Attenuation caused by direct rainfall on a C band radar: 1998 campaign of measurements in Nancy

by

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Introduction

In France, the monitoring and the measurement of rainfall by radar are primarily ensured by Météo-France, which manages the ARAMIS network of radars distributed on the whole of the metropolitan territory. This network consists of radars of the types S and C. One of these C band radar is located at 30 km in the East of Nancy. Its characteristics are summarised in table 1.

This radar has an antenna of 3.05m of diameter, protected by a radome of 5.70 m installed at the top of a 10 meters high tower (photo 1). This radome consists of a sandwich made up of a polyester skin and of a core of reticulated PVC foam from 10 to 12 mm thickness. As a result of the moulding, the radome is originally covered with a fine wax film which favours the sliding of water. Since its installation, the radome was cleaned only one time after 7 to 8 years of utilisation, what seems one rather long period. The radome is naturally ventilated to avoid the problems of condensation inside the cupola.

In Nancy, the *Centralised Technical Management (CTM)* department of the Urban Community uses images of this radar in operational mode since Mars 1995. The device used includes a visualisation and an animation of all the images, as well as an automatic comparison between radar data and the measurements carried out by the dense rain gauge network of the agglomeration. After three years of use, repeated observations of the CTM department resulted in a particular interest for the problems of attenuation during rains directly over the radar. Such phenomena of attenuation were supposed during heavy rainfall intensities on the radar, with for consequence to cause an undervaluation of rainfall on the whole of the radar image.

In order to characterise the importance of this phenomenon, NANCIE, the Urban Community of Grand Nancy and Météo-France realised a campaign of measurements on the site of the radar. This campaign, initially envisaged with 6 months of duration, was finally conducted during 11 months from January to December 1998. It results in a significant collection of data which can be supplemented by the current measurements of the partners.

In first part, this communication presents the device used for this campaign as well as a summary of the data collected in 1998. In second part, first observations are presented which indicate that relatively low rainfall intensities on the radar can produce a significant under-valuation of the precipitation on the whole radar images.

Diameter of the antenna	3.05 m
Protection of the antenna	5.70 m radome
Wavelength	5 cm
Acquisition mode	PPI
Duration of a turn of antenna	≅ 70 seconds
Elevation of the radar beam	0,7°
Aperture of the radar beam	1,25°
Digitalisation of the data	54 levels
Size of the images	512*512 km²
Frequency of the images	5 minutes

Photo 1 & Table 1: Characteristics of measurements of the Réchicourt-La-Petite radar, near Nancy.

Campaign organisation

Radar is situated in rural area, on a plateau located at about thirty kilometers in the east of Nancy. Major rains coming from the western sector or the western south sector, the Nancy Agglomeration is thus situated upstream the radar in comparison with the general direction of displacement of the rainy zones. This situation presents many interests for this campaign of measurements : when rains approaching from the west are going over Nancy then over the radar, the attenuation of the front of rainfall is reduced; later, radar measurements over Nancy can be degraded by attenuation phenomena on the way of the radar beam (presence of intense rain cells) or by attenuation caused directly by rainfall over the site of the radar. The short distance between radar and agglomeration was a factor favouring the observation of many rainy events giving simultaneous rainfall on the two sites.

An instrumental area of 100m² was placed at the disposal of the experiment by a farmer, in a sheep pen located in the immediate vicinity of the radar, but preserving a distance of 100 meters between the instrumented area and the building of the radar (photographs 2 & 3). This surface had to be fenced in order to prohibit the access to the animals.

The technical department of the Urban Community of Grand Nancy installed a rain gauge with a resolution of 0.2 mm rain (tipping-bucket rain gauge), as well as a weather station recording temperature, moisture, direction and speed of the wind. The *Meurthe et Moselle* District Centre of Météo-France erected a wind mast of 10 meters high, at the top of which the anemometer and the vane of the weather station were fixed (no lightning protection was carried out by reason of the importance of the investments necessary to obtain an effective protection). Two lines protected by an armed sheath were posed on the ground to connect the site of measurement to the building of the radar. They have been used to ensure the data transfer and the power supply for the sensors. This one was ensured via an uninterruptible power supply (UPS) in order to avoid the small interruptions of power. In the event of prolonged power failure, the power supply was automatically assured by the generating unit of the building.

Rain gauge data and weather station data were recorded on two separated devices (Newlog boxes), in order to limit the problems of interference. These data were remotely collected each week by the *Metrology* department of the Urban Community, via a modem and the telephone line of the building.

In the course of the campaign, the criticism of the data was ensured at two levels :

- the first criticism was carried out during the weekly data collection by the *Metrology* department, in order to quickly detect problems of sensors functioning;

- a more detailed criticism was carried out by NANCIE at the time of a primary treatment of these data, after the data extraction from archives. This primary treatment was constituted of two stages:
  - to format and to set the data in a structured data bank, specific to the campaign of measurement;
  - to integrate the data in the hydrological data bank of the Urban Community, which has allowed a direct comparison with the measurements of the sensors network installed on the territory of the Agglomeration;

The technical staff of Météo-France has ensured itself of the correct operation of the installations at the time of their weekly visits at the building of the radar (amongst other things, verification of the state of the rain gauge cone). During the campaign of measurements, several interventions of the *Metrology* department of the Urban Community have been necessary, following problem identifications on the sensors or on the recording devices by the data criticism.

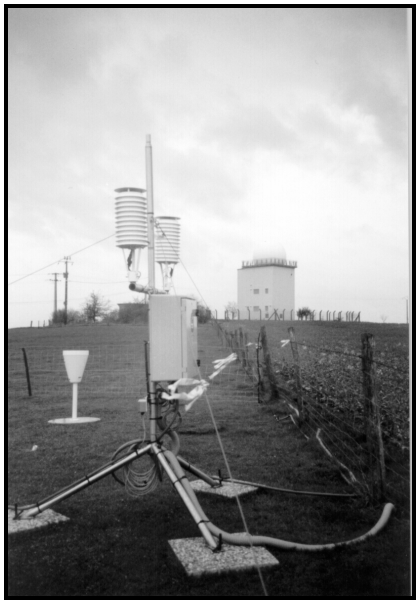


Photo 2 : Weather station and rain gauge installed 100 meters from the radar

Photo 3 : General sight of the sensors from the building of the radar. From right-hand side to left side: the wind mast and its sensors, the rain gauge and the weather station on the ground.

Data collected

Table 2 indicates the various time steps used for the data collection.

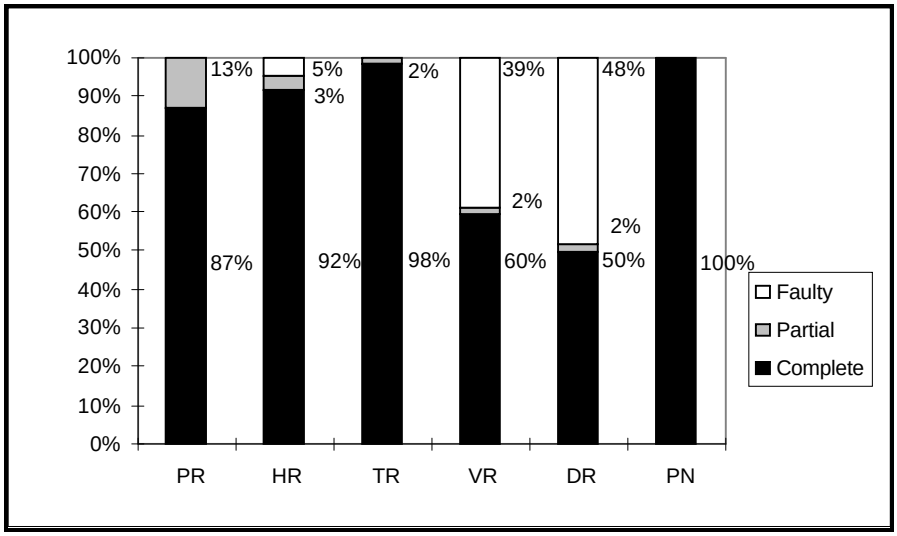
Data	Time steps
Radar	5 minutes
Relative humidity	10 minutes
Temperature	10 minutes
Wind direction	1 minute
Wind speed	1 minute
Rain gauge	tipping-bucket of 0.2 mm of rain

Table 2 : Data types

The criticism carried out by NANCIE on data collected has allowed elimination of many interference observed on the recordings of rain gauge measurements, as well as elimination of the periods corresponding to the

problems of sensors functioning. Periods corresponding to negative temperature on the ground were also eliminated, the sensors not being heated. Lastly, each series of radar images recorded was entirely visualised and commented.

The result of this criticism has led to retain 62 rainy days with radar images having correctly covered the rainy events on the radar. Figure 1 shows the data collection performance for the other sensors, during the rainy events of these 62 days. In spite of the distance of the site of measurement, one notes that except the wind sensors, the rate of complete operation are at least equal to 90%. For the wind sensors, the lack of spare parts in Nancy has been the cause of two prolonged periods of breakdown, between which the sensors functioned correctly.



PR= rain gauge near the radar

HR= relative humidity

TR= temperature

VR= wind speed

DR= wind direction

PN= rain gauges at Nancy

Figure 1: Assessment of the sensors operation for the 62 rainy days retained according to radar images.

The ground measurements carried out on the radar site are supplemented by data usually recorded by the partners of this campaign. One can quote:

- radar images which were stored by Météo-France and by the Urban Community.
- measurements of the dense sensors network of the Urban Community, comprising 24 rain gauges and 6 weather stations.
- measurements of rain gauges and weather stations managed by Météo-France (including the Nancy-Tomblaine site on the outskirts of the agglomeration). One can also note that two radiosonde explorations of the atmosphere are carried out daily on the site of Nancy-Tomblaine.

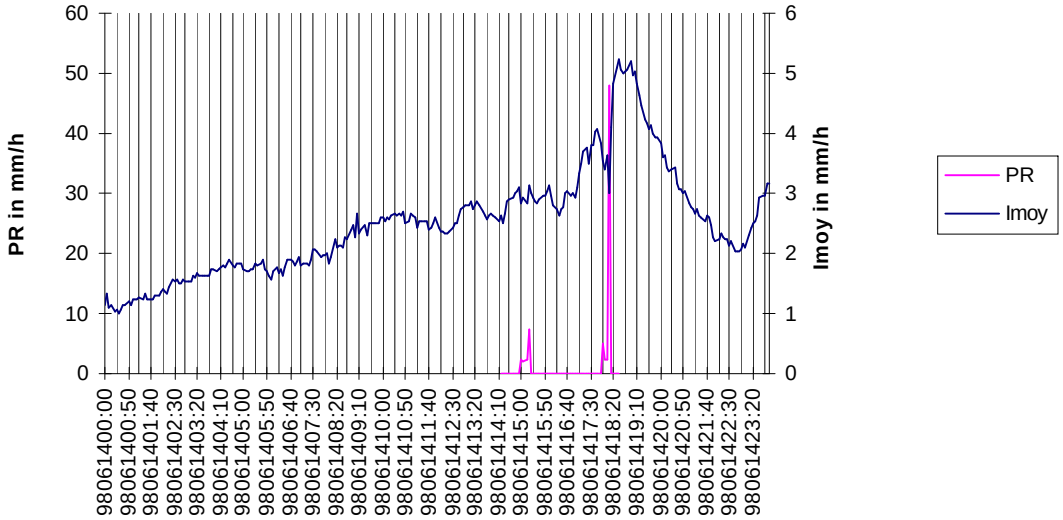
First observations

A first reduced analysis of the data was realised by NANCIE in order to determine the rainy events most interesting. This analysis has consisted to compare radar images with measurements of the rain gauge installed near the radar. The mean rainfall intensity *Imoy* for all the rainy pixels (zero values excluded) was calculated for each radar image, after a reflectivity-intensity transformation carried out using the standard relation : $Z = 200R^{1,6}$. Then, the evolution of the *Imoy* values was compared with that of the PR measurements.

Many factors influence the *Imoy* values. Nevertheless, it is possible to observe brutal decreases of the *Imoy* values concomitant of peaks of rainfall measured by PR (figure 2). After verification, these rapid variations of

Imoy values really correspond to a general decrease of pixel values of the images concerned, except the pixels covering directly the radar site for which one generally observes strong levels of reflectivity. These variations of *Imoy* are interpreted like the result of a phenomenon of attenuation on the radar level. The principal hypothesis put forward to explain this attenuation phenomenon is the formation of a water film on the radome protecting the radar antenna.

a)



b)

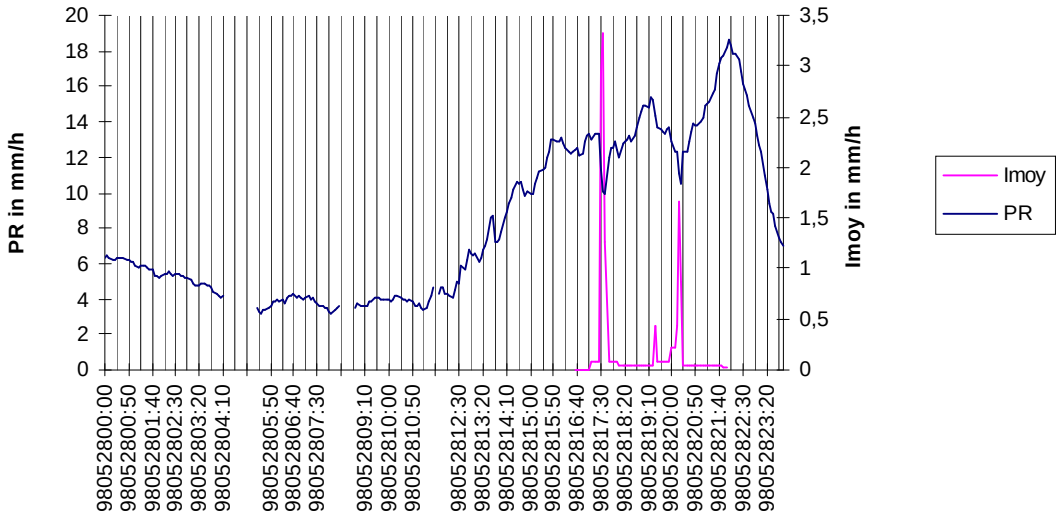


Figure 2 : Evolution of the mean radar rainfall for the entire image (*Imoy*) in relation to the rainfall intensities (PR) recorded by the rain gauge located 100 meters from the radar (in mm/h averaged during 5 minutes).
a) PR exceeding 45 mm/h during 5 minutes b) PR below 20 mm/h during 5 minutes

Comments

The first reduced analysis carried out using only radar measurements and measurements of the rain gauge installed 100 meters from the radar makes it possible to detect only peaks of attenuation in connection with peaks of rainfall. Considering relatively low rainfall intensities for which such peaks of attenuation have been detected, it is nevertheless to be feared that a significant attenuation can occur for more continuous and relatively frequent rains. The demonstration would require a more complete exploitation of the data, and in particular the use of the ground reference which is constituted by the dense rain gauge network of the Urban Community of Grand Nancy.

The decreases of radar measurement estimated by this preliminary study represent about 10 to 25% of the average rainfall intensity, attributed to peaks of rainfall over the radar ranging between 10 and 45 mm/h (averaged values during 5 minutes). Such attenuation could be very detrimental to the quantitative estimate of rainfall from measurements of the Réchicourt-La-Petite radar, and may be for rainfall measurements of all the C band radars of similar type constituting a part of the ARAMIS network.

On the practical level, one can suggest to take more interest in the coating of the radome surface of this radar type, and to modify the frequencies and the procedures of maintenance of these surfaces.

On the research level, theoretical models exist to simulate the water film formation on radomes. These models allow to simulate attenuation, in function of the rainfall intensities and of the weather conditions (wind, temperature), and eventually propose correction factors of this attenuation. The LTHE team (Grenoble, France) has already worked on such models. Complete data relating to about ten rainy events were transmitted to the LTHE, in order to test some of these theoretical models and to adjust parameters of these models to explain the magnitude orders of the observed attenuation.

Acknowledgements

This campaign of measurement was entirely carried out using the means and personnel of the three partners who are:

- NANCIE, International Water Centre of Nancy,
- the Urban Community of Grand Nancy,
- the *Meurthe et Moselle* District Centre of Météo-France.

Complementary radar data were also extracted and transmitted to us by the Exploitation Central Service of the Meteorology (SCEM - Météo-France, Toulouse) in order to complete the recorded data bank.

The campaign has been carried out thanks to the complementarity of competence and technical means of the three partners. One can in particular underline the involvement of the engineering departments of the Urban Community of Grand Nancy, which have showed a constant interest in the topic of radar measurement of rainfall since many years, and have brought an essential technical support to several studies.

Beyond the means as men and materials implemented by the partners, one can underline the collaboration spirit which has prevailed between the teams which have took part in this campaign. One can also thank Mr. Guillaumont, farmer, who has accepted the enclosure of a part of his property during nearly one year, and has allowed without difficulties a prolongation of the campaign of measurement for a final duration equal to the double of the one initially envisaged.