Here we reply to each comment raised by Anonymous Referee #1. The comments of the referee are given in italics and our replies in regular type**.**

Anonymous Referee #1

This paper gives a thorough discussion of possible influences on EC concentrations and deposition at the ice core site. I have a few comments.

(1) The authors need to clarify whether all the meltwater percolates and refreezes in the current year's layer, or whether some exits the glacier. If there is significant runoff, then the snow accumulation on Figure 3c does not accurately represent the snowfall. The snowfall rate in the latest years could be larger than shown, because of the trend to increased melt (and maybe increased runoff). An increasing snowfall rate would lead to increased EC deposition (Figure 3b) by wet deposition even with no change in scavenging efficiency.

The reviewer makes several fair points. We will clarify the issue in the revised version of the manuscript. Unfortunately, any reliable meteorological measurements that affect the snow accumulation rate of the ice coring site (precipitation, sublimation, evaporation, runoff) are missing from the ice core site. Therefore, we must rely on the inferred information from previous studies of the ice core as well as the expertise of scientists visiting the Holtedahlfonna annually on several occasions. First of all, no significant summer melt induced surface runoff has been observed at the Holtedahlfonna ice coring site during field work campaigns in the recent years. Therefore, we assume that most of the melt water percolates and refreezes in the current year's snow layer as observed by e.g. Pfeffer and Humphrey (1996). In addition to visual observations at the ice coring site, the detailed ion measurements made by Beaudon et al. (2013) give further information on the amount of melt at Holtedahlfonna in the past. Beaudon et al. (2013) present a high-resolution record of several ions from the very same ice core as used in our EC measurements. Different ions are elusive at different efficiencies and thereby percolate with different efficiencies through the snow pack. Generally, Beaudon et al. (2013) suggest that the Holtedahlfonna ion record is disrupted since 1980 due to runoff. However, this may not be critical for EC which is much less elusive that the ions and has been shown to remain within the current year's snow pack despite of summer melt (Doherty et al., 2013; Xu et al., 2012). Since 1990 the ion inferred melt index turns to a decrease (Figure 5a) and we say: "…the melt index fails in the most recent part of the ice core where the summer melt has been much more extensive and thus the ions have been washed out from the annual snow pack (Beaudon et al., 2013) (though not penetrating into the snow of the previous year due to impermeable ice layers; c.f. Pfeffer and Humphrey, 1996)." We will further clarify this issue in the revised version of the manuscript by stating that, as observed in Pfeffer and Humphrey (1996), some melt water which percolates deep enough in the current year's snow pack to reach the previous year's ice layer, may flow laterally at the bottom of the current year's snow pack. Understandably, this flow is very slow and no significant amounts of water are lost from the ice core by this process. However, some of the most elusive ions are (Beaudon et al., 2013). Thereby, we do not believe that the summer melt induced runoff at the ice coring site is even at the top of the ice core so strong that it would significantly affect our EC record.

Secondly, it is true that the snow accumulation rate presented in Fig. 3c does not accurately represent the snowfall at Holtedahlfonna alone. As mentioned above and in the text, we do not have data of the snowfall at Holtedahlfonna. The measured snow accumulation rate represents the result of all snow accumulating and subtracting processes during a year. Snow as well as rain fall will increase it while evaporation during melt, sublimation and possible limited lateral flow of melt water during the summer melt will decrease it, as stated in the text (page 13215 lines 8-12). However, these summer-time water losses are expected to have a rather small effect on the whole year's snow accumulation (Pfeffer and Humphrey, 1996), as mentioned in the text. This is because the amount of water lost by these processes from the glacier during summer months is assumed to be very low in comparison to the annual snowfall. Thereby, increased melt is likely to have only a minor impact on the EC concentration trend. However, if runoff would account for significant amounts of the measured snow accumulation rate during the last decades, but at the same time the EC would stay behind in the annual snow pack, then runoff would have a significant effect on both the measured EC concentrations and deposition. Here, the reviewer has made a fair point and we will include this hypothesis in the revised version of the manuscript. However, as stated above, we believe runoff has not had a significant influence on the EC trend seen in our results because it has an insignificant effect on the whole year's snow accumulation rate.

Finally, the referee suggests that an increasing snowfall rate would lead to increased EC deposition (Figure 3b) by wet deposition even with no change in scavenging efficiency. Again, we have no snowfall measurements from the coring site but our snow accumulation data does not suggest a significant increase in snow-fall during the last decades (Fig. 3c). However, if we assume that the snow-fall at the glacier has increased, the referee is correct that this would increase the EC deposition. However, if we assume that the BC scavenging efficiency stays constant (as suggested by the referee) and the EC deposition increases due to increased snowfall, then the EC concentration would not increase simultaneously. This is because the EC concentration depends on the amount of water per sample. Thereby, if scavenging efficiency stays constant but snow-fall increases, the EC concentrations in the ice are actually diluted and should decrease. Consequently, as mentioned in the text (in the summary), increased scavenging efficiency is the only process able to simultaneously explain increasing EC concentration and deposition in the ice core. To clarify this, we will mention this in the revised version of the manuscript also in the section discussing scavenging and not only in the summary and conclusions section.

In summary, we will mention in the revised version of the manuscript that both EC concentrations and deposition could have increased during the recent decades with stable BC scavenging efficiencies, if precipitation and runoff at the ice core site would have increased significantly at the same time, as suggested by the reviewer. However, the magnitude of these changes would have had to been higher than what can be assumed. Thereby, increased scavenging efficiency is the most likely explanation for our recorded trend.

(2) To test for the combined effects of increased melt-consolidation and increased runoff, the authors might correlate the BC concentration for individual years with summer temperature at Ny-Alesund as a proxy for the amount of melt at Holtedahlfonna.

This is a fair suggestion made by the referee. However, we do not think that this suggested correlation would be valuable. Again, temperature measurements are missing from the glacier. Temperatures are available from Ny-Ålesund since 1934 and from the Svalbard airport since 1911 as shown in Figure 5b. However, these temperature measurement sites are close to sea level whereas the glacier is at 1150 m a.s.l.. In summer months the temperature measurement sites may record temperatures above 0°C indicating melt whereas temperatures on the top of the glacier may still be well below zero. Therefore, the correlation may not be very useful.

In addition, we do not understand how such a correlation would give any further information in addition to the inferred melt index (Figure 5a) on the amount of runoff at the glacier. The use of the melt index (log ([Na^+]/[Mg^{2+}]) has been thoroughly tested for the Holtedahlfonna glacier and proven to be the most reliable proxy for melt at the glacier (Iizuka et al., 2002). We do not believe that the current understanding on the combined effect of certain BC concentrations and temperature on glaciers is good enough to predict at which values 1) melt begins, and 2) melt exceeds a threshold at which the melt causes actual runoff of water at the top of the glacier. We want to stress that based on the current understanding there is no actual surface runoff of melt water from the ice coring site even at the present (or if there is, then very limited), as discussed in context to the previous referee comment. We believe that our reply and suggested additions to the revised manuscript version based on the previous question covers this referee comment as well.

(3) The citation to Jenkins et al. (2013) should be dropped. That draft paper, submitted to TC, was rejected. Unfortunately the editors of TC are not being forthright about their decision; the TCD version simply lists "Review Status" with the euphemism "A final paper in TC is not foreseen."

We will drop the Jenkins et al. (2013) citation from the manuscript.

Minor comments on terminology:
(4) Section 3.2 paragraph 2. "We chose to calculate deposition rather than fluxes . . . ." In normal usage, these two terms are synonyms, with the same units (mg m-2 yr-1). Some explanation is needed (for example giving the units of each), or else a change in terminology.

We will clarify this in the revised manuscript. Deposition and flux are synonyms with the same unit (mg m-2 yr-1) but they are calculated differently, as implicated in the text. Deposition is calculated by dividing the total amount of EC in a (filter) sample by the cross section of the ice sample divided by the amount of years covered in one filtered ice sample, as mentioned in the text. Flux on the other hand is calculated by multiplying the measured EC concentration by the snow accumulation rate. We will clarify this in the revised version. As mentioned in the text, flux calculation incorporates snow accumulation rates from the ice core and therefore adds a source of uncertainty by introducing an additional variable. In addition, the snow accumulation rate data of the ice core is quite coarse. Therefore, we think that deposition presents higher quality data in this case than fluxes. Generally, flux and deposition calculations will give the same results.

(5) page 13209 lines 18-20. ". . . northern Eurasia . . . regional sources . . ." Does "regional" here refer to the northern Eurasia region, or is "northern Eurasia" instead being contrasted to a more restricted region?

This is a fair point and our statement in the manuscript needs some clarification in the revised manuscript version. With regional sources we mean northern Eurasia.

Technical corrections:
(6) p 13208 line 16. "McConnell et al. 2010". The citation in the reference list has a single author.

We will correct the citation in the revised manuscript.

(7) p 13222 line 15. Change "Salzman" to "Saltzman".

Will be done.