Reply to comment by Remo van Tilburg

We thank Mr. R. Tilburg for the helpful comments and have implemented the suggestions as described in details below.

General comments

1. According to the section 2.2 Methods (P8982) four CP-El Niño and two EP-El Niño events have occurred during the research period. These events are then investigated on anomalies. Though, there is only tested on values different than zero for all measurement stations during these events. As far as I understand, these values are then averaged and presented in figures 2, 4, 6 and 7. This can give false insights and might change the outcome of this research. Because, when you average over multiple events one large anomaly can change the outcome. On top of this, it is mentioned that a Monte Carlo technique has been applied in order to test statistical significance. Though, this is mentioned without any motivation. This can cause question marks as readers want to know why this is performed and how. I suggest therefor elaborating this and perhaps making a figure to explain this more in detail, as this part is the core of the

Response: In the manuscript, we tested whether the runoff anomalies during the two types of El Niño years are different from its climatology mean. The composite method is a commonly used methodology (Kao and Yu, 2009; Mo, 2010) to highlight the common features of the signals of El Niño. We do notice that one extreme value may change the outcome in averaging the values across several events, thus statistical tests such as a Monte Carlo test was carried out in the study (Mo, 2010; Wilks, 2011). We have included the explanation in the revised manuscript.

2. It is not clear why the use of the Evapotranspiration data (ERA-Interim), obtained from the European Centre for Medium-Range Weather Forecasts (ECMWF) is chosen. No motivation is given and the only reference given is to the paper of Dee (2011), which only describes the performance compared to the older ERA-40. When searching for the accuracy of this data set, some papers suggest that the ET values of ERA-Interim are overestimated (Mueller et al., 2011; Vinukollu et al., 2011). When using wrong ET data, calculations will give false results and figure 7 might be incorrect. Also, as the ET data is used to calculate runoff these values will also be incorrect. Therefore, I miss the motivation of the choice of the ERA-Interim for this paper and there might be better ET data available according to the papers. On top of this, a proper discussion about potentially false input data is missing and should be included.

Response: ERA reanalysis data sets are widely used in the climate community. Compared with the ERA-40, ERA-Interim has many improvements (e.g., the use of four-dimensional variational analysis, a revised humidity analysis, variation bias correction for satellite data, etc.), particularly in the hydrologic cycle variables (Uppala et al., 2008). Moreover, ERA-Interim is available in near real time. There are numerous studies of hydrology or hydroclimatology using ERA-Interim data (Balsamo et al., 2015; Chiodo and Haimberger, 2010; Huang et al., 2013; Johannessen and Ohmura, 2011; Pfahl et al., 2014; Romanou et al., 2010; Škerlak et al., 2014; Tuinenburg et al., 2012; Van der Ent and Savenije, 2011; van der Ent et al., 2010). In the study, we did not use ET to calculate runoff. Instead, we plotted composite maps of the spatial patterns of ET during the two types of El Niño in order to understand whether the runoff pattern follows precipitation pattern or ET pattern. According to the comment, we changed the reference of ERA-Interim to Uppala et al. (2008).

3. A study regarding determination of an El Niño by investigating only runoff patterns can be included to improve the quality of this paper. At this moment, an El Niño event is determined in advance and with this point of view, runoff patterns correlated to a type of El Niño are investigated. Additionally, I would suggest determining the same patterns the other way around. Thus, taking runoff data in account and focus if an El Niño event can be determined from this data. When results are positive, correlating these specific patterns to an El Niño event can draw a more solid conclusion.

Response: As the most important climate mode in the Earth system, El Nino event significantly impacts weather, climate and hydrology (including runoff) both globally and regionally. Climate variables such as precipitation, temperature and runoff vary/change associate with the mode changes of El Nino/Southern Oscillation (ENSO), not the other way around. Our goal is to characterize the different impacts of the two types of El Niño on runoff over the US, not to identify the two types of El Niño based on runoff in the US. To identify different types of El Niño, we use widely used ENSO indices-sea surface temperature in the equatorial Pacific (Trenberth, 1997; Yu and Kim, 2013).

4. During section 3.2.2 WRRs (P8985), some values are used to convince the negative/positive runoff anomalies during a specific El Niño event. The values represent fractions of the amount of WRRs experiencing the corresponding runoff. Though, all values are more or less around 50.

Response: What we want to emphasize in this paragraph is the 18 WRRs have similar responses on seasonal scales as those on annual scales throughout El Niño years. Except for the three climatic regions we identified (NE, PNW and WNC), the responses of runoff to the two types of El Niño are pretty similar in other regions. Thus, it is not surprise that the values are close to 50%.

5. Some assumptions made in this paper are without any motivation or discussion. Also due to the fact that climate variability is not constant, triggers me to search for a discussion. Unfortunately, this is lacking in this paper. I would suggest that some comments I mention in this review could be explained in such a section, causing the paper to be much stronger. On top of this, it can recommend further study on this topic. In the current paper only one suggestion has been mentioned for further study, which is due to scarcity of gauging stations.

Response: We added a *discussions* section in the revised manuscript as suggested (section 4).

Minor Issues

*1. The grid data from the model output is discussed in section 2.1 Data and at the end of this section the paper mentions that all grid data is re-gridded into a resolution of 0.5*0.5°. Here I am missing some motivation why this choice has been made, or why it was necessary to do so.*

Response: Different climate models usually have different resolutions (Taylor et al., 2012). In order to do pattern correlation, multi-model ensemble analysis, we have to re-grid model outputs so that all climate/hydrological variables have the same resolution (Mo, 2010; Power et al., 2013). In the current research, observed precipitation data is at the resolution of 0.5°, we thus used the same resolution by re-gridding all of the model output.

2. At P8983 L25, the word specifically has been used. This will put focus on the first coming piece of sentence, which is about the runoff anomalies of the NE region. Though, these specific anomalies aren't that unique compared to the other regions that are described as well. I would suggest that the word "Specifically" needs to be removed, or the sentence needs some reconstruction.

Response: Before the word 'specifically', we first gave a general description for the three climatic regions. We, then, described the three regions one by one in details. We thus prefer to keep the word 'specifically'.

3. P8983 L6: "Specifically, during CP-El Niño years (Fig. 2a), significant below-average runoff was observed in the whole Northern US, with extremely dry conditions of up to 180 mm yr^{-1} (-31 %) in Northeast (NE) and (-11 %) Pacific Northwest (PNW) regions. " Here, for the Pacific Northwest region the amount of mm yr^{-1} is missing. On top of that, it is not directly clear that these numbers are about precipitation; perhaps mention it instead of using "dry conditions".

Response:
The value -180 *mm* yr^{-1} does not miss, which is around 31% of the climatology mean in NE region and 11% in PNW region, respectively. We have rewritten the sentence to make it clear in revised version (L165). This figure (Fig. 2) is composite of runoff, not precipitation, which has been described in the figure caption.

4. P8986 L21: "Nonetheless, such differences in El Niño frequency do not affect the main results (not shown)". I am confused why only such a short comment is given for neglecting this. Still, it would improve the paper by explaining it.

Response: There are several indices to define El Niño (Yeh et al., 2009; Yu and Kim, 2013). However, such different indices will not affect the overall composite results of climate variables. (Yeh et al., 2009). We did not repeat this, but cited Yeh et al., (2009) in the current manuscript. We tested our results by using different indices, and could not find significant discrepancies of the composite results.

Specific Comments:
1. P8979 L20: "Mo (2010) reported that the ENSO influences…", here ENSO is used as an abbreviation determined in another report. It would be better to use the whole definition, El Niño-Southern Oscillation.

Response: We have corrected this in the revised manuscript.

2. P8981 L23: "available at

http://www.esrl.noaa.gov/psd/data/gridded/data.precl.html", I would prefer to refer it to another place, instead of leaving a whole URL in the tekst. Idem for P8981 L26: "available at http://apps.ecmwf.int/datasets/".

Response: We prefer to list the full URLs so that readers could easily know where to access the data.

3. Figure 3: I would recommend changing the colors. This is due to the fact that previous figure (Figure 2), is using the same color scale associating blue and red with high and low anomalies respectively. Therefore, these colors might cause some confusion. This corresponds to Figure 5 as well.

Response: The warm color-red and cold color-blue are distinctive to indicate the two types of El Niño. So we prefer to keep this color-map.

4. Figure 6 and 7: I assume the black marks on the figure correspond to the 0.05 significance of the MC test. It is very hard to see this though, perhaps show it in the legend.

Response: Yes, the dots indicate the results at those grid points pass the significance test. We added a sentence in the caption to clearly indicate this.

References

Balsamo, G., Albergel, C., Beljaars, A., Boussetta, S., Brun, E., Cloke, H., Dee, D., Dutra, E., Muñoz-Sabater, J., et al. (2015). ERA-Interim/Land: a global land surface reanalysis data set. *Hydrology and Earth System Sciences, 19*(1), 389-407.

Chiodo, G., and Haimberger, L. (2010). Interannual changes in mass consistent energy budgets from ERA-Interim and satellite data. *Journal of Geophysical Research: Atmospheres (1984–2012), 115*(D2).

Huang, Y., Salama, S., Krol, M., Velde, v. d. R., Hoekstra, A., Zhou, Y., and Su, Z. (2013). Analysis of long-term terrestrial water storage variations in the Yangtze River basin. *Hydrology and Earth System Sciences, 17*(5), 1985-2000.

Johannessen, O. M., and Ohmura, A. (2011). Accumulation over the Greenland Ice Sheet as represented in reanalysis data. *Advances in Atmospheric Sciences, 28*(5), 1030-1038.

Kao, H.-Y., and Yu, J.-Y. (2009). Contrasting eastern-Pacific and central-Pacific types of ENSO. *Journal of Climate, 22*(3), 615-632. doi: 10.1175/2008JCLI2309.1

Mo, K. C. (2010). Interdecadal modulation of the impact of ENSO on precipitation and temperature over the United States. *Journal of Climate, 23*(13), 3639-3656. doi: 10.1175/2010JCLI3553.1

Pfahl, S., Madonna, E., Boettcher, M., Joos, H., and Wernli, H. (2014). Warm conveyor belts in the ERA-Interim dataset (1979–2010). Part II: Moisture origin and relevance for precipitation. *Journal of Climate, 27*(1), 27-40.

Power, S., Delage, F., Chung, C., Kociuba, G., and Keay, K. (2013). Robust twenty-first-century projections of El [thinsp] Nino and related precipitation variability. *Nature, 502*(7472), 541-545. doi: 10.1038/nature12580

Romanou, A., Tselioudis, G., Zerefos, C., Clayson, C., Curry, J., and Andersson, A. (2010). Evaporation-precipitation variability over the Mediterranean and the Black Seas from satellite and reanalysis estimates. *Journal of Climate, 23*(19), 5268-5287.

Škerlak, B., Sprenger, M., and Wernli, H. (2014). A global climatology of stratosphere–troposphere exchange using the ERA-Interim data set from 1979 to 2011. *Atmos. Chem. Phys, 14*(2), 913-937.

Taylor, K. E., Stouffer, R. J., and Meehl, G. A. (2012). An overview of CMIP5 and the experiment design. *Bulletin of the American Meteorological Society, 93*(4), 485-498. doi: 10.1175/BAMS-D-11-00094.1

Trenberth, K. E. (1997). The definition of El Nino. *Bulletin of the American Meteorological Society*, *78*(12), 2771-2777. doi: 10.1175/1520-0477(1997)078<2771:TDOENO>2.0.CO;2

Tuinenburg, O., Hutjes, R., and Kabat, P. (2012). The fate of evaporated water from the Ganges basin. *Journal of Geophysical Research: Atmospheres (1984–2012)*, *117*(D1).

Uppala, S., Dee, D., Kobayashi, S., Berrisford, P., and Simmons, A. (2008). Towards a climate data assimilation system: status update of ERA-Interim. *ECMWF newsletter*, *115*(7), 12-18.

Van der Ent, R., and Savenije, H. (2011). Length and time scales of atmospheric moisture recycling. *Atmospheric Chemistry and Physics*, *11*(5), 1853-1863.

van der Ent, R. J., Savenije, H. H., Schaefli, B., and Steele-Dunne, S. C. (2010). Origin and fate of atmospheric moisture over continents. *Water Resources Research*, *46*(9).

Wilks, D. S. (2011). *Statistical methods in the atmospheric sciences* (3rd ed. Vol. 100): Academic press.

Yeh, S.-W., Kug, J.-S., Dewitte, B., Kwon, M.-H., Kirtman, B. P., and Jin, F.-F. (2009). El Niño in a changing climate. *Nature*, *461*(7263), 511-514. doi: 10.1038/nature08316

Yu, J. Y., and Kim, S. T. (2013). Identifying the types of major El Niño events since 1870. *International Journal of Climatology, 33*(8), 2105-2112. doi: 10.1002/joc.3575