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



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Hypothesis and Objectives

In the changing climate that many studies predict, an increase in temperature may increase the probability of rain events during winter.

Coinciding rain and snowmelt can increase the potential for extreme flood events in a river basin.

This study's aims are:

to analyse recent changes in rain-on-snow (RoS) events over the European continent and

to assess their flood potential based on the RoS event of January 2011 in Germany as an example.

E-OBS Data Version 6.0: daily temperature and precipitation from 1950 to 2011 on a 0.25° grid interpolated from climate stations for the entire European continent.

Streamflow records from over 300 gauging stations for the river basins Rhine, Danube, Elbe, Oder and Ems.

Methods

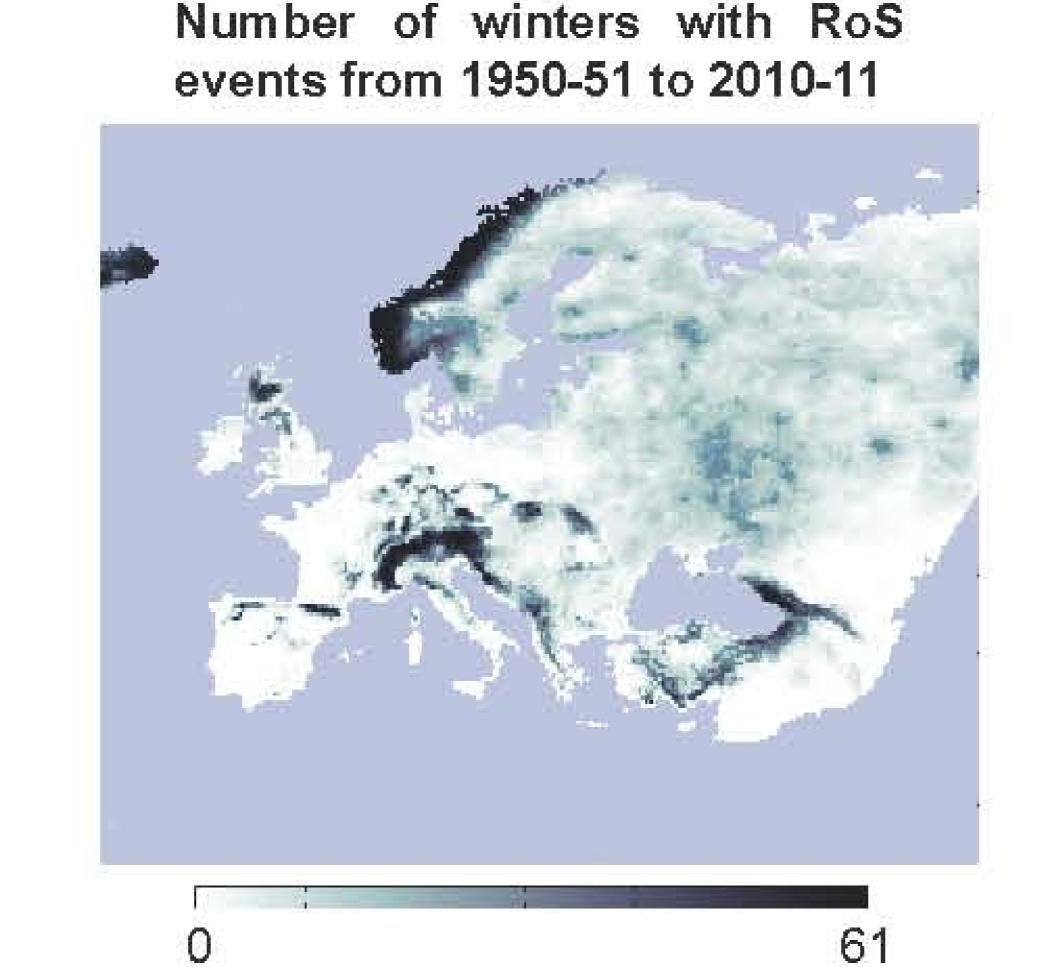
Precipitation accumulates as snow when temperature is < 0°C. Snowmelt is estimated with a simple temperature index model:

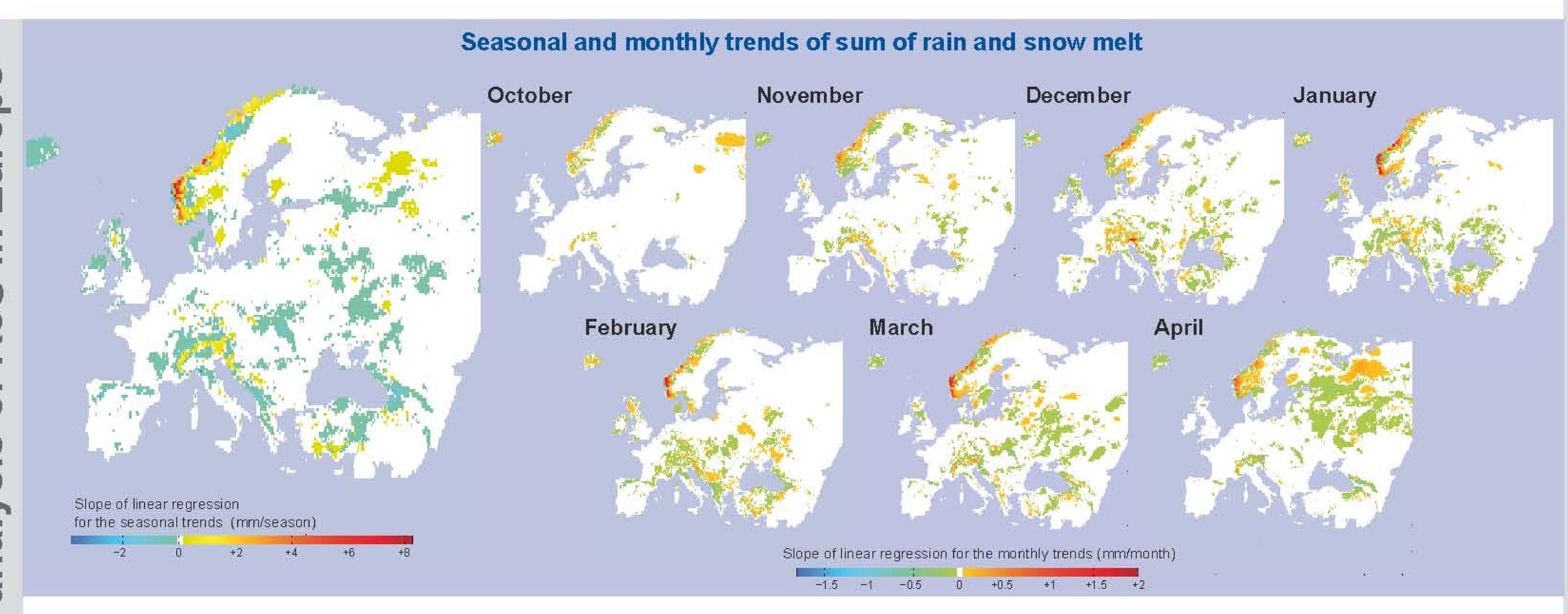
M = CM (Ta-Tb), $CM=3 \text{ mm/}^{\circ}\text{C day}$, $Tb=0^{\circ}\text{C}$ where M is the snowmelt (mm/day),

CIVI is the melt factor in mm/(°C day), Ta the average temperature (°C), and Tb the base temperature (°C).

Daily snowcover (as snow water equivalent, SWE) and snowmelt M are estimated from mid-September to

A RoS event is defined as at least 10 mm rain (liquid precipitation) on a minimum of 10 mm SWE (snowcover). Trends in the sum of rain and snowmelt from RoS events are calculated using a linear regression with time.





Results

In Europe, RoS events occur mostly from February to April.

The sums of rain and snowmelt in April show the most positive trend values over the last 61 years.

Central Europe is mostly affected during February and March.

The Northern and Eastern parts of Europe are mostly affected during April.

Generally, Scandinavian and high elevation areas (e.g. the Alps) show positive trends of RoS sums, especially in spring.

Lowlands in central Europe have negative trends. The latter is mainly due to overall decreasing amount of snow in early spring and therefore decreasing probability of snowcover before a rain event.

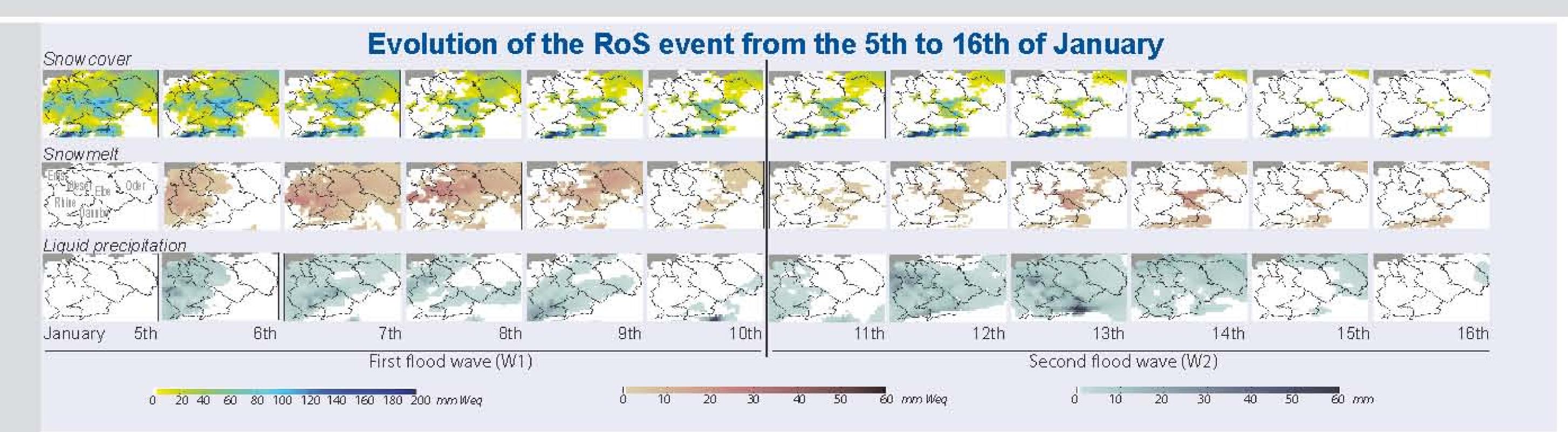
Conclusions

In a context of climate change, RoS events will very likely occur with a higher magnitude in late winter and early spring in Scandinavia and in high elevated areas like the Alps.

Depending on the location, the trends behave differently, mostly due to the persistence of snowcover.

This method can be used to identify sensitive areas in Europe.

The combination of these results with streamflow data clearly defined snowmelt as the main flood factor in January 2011. The RoS event of January 2011 in Germany had considerable consequences on runoff generation for very large areas and led to unusual flood events in the wintertime.

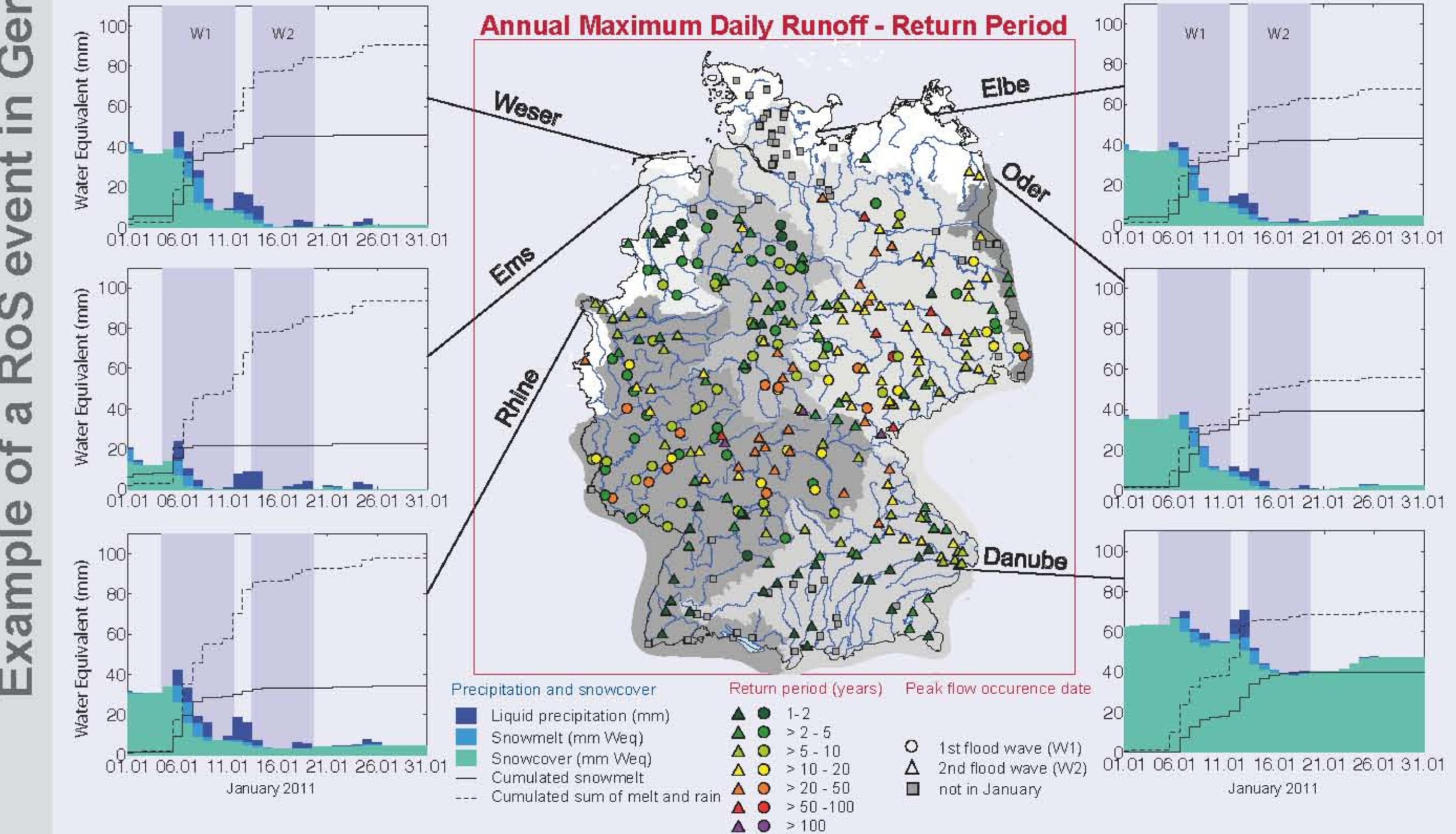


Germany's rain-on-snow event in January 2011

A two waves flood event (graphs below) occured over the river basins Rhine, Danube, Elbe, Weser, Ems and Oder mainly due to very high snowcover at the beginning of January and coinciding precipitation and rise of temperature starting from 5th of January 2011: The first flood wave (W1) was caused by snow melt spreading from West to East. During the second wave (W2) on the 10th of January most of the snow in the western part of Germany had already melted and liquid precipitation played a more significant role in this area. However, in central Germany snowcover was still substantial at the time and the RoS event caused annual maximum daily runoff with up to 100-year return periods in the upper parts of the Elbe, Weser and Rhine basins.

These RoS event floods in January caused the annual maximum daily runoff in 2011 at almost all gauing stations (map below). The flood corresponds to the highest return periods in Central Germany, especially in the Elbe basin where water levels were already very high before the flood due to a very wet autumn in 2010. In the lower parts of Rhine, Weser and Danube, most of the stations showed return periods of less than 10 years. Consequences of the January flood event were a restriction of navigation on the Rhine and large indundated areas in Elbe basin. Many other local impacts were observed all over Germany.





Reference: Kohn, I., Freudiger, D., Rosin, K., Stahl, K., Weiler, M. und Belz, J. (2013 / in Norb.). Das hydrologische Extremjahr 2011: Dokumentation. - Enordnung, Ursachen und Zusammenhänge. In: Mitteilungen Nr. 29, Bundesanstalt für Gewässerkunde (Hrsg.), Koblenz

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