Ensemble seasonal hydrological forecasting in Europe: ECMWF vs. Climatology

Ilias Pechlivanidis, Henrik Spångmyr, Thomas Bosshard, and Jonas Olsson

HEPEX 2015
23 September, Norrköping, Sweden

New version of the pan-European model, E-HYPEv3.0 – *release Feb 2015* :

TASKs

SMHI team members:

(Some) new input data and more observed data



Model improvements:

- New process descriptions of snow, ice and ET

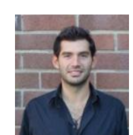

- Human abstractions, updated irrigation, more regulations


- New aquifers and groundwater routines

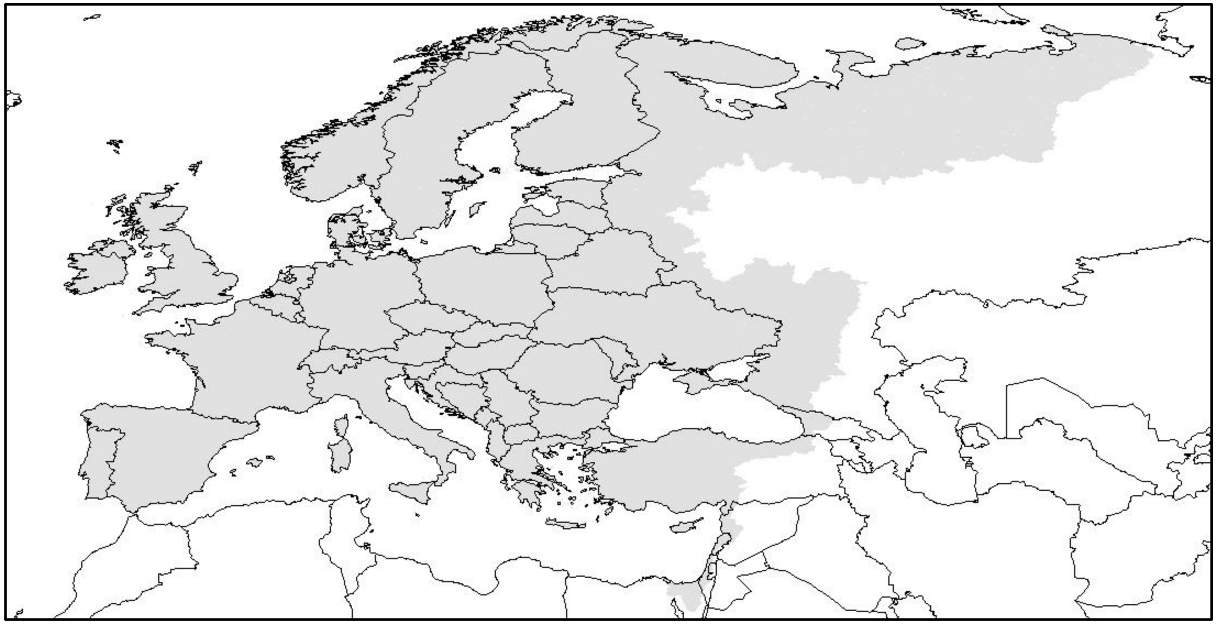
- Additional lakes & parameters and river areas


- More nutrient sources and new water temperature


- New method for regionalisation of parameters
- More evaluation methods and performance criterias

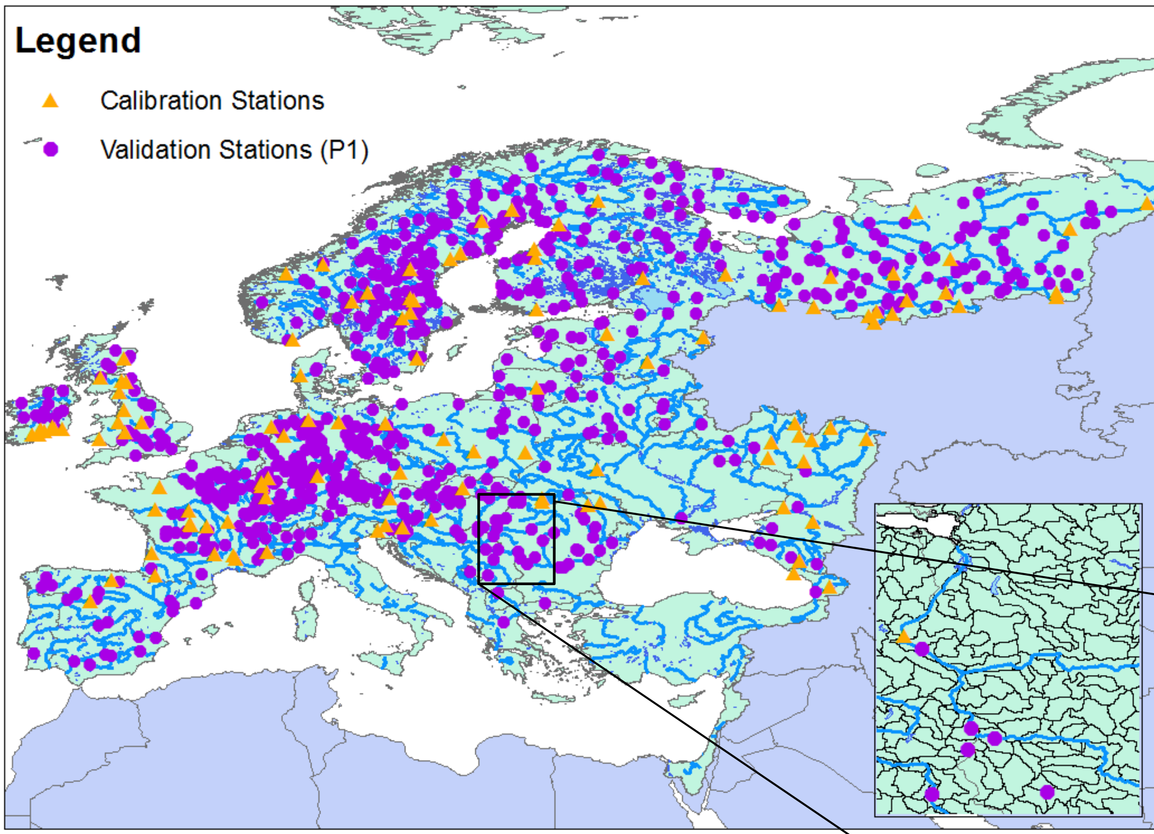



Datasets



Characteristic/Data type	Info/Name	Provider
Total area (km^2)	8.8 million	-
No. of sub-basins	35408 (mean size 215 km^2)	-
Topography (routing and delineation)	hydroSHEDS (15 arcsec)	Lehner et al. (2008)
Soil characteristics	Harmonised World Soil Database (HWSD)	Nachtergaele et al. (2012)
Land use characteristics	CORINE	Bartholomé et al. (2002)
Reservoir and dam	Global Reservoir and Dam database (GRanD)	Bernhard et al. (2011)
Lake and wetland	Global Lake and Wetland Database (GLWD)	Lehner & Döll (2004)
Irrigation	Global Map of Irrigation Areas (GMIA)	Siebert et al. (2005)
Discharge	GRDC, EWA and others (around 2600 stations)	http://www.bafg.de/GRDC
Precipitation	WFDEI (0.5^o x 0.5^o)	Weedon et al. (2014)
Temperature (mean, min, max)	WFDEI (0.5^o x 0.5^o)	Weedon et al. (2014)
Snow cover area	GlobSnow	Luojus et al. (2013)

The European HYdrological Predictions for the Environment model, E-HYPE v3.0



Large database of spatially distributed gauging stations

- Multi-basin modelling approach:
  - Evaluate our model structure
  - Get the most information possible from the available data
  - Avoid getting the right performance for the wrong reasons
  - Evaluate the model performance in ungauged basins (of varying size and characteristics)
  - Discover errors in input data, anthropogenic influences or model processes

SMHI

A calibration procedure to separate processes

0. Benchmark = E-HYPE2.5

0. Starting Parameters

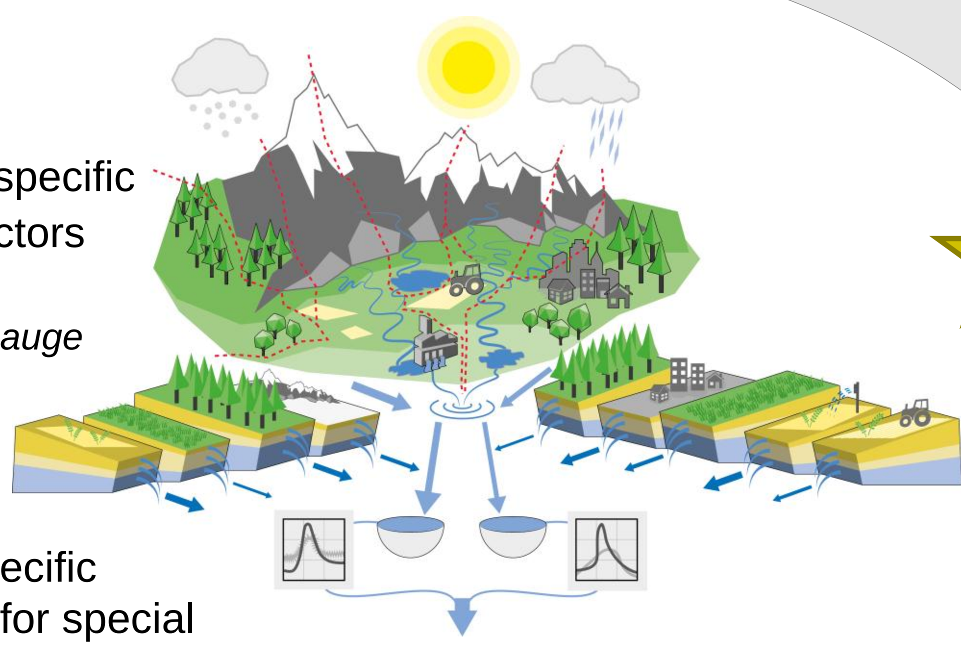
2. Calibrate to specific data for specific processes *(e.g. snow depths for snow, mass balance for glaciers, satellite for evapotranspiration)*

3. Calibrate Runoff Generating parameters: i.e. specific landuse & soil-type to clustered gauge groups *(e.g. field capacity, wilting point for a group of stations with mostly fine soil)*

4. Calibrate general routing parameters to calibration gauge set. (river routing, lake routing, general dam regulation)

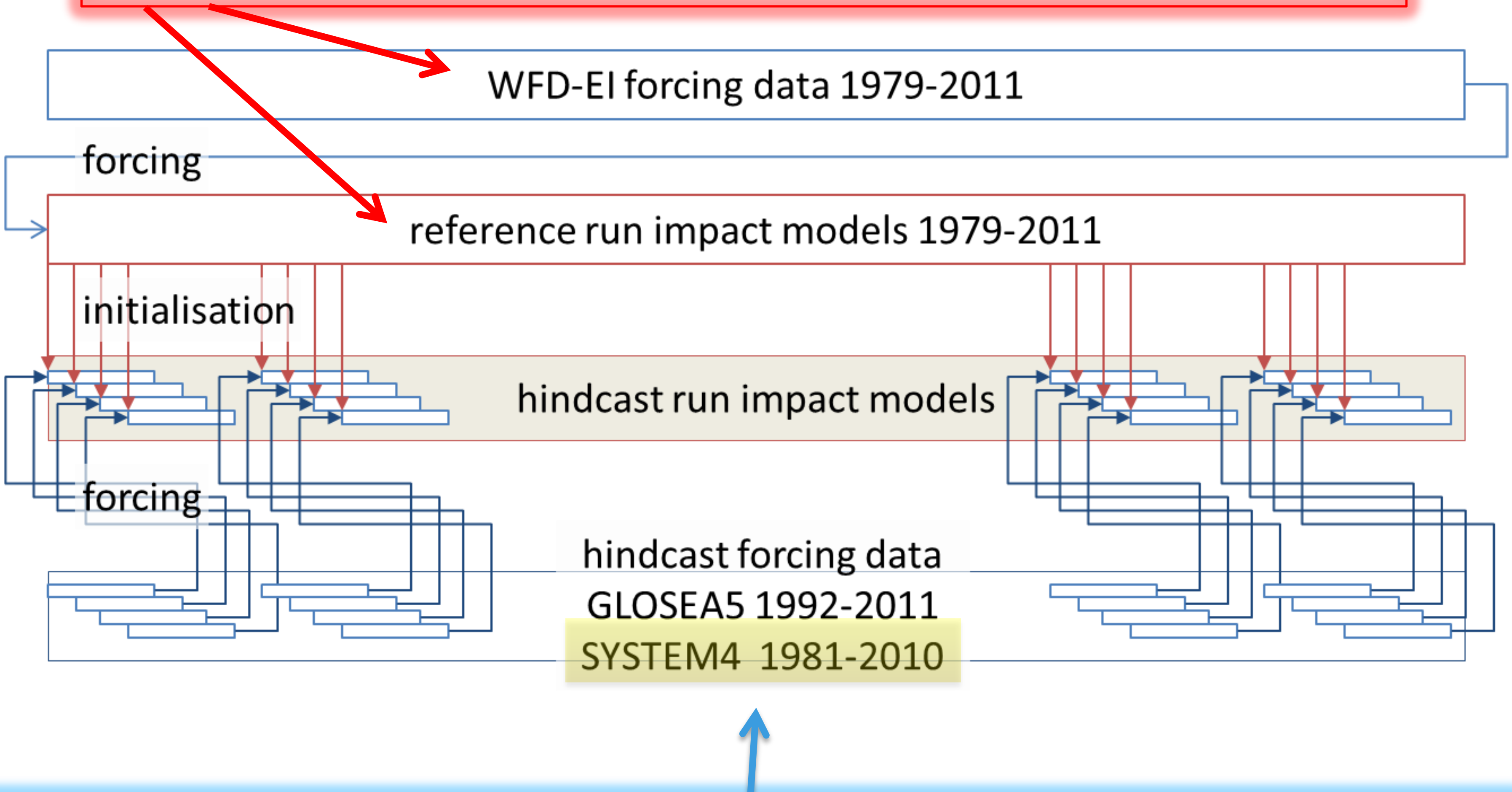
5. Calibrate specific parameters for special hydrological elements to nearest gauge downstream *(e.g. lakes, irrigation, reservoirs, aquifers)*

6. Calibrate catchment specific parameter adjustment factors based on physiographic similarities – *to clustered gauge groups*



Forecasting protocol

WFDEI data were re-formated for E-HYPE
Link E-HYPE to SMHI's AEGIR system for automating the model runs

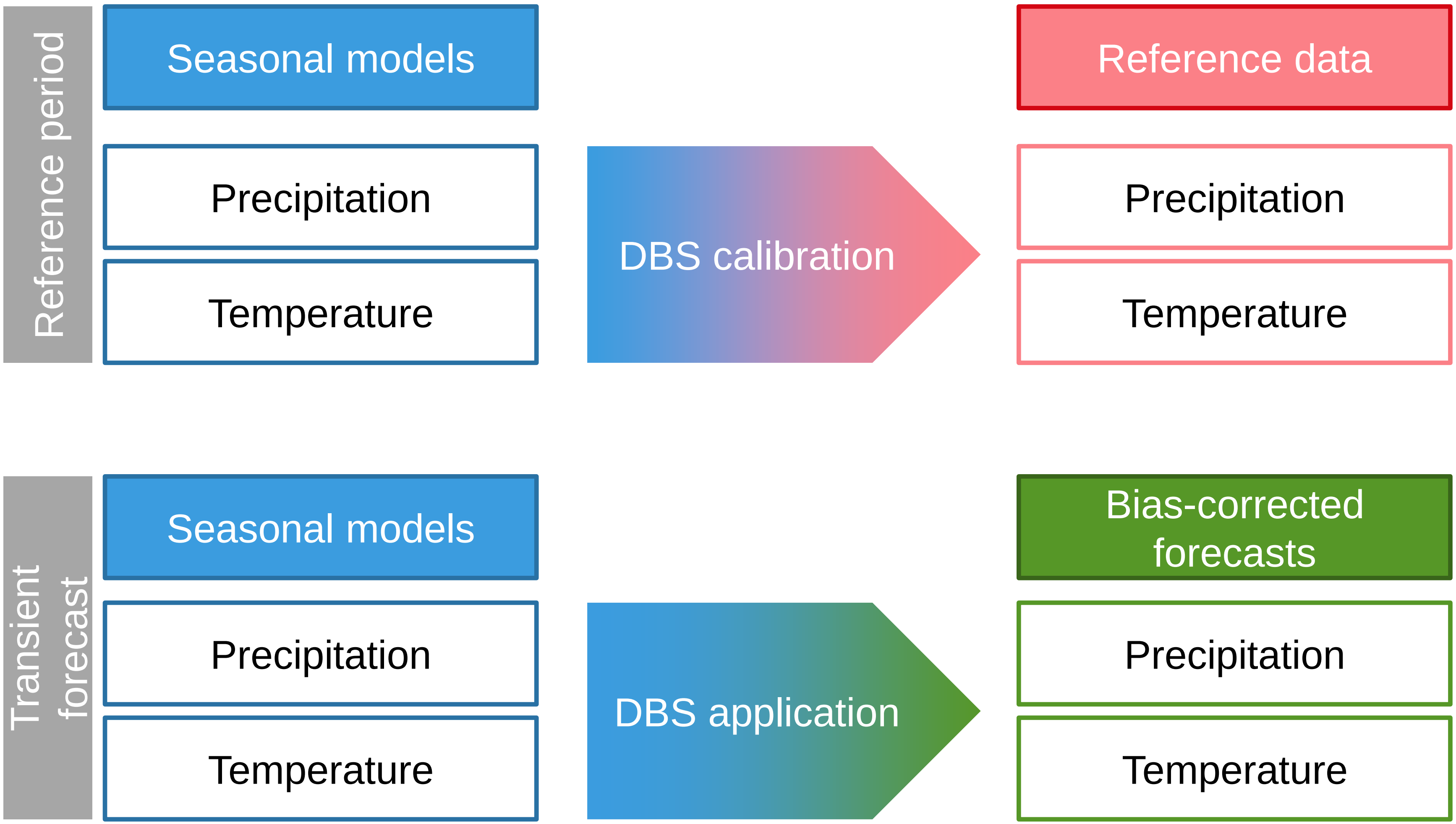


Projections from System4 (15 members initialised every month) were downloaded, bias corrected using the DBM method, and re-formated for E-HYPE

DBS bias-correction method

SMHI

Bias correction: DBS (Yang et al., 2010)



Methodology

SMHI

- Evaluation at >1200 stations for lead time 0 – 2 – 4 months ahead and all 15 ensemble members:
  - Monthly evaluation (in terms of timing, variability and volume)
- Focus on 3 European rivers
  - Evaluation for all lead times and months
- Classification And Regression Trees (CART)
  - Link performance with physiographic-climatologic characteristics

Performance metric of forecasting system

$$KGE = 1 - \sqrt{(r-1)^2 + (\alpha-1)^2 + (\beta-1)^2}$$

where *cc* is the linear correlation coefficient between observed and simulated records, *alpha* is a measure of variability in the data values (equal to the standard deviation of simulated over the standard deviation of observed), and *beta* is equal to the mean of simulated over the mean of observed.

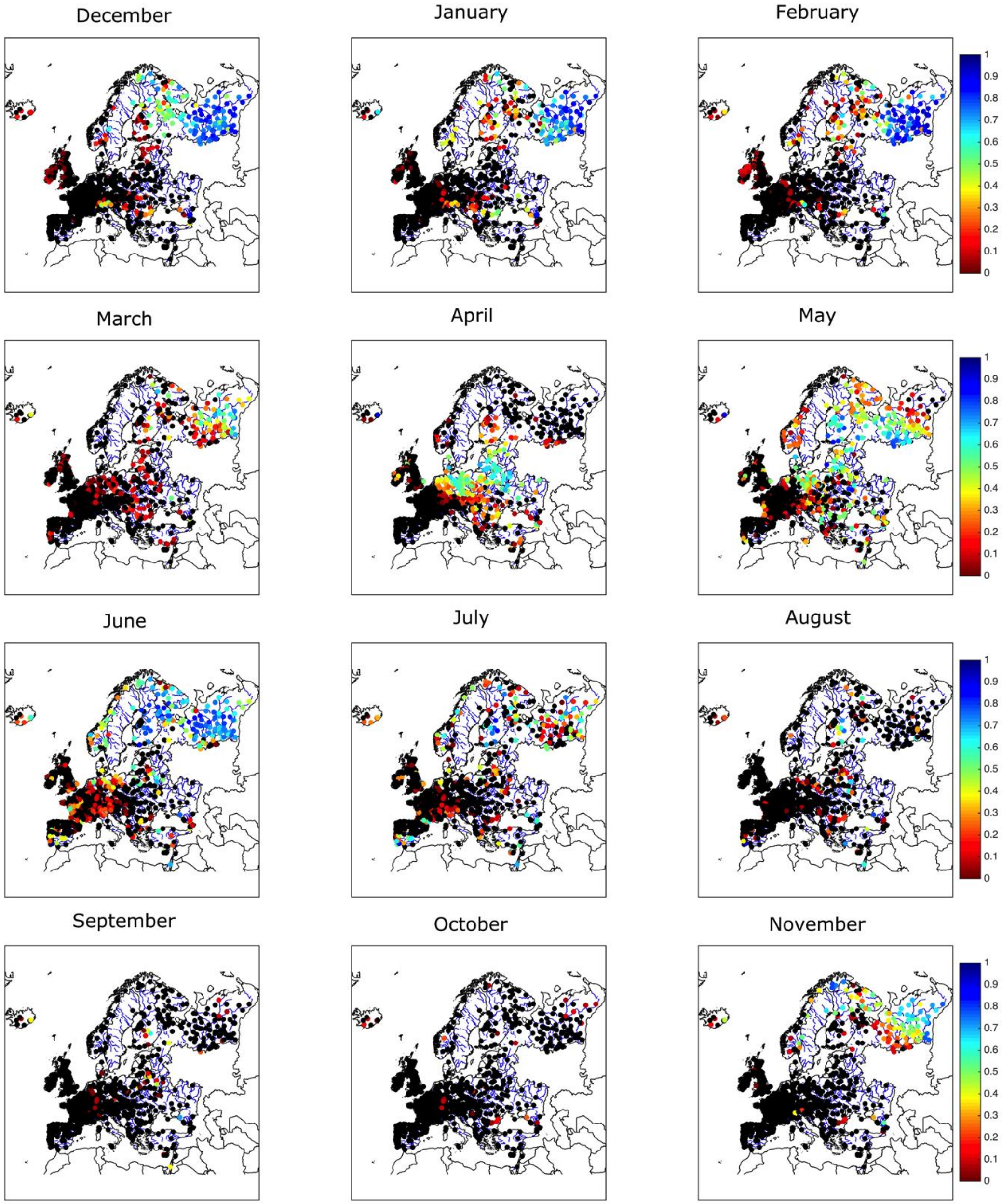
Improvement criterion: *I = (ALT - REF) / (1 - REF)*

Hydrological forecasting skill

SMHI

KGE

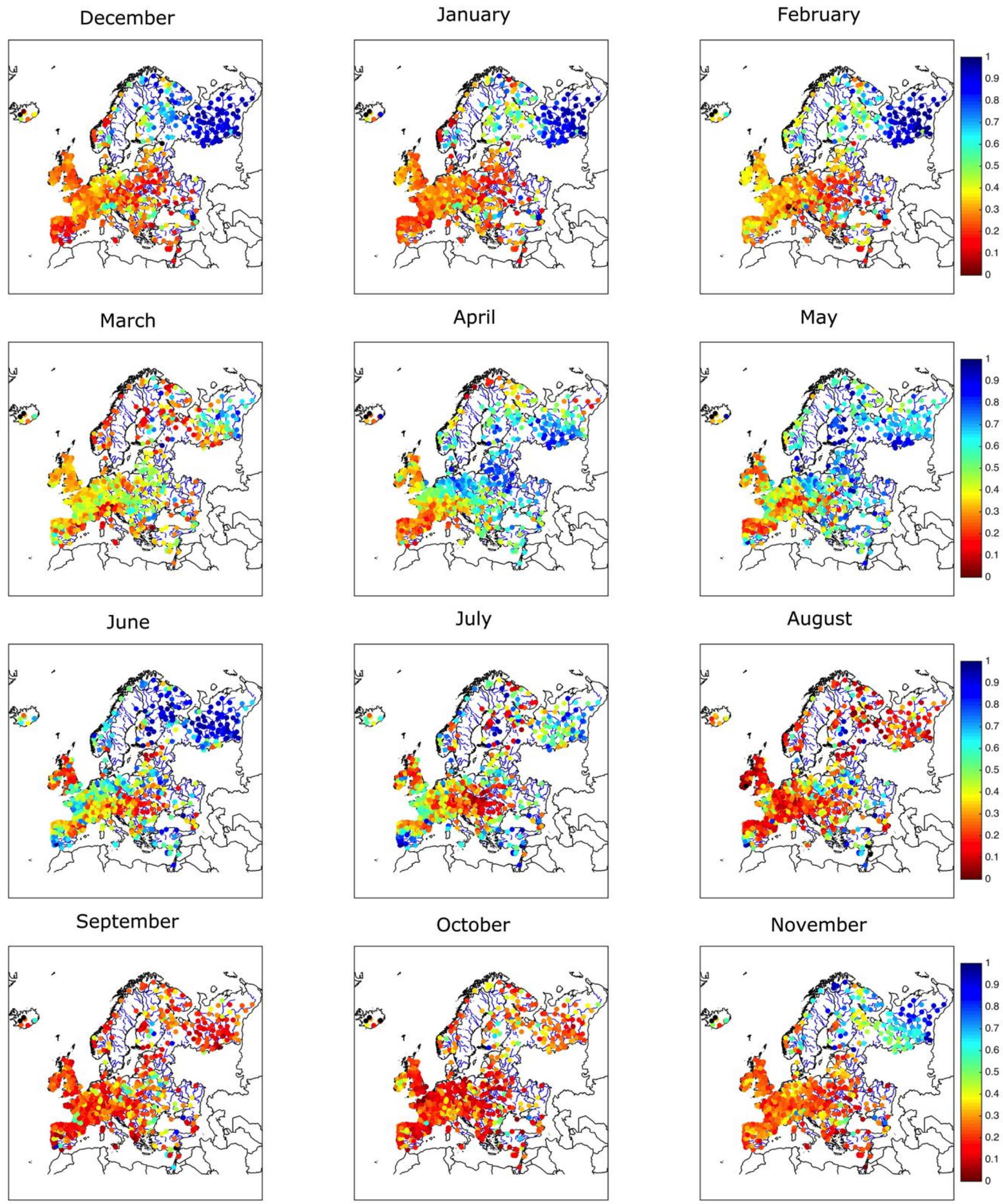
Lead month: 0



Hydrological forecasting skill

cc
(timing)

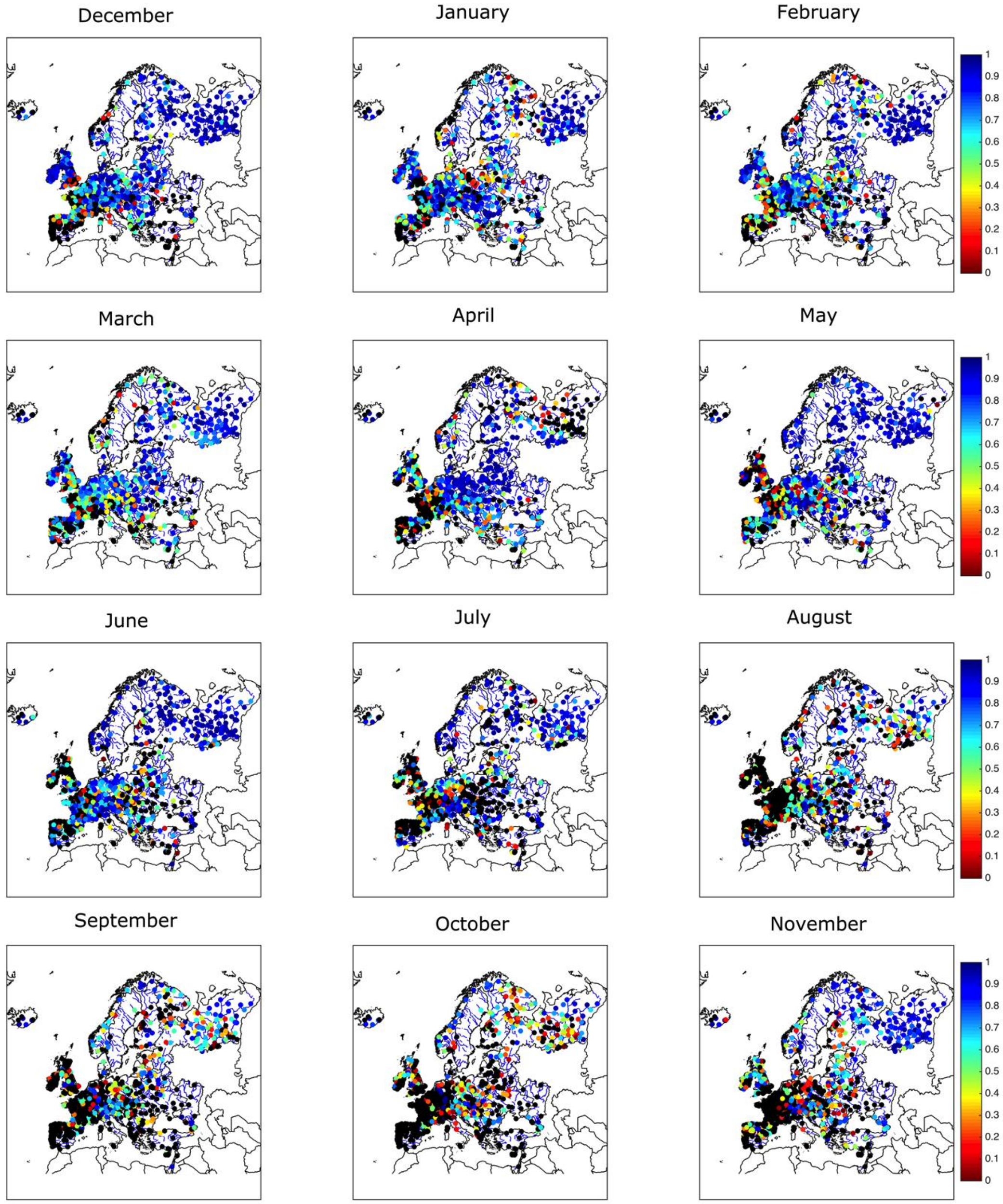
Lead month: 0



Hydrological forecasting skill

alpha
(variability)

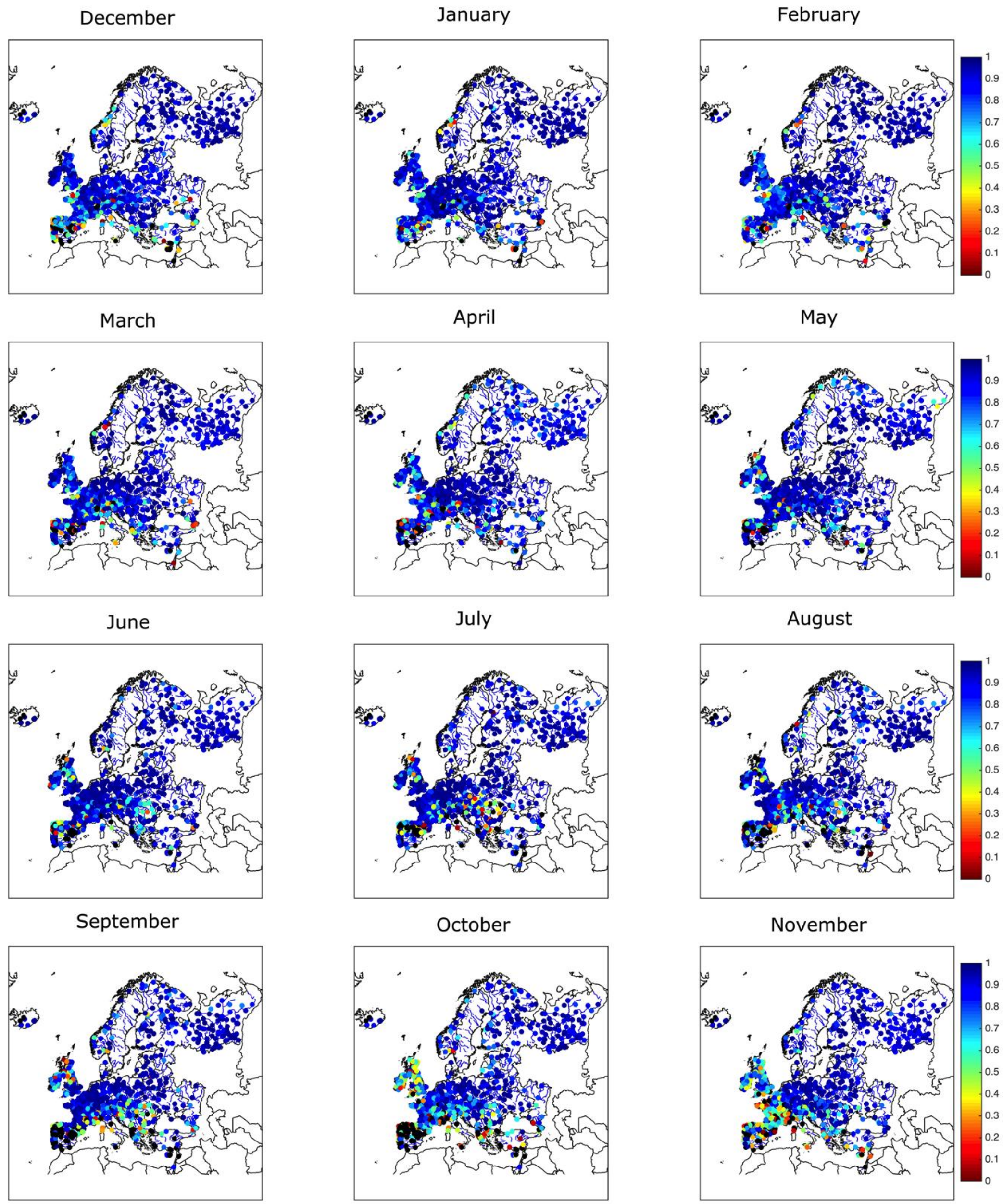
Lead month: 0



Hydrological forecasting skill

beta
(volume)

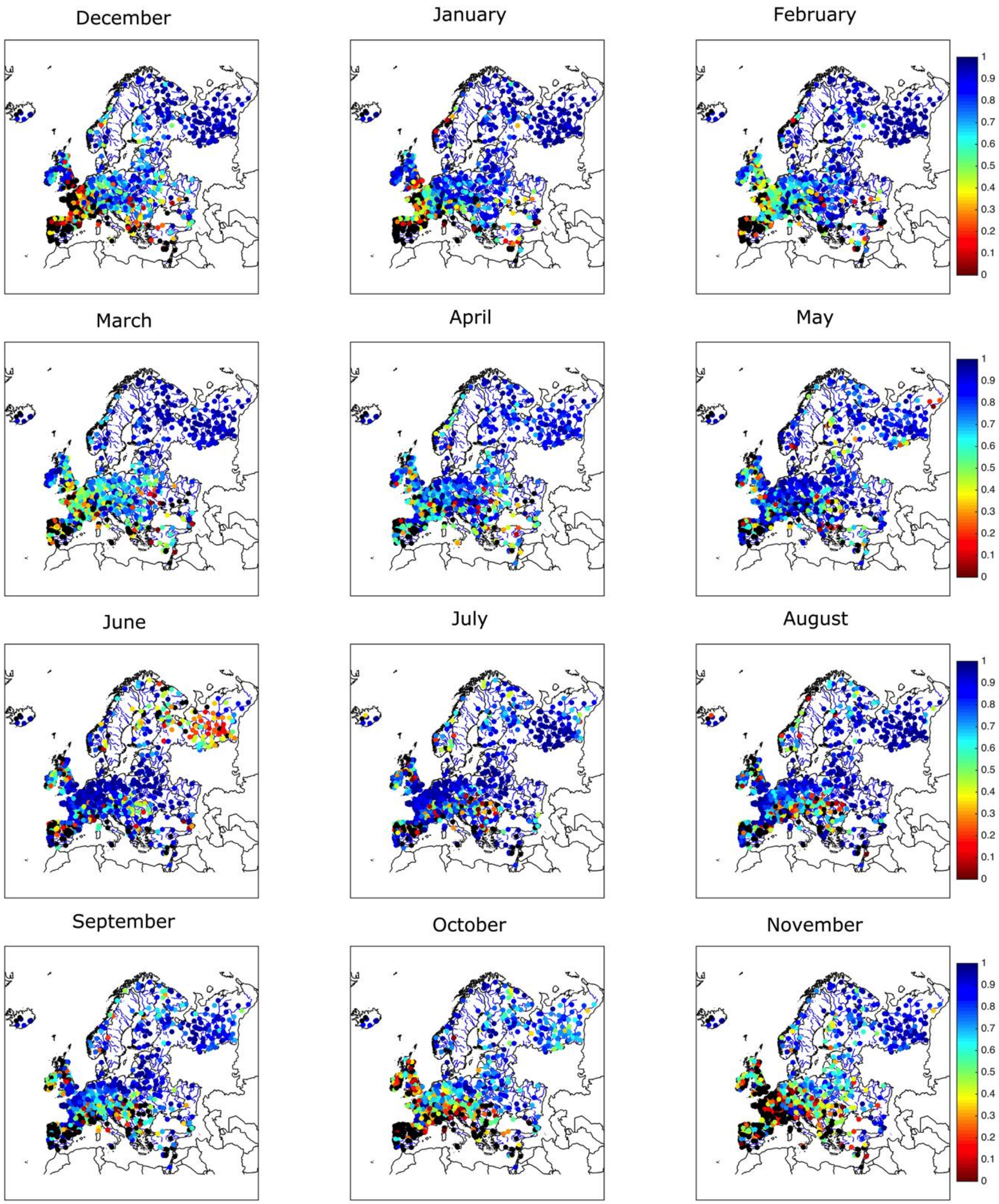
Lead month: 0



Hydrological forecasting skill

beta
(volume)

Lead month: 2

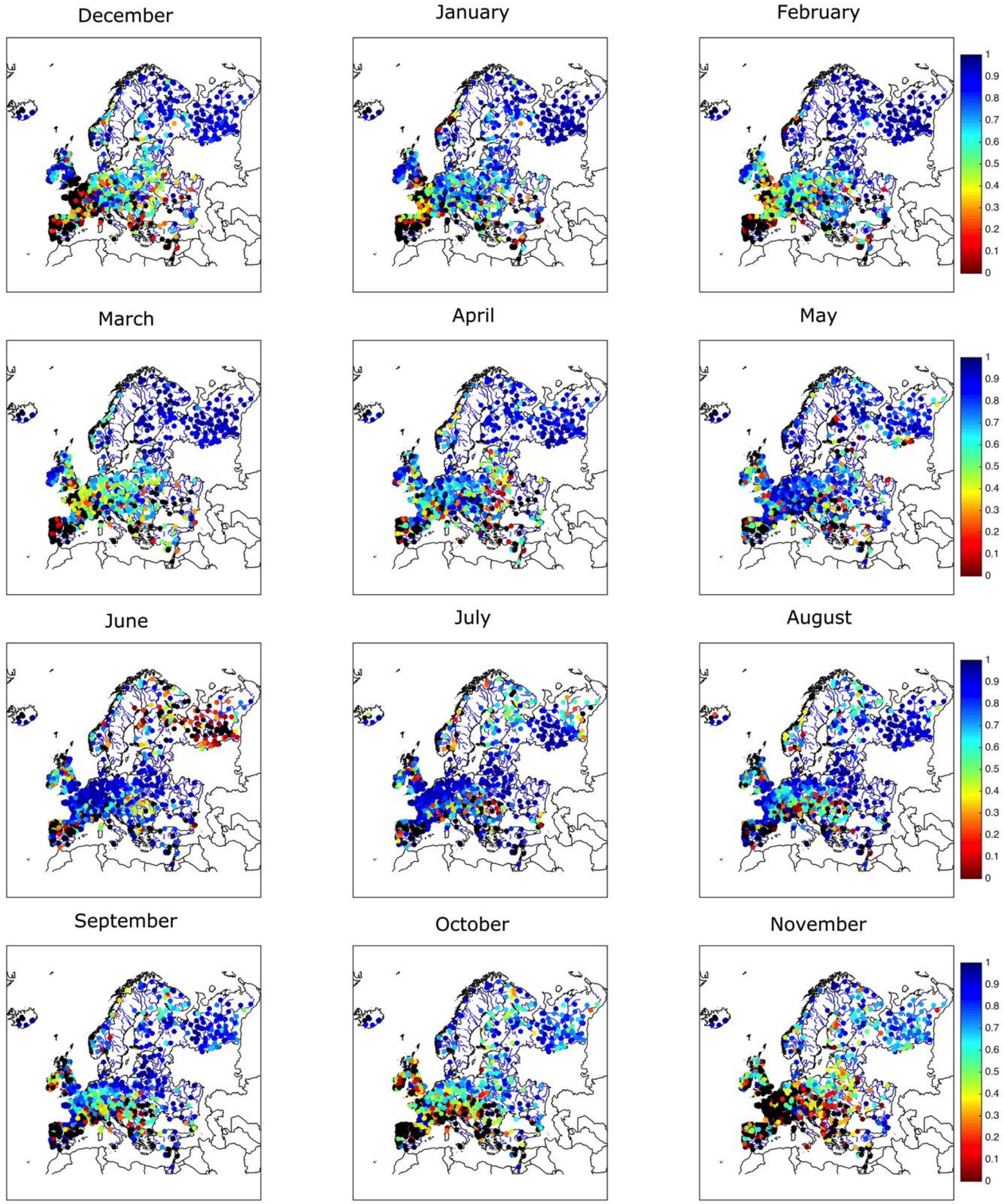


Hydrological forecasting skill

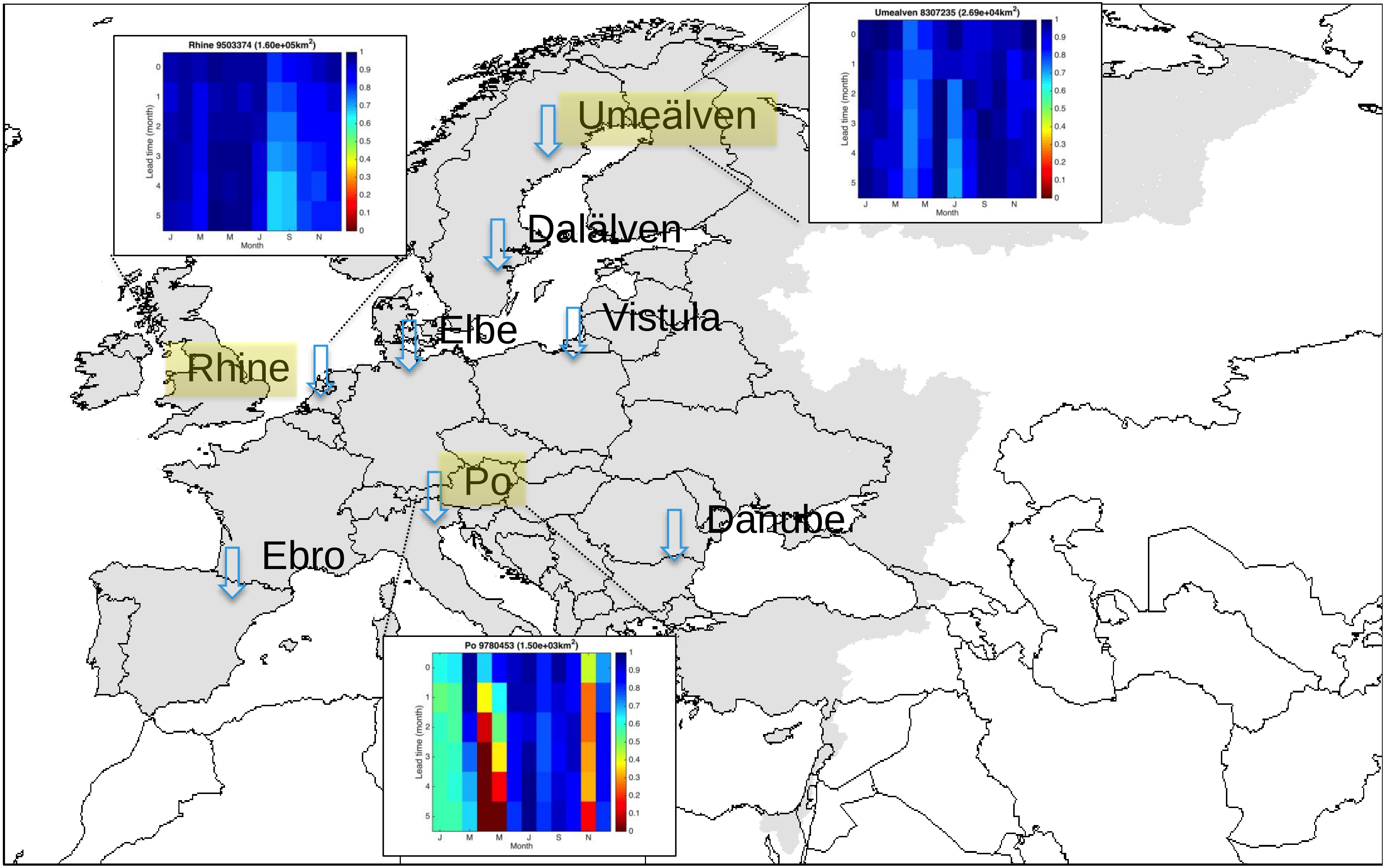
SMHI

beta
(volume)

Lead month: 4



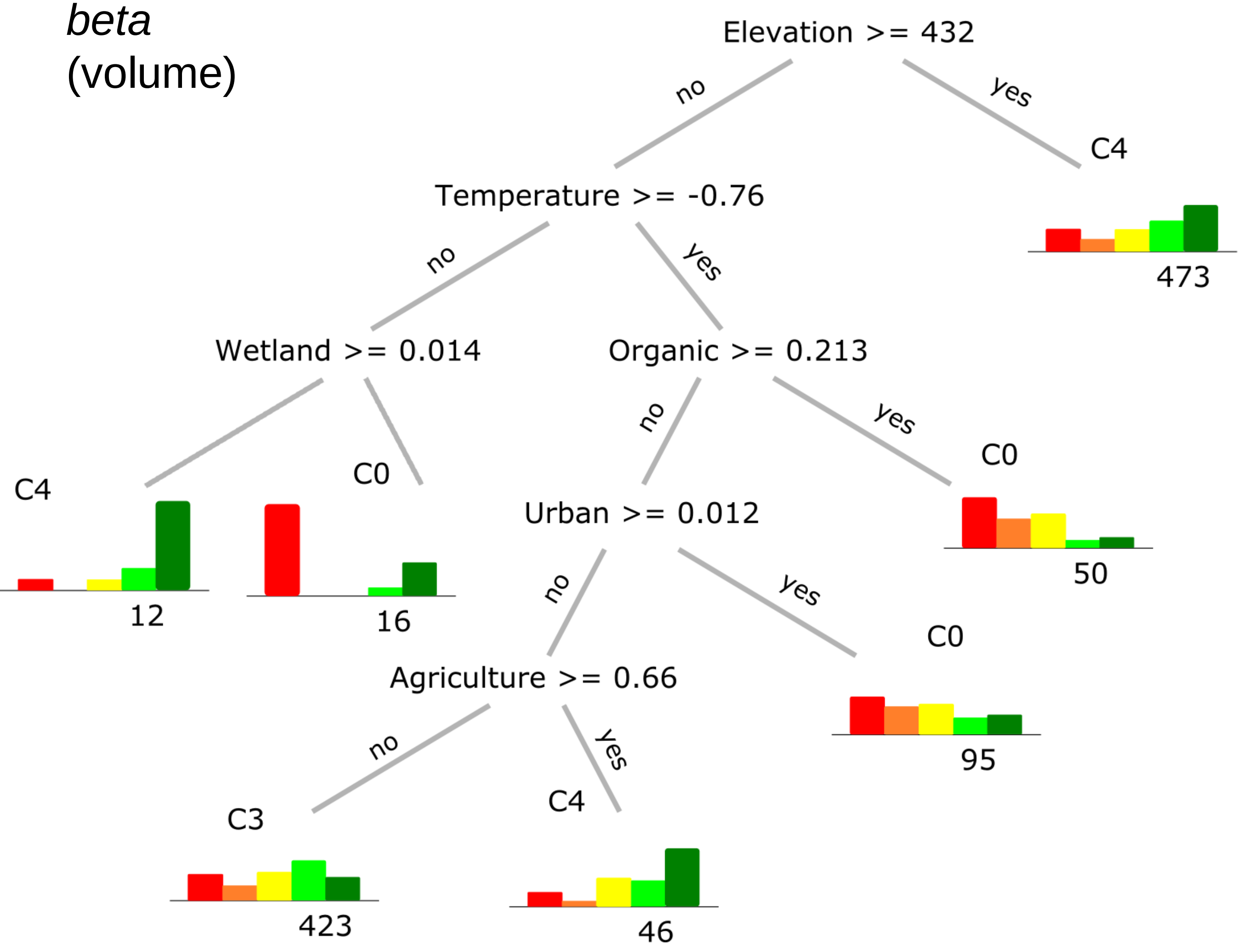
Seasonal hydrological forecasting skill

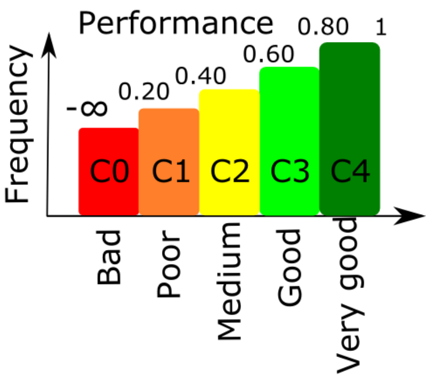


Classification And Regression Trees

SMHI

beta
(volume)





Lead month: 2

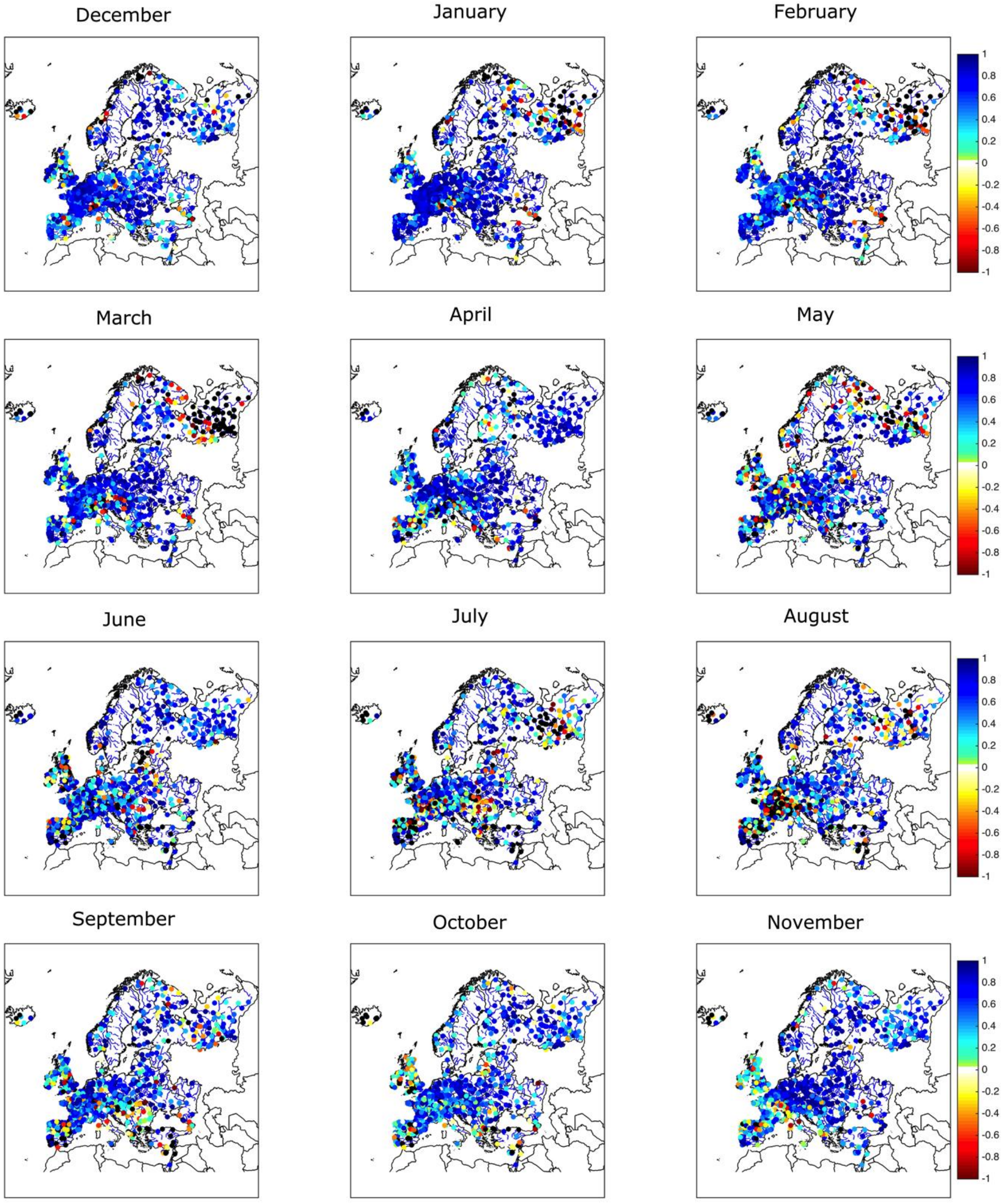
Month: March

Hydrological forecasting skill

SMHI

beta
(volume)

ECMWF
System 4
vs.
Climatology



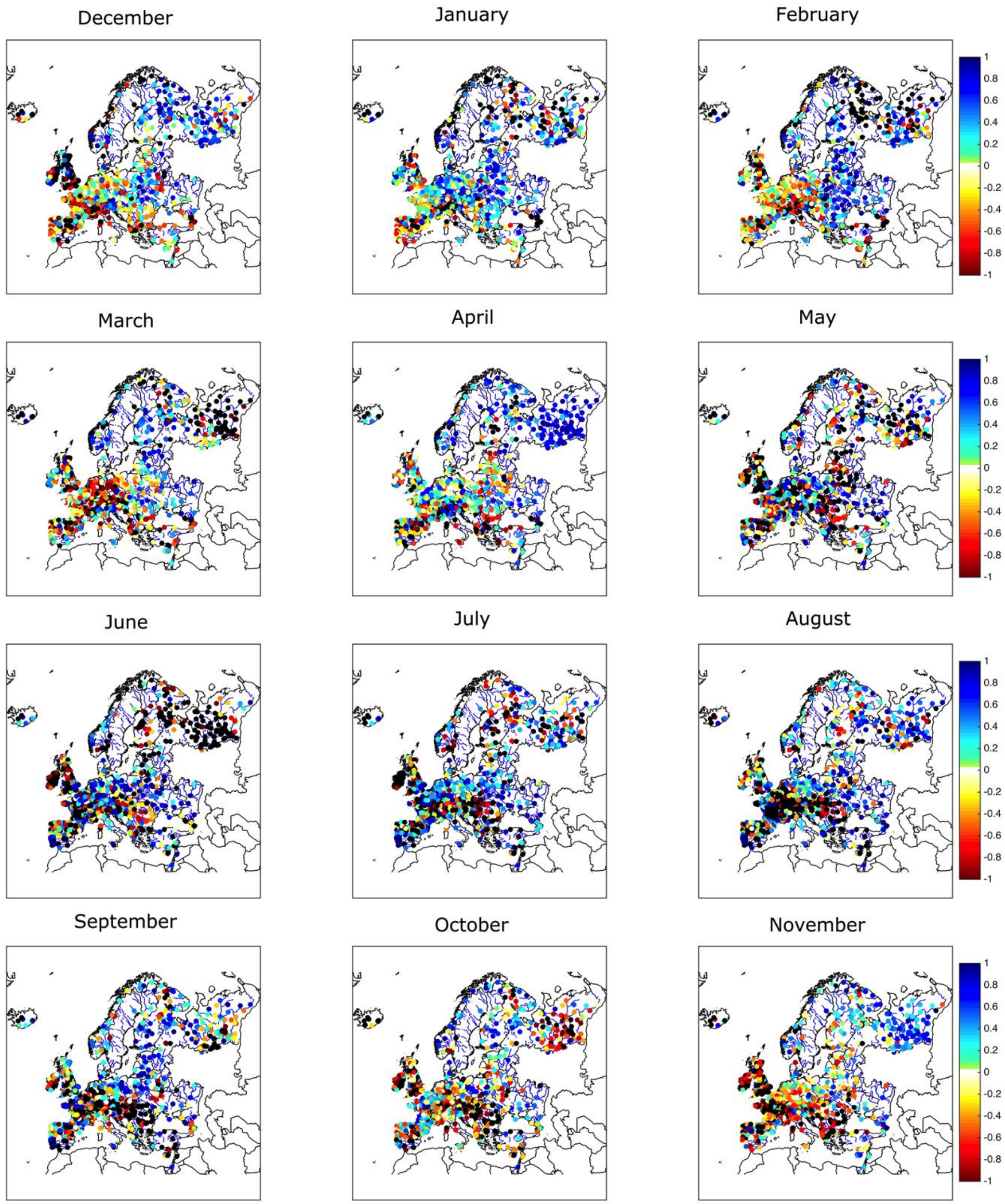
Lead month: 0

Hydrological forecasting skill

beta
(volume)

Lead month: 2

ECMWF
System 4
vs.
Climatology



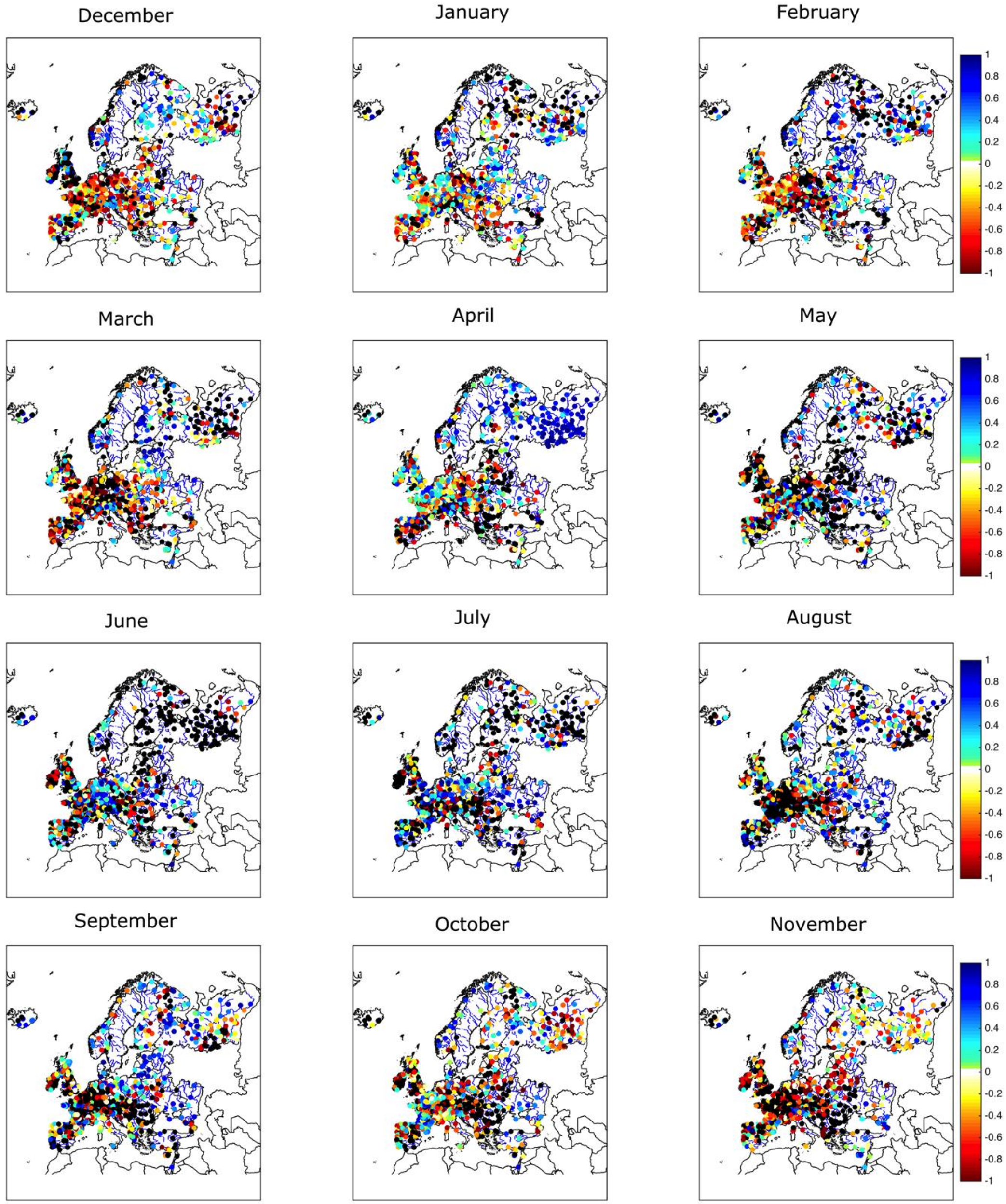
Hydrological forecasting skill

SMHI

beta
(volume)

Lead month: 4

ECMWF
System 4
vs.
Climatology



Conclusions

The evaluation spots the strengths and weaknesses of ensemble seasonal forecasts from ECMWF System 4 (15 members), including trends of performance in various months and lead times.

- ❑ Forecasting skill in northern Europe; however skill deteriorates as a function of lead time (particularly in central Europe).
- ❑ Hydrological forecasts cannot represent the timing and variability of the "observations"; better skill with regard to volume.
- ❑ CART shows that elevation and temperature can affect the model performance (bias correction artifact ?)
- ❑ Forecasting using climatology is more skillful at high lead months, particularly in central Europe and Mediterranea.

Future work

- ❑ Assimilation of EOs to improve calibration and initialisation
- ❑ Sensitivity analysis to initial hydrologic conditions
    - Initial soil moisture
    - Snow
    - Initial level of surface water (e.g. lakes, reservoirs)

SMHI

This study is based on the hard work of all the researchers in hydrology at SMHI

Thank you for your attention!!

Please share your insights with us!!