Simultaneous X-band and K-band study of precipitations

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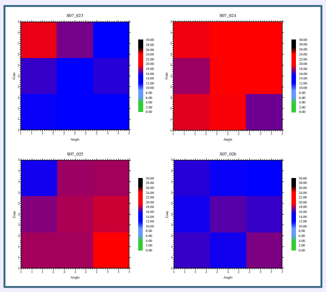
Introduction

One of the core research areas of the "Laboratoire de Météorologie Physique" (LaMP) at the "Observatoire de Physique du Globe de Clermont-Ferrand" (OPGC) is the study of clouds and precipitations, and their corresponding microphysical processes, both from the modeling and the observational point of vues. In order to improve its observation capabilities of precipitations, LaMP/OPGC has entered an agreement with the "Max-Plank-Institute für Meteorologie" and the University of Hamburg to acquire a low cost high resolution X-band radar developed by the team of Gerhard Peters. In order to gain experience with such a system, we have been looking at data collected by the prototype X-band radar and a set of K-band micro-rain radars (MRR) deployed during the LAUNCH-2005 campaign which took place around Lindenberg Observatory during September – October 2005. The X-band radar used a fixed elevation of 11.2° for its 2.4° degree pencil beam and was operated with a spatial resolution of 60m in range and 2° in azimuth, and with a temporal resolution of 30s. The 13 MRR systems were aligned over a 6 km line at a distance comprised between 3.5 and 6 km from the X-band radar. The vertically looking MRR resolution was set to 20s and 100m. In this study, in step with the AQUARADAR investigations, we will consider the variability of precipitations with both systems, and then focus on the common volumes of the X-band radar and the various MRR's in order to investigate the corresponding Z-R relationship.

Precipitation variability



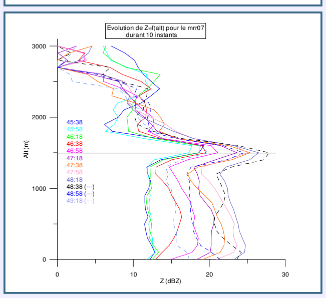


Figure 1 illustrates the high temporal and spatial variability of precipitations as revealed by the X-band radar. Indeed, the four panels presented are successive 30 seconds reflectivity plots for 9 adjacent radar pixels (i.e., each 60 m in range and 2° wide, while the central pixel corresponds to a common volume with one of the MRR system). The reflectivity range goes from 0 to 30 dBZ. Apparently, a narrow band of light precipitations passes quickly across the observed volume within this short time frame and shows about a 10 dBZ increase with regards to the background field at that time.

Likewise, the MRR systems are well adapted to demonstrate the high temporal variability of precipitations. In Figure 2 we show 12 successive reflectivity profiles 20 seconds apart obtained with such a radar. The bright band at about 1.5 km of altitude is clearly visible. The advancing "rain front" is also well documented with a maximum in the precipitation reflectivity profiles which descends in time before the rain start decreasing.

Figure 3 presents the evolution of a precipitation field across the line of MRR's. Each panel is a contour plot based on the MRR individual reflectivity profiles where the X-axis is the ground distance along the line of radars, and the Y-axis the altitude (0 to 2.1 km). One can clearly see the propagation of precipitation field along the different radars from right to left. Interestingly, one can also notice the "spots" associated with the bright band above each radar at about 1.5 km, as well as a "core" of higher precipitations which seems to "fall" between panels 2 and 3, indicating that the precipitation field has also a relative displacement in the direction perpendicular to present line of radars.

Figure 1 (top) & Figure 2 (bottom)

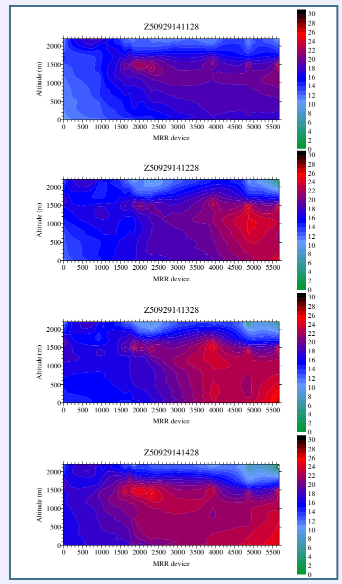


Figure 3

X band ZR relationship determination

We will now focus on the common volumes observed with both the X-band radar and the various MRR systems. These volumes range from 3.5 to 6 km from the X-band radar, corresponding to altitudes of 680 to 1160 meters. The reflectivities from the X-band radar and a MRR for one of such common volume are shown in figure 4a for a period of 2 days, while a zoom for a single hour is presented in in figure 4b. Obviously, the reflectivities from the two types of radars do correspond very well. In the lower panel, the slight differences can be attributed to the sampling strategies as well to slightly different volumes. Indeed, the geometrical dimensions of the two radar beams are different while their axis do not intersect exactly. Thus, while the "most common" volume" has been selected, there can be some vertical and horizontal separation of their respective centers.

In any case, this gives us confidence in using such common volumes in order to determine the Z-R relationships to be applied to the X-band reflectivity field in order estimate the corresponding rain-rate. To estimate R with the X-band radar the procedure is as : the MRR measured Z and estimated R are used to derive the Z-R relationship which is then applied to the X-band radar Z measurements in order to calculate a corresponding R which, in turn, is compared to the MRR derived value. This method, rather than using the MRR R with the X-band Z to derive the Z-R relationship, proved necessary to account for the differences in atmospheric volumes sensed with the different radars.

Furthermore, we have subdivided the studied period into different rain regimes characterized by rising, stagnating and decreasing intensities, respectively. This proved necessary given the observed difference of drop size distribution spectra between rising and decreasing rain where rising rains have larger drops than decreasing rains as shown in Figure 5. Finally, Figure 6 clearly demonstrates the benefits of using multiple Z-R relationships. On the left panel, the MRR original R values are compared to the X-band retrieved ones with a single Z-R function. On the right panel, the X-band retrieved R values are calculated with multiple Z-R functions associated with the different rain regimes. The corresponding mean rain rates are 11.08 mm/h for the MRR, and 8.41 mm/h and 11.65 mm/h for the X-band radar using a single or multiple Z-R relationships, respectively.

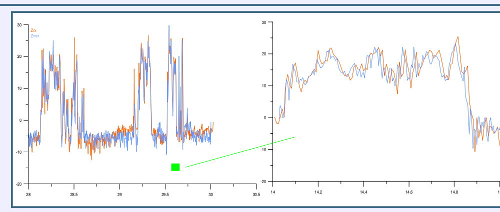


Figure 4

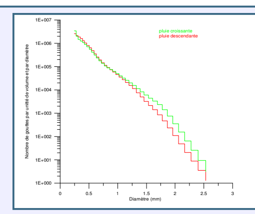


Figure 5

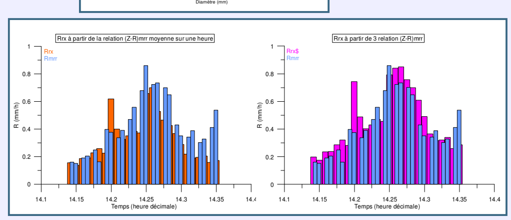


Figure 6

Conclusion and Perspectives

This is a very preliminary study which needs to be confirmed with much more data. However, it already indicates the possibility to perform good rain rate estimation with the prototype low cost X-band radar developed when adequate characterization of the various rain regimes is taken into account. The task at hand is not trivial given the wide range and variability of precipitations which can be encountered.

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