Changing frequencies and temperature characteristics of atmospheric circulation patterns in the Saxon-Czech border area

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Abstract. The Grosswetterlagen classification scheme for atmospheric circulation patterns (BAUR 1943, HESS & BREZOWSKY 1952) allows for the characterization of meteorological situations by means of local climate parameters. On the basis of this concept, the change in frequency and temperature characteristics of the most frequent Grosswetterlagen were investigated in the Saxon-Czech border area. Particularly the changes in seasonal temperature anomalies of different circulation patterns show a temperature increase that cannot be explained completely by the variability of the circulation regime and thus, are an indicator for the effect of global temperature changes on the regional scale.

Key words

Circulation patterns, Czech-Saxon border region, Grosswetterlagen, Interklim, Temperature anomalies

Introduction

Large-scale atmospheric circulation influences the climatic conditions on the regional scale. The Saxon-Czech border area is characterized by complex orographic conditions. Mountain ranges and ridges such as the Ore mountains affect the regional characteristics in dependence of the present circulation conditions. The methodology of subjective classification of circulation patterns according to BAUR (1943) and HESS & BREZOWSKY (1952) allows for a classification of atmospheric conditions and can be applied to derive effects on the meteorological elements on the local and regional scale.

Material and methods

The study area covers the whole Ore mountain area and ranges from Saxon midlands in the north to the Bohemian basin in the south, extending from the Vogtland area in the west to the Giant mountain area in the eastern part. On the Czech side this area includes the Karlovarsky, Ustecky and Liberecky kraj. The Saxon area represents the regional planning associations Region Chemnitz, Oberes Elbtal/ Osterzgebirge and Oberlausitz-Niederschlesien.

Observational data from Deutscher Wetterdienst (DWD) and Czech Hydrometeorological Institute (CHMU) was provided via the Saxon climate information system REKIS. In total data from 20 stations was used for further analysis. Processing of daily temperature data included checking for plausibility ranges. Further processing applied a simple gap filling algorithm, particularly replacing missing monthly values with long-term monthly means from 1961-2010 and missing daily values with current monthly mean values. A threshold of required data availability was set to 75% of daily data per month for inclusion of the respective station.

The meteorological station data was linked to the daily series of Grosswetterlagen (WERNER et al. 2010) in order to calculate seasonal mean temperature characteristics for the predominant circulation types (with occurrence ≥5%): WZ, BM, HM, NWZ, TRM, WA and TRW. Those characteristics and the respective anomalies to 1961-1990 mean conditions were used to identify decisively influencing circulation patterns on the regional scale. In a final step changes of Grosswetterlagen-specific anomalies were calculated for the periods 1991-2009 (analysis period) compared to 1961-1990 (reference period) to assess the magnitude of global atmospheric changes on the European atmospheric circulation and the respective regional climatic effects.

Results and discussion

The change in frequency of occurrence of circulation patterns is marked by partly distinct seasonal changes between the time periods 1961-1990 and 1991-2009. The generally most frequent WZ-situation occurred more often in summer (increase from 14 to 18%) and less frequent in autumn period (19 to 13%) during the period of 1991-2009. Frequency of BM increased especially during spring (7 to 13%) and also in summer (11 to 14%). For HM a weak increase of occurrence during winter season and a remarkable decrease in autumn from 9 to 3% can be stated. NWZ shows a decrease of frequency in summer (6 to 3%) and thus played only a minor role during the last two decades. WA shows tendencies of decrease in occurrence, especially in summer and autumn. In contrary, TRM showed a strong increase in all seasons, especially noticeable in both, winter and spring (3 to 8%) as well as summer (5 to 8%) while TRW shows no remarkable changes.

Table 1: *Annual [%] of Grosswetterlagen in different time periods*

GWL	1961-2009	1961-1990	1991-2009
WZ	16.0	15.9	16.2
BM	10.6	9.5	12.4
HM	6.0	6.4	5.4
NWZ	5.2	5.0	5.5
TRM	5.2	3.9	7.3
WA	5.2	5.7	4.5
TRW	5.1	4.9	5.4

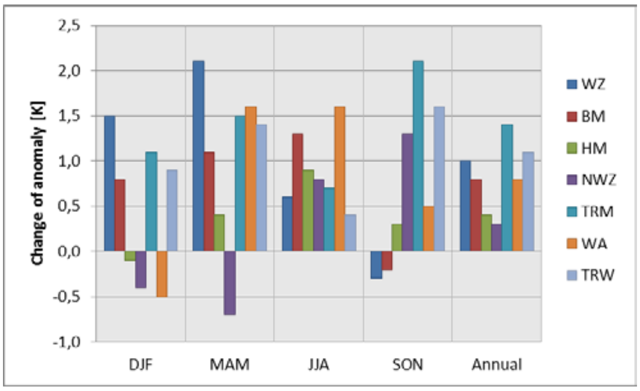

Figure 1: *Change of seasonal temperature anomalies for circulation patterns between 1991-2009 and 1961-1990*

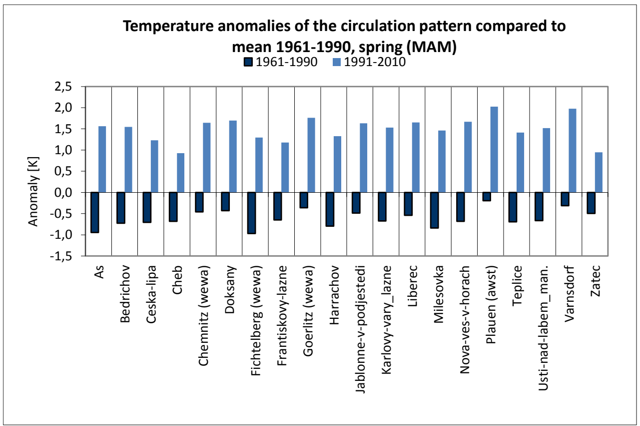

Figure 2: *Spring temperature anomalies for circulation pattern WZ in the periods 1961-1990 and 1991-2009*

<u>WZ</u>

Over all seasons the most frequent circulation pattern is WZ (cyclonal westerly situation) with a frequency of 16% (table 1). In the study area this circulation pattern is connected with mild and moist summer and likewise mild winters with rich of snow situations in mountain ranges. While the annual frequency of occurrence has not changed between the two time periods, the seasonal frequency has increased in summer (14 to 18%) and decreased in autumn (19 to 13%), the other seasons frequencies remain unchanged. However, the seasonal temperature characteristics of the circulation pattern itself have changed remarkably in all seasons, including winter and spring.

For winter, the mean temperature of this pattern increased from 1.6 K in the reference period to 3.1 K in 1991-2009 over all stations. Accordingly, the typical mild characteristics of the circulation pattern are more pronounced in 1991-2009. The temperature anomaly of the days with WZ situation thus increased by 1.5 K over all stations. Local values range from 0.6 K (Cheb) to 2.1 K (Nova-ves-v-Horach station).

During the period of 1961-1990, WZ circulation pattern is representative for negative anomalies during spring season (fig. 2). These cool conditions (anomaly compared to the mean of all circulation types: -0.6 K) are not existent in the period 1991-2009 anymore, where WZ is characterized by an anomaly of +1.5 K. This warming effect of 2.1 K is visible over all the study area. As the frequency of WZ-occurrence has not changed substantially during spring time, this warming effect of 2.1 K (over all stations) cannot be attributed to changes of the circulation regime, but a different source of warming.

The frequency of WZ-situations in summer has however increased. During the period of 1961-1990 the temperature anomaly of WZ during summer is negative and averages -0.8 K over all stations. Averaging all circulation types, there is a temperature increase during summer months of 1.1 K over all stations. The respective warming of 0.6 K on days with WZ-situations still depicts a temperature anomaly of -0.2 K for the circulation type in 1991-2009 and indicates that other circulation types are linked to a stronger temperature increase in summer than WZ.

During autumn, WZ-situations are generally connected to slightly positive anomalies (+0.6 K over all stations, exceptions in high altitudes). In contrary to the other seasons there is decrease in temperature anomalies of about 0.3 K in the period of 1991-2009 (mean of all stations). In regard to the seasonal mean temperatures the aforementioned decreasing frequency of the circulation type during this season however counterbalances this trend, so that in average over all circulation types no decrease of temperature can be stated (increase of ca. 0.2 K).

<u>BM and HM</u>

The high pressure situations BM and HM are generally characterized by negative temperature anomalies in winter and positive anomalies in summer. An exception is Fichtelberg mountain station in 1213 m above sea level in case of HM (positive anomaly of 1.3 K) as a consequence of inversion weather situations. As for the change of winter anomalies between 1961-1990 and 1991-2009 BM situations show a warming trend of 0.8 K over all stations. In contrast to this the change of anomalies for HM situations is indifferent and ranges from -0.7 K (Karlovy-Vary Lazne station) to +0.7 (Fichtelberg station), averaging to -0.1 K over all stations.

Spring BM situations show a warming of about 1.1 K. While this situation showed no distinct anomaly during 1961-1990, it is linked to positive anomalies compared to other circulation patterns in the period 1991-2009. The increase of spring anomalies for HM is less notable (+0.4 K over all stations). At some stations the situation was connected with negative anomalies at Ceska-Lipa (-0.3 K) and Frantiskovy-Lazne station (-0.5 K) in the period 1991-2009. Summer temperature anomalies have increased by 1.3 K (BM) and 0.9 K (HM). Regarding autumn season, BM shows clear positive anomalies (+0.9 K over all stations), while HM is connected with negative temperature anomalies (-0.8 K) at most stations. Mountain stations in general, but especially Fichtelberg station is again an exception (+1.7 K) due to the station altitude. The change of the autumn anomaly during both periods is not as consistent as during other seasons for those circulation patterns. For BM situations values range from -0.7 (Milesovka station) to +0.3 K (Doksany station). The mean change of anomalies over all stations is -0.2 K. In case of HM, the change of anomaly is as indifferent and amounts to 0.3 K, ranging from -1 K at Fichtelberg station to +1.3 K at Doksany station, while there is no distinct signal at the majority of the stations.

The characteristics of less frequent circulation patterns are described below. According results have to be interpreted with regard to the actual seasonal frequency of occurrence.

NWZ

Circulation pattern NWZ is linked to positive anomalies (exception Fichtelberg) in winter which have decreased by 0.4 K from 1.1K (1961-1990) to 0.7 K in the period of 1991-2009. For the other seasons negative temperature anomalies are characteristic for this circulation type. The decrease of temperature anomaly is also visible in spring (-0.7 K) while summer and autumn NWZ situations are characterized by an anomaly increase of 0.8 K and 1.3 K respectively.

TRM

This situation is typically connected to negative temperature anomalies throughout all seasons. The strongest seasonal warming signal in the period 1991-2009 occurred in autumn (+2 K), followed by spring (+1.5 K) and winter (+1.1 K). The increase of summer anomalies is less pronounced (+0.7 K).

WA

Except for spring WA occurrences are represented by positive temperature anomalies, strongest anomaly in winter with +3 K. It is remarkable, that the winter anomaly has decreased by -0.5 K in 1991-2009 compared to 1961-1990. The role of less intensive jet stream and related increase of inflowing cold air masses from North Asia has to be investigated further. Regarding spring, this circulation pattern showed mostly negative anomalies during 1961-1990 and is characterized by a positive anomaly (+1.1 K) in the period 1991-2009. The corresponding change of anomalies of +1.6 K can also be stated for summer season, while the autumn signal is much weaker (+0.5 K).

TRW

In 1961-1990 TRW situations show positive temperature anomalies especially in spring (+2.7 K). Increase of anomalies is strongest in autumn (+1.6 K) and spring (+1.4 K) resulting in a remarkable anomaly increase to +4,1 K in spring season.

Conclusions

Over all stations there is an average increase of mean temperature by 0.8 K between the period 1991-2010 compared to 1961-1990. The seasonal characteristics of circulation patterns have changed during these periods. In most cases a clear warming signal can be identified. In case of circulation patterns with unchanged frequencies of occurrence, the warming cannot be explained by circulation effects and can thus be attributed to “Global Warming Background”. In this context, the effects of global temperature change become visible also on a regional and local scale. The unchanged frequency of occurrence and the simultaneously increased temperature anomaly of WZ-situations in winter and spring season are a striking example. Negative changes of anomalies could be stated for WZ and BM in autumn, HM in winter and NWZ in winter and spring, respectively.

Particularly with their increased frequency, the TRM and TRW circulation patterns have become a defining element for the climate conditions in the study area during the recent years. Many phenomena and extreme events were directly linked to the appearance of those circulation regimes. Imposing regional examples as the flood of august 2002 or summer 2010 in Saxony and Czech Republic underline the role of the increased frequency of those circulation types for a wide range of public sectors.

Further analysis is required especially regarding other climate parameters as well as on the base of a datasets with higher spatial density or resolution, respectively. Thus, the preparation and provision of consistently processed transnational datasets is substantial for further analyses, particularly on the regional and local scale in the border region.

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