UERA
Uncertainties in Ensembles
of Regional ReAnalyses

Uncertainty in the Analysis of Daily Precipitation – Insights from an Ensemble Analysis for the Alps

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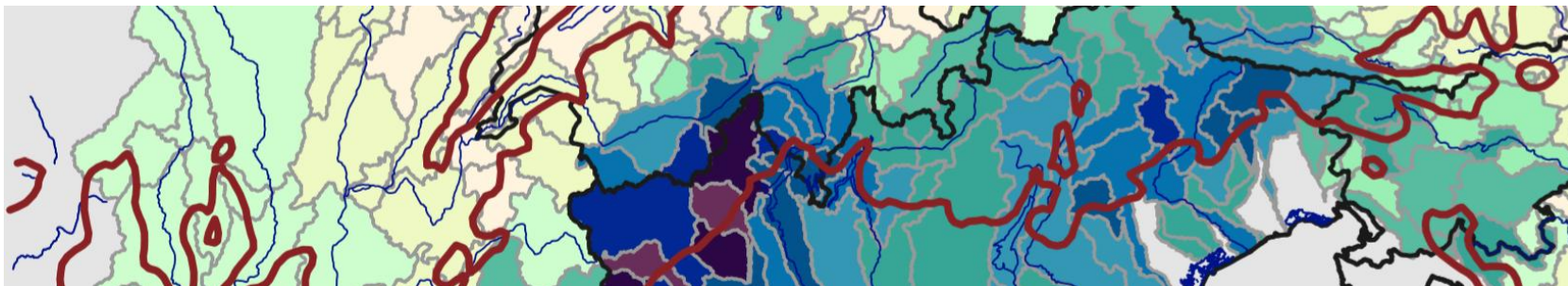
Motivation

- Spatial precipitation analyses are subject to error
  - Limited observations & predictability, measurement errors
  - Representativity errors (ambiguities about scale)

- Classical treatment of uncertainty is unsatisfactory
  - summary measures only
  - no information about scale dependence

- User want to trace uncertainties through applications
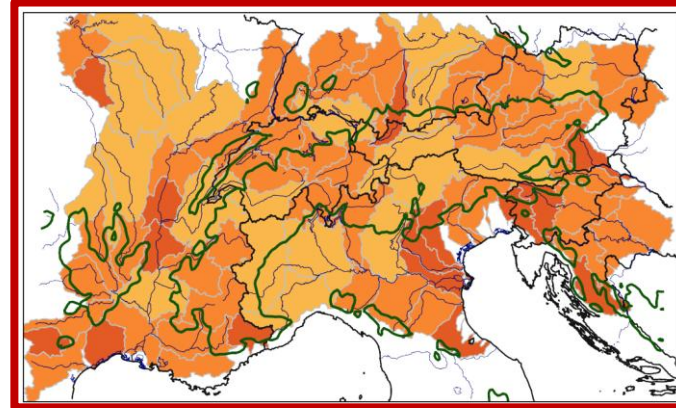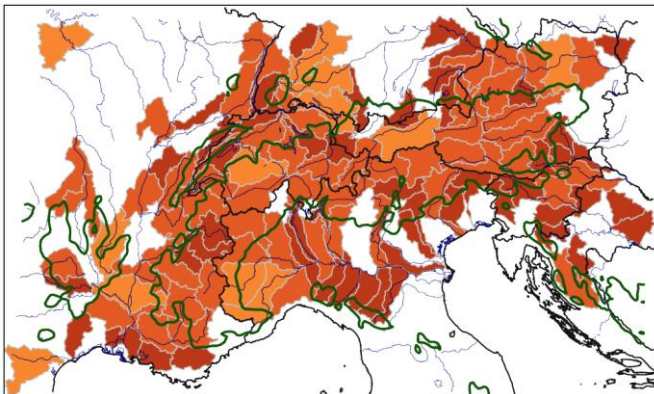 - Ensemble analyses are attractive

MeteoSwiss

Hydrological Units
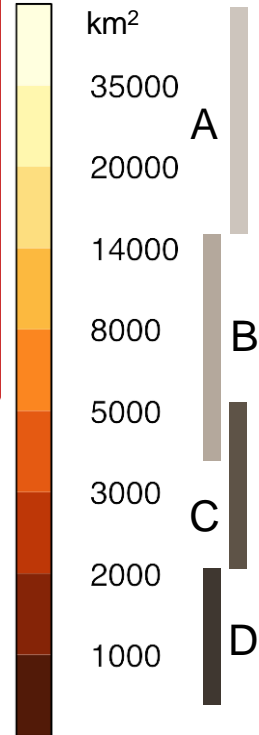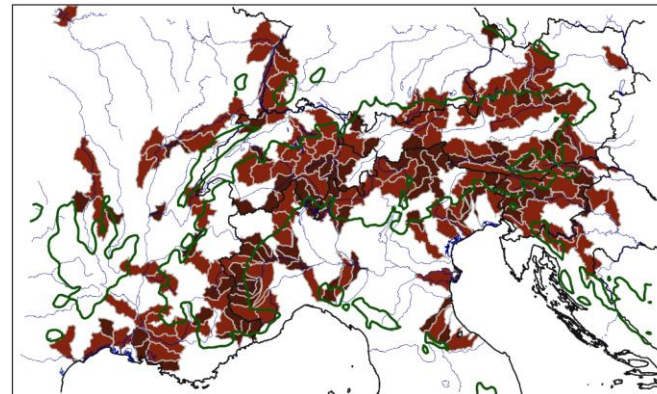
A: 14'000-44'000 km^2
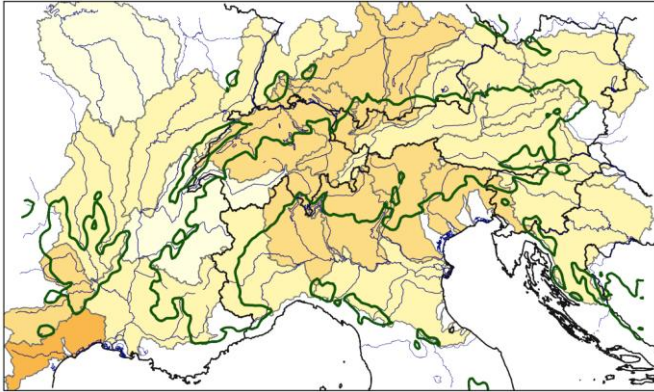
B: 3'500-14'000 km^2

C: 2'000-5'000 km^2

D: 500-2'000 km^2

European River Catchments Dataset of EEA
altogether 534 hydrological units

Probabilistic Method

- Stochastic Model: Trans-Gaussian Random Fields
  - Box-Cox power transform
  - exponential spatial covariance & nugget effect
  - 5 parameters: transf. exponent, intercept, nugget, sill, range

- Inference: Bayesian
  - posterior (joint) distribution of model parameters
  - MCMC sampling with locally adaptive jump proposals

- Ensemble of Catch. Means: Conditional Simulation
  - at points of high-res grid within catchment ($\leq$ 1 km)
  - conditioned on rain gauge data
 - average over all points in catchment (upscaling)

Ensembles in Gridding

- Several earlier proposals ...
  - Ahrens & Jaun 2005, Bellerby & Sun 2005, Pappenberger et al. 2009, Moulin et al. 2009, Wilson et al. 2014, ...

- ... suffer from methodological limitations
  - Gaussian model   > Trans-Gaussian model
  - Spatial stationarity in large domains   > Sub-regional application
  - Neglect parameter uncertainty   > Bayesian inference
  - Ambiguous in spatial support   > Well-defined units
  - Reliability not verified   > Evaluation
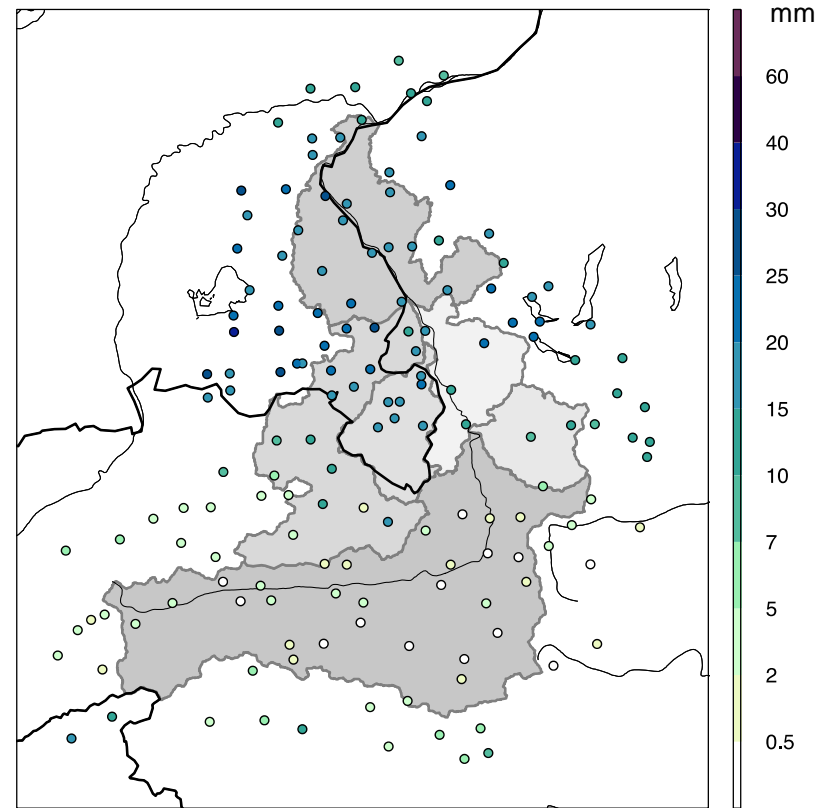 - Measurement errors neglected   > X (plans for future)

Example – Data
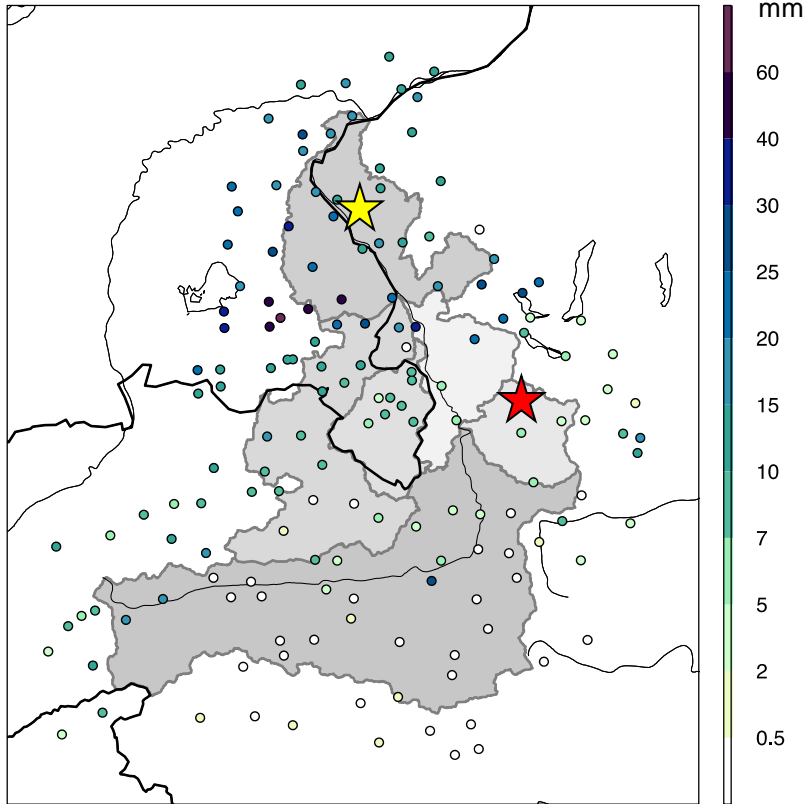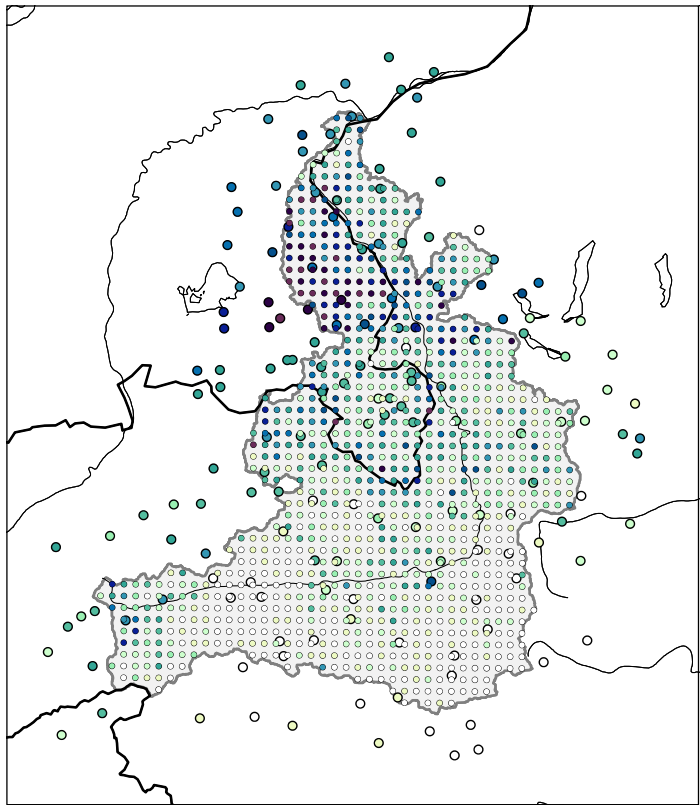

1990.06.30, convective   1990.10.29, stratiform

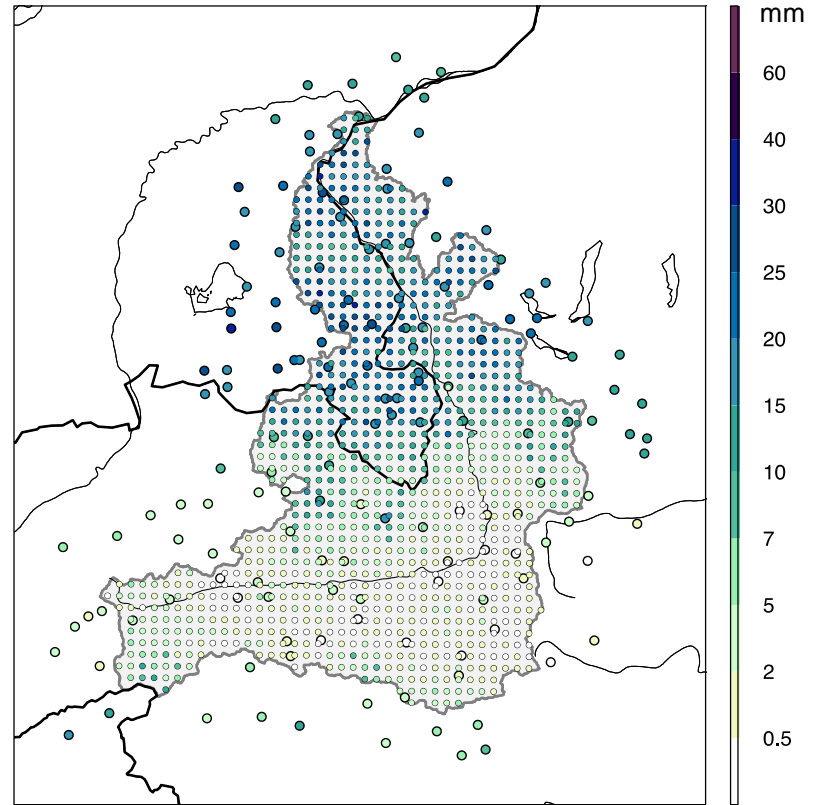Salzach (6738 km^2), Lower Salzach (1086 km^2), Lammer (395 km^2)

Example – Simulation

1990.06.30, convective   1990.10.29, stratiform
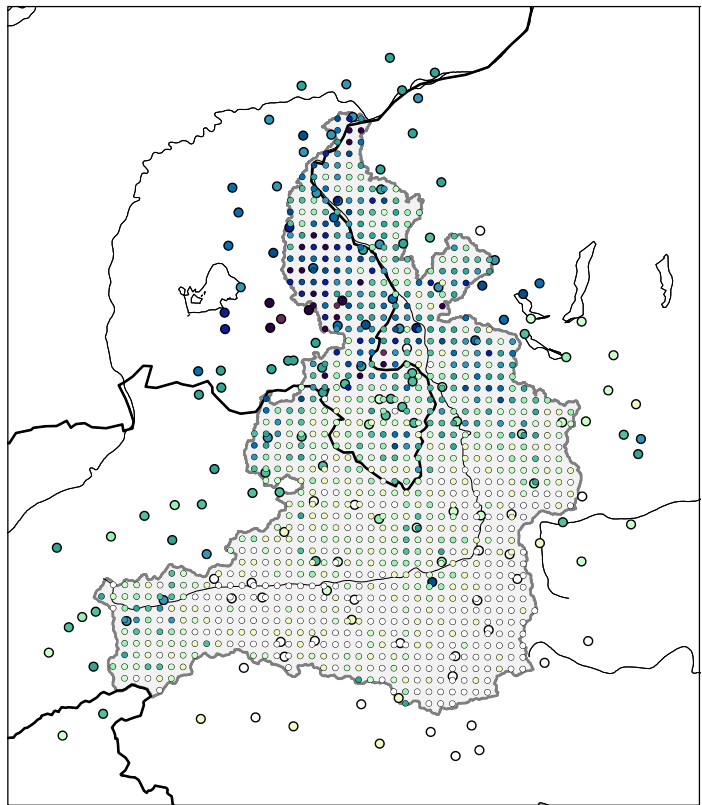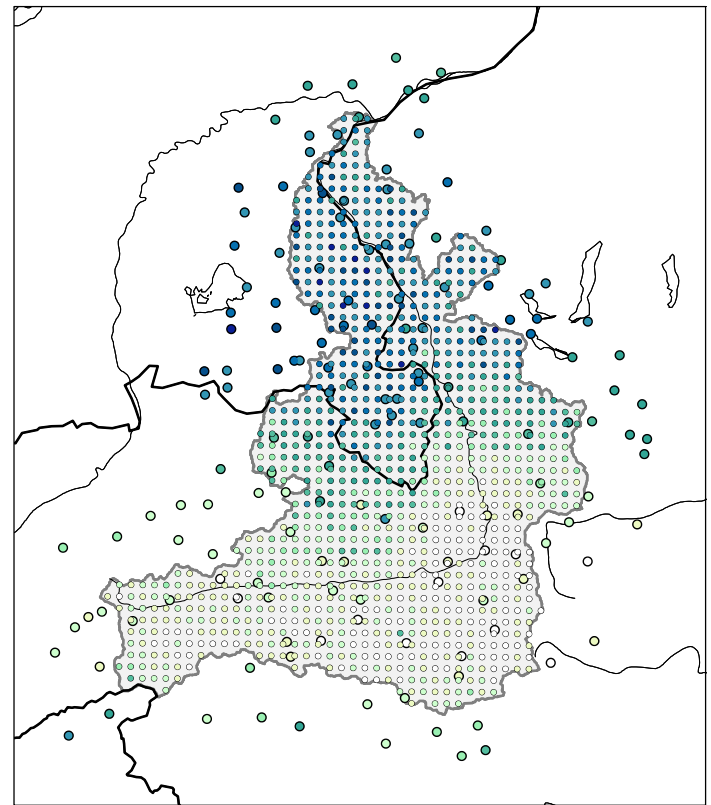
Ensemble Member

Example – Simulation

1990.06.30, convective

1990.10.29, stratiform

Ensemble Member

Example – Simulation

1990.06.30, convective

1990.10.29, stratiform

Ensemble Member

Example – Simulation

1990.06.30, convective
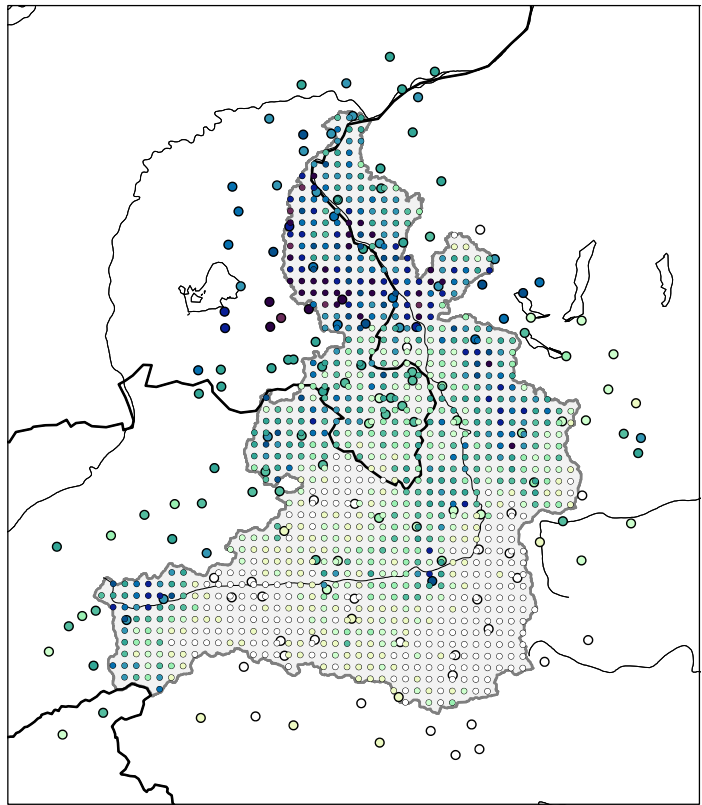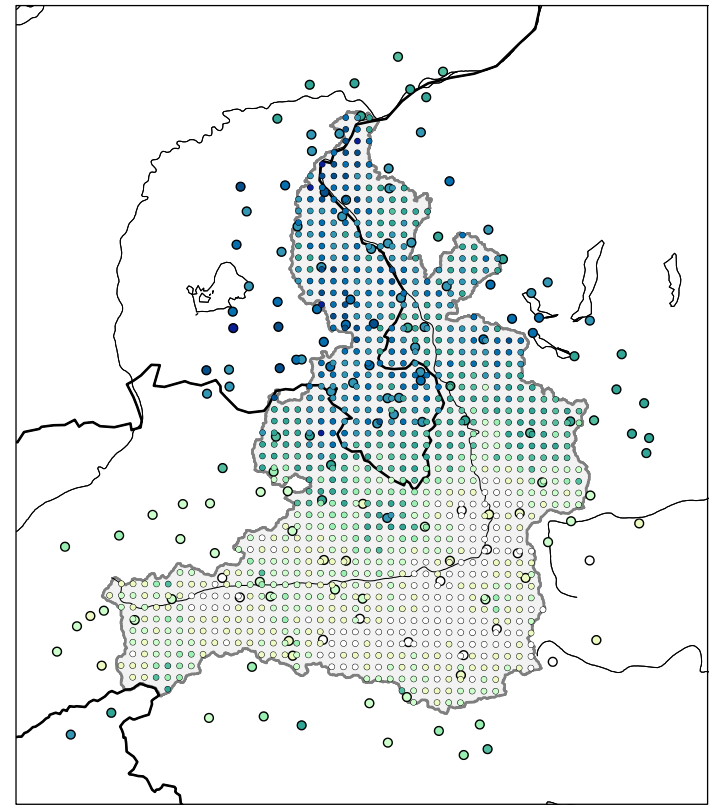
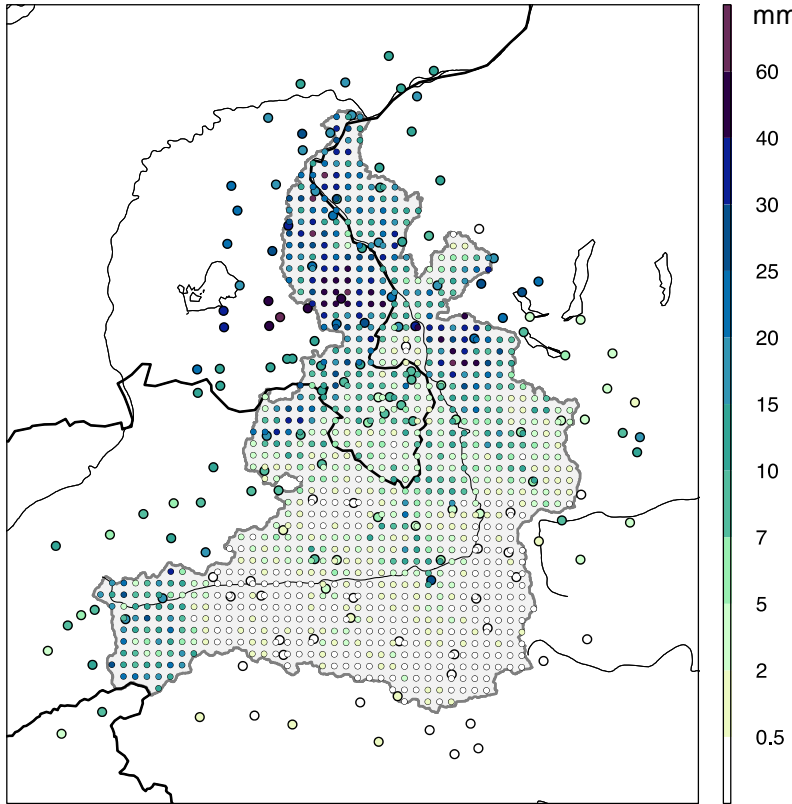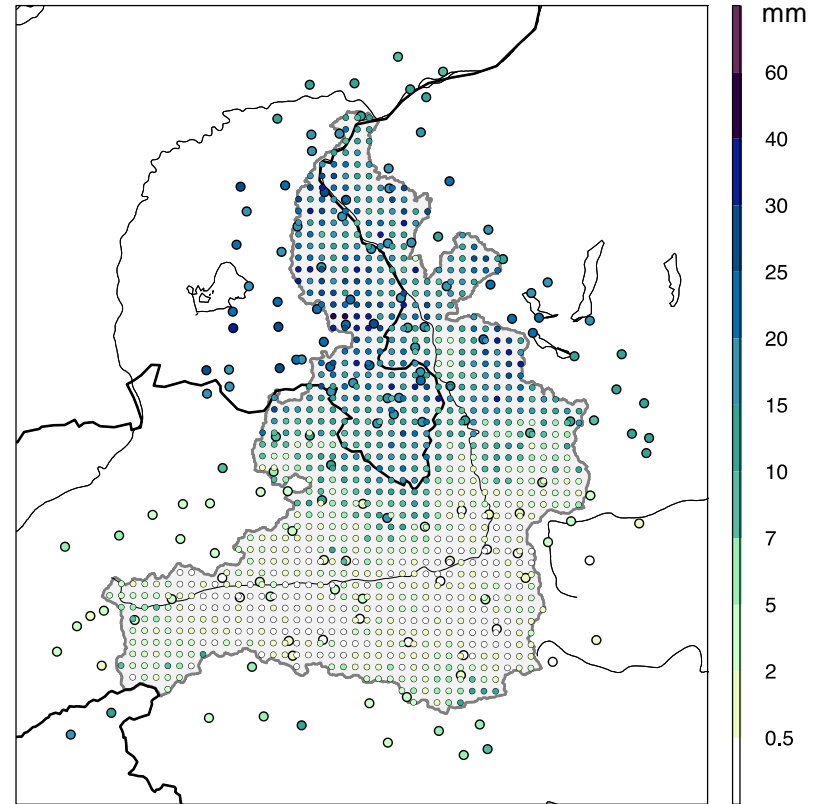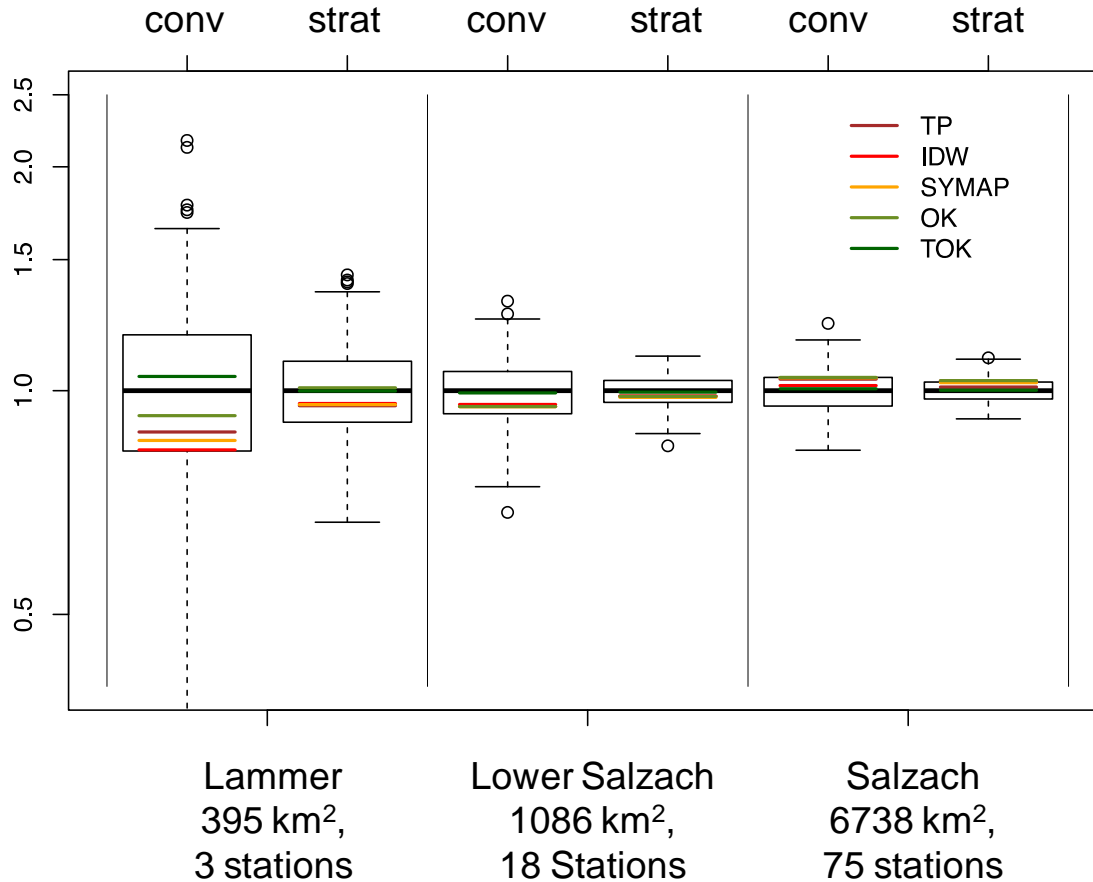1990.10.29, stratiform

Ensemble Member

Example – Ensemble Spread

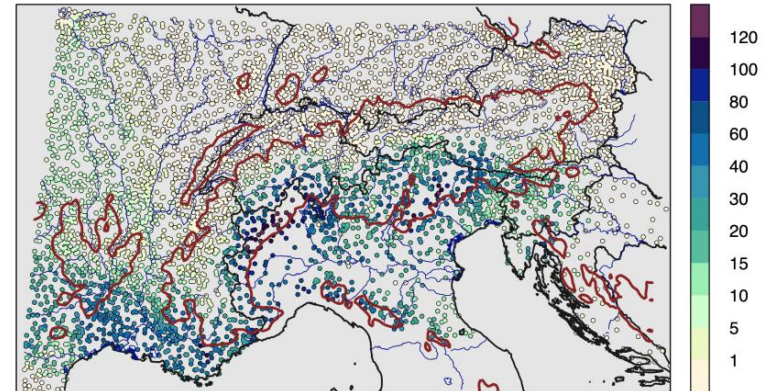spread of catchment mean, relative (i.e. divided by median)
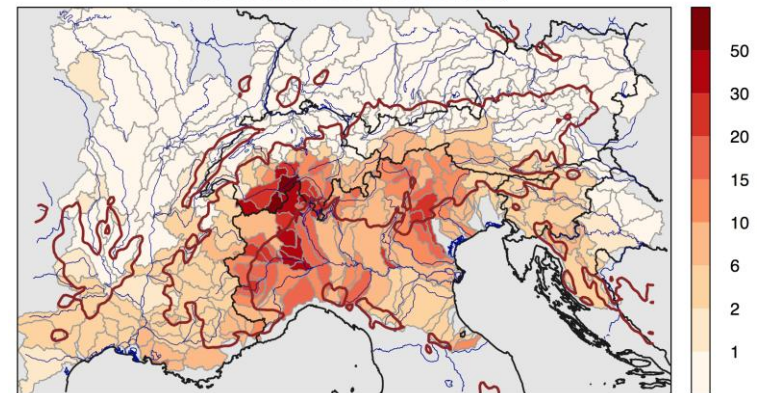
Pan-Alpine Probabilistic Dataset

- Area-mean precipitation over hydrological units in the Alps

- Input data as for APGD
  - Isotta et al. 2014
  - ~6000 rain gauge obs per day

- 100 ensemble members
- 534 hydrological units,
  - based on EEA catchment DS
  - four hierarchical scales

- daily, 1971-2008
- 12 years processed so far

2008.11.04
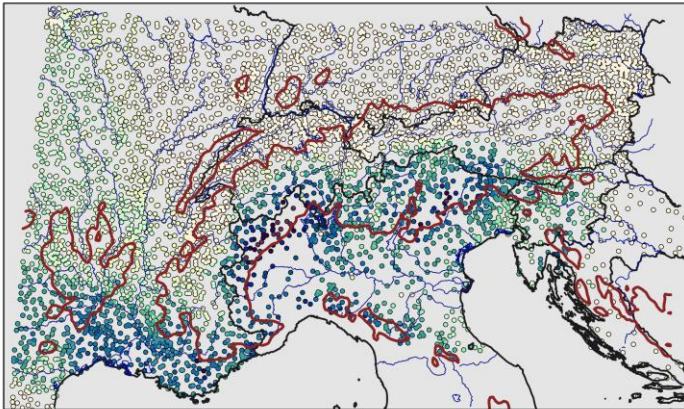

station measurements (mm)

90% ensemble inter-quantile (mm)

Case 2008.11.04

Scale B: 3'500-14'000 km²

station measurements (mm)

90% ensemble inter-quantile (mm)

Scale C: 2'000-5'000 km²
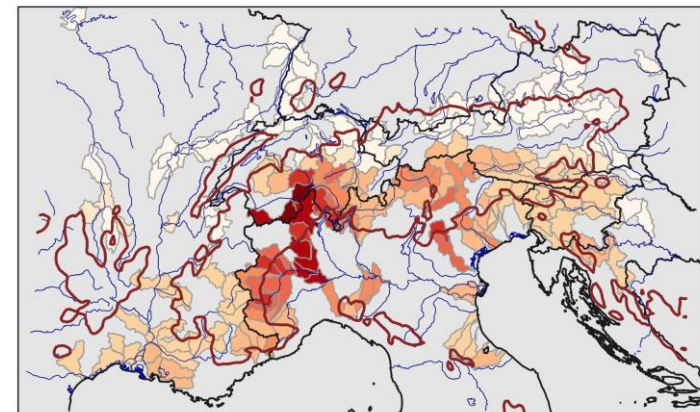
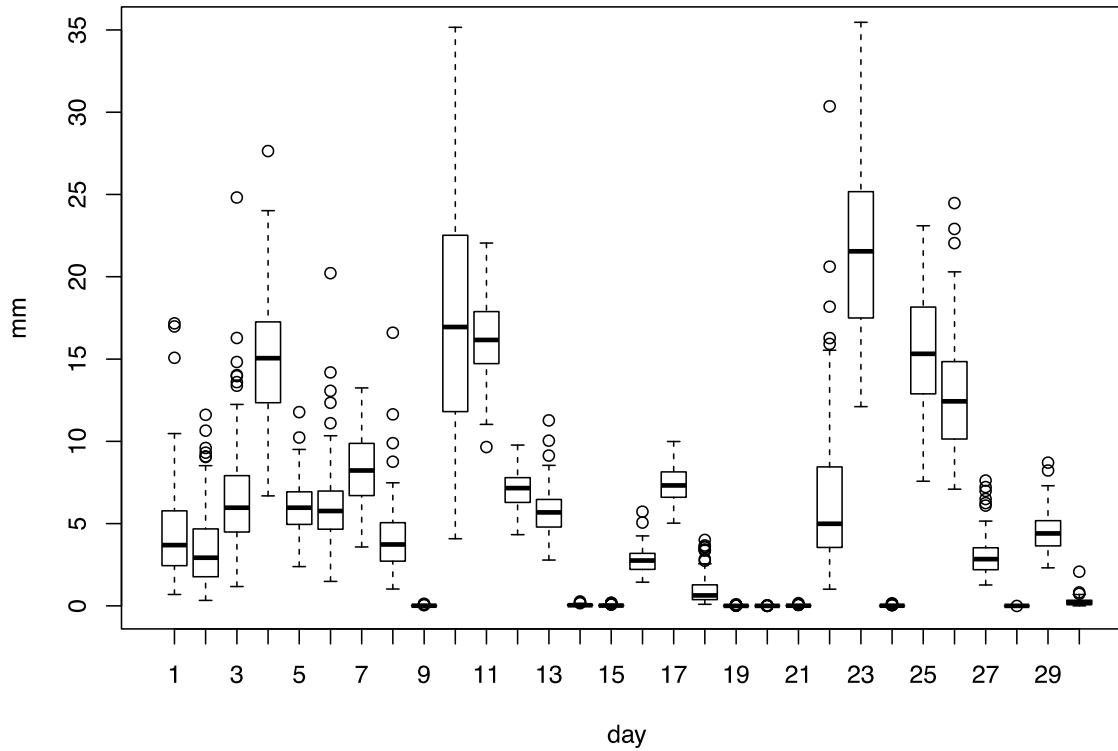Scale D: 500-2'000 km²

90% ensemble inter-quantile (mm)

90% ensemble inter-quantile (mm)

Magnitude of Uncertainties

Lammer (395 km^2, 3 stations within)
June 2008

Climate Indices

Median · Spread

FRE · Q95

Wet-day frequency, median (mm) · Wet-day frequency, 90% inter-quantile (relative)
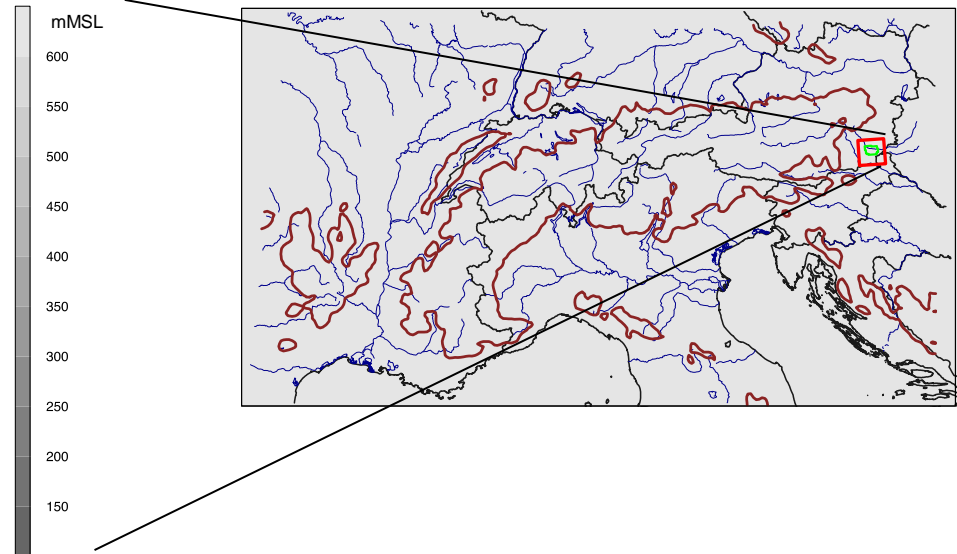
Q95 median (mm) · Q95 90% inter-quantile (relative)
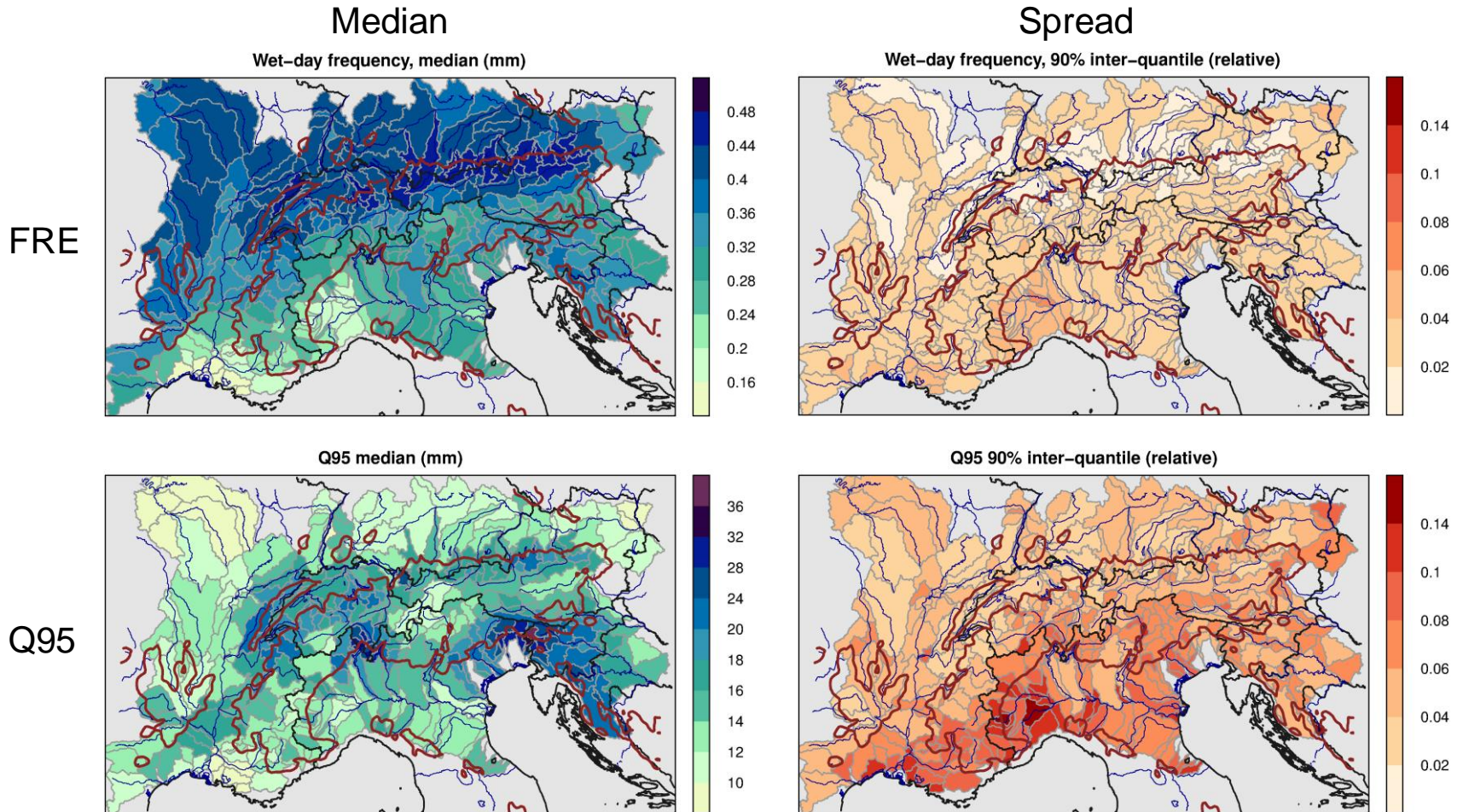
2000 – 2008, annual

Wegener Net
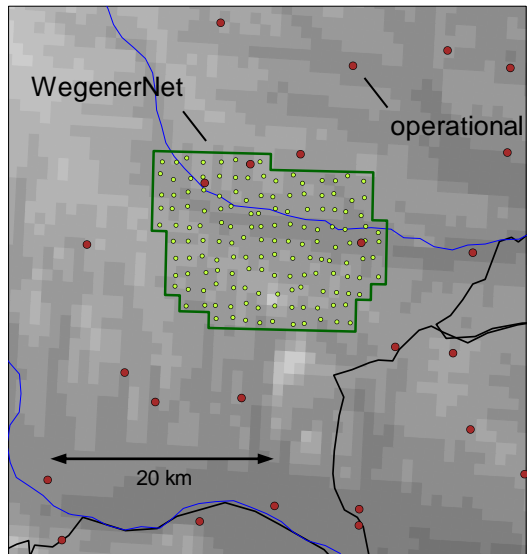
An experimental network of high-resolution climate stations

20 x 15 km domain
150 stations, regularly spaced

5-min time resolution
2007 – present

wegenernet.org
Kirchengast et al. 2014; Sungmin et al. 2016

Evaluation

mean over all WN-Stations = reference
112 days
2007-2008, ≥ 1 mm, no missings, no snowfall

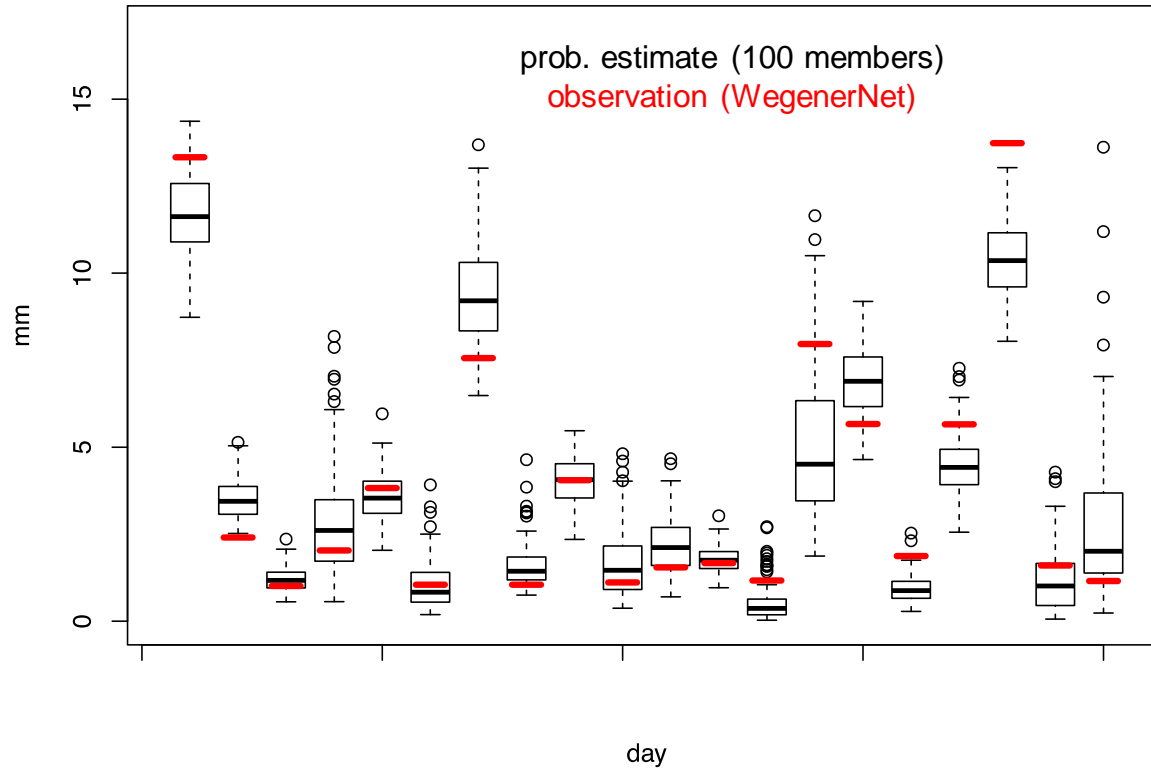probab. estimate of area mean in WN-domain
from operational data in 30-km neighbhd.
(49 stations)

Evaluation

Example: first 20 days

prob. estimate (100 members)
observation (WegenerNet)

Evaluation

PIT Histogram, 112 days
Trans-Gaussian
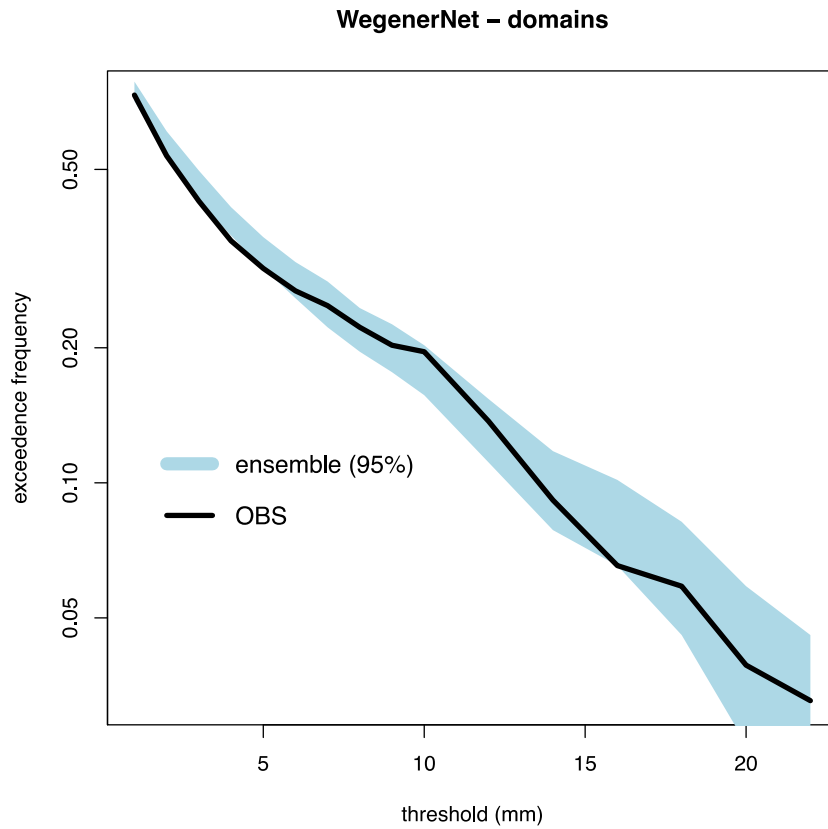
PIT Histogram, 112 days
Gaussian

Evaluation
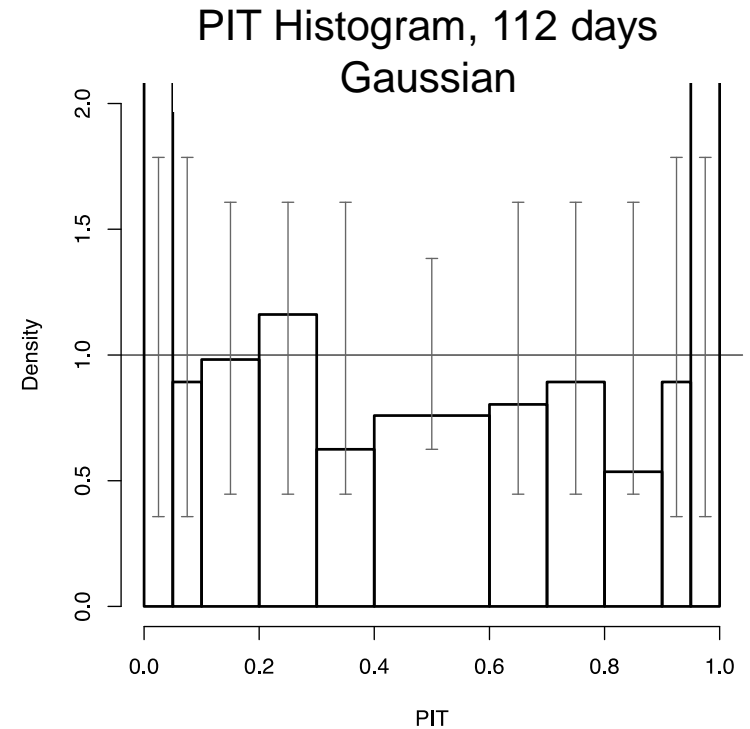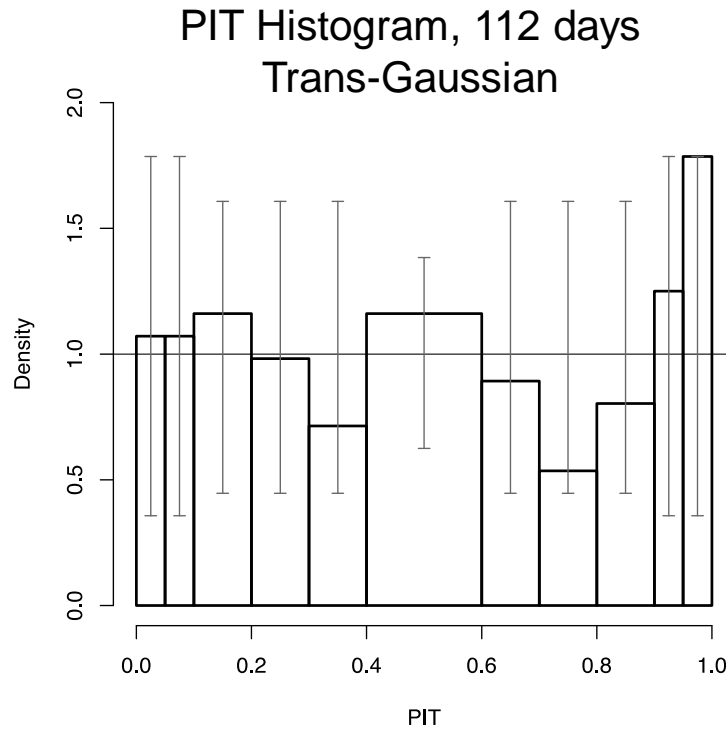
WegenerNet – domains

Exceedence frequency of daily area mean over WegenerNet domain

112 wet test days

Ensembles on a grid?

- ... possible but ...

- ... boundaries within domain are unavoidable
  - need modelling and simulation over sub-regions
  - ensemble members are inconsistent across boundaries
  - hydrological units are a natural sub-division for users

- ... computationally demanding at high resolution
  - conditional simulation always delivers point-scale precip.
  - need upscaling from much finer "primary" grid
  - affordable for $\geq 400\text{-km}^2$ catchs/pixels

Evaluation Regional Reanalyses
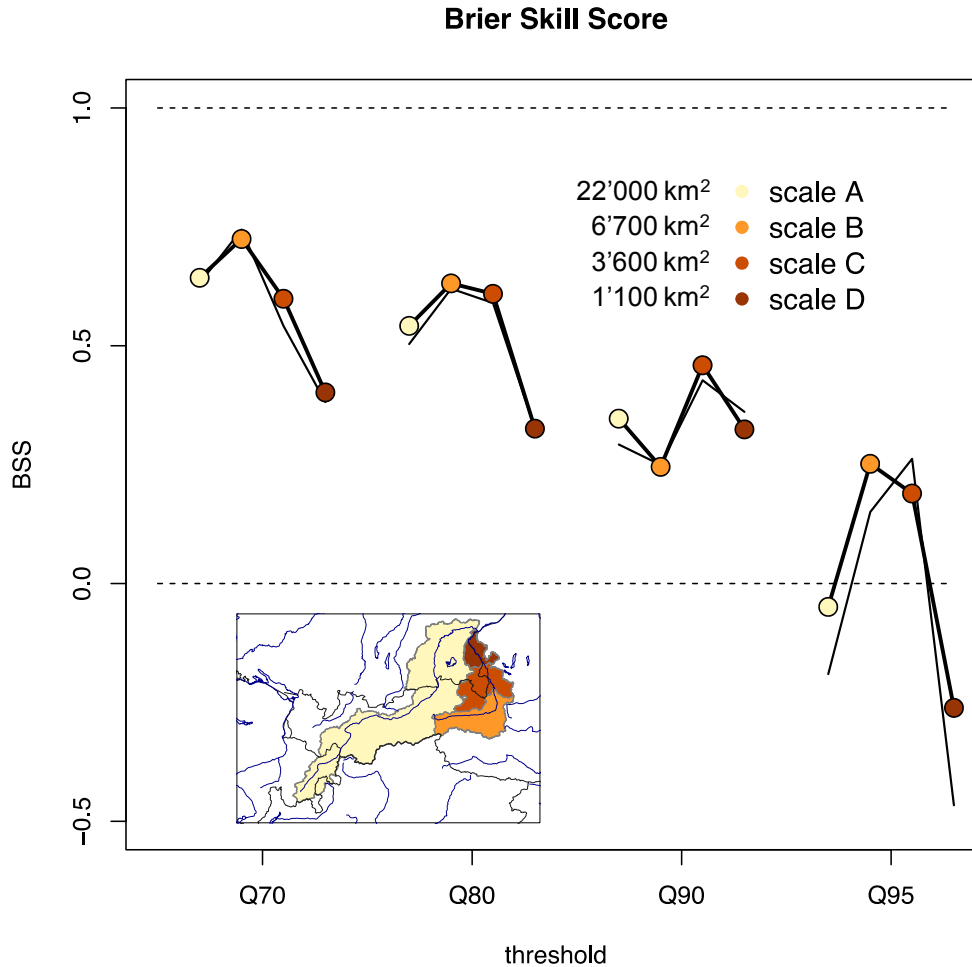
Brier Skill Score

Brier Skill Score

Preliminary UKMO
Regional Reanalysis
20 ensemble members
~25 km resolution
Jan.-May 2008

Conclusion

- A method for probabilistic precipitation analysis

- Addresses limitations of previously proposed ensemble techniques

- Ensembles largely consistent with independent obs.

- Uncertainties ...
  - ... vary with nature of precip, station density, size of area
  - ... happen to be very large (factor of 5 for 400-km^2 means)
  - ... are still considerable for climate indices of extremes
  - ... are larger than spread between deterministic analyses

- Reliable ensembles allow tracing uncertainties into applications