Response to referee #1 comments

Specific comments

1- In various places, the conclusions drawn are only weakly supported by the results. For instance, it is claimed that the assimilation of DWR data improves the precipitation forecast. However, AIREP and SYNOP data were also ingested in the mesoscale assimilation system. To what extent the forecast improvement can be ascribed to the DWR data? This issue must be discussed and possibly clarified by running an additional experiment with the sole radar observations. Otherwise, the conclusion and even title should be amended to avoid over-selling.

- In a first analysis the experiments were conceived to highlight the impact of DWR data on QPF, in fact you can make a comparison between Exp0 and Exp1, where the only difference is the assimilation of DWR data (so the experiment with the sole radar observations has already run). Then, with the other experiments where also SYNOP and TEMP data are ingested, you can discern the gain in the assimilation using a different set of Initial Conditions, that is a critical point in the numerical weather prediction. It has to be noticed that the assimilation of TEMP and SYNOP data is affecting only coarse domains because of the lack of data on domain 3. We added a sentence to highlight this feature in the experimental set up section.

2- More generally, even if the results are encouraging, the improvement in the precipitation forecast is fairly limited and would require additional case studies to be really confirmed. This point should be acknowledged in the conclusion.

- We agree with the reviewer that additional case studies are necessary to confirm the improvement in the precipitation forecast. We have added the following sentence in the conclusion: "Additional case studies will be carried out in the future to quantify the percentage of success of WRF-3DVAR in assimilating DWR data to improve precipitation forecast. Moreover we are exploring the possibility of extending the radar assimilation procedure using data from several operative radars located in Central Italy, including also dual-polarization systems."

3- The text would need to be more polished. Some pieces of information are unnecessarily repeated. Some sentences are unclear and some grammatical constructions incorrect.

- The text has been revised. An additional grammar and language check has been performed.

Minor points

P7315 >> Remove or correct the third item in the affiliation list as it is strictly identical to the first one.

- The third item has been removed and replaced with M. Montopoli [1,2]

P7316, L20 >> L 20 more accurate than what? The introduction is too much focused on the WRF/MM5 system. Some references on similar experiments based on simpler methodologies (e.g. latent heat nudging) or more advanced one (e.g. from the ARPS community) should be quoted to

provide a better picture of the state of the art. Many repetitions of the word "important", in the introduction, try to be more precise or more imaginative.

- More accurate than the experiments conducted using cold-start.
- The introduction is mainly focused on the WRF/MM5 system because variational data assimilation technique is that one we have chosen to conduct the research. Nevertheless, we agree with the reviewer in providing some hints on other data assimilation methodologies. The following sentence has been added in the text: "…assimilation approaches that ingest local observations are essential to improve the forecast. Over the last 80 years or so, different methods of data assimilation have been succeeded: the successive corrections method or SCM, the optimal interpolation or OI, the variational methods 3D-Var and 4D-Var, the Kalman filter or KF."

- We tried to use more precise words instead of "important" in the introduction.

P7321, L4 >> referred to –> found in L 7 velocity –> vorticity (?)

- P7321, L4 >>'can be found in'

- P7321, L7 >> 'velocity potential'

P7322, L21-22 >> not very clear, reformulate

- These lines has been modified as follows: "To directly assimilate radar reflectivity, the total water mixing ratio q_t was chosen as control variable and a warm rain process was introduced (Dudhia, 1989) into the WRF-3DVAR system".

P7324, L3 >> Weather Research and Forecasting –> WRF L 19 "which accounts for ECMWF data on Mediterranean Basin" Unclear

- P7324, L3 >> ***'WRF model'***

- the line "which accounts for ECMWF data on Mediterranean basin" has been removed

P7325, L5 >> Remove here "using a specific B calculated for each domain" and modify line 10 "For Exp1, 2 and 3 a specific ..." to avoid repetition

- We accept the advice of the reviewer: line 5 "using a specific B calculated for each domain" has been removed; line 10 has been modified "For Exp1, 2 and 3 a specific background error ….."

P7326, L8 >> If the Pratica Di Mare sounding is used in the assimilation, it is quite surprising that the mesoscale assimilation (i.e the initial conditions of exp.1) does not succeed in reproducing better the observed moisture profile above 600 hPa.

- The PDM sounding is NOT assimilated in Exp1. The sounding is assimilated only for Exp2 and Exp3 both having ICs produced by WRF output. If the assimilation does not succeed in reproducing better the observed moisture profile means that the model output is too far from the real atmosphere.

P7328, L23-25 >> The results are not so convincing. Exp3 shows improvement for thresholds under 15 mm/h but degradation for higher thresholds (mainly due to overestimation as clearly indicated by

the FAR). Here, it would be wiser to highlight the improvement obtained between Exp2 and Exp1. Actually, this is only figure which can support your conclusion regarding the positive impact of a warm start.

- We agree with the reviewer, so we replaced the lines as follows: "Figure 13 shows the results for the previous indexes for the 12h accumulated rainfall as a function of different thresholds. ACC, FBIAS and ETS show improvements obtained for Exp2 (Fig. 13, green line) with respect to Exp1 (Fig. 13, red line), for thresholds higher than approximately 15 mm/12h. Accordingly, the FAR index for Exp2 shows values lower than for the others. Also Exp3 produces best values for ETS at thresholds below 15 mm/12h, but rapidly degrading for higher thresholds. These results support the previous finding that the experiment performed using the ICs produced by a warm start improve the forecast."

P7343 >> Remove the unreadable green text.

- The green text in the tephigrams of Fig.7 have been removed.

P7345 >> Indicate in the caption the corresponding height or pressure level unless you are plotting the maximum of reflectivity.

- The corresponding height has been indicated in the caption of Fig. 9, 14, 15, 16.

P7347 >> Remove the black contours to clear up the figure (provincial borders would be more helpful than unspecified topographical contours)

- Black topographical contours have been thinned in the Fig. 11.