## Author response to anonymous referee #1

Thank you to referee #1 for reading the manuscript and for his/her valuable comments. In the following, the referee's comments are reproduced, and my responses are in blue. Please note that I am instructed by the journal to give responses before preparing a revised manuscript, but I highlight here any changes that I plan to make in the revision.

This paper describes a DA system that has been built for the ABC model of Petrie et al. (2017). The entire system, ABC-DA, is described as flexible, configurable, and efficient enough to be run on a personal computer. One of the stated applications of the ABC-DA is to study convective-scale DA. This system could also clearly be used as a teaching aid for DA students. Section 4 gives a tutorial on variation data assimilaton and a practical "how to" for constructing a 3DVar system. Section 4 gives a tutorial on control variable transforms (CVTs) and is also a practical "how to" for developing CVTs. These two sections are well written tutorials which, by themselves, could serve as a good teaching aids.

I would recommend the publication of this paper after the author addresses a few minor comments.

1. Figure 7 might be more easily interpreted if the correlation rather covariance were plotted. It is not easy evaluate the importance of the cross-covariances (columns 2 & 3).



- (a) I have computed the correlations (FYI as above), but a certain amount of information that I wish to show is unfortunately lost in such plots, compared to the covariances (i.e. information on the implied variances as well as the correlation patterns), so I would like to keep the covariances in the paper rather than the correlations, if the reviewer agrees.
- (b) On the importance of the cross-correlations, I will add (to the discussion around Fig. 7) an interpretation of these in terms of their effect on the analysis increments. Essentially the cross-correlations show how

the assimilation of a  $\tilde{\rho}'$  measurement at the yellow cross position in Fig. 7 will affect variables like r' and b'.

- 2. A ensemble of forecast perturbations is used for training/developing the CVT. The author describes this raw ensemble in this way: "We regard the raw covariances as a guide to the 'true' covariances that should ideally be modeled by the CVT.". In principal, the ensemble could be made large enough to provide a very accurate covariance, from which the implied covariances (from CVT choices) could be directly evaluated. Is the model state size too large to create a full rank (or nearly full) for this type of comparison?
  - (a) Yes, indeed the model state is too large to create a full rank estimate of the B-matrix. I will slightly reword the sentence cited above to point out the limitations of the raw covariance plot, "We regard the signals contained in the raw covariances as a rough (row-rank) guide to the covariances that should ideally be modelled by the CVT."
- 3. Following on comment #2. If the training ensemble is of low rank, then it is well known that the covariances must be localized. It is possible that the covariance used for the experiments (i.e. bottom row of Figure 7) should be localized before used for developing the CVT?
  - (a) This is true, but the raw covariances still contain a signal that is useful (see my reply above).
  - (b) Localisation is not required to develop the CVT though. I will add a new appendix (new appendix A) to show that the information contained in the calibration population is more than enough to determine the CVT. Briefly, there are about 10<sup>5</sup> pieces of information of the covariance model that need to be determined during the calibration (things like vertical modes, and spectra), but 28 × 10<sup>6</sup> pieces of information is provided in the form of 260 super-ensemble members.
- 4. There is much current research on using ensembles to represent the B matrix in variational DA. Can you comment on any plans to incorporate the ability to directly use an ensemble to perform the background covariance multiply, or possibility a hybrid approach?
  - (a) This is something that certainly could be done. I have no plans at present, but I will expand a bit the path to this at the end of the summary of the paper.