Impacts of Climate Change on European Minimum Flows under Global Warming of 1.5, 2, and 3°

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Introduction

- ✓ Under climate change, droughts could become more frequent, severe, and longer-lasting in Europe.

  Hydrological drought ⟶ water shortage in the hydrological system

- ✓ Hydrological drought is characterized by low streamflow statistics (e.g., block minima).

Objective

1) To find an appropriate probability distribution for describing 7-day annual minimum streamflow in Europe.
2) To explore projected changes in 7-day annual minimum streamflow as a proxy of hydrological droughts.

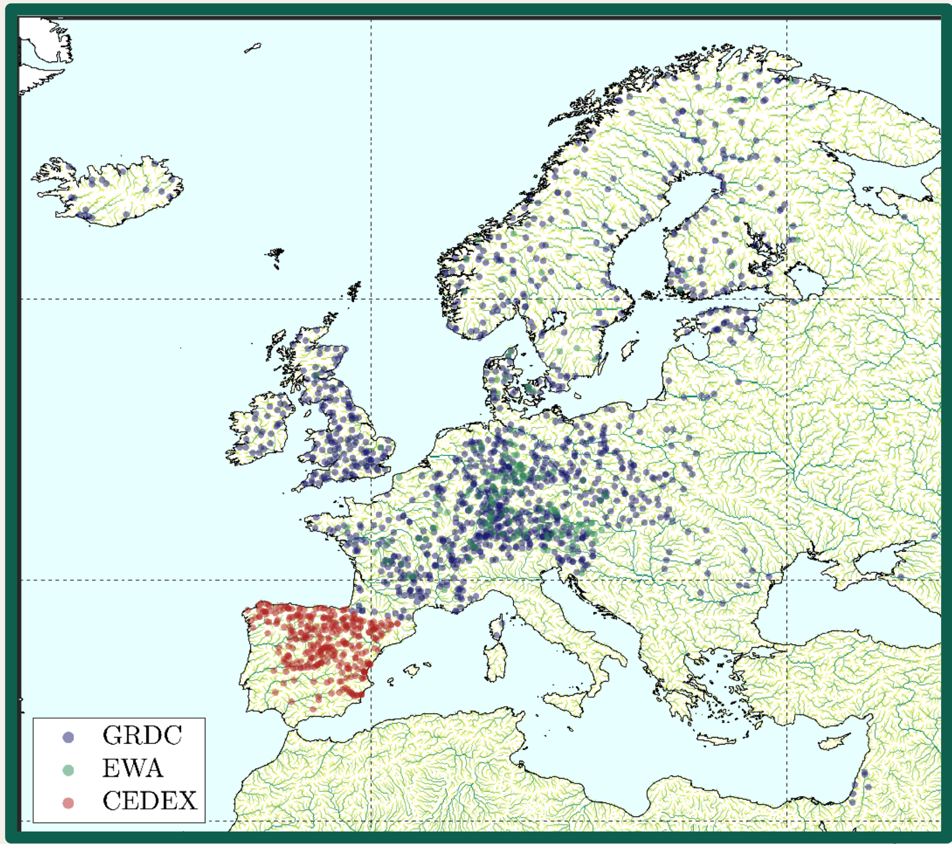
Data and methods

What is the best distribution to adjust the minimum flow in Europe?

Selection of river station

- Daily discharge from three sources:
  - ✓ **GLOBAL:** Global Runoff Data Center (GRDC) archive
  - ✓ **EUROPE:** European Water Archive (EWA)
  - ✓ **SPAIN:** Anuario de aforos digital (CEDEX)
- Selection of river stations with 30 years of data from 1961 to 2019 and less than 20% missing values.
- Quality control and deduplication (Gudmundsson et al., 2018; Gudmundsson and Seneviratne, 2016) → **1561 river stations**
- Distinction between frost and nonfrost seasons (Forzieri et al., 2014).
- Computation of the 7-day annual minimum streamflow.

Fig. 1: Location of river stations.



Distribution fitting

Six 3-parameter probability **distributions**

- ✓ Generalized Extreme Values (GEV)
- ✓ Generalized Logistic (GLO)
- ✓ Generalized Pareto (GPA)
- ✓ 3-parameter lognormal (LN3)
- ✓ Pearson Type III (PE3)
- ✓ 3-parameter Weibull (WEI)

Three Goodness-of-fit **tests**

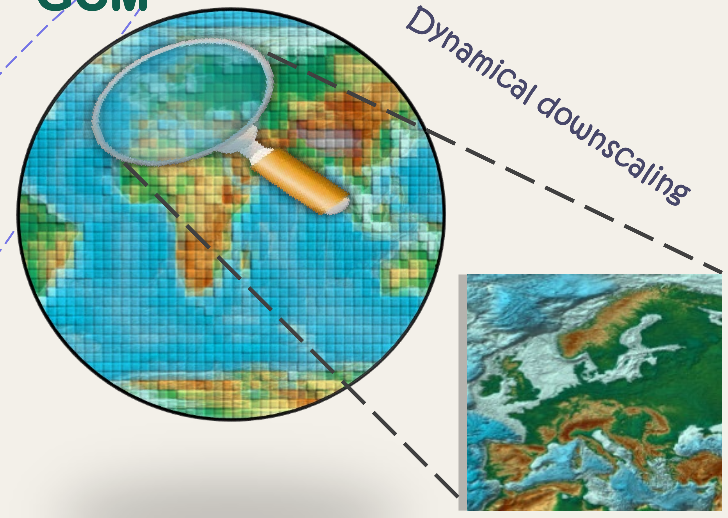
- ✓ Kolmogorov–Smirnov (KS)
- ✓ Anderson-Darling (AD)
- ✓ Cramér-Von Mises (CVM)

Data and methods

Changes in the 7-day annual minimum streamflow have been analyzed using the following scheme:

GCM

CNRM-CM5
CanESM2
CM5A
EC-EARTH
MPI-ESM-LR
HadGEM2-ES
MIROC5
NorESM1-M



Dynamical downscaling

RCM

CCLM4-8-17
COSMO
ALADIN63
HIRHAM5
REMO2015
RegCM4.6
WRF381P
RACMO22E
REMO2009
RCA4
WRF361H

EURO-CORDEX (Jacob et el., 2014)

45 GCM-RCM COBINATIONS

HISTORICAL **RCP 8.5**

Total runoff → **River discharge** → **7-day low flow** → **Annual minimum values**

Routing with scheme derived from CHyM (Coppola et al., 2007)

Frequency Analysis ↔ Adjustment to conditional probability distribution

1995-2014 **REFERENCE PERIOD**

1.5 ºC warming level | **2.0 ºC warming level** | **3.0 ºC warming level**

Relative to the preindustrial period (1861-1900)

Results

Distribution Fitting

Table 1 Rank sum of the six probability distributions (GEV, GLO, LN3, PAR, PE3, and WEI) according to the three Goodness-of-Fit tests (KS, AD, and CVM).

Nonfrost season

	GEV	GLO	LN3	PAR	PE3	WEI
KS	**5418**	5194	4859	4954	5251	5084
AD	**5424**	5126	4916	4864	5274	5168
CVM	**5390**	5199	4899	4873	5294	5123

Frost season

	GEV	GLO	LN3	PAR	PE3	WEI
KS	1842	1855	1715	1763	**1855**	1835
AD	**1901**	1801	1688	1735	1893	1851
CVM	**1885**	1804	1697	1758	**1885**	1840

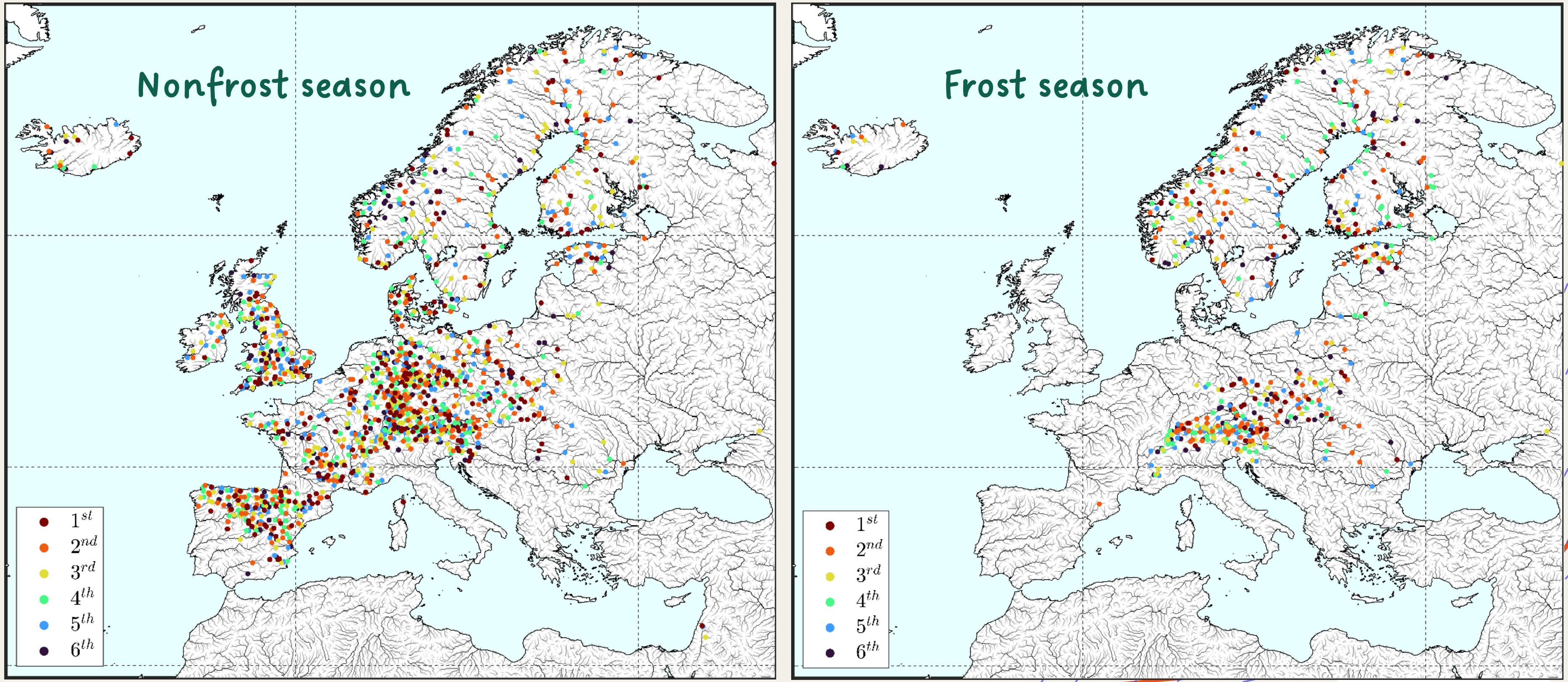
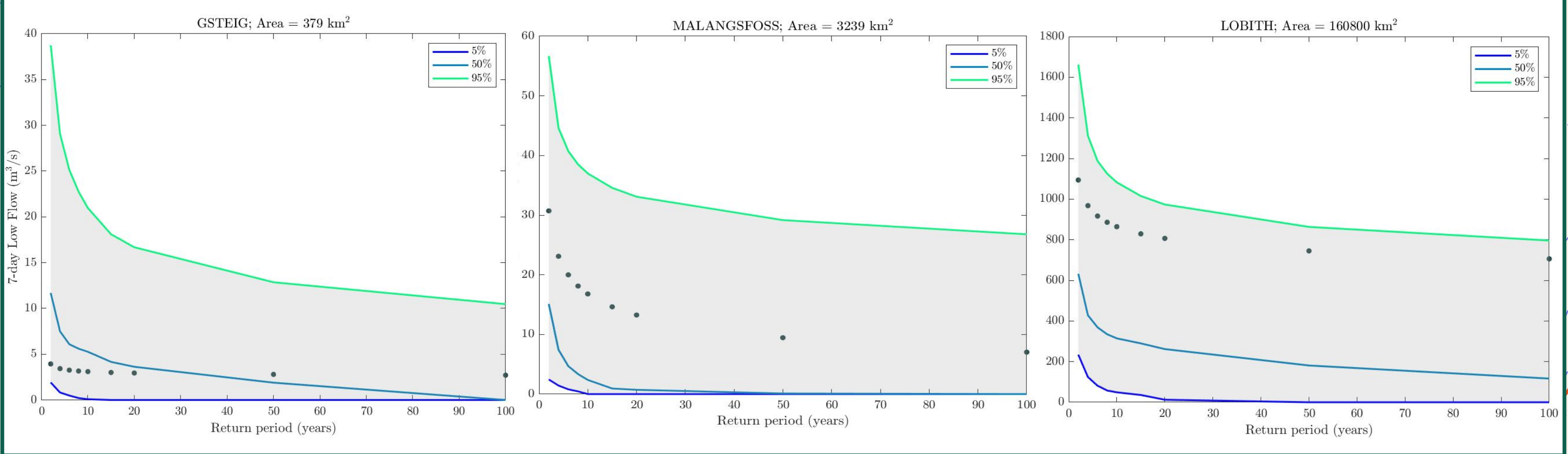


Fig. 2: Rank sum order for GEV according to AD.

Results

Evaluation of the multi-model ensemble performance

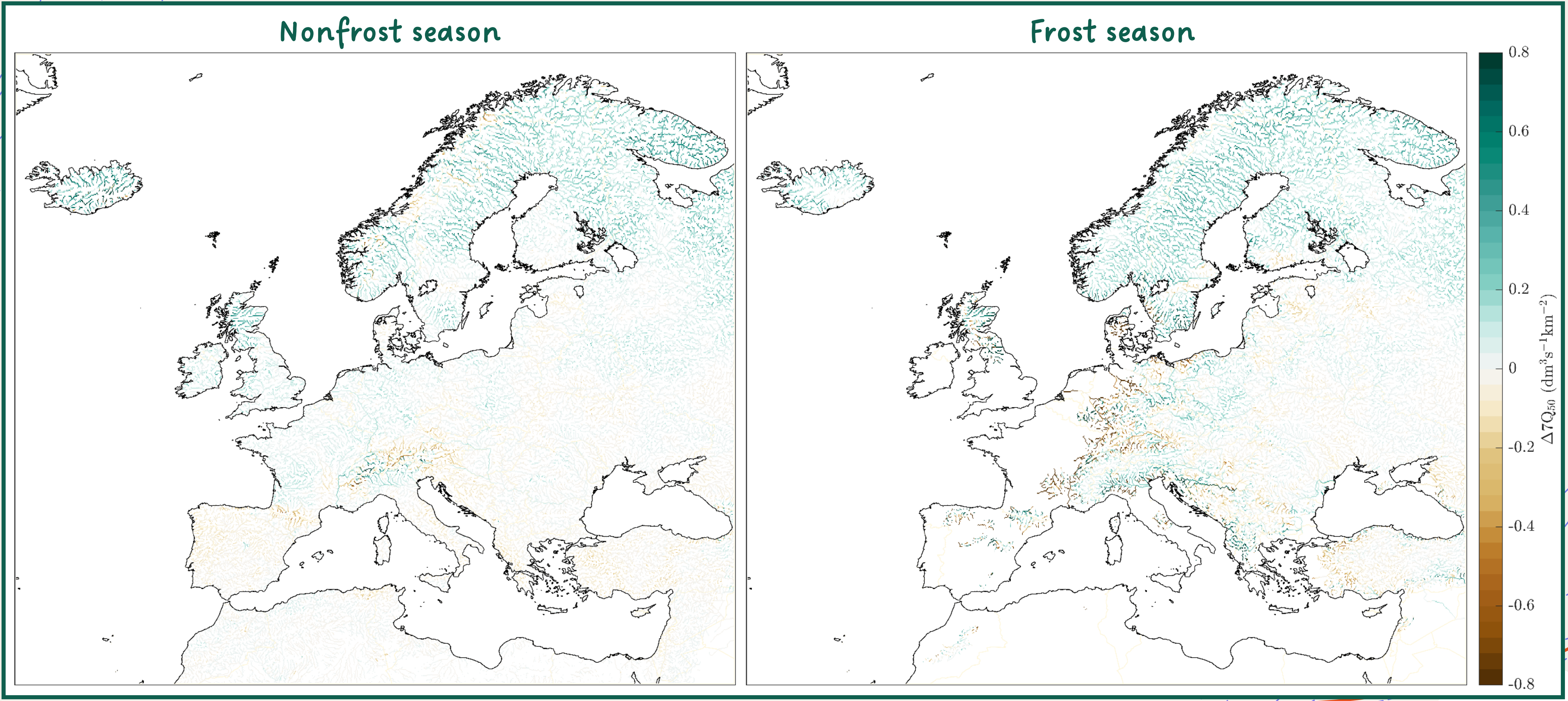
Fig. 3: Low flow-duration versus return (recurrence in years) period curves for multi-model ensemble members percentiles (5, 50, and 95%) and observations at a small (drainage area < 1.000 km^2) (Gsteig, Lutschine river, CH), medium (1.000 km^2 < drainage area < 10.000 km^2)(Malangsfoss, Malselva, NO), and large (drainage area > 10.000 km^2) (Lobith, Rhine River, LN) river stations.



Results

Projections for 1.5 ºC warming level

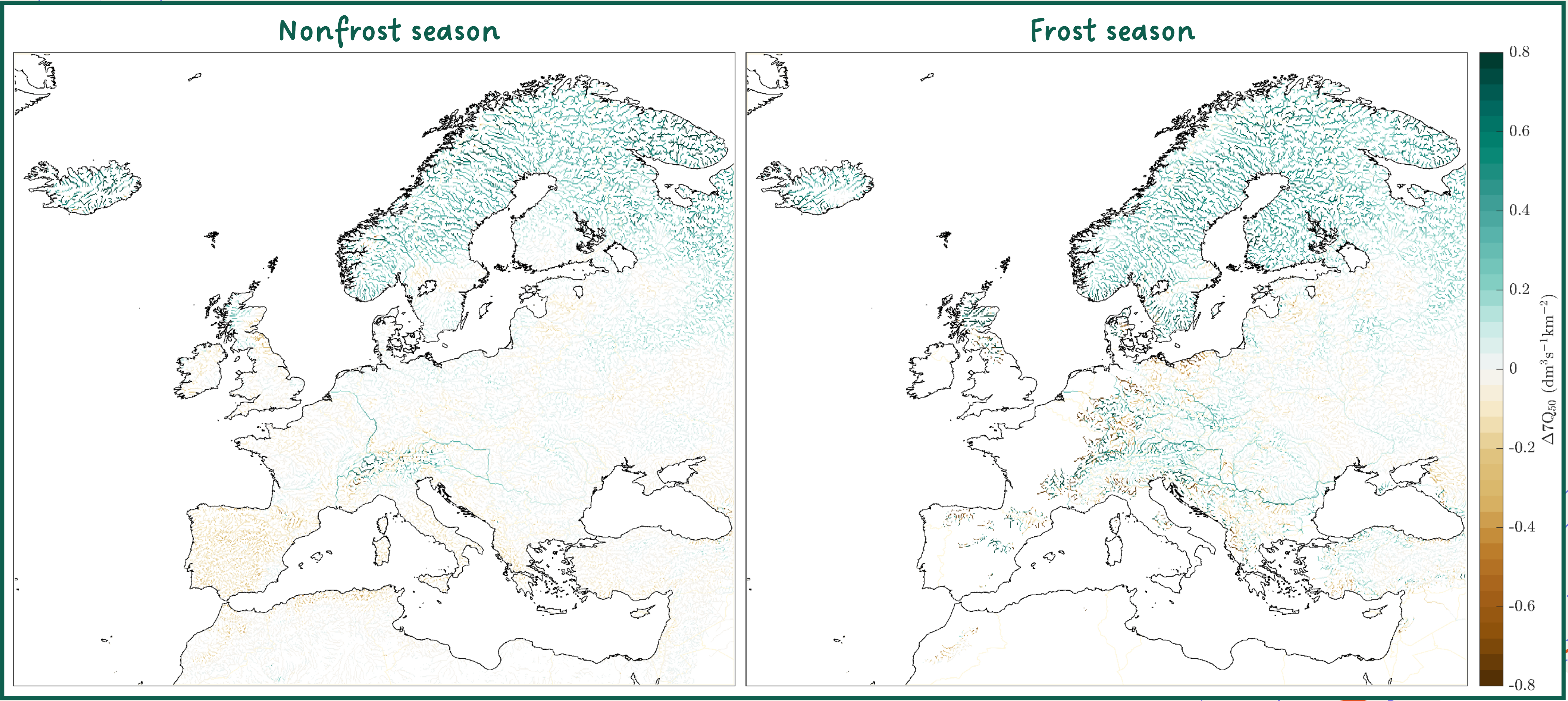
Fig. 4: Changes per unit catchment area ($dm^3\ s^{-1}\ km^{-2}$) in 7Q50 for a warming level of 1.5 ºC defined relative to the preindustrial period (1861-1900) in relation to the reference period (1995-2014).



Results

Projections for 2.0 ºC warming level

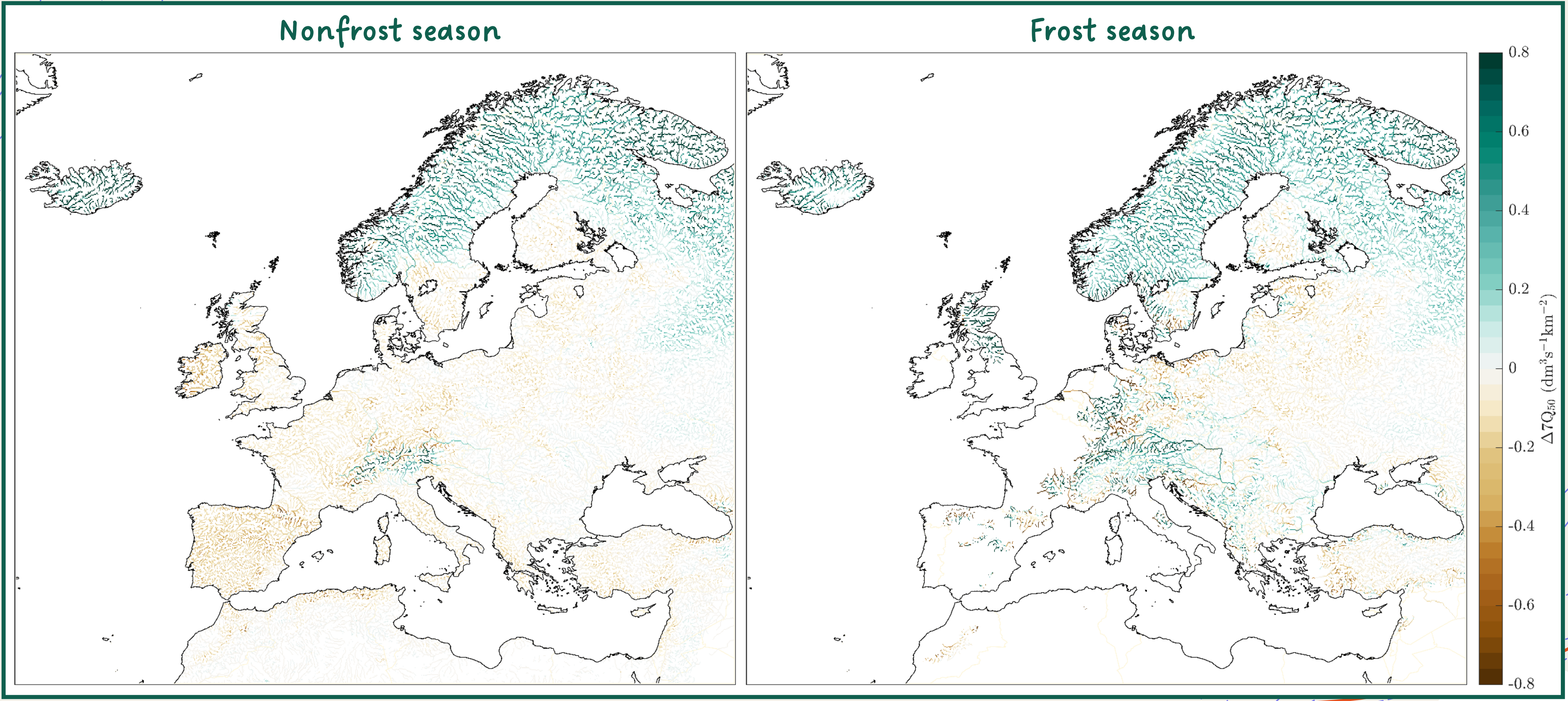
Fig. 5: Changes per unit catchment area (dm^3 s^{-1} km^{-2}) in 7Q50 for a warming level of 2.0 ºC defined relative to the preindustrial period (1861-1900) in relation to the reference period (1995-2014).



Results

Projections for 3.0 ºC warming level

Fig. 6: Changes per unit catchment area ($dm^3\ s^{-1}\ km^{-2}$) in 7Q50 for a warming level of 3.0 ºC defined relative to the preindustrial period (1861-1900) in relation to the reference period (1995-2014).



"thank you for your ATTENTION ;)"

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Supplementary information
Evaluation of the multi-model ensemble performance

Fig. 1S: 7Q6 from the multi-model ensemble for (a) nonfrost and (b) frost seasons. Dots show the corresponding 7Q6 values for the river stations analyzed.