REVIEW: The influence of El Niño-Southern Oscillation on cool-season precipitation variability in the arid Middle East

General Remarks:

The authors addressed all previous comments, while providing evidence and additional analysis to affirm their results. After reviewing the authors response, I believe that my main comment still stands, which is that the rain enhancing signal of positive ENSO is more nuanced than what the extended season composite analysis suggests, and therefore should be communicated to the reader with a grain of salt. This is based on:
(1) No clear signal in mid-winter, when most precipitation occurs in the region (Fig. 3a).
(2) Linear regression showing no statistically significant relationship for positive ENSO (Fig. 3e, R4e, R5e).
(3) Strong heterogeneity between decades (Figs. R4a,R5a), which also includes sensitivity to the choice of the climatology period (Figs. R4d,R5d).
While I believe this point is an important caveat for the premise of the article, I recognize that it does not materially affect the study's mechanistic findings or overall conclusions. Accordingly, I leave it to the editor and the authors to determine whether incorporating this point is warranted (particularly at the end of Section 3 and/or in the Summary).

We thank the referee for reviewing our revised manuscript. Following the comment that the precipitation increase during a warm ENSO is more nuanced than what the composite analysis suggests, we had another thorough and critical look at our results. Importantly, we have now added additional evidence, showing that the precipitation increase during El Niño is substantial and significant, refuting the presumption that this finding "has to be communicated with a grain of salt". Fig. R1 below, also added as Fig. 2e in the newly revised manuscript, shows the distribution of spatially aggregated precipitation amounts during the cool season for all three ENSO phases. Relative to climatology, we find a significantly large precipitation mean for El Niño and significantly small precipitation mean for La Niña. Neutral ENSO conditions show a precipitation mean close to the multi-year climatological mean. In other words, this added analysis presents clear evidence that cool-season precipitation in the Middle East is significantly increased during El Niño. We have added the following sentences to the beginning of the 3rd paragraph of section 3.

"The statistical distribution of spatially aggregated precipitation differs substantially among ENSO warm, neutral, and cold phases (Fig. 2e). Relative to climatology, the spatially aggregated mean precipitation is significantly higher during El Niño and significantly lower during La Niña. Consistent with these differences between ENSO warm and cold phases, the interquartile range of precipitation during El Niño lies entirely above the interquartile range of precipitation during La Niña (red and blue boxes in Fig. 2e)."

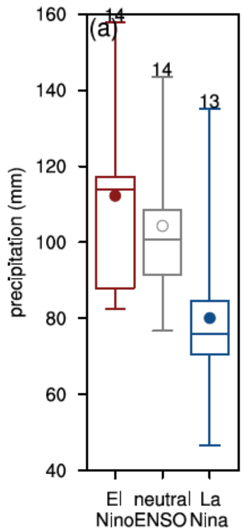

Figure R1, also included as Fig. 2e in the revised manuscript, shows the distribution of spatially aggregated precipitation during the ENSO warm, neutral and cold phases. The boxes denote the lower and upper quartiles, the whiskers the minimum and maximum values, and the line in the middle the median. The spatially aggregated mean is shown by the circles, filled at the $p < 0.05$ significance level and open circles for non-significance anomalies relative to climatology. The sample sizes are indicated in the number above the boxes.

Specifically, in response to the three points raised by the referee above:
1. We agree that in mid-winter months, i.e., January and February, the precipitation anomalies during El Niño conditions are very similar to those during La Niña conditions (Fig. 3a,c). Instead, precipitation anomalies are significant and positive during neutral ENSO conditions during the month of January. This point was already explicitly mentioned in the original manuscript in the following sentences (in Section 3):

"During the core winter months of January and February, precipitation tends to be higher under neutral ENSO conditions compared to both El Niño and La Niña conditions, with a significant increase in the spatially aggregated mean for the month of January at $p < 0.1$ *(Fig. 3b). Consistent with this notion, Hoell et al. (2015a) documented different correlation patterns of hydroclimate conditions over Southwest Asia with tropical Pacific SST anomalies for the month of January compared with other cool-season months."*

And in the 2nd paragraph of the summary:

"In the core winter months of January and February, precipitation increases under neutral ENSO conditions."

For these reasons, we consider this point adequately and sufficiently covered.

In addition, it should be noted that March is the month with most precipitation, when El Niño mean values are higher than during neutral ENSO or La Niña conditions, not the core winter months.

2. It is correct that the *slope* of the precipitation as a function of the Nino3.4 index for the El Niño regime (Nino3.4 > 0.5) is not significant given the p-value of 0.41 (Fig. 2e of the first revised version of the manuscript and Fig. 2f of the second revised version). This suggests that the rate of change in precipitation with increasing strength of El Niño (i.e., the slope) is non-significant. However, this is a very different thing from saying that there is no significant relationship [between precipitation and ENSO] for [a] positive [phase of] ENSO. In fact, the newly added evidence, please see above, shows that precipitation is significantly increased during El Nino conditions compared with climatology.

Having said that, we realized that the text in the revised manuscript was unclear on this point. We have now replaced some text from the 3rd paragraph of section 3:

"Linear regression of cool-season precipitation amounts as a function of the Nino3.4 index shows that precipitation increases by approximately 25.5 mm and 9.1 mm per degree of central Pacific SST anomaly Nino3.4 index values below -0.5 and above 0.5, respectively, corresponding to nearly a factor of 3 difference. The precipitation response to ENSO forcing is…".

By

"Linear regression of cool-season precipitation as a function of the Nino3.4 index shows a change in precipitation per degree of central Pacific SST anomalies (i.e., the slope) of approximately 25.5 mm $℃^{-1}$ *and 9.1 mm* $℃^{-1}$ *for Nino3.4 index values below –0.5 and above 0.5, respectively, a nearly threefold difference (Fig. 2f). The slope in precipitation to ENSO forcing is…".*

3. The asserted "strong heterogeneity" in the spatial distribution of precipitation anomalies between decades (i.e., 1979-1999 and 2000-2020) can reasonably be assumed to result from the very low sample size, being 6 and 8 El Nino years during the periods 1979-1999 and 2000-2020, respectively (see Figs. R4a, R5a from the previous response). While the slope in precipitation as a function of the Nino3.4 index may be sensitive to the chosen period, we note again that the mean precipitation values during El Niño are substantially larger than climatology for both sub-periods with significance for the second half of period only, when the slope is nearly neutral (Fig. R2 below). This shows that the positive precipitation anomalies during El Niño hold for both climatological sub-periods.

Given this new evidence, we removed the last two sentences in the 3rd paragraph of section 3, which elaborated on the changes in slope for the two sub-periods, which appear less relevant given the new evidence based on actually precipitation amounts across ENSO phases for both sub-periods.

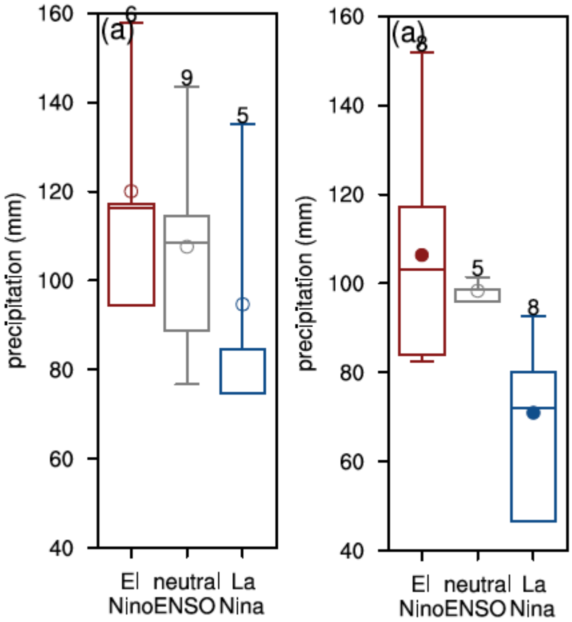

Figure R2, as Fig. R1, but based on sub-periods 1979-1999 (left) and 2000-2020 (right).

In summary, these arguments along with added analysis presents clear evidence that the precipitation increase during cool season for El Niño is substantial and significant. We hope that this response and the newly added analysis take away the referee's concern. We thank the reviewer for drawing our attention to this point, which helped us to strengthen the manuscript.