

We thank the reviewers for their insightful feedback. We have substantially revised the manuscript as a result. Mainly, we revised and coordinated almost all of the figures and improved upon the writing quality of the text based on the suggestions provided. We also revised the source classifications and redid any calculations resulting from such changes, all of which are reflected in the manuscript.

Reviewer 3

This study reports new aerosol observations from the summertime ARM ACME-V field campaign on the North Slope of Alaska. Their results indicate that oil exploration activities in Prudoe bay may contribute significantly to local aerosol concentrations. In particular, they observed high concentrations of nucleation mode particles in the area. These observations are novel and interesting and certainly add to the scientific discourse. However, many of the conclusions presented I feel are not fully justified by the results discussed. Additionally, the paper is difficult to read in several sections and requires clarification on several points. Please see below for specific instances.

Major comments:

Page 2 lines 3-4 This entire sentence is very confusing, what do the authors mean by 'beyond greenhouse gases' and which 'climate feedback' are they referring to? Please refer to the specific feedback (I assume ice-albedo) and rewrite the sentence to improve clarity.

We specified that this is the ice-albedo feedback and reworded the sentence to, "In addition to the ice-albedo feedback described above, the principal atmospheric constituents that perturb the surface energy budget are clouds and aerosols."

Page 2 line 5 'indirectly impact radiation through their role in cloud lifecycle' Aerosol can indirectly result in radiative forcing by increasing cloud lifetime, changing albedo and (in the case of INP) changing cloud phase. Please rewrite the sentence to address generalities (cloud microphysics) or specific processes.

We rewrote the sentence so that it says 'roles in the modulation of cloud microphysics'.

Page 3 line 3 'The Arctic atmosphere can be highly stratified' This statement is included without explanation or more (crucially) reference. Please cite a supporting reference.

We added two key references.

Page 3 lines 3-4 'at the height at which cloud modulation by aerosols occurs' This statement is very vague. To what height are you referring? Cloud base in the Arctic can be extremely low.

Good point, Arctic cloud base can indeed be extremely low. We removed 'at the height at which cloud modulation by aerosols occurs' that sentence.

Page 3 lines 4-5 'have focused in evaluating Alaskan Arctic aerosol sources' Why would focusing on aerosol sources help our understanding of higher altitude aerosol in the Arctic? I assume the authors mean specifically sources of higher altitude aerosol?

We changed this sentence to read, "Accordingly, numerous airborne campaigns have focused on evaluating sources of mid- to upper-tropospheric aerosol and aerosol-cloud interactions."

Page 3 lines 23-26 This statement seems to be conflating future and present sources of aerosol in the Arctic and while forest fires are indeed an important source the relative importance of local vs transported aerosol is not well understood. Thus, while 'great importance' may be justified for boreal forest fires (during some periods of the year) I would prefer more nuance when discussing local fossil fuel and BB combustions (by which I'm assuming the authors mean domestic wood burning?).

We are referring to projected increases in forest fires due to a warming climate. Domestic wood burning should not play a dominant role in the summertime in this region, particularly when compared to the widespread forest fires. However, to make this sentence clearer, we changed to, "In the context of warming temperatures, emissions from oil

extraction, added shipping routes due to a reduction in sea ice extent, and wildfires are expected to increase in sub-Arctic boreal regions (Randerson et al., 2006; Gautier et al., 2009; Harsem et al., 2011; Peters et al., 2011; de Groot et al., 2013; Roiger et al., 2015). Thus, regional fossil fuel and biomass burning combustion sources will further contribute to the aerosol population may serve as an increasingly crucial source of aerosol in the future.”

Page 4 line 7 ‘predominantly decoupled’ Why is the summertime Arctic decoupled? And is this also true for the sub-Arctic region that this paper focuses on? If the Arctic is less polluted in the summer (because as your references suggest it is decoupled from the mid-latitudes) does this not suggest that local sources are unimportant?

Thank you for pointing this out. Previous work does show that sub-boreal regions can still contribute. We referred to midlatitudes as those in the lower 48, but realize this is not correct. Thus, we simplified the sentence to, “The Arctic summertime atmosphere is historically less polluted as compared to the rest of the year (Quinn et al., 2002; Leitch et al., 2013; Heintzenberg et al., 2015), thus it is critical to assess the impacts of potentially important local sources of summertime aerosol on Arctic radiation and cloud microphysical processes.”

Page 6 lines 23-24 ‘Hotspots of larger particles.. were not observed near Prudhoe bay (not shown)’ I don’t understand why you include this sentence were you expecting to see larger particles?

This sentence was removed.

Page 7 lines 2-10 Here you suggest that predominance of larger particles above the BL is the result of growth during vertical transport and dynamical restriction of nucleation mode particles in the BL. It surely can’t be the result of both?

We changed this sentence to say ‘or’ to demonstrate that it could be from one or the other process.

Page 8 lines 4-9 beginning ‘in terms of indirect forcing’ Is the argument here that accumulation mode aerosol derived from nucleation have an impact on cloud properties or that the nucleation mode particles affect cloud directly? If the latter, please explain why marine aerosol may be more hygroscopic than sulphate. Petter et al., (2007, ACP) suggest similar kappa values for both.

The purpose of this paragraph is to provide broader implications for the direct and indirect impacts of aerosols from this source from previous work. It appears the beginning of that sentence caused confusion, so we removed it. We did not intend to indicate that marine aerosol may be more hygroscopic than sulfate. However, in addition to the sulfate, oil extraction and marine emissions include a host of different organic species that partition to the particle phase, which are not very hygroscopic. Thus, it is difficult to say which general emission source would produce the most hygroscopic aerosol, and is why we broadly state that their hygroscopicities could vary.

Page 8 line 9-11 beginning ‘In general, our results’ Given your previous statement that the aerosol appears to have a trivial direct forcing effect and extremely uncertain indirect effect is your final statement really justified?

This sentence was removed.

Page 8 lines 27-29 Why would you expect to observe an ‘abundance of coarse and accumulation mode particles’ if the wildfires generate secondary organic aerosol?

Although SOA is generally smaller in nature, they can age as they are transported and grow in size. We clarified this here.

Page 8 line 31 ‘Which are higher than standard summertime and even springtime haze concentrations’ what is the ‘standard’ concentration and why have you not provided citations here?

See response to analogous comment by reviewer 1. This part of the sentence was removed.

Page 9 lines 11-13 ‘Our observations are parallel to previous summertime observations from regional boreal fires in that they produce substantial quantities of aerosol...’ I’m genuinely unsure what you mean by this sentence although I am confident that it is not your observations producing aerosol. Please clarify.

We changed to 'in that such fires produce substantial quantities of aerosol' to clarify that we meant they are produced from fires.

Page 11 lines 10-11 'but demonstrating the larger impact of nucleated aerosol in the vicinity surrounding Prudoe bay' Assuming you mean climate impacts I fail to see how this study demonstrates any impact from these aerosol. You state on page 7 (lines 31-33) that you didn't observe any direct forcing. I also see no evidence (from these observations) of the indirect impact. Please clarify whether the observations reported here do or do not suggest a significant indirect aerosol forcing from emissions in Prudoe bay and provide greater justification for this conclusion.

We intended to suggest that this is a larger source than previously reported. To reflect this, we changed the sentence to, "Probably the most notable observation was that Prudhoe Bay is a persistent but localized source of black carbon and especially nucleated aerosol, supporting previous findings at Utqiagvik from Kolesar and colleagues (2017) and Gansch and colleagues (2017), but demonstrating the larger influence of particle nucleation on the aerosol population in the vicinity surrounding Prudhoe Bay." Additionally, the impacts of these aerosols are detailed by Maahn et al. (2017).

Page 11 lines 18-21 'With both fire activity and oil exploration projected to increase in a warming climate, these sources will likely continue to make significant contributions...' Previously the authors have stated that emissions in Prudoe bay have a localized impact only, with this in mind can the authors justify so strong a statement on the importance of future oil exploration to Arctic aerosol?

Even though this source is what we call localized, the HYSPLIT dispersion analyses indicate that dispersion is highest within a 2 degree region, but lower mass concentrations are transported over the entire study area. Thus, a fraction of these particles is transported regionally and could thus have implications for regional climatic impacts. We think this statement is relevant for our results, but have clarified what we mean by 'localized' throughout the manuscript.

Minor comments

Page 2 line 3 Missing 'the' before climate feedbacks. However, to improve clarity I would suggest replacing 'climate feedback' with 'ice-albedo feedback' (please see first major comment)

Added 'the' and changed to 'ice-albedo feedback'.

Page 2 line 6 Use of the phrase 'hinges' is colloquial I would suggest changing to 'depends'

Done.

Page 2 line 7 'inherently depends' is a redundancy please delete inherently

Done.

Page 2 line 7 Replace 'atmospheric processing' with age

Changed to 'extent of aging'.

Page 4 line 9 'important sources of aerosol' You mean important local sources of summertime aerosol?

Yes, changed to 'local sources of summertime aerosol'.

Page 4 line 11 To improve clarity please replace 'such' with local

Done.

Page 6 line 31- Page 7 line 32 Please split your citations to differentiate between those referencing flaring emissions and those referencing nucleation mechanisms.

These are already split up.

Page 7 line 2 Please change ‘removal of particles’ to ‘transfer of particles’ or equivalent. Removal suggests removal of the particles from the atmosphere.

Changed to ‘transition of particles’.

Page 7 line 13 Please cite Stohl et al., 2013 (<https://www.atmos-chemphys.net/13/8833/2013/>) in reference to BC emissions from flaring.

Done.

Page 7 line 27 Please replace ‘loss’ with ‘transition’. The particles aren’t lost there just bigger.

Done.

Page 8 line 7 Are you referring to diameter or radius here in reference to CCN?

Clarified that this is referring to diameter.

Page 8 line 16 ‘evidenced by the elevated AOD originating from central Alaska’ The elevated AOD is the result of aerosol originating from central Alaska. I would suggest rewording to ‘the elevated AOD originating from central Alaskan wildfires’ or equivalent.

Changed to ‘the elevated AOD originating from the central Alaskan wildfires’.

Page 8 line 17 ‘extended until the end of Jul’ What was extended until the end of July?

Changed sentence to, “ACME-V flights were impacted by the high AOD regions from late-Jun until end of Jul.”

Page 10 lines1-2 I agree with this statement but both of the papers cited are concerned only with the Alaskan Arctic. I would also suggest citing Garrett et al., 2010 <http://journals.co-action.net/index.php/tellusb/article/view/16525/0>, Browse et al., 2012 <https://www.atmos-chem-phys.net/12/6775/2012/> or Eckhardt et al., 2003 <https://www.atmos-chem-phys.net/3/1769/2003/acp-3-1769-2003.html> (among others).

Thank you for bringing the suggested references to our attention. We have added all three to this sentence.