Nonlin. Processes Geophys. Discuss.,
doi:10.5194/npg-2016-81-AC1, 2017

Nonlinear Processes in Geophysics
Discussions
Open Access
EGU

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.

Victor José García-Garrido et al.

a.m.mancho@icmat.es

Received and published: 7 April 2017

Answer to Referee 1

We wish to thank this referee for his/her very insightful comments. In our opinion, addressing these comments has helped us to strengthen the manuscript.

Specific comments

1. *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 The authors summarize the scientific findings that followed the discovery of the Antarctic ozone hole, but they do not cite any study at all (i.e. Chubachi 1984, Molina and Molina 1987, Bowman JAS 1993; JGR 1993,*

Printer-friendly version

Discussion paper

Manney et al. JAS 1994, etc.).

We added “Solomon (1999; and references therein)”. We also added “Chubachi, S., 1984a and Solomon” (1988; and references therein).

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.*

Thanks for pointing this out. We have added McIntyre and Palmer (1983) and Bowman (1996).

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?*

We have paid close attention to this comment. The Introduction starts with a new paragraph that addresses this concern. We state that the goal is to extract the physical mechanisms underlying notable transport features observed in complex data sets. We gain new insights into the fundamental mechanisms responsible for complex fluid parcel evolution, such as those associated with Rossby wave breaking phenomena, and describe a simple model having the ability to capture transport features, such as filamentation and vortex breaking. We have also added more discussion in the conclusions.

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

We have added Wiggins (2005) and Samelson and Wiggins (2006).

5. *Page 5, line 26. The authors justify 2-D trajectories on the basis of isentropic motions with timescales of 10 days. If* $\tau = 15$ *days, that means the trajectories expand* $2\tau = 30$

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. Page 5, line 26. The authors justify 2-D trajectories on the basis of isentropic motions with timescales of 10 days. If $\tau = 15$ days, that means the trajectories expand $2\tau = 30$ 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.

We have added a paragraph addressing this comment at the end of section 2.2.

6. *Figure 3, 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.*

In view of these comments the description of the pinching was rewritten and extended at the end of section 4.

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.*

Throughout the manuscript we have replaced the expression "caused by the formation of a HT" by "occurred when a HT forms".

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.*

The reviewer is correct. In the context of the kinematic model, the modes are given. We have based our specifications of the modes on the observation. The text have been revised to clarify this notion.

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?*

The filaments mentioned by the referee, are related to the presence of hyperbolic trajectories that we link to wave breaking phenomena. In order to illustrate this in more detail we have rewritten section 4. Prior to the figure presenting the filaments mentioned by the referee, the kinematic model is adjusted to a stationary case, in which hyperbolic trajectories can be explicitly calculated as the velocity field is stationary (see new figure 6a)). Then the problem becomes non stationary by imposing a phase speed to the wave 2, and for slowly propagating waves hyperbolic trajectories are identified which are also rotating (see new figure 6b)). The pattern eventually produces filamentation in the pattern of M (see figure 7 a)) by making in the kinematic model the amplitude of wave 2 time dependent.

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.*

Yes, we have selected perturbation amplitudes in accordance to the reanalysis data.

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?*

Section 5 has been rewritten and an explicit calculation of the forcing h is reported, that achieves the conservation of potential vorticity Q for one of the proposed Ψ. The calculation is illustrated for a simple Q choice but it could be repeated for more realistic Q distributions as far as they are defined as piecewise constant functions.

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.*

Done

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

Contours were added to the figures. Thanks for pointing this out.

Please also note the supplement to this comment:
http://www.nonlin-processes-geophys-discuss.net/npg-2016-81/npg-2016-81-AC1-supplement.pdf

---

Interactive comment on Nonlin. Processes Geophys. Discuss., doi:10.5194/npg-2016-81, 2016.