Evaluation of a conditional simulation approach to quantify the uncertainty in spatial rainfall

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Benjamin Renard[1], Etienne Leblois[1], Mark Thyer[2], Dmitri Kavetski[2], George Kuczera[3]

(1) Irstea, UR HHLY Hydrology-Hydraulics, Lyon, France (2) University of Adelaide, School of Civil, Environmental and Mining, Australia (3) University of Newcastle, School of Engineering, Australia

Introduction: Spatial rainfall uncertainty

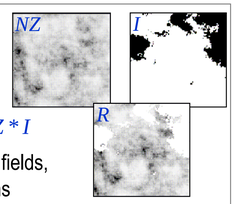
Rainfall uncertainty
- Incomplete coverage of the raingauge network
- Catchment areal rainfall for lumped models
- Spatial rainfall for distributed models

Hydrologic modeling
- Quantifying data errors is a prerequisite to understand uncertainty in hydrologic models
- Disentangling data and structural errors

Objectives
- Develop a conditional simulation (CS) approach to quantify rainfall spatial uncertainty
- Evaluate its reliability in validation mode

Quantifying the uncertainty in spatial rainfall using a rainfall simulator and conditional simulations

Rainfall simulator



General principles

Simulation of 3*D*-fields (2*D*+*t*)

Decomposition in two independent fields: non-zero rainfall and indicator, $R = NZ * I$

At its core, the simulator generates Gaussian fields, then transforms them using at-site distributions

Specifications & Estimation

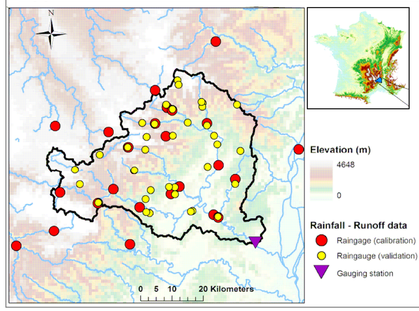
At-site distributions
- *Some continuous distribution (e.g. gamma) for the non-zero field*
- *Bernoulli distribution for the indicator*

Spatio-temporal variograms
- ⚠ *Transformation by at-site distributions alters correlations*
- *Corrections needed* (see **[1, 2, 3]**)

Simulation

Conditional or unconditional
- *Conditional simulation (CS): at gauged pixels,* $R_{sim} = R_{obs}$

Application: the Ardèche catchment (2240 km²)

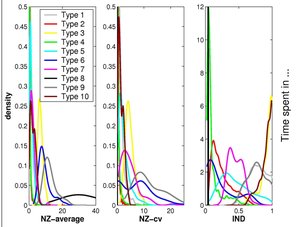


Hourly *R*, 64 gauges

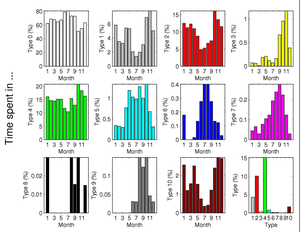
- *Cévennes-Vivarais Mediterranean Hydrometeorological Observatory Database* **[4]**
- *Period 2000 - 2008 (included)*
- *25 gages for calibration, 39 for validation*

Application: the Ardèche catchment (2240 km²)

Step 1: definition of homogeneous rainfall types
- Cluster all hourly time steps into 10 "rainfall types"
- Clustering based on three variables:
  - *(i) mean and (ii) CV of non-zero R; (iii) fraction of rainy gauges*
- Kohonen self-organizing map + agglomerative hierarchical clustering

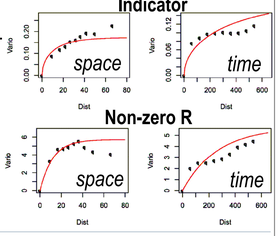


Distribution of variables within each type

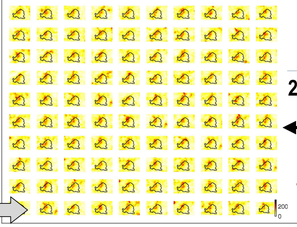


Seasonality of rainfall types

Step 2: estimation
- Estimate space / time variograms + parameters of at-site distributions
- Type-specific estimates



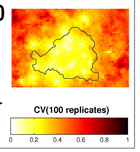
Step 3: Simulation



24 November 2010

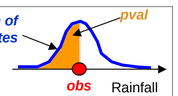
100 CS

and their CV

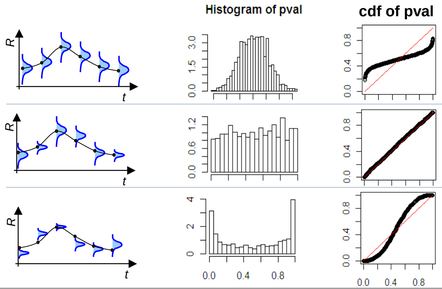


Reliability of conditional simulations

Reliability assessment



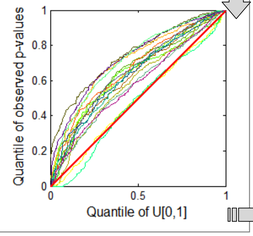
- Are observations consistent with CS replicates?
- At each time step, compute $pval_t = F_t(obs_t)$
- If CS reliable, ($pval_t$) realizations from a uniform distribution
- Cf. PIT diagnostic in ensemble forecasting



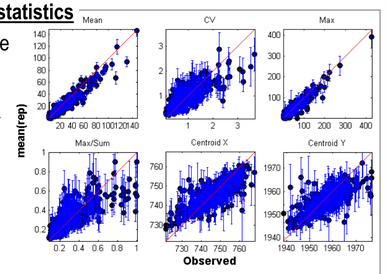
Evaluation using validation raingauges
- Aggregation at a daily time step
- Each line = 1 validation site

Results
- Tendency to under-prediction

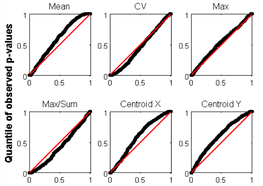
Going further…
- In a hydrologic modeling perspective, important to evaluate the spatial structure in addition to station values



Evaluation using spatial statistics
- At each time step, compute spatial statistics on all validation sites
  - *Spatial mean, CV and Max*
  - *Max/Sum ('concentration')*
  - *XY of rainfall centroid*
- obs. vs. mean(CS rep), bars = stdev(CS rep)
- Overall good consistency

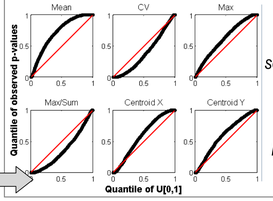


Daily rainfall



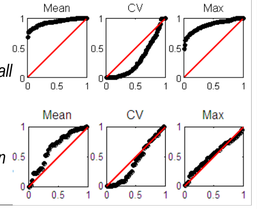
- Good reliability at a daily time step
- Larger discrepancies for hourly rainfall
- Reliability highly variable amongst rainfall types
- In general, 'heavy' rainfall types are the most reliable

Hourly rainfall



Type 4 *Small and scattered rainfall*

Type 9 *Heavy autumn rainfall*



Conclusions

Reliability of CS to quantify the uncertainty in spatial rainfall
- Acceptable at a daily time step, less reliable for hourly rainfall
- Rainfall types corresponding to heavy rainfall events are in general more reliable than small and scattered rainfall types

Avenues for improvement
- "Fuzzy" clustering of rainfall types
- Introduce spatial drift (elevation)
- Introduce advection (wind)

Future applications
- Uncertainty propagation in hydrologic model
- Identification of structural errors?
- Decomposition of uncertainty sources

[1] Renard, B., D. Kavetski, E. Leblois, M. Thyer, G. Kuczera, and S. W. Franks. **2011**. Towards a reliable decomposition of predictive uncertainty in hydrological modeling: Characterizing rainfall errors using conditional simulation, Water Resour. Res, 47.
[2] Lepioufle, J.-M., E. Leblois, and J.-D. Creutin. **2012**. Variography of rainfall accumulation in presence of advection, J. Hydrol., 464-465.
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[4] Boudevillain, B., G. Delrieu, B. Galabertier, L. Bonnifait, L. Bouilloud, P.-E. Kirstetter, and M.-L. Mosini. **2011**. The Cévennes-Vivarais Mediterranean Hydrometeorological Observatory database, Water Resour. Res, 47.

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