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EXTREME PRECIPITATION AND DRY PERIODS CLIMATE TRENDS IN SAXONY, 1951—2000

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Summary:
Changes in the frequencies and intensities of extreme precipitation and drought are investigated in the context of global climate change and the increasing average precipitation over Central Europe. Changes of regional precipitation patterns and extremes in Saxony were analysed from 1951 to 2000. Based upon those data, an annual redistribution of precipitation becomes visible.

The precipitation sum decreased at most stations during the summer months, but increased in the winter half of the year. Similar trends have been observed for the amount and likeliness to exceed the 90th and 95th percentile. Regions with a relatively large increase/ decrease in the half year precipitation sum show comparatively large positive/ negative 90% percentile trends. The decrease during the summer months is particularly high in northern Saxony. The 99th percentile gives positive results for about half of the stations for both halves of the year. Negative summer trends occur especially in northern, eastern and central Saxony. Likewise in northern Saxony, the decrease of the maximum daily precipitation was most pronounced. The maximum daily precipitation in winter is only half as high as in summer, but most stations showed a positive trend.

The maximum length and frequency of dry periods increased during summer. The situation is just the opposite in winter, and there is a trend to more humid conditions. The maximum length of dry periods is particularly high in eastern Saxony. This trend to increased summer drought is of very high significance for water management and has consequences for the regional biosphere.

Introduction

The range of the natural climate is very large and extreme events have always occurred (HOUGHTON 1997). In the last decades changes of different climatic elements were determined, which are supposed to have anthropogenic causes. Since 1861 the global average temperature of the earth's surface has increased by about 0.6 ± 0.2°C, parallel to the increased greenhouse gas concentrations in the atmosphere (HOUGHTON et al. 2001). This heating of the atmosphere has certainly effects on other climatic elements; e.g. a reinforcement of the global water circulation is expected (TRENBERTH 1999). Despite obvious global tendencies and projections, there are substantial regional deviations from these global means. However, investigations regarding regional climate changes (RAPP & SCHÖNWIESE 1996; SCHÖNWIESE et al. 2003) are still rare today.

It is believed that the global climatic change is accompanied by an increase of the occurrence of extreme climatic events (HOUGHTON et al. 2001). An extreme weather event is an event that is rare within its statistical reference distribution at a particular place (HOUGHTON et al. 2001). There exist various definitions of “rare”. Normally, an extreme weather event would be at least as seldom as the 10th or 90th percentile. Changes in the frequency of many extremes can be surprisingly large for seemingly modest mean changes in climate. Due to the sensitivity of human infrastructures as well as ecosystems towards extreme events is of great importance to know the probability of their occurrence for estimating the economic influence of climatic change. The severity of Climate Change consequences depends to a considerable degree on the occurrence of extreme conditions. Extreme events are therefore interpreted as a key aspect of Climate Change (HOUGHTON et al. 2001).

Existing analyses show that there exist regional differences in size and direction of the climatic changes (Central Europe and Germany: RAPP & SCHÖNWIESE 1996; Saxony: FREYDANK 2001; BERNHOFER et al. 2002, Hänsel et al. 2005). This work focuses on the region Saxony and examines 103 precipitation stations regarding the extreme precipitation events. The analyses refer to the period 1951–2000 and deal with strong pre-

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cipitation events as well as dry periods and their trends.

Database and methods

The Saxon climatic data base is the source of the analysed data. This data base has been provided within the research project CLISAX (Statistical assessment of regional climate trends in Saxony) of the Saxon state agency of environment and geology (BERNHOFER & GOLDBERG 2001). Altogether, 103 stations from Saxony and bordering parts of Brandenburg, Saxony Anhalt, Thuringia and Bavaria were examined. The time series are 50 years long (1951–2000).

Extreme precipitation: For defining extreme precipitation events various thresholds exist, firstly fix thresholds, usually 10 and 20 mm daily precipitation (FREYDANK 2001), and secondly thresholds depending on the precipitation distribution. Since individual precipitation stations frequently differ in their precipitation characteristics, the use of distribution-dependent threshold values is recommended. According to the recommendations of NICHOLLS & MURRAY (1999) the annual size and the excess frequency of the 90th, 95th and the 99th percentile of the climatic normal period (1961/90) were analysed.

Dry periods: Dry days are defined as days without hydrological effective amounts of precipitation; the threshold value is 1 mm precipitation per day. A dry period is a continuous succession of dry days, which persists for at least 11 days.

Trend analyses: Trends were determined by linear regression. The significance of the trends was determined by the non parametric MANN-KENDALL trend test. This trend test is suitable for time series without normal distribution and non-linear trends (RAPP 2000). The trend test evaluates a relative increase or decrease. Note that the significance statement may not be referred to the linear trend (RAPP 2000).

Results

Especially the summer and the winter half year are generally showing the regionally most uniform trends. When looking at seasons (months DJF, MAM, JJA, SON), the intensity of the trends is partly decreasing and the regional differences are increasing. Therefore only the half year trends are discussed in this paper. In the following illustrations, the centre of each symbol corresponds to the geographical position of a station.

Precipitation amounts: A clear internal-annual rearrangement of the precipitation similar to the investigations of RAPP & SCHÖNWIESE (1996) for Germany has been detected in Saxony (

Table 1). The yearly trends are mostly small and non significant due to the opposite directions of the half year trends. In most cases they are smaller than the trend for Germany computed by RAPP & SCHÖNWIESE (1996). These authors attribute the increased precipitation in winter to an intensification of the zonal circulation. Cyclonic weather conditions bring the largest precipitation amounts to Germany. In Saxony the Cyclonic westerly air streams, Europe's most frequent weather situation, showed a decreasing occurrence in summer (vegetation period) and an increase during winter (period 1951-2000; WOLF 2001). This weather situation is connected with changeable weather; showers as well as long continuing precipitation may occur. The trends of the cyclonic west situation fit very well with the half year precipitation trends of Saxony (decrease of the precipitation in summer and increase in winter).

Table 1: Annual and half yearly average rainfall of 103 stations, and number of stations with positive/ negative relative linear precipitation trends (1951—2000)

Rainfall	Average rainfall (mm)	Number of stations with		Mean trend of all stations (%)
		positive trends	negative trends	
Annual	693	54	49	0.8
Summer	400	15	**88**	-10.1
Winter	294	**93**	10	16.3

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In the North of Saxony, the negative summer trend is especially high. This region is used for agriculture and has already the lowest yearly rainfall amounts. A continuation of this trend to lower rainfall depths in summer will increase the irrigation-problem. It can also lead to changes in the composition of the natural vegetation (e.g., shift of the forest border).

High intensity rainfall: The size and the excess frequency of the 90th, 95th and the 99th percentiles, as well as their trends, were examined.

Size of the percentiles. In Saxony the 90th percentile corresponds on average to 6 mm, the 95th percentile to 10 mm and the 99th percentile to 20 mm daily precipitation. This means that generally the 95th percentile corresponds to the commonly used fix threshold of 10 mm and the 99th percentile to the 20 mm threshold. However, the size of the percentiles differs regionally as a function of the altitude and the connected average precipitation sums. In the lowland regions of Saxony, the percentiles are clearly smaller (95th percentile: 7-9 mm, 99th percentile: 16-20 mm) as in the more mountainous regions like the Erzgebirge (95th percentile: 10-13 mm, 99th percentile: 20-25 mm). In the half years as well as in the seasons the described difference between fix and variable thresholds becomes even more obvious; e.g. the percentiles for the summer half year are approximately 30% larger than those of the winter half year.

Percentile trends. During the summer half year, size and excess frequency of the 90th and 95th percentiles decrease at most Saxon stations, whereas in the winter half year an increase could be observed (Table 2). Regions with a relatively large increase/decrease of the half year precipitation sums also show relatively large positive/negative trends of the 90th percentile. Accordingly, the decreases during summer are particularly high the Northern parts of Saxony.

Table 2: Annual and half yearly averages of the size and excess frequency of the 90th percentile, and number of stations with positive/ negative relative linear 90th percentile trends (1951—2000)

90th percentile	Average size (mm)	Number of stations with		Mean trend of all stations (%)
		positive trends	negative trends	
Annual	5.8	64	39	1.8
Summer	6.6	25	**78**	-6.2
Winter	5.0	**95**	8	13.8
	Average excess frequency			
Annual	36.2	53	50	0.8
Summer	18.2	23	**80**	-8.9
Winter	18.4	**91**	12	17.9

Choosing a higher threshold (99th percentile) results in more frequent positive trends for the summer half year (Table 3). Exceptions from this trend of increasingly high intensity rainfall in summer occur particularly in Northern and Eastern Saxony. In the winter half year increasingly more stations are showing negative trends for the exceedance frequency of the 99th percentile.

Maximum daily precipitation. The time series of the maximum daily precipitation sums was examined as an example for the most extreme precipitation event of each year. At most stations, the height of the maximum daily precipitation has decreased during the entire as well as the summer half year (Table 4).

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Table 3: Annual and half yearly averages of the size and excess frequency of the 99th percentile, and number of stations with positive/ negative relative linear 99th percentile trends (1951—2000)

99th percentile	Average size (mm)	Number of stations with		Mean trend of all stations (%)
		positive trends	negative trends	
Annual	19.7	46	57	-0.8
Summer	23.1	41	62	-3.9
Winter	14.4	66	37	5.4
	Average excess frequency			
Annual	3.8	50	53	1.8
Summer	2.0	51	52	-2.5
Winter	1.8	64	39	15.6

Table 4: Annual and half yearly average maximum rainfall at 103 stations, and number of stations with positive/ negative relative linear trends of maximum rainfall (1951—2000)

Maximum daily rainfall	Average maximum daily rainfall (mm)	Number of stations with		Mean trend of all stations (%)
		positive trends	negative trends	
Annual	93.0	24	**79**	-14.8
Summer	93.0	23	**80**	-14.9
Winter	44.4	**70**	33	8.5

Again the negative trend in the summer half year is particularly pronounced in Northern Saxony. In the winter half year the maximum daily precipitation sums are mostly much smaller (about 50%) than those in the summer half year. For the observation period 1951–2000, a small increase in maximum daily precipitation heights was determined for the winter half year at most Saxon stations. Exceptions are especially the stations in East Saxony, showing negative trends.

Dry periods: The longest dry period of a year is about 23 days long and approximately 5 dry periods occur with a minimum length of 11 days per year. According to the altitude and characteristic precipitation sums, regional differences in the size of these values can be monitored. In lowland regions (North, East and Central Saxony), the maximum duration of dry periods as well as the frequency of long-continuing dry periods is larger than in the more mountainous regions. The maximum length of dry periods is with an average of 16 days in the summer half year shorter than in winter, where the longest dry period duration averages about 21 days. This reflects the influence of convective precipitation in summer. Dry periods are more often interrupted by showers in the summer than in the winter half year. In summer there are occurring approximately 2 dry periods, whereas in the winter half year on the average 3 dry periods have been observed.

Table 5: Annual and half yearly average duration of the longest dry period at 103 stations, and number of stations with positive/ negative relative linear trends of maximum dry period duration (1951—2000)

Longest dry period	Average length of the longest dry period	Number of stations with		Mean trend of all stations (%)
		positive trends	negative trends	
Annual	22.6	21	**82**	-11.8
Summer	16.3	**93**	10	15.5
Winter	20.8	2	**101**	-25.3

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During the summer half-year the maximum duration (Table 5) as well as the frequency of dry periods (Table 6) has increased. During the winter half-year a development towards less dryer conditions has been observed. Caused by these opposite directions of the half year trends the described differences between the half-years become smaller.

Table 6: Annual and half yearly average frequency of dry periods lasting at least 11 days at 103 stations, and number of stations with positive/ negative relative linear trends of the number of dry periods (1951—2000)

Dry periods lasting >= 11 days	Average frequency of at least 11 days lasting dry periods	Number of stations with		Mean trend of all stations (%)
		positive trends	negative trends	
Annual	5.1	59	43	1.7
Summer	2.1	**93**	10	24.4
Winter	2.9	16	**86**	-16.0

The observed development towards dryer conditions during the summer half year can lead to increased problems for agriculture, forestry, natural ecosystems as well as drinking and industrial water supply.

Conclusions

For the observation period of 50 years changes have been ascertained for all analysed quantities. The described changes are in agreement with those projected in the context of global warming (HOUGHTON et al. 2001). It is expected that the warming of the troposphere is accompanied by an intensification of the global water circulation. Like the IPCC detected for the middle and high latitudes of the northern hemisphere a slight increase in precipitation sums could be observed in Saxony. The changes in frequency of extreme precipitation events were particularly high in regions with high precipitation trends.

A decrease of the maximum daily precipitation sums was monitored for almost all stations during the summer half year. Because the time series of maximum daily precipitation does only consider the most extreme event per (half) year it is most strongly affected by chance. Extreme precipitation events exceeding the 99th percentile threshold have increased at about half of the stations in both half years. Whereas less extreme events indicated by the size and exceedance of the 90th and 95th percentile showed predominantly negative trends in the summer half year and opposite trends in the winter half year.

While it is not possible to predict future conditions by just extrapolating the computed trends, the diagnostic trends are the basis for models forecasts about future climate developments (Enke et al. 2000, 2002; Sillmann 2003). However, if some of the observed trends continue, Saxony will have to deal with serious problems independent of the causes of such changes. Problems could comprise prolonged and/or more frequent dry periods especially in the vegetation period as well as more frequent extreme precipitation events.

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