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REAL TIME WEATHER RADAR DATA PROCESSING FOR URBAN HYDROLOGY IN NANCY

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Abstract. A real time weather radar data processing system has been under development in Nancy since 1994. This evolutionary system is operational and radar data are used to improve the management of the sewer system of the urban community in accordance with two objectives : protection against flooding and reduction of pollution overflows. The first part of this paper presents the real time processing carried out directly by the computer which receives radar data every five minutes. This processing includes verifying the radar measurements by rain gauge data, identifying a type of rain event, forecasting rainfall evolution, and producing alarm signals. The second part presents the way used to integrate radar data into the Centralised Technical Management system of the sewer network, radar information being available using the same tools as other types of hydrological data.

1 Introduction

The sewage system of Nancy, as of the majority of the larger European urban centres, is of the combined sewer network type, designed to convey a mixture of wastewater and storm water, which is connected to limited capacity sewage treatment plant. Sewage system managers face difficulties linked to rainy weather. In the past, the major problem was to control the wet weather flow to protect urban area against flooding. The European Directive of May 1991 regarding the Urban Treatment of Waste Water now requires local authorities to take into consideration the treatment of polluted water transported by the sewage network both during dry and wet weather, with the exception of periods of exceptional rainfall.

To best meet these objectives, sewage system managers must adapt the management of the sewage system to each rain event. In this condition, the weather radar is a precious tool in evaluating the spatial structure of the rain areas and in anticipating the very short-term evolution of precipitation over the City and it's suburbs.

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2 Description of the real time process developed

Since 1994, a real time weather radar data processing has been developed in accordance with the requirements of the operational department in charge of sewage system management in Nancy.

This real time processing is operational and receives radar data every five minutes from the Météo-France radar located 30 km to the East of Nancy (wavelength = 5cm). This evolutionary system has been used to determine better utilisation of radar data for urban hydrology in Nancy, and include a range of treatments (figure 1). These treatments takes advantage of both the qualitative and quantitative information about rainfall contained in the radar data.

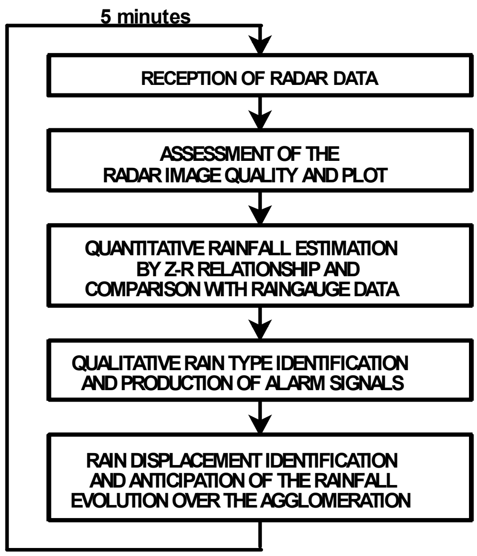

Figure 1. Real time data processing

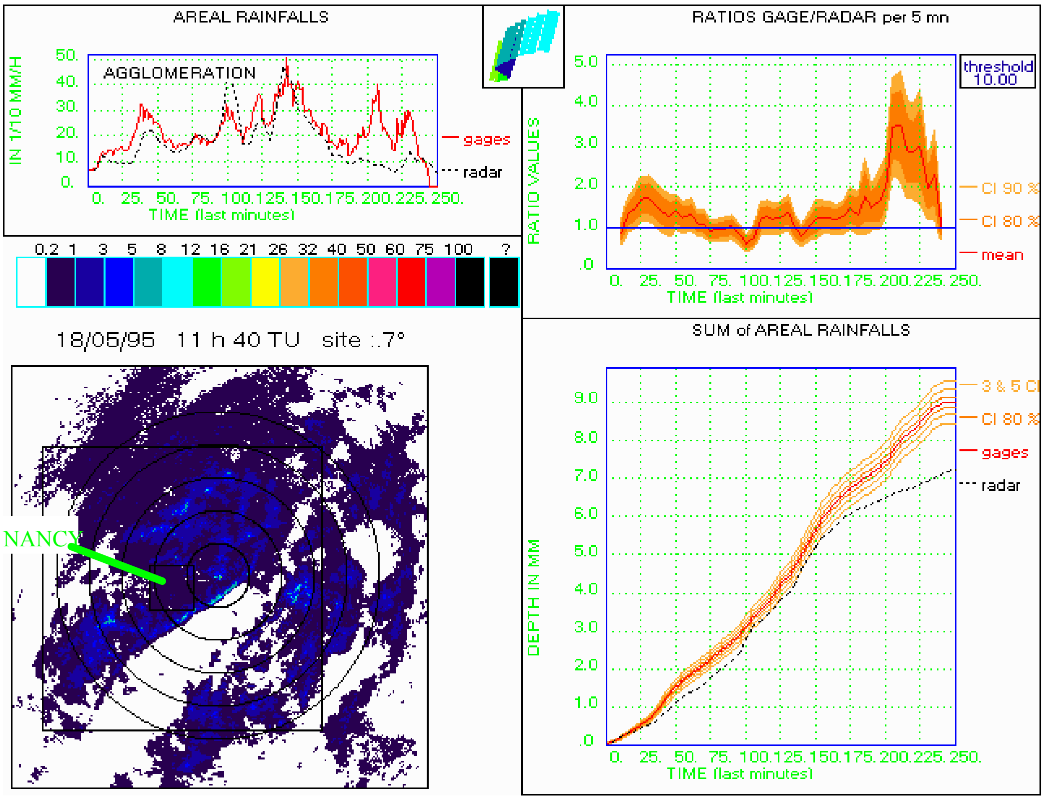

Figure 2. Example of operational display for the comparison between areal rainfall values estimated from radar and gauge data (12 gauges network). In this example, a significant bias is bring out for the last hour.

2.1 Assessment of the radar image quality and plot

The first stage of treatment is intended to assess the quality of the radar image recorded and involves for each image :

- verifying that the radar data has been correctly received,
- detecting transmission errors,
- assessing the amount of ground clutter partly filtered by the Météo-France procedure,
- selecting the most interesting images for automatic saving in accordance with various criteria, in order to create a data bank,
- plotting the radar image with a zoom on the territory of the Nancy Urban Community.

2.2 Exploitation of quantitative information : rainfall estimation and validation

The second stage of treatment involves estimating and validating rainfall rates, as well as estimating areal rainfalls over urban catchment areas. Rainfall rates are estimated from radar data by a previously selected Z-R relationship (by default, the Marshall-Palmer Z-R relationship). These estimations are validated by comparison between areal rainfall values calculated from radar and gauge data over the centre of the Nancy Urban Community's territory (130 km² area). Areal rainfall values estimated from gauge measurements are not absolute references but values with confidence intervals estimated by a geostatistical approach described in Faure et al, 1996 : rainfall values and confidence intervals are estimated on line by kriging data recorded by a 12 gauges network. These confidence intervals take into account uncertainties about rain gauge measurement of a rainfall field and allow to estimate confidence intervals for the values of criteria used for the gauge/radar comparisons. This method makes radar and rain gauge data more coherent, and realises a more objective comparison between these very different sources of data, bringing out the really significant bias (Faure et al, 1994).

Figure 2 shows an example of the operational display for the comparisons. Lower left image plots the latest radar image received. Upper left graph shows the evolution of areal rainfall estimated over the 130 km² area for the last 250 minutes, with an accumulation period of 5 minutes for radar rainfalls and of 1 minute for gauge rainfalls. Upper right graph indicates the ratios between radar and gauge rainfalls for accumulation periods of 5 minutes, with two confidence intervals (CI=80% and CI=90%). Only gauge rainfall values above a threshold of 1 mm/h are considered. A bias value is proposed if the confidence intervals not include the ratio value 1 (indicated by the horizontal dark line). Lower right graph indicates the evolution of the sum of areal rainfalls cumulated from the beginning of the rain event. Beginning and ending of a rain event are defined by an hourly period corresponding to cumulated gauge rainfalls below 0.1 mm. Sum of the gauge areal rainfalls is plotted with tree confidence intervals (CI=80%, 99.7%, 99.999%).

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Type of rain	**Form of the rainfall areas**			
type 0 : no rain				
type 1 : homogeneous low intensities	Isolated areas	continuous areas (> 3000 km²)	very large areas (> 200 km long)	long rain band of few km wide
type 2 : important intensities	Isolated areas	continuous areas (> 3000 km²)	very large areas (> 200 km long)	long rain band of few km wide
type 3 : very heavy rainfall cells detection	Isolated areas	large areas	orientated areas	

Table 1. Type of rain events and form of rainfall areas defined

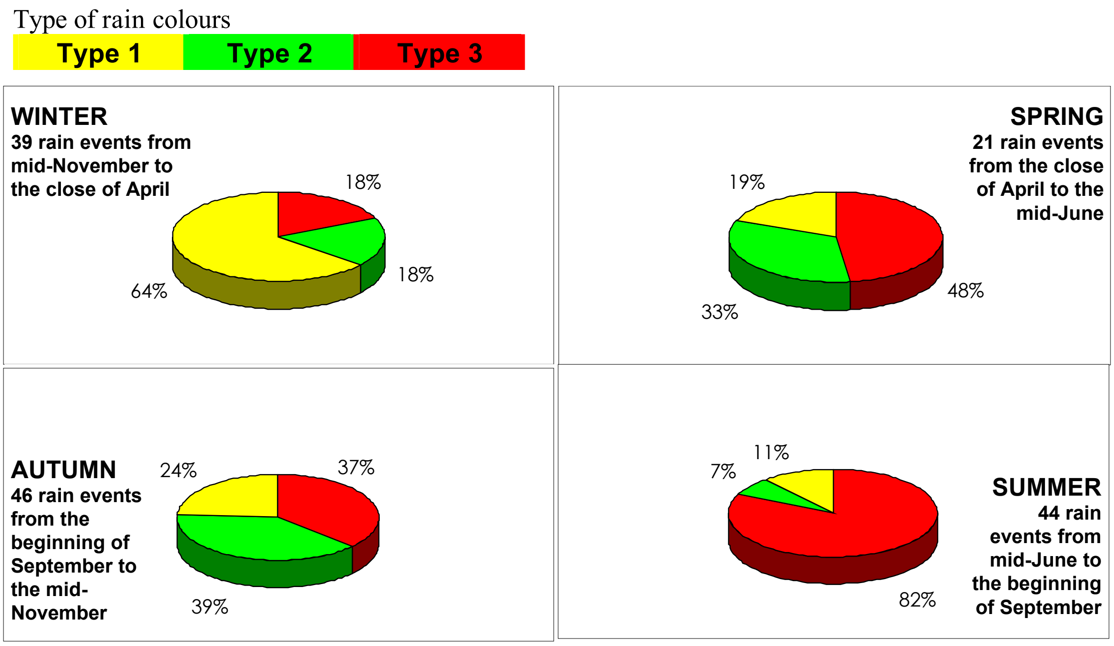

Figure 3. Annual distribution of the maximum value (1, 2 or 3) of the type of rain identified for a rainy day, from 03/03/95 to 18/11/96. Four seasons have been distinguished that are in accordance with statistics on gauge data.

2.3 Exploitation of qualitative information : rain type identification

Analysing the frequency distribution of the pixel values of radar images allow to link up these images with tree typical types of rain events : homogeneous areas of low intensities, more important intensities but no detection of very heavy rainfall cells, detection of very heavy rainfall cells. Analysing the spatial distribution of the pixel values and the spatial auto-correlation of the radar images can define the form of the rainfall areas for the three types of rain (Table 1). An automatic heavy rain cell detection and classification complete this description.

The objective is to realise an on line identification of different type of rain event corresponding to different hydrological risks for the sewer network. This information is used when choosing between different sewage system management strategies : for example, optimising the protection against flooding or the reduction of rain water pollution overflows. The evolution of the type of rainfall identified produce alarm signals and can induce managers to make actions on the sewer system.

The type of rain identified has been saved for each radar image, and the maximum value of this type has been determined for each rainy day in Nancy from 1995 to 1996. Figure 3 shows the annual distribution of this maximum value (1, 2 or 3), for the radar images recorded from 03 March 1995 to 18 November 1996. Results show that it is not possible to define seasons with very heavy rainfall cells or not. Each rain event need on line identification.

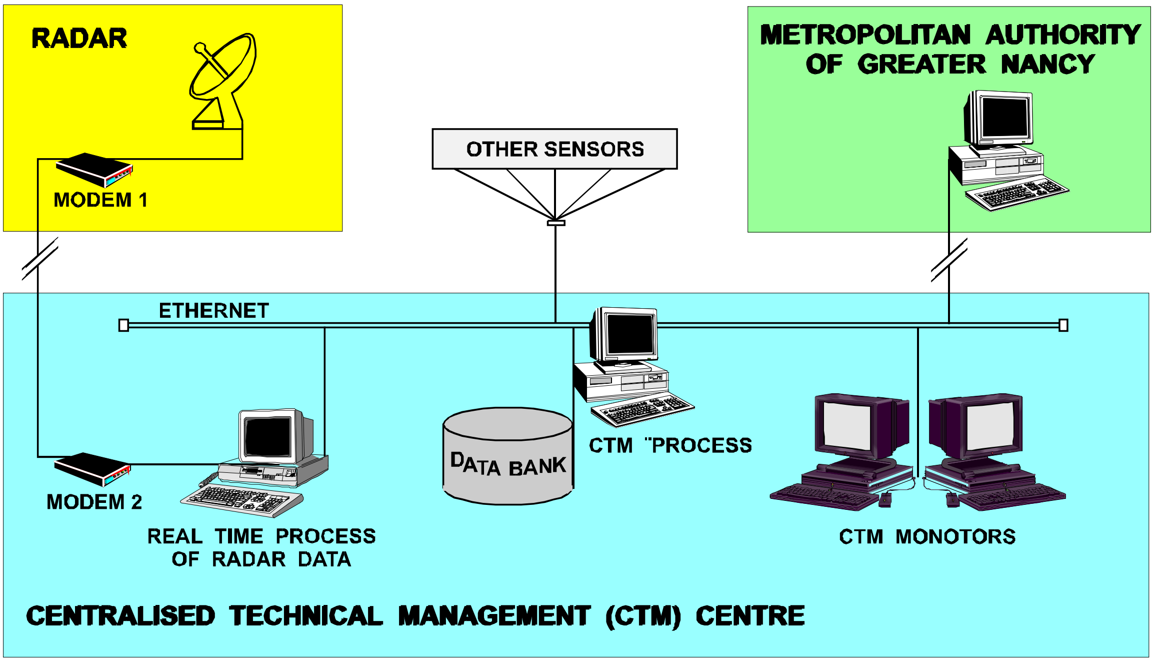

Figure 4. Integration of radar data into the Centralised Technical Management system of the Nancy Urban Community. Radar data are available in real time on the CTM monitors for the sewage network controller, and by way of the Ethernet network for the CTM managers in the metropolitan authority centre.

2.4 Anticipation of rainfall evolution over the City

A forecasting software has been developed for the managers of the sewage system of Nancy. This software, included into the real time weather radar data processing, determines rainfall displacement between two radar images for several rectangular areas covering the entire surface area of the radar images. These displacements are determined by cross-correlation between two parts of successive radar images. An original feature is the indication of a reliability value for all the identified displacements. Then, rainfall rate maps are forecast assuming that the displacements are constant for short-range forecasting (0 to 55 minutes). A limited increase or decrease in rainfall intensities is taken into consideration for the map forecasting, like the reliability values of the movement vectors. These forecast maps are used to estimate areal rainfalls over catchment areas.

A study has been carried out for estimate the limits of these radar rainfall forecasting for the sewage network management of Nancy, in particular the management of the Gentilly storm water tank (Faure et al, 1999). Although radar data monitoring improves the assessment of weather situation and allows the anticipation of rainfall evolution in operational situation, the results show that the accuracy of quantitative forecasts is limited for small urban catchment areas. For the type 3 of rain event, this limitation is very important and seems to may be attributed principally to the very important variability in space and time of rainfall rates and to the short life cycle of the heavy rainfall cells. For the smallest catchment areas, in case of wrong initial option of management, the possible forecasting range seems shorter than the time necessary to make the sewage network safe.

These results, and the feedback of the Nancy experience, have led to develop a new sewage system management strategy based on predefined management scenarios and the real time identification of the type of each rain event. This strategy, using a "potential known risk" concept defined with the assistance of the Urban Community's data bank, is close to that used by other managers of sewer networks in France (Browne et al, 1998).

3 Integration of radar data into the Centralised Technical Management system of the Nancy Urban Community

The Centralised Technical Management (CTM) centre supervises both the water supply network and the combined sewer system of the Nancy Urban Community. Every five minutes, radar data are received and treated on a personal computer. Then, radar images and real time processing results are transmitted to the CTM process as showed in figure 4. This information is used in real time by the CTM controller to monitor and forecast rainfall evolution.

Radar images and processing results are available by using the same tools as for other hydrological data, and alarms signals generated by the real time radar data processing modify the display on the CTM monitors. These signals are recorded in a specific data bank of the CTM process along with all signals and warnings coming from other sensors. Figure 5 provides an example of an operational display used on rainy days and based on four windows automatically refreshed. The upper left window plots the latest radar image received. The estimation of the ratio between gauge and radar rainfall measurements is indicated and the displacements identified are plotted with colours function of their reliability values. The upper right window presents the real time data recorded with the rain gauge network, and indicates the status of radar data reception as well as the type of rain detected. The lower left window is a control tool of the sewer network of a catchment area, which indicates the operating state of different sewage facilities and allows actions on storage facilities. The lower right window displays the signal communication status.

To complement these tools, a software developed in Nancy provides a graphic review of the latest radar images received with zoom capabilities. The determined movements of rainfall and their reliability values are displayed, as well as the anticipation of the evolution of rainfall over the Urban Community, taking into account the limitations of use defined by the research results.

4 Conclusion

This application of weather radar data has been developed in direct collaboration with the operational department in charge of sewage system management in Nancy. Its functions are directly in accordance with the operational requirements.

A main feature of the data processing is the taking into account of incertitude about data and results (about rainfall estimation in radar - rain gauge comparisons, about movement vectors in rainfall forecasting, and range forecasting limitation for very small catchment areas). This approach have conduced to take advantage of qualitative radar information as the type of rain event detected, to overstep the limits linked to the quantitative results usage.

An other characteristic is the real time integration of the processing results into the Centralised Technical Management system, That requires a continuous running with no inopportune alarms. This needs equally a real integration of radar data into the existing management tools to make easier the appropriation by the CTM controllers. For this, the limitation in use have not been masked, but has been the object of a continuous training of the technical staff. Today, after four years of utilisation, radar data have been correctly integrated in the everyday usage, and it is difficult to imagine managing sewer network without it.

At the beginning of 1999, radar data are used principally to increase security for the technical interventions into the sewer network, to alert and to call up the technical staff and the managers on duty in case of important coming storm, to confirm local alarm for the fire brigade of the Nancy Urban Community in same case, and to help the human anticipation in sewer system management facing flooding risks. An application project supported by the European Life programme is currently underway in Nancy, using radar data to secure the sewage management system. The goal is to optimise the use of an existing storage basin to conciliate flood risk management and the reduction of pollution overflows into the natural environment.

5 Acknowledgements

The development of this radar data processing form part of a major research programme carried out in partnership with the International Water Centre (NANC.I.E.), the Greater Nancy Urban Community, the Laboratoire Central des Ponts et Chaussées (LCPC), Anjou-Recherche (Générale des Eaux Group), and the Rhine-Meuse Water Agency.

The geostatistical approach used for radar - rain gauge comparisons have been inspired by research works realised by the LCPC and the Laboratoire d'étude des Transferts en Hydrologie et Environnement (LTHE).

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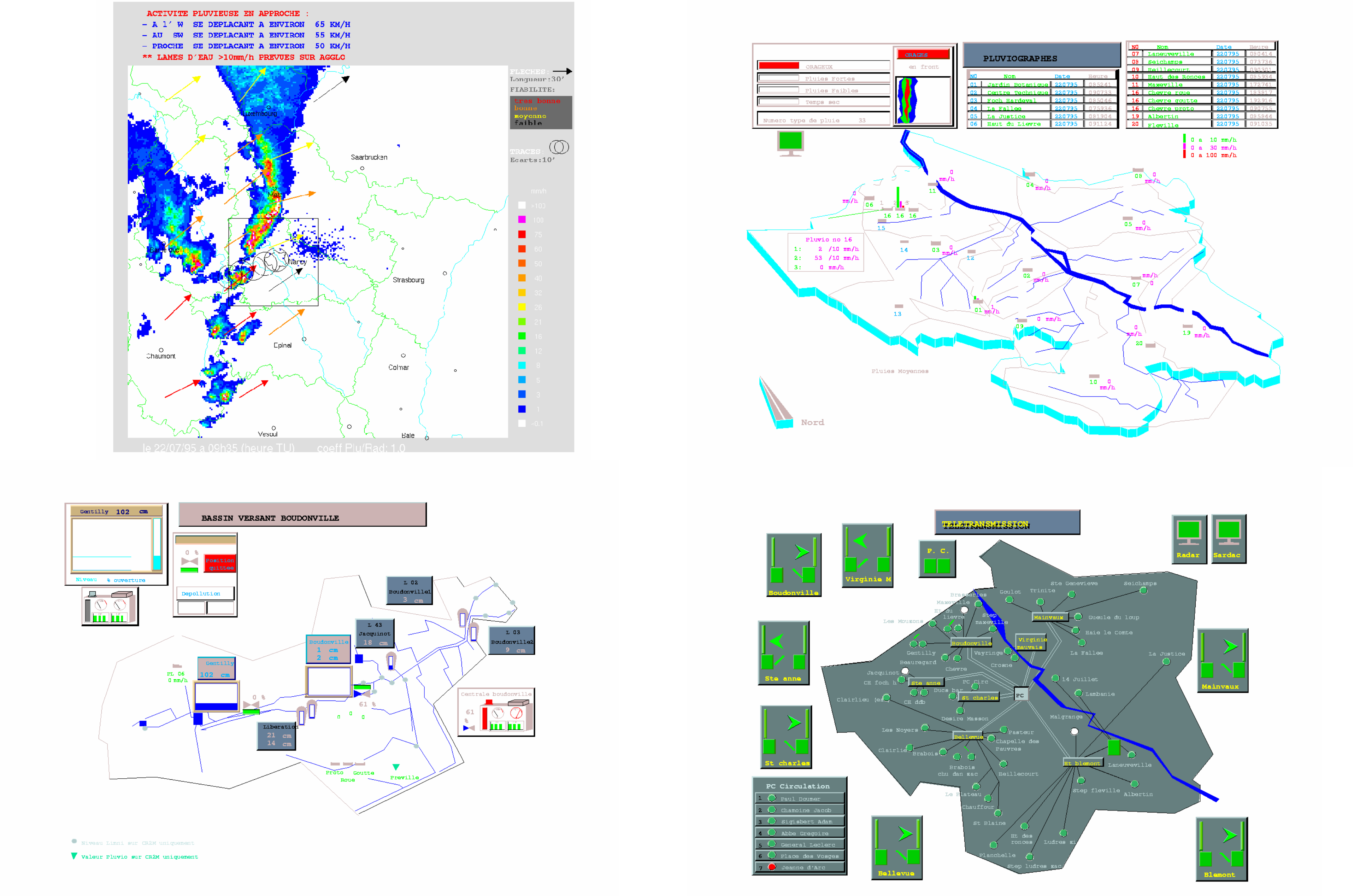

Figure 5. Example of an automatically refreshed display used on rainy days : the CTM monitor is discarded on four windows.