Review of the Paper « Impact of Convectively Coupled Tropical Waves on the composition and vertical structure of the atmosphere above Cabo Verde in September 2021 during the CADDIWA campaign »

Now : « Impact of Convectively Coupled Tropical Waves on the composition, the vertical structure of the atmosphere and Tropical Cyclogenesis in the region of Cabo Verde in September 2021 during the CADDIWA campaign »

Dear Editor

Thank you for allowing us to enhance the paper quality. We appreciate the reviewers' valuable assistance and thoughtful feedbacks. All the suggested modifications from the reviewers have been incorporated. The structure has been extensively revised, as suggested by the reviewers, to improve clarity. Figures have been reordered accordingly, previous Figures 11, 12 & 13 are now compacted in Figures 8 & 9 and former Figure 10 has been discarded to improve readability and make the article more straightforward.

Please find in the following the detailed answers to the reviewer's comment. Text in red indicates direct quotes from the manuscript.

Reviewer #1

1) Section 2.1 Data: This section would really benefit from a detailed table that includes all data sources, resolution, variables, time period for the climatology if applicable, etc. It's hard to follow all the details and differences in temporal availability in the text.

Table added in the text as required, and former figure 8 that compares all data sources has been moved to the data section and now is discussed earlier in paper.

2) Page 7, lines 166-167: I'm worried that using a Kelvin filter that includes frequencies higher than 0.3cpd is essentially filtering noise. Figure 1c shows that even for 5 years 2018-2022 there is no coherent signal above 0.3cpd. Taking this together with Figure 3c and 3d, I wonder whether there is actually a Kelvin signal present during this time? Wheeler and Kiladis (1999) cut off the Kelvin wave filter at 0.4cpd and wave number 14 to exclude those regions that don't have a lot of Kelvin wave power. It is not clear what exactly is done here, as the mask in Figure 1a is larger than the region used in Wheeler and Kiladis (1999)

This has been clarified in the text (l193-196). The cut offs at 0.4 cpd and wave number 14 were indeed implemented following Wheeler and Kiladis (1999).

Specific comments

1. Page 2, line 25: ”... different structural (Pytharoulis and Thorncroft, 1999; Chen, 2006) and spectral structures...” This is not clear, please rephrase. I assume the sentence is supposed to emphasize the spatial and temporal differences in the structure of the northern and southern tracking AEWs?

This sentenced has been rephrased as:

> They will be referred to as TD-AEW in the following. Waves from each wave track present significant differences in their horizontal and vertical structure (Pytharoulis and Thorncroft, 1999; Chen, 2006), as well as different period and wavelength (Jonville et al., 2024a).

2. Page 2, line 29: ”TD-AEWs” This acronym has not been defined yet.

Definition of the acronym added L24.

3. Page 2, lines 47-48. ”... of higher frequency waves.” and ”... convective activity inside such waves,...”

Corrected in the text.

4. Page 5, line 133: ”... 2 to 5 days and westward planetary wave number...”

Corrected in the text.

5. Page 5, line 143: Do you mean a red noise spectrum?

Corrected in the text.

6. Page 7, line 163: ”... wave, two-year data series of TCWV are padded...” Which two years? Please specify.

Corrected in the text.

7. Page 7, line 164: ”... long series of zero...”

Corrected in the text.

8. Page 7, line 174: ”In order to study the vertical ...”

Corrected in the text.

9. Page 9, lines 211-212: I don’t think this is the case. Figure 7b here (https://link.springer.com/article/10.1007/s00382-009-0697-2) shows that Kelvin filtered precipitation variance peaks around 5N in the Atlantic.

The reference to the article has been added in the text. The Kelvin wave composite is now computed based on the 10°S-10°N averaged TCWV decomposition to better capture the wave structure. This adjustment results in a peak around 5°, consistent with the findings of the referenced article. This is discussed L248.

10. Page 13, lines 282-283: Figure 5b shows significant Kelvin wave variance over the continent. Or maybe I am misunderstanding something?

Indeed, precision added in the text.

11. Page 14, lines 287: ”...September 2021 (see Figure 7a), during...” Should this be Figure 7c?

Corrected in the text.

12. Page 15, line 295: ”For tropical perturbation Pierre-Henri, ...” I assume this is the same as the AEW labeled PH? This should be mentioned here or above. I see it is mentioned in the figure caption, but I would suggest also mentioning it in the main text. I missed the caption the first time.

Indeed, PH is the acronym for Pierre-Henri. Precision on the names of the events added at the beginning of section 6.

13. Page 22, line 475: ”... modelisation...” Not sure that this is a word in english, modeling or model development would be more appropriate.

Corrected in the text.

14. Page 22, line 477: ”... development Hankes et al. (2015); Duvel (2021); ?.” There seems to be a citation missing?

Corrected in the text.

Figure 1: For panels b and c what are the contours? This needs a colorbar or labels on the contour lines.

Colorbar added to the figure.

Figure 5: The title should have units degrees west instead of negative degrees east. The y-axes need labels.

Figure modified according to the recommendation.

Figure 11: The caption reads: ”The grey zones show where a significant gap in the two profiles is found,...” I’m having a hard time figuring out which of the two greys in the background is the significant one. Also, does this mean significant difference in the temperature or dewpoint soundings? They can’t always be both significantly different at the same levels?

Area are marked in dark grey on the Skew-T when either one of the two parameter is significantly different between the two phases. This allow identifying vertical levels where there is a significant difference in the thermodynamic structure, related to either temperature or humidity. Explanation added in the caption.

Reviewer #2

The manuscript discusses the impacts of convectively coupled tropical waves on the atmosphere in the eastern Atlantic regions. This study analyzed the interaction between these waves in detail. However, the current manuscript is somewhat dense and difficult to follow. Some viewpoints would benefit from further elaboration and discussion. I recommend a major revision, as revising or reorganizing the content would help readers better understand the significance of this work.

The paper has been extensively restructured. Especially, a better distinction was made in the text between the impacts of the tropical waves on the structure of the atmosphere and on tropical cyclogenesis. The mention to tropical cyclogenesis has been added in the tittle. Some paragraph were added to improve the clarity of the message and some figures have been removed or simplified.

The authors should explain why these four events (Larry, Pierre Henri, Peter, and Rose) are discussed in this study and how they are defined. This could be clarified further in Section 2. In addition, 'Larry' is not labeled in any figure (it only appears in the caption of Figure 9). Furthermore, if the authors primarily focus on the time period of these events, presenting only the time range from September 1 to September 21 (or September 25) in Figures 7–9 may make the results clearer.

All discussions relative to Tropical Cyclogenesis have been moved to section 6 and better introduced (cf L360-367) :

> The sections above have shown that Tropical Waves play a role in structuring the thermodynamics and composition of the atmosphere. In this section, the impact of Tropical Waves interplay on tropical cyclogenesis and dust outburst will be highlighted. To do so, two viewpoints will be adopted : Figure 10 present Hovmöllers each type of waves on the whole Atlantic basin, and Figure 11 shows the variation of TCWV and dust AOD at the location of Sal, Cabo Verde, in relationship with time series of wave filtered signal at the same location. Four events of interest were captured by the instruments of the CADDIWA campaign. are TC Larry, TD Pierre-Henri (PH, unofficial name used in all papers of the CADDIWA campaign, see Flamant et al. (2024); Jonville et al. (2024a)), TS Peter and TS Rose (named by the National Hurricane Center). The environments of the MRG-TD1 on which the last three event developed were sampled by the aircraft during the campaign, while Larry was only observed from ground-based measurements.

The label for hurricane Larry has been added to figure 11 (formerly figure 9). The trajectories of the convective system and TC genesis have also been added to the Hovmöller (figure 10, formerly figure 7). The choice was made to keep all events in the time window, especially to discuss the impact ER waves before and during the active phase of Pierre-Henri.

2. In Figures 5 and 6, the ER waves strongly drive the AOD variance south of the AEJ (10°N–15°N), where their contribution to the TCWV variance is relatively weak. Is this because ER waves typically have strong zonal winds south of the maximum TCWV anomalies (Figures 3a and 3b)? The impact of wind anomalies on AOD variance may also be worth discussing in the main text.

Thanks for the suggestion. A discussion was added in the main text on this specific point L240-241:

> This might be explain by the strong westerlies associated with humid phase of ER (see Fig 4a) south of the AEJ, that prevent exit of air masses from the continent.

3. I got lost many times while reading Sections 5 and 6, perhaps because many figures are discussed interchangeably without clear figure references. Additionally, in Figures 11–13, I am curious whether the differences between the phase composites for MRG-TD waves (ER waves) could also be influenced by ER waves (MRG-TD waves). Since multiple wave activities coexist simultaneously (Figure 7), the phase composites of the sounding raw data would be affected by all of these waves (Figures 11–13).

As presented above, section 5 and 6 were restructured and simplified to improve clarity. As for the cross-talk between a phase composite and another type of wave, the distribution of soundings ensures that the composites are not too biased. Figure 11 shows this distribution. Especially, for MRG-TD2, two peaks of TCWV and one trough were sampled during a negative ER phase, and two peaks and two troughs during a positive ER phase. For MRG-TD1, 2 peaks and 3 troughs

were sampled during ER negative phase, one peak is collocated with a neutral phase and 3 peaks and 3 troughs during the positive phase. There is therefore a good balance of all ER conditions in the composites of MRG-TD, and vice versa.

Specific comments

1. Line 30: “Kiladis et al. (2006) showed…”

Corrected in the text.

2. Line 40: “…by Kelvin waves (…”

Corrected in the text.

3. Line 121: There should be a space between ”..twice a day” and “(at 0000UTC and 1200UTC)”

Corrected in the text.

4. Line 129: “…(see Figure 1a)”

Corrected in the text.

5. Line 131: “…coupled waves (Wheeler and Kiladis, 1999)”

Corrected in the text.

6. Line 135 and Figure 1: The MJO is not labeled in the Figure 1.

7. Line 167: “Fig. 1a for a …”

Corrected in the text.

8. Line 181: “…shown on Figure 2…”

Corrected in the text.

9. Line 250: “(Figures 5 and 6)…”

Corrected in the text.

10. Lines 267-271: This paragraph discusses the results from Figures 5d and 6d. Thus, I would suggest labeling 'Figure 5d' and 'Figure 6d' to make the text clearer for readers. In addition, in Line 271, I believe the authors meant to refer to MRG-TD1 rather than MRG-TD2 waves (at 3°N).

Corrected in the text.

11. Lines 276 and 431: I would suggest that ER waves are the main driver of TCWV variance near the equator and “north of 20 N”, because one of their peaks is observed within 20 N-25N (Figures 5b and 6b).

Corrected in the text.

12. Line 281: According to Figure 5b, I suspect the authors meant to refer to “except for TCWV north of the AEJ above the continent in September 2021”

Corrected in the text.

13. Line 287: It is for ER event, so it should be “(see Figure 7c)” rather than Figure 7a.

Corrected in the text.

14. Figure 7 caption: I think that the shadings are TCWV “anomalies”, which should be noted in caption. In Lines 3-4 of Figure 7 caption, it should be “but for MRG-TD1 and MRG-TD2 waves (black and magenta contours)”

Corrected in the text.

15. Lines 344-345: How do we know TS Larry less than 300NM south of Cape Verde? Perhaps it needs to be marked as “not shown”

Precision added in the text.

16. Line 347: “…(Figure 9a)..”

Corrected in the text.

17. Line 351: “…of a Kelvin wave on…”

Corrected in the text.

18. Line 477: “…; Duvel (2021); ?…” is it missing the reference?

Corrected in the text.

19. Figures 11-13. Line labels below the panel a and b are different. (Below panel b) Dashed lines should be dew point, right?

Indeed the dashed line represented dew point. However, to simplify the discussion, reanalysis panels are deleted from figure 11-13.

Reviewer #3

Unfortunately, I found the paper to be quite a challenge to read. I think it could be improved if it was shortened with greater focus on the more important results and perhaps spreading the current content across more than one paper. I also found some of the analysis and results confusing, as detailed below. I hope the authors can consider these points to generate a new and improved manuscript for journal submission.

The paper has been extensively restructured. Especially, a better distinction was made in the text between the impacts of the tropical waves on the structure of the atmosphere and on tropical cyclogenesis. The mention to tropical cyclogenesis has been added in the tittle. Some paragraph were added to improve the clarity of the message and some figures have been removed or simplified.

Specific comments

Abstract, line 1 and elsewhere. In most previous on tropical waves the acronym TD has referred to Tropical Depression, not Tropical Disturbance.

Corrected in the text.

Abstract, line 3. What does it mean for the MRG-TD tracks to be "mingled in the literature"?

Clarified in the text:

> Methods of the literature struggle to distinguish the two MRG-TD tracks.

Abstract, lines 11-14. The title and the previous text of the abstract suggest that the paper is about dust and atmospheric thermodynamics only, so this inclusion of a discussion of tropical cyclogenesis seems off-topic.

Title changed to better reflect the content of the study, including tropical cyclogenesis.

Introduction, line 87. You say that you follow the method of Wheeler and Kiladis (1999) but the "protocol" of Janiga et al. (2018). Please include a sentence saying how the method of Janiga et al. differs from Wheeler and Kiladis (1999).

Corrected in the text.

Section 2, line 129. What do you mean by the "Real" shallow water model?

Replaced by “shallow water model” in the text.

Line 139. The important point to add here is that the wavenumber-frequency filtering will output wave-like structures from input that is purely red-noise, so it is not always straightforward to attribute the output to a theoretical wave.

Precision added in the text:

> Though the method can be sensitive to wave pattern generated by red noise, it allows the attribution of each component of the signal to a theoretical wave.

Figure 1a. In the introduction you said that you used the protocol of Janiga et al. (2018), but they used different regions of wavenumber and frequency for filtering as displayed in this figure. What did you use?

Precision added in the text:

> “The protocol described in Janiga et al. (2018), that consists in taking two years of data, followed by two years of zero before computing the Fourier Transform.”

Figures 1b and 1c. The period 2018-2022 is clearly not long enough to get a clear picture of the waves in the spectrum. I suggest you use a longer period. Also, does your spectrum use data from all longitudes, or is it focussed on the Africa-Atlantic region?

In the revised version of the MS, the period of analysis was extended to 2012-2022.

Line 158. Say: "Figure 1 shows that the wavenumber-frequency domains of MRG and TDs do overlap significantly".

Corrected in the text.

Line 191. Here you say that you base the composite horizontal structure on the TCWV data averaged for 0-20˚N but at line 170 you said 0-15˚N. Which is correct?

The base is 0-20°N. Corrected in the text.

Figure 3. I am confused by the composites presented in Figure 3. Why aren't the TCWV structures more symmetric or anti-symmetric about the equator? If you do the wave filtering using the

symmetry constraints of Wheeler and Kiladis (1999), as implied by Figure1bc, then I expect that the TCWV composites should be more symmetric (or anti-symmetric) than what they are.

Following Janniga method, the TCWV is filtered independently for each latitude, therefore no criterion of symetry is applied.

Figure 3cd. I see nothing in this composite structure that resembles a theoretical Kelvin wave. I think you are instead looking at an artefact of the red noise background. My conclusion that it is an artefact is supported by Figure 5 that shows the Kelvin wave signal is maximized at about 30˚N, which is unlike the theoretical Kelvin wave structure which should be within about 15 degrees of the equator for the equivalent depths that you are considering.

The Kelvin composite is now computed for averaged TCWV Kelvin signal averaged between 10°S and 10°N instead of 0°-20°N before. It shows a more consistent Kelvin structure.

Figure 3 caption. You say that the number of events for the composites is included in the titles, but I don't see that.

Reference to the figure title removed in the caption. The number of event is indeed in the caption only.

Figure 5. As I said above, I do not trust the results presented for the Kelvin wave. I think it is an artefact of the method.

The filter is applied independently at each latitude, therefore the method cannot be responsible for meridional coherence of the signal. If red noise were to generate a signal, no such meridionaly coherent structure would be observed.

Changing the window on the basis of which the horizontal composite is computed allowed us to better identify a theoritical Kelvin wave. Its dynamics especially, that tends to increase the monsoon above the continent in the humid phase may explain that unexpected peak at 18°N. A smaller peak is present on all panels at 5°N, which is consistent with the findings of Tulich et al (2011). Explanation added in the MS L243-249.

Figure 5. The caption says it is the "Relative importance of tropical wave signals". Rather, it is the Squared correlation coefficient between the filtered wave signals and the associated variable. It should be noted that this is likely an overestimate of the relative importance given that there is likely a lot of noise that also contributes to the variability in the wave filtered fields.

Caption modified according to the recommendation.

Figure 6. Once again, the location of the peak of the Kelvin wave "relative importance" does not make physical sense with regards to the Kelvin wave structure which should be centred near the equator.

Same discussion as for figure 5.

Figure 7. You have labels for tropical storms Rose, Peter, and Pierre-Henri, but you do not show their actual genesis time/location or their track, just a vague timing.

Trajectories of the convective system and genesis location have been added to the Hovmöller.

Line 344. You mention TS Larry here, but it is not shown on Figure 7.

Label for Larry added in Figure 7.

Conclusions versus title. Much of the conclusions focussed on the tropical storms and TC genesis which was not reflected in the title.

Title changed to better reflect the content of the article, incl. the link with tropical cyclogenesis.