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Interactive comment on “Comparison of the ensemble Kalman filter and 4D-Var assimilation methods using a stratospheric tracer transport model” by S. Skachko et al.

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We appreciate very much the Anonymous Referee 1's comments. We have answered all questions. Each answer starts with “ANSWER:”. We have kept the original Referee's comments in Bold.

1. In section 2.4, the paper describes the method to generate initial ensemble members and model errors in EnKF. It is not clear from the paper whether the initial ensemble members were created at the beginning of every 24-hour assimilation cycle or only at the beginning of the 6-month run. If it is at the beginning of every 24-hour assimilation cycle, the EnKF implemented in this paper did not

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take the advantage of the flow-dependent error covariance from one-assimilation cycle to the next. If it is at the beginning of the 6- month run, then it is not clear whether the constant magnitude model error is sufficient to overcome the filter divergence. I suggest the authors to clarify this point in this text.

ANSWER: We followed the suggestion of the referee and added the explanation to the second paragraphe of the Sect 2.4: 'The EnKF uses flow-dependent ensemble forecast error covariance (12) evolving in time with the ensemble. On the contrary, 4D-Var reinitializes the background error covariance every 24 h.'

2. EnKF can easily calculate the uncertainty of the analysis field along with the mean state, while 4D-Var would need approximation to obtain analysis uncertainty. I suggest authors adding some discussion about the uncertainty estimation from the EnKF, and adding the range of OMF statistics from EnKF when compared to 4D-Var estimates, such as in Figures 3, 4, 5, and 6.

ANSWER: The aim of the present paper is to compare properly both systems on their best possible level of performance in the form as they are usually used. As far as 4D-Var does not provide the analysis uncertainty, we decided not to include this discussion in the paper. However, we estimated the EnKF analysis error obtained in our experiments. This estimation is performed using the variance of the ensemble of analyses. It was found that the analysis error in the observation space is less than 0.5% from the background state, which makes its graphical representation difficult. The analysis error remains stable in the whole model domain and does not exceed 3.5% from the background state during the whole experiment.

3. The authors manually tuned the magnitude of model error term and the observation error in the paper. In the conclusion, the authors argued that EnKF requires more tuning than 4D-Var to get comparable performance even with relatively easier implementation. It is known that EnKF needs inflation in the background error covariance to avoid filter divergence, equivalent to the model error

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term in this paper, Anderson, J. L (2007b, 2009) and Miyoshi (2011) have discussed adaptive inflation. Li et al. (2009) discussed estimating the adaptive inflation factor and observation error covariance simultaneously in EnKF. I recommend the authors implementing the adaptive inflation method and observation error estimation strategy to their EnKF. The implementation of these methods would significantly reduce the tuning time for EnKF. If these methods could not apply in their EnKF, the authors should add some comments on why.

ANSWER: We agree with the referee that the automatic calibration procedure would be useful in the EnKF system, especially for the future work using full stratospheric chemistry set and instantenous assimilation of different chemical species. We added the following phrase to the last paragraph of conclusions: 'The application of the EnKF method to the full-chemistry model may require a careful tuning procedure for each chemical species, a task that can be time consuming. Hence an adaptive calibration procedure of the error covariances (similar to Li et al. (2009)) should be implemented.'

Minor comments: There are several places with spelling and grammar mistakes.

1. Line 25 on Page 357: "...the differences (bias) between observations and forecasts, as well as the and their standard deviation", should be: "...the differences (bias) between observations and forecasts, as well as their standard deviation".

ANSWER: Done.

2. Line 13 on page 359: "the 4D-Var providing values slightly lower than those from the EnKF". It should be: "the 4D-Var providing values slightly lower than those from the EnKF".

ANSWER: Done.

3. Line 23 on page 360: "the standard deviation is smoother than displayed by the χ^2 ", should be: "the standard deviation is smoother than displayed by the

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χ^2 ”,

ANSWER: Done

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