ITEM-BY-ITEM FINAL RESPONSE (1st August 2013)

Title: Mesoscale numerical analysis of the historical November 1982 heavy precipitation event over Andorra (Eastern Pyrenees)
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We wish to thank the anonymous reviewer for their comments which have highlighted parts of our manuscript requiring further clarification and will improve the final version of the manuscript.
This document contains the answers and the relevant changes (in black) made from the suggestions and comments of the anonymous referee #1 (grey). In our response, all page and line numbers refer to the NHESSD document.

General comments

This nice paper provides an interesting analysis of a heavy rain event affecting Andorra and the surrounding regions in November 1982. The event has been divided into 4 different phases, which have been deeply analyzed in order to identify the relevant mesoscale mechanisms. The synoptic analysis is appropriate and very well organized. The description of the simulation results is also very detailed and accurate. The use of data from a geomorphological survey for the model validation is interesting and pretty new. Also, the bibliography seems appropriate in order to collocate this study in the general framework of orographic precipitation theory.

Specific comments

Figure 1: why did you choose the eastern boundary of the inner domain so close to that of the 2nd domain? In this way, some eventual unrealistic features due to the presence of the lateral boundaries may affect the area affected by precipitation in the inner domain.

The eastern border of the inner domain has been chosen sufficiently far away from the area of meteorological interest (the Pyrenees), but also avoiding to be so close of the 2nd domain (120 km) and guarantying an adequate lateral-boundary buffer zone . The model dynamics configuration of some parameters (time step, diffusion …) has been also adjusted accordingly to the highest resolution of the inner domain. We consider that for this particular event mainly characterized by a south-westerly flow, the distance between the eastern borders as well as their location over the sea -avoiding strong forcing due to steep orography- are appropriate and do not affect the precipitation field over the studied area.

P2502L5: it is not clear how the dynamical downscaling results were generated.

The ERA-INTERIM reanalyses (~80 km) were scaled down to a 40 km grid. The dynamical downscaling has been done with the MESO-NH limited area model over a domain which covers the area of interest at 40 km horizontal resolution. This point has been clarified in the manuscript:

"The evolution between the 6 November 1982 at 12 UTC and the 7 November 1982 at 12 UTC is presented in Figure 6. The ERA-INTERIM reanalysis with approximately 80 km of horizontal resolution (Dee et al., 2011) have been used as initial and lateral boundary conditions by the

MESO-NH model and scaled down over a domain which covers Western Europe, Northern Africa and the eastern part of North Atlantic Ocean at 40 km horizontal resolution (Fig. 1a)."

P2503L19: "a surface convergence zone was formed". Looking at Fig. 6b, I found some analogies with the Aude case discussed in Nuisser et al. (2008), in particular with Fig. 19c. I think that the paper would gain in generality by analyzing the similarities with other case studies, like the Aude case, in the area, as you partially already did in the Conclusions.

There are some similarities between this HPE and the Aude case, especially during phase 2, when a convective system affected the Eastern edge of the Pyrenees. During this stage a SE low level jet and a convergence zone of warm and humid air advected from the Balearic Islands feeding the convective activity. In order to reflect this similarity, a sentence has been added in Section 4.2 (Phase 2)

"This organized convection had some similarities with the MCS described by Nuissier et al. (2008) during the catastrophic Aude event (their figures: 7b, 19c, 24a)."

P2504L25: A spin-up time at the beginning of the simulation should be considered. Thus, since you are evaluating the rainfall in the total 48 h simulation, then I expect that the rainfall amount in the first 6-8 hours is not relevant.

Yes, you are right. Light rainfall started the 6 November at midday, allowing the simulation to have 6 hour of spin-up time to generate precipitation. Additional simulations (not showed in the article) with 12 hours of spin-up, (6 November 00 UT), were performed in order to evaluate the sensitivity to the time of the initial conditions.

P2507L6-7: "probably the rate of evaporation that rainfall suffers is underestimated. This hypothesis is based on the fact …": this part is not clear. Maybe the overestimation is just a consequence of the stronger uplift induced by mountains which are higher in the simulations than in reality?

The hypothesis that we made, as we tried to explain in the text, is based on the fact that observed precipitation on the leeward of the Pyrenees and the maximum over the ridge is fairly well estimated by the model. Therefore, we considered that the orographic uplift, the altitude of the mountain peaks and the evaporation rate in the lee side of the Pyrenees are accurately reproduced. In consequence, the rainfall overestimation in the lee valleys of Andorra would be mainly due to the higher elevation assigned by the model compared to their real altitude. Thus the precipitation suffered a rate of evaporation lower than expected.

We have slightly modified the text to clarify our hypothesis. Instead of:

"And probably the rate of evaporation that rainfall suffers is underestimated. This hypothesis is based on …"

The new text is:
"… and probably the precipitation simulated by the model suffers a rate of evaporation lower than in reality. This hypothesis is based on the fact that the model is able to reproduce approximately

the location of rainfall maxima and their altitude (close to the peaks) and also the rainfall shadow in the leeward of the Pyrenees but not in the Andorran valleys."

P2508L17: "and at the latest till 4 h after the initial time…". It is not clear the reason of this constraint.

This constraint is based on the fact that the mean SW horizontal flow was around 80 km/h. The distance covered in 4 hours is about 320 km, which guarantees that the air parcels do not go out of the 2.5 km domain.

P2509L23-24: "the orographic uplift of the conditionally unstable air mass breaking up the subsidence inversion": the orographic uplift should allow the air parcel to reach the LFC; breaking up the subsidence inversion depends on LFC and the vertical profile of temperature between LFC and the inversion, which is not related to the orographic uplift.

We agree that the sentence is not correct and wrongly relates two mechanisms. To avoid this wrong connection, the sentence has been modified according to your comments:

"the orographic uplift of the conditionally unstable air mass. Low level advection of warm air eroded the subsidence inversion and modified the lapse rate temperature profile."

P2511L24: "flow around …": you can estimate the tendency of the flow to move around or over the mountain in term of nondimensional mountain height hN/U (h maximum mountain height, N Brunt-Vaisala frequency, U wind speed -the last two calculated in the lower 1.5-2 km for an upstream sounding-). For values of this parameter approximately above 1-1.5, a "flow around" regime should be expected (Jiang, 2003; Miglietta and Buzzi, 2001)
Jiang, Q. 2003: Moist dynamics and orographic precipitation. Tellus, 55A, 301–316
Miglietta, M. M. and Buzzi, A. 2001: A numerical study of moist stratified flows over isolated topography. Tellus, 53A, 481–499

We agree that this non-dimensional analysis is very interesting to characterize the interaction of the upstream flow with the mountains and its tendency (flow over or around). In fact, in a recent previous work (Trapero et al., 2013) we have started to apply this kind of analysis and examine the complexity of applying theoretical results obtained from 2 and 3D idealized simulations to numerical simulations with dynamic evolving conditions over areas with complex orography as the Eastern Pyrenees. Future work will go further into this aspect and will include a non-dimensional parameter study in order to confirm our hypothesis.

Trapero, L., Bech, J., Lorente, J.: Numerical modelling of heavy precipitation events over Eastern Pyrenees: Analysis of orographic effects, Atmos. Res., 123, 368-383, ISSN 0169-8095, doi: 10.1016/j.atmosres.2012.09.014, 2013.

Additionally, we have modified the sentence in order to better localize the suggested convergence zone:
"The southerly winds that affected the Pre-Pyrenees created a local south-easterly circulation probably to flow around the Port del Compte massif (just south of Cadi range) and converge with the dominant south flow along the Segre Valley (south of Andorra)."

P2513L28: it is not clear in which way the strong wind shear enhanced vertical motion due to the interaction between vorticity and orography. Please, explain better.

The text has been modified in order to clarify the interaction of the vertical wind shear and the orography. Instead of: *"Furthermore, a distinct low level jet (LLJ) of 30 m/s around 1500 m generated a strong wind shear which contributed to enhance upward motion on the south slopes of the Pyrenees due to the interaction between horizontal vorticity and orography."*

The new text is:

"Furthermore, a distinct low level jet (LLJ) of 30 m/s around 1500 m, favouring strong vertical wind shear, generated a layer of negative horizontal vorticity. This layer interacted with the orography contributing to enhance the upward motion on the south slopes of the Pyrenees."

Technical corrections

P2496L3-4: one of the most catastrophic flash-flood events was recorded in the Eastern Pyrenees -> was recorded one of the most catastrophic flash-flood events in the Eastern Pyrenees
It has been corrected.

P2498L5: the country with the highest average elevation -> the highest country on average
It has been corrected.

P2498L12: the importance of natural hazards management in this Pyrenean country was highlighted -> it was highlighted the importance of natural hazards management in this Pyrenean country.
It has been corrected.

P2498L29: phenomena -> phenomena's
It has been corrected.

P2500L5: recognized -> recognize
It has been corrected.

P2500L24: The cloud-free dry area associated to the cold air can be also recognized in the satellite image. -> It can be also recognized in the satellite image the cloud-free dry area associated to the cold air.
It has been corrected.

P2502L3: is -> are
It has been corrected.

P2502L16: eastward -> westward
It has been corrected.

P2502L18: On -> On the
It has been corrected.

P2506L12: maxima -> maximum

It has been corrected.

P2507L1: the -> to the
It has been corrected.

P2507L3: simulation -> simulations
It has been corrected.

P2507L6: higher -> highest
It has been corrected.

P2507L16: precipitation for more
It has been added.

P2509L8: this -> these
It has been corrected.

P2509L11: These features -> This features
It has been corrected.

P2510L9: SE -> NE
It has been corrected.

Figure 12: do the dashed lines refer to regions above 1500 m elevation? Please add in the caption.
It has been added in the caption figure.

P2511L27: 10 km or 2.5 km?
It has been clarified, and 10 km has been modified by 2.5 km.

P2512L22: SW -> SO
It has been corrected.

P2513L5: wind -> winds
It has been corrected.

Figure 17: the vertical extension on Figure 17b and c is missing
The figure has been completed with the vertical dimension.

P2518L10: their -> its
It has been corrected.