INSTITUT D'AERONOMIE SPATIALE DE BELGIQUE

3 - Avenue Circulaire
B - 1180 BRUXELLES

AERONOMICA ACTA

A - N° 83 - 1971

Upper atmospheric densities between 155 and 165 km by observation of AlO clouds

by M. ACKERMAN and P. SIMON

BELGISCH INSTITUUT VOOR RUIMTE-AERONOMIE

3 - Ringlaan
B - 1180 BRUSSEL

FOREWORD

"Upper atmospheric densities between 155 and 165 km by observation of AlO clouds" by M. Ackerman and P. Simon which is the result of a partical set of observational conditions by traking AlO clouds released from two rockets launched in Sardinia. It will be published as a Research Note in "Planetary and Space Science".

AVANT-PROPOS

"Upper atmospheric densities between 155 and 165 km by observation of AlO clouds" par M. Ackerman et P. Simon est un résultat basé sur l'analyse de nuages d'oxyde d'aluminium observés grâce au lancer de deux fusées en Sardaigne. Ce travail paraîtra dans "Planetary and Space Science".

VOORWOORD

"Upper atmospheric densities between 155 and 165 km by observation of AlO clouds" door M. Ackerman en P. Simon is het resultaat van de analyse van de aluminium oxydewolken die werden waargenomen bij raketlanceringen in Sardinië. Dit werk zal verschijnen in "Planetary and Space Science".

VORWORT

"Upper atmospheric densities between 155 and 165 km by observation of AlO clouds" durch M. Ackerman und P. Simon ist ein Resultat der Analyse von AlO Wolken, die in Sardinie mit zwei ESRO Raketen gebildet wurden. Diese Arbeit wird in "Planetary and Space Science" herausgegeben werden.

UPPER ATMOSPHERIC DENSITIES BETWEEN 155 and 165 KM BY OBSERVATION OF AlO CLOUDS

by

M. ACKERMAN and P. SIMON

Abstract

Thermospheric densities have been deduced from diffusion coefficients measured on AlO clouds released by ESRO rockets. The results are compared with previous data and the role of vertical motions of artificial clouds in the interpretation is emphasized.

Résumé

Des densités thermosphériques ont été déduites de la mesure du coefficient de diffusion de nuage d'AlO formés à partir de fusées ESRO. Les résultats sont comparés avec des données précédentes et l'accent est placé sur le rôle des mouvements verticaux des nuages artificiels dans l'interprétation des données.

Samenvatting

Uitgaande van de diffusiecoëfficiënten van een AlO wolk gevormd bij middel van ESRO raketten werd de dichtheid van de thermosfeer bepaald. De bekomen resultaten worden vergeleken met vroegere gegevens en het verschil wordt bij de interpretatie op rekening gebracht van de vertikale beweging van de kunstmatige wolken.

Zusammenfassung

Thermosphärische Dichte werden aus Messungen der Diffusions koeffizienten von AlO Wolken (ESRO Raketen) festgestellt. Die Ergebnisse werden mit früheren Daten verglichen und der Einfluss von senkrechten Bewegungen der Wolken wird beschrieben.

In a recent article, von Zahn (1970) has compared mass densities derived from satellite drag data for an altitude of 150 km with densities determined by mass spectrometers, EUV extinction measurements and observation of luminescent clouds. Results from this last method are summarized in table 3 of his article and an average density value is deduced. The two values given by Rees et al. (1969) which are quoted have now to be replaced in that table by the revised ones (Rees et al., 1970) which are 34% lower. The fact that such a correction reduces, by 10%, the average of all the data obtained from luminescent clouds indicates that new measurements are still needed to make a stastitical analysis worthwhile. In addition, the scatter of the various values is high amounting up to 50% of the mean value and the probable error is of the order of 20%. As specified by von Zahn (1970), part of the scatter of the data is due to the various choices made by the different authors for the physical parameters required for the interpretation of the measurements. These parameters are the mean collisional diameter of the interdiffusing molecules and the mean atmospheric molecular weight ; even if there is no great uncertainty about the latter,values of the collisional diameter have still to be assumed.

An other source of error which has apparently not received much attention up to now is the influence of the vertical motion of luminescent clouds. Evidence for this will be given in the present note which is primarily intended to report new results obtained in the frame work of the sounding rocket programme of the European Space Research Organisation (ESRO). The experiments were performed by means of the payloads S 64-1 and S 64-2 launched from Sardinia on July 6 and 13, 1969 respectively. The launch times were 2030 and 2021 LMT. Releases took place at low (158 and 155 km) and high (275 and 278 km) altitudes. For both flights the AlO clouds formed at low altitudes where observed during sufficiently long periods to allow good diffusion measurements to be made. Cameras equipped with lenses having apertures of f/2.8 and f/0.87 were used to photograph the clouds at a zenith distance of the order of 15°. Especially on July 13, the half gaussian diameter of the low altitude cloud was measured over a period of 660 seconds and a significant increase with time of the diffusion rate was observed. This phenomenon was correlated with the upward motion of the cloud deduced from triangulation data (Ackerman and Van Hemelrijck, 1971). The photographic observation of the high-altitude clouds was of too short duration to allow worthwhile diffusion measurements to be made.

Atmospheric densities, ρ were computed by means of the relation

$$\rho = \frac{3\,M_1}{8\sigma^2\,D_{12}N}\left(\frac{RT}{2M^*\pi}\right)^{1/2}\ \mathrm{g\ cm^{-3}} \qquad (1)$$

where R and π have their usual meaning and N is the Avogadro's number. The temperature T, was deduced from the analysis of the AlO spectra. The diffusion coefficient D_{12} of AlO into the atmosphere was obtained by plotting the square of the gaussian half width of the clouds versus time. A mean atmospheric molecular weight M_1, of 23.5 g mole^{-1} was chosen (Nicolet 1964) leading to a value of the reduced mass M*, equal to 15.2 g mole^{-1}.

The results are summarized in Table 1 where the temperatures are also listed for the two experiments. The value of the collisional diameter σ used in equation 1 has been taken equal to 3.32 x 10^{-8} cm after comparison (Simon, 1971) of the data available for various molecules including oxygen compounds. The density value marked with an asterisk has been deduced from photographs taken through an interference filter centred at 4670 Å in the $\Delta v = +1$ sequence of the AlO spectrum.

The first conclusion to be drawn from Table 1 relates to the vertical motion of the clouds observed in these experiments and discribed in more detail by Ackerman and Van Hemelrijck (1971). Particularly in the case of the S 64-2 experiment, the same cloud allows density determinations to be made over an altitude range of 10 km. If only the release altitude (155 km) had been considered, the assigned density of 1.12 x 10^{-12} g cm^{-3} would have been in error by 60%. As shown in Fig. 1, the results reported

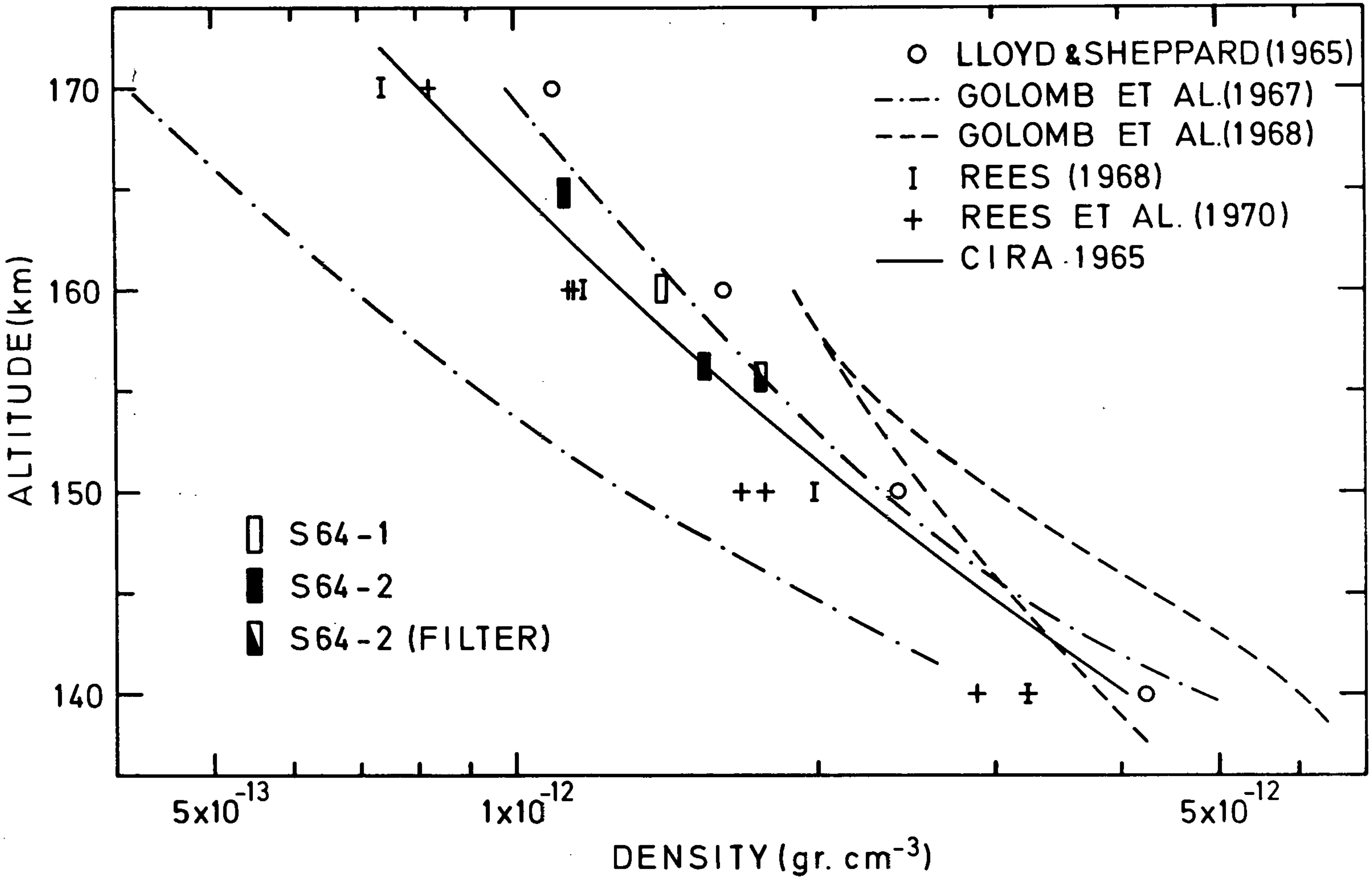

Fig. 1.- Observed and model atmospheric densities versus altitude between 140 and 170 km.

here agree within 10% or better with the values of the CIRA 1965 mean atmospheric model, which are lower. The results of other authors are also shown. The comparison is, however, not straightforward. All experimenters seem to have used a mean atmospheric molecular weight of 28, Lloyd and Sheppard (1965) excepted, since they used a value taken from a model. Unfortunately, they did not have a temperature measurement. Golomb et al (1967, 1968) have deduced the densities from the self diffusion coefficient of air D_{11} taken equal to $1.25 \times D_{12}$. On the other hand our choice of the mean collisional diameter and atmospheric molecular weight corresponds to a ratio $D_{11}/D_{12} = 1.4$. This difference could account for our results being 12% lower than those reported by Golomb et al (1967, 1968). The use by Rees et al (1970) of a mean atmospheric molecular weight equal to 28, and of a mean collisional diameter 3.6% higher than used in this work, would tend to yield values 5% higher than those reported here by us while these are already higher by approximately 20%.

As already pointed out by von Zahn (1970) the scatter of density values at about 150 km should not be as great as the observations of luminescent clouds seem to indicate. This discrepancy would not be much reduced if, in the reduction of the measurements, the same values of molecular parameters had been used. The results obtained with the ESRO payloads S 64-1 and S 64-2 show that vertical motions of artificial clouds could possibly explain some of the scatter observed in the results.

ACKNOWLEDGEMENT

We express our thanks to Professor M. Nicolet for his advice and for his interest in this work.

TABLE I.- Atmospheric temperatures (T) and densities (ρ) deduced from the observed AlO clouds

Payload (N)	Altitude (km)	T(°K)	ρ(g.cm^{-3})
S 64-1	160	645	1.40×10^{-12}
S 64-2	156	660	1.55×10^{-12}
	156*	660	1.76×10^{-12}
	165	660	1.12×10^{-12}

* Measurement at 4670 Å.

REFERENCES

ACKERMAN, M. and VAN HEMELRIJCK, E. (1971), Measurement of upper atmospheric winds at 160 and 275 kilometers. J. Geophys. Res., in press.

CIRA, 1965, Cospar International Reference Atmosphere 1965 ; North-Holland Amsterdam.

GOLOMB, D. , HARANG, O. and DEL CRECO, F.P.(1967). Upper Atmosphere densities and temperatures at 105-165 kilometers from diffusion and spectral intensity of AlO trails. J. Geophys. Res. 72, 2365-2370.

GOLOMB, D., DEL CRECO, F.P., HARANG, O., JOHNSON, R.H. and MacLEOD, M.A. (1968). Neutral diffusion coefficients, temperatures and densities in the lower thermosphere. Space Research, 8, 705-712.

LLOYD, K.H. and SHEPPARD, L.M. (1965). Atmospheric structure in lower thermosphere. Planet. Space Sc. 13, 1313.

NICOLET, M. (1964), Aeronomiya. Mir, Moscou.

REES, D. (1968), Determintations of upper atmosphere structure above 90 km by optical observations on rocket-borne chemical releases. Space Research, 8, 909-919

REES, D., ROPER, R.W., LLOYD, K.H. and LOW, C. (1969), High altitude profiles of wind velocity, temperature and density. Paper presented at 12th Cospar Meeting, Prague.

REES, D., ROPER, R.W., LLOYD, K.H. and LOW, C. (1970), Determination of the structure of the atmosphere between 90 and 250 kilometers using contaminant releases I. Woomera, May 1968. Phil. Trans. Roy. Soc. London.

SIMON, P. (1971), Détermination de la densité de la thermosphère terrestre par l'observation de la fluorescence de nuages artificiels d'oxyde d'aluminium. Bull. Acad. Roy. Belgique, Cl. Sc. 57, in press.

VON ZAHN, U. (1970), Neutral air density and composition at 150 kilometers. J. geophys. Res. 75, 5517-5527.