

Interactive comment on “Aerosol-induced high precipitation events near the Himalayan foothills” by Goutam Choudhury et al.

Goutam Choudhury et al.

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1. L 21- you mention "net orographic precipitation". Is it any different from "orographic precipitation"? Is there something that's missing?

Reply: We apologize for the confusion. By net orographic precipitation we mean the total precipitation over the orography (leeward side + windward side). We have removed the word "net" in the revised version.

2. Is there any specific reason for selecting the MSE values only for lower levels? The proper reason should be described in the manuscript. Why not mid or upper levels? Do they also show similar pattern of variation as lower level MSE?

Reply: As suggested by Fan et al. (2015), the moist static energy gets accumulated

in the lower levels following AEI mechanism. That is why we have shown the low level MSE composites. Nevertheless, we have also checked for mid and upper level MSE composites but could not find such pattern. We have modified the lines 26 - 29 in the Introduction Section as follows. "First, the suppression of convection in the urban polluted basin by absorbing aerosols during daytime reduces the consumption of low-level Moist Static Energy (MSE). Second, during nighttime, this accumulated low-level MSE is transferred towards the mountains downwind where the now more humid air mass undergoes orographic lifting which results in anomalously high precipitation over the mountains."

3. L 121-122- you explain that there is a hint towards a connection between the aerosol accumulation and increase in lower level MSE within and around the domain because of AEI effect. A comment on the cause of this connection after this point will help in better understanding.

Reply: We agree with the reviewer. We have modified the lines 126 - 129 of the manuscript as follows. "The presence of absorbing aerosols within the BLH may have warmed the lower atmosphere increasing the low level stability and suppressing the convection during the day time, thus preventing the consumption of MSE. This may have resulted in accumulation of MSE in the lower levels as seen in Figure 2."

4. First you show that AOD and MSE have similar pattern of variations and have statistically significant correlation. Then you try to verify it meteorologically by analyzing BLH, CAPE, OLR, and precipitation pattern. Why do you bring CAPE into picture? Is CAPE related to the aerosols in such scenarios? Is there any feedback process involved? Please include proper explanation in the manuscript.

Reply: We apologize for the confusion here. The absorbing aerosol present within the boundary layer may result in warming the low atmosphere and thus create a temperature difference between low and mid atmosphere – an increase in CAPE. We have added the following explanation along with three references in the manuscript in lines

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"The presence of absorbing aerosols within the planetary boundary layer may result in an increase in temperature in the lower atmosphere. This can result in higher CAPE values above the convection condensation level (Wang et al., 2013; Sarangi et al., 2015; Li et al., 2017). Please note that many recent studies have highlighted that Aerosol Invigoration effect (Rosenfeld et al., 2008; Fan et al., 2018) is a relevant phenomenon over this region during monsoons (Sarangi et al., 2017, 2018). Aerosol-induced microphysical changes (like smaller cloud droplets) cause the droplets to move higher up in the atmosphere instead of falling down as rain. As such, the ratio of ice to liquid water content in the clouds increase in such invigorated clouds. A higher CAPE (induced due to the aerosol radiative effect) can further add to the cloud invigoration and lead to more ice formation, and thus higher rain rate eventually. Moreover, higher CAPE anomalies on the severe event days in the presence of higher AOD values are representing the possibility of a severe event as the convection grows for a longer time with more accumulation of MSE, CAPE and AOD, going to a positive feedback cycle."

5. The main inference from this study is that the aerosols enhance the "instability" and moisture supply providing the extra energy for extreme precipitation events over the Himalayan Foothills, downwind of polluted IGP. However, the title of this manuscript is "Aerosol-induced high precipitation events near the Himalayan foothills". The word "induced" can be misleading. Please change it to "enhanced" or something similar.

Reply: We agree with the reviewer on this and have changed the title to "Aerosol-enhanced high precipitation events near the Himalayan foothills"

6. The conclusion is missing an overall explanation of AEI mechanism in context of the high precipitation events over the Himalayan region. The second point (L 182-184) describes it in very short, but it needs to be explained properly.

Reply: We agree with the reviewer. We have elaborated the second point in the conclusion of the revised manuscript as follows. "Spatio-temporal pattern of low-level MSE

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coincides with that of the AOD for the selected events. It may be a result of the warming effect of aerosols in the lower atmosphere which increases (decreases) the stability in the lower (mid) levels. This mechanism is further supported by the occurrence of negative BLH anomaly and high positive CAPE values within the selected domain. This indicates that the aerosols can have a substantial impact in increasing the magnitude of the orographic precipitation by AECl effect."

7. L 195- Please include a reference of Figure S1 of the supplementary.

Reply: We thank the reviewer for pointing this out. We have included the reference in the revised manuscript.

Minor Comments: 1. The work by Fan et al. (2015) is the base of your present work on the Himalayan Foothills. However, the results from Fan et al. (2015) were based on modelling studies and it should be mentioned in the introduction when you discuss about AECl mechanism in L22.

Reply: We thank the reviewer for pointing this out. We have modified this in the introduction Section in the line 23 as follows. "The modelling results of Fan et al. (2015) show that absorbing aerosols from the polluted Sichuan Basin by virtue of ARI can increase the magnitude of high precipitation over mountainous regions downwind through aerosol-enhanced conditional instability (AECl)."

2. L 57- "Section 3 discuss" to "Section 3 discusses"

3. L 63- the domain is "inspired from" to "inspired by"

4. L 70- "toMODIS" to "to MODIS"

5. L 94- "underestimation" to "the underestimation"

6. L 129- "general" to "general,"

7. L 138- "radiative" to "the radiative"

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8. L 158- "ample" to "an ample" & "HP event" to "the HP event"

9. L 166- "cell" to "cells"

10. L 167- "large amount" to "huge amount"

11. L 189- "vicinity of the domain (IGP)" to "vicinity (IGP) of the domain"

Reply to 2-11: We are very thankful to the reviewer for pointing these minor grammatical errors in the manuscript. We have modified all of them in the revised one.

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