Rainfall retrieval in urban areas using commercial microwave links from mobile networks: A modelling feasibility study.

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1. Introduction

Accurate rainfall measurement is an important issue in hydrometeorological applications such as flood warning and water resource management systems. Even though networks of rain gauges and weather radar systems are used to measure rainfall, many cities worldwide are not well equipped with these devices. However, cities are equipped with mobile telecommunication networks. As mobile networks are concentrated in urban areas they can bring a self-sufficient approach for rainfall mapping in a given area[1,2,3].

The **main objective** of this study is to exploit whether cellular networks could be used to retrieve rainfall fields in cities.

2. Study area and Data sets

a. Study area

- Location: The central part of Nantes city, France;
- Area: ~ 1368 km^2;
- 256 microwave antennas operate at 18, 23 and 38 GHz.

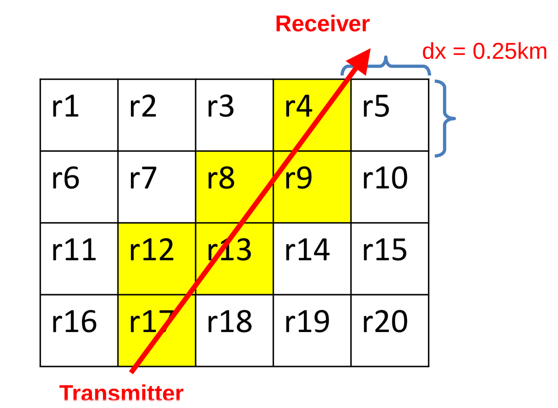
b. Weather radar maps

- Location: 10 km of north of Nantes;
- Spatial resolution: 0.25x0.25 km^2
- Temporal reosolution: 5 minutes interval;
- Area: ~ 100x100 km^2 ;
- 1000 radar rainfall fields representing four types: light rain, shower, poorly organized and organized storm.

3. Methodology

A simulation study consists of three stages:

Step 1: We simulate the measurement of total attenuation along each HF link using empirical relation (k-R).



Signal direction from Transmitter towards receiver in a dicretized map

Microwave link is discretized with a resolution of rainfall map (0.25km x 0.25km). Then, attenuation in each intersected part of the link is computed using an empirical relation between rainfall rate and attenuation

$$A = L * a * R^b + \varepsilon \qquad (1)$$

where, a and b – power law coefficients depend on frequencies, polarization, drop size distribution; R – Average rain rate [mm/hour]; ε – measurement error[4].

Step 2: Retrieval of rain map is performed by nonlinear statistical algorithm [5]

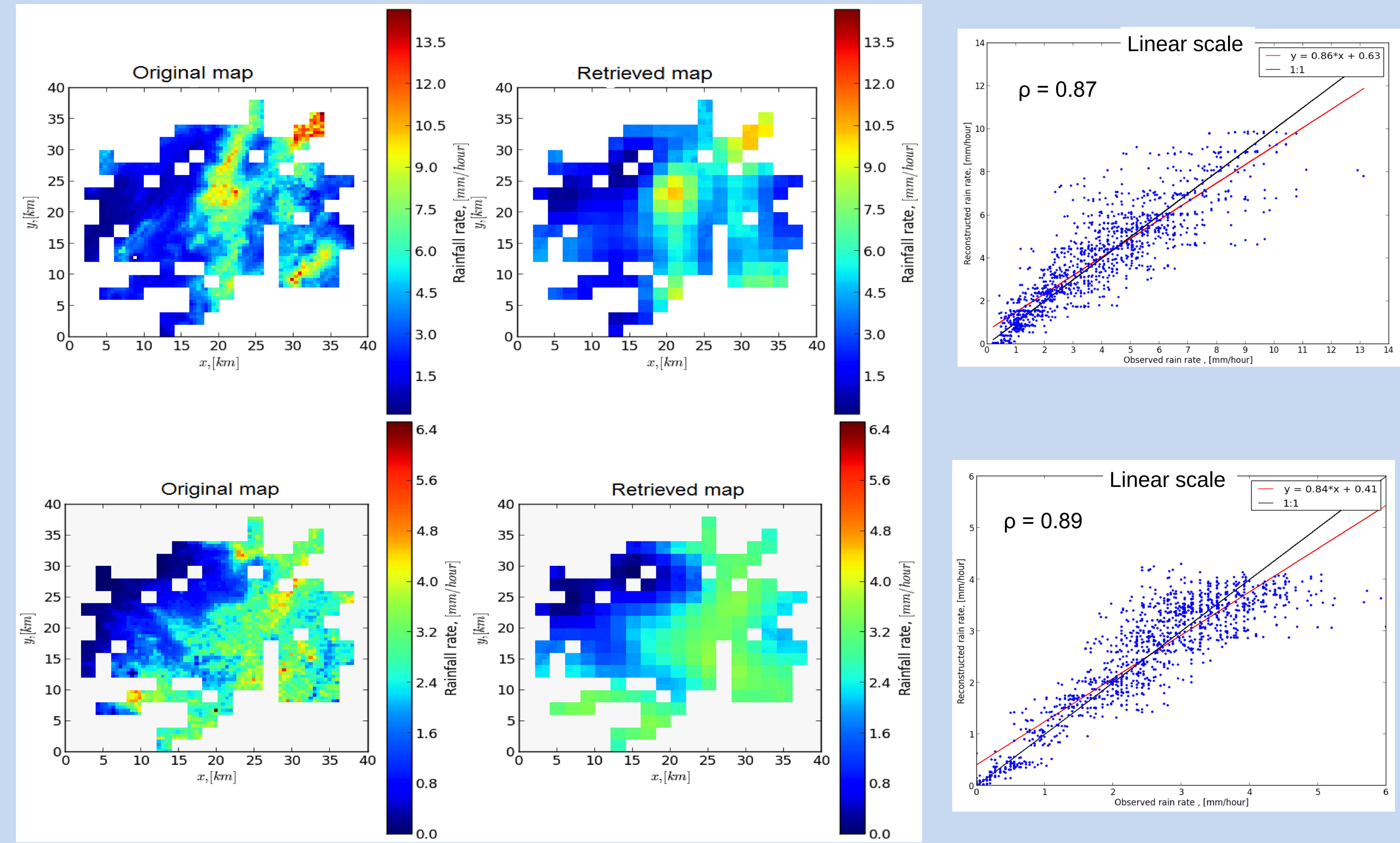
Step 3: Compare the retrieved map with true map

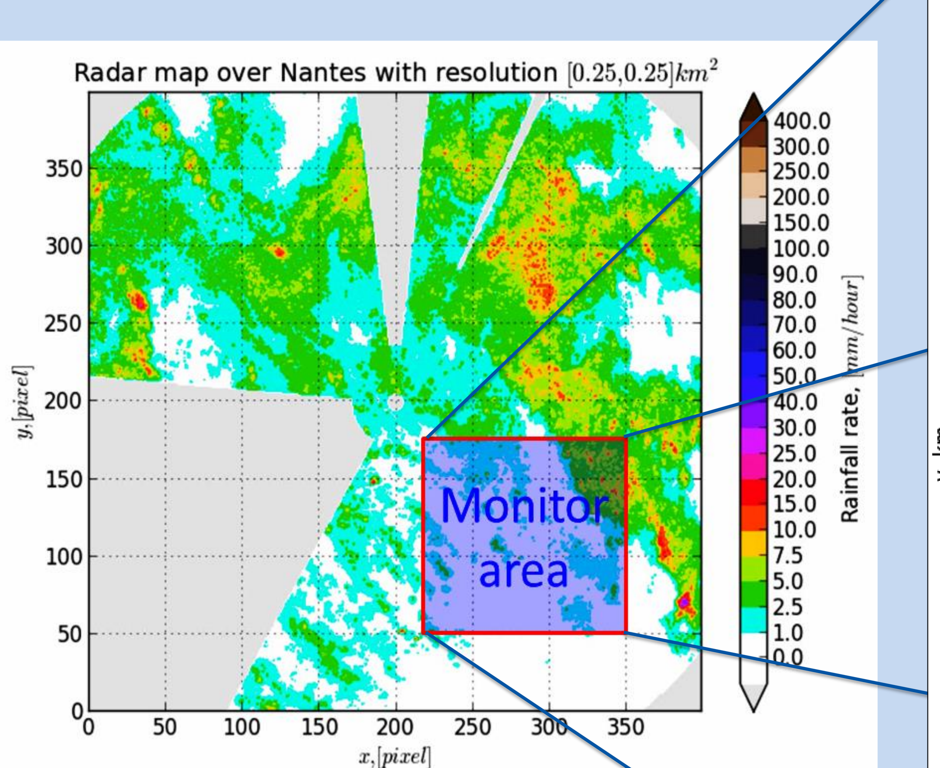
$$\hat{r}_{k+1} = r_0 + C_{r0r0} * G_k^T * \left(C_{d0d0} + G_k * C_{r0r0} * G_k^T\right)^{-1} * [d_0 - g(\hat{r}_k) + G_k * (\hat{r}_k - r_0)]$$

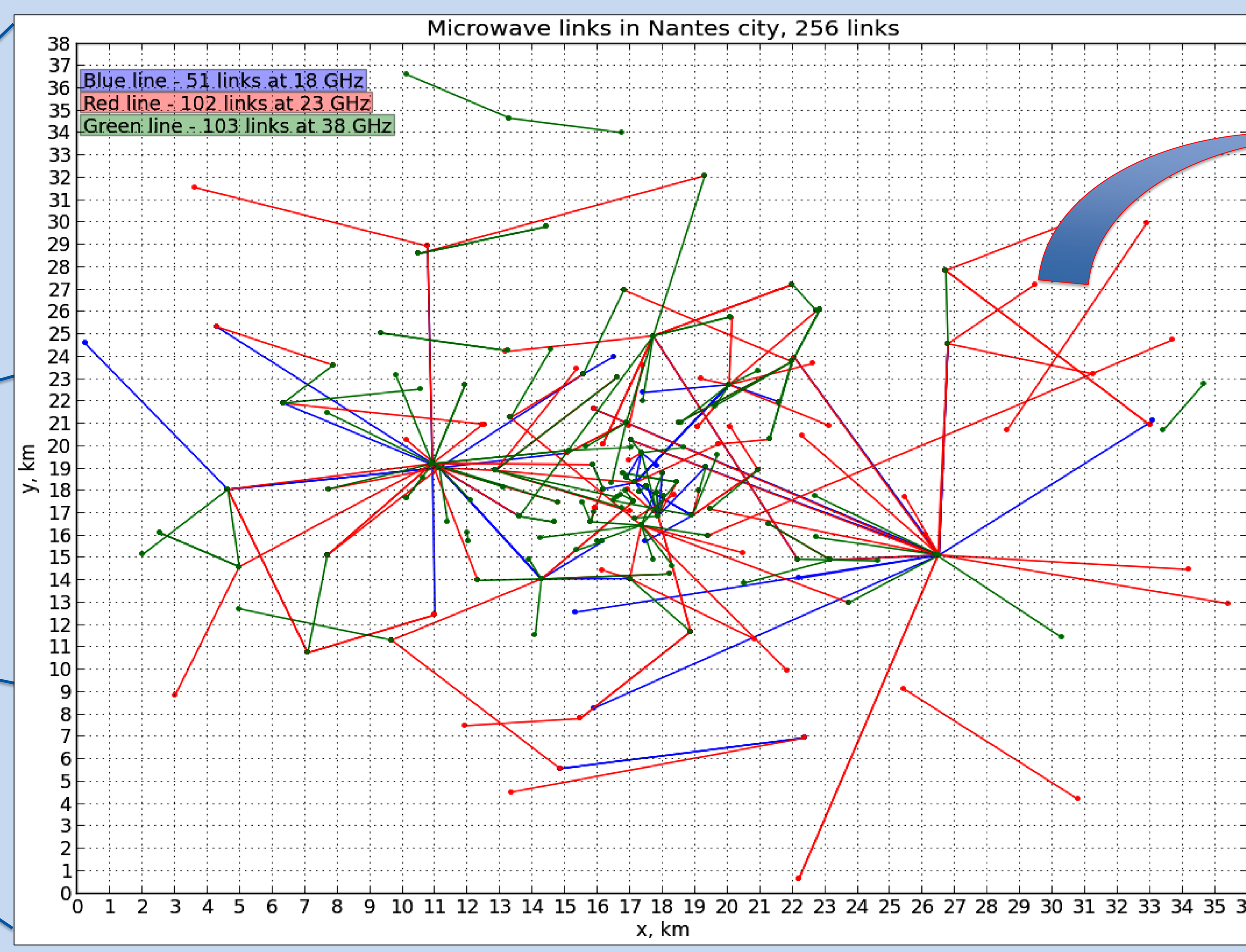
where,

$\hat{\boldsymbol{r}}_{\boldsymbol{k}}$- Solution vector; $\boldsymbol{r_0}$ – A priori rainfall vector ($\boldsymbol{r_n}$); $\boldsymbol{d_0}$ – Observed data vector ($\boldsymbol{d_m}$); $\boldsymbol{C_{r0r0}}$ – Covariance matrix of rainfall rate,; $\boldsymbol{C_{d0d0}}$ – Covariance matrix of observed data; $\boldsymbol{G_k}$ - Jacobian matrix $\frac{\partial g(r)}{\partial r}$; $\boldsymbol{G_k^T}$ - Transpose of Jacobian matrix; $\boldsymbol{g(r)}$ – Rainfall attenuation function: $\boldsymbol{g(r)} = \boldsymbol{l} * a * r^b$; k – Iteration number.

Comparison between retrieved and original map





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4. Results and future works

Primarily obtained results for 20 rainfall maps are encouraging, because they are consistent with observed data.

The main part of the work in progress and aims the following future works:

(i) Sensitivity analysis;

(ii) Evaluation with rainfall fields displaying different variabilities.

(iii) Assessment of the importance of the network topology and error sources .

5. References

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