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The ASTAR 2007 April 14 haze layer: The radiative effect of an aged and internally mixed aerosol in the Arctic

A.-C. Engvall (1), J. Ström (2,3), P. Tunved (3), H. Schlager (4), and A. Minikin (4)

(1) Norwegian Institute for Air Research, Kjeller, Norway (ace@nilu.no), (2) Norwegian Polar Institute, Tromsø, Norway (johan@itm.su.se), (3) Department of Applied Environmental Science - Atmospheric Science Unit, Stockholm University, Stockholm, Sweden (peter.tunved@itm.su.se), (4) Institut für Physik der Atmosphäre, Deusches Zentrum für Luft- und Raumfahrt (DLR), Oberpfaffenhofen, Germany (Andreas.Minikin@dlr.de, Hans.Schlager@dlr.de)

INTRODUCTION

The ASTAR project (Arctic Study of Tropospheric Aerosol and Radiation) is aimed at investigating the physico-chemical properties of the Arctic tropospheric aerosol by means of aircraft measurements. The goal of the program is to provide an observational dataset for improving not only the assessment of the direct and indirect effects of aerosols on the Arctic radiative balance, but also the aerosol parameterisation in the regional climate model HIRHAM [Rinke, et al., 1999; Treffeisen, et al., 2005]. The ASTAR 2007 campaign was conducted from March 18 – April 18 in 2007, Svalbard. This timing was chosen to make the measurements span during the Arctic spring due to its frequent Arctic hazes. In the present study we focus on an aerosol layer observed north of Svalbard at an altitude of around 3 km during the campaign. Due to recent discussions about the Arctic temperature amplification and the importance of soot in the atmosphere and its radiative effects, the aim of the present study is to evaluate the potential magnitude of the radiative effects such a haze layer might have in the Arctic.

METHODS

In the present study we have analysed in-situ observations of aerosol number densities of particles larger than 10 nm and 260 nm in diameter (henceforth denoted N10 and N260, respectively), aerosol size distributions, aerosol light scattering and absorption, and concentrations of carbon monoxide (CO) and ozone (O3). The measurements were conducted from the German DLR Falcon 20 research aeroplane. N10 was measured using a condensation particle counter (CPC) model TSI 3010. The aerosol size distribution between 17 and 239 nm was measured with a Differential Mobility Particle Sizer (DMPS) in stepwise mode utilising 13 bins, each of which was measured during 10 s. The aerosol size distribution between 260 and 2200 nm was observed with an optical particle counter (OPC) GRIMM, model 3.709, which sized the particles in 12 bins at 1 Hz. We also used information about the mixing state of the aerosol in the size range between 17 and 239 nm obtained from a volatility DMPS (V-DMPS).

Information about the light-absorbing properties of the aerosol was obtained from a custom-built particle soot absorption photometer (PSAP), which provided the particle light-absorption coefficient [U+F073]sp at a wavelength of 525 nm. From this we estimated the black carbon mass concentration (BC, ng m-3) by using the commonly employed specific absorption coefficient 10 m2 g-1 [Petzold, et al., 1997]. As a part of the quality control, an intercomparison was made with measurements from the Zeppelin station (474 m.a.s.l.) at Ny-Ålesund [Ström, et al., 2003; Engvall, et al., 2008]. This indicated good agreement between the airborne and the ground-based size-distribution results for particles of diameter smaller than approximately 200 nm. To investigate the radiative effects of the enhanced aerosol layer a one-dimensional radiation model was used to simulate the amplified heating rate (K day-1). The calculations were based on in-situ measurements of the input variables, viz. relative humidity (RH), temperature (T), pressure (p), aerosol size distribution, and the scattering and absorption properties of the aerosols, for more details see [Treffeisen, et al., 2007].

CONCLUSIONS

Transport of pollutants from the mid-latitudes into the Arctic free troposphere may give rise to a heating rate within the plume of up to 1.3 K day-1, dependent on the properties of the plume and the surface albedo. The surface properties, in this study ice/snow covered or ice-free ocean, are of importance since the latter case with a low albedo shows a 25-30% decrease of the heating rate compared to the snow/ice case. These results can be compared to those obtained by [Treffeisen, et al., 2007], who estimated a heating rate of 1.7 K day-1 at an altitude of 0.5 km based on the observed concentrations of particles, soot, and aerosol scattering during the highest pollution event ever recorded at Svalbard. We have shown that upper-layer transport of soot from lower latitudes into the Arctic may be of importance for the radiative budget in the Arctic troposphere. The overall impact of these events is however difficult to quantify due to the high altitudes at which the transport take place.

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