Authors' response to RC3

Black text: Referee comment

Blue text: Authors' response

We greatly appreciate your recommendations for improving our manuscript. Our response and revision plans are provided below.

1. I think the representativeness of the statistical analysis should be placed in a better perspective and with clearer justifications. I am particular concern on how they attribute the correlations to the specific dominance of a driver. This requires a much in-depth elaboration throughout all the paper.

We admit that the description of statistical analysis in our previous manuscript is not clear enough, especially the dominance analysis method (Azen and Budescu (2003) (https://doi.org/10.1037/1082-989X.8.2.129)) that we applied to compare the relative importance of predictors in multiple regression. We will provide more detail of dominance analysis in a revised manuscript as follows:

"Stepwise multiple linear regression (Draper and Smith, 1998; Clow, 2010) is used to determine the significant (5% significance level assessed by an F-test) predictor variable in explaining NHD temporal variability for each grid cell. Next, the dominance analysis approach (Budescu, 1993; Azen and Budescu, 2003) is applied to compare the relative importance of those selected variables. The total variance among a set of predictors can be fully partitioned by dominance analysis even if the predictors are correlated (Vize et al., 2019). The issue of collinearity among predictors is addressed by examining the unique variance accounted for by the predictor across all possible regression sub-models involving the predictor. Dominance analysis is completed through an exhaustive set of pairwise comparisons among the predictors. The comparisons can be examined by three types of dominance: complete dominance, conditional dominance, and general dominance (Nimon & Oswald, 2013). To be completely dominant, a predictor must account for a greater amount of outcome variance than another predictor across every sub-model comparison. The conditional dominance of different predictors is conditional on what sub-model level is being examined. We applied the general dominance in this study, which is determined by taking the average amount of variance accounted for by a predictor across all sub-models and comparing it to other predictors. General dominance weights can be calculated for each predictor in a set and represent the relative proportion of R^2 attributable to a predictor."

2. I believe it is interesting to provide a global perspective, but I think the authors are in a position to provide more evidence at the regional scale. For instance, in Figure 3, they could select representative regions characterized by differentiated ecosystems and explain in more detailed the differences. At figure 3b, it is clear that the Amazonian basin has a contrast behavior in two areas that is also observed in Figure 7. Why? Could they please elaborate and provide more detail explanation supported by figures?

Thanks for pointing out such an interesting perspective that is worthy of further discussion. The Amazonian basin shows contrast behavior in two areas, which might be related to their different topography. In the part of the Amazonian basin where moisture deficit dominates elevated CO_2

in influencing the occurrence of hot extremes, topography is relatively flat. While in and to the south of the basin, topography is featured with mountain ranges and plateaus, where it is found elevated CO_2 is more important (Figure 7). In addition to this example, we will also discuss other representative regions characterized by different topographic and climatic patterns, in line with what the reviewer suggested based on ecosystems:

“In mountain ranges, for example, the Andes in South America, the Rockies in North America, and plateau sections such as the Brazilian Plateau and the Mongolian Plateau, interannual variability of root zone moisture is likely small due to steep topography, low energy input and temperature. In extreme dry regions, such as deserts in West Asia and North Africa (Sahara), root zone moisture is likely too small in volume to make significant impact on land surface energy partitioning. In those regions elevated CO_2 dominates moisture deficit in influencing the occurrence of hot extremes.

Areas where moisture deficit dominates elevated CO_2 in influencing the occurrence of hot extremes tend to be flat with thick soils, such as the North American Great Plain, the West Siberian plain and the North China Plain. Some moisture deficit dominant areas including India, Australia, South Africa, and the eastern tip of Brazil have one common characteristic that their interannual rainfall variability is high (Fatichi et al., 2012).” (see the figure shown below, Fig. 1 in https://doi.org/10.1175/JCLI-D-11-00356.1).

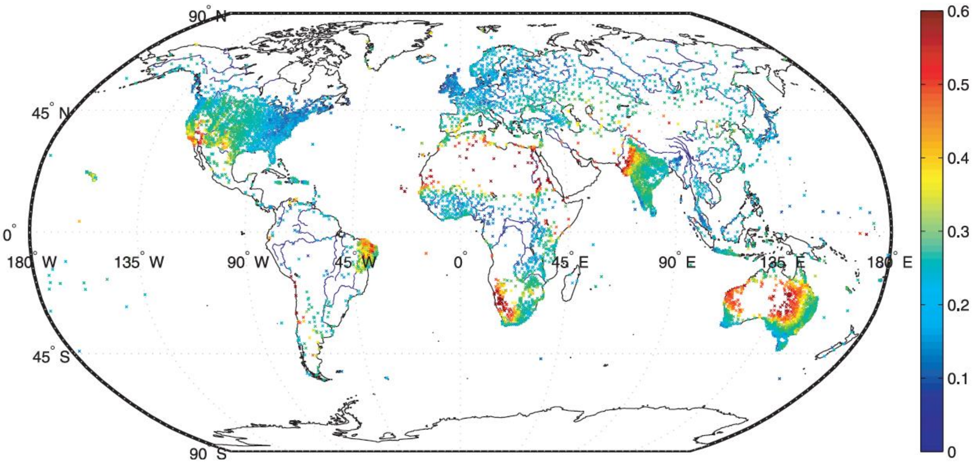
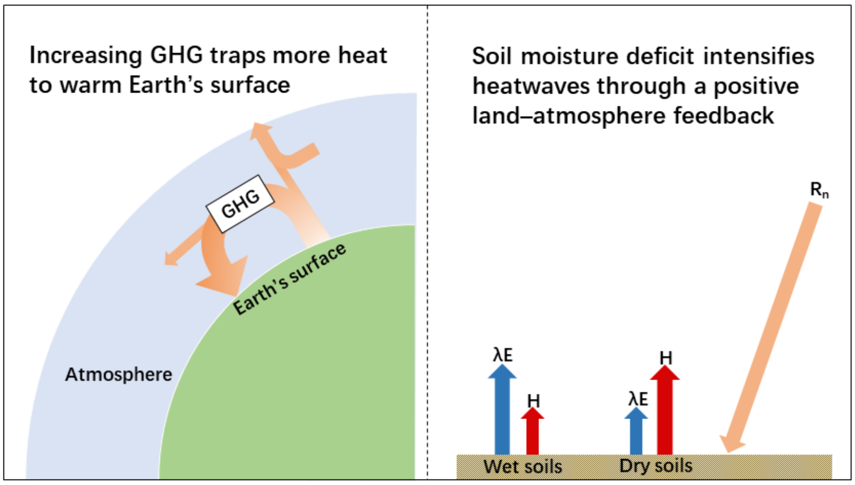


FIG. 1. The global map of C_v. Only stations with >50 yr of observations are included (n = 8197).

3. Closely connected to this, I miss more in-depth explanations on the causality of their effects. There are some attempts to explain a connection of feedbacks (lines 131-133), but in the majority of the results the reader is left out. In my opinion, at section 3.3 (I will call it discussion) the authors have an unique opportunity to provide some diagrams that show the feedback relations and the effects of the enhancement of CO2 or soil deficit in the hottest month.

Thanks for your suggestion, we will improve the discussion on causal relationship between hot extremes versus atmospheric CO_2 concentration and soil moisture by using a diagram with more detailed descriptions in the revised manuscript. As shown in the left panel of the diagram below, when infrared radiation is emitted by Earth’s surface, some is absorbed by greenhouse gas and re-emitted in all directions by the atmosphere. Consequently, increasing GHG warms the Earth’s surface and the lower atmosphere. As the major component of GHG, elevated CO_2 tends to increase the likelihood of hot day occurrence.

The physical connection between soil moisture and hot extremes has been explained in the article *Extreme heat rooted in dry soils*, (Alexander, 2011, doi:10.1038/ngeo1045). Local soil moisture conditions strongly influence partitioning of net radiation on the surface into sensible heat and latent heat (right panel in the diagram shown below). Since the heat source of near-surface air during daytime is directly from sensible heat flux, it is reasonable to expect an association between number of hot days and soil moisture. The negative correlation can reflect a causal relationship between hot extremes and soil moisture deficit, either way, but in the hottest month it is more likely to reflect the feedback of dry soil to the lower atmosphere. Based on the mechanism that low soil moisture availability reduces evaporative cooling and increases atmospheric heating from sensible heat flux (Alexander, 2011), Mueller and Seneviratne (2012) (doi: 10.1073/pnas.1204330109) used correlation between hot days in the hottest month and 3-month SPI (a proxy for soil moisture) as coupling diagnostic to identify hot spots at a global scale. Those hot spots agree well with transitional climate regions (Koster et al., 2004 (doi: 10.1126/science.1100217); Seneviratne et al, 2010 (doi: 10.1016/j.earscirev.2010.02.004)) where soil moisture strongly constrains evapotranspiration variability and thus result in feedbacks to the atmosphere.



Although we have discussed the causal relationship between hot extremes and soil moisture deficit in the previously submitted manuscript, both reviewers mentioned that it was not clear enough. We will improve the relevant explanation in next revision.

4. In my opinion, there is a driver that is missing in the discussion: the water vapour pressure deficit. What is the role played by this variable in enhancing the warming of the hot extremes? Could they calculate it also using their wavelet analysis and then relate it to their findings?

Yes, both VPD and soil moisture have effects on surface energy partitioning and thus near-surface temperature. We did not include VPD in this analysis because the effect of VPD is strongly nonlinear, and on the other hand, reduced soil moisture (most likely occur in warm season (hottest months)) is reported to weaken the influence of VPD on surface energy partitioning (doi:10.1029/2006JD007161). In addition, Liu at al., (2020) (doi:10.1038/s41467-020-18631-1) compared the relative role of soil moisture and VPD in limiting ecosystem production at the global scale and reported that dryness stress on ecosystem production is dominated by soil moisture. Therefore, we believe that the application of soil moisture alone can satisfy our study purpose.

We agree with you that discussion relevant to VPD is missing in our manuscript, we will modify it in the next revision.

5. The wording throughout the article is casual and not very exact. Would it be possible to identify the important ecosystems like the tropical rain forest, temperate or boreal forests instead of mentioning the continents (Africa, South America,...)?

We would like to explain that we describe the specific regions by continents follows the way that many previous studies used to identify hot spots of land-atmosphere coupling (e. g., doi/10.1175/JHM510.1; doi/10.1016/j.earscirev.2010.02.004; doi/10.1029/2010GL042764). We are pleased to adopt your suggestion to discuss representative regions characterized by different topographic and climatic patterns in the revised manuscript. The details are provided in our reply to your comment 2 above.

6. Figure 8 at section 3.3 appears out of the blue. In my opinion, it needs to be removed or much better embedded. As an alternative, un my opinion preferable, the extra space should be addressed to a more in-depth explanation of the cause-effects dominance of either enhanced CO2 or soil moisture deficit on the hot extremes.

We will follow your suggestion to remove Figure 8. In the next revision, we will add more explanation on the causality of effects of elevated CO_2 and soil moisture deficit on hot extremes, such explanation has been shown in our reply to your comment 3 above.