Evaluation and correction of uncertainty due to Gaussian approximation in radar – rain gauge merging using kriging with external drift

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This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 607000.

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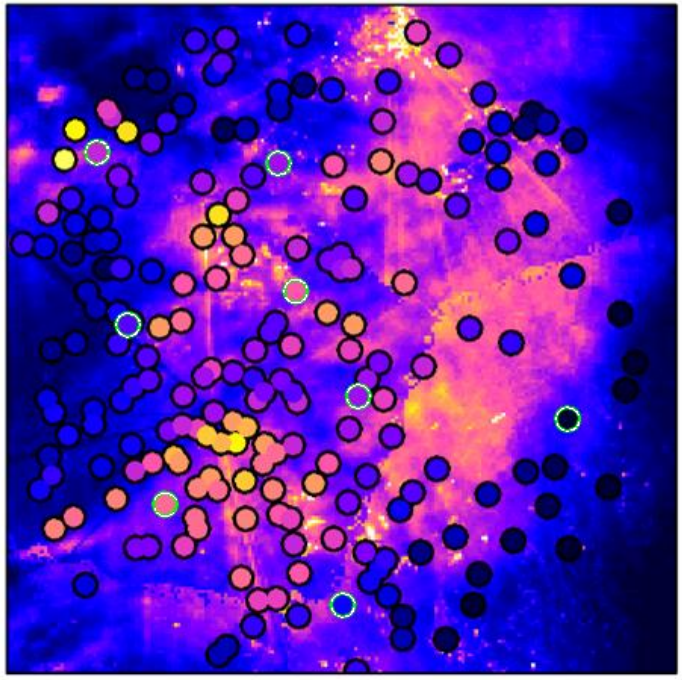
Merging Radar – Rain Gauge

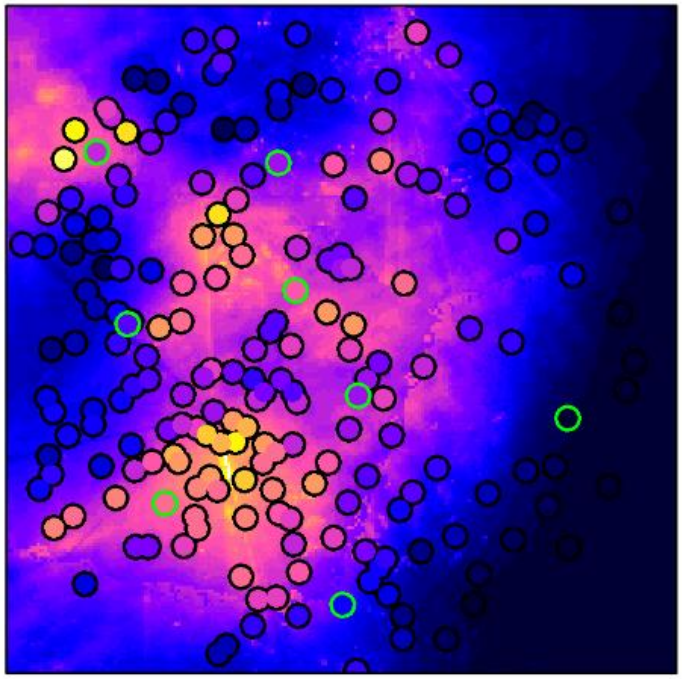
Trying to keep the advantages of both:

- Radar: areal estimates, wide coverage, high spatial resolution
- Rain Gauges: higher accuracy

Radar and Rain Gauges



Merged product and Rain Gauges



Kriging with External Drift

KED is one of the best and most efficients merging methods

1. The estimate is based on the kriging interpolation of rain gauges
2. The mean of the process is modelled as a linear function of the radar (external drift)
3. It also estimates the uncertainty associated with the prediction (kriging variance)
4. The process is assumed to be Gaussian

Gaussian assumption

- Kriging methods assume the process to be Gaussian
- KED assumes the rainfall residuals to be Gaussian

$$\textbf{Residuals} = \text{True rainfall} - \text{process mean (or drift)}$$
$$\approx \text{Rain gauge rain} - \text{linear function of radar rain}$$

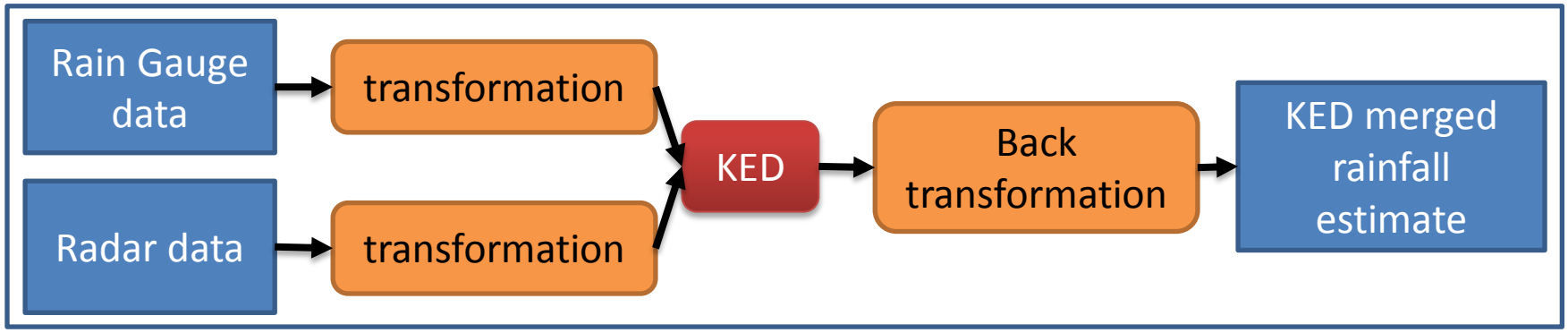
- Rainfall is not Gaussian, neither are the residuals.
- Transforming rainfall to a Gaussian variable improves Gaussianity of the residuals too.

Comparing methods

Possible solutions:

- Analytical transformations (Box-Cox)
- Empirical transformations (Normal Scores)
- ~~Indicator Kriging~~ → Controversial
- ~~Disjunctive Kriging~~ → Not easily adaptable to KED
- Singularity analysis

Box-Cox transformations



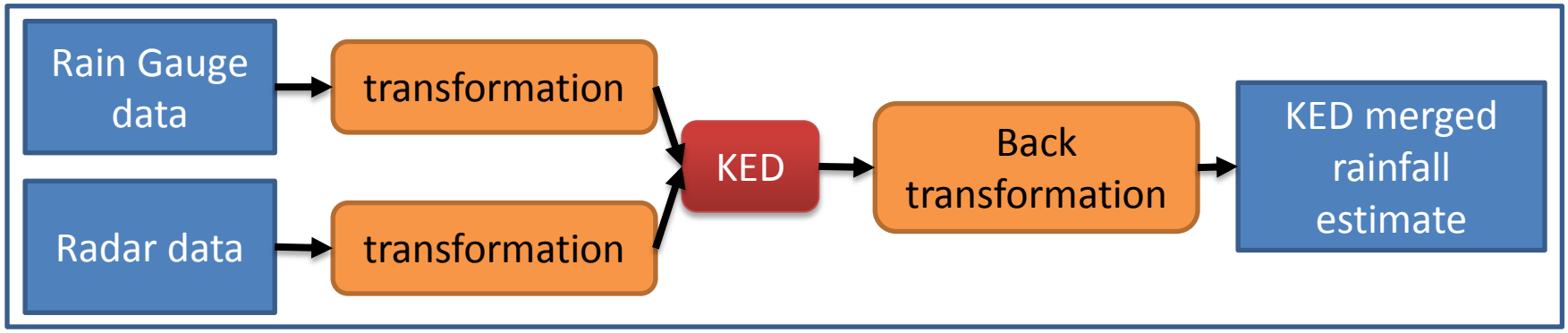
Box-Cox Transformations:

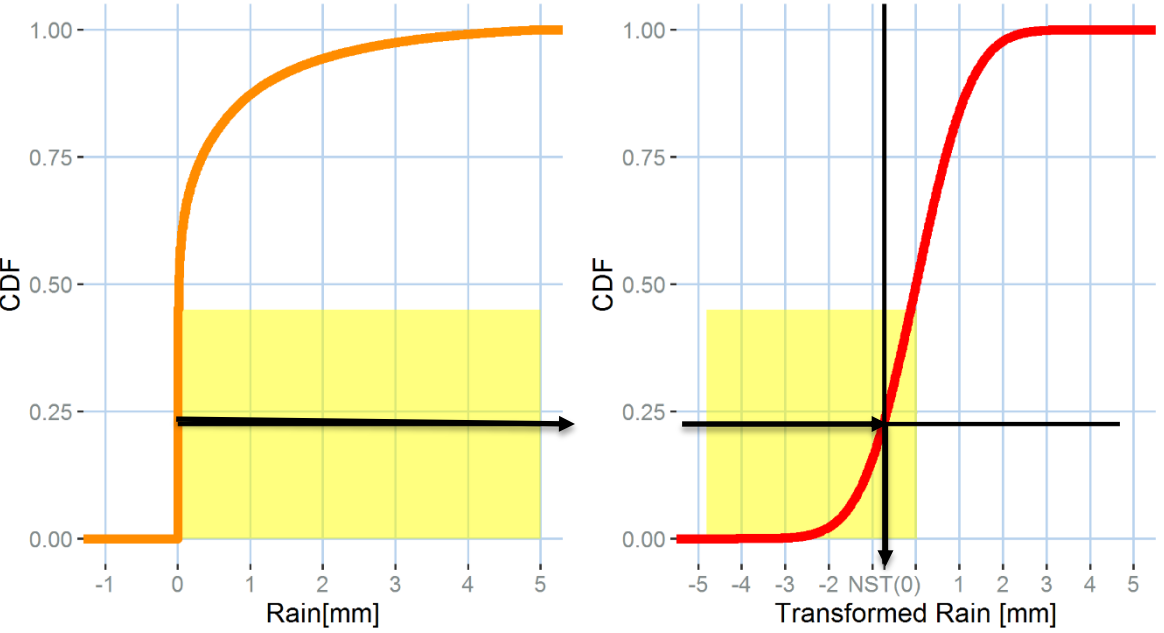
$$y = \begin{cases} \log(x) & if \ \lambda = 0 \\ \frac{(x^{\lambda}-1)}{\lambda} & if \ \lambda \neq 0 \end{cases}$$

1. $\lambda = 0.5 \rightarrow$ Square root
2. $\lambda = 0.25 \rightarrow$ Square root – Square root
3. $\lambda = 0.1 \rightarrow$ Almost Logarithmic
4. Optimal time-variant λ [0.2, 1]

According to Erdin et al. (2012)

Normal Score Transformation (NST)

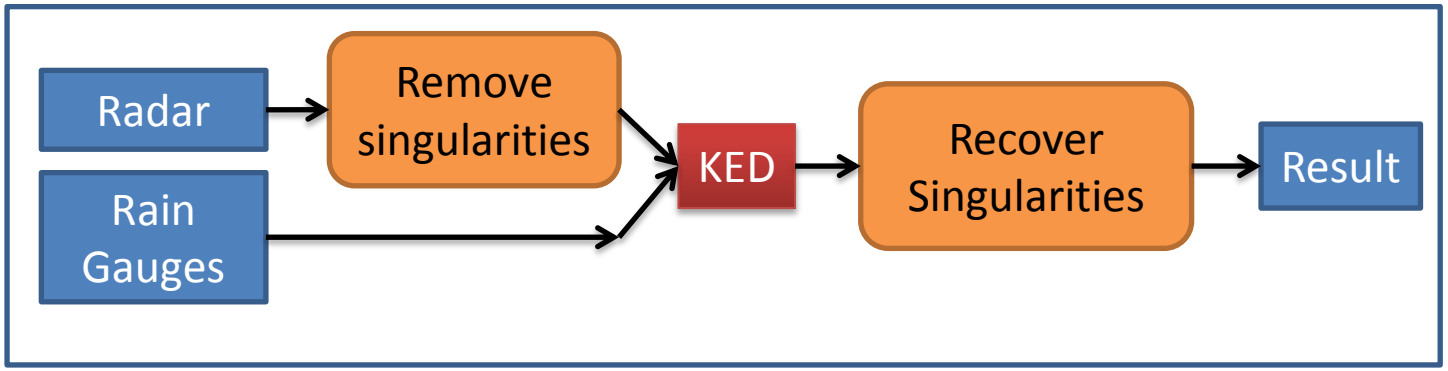




- Empirical relationship between quantiles
- It requires continuous strictly increasing CDF
- Some adaptations for rainfall

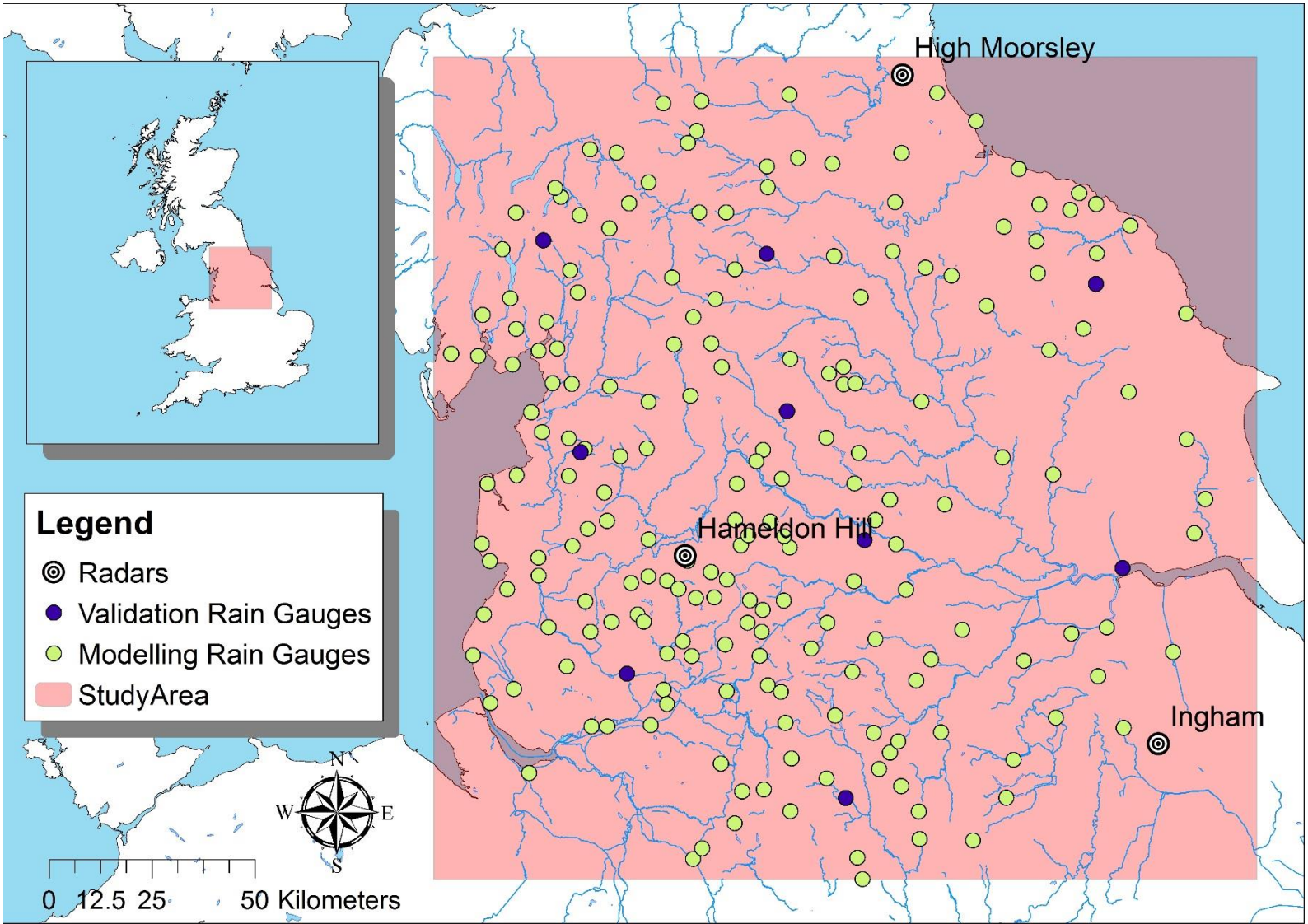
Singularity analysis

- Fractal theories, adapted to Bayesian rainfall merging by Wang et al. (2015).
- ***Local Singularity:*** structure in which the areal average follows a power function of the considered area
- Singularities are charcteristic of non-Gaussian structures, removing them makes a field more Gaussian.
- Need aereal characteristics, cannot be applied to point measurements in KED

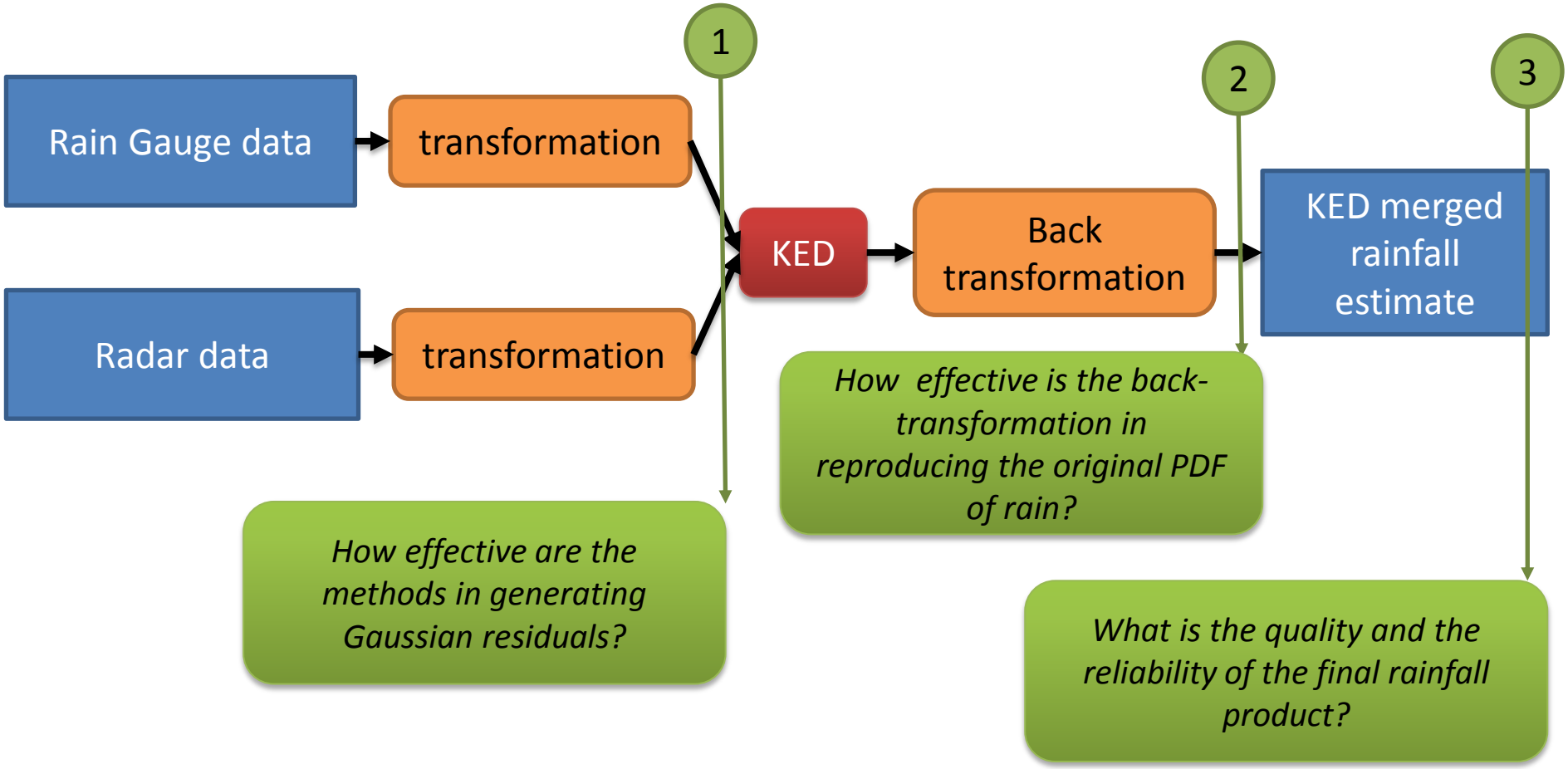


Case study

	START	END
EVENT 1	2009-03-25 23:00	2009-03-26 18:00
EVENT 2	2009-06-17 06:00	2009-06-17 19:00
EVENT 3	2009-07-06 10:00	2009-07-06 20:00
EVENT 4	2009-09-02 15:00	2009-09-03 23:00
EVENT 5	2009-11-29 00:00	2009-11-29 23:00
EVENT 6	2009-12-05 15:00	2009-12-06 13:00



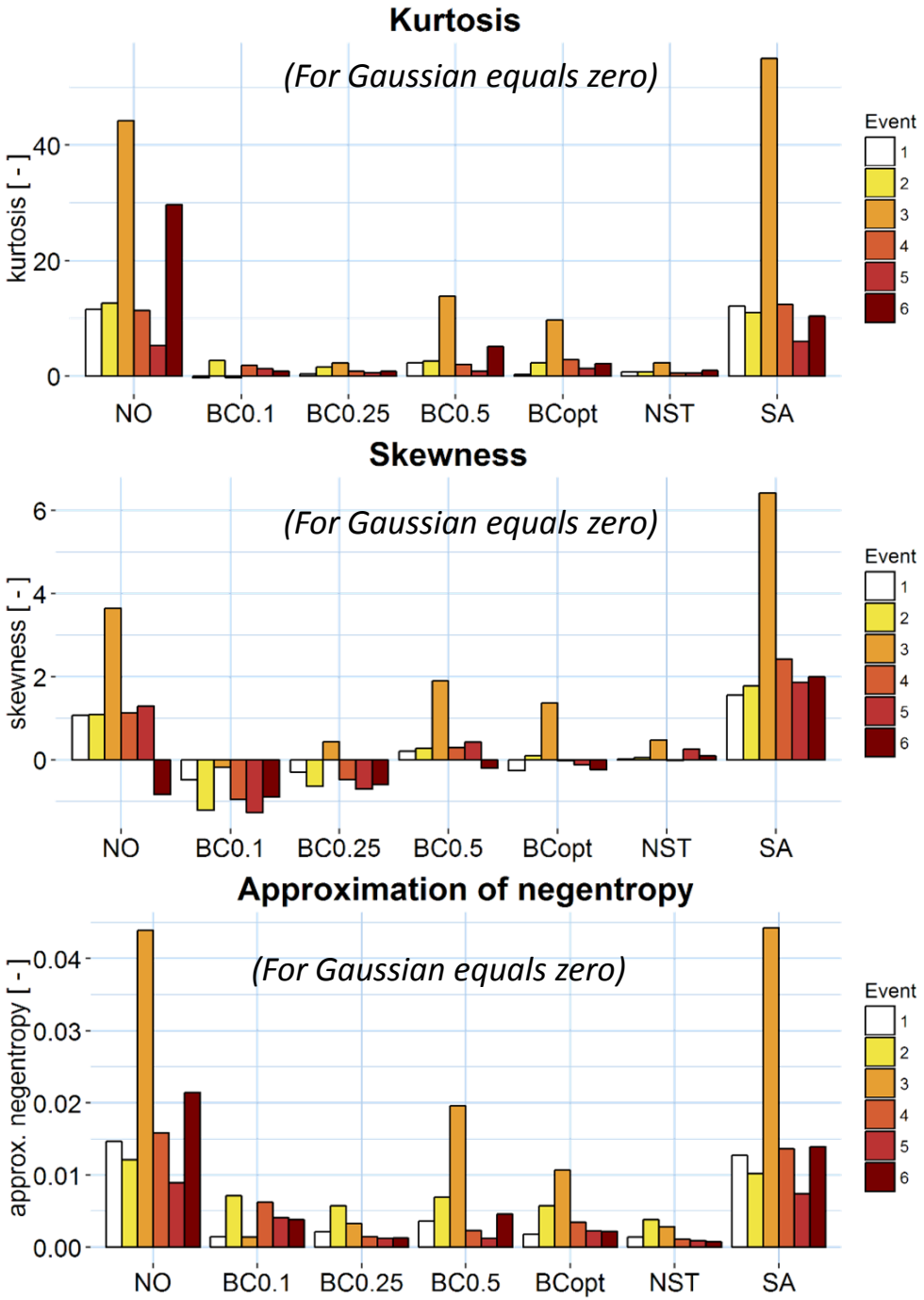
Evaluation techniques



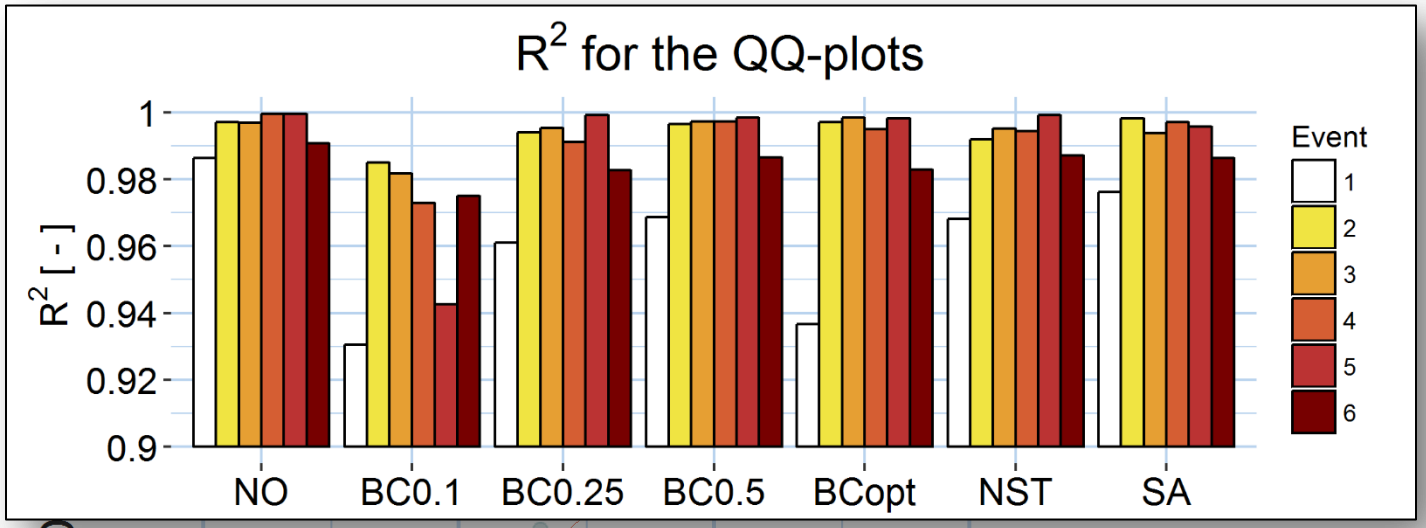
Gaussianity Test

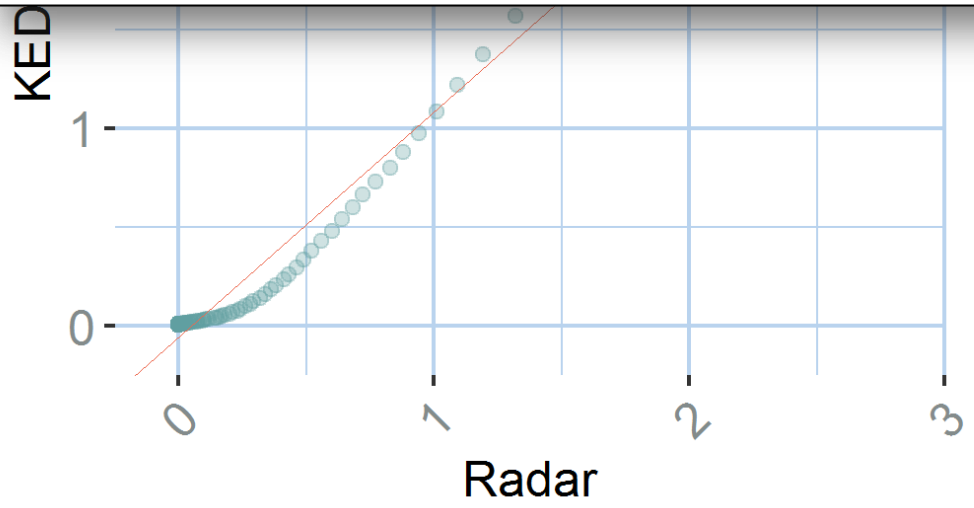
X No Transformation
X Singularity Analysis

✓ Box-Cox
✓ Normal Scores



Rainfall distribution reconstruction





X Box-Cox $\lambda = 0.1$

✓ Other

(We use a linear function of the radar for the original distribution)

Validation with Rain Gauges

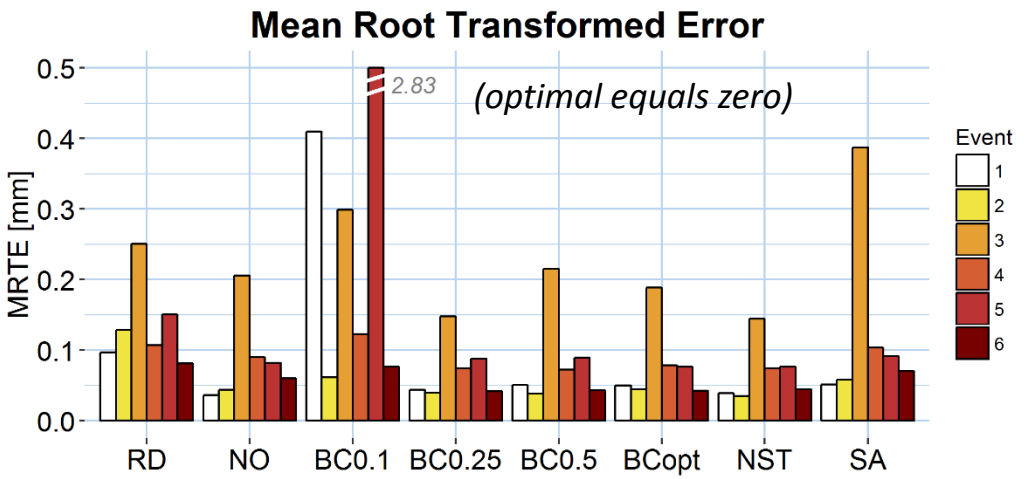
X Singularity Analysis

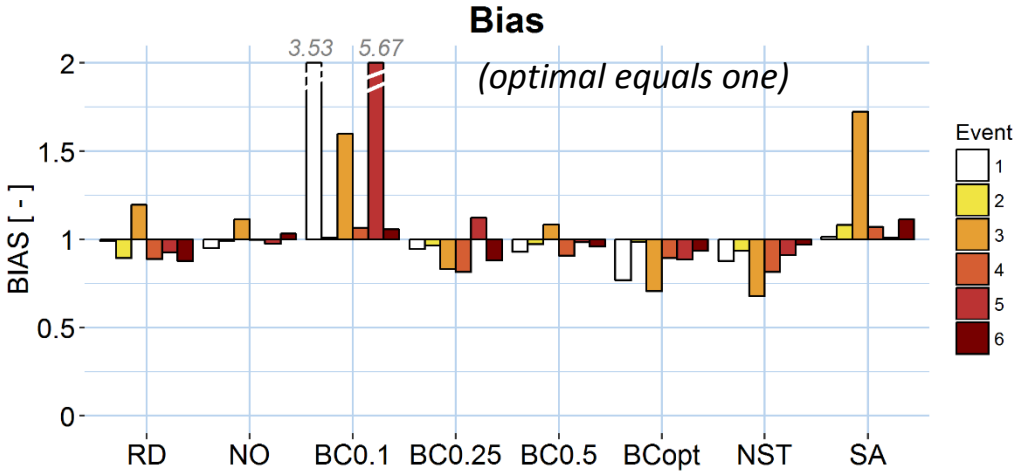
X Box-Cox $\lambda = 0.1$

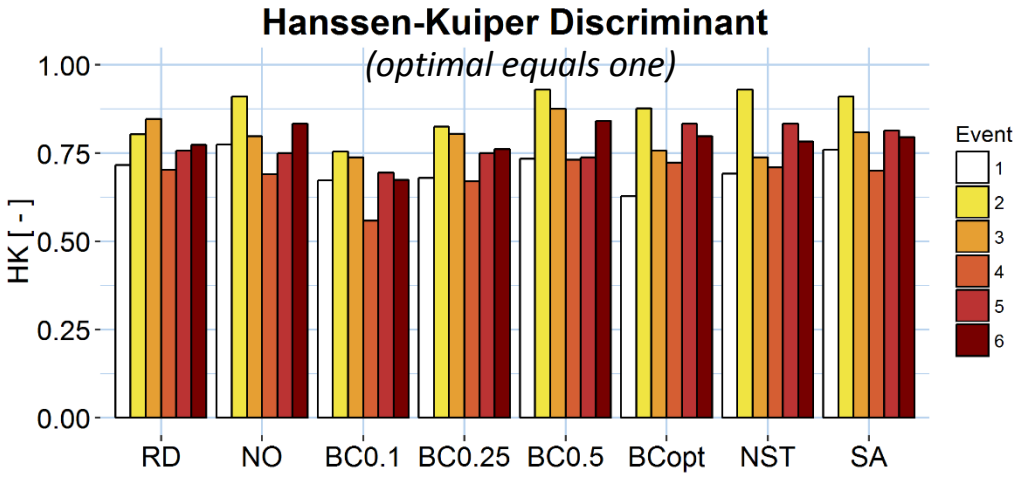
✓ Other Box-Cox

✓ Normal Scores

✓ No Transformation



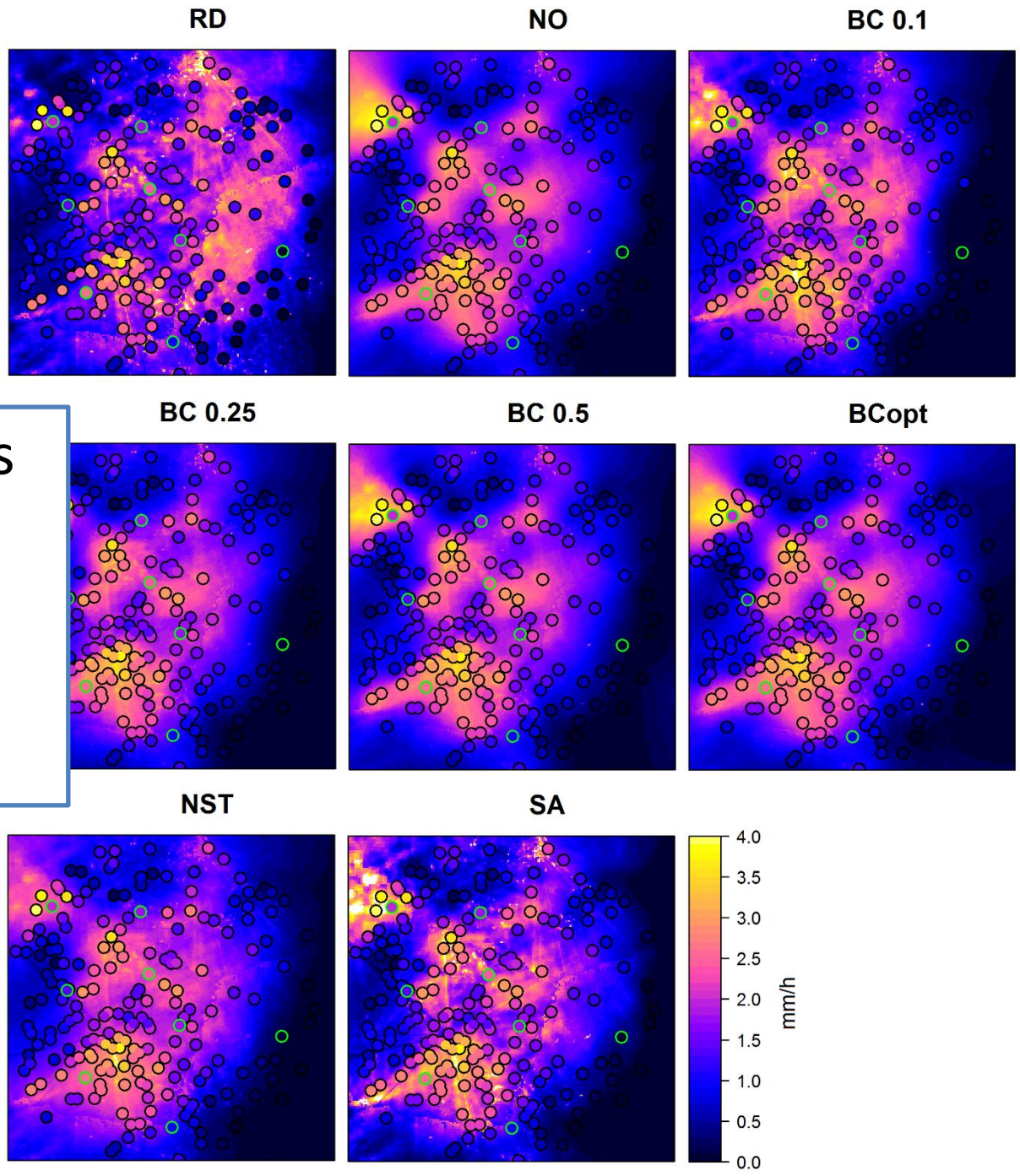




Qualitative evaluation

- X Singularity Analysis
- X No Transformation

- ✓ Box-Cox
- ✓ Normal Scores



Summary

	KURT	SKEW	APPROX. NEGENTR.	R^2	MRTE	BIAS	HK	GENERAL EVALUATION
NO TRANSFORMATION								OK
BOX-COX 0.1								NEGATIVE
BOX-COX 0.25								POSITIVE
BOX-COX 0.5								OK
BOX-COX OPTIMAL								OK
NORMAL SCORES								POSITIVE
SING. ANALYSIS								NEGATIVE

1. Box-Cox with low λ introduces a high bias
2. Singularity analysis not suitable for KED
3. Merging improves the results
4. Transformations are helpful, but more important in specific applications
5. Box-Cox with $\lambda = 0.5$ and $\lambda = 0.25$ have analytical back-transformation

Conclusions

- Square root or square root – square root transformations are recommended because of:
  - ✓ Good skills
  - ✓ Analytical back-transformation
  - ✓ Simplicity
- Normal Score Transformation performs well, but more complex
- Box-Cox with low λ and Singularity Analysis are not suitable
- Transformations improve the estimations, but not significantly
- In specific applications transformations may be important

Thank you!!!

Acknowledgements:

This work was carried out in the framework of the Marie Skłodowska Curie Initial Training Network QUICS. The QUICS project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 607000. The authors would like to thank the UK Met Office and the Environment Agency, which provided the radar rainfall data and the rain gauge data to develop this study, and the British Atmospheric Data Centre for providing access to the datasets. M. A. Rico-Ramirez also acknowledges the support of the Engineering and Physical Sciences Research Council (EPSRC) via Grant EP/I012222/1. A special thank is also for Dr. Andreas Scheidegger and Dr. Jörg Rieckermann, from EAWAG, and Antonio M. Moreno Rodenas, from TU Delft, for providing technical and scientific feedback.

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