by Marc Berenguer & Daniel Sempere-Torres

RAIN IN SPAIN

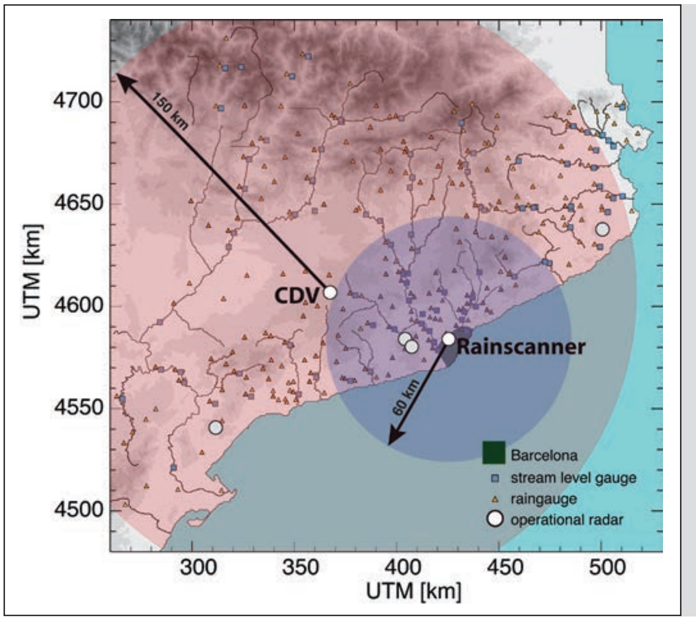
Adding value to the measurements of an X-band radar on Catalonian coast

Rainscanner@Barcelona is an experiment assessing the hydrological value of a small X-band radar in urban areas

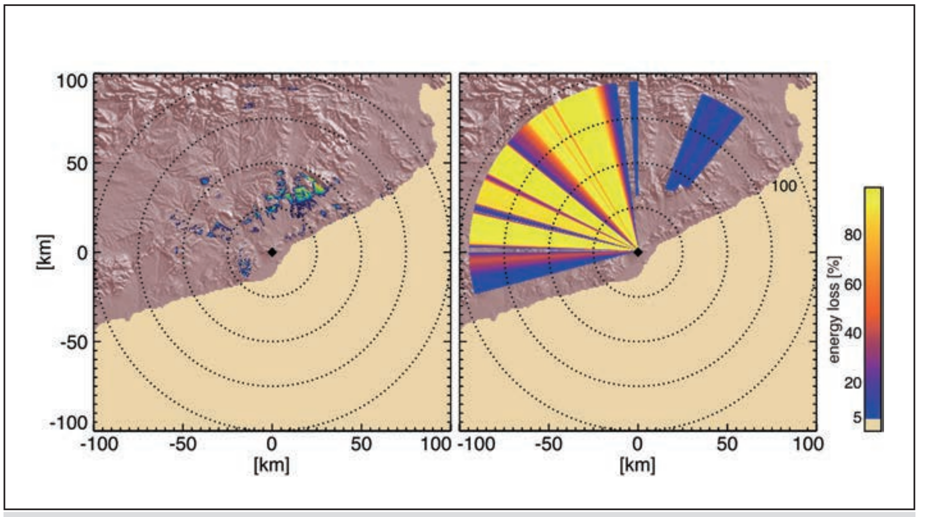
In the Mediterranean region, the rapid evolution of local thunderstorms plays a major role in the flooding of urban areas. Consequently, efficient decision-making in the context of flood control centers requires the monitoring of the high space and time variability of the rainfall affecting the fast-responding urban catchments. Traditionally, these needs have been met using telemetered rain-gauge networks (generally between one and five rain gauges per 25km^2 in urban areas). However, the cost of maintaining these networks, and the problems induced by errors in rainfall estimation, are drawbacks.

The city of Barcelona in Catalonia, Spain, is located on the coastal slopes of the Littoral mountain chain and is frequently affected by intense convective precipitation, especially at the end of summer and during autumn. These events can locally accumulate over 100mm in a few hours. The mountains (with maximum heights of around 500m AMSL) run parallel to the Mediterranean coast at a distance of about 7km. Therefore, the basins constituting the drainage network of the city show an elongated shape from the hills to the sea, with steep topographical profiles. This particular

Visibility of the X-band radar located at the Fabra Observatory (414m AMSL) over the Barcelona metropolitan area



Location and coverage of the X-band radar covering the Barcelona metropolitan area (the blue shade shows the 60km coverage of the Rainscanner unit during the experiment); the white circles show the location of the C-band radars of the network of the Catalan Weather Service (the red shaded area shows the 150km coverage of the Creu del Vent -CDV-C-band radar); the orange triangles and blue squares correspond to the location of rain and stream level gauges



Simulation of the interception of the radar beam with the terrain for the Rainscanner located at the Fabra Observatory. Left, expected ground clutter; right, expected power loss due to beam blockage. The location of the radar at the Fabra Observatory guaranteed very good visibility of the metropolitan area of Barcelona and had a blocked sector of about 120° to the northwest due to the presence of the summit of the Collserola mountain (516m AMSL)

configuration promoted the development of an urban drainage system, including pumping stations, water reservoirs, and a real-time flood warning system, to manage the rainfall events affecting the city.

This is an experiment to assess the interest of a small, low-cost X-band weather radar for quantitative precipitation estimation in an urban environment carried out in Barcelona. One of the main interests of these radars is that the high resolution of their measurements (~1 minute and ~100m) suits the needs of different applications such as rainfall monitoring or run-off forecasting in an urban context.

The experiment

The experiment was carried out between October 2011 and May 2012. During this period, an X-band radar Rainscanner RS90 (manufactured by Selex-Gematronik) was continuously operated. The radar was located in the Fabra Observatory (414m AMSL) covering the metropolitan area of Barcelona. The radar operates at a single elevation angle to produce rainfall maps with resolutions of 100m and one minute, and covers an area up to a maximum range of 60km.

The goal of the experiment was adding quantitative value to the measurements of the X-band radar to evaluate its interest for urban hydrology. With this aim, the ProRad radar-processing package developed by the Centre of Applied Research on Hydrometeorology at the Technical University of Catalonia has been adapted to the specificities of the Rainscanner radar and adjusted for the area of study.

In the evaluation of the produced high-resolution rainfall fields, data from other instruments have been used. These include the five-minute records of the rain gauge networks of CLABSA (the company in charge of managing Barcelona's sewage network) and Catalan Water Agency, and the observations of the Catalan Weather Service's CDV C-band radar (located about 60km from the Fabra Observatory). This is a regional radar of the Catalan radar network with a volumetric scanning protocol and coarser resolutions in space and time (1km and six minutes).

Quantitative precipitation estimation

The basis of the developed quantitative precipitation estimation (QPE) scheme is the ProRad radar-processing package, which is operationally implemented to generate the QPE maps of the Catalan Weather Service radar network (composed of four C-band radars).

The designed QPE production is based on a two-stage protocol. In the first stage, Rainscanner data is processed to compensate the effects of the interception of the radar beam with non-meteorological targets (mainly tall buildings and towers or the terrain): firstly, the spurious echoes appearing at the location of these targets (known as ground clutter); and secondly, a shadow-like region of systematic underestimation beyond the target due to the partial or total blockage of the beam. The ProRad package has a module to mitigate these effects. The radar measurements affected by ground clutter are identified based on the horizontal gradients of the reflectivity field and on the accumulation of reflectivity maps in dry conditions.

The reconstruction of the reflectivity field in these areas is based on horizontal interpolation. Finally, beam blockage effects are compensated considering the power loss simulated over a digital elevation model, considering the beam shape, and the power distribution within the beam.

The second processing stage consists of converting Rainscanner reflectivity observations into high-resolution surface rainfall estimates. With this aim in mind, volumetric information about the regional C-band radar has been used in several steps of the processing chain. These include: monitoring of the stability of the radar signal; the extrapolation of elevated reflectivity observations to the surface according to the vertical profile of reflectivity (VPR); and the conversion of surface reflectivity, Z, into rain rate, R. For the last two steps, a pre-classification of the type of precipitation (mainly, in the categories 'convective' and 'stratiform') based on volumetric C-band observations is implemented, which enables the

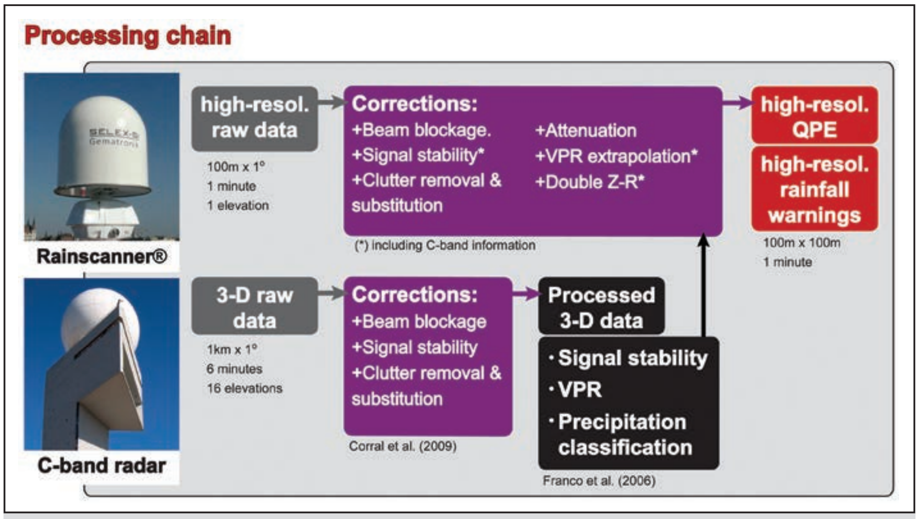
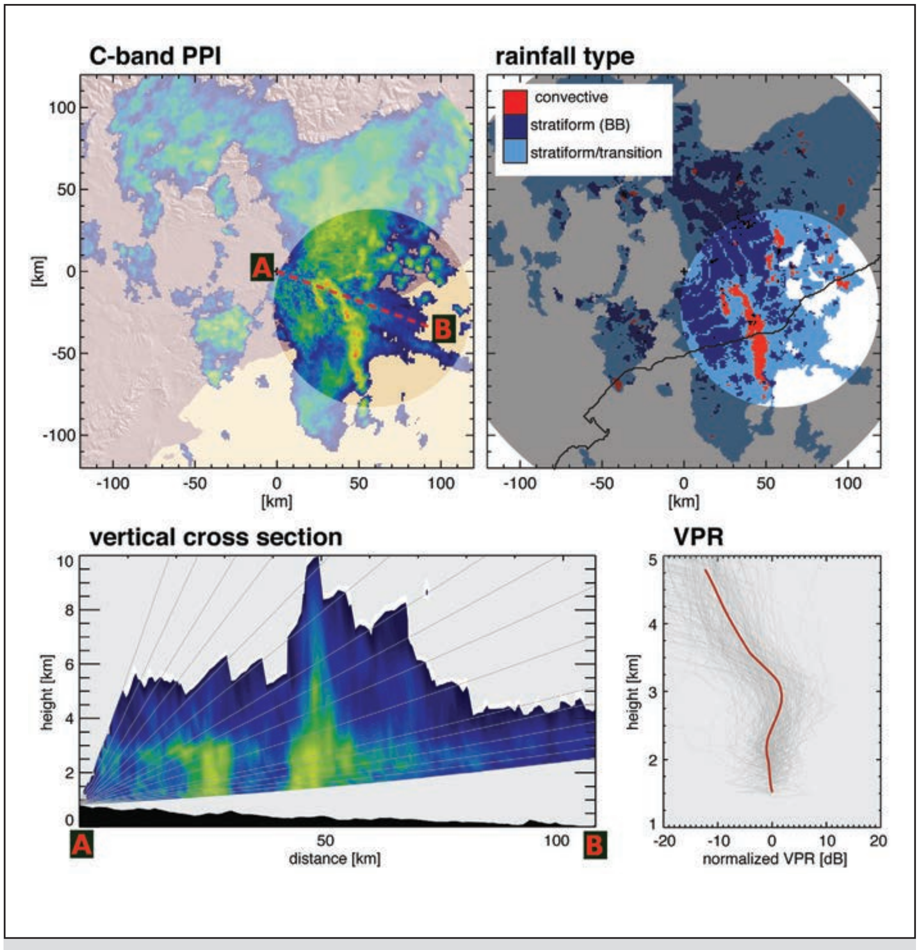


Figure 4: Scheme of the QPE system used to produce high-resolution rainfall estimates from Rainscanner observations



Volumetric C-band CDV information used in the production of high-resolution rainfall products within the ProRad processing package. Top: maps of reflectivity (left) and precipitation classification (right) corresponding to the lowest elevation of the CDV C-band radar (the non-shaded area corresponds to the Rainscanner domain). Bottom: vertical cross-section (left) and vertical profiles of reflectivity (right) of the CDV reflectivity field over the Rainscanner domain

use of VPRs and Z-R relationships representative of each type of precipitation.

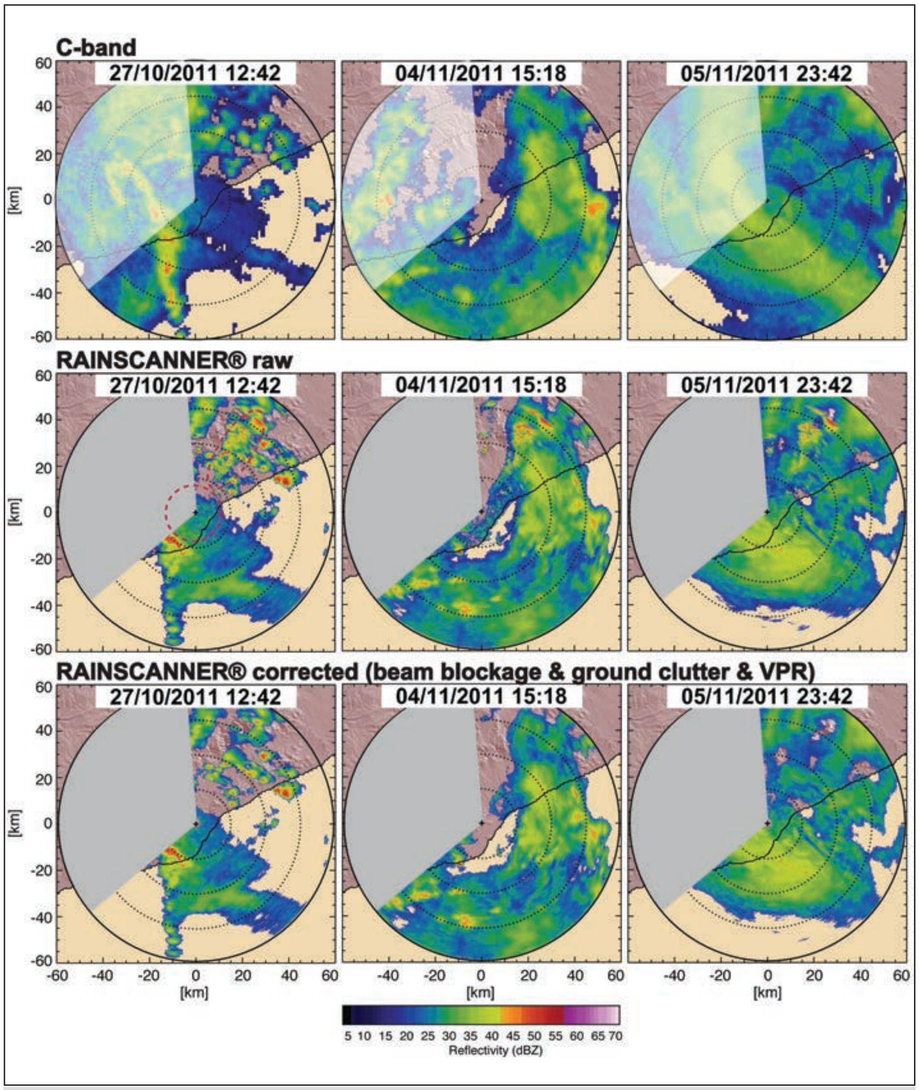
Also, a module for monitoring path attenuation of Rainscanner observations due to intense rainfall (more significant at X-band) has been implemented, especially to detect areas where total extinction occurs. The QPE products generated with the developed QPE scheme take advantage of the very high-resolution of Rainscanner observations, as well as the volumetric observations of the regional C-band radar network.

High-resolution rainfall maps

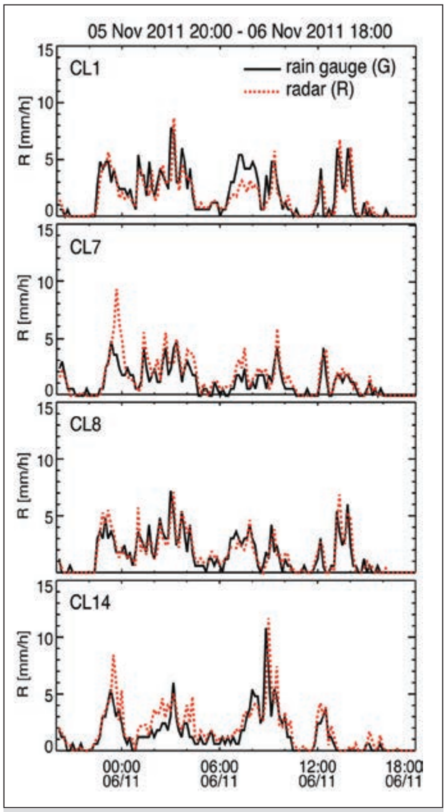
As mentioned above, the QPE scheme developed uses volumetric information of a regional C-band radar in the processing of the high resolution Rainscanner observations. The comparison of the lowest elevation PPIs for the Creu del Vent C-band radar and for the Rainscanner at Fabra Observatory over a common domain shows a clear correspondence between the reflectivity fields of the two radars (beyond the differences in their sensitivity).

The most evident differences between them can be attributed to path attenuation due to intense precipitation (particularly clear in the case of October 27, 2011). It is also very clear that the high resolution Rainscanner observations permit a more defined depiction of small convective cells and of the reflectivity gradients in the most convective situations.

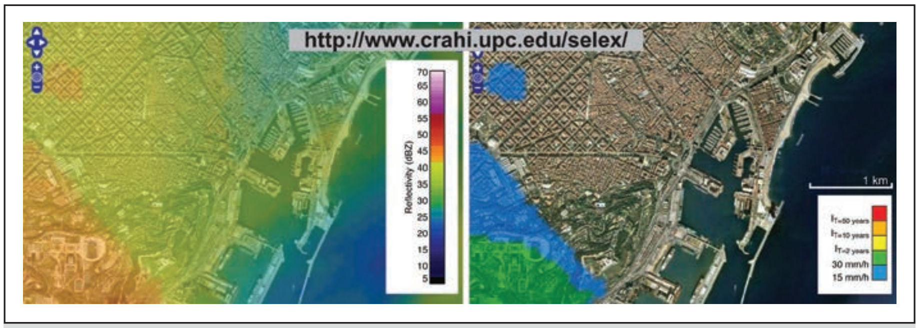
The analysis of the QPE products shows the effect of the reconstruction of the reflectivity field in the areas affected by ground clutter, as well as the effect of the extrapolation of the observations to the ground. Also, radar products show a good agreement with the observations of the rain gauge networks in the area, with the reproduction of the time



Reflectivity fields observed over the analysis domain during the period of the experiment (from left to right, October 27, November 4, November 5, 2011). Top row: lowest-elevation reflectivity maps observed with the CDV C-band radar (top row). Middle row: raw reflectivity fields observed with the Rainscanner unit at the Fabra Observatory (the dashed ellipses show the areas most affected by ground clutter). Bottom row: QPE maps after implementing the ProRad QPE scheme adapted to Rainscanner observations



Time series of rain gauge (solid black line) and Rainscanner QPE products (dotted red line) over four gauge locations within the metropolitan area of Barcelona for the rainfall event of November 5 and 6, 2011



Screen captures of the display over the city of Barcelona for the event of October 27, 2011. Left, reflectivity field; Right, rainfall warnings. The blue and green areas correspond to thresholds of 15 and 30mm/hr

variability of the estimated rainfall intensities being especially remarkable.

Rainfall warnings in an urban context

The QPE products presented above have been implemented within the framework of a warning system to support the monitoring of urban floods. The system issues different warnings according to the exceedance of rainfall thresholds, set either based on operational criteria or on the probability of exceedance. For the city of Barcelona, two intense rainfall warnings (based on empirical rainfall thresholds) and four urban flood warnings (based on the exceedance of rainfall for return periods of 5, 10, 50, and 100 years) were used. The resolution of these warnings fits the requirements of urban applications of radar QPE products, compared with the typical resolution of regional C-band radar products (of the order of 1km). ∎

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