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## Rainfall at Urban Hydrological Scales : Opportunist use of TV-SAT Receivers Network

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## Feasibility Study



A measurement system (Figure 1) allows estimating integrated rain attenuations along satellite-ground links (depending on the freezing level and on the relative position of the satellite from the receiver) with a high temporal resolution (15s) see [Barthes and Mallet (2013)]. A 4D-VAR assimilation algorithm (Figure 2) using an advection numerical scheme has been applied on 4 rain attenuation times series recorded by a single Ku band TV-SAT receiver during HyMeX experiment. The obtained rainfall fields [Mercier et al. (2015)] at resolution 10s and 0.5x0.5 km<sup>2</sup> have been validated against co-located radar maps and rain gauges data.



Rain attenuation times series that could be observed along satellite-ground links by a virtual Ku band TV-SAT receivers network located in Guyancourt urban area are simulated. Different Ku receivers network configurations are simulated. The 4D-VAR assimilation algorithm is applied to retrieve corresponding rain fields. Rain fields obtained with the assimilation algorithm applied to a network configuration with 21 and 73 links respectively are compared with original rain field.

### Opportunist measurement

The aim of this work is to rebuild rainfall fields at small scale (around 30 \* 30km<sup>2</sup> with 0,5 \* 0,5km<sup>2</sup> grid boxes) from measures of attenuation of electromagnetic waves. These waves come from geostationary TV satellites and are in the Ku band (around 12GHz).

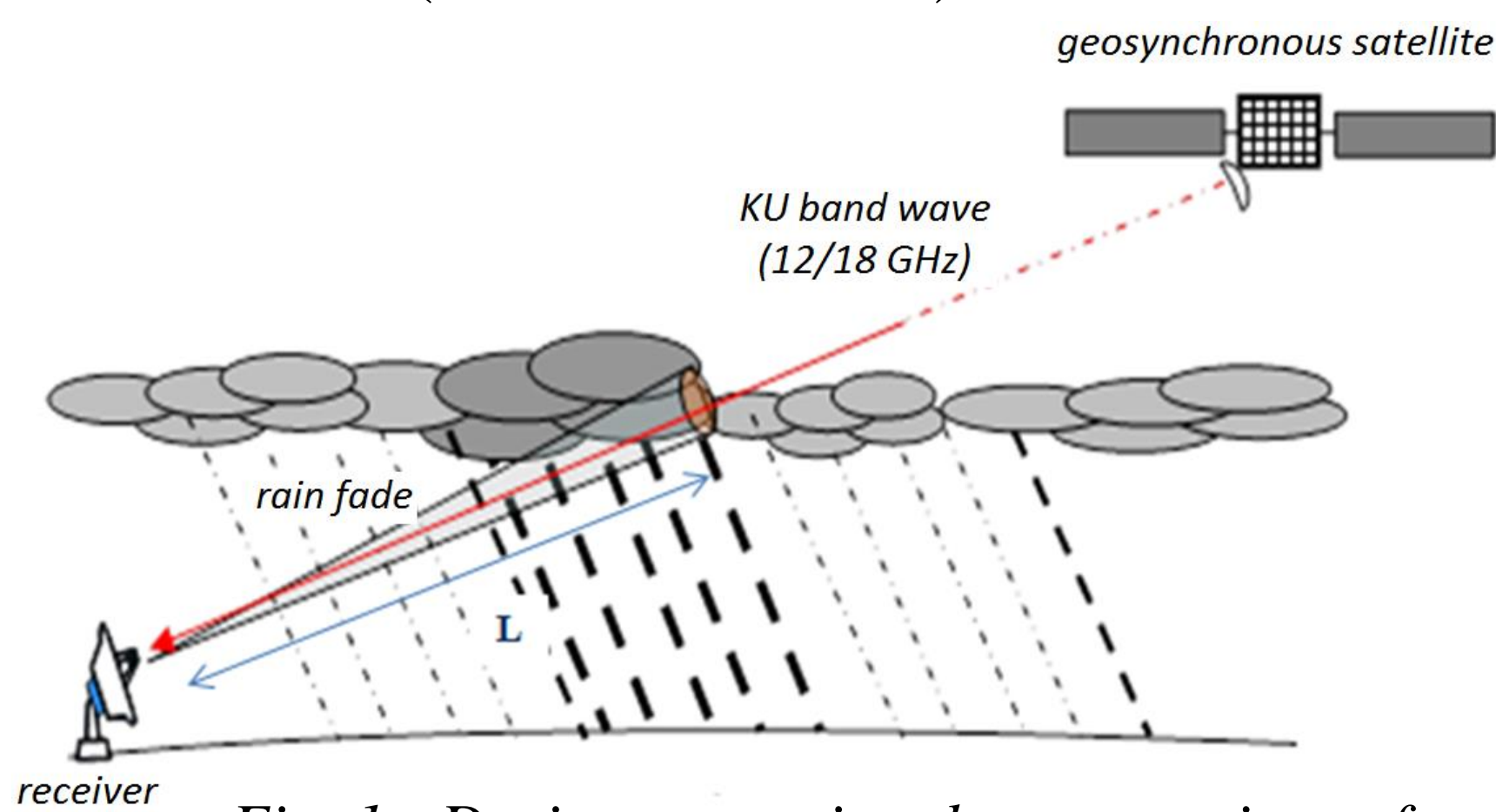


Fig. 1 : Device measuring the attenuations of the microwaves of the KU band

### 4D VAR Assimilation algorithm using YAO software ( LOCFAN )

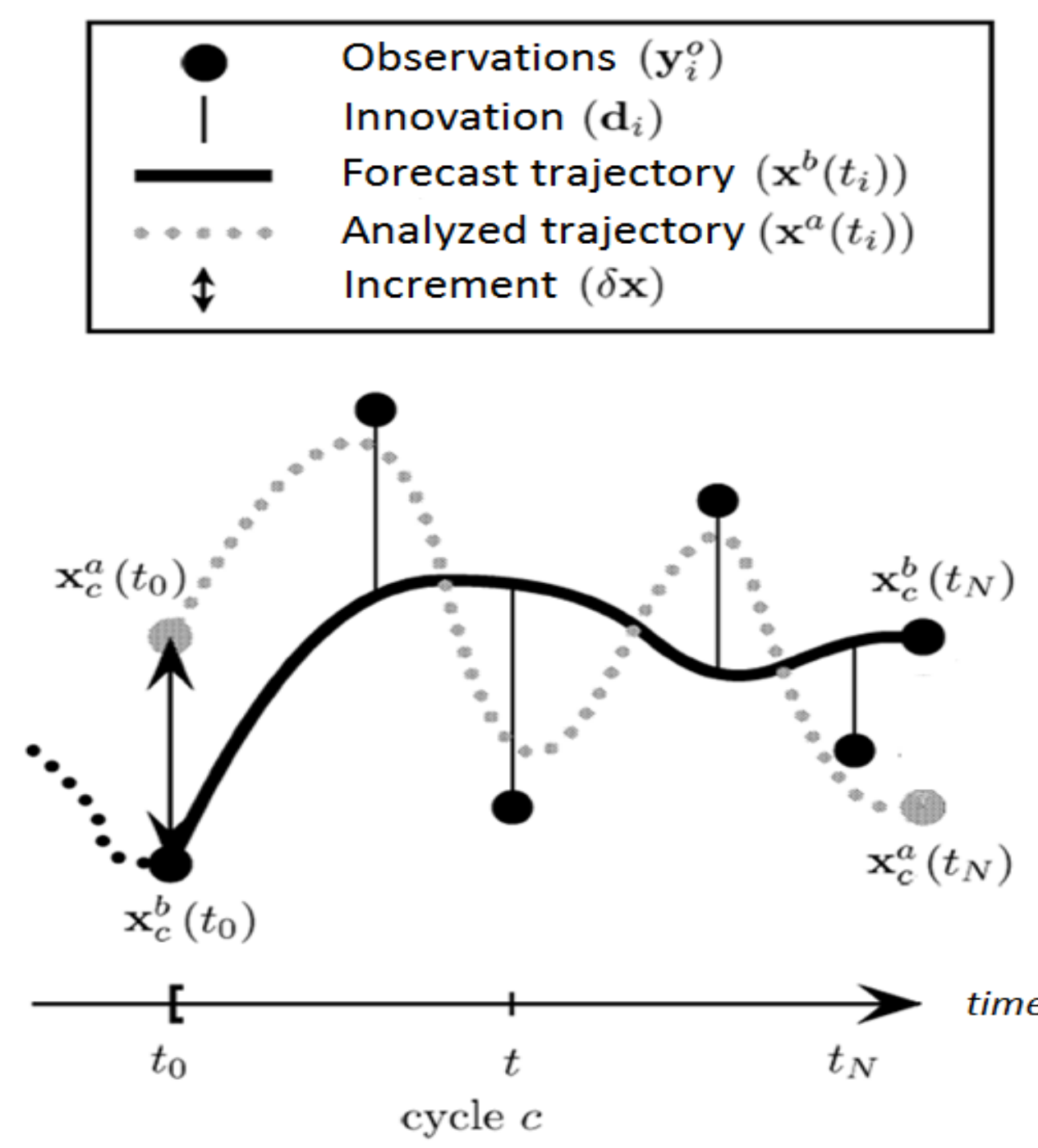


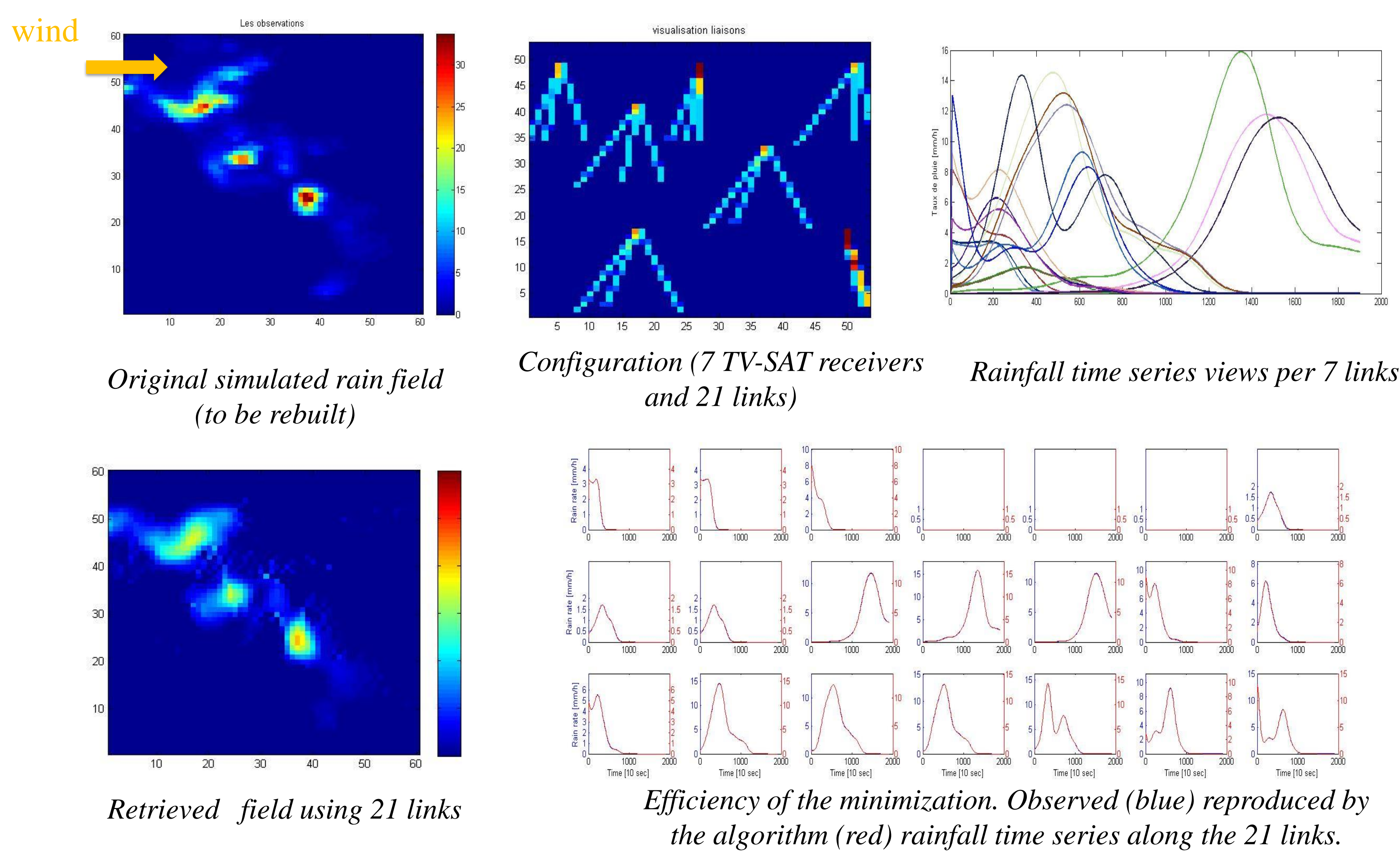
Fig. 2 : Principle of the 4D-VAR data assimilation

Cost function of the assimilation algorithm :

$$J(R^0) = \underbrace{\sum_{n=1}^N \|y_n - HR^n\|^2}_{\text{Gap with the observations}} + \underbrace{\alpha \sum_{n=1}^N \left( \sum_{i,j} \|R_{ij}^n - \bar{R}_{ij}^n\|^2 \right)}_{\text{Filter term}}$$

- $R^0$  is the initial rainfall field discretized on a spatio-temporal grid.  $R^n$  is this initial field propagated by an advection numerical scheme from  $t_0 = 0$  to  $t_n = n\Delta t$
- $y_n$  contains the observations available at time  $n$  (rain gauges and KU-waves).
- $H_n$  is the operator projecting the field  $R^n$  on the observations space at time  $n$
- $R_{ij}^n$  is the mean rainfall around grid point  $(i, j)$
- $\alpha$  is a coefficient to balance the weight of the 2 terms

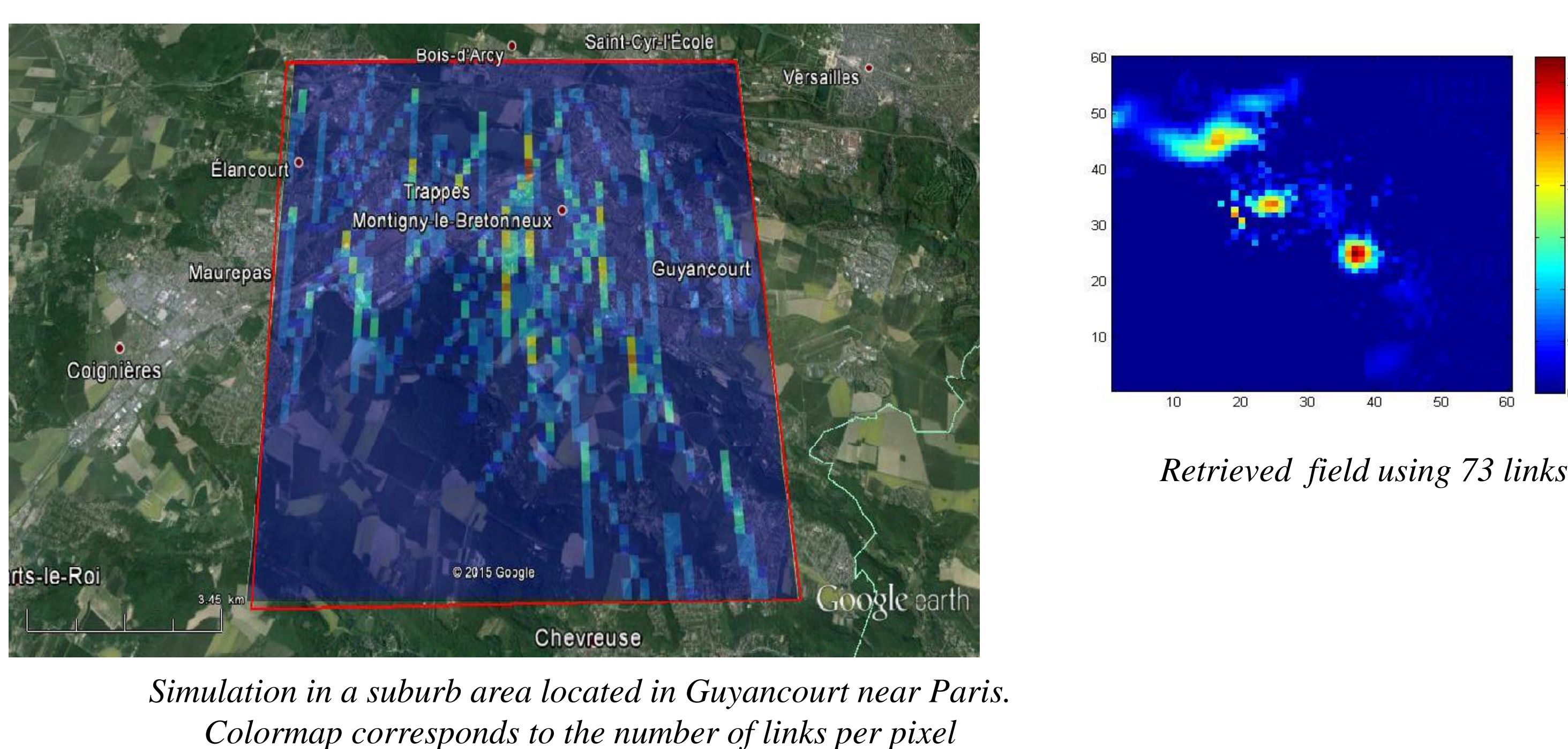
### Results and analysis : configurations 21 links



### Conclusion & perspectives

- TV-SAT measurements networks can be used in assimilation algorithm to retrieve rainfall fields.
- A large number of links allows estimating original rain field including rain cell structure with a very accurate estimation
- fine scale resolution retrieval (10 s and 500 x 500 m)
- urban area all over the world (conditioned by the presence of TV SAT receivers)
- TV-SAT measurements can be easily merged with other observations type (raingauges) in the assimilation algorithm.

### configuration 73 links



### References :

Mercier, F., Barthes, L., Mallet, C. : Estimation of fine-scale rainfall fields using broadcast TV-SAT links and 4D-VAR assimilation method, Journal of Atmospheric and Oceanic Technology, 2015, accepted.

Barthes L., Mallet C., Rainfall measurement from opportunistic use of Earth-space link in Ku band. Atmospheric Measurement Techniques, 2013, 6 (8), pp.2181-2193.

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