FACT SHEET: Climate change, air pollution and ecosystems in the Polish-Saxon border area

LANDESAMT FÜR UMWELT, LANDWIRTSCHAFT UND GEOLOGIE

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KLAPS

Climate change, air pollution and critical load of ecosystems in the Polish-Saxon border region

Foreword

The EU project KLAPS (Climate change, air pollution and critical load of ecosystems in the Polish-Saxon border area) determines the trans boundary influence of climate change on concentration and deposition of air pollutants, supra-regional impacts on environmental load limits and the influence of changing climatic conditions on population, tourism and agriculture. The fact sheet briefly and concisely summarises the results obtained within the project KLAPS. Information about current and possible future trends of climate and air quality as well as the impact of climate change are presented according to target groups. Detailed overviews of the applied methods and results are given in *"Climate in the Polish-Saxon border area"* (Mehler et al. 2014) and *"Climate projections, air pollution and critical load of ecosystems"* (Schwarzak et al. 2014). The project is financed by the European Regional Development Fund (ERDF) as an INTERREG IV A project within the cross-border cooperation programme between Poland and Saxony 2007–2013.

Project partners are the Saxon State Agency for Environment, Agriculture and Geology (Lead Partner), and on the Polish side, the Department of Climatology and Atmosphere Protection of the Institute of Geography and Regional Development at the University of Wrocław and the Institute of Meteorology and Water Management – National Research Institute, Wrocław branch.

Objective of the cross-border project is to raise awareness of the inhabitants and stakeholders as well as knowledge transfer to ensure suitable and early mitigation and adaptation measurements on climate change in the border region.

Regional climate change

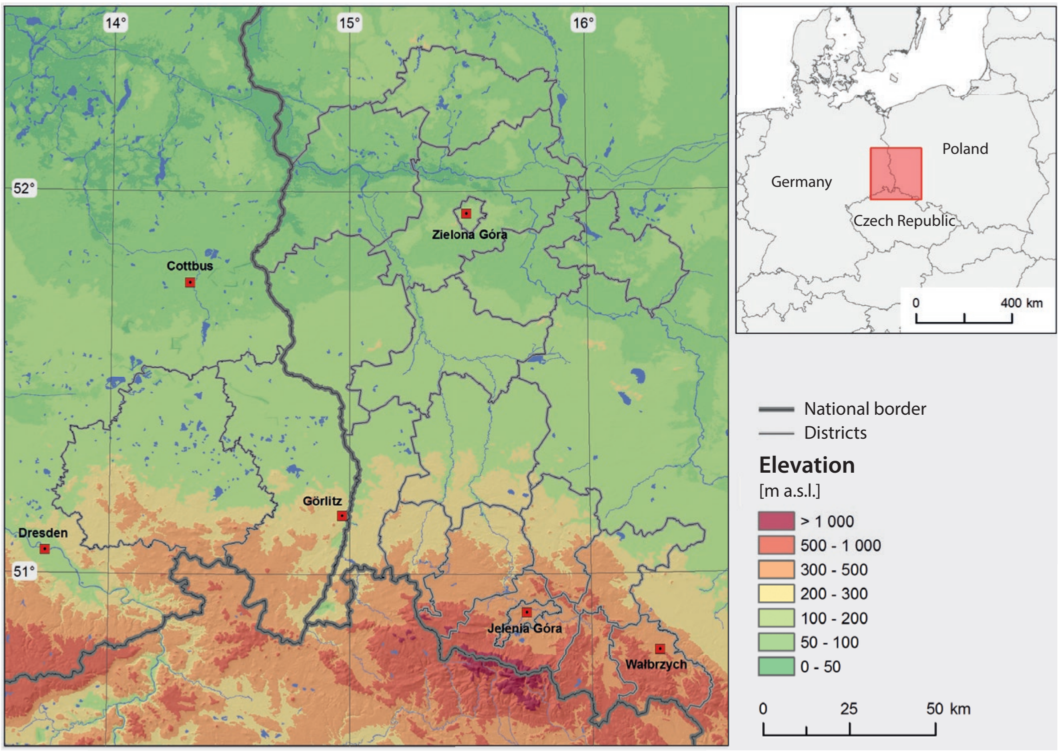
General climatic conditions

The project region is situated in a climatic transitional zone between maritime Western European and continental Eastern European climate in the west wind zone (Fig. 1).

Regional climatic differences are decisively influenced by altitude and mountains as the Ore Mountains, Zittau Mountains, Jizera and Giant Mountains in the south of the project area. While air temperature is decreasing with increasing height, the precipitation amount is rising. Thus, there is a huge difference in average annual air temperature between the lowlands (e.g. Lindenberg 8.9 °C) and the mountains (e.g. Śnieżka 0.8 °C) (Fig. 2). Regarding distribution of precipitation, the position of the mountains relative to the main wind direction West-Southwest is also crucial. Topography related effects, which cause cloudiness and precipitation formation on the Luv side (windward side) as well as shadowing effects which comes with decreasing cloudiness on the Lee side (downwind side) of the mountain ranges could be observed. Within the project area, these effects lead to relatively low precipitation totals in the eastern Ore Mountains and relatively high precipitation totals in the Jizera and Giant Mountains in the same altitudes.

Additional topographic influences are represented by small-scale climate variability (e.g. pools of cold air, temperature inversions), which have a profound influence on agriculture and air pollution conditions. With South-Southwest flow direction “foehn effects” (mild wind) are likely to occur. Foehn wind leads to an increase of average temperatures at the northern slopes of the mountains, while cooler temperatures at the southern slopes are measured. In contrast the so called “Bohemian wind” indicates cold temperatures, longer lasting snow cover

Figure 1
KLAPS Project region



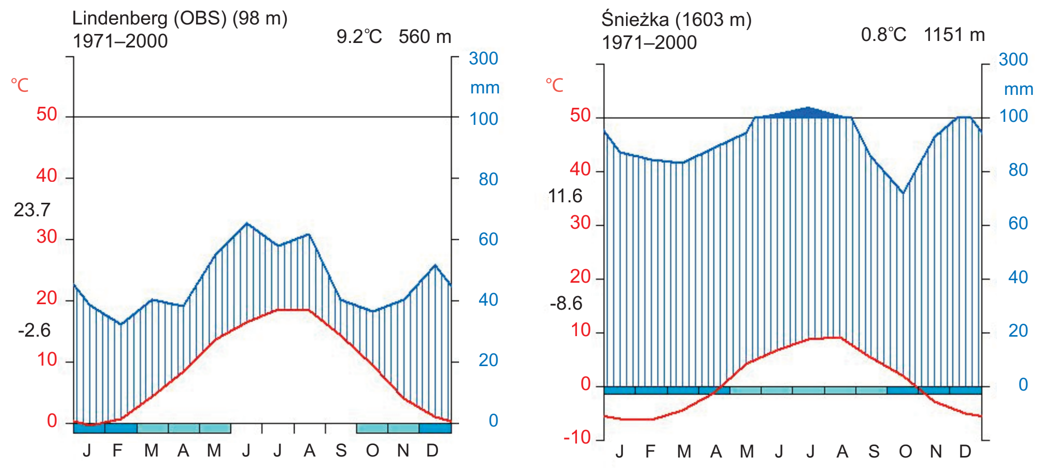


Figure 2

Climate diagrams after Walter/Lieth for time period 1971–2000 (left = monthly mean temperature (T_X+T_N/2) (red); values left side: monthly mean of maximum temperature of warmest month (above), monthly mean of minimum temperature of coldest month (below); right = monthly mean precipitation amount (blue); below = frost months (dark blue); probably potential frost months (light blue))

period and late thaw conditions in the valleys of Neisse and Elbe as well as along Brama Lubawska and Kamienna Góra valley basin just to the east of the Giant Mountains, compared to the other lowland areas.

Climate observation

Long term meteorological measurements throughout Central Europe have proven that climate is changing and average air temperature is rising about 1 °C since 1900. Also the Polish-Saxon border area is affected by climate change. Analyses show a significant absolute warming trend of the average air temperature about +1.1 °C during the period 1971–2010. The strongest and most significant warming trend of +1.6 °C and +1.8 °C is detected in spring and summer, respectively. In autumn and winter calculated warming trends are more moderate with +1.0 °C and +0.2 °C, respectively.

The analysis of trends of climatological days (e.g. summer days, hot days, frost days) reflects the increasing mean temperature (Tab. 1). A significantly increased frequency of summer and hot days is measured. In contrast the occurrence of frost and ice days shows an opposing trend and is not significant. The thermal growing season lasts approximately four weeks longer and also frost free periods have increased significantly. In contrast, the slight increase of the frost periods indicates, that the risk for late frost is also likely to occur despite warming trends.

Increasing trends for precipitation of +20 mm and +42 mm are observed both in summer and in the winter half year, respectively. At the same time dry periods of at least eleven days as well as heavy precipitation events show a slightly rising frequency in summer. Due to increasing global radiation, the average annual potential evaporation increases by +69 mm in the project area. Further in terms of climatic water balance, which is calculated from the variables precipitation minus potential evaporation, a negative trend of -88 mm is already observed in the summer half year. This water deficit cannot be compensated by the positive trends in winter.

Table 1

Average value of selected climate parameters in the period 1971–2000 and absolute trend and range (low lands and ridges) in the period 1971–2010[1]

Parameter	Description	Unit	Average 1971 – 2000	Absolut trend 1971 – 2010
Average annual temperature	January to December	°C	7.5 (9.0 – 3.6)	1.1 (1.2 – 1.2)
Temperature in spring	March to May	°C	7.1 (8.6 – 2.7)	1.6 (1.8 – 1.7)
Temperature in summer	June to August	°C	16.0 (17.6 – 11.7)	1.8 (1.8 – 1.8)
Temperature in autumn	September to November	°C	7.6 (9. – 3.9)	1.0 (1.0 – 1.1)
Temperature in winter	December to February	°C	-0.8 (0.6 – -4.2)	0.2 (0.5 – 0.3)
Summer days	T_{max} > 25 °C	d	28 (41 – 4)	12 (16 - 3)
Hot days	T_{max} > 30 °C	d	5 (8 – 0)	3 (6 – 0)
Tropical nights	T_{min} > 20 °C	d	0.4 (0.5 – 0)	0.4 (0.4 – 0.1)
Frost days	T_{min} < 0 °C	d	110 (88 – 170)	-6 (0.6 – -23)
Ice days	T_{max} < 0 °C	d	38 (21 – 84)	3 (2 – -7)
Cold sum	∑T< 0 °C. 1.11.–31.03.	-	256 (165 – 554)	5 (-6 – -53)
Heat wave	Min. 6 days T_{max} > 90th percentile 1971–2000	amount	0.6 (0.6 – 0.7)	1 (1.4 – 0.8)
Duration of frost period	Amount between first and last frost day	d	32 (23 – 63)	4 (3 – 6)
Duration of frost free period	Amount between first and last frost free day	d	163 (173 – 127)	23 (30 – 16)
Growing season length	Amount of days T_{avg} > 5 °C for min. 6 days	d	221 (253 – 142)	28 (34 – 39)
Precipitation in summer half year (SHY)	April to September	mm	465 (350 – 634)	20 (31 – -21)
Precipitation in winter half year (WHY)	October to March	mm	373 (258 – 548)	42 (31 – 45)
Dry periods in SHY	Min. 11 days < 1 mm precipitation	amount	2.0 (2.4 – 1.2)	0.3 (0.3 – 0.2)
Days with heavy precipitation in SHY	Precipitation > 99th percentile	d	0.7 (0.6 – 0.8)	0.2 (0.2 – -0.3)
Days with heavy precipitation in WHY	Precipitation > 99th percentile	d	0.7 (0.6 – 0.9)	-0.3 (-0.5 – -0.2)
Potential evaporation	after Turc-Wendling	mm	605 (661 – 518)	69 (69 – 62)
Climatic water balance in SHY	Precipitation – pot. evaporation	mm	-44 (-116 – 543)	-88 (-52 – -159)
Climatic water balance in WHY	Precipitation – pot. evaporation	mm	189 (78 – 371)	33 (14 – 78)
Sunshine duration	Sunshine hours	h	1492 (1653 – 1377)	252 (246 - 215)

1 Table 1 is supplemented by using the results of the EU project NEYMO https://publikationen.sachsen.de/bdb/artikel/22580

Parameter	Description	Unit	Average 1971 – 2000	Absolut trend 1971 – 2010
Growing degree days	$\sum_{01.04.}^{31.10.} \frac{T_{max}+T_{min}}{2} - 10°C$	°C	954 (1106 – 38)	214 (265 – 120)
Sum of active temperatures	$\sum_{01.04.}^{31.10.} \frac{T_{max}+T_{min}}{2} \geq 10°C$	°C	2579 (2871 – 379)	419 (496 – 281)
Hydrothermal coefficient of Selyaninov	HTC = R / 0.1 ΣT	-	0.94 (0.56 – 4.04)	0.03 (0.24 – -1.53)

Table 2
Average values of selected agrometeorological parameters in the period 1971–2000 and absolute trend and range (lowlands and ridges) in the period 1971–2010 based on gridded data

Agrometeorology

Agrometeorology mainly involves the interaction of meteorological and hydrological factors and their influence on agriculture and forestry. Temperature based agrometeorological indices like Growing Degree Days (GDD) or Sum of Active Temperatures (SAT) show a significant positive trend of +214 °C and +419 °C in the period 1971–2010 as well (Tab. 2). Particularly evident trends could be found in the lowlands, while smaller trends are calculated for the mountain regions. In addition to spatial variations between regions in the lowlands and the ridges a high year-to-year variability exists.

Based on the dimensionless drought indicator Hydrothermal Coefficient of Selyaninov (HTC), which is calculated using air temperature and total precipitation amount during the growing season, hydro-climatic conditions for the vegetation can be determined. According to its classification in the lowlands dry conditions (HTC < 1) can be observed, while humid conditions (HTC > 1.3) prevail in higher altitudes due to a higher rainfall amount. The absolute trend shows a slightly positive development in the lowlands and an evident negative trend on the ridges of -1.53.

Biometeorology

Biometeorology studies the interactions between weather and ecosystems, organisms and the human body. Climate and weather conditions have a major influence on bioclimatic and touristic suitability at a location. The spatial and temporal variability of bio-thermal conditions in the project region are illustrated based on the Universal Thermal Climate Index (UTCI) (Fig. 3). "Moderate cold stress" (-13 to 0 °C) can be observed in the lowland and foreland of the mountains during the cold season. While "severe cold stress" (-27 to -13 °C) rarely occurs, "moderate heat stress" (26 to 32 °C) is observed during the summer months July and August in the northern part of the project region. In higher altitudes, the frequency of „severe cold stress" is rising due to falling temperatures and higher wind speeds. In summer „thermal comfort" (9 to 26 °C) is predominant, „heat stress" is not observed in the mountains. In general a significant positive trend is calculated (e.g. Lindenberg: +1.7 °C) for UTCI in 1971–2010, especially due to rising temperature trends.

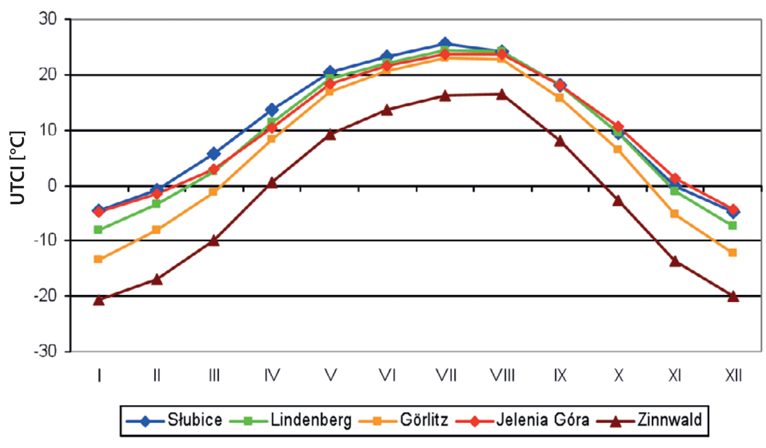


Figure 3
Average annual course of UTCI for selected stations in the period 1971–2010

The Tourism Climate Index (TCI) is useful to determine the touristic recreation potential (except winter sport activities) (Tab. 3). There are huge spatial and temporal differences in the project region, reaching from “extremely unfavourable” to “excellent” conditions. “Excellent” conditions (≥ 80) are reached during summer for lower located stations (e.g. Lindenberg, Cottbus, Legnica). Such high values are mainly caused by high temperatures, low relative humidity and high sunshine duration during summer at these stations. While “partially favourable” to „good“ conditions are observed in the transition seasons, in winter only „unfavourable“ conditions are reached. With rising altitude, low temperatures, high relative humidity, high wind speeds and precipitation as well as unfavourable radiation conditions compared to the lowland, the usefulness of touristic potential according to TCI is decreasing. In Zinnwald “very unfavourable” conditions in winter and “acceptable” conditions from May to August can be observed. For Śnieżka conditions vary from “extremely unfavorable“ to “partially favorable” from winter to summer.

Another opportunity to present the touristic suitability of weather conditions is given by the Climate-Tourism-Information-Scheme (CTIS). While heat stress (PET > 35 °C) is rarely observed throughout the year, higher frequency of cold stress (PET < 0 °C) is noticed from November until March. Regarding sunny days (NN <5/8), windy days (v > 8 m/s), foggy days (U > 93 %), sultry days (DD > 18 hPa), dry days (RR ≤ 1 mm) and days with higher precipitation (RR ≥ 5 mm) better conditions are reached in the lowlands compared to the mountains. Especially more frequent foggy and rainy days have a negative influence on tourism potential in the southern part of the project region. In contrast, climate conditions for winter sport activities like cross country (SN > 10 cm) and downhill (SN > 30 cm) skiing are very suitable in the mountain regions from January to March..

Furthermore, the trend analysis shows a decreasing frequency of days with snow cover above 10 and 30 cm. However, due to the high variability of snow cover statistical significance cannot be calculated.

Table 3

Classification of monthly TCI-values for selected climate stations in the period 1971–2010

(SLU – Słubice, COT – Cottbus, LIN – Lindenberg, LEG – Legnica, ZG – Zielona Góra, DRE – Dresden, w KUB – Kubschütz-Bautzen, GOR – Görlitz, JG – Jelenia Góra, ZIN – Zinnwald, SN – Śnieżka)

Month/Station	SLU	COT	LIN	LEG	ZG	DRE	KUB	GOR	JG	ZIN	SN
I	39	39	38	40	38	41	37	37	41	27	12
II	41	41	41	43	41	41	41	40	41	31	12
III	47	47	47	49	47	47	45	44	47	37	26
IV	56	56	56	56	56	56	54	56	54	47	28
V	65	71	67	67	63	63	61	63	59	52	37
VI	77	81	80	76	75	72	74	74	67	51	38
VII	77	81	80	78	79	76	76	78	71	53	36
VIII	77	81	80	80	79	76	74	77	73	53	44
IX	64	67	65	67	58	61	59	63	56	49	37
X	51	52	52	52	53	50	52	54	53	42	33
XI	44	43	43	43	39	43	41	42	44	32	22
XII	38	37	37	41	37	37	37	36	39	27	20

impossible · extrem unfavorable · very unfavorable · unfavorable · partially unfavorable · acceptable · good · very good · excellent · ideal

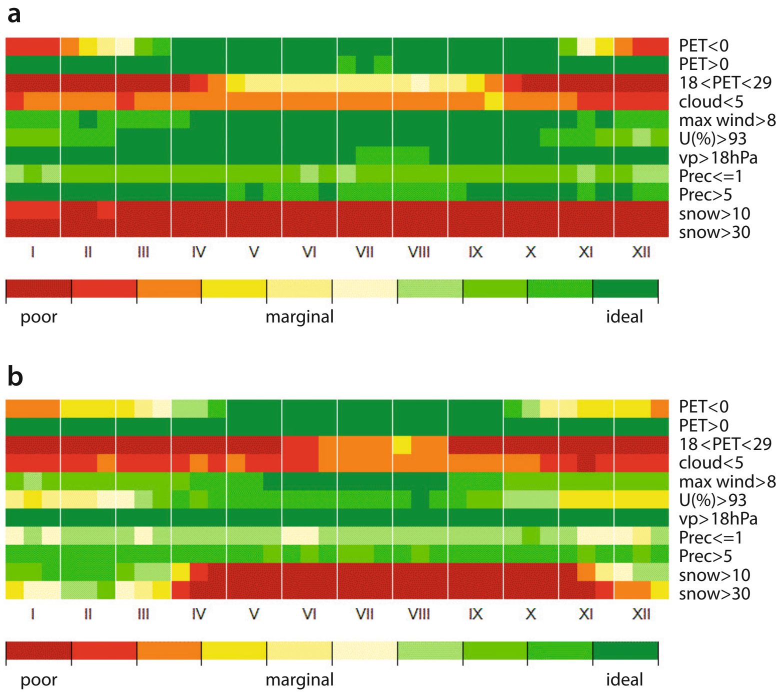


Figure 4
CTIS for 10-day periods for a) Lindenberg and b) Zinnwald in the period 1971–2010

Climate projections

Based on climate projections it is modelled, that further emissions of greenhouse gases cause a future global warming up to +4 °C until the end of the 21st century which is connected with evident changes in the climate system. Hence, the aim of the European Union is to keep global warming lower than +2 °C compared to the preindustrial level. The climate scenario RCP2.6 represents the necessary assumptions regarding emissions and radiative forcing in order to reach and keep the „2-degree-target“.

Within KLAPS a so called "scenario-ensemble" (A1B, RCP2.6, RCP8.5) illustrates the possible bandwidth of future climate change in the Polish-Saxon border region. Compared to 1971–2000 an average annual warming trend between +1.1 °C and +1.6 °C in the period 2021–2050 and between +1.0 °C and +3.5 °C in the period 2071–2100 is modelled, respectively (Fig. 5). The highest temperature rise is expected in summer. Spatial differences between lowland and mountains reach from ±0.0 to +0.3 °C

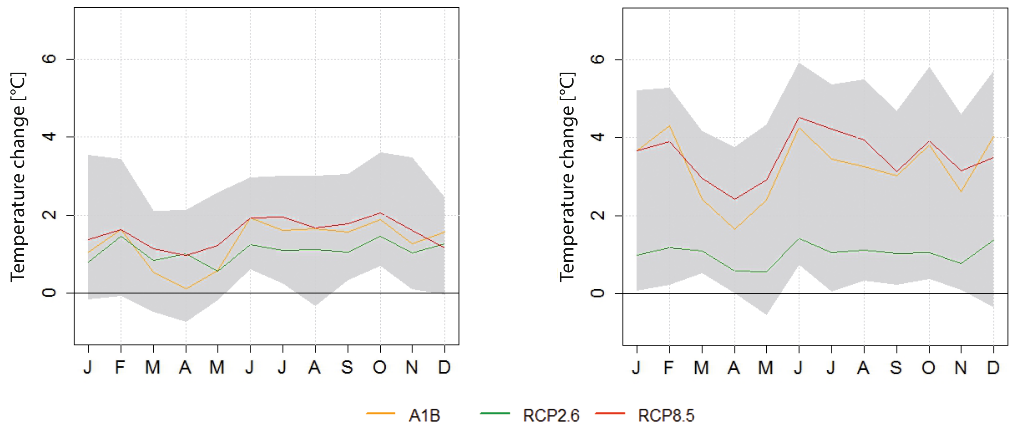


Figure 5
Temperature change [°C] 2021–2050 (left) and 2071–2100 (right) compared to 1971–2000 in the KLAPS project region

The currently observed increasing frequency of warm days and heat waves are expected to continue in the future (Fig. 4). In contrast, a decreasing frequency of cold days and the duration of frost periods are modelled, especially at the end of the 21st century. A strong increase of the growing season length contrasts with decreasing precipitation totals in the summer half year. While observations show slightly increasing precipitation trends, decreasing trends are projected under all scenarios for the summer half year as well as for annual conditions. Dry periods show a slight, but not robust increase in the summer months. With regards to heavy precipitation, no trend is calculated. Due to increasing evaporation and decreasing rainfall, the climatic water balance strongly decreases during the summer months with a high bandwidth between all selected scenarios. Even in the winter months, a slight decrease is projected with negative consequences on the water availability in the project area. In general, the projected change signals are more pronounced at the end of the 21st century.

Table 4
Scenario based bandwidth of climate change signals in the periods 2021–2050 and 2071–2100 compared to1971–2000 (global forcing: ECHAM5 and MPI ESM-LR; regionalisation: WETTREG 2013)[2]

Parameter	Unit	2021–2050	2071–2100
Average annual temperature	°C	1.1 – 1.6	1.0 – 3.5
Temperature in spring	°C	0.4 – 1.1	0.8 – 2.8
Temperature in summer	°C	1.2 – 1.9	1.2 – 4.3
Temperature in autumn	°C	1.2 – 1.8	1.0 – 3.4
Temperature in winter	°C	1.2 – 1.3	1.0 – 3.6
Summer days	d	10 – 18	11 - 41
Hot days	d	3 – 6	4 – 20
Tropical nights	d	0.5 – 0.8	0.5 – 5
Frost days	d	-18 – -22	-18 – -50
Ice days	d	-9 – -11	-10 – -26
Cold sum	-	-70 – -90	-78 – -194
Heat wave	amount	1 – 2	1 – 6
Duration of frost period	d	-8 – -10	-10 – -25
Duration of frost free period	d	12 – 18	10 – 39
Growing season length	d	18 – 25	16 – 56
Precipitation summer half year (SHY)	mm	2 - -19	-12 – -68
Precipitation winter half year (WHY)	mm	3 – 5	6 – 17
Dry periods SHY	amount	0.0 – 0.1	0.1 – 0.4
Days with heavy precipitation SHY	d	0.0 – -0.1	-0.1 – -0.2
Days with heavy precipitation WHY	d	0.0 – 0.1	0.0 – 0.1
Potential evaporation	mm	25 – 51	24 – 102
Climatic water balance SHY	mm	-15 – -56	-30 – -139
Climatic water balance WHY	mm	-1 – -4	2 – -10
Sunshine duration	h	63 – 164	57 – 327

2 Table 4 is supplemented by using the results of the EU project NEYMO https://publikationen.sachsen.de/bdb/artikel/22580

Agrometeorology

According to all selected climate change scenarios an increase in growing degree days and sum of active temperatures is projected until the end of the 21st century (Fig. 6). Similar to climatological days a high spatial variability between lowlands and mountains is modelled.

In contrast, the Hydrothermal Coefficient (HTC) shows a decreasing trend, especially in the mountain areas. This means that regions that are currently characterised by water deficit, continue to expand to higher altitudes in future. Depending on the scenario, the drought limit (HTC < 1) is located at 450 m a.s.l. (RCP2.6) and 550 m a.s.l. (RCP8.5), respectively.

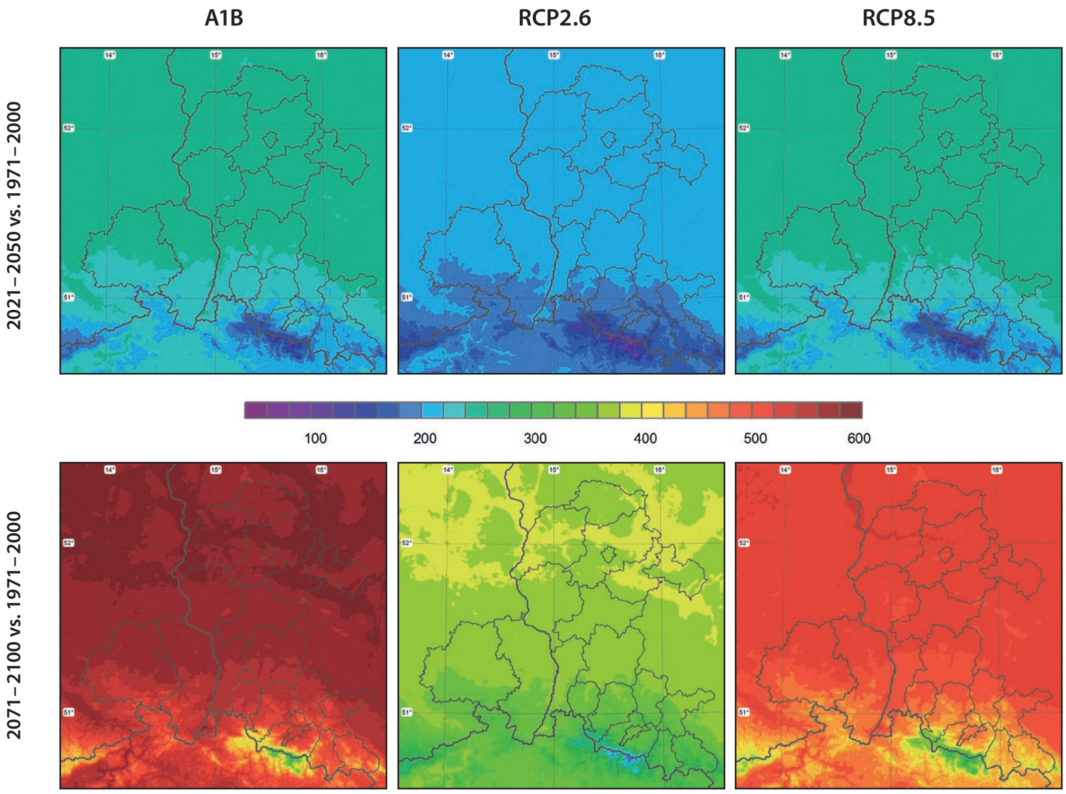


Figure 6
Change signal of growing degree days [°C] in the periods 2021–2050 (top) und 2071–2100 (bottom) compared to 1971–2000 in the KLAPS project region

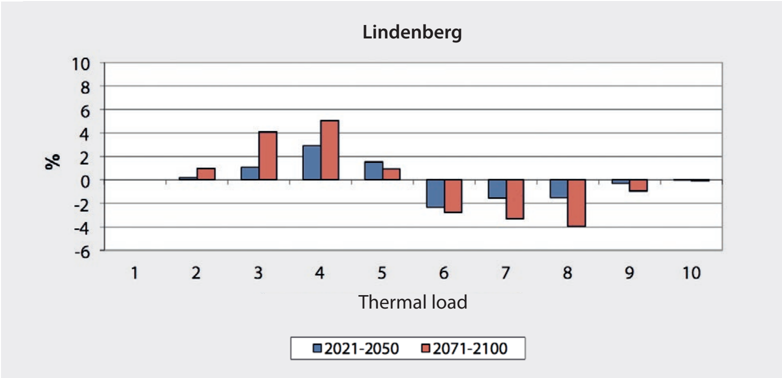
Parameter	Unit	2021–2050	2071–2100
Growing degree days	°C	204 – 239	362 – 555
Sum of active temperatures	°C	313 – 342	531 – 808
Hydrothermal Coefficient of Selyaninov	-	-0.13 – -0.09	-0.31 – -0.17

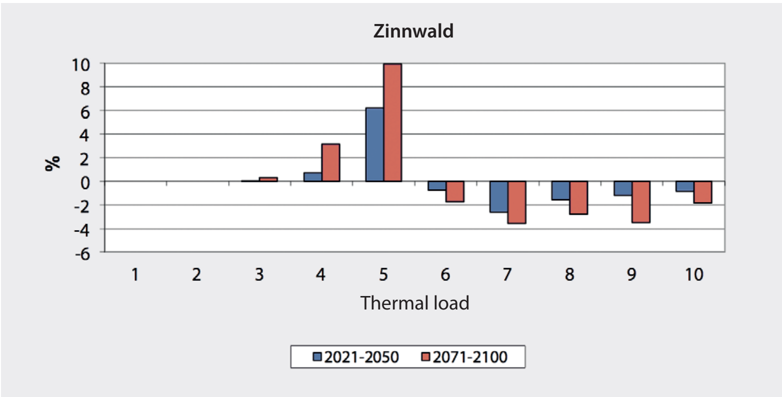
Table 5
Scenario based bandwidth of agrometeorological change signals in the periods 2021–2050 and 2071–2100 compared to 1971–2000 based on gridded data (global forcing: ECHAM5 and MPI ESM-LR; regionalisation: WETTREG 2013)

Biometeorology

Future bio-thermal and touristic conditions are characterised by a significant spatial and temporal variability in the project region. Most evident changes and influences on tourism are projected under the scenarios A1B and RCP8.5 at the end of the 21st century. Mainly due to an increase in air temperature, more frequent sunny days and decreasing wind speed an increase in frequency of heat stress during summer season is expected in the lower located areas (Fig. 7). In the mountains changes in meteorological conditions will lead to more appropriate conditions for tourism activities during summer. The frequency of cold stress is decreasing in winter; however, negative effects for winter sport tourism are very likely to occur. By reaching the "2-degree-target" (RCP2.6) the usefulness of weather for tourism and recreation would be less negatively affected in the lower areas of the Polish-Saxon border region.

Figure 7
Differences in the frequency [%] of particular thermal loads in the periods 2021–2050 and 2071–2100 compared to 1971–2000 under emission scenario RCP8.5
(1 = extreme heat stress,
2 = very severe heat stress,
3 = severe heat stress,
4 = moderate heat stress,
5 = no thermal stress,
6 = slight cold stress,
7 = moderate cold stress,
8 = severe cold stress,
9 = very severe cold stress,
10 = extreme cold stress)





Air pollution

Due to large brown coal mining and combustion and an intensive chemical industry during the 70s and 80s, the area between Saxony, Lower Silesia and Bohemia was known as the "Black Triangle". After the year 1990 the emissions of coal combustion was significantly abated. Potential reasons are ecology, but also political and economic changes in Central Europe. The emission abatements were especially significant for sulphur (SO_2) and oxidised nitrogen (NO_x). Based on emission projections for the year 2030 the downward trend is very likely to continue in future (Fig. 8). For ammonia (NH_3), after a slight decrease in 2005, emissions are expected to stay on a constant high level with 30 Gg towards the year 2030.

Following the general emission trend, a continuing reduction in the deposition of sulphur and oxidised nitrogen is modelled (Fig. 9). In contrast, the deposition of reduced nitrogen remains at a constant level. Moreover, deposition of NH_x brings majority of the nitrogen mass deposited in the KLAPS project area after year 2005.

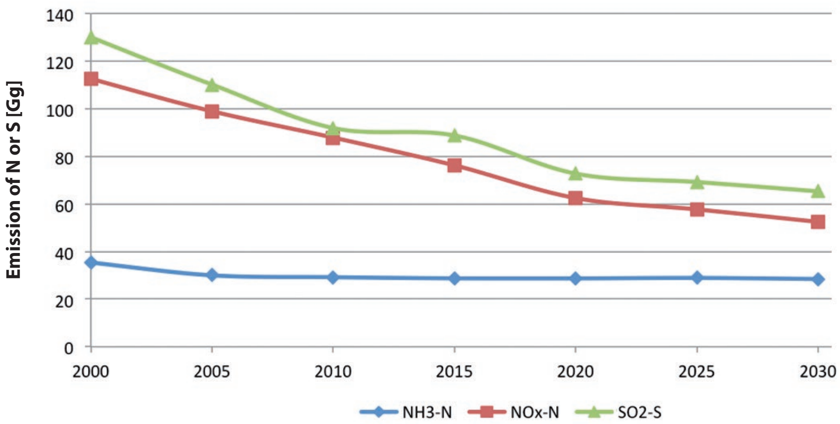


Figure 8

Emission changes [Gg] of SO_2, NO_x and NH_3 in the KLAPS project region in the period 2000–2030 (5-year-steps)

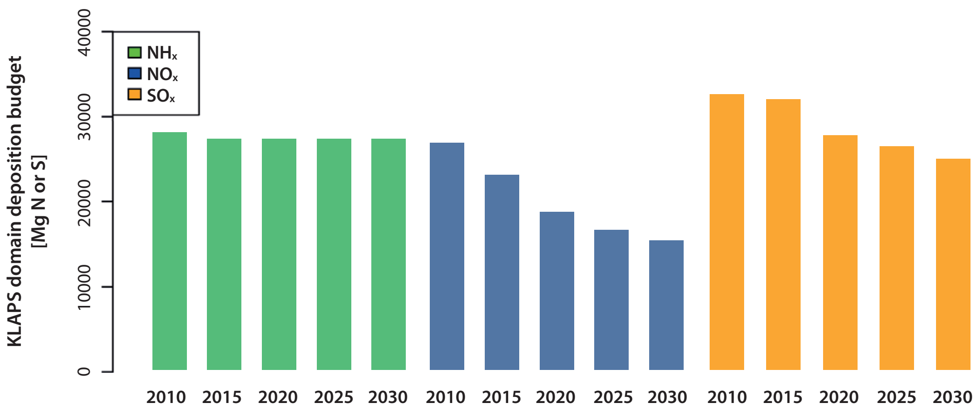


Figure 9

Deposition budget of SO_x, NO_x and NH_x in the period 2010–2030 (5-year-steps) in the KLAPS project region

Spatial distribution of oxidised sulphur (SO_x) and reduced nitrogen (NH_x) in the year 2010 are presented in Fig. 10. The largest deposition is modelled for mountainous areas (because of high wet deposition) and in close vicinity of the largest emission sources. These results are confirmed by measurements of IMGW-PIB.

In addition to changes in emissions, an influence of climatic changes on depositions of various air pollutants is visible. Especially at the end of the 21st century deposition rates are decreasing by approx. 0.5 Gg compared to 2021–2050 under the scenarios A1B and RCP8.5 (Fig. 11). This is primarily due to the projected decrease in annual total of precipitation in the entire project region. Overall, deposition reduction due to climate change is smaller compared to changes in emission abatements.

Figure 10
Total deposition of SO_x (left) and NH_x (right) in the year 2010

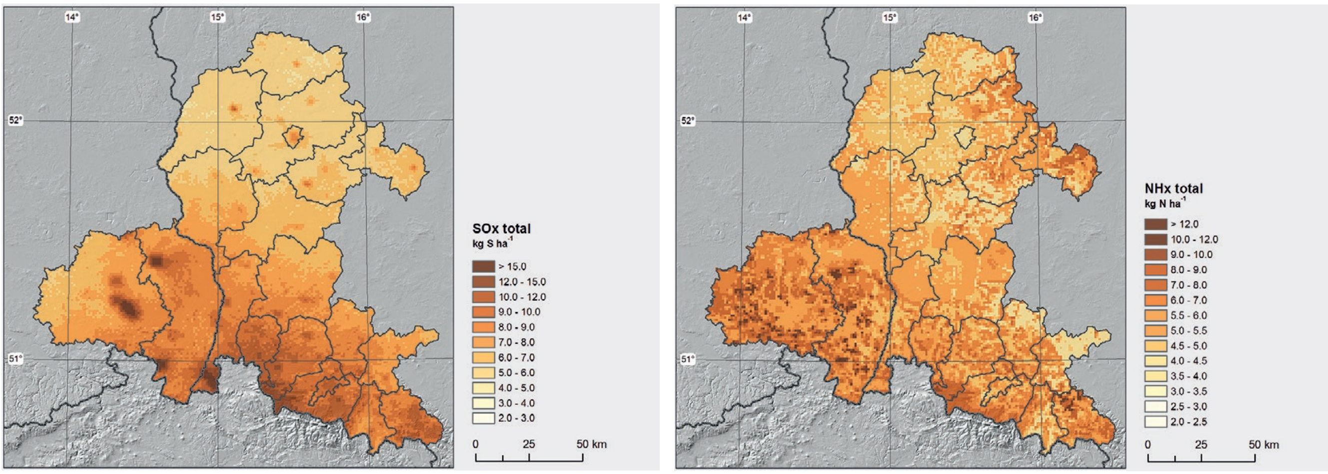
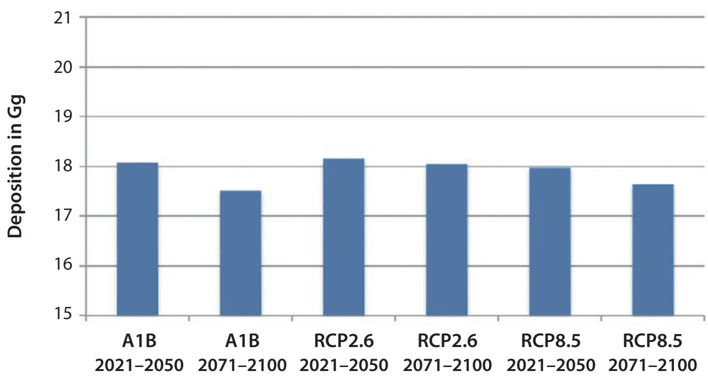


Figure 11
Sulphur deposition [Gg] under selected climate scenarios and emission prognosis in the year 2030 in the KLAPS project region



Critical Load of ecosystems

Efforts in recent decades to reduce air pollution are reflected in the project area based on the environmental load limits, the so called critical load. At present decreasing sulphur depositions lead to a potential acidification risk in only 10 % of the observed ecosystems (Fig. 12). In particular coniferous forests are sensitive to acidification. According to future sulphur deposition prognoses almost all ecosystems will be protected against acidification in the year 2030. Despite nitrogen abatements an eutrophication risk is identified in more than 60 % of the receptor area in the year 2010. Affected ecosystems are coniferous forests but also marshes and peat bogs show a relatively high risk of eutrophication. In the year 2030 eutrophication risk is likely to reach 40 % of the ecosystems. The overall goal to protect all of the ecosystems from acidification and eutrophication, which is defined by the Convention on Biodiversity (CBD), cannot be achieved with the current abatement efforts.

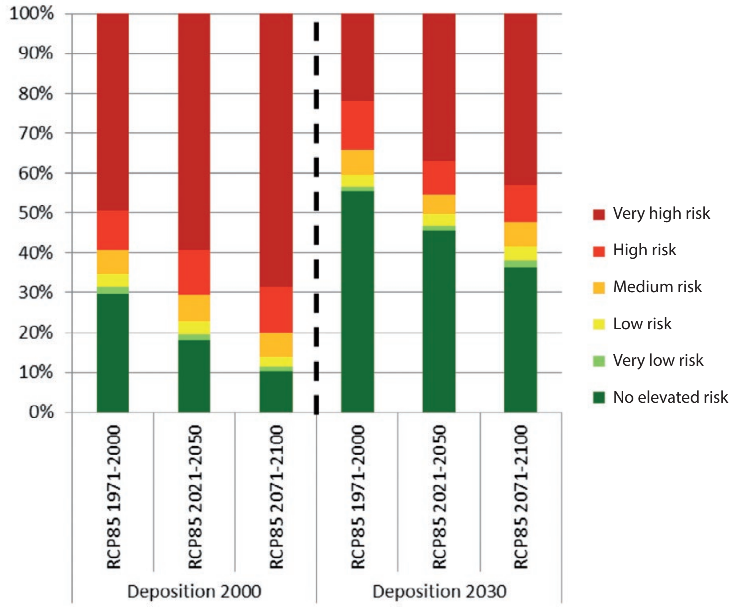
Figure 12
Exceedance of Critical Load for acidification (top) and eutrophication (below) dependent on deposition prognoses in the period 2000–2030

The interactions between reduction of deposition driven by environmental protection policies and effects of predicted changes in the climate need to be considered as well. Rising temperatures and decreasing annual precipitation sums lead to increasing sensitivity of ecosystems against nitrogen depositions, at least at the end of the 21st century (Fig. 13). The most negative effect is given under RCP8.5 run 1, while under RCP2.6 an increase in sensitivity is less significant. On average the difference between the critical load for eutrophication is about 3 kg N ha^{-1} a^{-1} in both scenarios.

In total only half of the measurements to reduce emissions have positive effects on the protection of ecosystems. The other half is compensated due to changed climate conditions. Hence, future air pollution policies should integrate both, emission as well as climate changes.

Figure 13

Risk classes for eutrophication of ecosystems dependent on depositions in the year 2000 (left) and 2030 (right) and different climate periods under scenario RCP8.5 run 1



Consequences of climate changes

Based on the results obtained in the project KLAPS statements for expected climate change impacts in the study area can be derived for the investigated fields. Additionally, conclusions reached by a number of previous studies (e.g. NEYMO, REGKLAM, vulnerability study for Saxony, etc.[3]) are supplemented to the following overview. The following list does not claim to be complete and may differ from the general statements because of regional and local characteristics.

Agriculture

- improved yield profitability, especially in cool growing regions of the highlands in the southern part of the project region
- increasing yield and quality of fruits and wine grapes with rising sunshine duration in autumn
- increasing yield of winter fruits and thermophilic crops under sufficient water availability conditions
- decreasing yield stability due to high annual variability
- especially in the northern part of the project area yield losses due to negative climatic water balance during the growing season
- higher yield variation on sandy soils in case of water requiring crops like corn, potatoes and beets particularly in dry years
- increased drying of soil in the summer season due to increased evaporation and increasing frequency and duration of dry periods
- increasing risk potential of loss of fertile agricultural soils by water erosion due to heavy rainfalls, especially after previous droughts
- qualitative loss to total failure of crop due to heavy rainfall and hail events (e.g. wine, tree fruits)
- increased wind erosion during dry periods
- late frost risk due to early growing season and early seeding
- immigration and spreading of thermophilic pest species
- in some cases, limited use of pesticides during heat and dry periods

3 References given in *further information on climate change mitigation and adaptation in Saxony* (page 21)

Forestry

- shifting of silviculture regions due to climatic changes (warmer and drier conditions)
- occurrence of new forest compositions (sparse forests)
- changing occurrence and distribution of native tree species
- especially in the higher altitudes natural or deliberate spread of thermophilic tree species
- loss of vitality and reduction of timber volume in the lowlands due to negative climatic water balance and dry periods during the summer months
- reduced productivity of spruce due to drought stress
- increased reproduction and immigration of new species of insects
- increased risk of forest fires

Water balance and water management

- especially in the lowland declining groundwater levels due to reduced groundwater recharge as a result of decreasing rainfall, increasing evaporation rates and supply of surface water during dry periods in the summer months
- changes in substance conversion, dissolution properties and groundwater biology due to higher groundwater temperatures
- increasing risk potential of river ecosystems due to periods of low water and increased water temperatures
- increasing reduction, siltation or more frequent drying up of water bodies with a small catchment area by increased evaporation and precipitation deficits
- reduction of runoff by rainfall deficits in summer
- reduced inflows to reservoirs
- significant negative climatic water balance during the summer months
- risk of blue-green algae bloom by rising water temperatures and radiation, nitrogen and phosphor oversupply and reduced inflow in the summer season
- worsening of ecological conditions due to increased sediment and pollutant discharges during heavy rainfall events
- increasing risk potential of local flooding and backwater of wastewater systems
- increasing flood risk due to convective heavy rainfalls in summer
- reduction of flood probability as a result of decreasing snow cover (snow melting water) due to warmer temperatures in winter
- acidification risk of mining lakes and ground water due to delayed flooding or a lack of water supply


Picture: LfULG


Picture: LfULG

Aquaculture and fish farming

- destruction of fish farms by heavy rainfall and flooding
- interruption of winter rest and energy losses of fish due to a lack of ice cover and higher water temperatures
- increasing problems of new fish diseases
- loss of profit and fish mortality due to water shortage

Settlement areas

- increased air pollution due to more frequent and longer lasting dry periods
- destabilization of urban soil water balance
- impairment of vitality and important regulatory function of urban green areas due to more frequent and longer lasting dry periods and changed site conditions
- requirement of technical changes in buildings (e.g. demand for air conditioning in summer, heat protection, flood protection)
- impairment of indoor climate due to warmer temperatures
- reduced need for heating in winter

Population

- decreasing quality of stay and well-being of the population due to warmer temperatures (e.g. hot days, tropical nights and heat waves)
- increasing health problems (e.g. allergies, infectious diseases, cardiovascular disorders) due to warmer temperatures and increased particulate air pollution
- decreasing cold stress in winter

Tourism

- extension of the climate-related travel time
- extension of the open-air season (e.g. beer garden and swimming season)
- increased heat stress, particular in cities and lowlands
- increasing tourist potential of higher altitudes in summer
- shortening or absence of the winter season by decreased snow cover
- increasing weather variability
- increased impact of weather extremes on the tourism potential of a region

Further information on climate change mitigation and adaptation in Saxony

Climate Adaptation in Saxony – website of the SMUL:
www.klima.sachsen.de

Energy and Climate Programme of Saxony 2012:
http://www.umwelt.sachsen.de/umwelt/klima/30157.htm

Climate Compendium Saxony – Climate Strategies:
http://www.umwelt.sachsen.de/umwelt/download/Klimakompendium_ST.pdf

Regional Climate Information System:
www.rekis.org

Regional Climate Change Adaption Programme for the Model Region Dresden:
http://www.regklam.de/fileadmin/Daten_Redaktion/Publikationen/Regionales-Klimaanpassungsprogramm_Lang_121101.pdf

Climate change and agriculture – adaptation strategy of agriculture to climate change in Saxony:
https://publikationen.sachsen.de/bdb/artikel/11557

Adaptation of the Saxon crop farming to climate change:
https://publikationen.sachsen.de/bdb/artikel/11449

Vulnerability analysis of Lusatia and Lower Silesia:
http://www.rpv-oberlausitz-niederschlesien.de/projekte/regionales-energie-und-klimaschutzkonzept-klimaanpassungsstrategie/regionale-klimaanpassungsstrategie/ergebnisse.html

Good Practice Guide – tourism and biodiversity in a changing climate:
http://www.bfn.de/fileadmin/MDB/documents/themen/sportundtourismus/Leitfaden_IOER_barrierefrei.pdf

Analysis of the need for action on climate adaptation:
Bernhofer, C. et al. (2007): Analyse zum Handlungsbedarf im Bereich Klimaanpassung. Studie im Auftrag des Landesamtes für Umwelt und Geologie, Dresden.

Publications in the EU project KLAPS

Project publications (online and printed version available):

Volume 1: Climate in the Polish-Saxon border area:
https://publikationen.sachsen.de/bdb/artikel/21673

Volume 2: Climate projections, air pollution and critical load of ecosystems:
https://publikationen.sachsen.de/bdb/artikel/23356

Project reports (online available):

Critical load of ecosystems: https://publikationen.sachsen.de/bdb/artikel/22073

Development of windroses for KLAPS: https://publikationen.sachsen.de/bdb/artikel/23037

Ozone analysis in the Polish-Saxon border area: https://publikationen.sachsen.de/bdb/artikel/12687

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