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

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Rainfall is usually measured by networks of rain gauges and weather radars. Many cities worldwide are not supplied with these devices; however, they are generally equipped with mobile telecommunication networks. Mobile networks use atmospheric Hyper-Frequency (HF) links whose transmitted signal power is attenuated by rainfall. Measuring that signal attenuation along each link could allow the measurement of path-averaged rainfall [Leijnse et al 2007, Overeem et al 2013, Messer et al 2006, Guili et al 1991, Zinevich et al 2008, Cuccoli et al 2011]. As HF links are concentrated in cities, these networks could constitute a self-sufficient approach to monitoring rainfall in urban areas.

We adopt a simulation approach in order to study the feasibility of mapping rainfall fields at the city scale by means of existing HF links. Our domain of study is the central part of the city of Nantes, France, where the density of cellular networks is greatest. As a basis, we use a data set consisting of hundreds of weather radar images recorded by the Météo-France C band weather radar at high spatial (250m x 250m) and temporal (5 minute) resolutions located about 10 km north of the center of Nantes. We convert these images into rainfall maps using the Z-R relation and consider them as reference rainfall fields.

The simulation is performed as follows. First, we simulate the measurement of total attenuation along each HF link using a rain-attenuation model based on Mie theory and a known drop size distribution in a continental temperate climate. This procedure is applied for 256 real radio links operating at different frequencies (18, 23, 38 GHz) with lengths ranging from 0.4 to 16 km. This helps us to substitute the attenuation data for the signal power received from microwave links. Error sources affecting measurement accuracy are introduced as a zero-mean Gaussian distributed random variable with variance of 10% of total attenuation. The retrieval of the rainfield is performed by a nonlinear algorithm [Tarantola and Valette 1982] based on the general nonlinear least square criterion. The a priori knowledge used to initialize the algorithm heavily influences the model outcome if the stated problem is underdetermined.

In order to evaluate the performance of our model, we carry out a series of rainfall retrieval tests for various rain events (convective and stratiform) with different time intervals. We evaluate retrieval efficiency by comparing observed rain fields with retrieved ones. We perform a sensitivity analysis to define the model's limitations and capabilities by considering essential factors, namely spatial and temporal rainfall structure, the geometry of HF link networks, the choice of a priori information and associated errors.