

Reply Topic editor decision:

As both reviewers gave very positive comments on this manuscript, I suggest that the manuscript be accepted after the reviewers' and my minor comments/suggestions are adequately addressed.

We once again thank the editor for their feedback. We are glad our changes have been well received. Below we address the new comments.

Fig 3 and Fig. 12a, d are the same. Since Figure 3 is only used for an example with little explanation, there is no need to duplicate the plots.

We have removed figure 3. The references in the text now point to the other figure. (now figure 11a and 11b). The text has also been slightly to accommodate this:

“Figure 11b shows satellite observations over Europe, with the associated superobservations in figure 11a”

The air mass factor uncertainty is the only one with a horizontal correlation pattern. Referring to Fig. A2b and mentioning the correlation length (32 km) in section 4.3 would be clearer for the readers.

We have added the correlation length on line 362:

“Here we find a correlation length of 32 kilometres.”

However we believe that we should not refer to figure A2b from here, because the main text does not contain enough information to properly interpret the figure. A reader that would jump from section 4.3 to Fig. A2b and back will probably misunderstand the figure and get a wrong idea on the method we use to calculate the correlation length.

We do add an approximate correlation for the air mass factor that results from this correlation length for a 0.5 degree superobservation on line 375:

“For a 0.5 degree superobservation this gives $C \approx 0.3$ ”

Please clarify what you meant by "the observation uncertainty is fully correlated in space" for the data assimilation experiments. $c=1$ for all three uncertainties and RE?

Here we mean that the correlation C from equation 11 is equal to 1 ($C=1$). We have added the correlation values for the uncorrelated experiment on line 528:

"The standard superobservations, with modified uncertainty assuming that the observations are fully uncorrelated in space ($C=0$, fig. 12d)."

And for the fully correlated experiment on line 530

"The standard superobservations with modified uncertainty assuming that the individual observations are fully correlated in space ($C=1$, fig. 12b)."

Also we add these values to the description of figure 12:

"Figure 12. Panel showing various methods of pre-processing uncertainties for data assimilation and the RE on 2018-09-08 for $q_a > 0.75$. (a) superobservation uncertainty constructed for this research (b) fully correlated uncertainty ($C=1$) (c) representation error (d) uncorrelated uncertainty ($C=0$)"

Please clarify what is used for $O_{t,x,y}$ in the RMSE calculation since four experiments use different superobservations.

On line 540 we clarify this variable:

"Here $O_{t,x,y}$ are the observations associated with the experiment (1, 2, 3: fig. 11a and 4: fig. 11d) and $F_{t,x,y}$ are the forecasted values. This is shown in figure 13."

Referee #1 report:

I would like to thank the authors for greatly improving the manuscript. The paper seems ready for publication.

We thank the referee for reading our revised manuscript. We are glad the changes were well received

Referee #2 report:

The authors had thoroughly addressed my comments and questions. The revised manuscript has significantly improved its readability and content compared to the previous version. Excellent work!

I only found a few typos in the revised manuscript that could be addressed during the proofreading stage:

We thank the referee for reading the manuscript, we are glad the changes were well received. Also we thank you for your thorough inspection of the revised manuscript and catching these mistakes. We address them below:

Line 405: There was no equation 8a in the manuscript. I think the authors are referring to equations 16 or 17.

Thank you for catching this mistake, we now refer to equation 17.

Line 481: Please consider changing the symbol of superobservation uncertainty from $(\sigma_{sob})^2$ to $(\sigma_s)^2$ in alignment with the definition in equation 10.

The symbol should be consistent. We have changed line 481 to:

“Figure 10 shows the contributions to the superobservation uncertainty (σ_s^2) as a function of the tropospheric NO₂ column.”

Line 598: The HARP toolbox first appeared in Section 3.1; please consider defining the acronym in this section.

We now define the HARP acronym on line 221:

“This method of averaging is similar to spatial binning using the Data harmonization toolset for scientific earth observation data (HARP)”

Line 600 now reads:

“This is similar to the method of Inness et al. (2019b) and the HARP spatial binning method for total uncertainty variables”

Changes to colour schemes:

We have updated the colour schemes on the following figures to make them more readable for readers with colour vision deficiencies:

- Figure 10
- Figure 11
- Figure 12
- Figure 13a
- Figure 14a
- Figure A2 b, c and d
- Figure C1