Streamflow prediction in River Rhine: Exploring combinations of bias-correcting forcing ensembles and bias-correcting streamflow ensembles

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Presentation outline

1. Introduction
2. Materials and methods
3. Results
4. Summary–Conclusions–Discussion
5. Closing remarks

Introduction

Problem Statement

- ensemble streamflow predictions are often biased in mean and spread
- to some degree, statistical post-processing (bias–correction) may resolve this
- another option: statistical processing of *forcings* (pre–processing)
- Research question: what, in addition to post–processing, is the added value of pre–processing and when is it justified?

Bias in 'raw' ensembles

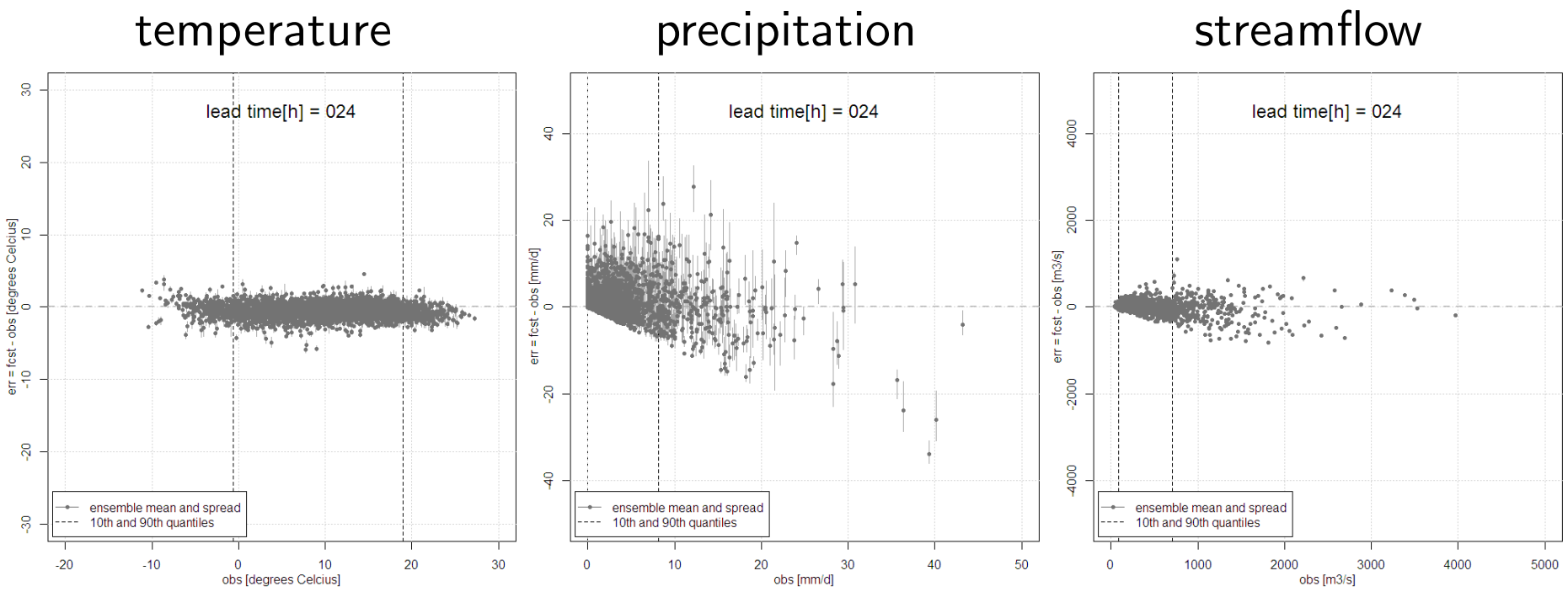
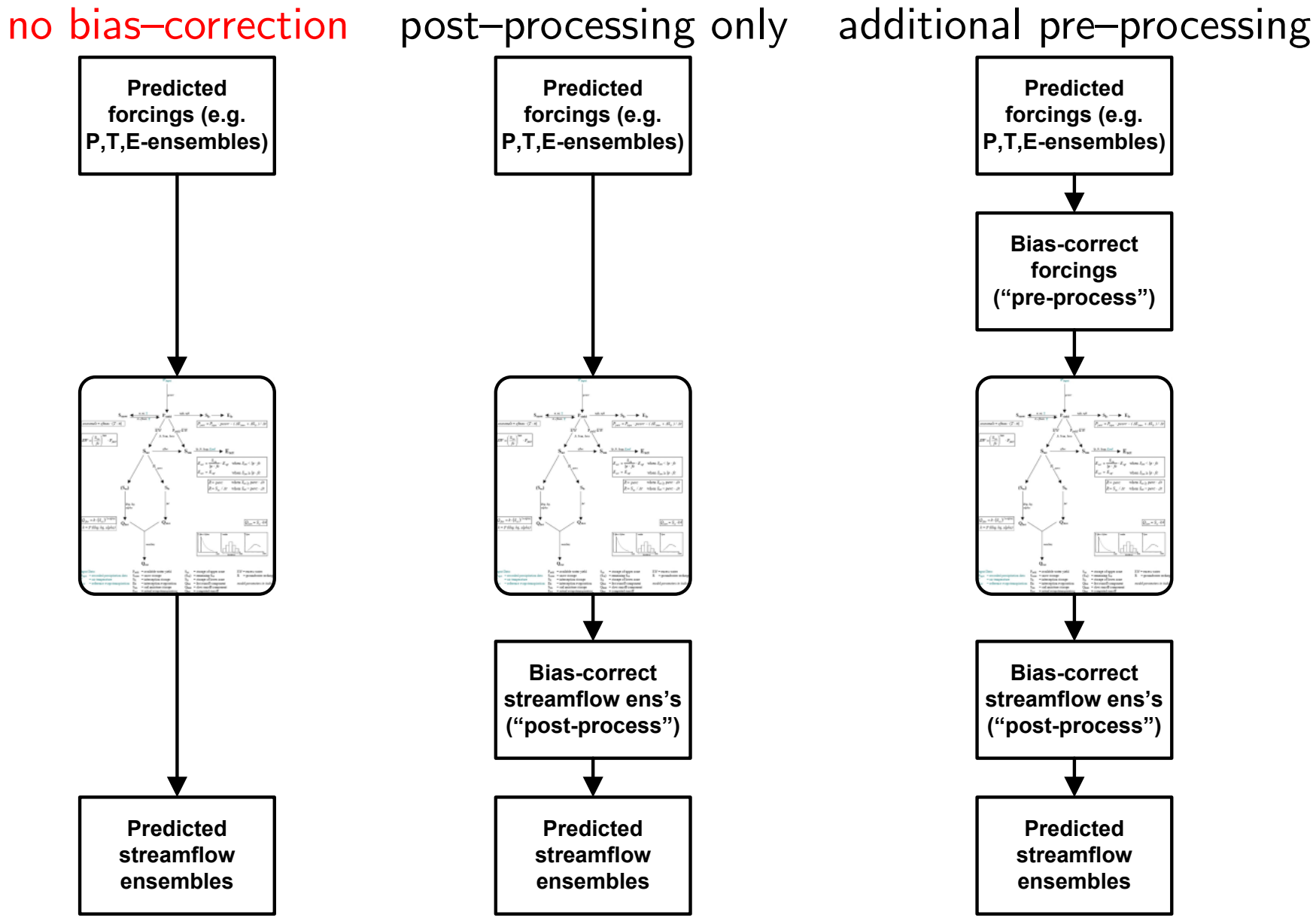


Figure: Forecast error versus observations for 'raw' temperature (left), precipitation (middle) and streamflow (right) ensembles

Research design



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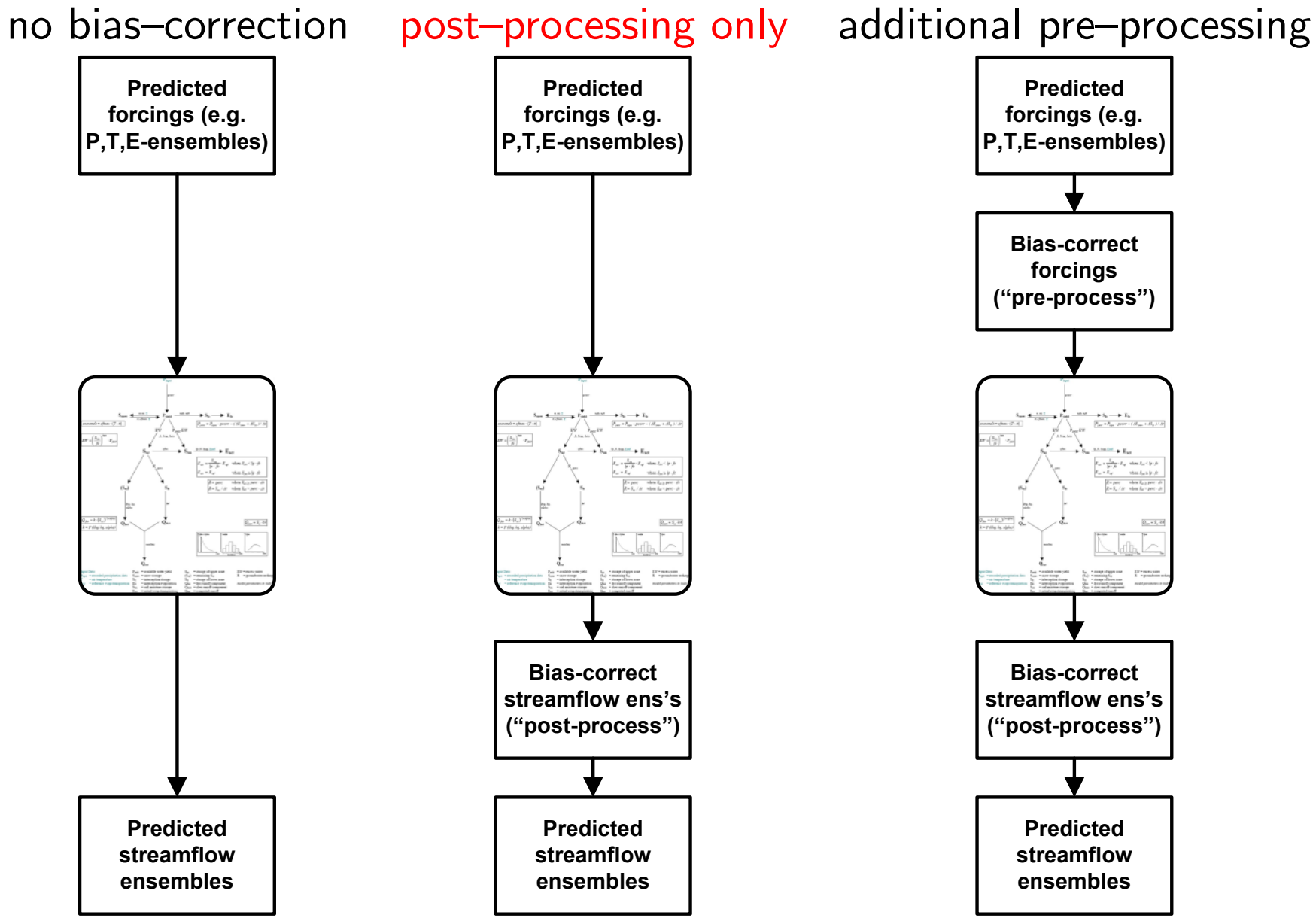

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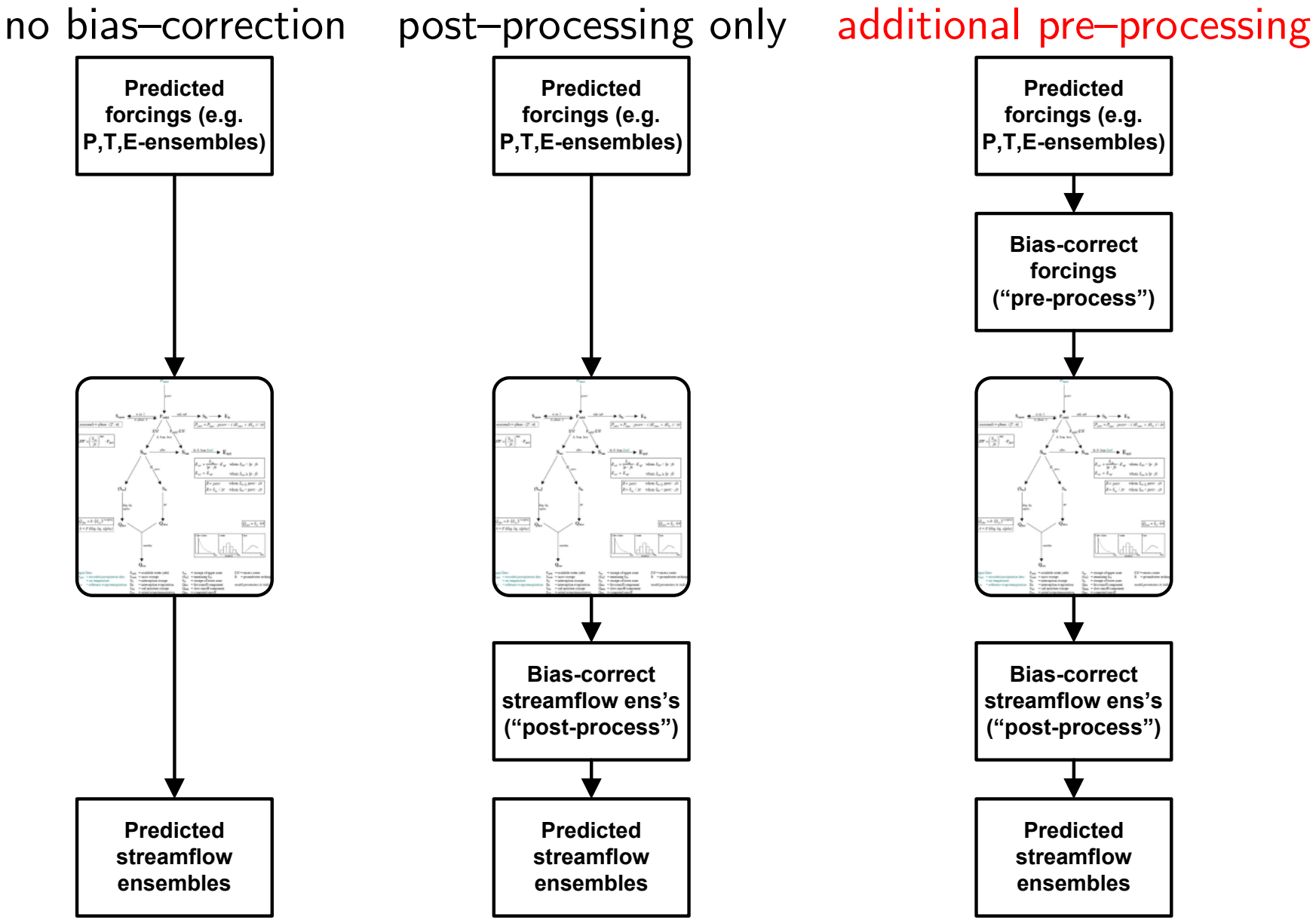
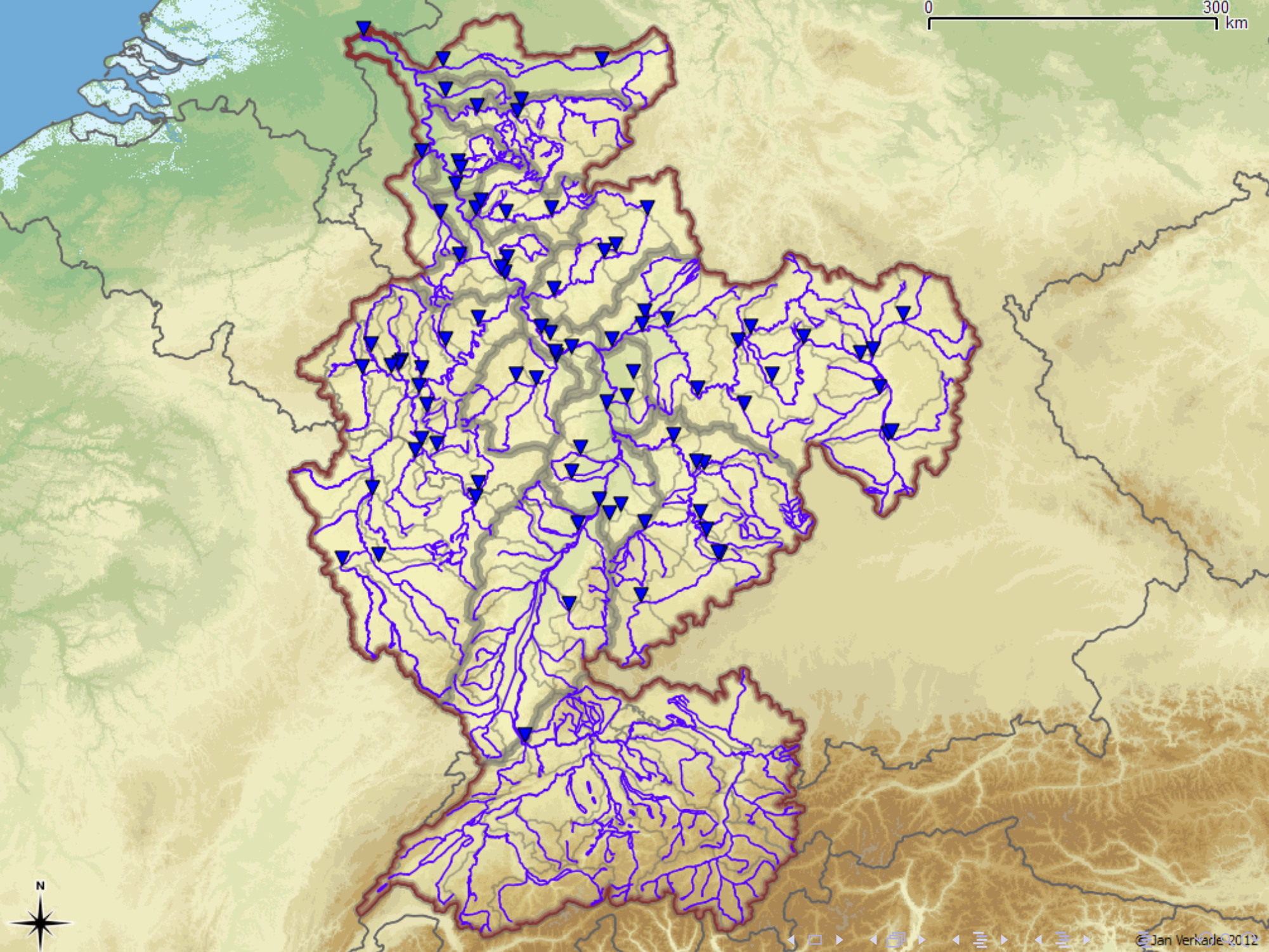
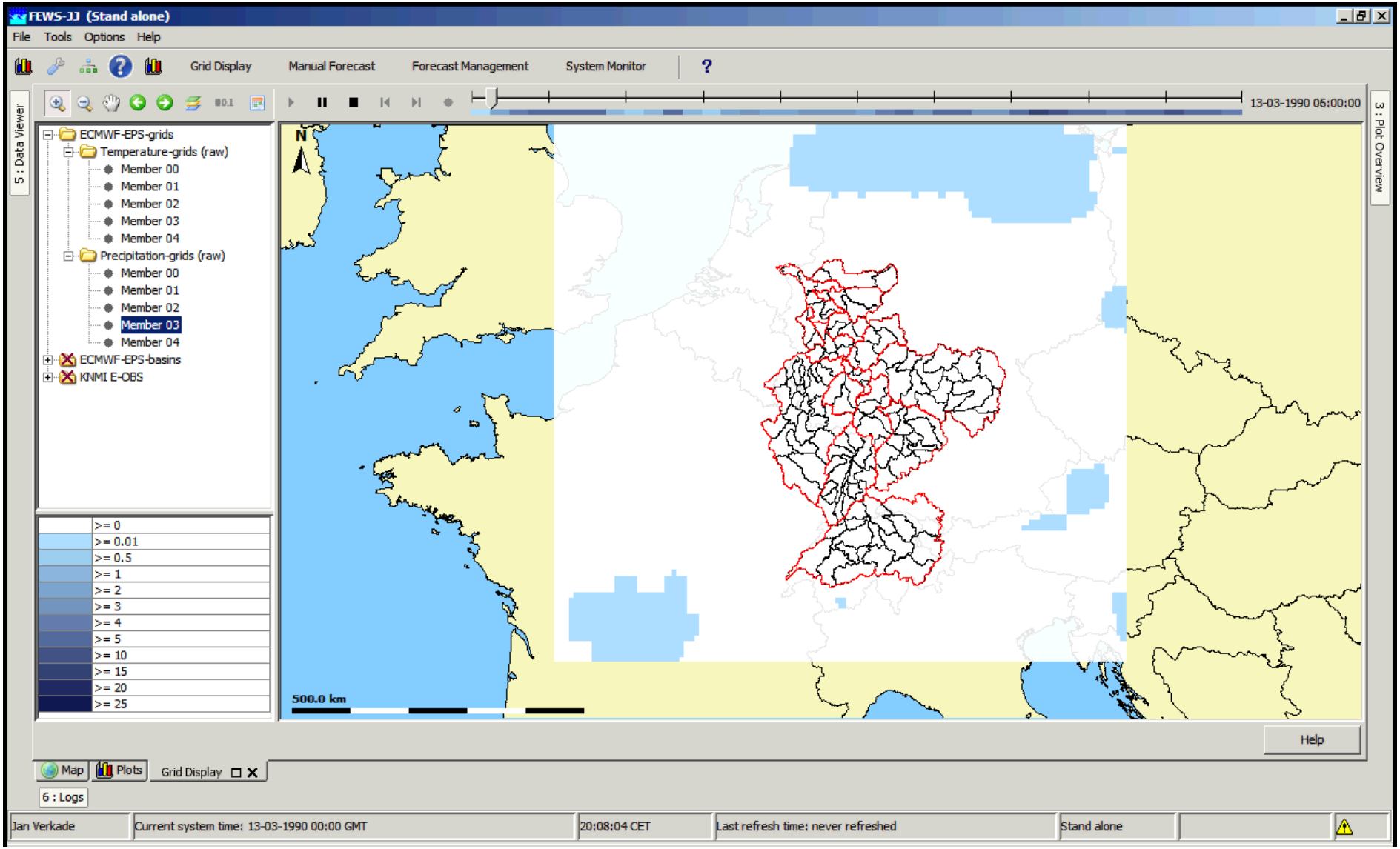



0
300
km
N
© Jan Verkade 2012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Grid Display
Manual Forecast
Forecast Management
System Monitor
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5 : Data Viewer
3 : Plot Overview
ECMWF-EPS-grids
Temperature-grids (raw)
Member 00
Member 01
Member 02
Member 03
Member 04
Precipitation-grids (raw)
Member 00
Member 01
Member 02
Member 03
Member 04
ECMWF-EPS-basins
KNMI E-OBS
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>= 0.01
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>= 1
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Jan Verkade
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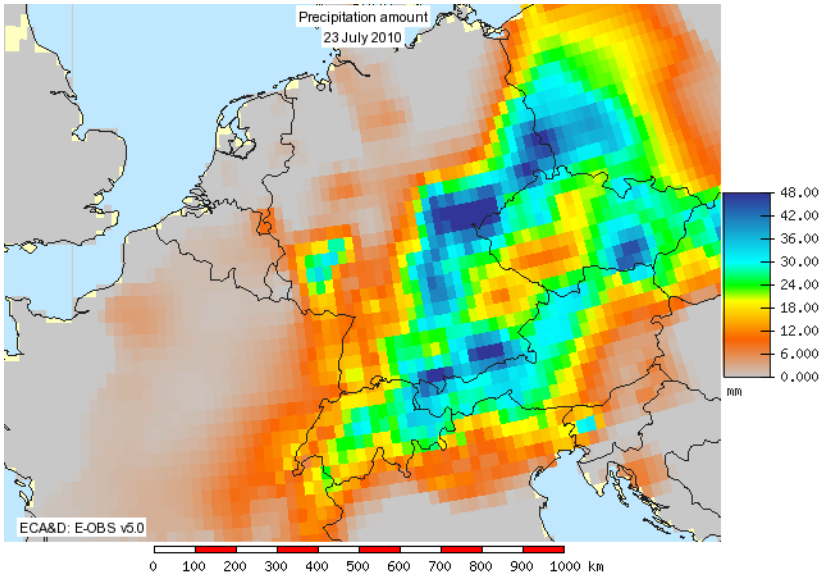
Stand alone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42.00
36.00
30.00
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18.00
12.00
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mm
ECA&D: E-OBS v5.0
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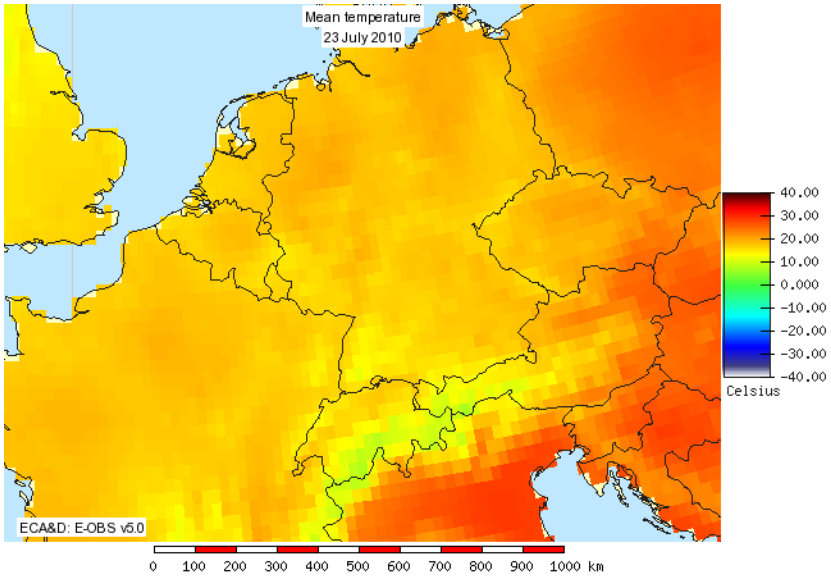
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ECA&D: E-OBS v5.0
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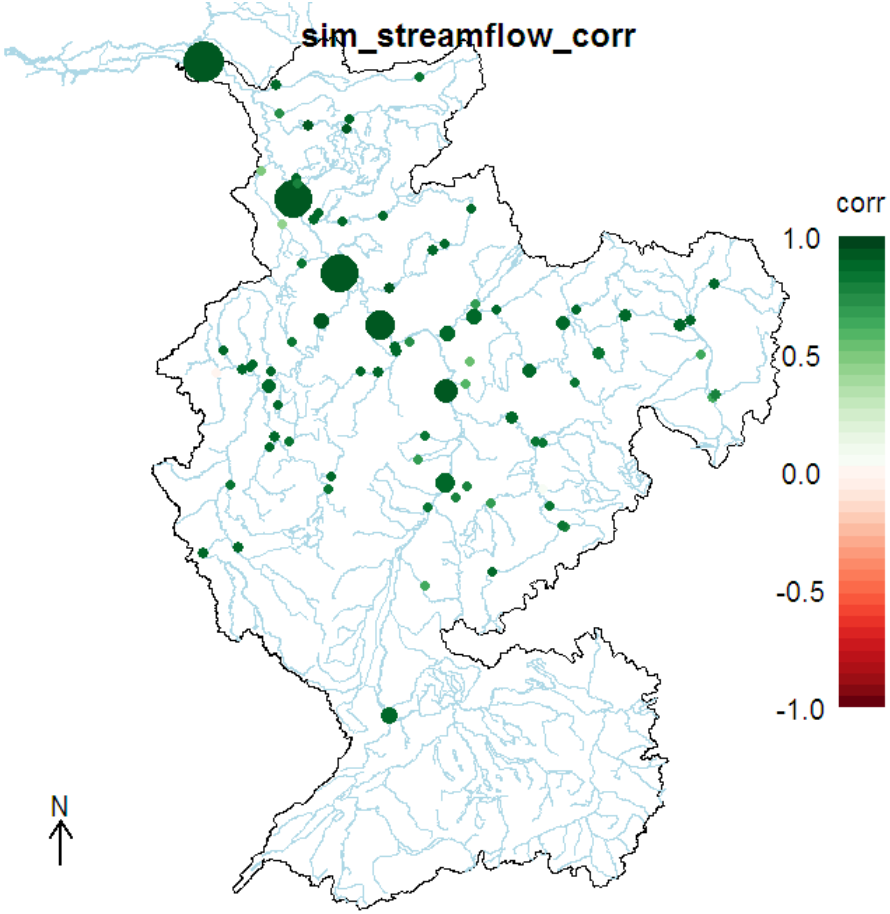
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-1.0
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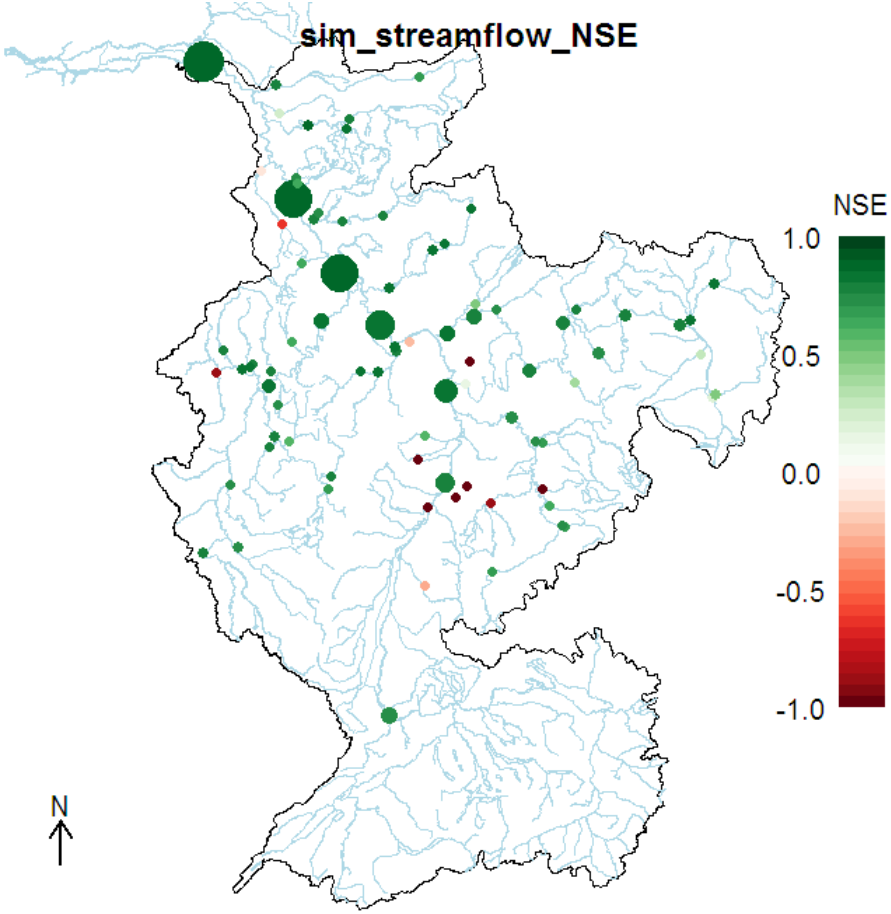
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-1.0
N

Bias-correction I

Principles

- Predictand Y = observed temperature, precipitation or streamflow. Assumed unbiased!
- Potential predictors $X = \{X_1, \ldots, X_5, \ldots, X_m\}$; biased.
- The bias—corrected forecast:

$$F\left(y|x_1, \ldots, x_m\right) = P\left[Y \leq y \mid X_1 = x_1, \ldots, X_m = x_m\right] \forall y$$

- for each lead—time and each location separately
- After bias-correction: "Schaake Shuffle" (Clark et al., 2004) to maintain spatial and temporal patterns ("traces")

Bias-correction II

Temperature

- linear regression (Gneiting et al., 2005; Hagedorn et al., 2008)
- $P\left[Y \leq y|\mu_X\right] = \Phi\left(\beta_0 + \beta_1\mu_X, \sigma_X\right)(y)$
- objective function: minimise MSE

Precipitation

- logistic regression (Hamill et al., 2008)
- $P\left[Y \leq y|\mu_X\right] = 1 - \frac{1}{1 + \exp^{\beta_0+\beta_1\mu_X}}$
- threshold-based technique, "non–parametric"
- objective function: maximise log-likelihood

Bias-correction III

Streamflow

- Krzysztofowicz approach: Hydrologic Uncertainty Processor (Krzysztofowicz, 1999)
- Prior: unconditional climatology
- Posterior: distribution of flow conditional on ensemble mean

Ensemble verification

- Continuous Ranked Probability Score, expressed as skill
  - measure for both reliability/calibration and sharpness/refinement
  - *skill* ranging from $-\infty$ to 1; 0 indicates skill equal to baseline, 1 indicates perfect skill
- skill relative to 'previous' case (!)
- metrics computed using Ensemble Verification System (Brown et al., 2010)

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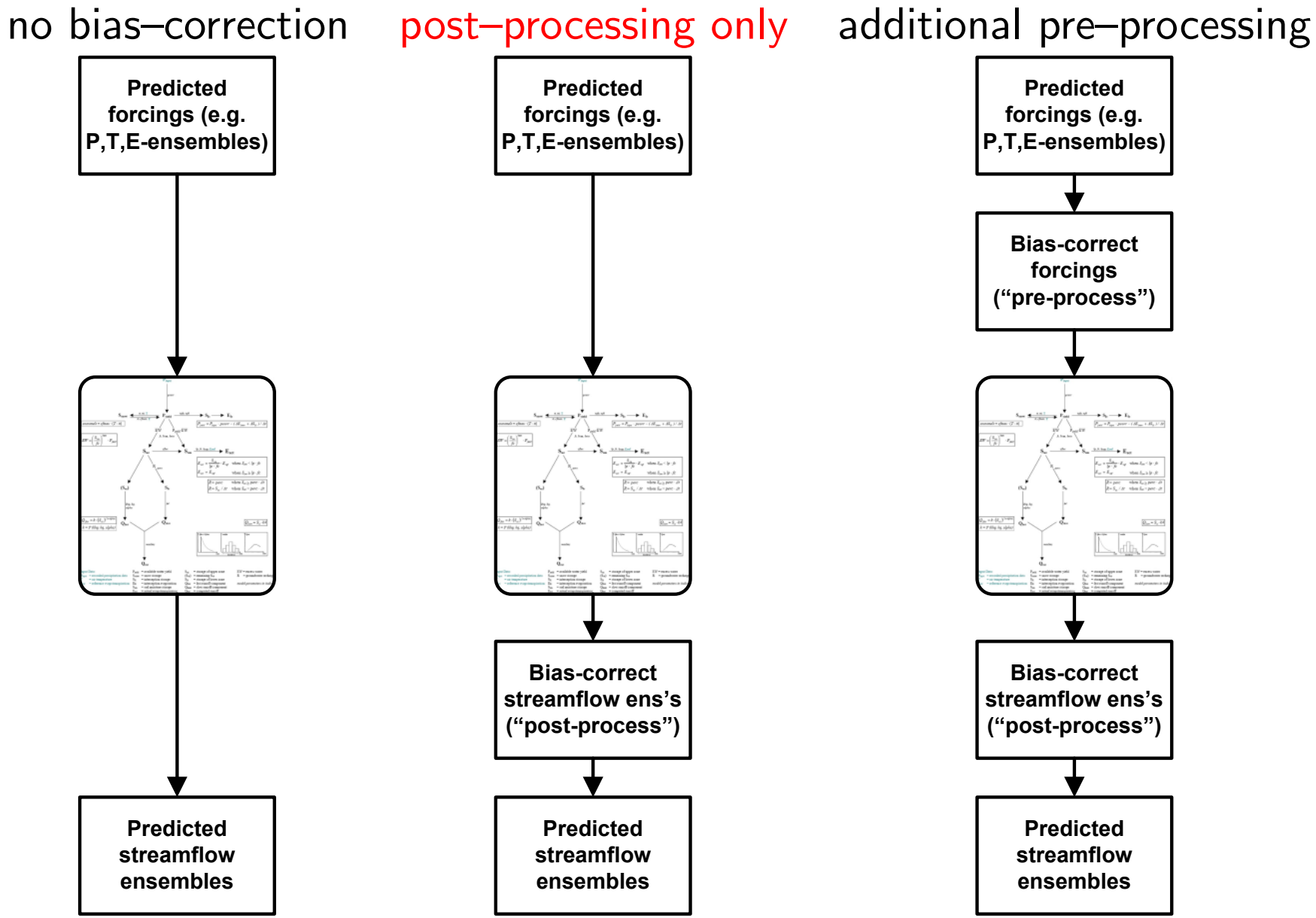
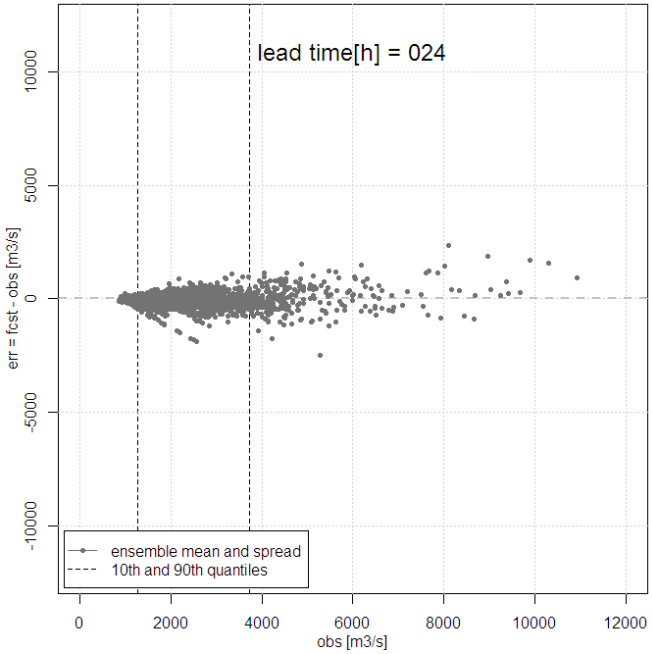
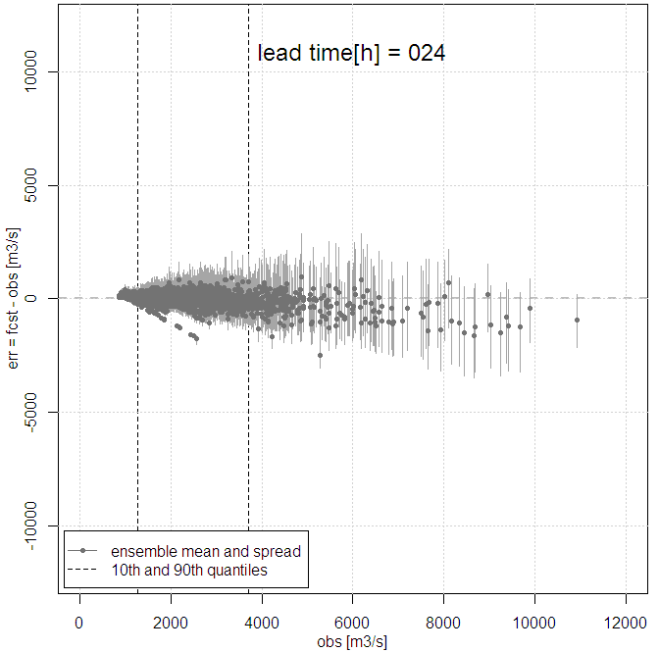
Research design



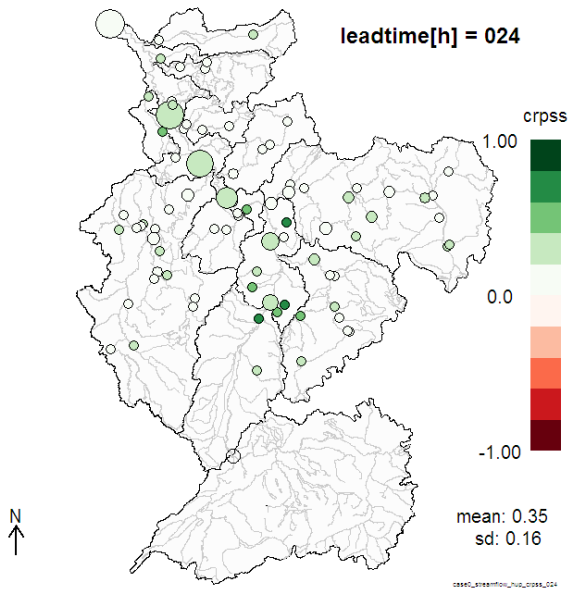
raw Q–ens error v. obs

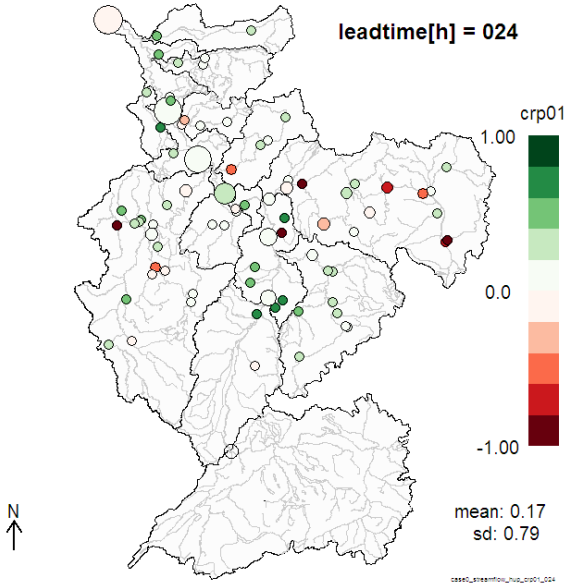


bias-corrected Q–ens error v. obs

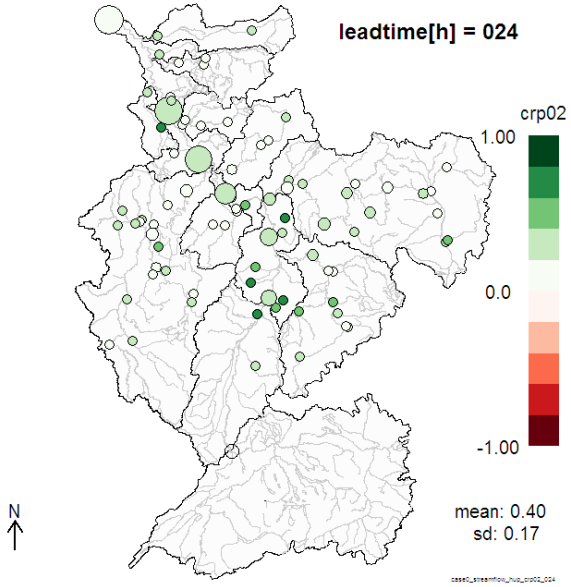


overall CRPSS

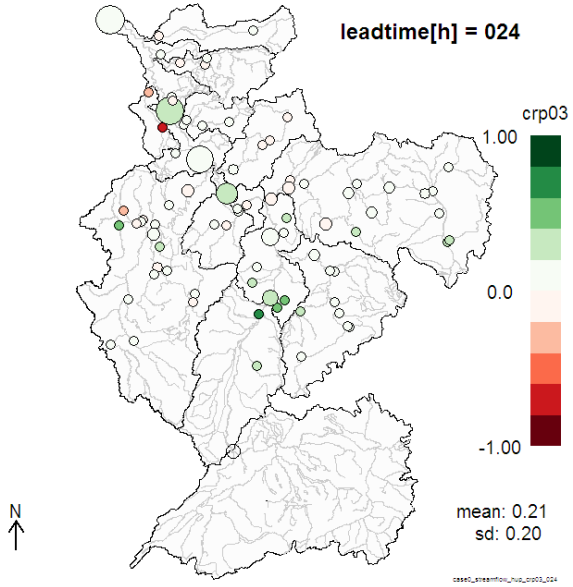




CRPSS (obs $\leq$ 10th quant.)

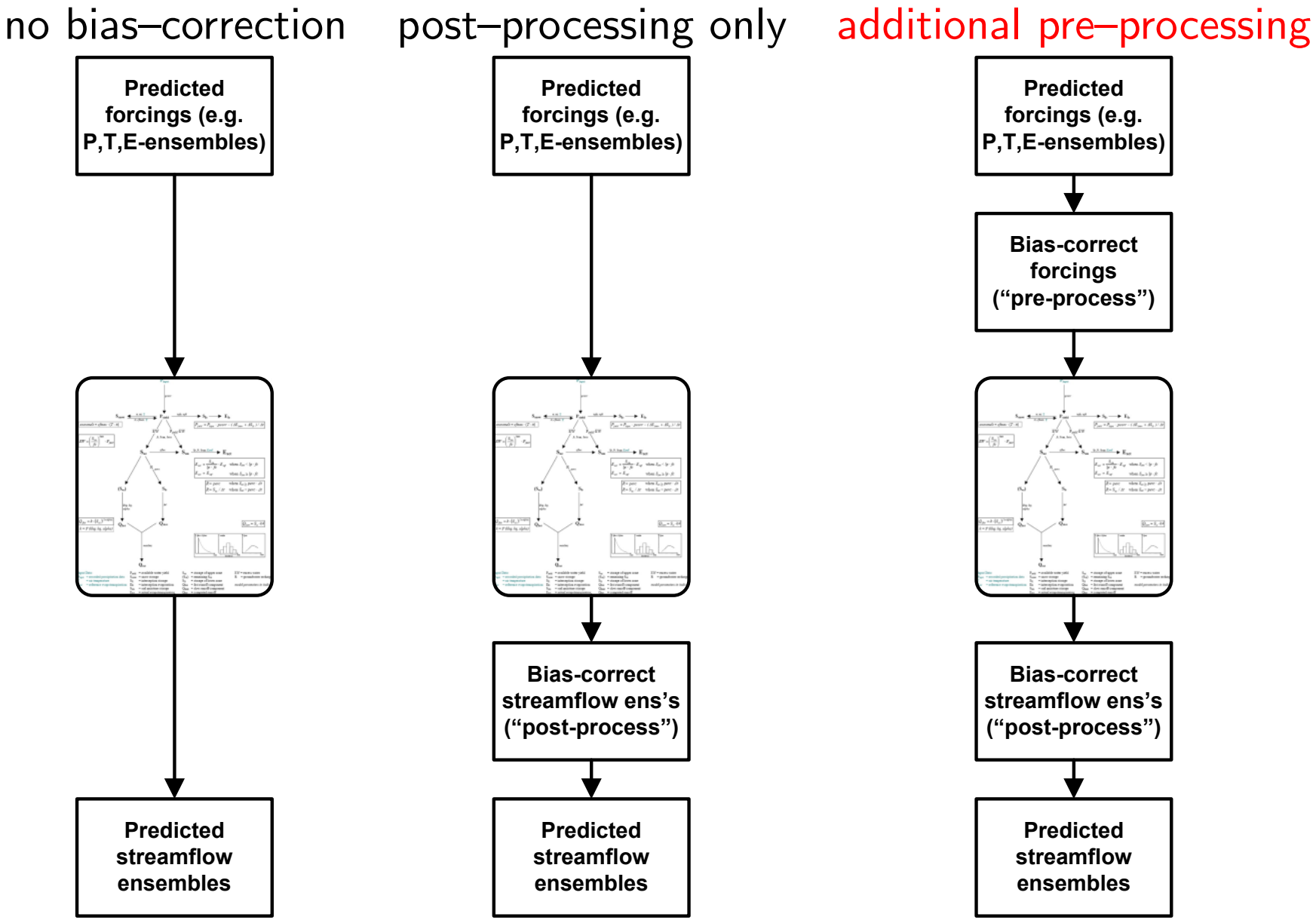


CRPSS (10th quant. $<$ obs $<$ 90th quant.)

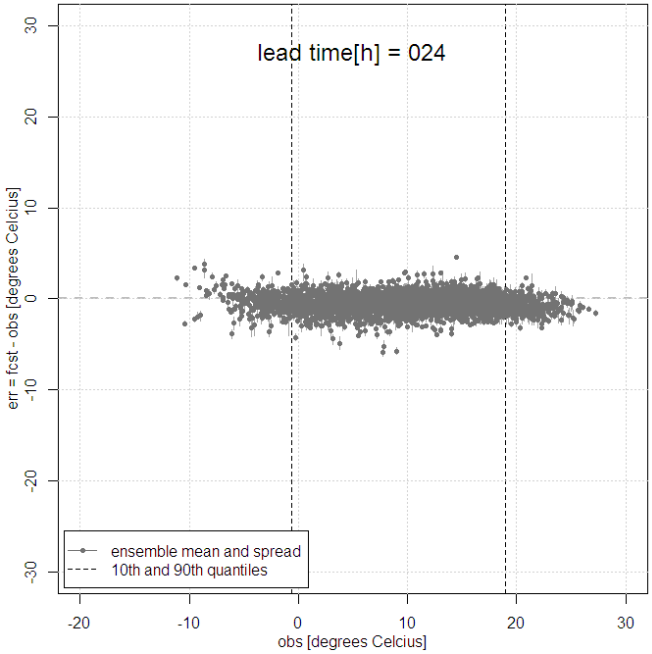


CRPSS (obs $\geq$ 90th quant.)

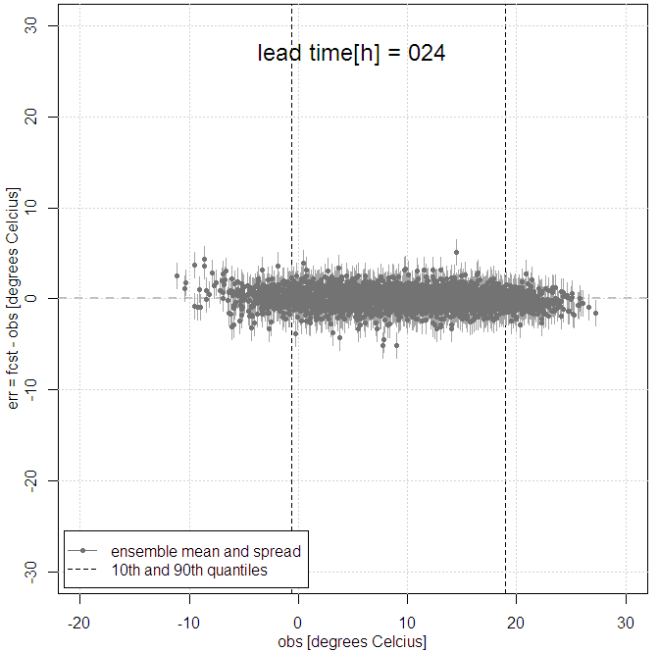
Research design



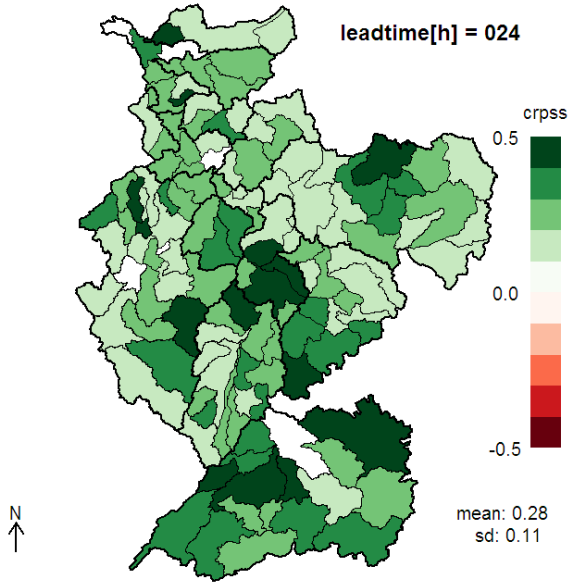
raw T–ens error v. obs

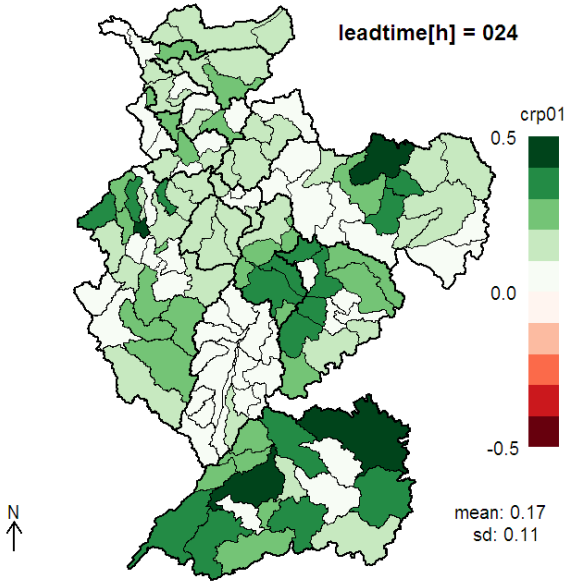


bias-corrected T–ens error v. obs

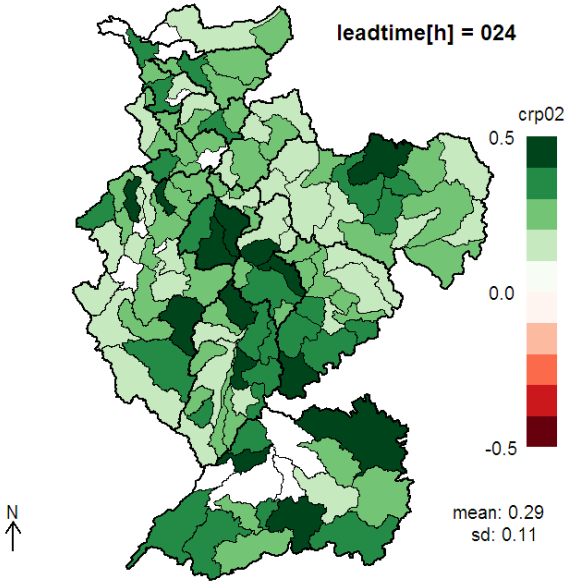


overall CRPSS

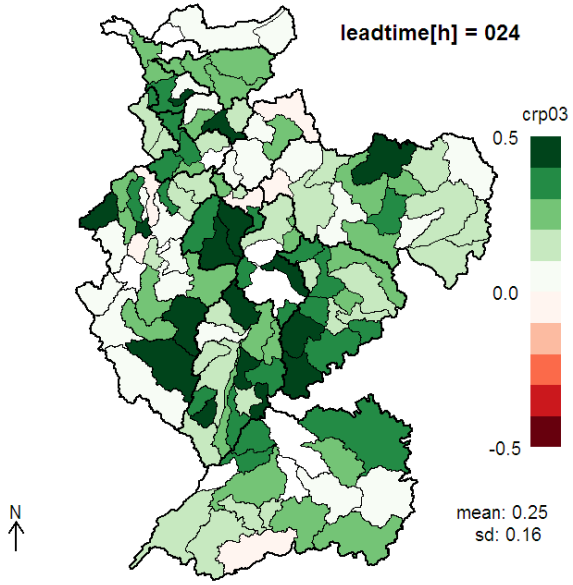




CRPSS (obs $\leq$ 10th quant.)

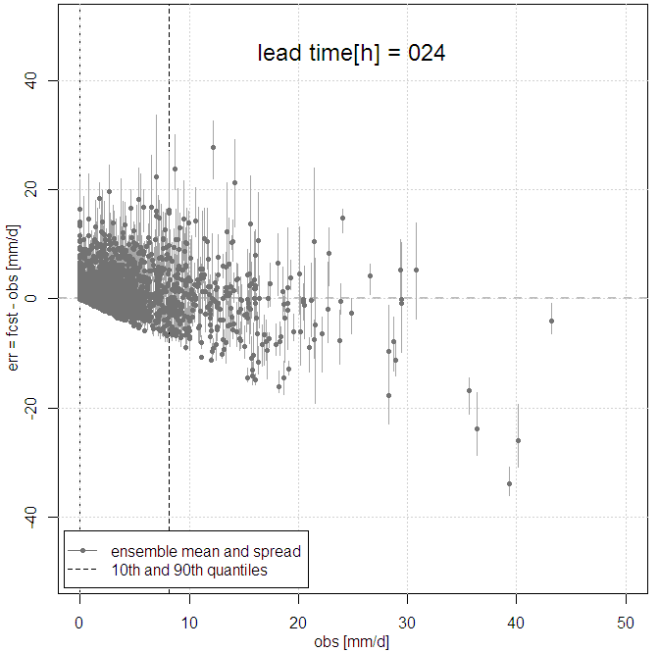


CRPSS (10th quant. $<$ obs $<$ 90th quant.)

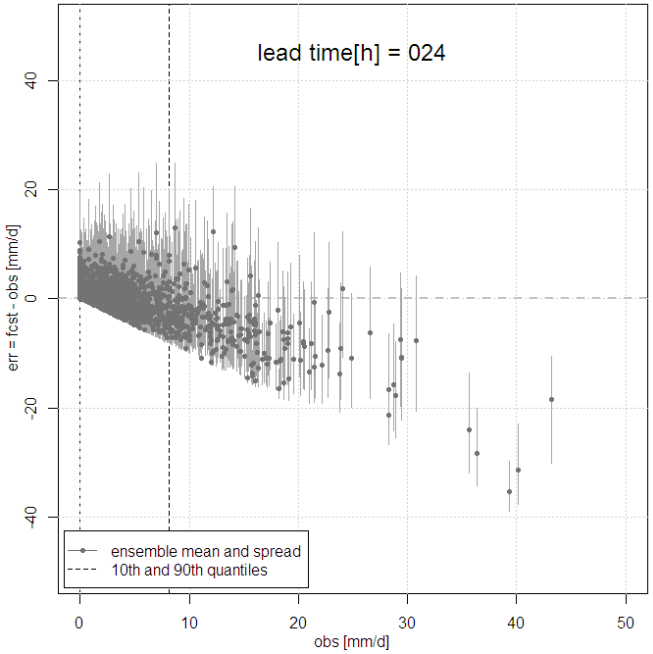


CRPSS (obs $\geq$ 90th quant.)

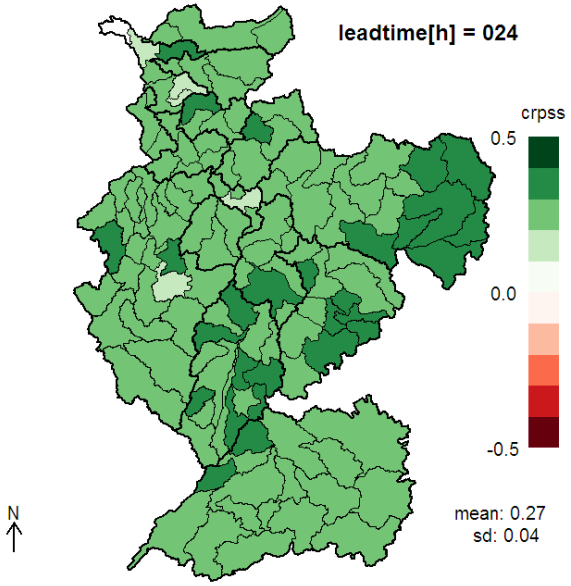
raw P–ens error v. obs

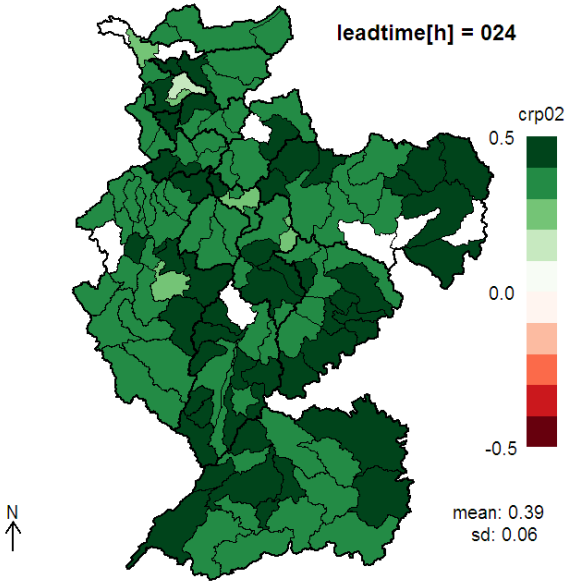


bias-corrected P–ens error v. obs

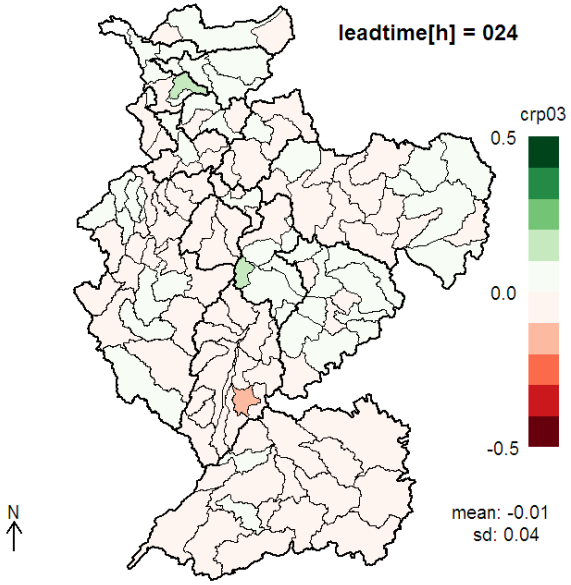


overall CRPSS



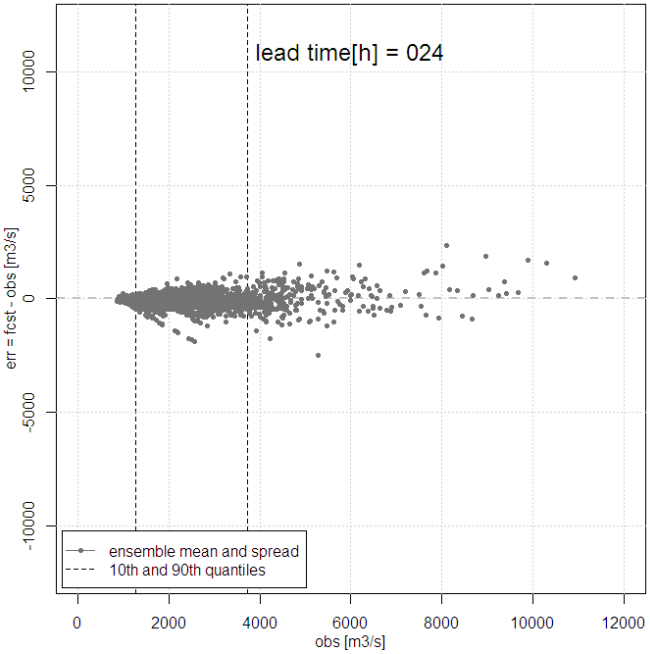


CRPSS (obs $<$ 90th quant.)

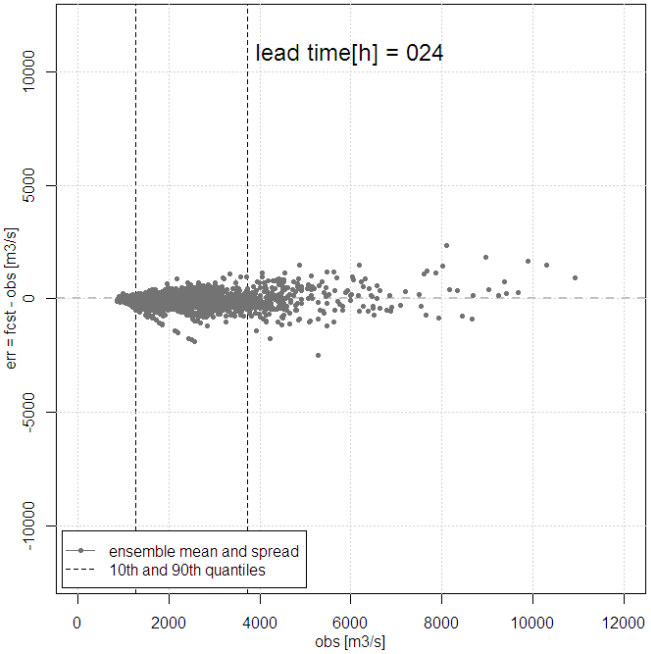


CRPSS (obs $\geq$ 90th quant.)

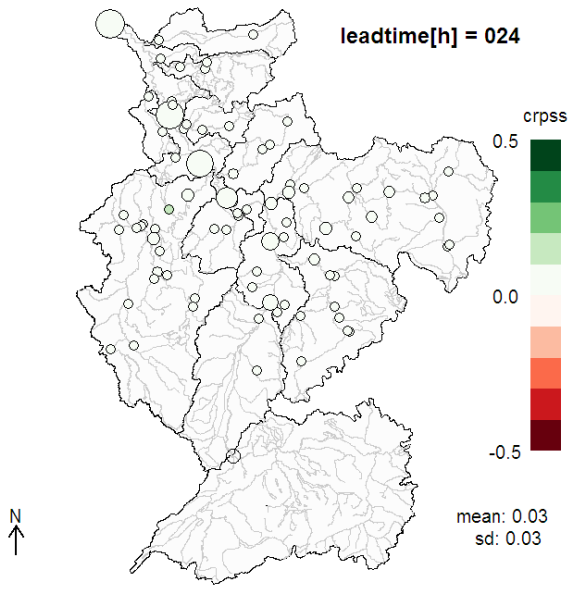
raw Q–ens error v. obs

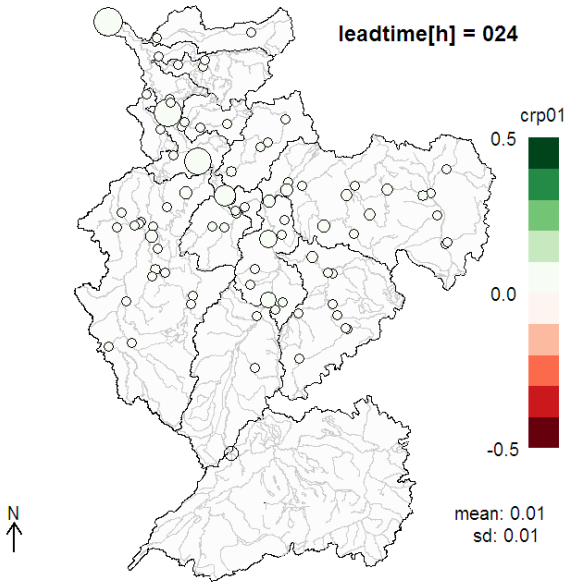


"semi–raw" Q–ens error v. obs

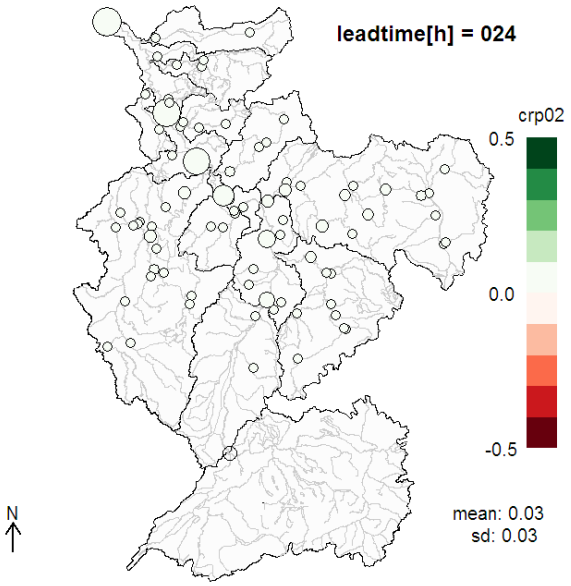


overall CRPSS

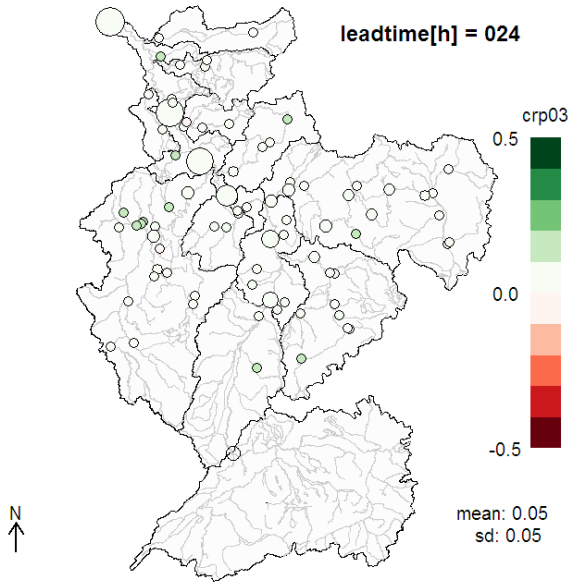




CRPSS (obs $\leq$ 10th quant.)

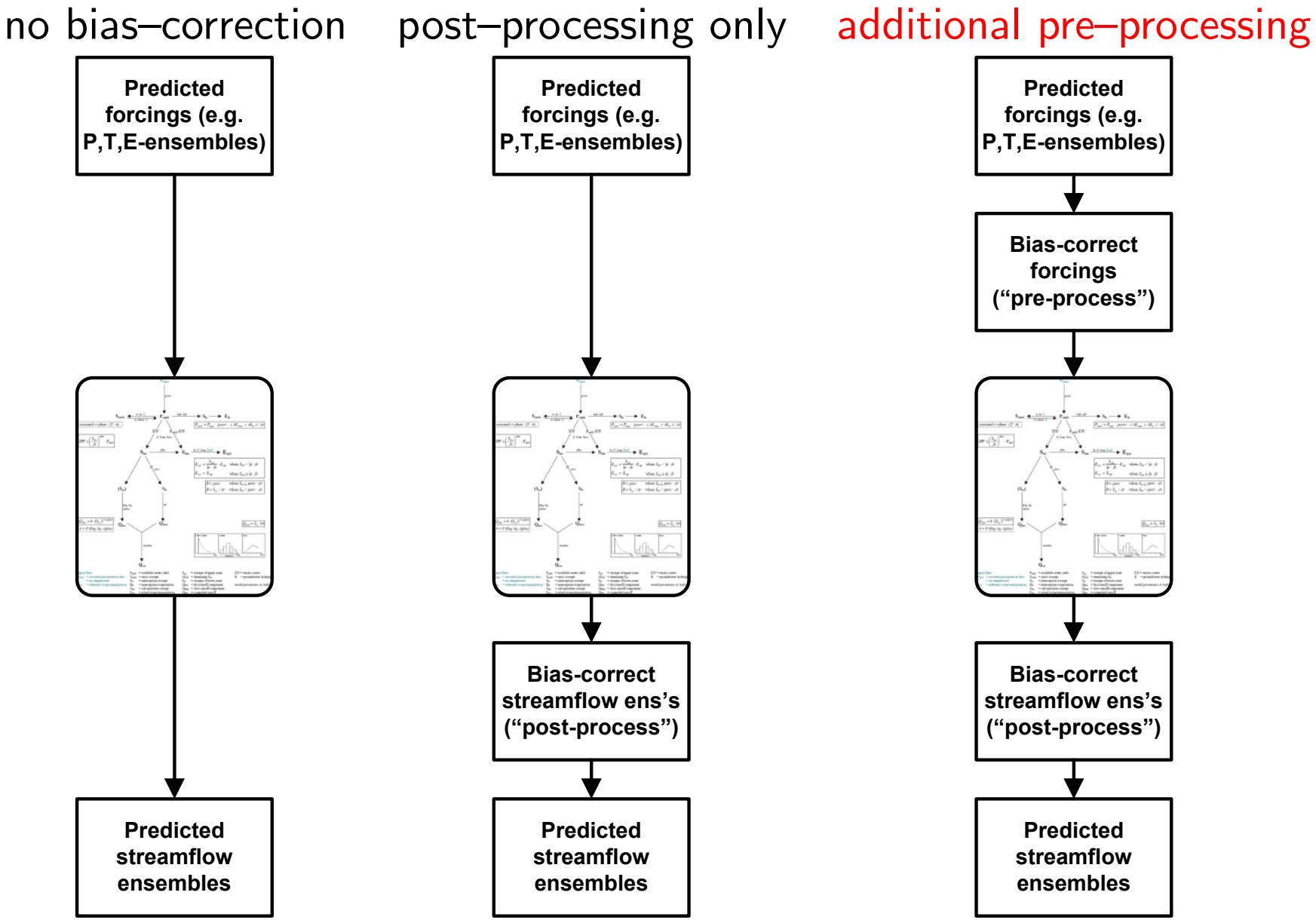


CRPSS (10th quant. $<$ obs $<$ 90th quant.)

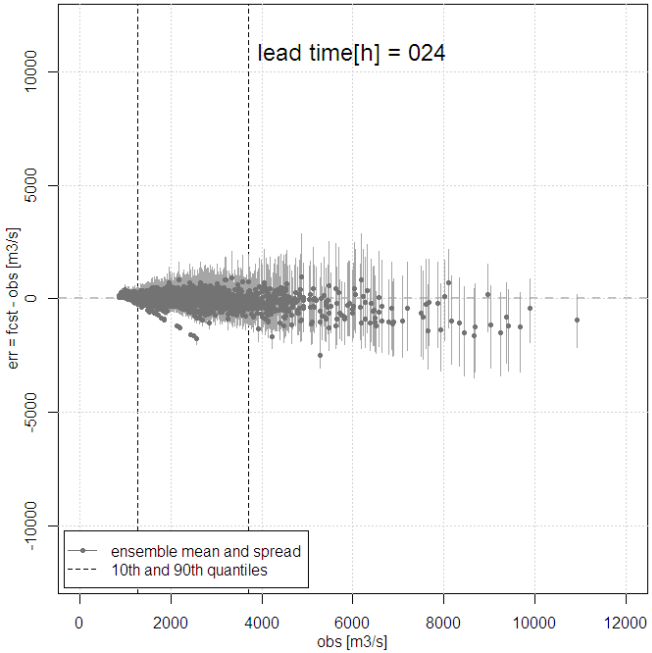


CRPSS (obs $\geq$ 90th quant.)

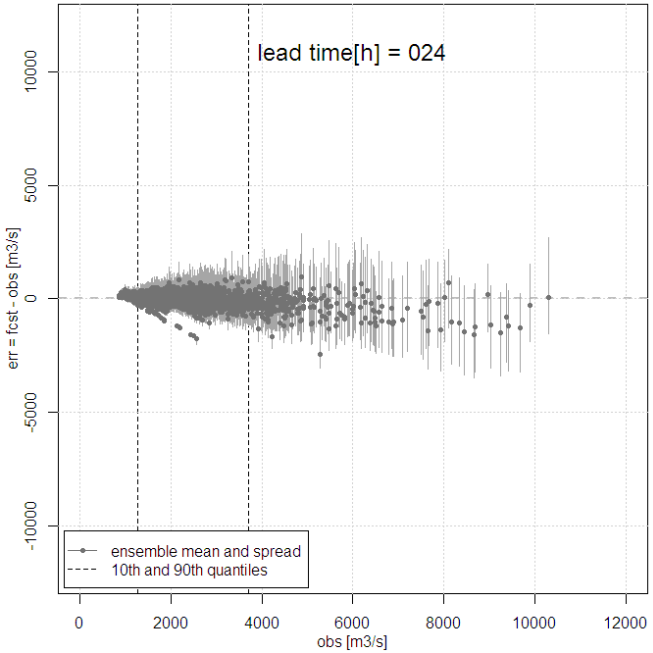
Research design



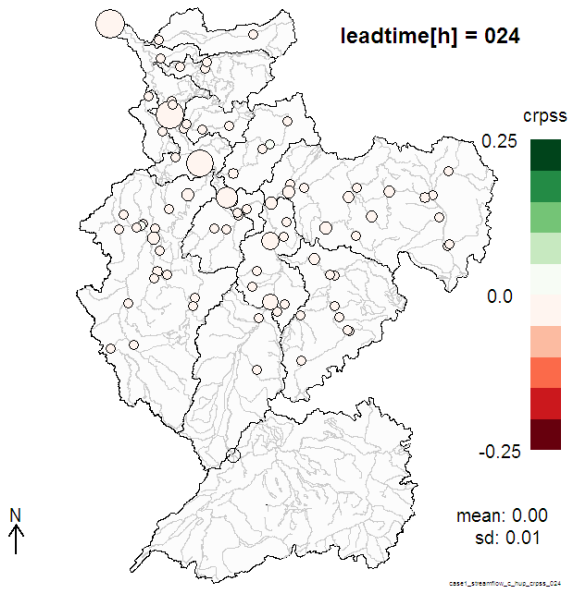
post–processed Q–ens error v. obs

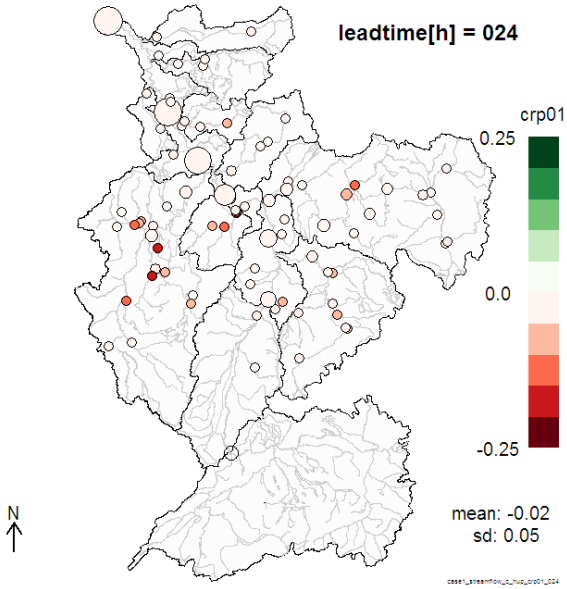


(bias-corrected)^2 Q–ens error v. obs

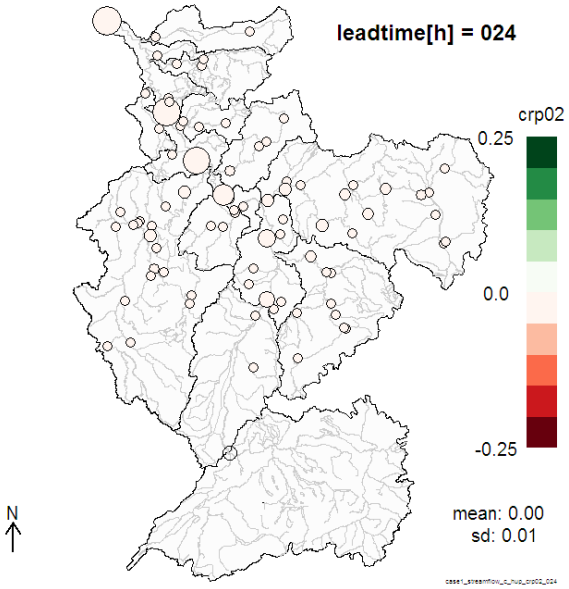


overall CRPSS

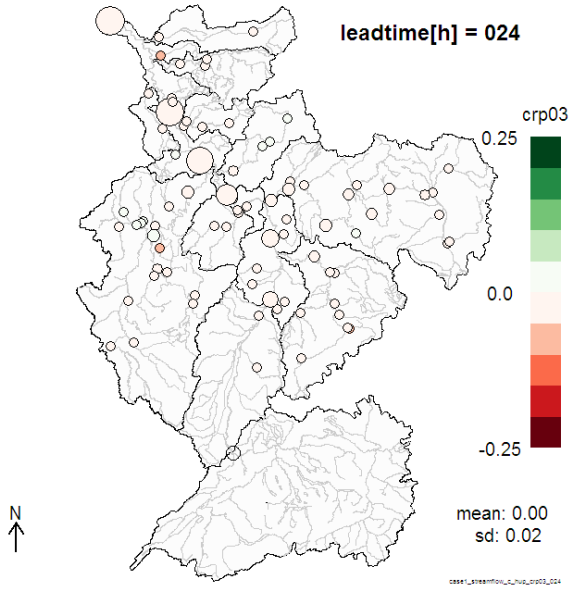




CRPSS (obs $\leq$ 10th quant.)



CRPSS (10th quant. $<$ obs $<$ 90th quant.)



CRPSS (obs $\geq$ 90th quant.)

Summary–Conclusions–Discussion I

- raw ensemble P, T and Q predictions show reasonable skill
- post–processing:
  - increases skill of predicted Q–ensembles considerably
- pre–proceccing:
  - pre–processing results in reasonable increase in overall skill of predicted forcings
  - conditional biases in forcing ensembles not easily reduced
  - and lead to mixed results in terms of streamflow ensembles (compared to raw forecasts)
- pre–processing in addition to post–processing
  - results in more or less similar skills compared to the 'post–processing only' scenario
- overall skill of 'raw' forcing ensembles is quite good and not easily improved
- further analysis required: uncertainty in predicted forcings versus uncertainty in initial conditions

Summary–Conclusions–Discussion II

- conditional biases are main issue to be addressed
- use of likelihood–base rate metrics and associated decomposition to direct further research

Bibliography I

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