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PROBLEM OF CLIMATIC CHANGES IN THE CZECH REPUBLIC MINING AREA

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ABSTRACT

The Brown Coal Research Institute j. s. c. is realising the long term research and survey of the mining area of the Most Basin. One of new important tasks is problem of climatic changes. The Most Coal Basin area is known for its largest Czech brown coal deposit. It is situated in the region of North Western Bohemia - Czech mining region. The main mining companies are the North Bohemian Mines, j.s.c. and the Seven Group j.s.c. The main mining localities are the Bílina open pit mine, the Libouš open pit mine, the Vršany open pit mine and the ČSA open pit mine. The Most Coal Basin is in general known as dry part of the Czech Republic.

The article presents the development of the climatic situation in all the Czech Republic, the main attention is devoted to the mining region of the North Western Bohemia situation. It was applied data of the Brown Coal Research Institute (VUHU), data gained by mining companies, data gained by the Czech Hydro - Meteorological Institute (ČHMÚ) and very important data from regional met - stations Kopisty, Kočkov and Milešovka. The most significant factors for quantifying of the climatic changes were temperature and precipitations, the pressure and wind were evaluated too. The baseline of the most important graphs is 1961 (period 1961 – 2019).

The article summarises the main climatic incidents from 1990 too. High level of rainfall is danger from point of view of mining operations, low level of rainfall is danger from point of view of restoration and revitalisation of the landscape. The prediction of the Czech Republic climatic changes in future is described in the last part of this article.

The research was realised with support of EU research programme „The impact of EXtreme weather events on MINing operations", project No 847250 – TEXMIN - RFCS-2018.

Keywords: mining area, temperature, precipitations, climatic changes

INTRODUCTION – EUROPE AND CZECH REPUBLIC

The Czech Republic is situated in the middle Europe. The location of the European continent is the main cause of significant regional climate variability. As there is an exceptionally dense network of long-term measuring stations in Europe, which is further complemented by a number of distance measurements, analyses of change trends are (perhaps with the exception of North America) significantly more accurate than anywhere else on the planet. The temperature of the European continent increased by an average of 1,2 °C over the last century, of which 0,45 °C has increased over the last three decades, almost half the global level. While the average growth trend across

Europe has been around 0,1 °C / 10 years in the last century, it has more than doubled in the last 30 years. As the temperature above land rises faster than the surrounding ocean, there are often significant regional differences in temperature changes in Europe as well. If we compare the deviations of the average ground temperatures in 1991 - 2008 from the average in 1961 - 1990, we find that southern Europe is warming relatively the slowest (the average linear trend of temperature increase recalculated for decades is 0,43 °C), more central Europe (0,48 °C) and the fastest changes occur in the northern part of the continent (0,67 °C) - with increasing latitude, the temperature increase in Europe increases. There are also seasonal differences - Europe as a whole warms the most in spring and summer (due to the increased frequency of episodes with extremely high temperatures) and the least in the autumn months. Low extreme temperatures are less frequent. The average number of summer days has doubled in the last century, and the number of tropical days has even tripled. Nine years from the thirteen-year period 1996-2008 were among the 12 warmest since 1850; the warmest years were 1998 and 2005. In the context of the zonal variability of the European climate, the differences may be different [1].

CLIMATE CHANGE IN THE CZECH REPUBLIC

The trend of change in the Czech Republic is taking place in the context of climate change in Europe. The two main climatological characteristics that are most subject to the ongoing changes in the Earth's climate system and about which we have the most information - temperature and precipitation - can serve as basic indicators of climate change.

The outputs of the regional climate model ALADIN-CLIMATE / CZ controlled by the global model ARPEGE and operated in ČHMÚ can be used to estimate the further development of the climate in the Czech Republic and directly mining area of the North Western Bohemia. The model is based on a numerical prediction model for a limited area, which performs the calculation of climatological characteristics for a limited area, in this case for Central Europe. Its main advantage is the ability to simulate climate with much better spatial resolution than what global models (GCM) are capable of. While GCMs now routinely operate with a resolution of 200–300 km, RCM ALADIN-CLIMATE / CZ has demonstrated the ability to simulate climatic characteristics in sufficient quality with a resolution of 10–25 km, which is particularly important in Central European conditions. In the network of points in which GCM works, it is not possible to capture with sufficient accuracy the very existence of smaller mountain areas, such as the Krkonoše Mts., Šumava Mts., Krušné hory Mts., but to a large extent also the Alps. The models are not even able to simulate well the influence of these mountains on the dynamics of the atmosphere, the existence of wind and leeward effects, etc. Each regional model works in relation to the global model. First, appropriate simulations are performed using GCM, which will provide the necessary information about the development of large-scale processes in the atmosphere (scales of the order of 103 km). The results are then taken over by the RCM, which refines and regionalizes the results in more detail, up to a scale of 101–102 km. Updated regional scenarios for the Czech Republic with a probable outlook for changes in the period around 2030, 2050 and 2100 are the basic basis for follow-up studies of the impacts of climate change on a national scale. Scenarios do not consider natural climate

fluctuations; contributions of natural and anthropogenic climate variability can be mutually compensated, or add. Due to the uncertainties of the outputs of global climate models and methods of regional downscaling, the outputs of regional models for the territory of the Czech Republic are burdened with a higher degree of uncertainty than the outputs of models for the territory of the European continent, resp. the whole planet. The precipitation mode projections also show a higher degree of uncertainty compared to a similar temperature regime projection.

Model for temperature development until 2030

The results of simulations with the ALADIN-CLIMATE / CZ model suggest that the average temperatures by the end of the third decade of this century would increase in the A1B scenario by values according to the following table compared to the period 1961–1990:

Tab. 1: Seasonal changes of average temperature (°C) for the period around 2030 in the North Western Bohemia (mining region) in comparison with the period 1961–1990 according to the simulation RCM ALADIN-CLIMATE / CZ for scenario A1B

	spring	summer	autumn	winter	year
minimum	0,8	0,7	0,9	0,8	0,8
10% quantile	0,9	0,9	1,0	1,0	0,9
25% quantile	1,0	1,0	1,1	1,1	1,0
median	1,2	1,1	1,2	1,1	1,1
75% quantile	1,3	1,2	1,3	1,2	1,2
90% quantile	1,4	1,3	1,4	1,3	1,3
maximum	1,7	1,6	1,5	1,5	1,6

The trend of the observed increase in average annual temperatures (0,24 °C / 10 years) corresponds to the global values as well as the values reported for Europe (0,2 °C / 10 years).

Like changes in average temperatures, maximum and minimum temperatures are likely to change. The maximum temperatures will tend to increase more markedly in winter and summer, the minimums especially in summer, partly also in autumn and winter. If we compare the model temperature trends with the current ones, it can be expected that by the end of the third decade of this century, temperatures will be more at the level of higher quantiles. It is also possible to find an acceptable continuity of results in terms of seasonal changes and a really faster increase in average winter and autumn temperatures.

Model for temperature development until 2100

Climate models agree that air temperatures will continue to rise, depending on the RCP (Representative Concentration Pathways) emission scenario. The most commonly used are RCP 4.5, which allows for a slight decrease in the amount of CO_2 in the air. On the contrary, the emission scenario 8.5 is set for no change in the amount of CO_2 concentrations. By 2050, temperature growth will be the same without the influence of the emission scenario, as the landscape will no longer be able to respond to changes in greenhouse gas concentrations, but developments in the second half of the century are already dependent on the given emission scenario. According to RCP 4.5, the warming will occur by about 2,0 °C at the end of the century, and according to RCP 8.5 to 4,1 °C.

For the territory of the Czech Republic, the following graphic outputs were processed for the parameters of the average annual temperature.

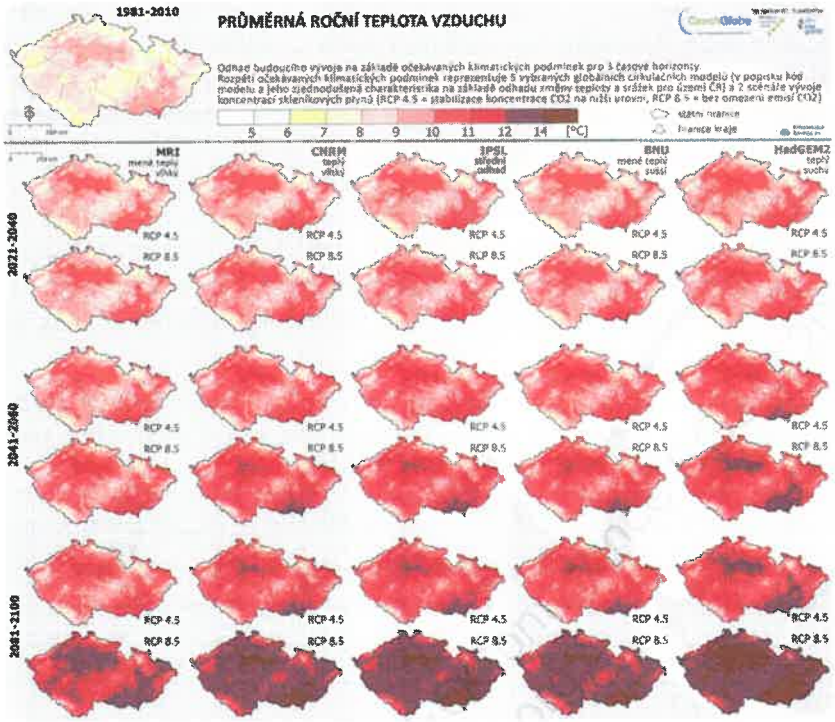

Fig. 1: Development of the average annual air temperature depending on the emission scenario of RCP according to the mentioned global models in the outlook to the year 2100 (Source: Institute of Global Change Research of the ASCR, v. v. i.)

For the area of the North Western Bohemia, where the mining area of interest is located, the following average temperature values were derived for individual climate models. A graph was also compiled for the average IPSL model.

Tab. 2: Development of the average temperature of the mining region (N – W Bohemia) for individual climate models (Met – Station Kočkov, Ústí nad Labem City)

Years	Emission scenario	Climate model				
		MRI	CNRM	IPSL	BNU	HadGEM2
1991-2010	-	9.8				
2021-2040	RCP 4.5	10,2	10,5	10,5	10,5	10,6
	RCP 8.5	10,4	10,7	10,8	10,8	10,9
2041-2060	RCP 4.5	10,5	11,0	11,6	11,5	11,6
	RCP 8.5	11,0	11,4	11,9	11,8	12,0
2081-2100	RCP 4.5	11,1	11,9	12,6	12,5	13,0
	RCP 8.5	12,0	12,7	13,2	13,1	13,5

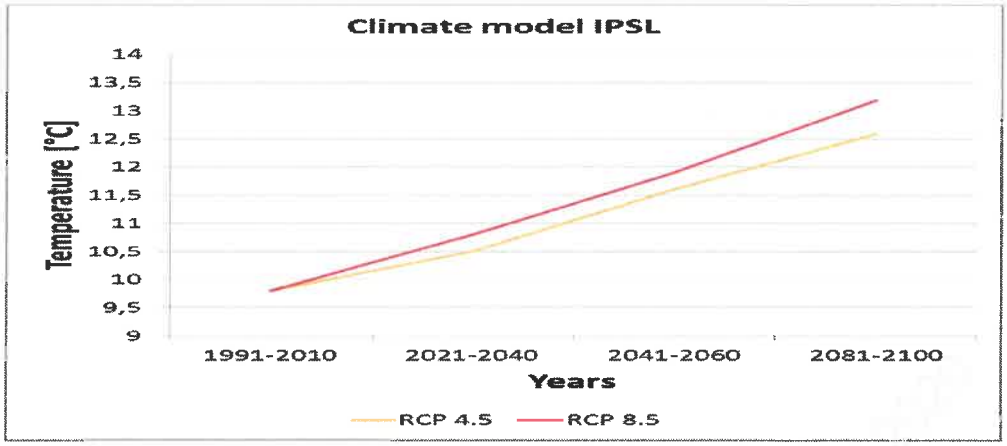

Fig. 2: Projection of average temperatures in the mining region (N – W Bohemia) according to emission scenarios (Met – Station Kočkov, Ústí nad Labem City)

Model for precipitations development until 2030

The simulated changes in precipitation totals indicate the possibility of a slight increase in annual totals (on average by about 4% compared to the period 1961–1990), higher in winter and spring, lower in summer and autumn. The ranges between the quantile values indicate the persistence of significant variability in average precipitation totals. The values for the second half of spring and summer, together with increased evaporation, signal the risks of an increase in soil moisture deficit.

Tab. 3: Seasonal changes in precipitation totals (share) until 2030 compared to the period 1961–1990 according to the RCM ALADIN-CLIMATE / CZ simulation for scenario A1B

	spring	summer	autumn	winter	year
minimum	0,94	0,84	0,83	0,72	0,83
10% quantile	1,02	0,92	0,95	0,82	0,93
25% quantile	1,07	0,96	1,00	0,87	0,98
median	1,12	1,03	1,08	0,92	1,04
75% quantile	1,17	1,10	1,13	0,97	1,09
90% quantile	1,24	1,17	1,25	1,01	1,17
maximum	1,34	1,31	1,44	1,08	1,29

Comparison of model precipitation totals suggests that the agreement of simulations with the results of existing observations is significantly lower for precipitation. Rather, precipitation totals can be expected to be lower, but the probability of an increase in winter precipitation totals is high.

Model for precipitations development until 2100

Modelling of precipitation development is more difficult than temperature modelling. For the territory of the Czech Republic, the following graphic outputs were processed for the parameters of the average annual precipitation.

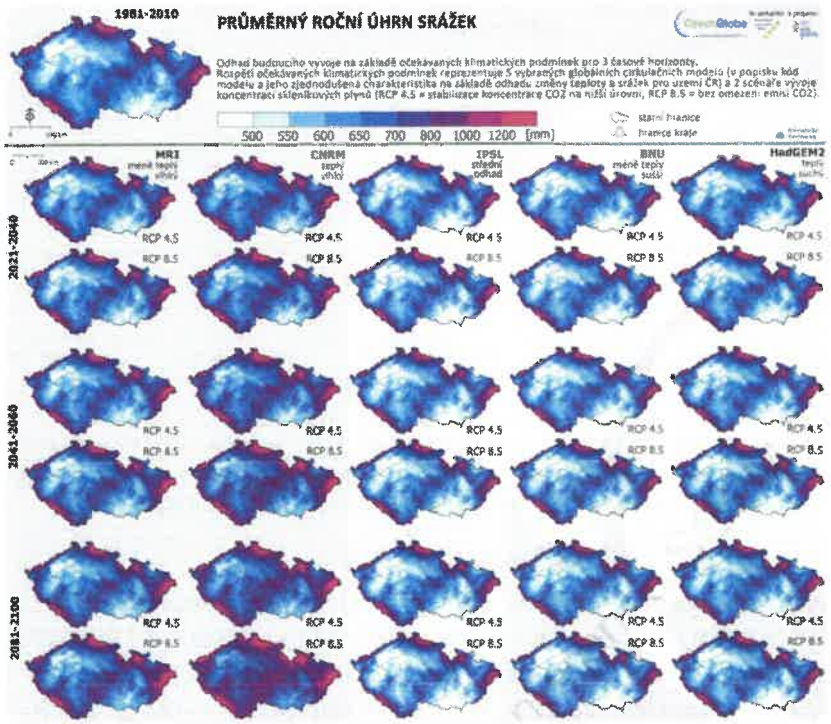

Fig. 3: Development of average annual precipitation depending on the emission scenario of RCP according to the mentioned global models in the perspective until 2100 (Source: Institute of Global Change Research of the ASCR, v. v. i.)

For the area of the North Western Bohemia region, where the mining area of interest is located, the following average precipitation values were derived for individual climate models. A graph was also compiled for the average IPSL model.

Tab. 4: Development of average precipitation of the mining region (N – W Bohemia) for individual climate models (Met – Station Kočkov, Ústí nad Labem City)

Years	Emission scenario	Climate model				
		MRI	CNRM	IPSL	BNU	HadGEM2
1991-2010	-	636				
2021-2040	RCP 4.5	648	652	638	635	630
	RCP 8.5	650	658	630	628	625
2041-2060	RCP 4.5	661	669	625	620	622
	RCP 8.5	668	684	630	618	615
2081-2100	RCP 4.5	675	690	610	607	600
	RCP 8.5	689	706	605	601	595

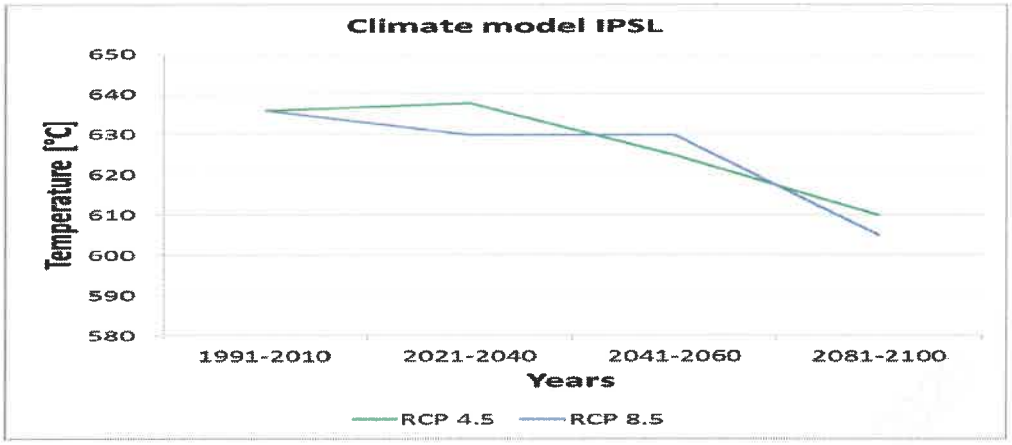

Fig. 4: Projection of average precipitation of the mining region (N – W Bohemia) according to emission scenarios (Met – Station Kočkov, Ústí nad Labem City)

The Most Coal Basin area is known for its largest Czech brown coal deposit. It is situated in the region of North Western Bohemia - Czech mining region. The main mining companies are the North Bohemian Mines, j.s.c. and the Seven Group j.s.c. The main mining localities are the Bílina open pit mine, the Libous open pit mine, the Vrsany open pit mine and the CSA open pit mine. The North Western Bohemia is very important industrial region of the Czech Republic.

The region of the Most Coal Basin is relatively hot area in the comparison with the general situation of the Czech Republic, but we did not discover the extreme situation during last 20 years. The impacts of temperature to mining activities are not so hard as impacts of extreme (maximum or minimum) rainfall. The extreme values of rainfall are very important for mining operation. It is observe the relatively humid period from 2000 to 2010 and relatively dry period from 2010 to 2019. The minimum and maximum values of rainfall are the source of main observed incidents. High level of rainfall is danger from point of view mining operations, law level of rainfall is danger from point of view of restoration and revitalisation of the landscape damaged by mining. The Most Coal Basin area is very danger from point of view erosion effects and landslides. The main reasons of these phenomena are geological situation and extreme climatic events, primarily combination of dry weather and torrential rainfall.

The literature research has shown that there is no clear direct evidence that refers to hard mining accidents caused by heavy rainfall events or climatic changes. Any accidents from the period 2000 – 2019, described in this chapter, are quite important from point of view of mining operations and restorations.

- The exceptional rainfall in the beginning of the August 2002 was the source of flooding of the large areas of the Czech Republic, primarily of the southern, western, central and northern part of Bohemia. It caused great damage, more than 70 billions Czech Crowns. 17 people died in this incident. The mine damages were great too.
- The very danger landslide was reactivated during January 2011. The landslide area was situated in the slope of the ČSA open pit mine near the Krušné Hory Mts. The main reason of this incident was combination of the geological and climatic situation [2].

- The catastrophic landslide was in July 2013. The landslide area was situated in the slopes of the České Středohoří Mts. near the village Dobkovičky. It was destroyed the highway D8 and local railway. The main reason of this incident was combination of the very dangerous geological situation and climatic situation. It caused great damage, more than 1 billion Czech Crowns.
- Extreme dry season in the period May – November 2018 caused great damages in Czech agriculture and in forest restorations in areas after brown coal mining [3].

CONCLUSION

Development trends of climatological characteristics and more frequent occurrence of extreme weather conditions are already reflected in changes in the water regime, in agriculture and forestry and partially affect the health of the population. Even in the short term, a further increase in the negative impact on individual components of the natural environment can be expected and relatively new impacts on energy, recreational opportunities and tourism, as well as on the overall well-being of the population, should be expected.

The input of the expected increase in temperature and decrease in precipitation is favorable for the mining operation in terms of congestion and mining stability, mining safety and mining costs. The situation is different in the area of reclamation works. The input of expected climate change is very unfavorable in this case. The main reasons are mainly the high level of seedling loss during forest reclamation due to hot and dry periods, the need for very expensive, radical changes in technical and biological reclamation methodology.

Combinations of extreme drought and torrential rains are very dangerous for mining operations.

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