Exploring the causes of rare extreme precipitation events in the south-eastern Alpine forelands

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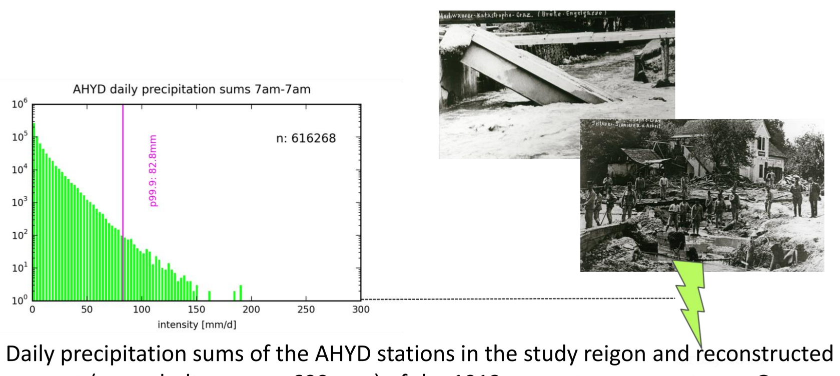
Exploring Rare Extreme Events (REEs)

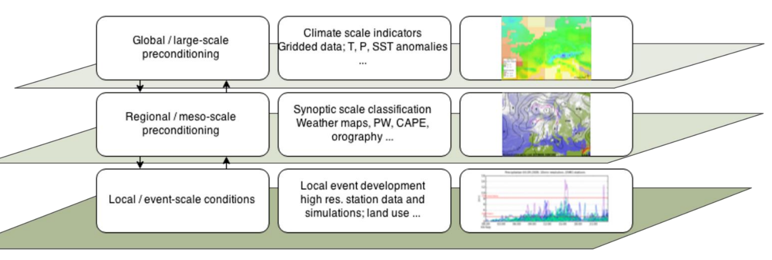
There is still considerable uncertainty in understanding the character of precipitation in space and time and how it will change in a warming climate. It is crucial for societies to understand how extreme precipitation events will emerge, e.g., for contingency planning and adaptation measures.

There is evidence that maximum precipitation intensities increase with rising temperatures, and that the increases relate to convective processes. Data on extremes is naturally sparse, which is why statistical studies, though useful and applied in several fields, are inevitably accompanied by large uncertainties. For events in the very far tails of probability density functions - or outliers - these statistical uncertainties go sky high, and the estimated probabilities keep silence about the physical processes that cause these rare extremes.

Thus we take a process-oriented approach and analyse the physical preconditioning of the largest precipitation events in the climate-sensitive south-eastern Alpine forelands. Several ´freak´ events are known to have poured down more than 300 mm over parts of our study region within just a few hours. We hypothesize that in order to generate rare extremes of this kind, larger scale global and regional preconditioning and local event conditions need to interfere. Furthermore, these specific patterns might allow us to make a physically plausible delineation of the ´freak´ events as opposed to the more frequent statistically describable extremes (e.g., by annual return periods).



Daily precipitation sums of the AHYD stations in the study reigon and reconstructed amount (green bolt, approx. 600 mm) of the 1913 rare extreme event near Graz, Austria.



Process scales and examples of data products to be included in the analysis. The cross-scale perspective allows for a two-way analysis, e.g., when conditions are met, but no extreme was recorded.

Character & Conditioning of REEs

To better understand the uncertainties associated with rare extreme precipitation events, we analyse the spatio-temporal character of extreme events and the conditions that favour their emergence to find answers to the following research questions:

1. Are there thresholds that sparate rare extreme events (REEs) from statistical extreme events (SEEs), and which physical processes push extreme precipitation events beyond this/these threshold/s?

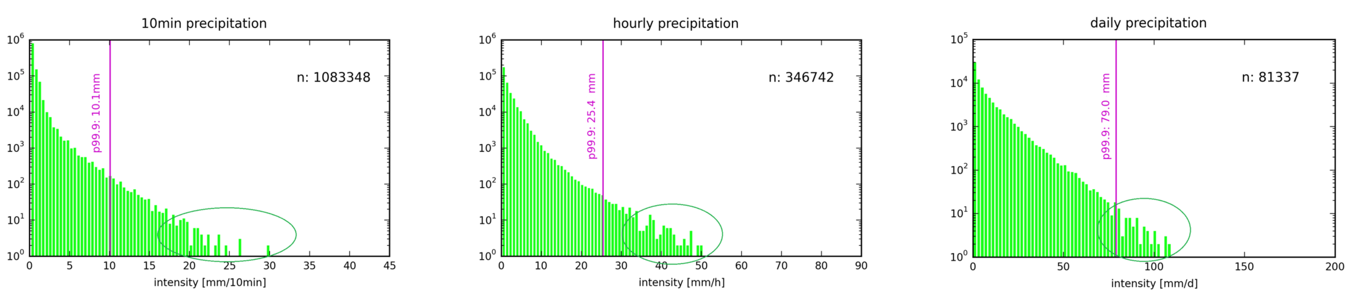
2. Are there patterns of preconditioning on the spatio-temporal event-, meso-, and macro-scales

- especially considering feedback interactions - that characterize REEs and distinguish them from SEEs?

3. Can the findings on event- and regional scale preconditioning learned from the recent past be transferred and used to draw physically plausible assumptions on future event conditions in a warming climate?

An overarching `uncertainty question´ flanks our research, because we want to find ways to actively deal with and embrace the inevitable uncertainties:

4. How can we deal with and take into account observation, sampling and physical uncertainties, and the propagation of these uncertainties throughout the analysis?



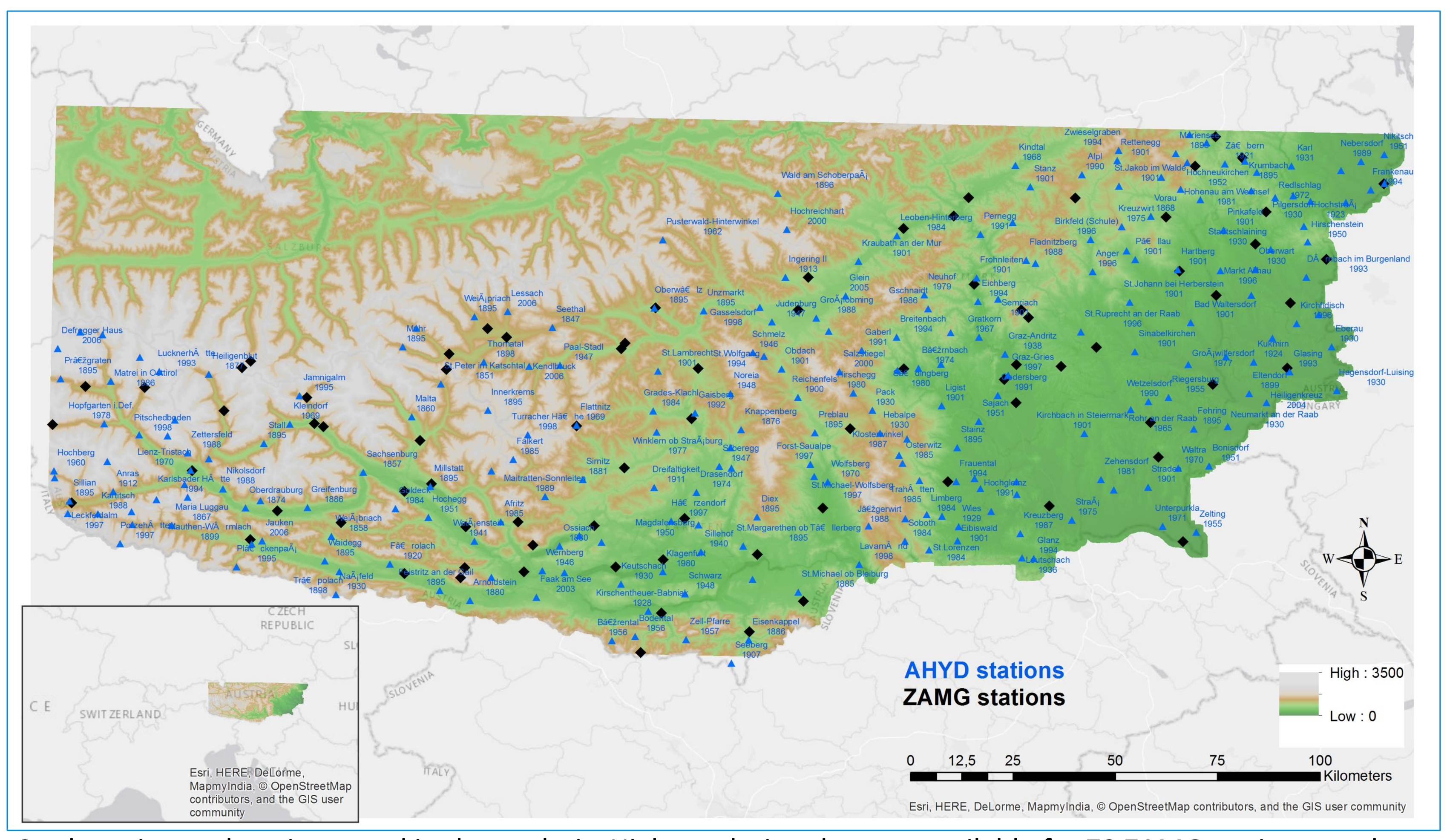
Observations from the ZAMG stations (pink lines: 99.9th percentile). Uncertainty in probability density functions naturally becomes higher in the far tails. Looking for physically plausible conditioning patterns for the rare extremes can help understand the uncertainties.

Often the elephant in the room: uncertainty

High Resolution & Event-based

The study region of the south-eastern (Austrian) Alpine foreland region extends south of the main eastern Alpine ridge from approx. 12°E to 16°E. Using mainly daily precipitation sums, previous studies have examined synoptic patterns of heavy precipitation (Seibert et al. 2007) and the climatology of extremes (Prettenthaler et al. 2010). Two datasets of station-based high resolution precipitation records (Austrian Hydrographic Service AHYD and National Weather Service of Austria ZAMG) allow us to lay a magnifying glass over our study region and to analyse the spatio-temporal character of distinct extreme precipitation events as defined out of the high resolution datasets.

After an initial analysis of the station data, the findings on the events‘ character are connected to the event preconditioning on the climate, synoptic and local event scale. The focus on rare extreme events and process oriented research approach allow us the in-depth study of an overseeable sample of events and to check the respective station and conditioning data for plausibility.



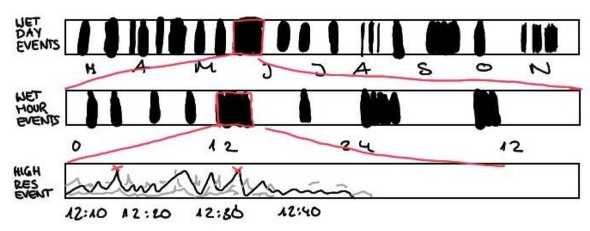
Study region and stations used in the analysis: High resolution data are available for 79 ZAMG stations used (10 min) and for approx. 120 of the 225 AHYD stations (5 min) since the 1990s and early 2000s.

Initial Analysis

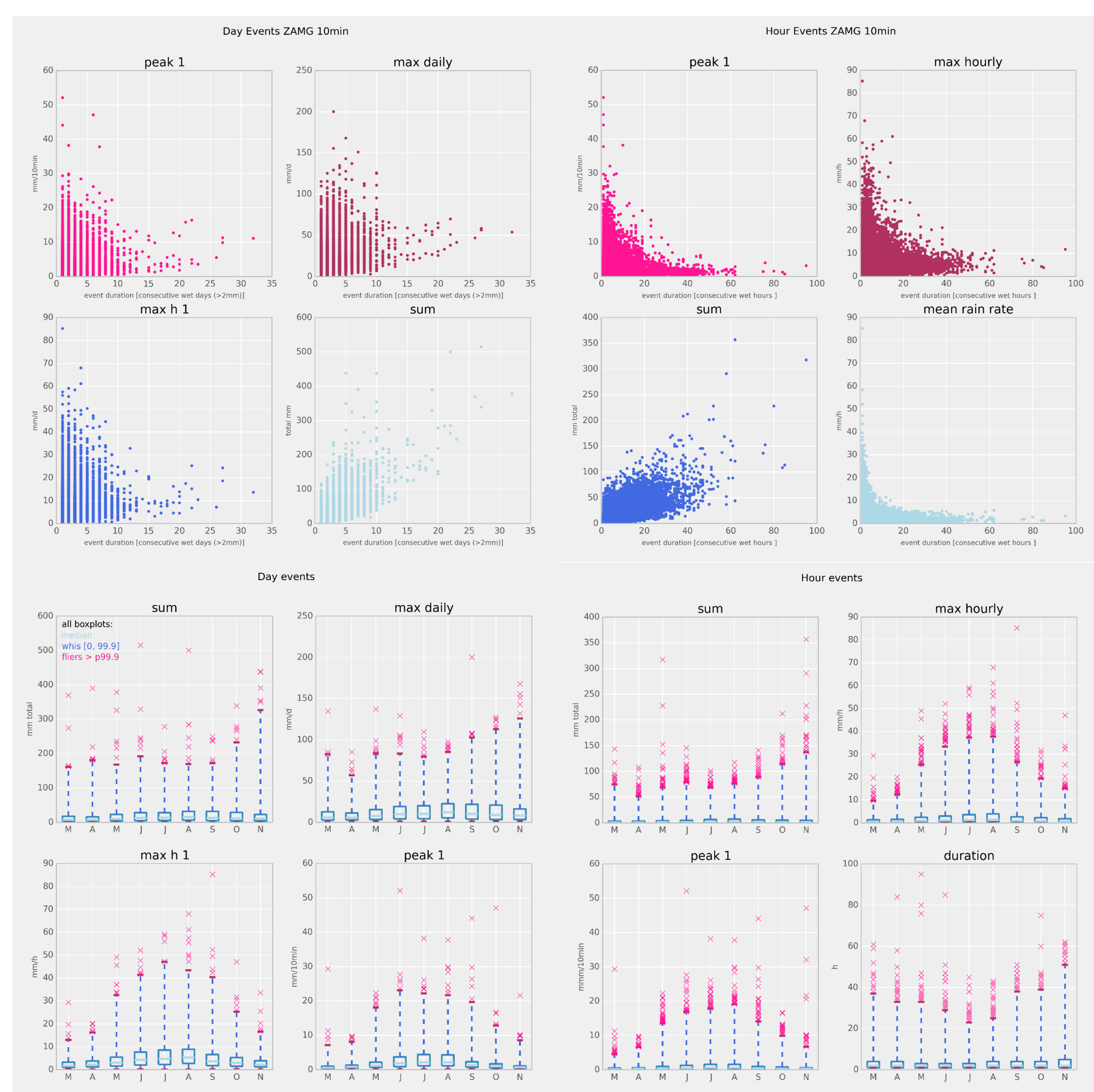
In a first step, we define precipitation events stationwise as time spans of consecutive wet days, where a wet day must have seen a precipitation sum of at least 1 mm/d (day events). Within these wet days, we distinguish hour events after the same principle with a wet hour precipitation sum of 0.2mm/h. We then calculate a ranked skill score *RSS* for each event based on a set of event indicators that serve as a first characterization of our sample:

$$RSS = \frac{1}{\frac{1}{n}\sum r};\ r \in \left(\frac{1}{\tau}, I_{max}, I_{mean}, P_1, P_2\right),$$

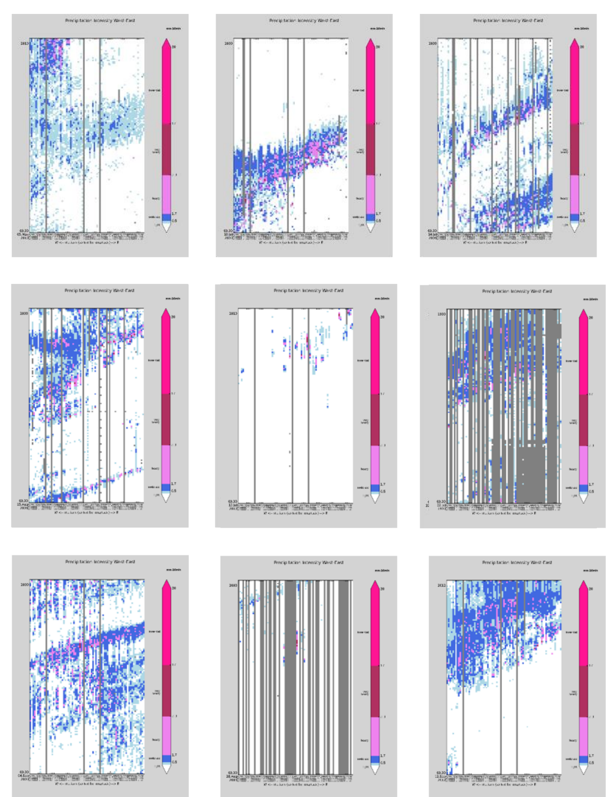
with the n ranked indicators r: inverse of event duration τ, event max and mean intensity I_{max}, I_{mean}, high resolution precip peaks P_1, P_2. Thus RSS range from 0 (not extreme) – 1 (extreme).



Definition of day events and hour events as sequences of consecutive wet hours/days.



Selected RSS indicators of day and hour events plotted dependent on event duration (top panels) and month (lower panels). Short duration, localized, high intensity convective summer extremes are of primary interest both due to the challenges they pose to climate modelling and the possibilities our high resolution data have to offer.



The spatial character of extreme precipitation events is more difficult to assess for highly localized and shorttime convective events. ZAMG 10 min station records sorted by longitude for examples of days with extreme events.

References: Seibert, P., A. Frank, and H. Formayer (2007). Synoptic and regional patterns of heavy precipitation in Austria Theoretical and Applied Climatology 87 (1-4), 139–153. Prettenthaler, F., A. Podesser, and H. Pilger (Eds.) (2010). Klimaatlas Steiermark. Studien zum Klimawandel in Österreich. ÖAW Verlag.

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Der Wissenschaftsfonds.