MEDITERRANEAN SYNOPTIC SCALE INGREDIENTS INVOLVED IN HEAVY PRECIPITATIONS EVENTS TRIGGERING OVER SOUTHERN FRANCE: A CLUSTERING APPROACH

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1. INTRODUCTION

This study is aiming at caracterizing the large scale environments favouring the Heavy Precipitation Events (HPEs) that occur over the French Mediterranean coast during the fall season.

First, the interactive links between the synoptic dynamics on the one hand and the rainfall on the other, are statiscally sampled from the present period thanks to robust reliable datasets. The different synoptic classes of situations are sorted by two automatic classifications, one from the whole variability and another from a significant rainfall set of events. Then, from one or several classes that are associated whith the HPEs we can draw up the major meteorological ingredients of these events, in terms of baroclinic intensity, low level conditions of current and moisture, or even in terms of frequencies or rain spatial distribution.

Secondly, one final objective of this work would be to investigate how these events could be modified or interact in a future climate. Therefore, we would assess, in the present period, how these classes are able to fairly discriminate the HPEs in order to detect their analogues in climate simulations. Then, it would give the opportunity to run high resolution model simulations initialized by climate model outputs to figure out the hydrometeorological impact of such extreme events in the future.

2. LOW FREQUENCY CLUSTERING

2.1 Data

The data comes from the 40 years reanalysis database available at the European Center for Medium-Range Weather Forecasting (ECMWF), ERA40 (Uppala et al., 2005), between 1958 and 2001 with a daily time step (12UTC). The geopotential height (Z) at 500 hPa has been chosen to be a fair signature of the mid-troposphere synoptic dynamics, Vautard (1990). The fields are interpolated on a 1.5˚ latitude longitude regular grid on a domain, from 24˚W to 39˚E, 25.5˚and 63˚N, wide enough to encompass the Mediterranean area and to take into account the impinging Atlantic systems and the connections with other climatic basins.

We used 480 stations from The Meteo France rainfall gauges network that covers the region. Then, we selected two sets of rainfall events : (i) 1210 Significant Rainfall Events (SREs) are defined when 2 stations at least exceeded their quantile 97%, while (ii) the HPEs are defined, in this study, with the same criterion but with the quantile 99,9%. We also checked out that these HPEs are consistent with the recommended inventories at Meteo France, Jacq (1994).

The climate simulation has been performed with the Atmospheric Oceanic Regional Climate Model (AORCM) (Somot et al., 2007) with the GICC A2 scenario. The spatial resolution are respectively 1/2˚ for the atmospheric model, and 1/8˚ for the oceanic one.

2.2 The Mediterranean Fall Weather Regimes Classification

Weather Regimes are defined here in the sense of Vautard (1990), as recurrent patterns of the low frequency part of the Z at 500 hPa. The classification algorithm is based on the dynamical clustering method as implemented by Michelangeli et al. (1995), which helps determining the most significant classification.

For the fall season (from september to december), we obtained a 7 weather regimes classification. During the winter season, a preliminary study has shown the existence of 6 weather regimes (Joly et al., 2005) (from

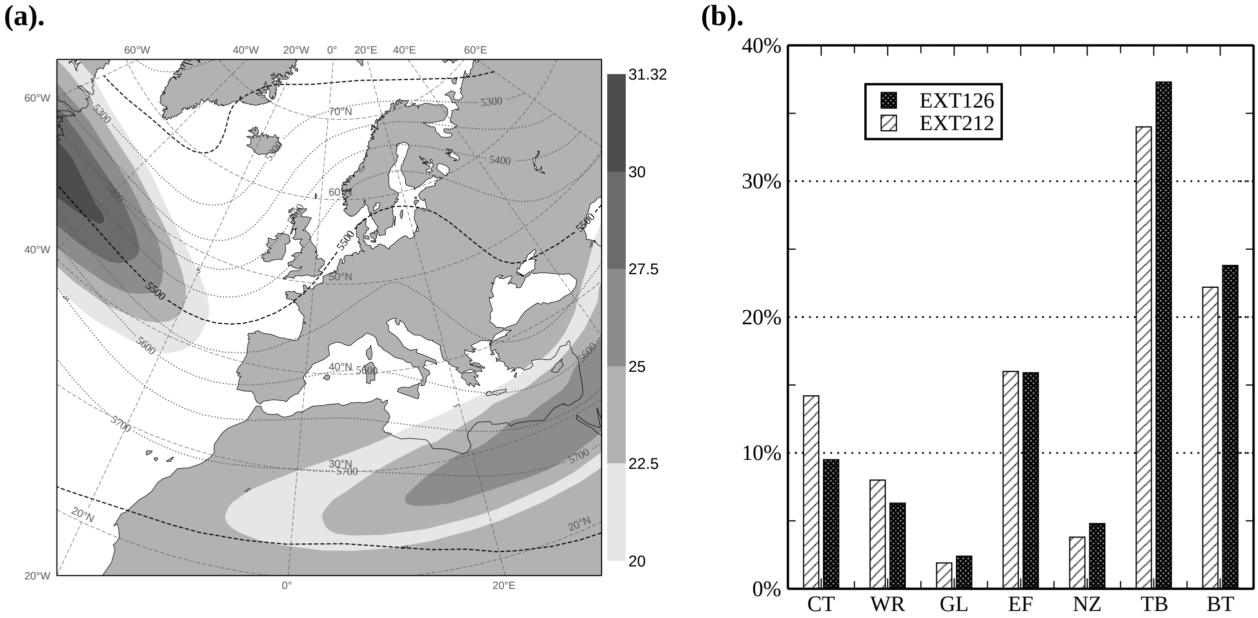

Figure 1: (a). One of the 7 Mediterranean fall weather regimes: the "Trough and Blocking" regime (the wind velocity on the 2PVU surface is in grey shadings, and the Z at 500 hPa is in grey contours) - (b). the distribution of extreme rainfall events among the Weather Regimes, for two classes of extremes one with 126 events, and a less intense one with 212 events (on the x-axis are the initials of the regimes, TB is the Trough and Blocking shown in panel (a), the y-axis are the pourcentage of extreme events included in the corresponding regime among all the extreme events).

November to March), but the two classifications differ only by an additional regime for the fall season (the other 6 are merely identical). For the winter period, since this is the season of the maximum synoptic activity over the Northern Atlantic, the links between the Mediterranean regimes and their well-known Atlantic analogues are very strong. Two Mediterranean regimes are similar to the Blocking and the Zonal ones, the four others are combining the Southern Zonal and the Atlantic Ridge. Concerning the HPEs during the winter, they were found to occur in one major regime, which has proved the low frequency organisation of the geopotential is significantly impacting the probability to have an intense rainfall event (Sanchez et al., 2007). Concerning the fall season, there are two regimes favouring the HPEs, one is presented in Fig. 1-(a). Eventhough these two regimes gather more than 60% of the extreme events (see Fig. 1-(b)), since no singular regime can be associated with these events, this discrimination potential has to be further assessed by identifying some refined organisations of the synoptic conditions for SREs days only, as performed for the Alps region in Plaut and Simmonet (2001). This is presented in section 3.

3. SIGNIFICANT RAINFALL EVENTS CLUSTERING

The classification of the Z at 500 hPa is then performed for the SREs days, and it leads to 4 classes. All the classes mean composite of the geopotential consist of a main trough roughly over western Europe, and a ridge to the East of the domain for Class 1, to the North for Class 2 and 3, and to the west for Class 4. As Class 1 and 3 are gathering most of the HPEs, one can infer the most prominent features of the synoptic forcing of the HPEs are mainly the presence of a strong baroclinic anomaly over the western coast of Europe and close to Spain, but also the amplitude of the ridge in the case of Class 1. The latter may play an important role upon the forcing of southeastern low level circulations towards the french mediterranean coast.

Of course, these mid-tropospheric conditions are not sufficient to explain the triggering and quasi-stationarity of the heavy precipitating systems. From the ERA40, we have also examined the mean values of each class of the wet-bulb potential temperature and the wind at 925 hPa (see the example for the Class 3. on Fig. 2). These composites show the existence of a strong anomaly of moist and warm air and a strong convergent south-easterly flow over the region. This is robust enough and of such a scale that these features are captured by

ERA40, and highlighted rather than smoothed by. These results compound with those obtained by numerical studies on extreme cases (Ducrocq et al. (2007b) and Nuissier et al. (2007a) among others).

(a). (b).

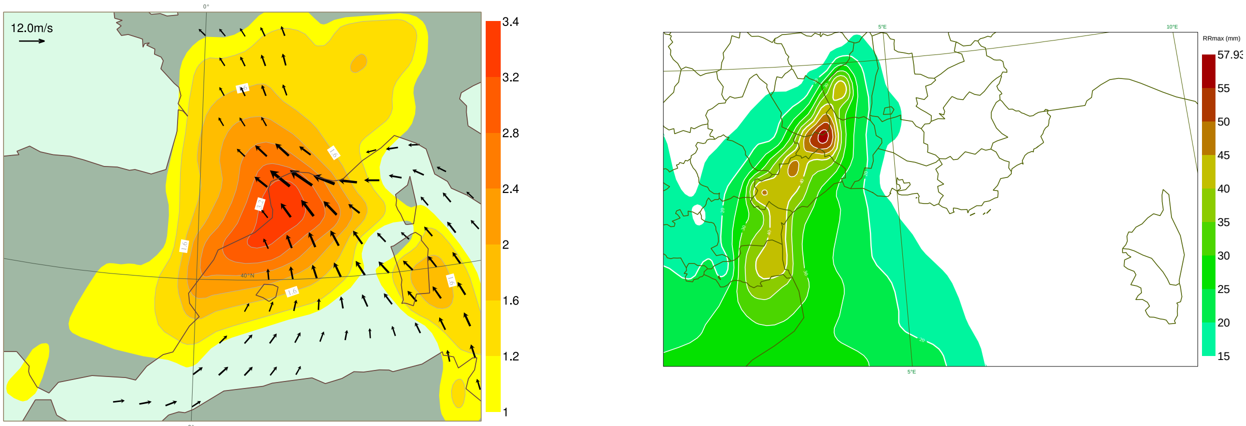

Figure 2: Low-level composites for SREs Class 3: (a). wet-bulb potential temperature anomaly (in red shadings) and the wind at 925 hPa - (b). Rainfall Meteo-France gauges composite of the HPEs days belonging to Class 3 (mm).

(a). (b).

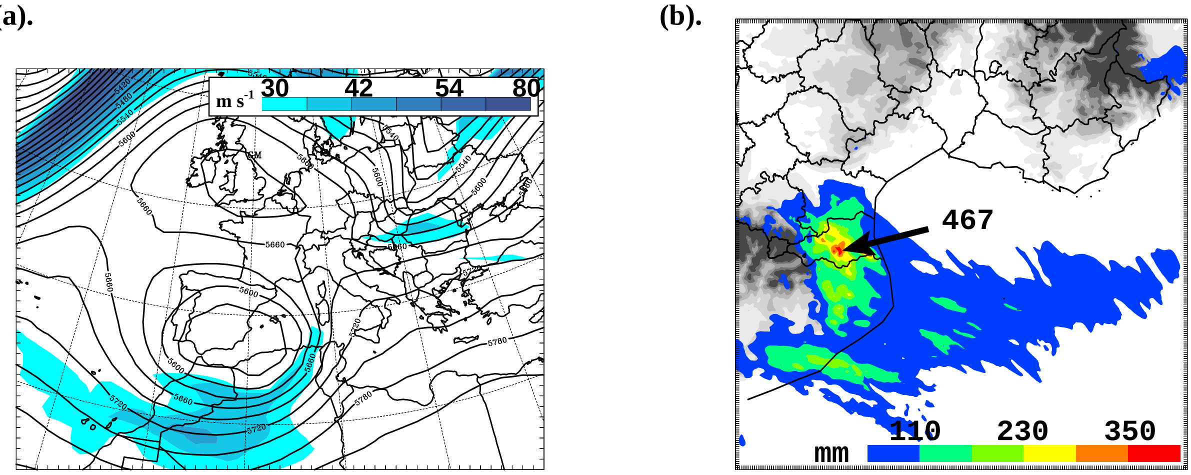

Figure 3: 500 hPa geopotential height (solid lines) and wind velocity on the 1.5PVU surface (coloured areas) from the AORCM in panel (a) and 24-h accumulated simulated rainfall from Meso-NH in panel (b).

4. CLIMATE SIMULATIONS DOWNSCALING

The French Meso-NH non-hydrostatic mesoscale numerical model Lafore et al. (1998) has been used for the simulations of HPEs from the AORCM ARPEGE - Climat /OPAMED8 Somot et al. (2007). The high-resolution numerical simulations presented here use two nested domains with nearly 2.5-km and 10-km grid meshes respectively. For these preliminary tests, the situations have been selected first from the time series of precipitations from the AORCM and then by looking at the spatial distribution of a few fields. Then, the fields from the climate model have been used as initial and boundary conditions for high-resolution simulations with the Meso-NH model. Two situations have been considered and Fig. 3 shows that one of the two cases contains similar synoptic-scale ingredients strongly favourable to heavy precipitation. The upper-level meteorological environment over the region is characterized by a strong diffluent south to south-easterly flow induced by a pronounced deep tropospheric trough located over Southeastern Spain and a ridge anchored over the British Isles. At low-levels, a southerly to easterly moderate to intense flow provides significant conditionally unstable and moist air as it moves over the Mediterranean Sea. After a 24-h integration period, the maximum rainfall reaches 467 mm over the Eastern flanks of Pyrenees, showing the ability of the Meso-NH model to simulate HPEs initialized from the AORCM fields. Furthermore, the results underline also the capability of the AORCM to reproduce propitious environmental conditions associated to HPEs.

5. CONCLUSION

In this study, we focused on the large scale environments leading to HPEs over the Southeastern mountainous region of France. First, automatic classification has been successfully applied to investigate the synoptic variability of the climatological period of such events, the fall season (September to December). The SREs clustering leads to three classes associated with HPEs, providing a set of relevant ingredients associated to the occurence of HPEs. A preliminary attempt to initialize a high-resolution numerical model with climate model ouputs has validated the downscaling approach. The next steps are to select cases automatically from the AORCM simulations using the discriminating patterns in order to study the evolution of their frequency and to perform detailed simulations of the most significant events.

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