RAINFALL SIMULATION

A GEOSTATISTICAL APPROACH

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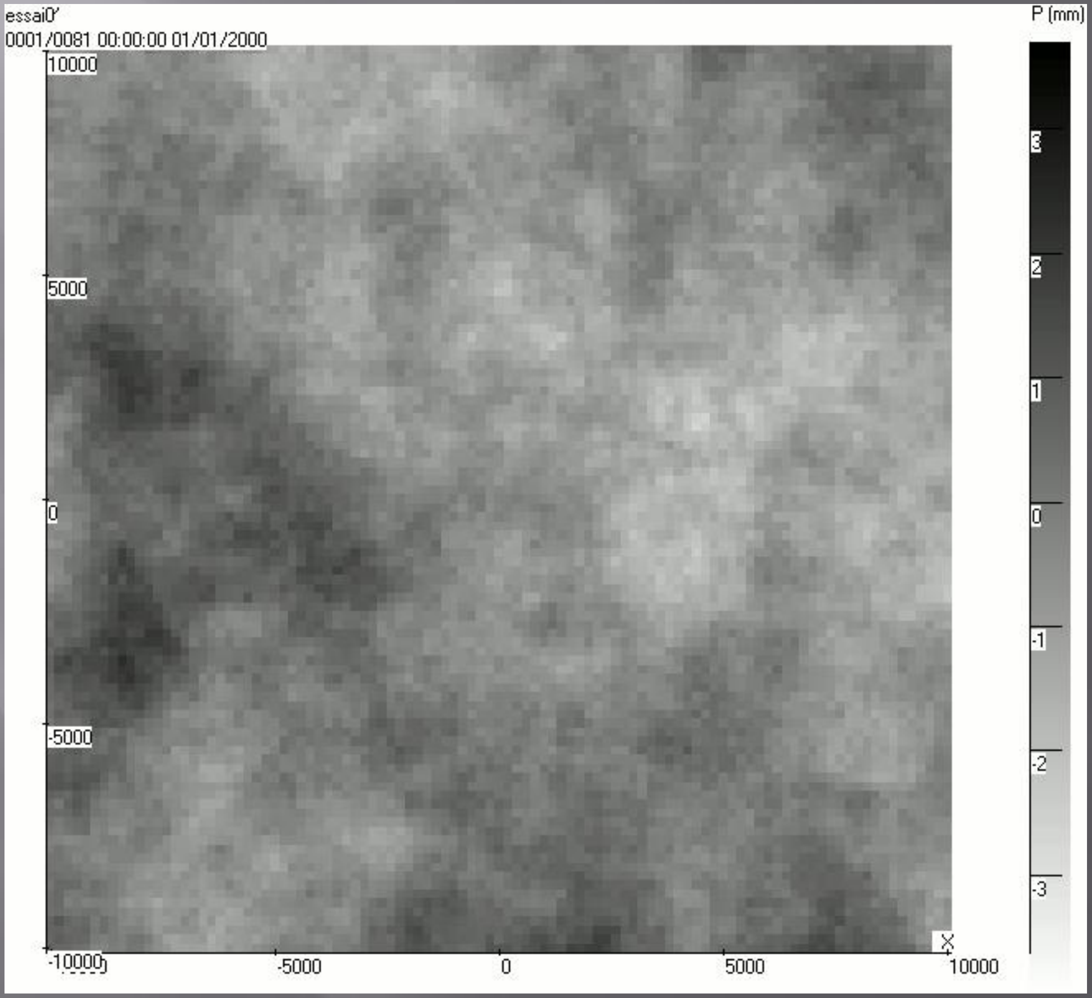
An hydrologist perspective

- Each river basin has an area and a characteristic duration. Along a river network a range of such areas and durations is met.
- A stochatic simulation of rainfall targeting hydrology should respect basin-rainfall distribution across a reasonable range of such supports.
- The above may be not feasible, but average and standard deviation would be a good start.

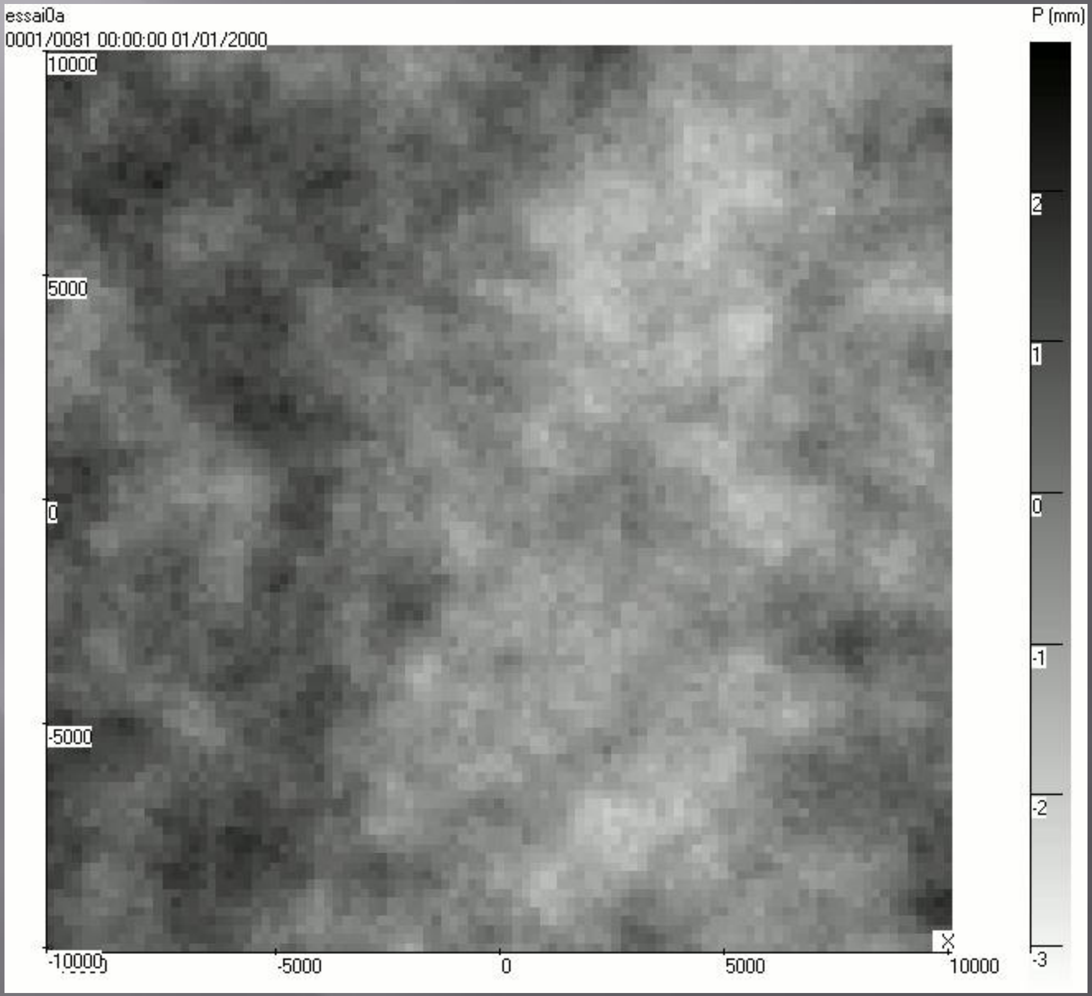
Conceptual model

- Over a study area, at any time, the rainfall field can be seen as the realization of a stationnary random process of order two (SRF-2).
- After some time, the rainfall characteristics will change ; we decide to consider the local climate as a set of rainfall types alternating in time.
- A rainfall type will be defined by its point distribution and its spatio-temporal structure. The simulation should respect them.
- This talk is about simulation of one such homogeneous rainfall type.

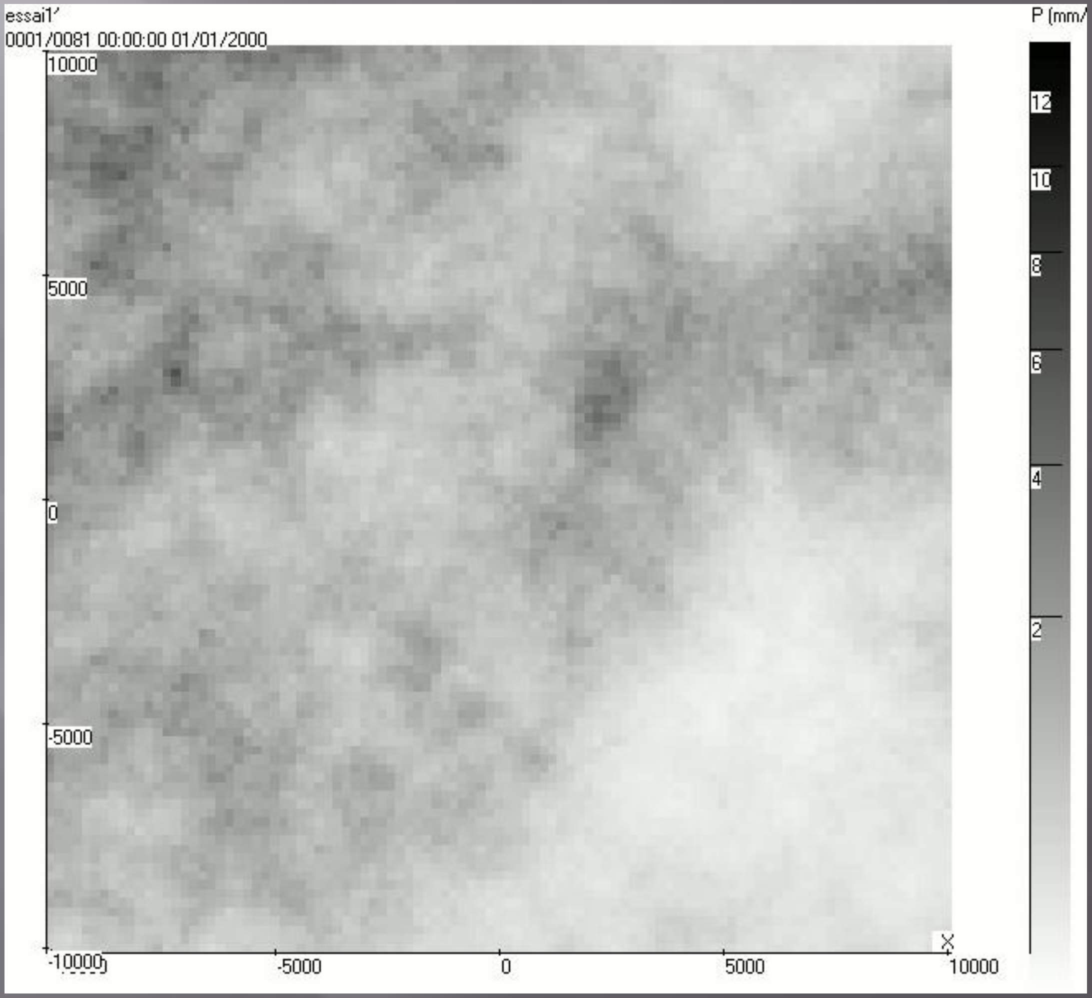
Here is a 3D Gaussian field



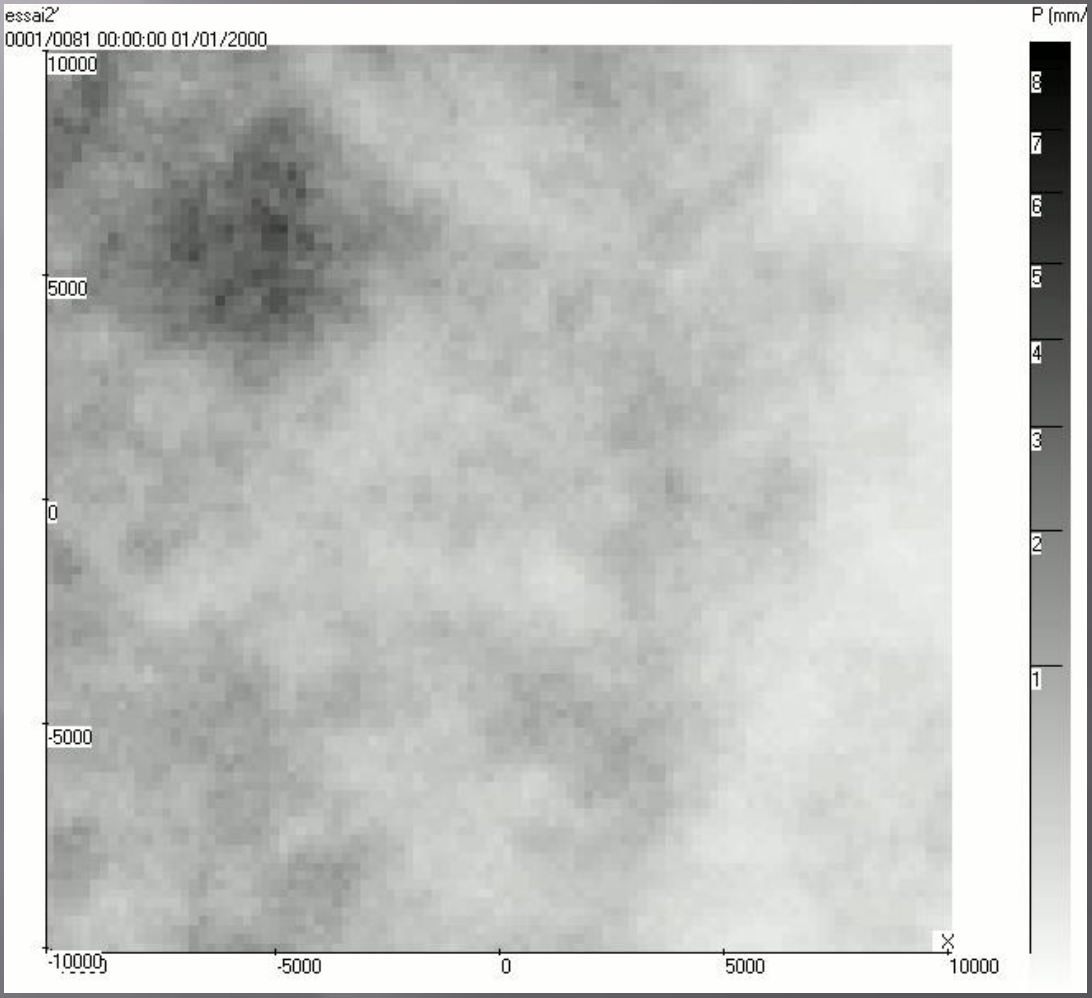
Considering X,Y,Z as X,Y,T with U_T=L/D



Changing the point distribution to the one of « non-zero rainfall »



Adding an uniform advection here $u^*=U_{adv}/U_T < 1$



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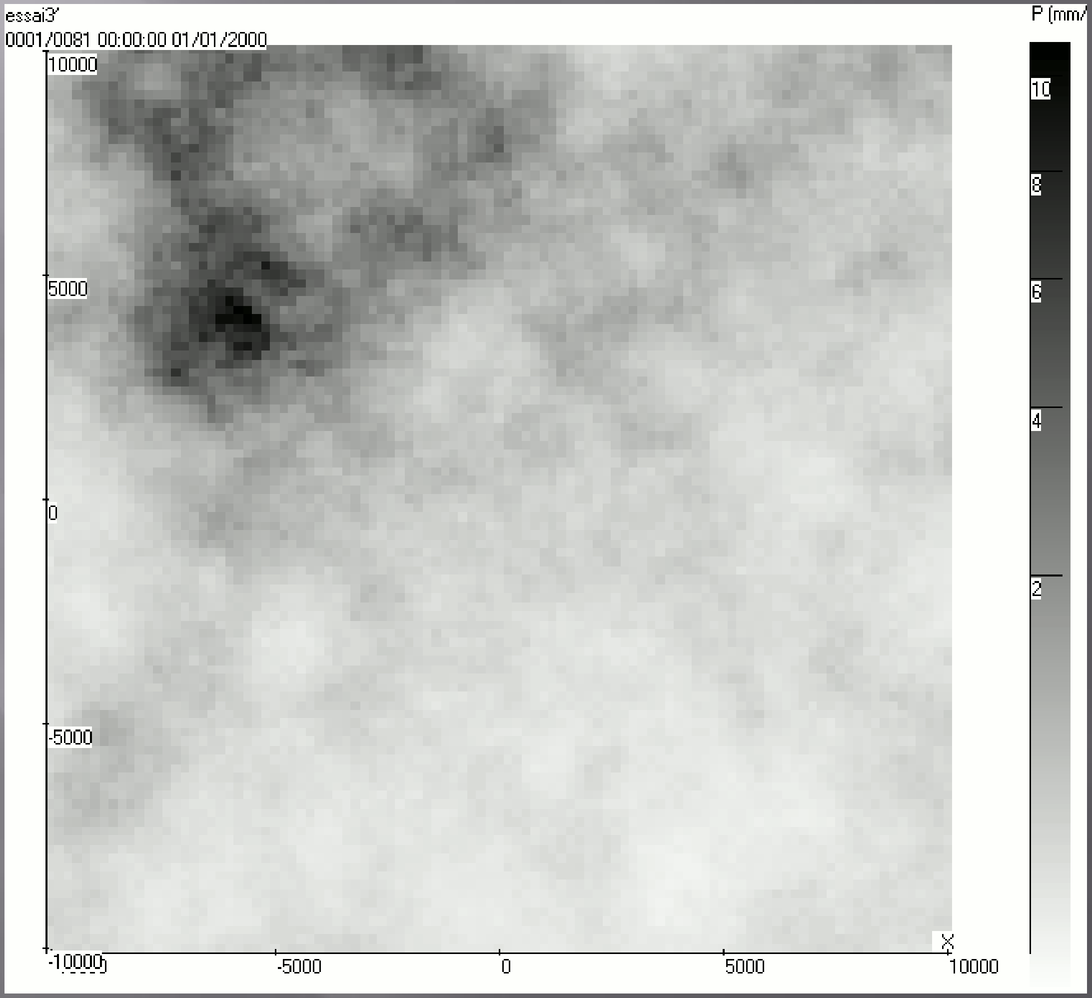
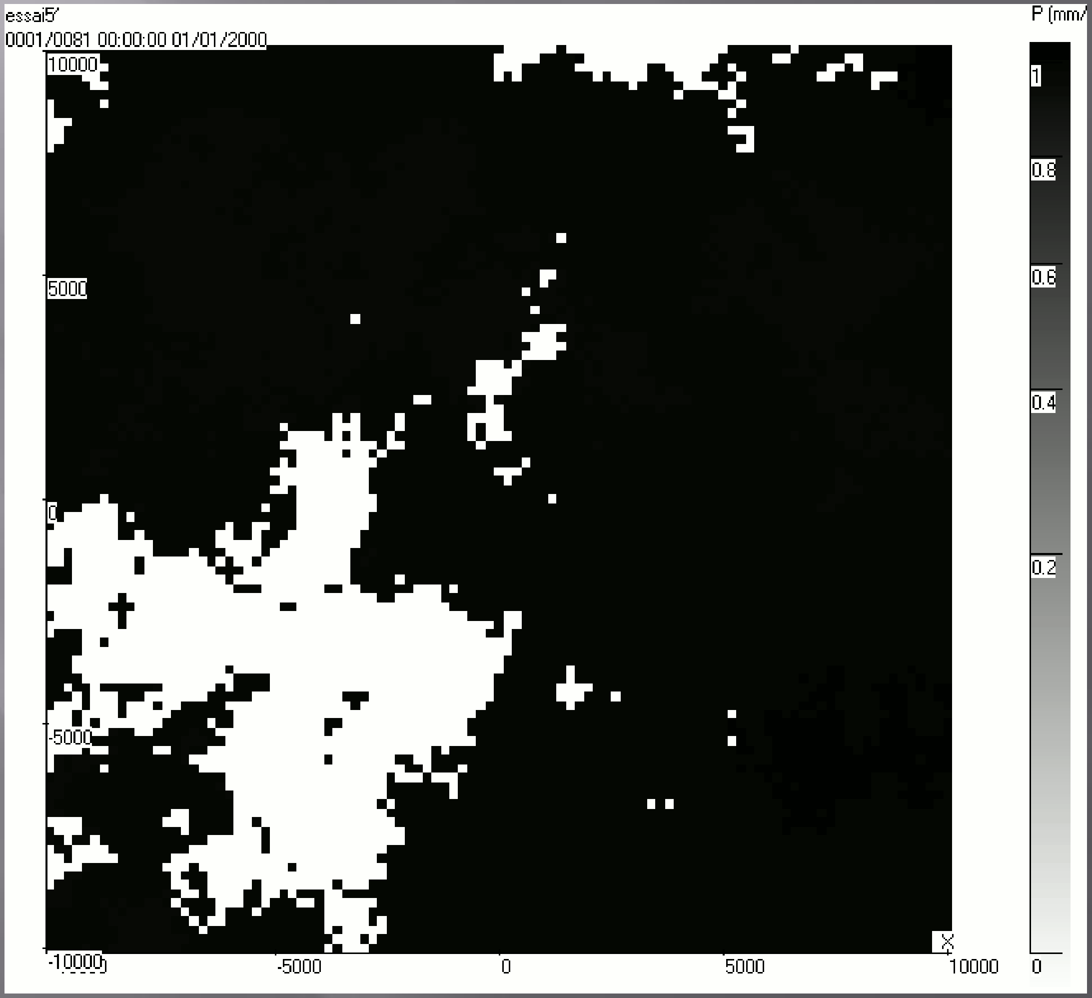
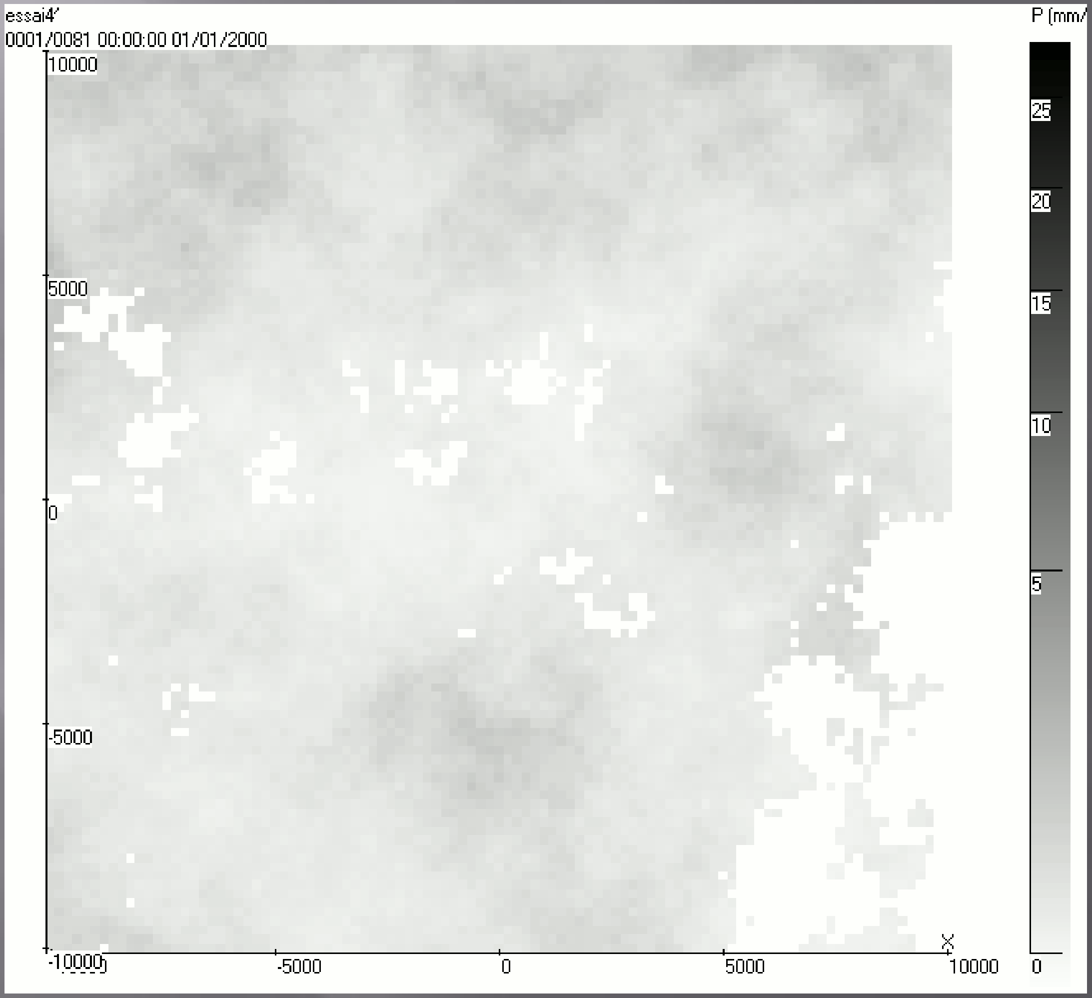


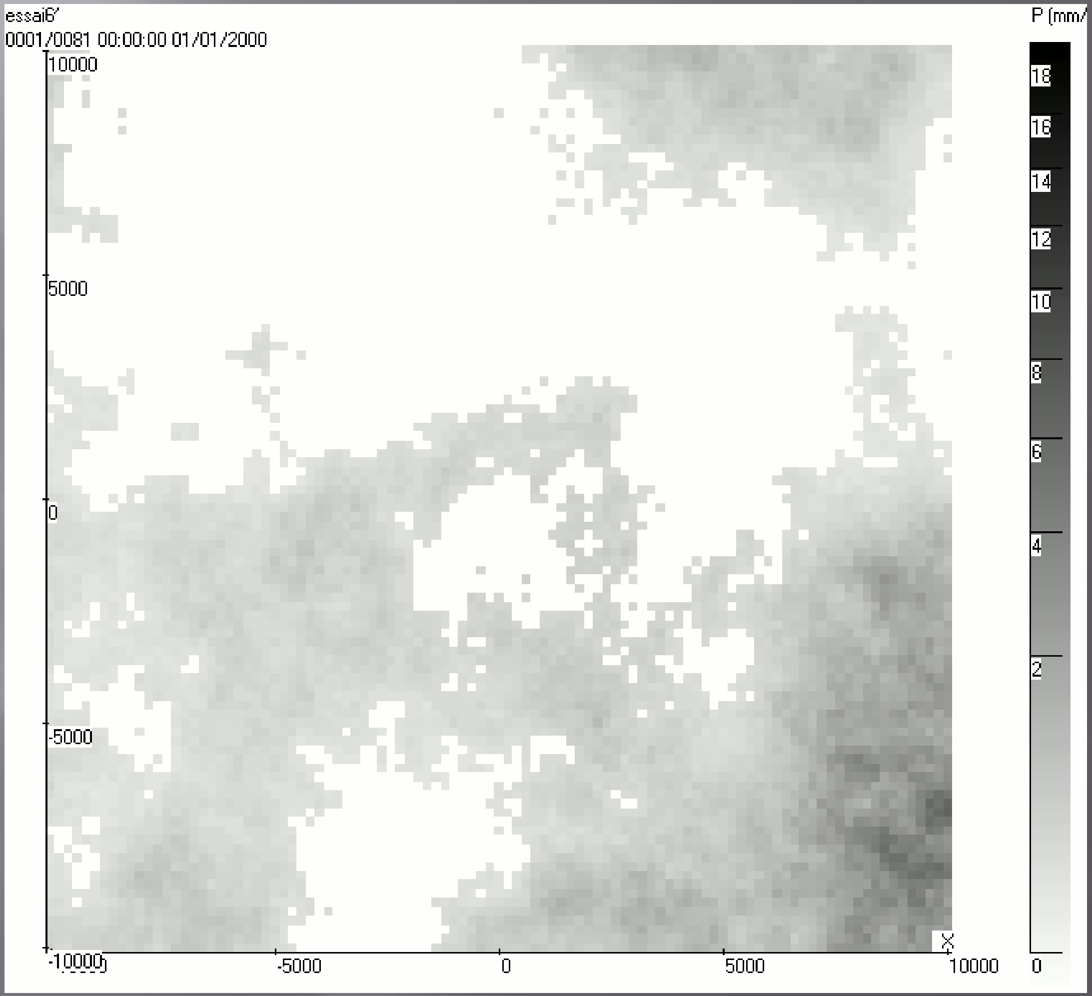
Intermittency (a tresholded Gaussian)



Composite [independent case]



Composite [with correlation]



Advection effect on structure

Lagrangian time-covariance $CL(t/D)$ for an observer following the flux
Eulerian time-covariance $CE(t/D)$ for a ground observer
Spatial covariance $C(h/L)$ for both

Main relations (along the advection line)

$CL(t/D) = C(h/L)$ for $U_T = L/D$ (Taylor velocity)
$CE(t/D) = CL(f\, t/D)$ where $u^* = U_{adv}/U_T$ and $f = \sqrt{1 + u^{*2}}$

Especially $CE(t/D) \leq CL(t/D)$

« Frozen field hypothesis » is a when u*>>1

Then the Eulerian observer only experiences changes due to advection

$$CE(t/D) = C(t.U_{adv}/D)$$

Variography of composite field

Variograms

- of intermittency γ_{ind}
- of « non-zero » rainfall γ_{nzr}
- of transition across rainy area γ_{tra}

(pairs with either P(x)>0 or P(x+h)>0, not both)

The composite field variogram is

$$\gamma_{tot} = 2\,\gamma_{ind}\,\gamma_{tra} + (E_{ind} - \gamma_{ind})\,\gamma_{nzr}$$

Homogeneous rainfall accumulation

- The change of variogram due to aggregation over support (area, duration) can be evaluated by numerical integration – no simulation needed (keyword “variogram for blocks”).
- Accumulated rainfall statistics may be evaluated but some are tricky
  - wet fractions grows to 1
  - variability fades away ; this may not hold for NZR until wet fraction is about 1
  - even if present at point scale, independence between NZR and IND vanishes in aggregation ; in accumulated fields values tehrefore tend to be higher in the middle of rainy areas, and lower at their limit.
- This holds for space and time.
- However, homogeneity of rainfall is more a working concept than a reality.

Ongoing research

Handling heterogeneity in time

- Clusterization of rainfall into homogeneous groups ; sequencing rainfall types in time (HMM)
- The distribution of areal rainfall turns out to follow a mixture model; the contribution of mixture components to the heavy rainfall is a function of the area.

Handling heterogeneity in space

- The Hosking-Wallis approach can be used to reduce *moderate* spatial shifts (merging local distributions into a joint one with local deviations).

Conditionnal simulations possible, usefull for

- Uncertainty for events recorded at raingauges
- Possibly radar precip. estimates tracking and nowcasting

Refs

[analysis of intermittent rainfall] Lepioufle, 2009, PhD dissertation (*in French)*

[using rainfall conditionnal simulations in hydrology] Renard et al., WRR 2011

[variography of network rainfall] Lepioufle et al., JH 2012

[variography of radar rainfall] Emmanuel et al., JH 2012

[general approach] Leblois, HDR, 2012, (*in French)*

[simulation of advected intermittent rainfall] Leblois and Creutin, WRR 2013

[on frozen hypothesis] Leblois et al., submitted JHM

[classification and sequencing of rain] Leblois et al., in prep.