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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Drought-induced biomass burning as a source of black carbon to the Central Himalaya since 1781 CE as reconstructed from the Dasuopu Ice Core" *by* Joel D. Barker et al.

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We thank Referee #1 for their thoughtful and insightful comments. We have responded to their comments in the manuscript as described below.

L 43: Thank you for alerting us to the fact that the cited reference focusses on Himalayan glaciers only. As our focus is on glaciers on a global scale, we have removed the Sakai and Fujita (2017) reference and instead cited Gregory and Oerlemans (1988) for the global response by glaciers to warming, Xu et al. (2012) for

albedo effects on glacier melt, and Raper and Braithwaite (2006) for a decrease in precipitation as snow as being a factor for glacier mass loss. Further, we have modified the text to state that "While warming summer temperatures resulting in increased glacier mass loss (e.g. Gregory and Oerlemans, 1998) and decreasing precipitation as snow (Raper and Braithwaite, 2006) are important factors contributing to glacier mass wastage globally. . .".

L179: We welcome Referree #1's recommendation and have included the recommended figure as Suppl. Fig. 4.

L192: This is a point that Referee #2 raised as well. No, we are unable to estimate the portion of BC that could potentially be lost during sample melting in a polyethylene sample bag. However, Wendl et al. (2014) report that no significant BC particle loss occurs until ∼3 days of storage in polypropylene vials at room temperature, and that there is less adherence at cooler temperatures. Lim et al. (2014) confirm these results and indicate that melting at room temperature is preferable to melting in a warm bath. Meinander et al. (2020) suggest that some EC adherence to polyethylene sample bags may occur, but that EC heterogeneity in the sample (in this case snow) exceeds any particle adherence that may have occurred.

Our ice samples were melted over the course of no more than an hour (less than 3 days) and our samples did not reach room temperature prior to transfer to the polypropylene vial followed by sonication. While we cannot rule out the possibility of particle adherence to the polyethylene sample bags during melting, we suggest that any adherence would be minimal because of the short melting period (< 1 hour) at cool temperatures (< room temperature). Further, we suggest that the extent of any possible particle adherence would be similar between individual samples because all samples were melted in an identical manner.

L 198: We have added the nebulization efficiency for the nebulizer (U5000) based on 2 references that are provided as follows: ". . .CETAC U-5000AT+ ultrasonic nebulizer

(Teledyne CETAC Technologies, Omaha, U.S.A.; ∼18% nebulization efficiency at 220 nm, 356 nm, and 505 nm particle size (Menking, 2013, Wendl et al., 2014))…"

L205: Thank you for bringing this to our attention. We have added test stating the calibration standard range as follows "A 5-point calibration curve (∼0.75 – 12.5 ppb)…".

L233: This is a point that Referee #2 highlighted as well. Thank you for bringing this to our attention. We did not intend to use "deposition" as a quantitative entity here, but rather as a process by which rBC in the atmosphere is transferred onto the glacier surface for incorporation into the firn and glacier ice. For clarity, we have rewritten the text as "…characterization of the rBC deposited onto the Dasuopu glacier…". We have also added clarification where the term "deposition" occurs elsewhere in the manuscript, using the word "concentration" when referring to rBC content in the ice core, rather than "deposition".

L211: We are unsure what Referee #1 is referring to here. The flux as plotted in Fig 2b is an annual flux (ug/cm2/yr).

L284: The point that we should use post-1944 (discontinuous firn sampling) data with extreme caution is well taken. With this in mind, we note that the core has "elevated [rBC] concentrations during the 1960s and 1970s" (line 302-303), and while we cannot comment with certainty regarding the frequency of these high rBC events, the observation that high rBC concentrations are present in the firn section is supported by the data presented. We are careful to caution the reader that the discontinuous sampling in the firn section presents problems in comparing rBC concentrations and fluxes to other ice core records over this time period (line 561-562).

L284: Thank you for pointing out our error in including the discontinuous firn data in the median calculations for both the rBC record and the rBC flux. Fig 2 has been modified to include only the continuous ice section in the Dasuopu core.

L303: Thank you for highlighting the need for clarification here. At scale a = 6, we

are focusing on the ∼annual scale in the rBC record. At a = 27 (∼4.5 years) we are focusing on sea surface temperature (SST) oscillation in the Cape Hatteras region of the North Atlantic which should influence westerly circulation to the Dasuopu cite during winter months. 4.5 years has been identified as the middle value of 3 modes of SST oscillation by Feliks et al. (2011). At a =512, we detect a large scale shift using a scale encompasses the entire record in one pass. Text to clarify our choice of modes has been added to Section 3.2 as follows: "We chose to examine 3 modes of variability within the spectral analysis (Fig. 4b), 2 of which correspond to North Atlantic sea surface temperature (SST) because of the important role of westerly atmospheric circulation in the Dasuopu region during the winter non-monsoonal season (Davis et al., 2005); the annual frequency that is that is responsible for 90% of the variance in the seasonal cycle of SST in the North Atlantic (Feliks et al., 2011), and ∼4.5 year variability that is the middle value of 3 modes of SST oscillation (3.7, 4.5, and 6.2 years; Feliks et al., 2011) in the Cape Hatteras region of the North Atlantic (44 °N, 47 °W). A third mode of variability (∼85 years) was chosen to identify longer-term variation in the rBC record."

L304-309: This is a good point and we deliberately constructed the spectral analysis to take discontinuities in the ice core into account. We constructed the data input for the spectral analysis to consider each rBC measurement as an individual data point rather than being tied to a linear time distribution. As such, while the rBC measurements are arranged chronologically, they do not represent a specific point in time. The assignment of "time" occurs as the last step in the process when we examine which samples are associated with phenomena identified by the spectral analysis. As such, data gaps or discontinuous sampling minimally influences the spectral output, and the discontinuous firn section can be included in the analysis. We are aware of possible border or "edge" effects. Edge effects will be most noticeable at larger scales where the wavelet is truncated at the edges of the dataset. Conversely, edge effects are less at finer scales were the wavelet itself is "smaller" and thus less truncated at the edge of the dataset. Consequently, we do not make strong inferences from the results

of the spectral analysis near the end-points of the dataset, particularly at large scale (L509-516).

L316: Fig. 4e shows that the spectral coefficients do not dip below 0 after ∼1877 CE (ie: the shift to there being no negative coefficients occurs at ∼1877 CE). This point is highlighted in the figure. We have added the text "The a = 512 (∼85 year) mode identifies a shift from some samples with negative spectral coefficients (values below zero) to those with positive spectral coefficients at ∼1877 CE (Fig. 4e)." (L330) for clarification.

L375: We appreciate this point and this is an issue that we struggled with when writing the manuscript. It is difficult to demonstrate a process occurring at an annual or seasonal scale over the broad period covered by the ice core. This is why we chose 3 intervals to highlight the relationship between isotopic composition, dust concentration, and rBC concentration. In an effort to show this relationship over a broader analytical "window" we have included a new analysis using spectral coherence of rBC concentration and d18O over a ∼50m section of the ice section. This analysis shows the strength of correlation between d18O and rBC concentration at multiple period scales as well as any phase lag in this correlation. We hope that this proves to be a more effective way of showing the seasonality of rBC concentration though this section of the ice core.

L402: We are unsure what Referee #1 is referring to here. Fig 2b shows the rBC flux as an annual flux.

L530-557: We appreciate Referee #1's suggestion here. Originally, only anions were analyzed by Thompson for the Dasuopu core, and although we were able to obtain unpublished potassium data for the Dasuopu core, we were cautioned that its accuracy was questionable. Analysis of this suspect record indicated that there is no correlation between K+ and rBC at raw, 1 standard deviation from the mean and 2 standard deviations from the mean, and given that the result does not alter the conclusions, and that the K record is of questionable quality, we did not include it in the submitted manuscript.

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