Geosci. Model Dev. Discuss., 8, C2486–C2489, 2015
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Geoscientific Model Development Discussions
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8, C2486–C2489, 2015

Interactive Comment

Interactive comment on "Assimilating compact phase space retrievals of atmospheric composition with WRF-Chem/DART: a regional chemical transport/ensemble Kalman filter data assimilation system" *by* A. P. Mizzi et al.

Anonymous Referee #1

Received and published: 13 October 2015

This paper illustrates and discusses the results of a number of data assimilation (DA) experiments with the WRF-Chem model and the DART suite of data assimilation algorithms. All DA experiments consider a state vector including meteorological and selected chemical variables. A series of experiments assimilate pre-processed CO retrievals from MOPITT while a control experiment only assimilates meteorological observations. A variation of the QOR assimilation methodology (denoted as CPSR) is also introduced. Results for a number of month-long experiments show that assimilation of QOR and (considerably fewer) CPSR retrievals reduces CO RMS errors and

biases with respect to MOPITT retrievals more significantly that when only met data are assimilated. This is an interesting and useful paper that I recommend for publication after addressing the points noted below.

General comments

I have a few theoretical issues on the definition of CPSR profiles, which are detailed below. In Section 2 the authors consider the covariance of U_0ˆT \epsilon, given by U_0ˆT E_m U_0 and then they apply to it an SVD transform and inverse scaling "similar to that used by Migliorini et al. (2008)". In that paper, however, E_m is first expressed in terms of its eigenvector decomposition and then the retrieval is scaled with the inverse of the "square root" of E_m (see Migliorini et al. (2008), their section 5). If the same procedure was applied here, U_0ˆT E_m U_0 would have become equal to U_0ˆT U_0 = I. In my opinion, transforming U_0ˆT E_m U_0 instead, at a later stage, is an unnecessary complication. Furthermore, the authors apply to U_0ˆT E_m U_0 a SVD transform rather than an eigenvector decomposition. This makes me not so sure that the "final form of the observation error covariance" is the "truncated identity matrix" as stated in Section 5, as it becomes equal to \Sigmaˆ{1/2} \Psiˆ T \Phi \Sigmaˆ{-1/2}. And as far as I can see, \Psiˆ T \Phi is different from the identity matrix. This problem would have been avoided if an eigenvector decomposition was used instead of an SVD. Finally, the compression approach used by the authors is conceptually equivalent to that in Eq. 24 of Migliorini et al. (2008) in the specific case when the considered forecast error covariance matrix is the identity matrix. This should be noted in the paper, as well that this simplification has the drawback that the compression is not based on a realistic estimate of the information content of the observations (as in the case of Eq. 24 of Migliorini et al. (2008)). If the authors agree with my comments I would recommend that they rerun the CPSR assimilation experiments (even just for a shorter, test period) with the amended definition of CPSR using an eigenvector decomposition rather than SVD and check how their verification results change.

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Specific comments

- Introduction: The paper Migliorini, S. (2012), On the equivalence between radiance and retrieval assimilation, MWR should also be referenced as relevant to this paper.

- Eq (3) and later: it is not clear what is the benefit of Eq 3 that is not already in Eq 1, given that the retrieval error is unknown. Practically the only quantity that can be calculated is the left term of Eq 1, not that of Eq. 3.

- Typo in the SVD decomposition of U_0ˆT E_m U_0 above Eq 5: Psi should have a transpose sign.

- P7699 L20 “The result should be an identity matrix”: This is only the case if an eigen-decomposition is used in place of the SVD.

- Section 4: replace “vertical grid points” with “vertical levels”.

- Section 4 “vertical localization”: This concept is introduce here but more information should be given about the chosen radius of horizontal and vertical localization (and the reader should also be referred to section 7.5)

- End of section 4: It is not clear what was done in terms of vertical error correlations of emission perturbations. Did you take those into account? Note that MOPITT retrievals may have done so (actually it would be good to know about that too).

- Section 5: It would be good to have more information on the specific flavour of the DA system used within DART for the experiments in this paper.

- End of section 5: it is not clear what Cm is, as the “measurement error in retrieval space” or retrieval noise is given by K Ca KˆT, not by Cm. Also there must be a typo in the definition of Cm, given that I + (A – I)ˆT is equal to AˆT.

- Section 6: “DART horizontal localization”. Please provide more details (see above)

- Section 6 “DART clamping”: just a minimum threshold?

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- Section 7.1: replace “assimilation sparse observations” with “assimilation of sparse..”

- Section 7.1 L10 “the results are consistent with Fig 1”: this is difficult to say at this stage, before the explanations given later.

- Section 7.1 L5: It is not so evident to me that IC/BC effects can be ruled out completely.

- Section 7.2 L5: I believe c_r U_0 should instead be written as U_0 c_r, for dimensional reasons.

- Section 7.2 L20 “that can also indicate a contribution..but not always”: It seems to me that this is always the case for QOR residuals

- Section 7.2 L20: “When components of the retrieval...”: I don’t quite understand this statement, as I believe QOR removes precisely the components of the prior that lie in the range of A (I guess except in the limiting case when A = I). Please clarify.

- Section 7.2 L25: “This analysis shows...” I don’t think the sentence is justified by the discussion above (see my previous comments).

- Section 7.4 “zeroing of the cross-correlations”: In Migliorini et al. (2008) a scaled inverse transform on the observation error was used (their Eq. 23) rather than zeroing of the cross-correlations.

- Section 7.5 L5 “transformed averaging kernel”: please clarify what you mean by transformed here.

- Figure 1 caption: add “domain” to “represents the WRF-Chem”.

- Figure 2. I believe the solid lines in both panels represent the same data. Consider explaining that in the caption.

Interactive comment on Geosci. Model Dev. Discuss., 8, 7693, 2015.