Review of "Assimilation of IASI partial tropospheric columns with an Ensemble Kalman Filter over Europe" by Coman et al.

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Overview

This paper explores the potential of IASI column ozone observations to constrain a regional chemistry transport model unsing an Ensemble Kalman Filter, focusing on a special case in July 2007. The paper demonstrates clearly that the assimilation is able to improve the agreement between the model and two types of independent observations, but also that the improved modeled ozone fields do not necessarily yield improved forecasts.

This paper is interesting and presents a useful analysis of the impact of IASI data. However, the language describing the assimilation approach is at times ambiguous and not in line with the jargon of the data assimilation community. Considerable time is spent on the rather obvious result that assimilation improves the fit of a model to the assimilated observations; the paper could be made far more concise by focusing instead on how much information can be gleaned from the IASI observations, rather than showing that the assimilation "works".

In the following review, all page numbers will be referred to by the last two digits only (e.g. *P45* for page 26945).

General Comments

1. An Ensemble Square Root Filter (EnSRF) is used to perform the assimilation, but the method is referred to as an Ensemble Kalman Filter (EnKF) throughout the study. Thus it comes as a major surprise to the reader when the EnKF is described up to halfway through Section 4, and suddenly the switch is made to EnSRF. Even though the EnSRF is considered a variation of the standard EnKF, the present-day data assimilation literature considers these to be two different algorithms, with the moniker "EnKF" implying the classical, "perturbed-observation" Ensemble filter described Evensen (1997) and Burgers

et al. (1998). Therefore I strongly recommend that the method be referred to as EnSRF throughout the paper, including the abstract.

2. Four figures (Figs. 4-7) are dedicated to showing that the assimilation of ozone data into the model results in a better fit of the model to the assimilated observations. However, an improved fit to the assimilated observations is actually an expected result of any working assimilation scheme and doesn't really tell us anything about either the quality of the assimilation scheme or the knowledge gained by assimilating observations (in other words, if we were only interested in fitting the model to observations, we might as well throw away the model and only look at observations). I recommend greatly reducing the discussion of observational fit, and instead devoting more space to discussing the impacts of IASI ozone assimilation on the modeleled ozone, e.g. by examing the reduction in ensemble spread as the assimilation progresses.

Specific Comments

1. P45, L28: The distinction that sequential algorithms are used for real-time analyses and retrospective algorithms for reanalyses is not entirely valid, since, for example, 3D-Var is considered sequential but is used in the ERA-40 reanalysis (Uppala et al., 2005).

2. P47, L11: The introduction seems to makes a distinction between (a) assimilation of total column ozone, (b) assimilation of ozone on the free-troposphere, and (c, line 11) assimilation of ozone for purposes of air quality. However, at least to this reader, it's not obvious that there even is a distinction between these areas. Can you explain, for example, why the free-troposphere assimilation studies cited in the first paragraph on P47 would not fall in the category of air quality?

3. P47, line 26: The use of "poorly documented" here tends to imply that the multitude of studies that have just been cited about tropospheric ozone concentration and its evolution, are poorly written. Surely the authors are simply making the point that, despite the studies above, key information is still missing. This paragraph could be written more clearly to show exactly what exactly is missing in our understanding after all the cited studies are considered (presumably it's the fact that observations are still very sparse?).

4. P50, L25: "Degrees of freedom" is not synonymous with "an independent piece of information", so this sentence should be rephrased,

e.g. by writing in the parentheses something like, “i.e. increasing the degrees of freedom, or DOF, of the signal”. Moreover the connection between DOF of a retrieved column and the amount of independent information is unclear, mainly because no information is given about how the DOF shown in Fig. 2 are computed. P52, L4 states that the 0-6km columns “do not contain an independent piece of information“. – What does this mean?

5. P54, L9: I object to the description of the EnKF as a “3-D” assimilation method. Even though it is sequential (not retrospective), an important trait of the EnKF is that it evolves background error information forward in time, which is exactly what is meant when referring to 4-D methods.

6. P56, L1: Equation (1) describes the update at every timestep, not just the initial one. Thus, $\left(\Psi_i^f\right)_{i=1,N}$ refers to the ensemble at any, not just the initial, time. Thus the word *initial* should be deleted here.

7. P56, L3: This sentence just describes what happens in eq. (1), which is not unique to the EnKF (the same thing is done in OI, variations on the EnKF, and variations on the linear KF) and thus not really “the key” to this method. Rather, the distinguishing trait of the EnKF is the use of an ensemble to get the covariance matrices, i.e. eq. (4).

8. P56, L19: “...ten times larger” – than what? The comparison here could be to any number of things (numerical weather prediction, climate reanalyses), so this should be made more clear. Moreover, it is not obvious that more observations require larger ensembles than are typically used - please explain this, and why 100 ensemble member makes the problem ill-conditioned. Also, this paragraph currently reads as though covariance localisation is necessary in a wide range of applications *because* the AQ problem has more observations – which of course doesn’t make any sense. In fact, covariance localisation is used because, in almost all problems, the state to be estimated much larger than the ensemble, which causes spurious correlations due to sampling error. This problem is separate from the issue of more observations, and this should be made clear.

9. P57, L6, and elsewhere: It has already been explained that the EnSRF is being used in this study, so it is inappropriate (and potentially misleading) to introduce it as “Ensemble Kalman Filter” here (see general comment above).

10. P57, L15: Actually, more basic ways to initialize an ensemble also exist (e.g. one could select initial conditions from a long model sim-

ulation, or just perturb a set of initial conditions) - that is worth mentioning.

11. P58, L20: I don't see a reason to split the discussion on localisation between this paragraph and the last paragraph of Section 4.1 It would be more straightforward to describe localisation entirely in one place.

12. P59, eq. 6: It seems as though eq. (6) would be more appropriately placed in the earlier discussion of the averaging kernel (Section 2). This would make that section clearer, and then A would already be defined by the time at eqn. (5) is introduced.

13. P60, L18: Modest reductions in the RMSE as ensemble size / patch size are increased does not reflect robustness of a DA system, but rather the saturation of errors, i.e. the fact that all other errors (model error and observation error) are so large that increasing the ensemble size doesn't improve the accuracy.

14. P60, L22: I don't see a reduction of RMSE by increasing path size from 20 to 30, in fact in three cases (ens. sizes 10, 20, and 80), larger patch size slightly increases RMSE.

15. P61, L1-2: How is the slope of the IASI-Model scatterplot different from the correlation coefficient between them? If the difference is only numerical, there is no benefit to showing both numbers.

16. Fig. 4: It is difficult from comparing these three panels, to see where the modeled ozone fields are corrected the most strongly. A more informative plot would be to show the ensemble mean assimilation increment (analysis - forecast); this would show where the observations had the most impact, especially when compared to the difference fields between the forecast and observations, and analysis and observations.

17. P61, L3: It is pointed out that the situation depicted in Fig. 4 could have a larger than usual model bias. How should this affect our interpretation of Fig. 4?

18. Fig. 5: It is not really surprising that the analysis O_3 fields are similar to the observations, since this is exactly what the assimilation is designed to do. Again, it would be more interesting to see an analysis-forecast increment field. It would also be informative to show how the ensemble spread changes after assimilation, since this would show us where the IASI observations had the most impact.

19. P61, L1-2: I am not convinced that the correlation between the model and observations before and after assimilation is an interesting result

here. Showing that correlation increases merely shows that assimilation is able to make some sort of fit to observations (which it has to if the assimilation is working), but it tells us nothing about whether this fit was achieved for the right reasons, or whether the model was actually improved by assimilation.

20. Fig. 7: I am not convinced that Fig. 7 shows anything that hasn't already been shown at this point, i.e. that the analysis is closer to the observations than the prior, which in itself is not even very surprising.

21. P63, L25-26: It is unclear what is being compared here – does "innovations" refer to the difference between the observations and the forecast following assimilation?

22. P67, first paragraph: Here it would be good to clarify that the *bias* is actually the bias with respect to Mozaic, not some sort of general bias. This is especially important since the bias with respect to soundings (Fig. 12) is not really reduced with the assimilation.

23. P67, L8-25: Assimilation improves the agreement between the model and MOZAIC as well as ground-based stations, but not for the ozonesondes. However, I don't think this is very troubling since both the reference run and the EnKF analysis are mostly within the uncertainty level of the ozonesonde composite (Fig. 12). However, some discussion of why the EnKF might fail to improve the fit to the sondes would be helpful. Here it would also be helpful if Figs. 11 and 12 had the horizontal axes; this would make it easier to compare the error bars for each of the independent measurement types.

Technical Corrections

1. P45, L2: "AQ" is introduced here as an abbreviation for air quality, but not really used until P56. It would be better to be more consistent.

2. P45, L9: If "Regional Chemical Transport Model" refers to a specific model, it should be cited, and if it referes generally to regional CTMs, it should be written in lower case. The abbreviation RTCM is used on P53, L2, but has not been formally defined anywhere.

3. P46, L20: "began to be set-up" sounds awkward. Perhaps, "was begun" will suffice.

4. P46, L27: It's unclear whether the reference to Dethof and Holm (2002) refers to the ECMWF ozone assimilation, or just the SCIAMACHY instrument. Both this reference and the one to Eskes et al. (2003) should be more strategically placed to make clear what there references refer to.

5. P48, L20: The wording in the first sentence here is awkward, since no assimilation framework has been introduced at this point in the paper. Maybe a more simple way to say this is: “The assimilation of IASI data has already been studied.”

6. P54, L25: More simply: In the EnKF, the ensemble mean and covariance *are presumed to fully* describe the PDF *of both the prior and assimilated fields, which are assumed to be Gaussian*.

7. P55, L3: up-date $\rightarrow$ update.

8. P57, L11-12: This sentence would be better placed after the one stating that the filter is used for state (not parameter) estimation.

9. P58, L9: regrouped $\rightarrow$ grouped.

10. P60, L203: Delete “which” and “were” for a more concise sentence.

11. P61, L15: Since the simulation only covers one month, “monthly averaged mean” can just be “mean”.

12. Fig. 8: It would be far more straightforward to the reader to refer to the zones as “NorthEast”, “NorthWest”, etc., rather than the letters.

13. P65, L22-23: There is no need to put these phrases in quotes.

14. P65, L25: Figure 10 should be introduced before individual curves in it are referenced.

15. P65, L25: “Simulated ozone levels *in the reference simulation* are larger in the...”

16. P68, L7: The sentence beginning with “Especially...” is not complete.

17. P69, L10: *spatial* differences.

References

Burgers, G., van Leeuwen, P. J., and Evensen, G. (1998) , *Mon. Wea. Rev.* $\mathbf{126}$, 1719

Evensen, G. (1997) , *Mon. Wea. Rev.* $\mathbf{125}$, 1342

Uppala, S. M., Kallberg, P., Simmons, A., Andrae, U., Bechtold, V., Fiorino, M., Gibson, J., Haseler, J., Hernandez, A., Kelly, G., Li, X., Onogi, K., Saarinen, S., Sokka, N., Allan, R., Andersson, E., Arpe, K., Balmaseda, M., Beljaars, A., and Berg, L. V. D. (2005) , $\mathbf{131(612)}$, 2961