Report on climate change projections and changes in climate extremes for the Republic of North MACEDONIA

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Vladimir Djurdjevic
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Contents

SUMMARY

<u>Highlight message</u>

According to these simulations, Macedonia will face hotter and drier climate in the future. Amplitude of this change primarily will be related to the future concentration of GHG. Associated with hotter climate in future, increase in hot extremes and decrease in cold extremes are expected. Even that drier condition is expected on average on annual level, analysis reveals potential increase in daily extreme precipitation that will introduce higher risk of flash floods. On the other hand, expected decrease in summer precipitation and extension in duration of consecutive dry days, will increase risk of drought. Finally due to warmer climate, in general, expected growing season length will increase on average.

For three different GHG emissions scenarios, RCP2.6 (*low*), RCP4.5 (*mid*) and RCP8.5 (*high*) future climate projections of essential climate variables, temperature and precipitation and climate indices derived from these variables are presented for territory of Macedonia. Analysis covers period from 2006 to 2100, and all changes were presented with respect to the reference period 1986-2005. The results were obtained from EURO-CORDEX database, from which results of three regional climate models were analyzed for *low* and seven models for *mid* and *high* scenarios.

TEMPERATURE AND PRECIPITATION

TEMPERATURE

According to the results, it is expected that temperature increase will continue in the future. The amplitude of the increase, at the end of this century, primarily depend on the future GHG emissions, clearly indicating that future climate condition in the country will be partially determent by the success of international implementation of different polices related to the GHG emissions reduction. In case of *low* scenario the annual mean temperature increase by the end of the century will be 1,5 °C, and in case of *mid* and high scenarios increase will be 2,5 °C and 5 °C respectively. In some part of the country temperature increase is even above 5 °C in case of *high* scenario. For the middle of the century the differences between temperature increase for different scenarios are much smaller, which is not surprising, since that GHG concentrations during this period are much closer to each other. The expected temperature increase for the middle of the century are 1 °C, 2 °C and 2.5 °C for *low*, *mid* and *high* scenario respectively. For the near future (period 2016-2035) for all three scenarios expected increase of temperature is about 1 °C. Analyzing temperature changes for different seasons, in case for *mid* and *high* scenario, the season with highest temperature increase is summer (Jun-July-August), and by the end of the century temperature increase (for *high* scenario) is above 5.5 °C in some parts of the country. In case of *low* scenario there is no substantial differences between different seasons. Similar patterns of changes were found in future daily minimum and maximum temperatures. To some extent higher increase in daily maximum temperature were found in comparison to daily mean and minimum temperature. For summer season, increase in daily maximum temperature for the end of the century is above 5 °C for the whole country, which can be considered most significant change found in temperature analyses presented in this report.

PRECIPITATION

Analysis of precipitation shows more complex patterns of change in comparison to temperature. In case of *low* scenario, there is no clear signal of precipitation change in the future, except precipitation increase during the September-October-November season. For other two scenarios, annual precipitation decrease is expected, manly driven by significant decrease in summer precipitation. For *mid* scenario annual precipitation decrease is up to -20% with decrease for summer precipitation of -30%, and for *high* scenario decrease in annual precipitation is up to -30%, and -40% for summer precipitation, by the end of the century. Also spring season (March-April-May) also shows consistent pattern of precipitation decrease over the century, but with smaller amplitude. For the middle of the century *mid* and *high* scenarios also snows decrease in summer precipitation, up to -30% in both.

According to the results Macedonia will face hotter and dryer climate in the future, and amplitude of the change will be primarily related to the future concentration of GHG.

EXTREMES

Thru the analysis of different climate indices, future change in meteorological and climatological extremes were accessed. In the future the decrease in cold and increase in hot extremes is expected. Similarly to the temperature analysis differences between scenarios are pronounced for the end of the century (period 2081-2100), and for the near future (period 2016-2035) there is almost no difference between them. For the middle of the century (period 2036-2065) changes of *mid* and *high* scenarios are much more similar in comparison to *low* scenario.

COLD EXTREMES

For the near future expected decrease in frost days is between -20 and -30 days per annum regardless scenario. By the end of the century decrease in the *low* scenario will remain the same, and for *high* scenario decrease is between -50 and -60 days. For the middle of the century change is between these upper and lower bounds of *low* and *high* scenarios. The change in ice days is very similar to the change of frost days, except that amplitude of change is smaller, for near future change is from -2 to -5 days, and for the end of the century it is up to -20 days for *high* scenario. Cold waves will be shorter in the future, and for the *high* scenario disappearance of cold waves is possible.

HOT EXTREMES

Hot extremes are expected to increase in the future. The simulated increase in summer days for the near future between 20 and 30 days. For the end of the century for *low* scenario change will remain the same but for *high* scenario increase will be between 50 and 60 days per annum, over the majority of the country. Increase in tropical night are mainly projected to the low altitude areas. For the near future increase are between 5 to 20 days. For the end of the century significant increase is expected in the case of *high* scenarios, and in low altitude areas increase of more than 60 days can be expected. Finally, increase in duration and frequency of heat waves over the whole territory can be expected. For the near future the increase in frequency has values from 1 to 3 more events in 20-year period for all scenarios. By the end of the century, in case of *high* scenario this change can increase up to 40 more events in 20-year period in western and eastern part of the country. The duration of heat waves for is projected to increase up to 25 more days by end of the century, in case of *high* scenario.

PRECIPITATION EXTREMES

Because of high spatial and temporal variability of extreme precipitation, there is no uniform signal between scenarios in their expected changes in the future. On the other hand both analyzed indices, daily maximum precipitation and number of days with precipitation above 40 mm/day, shows in general positive change in the future, for all analyzed periods and scenarios. Upper limits of change is 60% increase in number of days with precipitation above 40 mm/day, and 20% increase in daily maximum precipitation accumulation. The physical background of this change is fact that warmer atmosphere that can holds more water vapor (7% more water vapor in 1 °C warmer air) indicating higher chances for more extreme precipitation, and consequently higher chances for induced flash foods.

Analysis of consecutive dray days index reveals that in the future the risk of drought will increase. In the near future increase in the number of consecutive dry days is between 5 and 20 days, depending on location and scenario. For the end of the century in case of *high* scenario expected increase is above 30 days. This increase is consistent with the projected decrease in summer precipitation, especially in case of *mid* and *high* scenario.

GROWING SEASON LENGTH

Due to temperature increase, the extension of growing season length is expected. For the near future increase in growing season length is between 5 and 20 days. For the end of the century, in case of *high* scenario expected increase is 50 more days (almost 2 months), for the majority of the country, with means almost 2 more month of growing season.

INTRODUCTION

This report will present the results future climate change projections for Macedonia, under ECP2.6, RCP4.5 and RCP8.6 scenarios of future concentrations of greenhouse gases used in the Fifth Intergovernmental Panel on Climate Change (IPCC). The analysis will include annually and seasonally changes in essential climate variables: mean daily temperature, minimum daily temperature, maximum daily temperature and daily precipitation. Four seasons will be defined as, December-January-February (DJF), March -April-May (MAM), June-July-August (JJA) and September-October-Novembers (SON). In addition to these results, changes in selected extreme climate indices are presented, as indicators of the possible changes in the intensity and frequency of extreme weather and climate events. All future changes will be presented for the period from 2016 to 2100 (within three subperiods are selected) and with respect to the reference period 1986-2005, which was used as the reference and in the last Fifth Intergovernmental Panel on Climate Change. Focus will be placed on three future twenty-year long periods: the near-future period 2016-2035, the middle of the twenty-first century 2046-2065, and the end of the twenty-first century 2081-2100, which were also selected to be compliant with the analysis in the Fifth Intergovernmental Panel on Climate Change. In this regard, the analyzes presented in this report can easily compared with the results of the references in the IPCC publications.

GHG EMISSIONS SCENARIOS

For the Fifth Report of the Intergovernmental Panel on Climate Change four so-called Representative Concentration Pathway (RCP) scenarios for future global concentrations of greenhouse gas: RCP8.5, RCP6.0, RCP4.5 and RCP2.6 were used as an input for climate model projections. These scenarios represent possible changes in the concentrations of greenhouse gases in the atmosphere in the period 2006-2100. Scenarios RCP2.6 and RCP4.5 assume that, greenhouse gases concentrations will stabilize in the future, while under RCP8.5 and RCP6.0 scenarios, their concentrations will continue to increase, or follow trends observed in the past (Figure 1). Scenario RCP2.6 further assumes that, in the second half of this century, the concentration of greenhouse gases could will decline, requiring anthropogenic emissions to be net-zero at one point.

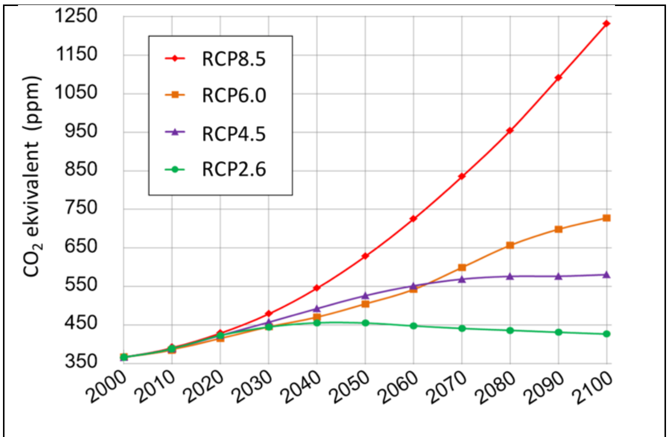


Figure 1 Future concentrations of greenhouse gases for four different scenarios.

CLIMATE MODELS AND FUTURE PROJECTIONS

For different scenarios of future concentrations of greenhouse gases, with climate models that use these concentrations as input variables, appropriate climate projections can be obtained. For this report regional climate models were used. Regional Climate Models have significantly better horizontal resolution in comparison to Global Climate Models, usually of the order of 10 km. Based on their results it is possible to estimate the regional spatial changes of the selected variables.

The results of regional climate models are taken from the EURO-CORDEX database, which is the reference database of climate projections for Europe, and which has been the basis of many climate studies in Europe in recent years. Also, this database forms the basis for the European Union's Copernicus Climate Change Service program. The horizontal resolution of the downloaded data is 11 km. Also, the so-called bias-adjusted data were taken. Bias-adjusted data are climate projections from which the systematic model errors in the model results are removed. The data from which systematic model error has been removed allow the estimation in future projections of selected climate indices to be more reliable. Seven regional climate models for RCP4.5 and RCP8.5 scenarios were taken from this database: CCLM4-8-17_v1 (r1i1p1 run identifier and CNRM-CM5 global model for boundary conditions), CCLM4-8-17_v1 (r12i1p1 run identifier and EC-EARTH global model for boundary conditions), RACMO22E_v1 (r1i1p1 run identifier and EC-EARTH global model for boundary conditions), RCA4_v1 (r1i1p1 run identifier and IPSL-CM5A global model for boundary conditions), CCLM4-8-17_v1 (r1i1p1 run identifier and MPI-ESM global model for boundary conditions), REMO2009_v1 (r1i1p1 run identifier and MPI-ESM global model for boundary conditions) and REMO2009_v1 (r2i1p1 run identifier and MPI-ESM global model for boundary conditions). For RCP2.6 there were less available models and analysis was done with three different regional climate models: RCA4_v1 (r12i1p1 run identifier and EC-EARTH global model for boundary conditions), REMO2009_v1 (r1i1p1 run identifier and MPI-ESM global model for boundary conditions) and REMO2009_v1 (r2i1p1 run identifier and MPI-ESM global model for boundary conditions). Since that number of models for RCP8.5 and RCP4.5 are different in comparison to the number of models for RCP2.6 comparison between results from them should be taken with care.

The analyzed indices are given in Table 1.

Table 1. Indices definition.

Index	**Definition**
FD	Number of frost days: Annual count of days when TN (daily minimum temperature) < 0°C.
ID	Number of icing days: Annual count of days when TX (daily maximum temperature) < 0°C.
CSDI	Cold-spell duration index: Annual count of days with at least 6 consecutive days when TG <10^{th} percentile (cold waves).
SU	Number of summer days: Annual count of days when TX (daily maximum temperature) > 25°C.
TR	Number of tropical nights: Annual count of days when TN (daily minimum temperature) > 20°C.
WSDI	Warm spell duration index: Annual count of days with at least 6 consecutive days when TX > 90^{th} percentile (extreme heat waves).
RR40	Annual count of days when daily precipitation ≥ 40mm.
RX1D	Yearly maximum 1-day precipitation.

CDD	Maximum length of dry spell, maximum number of consecutive days with daily precipitation < 1mm.
GSL	Growing season length: Annual (1st Jan to 31st Dec in Northern Hemisphere (NH), 1st July to 30th June in Southern Hemisphere (SH)) count between first span of at least 6 days with daily mean temperature TG>5°C and first span after July 1st (Jan 1st in SH) of 6 days with TG<5°C. (TG – mean daily temperature)

TEMPERATURE AND PRECIPITATION CHANGE

The annual and seasonal change in the **mean daily temperature** is given in Figures 2a, 2b and 2c[1] and for the RCP2.6, RCP4.5 and RCP8.5 scenarios, respectively. In case of RCP2.6 (Figure 2a) scenario mean daily temperature will continuously increase, from about 1 °C in the near future to about 1,5 °C by the end of the century. In terms of warming there are no substantial differences between different seasons.

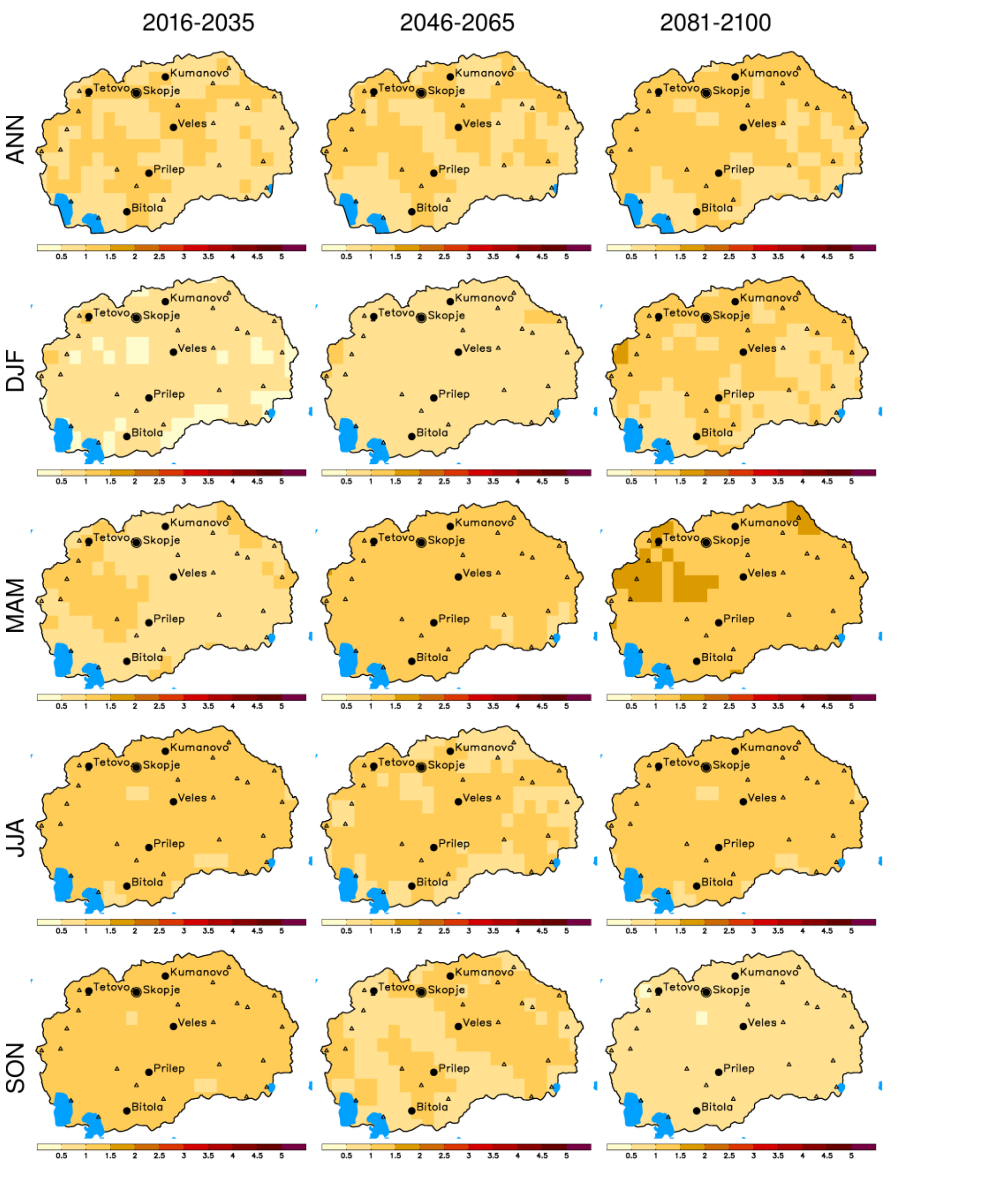


Fig. 2a Future daily mean temperature change, for three future periods, 2016-2035, 2046-2065 and 2081-2100 with respect to the period 1986-2005, on annual level and for winter (DJF), spring (MAM), summer (JJA) and autumn (SON), for the RCP2.6 scenario.

[1] On all figures, selected cities are presented with circles, and meteorological and climatological stations with small triangles.

In case of RCP4.5 (Figure 2b) scenario mean daily temperature will continuously increase, from about 1 °C in the near future to about 2,5 °C by the end of the century. In terms of warming there are no substantial differences between different seasons. The highest warming is expected for summer season for all future periods. For the middle of century, for other three seasons (winter, spring and autumn) the warming is almost of the same order, but is more pronounced for winter for the last analyzed period.

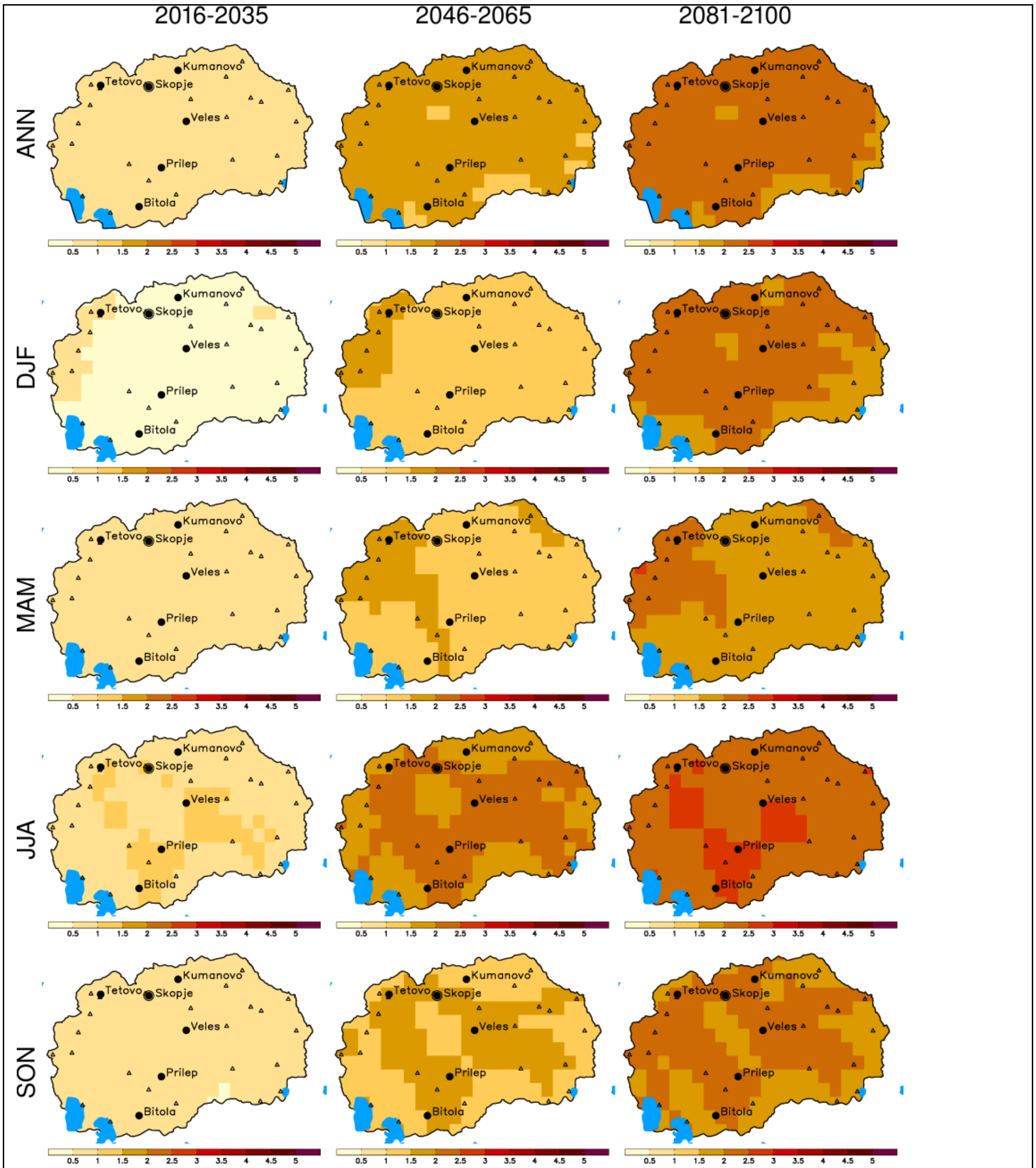


Fig. 2b Future daily mean temperature change, for three future periods, 2016-2035, 2046-2065 and 2081-2100 with respect to the period 1986-2005, on annual level and for winter (DJF), spring (MAM), summer (JJA) and autumn (SON), for the RCP4.5 scenario.

Mean daily temperature will continuously increase, form about 1 °C in the near future to more the 5 °C by the end of the century, in case of RCP8.5 (Figure 2c). The highest warming is expected for summer season for all future periods. For the middle of century, for other three seasons (winter, spring and autumn) the warming is almost of the same order, but for the end of the century, higher warming is expected for winter in comparison to spring and autumn.

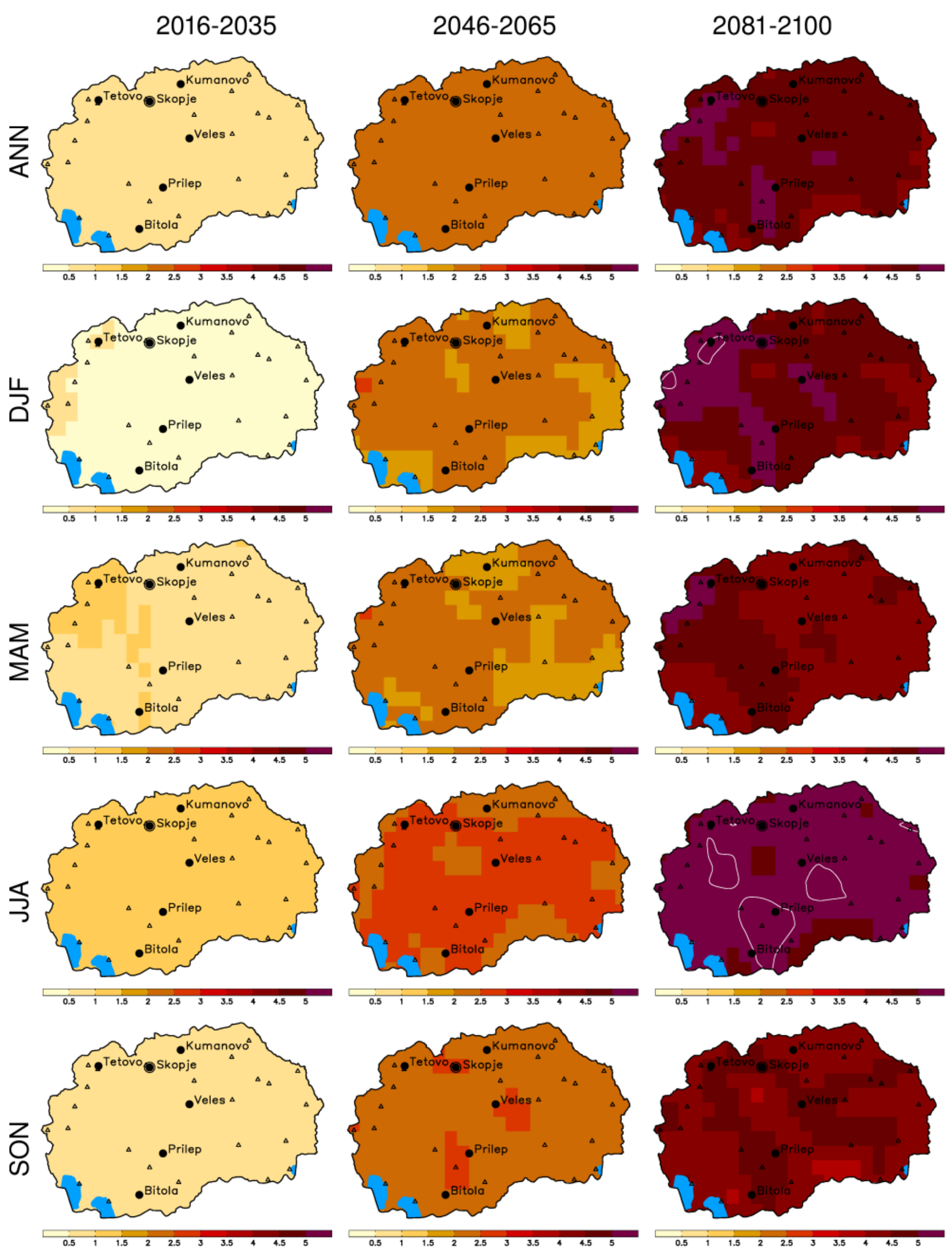


Fig. 2c Future daily mean temperature change, for three future periods, 2016-2035, 2046-2065 and 2081-2100 with respect to the period 1986-2005, on annual level and for winter (DJF), spring (MAM), summer (JJA) and autumn (SON), for the RCP8.5 scenario. White line represent 5,5 °C isoline.

Annual and seasonal **minimum daily temperature change** is given in Figures 3a, 3b and 3c, and for the RCP2.6, RCP4.5 and RCP8.5 scenarios, respectively, for different periods during the 21st century. For scenario RCP2.6 (Figure 3a) similar to daily mean, minimum daily temperature will continuously increase, from about 1 °C in the near future to more the 1,5 °C by the end of the century. Differently, spring is the seasons with the highest increase for the period at the end of the century, and changes for other three seasons, are similar to the change of mean daily temperature.

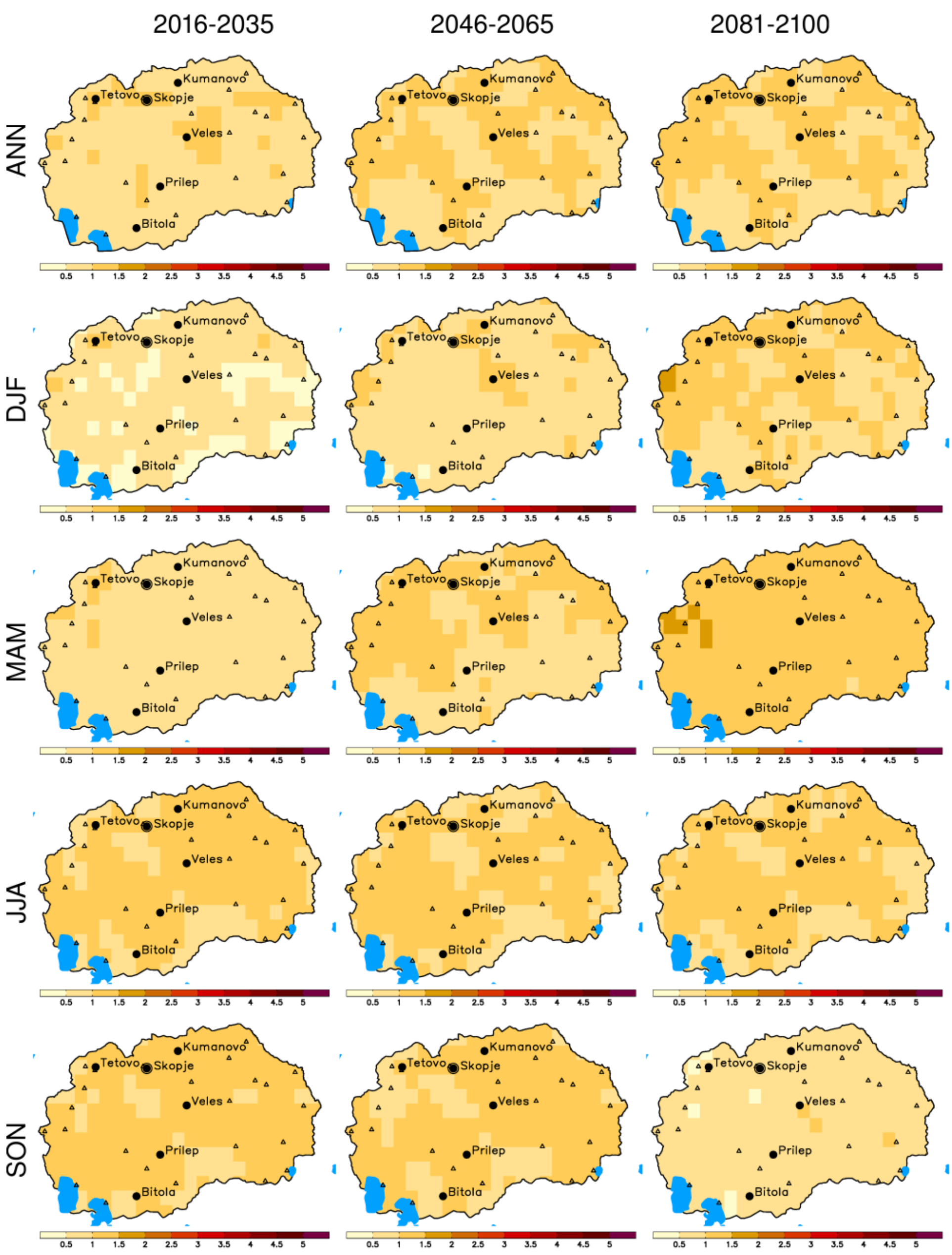


Fig. 3a Future minimum daily temperature change, for three future periods, 2016-2035, 2046-2065 and 2081-2100 with respect to the period 1986-2005, on annual level and for winter (DJF), spring (MAM), summer (JJA) and autumn (SON), for the RCP2.6 scenario.

For scenario RCP4.5 (Figur**e 3b) minimum daily temperature will co**ntinuously increase, form about 1 °C in the near future to more the 2,5 °C by the end of the century. Summer is the seasons with the highest increase for the period at the end of the century, with some areas in which increase is above 2.5 °C, and changes for other three seasons, are similar to the change of mean daily temperature for same scenario.

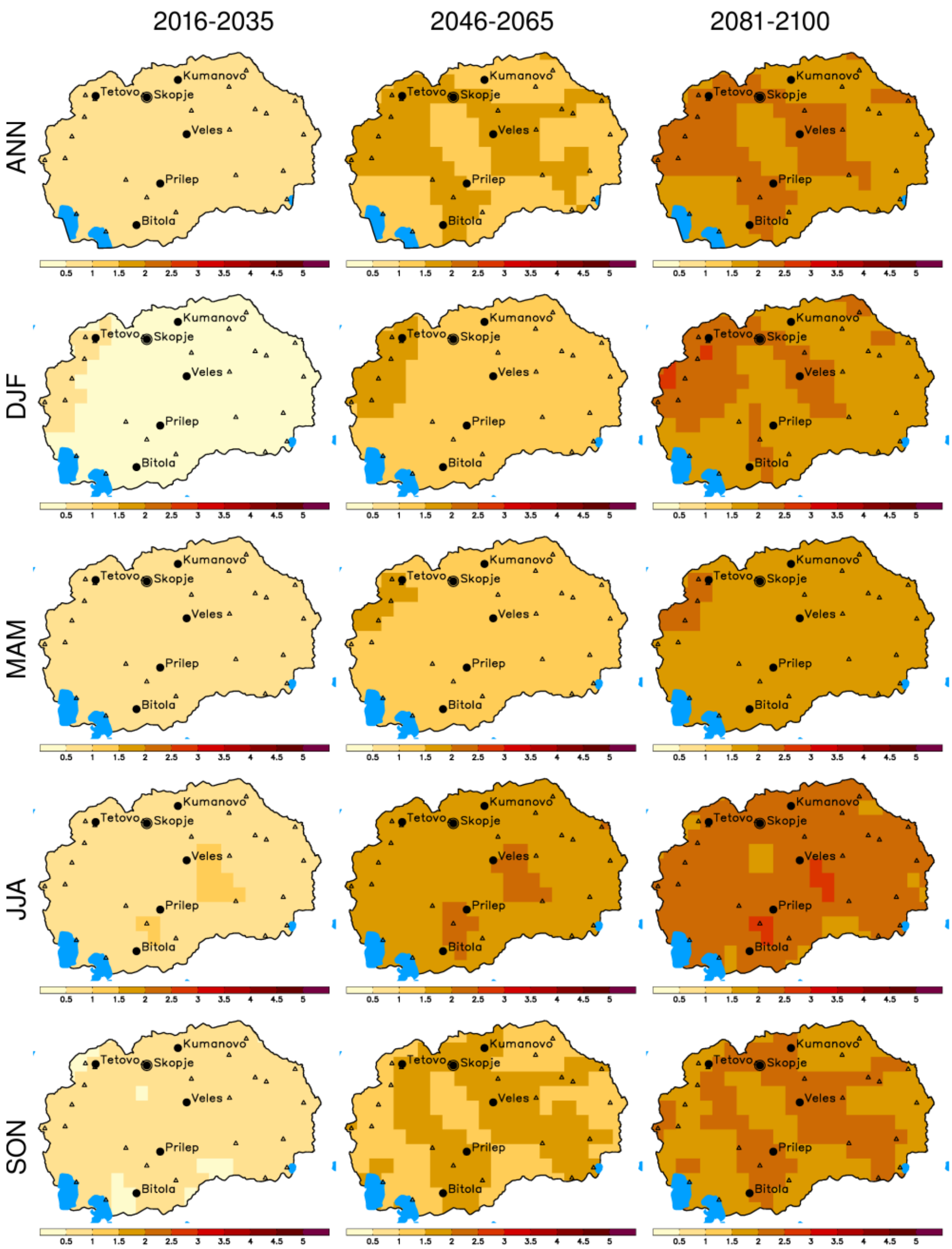


Fig. 3b Future minimum daily temperature change, for three future periods, 2016-2035, 2046-2065 and 2081-2100 with respect to the period 1986-2005, on annual level and for winter (DJF), spring (MAM), summer (JJA) and autumn (SON), for the RCP4.5 scenario.

For scenario RCP8.5 (Figure 3c), minimum daily temperature will continuously increase, from about 1 °C in the near future to more the 5 °C by the end of the century. Again, summer is the seasons with the highest increase, and changes for other three seasons, are similar to the change of mean daily temperature.

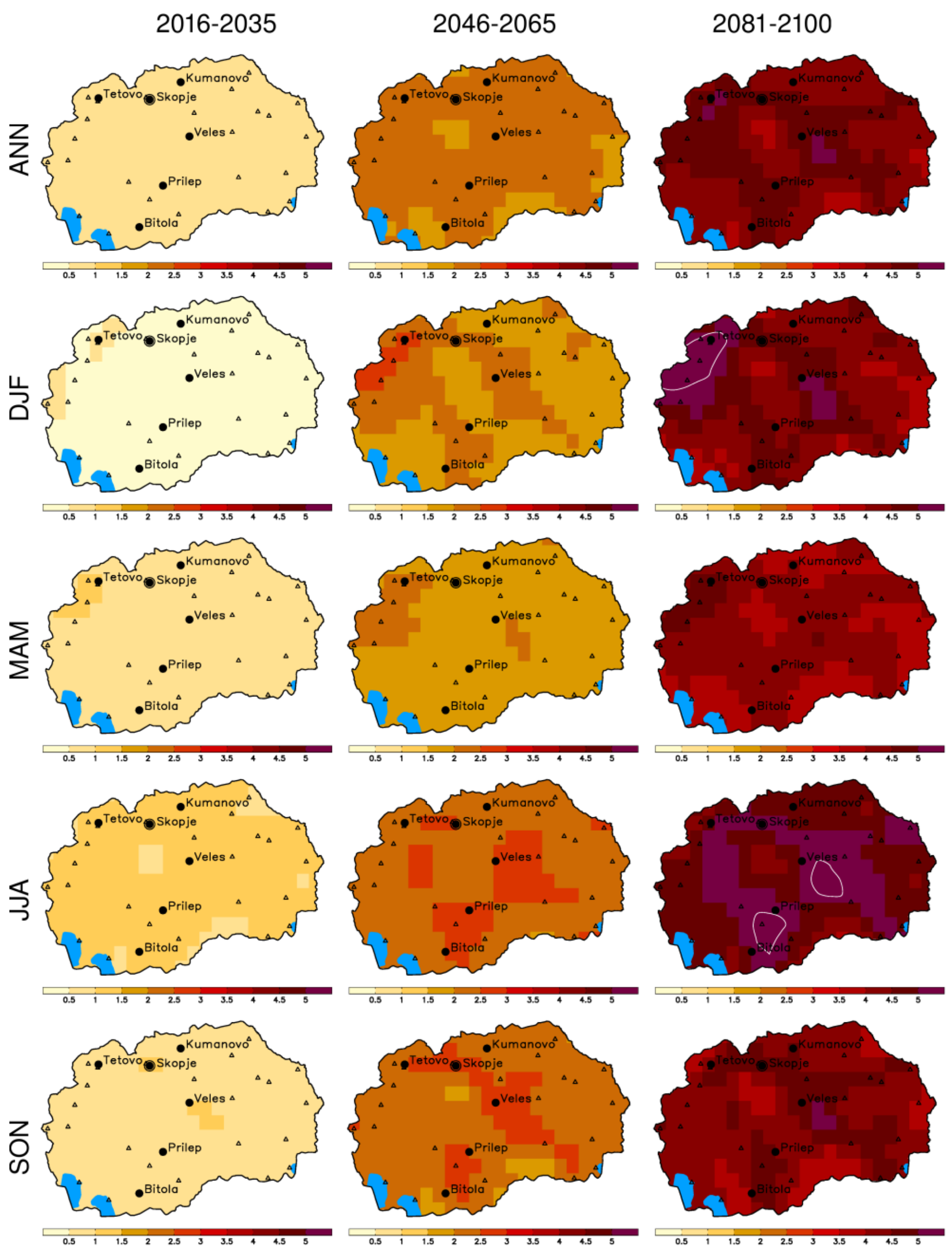


Fig. 3c Future minimum daily temperature change, for three future periods, 2016-2035, 2046-2065 and 2081-2100 with respect to the period 1986-2005, on annual level and for winter (DJF), spring (MAM), summer (JJA) and autumn (SON), for the RCP8.5 scenario. White line represents 5,5 °C isoline.

For the three future periods, annual and seasonal **maximum daily temperature** change is given in Figures 4a, 4b and 4c, and for the RCP2.6, RCP4.5 and RCP8.5 scenarios, respectively, for the 21st century. Changes are similar to the change of mean daily and minimum daily temperature and it is form about 1 °C for the beginning of the century to 1,5 °C for the end of century for RCP2.6 (Figure 4a) and form 1 °C to 5 °C by for the RCP8.5 scenario (Figure 4c). On the other hand, the amplitude of change is to certain extent higher in comparison to annual and seasonal average of the mean and minimum temperature. Comparing all three temperatures it is expected that change will be highest for maximum, then for mean daily, and finally from minimum daily temperature.

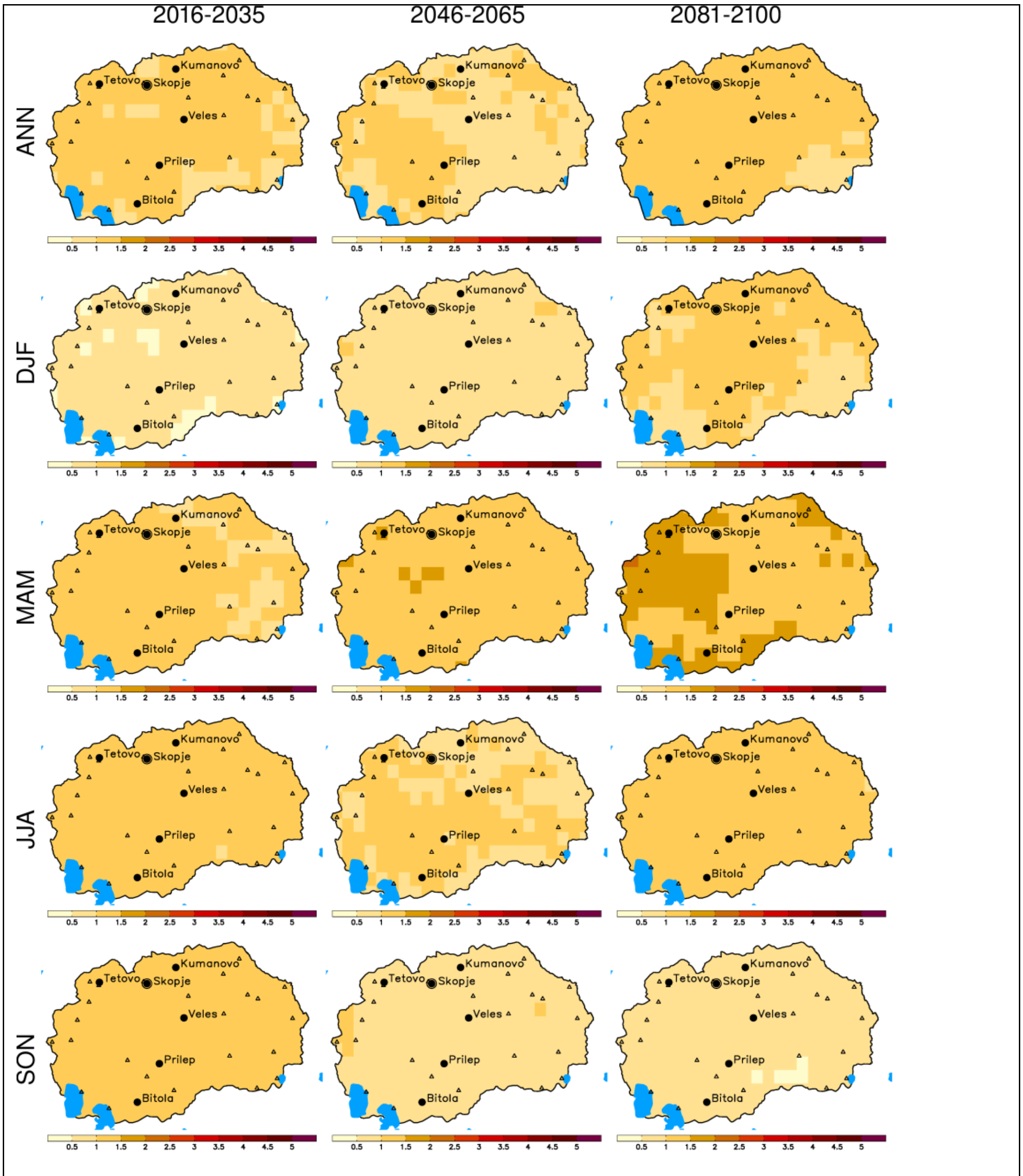


Fig. 4a Future maximum daily temperature change, for three future periods, 2016-2035, 2046-2065 and 2081-2100 with respect to the period 1986-2005, on annual level and for winter (DJF), spring (MAM), summer (JJA) and autumn (SON), for the RCP2.6 scenario.

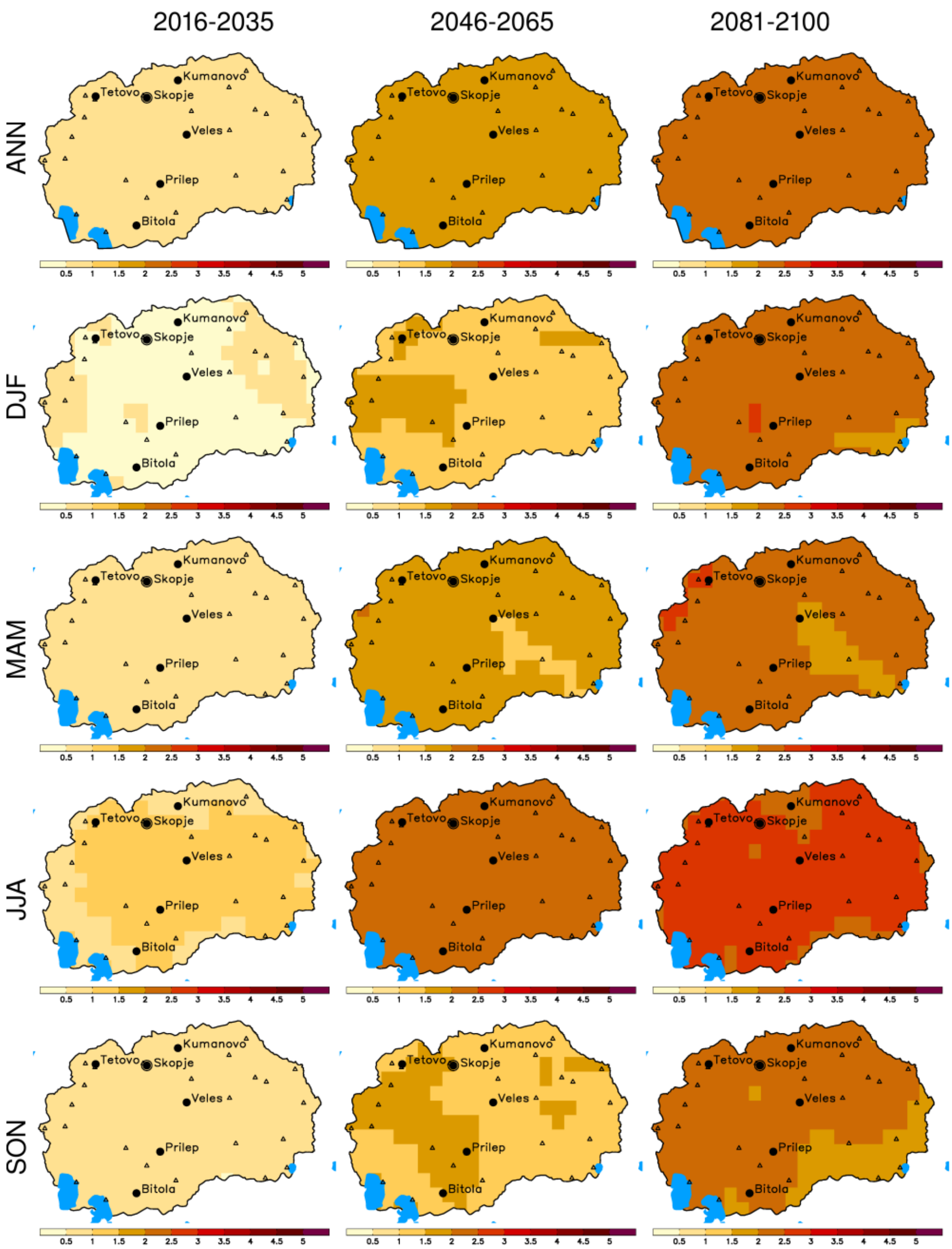


Fig. 4b Future maximum daily temperature change, for three future periods, 2016-2035, 2046-2065 and 2081-2100 with respect to the period 1986-2005, on annual level and for winter (DJF), spring (MAM), summer (JJA) and autumn (SON), for the RCP4.5 scenario.

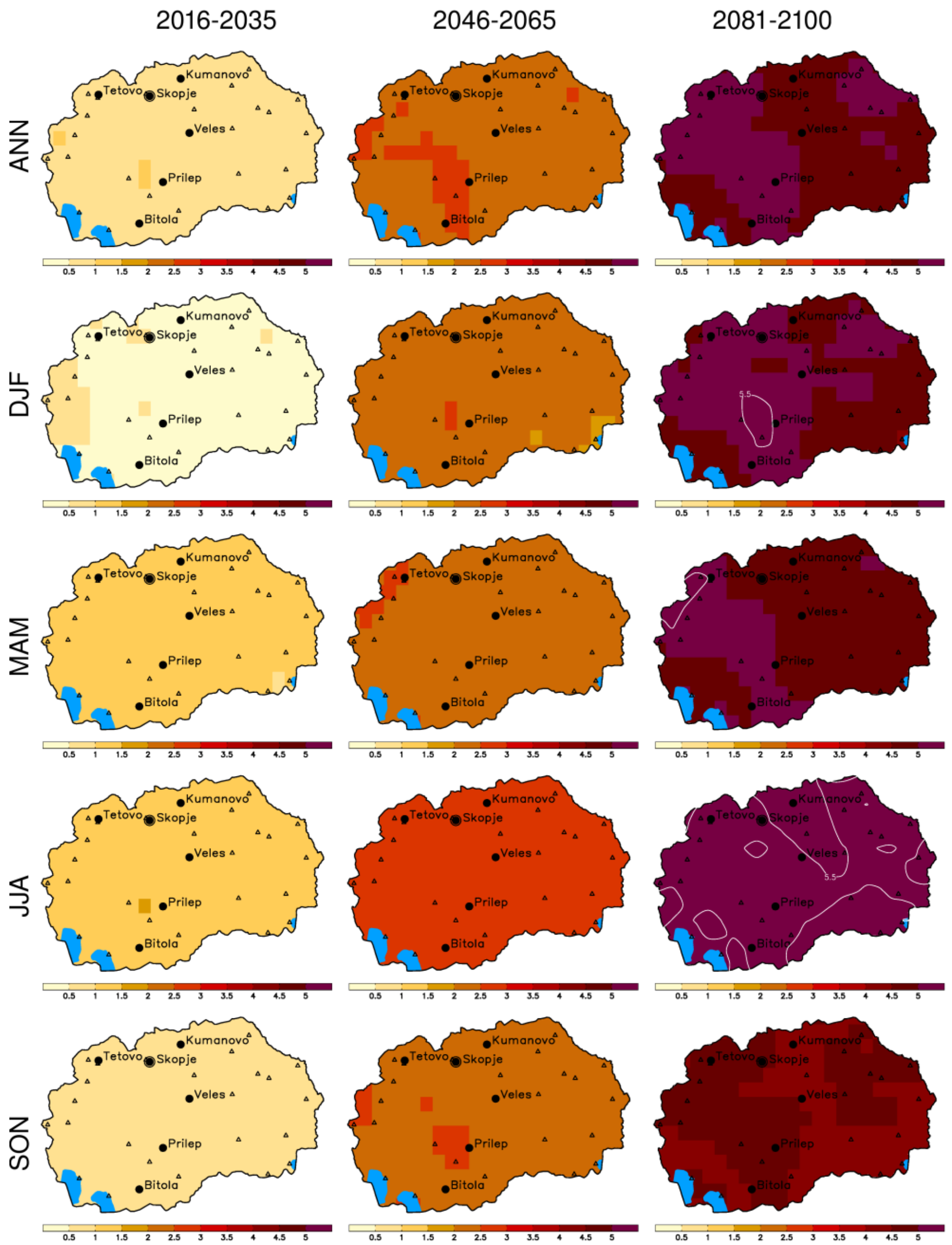


Fig. 4c Future maximum daily temperature change, for three future periods, 2016-2035, 2046-2065 and 2081-2100 with respect to the period 1986-2005, on annual level and for winter (DJF), spring (MAM), summer (JJA) and autumn (SON), for the RCP8.5 scenario. White line represent 5,5 °C isoline.

In case of temperature change, mean, minimum and maximum, it is clear that future change of GHG concentration has a dominant role in future climate change in Macedonia.

For the three future periods, annual and seasonal **precipitation change** for three future scenarios, RCP26, RCP4.5 and RCP8.5 are given in Figures 5a, 5b and 5c, respectively. For RCP2.6 (Figure 5a) on the increase of precipitation is expected for the middle and end of century, this change is positive but not significant. For winter and spring precipitation change is not significant in amplitude, and increase and decrees does not shows and regular pattern. What is interesting is that for summer for the middle of century increase is projected, but significant decrease up to 20% for the end of century. Finally for SON season for middle and end of century clear pattern of positive increase of +20% (for the end) is projected.

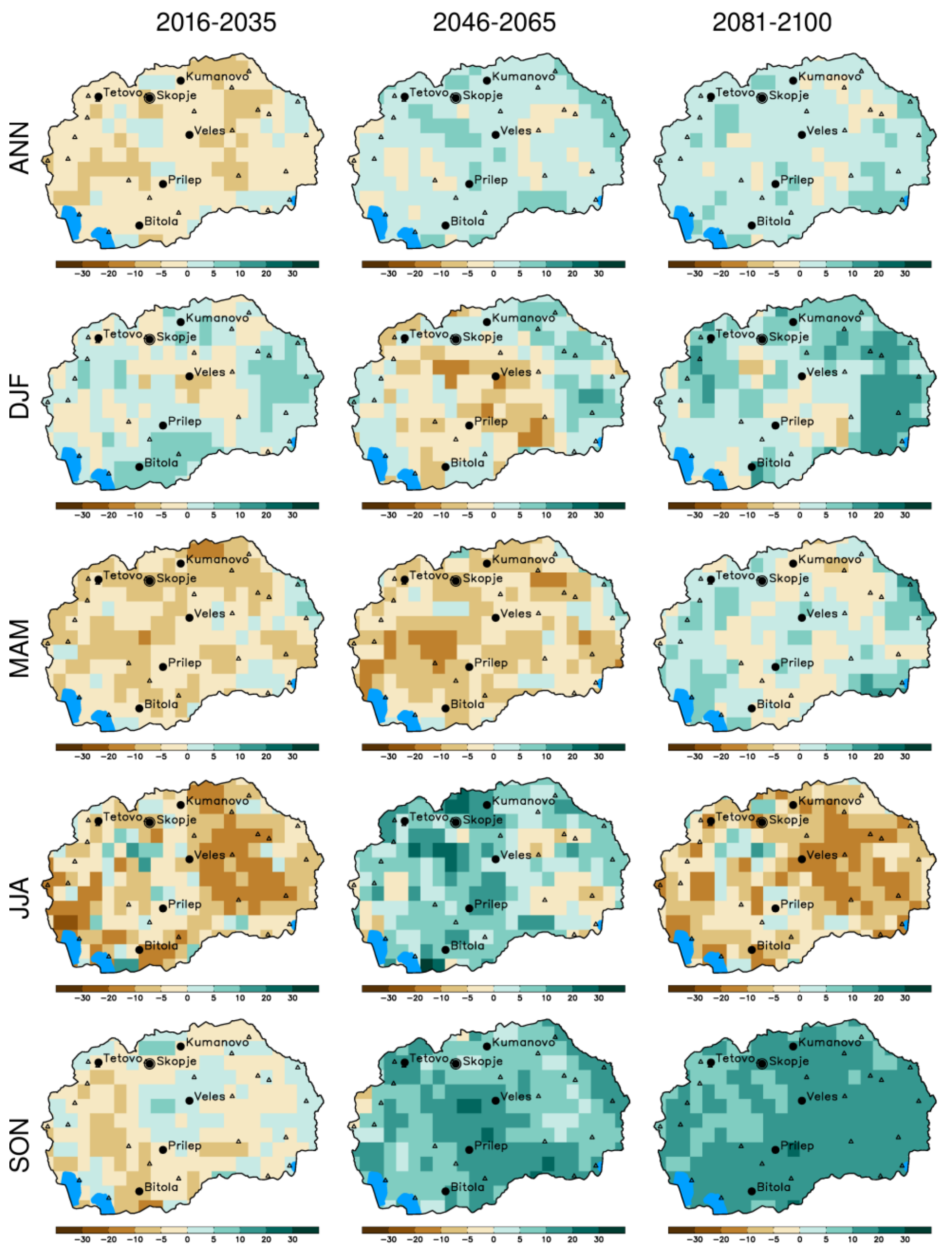


Fig. 5a Future precipitation change, for three future periods, 2016-2035, 2046-2065 and 2081-2100 with respect to the period 1986-2005, on annual level and for winter (DJF), spring (MAM), summer (JJA) and autumn (SON), for RCP2.6 scenario.

In case of RCP4.5 scenario (Figure 5b) for all three future periods decrease in annual, spring and summer precipitation is expected, clearly pronounced for the summer season, with decrease higher then 20%. For autumn, for first two periods increase is expected over the majority of territory, but for the last period decrease is projected. For winter there is no clear signal in change since that for all three period +/-5% of change is dominant over majority of territory.

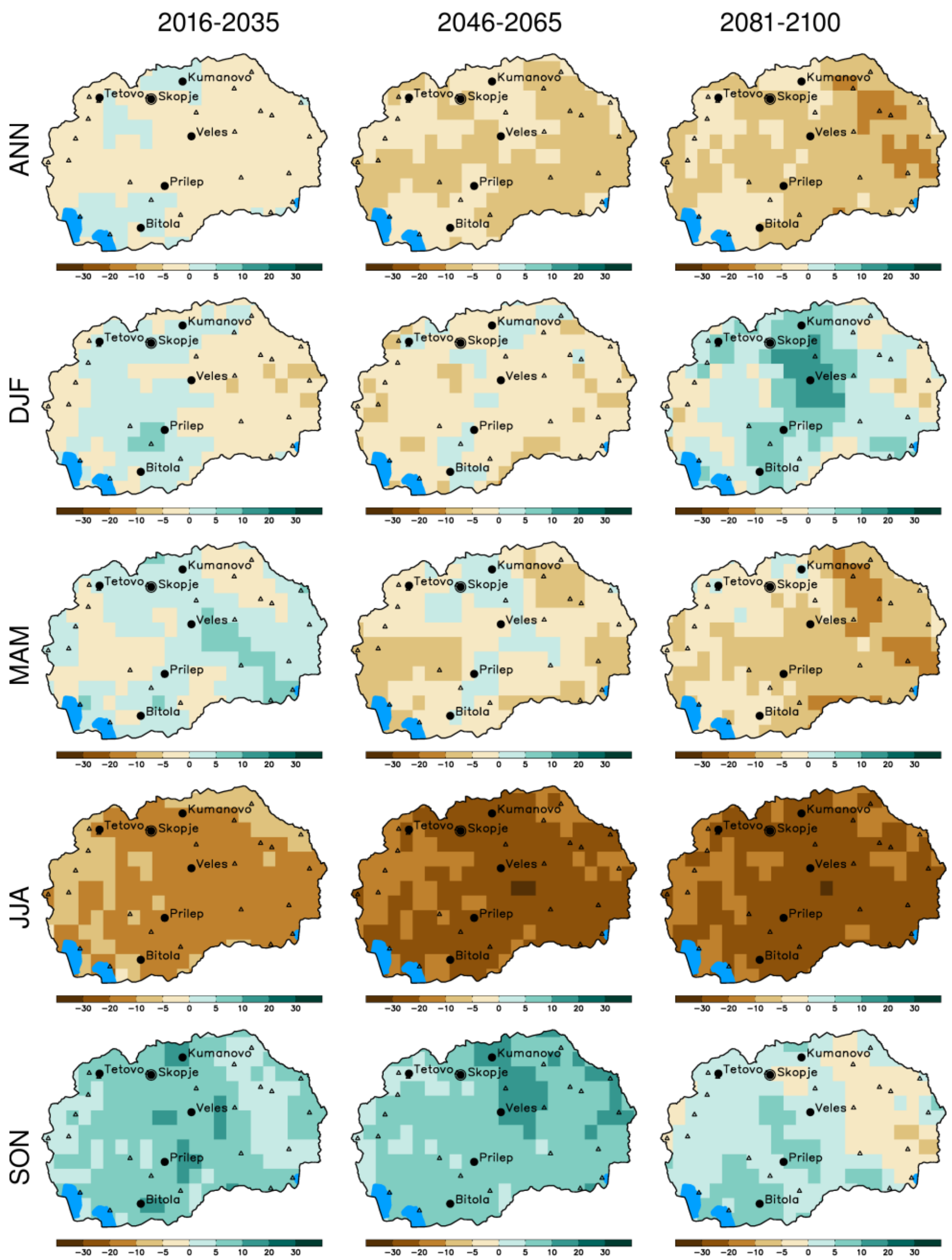


Fig. 5b Future precipitation change, for three future periods, 2016-2035, 2046-2065 and 2081-2100 with respect to the period 1986-2005, on annual level and for winter (DJF), spring (MAM), summer (JJA) and autumn (SON), for RCP4.5 scenario.

For the scenario RCP8.5 (Figure 3c) for all three future periods decrease in annual, spring and summer precipitation is expected, clearly pronounced for the summer season, with decrease higher then 40% in some regions. For winter and autumn, for first two periods increase is expected over the majority of territory, but for the last period for winter season, about half of country has increase and half decrease, and for autumn decrease of up to 15% is dominated.

It is interesting that RCP8.5 and RCP4.5 scenarios have more similarities in terms of precipitation change in comparison with RCP2.6, which lead us to conclusion that again, future concentrations of GHGs (stabilization scenario or non/stabilization), will play major role in future precipitation change in Macedonia.

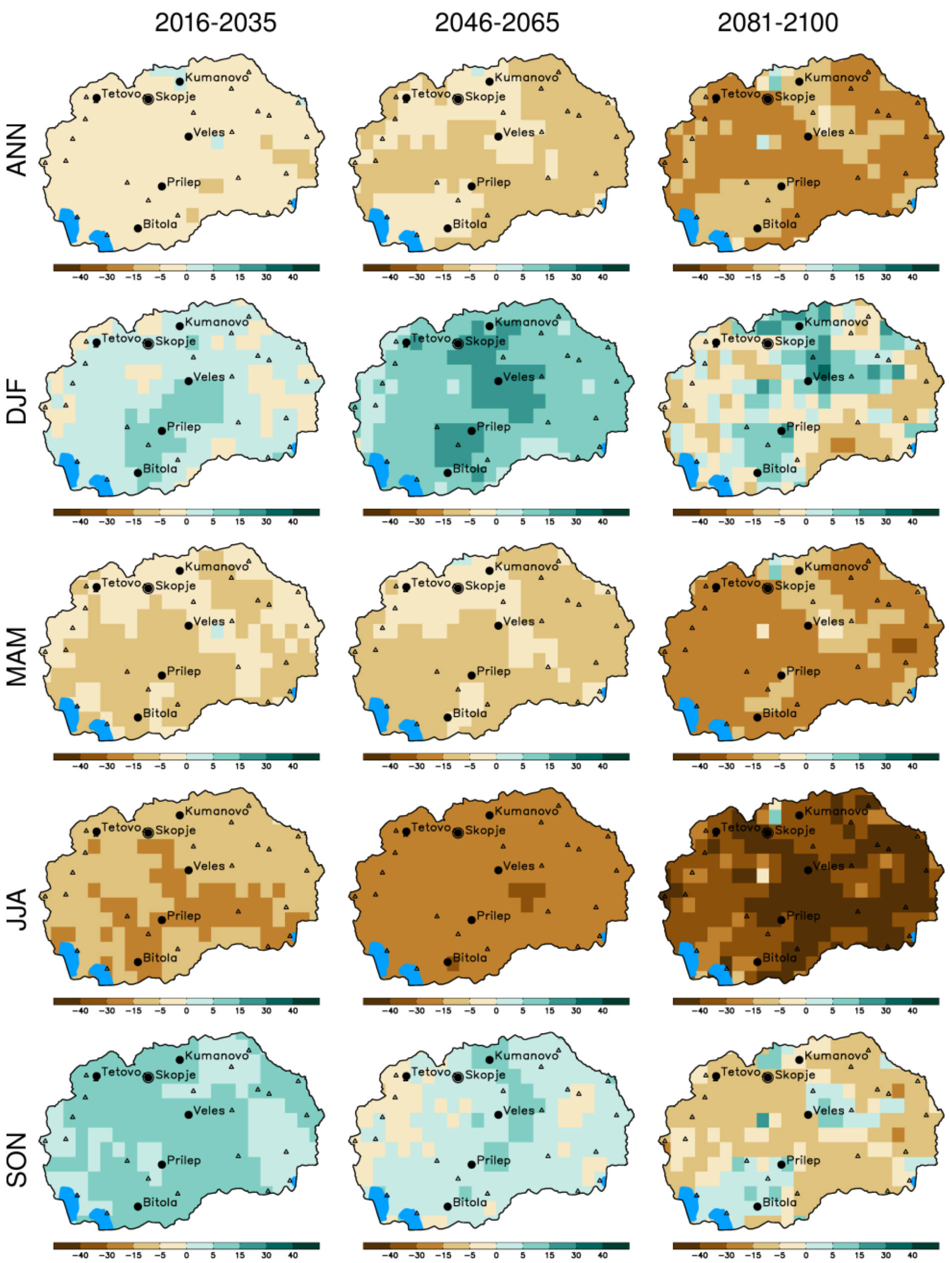


Fig. 5c Future precipitation change, for three future periods, 2016-2035, 2046-2065 and 2081-2100 with respect to the period 1986-2005, on annual level and for winter (DJF), spring (MAM), summer (JJA) and autumn (SON), for RCP8.5 scenario.

CLIMATE INDICES CHANGE

FROST DAYS

On Figure 6, for the RCP2.6 (*low*), RCP4.5 (*mid*) and RCP8.5 (*high*) scenarios, annual change in number of frost days (FD) is presented for three future periods. For the near future expected decrease is about 10-20 days for all scenarios. For *low* scenario this change will remain up to the end of the century, but for other two higher emission scenarios, change in decrease for the middle of century will be higher, approximately 20-30 days. More pronounced, > 50 days, and widespread decreases are expected under a *high* scenario during the 2081-2100 period compared to the 1986-2005 period. The biggest decreases are simulated over high altitude areas, which is partly due to the higher frost days experienced in these areas under the present (1986-2005) period and partly due to the higher increases in minimum temperatures experienced during DJF under this scenario (see figure 3c).

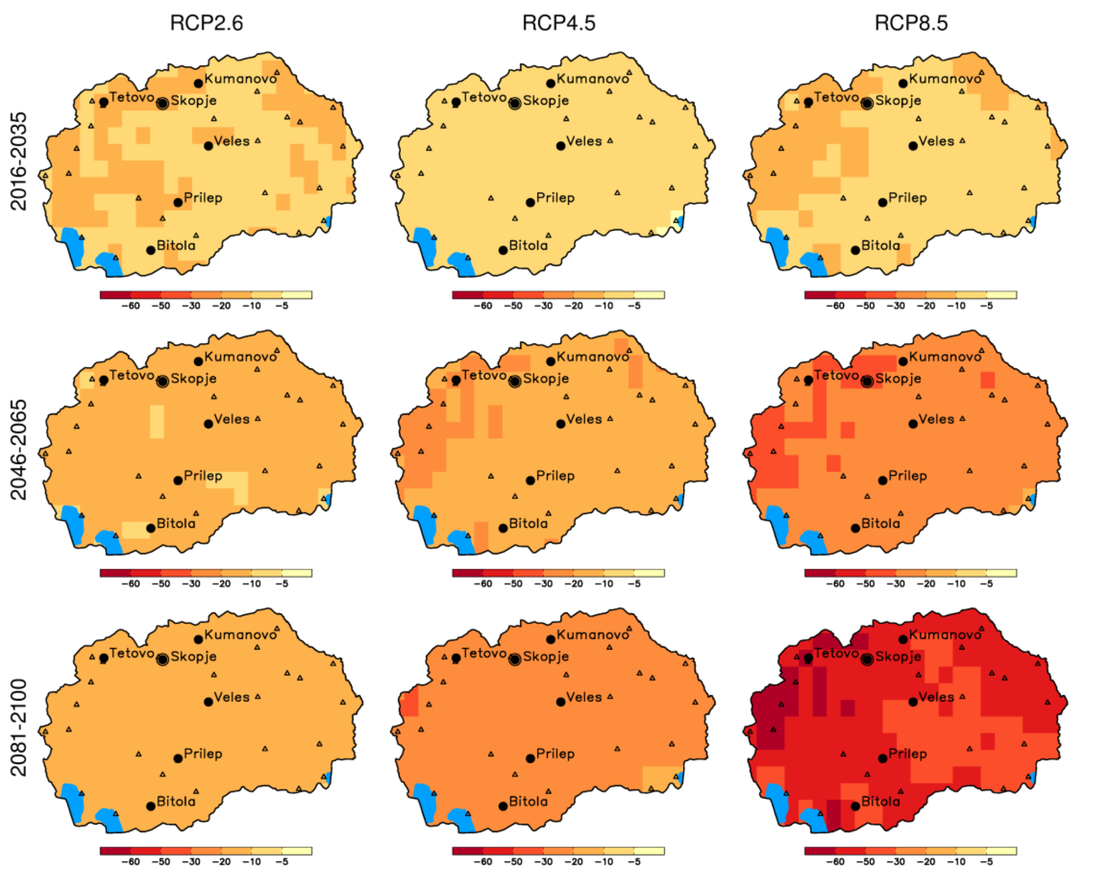


Fig. 6 Future annual change in frost days, for three future periods, 2016-2035, 2046-2065 and 2081-2100 with respect to the period 1986-2005 for the RCP2.6, RCP4.5 and RCP8.5 scenarios.

ICE DAYS

On Figure 7, for the RCP2.6 (*low*), RCP4.5 (*mid*) and RCP8.5 (*high*) scenarios, annual change in ice days (ID) is presented for three future periods. The number of the frost days is expected to the decrease, for all scenarios and future periods. The change is very similarly to decrease in frost days(Figure 6), but the change is lower since the number of ice days is generally smaller in both the current and future periods when compared to the number of frost days.

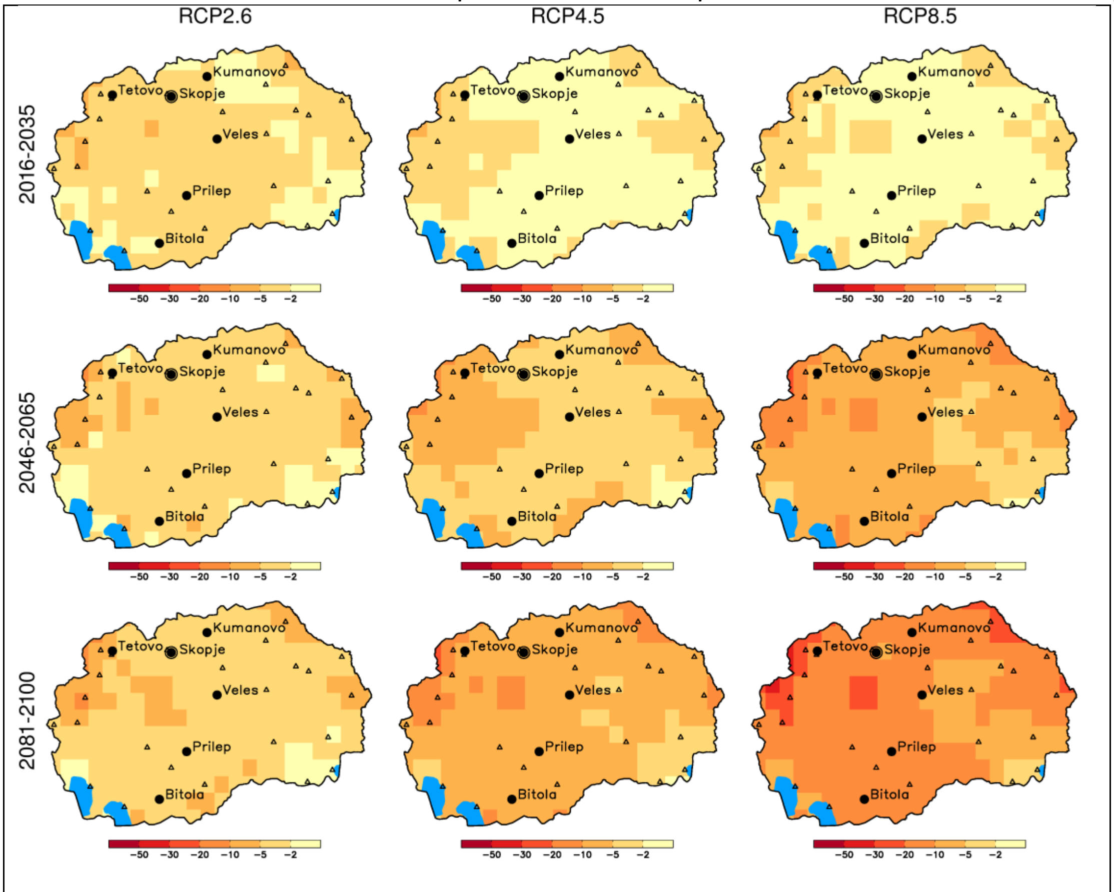


Fig. 7 Future annual change in ice days, for three future periods, 2016-2035, 2046-2065 and 2081-2100 with respect to the period 1986-2005 for the RCP2.6, RCP4.5 and RCP8.5 scenarios.

COLD WAVES

On Figure 8, for the RCP2.6 (*low*), RCP4.5 (*mid*) and RCP8.5 (*high*) scenarios, annual change in cold waves is presented for three future periods. Again, the patter of change in terms of scenarios and future periods are very similar to change in frost days and ice days. For the near future the expected decrease is same for all scenarios and is about one day shorter cold waves (with maximum change of -3 days). For the end of the century the biggest change is for the *high* scenarios, and it is up to 8 days shorter cold waves on average for 20 years, which means almost disappearance of cold waves in case of RCP8.5.

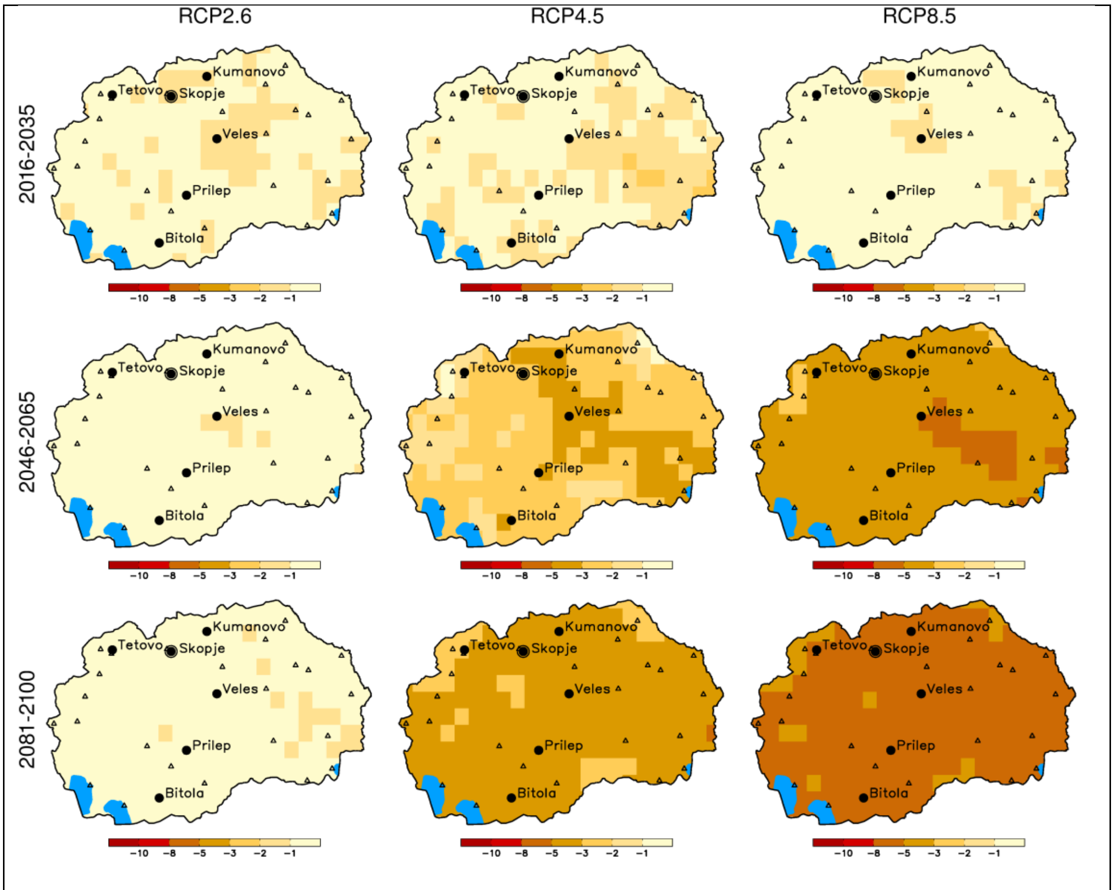


Fig. 8 Future annual change in cold waves (CSDI), for three future periods, 2016-2035, 2046-2065 and 2081-2100 with respect to the period 1986-2005 for the RCP2.6, RCP4.5 and RCP8.5 scenarios.

SUMMER DAYS

On Figure 9, for the RCP2.6 (*low*), RCP4.5 (*mid*) and RCP8.5 (*high*) scenarios, annual change in summer days (SU) is presented for three future periods. The number of the summer days is expected to increase up to 20 days for the *low* scenario in all three periods. For all three scenarios changes are the same for near future. For the *mid* scenario further increases are expected up to 30 days, for middle of the century, and up to 40 days for the end of the century. For *high* scenario the changes for the middle of the century are very similar to changes of *mid* scenario for the end of the century, but for the last period changes are larger, and for the majority of the territory, expected increases are about 60 to 70 days, in comparison to the 1986-2005 period.

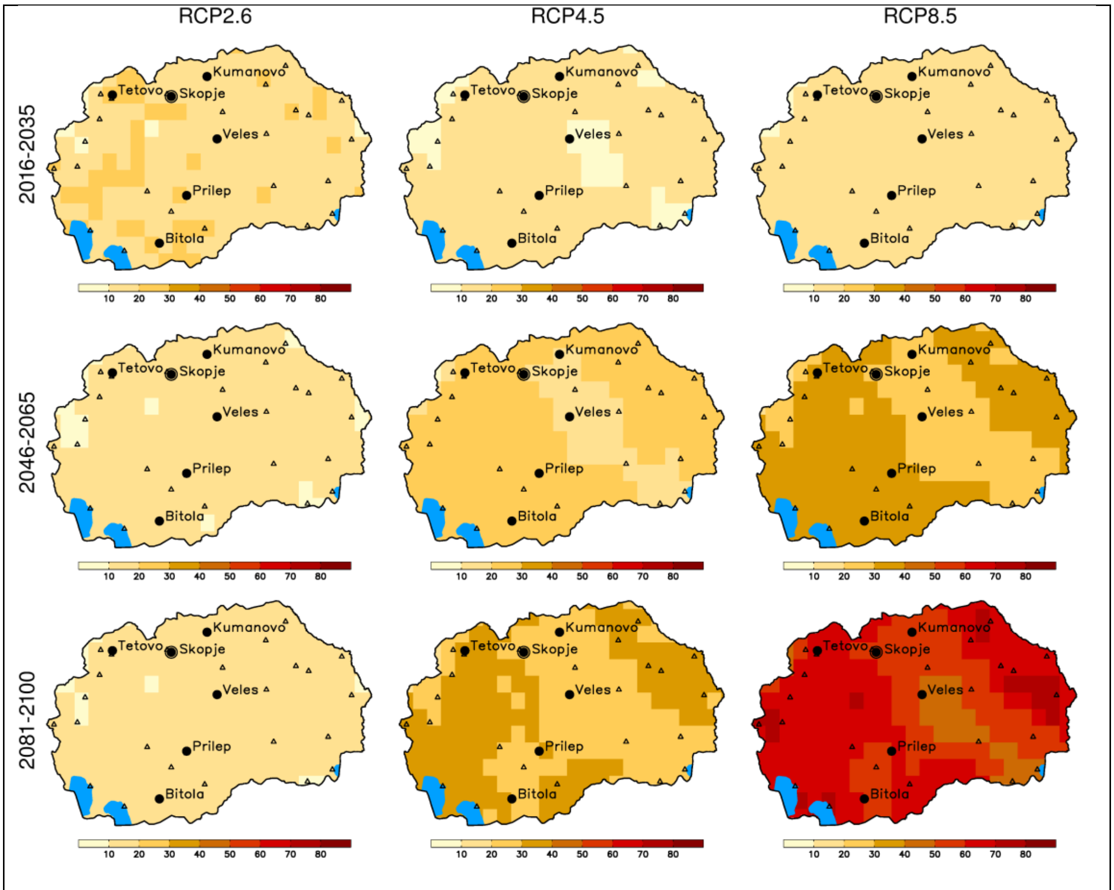


Fig. 9 Future annual change in summer days, for three future periods, 2016-2035, 2046-2065 and 2081-2100 with respect to the period 1986-2005 for the RCP2.6, RCP4.5 and RCP8.5 scenarios.

TROPICAL NIGHTS

On Figure 10, for the RCP2.6 (*low*), RCP4.5 (*mid*) and RCP8.5 (*high*) scenarios, annual change in tropical nights (TR) is presented for three future periods. It is clear that increases in tropical nights are expected to be larger in areas with lower altitude. For the near future change is the same for all scenarios and is about 5 days more of tropical nights, with maximum of 10 days. In other two periods change is the same for *low* scenario, but for *mid* and *high* scenario maximum increases reach up to 30 days more of tropical nights for the period 2046-2065. Finally, for the end of the century and *high* scenario the maximum increases in low altitude areas are +60 days, and in the mountains approximately +10 days.

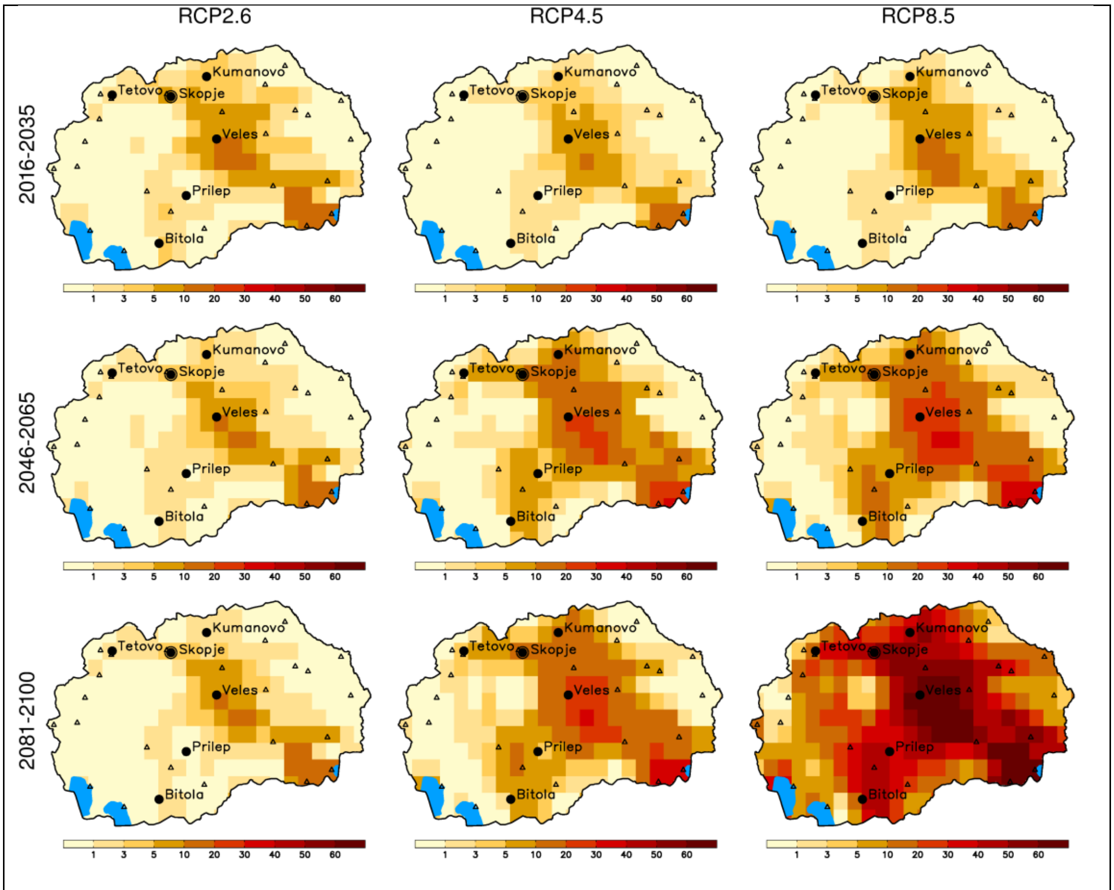
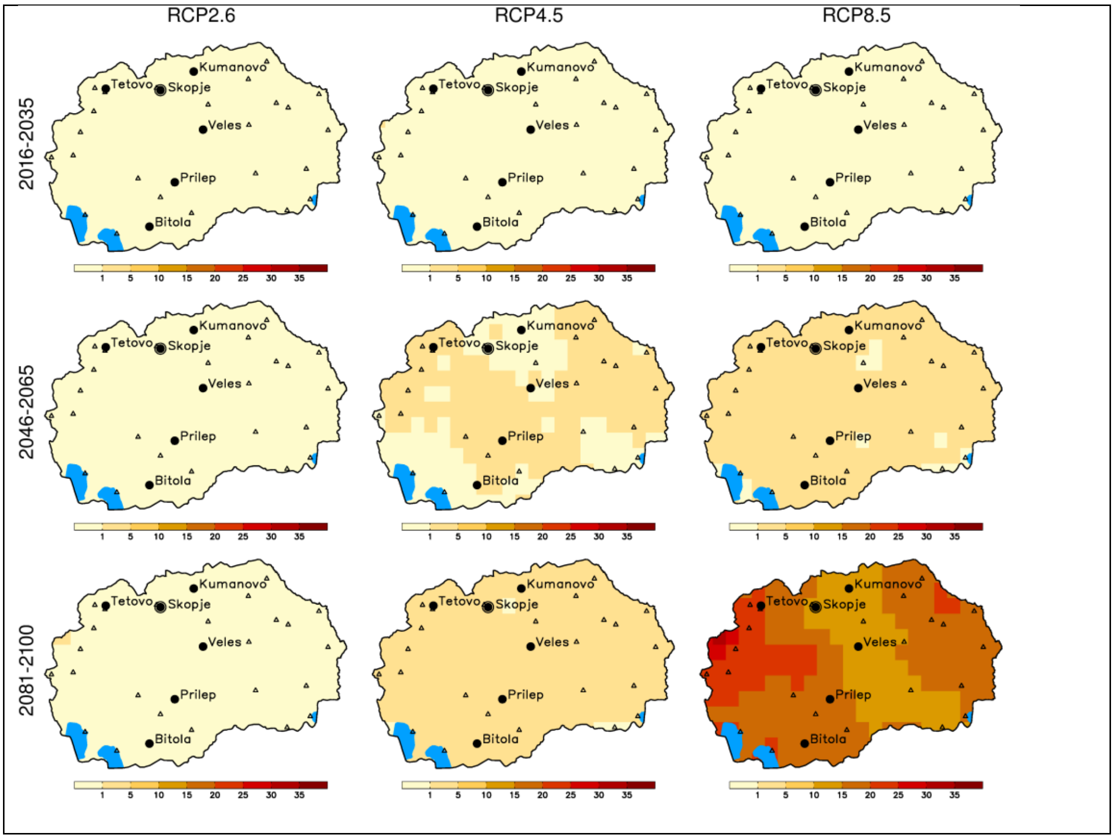


Fig. 10 Future annual change in tropical nights, for three future periods, 2016-2035, 2046-2065 and 2081-2100 with respect to the period 1986-2005 for the RCP2.6, RCP4.5 and RCP8.5 scenarios.

EXTREME HEAT WAVES

On Figure 11, for the RCP2.6 (*low*), RCP4.5 (*mid*) and RCP8.5 (*high*) scenarios, annual change in extreme heat waves (WSDI index) is presented for three future periods. The duration of the heat waves (upper panel) is expected to the be the same in the future for the RCP2.6 but on the other hand it is expected to increase for other two scenarios. For the *high* scenario and for the last period over majority of the territory, expected increases in duration are approximately 20 days, in comparison to 1986-2005 period. The number of heat waves (lower panel) is expected to also increase; on average one more event for RCP2.6, but more events for other two scenarios. For the *mid* scenario change for the last period is the same as the change for the high scenario for the middle of century, and it is about 6 more events during 20-year period. For the last period and *high* scenario on majority of the territory, there is significant increase up to 40 more events in 20-year period.



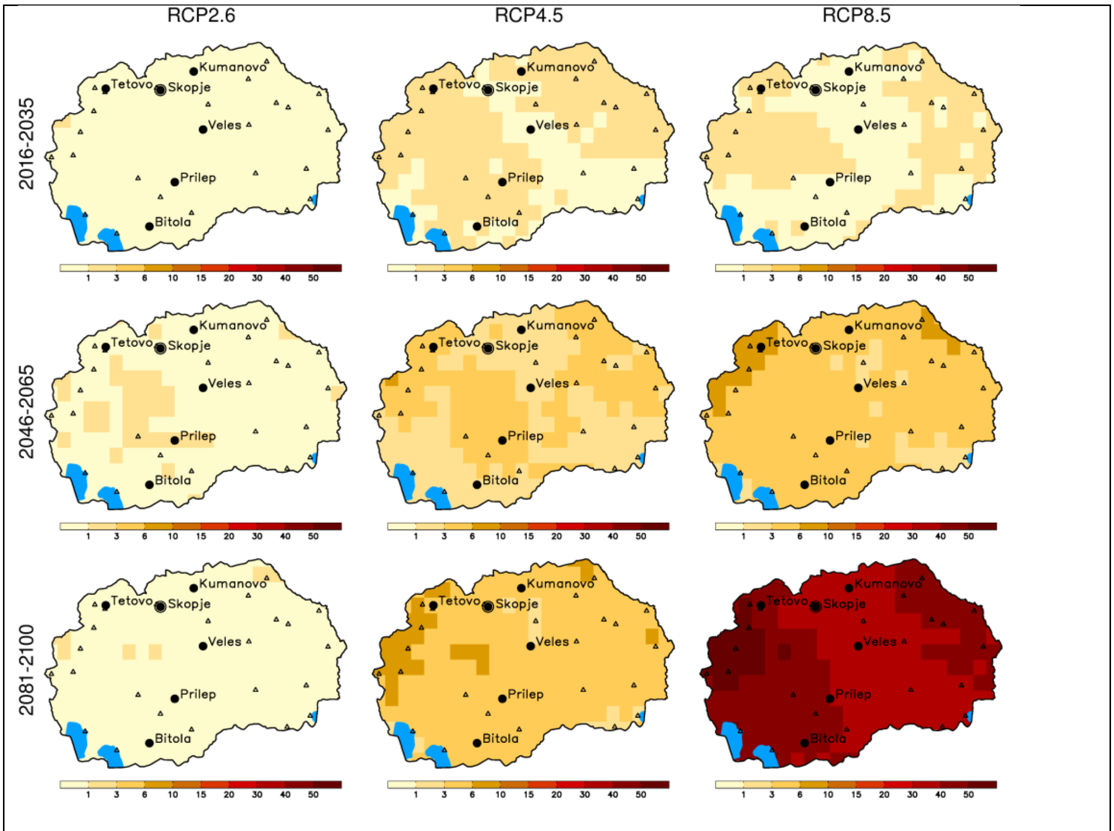


Fig. 11 Future annual change in extreme heat waves (WSDI), for three future periods, 2016-2035, 2046-2065 and 2081-2100 with respect to the period 1986-2005 for the RCP2.6, RCP4.5 and RCP8.5 scenarios. On upper heat wave duration change is presented (in days), and on the lower frequency of the heat waves (number of events in 20 years period).

GROWING SEASON LENGTH

On Figure 12, for the RCP2.6 (*low*), RCP4.5 (*mid*) and RCP8.5 (*high*) scenarios, annual change in growing season length (GSL) is presented for three future periods. The growing season is expected is expected to the increase 10-20 days for *low* scenario in all three periods. For all three scenarios change is similar for the near future. For the *mid* scenario further increase is expected up to 30 days, for middle of the century, and up to 40 days for the end of the century. For *high* scenario the change for the middle of the century is very similar to change of *mid* scenario for the end of the century, but for the last period increases are on average highest and cover the majority of the territory; expected increases are from 40 to 60 days, in comparison to 1986-2005 period.

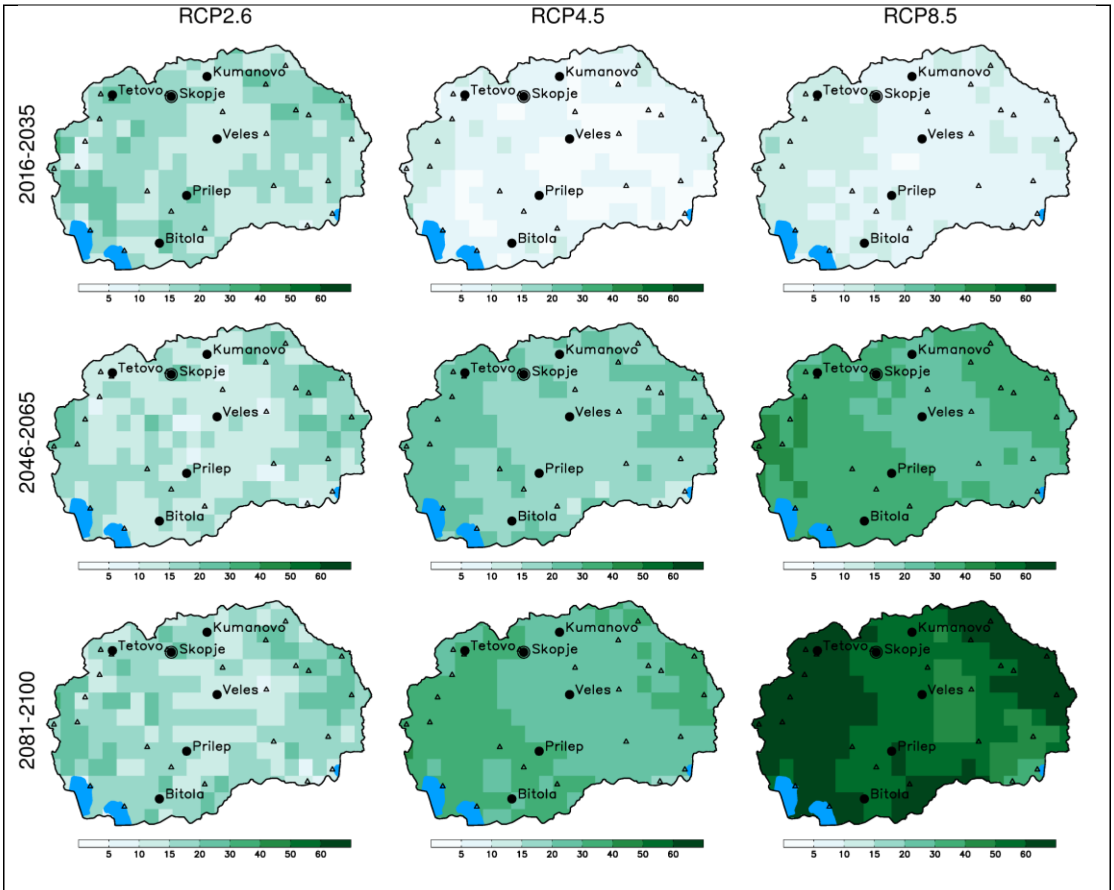


Fig. 12 Future annual change growing season length, for three future periods, 2016-2035, 2046-2065 and 2081-2100 with respect to the period 1986-2005 for the RCP2.6, RCP4.5 and RCP8.5 scenarios.

NUMBER OF DAYS WITH EXTREME PRECIPITATION

On Figure 13, for the RCP2.6 (*low*), RCP4.5 (*mid*) and RCP8.5 (*high*) scenarios, annual change in number of days with extreme precipitation (days with daily precipitation above 40 mm) is presented for three future periods. The number of extreme events is expected to the increase in comparison to 1986-2005 period for all periods and all scenarios. Due to the warmer atmosphere that can holds more water vapor, the increase in many parts of the country is higher than 60% more of these days in all three future periods. It is indicative that maximum change is present in same areas predominantly in low altitude part of the country and in the south-west.

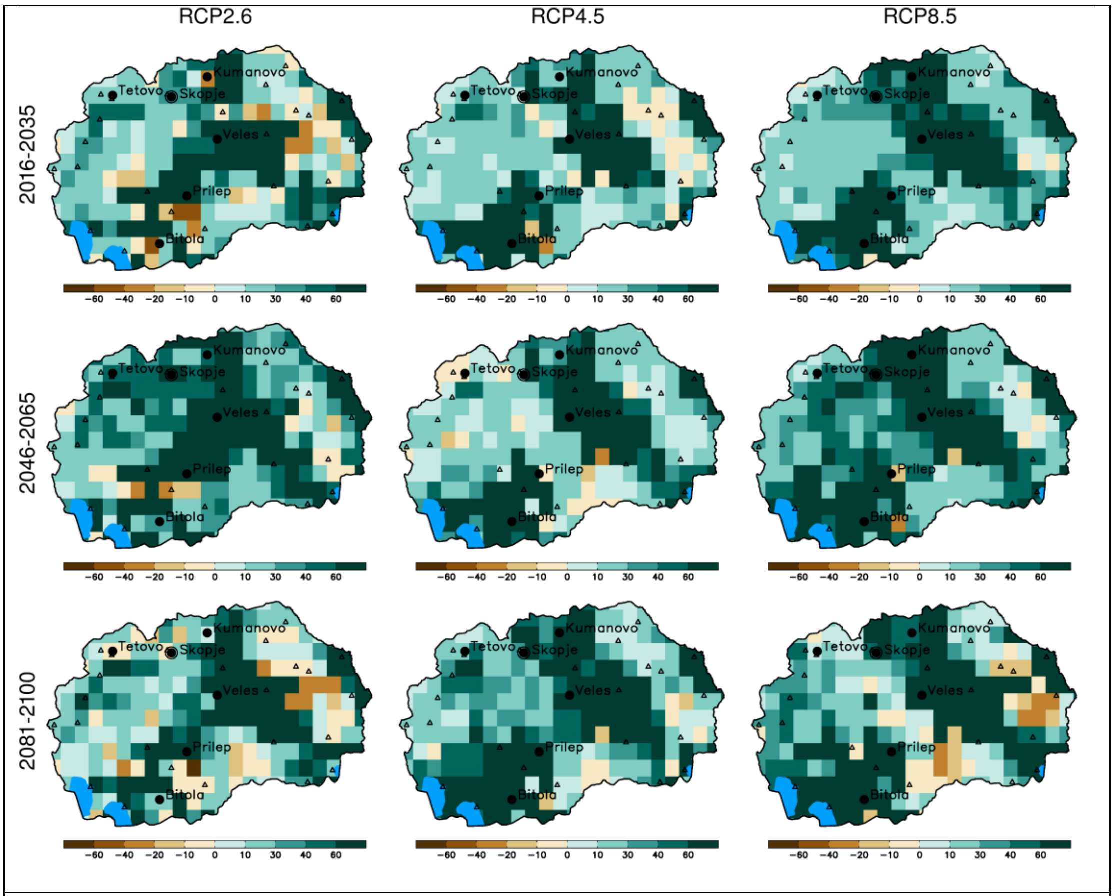


Fig. 13 Future annual change in number of extreme precipitation events (RR40), for three future periods, 2016-2035, 2046-2065 and 2081-2100 with respect to the period 1986-2005 for the RCP2.6, RCP4.5 and RCP8.5 scenarios.

DAILY MAXIMUM PRECIPITATION

On Figure 14, for the RCP2.6 (*low*), RCP4.5 (*mid*) and RCP8.5 (*high*) scenarios, annual change in daily maximum precipitation accumulation (RX1D) is presented for three future periods. The daily extreme precipitation is expected to the increase in comparison to 1986-2005 period, over majority of the territory. The change is similar for all scenarios and all future periods. For the near future increase is about 0-10% (with some areas expected to experience reductions in magnitude), and for the middle of the century increases are expected in northern and western parts to be above 10%. Similar changes are expected for the end of the century for *low* and *mid* scenario. For the *high* scenario for the end of the century increases in some places are expected to be higher, reaching approximately 20% greater precipitation amounts.

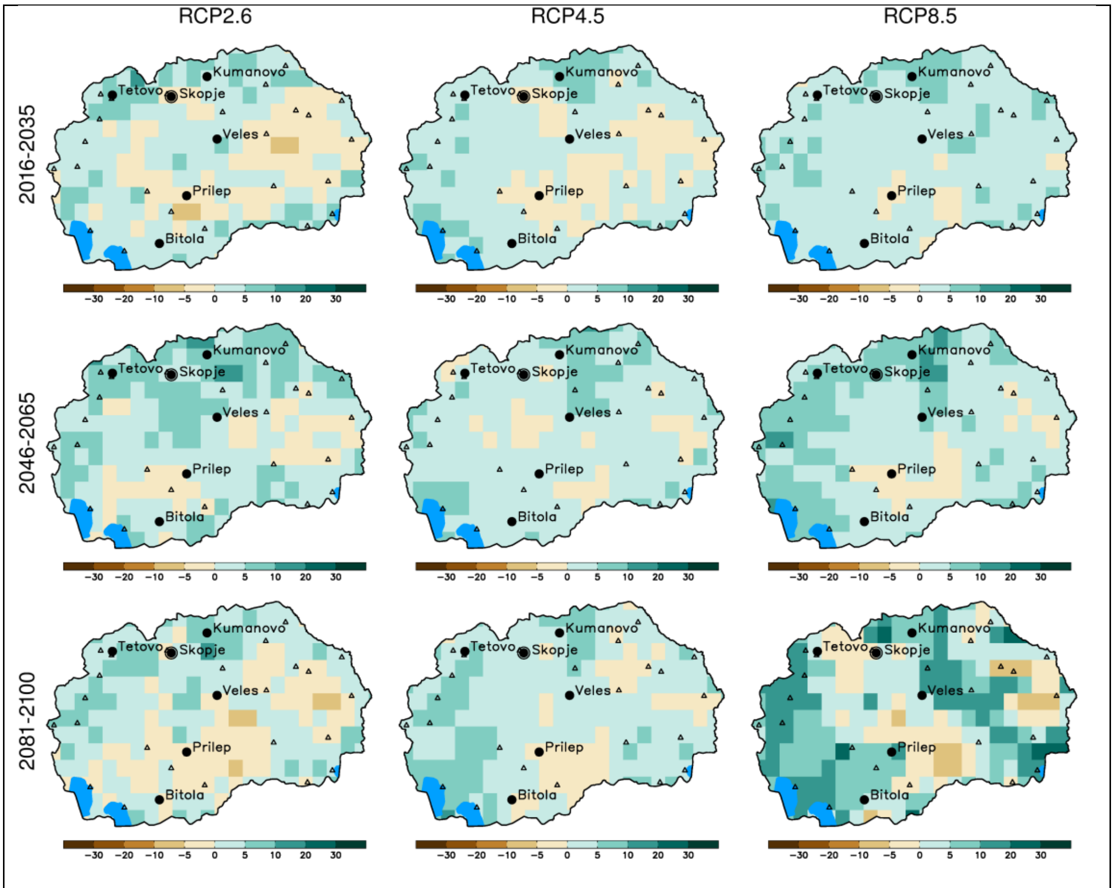


Fig. 14 Future change in annual daily extreme precipitation change (RX1D), for three future periods, 2016-2035, 2046-2065 and 2081-2100 with respect to the period 1986-2005 for the RCP2.6, RCP4.5 and RCP8.5 scenarios.

CONSECUTIVE DRAY DAYS

On Figure 15, for the RCP2.6 (*low*), RCP4.5 (*mid*) and RCP8.5 (*high*) scenarios, annual change in consecutive dray days index is presented for three future periods. The number of consecutive dray days is expected to the increase in comparison to 1986-2005 period, and for the last period on majority of the territory, and for the *high* scenario, length will increase for more than 30 days indicating higher risk for drought onset. For *mid* scenario for the last period, length will increase up to 30 days, and for *low* scenario for the last period, length will increase up to 20 days.

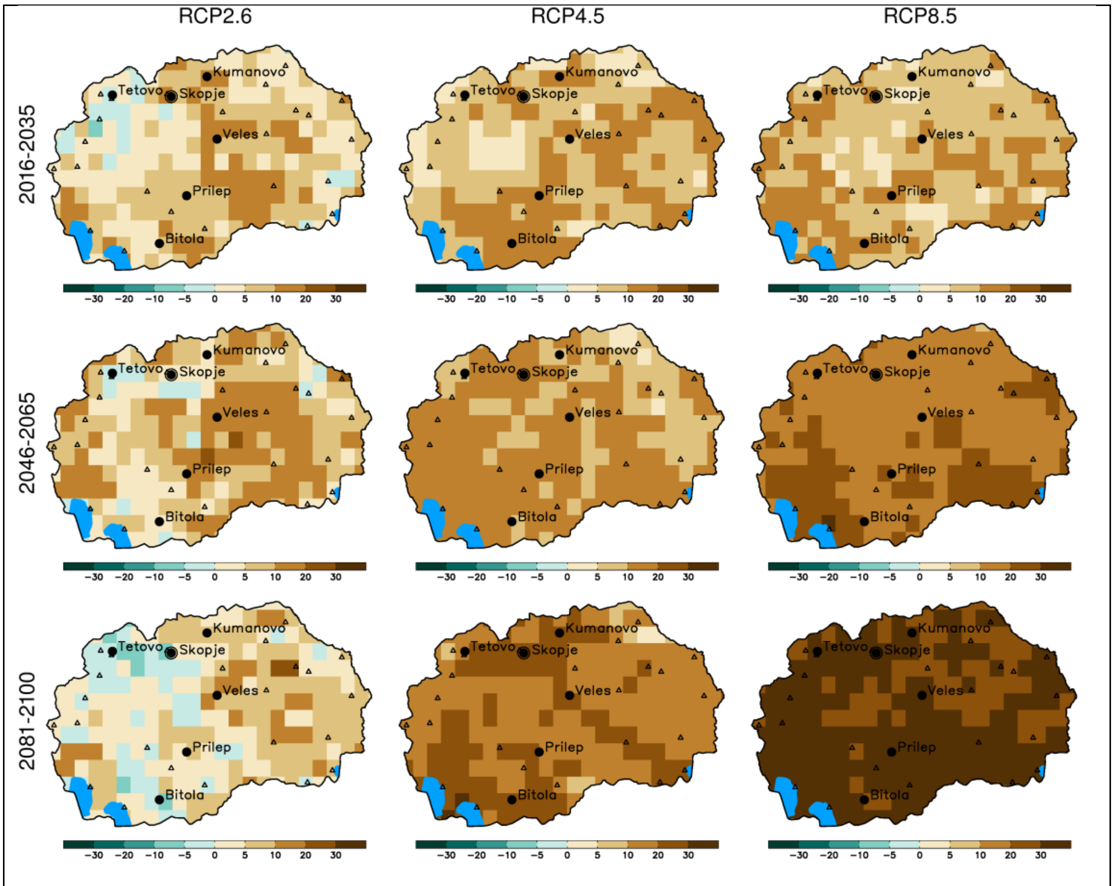


Fig. 15 Future annual change in consecutive dry days, for three future periods, 2016-2035, 2046-2065 and 2081-2100 with respect to the period 1986-2005 for the RCP2.6, RCP4.5 and RCP8.5 scenarios.