How will the occurrence of extreme weather events in the German Rhine change by the end of the 21st century?

This information sheet is one in a series describing how the frequency and intensity of extreme weather events may change by the end of the 21st century in response to global warming. The regional information presented here was obtained using state-of-the-art climate modeling and regional downscaling techniques developed during the STARDEX European Union-funded research project. These methods and the STARDEX approach are described in an accompanying overview information sheet.

Extremes in the Rhine basin

The Rhine basin has seen a number of extreme events of precipitation and temperature in the recent past, which have had severe economic and social impacts. The 2003 Summer persistent record temperature, for instance, claimed thousands of lives and economic losses in billions of Euros. The economic impact of extreme temperature is manifested in incidents like forest fire, a reduction in power production due to insufficient water to drive hydropower plants or warming of the water which is needed for cooling power production plants, as well as disruption of inland shipping facilities due to inadequate water levels.

Similarly, the extreme precipitation events of December 1993 and January 1995 caused extreme flooding in the basin, which claimed economic losses of 0.4 and 0.3 billion USD respectively. Many of the floods in the basin in the recent past were caused by persistent precipitation over a number of days, i.e., it was the cumulative effect of rainfall in consecutive days rather than an intense precipitation on a single day that caused them. The total amount of rainfall in the last 10 days of January 1995, for example, was twice the long-term average for the whole month of January.

Figure 1: The 1995 flooding in the Rhine (Cologne)

Past changes in extremes

The extremes of both temperature and precipitation have shown significant changes in the past half century within the German Rhine basin, with seasonally variable degree of changes. Both the maximum and minimum extreme temperatures have shown an increasing trend in all seasons except in autumn, where they showed the opposite trend. They have shown more increase in winter than in summer. Over the period 1958 to 2001, the mean of the 90th percentile maximum daily temperature has increased by 2.7°C and 1.4°C respectively in winter and summer (Figure 2). The mean of the 10th percentile minimum daily (cold-night threshold) temperature has also increased by 2.1°C and 1.1°C respectively in winter and summer over the same period. Annually, however, the extreme minimum has shown more increase than the extreme maximum over the same period (1°C and 0.6°C respectively).

The intensity and frequency of extreme daily precipitation has shown an increasing trend in all seasons except in summer. The strongest increase has been noted in winter. The mean of the 90th percentile rain day amount has shown a rise by 20% in winter over the period 1958 to 2001, while it dropped by 6% in summer over the same period. Similarly, the percentage of seasonal rainfall resulting from events exceeding the long-term 90th percentile amount has risen by 47% in winter and dropped by 9% in summer over the same period. The maximum five day total rainfall, which is an important measure of extreme from the point of view of flooding in a basin like the Rhine, has also shown an areal average rise by 37% in winter (Figure 3) while it dropped by 11% in summer.

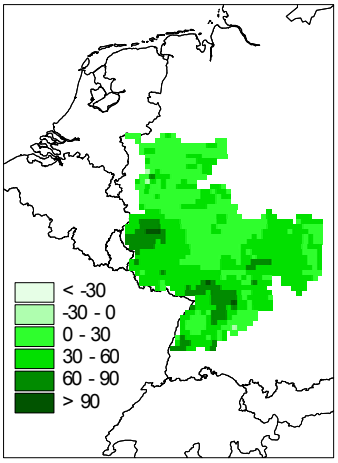
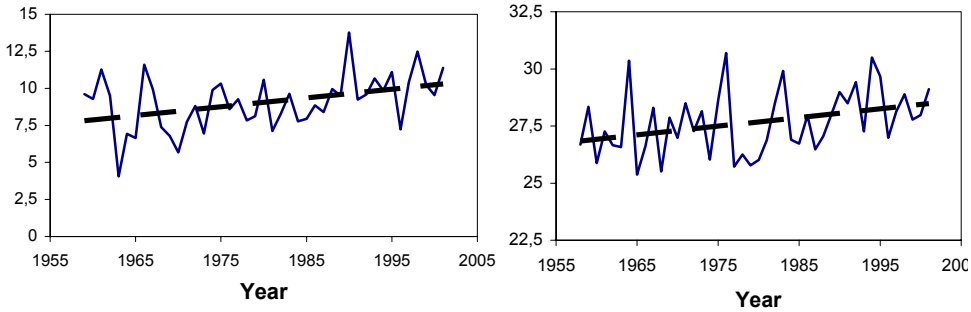


Figure 3: Percentage change in the 5 day total rainfall in winter over 1958 to 2001.



Winter Summer

Figure 2: Evolution of the 90th percentile maximum (hot-day) temperature °C

The maximum dry spell length, on the other hand, has significantly decreased in winter and increased in summer (a 10% decrease in winter and a 15% increase in summer).

Future changes in extremes

The possible future changes in the extremes of precipitation and temperature were constructed using two different statistical downscaling methods (see the accompanying overview information sheet for these methods) driven by outputs of HadAM3P run for the SRES emission scenarios A2 and B2 for the period 2070 - 2100.

Both the mean and the extreme of the minimum and maximum temperatures show an increasing tendency under both emission scenarios for the future. Higher increases are expected in summer and the winter increases are less compared to the changes in the other seasons. Although both models show consistency in simulating the direction of future changes in the temperature extremes, there is a noticeable difference in the magnitudes of the changes projected by the two models. However, the general tendency is that the maximum temperature increases more than the minimum and the extreme maximum increases more than the mean of the maximum while the extreme minimum increases less than the corresponding mean in all seasons. The increase in both the minimum and maximum temperatures is accompanied by increasing variability of the corresponding temperatures in summer. The changes under the B2 scenario are less severe than the corresponding changes under the A2 scenario as shown in Figure 4.

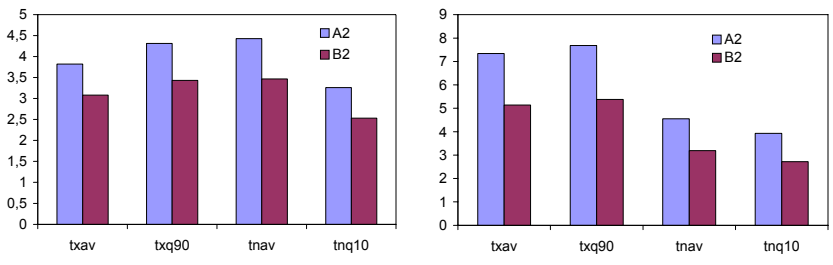


Figure 4: Changes in the mean values of the temperature indices (°C) over the period 2070-2100 relative to 1960-19990.

The projections made by the two models for precipitation extremes are less consistent than those made for temperature extremes. Only in winter do they show consistency in the direction of the changes in many of the attributes of extreme precipitation. Accordingly, they project an increase both in the intensity and frequency of extreme precipitation as well as the amount of the mean precipitation in winter. While one of the models projects a 40% increase in the mean winter precipitation, the other projects a 50% increase relative to the present amount for scenario A2. The intensity of the extreme precipitation, however, is increased to a lesser extent. Not only will the intensity and frequency of occurrence of the extreme precipitation increase, but also the interannual variability will increase significantly. The cumulative five day total precipitation shows an increase by up to 50% relative to its present mean value for Scenario A2 as shown in Figure 5. The projection made to the maximum dry spell length, on the other hand, is uncertain as the two models indicate a change signal in the opposite direction.

As in the case of temperature extremes, the changes in the precipitation extremes are less for emissions scenario B2 compared to that of A2.

For seasons other than winter, no definite statement can be made about the future changes in precipitation extremes as there happens to be higher uncertainty in the projections made by the models. The directions of the changes projected by the two models are generally inconsistent.

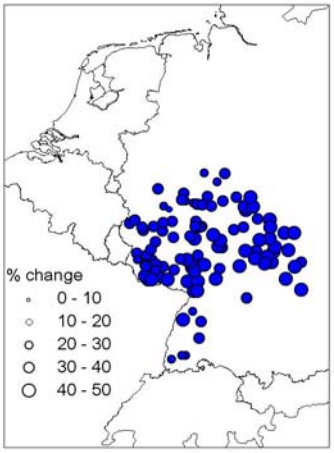


Figure 5: Percentage change in the mean of the winter 5-day total rainfall over 2070-2100 relative to 1960-1990 under scenario A2. Blue fillings show significant changes.

In summary, significant increases in temperature extremes are expected by the end of the 21st century with more severe increases in summer accompanied by higher interannual variability. A similar increase is expected in the magnitude and frequency of occurrence of intense precipitation in winter, but nothing can be said about the possible changes of precipitation extremes in the other seasons.

Reference and further reading

Hundecha, Y. and A. Bárdossy, 2005: Trends in daily precipitation and temperature extremes across western Germany in the second half of the 20th century. *Int. J. Climatol.* **25:** 1189 - 1202.

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