Hydrol. Earth Syst. Sci. Discuss., 11, C190–C194, 2014
www.hydrol-earth-syst-sci-discuss.net/11/C190/2014/

Hydrology and Earth System Sciences
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Discussions

Interactive comment on "Selection of intense rainfall events based on intensity thresholds and lightning data in Switzerland" *by* L. Gaal et al.

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Received and published: 27 February 2014

Our paper presented a method to select intense rainfall events with a common physical nature for the statistical analysis of rainfall extremes. We proposed that this common nature is the presence of convection in intense summer thunderstorms, which are identified on the basis of exceeding a threshold for peak 10-min intensity during the storm. The novel contribution of the paper is the connection of this threshold I* with the presence of lightning and the statistical testing of the performance of the selection method for 4 stations in Switzerland.

The reviewer acknowledges the novelty of our work in the methodology and testing of the performance/robustness of the selection method, and raises three questions which

we discuss in greater detail in this response and will address in the final revision of our manuscript.

1. More stations to analyze

The reviewer would have liked to see "more stations/locations beings used to give a more significant statistical meaning of the results, and possibly more data sets being used for a comparison purpose". We state several times in the paper that we have chosen 4 stations out of the 62 SwissMetNet stations in our database to illustrate the selection method in this paper. The choice of these four stations was not accidental, they represent what to our best knowledge are "representative" stations in four different climatological regions in Switzerland. All stations are in fact shown in Fig. 1 to make this more clear to the reader.

We stress that the goal of the paper is to present the methodology and the use of lightning data in detail. The lightning data are unique in that they are station measurements made over a rather long period of time. These data to our knowledge have not yet been presented in the scientific literature and so their assessment, e.g. datasheets such as Fig. 4, are an important part of the paper and require their space. In the paper we wanted to show that clear distinctions in the probability distributions of the main storm properties for our intense storm subset exist. These are for instance evident in the plots in Figs. 9 and 10 and do indeed compare stations with completely different climatologies. Adding many more than 4 stations would have made this visual comparison impossible.

As we state in the Conclusions, the next step is the extension of the analysis to all 62 stations and the regionalization of the results. This will be a companion follow-up paper which we will be submitting to HESS shortly. We are convinced that the separation of our analysis into two papers: one focusing on the selection methodology and lightning data on the basis of 4 representative station data; and the second focusing on the spatial distribution of intense storm properties across Switzerland and their regionalization, is sensible from the content point of view, and in fact the only way that we could explain the relevant details without making a single paper excessively long and unreadable. To this end we think that the four stations we have selected are adequate to present the methodology and in fact they do provide a first-order comparison that is climatologically relevant.

2. More details about the intensity threshold calibration

The reviewer states that "perhaps a few, more general, details can be added in this paper that explain the method for determining and calibrating intensity thresholds, and how this relates to the generally defined extreme rainfall events seen in previous studies." The comparison between different thresholding approaches to rainfall extremes is indeed an interesting question and requires more elaboration in the context of our work.

The traditional approach to the analysis of extreme rainfall is the standard depth-duration-frequency (DDF) curve applied to annual maxima or peaks over a threshold (POT), where for a given duration, the most extreme rainfall depths (intensities) in a year are selected and their probability of occurrence is estimated. Estimation methods for the analysis of annual and POT extremes are well known and reported in the literature (e.g. Katz et al., 2002) as well as the mathematical framework for studying DDF curves (e.g. Koutsoyiannis et al., 1998). Estimation uncertainties are related to fitting an extreme value distribution to the selected data (mostly GEV-type) and functional forms for the DDF relation parameters, and these may be quantified from station as well as weather radar data (e.g. Overeem et al., 2008; 2009). The result is an estimated rainfall intensity for a given duration and return period. The threshold intensity comes from the minimum observed annual extreme in the record (annual maxima), or the choice of the average number of events per year (POT). It's basis is purely statistical, it is record period and duration-dependent.

Our approach is different in two main ways: (1) We are looking at rainfall events as

independent outcomes of atmospheric water vapour fluxes and precipitation formation processes. We do not fix a-priori a given rainfall duration in the analysis (like in DDF curves) but we study several event properties (total depth, peak intensity, event duration) and their statistics. (2) We select events which have a common physical origin and genesis, i.e. the presence of convection, insofar as it is reflected in a high peak 10-min intensity during the event. In this way we select many events, which are both short and long, with different rainfall totals, for the analysis, in contrast to only extreme intensities for DDF curves. Our threshold on peak 10-min intensity I^* is calibrated with lightning data, which are independent measurements. To us this threshold has a physical meaning, as a short-term rain intensity which was exceeded in most convective rainfall events at a given station.

The consequence is that our threshold I^* is not in fact directly comparable with POT or any other intense rainfall thresholds which are purpose-driven. There are very few studies which attempt to objectively define what extreme rainfall is, e.g. see Llasat et al. (2001) for an example. Most studies define subjective thresholds based on hydrological risk, monitoring issues, or meteorological considerations. Some of these are discussed in Section 4.1 in our paper. At this point we can say that despite the fact that our thresholding is different from the DDF approach, the statistics of extremes in our selection of intense storms agree reasonably well with the HADES (Hydrological Atlas of Switzerland) estimates from DDF analysis, where the 1 hr duration extremes with a return period 2.33 yr ranged between 18-34 mm/hr at our four study sites, while our selection gave peak rainfall intensities with a non-exceedance probability p=0.8 (i.e. the largest 5-6 events per year) between 13-40 mm/hr. We will clarify these selection aspects and the nature of the thresholds in the final manuscript.

3. Reasons for using parametric and non-parametric correlation coefficients

The reviewer asks us to explain why we use both Pearson correlation and Spearman rank correlation in the analysis. The two types (parametric and non-parametric) of correlations did not appear in the manuscript by chance. The Pearson correlation coefficient is used, in accordance with previous literature, for quantifying the auto-correlation in 10-min rainfall which leads to the critical duration required for rainfall de-correlation and the definition of independent storms in Section 2.3. The Spearman rank correlation coefficient is used to identify the cross-correlation between storm properties in Section 4.3. The reason to use a non-parametric correlation here is that we intend to develop the relations between these properties for statistical multivariate analysis with the method of copulas. Copula parameters depend on the rank correlation between the variables, which are generally quantified with a non-parametric correlation like Spearman correlation in the literature. We acknowledge that this reason did not come across in the paper and we will revise the affected section of the paper accordingly.

References

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 11, 593, 2014.