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simultaneous observation between 20 and 40 km**

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**P. AIMEDIEU, A.J. KRUEGER,
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B E L G I S C H I N S T I T U U T V O O R R U I M T E - A E R O N O M I E

3 - Ringlaan
B - 1180 BRUSSEL

FOREWORD

The paper "Ozone profile intercomparison based on simultaneous observation between 20 and 40 km" is accepted for publication in Planetary and Space Science.

AVANT-PROPOS

L'article "Ozone profile intercomparison based on simultaneous observation between 20 and 40 km" sera publié dans "Planetary and Space Science".

VOORWOORD

Het artikel "Ozone profile intercomparison based on simultaneous observation between 20 and 40 km" zal verschijnen in "Planetary and Space Science".

VORWORT

Die Arbeit "Ozone profile intercomparison based on simultaneous observation between 20 and 40 km" wird in "Planetary and Space Science" herausgegeben werden.

OZONE PROFILE INTERCOMPARISON BASED ON
SIMULTANEOUS OBSERVATION BETWEEN 20 AND 40 KM

by

P. AIMEDIEU*, A.J. KRUEGER⁺, D.E. ROBBINS^o and P.C. SIMON**

- * Service d'Aéronomie du CNRS, B.P. n° 3, F-91370 Verrières-le-Buisson, France.
- + NASA Goddard Space Flight Center, Greenbelt, Maryland 20771, USA.
- o NASA Lyndon B. Johnson Space Center, Houston, Texas 77058, USA.
- ** Institut d'Aéronomie Spatiale de Belgique, 3, Avenue Circulaire B-1180 Bruxelles, Belgique.

ABSTRACT

The vertical distribution of stratospheric ozone has been simultaneously measured by means of five different instruments carried on the same balloon payload. The launches were performed from Gap during the intercomparison campaign conducted in June 1981 in southern France. Data obtained between altitudes of 20 and 40 km are compared and discussed. Vertical profiles deduced from Electrochemical concentration cell sondes launched from the same location by small balloons and from short Umkehr measurements made at Mt. Chiran (France) are also included in this comparison. Systematic differences of the order of 20 percent between ozone profiles deduced from solar UV absorption and in situ techniques are found.

Résumé

La distribution verticale de l'ozone stratosphérique a été mesurée simultanément à l'aide de cinq instruments différents intégrés sur la même charge utile. Les ballons stratosphériques ont été lancés depuis Gap pendant la campagne d'intercomparaison menée en juin 1981. Les données obtenues entre des altitudes de 20 et 40 km sont comparées et discutées. Des profils verticaux, déduits de sondes électrochimiques lancées du même endroit par de petits ballons et des mesures Umkehr faites au Mont Chiran (France) sont aussi inclus dans cette comparaison. Des différences systématiques de l'ordre de 20% entre les profils d'ozone déduits de l'absorption du rayonnement UV solaire et des techniques in situ sont mises en évidence.

Samenvatting

De verticale verdeling van stratosferische ozon werd gelijktijdig gemeten d.m.v. vijf verschillende instrumenten gedragen door eenzelfde nuttige lading per ballon. De lanceringen werden gedaan te Gap tijdens de vergelijkende campagne geleid in Zuid-Frankrijk in juni 1981. De gegevens verkregen tussen hoogten van 20 en 40 km worden vergeleken en zullen besproken worden. Vertikale profielen, afgeleid uit elektrochemische sondes, die gelanceerd werden vanuit dezelfde plaats d.m.v. kleine ballons, en uit Umkehr metingen die verricht werden te Mont Chiran (Frankrijk), zijn eveneens in deze vergelijking opgenomen. Systematische verschillen van de grootte van 20% tussen ozonprofielen, afgeleid uit UV zonnc-absorptie, en in situ technieken werden gevonden.

Zusammenfassung

Die Vertikalverteilung von stratosphärische Ozon ist gleichzeitig gemessen worden mittelst fünf verschiedene Instrumenten, getragen durch einseibste Nutzlast per Ballon. Die Lancierungen sind getan worden in Gap während die vergleichende Kampagne geführt in Sud-frankreich in Juni 1981. Die Daten bekommen zwischen Höhe von 20 und 40 km sollen vergleicht und diskutiert werden. Vertikalprofilen, deduziert aus elektrochemische Sonden, lanciert von der selbste Platz mittelst kleine Ballonen, und aus Umkehr-Messungen getan in Mont Chiran (Frankreich), sind auch in diese Vergleichung geschrieben. Systematische Differenzen von der Grösse eines 20 Prozent zwischen Ozonprofilen, deduziert aus UV Sonne-Absorption und in situ Techniken sind gefunden.

INTRODUCTION

Many measurement techniques have been used over the past several years to determine ozone profiles in the stratosphere. They include standard techniques for routine observations, such as the ground-based Umkehr observations for solar elevation angles of less than 30° and the small balloon techniques based on two types of electrochemical instruments, the Brewer-Mast (BM) and the Electrochemical Concentration Cell (ECC) type.

Other techniques have been used with large research balloon payloads. They are based on chemiluminescent, UV absorption and mass spectrometer in situ measurements or on UV absorption measurement by means of filter radiometers and solar spectrometers using the sun as a source.

These observing programs have been developed for the study of the long-term variation in stratospheric ozone and for the validation of satellite ozone profile measurements. Consequently, the various experimental techniques with their own uncertainties should be compared within a specific campaign in order to understand differences between measurements, to improve the reliability of the existing data, and to insure the continuity in future observations.

The purpose of this paper is to present the intercomparison results of ozone profiles deduced from simultaneous measurements obtained during the intercomparison campaign conducted in June 1981 in southern France. In this paper, only data obtained between 20 and 40 km will be discussed. Intercomparisons at lower and higher altitudes are discussed elsewhere (Megie and Pelon, 1983; Monnanteuil et al., 1983).

CURRENT CONCLUSIONS OF PREVIOUS INTERCOMPARISON

CAMPAIGNS

Until now, only few intercomparison campaigns of ozone profile measurements above 20 km of altitude have been performed. The first campaign took place during the summer of 1953 in Arosa (Switzerland). Data obtained from four different techniques are published in Brewer et al. (1960). Balloon measurements, namely the Brewer's electrochemical sonde and the Paetzold's optical sonde, provided vertical distributions below an altitude of 25-30 km. More recently, intercomparison results between 20 and 40 km based on the Dasibi instrument from NASA JSC and the mass spectrometer from the University of Minnesota have been published by Mauersberger et al. (1981). Other results obtained from balloon campaigns, namely the last flight of the Stratcom series, the SABE 2 (Solar Absorption Balloon Experiment) flight and the LIP (LIMS Instrument Package) flight series, and from rocket campaign conducted jointly by WMO, FAA and NASA in 1979, have been reported in the NASA-WMO report on the stratosphere (WMO, 1982). From these intercomparisons, systematic differences have been found between several experimental techniques.

From both the Stratcom and the SABE 2 flights, ultraviolet radiometers gave larger ozone density values than those derived from the various in situ observations, 30 percent for instance at 35 km during the SABE 2 flight. It should be pointed out that, since atmospheric pressure is measured independently by each ozone sensor, differences observed between some instruments could reflect error in both ozone and pressure measurements.

Data obtained in September 1980 from a mass spectrometer and Dasibi instrument (Mauersberger et al., 1981) agreed over the whole altitude range of measurement. Lower density values above 35 km were obtained previously in 1978 with the UV absorption instrument. This

resulted from the need to correct for a pressure differential between the absorption cell and the outside ambient pressure measurement as mentioned by Mauersberger et al. (1981).

Umkehr derived profiles were generally lower during the SABE 2 flight than the values from the UV radiometers for altitudes above 31 km but this method also gives lower values than generally observed around the main maximum by other routine ozone sounding techniques (WMO, 1982).

AVAILABLE DATA

Table 1 lists the different ozone sensors that provided data for the intercomparison of ozone profiles between 20 and 40 km. During the first flight on June 19, 1981, data were obtained from four vertical excursions of the gondola as described by Chanin (1983). The first ascent started just before dawn in order to allow the comparison with the Lidar observations. Sunrise occurred when the balloon reached about 15 km of altitude. The two ultraviolet radiometers were not designed to provide reliable observations for large zenith angles and consequently no profiles were reported from these two instruments for the first ascent. On the other hand, because of possible degradation of the reactive solution used in the Brewer-Mast sonde on board of the large balloon, only data obtained during the first ascent have been taken into account. In addition, the Dasibi instrument unfortunately failed after reaching the first ceiling and only provided measurements during that first ascent. Consequently, intercomparison between in situ and UV radiometer measurements is not straightforward. Nevertheless, assuming that over the longitudinal range covered during this flight there is no significant change in the ozone profile above 22 km - this seems to be confirmed by the 3 profiles obtained by Krueger et al. (1983) and by Amedieu (1983) - the intercomparison of all experimental techniques will be discussed below. Umkehr and ECC data were not obtained from the

TABLE 1.- Available data for ozone profiles between 20 and 40 km.

Sensor	Location	Flight June 9, 1981		Flight June 26, 1981	
		<u>1st a*</u>	<u>1st d⁺</u>	<u>2nd a*</u>	<u>2nd d⁺</u>
Short Umkehr (Univ. Reims)	Ground-based Mt. Chiran	X			
Chemilumiscent Sonde (Service d'Aéronomie)	Large balloon	X	X	X	X
Brewer Mast Sonde (EERM)	Large balloon	X			
Dasibi (NASA-JSC)	Large balloon	X			X
UV solar radiometer (IASB)	Large balloon		X	X	
UV solar radiometer (NASA-GSFC)	Large balloon		X	X	X
ECC sondes (NASA-WFC)	Small Balloons Gap.	X	X		X

* a = ascent

+ d = descent

same location but these soundings were made at sufficiently close distances to be taken into account here. During the second flight on June 26, 1981, only two vertical distributions up to 40 km of altitude are available. The Brewer-Mast sonde failed above 25 km of altitude and the optical sonde data were obtained only during the sunlit part of the flight, especially during the payload descent under parachute. These latter observations are however more difficult to analyze and the preliminary results will not be discussed in this work.

RESULTS AND DISCUSSION

The conditions of observation during this intercomparison campaign are described extensively in Chanin (1983).

The experimental techniques and results for each instrument are published separately in the same volume (Aimedieu, 1983; Krueger *et al.*, 1983; Robbins, 1983; Roeland *et al.*, 1983; Marché *et al.*, 1983). From the profile intercomparison below 25 km, published by Megie and Pelon (1983), it is clear that the electrochemical instruments, namely the ECC sondes, provide reliable data up to 24 km. Figure 1 shows that the discrepancies between all these soundings increase with the altitude, reaching a factor 2 at 33 km. Consequently ECC soundings are only valid for altitudes below 25 km.

For the first flight on June 19, 1982, the ozone profiles obtained during the first ascent and reported by Aimedieu (1983) and Robbins (1983) disagree by about 15 percent near the main ozone maximum around 23 km of altitude (figure 2). The agreement above 27 km is better. In addition, the detailed structures of the ozone profile are not always well correlated. Table 2 lists the vertical distribution of ozone obtained with the Brewer-Mast sonde on board the same gondola. Figure 2 shows that these data are in good agreement with those of Robbins (1983) even above 25 km. Unfortunately it is not possible, with only one comparison, to conclude on the reliability of the Brewer-Mast

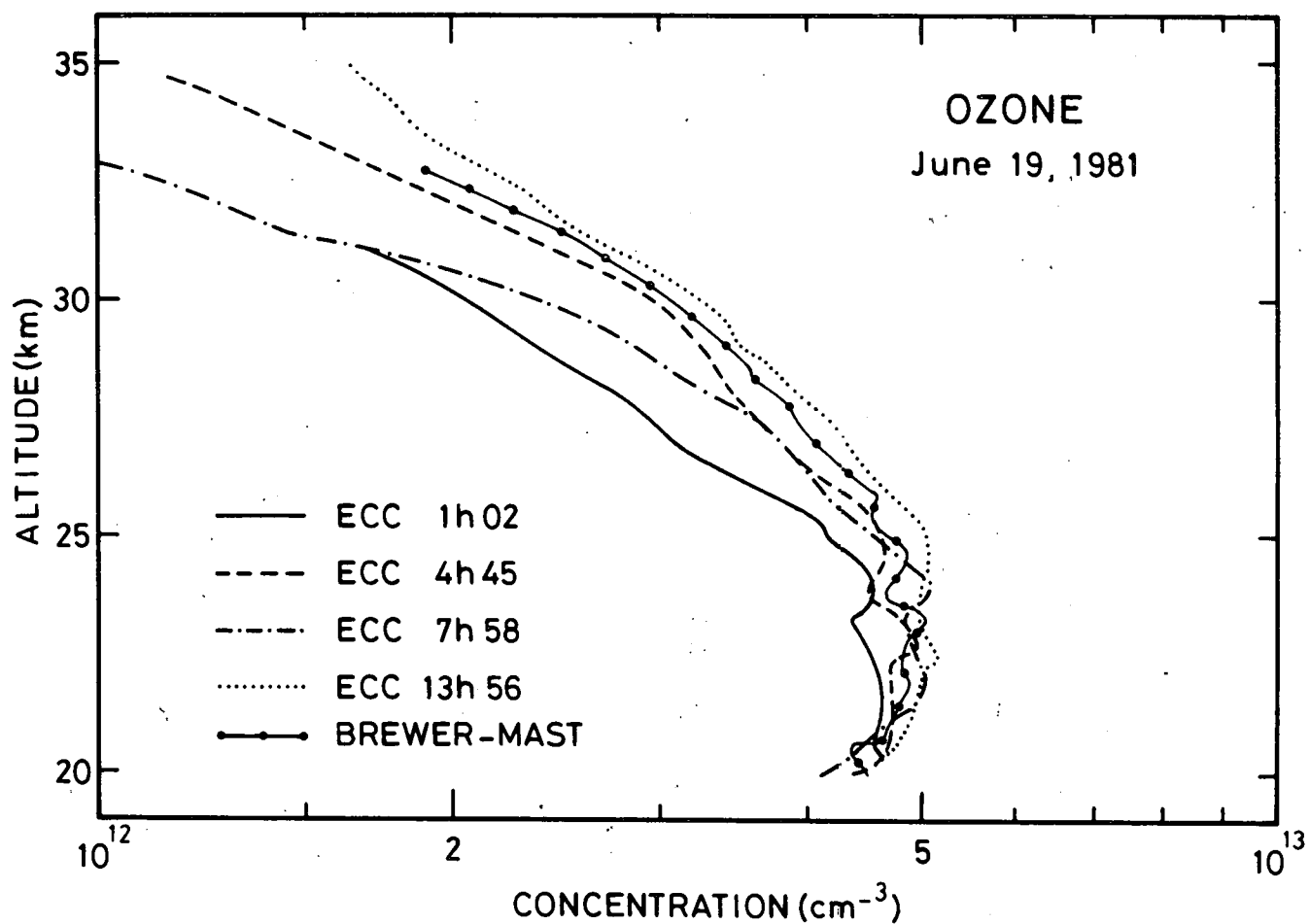


Fig. 1.- Ozone vertical distribution for altitudes between 20 and 35 km as measured on June 19, 1981, by four ECC sondes. The Brewer-Mast data are also given for comparison purposes.

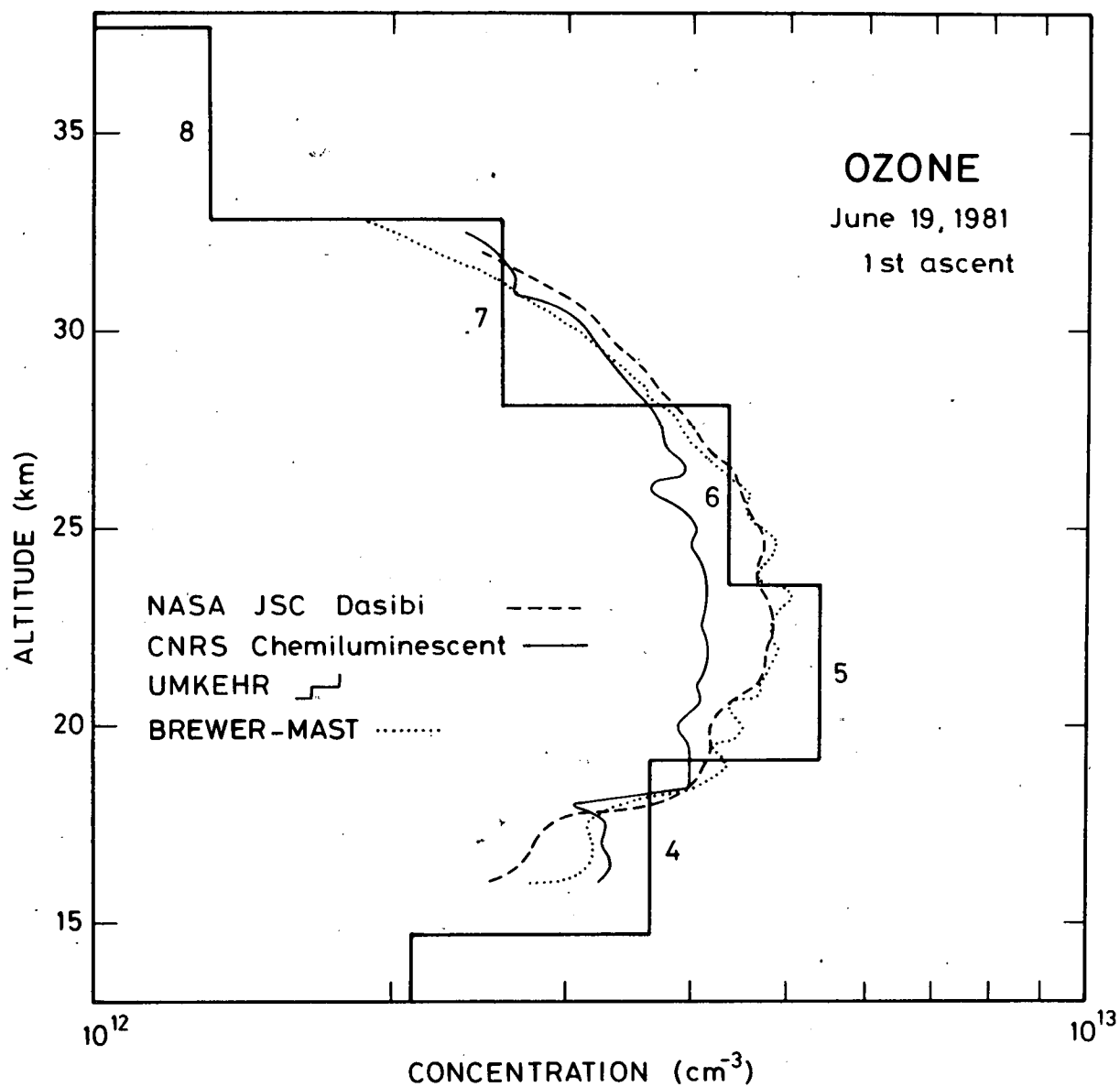


Fig. 2.- Ozone vertical distribution for altitudes between 15 and 40 km as measured on June 19, 1981, by the three in situ instruments. The short Umkehr profile obtained at Mt. Chiran is also given for comparison purposes.

TABLE 2.- Ozone vertical concentration (molecules.cm⁻³) versus altitude as measured by the four ECC and the Brewer-Mast sondes on June 19, 1981.

Altitude km	Brewer-Mast 1st ascent	ECC 1h02	ECC 4h45	ECC 7h58	ECC 13h56
20.0	4.55x10 ¹²	4.31x10 ¹²		4.11x10 ¹²	4.35x10 ¹²
20.5	4.36	4.58		4.42	4.69
21.0	4.71	4.58		4.60	4.87
21.5	4.80	4.61	4.68x10 ¹²	4.98	4.93
22.0	4.88	4.57	4.73	5.04	5.02
22.5	4.83	4.54	4.79	4.95	5.16
23.0	4.93	4.50	5.00	4.88	5.04
23.5	4.97	4.48	4.71	4.86	4.98
24.0	4.72	4.54	4.46	5.08	5.02
24.5	4.91	4.39	4.66	4.82	5.07
25.0	4.68	4.17	4.60	4.54	5.05
25.5	4.58	4.00	4.51	4.30	4.92
26.0	4.53	3.62	4.27	4.10	4.64
26.5	4.28	3.41	3.99	3.96	4.44
27.0	4.08	3.07	3.77	3.79	4.30
27.5	3.97	2.90	3.62	3.57	4.16
28.0	3.78	2.78	3.46	3.32	3.94
28.5	3.61	2.57	3.37	3.07	3.76
29.0	3.53	2.40	3.25	2.88	3.51
29.5	3.23	2.22	3.11	2.60	3.43
30.0	3.08	2.05	2.96	2.33	3.26
30.5	2.84	1.89	2.72	2.07	3.01
31.0	2.67	1.73	2.44	1.76	2.78
31.5	2.46		2.21	1.44	2.53
32.0	2.20		2.01	1.27	2.40
32.5	1.99		1.81	1.34	2.24

TABLE 2.- cont.

Altitude (km)	Brewer-Mast 1st ascent	ECC 1h02	ECC 4h45	ECC 7h58	ECC 13h56
33.0			1.63	9.91×10^{11}	2.05
33.5			1.49	8.93	1.90
34.0			1.34		1.81
34.5			1.20		1.72
35.0					1.62

sondes above 25 km. Further simultaneous measurements, with several sondes, are needed to confirm the result obtained during this campaign. The Umkehr profile obtained from Mt.Chiran (Marché *et al.*, 1983) and reported on figure 2 gives lower values around 30 km and higher values below 22 km. The cross over is situated in layer number 6, between 23.6 and 28.4 km. In addition, the altitude of the main maximum, situated in layer number 5, seems too low when compared to the other three profiles. Between 10 and 38 km, the estimated error in the short Umkehr measurements is between ± 5 and ± 9 percent. Robbins (1983) claims a total rms uncertainty of ± 1.6 percent in the same altitude range and Aïmedieu (1983) an accuracy varying from ± 8 percent at 16 km to ± 15 percent at 38 km.

The error budget analysis made by Robbins (1983) shows that, in the case of in situ UV absorption measurements, the uncertainty on the ozone absorption cross-section is the main contribution to the total rms uncertainty. In the case of the chemiluminescent measurements, the error is mainly due to the value of the air-reactant mixture flow and to the laboratory calibration performed by means of a Dasibi instrument. Considering the quoted accuracies for both techniques, it appears that a large amount of the data obtained simultaneously by in situ instruments are consistent. Nevertheless, discrepancies as large as 15 percent around the main ozone maximum are significant. They have to be explained by further analysis of the data reduction techniques and the experimental problems associated with measurements in the stratosphere and in the laboratory. On the other hand, comparison with the Umkehr results is in contradiction with the previous conclusions reported in the NASA-WMO report on the stratosphere (WMO, 1982), claiming that in situ techniques yield in general higher concentration near the ozone maximum than the Umkehr observations. As discussed by Megie and Pelon (1983), the presence of aerosol particles due to high volcanic activity since May 1980 could explain the higher ozone concentrations deduced by the Umkehr observations in layers 4 and 5, situated around 20 km.

Figure 3 and 4 show the ozone profiles obtained respectively from Krueger et al. (1983) and by Roeland et al. (1983). In both figures, the ozone vertical distribution measured with the in situ UV absorption instrument (Robbins, 1983) is reported for comparison purposes. The average profiles based on each instrument are shown in figure 5. Differences between the two in situ techniques have been already discussed. Taking as a reference the JSC Dasibi vertical distribution, it shows clearly that the two UV radiometers give ozone concentrations systematically higher by about 20 percent. The differences between the two UV radiometers are given in Table 3. They are generally less than 10 percent, that means within their uncertainties. The best agreement is found for altitudes corresponding to an optical thickness close to 1 as illustrated by figure 6 on which the optical depth encountered during the balloon vertical excursions are reported versus time. Further analysis and new measurements are needed to explain such disagreements between ozone profiles obtained by similar techniques during the same flight, but the estimated uncertainty for filter radiometers is mainly due to the error in the absorption cross-section (± 5 percent). This method could also introduce larger errors in both ends of the altitude range because the data correspond to lower and higher optical depth (cfr. figure 6). In addition, the UV differential absorption technique seems very sensitive at lower and higher altitudes to the measured values of the instrument spectral parameters as described by Roeland et al. (1983). It should be noted that the 4 percent of difference between results deduced from the two active channels used by Krueger et al. (1983) emphasis the need of intercomparison at several wavelengths.

For the second flight on June 26, 1981, the only available data are those obtained by Amedieu (1983) and Robbins (1983) both using in situ techniques. They are represented on figure 7. The agreement is good, the maximum discrepancy being 10 percent around 26 km (data below 20 km are not considered here). Such difference is not significant taking into account the inaccuracies in both measurements. Comparison

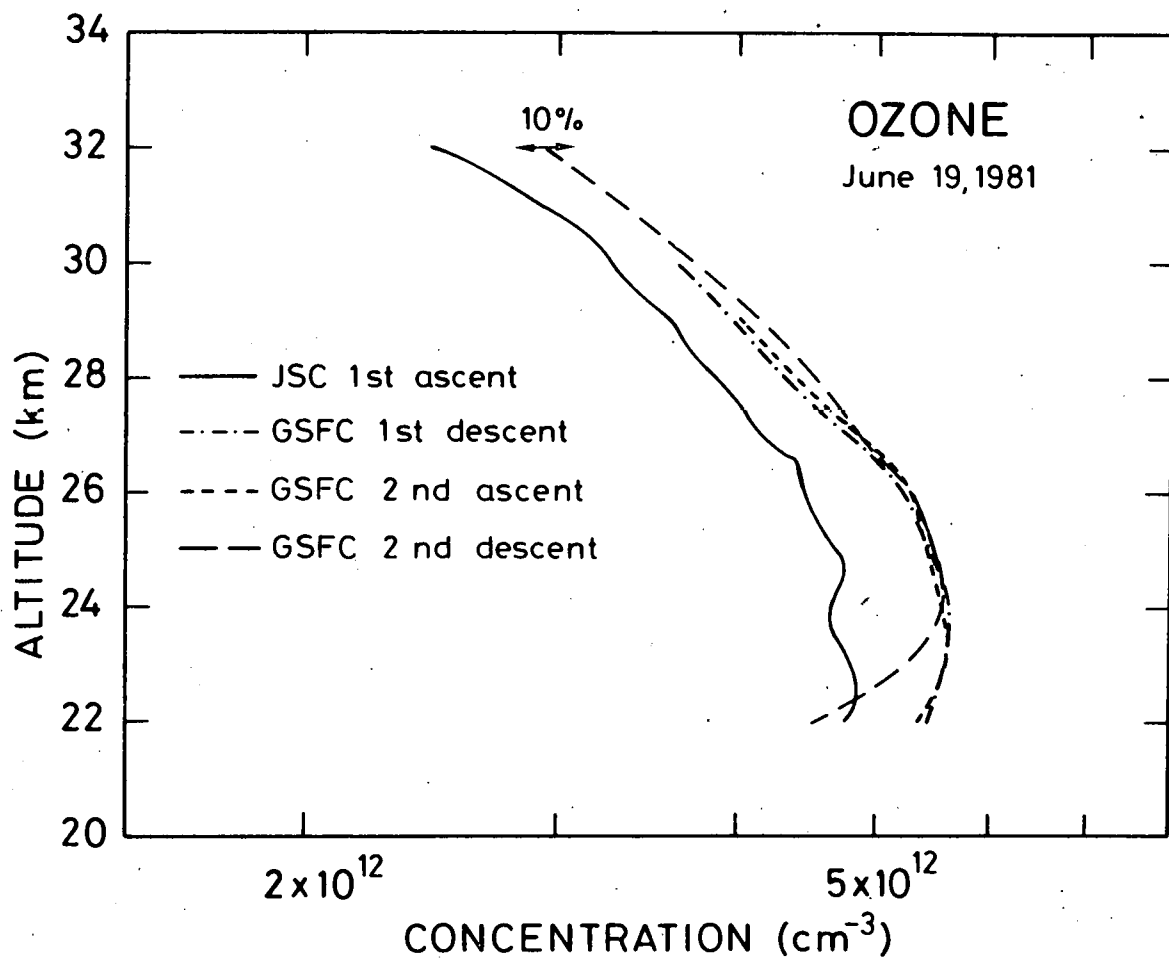


Fig. 3.- Ozone vertical distribution for altitudes between 22 and 32 km as measured on June 19, 1981 by the NASA-GSFC UV filter radiometer (Krueger et al., 1983). The profile obtained by Robbins (1983) is given for comparison purposes.

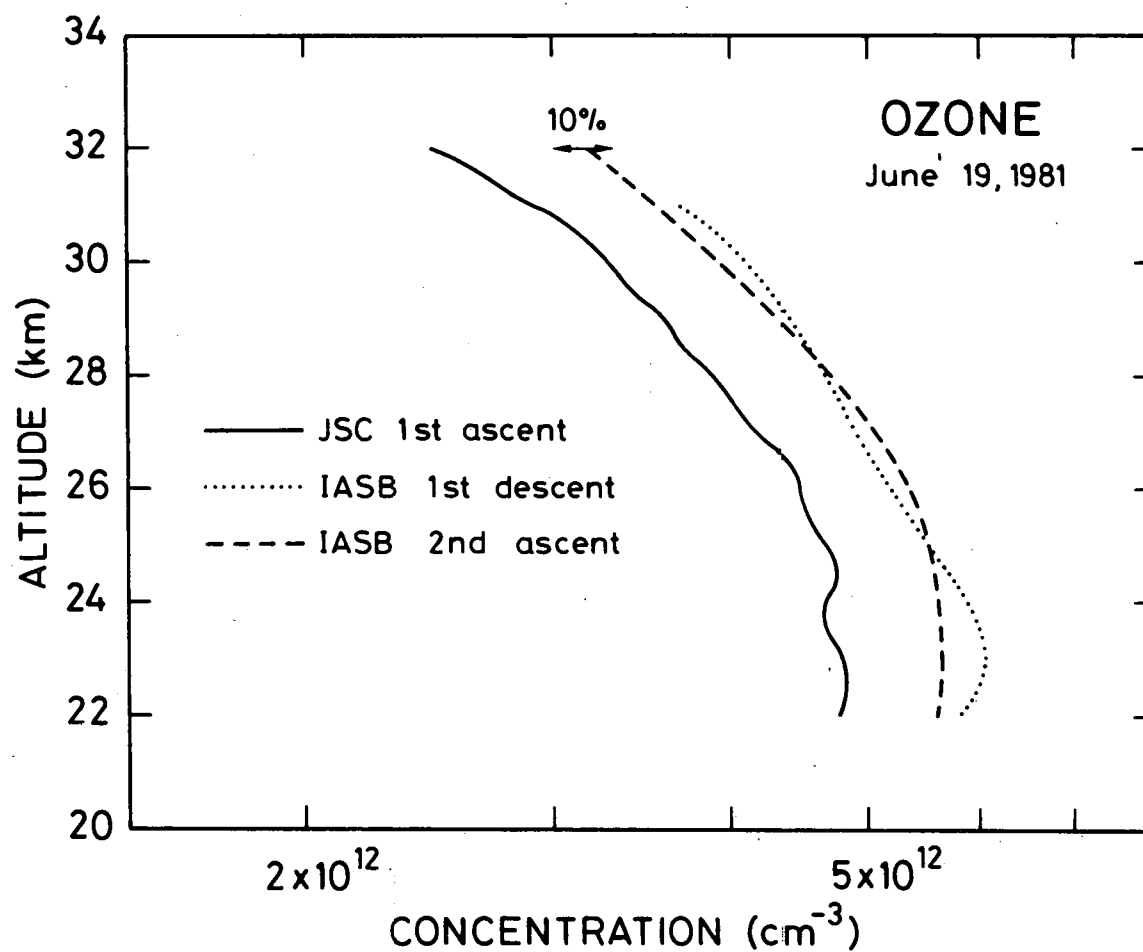


Fig. 4.- Ozone vertical distribution for altitudes between 22 and 32 km as measured on June 19, 1981 by the IASB UV filter radiometer (Roeland et al., 1983). The profile obtained by Robbins (1983) is given for comparison purposes.

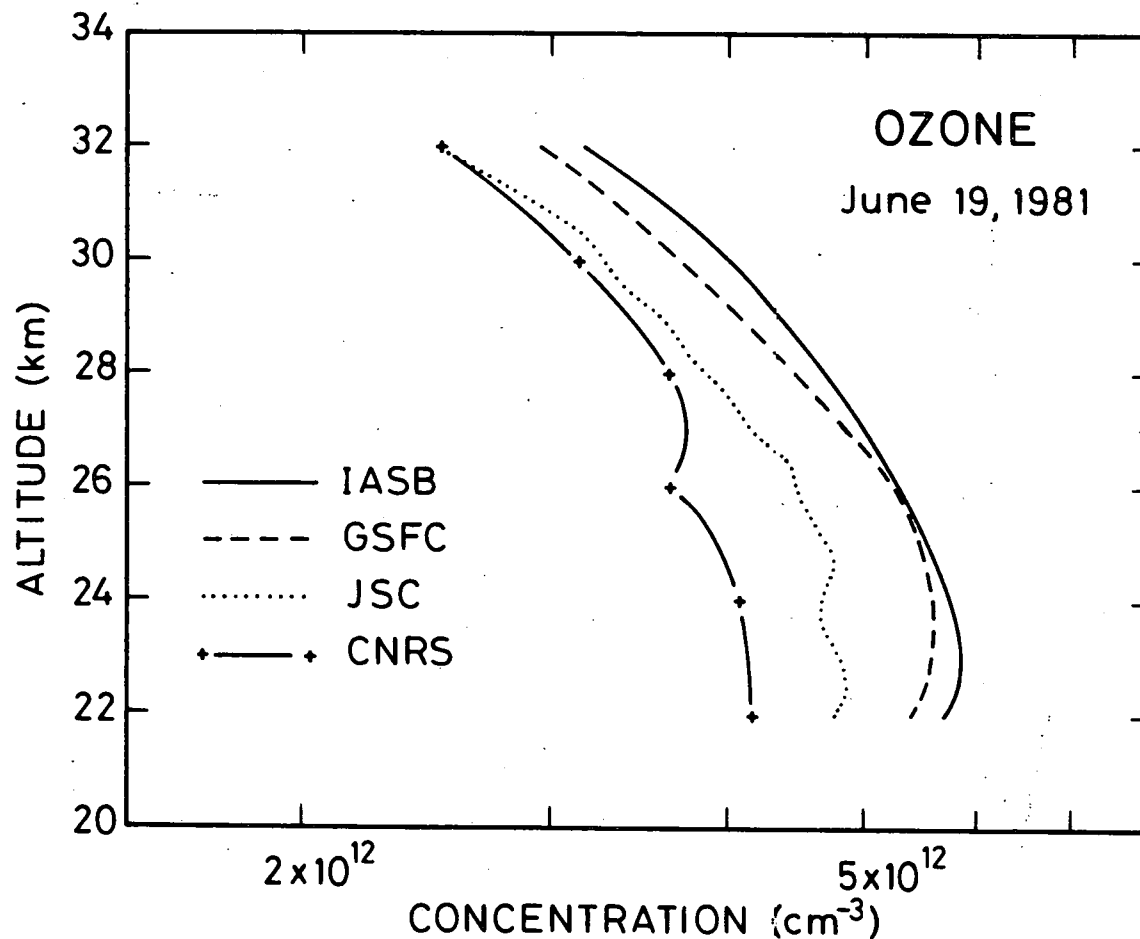


Fig. 5.- Average ozone vertical distribution (22-32 km) as measured on June 19, 1981 by the two in situ instruments (JSC and CNRS) and the two solar UV absorption radiometers (IASB and GSFC). Data below 24 km obtained by Krueger et al. (1983) during the 2nd descent are not taken into account.

TABLE 3.- Ozone vertical concentration (molecules.cm⁻³) versus altitude
as measured by the two solar UV radiometers on June 19, 1981.

Altitude (km)	Descent 1			Ascent 2		
	IASB	GSFC	Ratio	IASB	GSFC	Ratio
22	5.80x10 ¹²	5.43x10 ¹²	1.07	5.60x10 ¹²	5.35x10 ¹²	1.05
23	6.07	5.56	1.09	5.64	5.59	1.01
24	5.87	5.62	1.04	5.61	5.57	1.01
25	5.53	5.45	1.01	5.54	5.43	1.02
26	5.20	5.22	0.996	5.35	5.29	1.01
27	4.91	4.79	1.03	5.06	4.86	1.04
28	4.66	4.32	1.08	4.71	4.39	1.07
29	4.40	3.97	1.11	4.32	4.02	1.07
30	4.11	3.63	1.13	3.92		
31	3.67			3.52		
32				3.17		

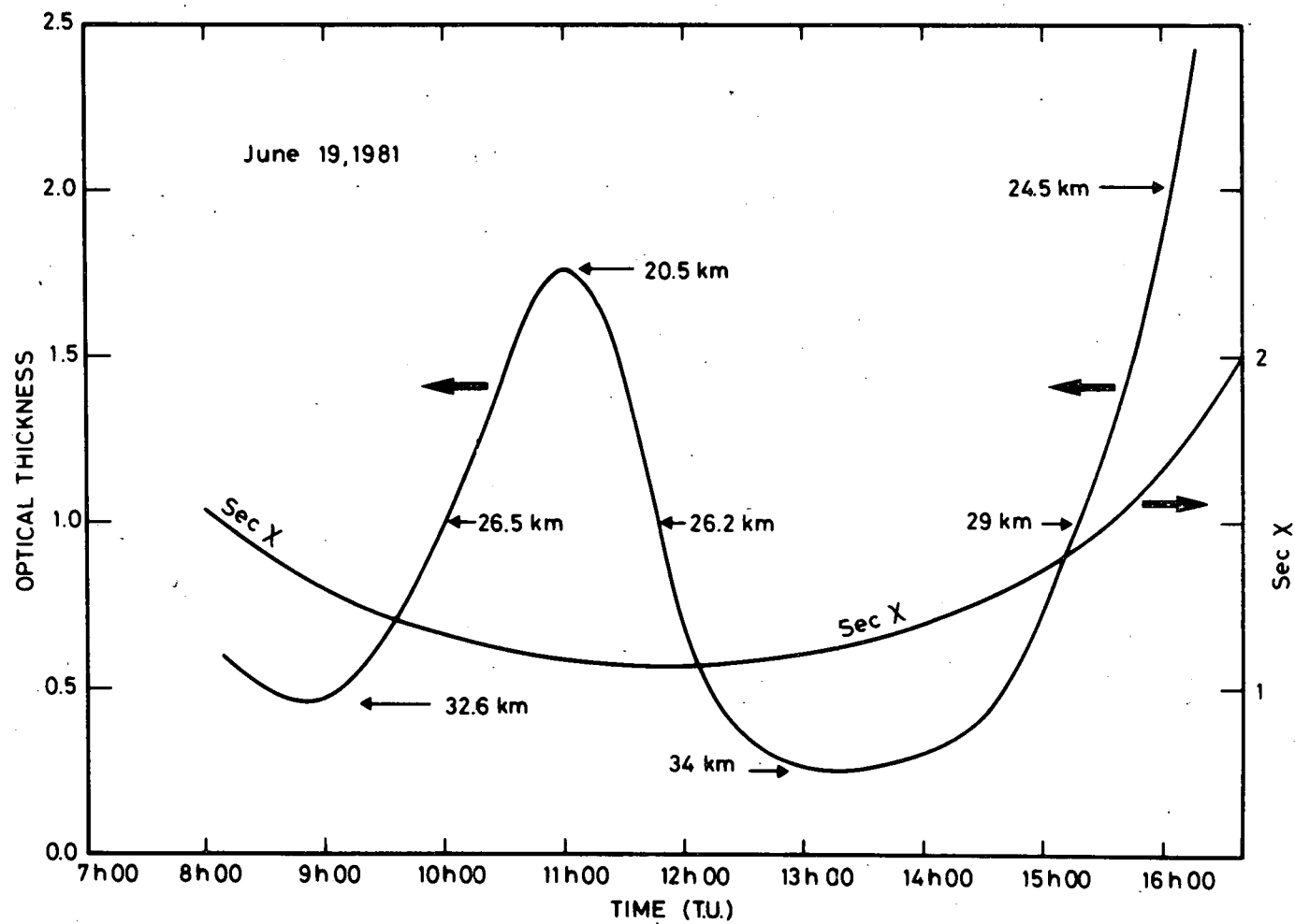


Fig. 6.- Optical thickness observed during the flight on June 19, 1981, versus time. The secant of the solar zenith angle and typical altitudes are also indicated.

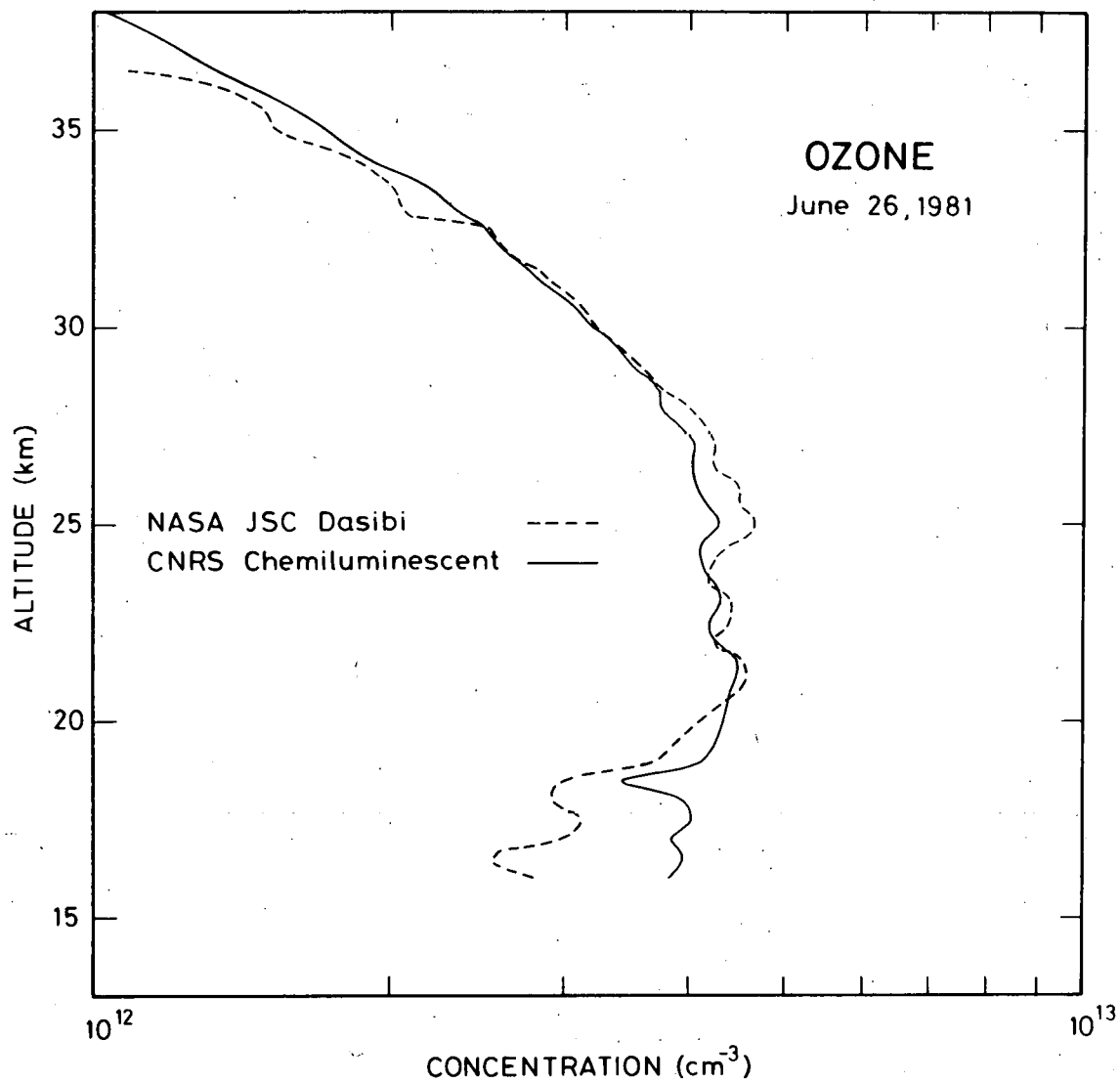


Fig. 7.- Ozone vertical distribution for altitudes between 15 and 40 km as measured on June 26, 1981 by the two in situ instruments.

with the data obtained during the first flight on June 19, 1981, indicates that the day-to-day variations above 25 km of altitude are not larger than the experimental uncertainties during this campaign.

In conclusion, the basic disagreement between in situ and solar UV filter radiometer measurements is confirmed. It appears that the solar absorption data give ozone concentrations that are 20 percent larger than the in situ techniques. Further investigations are needed to explain such divergences. Filter radiometers should fly with solar spectrometers which are able to provide data with a better accuracy covering the whole altitude range. Filter radiometers are obviously limited by the number of wavelengths used in the solar UV absorption measurements, which consequently increase the uncertainties. A sensitivity calculation for the parameters like the solar spectrum, filter transmissions, etc. should be performed. On the other hand, a careful analysis of wall-loss problems and laboratory calibrations for in situ techniques should also be made in order to identify the principal sources of errors in such measurement techniques. Nevertheless, the good agreement between in situ UV absorption and mass spectrometer measurements reported by Mauersberger et al. (1981) suggests that the wall-losses could not be the main source of uncertainties because this problem is not encountered in the mass spectrometer. On the other hand, the chemiluminescent instrument should also be calibrated using the balloon-borne Dasibi instrument to make future investigations more comparable. This campaign also shows that the ECC sondes provide reliable data only below 25 km. Differences as high as a factor of 2 have been found around 33 km, between the four soundings performed on June 19, 1981, from the same location.

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