Review of Lestrelin, H., B. Legras, A. Podglajen, and M. Salihoglu, Smoke-charged vortices in the stratosphere generated by wildfires and their behaviour in both hemispheres: comparing Australia 2020 to Canada 2017, Atmos. Chem. Phys. Disc., 2020

General Comments

This paper details the dynamics of a newly-discovered phenomenon associated with large pyroCb smoke plumes in the stratosphere, namely the self-organized anticyclonic vortices that are formed due to absorption of solar radiation by black carbon within the plumes. A comparison is made between the 2019-2020 Australian plumes and several plumes associated with large Canadian fires in 2017. Detailed analysis of the Canadian plumes use the Lait Potential Vorticity (PV) from ERA5 to track the vortex evolution and to examine the composite dynamical structures of the vortex. ERA5 ozone is also used to successfully track the vortex locations. Composites of PV, temperature, and ozone help to further understand these features. The paper also details how these features are maintained in the analyses by assimilation of temperature and ozone data, and it examines various dynamical indices to test whether the vortices are in balance and/or inertially unstable. This paper provides an excellent addition to the study of smoke-induced dynamics.

Specific Comments

Line 10: You use the term “low absolute potential vorticity” here. Just to be clear, does this mean low magnitude (i.e., absolute value) of the potential vorticity?

Line 83: I don’t think “g is the free-fall acceleration” is necessary, since “g” isn’t in Eq. (1).

Lines 112-114: Quoting from the paper, “we used both Π and the ozone anomaly defined as the deviation with respect to the mean at the same latitude and altitude.” So are both Π and ozone defined using the anomaly with respect to the zonal mean, or is just ozone calculated as the anomaly, while Π is the raw value from Eq. (2)? This sentence could be read either way.

Lines 112-114: As mentioned by the authors, the commonly used PV has a disadvantage of large background vertical gradient. While Khaykin et al. (2020) used relative vorticity, Kablick et al. (2020) used the “regular” PV to analyze the 2019-2020 Australian smoke plumes. They used the PV anomaly relative to the zonal mean in units of percent of the absolute value of the zonal mean PV. This alternate approach also reduces the influence of the large background gradient.

Line 139-142: You talk about the “kernel of almost zero PV and low ozone....” To visualize this statement, it would be interesting to see latitude/altitude cross-sections of PV and ozone along the CALIPSO track to compare with Figures 1 and 2.

Line 147 (also Lines 158 and 394) : I am unfamiliar with the term "thalweg". Are you referring to a trough? Could you provide some dynamical field on the maps to indicate where this is occurring to help visualize the point you're making?

Line 194-195: Is the statement "it differs from the 2020 case where such effect is not observed for any of the three vortices" referring to results in Khaykin et al. (2020)?

Section 3.5. This section provides a helpful reference of other papers that have studied this event. The PV anomaly associated with smoke during the Canadian event was also examined in a recent paper by Allen et al. (2020). While that paper focused primarily on the "Koobor" vortex, they also included a PV anomaly map for 28 August 2017 associated with what this paper calls "Vortex A" (see Figure 16 of the following reference).

> Allen, D. R., M. D. Fromm, G. P. Kablick III, and G. E. Nedoluha, 2020: Smoke With Induced Rotation and Lofting (SWIRL) in the Stratosphere, J. Atmos. Sci., 77, 4297-4316, https://doi.org/10.1175/JAS-D-20-0131.1.

Line 243-245: It is interesting that the 2017 case doesn't show the temperature dipole. Is that simply due to the contours chosen (i.e., the warm anomaly is really there, but it is less than 1.0 K)?

Line 252: It is unclear exactly how you calculate the horizontal length scale L_h. The text says it is defined as "the diameter of the ring of wind speed maximum". Do you calculate the diameter from the wind speed explicitly for each case? If so, does the wind speed calculation involve removing the background wind in order to focus on the wind associated with the anticyclone?

Line 256: Similarly, L_z is "the vertical extent of the vorticity contour at maximum wind speed". Is this calculated explicitly? Would it be possible to include some more details on this calculation?

Line 257: You say "the 2017 vortex A being about 8 times smaller in volume than its gigantic 2020 counterpart". This difference seems too large. If the cloud is considered as a cylinder, then volume is $V=\pi(L_h/2)^2 L_z$. Using numbers from Table 1 we get $V_A = \pi(686/2)^2\ 3.5 = 1.3\times10^6\ km^3$, and $V_{Koobor} = \pi(784/2)^2\ 6.1 = 2.9\times10^6\ km^3$. So Koobor is only 2.9/1.3=2.2 times larger in volume than vortex A. Are these estimates correct, or do you use another method to estimate volume?

Line 263: You may want to define the condition for inertial instability here.

Line 328-330: It looks like the dates used for the Australian vortex are 2-27 February in Figure 8 (mean structure), Figure 9 (heating rate, temperature and vorticity tendencies), and Figure 11 (ozone tendencies), but for Figure 10 (PV increments) the dates are 7-19 January. It there a particular reason that different dates are chosen for PV? Are the mean composites and increments of PV much different if you calculate them for the different periods? Also, are the green lines on Figure 10 from 7-19 January or 2-27 February?

Line 335: The northwest-southeast tilt of the PV increments for the Koobor vortex, shown in Figure 10a, is interesting. In the recent analysis by Allen et al. (2020), they examined how Koobor tilts with height and found a NW-SE tilt of the vortex in January. They used a dynamical argument to show how this tilt may develop from internal vortex dynamics in a shear flow. The PV increments shown in this paper appear to support this observed dynamical structure. Also, would the same argument you make in Appendix B apply to the ozone structure seen in Figure 11?

Line 344: Does "low absolute PV" mean low magnitude (i.e., low absolute value of PV)?

Line 408: May want to define terms explicitly in the text here, particularly W and Λ. I assume these are vertical wind and vertical shear of the zonal wind. They are indirectly defined in the Table B1, but not in the text.

Line 416: How is the wind shear estimate calculated here (i.e., what time range is used)?

Figure 3 caption: Could you include in the caption what time of day was used for the PV analyses?

Figure S4: Is this calculated with normal PV or with the Lait PV? Also, as a reference, it would be useful to include the zonal mean PV on this plot. This should become increasingly negative with time as the parcel ascends. Do the Canadian plumes show a similar behavior?

I enjoyed the animations in the supplementary material. I assume the PV used in the animations is the normal PV, not the Lait PV, right?

Lastly, there are quite a few different names used in this paper for different aspects of this new phenomenon. For example the terms "smoke-charged vortex", "smoke charged pancake vortex", "smoke vortex", "smoke plume", "smoke bubble", and just "bubble" could possibly be condensed into fewer descriptions. The Australian plumes are called "Koobor", "2nd Vortex", and "3rd Vortex", while the Canadian plumes are "Vortex O" (also called "mother vortex"), "Vortex A", "Vortex B1", and "Vortex B2". Different terms are also used for "Koobor", such as "main vortex", and "major vortex". Given this is such a new discovery, to avoid potential confusion, terms could be consolidated and defined (e.g., how does the term "bubble" differ from the terms "plume" and "vortex"). Looking forward, do you have any recommendations for a general scheme as to how these events can be categorized, in order to separate them from stratospheric smoke plumes that do not show a dynamical signature? Allen et al. (2020) coined a new term for this phenomenon, "Smoke With Induced Rotation and Lofting (SWIRL)", an acronym that accounts for the aerosol source as well as for two of the obvious dynamical aspects of the phenomenon.

Technical Corrections

Line 5: change “find” to “finds”

Line 15: change “monoxyde” to “monoxide”

Line 23: change “wildfire” to “wildfires”

Line 43: may want to spell out “CALIPSO”

Line 152: change “event” to “events”

Line 160: Should “Fig. 3a” be “Fig. 3b”?

Line 175: Typo “Fig. fig:CALIOPa”

Line 196: Figure 7 is referred to before Figure 6. I would suggest reversing the order of the figures.

Line 189: change “WaS” to “was”

Line 191: may want to spell out “GOME”

Line 218: change “stations” to “station”

Line 286: What is “beta drift”?

Line 317: change “(c,g)” to “(c,f)”

Line 353: change “wilfires” to “wildfires”

Line 395: change “in a an” to “in an”

Figure 3 Caption: “PVU” is used here, but it isn’t defined until the Figure 8 caption. May want to define it here. Also, is the “ERA5 tracking” referred to here using the PV or ozone method?

Figure 5 Caption: I think that “orange” and “green” in the figure caption aren’t consistent with the lines on the figure.

Figure A1: What are the axes on these plots?