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Nonlinear Processes in Geophysics
Discussions
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Interactive comment on "A Simple Kinematic Model for the Lagrangian Description of Relevant Nonlinear Processes in the Stratospheric Polar Vortex" *by* Victor José García-Garrido et al.

Anonymous Referee #1

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In this paper, the authors construct a 2-D kinematic model of the Antarctic stratospheric polar vortex using the first three components of an axisymmetric stream function (i.e. a "mean flow", and waves with zonal wave number one and two). They highlight hyperbolic trajectories and their manifolds of such a flow by means of the so-called Lagrangian Descriptor or function M, and discuss the qualitative similarities to the Lagrangian structures obtained from atmospheric reanalyzed data (ERA-Interim) on isentropic surfaces during the major mid-winter warming of September 2002.

The paper is clear and well written, and most of the results are interesting, but the authors should do a much better job putting the paper and the results in context before meriting publication. I recommend publication after major revision.

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Discussion paper

Specific comments:

1. First paragraph (line 10-, page 1). The authors summarize the scientific findings that followed the discovery of the Antarctic ozone hole, but they do not cite any study at all (i.e. Chubachi 1984, Molina and Molina 1987, Bowman JAS 1993; JGR 1993, Manney et al. JAS 1994, etc.).

2. Page 2, line 16. "De la Camara et al (2013) suggested that HTs are representative of cat's eye structures. . .". McIntyre and Palmer (Nature 1983, JASTP 1984) and Bowman (JAS 1996) might be better references for this suggestion.

3. Page 2, line 25. "Our goal in the present study is to identify essential features in the filamentation process associated with the breakdown of the polar vortex. . ." I think the authors need to explain better the need for this study, putting it more in context. Why is this study interesting? Is this the first time anyone tries to show Lagrangian coherent structures during a sudden warming? What new insights into the dynamics of the polar vortex do you expect to gain from the analysis?

4. Page 4, line 15. Please cite some works as examples.

5. Page 5, line 26. The authors justify 2-D trajectories on the basis of isentropic motions with timescales of 10 days. If τ = 15 days, that means the trajectories expand 2τ = 30 days. Is the 2-D motion approximation still valid? It would be useful to estimate the error growth of the 2-D trajectories (with respect to 3-D trajectories) with increasing τ.

6. Figure 5, caption. "Notice the change in wind direction from westerly to easterly . . . giving rise to the pinching of the SPV". The change in sign in zonal mean quantities does not reflect a particular change in the horizontal geometry of the vortex. Stratospheric warmings have been reported as displacement and split events (roughly wave-1 and wave-2 phenomena), but the zonal mean behavior of the zonal mean wind is rather similar. I would put it the other way round; it is the radical change in the vortex position and/or geometry during stratospheric warmings that gives rise to the change

in zonal mean wind direction.

7. Page 9, lines 3-5. “Finally, the breakup of the SPV on the 24th September 2002 depicted in Fig. 4 b) is caused by the formation of an HT in the interior of the vortex whose manifolds connect the interior and the exterior of the jet, allowing for the interchange of air through the barrier.” From my point of view, the hyperbolic trajectory is a kinematic manifestation of a dynamical process. I am not sure if it is correct to state that the formation of the HT is the cause of the vortex breakdown.

8. Page 9, lines 7-8. Z0 is not independent of Z1 and Z2. In fact, linear theory states that the transient convergence of wave activity decelerates the mean flow, and this in turn affects the propagation and dissipation of the planetary waves.

9. Page 11, lines 16-18. In dynamically consistent models, those filaments could be related to wave breaking phenomena, or nonlinear vortex-vortex interactions. What is the reason for their presence in the kinematic model?

10. Page 13, lines 12-19 (Figure 7). I wonder if the amplitude reduction of Ψ_0 and amplification of Ψ_2 used to construct Fig. 7 is somewhat similar to what happened with Z0 and Z2 in the reanalysis data during the split event.

11. Section 5. It is possible that I have not followed the argument here. What are the values of *C* and *h* that you need to conserve *Q* in your kinematic model? Are those values within the range of values used in shallow water models for the study of polar stratospheric dynamics?

Technical comments:

12. Figure 1, caption. “... coherent structures above and below the SPV”. Please replace *above* and *below* with *over the South Atlantic* and *south of Australia*.

13. Figures 2 and 5 (and some movies). Please improve the color scale, the figures look blurry.

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