EGUsphere, author comment AC1
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Reply on RC1

Giorgio Doglioni et al.

Author comment on "Dynamical perturbation of the stratosphere by a pyrocumulonimbus injection of carbonaceous aerosols" by Giorgio Doglioni et al., EGUsphere, https://doi.org/10.5194/egusphere-2022-80-AC1, 2022

Answers to Reviewer #1

This paper describes a simulation of a large stratospheric smoke plume injected by an intense pyroCb event in Canada. Emphasis is placed on the successful simulation of a stratospheric anticyclone induced by diabatic heating within the plume. Radiative interactions of aerosols (coupling with meteorology) facilitate a realistic anticyclone that is comparable with observations in previous studies. This work represents a major advancement in aerosol modeling with radiative coupling, and is the most detailed simulation to date of the SWIRL (Smoke With Induced Rotation and Lofting) phenomenon. I therefore recommend publication after addressing the comments below.

General comments

While it is VERY impressive that GEOS was able to simulate a realistic SWIRL, I did have some difficulty reconciling the results with real-world observations. I became heavily dependent on looking at the work by Lestrelin et al. Readers will want a quick way to compare the timing, magnitude, and location of the simulated SWIRL with what actually happened. It's okay to reference Lestrelin for some of this, but I think you need to have at least one direct comparison in the current manuscript. For example, can you add a second panel to Figure 2 highlighting the actual path and timing of the observed SWIRL? Is it the same path as Figure 6 in Lestrelin et al? How does the location and altitude of the observed SWIRL on 23 Aug compare with the simulation?

We thank the reviewer for this insightful comment.

According to Lestrelin et al. (2021), the vortex on the 23rd August is located at about 20° W 45°N with a potential temperature of 420 K. In the simulations, on the same day, the vortex is located at about 60°W 37°N and has a 470K potential temperature. Thus, in the simulation, the eastward transport of the vortex is less pronounced than in the real world, while the meridional displacement is larger. Also, the vortex is 50 K higher in the simulation than in the observations.

We have added a panel to Figure 2 showing the path and timing of the observed SWIRL (vortexes A and O of Figure 6 in Lestrelin et al) and added text about the comparison between the results of the simulation and real-word observations.

Additionally, we added a comparison of the potential temperature of the SWIRLs in observations and simulations in plot 9d.Several comments about the results of this comparison are reported in lines 287-300 of the revised paper.

This analysis focuses on the SWIRL at lower latitudes. Did the observed SWIRL stall for 7 days such as in the simulation? Do you know why the GEOS simulations were unable to identify the other SWIRLS identified by observations (e.g., Lestrelin et al)? Is it simply a function of differences in meteorology caused by the free running simulation? Some discussion of this is likely warranted.

Reply: the observed SWIRL did not stall over the Atlantic (see Figure 2, panel (b)).

More specifically, while in the real world the initial SWIRL (Vortex O, Lestrelin et al. 2021) reaches Europe around the 24th of August after an unimpeded trip across the Atlantic, the simulated SWIRL stalls for several days (until the 24th August) over the Atlantic just off the US East coast. The stalling of the SWIRL is caused by the action of the large scale circulation that eventually redirects it to the west.

Concerning the splitting of the plume and the formation of offspring SWIRLs, we did not find evidence of such an occurrence in the simulation. As shown by Lestrelin et al, the formation of offsprings occurs following the elongation and stretching of the main vortex, caused by its interaction with the ambient wind shear. In our simulation the most pronounced example of such an interaction occurs during the stalling of the vortex, where the lowermost part is stretched to the east, while the upper part remains compact and eventually starts to move towards the west. However, when our tracking algorithm is applied to the lowermost remains of the SWIRL proceeding towards Europe in the days following this event no offspring circulation is found.

The dynamics of the stretching appears to be crucial in the generation of offspring, and the ambient meteorology plays a major role in this process. Also, the magnitude of the stretching is also affecting directly the absorbing aerosol concentration, which is a key parameter in the generation and maintenance of a SWIRL.

Thus, the lack of offspring circulations (but in general, the differences in smoke transport) is given by the differences in meteorology between the free running simulation and the real world.

We have added several statements about this issue in the text (Lines 184-204).

Additionally, the discussion in Section 3.1 should include a bit more information on the limitations of using a free running simulation. Basically, provide a 1-2 sentence summary of what is in the Appendix. Perhaps make it clear that the replay mode is a good proxy for the observed plume, but you have to use free running methods here for reasons X, Y, Z.

We have added some more details about this issue in Lines 163-169.

In summary, I was a bit lost on how I could quickly compare the SWIRL simulation results with real-world observations. It's okay if the simulated plume takes a radically different path from the obs, but you'll need to explain that in the context of the free running simulation type used here. Basically, that subtle changes in ambient meteorology (e.g., relying forecast fields) can have a significant effect on plume transport. That's a limitation of doing a study like this, but it's the only way without adding much more complicated ensemble work or something similar. Some of this is already provided in certain parts of the manuscript, but a little reorganization would help, especially making these aspects more clear early on.

Reply: we thank the reviewer for this beneficial comment. In response, we have reorganized the text as suggested, addressing this issues in Lines 76-84.

The meteorology in a free running simulation is necessarily different from the observed one and thus a direct comparison can only be limited.

This is the price to be paid to the free running configuration of the simulation, but as the reviewer pointed out, this is the only way without doing a much more complicated work involving an ensemble of free running simulations.

We have added text that hopefully makes this clearer, also specifying that the aim is not to reproduce the observations faithfully, but to generate a realistic SWIRL following a PNE-like aerosol injection. From this point of view, the comparison with the observations must be intended as an instrument to evaluate whether the simulated SWIRL is realistic, but also to underline the importance of the background meteorology in the determination of the SWIRL evolution.

Specific Comments

Abstract line 1: Better to say that the PNE took place during the "evening and nighttime hours". The most intense pyroCbs developed before sunset.

Corrected as suggested.

Lines 33-35: Note: The PNE actually had 7 individual pyroCbs, including the 5 identified by Peterson et al 2018 and two more that occurred after sunset identified by Fromm et al 2021. The majority of the smoke likely reached the stratosphere via the 4 largest pyroCbs highlighted by Peterson et al 2018.

Fromm, M. D., G. P. Kablick, D. A. Peterson, R. A. Kahn, V. J. B. Flower, and C. J. Seftor (2021), Quantifying the Source Term and Uniqueness of the August 12, 2017 Pacific Northwest PyroCb Event, Journal of Geophysical Research: Atmospheres, 126(13), e2021JD034928, doi:https://doi.org/10.1029/2021JD034928.

Corrected and integrated as suggested.

Lines 120-121: double negative is confusing. Perhaps use something like: "These criteria constrain PV anomalies to those associated with the presence of high carbonaceous aerosol concentrations."

Corrected as suggested.

Figure 2: perhaps mark the PNE source region for reference?

Added the PNE source region in figure 2 as suggested.

Line 164: change "Caribbeans" to "Caribbean Sea"

Corrected as suggested.

Lines 251-254: This is a long and slightly confusing sentence. Please revise and/or clarify.

The text was integrated and revised (lines 287-300).

Fig. 9e and d are referenced before Fig. 9a and b?

The order of the plots has been changed according to the referencing order in the text.

Line 274: fix "(9f)"

Corrected as suggested.

Fig. 9c. Caption states that the three curves are averages, but the legend uses "TOT" and "AER HR". This is confusing. There is enough space to make a more descriptive legend here.

The legend has been expanded.

Line 300: confusing sentence

Revised. (lines 371-372).

Line ~305 to the end: This ending text might be better suited for a separate section called something like "discussion and limitations". The preceding text covers the actual conclusions I think. You could then end with a "big picture" paragraph highlighting the advance this study makes in plume modeling and future directions.

Revised.

References

Lestrelin, H., Legras, B., Podglajen, A., and Salihoglu, M.: Smoke-charged vortices in the stratosphere generated by wildfires and their
behaviour in both hemispheres: comparing Australia 2020 to Canada 2017, Atmospheric Chemistry and Physics, 21, 7113–7134,495
https://doi.org/10.5194/acp-21-7113-2021, 2021.