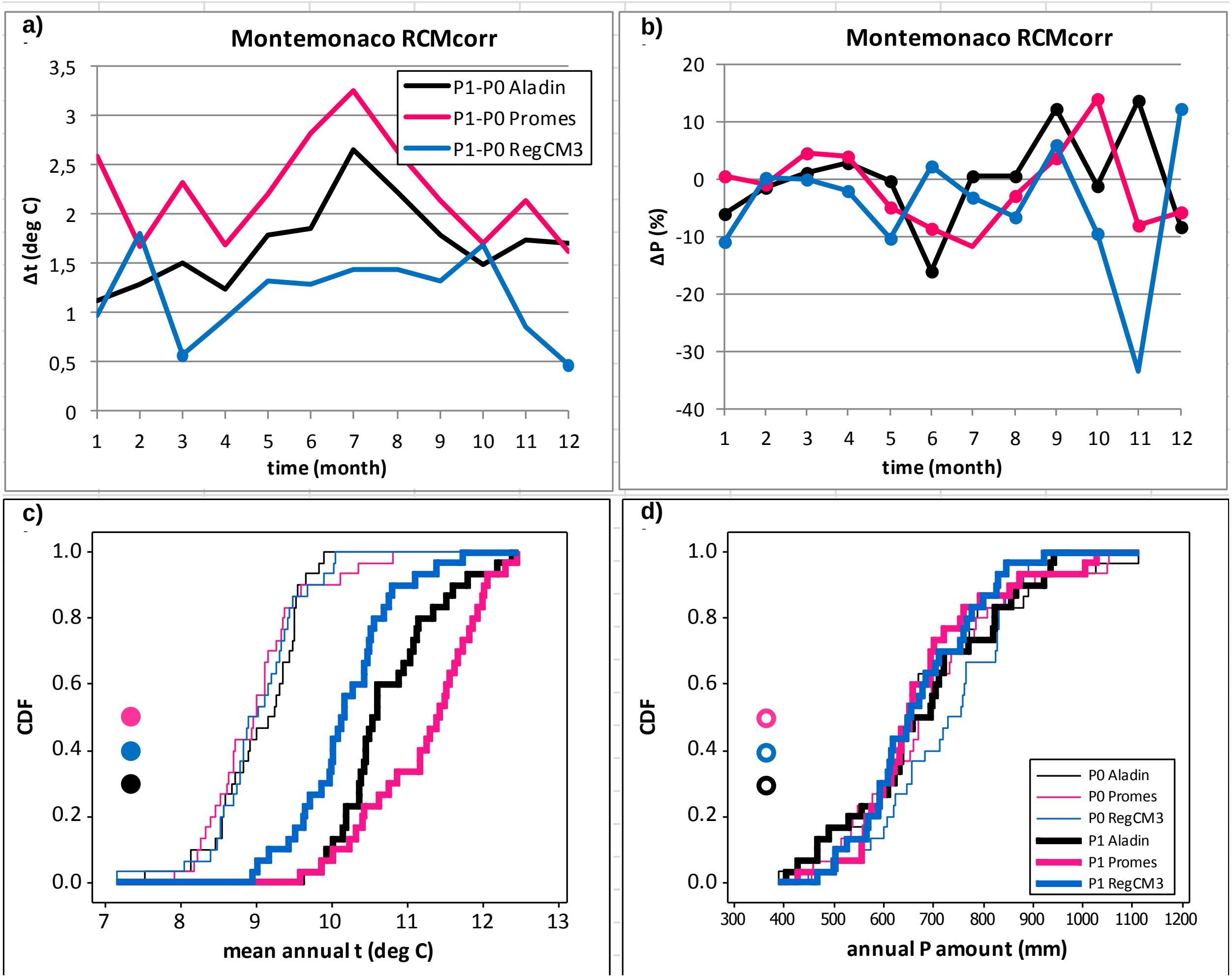


Figure 3.2.2-6. Montemonaco station: a) monthly mean temperature P1 vs. P0 change; b) relative monthly precipitation P1 vs. P0 change; c) empirical cumulative distribution functions CDFs of mean annual temperature in P0 and P1; d) same as c) but for annual precipitation amount. Time periods are: P0 1961-1990 and P1 2021-2050. Statistically significant differences in a) and b) according to the Wilcoxon-Mann-Whitney nonparameteric rank-sum test and 5% significance level are marked by the filled circles. Statistically significant differences according to the Kolmogorov-Smirnov test and 5% significance level between CDFs in two periods for every model in panels c) and d) are marked by the filled circles. Model time series are RCMcorr.

3.2.3. Ostuni test area (Apulia Region)

From Annex 2 Report 2.3.:

An assessment of the present and future climate is based on the results from numerical simulations of the three regional climate models that were also analysed for the purpose of the CC-WaterS project. These models participated in the ENSEMBLES project.
The regional climate models (RCMs) used are the Aladin, Promes and RegCM3 models. The RCMs were forced by the observed concentrations of the greenhouse gases (GHGs) from 1951 to 2000; from 2001 onwards the IPCC A1B scenario of the GHGs emissions is applied. The initial and boundary data for each RCM were provided from different global climate models (GCMs): the ECHAM5 GCM data were used to force RegCM3, Aladin was forced by the Arpege GCM and Promes was forced by the HadCM3Q GCM. The following two abbreviations are used in the report:

1. RCMcorr: the RCMs' output was bias corrected by EOBS data.
2. RCMcorr_adj: this is further adjusted model time series due to the differences between EOBS data and local observations.

Climate and climate change characteristics based on observed data

The Ostuni test area is located in the Apulia region (south of Italy); the climate is tipically Mediterranean, with hot and dry summer and wet and temperate winter.
The current climate analysis presented in this report has been performed considering 9 temperature stations and 9 rainfall stations, whose location within the study area is shown in figure 3.2.3-1.

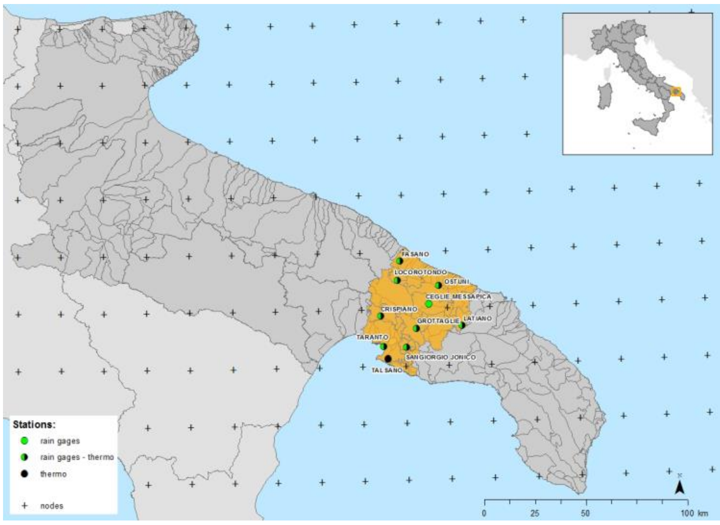


Figure 3.2.3-1. Ostuni area, Apulia Region, Italy

The available air temperature time series have been analysed in terms of the basic statistics (mean, standard deviation, maximum and minimum) at annual and seasonal time scale for the reference period 1961-1990 (*P0*) and for the whole observation period 1950-2007 (P_{obs}).

Some remarks on possible trends of temperature can be done:

1. A significant variability among stations exist, mostly in terms of trends. It is hard to infer a common tendency for all the stations. However, at annual scale considering the whole observation period P_{obs} the majority of the stations present a tendency to increase; only for 1 out of 9 there is a slight but significant tendency to decrease. Different results can be inferred considering the base-line period *P0* during which 5 stations out of 9 indicate a decrease of temperature (although statistically significant in only 1 case) and 4 out of 9 indicate an increase (statistically significant in only 1 case). In general, at annual scale can be observed a general increase of the temperature if one considers the whole observation period, and a stationarity if one consider the base line period 1961-1990.

2. Such an increasing temperature tendency appears to be mostly related to an increase of the summer temperature.

3. Also the other seasons present a general tendency to increase temperatures during the period of observation, but the number of stations for which such a tendency is statistically significant are less.

4. We can conclude that a general increase of annual temperature is observed for the whole observation period (1960-2007), due to an increase of temperature (particularly during summer) during the last two decades (1991-2007). This climatic signal is not observed in all the stations, suggesting that local climate can be superimposed to the regional and/or global climatic trend.

In figure 3.2.3-2 data for Ostuni climatological station is given. In the report made by FB3, the same data is shown for nine stations.

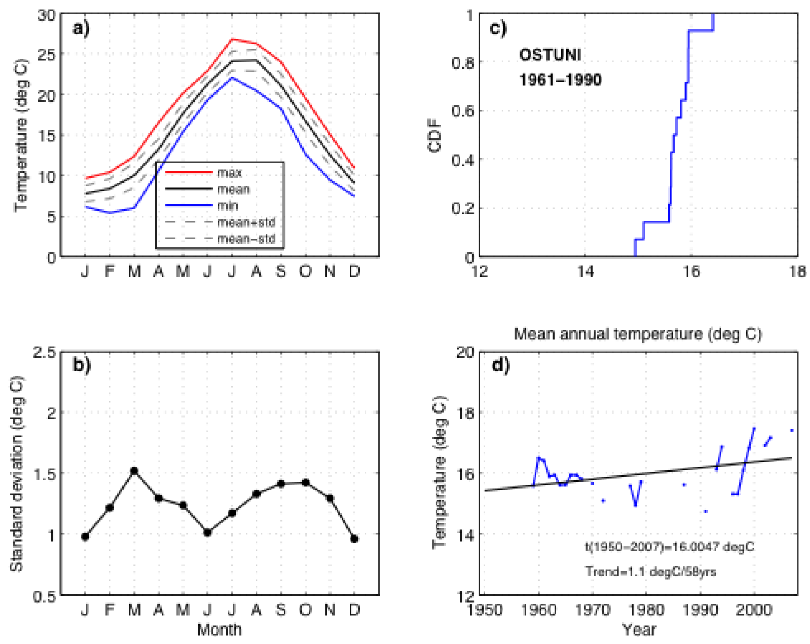


Figure 3.2.3-2. Annual cycle of mean monthly air temperature (a) and standard deviation (b), cumulative distribution of mean annual air temperature (c) and time series of mean annual air temperature with fitted trend line for the period 1950-2007 (d) for Ostuni climatological station.

The available precipitation time series have been analysed in terms of the basic statistics (mean, standard deviation, maximum and minimum) at annual and seasonal time scale for the reference period 1961-1990 (*P0*) and for the whole observation period 1950-2007 (P_{obs}).

Some remarks on possible trends of precipitation can be done:

1. In terms of annual mean, the precipitation regime appears to be uniform over the study area (this value ranges from 486 mm/year to 716 mm/year, if one considers the P_{obs} period).

2. A very high interannual variability can be observed, both considering the min and max values, and considering the percentile.

3. Concerning the trends, it is possible to observe a general decrease of annual precipitation, both for the base line period *P0* and for the whole observation period P_{obs}. However, such a decrease, although observed in all the rain gauges, it is never statistically significant. This is probably due to the high interannual variability.

4. The analysis of the seasonal trends suggests that the decrease of precipitation observed at annual scale (although not significant) is mainly due to a decrease of the winter precipitation, which is observed in all the stations for the period P0. A similar decreasing trend is observed also if the whole observation period is considered: however, such a trend is generally not significant. The last observation lead to two important consequences: a) concerning precipitation, the base line 1961-1990 (which is usually considered stationary from a climatic point of view) is not stationary; b) the impact of a decreasing in precipitation on the Ostuni aquifer and on the possible salt intrusion is currently ongoing.

In figure 3.2.3-3 data for Ostuni climatological station is given. In the report made by FB3, the same data is shown for nine stations.

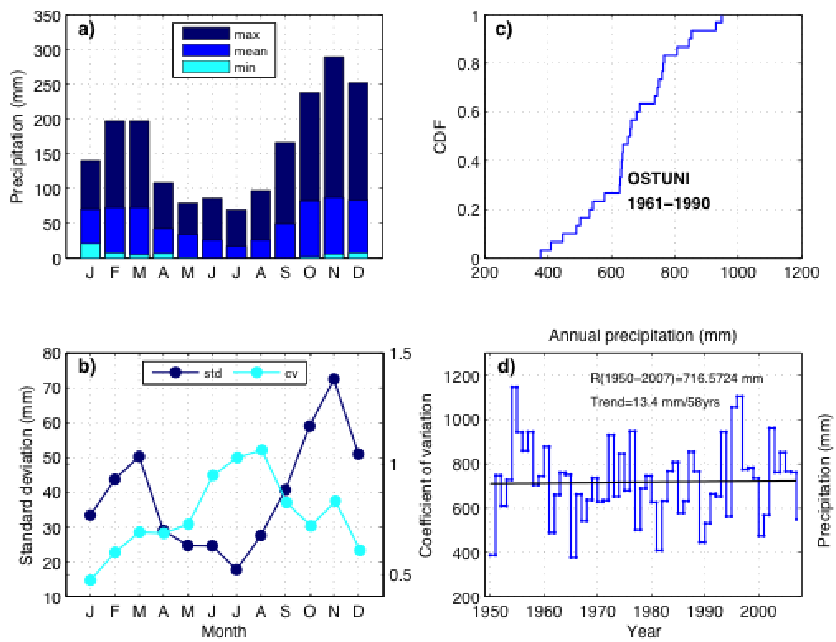


Figure 3.2.3-3. Annual cycle of mean monthly precipitation amounts (a), standard deviation and coefficient of variation (b), cumulative distribution (c) and time series of annual precipitation with fitted trend line for the period 1950-2007 (d) for Ostuni climatological station.

Climate and climate change simulations for future

In the following, results from the Regional Climate Models are compared to the observations and the model scenarios are analyzed, mainly in terms of trend.
As already explained in the introduction we used two different types of time series:

1. RCMcorr: bias corrected model output by EOBS data.
2. RCMcorr_adj: RCM model output downscaled to the observed time series through a q-q plot procedure.

Basically, in the first time series only the bias are corrected, while through the second procedure all the cumulative density function is corrected.

In this report only the data for Ostuni climatological station is extracted, and shown in following figures.

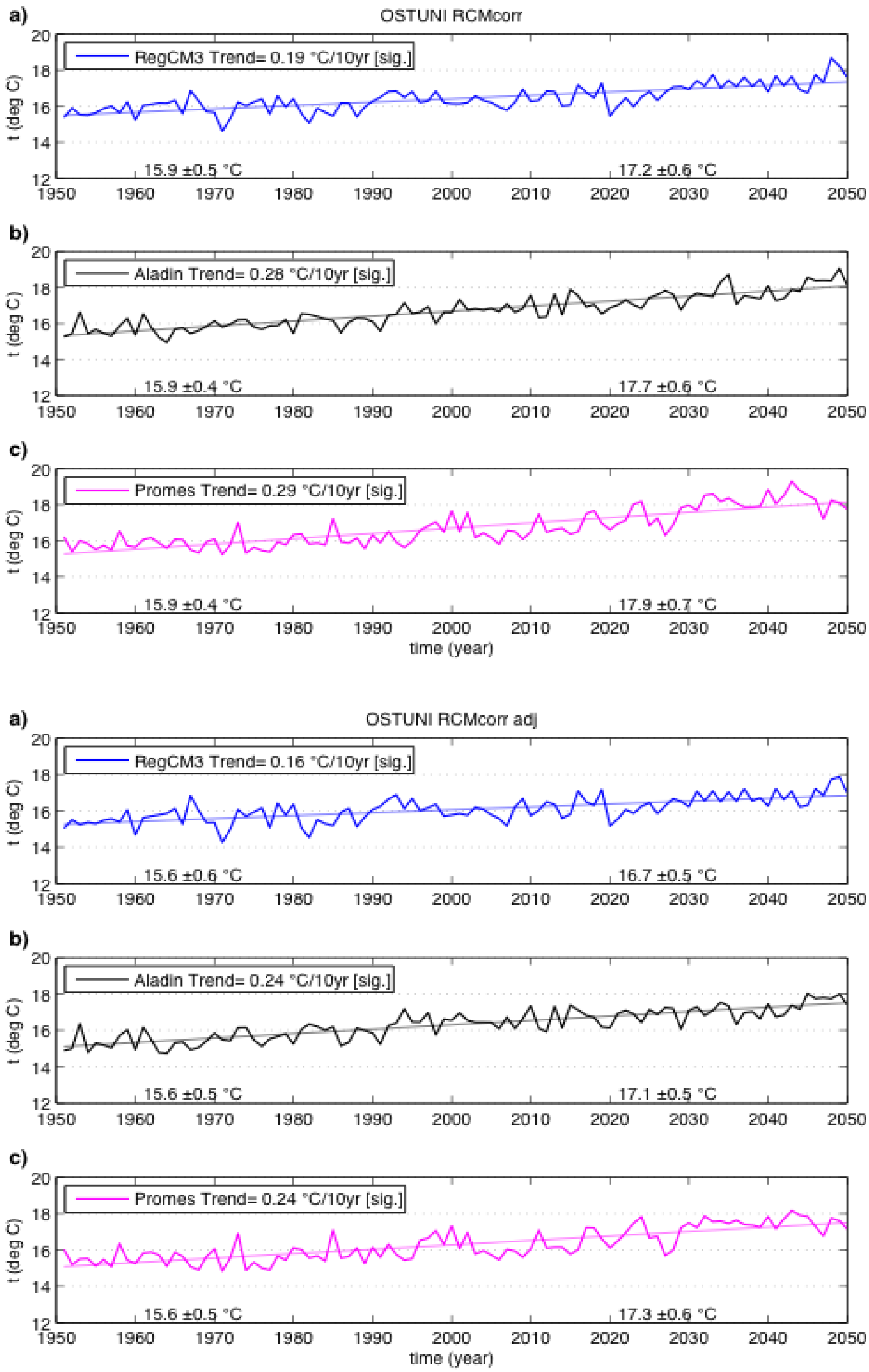


Figure 3.2.3-4. Ostuni station: annual mean temperature and associated linear trend in a) RegCM3, b) Aladin, c) Promes. Decadal trend based on the entire time series is shown in panel legends. The statistical significance of the trend is assessed using the Mann-Kendall test and 5% significance level. Additional numbers at the bottom of each panel are mean values and standard deviations during P0 (1961-1990) and P1 (2021-2050). Model time series: RCMcorr (above); RCMcorr_adj (below).

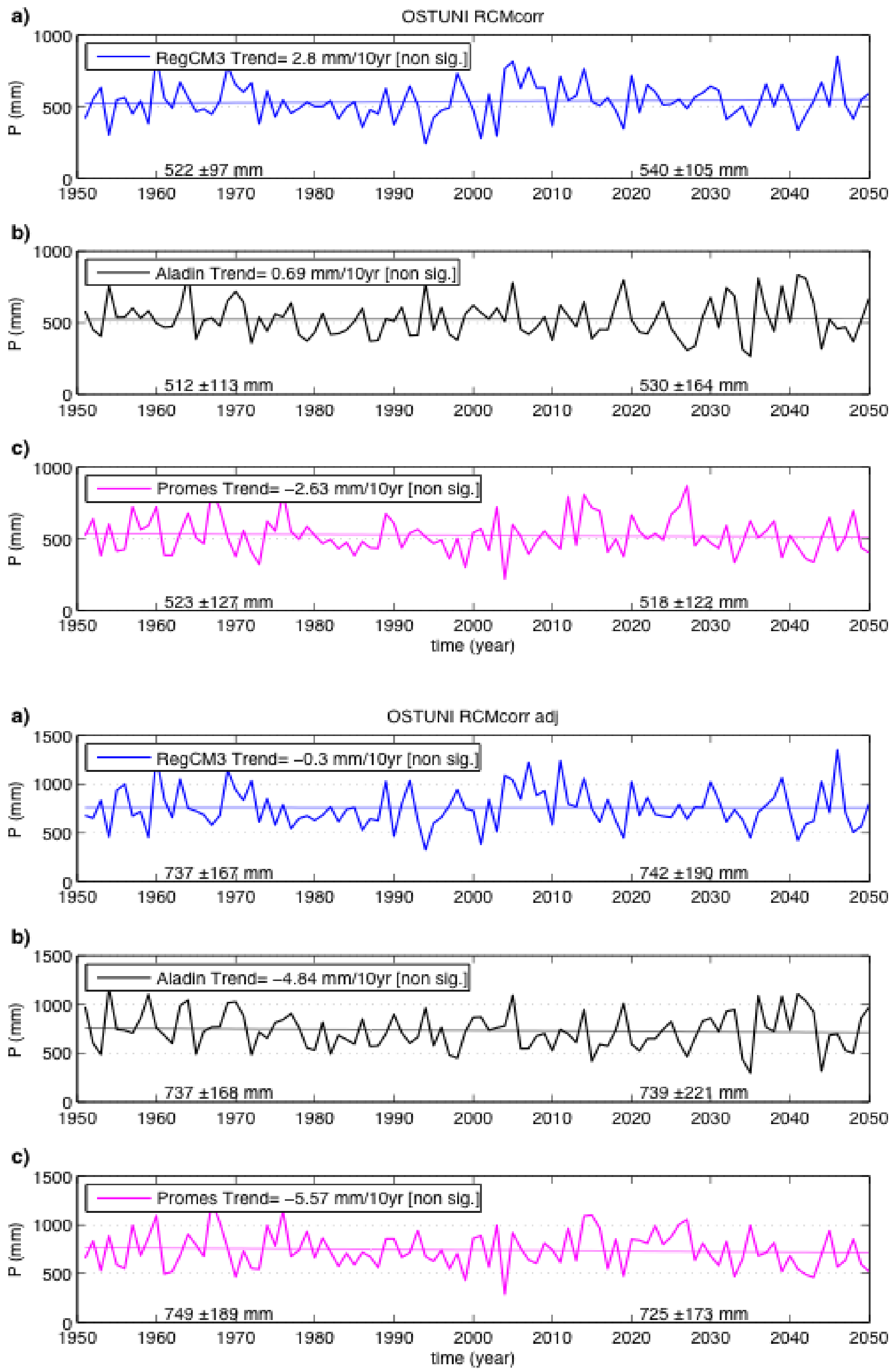


Figure 3.2.3-5. Ostuni station: annual precipitation amount and associated linear trend in a) RegCM3, b) Aladin, c) Promes. Decadal trend based on the entire time series is shown in panel legends. The statistical significance of the trend is assessed using the Mann-Kendall test and 5% significance level. Additional numbers at the bottom of each panel are mean values and standard deviations during P0 (1961-1990) and P1 (2021-2050). Model time series: RCMcorr (above); RMcorr_adj (below).

The following tables show a comparison among stations and among RCM for temperature and precipitation trends.

Table 3.2.3-1. Temperature trends computed considering different RCM (RegCM3, Aladin and Promes) and different downscaling methodologies (bias correction: corr; q-q plot: corr_adj). The trends are expressed in °C/10yrs.

	TEMPERATURE TREND 1955-2050					
	RegCM3		ALADIN		PROMES	
%	**corr**	**corr_adj**	**corr**	**corr_adj**	**corr**	**corr_adj**
CRISPIANO	0.19	0.17	0.28	0.25	0.29	0.26
FASANO	0.19	0.21	0.28	0.33	0.29	0.32
GROTTAGLIE	0.19	0.19	0.28	0.37	0.29	0.34
LATIANO	0.19	0.17	0.28	0.27	0.29	0.27
LOCOROTONDO	0.19	0.19	0.28	0.29	0.29	0.29
OSTUNI	0.19	0.16	0.28	0.24	0.29	0.24
SANGIORGIO JONICO	0.19	0.18	0.27	0.33	0.27	0.30
TALSANO	0.19	0.16	0.27	0.24	0.27	0.24
TARANTO	0.19	0.15	0.27	0.23	0.27	0.24

Table 3.2.3-2. Precipitation trends computed considering different RCM (RegCM3, Aladin and Promes) and different downscaling methodologies (bias correction: corr; q-q plot: corr_adj)

	PRECIPITATION TREND 1955-2050					
	RegCM3		ALADIN		PROMES	
mm/10yrs	**corr**	**corr_adj**	**corr**	**corr_adj**	**corr**	**corr_adj**
CELLE MESSAPICA	2.8	-0.95	0.69	-4.87	-2.63	-7.43
CRISPIANO	0.49	1.4	-2.16	3.66	-2.24	-9.18
FASANO	-0.02	-0.72	-1.51	-4.71	-2.47	-7.62
GROTTAGLIE	-0.02	0.73	-1.51	0.49	-2.47	-8.21
LATIANO	2.8	3.66	0.69	-4.4	-2.63	-6.31
LOCOROTONDO	-0.02	0.12	-1.51	-6.48	-2.47	-8.39
OSTUNI	2.8	-0.3	0.69	-4.84	-2.63	-5.57
SANGIORGIO JONICO	1.28	1.33	3.73	1.72	-3.95	-7.78
TARANTO	1.28	0.67	3.73	3.8	-3.95	-6.74

From tables 3.2.3-1 and 3.2.3-2 it is possible to infer that:

1. Concerning the temperature, the climatic signal over the area is uniform. In other words, the correction due to the downscaling does not affect the tendency to the increasing temperature forecast by all the RCMs. It is approximately +0.2 °C/10yrs over the period 1955-2050 (for the RegCM3 time series).

2. Concerning the precipitation, the climatic signal over the area, once chosen the RCM, is strongly not uniform, both adopting only the bias correction (*corr*) and adopting the q-q plot correction (corr_adj). The signs of such trends are not equal for all the stations: in other words, at some nodes RegCM3 forecast an increase of precipitation and in some other nodes RegCM3 forecast a decrease.

3. Applying a q-q plot correction (*corr_adj* time series) the trends significantly change both in sign and modulus (for example, for the Ostuni station, the trend is +2.8 mm/10yrs considering the *corr* time series and -0.30 mm/10yrs considering the *corr_adj* time series). This indirectly means that the correction of the tails of the distributions strongly affect the assessment of the trend.

4. A comparison among RCMs temperature scenarios (table 3.2.3-1) shows that the Aladin and Promes RCM forecast a higher increase with respect to RegCM3. As a consequence, for developing impact scenarios of climate change on the Ostuni area, it appears more suitable to adopt the worst temperature scenarios from Promes and Aladin, neglecting the RegCM3.

5. Precipitation scenarios from Promes (table 3.2.3-2) indicate a uniform in space decrease of precipitation, both for *corr* and *corr_adj* time series; such a decrease is in the order of 2.5 mm/10yrs if the only bias correction is applied, while a correction of the tail distribution lead to a higher decrease, in the order of 8 mm/10yrs.

6. Also Aladin RCM forecast a tendency to reduction of precipitation, although less significant than Promes and not uniform in space.

7. As a conclusion the worst scenarios, in terms of possible water shortage and salt intrusion in the Ostuni area, are obtained from Promes RCM. We suggest to use this model for the next impact studies on the test area aquifer.

3.3. Slovenian test areas
(Kobariški stol, Mia, Matajur and Mirna River catchments)

From Annex 2 Report 2.4.:

In the first part observed air temperature and precipitation from two meteorological stations (Bilje and Portorož) positioned on the west of Slovenia is analyzed. Climate characteristics and variability are presented for 1961 – 1990 reference time period and trends are calculated for the whole span of available data, i.e. 1956 – 2011 for temperature and 1961 – 2011 for precipitation. Data is presented on monthly, seasonal and annual average basis. The second part of the report comprises simulation of present and future climate based on three different regional climate models; Aladin, Promes and RegCM3. The analyses were performed with RCM corrected and RCM corrected & adjusted data.

Climate and climate change characteristics based on observed data

Slovenian test areas are positioned along the western Slovenian border with Italy (Kobariški stol, Mia and Matajur) and south-western border with Croatia (supply area of Mirna river). On this area two main meteorological station were selected to present climate and climate change characteristics (temperature, precipitation) of this area.

In the Slovenian Adriatic area there are two meteorological stations situated approximately 35 km apart (Figure 3.3-1).

Figure 3.3-1. Geographical position of Bilje and Portorož meteorological stations (red stars) and locations of test areas (blue fields) (Geopedia, 2014).

Bilje meteorological station

In Bilje station the coldest month is January and the warmest July. According to standard deviation and coefficient of variation the temperature is most variable in the winter months and quite uniform in summer. Annual air temperature exhibits slight increase of temperature during observed period (Figure 3.3-2), but the trend is statistically significant at 5% level for winter, spring and summer season. Table 3.3-1 shows decadal air temperature trends (°C/10 years) for Bilje station based on 1956 – 2011 data series.

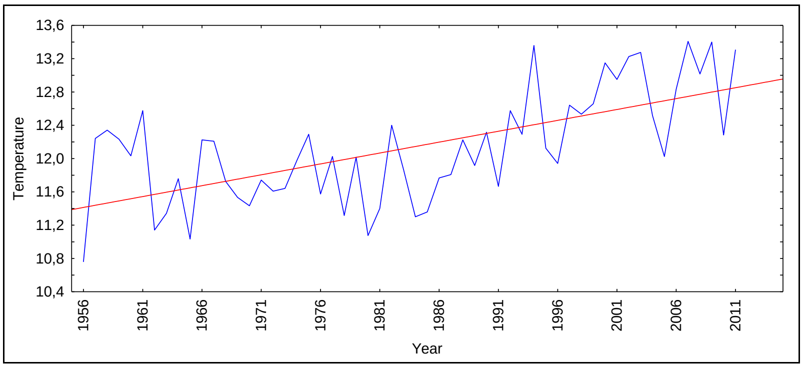


Figure 3.3-2. Time series of annual mean temperature (°C) with fitted trend line for the period 1956-2011 for the meteorological station Bilje.

*Table 3.3-1. Decadal air temperature trends (°C/10 years) based on 1956 – 2011 data series for Bilje meteorological station. * − statistically significant trend at 95 % probability.*

Winter	Spring	Summer	Autumn	Year
0.23*	0.34*	0.35*	0.13	0.26

In Bilje station the driest month is on average February and the wettest November, although the precipitation maximum is observed September. On average spring is the wettest and winter is the driest season. According to standard deviation and coefficient of variation, annual precipitation is the most variable in October and the least in April and May.

Time series of annual precipitation for the period 1961-2011 is shown in Figure 3.3-3. Annual, winter, spring and summer precipitations seem to decrease and autumn precipitation to increase during the observed period, but the annual and seasonal trends are not statistically significant at 5% level (Table 3.3-2). In Table 3.3-2 decadal precipitation trends (mm/10 years) for Bilje station based on 1961 – 2011 data series are presented.

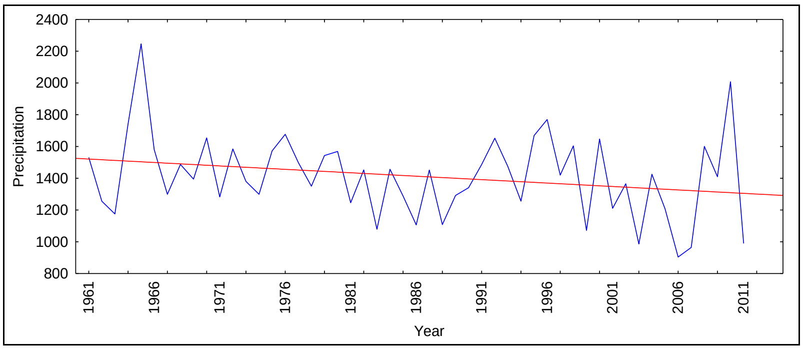


Figure 3.3-3. Time series of annual precipitation (mm) with fitted trend line for the period 1961-2011 for Bilje meteorological station.

*Table 3.3-2. Decadal precipitation trends (mm/10 years) based on time period 1961 – 2011 for Bilje meteorological station. * - statistically significant trend at 95 % probability (not observed).*

Winter	Spring	Summer	Autumn	Year
-3.5	-4.8	-6.4	0.3	-3.6

Portorož meteorological station

In Portorož station the coldest month is January and the warmest July. According to standard deviation and coefficient of variation, the temperature is most variable in the winter months and quite uniform in summer.

Figure 3.3-4 shows time series of annual mean temperature (°C) with fitted trend line for the period 1956-2011. Annual air temperature exhibits slight increase of temperature during observed period, but the trend is statistically significant at 5% level for winter and summer season (Table 3.3-3). Decadal air temperature trends (°C/10 years) are shown in Table 3.3-3.

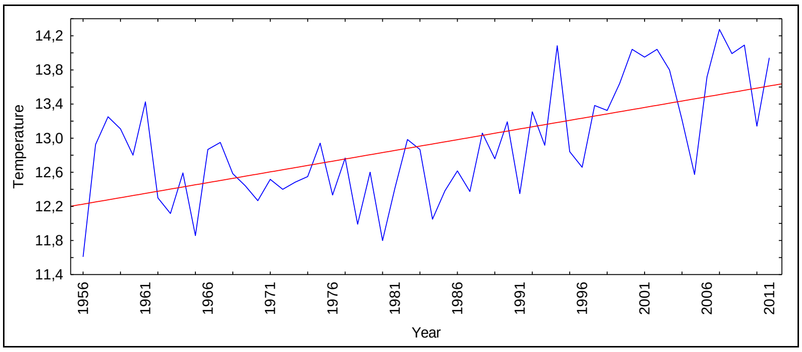


Figure 3.3-4. Time series of annual mean temperature (°C) with fitted trend line for the period 1956-2011 for Portorož meteorological station.

*Table 3.3-3. Decadal air temperature trends (ºC/10 years) based on 1956 – 2011 data series for Portorož meteorological station. * - statistically significant trend at 95 % probability.*

Winter	Spring	Summer	Autumn	Year
0.28*	0.29	0.31*	0.13	0.25

In Portorož the driest month is on average February and the wettest September, where also the precipitation minimum and maximum are observed. On average autumn is the wettest and winter the driest season. According to standard deviation and coefficient of variation, annual precipitation is most variable in October and least variable in April, May and June.

Time series of annual precipitation (mm) with fitted trend line for the period 1961-2011 is shown in Figure 3.3-5. Annual, winter, spring and summer precipitation seem to decrease and autumn precipitation to increase in the observed period, but the only statistically significant trend at 5% level is observed for spring (Table 3.3-4). Table 3.3-4 shows decadal precipitation trends (mm/10 years) for Portorož station based on 1961 – 2011 data series.

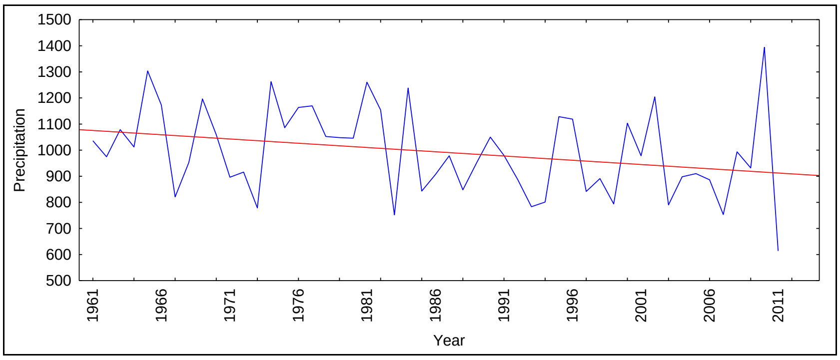


Figure 3.3-5. Time series of annual precipitation (mm) with fitted trend line for the period 1961-2011 for the meteorological amounts station Bilje.

*Table 3.3-4. Decadal precipitation trends (mm/10 years) based on 1961 – 2011 data series for Portorož meteorological station. * - statistically significant trend at 95 % probability.*

Winter	Spring	Summer	Autumn	Year
-1.6	-4.7*	-4.9	0.3	-2.7

Climate and climate change simulations for future

Bilje meteorological station

RCM bias corrected models

For the all three models, time series of annual mean temperatures with fitted linear trend is shown on Figure 3.3-6.

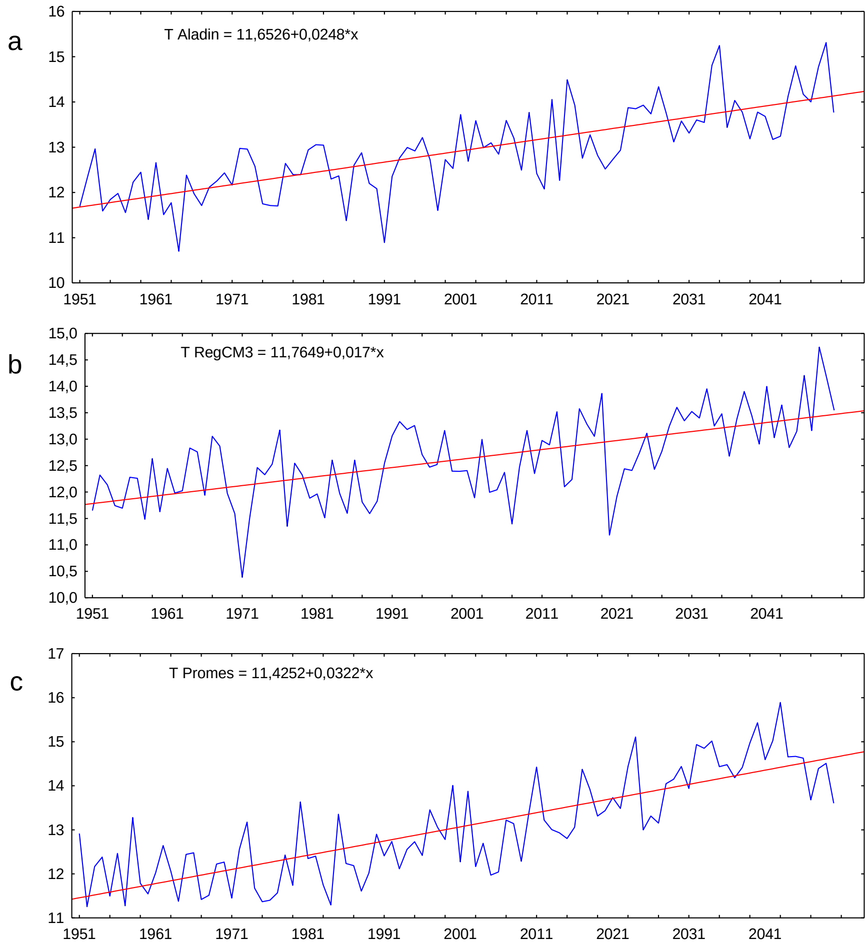


Figure 3.3-6. Annual mean temperature and fitted linear trend of Bilje meteorological station after a) Aladin, b) RegCM3 and c) Promes model. Trends for all three models have statistically significant regression at 5 % significance level. Model time series are RCMcorr.

For all three models, time series of annual precipitation amount with fitted linear trend are shown on Figure 3.3-7.

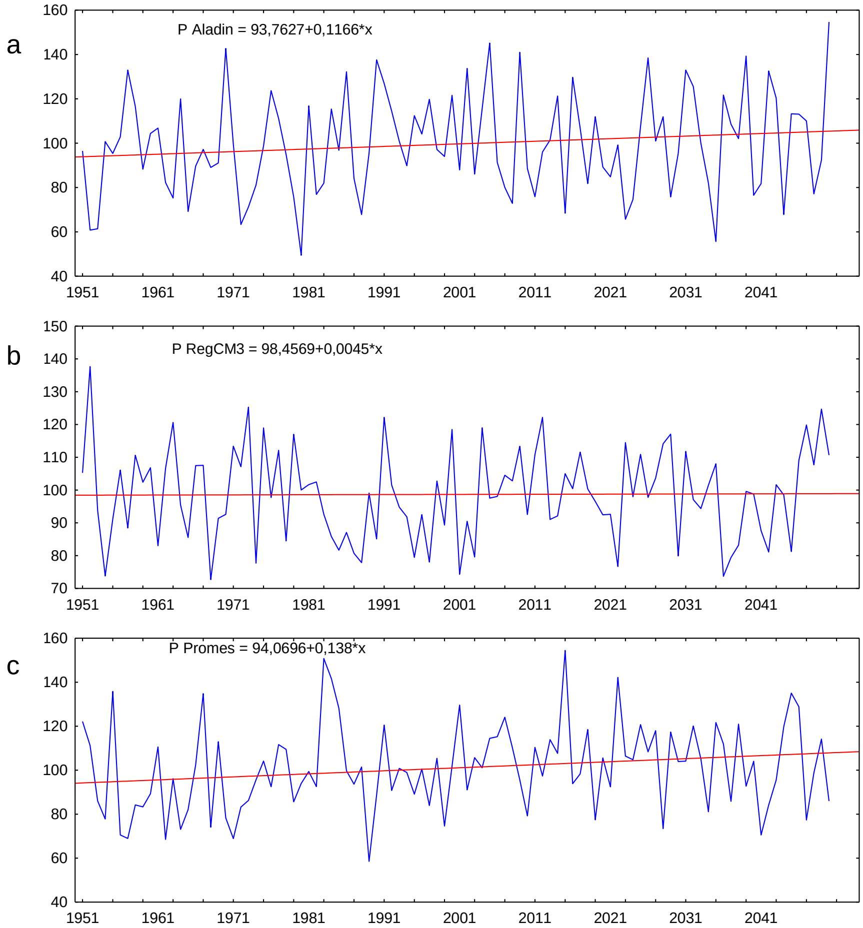


Figure 3.3-7. Annual precipitation amount and fitted linear trend of Bilje meteorological station after a) Aladin, b) RegCM3 and c) Promes model. Aladin and RegCM3 models have statistically non-significant trend at 5 % significance level, and for Promes the trend is statistically significant. Model time series are RCMcorr.

RCM bias corrected and adjusted models

For the all three models Figure 3.3-8 shows time series of annual mean temperatures with fitted linear trend.

According to Mann-Whitney test comparisons of monthly mean temperatures between P0 (1961-1990) vs. P1 (2021-2050), statistically significant differences at 5% significance level were found for all models and months, except for RegCM3 in December (Figure 3.3-9). The increase of temperatures in future is proven also by Kolmogorov-Smirnov test.

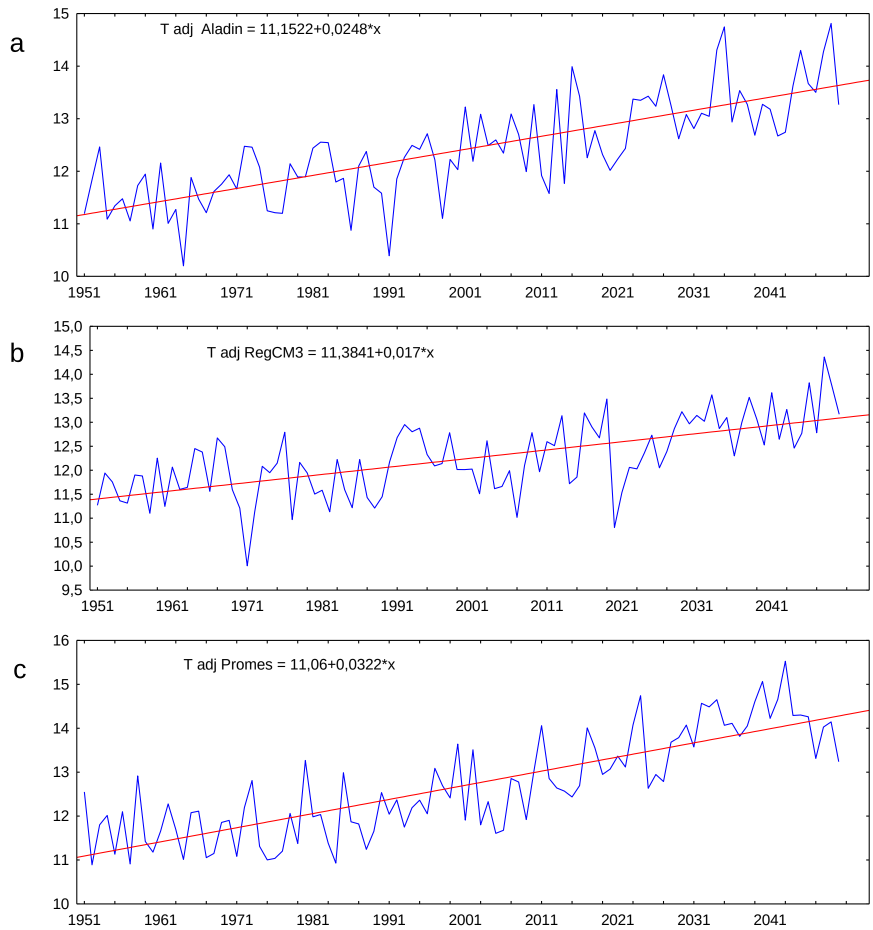


Figure 3.3-8. Annual mean temperature and fitted linear trend of Bilje meteorological station after a) Aladin, b) RegCM3 and c) Promes model. Trends for all three models have statistically significant regression at 5 % significance level. Model time series are RCMcorr_adj.

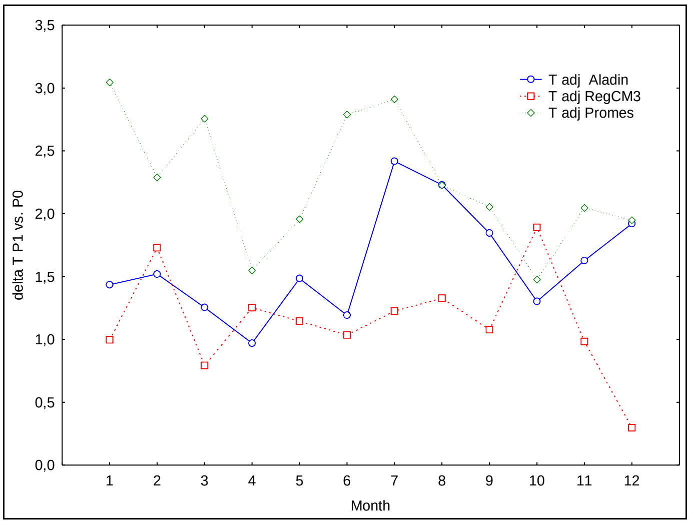


Figure 3.3-9. Monthly mean temperature P0 (1961-1990) vs. P1 (2021-2050) change for Bilje meteorological station. Differences are statistically significant for all models and months, except for RegCM3 in December, according to Mann-Whitney test at 5 % significance level.

For the all three models, time series of annual precipitation amount with fitted statistically non-significant linear trend for Aladin and RegCM3 models, and statistically significant for Promes model, is shown on Figure 3.3-10.

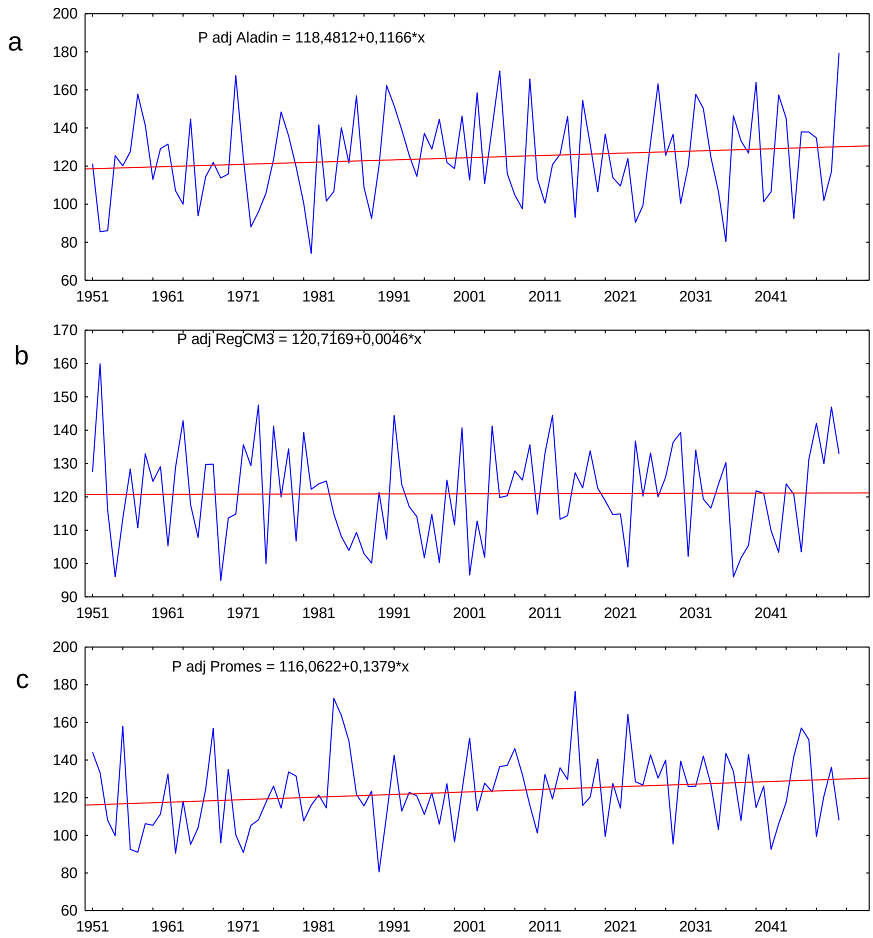


Figure 3.3-10. Annual precipitation amount and fitted linear trend of Bilje station after a) Aladin, b) RegCM3 and c) Promes. Aladin and RegCM3 have statistically non-significant trend at 5 % significance level, and for Promes the trend is statistically significant. Model time series are RCMcorr.(RCMcorr_adj)

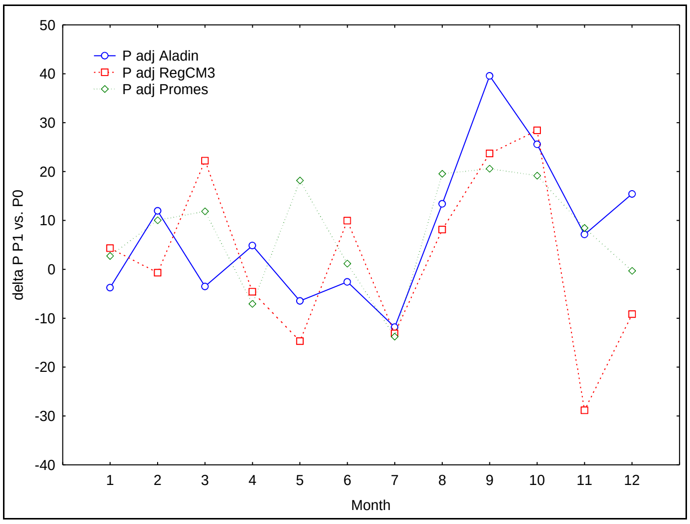


Figure 3.3-11. Relative monthly precipitation of Bilje meteorological station for P0 (1961-1990) vs. P1 (2021-2050) change. Differences are statistically non-significant for all stations and months according to Mann-Whitney test at 5 % significance level.

Portorož meteorological station

RCM bias corrected models

For all three models, time series of annual mean temperatures with fitted linear trend is shown on Figure 3.3-12. Trends for all three models are statistically significant at 5% significance level.

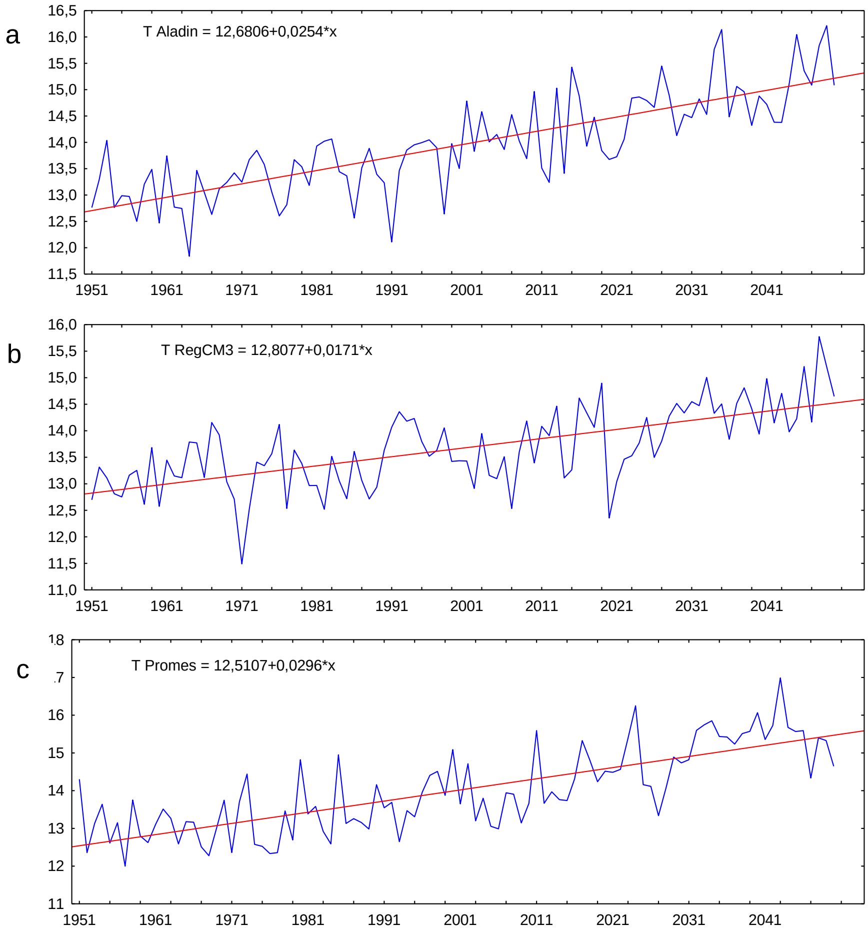


Figure 3.3-12. Annual mean temperature and fitted linear trend of Portorož meteorological station after a) Aladin. b) RegCM3 and c) Promes. Trends for all three models have statistically significant regression at 5 % significance level. Model time series are RCMcorr.

For all three models, time series of annual precipitation amount with fitted statistically non-significant linear trend is shown on Figure 3.3-13.

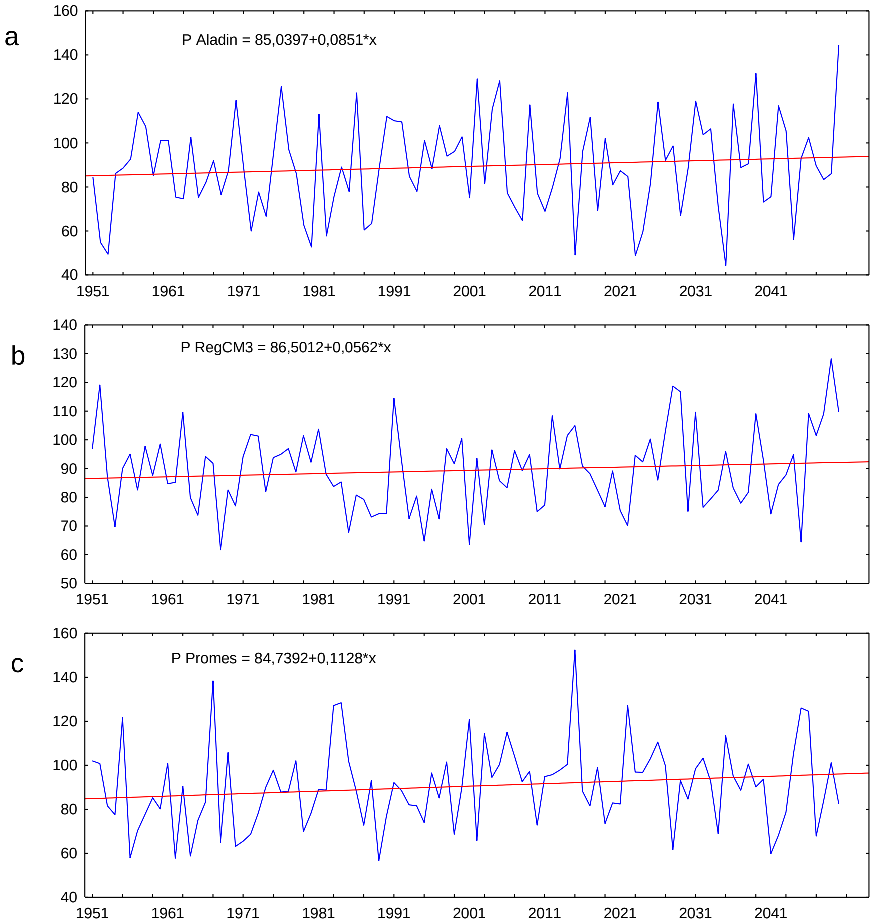


Figure 3.3-13. Annual precipitation amount and fitted linear trend of Portorož meteorological station after a) Aladin, b) RegCM3 and c) Promes model. All three trends have statistically non-significant regression at 5 % significance level. Model time series are RCMcorr.

RCM bias corrected and adjusted models

For the all three models Figure 3.3-14 shows time series of annual mean temperatures with fitted linear trend. Trends for all three models are statistically significant at 5 % significance level.

According to Mann-Whitney test comparisons of monthly mean temperatures between P0 (1961-1990) vs. P1 (2021-2050) show statistically significant differences at 5% significance level for all models and months, except for RegCM3 in March and December (Figure 3.3-15). The increase of temperatures in future is proven also by Kolmogorov-Smirnov test for Aladin and Promes models.

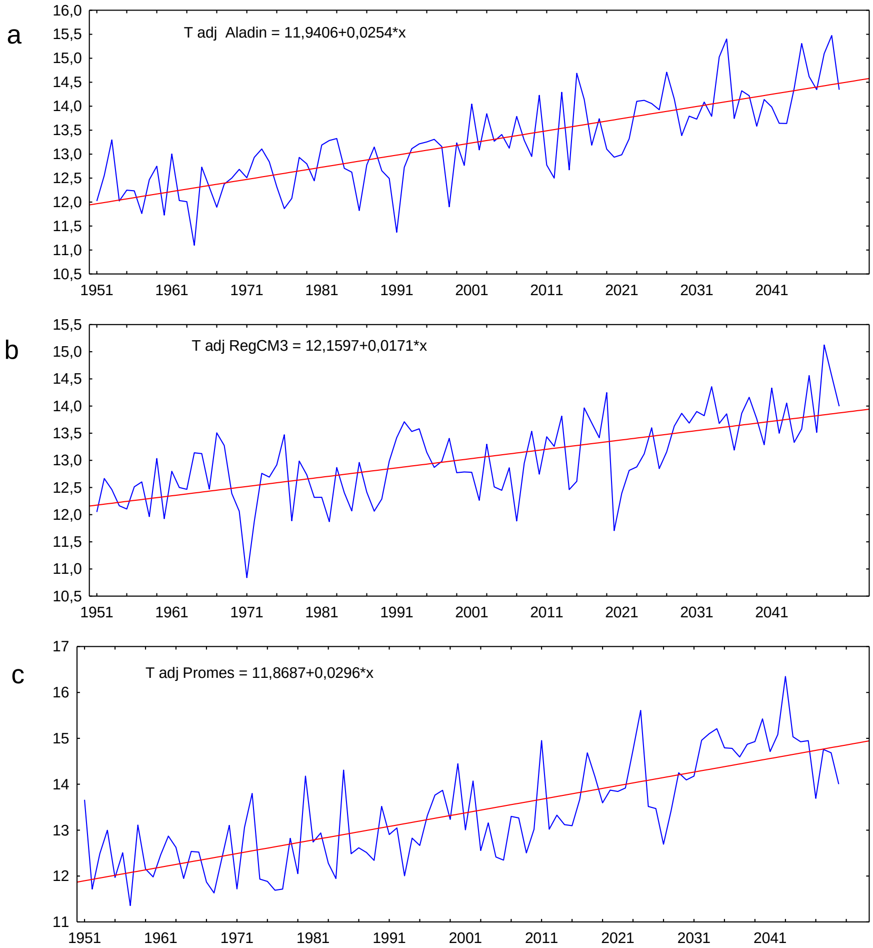


Figure 3.3-14. Annual mean temperature and fitted linear trend of Portorož meteorological station after a) Aladin. b) RegCM3 c) Promes. Trends for all three models have statistically significant regression at 5 % significance level. Model time series are RCMcorr_adj.

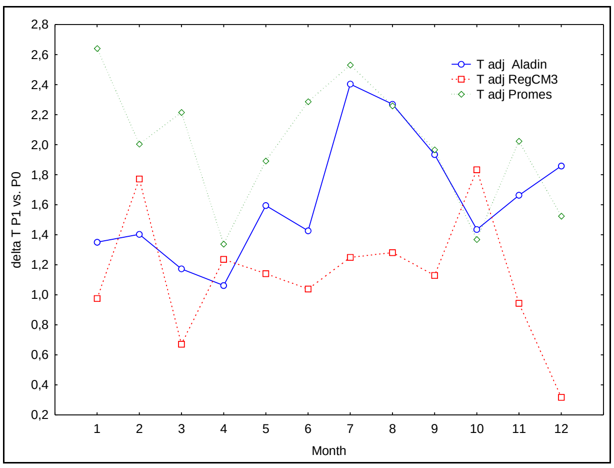


Figure 3.3-15. Monthly mean temperature of Portorož meteorological station for P0 (1961-1990) vs. P1 (2021-2050) change.

For all three models, time series of annual precipitation amount with fitted statistically non-significant linear trend is shown on Figure 3.3-16.

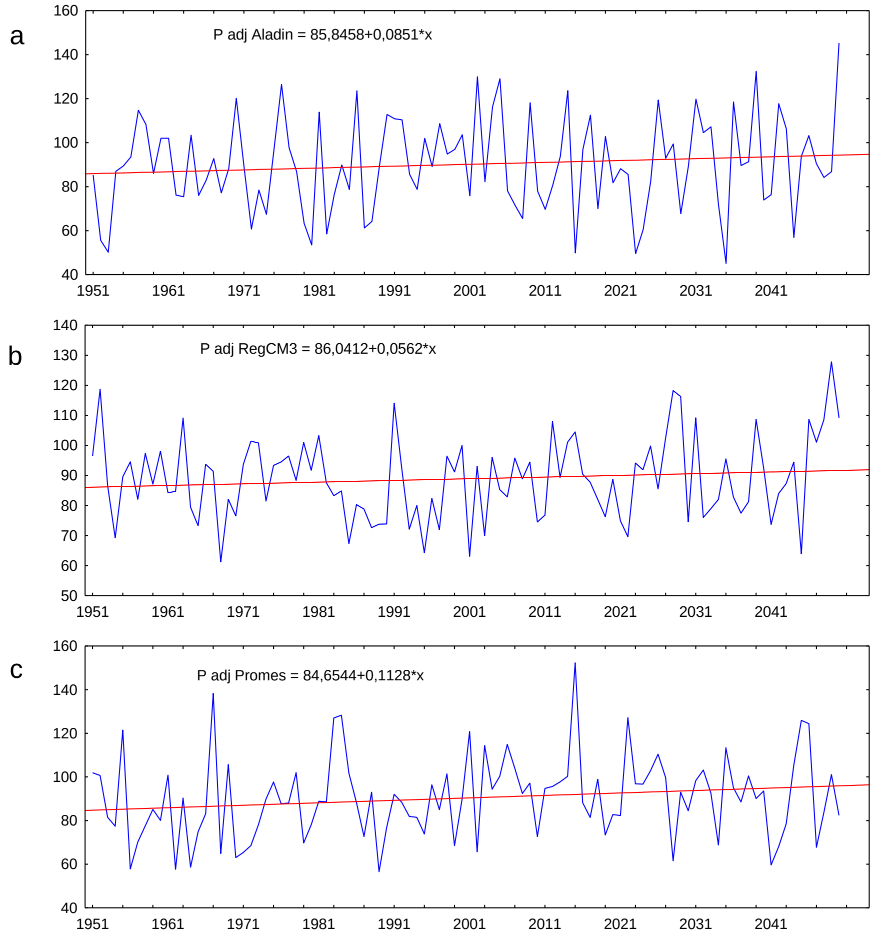


Figure 3.3-16. Annual precipitation amount and fitted linear trend of Portorož meteorological station after a) Aladin, b) RegCM3 and c) Promes model. All three trends have statistically non-significant regression at 5 % significance level. Model time series are RCMcorr_adj.

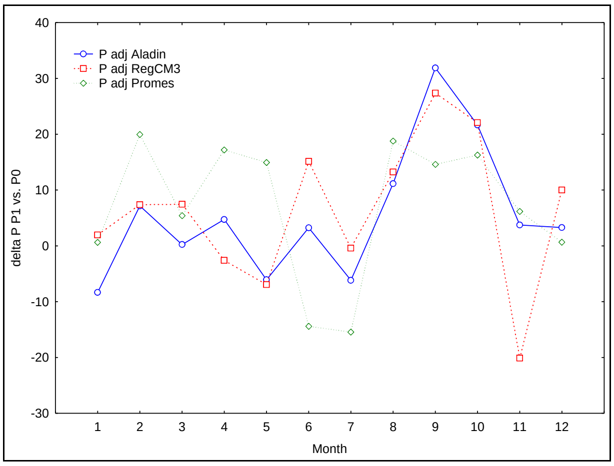


Figure 3.3-17. Relative monthly precipitation of Portorož meteorological station for P0 (1961-1990) vs. P1 (2021-2050) change.

3.4. Croatian test areas

From Annex 2 Report 2.5.:

An analysis of the observed and simulated climate and climate changes is presented for the two catchments in Croatia: the river Mirna (test area 1: Northern Istria) and the spring Prud (test area 2: Prud catchment and Korčula).
In Appendix 3 of the report made by FB8, the results of an additional climatological analysis of observations from the four locations in the river Neretva catchment (Bosnia and Herzegovina) are presented. Data for analyses are prepared by FB12.

General climate characteristics, climate variability and trends in the Mirna River and in the Prud wellspring catchment are analysed from the available DHMZ climatological data. They include measurements of air temperature and precipitation amounts from the reference climate period 1961-1990. Observed trends are estimated from a longer period: 1961-2012.

An assessment of the present and future climates is based on the results from numerical simulations of the three regional climate models that were also analysed for the purpose of the CC-WaterS project. These models participated in the ENSEMBLES project. In this report, analysis of the model data is carried out for those model grid cells which were the closest to the locations of the Pazin climatological station (thus representing the Mirna River catchment) and the Opuzen climatological station (representing the Prud spring catchment).

The regional climate models (RCMs) used are the Aladin, Promes and RegCM3 models. The RCMs were forced by the observed concentrations of the greenhouse gases (GHGs) from 1951 to 2000; from 2001 onwards the IPCC A1B scenario of the GHGs emissions is applied. The initial and boundary data for each RCM were provided from different global climate models (GCMs): the ECHAM5 GCM data were used to force RegCM3, Aladin was forced by the Arpege GCM and Promes was forced by the HadCM3Q GCM. For the present climate, models are compared with the local DHMZ observations and with the EOBS gridded temperature and precipitation data. The following two abbreviations are used in the report:

1. RCMcorr: the RCMs' output was bias corrected by EOBS data.
2. RCMcorr_adj: this is further adjusted model time series due to the differences between EOBS data and local DHMZ observations.

Climate and climate change characteristics based on observed data

The Mirna River catchment (test area 1: Northern Istria)

The analysis is based on monthly, seasonal and annual averages of air temperature and precipitation amounts over the reference climate period 1961-1990. The catchment includes 4 climatological stations providing both temperature and precipitation data and 8 rain-gauge stations from the period 1961-2012.

The climate of the Istrian peninsula is determined by the mid-latitude air circulation and it is modified by the influence of the sea. The maritime impact penetrates the lowland of the peninsula, in particular the valley of the Mirna River. In addition to the direct cyclogenetic effects of the northern Adriatic Sea, the climate of the area is strongly modified by orography of the Učka and Ćićarija mountains, the mountainous region of Gorski Kotar and the Dinaric Alps. The latitude determines primarily the amount of sunshine and radiation that this area receives during the year and the mid-latitude circulation systems impact local weather and climate. Stable, clear and dry summer weather, typical of the Azorean high, is interrupted by frequent occurrences of instabilities and local storms. In the cold part of the year and during the night time, the local turbulence is weak and the impact of local conditions (e.g. orography and land-sea contrast) become dominant. In anticyclonic situations during the night and in winter (DJF), an increased, locally specific, cooling may occur. For anticyclones of the cold part of the year, especially in winter, the bora wind is typical for the northern Adriatic. It blows from the northeast quadrant and is known for its gusts and high speeds. In Istria, the bora dominates on the coast. The cyclonic activity, typical for the winter, early spring and late autumn, is important for the precipitation regime and cloudiness over the region.

The local climate characteristics are described for the 1961-1990 period recommended by the World Meteorological Organization as the referent period for the present climate conditions. Seasonality is described in terms of annual cycle of the mean monthly air temperature and precipitation, and their interannual variability by standard deviation of monthly means and coefficient of variation for precipitation (i.e. standard deviation divided by the mean). The discussion of extremes in the annual and seasonal air temperature and precipitation averages is based on percentiles calculated from the empirical cumulative distribution function (CDF).

The annual cycle of air temperature monthly averages over the Mirna River catchment is well defined: the maximum occurs in July (from 20.4°C to 22.2 °C) and the minimum in January (from 2.5 °C to 4.6 °C; see Figure 3.4-1a), indicating a typical maritime annual cycle with autumn (SON) being warmer than spring (MAM).

The annual course of standard deviations (std) of mean monthly air temperatures indicates the highest variability in the cold part of year, especially in February. However, the monthly values of std range between 0.9°C (June or July) and 2.0°C (February) indicating that interannual variability is generally small due to a strong influence of the sea, which moderates temperature extremes (Figure 3.4-1b).
Empirical cumulative distribution of the mean annual air temperature for Pazin is given in Figure 3.4-1c. In the annual cycle of the percentiles of mean daily air temperature, the difference between the 98th percentile and the 2nd percentile is the largest in winter due to the highest variability in winter months, particularly in February.

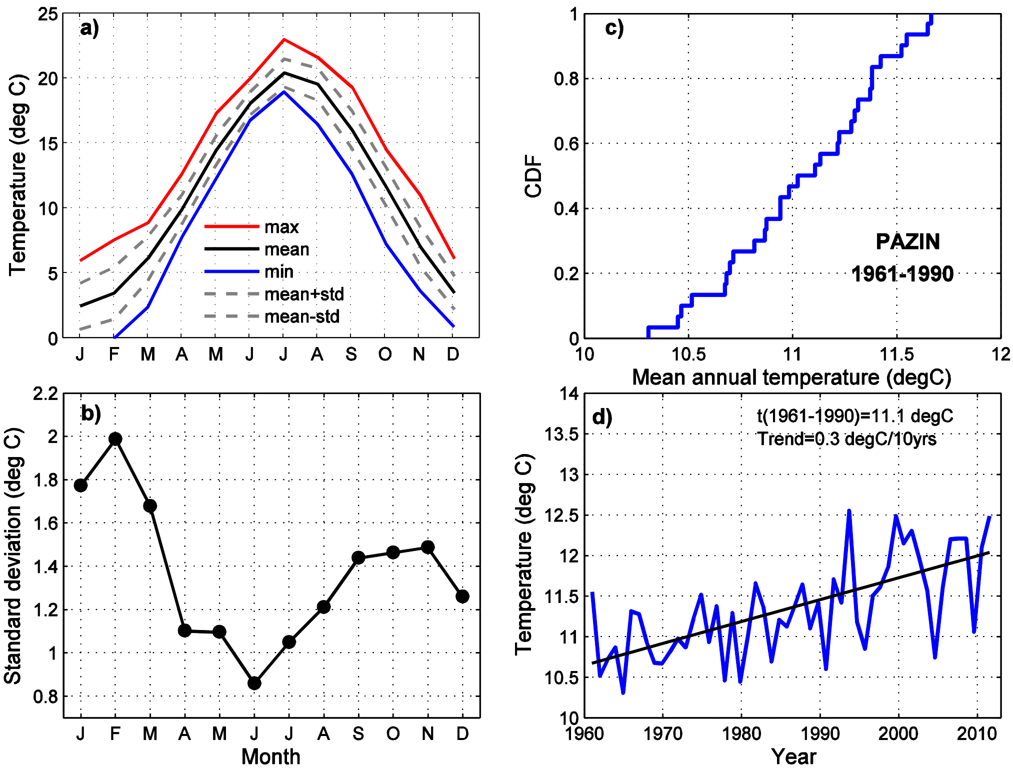


Figure 3.4-1. Annual cycle of (a) mean monthly air temperature, (b) its standard deviation, (c), cumulative distribution of mean annual air temperature for the period 1961-1990 and (d) time series of mean annual air temperature with fitted trend line for the period 1961-2012 for the meteorological station Pazin.

The Mirna River catchment has a mix of the maritime and continental types of annual cycle which is characteristic for the inland Istrian peninsula. The lowest precipitation amount generally occurs during the warm period of year (Fig. 3.4-2a); the minimum in annual cycle appears in July (between 54 mm near the coast and 80 mm in the inland of Istria), while the maximum occurs in November (105 mm - 134 mm). However, there is a second minimum that occurs in February (59 mm – 80 mm) thus resulting in the similar proportion (49% to 51%) of the cold (October to March) and warm (April to September) half-year in total annual precipitation amount. Seasonally, the highest precipitation amounts (295 mm – 336 mm) are received during autumn months (September-October-November); while in other seasons the precipitation amounts are quite similar. In the inland of Istria at some locations the minimum precipitation amounts can also be found in winter. The dominant cold southeast advection over the Istrian peninsula contributes to the persistent, stable inversion conditions in winter which are characterised by long periods without precipitation.

In some years there is a significant deviation in monthly amounts from the average precipitation conditions. Coefficient of variation indicates a higher interannual variation in mean monthly precipitation during the cold half-year, particularly in October ranging from 80% to 90% (Fig. 3.4-2b).

Cumulative distribution (CDF) of annual precipitation is shown in Fig. 3.4-2c. The empirical CDF gives the general insight into the precipitation amount distribution shape providing the expecting probabilities of the observed amounts. For all the given return levels in the right tail of the distribution (90^{th} to 99^{th} percentile), the highest values of precipitation amounts can be found in the autumn months. On the other hand, extremely dry seasons are those with precipitation amount lower than the 2^{nd} percentile. The lowest value of the 2^{nd} percentile is generally found in the summer months; however, in the northern part of the catchment (Abrami) the minimum value is obtained during the winter.

The differences in the CDFs across a small region such as the Mirna River catchment reveal the overall large spatial variability of precipitation amounts.

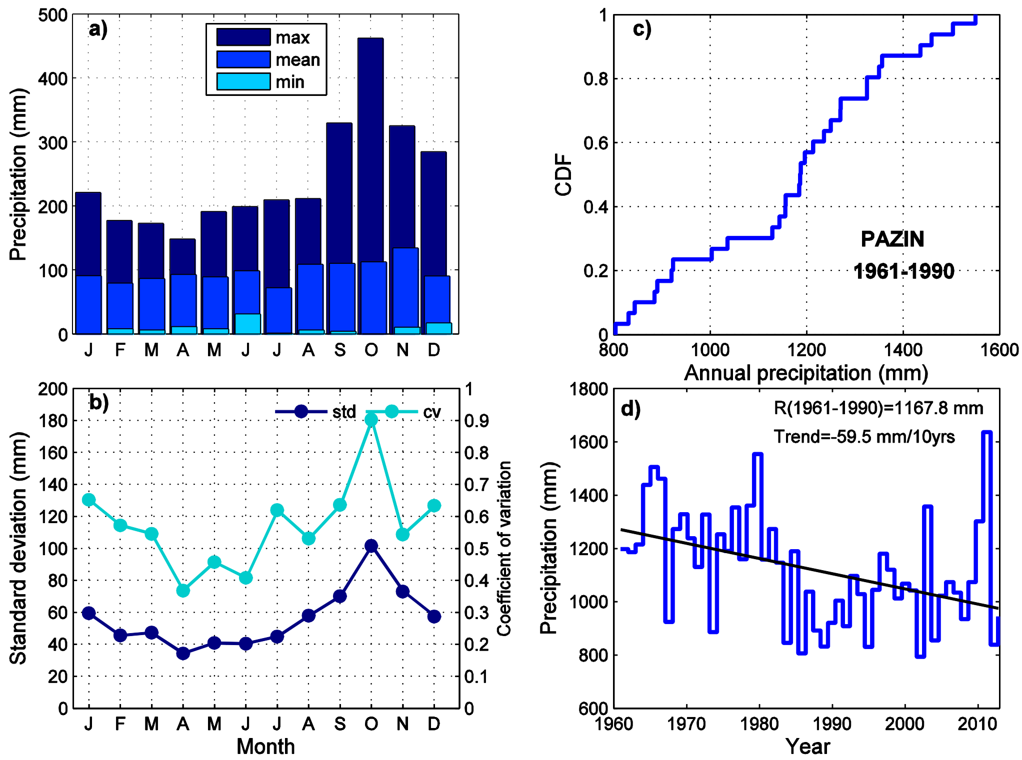


Figure 3.4-2. Annual cycle of (a) mean monthly precipitation amounts, (b) standard deviation and coefficient of variation, (c) cumulative distribution of annual precipitation amounts for the period 1961-1990 and (d) time series of annual precipitation amounts with fitted trend line for the period 1961-2012 for the meteorological station Pazin.

Trends have been estimated by the Kendall's tau method (or Sen's slope). A linear trend is also calculated and given for comparison. The trends are expressed as decadal values for both variables. Additionally, the trends in precipitation amounts are given as the percentage of the corresponding seasonal and annual means from 1961-1990 period. The statistical significance of the trend is estimated using the non-parametric Mann–Kendall test.
The examples of time series of mean annual temperature and precipitation amounts are given in Figs 3.4-1d and 3.4-2d with the associated trend lines and with the given mean values from the reference period 1961-1990.

The trend results reveal the statistically significant increase in annual mean *air temperature* (0.1-0.3°C/10yrs) since 1961 in the Mirna catchment. The annual mean temperature increase is predominantly due to the significant increase in spring (0.2-0.3°C/10yrs) and summer (0.3-0.5°C/10yrs) mean air temperature. Changes observed in the cold half-year are very weak.

The trends in *precipitation* amounts show the significant decrease in annual totals (4-5%/10yrs) over the Mirna River catchment. There is a consistent decrease of precipitation amounts in all seasons, nevertheless decrease in annual amount is mainly forced by a decrease in the warm seasons (spring and summer).

Climate and climate change simulations for future

Pazin climatological station

For the period 1951-2050, all three bias corrected models simulate statistically significant increasing trends in the mean annual temperature from 0.17 °C/10yr in RegCM to 0.31 °C/10yr in Promes (Fig. 3.4-3). It should be emphasised here that, in the model simulations for the period 1951-2000, the observed concentrations of the greenhouse gases (GHGs) is used, and in the period 2001-2050, the models were forced by the GHGs concentrations for the IPCC A1B scenario. In the period 1961-2012, when the DHMZ observations were available, all three models agree with the observations in the simulated sign of trend, but with a lower than DHMZ observed magnitude of trend (0.3 °C/10yr). For the two periods analysed (1951-2050 and 1961-2012), linear trends of the simulated mean seasonal temperature are generally highest in the summer and in the Promes model, and most of seasonal trends are statistically significant.
All three bias-corrected models simulate increasing trend in the annual precipitation amount for the period 1951-2050 (Fig. 3.4-4). However, in all the models, these trends are not statistically significant. For the period 1961-2012, when DHMZ observations at the Pazin station show statistically significant decreasing trend in annual precipitation amount (-52.5 mm/10yr), only RegCM3 simulates the same sign of the trend as observed, but with greatly reduced amplitude and no statistical significance. Even for seasonal precipitation,

trends are rarely statistically significant and are model dependent in terms of both the amplitude and sign. This implies that, according to the CC-WaterS bias corrected RCMcorr simulations presented here, no robust estimates of significant precipitation change could be made for the first part of the 21st century.

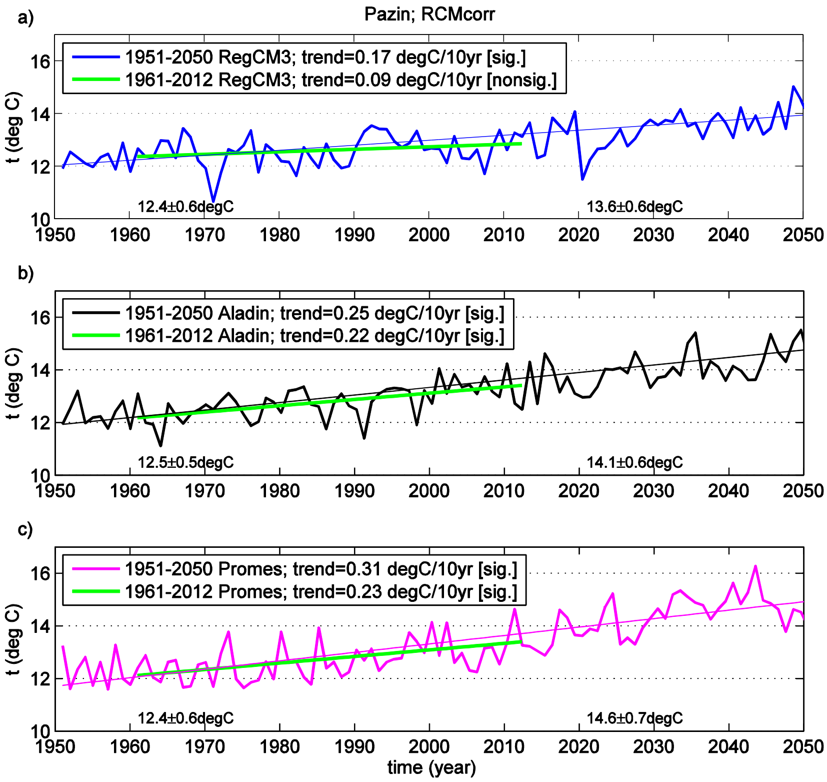


Figure 3.4-3. Pazin station: annual mean temperature and associated linear trend in a) RegCM3, b) Aladin, c) Promes. Trend based on the entire time series (1951-2050) is in the same colour as the corresponding time series and trend based on the 1961-2012 period is in green in every panel. The numbers at the bottom of each panel are mean values and standard deviations for the periods P0 (1961-1990) and P1 (2021-2050). The model time series are for RCMcorr.

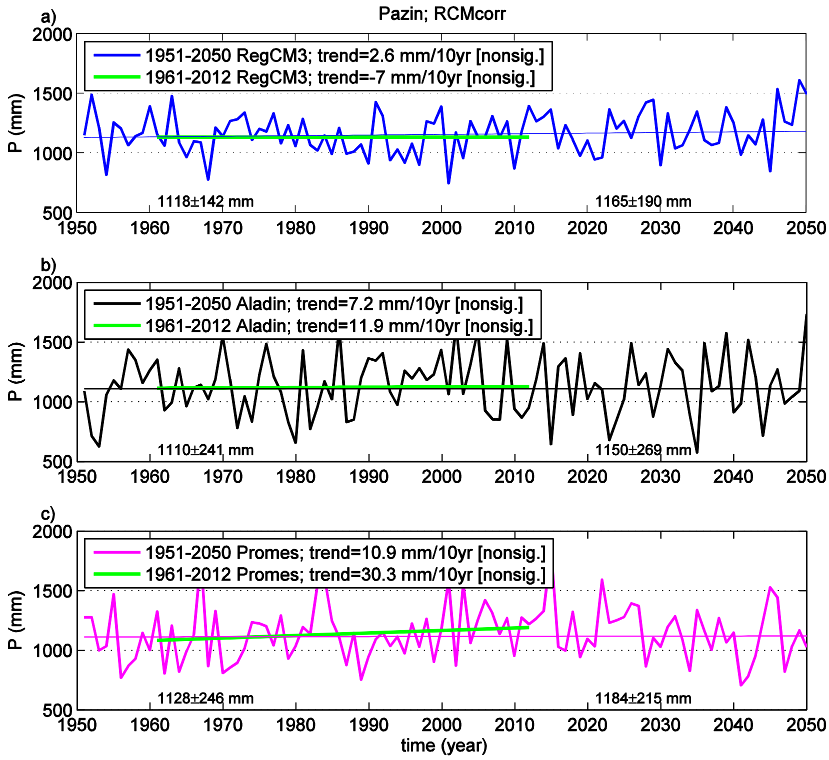


Figure 3.4-4. As Fig. 3.4-3 but for annual precipitation amounts.

Since bias correction of the RCM values (RCMcorr) is based on the EOBS data, the differences between EOBS and DHMZ observations, require an additional adjustment of the RCMcorr values to be comparable with the DHMZ data. Adjustment differences are applied on the RCMcorr time series to obtain RCMcorr_adj.

Lastly, we analyse projected climate changes for the RCMcorr data; similar results are obtained for the RCMcorr_adj data because of the additive nature of the applied adjustment. All three regional climate models simulate an increase in mean monthly air temperature from the reference period 1961-1990 to the future period 2021-2050. The projected warming is in most cases statistically significant and ranges between 0.5 °C in RegCM3 for December and 3 °C in Promes for July (Fig. 3.4-5 a). The Promes model tends to simulate a larger temperature increases for most months in the year than the other two models. As for precipitation, the projected changes between P0 and P1 are statistically significant only in two cases although the models are relatively close to each other. It appears that the prevalent sign of changes indicates an increase in precipitation (i.e. most changes are positive); however, they vary in amplitude generally between -20% and 20% (Fig. 3.4-5 b).

The warming signal in all three models is also present in the empirical cumulative distribution functions CDFs of the mean annual temperature (Fig. 3.4-5 c). For all three models, CDFs of annual precipitation amounts in the P0 and P1 periods are not significantly different (Fig. 3.4-5 d).

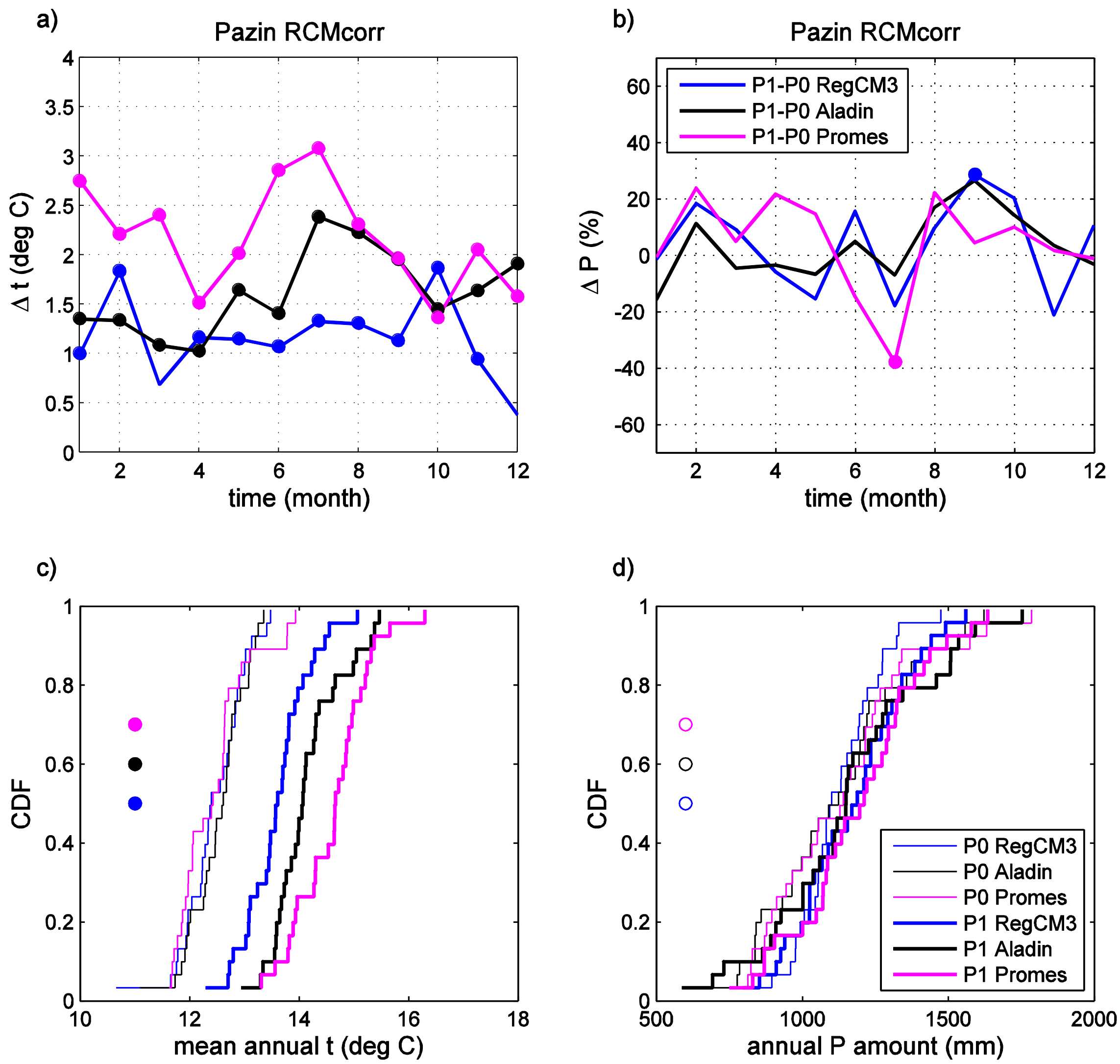


Figure 3.4-5. Pazin station: P1 vs. P0 change for a) monthly mean temperature (in °C); b) relative monthly precipitation change (in %); c) empirical cumulative distribution functions CDFs of mean annual temperature in P0 and P1; d) same as c) but for annual precipitation amount. Time periods are: P0 1961-1990 and P1 2021-2050. Statistically significant differences in a) and b) according to the Wilcoxon-Mann-Whitney nonparameteric rank-sum test at the 5% significance level are marked by solid circles. Statistically significant differences according to the Kolmogorov-Smirnov test at the 5% significance level between CDFs in the two periods for every model in panels c) and d) are marked by solid circles. Model time series are RCMcorr.

Climate and climate change characteristics based on observed data

Prud Spring catchment (test area 2: Prud catchment and Korčula)

The climatological analysis for the air temperature and precipitation data series is deduced from the meteorological station Opuzen. The analysis is based on monthly, seasonal and annual averages of air temperature and precipitation amounts over the reference climate period 1961-1990.

The climate characteristics of the spring Prud catchment are determined by the mid-latitude air circulation and modified by the influence of the sea that reaches deep into the mainland through the valley of the Neretva River, to a lesser extent they are governed by the altitude, relief configuration, soil type, etc. It is under the influence of the subtropical high pressure zone during summer, with dry and warm weather. The sea, with its large thermal capacity, moderates air temperature extremes: it has cooling effect in summer and reduces the cold in winter. In contrast to the Neretva River valley, the climate of the Prud area is also largely determined by local orography that prevents a direct influence of the sea. The carstic soil type of the neighbouring hills contributes to warming in the summer. During the cold part of the year the area is within the zone of the main western winds that dominate mid-latitudes, with a constant change of low and high pressure systems.
The local climate characteristics are described for the years 1961-1990.

The annual cycle of air temperature monthly averages over the spring Prud catchment within the lower Neretva river catchment has maritime characteristics with autumn being warmer than spring by 1.8°C on average. The winters are mild with average air temperature of 7.4°C and the summers are moderately warm (23.8°C). On average, July is the warmest month with an average air temperature of 24.9°C, followed by August (24.2°C). In some years, the coldest month may be with equal probability January, February or December, and on average the coldest month is January (6.5°C).
Standard deviation of mean monthly air temperature ranges between 0.8°C (July) to 1.9°C (February) indicating that interannual variability is small due to a strong influence of the sea, which moderates the air temperature extremes (Fig. 3.4-6b). July is the least likely to change its thermal character and February is the most unstable month.
Empirical cumulative distribution of the mean annual air temperature for Opuzen is shown in Fig. 3.4-6c. In the annual cycle of the percentiles for mean daily air temperature, the difference between the 98th percentile and the 2nd percentile is the largest in February (6.8°C) and November (6.6°C) and the smallest in July (2.6°C). These differences are reflected in seasonal differences: the largest are in the autumn (3.7°C) and winter (3.4°C).

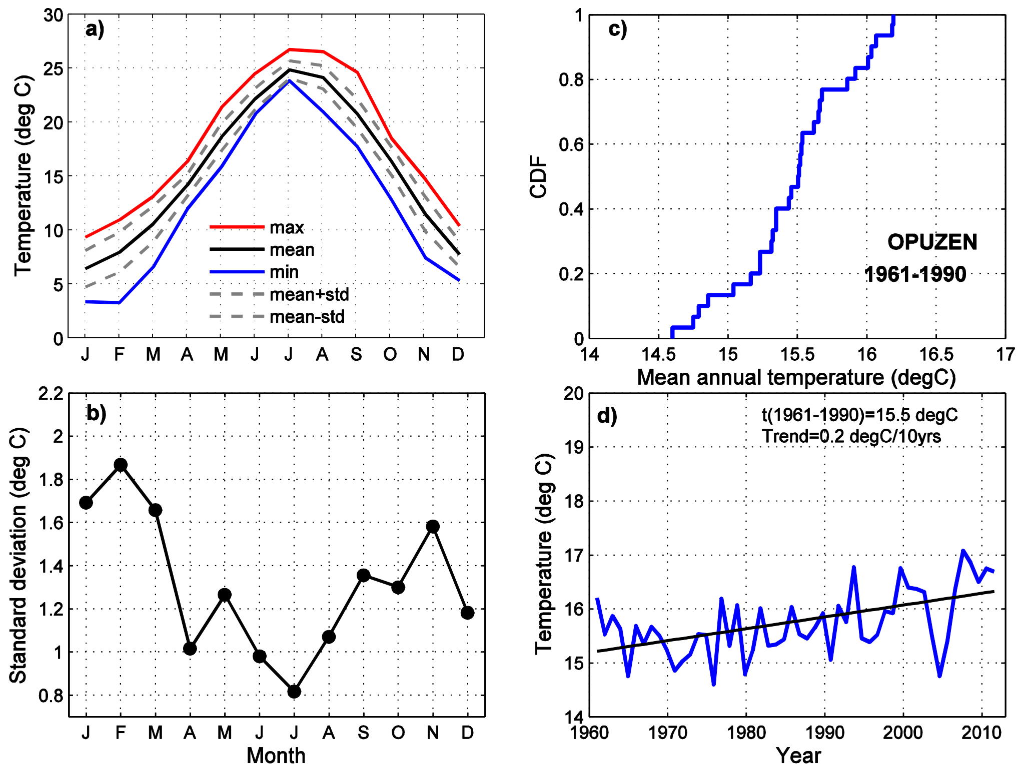


Figure 3.4-6. Annual cycle of (a) mean monthly air temperature, (b) its standard deviation, (c) cumulative distribution of mean annual air temperature for the period 1961-1990 and (d) time series of mean annual air temperature with fitted trend line for the period 1961-2012 for the meteorological station Opuzen.

The spring Prud catchment within the lower Neretva river catchment has the maritime annual cycle. The differences in annual total precipitation between the locations at low altitudes (e.g. Opuzen 3 m) and parts of the basin at about 400 m a.s.l. (e.g. Veliki Prolog 433 m) are higher in the cold part of the year (21% to 38%) than in the warm part (up to 14%). During the cold half-year (October to March) this area receives more precipitation than in the warm half year (on average 66% of the annual total in Opuzen and 70% in Veliki Prolog). Monthly amounts are above 150 mm from October to December in Opuzen (the Neretva River delta) and at the higher altitudes distant from the sea (Veliki Prolog) they occur from October to March having maximum in November (180 mm in Opuzen and 221 mm in Veliki Prolog). The lowest monthly precipitation amounts occur in the warm period of the year (April to September). The summer precipitation amounts slightly over 13% of the annual precipitation, and the monthly minimum is in July (36 mm).

In some years a significant deviation in monthly amounts from the average precipitation conditions is observed (Fig. 3.4-7b). There were years when in the autumn and winter months, with normally abundant precipitation, less than half of the monthly average precipitation was recorded. In the summer months there were occurrences of very little or no rain, or on the other hand, that the average monthly amount was exceeded several times over. Coefficient of variation indicates such a high interannual variation in the mean monthly precipitation amounts that are higher than 50% (April).

Cumulative distribution function (CDF) of annual precipitation is shown in Fig. 3.4-7c. According to the Opuzen data, the annual precipitation amount over 1637 mm can be expected once in 10 years (90th percentile), and over 1727 mm once in 50 years (98th percentile). For all observed return levels at the right tail of the distribution (90th to 99th percentile) the highest seasonal values of precipitation amounts can be found for the winter and autumn. Differences between these two seasons decrease for higher percentiles. On the other hand, extremely dry seasons are those with precipitation amounts lower than the 2nd percentile. This value is the lowest for summer (21 mm) and the highest for autumn (182 mm). On monthly scale, there may be no precipitation at all from July to October and in January, while for other months the 2nd percentile values range between 11 mm and 34 mm (not shown).

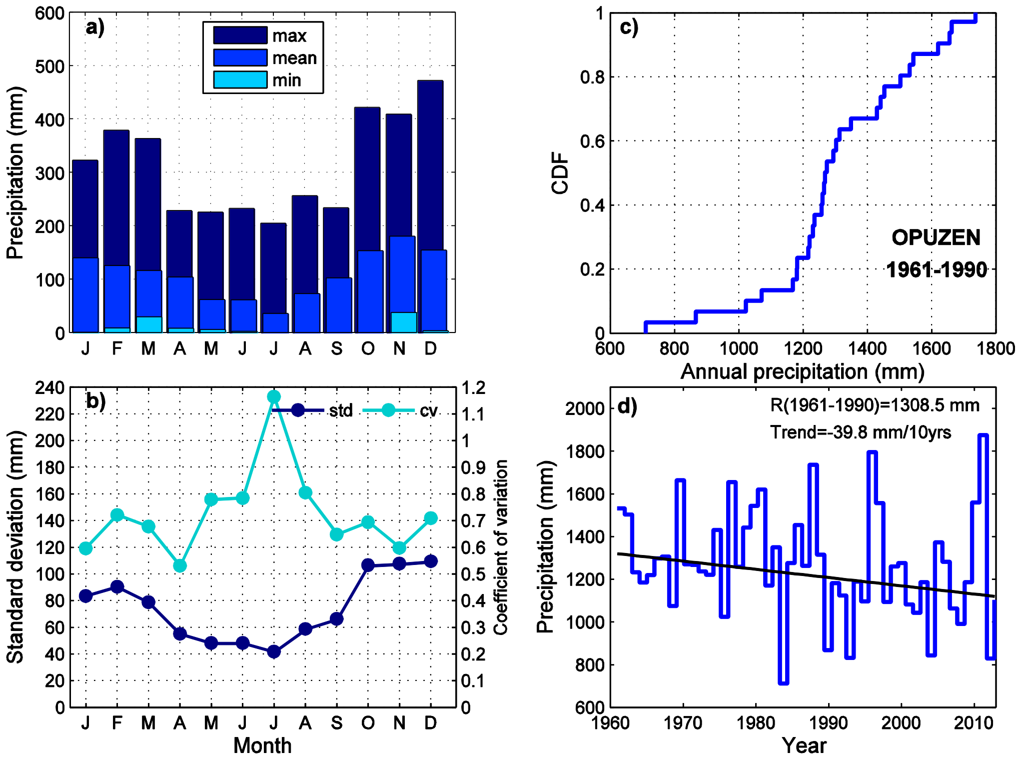


Figure 3.4-7. Annual cycle of (a) mean monthly precipitation amounts, (b) standard deviation and coefficient of variation, (c) cumulative distribution of annual precipitation amounts for the period 1961-1990 and (d) time series of annual precipitation amounts with fitted trend line for the period 1961-2012 for the meteorological station Opuzen.

Time series of the mean annual air temperature and precipitation amounts, with associated trend lines and their mean values from the reference period 1961-1990 are shown in Fig 3.4-6d and Fig. 3.4-7d, respectively.
During the period 1961-2012, the mean annual air temperature anomalies are mainly positive. During the recent 20 years air temperature trend is amplified. The consequence of such temperature fluctuations is that eight out of ten warmest years in the observed 52-years period were recorded in the first decade of the 21st century. The annual trend reveals the statistically significant increase in the mean air temperature of 0.2°C/10yrs since 1961 according to the Opuzen data. The annual temperature increase is predominantly due to a significant increase in the summer (0.3°C/10yrs) and spring (0.2°C/10yrs) mean air temperature.

The trends in precipitation amounts reveal drying in the annual (-3.0 %/10yrs) and seasonal amounts according to Opuzen data, although they are not statistically significant. The main contribution to annual drying primarily comes from the reduction in summer precipitation totals (-8.2%/10yrs).

The combined influence of observed meteorological parameters, air temperature and precipitation, effects water balance components. The detected increase in air temperature in spring and summer causes an increase in evapotranspiration. When associated with a decreasing tendency in precipitation in all seasons, but especially in summer, the precipitation deficit is expected to increase in the warm season. At the same time runoff and the filling of aquifers in autumn and winter could be reduced due to negative precipitation trends in these seasons, and could have impact on water supply.

Climate and climate change simulations for future

Opuzen climatological station

All three bias corrected models simulate statistically significant increasing trends in the mean annual temperature for the period 1951-2050 amounting to 0.19 °C/10yrs in RegCM, 0.27 °C/10yrs in Aladin and 0.31 °C/10yr in Promes (Fig. 3.4-8). For the period corresponding to the available DHMZ observations (1961-2012), all three models agree with observations in the sign of trend, and simulated trend slopes, except for RegCM3, are close to the observed slope (i.e. 0.2 °C/10yrs in DHMZ observations for Opuzen). Similar to the Pazin climatological station, trends of the mean seasonal temperature are highest for the summer season and when using the Promes model, and are statistically significant in most cases.

For annual precipitation in the period 1951-2050, RegCM3 and Aladin simulate an increasing trend while Promes simulates a decreasing trend (Fig. 3.4-9); however, these trends are not statistically significant. For the period 1961-2012, when the DHMZ annual precipitation amounts show a non-significant decreasing trend (i.e. -31.8 mm/10yr), all models simulate trend of the opposite sign with increasing trends slopes smaller than 5 mm/10 yrs. Again, the climate change signal of the CC-WaterS simulations is weak for the first part of the 21st century and no significant trends in seasonal precipitation are found.

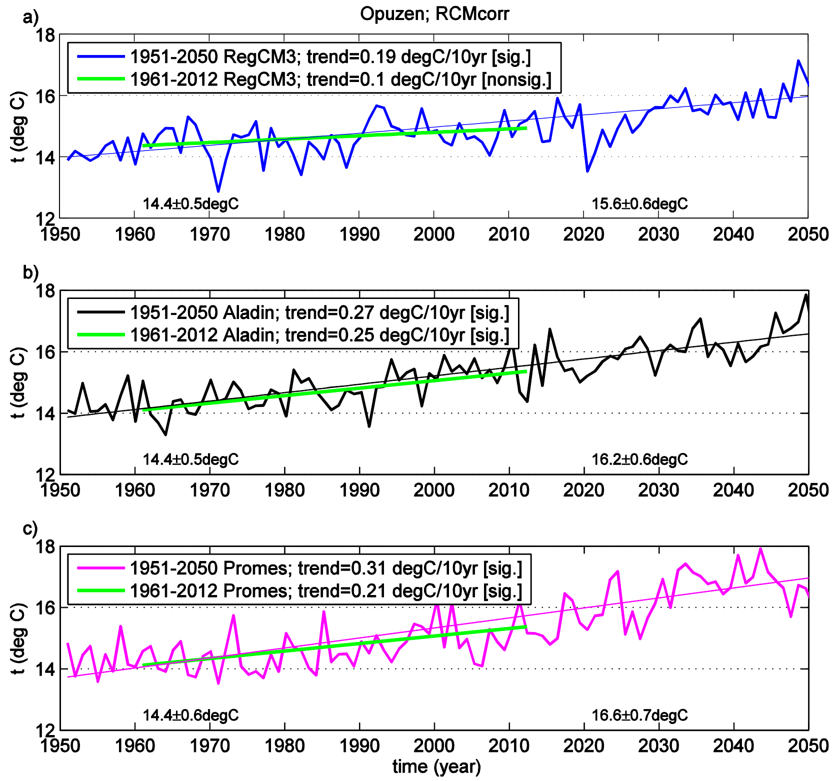


Figure 3.4-8. Same as Fig. 3.4-3 but for the Opuzen location.

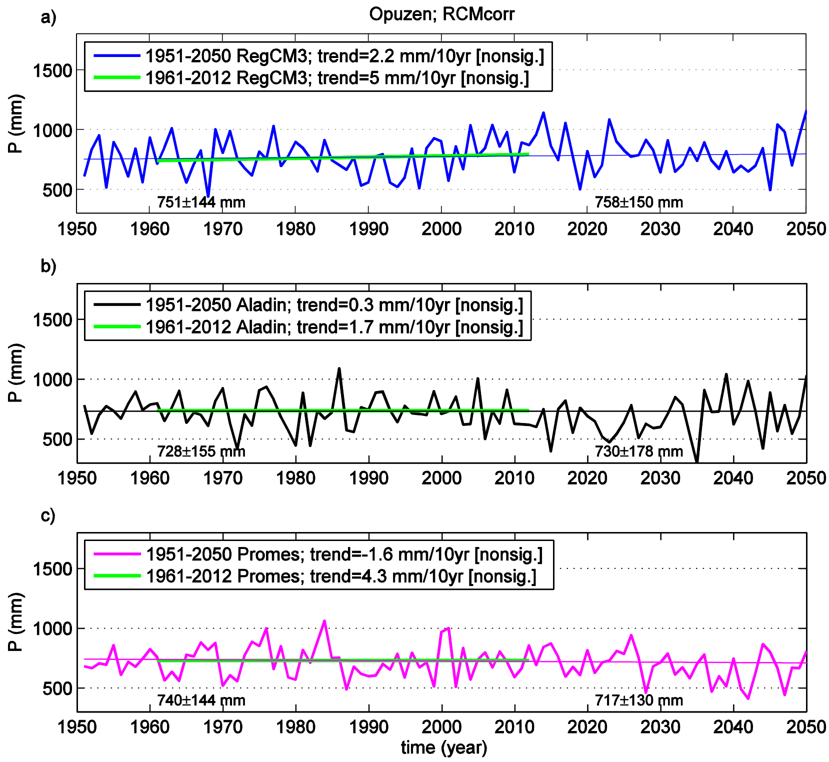


Figure 3.4-9. Same as Fig. 3.4-4 but for the Opuzen location.

RCMcorr_adj time series for the Opuzen station are prepared in the same manner as for the Pazin station.

For the projected climate changes of the RCMcorr data an increase in the mean air temperature by mid-21st century, i.e. in P1 relative to P0, is simulated by all three RCMs (RCMcorr; Fig. 3.4-10 a). The projected warming in the 2021-2050 period ranges between 0.5 °C and nearly 3.5 °C and in most cases is statistically significant. The Promes model tends to simulate a larger temperature increase than the other two models. On the other hand, the amplitude of projected precipitation change varies greatly throughout the year from one model to the other (between -60% and +60% in P1 relative to P0), but even so it is almost insignificant (Fig. 3.4-10 b).

The warming signal is also present in the empirical cumulative distribution functions, CDFs, of the mean annual temperature (Fig. 3.4-10 c), and for all three models, CDFs in P1 and P0 periods are significantly different according to the Kolmogorov-Smirnov test at the 5% significance level. Corresponding CDFs for the annual precipitation are not significantly different (Fig. 3.4-10 d).

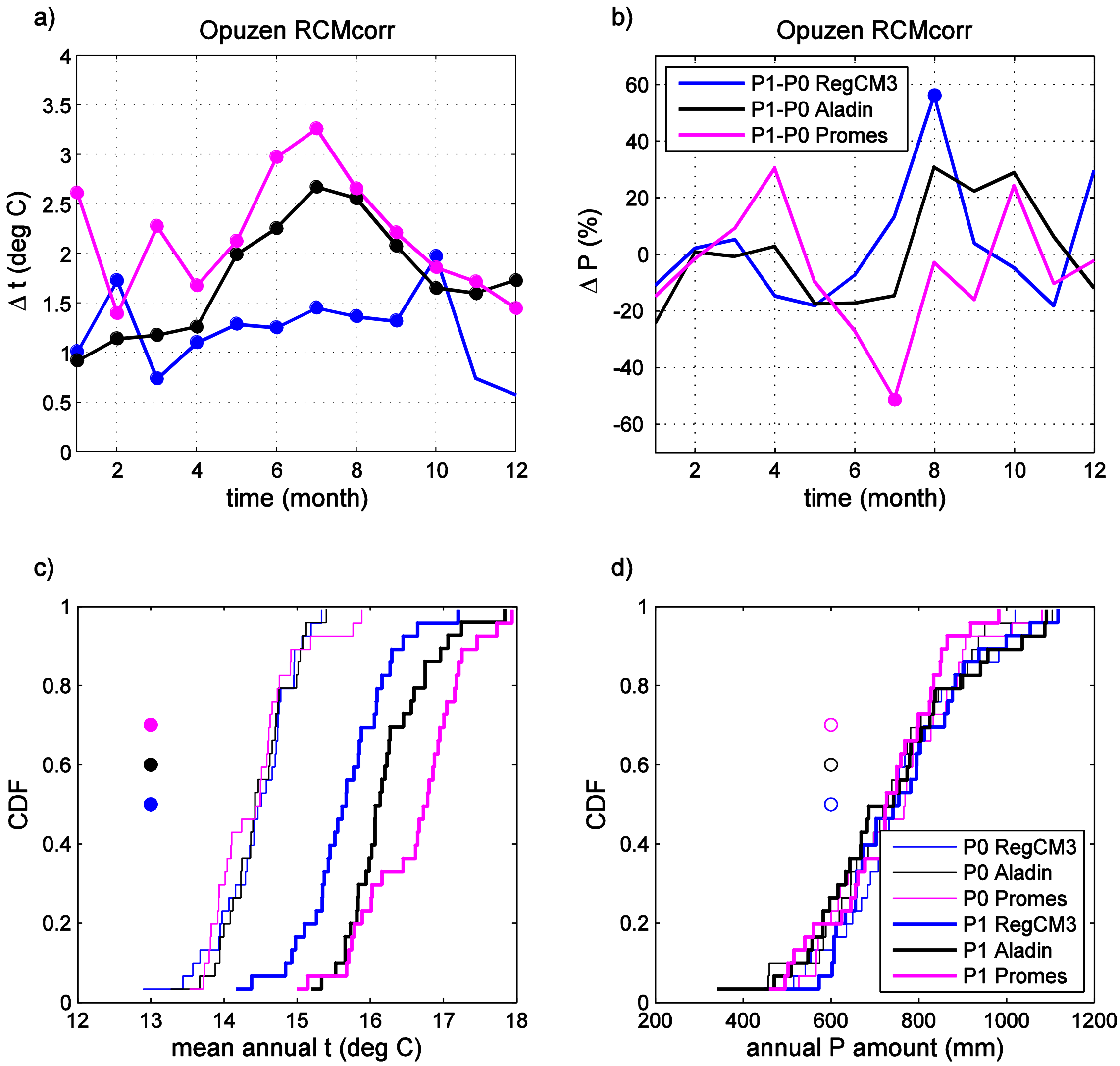


Figure 3.4-10. Same as Fig. 3.4-5 but for the Opuzen location.

3.5. Test area in Nikšić, Montenegro

From Annex 2 Report 2.6.:

In this study the climatological data presenting general climate characteristics, climate variability and trends at the temperature station Nikšić and precipitation stations Nikšić and Lukovo, the Zeta River catchment is shown. The present climate characteristics include measurements of air temperature and precipitation amounts from the reference climate period 1961-1990; while the future characteristics are estimated from the simulations of the regional climate models from the CC-WaterS project (based on the ENSEMBLES project). The regional climate models are Aladin, Promes and RegCM3. For 2m temperature and precipitation, time series for each model were considered and for present climate they are compared with local observations.

Climate and climate change characteristics based on observed data

Table 3.5-1. Geographical station data (elevation h, longitude ϕ, latitude λ) and the available measurement time periods for temperature (T) and precipitation (P) data for 2 stations near Nikšić.

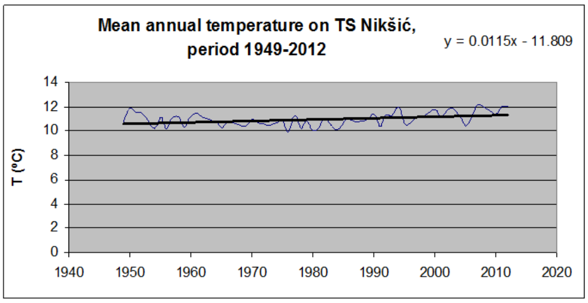
	Station	*h* (m.a.s.)	ϕ (°)	λ (°)	T	P
1.	Nikšić	627	42,78° N	18,94° E	1949-2012	1949-2012
2.	Lukovo	838	42,81° N	19,02° E	No data	1960-2012

Observed period for T station Nikšić is 1949-2012. For *Serbia* period which exhibit a close similarity to estimated longterm temperature and precipitation trends is from 1949 to 2006. We can not be sure that this period is also convenient for Montenegro, but we present, where available, the trends for this period also.

Table 3.5-2. Decadal air temperature trends (°C/10 yrs) for Nikšić temperature station for 1949-2012 and 1949-2006 data series.

	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Year
	Winter			Spring			Summer			Autumn			
	Temperature station **Nikšić**												
°C/10yrs 1949-2012	-0.14	0.21	0.08	0.16	0.05	0.20	0.29	0.28	0.25	-0.04	0.08	-0.02	0.12
	0.05 *			0.13 *			0.27 *			0.01 *			
°C/10yrs 1949-2006	-0.16	0.21	0.07	0.11	-0.11	0.17	0.21	0.19	0.07	-0.17	0.11	-0.11	0.05
	0.04 *			0.06 *			0.15 *			-0.06 *			

* As average of trends in three months



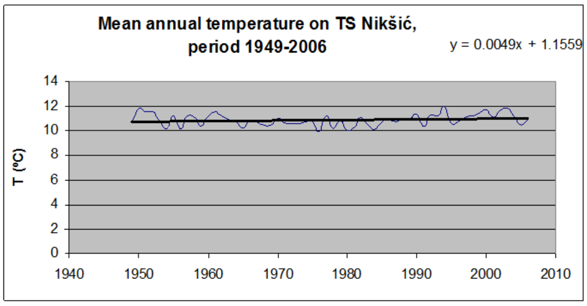


Figure 3.5-1. Observed mean annual temperature data with trends on TS Nikšić, periods 1949-2012 and 1949-2006

Table 3.5-3. Decadal trends (mm/10years and %/10years) for Nikšić and Lukovo precipitation stations for available data series (PS Nikšić: 1949-2012 and PS Lukovo: 1960-2012), and additionally for PS Nikšić periods 1949-2006 and 1960-2012.

	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Year
	Winter			Spring			Summer			Autumn			
	Precipitation station Nikšić												
mm/10yrs 1949-2012	-3.2	-2.6	-2.3	1.5	8.3	-0.8	-3.7	-2.2	1.5	5.3	2.4	-1.3	2.6
	-2.74 *			2.98 *			-1.47 *			2.11 *			
mm/10yrs 1949-2006	-11.8	-8.7	-7.4	-1.0	12.8	-0.9	-5.9	-1.6	6.8	9.7	2.8	-2.0	-7.2
	-9.32 *			3.63 *			-0.23 *			3.52 *			
mm/10yrs 1960-2012	5.3	-3.5	-1.6	-10.1	-2.8	3.1	-3.1	-9.3	-2.9	3.6	0.1	-12.3	-33.7
	0.04 *			-3.27 *			-5.12 *			-2.88 *			
%/10yrs 1949-2012	-1.2	-1.4	-1.2	0.9	5.2	-0.7	-4.2	-4.3	2.1	3.8	1.2	-0.5	0.14
	-1.26 *			1.80 *			-2.11 *			1.50 *			
%/10yrs 1949-2006	-4.5	-4.6	-3.9	-0.6	7.9	-0.9	-6.7	-3.0	8.9	6.9	1.4	-0.7	-0.38
	-4.34 *			2.15 *			-0.27 *			2.53 *			
%/10yrs 1960-2012	2.0	-1.8	-0.9	-6.0	-1.6	2.9	-3.6	-16.7	-3.8	2.5	0.0	-4.2	-1.72
	-0.21 *			-1.58 *			-8.06 *			-0.54 *			
	Precipitation station Lukovo												
mm/10yrs 1960-2012	-10.1	-14.1	-6.5	-14.5	-12.1	-0.4	-6.2	-8.1	-8.2	1.4	-5.9	-21.6	-104.2
	-10.19 *			-9.00 *			-7.48 *			-8.68 *			
%/10yrs 1960-2012	-5.0	-8.8	-4.1	-9.9	-8.1	-0.4	-7.2	-15.3	-10.6	1.1	-3.1	-8.2	-6.1
	-5.96 *			-6.11 *			-11.05 *			-3.38 *			

* As average of trends in three months

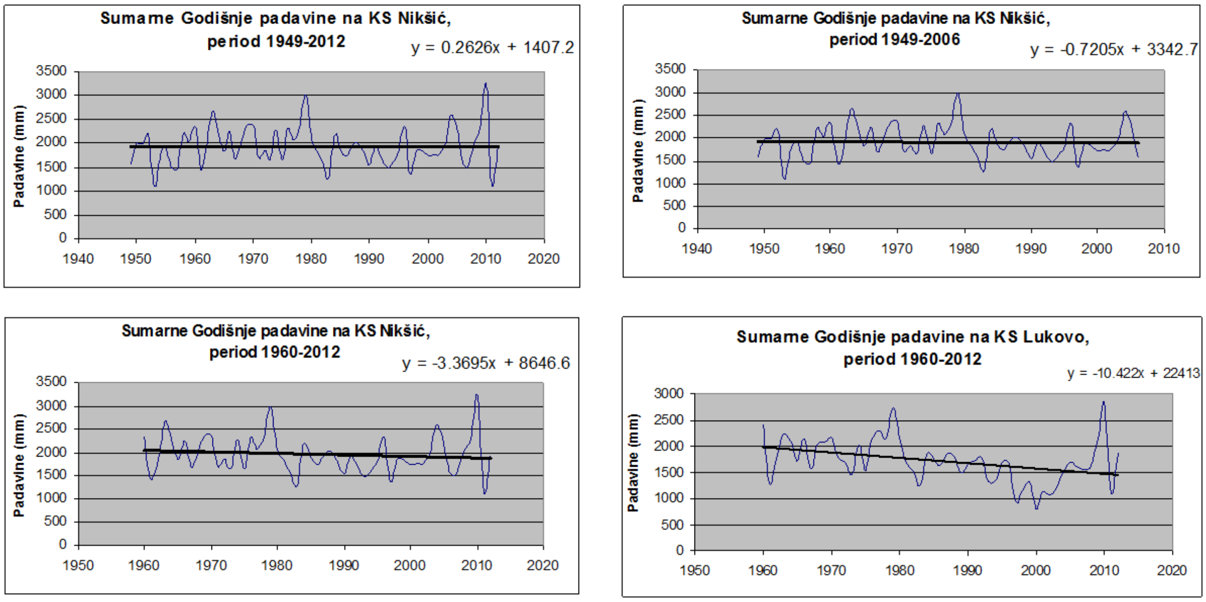


Figure 3.5-2. Observed Sum annual precipitation data with trends on PS Nikšić, periods 1949-2012, 1949-2006 and 1960-2012, and PS Lukovo 1960-2012.

Climate and climate change simulations for future

We have download temperature and precipitation data from CCWaterS project.

Figure 3.5-3 a-c shows mean annual corrected temperatures with trend for TS Nikšić for all three models (period 1951-2050).

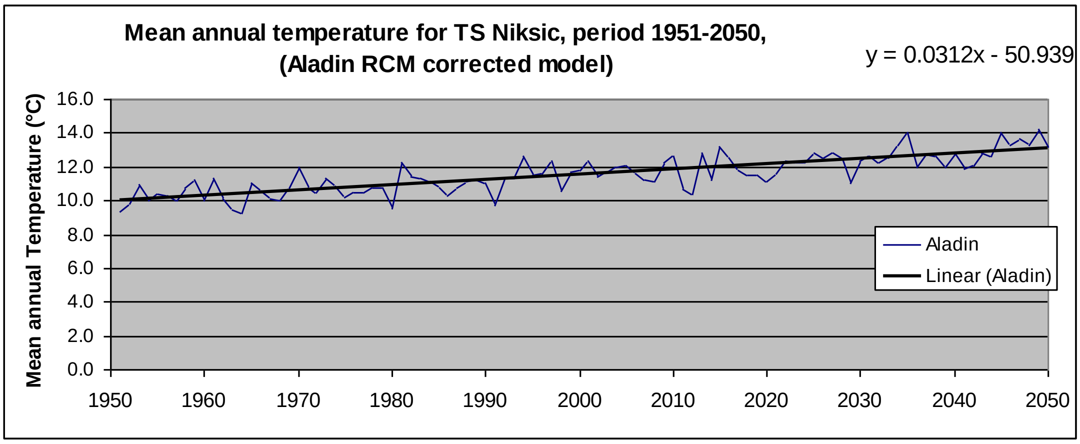


Figure 3.5-3a RCM Aladin

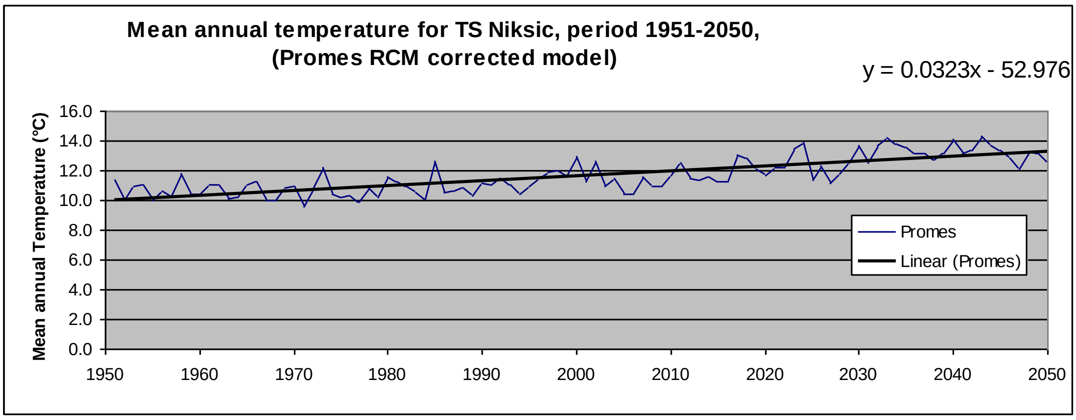


Figure 3.5-3b RCM Promes

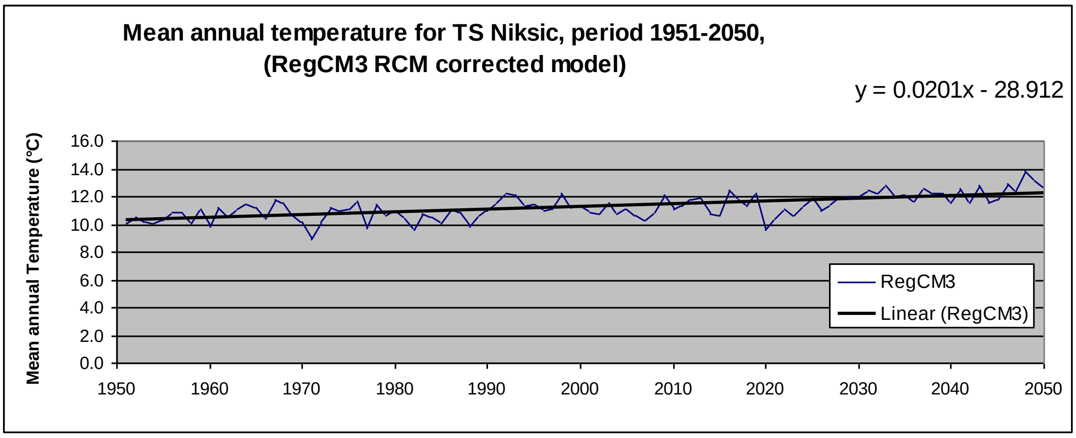


Figure 3.5-3c RCM RegCM3

Figure 3.5-4 a-c shows mean annual corrected precipitations with trends for PS Nikšić for all three models (period 1951-2050).

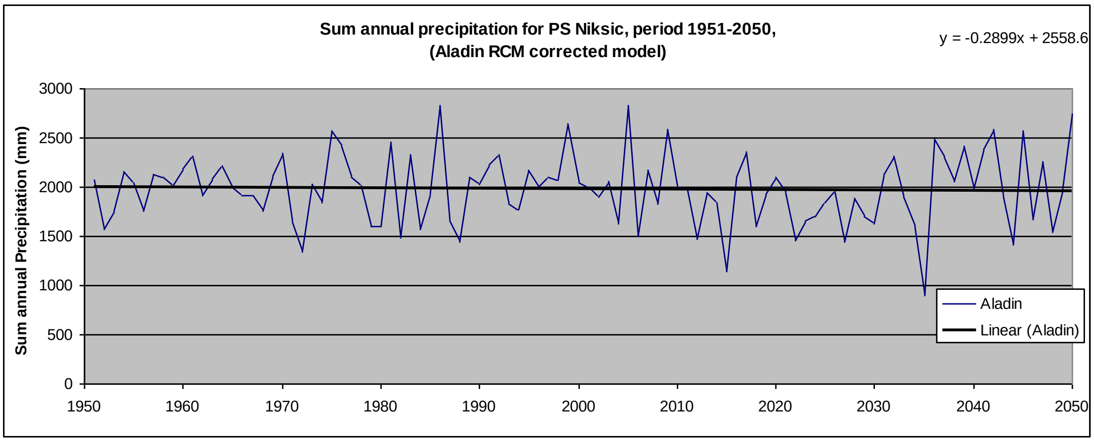


Figure 3.5-4a RCM Aladin

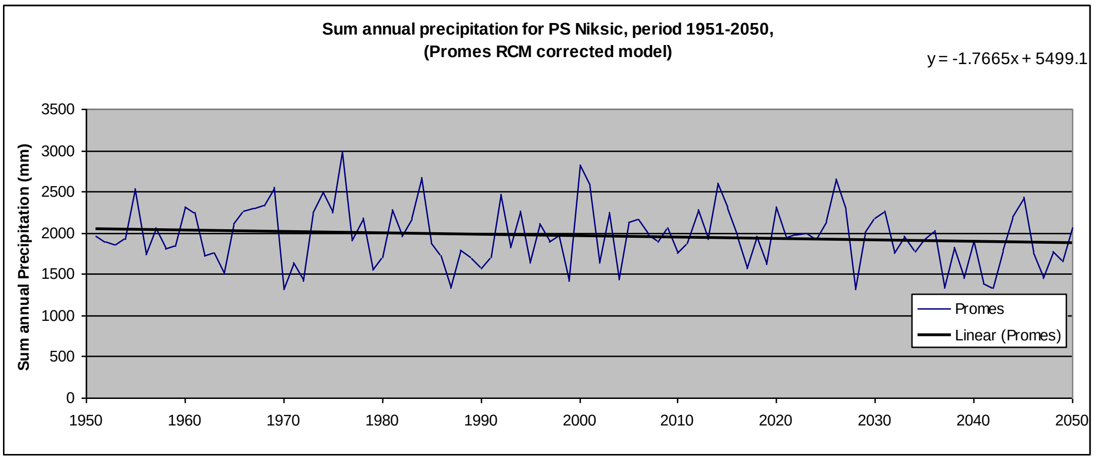


Figure 3.5-4b RCM Promes

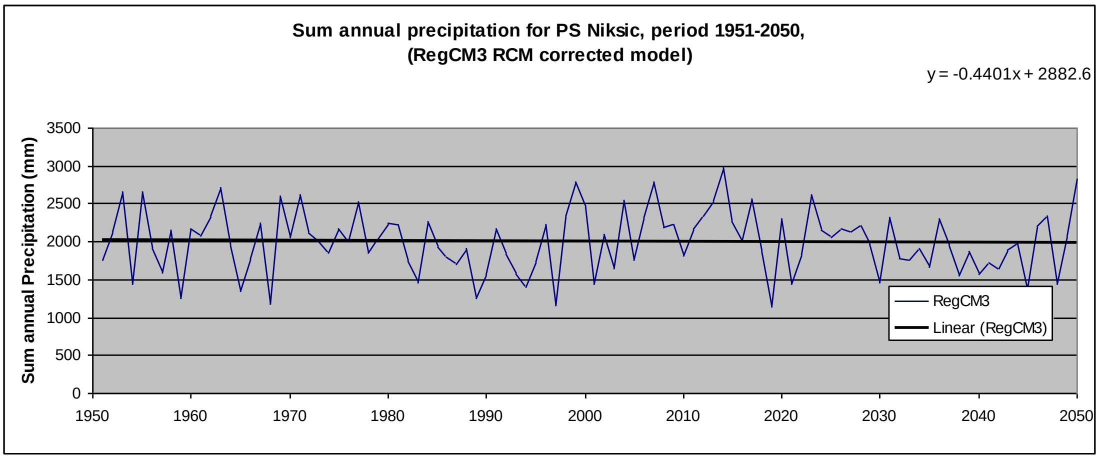


Figure 3.5-4c RCM RegCM3

Figure 3.5-5 a-c shows mean annual corrected precipitations with trends for PS Lukovo for all three models (period 1951-2050).

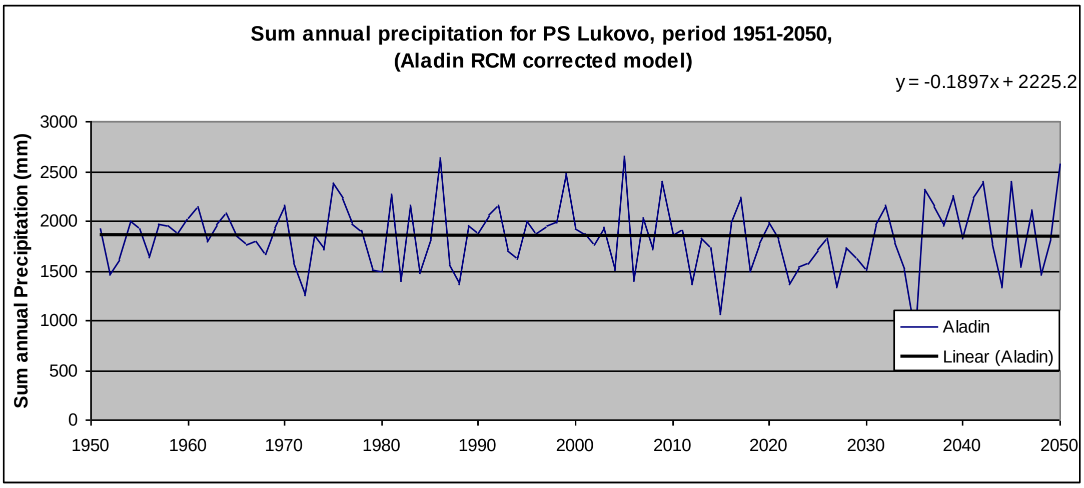


Figure 3.5-5a RCM Aladin

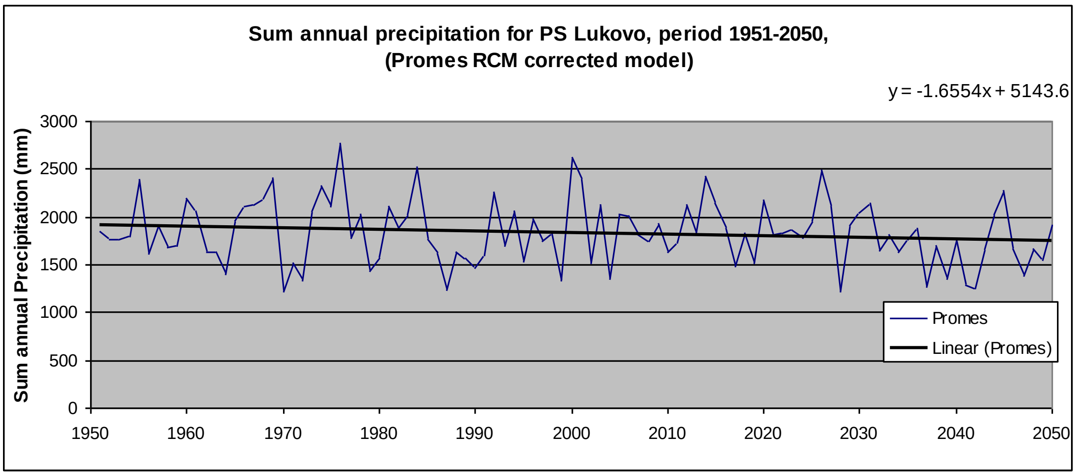


Figure 3.5-5b RCM Promes

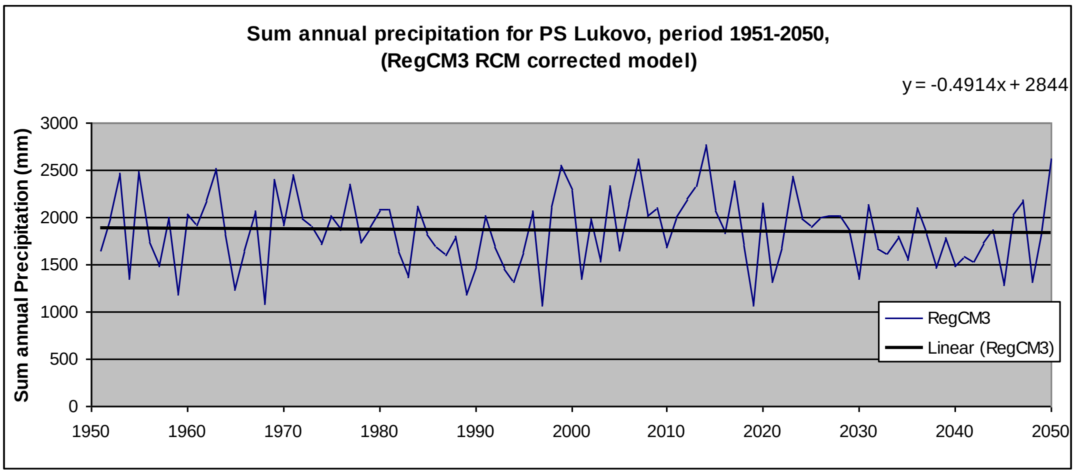


Figure 3.5-5c RCM RegCM3

Observed temperature trend for TS Niksic are in the range 0.5 – 1.0 °C / 100 years, which is similar to region and whole world average. Seasonal increasing trends have been observed in winter, spring and particularly summer, while decreasing trend is observed for autumn.

Observed precipitation trends for PS Niksic and PS Lukovo differ a lot. It seems that a slightly decreasing P trend is observed at annual level, but reliability of this claim is not high. Regarding seasonal P trends, even results indicate possibility that decreasing trend have been observed in winter, spring and particularly summer, while slightly increasing trend could be present for autumn, uncertainty is very high.

In analyzed RCMs models, extremely big differences between observed and projected values (especially for P) didn't help us a lot.

One T and two P stations are too low number to make some more precise conclusion. The results of these T and P stations just indicate possible climate change of this part of Montenegro. The reliability of T trends could be assessed as relativelly high, while for P is much lower. Future prediction is much more uncertain, especially for precipitation.

3.6. Albanian test area

From Annex 2 Report 2.7.:

The Drin River Basin is located in the Western Balkans and it is shared between Albania, Greece, Kosovo, Macedonia and Montenegro. The basin represents a very complex water system where Rivers, lakes, wetlands, groundwater interact with each other and create a very rich ecosystem in terms of natural resources. The total catchment area of the basin is around 19,600 km2 and it includes the Black Drin, White Drin and Buna River, as well as the Shkodra, Ohrid and Prespa lakes. The Black Drin originates from Lake Ohrid and flows up north crossing the border between Macedonia and Albania and meets the White Drin which rises in Kosovo. They flow together as Drin River through the territory of Albania until they meet the Buna River and discharge finally to Adriatic Sea. On the other hand, the water from Prespa Lakes, which are shared between Albania, Greece and Macedonia, flows to Lake Ohrid through the porous underground karstic formations. The basin represents great importance in terms of natural resources not only on national level for the riparian countries but also in the global level. Shkodra Lake is the largest lake in the Balkan Peninsula. Ohrid Lake is one of Europe’s deepest and oldest lakes and the deepest lake in the Balkans.

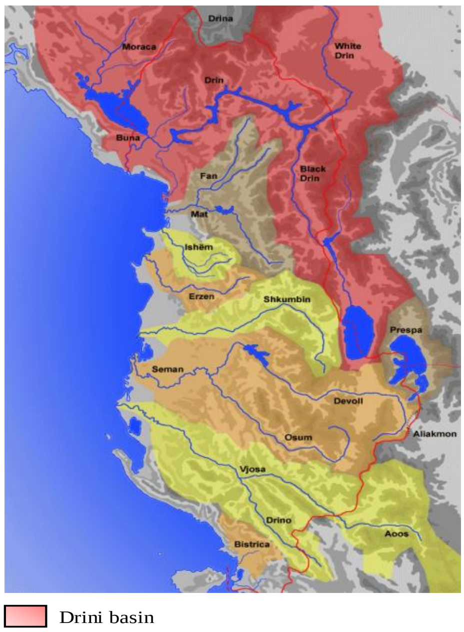


Figure 3.6-1. River basins map of Albania

There are consider 5 meteorological stations to perform climate change study. The meteorological study consider in this study are as following: Theth, Shkoder A, Shishtavec, Peshkopi, Shupenze (Figure 3.6-2).

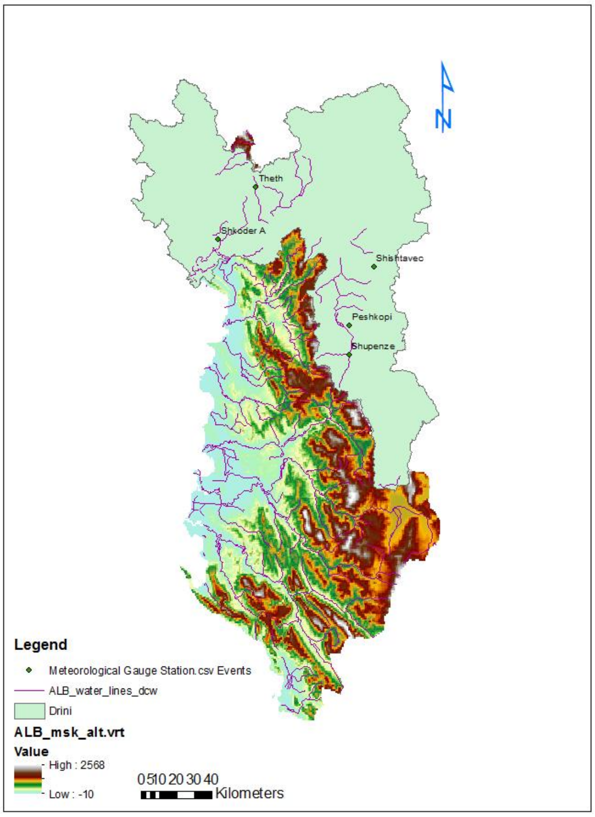


Figure 3.6-2. Meteorological stations location

In the report made by FB11, a description of empirical approaches (four models to estimate average annual runoff) is given, for the estimation of the impacts of climate change on some aspects of flow regime.

Also, impact assessment using hydrological models is described, including the WatBal model developed for assessing the impact of climate change on river basin runoff.

Climate and climate change characteristics based on observed data

Precipitation (1961-1990)

Meteorological stations considered for this purpose are as following: Theth, Shkoder A, Shupenze, Shishtavec, Peshkopi. The reason why are consider these stations is to have an accurate overview of climate variability over entire basin. Concerning to the rainfall regime below (Figure 3.6-3) is shown variability of yearly average rainfall.

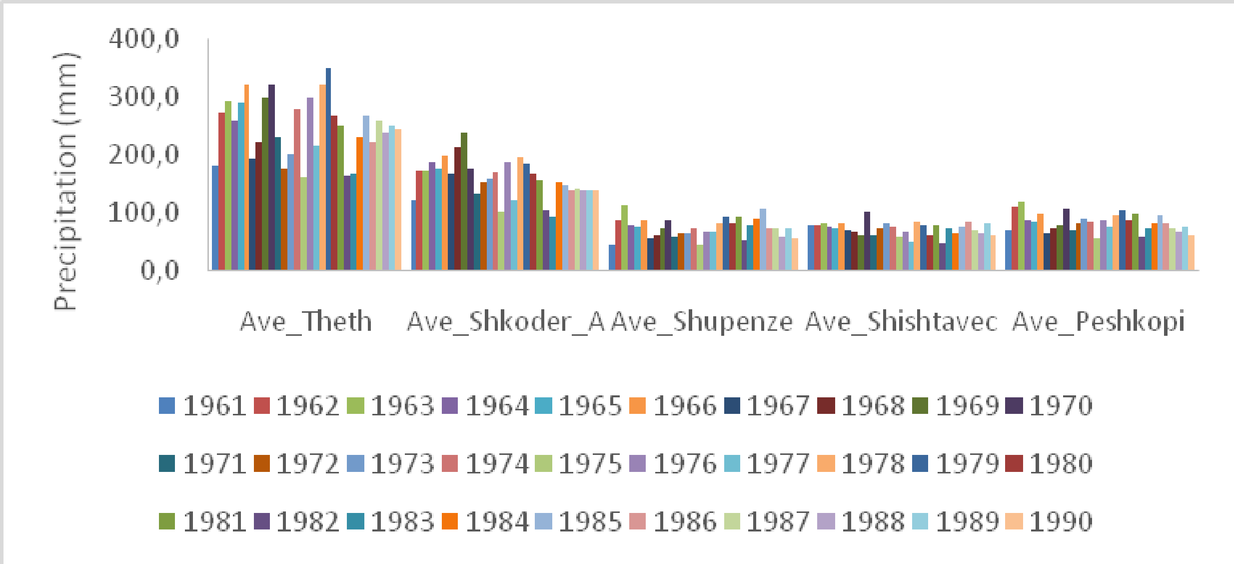


Figure 3.6-3. Yearly average precipitation variability

In both scenarios (i.e. monthly and yearly average rainfall variability), among 5 stations 2 of them, respectively Theth and Shkoder A are characterized from rainfall intensity, in mean time from high variability through the months and years. This high variability for 2 stations mostly is due to geomorphology and positioning of these stations. While 3 other stations almost they have the same variability through the months and years also with each other.

Cross-correlation through the years between 5 considered stations is shown in the report made by FB11. There 2 group's (Theth and Shkoder A, Shupenze, Shishtavec and Peshkopi) which are representing a weak Cross-correlation between each other, while between stations that are representing each group there is a good Cross-correlation.

Temperatures (1961-1990)

Concerning to the variability of temperatures for all 5 stations considered for analyzing of climate change over entire Drini River basin, below (Figure 3.6-4) is shown yearly average variability for each respective station. Station "Shkodra A" is representing the highest temperature compare with other stations. While lowest temperature is noticed at "Shishtave". Variability of temperature through all the stations is almost the same (i.e. not big differences). This happened because temperature depends on the average velocity of the air molecules and their mass, and so temperature generally increases with air density.

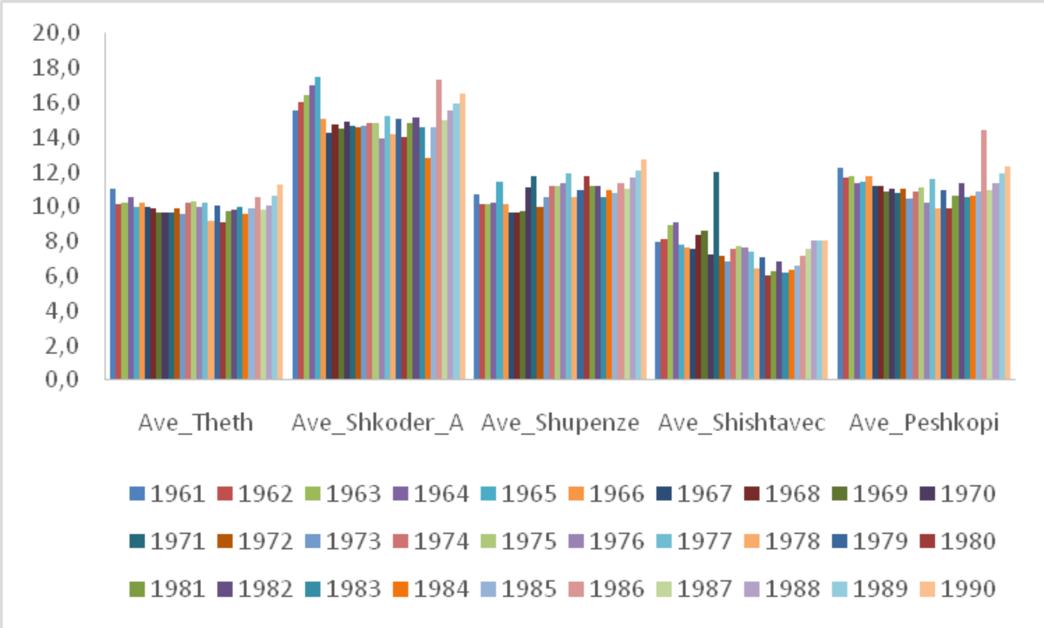


Figure 3.6-4. Yearly average temperatures variability

Cross-correlation through the years between 5 considered stations is shown in the report made by FB11. Different from cross-correlation between stations concerning to the precipitations variability where a significant differences is noticed, while concerning to the temperatures variability there is a good cross-correlation between all stations. Sure that if we compare variability of temperatures linked to Theth and Shkoder A with three other stations there are some differences but not significiant.

Climate and climate change simulations for future

Precipitation

The precipitation total during winter, related to 1990, is likely to decrease an average of -8.0% (-4.3 to -12.4%) by 2050; 11.9% (-5.7 to -23.7%) by 2080 and 13.7% (-4.7 to -29.4%) by 2100; during spring this is likely to decrease up to 6.9% (-5.9 to - 8.1%°C) by 2050; 12.3% (-9.0 to -17.7%°C) by 2080 and 15.0% (-10.1 to - 22.2%°C) by 2100.

Table 3.6-1. Projections of annual precipitation changes (%) related to 1990

Years	2030	2050	2080	2100
A1BAIM (aver)	-3.9	-8.1	-12.9	-15.5
A2ASF (min)	-2.6	-5.5	-8.4	-9.0
A1FIMI (max)	-5.4	-11.0	-21.0	-26.1

A- A1BAIM scenario (Average values)
L- B1IMA scenario (Low values)
H- A1FIMI scenario (High values)

The highest decrease in average precipitation is likely during summer, up to -24.6% (-16.5 to -33.9%) by 2050; -45.7% (-36.0 to -58.8%) by 2080 and -54.8% (-44.2 to -71.8%°C) by 2100.

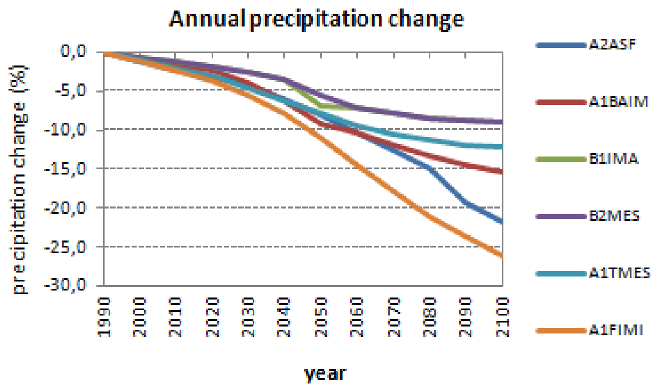


Figure 3.6-5. Projections of annual precipitation (%)

The high decrease in precipitation, combined with the high increase in temperature, might lead to prolonged summer droughts over the area. The demand for water could increase, especially in summer. Decrease in total precipitation combined with higher evaporative demand would probably result in less river flow (run-off). Water resources are likely to be further stressed due to a projected growth in demand and climate-driven changes in supply for irrigation, cities, industry and environmental flows. The increased temperatures expected in summer could lead to higher local precipitation extremes and associated flood risks in project area.

The number of rainy days with hazardous rainfalls is expected to increase by approximately 4 - 5 days by 2100 time horizons. An increase of SPI3, (cases of moderate, severe and extremely dry weather) to approximately 18 cases by 2030, and 20, 22 and 24 cases by 2050, 2080 and 2100 respectively is expected. Increasing spring temperatures will accelerate soil temperature increases from winter minima and extend suitable zones for summer crops and lengthening of their growth season. The length of the growing season is projected to increase from 263 days in 1990 to potentially 289 days in 2100.

Temperature

The likely changes (averages) in annual temperature for different scenarios and time horizons reveal a likely increase in seasonal and annual temperatures related to 1990 for all time horizons. The annual temperature is likely to increase up to 1.8°C (1.3 - 2.4°C) by 2050; 2.8°C (2.1 - 4.1°C) by 2080 and 3.2°C (2.3 - 5.0°C) by 2100.

Table 3.6-2. The likely changes in annual temperature (°C)

Years	2030	2050	2080	2100
A1BAIM (aver)	1.2	1.8	2.8	3.2
A1FIMI (max)	1.3	2.4	4.1	5.0
A2ASF (min)	0.8	1.3	2.1	2.3

The scenarios project the lowest increase in temperature for winter compared to other seasons with higher increases in absolute values likely for spring temperatures related to 1990 for the same scenarios - increases up to 1.6°C (1.3 - 2.2°C) by 2050; 2.5°C (1.7 - 3.6°C) by 2080 and 3.0°C (1.9 - 4.4°C) by 2100 (figure 3.6-6). Summer projections indicate increases in annual temperature up to 2.7°C (2.4 - 3.6°C) by 2050; 4.3°C (3.1 - 6.3°C) by 2080 and 5.1°C (3.4 - 7.7°C) by 2100. Such a situation is likely to result in increases to the frequency and/or intensity of extreme weather events. It is known that the relationship between averages and extremes is often non-linear. For example, a shift in average temperature is likely to be associated with much more significant changes in very hot days.

The average autumn temperature is likely to increase up to 1.8°C (1.5 - 2.3°C) by 2050; 2.9°C (2.2 - 4.1°C) by 2080 and 3.5°C (2.4 - 5.0°C) by 2100. The expected changes in surface air temperatures will lead to changes in air humidity. This combination is likely to influence the increases in the heat index (which is a measure of the combined effects of temperature and moisture). More frequent and severe droughts with a consequent greater fire risk are likely.

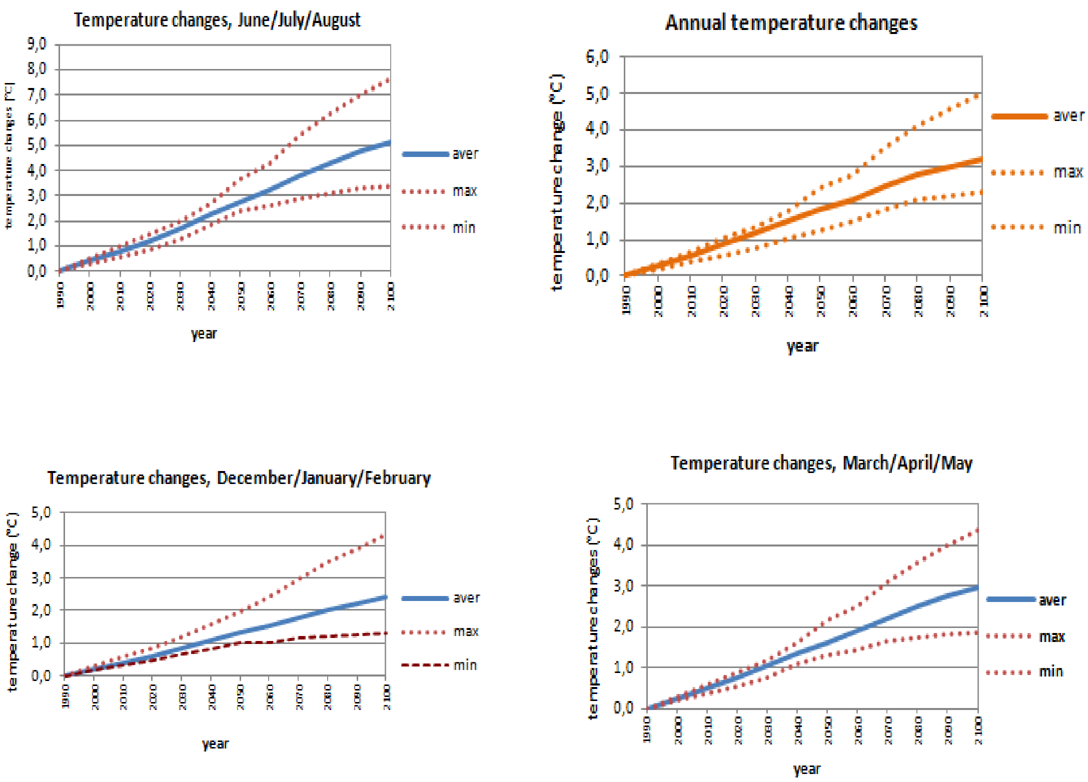


Figure 13.6-6. Annual temperature projections (summer, average, winter, spring)

A reduced temperature range, resulting from a higher rate of increase in minimum versus maximum temperatures, is likely to occur over nearly all land areas. Frost days and cold waves are very likely to become fewer. The number of days with temperatures in excess of 35°C will become more frequent and is expected to increase by about 10 days by 2100 compared to present. As a consequence of this, the number of heat wave days are expected to increase too with about 80, 95, and 120 days with a heat wave likely to be registered by the years 2050, 2080 and 2100 respectively. Warmer winters would reduce “heating degree days” and the demand for heating energy. Increases in air temperature are also projected to lead to an increase in “cooling degree days”.

Cold days are currently an infrequent phenomenon and likely to become even more in-frequent under climate change scenarios for the area. Based on the correlation between the numbers of days with a cold wave and the average temperature for winter months (period 1961 - 2008), it is calculated that the number of days with cold waves will be approximately 10 days by 2030, 7 days by 2050 and 5 days by 2080.

Warmer average and extreme temperatures will enhance the demand for freshwater and water for irrigation purposes, especially for soils with low water-storage capacities. If precipitation declines, the project area would face substantially increased risks of summer water shortages. If temperature increases too much, faster respiration may tip the balance towards plants becoming a CO_2 source.

3.7. Greek test area

From Annex 2 Report 2.8.:

The test area is the Corfu island located in the northwestern side of Greece belonging to the Ionian Islands Region. It extends approximately between latitude 39° 21’ 00” and 39° 49’ 00” and longitude 19° 37’ 00” and 20° 06’ 00”. The island’s surface is 588 Km^2, its length is 64 Km and its width 32 Km (in its wider part). The coastline reaches 217 Km and its altitude is about 914 m (Pantokratoras mountain).

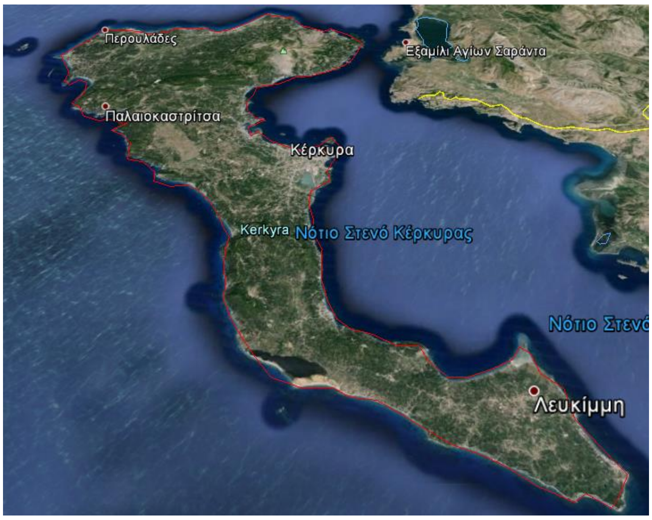


Figure 3.7-1. The Test area “Corfu island” (in red) (from Google Earth)

The River Basin Management Plan of Epirus identify surface waters including three small rivers, 3 lagoons and 3 groundwater bodies in Corfu. Locally there are high concentrations of chlorides in the coastal zones because of the sea intrusions due to excessive pumping and natural causes.

Climate and climate change characteristics based on observed data

The local climate characteristics are provided for the 2013 and 2014 in detail while the temperature's and the precipiation average values are given from 1955-1997 from the Hellenic National Meteorological Service.
Seasonality is described in terms of annual cycle of the mean annual precipitation and temperature, their standard deviation (of monthly mean) and the coefficient of variations. The discussion of the extremes is based on percentiles calculated starting from the empirical values expressed as cumulative distribution function (CFD).

For the present research, were analyzed the data for the rainfall and temperature stations present in the study area with good quality time-series.

In the island of Corfu there is an active meteorological station in Gouvia at an elevation of 1.13m, latitude 39o36’0’’ and longitude 19o54’0’’(Figure 3.7-2.).

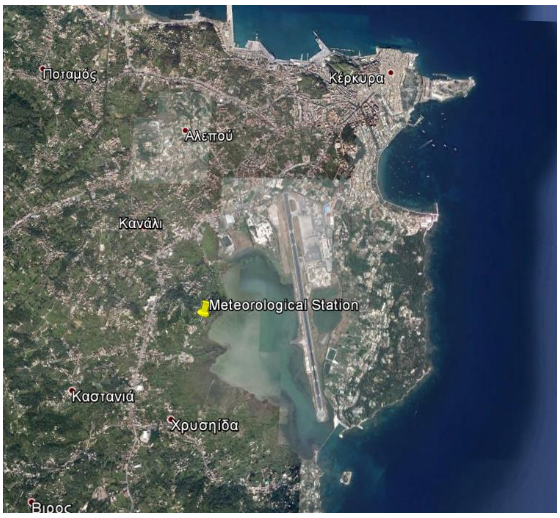


Figure 3.7-2. The meteorological monitoring stations of the test area (Google earth)

Temperature

<u>Years 2013 and 2014</u>

Temperature is analyzed in the meteorological station in Corfu.

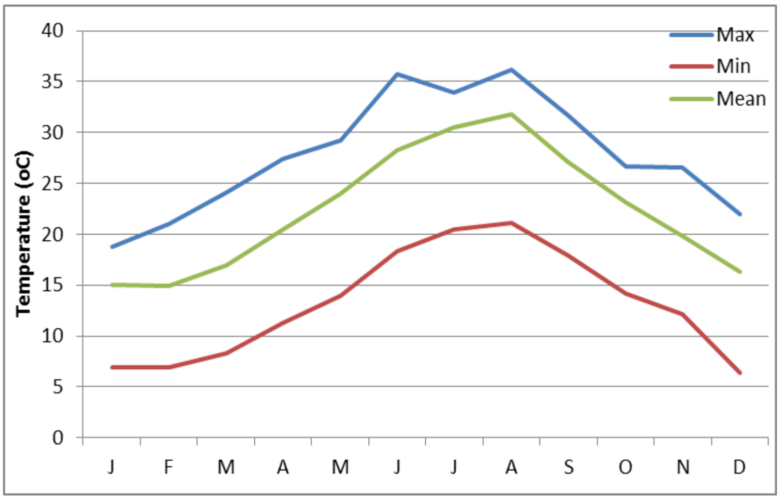


Figure 3.7-3. Annual cycle for the mean monthly air temperature [°C] (2013-2014)

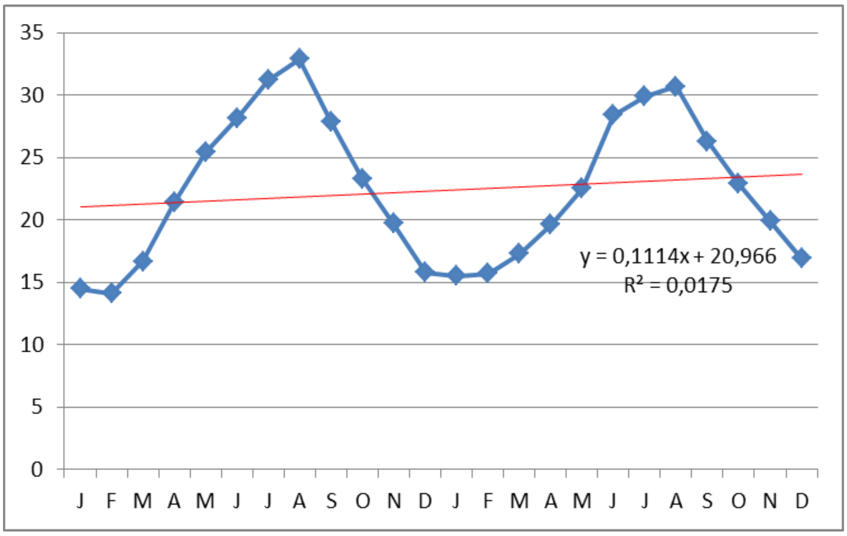


Figure 3.7-4. Time series of mean annual air temperature with the fitted trend for the period 2013-2014 for the meteorological station of Corfu

The temperature in Corfu varies greatly. The data include only 2013 and 2014 (Figures 3.7-3, 3.7-4). The maximum temperature is about 36 °C and the minimum 6 °C. The standard deviation of the mean monthly temperature varies a lot (0.05-1.15°C) but there is no safe conclusion drawn since the study period is only 2 years. The temperature trend is positive.

Period 1955-1997

Figure 3.7-5 shows the mean, max and min temperatures from 1955-1997 in Corfu. In general the climate is the Mediterranean one.

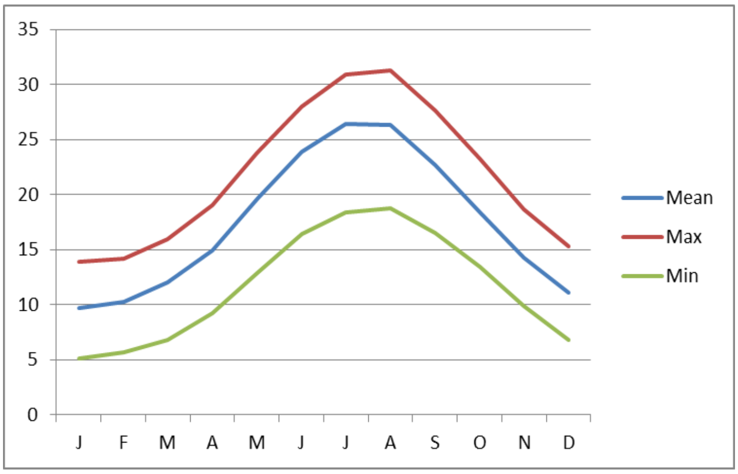


Figure 3.7-5. Annual cycle for the mean monthly air temperature [°C] (1955-1997)

Period 1975-2004

Additional data for the period 1975-2004 provide the average temperature values for Corfu Island.

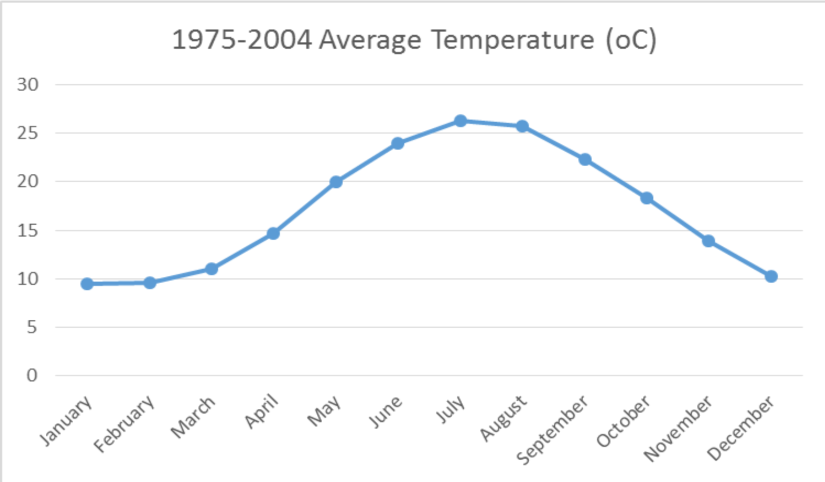


Figure 3.7-6. Annual cycle for the mean monthly air temperature [°C] (1975-2004)

It is worth noting that when the 4 different temperature datasets are compared (Figure 3.7-7), the temperature values are increased in January, February, March, November and December in more recent years. During spring and summer the mean temperature remains more or less the same. It seems that climate change makes autumn and winter less cold.

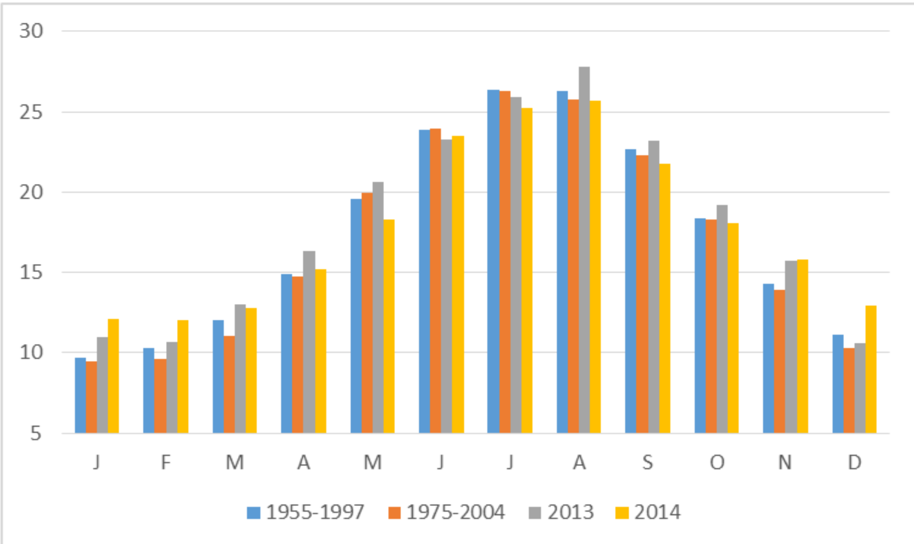


Figure 3.7-7. Annual cycle for the mean seasonal air temperature [°C] compared for the periods: 1955-1997; 1975-2004; 2013; 2014

Data gathered from the meteorological station of Corfu from 1956-2010 show that the mean temperature tends to increase with a trend of +0.089 and significance 0.131 (Figure 3.7-8).

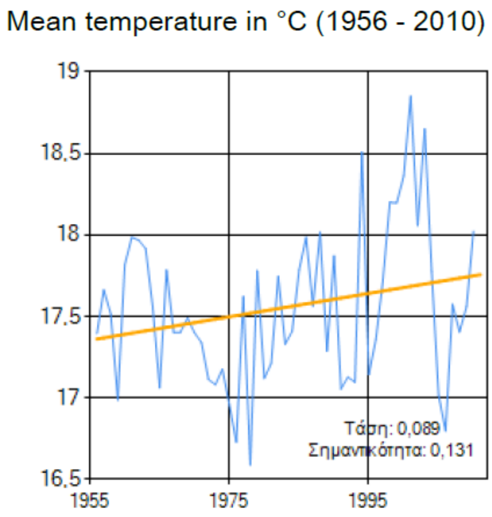


Figure 3.7-8. Annual cycle for the mean air temperature [°C] for 1956-2010

Precipitation

<u>Years 2013 & 2014</u>

For the test site area, the precipitation recorded in 2013-2014 and the average precipitation (1955-1997) is analyzed.

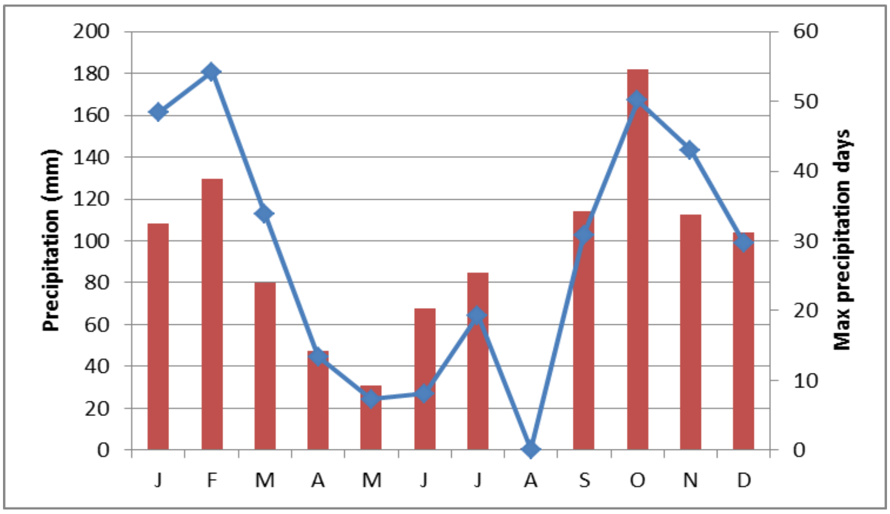


Figure 3.7-9. Annual cycle mean precipitation amounts in mm and maximum raining days for the period 2013-2014 for Corfu

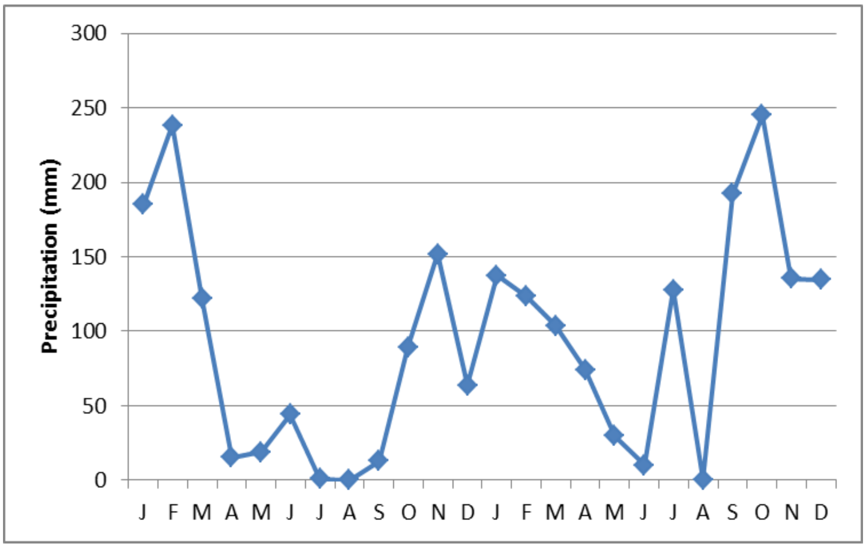


Figure 3.7-10. Time series of mean annual precipitations for the period 2013-2014 for Corfu

Period 1955-1997

In the test area, the average annual rainfall is calculated for the period of 1955-1997 for Corfu station. The highest precipitation occurs in autumn and winter (also in total raining days) and the lowest in the summer months. There is variability in precipitation.

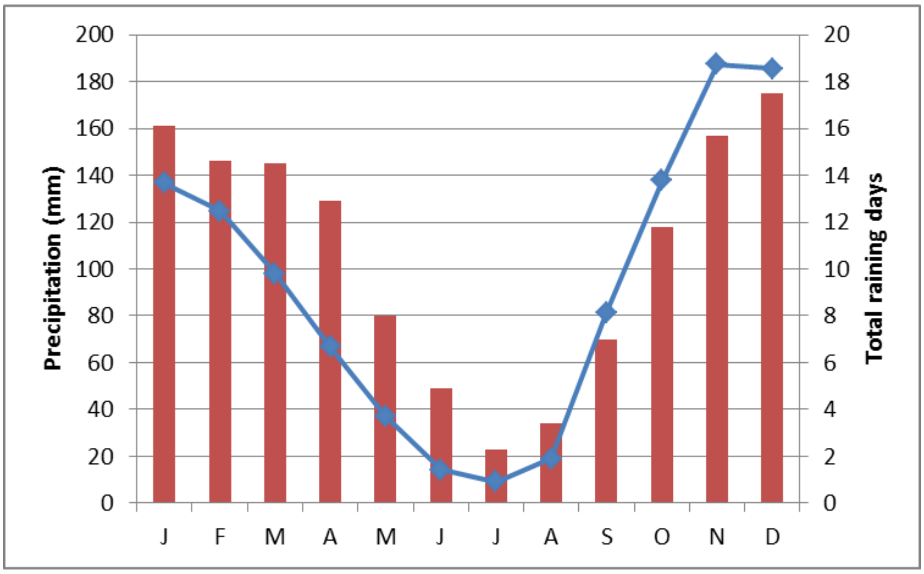


Figure 3.7-11. Annual cycle mean annual precipitation amounts in mm and maximum raining days for the period 1955-1997 for Corfu

It is generally concluded from the Strategic Environmental Impacts Assessment of Epirus that the precipitation varies from one year to the other.

Period 1975-2004

Additional data for the period 1975-2004 provide mean precipitation values for the test area.

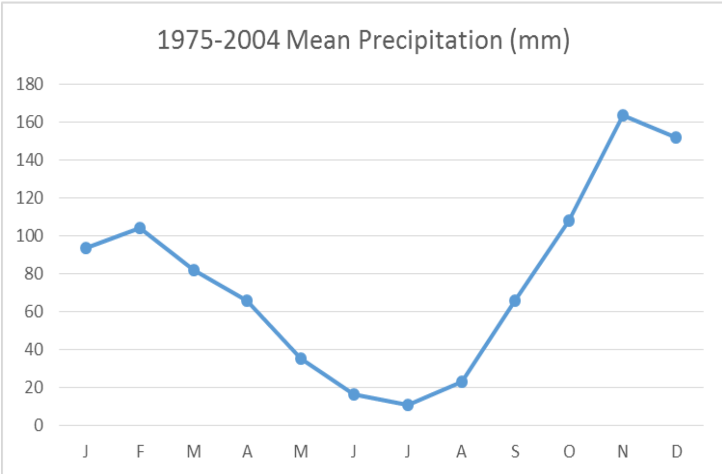


Figure 3.7-12. Annual cycle mean monthly precipitation amounts in mm for the period 1975-2004 for Corfu

The results from the comparison of the mean precipitation values for the 4 time periods show that in general there is a reduction in precipitation values but there are big variations (Figure 3.7-13).

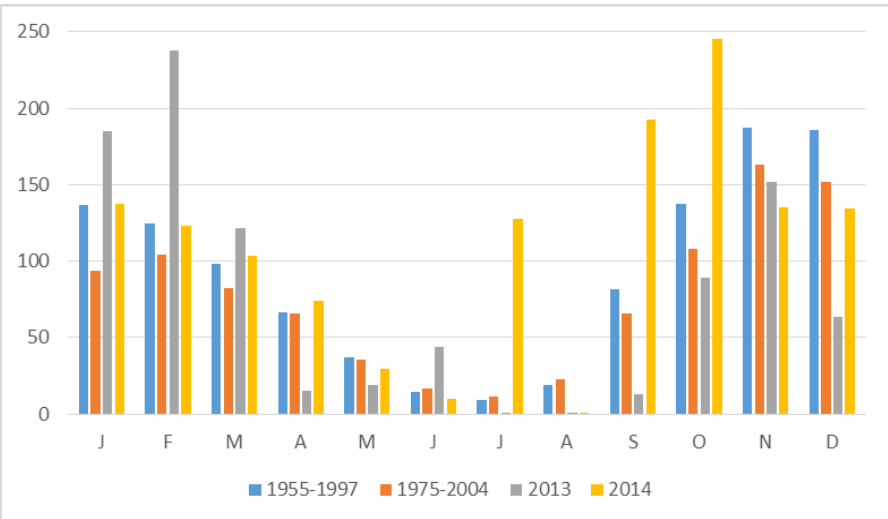


Figure 3.7-13. Annual cycle mean monthly precipitation amounts in mm for the periods: 1955-1997; 1975-2004; 2013; 2014

Data gathered from the meteorological station of Corfu from 1956-2010 show that the precipitation tends to decrease with a trend of -3.628 and significance 0.033 (Figure 3.7-14).

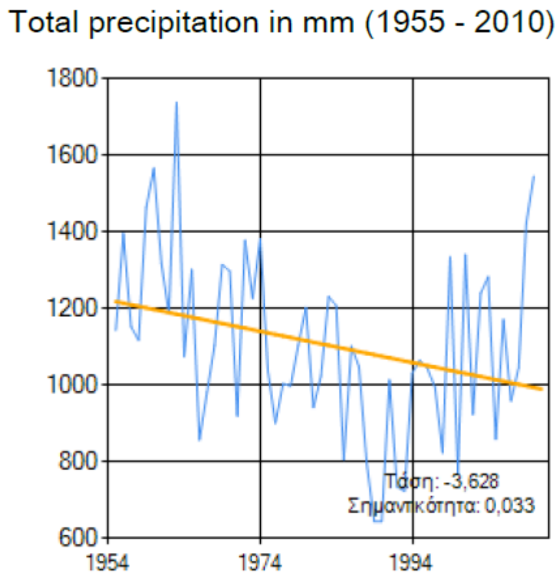


Figure 3.7-14. Annual cycle precipitation amounts in mm for the period 1955-2010

Climate and climate change simulations for future

Four models are used to simulate climate conditions in the test area of Corfu: Ensemble (scenario A1B); Prudence (scenario A2); Prudence (scenario B2); and REGCM (scenario A1B). The work has been elaborated by the project Geoklima. The simulation models results for the Corfu test area are presented in Table 3.7-1 for the period 1961-1990 and 2021-2050.

The results show that temperature is expected to increase (minimum, maximum and average values) during all the seasons and annually. The model showing the highest temperature increase is Prudence scenario A2, followed by Prudence scenario B2, while Ensemble and REGCM models provide comparative values (Figures 3.7-15.-3.7-18.). The average annual mean temperature is expected to increase from 1.23°C to 4.27°C. The total precipitation is expected to decrease especially in the summer months (Figure 3.7-18). In the winter months two out of four models predict a slight increase in total precipitation values. Total annual precipitation values are expected to decrease from 3.93% to 25.4% depending on the model.

Table 3.7-1. Changes in minimum, maximum, average temperature and total precipitation values predicted by climatic simulation models for Corfu area (period 2021-2050)

	Ensemble (A1B)					**Prudence (A2)**					**Prudence (B2)**					**REGCM (A1B)**				
Change in	Winter	Spring	Summer	Autumn	Year	Winter	Spring	Summer	Autumn	Year	Winter	Spring	Summer	Autumn	Year	Winter	Spring	Summer	Autumn	Year
minimum air temperature (ºC)	1,04	0,89	1,52	1,51	1,24	3,58	3,29	5,55	4,26	4,17	2,46	2,39	4,43	3,12	3,1	1,14	0,77	1,52	1,36	1,19
maximum air temperature (ºC)	0,98	0,93	1,5	1,51	1,23	3,81	3,77	6,19	4,68	4,61	2,43	2,48	4,78	3,4	3,27	1,15	0,9	1,53	1,47	1,26
average air temperature (ºC)	1,01	0,91	1,51	1,49	1,23	3,58	3,44	5,76	4,32	4,27	2,37	2,42	4,51	3,2	3,12	1,15	0,87	1,53	1,15	1,25
total precipitation (%)	2,29	-13,9	-11,13	-5,31	-3,9	-1,47	-15,1	-60,01	-24,88	-25,4	5,94	-1,19	-44,54	-3,15	-10,7	-16,56	-6,3	-44,01	-9,19	-7,9

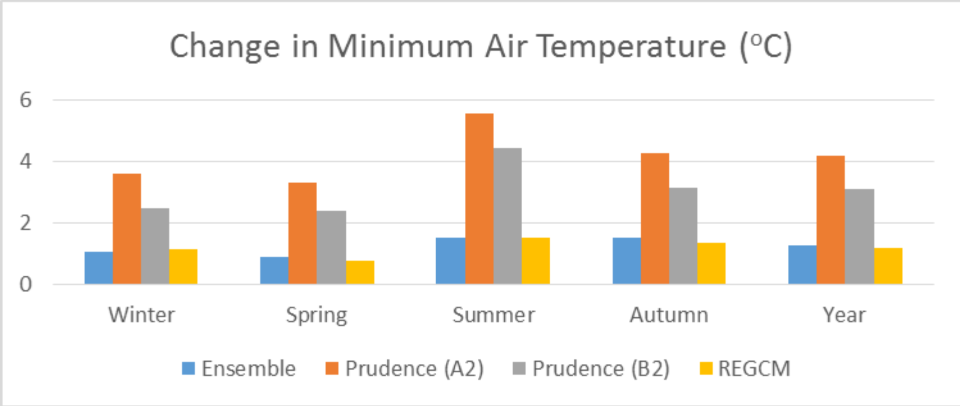


Figure 3.7-15. Change in minimum air temperature values (°C)

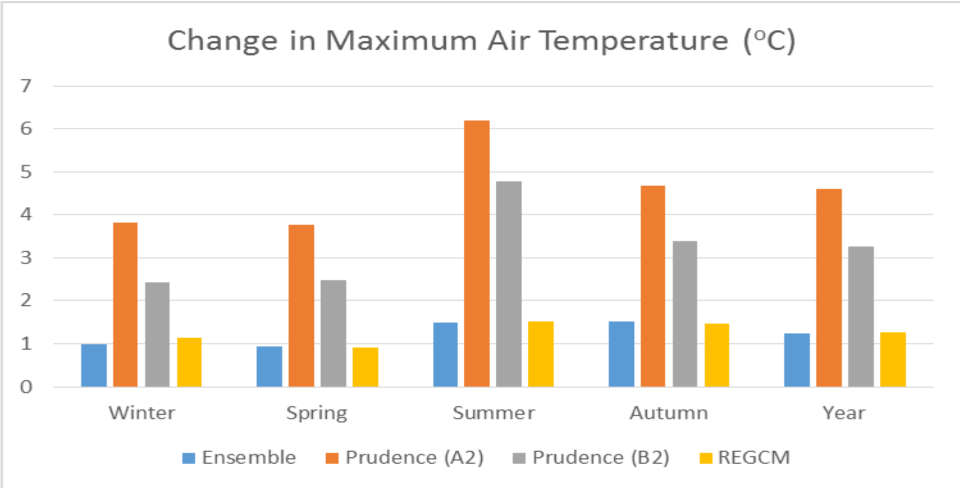


Figure 3.7-16. Change in maximum air temperature values (°C)

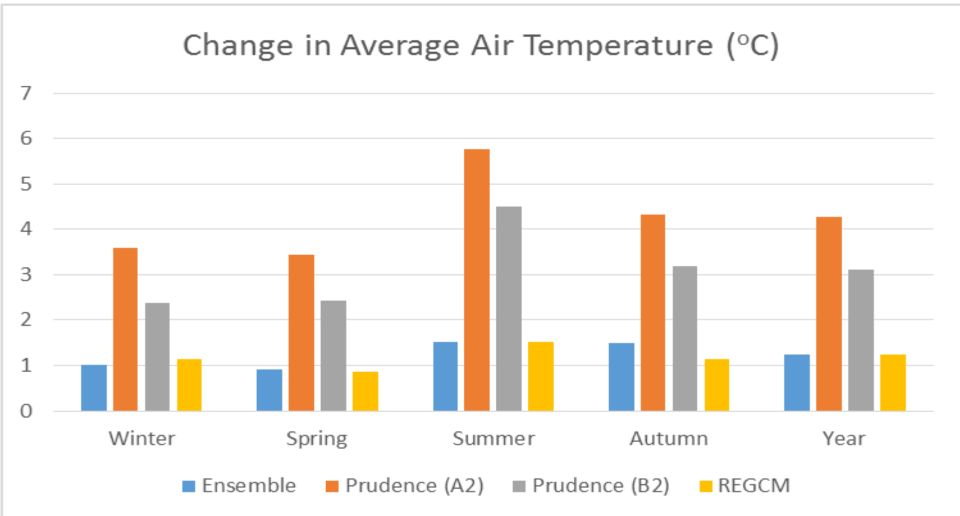


Figure 3.7-17. Change in average air temperature values (°C)

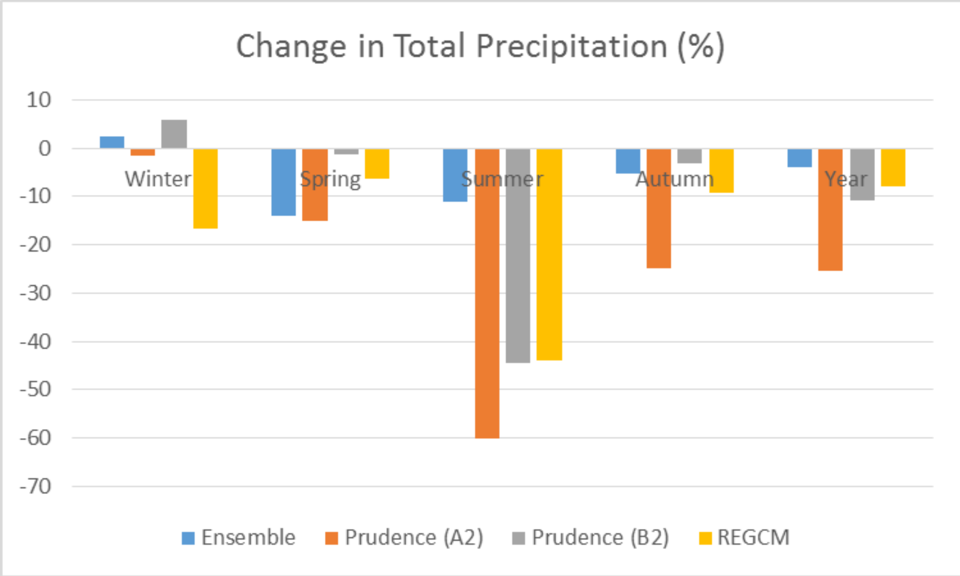


Figure 3.7-18. Change total precipitation values (%)

3.8. Conclusion

Based on the collected reports from PPs on test area level, it can be concluded that in all test areas an increase of temperature is predicted in the future period. In Ostuni, Aladin and Promes forecast a higher increase in temperature than the RegCM3, which makes Aladin and Promes more suitable to use for impact scenarios of climate change. In Croatian test areas, model Promes simulated a larger temperature increase than the other two models.

Precipitation trends are diverse, they vary depending on the selected station, model (Aladin, Promes, RegCM3 or other) and time series (RCMcorr or RCMcorr_adj). In test area Ostuni, the trends were significantly changed in sign and modulus, when applying corr_adj time series. Model Promes showed the worst scenarios in terms of possible water shortage and salt intrusion in Ostuni. In most of the cases, precipitation trends are not statistically significant.

In test areas ATO3 (Marche Region) and Northern Istra (Croatia) results showed that according to the presented RCMcorr simulations, no robust estimates of significant precipitation change could be made for the first part of the 21st century.

In the report for Montenegro test area in Nikšić, it was concluded that due to a low number of considered stations, the results that are shown indicate just a possible climate change in that part of the country. Also, the reliability of temperature trends is considered relatively high. On the other hand, future prediction for precipitation is very uncertain.

In Albanian test area precipitation is expected to decrease, but the number of rainy days with hazardous rainfalls is expected to increase.

Most important data about climate characteristics based on observed temperature and precipitation on test area level are shown in Table 3.8-1.
Most important data about climate and climate change simulations for future scenarios on test areas regarding temperature and precipitation are shown in Table 3.8-2.

Table 3.8-1. Climate change characteristics based on observed data in Adriatic region (test area level)

	Period	Temperature	Precipitation
Test area Isonzo Plain (Friuli Venezia Giulia Region, ITALY)	reference period 1961-1990; T trend Gorizia station 1941-2011, T trend Torviscosa station 1941-2011, T trend Alberoni station 1972-2011; P trend Gorizia station 1961-1990, P trend Torviscosa station 1951-2011, P Trend Alberoni station 1925-2011;	Three meteorological stations were analyzed: Gorizia prese CBPI, Torviscosa and Alberoni, close to Monfalcone. Gorizia is clearly indicating a positive trend with increasing temperatures from 12,5°C recorded during the 40s, till the 14,3°C of the actual measures. Torviscosa is going from 12,2 to 14,3°C even if data are affected by a not so good quality time-series (some annual values are interpreted due to the data scarcity). Also Alberoni station indicates an increase in the temperature during the last period, with values that goes from 14,2°C to 15,1°C. Here temperatures are always higher than the other examined stations due to the sea influence. For Gorizia the Trend is of 0,2°C/10y, with a mean temperature value in the analyze period (1941-2011) of 13,4°C; for Torviscosa the Trend is of 0,6°C/10y, with a mean temperature value in the analyze period (1941-2011) of 13,5°C. For Alberoni station the Trend is of 0,4°C/10y, with a mean temperature value in the analyze period (1972-2011) of 14,4°C.	Three different stations were analyzed: Gorizia prese CBPI, Torviscosa and Alberoni (Monfalcone). Regarding the precipitation trends, looking at the stations, the situation is completely different. There is no homogeneity in the behavior. At Gorizia station, the total amount has a decreasing trend. What is also changing is the fluctuation and distribution within the months, with the increasing in June and September and decreasing in January and April. If we look at the trimester SON, the decreasing trend over 10y is important. The calculated Trend is of -38mm/10y (period 1961-1990), with a mean value of 1397,5 mm computed for the reference period 1961-1990 (R). At Torviscosa the general trend is negative, with a decreasing of the precipitations since 1950. The only positive time of the year is the autumn. The calculated Trend is of -1,2 mm/10y (period 1951-2011) with a R value (1961-1990) of 1194,0 mm. At Alberoni station, the Trend is of 1,4 mm/10y (period 1925-2011) with a R value (1961-1990) of 1108,23 mm.
Test area ATO 3 (Marche Region, ITALY)	reference period 1961-1990; T trends: 1957-2007 (2008 for station Lornano); P trends: 1951-2007 (2008 for Lornano) (with only few data missing)	For Lornano and Montemonaco stations: The trend results reveal the statistically significant increase in annual mean air temperature (0.3°C/10yrs). The annual mean temperature increase is predominantly due to the significant increase in spring (0.2-0.4°C/10yrs) and summer (0.2-0.5°C/10yrs) mean air temperature. Changes observed in the cold half-year are very weak.	In some years there is a significant deviation in monthly amounts from the average precipitation conditions. There is an overall large spatial variability of precipitation amounts. For Lornano and Montemonaco stations: The trends in precipitation amounts show the significant decrease in annual totals (2-5%/10yrs). There is a consistent decrease of precipitation amounts in all seasons. (The trends in precipitation amounts are given as the percentage of the corresponding seasonal and annual means from 1961-1990 period.)
Test area Ostuni (Apulia Region, ITALY)	reference period 1961-1990 (P0); whole observation period 1950-2007 (Pobs)	Analysis has been performed considering 9 temperature stations. A significant variability among stations exist. However, at annual scale considering the whole observation period Pobs the majority of the stations present a tendency to increase; only for 1 out of 9 there is a slight but significant tendency to decrease. Different results can be inferred considering the base-line period P0 during which 5 stations out of 9 indicate a decrease of temperature, and 4 out of 9 indicate an increase (stationarity in the base line period P0). A general increase of annual temperature is observed for the whole observation period, due to an increase of temperature (particularly during summer) during the last two decades (1991-2007). This climatic signal is not observed in all the stations, suggesting that local climate can be superimposed to the regional and/or global climatic trend.	Analysis has been performed considering 9 rainfall stations. In terms of annual mean, the precipitation regime appears to be uniform over the study area. It is possible to observe a general decrease of annual precipitation, both for the P0 and Pobs. However, such a decrease, although observed in all the rain gauges, it is never statistically significant. This is probably due to the high interannual variability. The analysis of the seasonal trends suggests that the decrease of precipitation observed at annual scale (although not significant) is mainly due to a decrease of the winter precipitation, which is observed in all the stations for the period P0. A similar decreasing trend is observed also if the whole observation period is considered, but generally not significant. For precipitation, the base line period P0 is not stationary. The impact of a decreasing in precipitation on the Ostuni aquifer and on the possible salt intrusion is currently ongoing.

Test areas in SLOVENIA (Kobariški stol, Mia, Matajur and Mirna River catchments)	1961-1990 reference period; 1956-2011 for T trends; 1961-2011 for P trends	Bilje station: Annual air temperature exhibits slight increase during observed period. Decadal air temperature trends (°C/10 years, *−statistically significant trend at 95% probability): Winter (0.23*), Spring (0.34*), Summer (0.35*), Autumn (0.13), Year (0.26). Portorož station: Annual air temperature exhibits slight increase during observed period (1956-2011). Decadal air temperature trends (°C/10 years, *-statistically significant trend at 95% probability): Winter (0.28*), Spring (0.29), Summer (0.31*), Autumn (0.13), Year (0.25).	Bilje station: Annual, winter, spring and summer precipitations seem to decrease and autumn precipitation to increase during the observed period (1961-2011), but the annual and seasonal trends are not statistically significant at 5% level. Decadal precipitation trends (mm/10 years): Winter (-3.5), Spring (-4.8), Summer (-6.4), Autumn (0.3), Year (-3.6). Portorož station: Annual, winter, spring and summer precipitation seem to decrease and autumn precipitation to increase in the observed period (1961-2011), but the only statistically significant trend at 5% level is observed for spring. Decadal precipitation trends (mm/10 years, *-statistically significant trend at 95% probability): Winter (-1.6), Spring (-4.7*), Summer (-4.9), Autumn (0.3), Year (-2.7).
Test areas in CROATIA (1. Northern Istria - river Mirna catchment; 2. Prud catchment and Blatsko polje on Korčula)	reference period 1961-1990; trends: 1961-2012	Mirna River catchment (test area 1- data for three stations): The trend results reveal the statistically significant increase in annual mean air temperature (0.1-0.3°C/10yrs) since 1961 in the Mirna catchment. The annual mean temperature increase is predominantly due to the significant increase in spring (0.2-0.3°C/10yrs) and summer (0.3-0.5°C/10yrs) mean air temperature. Changes observed in the cold half-year are very weak. Prud Spring catchment (test area 2- Opuzen station): During the period 1961-2012, the mean annual air temperature anomalies are mainly positive. During the recent 20 years air temperature trend is amplified. The consequence of such temperature fluctuations is that eight out of ten warmest years in the observed 52-years period were recorded in the first decade of the 21st century. The annual trend reveals the statistically significant increase in the mean air temperature of 0.2°C/10yrs since 1961. The annual temperature increase is predominantly due to a significant increase in the summer (0.3°C/10yrs) and spring (0.2°C/10yrs) mean air temperature.	Mirna River catchment (test area 1- data for three stations): The trends in precipitation amounts show the significant decrease in annual totals (4-5%/10yrs) over the Mirna River catchment. There is a consistent decrease of precipitation amounts in all seasons, nevertheless decrease in annual amount is mainly forced by a decrease in the warm seasons (spring and summer). (The trends in precipitation amounts are given as the percentage of the corresponding seasonal and annual means from 1961-1990 period.) Prud Spring catchment (test area 2- Opuzen station): The trends in precipitation amounts reveal drying in the annual (-3.0 %/10yrs) and seasonal amounts, although they are not statistically significant. The main contribution to annual drying primarily comes from the reduction in summer precipitation totals (-8.2%/10yrs).

Test area in Nikšić (Zeta River catchment), MONTENEGRO	reference period 1961-1990; T trends: 1949-2012, 1949-2006; P trends: Nikšić station (1949-2012, 1949-2006, 1960-2012), Lukovo station (1960-2012)	Nikšić station: Decadal air temperature trends (°C/10 yrs): Year (0.12 for 1949-2012); Year (0.05 for 1949-2006). Seasonal increasing trends have been observed in winter, spring and particularly summer, while decreasing trend is observed for autumn.	Nikšić station: Decadal trends: Year (2.6 mm/10yrs and 0.14 %/10yrs for 1949-2012) Year (-7.2 mm/10yrs and -0.38 %/10yrs for 1949-2006) Year (-33.7 mm/10yrs and -1.72 %/10yrs for 1960-2012) Lukovo station: Decadal trends: Year (-104.2 mm/10yrs and -6.1 %/10yrs for 1960-2012) Observed precipitation trends for PS Niksic and PS Lukovo differ a lot. It seems that a slightly decreasing P trend is observed at annual level, but reliability of this claim is not high. Regarding seasonal P trends, even results indicate possibility that decreasing trend have been observed in winter, spring and particularly summer, while slightly increasing trend could be present for autumn, uncertainty is very high.
Test area Drini Basin, ALBANIA	1961-1990	Station Shkodra A is representing the highest temperature compare with other stations. While lowest temperature is noticed at Shishtave. Variability of temperature through all the stations is almost the same.	Meteorological stations considered for this purpose are as following: Theth, Shkoder A, Shupenze, Shishtavec, Peshkopi. In both scenarios (i.e. monthly and yearly average rainfall variability), among 5 stations 2 of them, respectively Theth and Shkoder A are characterized from rainfall intensity, in mean time from high variability through the months and years. This high variability for 2 stations mostly is due to geomorphology and positioning of these stations. While 3 other stations almost have the same variability through the months and years also with each other.
Test area Corfu island, GREECE	1955-1997; 1975-2004; 2013; 2014; 1956-2010;	In the island of Corfu there is an active meteorological station in Gouvia. Years 2013 and 2014: the temperature in Corfu varies greatly. The temperature trend is positive. It is worth noting that when the 4 different temperature datasets are compared (1955-1997; 1975-2004; 2013; 2014), the temperature values are increased in January, February, March, November and December in more recent years. During spring and summer the mean temperature remains more or less the same. It seems that climate change makes autumn and winter less cold. Data from 1956-2010 show that the mean temperature tends to increase with a trend of +0.089.	In the island of Corfu there is an active meteorological station in Gouvia. Period 1955-1997: it is generally concluded from the Strategic Environmental Impacts Assessment of Epirus that the precipitation varies from one year to the other. The results from the comparison of the mean precipitation values for the 4 time periods (1955-1997; 1975-2004; 2013; 2014) show that in general there is a reduction in precipitation values but there are big variations. Data from 1956-2010 show that the precipitation tends to decrease with a trend of -3.628 (mm).

Table 3.8-2. Climate and climate change simulations for future scenarios in Adriatic region (test area level)

	Station	Model	SRES scenario	Reference period	Time period	Temperature	Precipitation
Test area Isonzo Plain (Friuli Venezia Giulia Region, ITALY)	station Gorizia CBPI	The regional climate models (RCMs) used are the Aladin, Promes and RegCM3 models. The initial and boundary data for each RCM were provided from different global climate models (GCMs): the ECHAM5 GCM data were used to force RegCM3, Aladin was forced by the Arpege GCM and Promes was forced by the HadCM3Q GCM. RCM corr is further adjusted model time series due to the differences between the CCmodels data and local observations.		1961-1990	2001-2100	Annual mean temperature (corrected models): all models are showing an increase of about 0.34°C/10y (ARPEGE), 0.38°C/10y (ECHAM5) and 0.17°C/10y (PROMES). (models: CNRM-RM5.1 (or ALADIN) forced by ARPEGE, ICTP-REGCM forced by ECHAM5 and UCLM-PROMES forced by HadCM3Q0)	Annual precipitation amount corrected (RCMs corr): the trend for the ARPEGE values is of -28 mm/10y, for PROMES is of -12 mm/10y, and for ECHAM5 is of -26 mm/10y. All models are indicating a decreasing trend.
	station Torviscosa				2001-2100	RCMs corr: the temperature value is slighting increasing with a trend for the ARPEGE model of 0.3°C/10y, for PROMES of 0.5°C/10y, for ECHAM5 with values of 0.4°C/10y.	Annual precipitation amount corrected (RCMs corr): the trend for the ARPEGE values is of -22 mm/10y, for PROMES is of -30 mm/10y and for ECHAM5 is of -11 mm/10y. All models are indicating a decreasing trend.
	station Alberoni				2001-2100	RCMs corr: the temperature value is slighting increasing with a trend for the ARPEGE model of 0.3°C/10y, for PROMES of 0.5°C/10y, for ECHAM5 with values of 0.4°C/10y.	Annual precipitation amount corrected (RCMs corr): the trend for the ARPEGE values is of -19 mm/10y, for PROMES is of -13 mm/10y, and for ECHAM5 is of -6 mm/10y. All models are indicating a decreasing trend.
Test area ATO 3 (Marche Region, ITALY)	station Lornano	Three regional climate models that were also analysed for the purpose of the CC-WaterS project (Aladin, Promes and RegCM3). The initial and boundary data for each RCM were provided from different global climate models (GCMs): the ECHAM5 GCM data were used to force RegCM3, Aladin was forced by the Arpege GCM and Promes was forced by the HadCM3Q GCM. The following two abbreviations are used: 1. RCMcorr: the RCMs' output was bias corrected by EOBS data. 2. RCMcorr_adj: this is further adjusted model time series due to the differences between EOBS data and local stations observations.	The RCMs were forced by the observed concentrations of the greenhouse gases (GHGs) from 1951 to 2000; from 2001 onwards the IPCC A1B scenario of the GHGs emissions is applied.	1961-1990	1951-2050	*RCMcorr:* For the period 1951-2050, all three bias corrected models simulate statistically significant increasing trends in the mean annual temperature from 0.16 °C/10yr in RegCM3 to 0.30 °C/10yr in Promes. In the period 1961-2007, when the local observations were available, all three models agree with the observations in the simulated sign of trend, with a magnitude of trend similar to that of the local observations (0.3 °C/10yr).	*RCMcorr:* Two of the three bias-corrected models (RegCM3, Aladin) simulate decreasing trend in the annual precipitation amount for the period 1951-2050, while the third one (Promes) simulates opposite sign of the trend. However, in all the models, these trends are not statistically significant. For the period 1951-2008, when local observations at the Lornano station show decreasing trend in annual precipitation amount (-36.3mm/10yr), RegCM3 and Aladin simulate the same sign of the trend as observed, but with greatly reduced amplitude and no statistical significance. This implies that, according to the CC-WaterS bias corrected RCMcorr simulations presented here, no robust estimates of significant precipitation change could be made for the first part of the 21st century.
	station Montemonaco				1951-2050	*RCMcorr:* For the period 1951-2050, all three bias corrected models simulate statistically significant increasing trends in the mean annual temperature from 0.17 °C/10yr in RegCM3 to 0.32 °C/10yr in Promes. In the period 1961-2008, when the local observations were available, all three models agree with the observations in the simulated sign of trend, with a magnitude of trend similar to that of the local observations (0.33 °C/10yr).	*RCMcorr:* All three bias-corrected models simulate decreasing trend in the annual precipitation amount for the period 1951-2050, even if, for all the models, these trends are not statistically significant. For the period 1951-2008, when local observations at the Montemonaco station show decreasing trend in annual precipitation amount (-26.6mm/10yr), the models simulate the same sign of the trend as observed, but with greatly reduced amplitude and no statistical significance. This implies that, according to the CC-WaterS bias corrected RCMcorr simulations presented here, no robust estimates of significant precipitation change could be made for the first part of the 21st century.
Test area Ostuni (Apulia Region, ITALY)	a) data for station Ostuni is extracted (10 stations are shown in the report)	Three regional climate models that were also analysed for the purpose of the CC-WaterS project (Aladin, Promes and RegCM3). The initial and boundary data for each RCM were provided from different global climate models (GCMs): the ECHAM5 GCM data were used to force RegCM3, Aladin was forced by the Arpege GCM and Promes was forced by the HadCM3Q GCM. The following two abbreviations are used: 1. RCMcorr: the RCMs' output was bias corrected by EOBS data. 2. RCMcorr_adj: this is further adjusted model time series due to the differences between EOBS data and local observations (RCM model output downscaled to the observed time series through a q-q plot procedure).	The RCMs were forced by the observed concentrations of the greenhouse gases (GHGs) from 1951 to 2000; from 2001 onwards the IPCC A1B scenario of the GHGs emissions is applied.	1961-1990	1951-2050	*Ostuni station - RCMcorr:* Annual mean temperature decadal trend (°C/10yr) - RegCM3 (0.19), Aladin (0.28), Promes (0.29). *Ostuni station - RCMcorr_adj:* Annual mean temperature decadal trend (°C/10yr) - RegCM3 (0.16), Aladin (0.24), Promes (0.24).	*Ostuni station - RCMcorr:* Annual precipitation amount decadal trend (mm/10yr) - RegCM3 (2.8), Aladin (0.69), Promes (-2.63). *Ostuni station - RCMcorr_adj:* Annual precipitation amount decadal trend (mm/10yr) - RegCM3 (-0.3), Aladin (-4.84), Promes (-5.57).
	b) comparison among all 10 stations				1955-2050	Concerning the temperature, the climatic signal over the area is uniform. There is increasing temperature forecast by all the RCMs. Aladin and Promes forecast a higher increase in temperature with respect to RegCM3. Aladin and Promes are therefore more suitable to use for impact scenarios of climate change.	Concerning the precipitation, the climatic signal over the area is strongly not uniform. The signs of such trends are not equal for all the stations (in some nodes an increase of precipitation, in some nodes a decrease). Applying a q-q plot correction (*corr_adj*) the trends significantly change both in sign and modulus. Precipitation scenarios from Promes indicate a uniform in space decrease of precipitation, both for *corr* and *corr_adj* time series; such a decrease is in the order of 2.5 mm/10yrs for *corr*, and in the order of 8 mm/10yrs for *corr_adj*. Also Aladin forecasts a tendency to reduction of precipitation, although less significant than Promes and not uniform in space. The worst scenarios, in terms of possible water shortage and salt intrusion, are obtained from Promes.

Test areas in SLOVENIA (Kobariški stol, Mia, Matajur and Mirna River catchments)	station Bilje	Regional climate models: Aladin, Promes and RegCM3. The analyses were performed with RCM corrected and RCM corrected & adjusted data.		1961-1990	1951-2050	*RCM bias corrected models (RCMcorr):* Decadal temperature trend - Aladin (0.25), RegCM3 (0.17), Promes (0.32). Trends for all three models have statistically significant regression at 5% significance level. *RCM bias corrected and adjusted models (RCMcorr_adj):* Decadal temperature trend - Aladin (0.25), RegCM3 (0.17), Promes (0.32). Trends for all three models have statistically significant regression at 5% significance level. The increase of temperatures in future is proven also by Kolmogorov-Smirnov test.	*RCM bias corrected models (RCMcorr):* Decadal precipitation amount trend - Aladin (1.17), RegCM3 (0.04), Promes (1.38). Aladin and RegCM3 models have statistically non-significant trend at 5% significance level, and for Promes the trend is statistically significant. *RCM bias corrected and adjusted model (RCMcorr_adj):* Decadal precipitation amount trend - Aladin (1.17), RegCM3 (0.05), Promes (1.38). Aladin and RegCM3 have statistically non-significant trend at 5% significance level, and for Promes the trend is statistically significant.
	station Portorož				1951-2050	*RCM bias corrected models (RCMcorr):* Decadal temperature trend - Aladin (0.25), RegCM3 (0.17), Promes (0.30). Trends for all three models have statistically significant regression at 5% significance level. *RCM bias corrected and adjusted models (RCMcorr_adj):* Decadal temperature trend - Aladin (0.25), RegCM3 (0.17), Promes (0.30). Trends for all three models have statistically significant regression at 5% significance level. The increase of temperatures in future is proven also by Kolmogorov-Smirnov test for Aladin and Promes models.	*RCM bias corrected models (RCMcorr):* Decadal precipitation amount trend - Aladin (0.85), RegCM3 (0.56), Promes (1.13). All three trends have statistically non-significant regression at 5% significance level. *RCM bias corrected and adjusted models (RCMcorr_adj):* Decadal precipitation amount trend - Aladin (0.85), RegCM3 (0.56), Promes (1.13). All three trends have statistically non-significant regression at 5% significance level.
Test areas in CROATIA (1. Northern Istria - river Mirna catchment; 2. Prud catchment and Blatsko polje on Korčula)	station Pazin (Test area 1: Northern Istria - river Mirna catchment)	Three regional climate models that were also analysed for the purpose of the CC-WaterS project (Aladin, Promes and RegCM3). The initial and boundary data for each RCM were provided from different global climate models (GCMs): the ECHAM5 GCM data were used to force RegCM3, Aladin was forced by the Arpege GCM and Promes was forced by the HadCM3Q GCM. The following two abbreviations are used: 1. RCMcorr: the RCMs' output was bias corrected by EOBS data. 2. RCMcorr_adj: this is further adjusted model time series due to the differences between EOBS data and local DHMZ observations.	The RCMs were forced by the observed concentrations of the greenhouse gases (GHGs) from 1951 to 2000; from 2001 onwards the IPCC A1B scenario of the GHGs emissions is applied.	1961-1990	1951-2050 P1 (2021-2050) vs. P0 (1961-1990) change	*RCMcorr*: For the period 1951-2050, all three bias corrected models simulate statistically significant increasing trends in the mean annual temperature from 0.17 °C/10yr in RegCM to 0.31 °C/10yr in Promes. For the analysed period (1951-2050), linear trends of the simulated mean seasonal temperature are generally highest in the summer and in the Promes model. Similar results are obtained for the RCMcorr_adj data. All three RCMs simulate an increase in mean monthly air temperature from the reference period 1961-1990 (P0) to the future period 2021-2050 (P1). The projected warming is in most cases statistically significant and ranges between 0.5 °C in RegCM3 for December and 3 °C in Promes for July. The Promes model tends to simulate a larger temperature increases for most months than the other two models.	*RCMcorr*: All three models simulate increasing trend in the annual precipitation amount for the period 1951-2050. However, these trends are not statistically significant. Even for seasonal precipitation, trends are rarely statistically significant and are model dependent in terms of both the amplitude and sign. This implies that, according to the CC-WaterS bias corrected RCMcorr simulations presented here, no robust estimates of significant precipitation change could be made for the first part of the 21st century. The projected changes between P0 and P1 are statistically significant only in two cases. It appears that the prevalent sign of changes indicates an increase in precipitation; however, they vary in amplitude generally between -20% and 20%.
	station Opuzen (Test area 2: Prud catchment and Blatsko polje on Korčula)				1951-2050 P1 (2021-2050) vs. P0 (1961-1990) change	*RCMcorr:* All three bias corrected models simulate statistically significant increasing trends in the mean annual temperature for the period 1951-2050 amounting to 0.19 °C/10yrs in RegCM, 0.27 °C/10yrs in Aladin and 0.31 °C/10yr in Promes. Trends of the mean seasonal temperature are highest for the summer season and when using the Promes model. An increase in the mean air temperature in P1 relative to P0, is simulated by all three RCMs. The projected warming in the P1 period ranges between 0.5 °C and nearly 3.5 °C and in most cases is statistically significant. The Promes model tends to simulate a larger temperature increase than the other two models.	*RCMcorr:* For annual precipitation in the period 1951-2050, RegCM3 and Aladin simulate an increasing trend while Promes simulates a decreasing trend; however, these trends are not statistically significant. Again, the climate change signal of the CC-WaterS simulations is weak for the first part of the 21st century and no significant trends in seasonal precipitation are found. The amplitude of projected precipitation change varies greatly throughout the year from one model to the other (between -60% and +60% in P1 relative to P0), but even so it is almost insignificant.

Test area in Nikšić (Zeta River catchment), MONTENEGRO	station Nikšić	Regional climate models from the CC-WaterS project (based on the ENSEMBLES project). The regional climate models are Aladin, Promes and RegCM3.		1961-1990	1951-2050	*RCM corrected models:* Mean annual temperature trend equation: Aladin (y= 0.0312x - 50.939), Promes (y= 0.0323x - 52.976), RegCM3 (y= 0.0201x - 28.912). One T and two P stations are too low number to make some more precise conclusion. The results of these T and P stations just indicate possible climate change of this part of Montenegro. The reliability of T trends could be assessed as relativelly high.	*RCM corrected models:* Sum annual precipitation trend equation: Aladin (y= -0.2899x + 2558.6), Promes (y= -1.7665x + 5499.1), RegCM3 (y= -0.4401x + 2882.6).
	station Lukovo				1951-2050	/	*RCM corrected models:* Sum annual precipitation trend equation: Aladin (y= -0.1897x + 2225.2), Promes (y= -1.6554x + 5143.6), RegCM3 (y= -0.4914x + 2844). One T and two P stations are too low number to make some more precise conclusion. The results of these T and P stations just indicate possible climate change of this part of Montenegro. The reliability of T trends could be assessed as relativelly high, while for P is much lower. Future prediction is much more uncertain, especially for precipitation.
Test area Drini Basin, ALBANIA	5 stations: Theth, Shkoder A, Shishtavec, Peshkopi, Shupenze	A1BAIM scenario (Average values) A2ASF scenario (Min values) A1FIMI scenario (High values)		1990	Years: 2030, 2050, 2080, 2100	The likely changes in annual temperature for different scenarios and time horizons reveal a likely increase in seasonal and annual temperatures related to 1990 for all time horizons. The annual temperature is likely to increase up to 1.8°C (1.3 - 2.4°C) by 2050; 2.8°C (2.1 - 4.1°C) by 2080 and 3.2°C (2.3 - 5.0°C) by 2100. The scenarios project the lowest increase in temperature for winter compared to other seasons, with higher increases in absolute values likely for spring temperatures related to 1990 for the same scenarios - increases up to 1.6°C (1.3 - 2.2°C) by 2050; 2.5°C (1.7 - 3.6°C) by 2080 and 3.0°C (1.9 - 4.4°C) by 2100. Summer projections indicate increases in annual temperature up to 2.7°C (2.4 - 3.6°C) by 2050; 4.3°C (3.1 - 6.3°C) by 2080 and 5.1°C (3.4 - 7.7°C) by 2100. Such a situation is likely to result in increases to the frequency and/or intensity of extreme weather events. The average autumn temperature is likely to increase up to 1.8°C (1.5 - 2.3°C) by 2050; 2.9°C (2.2 - 4.1°C) by 2080 and 3.5°C (2.4 - 5.0°C) by 2100. More frequent and severe droughts with a consequent greater fire risk are likely. A reduced temperature range is likely to occur over nearly all land areas. Frost days and cold waves are very likely to become fewer. Cold days are currently an infrequent phenomenon and likely to become even more infrequent. The number of days with temperatures in excess of 35°C will become more frequent and is expected to increase by about 10 days by 2100 compared to present.	The precipitation total during winter, related to 1990, is likely to decrease an average of -8.0% (-4.3 to -12.4%) by 2050; 11.9% (-5.7 to -23.7%) by 2080 and 13.7% (-4.7 to -29.4%) by 2100; during spring this is likely to decrease up to 6.9% (-5.9 to - 8.1%°C) by 2050; 12.3% (-9.0 to -17.7%°C) by 2080 and 15.0% (-10.1 to - 22.2%°C) by 2100. The highest decrease in average precipitation is likely during summer, up to -24.6% (-16.5 to -33.9%) by 2050; -45.7% (-36.0 to -58.8%) by 2080 and -54.8% (-44.2 to -71.8%°C) by 2100. Projections of annual precipitation changes (%) related to 1990: -8.1% (-5.5 to -11%) by 2050, -12.9% (-8.4 to -21%) by 2080, -15.5% (-9 to -26.1%) by 2100. The high decrease in precipitation, combined with the high increase in temperature, might lead to prolonged summer droughts over the area. The increased temperatures expected in summer could lead to higher local precipitation extremes and associated flood risks in project area. The number of rainy days with hazardous rainfalls is expected to increase by approximately 4-5 days by 2100. An increase of SPI3, (cases of moderate, severe and extremely dry weather) to approximately 18 cases by 2030, and 20, 22 and 24 cases by 2050, 2080 and 2100 respectively is expected.
Test area Corfu island, GREECE	station in Gouvia	Four models are used to simulate climate conditions: Ensemble (scenario A1B); Prudence (scenario A2); Prudence (scenario B2); and REGCM (scenario A1B). The work has been elaborated by the project Geoklima.	Ensemble (scenario A1B); Prudence (scenario A2); Prudence (scenario B2); REGCM (scenario A1B).	1961-1990	2021-2050	The simulation models results for the Corfu test area are presented for the period 1961-1990 and 2021-2050. The results show that temperature is expected to increase (minimum, maximum and average values) during all the seasons and annually. The model showing the highest temperature increase is Prudence scenario A2, followed by Prudence scenario B2, while Ensemble and REGCM models provide comparative values. The average annual mean temperature is expected to increase from 1.23oC to 4.27oC depending on the model.	The simulation models results for the Corfu test area are presented for the period 1961-1990 and 2021-2050. The total precipitation is expected to decrease especially in the summer months. In the winter months two out of four models predict a slight increase in total precipitation values. Total annual precipitation values are expected to decrease from 3.93% to 25.4% depending on the model.

4. SUMMARY

In this joint report, the most important parts extracted from the reports collected from PPs are shown, on national, regional and test area level.

Two parameters were considered in the reports - temperature and precipitation, and their observed and simulated changes (trends). Climate and climate change simulations for future are obtained by using different models, with chosen SRES scenarios. The purpose of those reports is to provide an input for further analyses in 4.2. and 4.3. activities.

Conclusions were made based on the collected data. Increase of temperature is predicted in all countries (and all test areas) which participate in DRINKADRIA project. Regarding the precipitation, changes vary in the sign depending on the season, part of the country, analyzed period and the months of the year. It is stressed that those predictions are less reliable. For test areas, precipitation trends vary depending on the selected station, model and time series (RCMcorr or RCMcorr_adj).

Annex 1:

1.1. Report: Climate and climate change data for Italy
1.2. Report: Climate and climate change data for Friuli Venezia Giulia Region (Italy)
1.3. Report: Climate and climate change data for Marche Region (Italy)
1.4. Report: Climate and climate change data for Apulia Region (Italy)
1.5. Report: Climate and climate change data for Slovenia
1.6. Report: Climate and climate change data for Croatia
1.7. Report: Climate and climate change data for Bosnia and Herzegovina
1.8. Report: Climate and climate change data for Montenegro
1.9. Report: Climate and climate change data for Serbia
1.10. Report: Climate and climate change data for Albania
1.11. Report: Climate and climate change data for Greece

Annex 2:

2.1. Report: Climate and climate change data for test area Isonzo Plain (Italy, Friuli Venezia Giulia Region)
2.2. Report: Climate and climate change data for ATO 3 test area (Marche Region, Italy)
2.3. Report: Climate and climate change data for the Ostuni test area (Italy, Apulia Region)
2.4. Report: Analysis of observed and simulated climate and climate change for Slovenian test areas (Kobariški stol, Mia, Matajur and Mirna River catchments)
2.5. Report: Climate and climate change data for test areas in Croatia (with data from Bosnia and Herzegovina)
2.6. Report: Climate and climate change data for test areas in Nikšić, Montenegro
2.7. Report: Climate change for Drini Basin (test area in Albania)
2.8. Report: Climate and climate change data for test area in Greece

Climate and climate change database for Adriatic area – Rijeka 2015

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Adriatic IPA
Cross Border Cooperation 2007-2013

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