POINT-BY-POINT FINAL RESPONSE REFEREE #2 (3rd October 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 going more deeply into the explanation and will improve the final version of the manuscript. One of these new points has been added as an Appendix at the end of the manuscript.

This document contains the answers and the relevant changes (in black) made from the suggestions and comments of the anonymous referee #2 (grey). In our response, all page and line numbers refer to the NHESSD document.

General comments

The paper overall is interesting and well-written, and it tackles the very important topic of the predictive ability of extreme hydro-meteorological events in complex topography areas by means of cloud-permitting numerical model simulations.

However the manuscript can be improved, in my opinion, by considering the application of the following suggestions:

a) in the "Model settings" section the choice of the microphysics scheme is poorly motivated, also in consideration of the extreme hydro-meteorological nature of the event under consideration. The same consideration holds for the convection scheme;

We have reviewed section 3.1 Model Settings to better motivate our choices considering in particular the heavy precipitation event we are studying. In particular in page 2505 line 6, we have changed the original sentence: “Both the physical and dynamical configuration of the model is based on Duffourg and Ducrocq (2011).” changed into:

“The physical and dynamical configurations of the Meso-NH model have been selected in order to best describe the microphysical and convective processes characteristic of heavy precipitation events that take place in summer or autumn in southern France, with remarkable influence of the Mediterranean Sea and of local circulations induced by complex topography. This Meso-NH model configuration was also used by Nuissier et al. (2008), Duffourg and Ducrocq (2011), Bresson et al. (2012), Fresnay et al. (2012) or Vié et al. (2012) among others.”

We also changed the following sentences

“The model microphysics is based on a 1-moment mixed microphysical scheme which combines a Kessler scheme for warm processes and a three-class ice parameterization (Caniaux et al., 1994; Pinty and Jabouille, 1998) which governs the prognostic equations of the six water species defined (water vapour, cloud water, rain water, ice, snow aggregates and graupel). The representation of hydrometeors in 5 classes allows describing precisely the water cycle and related cloud processes.”

“The sub-grid-scale effect of deep convection is parameterized for horizontal resolutions of 40 and 10 km by the Kain–Fritsch-Bechtold scheme (Bechtold, 2001), whereas for the 2.5 km inner domain no scheme for deep convection is activated as it is explicitly resolved – see for example Seity et al. (2011).”

b) again in the "Model settings" section, it is noticed that the the eastern boundary of 2.5 km domain is very close to 10 km domain eastern boundary. Can this be an issue generating non-linear spurious effects in that portion of the modeling 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 to the 2nd domain (120 km) and ensuring 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.

c) The discussion in the section "Quantitative precipitation forecast (QPF) validation" is very qualitative, despite the title. The authors do not present any quantitative intercomparison between QPF and QPE and this ampers the value and understanding of their results. I would strongly encourage to consider at least some of the ’neighborhood verification’ methods available in literature (Ebert, 2008; Weusthoff et al. 2010) and specific for high-resolution modeling results

- Ebert EE, 2008: Fuzzy verification of high-resolution gridded forecasts: A review and proposed framework, Meteor Appl,15, 51-64.
- Weusthoff T et al: 2010, Assessing the benefits of convection permitting models by Neighborhood Verification - examples from MAP D-PHASE, Mon Wea Rev, 138 (9), 3418-3433.

Following this suggestion we have considered two fuzzy verification methods described in Ebert (2008) for our QPF verification analysis: the multi-event contingency table (Atger, 2001) and the conditional square root of RPS (Germann and Zawadzki, 2004). We have commented this in section 3.2 and we have added a new Appendix with more details.

The last paragraph of section 3.2 has been modified: "Additionally, two fuzzy verification methods described in Ebert (2008) have been applied to QPF verification: the multi-event contingency table (Atger, 2001) and the conditional square root of RPS (Germann and Zawadzki, 2004). Results confirm the skill of the Meso-NH model precipitation forecast at 2.5 km in properly reproduce this heavy precipitation event over the Eastern Pyrenees – see Appendix A for details. These good results, obtained from both the qualitative and quantitative verification, ensure that the simulation is representative of the mesoscale environment that leads to this HPE."

Appendix A: fuzzy verification of the high resolution QPF.

To objectively complement the previous qualitative evaluation presented in section 3.2, two fuzzy verification techniques have been applied to 48 hour accumulation forecasts at 2.5 km spatial resolution. The validation is focused on the sub-domain of 105x100 grid boxes shown in Fig. 7. As described in Ebert (2008), opposite to traditional verifications, neighbourhood (fuzzy) verification assumes that it is acceptable for the forecast to be slightly displaced and still be useful. As we are interested in verifying the forecast in particular locations of interest (raingauge observations) two methods that follow a single observation-neighbourhood forecast strategy were chosen (Ebert, 2008): the Multi-Event contingency table (ME) and the Conditional square root of RPS (CS).

The ME method (Atger, 2001) considers a forecast useful if it predicts at least one event close to an observed event. An event is the occurrence of a value exceeding a certain threshold of rainfall intensity (i.e. mm/48h). The standard score used for that method is the Hansen and Kuipers (HK) score:

$$HK = H - F \qquad \text{(A1)}$$

where:

$$H = \frac{hits}{hits + misses} \qquad \text{(A2)}$$

$$F = \frac{false.alarms}{false.alarms + correct.rejections} \qquad \text{(A3)}$$

The HK measures the ability of the forecast system to separate the observed 'yes' cases from the 'no' cases.

The CS method (German and Zawadzki, 2004) represents the following decision model: "A useful forecast is one that has a high probability of matching the observed value". Unlike ME method, the CS includes the intensity directly into the calculation of scores instead of verifying the occurrence or probability of events. The score used is:

$$CSRR = \frac{\sqrt{RPS}}{\overline{P_{x>0}}} \tag{A4}$$

with:

$$RPS = \frac{1}{M-1}\sum_{m=1}^{M}(CDF_{y,m} - o_m)^2 \tag{A5}$$

where M is the number of forecast categories and $CDF_{y,m}$ is the cumulative probability of the forecast exceeding the threshold for category m, and o_m is an indicator (0=no, 1=yes) for the observation in category m.

A perfect forecast would have a score of 1 for HK and 0 for CSRR. Figure A1 shows the fuzzy verification results from both techniques. For ME method results vary in both intensity and spatial scale (x and y axes respectively). This approach allows us to identify the scale-intensity combination at which the highest resolution forecast performs better. CSRR results are only function of neighbourhood window size (spatial scale).

The HK score presents the highest values for extreme intensities (>250 mm) and low to moderate scales (2.5 to 27.5 km), showing the skill of the model in predicting the heaviest precipitation close (few km) to the observations. For spatial scales it is the finest grid (2.5 km) the one that achieves highest values for light and moderate intensities. It can be interpreted that at high spatial resolution the forecast predicted rain rates of similar magnitude that the observations. The large number of hits and correct rejections highlight the model performance in detecting the strong spatial gradient of precipitation over the complex topography of the study area. Finally, the CSRR confirms that it is at finest scales (2.5 km) where the best match between forecast and the observed intensity distribution is detected – see the decreasing values of CSRR with decreasing spatial scales, with a minimum at 2.5 km.

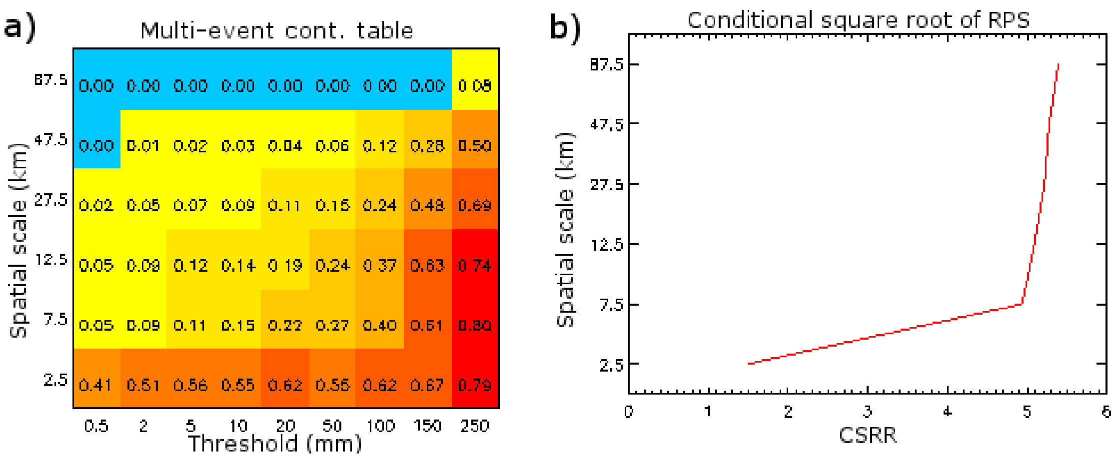

Figure A1. Fuzzy verification of the precipitation forecast shown in Figure 7. The red colours indicate good performance according to the decision model used by the ME method, while blue colours indicate poor skill.

d) In the Conclusions section the authors mention the topic of the convective timescale, based on Molini et al (2010), but they don’t provide any estimate of it. Some explanation about this decision should be provided;

The methodology proposed by Molini et al. (2011) for classifying severe rainfall events depending on the convective time scale parameter (τ) is based on gridded hourly precipitation rates derived from raingauges.
Particularly, as we have detailed in section 2.1, raingauge observations available for this heavy precipitation event only have daily temporal resolution. This factor represents the major constraint for the computation of the τ temporal evolution. Additionally, spatial interpolation of daily raingauge data over the complex orography of our study area (Pyrenees) would require an appropriate precipitation analysis, ideally with a denser raingauge network or weather radar data, which are not available.

We have slightly modified the text to point out these constraints:

“Future work which would require higher density and temporal resolution of precipitation observations could include a predictability analysis of the different event phases similarly as performed by Rebora et al. (2013), or Kiel et al. (2013).

Finally the text needs considerable editing and typesetting.

Several corrections have been made in the manuscript and they are listed below:

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

P2498L5: the country with the highest average elevation -> the highest country on average

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.

P2498L29: phenomena -> phenomena’s

P2500L5: recognized -> recognize

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.

P2502L3: is -> are

P2502L16: eastward -> westward

P2502L18: On -> On the

P2506L12: maxima -> maximum

P2507L1: the -> to the

P2507L3: simulation -> simulations

P2507L6: higher -> highest

P2507L16: precipitation for more

P2509L8: this -> these

P2509L11: These features -> This features

P2510L9: SE -> NE

P2512L22: SW -> SO

P2513L5: wind -> winds

P2518L10: their -> its