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

Nawal Akrou, François Mercier, Cécile Mallet, Laurent Barthès

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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 km² 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 * 30km² with 0,5 * 0,5km² grid boxes) from measures of attenuation of electromagnetic waves. These waves come from geostationary TV satellites and are in the Ku band (around 12GHz).

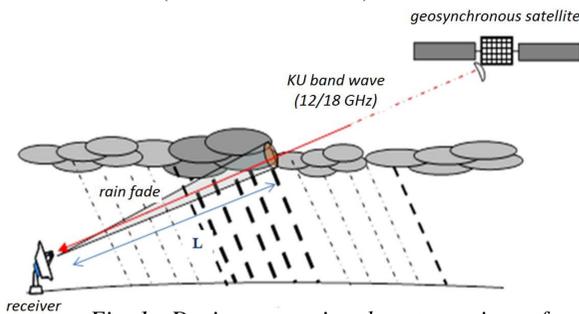


Fig. 1 : Device measuring the attenuations of the microwaves of the KU band

4D VAR Assimilation algorithm using YAO software (LOCFAN)

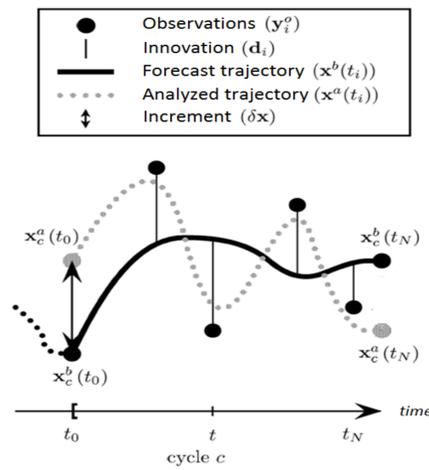


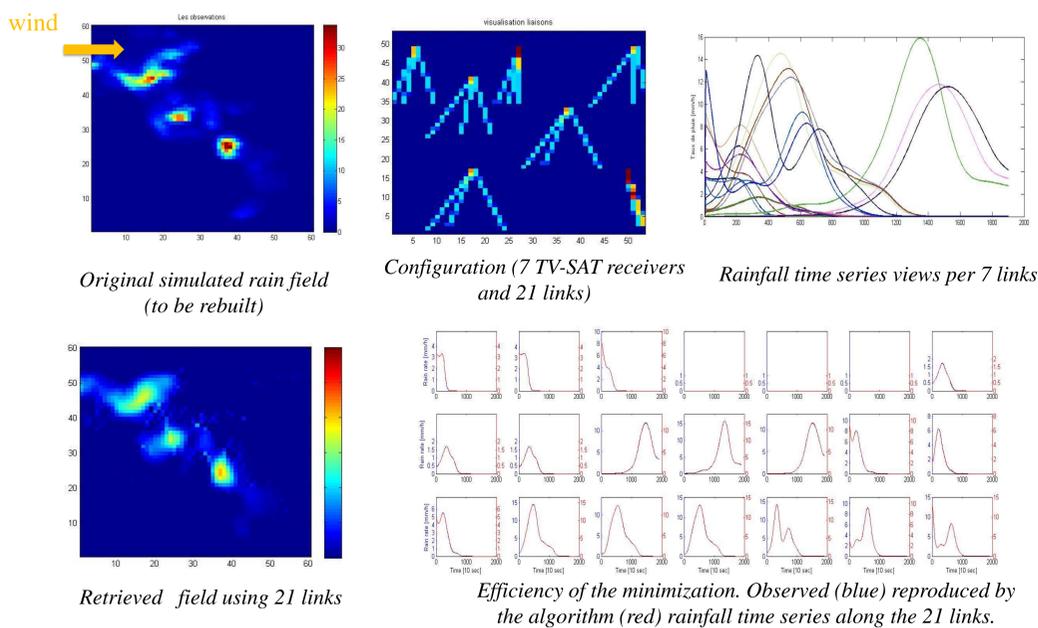
Fig. 2 : Principle of the 4D-VAR data assimilation

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)
- α is a coefficient to balance the weight of the 2 terms

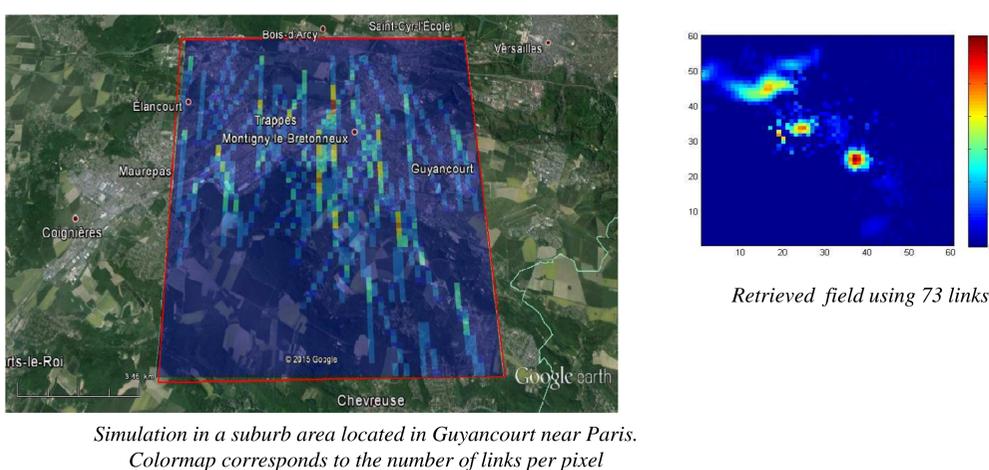
Results and analysis : configurations 21 links



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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