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Geostatistical combination of radar and rain gauges – does data transformation improve uncertainty estimates?

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Motivation

- Enable applications of probabilistic spatial precipitation estimates, e.g. precipitation ensembles for hydrological modeling

Aims

- Apply Trans-Gaussian kriging for geostatistical radar-gauge combination in Switzerland
- Better satisfy theoretical assumptions of geostatistics
- Illustrate effect of data transformation on point estimate and uncertainty
- Evaluate and compare reliability of probabilistic precipitation estimate by different transformation levels

Data

- Operational hourly composite of 3 C-band radars (Germann et al., 2006) (Fig. 1), 1x1km resolution
- Quality checked hourly data of 75 automated gauges (Fig. 1), average inter-gauge distance 25 km

Methods

- Kriging with radar as external drift (KED) (e.g. Haberlandt, 2007)
- Isotropic exponential variogram REML (restricted maximum likelihood)
- Cross-validation
- Box-Cox transformation of radar and gauge values

$$Y' = \begin{cases} \dfrac{Y^{\lambda}-1}{\lambda} & \lambda \neq 0 \\ \log(Y) & \lambda = 0 \end{cases}$$

- Comparison of different transformation strengths:

λ = 1	**no transformation**
λ = 0.5	**square root transformation**
λ = 0.1	**close to log transformation**
λ by MLE	**estimated for each hour**

- MLE for λ: maximizing likelihood of linear radar-gauge relation with Gaussian errors, beta prior distribution, positive on [0.2, 1.5]

Example case, June 2008

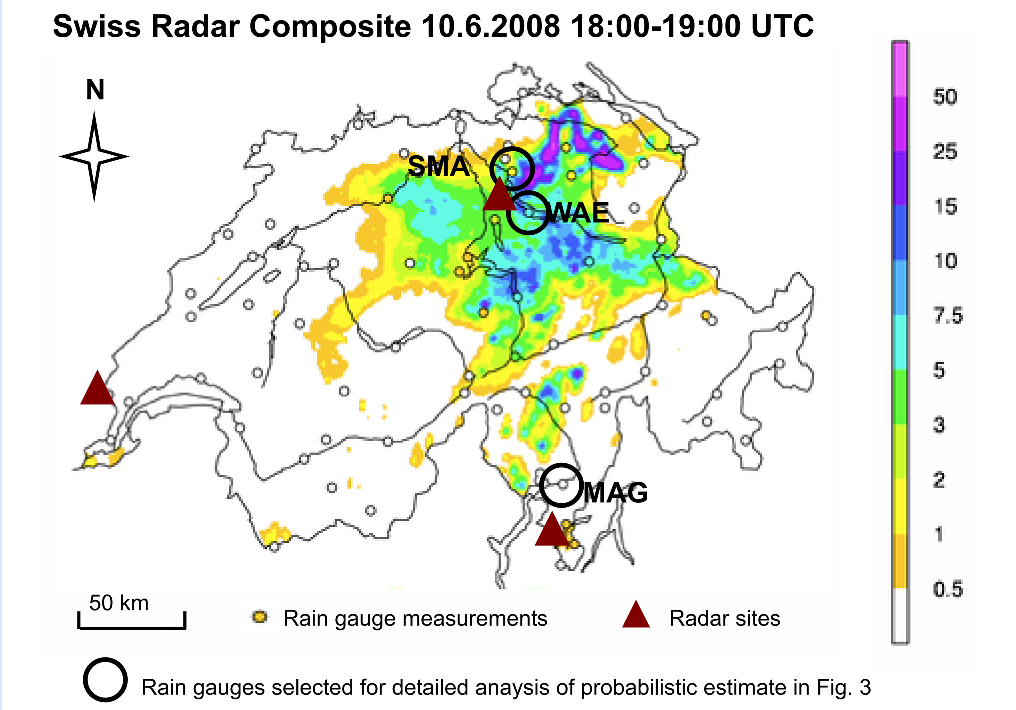

FIG. 1. Map of radar composite and rain gauge measurements showing hourly accumulated precipitation of example case.

Example case, June 2008

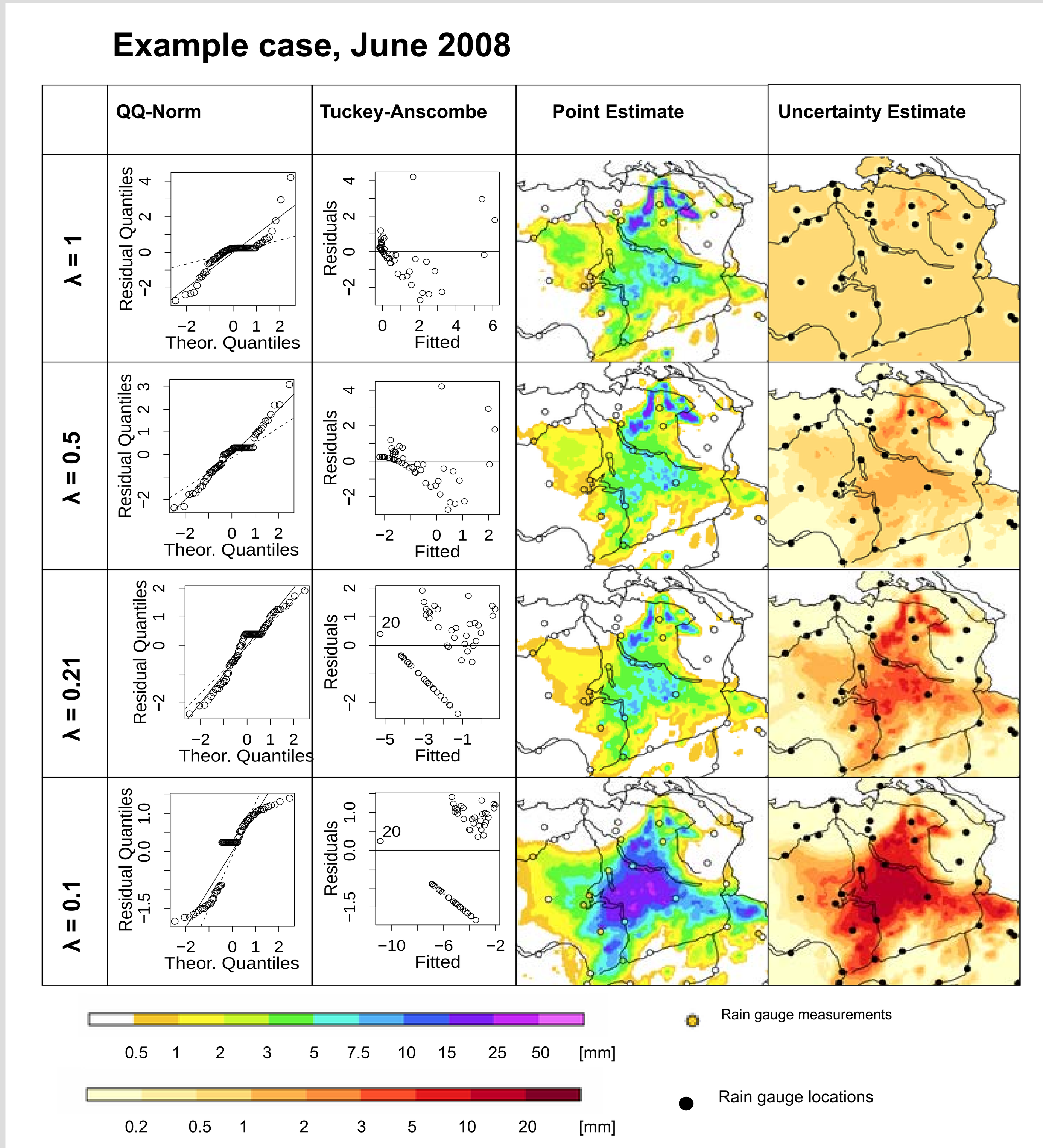

FIG. 2. Example case 10.6.2008 18:00-19:00 UTC. Rows compare different transformation levels for radar and rain gauge data.
First two columns: plots to assess fulfillment of model assumptions: QQ-Norm plot of standardized residuals - standardized residuals vs. fitted values (Tuckey-Anscombe)
Third column: map sections of point estimates and observed gauge measurements
Last column: map sections of $0.5*(Q_{0.84}-Q_{0.16})$, a robust measure of uncertainty estimate, and station locations.

Probabilistic estimates at selected gauges

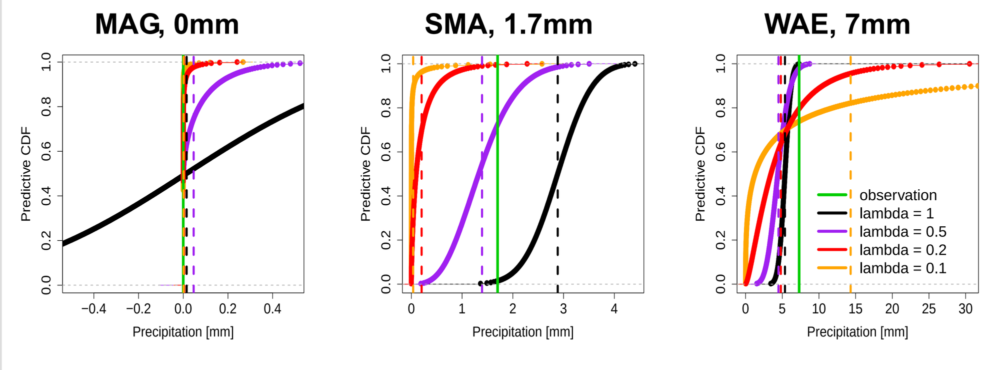

FIG. 3. Cross-validated cumulative probabilistic precipitation estimates by KED for 10.6.2008 18:00-19:00 UTC at selected gauge locations (circled in Fig. 1). Comparison of different transformation levels: no transformation (λ=1), square root transformation (λ=0.5), transformation with estimated λ by MLE (λ=0.21) and close to log transformation (λ=0.1). Dashed lines indicate point estimates, solid green line and amount in title show observed precipitation.

Results

Suitable Data Transformation (λ by MLE)

- Model assumptions better fulfilled (Fig. 2): heteroscedasticity eliminated, residuals closer to Gaussian distribution
- Precipitation estimate restricted to non-negative values (Fig. 3)
- Uncertainty estimate positively skewed and positively dependent on precipitation amount (Fig. 2 & Fig. 3)
- Better performance of probabilistic estimate in general (Fig. 4)
- Helps not to miss heavy precipitation (Fig. 4 & Fig. 5)

Exaggerated Data Transformation (λ < 0.2)

- Separates residuals (wet radar/dry gauge vs. others) (Fig. 2)
- Exaggerated upper quantiles → positive bias in point estimate (Fig. 2 & Fig. 3)

Systematic evaluation 2008

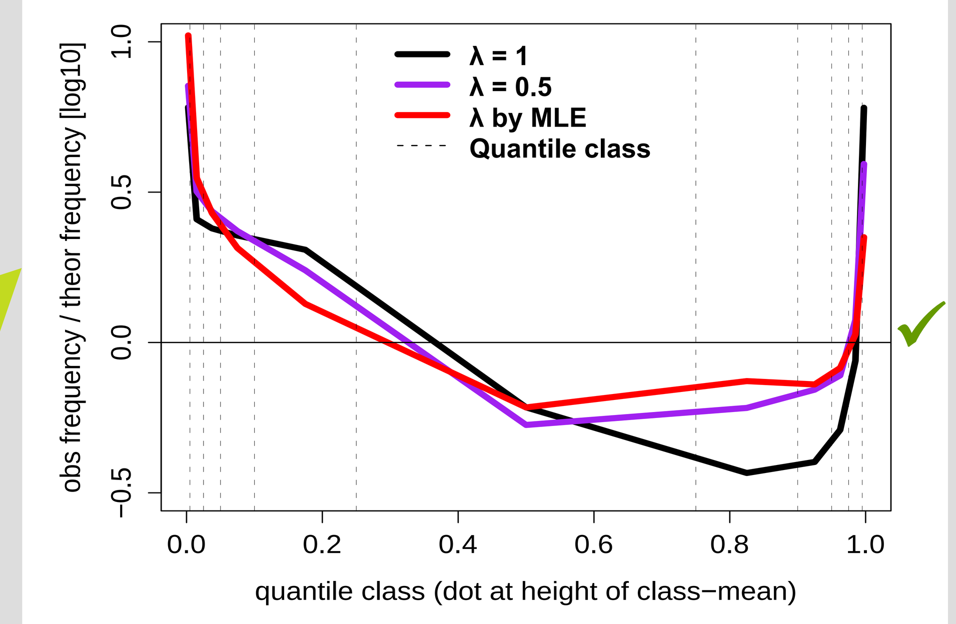

FIG. 4. Systematic evaluation of probabilistic estimate in 2008:1438 hourly accumulations with minimum of 10 wet gauges (≥0.5mm): log(obs.freq/theor.freq) (zero for perfect estimate) in different quantile classes comparing probabilistic precipitation estimate of different transformation strengths.

Systematic evaluation 2008

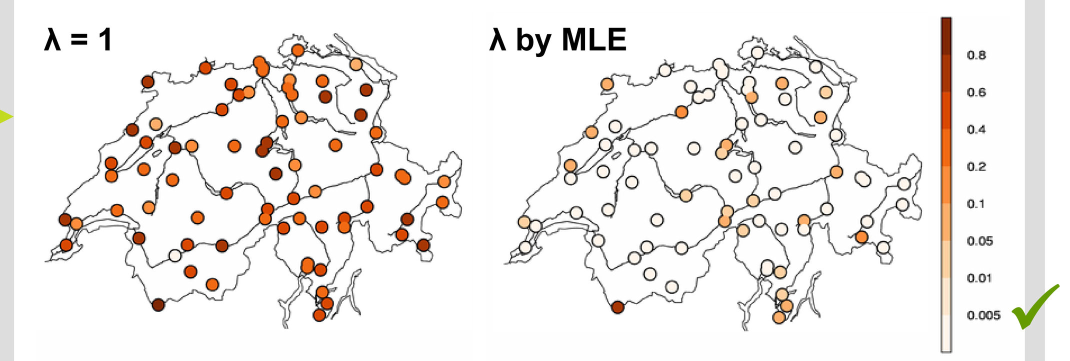

FIG. 5. Fraction of observed heavy precipitation (>5mm) considered as extremely unlikely(P≤ 0.005) by cross-validated probabilistic estimate, i.e. $Q_{0.995}$ below observed precipitation amount. Based on the 1672 observations >5mm in the systematic evaluation 2008 for λ=1 and λ by MLE.

Conclusions

- Box-Cox transformation can improve fulfillment of model assumptions and probabilistic precipitation estimate in geostatistical radar-gauge combination
- Uncertainty estimate becomes increasingly skewed and dependent on precipitation amount with increasing transformation strength
- Box-Cox transformation with suitable λ particularly helpful to improve the inclusion of heavy precipitation in the probabilistic estimate
- Finding a λ that suits the data is crucial
→ several criteria could be optimized: homoscedasticity, Gaussian distribution, radar-gauge relation
→ too small values of λ (<0.2) can introduce bias to point estimates → should be avoided

References

Germann, U., G. Galli, M. Boscacci, and M. Bolliger, 2006: Radar precipitation measurement in a mountainous region. *Q. J. R. Meteorol. Soc.*, **132**, 1669–1692.
Haberlandt, U., 2007: Geostatistical interpolation of hourly precipitation from rain gauges and radar for a large-scale extreme rainfall event. *Journal of Hydrology*, **332**, 144–157.

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