A 5-YR CLIMATOLOGY OF MESOSCALE ENVIRONMENT ASSOCIATED WITH HEAVY PRECIPITATING EVENTS OVER SOUTHERN FRANCE.

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Abstract: In this study, a climatological approach is developed to characterize the mesoscale environment in which heavy precipitating events (HPEs) grow over a mountainous Mediterranean area. This climatology based on 3D-var mesoscale data assimilation (VARPACK ALADIN) is realized for heavy precipitating events over a 5-year period considering cases with daily precipitation greater than 150 mm between 15 August and 31 December. The analysed data are surface mesonet, radiosounding and satellite data. The guess is provided by a 6-hour ALADIN forecast.

Then, different diagnostics are used to document the time evolution of mesoscale features associated with the HPEs such as low-level jets (intensity, orientation, moisture transport ...) and other key ingredients (CAPE, Precipitable Water, moisture convergence ...). This is performed for the different phases of the life cycle which are determined from the observed hourly precipitation and lightning data. To underline differences on these diagnostics according to the localisation of precipitation, four domains are considered (Languedoc-Roussillon, Cévennes-Vivarais, South Alps and Corsica areas). Thus, composite analyses are obtained by averaging these diagnostics for each domain.

Keywords: *ICAM, 3D-Var mesoscale analysis,heavy precipitating systems, mountainous area*

1. INTRODUCTION

Mediterranean area is regularly affected by heavy precipitating events (HPEs) potentially associated with devastating flash floods. Southern France is particularly subjected to this risk. The configuration of this area is propitious for triggering these HPEs. Indeed, the Mediterranean sea acts as a vast heat and moisture reservoir from which these systems pump their energy. Moreover, the steep orography (Massif Central, Pyrenees, South Alps) induces low-level convergence and favours upward motion.

In the course of these last years, the flagship case is without doubt the paroxysmal Gard flooding in 8-9 september 2002 that produced more than 543 mm in 24 hours. Using high-resolution simulations, Nuissier et al. (2007) and Ducrocq et al. (2007) have studied the synoptic and mesoscale features associated with this mesoscale convective system. This flooding disaster caused 23 casualties and more than 1.2 billions euros damages. Without reaching this destructive level, many other severe HPEs occurred over this area during these last years. A climatology approach is used here to describe the mesoscale environment in which these systems grow. Different diagnostics are used to document the time evolution of mesoscale features associated with these HPEs (Lin et al., 2001; Ricard, 2005) such as low-level jets (intensity, orientation, moisture transport ...) and other key ingredients (CAPE, Precipitable Water, moisture convergence ...).

2. DATA AND METHOD

2.1 HPEs Database

As a first step a database of HPEs has been elaborated. We select the precipitating systems with daily precipitation more than 150 mm that occurred over southern France between the 15 August and 31 December for a 5-year period (2002-2006). We focus on the autumn period because the HPEs mostly occur during this season. Hourly raingauges and lightning data are used to examine the life cycle of each event and determine its different phases (initiating, mature and dissipation phases). For the heaviest precipitation events ($\geq$ 200 mm/day), the mature stage occurs more frequently in the morning and the dissipation stage in the first part of the night. The mean duration is about 29 hours (ranging from 13 to 58 hours). Compared to the climatology over a 40-yr period (1967-2006) (Fig. 1a) the monthly distribution for the five last years (2002-2006) (Fig.1b) highlights also a peak occurrence for HPEs ($\geq$150 mm/day) in October. Table 1 shows the number of precipitating events with daily precipitation superior to 150 mm and 200 mm. Over the 2002-2006 period, there are 23 days [50 days] with daily precipitation superior to 200 mm [to 150 mm]. There is a great interannual variability with an annual mean of about 4 days above 200 mm and 10 days above 150 mm. Indeed, the year 2003 totals the larger number of cases, contrary to the year 2004 that totals the weakest number. There is an increase for the 5 last years compared to the entire 40-yr period.

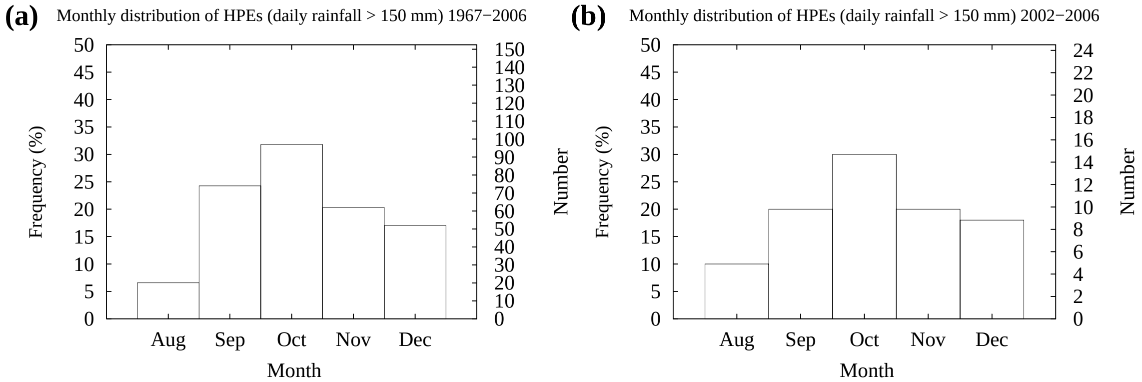

Figure 1: Monthly distribution between 15 August and 31 December of precipitating events with daily rainfall superior to 150 mm over 1967-2006 (left) and over 2002-2006 (right).

Table 1: Yearly distribution of days with daily rainfall superior to 150 mm or 200 mm (between 15 August and 31 December), the distribution (and mean) over 2002-2006 and 1967-2006 periods is also displayed.

Daily rainfall	2002	2003	2004	2005	2006	2002-2006 (mean)	1967-2006 (mean)
$\geq$ 150 mm	8	15	5	9	13	50 (10)	305 (7.6)
$\geq$ 200 mm	3	8	2	5	5	23 (4.6)	149 (3.7)

2.2 Mesoscale analyses

In a second step, 3D-Var mesoscale analyses (VARPACK ALADIN) (Auger, 2005), with a resolution of around 10 km, are performed for each HPE. The guess is provided by a 6-hour ALADIN forecast run from a ARPEGE large scale analysis with coupling every 3 hours. The analysed data are surface mesonet (2m temperature and relative humidity, 10m winds), buoy and ship data, AMDAR-ACAR aircraft observations, wind profilers observations, radiosoundings and satellite data (QuikSCAT and SEVERI from 2005). In comparison with mesocale analysis based on optimal interpolation (Calas et al., 2000), 3Dvar analysis is multivariate and enables to take into account a higher number of observations. These reanalyses, realized every six hours during the life cycle of HPEs allow to document the time evolution of key parameters and to characterize the mesocale environment associated with HPEs. Composite analysis is performed with all HPEs during the different phases. Then, in function of the location of heavy rainfall, four domains are considered: Languedoc-Roussillon(LR), Cévennes-Vivarais (CV), South Alps (SA) and Corsica (C) areas. Composite analyses are also performed for each domain.

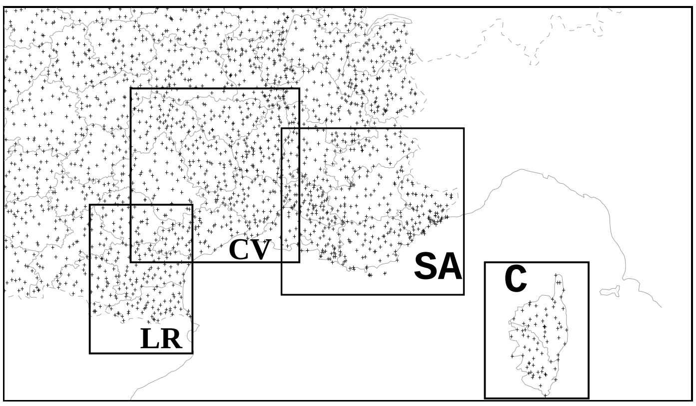

Figure 2: Location of the four domains: LR (Languedoc-Roussillon), CV (Cévennes-Vivarais), South Alps (SA) and C (Corsica). Raingauge stations are represented by black crosses

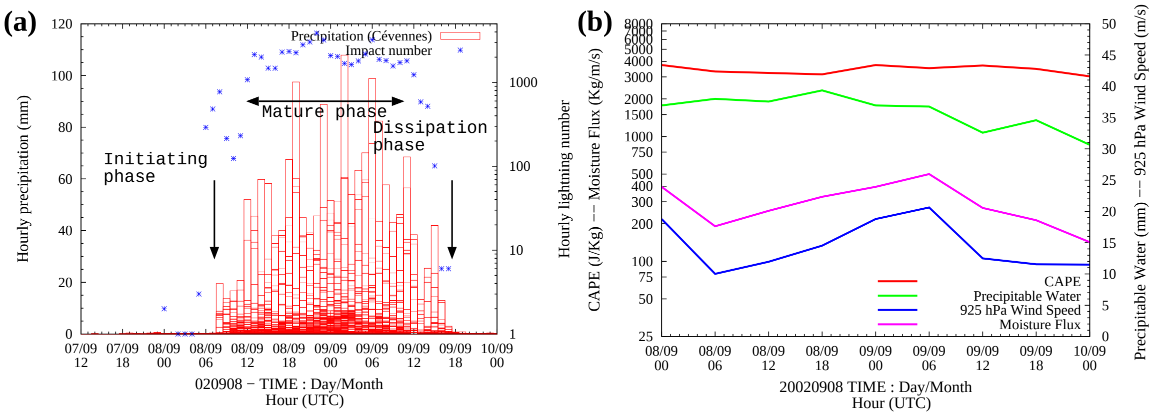

Figure 3: (a) Life cycle of a HPE (8-9 September 2002) represented by hourly rain gauges data (mm) and ligthening impact number (blue crosses). (b) Time evolution of maxima of CAPE(J/Kg), PW (mm), 925 hPa Wind speed(m/s), 1000-700 hPa integrated moisture flux(kg/m/s) during the life cycle of the HPE over the area [45N-41N,3E-8E].

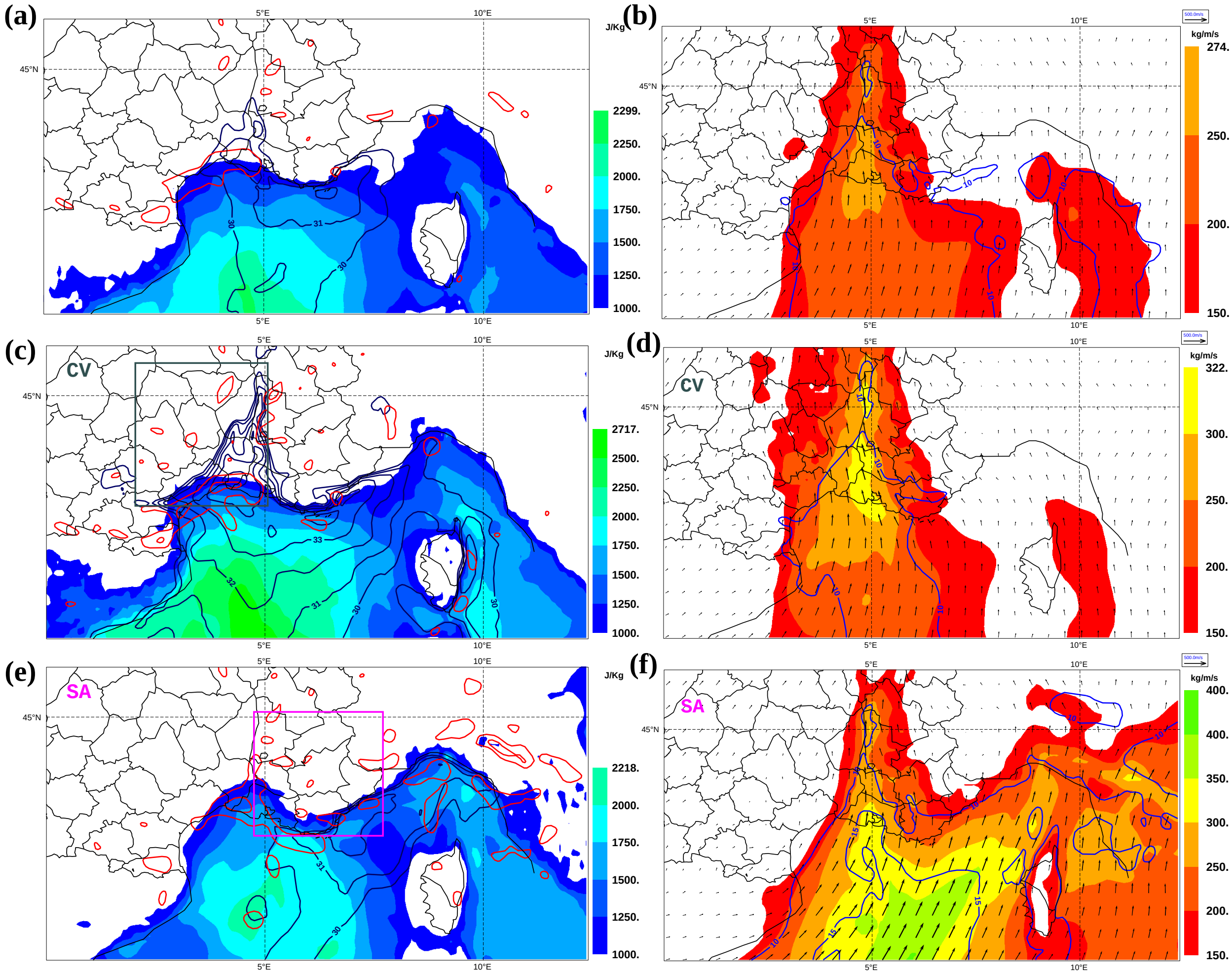

Figure 4: Composite analysis for all HPEs (at least 200 mm) over 2002-2005 (17 cases) (top), for HPEs that occurred over the CV area (middle) and SA area (bottom). Left column: CAPE (shaded contours every 250 J/Kg), precipitable water (contours every 1 mm above 30 mm; blue lines) and Moisture flux convergence (contours every 1E-6 s-1; red lines). Right column: 1000-700 hPa integrated moisture flux (shaded contours every 50 Kg/m/s), 925 hPa wind speed (contours every 5 m/s above 10 m/s; blue lines).

3. RESULTS

Figure 3a shows the life cycle of a HPE: the Gard flooding case that occurred the 8-9 September 2002. Figure 3b shows the evolution of maxima values of CAPE, PW, humidity flux and 925 hPa wind speed derived from mesoscale analyses. During this event, CAPE values remain high. PW has a high value during the initiating phase, it increases slowly during the development phase and reaches a maximum around 18 UTC the 08 September, then it slowly decreases. The moisture flux increases with the acceleration of the low-level jet, both reach their maximum around 06 UTC the 09 September, then they decrease and the system dissipates. There is a great variability of these parameters for the different HPEs.

The composite analysis for all the heaviest PEs during their mature phase (Fig. 4a,b) over the 2002-2005 period shows that the moisture flux has a southerly orientation, the most intense flux comes from Mediterranean Sea and rushes into the Rhône Valley (between the Massif Central and the Alps). Precipitable water is higher along the coast at foothills of Cévennes and South Alps, at the entrance of the Rhône Valley and upstream over the sea. There is also an area of strong instability upstream over the sea. The low-level jet brings humidity and energy northerly.

Now, if we consider only the HPEs that affected the CV area (heavy precipitation that occurred inside the grey box in Fig. 4c) Figure 4d shows that the flux humidity is stronger than for the complete composite (Fig. 4b) due to the higher values of humidity. The southerly low-level jet has a slight east component when reaching land. Strong moisture convergence (MOCON) takes place along the foothills of the Cévennes favouring the triggering of precipitating cells.

For HPEs occurring over the South Alps area (inside the pink box in Fig. 4e), the moisture flux is more intense, this is related to a faster low-level jet ($\geq$ 15 m/s). The orientation of the jet is also different: it has a southwesterly orientation from Mediterranean Sea towards the South Alps and the Gulf of Genoa. The strip of high PW streches from the Mediterranean Sea to the Gulf of Genoa with higher values at the foothills of the Alps.

For HPEs occurring over the Languedoc-Roussillon area, the low-level jet has a southeasterly orientation with high values of MOCON and moisture flux along the Languedoc-Roussillon coast and high values of CAPE offshore (not shown).

To sum up, low-level moisture flux impinges the region where heavy rainfall occurs. Moisture and instability sources are located upstream, indeed, the moisture and instability are transported by low-level jets toward the target area. Moisture convergence is high just before reaching the target area and certainly helps with orographic forcing to trigger precipitating cells.

4. CONCLUSION

Currently, we are extending these composite analyses to precipitating events with daily rainfall superior to 150 mm over the 5-year period (2002-2006). Other diagnostics will be also considered and mesoscale features will be related to synoptic patterns. Results will be shown at the conference.

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