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Possible consequences of climate change on viticulture in Bosnia and Herzegovina

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Abstract: The paper analyzes the possible changes in the vineyard index via multi-criterion climatic classification system for grape-growing regions on the basis of results and a regional climate model EBU-POM for the periods 2001-2030 and 2071-2100 under A1B and A2 scenarios. Three indexes of climate multi-criterion classification of vineyards, Heliothermical index, drought index and night freshness index were calculated based on a set of values, mean daily temperature, maximum daily temperature, minimum daily temperature and daily rainfall accumulation for locations of Banja Luka, Sarajevo and Mostar. As demonstrated, the trends are expected to have a significant influence on viticulture sector in Bosnia and Herzegovina. The most significant changes are expected in the second half of the 21st century. The increasing temperatures, which are extending the growing season, and the increasing accumulation of heat influencing the yield and the potential of ripening grapes are expected as well. As a result of the change of climate conditions, the existing vine varieties and more arid and warm climate types should be taken into account during the design of adequate measures for irrigation and protection of potential diseases and pests. However, it should be noted that the modified climatic conditions are likely to introduce new vine varieties typical of regions with drier and warmer climate, but this is currently very improbable in Bosnia and Herzegovina. It may be expected that the border areas in which it is possible to grow a particular variety will be shifted to higher altitudes.

Key words: Climate change, growing grapes, index, temperature, Bosnia and Herzegovina,

Introduction

Bosnia and Herzegovina is located in the region of the Western Balkans and the annual temperature increase of over 1.3◦C is already being witnessed along with the decreasing rainfall during the growing season (Trbic, et al 2013; Trbic et al. 2018;). The global temperature increase affects the production of grape and wine industry worldwide. Depending on the region and the intensity of the impact of climate change, it can have a both positive and negative impact on viticulture (Laget, F. et al 2008; Jones, Davis, 2000, Ramos, et al. 2008; Hall, Jones, 2009; Jones, , 2005). Growth in CO_2 concentration has a positive effect on the growth of grapevine biomass (Bindi, et al. 2001; Moutinho-Pereira, et al. 2009; Santos, J.A, 2011). It is expected that the anthropogenic impact on climate change will continue by increasing the concentration of GHG. Knowledge of the intensity and expected changes is very important for the selection and possibilities of adaptation to climate change (IPCC, 2013; Trbic, et al. 2017; Popov et al. 2018; Popov, et al. 2019). Impacts of climate change on agriculture are primarily negative but may be positive as well. One of the positive

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effects refers to the cultivation of vines which are now showing positive trends and good practice. According to climate scenarios of EBU-POM climate model (Fig.1) and the downscaling projected for the space of Bosnia and Herzegovina by the end of the 21st century, there are expectations of the increase in temperature and decrease in precipitation in the growing season (Djurdjevic, V., Rajkovic, B., 2008; Marsland, 2003; Roeckner, 2003; Jungclaus).

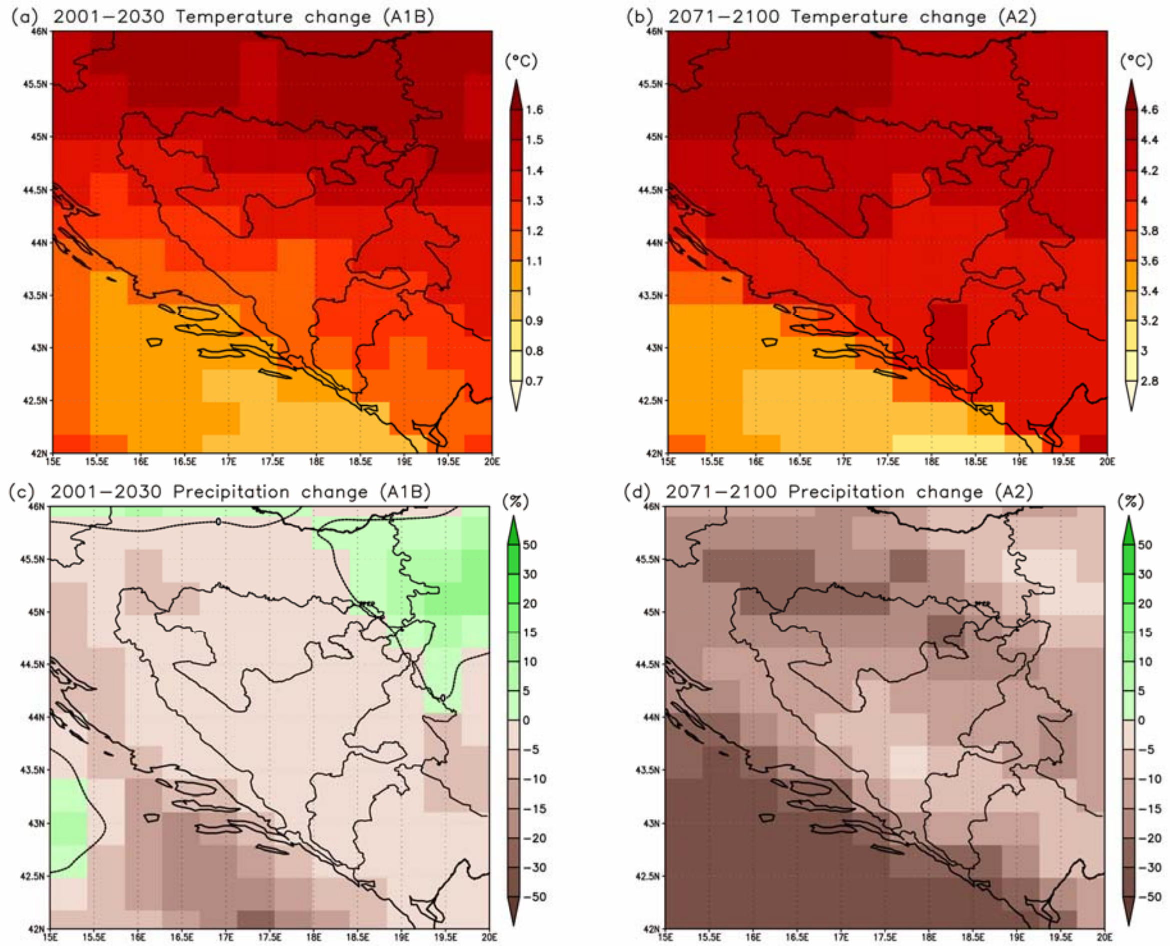

Fig. 1. Changes in growing season in region of Western Balkan: average daily temperature (ΔTgs) and growing season average precipitation (ΔRgs) for 2001–2030 under the SRES A1B scenario (a and c) and for 2071–2100 under the SRES A2 scenario (b and d) relative to the 1961–1990 reference period

Material and methods

Using the results of a regional climate model EBU-POM, we calculated possible changes in vineyard index under the climate multi-criterion classification. The projections refer to the 2001-2030 and 2071-2100 periods, and A1B and A2 scenarios. Three indexes of more climate multi-criterion classification of vineyards, Heliothermical index, drought index and index of freshness of the night, can be calculated on the basis of a set of values, mean daily temperature, maximum daily temperature, minimum daily temperature and daily rainfall accumulation for a chosen location and during the selected time period [9]. Locations of Banja Luka, Sarajevo and Mostar were selected for this study [Fig.2]. The values of these indices indicate that the selected locations are suitable for the cultivation of certain varieties of vines and that the future changes may indicate the degree of vulnerability of certain varieties due to altered climate conditions. The possibility of cultivation of vines depending on the climatic conditions of an area can be estimated by calculating the appropriate index, i.e. HI - heliothermical index, DI - drought index and CI – night freshness index (Tonietto, Carbonneau, 2004; Ruml, 2012).

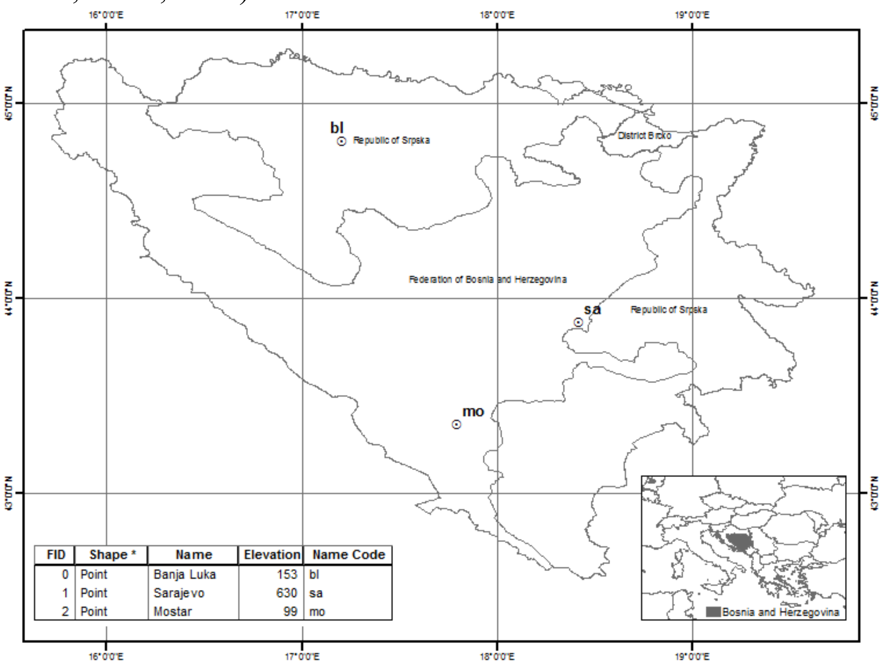

Fig. 2. Location of climatological stations in Bosnia and Herzegovina used in the study

These indices depend on two meteorological elements commonly used to characterize the local climate: temperature at 2 meters altitude and precipitation. Indexes can be calculated by using the multi-year series of the appropriately monitored parameters during the growing season of the vine from April 1st to September 30th. The exact definition of the term is provided in equations (1) where T is the mean daily temperature, Tx is the maximum temperature, Tb is base temperature for vines, d is the coefficient length of days, W0 is the initial soil moisture (200 mm), P is daily rainfall accumulation, Et is the moisture loss by evaporation, Es is the consequence of bare ground, and Tn is the minimum daily temperature. The values of Et and Es can be calculated via the corresponding values of potential evapotranspiration.

$$\sum_{01.04.}^{30.09.} \frac{(\mathbf{T} - \mathbf{T_b}) + (\mathbf{T} - \mathbf{T_x})}{2} \mathbf{d}$$

$$DI = W_0 + \sum_{01.04.}^{30.09.} [P - (E_t - E_s)] \qquad (1)$$

$$CI = \frac{1}{N} \sum_{01.09.}^{30.09.} T_n$$

The appropriate categories and the limit values of index that separate individual climate categories are given in Table 1.

Table 1. Border value and the appropriate categories of index of climate multi-criterion classification.

Viticulture climate indexes	Climate classes	Acronym	Class interval
Dryness Index (DI, mm)	Humid	DI-2	150 < DI
	Sub-humid	DI-1	50 < DI ≤ 150
	Moderately dry	DI+1	-100 < DI ≤ 50
	Very dry	DI+2	DI ≤ -100
Heliothermical Index (HI)	Very cold	HI-3	HI ≤ 1500
	Cold	HI-2	1500 < HI ≤ 1800
	Cool	HI-1	1800 < HI ≤ 2100
	Warm	HI+1	2100 < HI ≤ 2400
	Hot	HI+2	2400 < HI ≤ 3000
	Very hot	HI+3	3000 < HI
Cold Night Index (CI, °C)	Hot nights	CI-2	18 < CI
	Warm nights	CI-1	14 < CI ≤ 18
	Cool nights	CI+1	12 < CI ≤ 14
	Cold nights	CI+2	CI ≤ 12

Also, the same indices can be calculated by using the model values, which would also be the indirect method for model verification. In our case, the observed multi-year period would be the 1961- 1990 period given that this period was covered and observed for model values. To get an answer to the question about the possible impact of climate change on the cultivation of grapes for the region of interest, the value of the indices can be calculated by using the results from the selected scenarios and the time horizon in the future. Since the model results contain a certain level of error / deviation model verified through simulation of the existing climatic conditions (simulation for the period 1961-1990), one should expect that this will be a noticeable deviation in the values of individual indices, especially in the case of non-linear dependence of the index of the basic meteorological parameters, or in the case where the index is a combination of several parameters so that it can reach the superimposition of the individual errors. To avoid this kind of 'infecting' the results of the model deviation (bias), a statistical method, quintile, and correction model results (Piani, et al. 2010; Dettinger, 2004) were proposed, which assumed that the results of the model for the integration period 1961-1990 were statistically corrected by using observed data for the same period. The correction factors are derived from the difference between the cumulative density function of two sets of data, the observed ones and the model, so that after the application of correction factors to a model series, the corrected and observed series have approximately the same density distribution. The same correction would be applied for simulations of future climate, which would eliminate the discrepancy model in this series.

Results and Discussion

Fig. 3. displays the values of mean monthly temperature (upper graph) and monthly accumulated precipitation (bottom graph) in Banja Luka from 1961 to 1990 obtained from observation model with no statistical correction results and after the statistical adjustments to the model results. The model has a maximum deviation medium temperature for the months of December, January and February and the deviation was positive in relation to the observation (the so-called positive bias) for all the months as well. The biggest departures is in January and it is approximately about 3°C. As for the rainfall during the first half of the model, it has a positive bias in relation to the observed values but in the second half of the bias it is negative. It is also interesting to note that on the basis of the model of climate month with maximum precipitation, it is June. After statistical adjustments of raw model results, we see that the deviation of model results is significantly reduced in the case of temperature and in case of precipitation.

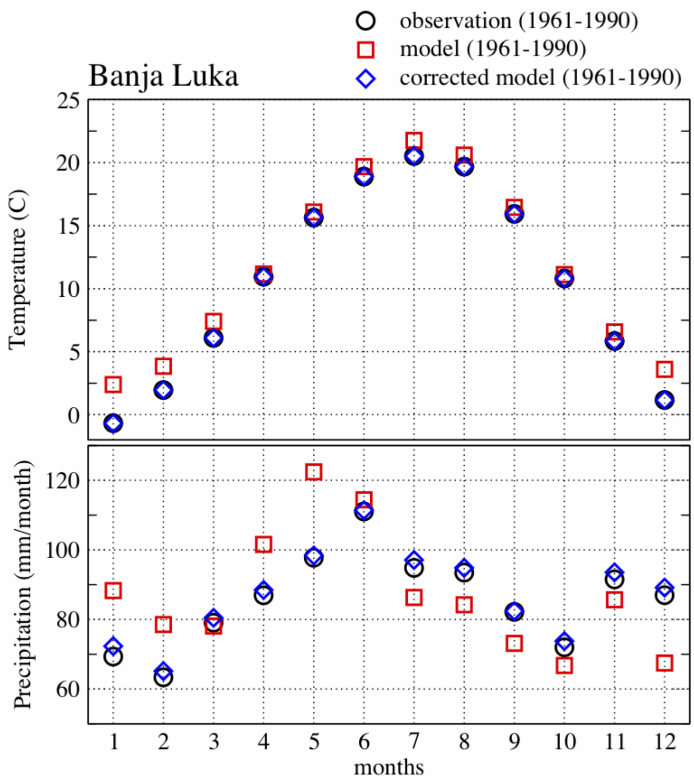

Fig.3. The values of mean monthly temperature (upper graph) and monthly accumulated precipitation (bottom graph) in Banja Luka in the 1961 to 1990 period, calculated for observations (black circles), model with no statistical correction (red squares) and model after statistical correction of results (blue diamonds).

Fig.4 shows the values of the three indices of multi-criterion climate classification, helio index, drought index and the night freshness index for the 1961-1990 and 2001-2030 periods according to A1B scenario, and for the 2071- 2100 periods according to A1B and A2 scenarios. For the 1961-1990 period, the index value is calculated from the observations and the values are obtained from the model-based integration after statistical adjustments for the same time period. The numerical values of the index are given in Table 2. We see that for the 1961-1990 period, the model-based value after statistical adjustments differ slightly in comparison with the values obtained from the observation. This test of indices comparison can be considered as the indirect verification of the model itself.

We also see that in the 1961-1990 period, among the three locations in the same category of drought indices (categories humid), it is Banja Luka that has the highest value of the index, followed by Sarajevo and Mostar (the location of driest climate and lowest index values in this category). As for the heliothermical index, there are differences among the locations - Sarajevo is in the category of cold, Banja Luka in the category of cool and Mostar is in the category of hot, so all three sites are located in different categories. Finally, according to the night freshness index, Banja Luka and Sarajevo fall into the category of cold nights with the values of the index of 10.1 and 9.7, respectively, while Mostar is in the category of warm nights with an index value of 15.3.

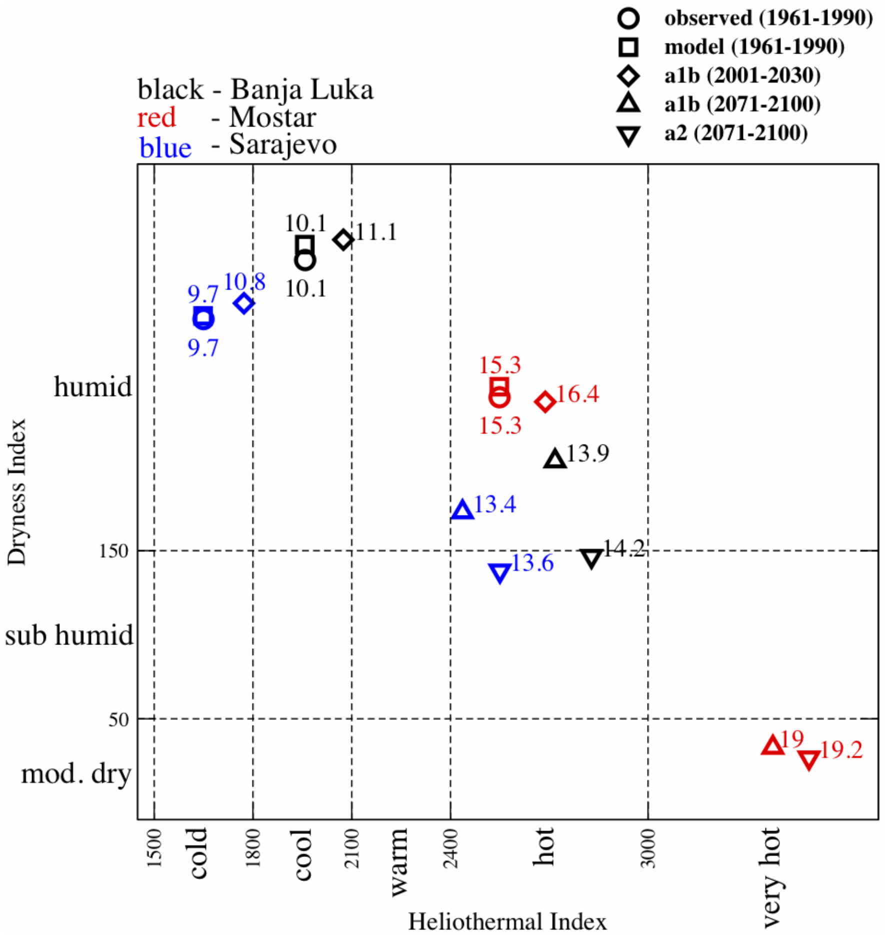

Fig.4. The values of the multi-criterion climate classification for three selected sites - Banja Luka (black symbols), Mostar (red symbols) and Sarajevo (blue symbols).

The heliotermical index and the corresponding category is read on the x-axis, drought index on the y-axis and for the night freshness index the number is given next to the appropriate symbol. The corresponding values obtained from observations for the 1961-1990 period are given in circles, the model results are given in squares; for the 2001-2030 period and scenario A1B the values are given in rhomboids; for the 2071-2100 period and scenario A1B the values are given in upright triangles; and for the 2071-2100 period and scenario A2 the values are provided in inverted triangles.

For the 2001-2030 period, there is a noticeable shift in values of heliotermical index compared to the change in the index of drought, which moved towards higher values compared to the 1961-1990 period; the value of the index of drought in the case of Banja Luka and Sarajevo is slightly positive, and in the case of Mostar it is slightly lower than in the 1961-1990 period. For all three locations, all three indices in this period remain in the same categories as well as for the 1961-1990 period.

For the 2071-2100 period, we see that the changes are quite "serious" for all three indices and all three locations, especially in the case of A2 scenario. In the case of Banja Luka and Sarajevo, the heliotermical index has moved two or three categories in relation to the 1961-1990 period and Sarajevo moved from the category of cold into the category of hot, whereas Banja Luka moved from the category of cool into the hot category. For the location of Mostar, this index goes from hot categories to the category of very hot. As far as drought index as concerned, we see that in the case scenario A2 and locations of Banja Luka and Sarajevo the index passes from category of humid into the category of sub humid, while in the case of Mostar it moves even for the two categories and into the category of moderately dry for both scenarios. Interestingly, the relative ratio of the index in the picture (Figure 2) remains the same in the future.

Table 2. The values of the multi-criterion climate classification for three selected sites of Banja Luka, Mostar and Sarajevo for the selected time period and scenarios.

Location	Index	Observation 1961-1990	Model 1961-1990	A1B 2001-2030	A1B 2071-2100	A2 2071-2100
Banja Luka	HI	1958.65	1957.68	2074.95	2717.83	2828.48
	CI	10.08	10.07	11.13	13.91	14.20
	DI	322.92	332.02	334.98	203.28	146.74
Sarajevo	HI	1649.68	1648.66	1773.02	2436.59	2550.38
	CI	9.73	9.72	10.79	13.39	13.62
	DI	287.75	289.65	297.13	172.96	138.04
Mostar	HI	2549.29	2548.34	2688.06	3379.37	3489.24
	CI	15.29	15.28	16.36	19.00	19.24
	DI	241.19	247.53	238.56	32.95	26.85

The time horizon is becoming further and conditions are warmer and drier than they were during the 1961-1990 period so all three locations maintain relative proportions. Also, that is interesting because according to these indices, the air in Banja Luka and Sarajevo for the 2071-2100 period and A1B scenario is close to the climate of Mostar for the 1961-1990 period, and according to the A2 scenario it is drier and warmer than the air in Mostar for the 1961-1990 period. We see that in all three locations index freshness night under scenarios A1B and A2 for the period 2071 to 2100, be extended for one category than in the period 1961-1990. The exception is Banja Luka and A2 scenario according to which the index has shifted to two categories of cold nights into the warm nights. Santos *et al.* developed a statistical grapevine yield model that uses monthly mean temperatures and monthly precipitation sums as predictors (Santos, 2011). The model explains over 50% of the total variance in the grapevine yield time series. Based on ensemble climate simulations under the A1B emissions scenario, the model project shows a slight upward trend in grapevine yield until the 2050s, which is followed by „a much steeper and continuous increase until the 2090s“.

Conclusion

Based on the foregoing analysis, we can conclude that the expected climate change has a primarily positive effect on the cultivation of Bosnia and Herzegovina. If there comes to a further increase in the concentration of greenhouse gases under one of two scenarios considered, we may expect serious changes in climatic conditions that would determine the possible locations of the observed potentials for growing grapes. It is certain that in the case of existing vine varieties and as a result of the change of climatic conditions, the more arid and warm climate types should be taken into account for the design of adequate measures for irrigation and protection from potential diseases and pests. Increasing temperatures in Posavina (the northern part of Bosnia and Herzegovina, which is under the influence of moderate continental climate) today facilitates the cultivation of varieties that are inherent in the Herzegovina region (southern part of Bosnia and Herzegovina) or in areas with sub-Mediterranean climate. This primarily refers to varieties of cormorant, white wine, Tamjanika and Chardonnay. It is certain to expect migration of other vine varieties that have so far been cultivated in warmer climates (Spain, Portugal, France, Italy, Australia, Serbia, Montenegro, Greece, etc.) (Detinger, et. Al. 2004; Webb, 2007). However, it should be noted that the modified climatic conditions are likely to introduce new vine varieties, typical of regions with a drier and warmer climate, the potential of which is usually poor in the territory of Bosnia and Herzegovina. The best example for this is the variety Shiraz (Syrah), which has been intensively grown in south of Herzegovina since 2011.

Finally, it is likely to expect that the border areas, in which it is possible to grow a particular variety, will be moved to higher altitudes. The obtained results can provide useful guidance for planning future development of viticulture in Bosnia and Herzegovina. This work may serve as a basis for additional studies that would be the framework for the development of adaptive strategies to climate change. Particular attention in the adaptive strategy papers should be given to the positive effects of the expected climate change, which certainly applies to the sector of vine cultivation.

Acknowledgements

The authors are grateful to the Ministry of Science and Technology of the Government of Republic of Srpska for the assistance provided in the research. Besides, the authors acknowledge the Max Planck Institute (MPI) and the German Climate Computing Centre (DKRZ) for providing and enabling access to the ECHAM5/MPI-OM data, disseminated through the World Data Center for Climate (WDCC).

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