Anonymous Referee #1

Received and published: 8 May 2017
Title: A meteo-hydrological modelling system for the reconstruction of river runoff: the case of the Ofanto river catchment Authors: Verri et al.
Recommendation: Major revisions
The paper describes the implementation, tuning and application of WRF-HYDRO to a selected watershed in southern Italy. The paper describes in detail the problems found in the implementation of the system and is interesting, especially for researchers facing with similar tasks. Anyway, I think that some points should be clarified to make the paper more mature for publication.

MAJOR POINTS:
- P(page)5 L(line)7-P5L7: "nested in two-way mode": in my experience a two-way coupling is not the best way to deal with precipitation, since it improves the coarse grid results but makes worse the output in the inner grid, which is your target (you did not show the simulated precipitation in the outer domain, but I expect that it is very similar to that in the inner domain, isn't it?): did you play with these options?
Authors:
The experimental design is hereafter clarified and we provide references to several studies, which use the two-way coupling for the reconstruction of local rainfall events in the same region.
The two domains set-up (Figure 1) is conceived to capture the genesis and the development of the mesoscale cyclonic patterns responsible for the heavy rain events in the coarse domain, moreover the finer grid mesh of the inner domain enables to reconstruct the local convection including the orography effects in the region of interest, i.e. the South-Eastern Italy.
Overall we found that the two-way coupling mode improves the precipitation reconstruction at local scales. Several studies recommend the two-way coupling for reconstructing heavy rainfall on local scales: Miglietta et al. (2008), Moscatello et al. (2008), Federico et al. (2008), Laviola et al. (2011), Mastrangelo et al. (2011) among the others. Moreover all the studies cited above focus on rainfall events occurred in our region, i.e. the South-Eastern Italy.
We provided more details in section 3 (page 5) that now reads as follows:
"*The two domains set-up (Figure 1) aims to capture the genesis and the development of the mesoscale cyclonic patterns responsible for the heavy rain events in the coarse domain, moreover the finer grid mesh of the inner domain enables to reconstruct the local convection including the orographic effects in the region of interest, i.e. the South-Eastern Italy.*
We tested different extensions and grid spacing of the coarse domain and we compared the 2-domains approach with the 1-domain only set-up. We found that a two domain, two-way coupling set up improves the reconstruction of precipitation at local scales (not shown)"
In the revised manuscript we also stressed the previous studies that we considered as a benchmark for setting up our experimental design, including the two-way nesting method:
"Overall our experimental design is based on the past studies of WRF for local rainfall events in the same region that stressed the two-way nesting: Miglietta et al. (2008), Moscatello et al. (2008), Federico et al. (2008), Laviola et al. (2011), Mastrangelo et al. (2011) among the others."

- P5L23: ": : : convection is assumed to have been solved explicitly, was found to perform better in the inner domain: : :": since the tuning is an important part of your study, please could you provide some additional information? In which way does the run without parameterization in the inner grid perform better? Did you try also the case with parameterization active in none (or in both) of the grids? (since you are in the grey zone for convection, it is difficult to anticipate which of these implementations would give better outputs);

Authors:
In our study we tested the model sensitivity to the convection parameterization for the inner domain, looking at the numerical results in terms of the near surface atmospheric fields including the precipitation one. The validation of the precipitation field shows that the explicit convection performs better that the Kain-Fritsch parameterization scheme (Kain, 2004). This was an expected result and thus we didn't provide more details in the text.
Probably the reviewer's concern about the use of the explicit convection in our inner domain (with 2km as horizontal spacing) is related to the fact that this grid spacing is only in 'convection permitting' scale range (i.e. horizontal grid spacing less that 4 km, as defined in the review paper by *Prein et al., 2015*). Several studies on severe convective weather forecasts have already documented that a grid spacing of few kilometers is sufficiently fine to ensure a successful reconstruction of convection, its mesoscale organization, and associated precipitation with no active convective parameterization scheme: *Done et al. (2004), Weisman et al. (2008), Kain et al. (2008), Schwartz et al. (2009) & (2010),* among the others. Focusing on our target region, similar studies based on WRF code and pointing to the reconstruction of local rainfall events (e.g. Miglietta et al., 2008; Moscatello et al., 2008; Federico et al., 2008; Mastrangelo et al 2011; Laviola et al., 2011) have already proved the benefits of working with the explicit convection in the "convection permitting" scale range.
The studies cited above have been added the revised manuscript.
Further details are provided in section 3.1 and they read as follows:
"Our sensitivity tests shows that in the inner domain the explicit convection works better than the convection parameterizationeven if the grid spacing is only in the 'convection permitting' scale range (Prein et al., 2015). This is documented by previous studies on severe convective weather forecasts: Done et al. (2004), Weisman et al. (2008), Kain et al. (2008), Schwartz et al. (2009) & (2010), among the others."

- P6L12: from what you write later (P8L28), I understand that an optimal range for precipitation simulation is 36-72 hours; however, from Fig. 4, it appears that the WRF runs start every 3 days, making the model skill dependent on the initial time of the simulation (i.e., a simulation starting the same day as the heavy rain will reproduce the event worse than a run starting 36 hours earlier); on the other hand, you show in Table 2 that Experiment 2 starts on the same day as the heavy rain event 2: : :: I am quite confused;

Authors:
We thank the reviewer for pointing out this weakness in the text, as it led to a misunderstanding that we corrected in the revised manuscript.
The concatenation procedure we adopted is the one described by the reviewer: a chain of 72h runs with the reinitialization option. However we should better clarify what we found out about the optimal model spin-up time.
We performed two simulation experiments, each of them done for 2 different seasons (winter 2011 and autumn 2013). They were done simply concatenating 72 hours hindcasts, re-initialized every 3 days. The first experiment contained the heavy rainfall Event 1 that was found to occur 48h later than the start time of the hindcast. The second experiment contained the heavy rainfall Event 2 that was found to occur at the the start time of one of the re-initialization hindcasts.. We performed extra WRF 72h runs to test the sensitivity of Event 1 and 2 to the initialization time and we found out that the optimal spin-up time for capturing the peak events is 1.5 days. The results of the different initialization and spin up times for Event 1 are shown in Figure 8 and commented in the text. For this reason we mentioned as one of our future plans the development of a robust WRF ensemble, which consists of overlapping chains of 72h simulations with a delayed start-time (See Conclusion section).
To avoid any misunderstanding we re-wrote two sentences of section 4.2.1 and they read as follows:
-Sentence at page 8 line 21 has been modified as follows: "*In addition to Experiment 1 and Experiment 2 we performed extra WRF 72h runs focusing on specific events to test the sensitivity of the simulated precipitation in relation to the initialization time: the panels of*

Figure 8 highlight the differences between the 24h cumulated precipitation on February 18th 2011 started 14 hours and 38 hours before the rain peak of Event 1 ."

-Sentence at page 8 line 26 has been modified as follows: "*We conclude that our WRF model would need to be re-initialized approximately 1.5 days earlier than the start of the heavy rain events to increase skill in the predicition of precipitation. . For this reason as a future step we plan to develop a robust WRF ensemble, which consists of overlapping chains of 72h simulations with a delayed start-time*"

By the way we believe the underestimation of the river runoff peak triggered by Event 2 (Figure 10) is partially due to the Event 2 onset overlapping the start time of WRF 72h simulation, we added this comment in section 4.3.2:

"*It should be also noted that the Event 2 onset overlaps the start time of WRF 72h simulation (Table 2) and this probably affects the underestimation of the runoff peak starting on December 2nd 2013*".

- P7L30-: : :: I think the meteorological description would greatly benefit from adding mean sea level pressure contour lines in the right side of Figs. 6 and 7; also, temperature at 850 hPa is more relevant than at 2 m from a meteorological perspective;

Authors:

We modified both Fig. 6 and Fig. 7 making them more informative as suggested by the reviewer. We added mean sea level pressure contours on the left panel and we replaced 2m Temperature with 850hPa Temperature on the right panel. We agree the pictures provide now a more comprehensive description of the Events from a meteorological perspective.

Overall we slightly modified the description of the pictures as follows:

"*Figure 6 and Figure 7 provide the mesoscale maps of the two severe weather events occurred on March 1st 2011 (Event 1) and December 1st 2013 (Event 2).*

The 500hPa geopotential maps highlight how the upper level features affect the lower level cyclogenesis. WRF maps for Event 1 show a strong trough of low pressure at 500hPa centered over the Western Mediterranean Sea (left panel in Figure 6), which is due to a cold front (not shown) progressing eastward. At lower levels a strong synoptic wind, coming from the southeast and blowing over the warm Ionian Sea reaches the Italian Peninsula (right panel in Figure 6. The left panel of Figure 7 shows the 500hPa geopotential maps for Event 2: a weak trough covers the Western Mediterranean Sea in the upper troposphere, with a small but deep cyclonic core south of Sicily. This corresponds to a strong cyclonic circulation at a lower level (right panel Figure 7) with a mslp gradient reaching 16 hPa in the cyclone eye. This cyclone is situated almost directly beneath the cutoff low in the 500hPa height field and corresponds to a southerly wind carrying warm-moist air reaching the Southern Italy and a colder wind developing downslope of the Balkans"

The new figures 6 and 7 are reported below for convenience.

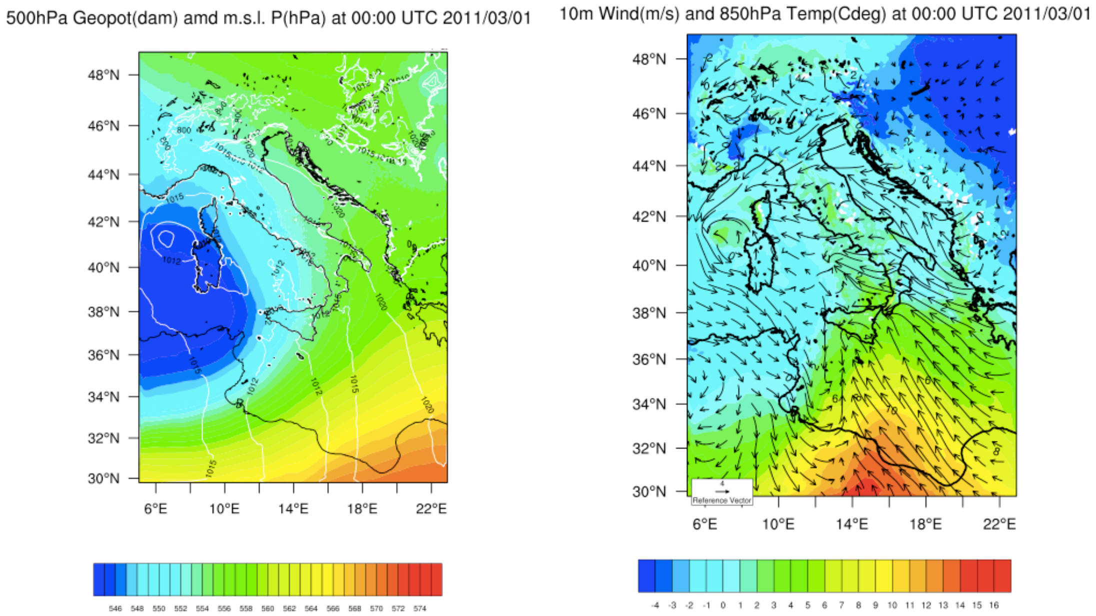

Figure 6. Mesoscale maps during the weather storm on 1 March 2011 (Event 1). Left panel: WRF (domain1) Geopotential height (in dam,colours) at 500hPa and mean sea level pressure (in hPa, white lines). Right panel: WRF (domain1) 850hPa Temperature (in C, colors) and 10m wind (in m/s, black arrows)

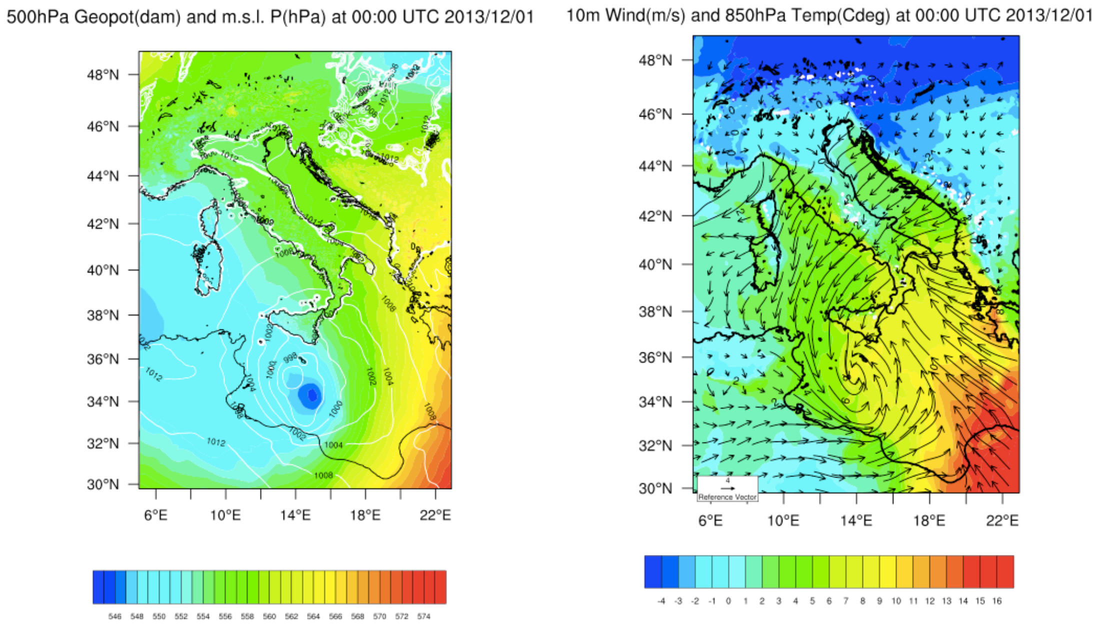

Figure 7. Mesoscale maps during the weather storm on 1 December 2013 (Event 2). Left panel: WRF (domain1) Geopotential height (in dam,colours) at 500hPa and mean sea level pressure (in hPa, white lines). Right panel: WRF (domain1) 850hPa Temperature (in C, colors) and 10m wind (in m/s, black arrows)

- P12L11: I do not see much change by comparing Fig.9 with Fig. 12: can you quantify the improvement?

Authors:

We calibrated the tunable coefficients of the aquifer sub-model and the final configuration is the one ensuring the best reconstruction of the river baseflow, which is associated with the low flow depth values between events in the hydrograph. In order to make a quantitative comparison between the bottom panel of Fig.9 and Fig.12 more clear, we overlapped the two hydrographs, with and without the aquifer parameterization, in the same picture (i.e. Fig.9). A better reconstruction of the minimum values of the flow depth can be detected in January 5^{th}

to 20th and on February 5th to 20th when the aquifer is switched on. In the revised manuscript we added: "*On the other hand, the acquifer parametrizations do not impact the quality of the reconstruction because of the small Ofanto catchment acquifer capacity, as shown in Fig.9 (i.e. CV(RMSE) index reduces of only 2% when the aquifer is switched on and the correlation is almost the same)*".
We maintained this analysis in section 4.3.2 but we removed it from the Conclusions.
New Figure 9 is attached below for convenience

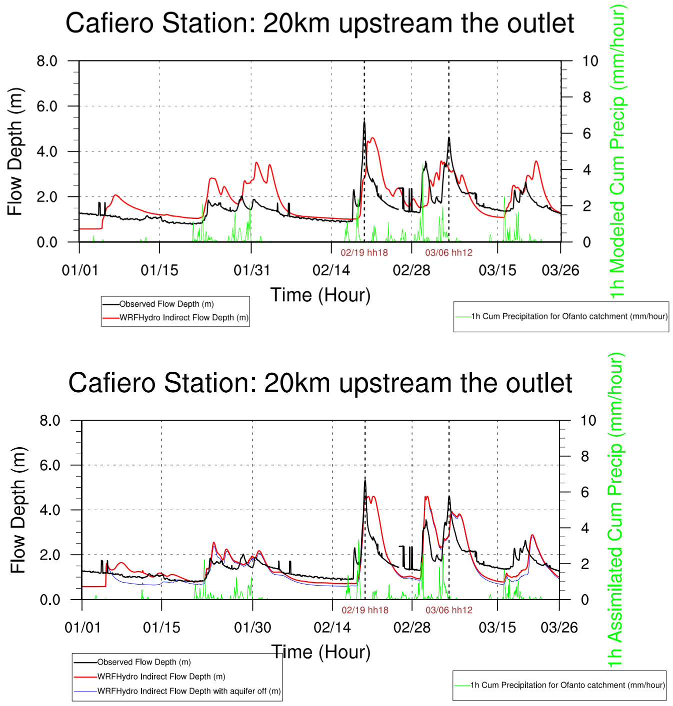

Figure 9. Validation of the Ofanto discharge for Experiment 1 at Cafiero Station. Top panel: modelled precipitation. Bottom panel: assimilated precipitation. The blue timeseries refers to the additional experiment performed with the aquifer switched off

MINOR POINTS:
- P2 L20, P6L24: "where the power spectrum of the turbulence reaches its peak and thus the convective motions and precipitation are only partially resolved": the fact that convection is not properly resolved is not only a consequence of turbulence, but mainly depends on the fact that the grid spacing is not sufficient to explicitly resolve the individual convective cells/systems;

Authors:
We agree, the sentence is misleading thus we tried to better clarify our point:
"The grid spacing of mesoscale meteorological models does not allow to fully resolve the scales of the single convective cells/systems (Moeng et al., 2007; Shin et al., 2013)"

- P3L14:Â˘ a" : : : characterize southern Italy : : :"

Authors:
Thanks for the correction

- P3L29: what do you mean with "local"? Is it a single point climatology or a basin-average?

Authors:
We mean basin-average. Thanks for the remark

- P4L14: ": : is frequently subject to lee cyclogenesis: : :": are you sure? If yes, you need to add a reference showing this point from a climatological perspective;

Authors:

We agree and rewrote the sentence above citing the studies which investigated events occurred in the last two decades :

"*Concerning the meteorological modelling, the case study is located in the Southern Italy, where several heavy rainfall and flash flood events have occurred in the last decades triggered by lee cyclogenesis and convective instability (Federico et al., 2008 & 2009; Moscatello et al., 2008; Miglietta et al., 2008; Mastrangelo et al., 2011).*"

- P4L20: a more appropriate reference for the case of November 2004 is Mastrangelo et al. (2011): Mechanisms for convection development in a long-lasting heavy precipitation event over southeastern Italy, Atmospheric Research, 100, 586-602, 2011;

Authors:

We included this reference, thanks.

- P4L30: "The WRF and WRF-Hydro systems are coupled 1-way";

Authors:

Thanks for the correction

- P5L20 and elsewhere: YSU, not YUS;

Authors:

Thanks for the correction

- P5L23: microphysics not mycrophysics;

Authors:

Thanks for the correction

- P5L24: the proper reference is: Thompson et al., 2008. Explicit forecasts of winter precipitation using an improved bulk microphysics scheme. Part II: Implementation of a new snow parameterization. Mon. Weather Rev. 136: 5095–5115. The reference you put refers to an older version of the scheme.

Authors:

We corrected it, thanks

- P6L20: "uncertainties are large in mesoscale models due to unresolved meso-scale processes": although they may contribute, this is not the only reason for possible model failures;

Authors:

Thanks for the remark. We modified this sentence to make it more general:

"The simulation of the localisation, amount and timing of precipitation is crucial for the reconstruction of a river runoff time series but uncertainties are large in mesoscale models, particularly due to unresolved mesoβ and mesoγ scale processes".

- P6L21: "grid spacing" is more appropriate than "horizontal resolution";

Authors:

Thanks we corrected it

- P7L12: Is the OA+LS method based on 30 minute raingauge data or 24 hour cumulated rainfall?

Authors:
As we already explained in the section 3.2 and in the Appendix B, the OA+LS method is applied on hourly basis: the observed precipitation is recorded every 30 minutes but we used the precipitation cumulated over 1 hour.

- P7L29: ": : :trough : : : which is due to a cold front: : :": is it the cold front responsible for the trough or the opposite? I suggest to use "associated" instead of "due";

Authors:
The synoptic analysis few days before the Event 1 and Event 2 indicates the intensification of the tough at the 500hPa level is accompaniend at the surface by the strengthen of a warm-moist wind coming from the South and a cold wind on the lee-side of the Balkans,which encircle the low level cyclonic core..
We modified our misleading sentences, see major point P7L30 for the details.

- P8L2: again: is the cyclone triggered by the winds or the opposite?

Authors:
See the above point -P7L29.

- P8L5: "mesoscale convective systems: : :": I do not see mesoscale convective systems: do you mean cyclones?

Authors:
We replaced "mesoscale convective systems" with "cyclones".

- P9L19: WRF-ASS: this is not really assimilation, but the result of a post-processing technique;

Authors:
Thanks for the remark, we actually refer to "correction procedure" through the text. We removed "WRF-ASS precipitation" with "corrected WRF precipitation" to avoid misunderstanding.

- P11L22: are you comparing the result of your post-processing technique with the results of a simulation starting from a 3DVAR analysis? In that case, the comparison is not fair;

Authors:
Actually we performed a "post-processing correction method" based on the Objective Analysis plus the Least Squares Method while Yucel (2014) considers a 3D-Var assimilated field. The comparison is conceived to stress the level of accuracy of our corrected precipitation with respect to previous studies even based on more advanced correction tools as the 3D-Var.

- P11L27: ": : : observed water level peak : : :";

Authors:
Corrected, thanks

- P12L20: are the flash floods really frequent in the area? Can you quantify their frequency?

Authors:
Thanks for the remark. We modified our statement as already explained at point -P4L14

- P13L10: ": : an operational meteo-hydrological forecasting system : : :": how do you think this technique can be used operationally? If you adjust the precipitation field at the initial time, you should adjust also the dynamic and thermodynamic fields to be compatible with this : : :

Authors:
This is intended as a future step so not enough detailed in the presented study. We will keep

in mind your remark.