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Interactive Comment

Interactive comment on “Inclusion of potential vorticity uncertainties into a hydrometeorological forecasting chain: application to a medium size basin of Mediterranean Spain” *by* A. Amengual et al.

A. Amengual et al.

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General comments

The authors deeply appreciate the comments and suggestions on the study made by the reviewer. The referee points out the deficiencies found for some of the study cases of the hydrometeorological forecasts in correctly reproducing the localization, timing and amounts of precipitation over the Llobregat river basin. The present manuscript presents a methodology to generate a meteorological ensemble by applying the invertibility principle of Ertel potential vorticity. This technique allows us to modify the upper-level synoptic structures in the initial and boundary conditions. The manuscript discusses the advantages and limitations when applying this technique for ensemble generation as well. The main goal of the present study is to test the viability of runoff predictions driven by NWP model forecasts over a medium size basin of the Spanish Mediterranean area from an operational viewpoint, rather than to deeply examine at the process level the poorly performing forecast cases. The authors recognize that it is a highly interesting issue to address, but out of the scope of the present manuscript. In this worth to note that the performance of the deterministic NWP models' simulations for intense precipitation events depends besides on the particular NWP model used, on the initial and boundary conditions used to initialize the models, as well as on the specific meteorological features driving each particular case study.

Specific comments

1. The current study does not pursue an evaluation of the MM5 mesoscale model for predicting rainfall or other meteorological variables. These issues have been widely examined in a broad spectrum of previous studies. In particular, many studies have been devoted in the numerical study of intense precipitation events, often convectively-driven, through the MM5 model. This is a well-tested NWP model to simulate high-resolution quantitative precipitation forecasts. For further information, we refer the reviewer to the MM5 Community Model Homepage: http://www.mmm.ucar.edu/mm5/ and the referenced publications contained therein. Some examples of works dealing with the performance of the MM5 model for our study area are:

Romero, R., C. A. Doswell III, and C. Ramis, 2000: Mesoscale numerical study of two cases of long-lived quasistationary convective systems over eastern Spain. Mon. Wea. Rev., 128, 3731-3751.

Romero, R., 2001: Sensitivity of a heavy rain producing Western Mediterranean cyclone to embedded potential vorticity anomalies. Quart. J. R. Meteorol. Soc., 127, 2559-2597.

Homar, V., R. Romero, C. Ramis, and S. Alonso, 2002: Numerical study of the October

2000 torrential precipitation event over eastern Spain: Analysis of the synoptic-scale stationarity. Annales Geophysicae, 20, 2047-2066.

Homar, V., R. Romero, D. J. Stensrud, C. Ramis, and S. Alonso, 2003: Numerical diagnosis of a small, quasi-tropical cyclone over the Western Mediterranean: Dynamical vs. boundary factors. Quart. J. R. Meteorol. Soc., 129, 1469-1490.

Mariani, S., M. Casaioli, C. Accadia, M. C. Llasat, F. Pasi, S. Davolio, M. Elementi, G. Ficca, and R. Romero, 2005: A limited area model intercomparison on the "Montserrat-2000" flash-flood event using statistical and deterministic methods. Nat. Haz. and Earth. Syst. Sci., 5, 561-581.

Anquetin, S., E. Yates, V. Ducrocq, S. Samouillan, K. Chancibault, S. Davolio, C. Accadia, M. Casaioli, S. Mariani, G. Ficca, B. Gozzini, F. Pasi, M. Pasqui, A. Martín, M. Martorell, R. Romero, and P. Chessa, 2005: The 8 and 9 september 2002 flash flood event in France: A model intercomparison. Nat. Haz. and Earth. Syst. Sci., 5, 1-14.

Furthermore, the main goal of the present study is to evaluate the runoff predictions driven by MM5 mesoscale model forecasts over a medium size basin rather that to do an intercomparison among different NWP models. The authors agree with the reviewer that this is an issue of the maximum interest, but out of the scope of the present study. In fact, we are currently testing the WRF model at the Group of Meteorology. We expect than in a next future, we will be able to carry out intercomparison studies on the performance of both models by simulating other intense precipitation episodes.

It is worth to remark that the deficiencies found in forecasting the QPFs for some of the episodes under study could come from inaccuracies in the initial and boundary conditions of the ECMWF forecasts used to drive the mesoscale model. As it has been mentioned in the manuscript, the 'Montserrat' flash-flood event was studied by the authors in a previous study, but by using NCEP analyses rather than ECMWF forecasts to initialize the MM5 mesoscale model. The NWP model was found suitable to simulate the spatial and temporal scales of the high-resolution precipitation fields at the basin scale as well as the rainfall amounts. Therefore, it was possible to force in a one-way mode the hydrological model in order to reproduce in an accurate way the observed discharges.

2. The authors will include in the introduction of the revised manuscript new information and references dealing with other methods for generating NWP rainfall ensembles. However, the current study does not pursue a discussion/comparison with other methods for NWP rainfall ensemble generation, but to present the methodology to generate an EPS by applying PV perturbations in a realistic way. We will include in section 5 additional comments in order to express more clearly the methodology for calculating the PV displacements and intensity errors (see point 5).

3. We agree with the reviewer that this statement is vague and open to misinterpretation. Therefore, it will be reworded and new comments will be added in the revised paper in order to clarify its meaning. Essentially, we have tried to encompass the uncertainties found in the initial and boundary conditions of the large-scale forecasts by introducing an EPS which address the sensitivity of the hydrometeorological events to the errors in the precise representation of the upper-level precursor troughs on the synoptic scale.

4. In the technical information of the automatic pluviometric stations of the Automatic Hydrological Information System (SAIH) network of the Catalan Agency of Water (ACA) it is defined a margin of error of the equipment of 4 %. ACA carries out a set of quality control procedures for the automatic rain-gauge network, first by revising that the rainfall data registered in the databases are not wrong owing to hardware problems, which sometimes can produce anomalous values. Then, ACA makes sure that the precipitation values are comprised within a confidence range of plausible values. ACA also checks the consistency of the precipitation amounts for a fixed pluviometric station by evaluating these values with the rain-gauges around this one.

Unfortunately, the authors do not have available independent data for the case studies (such as rainfall data estimations derived from radar or satellite) to compare with. With such a dense raingauge network as the ACA system (126 stations) the derived rainfall field is believed to be superior to satellite or radar-derived fields.

The authors will provide new references in the revised manuscript for the kriging method used in the study as well as the value of the parameters used for the application of this method. To study the sensitivity of the results to the grid length chosen, we have applied the kriging interpolation method for the 16-17 November 1996 episode and for the following horizontal grid resolutions: dx = 100 m, 500 m, 1 km, 2.5 km, 5 km and 10 km. Furthermore, the mean and standard deviation corresponding to the different kriged precipitation fields have also been computed (it has not been possible to attach these figures in the interactive author comments).

dx = 100 m, mean= 62.7 mm, sd=22.3 mm

dx = 500 m, mean=62.7 mm, sd=22.2 mm

dx = 1 km, mean=62.6 mm, sd=22.2 mm

dx = 2.5 km, mean=62.4 mm, sd=22.1 mm

dx = 5 km, mean=62.0 mm, sd=22.0 mm

dx = 10 km, mean=61.4 mm, sd=21.5 mm

It can be appreciated in these figures that for horizontal grid resolutions up to 2.5 km, the interpolated precipitation fields appear to be little sensitive to the grid length. Furthermore, a degradation of the small-scale features in the gridded rainfall amounts can be observed from dx= 5 km. It appears that there is not an additional gain of information for the gridded rainfall patterns by considering grid lengths up to 2.5 km. It is worth to note that the horizontal grid resolution used to generate the rainfall spatial distributions in the study has been of 1 km.

5. In order to clarify the description of the method for calculating the PV displacements

and intensity errors additional comments will be added in the revised manuscript. An additional reference will be introduced where the methodology to generate the EPS is exhaustively described. This complementary paper will allow to the reader to make easier the understanding of the procedure.

6. The spin-up time of a mesoscale primitive-equation model as MM5 is estimated in the range of 4-8 h. Below we indicate the simulation start time for each case, compared with the time when the intense hydrometeorological episode starts. It can be observed that in all case studies the spin-up time is reached well before the heavy rainfall occurs:

- 16-17 Nov 1996: simulation starts at 16 Nov 00 UTC: intense rainfalls occur from 12 UTC

- 17-18 Dec 1997: simulation starts at 17 Nov 00 UTC: intense rainfalls occur from 12 UTC

- 09-10 Jun 2000: simulation starts at 9 Jun 00 UTC: intense rainfalls occur from 10 June 00 UTC

- 29-30 Aug 2004: simulation starts at 29 Aug 00 UTC: intense rainfalls occur from 30 Aug 14 UTC

7. The reviewer suggests an evaluation of the reliability of the MM5 forecasts relative to the gauge data by using spatial scale dependent measures. In the present manuscript, the precipitation forecasts have been evaluated at subcatchment scale since numerous previous studies have found suitable this approach in order to evaluate the QPFs for hydrological purposes. For example, Yates et al. (2005) and Chancibault et al. (2006) pointed out that it is possible to rely on hourly rainfall fields as input in subcatchment units for discharge forecasts for basins larger that 500 km2. Furthermore, dependent and independent comparisons between hydrological and atmospheric model results, stream-flow and rain-gauge data demonstrate the usefulness of hydrological models as a validation tool for high-resolution QPFs ($<$ 10 km2). See, for example, Benoit et

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al., 2000; Jasper and Kaufmann, 2003; Ludwig et al., 2003; Chancibault et al., 2006.

Yates, E., Anquetin, S., Ducrocq, V., Creutin, J.-D., Ricard, D. and Chancibault, K. 2006 Hydrological validation of the simulated rain fields. Meteorol. Appls., 13, 1–20.

Chancibault K, Anquetin S, Ducrocq V, Saulnier G-M. 2006. Hydrological evaluation of high-resolution precipitation forecasts of the Gard flash-flood event (8–9 September 2002). Q. J. R. Meteorol. Soc. 132: 1091–1117.

Benoit R, Pellerin P, Kouwen N, Ritchie H, Donaldson N, Joe P, Soulis ED. 2000. Toward the use of coupled atmospheric and hydrologic models at regional scale. Mon. Weather Rev. 128: 1681–1706.

Jasper K, Kaufmann P. 2003. Coupled runoff simulations as validation tools for atmospheric models at the regional scale. Q. J. R. Meteorol.Soc. 129: 673–692.

Ludwig, R., Taschner, S. and Mauser, W. 2003. Modelling floods in the Ammer catchment: Limitations and challenges with a coupled meteo-hydrological model approach. Hydrol. Earth Syst. Sci., 7, 833–847

8. The authors agree with the reviewer that an increase of the horizontal resolution in the MM5 model experiments when orographic effects are thought to be dominant could help to better resolve these effects. However, MM5 model configuration for the present study has been designed as in the real-time operational version currently available at the University of the Balearic Islands (see, for instance, http://mm5forecasts.uib.es/). As it has been exposed in the manuscript, the main goal of the present work is to evaluate the feasibility of runoff forecasts driven by MM5 model within a real-time hydrometeorological chain forecasting framework. For this reason, we did not carry out these experiments at a higher resolution in order to better resolve the orographic effects.

Minor comments

1. The style of some expressions used in the manuscript will be corrected in order to

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improve its readability.

2. Typos will be corrected in the revised manuscript.

3. The internal basins of Catalonia will be highlighted in shaded grey in order to improve the visibility of Figure 1.

4. Figure 3 will be corrected in the revised paper.

5. Figure 7 does not show the orography of the MM5 model in shading grey. Simply, we have used the shading to highlight an independent high-resolution orography within the model domains. Nevertheless, we will include a colour-bar.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 6, 535, 2009.