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Rainfall variability derived from HYDRIX radar, using ZPHI® algorithm

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1 Introduction

Accurate estimation of rainfall is crucial for many purposes, as for crop yield assessment, water resource management and flood survey. The main objective of the study is to assess the capability of X-band polarimetric radar measurements to derive the temporal and spatial variability of the rainfall.
The data used were collected by a 25 rain gauge network and by the X-band polarimetric radar HYDRIX during a one year experiment. The radar data are processed in real time by ZPHI® algorithm to deliver the rainfall rate. The statistics are computed in terms of spatial correlation, Nash coefficient and bias.

2 Experimental setup

The radar scanning zone is a single elevation azimuth sector spanning from 200° to 275°, with a maximum range of 60km. The 3 deg/s antenna speed ensures a revisit time less than 30 s long in average.
To capture rain during cold seasons, the exploration is performed at a low elevation angle. Initially, this elevation was set to 1.5°, but top of trees located a few tens of meter in front of the radar caused significant partial beam filling from 200° to 235° azimuth. To reduce such an effect, the antenna elevation was raised to 2.2° at end of October 2004.
The radar coverage sector overflows 25 tipping bucket gauges, 8 of which are located within the partially masked zone. This gauge network is spread quite close to the radar, with a maximum distance of 25 km far from the radar.

Over the one year experiment, various meteorological situations have been observed, from the weak rain to intense rain during the summer, with one event characterized by instantaneous rain rates larger than 150mm/h. The average rain was equal to 5mm/h.

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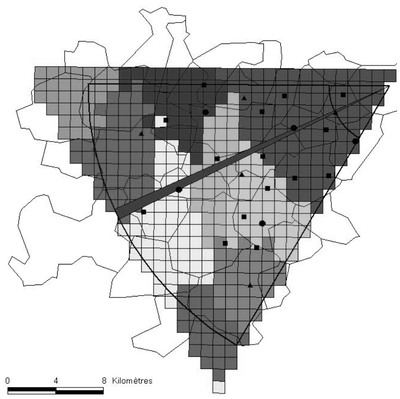

Fig. 1. radar coverage sector and rain gauges locations. The grey shading stands for various type of farming.

3 Data processing

The radar data were processed in real time with algorithm ZPHI® to retrieve rain rate and parameter N_0* (Testud et al., 2000). The radar rain rates were then interpolated at a 1 km resolution geographic grid, using Cressman filtering. They were integrated over 6min time interval to fit the primarily time sampling of the rain gauges.
Two other algorithms are used for comparison purpose, a classical Z-R relationship with and without attenuation correction from ZPHI®. In both cases the N_0* is set to a constant value optimized for the region ($\sim 10^{6.4}$).

4 Statistics

One year of data were collected to compute the statistics. Various criteria are used: the Nash, the linear Pearson coefficient and the slope of the orthogonal fit (Table 1).
Applying Z-R to the original reflectivity results in a large underestimation of 32% when compared with gauge measurements and a significantly low Nash coefficient.
Correcting the reflectivity for attenuation brings an improvement: the Nash and the correlation increase by 4 and 5 points respectively.

In addition to attenuation correction, ZPHI® performs a N_0* adjustment, largely improving all criteria.

Table 1. Statistics of the comparison between radar and gauges, 3652 points, 1hour integration.

Algo	Slope	Pearson	Nash
ZPHI®	0.88	0.92	0.84
$R(Z_{corr})$	1.09	0.85	0.66
$R(Z_{att})$	0.68	0.80	0.62

When considering time integration of 30mn and 18mn instead of 60mn, the performances of ZPHI® are only reduced by 0.5 and 1 points respectively on the Nash coefficient (Table 2)

Table 2. Influence of the integration time, ZPHI® algo.

ΔT[mn]	N	Pearson	Nash
60	3652	0.92	0.84
30	4968	0.89	0.79
18	6482	0.86	0.74

5 Rain spatial variability

To characterize the rain variability, the spatial correlation has been computed from the radar measurements, following the work of Gebremicheal and Krajewski (2004) in which the rainfall distribution is represented by a bivariate mixed lognormal model (Shimizu, 1993). The spatial correlation is then fitted using a three-parameter exponential model:

$$\rho(h) = \rho_0 \exp\left[-\left(h / R_0\right)^F\right] \qquad (1)$$

where h is the separation distance, F is the shape parameter, R_0 is the correlation radius, and ρ_0 defines the nugget error. When considering spatially average radar data, the area ($1 \times 1 km^2$) correlation function $\rho_A(h)$ is used instead of (1) as defined in Gebremicheal and Krajewski (2004).

The area correlation function ρ_A fits perfectly the measurements (Figures 2-5) for both 1hr and 6mn rain accumulation. The associated point correlation function ρ exhibits lower correlations up to 8km separation distance. The large reduction is observed at short distances and for the more convective events.

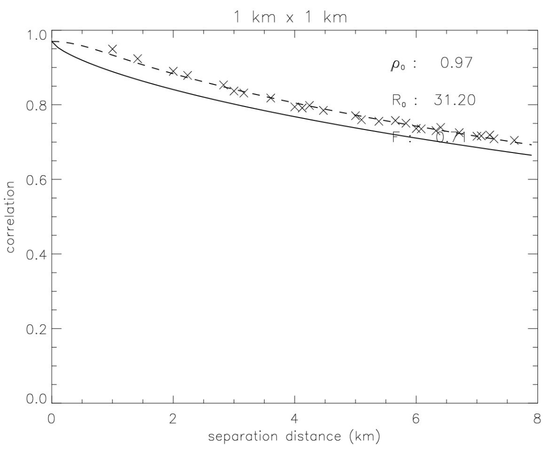

Fig. 2. spatial correlation derived from one month (October 2004) of hourly rain retrieved from radar measurements by ZPHI®. The fitted function $\rho_A(h)$ and $\rho(h)$ are represented by the dash and the solid line respectively.

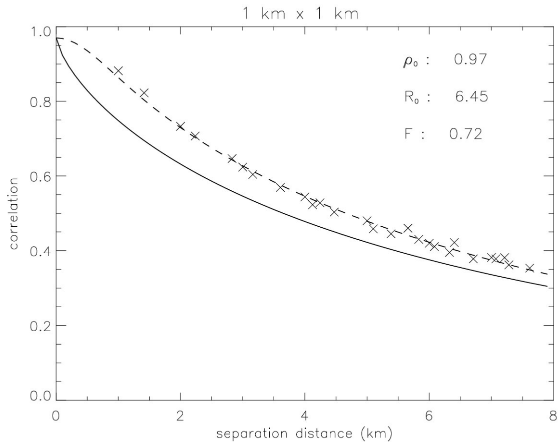

Fig. 3. same as figure 2, but selecting only rain rate > 3 mm/h.

The correlation radius decreases rapidly when considering only higher rainfall rates. For 1hr rain rates, R_0 drops from 30km to 6.5km when selecting rain rates higher than 3mm/h. The same tendency can be observed for the 6mn rain rates.

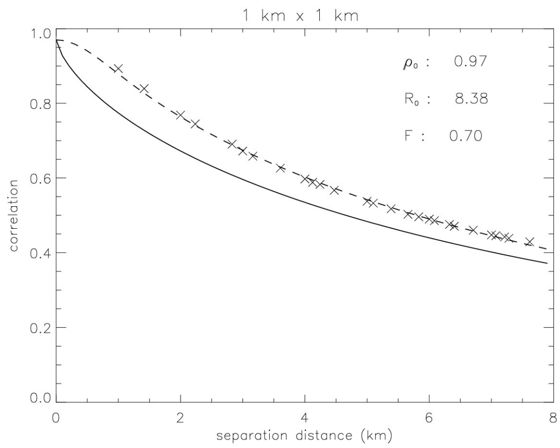

Fig. 4. same as figure 2, for 6mn rain rates.

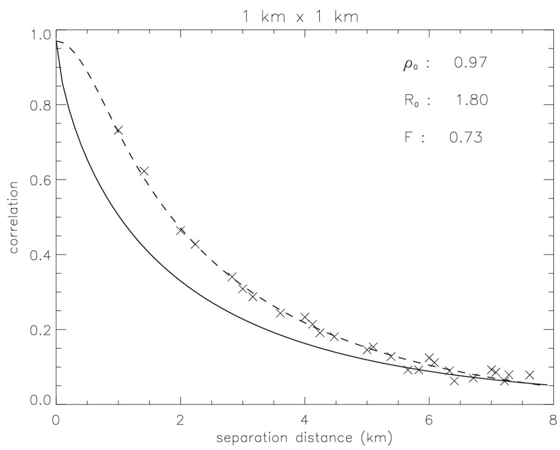

Fig. 5. same as figure 4, but selecting only rain rate > 10 mm/h.

When comparing with gauge data, the spatial correlation of the rain estimated by ZPHI® exhibits very similar characteristics with a radius of around 6km. But with a standard Z-R relationship, when neither attenuation nor N_0^* is corrected, the radius drops to 4.5km.

Table 3. 6mn rain spatial correlation derived form one year of co-located radar and gauges measurements. ρ_0 is set to 0.97 for all fits.

	F	R_0 [km]
Gauges	0.85	5.72
Radar ZPHI®	0.96	6.09
Radar $R(Z_{att})$	1.31	4.54

6 Summary

One of the objectives of the experiment has been validating the rainfall measured by the "Hydrix+ZPHI" radar system, compared with that measured by a network of 25 rain gauges. The results presented in this paper show a very good agreement between the ZPHI®-derived radar rainfall and the gauge measurements.

The spatial correlation of the rain exhibits a large variation both function of the time integration and of the intensity of the rain event. In those conditions, the correlation radius can vary from more than 30km to less than 2km.

The rain variability derived from the radar has been compared to the one measured by the gauges network. When using a standard Z-R relationship, the spatial correlation drops more rapidly with a correlation radius 20% smaller than the gauge one. Similar results have been obtained by Gebremicheal and Krajewski (2004), which suggested this to be due to random error more significant from radar than from gauge measurements.

However results presented in this paper show that radar derived rain estimate are significantly improved by ZPHI®, in terms of spatial correlation that perfectly fits with gauges derived ones.

References

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