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OPTIMIZATION OF METEORIC WATER AND SEWAGE COLLECTING SYSTEM IN THE CENTRE OF GENOA

MAURO BOCHICCHIO
CNR at AMGA
Genoa, Italy

PAOLA LATONA
CNR at AMGA
Genoa, Italy

CRISTIANO MASCIULLI
AMGA
Genoa, Italy

An attempt in improving a urban wastewaters treatment system is presented. The analysed system is the area of Genoa historical centre, that is crossed by eight creeks draining the sub-basins of interest. The collected wastewaters and meteoric waters reach a coastal trunk sewer, that leads the sewage to a treatment plant. During a storm event, the water collected from drainage area is more than wastewater treatment plant (WWTP) capacity, and in such cases part of the water has to be discharged without any treatment into the receiving body, seriously impacting the harbour sea water. One of the objectives included into the research project carried out by AMGA Group is to model the control of a bigger water volume (e.g. through the temporary storage of water in tanks to laminate flow picks) in order to manage flood phenomena and pollution occurrences.

The first step of the research activity is aimed at collecting measured data in order to build small scale rainfall fields through the integration of traditional raingauge data with distributed radar data. The next step is aimed at simulating the hydrological response of the drained area, in order to characterize the flow and to associate it the pollutant charge. The abovementioned research activities are aimed at demonstrating how appropriate models can improve the efficiency of WWTPs through control strategies, using retention tanks (existing or going to be built) and/or devices such as pumping station and sluice gates, allowing the drainage system and the retention tanks be able to take water at the time the rainfall event is coming.

Project results are expected to be used in other Mediterranean areas, characterized by the same boundary conditions.

INTRODUCTION

Azienda Mediterranea Gas e Acqua (AMGA S.p.A.) has been active for a long time in the development of meteorological sensors: the implementation of a sensor aimed at monitoring rainfall fields started years ago with the aim of optimizing the management of urban catchments. In the framework of a new research project, a consortium has been established with two other companies based in Genoa having complementary skills and know-how for the project development: the radar specialists APELMAR KODEN Italia and the software house IBR SISTEMI. Furthermore in December 2005, to further scientific fallouts, a research group has been created by AMGA in cooperation with Consiglio Nazionale delle Ricerche (CNR) with the specific objective to define useful models for extrapolating rain fields through integration of data from the existing raingauge network with radar images.

The abovementioned team has developed the on-going research, dealing with the optimization of an integrated multi-objective system, focusing their efforts on radar hydrology application.

The most innovative aspect of this project is the type of radar chosen: it has been used a marine radar which, thanks to its widespread presence in the market, is available at much lower costs (and therefore affordable by most users) if compared with other radars usually employed in this sector. This type of radar is characterized by emissions in the X (instead of C or S) band range: it broadcasts electromagnetic waves at a frequency of 9410 MHz. The adopted model has an emission power of 12 kW ensuring coverage up to 133 km and is completed controlled digitally.

THE RADAR SYSTEM

The radar has been installed in Genoa, at Forte Begato location, in December 2005. The site has a high of 450 m. a.s.l. and it has been selected, after a thorough study, for its position over the gulf of Genoa; in spite of the local complex topography, the chosen location allows a good visibility of the historic district which is under survey with the purpose of identifying suitable management policies leading to a mitigation of heavy rainfalls in the pilot area (see Figure 1).

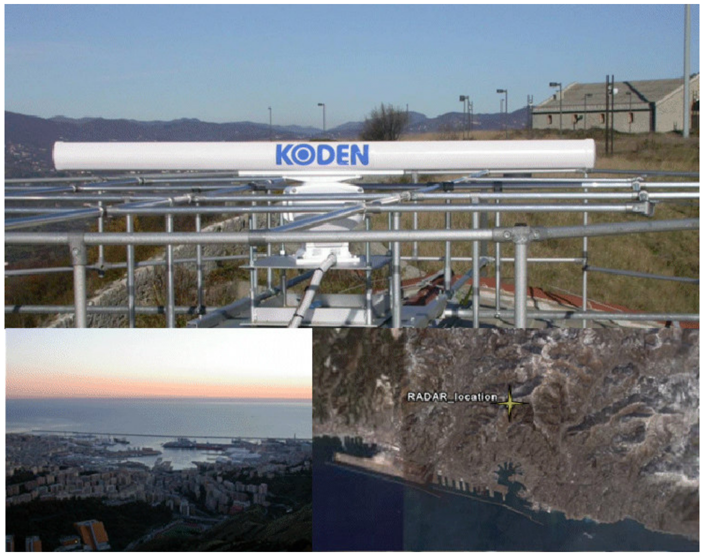

Figure 1: Radar location, Genoa sight and planimetric sight (© Google Earth)

The sensor aims at detecting rainfalls. When the signal emitted by the radar hits buildings, it generates a ground-clutter, disturbing rainfall detection.

In spite of the high installation level this effect heavily influences detections. To reduce this disturbance a filter, consisting of a metallic network with meshes lower than 1 cm ($< \frac{1}{4} \lambda$), has been situated under the antenna rotation plane. The image has been improved, even if the disturbance is always present when the radar hits mountains (mountain-clutter).

Radar calibration is characterized by different parameters to be optimized in compliance with the target.

The radar under survey is able to discriminate the reflected signal intensity on eight levels: 0 to 7, where 7 indicates that the signal exceeds the maximum threshold. The mode "gain" changes the receiving antenna sensitivity and, consequently, the maximum threshold level. Also the size of the area under survey can be modified from 0.5 up to 133 km. Exploring the sky at different distances provide important information on the approaching fronts. The interdependence between setting parameters makes complex the definition of automated setting procedures. Furthermore large coverage area setting makes view worse at closer ranges.

For these reasons a program is being developed to perform measurements under various conditions to achieve an effective image for rain field analysis.

The data amount is another important factor for analysis: the radar is able to perform up to 4096 scannings (sweep) per 1 antenna spin and to divide each sweep into 512 segments. The system takes two seconds to perform a complete spin.

System management

Logics have been introduced in radar operation. The system alternates intervals of operation and stand-by modes to collect only significant measures. The sequences of measurements collected during operation intervals allow to define averages and eliminate possible instantaneous disturbances. Furthermore it is possible to exclude signal on angular sectors that cannot, due to the presences of obstacles, provide useful information and that, for safety reasons, must not be illuminated. Introducing these techniques has involved a reduction in operating costs by prolonging the magnetron lifetime and a dramatic decrease in the amount of electromagnetic radiations.

The reflectivity signals received during the sensor operation are stored for post-processing at the AMGA Technology and Environmental Services Control Room. Post-processing of data files initially involves statistical processing. The acquired information is used to establish a correlation between images and rainfall events.

ANALYSIS OF RESULTS

Analysis of images

Since the installation of the radar sensor, two rainfall events and one snowfall event have taken place, the following synthesis describes the results of the related processing.

Let’s analyze the images of the two rainfall events happened within one-month from each other (see Figure 2 and Figure 3).

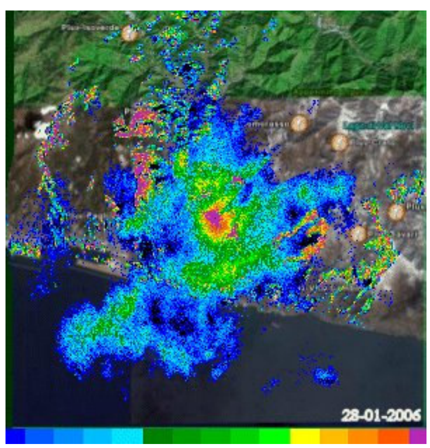

Figure 2: Frame of 28-01-2006 event.

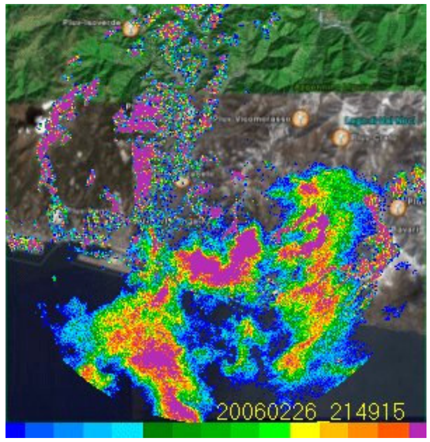

Figure 3: Frame of 26-02 -2006 event.

By comparing the two rainfall events we can observe that, the dominating color characterizing the event of 28th January 2006 is blue, which shows a low reflectivity and consequently a not very intense precipitation; on the contrary, the rainfall event of 26th February 2006 is characterized by all the colors in the range from blue (low reflectivity) to violet (maximum reflectivity). Both images show spatial irregularity and discontinuity, which are typical of the meteorological quantity under survey. This irregularity is also temporal: the rainfall structure takes different forms over very short temporal lapses.

Reflectivity data of the rainfall event have been processed and compared with data surveyed by the raingauges network. The Figure 4 shows that there is a good correspondence between observed rain and reflectivity measured by radar around the considered raingauge.

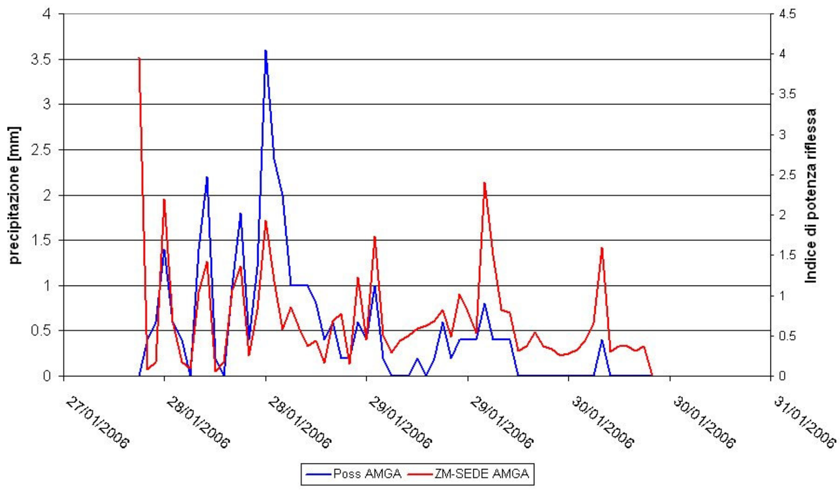

Figure 4. Raingauge data (blue line) and reflectivity (red line) comparison.

By the use of an empirical law, we have computed the rain rate from radar reflectivity, see Eq. (1), where α and β are parameters depending from the events and the station that is considered, Pcalc is calculated rain, Zr is the average reflectivity and Z_0 is a threshold value of reflectivity.

$$P_{calc} = \alpha(\exp(Z_r - Z_0))^{\beta} \qquad (1)$$

Then observed and calculated precipitation have been compared (see Figure 5). Even in this case, there is a good timing among observed rain peaks and calculated from reflectivity, using Eq. (1), with different values of gain for radar detection.

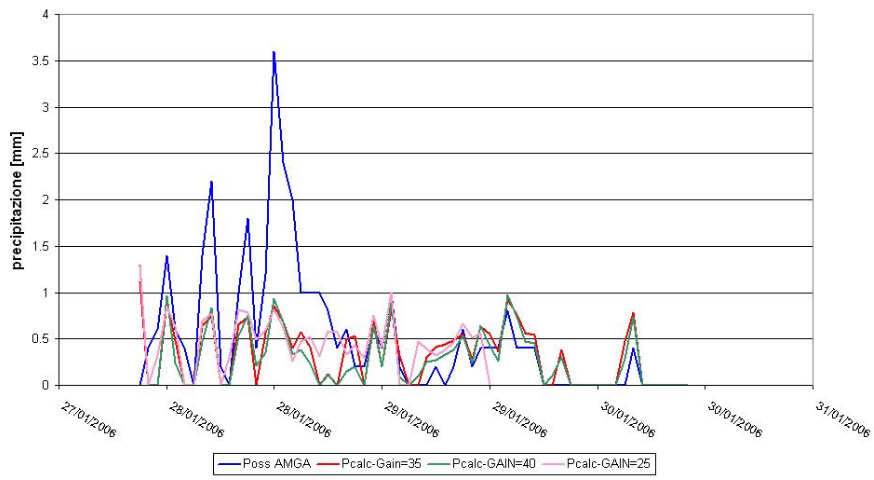

Figure 5: Comparison among raingauge data (blue line) and precipitation calculated by reflectivity at different gain.

Integration of radar data with rain-gage data is the next step of the research project : at this moment radar images are more useful for detecting rain cell location but still not for quantifying it.

Now-casting analysis

Radar maps analysis can be really useful to forecast rain structure motion. The motion of the rainfall pattern has been studied on the basis of weather radar measurement; the analysis was based on cross-correlation techniques that required no significant changes in the meteorological pattern over successive moments[1]. This hypothesis cannot always be satisfied, because of high intermittence of the rainfall field.

Only few but important steps of now casting research have been done. For studying the dynamics of the event, the rain field was approximated with an ellipsis (see Figure 6). The coefficient of covariance matrix are the central moments of inertia relating to a specific spatial distribution of point with a mass normalized in respect of the precipitation flux[2]. The model aims to calculate kinematics characteristics of ellipsis: the statistical analysis of them will lead to get information on the more probable position of the ellipsis in the next future.

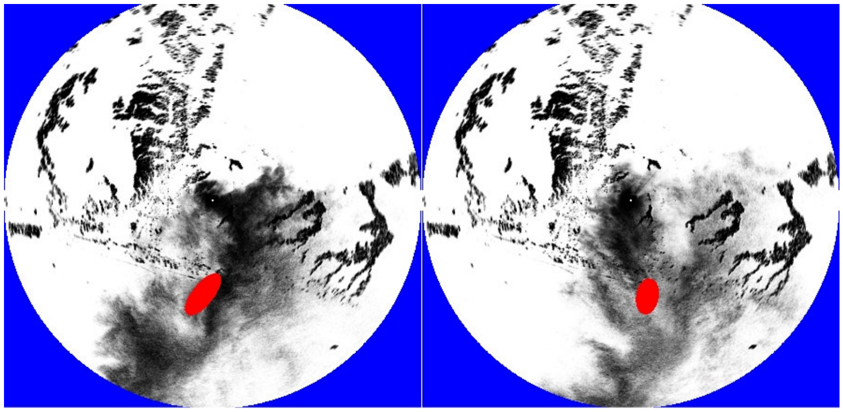

Figure 6: Ellipsis representing rainfall fields.

CONCLUSIONS

The research activity is aimed at developing a system for real-time collection and representation of data on rain fields evolution.

Furthermore the monitoring network of rainfalls and water streams in the pilot area has been updated in order to be used for real time calibration purposes operating reliable simulating models aimed at forecasting the consequent quality and quantity responses of streams.

In the future, a model to improve the urban drainage system management through simultaneous use of ground data and radar images will be developed.

Utilization of radar data for short-term forecast is a further target to be achieved.

These forecasts could be used also in case of emergency to get more detailed information on the urban territory and optimize first-aid actions during extreme meteorological events.

REFERENCES

[1] Collier C.G., "*Applications of Weather Radar Systems"*, 2nd edition, Wiley-Praxis, (1996).

[2] Ranzi R., Bacchi B., *"Analysis and forecasting of rainfall fields observed using radar"*, Advances in Distributed Hydrology, edited by Rosso R., Becchi I., Bemporad G. & A. Peano, Water Resources Publication, Fort Collins, Colorado, 1994.