Flash-Flood generating storms
State of the art in the Mediterranean climate context

Sandrine Anquetin and collaborators

Laboratoire d'étude des Transferts en Hydrologie et Environnement, Grenoble, France

Sandrine.anquetin@ujf-grenoble.fr

General Context

Global warming is expected to favor larger rainfall accumulations due to the increase of water vapor content ensuing from warmer air temperature. If the increase of temperature is now fully established at both global and regional scales (IPCC, 2007), the intensification of moisture-related phenomena still presents large uncertainties in particular at regional scales. Christensen et al. (2007), for instance, reported that intense precipitation events are likely to increase over Central Europe in the winter, but that the trends over the Mediterranean basin remain uncertain due to the **complex interactions at several scales** (presence of topography; interactions and feedbacks between atmosphere – ocean – land processes) **driving Mediterranean ecosystems**.

This region has been identified as one of the two main "hot-spots" of climate change (Giorgi, 2006). Addressing the issue of rainfall evolution in a context of climate change requires **improving the regional climate understanding and, in particular, the role of the topography in the Mediterranean rainfall regime,** both in terms of ordinary and extraordinary rainfall.

Frei and Schär (1998) analyzed high-resolution rain-gauge observations of daily rainfall to produce a precipitation climatology extending from the Western Alps (i.e. Massif Central, in France) to the Eastern Alps. They demonstrated that the southeastern part of the Massif Central (i.e. **Cévennes - Vivarais**) **was one of the five rainiest areas of the region**.

As far as the extreme rainfall is concerned, Molinié et al. (2012) pointed out, on an annual average basis, that at equivalent altitudes, extreme rainfall are higher above the Cévennes-Vivarais region than above the Alps foothills. Nuissier et al. (2008) showed that there is a prevailing location (i.e. over the southeastern flanks of the mountain ranges) for intense events with daily rainfalls exceeding 200 mm.

These intense precipitating events lead to **hydrological risk**, such as flash floods that rank among the most severe natural disasters in terms of number of people affected, number of fatalities and economic losses (Ruin et al., 2008). Flash floods result from interactions between heavy precipitation generating storms, induced and/or enhanced by orography, and the catchments able to rapidly concentrate the storms water in relation with the topography. **Because global warming** will likely result in an increase of flash-flood frequency (Huntington, 2006), **there is a need to improve the understanding of flash flood generating storms and their interaction with the topography.**

Mediterranean Precipitation Structure over Orography

The presentation will focus on coastal **orographically-driven and orographically-enhanced** precipitation events in the Mediterranean region that lead to flash floods. It aims at presenting new insights concerning **the physical processes** that govern their **specific scales of variability** and their location **with respect to the mountain range**.

The amount of precipitation is related to the characteristics of the precipitating system (**intensity, duration, extension**) and **its motion**. Stationary systems likely lead to larger amounts of precipitation. Over the Cévennes – Vivarais, **two main types of stationary precipitating systems, leading to intense precipitation,** have been identified: quasi-stationary mesoscale convective systems (**MCS;** e.g. Ducrocq et al, 2008) and stationary shallow orographic convection, often organized in bands parallel to the impinging flow (called hereafter Banded Orographic Convection (**BOC**); e.g Miniscloux et al., 2001). They differ not only from their spatial scales (vertical and horizontal extents), but also by their time scale and their rainfall intensity. The duration of the MCSs is several hours while BOC systems may last one or two days. Rainfall intensities may reach several tens of $mm.h^{-1}$ in the first case while they do not exceed 10 to 15 $mm.h^{-1}$ in the second case.

For climatological issues, Molinié et al. (2012) showed that **the statistical distribution of local intense rainfall strongly depends on the accumulation time.** At daily time step, the signature of the relief is clearly visible on the maps as the maxima are concentrated along the mountain range, whereas at smaller time steps (e.g. hourly) no specific trace of the relief is observed. The authors justified this result by **the atmospheric conditions and the nature of the precipitating systems**. Intense hourly rainfall may be attributed to deep convection (MCS) whereas heavy precipitation events at the daily time step may result from long-lasting and mixed stratiform / convective precipitation (BOC). Godart et al. (2011) showed that despite the small hourly rainfall intensity during BOC events, these systems may contribute to 40% of the rainfall regime in the Cévennes-Vivarais area. Several studies characterized the atmospheric conditions prevailing during precipitation events over the Cévennes-Vivarais region (Godart et al., 2010; Ricard et al., 2011). They showed that intense precipitating events, resulting from MCS and/or BOC, are associated with complex interactions of synoptic circulation and local topography.

Since these precipitating systems directly affect **flash-flood genesis** in mountainous area, our scientific approach addresses this **continuum of precipitation systems** ranging from banded shallow convection (BOC) to stationary fully developed mesoscale convective systems (MCS). It relies on:

i) A specific **hydrometeorological observation device** (Fig.1) implementing during the HyMeX enhanced observation period (EOP, 2010-2014; Ducrocq et al. (2013)) and the 2012 and 2013 special observation period in the French Mediterranean mountainous regions (i.e. Cévennes-Vivarais);

ii) Innovative **scaling analysis of the surface precipitation** based on statistical analysis constrained by the atmospheric physics;

iii) **Hydrometeorological numerical simulations** of precipitation events and the associated flash flood (Fig.2).

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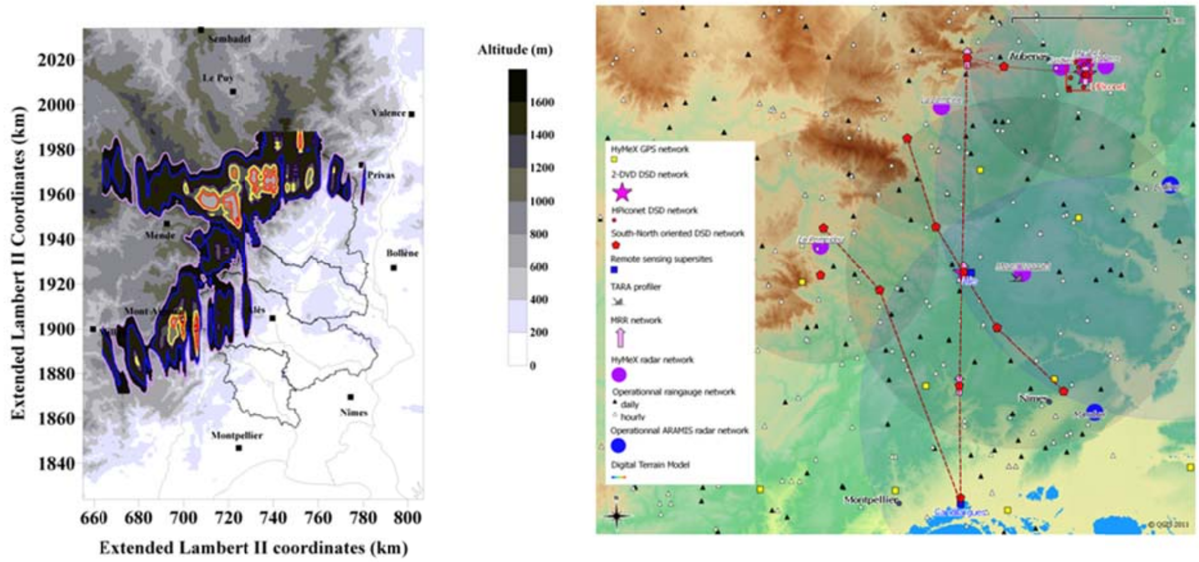

Figure 1: (left) Climatology of the orographic precipitation (Godard et al., 2011); (right) Hydrometorological observation device implemented during HyMeX.

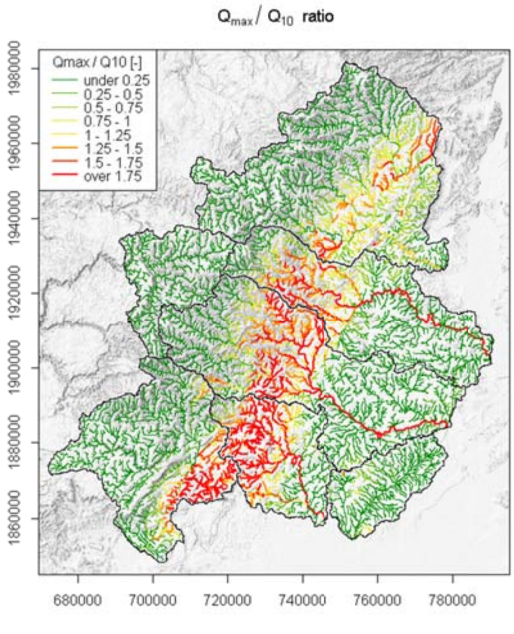

Figure 2: Ratio between the simulated maximum discharge and the 10-year return period discharge. Case of the November 2008 flash-flood event in the Cévennes-Vivarais region (Vannier, 2013)