For clarity, we repeat the reviewer comments in normal font, followed by our answers in italic font.

The manuscript by Stohl et al. presents a sensitivity study on black carbon where authors try to solve the BC modeled underestimation by more detailed description of emissions. This is very important topic, since lots of models are struggling with BC underestimation in high latitudes, especially in winter and early spring, which, in turn, influence the radiation balance calculations. To my opinion, the goal to "only explore the sensitivity of Arctic BC to changes in the emission treatment" is achieved. Manuscript is well structured and written. However, I would like to clarify points mentioned below.

Thank you for the overall positive assessment. Indeed, this is mainly a sensitivity study. Hopefully, complex aerosol models will allow a more complete assessment.

p. 9568, line 13 You say that "In March, flaring even accounts for 52 % of all Arctic BC near the surface. " What is the seasonality in gas flaring contribution to Arctic? Those plots, together with footprints (for case studies 3.3.2) will help for better understanding the modeled peaks.

We are not entirely sure what you are suggesting. Do you mean seasonality of emissions or seasonality of source contributions? And how would footprints relate to this? Do you mean to show plots of all of these? The seasonality of flaring source contributions is shown in Fig. 8 for the six Arctic stations, although not in relative terms. We have now added a Figure 12, the right panel of which shows the relative contribution of gas flaring emissions to total modeled BC at the Zeppelin station, also for constant-lifetime tracers. Furthermore, Fig. 7 shows Arctic-mean source contributions for January and July which, together with the reported maximum value of 52% for March should give a relatively clear indication of the relative source contributions. For plots of the emission sensitivity footprint, we refer the reader to the paper of Stohl (2006), which shows such footprints and discusses them in detail.

We do not have enough information to quantify seasonality of gas flaring emissions. Basically, the operation continues all year through and one would not expect a strong seasonal cycle. An exception could be for oil production facilities where some of the associated gas could be used for heating and auxiliary equipment; in such case flaring might slightly decline with very cold weather but we lack any specific evidence to quantify such effect and distribute it spatially.

p.9569, line 24 Meinander at al. (Atmos. Chem. Phys., 13, 3793–3810, 2013) "Spectral albedo of seasonal snow during intensive melt period at Sodankyla , beyond the Arctic Circle" is an interesting work, which might be refereed to.

Indeed an interesting paper, we have now cited it in the introduction section.

p. 9570, line 3 Dou et al. (Atmos. Chem. Phys., 12, 7995–8007, 2012) mentioned model underestimating BC concentrations in the middle and lower troposphere. They suggested to run the model for the case of possibly lowest number of forest fires.

Indeed, this is not a clear feature, and therefore we wrote that "some of the models overestimate BC". We cited the Koch paper, as it includes many models and refrain from citing an individual *model study here. If we cite Dou et al., we would also have to cite papers (and these are more) reporting underestimates.*

p.9570, line 8 there are opposite opinions on the role of wet scavenging in BC underestimation. Liu et al. (Geosci. Model Dev., 5, 709–739, 2012) say that " The model still underestimates observed BC median mixing ratios in the Arctic in spring, which suggests a model bias of wet scavenging for the accumulation mode aerosol and/or underestimated local emissions in the model during the spring season. However, Heinola et al. (Atmos. Chem. Phys., 13, 4033–4055, 2013) studied the reason for the BC underestimation in REMO-HAM by further examination of the precipitation data from both measurements and model and showed that there is no correlation between REMO's excessive precipitation and BC underestimation. Based on the case studies, Heinola et al. (2013), concluded that the excessive wet removal is not the main cause of the low black carbon concentration output.

We have added these two papers in the introduction and extended the discussion of emissions versus wet scavenging, to accommodate these two studies as well as Browse et al. (2012).

p.9573, line 15 (cont. from point p. 9568, line 13) please, write a bit more about the gas flaring database (temporal, spatial resolution). Do you operate with annual numbers only? How could you then estimate the contribution to Arctic in March? Using the annual average and transport model? If flaring monthly data available, would be interesting to see the annual variability

Gas flaring is a rather constant activity, as oil production is also rather constant throughout the year. Where the gas cannot be stored or transported, the excessive (associated) gas is being flared. There may be special conditions when flaring is interrupted (e.g., extremely low temperatures) but these are likely not frequent. In our data set we assume annually constant emissions (see comments above). The simulated seasonal cycle of BC in the Arctic is entirely due to transport and wet scavenging. The effect is particularly strong for flaring emissions because of the high latitude of this source and because it is located exactly in the region with frequent direct transport into the Arctic in winter/spring. The nominal resolution of the emission data is 0.5x0.5 degrees. However, gas flaring emissions are aggregated in rather large regions as shown in Fig. 1. The location of individual flares is not represented in this data set; for more detail on available data from NOAA that has been used for gridding the emissions see http://ngdc.noaa.gov/eog/interest/gas_flares.html.

p.9574, line 10 In the case study there is a class "biomass burning". Which emissions does it include? Is it combination of agricultural and open biomass burning classes? What is the vertical structure for that class?

It is open biomass burning without agricultural burning, which is considered separately. Agricultural burning in the Northern Hemisphere is assumed to start only in March, so its contribution is zero in February and it is not shown. Also the contribution of open biomass burning other than agriculture is close to zero, so this source is not important for the case study. Biomass burning emissions are injected into the model between the ground and 100 m above.

p.9575, line 7 according to figures 8 and 9, gas flaring contribution to BC is much less than 80%. Is that because of the changes in contributions of BC components on the way to the recipient? Please, explain

Yes, BC in the Arctic does not exclusively come from north of 66 degree N but also includes long-range transport from other source regions where flaring contributes much less.

p.9583, line 2 How strong (in numbers) is that increase? Would be interesting to see the difference (yearly-daily) maps

This is a side result, since the larger absolute differences occur in winter, so we do not show a map for summer. However, the Arctic-average difference can be clearly seen in Fig. 4. It is about a doubling of the (however, very low) EBC concentrations.

p.9585, line 25 I personally do not see the reason and possibility to compare the cleaned-for-biomass-burning measurement data with modeled (including biomass burning component) data. Excellent that you compared the model with "not-cleaned" data. That comparison should be on Figure 8.

The screening of Barrow data is not done to remove biomass burning emissions but to remove the influence of local emissions from the town of Barrow. However, this seems to also remove some data influenced by biomass burning. We have inserted the words "local pollution" and "unintentionally" to make clear that the screening is not targeted towards biomass burning events.

It is not clear whether screened or unscreened data are most appropriate for a comparison with a model (certainly the model does not resolve the local emissions). Therefore, we chose to use the "official" Barrow data which are available from NOAA. John Ogren was nice enough to remove the screening for us but these data are not normally available.

p.9585, line 27 "by" instead of "bye"

Thanks, corrected.

p.9586, line 21 It is not only that "the model fails to capture March peak". There is an opposite trend in BC between modeled and measured values in January-April and no explanation to it.

We think it is virtually the same to say that the March peak is not captured or to say that the systematic increase to this peak from January to March is not captured (the peak follows the increase). More importantly, this deficiency seems to be common to almost all models and it lacks a satisfying explanation. However, the flaring contribution at least helps to reduce the model deficiency.

p.9587, line 10 I disagree that it makes sense to verify model on the measured dataset, which includes inter-annual variation (here : not controlled - varied from year to year – biomass burning). It might bring the extra computation costs, but for the comparison with measured data the same period should be modeled.

We agree. However, the emission data set we used was not available for the years 2006 and 2007, so this is not only a matter of running the model but also one of the availability of emission data. Therefore, we cannot do a direct comparison using exactly the same time periods for all sites. However, for four of the six sites, the same years were used, and for Station Nord only one year was missing.

p.9587, line 20 I disagree with the statement “quite well”. There are lots of disagreements which are not enough discussed and explained. It would be interesting to see the difference between different model runs: - annual residential combustion vs daily resolved - no flaring vs flaring included and comparison to the measured BC. In that case, the model enhancement will be seen more clearly

We have revised our writing. We have removed the words “quite well” and have explicitly mentioned that the simplified treatment of wet scavenging is the likely source of much of the remaining discrepancies. We are surprised that the reviewer asks for comparisons of annually vs. daily resolved residential combustion emissions and flaring vs. no flaring. All of that is shown in Fig. 8 (blue line is annually constant residential combustion emissions, which can be compared to the red-shaded area; brown area is the flaring contribution).

p.9588, line13 Is there a seasonality in flaring activity, or this is mainly the vertical structure of the atmosphere and transport paths, which result in enhanced flaring component in winter and early spring?

It is mainly a transport effect, with very efficient transport from the flaring region into the Arctic in winter. High static stability also contributes, which keeps the flaring emissions close to the surface. There is no seasonality in the emissions, as mentioned earlier.

p.9588 would be interesting to see the footprints for “low” and “high” BC episodes

The footprint for the most interesting episode is shown in Fig. 10. See Hirdman et al. (2010) for an analysis of high vs. low BC episodes at Zeppelin, Alert, Barrow and Summit. This analysis actually points to the flaring region, but at the time of writing, Hirdman et al. were not aware of this large emission source in exactly the “required” region, so flaring is not mentioned in this earlier paper.

Figures: Fig. 1. Short-cuts from figure titles (e.g. Ene, Ind, ets.) should be in the capture.

Changed as suggested.

Fig. 7. Suggest to keep the same scale for x-axis (for easier comparison) In current version, fonts for titles and colorbars are not easy to read

Fonts should be easier to read in a final ACP version, since ACP uses portrait format and portrait figures will thus be larger than in the ACPD landscape format. We decided to leave the axes as they are because July results would be much harder to see with a ca. 33% extended x-axis.