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Interactive comment

Interactive comment on "Applying a new integrated mass-flux adjustment filter in rapid update cycling of convective-scale data assimilation for the COSMO-model (v5.07)" *by* Yuefei Zeng et al.

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To Reviewer 2

Major Comments

This manuscript proposed a new integrated mass-flux adjustment filter. For the convective-scale data assimilation, data assimilation cycles from a twin experiment showed that the integrated mass-flux adjustment preserved the main structure of cold

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pools and primary mesocyclone properties of supercells, although it degraded the priors and posteriors. The 3-h free forecast showed that the integrated mass-flux adjustment obtained more skillful forecasts after one hour and alleviated the imbalance caused by data assimilation, although the surface pressure tendency showed a spin-up feature. The integrated mass-flux adjustment for the LETKF is applied for rapid update cycling of convective-scale data assimilation in this study, but it can also be applied for synoptic-scale data assimilation. Imbalance caused by intermittent data assimilation is an essential problem, especially for applications favorable balanced atmospheric states. The manuscript is scientifically sound and well written. My recommendation is between minor and major.

Answer: Thank you very much for your kind acknowledgment of our work.

1. l28-30, this statement about IAU is unclear. There are four-dimensional IAU (4DIAU) that takes into account temporal variations of increments and has advantages over the commonly used 3DIAU (Lei and Whitaker 2016). Thus the IAU could be suitable for rapid cycling with short data assimilation windows. Moreover, a recent study showed that with more frequent updates, i.e., short data assimilation windows, the imbalance caused by data assimilation is reduced, while the 3DIAU/4DIAU are still helpful to reduce the imbalance but with smaller impacts (He et al. 2020).

Answer: The IAU has been used in practice for convective-scale data assimilation, but the update frequencies are usually not shorter than one hour. The performance of IAU for the ultra-rapid update cycle such as 6 min in this work has not been examined so far to our knowledge. Results of He et al. 2020 are based on large-scale data assimilation with update frequencies from 12 hours to 1 hour. It is very different in spatial and temporal scales of our work. Therefore, their conclusion may not hold for convective-scale data assimilation. Actually as shown in Bick et al. 2016, the rapid

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updates (from 1 hour to 5 min) keep imbalance at high levels within cycles. The same statement can be also found in Pierre Brousseau et al. 2008. We rephrased the text.

Bick, T., Simmer, C., Trömel, S., Wapler, K., Stephan, K., Blahak, U., Zeng, Y., and Potthast, R.: Assimilation of 3D-Radar Reflectivities with an Ensemble Kalman Filter on the Convective Scale, Quart. J. Roy. Meteor. Soc., 142, 1490-1504, 2016.

Pierre BROUSSEAU, Francois BOUTTIER, Gwena|elle HELLO, Yann SEITY, Claude-FISCHER, Loik BERRE, Thibaut MONTMERLE, Ludovic AUGER, Sylvie MALARDEL: A prototype convective-scale data assimilation system for operation : the Arome-RUC, HIRLAM Technical Report No. 68, 2008

2. l92-93, how the integrated mass flux method be sensitive to the choice of f(z)? Any validation for the choice of f(z)?

Answer: The function f should distribute the integrated adjustment over the column to correct the wind field. We assume the corrections should be larger at places where the analysis increments of the wind field are larger. The idea is similar to Hamrud et al. 2015, who used the analysis spread of the wind field instead of the analysis increment. We rephrased the sentence.

3. l120-121, it would be helpful to give the function of vertical localization length scales.

Answer: We added "i.e., the weights assigned to observations are scaled by the the 5-th order Gaspari-Cohn function (Gaspari and Cohn, 1999), which depends on the vertical and horizontal distances of observations to the analysis grid point".

4. l133-134, how to get the priors and posteriors of the deterministic forecast for the assimilation cycles? This question also applies to the plot contents of Figures 3-6.

Answer: We added "the analysis of the deterministic run is computed by applying the Kalman gain for the ensemble mean to the innovation of the deterministic run (Schraff et al. 2016)".

5. l148-149, is this the opposite? The correlations between integrated mass flux divergence and surface pressure tendency are mainly "inside" the convective regions?

Answer: The integrated mass-flux divergence is proportional (in magnitude) to the surface pressure tendency in case of hydrostatic pressure (i.e., non-convective regions) as shown by Eq. (2). It can be clearly seen in the last column of Fig. 3 that the patterns of integrated mass-flux divergence and the surface pressure tendency are comparable in the non-convective regions, and the former one has much more strong signals within the convective regions. We rephrased the sentence.

6. l157-159, it would be helpful to provide some explanations for the degradation of errors caused by the integrated mass flux divergence. Intuitively, by adjusting the integrated mass flux, a more balanced analysis could be obtained, which is preferable for improved forecasts. Could this intuitive hypothesis be true for large scale applications? Since E_VrZ_6m_f has larger errors and spread than E_VrZ_6m, especially for later times, E_VrZ_6m_f might have smaller increments than E_VrZ_6m. The smaller increments might not be large enough to correct the prior errors, although it is better balanced?

Answer: It should be emphasized that the integrated mass-flux divergence filter is a post-processing method. The analysis is an "optimal" estimate in terms of RMSE of the model state, however, it may be poorly balanced if for instance too small localization radius is applied or observations are very unevenly distributed. The divergence filter is done after the analysis step, it is aimed to reduce the imbalance but does not take the accuracy of model state into account, thus the RMSE of model may increase after this post-processing.

7. l175, why the spin-up shows in E_VrZ_6m_f but not in E_VrZ_6m? Since the spinup show in E_VrZ_6m, does it mean that the adjustment based on integrated mass flux is too much?

Answer: The filter may introduce some unbalanced modes that are not the solutions of the governing equations of the model. This can be attributed to the fact that the filter currently depends on the distribution function f, which is defined in an ad hoc manner. As stated in outlook, we are going to extend the filter to 3D, and the wind is corrected by analyzed mass-flux from level to level. This may lead to a more balanced filter.

8. l178-86, the results of forecasting are based one forecast launched at 15:00 UTC. To draw statistically significant conclusions, more than one forecast is preferred. Can the forecast be launched at different hours, so that more general conclusions can be obtained?

Answer: Statistical significance has been rarely used in the discussion of OSSE results for convective-scale data assimilation (e.g., Snyder and Zhang, 2003; Tong and Xue, 2004) since the test period is very short and the amount of samples is very small. To obtain somehow more robust statistics for the given circumstances, ensemble forecasts are used in addition to the deterministic run. We emphasized this in the text.

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