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Lidar and sun-photometer measurements of Saharan dust above the Atlantic Ocean

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Introduction

Lidar and sun-photometer measurements of aerosol have been performed during cruises of the German research vessel Polarstern in 2000, 2002 and 2003 from the southern hemisphere to the northern hemisphere and *vice versa*. In the latitude range between 10°N and 35°N layers of dust have been frequently observed. Analysis of our data as well as backward trajectories prove, that the aerosol is mineral dust from the Sahara desert. Based on the lidar and photometer measurements, the optical properties can be determined to a very good accuracy and be contrasted to those of sea salt aerosol in the boundary layer. Based on scattering theory the microphysical properties are analysed.

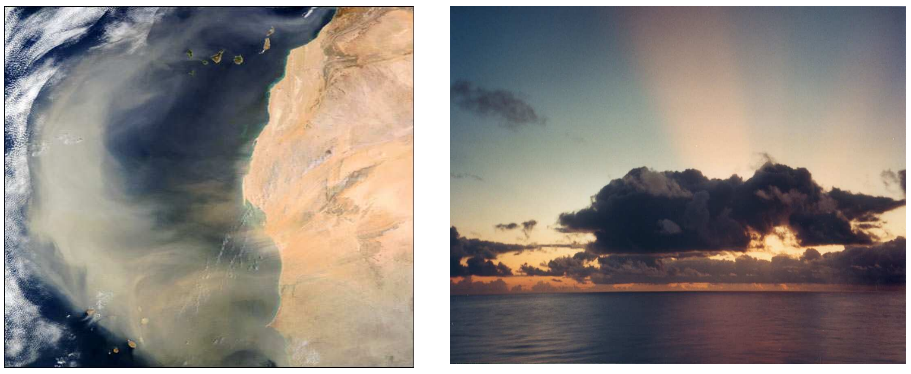

Fig 1 Outbreak of Saharan dust imaged by the Moderate Resolution Imaging Spectroradiometer (MODIS) (left, courtesy of NASA's earth observatory) The image on the right was taken on Polarstern during the event shown in Fig.2, the dust becomes visible during sunset, when single rays pass through the layer.

Instruments

Raman Lidar	Aerosol and cloud backscatter profile Depolarization and color index of cloud and aerosol Water vapor profiles from 0.5 to 10 km
Sun-photometer:	Optical depth at 14 wavelengths ranging from 360-1100 nm
Radiosondes:	Profile of the temperature, pressure and the relative humidity

Observations

Dust originating from the Sahara desert (see fig. 3) was detected by means of our Raman lidar: In Fig. 2 and 4 two layers can clearly be separated: The planetary boundary layer (PBL) is rich in aerosol, the optical depth of the PBL in these cases is about 0.2. The particles in the PBL do not depolarize indicating that they are liquid and spherical. The color index of around 1 - decreasing with altitude - suggests particle radii in the sub-µm range, increasing with altitude. The optical parameters of the Saharan dust layer above the PBL are very different. The depolarizatoin is greater than 10%, which means that the particles are not spherical. The color ratio is about 0 or below. This behavior is typical for Saharan dust. It can be explained by the absorption behavior and the size of the dust particles (Immler & Schrems, 2003). The latter is in the range of about 1 µm. Backward trajectories (fig.3) confirm the Saharan origin of sampled air.The optical depth of the Saharan dust layer shown in fig.2 is about 0.1. It is therefore a rather weak event. Photometer measurements of the aerosol optical depth at wavelength between 355 and 1068 nm in the years from 1997 to 2003 (fig.6). All indicate the presence of Saharan dust north of the equator. In Febuary 2003 values as high as 0.7 were reached.

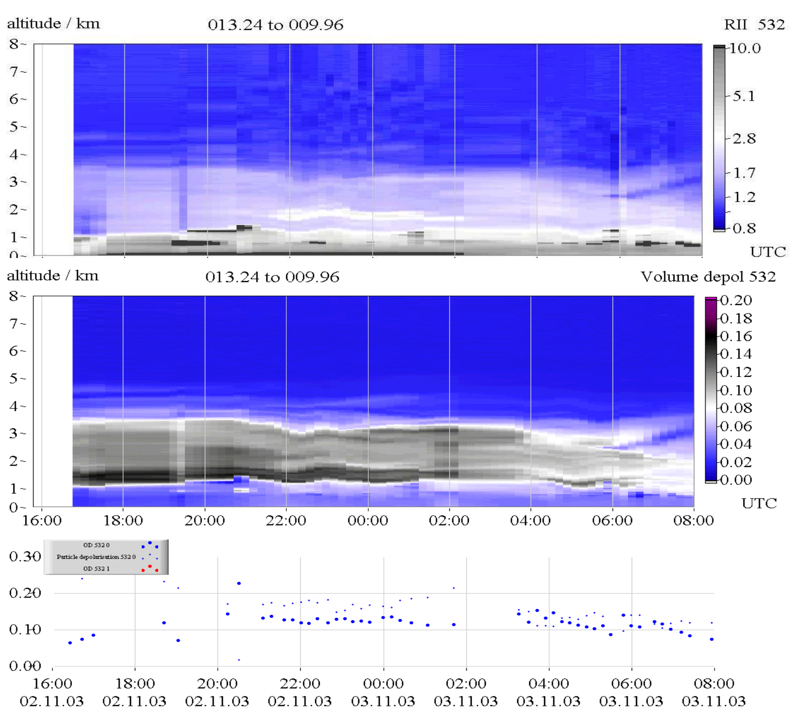

Fig 2 Lidar data of Saharan dust detected around 10°N during the cruise ANT XXI/1 in November 2 -3, 2003. The upper plot shows the backscatter ratio and the plot in the middle shows the depolarization. The depolarizing dust layer between 1 and 4 km altitude can clearly be seen. The lower plot gives the optical depth (AOD) and the mean depolarization. The color index determined at 532 nm and 355 yields values around -0.75.

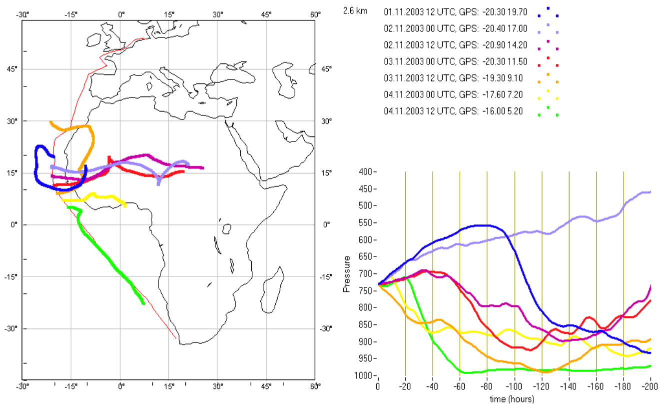

Fig. 3 Backward trajectories retrieved for the air sampled in 2.6 km altitude above the ship. When dust was observed by the lidar in that altitude, the trajectories trace back to the Saharan region.

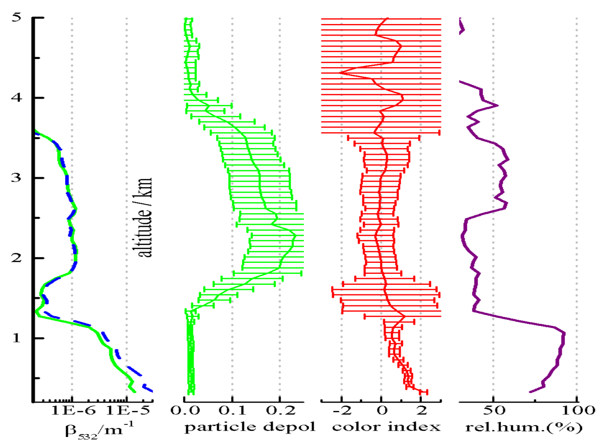

Fig. 4 Lidar profiles measured on Nov 1st, 2003 at 17°N, 20°W. Plotted is the backscatter ratio (left) particel depolarisation, the color index an the aerosol backscatter coefficient. Green: 532 nm blue 355 nm

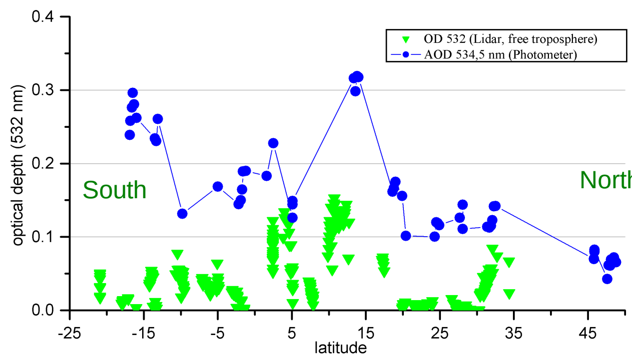

Fig. 5 Aerosol optical depth retrieved from lidar (red) and sun-photometer (blue) measurements as a function of latitude. Using the lidar data,the AOD was determined from the backscatter profiles from 0.5 to 7 km using a constant extinction to backscatter ratio of 40 sr. The green point give the AOD of the lower free troposphere (from top of PBL to 7 km).

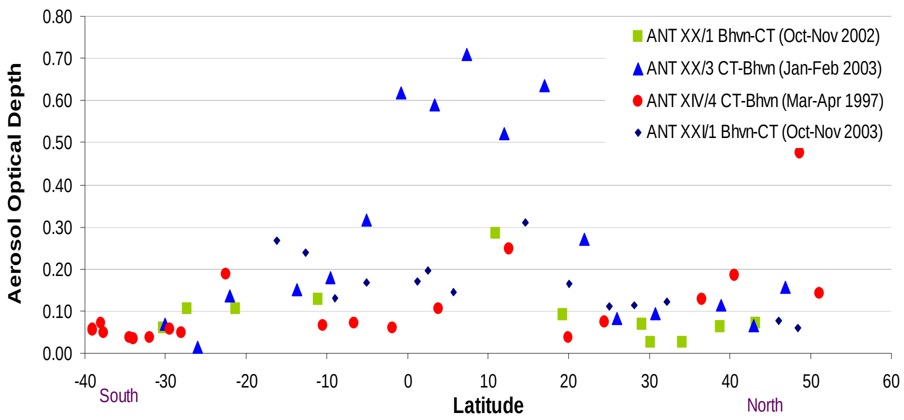

Fig. 6 Aerosol optical depth retrieved from sun-photometer data measured during four cruises of Polarstern between Cape town and Bremerhaven. In all of these data, elevated values north of the equator indicate the presence of Saharan dust. The high AOD in the southern hemisphere are due to biomass burning aerosols coming from southern Africa.

Conclusions:

- Lidar and photometer measurements made aboard RV Polarstern during an Atlantic transect provided detailed information on the occurrence and the optical properties of Saharan dust.
- Saharan dust can uniquely be identified by lidar measurements. Typical for the mineral aerosol is strong depolarization (> 10%) and a color index < 0.
- Dust is frequently observed in the latitude range between 10°N and 35°N in variable amounts ranging up to 0.7 in terms of the optical depth. It is typically observed in an altitude range between 1.5 and 5 km.

References:
Immler F., O. Schrems, 2003; Vertical profiles, optical and microphysical properties of Saharan dust layers determined by a ship-borne lidar , Atmos. Chem. Phys., Vol. 3, , 1353-1364
Sandradewi, J., 2003, A study of the meridional aerosol distribution over the Atlantic and polar regions, Master thesis, AWI Bremerhaven & University of Bremen.
Thanks to the BADC for providing trajectory calculation and access to the ECMWF data.