TORRENTIAL RAIN EVENTS OVER THE CÉVENNES-VIVARAIS REGION

V. Ducrocq[1], C. Lebeaupin[1], D. Ricard[1], H. Giordani[1]

[1] Centre National de Recherches Météorologiques
Météo-France, Toulouse, France
E-mail: veronique.ducrocq@meteo.fr

Abstract: High resolution numerical simulations of recent flash-flood events that have occurred over Mediterranean coasts are used to underline the physical mechanisms leading to the stationary of the precipitating systems and the predictability associated with such events. Three cases, including the two last extreme flash-flood events over Southeastern France, have been simulated : the 12-13 November 1999 catastrophe over the Aude region (MAP IOP16), the 8-9 September 2002 flash-flood over the Gard region and the less paroxysmal event of 13-14 October 1995 over the Cévennes-Vivarais relief. Sensitivity to the initial conditions, to the Massif Central relief and to the Sea Surface Temperature (SST) has been studied.

***Keywords** – quasistationary Mesoscale Convective System, Flash-Flood, high-resolution modelling, SST*

1. INTRODUCTION

As other western Mediterranean regions, Southeastern France is prone to devastating flash-floods during the fall season. The precipitation climatology of Frei and Schär (1998) evidenced the Cévennes-Vivarais region, the southeastern part of the Massif Central, as one of the most rainy areas of the Southern Europe. In most cases, large amount of precipitation is cumulated in less than one day when a mesoscale convective system

(MCS) stays over the area during several hours. In this western Mediterranean region, the Mediterranean Sea and the orography form a strong topographic component acting on the genesis and evolution of the quasi-stationary convective systems (Fig. 1). Mediterranean Sea provides the moisture supply to the strong low-level southerly flow that impinges the low mountain range of the Massif Central; moreover the Alps and Pyrenees can produce deflection of low-level flow and convergence that favor triggering of convection upwind of the Massif Central.

The aim of the study is to examine, thanks to high-resolution MESO-NH simulations, several recent flash-flood events in order to underline the physical mechanisms leading to the stationarity of the precipitating systems as well as the predictability associated with such events. Three cases, including the two last extreme flash-flood events that occurred over Southeastern France have been simulated.

Numerous sensitivity experiments have been carried out on these cases; we provide here an illustration of the sensitivity to the initial conditions, to the sea surface temperature and to the Massif Central relief.

Figure1. Characteristics of the topography of the Cévennes-Vivarais region

2. CASE DESCRIPTION

Three heavy precipitation cases observed on October 13-14th 1995 (case A), November 12-13th 1999 (MAP IOP16, labeled as case B here) and September 8-9th 2002 (case C) have been selected . For each case, a large amount of rainfall totals can be attributed to a quasi-stationary MCS. Accumulated surface precipitation during the events reach about 260 mm for case A, 620 mm for case B and 690 mm for case C. Cases B and cases C are the two last extreme flash-flood events that Southeastern France experienced. Maximum of precipitation is located over the Massif Central foothills for case A (*see* Fig. 1 for location), whereas it is located over less mountainous areas for cases B (Aude department) and C (Gard department). Strong synoptic forcing is associated with cases B and C, whereas weaker synoptic forcing prevailed for case A. A detailed meteorological description of cases A and B are provided in Ducrocq et al (2002) and Ducrocq et al (2003), and in Delrieu et al (2004) for case C. A common characteristic of theses events are the low-level southerly jets that prevailed over the Mediterranean sea, feeding on unstable and moist air the quasi-stationary MCS (Fig. 2).

3. EXPERIMENTAL DESIGN

The numerical simulations have been performed with the MESO-NH model (Lafore et al, 1998). The model configuration considers two way interactive grids, at about 10km and 2.5 km, respectively. The characteristics of the physical package used for the two grids are the same as those described in Ducrocq et al (2002) or Lebeaupin et al (2005). Several sensitivity experiments have been carried out. The first one set considers sensitivity to initial conditions (Table 1). Experiments ARPhh (or CEPhh) start from the large scale ARPEGE or IFS analyses valid at hh, whereas experiments RADhh start from mesoscale initial conditions based on mesonet surface observations, radar reflectivity and infrared brightness temperature following Ducrocq et al (2000)'s method. For experiments AMAhh, only the surface observations analyses of Ducrocq et al (2000)'s method are applied, allowing to isolate the impacts of the low-level conditions. Results of these experiments in term of QPF are described in Ducrocq et al (2002) for cases A and B and in Ducrocq et al (2004) and Chancibault et al (2005) for cases C. The second set of experiments considers the impact of the initial SST field over the Mediterranean sea on forecast of heavy precipitating events. Experiments NOAhh use a SST field derived from NOAA satellite instead of in-situ buoys and ships data analysis used for ARPhh. The SST fields from NOAA satellite have almost the same average values over the Mediterranean basin as the in-situ SST analysis for our cases, but exhibit more mesoscale patterns. Experiments STAPxx [STAMxx] increase [decrease] the in-situ buoys and ships data analysis by xx=3K and xx=1.5 K over the Mediterranean sea. The SST is kept constant during the MESO-NH run, with a run duration typically of 18-24 hours. The impact of the Massif Central's relief is then examined through experiment ZEROhh which removes the relief of the Massif Central; other mountain ranges are kept identical as in the reference experiments.

Table 1. Characteristics of the sensitivity experiments performed on each case.

	Case A	Case B	Case C
Sensitivity to the initial conditions:			
Large scale initial conditions from ARPEGE or IFS analyses: **ARPhh** or **CEPhh**	Yes	Yes	Yes
Mesoscale initial contitions from Ducrocq et al (2000) : **RADhh**	Yes	No	Yes
Only surface observations analysis from Ducrocq et al (2000)'s initialization: **AMAhh**	Yes	No	Yes
Sensitivity to the SST:			
NOAA/AVHRR satellite SST : **NOAhh**	No	Yes	Yes
Warming/cooling of SST over the Mediteranean sea: **STAPxx/STAMxx**	No	Yes	Yes
Sensitivity to the Massif Central's relief:			
Without Massif Central range: **ZEROhh**	Yes	No	Yes

4. RESULTS

4.1 Sensitivity to the initial conditions

It is here illustrated on case C how sensitivity experiments may help to understand the physical mechanisms that lead to the stationarity of the Mesoscale Convective System at a quite unusual location. Indeed, for that case, the maximum of precipitation is located over the less mountainous areas of the Gard region rather than as often observed over the Cévennes-Vivarais foothills. Figure 3 shows a comparison of accumulated surface rainfall between the observation and the 2.5 km MESO-NH simulations. When large scale initial conditions (Exp. ARP12) are used, the model places the heavy precipitation over the Massif Central crests, whereas the most active convection was observed mainly over the upwind lower mountainous areas, resulting in an location error of the precipitation maximum of more than 80 km. When we introduce more mesoscale details into the initial state using mesonet surface observations (Exp. AMA12), more realistic precipitation fields are simulated: the heaviest precipitation is now located over the upstream lower mountainous areas, i.e. over the Gard department. Adjusting the humidity to saturation inside the convective system in formation at 12 UTC on the basis of radar and satellite data (Exp. RAD12) improves again slightly the location of the maximum of precipitation. As the AMA12 and RAD12 experiments have placed the maximum of convective activity over the Gard department, these simulation can be exploited in order to explain the location of the maximum of observed precipitation over the Gard department. Firstly, when the initial states of ARP12 and AMA12 are compared, it appears that the initial state of AMA12 is colder in the lower layers over the Gard region. This cooling is associated with the MCS that is already formed over the region at 12 UTC the 8th . The signature of the cold pool is recorded in the 2-m temperature observations that are analysed to produce the initial state of AMA12. The initial state of AMA12 differs also from the ARP12 one in the lower layers by a more intense and moist low-level south-easterly jet over the south-western regions.

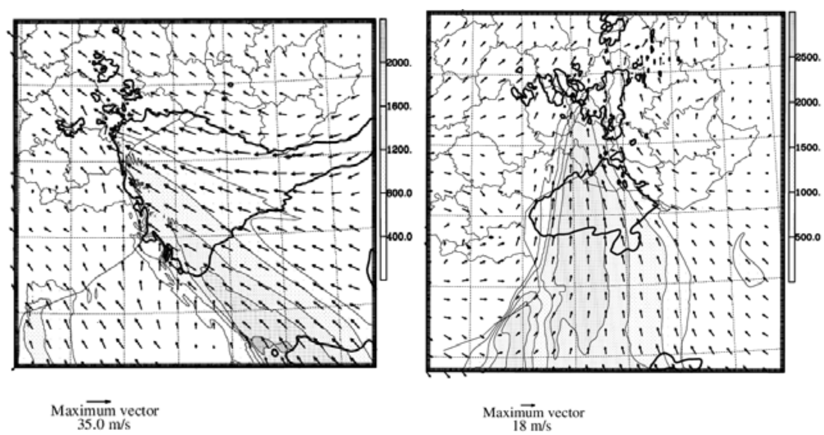

Figure 2. 30-m AGL wind vectors and CAPE (grey scale in J kg^{-1}) for: a) case B at 00 UTC, 13 November 1999 from ARP12; b) case C at 00 UTC , 9 September 2002 from ARP12. The thick line delineates area with winds greater than 12 m s^{-1}.

Although the ARP12 and AMA12 experiments share same mid-to-upper level conditions propitious to the development of a quasi-stationary MCS (i.e. slow-moving synoptic pattern, upper level divergent flow, PV anomaly approaching the area,...), only AMA12 is able to locate the maximum of precipitation at the right location. Therefore, it can be deduced that the precise location of maximum of convective activity is directly linked to the low-level mesoscale patterns, and in particular to the facing of the low-level moist and conditionally unstable jet with the cold pool generated by both the first convective cells that traveled over the region and by the MCS itself afterward.

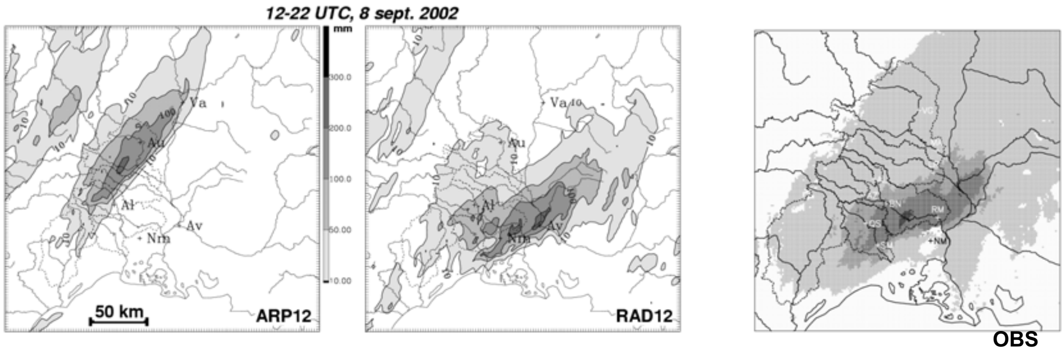

Figure 3. Case C : Cumulative surface rainfall (grey scale in mm) from 12 to 22 UTC, 8 September 2002 from : a) ARP12 Exp.; b) RAD12 Exp. ; c) radar Nîmes data.

4.2. Sensitivity to the SST

Results of the sensitivity experiments highlight that a warming of the Mediterranean SST (Exp. STAP3 and STAP1.5) increases intensity of the convection and of the maximum of accumulated surface rainfall. A warmer SST increases surface fluxes at the sea-atmosphere interface, which in turn moisten and destabilize low-levels up to 2000-3000 m. This results in an intensification of the deep convection, evidenced for example by a larger graupel content (Fig. 4). In the opposite, *i.e.* when the SST is cooled, the low-levels are less humid and less unstable. It reduces significantly the available energy for the MCS resulting in a less active convective part of the MCS (weaker graupel contents on Fig. 4) which may even disappears after a few hours. Using a higher resolution SST field (Exp. NOAhh) which has almost the same average value as the reference SST (Exp. ARPhh) has minor impacts on the convection.

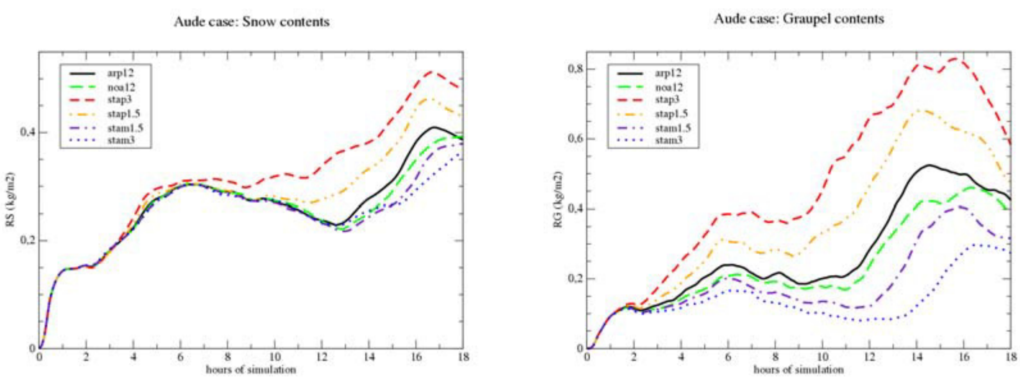

Figure 4. Case B : Temporal evolution of snow and graupel contents (in kg m^{-2}) averaged over a 3D box including the precipitating system.

4.3 Sensitivity to the Massif Central relief

When the Massif Central relief is removed (Exp. ZEROhh), the convection is suppressed for case A. The upslope triggering and enhancement of the convection by the relief of the Massif Central is made impossible. For case C, besides the triggering and enhancement of the convection by the Massif Central range, it also plays also a role in blocking the cold pool associated to the quasi-stationary MCS in the Rhone valley.

5. CONCLUSION

Although developing in a slow evolving synoptic environment propitious to quasi-stationary MCS, the precise location of the epicenter of the surface rainfall is mainly governed by mesoscale features such as converging low-level southerly jets that moisten over the Mediterranean sea and impinge the relief of the area or as blocking of the cold pools by the orography leading to the stationnarity of the low-level forcing.

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