A new approach for the description of discharge extremes in small catchments

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Introduction

Several catchments in Northwestern Switzerland have been recurrently flooded within the past years. Statistical models that consider all flood processes under the same distribution are commonly used in this region for estimating flood protection measurements. However, this approach does not represent the weather variability in time and does not differentiate between flood mechanisms. On the contrary, floods provoked by several mechanisms (e.g. flash floods, rain-on-snow floods, snowmelt floods, etc.) are assumed the same and equally likely to occur.

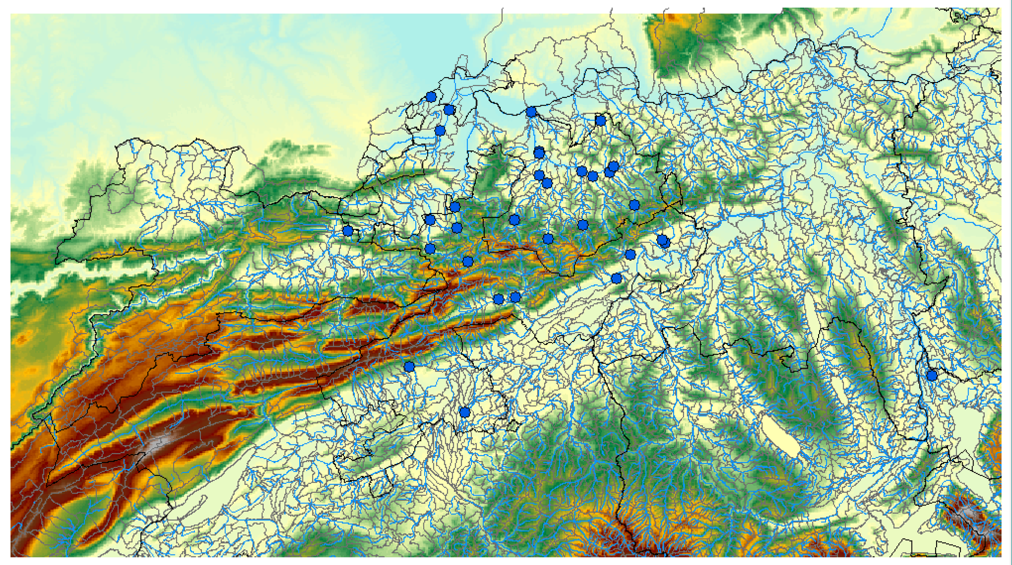

Fig. 1 Northwestern Switzerland drainage net. The discharge stations with high temporal resolution used are the highlighted blue points.

We investigate regional patterns and dominant parameters that differentiate flood processes, by using discharge observations with high temporal resolution (I.g. 10-15 min) of different catchments sizes (~10 to 74 km^2).

Motivation

895 flood events were obtained by using the peak over a threshold (POT) approach. Fig. 2 illustrates the frequency of occurrence of POTs and annual maximum floods (AMax) over the twelve calendar months. Both have a similar frequency distribution over the months: the maximum number of occur in July for the summer season (Apr-May-Jun-Jul-Aug-Sept) and in December for the winter season (Oct-Nov-Dec-Jan-Feb-Mar). Nevertheless the frequency of the POT floods has a smoother distribution, which indicates that the AMax method misses important floods of the not dominant months.

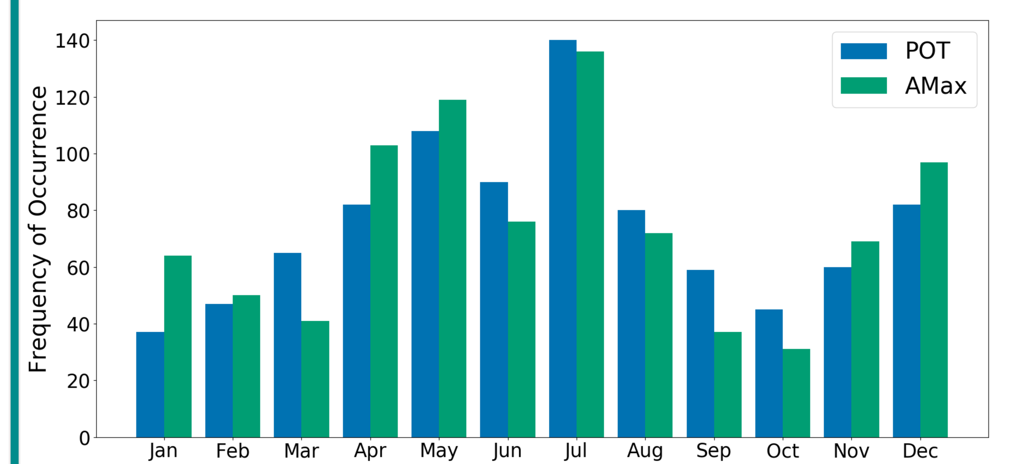

Fig. 2 Flood frequency of occurrence per month considering all catchments. AMax: annual maximum floods. POT: Peak over a threshold floods.

Fig. 3 displays that the period Jun-Jul-Aug has on average the highest number of floods in the majority of the catchments. It suggest that flooding in the south hills of the Jura mountains occur in other months than in the rest of Northwestern Switzerland.

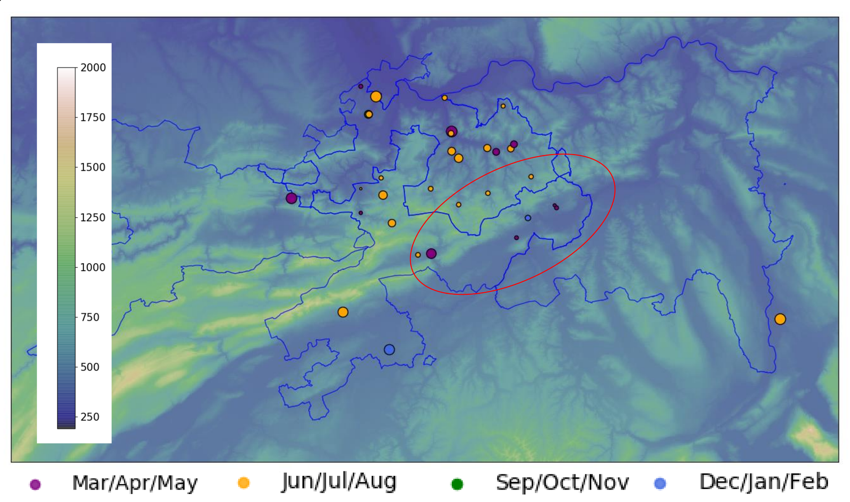

Fig. 3 Frequent season with flood occurrence (POT floods). The marker size indicates catchment area.

Once the extreme floods are identified, flood hydrograph are separated by finding the equilibrium of the discharge difference $\Delta Q(t)$, (see example in Fig. 4):

$$\Delta Q(t) = Q(t) - Q(t - \Delta t)$$

$\Delta Q(t)$: Discharge difference within time interval

$Q(t)$: Discharge of the interval

$Q(t - \Delta t)$: Discharge of the previous interval

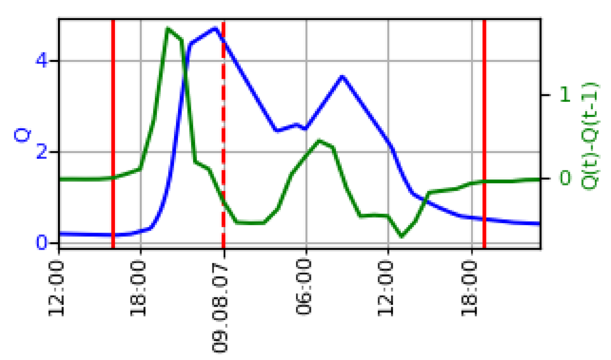

Fig. 4 Example hydrograph separation

As an example, the obtained flood hydrographs of two stations are displayed in Fig. 5 with the color indicating the season when the flood event occurred. The curves in Fig. 5 show that the hydrograph shapes are different and correspond to different mechanisms. Sep-Oct-Nov floods do not occur very frequently and have rather small peaks, which agrees with the data in Fig. 2. Jun-Jul-Aug floods have sharp and slim peaks, which are indicators of flash floods produced by convective precipitation. Larger floods with a long period are typical of Mar-Apr-May.

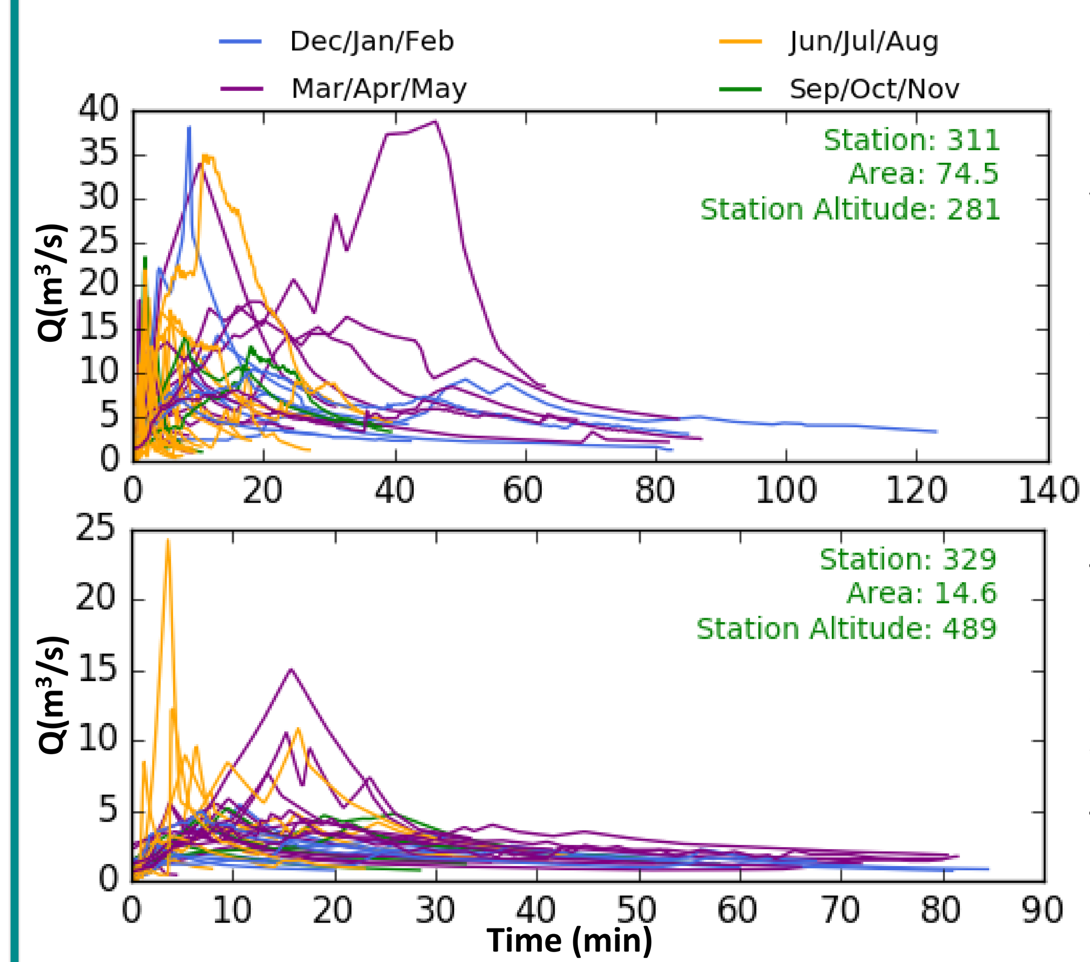

Fig. 5 POT hydrographs of two discharge stations. Color coded with the season at which the flood occurred.

Precipitation Entropy

We investigate the entropy of precipitation as a parameter that describes the meteorological input of the flood event. Higher entropy values indicate that the input is uniformly distributed within all intervals of the evaluated period. On the other hand lower entropies indicate that the precipitation came within a short time interval.

$$H = -\sum_{i=1}^{N} r_i log(r_i)$$

where: $r_i = \frac{P_i}{\sum_{i=1}^{N} P_i}$

$0 \leq r_i \leq 1$

$0 \leq H \leq log(N)$

P_i: Precipitation of the interval

N: Intervals (Measurements)

Fig. 6 illustrates the spatial linear correlation coefficient of the entropy and the daily precipitation for extreme precipitation events of different durations (selected with different aggregations). The space correlation of the entropy and the daily precipitation increase as the duration of the extreme event does (Fig. 6), because poor entropy correlations correspond to local convective events (Top) and larger entropy correlations correspond to frontal events, that take place in larger areas (Bottom). For all durations analyzed (only 30 min and 360 min shown), the entropy correlations are larger than the daily precipitation correlations. Fig. 6 suggests entropy as a better estimator of the spatial distribution of the meteorological extremes than the daily precipitation.

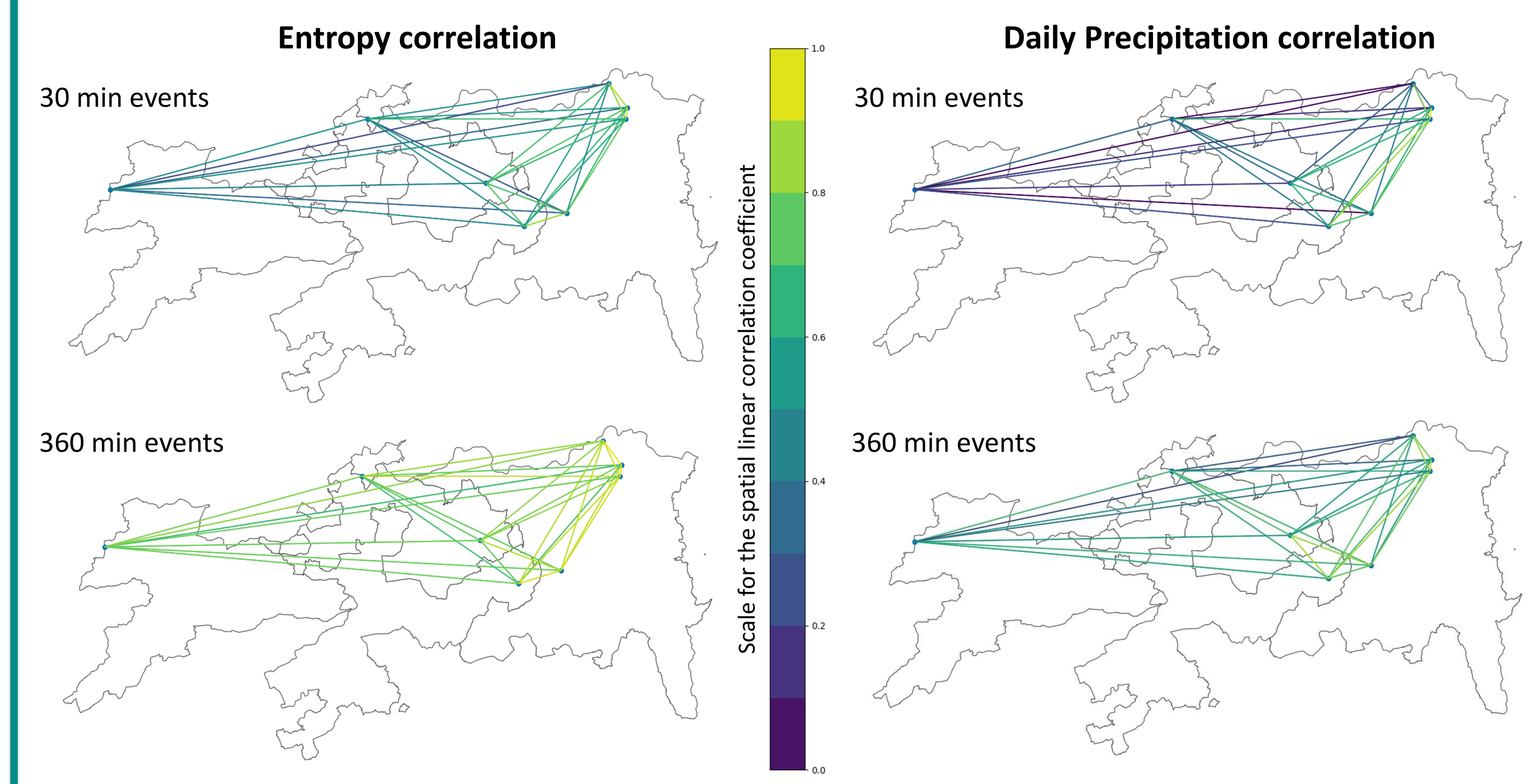

Fig. 6 Entropy and daily precipitation space correlation for 30 min and 360 min extreme event duration

Next the entropy for the time interval of 12 hours before a flood peak was calculated for all flood events. Fig. 7 shows the results of the average entropy for each station. A regional pattern is identified, with the entropy being usually smaller below the mountains towards Basel. More catchments should be included in order to disclose further regional patterns.

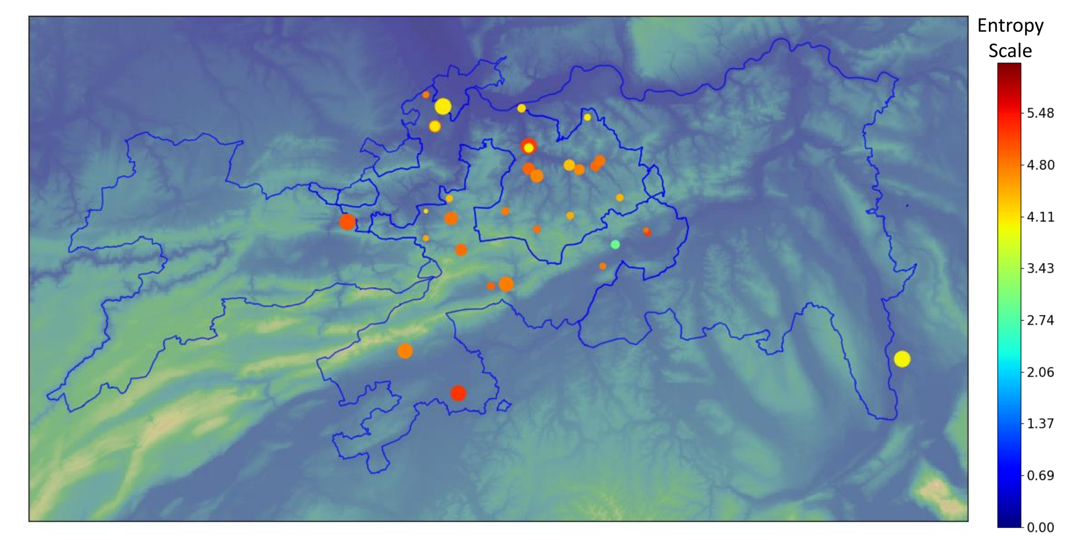

Fig. 7 Average Entropy of POT floods. Entropy calculated for 12 hours before the occurrence of the peak. The marker size indicates catchment area.

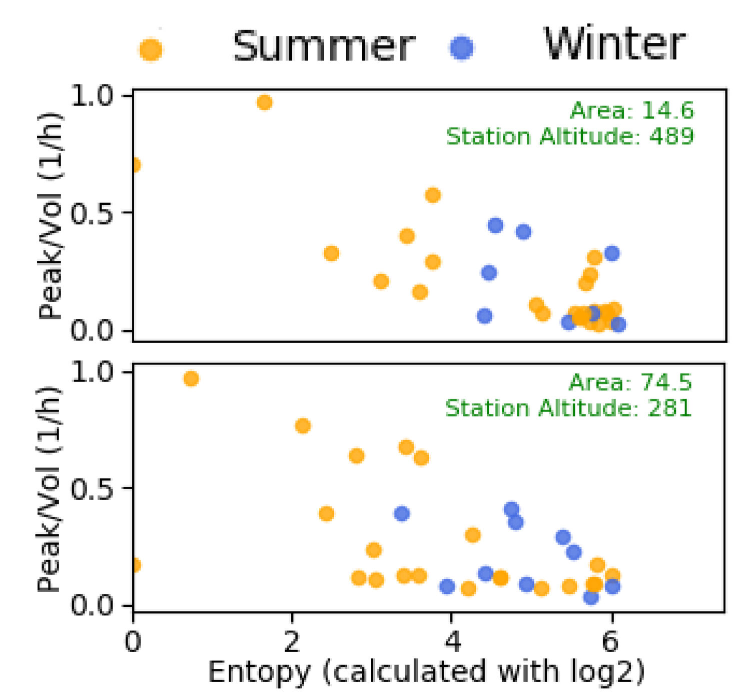

Fig. 8 Precipitation entropy 12 hours before flood peak vs. Peak/Volume ratio. For two different catchments

Fig. 8 shows the entropy (for the interval 12 hours before the peak) vs. the peak to volume ratio of the the summer and winter seasons. In winter the entropies are by average higher than those in summer, due to the presence of convective precipitation in summer (Fig. 8). This is also notable by the higher average peak to volume ratios, where convective precipitation leads to flashfloods.

Acknowledgments

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