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Interactive comment on "Multivariate localization methods for ensemble Kalman filtering" *by* S. Roh et al.

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In most implementations of the Ensemble Kalman Filter (EnKF), ensemble covariances between distinct variables defined at the same location in space-time are not attenuated. This paper successfully makes the point that, in some circumstances, EnKF performance would be improved by attenuating such inter-variable correlations.

The paper identifies simple ensemble covariance attenuation strategies for covariances between variables of different types such as zonal wind and temperature. The proposed strategies all guarantee the symmetry and semi-positive definiteness of the localized covariance matrix. The utility of the proposed approaches is evaluated using an idealized chaotic system with fast and slow variables. For this particular system and a fairly dense observing network, it is found that attenuating the inter-variable ensemble

covariances improves EnKF performance.

The inter-variable covariance attenuation methods given by equations (6)-(9) and the associated discussion appear to pertain to the case when there are just two distinct variables at each grid-point. The paper would be of greater interest if corresponding formulae were given for the general case where there were M distinct variables at each model grid point.

The numerical experiments performed in this paper would be more informative if an effort had been made to establish the magnitude of the true error correlations between the slow (X) and fast (Y) variables in the system considered. It is only when that number is known that the potential gain of not zeroing out the intervariable correlations can be quantified.

Another issue the authors might aim for in revising their paper is to come up with some rules of thumb to predict from the true error correlation and known random ensemble size when (a) there would be little to be gained in attenuating inter-variable ensemble correlations, or (b) there would be little to be gained in keeping any of the inter-variable ensemble correlation, or (c) partial attenuation of the inter-variable correlations would be helpful.

Specific Comments:

1. P837, 2 paragraphs beginning on line 3. I disagree with the sentiment that (1) and (2) only solve the formal data assimilation problem when Pˆb is invertible. This is incorrect. For linear observation operators (1) and (2) give the Best Linear Unbiased Estimate (BLUE) or minimum error variance estimate for a linear gain regardless of the rank of Pˆb, see, for example, Section 4.2 of Daley's, 1991 monograph on data assimilation. Pˆb is highly rank deficient in many dynamical systems of interest so an incorrect suggestion that (1) and (2) are somehow inappropriate ought to be avoided.

2. Equations (6)-(9) only appear to pertain to the case where the system has two

distinct variable types at each grid point. The paper would be significantly strengthened if you could give the equations that guarantee positive definiteness for a system that has more than two distinct variables defined at each grid point.

3. As a check on the EnKF code and to quantify the upper limit of the usefulness of X-Y covariances, I think the paper would be stronger if you added another experiment in which the ensemble size was 16 to 32 times larger than the 40 member ensemble you considered here. With that experiment, you should be able to isolate the data assimilation value of accurately estimating X-Y covariances.

4. The conclusions need to admit that the found superiority of the Askey localization function over the Gaspari-Cohn localization function may not extend to other chaotic models or observation networks. Askey might be better when the true correlation function looks more like the Askey function than the Gaspari-Cohn function and vice-versa?

Minor Specific Comments:

5. Abstract, line 8: Change “entry-wise” to “element-wise”.

6. Equation (2): Most EnKFs do not use the linearized observation operator in the definition of the gain. Thus, (2) or the discussion around it needs to be changed so that the reader is fully aware of the EnKF’s ability to directly estimate covariances between forecasts of variables that are non-linear functions of the state and the state variables themselves.

7. P843, line 14. To more clearly define s give an example e.g “if the state is defined at a particular instant on a latitude, longitude, height grid then s=3” – if that’s what you mean.

8. Equations (12) and (13): The relationship between this model and model 3 of Lorenz (2005, JAS) needs to be pointed out.

9. P847., lines 6-11. I think it would be clearer if you replaced “cross-covariances are set to zero ” with “covariances between X and Y variables are set to zero” – if that’s

what you mean. Also, I’m not sure what you mean by “marginal covariances”. Do you mean X-X and Y-Y covariances? Please clarify these issues in the revised text.

10. Very little was said about Figures 8-11. Either discuss each one individually or replace some of them with a summary statement of what they indicate.

Interactive comment on Nonlin. Processes Geophys. Discuss., 2, 833, 2015.