The Summer Flooding 2005 in Southern Bavaria – A Climatological Review

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The Flood-Event

During the second half of August 2005 severe floodings occurred in the northern central Alps. Following heavy precipitation on the 21 August major Swiss cities like Interlaken, Luzern and the capital Bern were flooded. On the following day a number of rivers in southern Bavaria including Lech, Iller, Isar, Inn and also Danube flooded vast areas. Amongst other cities Garmisch-Partenkirchen, Kempten and Regensburg were affected by major inundations. In some regions the river gauges even exceeded the level of the century flooding of 1999.

The Synoptic Situation

Although the floodings caused regionally disastrous effects the observed precipitation sums did not exceed former maxima of gauge observations at any station. Instead, the extraordinary flooding resulted from the particular interaction of several meteorological and hydrological processes. A detailed discussion can be found in Rudolf et al. (2006).

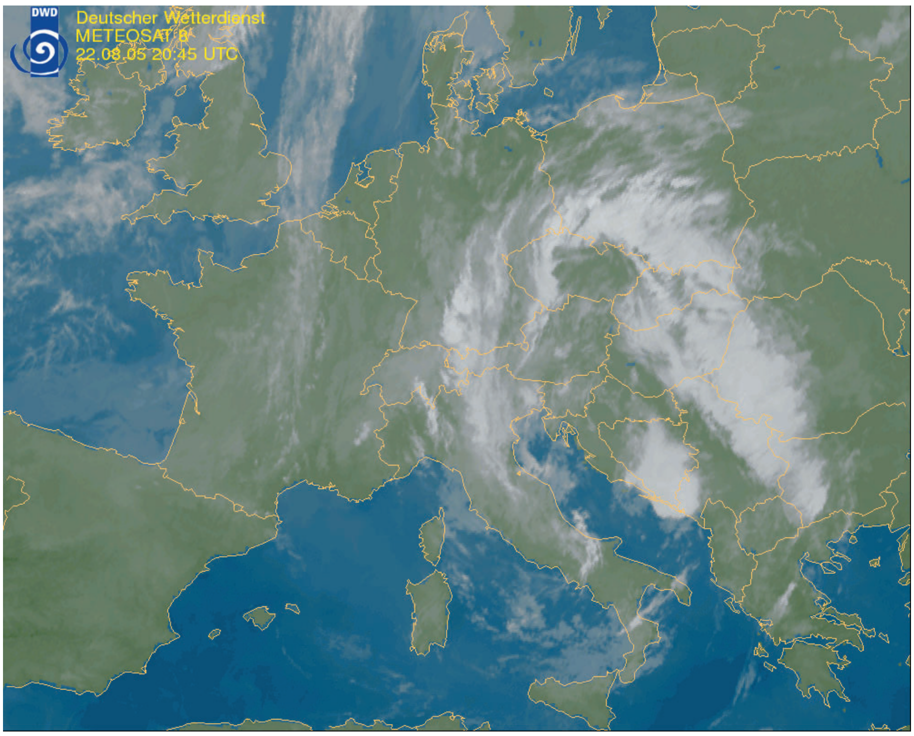

Fig. 1 Infrared satellite image (METEOSAT 8) for 22 August 2005, 20:45 UTC resp. 22:45h Mean European Summer Time (MEST).

Several days before the high precipitation amounts occurred a cut-off low was separated from the meandering flow over the south-western part of Europe. Crossing the northern part of the Mediterranean this low pressure system took up a considerable amount of humidity. On the 22nd, the South-western Bavarian region was located west of the cyclone under a dense and convective cloud band (see Fig. 1). The northern slope of the alps forced lifting of the air masses being advected with high velocity from the North, and led to a further amplification of condensation processes and locally extreme precipitation events. The emergence of the resulting floods was furthermore promoted through soil characteristics. Following a period of high precipitation during July and the beginning of August 2005 soils were already water saturated. Thus all the precipitated water was directly transferred into surface run-off.

Forecast and Warning

The weather development that led to the flooding was well observed and forecasted. The local model (LME) of the German Weather Service (DWD) predicted precipitation amounts close to the observed ones. As a consequence DWD informed the responsible agencies well in advance and gave the public warning of heavy precipitation. Fig. 2 (left panel) shows the precipitation forecast issued 22 August 2:00h Mean European Summer Time (MEST) for the 24h period starting 22 August 8:00h MEST. The right panel of Fig. 2 shows the interpolated observed precipitation from 1377 stations within the same period. The good agreement of both these maps obviously demonstrates that the daily precipitation total of this event was well forecasted. The regional Unwetterwarnzentrale (engl. storm warning centre) of DWD residing in Munich issued its first warning at 21 August 8:00h - well in advance of the event.

Climatological Evaluation

Fig. 3 shows the observed precipitation of 22 August for several stations within Bavaria and Austria. Only a small region of southern Bavaria faced extraordinary extreme precipitation. Most pronounced around Reutte and Oberstdorf with values above 100mm/day and an observed maximum precipitation of 189mm/day at Reutte/Tirol. However, precipitation rates of more than 100mm/day are not unusual within the Alps. Stations situated in the alpine foothills like Kempten (with 67.5mm/day) faced less extreme precipitation. Also at very high altitude stations like Zugspitze (2962m altitude) precipitation was less extreme (45.8mm/day).

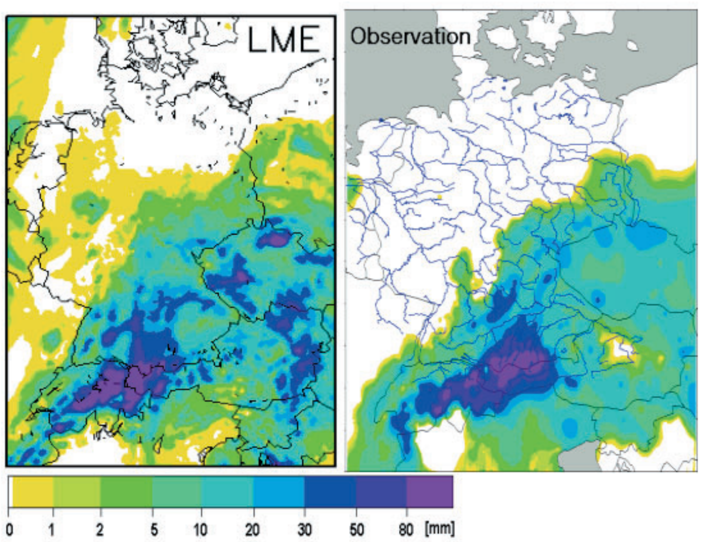

Fig. 2 Precipitation forecast issued 22 August, 2:00h for a 24-hours period starting 6 hours later (left panel) and observed precipitation interpolated from 1377 stations (right panel).

For some of the stations shown in Fig. 3 long time series of daily precipitation observations exist. Those time series allow estimating return periods. At the station Kempten observations since 1896 are available. From these nearly 40,000 observed daily precipitation sums 14 exceed the observation of 22 August 2005. This suggests a return period of less than 8 years. The precipitation amount at Mount Zugspitze usually is exceeded twice a year.

However, at Garmisch, Oberstdorf and Oberstaufen the precipitation amount of 22 August 2005 was only exceeded once in their records consisting of more than 25,000 days each. At the station of Garmisch a considerably higher precipitation sum was observed during the precipitation event of 21 May 1999 which led to devastating floods. Assuming stationarity, i.e. the probability of an extreme precipitation event should not depend on time, we estimate a return period of the order of 100 years, given the observed records. Since the most extreme observed precipitation sums reflect small scale convective precipitation events, the estimated return period reflects the probability that the stations under consideration are affected by those events. However, if the meteorological situation had been only slightly different another but neighboured region would have been hit. Therefore, the probability that such an event occurs not exactly at the same location but shifted along the northern bounds of the Alps is higher. As a consequence the return period for such an event to occur somewhere in the alpine region is considerably below 100 years.

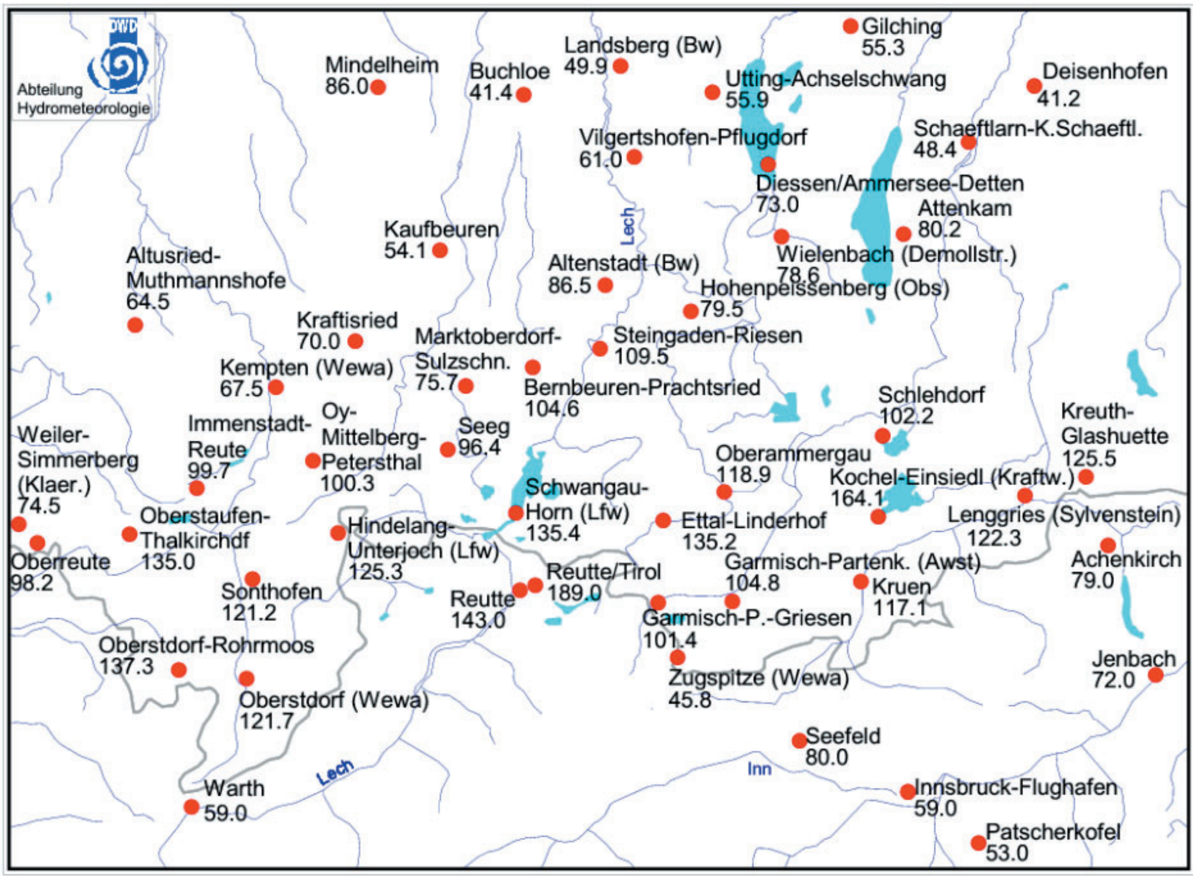

Fig. 3 Observed precipitation in mm/day at 22 August 2005.

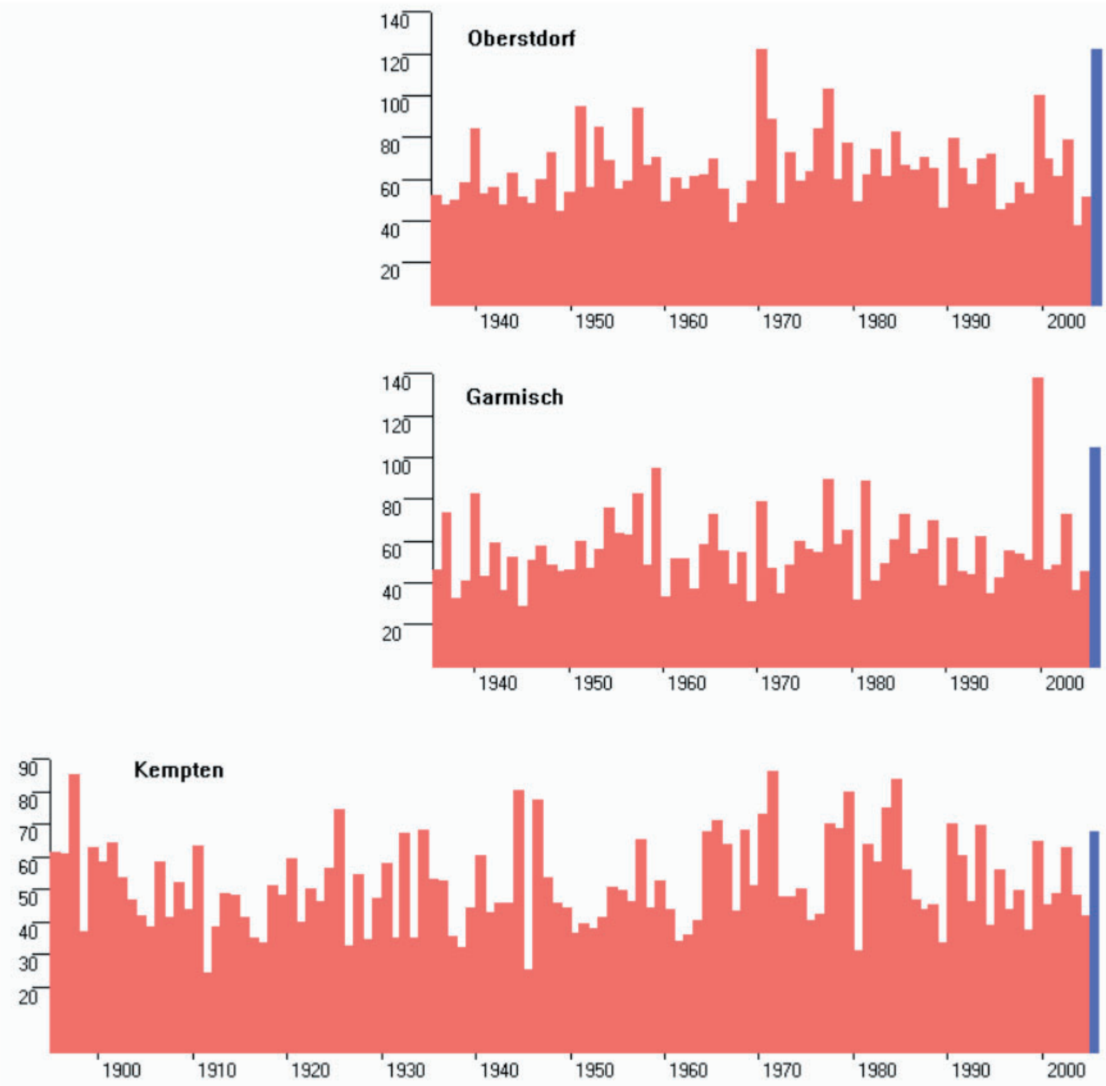

Fig. 4 Time series (red) of highest daily precipitation sum per year (in mm/day) for the stations Oberstdorf, Garmisch und Kempten. Blue column is precipitation sum of 22 August 2005.

Against the background of global climate change the question may be asked whether or not the probability for an extreme precipitation event like that under consideration has risen or fallen. In fact there is some conceptual framework arguing that heavy precipitation events should become more intensive in case of global climate change (Trenberth, 1999).

In order to investigate whether or not the most extreme precipitation events lead to higher precipitation sums within the recent years Fig. 4 shows the records of the highest observed daily precipitation sum per year for the 3 stations Oberstdorf, Garmisch and Kempten. These time series do not reveal a systematic increase in the intensity of the highest daily precipitation sums per year.

Finally we focus on the second point that was essential for generating the flood: the saturated soils. These resulted from fertile precipitation during the weeks before the extreme event. If monthly precipitation totals increase also soil saturation increases on average. This in turn promotes the vulnerability of river catchments to floods triggered by short-lived but extreme precipitation events.

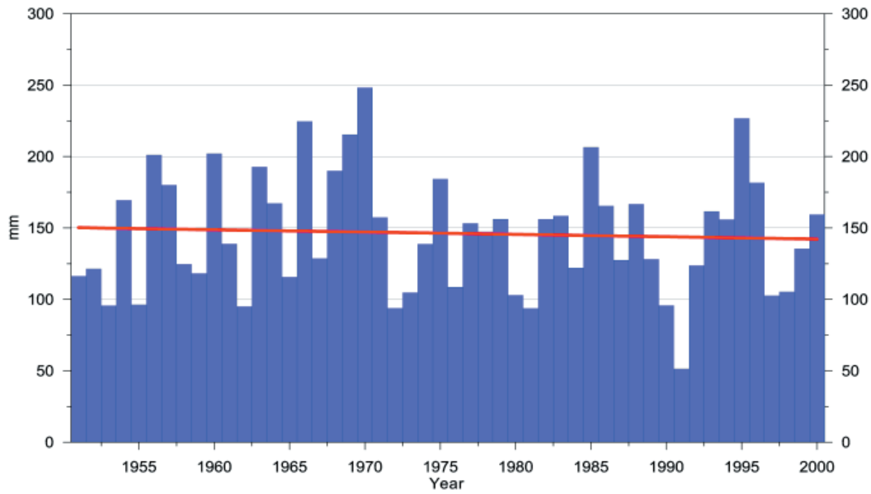

Fig. 5 Time series of monthly mean August precipitation for the region 9°-12°E and 46.5°-48°N (blue columns) and linear trend (red line).

In order to investigate the regional trend in monthly August precipitation for the central northern alpine and pre-alpine region a 50-year gridded dataset with .5° spatial resolution of observed monthly precipitation sums created on the basis of homogeneity tested, long and nearly gap-free records is used (Beck et a., 2005). Spatially averaged August precipitation sums for the region bounded by 9°-12° East and 46.5°-48° North are calculated and the respective time series since 1951 is shown in Fig. 5. A negative linear trend of about 7% over the period 1951 to 2000 becomes visible reducing average August precipitation from about 150mm at the beginning of this period to about 140mm at the end. However, given the high precipitation variability this negative trend is not significant on a 90% level of significance.

Trömel and Schönwiese (2005) showed that temporal changes in precipitation variability exceed changes in precipitation averages which may suggest a decoupling of extreme and average precipitation. Grieser and Beck (2003) found significant increases in both, days with extreme precipitation and precipitation sums on days with extreme precipitation. However, they defined a day with extreme precipitation as a day having a return period of 100 days. Thus their statistics based on daily data for the period 1901 – 2000 describe less extreme events. Moreover they found significant trends only in winter or for the shorter subperiod from 1961 to 2000.

Summary and Conclusion

The flood that occurred in the second half of August 2005 at the northern Alps resulted from extreme rainfall (with a return period of up to 100 years for a small region) on saturated soils. The extreme rainfall itself was caused by a rather rare meteorological situation implying the advection of warm and humid air masses from the Mediterranean that circled eastward around the Alps and cooled down on the northern side which led to condensation and continuous rainfall. Furthermore due to forced lifting at the northern slopes of the Alps precipitation locally reached outstanding intensities.

The potential hydrometeorological effects resulting from this synoptic situation were early recognized by the German Meteorological Service (DWD) and respective warnings were issued well in advance of the event.

As the flooding arose from the combination of unfavourable hydrological preconditions (water saturated soils) on the one hand and a triggering meteorological event (extreme daily precipitation) on the other hand long-term variations of both factors were investigated in order to place this event in a broader context of global climate change.

Given long records of station observations within the affected region neither a long term positive trend of monthly mean August precipitation (which can be used as an indicator for water saturation of soils) nor positive trends in the very extreme daily precipitation sums can be detected. Therefore, this individual event can not be regarded as a consequence of long-term global climate change. However, previous work suggests an increase in more moderate extreme precipitation (return times of 100 days) especially in recent years but mainly in the winter half-year. This may reflect a tendency of central european climate characteristics towards less continentality as assumed by Beck et al. (2006).

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