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Projected changes in winter climate in Beskids Mountains during 21st century

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We have investigated the future changes of climate conditions during the winter season in the Beskids Mountains. During the 21st century mean winter temperature will increase by 2.0–6.3 °C and winter precipitation will increase by 12.5 – to 17.5 % - depending on the scenario. Higher winter temperatures will be reflected in the reduced number of frost days, the number of which may drop by 40 % according to the RCP8.5 scenario. Whilst our study expects general increase in precipitation, higher temperatures will lead to an increased evapotranspiration and also change in the form of precipitation from solid (snow, rime) to liquid (rain, drizzling). Such trends could further propel the unfavorable changes in the water balance budget.

Key words: climate change, winter season, Euro-CORDEX, Lysá hora

Introduction:

In recent decades we have witnessed ongoing climate change, which is reflected primarily in an increase of air temperature, but also in changing precipitation characteristics. In conjunction. these processes can have an impact on snow conditions. During recent years, air temperatures have been significantly above average and the winter seasons of 2014/2015 and 2015/2016 were among the warmest recorded winters since 1800. The last six winters were also poor regarding the quantity of snow, mainly due the above average temperatures (Zahradníček et al 2017A, Zahradníček et al 2017B).

Acombination of higher temperature and drier winters (i.e., the lower amount of snow) has caused problems in water management, agriculture, and various sectors of the local economy. These adverse climate conditions result in a less intensive replenishment of underground and surface water reservoirs. Additionally, vegetation loses its insulating snow cover during the cold season. Climate conditions in the mountains are also crucial for tourism throughout winter seasons. Warm winters with low amounts of snow can thus cause significant financial loses as, for example, ski resosts are forced to use artificial snow. This is yet another burden for the already strained water resources in the area. However, last winter, due to the unusually high temperatures, artificial snow could not be used.

Our recent studies (e.g., Štěpánek et al 2016) have been focused on the projection of climate change in the whole of the Czech Republic on the seasonal time scale using the outputs of regional climate models. The aim of this study is to investigate the effect of climate change over a smaller territory of Beskid Mountains and describe the uncertainty of future development as it is projected by various climate models. Our work complements the previous research of snow conditions over the Czech Republic as a whole (Zahradníček et al. 2016).

Data and methods

Specifically, The Beskid Protected Landscape Area has been selected as our area of interest (Fig. 1). It is elevated and mainly forested area with rough climate. The spatial statistics were calculated from interpolated map layers for current (1981–2010) and future climate (2021–2100). The regression technique was used as an interpolation method, also utilizing external predictors such as altitude, slope, roughness and geographical position. This technique has been developed by Petr Štěpánek (Štěpánek el al 2016). The two meteorological stations operated by the Czech Hydrometeorological Institute were selected as the data source for the trend analysis. Lysá hora (1322 m a.s.l.), a typical mountain station, has been complemented by the Ostrava – Mošnov station (250 m a.s.l.) that represents a lowland zone outside the national park.

Winter temperature, precipitation and the number of frost days have been analyzed. A frost day is defined as a day with its minimum temperature below zero. It is an important climate index for the evaluation of winter conditions.
Our analysis of future climate conditions is based on regional climate model (RCM) simulations prepared within the European part of the global Coordinated Regional Climate Downscaling Experiment (CORDEX, www.cordex.org). CORDEX is an international effort supported by the World Climate Research Program (WRCP) and aimed at producing a set of climate change projections covering individual world regions with multiple RCMs and several greenhouse gas emission scenarios.

The European CORDEX domain is addressed within the frame of the Euro-CORDEX subproject (www.euro-cordex.net). Model experiments performed within the Euro-CORDEX sub-project have been executed with two spatial resolutions: 0.44 degree and 0.11 degree. In our paper we focus only on 0.11 degree resolution experiments forced by RCP2.6 (van Vuuren et al. 2007), RCP 4.5 (Clarke et al. 2007) and RCP 8.5 (Riahi et al. 2007) scenarios, respectively.

The climate simulated by numerical models shows systematic deviations from reality (true observed climate) which limits their applicability to impact models. Therefore, climate model outputs have to be post-processed to match the observed climate (Maraun 2013, Christensen et al. 2008). In our approach we adopted the quantile matching (QM) method as described in Déqué (2007). The QM method has been applied on a daily basis and for each grid box/location separately. To be suitable for

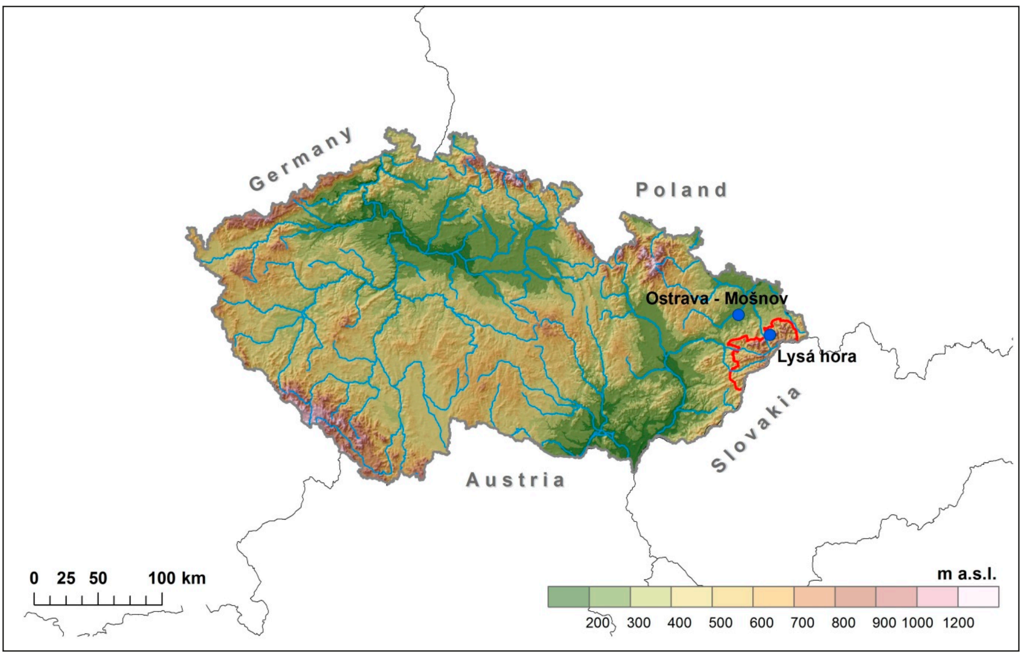

Fig. 1: Beskids Mountains region and the two selected meteorological stations.

impact studies where station data are preferred (because they are also available for the current climate), correction/localization was conducted by finding the nearest grid points for a given location (station) and applying the correction several times (5 times in case of precipitation, up to 10 times in the case of other elements). In practice, the first (nearest) neighbor was applied as the final correction, but the other results were used to evaluate uncertainty coming from the correction process. More details are to be found in Štěpánek et al. 2016. Five Euro-CORDEX models and two emission scenarios (RCP 4.5 and RCP 8.5) were selected for spatial analysis of the whole Beskid Mountains region (CNRM-CM5_ALADIN53, EC-EARTH_RCA4, EC-EARTH_RACMO22E, HadGEM2-ES_RCA4, MPI-ESM-LR_CCLM4. 8. 17). For the trend analysis of the two representative stations the median of all the Euro-CORDEX models and three emission scenarios (RCP 2.6, 4.5, 8.5) were chosen.

Results

Temperature

Average winter air temperature in the Beskid Mountains region is -2.5 °C (Fig. 2). The predicted increase of air temperature up to the year 2050 is similar for both emission scenarios (RCP 4.5 and 8.5) (Tab. 1). For the second half of this century the difference between the two scenarios is more prominent. In the near future period of 2021–2040 the predicted average temperature change from five selected climate models is +1.5 °C when compared to the current climate. For the period 2061-2080 the difference is higher. Average mean temperature growth as projected by the RCP 4.5 scenario will be about 2.5 °C or even 3.6 °C by RCP 8. 5. The highest warming of about 2.8 °C (RCP 4.5) or 5.4 °C (RCP 8.5) will be observed by the end of the century.

HadGEM2-ES_RCA4 is the warmest model for the Beskid Mountains region during the winter season. The increase in air temperature at the end of the century in the worst-case scenario would be up to 6.2 °C. On the other hand, the lowest warming is predicted by model MPI-ESM-LR_CCLM4. 8. 17, with warming by 2.0 (RCP4.5) or 4.7 °C (RCP 8.5). The winter temperature could change from -2.5 °C in the current climate to up +3.8 °C in the worst-case scenario or up to -0.5 °C in the most optimistic calculation by the end of the century.

The trend in temperature increase is observed in both selected stations (mountain and lowland) in the current climate (Fig. 3). In the lowland station Ostrava – Mošnov a statistically significant trend is observed in all seasons and annual values in the period 1961-2015 (Tab. 2). The warming signal at the mountain station at Lysá hora is weaker. Statistically significant values are calculated only in the case of the annual, spring, and summer seasons. In winter months there is no statistically significant trend at Lysá hora. In the future climate, the highest positive trend is again projected by the RCP 8.5 emission scenario. The increase in winter temperature

Tab. 1: Predicted change in winter temperature during period 1981–2010 in the Beskid Mountains region by five Euro-CORDEX climate models (CNRM-CM5_ALADIN53, EC-EARTH_RCA4, EC-EARTH_RACMO22E, HadGEM2-ES_RCA4, MPI-ESM-LR_CCLM4. 8. 17 with two emission scenarios (RCP 4.5, RCP 8.5).

		2021–2040	**2041–2060**	**2061–2080**	**2081–2100**
RCP 4.5	CNRM-CM5_ALADIN53	1.1	1.3	2.5	2.9
	EC-EARTH_RCA4	1.4	1.8	2.5	3.3
	EC-EARTH_RACMO22E	1.2	1.0	1.8	2.5
	HADGEM2-ES_RCA4	2.5	2.9	4.0	3.4
	MPI-ESM-LR_CCLM4. 8. 17	1.2	1.0	1.5	2.0
RCP 8.5	CNRM-CM5_ALADIN53	1.1	2.2	3.9	5.0
	EC-EARTH_RCA4	2.2	3.4	3.1	6.0
	EC-EARTH_RACMO22E	1.3	1.3	3.0	5.2
	HADGEM2-ES_RCA4	2.5	3.1	4.6	6.2
	MPI-ESM-LR_CCLM4. 8. 17	0.6	1.7	3.4	4.7

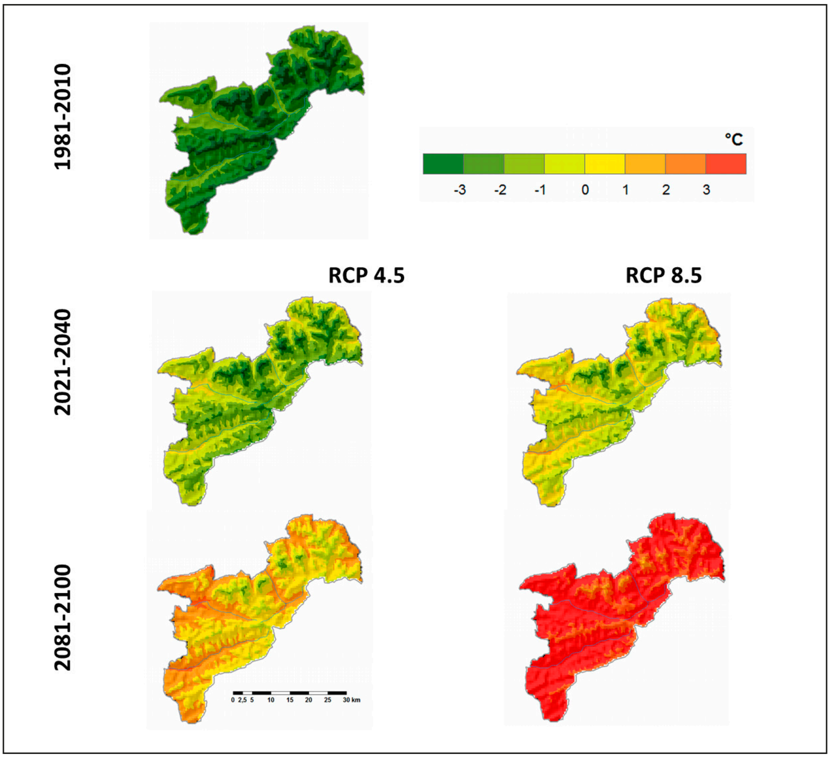

Fig. 2: Example of simulated mean winter temperature in the Beskid Mountains Region as provided by the model EC-EARTH_RCA (see Table 1) during the current period (1981–2010) and in the future climate 2021–2040 and 2081–2100 with two emission scenarios (RCP 4.5 and 8.5).

will be about 0.56 °C/10 years at Lysá hora and about 0.64 °C/10 years at Ostrava – Mošnov in the period 2021–2100. Winter warming projected by RCP 8.5 is stronger than the annual trend values or in other seasons (the same statement is valid for summer at Lysá hora). The statistically significant trend in the winter modeled by RCP 4.5 is observed only for the whole period 2021-2100, but not for shorter periods (2021–2060 and 2061–2100). The change will be about 0.23 °C/10 years at Lysá hora and 0.27 °C/10 years at Ostrava–Mošnov. As in the case of RCP 8.5, the warming in winter is predicted to be more intensive than in the other seasons. Finally, no statistically significant warming is calculated by RCP 2. 6.

Precipitation

The variability of precipitation prevails over its trend in the climate of the Czech Republic as a wholle. Precipitation sums are distinguished by high spatially and temporal variability. This is determined mainly by atmospheric circulation, the amount of precipitation depends on the type of synoptic situation. The complex orography of the Czech Republic also has a significant influence (Štěpánek et al 2016).

The average amount of winter precipitation for the Beskid Mountains region is 221.7 mm (Fig. 4). Selected climate models calculated a higher amount of precipitation in the winter in the Beskid Mountains in the future climate (Tab. 3). The lowest increase is expected for the near future (2021–2040) period. Two models (EC-EARTH_RACMO22E, MPI-ESM-LR_CCLM4. 8. 17) even calculated a slightly lower precipitation amount than in the current climate in the case of the RCP 8. 5. Average change from five selected models by both scenarios ranges from +12.5 to +17.5 % for the period 2021–2100. There is no observed significant difference between RCP 4.5 and 8. 5. Uncertainty between models in case of precipitation is higher than in the case of temperature comparison. In the near future (2021–2040) the range of

Tab. 2: Linear trends (°C/year) calculated for Lysá hora (mountain station) and Ostrava – Mošnov (lowland station) in the current climate and future climate predicted by the Euro-CORDEX project (median of all 11 models) –statistically significant trends are in bold (for p = 0.05).

Lysá hora						
	Period	**YEAR**	**DJF**	**MAM**	**JJA**	**SON**
	1961–2015	**0.20**	0.11	**0.25**	**0.36**	0.06
RPC 2.6	2021–2060	**0.23**	0.19	**0.43**	0.07	**0.23**
	2061–2100	-0.12	0.03	-0.26	-0.12	-0.14
	2021–2100	**0.06**	0.05	**0.13**	0.01	0.03
RCP 4.5	2021–2060	**0.29**	0.20	**0.24**	**0.30**	**0.30**
	2061–2100	**0.14**	0.15	**0.19**	-0.02	0.09
	2021–2100	**0.20**	**0.23**	**0.20**	**0.20**	**0.18**
RCP 8.5	2021–2060	**0.44**	**0.58**	**0.44**	**0.48**	**0.52**
	2061–2100	**0.59**	**0.60**	**0.60**	**0.73**	**0.54**
	2021–2100	**0.52**	**0.56**	**0.50**	**0.57**	**0.50**
Ostrava–Mošnov						
	Period	**YEAR**	**DJF**	**MAM**	**JJA**	**SON**
	1961–2015	**0.34**	**0.37**	**0.35**	**0.47**	**0.18**
RPC 2.6	2021–2060	**0.20**	0.19	**0.36**	0.00	**0.23**
	2061–2100	-0.10	0.05	-0.21	-0.09	-0.13
	2021–2100	0.05	0.06	**0.11**	0.00	0.02
RCP 4.5	2021–2060	**0.24**	0.22	**0.23**	**0.25**	**0.27**
	2061–2100	**0.14**	0.17	**0.18**	-0.02	0.11
	2021–2100	**0.20**	**0.27**	**0.17**	**0.16**	**0.17**
RCP 8.5	2021–2060	**0.42**	**0.64**	**0.36**	**0.37**	**0.48**
	2061–2100	**0.54**	**0.71**	**0.53**	**0.59**	**0.49**
	2021–2100	**0.48**	**0.64**	**0.41**	**0.44**	**0.46**

prediction varies from 214 mm to 251.7 mm in the winter. Prediction spread for the far future (2081–2100) ranges from 230.1 mm to 289 mm in the winter.

For the Beskid Mountains region the winter snowfall is a key landscape feature as both local tourism (winter sports) and the water cycle (supplementation of surface and groundwater) are heavily dependent upon it. The last 6 winters have been mostly dry and warm. This has caused a drop in the amount of snow in the mountains of the Czech Republic by up to 35 % (Zahradníček et al 2016). Due to the generally higher mean temperature rain has been more often observed than snowfall as a form of precipitation. Consequently, even if the amount of rainfall increases in the future climate, the amount of snow could become stagnant or even decrease.

In the current climate, a statistically significant decreasing trend for the annual nad spring precipitation at Ostrava – Mošnov is observed (Fig. 5). In the case of Ostrava – Mošnov this trend is relatively high (-24 mm/10 years, Tab. 4). Winter precipitation at both investigated stations has not manifested any statistically significant trend. For the future climate, mostly increased amounts of precipitation are projected. A higher trend for the winter is calculated for the mountain station at Lysá hora. Model winter precipitation increased by about 3.7 mm/10 years according to RCP 4.5 and about 6.9 mm/10 years according to RCP 8.5 in the period 2021–2100. In the lowlands, represented by station at Ostrava – Mošnov the only statistically significant trend (of about 3.9 mm/10 years) is detected by simulations driven by the RCP 8.5 scenario.

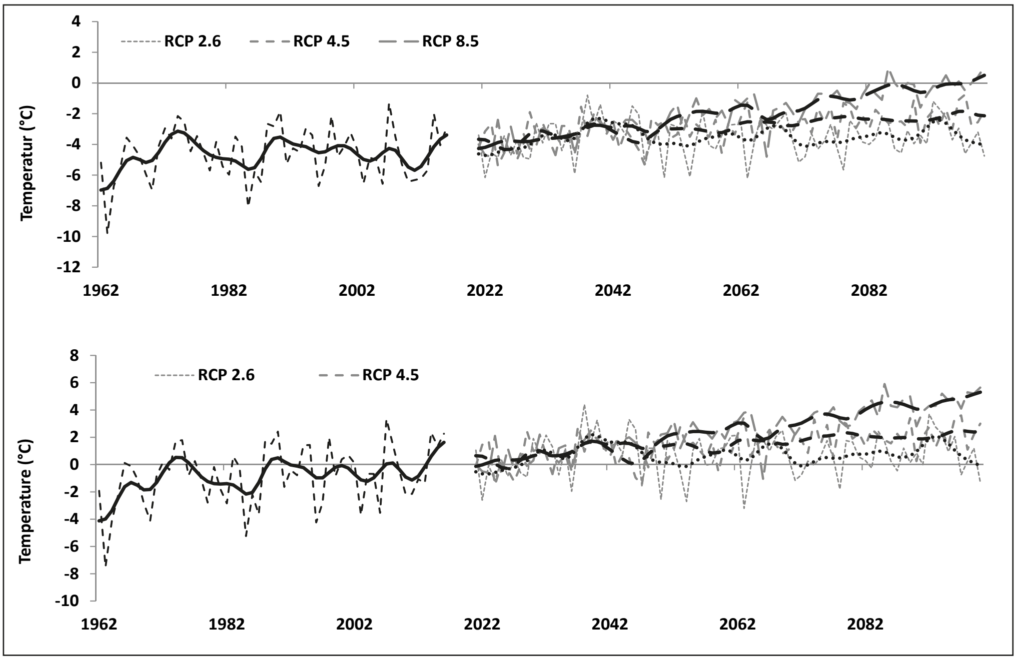

Fig. 3: Winter temperature at Lysá hora (top) and Ostrava – Mošnov (bottom) stations in the period 1961–2100 predicted by the median of the Euro-CORDEX group of models and three emission scenarios (RCP 2.6, 4.5 and 8.5).

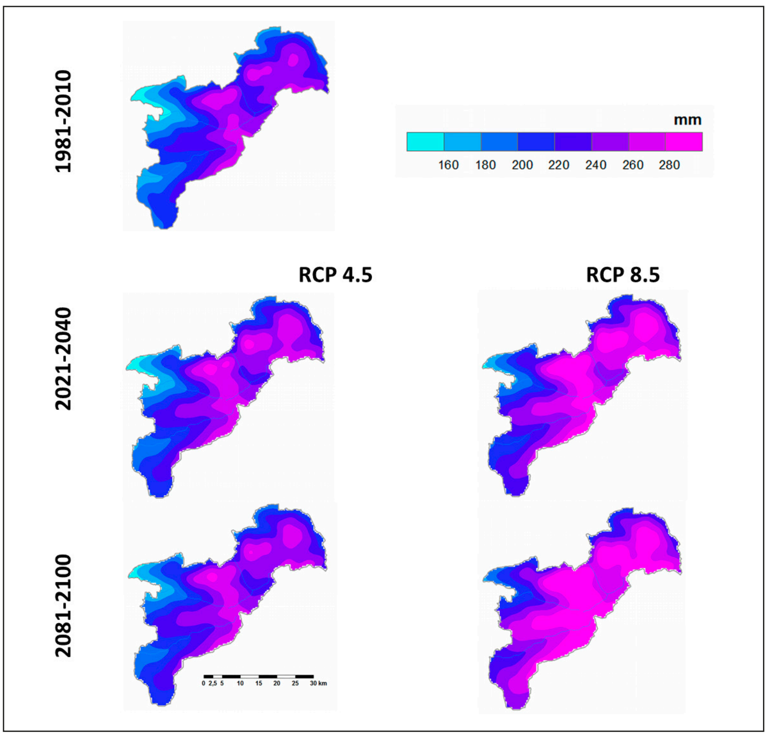

Fig. 4: Example of simulated winter precipitation in the Beskid Mountains region as provided by the EC-EARTH_RCA4 during the current period (1981–2010) and in the future climate periods of 2021–2040 and 2081–2100 with two emission scenarios.

Tab. 3: Predicted change (%) in winter precipitation during the period 1981-2010 in the Beskid Mountains region by five Euro-Cordex climate models (CNRM-CM5_ALADIN53, EC-EARTH_RCA4, EC-EARTH_RACMO22E, HadGEM2-ES_RCA4, MPI-ESM-LR_CCLM4. 8. 17 with two emission scenarios (RCP 4.5, RCP 8.5).

		2021–2040	2041–2060	2061–2080	2081–2100
RCP 4.5	CNRM-CM5_ALADIN53	105.9	118.1	106.9	113.3
	EC-EARTH_RCA4	104.7	110.6	116.3	104.3
	EC-EARTH_RACMO22E	106.4	113.3	107.6	113.4
	HADGEM2-ES_RCA4	110.0	113.9	126.5	103.9
	MPI-ESM-LR_CCLM4. 8. 17	113.5	116.4	121.1	127.5
RCP 8.5	CNRM-CM5_ALADIN53	102.3	119.7	108.3	112.0
	EC-EARTH_RCA4	113.0	129.0	122.6	119.3
	EC-EARTH_RACMO22E	96.5	110.8	107.3	113.5
	HADGEM2-ES_RCA4	111.7	111.2	111.6	114.2
	MPI-ESM-LR_CCLM4. 8. 17	97.5	115.2	115.9	130.4

Tab. 4: Linear trends (mm/year) calculated for Lysá hora (mountain station) and Ostrava – Mošnov (lowland station) in the current climate and future climate as simulated by the Euro-CORDEX project (median of all 11 models) –statistically significant trend values (for p = 0.05) are in bold.

Lysá hora						
	Period	**YEAR**	**DJF**	**MAM**	**JJA**	**SON**
	1961–2015	2.04	1.03	5.41	-18.55	14.91
RPC 2.6	2021–2060	48.58	-1.20	3.14	**51.89**	-11.17
	2061–2100	25.92	2.95	-0.02	0.34	18.58
	2021–2100	11.51	1.06	-1.38	6.49	4.75
RCP 4.5	2021–2060	-12.50	3.70	4.70	-21.54	0.33
	2061–2100	29.91	2.98	5.41	17.77	5.15
	2021–2100	11.77	**3.71**	**6.80**	-0.25	0.86
RCP 8.5	2021–2060	26.32	**16.90**	5.50	-0.61	5.41
	2061–2100	20.28	7.39	8.79	-11.97	5.70
	2021–2100	**13.23**	**6.93**	**8.16**	-7.50	4.28
Ostrava–Mošnov						
	Period	**YEAR**	**DJF**	**MAM**	**JJA**	**SON**
	1961–2015	**-23.53**	-3.17	**-10.55**	-9.64	0.02
RPC 2.6	2021–2060	23.40	-2.37	9.30	20.02	-4.64
	2061–2100	8.38	3.06	-5.91	1.67	8.73
	2021–2100	7.35	0.63	0.37	3.07	3.12
RCP 4.5	2021–2060	5.70	**4.71**	5.20	-8.23	4.23
	2061–2100	13.77	-0.16	4.22	9.21	4.78
	2021–2100	**6.67**	1.38	**5.98**	-1.23	1.48
RCP 8.5	2021–2060	14.19	**6.48**	4.54	2.45	0.76
	2061–2100	**23.24**	4.01	5.44	-0.42	2.73
	2021–2100	**14.41**	**3.93**	**4.98**	1.01	**2.68**

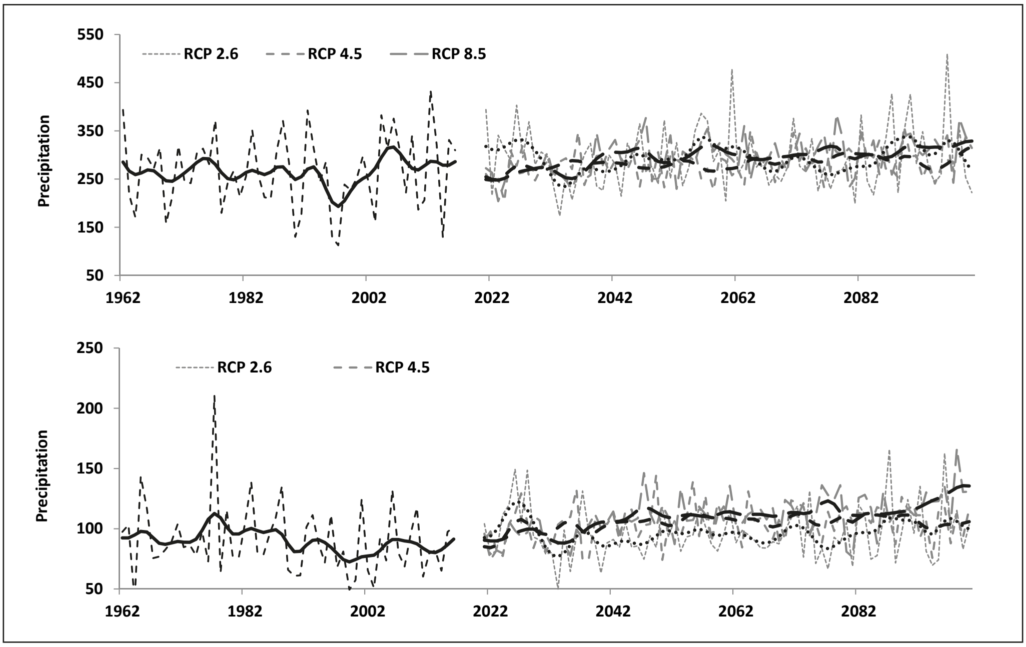

Fig. 5: Winter precipitation at Lysá hora (top) and Ostrava – Mošnov (bottom) station in the period 1961–2100 predicted by the median of the Euro-CORDEX group of models and three emission scenarios (RCP 2.6, 4.5 and 8.5).

Number of frost days

An increase in mean temperature often induces changes in other affiliated climatic characteristics. The important characteristics in the mountain regions are the number of frost days, which are defined as days with a minimum temperature below 0 °C. The average annual amount of frost days in the Beskid Mountains region was 76.1 in the period 1981–2010 (Fig. 6). Due to the predicted rise in mean air temperature we expect the number of frost days to decrease. This expected decrease will amount to 6 to 10 days up to the middle of the century. There is apparently no significant difference between the emission scenarios (Tab. 5). After the 2050s the difference between the two scenarios becomes more prominent. The average decrease in frost days calculated from the group of selected five models is about 13/30 (RCP 4.5/8.5) days compare to the current climate. It follows that in a pessimistic scenario these days will be 40 % less than at present.

The most profound decrease in the number of frost days is predicted by the HadGEM2-ES_RCA4 model. According to its output, only half of these days will be observed towards the end of the 21st century. By contrast, the smallest change is predicted by the MPI-ESM-LR_CCLM4. 8. 17 model. A decrease of only about 5 days is simulated in the case of RCP 4. 5. The general uncertainty based on the selected models and scenarios is rather high: we could expect that 38 to 71 frost days will be observed in the Beskid Mountains at the end of the century from most pessimistic and optimistic model outputs.

For the current climate, we observe a decreasing trend in the number of frost days at the station at Lysá hora (Fig. 7). This significant trend is not detected in winter, but in the spring, autumn, and annual values (Tab. 6). This would mean that temperatures below freezing now appear later in the autumn and are less common in the spring – i.e. winter starts later and ends earlier. Calculation of the linear trend is affected by the first and last value of the time series. The reason why no statistically significant trend is observed in the winter could be the particularly mild winter in the year of 1962 (Fig. 7). The decreasing trend is predicted by models in the winter by RCP 4.5 and 8.5 and for the whole year by all scenarios in the case of the Lysá hora station. The strongest trend is logically modeled by RCP 8.5 at about -2.6 days/10 years (Lysá hora) or -5.0 days/10 years (Ostrava – Mošnov) during the winter season.

Tab. 5: Predicted change in frost days number in the winter for the period 1981–2010 in the Beskid Mountains region according to the ensemble of five Euro-Cordex climate models (CNRM-CM5_ALADIN53, EC-EARTH_RCA4, EC-EARTH_RACMO22E, HadGEM2-ES_RCA4, MPI-ESM-LR_CCLM4. 8. 17 and with respect to two emission scenarios (RCP 4.5, RCP 8.5).

		2021–2040	2041–2060	2061–2080	2081–2100
RCP 4.5	CNRM-CM5_ALADIN53	-5.0	-5.7	-12.0	-12.8
	EC-EARTH_RCA4	-4.6	-4.0	-8.6	-13.0
	EC-EARTH_RACMO22E	-4.3	-4.8	-10.7	-17.4
	HADGEM2-ES_RCA4	-13.6	-13.1	-24.2	-18.5
	MPI-ESM-LR_CCLM4. 8. 17	-4.0	-2.7	-5.7	-5.5
RCP 8.5	CNRM-CM5_ALADIN53	-3.2	-9.6	-18.7	-25.3
	EC-EARTH_RCA4	-6.2	-5.6	-15.7	-28.7
	EC-EARTH_RACMO22E	-9.1	-17.4	-17.0	-35.8
	HADGEM2-ES_RCA4	-14.1	-14.3	-26.4	-37.9
	MPI-ESM-LR_CCLM4. 8. 17	-0.4	-7.0	-15.2	-24.5

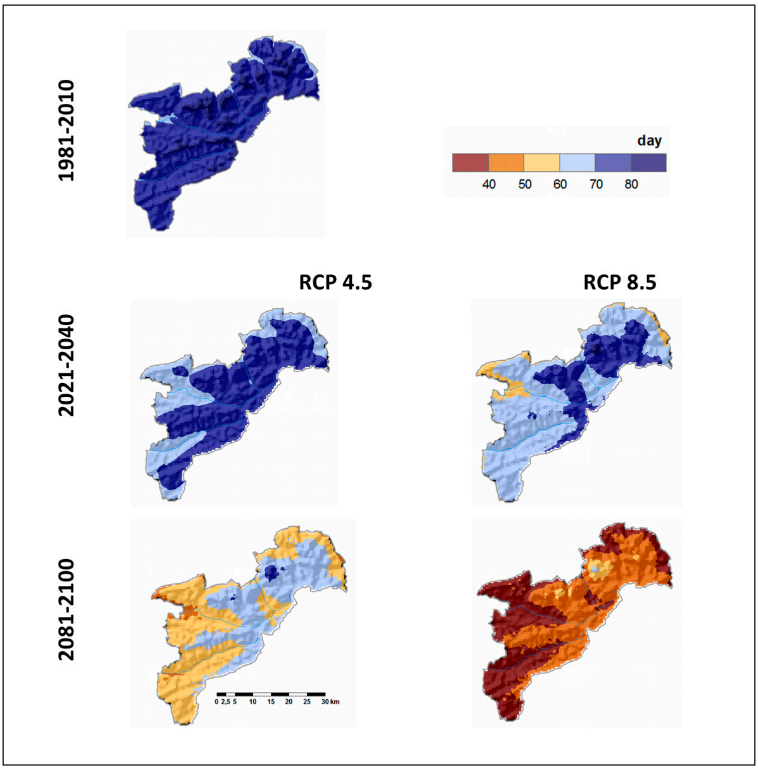

Fig. 6: Example of simulated winter frost days at the Beskids Mountains region as projected by the EC-EARTH_RCA4 model during the current period (1981–2010) and in the future climate periods of 2021–2040 and 2081–2100 with two emission scenarios.

Tab. 6: Linear trends (days/year) calculated for Lysá hora (mountain station) and Ostrava – Mošnov (lowland station) in the current climate and future climate simulated by the Euro-CORDEX project (median of the all 11 models) –statistically significant trend values (for p = 0.05) are in bold.

Lysá hora						
	Period	**YEAR**	**DJF**	**MAM**	**JJA**	**SON**
	1961–2015	**-5.53**	-0.19	**-2.75**		**-1.45**
RPC 2.6	2021–2060	**-6.14**	-1.03	**-3.94**		-1.16
	2061–2100	-0.77	0.07	0.09		-1.03
	2021–2100	**-1.46**	-0.01	**-1.32**		-0.10
RCP 4.5	2021–2060	**-3.92**	-0.55	**-2.16**		**-1.44**
	2061–2100	-1.29	-0.12	-0.96		-0.34
	2021–2100	**-3.06**	**-0.86**	**-1.22**		**-0.99**
RCP 8.5	2021–2060	**-7.54**	**-1.82**	**-3.29**		**-2.69**
	2061–2100	**-9.10**	**-3.35**	**-3.38**		**-2.46**
	2021–2100	**-8.03**	**-2.67**	**-2.91**		**-2.43**
Ostrava–Mošnov						
	Period	**YEAR**	**DJF**	**MAM**	**JJA**	**SON**
	1961–2015	-2.21	-1.51	0.05		-0.14
RPC 2.6	2021–2060	**-5.82**	-1.74	**-2.77**		-1.18
	2061–2100	2.74	-0.01	1.40		0.88
	2021–2100	-1.65	-0.34	**-1.15**		-0.10
RCP 4.5	2021–2060	**-2.67**	-1.56	-0.67		**-0.75**
	2061–2100	**-3.23**	-1.01	-0.48		-0.66
	2021–2100	**-3.27**	**-1.77**	**-0.90**		**-0.60**
RCP 8.5	2021–2060	**-8.30**	**-5.03**	**-2.31**		**-1.36**
	2061–2100	**-8.44**	**-5.55**	**-1.53**		**-1.19**
	2021–2100	**-7.84**	**-5.01**	**-1.89**		**-1.21**

Conclusion

An increase in mean winter temperature is projected for the Beskid Mountains region during the 21st century. The strongest warming is expected by the end of the century. Up to the middle of the century, temperature growth will be similar in both emission scenarios (RCP 4.5 and 8.5). However, during the second half of the century the difference between both scenarios appears to be more pronounced. The mean winter temperature will increase from -2.5 °C in the current climate to -0.45 °C (RCP4.5) or +3.8 °C (RCP8.5) by the end of the century. There is a different magnitude of warming signal between the lowland and the mountain station in the current climate. Warming at the mountain station Lysá hora is weaker. A statistically significant trend is calculated only in the case of the annual, spring and summer season, not in the winter season.

We observe a statistically significant decreasing trend in the Ostrava – Mošnov observations/measurements in the annual and spring precipitation but at the mountain station Lysá hora no similar trend is present as is the case in most of the observation stations in the Czech Republic. In the future, climate models and scenarios generally agree on the increase in the amount of precipitation. A higher trend for the winter is calculated for the mountain station Lysá hora. The average change from five selected models by both scenarios ranges from +12.5 to +17.5 % for the period 2021-2100. There is no significant difference between RCP 4.5 and 8. 5.

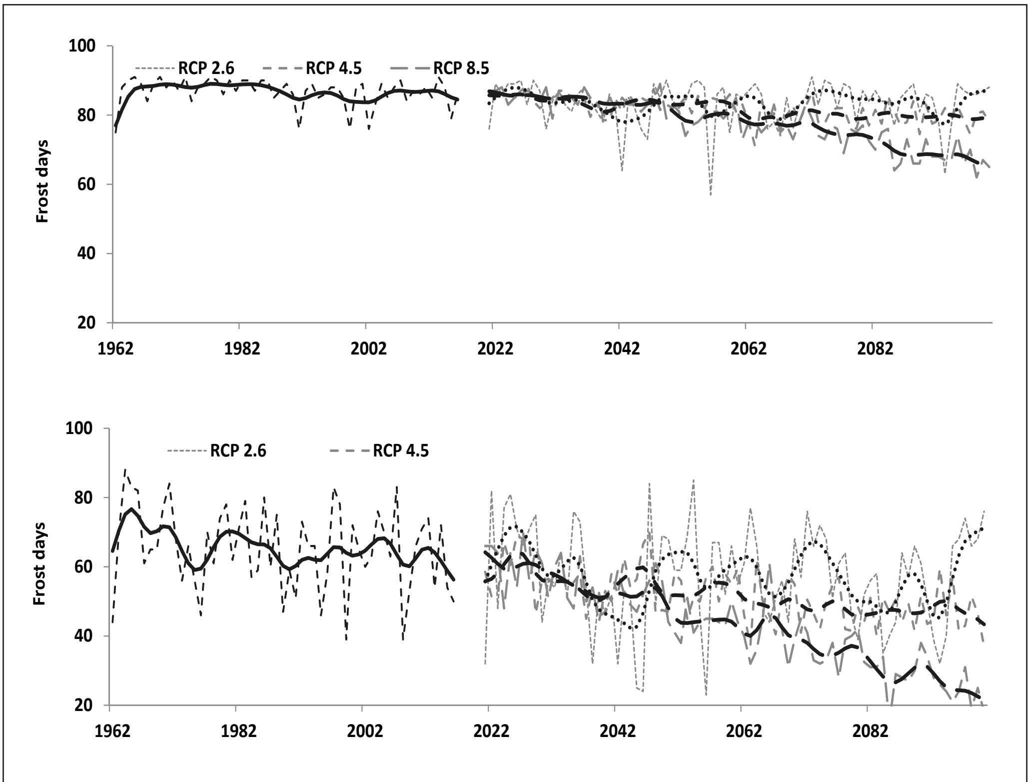

Fig. 7: Number of frost days in the winter at Lysá hora (top) and Ostrava – Mošnov (bottom) station in the period 1961–2100 predicted by median of the Euro-CORDEX model and three emission scenarios (RCP 2.6, 4.5 and 8.5).

Snow cover is a very important phenomenon in the Beskid Mountains region during the winter. Among others, the reasons are tourism (winter sports) and water management (supplementation of both surface water and groundwater). The last six winters were mostly dry and warm, and, due to the higher temperatures, rainfall was more frequent at the cost of snowfall periods. Thus, we expect that even in case of increased future precipitation rates the snow cover will be less common in the future.

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