Editor Decision: Publish subject to minor revisions (review by editor) (20 Mar 2021) by Peter Haynes
Comments to the Author:
I'd like to accept this without going back to the referees. In looking through the revised version of the paper I noticed some minor technical points which are listed below. Please can you address those.

More substantially, your reply to Referee 3 is not very clear about whether or not you have actually made any changes in response to the request for more information about assimilation etc. Your general point is fine -- that one can't included a tutorial on assimilation and you have given some useful comment in the reply. My impression is that you have made various changes in the text that make some of the important points re assimilation clearer -- but they are little scattered around in the text. Please can you provide an updated reply that makes it clear that you have included a bit more information/clarification on this topic -- and alongside that consider whether the information could be better organised in the text (and include that point in the updated reply if you do change something further).

We believe that the main reservation from referee 3 came from the fact that he (or she) does not see how one can produce a smoke vortex without smoke. We tried to clarify this issue in detail in the answer and we have added a few sentences in section 2.2.2 to explain how wind and vorticity can be retrieved from information mainly based on temperatures. This leads us to the notion of balance that we cannot fully discuss within the scope of this work and we refer to Mc Intyre, 2015, which is, in our opinion, an accessible discussion of this notion. The image below is extracted from the difference file produced by latexdiff between the submitted version and the updated revision. Additions are in blue. We refer also in our answer to the fact that the temperature increment cannot be interpreted as a heating rate. This is implicit in section 2.2.2 and is explained in section 4.2.1. We did not see what to add to this latter. Other points of the answer refer to the previous work of Khaykin et al. (2020). We have added the reference to our two sections in the answer.

2.2.2 Assimilation increment

The ERA5 is constrained by observations over repeated 12-hour assimilation cycles. ~~The~~ Over each cycle, the assimilation increment is defined ~~over each cycle~~ as the difference between the new analysis and the first guess provided as a final stage of a free forecast run of the model, initialized from the previous analysis 12 hours before. This definition can be applied to any of the basic variables of the model or to derived quantities like potential vorticity. In the ERA5, the assimilation increments can be calculated on each day at 6:00 and 18:00 UTC. In order to diagnose how the observations are forcing the vortices, we calculated the assimilation increments of temperature, vorticity, potential vorticity and ozone. Temperature and ozone determine the radiances that are measured by spaceborne instruments and are also directly accessible from in situ instruments. On the contrary, potential vorticity cannot be directly retrieved from any instrument and is indirectly constrained (see below). These three parameters are updated by the assimilation system in order to reduce the difference between observed quantities (typically radiances but also deviations of the GPS signal path) and simulated quantities (radiances that a satellite flying "above the model" would see). It is tempting to see the temperature assimilation increment as an additional heating but this is incorrect~~as the~~. The increment is calculated from an adjusted state, resulting from the iterations of the assimilation, in which both temperature and motion respond to the forcing by the observations~~that depend only on the temperature~~. As wind observations are much sparser than temperature observations, one would expect that analysis winds, and related quantities like

potential vorticity, are more poorly constrained and therefore less accurate than analysis temperatures. While this statement is true to a large extent in the tropics, in the mid-latitudes the temperature and wind fields are related through thermal wind balance. This equilibrium is enforced by the assimilation system which filters out the transient modes that deviate from it. Hence, thanks to this miracle of assimilation, assimilating the temperature signal of the vortex is sufficient to reconstruct the whole thermal and dynamical field associated with the balanced structure (McIntyre, 2015).

~~Neither~~ It should be noted here that neither the ECMWF operational analysis nor the ERA5 assimilate aerosol observations. The smoke plumes are ~~hence totally missing in the IFS~~totally absent from the IFS, where stratospheric aerosols were only accounted by mean climatological distribution during the periods of investigation, and it is only their dynamical vortical signature which are introduced in the model as described above.

I then expect to accept the paper (and will be able to assure Referee 3 that the their recommendation has been properly considered and that an appropriate response has been provided).

l10: "We analyze the dynamical structure of the vortices produced by these two wildfires and demonstrate how they are maintained
by the assimilation of data from instruments measuring the signature of the vortices in the temperature and ozone field."

Needs changing -- it is not data assimilation that maintains the vortices -- it is "assimilation of the real temperature and ozone signatures of the vortices that explains the appearance and maintenance of the vortices in the constructed dynamical fields"

The sentence kindly provided by the editor has replaced the previous version. We have tried to improve our english in the revised version, in particular to remove americanisms, but clearly this is not yet fully satisfactory.

l39: "In particular, a stratospheric rise of up to 30 K day−1 was diagnosed" -- this could be interpreted as a

heating rate (rate of change of temperature) or an ascent rate (expressed in terms of potential temperature). What is the intention -- to emphasise the large heating rate or the large ascent rate? If the latter then it might be clearer (particularly at this stage of the paper) to express it in terms of an equivalent rate of change of geometric heat.

It is a change of potential temperature, as shown in figure 4b of Khaykin et al. (2018). This is now mentioned in the text. We are somewhat reluctant to see a heating rate as a change of temperature, although it is a common and meaningful usage in many practical situation, as the first principle associates heating to a change of entropy, that is potential temperature.

l118: "This is true to a large extend" > "This is true to a large extent"

Correction done

l169: "This early stage is described in great details by Torres et al" > "detail" not "details".

Correction done