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Detection of trends in observed river floods in Poland

11-15 July 2022

Haaliste river, credit, Ilmar Roosmaa, www.Soomaa.com

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Outline

- Background
- Study area
- Data and methods
- Results
- European-scale flood study, example
- Summary

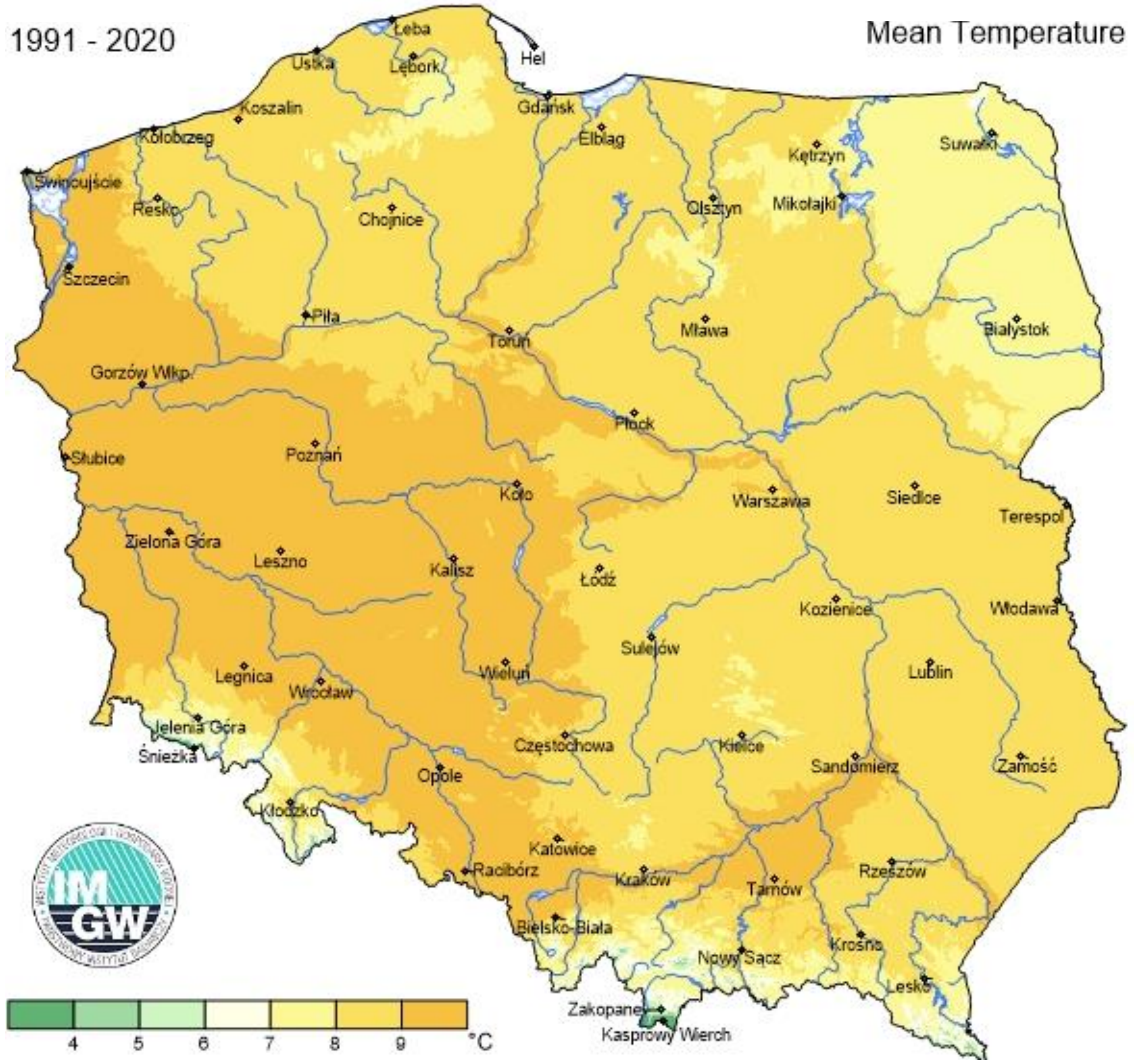
Justification

- Poland is recurrently affected by river floods **(e.g. 1997 – Odra basin; 2010 – Vistula basin)** with consequences for different human activities, economic aspects, infrastructure and even for human life.
- River floods are extreme events that are variable over time, however the **extreme high flow of rivers in Poland has been characterized by periods that depend on local conditions**, which can modify the impact of this hydrometeorological event.
- Global-scale and pan-European studies on annual maximum daily discharge and flood trends **have partially or completely left Poland out** of the analyses **due to the lack of free access to Polish** data.
- European studies that included Poland usually **used data until 2010.**

Study area

- **Poland** with a representative sample of flow gauges located in 12 major river basins.

- Annual total precipitation is approximately 500–700 mm/year
- Annual average temperature, 7.9°C



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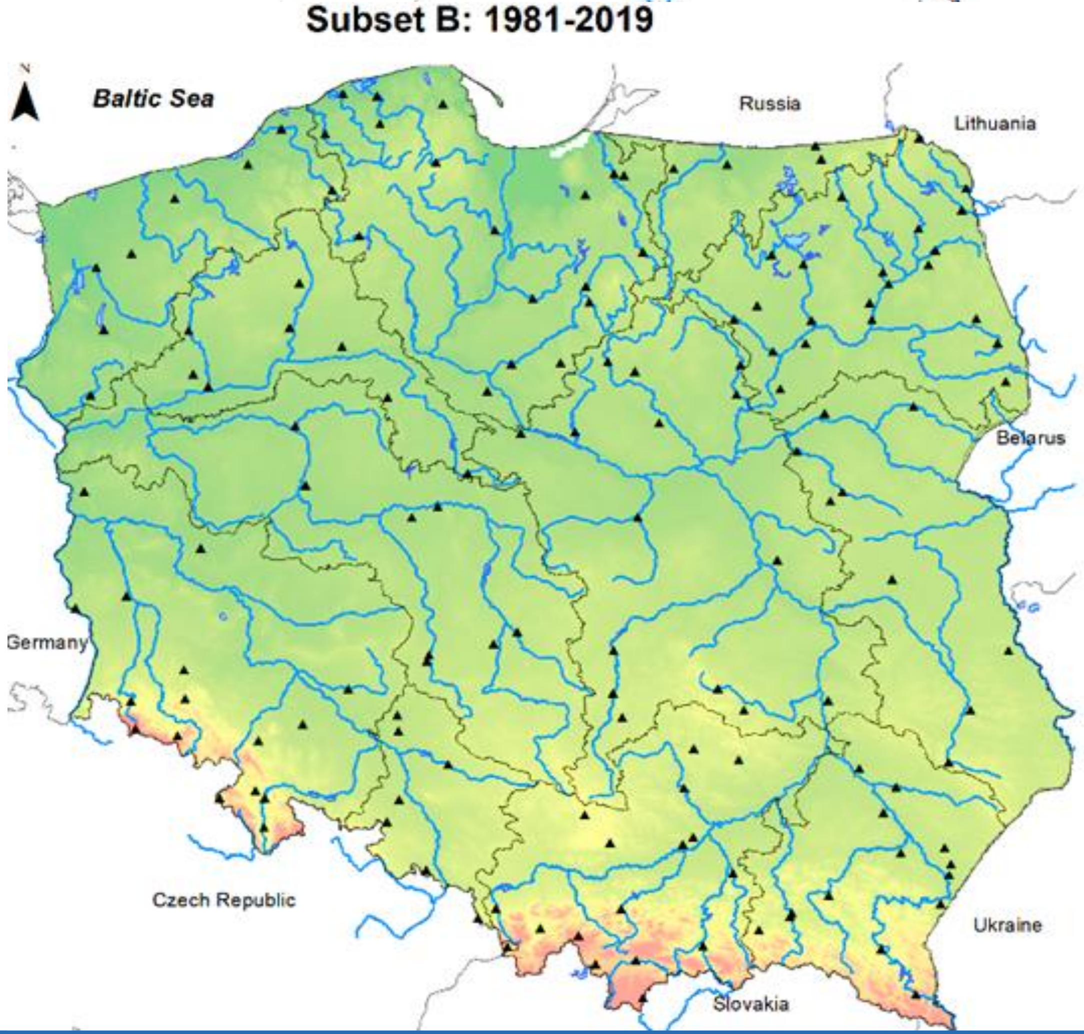
Data

- Flow gauges free of major human modifications, located in 12 major river basins.
- **Daily data** extracted from the Institute of Meteorology and Water Management-National Research Institute (IMGW-PIB).
- Representative sample of 146 gauges from two time periods:
  - 1956–2019 (subset "A“, **maximizing the temporal coverage**)
  - 1981–2019 (subset "B“, **maximizing the spatial coverage**)
- The median of catchment areas is 551 km^2 **(range 6 - 6931 km2)**



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Methods

We used the annual maximum daily flow and peak-over-threshold (POT) approaches:

- The annual maximum river flow (Q_MAX) is the **maximum** of the discharge recorded in a **hydrological year** (1 November – 30 October, in Poland).
  - ➢ Half-year indicators (for winter and summer) as the maximum flow values per half-year.

- POT is based on the **peaks above a defined threshold level**:
  - ➢ Predefined quantile (92.5th, 95th or 97.5th percentile) as a threshold, depending on the variable study conditions, with a dependence criterion of 30-day between two consecutive events.

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Methods

Peak-over-threshold (POT) and Annual maximum daily flow (Q_MAX) flood series

↓

Trends in selected river flood indicators: magnitude, frequency and timing

Non-parametric Mann-Kendall test (MK) and Sen slope	Chi-squared test on parametric Poisson and Sen slope
↓	↓
Magnitude Timing	Frequency

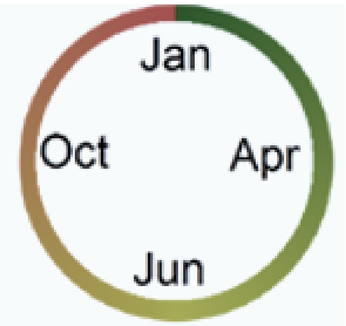
The Mann-Kendall test is based on:

$$S = \sum_{i=1}^{n-1} \sum_{j=1+1}^{n} sgn(X_j - X_i)$$

$$sgn(X_j - X_i) = \begin{cases} 1 \; if \; (X_j - X_i) > 0 \\ 0 \; if \; (X_j - X_i) = 0 \\ -1 \; if \; (X_j - X_i) < 0 \end{cases}$$

where X_j and X_i are the values sorted by data sequence and n is the length of the data set.

The trends of Q_MAX timing is presented by the application of **mean day of high flow (MDF)**, where the dates of flood timing were converted into an angular value:



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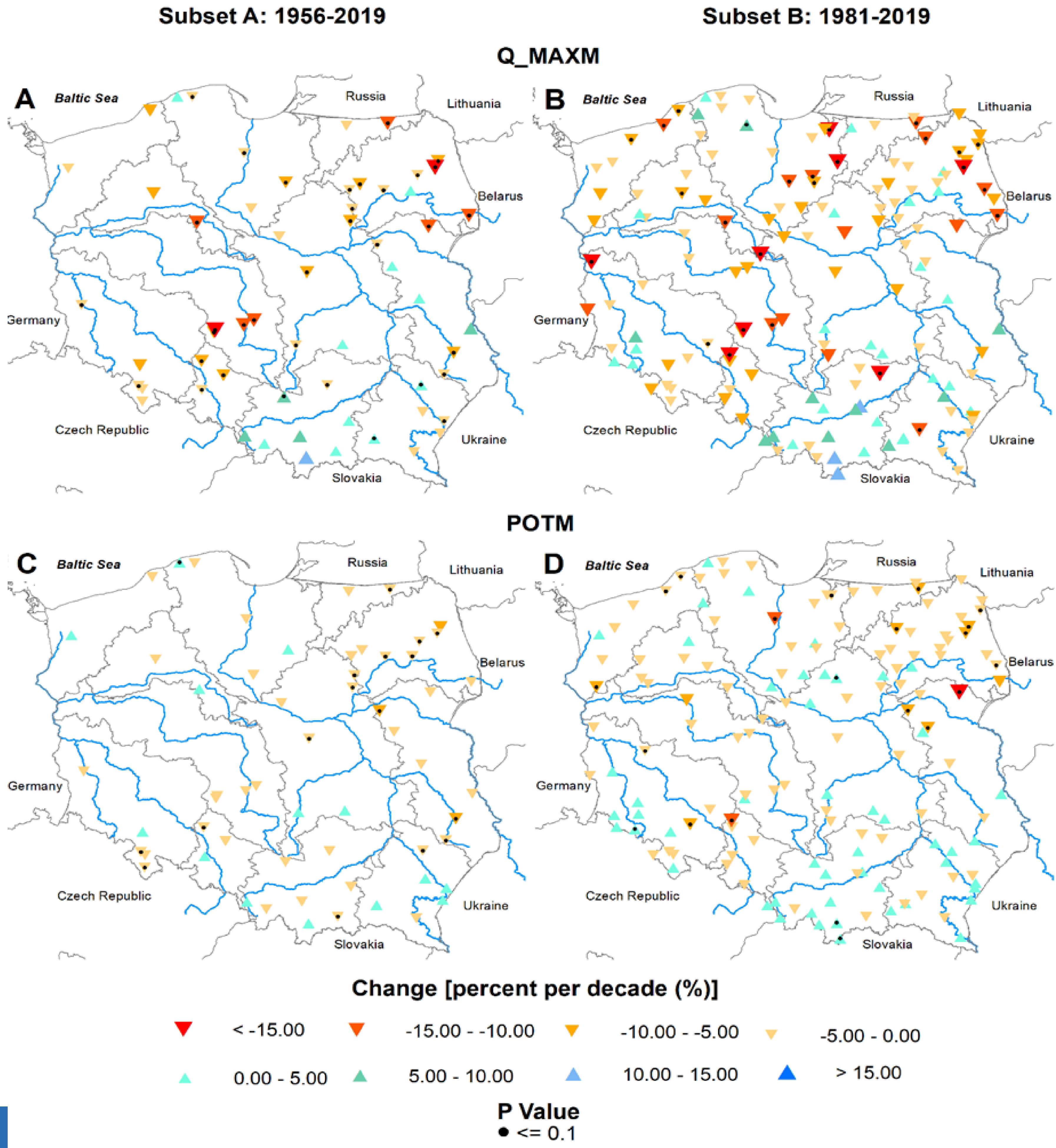
Results – flood magnitude

- General **decreasing** trend.
- **Upward trend in the southern** part of Poland.
- Statistical significance of 58% of gauges Subset A and subset B around 30%.
- The results show a generally coherent **pattern with previous European studies.**



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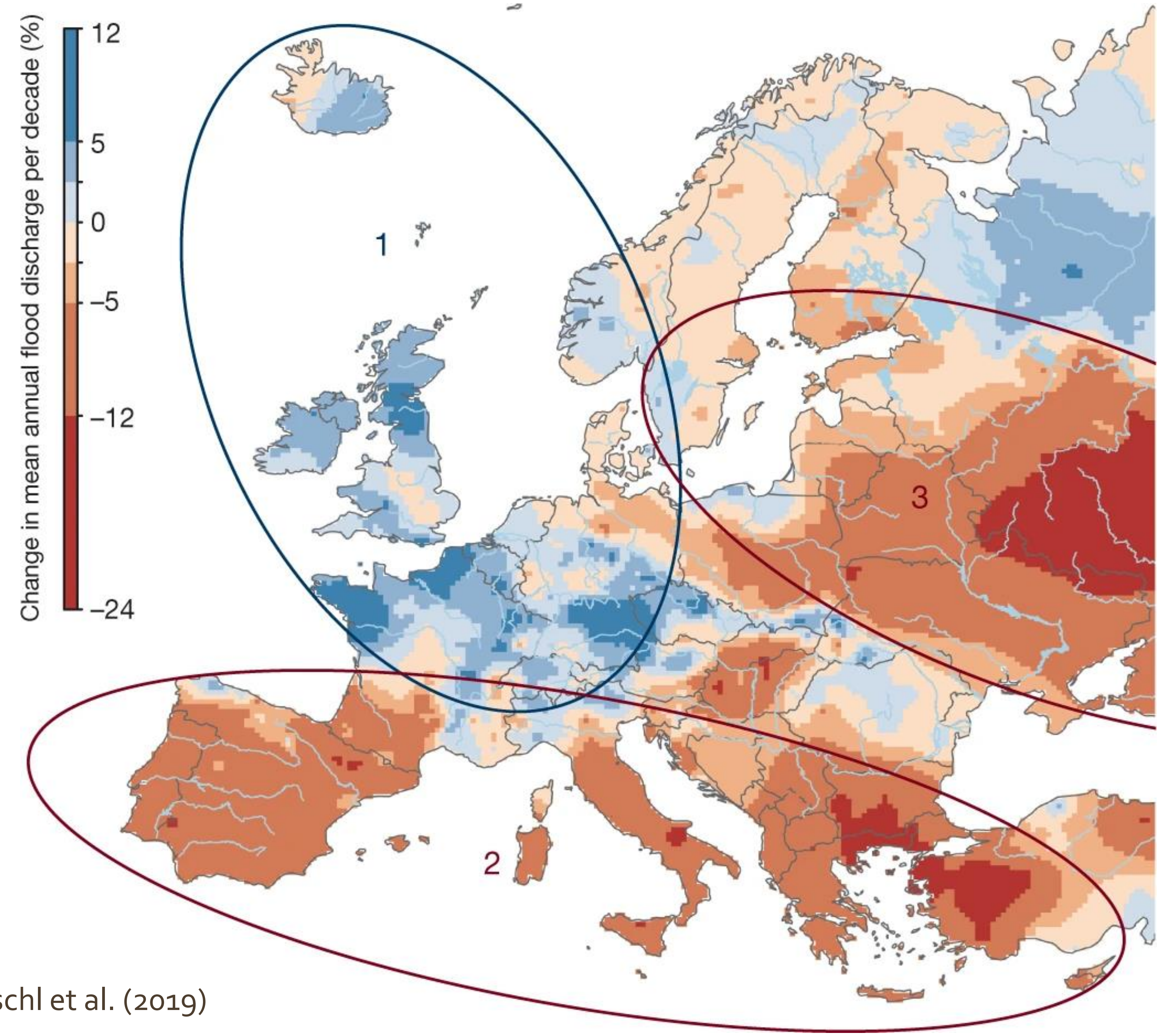
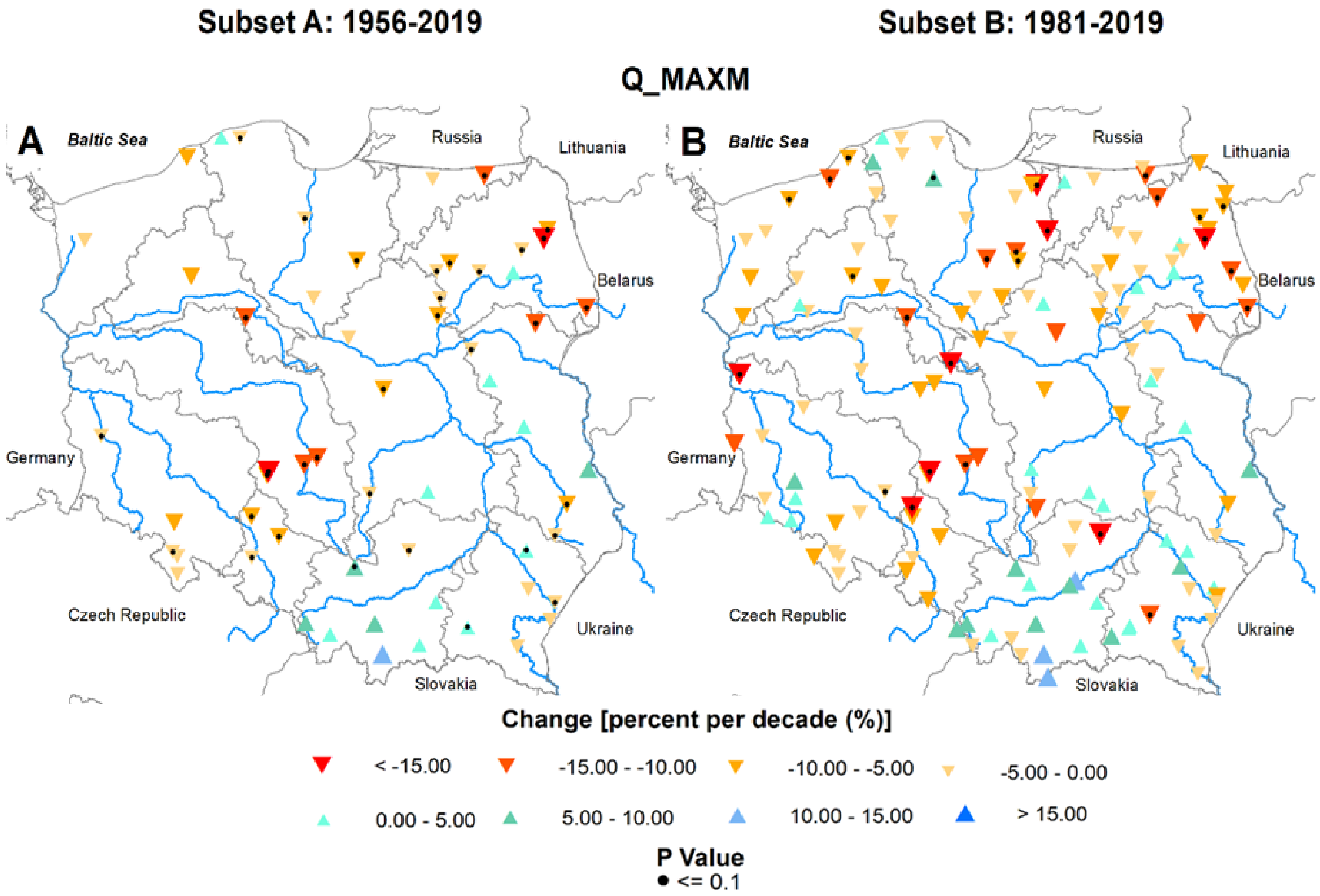
Results – flood magnitude



Blöschl et al. (2019)



The trend matches the one discovered by Blöschl et al. (2019), although we have not found a weak increasing trend in the coastal region.

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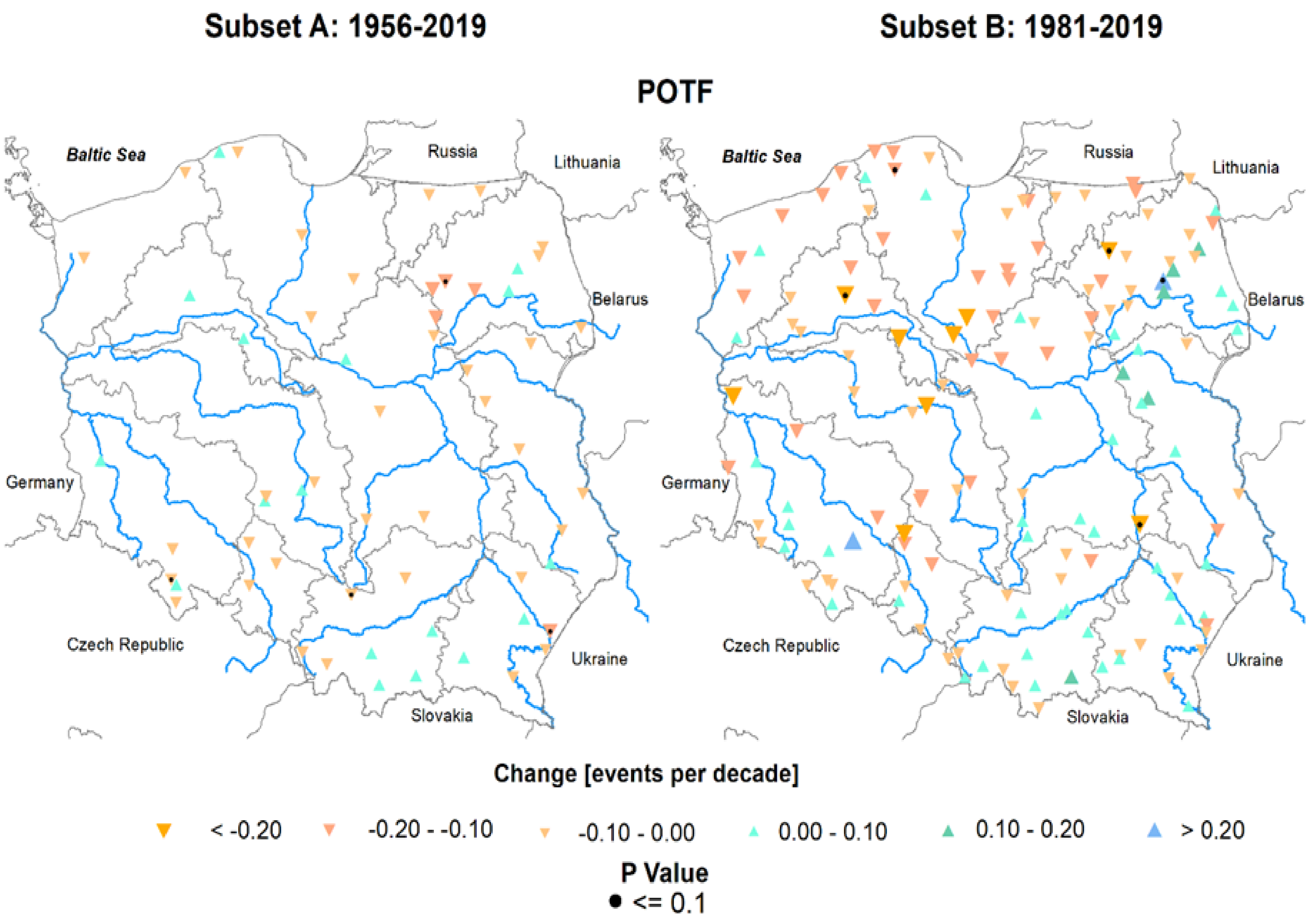
Results – flood frequency

- POT frequency **did not demonstrate an evident and significant trend** due to the low values of changes in events per decade.
- The increase of **flood frequency** refers mainly to the **southern area**.
- **The downward** trend was attributed to **less severe freezing and a decrease in the soil moisture around Poland.**



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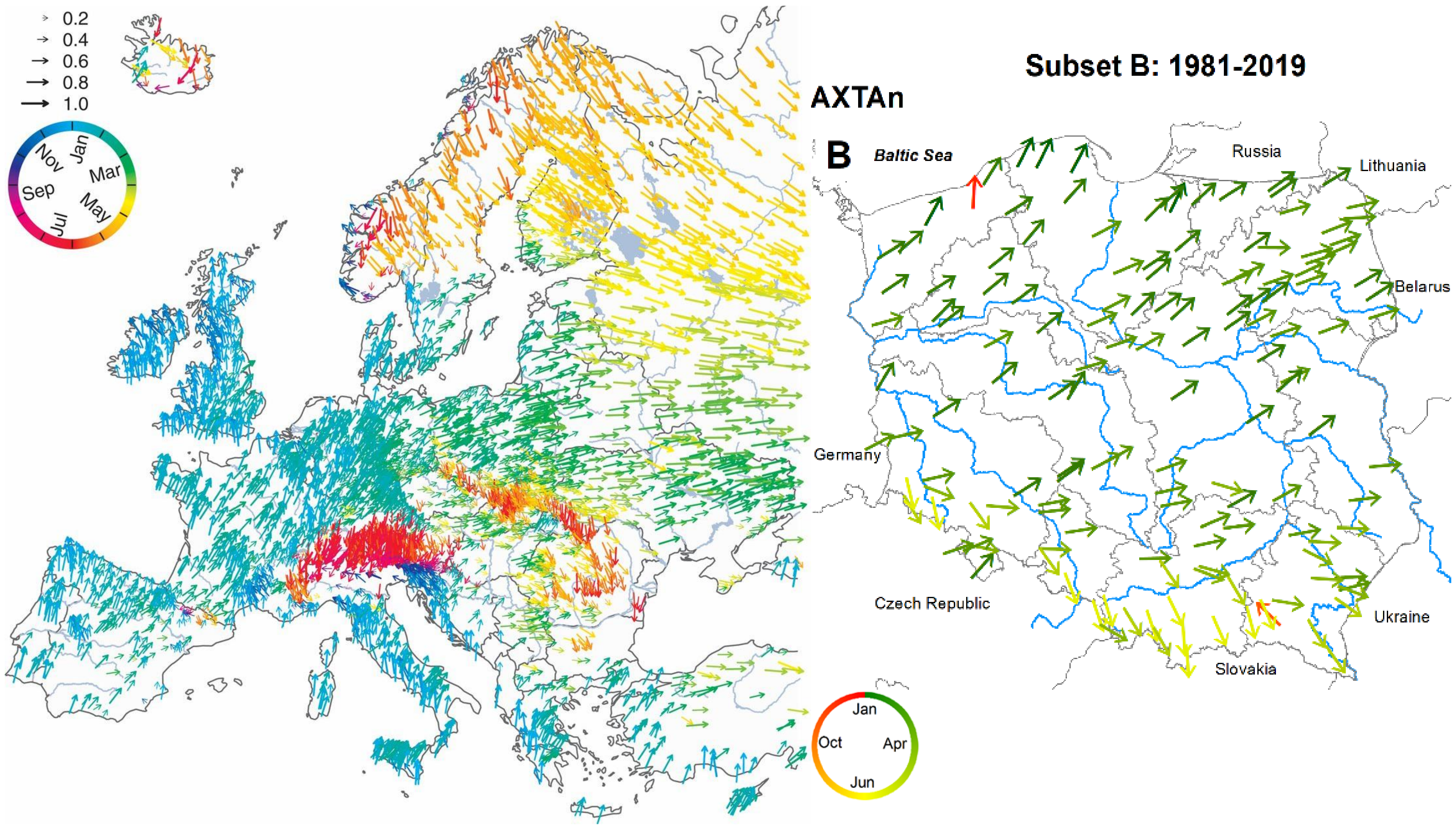
Results – flood timing

- Average flood timing in Poland
- The **northern and central part** is concentrated in **February-April**.
- **May-June** in the **southern-most basins**.
- The flood **timing between March-May** could be linked with the **North Atlantic Oscillation (NAO)** and the snowmelt processes.
- Our results agree with studies of flood timing in Europe based on observed data (Blöschl et al., 2017)



(Blöschl et al., 2017)

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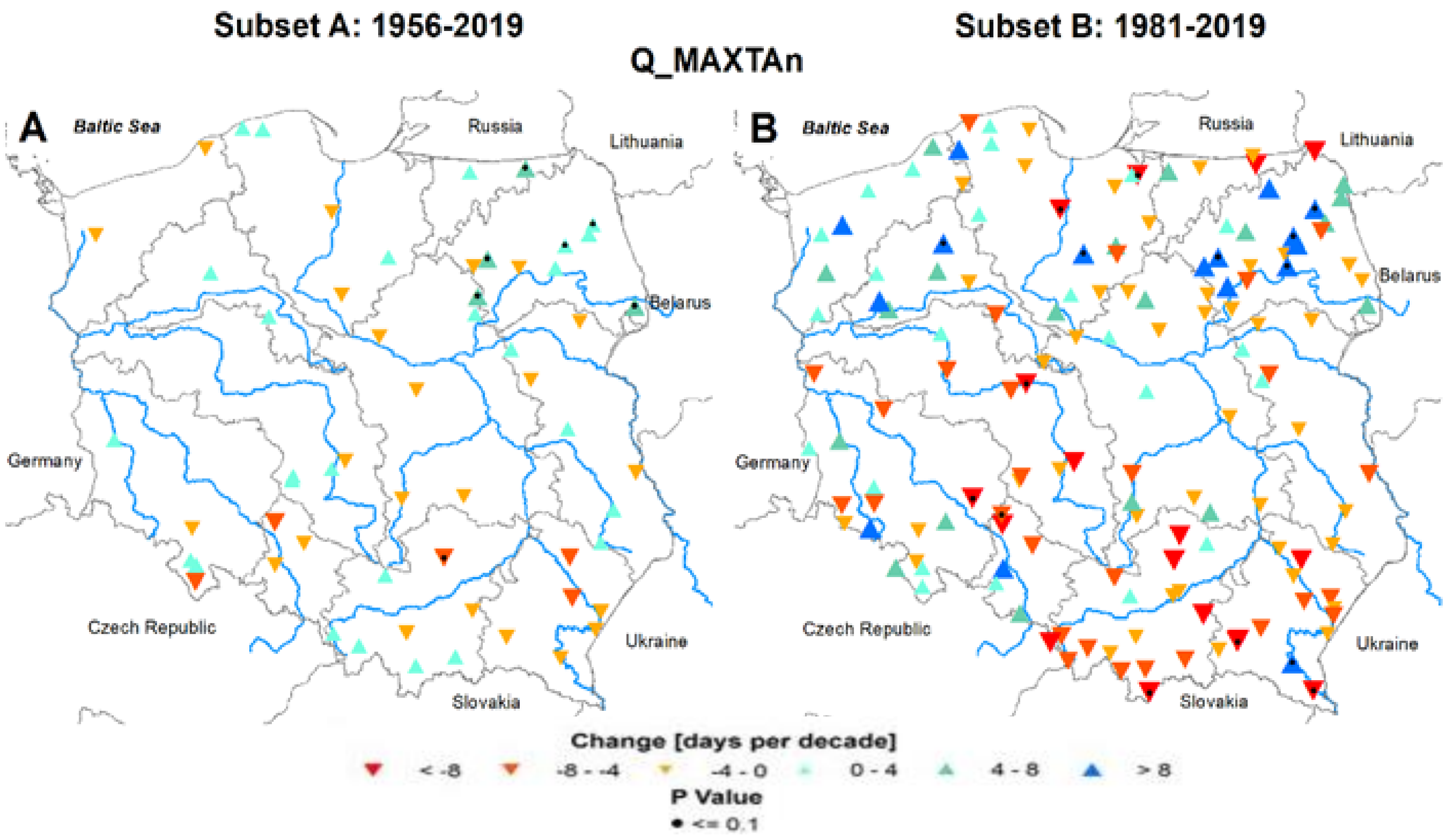
Results – flood timing

- **Decreasing trends (earlier)** prevail, especially in the **southern part** of the country.
- **Dominant increasing trend (later)** in the **north-western** part of Poland.
- Floods in the **lower Vistula Basin** and the **southern region** have been **associated with cyclones.**
- Only 10–11% of gauges showed statistical significance.



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Summary and outlook

- The use of **two complimentary methods** (POT and Q_MAX), allows for a **more comprehensive examination** of floods in the country.

- Comparison of two different subsets of data demonstrates **higher significance for longer time series** than in shorter time series.

- Trends in magnitude of floods illustrated a **visible spatial variability** over the river basins of the country with **an evident statistical significance.**

- The observed changes in magnitude, frequency and timing of floods obtained in our research **provide one of the first analyses of a rather under-studied topic in Poland**.

- The **influence of climate variation** on trend detection **should be considered**.

- All these changes, that were detected for recent years, **may not necessarily continue in the future due to climate change and other factors**.

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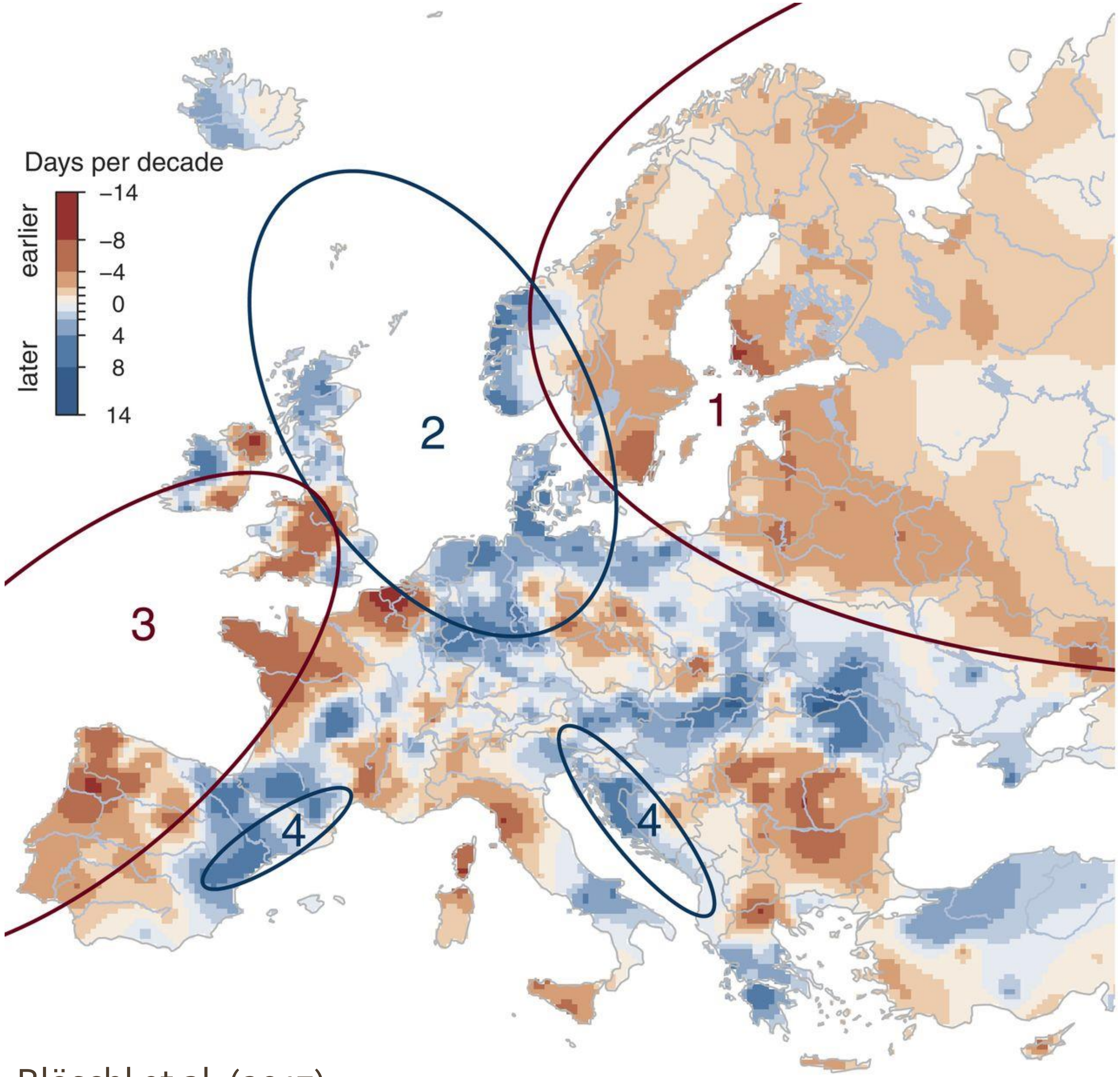
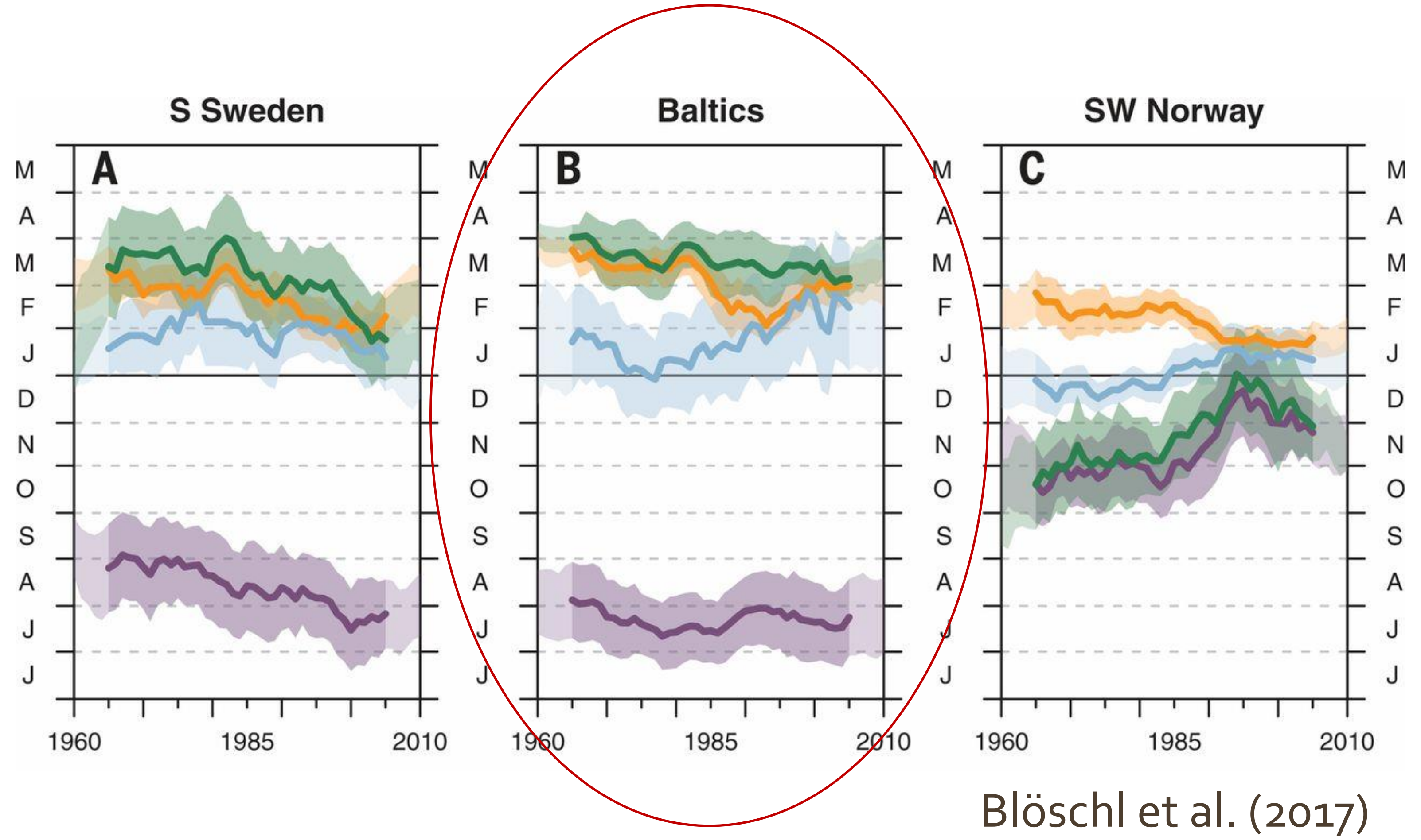
European-scale flood-timing trends (Baltic States)



Blöschl et al. (2017)



Blöschl et al. (2017)

Green, timing of observed floods; purple, 7-day maximum precipitation; orange, snowmelt indicator; blue, timing of modeled maximum soil moisture.

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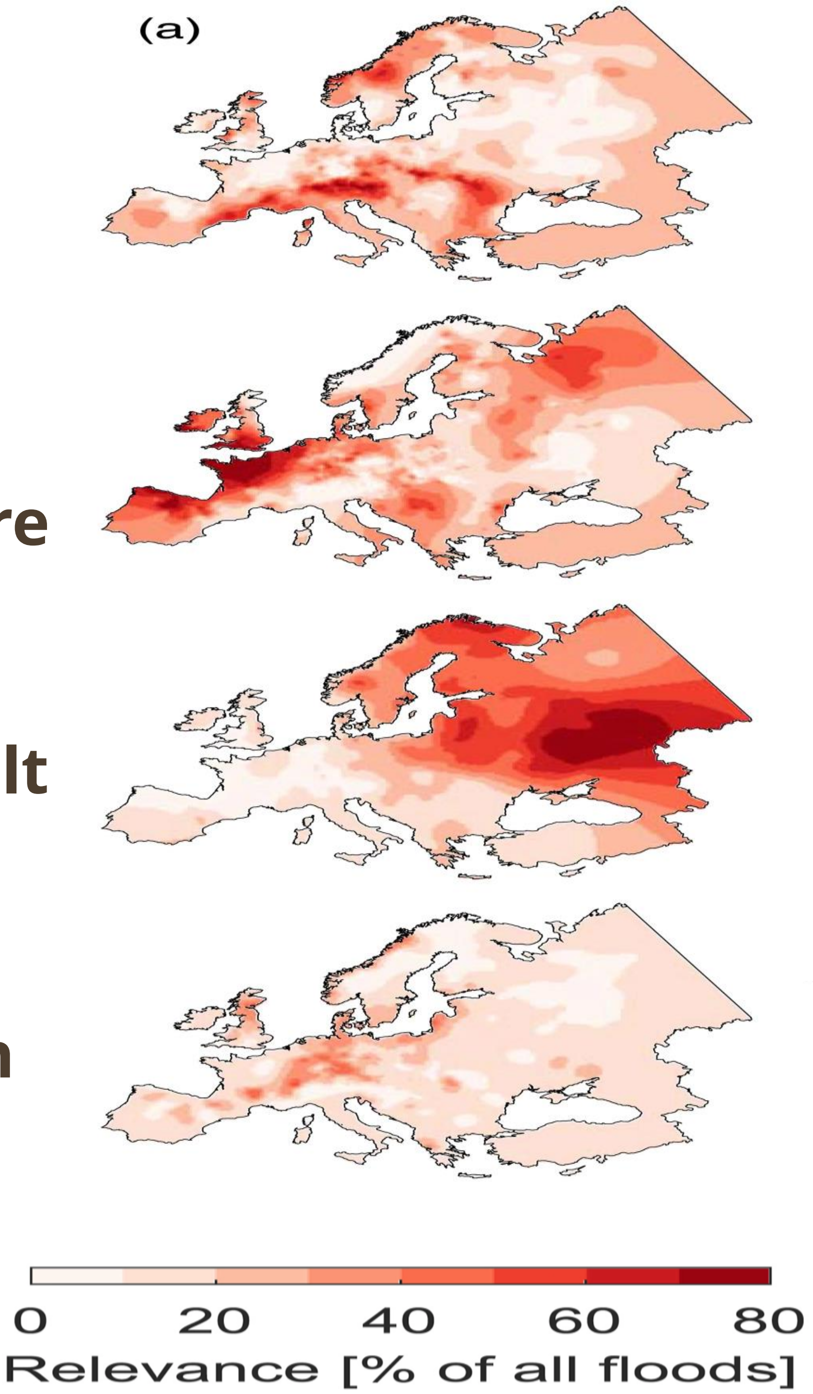
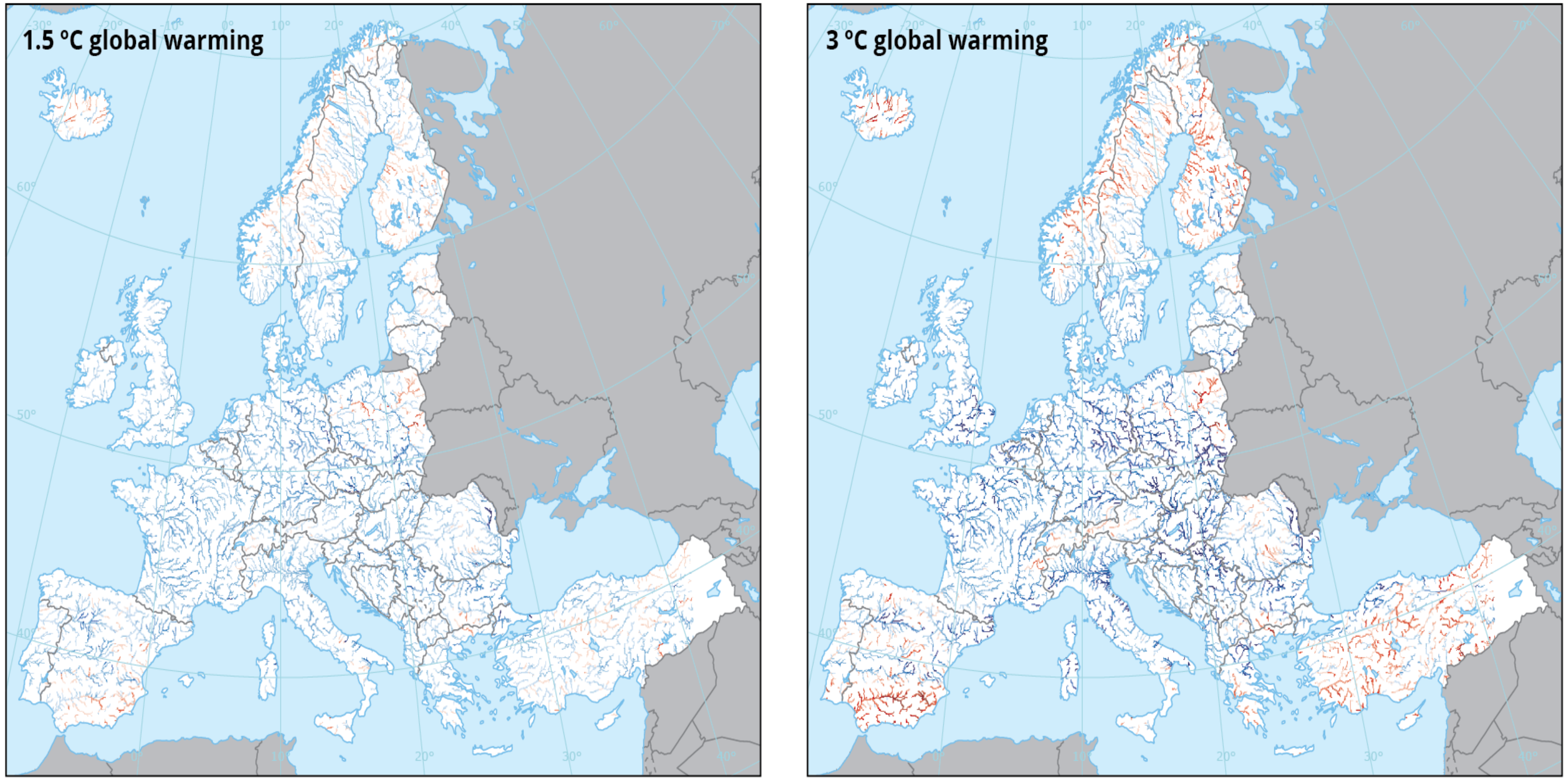
European-scale flood-drivers and projections (Baltic States)



Kemter et al. (2020)

Q100 floods are projected to increase in most European regions



Projected change in maximum 100-year daily river discharge for two global warming levels

European Environment Agency. (2021)

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