Review for

An objective identification technique for potential vorticity structures associated with African Easterly Waves

by

Ch. Fischer et al.

Summary:

The paper describes a sophisticated methodology how to identify, track and characterize potential vorticity (PV) structures associated with African Easterly Waves (AEWs). The method is split into three distinct steps: (i) AEW troughs are identified and tracked based on curvature vorticity (CV) on 700 hPa; (ii) the AEW troughs are used to associate 3D PV structures to the AEW; and (iii) the complex 3D PV structures are 'fitted' to best-matching ellipsoids to extract geometrical characteristics, e.g., horizontal orientation and vertical tilt. Based on this methodology, AEW PV structures are determined for the whole ERA5 dataset (1940-2023) and monthly occurrence frequencies, AEW-trough-centered PV composites, geometric characteristics are calculated. It is nice that the paper goes beyond a 'simple' description of a novel methodology, and does a first step in climatologically analysing the AEW-associated PV structures. It is, however, also clear that the analysis in the second part of the paper can (and is) only be a first step in this direction, and accordingly the authors also provide some specific ideas what could be done in forthcoming studies.
The paper is well written, the figures are well suited to explain the complex methodology, and the first climatological results are sufficient to trigger/motivate further studies. There are, however, several parts where the text could be a little clearer and more specific and/or the figures be simplified. Some suggestions for improvements, mostly minor, are listed below. If these suggestions are adequately addressed, I can recommend the study to be published in GMD, which seems to be the appropriate journal to describe this new algorithm.

Major comments:

1) Abstract: The abstract could be somewhat more specific, some of the statements remain rather vague. Further, some of the sentences are rather complicated or are not completely clear. Some examples:

- L3-5: "The dynamics of AEWs can be described in a PV framework and redistribution of PV by latent heat release links PV to the important cloud and rain processes within the wave" → rephrase in easier way.

- L5: What does 'comprehensive' mean in this context?

- L8-9: "These structures are subsequently characterized by low-dimensional descriptors, including spatial information, intensity, and geometric approximations." → This is rather vague, and some more specific details would be helpful. What 'spatial information', 'geometric approximations' are given?

- L10: 'A climatological analysis' → Please specify over which period the climatology is compiled.

- L14-15: 'statistical analysis of main axes agree on an downshear tilt of the PV feature over land, and a tilt to the south over the ocean' → What exactly is meant by 'statistical analysis'? The sentence could also rephrased in a more reader-friendly way.

- L17-19: “The low-dimensional representation of PV features enables the research on further statistical analyses, for example the relationship of these features with tropical cyclogenesis or as predictor for rainfall in the tropics” → Okay, I am not sure whether this outlook, advertisement for further use is appropriate or needed at the end of the abstract. Possibly, the focus is actually on the *low-dimensionality* of the PV-feature respresentation. If so, this should be made more clear to the reader.

2) Introduction: The introduction gives a nice overview on AEWs, i.e., about their relevance, characteristics and identification. What remains, however, less clear to me why it is worthwhile/important to study PV structures associated to the AEW. Of course, I fully understand why PV is important in extratropical dynamics and how it facilitates understanding of dynamical processes. This is much less clear in the tropics, where PV dynamics is less established. I would appreciate if the benefit of considering PV in AEW, in addition to more direct measures of diabatic processes (for instance, rainfall or diabatic heating), is discussed in somewhat more detail. From the results I see that the PV disturbances associated with and/or created by AEW display an interesting vertical structure (mean altitude, orientation, vertical tilt), which certainly is interesting. But, dynamically, how important are these PV structures? In particular, since the identified PV structures are not very coherent structures and display a rather complex substructure. A few sentences discussing this aspect would be nice.

3) **Climatology:** It is nice that the new method is applied to the whole ERA5 dataset and thus a climatology is compiled. I wonder whether Section 3 has the best-possible structure. At the moment, it starts with PV composites in Figure 4 and 5, then proceeds with trough-frequency maps in Figures 6 and 7, before returning in Figure 8 and 9 to some PV-structure characteristics. To me, it would have been more ‘natural’ to start with the maps of the AEW track frequencies, and then to combine and discuss all aspects of the identified PV structures (composites and geometric characterisation). I assume that the authors wanted to start with the PV composites, as they are the focus of the study. However, if they agree with my storyline argument, they might consider re-arranging the text.

A key result of the study is that the PV structures exhibit a different orientation over ocean and land. This is clearly discernible in the PV composites in Figure 4 and 5, but also in the geometric ellipsoid characterisation in Figure 9. The authors attribute this difference to the enhanced convection over land compared to the ocean, which I think is reasonable. We see, however, also temporal (longitudinal) development over land and over the oceans, and I wonder whether the it would be worthwhile to study not only the land-ocean contrast, but – similar to Figure 9 – to investigate also how the orientation parameters evolve as a function of longitude. In particular, is a tilting already discernible as the AEW troughs and PV structures move from their origin further inland towards the African west coast. I assume that such an analysis would be feasible with little effort, but could provide additional insight (and trigger new research).

In the composite fields, Figure 4 and 5, possibly some additional meteorological fields could be included. Would it, for instance, make sense to show also the wind speed, in particular in the latitude-pressure cross-sections, to see the AEJ together with the PV structures?

4) Summary & Conclusion: At some parts, the statmements in the conclusions could be more specific. As an example, L353-355 (These cross-sections…. Feature characteristics) remains rather vague. I would also appreciate if the conclusions are structured in a clearer way, in particular clearly separating results of the study (including the methods) and the potential applications in forthcoming studies. As a side remark, I like the detailed description of potential applications in L364-374, and this kind of PV-motivation might be missing in the introduction (see my point 2 above).

Specific comments:

- L29: “The potential vorticity (PV) framework is a fundamental fluid-dynamical concept” → ‘concept’ reads a little strange; can a ‘framework’ be a

- L62-65: I wonder whether it would be better to keep the research questions very concise, just the questions, and to move the context to another place. One, possibility would be to move L62-65 to L72, after ‘...is absolutely vital.’

- L76: The abbreviation ‘CV’ is introduced here; I would introduce it only later at L104, because at L104 I had to search for it.

- L92: Split the long sentence here: “...2017). The data is available on”

- L96: Is PV calculated on model levels, or based on pressure-level data?

- Section 2.2: The section could be more concise. For instance, the first paragraph gives a brief overview on the algorithm, then the first sentence of the second paragraph seem rather repetitive. I assume, that this sentence wants to introduce that the AEW identification builds on CV *anomalies*, which thus might be highlighted somewhat more.

- L120: “and the advection of CVAs must be equal to 0” → What does this exactly mean? How is the CVA advection determined, and must really be *exactly* zero?

- L126-130: Here, the tracking of the AEWs is described. It is based on a trough-overlap criterion, which at this place of the text is somewhat misleading as the AEW troughs are identified as lines, and thus makes the reader wondering whether really the overlap of the line objects is reasonable. It becomes clear further down in the text, when the forward-projected area for a tAEW trough is introduced and thus the next-step AEW trough have to fall into this area. It would be good not to mislead the reader ion the beginning.

- L133: “AEWs typically propagate with a speed” → “AEWs typically westward propagate with a speed”

- L137-138: “Consequently, … 6-hour difference” → Okay, but quite obvious to me and thus not really necessary.

- L150:152: “Therefore, different sets of tracks can be justified as a solution to this problem. Here, we adhere to the rule to generate tracks with the longest possible life span. This makes it easier to investigate the life cycle of these waves. To achieve that, the graph G is scanned and each node is assigned a time until dissipation” → It is okay to apply the longest-path criterion. However, it would be worthwhile to discuss in one, two sentences alternative approaches, and contrast the approaches with theie advantages and disadvantages.

- Figure 1: The figure nicely illustrates the single steps in the AEW trough identification. Would it make sense to show in panels (a) and (b) wind vectors or the streamfunction instead of streamlines, as the latter can be quite misleading as they do not include information on the wind speed and thus can produce rather artificial structures (whirls) where actually weaks are very weak. Also, the grey lines in panel (a), zero CVA advection, are rather difficult to see; and I wonder whether the streamlines are needed in panels (a) and (b). Finally, the authors might consider whether it would be better (and reasonable) to show in all three panels the same geographical domain.

- L156: “We discard parts of tracks with an average speed of less than 3 ms−1 at any given point in time” → How is the mean speed of the AEW tracks determined. This is not immediately clear as the tracked objects are line-objects.

- L166: “...and is available” → “...and it is available”

- Section 2.4: This section describes the AEW phase computation based on the Hilbert transform. To me, it was somewhat unexpected that the paragraph starts with the wave-associated PV. I see that the authors want to motivate their phase computation with the wave-relative location of convection and diabatic PV production. I wonder, however, whether this is the best place to motivate it, or whether this information fits more nicely into the introduction, hence allowing this section 2.2. to discuss directly the Hilbert tranform.

- L198: “that not near” → “that are not near”

- Figure 2: Are the streamlines really necessary in this figure? It would be better to make the figure less ‘noisy’. Further, as also in Figure 1, I would remove all country borders in the maps. They are no needed, as no specific countries are mentioned in the text; removing the border lines would ‘de-noise’ the figures.

- L219: “removes small outliers while preserving the shape of a structure” → What is exactly meant by ‘small outlier’? Is it thus a size/volume filter, i.e., too small PV features are removed? Some further details on the filtering technique might be helpful.

- Figure 3: The color-shading, strictly speaking, does not correspond to height (as mentioned in the caption) but to pressure. Provide also in the figure caption the unit of the shading (hPa).

- Section 2.7: I am not completely sure whether this mini-section is needed, as it is also included in the *Data Availability* section, or what is missing there you be added.

- Figure 6: Here, definitely, the country borders should be removed to make the meteorological fields more prominert; Make also the x-axis labels in the panel ‘Occurrence of PV in wavetroughs” consistent to the other panels

- L352: I would remove “and previous analyses within the field”; it is rather unspecific.

- L353: “around identified waves” → “around identified wave troughs”

- L376: remove ‘valuable’

- L356: To what is ‘Notable differences’ referring back? The sentence before addresses a comparison between PV features and observed/simulated rainfall data. Hence, does ‘differences’ refer to the comparison between PV and rainfall? This is not completely clear to me.