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Spatial analysis of intense thunderstorms in Switzerland and temporal trends in their occurrence

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Intense summer thunderstorms in the Alpine region are the cause of severe flooding, landsliding, and other natural hazards, with massive damage to infrastructure. It is important to know the inter-relationship of the properties of such events, and to be able to make statistical predictions on their severity, distribution in space, as well as changes in their frequency of occurrence. In this paper we present such an analysis on the basis of a large dataset of raingauges in Switzerland. The paper is organized in three parts.

First we make an objective selection of intense summer thunderstorms from the set of all events. For this we have recently developed a methodology (Gaál, Molnar and Szolgay, 2014, HESSD), which identifies intense summer thunderstorms on the basis of high resolution meteorological data (10 min time step) of MeteoSwiss. We made use of lightning strikes as external variable to identify intense storms, on the basis of the hypothesis that storms with strong convective lifting are commonly associated with lightning strikes. It was concluded that i) the peak 10 min intensity is a variable that is able to differentiate significantly between the storms accompanied or not by lightning, and ii) a station-dependent threshold rainfall intensity I^* can be found which allows for identifying intense storms with convective character as those where the peak intensity exceeds I^* regardless of their duration or total rainfall depth. We consequently use this methodology to select intense summer thunderstorms at 62 stations of the SwissMetNet network.

Secondly, we analyze the spatial distribution of the threshold rainfall intensity I^* across Switzerland, in order to examine its possible links to the climatological, topographic, and other characteristics. We find a strong connection between I^* and the spatial distribution of peak rain intensities, which indicates that the high Alpine region is not necessarily subject to high rain intensities. These are more present in the lowlands to the north of the Alpine divide and in southern Switzerland. The origin and nature of convection in those areas are more likely to generate very intense rain.

Thirdly, we look at changes in the convective character of the rainfall over the past 30-yr record. To this end we use a seasonal convection index defined on the basis of I^* at each station. This index represents a measure of 'convectiveness', i.e., the total rainfall depth as a result of convective storms relative to the total rainfall depth of all summer storms (Llassat, 2001, IJC). By non-parametric trend analysis we found that the seasonal convection index increases at most of the stations in Switzerland, and in about 20% of the cases this increase is statistically significant. Although our analysis indicates a consistent increasing tendency in the intensity and frequency of convective storms in Switzerland, it is not yet clear whether these can be traced to causal factors such as atmospheric warming, etc. However, if this trend persists it will have consequences for the prediction of damages due to such storms in the future.