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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Smoke-charged vortices in the stratosphere generated by wildfires and their behaviour in both hemispheres: comparing Australia 2020 to Canada 2017" *by* Hugo Lestrelin et al.

Hugo Lestrelin et al.

legras@lmd.ens.fr

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[acpd,discussion]copernicus

bernard.legras@lmd.ipsl.fr Lestrelin, Legras, Podglajen, Salihoglu

Answer to reviewer #3

Major comment

My strongest criticism, is related to the explanation how the reanalysis data, like ERA5 does work (sections 2.2.1 and 2.2.2). A more careful explanations would help to understand better this paper, especially if you assume that not every reader is an expert in the assimilation procedure. Because either ECMWF operational analysis nor the ERA5 reanalysis does assimilate the aerosol observations (the only pure observational evidence from CALIOP) it is difficult to imagine that ECMWF/EAR5 data does contain any smoke-related information at all. However, you show that in the PV/ozone fields (Figure 3/7) there are clear signatures of such smoke clouds. Thus, if these structures are reproduced by the reanalysis, the respective assimilation increments should be small...?

On the other hand, you also show that the assimilation increments within such structures (Figure 9) are really large. Is it true only within such "undetected clouds"? Maybe a separate figure (like Figure 7) but only for the assimilation increments would also help to follow the cloud? In any case I would recommend to explain better the applied method, especially the apparent contradiction between the "resolved" clouds in ERA5 data and unresolved properties manifesting in the "large" assimilation increments.

It is clearly beyond the scope of our work to provide a tutorial on assimilation which is a whole field by itself but we have tried to add some sentences to help the reader who is not familiar. And yes it is a wonder that the model reproduces a smoke vortex even if it does not contain smoke. The "miracle" is due to the fact that the vortex exhibits a strong thermal signature which is well detected by the satellites. This pattern is forced into the model by the assimilation and through the principle that the motion is balanced (McIntyre, 2015), the whole vortex is reconstructed with some accuracy. Over the continental regions the assimilation also uses ground based radio-soundings that contain

wind information. Therefore there is no contradiction between resolved and unresolved structures. The missing smoke heating rate is replaced by the assimilation increment, hence the amplitude of this later. In the supplement of Khaykin et al. (2020), it was shown how the deviation of the observations, with respect to the a priori simulated by the model, is reduced by the assimilation, and therefore how the information is used to guide the model. In this study, we are looking at the assimilation from the point of view of the model world and we diagnose the effect of the assimilation on the temperature and PV field. The delicate point is that the temperature assimilation increment cannot be simply interpreted as a heating rate because it diagnoses the final equilibrated state where momentum and temperature are in balance. Assimilation is an iterative procedure where the model is disturbed to get closer to the observation but it is done in such a way that the modification does not add transient riddles of gravity waves. It was shown in Khaykin et al. (2020), that if suddenly the assimilation procedure of new observations is stopped, which is what is done to produce a weather forecast, the vortex does not rise anymore but stays on the same isentropic level and its amplitude decays in about one week. We show in this study that this decay is mostly due to the longwave radiative exchanges that damp the thermal dipolar structure. This is done mostly by carbon dioxide and water vapour. In the real vortex, the longwave radiative effect of the aerosols can only accelerate this damping.

Minor comment

- *L103-106 difficult to understand...please reformulate (see my main point)*

  Several additions have been made to this section to improve clarity.

- *Figure 10 You mentioned in section 2.2.1 that you do not use the ERA5 PV but calculate your own PV from eq. (1). How do you proceed for the assimilation increments of PV discussed in section 4.2.2*

  We use our own calculation to get PV at the full vertical resolution of the model

  and not on a selected number of levels as provided by ECMWF. PV is calculated in the same way for the a priori state resulting from the forecast and for the new analysis. The increment is defined as the difference between these two quantities exactly as for the temperature.

References

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