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UERRA
Uncertainties in Ensembles of Regional ReAnalyses

A Multi-Year Probabilistic Precipitation Dataset for the Alps: Results and Evaluation

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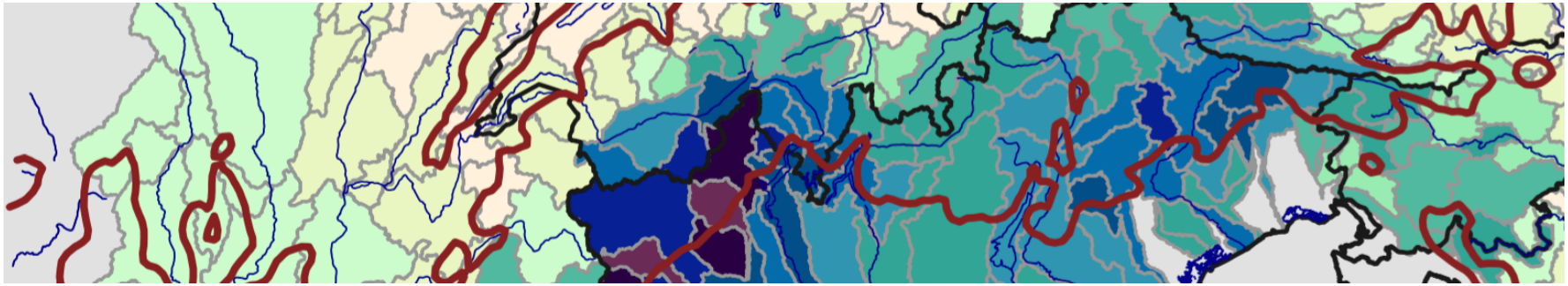


Motivation

- Spatial precipitation analyses are subject to error
  - Limited observations, limited predictability
  - Representativity errors (ambiguities about scale)
- Classical treatment of uncertainty is unsatisfactory
  - summary measures only
  - no information about scale dependence
- Ensembles are attractive
  - User can trace uncertainties through applications

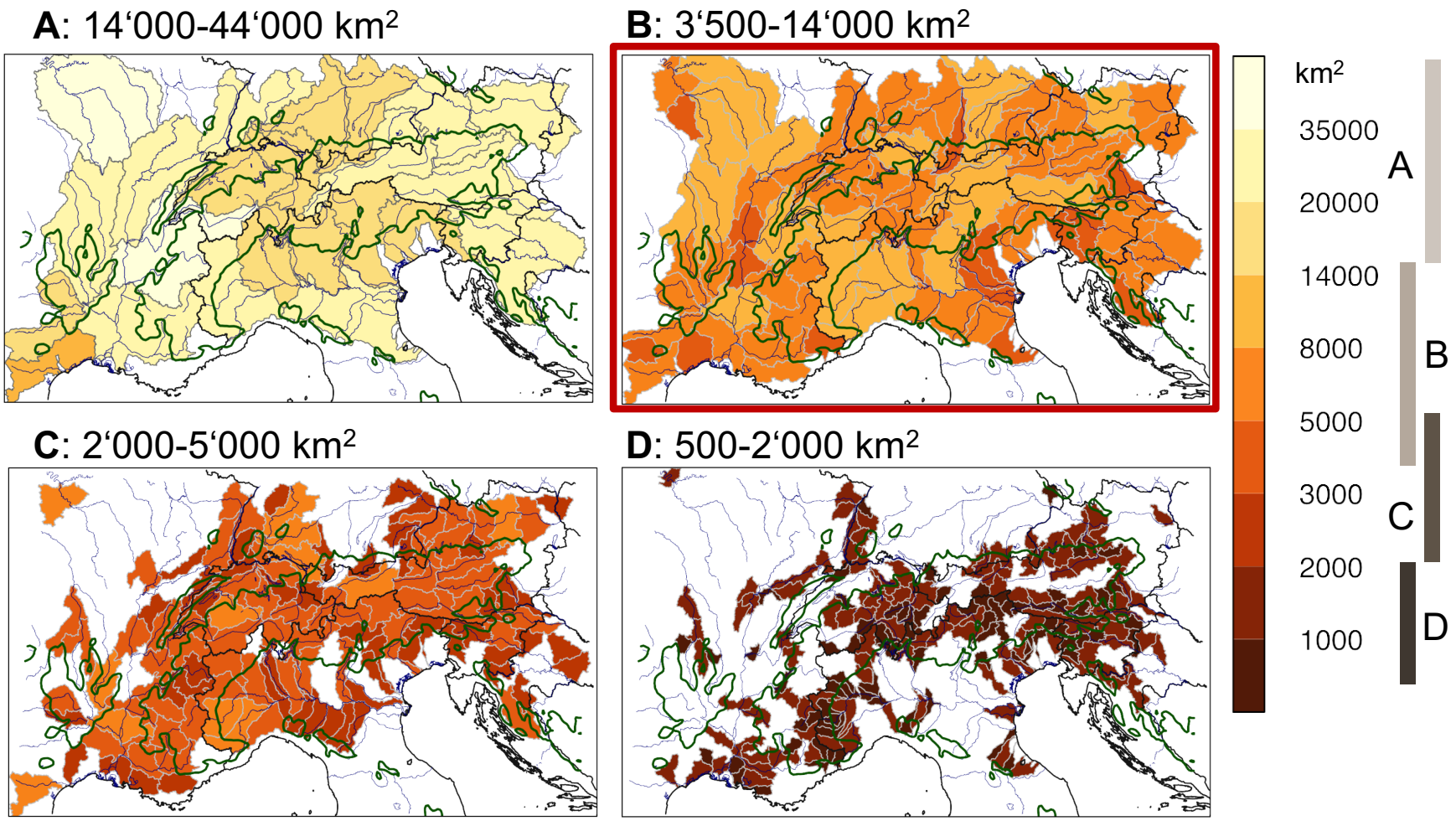
Ensembles in Gridding

- Stochastic simulation
  - ... based on "Gaussian random fields"
  - ... 2nd order stationary covariance
  - ... conditioned on observations

Ahrens & Jaun 2005
Bellerby & Sun 2005
Moulin et al. 2009
...

- Issues
  - Gaussian model is unrealistic for precipitation.
  - Spatial stationarity is unrealistic for large domains.
  - “Frequentist” simulation neglects parameter uncertainty.
  - Measurement errors not accounted.
  - Verification. Reliability of probabilistic estimates?
  - Better than “poor man deterministic ensemble”?

Hydrological Units



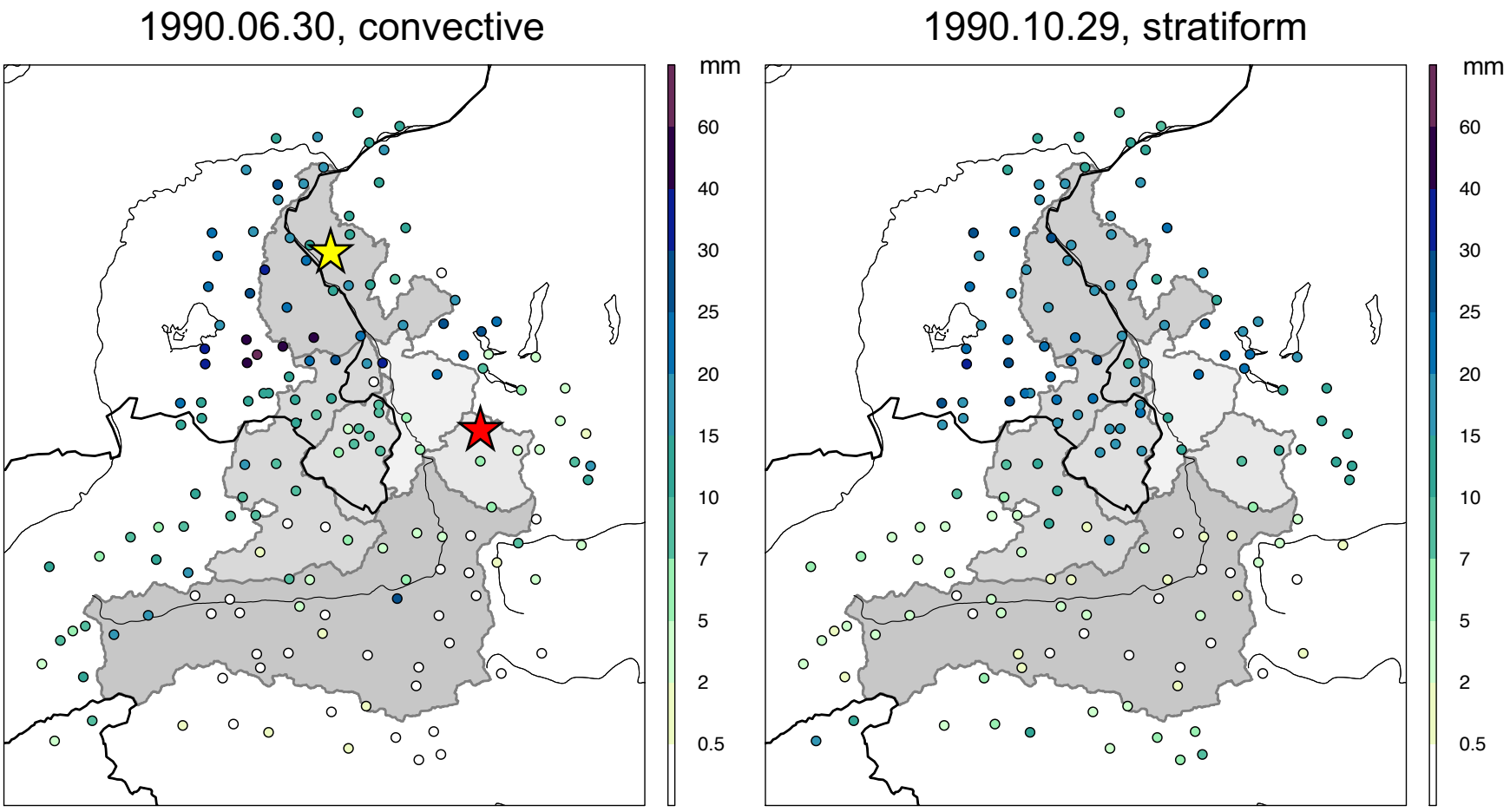
European River Catchments Dataset of EEA
altogether 534 hydrological units

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-resolution grid within catchment (≤ 1 km)
  - conditioned on rain gauge data
  - average over all points in catchment (upscaling)

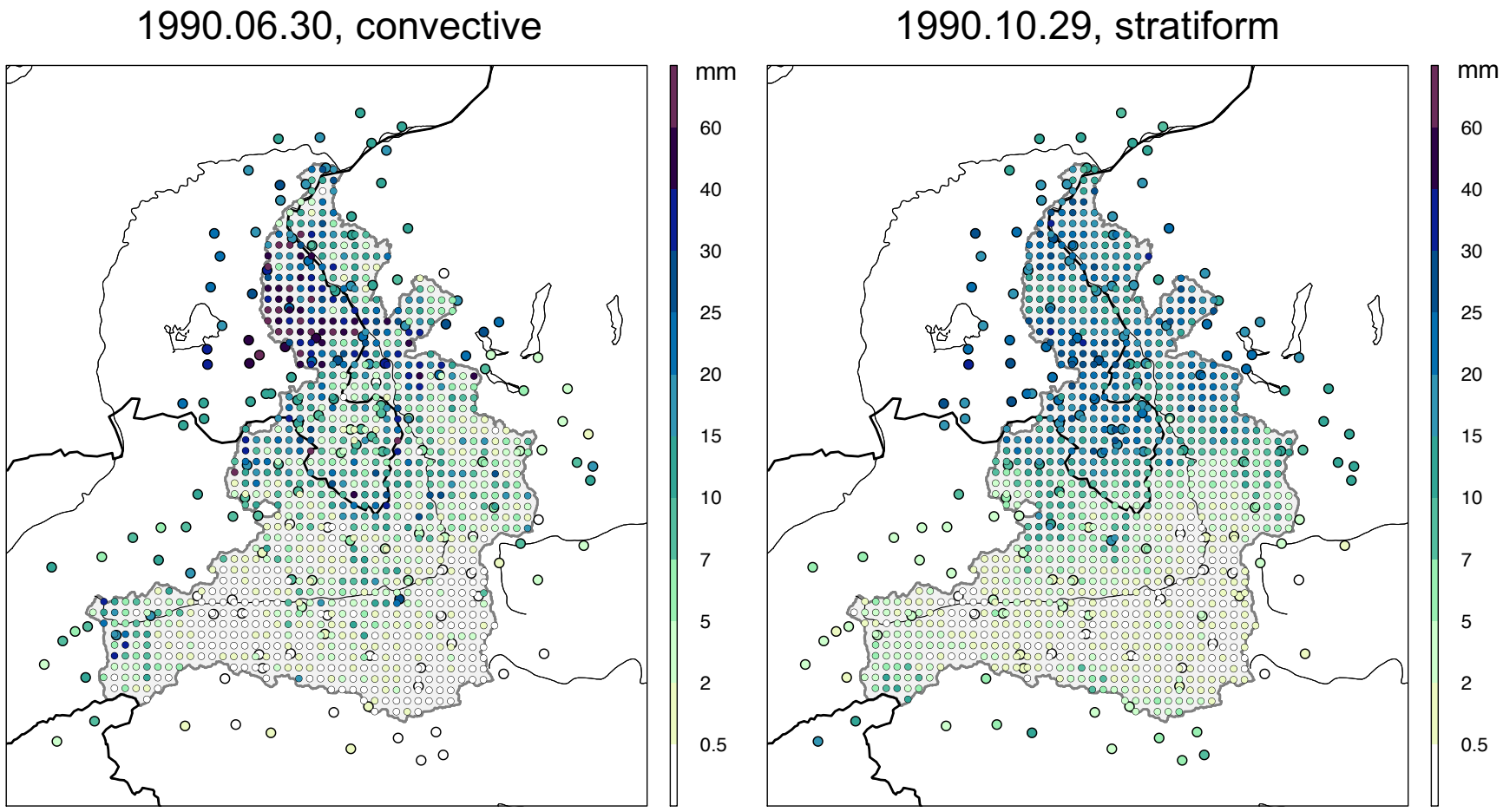
Extending ideas from: Ahrens & Jaun 2007, Moulin et al. 2009, Pappenberger et al. 2009, Erdin et al. 2012, Wilson et al. 2014

Example – Data

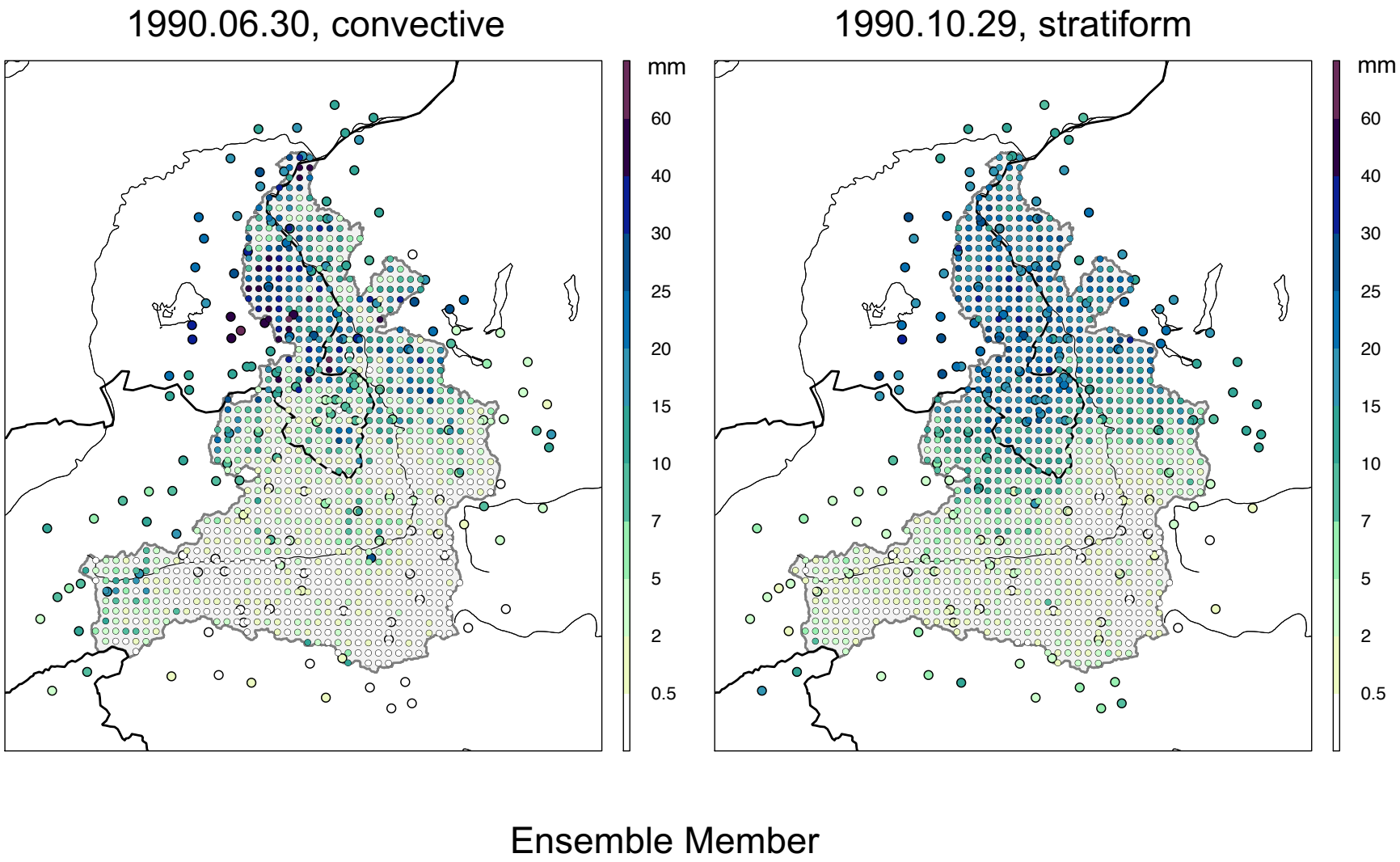


Salzach (6738 km^2), Lower Salzach (1086 km^2), Lammer (395 km^2)

Example – Simulation



Example – Simulation



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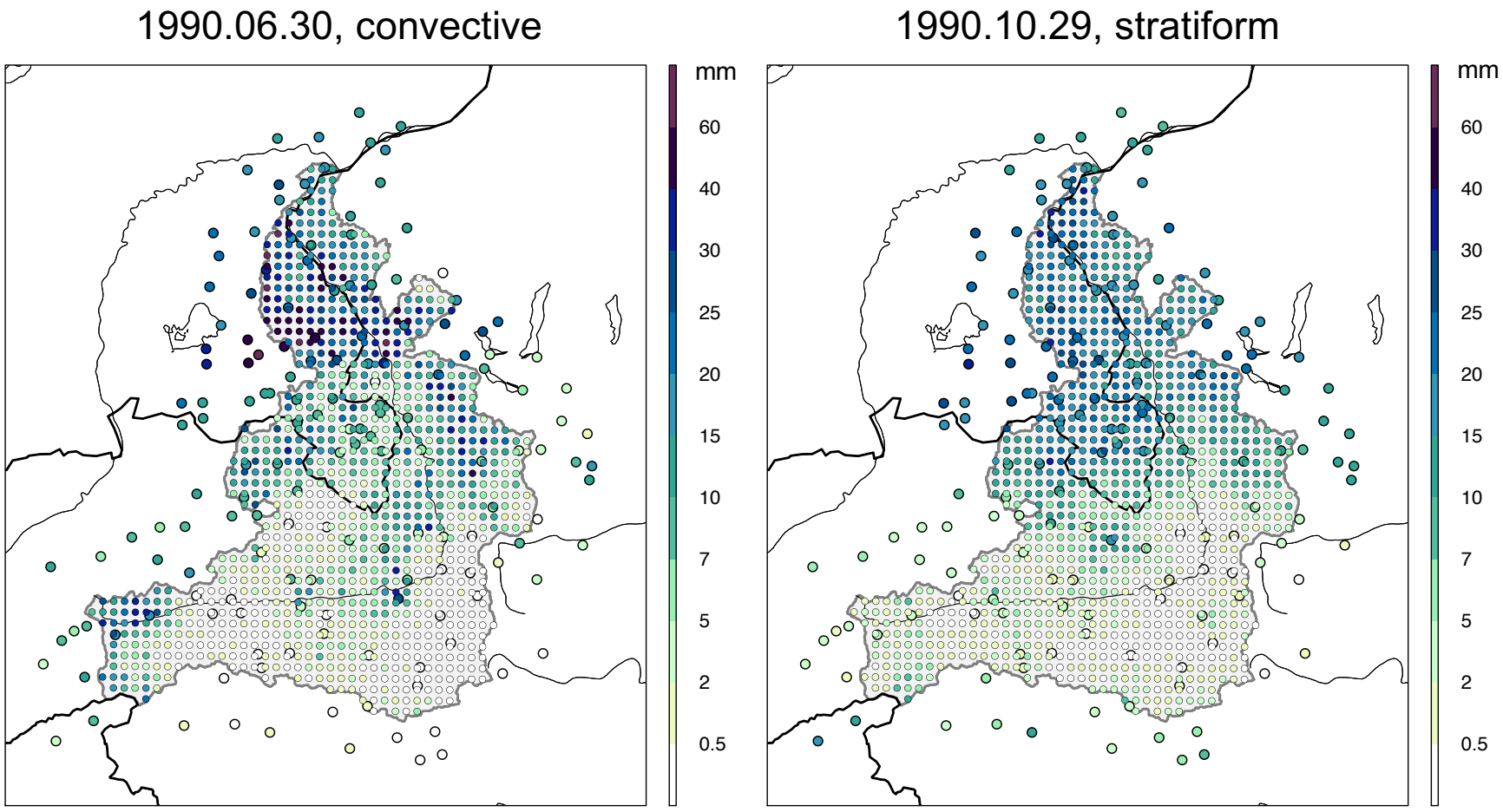
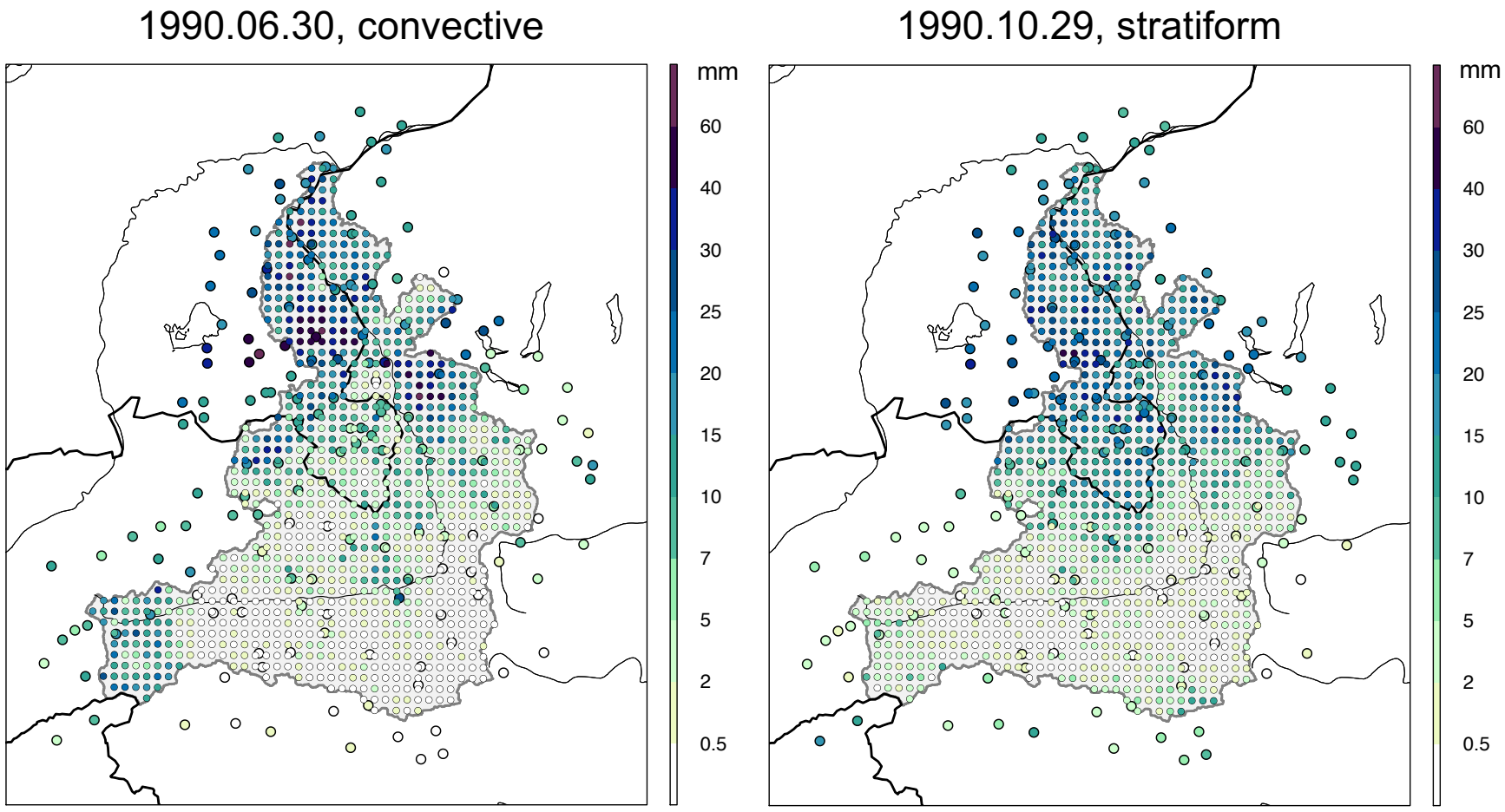
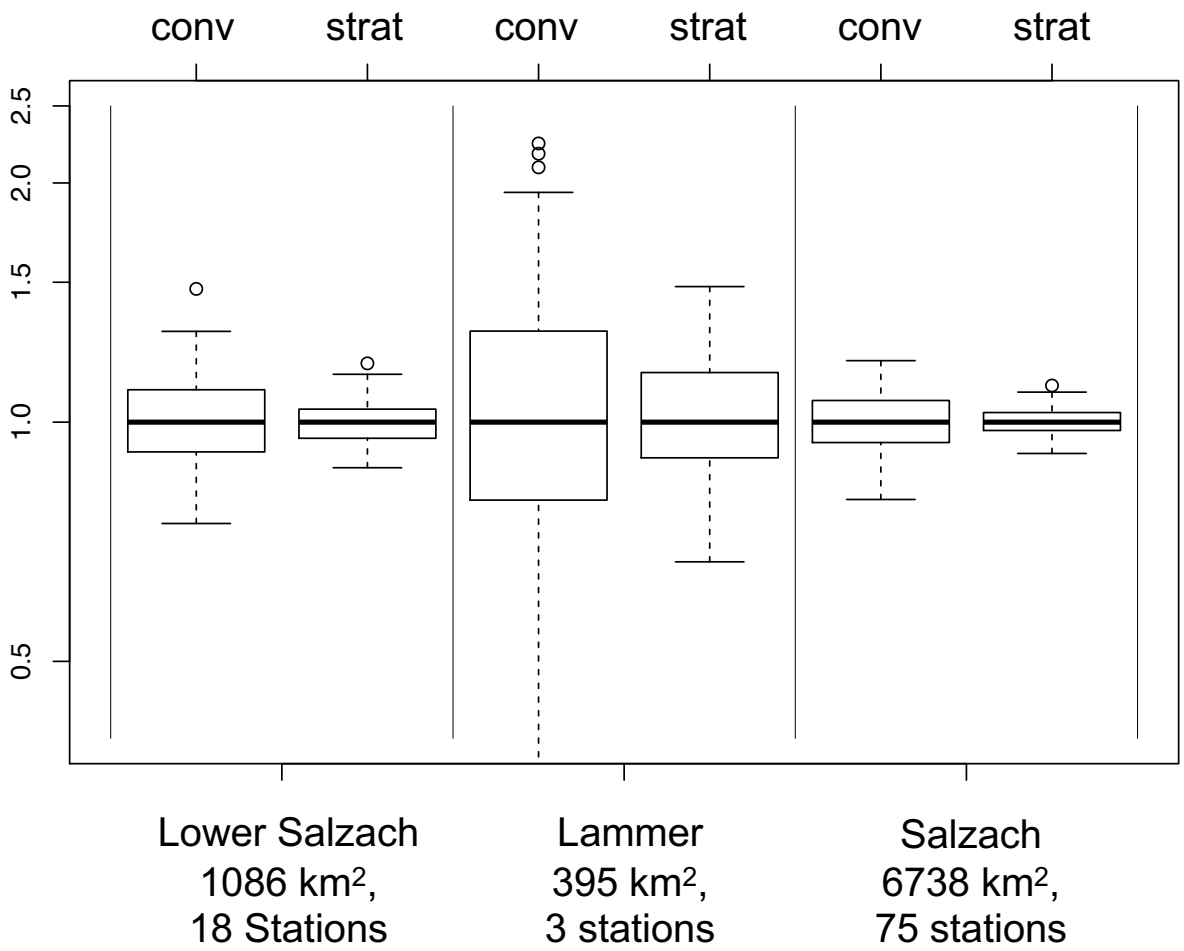


Example – Simulation



Example – Ensemble Spread



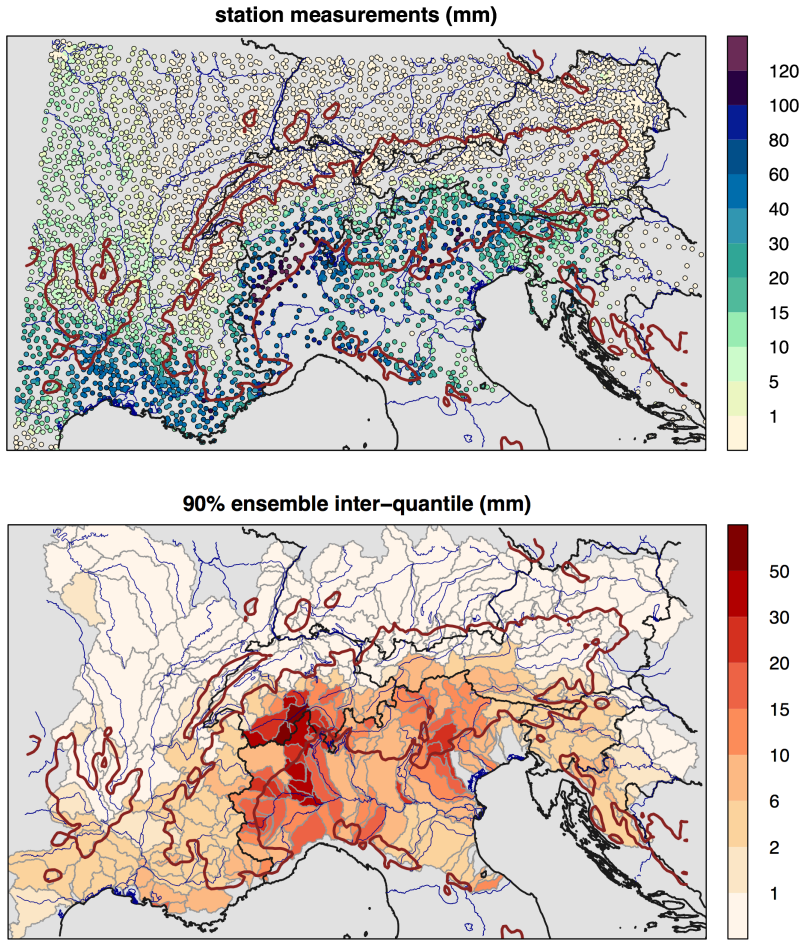
100 members

spread of catchment mean, relative (i.e. divided by median)

Pan-Alpine Probabilistic Dataset

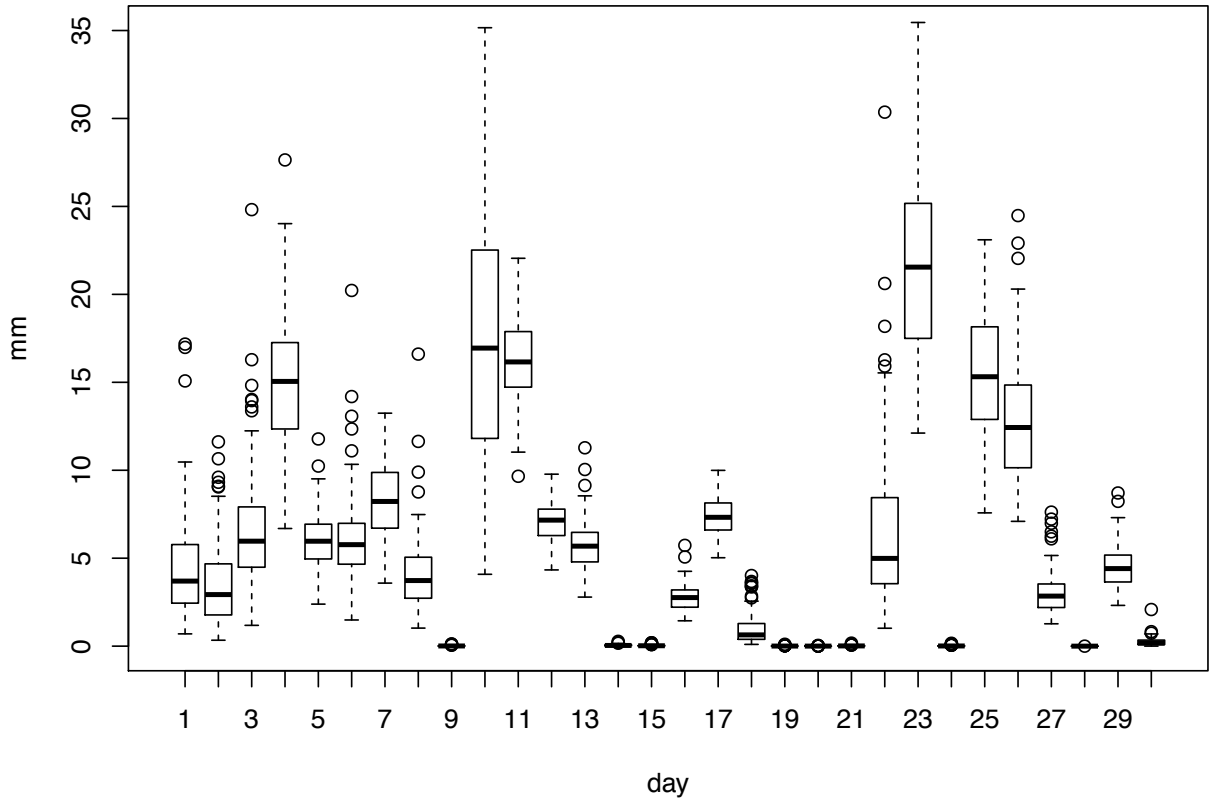
- Area-mean precipitation over hydrological units in the Alps
- Input data as for APGD
  - Isotta et al. 2014
  - ~6000 rain gauge obs per day
- 100 ensemble members
- 534 hydrological units,
  - based on EEA catchment DS
  - four hierarchical scales
- daily, 1971-2008
- 2003-2008 processed so far

2008.11.04

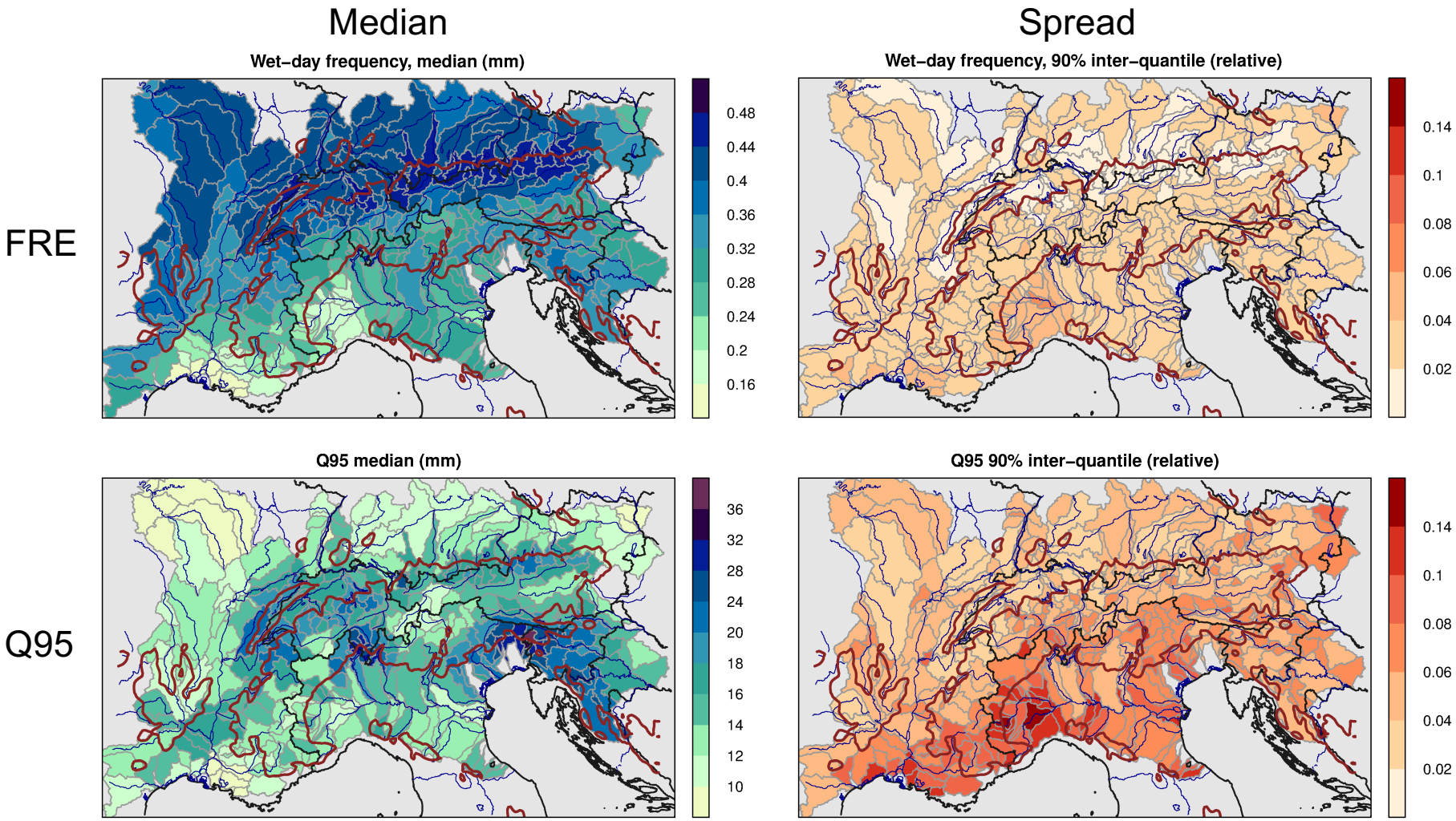


Magnitude of Uncertainties

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



Climate Indices

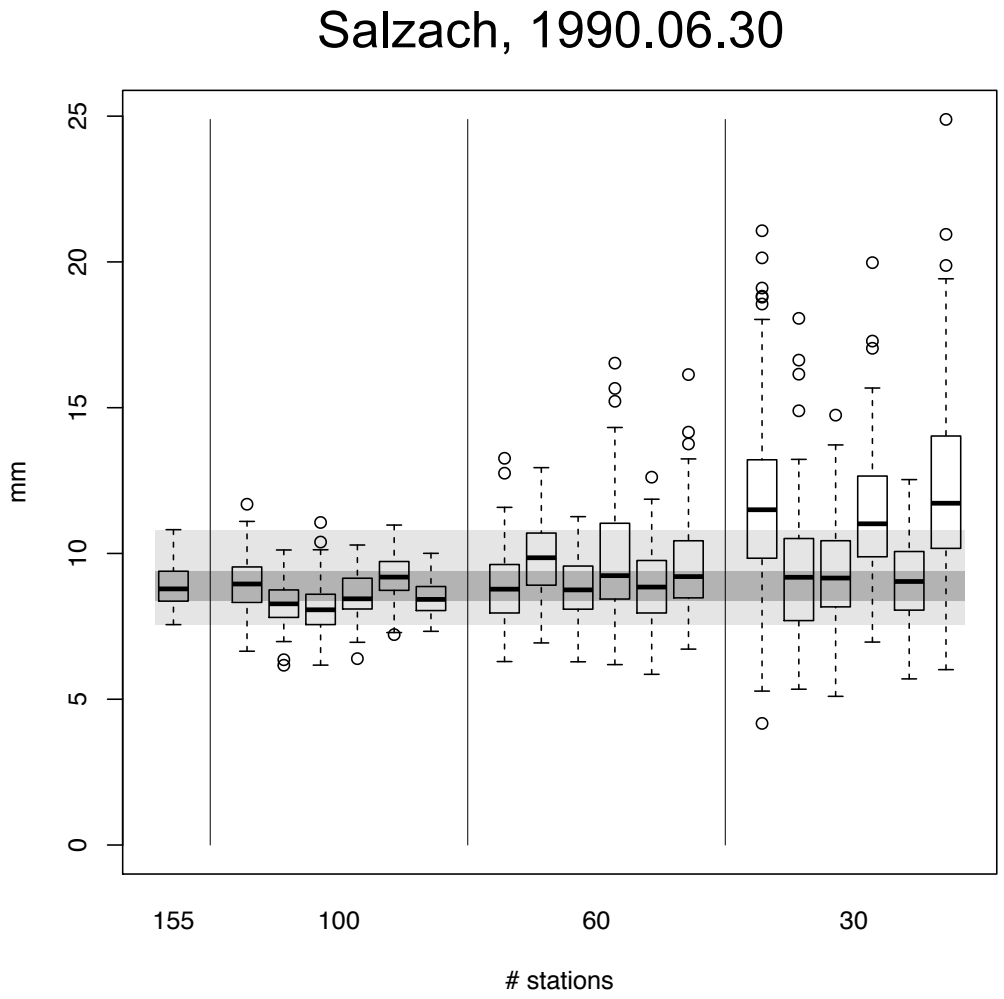


2004 – 2008, annual

Uncertainty and Station Density

Experiment with randomly “diluted” station data

Box Plot:
Probabil. Ensembles

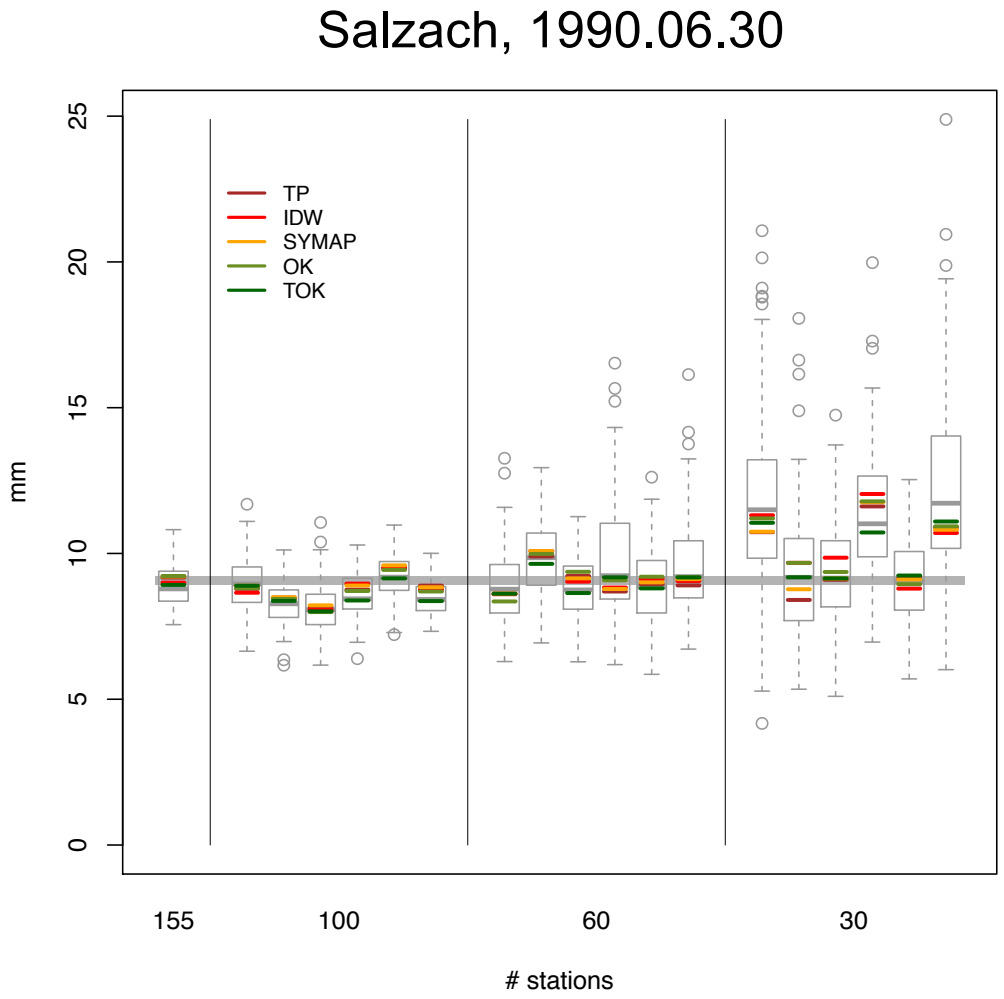


Uncertainty and Station Density

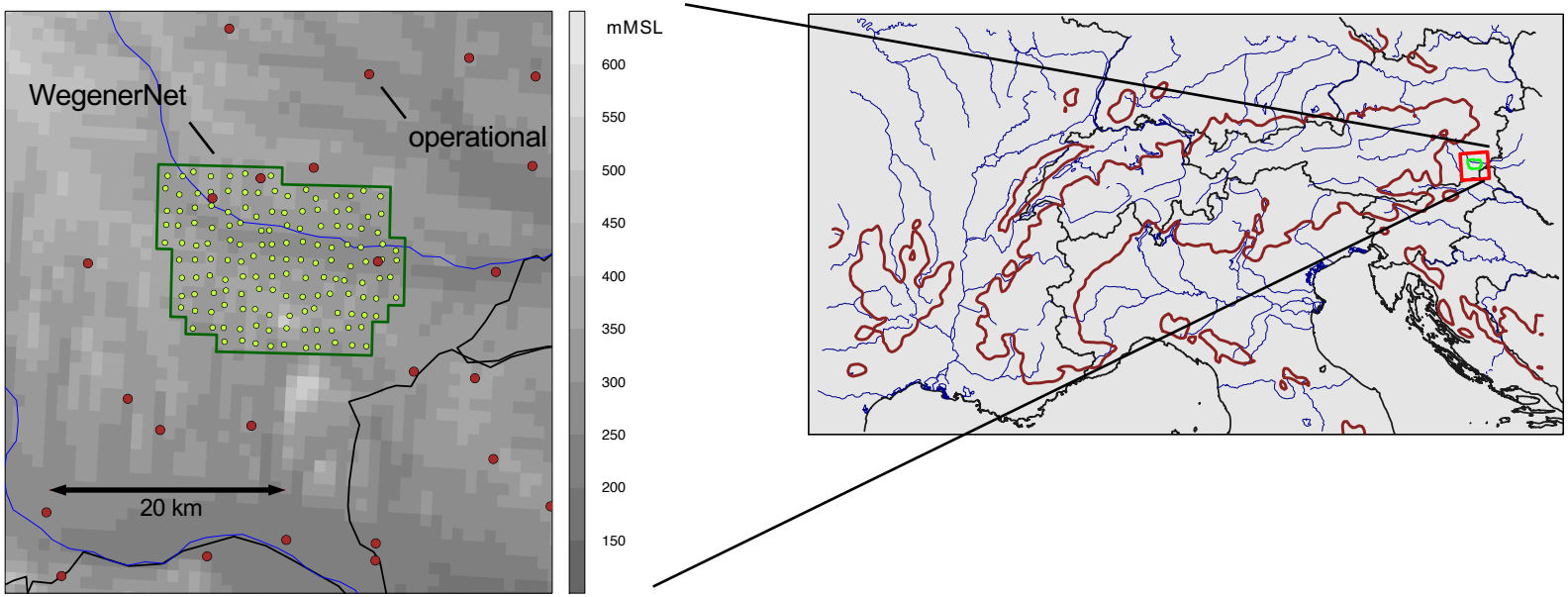
Experiment with randomly “diluted” station data

Box Plot:
Probabil. Ensembles

Colour:
Determin. Ensembles
“poor man ensemble”



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

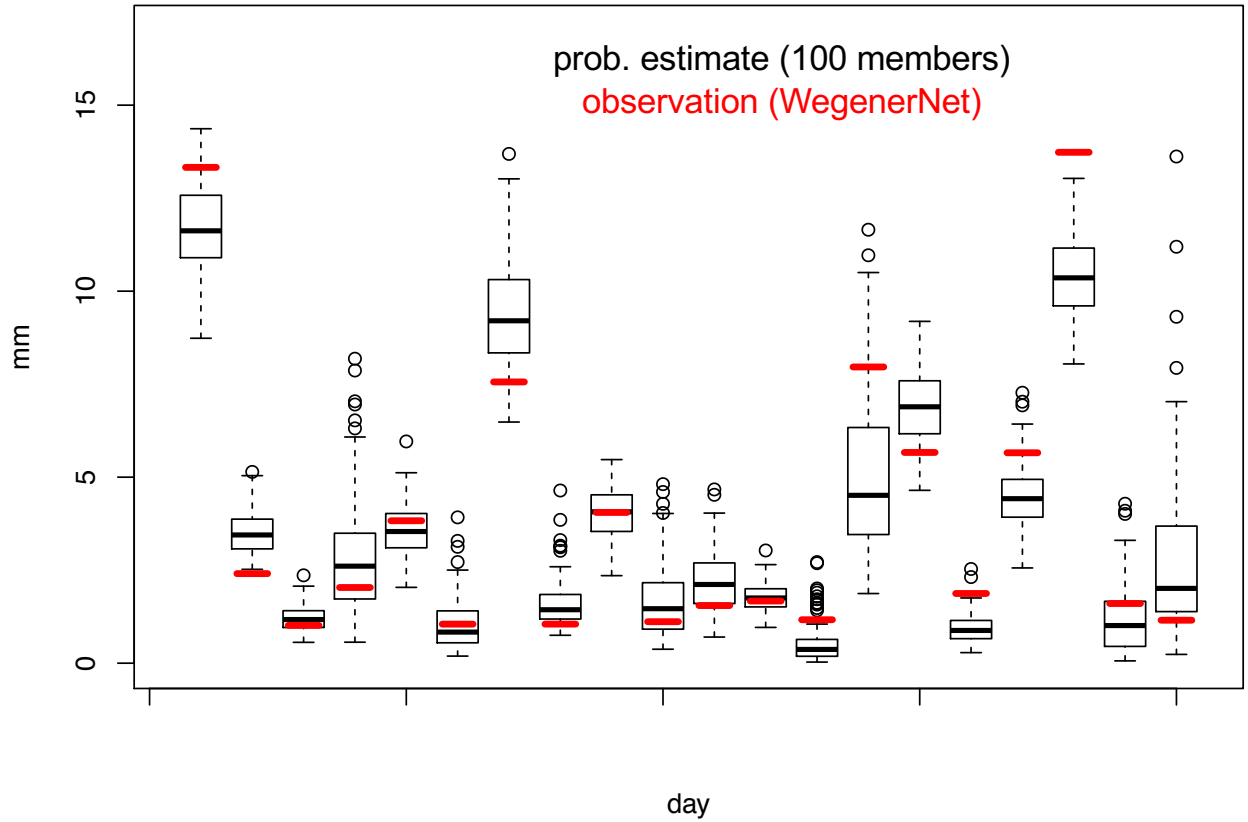
Evaluation

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

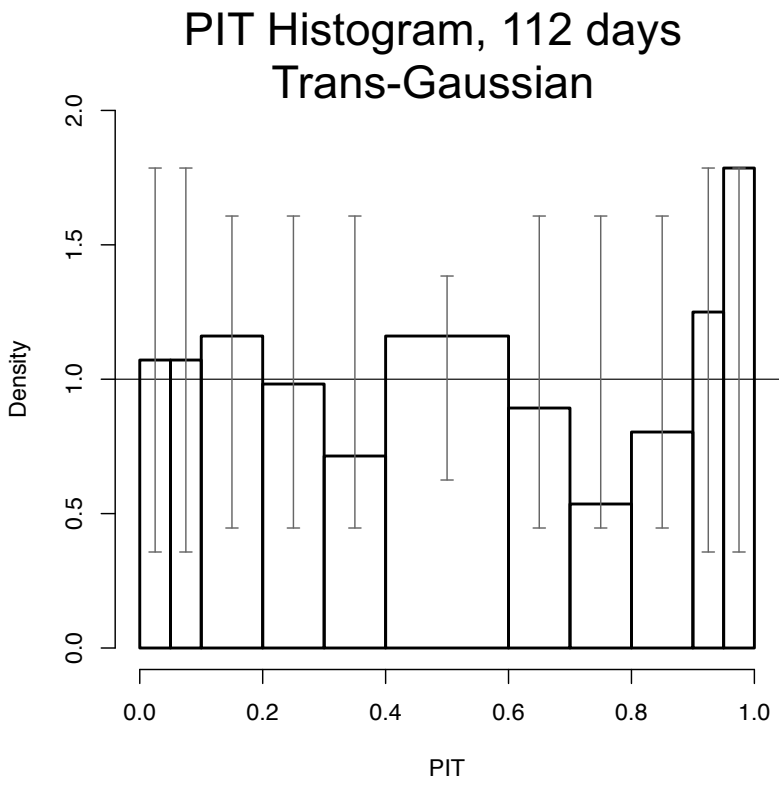
probab. estimate of area mean in WN-domain
from operational data in 30-km neighbhd.
(49 stations)

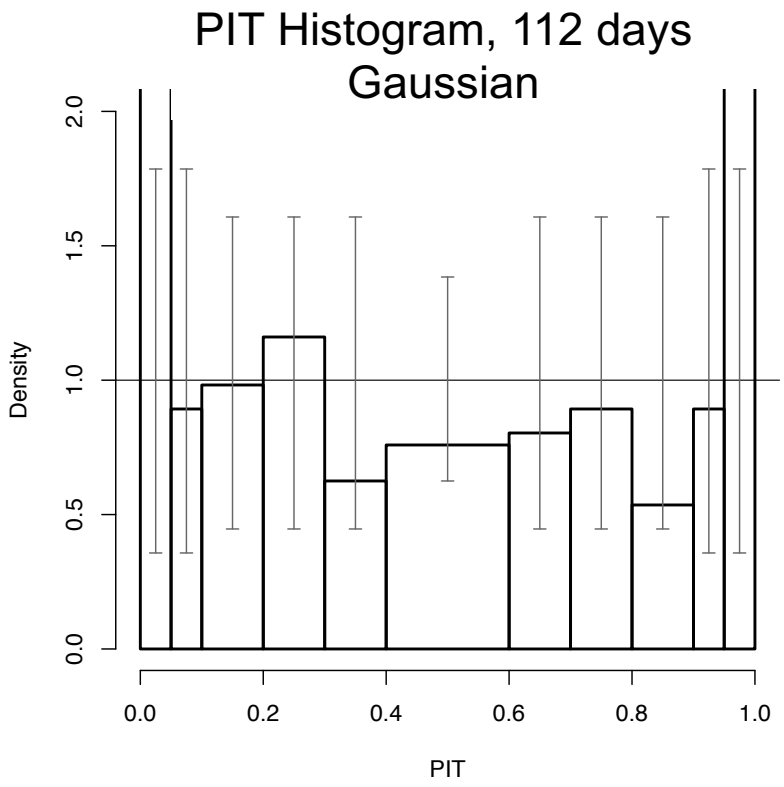
Evaluation

Example: first 20 days



Evaluation


PIT Histogram, 112 days
Trans-Gaussian
Density
0.0
0.5
1.0
1.5
2.0
0.0
0.2
0.4
0.6
0.8
1.0
PIT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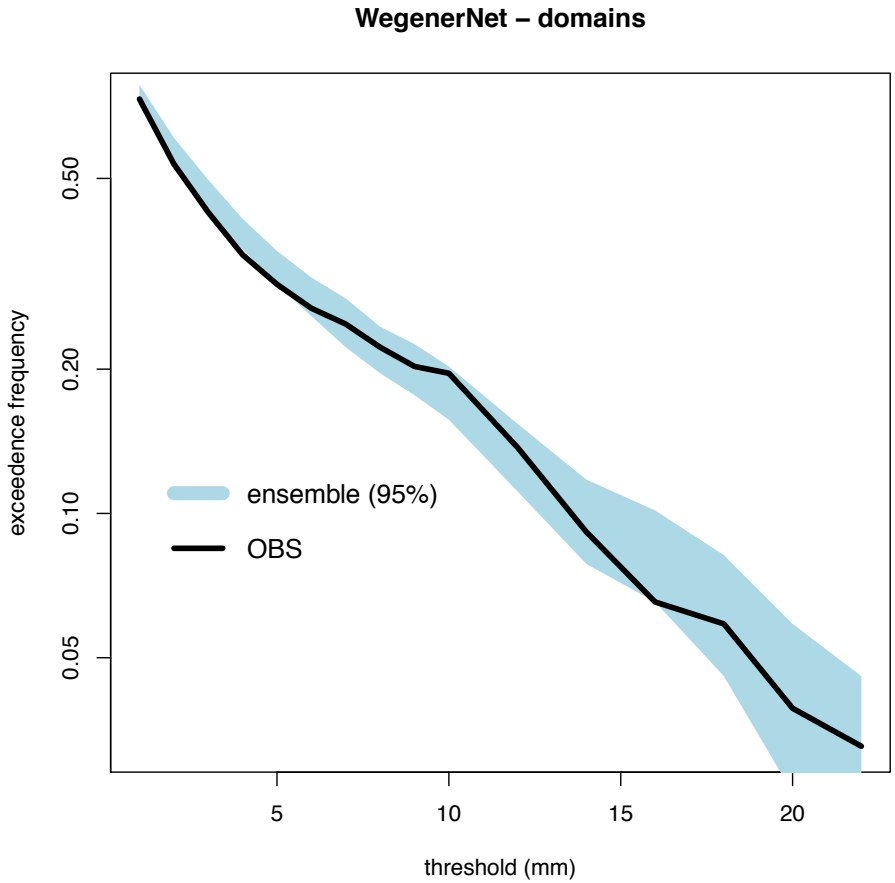
Evaluation



Exceedence frequency of daily area mean over WegenerNet domain

112 wet test days

Why not a Grid?

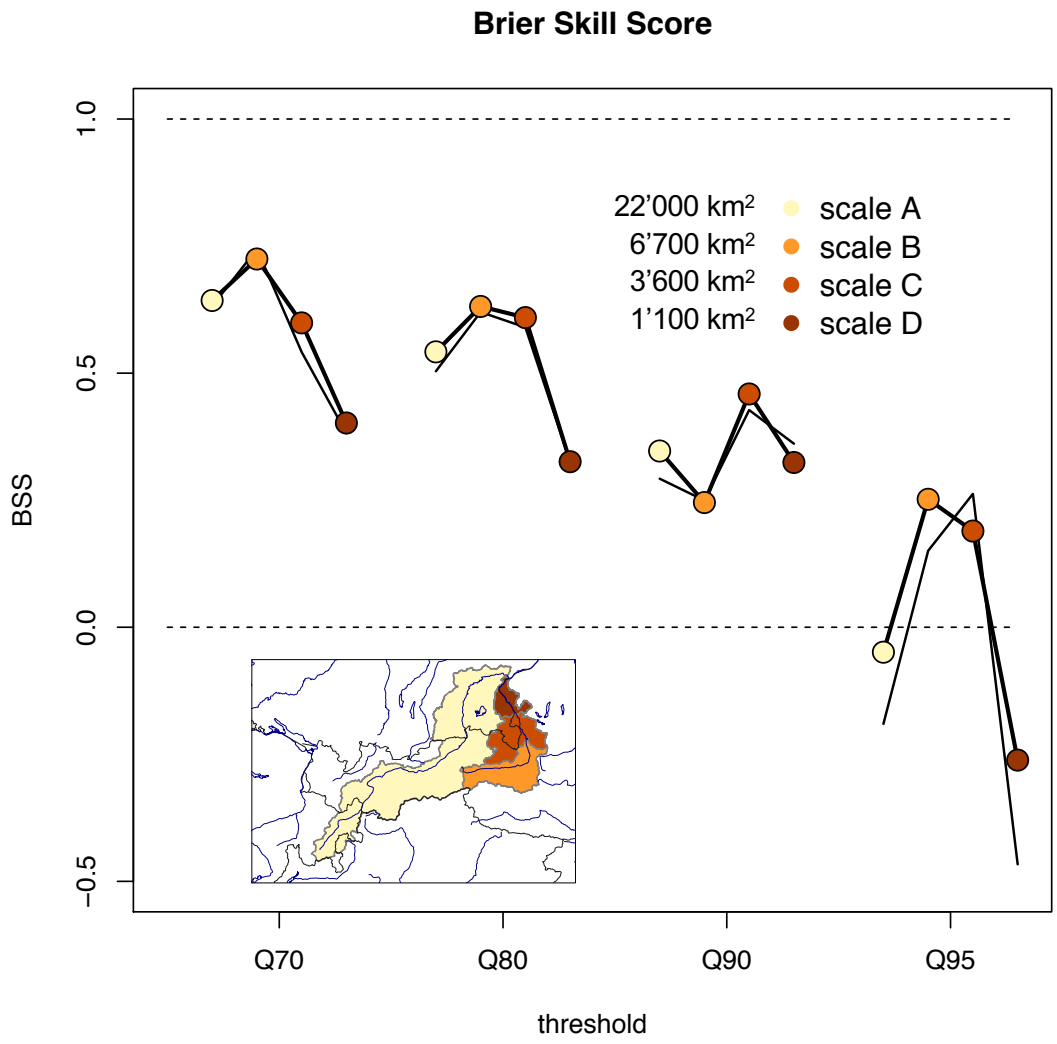
- Boundaries within domain are unavoidable
  - ‘global’ simulation assumes unrealistic stationarity
  - need modelling and simulation over sub-regions
  - ensembles are inconsistent across boundaries
  - hydrological units are a natural sub-division for users

- High-resolution grids are computationally demanding
  - conditional simulation always delivers point-scale precip.
  - need upscaling from much finer “primary” grid
  - for ≥400-km^2 catchs proper upscaling is affordable

Conclusion

- A method for probabilistic precipitation analysis
- Addresses limitations of classical conditional simulation
  - Trans-Gaussian model > precipitation is not Gaussian
  - Bayesian inference > account for uncertainty of model
  - Sub-regional application > cope with non-stationarities
- 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 larger than spread between deterministic analyses
- Use ensemble dataset for evaluation

Evaluation Regional Reanalyses



Brier Skill Score

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