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FOREWORD

The article "SAGE II Aerosol Extinction and Scattering Data from Balloon Borne Photography" has been presented at the COSPAR meeting in Toulouse and will appear in Advances of Space Research.

AVANT-PROPOS

L'article "SAGE II Aerosol Extinction and Scattering Data from Balloon Borne Photography" a été présenté à la réunion du COSPAR à Toulouse et paraîtra dans Advances of Space Research.

VOORWOORD

Het artikel "SAGE II Aerosol Extinction and Scattering Data from Balloon Borne Photography" werd voorgesteld tijdens de COSPAR vergadering in Toulouse en zal verschijnen in Advances of Space Research.

VORWORT

Der Artikel "SAGE II Aerosol Extinction and Scattering Data from Balloon Borne Photography" wurde vorgestellt während der COSPAR Tagung in Toulouse und wird herausgegeben werden in Advances of Space Research.

SAGE II AEROSOL EXTINCTION AND SCATTERING DATA FROM BALLOON BORNE PHOTOGRAPHY

by

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Abstract

Earth limb radiance and extinction near sunset have been observed from a balloon borne gondola nearly simultaneously and on air masses close to those probed by the SAGE II instrumentation on April 22, 1985. The results show the importance of accuracy of the altitude determination on the aerosol measurements. They indicate an important altitude dependence of the stratospheric aerosol granulometry in agreement with SAGE II results.

Résumé

L'extinction lumineuse et la luminance du limbe terrestre ont été observées au coucher du soleil quasi simultanément sur des masses d'air voisines à partir d'une nacelle stratosphérique et par l'instrumentation SAGE II le 22 avril 1985. Les résultats montrent l'importance de la précision de la détermination de l'altitude sur les mesures d'aérosols. Ils indiquent une variabilité de la granulométrie de l'aérosol stratosphérique en fonction de l'altitude.

Samenvatting

Metingen vanuit een ballongedragen stratosfeergondel van de radiantie en extinctie van de aardse kim bij zonsondergang, werden bijna gelijktijdig uitgevoerd met waarnemingen van SAGE II op 22 april 1985 aan naburige luchtmassa's. De resultaten tonen aan dat het uiterst belangrijk is om nauwkeurig de hoogte te bepalen bij aërosolmetingen. Ze wijzen op een belangrijke hoogte-afhankelijkheid van de granulometrie der stratosferische aërosols, in overeenstemming met de resultaten van SAGE II.

Zusammenfassung

Messungen aus einem stratosphärischen Ballon der Strahldichte und der Auslöschung des irdischen Horizontes bei Sonnenuntergang, wurden fast gleichzeitig getan mit Beobachtungen von SAGE II am 22 April 1985 auf angrenzenden Luftmassen. Die Resultaten zeigen dass es sehr wichtig ist die Höhe genau zu bestimmen mit Aerosolmessungen. Sie deuten auf einer wichtigen Höheabhängigkeit der Granulometrie des stratosphärischen Aerosols, übereinstimmend mit den Resultaten von Sage II.

INTRODUCTION

The need for the observation by other methods of the quantities to be derived from the operation of the second Stratospheric Aerosol and Gas Experiment /1/ package has prompted the work described here. For the comparison of remote sensing data gathered from the satellite and from balloon gondolas to be meaningfull the observations must be as close as possible both timewise and geographically. A balloon gondola has been flown in the afternoon twice : on November 10, 1984 and on April 22, 1985. In the first case the stratosphere appeared horizontally very inhomogeneous and air parcels observed by the two methods were much further away from each other than in the second case where the conditions were excellent as shown in figure 1. The results of the second flight will be discussed here.

METHOD

The horizontally orientable balloon gondola carried two sets of 3 photographic cameras equipped with optical filters centered at 0.84, 0.45 and 0.37 µm. The sets were directed at 180° from each other. Neutral optical filters limited the field of direct view of 5° above the horizontal. With the sun near 10° elevation photographs of the earth limb were taken at all azimuths. When the sun elevation reached 5° a neutral density filter was put in front of the camera set oriented towards the sun in order to photograph the solar disk at elevations down to - 5° in order to determine atmospheric extinctions. The gondola included pressure, temperature, humidity sensors and a Brewer-Mast ozone sonde. On April 22, 1985, the gondola was flown from the CNES range in the south west of France and reached 36 km altitude.

The observed limb radiances were treated in a similar fashion as previously /2/. The observedd atmospheric extinctions were used in the inversion process of the data as well as to deduce the atmospheric radiance versus altitude for attenuated solar irradiance.

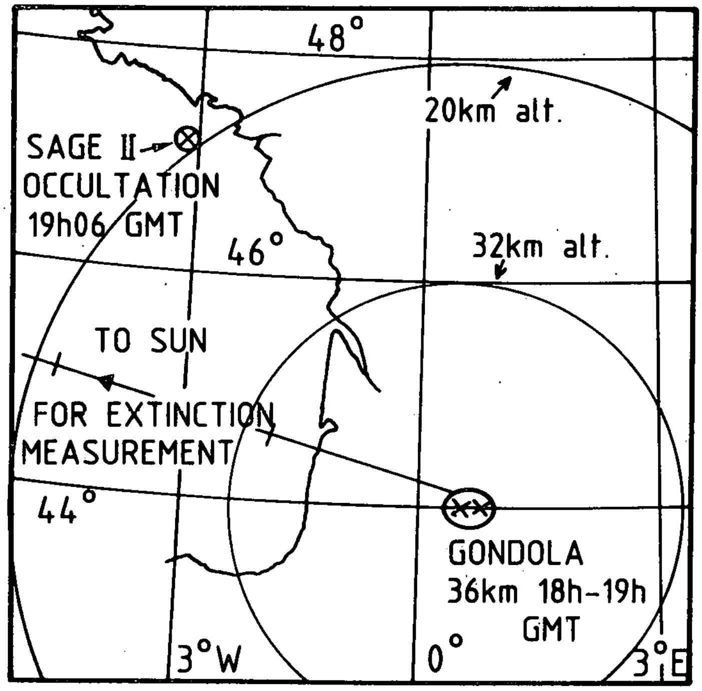

Fig. 1.- Map of the observation scene. The change of the position of the balloon gondola during observation was very small. Observation at 2° and 4° depression angles reached tangent altitudes equal to 32 and 20 km altitudes represented by two circles. The SAGE II extinction profile was located on the 20 km altitude circle.

The so derived atmospheric radiance, L, is

$$L = \pi\alpha^2 L_\odot \sigma n (p_\theta / 4\pi) \quad (1)$$

where α is the angular solar radius, $L_\odot$ is the solar radiance, n is the scatterer's number density, σ is the total scattering cross section and p_θ is the scattering phase function. It has been shown /2/ that this latter parameter follows well the Henyey-Greenstein relationship according to which p_θ at 30° scattering angle, equals 3 with an uncertainty of ± 15% for the range of phase function asymetry factors from 0.4 to 0.7 as shown in Figure 2. A value of $p_\theta = 3$ has thus been used to derive the total extinction, $n\sigma$, from scattering due to aerosols after subtraction of air scattering.

OBSERVATIONS

The vertical distributions of temperature and ozone observed during the balloon ascent are shown in Figure 3. The ozone sonde electrolyte boiling at 34 km altitude precluded to obtain data at higher altitudes. The aerosol extinction derived from aerosol scattering at 30° scattering angle is shown on Figure 4 for the three wavelengths.

DISCUSSION

The SAGE II raw extinction data have been inverted for the sake of comparison of the inversion algorithms. The data at 1.02 µm have been used since there are closest to our data at 0.84 µm in wavelength where ozone, NO_2 and other trace species have a very small interaction. The results shown in Figure 5 are in very good agreement and lead to a negligeable extinction above 28 km. This cannot be accepted in view of the extinction observed from scattering at shorter wavelengths. It has thus been assumed that a small geometric altitude error would have to be taken into account in the SAGE II data. The SAGE II total extinction profile has thus been lifted by 1.2 km. The inverted local extinctions

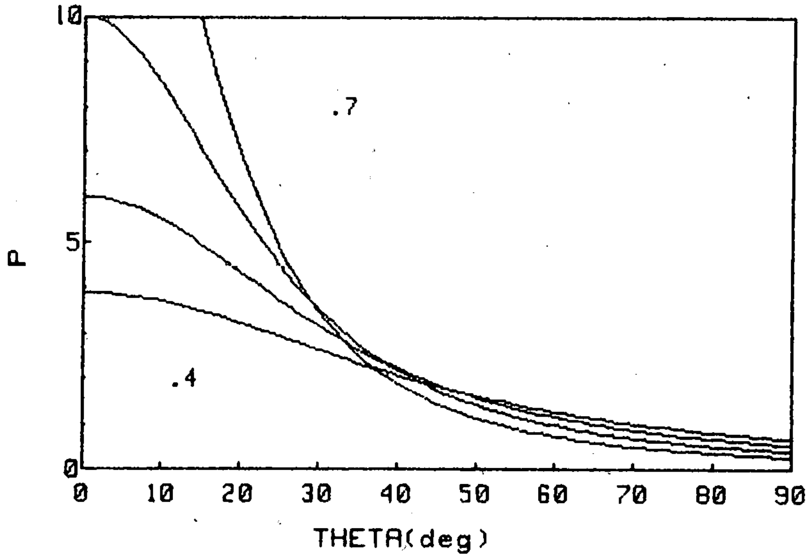

Fig. 2.- The scattering phase function P is shown versus scattering angles from 0 to 90° for asymetry parameters equal to 0.4, 0.5, 0.6 and 0.7.

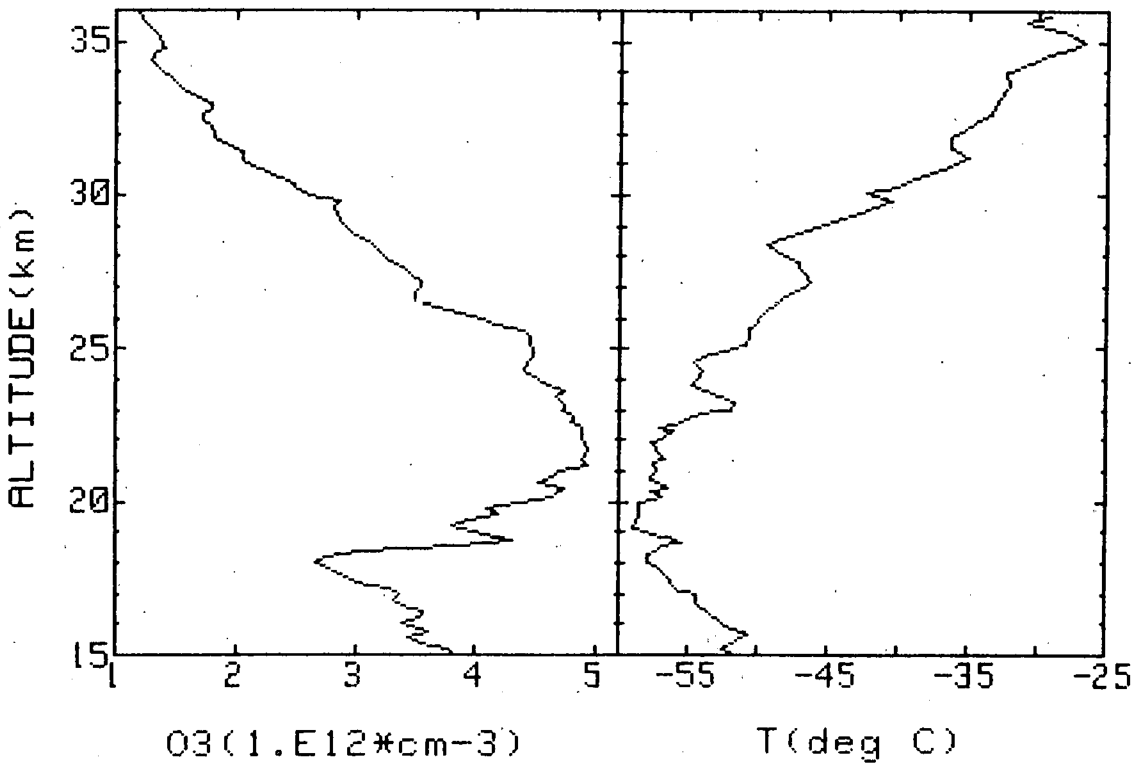

Fig. 3.- Vertical distribution of ozone and of temperature observed during the balloon ascent.

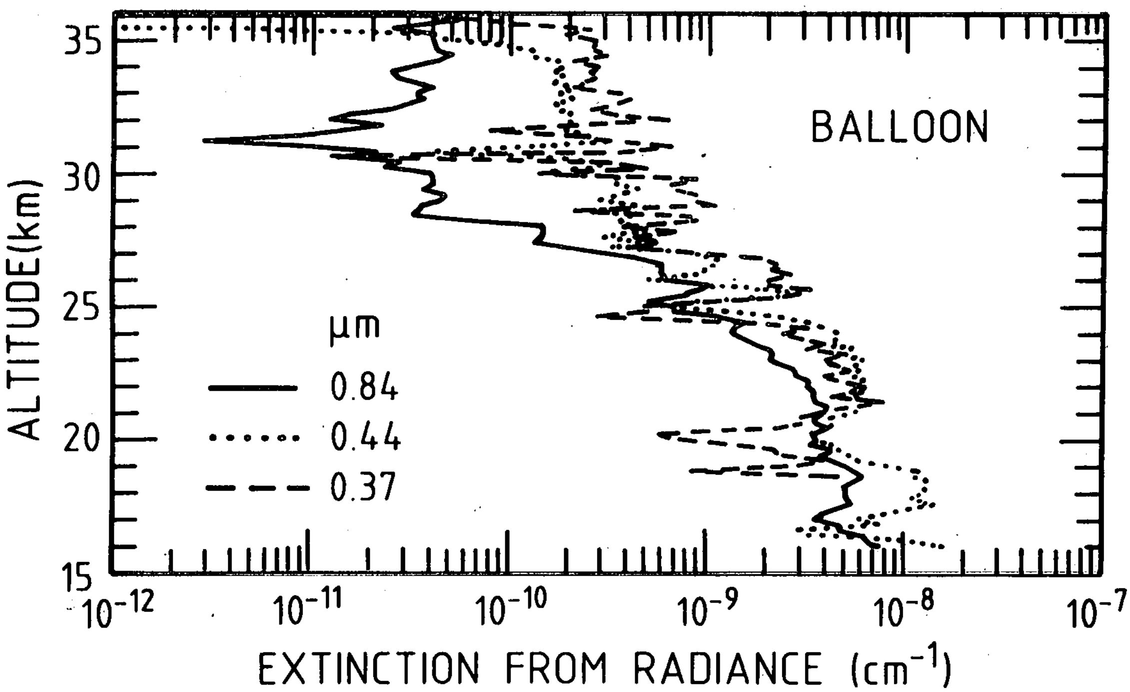

Fig. 4.- Aerosol extinction versus altitude at the three observation wavelengths.

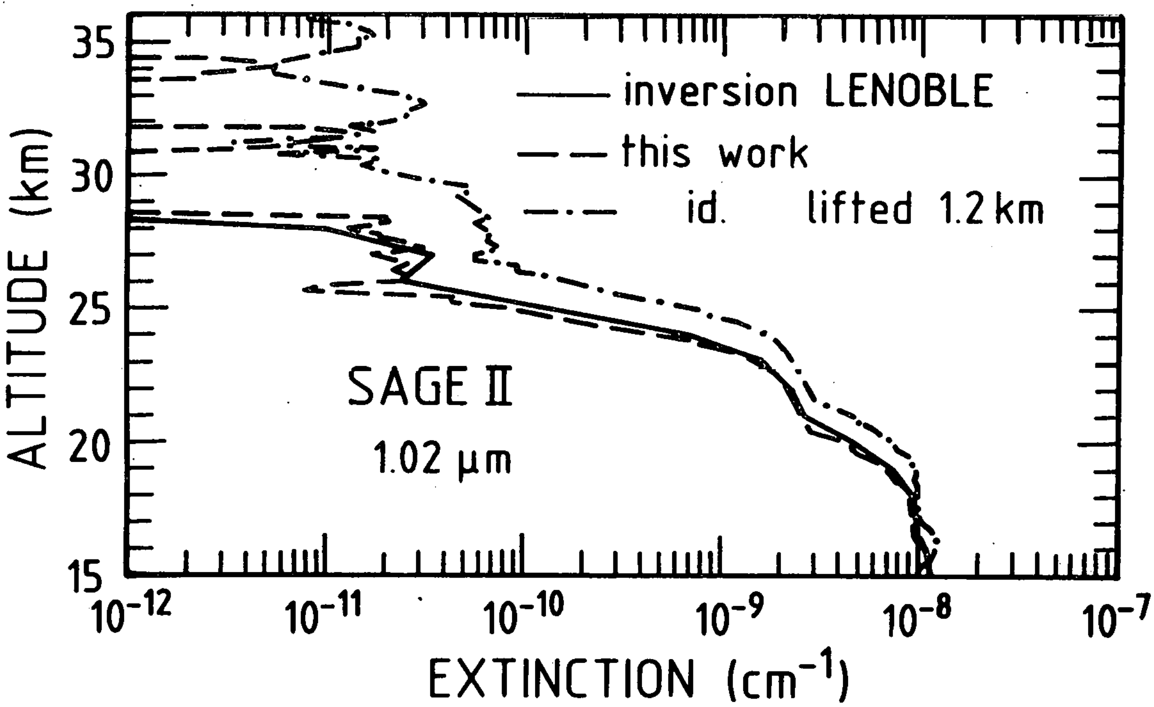

Fig. 5.- Results of inversion of raw slant extinction data (this work) compared with those derived by Lenoble /3/. The comparison shows a satisfactory agreement particularly at altitudes lower than 27 km. At higher altitudes the aerosol extinction derived by subtraction of air scattering is very small explaining the disagreement. The effect of changing the atltitude of the raw data by 1.2 km appear very important above 24 km.

are also shown on Figure 5. Their comparison with our data at 0.84 µm are shown in Figure 6.. This shows the large influence of a small uncertainty on the geometry for the retrieval since we discuss here the altitude or position of a spacecraft at 600 km altitude within less than one nautical mile. Figure 7 shows the result of a revised inversion of the SAGEE II data while Figure 8 shows the result of an upwards shift by 1 km. The ozone vertical distributions corresponding the conditions of Figures 7 and 8 are respectively shown in Figures 9a and 9b. The NO_2 extinction at 0.44 µm observed by means of the balloon gondola is shown in Figure 10 with the NO_2 extinction at 0.448 µm derived from SAGE II data corresponding to the conditions of Figures 7 and 8.

Our data show a large variation of the aerosols granulometry versus altitude as indicated by the variation of extinction with wavelength. This dependence is shown n Figure 11 where the extinction normalized at 0.37 µm is shown versus wavelength for two altitude regimes : 23 km and higher than 28 km. In this latter case the Angström coefficient is between 3 and 4 indicating the presence in the upper stratosphere of very small particles. The Angström coefficient shows smaller values at 23 km altitude below 0.84 µm and changes sign above 0.37 µm. At this wavelength appear much more pronounced at 24.5 and at 20 km than at larger wavelengths pointing towards the variability of the aerosol granulometry versus altitude. The balloon observations of solar extinction is of course more difficult, particularly by means of photographic photometry than the radiance observation. However the aerosol extinction is large enough at 18 km to allowa reliable evaluation. The point in Figure 6 shows the direct observation of aerosol extinction at 0.84 µm. It is found in good agreement with the SAGE II data and higher than the value deduced from scattering. A part of the discrepancy may be due to a single scattering albedo being smaller than unity.

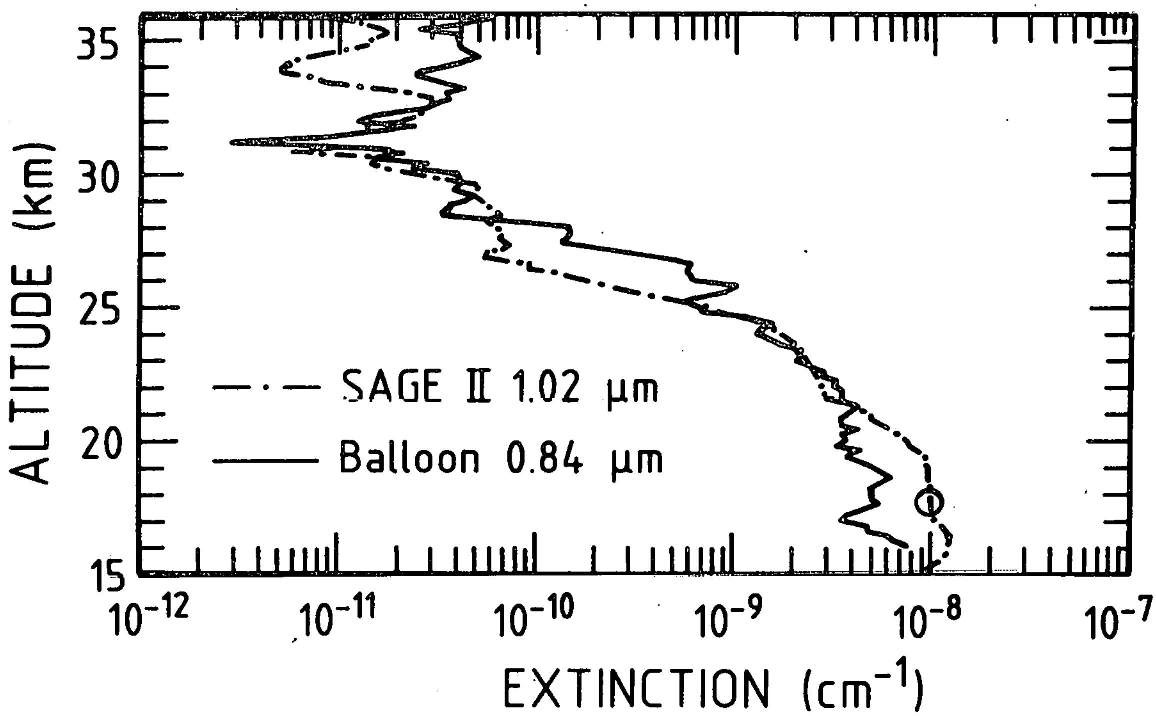

Fig. 6.- Comparison of the extinction derived from the radiance observed with the balloon gondola with the SAGE II extinction retrieved from slant extinction lifted by 1.2 km. The dip at 31 km coincides for both. The layer at 26 km appears on the photographs as an irregular feature which may not have been in the field of view of SAGE. A disagreement appears below 20 km. The extinction at 18 km observed directly from the balloon agrees with the SAGE observation and is higher than the extinction deduced from the radiance.

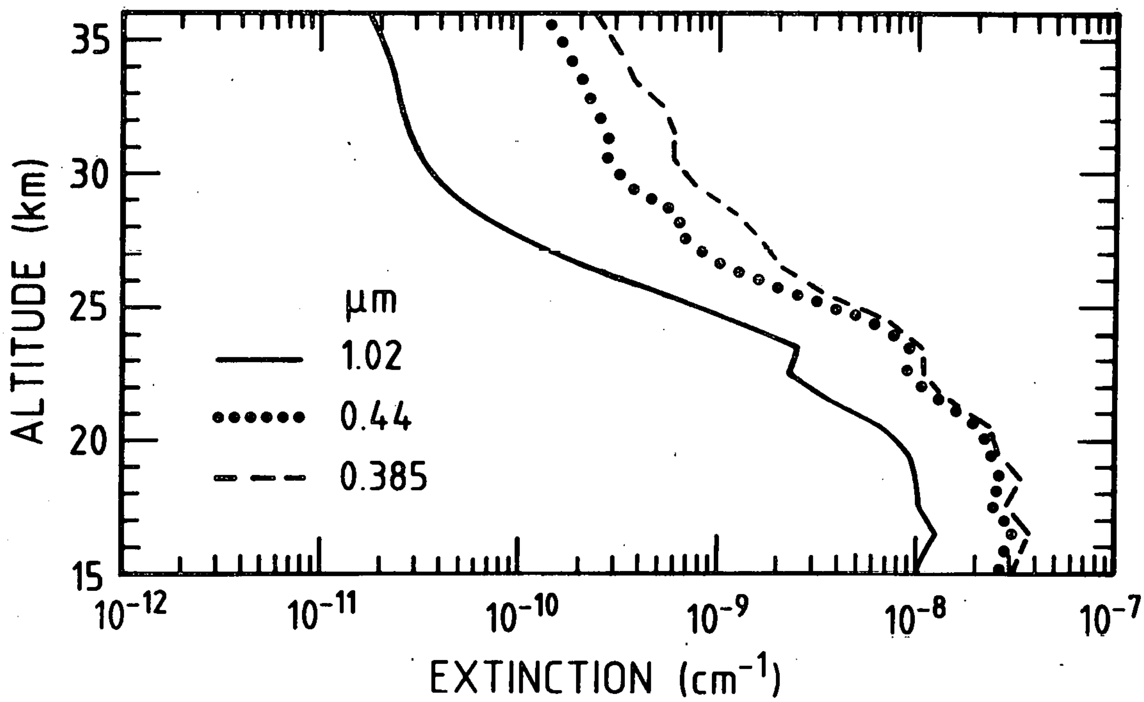

Fig. 7.- Revised extinction derived from SAGE data (see text).

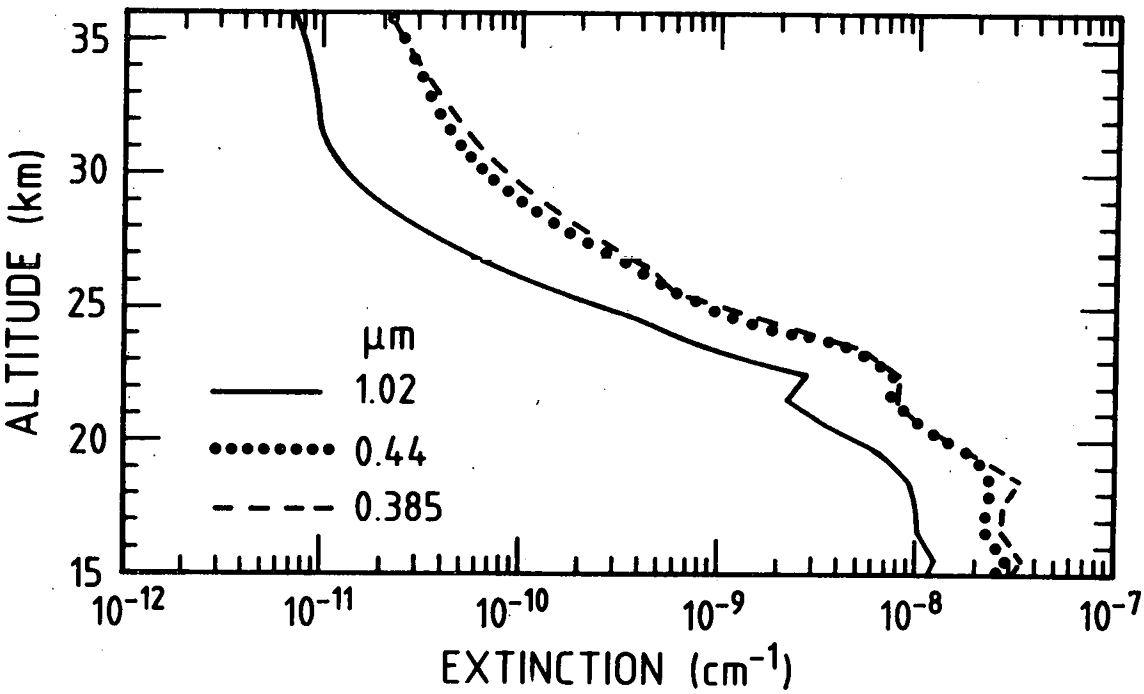

Fig. 8.- Revised extinction derived from SAGE data shifted upwards by 1 km relative to figure 7.

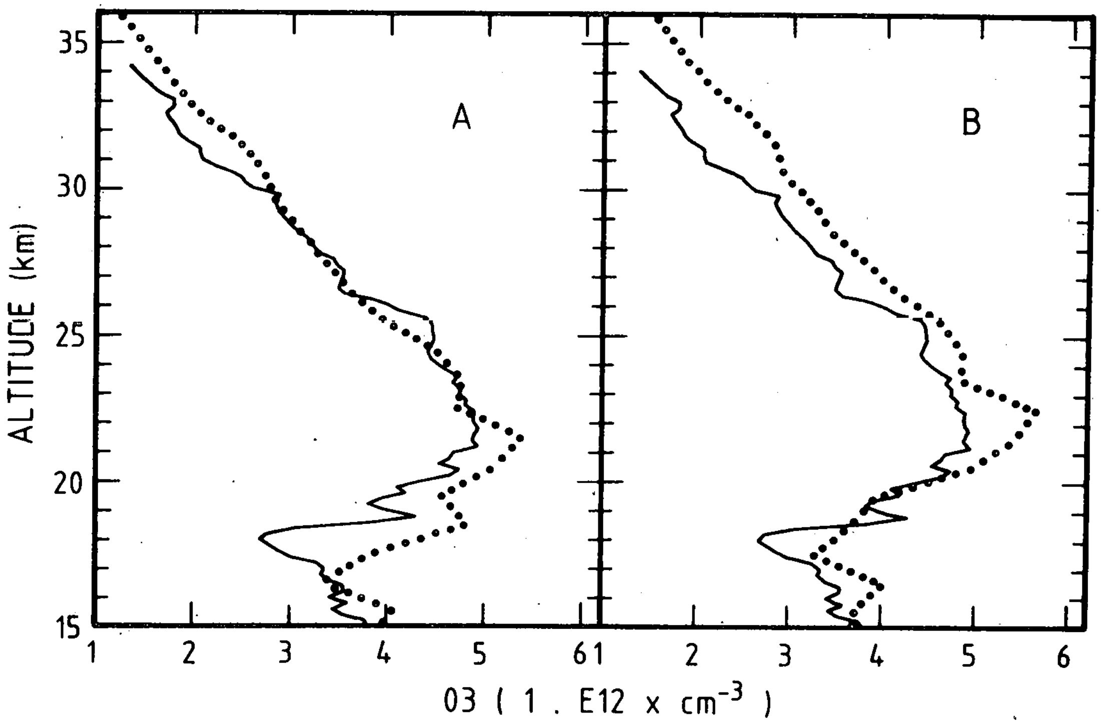

Fig. 9.- Ozone number density versus altitude. The continuous line corresponds to figure 3. The values deduced from SAGE data are represented by the dotted curves : A, conditions of figure 7; B, conditions of figure 8. The extinction cross section of O_3 at 0.6 µm has been taken equal to 4.89×10^{-21} cm^2.

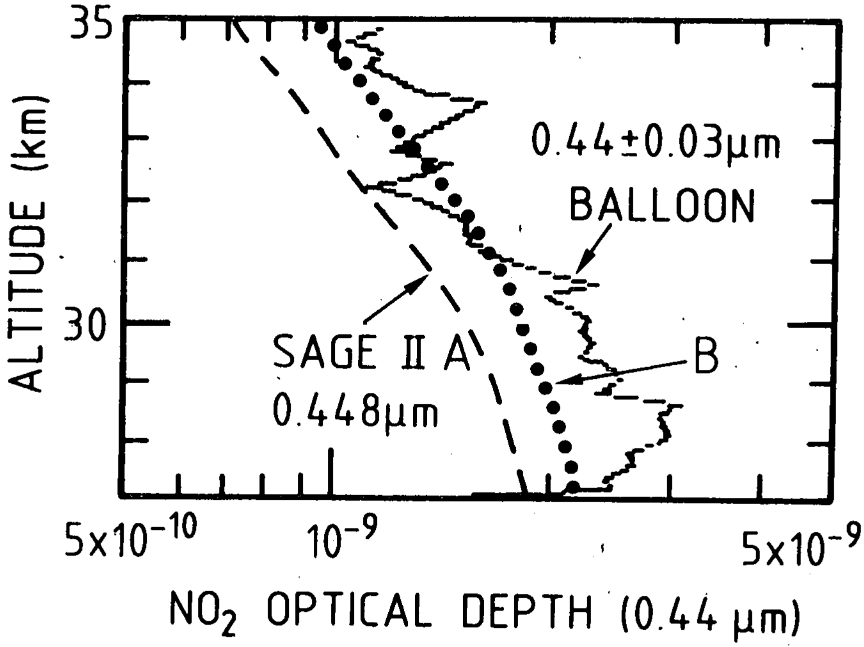

Fig. 10.-Extinction observed directly from the balloon gondola at 0.44 μm from which extinctions due to aerosols, air and ozone have been subtracted. The NO_2 extinction at 0.448 μm derived from the SAGE data are shown by the dashed curve (conditions of figure 7) and by the dotted curve (conditions of figure 8).

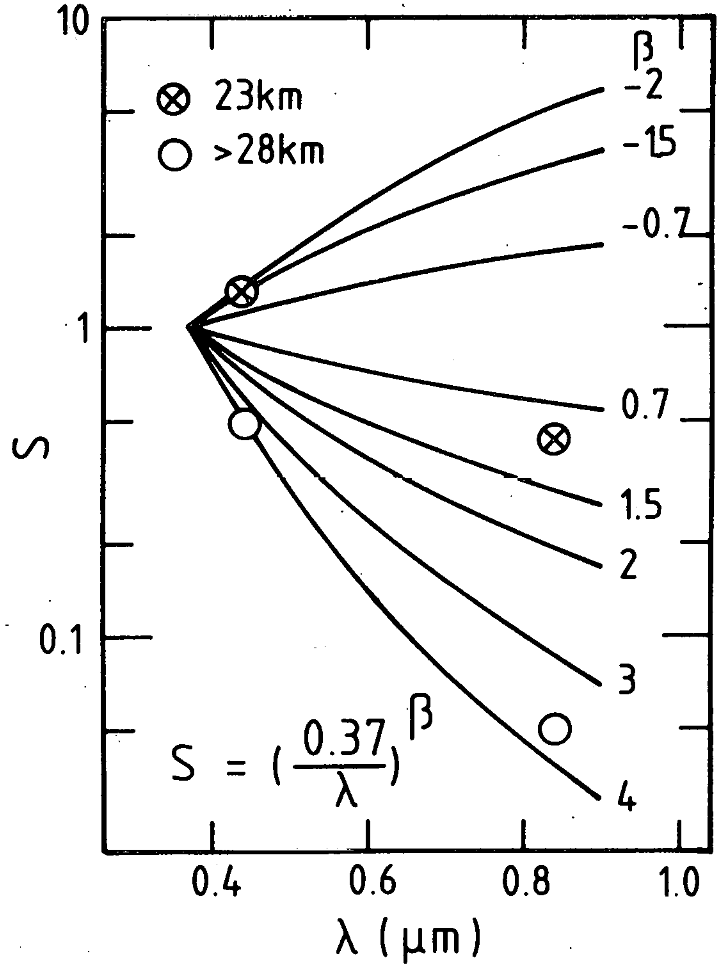

Fig. 11.-Wavelength dependence of the extinction derived from the observed radiances at 23 km and above 28 km altitude. The curves represent the dependence of the Angström coefficient, B. All values are normalized at 0.37 μm (see text).

CONCLUSION

This work shows the interest of simultaneous observations and points to their requirement and to a need for a detailed analysis of the data in such situations. Some of these aspects will be discussed in a companion paper /3/. The difference observed for the aerosol extinction will have to be further analysed.

REFERENCES

1. M.P. McCORMICH, SAGE II : An Overview, Ad. Sp. Res. this issue.
2. M. ACKERMAN, C. LIPPENS and C. MULLER, Stratospheric aerosol properties from earth limb photography, Nature, 292, 587-591 (1981).
3. J. LENOBLE, Validation of SAGE II data Inversions by the European Correlative Experiments, Ad. Space Res., this issue.