

Response to editor comments on “Idealised simulations of cyclones with robust symmetrically-unstable sting jets” by Volonté et al.

wcd-2019-8 - A. Volonté on behalf of all authors, 28 January 2020

Dear Editor,

Many thanks for taking time to assess our manuscript and for your comments which have improved its style and the presentation of its content. Below we respond to each of these comments.

Our responses are given in *green italic* font, while new text in the manuscript is indicated in **red**, here and in the manuscript.

0) Maybe a matter of taste, but I find that overall you use too few commas for a good reading flow. Instead sometimes you use semi-colons to concatenate sentences that could easily "survive" on their own.

We have reread the manuscript looking for places to add additional commas and remove semicolons. We have added 4 commas to the introduction and removed 9 semi-colons from the text (either changing them to full stops or colons). Note that many of the semi-colons we use act as separators for lists and so it is not appropriate to remove them.

1) L94–96: Sentence is hard to read, please reword.

The sentence has been rephrased and hopefully clarified. It now reads:

PV decreases along these three trajectories as they ascend and gets very close to zero on one of them at 01 UTC 3 January, the time at which the trajectories reach their minimum pressure level and start to descend.

2) L97: remove "possible"

Removed.

3) L114–137, new section on initial conditions: While the content is fine, I find the quality of writing inferior to the rest of the paper. Some expressions are somewhat colloquial and some sentences are a bit too long and unnecessarily complicated. I invite the authors to go over this part once again and sharpen the message.

We have reworded these lines as follows:

The initial base state used is generated using an algorithm based on, and ultimately very close to, that of Polvani and Esler (2007), referred to as PE hereafter. However, two issues arise from their formulation. The first is that their derivation is based upon geostrophic thermal wind balance in the hydrostatic primitive equation (HPE) set. This approximate set ignores various terms, including some Coriolis terms and some metric terms (e.g. White et al (2005)). As a result, a ‘balanced’ state in the HPEs is not perfectly balanced in a less approximate equation set (and vice versa). The MetUM solves the non-hydrostatic deep atmosphere dynamical equations on a sphere, so the balanced initial state found by PE is only approximately balanced when used in the MetUM. This initial imbalance is quite physically unrealistic and generates an initial transient flow (largely gravity waves) that, at the

resolutions used, can result in an unstable response. Baker et al (2014) followed the pragmatic approach of first running for a "number of timesteps" in a lower-resolution, larger-area version of the model with fixed lateral boundary conditions on all four boundaries. This was found to sufficiently damp the transient response and settle to a balanced field that could be numerically interpolated to the required grid. However, we have derived an equivalent to geostrophic thermal wind balance in the non-hydrostatic deep atmosphere and hence removed this initial imbalance. To our knowledge this result has not been previously published, so it is included in Appendix A1. The initial state produced is equivalent to that of PE but for a non-hydrostatic, deep atmosphere model.

A more significant issue with the initial conditions used by Baker et al (2014) was their rather cold overall temperature, discussed above. This temperature structure arises from the PE initial state; it is of only minor importance in PE's dry simulations, but restricts the magnitude of diabatic forcing by phase changes. In this study a simple method to adjust the entire vertical virtual potential temperature (θ_v) profile to make that at the jet centre equal to the reference has been devised, the details of which are also given in Appendix A1.

Any upper-level jet in thermal wind balance must have lower static stability in the upper troposphere to the south of the jet compared with that to the north. The state used in this paper was chosen to have a realistic static stability in the middle of the jet. The profile is close to neutrality in the upper troposphere south of around 40° N. In fact, it is very weakly statically unstable, but not sufficiently to generate either a dynamical response or significant unstable mixing through the turbulence scheme, and, if unperturbed, it was found that the whole state remained essentially unchanged through a 10-day integration apart from some very minor wave activity in the upper stratosphere. We thus judged that the tiny adjustment required to remove this very small static instability was not necessary. Furthermore, a larger adjustment to increase the static stability in this region would have led to a reduced baroclinic growth rate, and the aim was to produce condition believed more conducive to SJ development.

4) L361: use abbreviation "SJ"

"sting jet" replaced with "SJ" here and for two other occurrences in the text, thanks.

5) Caption Fig. 6: transects -> lines

Done.

6) L400: missing brackets?

Brackets added (and moved to the end of the sentence), thanks for spotting this.

7) L410-412: split into two sentences

Sentence split in two, see below:

This overall situation is consistent with the mechanism, outlined in Volonté et al. (2018), of slantwise circulations generating negative horizontal relative vorticity that can be eventually tilted into the vertical to trigger II and SI too. In fact, SI is generated if, as a consequence and as is the case here, not only ζ_z but also PV decreases below zero.

8) L594–595: sentence does not read well, either add commas or break in two

The sentence now reads:

This has an available potential energy (APE) associated with it. **However**, there is likely to be release going on at the same time as generation, so it is difficult to quantify the amount.

9) L600: you have now introduced the abbreviation "KE" and should use that consistently.

We agree, corrected.

10) L604: comma after "SJ"

We disagree on adding that comma because that would imply that "if this does contribute to the primarily tangential speed of the SJ" could be removed from the sentence without affecting its meaning, which is not true.

11) L607: comma before "so". I would refrain from including entire sentences in brackets.

The comma has been added and the brackets removed from the following sentence.

12) L609: I am not sure I really understand that last sentence. What do you lose if you omit it?

Agreed. Sentence removed.

13) Acknowledgements: I think the reviewers deserve a mentioning here.

We agree, acknowledgements added.