Weather radar precipitation estimates vs lightning flash rates: overview of HyMeX SOP1 cases

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1 Introduction

The objective of this study is to present an overview of the first Special Observing Period (SOP 1) of the Hydrological cycle in Mediterranean Experiment (HyMeX) international programme over Catalonia (NE Spain) - see Figure 1. SOP 1 took place in autumn 2012 in the Western Mediterranean basin and the studied region was one of the target areas of the field campaign to study precipitation events during the so-called Intensive Observation Periods (IOPs) - see Ducrocq et al. (2013) for further details.

Five different IOPs are considered to examine total lightning data (cloud-to-ground CG and intra-cloud IC flashes) vs weather radar and raingauge precipitation observations over Catalonia.

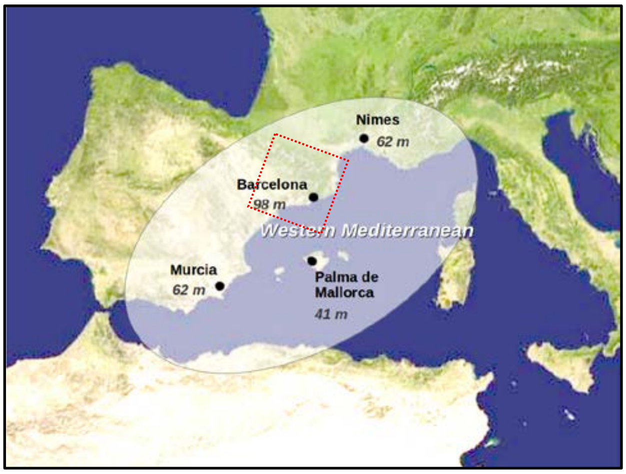

Figure 1: Region of study showing the approximate location of Catalonia (red dashed square) and the four radiosonde sites (Nimes, Barcelona, Palma de Mallorca and Murcia and heights) considered. Background map of Western Mediterranean area adapted from the HYMEX web site (http://www.hymex.org).

2 Data and Methodology

2.1 Data

Radar estimates were derived from corrected observations obtained with a C-band Doppler radar network of the Meteorological Service of Catalonia (hereafter SMC) using the EHIMI processing system (Sánchez-Diezma et al., 2002; Bech et al., 2005). Precipitation data was collected by 165 rain gauges (hereafter XEMA) covering Catalonia, also operated by the SMC.

Lightning information was collected by the SMC LS8000 (VAISALA) lightning detection system (hereafter XDDE). The detection system combines two sensors: one which works in the VHF range and another which works in the LC range, providing total lightning data (IC and CG flashes).

Four radiosonde stations in the Western Mediterranean were used to derive Total amount of Precipitable Water (TPW), atmospheric instability indices and freezing level:

- Barcelona, operated by Servei Meteorològic de Catalunya.
- Murcia, operated by Agencia Española de Meteorología (hereafter AEMET)
- Palma de Mallorca, operated by AEMET
- Nîmes-Courbessac, operated by Météo-France

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2.2 Methodology

2.2.1 Rain Gauges vs Radar

Hourly radar precipitation estimates have been compared with collocated rain gauge measurements. The statistic selected to evaluate the uncertainty of the radar quantitative precipitation estimates (QPE) products is the BIAS (Gjertsen et al., 2004) defined as follows:

$$BIAS(dB) = 10 \cdot log\left(\frac{R}{G}\right) \tag{1}$$

2.2.2 Flashes and precipitation

Circular domains of radius 3, 6 and 9 km have been defined around the rain gauges. The total amount of hourly and daily CG+, CG- and IC flashes occurring inside the domains has been recorded.

2.2.3 RLR

The relation between rainfall and lightning is usually quantified as the Rainfall-Lightning ratio (hereafter RLR). This ratio estimates the convective rainfall volume per cloud-to-ground (CG) lightning flash (Tapia et al., 1998).

The RLR has been calculated in a grid which covers Catalonia, with a grid cell size of 5kmx5km. Pixels with no lightning activity have been discarded in order to discriminate the stratiform precipitation.

2.2.4 TPW

As the radiosonde registers measurements at a finite number of levels, *TPW* is calculated as follows:

$$TPW = \frac{1}{g} \sum_{i=1}^{n} q_i \; \Delta p_i \tag{2}$$

where g is the acceleration due to gravity, n is the number of atmospheric layers considered and q_i is the mean specific humidity corresponding to atmospheric layer i with a pressure increment Δpi. The specific humidity is not a direct measurement of the radiosonde but can be written in terms of the dew point temperature (see for example Campmany et al., 2010). The total amount of precipitable water has been differentiated in two layers: low-tropospheric precipitable water and mid-tropospheric precipitable water, considering the limit between both layers at the level of 850 hPa.

3 Results

3.1 Rain Gauges vs Radar

A general underestimation of the radar precipitation estimates compared to rain gauges was found, similar to previous analysis (Trapero et al, 2009) – see Figure 2.

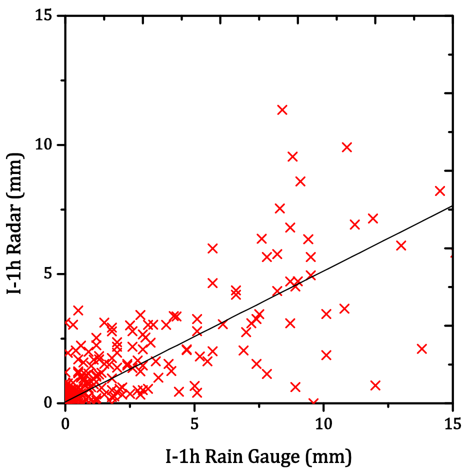

Figure 2:Hourly radar precipitation estimates vs. Hourly precipitation recorded in XEM during IOP2.

Negative biases ranging from -4.5 to -7.7 dB have been noticed between radar precipitation and rain gauges. These values have been compared with the mean BIAS calculated for each day of the year during the period 2008-2013. Lower BIASES take place during the summer season; however after 1st September the values increase significantly. Main reasons for these differences between radar QPE and gauge observations are related to the Z-R relationship used in the radar operational chain, which may not be adequate. Also the differences could be due to possible attenuation of the radar energy in extended heavy rainfall or hardware calibration issues.

3.2 Flashes and precipitation

Correlations between all type of daily flashes (IC and CG) and total rainfall accumulated aren't conclusive, neither hourly nor daily. The correlation coefficients obtained for the case studies are about R^2=0.1 – see Figure 3. Other studies for the same region show good correlations with R^2 ranging from 0.4 to 0.7 (Pineda et al., 2006; Pineda et al., 2007). However, these studies analyse the precipitation and the lightning during the summer season.

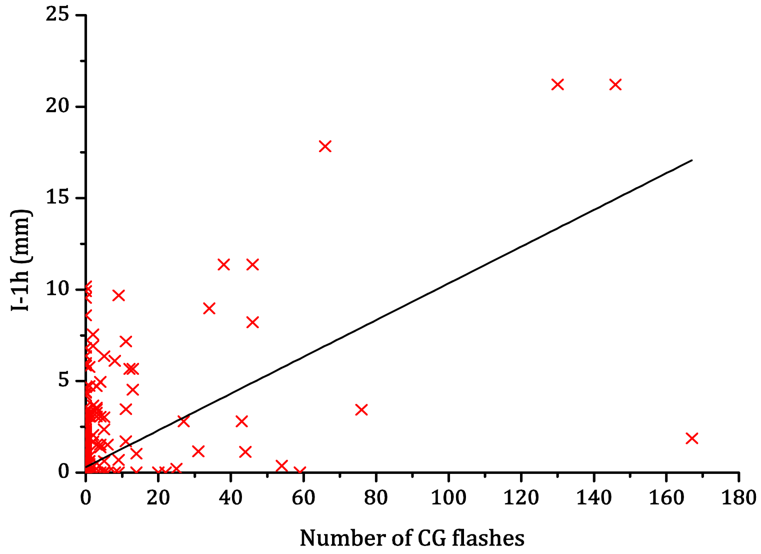

Figure 3: Hourly CG flashes recorded vs. Hourly radar precipitation estimates, in a 9km circular domain during IOP2.

3.3 RLR

The average hourly Rainfall–Lightning Ratio (RLR) was $69 \cdot 10^3$ m^3/CG flash, within the range of values found for individual thunderstorms reported previously in the literature (Kempf and Krider 2003, Pineda et al. 2007) for daily overall Rainfall-Lightning Ratio. Nevertheless, the daily overall RLR obtained was $298 \cdot 10^3$ m^3/CG flash, a value significantly higher in magnitude than those obtained in other studies. Intense storms tend to produce lower RLR values than moderate storms. It is found an increase of the RLR during the fall season, which indicates a convection regime change. Devastating flash floods occur almost every year somewhere in the Western Mediterranean basin, and these events tend to be most frequent and intense during the fall.

3.4 TPW

Average radiosonde data over the SOP1 indicated values of total precipitable water above those of the previous ten year period (0.5-1.5 standard deviations). This anomaly was much greater in mid-tropospheric levels. Low-tropospheric PW showed a more constant behaviour over time than mid-tropospheric PW - see Figure 4. Local TPW maxima were observed in soundings were the contribution of mid-tropospheric PW was exceptionally high.

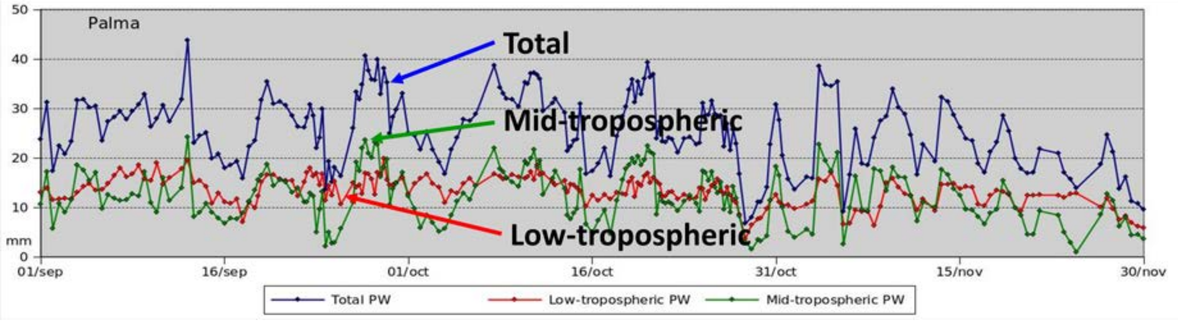

Figure 4: Evolution of TPW (mm) in Palma de Mallorca during autumn 2012.

The common behaviour observed in all stations was a decreasing trend of TPW values throughout the autumn after reaching its annual maximum at the end of summer. Even so, it is possible to identify fluctuations of such a temporal order that might be associated with synoptic scale phenomena and would be related to changes in the dominant flow direction, which determine the moisture availability as shown in Figure 5.

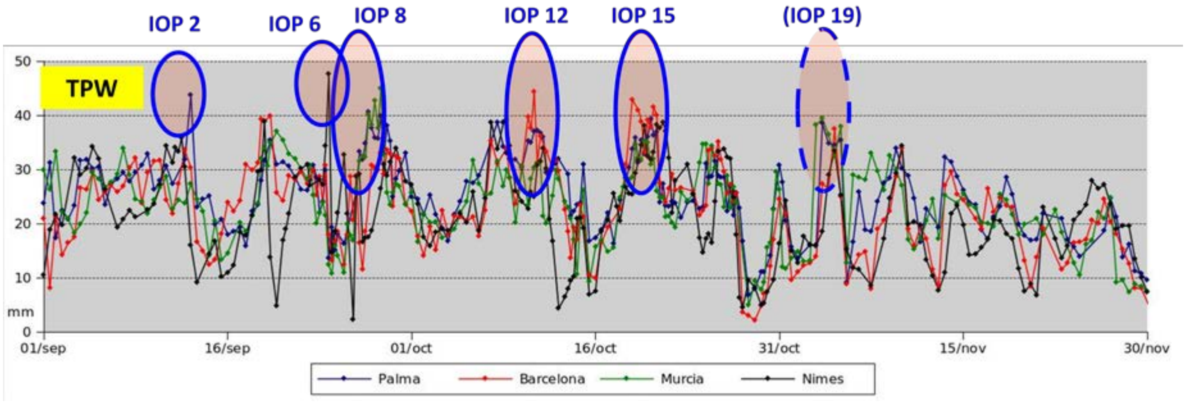

Figure 5: Evolution of TPW (mm) in the four radiosonde stations, and the Intensive Observation Periods (IOP) studied.

According to its annual cycle, the freezing level tended to decrease in autumn after presenting highest and most stable values during summer. During autumn 2012 it showed significant fluctuations due to the intrusion of cold air masses, which became more and more frequent throughout the season, related to an increase in baroclinic instability – see Figure 6.

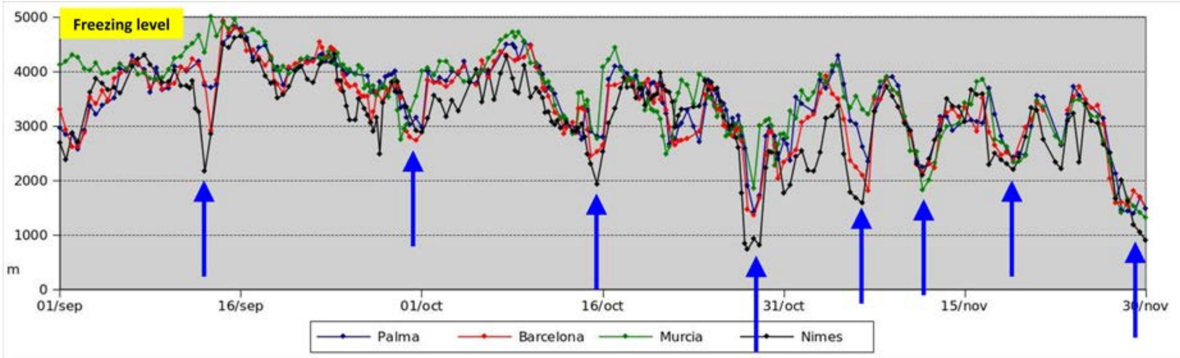

Figure 6: Evolution of freezing level (m) in the four radiosonde stations studied, highlighting with arrows the IOPs studied.

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