Response to reviewer-1 on NHESS article: Hydrometeorological multi-model ensemble simulations of the 4 November 2011 flash-flood event in Genoa, Italy, in the framework of the DRIHM project

The authors would like to sincerely thank the reviewer for his/her comments which helped to improve the quality of our paper

Page 7, line 4 "how is this produced? Can you see it somehow?"

The low-level south-easterly flow is a by-product of the large-scale meteorological situation, whereby an upper-level trough leads to south-westerly mid-tropospheric flow over the target zone, which at lower levels induces a south-easterly flow. A representation of this situation is given in Figure 2 (a) and (b). The authors believe that these two figures clearly represent the meteorological situation. Does the reviewer agree, or does he/she wish further graphical proof to be inserted?

Page 7, line 4 "What was causing this?"

The MCS for this case was very closely related to the line of convergence between the cold northerly outflow and the southeasterly flow at low levels. An oscillation in the most intense rainfall patterns was thus due to a shift in the convergence line. The authors have included a reference to the article by Buizzi et al. (2014) where a much more detailed description of the meteorological situation is given.

Page 8, lines 9-11 "Is this hydrostatic?"

This is indeed a hydrostatic formulation, but the authors can understand the confusion. The sentence has been modified in the text to make things a little clearer:
"This version of WRF presents an alternative approach to non-hydrostatic modelling, whereby the hydrostatic model has been extended to include the nonhydrostatic motions, thus preserving the favourable features of the hydrostatic formulation. However, the model is classified as non-hydrostatic"

Page 8, lines 19-20, "Shortening this, better to indicate a reference"

The lines "The model uses a forward-backward scheme for horizontally propagating 20 gravity-inertia fast waves, an implicit scheme for vertically propagating sound waves" have been modified to include a reference and now read " :
"Detailed description of model dynamics can be found in: Janjic et al., (2001, 2003)."

Page 9, lines 8-9, "They were upgraded every?"

The BC were upgraded every 3 hours. This is now specified in the text.

Page 10, lines 1-3 "What about convection? Was it activated at 5km? What about BC were upgraded every?"

No cumulus parameterisation scheme was used at the 5km resolution for the WRF-ARW model. This was done due to the results of a number of previous tests whereby the model performed most accurately with explicit representations of convection at both 5km and 1km. The BC are updated every 3 hours, as for the WRF-NMM configuration. These facts are now stated in the text as follows:
"…soil diffusion scheme. Following the results of a series of preliminary tests on the cumulus parameterisations, it was seen (not shown) that the model performed most accurately when convection was explicitly represented at both 5km and 1km horizontal resolution."
"…along with the IC and BC (updated every 3 hours) of the parent domain…"

Page 13, line 12 "Does the model use a DTM?"

The model does use a DTM and the following lines have now been included:
"DRiFT uses a DTM to estimate slopes, flow directions, channel paths and corrivation times. Moreover, model includes in its runs a curve number map to estimate the maximum soil moisture value for each cell."

Page 13, line 23 "What about small catchments? Can it correctly reproduce flood for them?"

In small catchments (less than 10 km2) a more detailed representation of hydrologic processes than that provided by RIBS may be required to reproduce flood hydrographs. The simplified representation included in RIBS is more suitable for larger basins, where errors may be compensated. The following text has been included in the paper:

"Small basins would benefit from the use of more complex models to adequately reproduce the observed flood hydrograph."

Page 15, lines 7 –21 "Shorten the model description"

The model description is shortened considerably (adding one reference that gives a more complete overview):

"The Hydrologiska Byrans Vattenbalansavdelning (HBV) model is a conceptual semi-distributed hydrological model that was developed in the early 70's by the Swedish Meteorological and Hydrological Institute (SMHI) (Bergström 1976). In the early 90's a comprehensive re-evaluation of the HBV model routines was carried out (Lindström et al., 1997), which resulted in the HBV-96 version. In this study the wflow_hbv model is used for modelling the Genoa flash flood. This hydrological model is based on the HBV-96 model and is part of the recently developed open source modelling environment OpenStreams (2014), which is suitable for integrated hydrological modelling based on the Python programming language with the PCRaster spatial processing engine (Karssenberg et al., 2009; PCRaster, 2014). The advantage of using OpenStreams (2014) is that it enables direct communication with OpenDA (2014), an open source data assimilation toolbox. OpenDA (2014) provides a number of algorithms for model calibration and assimilation and is suitable to be connected to any kind of environmental model (e.g., Ridler et al., 2014).
The wflow_hbv model (one of the hydrologic models available in OpenStreams) requires gridded time series of precipitation, temperature and potential evaporation as input data. Besides dynamic data, static input data as a DEM, land cover map, soil map and model parameters per soil and/or land use type are required. For each of the wflow_hbv grid cells, the water balance and resulting runoff is computed. The model consists of three routines: a snow routine, a soil routine and a runoff response routine, specific runoff is routed by a kinematic wave approach, for more details on the HBV-96 model see Rakovec et al. (2014) or OpenStreams (2014).
For the Genoa flash flood, a wflow_hbv model was set-up with an hourly timestep. The river network was derived with OpenStreams (2014) preprocessing functions using spatial data extracted from SRTM 3 arc-second resolution DEMs and from the GLC2000 project. The final grid size of the WFLOW_HBV model IS 0.001o latitude/longitude. Precipitation data was available from twenty four precipitation stations and one hydrological station, Passarella de Firpo. Temperature data was available from only four stations. The measured data was interpolated to grids using Thiessen polygons. Since measured data for potential evapotranspiration was not available, monthly mean values were calculated with Penman´s formula and used as input for the model of the Bisagno river basin. In order to perform the forecast, use was made of hourly model outputs converted to the same grid format as the WFLOW_HBV model of the Bisagno river basin using the closest distance between available values at spatially distributed locations. Dynamic input data for the model were available for periods from 2006 onwards. Continuous time series were available for calibration and verification from December 2006 until June 2011."

Page 16, line 2 "How did you downscale the model output?"

The NWP model output is downscaled using the closest distance between available values at spatially distributed locations to provide the input at the model resolution.

Page 18, line 12 "it seems that the wind direction for both WRF is driven by the coastline contributing to a southeast wind component whereas MNH-ARP wind is shuting over the target area favoring the rainfall "

The authors agree with the reviewer when he/she says that the coastline contributes to the wind component. The authors also concur with the reviewer's reading of the situation saying that the wind pattern over the target area in MNH-ARP favours rainfall. However, the authors still believe that the most important contributing factor to the different rainfall descriptions between the different models is the accuracy with each the convergence line is forecast. As noted in several studies (Buizzi et al. 2014, Fiori et al. 2014), this convergence line was responsible for the heavy rainfall amounts and thus its description is imperative to having accurate rainfall over the target area.

Page 20, line 23 "I believe you can reduc ethe uncertanty especially accounting for the indication coming out from the ensemble forecast results. Did you try to change the rate of evaporation in WRF-ARW simulation?"

The authors agree with the reviewer when he/she suggests that the uncertainty may be reduced when taking the ensemble forecast results into account. However, the authors believe that such uncertainty is case sensitive and thus the use of ensembles is imperative in such highly precipitating events.
The authors did not change the rate of evaporation in the WRF-ARW simulation, but do appreciate the idea. The authors would expect the result to be as was found for a change in the rate of evaporation in the Meso-NH simulations.

Page 21, line 10 "Please explain"

We agree with the reviewer on the importance of elaborating on this idea. The following text has been added:

"In the context of early warning the main concern is the detection of a potentially dangerous event to properly organize civil defence activities. At an early stage of storm development the analysis is based on precipitation forecasts from different models and therefore large uncertainties may be expected on the exact location and amount of predicted rainfall thus preventing an accurate prediction of peak flow."

Page 23, line 4-5 "How do you explain the similar response of RIBS simulation in deterministic and probabilistic modes?"

The perturbations introduced to run RIBS in its probabilistic mode were taken from the probability distribution of three variables (f, Cv and Kv). However, the probability distribution of these variables is based upon values used in previous case studies. Given that only one previous case study was used in calculating the probability distribution, the low dispersion or weak response to the perturbations is understood.

Page 23, line 12 "This is true, but I do not understand why you got a different response in Fig.14"

Fig.14 shows each of the hydrological models driven by the MNH-MWF ensemble, with the lines (1)-(4) representing the different evolutions corresponding to the 4 possible hydrological model configurations. The response in Fig.14 is not different from that of Fig.15 and this can be seen by taking evolution (3) of Fig.14 for example. This is the response of the DriFt model being forced by the MNH-MWF ensemble. The corresponding evolution on Fig.15 can be seen by looking at evolution (5) on the figure in the bottom left of Fig.15. Comparing the two evolutions shows that they are in fact the same.

Page 24, lines 14-15 "Although the exact location of the convergence was quite different among the models. Would the models settings playing a major role on this?"

The authors agree with the reviewer that the model settings would have a role in finding the correct location of the convergence. However, the authors tend to think that the differences in the horizontal resolution of the different models is perhaps the most important factor in correctly locating the convergence line, especially since the local orography played such a key role in controlling the cold outflow from the Po Valley.

Page 33, Table 1 "Please explain"

These table headings have been changed and are hopefully now clearer:

"Rain Source   Description   No. of members   Resolution(km)
No. of DriFt and HBV members   No. of RIBS members"