Synchronicity and drivers of river flooding

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Main questions to be addressed

- When do floods typically occur?
- Which mechanisms drive these floods?
- To what extent do floods simultaneously occur across multiple catchments?

Floods seasonality shows distinct regional patterns

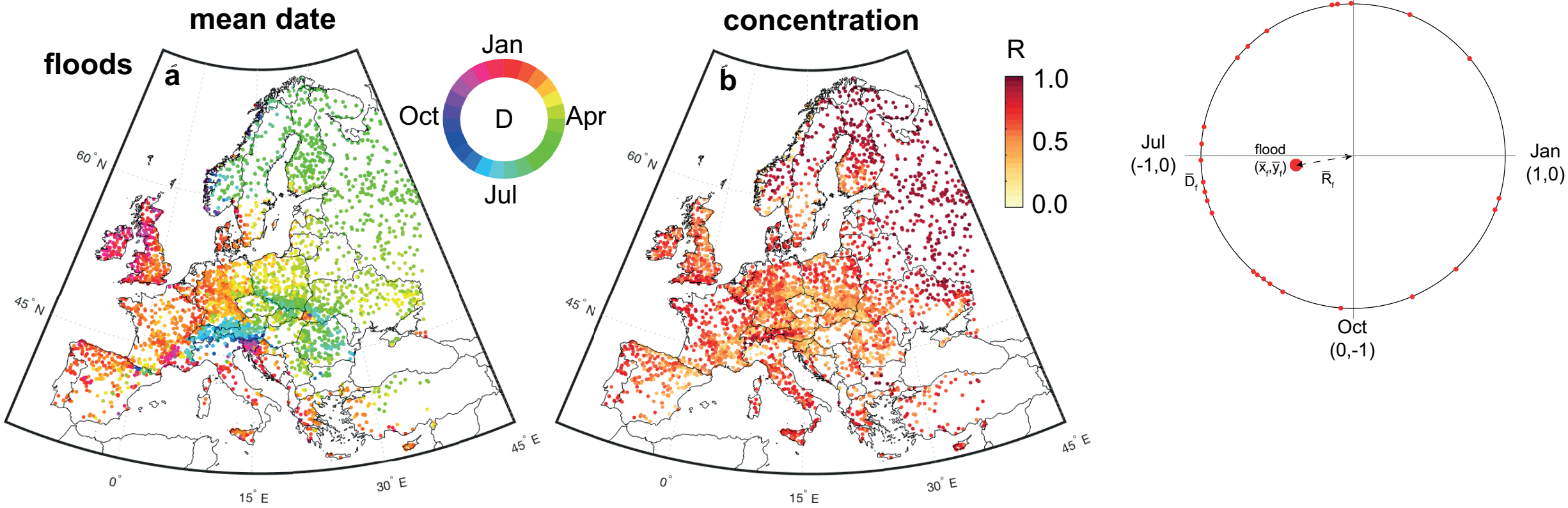
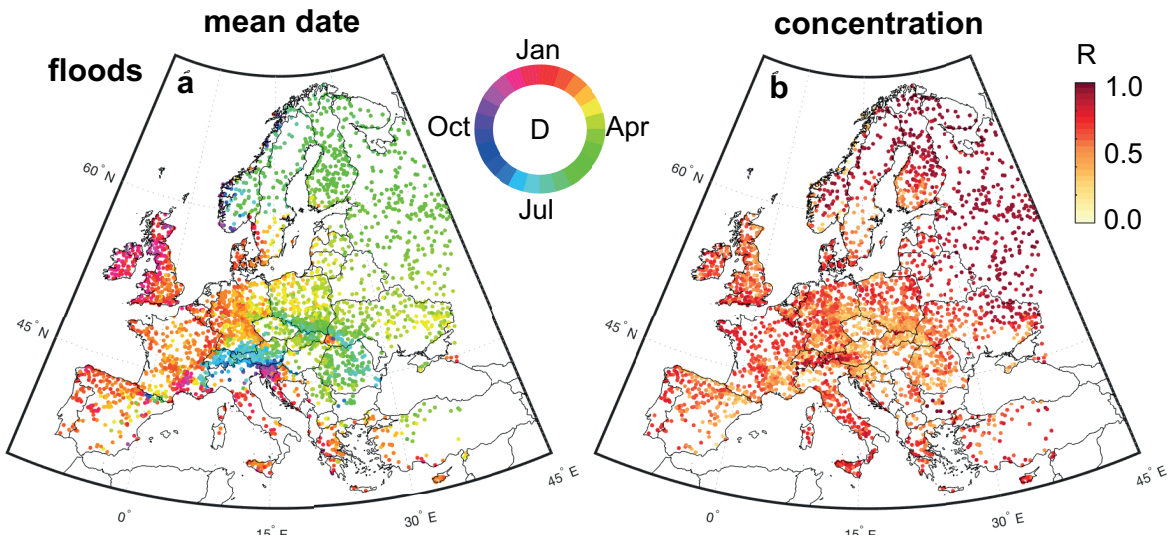


Figure. The spatial pattern of the timing of maximum annual flows and their concentration

Berghuijs et al. (2019) WRR

Seasonality of floods is unlike that of extreme precipitation



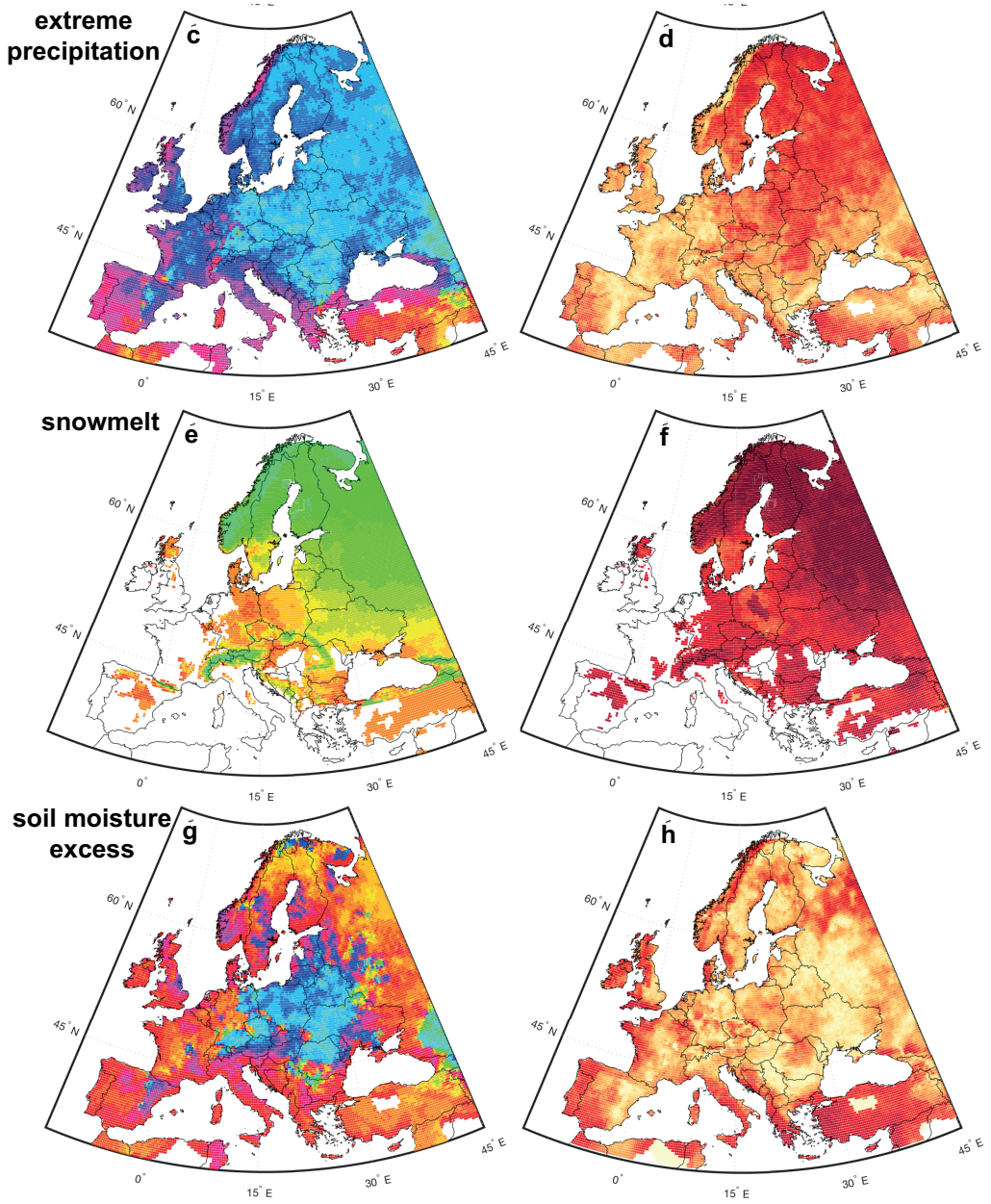


Figure. The spatial pattern of the timing of maximum annual flows and the flood-driving mechanisms (panels a, c, e, and g) and their concentration around their mean date of occurrence (panels b, d, f, and h) over the period 1960-2010

Berghuijs et al. (2019) WRR

Mixing analysis for flood drivers allows inferring their relative importance

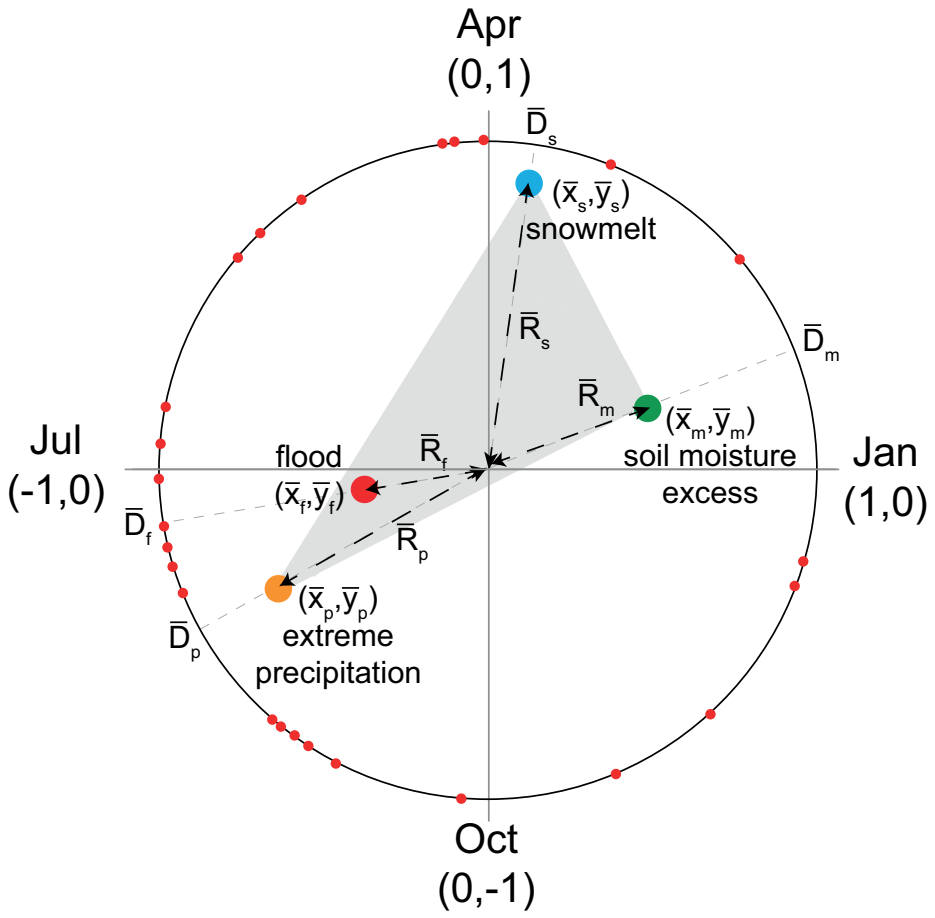


Figure. The seasonality characteristics of floods and flood-generating mechanisms characterized by circular statistics for the Reuss river (Switzerland, 46°38′34.8″N 8°35′24.0″E). The dates of occurrence of each year, $D_{i,k}$ (day of year), fall on the unit circle (here only shown for floods). These dates are used to derive the mean cosine and sine components, x_i and y_i , and thus to estimate the mean date of flooding. The concentration, R_i (dimensionless), expresses how tightly occurrences are clustered around the mean date, and the subscripts indicate the process of interest (f = flood, p = precipitation, m = soil moisture excess, and s = snowmelt). The cosine and sine components of the flood generating mechanisms are used to infer their relative importance as flood drivers by comparing their seasonality statistics, which yields α_p = 0.77, α_m = 0.03, and α_s = 0.20 in this example. Thus, in this catchment, the majority of flooding is driven by extreme precipitation events.

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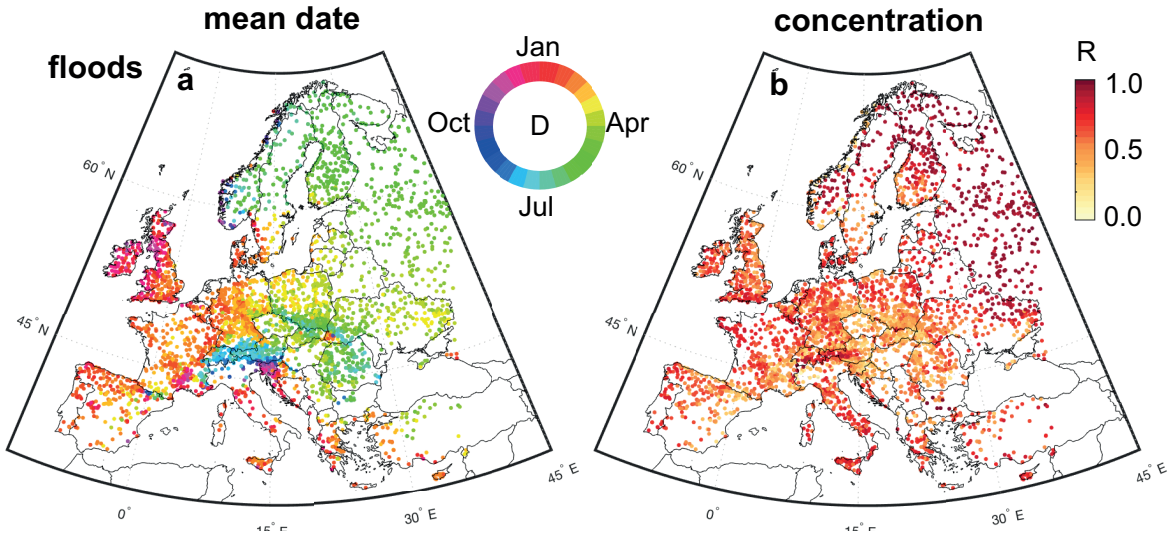
Seasonality can be used to infer the importance of flood drivers



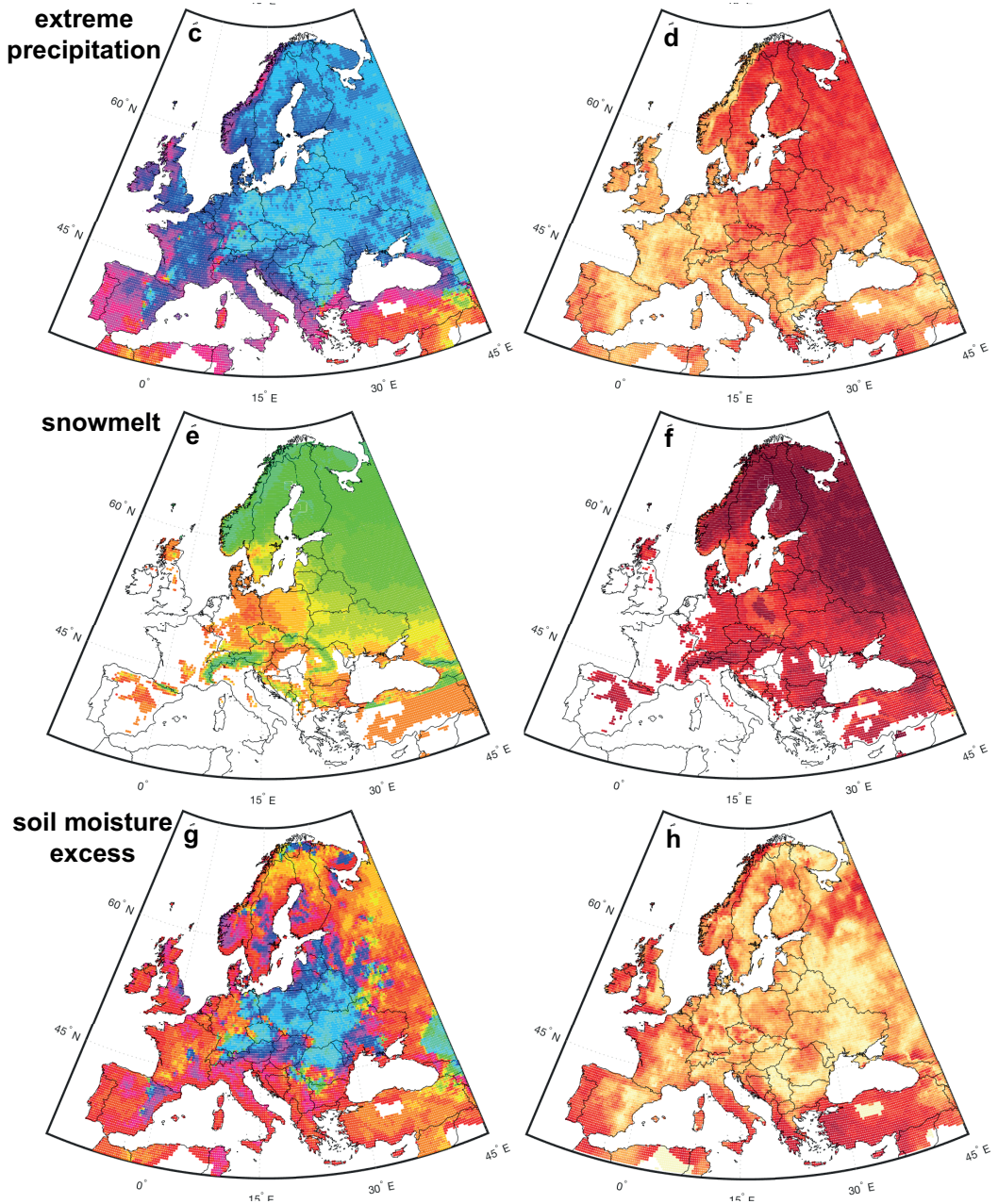


Figure. The spatial pattern of the timing of maximum annual flows and the flood-driving mechanisms (panels a, c, e, and g) and their concentration around their mean date of occurrence (panels b, d, f, and h) over the period 1960-2010

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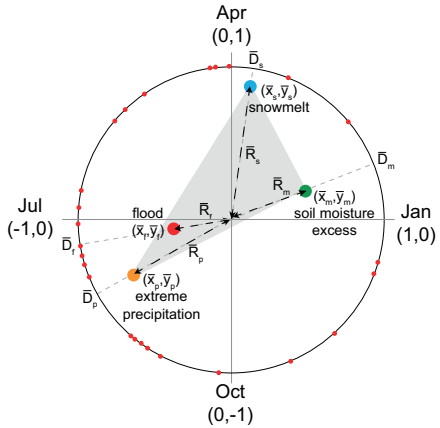
Most floods are caused by sub-extreme precipitation with high antecedent soil moisture, not by peak rainfall.



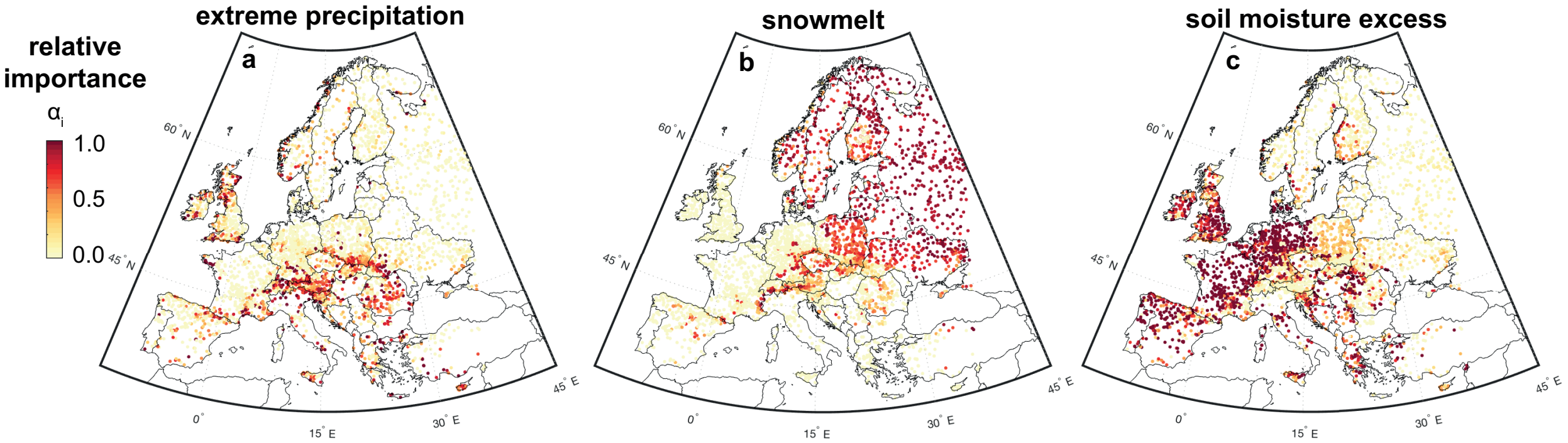


Figure. The spatial pattern of the relative importance of precipitation floods (panel a), snowmelt floods (panel b), and soil moisture excess (panel c) over the period 1960-2010 for the 3,777 catchments that have at least 20 years of data.

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These relative importance of these drivers has not changed much during 1960-2010

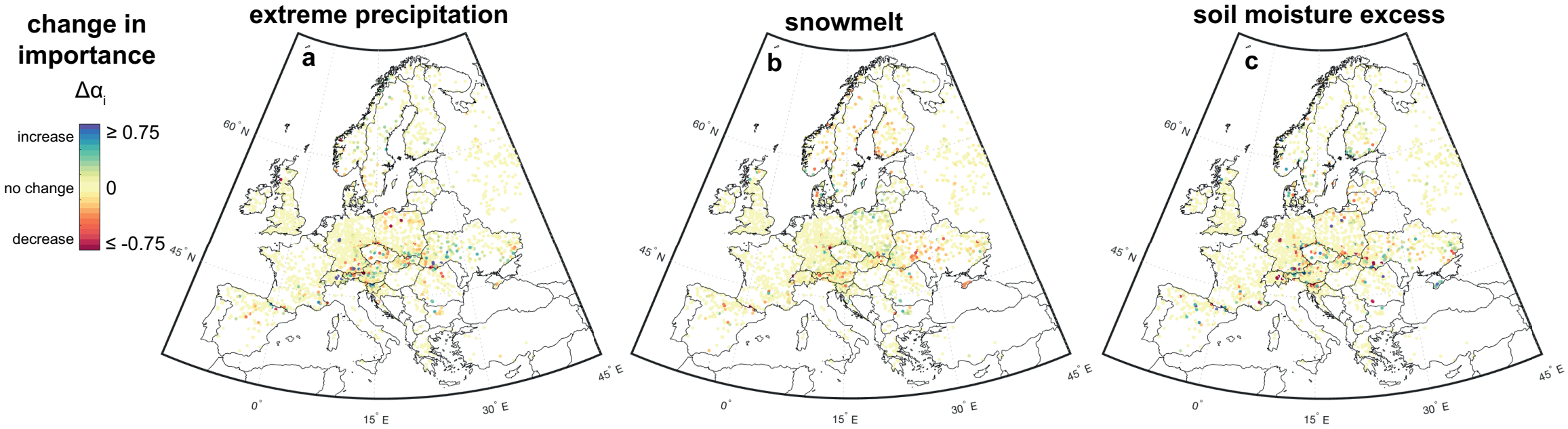

Figure. The spatial pattern of changes in the relative importance of precipitation floods (panel a), snowmelt floods (panel b), and soil moisture excess floods (panel c) between the periods 1960-1984 and 1985-2010.

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Also in the US, seasonality of floods is unlike that of extreme precipitation

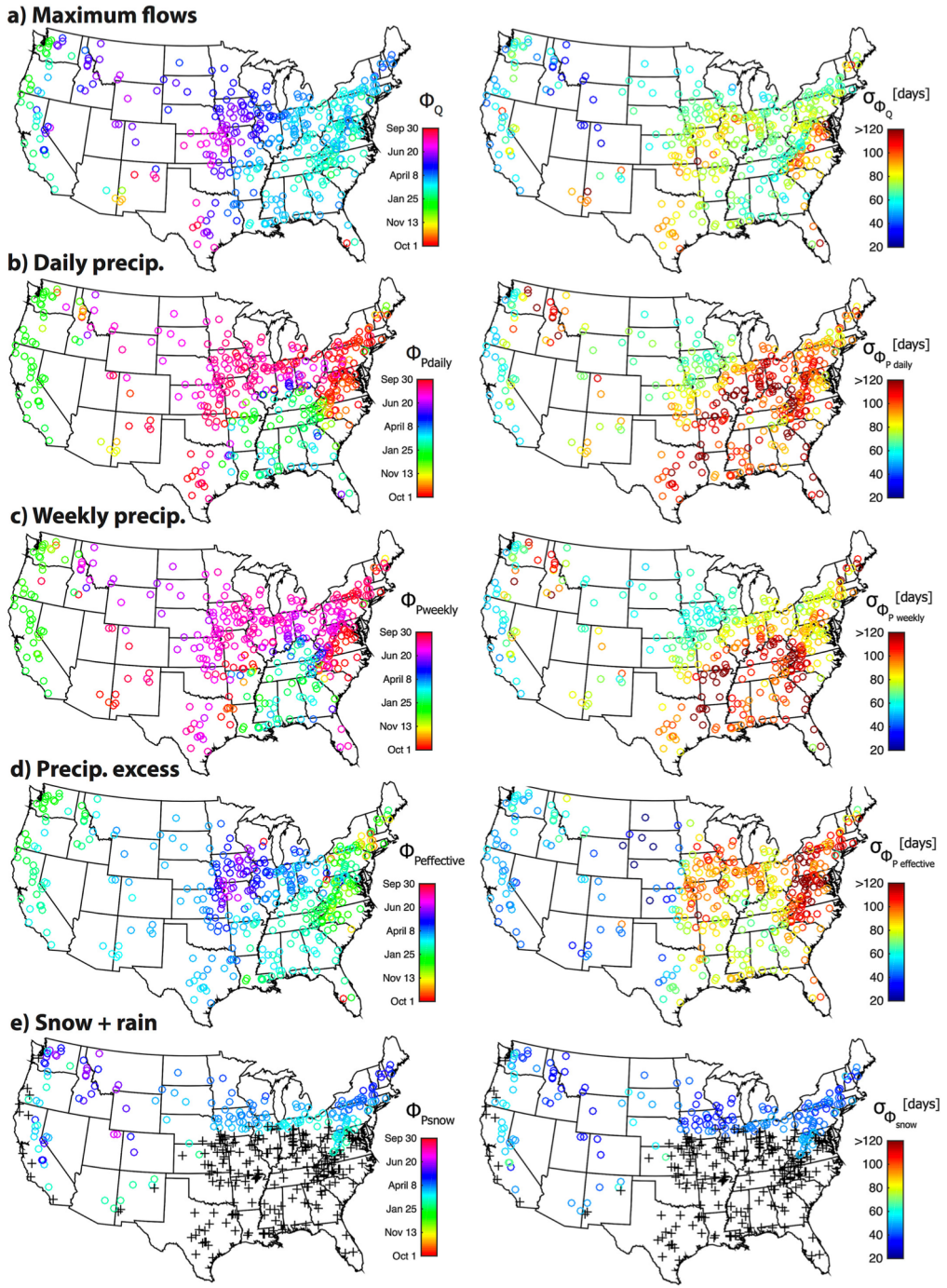


Figure. Left-hand column shows the mean month of occurrence and the right-hand column shows the year-to-year variability in that seasonality of (a) maximum annual daily flow, (b) maximum daily precipitation, (c) maximum weekly precipitation, (d) maximum precipitation excess, and (e) maximum snowmelt. Black crosses indicate that the data were not calculated due to an absence of significant snow (<10% of total precipitation).

Berghuijs et al. (2016) GRL

Most floods are caused by sub-extreme precipitation with high antecedent soil moisture, not by peak rainfall

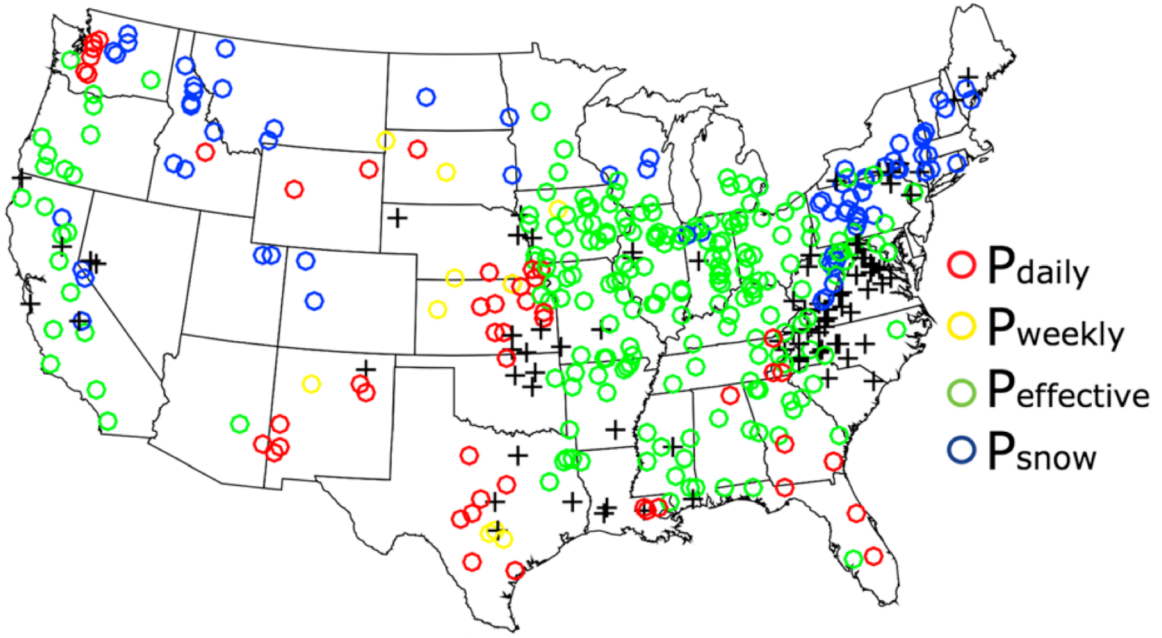
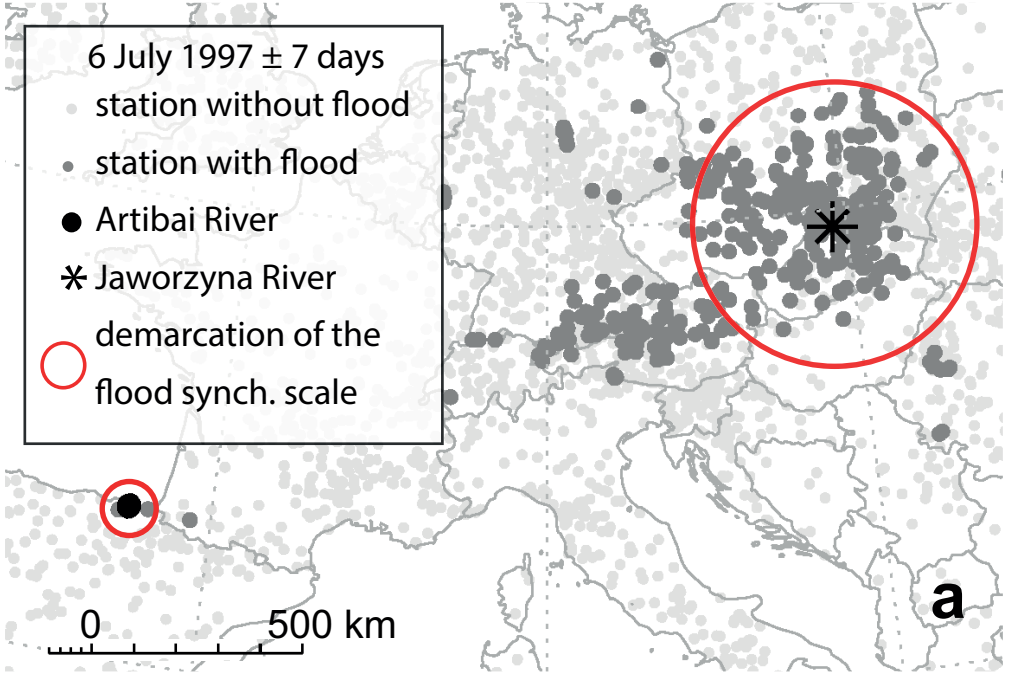
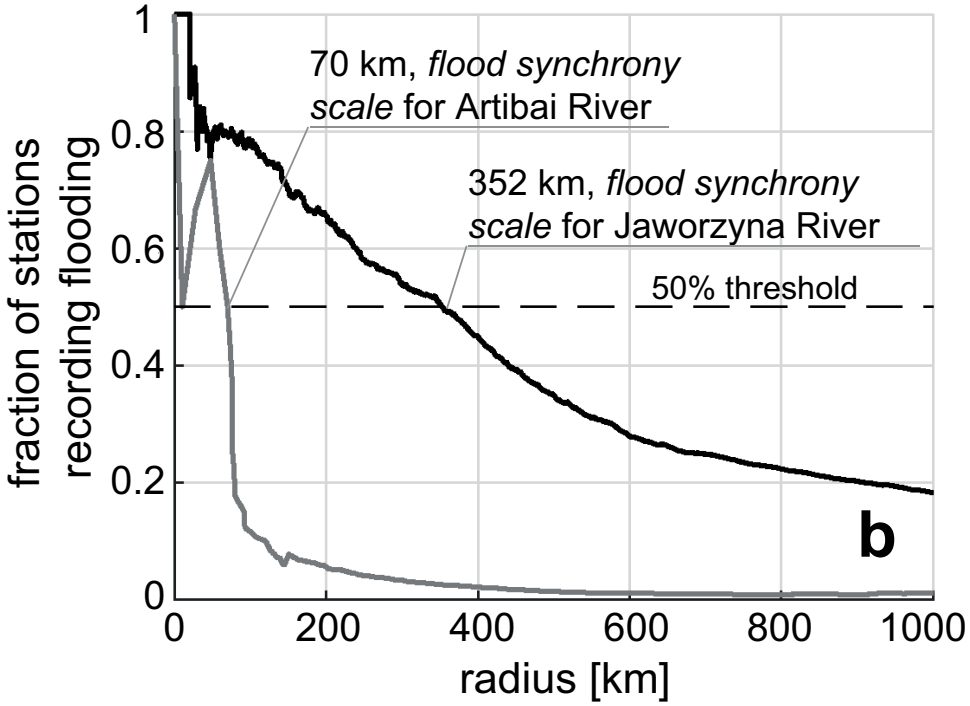


Figure. The flood-generating mechanism that explains most of the seasonality and variability of annual floods. Black crosses indicate that all mechanisms were rejected.

Berghuijs et al. (2016) GRL

When rivers flood, surrounding rivers often flood at the same time





Flood synchrony scale is maximum radius around an individual river gauge within which at least half of the other river gauges also record flooding almost simultaneously

Berghuijs et al. (2019) GRL

Floods occur over much larger areas than individual drainage basins

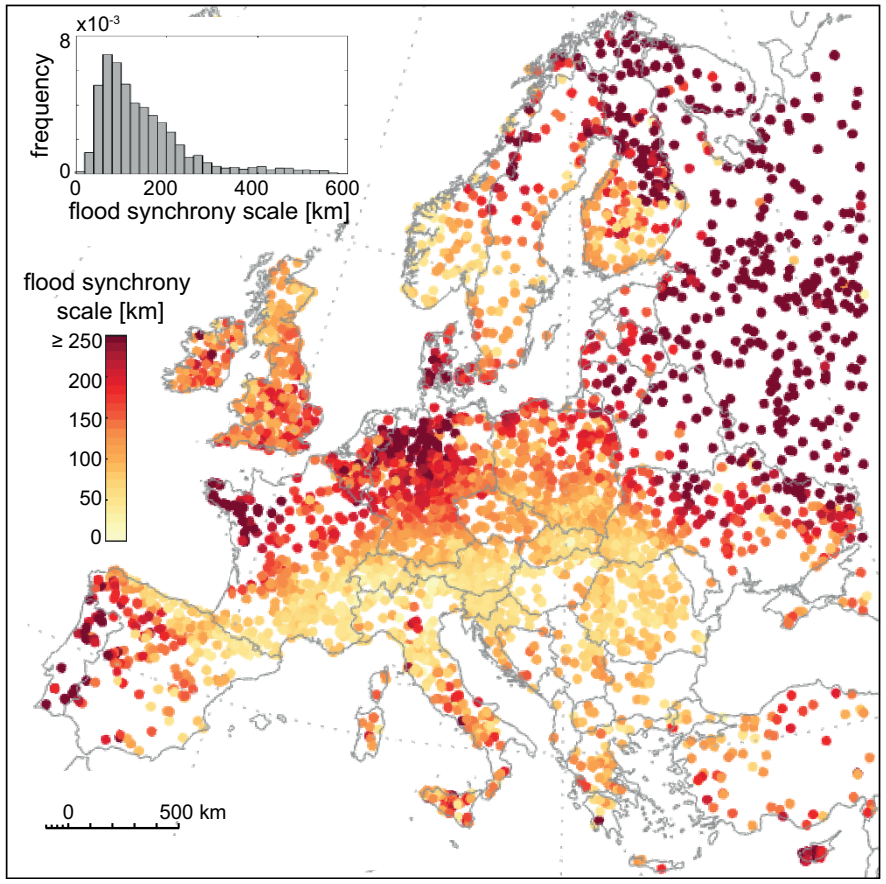


Figure. Flood synchrony scales across Europe over the period 1960–2010. Site-averaged flood synchrony scales vary regionally by over an order of magnitude. Floods are spatially correlated over large distances in most of western and northeastern Europe, whereas flooding in a band stretching from northern Spain toward the Alps, into central Europe, and the Carpathians is much more localized

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In Europe floods have become more spatially extensive

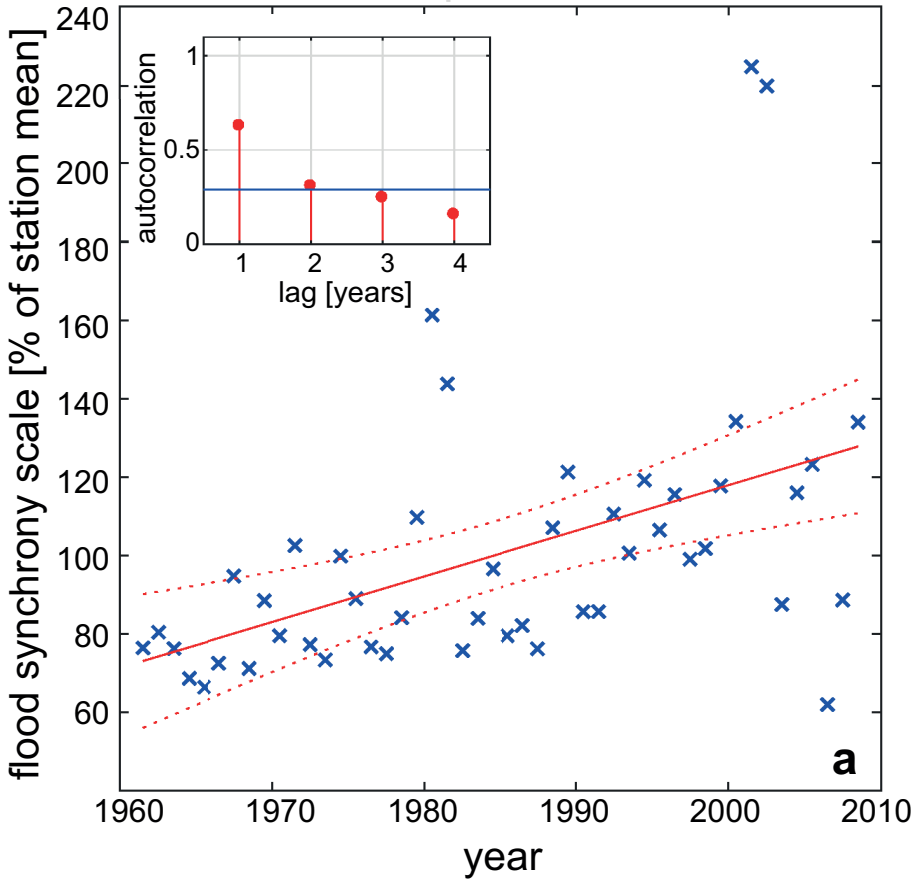

Figure. European flood synchrony scales have been growing overall, but trends differ regionally. Annual flood synchrony scales, averaged across all available stations (a), have grown by roughly 50% over the period 1960–2010 (trend is significant at $p < 0.01$; dotted lines indicate $p = 0.05$ confidence bounds). Detrended flood synchrony values are also serially correlated, indicating that years with above-average flood synchrony tend to follow one another (see inset to panel(a)

Berghuijs et al. (2019) GRL

Summary

- Seasonality of floods is unlike that of extreme precipitation
- Seasonality can be used to infer the importance of flood drivers
- Most floods are caused by sub-extreme precipitation with high antecedent soil moisture, not by peak rainfall
- Floods occur over much larger areas than individual drainage basins
- In Europe floods have become more spatially extensive

Read more:

- Berghuijs et al. (2019) The relative importance of different flood-generating mechanisms across Europe, *WRR*
- Berghuijs et al. (2019) Growing spatial scales of synchronous river flooding in Europe, *GRL*
- Berghuijs et al. (2016) Dominant flood generating mechanisms across the United States, *GRL*

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