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Chaire Hydrologie pour une Ville Résiliente

ENPC radar : 7 lessons

by Ioulia Tchiguirinskaia

HM&Co/ENPC

May 7, 2019

RainGain approach

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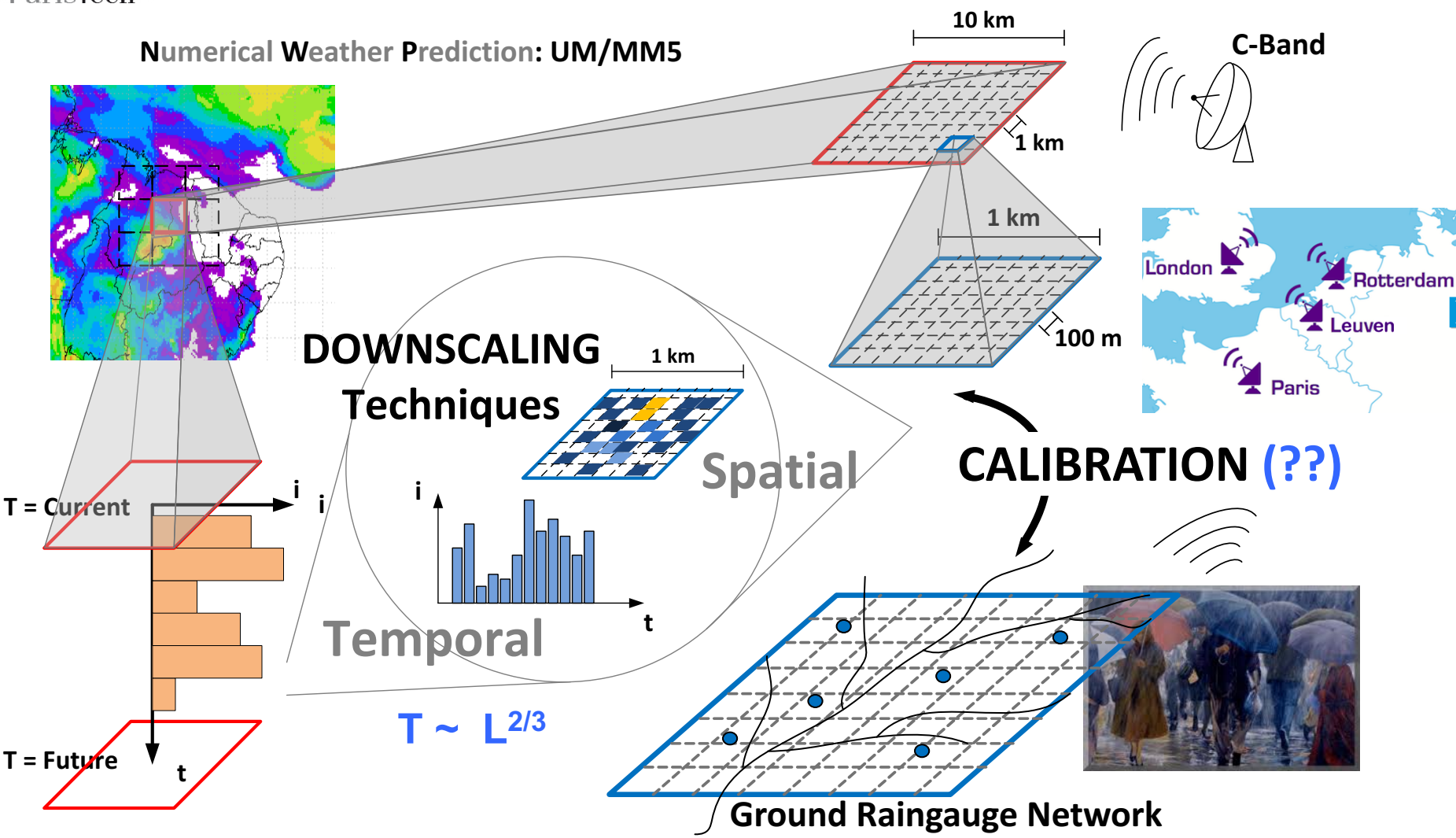
➢ Combining several techniques with nowcasting



From one scale to an other « zoom »

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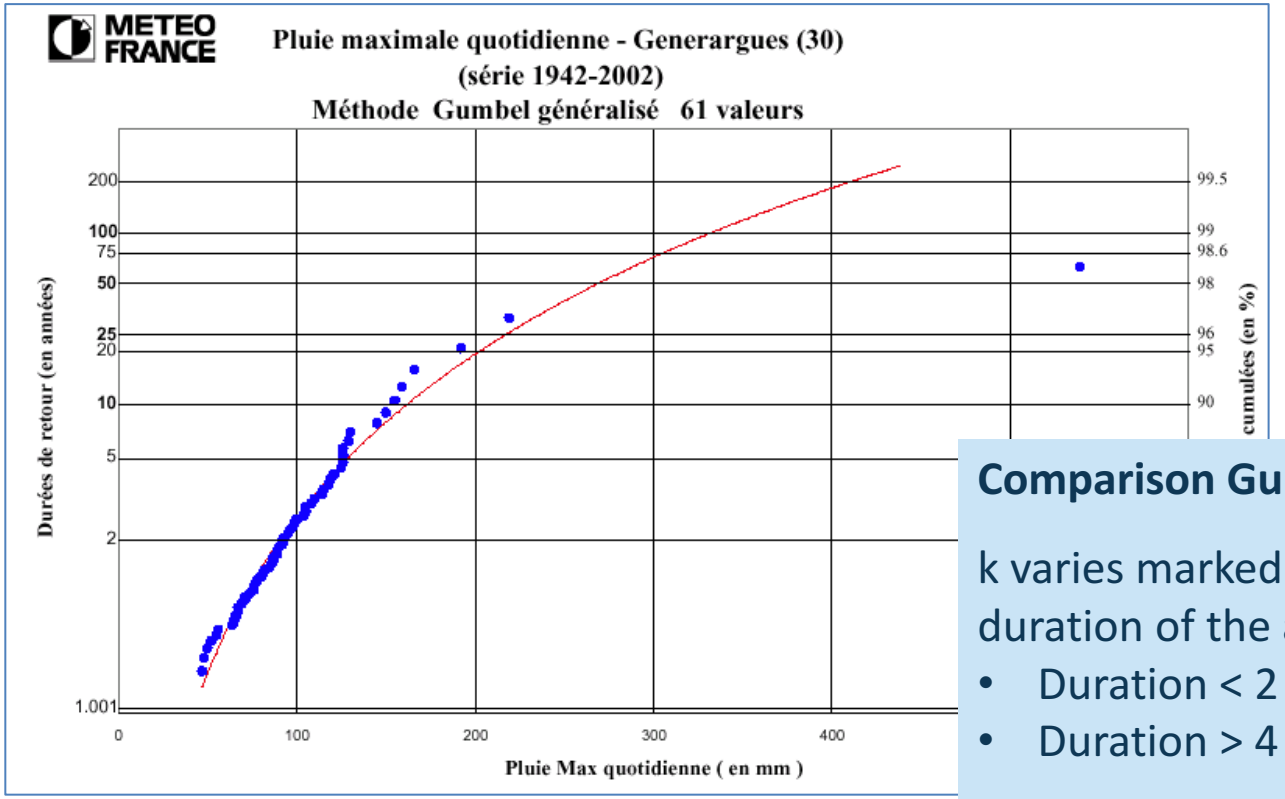
- **Forward zoom: "downscaling"**

Down way to finer scales => Multiplicity of details of the field

- **Backward zoom: "upscaling"**

Up way to larger scales => Smoothing of details, averaging



60 years ! to start adjusting the GEV distribution

Comparison Gumbel – GEV:

k varies markedly depending on the duration of the accumulated rainfall:

- Duration < 2 days: Fréchet law ($k < 0$);
- Duration > 4 days: Weibull law ($k > 0$).

J.-M. Veysseire, 2005

Indeed, extreme events cluster!

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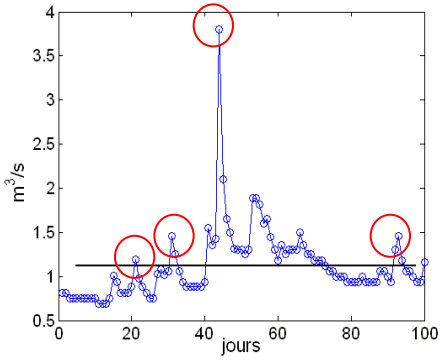
- The GEV theory requires short range correlations
- Many attempts to derive "quasi-independent" events:

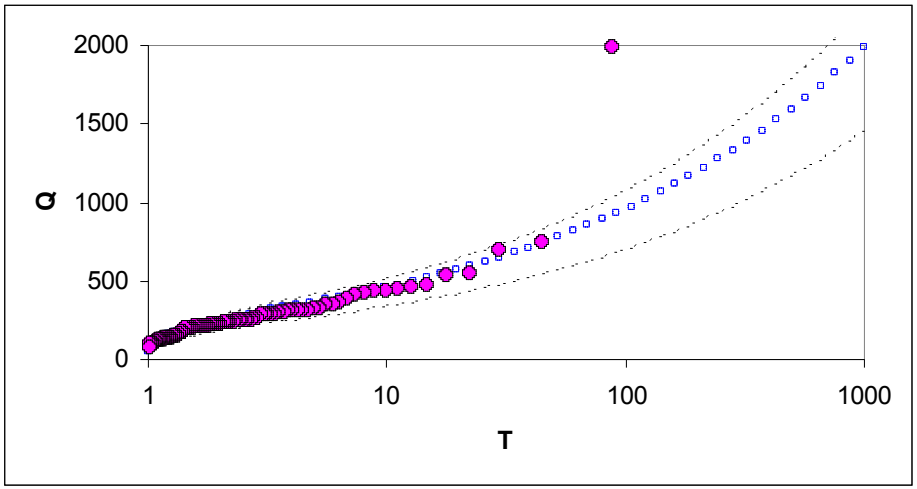
e.g., P.O.T. =>

but how to adequately define the threshold?



- **Use of multifractals, with long range correlations, to estimate quantiles**

~16000 gauges in US and Canada



1996 Saguenay flood of 2000 m³/s has return period of:

- T = 1000 years for UM analysis (comparable with Fréchet law);
- T ~ billions of yeas with Gumbel law.

Tchiguirinskaia et al., 2012

Hydrologie pour une Ville Résiliente

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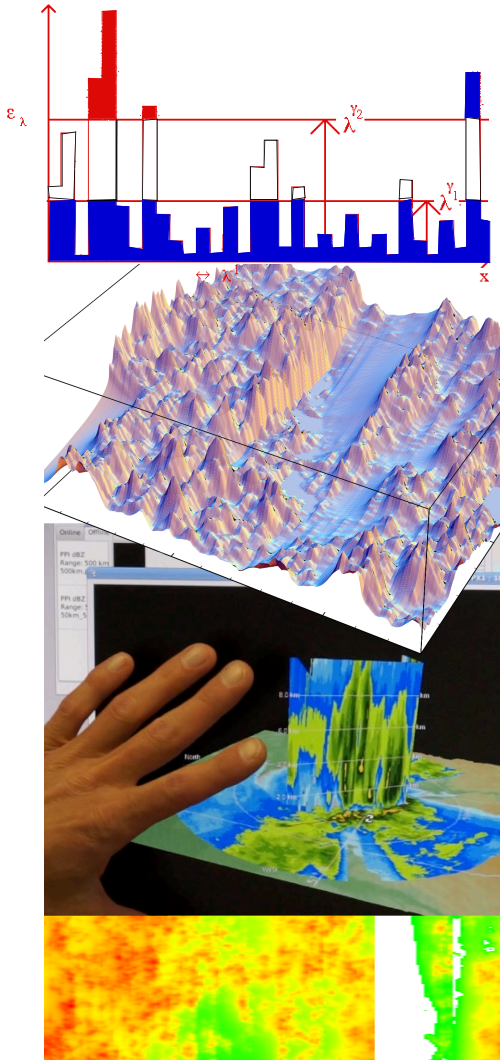
➢ Improving the approach

- **Space-time fields:** Basic hydrological quantities, water cycle elements, etc.
- **Stochastic models:** High resolution measurements =>
  - Space-time modeling, long range correlations, transfer functions, forecasting;
  - More reliable predictions of extremes, limits of predictability.
- **Scale:** Hydrological systems are strongly anisotropic => Need to use physical scale, i.e. defined by dynamics.
- **Multifractals:** Generic nonlinear scaling process, provides natural framework:
  - Scaling law is not unique;
  - Its exponent sensitively depends on the threshold;
  - Scaling laws of extremes are drastically distinct from average ones.



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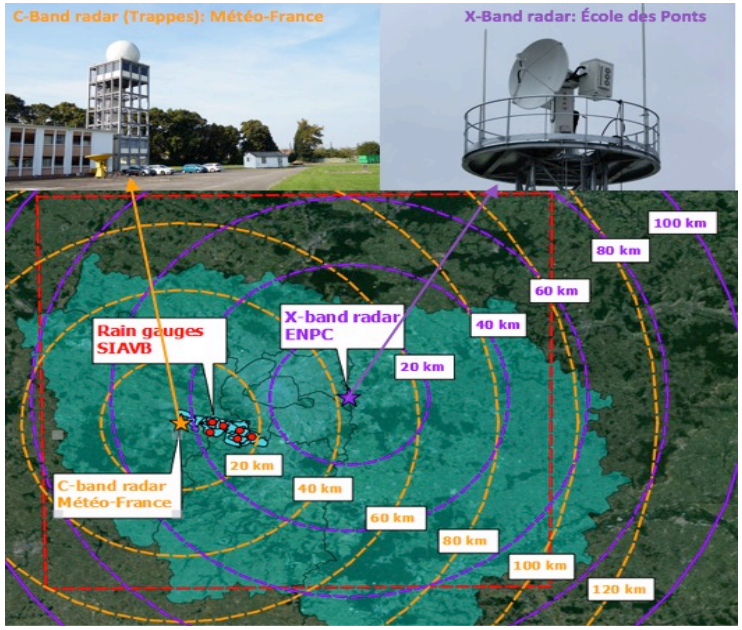
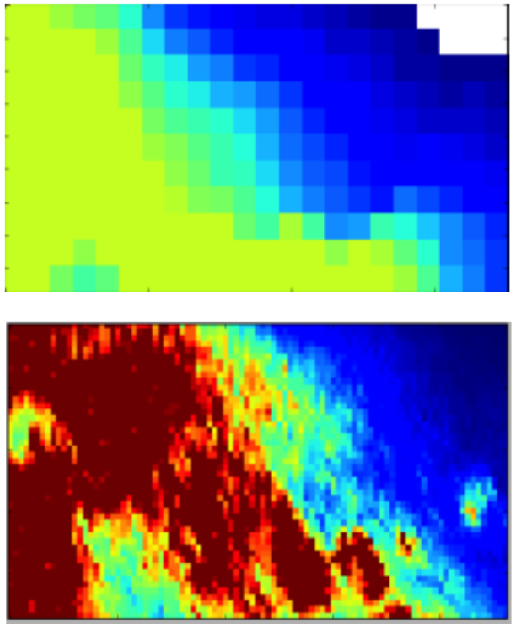
➢ Multiscale monitoring of urban interaction

- ✓**ENPC polarimetric X-band radar**: Structuring compenent of the Chair
- ✓**1st important research instrument in environnemental observation covering IdF** (in use since May 2015):
  - ▪Volumic scan ≠ SIRTA instrumentation
  - ▪Measuring range: 100 km; Radial resolution: 100 m; Sensitivity of -110 dBZ



C-band data

X-band data



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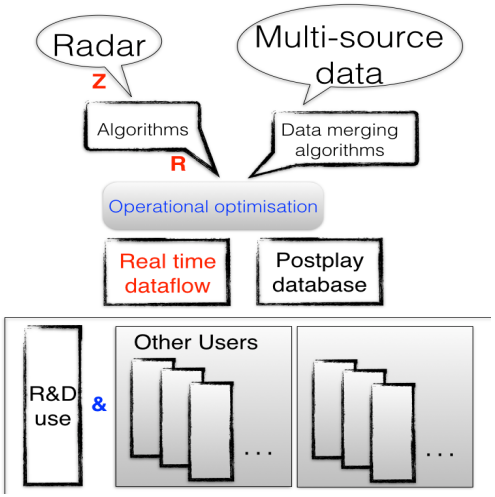
➢ Why X-band radar?

Provides a spatialised precipitation field = > Able to anticipate the rainy event

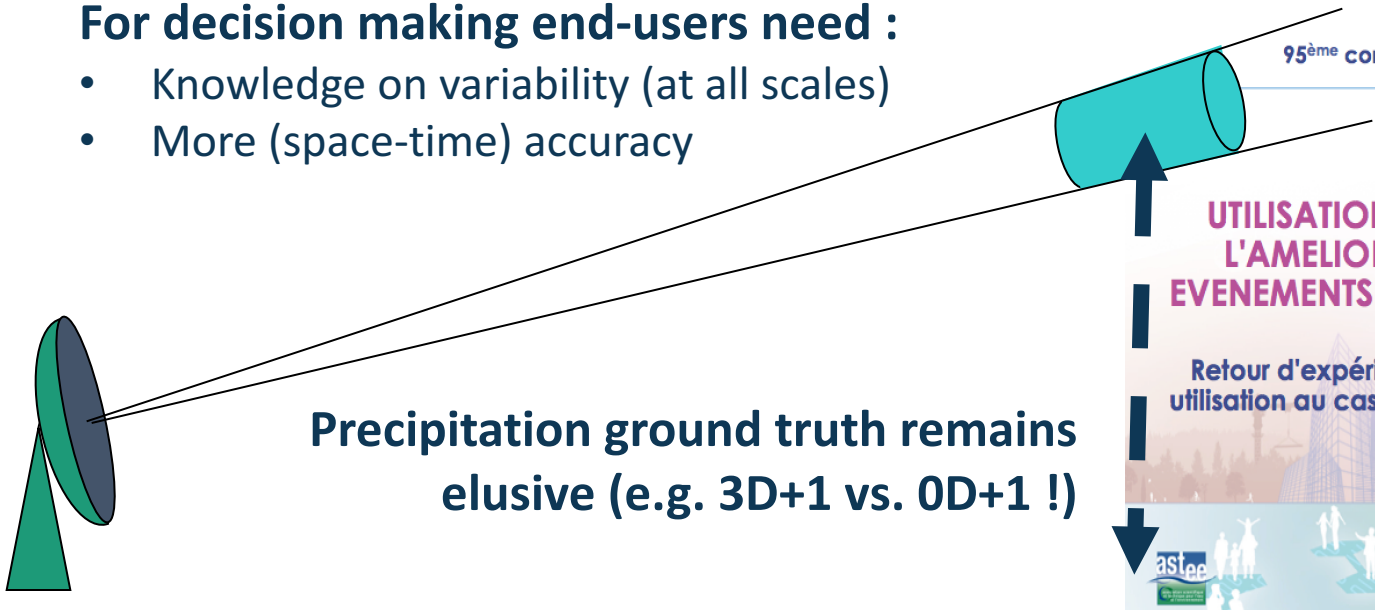
➢ Why polarimetric?

- Exploits the non-spherical nature of hydrometeores = > Hydrometeores classification
- Multiplicity of measured parameters = > Improved rainfall estimation



For decision making end-users need :

- Knowledge on variability (at all scales)
- More (space-time) accuracy



Precipitation ground truth remains elusive (e.g. 3D+1 vs. 0D+1 !)

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➢ 7 lessons of empirical evidence

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✓Downscaling… a gauged basin becomes ungauged => data merging impact

✓Smaller scales amplify numerous “uncertainties”

✓Scientific deadlocks not to be underestimated, a root to nowcasts:

- extreme variability over a wide range of scales => conventional statistics at odd with it !

✓Case studies and products cannot substitute to theoretical arguments

✓Hydrological “truth”/impacts also elusive: models/SaaS should be adapted to “new” scales

✓Still missing a convincing, multiscale, stochastic rainfall model

however, already many insights !

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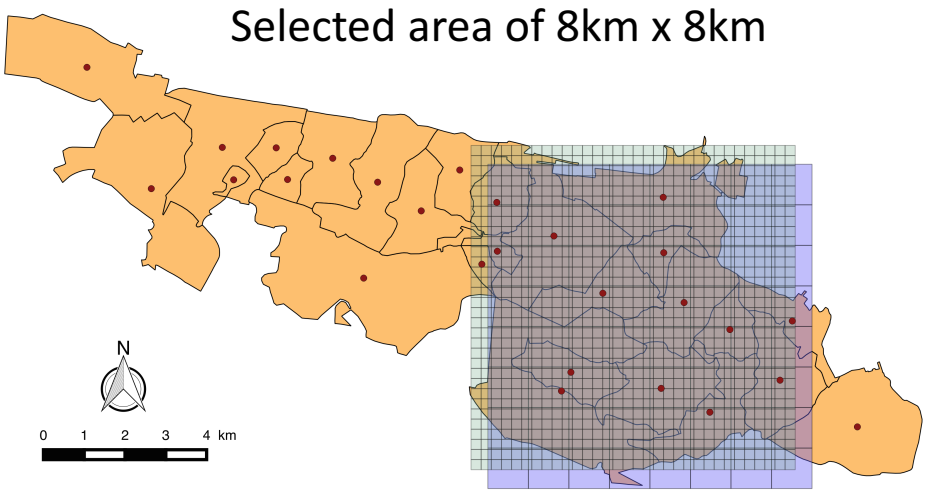
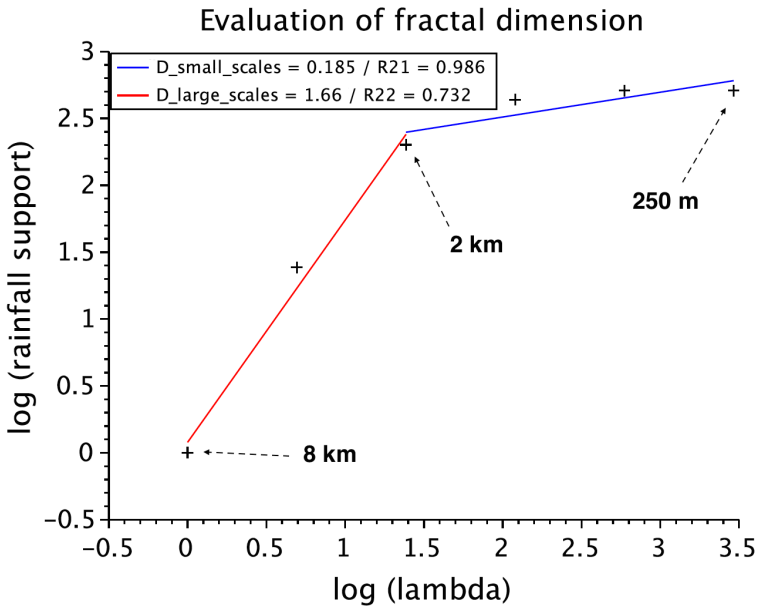
- Downscaling… At what scale a gauged basin becomes ungauged?





Virtual rain gauge network over the X-band grid (I. Paz, PhD 2018)

- Spatial scaling break at 2 km (comparable to the mean size of the sub-catchments)
- In order to obtain the same fractal dimension through all scales (as that of the large scales), the new network should contain approximately 315 rain gauges (instead of just 15, as in this case)

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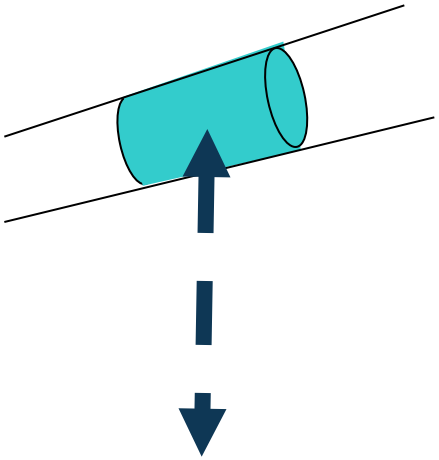
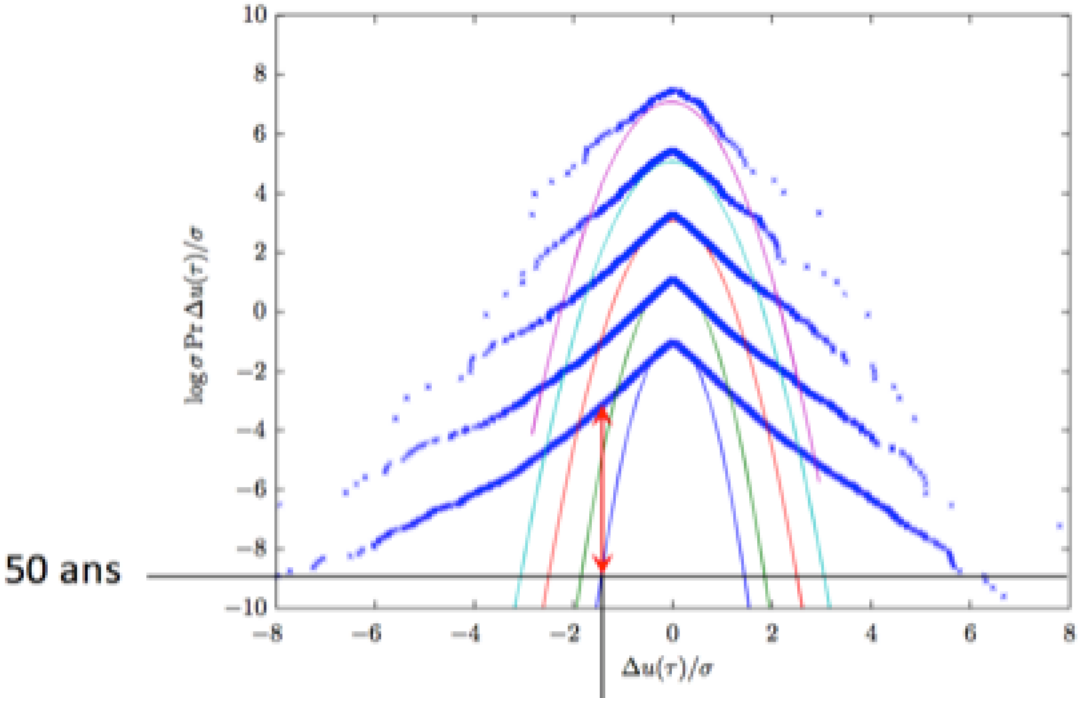


Strong horizontal drift, in fact, the tragectory is very complex and strongly anisotropic



Small scale fluctuations of wind => *Prob* of wind shears:

- **Every 5 hours there is an event of 50 years !** (G. Fitton, PhD 2013)
- Multifractal simulations of vector velocity fields
- Ensemble predictions

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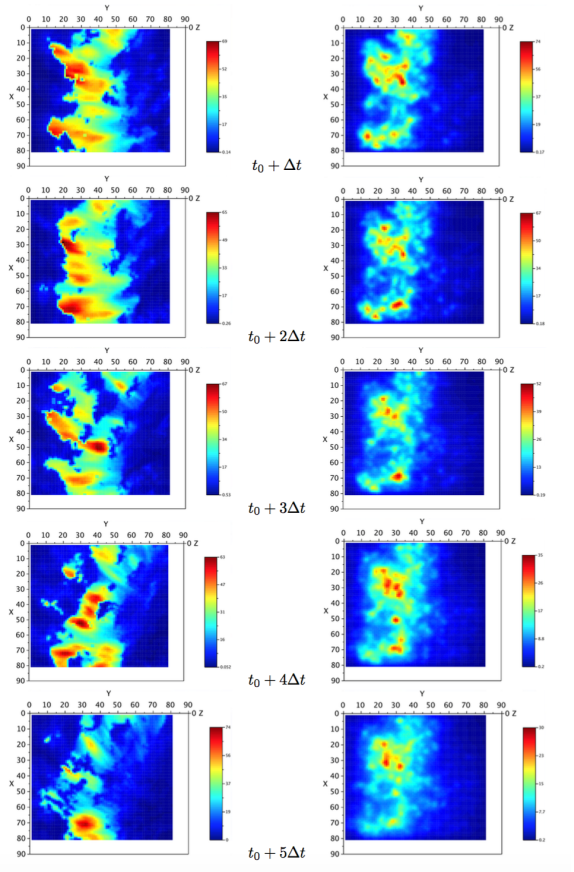
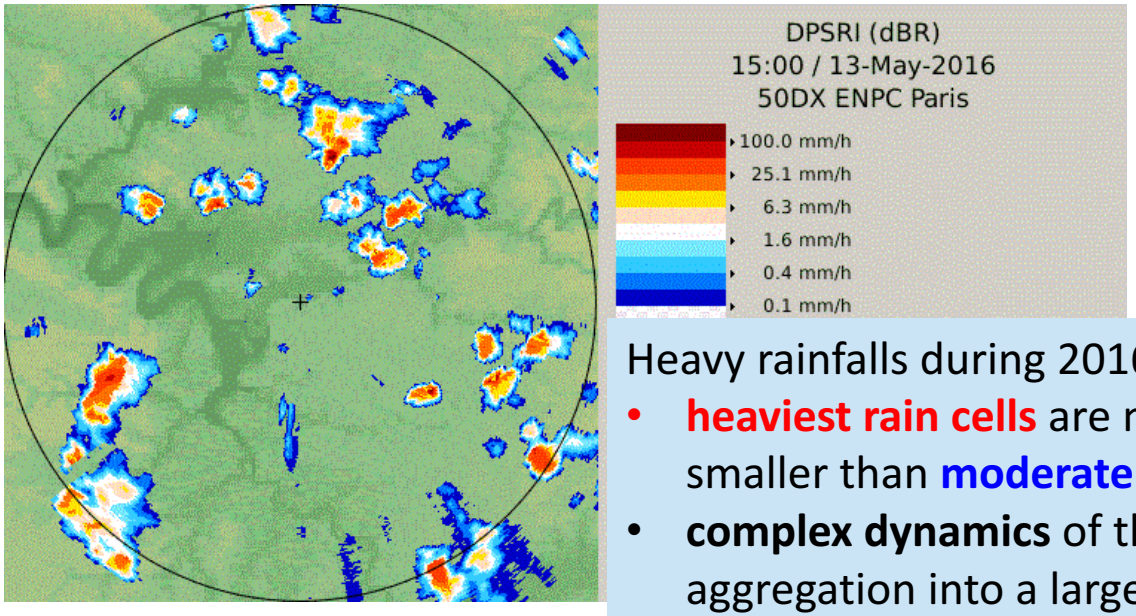
- Smaller scales amplify numerous “uncertainties”
- Nowcasts: *right statistics* of vector velocity fields

20 km x 20 km
250 m x 250 m x 3’25’’



I. Paz, PhD 2018



Heavy rainfalls during 2016:

- **heaviest rain cells** are much smaller than **moderate ones**
- **complex dynamics** of their aggregation into a large front

« …c'est vraiment très local et difficilement prévisible »

Marc Hay

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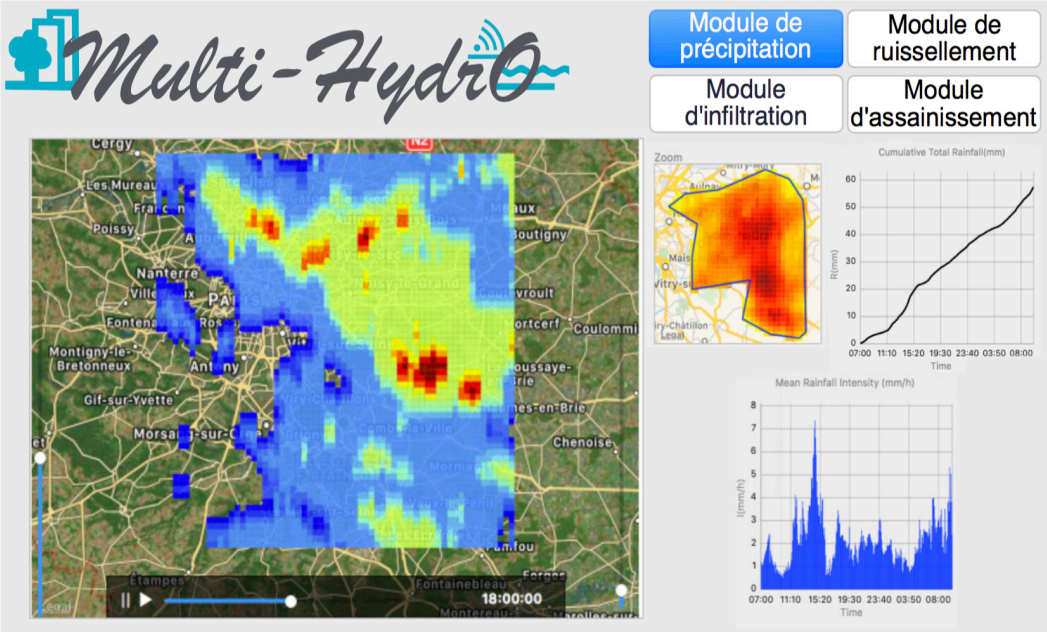

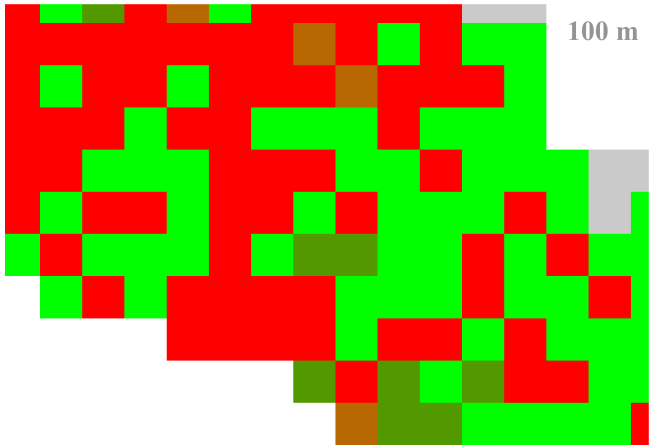

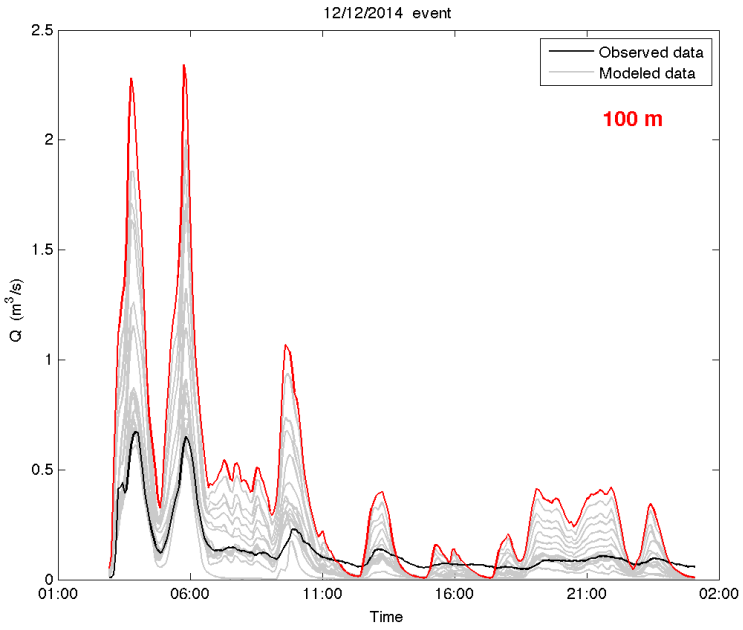

GIS oriented multi-scale modelling (A. Ichiba, PhD 2016):

- Analyse phenomena at the appropriate scale
- Imagining management solutions at the local level (neighbourhood, street,...)

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✓We cannot solve our problems with the same level of thinking that created them (A. Einstein)

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- Towards SaaS adapted to “new” scales