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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Drier spring over the US Southwest as an important precursor of summer droughts over the US Great Plains" *by* Amir Erfanian and Rong Fu

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We thank the anonymous reviewer for taking the time to review our manuscript and providing useful comments. Below is our point-by-point response to the Reviewer's comments.

Response to Anonymous Referee #2

"This paper aimed to address the processes that lead to two summer droughts over US GPs in 2011 and 2012. The authors conducted a moisture budget analysis with two reanalysis products to show that zonal advection of anomalous moisture by mean winds

is the dominant process that preceded and contributed to the two summer droughts. While the moisture budget is suitable for the authors' aim, a major concern appears as to whether the resolution of the data used is high enough to close the budget. If the error term is comparable to the main terms (P-ET and moisture flux convergence), a further breakdown into different terms (advection, mass convergence, etc.) will be meaningless. This seems to be the case in the current manuscript. For example, as indicated around Line 285, the imbalance in the budget is as large as 1.5mm/day over the US central plains, and is comparable to the maximum P-E deficit of 1-3mm/day (âĹijLine265) and the breakdown terms shown later. This large error is clear in Fig. 5 (e&f vs a&c) over the US GPs. To solve this issue, the authors should either show that at the current resolution the error terms are indeed much smaller compared to the breakdown terms presented in Fig. 6-7, or if that's not the case, try to use higher resolution data to reduce the error. In either case, it's necessary to include the error terms in Fig. 6-7."

Response: 1) The impact of resolution on the accuracy of our numerical calculations was measured by the MFC(ERAInterim)-MFC(calculated) error metric, which indicates near zero errors over the GP (Figure 5d), significantly smaller than MFC or P-E. The budget imbalance, MFC-(P-E), is primarily due to the parameterization of moist processes and the moisture budget in the Reanalysis not being closed, and minimally affected by the resolution of the data used in our calculations (as shown by nearly identical imbalances over the GP for both MFC(ERAInterim) and MFC(calculated) in Figures 5e and 5f).

2) The magnitude of mean bias (the climatological imbalance in Figure 5) does not support the argument made in this comment as a large yet constant imbalance (zero variability) cannot account for even a small variability in the MFC. The key factor to look at here is the variance and whether or not the range of year-to-year variability of the residual is large enough to mask the anomalies of MFC or the breakdown terms. This was investigated by a more detailed analysis of the imbalance in Figure 1 (below).

For both regions, the climatological imbalance indicates mean bias magnitudes of about 1mm/d in April, May, and June and less than 0.5 mm/d for rest of the year and a standard deviation that remains in the 0 to 0.5 (mm/d) range year-round. For the two droughts of 2011 and 2012, the imbalance remains about equal to or less than 0.75 and 0.5 mm/d year-round, respectively, which is four to six times smaller than the zonal moisture advection anomalies during the onset of both droughts (2.5 to 3 mm/d) and cannot mask variability of the advection term.

"Some minor issues: Section 2.1: the moisture budget equations are not clearly derived. The authors started by combining continuity and moisture equations to get the commonly used flux form of moisture equation (1), but then broke it down to the advection form in (2) to suit their aim, which seems circular and confusing. I urge the authors to rederive these equations (1-6), maybe by following some papers cited (such as Seager and Naomi 2013)."

Response: Eq. 1 (the flux form of moisture budget) is replaced with the conservation of water vapor in the revised manuscript, as suggested by this comment.

"Line124: "the transient and stationary terms refer to the monthly mean and six-hourly departure " should be "the stationary and transient terms refer to the monthly mean and six-hourly departure""

Response: The order is fixed as suggested.

"Line 268/293/etc: the usage of "moisture flux convergence" is confusing, and doesn't seem to follow the convention. When P-E>0, the moisture flux divergence term in equilibrium should be negative and by convention is interpreted as "moisture flux convergence". Please clarify."

Response: Convergence is defined as -1*divergence (L277) and the moisture flux convergence (MFC) refers to the left side of Eq. 2 and represents the negative total moisture divergence flux which is consistent with the literature (e.g. Banacos and Schultz,

2005). To remove potential confusions, a detailed definition of MFC has been included in the revised manuscript (L126).

Banacos, Peter C., and David M. Schultz. "The use of moisture flux convergence in forecasting convective initiation: Historical and operational perspectives." Weather and Forecasting 20.3 (2005): 351-366, https://doi.org/10.1175/WAF858.1

"Line 388: 'coverability' –> covariability"

Response: Fixed as suggested.

Figure 1. The annual cycle of the moisture imbalance for the numerically calculated moisture tendencies (MFC(calculated)-(P-E)) averaged over the US a) SGP and b) NGP for the 1979-2018 climatology (solid black) overlaid with the one standard deviation envelope, the SGP in 2011 (solid blue), and the NGP in 2012 (dashed blue), versus the zonal moisture advection anomalies for the SGP in 2011 (solid red) and the NGP in 2012 (dashed red). All the units are in mm/d.

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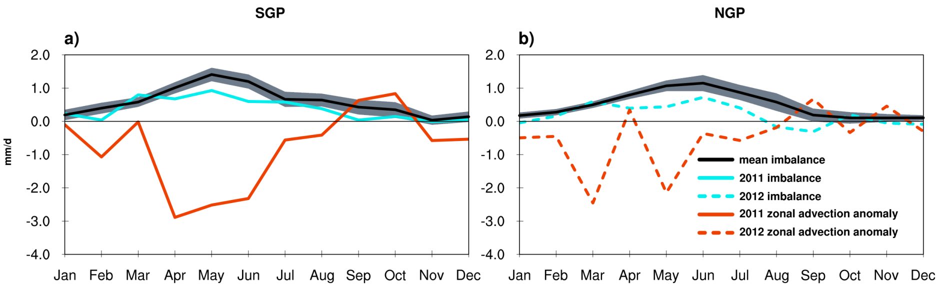

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