



## **Large-scale analysis of changing frequencies of rain-on-snow events over Europe and their impact on floods**

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Rain-on-snow (RoS) events are very interesting processes because they depend not only on the rain intensity and amount but also on the freezing level, the snow water equivalent, the snow energy content and on the areal extent of the snowpack. Cumulating rain and snowmelt can consequently increase the magnitude of extreme flood events in a river basin, especially in the context of climate change where most of the studies predict an increase in temperature and therefore an increased probability of rain events in wintertime. This study analyzed the frequency and magnitude of RoS events over the European continent and identified local trends with a simple temperature-index snow model. The European Climate Assessment and Dataset (E-OBS Data Version 6.0) provided precipitation and temperature data from 1950 to 2011 on a  $0.25^\circ$  grid interpolated from climate stations for the entire European continent. In addition, the RoS flood that affected Germany in January 2011 was analyzed in more detail to validate the relevance of the estimated rain and snow water contribution and to illustrate the possible impact of RoS events on the return periods of extreme floods. An extensive database of streamflow records from over 300 gauging stations for the large central European river basins Rhine, Danube, Elbe and Oder was used in addition to the meteorological E-OBS database. Most series are long and cover several events, so that return periods could be calculated. Results from the Pan-European analysis show that RoS events occur mostly in late winter and spring (February to April) over the whole European continent. Central Europe is especially affected in February and March while RoS events affect the Northern and Eastern parts of Europe from October to April. Generally Northern and Eastern areas as well as high elevation areas (e.g. the Alps) show positive trends of RoS frequencies over the past 61 years (especially in spring), while lowland of central Europe show decreasing trends. The latter is mainly due to decreasing snowcovers decreasing probability of snowcover during rain events. The analysis of the January 2011 flood events in Germany clearly links snowmelt and RoS processes to the floods all over the river basins and increasing return periods downstream were systematically observed.