

## ***Interactive comment on “Spatio-temporal variability and light absorption property of carbonaceous aerosol in a typical glacierization region of the Tibetan Plateau” by Hewen Niu et al.***

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Received and published: 8 February 2018

### RC 2 Anonymous Referee #1

Comments to the Author This manuscript presented a topic with spatial and temporal variability and light absorption property of carbonaceous aerosols (OC and BC) in a typical glacierization region of Tibetan plateau. However, there are several key issues that authors should address and enhance/clarify (see below):

(a) The annual mean OC/BC ratio was found to be highest in the monsoon season and lowest in winter. The author needs to mention, which types of photochemical reactions

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are involved that increased OC/BC ratio. Generally, photochemical reaction changing their physical and chemical properties from the original molecule of the substance. When this occurs, these molecules tend to form a new structure, or combine with each other or other molecules. This may change the state of OC or BC or OC/BC ratios.

Response: Following the great suggestion, we have added a discussion to the manuscript as follows. “The aging process of BC (or soot) resulting from photochemical oxidation by molecular O<sub>2</sub> and the photooxidation of OC (Han et al., 2012) were likely involved and increased OC/BC ratio. Photochemical reaction can change their physical and chemical properties from the original molecule of the substance (alkyne C-H ( $\equiv$ C-H) and aromatic C-H (Ar-H)) (Kirchner et al., 2000; Cain et al., 2010). When this occurs, these molecules tend to form a new structure by combining with each other or with other molecules (carbonyl C=O and ether C-O) (Daly and Horn, 2009; Cain et al., 2010; Nieto-Gligorovski et al., 2008), which may change the state of OC, BC or OC/BC ratios. The photochemical oxidation by O<sub>2</sub> under sunlight is an important aging process for BC (Han et al., 2012).”

(b) Author mentioned that tourism activities in monsoon season were attributed to relatively high OC/BC ratios in Mt. Yulong region, especially in GHZ basin. Firstly, author did not define tourism activities in whole manuscript. Second, how do author think “tourism activities” term used for vehicles or buses emission. Please explain in scientific literature that indicates tourism related activities contributed to OC, BC emissions with reference to justify the statement.

Response: Following the suggestion, we have now explained a little more about how the tourism related activities contributed to OC, BC emissions along with some references (i.e. Borrego et al., 2000; Cong et al., 2015a; Shi et al., 2017). Below is the revised text: “. . .The seasonal variation of carbonaceous aerosols found in the GHZ basin was different from that found in Mt. Yulong. It is likely related to the distinct elevation difference (nearly 1,500 m) and different amount of local human activities (here mainly referring to tourism related activities) between the Mt. Yulong and the GHZ

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sampling sites. The GHZ site location is close to a parking lot for private vehicles and touring buses and a visitor service center that involves food cooking. These tourism activities can contribute to local emissions of carbonaceous aerosols and precursor gases for SOC (Borrego et al., 2000; Cong et al., 2015a; Shi et al., 2017). However, we don't have direct observational evidence to support this."

(c) In the result and discussion part "human activities" creating difference in Mt. Yulong and GHZ basin. This is a major observation indicated by author, but there is no concrete evidence available to support the results particularly what types of human activities?

Response: Human activities in our manuscript mainly refer to local tourism related activities, including the use vehicles and food cooking near the sampling site. This has been clarified in the text. Please also refer to our response to the comment (b) for more details added to the revised manuscript.

(d) Comments: Authors stated that "A large amount of biomass burning emissions in the high atmosphere (around 5000 m asl) in Mt. Yulong were probably long range transported from source regions". This observation is supported by the higher BC concentration than OC especially during monsoon season to post monsoon season. How do authors assume this observation without performing Trajectory analysis with HYSPLIT model? In order to find the transport of pollutant emission from biomass burning, author needs to perform trajectory analysis during the study period to support the results for Dec. 014 and Dec. 2016.

Response: Following the suggestion, we performed trajectory analysis with the HYSPLIT model. From the monsoon season to post monsoon season, the trajectory of air mass reaching the sampling location changed much. In the monsoon season, the air mass (and pollutants) mainly originated from southwest and southeast monsoons, while in the post monsoon season it mainly came from the west. However, we still cannot verify the source type. In response to similar comments from RC1, we have

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revised the text and removed the unverified statements.

Fig. 7 Seven-day backward trajectory analysis with HYSPLIT model (a) in the monsoon and (b) post monsoon seasons during the study period (Source at 27.01 N, 100.20 E). The trajectories of air mass in the plot were the average of a few episodes. The two heights are the elevation of Mt. Yulong and GHZ, respectively.

(e) Authors selected experiment dates (December 2014-December 2016) for time series of meteorological parameters at Mt. Yulong. On the other hand, in model experimental part for CAM5, selected dates are 2010 to 2014, although the author stated the reason but for actual results synchronization, it should be similar dates to give clearer picture and what is base to select there years?

Response: we totally understand the concern here, which is similar to the major comment 3) of RC1. Please refer to our response there regarding the limitation and purpose of the climate model results. This has been clarified more in the revised manuscript.

(f) In result and discussion parts, author mentioned "seasonal changes in BC and OC sources (e.g., biomass burning vs. fossil fuel combustion) might play an important role for the variations of OC/BC ratios". How does seasonal change affect in OC/BC ratio? Explain the reason and factors involved in this change.

Response: We totally understand the concern here, which is similar to the comment 12) of RC1. Below is the revised text: "An obviously higher BC and OC concentrations were found in the post-monsoon season at the Mt. Yulong site and in winter season at the GHZ site (Fig. 4 and 5) when wet removal by precipitation is inefficient. This suggests the importance of seasonal changes in sources (Carrico et al., 2003; Cong et al., 2015b; Wan et al., 2017). In addition, OC/BC ratio was usually employed to evaluate the combustion fuel sources. Previous studies reported that the global mean of OC/BC by biomass burning was higher than fossil fuel burning (Bond et al., 2004; Cao et al., 2010; Lioussé et al., 1996). Vehicle emissions from numerous touring buses in the GHZ basin play an important role in the variations of OC/BC ratios.

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(g) How did author's calibrate the particulate sampling apparatus (TH150-Tianhong INST group)? And the quality assurance of this apparatus is not explained in manuscript.

Response: We calibrated the particulate sampling apparatus by weighting the mass of atmospheric gas filtrated by a vacuum pump, and recording the temperature of gas to calculate the virtual volume of gas during a specific collecting timescale. Then we made comparisons between the calculated value and the displayed volume of gas in the apparatus. In addition, we adjusted the flow of TSP (i.e. total suspended particulate), and recorded the meteorological parameters during the sampling period to timely calibrate the apparatus in case of inaccuracy. The quality assurance of this apparatus is explained in the revised manuscript: "The quality assurance of this apparatus (TH150-A) is demonstrated by the difference between manually calculated volume of gas and automatically recorded value. The volume of atmospheric gas was usually recorded automatically by the apparatus. The air (and suspended particulates) was sampled at a flow rate of 100 L min<sup>-1</sup> with an accuracy of  $\pm 2.5\%$ , and each sample was collected for 24 h using a stable vacuum pump, which had a good quality and performance (e.g., running steadily with low noise level)."

Some minor revision is as follows: (a) In the abstract part line 2-3 write down the name for adjoining areas.

Response: In addressing a comment of RC1, we deleted this sentence (... adjoining areas) in the abstract focus just on the most important and exciting findings.

(b) In the introduction part line 1-2 add Bond et al. 2007 reference to support the statement.

Response: We have now added Bond et al. (2007) reference to support the statement.

(c) In the introduction part line 3 use words as "human health and living species" instead of using "living organisms"

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Response: We have changed the "living organisms" to "human health and living species" in the revised manuscript.

(d) In the introduction part line 4 reference is missing.

Response: We have now added references for these points. "... visibility (Park et al., 2003), atmospheric radiative balance (Bond et al., 2013; Schuckmann et al., 2016), and the surface albedo of snow and ice (Gertler et al., 2016; Kaspari et al., 2014; Niu et al., 2017a, b)."

(e) Page 4; line 4 Tibetan plateau (TP), abbreviation is already used in abstract part, so need to use full word.

Response: The sentence contains "Tibetan plateau (TP)" in the abstract was deleted, so the "TP" is now spelled out in the introduction, but we made sure that only the abbreviation is used thereafter.

(f) Page 5; line 12 please elaborate the model names that are not considered absorption by OC with reference.

Response: There are many of them, but we have now added one model name (CESM) and references as an example. CESM is a very popular community model that has many users, which is also used in this study. "However, light absorption by OC has not yet been taken into consideration in many climate models, e.g., various versions of the Community Earth System Model (CESM) (Flanner and Zender, 2006; Wang et al., 2013; Qian et al., 2015; Liu et al., 2016), ..."

(g) In material and method part page 5; Line 29. This statement needs reference to support the arguments.

Response: This sentence doesn't add much useful information to the paper, so we have decided to remove this sentence.

(h) Page 6, line 13; use some other words instead of using "But".

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Response: Changed to "However, it becomes . . .".

(i) Page 6; line 16, Is there any other pollution sources? if yes please mention and explain their sources.

Response: Yes, there are other minor pollution sources. We have now mentioned them in the revised manuscript. The following is the revised statement. "Besides the major emissions from tourist vehicles, there are some other limited pollution sources, such as agricultural waste burning, (open fire) biomass burning, and crustal aerosols (Niu et al., 2014, 2016) near the study sites."

(j) Page 9; line 20, write down "Then they" instead of using "They then"

Response: Changed as suggested.

(k) Page 10; line 20 reference is missing

Response: We have added some references to support the statement: It is quite likely that frequent rainfall events with occasional dust (e.g., Dong et al., 2011; Niu et al., 2014) from anthropogenic activities (Shrestha et al., 2000) during the monsoon in 2015 are responsible for this unusual phenomenon (i.e. relatively high content in monsoon season in 2015).

(l) Page 12; line 7 what type of human activities involved between Mt. Yulong and the GHZ sampling sites?

Response: The involved human activities are vehicle emissions and visitor services near the GHZ site but only sightseeing on Mt. Yulong. We have now made it clear in the revised manuscript. The following is the revised text. "...The GHZ site location is close to a parking lot for private vehicles and touring buses and a visitor service center that involves food cooking. These tourism activities can contribute to local emissions of carbonaceous aerosols and precursor gases for SOC (Borrego et al., 2000; Cong et al., 2015a; Shi et al., 2017). However, we don't have direct observational evidence to support this."

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(m) Page 14; line 17 write down the full name for "QSMS".

Response: There was a typo in the abbreviation, which is supposed to be "QOMS". It stands for Qomolangma (Mt. Everest) Station for Atmospheric and Environmental Observation (Cong et al., 2015b).

(n) Page 17; line 11 add "in BC emission" after "contribution".

Response: Revised as suggested. "East Asia has a dominant contribution in BC emission in the monsoon and post-monsoon seasons, ..."

(o) Page 41; Fig. 11. Is there any major difference or key observation that author found in current study which is actually different from others. Please explain in the footnotes of Fig.11.

Response: We have added a key message from the comparison in the caption of Fig. 11 (Fig. 12 of the revised manuscript): "Annual mean BC concentrations at Mt. Yulong were rather low ( $\sim 1.5 \text{ g m}^{-3}$ ), while most of the compared BC concentrations (counted by number of measurements) were within the range of  $1.0\text{-}2.5 \text{ g m}^{-3}$ ."

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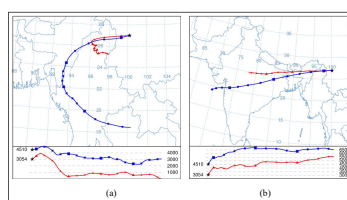


Fig. 7 Seven-day backward trajectory analysis with HYSPLIT model (a) in the monsoon and (b) post monsoon seasons during the study period (Source ★ at 27.01 N, 100.20 E). The trajectories of air mass in the plot were the average of a few episodes. The two heights are the elevation of Mt. Yulong and GHZ, respectively.

Fig. 1. Fig. 7

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