SEE2020 SERIES

STUDY ON CLIMATE CHANGE IN THE WESTERN BALKANS REGION

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RegionalCooperationCouncil

Study on climate change in the Western Balkans region

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Sarajevo, 2018

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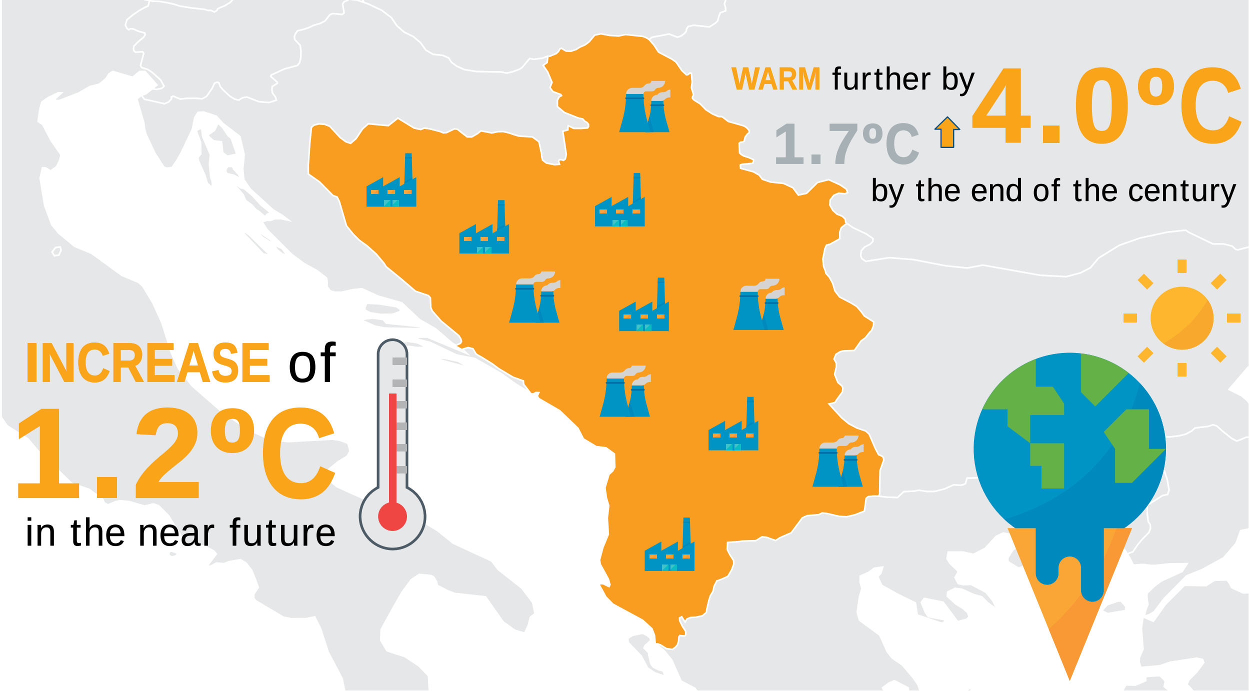
SUMMARY

Western Balkans (WB) region consists of six economies (Albania, Bosnia and Herzegovina, Kosovo*, Montenegro, Serbia and The Former Yugoslav Republic of Macedonia), occupying the territory of about 208 000 km2 with population of about 18 million. The region spreads over the low altitude Pannonia valley on the north, hilly and mountain regions towards central-south and west, and coastal area of the Adriatic Sea. Spatial climate variability, from coastal subtropical to temperate continental with high mountains in between, gave this area large diversity in vegetation cover, which is considered as natural treasure of the region (Figure S1, left panel). People are mainly engaged in activities within weather and climate related sectors, such as agriculture, forestry, tourism and supporting services. All economies have a common goal of increasing income per capita, while reducing the percentage of unemployed citizens. As candidates and potential candidates for EU accession, all are motivated to respect the Paris Agreement and to achieve EU2020 and EU2030 goals in Greenhouse Gas (GHG) emission reduction, to increase energy efficiency and energy production from renewable sources. Under the great impact of global warming and significantly vulnerable to climate change, with observed temperature increase of 1.2ºC and destined to warm further by 1.7 - 4.0˚C depending on the global effort in GHG emission reduction (Figure S1- right panel), WB economies analyse and report on adaptation options, with optimal selection and prioritisation in compliance with mitigation measures. The burden of the total work related to climate change issues, required to implement within each economy, is recognised as significant setback because of the lack of human and financial resources, which motivates renewal and development of regional collaboration.



Basic information on climate change in the Western Balkans show alarming increase of temperature over the whole territory with observed temperature increase of 1.2ºC in the near future and destined to warm further by 1.7 – 4.0˚C by the end of the century, depending on the global effort in GHG emission reduction.

Data: RCC's Study on Climate Change in the Western Balkans Region, May 2018

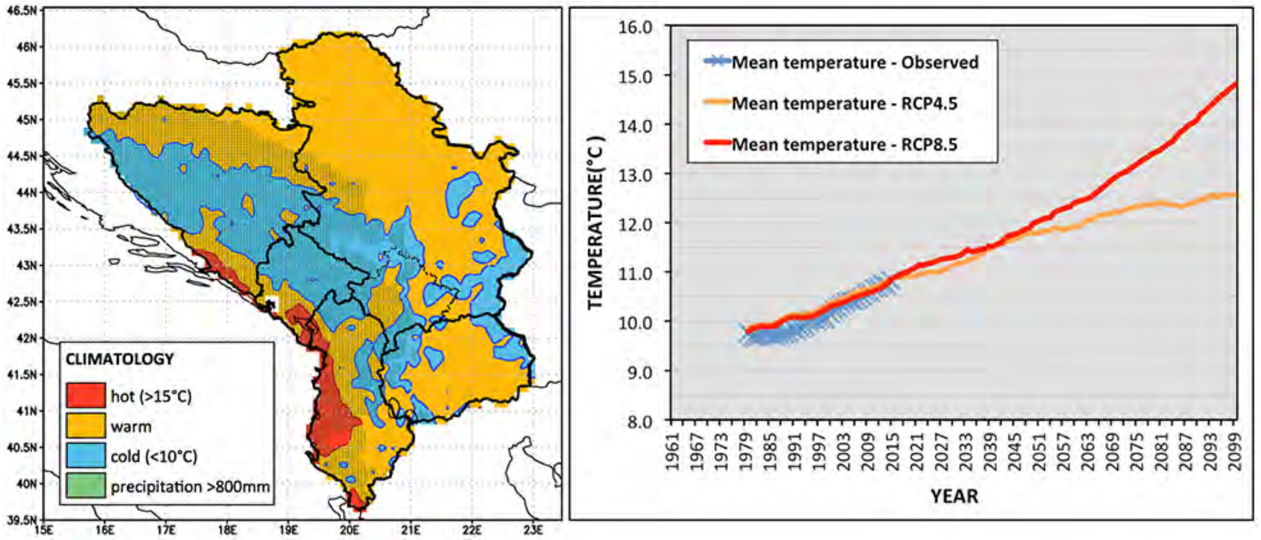


Figure S1. *Climatology of the WB region (left panel), with distinguished coastal areas (marked as "hot" – red), mountain areas (marked as "cold" – blue) and areas with temperate and temperate-warm climate (marked as "warm" – orange). The area with highest annual precipitation is shaded (green dots). Mean annual temperature, averaged over the WB region, is shown on the right panel. The data represents average values for the 20-year period, assigned to the last year of the period ("moving average" approach), and are calculated for the period 1961-2100. Values obtained from observations are in blue, from regional climate models median according to stabilisation (RCP4.5) scenario are in orange, and according to continuous rise (RCP8.5) scenario are in red.*

Integral vulnerability and risk assessment of the WB economies provided the insight on common issues related to climate change. Guided by the analysis performed in the Study on Climate Change in the Western Balkans Region (May 2018), supported by the South East Europe (SEE) 2020 Strategy (2013) and Intergovernmental Panel on Climate Change 5th Assessment Report (IPCC AR5, 2014), WB priorities in adapting to climate change and mitigating its impacts are identified. As the most probable, according to the current human behaviour, two scenarios of global GHG emissions, represented with IPCC AR5 Representative Concentration Pathways scenarios (RCP), are selected to mark the lower and higher thresholds for future climate change: stabilisation (RCP4.5) scenario as lower end – in case of global GHG emission reduction after 2040, and continuous rise (RCP8.5) scenario as higher end – in case none of the global GHG emission reduction measures are implemented, also called "business as usual" scenario.

Basic information on climate change in WB region (Figure S2, ΔT values) show alarming increase of temperature over the whole territory:

- during the near future (2016-2035) period, which is already happening, mean annual temperature increase is expected to reach 0.5-1.0ºC, but with constant global GHG increase up to 1.5ºC;
- during the mid-century (2046-2065) period, mean annual temperature increase is expected to reach 1.0-2.0ºC, and up to 2.0-3.0ºC with continuous rise of global GHG;
- during the end of the century (2081-2100) period, mean annual temperature increase behaviour shows that even if global GHG emissions stabilise it will continue the rise for additional 0.5-1.0ºC since the mid-century period (up to 2.0-3.0ºC with respect to present climate), and in case of constant global GHG increase, the temperature increase will reach 4.0-5.0ºC over the whole region with respect to the present climate;
- summer temperature (June-July-August: JJA) increase is higher than the mean annual up to 0.5-1.0ºC, and in case of constant global GHG increase, the temperature for this season will exceede 5.0ºC increase at the end of the century period compared to the present climate;
- somewhat lesser increase of temperature (up to 0.5ºC) can be expected only on far north of the region (north Bosnia and Herzegovina, and north Serbia), but compared to the intensity of change this difference is not significant.

Accumulated precipitation change is more complex to analyse (Figure S2, ΔP values), where most important conclusions are:

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* This designation is without prejudice to positions on status, and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo declaration of independence

- noticeable change in annual accumulated precipitation starts from the mid-century period, with gradient of change that shows increase in the northern parts of the region (north Serbia) and intensifying decrease towards the south, including coastal areas;
- by the end of the century drying of the WB region will prevail;
- impact of climate change is more visible in change of annual precipitation distribution, which is evident from severe drying of the summer (JJA) season, more pronounced towards the south of the region and in coastal areas.

Impact of climate change on the climate system and especially human livelihood requires complex analysis of different climate indices and indicators. Most significant impact signals, relevant for two seasons (summer and winter) that best reflect the climate change in WB region (Figure S3), are summarised and outlined here. Mapping of high risk areas shows:

- summer drying and heating, already observed, will continue this trend with increased frequency and duration of heat waves, which threatens the whole WB region by the end of century in case of constant global GHG increase, with extension of dry period especially in the south and near coast and coastal areas;
- winter season will receive more extreme precipitation, as well as more of total accumulated precipitation, over the regions with temperate continental climate, and alarming loss of snow pack is expected.

In general, climate change shows intrusion of sub-tropical climate further to the north, leaving coastal and southern areas very hot and dry during the summer season which is expected to have prolonged duration by one to two months increasingly, from near future to the end of the century.

Climate change impacts, which are observed and reported in official documents by WB economies, tend to intensify in the future:

- environmental signals: increased frequency and duration of heat waves and drought – frequently overlapping; early start of vegetation; increased frequency of flooding, increased frequency and spreading of forest fires, forest defoliation and mortality, decreased river discharge;
- sectorial vulnerability: more frequent decrease in yield quality and quantity (risks of drought, high temperatures and late spring frost), increased summer energy consumption, decreased drinking water supply especially during summer; potential for, or already recorded, spread of new diseases.

The climate change shows in the **Western Balkans** intrusion of **sub-tropical climate** further to the north, leaving coastal and southern areas very **hot and dry** during the summer season which is expected to have prolonged duration from near future to the end of the century.

Data: RCC's Study on Climate Change in the Western Balkans Region, May 2018

Overall analyses recognise the *human health, safety and life quality as highly vulnerable to natural hazards and sectorial weather related losses.* The risk assessment shows significant increase of such vulnerability in the future and thereby defines it as the top priority that requires immediate attention according to the following list, which is developed by prioritising optimal measures considering the urgency-cost-benefit analysis:

- development of WB early warning system, information dissemination and preparedness of the general public, supported by readiness of governmental institutions related to disaster risk management;
- implementation of WB seasonal forecast in decision-making, and efficient dissemination of forecast data to stakeholders;
- adapt food production by implementing WB short-term to seasonal weather forecast and climate change information in decision-making (timing of sowing, varieties and hybrid selection, adaptation of agro-technical measures, housing for livestock, etc.);
- plan and develop sustainable irrigation systems where necessary, optimal to water availability and applying rainfall harvesting approach;
- supress forest degradation by immediately implementing the long-term planning;
- optimise energy production/availability according to inter-annual consumption assessment;
- constant re-evaluation of impacts, measures, efficiency and plans, supported by exchange of expertise, knowledge and implementation in education.

Specifics and more details on the presented results, vulnerability and risk assessment and outlined priorities with recommendation for their implementation are described in the document Study on Climate Change in the Western Balkans Region, Regional Cooperation Council (RCC), May 2018.

BOSNIA AND HERZEGOVINA

	ΔT(°C)-ANN		ΔTx(°C)-JJA		ΔP(%)-ANN		ΔP(%)-JJA	
	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
near future	0.5-1	0.5-1	0.5-1	1-1.5	-5,+5	-5,+5	-10,0	-10,0
mid-century	1-2	1.5-3	1.5-3	2-3	-5,+5	-5,+5	-30,-10	-20,-10
end of century	1.5-3	4-5	2-3	> 4(5)	-5,+5	-10,-5	-20,-10	> -10(-30)

SERBIA

	ΔT(°C)-ANN		ΔTx(°C)-JJA		ΔP(%)-ANN		ΔP(%)-JJA	
	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
near future	0.5-1	0.5-1.5	0.5-1.5	1-1.5	-5,+5	-5,+5	-10,+5	-10,+5
mid-century	1-2	1.5-3	1.5-3	1.5-3	-5,+5	0,+20	-20,-10	-20,+5
end of century	1.5-3	4-5	1.5-3	> 4(5)	-5,+10	-20,+10	-20,-5	-30,-10

MONTENEGRO

	ΔT(°C)-ANN		ΔTx(°C)-JJA		ΔP(%)-ANN		ΔP(%)-JJA	
	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
near future	0.5-1	0.5-1.5	0.5-1.5	1-1.5	-5,+5	-5,0	-20,-5	-10,0
mid-century	1-2	1.5-3	2-3	2-3	-10,0	-5,0	-30,-10	-30,-10
end of century	1.5-3	4-5	2-3	> 5	-5,0	-20,-10	-20,-10	> -30

KOSOVO*

	ΔT(°C)-ANN		ΔTx(°C)-JJA		ΔP(%)-ANN		ΔP(%)-JJA	
	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
near future	0.5-1	0.5-1.5	1-1.5	1-1.5	-5,0	-5,0	-20,-10	-20,-10
mid-century	1.5-2	2-3	2-3	2-3	-10,+5	-5,+5	-20,-10	-20,-10
end of century	2-3	4-5	2-3	> 5	-5,+5	-20,-10	-30,-10	-30,-20

ALBANIA

	ΔT(°C)-ANN		ΔTx(°C)-JJA		ΔP(%)-ANN		ΔP(%)-JJA	
	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
near future	0.5-1	0.5-1	0.5-1	1-1.5	-5,+5	-5,+5	-20,-10	-20,-10
mid-century	1-2	1.5-3	2-3	2-3	-10,0	-10,0	-30,-10	-30,-20
end of century	1.5-2	4-5	2-3	> 5	-5,+5	-20,-10	-30,-10	> -30

THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA

	ΔT(°C)-ANN		ΔTx(°C)-JJA		ΔP(%)-ANN		ΔP(%)-JJA	
	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
near future	0.5-1	0.5-1.5	1-1.5	1-1.5	-10,0	-10,0	-20,-10	-20,-10
mid-century	1.5-2	2-3	2-3	2-3	-10,0	-10,-5	-30,-10	-30,-10
end of century	2-3	4-5	2-3	> 5	-10,0	-20,-10	-30,-10	> -30

Figure S2. *Change of the mean annual (ΔT-ANN) and summer mean maximum (ΔT-JJA) temperature (°C), and change of the mean annual (ΔP-ANN) and mean summer (ΔP-JJA) accumulated precipitation (%), for the near future (2016-2035), mid-century (2046-2065) and end of the century (2081-2100) periods with respect to the base (1986-2005) period, according to the stabilisation (RCP4.5) and continuous rise"(RCP8.5) scenarios of GHG emissions (IPCC AR5, 2014). Values marked with red present the increase of temperature, orange - decrease and green - increase of the precipitation. Intensity of the colours matches the intensity of change.*

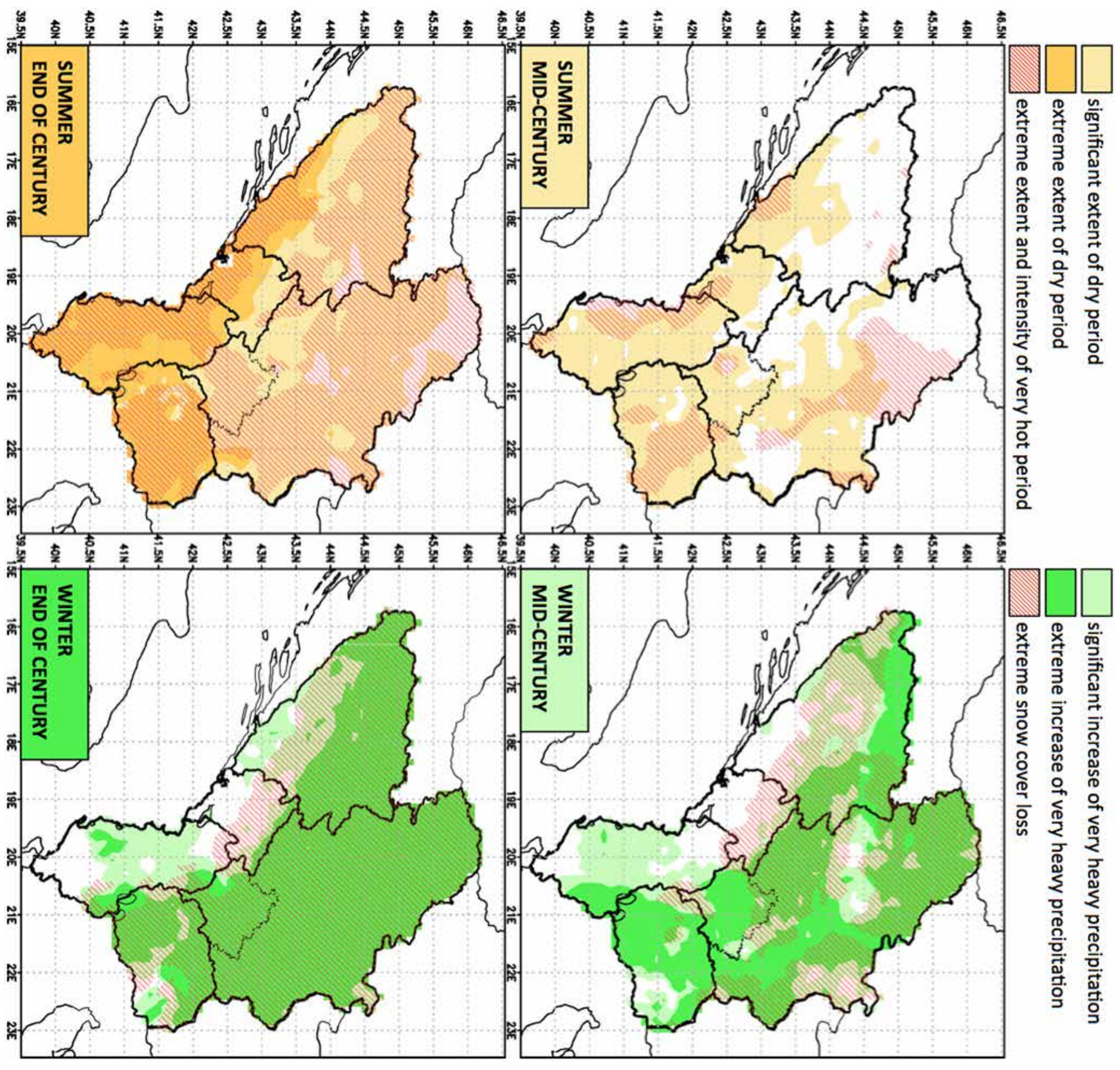


Figure S3. *Maps of the most pronounced risks related to climate change over the WB region, derived from both scenarios (RCP4.5 and RCP8.5) taking the higher values into consideration. Two seasons are selected, summer (left panels) and winter (right panels), for two periods, mid-century (upper panels) and end of the century (lower panels). Maps show areas with most pronounced changes in comparison to present climate. Presented indicators are of utmost importance for each season: summer – increase of dry and very hot period, winter – increase of very heavy precipitation and decrease/disappearance of snow pack.*

FOREWORD

This Study aims to support the Western Balkans region in creating its sustainable development cycle coordinated by the priorities of the WB economies, which is in compliance with global and EU responsibilities, releasing some burden of extensive work expected from each economy to implement. It provides quantitative data for implementation of the South East Europe 2020 Strategy, decision-making process and supports further advance in the work of the Regional Working Group on Environment. In addition to its initial motive, the Study analyses and outlines the issues of cross-border dependence, which require WB coordinated approach. Results obtained during this Study are beyond the presented conclusions, and hopefully will find purpose in further detail assessments of more specific issues related to future planning.

WESTERN BALKANS SUSTAINABLE DEVELOPMENT CYCLE

Like in natural cycles, for example cycles of energy, water and carbon, human activities must be coordinated by artificially created cycles, which are in compliance with natural ones, in order to sustain the survival. Development of industry disrupted the natural carbon cycle, which led to disorder in other natural cycles and thereby call in question sustainability of human life as it is. To restore natural balance and sustainability of human development, global effort has been reinforced to create artificial cycle of human society behaviour and harmonise it with nature. The complexity of such cycle requires coordination from global to local level, which means global sustainable development cycle (SDC) must be supported by regionally created gear wheals, i.e. regional SDCs.

The chart (Figure WB-SDC) describes simplified workflow or “cycle” of the functioning mechanism necessary to ensure human livelihood quality and sustainable development of a region, like the one sampled here – Western Balkans (WB) region. The foundation of WB SDC is information provided by the economies, mainly through their climate change policy framework. Following the chart, the main branches of the assessments performed by the economies are: climate change (climatological parameters and indices), and impacts on human health, economy sectors and environment reflected through number of indicators. Horizontal connections between activities related to the listed branches are very complex, and not presented here where WB SDC is in focus; however became important within economies’ self-assessment. All branches systematically trace climate change impact from bottom up, as listed in the chart. Human health is an exception, ending with risk assessment and not providing priorities, because every observed risk is considered important. The link between environment and climate change, marked with dashed line, has distinguished relation on global level, because natural processes triggered with global warming in total tend to increase climate change signals, such as melting of permanent snow and glaciers that lead to enhanced warming. This effect becomes more pronounced on smaller scales and is possible to reach significance at local level. After information from all branches are collected and coordinated, priorities are outlined. To this end, two more outputs are needed: assessment of benefit and complexity of proposed measures implementation, which considers cost analysis, and definition of future deadline for proposed activities. Economies’ self-assessment must be coordinated with strategies of the wider region and, finally, with global strategy.

Regional strategy of the wider region, which in this case is considered to be South East Europe (SEE) or European Union (EU), coordinates information from the region with global efforts stated in the Paris Agreement. It is more focused on mitigation activities related to reduction of GHG emissions, increase of energy production from renewable sources and energy efficiency. However, some of them include adaptation measures and measures for mitigation of climate change impacts on economies’ branches. The Paris Agreement tends to strengthen the latter and to engage economies to plan, implement and report on such measures. This reflects the main motive of this Study – to support adaptation and mitigation measures in favour of future climate change adapted economic development and to prevent or reduce negative impacts.

After coordinating assessments carried out by the economies with the planned regional strategy, WB priorities have been outlined. To continue WB SDC, regional WB cooperation must be established or existing must be strengthened. Also, in the absence of coordinated approaches in climate change branch in economies’ self-assessment, it is necessary to provide an integrated climate change assessment for the whole WB region that implements the latest Intergovernmental Panel for Climate Change Assessment Report (IPCC AR, in this case IPCC AR5) knowledge and approach in the analysis, which makes the results current and comparable to other regions and to global assessments. Collected information on WB priorities, cooperation and climate change impacts, must go through verification. It will confirm that they support the needs of each economy and their potential to implement proposed measures. The final outcome is the optimised list of priorities and recommendations for their implementation throughout the WB region. Implementation needs to be done within each economy separately with which WB SDC is completed.

The next and following go-passes (repetitions) of the SDC are supplemented with additional reporting on success of implemented measures and renewed economies' self-assessment, which provide up-date to prolonged regional strategy development. All listed activities contained within the branches showed on the chart need not be repeated if significant change has not been imposed, such as a new bounding agreement or new IPCC AR, etc. Thereby, the first SDC go-pass is most difficult to achieve and most extensive, but following cycles should be an efficient part of the complex global SDC.

WB SUSTAINABLE DEVELOPMENT CYCLE

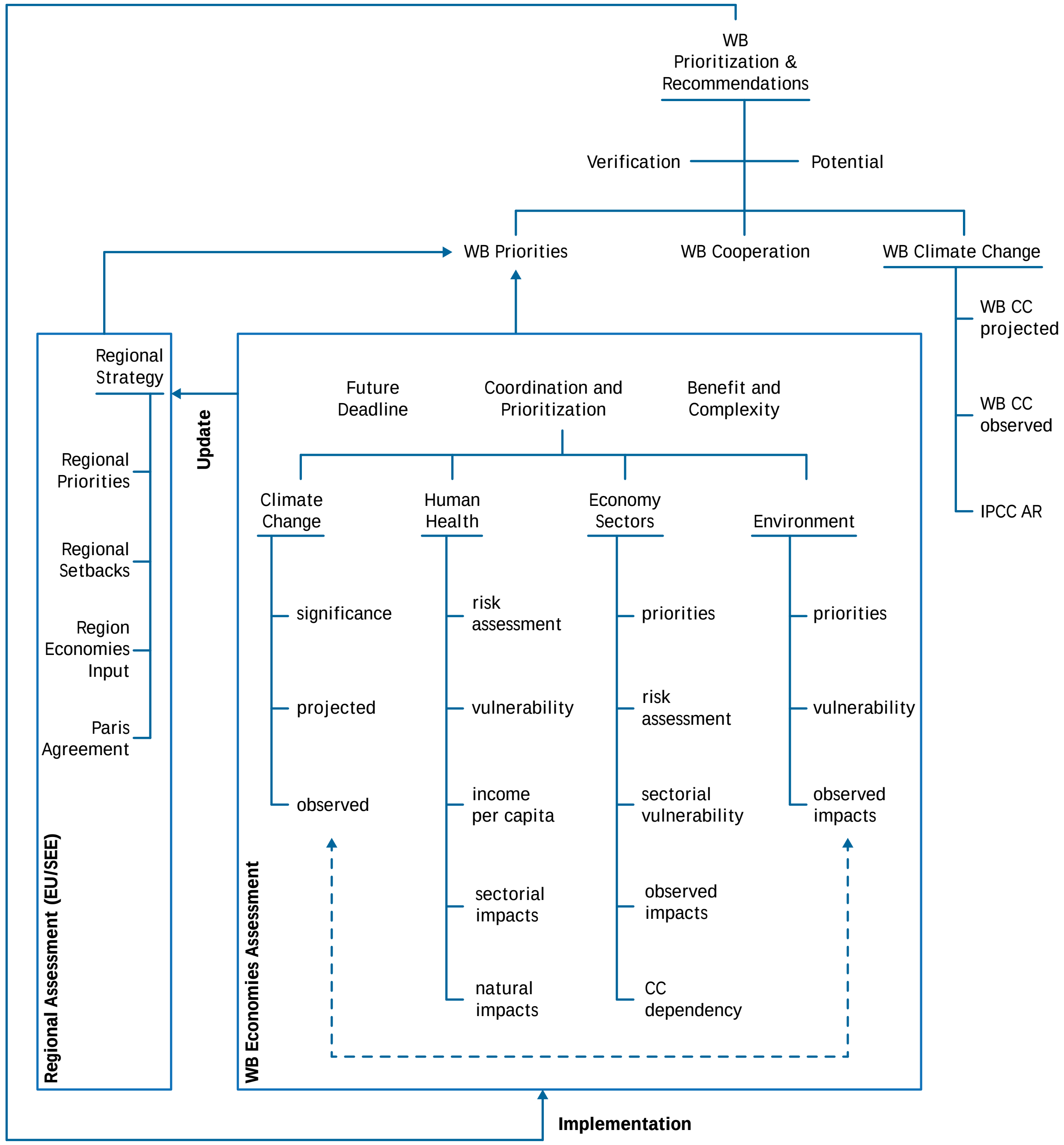


Figure WB-SDC. *The chart of Western Balkans Sustainable Development Cycle*

1. INTRODUCTION

Climate change is proven to manifest its negative impact on the Western Balkans region, with more pronounced changes than globally averaged. WB is the area with high spatial natural diversity and consists of six economies (Albania, Bosnia and Herzegovina, Kosovo*, Montenegro, Serbia and The Former Yugoslav Republic of Macedonia). Coordinated approach in studying climate change and planning the activities to mitigate negative impacts and to adapt to climate trend represents a challenge, however justified by strong motivation since economies individually recognised a lack of capacities to self-sustain in overcoming climate change related problems.

Activities related to climate change mitigation and adaptation, which lead to implementation of specific measures in practice and regulations in policies, are based on analysis of collected data to evaluate present state with necessary scientific upgrade involving climate modelling of the future. This highlights the uniqueness of climate change problem, where fast development and high reliability of scientific findings are required and immediately applied for the purpose of practice and decision-making up to the governmental level.

WB economies employed significant effort to collect and comprehend all relevant data and analysis for their region, consisting of natural, socio-economic and political issues and relating them to climate change mitigation and adaptation demands. Since WB economies are candidates for European Union (EU) accession (except Bosnia and Herzegovina and Kosovo*, which are recognised as potential candidates) and Parties (non-Annex I) to the United Nations Framework Convention on Climate Change (UNFCCC, except Kosovo* that, nevertheless, responds according to the requirements of the Convention), they are all motivated to implement EU2020 Strategy and meet EU2030 goals in GHG emission reduction and to increase energy efficiency and energy production from renewable sources, while regularly monitoring climate change and its impacts on different sectors, analysing future scenarios and prioritising adaptation measures in the effort to apply systematic approach in compliance with mitigation demands. This work requires dynamical approach because of the accelerated and devastating climate change impact on the WB region, indicating that regular update of knowledge, planning and implementation in practice is required. Combined with urgency and importance, such tasks require extensive and complex engagement and coordination of expertise in interdisciplinary, scientific, cross-sectorial, decision- and policy-making activities.

Collected knowledge on the related issues in the WB region indicates the common needs. The outlined features include a lack of human resources to deal with the climate change issues, high vulnerability and proposal for coordinated work at regional level to ensure sustainable development and improve life quality. Regional approach, motivated by implementation of SEE 2020 Strategy, must be initialised with integrated analysis of present and future climate change impacts for the whole region, ensuring comparability with Intergovernmental Panel on Climate Change 5th Assessment Report (IPCC AR5). This Study is employed to provide scientific base, the initial activity for latter prioritisation of measures and implementation in practise and policies, for the purpose of comprehending the climate change issues at regional level.

The Study contents is divided into the overview of most relevant information about the WB region to provide basic background knowledge, analysis of the observed climate change, analysis of the future climate change, highlights of the most pronounced climate change impacts with risk assessment, discussion on recommendations for the further studies and analysis derived from presented results and collected documentation, and final summary of this Study in concise form with outlined highlights that can be considered as stand-alone material.

2. BACKGROUND KNOWLEDGE

Six WB economies cover the area of about 208 000 km^2 and have population of about 18 million in total, with straight latitude-longitude distance north-south of about 700 km and west-east 670 km (Table 1). High natural and social spatial variability over the relatively small region complicate integral assessment, because of the large diversity of methodologies applied and number of documentation provided by each economy, which is the main motivation for implementation of this Study. Two most significant sectors in WB region are outlined: agriculture and forestry, because of their significance to GDP, income per capita and/or spatial area coverage (Table 1). They represent good examples for assessment and prioritisation in case of need for near future and for far future planning.

Table 1. WB economies relevant data

	Area (km^2)	Population	Agriculture (% of GDP)	Forest (% of area)
Albania [1]	[1]28 745	2 821 997	19.5	36
Bosnia and Herzegovina [1]	[1]51 209	3 791 622	8.6	53
Kosovo* [2]	[2]10 908	1 907 592	14.1	47
Montenegro [1]	[1]13 812	620 029	7.4	60
Serbia [1]	[1]88 361	7 058 322	10.0	29
The Former Yugoslav Republic of Macedonia [1]	[1]25 713	2 022 547	11.5	39

[1] Data are derived from National Communications;
[2] data is derived from Climate Change Framework Strategy.

WB region lies on a complex terrain, which spreads over the low altitude Pannonia valley on the north, hilly and mountain regions towards south and west, and coastal area of the Adriatic Sea (Figure 1). Higher areas are distinguished from low altitudes with 10°C isotherm. Highest values of annual precipitation are over the western part of the WB region, and in steep coastal areas, with decreasing gradient towards the east and south-east of WB. Climate and, consequently, spatial variability of vegetation coverage are natural treasures of this region. Hot summers and cold winters are reflecting the continental, but recently temperate continental climate at the north. Summers become mild in high altitudes with prolonged duration of higher snow. Coastal areas are characterised by sub-tropical Mediterranean climate, with hot summers and mild winters. Spatial and annual variation in precipitation in the region is under the influence of temperate continental and Mediterranean regime. Maximum precipitation in coastal areas is seen in the colder part of the year, and on the north during the late spring and early summer, leaving central parts as the mixture of both with prevailing influence depending on the location, i.e. distance from the sea.

WB economies are considered medium to highly vulnerable to climate change, because of the relatively high percentage of population employed in weather and climate related sectors, such are agriculture, forestry, tourism, etc. Also, high unemployment rate is an evident common setback for the whole region.

WB economies provided data, analysis and proposed measures related to climate change issues, adaptation and mitigation, with distinguished similarities:

- constant improvement in complexity of reporting and data analysis;
- undoubtedly proving and recognising that climate and, consequently, living environment and economic practice (except the introduction of new technologies) are no longer static or slowly evolving, but rather characterised by significant trend of change;
- high motivation to meet the requirements related to EU accession;
- extra effort to protect small stakeholders;
- harmonized implementation of mitigation and adequate planning of adaptation measures;
- highlighting the priority and necessity of integration of climate change aspects in existing environmental and other relevant policies;
- use the maximal potential to develop and implement strategy which leads to sustainable development and preferably sustainable increase of income per capita;
- introduce climate change in education and raise awareness;
- coordinate the inter-disciplinary and cross-sectorial collaboration through representative body (for example National Committee), which consists of parties from academia, government bodies, private sector and civil society and is under the responsibility of Ministry of Environment or other ministries with environmental obligations;
- besides other obstacles, all economies outlined a lack of sufficient human resources as significant problem to comprehend the wide range of activities and commitments under the UNFCCC.

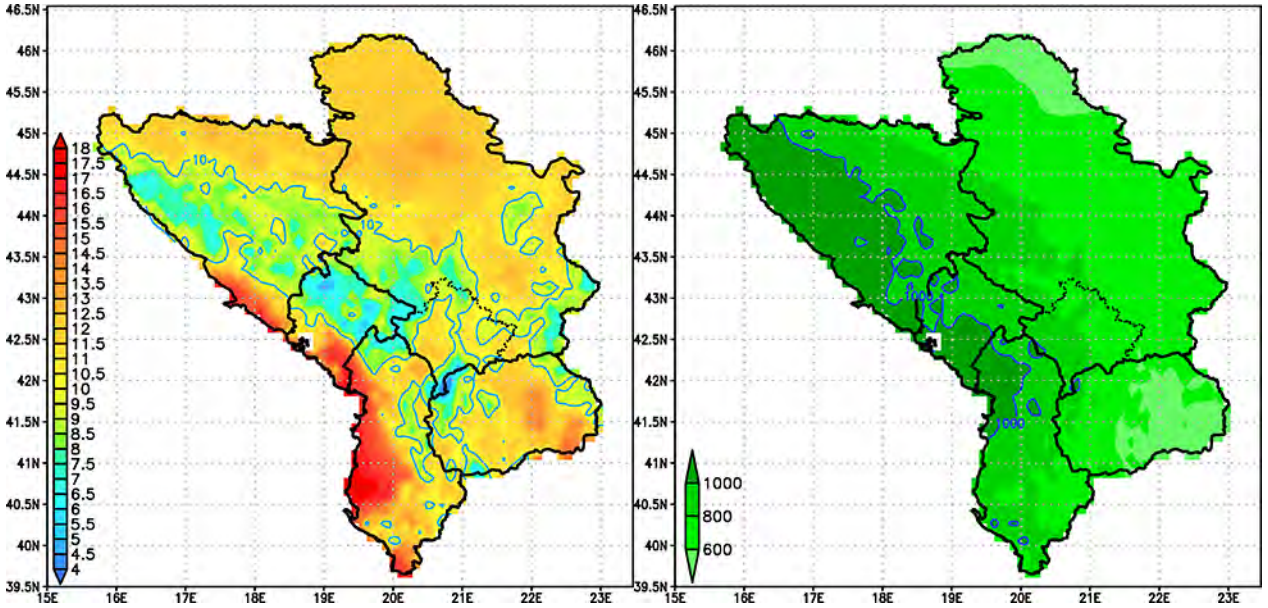


Figure 1. *Mean temperature and annual accumulated precipitation for the period 1996-2015*

General conclusions withdrawn from the available documentation (provided in the List of References) are:

- the whole region is under the significant increase of temperature, with most pronounced signal over Montenegro and Bosnia and Herzegovina, and lesser over The Former Yugoslav Republic of Macedonia;
- precipitation changes are not significant in general and are reported to increase over the most part of the region, except more pronounced decrease over Albania;
- expected future changes in general follow the observed trends, with more severe temperature increase and precipitation decrease during the summer by the end of the century;
- annual precipitation increase, with respect to the selected climatological baseline periods, will continue by the half of the century, when its tendency changes and starts to decrease over the region, which makes it important for long-term planning;
- annual regime and cumulative distribution of precipitation by intensity also change, favouring spread of sub-tropical regime further to the north with increase of high precipitation share in total values;
- consequences of climate change are well reviewed and are already evident mainly in sectors of agriculture, forestry and water resources, with occasional signals related to health;
- all economies reported high risk of extreme events: heat waves, droughts and floods;
- depending on economic priorities other sectors are also reviewed: tourism, cultural heritage, services, etc.

Adaptation priorities for reducing the vulnerability and risks, which are prioritised within the economies and have importance for the whole or major part of the WB region, are:

- *agriculture*: develop irrigation systems optimal to water resource capacities, reduce risk of late spring frost and high summer temperatures, optimise hybrid and variety selection and apply appropriate agro-technical measures to reduce the risk of reduction in yield mass and quality; better housing for livestock and regular food control; provide education to farmers;
- *water resources*: protect drinking water quality and optimise its consumption, develop and improve water supply systems, and avoid unnecessary losses; improve monitoring of surface and underground watercourses; improve river management and protect vulnerable areas from flooding;
- *forestry*: improve protection from fires by strengthening monitoring capacities and readiness for fire suppression; monitor and protect from pests, fungi and diseases; implement long-term planning for species displacement to reduce climate change induced mortality;
- *health*: improve emergency response during the extreme events; improve monitoring of drinking-water quality; improve dissemination of information related to health risk; monitor appearance of new diseases especially the ones carried by vectors (insects);
- *other*: participate in early warning system development and warning dissemination and improve preparedness of general public; improve monitoring related to biodiversity; protect cultural heritage from extreme weather events; focus summer tourism development at higher altitudes and prevent losses during mild winter seasons in ski centres; create seeds treasury of rare and autochthonous varieties to prevent their extinction; introduce climate change knowledge in education to ensure sustainable development, etc.

Quantifying integrated conclusion on the severity of climate change impact for the whole WB region, and spatial distribution of vulnerability and risk assessments, has several setbacks due to the difference in methodologies used for economies' self-assessment:

- use of different baseline period as climatological normal;
- use of different models, statistically downscaled Global Climate Models (GCMs) or Regional Climate Models (RCMs), some with and some without models bias (systematic model error) correction;
- use of different scenarios, but still mainly relying on IPCC AR4 scenarios.

Taking into consideration knowledge collected on the WB region climate change related issues, this Study aims to provide basis for further work in this field enabling upgrade of assessment and planning with regional component, and possible regional cooperation on common issues.

This Study recognised the need for integrated regional analysis of climate change in the WB area by using the methodology which implies high quality and reliability of the results and supplements the collected knowledge. This unified approach quantifies the global warming impact on climate change on regional level and is in compliance with IPCC AR5, which is the main scientific support to the Paris Agreement, signed by WB economies (except Kosovo* that is not part of the UNFCCC, but responds according to the requirements of the Convention).

3. OBSERVED CLIMATE CHANGE

This section will provide concise analysis of the observed climate change in the WB region, using analysis of the observed temperature and precipitation and collected knowledge on the observed impacts reported by the WB economies, relevant on the regional level.

To evaluate impact of global warming on climate change throughout the WB region, two meteorological parameters are selected: temperature (daily mean, maximum and minimum) and precipitation (daily accumulation). Daily values for the period 1961-2015 are analysed, defining the period 1961-1980 as the "past" climate baseline period, and 1996-2015 as the "present" climate period. The trend of temperature increase became significant since the 1980s in the WB region which supports the selection of the past climate period as the one with closest characteristics to the preindustrial climate, since longer period of observation before the 1960s is not available in the required quantity and quality. Use of 20 years for climatological period is in accordance with the IPCC AR5 and with the next Chapter of this Study, where future climate change results are presented. More details on the methodology used for observed data manipulation and data sources can be found in the Appendix.

3.1 Observed temperature and precipitation change

Average temperature for the whole region in the present climate period is 10.9°C, and has increased by 1.2°C with respect to the past climate period. Annual accumulation of precipitation averaged over the region did not change; the present climate value is 807 mm with 0.2% change relative to the past climate. Figure 2 shows mean annual values for the WB area averaged values, together with moving averages for different averaging intervals (5, 10 and 20 years) with the values assigned to the last year of the averaged period. This approach provides better comprehension of temperature and precipitation climatological and sub-climatological change. Results show that significant temperature increase began during the 1980s. Precipitation has been reducing during the 1980s and 1990s to then begin to increase and returned, in present climate, to the values from the period defined as past climate. This is the reason for a small change of 0.2%.

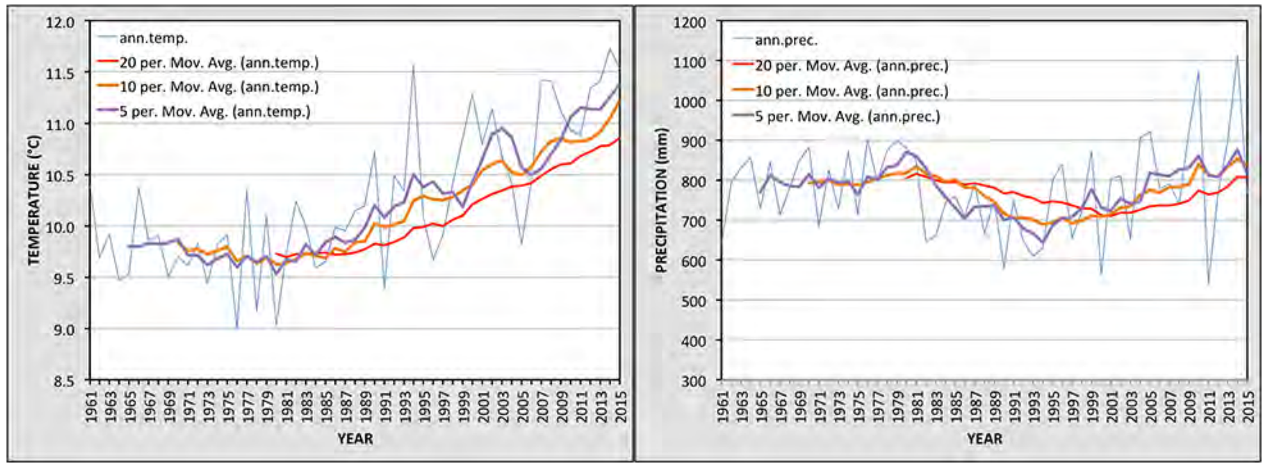


Figure 2. *Mean temperature and annual accumulated precipitation averaged over the WB region, and moving averages for 5-yr, 10-yr and 20-yr period, with values assigned to the last year of the averaged period.*

Spatial variation of the difference between the present and past climate annual values is presented in Figure 3, together with average 10-year trend slopes. Temperature increase is intensifying from south to north. Over The Former Yugoslav Republic of Macedonia and central and south Albania changes are in the interval from 0.5°C to 1.0°C, and over the north Albania and other four WB economies within the interval 1.0-1.5°C. Average 10-yr trend calculated for the whole 1961-2015 period has similar spatial distribution of intensity of change, with values from 0.15°C to 0.2°C/10yr over the most part of the territory, decreasing towards the south, and increasing mainly over the central part of the region, exceeding the value of 0.2°C/10yr. Spatial distribution of the maximum (Tx) and minimum (Tn) temperature increase (provided in the Appendix) shows more intense Tn than Tx change in southeast parts of the region, exceeding 1.0°C. However, increase of Tx is much higher in northern part of Albania and over the territories of Kosovo*, Montenegro, Bosnia and Herzegovina and Serbia with values in the interval from 1.0°C to2.0°C. Tn increase over this area is mainly 0.5-1.5°C.

Spatial distribution of annual accumulated precipitation change shows a change in major part of the area within the interval from -5% to +5% in favour of precipitation increase, and in some parts of up to about 10% increase. Albania and western parts of The Former Yugoslav Republic of Macedonia show decrease and most pronounced signal on the side towards coastal area, mainly up to 20%. Average 10-yr trend calculated for the whole 1961-2015 period has similar spatial distribution, showing the trend of increase of mainly 10-20mm/10yr, but negative trend over Albania of 10-30mm/10yr, increasing towards the northern coastal region.

Seasonal analysis of temperatures and precipitation are done for the December-January-February (DJF – winter), March-April-May (MAM – spring), June-July-August (JJA – summer), and September-October-November (SON– autumn). Figures are available in the Appendix. Least affected seasons are autumn and spring with values for average mean, maximum and minimum temperature increase mainly within 0.5-1.5°C interval. Larger Tn than Tx increase is observed during autumn, while during spring larger Tx than Tn increase is observed. Winter season has temperature increase of 1-1.5°C over the largest part of the region, with more pronounced Tx increase of 1.5-2.0°C especially in the central parts. Heating during the summer season has undoubtedly the highest values. Mean annual temperature increase is 2-2.5°C over the large part of the region, mainly in Bosnia and Herzegovina, Montenegro and Serbia. Average maximum temperature increase has far more pronounced change than average minimum, with values of highest increase over 2.5°C mostly over Bosnia and Herzegovina, Montenegro and some parts of Serbia.

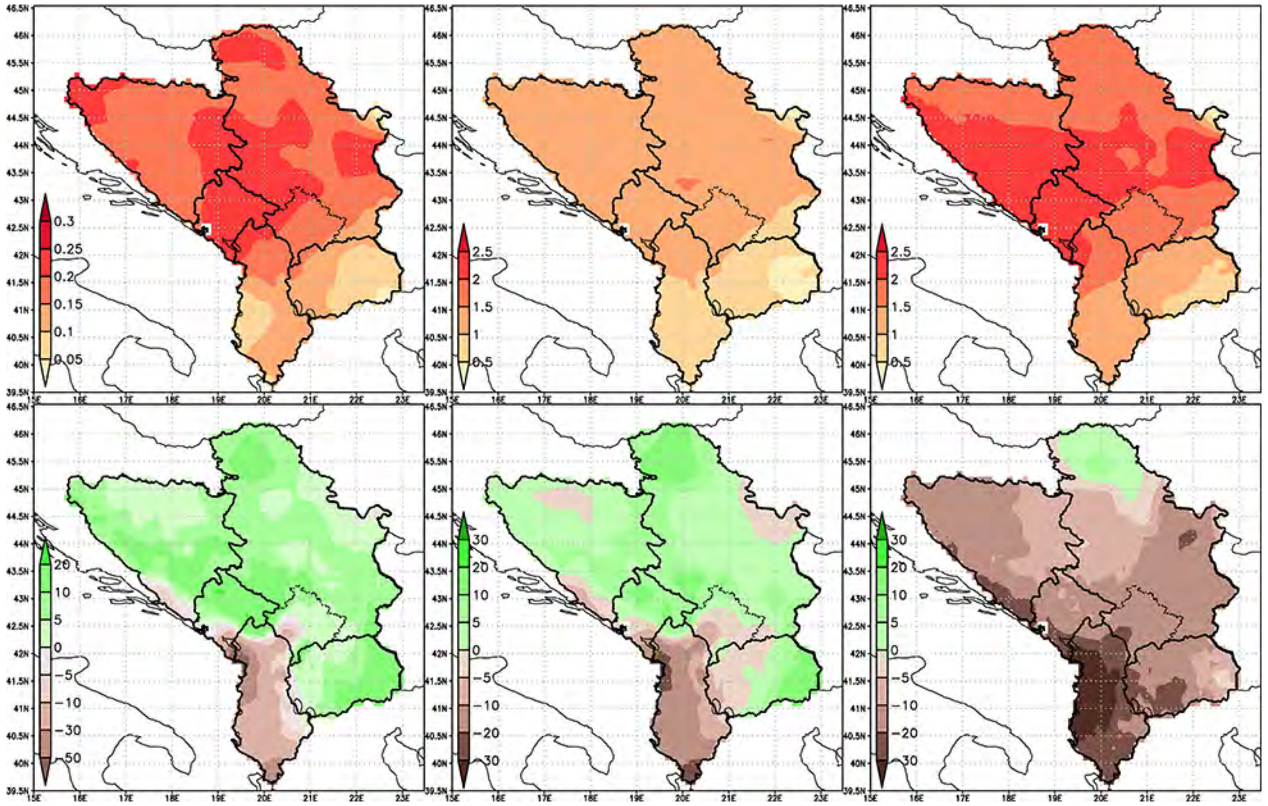


Figure 3. *Mean 10-yr trend for the period 1961-2015 (left panels) for temperature (°C) and annual accumulated precipitation (mm), mean temperature (°C) and annual accumulated precipitation (%) change (middle panels) and the same for JJA season (right panels) for present climate period with respect to the baseline period; temperature data are in upper panels and precipitation in lower panels.*

3.2 Observed change of climate indices and indicators

Presented results outstand the fact that temperature over the whole region is increasing faster than global average trend, with especially pronounced signal during the summer season and even more accelerated increase of maximum temperature which highlights the alarming disturbance of WB climate. Overall results of the analysis are in compliance with the observed climate change impacts listed in National Communications of the WB economies and provide regionally integrated data for risk assessment and prioritising the adaptation options of regional importance. Some of the common consequences of climate change impacts have more pronounced signal over the whole region:

- increased duration and frequency of heat waves and droughts;
- increased risk of flooding;
- forest degradation related to increased fire frequency and spreading, defoliation and mortality;
- early growing season start and high risk of late spring frost, decrease in yield quality during the years with warmer and/or drier growing period;
- decreased average river discharge and problem with drinking water quality and supply especially during summer season;
- increased energy consumption during summer season;
- increased health and safety risks.

In addition to the climate change impacts of regional importance, diversity of significant impacts is outlined by the economies, which are observed to have high local importance. Results of this Study may support further analysis of these specific issues, because of the high spatial resolution analysis.

4. FUTURE CLIMATE CHANGE

The main task in this Chapter is to present the future climate change impacts in compliance with IPCC AR5 approach analysing the temperature and precipitation, indices and indicators selected according to the highlighted priorities of the region.

Climatological periods for the analysis are adopted following the latest IPCC AR5: 1986-2005 as the baseline period; 2016-2035 as the near future period; 2046-2065 as mid-century period; and 2081-2100 as end of the century period. Selected periods serve the purpose of planning requirements for diversity of activities, for example agriculture finds most use in the near future planning, while the long-term predictions are needed in forestry and for water resources. For future periods two Representative Concentration Pathways (RCP) scenarios are selected, which find most use in planning activities, according to the current trends: RCP4.5 (stabilisation scenario, with GHG emission peak around 2040 and afterwards declining) and RCP8.5 (continuous rise scenario, where GHG concentration continues to increase by the end of the century, known as business-as-usual scenario). For proper preparedness for the upcoming changes RCP4.5 scenario will be considered as best possible scenario (lower end) and RCP8.5 as extreme scenario (higher end) in this Study. It should be stressed that according to the present trends it is more likely to reach climate disturbance prevailing towards RCP8.5 projections than to stay in stabilisation scenario, which requires the use of both for proper assessment. The high resolution multi-model approach has been applied, using CORDEX model results of nine Regional Climate Models (RCMs). This way most probable future outcome can be evaluated, and thereby impact studies, prioritisation and decision-making could be supported by data with high confidence. RCMs median value is adopted as most probable and used in analysis of the results. More information about the methodology for data manipulation and sources of data can be found in the Appendix.

Figure 4 presents moving average of the area averaged mean temperature for 20-yr periods (climatological intervals) for observed and ensemble median, maximum and minimum values, which demonstrates the spread of different model results and proves good choice of the ensemble.

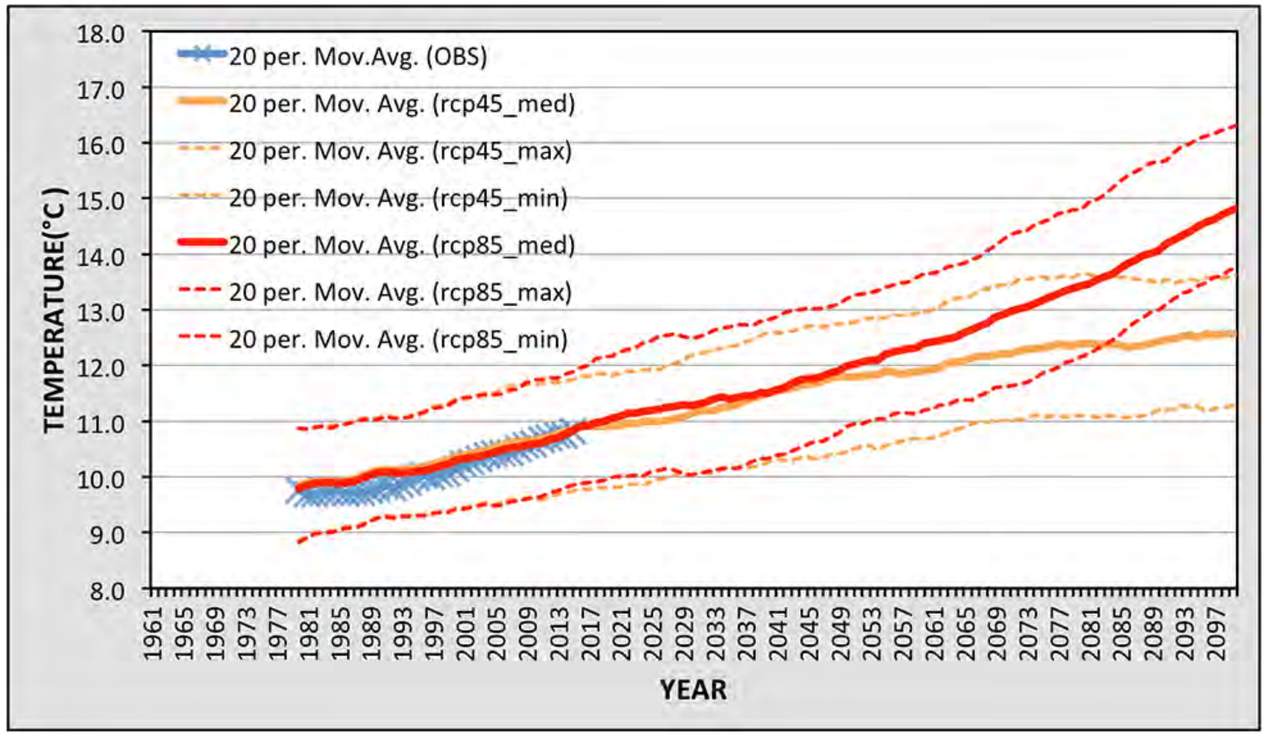


Figure 4. *Area averaged mean temperature 20-yr moving average for observed values and model ensemble median, maximum and minimum data according to the RCP4.5 and RCP8.5 scenario; averaged values are assigned to the last year of the 20-yr period.*

The ensemble median change is denoted as statistically significant if it is found that the change is significant for more than 50% of the models in the ensemble, and it distinguishes the change far beyond the natural variability.

In this Study the following climate parameters and indices have been analysed:

- standard climate parameters:
  - mean temperature, seasonal and annual;
  - mean minimum temperature, seasonal and annual;
  - mean maximum temperature, seasonal and annual;
  - mean annual and seasonal precipitation accumulation;
- temperature related indices:
  - number of frost days (Tn<0°C), annual;
  - number of icing days (Tx<0°C), annual;
  - number of very hot days (Tx>35°C), annual;
  - number of heat waves (at least 6 consecutive days with Tx>35°C);
  - average maximum length of heat waves;
- precipitation related indices:
  - number of days without precipitation;
  - number of days with very heavy precipitation (RR>20mm);
  - percent of total precipitation accumulated in days with very heavy precipitation;
- special climate indicators:
  - growing season duration, start and end date, for the biological minimum of 10°C;
  - very hot dry spells (HDS) – average maximum length of consecutive very hot and dry days and number of appearance of at least 6 consecutive days with Tx>35°C;
  - Seljaninov Hydrothermal Coefficient (SHC) and number of when values for April-September and June-August are both <1 – index that shows the climate suitable for maize growing;
  - Ellenberg's Climate Quotient (ECQ) – index that shows the climate suitable for beech growing.

According to the knowledge collected from the WB economies' documentation, significant reduction of maize yield is detected during the dry years, higher than of other crops. Seljaninov hydrothermal coefficient values lower than 1 show dry conditions for maize cultivation, 1-1.3 insufficiently humid, and above humid. It is calculated for the growing period of maize April-September and for the period June-August when maize needs water but is at high risk of draught. When both values are below 1 that year is considered unsuitable for maize growing without irrigation. Also, according to the collected knowledge, beech is spread wide across the region and its vulnerability has already been detected, which makes it a regionally important indicator. Ellenberg's climate quotient is used for assessment of suitable habitat for beech and mixed forest (beech and oak). If the values are below 20 it is considered that it is suitable for beech forest, and if values are between 20-30 beech can coexist with oak in mixed forest habitat.

4.1 Future temperature and precipitation change

The main climate parameters are averaged, mean maximum and minimum temperatures, and mean accumulated precipitation. Figure 5 and Figure 6 contain the most relevant maps of temperature and precipitation change while values obtained for all seasons and all scenarios can be found in the Appendix.

During the near future period (2016-2035) with respect to the baseline period (1986-2005) the expected temperature and precipitation changes are:

- according to the RCP4.5 scenario:
  - temperature change is significant over the whole region, with average increase of 0.8°C, and seasonally significant change is expected during the JJA and SON, with more significant change in Tn than Tx;
  - precipitation change has no significant change in annual nor in seasonal values over the region, mean annual accumulation change is within the -5% and +5% interval, with decrease over the major part of the region during the JJA;
- according to the RCP8.5 scenario:
  - temperature changes are significant over the whole region with average regional increase of 1.0°C, reaching highest increase during the JJA;

  - precipitation change shows similar signal as in stabilisation scenario, but with somewhat different distribution.

During the mid-century period (2046-2065) with respect to the baseline period (1986-2005) the expected temperature and precipitation changes are:

- according to the RCP4.5 scenario:
  - mean temperature area averaged increase is 1.6°C, with most pronounced change in JJA and in Tx, within the values between 2.0°C and 3.0°C over the major part of the region;
  - precipitation change still does not show statistically significant change in mean annual accumulation nor in seasonal values, but the annual values decrease tend to spread over the region, and during JJA the whole region suffers the decrease;
- according to the RCP8.5 scenario:
  - mean temperature area averaged change is 2.1°C, and spatial analysis shows above 2.0°C over the major part of the region during the most part of the year;

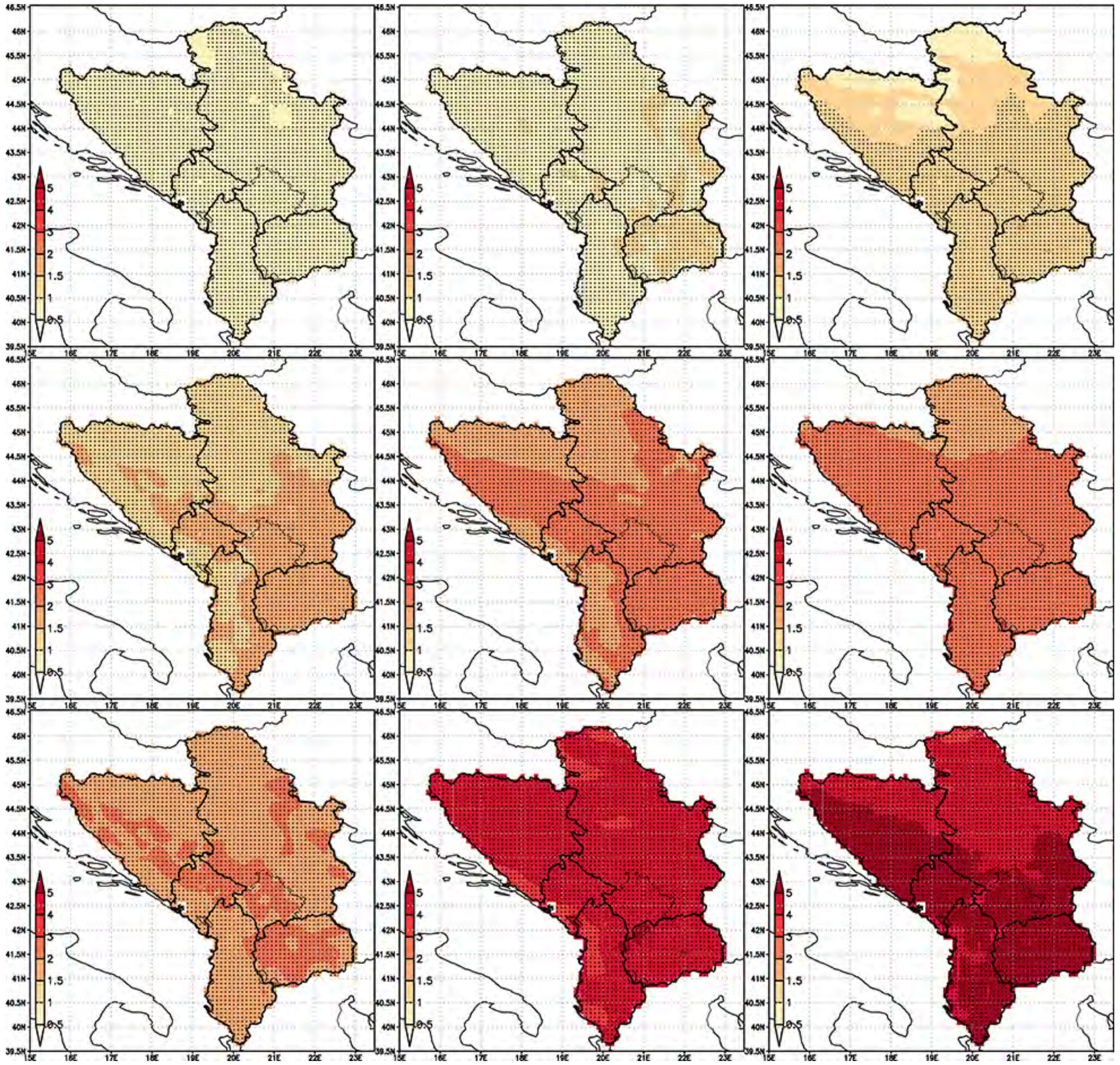


Figure 5. *Temperature change (°C) for the near future (top row), mid-century (middle row) and end of the century (bottom row) periods with respect to the baseline period for mean annual values according to RCP4.5 (left), to RCP8.5 (middle) and mean JJA maximum temperature according to RCP8.5 (right); statistical significance is marked with dots.*

  - precipitation change decrease becomes significant over Albania and part of Montenegro during JJA and, including The Former Yugoslav Republic of Macedonia but not statistically significant, the values of decrease are over 20%; other seasons and annual values do not show significant change.

During the end of the century period (2081-2100) with respect to the baseline period (1986-2005) the expected temperature and precipitation changes are:

- according to the RCP4.5 scenario:
  - temperature increase shows stabilisation and area averaged increase is 2.0°C, with more pronounced increase of Tx during the JJA and SON;
  - precipitation change is stabilised, as noticed in the temperature change, stayed over the southern parts of the region, where values are over 20%;
- according to the RCP8.5 scenario:
  - temperature will not stabilise and will continue to significantly increase, reaching area averaged value of 4.4°C, with most pronounced

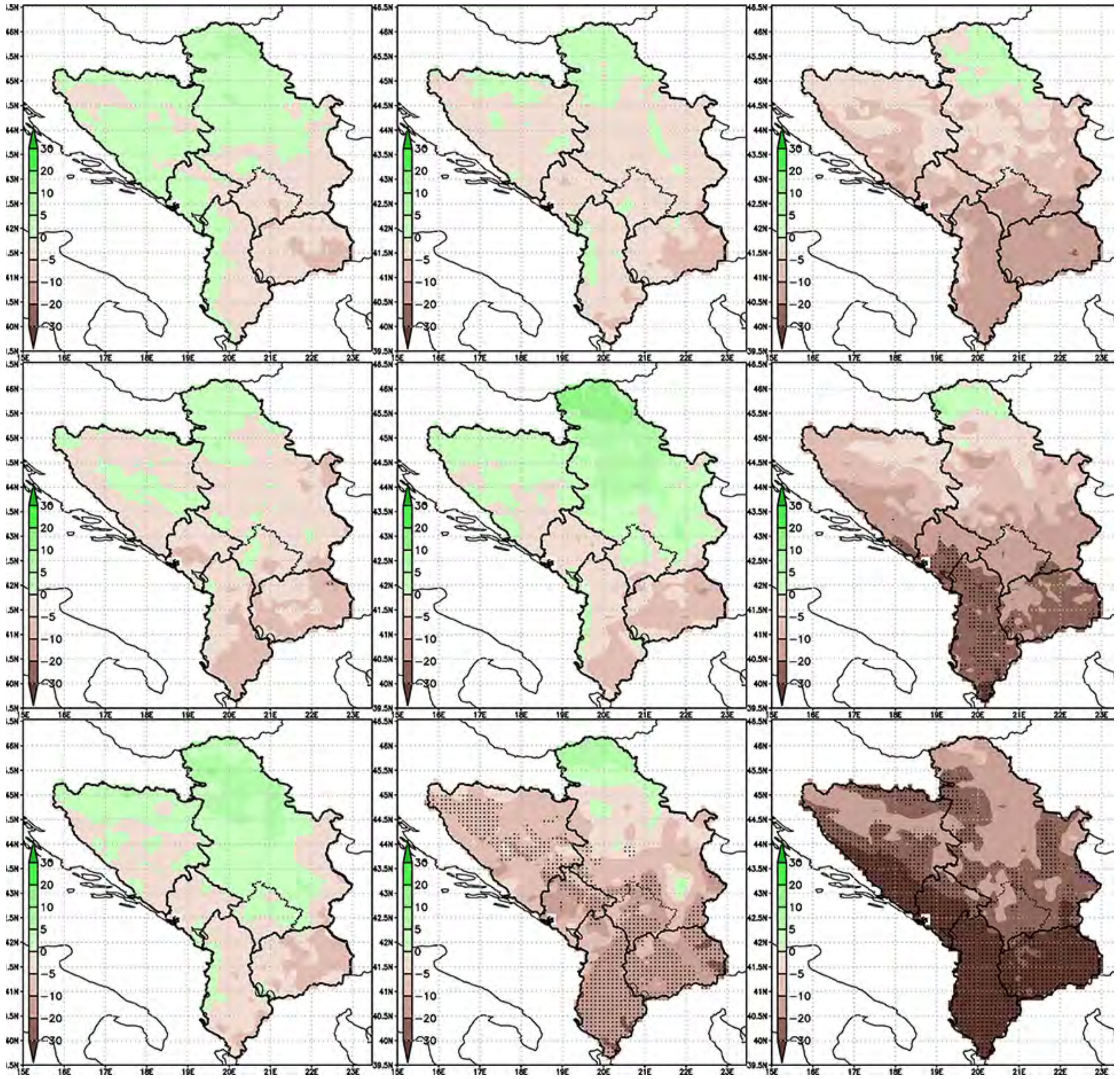


Figure 6. *Accumulated precipitation change (%) for the near future (top row), mid-century (middle row) and end of the century (bottom row) periods with respect to the baseline period for mean annual values according to RCP4.5 (left), to RCP8.5 (middle) and mean JJA according to RCP8.5 (right); statistical significance is marked with dots.*

increase during JJA with values over 5.0°C over major part of the region;

- precipitation decrease is significant in annual values, because of the severe decrease during the JJA season, over 20%, over the large part of the region and even over 30% in southern Bosnia and Herzegovina, Montenegro, Albania, and The Former Yugoslav Republic of Macedonia, except in northern part of Serbia where significant increase is expected during the DJF.

4.2 Future change of climate indices and indicators

The most significant findings related to the temperature and precipitation indices and specifically selected climate indicators are listed in this Section. Change of some selected indicators is presented in Figure 7, while other results can be found in the Appendix.

During the near future period (2016-2035) with respect to the baseline period (1986-2005) the following changes are expected:

- number of frost days is expected to decrease by 5-10 days according to RCP4.5 scenario, but with significant decrease (10-20 days) over the southern and higher altitude parts of the region;
- number of icing days tend to decrease by 0-5 days with possible higher decrease over some mountain areas in central parts;
- number of very hot days will increase by 5-10 days and with higher significant values over some parts (coastal areas of Albania, Podgorica region in Montenegro, The Former Yugoslav Republic of Macedonia, northern and central Serbia, and some parts of Bosnia and Herzegovina);
- average heat waves length and frequency of appearance are slightly increasing with highly probable significant change over some regions in southern parts, which signals the increase in probability of appearance to be more extreme than observed; especially in coastal areas of Albania, southern Bosnia and Herzegovina, Podgorica region in Montenegro and southeast of The Former Yugoslav Republic of Macedonia;
- change in the number of dry days is not significant, but it is more pronounced during summer, and annually tend to increase by 5-15 days over the region, mainly during the JJA, except in northern parts;
- very heavy precipitation increase in number of days and percentage of total accumulation are not statistically significant, but are most pronounced over the northern part of Serbia (Vojvodina) according to RCP8.5, as well as an increase of very heavy rain accumulation percentage;
- duration of growing season is expected to increase by 10-20 days, with somewhat more pronounced shift towards the earlier dates (5-10 days) throughout the region; this change has significance for some parts that have higher increase in temperature (southern and western parts);
- HDS is slightly increasing, mainly over southern parts;
- SHC shows shift towards dry conditions mainly over Serbia and towards insufficiently humid in other relevant parts, and over 10 years in this 20-yr period (even up to 14 years in lowest altitudes) will become unsuitable for maize growing without irrigation;
- ECQ shows reduction of suitable territory for beech survival over some small parts (for example in east Serbia), and in general retreatment towards higher altitudes, but potentially significant since the signals of vulnerability are already observed.

During the mid-century period (2046-2065) with respect to the baseline period (1986-2005) the following changes are expected:

- significant decrease of frost days throughout the whole region by 10-20 days according to RCP4.5 and 20-30 days according to RCP8.5 scenario in major part of the region;
- significant decrease of icing days throughout the whole region by 5-10 and 10-20 days according to RCP4.5 and RCP8.5 respectively;
- significant increase of very hot days in parts of lower altitudes (10-20 days), but most pronounced in coastal and near coastal areas and central to south-eastern part of The Former Yugoslav Republic of Macedonia (20-30 days);
- duration and frequency of heat waves appearance have significant increase over the low altitudes, coastal and near coastal areas and parts of The Former Yugoslav Republic of Macedonia, reaching values of +1 heat wave each year and with increased duration over 5 days or more;
- increase of dry days is 5-10 days over the major part of the territory, with significant change in southern parts (within Albania and The Former Yugoslav Republic of Macedonia); the change is most pronounced during JJA;
- number of days with very heavy precipitation shows noticeable increase throughout the region, significant over the north parts of Serbia (Vojvodina), while in regions which already have large number of such days the increase is much lesser relative to the present values; very heavy rain percentage has most increase over the region where these events are not common (north Bosnia and Herzegovina, Serbia, Kosovo*, parts of The Former Yugoslav Republic of Macedonia), even of around 30% during DJF and MAM, while during JJA the decrease is seen over the southern part of the region, and according to RCP8.5 increase in Vojvodina becomes significant;
- growing season is expected to have significant increase of up to 20-40 days, depending on scenario, in favour of early start date in most parts of the region of up to 20-30 days; however in coastal areas heating almost caused disappearance of dormant season for the plants with biological minimum of 10°C;
- HDS coincide with heat waves, which means that periods with hot temperatures will be combined with very dry periods;
- SHC shows wider spread of dry conditions mainly over Serbia, while in other parts insufficiently humid climate for maize is spreading, the number

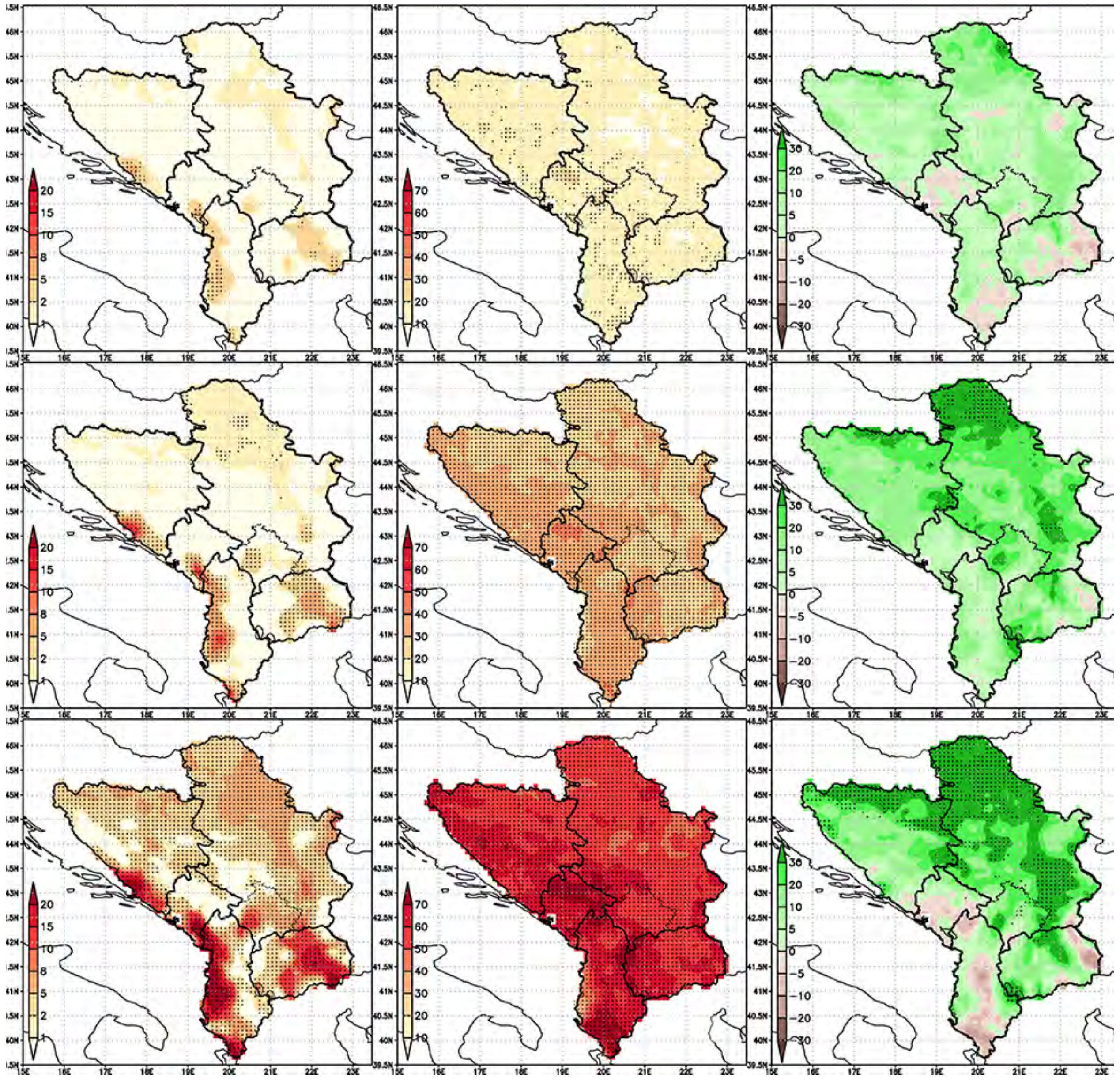


Figure 7. *Change of average maximum length of very hot dry spells (in days, left), growing season duration (in days, middle) and change of total precipitation accumulated in days with very heavy precipitation (in %, right) during the near future (upper panels), mid-century (middle panels) and end of the century (lower panels) period; all presented results are according to RCP8.5, while RCP4.5 results are presented in the Appendix.*

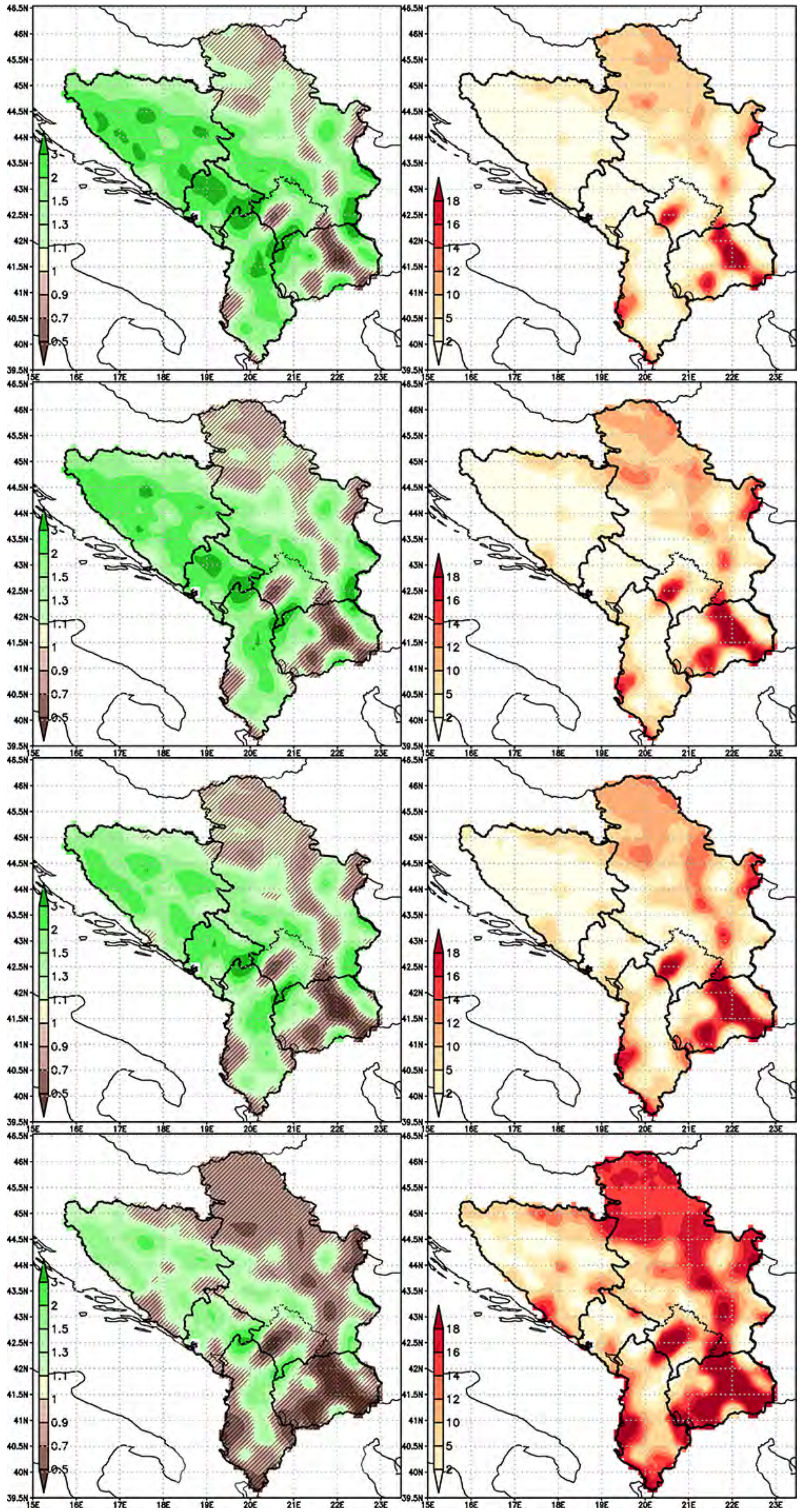


Figure 8. *SHC values for the baseline period, near future, mid-century and end of the century period (from top to bottom – left panels), where shaded area marks the need for planning (yellow) or necessary (brown) irrigation, and number of years (of total 20yr period) with both SHC (April-September and June-August) values bellow 1 – unsuitable for maize growing; all presented results are according to RCP8.5, while RCP4.5 results are presented in the Appendix.*

of years unsuitable for maize growing without irrigation in 20-yr period is very possible to be more than 14 over the north and central Serbia;

- ECQ index shows increase in unsuitable climate conditions and further retreatment towards higher altitudes, for both mixed and beech forest.

During the end of the century period (2081-2100) with respect to the baseline period (1986-2005), and considering that by the end of the century RCP4.5 scenario stabilises, more pronounced changes are expected according to the RCP8.5 scenario. According to RCP8.5 the following changes are expected:

- decrease of frost days is over 50 days over the whole region, which makes it a rare event, and icing days will appear only in mountain regions but with a decrease of over 25 days;
- appearance of hot days in higher altitudes, increase by 20-30 days in lower altitudes, and most pronounced increase in coastal and near coastal areas and large part of The Former Yugoslav Republic of Macedonia and Kosovo* of over 35 days;
- frequency of heat waves is increasing up to 2 days over the whole region with prolonged duration of 5-10 days; it is possible for heat waves to appear in high altitudes once in 10 years, but coastal, near coastal areas, large part of The Former Yugoslav Republic of Macedonia and Kosovo* are expected to have 2-5 more heat waves during a year with increased duration of over 15 and in coastal areas even over 20 days;
- increase in very heavy precipitation days is significant, reaching values between 5-10 days in some northern parts of the region and southern Serbia, being especially pronounced during DJF; very heavy precipitation percentage follow the same pattern of change, however over the coastal, near coastal and southern part of the region (Albania) decrease is significant during JJA, with values of over 30%;
- growing season period will be prolonged by 50-70 days, with more pronounced change in the higher altitudes, and with larger shift of the start date, the values reaching over 30 days throughout the whole region, with over 40 days in southern parts, and over 50 days in south Albania;
- HDS have highly significant change over the region showing prolonged duration throughout the whole region, except in highest altitudes, of over 8 days in Serbia and over 20 days in coastal areas;
- SHC shows unsuitable conditions for maize growing, and in most productive areas almost all years during this period will not be productive;
- ECQ index shows high risk of forest mortality, and highly probable widespread disappearance of beech.

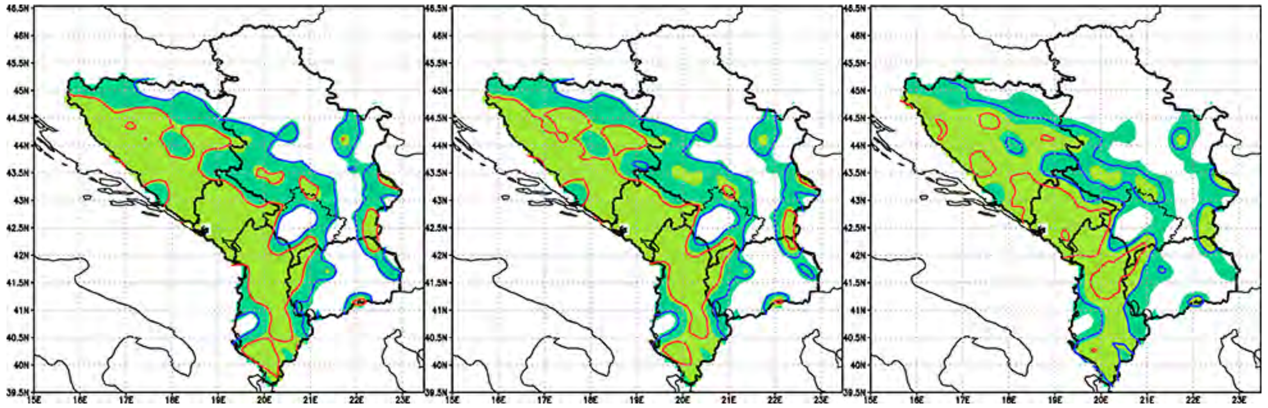


Figure 9. *Suitable climate conditions in baseline period for mixed beech-oak forest (dark green) and for beech forest (light green), with assessment of suitable conditions of mixed (blue line) and beech (red line) forest for near future (left), mid-century (middle) and end of the century (right); assessment is done using ECQ and presented results are according to RCP8.5, while RCP4.5 data are presented in the Appendix.*

Additionally, evaluation of suitable beech habitat change by altitude is done. The percentages of total WB region with suitable climate conditions for mixed beech-oak forest and beech forest by altitude and in total are presented in Table 2. Going further to the future, decrease of suitable climate conditions for beech survival is noticeable on higher grounds throughout the WB region. Continuous decrease in percentage of area with suitable climate conditions is significant by the end of the century, which means that already observed vulnerability will inevitably increase and extend.

Table 2. Percentage of WB region with suitable climate conditions for mixed beech-oak forest and beech forest over different altitudes, according to RCP4.5 and RCP8.5 scenarios.

	RCP4.5				RCP8.5			
	1985-2005	2016-2035	2046-2065	2081-2100	1985-2005	2016-2035	2046-2065	2081-2100
	mixed beech-oak & beech forest				**mixed beech-oak & beech forest**			
alt <500m	20.0	19.4	16.9	17.6	20.3	18.6	18.1	12.3
alt 1000m	24.6	23.1	21.1	21.8	24.6	22.5	21.8	15.2
alt 1500m	15.5	15.1	14.6	14.6	15.6	15.0	14.7	12.2
alt 2000m	4.2	4.2	4.1	4.1	4.2	4.2	4.1	3.7
alt >2000m	0.4	0.4	0.3	0.4	0.4	0.4	0.3	0.3
total	64.8	62.2	57.0	58.5	65.2	60.8	59.0	43.7
	beech forest				beech forest			
alt <500m	6.7	6.1	4.2	4.2	6.8	5.4	4.5	1.7
alt 1000m	12.7	11.3	9.1	9.0	13.0	10.4	9.3	3.6
alt 1500m	11.2	10.1	8.3	8.3	11.2	9.8	8.5	4.2
alt 2000m	3.7	3.4	3.1	3.2	3.7	3.3	3.1	1.6
alt >2000m	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
total	34.7	31.2	25.0	25.0	35.1	29.3	25.8	11.5

5. CONCLUSIONS ON IMPACTS OF CLIMATE CHANGE AND RISK ASSESSMENT

Based on the previous results, observed and projected climate change and its impacts, and results obtained from relevant official documents in the region, the important regional high risk changes are as follows:

- intrusion of sub-tropical climate to the north;
- increase of heat waves, dry days and extreme precipitation;
- more pronounced rotation of severe drought and heavy rains, with appearance of extreme storms in summer that most likely cause flash floods, severe high winds and hail damage.

When it comes to impacts on sectors those are:

- *agriculture*:
    - extreme disturbance of phenology dynamics,
    - increased risk of late spring frost in the near future,
    - decrease in yield mass and quality progressively by the end of the century and gradual decrease in climate suitability for present varieties,
    - livestock breeding at high risk due to high temperatures, possible food quality decrease and highly probable degradation of pastures,
    - increased land erosion and degradation, related to intensive precipitation events and severe droughts with high temperatures;
- *forestry*:
    - high risk of widespread forest degradation related to the increased fire frequency and spreading, flash floods and mortality because of the faster climate change than natural migration,
    - widespread disappearance of present taxa (varieties) over the region;
- *water resources:*
    - decrease or absence of snow cover in high altitude regions, spring river discharge decrease and reduced regeneration of soil water reservoir,
    - highly probable decrease of summer river discharge, longer and more frequent hydrological droughts,
    - increased frequency of high intensity precipitation, increased risk of flash and river floods,
    - highly probable seasonal deficiency in drinking water;
- *human health:*
    - increase in frequency and intensity of heat waves,
    - highly probable drinking water quality reduction,
    - highly probable wider spreading and intrusion of new vector-borne diseases;
- *other:*
    - degradation of natural habitats because of the slower natural migration of species than the climate change intensity,
    - highly probable increased risk in land transport infrastructure related to the increase in flood frequency and intensity, extreme temperatures, soil erosion and landslides.

It is worth mentioning that somewhat drier conditions are expected during the mid-century according to the RCP4.5 (stabilisation) scenario and related indices and indicators have more pronounced changes than under RCP8.5 (extreme) scenario; however in general both scenarios results show similar patterns of change by the half of the century. By the end of the century RCP8.5 shows much more pronounced changes and is recommended to be considered as higher end threshold for future planning.

In addition to the selected indicators related to agriculture and forestry, it is of utmost importance to study water resources in more details, since the obtained results point out to alarming disturbances in this sector. This is beyond the scope of this Study since long-term hydrology observations were not available.

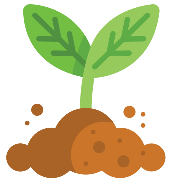
The selected top priorities at regional level, outlined from the most urgent ones and having in mind capacities for their implementation, are:

- protect human health and safety;
- adapt food production by implementing recommendations on variety and hybrid selection and on optimal agro-technical measures; provide housing for livestock;
- develop sustainable irrigation systems, optimal to water availability;
- supress forest degradation by immediately implementing the long-term planning;
- optimise energy production/availability according to inter-annual consumption assessment.

The listed priorities recognise the human health and safety as the top priority in the WB region, and consider the protection from extreme weather events, outbreaks of new diseases, ensuring food quality and availability, and protection of the living environment.

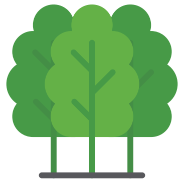
Overall analyses of the **climate change** in the western Balkans recognise the **human health, safety and life quality** as highly vulnerable to natural hazards and sectorial weather related losses.

Following sectors will experience the biggest impacts:



AGRICULTURE

(food quality decrease, land erosion and degradation, etc)



FORESTRY

(high risk of widespread forest degradation , disappearance of present taxa, etc)

WATER RESOURCES

(deficiency in drinking water, etc..)

HUMAN HEALTH

(increase of heat waves, intrusion of new vector-borne diseases, etc)

Data: RCC's Study on Climate Change in the Western Balkans Region, May 2018

6. RECOMMENDATIONS

Having in mind the selected top priorities mentioned in the previous Chapter, which require attention of each WB economy, it is possible and of high importance to outline the recommendations that are most applicable and effective if implemented at regional level. To reduce burden on a single WB economy in resolving climate change related issues, in particular given the lack of human resources and other capacities, it is highly recommended to enhance and focus regional cooperation on the following priorities:

- implement reliable WB regional early warning system and provide efficient information dissemination;
- implement regional long range weather forecast system (from monthly to seasonal) and provide data dissemination among relevant sectors in order to optimise recommendations needed for agriculture and energy sector;
- ensure exchange of knowledge and expertise on regional level by strengthening regional intra- and inter- disciplinary communication, in order to provide best quality information for decision-makers and best climate change policy implementation, as presented in this Study;
- increase quality of regional risk assessment, prioritisation and decision-making with exchange of observed data and cross-border communication;
- continue regional planning and prioritisation of common issues, more detailed analyses and long-term planning.

Top priority recommendation for the WB region is to ensure human health, safety and life quality including development of warning systems, information dissemination and preparedness of the general public, supported by readiness of governmental institutions related to disaster risk management. Exchange of expertise and share of responsibilities at regional level are measures with the best cost-benefit ratio to strengthen capacities and identify the potential of WB economies to provide contribution at regional level.

A good example for implementation of the proposed activities are Draught Management Centre for South-Eastern Europe (DMCSEE), and South-East European Multi-Hazard Early Warning Advisory System (SEE-MHEWS-A) initiated by the World Meteorological Organisation (WMO). For efficient implementation of top priority measures, it is highly recommended to deploy and expand the activities of South-East European Consortium for Operational Weather Prediction (SEECOP) established in March 2015 and supported by the directors of hydro-meteorological services of the WB economies.

Medium to long-term weather forecasting, which includes statistical assessment, finds its use in planning of activities, particularly in agriculture and energy sector, providing data necessary for risk and financial loss reduction. Responsible institution for climate monitoring and long-term forecast in the region is South East European Virtual Climate Change Centre (SEEVCCC) hosted by the Hydrometeorological Institute of Serbia. It is recommended to expand its activities to serve the regional needs and sectorial priorities, and to ensure dissemination of information.

Reduction of climate change risk and impact by applying adaptation measures in the upcoming decades is well analysed in officail documents prepared by WB economies. In addition to activities on GHG emission reduction integrated in the EU accession process, increase of energy efficiency and energy production from renewable sources, and having in mind complex work in implementation of climate change policy related to adaptation and risk reduction measures, it is highly recommended to apply "a parallel" approach and implement adaptation measures simultaneously at governmental and stakeholder levels. Action plans for implementation of strategies on climate change should promote implementation of adaptation measures using a bottom-up approach. This means involving a wide range of stakeholders and citizens and increasing their awareness and knowledge on ways to protect their livelihood.

Climate change impact assessment should be an integral part of planning activities (such as planning of construction of roads and dams, designing of irrigation systems, etc.) regulated by new standards and regulation to be adopted by relevant authorities. In this way, climate and related threats would be considered as variable in time, and thereby possibilities of false assessment based on past climate data would be avoided. Standards should define the length of past and future periods for climate analysis, according to the planned activities, and propose revision of this analysis. A good example is agricultural production which is highly dependent on weather and relays on subsidies provided under the legislation.

This Study is developed based on IPCC AR5 report, by identifying common needs with the aim to provide added value to climate change impact assessment on local level. High resolution multi-model approach provides detailed data with high reliability, appropriate for use in separate analysis of WB economies. It also reduces the burden of extensive work related to regular reporting to the UNFCCC and strategic planning. It is highly recommended to establish a WB regional database with high resolution gridded daily observed database (possibly on 1 km resolution) with permissions for use regulated by MoU and if necessary, database of high resolution bias corrected ensemble climate models data, which are selected and recommended by the relevant experts. Such WB climate change database can significantly contribute to increasing the efficiency and quality of climate change impact and risk assessment.

Results and recommendations from this Study should support WB economies in developing their policy frameworks, following integrated regional approach in implementation of adaptation measures and mitigation of negative climate change impacts in the WB region. The following Chapter presents the EU policy on climate change and provides information on actions carried out in the WB region.

7. CLIMATE CHANGE POLICY FRAMEWORK IN THE WB REGION

Climate policy framework of the economies in the region is created based on the obligations under the UNFCCC and the process of accession to the EU (except Kosovo* that, nevertheless, is motivated to respond according to the requirements of the Convention). All economies in the region, which are the UNFCCC Parties, have non-Annex I status, meaning that they are obliged to submit National Communications (NC) and Biannual Updated Reports (BUR). Submission of the NC is an obligation defined under the UNFCCC, while new reporting obligation was introduced in 2015 through the BUR submissions. The latter was introduced in order to enhance reporting in NCs of Annex I Parties, to present progress in achieving emission reduction, and to report on provision of financial, technology and capacity-building support to non-Annex I Parties.

All economies in the region which are UNFCCC Parties regularly prepare and submit their NCs and BURs (financially and technically supported by the Global Environmental Facility (GEF) while implementing agency, usually United Nations Development Programme (UNDP), present their national and regional development priorities, objectives and circumstances, on the basis of which they will address climate change and its adverse impacts. In accordance with the UNFCCC rules the NCs of the economies in the region contain information on observed climate change and scenarios, as well as assessment of vulnerability and adaptation measures, including identification of most vulnerable areas. Moreover, all of the economies submit their Intended National Determined Contributions (INDC) as their contribution to the Paris Agreement on Climate Change. The UNFCCC latest recommendation is to include vulnerability and adaptation (V&A) assessment in revised and updated National Determined Contributions (NDC). GHG emission reduction targets are an integral part of INDCs of UNFCCC Parties from the region, while V&A is already included in Serbian INDC.

From the policy perspective, the process of accession to the EU is more demanding and detailed. However, at the same time it provides good basis for better and more efficient fulfilment of obligations under the Paris Agreement, especially when it comes to achievement of GHG emission reduction targets that are submitted (by the economies in the region) as part of their INDCs.

The EU climate policies are defined for the specific period of time. Therefore, for the period 2013-2020, the EU climate legislative framework contains six main pieces of legislation, collectively called the climate and energy package (adopted in April 2009):

1. Directive 2009/29/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 2003/87/EC so as to improve and extend the greenhouse gas emission allowance trading scheme of the Community;

2. Decision No 406/2009/EC of the European Parliament and of the Council of 23 April 2009 on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020, referred to as the Effort Sharing Decision;

3. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC15;

4. Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels;

5. Regulation (EC) No 443/2009 of the European Parliament and of the Council of 23 April 2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO2 emissions from light-duty vehicles;

6. Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009 on the geological storage of carbon dioxide.

The EU's Policy framework for climate and energy in the period from 2020 to 2030 (EU 2030) and Roadmap for moving to a competitive low carbon economy in 2050 (EU 2050) are the two documents of highest importance for the upcoming decades. Legislative tools for the first policy framework are currently under development, while the Roadmap for 2050 provides long-term strategic framework.

In the context of reporting, including to the UNFCCC, the EU Regulation 525/2013 of the European Parliament and of the Council of 21 May 2013 on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change and repealing Decision No 280/2004/EC (Monitoring Mechanism Regulation, MMR) is of highest importance. The availability of solid statistical information is still one of the essential elements of the EU climate policy. Therefore, transposition and implementation of this piece of legislation in WB economies is particularly important, and at the same time it will ensure better and more efficient reporting to the UNFCCC.

The process of EU accession requires full alignment of national legislation with the EU acquis (transposition), while the negotiation process between the European Commission (EC) and specific EU candidate determines the deadlines for full implementation for each specific piece of legislation in the economy in question. Due to the status of EU candidate, WB economies (except Kosovo* and Bosnia and Herzegovina) are in the process of transposition of the above mentioned EU legal acts.

Certain progress is seen in all WB economies in the field of renewables and energy efficiency, mainly owing to the obligations under the Energy Community Treaty signed by all WB economies more than a decade ago.

Preparation of Low Carbon Development Strategy (LCDS) is important from both perspectives: obligations under the UNFCCC and the EU. In this respect, it is important to mention that Serbia is in the process of finalising, while The Former Yugoslav Republic of Macedonia is in initial stage of planning the preparation of the LCDS. Other WB economies prepared their LCDSs mostly as a framework rather than a detailed operational plan specifying all necessary actions. Moreover, with the Paris Agreement and request for updating of INDCs, there is a need for update of LCDSs as well. In addition, these strategies need to be implemented in a way that is consistent with the EU 2030 framework on climate and energy policies and the EU 2050 low carbon economy roadmap, and well integrated into all relevant sectors.

Concerning adaptation, there are no obligatory provisions in the EU legislation. Only the MMR prescribes the necessity to report on status of national adaptation planning and strategies, outlining implemented and planned actions to facilitate adaptation to climate change. At the same time, the Paris Agreement underlines the need for development of National Adaptation Plans (NAPs) and establishment of appropriate and efficient processes for planning and implementation of adaptation measures and actions. The WB economies, except Serbia and The Former Yugoslav Republic of Macedonia, have prepared their NAPs. Green Climate Fund provides financial resources (up to US$ 3 million) to the UNFCCC Parties for establishment of planning and implementation processes for adaptation measures and actions, including development of NAPs.

Taking into account the obligations under the UNFCCC, the process of harmonisation with the EU acquis and high vulnerability of the region, development of legislation transposing the MMR could significantly contribute to better adaptation planning and its integration into all relevant sectors. Moreover, joint identification of vulnerability and adaptation possibilities, as the main motive for development of this Study, as well as implementation of adaptation actions and measures at regional level, could ensure climate resilient and sustainable development of all economies in the WB region.

LIST OF ABBREVIATIONS

AR	Assessment Report
BUR	Biannual Updated Report
CORDEX	Coordinated Regional Climate Downscaling Experiment
DJF	Winter season (December-January-February)
DMCSEE	Draught Management Centre for South-Eastern Europe
EC	European Commission
ECQ	Ellenberg's Climate Quotient
EU	European Union
GCM	Global Climate Model
GEF	Global Environmental Finance
GHG	Greenhouse gasses
HDS	Very hot dry spells
INDC	Intended National Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
JJA	Summer season (June-July-August)
LCDS	Low Carbon Development Strategy
MAM	Spring season (March-April-May)
MMR	Mechanism for monitoring and reporting greenhouse gas emissions
NAP	National Adaptation Plan
NC	National Communication
NDC	National Determined Contribution
RCM	Regional Climate Model
RCP	Representative Concentration Pathways
RR	Precipitation
SDC	Sustainable Development Cycle
SEE	South East Europe
SEECOP	South-East European Consortium for Operational weather Prediction
SEE-MHEWS-A	South-East European Multi-Hazard Early Warning Advisory System
SEEVCCC	South East European Virtual Climate Change Centre
SHC	Seljaninov Hydrothermal Coefficient
SON	Autumn season (September-October-November)
Tx	Maximum temperature
Tn	Minimum temperature
UNFCCC	United Nations Framework Convention on Climate Change
UNDP	United Nations Development Programme
V&A	Vulnerability & adaptation
WB	Western Balkans
WMO	World Meteorological Organisation

LIST OF DOCUMENTS AND RELEVANT LINKS

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Pavicevic S., *Climate Change Vulnerability Study in Montenegro*, 2012

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Second National Communication of the Republic of Albania under the United Nations Framework Convention on Climate Change, Ministry of Environment, Forestry and Water Administration, Albania, 2009

"Second National Communication on Climate Change of the Republic of Macedonia under the United Nations Framework Convention on Climate Change", Ministry of Environment and Physical Planning, The Former Yugoslav Republic of Macedonia, 2008

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SEE2020 Strategy - Jobs and Prosperity in a European Perspective, Regional Cooperation Council, 2013

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www.instat.gov.al (Institute of Statistics of Albania)

www.mvteo.gov.ba (Ministry of Foreign Trade and Economic Relations of Bosnia and Herzegovina)

www.fmoit.gov.ba (Ministry of Environment and Tourism of the Federation of Bosnia and Herzegovina)

www.vladars.net (Ministry of Spatial Planning, Civil Engineering and Ecology of the Republika Srpska)

www.bhas.ba (Statistical Agency of Bosnia and Herzegovina)

www.mmph-rks.org (Ministry of Environment and Spatial Planning of Kosovo*)

www.ask.rks-gov.net (Statistical Agency of Kosovo*)

www.mrt.gov.me (Ministry of Sustainable Development and Tourism of Montenegro)

www.monstat.org (Statistical Office of Montenegro)

www.ekologija.gov.rs, www.klimatskepromene.rs (Ministry of Environment of Serbia)

www.stat.gov.rs (Statistical Office of the Republic of Serbia)

www.moepp.gov.mk, www.klimatskipromeni.mk (Ministry of Environment and Spatial Planning of The Former Yugoslav Republic of Macedonia)

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http://dmcsee.org/ (Draught Management Centre for South-Eastern Europe)

https://public.wmo.int/en/projects/see-mhews-a (South-East European Multi-Hazard Early Warning Advisory System)

http://www.seevccc.rs (South East European Virtual Climate Change System)

APPENDIX

A1. Methodology

A1.1 Methodology Applied in Observed Climate Change Analysis

Since daily data from meteorological stations were not available for this Study, eOBS database has been used as a source. Database provides daily data for the chosen period 1961-2015 interpolated on regular lat-lon grid with resolution 0.25°. Its quality depends on observations provided to the eOBS database, especially if they reflect local specific climate characteristics, which cannot be visible if observations are not available to eOBS. To be in compliance with climate model results used in Chapter 4, daily data have been interpolated on the climate models resolution of 0.11° to provide more detailed spatial representation. The method of successive corrections has been applied for interpolation of daily data, which considers exact location and altitude of the data and creates gradients of change on daily level. This approach is an optimal combination of simplicity, computational efficiency and quality of obtained interpolated fields. This approach is common in interpolation of observed data for initialising numerical weather prediction models.

A1.2 Methodology Applied in Future Climate Change Analysis

CORDEX database has been used as a source of model data and nine regional climate models have been selected (Table A1). The resolution of the models is 0.11° (~11-12km).

To avoid interference of systematic model error – model bias - in assessment that can lead to false conclusions and misleading results, which are meant to support decision-making, bias corrected model data have been used. Single model approach lacks the probability evaluation. Specific problem in the WB region, which highlights the necessity for this approach, is the precipitation spatial change in trend sign, showing increase north of the WB region and decrease on the south in most of the climate models. Borderline of trend change is shifted among the models over the WB region, especially with high deviation in low resolution global models. Using the high resolution multi-model analysis most probable future outcome can be evaluated, and thereby impact studies, prioritisation and decision-making can be supported by data with high confidence. RCMs median value has been adopted as most probable and used in analysis of the results.

Assessment of statistical significance of the selected parameters change is calculated using the t-test for each model, which has the purpose to distinguish the change far beyond the natural variability. The ensemble median change is denoted as statistically significant if it was found that the change is significant for more than 50% of the models in the ensemble.

Table A1. Selected ensemble of regional climate models (RCM), driven by global climate models (GCM) and CORDEX ensemble member code.

GCM	RCM	ensemble
CNRM-CERFACS-CNRM-CM5	CCLM4-8-17	r1i1p1
ICHEC-EC-EARTH	CCLM4-8-17	r12i1p1
MOHC-HadGEM2-ES.rcp85	CCLM4-8-17	r1i1p1
MPI-M-MPI-ESM-LR	CCLM4-8-17	r1i1p1
ICHEC-EC-EARTH	HIRHAM5	r3i1p1
ICHEC-EC-EARTH	RACMO22E	r1i1p1
MOHC-HadGEM2-ES	RACMO22E	r1i1p1
MPI-M-MPI-ESM-LR	REMO2009	r1i1p1
MPI-M-MPI-ESM-LR	REMO2009	r2i1p1

A2. Results of Observed Climate Change

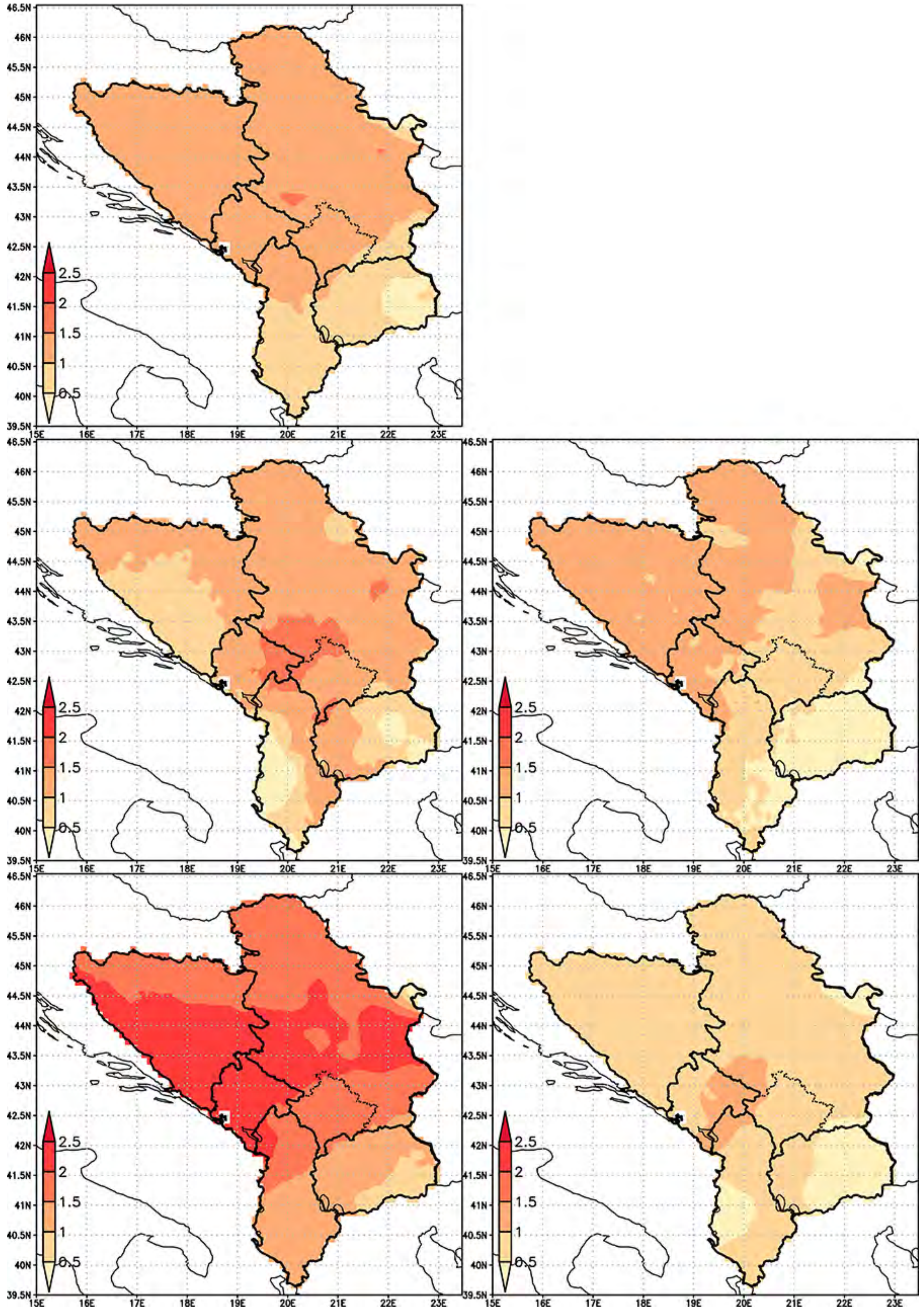

Figure A1. *Mean temperature change (°C) between 1996-2015 and 1961-1980 periods; annual in the upper row, DJF left in the middle row, MAM right in the middle row, JJA left in the bottom row, SON right in the bottom row.*

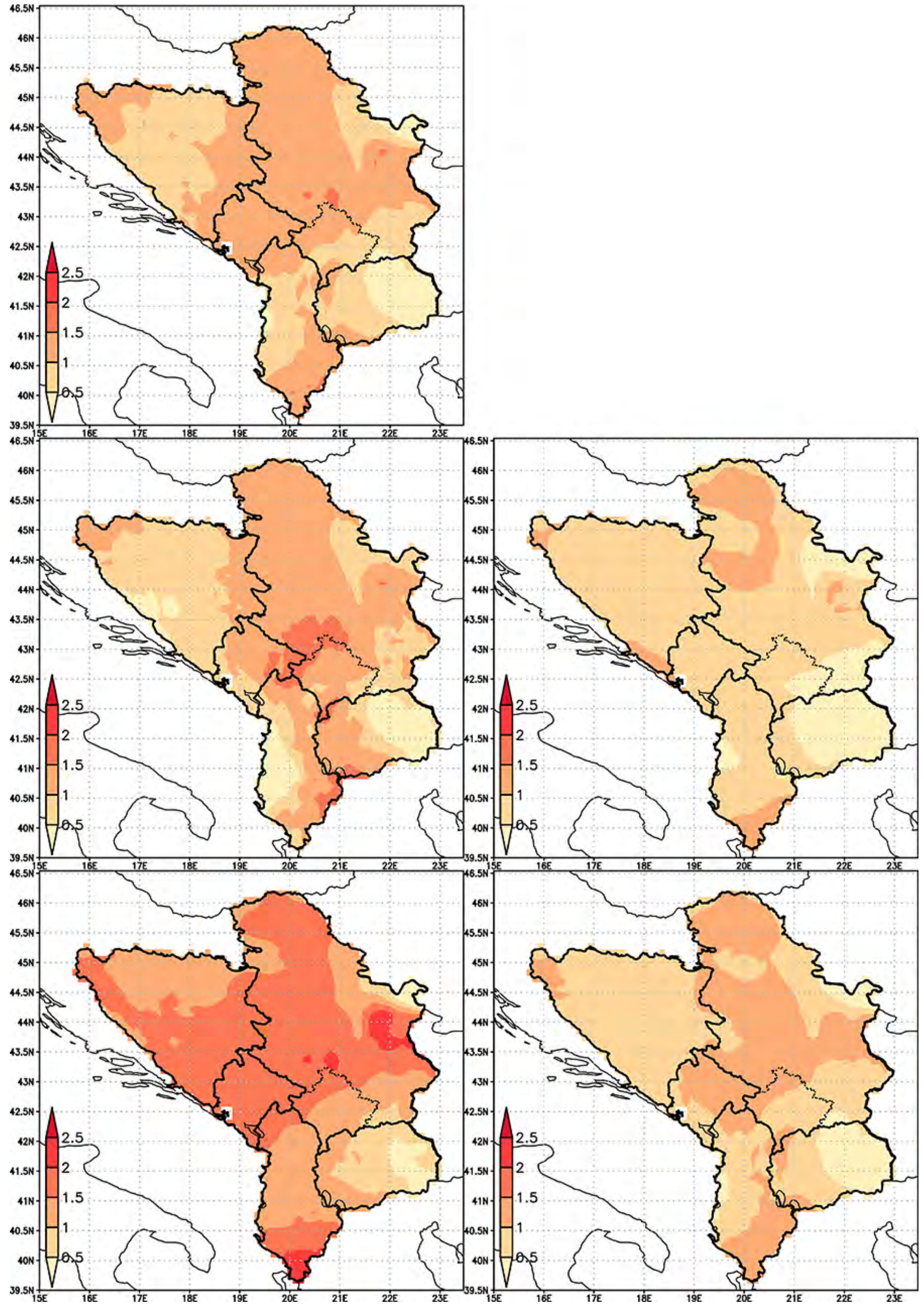

Figure A2. *Minimum temperature change (°C) between 1996-2015 and 1961-1980 periods; annual in the upper row, DJF left in the middle row, MAM right in the middle row, JJA left in the bottom row, SON right in the bottom row.*

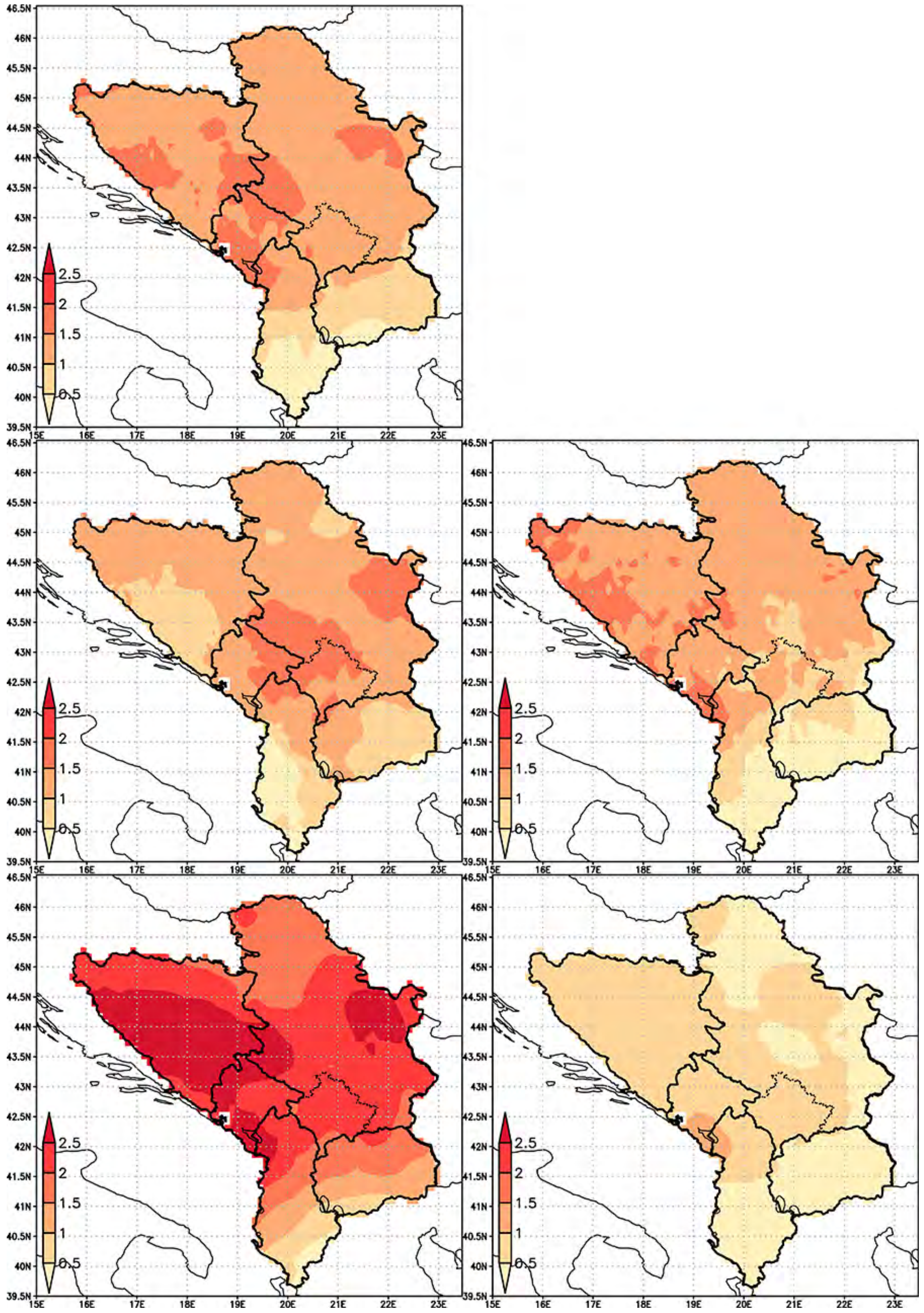

Figure A3. Maximum temperature change (°C) between 1996-2015 and 1961-1980 periods; annual in the upper row, DJF left in the middle row, MAM right in the middle row, JJA left in the bottom row, SON right in the bottom row.

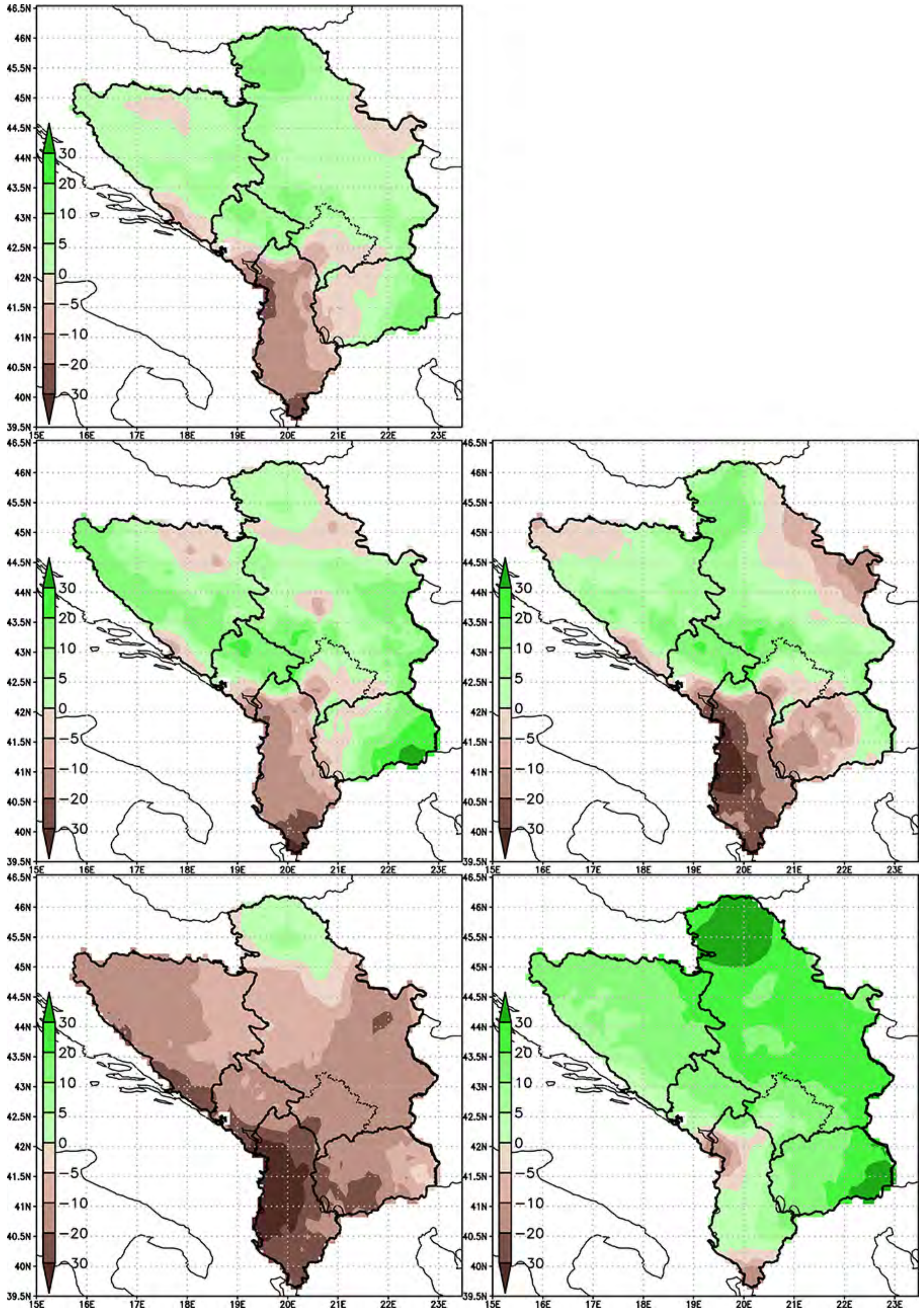

Figure A4. Accumulated precipitation change (%) between 1996-2015 and 1961-1980 periods; annual in the upper row, DJF left in the middle row, MAM right in the middle row, JJA left in the bottom row, SON right in the bottom row.

A3. Results of Future Climate Change

A3.1 Future temperature and precipitation change

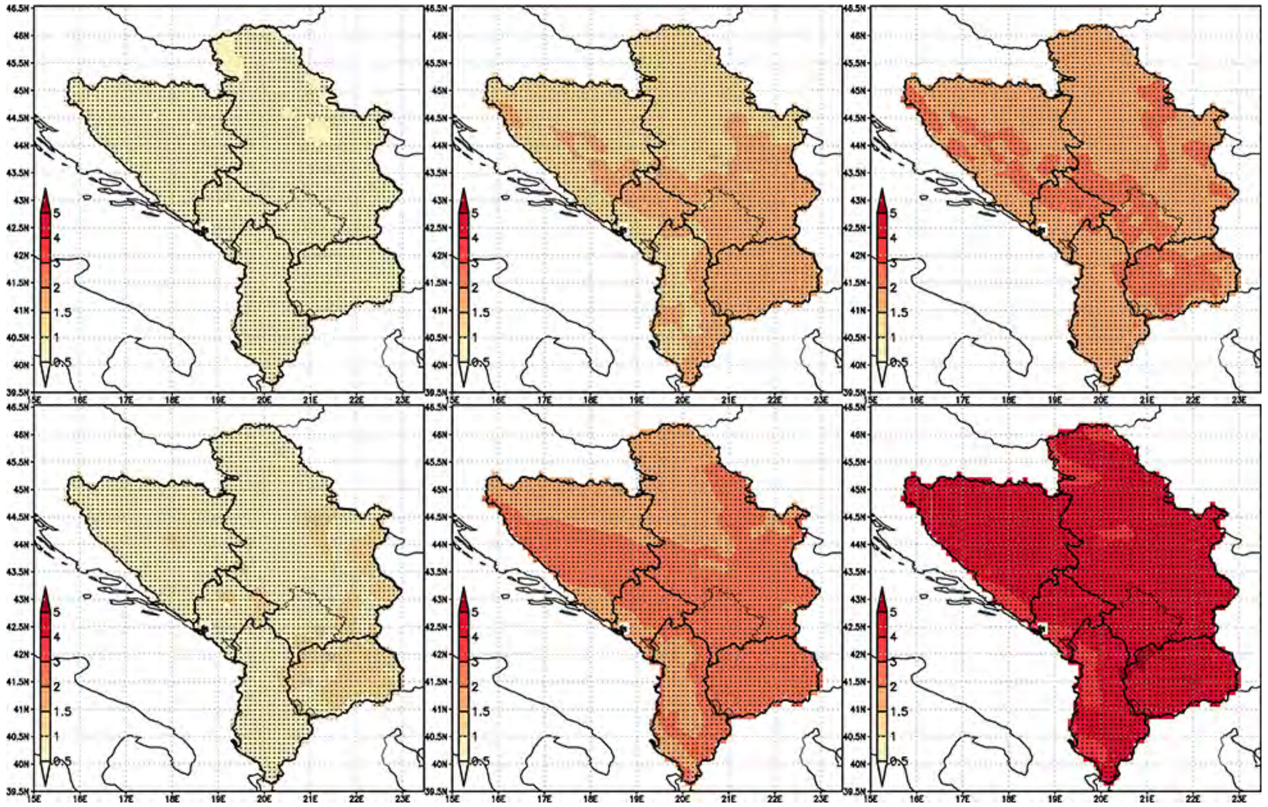

Figure A5. *Annual mean temperature change (°C) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1986-2005) according to the RCP4.5 (top row) and RCP8.5 (bottom row); statistical significance is marked with dots.*

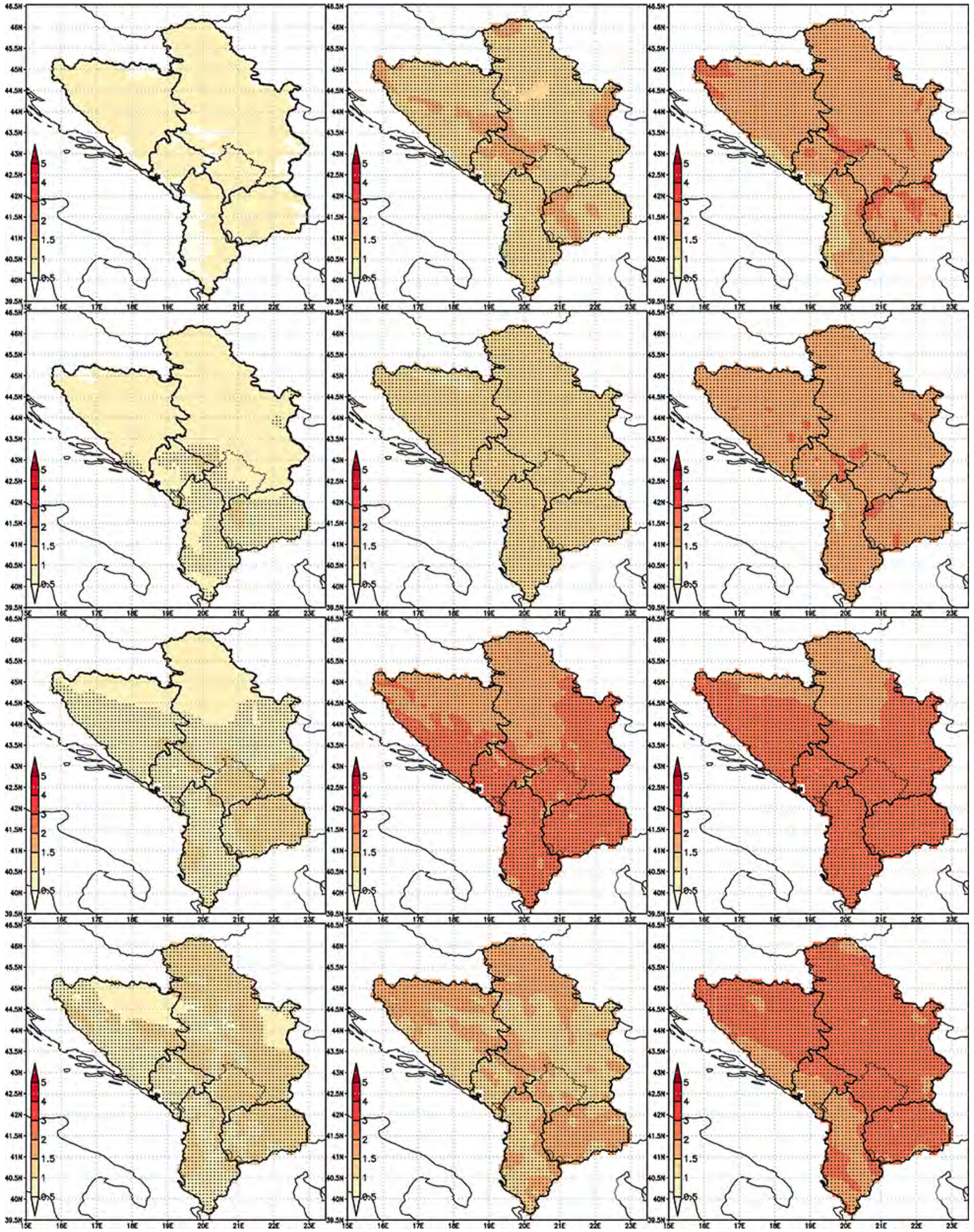

Figure A6. *Seasonal mean temperature change (°C) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1986-2005) according to the RCP4.5; DJF in the first row, MAM in the second row, JJA in the third row, SON in the fourth row; statistical significance is marked with dots.*

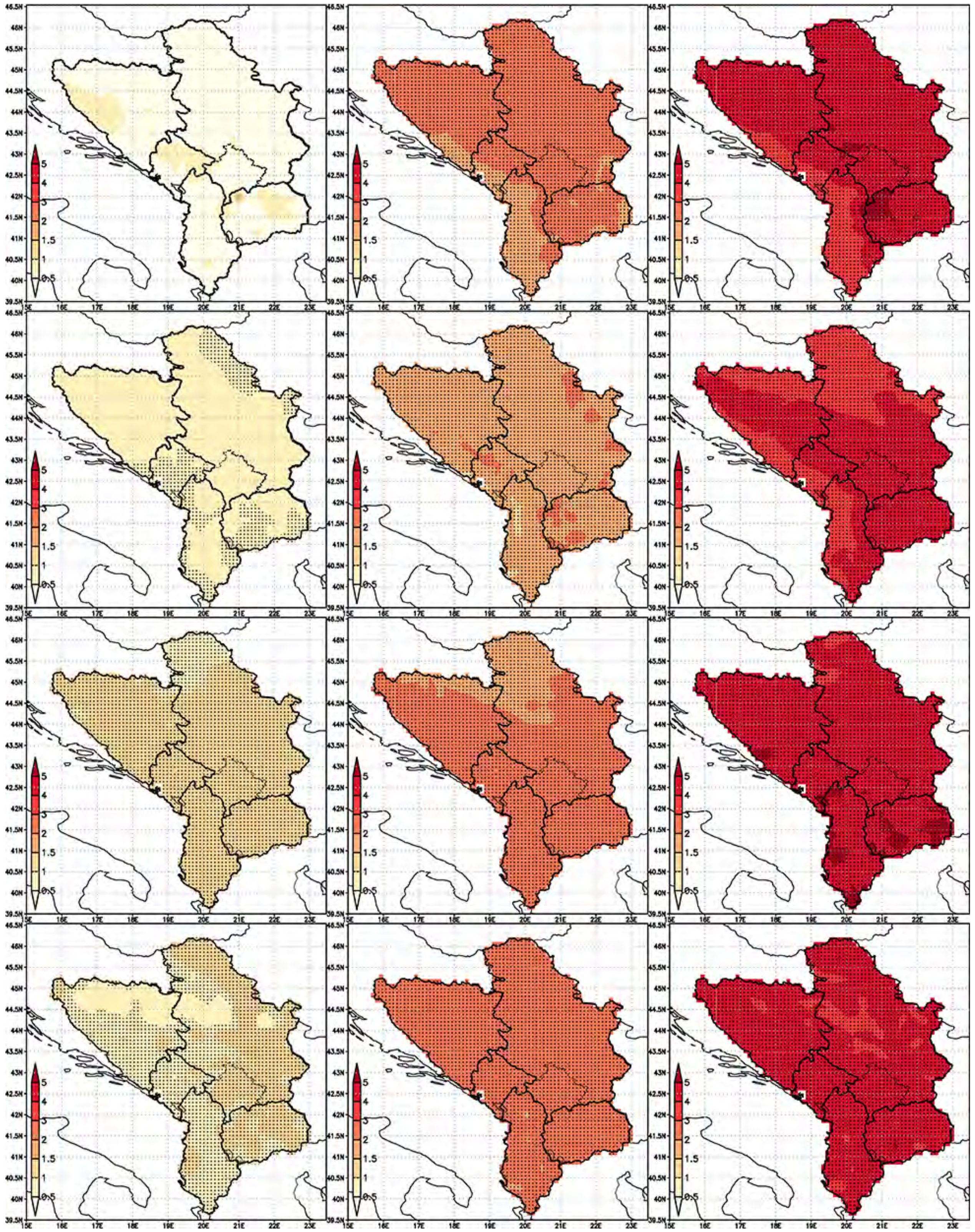

Figure A7. *Seasonal mean temperature change (°C) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1986-2005) according to the RCP8.5; DJF in the first row, MAM in the second row, JJA in the third row, SON in the fourth row; statistical significance is marked with dots.*

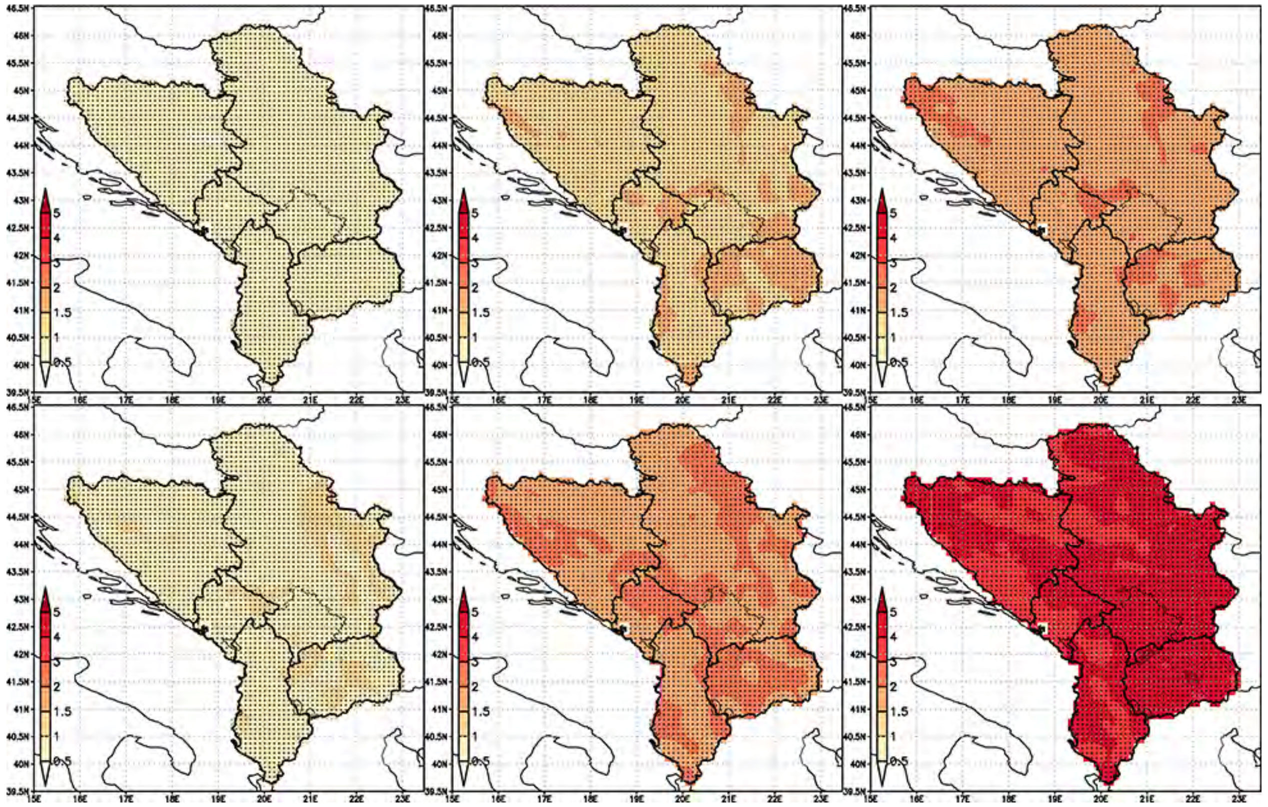

Figure A8. *Annual minimum temperature change (°C) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1986-2005) according to the RCP4.5 (top row) and RCP8.5 (bottom row); statistical significance is marked with dots.*

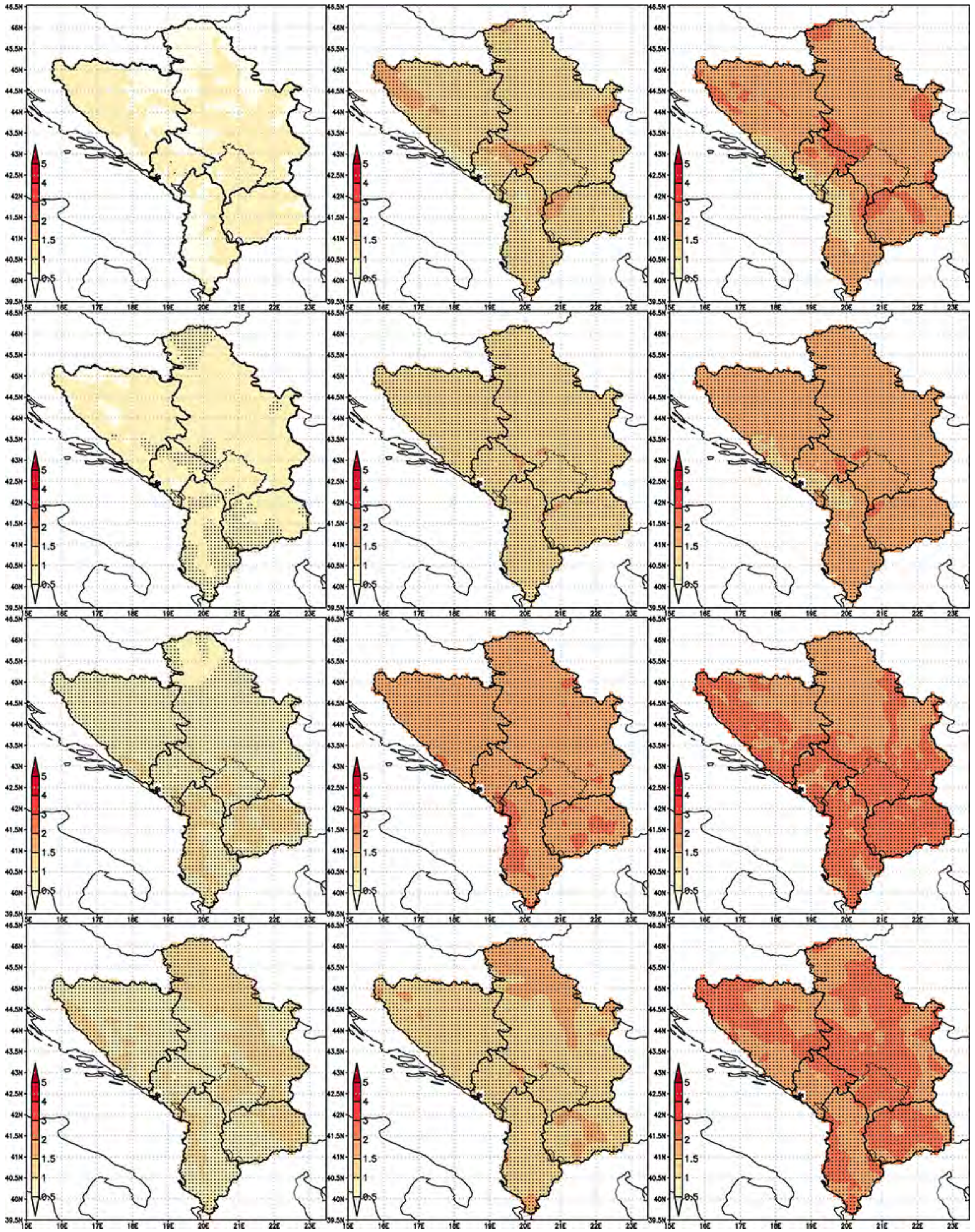

Figure A9. *Seasonal minimum temperature change (°C) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1986-2005) according to the RCP4.5; DJF in the first row, MAM in the second row, JJA in the third row, SON in the fourth row; statistical significance is marked with dots.*

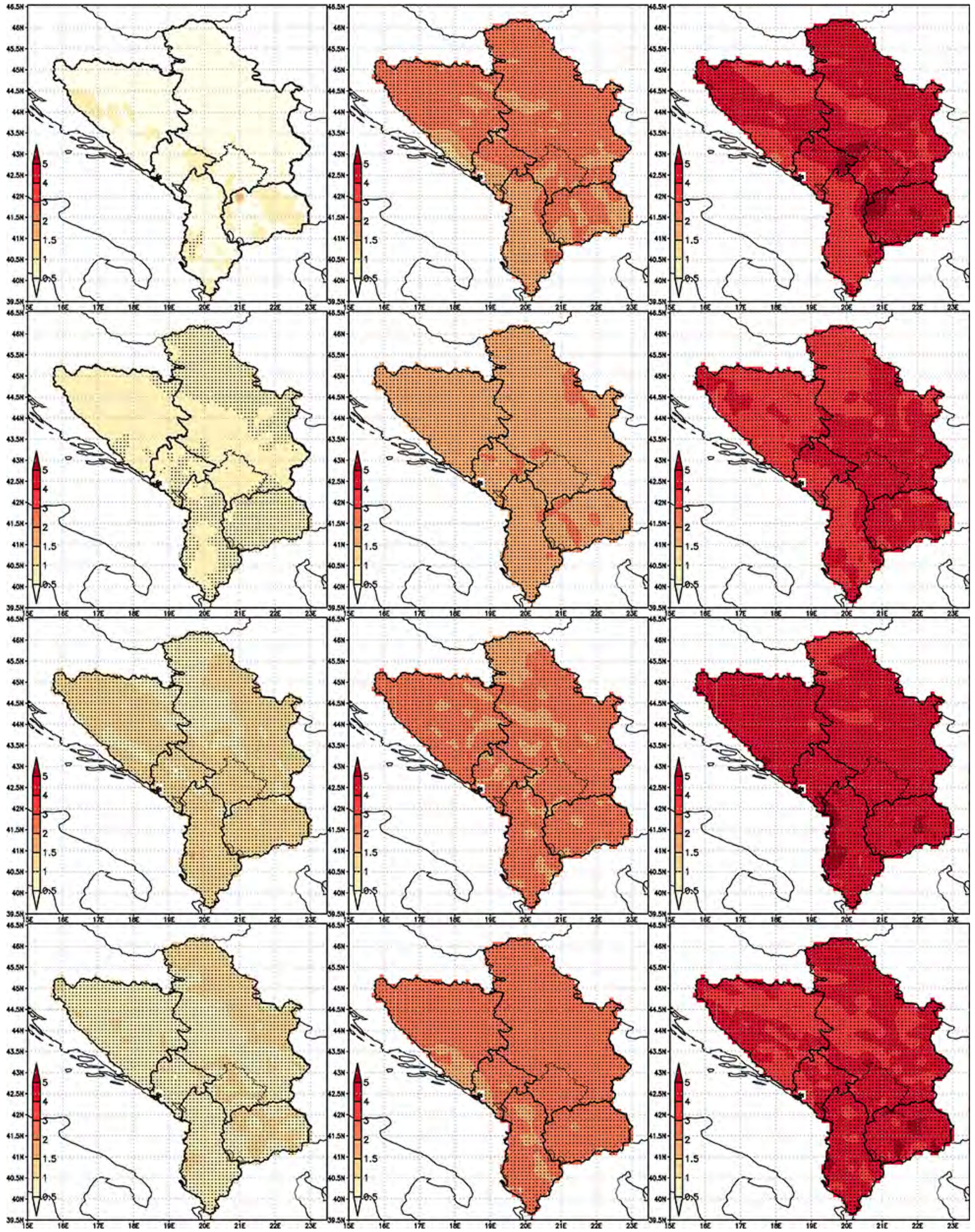

Figure A10. *Seasonal minimum temperature change (°C) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1986-2005) according to the RCP8.5; DJF in the first row, MAM in the second row, JJA in the third row, SON in the fourth row; statistical significance is marked with dots.*

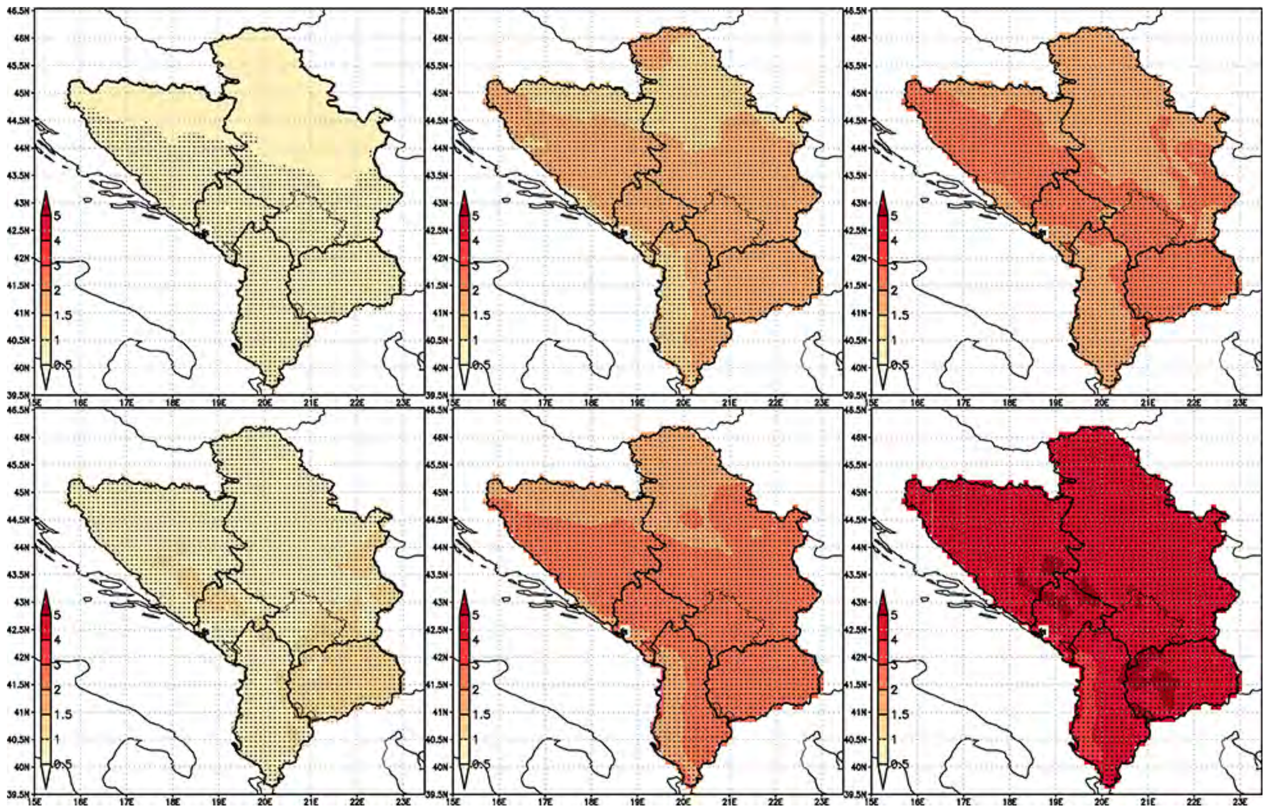

Figure A11. *Annual maximum temperature change (°C) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1986-2005) according to the RCP4.5 (top row) and RCP8.5 (bottom row); statistical significance is marked with dots.*

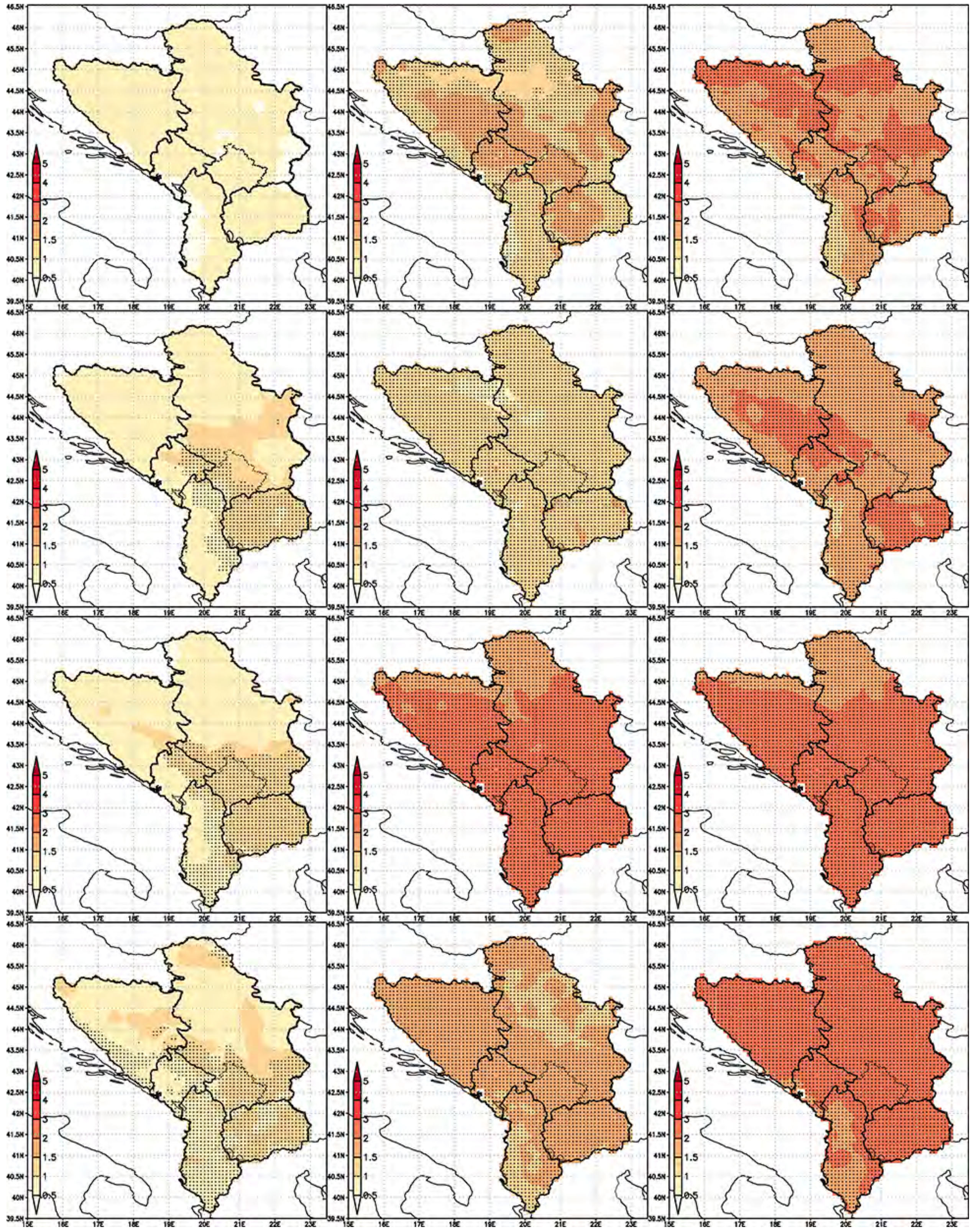

Figure A12. *Seasonal maximum temperature change (°C) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1986-2005) according to the RCP4.5; DJF in the first row, MAM in the second row, JJA in the third row, SON in the fourth row; statistical significance is marked with dots.*

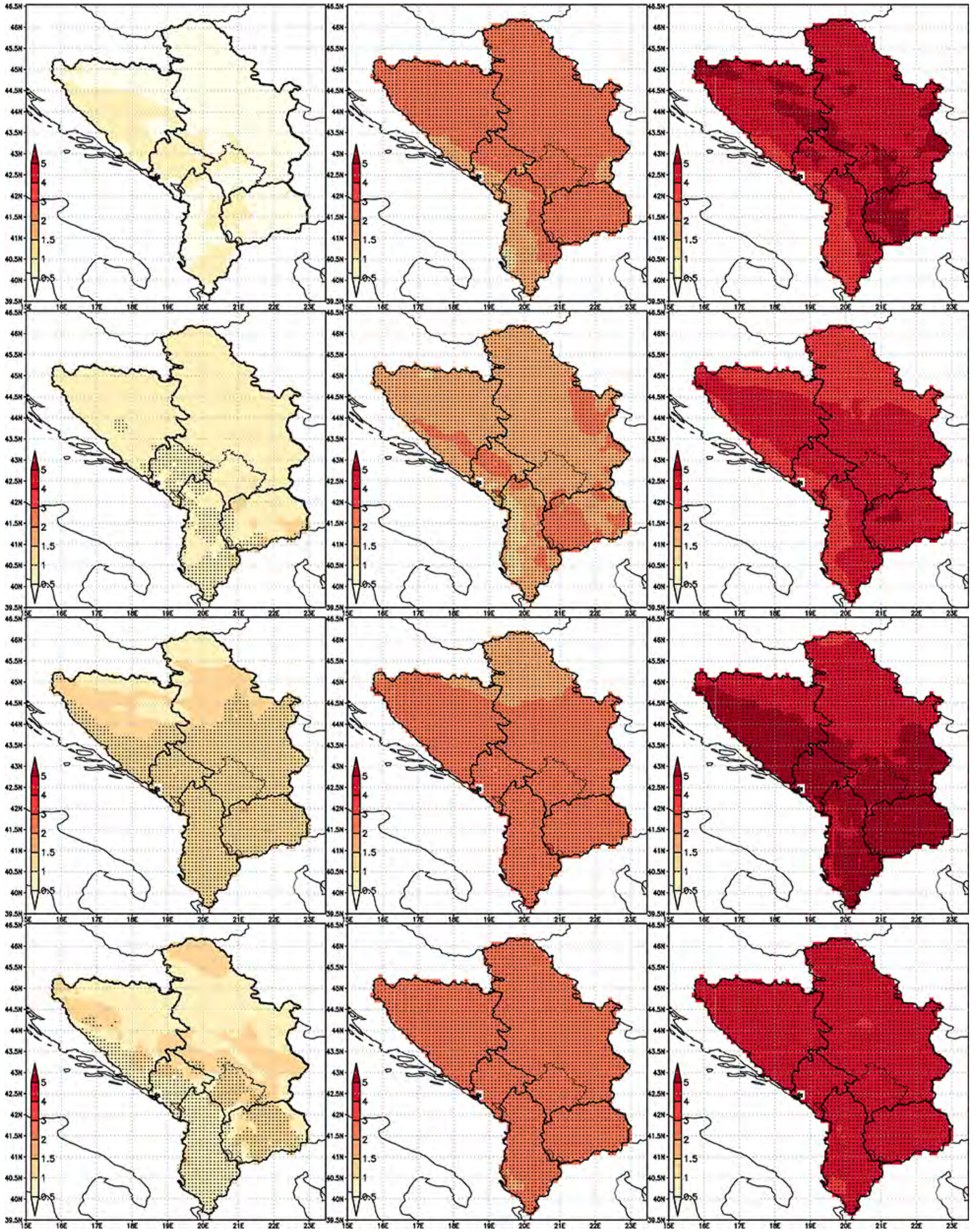

Figure A13. *Seasonal maximum temperature change (°C) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1986-2005) according to the RCP8.5; DJF in the first row, MAM in the second row, JJA in the third row, SON in the fourth row; statistical significance is marked with dots.*

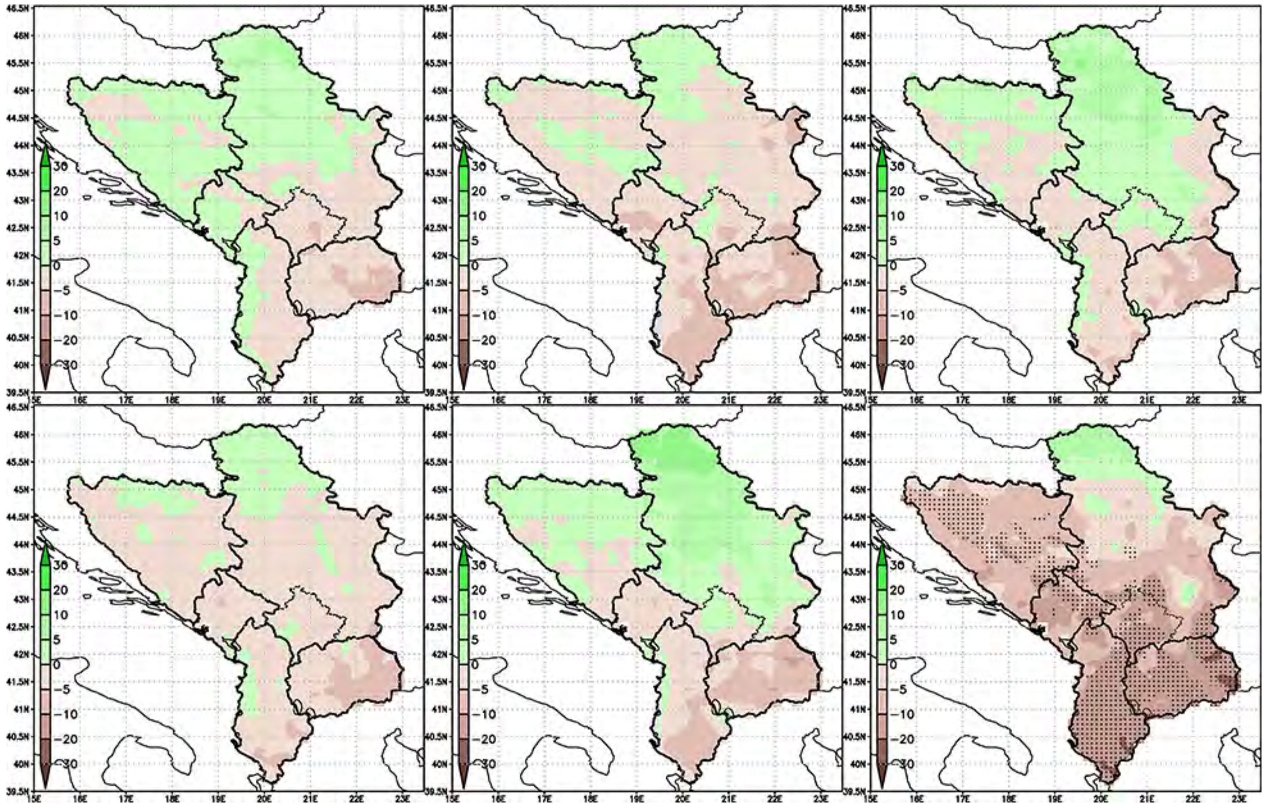

Figure A14. *Annual accumulation precipitation change (%) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1986-2005) according to the RCP4.5 (top row) and RCP8.5 (bottom row); statistical significance is marked with dots.*

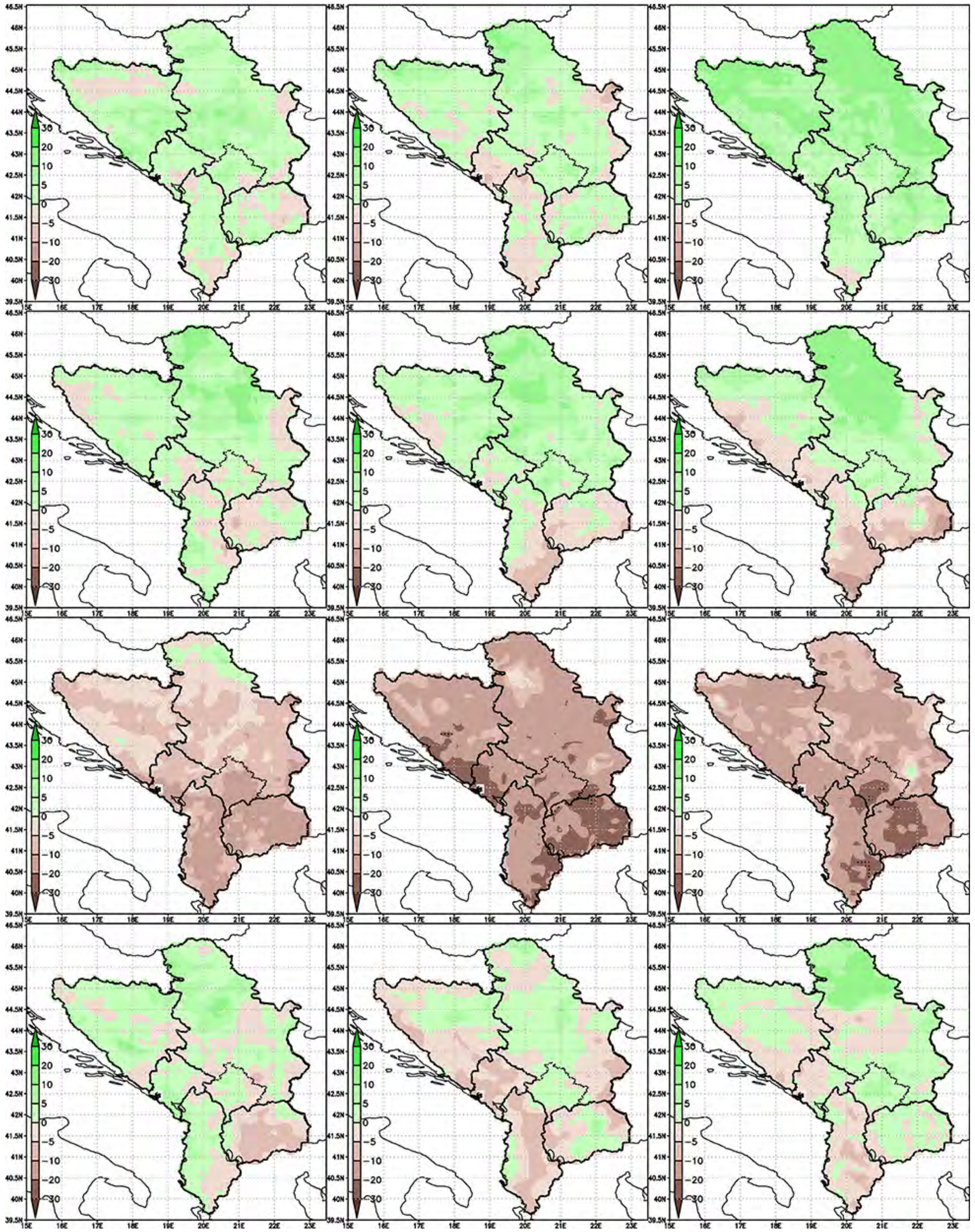

Figure A15. *Seasonal accumulated precipitation change (%) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1986-2005) according to the RCP4.5; DJF in the first row, MAM in the second row, JJA in the third row, SON in the fourth row; statistical significance is marked with dots.*

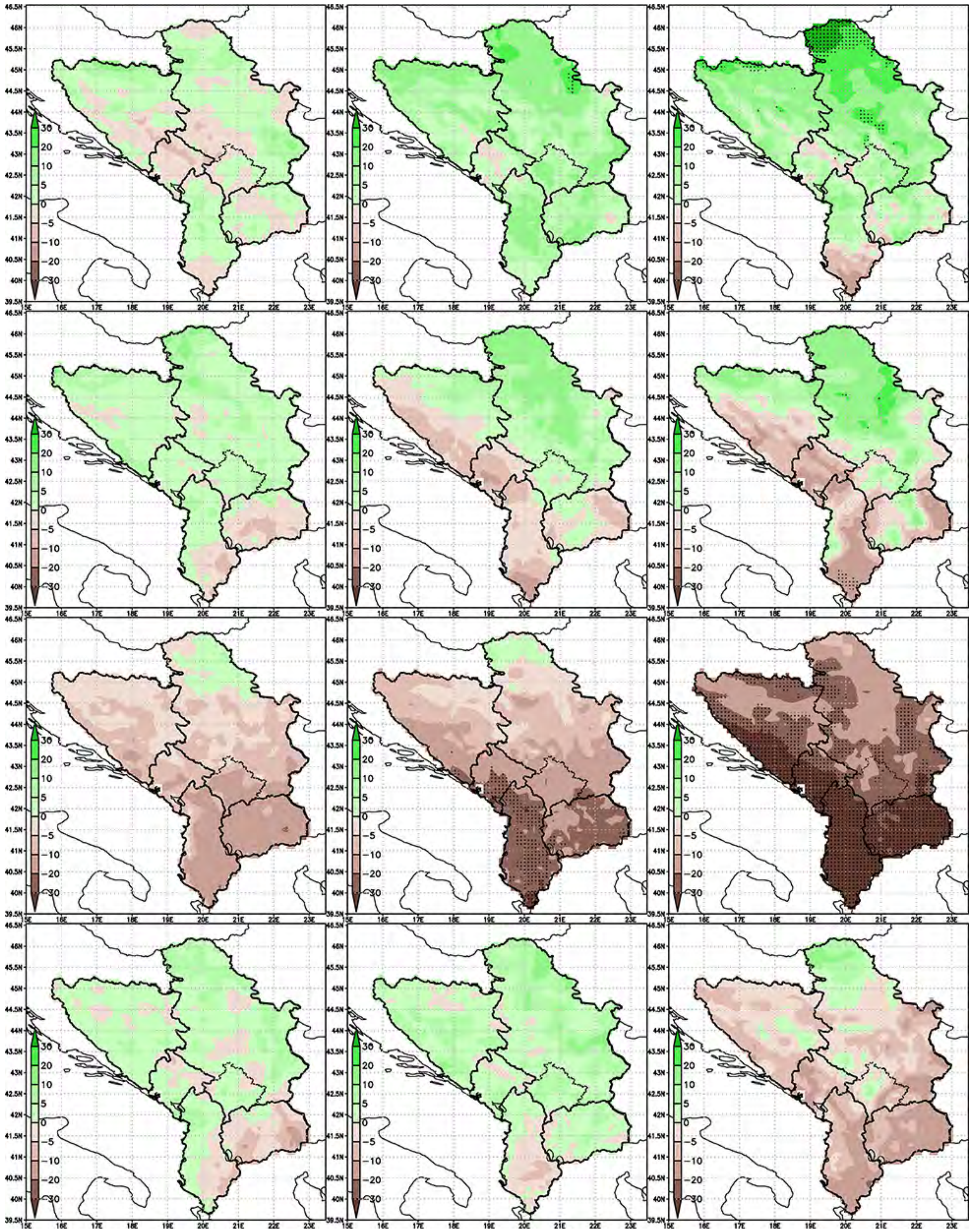

Figure A16. *Seasonal accumulated precipitation change (%) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1986-2005) according to the RCP8.5; DJF in the first row, MAM in the second row, JJA in the third row, SON in the fourth row; statistical significance is marked with dots.*

A3.2 Future change of climate indices and indicators

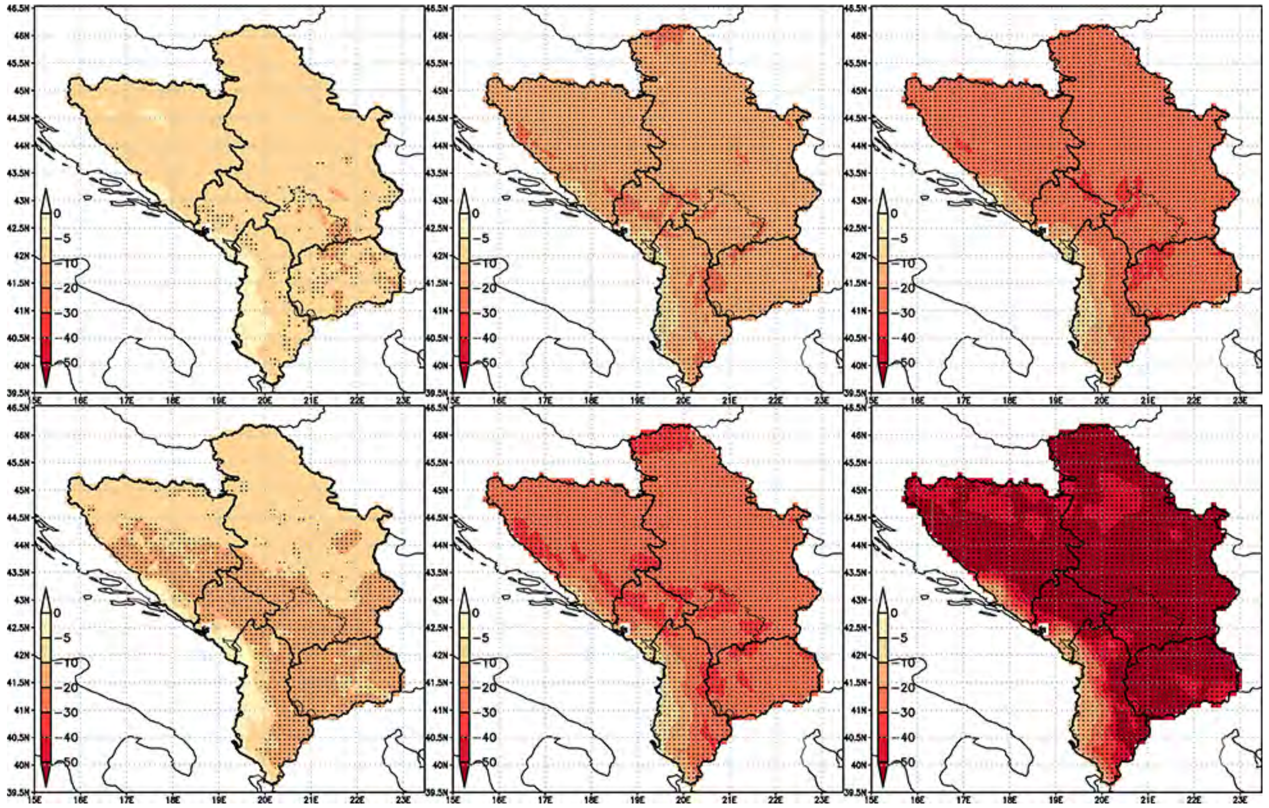

Figure A17. *Change in annual number of frost days (Tmin<0°C) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1986-2005) according to the RCP4.5 (top row) and RCP8.5 (bottom row); statistical significance is marked with dots.*

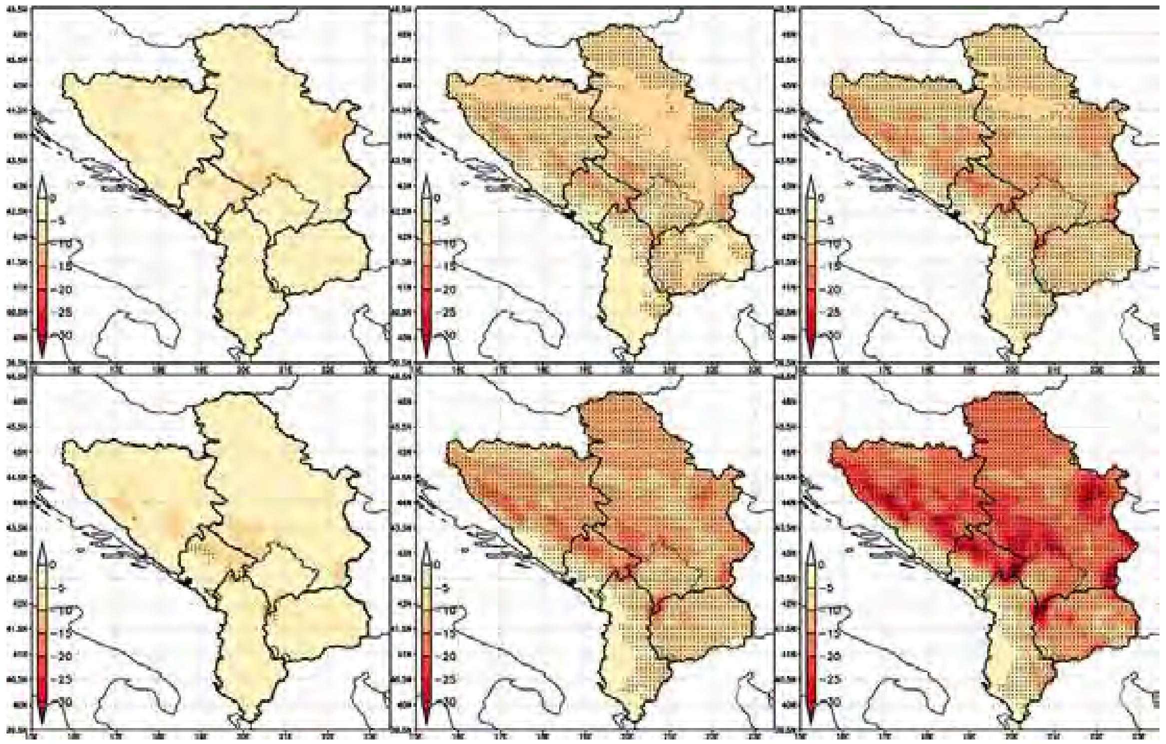

Figure A18. *Change in annual number of icing days (Tmax<0°C) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1986-2005) according to the RCP4.5 (top row) and RCP8.5 (bottom row); statistical significance is marked with dots.*

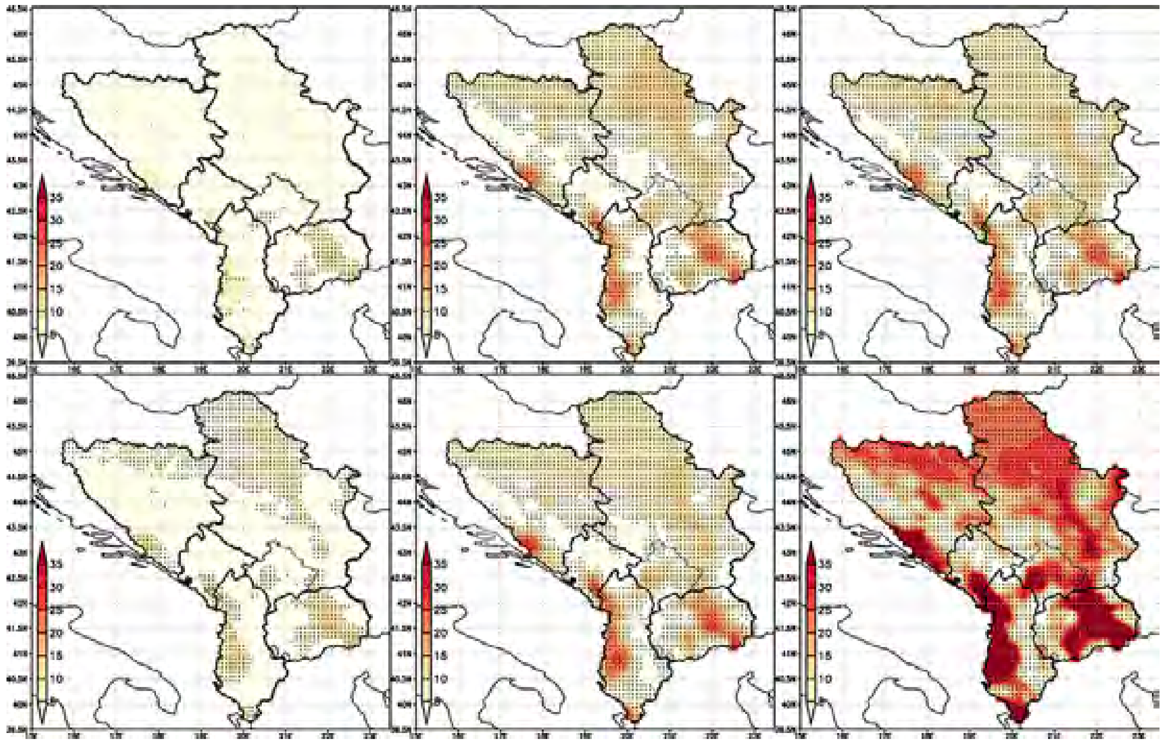

Figure A19. *Change in annual number of very hot days (Tmax>35°C) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1986-2005) according to the RCP4.5 (top row) and RCP8.5 (bottom row); statistical significance is marked with dots.*

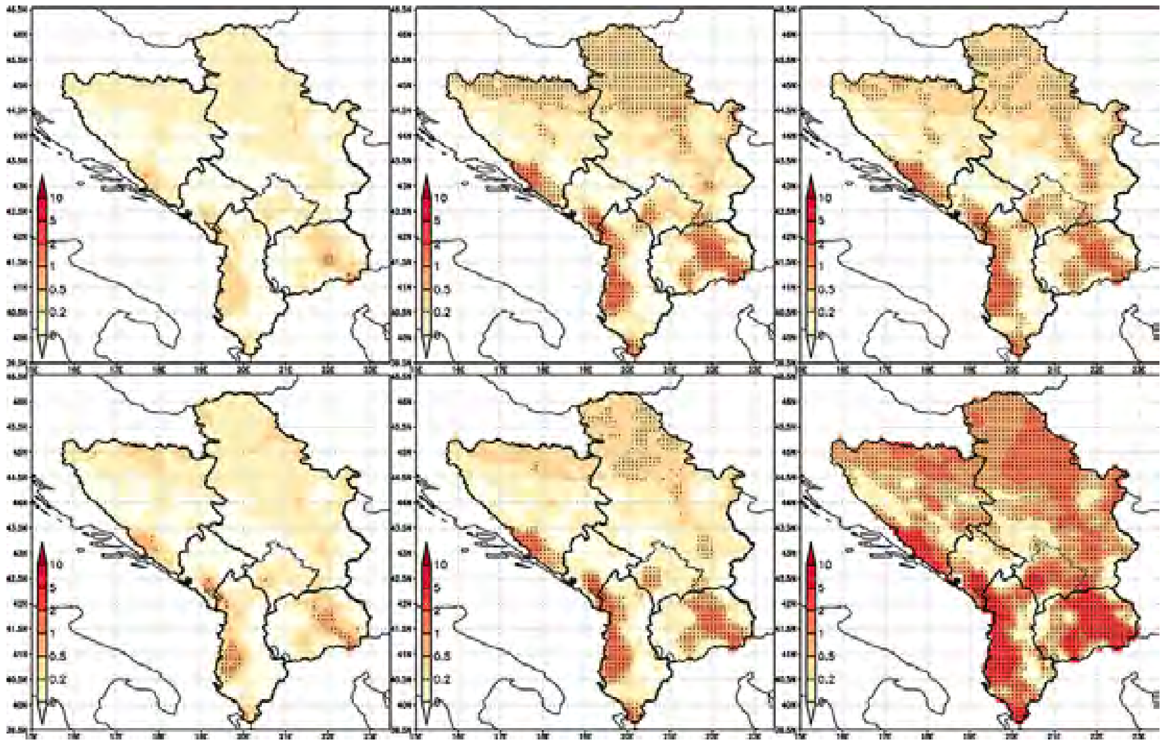

Figure A20. *Change in annual number of heat waves (at least 6 consecutive days with Tmax>35°C) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1986-2005) according to the RCP4.5 (top row) and RCP8.5 (bottom row); statistical significance is marked with dots.*

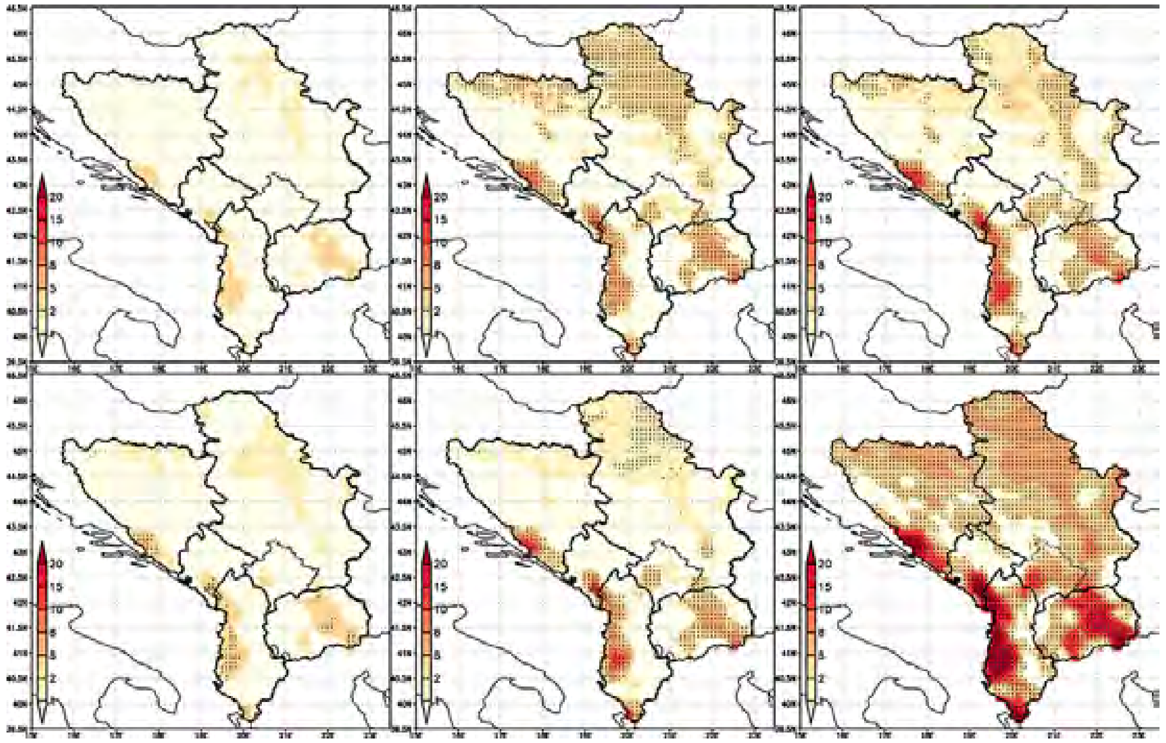

Figure A21. *Change in average maximum length of heat waves (days) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1986-2005) according to the RCP4.5 (top row) and RCP8.5 (bottom row); statistical significance is marked with dots.*

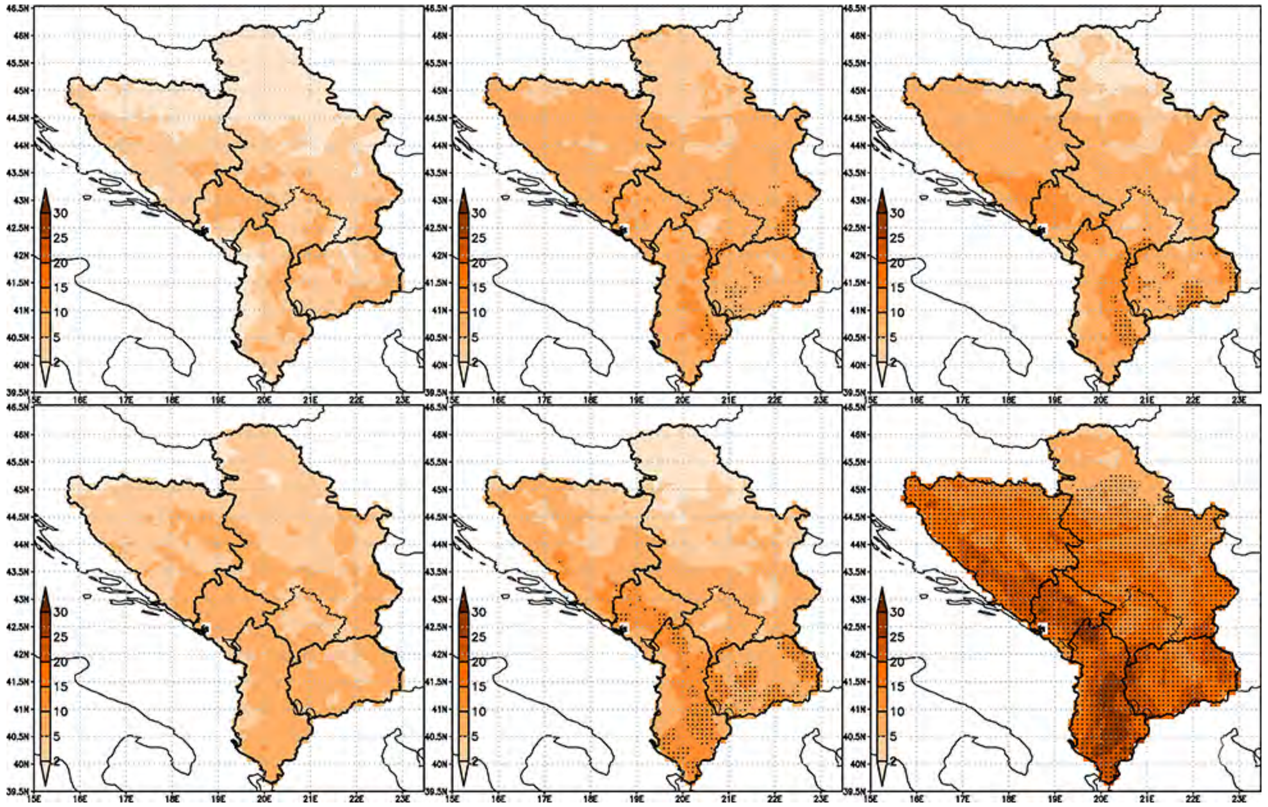

Figure A22. *Change in annual number of days without precipitation (RR<1mm) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1986-2005) according to the RCP4.5 (top row) and RCP8.5 (bottom row); statistical significance is marked with dots.*

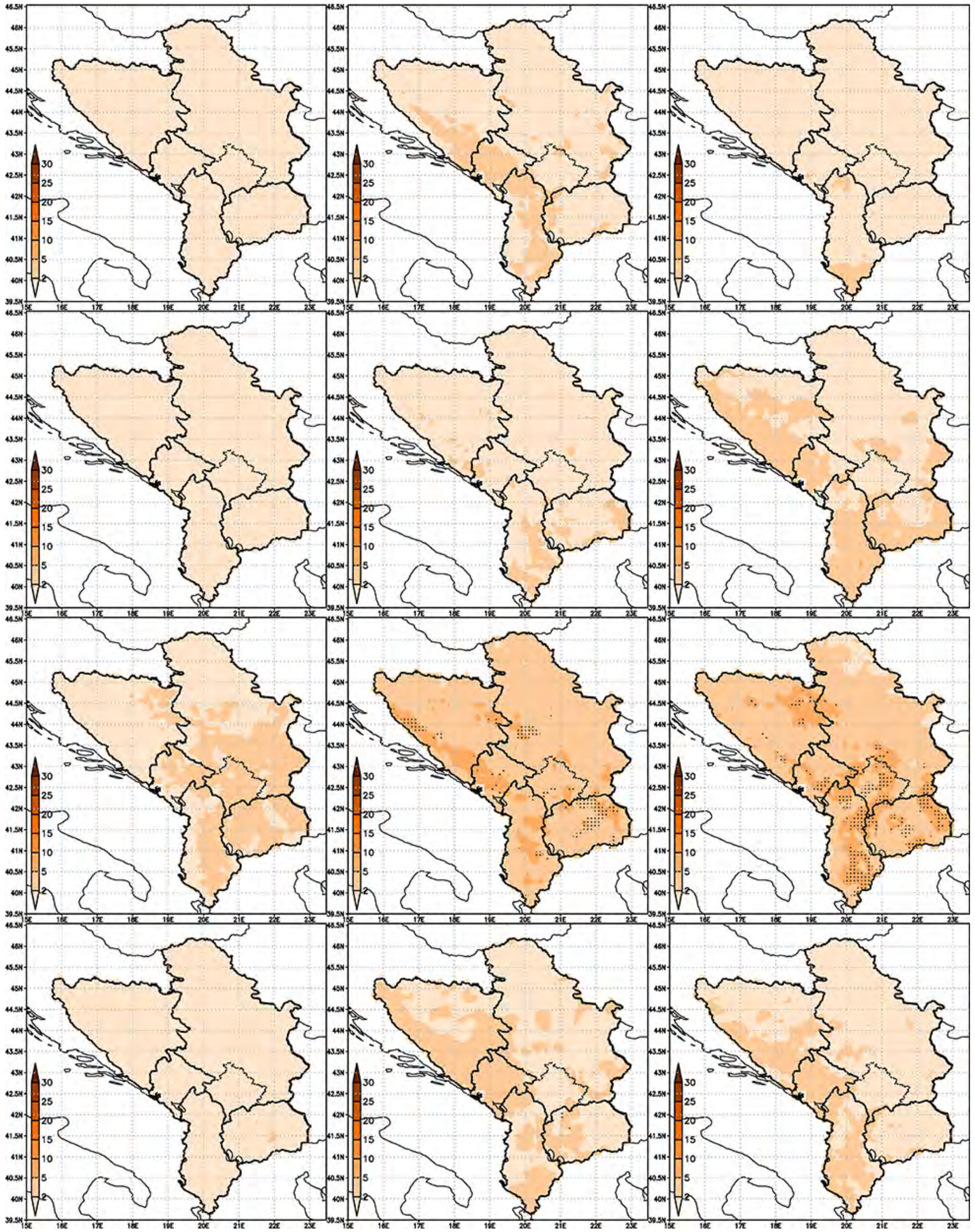

Figure A23. *Seasonal change in annual number of days without precipitation (RR<1mm) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1986-2005) according to the RCP4.5; DJF in the first row, MAM in the second row, JJA in the third row, SON in the fourth row; statistical significance is marked with dots.*

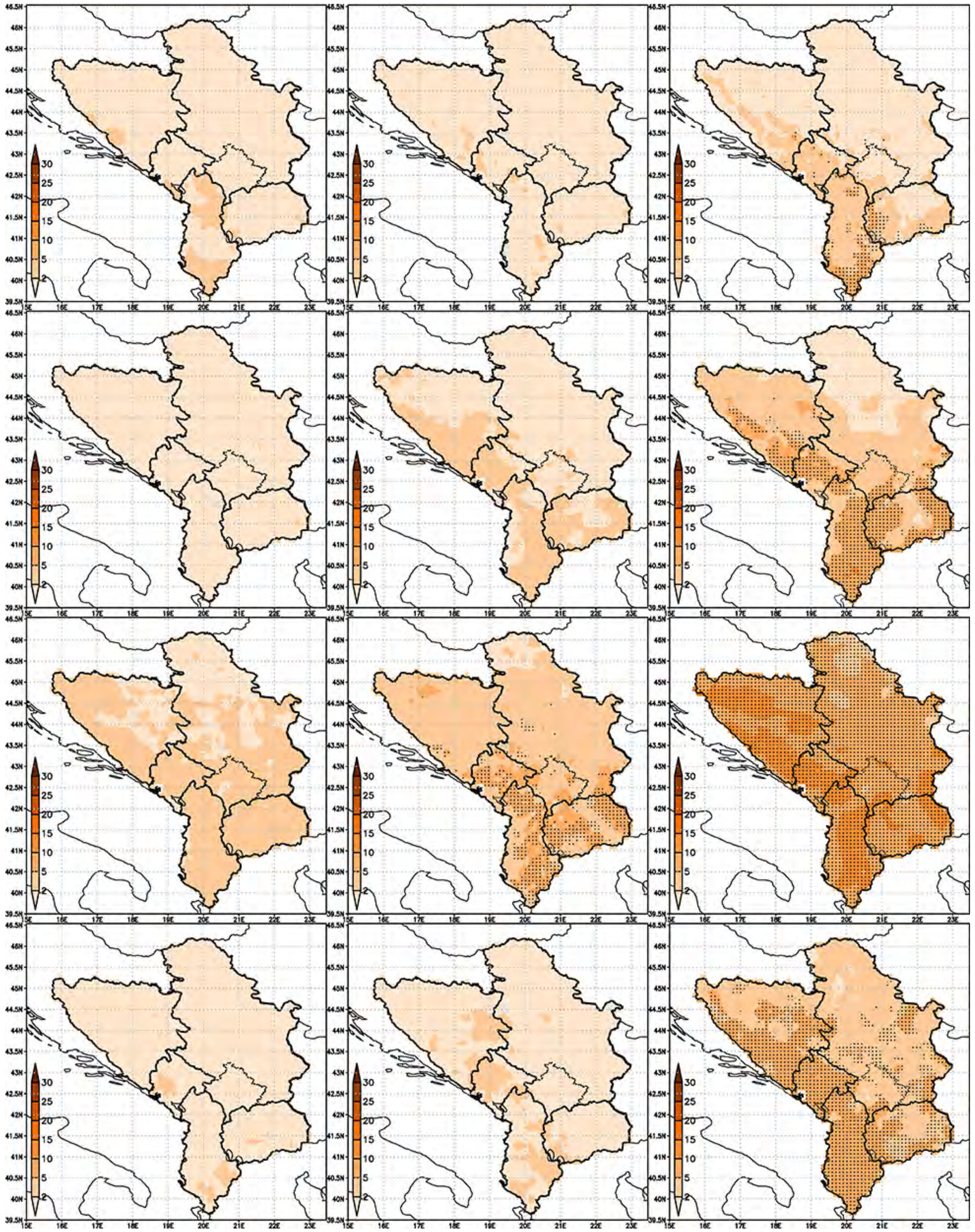

Figure A24. *Seasonal change in annual number of days without precipitation (RR<1mm) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1986-2005) according to the RCP8.5; DJF in the first row, MAM in the second row, JJA in the third row, SON in the fourth row; statistical significance is marked with dots.*

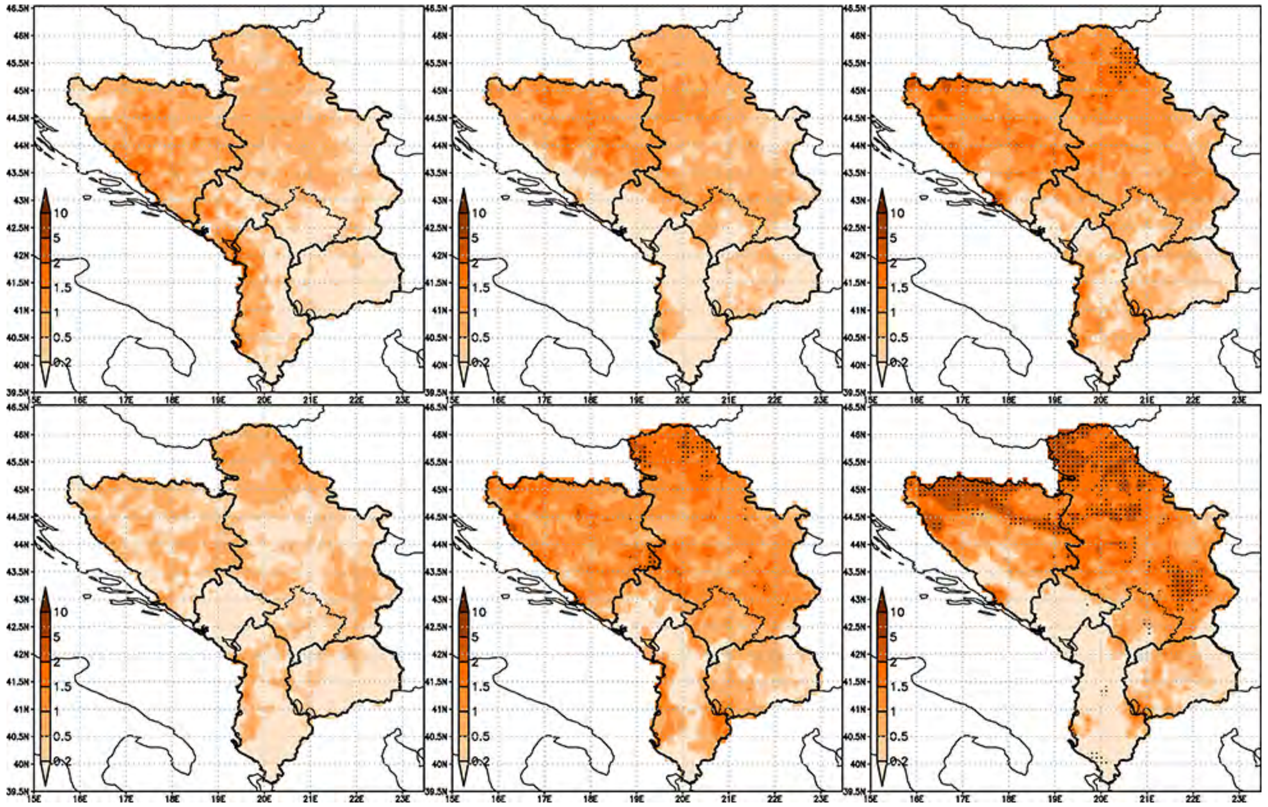

Figure A25. *Change in annual number of days with very heavy precipitation (RR>20mm) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1986-2005) according to the RCP4.5 (top row) and RCP8.5 (bottom row); statistical significance is marked with dots.*

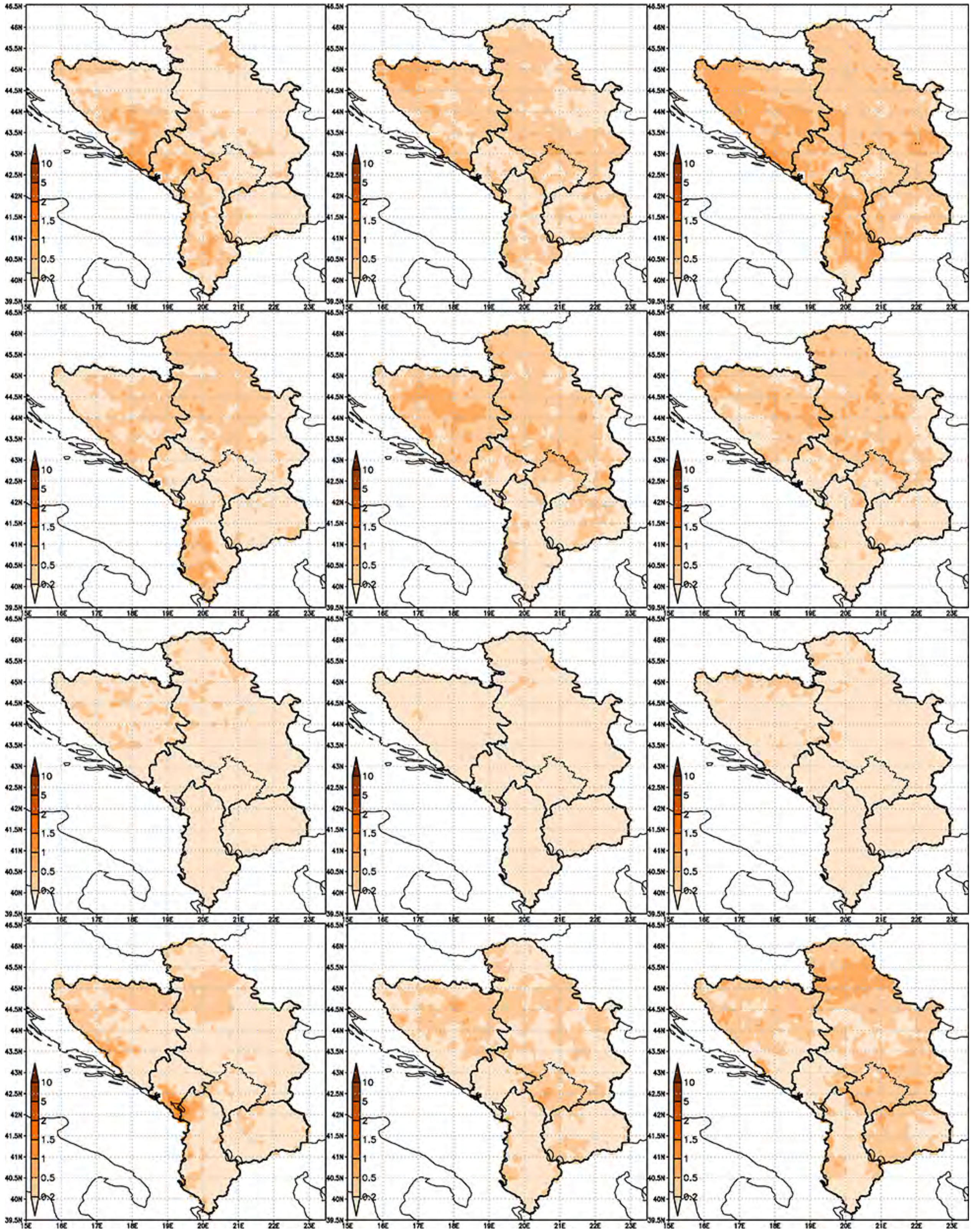

Figure A26. *Seasonal change in annual number of days with very heavy precipitation (RR>20mm) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1986-2005) according to the RCP4.5; DJF in the first row, MAM in the second row, JJA in the third row, SON in the fourth row; statistical significance is marked with dots.*

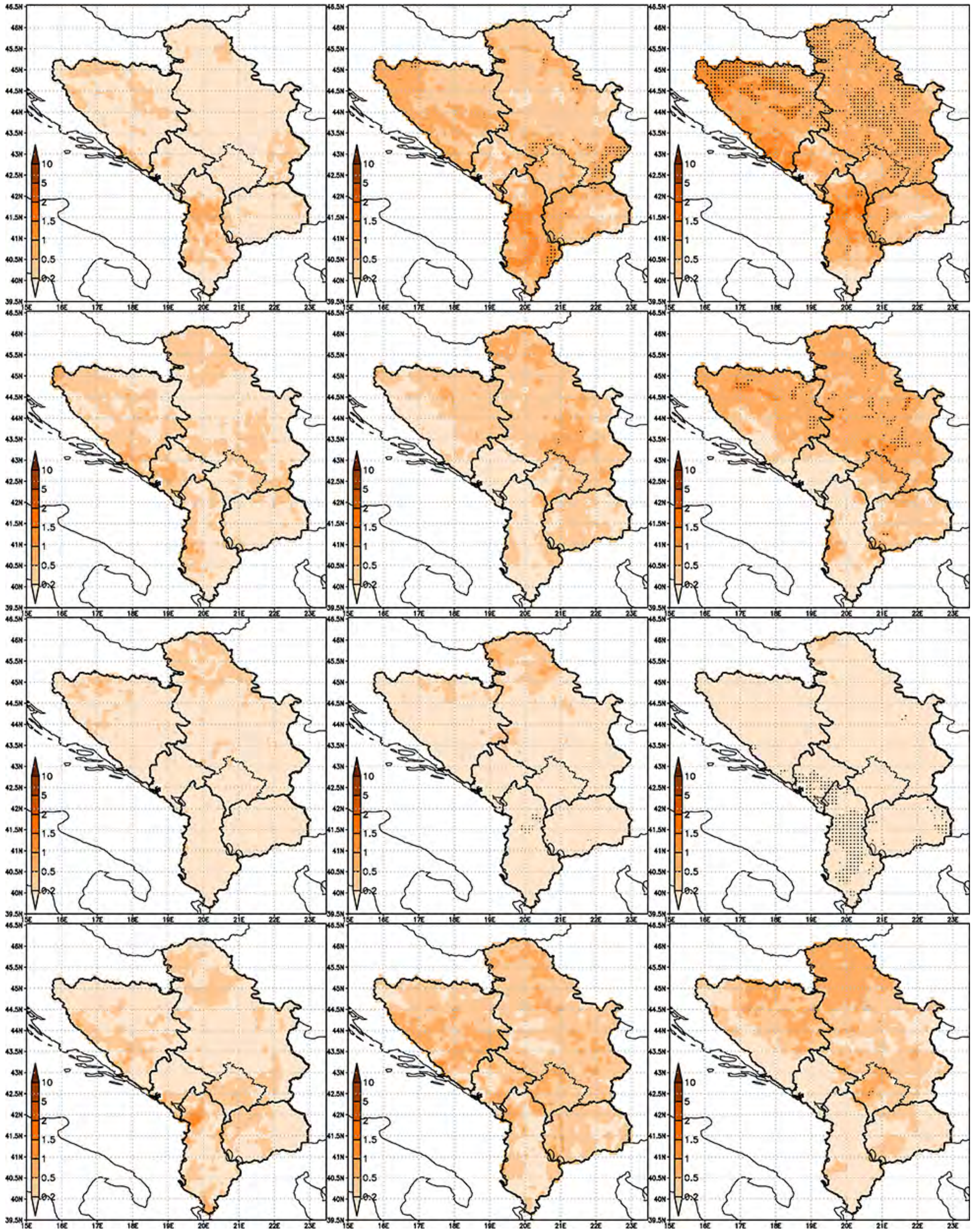

__Figure A27.__ Seasonal change in annual number of days with very heavy precipitation (RR>20mm) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1986-2005) according to the RCP8.5; DJF in the first row, MAM in the second row, JJA in the third row, SON in the fourth row; statistical significance is marked with dots.

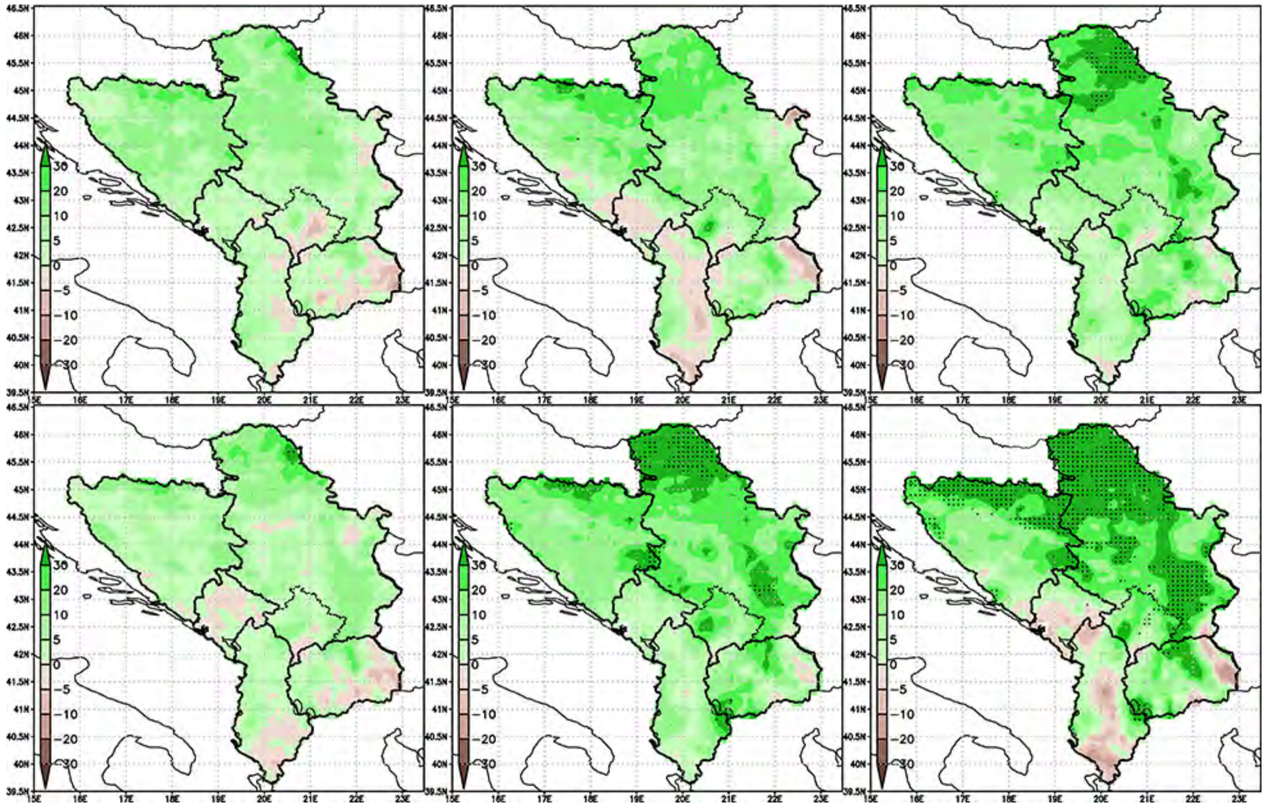

__Figure A28.__ Change in precipitation (%) accumulated in very heavy precipitation days (RR>20mm) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1986-2005) according to the RCP4.5 (top row) and RCP8.5 (bottom row); statistical significance is marked with dots.

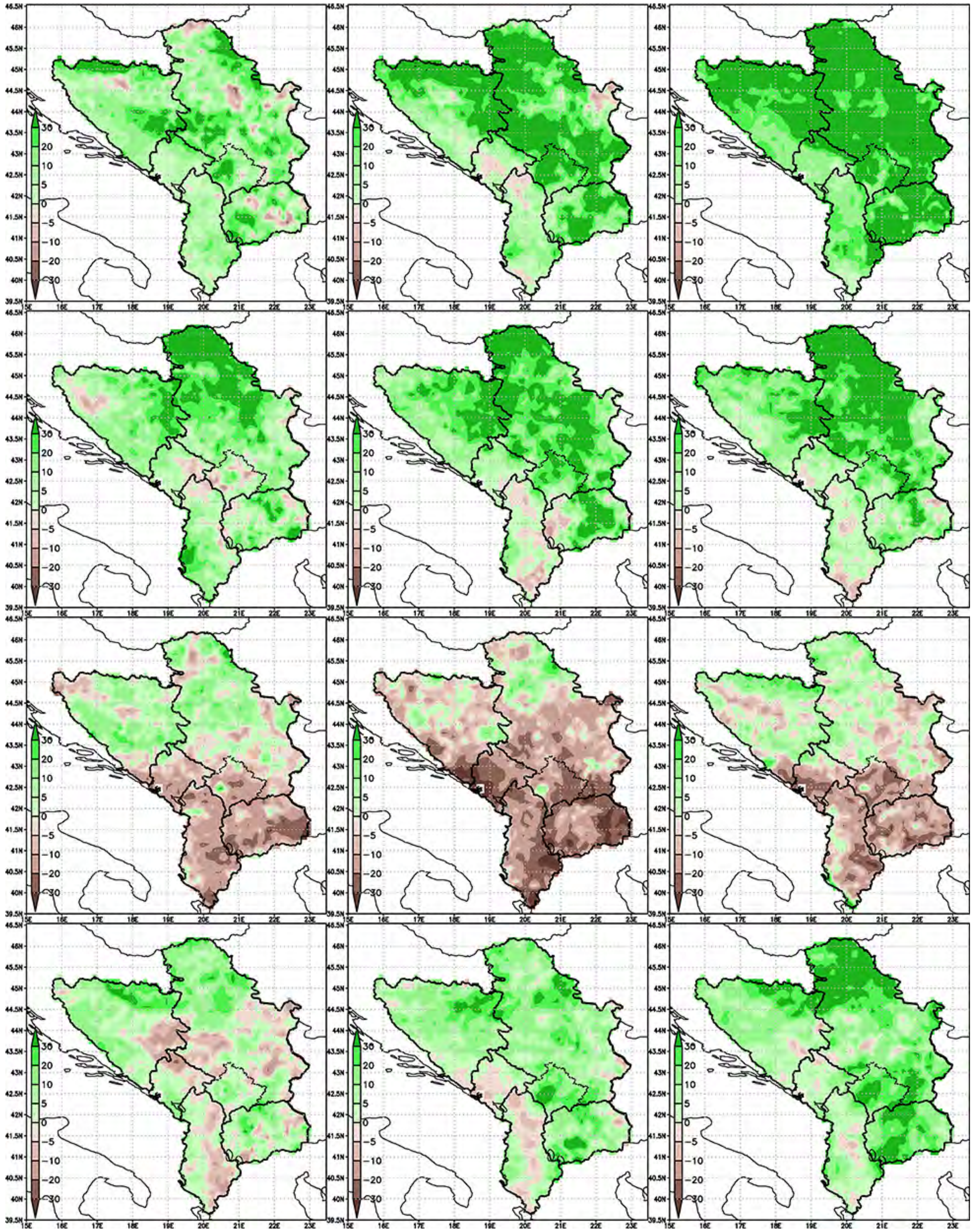

Figure A29. *Seasonal change in precipitation (%) accumulated in very heavy precipitation days (RR>20mm) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1986-2005) according to the RCP4.5; DJF in the first row, MAM in the second row, JJA in the third row, SON in the fourth row; statistical significance is marked with dots.*

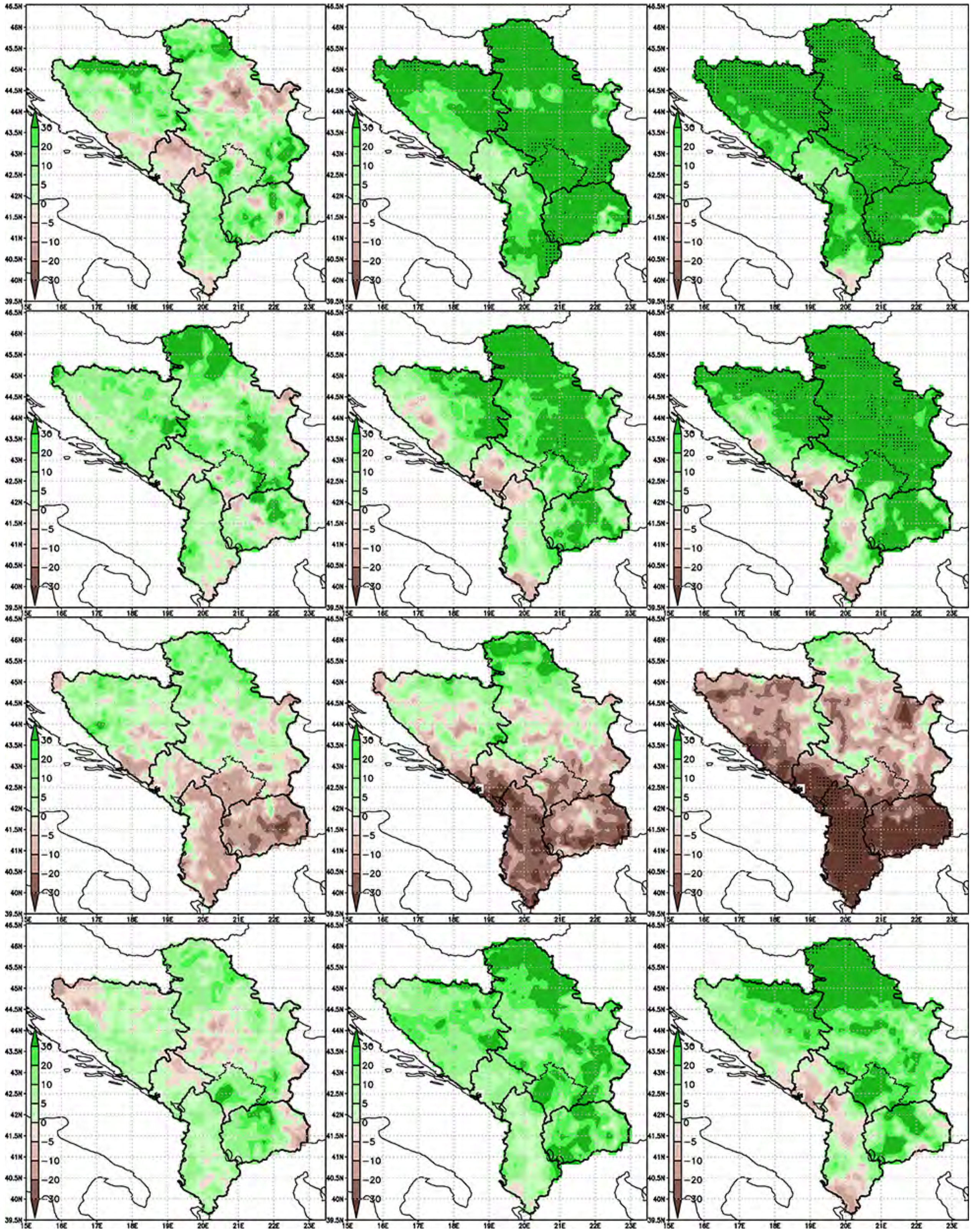

Figure A30. *Seasonal change in precipitation (%) accumulated in very heavy precipitation days (RR>20mm) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1986-2005) according to the RCP8.5; DJF in the first row, MAM in the second row, JJA in the third row, SON in the fourth row; statistical significance is marked with dots.*

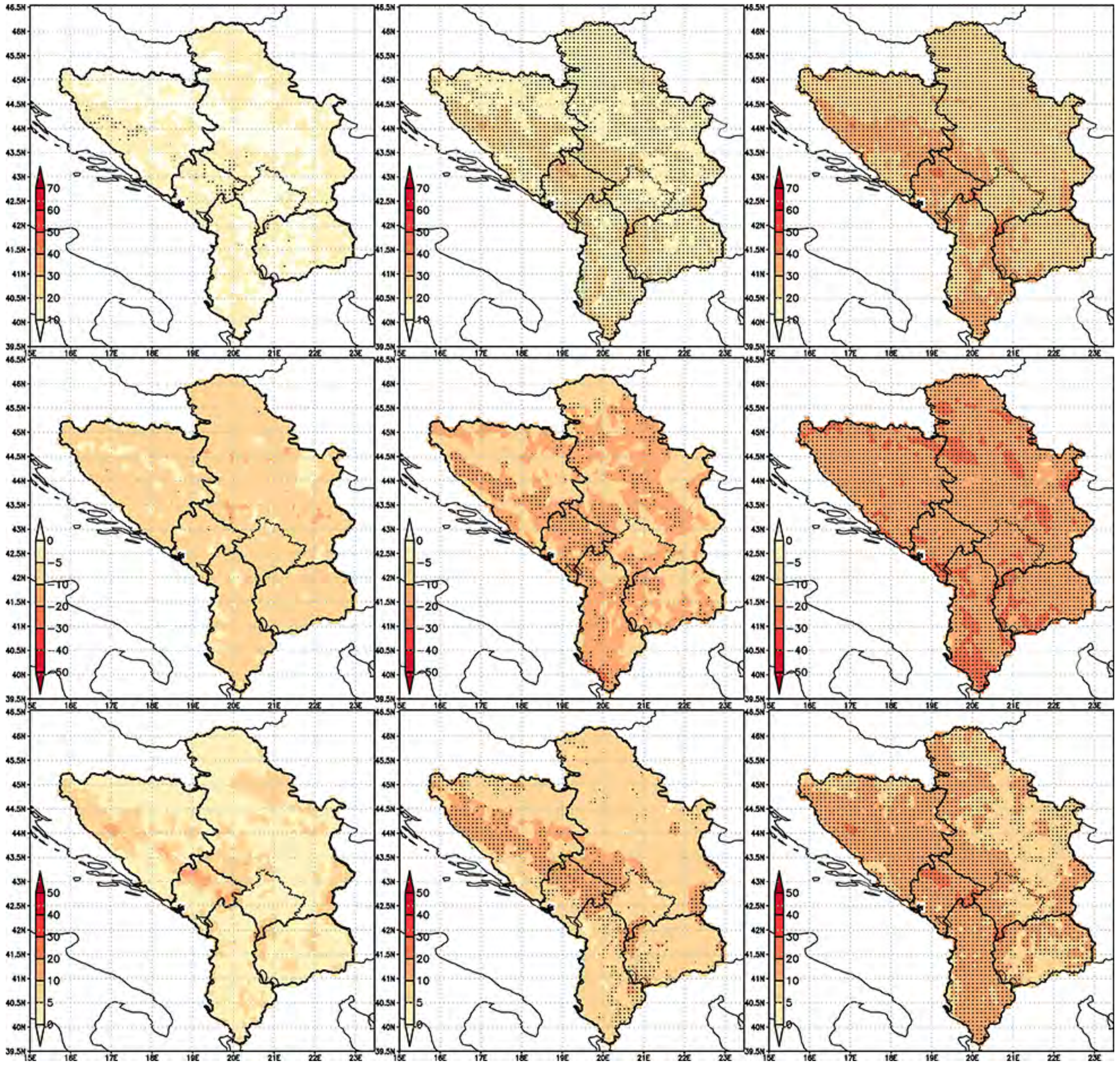

Figure A31. *Change in growing season duration (top row), start (middle row) and end date (bottom row) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1986-2005) according to the RCP4.5; statistical significance is marked with dots.*

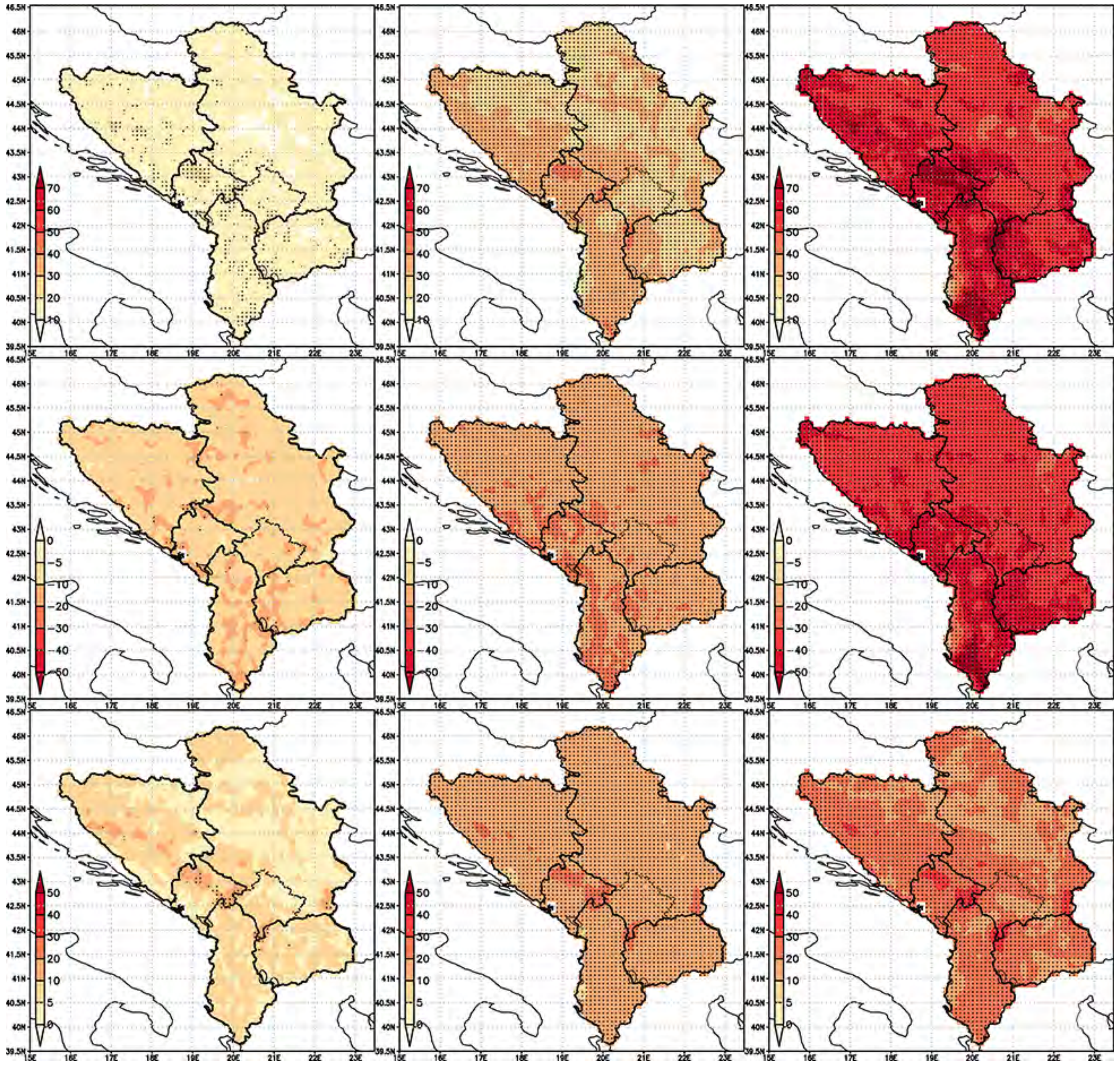

Figure A32. *Change in growing season duration (top row), start (middle row) and end date (bottom row) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1986-2005) according to the RCP8.5; statistical significance is marked with dots.*

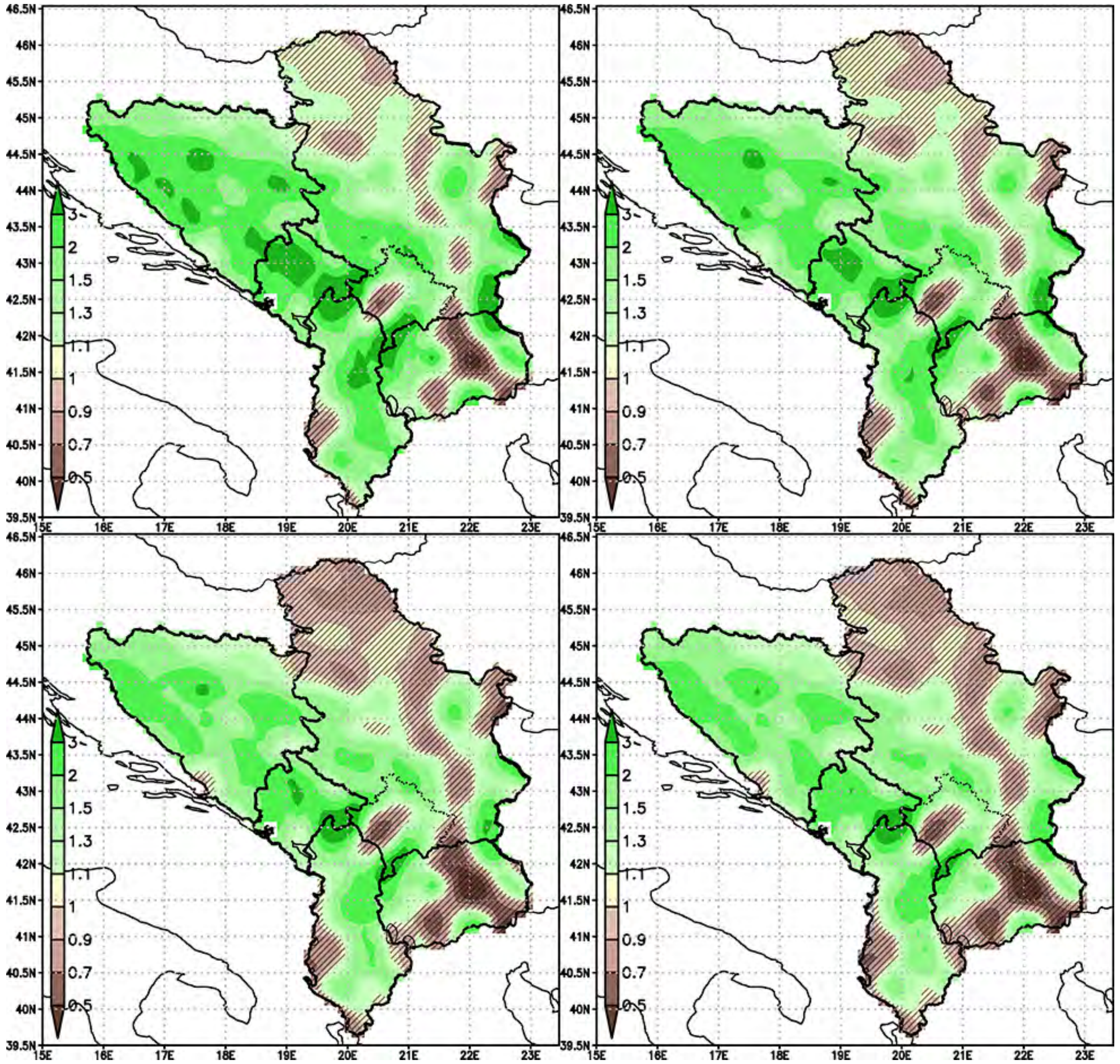

Figure A33. Average values of Seljaninov Hydrothermal Coefficient (from April to September) for the baseline period 1986-2005 (upper left), near future 2016-2035 (upper right), mid-century 2046-2065 (lower left) and end of the century 2081-2100 (lower right) periods according to the RCP4.5.

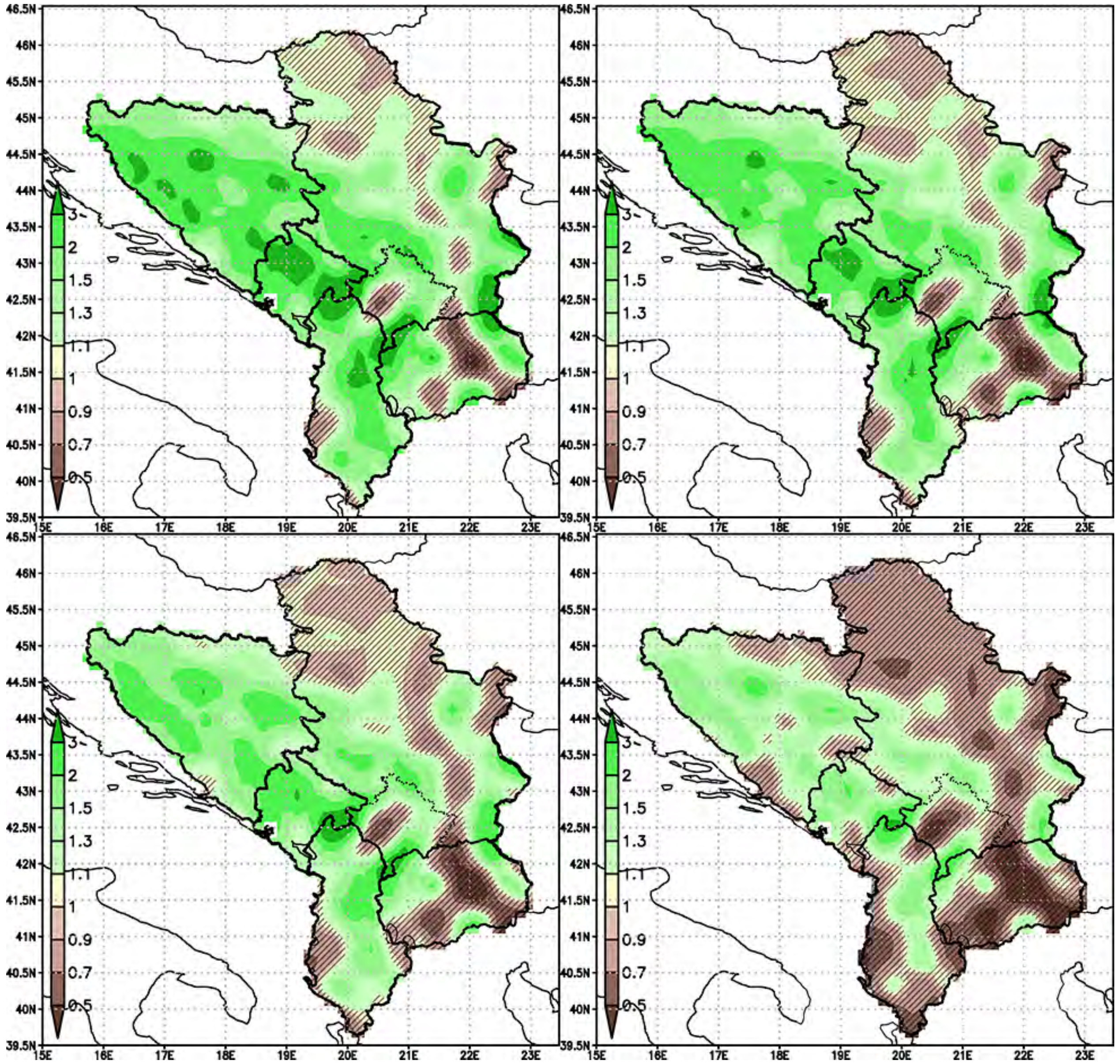

Figure A34. Average values of Seljaninov Hydrothermal Coefficient (from April to September) for the baseline period 1986-2005 (upper left), near future 2016-2035 (upper right), mid-century 2046-2065 (lower left) and end of the century 2081-2100 (lower right) periods according to the RCP8.5.

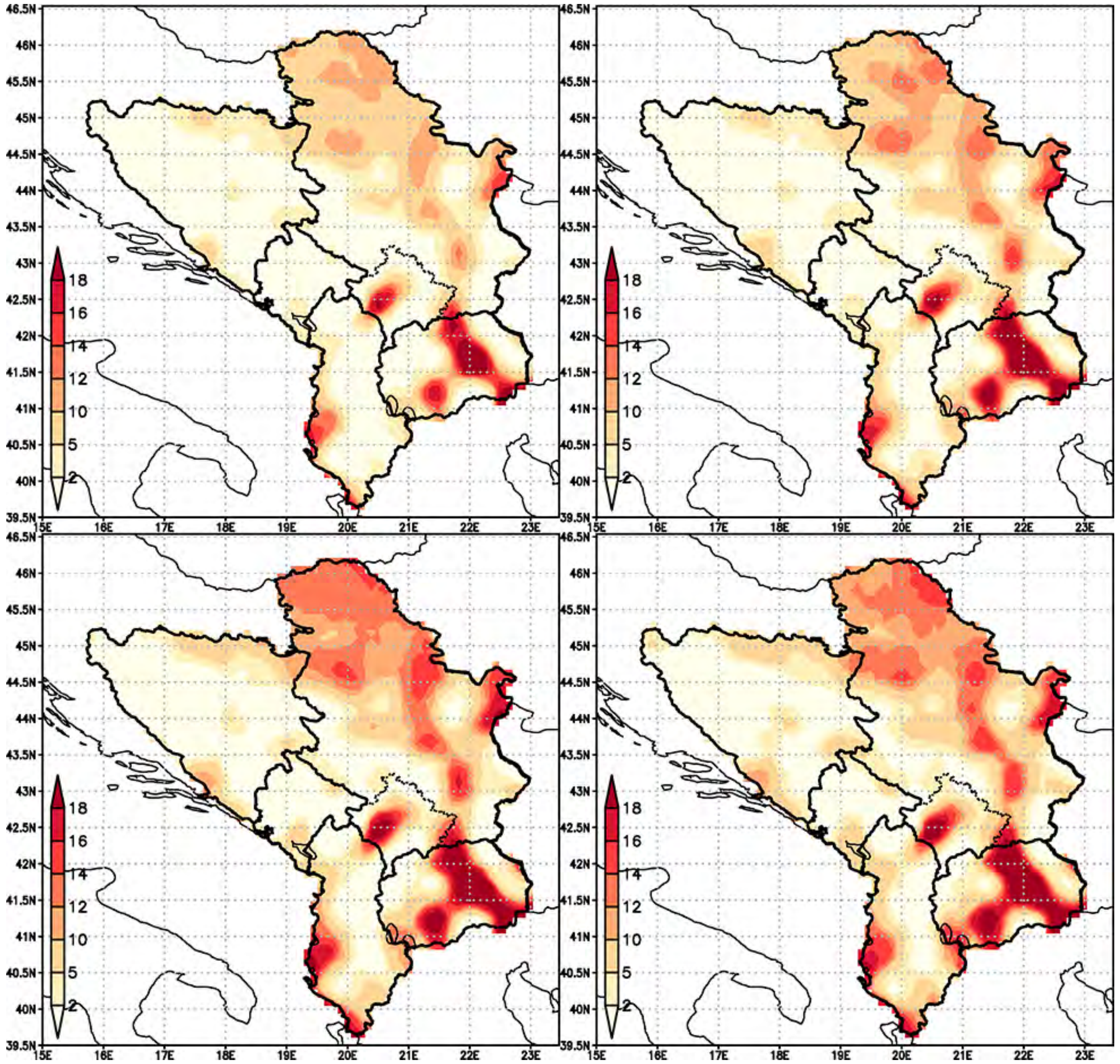

__Figure A35.__ Number of dry years (Seljaninov Hydrothermal Coefficients from April to September and from June to August less than 1) for the baseline period 1986-2005 (upper left), near future 2016-2035 (upper right), mid-century 2046-2065 (lower left) and end of the century 2081-2100 (lower right) periods according to the RCP4.5

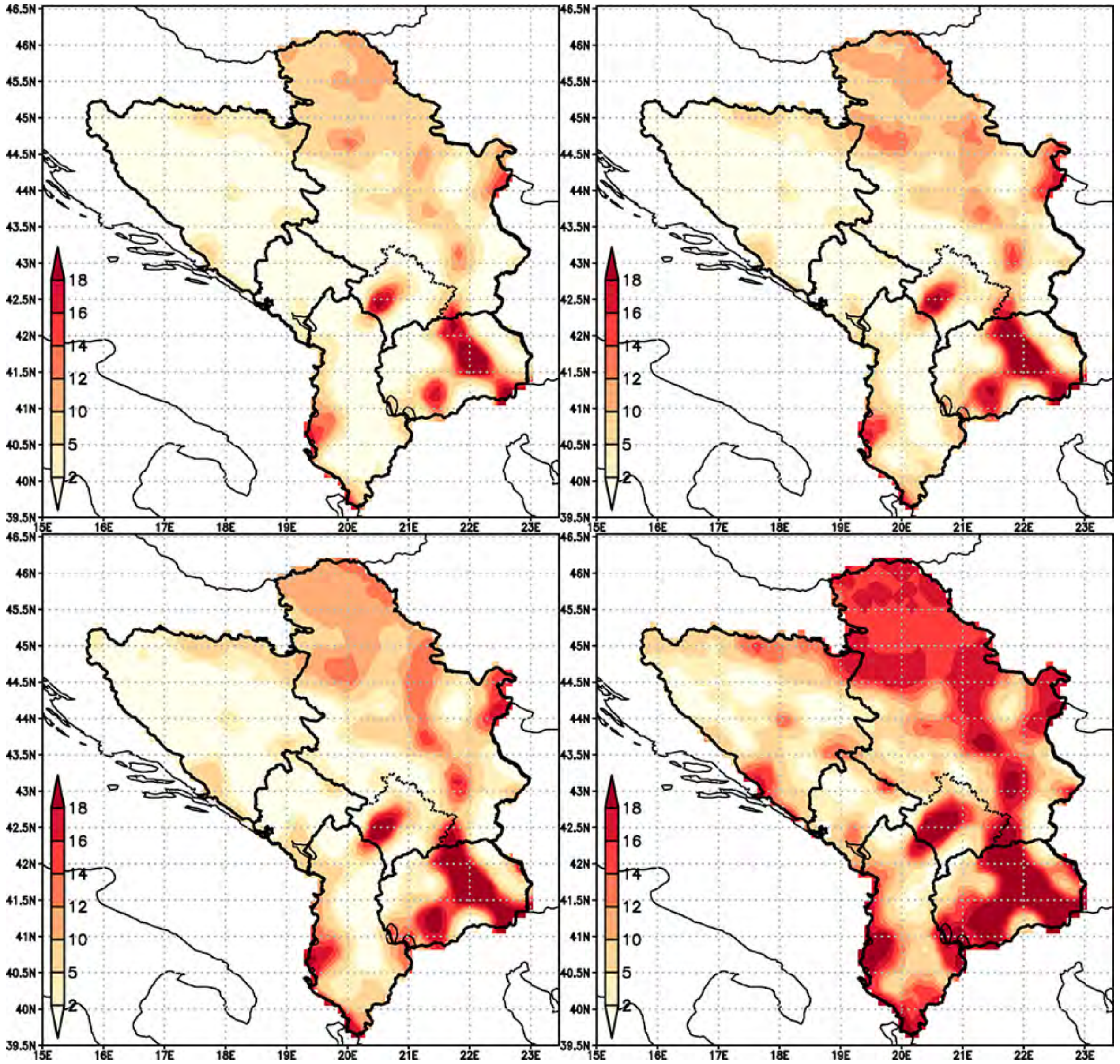

__Figure A36.__ Number of dry years (Seljaninov Hydrothermal Coefficients from April to September and from June to August less than 1) for the baseline period 1986-2005 (upper left), near future 2016-2035 (upper right), mid-century 2046-2065 (lower left) and end of the century 2081-2100 (lower right) periods according to the RCP8.5

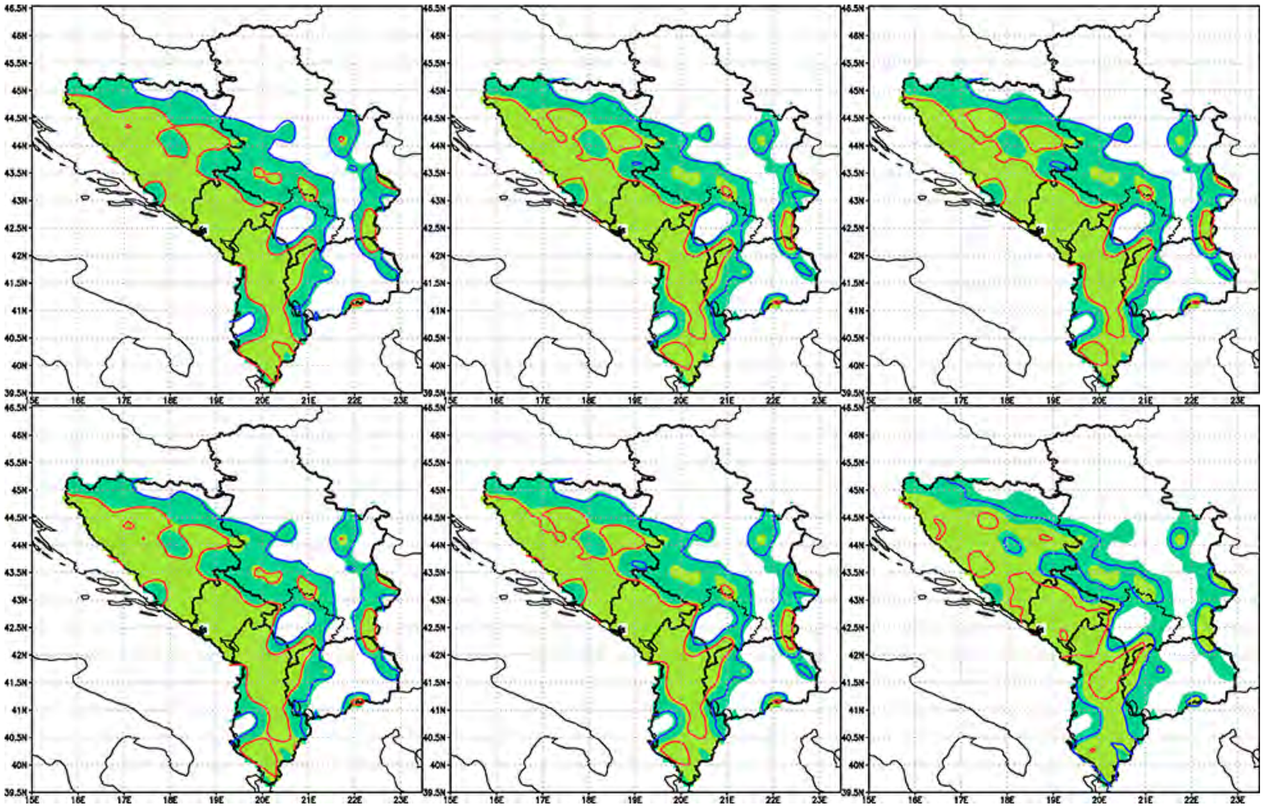

Figure A37. *Climate conditions suitable for beech forest (light green) and mixed beech-oak forest (dark green) in the baseline period (1986-2005) and its change (red line beech forest, blue line mixed beech-oak forest) for the near future 2016-2035 (left column), mid-century 2046-2065 (middle column) and end of the century 2081-2100 (right column) periods with respect to the baseline period (1981-2005) according to the RCP4.5 (top row) and RCP8.5 (bottom row).*

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