Clim. Past Discuss.,
doi:10.5194/cp-2016-97-AC1, 2017

Climate of the Past
Discussions

Interactive comment on "Ensemble cloud-resolving modelling of a historic back-building mesoscale convective system over Liguria: The San Fruttuoso case of 1915" *by* Antonio Parodi et al.

Antonio Parodi et al.

antonio.parodi@cimafoundation.org

Received and published: 4 February 2017

We thank referee 1 for his/her positive comments on the topic of the manuscript and the analysis we carried out and for the many useful suggestions that will help us in preparing an improved version of the manuscript. In the following, we address his/her comments.

Main comments

1. The 20th Century ensemble reanalysis at 2.0 degrees is used as boundary conditions for simulations with a 25km (âĹij0.22 degree) outer domain. In the analysis,

the poor alignment of the convergence zones is attributed to the low resolution of the reanalysis but this could be mitigated by introducing a WRF domain with 125km. This should be attempted at least for the four members analysed.

Reply: It is true that the ratio of the grid spacing for the driving data to that of our outer 25 km domain (roughly 1:9) is larger than what is normally recommended, and larger than the 1:5 ratio we use for our inner domains. Because of the large computational cost to run 56 ensemble members with each one including a refined 1 km domain, the decision originally had been made to only use 3 nests. Because we no longer have access to such a large amount of computer resources, we are unable to re-run all 56 members, but we recognize that the reviewer raises an interesting question. Therefore, with the limited resources remaining, we have chosen to re-run the 4 best members (1, 13, 22 and 37) adding a fourth outer domain with 125 km grid spacing (in addition to 25, 5, and 1 km grid spacing) (see Fig. 1). The comparison of 36 hour QPF for the innermost domain at 1 km grid spacing is provided in Figure 2: first row results corresponding to simulations driven by outermost domain at 25 km grid spacing, second row the same but with outermost domain at 125 km grid spacing. Heavier areal QPF can be seen in all members in the first row (our original configuration), both on the entire 1 km grid spacing domain (both on sea and land areas), and also on the smaller area over which the paper focuses. This statement is confirmed when comparing, for the 4 selected best members, the BIAS and MAE (in mm) over the available 64 raingauge stations in the runs using an outermost domain with 25 and 125 km grid spacing respectively.

The New Simplified Arakawa-Schubert (NSAS) scheme adopted in these additional simulations over the 125 and 25 km grid spacing domains has been revised, for deep moist convection, to make cumulus convection stronger and deeper to deplete more instability from the atmospheric column and result in the suppression of excessive grid-scale precipitation (Han and Pan, 2011). This can result, if applied even at very coarse grid spacing (125 km), in an overall reduction of the efficiency of the precipitation pro-

Table 1. BIAS and MAE (in mm) for the 4 selected best member ensembles over the available 64 raingauge stations in the runs having an outermost domain with 25 and 125 km grid spacing, respectively.

member	BIAS-d01 25 km	BIAS-d01 125 km	MAE-d01 25 km	MAE-d01 125 km
1	-19.8	-30	38.4	38.9
13	-14.6	-26.4	40.5	42.2
22	-21.8	-29.8	39.9	45.9
37	-18.2	-26.9	42.1	44.6

cesses, thus impacting also the results on the innermost domains down to 1 km grid spacing. We therefore believe it is advantageous to maintain our previously obtained results and to not introduce the extra 125 km domain, which adversely affects results, likely because of the NSAS scheme that we use.

2. The advantage of high resolution simulations is their ability to provide 3D information of an event. No analysis of the upper air results, vertical profiles or 2D vertical cross-sections has been presented. The dynamics of the storm evolution should be added to the manuscript.

Reply: the physical mechanism responsible for the generation of the back-building MCS observed on 25 september 1915 also has been recently explained by Fiori et al. (2016). Taking advantage of the availability of both observational data and modelling results at the micro-α meteorological scale, Fiori et al. (2016) provide insights about the triggering mechanism and the subsequent spatio-temporal evolution of the Genoa 2014 back-building MCS. The major finding is the important effect of a virtual mountain created on the Ligurian sea by the convergence of a cold and dry jet outflowing from the Po valley and a warm and moist low level south-easterly jet within the PBL. The same mechanism is active also for this case. Let us consider, as an example, the convective flow field at 06UTC on 25 september 1915 (see Figure 3), as predicted by member 1 of the ensemble. Panel A shows the 2 m potential temperature field together with the

10 m horizontal wind vector field: the colder and drier jet outflowing from the Po valley and the warmer and moister air from southern mediterranean sea are evident. Panel B shows, by means of the potential temperature along the cross section corresponding to the green dotted line of Panel A, also the thin potential temperature layer (virtual mountain) in front of the actual Liguria topography. This acts, in agreement with Fiori et al. (2016), to produce the strong convective cells in panel C (updraft velocity above 10 m/s) with the apparent back-building on the western side (less mature and intense cells around 8.4° latitude). The main updraft produces vertical advection of water vapor (panel D), thus resulting in significant production of rainwater (panel E), snow (panel F, significantly advected inland by the upper level south-westerly winds), and graupel (panel G). We will present this analysis in the revised version of the manuscript.

3. Although an ensemble of 56 members is produced, only 2 deterministic measures of individual ensemble members are presented but no analysis of the quality of such ensemble is provided. A shortcoming of deterministic measures of skill is that information about prediction uncertainties is not available, thus categorical measures like Brier skill score, continuous ranked probability score, ROC skill score are a useful tool to assess the quality of an ensemble forecast. In the following references examples such types of analysis can be found. Please add some categorical measures.

Reply: It is well know (Mass et al. 2002) that point-to- point verification measures like those usually used for traditional ensemble verification do not work well with fine grid spacing simulations, because a double penalty exists for spatial errors, which are extremely common for high intensity precipitation events. This problem is likely even worse when limited observations from 1915 are used. Object-based verification techniques have been developed in the last 10-15 years specifically because of these problems. The application of the MODE Object-based verification technique showed that twelve members out of the 17 members selected using the minimum divergence criterion have significant values (above 0.8) of the total interest function. More interestingly these twelve members perform well in some of the MODE-derived statistics presented

Table 2. CENTROID DISTANCE: provides a quantitative sense of spatial displacement of forecast. FCST AREA/OBS AREA: provides an objective measure of whether there is an over-or under-prediction of areal extent of forecast. FCST INT 50/OBS INT 50 and FCST INT 90/OBS INT 90 provide objective measures of Median (50th percentile) and near-Peak (90th percentile) intensities found in objects. TOTAL INTEREST: provides summary statistic derived from fuzzy logic engine with user-defined interest maps for all these attributes plus some others.

Parameter	Average	Standard deviation
PAIRED CENTROID DISTANCE (km)	114	62
FCST AREA/OBS AREA	1.10	0.90
FCST INT 50/OBS INT 50	0.73	0.06
FCST INT 90/OBS INT 90	0.62	0.11
TOTAL INTEREST	0.88	0.09

in the table below: in particular it is impressive that we obtain very satisfactory displacement errors with the very crude initialization of a 1915 reanalysis case.

For instance, the paper of Duda and Gallus (2013) found an average displacement distance (absolute error) for initiation of systems to be 105 km. Squitieri and Gallus (2016) show in Figs 7 and 8 the centroid of all MCSs forecasted by WRF and the centroid of observed MCSs for a sample of 15 strongly forced and 16 weaker forced events, and the distance between the averaged centroids is usually 100 km or more. Similar consideration also holds for the ratio between the near-peak (90th percentile) intensities found in the observed and predicted objects. We will present this information in the revised version of the manuscript.

4. The deterministic measures are also evaluated by comparing observations and simulations with different time spans. In lines 209-218 reference is made to rainfall depths for a 4 hour period thus QPE should be computed for the same time period as the simulation and only then should the evaluation be performed. In case that is not possible, the simulation should cover the same time period of the observations. Reply:

A comparison at an hourly level is basically meaningless (due to high variability within the simulations) and also impossible (no observational data are available on hourly scales). Furthermore the 12 hours covered by the observations and not covered by the model do not experience important precipitation (as supported with the notes on the past weather in the daily bulletins (e.g. "pioggia dal mattino" or "pioggia fino al pomeriggio"). Additionally the QPF in all 56 members for the period 12 UTC 24th – 00 UTC 25th is negligible over the entire Liguria Region (averaging below 1 mm in 12 hours). Therefore, verification statistics using the time periods we have chosen would not differ meaningfully from those performed if we had access to observations whose timing did match exactly the simulation period. We will mention this in the revised version of the manuscript.

Minor comments Figures 3 is very difficult to read. Since its quality cannot be enhanced I would suggest adding a figure 3b with the ensemble mean slp with the same domain and isobar resolution in order to better assess the resemblance between the 20th Century Reanalysis and the forecasted conditions on the 25th of September. The approximate pressure gradients in the Po Valley, Mediterranean and France, in both analysis, would be appreciated. Figure 4c is as difficult to read as figure 3. Figures 4a and b should represent the same domain as figure 4c. Same argument as before. In lines 209-218 reference is made to rainfall depths for a 4 hour period. If sub-daily precipitation is available please add either QPE or individual stations time series for the periods analysed in figures 10 and 11. The topography of the WRF plays a fundamental role in the development of the convective system but is missing from the manuscript. I suggest replacing the map in figure 8 with the model topography for all the domains. To facilitate the comparison with the real topography, I would suggest the merger with figure 1 as figure 1b. Also in figure 1 there is no reference to the source of the topographic map. Lines 95-100 – Paragraph is too long, please rephrase. Line 170 – The paragraph refers to 500hPa chart, i.e. figure 2b Line 178 – Should be figure 2a, not 2b Line 746 Y axis in figure 9 difficult to read. Reduce the resolution and increase the caption font. Line 755 – Indexation of figure 10 and 11, hard to follow. Attribute the indices sequentially. Legend should describe better the individual panel figures.

Reply: we agree on the comments on the figures: in the revised version of the manuscript, we will reformat and reorganising them according to the suggestions from the reviewer. We will also correct the errors he/she highlighted and rephrase the paragraph at lines 95-100. Moreover, we will improve and clean up the captions of figures 10 and 11. It is however not possible to attribute the indices sequentially because the 6 panels in figure 10 and the 6 ones in figure 11 refer to different ensemble members. The only comment that we cannot fulfil is that concerning sub-daily precipitation as the hourly time series are not available. The reference to rainfall depth for a 4-hour period (the period corresponding to the maximum recorded precipitation) is available for just one station, but there are no hourly data.

References Duda, J. D., Gallus Jr, W. A. (2013). The Impact of Large-Scale Forcing on Skill of Simulated Convective Initiation and Upscale Evolution with Convection-Allowing Grid Spacings in the WRF. Weather and Forecasting, 28(4), 994-1018. Fiori, E., L. Ferraris, L. Molini, F. Siccardi, D. Kranzlmueller, and A. Parodi (2016), Triggering and evolution of a deep convective system in the Mediterranean Sea: modelling and observations at a very fine scale.. Q.J.R. Meteorol. Soc. Accepted Author Manuscript. doi:10.1002/qj.2977. Han, J., Pan, H. L. (2011). Revision of convection and vertical diffusion schemes in the NCEP global forecast system. Weather and Forecasting, 26(4), 520-533. Mass, C. F., Ovens, D., Westrick, K., Colle, B. A. (2002). Does increasing horizontal resolution produce more skillful forecasts?. Bulletin of the American Meteorological Society, 83(3), 407-430. Squitieri, B. J., Gallus Jr, W. A. (2016). WRF Forecasts of Great Plains Nocturnal Low-Level Jet-Driven MCSs. Part II: Differences between Strongly and Weakly Forced Low-Level Jet Environments. Weather and Forecasting, 31(5), 1491-1510

Interactive comment on Clim. Past Discuss., doi:10.5194/cp-2016-97, 2016.

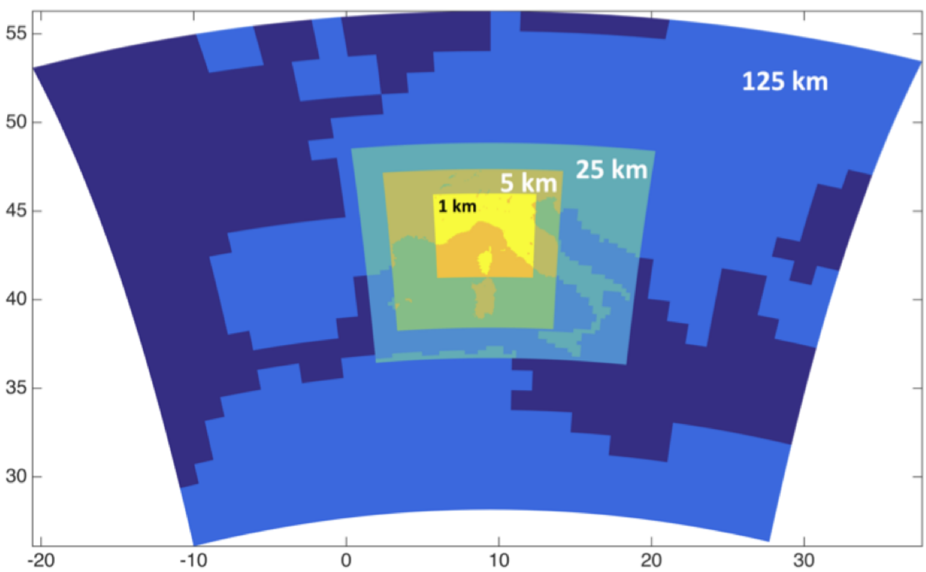

Fig. 1. ARF-WRF 4-domains setup.