Characterization of the stratospheric aerosols during SESAME from balloon borne measurements. Intercomparison of polarimetric and occultation data

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INTRODUCTION

Three experiments from the Laboratoire d'Optique Atmosphérique, RADIBAL, BOCCAD and BALLAD, were flown during SESAME phase III for characterizing the aerosol component of the polar stratosphere from passive radiative measurements. They were launched two times by CNES from Kiruna, aboard the same platform, on January 28, 1995 and on March 02, 1995, which was respectively within and outside the polar vortex, in order to detect possible differences in the aerosol characteristics. No PSC were observed on these occasions. The results of the experiments, which were operated simultaneously for the first time, are shown to be reasonnably consistent and they all indicate significant differences between in and out-vortex aerosol characteristics. The aerosol top layer was a few kilometers lower and the aerosol dimension was systematically smaller inside than outside the vortex.

MEASUREMENTS

RADIBAL and BALLAD both measure the radiance and the polarization of the diffuse sunlight for different scattering angles, by scanning the horizontal plane while the gondola is operated by CNES in a rotation mode. To retrieve vertical profiles of the aerosol characteristics, the RADIBAL 2° field of view radiometer operates during the ascent or the descent of the balloon while BALLAD acquires whole stratospheric profiles by scanning the Earth's limb from the balloon ceiling level on a vertically oriented CCD array. RADIBAL measures the radiance and the polarization ratio in channels centered at 850 and 1650 nm. BALLAD measures the radiances in channels centered at 450, 600 and 850 nm and polarizationin the 850 nm channel only. BOCCAD is an occultation experiment. It operates too from the balloon ceiling level during the sunset by imaging the sun on a CCD matrix, with large enough IFOV (10°x7°) to escape positionning problems. The slant optical thicknesses are measured at 443, 600, 780 and 850 nm, as a function of the known tangent height, which allows to derive vertical profiles of the extinction coefficients of the aerosol and also of ozone. Note that the aerosol and CCN counters of the Wyoming University were also aboard the gondola, but we here consider only the results of the LOA experiments.

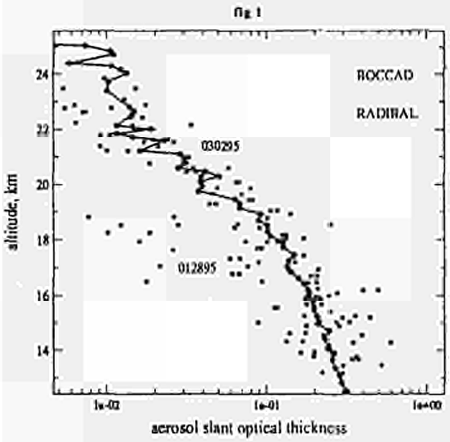
On January 28, 1995, the vortex was located above Kiruna; on March 02, 1995, it was away. The two flights were run according to nearly similar time schedules. The balloon take off was taken at about 10-11 UT and the ceiling level (15 hPa on 01-28-95, 6 hPa on 03-02-95) was arrived at 12-13 UT. RADIBAL was first operated during the balloon ascent. The vertical profiles of the aerosol characteristics derived by this way correspond to aerosols located a few tens of kilometers around the balloon. At the ceiling level, the rotation mode was maintained for a few tens of minutes during which BALLAD was operated. According to the limb geometry, the aerosols observed by BALLAD are a few hundred kilometers apart from the balloon. The prevailing low solar elevation combined with the gondola rotation allowed BALLAD and RADIBAL to scan almost the whole range of scattering angles. Then the gondola was stopped with BOCCAD turned towards the sun and the ceiling level was maintained till solar elevations as small as -4°, in order to allow sounding of the whole stratosphere.
The three experiments operated correctly but, for unknown reasons, parasitic oscillations of the gondola occured, especially on January 28 (about 1° amplitude).

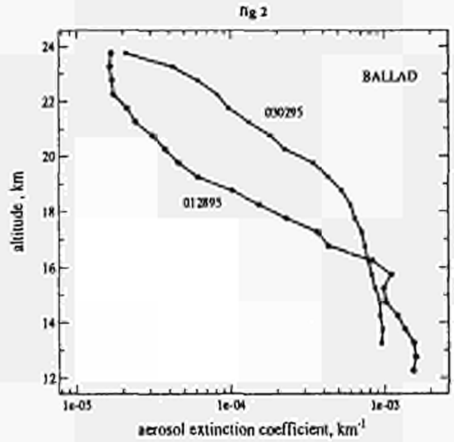
Because of the resulting variations of the air mass within the RADIBAL field of view, the angular features of the aerosol scattering are perturbed which makes the signal processing more delicate. No PSC were detected during the flights and the stratospheric aerosols only were observed.

RESULTS

Aerosol loadings

Figure 1 shows the profiles of the aerosol slant optical thickness at 850 nm, as derived from RADIBAL, for 01-28-95 and 03-02-95, and from BOCCAD for 03-02-95. The two experiments are in a good agreement. Note that the slant optical thickness is retrieved quite directly by the BOCCAD transmission measurements while it is derived from the RADIBAL radiances by processing iteratively the aerosol scattering phase function.
The top of the aerosol layer was clearly about 2/3 kilometers lower on 01-28-95 than on 03-02-95. Within the vortex, on 01-28-95, the stratosphere was quite free from aerosols above 18-20 km altitudes.
The aerosol extinction coefficients inverted from the slant optical thickness profiles have been reported in Figure 2. The results are derived from BALLAD, whose a single acquisition provides one entire radiance profile which is more efficient for inversion than the noisy data of RADIBAL. Figure 2 confirms the very different results for 01-28-95 and 03-02-95 and proves the good consistency between the experiments.





<u>Figure 1:</u> Profiles of the aerosol slant optical thickness at 850 nm, for January 28 and March 2. Points: RADIBAL results. Continuous curve: BOCCAD results for March 2.
<u>Figure 2:</u> Profiles of the aerosol scattering coefficient at 850 nm, for January 28 and March 2, as derived from the BALLAD measurements.

Aerosol Characteristics

The aerosol characteristics have to be derived from their scattering features. These are illustrated in Figure 3 by a few measurement sequences of RADIBAL for the 01-28-95 flight, i.e. for the worst case. The oscillations in the radiance diagrams correspond to the gondola oscillations. The polarization ratio, however, are hardly affected by this effect, which allows to fix reasonably the aerosol model. The aerosol characteristics were retrieved (ref. 1) by fitting the raw data with simulations performed for different sulfuric acid aerosol models parameterized by their effective radius. The best fit obtained is shown in Figure 3; results are more confident for the better data of the March 2 flight. The particle dimensions retrieved by this way for altitudes ranging from 12 to 15 km are typically $r_{eff} = 0.28 - 0.32\,\mu m$ for 01-28-95 and $r_{eff} = 0.35 - 0.40\,\mu m$ for 02-03-95, i.e significantly smaller inside than outside the vortex.

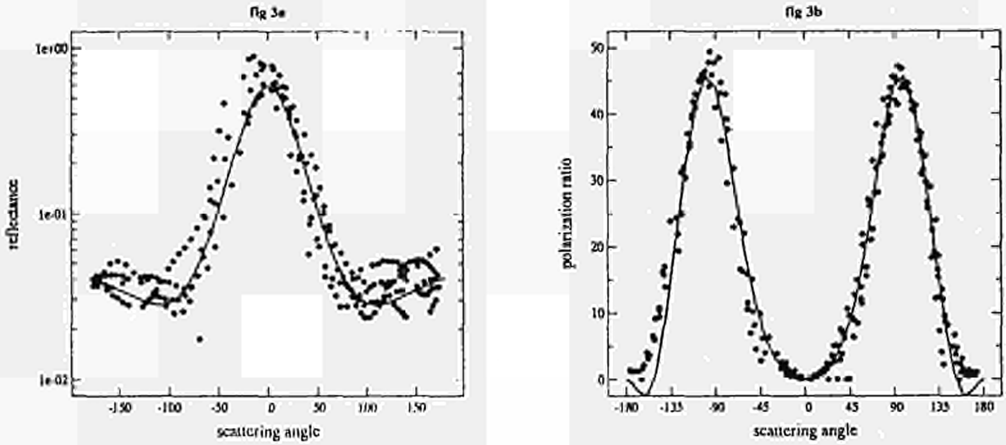
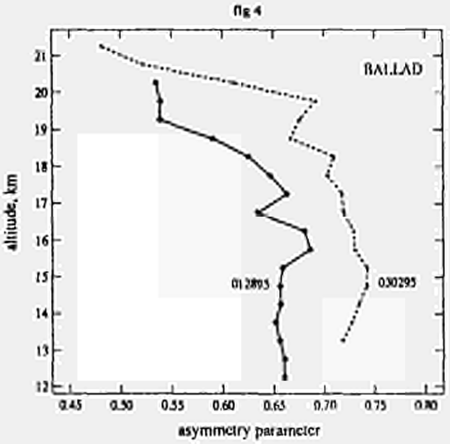


Figure 3: Points: radiance and polarization measurements, at 850 nm vs scattering angle, from RADIBAL near 15 km altitude on 01-28-95. Continuous curve: simulations for sulfuric acid particles with effective radius , $r_{eff} = 0.32\ \mu m$

For the case of BALLAD, polarization was not considered till now, but we inverted the radiance measured in the range of forward scattering angles. They were fitted (ref 2 and 3) by using for the particle phase function an Henyey Greenstein function whose the parameter g was adjusted. The retrieved profiles of g, at 850 nm, have been reported in Figure 4. The more isotropic scattering derived from the BALLAD observations within the vortex is again indicative of smaller particles. The order of magnitude of g is consistent with the aerosol models derived from RADIBAL.
Given the scattering cross sections of the particles, the estimated aerosol number density are about $n \approx 2-3\ cm^{-3}$ on 01-28-95 and $n \approx 1\ cm^{-3}$ on 03-02-95



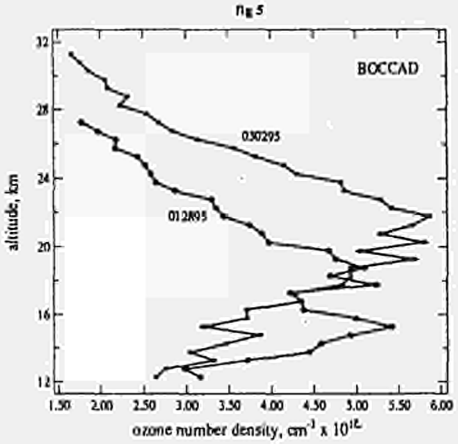


Figure 4: Vertical profiles of the asymetry parameter of the aerosol phase function, at 850 nm, derived from the BALLAD limb radiances in forward scattering directions.

Figure 5: Ozone concentration profiles derived from the multi-wavelength occultation measurements of BOCCAD

Ozone profiles

Finally, Figure 5 presents the vertical profiles of the ozone concentration derived from the BOCCAD measurements in the 600 nm channel. These profiles may be indicative also of subsidence within the vortex. These observations have been discussed in a previous paper (ref 3), especially concerning some evidence, near 16 km altitude in the 01-28-95 profile, of anticorrelation between the aerosol extinction coefficient and the ozone concentration profiles.

CONCLUSION

This first analysis shows good consistency between three different balloonborne aerosol observations. They all corroborate differences in the aerosol characteristics inside and outside the vortex. The lower altitude of the top of the aerosol layer inside the polar vortex is probably indicative of subsidence. May be the smaller dimension of the aerosols has the same origin. These smaller particles may come from the descent of upper stratospheric layers. Despite these differences, because compensation between the particle dimension and number density, the resulting estimates of the aerosol surface available for chemical heterogeneous processes are nearly the same inside and outside the vortex . More confident conclusion needs complete processing of the results, especially of the scattering and polarization diagrams. Further comparisons with the results of the University of Wyoming and with other aerosol observations performed during SESAME should be valuable.

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