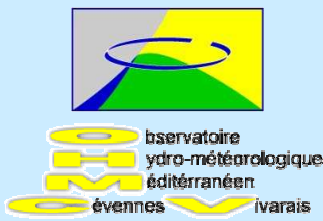


# The Bollène 2002 experiment: evaluation of processing strategies for radar QPE in the Cévennes-Vivarais region

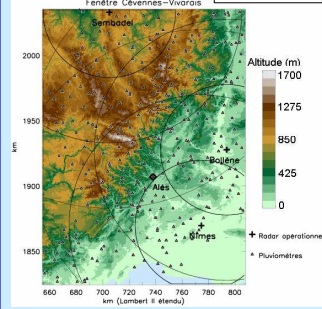
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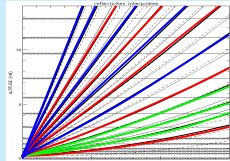


## OBSERVATION SYSTEM

The Bollène-2002 Experiment is aimed at evaluating the interest of a radar volumic scanning protocol for hydrological and meteorological applications in mountainous regions of southeastern France that are prone to intense and long lasting rain events.

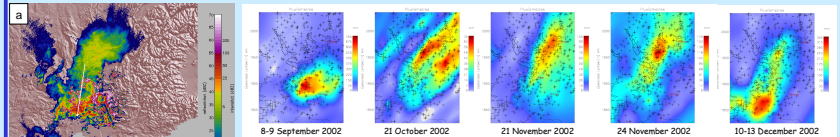


The Bollène S-band operational radar system belonging to the Météo-France ARAMIS network was operated with an experimental 2x8-elevation angle scanning protocol during the autumn 2002 (see the figure below). Networks of 400 daily rain gauges (1 per 80 km<sup>2</sup>) and 160 hourly rain gauges (1 per 200 km<sup>2</sup>) are available for validation purposes.



Experimental 2x8-elevation angle scanning protocol. Each 5 minutes protocol is represented in blue and red color. The green color correspond to the elevations used by both protocols.

## DATASET



The dataset collected is particularly rich with no less than 10 rain events that produced at least 50 mm at some location of the OHM-CV window.

The 8-9 September 2002 rain event is an exceptional rain event (Delrieu et al., 2004) with totals exceeding 200 mm over 5500 km<sup>2</sup> and reaching 700 mm in 28 hours. This catastrophic event resulted in 24 casualties and an economic damage evaluated to 1.2 billion euros. It was mainly due to a V-shape mesoscale convective system (MCS) that remained stationary during about 20 hours over the Gard region. The PPI image (a) and the vertical cut (b) show the convective and stratiform parts of the MCS at 0000 UTC on 9 September 2002. The apparent VPRs shown in (c) and (d) illustrate the spatial variations of the vertical structure of rainfall within the stratiform and convective parts of the MCS. Ground clutter is not filtered in (a) and (b) to show its strong influence at the lowest elevation angles. These last 2 features motivate the implementation of regional data processing techniques based on volume scanning protocol to improve as far as possible the quality of the 2D and 3D radar rain products.

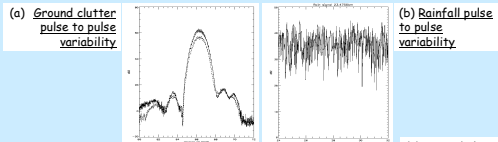
The maps of the total rain amounts observed by the daily rain gauge network for the 5 rain events selected are displayed above (note that the rain scale is different for each event). These events include a large variety of rain types: orographic rainfall, cold fronts and the 8-9 September 2002 MCS.

### References:

Delrieu, G., V. Ducrocq, E. Gaume, J. Nicol, O. Peyras, P.-E. Kirstetter, H. Andrieu, P. A. Ayrat, C. Bouvier, J. D. Creutin, M. Livet, A. Anquetin, M. Lang, L. Neppel, C. Obled, J. Parent-du-Chatelet, G. M. Saulnier, A. Wolpersdorf, and W. Wobrock, 2005: The catastrophic flash-flood event of 8-9 September 2002 in the Gard region, France: a first case study for the Cévennes-Vivarais Mediterranean Hydro-meteorological Observatory. *Journal of Hydrometeorology*, 6, 34-52.

## INNOVATIVE PROCESSING TECHNIQUES

### Dynamical ground clutter identification



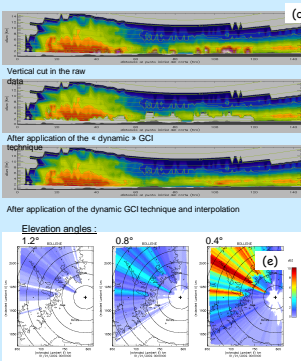
In addition to the average reflectivity, the pulse-to-pulse mean absolute difference (MAD) of the reflectivity is archived over Cartesian meshes of 1 km<sup>2</sup> (note that the radar PRF is 250 Hz and that a lapse of 5 ms is actually considered in the MAD evaluation).

A preliminary study, illustrated in (a) - (c), indicates that a selective ground clutter identification (GCI) is feasible. It relies on the MAD which reflects the degree of pulse to pulse variability and the absolute mean difference (AMD) to identify strong gradients at the ground clutter edges. These gradients result in an artificial increase of the MAD. Suitable thresholds were determined as function of the number of pulses to be averaged.

Within the Bollène 2002 Experiment, the method implemented relies on additional information collected during dry weather (magnitude, variability, occurrence of ground echoes) to increase the robustness and efficiency of the GCI.

(d) shows how the static (based only on dry weather maps) and dynamic GCI work for a vertical cut within the MCS of 8-9 September 2002. The dynamic GCI clearly preserves more information about rainfall in the convective region. An horizontal interpolation technique is found to be effective in filling the holes.

Furthermore, the masks were estimated using a Digitized Terrain Model of the region (e). PPI Pixels affected by masks greater than 2 dB are flagged as missing values. The reflectivity for smaller masks is corrected.



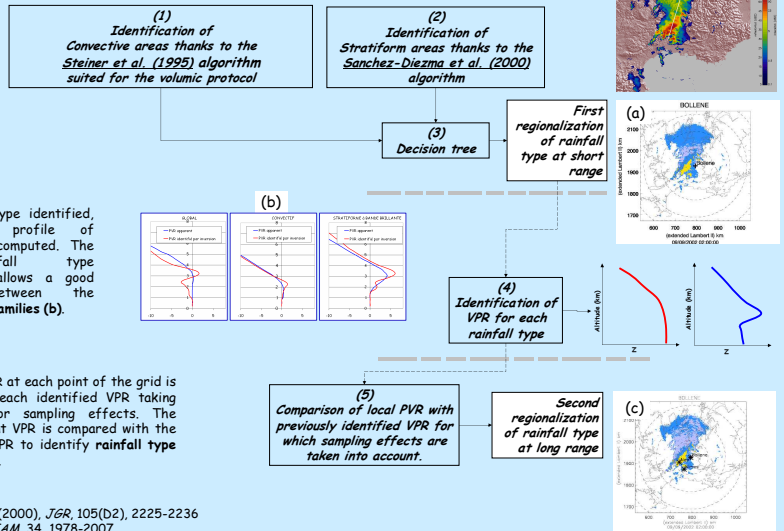
### Coupled VPR and rainfall type identification

The technique used to identify VPR and rainfall type within each individual 10 min radar volume is made of the following steps:

- 1) The **Sanchez-Diezma's algorithm** (Sanchez-Diezma et al. 1999) is used to estimate the altitude and location of an eventual bright band. Since the apparent VPRs are considered for this purpose, the location is mostly considered as a qualitative information in the following.
- 2) The **Steiner's algorithm** (Steiner et al. 1995) is applied to determine convective regions. The algorithm is applied for each individual PPI for elevation angles less than 5° rather than over a 2D composite (CAPPI for instance) like in the original version. This is aimed at avoiding mixing of vertical and horizontal gradients.
- 3) A **decision tree** is implemented in a third step to finalize the partition for each pixel in two classes: convective and non-convective. The reflectivity values along the vertical, the altitude of the bright band, the indexes of the mask and ground clutter occurrence at each elevation angle and the convective - non convective Steiner indexes are considered. (a) gives the resulting convective region (in yellow) for the case of the 09/09/2002 at 2h UTC; a bright band was identified for the pixels in light purple.

- 4) For each rain type identified, the vertical profile of reflectivity is computed. The first rainfall type regionalization allows a good distinction between the identified VPR families (b).

- 5) The apparent VPR at each point of the grid is simulated from each identified VPR taking into account for sampling effects. The obtained apparent VPR is compared with the local observed VPR to identify rainfall type at long range (c).



### References:

Sanchez-Diezma et al. (2000), *JGR*, 105(D2), 2225-2236  
Steiner et al. (1995), *JAM*, 34, 1978-2007.

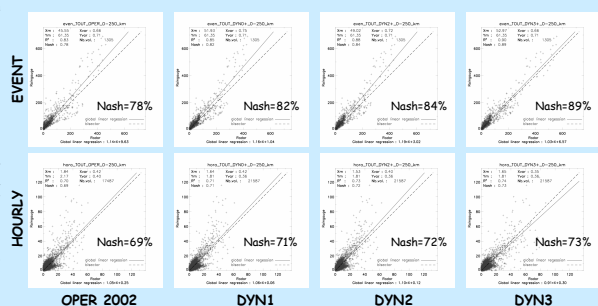
## EVALUATION

Four radar processing strategies were implemented and inter-compared with respect to the rain gauge network measurements:

OPER 2002: This strategy correspond to the processing that was operational in 2002. Basically, the GCI static method is used, the masks are corrected, no correction is done for VPR effects, the elevation-angle composition is based on radar range only (pseudo CAPPI composite), a single Z-R relationship is considered and an advection technique is applied for the temporal interpolation of the rain intensities.

The next three strategies rely on both static and dynamic information. They all use the dynamic GCI, a single Z-R relationship (so far), the Hydrologic composite technique (which is actually dynamical in that case since the VPR varies in time and eventually in space). They differ by the VPR identification method implemented. In all cases, climatological VPR is used when there is not enough information for the dynamical evaluation of the VPR:

DYN1: The apparent VPR evaluated close to the radar site (between ranges 10 and 50 km) is used for a VPR correction uniform in space.  
DYN2: The VPRs evaluated for the convective and non-convective areas over the OHM-CV window are used for a regional VPR correction.  
DYN3: Same as DYN2. Moreover suited Z-R relationships are applied for convective and non-convective areas. NEXRAD relationships (Z=300R<sup>1.4</sup> for convective rain and Z=200R<sup>1.6</sup> for others rain types) have been applied



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