EGUsphere, author comment AC1
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Reply on RC1

Tobias Necker et al.

Author comment on "Guidance on how to improve vertical covariance localization based on a 1000-member ensemble" by Tobias Necker et al., EGUsphere, https://doi.org/10.5194/egusphere-2022-434-AC1, 2022

We would like to thank the reviewer for valuable comments and suggestions. Below we respond to the reviewer's comments and summarise how we plan to address them in the revised manuscript. The original queries are bold, and our responses are normal text. Planned changes in the manuscript are italic.

RC1: 'Comment on egusphere-2022-434', Lili Lei, 04 Jul 2022

Summary

This manuscript uses a convection-permitting 1000-member ensemble simulation to examine the vertical localization. An empirical optimal localization is proposed, which minimizes the sampling error of correlations estimated from a 40-member ensemble comparing to those from the 1000-member ensemble. Vertical correlations and localization functions for different state variable and cross variables are systematically examined. Results show that different vertical localization functions are required for different variables and vertical height. Combination of the empirical optimal localization with adaptive sampling error correction is also investigated. The manuscript is well-written and could be a valuable contribution for the data assimilation community. I have several comments as below.

1) l22, It is more appropriate to say members of O(100), since Canadian Center has 2 groups of 128-member ensembles.
Reply: We are aware that Environment Canada has a larger ensemble than other forecasting centres and tried to address this by using the word “usually”. To our knowledge Environment Canada is the only centre that exceeds 100 members, while most other centres use about 40-50 members. For this reason, we think that O(100) might be misleading.
Some ensemble sizes:
En. Ca. - EnKF - 256 members
NCEP - deterministic EnSRF - 80 members
ECMWF - hybrid 4DVAR - 50 members
JAM - hybrid LETKF/4D-Var- 50 members
MeteoFrance - hybrid 4DVAR - 50 members

Korea - KIAPS-LETKF - 50 members
DWD - LETKF - 40 members

2) l100-105, the description of BCs is confusing. Is the GEFS 20-member analysis used 50 times to get 1000 BCs? Or climatological GEFS is sampled for 1000 BCs?
Reply: The 20-member analysis ensemble is used 50 times to reach 1000 BCs and afterwards combined with 1000 random climatologically scaled perturbations.
To avoid confusion, we will change the following sentences: "*These BCs combine 1000 climatologically scaled random perturbations with an analysis ensemble of the NCEP Global Ensemble Forecast System (GEFS). The GEFS 20-member analysis ensemble is used 50 times to reach 1000 BCs and afterwards combined with 1000 random climatologically scaled perturbations.*"

3) l197, there are increased correlations below 800hPa. Are there any physical explanations for this?
Reply: Following your question, we analysed temperature and hydrometeor profiles in the ensemble. Members with colder mid-tropospheric temperatures exhibited more upper-level clouds resulting in colder near-surface temperatures that likely are caused by stronger cloud shadowing.
We will add the following comment: "*This weak correlation is linked to cloud shadowing by mid-tropospheric clouds and resulting colder near-surface temperatures.*"

4) Eq. (5), is s the index for 40-member groups with S=25? Eq. (5) is similar to Eq. (1) in Lei and Anderson (2014).
Reply: Yes, the index for S is 25 as we use 25 40-member sub-samples (groups) to compute the EOL.
We will add the following sentence: K is the number of vertical columns in the domain, and S is the number of subsamples.
Eq. (5) is similar to Eq. (2) in Anderson (2007) and to Eq. (1) in Lei and Anderson (2014) but exhibits two essential differences: On the one hand, we consider the correlation coefficient instead of the regression coefficient. On the other hand, our cost function minimises the sampling error with respect to the 1000-member truth, which also results in different sums.

5) If the sample correlation r_40 tends to overestimate the true correlation r_1000, the EOL computed from Eq. (7) should be no larger than 1.0? As discussed by Lei and Anderson (2014), ELF can account for inflation compared to GGF. But I am not sure about the EOL in Eq. (7), which could be true since the true correlation is known. Can the authors provide some derivations on this statement?
Reply: The EOL can inflate sample correlations similar to the ELF but only by optimising sample correlations. The EOL can reach values larger than 1.0 if the true correlation/r_1000 is larger than the sample correlation/r_40. In our setting, this is unlikely as we apply multiple sample correlations that are usually larger than the true correlation given a sufficient number of subsamples. However, we got EOL values larger than 1 when combining the SEC with the EOL (see, for example, Fig 2 in the Supplement/Appendix). The EOL inflated sample correlations when the SEC was applied first and damped sample correlations too strong.
We will add the following sentences: "*Values larger than one can occur when the true correlation is larger than the sample correlation. For example, this can happen when estimating the EOL after applying other localization approaches.*"

6) Figs 2 and 7, how about the sample correlations estimated for cross variables?
Reply: It would also be possible to show and discuss the sample correlations. However, we believe that providing the sample correlations adds little additional information that is not

already supplied by the curves in Fig 2 and the corresponding EOL in Fig 3 (Fig 7 and 8, respectively). We. therefore, believe that including extra lines or figures would rather distract the reader. Fig 3 in the Supplement/Appendix shows the sample correlations for single variable pairs and 500hPa.

7) Figs 3-5, the UU EOL seems have values larger than 1.0. What is the exact value at the reference level? Why EOL estimates localization larger than 1.0 when sample correlations are close to 1.0? Intuitively, when sample correlations are close to the true correlations as 1.0, localization value goes to 1.
Reply: We will modify the x-axis (extended x range) in Figs 3-5, so the reader can see that the EOL values do not surpass 1.0 (see, for example, Fig 1 in the Supplement/Appendix). At the reference level, the EOL reaches a value of 1.0. Please also refer to our reply to comment 5, which addresses a similar point.

8) l258-260, this discussion is based on sampling errors in correlations. But for cycling data assimilation experiments, too strong taper for cross variables may result in too weak corrections.
Reply: Unfortunately, based on our experimental setting, we can only judge sampling errors in background sample correlations, which excludes a cycled assimilation environment. This means that the EOL is optimal in terms of sampling error in correlations but not necessarily optimal in terms of analysis or cycling performance.

9) l290, the "error reduction" is for estimated correlation, not for prior/posterior errors by using the EOL. Also it would be helpful to have some discussions about the estimated localization and localization applied for cycling data assimilation in the section of conclusions and discussions.
Reply: As mentioned in the previous point, we only can estimate localization and error reduction based on the background correlation/covariance. We want to avoid speculation and therefore prefer not to discuss potential localisation changes that might impact the error in a single or cycled analysis.
For clarity, we will add the following sentence: "*The result can be interpreted as a benchmark of the maximum possible correlation error reduction achieved by a domain-uniform height and variable-dependent localization. Note that results for optimizing the analysis may lead to different optimal localization values under some circumstances, but this is beyond the scope of this paper.*"

10) Section 3.1, a curious question, if the direct-variable EOL is applied rather than cross-variable EOLs, i.e., UU is applied for UU, UV, UT, and UQ, how about the correlation error reduction?
Reply: This is an interesting question. We tested this approach in one experiment and found an error reduction similar to ALL or SEC.
We plan to add the following sentences: "*Additionally, we tested the error reduction for applying the EOL estimated for self-correlations to both self- and cross-correlations of each variable (e.g., EOL derived from TT applied to TT, TQ, TU, and TV). For this setting, the error reduction was similar to ALL or SEC (not shown), which underlines the need to treat self- and cross-correlations differently.*"

11) l396-399, it would be helpful to add some dynamical explanations for these results.
Reply: Finding dynamical explanations would be interesting. We attempted to incorporate such a dynamical interpretation, but it is hard to distinguish between a coincidental correlation or a dynamically induced correlation (correlation does not imply causation). Additionally, we show results averaged over a very large sample of profiles during different atmospheric conditions. Thus, it seems impossible to provide a short explanation of dynamical reasons without speculation.

12) l407, the computational efficiency issue can be treated by model-space localization (Lei et al. 2018).
Reply: Keeping in mind the full range of ensemble DA methods implemented in various places, we are convinced that it is generally correct to say that other factors, e.g. computational efficiency, may also need to be considered. However, we will add "*may*" in this sentence to weaken the statement.

Please also note the supplement to this comment:
https://egusphere.copernicus.org/preprints/2022/egusphere-2022-434/egusphere-2022-434-AC1-supplement.pdf