Reply to reviewer #1

Thank you very much for your helpful comments. Based on your comments, we have improved the manuscript.

The title of the study is confusing. Is it about historical and future anthropogenic warming effects on the year 2015? — could future anthropogenic warming have an impact on a past year?

Based on the advice of the other reviewers, we changed the title to “Historical and future anthropogenic warming effects on droughts, fires and fire emissions of CO2 and PM2.5 in equatorial Asia when 2015-like El Niño events occur”. We investigated the historical anthropogenic warming effects on the 2015 event and also assessed how future warming can affect droughts, fire and emissions when 2015-like El Niño events occur in 1.5, 2.0 and 3.0 degree Celsius warmed climates. [lines 16-22, 59-95 and section 3].

Equally confusing is the abstract. For instance, “we suggest that historical anthropogenic warming increased the chances of meteorological droughts exceeding the 2015 observations in the EA area : : :..” (line 15-29). What does it mean exactly? Which period are those claims referring to?

Please note that we compare factual condition simulations (Hist) and counterfactual natural forcing condition simulations (Nat). In both ensembles, the SST is prescribed as that the 2015-like El Niño occurs. In the Nat ensembles, anthropogenic warming from the preindustrial to the present is removed from the SST data. By comparing these two large-member ensembles, we suggest that historical anthropogenic warming increased the probability of meteorological droughts exceeding a given threshold when the 2015 El Niño event occurred. [lines 16-18, 59-78, 146-159]

The abstract lacks fundamental clarity, so does the paper. It seems to me that the authors have not sorted out a coherent logic chain to tell a concrete story. Instead, the paper presents a series of model results without a clear rationale to make sense of it. Last but not least, several figures of this paper have been documented by previous studies as cited in the paper (in slight variations); I do not see added value from the duplication. Therefore, I recommend rejecting this paper in its current form.

Our explanations were not enough in the original manuscript. Therefore we have added many explanations of the experimental designs and our logics as mentioned below. We hope that these explanations help the reviewers and readers to better understand our results.

For example, in lines 59-78, we explain the probabilistic event attribution approach as follows: "Although Lestari et al. (2014) showed the anthropogenic effects on the *historical trends in droughts,* it is not clear how historical climate changes affected the *particular drought event of 2015.* Because extreme events can occur by natural variability alone, it is difficult in principle to attribute a particular event to anthropogenic climate change. However, comparisons of observations and large ensemble simulations can help us evaluate the degree to which human influence has affected the probability of a particular event (Allen 2003). Such an approach is called probabilistic event attribution (PEA) (Pall et al. 2011, Shiogama et al. 2013). In the PEA approach, two large ensemble simulations (e.g., 100 members) are generally performed. The first is historical simulations of an AGCM driven by the historical values of anthropogenic (e.g., greenhouse gases) and natural forcing (solar and volcanic activities) agents and by the observed sea surface temperature (SST) and sea ice concentration (SIC). The second is counterfactual natural runs driven by preindustrial anthropogenic and historical natural forcing agents and by the observed values of SST and SIC cooled according to estimates of anthropogenic warming (Stone et al. 2019) (see section 3 for more details). Note that the components of interannual variations in the SST data are not modified in the natural forcing ensemble. Therefore, for example, we can assess how anthropogenic warming affected the probabilities of drought events exceeding the observed value in the 2015 major El Niño year by comparing the distributions of members in historical and natural forcing ensembles. In this study, based on the PEA approach, we examine whether historical climate changes increased not only the probabilities of drought but also those of fire and fire emissions of CO_2 and $PM_{2.5}$ during the June-November dry season of 2015. Because the 10 member ensembles of Lestari et al. (2014) are too small to estimate probabilities of extreme events, we use 100 member ensembles of Shiogama et al. (2014). The lower computing costs of AGCM than AOGCM enable us to perform large ensembles, which are necessary for PEA."

In lines 79-95 we explain our future experiments and their relationships to the Paris Agreement goals and the emission gaps as follows: "Although Lestari et al. (2014) and Yin et al. (2016) showed increases in droughts and fires in the future projection ensembles of AOGCMs, it is not clear how future anthropogenic warming affects droughts and fire when events like the 2015 El Niño occur in a future warmer climate. It is important to investigate changes in extreme events at 1.5ºC and 2.0ºC warming levels to inform stakeholders after that the Paris Agreement set the 2°C long-term climate stabilization goal and moreover state pursuing 1.5 °C for stabilization (United

Nations Framework Convention on Climate Change 2015), but Lestari et al. (2014) and Yin et al. (2016) did not perform such analyses. In this study, we examine how the probabilities of drought, fire and fire emissions of CO_2 and $PM_{2.5}$ would change when major El Niño events like 2015 occur under 1.5ºC and 2.0ºC warmed climates. We analyse large (100-member) ensembles of the MIROC5 AGCM under the Half a degree Additional warming, Prognosis and Projected Impacts (HAPPI) project, which was initiated in response to the Paris agreement (Mitchell et al., 2016, 2017, 2018; Shiogama et al., 2019). These MIROC5 HAPPI ensembles have been used, for example, to study the changes in extreme hot days (Wehner et al., 2018), extreme heat-related mortality (Mitchell et al., 2018), tropical rainy season length (Saeed et al., 2018) and global drought (Liu et al., 2018) at 1.5ºC and 2.0ºC global warming. There is a significant "emissions gap", which is the gap between where we are likely to be and where we need to be (United Nations Environment Programme 2018). The current mitigation policies of nations would lead to global warming of approximately 3.2°C (with a range of 2.9-3.4°C) by 2100 (United Nations Environment Programme 2018). Therefore, it is worthwhile to compare changes in extreme events and impacts in cases where the 1.5ºC and 2.0ºC goals are achieved or not. Therefore, we perform and analyse a large ensemble of a 3.0ºC warmed climate."

It seems that you believe that Fig. 2 is a duplication. We do not insist to say Fig. 2 is a new result [lines 126-128]. Our main aims are that we combine those empirical functions (not new) with the large ensemble simulations of droughts to assess the climate change effects on fire and emissions when 2015-like El Nino events occur at the warming levels of the present, the Paris agreement goals and the current mitigation trajectory (new results).

Please see a few technical issues below (not an exhaustive list):
Line 47: "this study has three aims." What is its relevance given the studies mentioned in the previous paragraph?

We explain the relationships between the previous studies (Lestari et al. 2014 and Yin et al. 2016) and this study in lines 59-95 and 263-266.

Line 48: A higher-level introduction of the "probabilistic event attribution approach" is necessary for the readers to understand the concept. While technical details could refer to published papers, the general principle should be properly introduced.

We introduce further details of the "probabilistic event attribution approach" in lines 59-78 and 146-159.

Line 55-56: On what temporal horizon? This point is not clear at all. After reading the entire paper, it appears to me that the warming scenarios (1.5, 2.0, or 3.0 C) is defined regarding the reference year 2100. However, the simulated results in 2015 are discussed. This setting is problematic since the emission changes in each scenario are not linear across the century, what does it mean when comparing the first few years? The starting and ending point of the simulations are not clearly stated. The use of those simulations is not adequately justified.

We added SST anomalies of 1.5, 2.0, or 3.0 °C warmer climate (relative to the preindustrial) scenarios at the end of the 21st century taken from the RCP experiments of the CMIP5 AOGCMs for the observed 2006-2016 SST (HaISST) data. By using these experiments, we can investigate changes in droughts and fires when 2015-like El Nino events occur at the given future warmed levels, such as the 1.5°C and 2.0°C goals of the Paris Agreement. The computing cost of AGCM is lower than AOGCMs, which enables us to perform large ensembles (100 members for each experiment) that are necessary to estimate changes in the probabilities of extreme events. Please see lines 79-95 and 160-188 for more details.

Line 64: It will be helpful to state clearly how many ensemble members for each scenario, covering which period, based on what emission trajectory.

We state the ensemble numbers (100 for each experiment), period (11 or 10 years) and emission scenarios in section 3.

Line 77: “Although socio-economic factors are important for fire activities, we only examine the effects of climate change in this study.” “climate change” here refers to simulated climate given different forcing scenarios, which by definition accounts for socio-economic factors. Maybe, the authors are referring to local land-use change impact? It is important to make those distinctions to make sense of the results.

We rewrote the sentence to “Although conversions of forest and peatlands to agriculture and plantations of oil palm are also important factors for fire activities (Marlier et al., 2013, 2015; Kim et al., 2015), we do not examine the effects of land use change in this study. ” [lines 104-105]

Section 2. Compared to the papers cited here, I do not see any new contribution from this section. It just shows what has been done, without any new data or insight.

Our main results are that we combine those empirical functions with the estimated probability functions of droughts based on the large ensembles to assess the historical and future warming effects on the probabilities of fire and emissions. We do not say that section 2 presents new results, but we do show the empirical functions here in order to use them in the following sections. [lines 114-129 and 215-221]

Line 118: "Please note that both the Hist and Nat ensembles have the same spatial SST patterns as the 2015 El NinÌCˇ o event". How so?

Please see lines 146-159 for the details regarding the experimental design.

Line 124: If the simulation periods are 2006-2015, how come are they future simulations???

As mentioned above, we simulated extreme events when 2015-like El Nino events occur in the given future warming levels. [lines 18-22, 79-95 and 160-188]

Line 136: Why is showing sea ice (Fig. 5) relevant to this study? Similarly, it is not clear about the role of results showing in Figure 4 to Figure 7.

This is the second paper in which the 3°C runs of the HAPPI project have been performed. Although the first paper (Lo et al. 2019, using the different AGCM) briefly described the experimental design, it could not show the SST and ice patterns due to the limited space of paper. Therefore, we wanted to show the SST and sea ice patterns in Figs. 4-5 of the original manuscript. However, it is not necessary to include these figures in the main text. We have moved those to the supplementary material (Supplementary Figs. 2-4).

Figures 6 and 7 of the original manuscript (Figs. 4-5 of the current manuscript) are necessary in the main text to explain that the differences in the described SST between Niño 3.4 and the 30°S-30°N ocean clearly affect the vertical motion and precipitation anomalies in the EA region. Fig. 7 (Fig. 5 of the current version) is used to investigate why the precipitation anomalies of 1.5°C are slightly larger than those of 2.0°C. [lines 195-203]

Line 169: Are you comparing fire and fossil fuel emissions from Japan? Not clear.

We included this comparison because it was highlighted that the fire emissions of EA exceeded the fossil fuel emissions from Japan when the massive 2015 fire event occurred (e.g., Field et al. 2016). However, readers other than Japanese readers may be not interested in this comparison. Therefore, we have omitted this paragraph.

Line 192-194: By now, it is still difficult to understand what do they mean.
Line 192-212: The conclusion is far reached.
We hope that the additional explanations of the probabilistic event attribution approach and the experimental design mentioned above help you to understand our results and why we have reached these conclusions.

Line 197: “somewhat”?
We rephrased “somewhat” to “tended to increase” [line 259].