Response to Reviewer 2

Reviewer comments are provided in black font, while our replies are in blue.

This study investigates the prevalence and impact of westerly moisture transport events (WMTEs) on East Africa. The importance of moisture flowing from the Congo has been highlighted in previous studies, but this study applies a novel and more complex approach to identify the WMTEs. The method adapts previous work looking at atmospheric rivers for this tropical context. The method is applied to reanalysis and rainfall observation products. The impacts and wider features considered are rainfall, Madden Julian Oscillation (MJO) and tropical cyclones. For the methodological parameters and region chosen, the study finds that WMTEs are most prevalent during in January-February and are associated with a majority of rainfall in Tanzania during this period. Previously published relationships between WMTEs and the MJO are confirmed with this methodology. The results provide a more rigorous analysis than previous work of the connection between WMTEs and tropical cyclones, and finds there to be an association.
This manuscript is one of the best written and most thorough of any paper I've reviewed – thank you to the authors for making the review such an easy process. I consider the application of atmospheric river methodology to provide a useful step forward in rigour, and to have enabled the authors to provide some useful quantification of the phenomenon. I have no major objections to publication, but there's a few aspects that I think the authors need to clarify – there were a few bits of text where it was difficult to understand how the conclusions related to the presented figures. I outline these points below.

Thank you very much for your thorough review of our work and for your positive assessment of our manuscript. Please find below our responses to each of your comments.

L91 – 45 degrees. Is this plus/minus 45 or plus/minus 22.5 degrees. Please clarify.

This is plus/minus 45 degrees. We have updated line 91 to read "the direction of the moisture transport vector was within the range +/-45 degree of westerly"

L108 – The lat range used is quite a bit further south than in Finney et al. Whilst the sentence does not say anything incorrect, I think it is worth stating the difference clearly so that readers know to expect that there may be some fundamental methodological reasons for differences in results to Finney et al.

We provided more clarity about the differences in methodology at L108: "Though our study area includes the that of Finney et al. (2020), our results are not necessarily expected to be in agreement, because events in that study were detected using area averaged integrated vapour transport anomalies while here, WMTEs are detected by identifying specific contiguous regions where 700 hPa moisture transport met magnitude and direction criteria. Further, since we use a larger latitude range for our study region, our events did not necessarily affect their study region at all.

Sec2.2 - I'm would have liked supp text S1 to have been referenced in the methods section. I was pleased to stumble across it later in the paper, but it's really at this point that I want to dig into sensitivities.

We moved the reference to S1 to the methods section at line 94.

Sec2.2 - sensitivities to 500km distance to TC have not been discussed? Please share any findings you already have on this, and at least acknowledge this parameter choice when discussing the TC results in 3.2. In particular, the result in Finney et al. of suppressed occurrence of westerlies around Lake Victoria when TCs are in Mozambique channel would not be seen when using this constraint (I think). Please consider discussing this point more fully. Whilst, I think the authors have done a nice job analysing this, I think some further explaoration is needed to pick apart some of the regional details that might matter.

We performed a sensitivity analysis of how the fraction of TC-WMTEs changes as the distance threshold varies from 250 km to 750 km and found that each 250 km change in the distance threshold altered the number of TC-WMTEs going over the EEA line by only 3%. We added a description of this sensitivity analysis in the text at line 101 and included more details in the supplementary information, including Fig. R2.1.

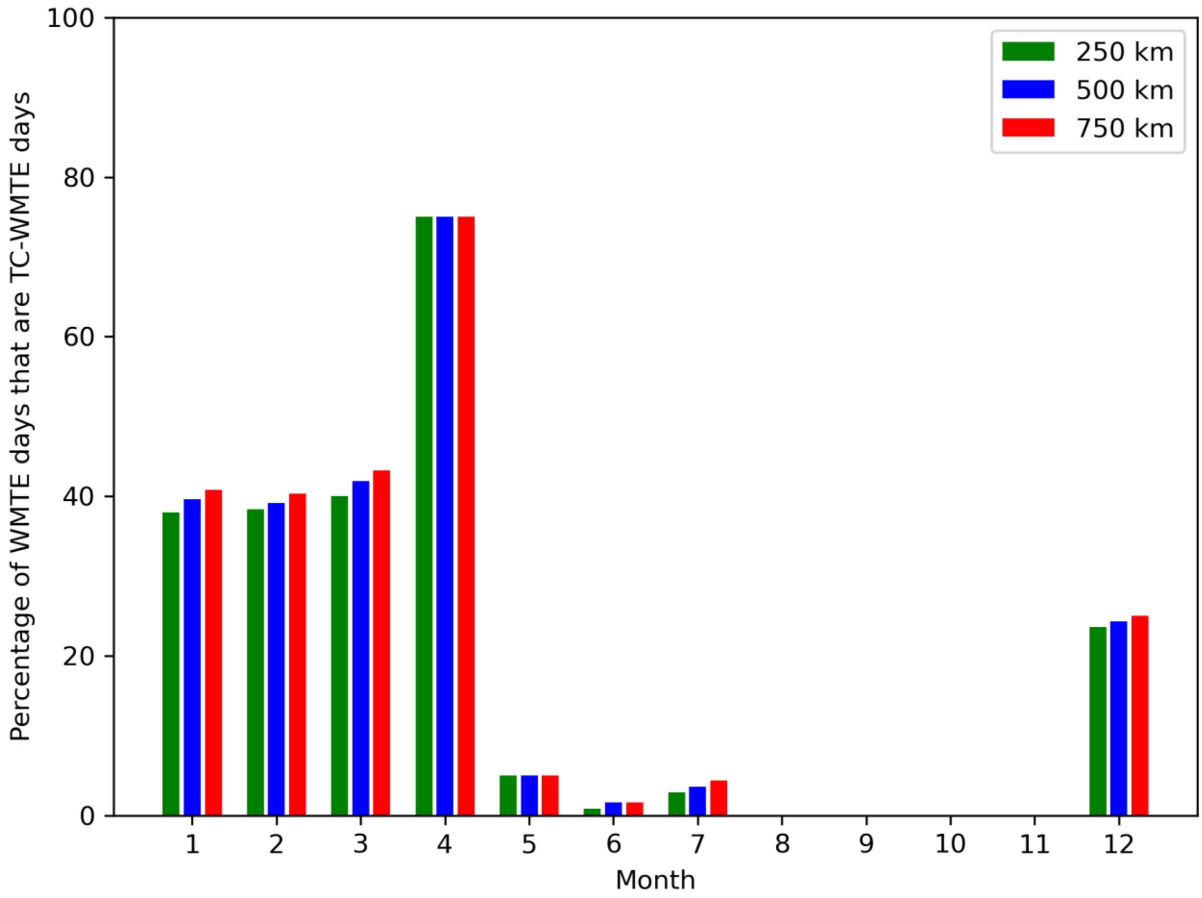

Figure R2.1. Percentage of WMTE days that cross the EEA line which were TC-WMTEs, varying the distance threshold from 250 km to 750 km

Sec2.3 - similarly to above comment, some sharing of any findings regarding sensitivity to precip attribution parameters, e.g. maxima separation distance.

We have added a description of findings regarding the sensitivity of these parameters at line 122. We also include description of a repeat analysis that we performed for R1 where we only attributed precipitation inside the WMTE mask. The new text reads as follows:

The sensitivity of this approach is reported in Konstali et al. (2024): the method is almost insensitive to changes in the wet-day threshold, and while it was more sensitive to changing the distance threshold from 500–1000 km, the method is half as sensitive as comparable approaches which attributed precipitation out to a fixed distance threshold away from the weather feature. For comparison, we repeated our analysis using the most conservative possible approach: only attributing precipitation inside the WMTE mask. Using this approach, precipitation amounts inside the region where WMTEs were common were reduced by around 50%, and as expected, precipitation outside this region decreases considerably (Fig. S8). However, we chose to retain the approach of Konstali et al. (2024) as past work has shown that on days with the westerly flow, there is often enhanced precipitation beyond the margin of the main region with westerly moisture transport (e.g., Kilavi et al., 2018; Collier et al., 2019).

Fig1 – It would be nice to see a range of different kinds of examples (including some that seem not to have worked quite as well) in order for readers to get a feel for this method. It's nice to have an example showing it worked nicely, but it's a new method so a few more in a supplementary figure would be appreciated.

We have added some more examples of events to the supplementary information: Fig R2.2 shows several days during a large precipitation event in the anomalously wet long rains of 2018 and Fig. R2.3 shows a more diverse range of examples. The text has been updated at line 124 as follows:

"More example detections are available in the SI, including a large precipitation event that persisted over multiple days during the anomalously wet long rains of 2018 (Fig. S4) and a variety of other examples providing some insight into the method (Fig. S5)."

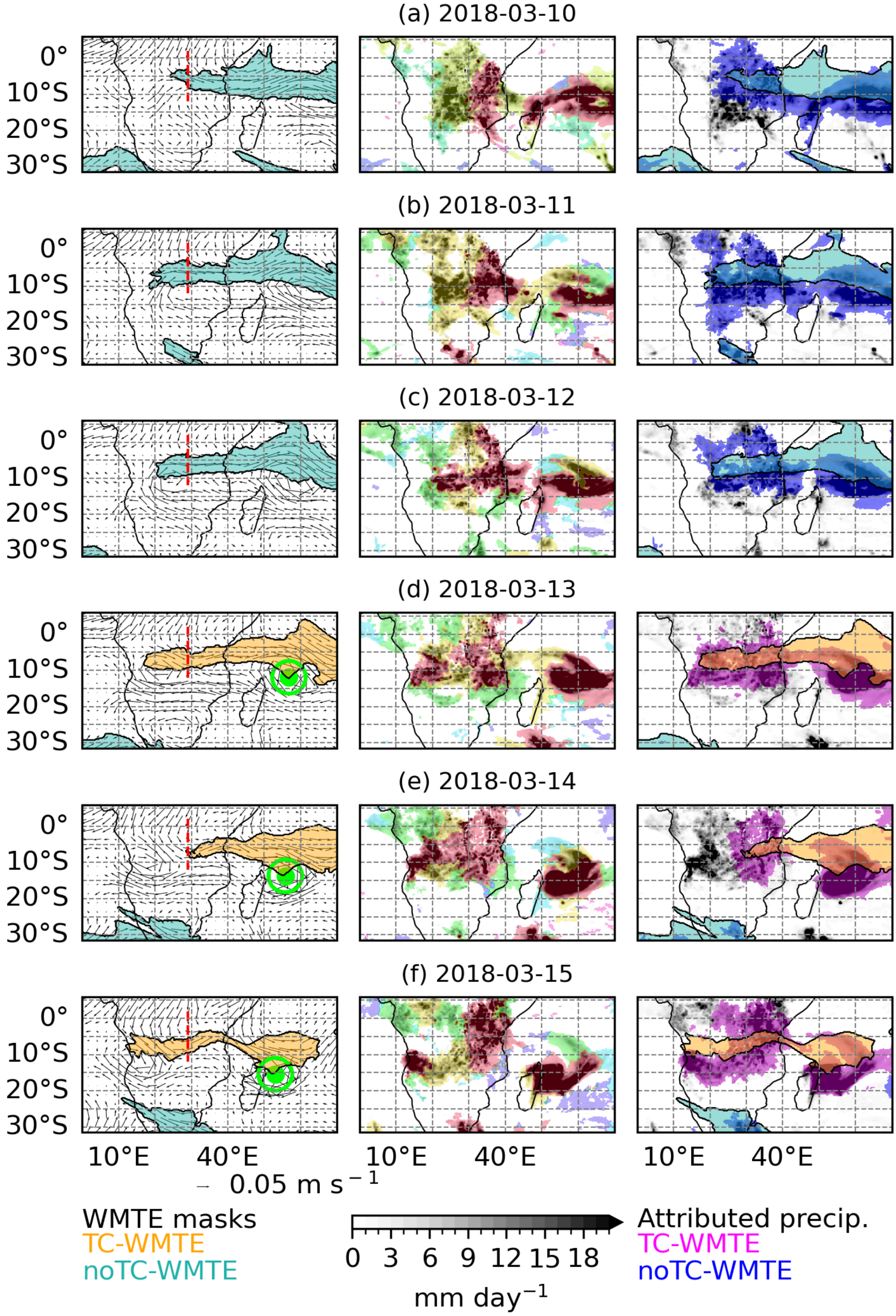

Figure R2.2. [New SI Fig.] Example WMTE detections during the long rains 2018. For each day, the left panel shows the 700 hPa moisture transport field along with the masks of detected WMTE masks. The red line is the EEA line that masks must intersect to be described as affecting EEA. The green dot present in (d-f) is TC Eliakim. The middle panel shows the daily ERA5 precipitation total and the precipitation objects. Each colour is a different object. The right plot shows the WMTE masks overlaid with the attributed precipitation.

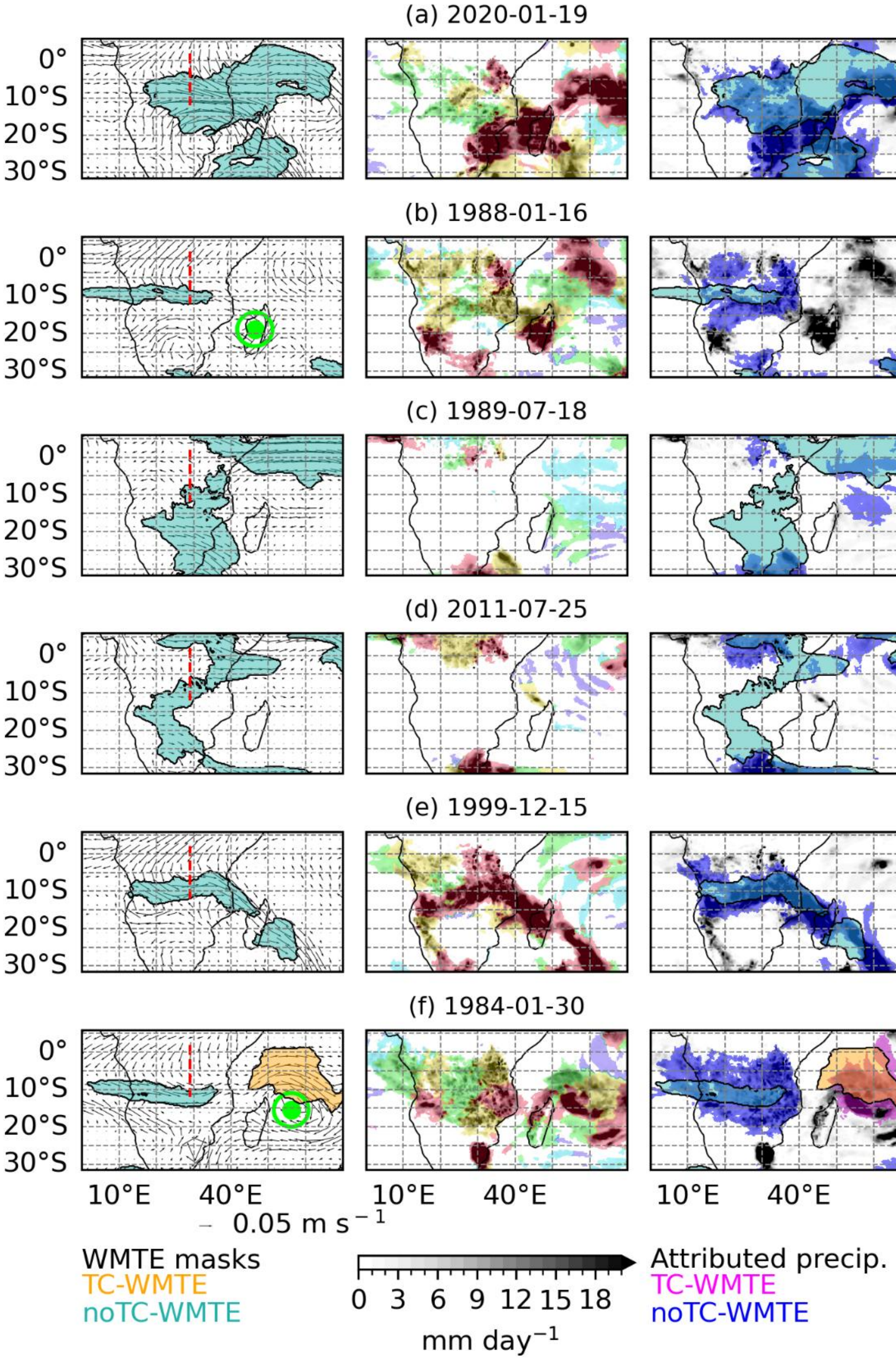

Figure R2.3. [New SI Fig.] Example WMTE detections. For each day, the left panel shows the 700 hPa moisture transport field along with the masks of detected WMTE masks. The red line is the EEA line that masks must intersect to be described as affecting EEA. The green dot present in (d-f) is TC Eliakim. The middle panel shows the daily ERA5 precipitation total and the precipitation objects. Each colour is a different object. The right plot shows the WMTE masks overlaid with the attributed precipitation.

We also included the following text in the supplementary information:

- Events had considerable variation in latitudinal and longitudinal extent. Some events were extremely wide (e.g. Fig. R2.3a), while others were narrower (e.g. Fig. R2.3b). Events usually extended into the Indian ocean, but sometimes extended further west (e.g. Fig. R2.3b)
- Most of the objects we detected showed very coherent moisture transport. But the very rare detections in JJAS tended not to be such structured objects, often appearing as a patchwork of areas of westerly transport (e.g. Fig. R2.3c, d). However, we inspected the set of detected events and confirmed that such events are extremely rare in the main months of interest in this study.
- The threshold approach occasionally resulted in seemingly coherent events being split into separate entities (e.g., Fig. R2.3e, f). In Fig. R2.3f, TC Galy is active off the coast of Madagascar, and there is a WMTE over EEA. There appears to be westerly moisture transport between the WMTE and the TC-WMTE associated with TC Galy, but the transport in this region did not exceed the 70th percentile threshold. It appears that these objects could be described by a single TC-WMTE. However, since the precipitation did not extend across the two objects, it is possible that the WMTE over EEA has a different driver.
- These examples also raise some questions about precipitation attribution: Fig. R2.2a and f show how on some days, especially when multiple westerlies were detected in the region, or when other convective systems like TCs were active, the region with attributed precipitation could extend very far from the edge of the WMTE mask. We chose to use this attribution method because previous work has shown that even areas rather distant from the main area of westerly transport experience enhanced precipitation on days with enhanced westerly moisture transport, and so this approach allows us to identify moisture that is associated both with WMTEs and interactions between WMTEs and other systems like the MJO.

Fig1 caption. “black dashed line” - I can’t see this well. I suggest maybe making it red, or something similar to make it stand out more.

We changed the colour of the line in the figure to red.

L126 / Fig2 caption – I don’t think this figure and results are based on the constraint of WMTEs crossing the EEA line? Otherwise panels such as fig2d wouldn’t make sense because they ahve no events over that line. Can you it clear that these maps are independent of that constraint.

Thank you for the clarification. We amended the figure caption to read: “Statistics of WMTEs detected in the whole domain: …”

Fig2 – have you considered including a metric for interannual variability? I imagine some years there might be quite a few more instances, and in some years no instances. Perhaps an IAV metric could be added as another row to indicate where such variability is high? Possible metric that could indicate something useful related to this... 95th percentile of yearly WMTEs events.

We added an extra row to Fig. 2 showing the 95th percentile number of days per month during a season with a WMTE present. In JF, we observed events persisting for up to 20 days.

In response to R1, we will add a “feature tracker” that will enable to look at the individual lifetime of a WMTE, rather than how long there are events present at a certain location.

Note that when we were making the new version of this figure, we found that we also see roughly one WMTE day per month in OND, which was not present in the version of the figure in the preprint, due to a mistake in the plotting code. This does not cause significant changes to our findings, as it means that we see events in MAM and OND at a similar rate, as part of the peak in JF. However, to retain consistency, we decided to add OND to Fig. 3.

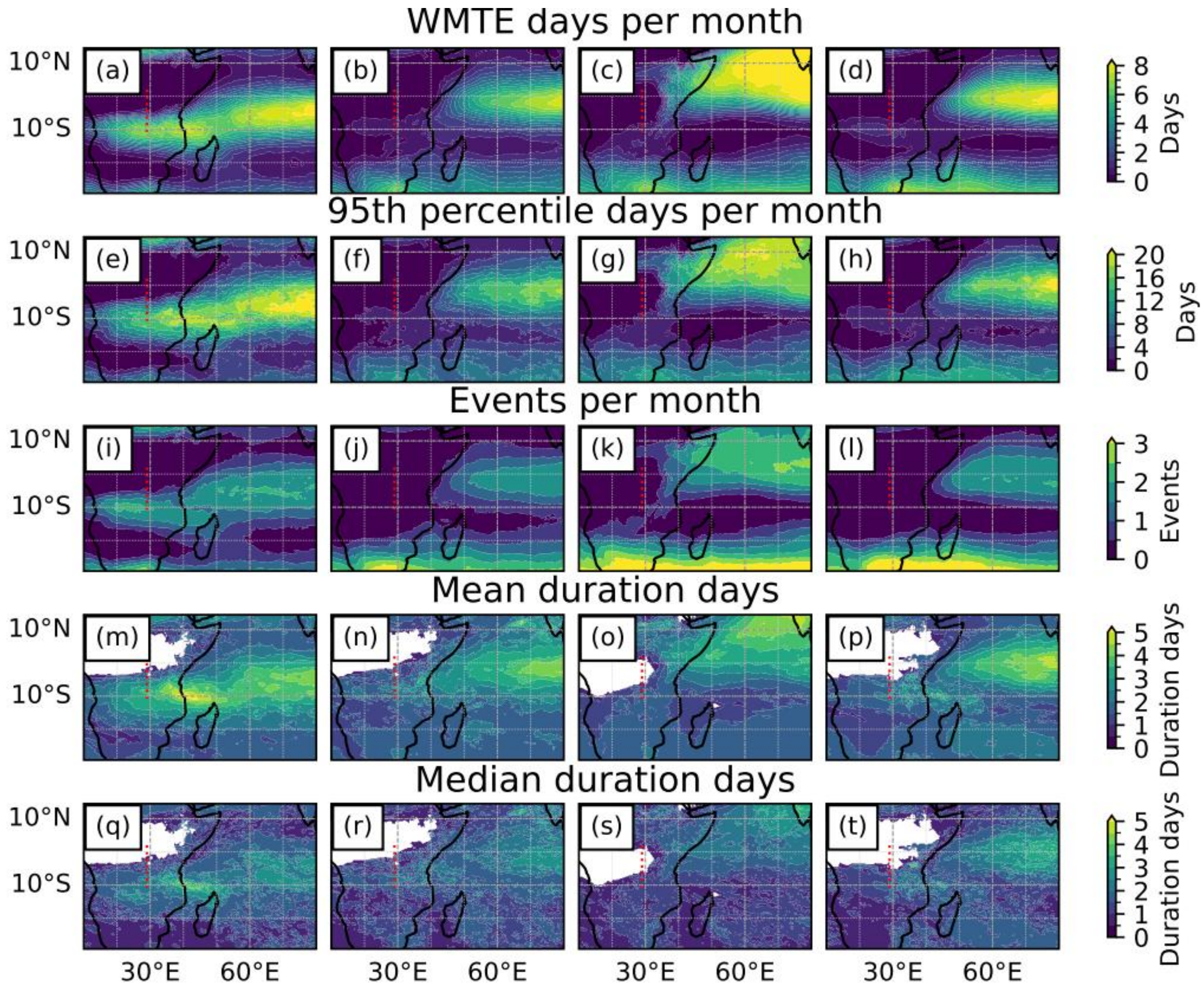

Figure R2.4. [New version of Fig. 2 in text] Statistics of WMTEs detected in the whole domain: (a–d) typical number of WMTE days per month. (e–h) 95th percentile number of WMTE days per month in a single year. (i–l) typical number of WMTEs per month, defined as periods of consecutive days where there was a WMTE present at that location. (m–p) mean duration of WMTEs. (q–t) median duration of WMTEs, in different seasons. White shading indicates areas where no events were detected and so no mean or median could be calculated.

L143– can you introduce to the reader why you are looking at the curl.

At line 143, we added “To identify possible connections between WMTEs and cyclonic activity, we also show the curl of the moisture transport field.”

L152 – TC_WMTE looks to have more intense curl and vectors than noTC_WMTE. Is this true? And is it significant? If so, could you mention it. Possibly showing a 4 column with the difference of these two would help see that more clearly.

We looked into these differences and also into the differences between WMTE and no WMTE days and decided to replace Fig. 3 with Fig. R2.5

Beyond the discussion already in the paper, based on the revised figure, we will add the following information to the results section

- Days with a WMTE have significant westerly moisture transport **anomalies** extending west and north from the region where WMTEs were particularly frequent
- On TC-WMTE days, westerly transport over EEA tended to be stronger and the region with enhanced westerly transport extended eastwards into the Indian Ocean. As expected, TC-WMTE days had stronger curl over the Indian Ocean, especially in the Mozambique channel, but these differences were only significant in JF.

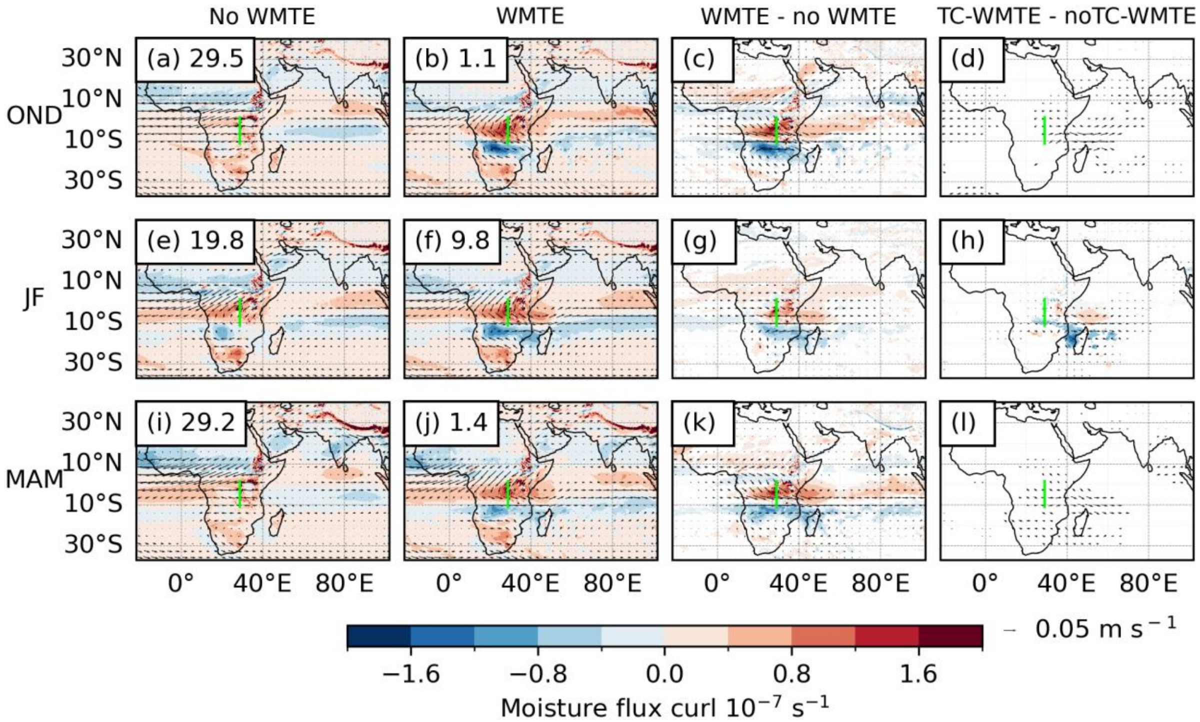

Figure R2.5. [New version of Fig. 3 in main text] Composites of 700 hPa moisture transport in (a–d) OND, (e–h) JF, and (i–l) MAM. (a, e, i) Days without a WMTE crossing the EEA line (2◦ N–12◦ S along 29◦ E), shown as the green line. (b, f, j) Days with a WMTE crossing the EEA line. (c, g, k) Difference between the composite of days with, and without, a WMTE crossing the EEA line. (d, h, l) Difference between the composite of days with a TC-WMTE crossing the EEA line and days with a noTC-WMTE (a WMTE that was not within 500 km of a TC) crossing the EEA line. The shading represents the curl of the moisture transport field. The numbers labelled in each figure show the average number of days per month in that composite. Differences are shown only where they were significant at the 95% level under a permutation test.

Fig3 – Whilst I think you have included the right main figure for your paper, there is part of the dynamics that is left out that you might like to add as supplement. Finney et al fig5 shows an intensification of low-level westerlies across the congo on westerly days. Adding a supp fig equivalent to fig3 but with 900 or 850hPa moisture flux or winds, might add a complimentary view of what goes on dynamically during WMTEs.

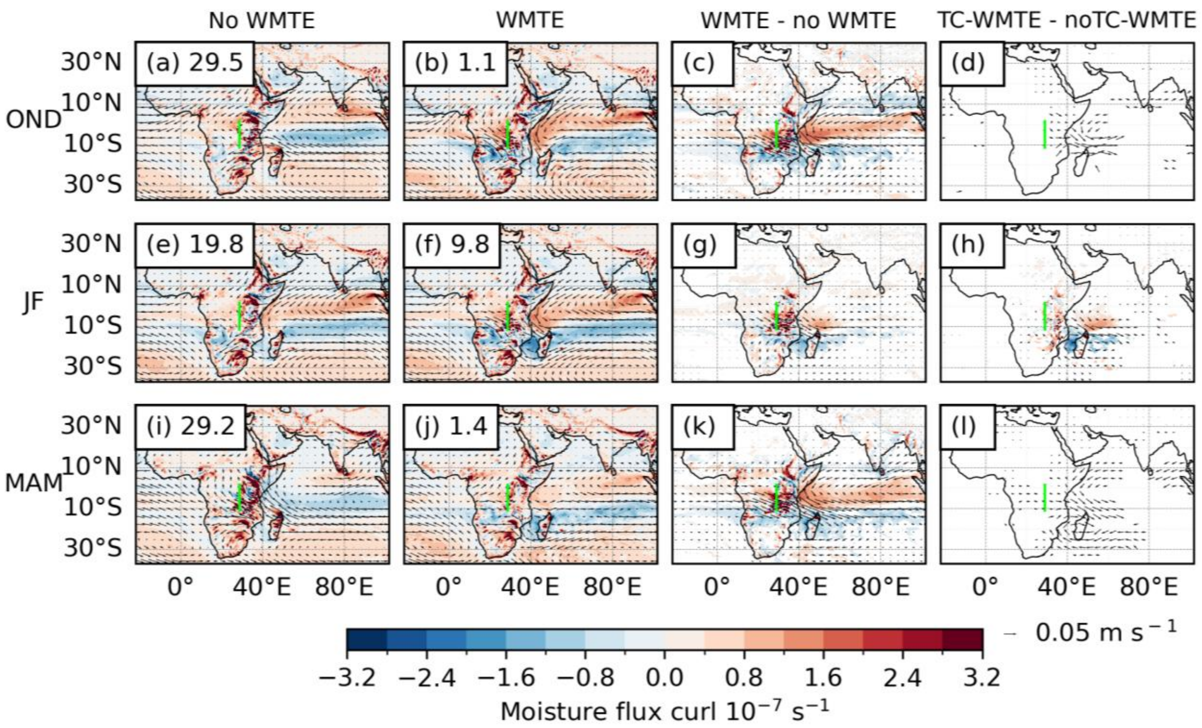

Figure R2.6. [] (as per Fig. 3 in main text but for 850 hPa) Composites of 850 hPa moisture transport in (a–d) OND, (e–h) JF, and (i–l) MAM. (a, e, i) Days without a WMTE crossing the EEA line (2◦ N–12◦ S along 29◦ E), shown as the green line. (b, f, j) Days with a WMTE crossing the EEA line. (c, g, k) Difference between the composite of days with, and without, a WMTE crossing the EEA line. (d, h, l) Difference between the composite of days with a TC-WMTE crossing the EEA line and days with a noTC-WMTE (a WMTE that was not within 500 km of a TC) crossing the EEA line. The shading represents the curl of the moisture transport field. The numbers labelled in each figure show the average number of days per month in that composite. Differences are shown only where they were significant at the 95% level under a permutation test.

Thank you for the suggestion. We made another version of revised Figure 3 for the supplementary information that shows the 850 hPa fields instead, shown in Fig. R2.6. We have added this figure to the SI and will add the following information in the results section:

- low level westerlies over the Congo are also enhanced during WMTE days compared to days without a WMTE
- In OND and MAM, low level anomalies also extend further west over the Atlantic. This is slightly different to the upper level, where anomalies extend further west only for MAM.
- Low level differences between TC-WMTEs and WMTEs are similar to the upper level: TC-WMTEs typically have stronger westerly transport over the Congo compared to noTC-WMTEs.

Fig 3 caption - “noTC-WMTE” is a bit confusing, I initially read it as “no(TC-WMTE)”. I don’t think you need to change it. But can you spell it out in the cpation instead of just saying a “noTC-WMTE crossing..”

We do define the “noTC-WMTE” acronym in line 98 in the methods section, but for clarity we have also amended the caption to describe noTC-WMTE as “a WMTE that was not within 500 km of a TC”

Fig4 hatching – I feel like it would be more useful to show where there is a significant difference compared to inactive days.

Thank you for the suggestion. We used Fisher's exact tests to see whether the total number of WMTE days at each grid box in that season during the set of MJO phases was significantly different from inactive MJO days. We performed one tailed tests and tested both alternative hypotheses, to highlight areas where, for a particular season, the number of WMTE days in those particular MJO phases was higher or lower compared to inactive days, with the 95% confidence level, including a Benjamini/Hochberg false discovery rate correction. In the new figure, dot (cross) hatching in each panel shows where WMTE days were more (less) common on days in that season on those MJO phases, compared to the inactive phase. It shows that the favourable phases significantly increase the rate at which WMTEs occur over large parts of EEA in OND, JF, and MAM, while decreases in the unfavourable phases are mostly insignificant over EEA except over limited regions. We have changed replaced Fig. 4 in the text with Fig. R2.7 and will add this information to the results section.

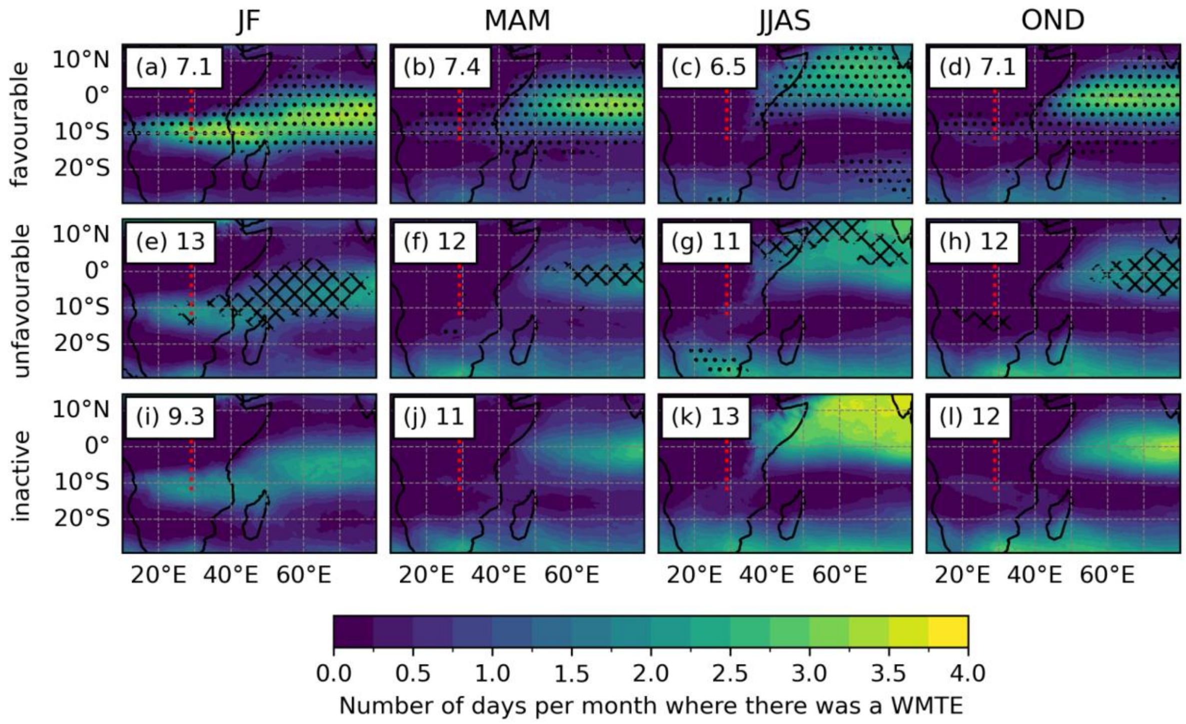

Figure R2.7. The relationship between MJO phase and the occurrence of WMTE days. The number of days per month with a WMTE in each grid box during: (a, e, i) JF; (b, f, j) MAM; (c, g, k) JJAS; (d, h, l) OND. (a–d) show favourable MJO phases (phases 2–4); (e–h) show unfavourable MJO phases (phases 1 and 5–8), and (i–l) show inactive MJO. The number on each panel indicates the average number of days per month in the MJO phases shown in that panel. Cross (dot) hatching shows areas where the rate of WMTE occurrence was significantly lower (higher) than the rate under inactive MJO using single tailed Fisher exact tests at the 5% level. The red dashed line shows the 'EEA line.'

L210 - "throughout the year" - I've struggled to follow how you can say this when your fig5 shows the full year and JF, but the full year is dominated by JF, I think? To say throughout the year, you'd need to look at MAM, JJAS and OND separately in your supplementary figures. This would be interesting to see, and would probably help compare to previous results, especially if you looked at MAM. I think you need adjust the text, if you don't analyse MAM on it's own.

We agree with your comment, we have amended line 210 to be "at least in JF"

We also repeated the analysis for MAM (Fig. R2.8) and OND (Fig. R2.9) and include these in the supplementary (Fig. S7-8). We have amended the main text at line 203 to be:

"In both MAM (Fig. S7) and OND (Fig. S8), the signal was much noisier, but in both seasons there were large regions in the central Indian Ocean, particularly during favourable MJO phases, where the risk ratio exceeds one. In MAM, the same is true for the inactive phases. Even for JF, the values are noisy with strong local fluctuations of opposing sign, making it hard to draw strong quantitative conclusions, but the analysis suggests that from October to May, TC presence is associated with an enhanced rate of WMTEs in most of the south-west Indian Ocean and during favourable MJO phases. In JF and MAM, the enhanced rate is also seen during unfavourable MJO phases and, in JF, when the MJO is inactive."

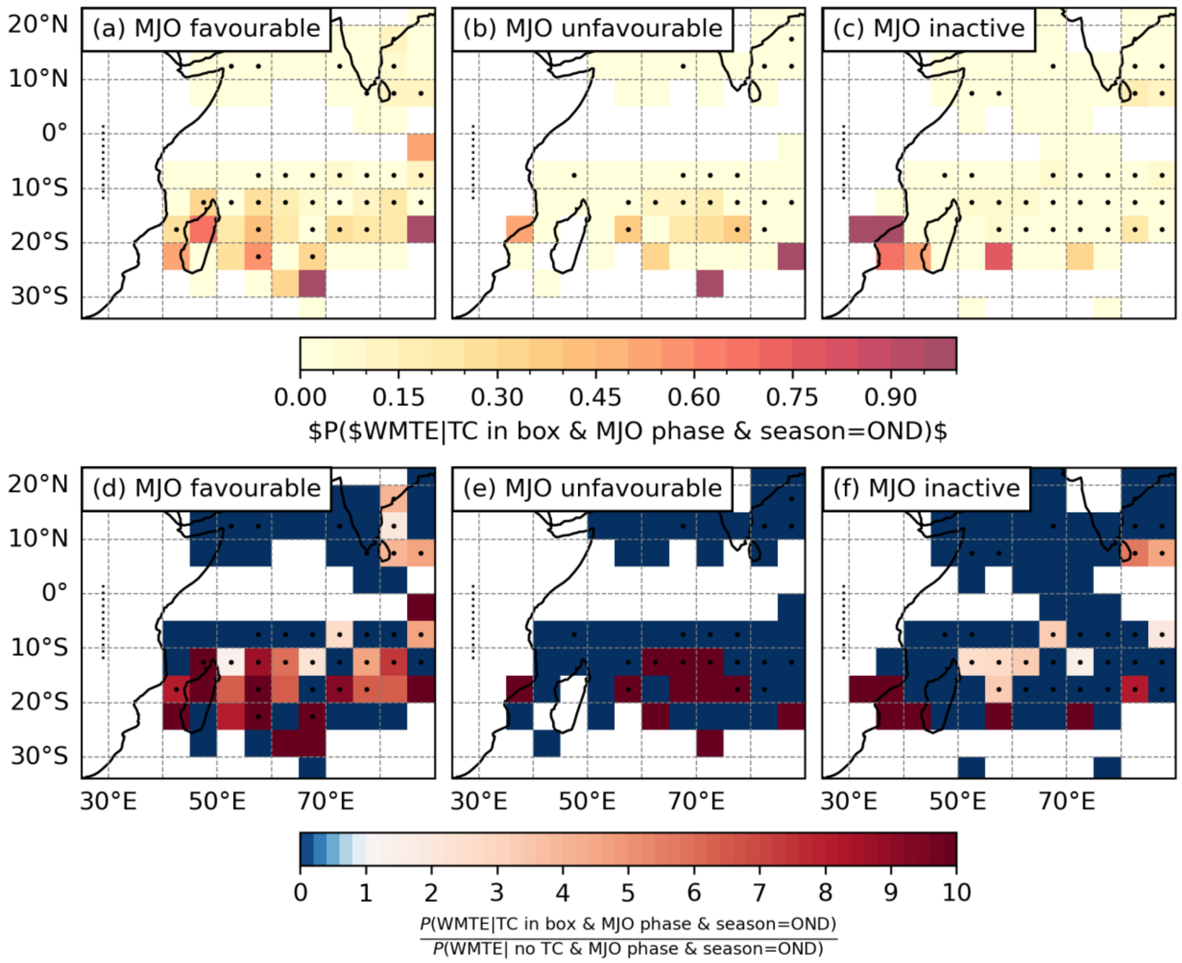

Figure R2.8. As Fig. 5 in main text, but all panels show MAM. How the presence of a tropical cyclone at different locations changes the probability of a WMTE day in EEA. (a–c) The probability of a WMTE crossing the line at 29°E from 2°N to 12°S, shown by the black dashed line, given the presence of a TC in 5° grid boxes. (d–f) Relative risk for each box, showing the ratio of the probability of a WMTE crossing the line given the presence of a TC, compared to the probability of a WMTE crossing the line, given there is no TC anywhere in the Indian Ocean. Boxes with a dot have at least 5 TC reports in the period 1980–2022. (a, d) MJO phases 2–4, (b, e) MJO phases 5–1, (c, f) MJO inactive

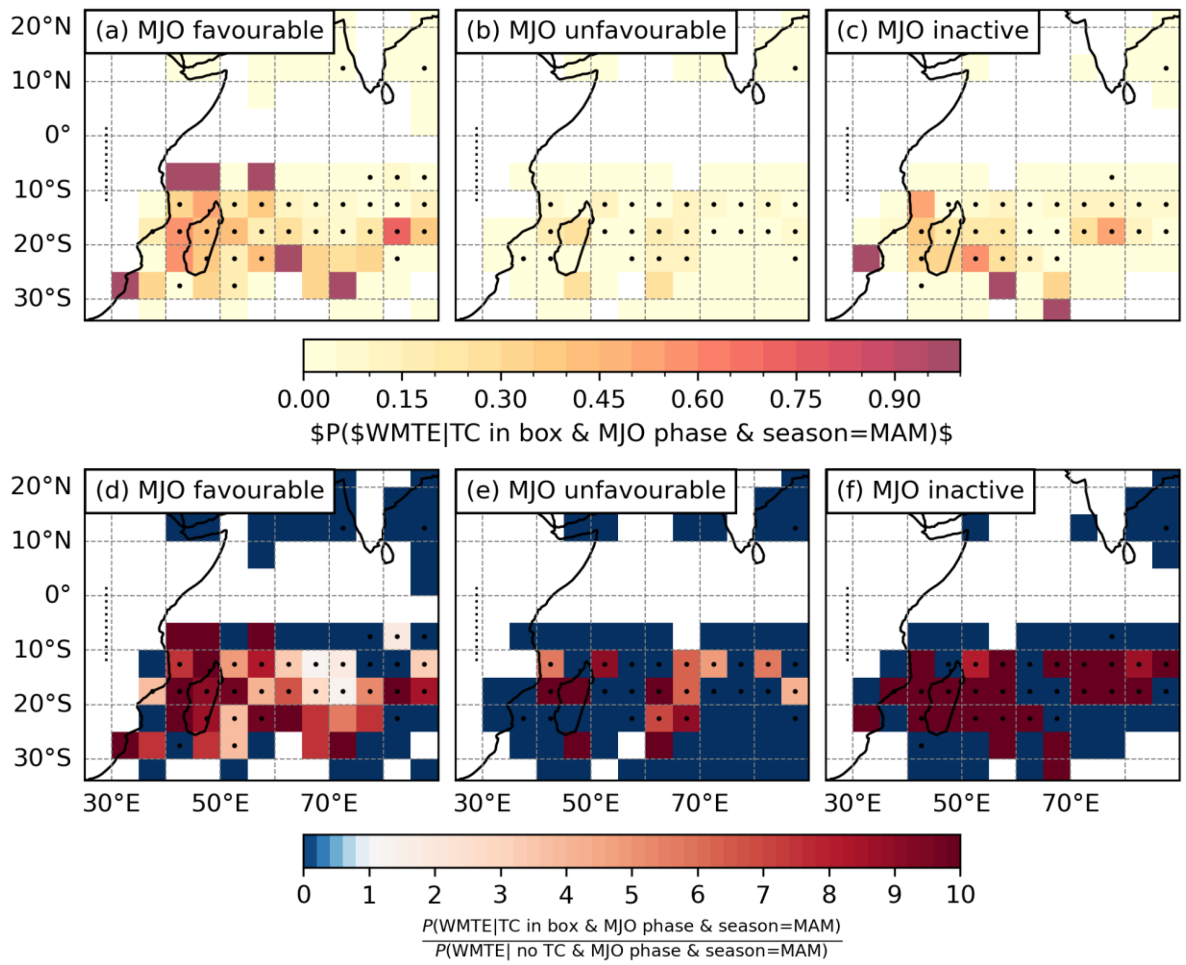

Figure R2.9. As Fig. 5 in main text, but all panels show OND. How the presence of a tropical cyclone at different locations changes the probability of a WMTE day in EEA. (a–c) The probability of a WMTE crossing the line at 29°E from 2°N to 12°S, shown by the black dashed line, given the presence of a TC in 5° grid boxes. (d–f) Relative risk for each box, showing the ratio of the probability of a WMTE crossing the line given the presence of a TC, compared to the probability of a WMTE crossing the line, given there is no TC anywhere in the Indian Ocean. Boxes with a dot have at least 5 TC reports in the period 1980–2022. (a, d) MJO phases 2–4, (b, e) MJO phases 5–1, (c, f) MJO inactive

L215-224 - There's also a slight other issue with your comparison to previous studies, because you have defined WMTE quite far south compared to the focus regions of previous studies. You may see a positive relation to WMTE because there is a WMTE over tanzania, but that WMTE is not spreading over Lake Victoria. I think you need to acknowledge this, and at least highlight the need for futrher research to pick it apart.

Good point. We have changed the text at line 221 to read: "Differences in the long-term patterns of WMTE, MJO and TC interactions likely arise because most of the WMTEs we detected were relatively far south compared to the study regions of previous studies. This highlights the need for further work exploring spatial variations in the relationship between precipitation, westerlies, and TCs in the EEA region."

L246 – Finney et al showed that westerly day rainfall was upto 200% of daily average rainfall. I would call this up to 100% increase, as daily rainfall would be 100%. Check your sure of your phrasing.

Thank you for pointing this out. We amended the text to read 100% increase.

Technical comments

L261 – typo – capital “S” on “WMTES”

Thank you for spotting this. We have amended the text