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Nonlinear Processes in Geophysics
Discussions

Interactive comment on "Insights on the three-dimensional Lagrangian geometry of the Antarctic Polar Vortex" *by* Jezabel Curbelo et al.

Anonymous Referee #1

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The paper presents an algorithm for the integration of air parcel trajectories in three dimensions and the computation of the "function M' for the analysis of Lagragian transport, and it is applied to atmospheric reanalyzed data for the study of the Antarctic stratospheric vortex. The paper is clearly written, and visualization of the Lagrangian geometry of the stratospheric vortex shows potential. However, the paper lacks of new scientific results. While I cannot recommend publication, I encourage the authors to address my concerns below and resubmit.

The paper consists of two parts. The first one (sections 2, 3 and 4.1), the data processing and methods for computing the Lagrangian geometry are presented. In the second part, the 3D function M is applied to the study of transport in the Antarctic polar vortex.

Regarding the first part, the authors state in the abstract "The present paper introduces

an algorithm for the visualization, analysis and verification of transport and mixing processes in three-dimensional atmospheric flows". While sections 2 and 3 present the methodology in a very clear and concise way, I do not a find significant novelty in this part of the paper.

- Neither the reanalysis data processing, nor the parcel trajectory methods are new (the way they handle the singularity at the poles in geographical coordinates seems identical to that published by some of the co-authors in De la Camara et al. 2012).
- The authors have published multiple articles analyzing transport in oceanic and atmospheric flows using the function M to highlight the Lagrangian geometry of such flows. The extension to 3D, while interesting, does not constitute a new advance from a methodological point of view since the authors have already introduced it in at least a couple of studies (Mancho et al. 2013, Lopesino et al. 2017). Besides, the function M is conceptually defined for n-dimensional fields (Mancho et al. 2013).
- I do not quite understand the verification part of the study. Section 4.1 visually compares maps of the function M obtained from 2D isentropic calculations and from full 3D calculations (Fig 1). But, if I am not mistaken, the authors use the same set of equations (5) for both the 2D and 3D calculations; the only difference is that in 2D the vertical velocity w is zero. Does this mean the authors verify their 3D integration code against itself?
- Figure 2 does a much better job at verifying the function M code by comparing maps of M with geopotential height and potential vorticity (PV) fields. Sadly, the authors do not discuss this figure at all (see lines 16-20). Why is the anticyclone that we see in the height field not visible in the PV or M fields? What are the expected differences between PV and M? What about the tongue of high PV (red

colors) wrapping around the vortex? Why is there no equivalent structure in the M map?
Also, it is rather confusing to analyze maps of these three diagnostics, each using different vertical coordinates. I recommend the authors to interpolate the data to a common horizontal surface.

Regarding the second part (section 4.2), where transport in the Antarctic polar vortex is studied, I have a couple of major concerns the authors might address.

1) The added value of the 3D calculations for the study of the stratospheric transport is not properly addressed. More specifically:

- It is argued throughout the paper that stratospheric motions are basically isentropic for timescales of 10 days. While I understand the authors choice of an integration time of 5 days in Fig. 1 to compare against isentropic trajectories, why using again tau = 5 days in section 4.2 to analyze the 3D Lagrangian geometry of the vortex? Are the results not practically identical to 2D isentropic calculations if the trajectories are integrated over time periods when the isentropic assumption is valid? A way of checking this point would be to perform isentropic calculations at different vertical levels in the stratosphere, and plot similar figures 3-8 (longitude versus height).
- I strongly encourage the authors to increase tau to explore the full potential of 3D calculations. Is there a value of tau over which the Lagrangian geometry from 2D (isentropic) and 3D significantly and 3D diverge?
- Besides, one problem of using the wind field in geometrical height coordinates is that it is difficult to assess what part of the vertical motion is due to the vertical displacement of isentropic surfaces. To prove the added value of the 3D calculations, I recommend using the velocity field in potential temperature surfaces (the vertical velocity would therefore be the heating rate, see Diallo et al 2012 ACP).

2) I do not see any new insights into the dynamics or transport of the polar vortex.

- The description of the evolution of the stratospheric flow during the spring season is, as the authors acknowledge, basically the same as that given in much earlier studies. What have we learned from the analysis of the function M? Is this description richer from that offered by dynamically relevant fields such as geopotential height or PV? I am afraid not.
- One needs a very trained eye to see the geometrical structures that the authors highlight in Figs. 7 and 8 (hyperbolic trajectories and invariant manifolds). How are these structures identified? How is its hyperbolic nature assigned? Also, those structures seem to be located in the outer side of the westerly jet, just in the region where Joseph and Legras (2002 JAS), with similar tools, described a region of chaotic motions. I think this paper does not offer new significant insights into the nature of this region. The fact that the authors identify vertical transport barriers (hardly seen by untrained eyes) does not mean that the motions responsible for those structures are three-dimensional. Again, a detailed comparison between 3D and isentropic calculations is needed.

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