Space-time downscaling of extreme rainfall using stochastic simulations, intense runoff susceptibility modeling and remote sensing-based pluvial flood mapping

Arnaud Cerbelaud[1,2,3], Etienne Leblois[3], Pascal Breil[3], Laure Roupioz[1], Raquel Rodriguez-Suquet[2], Gwendoline Blanchet[2], Xavier Briottet[1]

[1] Onera, DOTA, Université de Toulouse ; F-31055 Toulouse, France - arnaud.cerbelaud@onera.fr
[2] Centre National d'Etudes Spatiales (CNES), EO Lab ; Toulouse, France - arnaud.cerbelaud@cnes.fr
[3] Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environnement (INRAE), UR RiverLy ; Villeurbanne, France

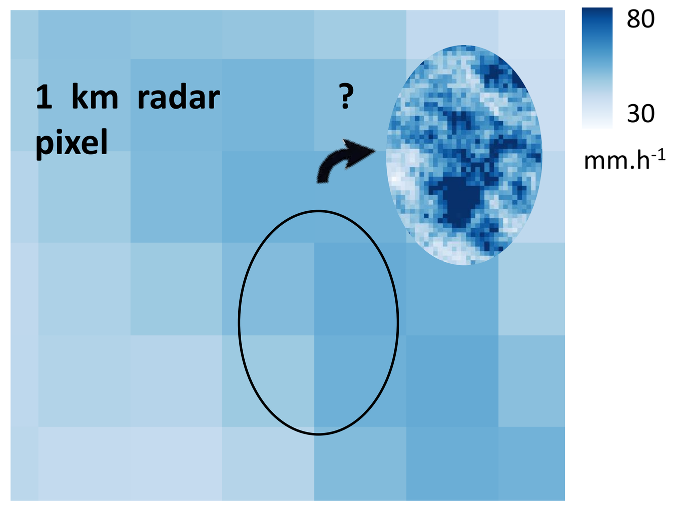
Session HS7.8: Spatial extremes in the hydro- and atmosphere: understanding and modelling
A.118 | EGU23-12249

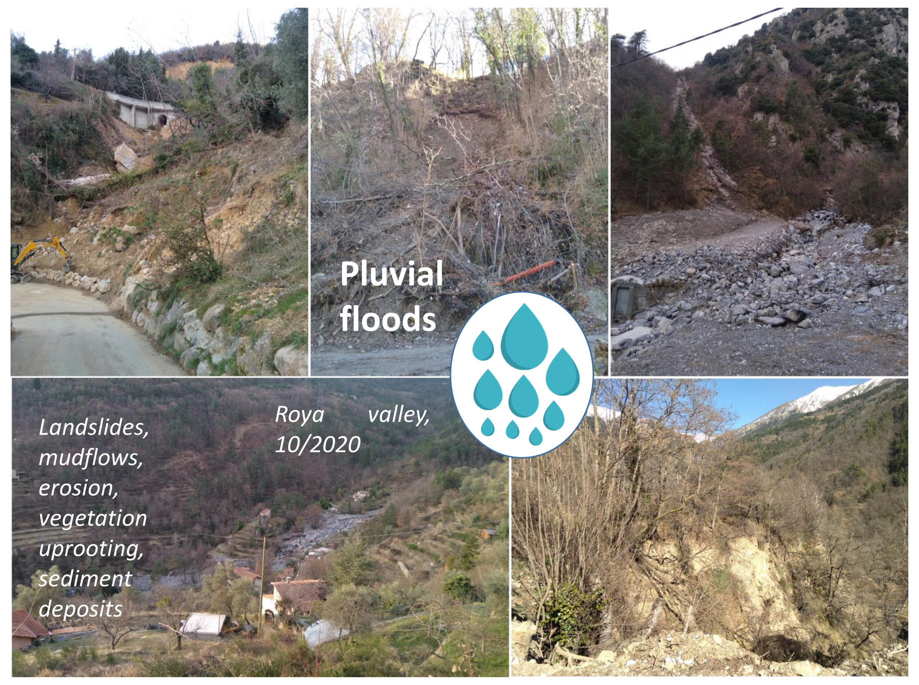
https://doi.org/10.5194/egusphere-egu23-12249

EGU 2023 — Sharing is encouraged

1. Background

Mean rainfall derived from radar ground instruments **underestimate most of the extreme values found at discrete locations** within radar pixels during intense events (on average ~ 70%, Peleg et al., 2018) ➡



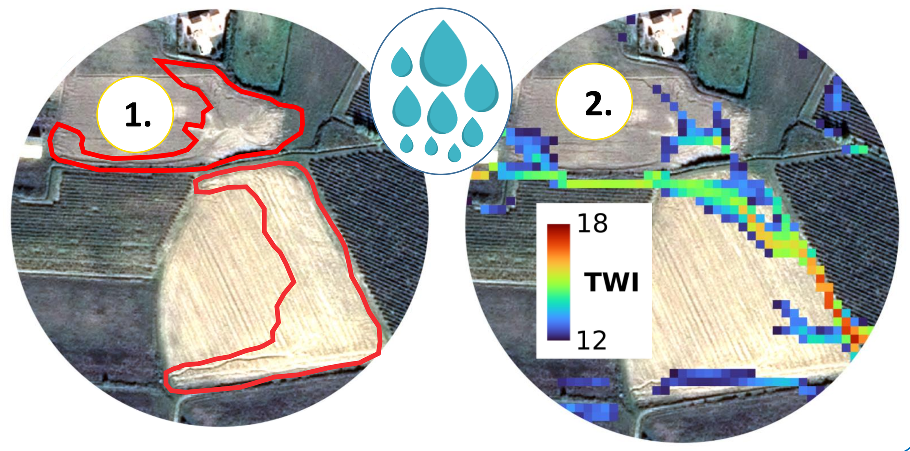


⬅ **Pluvial floods (or surface water floods,** i.e. floods happening independently of an overflowing water body) are caused by **extreme overland flow of rainwater** after short-term high-intensity extreme precipitation events. **They are highly correlated to local rainfall.**

GOAL

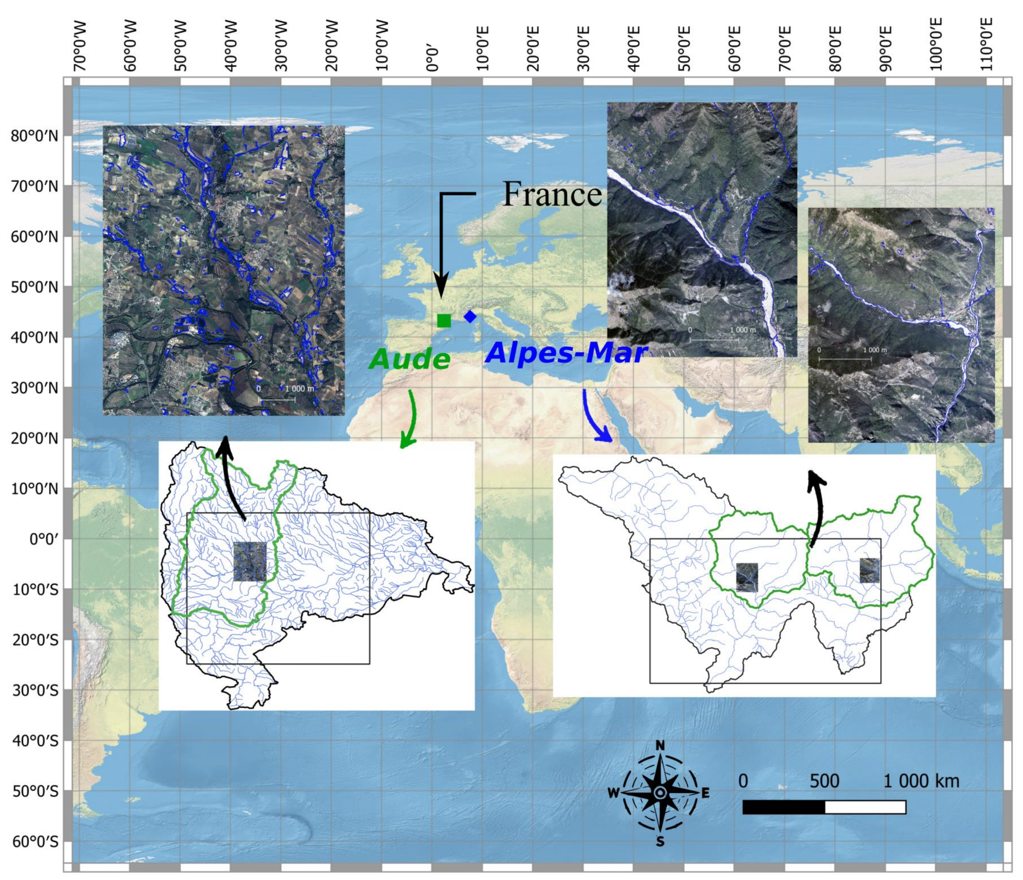
Infer the occurrence of locally higher (or lower) precipitation volumes at fine spatial scales (~ 50-100 m) from:

1. **the detection of pluvial flood damages**
2. **the inherent susceptibility to the occurrence of intense surface runoff**



2. Materials and Methods

Regions of interest: 2 study sites in the South of France during flash flood events (2018 – 2020)

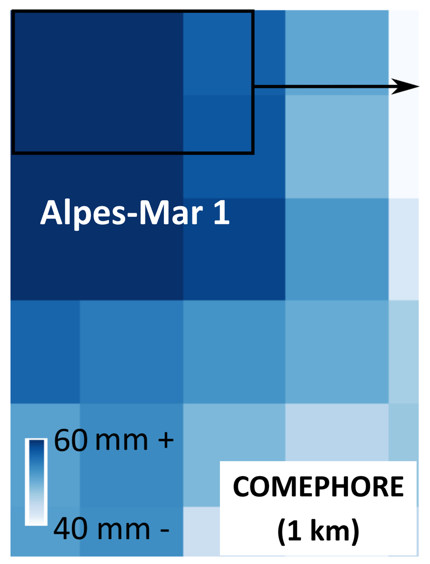


Idea: Combine

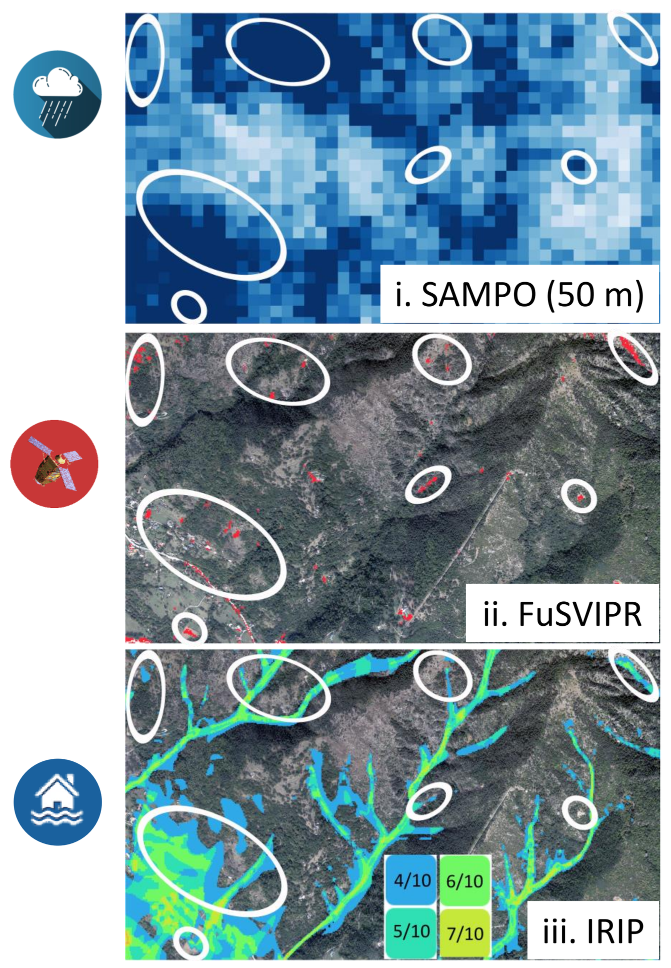
i. Downscaled hourly precipitation scenarios from the COMEPHORE radar data (1 km to 50 m) using a disaggregation tool derived from the SAMPO stochastic simulator (Leblois & Creutin, 2013; Chen, 2018)

ii. Pluvial flood impact maps derived from satellite imagery at very high resolution both in space & time (FuSVIPR method; Cerbelaud et al.)

iii. Intense surface runoff susceptibility maps from the IRIP© geomatics model (Dehotin & Breil, 2011)

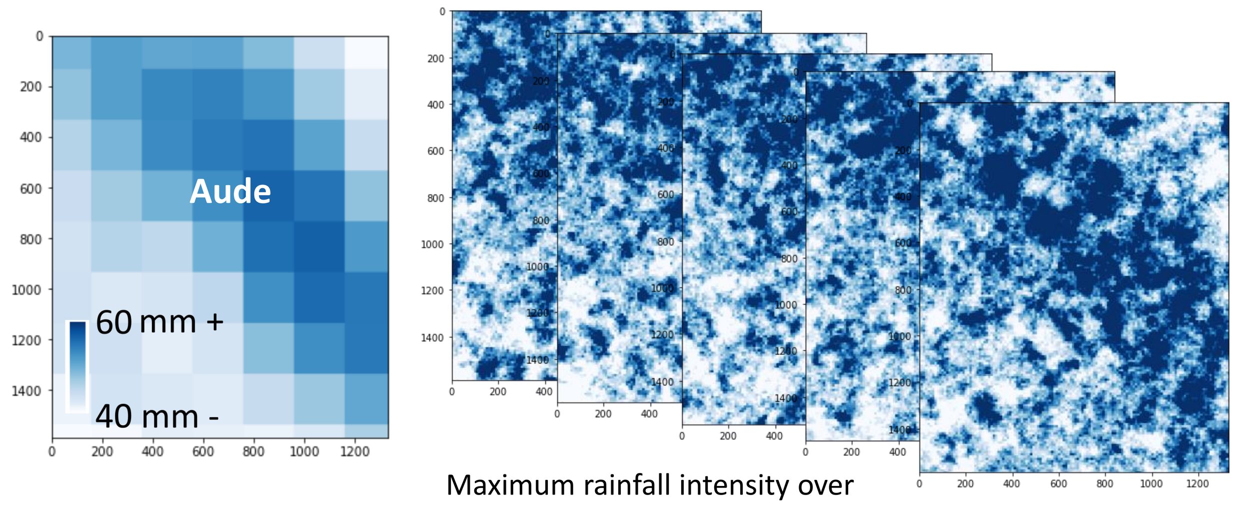


→ To support the disaggregation of rainfall at a fine spatial scale depending on where intense surface runoff was likely to occur, and where it actually occurred



3. Results:

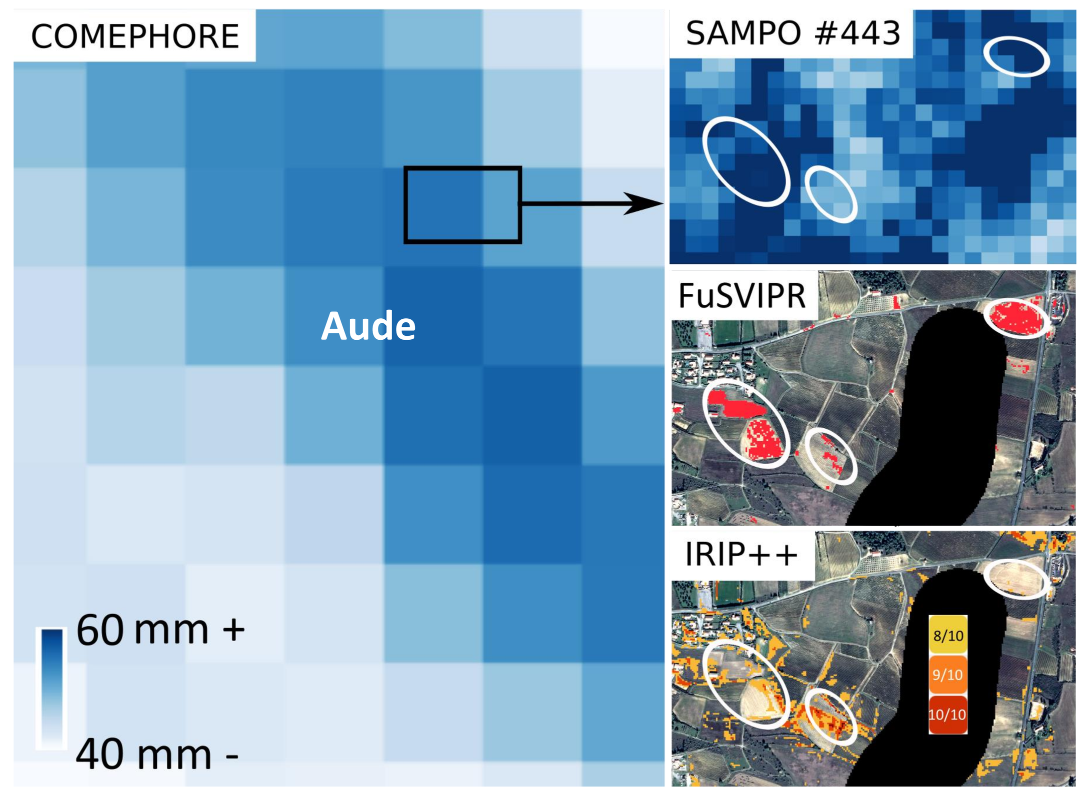
Multiple statistically consistent rainfall simulations (672 for each event) are generated at 50 m grid spacing over 12 hours using the SAMPO simulator:



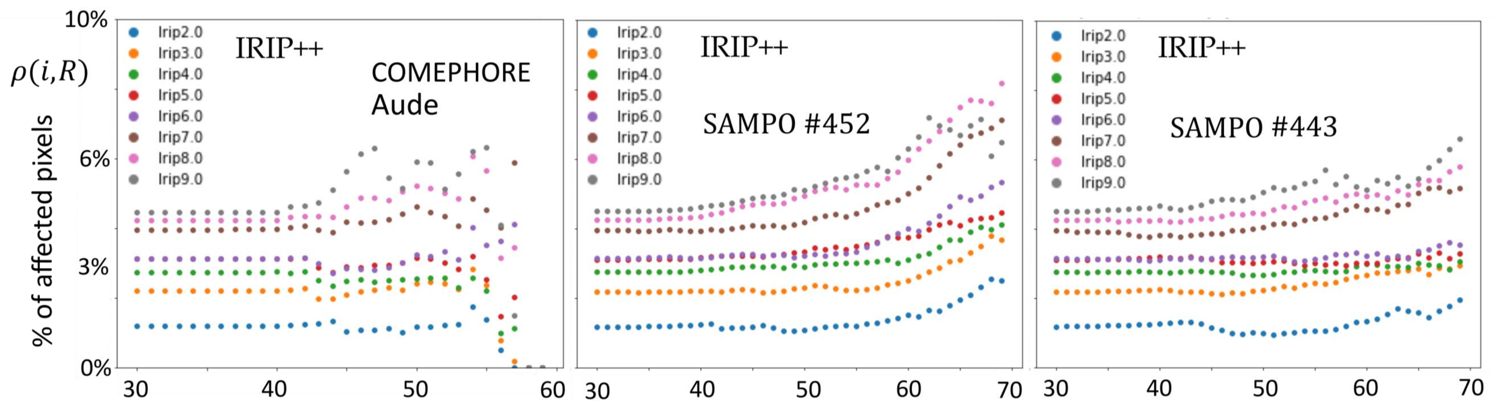
Maximum rainfall intensity over 60 consecutive minutes

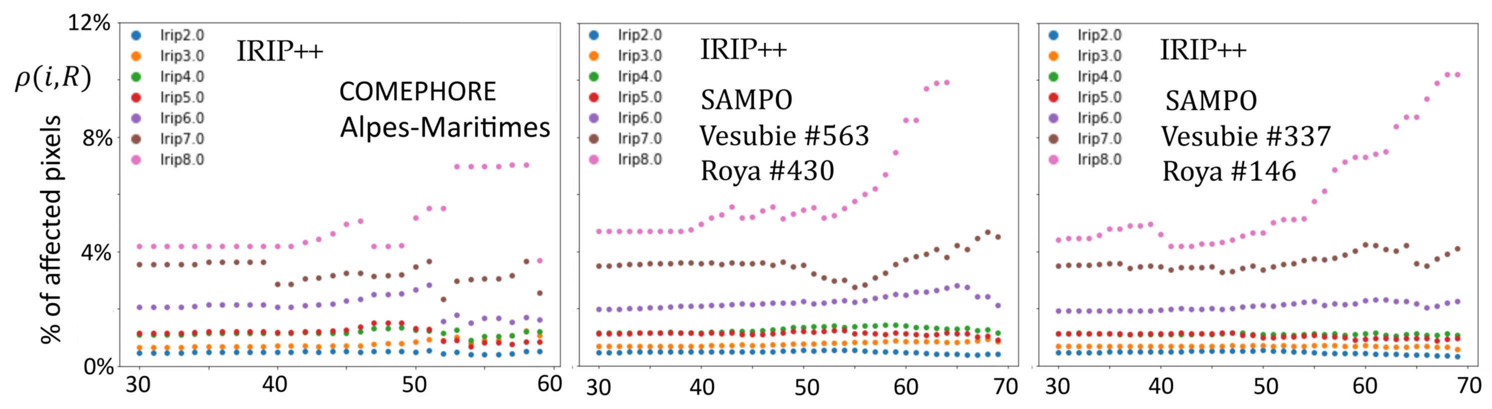
The optimal scenarios are chosen based on those yielding:

1. the highest ratios of pluvial flood damages with increasing rainfall intensities and increasing IRIP susceptibility levels.
2. the greatest negative relationship between the rainfall intensities and the IRIP susceptibility levels in impacted areas (higher rainfall intensities are required for pluvial floods to occur in less susceptible areas)



- The results below highlight the importance of observing and measuring rainfall at fine spatial scales to correctly assess the susceptibility to pluvial runoff:
  → up to 10% and more of highly susceptible areas affected by pluvial floods at extreme rainfall levels

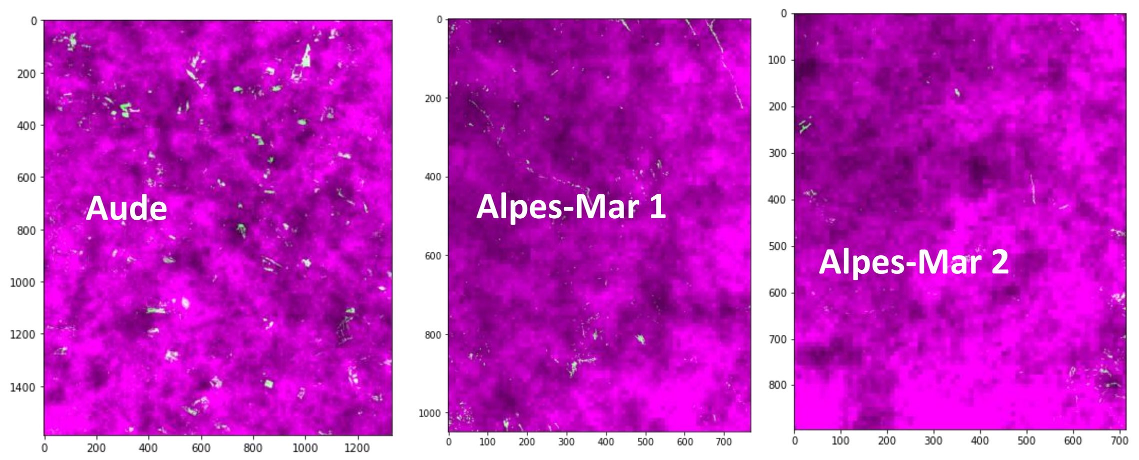




4. Conclusions

This methodology to support the disaggregation of extreme rainfall is only a concept at this stage. The best all-around downscaled precipitation patterns were not validated *per se*. They are just suggested based on exogenous knowledge on where intense surface runoff was likely to occur, and where it actually occurred.

The selected optimal time series could later be used as rainfall forcing in event-oriented distributed hydrological models (physically- or empirically-based). Some quantitative validation could then be obtained from comparing the actual impact maps to what these surface runoff and erosion models predict when fed with the disaggregated rainfall forcing.



Optimal downscaled rainfall scenarios at 50 m resolution stacked onto the satellite-based impact maps of pluvial flood damages

References

- Cerbelaud, A., Blanchet, G., Roupioz, L., Breil, P., Briottet, X., 2023. Mapping pluvial flood-induced damages with multi-sensor optical remote sensing: a transferable approach using change detection and very high spatial resolution. *Submitted*.
- Chen, S., 2018. Stochastic simulation of near-surface atmospheric forcings for distributed hydrology. PhD thesis. Université Grenoble Alpes (ComUE).
- Dehotin, J., Breil, P., 2011. Technical Report of the IRIP Project: Surface Runoff Flood Hazard Mapping (Technical Report) IRSTEA Hydrology-Hydraulic Research Unit: Lyon, France, 2011.
- Leblois, E., Creutin, J.-D., 2013. Space-time simulation of intermittent rainfall with prescribed advection field: Adaptation of the turning band method. *Water Resour. Res.* 49, 3375–3387. https://doi.org/10.1002/wrcr.20190.
- Peleg, N., Marra, F., Fatichi, S., Paschalis, A., Molnar, P., Burlando, P., 2018. Spatial variability of extreme rainfall at radar subpixel scale. *J. Hydrol.* 556, 922–933. https://doi.org/10.1016/j.jhydrol.2016.05.033.