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

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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
Kriging with External Drift

KED is one of the best and most efficient 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

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

• 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
• Disjunctive Kriging
• Singularity analysis

Controversial

Not easily adaptable to KED
Box-Cox Transformations:

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

1. \( \lambda = 0.5 \rightarrow \text{Square root} \)
2. \( \lambda = 0.25 \rightarrow \text{Square root} – \text{Square root} \)
3. \( \lambda = 0.1 \rightarrow \text{Almost Logarithmic} \)
4. Optimal time-variant \( \lambda \) [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 characteristic of non-Gaussian structures, removing them makes a field more Gaussian.

- Need aerial characteristics, cannot be applied to point measurements in KED.
Case study

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Legend:
- Radars
- Validation Rain Gauges
- Modelling Rain Gauges
- Study Area

Map showing the study area with radars, validation rain gauges, and modelling rain gauges.
Evaluation techniques

How effective are the methods in generating Gaussian residuals?

How effective is the back-transformation in reproducing the original PDF of rain?

What is the quality and the reliability of the final rainfall product?
Gaussianity Test

- No Transformation
- Singularity Analysis
- Box-Cox
- Normal Scores
Rainfall distribution reconstruction

(We use a linear function of the radar for the original distribution)
Validation with Rain Gauges

- Singularity Analysis: ✗
- Box-Cox $\lambda = 0.1$: ✗
- Other Box-Cox: ✔
- Normal Scores: ✔
- No Transformation: ✔

Mean Root Transformed Error (optimal equals zero)

Bias (optimal equals one)

Hanssen-Kuiper Discriminant (optimal equals one)
Qualitative evaluation

- Singularity Analysis
- No Transformation
- Box-Cox
- Normal Scores
Summary

1. Box-Cox with low $\lambda$ 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 $\lambda$ and Singularity Analysis are not suitable
• Transformations improve the estimations, but not significantly
• In specific applications transformations may be important
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References: