

Interactive comment on “Absorption, scattering and single scattering albedo of aerosols obtained from in situ measurements in the subarctic coastal region of Norway” by E. Montilla et al.

E. Montilla et al.

sipmogo@gmail.com

Received and published: 27 March 2011

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.

General comments

The main concern of the Reviewer is related with the lack of aerosol composition data but an investigation of aerosol chemistry was out of our goals with this paper. This

C1216

paper is not intended for an identification of sources for the subarctic aerosol, it is only directed to the evaluation of the optical parameters of aerosols and all the possible information that can be inferred from the optical properties.

We don't have any chemistry available for the period of this campaign but we did measured in previous campaigns the composition of local particles with a cascade impactor and posterior filter analysis by gravimetry and ionic chromatography for major anions and cations (Rodríguez et al., 2008). We tried on this work not to use more information than that provided by the optical data but, as the Reviewer made clear, we couldn't avoid in some points to present conclusions and comments based on other data we know. We corrected this point on the final version of the manuscript.

The other main suggestion of the Reviewer is the addition of trajectory analysis. This analysis had actually been done for the campaign and is being done for a period of several years, since our group started the measurements in the ALOMAR station. A detailed study is under revision for the Quarterly Journal of the Royal Meteorological Society: *Rodríguez et al., Aerosol characterization at the sub-Arctic site Andenes (69° N, 16° E), by the analysis of columnar optical properties*. For the period of this campaign some special events were selected for further evaluation. During those events the size distributions of aerosols in the fine and coarse fraction is also available (obtained from a SMPS and an APS) and the corresponding back trajectories were further examined. This can be made clear on the text.

The remaining suggestions and corrections pointed by the Reviewer were accepted and are detailed as follow.

Specific comments

- *Abstract, line 7:*
Yes. We mean “... which frequently are transported to the Arctic region”. The manuscript is now corrected.

C1217

- *Abstract and throughout:*
The Referee is completely right. We revised the accuracy of values presented to 1/100.
- *p.2163, lines 5-15:*
We completed the discussion with the following: "... Sulfate and nitrate aerosols from anthropogenic sources, are considered the primary particles responsible for net cooling. They scatter solar radiation and are effective as cloud condensation nuclei affecting the lifetime of clouds, the hydrological cycle and resulting in a negative radiative forcing that leads to a cooling of the Earth's surface. To some extent, they are thought to counteract global warming caused by greenhouse gases such as carbon dioxide (Boucher and Haywood, 2001). Sea salt and non-sea-salt sulfate have been reported as dominating the light scattering in the Arctic (Quinn et al., 2002). Also, for the Arctic, previous papers have reported the occurrence of large concentrations of biogenic scattering aerosol derived from the oxidation of atmospheric dimethylsulfide which results from oceanic phytoplankton processes (Quinn et al., 2002). The organic species have also been suggested as playing an important role for aerosol light scattering (Quinn et al., 2002). All these species have been reported as important components of the Arctic aerosol (Quinn et al., 2002; Ricard et al., 2002a,b; Leck and Bigg, 2005). On the other hand, light-absorbing particles, mainly ..."
- *p.2163, lines 20-22:*
We fully agree with the referee and changed the sentence accordingly.
- *p.2164, lines 20-25:*
We provided a better explanation for the spectral dependence of σ_a , σ_s and ω_0 as follows: "In the present work only results from aerosol absorption and scattering measurements are presented. Our primary goal was to investigate light absorption / scattering coefficients and their Ångström exponents, α_a , α_s , together with

C1218

the single scattering albedo. The Ångström exponents are described using an exponential fit, λ^α , that describes the dependence of the optical parameters on the wavelength. The determination of optical parameters as a function of wavelength is useful to distinguish between different aerosol types. For example, Rosen et al. (1979) measured $\alpha_a = 1.0$ for urban aerosol and Bond (2001) studied the spectral dependence of visible light absorption by carbonaceous particles emitted from coal combustion and found strong spectral dependency, $1.0 < \alpha_a < 2.9$, Mogo et al. (2005) measured on a coastal site in south Spain and presented $0.2 < \alpha_a < 2.0$ for the visible range of the spectrum and $0.2 < \alpha_a < 2.5$ for the UV range. Data with high spectral resolution is also presented for this campaign in ALOMAR by Montilla et al. (2011). On the other hand, the α_s can be used to infer information about the size of the particles as it relates inversely to particle size (Russell et al., 2010). Pereira et al. (2011) presented $\alpha_s = 1.4$ for aerosols dominated by sub-micrometer particles and Collaud Coen et al. (2004) presented α_s lower than 0.5 during Saharan dust events at Jungfraujoch. Also the wavelength dependence of ω_0 is characteristic of different aerosol species. Dubovik et al. (2002) found that for urban-industrial aerosols and for biomass burning the ω_0 decreases with increasing wavelength, while for desert dust, ω_0 increases with increasing wavelength (Collaud Coen et al., 2004). This wavelength dependence inversion can be explained by the greater size of the particles, for which the scattering process is dominated by geometric processes and should be wavelength independent. Furthermore, some dust particles are strong absorbers (as hematite) and the increase of absorption together with the decrease of scattering also can contribute to the change of ω_0 from positive to negative slope."

- *p.2165, lines 5-7:*
Corrected according to the Referee suggestion.
- *Section 2:*
The data is corrected for truncation errors according to Anderson and Ogren

C1219

(1998) and this is now made clear in the manuscript.

- *Section 3:*
As we said before, the values presented were reviewed to 2 significant figures.
- *p.2168, lines 0-4:*
Correct. We changed the statement to “The range of values of σ_s is ten times larger than the range of values of σ_a ”.
- *p.2168, lines 14-21:*
The station is located at a much higher level (380 m) respect to the possible sources. Almost no vehicles are driven to the the station and no snow mobile works there at that time of the year. There is a small airport near but we don't considered it could be responsible for the lower values presented as no special activity was registered on the airport on these days. Only 7 points were registered bellow 0.7 and most of the values are above 0.8. The seven points occurred at different hours of the day and no correlation could be established with any local occurrence that we were aware of. Back trajectory analysis was used to verify the origin of air masses on these days and hours and continental origin was observed in most of the cases, both, arriving directly on the station or performing an oceanic arc before reaching the station. With the available data, we can't be sure about what caused all those low values. Exception is made to the event of 29th July that may be attributed to biomass burning activities south from the station.
- *p.2169:*
Yes. These events were confirmed with data from a CIMEL sun photometer (from the AERONET network) located on the station. Also, back trajectories and MODIS images were analyzed and confirmed the dust events. This can be made clear on the text and one figure can be included as an example. Also, informa-

C1220

tion on size distributions from the APS instrument is available. Unfortunately no chemical composition is possible to obtain.

- *p.2170: and Figure 5:*
We agree with the Referee that, based only on optical data, it should be difficult to determine accurately the aerosol type and source. But again, our goal with this paper was to infer as much as possible from the optical data and not to make an exhaustive characterization of the local aerosol for which we obviously need to use complementary techniques.
- *p.2171: line 5-7:*
Certainly we can't exclude the possibility of a punctual local influence that we were not aware of, including from the airport. However, the days with higher values of σ_a and smaller ω_0 were analyzed with other techniques (Cimel, trajectories, MODIS) to support our conclusions. This can be made clear in the manuscript by adding this information: “..., allow us to describe the local as extremely clean and only episodically influenced by small particles resulting from long range transport. This conclusion is also supported by other techniques as analysis of the origin of air masses, MODIS images and columnar data from the CIMEL photometer (not shown here).”

References

- Anderson, T. and Ogren, J.: Determining aerosol radiative properties using the TSI 3563 integrating nephelometer, *Aerosol Sci. Technol.*, 29, 57–69, 1998.
- Bond, T.: Spectral dependence of visible light absorption by carbonaceous particles emitted from coal combustion, *Geophys. Res. Lett.*, 28, 4075–4078, 2001.
- Boucher, O. and Haywood, J.: On summing the components of radiative forcing of climate change, *Clim. Dynam.*, 18, 297–302, 2001.

C1221

- Collaud Coen, M., Weingartner, E., Schaub, D., Hueglin, C., Corrigan, C., Henning, S., Schwikowski, M., and Baltensperger, U.: Saharan dust events at the Jungfraujoch: detection by wavelength dependence of the single scattering albedo and first climatology analysis, *Atmos. Chem. Phys.*, 4, 2465–2480, 2004.
- Dubovik, O., Holben, B., Eck, T., Smirnov, A., Kaufman, Y., King, M., Tanré, D., and Slutsker, I.: Variability of absorption and optical properties of key aerosol types observed in worldwide locations, *J. Atmos. Sci.*, 59, 590–608, 2002.
- Leck, C. and Bigg, E.: Source and evolution of the marine aerosol – A new perspective, *Geophys. Res. Lett.*, 32, L19803, 2005.
- Mogo, S., Cachorro, V., Sorribas, M., de Frutos, A., and Fernández, R.: Measurements of continuous spectra of atmospheric absorption coefficients from UV to NIR via optical method, *Geophys. Res. Lett.*, 32, L13811, 2005.
- Montilla, E., Mogo, S., Cachorro, V., and de Frutos, A.: An integrating sphere spectral system to measure continuous spectra of aerosol absorption coefficient, *J. Aerosol Sci.*, 42, 204–212, 2011.
- Pereira, S., Wagner, F., and Silva, A.: Seven years of measurements of aerosol scattering properties, near the surface, in the southwestern Iberia Peninsula, *Atmos. Chem. Phys.*, 11, 17–29, 2011.
- Quinn, P., Miller, T., Bates, T., Ogren, J., Andrews, E., and Shaw, G.: A 3-year record of simultaneously measured aerosol chemical and optical properties at Barrow, Alaska, *J. Geophys. Res.*, 107, 4130, 2002.
- Ricard, V., Jaffrezo, J.-L., Kerminen, V.-M., Hillamo, R., Sillanpää, M., Ruellan, S., Liousse, C., and Cachier, H.: Two years of continuous aerosol measurements in northern Finland, *J. Geophys. Res.*, 107, 4129, 2002a.
- Ricard, V., Jaffrezo, J.-L., Kerminen, V.-M., Hillamo, R., Teinilä, K., and Maenhaut, W.: Size distributions and modal parameters of aerosol constituents in northern Finland during the European Arctic Aerosol Study, *J. Geophys. Res.*, 107, 4208, 2002b.
- Rodríguez, E., Frioud, M., Gausa, M., Stebel, K., Mogo, S., Prats, N., Torres, B., Toledano, C., Bastidas, A., Berjón, A., Cachorro, V., and de Frutos, A.: Optical properties of tropospheric aerosols derived from lidar and sun photometer measurements at ALOMAR (69N) in 2005 and 2006, *Opt. Pur. y Apl.*, 41, 183–190, 2008.
- Rosen, H., Hansen, D., Gundel, L., and Novakov, T.: Carbonaceous particles in the atmosphere, chap. Identification of the graphitic carbon component of source and ambient partic-

C1222

ulates by Raman spectroscopy and an optical attenuation technique, pp. 229–232, Lawrence Berkeley Laboratory, 1979.

- Russell, P., Bergstrom, R., Shinozuka, Y., Clarke, A., DeCarlo, P., Jimenez, J., Livingston, J., Redemann, J., Dubovik, O., and Strawa, A.: Absorption Angstrom Exponent in AERONET and related data as an indicator of aerosol composition, *Atmos. Chem. Phys.*, 10, 1155–1169, 2010.

Interactive comment on *Atmos. Chem. Phys. Discuss.*, 11, 2161, 2011.