Responses to Anonymou Referee #2' Comments

Dear reviewer,

We appreciate you for the helpful and inspiring comments. These comments are all valuable and helpful for revising and improving our paper, as well as the important guiding significance to our research. The following texts are our point-to-point responses, all comments are in black, and the replies are in red.

The authors investigated different impacts of two El Niño events on water quality over the Corn Belt region of US. The authors find that different El Niño events have different impact on TN and TP levels in the water on both annual and seasonal scales and these impacts are mainly driven by the changes of precipitation, as well as evaporation to a lesser extent. The manuscript is well written. The method of this study is solid and the results are well presented, providing new insights to the community. However, this paper needs some revisions before the acceptance for publication.

(1) The Corn Belt region is agricultural important. However, this is not clearly seen in the introduction section (Line 33-39). The authors need to added some sentences to describe why Corn Belt region needs your attention or why the water quality in this region is important, e.g., agriculture production/corn production, the fraction compared with the whole US. Besides, will a higher level of TN and TP in streamflow benefit agriculture or damage agriculture? These background information are missing, but imperative to the readers to highlight the importance of your study.

Reply: We have added background information on the Corn Belt region in the revised manuscript. Please also see below.

The Corn Belt is a very important area of the agricultural activity of the country, as 75% of the corn and 60% of the soybean produced in the U.S. are grown in the region (Thaler et al., 2021). The region's agricultural activities such as fertilizers contribute to the increase of nitrogen and phosphorus levels, which are responsible for the Gulf of Mexico hypoxic zone (Panagopoulos et al., 2014, 2015; Rabalais et al., 2007). The required nutrient reduction of the Corn Belt to decrease hypoxia is the highest among all regions in the Mississippi River Basin (Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, 2011). Hence, water quality changes in the Corn Belt region have been receiving considerable attention.

(2) Section 3.1.1 (1), a significance test is missing. Besides, why the results are shown in a table while for the results on seasonal scale (3.1.2 (1)) are displayed in bar plot? Maybe the authors should keep them consistent, all showing in bar plot. For the bar plot, an error bar should be added to show the spread.

Reply: We have removed Table 4 and re-plotted it as Fig. 2 in the revised manuscript. Figure 2 shows the detailed statistical information including the mean, median, 25th and 75th percentile, and the 10th and 90th percentile, of TN and TP at the outlets of the OTRB and UMRB during EP- and CP-El Niño years. To be consistent with the nutrients on the annual scale (Fig. 2), we also re-plotted Fig. 4 to replace the previous Fig. 3 in Section 3.1.2 on seasonal scales following the comment.

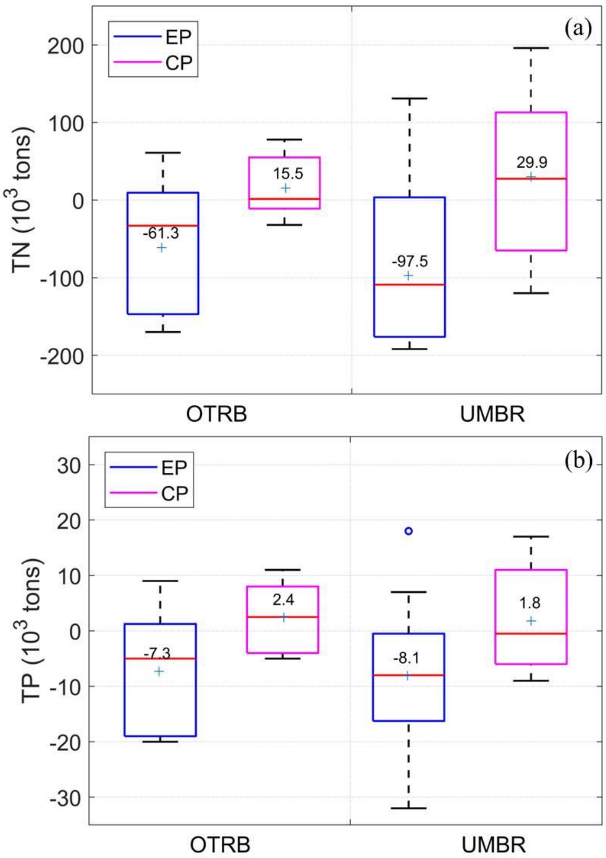

Figure 2. Box plots of annual (a) TN and (b) TP anomalies (unit: 10^3 tons) at the outlets of the OTRB and UMRB during EP-El Niño years and CP-El Niño years, respectively. The green plus (+), red solid horizontal line, box, and whisker ends indicate the mean, median, 25^{th} and 75^{th} percentile, and the 10^{th} and 90^{th} percentile, respectively. The data points outside the ranges are shown in hollow dots.

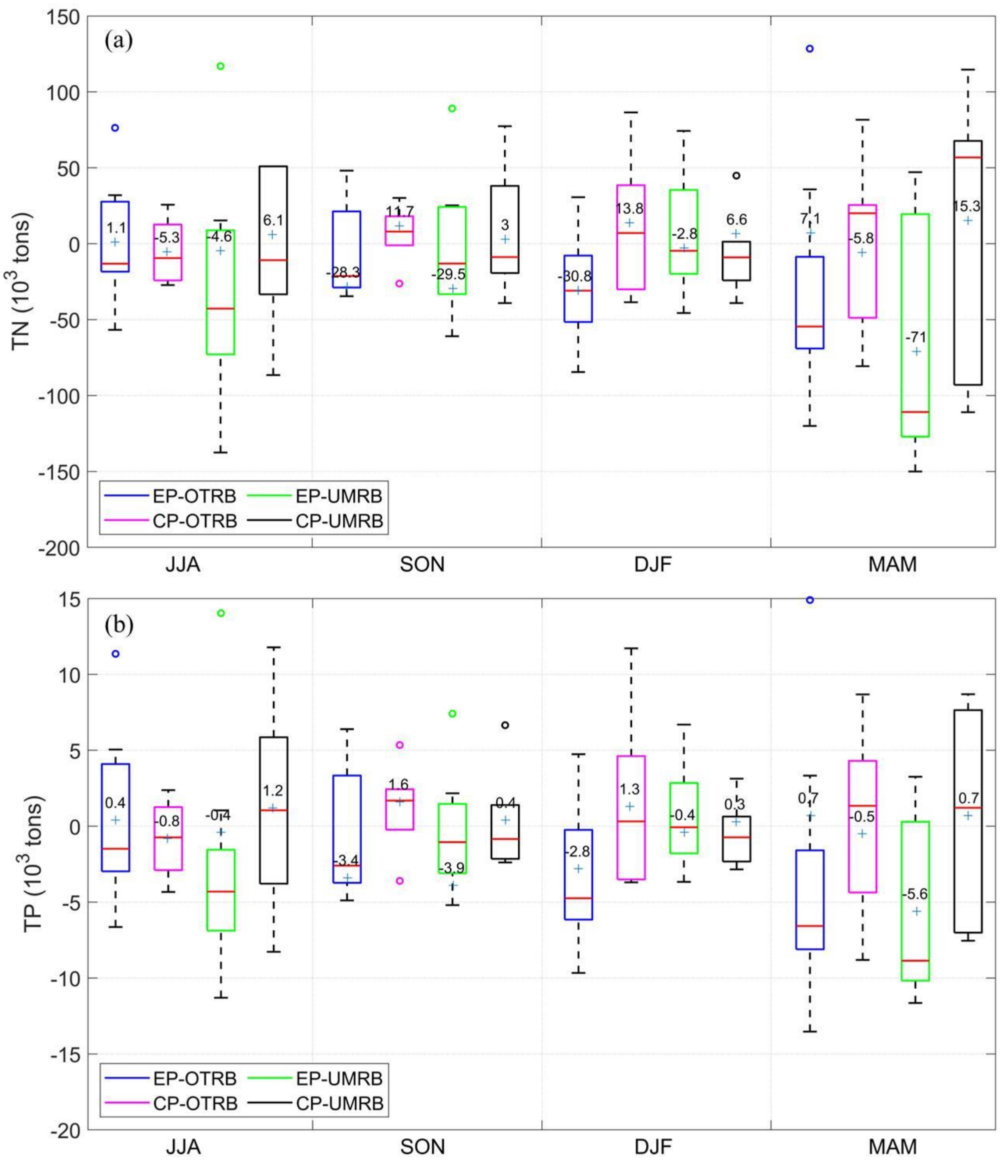

Figure 4. Same as Fig. 2 but for seasonal scales, i.e., summer (June-August, JJA), autumn (September-November, SON), winter (December of the current year and January and February of the following year, DJF), and spring (March-May, MAM).

(3) How the Monte Carlo test is performed in your study? This is also missing in the methods section.

Reply: Monte Carlo tests were performed following Mo (2010). We have added the details of the Monte Carlo test in Section 2.1 (Data). Please see below:

Composites of precipitation, temperature, runoff, evaporation, TN, or TP anomalies were formed based on randomly selected maps (Corn Belt Region) from the same types of El Niño years, respectively. The process was repeated 500 times. The statistical significance (p value) of the selected map can be determined from these 500 cases at each sub-basin. P values below 0.05 were considered significant, i.e., anomalies significantly different from zero at the 95% confidence level.

(4) More description of the model is needed. For example, what is the forcing data of the model? Does the forcing data include the two El Niño events? The resolution of the model?

Reply: The information on forcing data could be found in Section 2.1 (Data). Please see below:

The weather data (i.e., forcing data of the SWAT model), including precipitation and temperature, were obtained from 2,242 National Weather Service (NWS) stations in the study area. The forcing data included CP and EP-Niño events. Specifically, nine EP-El Niño events (1976–1977, 1979–1980, 1982–1983, 1986–1987, 1987–1988, 1991–1992, 1997–1998, 2006–2007, and 2015–2016) and six CP-El Niño events (1977–1978, 1990–1991, 1994–1995, 2002–2003, 2004–2005, and 2009–2010) occurred during the study period (1975–2016).

According to the comment, we also added more descriptions of the model, such as the spatial and temporal resolutions of the model in Section 2.2 (SWAT model description). Please see below:

In the SWAT model, a basin is partitioned into sub-basins, which are further divided into hydrological response units (HRUs). Runoff, sediment, and nutrient loads are simulated for each HRU and then aggregated for sub-basins. Thus, the spatial resolution of the model is measured by the number of HRUs and sub-basins. In total, the OTRB and UMRB included 152 and 131 sub-basins, respectively, and a total of 20,157 and 20,581 HRUs in the OTRB and UMRB. The model was calculated on a daily time scale and the results were analyzed on a monthly time scale.

(5) On seasonal scales, the authors find that the changes of nutrients level are stronger in spring and summer. However, El Niño is usually strongest during winter. Is there any explanation for this delay?

Reply: The explanation for stronger signals in spring and summer could be found in Section 4.1 as follows.

On seasonal scales, changes in nutrients' magnitudes were stronger in spring and summer, especially in UMRB. The heavy loading of nutrients was related to the agriculture activities during the growth period of crops in the Corn Belt. The major crops here are corn and soybean, which are often planted and fertilized in May and harvested in October (Chiang et al., 2014). Hence, the higher nutrient levels were likely associated with the removal of fertilizers from the soil during spring and summer.

(6) Line 327-328, in CP-ENYs, temperature decreased insignificantly, but evaporation increased significantly. Is there any explanation for this phenomenon, as by intuition, evaporation should decrease as temperature decreases.

Reply: The explanation for different patterns of evaporation and temperature could be found in Section 3.2.2 as follows:

Figure 7a showed that changes in evaporation did not share the same pattern with temperature change on the annual time scale. This might be due to the fact that temperature directly affected potential evapotranspiration (Neitsch et al., 2011), the ability of the atmosphere to remove water from the surface through both evaporation and transpiration; but the actual evaporation/evapotranspiration was also related to other variables such as the amount of water available for evaporation besides temperature.

(7) The authors identify that precipitation is the most crucial factor that influencing TP and TN concentration by controlling runoff. Does irrigation have an impact on runoff or nutrient level?

Reply: We agree with the reviewer that irrigation could impact runoff and thus nutrient levels; however, it is hard to quantify the exact effect of irrigation due to lack of the irrigation data over the Corn Belt. Existing documents suggest that vast acreages of corn and soybeans are watered by center pivot irrigation in the Corn Belt region, which uses an apparatus that sprays water across a field with a 75–90% efficiency, thus irrigation water mostly infiltrates into the soil (Grassini et al., 2011; 2014; Green et al., 2018). Precipitation likely plays a dominant role in runoff, we thus focus on the impact of precipitation on runoff and water quality in the study. We plan to test the results once detailed irrigation data are available. We have added the sentences in Section 4.5 (limitations and future work) following the comment.

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