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Modelling severe hail events over Austria using the metastatistical extreme value distribution

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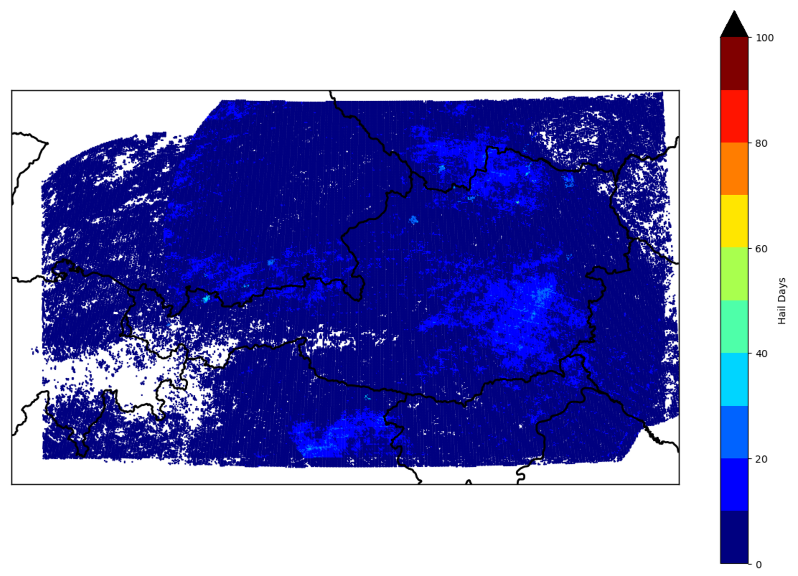
Data

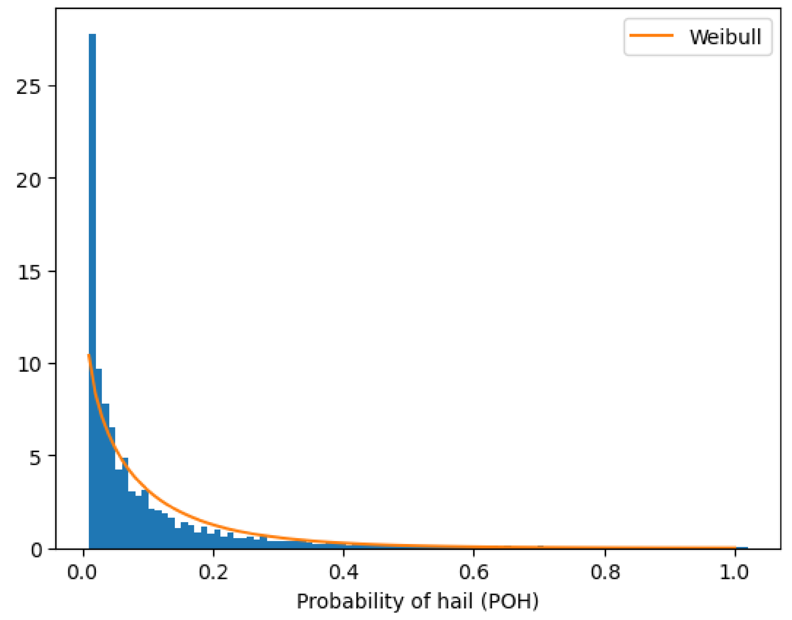
The radar archive at GeoSphere Austria was reprocessed using the Austrian Thunderstorm Nowcasting Tool A-TNT and quality controlled Maximum-expected-hail- size (MEHS) values were calibrated by hail reports to observed hail sizes. The new, comprehensive MEHS archive, is now reaching back to 2010.

Despite the reprocessing of GeoSphere Austria hail parameters, the available data set is still relatively small, making the calculation of return levels of severe hail events challenging. The picture below shows the total number of hail events derived from radar measurements from 2009 to 2022.



Distributional assumption ■

We make an assumption about the distribution of the POH values, allowing us to better catch the tail behavior. Several distributions were tested for this purpose. The Weibull distribution provides an overall reasonable fit, together with computational appealing properties. The image below shows a histogram of all observed hail events together with the estimated Weibull density.



Spatio-temporal model ★

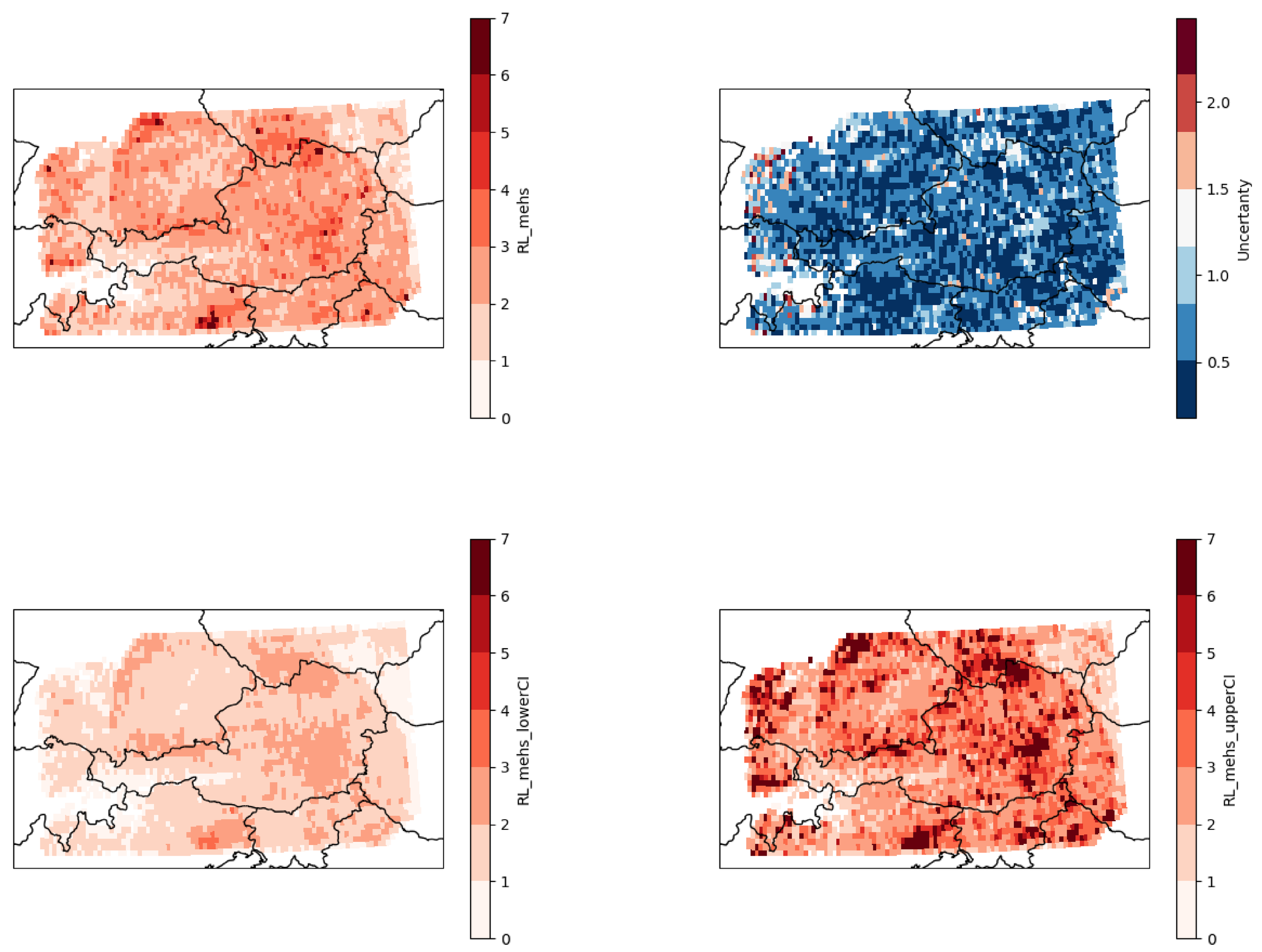
Employing the framework of generalized additive models for location, scale and shape (GAMLSS) we can model the distribution parameters depended on topographic information (longitude, latitude, altitude) as well as temporal information (year, day of the year), resulting in a full spatiotemporal model across the whole domain of Austria.

Metastatistical extreme value distribution ♦

Due to the rather small number of hail events the classical block maxima approach used in extreme value theory might be invalid, since the asymptotic conditions are not met. Instead we employ the approach of the metastatistical extreme value distribution (MEV) introduced by [1]. More precisely we use two slight modifications: for the estimation of return levels on individual cells we use a simplified version, assuming the probability distribution of daily hail events to be time-invariant. The incorporation of a seasonal effect requires another formulation of the MEV, in which not the number of event days per year is used, but the actual days on which hail was observed.

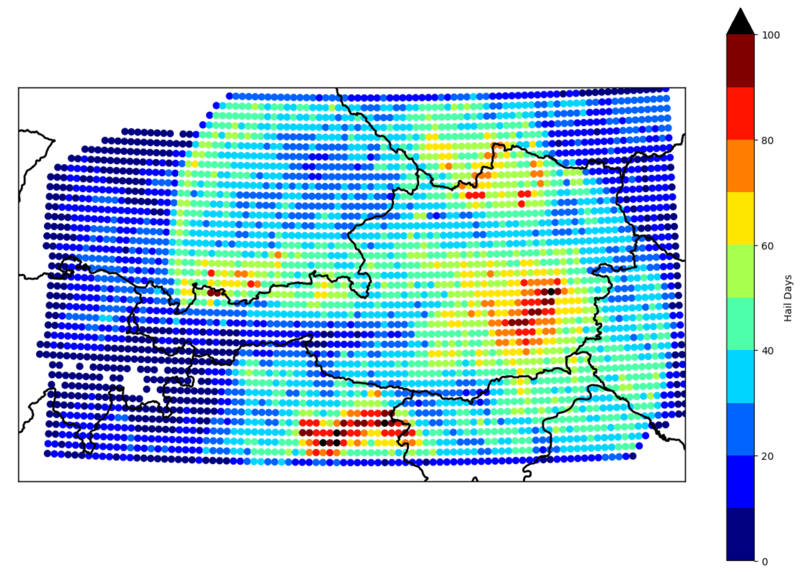
Return levels and uncertainties

Having the Distribution's parameters at hand, one is able to calculate the desired return levels. To address the uncertainty in this estimation, confidence intervals are calculated analytically using the Delta Method or using a Bootstrap procedure.



Extension: Data processing ■

As a step to improve the data quality, we aim to reduce remaining radar artifacts and employ the information of neighboring radar cells to smooth the map of hail observations. This is done via a Max-Pooling-Operator, which is to be tested for various kernel sizes. The result for a kernel size of 1/10 degrees is shown below.



Extension: Data enrichment through ERA5 reanalysis ♦

In order to extend our data, our target is to establish a model for predicting the POH values based on further atmospheric information (ERA5). The available hail observations serve hereby as the training dataset. The methods we want to use for this task are a neuronal network and a gradient boosted tree algorithm named LightGBM. The prediction itself is divided into two steps, in the manner of a hurdle model. Both parts suffer from a severe imbalance of the data, though, as the vast majority of the target variable, the POH, is either zero or near zero.

Extension: Additional priors ★

The GAMLSS framework allows for the incorporation of arbitrary many additional covariables, as long as they are available on the same grid as the desired output. To illustrate this we use the information of daily precipitation extremes to enrich the model with additional atmospheric information.

References:

M. Marani and M. Ignaccolo.
A metastatistical approach to rainfall extremes.
Advances in Water Resources, 79:121–126, 2015.

Acknowledgements:
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