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# A first dual polarization weather radar in the french network: test of its usefullness for hydrology

**J. Parent-du-Châtelet[1], J. Testud[2], H. Andrieu[3], and P. Tabary[1]**

[1]Centre de Météorologie Radar, Direction des Systèmes d'Observation, Météo France
[2]NOVIMET, 10/12 avenue de l'Europe, 78140 VELIZY France
[3]LCPC, Division Eau, F-44341 Bouguenais Cedex, France

**Abstract.** In the frame of the Météo-France Panthere project, a new dual polarization C-band radar has been installed in Trappes in april 2004. A one year operational test is designed to verify the improvement in rain rate estimation with dual polarization techniques.

After giving the main objectives of the Panthere project, this paper discusses the reasons for choosing the Parisian Region for this test : diversity of rain systems, vicinity of the major Roissy air-traffic platforms, validation networks, proximity of technical team. Next, the algorithms for computing the main dual polar observables $Z_H$, $Z_{DR}$, $\rho_{HV}$, $\Phi_{DP}$, $K_{DP}$ are given and the very dense validation network is described, with more than 1 hundred 1-hour available rain gages in a 50 km radius around the radar. A few disdrometers will also be deployed for this test. During the experiment, particular attention will be given to the test of the ZPHI algorithm (Testud et al., 2000) wich will be installed within the Meteo-France operational computer to produce real time rain-rate estimation. The methods used to evaluate the different rain-rate estimators, with respect to rain gages and disdrometers are finally presented.

## 1 Introduction

The problems due to DSD variations, precipitation type (snow, ice, rain,..) and signal attenuation by rain, are major questions for rain rate measurement accuracy by weather radars. The dual polarization radar, which supplies measurements in both vertical and horizontal directions, gives usefull parameters for a better characterization of the precipitation (Sauvageot 2000):

– the differential reflectivity $Z_{DR}$ is related to the mean drop diameter $D_m$, and also to the precipitation type;

– the differential phase between H and V polarisations (in deg. $km^{-1}$) which is insensitive to attenuations (by the rain, partial beam bocking, ..) is directly related to rain rate, but this parameter is too noisy to be used in an operational way.

Algorithms exist to deduce the DSD (drop size distribution) from Z, $Z_{DR}$ and $K_{DP}$ , and to compute the rain intensity R with these parameters, and several such relationship have been proposed in the frame of the experiment JPOLE (Ryshkov, 2003). The results obtained from JPOLE have bben considered good enough to upgrade the NEXRAD radars to polarimetry from fere to 2008. However, for C-band (and morover for X-band) operational networks, no such decision has yet been taken, on account of the remaining attenuation problems.

*ZPHI algorithm*

The new algorithm ZPHI (Testud et al., 2000) uses the differential phase rotation between two distant range gates, on the same ray, to estimate the integrated rain attenuation between these two range gates. This is then introduced in the attenuation correction algorithm (Marzouk and Amayenc, 1994) to correct for the rain attenuation. Therefore, the normalisation of the DSD by the No* parameter (Testud et al., 2001) leads to a more robust estimation of the DSD. The ZPHI algorithm seems to be a good candidate to measure the rain rate with attenuated wavelengths, such as C-band or X-band (Le Bouar et al., 2001).

## 2 The Panthere project

Due to the increasing interest for hydrology, nowcasting and assimilation by numerical weather forecast models, the PANTHERE project (Parent et al., 2003) has been launched in 2002 by Météo-France in partnership with the French Ministry of Environnement. Its main objectives are:

*Correspondence to:* J. Parent-du-Châtelet
(jacques.parent-du-chatelet@meteo.fr)

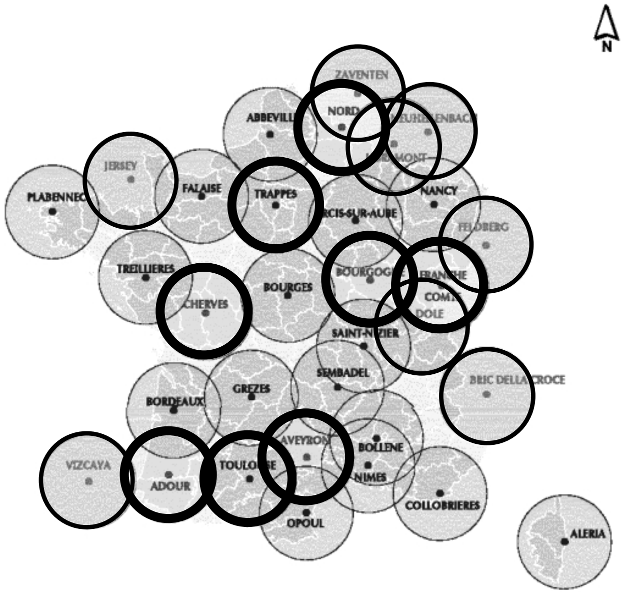


**Fig. 1.** The PANTHERE network in 2006. Each circle, of 100 km radius, is centered around a radar. The 8 foreign radars are circled by a thin black line. The 8 new Panthere radars are circled with a bold black line. These 8 radars will potentially become dual polarized.

– to densify the hydrological weather radar network by adding 6 new C-band radars to fill the main gaps;

– to replace two of the oldest radars of the network;

– to assess, and possibly to implement, the “new tehnologies” not yet used in the French operational network such as Doppler, volumetric exploration, and dual polarization.

At the end of the project, in 2006, France will be covered by 32 radar (Fig. 1) : 16 “classical” radars, 8 new Panthere-radars, and 8 foreign radars (Spain, Jersey, Belgium, Germany, Swiss and Italy).

Concerning Doppler, a new dual PRT technique has been developped (Tabary et al., 2004a) to estimate unambiguous radial velocities up to +−30 m/s, while keeping low prf (300 $s^{-1}$) in order to observe at large distances. Compared to wind measurements performed by radio-soundings just above the radar, the agreement is good enough (Tabary et al., 2004b) to decide to implement it on the operational network as soon as possible.

Concering volumetric exploration, several tests have been performed in 2002 and 2003 with the two operational radars Bollène and Nîmes, located in the South East of France. A real time algorithm for VPR estimation has been developped with these data (Gueguen et al., 2004). With the same dataset, a new algorithm have been developped for rain rate estimation, which corrects for ground echoes, partial beam blocking and VPR effects. The results have been compared to in situ measurements during a 6 months period (Lamarque et al., 2004) and the improvement is important enough to decide to implement it in the French operationnal network in 2005.

**Table 1.** Elevation angles for the Trappes radar, and rotating azimuth speed, planned for the test.

| | volumetric scans: 15°/sec | | hydrological scans: 7.5°/sec | | |
|---|---|---|---|---|---|
| h to h+5’ | 90° | 6° | 1.2 | 2. | 0.4 |
| h+5’ to h+10’ | 9° | 4.5° | 1.2 | 2. | 0.4 |
| h+10’ to h+15’ | 7.5° | 3.2 | 1.2 | 2. | 0.4 |

Concerning the dual-polarization, the project strategy is to buy the first new Panthere radar equiped with the technology, and to perform an extensive validation experiment. At the end of these experiment, and if the results are conclusive, the project will decide to equip the 8 new operationnal radars.

The main characteristics of the Panthere radars are the following:

| | |
|---|---|
| wavelength: | 5 cm, C-band |
| 3 dB beam-width: | 1° |
| rotating speed: | 7.5° or 15° $sec^{-1}$ |
| peak power: | 250 kw |
| pulse duration: | 1 to 2 $\mu$s |
| Doppler: | I and Q 16 bits floating points |
| dual-polar: | H and V simultaneously transmitted and received |

The I and Q data are provided by the radar through an ethernet gigabit link. They are input in the French radar computer CASTOR2 which performs basics integrations and computes meteorological and hydrological products.

The polarization parameters are computed as follows, on a polar grid 0.5°×250 m:

$Z_H = <I_H^2 + Q_H^2>$;

$Z_V = <I_V^2 + Q_V^2>$;

$Z_{DR} = Z_H / Z_V$ ;

$\Phi_{DP}$=argument$[<(I_H - jQ_H).(I_V + jQ_V)>/\mathrm{sqrt}(Z_H.Z_V)]$ ;

$\rho_{HV}(0)$=module$[<(I_H - jQ_H).(I_V + jQ_V)>/\mathrm{sqrt}(Z_H.Z_V)]$.

The radar scan mode will be as follows (Table 1):

The main scan period lasts 15 min, during wich volumetric and hydrological scans are interlaced. These last one are low elevation scans (0.4°, 1.2° and 2°), repeated every 5 min, with a low rotating speed, to get a good rain estimation above ground echos and at large distances. The volumetric scans will be used for nowcasting and for VPR estimation. The 90° elevation scan will be used to perform H/V calibration on rain echoes.

**Table 2.** Number of rain gages in the validation area, within a 50km or 100 km radius around the radar, and providing 6', 1h and 24 h precipitation amounts.

| range to the radar | gages Δt<6' | gages Δt<1 h | gages Δt=24 h |
|---|---|---|---|
| 0–50 km | 98 | 110 | 140 |
| 50–100 km | 20 | 51 | 170 |

## 3 The dual polarization test

This test will take place during 2005, in the Parisian region (within a 100 km radius around Paris City), with the Trappes radar 30 km SW of Paris.

The Parisian region has been chosen for several reasons:
i) First, the rain gage network is particularly dense (Table 2):

In particular, the gage network is very dense in some catchment sensitive for flooding problems (Fig. 2).

Also there are several well instrumented centers : the two main airport platforms of Orly and CDG, and especially the SIRTA CNRS platform (http://www.sirta.lmd.polytechnique.fr) with the C-band research weather radar RONSARD, and several, additional profilers (cloud radar, lidars, radiometers).

In addition to these instruments, Météo-France plan to install 4 disdrometers for the microphysical validation and DSD measurement verification.

ii) The second reason for choosing Parisian region is for its meteorological characteristics : this almost flat region does not generate any important orographic effects with meteorological features difficult to interpret. However the climate is not homogeneous and stratiform winter rains, with more or less heavy bright band, as well as convective summer rain, violent at times, several hail events in spring and generally a few snow events in winter. This diversity is an advantage for this validation experiment.

iii) Finally, and not least, the Trappes radar is very close to the electronic and computing teams of Météo-France, and the experiment will be much more easy to manage at home than in any place far from the teams.

After a qualification period, the radar will produce dual polarization data routinelly and the ZPHI algorithm will be installed in real time on the radar computer. This will produce rain masurement maps to the forecasters, and hydrologists, users who could evaluate their quality, relatively to the old product issued from single polarized radar.

The radar data will also be examined afterwards to quantify the improvement obtained by the dual polarization system. This work will be completely defined this autumn but we can already say that it will be devided into several tasks, one for each of the expected improvement to be tested. The data set, (radar and in situ measurement) will be different for each task, in order to enhance the adressed problem, and to get unquestionable conclusions. For example:

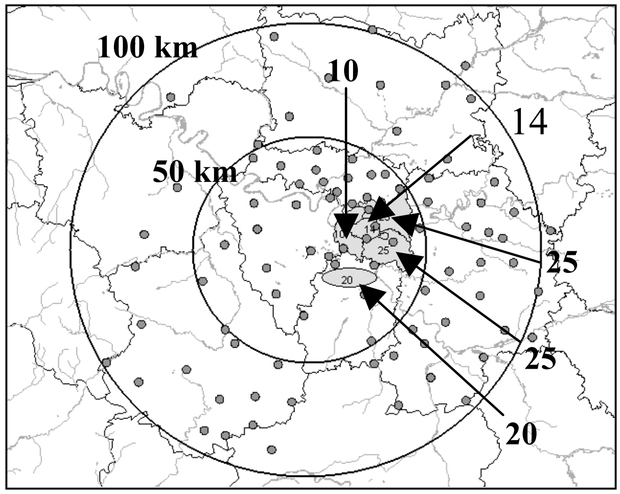


**Fig. 2.** 1 hour rain gages around the Trappes radar. Beside the Météo-France gage network (small circels), 5 important networks (in grey), implemented in 5 flooding catchments, are available near Paris, with a total of more than 160 gages within the 100 km radius.

- *artefacts detection.*This will be done by selecting a dataset evidencing ground echoes, clear-air echoes, aircraft-echoes, ... The objective will be to evaluate the detectability of these different artefacts versus SNR. In this case, the nature of the echo is indicated by its shape and no ground truth are needed.

- *attenuation measurement*. We will select data with reflectivity evidencing rain attenuation, and/or partial beam blocking. The validation can be obtain by comparing uncorrected/corrected rain estimations to the rain gages data in area close to the radar (to eliminate other sources of error). Additionally, for attenuation restricted to small area (like behind a heavy rain cell) or to a small amount of time, we can assume time or spatial local continuity, and the validation can be done by comparison with data in the vicinity, assumed to be non-attenuated.

- *DSD estimation.* This can be done only in the area close to the radar (r<30 km) to eliminate other sources of error, and above disdrometers. The data set must be selected to give a variety of DSD;

- etc. ...

## 4 Some preliminary results

The first Panthere radar has been installed in Trappes in April 2004. The first aim was to insure the operational continuity and the dual polar paramaters are available only as quick look. Some first examples are presented here in the Figs. 3 and 4:

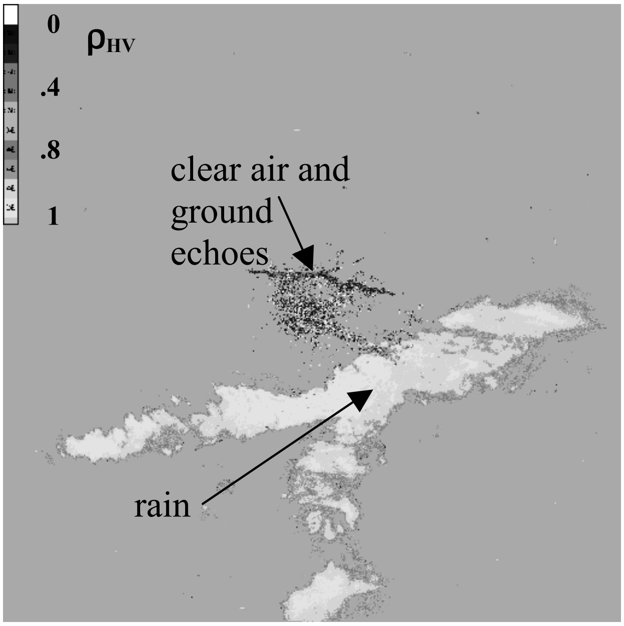


**Fig. 3.** Example of 512×512 km $\rho_{HV}$ map obtained with the Trappes radar. (26/05/2004 17h40 elevation angle = 0.4°).

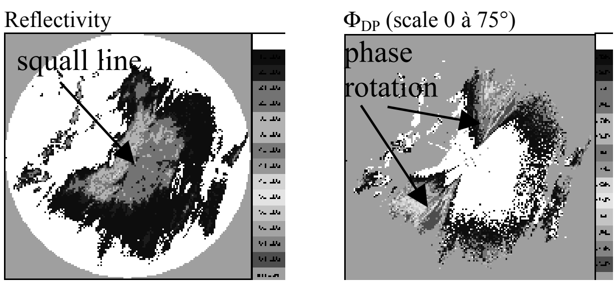


**Fig. 4.** Example of 512×512 km maps. Reflectivity (left), and $\Phi_{DP}$ (right) with a squall line crossing the Trappes radar. The phase rotation are clearly associated with the attenuation due to the squall line. (04/05/2004 17h15 elevation angle = 0.4°).

Figure 3 is an example of $\rho_{HV}$ on rain echos and artefacts (ground echoes and clear-air echoes). On this example, the corelation is clearly weak on artefacts, while it is high on rain echoes. This suggest, and we plan to test it, that $\rho_{HV}$ could be used to eliminate some artefacts.

Other examples, not presented here, show that the correlation is appreciably less in the bright band than in the rain, suggesting that this could be used to detect the bright band.

Reflectivity $\Phi_{DP}$ (scale 0 à 75°)

Figure 4 is an example of $\Phi_{DP}$ map (right) showing a rotation associated with a squall line (left), SW-NE oriented, crossing the radar from West to East. These data, which evidence raisonable differential phase rotation in the rain, are encouraging for the data consistency.

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