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Biogeosciences
Discussions

Interactive comment on "The impacts of recent drought and fire in lowland Bolivia on forest loss and regional smoke emissions" *by* Joshua P. Heyer et al.

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Dear reviewer,

Thank you for your comments and suggestions (Referee #3 comment). They have been shared with the coauthors, and will be considered in the updated manuscript. Below you will find responses to your comments, with the changes that will be made in the updated manuscript. Once again, we thank you for the useful comments that will help improve our manuscript.

Referee #3 comment: The authors use several data sources to study the controlling

factors on interannual fire variability in lowland Bolivia considering in their analyses protected (Noel Kempff Mercado National Park) and unprotected areas as well as different biomes and vegetation types. However, the vegetation types are poorly described just using MODIS land cover data without any ecological background. For example, what kind of deciduous needleleaf forest occur in this part of the Amazon forest which is dominated by angiosperms? It is not clear to which kind of wetlands the authors refer to. While in the text wetlands are characterized as seasonally-flooded types they are indicated as permanently flooded in figures 1, 4, and 5.

RESPONSE: The reviewer is correct. The Amazon is comprised and dominated by angiosperms. The inclusion of needleleaf forest was an error in the text and in the legend in Figs 4 and 5. To determine if there are deciduous needleleaf forest in lowland Bolivia a query search for the landcover classification was performed. The land cover type was not found. Therefore, needleleaf forest has been removed from the legends and in-text.

According to Gosling et al. (2005) and Junk et al., (2011), wetlands in the riparian corridors of Noel Kempff Mercado National Park are seasonally flooded savannas. The legend is mislabeled in Figures 1, 4 and 5. The figure labels will be changed from "permanently flooded" to "seasonally flooded" to more accurately represent the land cover type. We will also review/include the Junk et al. (2011) paper on wetlands in the southern Amazon in the updated manuscript.

Referee #3 comment: I miss a discussion on the main triggers causing the severe droughts in the Amazon. Reduced rainfall, higher-than-normal temperatures, and reduced atmospheric moisture during the wet and dry seasons are mainly caused by sea surface temperature anomalies in the tropical Atlantic and the Equatorial Pacific. This should be addressed in the discussion citing relevant literature.

RESPONSE: Sea-surface temperature anomalies in the tropical Atlantic and Equatorial Pacific were mentioned in original manuscript drafts. However, to conserve word

count, and to focus our paper on smaller-spatial scale climate forcing, we omitted discussions on sea-surface temperature anomalies in this manuscript version. In the updated manuscript, we will include discussions on sea-surface temperature anomalies with relevant literature cited.

Referee #3 comment: Recently, some papers discuss the vulnerability of different intact forest ecosystems (floodplains and non flooded forests) to wildfires in the Amazon (i.e., Flores et al. 2017 and studies cited in this paper), which also should be addressed in the discussion of the observed results. In many studies the spatial patterns of annual maximum cumulative water deficit (MCWD) during severe droughts are used to explain the consequent enhancement of active fire incidence. MCWD is a useful indicator of meteorologically induced water stress without taking into account local soil conditions and plant adaptations, which are poorly understood in Amazonia. Why did the authors not use this proxy to relate fire occurrence in the study region?

RESPONSE: The MWD can be used for the reasons mentioned by the reviewer, and has been used to study fire and drought in the Amazon (e.g., Aragão et al., 2007). Using the MWD, a link has been identified between rainfall anomalies, drought and fire in the Amazon. While soil conditions and plant adaptations are poorly understood, and we could have used the MWD, our study used the drought code (DC) to better understand how net drying of deep fuels impact fire in the southwestern Amazon. Lower DC values were observed during the wet season and higher DC values during the dry season, consistent with other studies (Field et al., 2015). We use the DC as an indicator of antecedent dry (wet) conditions during the wet and dry seasons, which influence high (low) DC values during the following fire season from August–October in lowland Bolivia. Other indices and metrics could have been used. However, the DC used in our study captured the relationship between drought and fire in lowland Bolivia. Further, the DC was calculated from raw MERRA2 precipitation estimates and MERRA2 rain gauge corrected data to address uncertainties in our analyses.

Referee #3 comment: The authors do not discuss the relationship between heavy

smoke from forest fires in the Amazon and the regional precipitation regime. Andreae et al. (2004), for instance, observed that smokes from wildfires in the Amazon result into a reduced cloud droplet size causing a delay of the onset of precipitation. Pyro-clouds cause a suppression of low-level rainout and aerosol washout and allows the transport of water and smoke to upper levels causing intense thunderstorms. These clouds, attaining the stratosphere, have profound radiative impacts on the climate system (see also Koren et al. 2008).

RESPONSE: We will mention the impacts of smoke on regional precipitation in the Amazon in the updated manuscript were appropriate (e.g., section 4.3). Results from Andreae et al. (2004) are very interesting, and certainly are relevant to our work. Thank you for mentioning this research to us.

Minor concerns:

Referee #3 comment: L. 19-20: I think it is the other way round: Bext visibility data are linked to the interannual Drought Code (DC), as the emission of aerosols is a consequence of anthropogenic fires favoured by droughts.

RESPONSE: While we acknowledge the importance of anthropogenic fire and drought in our paper, we do not specifically measure anthropogenic ignitions. While other research has certainly shown your point above to be true, we simply are reporting our results. Our results identified a link between drought and fire, and between drought and visibility. We do several times mention the importance of anthropogenic fires in lowland Bolivia and cite relevant literature.

Referee #3 comment: Please indicate the meaning of Bext the first time you indicate it.

RESPONSE: An explanation of the Bext is included section 2.2. of Methods and Data.

Referee #3 comment: L. 37-39: Recently deforestation rates increased again in the Brazilian Amazon, particularly in the Southern Amazon region.

RESPONSE: We will include a sentence or two regarding the current state of defor-

estation in the southern Amazon in the updated manuscript. From reading the short letter from Fearnside (2017), it seems that economic forcing plays a significant role in deforestation and fire in the region. The first introductory paragraph was modified to reflect this. Fearnside, P. (2017). Business as usual: a resurgence of deforestation in the Brazilian Amazon. Yale Environ, 360.

Referee #3 comment: L. 40-42: The authors should also refer to the severe drought in 2010 (Lewis et al. 2010, Aragão et al. 2018) which had much broader impacts in the Southern Amazon than the drought of 2005 which was spatially restricted to the SW-Amazon.

RESPONSE: We will discuss the importance of the 2010 drought and cite relevant literature (e.g., Lewis et al. 2010) in the updated manuscript.

Referee #3 comment: L. 90/91: The Amazon is dominated by angiosperms. What kind of deciduous needle-leaf forest are those?

RESPONSE: The deciduous needle-leaf forests are not present in our area of analyses, and will be removed from the legends for Figures 4 and 5.

Referee #3 comment: L. 92/93: This sentence has a contradiction as the authors mention seasonally inundated wetlands and refer to permanent wetland types. See the paper of Junk et al.(2011) on the classification of Amazonian wetlands and provide a better description of these ecosystems in the studied region.

RESPONSE: The Junk et al. (2011) description of hydromorphic climate savannas found in lowland Bolivia will be included in the updated manuscript.

Referee #3 comment: L. 229: For my knowledge the year of 2005, not 2004, was a severe drought year affecting this particular region (Lewis et al. 2010, Aragão et al. 2018). The year of 2007 was an El Niño Year, in 2010 El Niño and especially increased SST anomalies in the Northern Atlantic caused the severe drought in the Southern Amazon basin.

RESPONSE: The year 2005 was the severe drought year mentioned by Chen et al. (2013b). L. 229 was changed from 2004 to 2005. However, our results (fig 3 I,j) suggest that 2004 was a significant drought year as well for lowland Bolivia.

Referee #3 comment: L. 311: It is not clear whether fire season length from 1979–1996 decreased, or didn't change in lowland Bolivia. Are these observation based on different studies? However, only one study is cited (Jolly et al., 2015).

RESPONSE: This information is from Figure 3b from Jolly et al. (2015). The sentences below have been changed for clarity. Fire season length decreased or did not change in lowland Bolivia from 1996–2013, compared to fire season length from 1979 – 1996 (Jolly et al., 2015). However, from 1996–2013, fire season length increased in the Brazilian Amazon north and east of lowland Bolivia, compared to fire season length from 1979 – 1996 (Jolly et al., 2015).

Referee #3 comment: L. 328-330: Recent incentives and policies implemented in Brazil (revisions of its Forest Code) led to an increase of deforestation rates in recent years. Please specify the incentives and policies.

RESPONSE: This section was modified to discuss recent deforestation in the southern Amazon. Soares-Filho et al., 2014 Nepstad et al., 2014 Fearnside, P. (2017). Business as usual: a resurgence of deforestation in the Brazilian Amazon. Yale Environ, 360.

Referee #3 comment: The scales of figures 4 c,d are difficult to read.

RESPONSE: The scales are small, but clear if "zoomed in" to read them. If the scales were larger, they would interfere with the other graphics in the figures.

Referee #3 comment: Corrections: L. 125, 152, 154, 157, 174: Units should be consistently written in the exponential form (e.g., mm day–1)

RESPONSE: Corrections will be made in the updated manuscript.

Referee #3 comment: L. 317: Insert "of" between "impacts" and "drought conditions".

RESPONSE: Corrections will be made in the updated manuscript.

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