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Atmospheric Chemistry and Physics Discussions

Interactive comment on "In situ measurements of aerosols optical properties and number size distributions in a subarctic coastal region of Norway" *by* S. Mogo et al.

S. Mogo et al.

sipmogo@gmail.com

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This comment addresses the concerns raised by Anonymous Referee #1. We wish to thank the Referee for his interest in our work and his comments on the manuscript. The follow is a point by point response in which we intend to show how we had addressed each item mentioned in the review.

The main concern of the Reviewer is related with the lack of support data for particular transport events. We improved the manuscript by fully describing these aspects. The suggestions and corrections pointed by the Reviewer were accepted and are detailed

as follow.

Specific comments

- Title: Why is "subarctic" used in the title when the measurement location is north of the Arctic circle? Is it because the climate of this region is more typical of subarctic regions than regions further north? This may be confusing to some readers who, based on the title, will think the site is located further south than it actually is.
  The title is changed now and we explain in the text that due to the climate of the region the station is considered subarctic. In the section "2.1. Site description" we added the following explanation: "Despite being located north of the Arctic Circle, the station is considered sub-arctic due to the climate of the region."

- p. 32924, lines 22 - 24: What concentration of light absorbing particles does the albedo reduction of "1 to 3 %" and a "factor of 3" correspond to?
  We added this information in the text: "Clarke and Noone (1985) found that for a mass fraction of 10-40 ng g^{-1} soot, the snow albedo is reduced by 1–3 % in fresh snow and by a factor of 3 as the snow ages and the light-absorbing particles become more concentrated." More recent references were aldo added to the manuscript by suggestion of reviewer #2.

- p. 32924, lines 25 - 27: What is meant by "remote background aerosols"? In particular, how do they differ from "natural particles"?
  This is now clarified in the manuscript: "The Arctic summer provides an excellent environment for studying remote background aerosols (those containing natural compounds, such as sea salt and sulfuric acid, and anthropogenic pollutants, such as soot, resulting from transport to the region), as there are few local sources of anthropogenic particles."

- p. 32927, line 12: change to "...can occur in the summer..."
  Done.

- p. 32928, lines 6 - 7: The flow was controlled once a day or measured once a day?
  Corrected: "The flow to each instrument was measured once a day using an electronic bubble flowmeter (Gilibrator system, Gilian)."

- p. 32932, lines 27 - 28: Show the back trajectories for the periods of high scattering Angstrom exponents to verify that the source of the aerosol was long range transport from Southern Europe.
  This was an error in the manuscript, we didn't mean "from Southern Europe" but southern generically. We changed the text to: "These values may be due to long-range transport episodes from Central Europe and Russia." In the new Figure 1 the air mass arriving from the sector 2 (day June 21) is presented as an example of this situation. Explanation is added to the manuscript in the Section 3.1.

- p. 32933, lines 10 - 13: How were the dust events confirmed by CIMEL data - observations of high optical depths values? It would be helpful to show back trajectories and a MODIS image from these events.
  This explanation has been added to the manuscript: "If the daily aerosol optical depth exceeded a threshold value (given by the annual mean plus one standard deviation) and the extinction Ångström exponent was lower than 1.1, the day was classified as possible aerosol dust event (Rodríguez et al., 2011). The back trajectories and MODIS images were then analyzed to confirm the dust events." During the period reported in this paper, no evident dust event was observed and the possible dust that arrived at the station was always mixed with pollution or other particles making it difficult to show the exact source. However, a more clear event was detected on 31 May-5 June 2008 (Cimel data), before we started the in situ campaign and another event was detected in the same station and reported

by our group the year 2007. This event is fully described in Rodríguez et al. (2012), including the dust aerosol optical depth provided by the NAAPS model, the aerosol optical depth and the Ångström exponent provided by the Cimel sun photometer and the MODIS-Terra sensor. The reference to this event is also added to the manuscript, Section 3.1.

- p. 32934, first paragraph: It would be helpful to put the other stations that the ALOMAR data are compared to in the map shown in Figure 1.
  Done.

- Figure 5: In the figure, indicate the periods of each of the three types of aerosol conditions described in the text on p. 32934.
  Done. The new particle formation events are now indicated by arrows and the other periods are well identified in the figure's caption.

- p. 32935, first paragraph: Can anything be said about the source or composition of the newly formed particles based on measurements or the trajectory analysis? What air mass sector did they correspond to? Were they associated with frontal activity and subsidence from the upper troposphere? This type of discussion should be included here or in Section 3.4.
  We included this discussion in section 2.4. To relate the air masses with the source of the newly formed particles, the mixed layer depth was obtained from the Hysplit model, and the air mass for new particle formation event days was considered as a source of the aerosol particles that arrived and formed close to the measurement point if the 500 m air mass was inside the boundary layer for the majority of the time. In this work the connections between synoptic weather conditions and new particle formation events haven't been detailed, however Rodríguez et al. (2011) found that the air masses arriving from NNE, NW and W (for which the new particle formation events occurred more frequently) were associated with low-pressure systems, and precipitation was frequent for these cases.

We realize the importance of such investigation but we leave this analysis to future works in the region with more days available for the analysis.
This information has been added to the manuscript in Section 3.2: "The trajectory arriving from sector 4 (day August 3 - red line) is presented as an example of the most common air mass associated with the occurrence of new particle formation events. Thirteen cases were identified as potential new particle formation events; 54 %, 23 % and 15 % of those events corresponded to air masses arriving from sector 4 (NNE), sector 6 (W) and sector 5 (NW), respectively. These results are in agreement with the results published by Kulmala et al. (2005) for the Hyytiälä station and with those of Maso et al. (2007) for four Nordic stations (Hyytiälä, Aspvreten, Värriö and Pallas), which established the Arctic and North Atlantic areas as the sources of air masses leading to new particle formation."

- p. 32936, first paragraph: Describe the composition of the aerosol measured at the ALOMAR station and the criteria for inclusion in the "Northern European Aerosol" group.
This conclusion is based on the bimodal shape of the median size distribution, on the concentrations of the particles in each size range and on the shape of the area with greatest density of points in Fig. 7 (included now as supplementary material). The location of this area in Fig. 7 is typical of stations dominated by clean continental and atlantic aerosol with occasional influence of more polluted air masses. All the paragraph has been changed and this explanation has been added to the manuscript:"Based on the bimodal shape of the median size distribution, on the particle concentrations for each size range and on the shape of the area with the greatest density of points in the N_{30-100} versus N_{100} scatter plot, we conclude that the ALOMAR station is sufficiently similar to other Nordic stations and can be included in the group "Northern European Aerosol". This classification was presented by Asmi et al. (2011) (including the stations of Birkenes, Vavihill, Aspvreten, Hyytialä and Pallas), which refers to stations that are sufficiently

similar, with regard to these parameters, to be described as the same type dominated by clean continental and Atlantic aerosols but with the occasional influence of more polluted air masses." Further discussion on this point is now included as supplementary material.

- p. 32936, lines 8 - 21: The discussion of the Angstrom Exponent for scattering indicates that "two lines appear to represent different aerosol types" is not consistent with the statement in the previous section that the particulate composition at the ALOMAR station fits into the group "Northern European Aerosol", i.e., that there is only one aerosol type. Explain.
"Northern European Aerosol" is a classification based on the criteria from Asmi et al. (2011) that refers to the shape of the scatter density contour plot of the concentration of the particles in the Aitken mode versus the concentration of the accumulation mode. This classification doesn't mean that there is only one aerosol type, since the concentration of particles in each mode can be due to several aerosols types, including those resulting from new particle formation events and those transported to the region.

- p. 32936, lines 15 - 16: Can't the line with the smaller slope also correspond to dust particles since they are also relatively large in size?
Yes, in case of desert events, the dust particles also contribute to this line. This information has been added to the manuscript as follows: "The slopes of these lines depend on the particle size; therefore, these two lines appear to represent different aerosol types, and the Ångström exponent can be used to help identify the aerosol types, that can be the result of transport from different regions. The line with smaller slope is associated with larger particles and marine aerosols (also dust particles during desert events)."

- p. 32936, last sentence: Describe the physical signiĩňĄcance of the observation that "...decreases quickly in the 450nm/550 nm range and decreases less

abruptly in the 550 nm/700 nm range..."
This observation means that both coefficients are more sensitive to spectral variations at low wavelengths than at high wavelengths of the visible spectrum. This explanation has been also added to the manuscript.

- p. 32938, first paragraph: Why aren't MODIS images and CIMEL data included in the manuscript? A comparison of the surface in situ measurements with the column CIMEL data would indicate how representative the surface measurements are of the atmospheric column.
Yes, we agree with the reviewer at this point but there is a strong limitation to this comparison in our field study due to the short term of the campaign. Actually, the comparison of the surface in situ measurements with the columnar data is allays a complicated issue even in more favorable conditions of measurement. But in the ALOMAR station the problem is intensified by the strongly limited number of days with available columnar data due to cloudiness over the region. This situation leaves only a few days with data available from the CIMEL instrument and no significance can be attributed to the results. Because of this reason, the usefulness of the columnar data becomes restricted to punctual events that occur in days with clear sky. We added to the manuscript two references (Rodríguez et al., 2011; Rodríguez et al., 2012), where our group presents some of these events including CIMEL and MODIS data for the previous year (2007) but then no in situ data was available.

- Figure 12: It would be most convenient for the reader if the map shown in Figure 1 with the classiïňĄcation of air mass origins were shown here.
Figure 1 now presents the typical trajectories for each air mass origin classiïňĄcation. This location for the figure does not make sense any more, because with the new structure of the manuscript, the typical trajectories are discussed together with the aerosol parameters.

- Section 3.4: Typical trajectories for each air mass origin classiïňĄcation should be shown in a figure. Without seeing the actual trajectory, the reader does not have a sense of the distance the air masses traveled over the course of 120 h, and hence, has no idea of the actual source region. Do any of these calculated back trajectories support transport of dust to the site as hypothesized earlier in the paper? What regions of Southern Europe were responsible for the high scattering Angstrom Exponents shown in Figure 12 for air mass sectors 1, 2, and 3?
As we said before, figure 1 now includes the typical trajectories for each air mass origin classiïňĄcation. Unfortunately, no evident dust event was observed during the period reported in this paper and the potential dust that arrived at the station was always mixed with pollution or other particles making it difficult to track down the exact source. However, in August 2007 our group detected the presence of coarse dust aerosol particles in Andenes and that event is reported and fully analyzed in Rodríguez et al. (2012) (the dust aerosol optical depth provided by the NAAPS model, the aerosol optical depth and the Ångström exponent provided by the Cimel sun photometer and the MODIS-Terra sensor are presented in that work for the days of the event). This explanation has been also included in the manuscript.

- p. 32942, line 20: change to "...during the summer of 2008 at the ALOMAR station..."
Done.

- p. 32942, lines 26 - 27: change to "...leading to high single scattering albedos..."
Done.

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