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Rainfall Estimation Using Commercial Microwave Links (CMLs) Attenuations: Analyse of Extreme Event of 1st September 2009 in Ouagadougou

Ali Doumounia[1, 2], Moumouni Sawadogo[2, 4], Serge Roland Sanou[3], François Zougmoré[2]

[1]Department of Physical Sciences, Institute of Sciences, Ouagadougou, Burkina Faso

[2]Department of Physics, University Ouaga1 Pr Joseph Ki-zebo, Ouagadougou, Burkina Faso

[3]Department of Computer, Regulatory Authority for Electronic Telecommunications and Post, Ouagadougou, Burkina Faso

[4]Department of Project Services / Telecel-Faso Roll-Out, Technical Direction of Telecel Faso, Ouagadougou, Burkina Faso

Email address:
doumouniaali@yahoo.fr (A. Doumounia), ali.doumounia@ird.fr (A. Doumounia)

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Abstract: With the exponential increasing of mobile phone users, the CML network in West Africa is growing, and thus providing a high potential for CML-derived precipitation measurements. In this work we use the performances data of the CMLs to determine the rainfall quantities of the rainy event which marked the memory of the inhabitants of the capital Ouagadougou on September 1st, 2009. In this study we use the attenuation of a microwave link to establish the rain rate. The working frequency is 13 GHz, the path length 7.5 Km and vertical polarization. The time series of attenuation are transformed into rain rates and compared with rain gauge data. The method has successful in quantifying the rainfall. The correlation between 1 hour data of the microwave link and the rain gauge is 0.63. The cumulative rainfall bias during the event less than 5%. These results demonstrate the opportunity to use the microwave backhauling in mobile network to assess rainfall in Africa in this context where the hydrometeorological risk increases every day.

Keywords: Precipitations, Attenuation, Telecommunications, Floods, Quantitative Precipitation Estimation (QPE)

1. Introduction

Flash floods have become recurrent since the 2000s in the city of Ouagadougou, capital of Burkina Faso, between 2002 and 2012 Ouagadougou experienced many floods. Rainfall heights associated with flooding range from 43.8 mm to 263.5 mm. These floods have resulted in loss of lives, disaster victims, wounded, house collapses, and many other serious damage to the economic infrastructures. If we know the importance of rainfall for agriculture, we deplores the disasters that they cause during extreme events, such as the flooding of September,1st 2009 in Ouagadougou or nearly 264 mm of rain was measured in just 10 hours to the station synoptic of airport of ouagadougou. The images below illustrates the extent of the damage that the capital of Burkina faso experienced this September, 1st 2009.

Figure 1. *Flood of the 01/09/2009 in ouagadougou.*

However in this city, the observation network is almost non-existent, but this is not the case of mobile phones antennas. Recently, commercial microwave links (CML) from telecommunication networks have been suggested as a novel source of rainfall information [1-7], which could provide quantitative precipitation estimates (QPE). Rainfall monitoring based on commercial terrestrial microwave links has been tested for the first time in Burkina Faso, in Sahel [8], [9]. The objective of this study is to use the CML to estimate the quantity of water fallen during extreme event of 01/09/2009 to Ouagadougou. This is to demonstrate once again the potential of this new technique in measuring the amount of rain in sub-Saharan Africa.

2. Data and Methodology

The annual rainfall is explained mostly by organized mesoscale convective systems in Burkina faso. Within these systems, 75 to 80% of the rainfall is due to relatively short-lasting convective fronts characterized by medium to heavy rain rates; the convective front are followed by longer-lasting stratiform trails with intensities below 10–15 mm/h [8, 10]. The Ouagadougou instrumented site was initiated by the University of Ouagadougou, the meteorological services, and the Telecel Faso cellular communication operator to test and confirm the innovative methods for measuring rainfall on the extreme event of 1er september 2009. In collaboration with this national cellular phone operator, Telecel Faso, the attenuation on 7.5 km long microwave link (Xerox-Kouritenga) operating at 13 GHz was monitored at 1s time rate during the extreme event of 01/09/2009. The time series attenuation data are transformed into rain rates and compared with rain gauge data provide by meteo-office in the same time. In order to compute path-averaged rainfall intensities, received signal powers were obtained from Aviat microwave links of the national cellular communication network, Telecel Faso in the Burkina Faso. The received powers over 1second intervals were provided, based on 10 Hz sampling. The transmitted power was almost constant. The data have a resolution of 1 dB, and used vertically polarized signal. Data from the working were obtained from September, 1st 2009, to estimate rainfall. Figure 1, show the locations of the macrowave link which can be used to estimate rain-rate and the location of meteo-office raingage station in Ouagadougou airport. Raingage data set with temporal resolution of one hour.

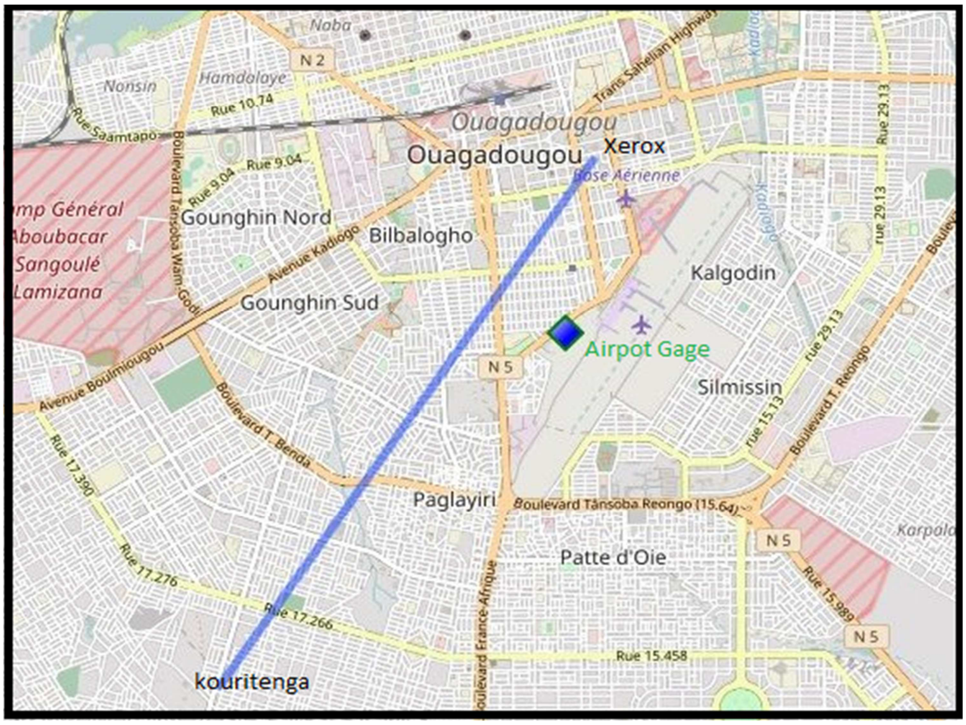

Figure 2. *Microwave link and raingage location.*

2.1. Microwave Link Data Processing

Attenuation by rain is not the only source of variation in the received signal. Depending on the operating frequencies, drops in the received signal can be due to changes in the air refractivity, dust, or technical problems such as antenna misalignment. Another source of attenuation is the water film that may deposit on the antennas during rainfall and can increase the apparent attenuation due to rain along the link [11–13]. This is not explicitly accounted for in the present work. The so-called baseline level, from which attenuation due to rain can be subtracted, is therefore a time-varying signal and must be determined. After several sensitivity tests or “moving window variance method” [14] was adopted and applied to 1hour time series (figure 3a). It consists in separating the dry periods from the wet periods on the basis of the signal (temporal) variance. When rainfall is present along the link, the signal drops rapidly due to rainfall attenuation, and the variance is higher than during the dry period. The baseline level for the dry periods is calculated from this principle, based on the one hour dry period that proceeded rainy period [8]. The attenuation due to rain is calculated as the difference between the received signal and the baseline. The results are illustrated in figure 3.

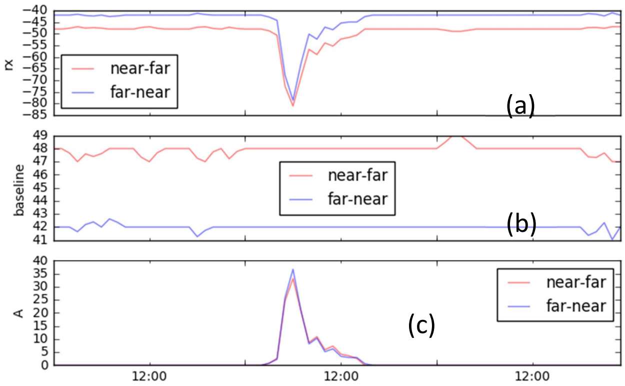

Figure 3. *a) Raw attenuation, b) Baseline, c) Rain attenuation.*

2.2. Conversion of Path Attenuation into Rainfall Rate

The conversion from attenuation to rainfall is based on the power law relationship between the specific attenuation A (dB/km) and the rain rate R (mm/h):

$$< R >= \left(\frac{PIA}{aL} \right)^{1/b} \tag{1}$$

The prefactor a (0.036) and exponent b (1.138) depend on the microwave frequency and the raindrop size distribution along the path. Drop size distribution data gathered during the African Monsoon Multidisciplinary Analyses (AMMA) campaign [10] and a Mie scattering code were used to study the A-R relationship for West African convective systems, at the temperature of 26°C, frequency of 13 Ghz and link length of 7.5 km. with these assumptions, equation (1) becomes (2)

$$< R >= \left(\frac{PIA}{0.036 * L} \right)^{1/1.138} \tag{2}$$

The microwave link provides the path integrated attenuation (PIA), which is the integral of the specific attenuation along a path of length L.

3. Results and Discussion

Figure 4 shown the rainy events, of September, 1st 2009. On this date, the microwave-link-based retrieval and the gauge rainfall are in very good agreement (correlation above 0.61 for the two direction attenuation). The shape of the link-based time series is smoother, as expected when comparing a 7.5 km path average rainfall with a point-scale measurement from a gauge. The timming of the events is good and the mean absolute bias for this extreme event is less than 2%. More work is planned on quantifying the uncertainties and sensitivities [12] for the specific link configuration and rain properties encountered in the region and providing a tentative error bar in addition to the rain occurrence and rain rate time series [11].

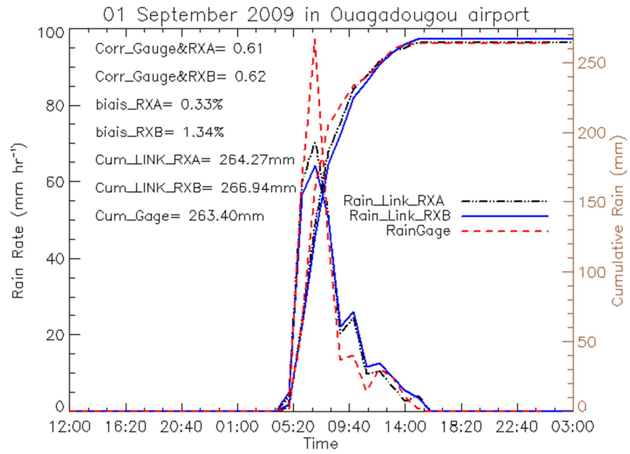

Figure 4. *CMLs rain estimate and gauge rain rate.*

4. Conclusions

This study devoted to finding the amount of rain fell on the 01/09/2009 in Ouagadougou using CMLs was a success. We have obtained an average bias less than 5%. And the analysis of the time series at 1 hour reveals that the hyetograms measured with rain-gage and those estimated from CMLs are great correlated for the two directions (an average of 0.62). This study confirms the potential of telecoms links for precipitation estimation in urban cities in Africa. Applications are expected in tropical urban hydrology and monitoring of extreme hydrometeorological events, such as floods that have affected many African cities in recent years. Cellular networks are denser in urban areas, with shorter links and higher operating frequencies. They could thus make it possible to realize the rain fields with a very good spatial resolution.

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