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/cm^2/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 ºN, 47 ºW). 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 $d^{18}O$ over a ~50m section of the ice section. This analysis shows the strength of correlation between $d^{18}O$ 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.

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

We appreciate Referee #2's point regarding presenting data vs depth before presenting data vs time. However, the rBC data, for example Figure 2a, is presented using the Thompson et al (2000) time-depth chronology that was established using $d^{18}O$, dust, and NO_3^- measurements and annual layer counting confirmation using the location of the 1963 CE beta radioactivity peak, and further calibrated using 2 major monsoon failures at 1790-1796 and 1876-1877 as benchmarks (L156-164). This chronology is used in Thompson et al (2000). Data in this publication are presented relative to time (years AD), and not depth. We have adopted the same convention.

Fig 2a presents raw data and 5 year median data. We do not specify that these are annual averages.

The point that "only averaged data can be interpreted with respect to signal intensity" is well taken and something that we considered during the data analysis. However, we purposefully performed the spectral analysis using individual samples rather than annual averages for precisely the reason that the Referee mentions. By inputting data as dimensionless samples (with respect to time, depth, annual layer thickness, sampling resolution) in chronologic order, we are a) not introducing artifacts due to variable sampling resolution and annual layer thickness; b) we preserve the signal of sudden increases and decreases in rBC concentration that is inherent in the dataset and is an important feature of the rBC record (this information is greatly muted using annual averages). We agree that the principle of spectral analysis is that values represent similar intervals, and we suggest that these intervals need not be "time" as suggested by Referee #2, but instead that the intervals can be similar entities (for example samples, or rBC concentrations), as we've done here.

Referee #2 states that they are "surprised that BC was purely interpreted as emitted from biomass burning. Potential contributions from combustion of fossil fuels were not discussed". We thank the Reviewer for their perspective, but we believe that we do not discount a potential contribution to the rBC record from fossil fuels, but rather show that a significant contribution from this source is not supported by available trace element data and rather aligns strongly with records or regional drought and, by extension, biomass burning. Most other studies examining BC records from ice cores in the region find that contributions from fossil fuels increase in the 1970s, which is a time period that is not well resolved in the Dasuopu BC record. We simply point out that the trace element and drought indices suggest that biomass burning may be an important source of rBC. We agree that our presentation is descriptive and we value Referee 2's suggeswion that we use a "more robust statistical approach" to support the correlation between regional drought and periods of high rBC concentration in the Dasuopu core. Unfortunately, in the time provided, we have been unable to conduct an analysis such as a spatial correlation analysis between the regions described in the PDSI maps and the Dasuopu glacier drilling cite. However, we would like to point out that we provide evidence from a trace element record, as well as 3 independent climate records, so

support our conclusions that rBC may be associated with dry conditions and associated biomass burning events.

We agree with Referee #2 that a direct comparison between the rBC record presented here for the Dasuopu ice core and the cores presented for East Rongbuk glacier by Ming We agree with Referee #2 that a direct comparison between the rBC record presented here for the Dasuopu ice core and the cores presented for East Rongbuk glacier by Ming et al. (2008) and Kaspari et al. (2011) is an excellent idea, we are limited by the discontinuous sampling of the firn layer of the Dasuopu core that spans the time periods presented by the East Rongbuk cores. We do provide a qualitative comparison on lines 303-305 where we state that "The discontinuous firn section of the core has elevated concentrations during the late 1960s – 1970s, consistent with observations from East Rongbuk glacier by Ming et al. (2008) and Kaspari et al. (2011) , and for Tanggula glacier by Xu et al. (2001)." This comparison, as well as a comparison with other glacier cites is shown in Fig. 1.

Referee #1 also questioned whether we had assessed BC particle loss during sample melting. I have repeated our response here:
"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."

We appreciate the suggestion that we cross check the annual layer counting with seasonal rBC increases in the Dasuopu rBC record. This is something that we attempted during our data analysis. In the end, we found that the presence of missing rBC samples (as described in the manuscript) introduced error to the cross-dating effort, rendering it unreliable.

L 57: Thank you. We have changed "European Industrial Revolution" to "Industrial Revolution".

L 99: Thank you, we have removed the false statement that EC is a form of BC.

L118: We explain that the importance of the Dasuopu core being from high elevation is that it allows us to sample from the free troposphere, distant from local sources of BC contamination (lines 126-134).

L 127: Implicit in the term “free troposphere” is that we are not influenced by sources of local BC contamination. The drill site on Dasuopu glacier is not influenced by down-valley meteorological conditions, as described by Li et al (2011) and cited in the manuscript). While not measured for this location specifically, and so not noted in the manuscript explicitly, the free troposphere in the central Himalaya begins at ~2.5 km elevation in the winter and 3.3 km elevation in the summer (Solanki and Singh, 2014). We have added this sentence for clarity (Line 135): “Generally, the lower limit of the free troposphere in the central Himalaya occurs at ~2.5 km in the winter and 3.3 km in the summer seasons (Solanki and Singh, 2014).”

L 136: Thank you. We have added this reference to line 138.

L 137: By “sub-annual resolution” we mean that we were able to obtain multiple samples per year of accumulation. We have replaced “sub-annual” with “seasonal” for clarity.

L 152: Information regarding the recovery of Dasuopu core 3 is described in detail in the Thompson et al (2000) publication, that is referenced in the manuscript. Thus, we believe that repeating this information is unnecessary and beyond the scope of this manuscript. Likewise, as described my Thompson et al (2000), the chronology was developed for core 3 (used here).

L 174: We’re not sure that we ever used the term “ultra-pure water”. We do write MQ water, and have replaced this initial description with “type 1 Milli-Q water” for clarity.

L 184: Thank you. We have added “2N” descriptor to HNO_3.

L 186: Thank you. We have replaced the brand “Ziploc” with “polypropylene”.

L 249-258: Yes, this is the data that Gabrielli et al (2020) used, and we have clarified this by writing “using methods described in Uglietti et al. (2014) and reported by Gabrielli et al. (2020).”

L 261: Thank you. We have replaced “geomorphology” with “topography”.

L 286: We think that this is a good suggestion, but at this point, we think that the effort involved to determine how much snow was deposited during the monsoon for the 64 m ice section of the core analyzed here for a piece of information that doesn’t contribute strongly to the findings of the manuscript is unwarranted.

L 289: Our mis-use of the term “deposition” throughout the manuscript was noted by Referee #1 as well. We have replaced “deposition” with “concentration” throughout the manuscript.

L 289-291: The point that we approach the relationship between $d^{18}O$ content, dust, and rBC in a qualitative way for discrete intervals in the core was noted by Referee #1 too. We respond to their, and your observation as follows: “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 $d^{18}O$ over a ~50m section of the ice section. This analysis shows the strength of correlation between $d^{18}O$ 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.”

L 551: Thank you for noting that omission. We have corrected the sentence as per your suggestion.

Fig 2: The secondary x axis (the 5 year median scale) is different than the rBC scale on the primary axis. I believe that this is the source of the confusion.

Fig 5: Thank you for pointing this out. We have added the following to the Figure caption: “Red and blue indicate a higher frequency and lower frequency air mass flow paths, respectively”.