Authors' response to comments on "ARCTAS-A ground-based observational campaign and meteorological context, interior Alaska, April 2008", by D. E. Atkinson, K. Sassen, M. Hayashi, C. F. Cahill, G. Shaw, D. Harrigan, and H. Fuelberg

October 24, 2011

We would like to thank the three reviewers for taking time to provide commentary about this manuscript. We have found the commentary to be very useful in honing the document focus and structure, and are satisfied that it represents a much stronger contribution as a result. In general, the comments centered around two main themes: organizational issues, which led to difficulties with conclusions drawn; and issues with instrumentation details. We have conducted a series of edits to address almost all of the concerns expressed by the reviewers. In the odd spot where we disagree, we offer our commentary/reasoning for doing so.

A word of commentary about this paper is in order. This document represents an assessment of particulate loading state as suggested by a suite of results from instruments in operation at the time of the ARCTAS mission. It is more exploratory in nature; that is, it did not start with a hypothesis but instead examined and then interpreted what was observed, ensuring conclusions made sense in terms of results from the instruments in operation at the time and were consistent with the broader meteorological context. As such, it is non-standard in its appearance which makes it difficult to follow. This we believe was the source of many concerns, and we have worked to target this organizational aspect in particular. Specific comments follow; our responses are in red.

Reviewer 1

Introduction: There is very little in the introduction about the modification for this research. Why is this research important. Why study aerosol types in the Arctic and the meteorological conditions under which they form?

The motivation for studying transport and haze issues in the Arctic resides within the broader concern of understanding pollutant and contaminant transport to this region. Studies have shown that contaminants tend to become concentrated in this north. Understanding where the source regions are, and under what atmospheric conditions and times of year they are most mobile, feeds into the broader issue of northern health research. There are also other physical considerations, for example, accumulation of dust/soot on the surface of snow and ice-covered areas reduces their albedo and can hasten seasonal melt. Comments to this effect have been added to the introduction.

Section 2.1: This seem to be a poorly written abstract for a conference, instead of providing information about the methodology used. Best to use present tense (is instead of were).

We have cleaned up the abstract to provide more information about the methods and we have switched to the present tense.

Section 2.2: Details are lacking on the instruments and methods used in this section. Without the addition of these detail there is no reason to reason to read further since there is no reason to believe the measurement are any good. Furthermore, there is no discussion of the particular instrument performance tests that were conducted during the operation of the instruments, nor any indication of when the instruments (OPC, CPC, etc) were last calibrated.

Our apologies about insufficient instrument detail. We were working under a word limit assumption that does not seem to be in effect; thus, throughout this section we have added relevant instrumental detail. Specifics changes to the text are indicated below, in response to the associated specific comments.

Section 3.1: This stuff is out of order. This section should be deleted and the paper re-organized. The poor organization of the paper, makes the science difficult to understand and impossible to discuss.

This short section was included here to allow the reader to place into context the results from the individual instrument data sets as described in sections 3.2-3.6, so that the reader knows where the paper is going. Given the non-standard format of this paper, it was felt that it is useful to keep it here. However, more elaboration concerning its placement has been added.

Section 3.2: This section need to be totally re-organized. The interpretation need to be moved to the end. The discussion of Figure 2 need to be cleaned up.

Agreed. This section has been restructured.

Section 3.4: I see no point to the SMPS data presented. It only covers a fraction of the time period under study (for some reason which is not explained). As presented, I don't see how this section adds anything to the analysis.

The SMPS data serve to add another instrumental result that further underscores a difference between the early period and the later period. Given reviewers' comments about lack of support for conclusions, it is felt warranted to include all lines of evidence. However, the way in which these data are presented has been modified; see below.

Section 3.5.1: I see very little point to this section.

Understanding the general climatic context is important to get a feel for the extent to which the meteorological context observed during the monitoring timeframe is typical or represents an anomaly. I this case, the observing period did indeed represent a strongly anomalous period; an overview of mean climate helps to clearly make that point. Knowledge of the mean climate state also allows the reader to understand why April tends to be period during which Arctic Haze is commonly observed.

Pg 16503 Line 19: What are the exact ground-based observations being refer to here. Is it aerosol type?

The observations made by the instruments described later in the document. This has been modified to be clearer.

Pg 16504 Line 16: There are three option available. What was used to obtain the data in this study?

0.694 µm. This has been clarified in the manuscript.

Pg 16504 Line 17: "A delay in servicing ..." Not performing routine maintenance on an instrument does not mean the laser output would be reduced. Exactly what was the problem with the instrument? How exactly did this result in reduced performance? What was this reduction, a reduction in the intensity of the laser? How was this know to be the case? What evidence can be provided that increasing the averaging time produced good data? What performance check were done that indicated that the CPL was performing correctly? What about a reference that describes in detail the CPL?

The reviewer is correct re: what would and would not cause changes to laser output. The delay in servicing comment is not in fact particularly relevant and has been removed. We have added a CPL technical reference, Sassen and Khvorostyanov (2008).

Pg 16505 Line 3-7: Not sure what is refer to as "total signal" When cloud are present, you'll measure properties of the clouds, it is only when clouds are not present that you measure a signal that is the result of the molecules in the atmosphere and the aerosols. It would seem that to study aerosol, you would need to screen for clouds and remove the backscatter that result from molecules. Has this been done?

"Total signal" means that the backscattered signals from both the aerosol and air molecules (which produce only a slight depolarization) are added together. This means that with a depolarizing aerosol, the aerosol concentration in air has an effect on the total delta ratio. The text has been modified to be more explicit.

Pg 16505 Line 25: Can not aged aerosol obtain a new moisture coating if the relative humidity is high enough? Isn't the fact that aerosols have a moisture coating or not more of a function of their relative humidity history than of their age? It could be that aged aerosol are more likely to be found in low relative humidity environment, and hence not have moisture coating. The Sassen et al., 1989 is about stratospheric aerosols, can this research be applied to lower tropospheric aerosol, which is the focus of this research?

Yes, aerosol can get wet or dried out repeatedly during transport- it depends what the RH locally is. The Sassen et al. 1989 paper is about modeled stratospheric aerosols, but was done in the lab and is thus of general relevance and applicability. The point here is that fresh smoke would absolutely have near-zero δ, which means that, if the return is smoke, an elevated δ means that it definitely is not locally generated. The text has been modified to make this point clearer.

Pg 16505 Line 5: What were the exact channel thresholds used in the OPC measurements?

Diameter of 0.3, 0.5, 0.8, 1.2, 2.0, 3.4, 5.0, and 7.0 um for sphere with refractive index of 1.40+0i. This has been added to the text.

Pg 16508 Line 8: Please give a reference to the instrument itself and not just projects were it was used. In these other projects, was the OPC used on a balloon?

"Iwasaki et al., 2007" is the best paper for reference. In this paper is described the optical system and calibration method of the particular OPC used at Fairbanks. The OPC was used on a balloon in this project. This reference has been added to the text.

Pg 16506 Line 7: What quality-checks were conducted on the recorded data? Were zero (filter) air check conducted on the OPC? Was the OPC spectrum compared to the SMPS spectrum?

Quality checks: The OPC was calibrated before launching. In addition to aerosol counts there were house keeping data which were returned by the unit that monitored the state of the OPC system throughout its sampling run, including conditions of pump and laser diode. In addition, immediately after recovery at Fairbanks further checks were run in addition to acquisition of calibration data. This verified that the system was in the same working order after the observation period as it was before launching.

Zero filter air checks: This was checked just before launch and just after recovery.

SMPS spectrum conversion: This was not done. The OPC usually observed size distributions with optically equivalent size for spherical particle with certain refractive indicies. Our OPC was calibrated for spherical particles with a refractive index of 1.40 - 0i.

Pg 16506 Line 18: Where was the X-Ray analysis performed? How were the samples stored before analysis? How long after the project was the analysis conducted?

The x-ray analysis was performed at Lawrence Berkeley National Laboratory's Advanced Light Source. The samples were stored on slide frames in sample storage boxes designed to hold these samples. The boxes were kept in a clean laboratory at room temperature. Previous experience with DRUM samples showed that they are stable under these storage conditions (including sulfuric acid aerosols). The samples were analyzed approximately seven months after collection (the first available analysis run after the sample collection).

Pg 16507 Line 5: The logged time doesn't really matter. What was the sampling time for a scan? Were both up and down scans conducted, used in the analysis?

Each observation is made from a five-minute continuous sample. Both up and down scans were made in that interval. This information has been added to the text.

Pg 16507 Line 7: Why do the charge equilibrium first and the drying afterwards? This is typically done the other way around.

In fact no explicit desiccation is performed on the sample because it is typically not required in this region (the Alaska Interior). Air samples taken from an already very dry air mass are drawn into a heated room which further desiccates the sample. The sentence has been altered with this comment.

Pg 16507 Line 9: The use of a reference stream is very confusing. An SMPS does not need a reference stream. It is not clear how it is being used, nor what is being done with it. Combining a reference stream and aerosol stream will just increase the total concentration of aerosol. Why would this need to be done? This paragraph does not describe a standard usage of an SMPS. Either the limited description is wrong or it needs a lot more explanation because it is some special configuration.

The first author apologizes for allowing this into the document. The reviewers are absolutely correct of course; an SMPS does not need a reference stream. The description of the SMPS and of its use has been corrected.

Pg 16508 line 19: Wouldn't “dust” have a higher depolarization ratio?

Yes, dust is a strong depolarizer, but only when present in high concentrations/sizes.

Pg 16509 line 3-4: Don't understand this refer to time averaged values. Averaged over what time interval? When referring to time averaged values, a different symbol should be used.

Signals are normally averaged to reduce the effects of signal noise- no special symbols are needed. Signal is averaging over a 10-min period. We have added the averaging period note.

Pg 16509 line 4-6: Sure it could be interpreted as pollution but why can't it also be interpreted as nonpollution aerosols?

We considered this but concluded that the source was local pollution for two reasons: the strongest returns are confined to the boundary layer, and the backscatter does not exhibit the layering that is associated with long-range transport of aerosol. Elsewhere in this response we indicate that there is no non-urban local source for aerosols at this time in Interior Alaska.

Pg 16509 line 6: What evident is there of this gradual build up until 13 April? Can you add a plot showing the hourly 1-2 km (or some height interval) average measurement for the same time period on each day that the lidar was operated.

Agreed, there is no basis for a gradual change from the data as presented; we have removed the word "gradual". However there is more aerosol is present in the atmosphere by April 13.

Pg 16509 line 14: It may be clear to you that a changed happen in mid-April, but it is not clear to me from reading the paper up to this point. Can you provide a plot showing the time series of average data that will make this change evident?

On Figure 2, examining the lidar plots for April 4, 2008 and for April 15, 2008 we feel shows a very clear difference, e.g., the prominent layering that has appeared by mid April (April 15) where none existed earlier in the month.

Pg 16509 line 22-24: Since this paper is about aerosols, can a cloud masks be applied to eliminate (show in one color) areas of clouds?

No cloud mask would work under these conditions- aerosols and clouds frequently mix together.

Pg 16510 line 4-6: This suggestion is not useful. Without upwind measurements showing that this low level is not present, there is no way to infer that it is local. Furthermore, the lidar measurements give no information about the source of the aerosols.

Low-level and depolarizing returns are common in Fairbanks when low-level inversions build up during winter, trapping urban aerosols. A comment to this effect has been added to the text.

Pg 16510 line 6-7: On 9 April the extent of the boundary layer is lower; however, the aerosol are distributed over a smaller vertical extent. Hence, the concentration increases and more backscatter. The "slight" increase in vertical structure may be the result of increase sensitivity in the measurement with the increase in concentration. This statement need more evidences to support it.

We didn't understand this comment. If we are reading this correctly, the comment implies that aerosols somehow have to be trapped in the boundary layer, which isn't the case and which we haven't suggested.

Pg 16511 line 6-7: What was the reason for the element concentrations being below minimum. Was it an unusually low aerosol year, or was the experimental design to use 3 hour sampling in error?

The instrument was not in error – concentrations were simply low. In fact the period immediately preceding the start of the experimental timeframe had an extraordinarily low atmospheric aerosol loading, a fact that was apparent even with a gaze across to the mountains.

Pg 16511 line 9: "... the largest concentrations ..." What type of concentration is referring to here, number concentration or mass?

This is indicated on the plot – mass concentration. It is also stated on line 26 of the same page: "...low concentrations, on the order of a few nanograms per cubic meter..."

Pg 16511 line 14: Both size fraction have accumulation mode particles, so the fact the aerosol grow into accumulation mode particle is not important. The large particles due to long-range transport are likely in elevated layers. Having less mass in the upper size range could also be the result of a poor sampling inlet. This is a reason that the paper need to present a lot more information on the sampling method. Including a detailed description of the sampling inlet used. Were the particles sampled wet or dry? Was the relative humidity controlled and/or monitored? The Seinfeld and Pandis, 2006 reference is useless in this context.

CATHY

Pg 16511 line 20: It is not clear what is defining these time periods. Are they defined based on the elemental filter measurements? If so, why talk about "trajectories that cross Northern Russia near Norilsk"? This sentence doesn't go here. I can't see what defines the "Arctic Haze" time period.

To quote the sentence five lines previous, Pg 16511 line 15: "Four distinct, multiday "epochs" appear in the aerosol composition data ***as defined by variations in concentration***." We are not really sure how to make it clearer. We are telling the reader what defines a typical Arctic Haze time period because we assume most who read this paper are not immediately familiar with this. Thus we describe aerosol species make up and back trajectory typical of Arctic Haze. The Norilsk comment informs the reader as to the typical source region for Arctic Haze episodes. That is, we are dealing with point source data that, on their own, are of little particular use and which require a source region context. Without this material we would entertain complaints that would take on the form, "The authors have not stated what constitutes a "typical" Arctic Haze episode, in make up or in trajectory."

Pg 16511 line 28: If this time period is defined by the total of all aerosol components, this time series needs to be included in Figure 3. What elements are included in this "total"?

Nowhere do we state that the time periods are defined by total aerosol loading. It would not make sense to simply "add up" all the individual species; it would certainly defeat the point of conducting species-differentiated sampling, the purpose of which is to identify different processes/source regions that are at work.

Pg 16512 line 1-6: What about changes in the height of the boundary layer? The lidar measurements show that on the April 9 and 13 the boundary layer was a lot lower than on April 4. Hence, the increase in this time period is that the aerosols are trapped closer to the surface, therefore the increase. Can the aerosol concentrations be normalized by the height of the boundary layer? Can this height be given in the time series?

Poker Flat has almost no local sources during this time period for the elemental signatures we are observing (using the elemental ratios as signatures of the aerosol sources). If the drum was only responding to the BL's going up and down, then the elemental ratios would have remained the same as the concentration changed. However, the elemental ratios changed and they resulting elemental signatures are not representative of local sources, so the aerosol sources are not local. Also, the trajectories do go back to the source regions for these signatures during the identified periods. The soil signatures we saw are the same ones we see over the Pacific Ocean when Asian dust is passing over the region. Again, during those cases, we see the aerosol signature at ground level when there are no local dust sources present (e.g., as observed when monitoring has been conducted in the Aleutian Islands, for example) and while an Asian dust cloud is being transported over the region (mainly at altitude).

Pg 16512 line 14-15: Why was the SMPS not run during 7 April to 15 April?

A power supply problem to the small building housing the instrument occurred. A note to indicate this mechanical issue has been added to the text.

Pg 16518 line 18-19: What three time series? I don't see this. The SMPS doesn't cover enough of the period to be useful. The lidar data presented is only on certain days. The impact data shows changes that are probably related to changes in the height of the boundary layer. There is not enough information given to know how to reproduce these time periods in another data set or for another scientist to find them in this one.

The three time series refer to the data sets from Drum sampler, Lidar, and SMPS. We disagree, that the SMPS data are not useful. For the periods during which it was active - the early period and the late period - the instrument shows clear differences in particle size distributions. Lidar data were selected on the basis of relatively cloud-free periods during which the layering is clear enough to be discussed in a worthwhile manner. Regarding impact data measurements, there were no local sources for any of the species observed. Crustal species require a deflation source; the Alaska Interior was covered with snow at this time. Fire species require a forest fire; again, this period was well before fire season start in Interior Alaska. Thus the impact sampler is clearly not responding to local sources. We really don't understand the comment, that not enough information has been given to reproduce these time periods. We are presenting raw drum sampler and lidar output, and very simply processed SMPS data. We are presenting all the information that we have. Ultimately it is a matter of interpretation. All three time series show distinct differences at different times, especially the Drum sampler. Each data set on its own is not complete enough; that is the entire reason for bringing together as many data sources as were in operation at the time. If we felt there wasn't a reasonable story we would not have written it as such. Each author is very competent in working with and interpreting output from their instruments and we feel the conclusions regarding the four main periods are entirely defensible. This doubly so because the synoptic and trajectory assessments provide clear support for progenitor events in Asia. The process was to see what the instruments suggested then see if it made sense using synoptics. The text will be altered to make this process clearer.

Figure 2: The caption needs to define what is being presented. There is no need to repeat the date in the caption since it is given in the plot titles. State where these measurements are made, with what Lidar. State what is given on the top (black and white) and bottom plots. These look like just different representation of the same data at a quick look but I assume the black and white plots are the signal return and the color is the backscatter of some wavelength (which is not given). Without this information how can these figures and the paper be understood? Make horizontal extent of the plots fill a page. The x and y axis titles and labels need to be larger. All fonts in figures should be approximately as large as the text in the figure caption. What the color bar at the top represents needs to be defined in the caption. What wavelength is the data for? Caption should state that these are all the measurements obtained on these days (assuming this is the case). The same y-axis range should be used for all days or an explanation given as to why that is not possible. The text refers to Fig. 2A etc.; hence, letters (a,b,c,d,e,f) need to be included in the figure on each plot as labels. Also, need to indicate what white areas in the backscatter plots are the result of.

These are standard lidar presentations of backscatter strength (black and white) and depolorization (color). Lidar wavelength is 694nm.This caption and plot information have been extensively revised to be more legible and self-contained.

Figure 3: Again in this figure, the fonts are too small. Should be about the same size as in the figure

caption. Figure caption needs lot more information. Where were the samples obtained. What was the sampling frequency. What type of analysis was conducted to obtain the component measurements? What size range are these measurements over? Would not showing symbols for each sample be better? Legend should include the symbols for each element. The time period for each epoch should be indicated on each plot in this figure.

We have added the requested information to the caption to make it more self-contained. We weren't sure what was meant by "symbols"; assumed this meant a little dot or something for each discrete sample, rather than presenting it as a line. Agree about identifying the four periods onto the plot.

Technical Corrections

We agree with the following corrections and suggestions.

Pg 16501 Line 23: "In April 2008 the NASA" The 'In April 2008' is an introductory phrases and a comma is required after 2008. See http://englishplus.com/grammar/00000074.htm as one example that explains the correct usage of commas after Introductory Phases. There are many places in the paper where Introductory Phrases are not followed by the required comma. Each sentence in the paper needs to be reviewed by the author to see if a comma is required after an Introductory Phase. The lack of commas makes the science difficult to understand.
Pg 16501 Line 25: "... with a broader objective of placing this in the context of radiative forcing and climate change." This is a long and confusing sentence that seems to be a collection of phases. When you get to 'placing this' it is not clear what 'this' refers to. I suggest breaking this up into two sentences and being direct by stating what 'this' refers to.
Pg 16502 Line 5: "... the project oversaw ..." I do not understand how a project can oversee things. People oversee and have oversaw things. Better to say the project included ...
Pg 16502 Line 6: "of atmospheric chemistry state". Isn't there a 'the' missing here?
Pg 16502 Line 8: "... focuses on the meteorological context ...". Really? There is nothing about the meteorology presented in the abstract. The conclusion given in the abstract talks about finding four different types of aerosols.
Pg 16502 Line 11: Another example of a comma needed for Introductory Phrase.
Pg 16502 Line 15: "Each provided ..." Be direct and state that it is "Each instrument provided ..."
Pg 16502 Line 15-16: Don't believe the hyphen is used correctly here. Probably want to enclose things in parentheses. The inclusion of nature, and quantity is confusion in the list. Seems like this should not be in the list but a description of type of measurements. Please re-word and make clearer.
Pg 16502 Line 17: Another example of a comma needed for Introductory Phrase.
Pg 16502 Line 17: Defining the measurement focus for this paper does not belong in the Introduction Section but in the Methods section. Here define and give background on the general objectives and questions to be addressed.
Pg 16502 Line 20: "... companion papers" It doesn't do the read any good to talk about these papers without given reference to them. Are these only planed paper and hence can't be referenced? If so, I don't think should be mentioned.
Pg 16502 Line 22: Another example of a comma needed for Introductory Phrase. I'll stop pointing these out from now on.
Pg 16502 Line 22-26: Please don't just state the Fuelbuer et al., 2010 talk about things but instead summary what was most important from that paper for understanding the research presented in this paper.
Pg 16502 Line 26: "The synoptic objective" There doesn't seem to be a non-synoptic objective. Isn't this just the objective of the paper that is being talked about here? Be more direct, "The objective is to build upon the ..." or "Our objective is to build upon .."
Pg 16503 Line 5: There is nothing related to this task presented in the abstract.
Pg 16503 Line 11: A reference to the Web or FTP site where the data was downloaded from would be

useful.
Pg 16503 Line 19: The use of 'were used'. The paper is reporting on this project so shouldn't it be present tense?
Pg 16503 Line 19: “The extent to which patterns ...” I see no point in this sentence. Describe the patterns and then state if they are typical or anomalous. This type of foreshadowing just goes to make scientific paper unnecessary long.
Pg 16503 Line 21: “typically mid to low-troposphere pressure level were used ...” Simply state what is done in the analysis methodology. Exactly what levels are used? Again, the use of past tense here is confusing.
Pg 16503 Line 23: “selected trajectory analyses ...” What exactly are these analyses?
Pg 16504 Line 2: “observationa array” Figure 1 does not indicate sampling locations. Just gives the location of Fairbanks and Anchorage. Figure caption states that measurements were obtained at Fairbanks “or” Poker Flat. Hence, two locations, with different instruments at both does not make an “observational array”.
Pg 16504 Line 5: This sentence is mixing an instrument description with analysis method. First describe the instrument and then talk about how measurements from them were used. Furthermore, talking about a case study analysis does not belong in a section describing the measurements used in the research.
Pg 16504 Line 21: “To obtain ...” This sentence is unnecessary long and confusing.
Pg 16505 Line 2: Missing some words in this sentence. The subscripts are defined but not the variables (beta, P)
Pg 16506 Line 10: This foreshadowing is not necessary. Delete sentence and add more information about the instrument. For example, what is the angle over which the aerosol light scattering is measured with the OPC. What frequency is the data recorded at? Is any dilution system used with the instrument? Was conductive tubing used throughout the aerosol inlet? What flow rate was the air flow sampled at? What aerosol reflective index was used to obtain particle size?
Pg 16506 Line 13: It has already been stated that the Poker Flat facility is 50 km north of Fairbanks, don't need to repeat it here again.
Pg 16506 Line 15: The Mylar strips are part of the sample so it is not possible for the instrument to “deposit” aerosol onto them. Please rephrase.
Pg 16506 Line 16: “was operated continuously ... “ between is better to use that over. Please give what the three size ranges are.
Pg 16506 Line 23: Again, it is not right to refer to a companion paper without providing the reference. Information about performance tests of the impact sampler is needed. Were blanks used? Were zero air performance test conducted? What procedure were used so samples were not contaminated?
Pg 16507 Line 12: “... these data” Be direct, state exactly what data you are talking about. How much variance in the data did the first two principal components account for. Need more details. Maybe this should be moved to a later section. After reading the rest of the paper, I see that this is talked about later; hence, delete here.
Pg 16507 Line 15: Again, don't talk about another paper without a reference.
Pg 16507 Line 20: Things are backwards here. A conclusion is stated before showing any time series data. Move remarks such as these to a Discussion Section. Present the data here.
Pg 16508 line 4-6: The need to state what is presented below and what will be present later indicates that the paper is not organized correctly. In a well organized paper, these types of statements are not needed. Delete/move this overview section, just start talking about the data collected.
Pg 16508 line 8-9: Again, this is an interpretation which needs to go after the data (measurements) are presented.
Pg 16508 line 13: “aerosol physical depth”, This is not good terminology. There are aerosols throughout the troposphere even if the Lidar doesn't get a backscatter return from them. Could use “that the depth of the lower troposphere increased”; however, you'll have to define what “lower troposphere” means or provide a reference or both.

Pg 16508 line 19-20: Sentence that tell what is discussed in other section indicate poor organization.
Pg 16508 line 21-25: The paragraph is out of place. Be direct and say these are periods when the Lidar was operated.
Pg 16508 line 26-27: Delete
Pg 16508 line 26-: Out of place, conclusion before showing the data.
Pg 16509 line 16-20: This information needs to go into the figure caption, not in the text. Figure captions should fully describe what is being presented in the figure, independent of the text. The text should discuss what interpretations the author believes show be taken from figure. The figure should include a legend showing the range of lidar power returns.
Pg 16509 line 21-22: Already discussed. Delete
Pg 16510 line 1: The plots should indicate that they start at 0.5 km. This is not clear in the plot. Label the lowest value. The figure caption show note that data in the first 200 m are not given because they are unreliable. This should not be noted in the text but in the figure caption.
Pg 16510 line 8: Again the conclusion is presented before the argument that leads to the conclusion. This is problem is apparent throughout the paper.
Pg 16510 line 9-11: Don't see what the discussion about the clouds add to this paper. I suggest to stay focused on the aerosols.
Pg 16510 line 19: "fine horizontal layers" Can a reference be provided to back up the statement that this is common for associated with long-range transport?
Pg 16511 line 15-19: Again the conclusion comes before the argument. Need re-organization. Also, I personally don't like the use of the term "epochs". Epoch is a "time in history". These time periods are not historical, they just refer to this time series of data. Better to use "multiday time period" or "time period".
Pg 16512 line 16-17: I had the question of how much of the variance was accounted for by the two components previously when reading the paper; hence, the paper is not well organized. Please address. Please give how much was accounted for in the first component and how much in the second.
Pg 16512 line 17: The component score needs to be defined.

Reviewer 2

This manuscript uses lidar data, chemical data from a DRUM sampler, and size distribution data from SMPS and OPC to describe changes in air masses over Fairbanks in April 2008. The manuscript reads like it was rushed to meet a deadline. It is poorly organized, repetitive, incomplete (what is the upper panel in figure 2, where is the legend in figure 9, the legend I figure 21 is not readable, the methods are poorly defined with nothing to assure us that they are meaningful), and grammatically challenged. Did the co-authors read this manuscript?
Scientifically the paper tries to identify distinct layers of aerosols with a lidar and then define these layers with ground based chemical measurements. This makes no sense to me at all. The limited SMPS data are used to describe two "components". Is there any statistical bases for this? Are the number size distributions below 3450m really different?
There may be a manuscript in this data set but it is not clear to me from what is presented here.

These comments fit under the general category of organization, which has been extensively dealt with via the more detailed comments provided by the other reviewers. Regarding the scientific objective, with respect, the reviewer is in error. The objective is not to use lidar to identify layers and then define them with ground based systems. Of course that makes no sense; the observations are not spatially coincident. Lidar results were interpreted to the extent that they could be on their own. Use of the ballon OPC sonde aided this process because it did afford an opportunity to conduct in situ size fraction sampling of layers the lidar was directly sampling. Use of the other, ground-based instruments was confined to defining the

occurrence and possible source for major aerosol events. This helped to then set the context in which lidar data were interpreted. The fact that the science objective was misconstrued we consider to result from shortcomings in the writing and manuscript organization, which have been heavily modified and which it is hoped result in greater scientific lucidity.

Regarding the SMPS data, the PCA approach has been dropped in favor of simply considering a representative fraction of "small" vs "large" particles.

Reviewer 3

This is a useful data set of aerosol properties in the Arctic that encompasses four distinct synoptic and aerosol source classes. It would be more valuable if more context to the broader ARCTAS experiment were added. Somehow this data and analysis need to be linked to the broader objective of ARCTAS in the context of radiative forcing and climate change.

We have inserted text to more clearly establish this linkage.

The title does not reflect the data or science of the manuscript. It is not only groundbased. It also includes remote sensing and sonde-based data. It focuses on aerosols and aerosol properties neither of which is mentioned in the title.

This is a valid point; the title will be modified accordingly.

Given that the drum sampler and meteorological data are the most complete and useful to ARCTAS goals and that they have been or are being published elsewhere (a companion paper and Fuelberg 2010) the value of this particular manuscript is in question. Significant revisions will be required to address the specific points enumerated below. The list is not exhaustive but point the direction of revisions that are needed.

These particular DRUM data will not be published elsewhere as things have turned out; the text will be changed to remove reference to a "companion paper". The Fuelberg paper conducts a much broader context for the entire mission, which ranged well over the Arctic Ocean, Canadian Arctic Islands, and Greenland. The synoptic contribution here is highly focussed on aspects of relevance to interpreting the aerosol loading time periods observed in the instrumental time series. Better clarification of the distinction between the two papers is in order, however, and has been added.

P16501 Asian smoke This term is not clear. Based on the discussion I would recommend this be termed

Agreed; this will be altered to "Siberian fire smoke".

P16503 "Epoch" isn't quite the right word. I suggest rather "event", eg., Identify the major atmospheric aerosol events . . ...

Agreed; this will be altered.

P 16504 observations (sp) Leave out mention of the radar if not used here. It is referred to in section 4 and supposedly section 4.1 but I cannot find that section or discussion.

Agreed; dropped.

P16505 The phenomenon of increasing d with particulate age occurs as the aerosol loses its moisture coating, exposing the irregular aerosol surface (Sassen et al., 1989). I would suggest that this is not the only mechanism for increasing d.

"Increasing D" - increasing delta (depol ratios). The first statement is expanded in the text – it is mentioned that particle coagulation could also lead to more irregular particle shapes and an increase in delta.

P16507 .. ingest.. I don't understand this term in this context. Is aerosol inlet flow meant?

Yes; this has been changed to more accurately reflect the process.

. . . differential mobility analyzer (DMA model 3071, TSI, St. Paul, MN, USA) . . . . condensation nucleus counter (CNC model 3010, TSI) . . .. . .

Changes to instrument reference made.

What was the inlet flow, to what RH was it desiccated, and how was this done?

GLENN + Calculate RH

How was the charge neutralization done to achieve Boltzmann equilibrium charge distribution. Reference Wiedensohler (listed but not used) here in this context.

Wiedensohler has been referenced.

I don't understand the purpose of the ammonium sulfate aerosol. Were there two SMPS systems? Or are the ambient and sulfate aerosol alternated. The Wang and Flagan reference is an adequate description for most of the SMPS. Explain what is different here eg, inlet, desiccation, sulfate reference.

Our apologies; the reference stream comment is in error – there was no reference stream – and the text has been modified. Instrument operation is standard for an SMPS.

Also what SMPS inversion program was used?

A commercial program that is sold by TSI, the instrument manufacturer. This is a standard, off the shelf program in wide use by the community. We have added reference to this in the text.

Was a size calibration of the SMPS system done, eg., with monodisperse sulfate or latex sphere particles?

Yes, calibration was performed using monodisperse Dow-Corning sulphate spheres.

Sun photometer and nephelometer are two very different types of instruments. What is meant and how do those relate to this study? If relation is minimal delete the sentences.

Reference to these instruments is not relevant has been dropped.

Terminology in section 3.1 is unusual. Opacity was not measured. I would term the four events to be - atmospheric aerosol events that differed significantly with respect to aerosol physical, chemical and optical properties. Quantify "significantly" here or later. The discussion revolves around aerosol types or events not aerosol activity – the term is usually reserved for cloud condensation activity if at all.

We agree with this and have modified the terminology. We have introduced aerosol event averages and standard deviation values for which a standard t-test has been conducted to establish "significance" in its proper statistical context.

Items 1 through 4 here are simply terms applied to the identified events. Define these aerosol types broadly including what is meant by pristine and smoke. Biomass burning smoke, long range transport of urban and industrial emissions, etc.

We have added more detailed descriptions.

P16508 The discussion in 3.2 relates to figure 2. State that early in the paragraph and refer to plots in figure 2 by date along with the discussion points. The lower panel in each plot is obviously depolarization ratio and the color scale is given. Is the upper plot backscatter signal? If so is it range corrected. This information should be in the figure caption. The dates in the figure caption are redundant with the heading on the plots themselves. Provide a quantification for the gray scale of the upper plot. Have the data been cloud cleared? Can a lidar ratio be applied?

A cloud filter was not applied because cloud and aerosols are often mixed.
RATIO? KEN?

P16509 Second paragraph answers some of above points. This paragraph should be earlier in the section or part of the instrument description as should the information about the overlap region. The color scale is at the top of figure 2 in the PDF file I received. In the discussion refer to color as well as altitude when point out depolarization events or layers for reader who are less versed in the interpretation of lidar data. There is considerable redundancy in the discussion of the lidar data in 3.2. It should be consolidated.

Understood. Significant structural reorganization and consolidation has been undertaken (see main response comment near top) to address these sorts of flow issues.

" weak boundary layer aerosol . . ." The aerosol is not weak. It is the lidar backscattering signal that is weak. Attention should be paid to the using best possible terminology throughout.

Fixed this.

P 16510 "The displays for the afternoon of 21 April (Fig. 2e) reveal a shift to still more strongly backscattering and depolarizing aerosols." Was the change in backscattering due to a change in particle size or concentration?

Particle concentration.

P16511 All of the aerosol concentrations obtained . . . All of the aerosol chemical mass

concentrations obtained . . .

Fixed this.

The peak mass concentration of sulfur is of little importance or interest. An event average would be more useful as a measure of the generally low species concentrations.

Cathy comment

This comment applies to later mention of spikes as well. The event average values, standard deviations and experimental uncertainties should be presented in a table as well as mentioned in the discussion.

Cathy comment. Should we do this? The point in my mind is the evolving time series story. Perhaps an average and sd for each time period; this might help the other reviewer who simply couldn't understand where the time periods had come from.

". . . nanograms per cubic meter . . . and . . . microns" can be abbreviated ng/m3 and μm, respectively, as in the figures.

Fixed this

Cloud processing and wet deposition are important over the time and distance scales of consideration here. Wet deposition is mentioned later with reference to this section but not mentioned here.

Fixed this

Which chemical size fraction is shown in figure 3? Section 2.2.3 only mentions one size increment. The caption in figure three should state the size range, eg., Drum sampler chemical species concentrations in the size increment x.xx to x.xx μm.

Fixed this

P16512 While SMPS data is highly valuable in general, the fragmented data set that was obtained here is of less value. The early and late periods should be specified with respect to how they fit in the four events. Given the limited data the principle component analysis is of no value and should be deleted. Simply present the size distribution and how it fits with the one OPC sonde data in the surface layer. Unfortunately the SMPS and Drum Sampler size ranges to not overlap well enough to allow any valid comparison of chemical mass with total volume or mass (assuming a density).

The PCA ananalysis has been removed. Instead time series consisting of averages of multiple channels for two representative size fractions ("small" and "large") have been introduced.

Loading patterns (not shown) indicate smaller size fractions (126 nm– 1000 nm) . . ... This is not clear since the SMPS upper size limit was 280 nm.

This has been removed altogether with the PCA analysis.

P16513 3.5 Regional-scale climate This is not climate but regional to continental scale

synoptic meteorology.

Agree in principle but verify text.

P16514 Figure 5 is a 925 mb geopotential height plot not a 'Pressure at 925 mb" - which does not make sense. Figure 6 caption should identify this as a geopotential height anomaly plot. The units of the scales should be included in the caption.

We have fixed this mistake and added units.

P16516 Without a size scale legend for the profiles in figure 9 it is impossible to make sense of the discussion. Reference is made to the high concentration of 100/cc. This is not high for remote continental conditions. The total aerosol number concentration should be given as well but not as a profile plot rather as the average for each identified layer. Figures 9, 10 and 11 are largely redundant and, given the log scales involved hard to interpret. Provide table of layer average values, total and for specific size increments, and figure 11 only.

VERIFY

References to be included

Hayashi, M., Iwasaka, Y., Watanabe, M., Shibata, T., Fujiwara, M., Adachi, H., Sakai, T., Nagatani, M., Gernandt, H., Neuber, R., and Tsuchiya, M.: Size and Number Concentration of Liquid PSCs: Balloon-Borne Measurements at Ny-Alesund, Norway in Winter of 1994/95, J. Meteorol. Soc. Jpn., 76, 549--560, 1998.

Iwasaki, S., Maruyama, K., Hayashi, M., Ogino, S.-Y., Ishimoto, H., Tachibana, Y., Shimizu, A., Matsui, I., Sugimoto, N., Yamashita, K., Saga, K., Iwamoto, K., Kamiakito, Y., Chabangborn, A., Thana, B., Hashizume, M., Koike, T., and Oki, T.: Characteristics of aerosol and cloud particle size distributions in the tropical tropopause layer measured with optical particle counter and lidar, Atmos. Chem. Phys., 7, 3507--3518, href{http://dx.doi.org/10.5194/acp-7-3507-2007}{doi:10.5194/acp-7-3507-2007}, 2007.

Masaharu Watanabe, Yasunobu Iwasaka, Takashi Shibata, Masahiko Hayashi, Motowo Fujiwara, and Roland Neuber. 2004. The evolution of Pinatubo aerosols in the Arctic stratosphere during 1994-2000, Atmos. Res., 69,199-215, 2004

Kenneth Sassen, Vitaly I Khvorostyanov. (2008) Cloud effects from boreal forest fire smoke: evidence for ice nucleation from polarization lidar data and cloud model simulations. *Environmental Research Letters* **3**:2, 025006

Wiedensohler, A. , An approximation of the bipolar charge distribution for particles in the submicron range, *J. Aerosol Sci.*, **19**, 387-389, 1988