European Geosciences Union
General Assembly 2021
Online | 19-30 April 2021

vEGU21: Gather Online

Recent spatio-temporal dynamics of floods of record across Europe

Fabio Arletti[1], **Simone Persiano**[1], **Miriam Bertola**[2], **Juraj Parajka**[2], **Günter Blöschl**[2], **Attilio Castellarin**[1]

[1] DICAM - University of Bologna, Bologna, Italy

[2] Institute of Hydraulic Engineering and Water Resources Management, Vienna University of Technology, Vienna, Austria

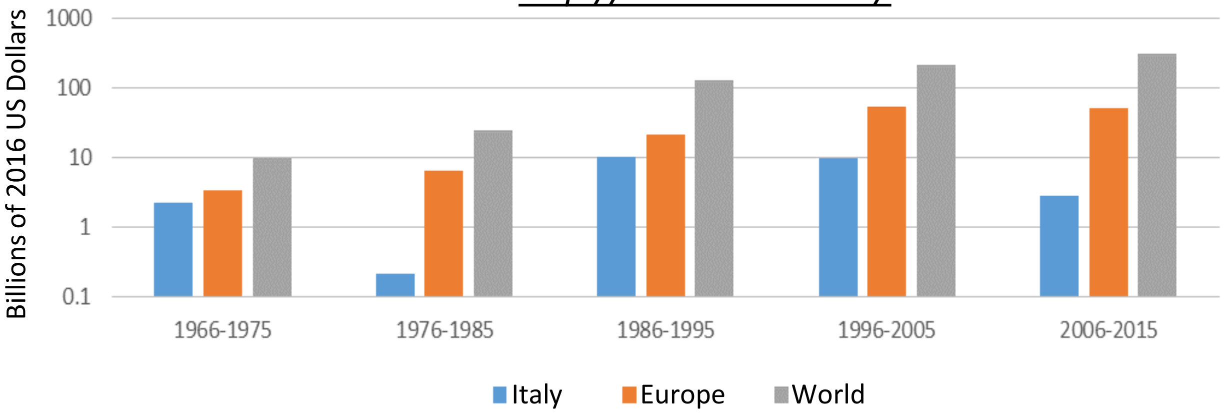
Presenting Author: **Attilio Castellarin**
DICAM - University of Bologna, Bologna, Italy

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

Motivation

Steady increase of economic losses and social consequences caused by flood events in Europe

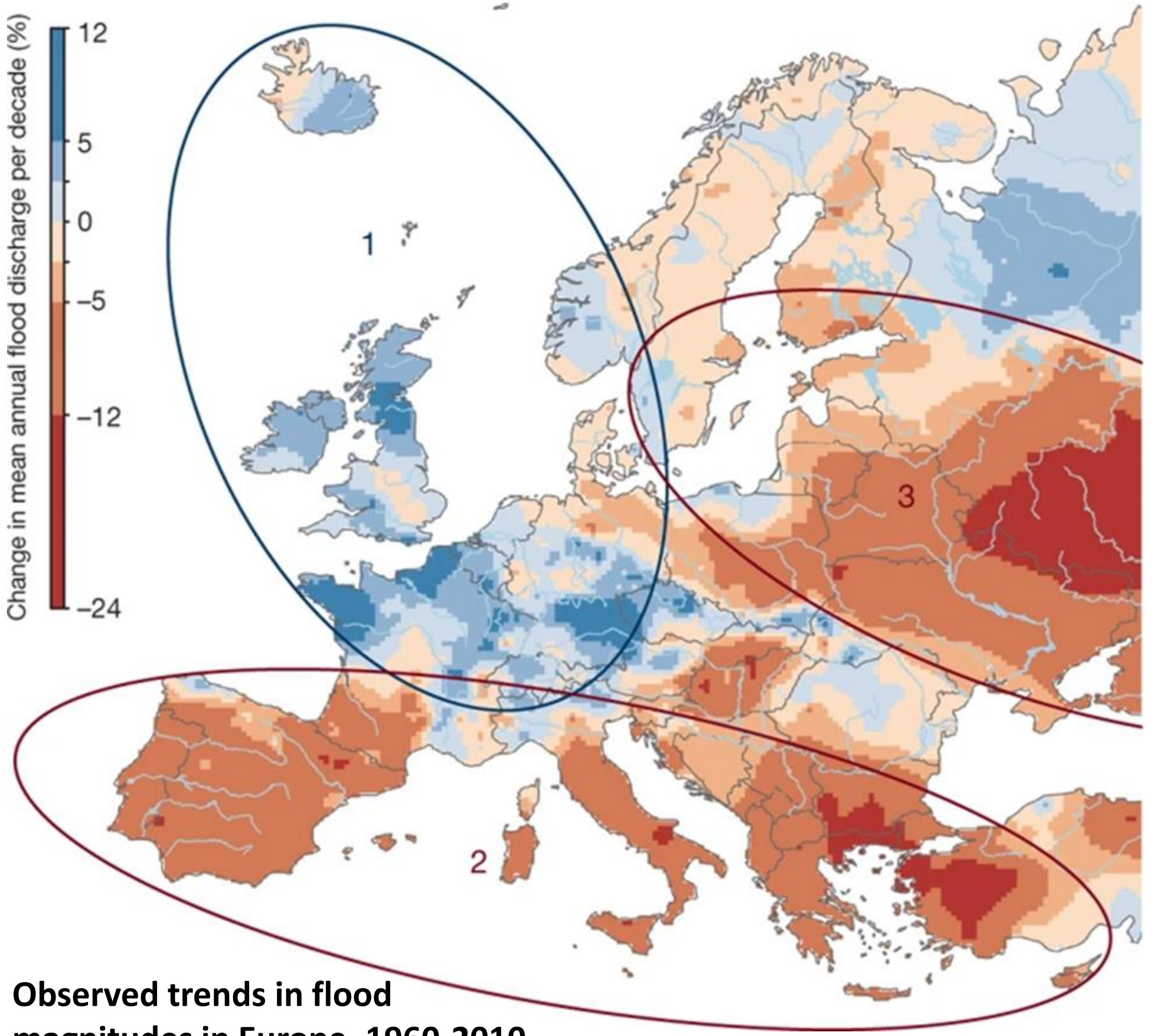
Data source: *http://www.emdat.be/*



Scientific community is making an effort to better understand **recent flood dynamics** and their evolution in space and time.

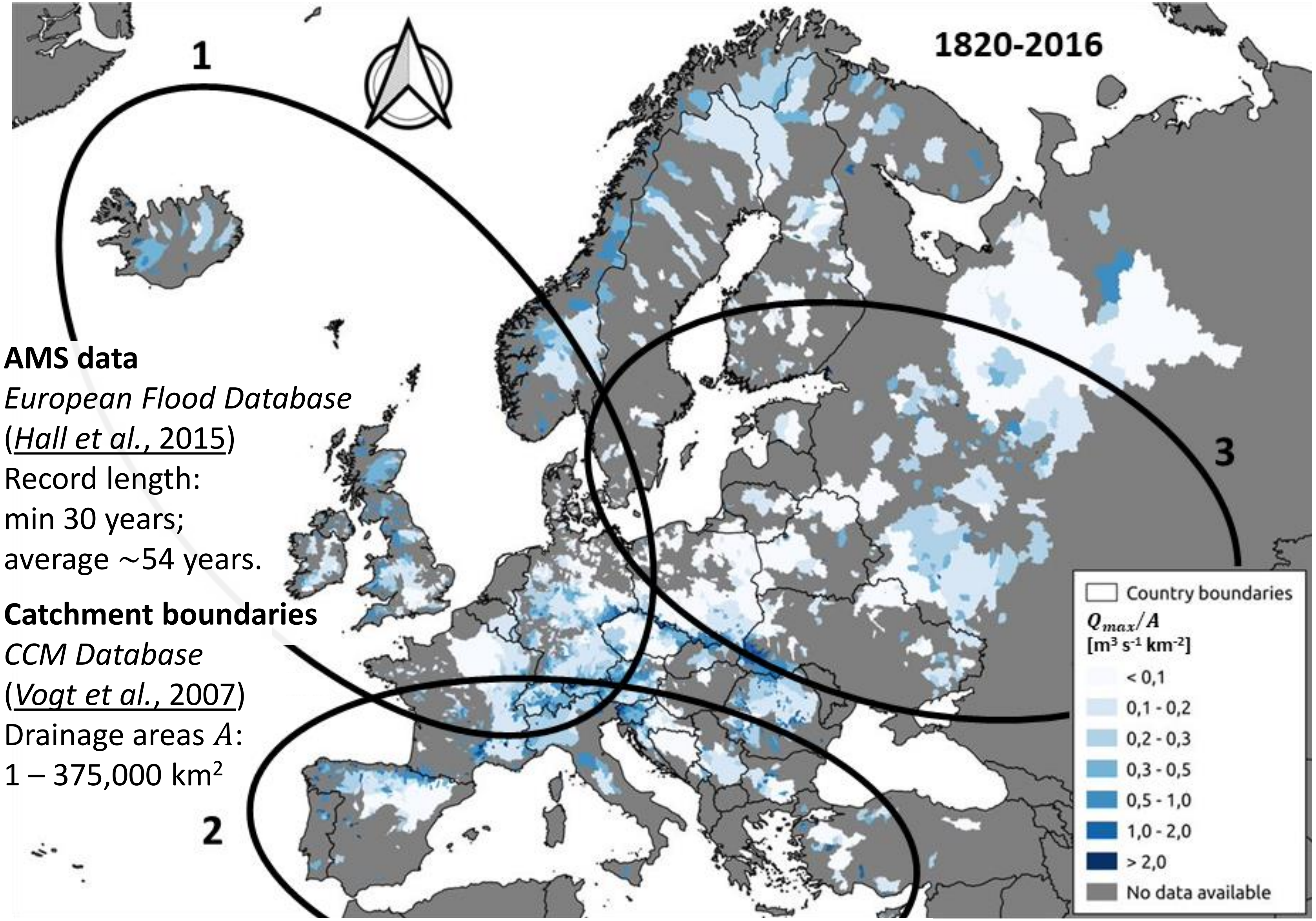
Observed river flood discharges in the past five decades (1960-2010) in Europe

- *Blöschl et al.* (2017, *Science*): clear patterns of change in **flood timing**
- *Blöschl et al.* (2019, *Nature*): significant changes in **flood magnitudes**



Observed trends in flood magnitudes in Europe, 1960-2010.
Source: *Blöschl et al.* (2019, *Nature*)

Aims and dataset



AMS data
European Flood Database
(*Hall et al.*, 2015)
Record length:
min 30 years;
average ~54 years.

Catchment boundaries
CCM Database
(*Vogt et al.*, 2007)
Drainage areas A:
1 – 375,000 km^2

Aim: to analyze the **spatial** and **temporal** variability of the **specific flood of record**

$$\textbf{SFOR} = Q_{max}/A$$

for a dataset of Annual Maximum Series (AMS) of peak flow discharges observed in **1820-2016** for **3413 catchments**

Spatial dynamics

- **1** - Northwestern Europe
- **2** - Southern Europe
- **3** - Eastern Europe

Temporal dynamics

- Overall period (**1820-2016**)
- Sub-period **1957-1986**
- Sub-period **1987-2016**

Analyses in terms of:

CLICK ON THE BUTTONS BELOW

SFOR and catchment area

Changes in SFOR in the last decades

Non-stationarity with theory of records

Atlas of interpolated SFOR across Europe

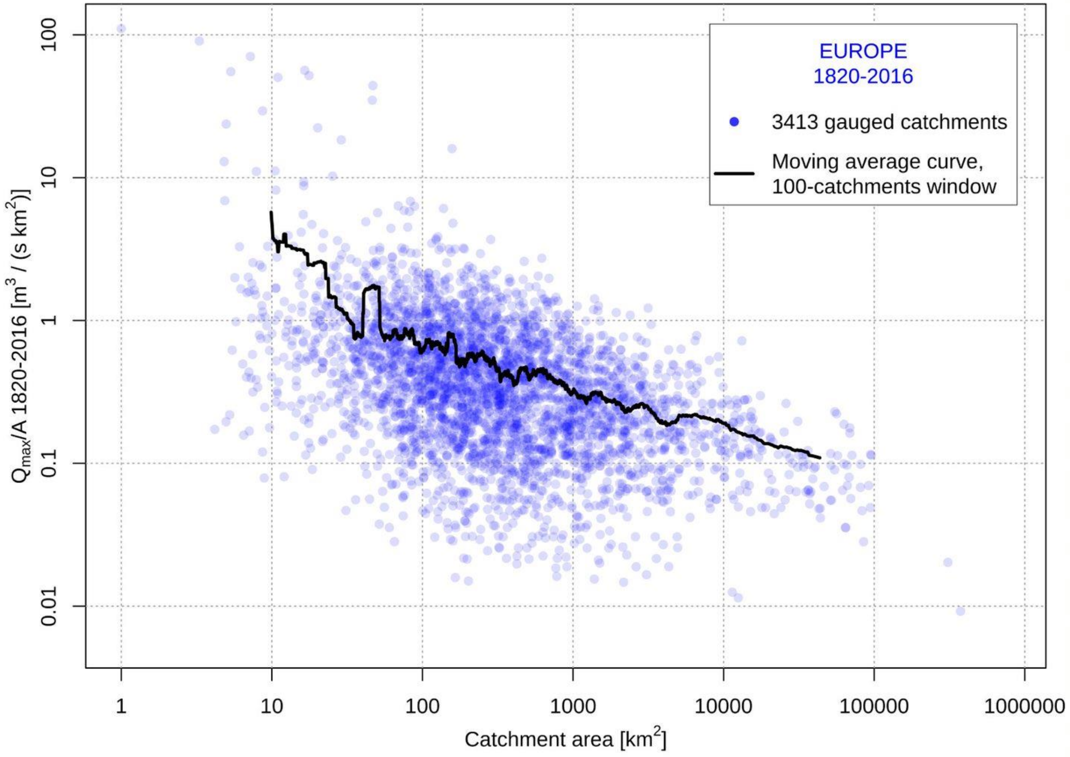
SFOR and catchment area

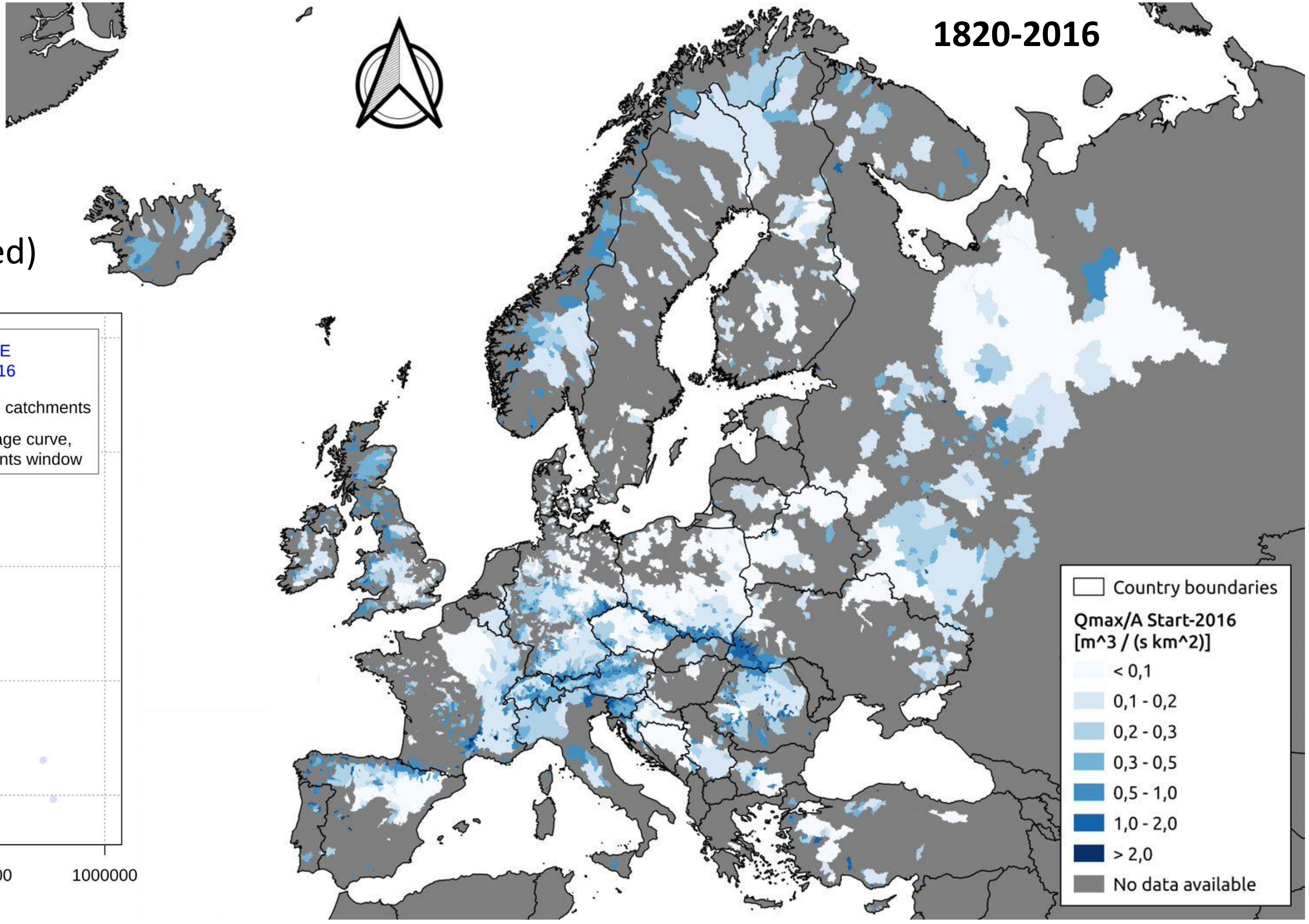
Spatial and temporal variability of the

SFOR (Specific Flood Of Record) $\frac{Q_{max}}{A}$

1820-2016 | 1957-1986 | 1987-2016

SFOR decreases with increasing A (as expected)



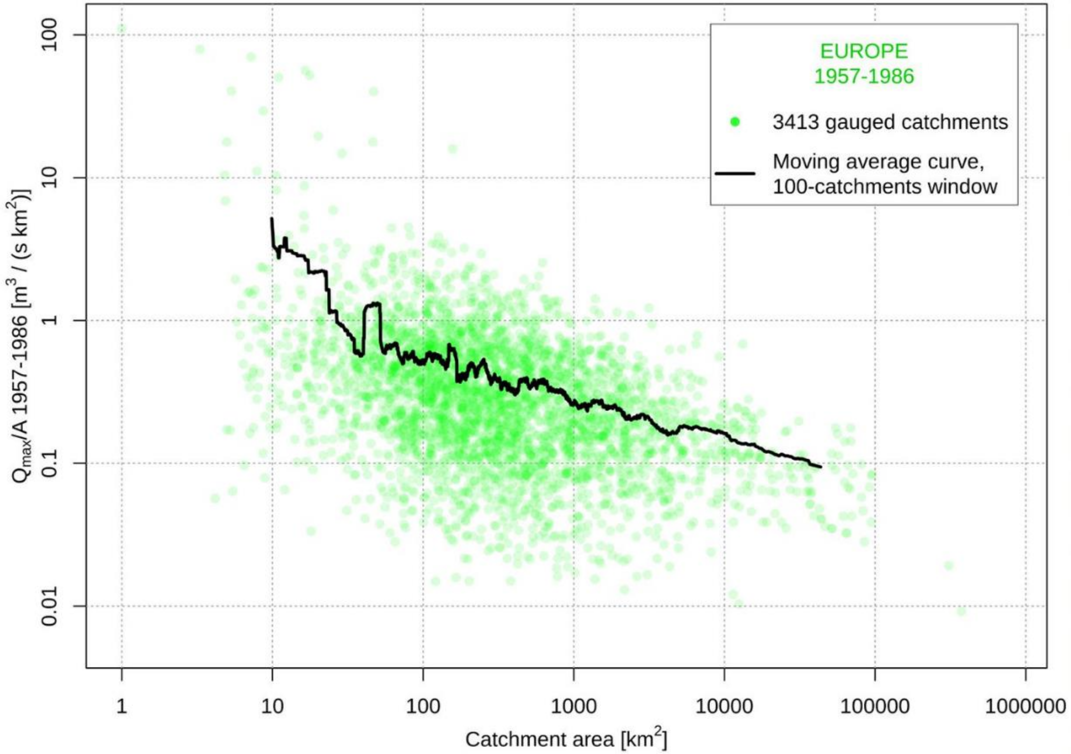


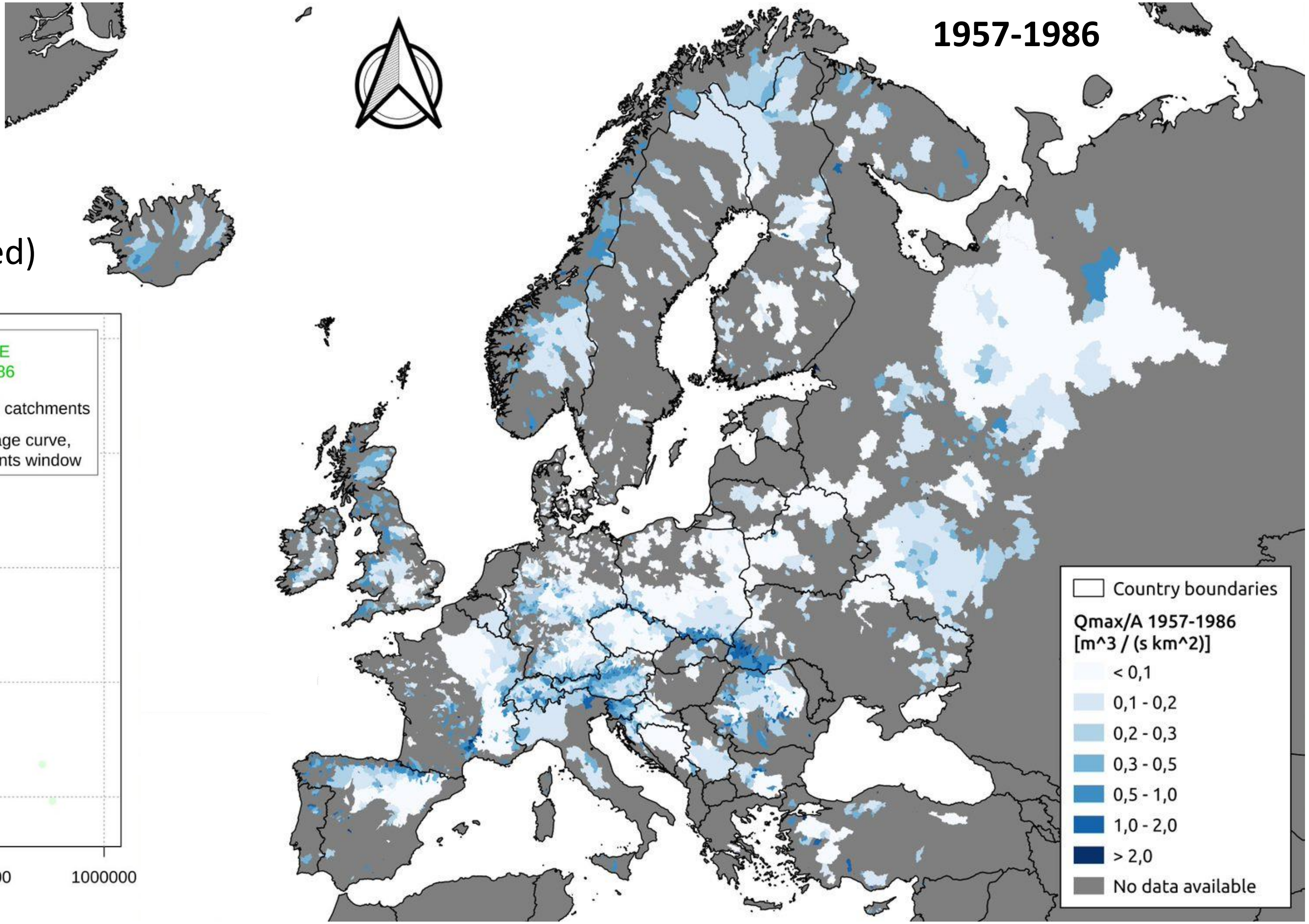
SFOR and catchment area

Spatial and temporal variability of the SFOR (Specific Flood Of Record) $\frac{Q_{max}}{A}$

1820-2016 | **1957-1986** | 1987-2016

SFOR decreases with increasing A (as expected)





SFOR and catchment area

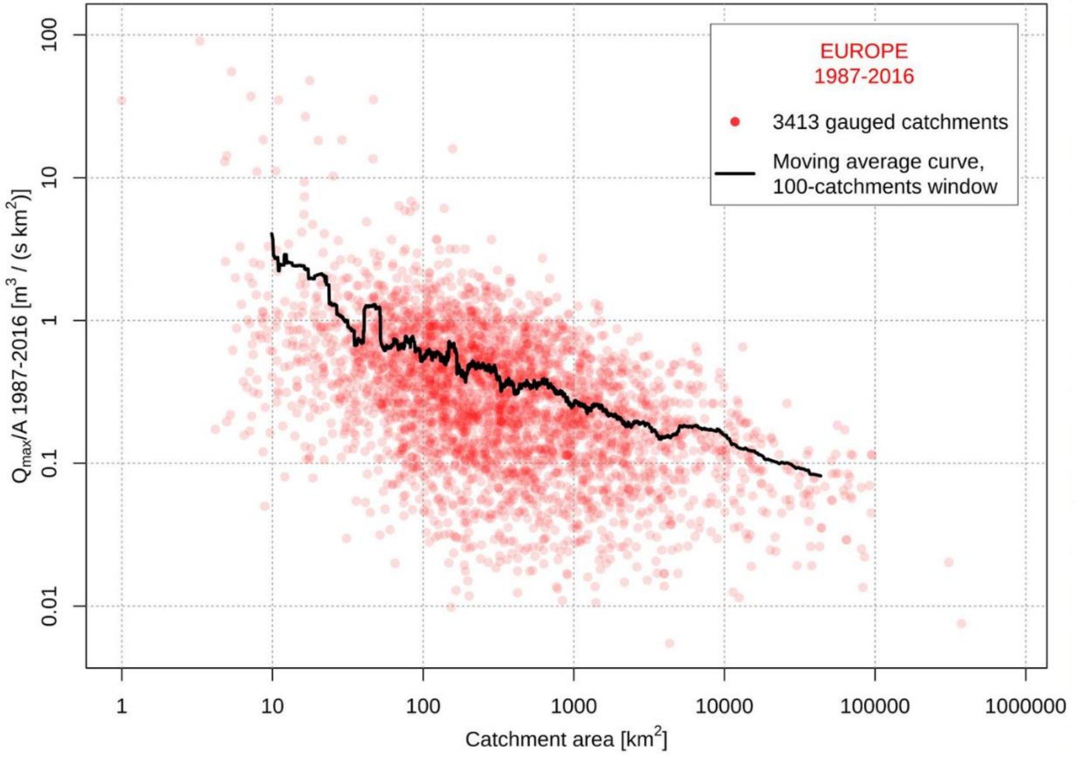
Back to Aims and dataset

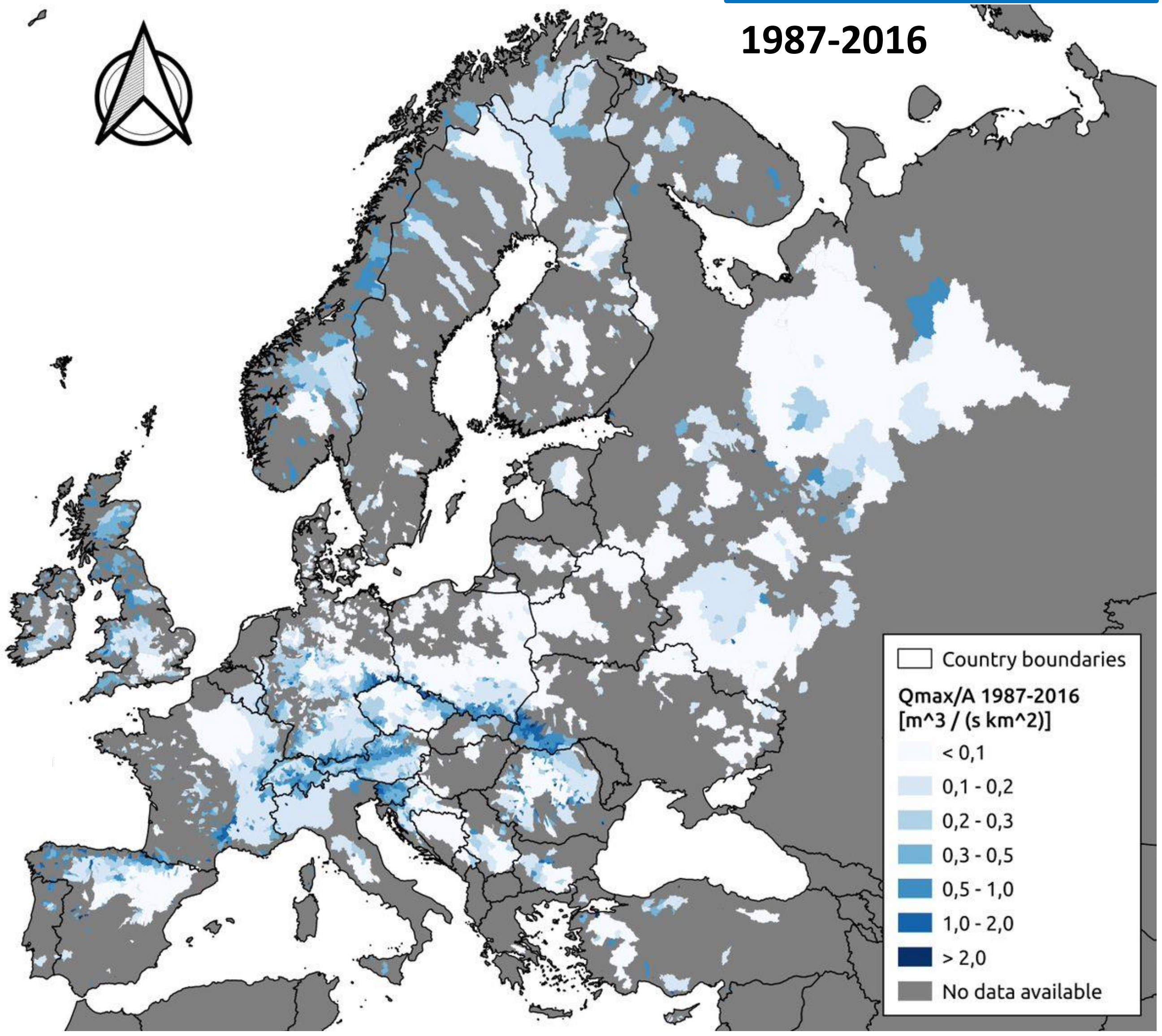
Go to Conclusions

Spatial and temporal variability of the SFOR (Specific Flood Of Record) $\frac{Q_{max}}{A}$

1820-2016 | 1957-1986 | **1987-2016**

SFOR decreases with increasing A (as expected)

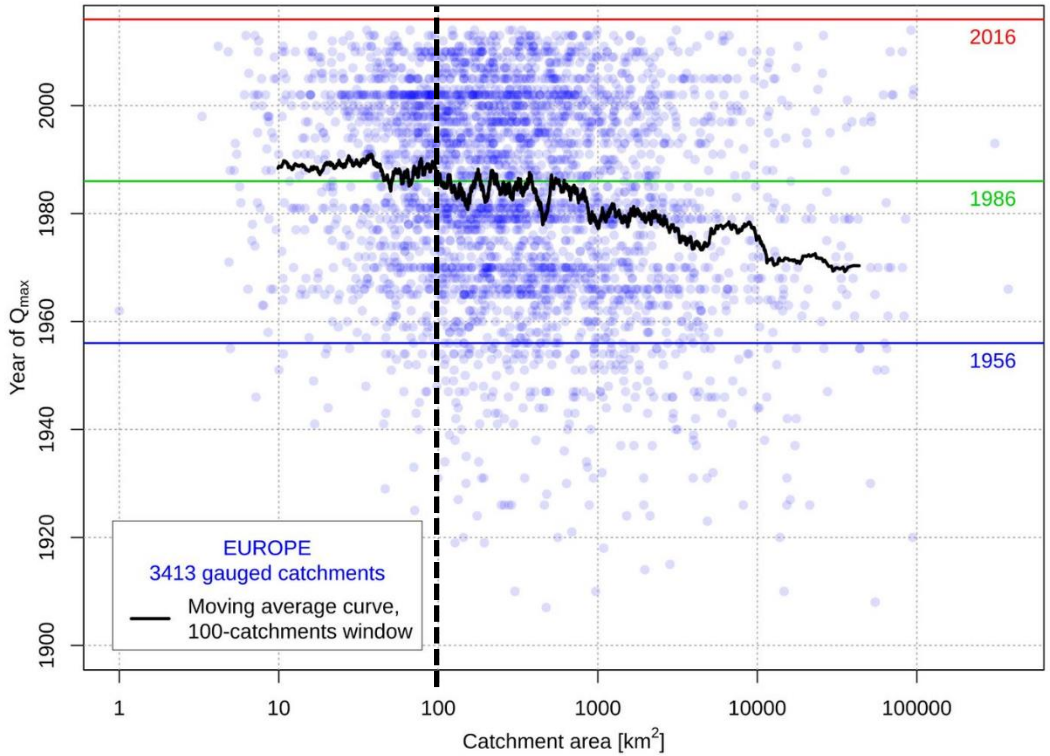


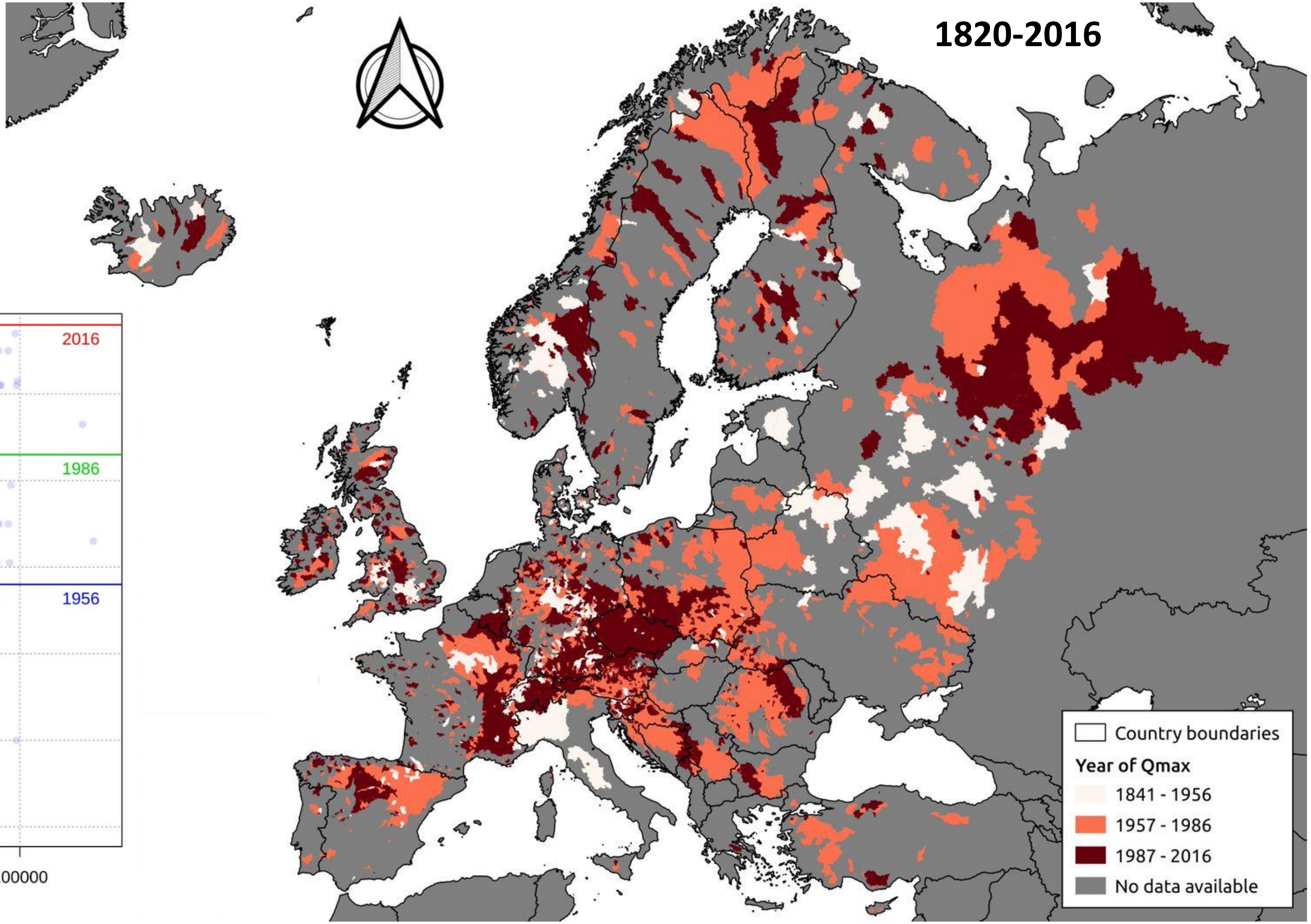


Changes in SFOR values over the last 30-60 years

SFOR values are mainly concentrated in the **last 30 years** (i.e. 1987-2016), especially in the area of **Central Europe**

Smaller catchments show on average a more recent occurrence of the record flood





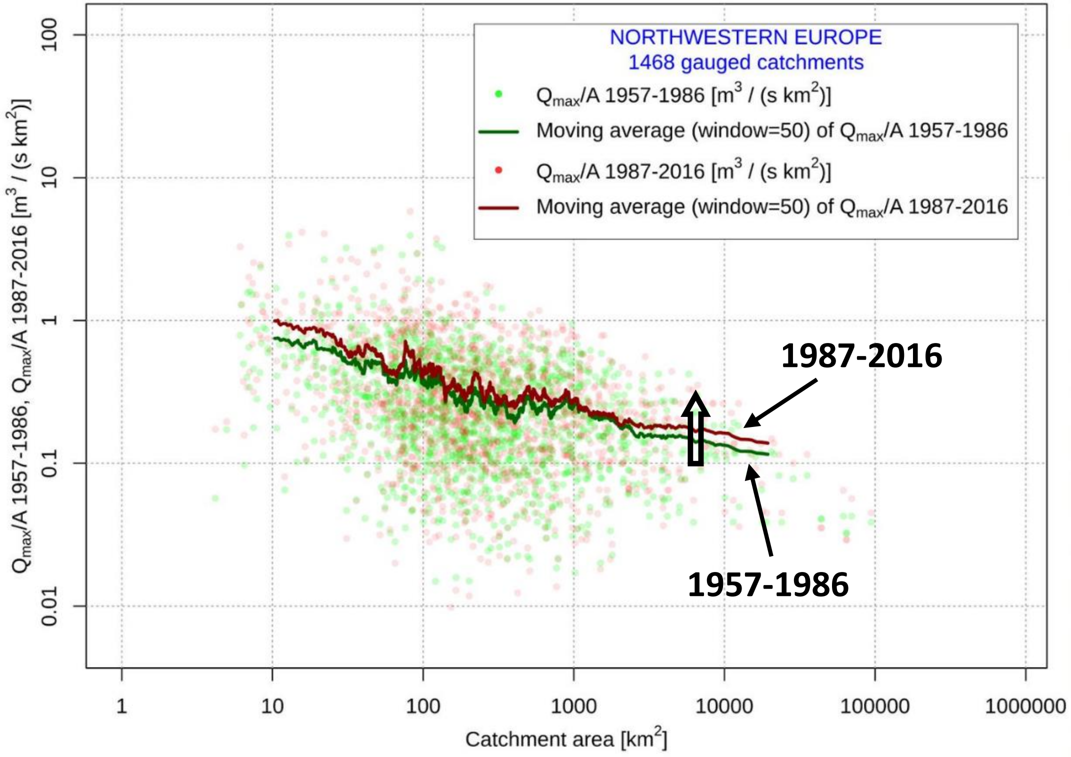
Changes in SFOR values over the last 30-60 years

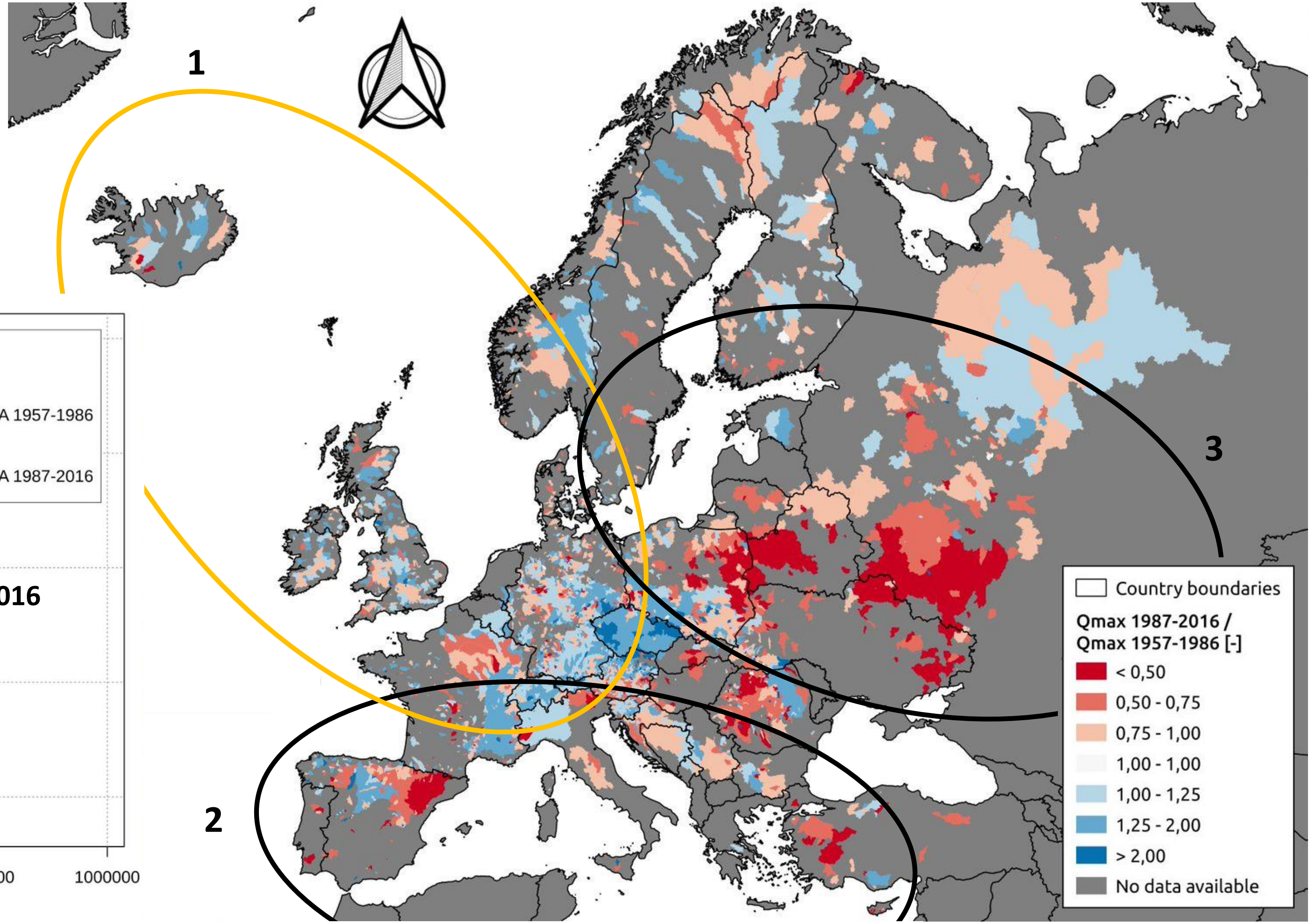
SFOR values changes from **1957-1986** to **1987-2016**

$$\frac{Q_{max\,1987-2016}}{Q_{max\,1957-1986}}$$

1 - Northwestern Europe

Generalized increase





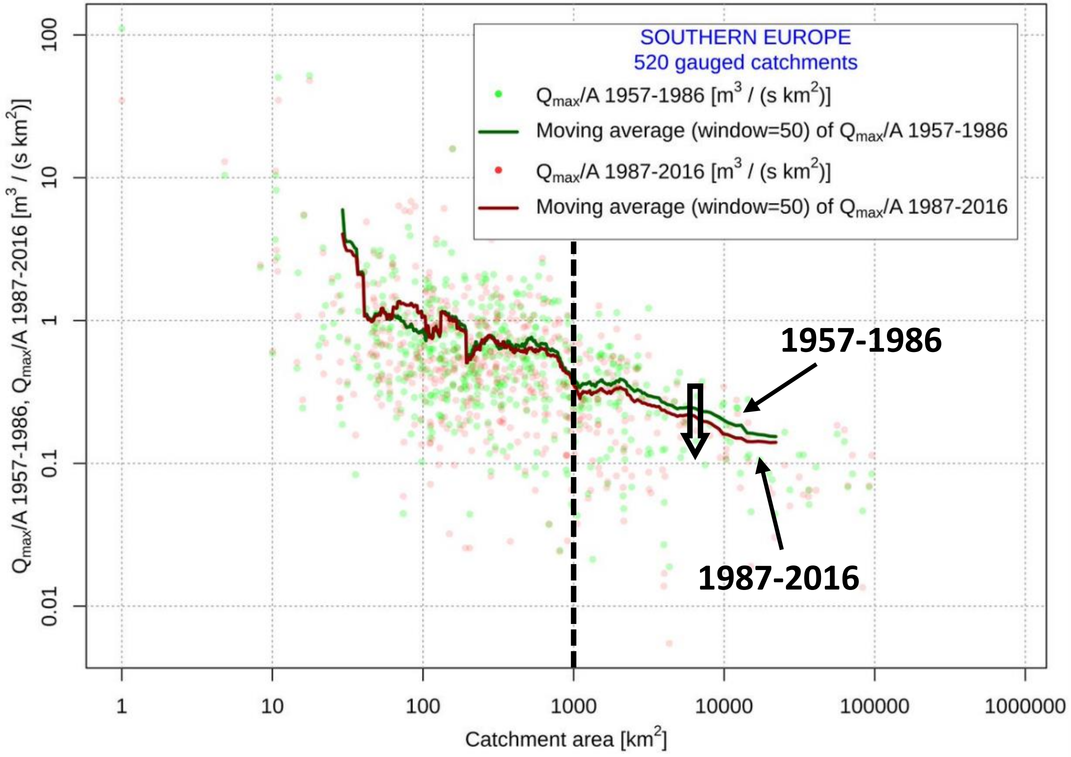
Changes in SFOR values over the last 30-60 years

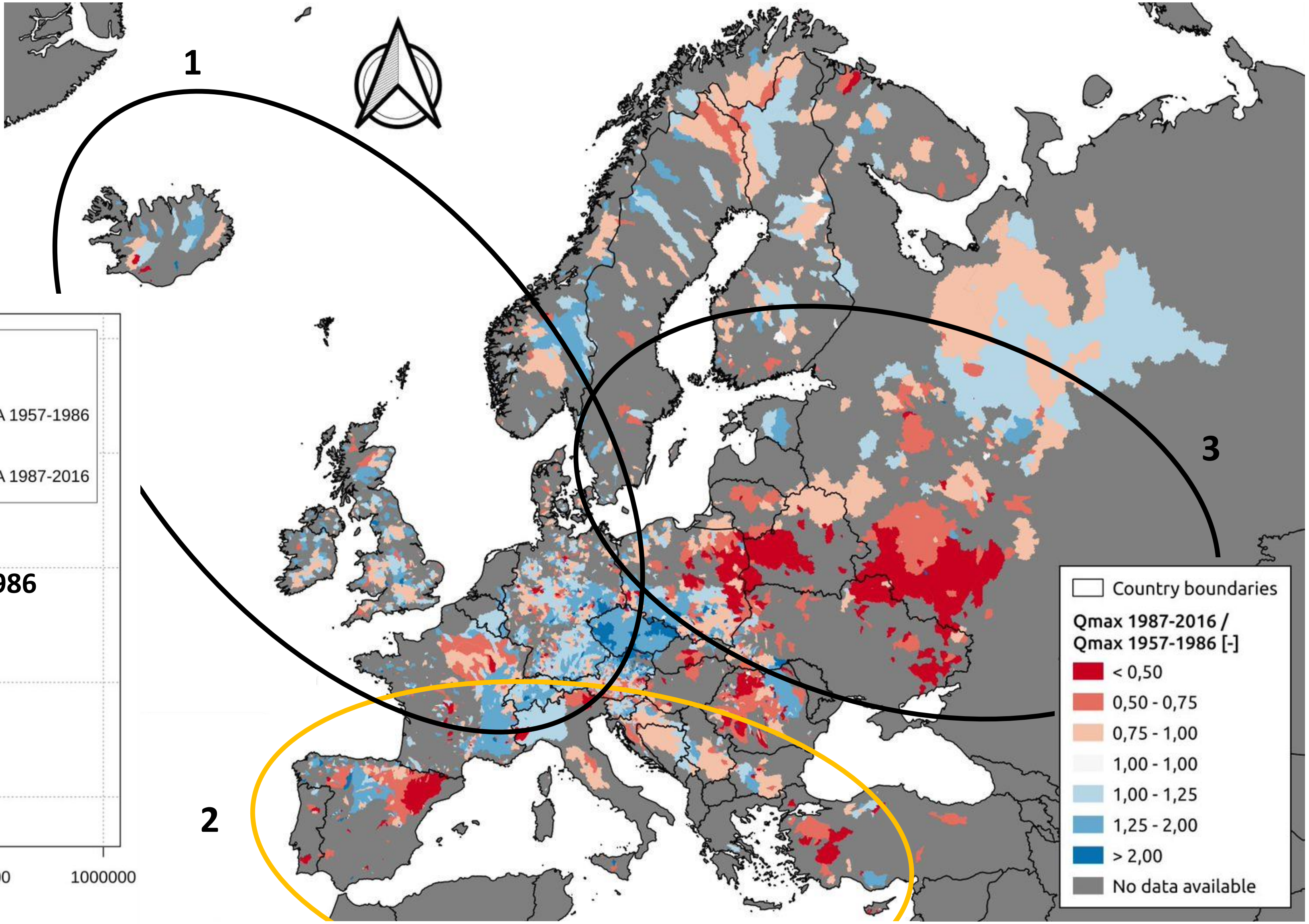
SFOR values changes from **1957-1986** to **1987-2016**

$$\frac{Q_{max\ 1987-2016}}{Q_{max\ 1957-1986}}$$

2 - Southern Europe

Generalized decrease (for A > 1000 km²)





Changes in SFOR values over the last 30-60 years

Back to Aims and dataset

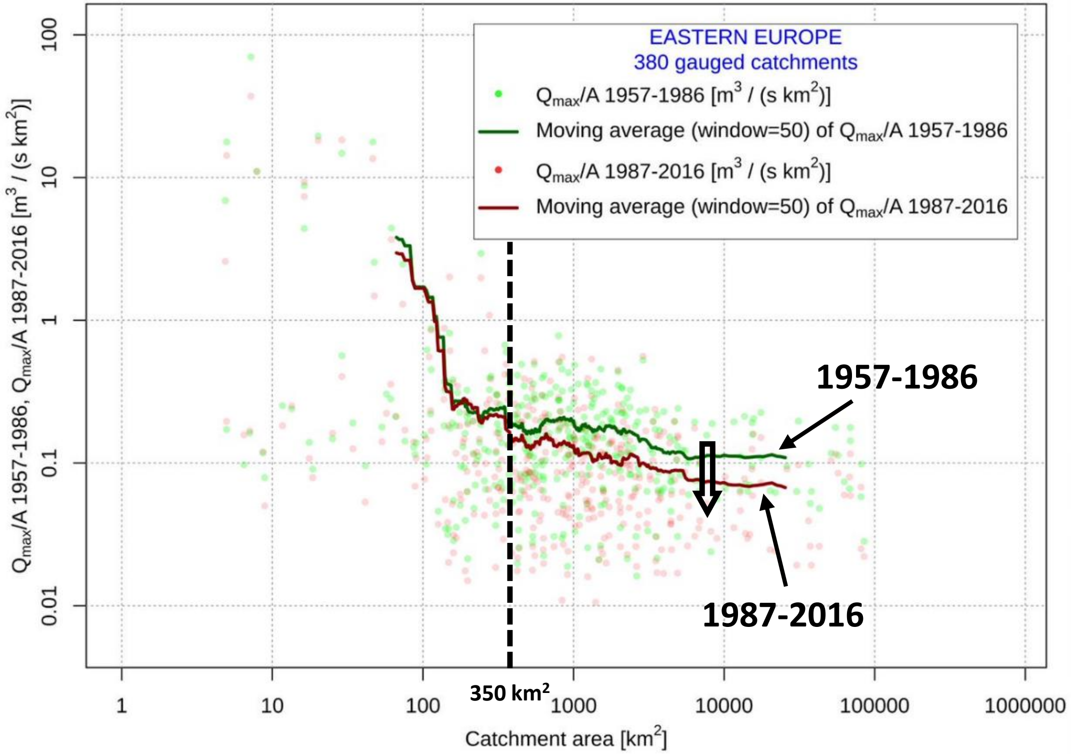
Go to Conclusions

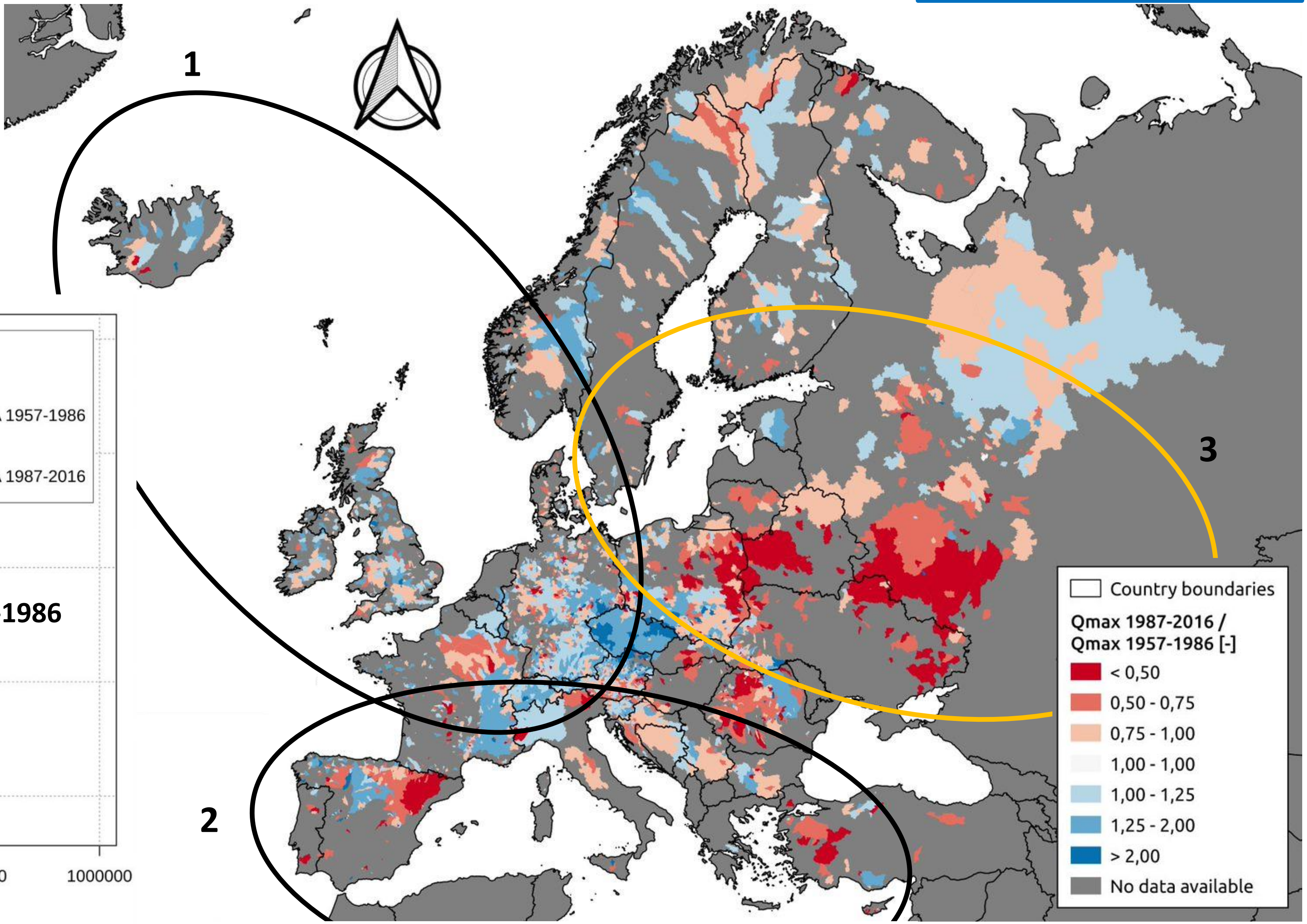
SFOR values changes from **1957-1986** to **1987-2016**

$$\frac{Q_{max\,1987-2016}}{Q_{max\,1957-1986}}$$

3 - Eastern Europe

Generalized decrease (for A > 350 km²)





Looking for non-stationarity: theory of record-breaking processes

Identification of non-stationarity with the

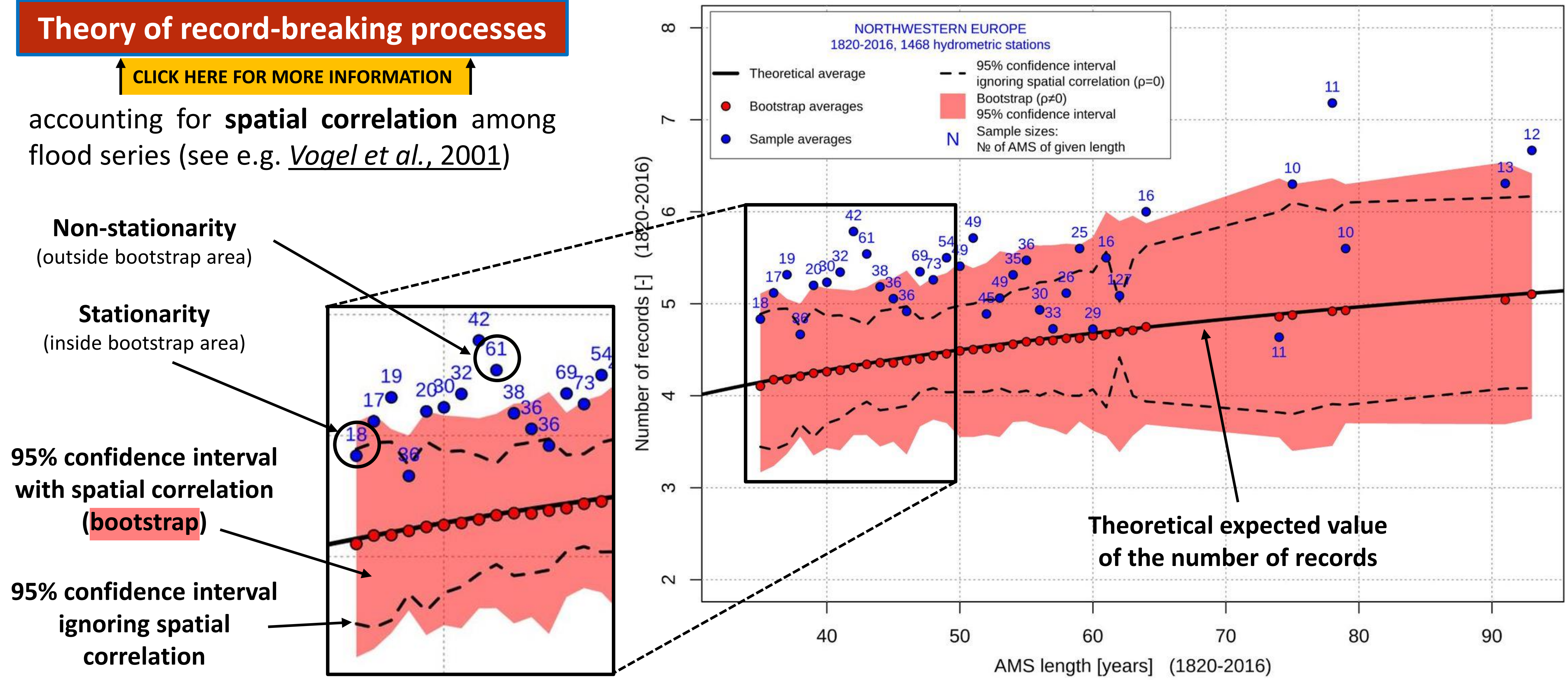
Theory of record-breaking processes

CLICK HERE FOR MORE INFORMATION

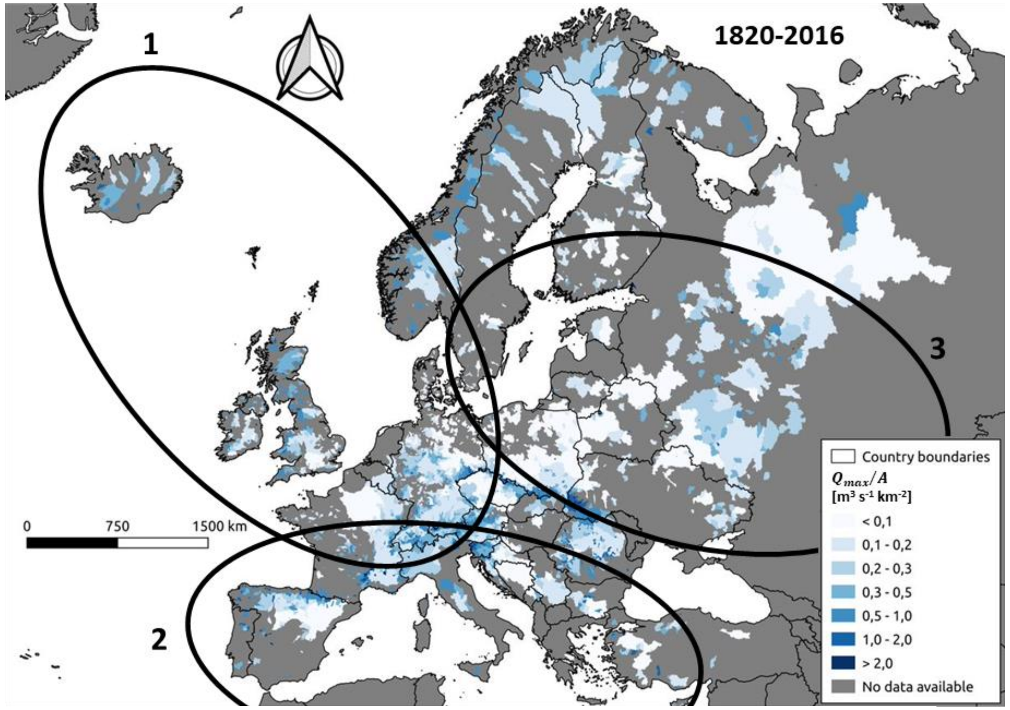
accounting for **spatial correlation** among flood series (see e.g. *Vogel et al.*, 2001)

1 - Northwestern Europe

Record length classes associated with at least 10 stations



Looking for non-stationarity: theory of record-breaking processes



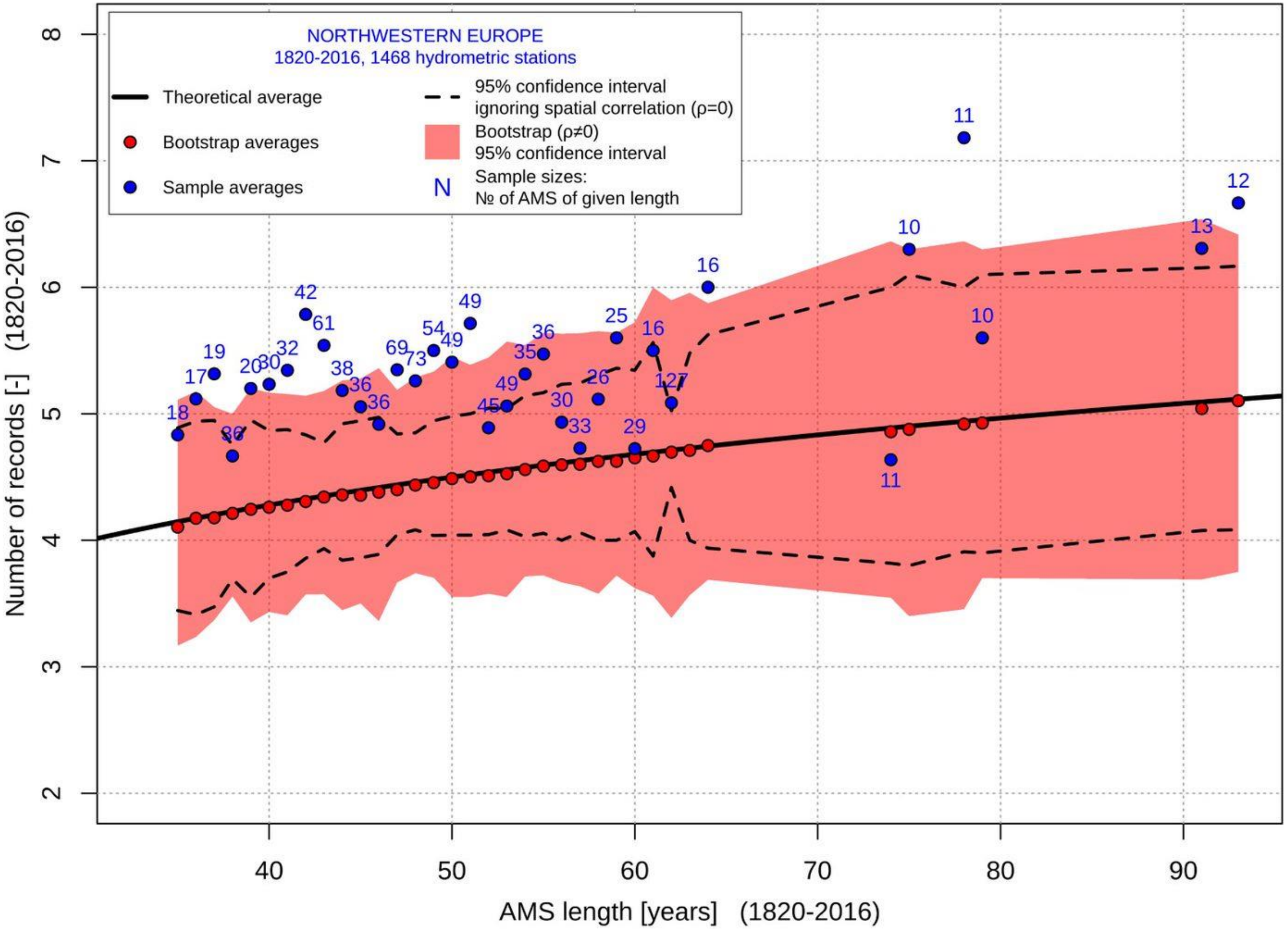
1 - Northwestern Europe

1468 stations

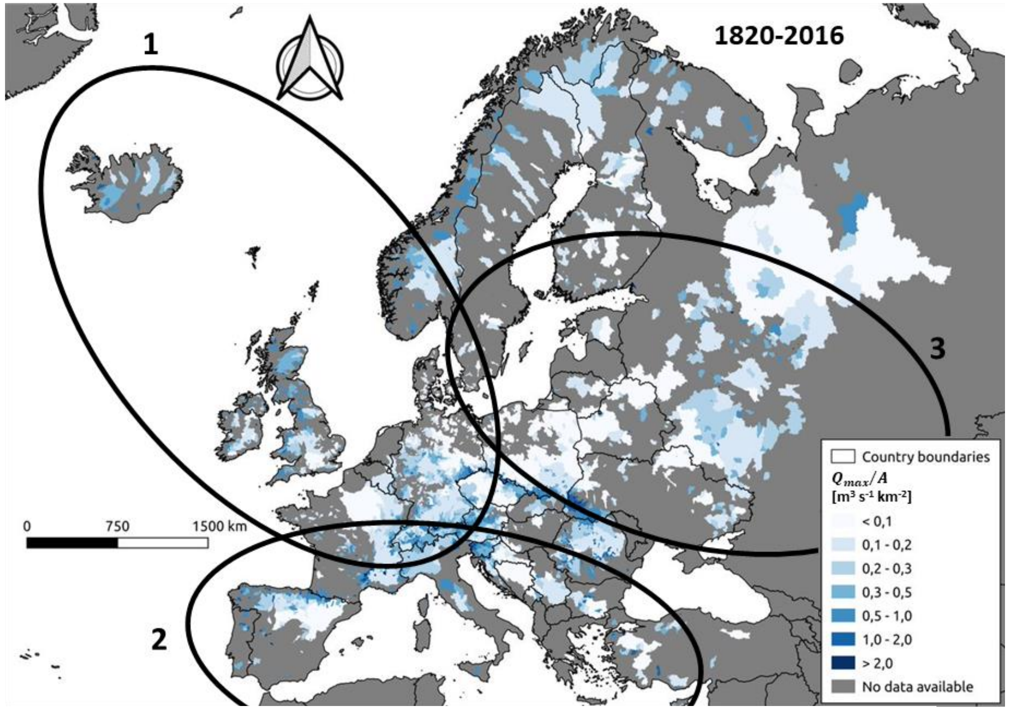
36 classes of record length
14 classes with **positive non-stationarity**

1 - Northwestern Europe

Record length classes associated with at least 10 stations

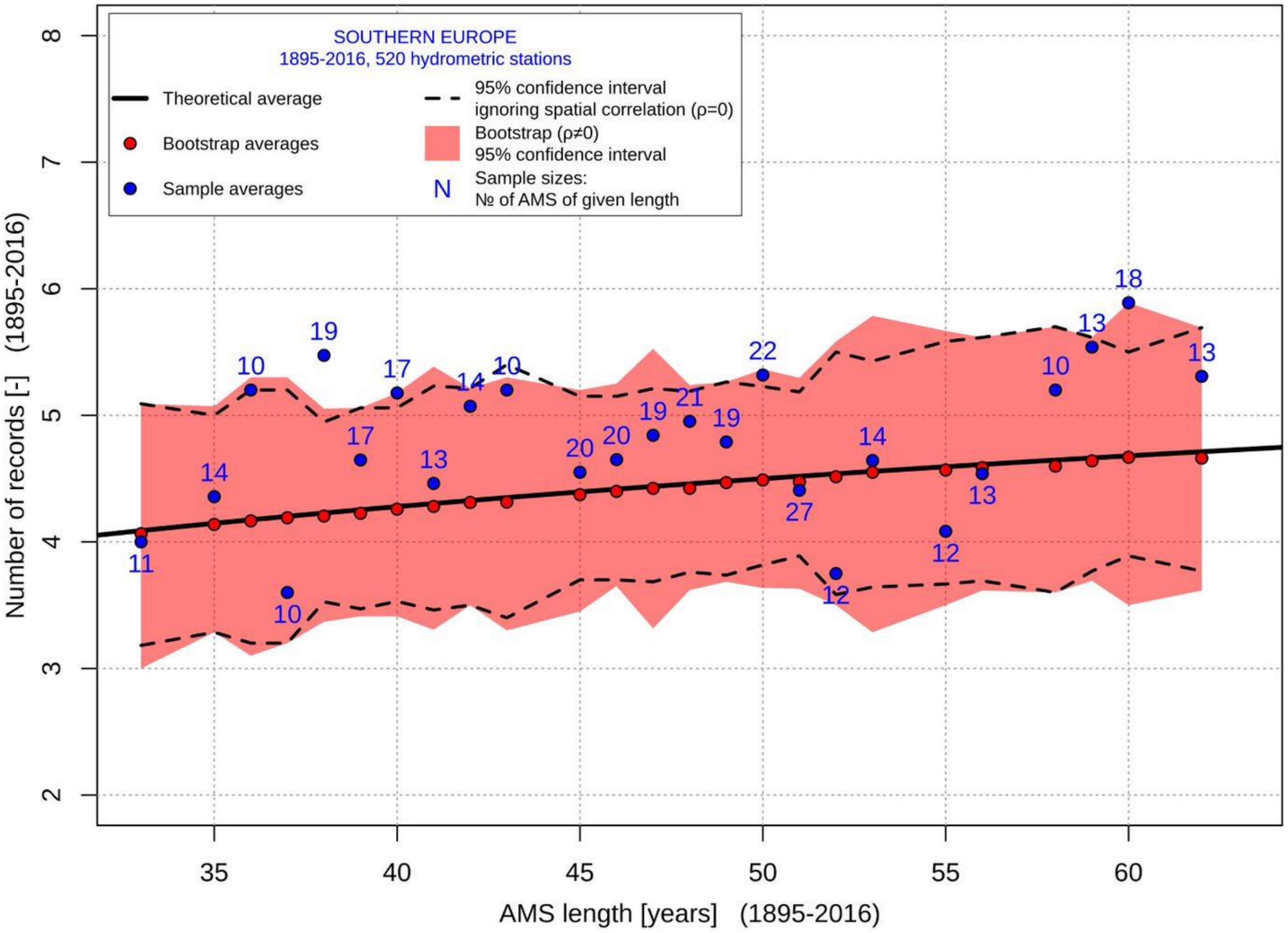


Looking for non-stationarity: theory of record-breaking processes



2 - Southern Europe

Record length classes associated with at least 10 stations



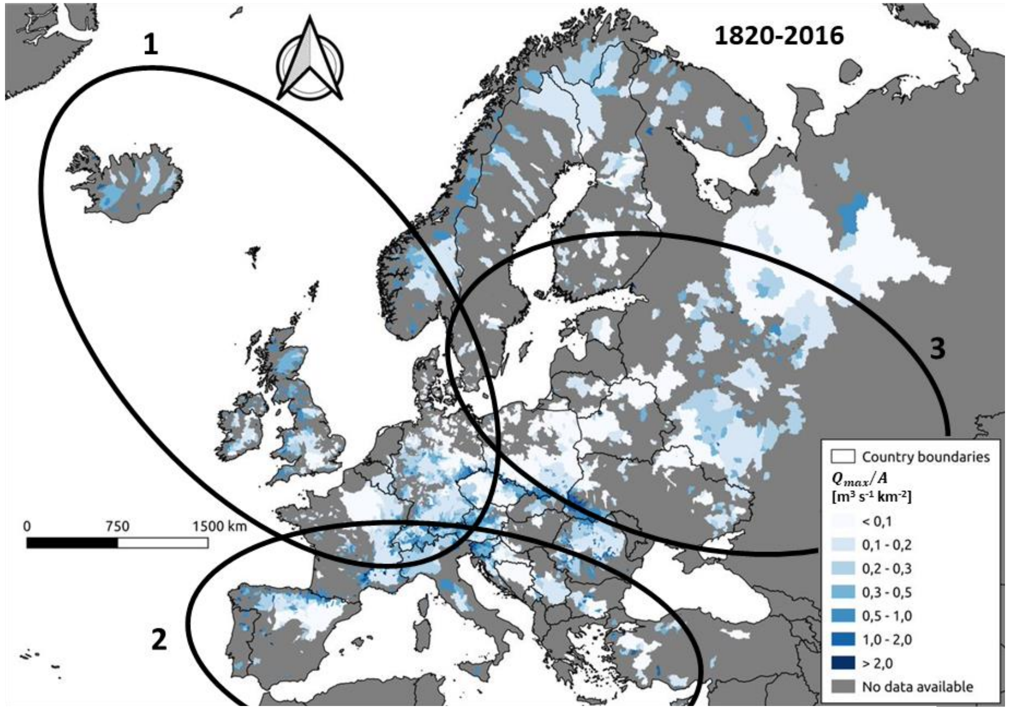
2 - Southern Europe

520 stations

25 classes of record length

3 classes with **positive non-stationarity**

Looking for non-stationarity: theory of record-breaking processes



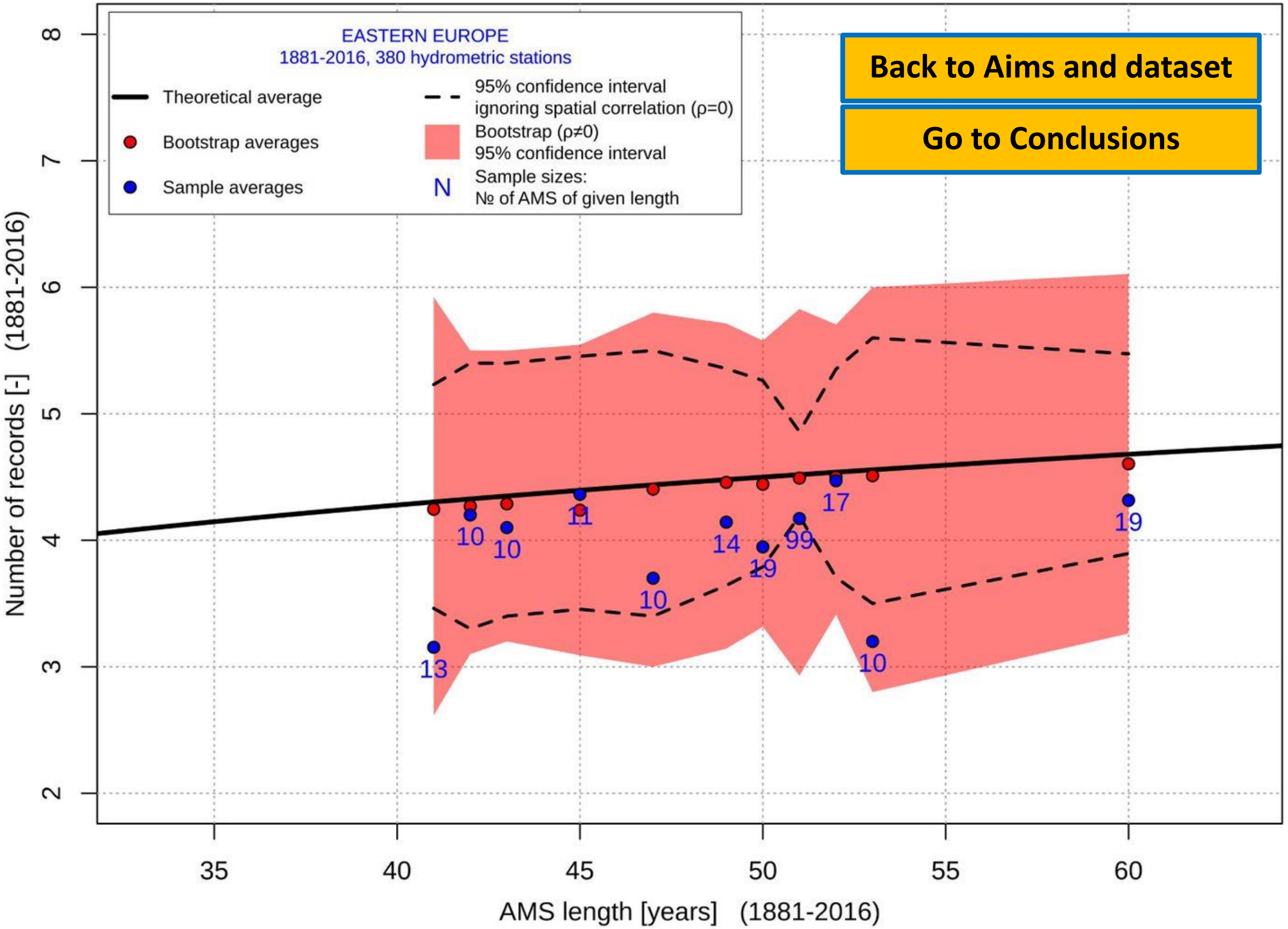
3 - Eastern Europe

380 stations

11 classes of record length
No classes with **non-stationarity**

3 - Eastern Europe

Record length classes associated with at least 10 stations

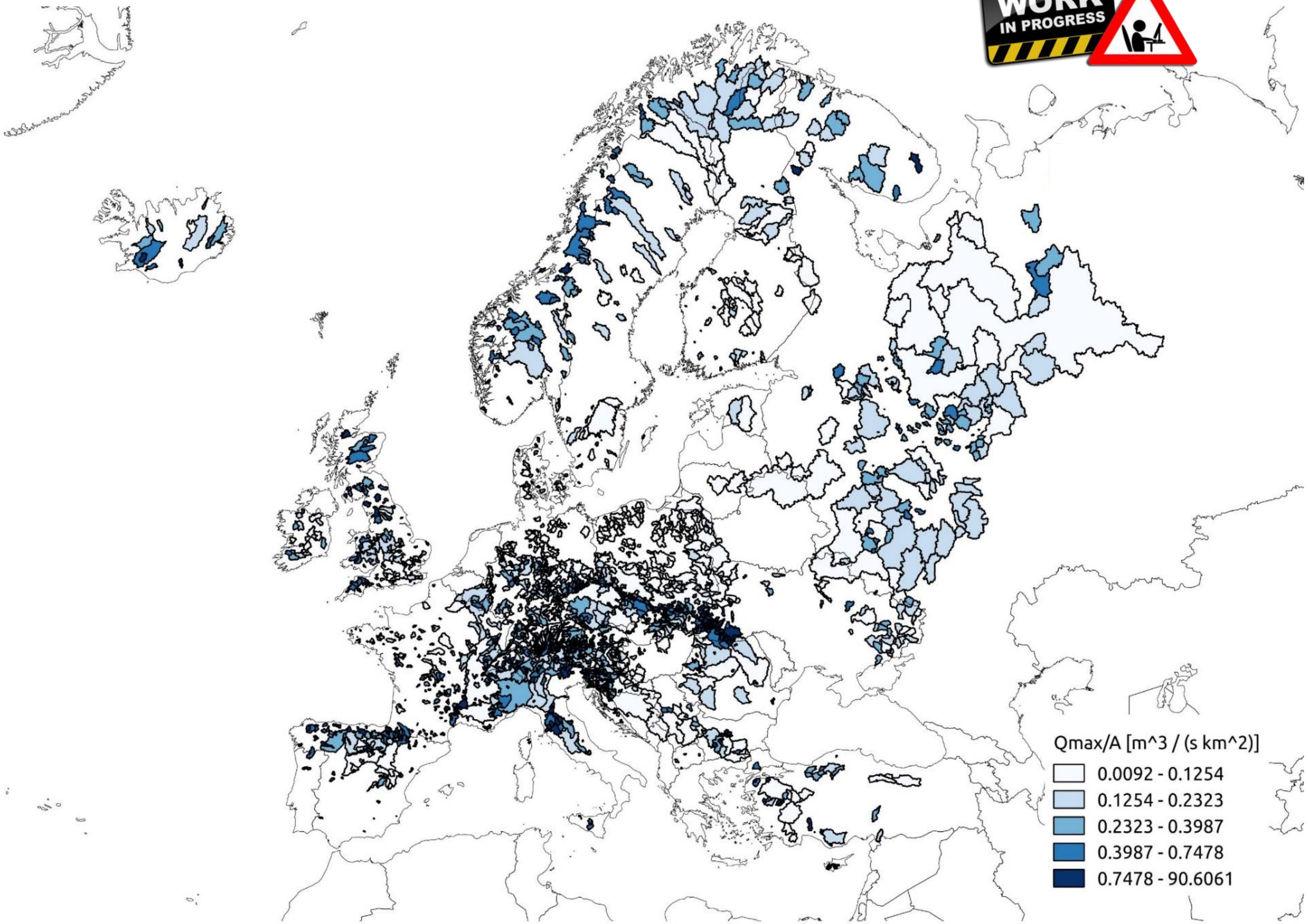


Back to Aims and dataset

Go to Conclusions

Atlas of interpolated SFOR across Europe

Continuous spatial representation of SFOR values



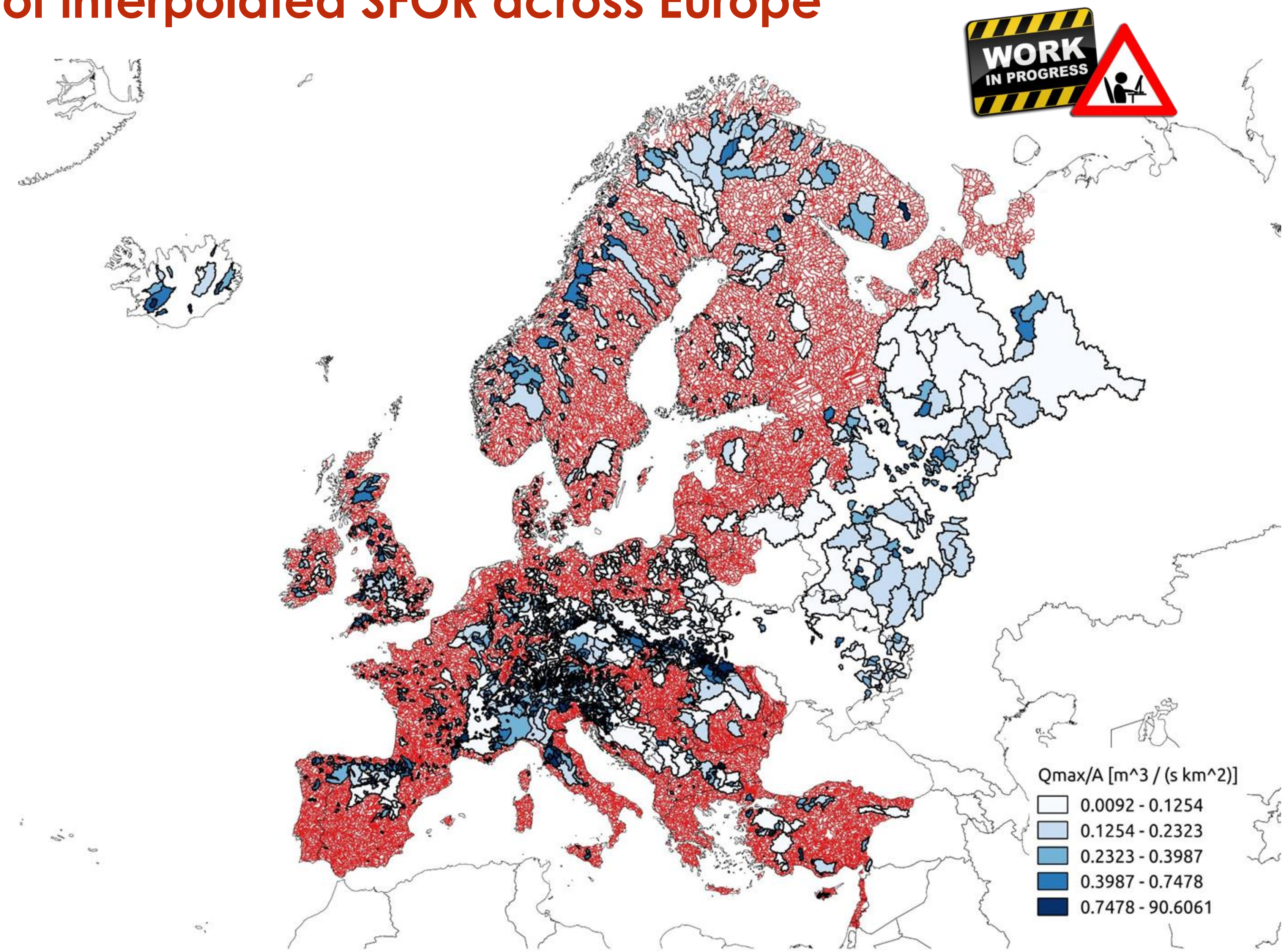
Atlas of interpolated SFOR across Europe

Continuous spatial representation of SFOR values

Interpolation of the 3413 observed SFOR values at **~30 000 elementary catchments** provided by the JRC (Joint Research Centre) of the European Commission.

Top-kriging (*Skøien et al.*, 2006)
Geostatistical procedure
Prediction at ungauged river cross-sections as *linear combinations* of the empirical information collected at *neighbouring* gauging stations:

- ✓ ***drainage area*** as non-point support
- ✓ ***nested structure*** of catchments (stream-network topology)



Atlas of interpolated SFOR across Europe

Back to Aims and dataset

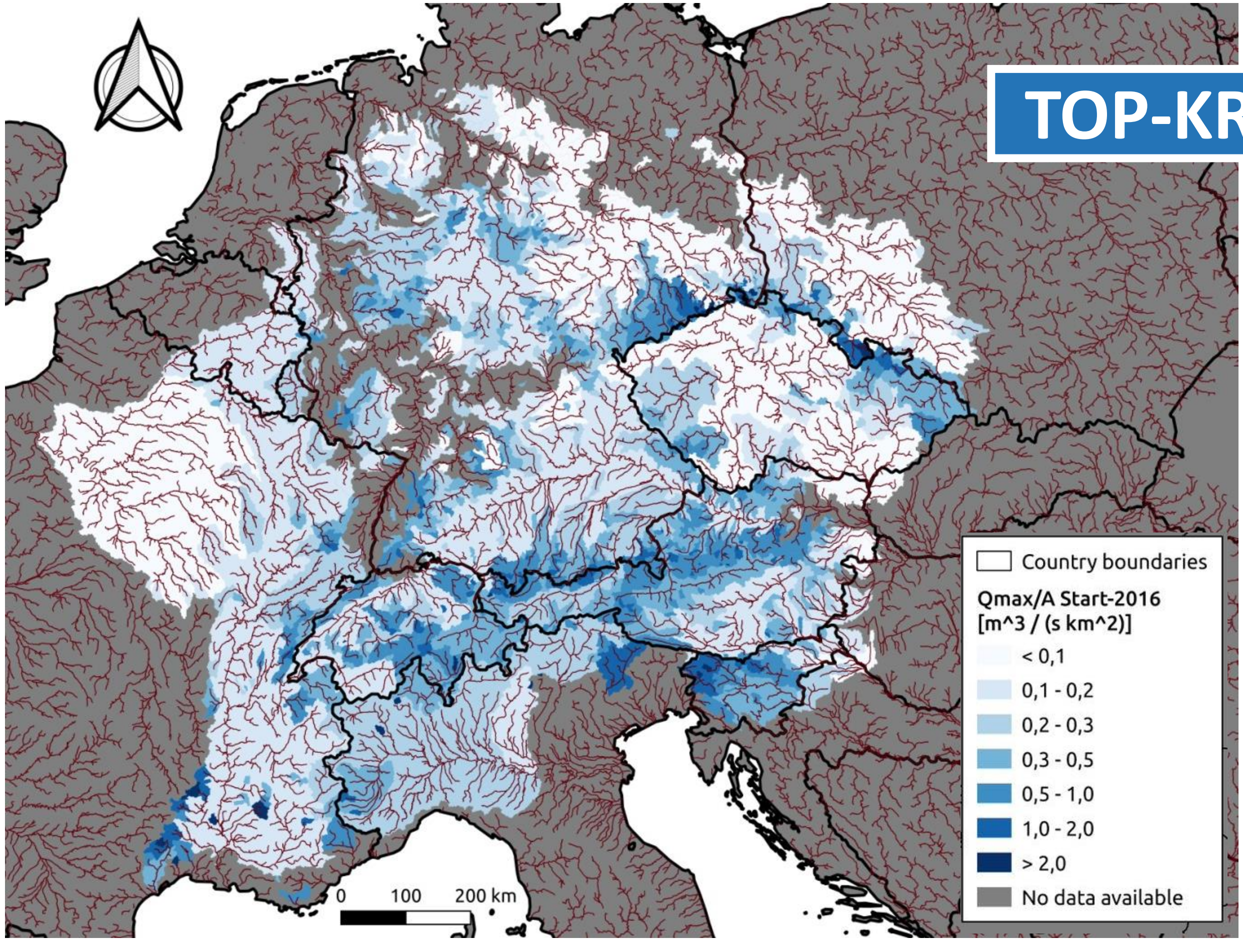
Go to Conclusions

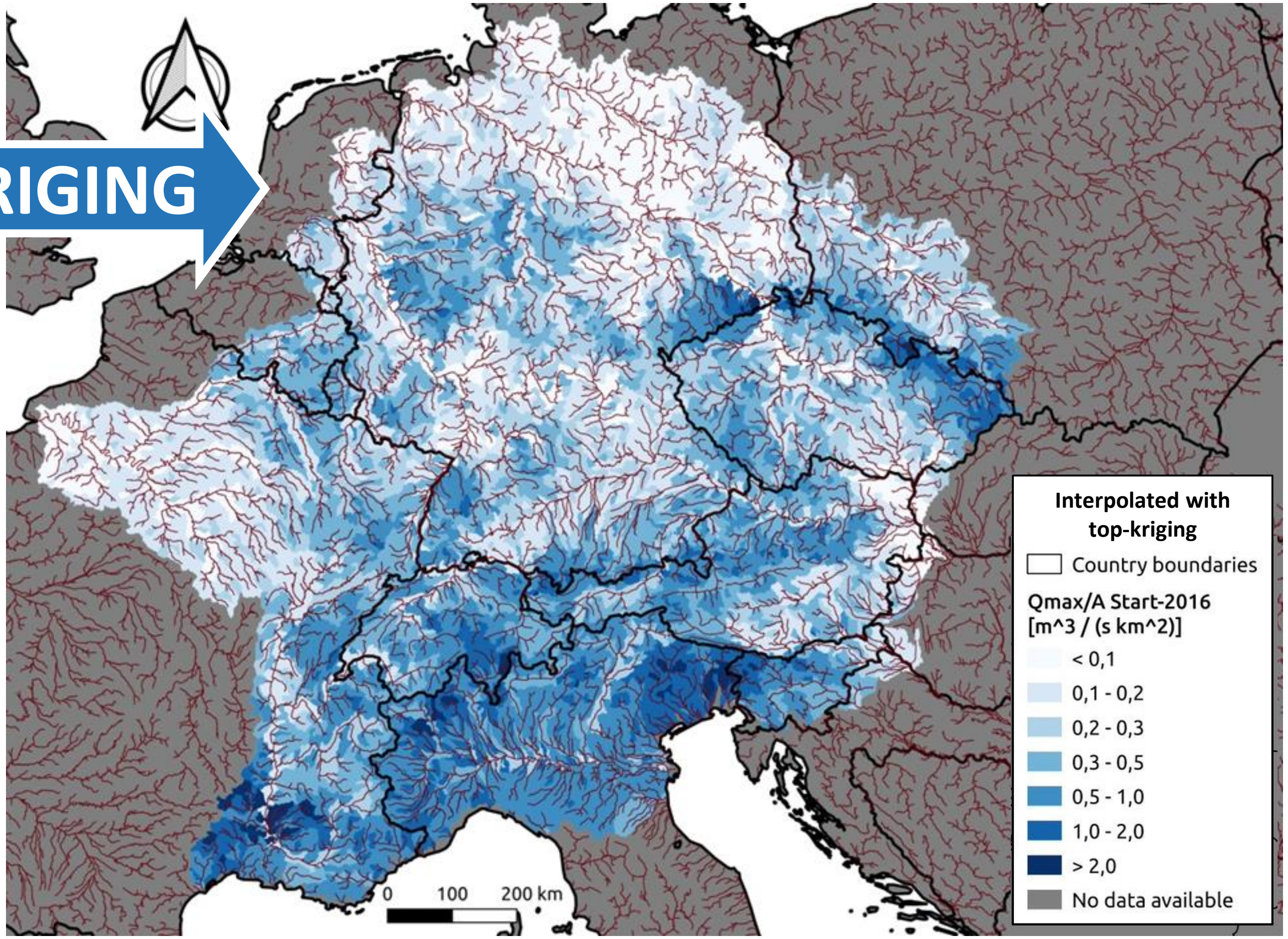
Test for the area of Central Europe

Geostatistical procedure, **Top-kriging** (*Skøien et al.*, 2006)

Hydrological consistency: SFOR increases from downstream to upstream (catchment size)

OBSERVED





PREDICTED

Conclusions

- The dependence of the specific flood of record (SFOR) on drainage area is confirmed across Europe (as expected, SFOR decreases with increasing drainage area).
- Floods of record are mainly concentrated in the last 30 years (i.e. 1987-2016), especially in the area of central Europe. Smaller catchments (A < 100 km^2) show on average a more recent occurrence of the record flood.
- The changes observed in the floods of record over the last 30-60 years are consistent with what observed in previous studies in terms of magnitude (*Blöschl et al., 2019, Nature*): increase in northwestern Europe, decrease in southern and eastern Europe.
- Analyses with the theory of record-breaking processes accounting for spatial correlation: evidence of significant non-stationarity in northwestern Europe, associated with an increase in magnitude (consistent with *Blöschl et al.,* 2019, *Nature*). Less evident changes in the other two macro-regions.
- Atlas of interpolated SFOR across Europe produced by using a geostatistical procedure (e.g. top-kriging) that is hydrologically consistent in terms of downstream-upstream relationship and drainage area size.

Back to Aims and dataset

The end

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

THANK YOU
FOR YOUR ATTENTION

Attilio Castellarin - attilio.castellarin@unibo.it
Simone Persiano - simone.persiano@unibo.it

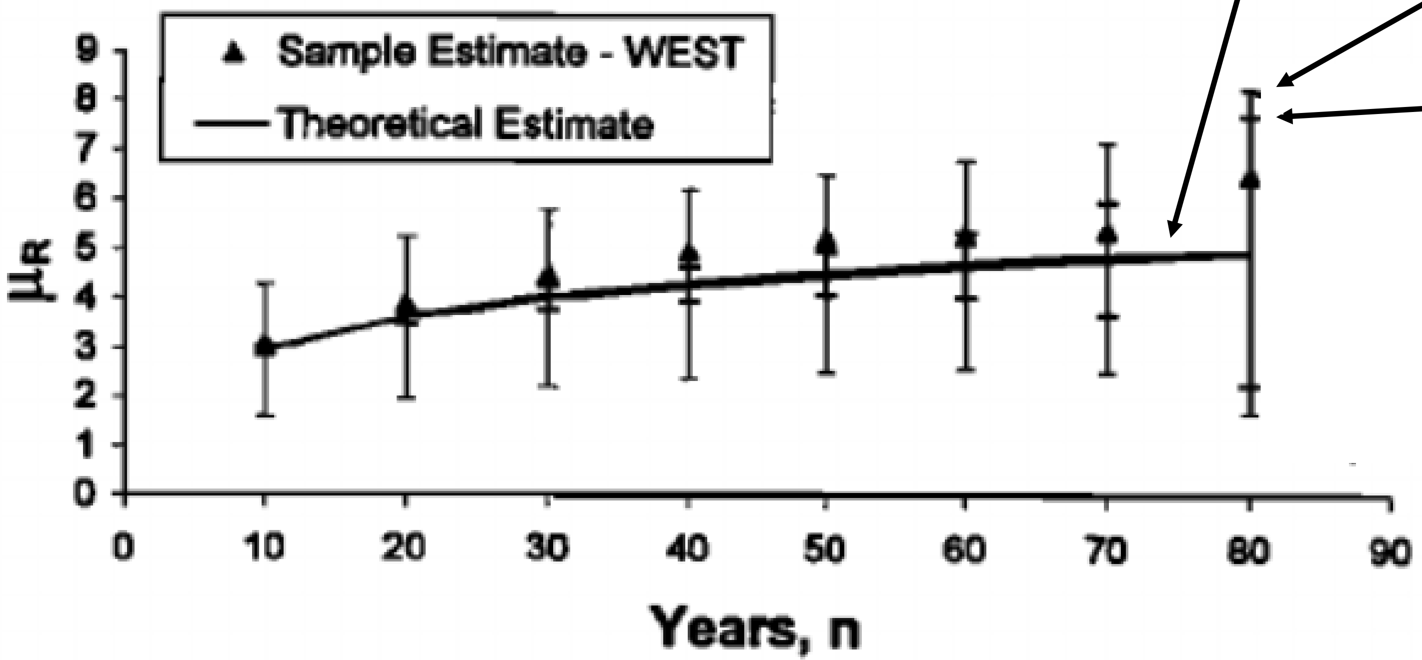
DICAM – University of Bologna

Theory of record-braking processes

Record event: event whose magnitude exceeds or is exceeded by all previously recorded event

The first observation of a series is defined to be a record event

Reference literature:
Chandler (1952), *Arnold et al.* (1998), *Vogel et al.* (2001)



Source: *Vogel et al.* (2001)

Theoretical expected value of the number of record events in an n-year sample (serially independent process)

$$\mu_R = \sum_{i=1}^{n} \frac{1}{i}$$

Approximate confidence intervals in a region with spatially correlated flood series

Approximate confidence intervals in a region with spatially uncorrelated flood series

Non-stationarity: when sample estimate falls outside the approximate confidence intervals

Vogel et al. (2001) applied the theory of record-breaking processes for identifying non-stationarity in hydrological records in the USA, highlighting the importance of **accounting for spatial correlation** (which can broaden the confidence intervals).

Back to the analyses