

Review for „Impact of radar data assimilation using WRF three-dimensional variational system for the simulation of a heavy rainfall case in Central Italy“ by Maiello et al.

General Vote

The manuscript describes current research with respect to quantitative precipitation forecasting (QPF). The authors apply the WRF model system including the 3DVAR with different assimilation approaches at high resolution to assimilate radar radial velocities and reflectivities simultaneously. An interesting point in this study is that a high altitude radar is used to enhance QPF over mountainous terrain which is important e.g. for flood forecasting. However, in my opinion a more detailed investigation of the results is necessary which would greatly improve the manuscript.

The figures are generally relevant but sometimes with a too low quality.

I recommend this article for publication after major revision and an additional grammar and language check.

I also suggest rearranging and summarizing sections 2, 3 and 4 for a more fluent reading of the manuscript.

Major comments

Abstract, I1: I guess it's the first assessment in Italy, not in general.

P7318, I15: Are you sure that radial velocities contain information on vertical motion? I think this can be misinterpreted.

P7320, I12: Please explain more about the filtering procedure as this can highly influence the results. Some numbers would be nice here.

P7320, I24: Do you think that setting a general error of 1m/s is appropriate? As the radar beam broadens with increasing distance, this error assumption is not valid at far distances. In my opinion an error of 1dBZ for reflectivity seems too small. I am not sure if the radar is that sensitive especially at far distances from the radar. Can you also say something about the measurement range?

P7320, I25: Is the whole assimilation window set to ± 5 minutes around analysis time? If so, you will miss a lot of information from the other observation types. Please comment on this and also include more information in the manuscript.

P7321, I6: Please explain the meaning of "control variables" in the manuscript.

P7322, I15: Why is the Richardson Equation important here?

P7323, I11-14: What is actually used in your study? The original formulation of Sun and Crook or the modified version from equation 3? I assume that you also adapted the tangent linear and adjoint code in the WRF 3DVAR system? If not, you will definitely run into trouble.

P7324, I20: Why does the NMC-method accounts for ECMWF data? The basic concept of the NMC method is to use forecast data to obtain a model related background matrix to have only a minor influence of the driving model!

P7325, section 4.3: Please explain in more detail which types of observations (SYNOP, TEMP) are used for which experiment and at which time they are assimilated (please also adjust table 1).

P7326, ll8-16: What does this mean? Does this indicate a good analysis? Please explain the results in more detail.

P7327: Are you sure that you can expect to reproduce a 4km event with a model resolution of 2.3km?

P7327, ll19-23: Do you have any ideas why this is the case?

P7327, l 25: I agree for the mountains, but I think one should distinguish between mountains and the environmental areas.

P7328, l17: Why did you decide to choose a different period here? This gives a little break in the manuscript.

P7328, l 17: I think here a bit more distinction is necessary. Do you have any explanation, why the FAR is larger for Exp3?

P7329, ll4-5: Also a single outer loop takes the nonlinearity into account. WRF uses the incremental method as described by Courtier et al. (1994). That means at the beginning the full non-linear operator is applied while during minimization, only the linear version of the operator is applied. So what is then the advantage of multiple outer loops?

P7329: I think a more detailed discussion about Fig. 17 is required here.

P7331, l1: Usually, a domain specific B-matrix does not require any tuning. That's one of the main reasons why you create a separate matrix for each domain.

Minor comments

I suggest changing the title a little bit like: "Impact of radar data assimilation for the simulation of a heavy rainfall case in Central Italy using the WRF 3DVAR".

- 1) P7316, l8: I think the main goal is to improve QPF...
- 2) P7317, l13: Reflectivity is not related to the amount of precipitation but to number density of the different hydrometeors.
- 3) P7318, ll2-5: I suggest to delete this sentence as it is repeated later and is not that relevant in the introduction.
- 4) P7318, l18: What is ARW? Readers not familiar with WRF may be confused.
- 5) P7318, ll25-27: I suggest to remove this sentence. If you are sure that this was never done before, you could "attenuate" this sentence a little bit.
- 6) I suggest to replace the heading of 2.1 with "Meteorological situation".
- 7) What is a cyclonic circulation? I guess you mean "low pressure system".
- 8) According to the heading of 2.2, this section should deal with radar data. Instead it starts with GTS data.
- 9) P7321, ll20-26: Usually **R** is not a well known matrix, especially not for radar data or non-conventional observations. **B** is not flow-dependent in case of applying it for a 3DVAR but a climatological estimate of the model errors for a specific period.

- 10) P7322, ll5-6: Is vertical velocity poorly estimated in the model or the observations? If you mean the model, why?
- 11) P7322, 17: What is "pseudo relative humidity"? What is the total water mixing ratio?
- 12) P7323, l 19: I guess it's the terminal velocity of raindrops.
- 13) Replace the heading of chapter 4 with "Experimental setup"
- 14) P7323: Which soil model was applied? The 5-layer model, the NOAH-LSM or the RUC model?
- 15) I suggest to name chapter 5 only "Results"
- 16) P7326, l5: What is a "thunder atmosphere"?
- 17) Should it be "K-Index" or KINX? Please check the whole manuscript.
- 18) Section 5.2: Do you mean "Impact of IC's on precipitation forecast"?
- 19) P7327, l3: Which boundaries?
- 20) P7327, ll 21-24: This paragraph is very difficult to understand.
- 21) Please check the grammar here. This sentence is very difficult to understand.
- 22) Section 5.3 could be "Statistical evaluation".
- 23) Replace EQTS with ETS, I think this is more common.
- 24) P7328, l 20: In my opinion the threshold is 10mm not 20mm. Please check.
- 25) Chapter 6 can be named "Impact of multiple outer loops on precipitation"...
- 26) Discussion of "EXP1_OL" and "EXP1_OL3" are missing here.
- 27) P7329, l 12: I still see some convection in Fig. 14.
- 28) Maybe one or two sentences can be added for the other experiments at the end of chapter 6.
- 29) P7330, first paragraph: I think you also used SYNOP and TEMP data?
- 30) P7330, l 13: Both sentences in the third item have the same meaning for me.
- 31) P7330, l20-23: Please discuss these two points a little bit more. Why can cycling be helpful and how can noise be introduced?
- 32) P7330, l 26: I think this is also very important here.
- 33) P7331, 3: Does this mean that you haven't thinned the data before it went into the 3DVAR? I am not sure if the 3DVAR works properly when you have 5 observations of the same type in one model grid cell.
- 34) Table 2: I think it is not necessary to give CAPE with an accuracy of hundredth.
- 35) Fig. 1: Maybe you can cut the area at 33°N. Is 10m wind in kts or m/s?
- 36) Fig. 3: AQ and RM is hard to read. Also the color table is a little bit unfortunate. Is nearly impossible to distinguish between light and moderate precipitation.
- 37) Fig. 4: I think you can remove Fig. "B" as this is not relevant for the manuscript.
- 38) Fig. 7 is too small and the numbers in the left corner are unreadable.
- 39) Fig. 9: You can think about giving letters to the subfigures. Then it is easier to cite them.
- 40) Description of Fig 10: "12h accumulated rainfall between 10UTC and 22UTC 20 May 2008 estimated by the Monte Midia radar".
- 41) Fig. 11: I think the wind barbs are not necessary when you show accumulated precipitation.
- 42) Fig. 12 has a bad quality.
- 43) Fig. 13: Is it really "mm/h" or "mm/12h"? Also suggest something similar like "The blue line shows Exp0, the red line...." In the figure caption.
- 44) Fig. 14--16: Please add the ovals here.
- 45) Fig. 17 is too small and please check the grammar in the figure caption.