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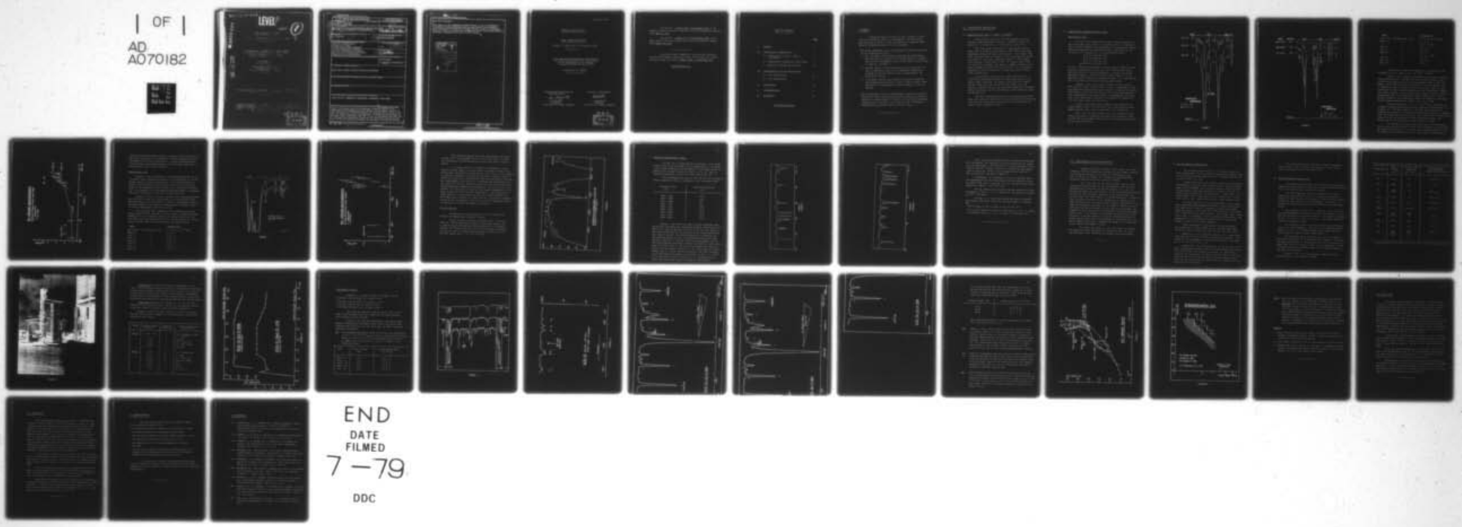

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LEVEL III

April 27, 1979

FINAL SCIENTIFIC REPORT

Period : 1 March 1976 - 28 February 1979

HIGH RESOLUTION TRANSMISSION MEASUREMENTS OF THE ATMOSPHERE IN THE INFRARED

M. MIGEOTTE
and collaborators

INSTITUTE OF ASTROPHYSICS
UNIVERSITY OF LIEGE
B-4200 LIEGE-OUGREE (Belgium)

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Measurements have been made of solar spectra from the International Scientific Station of the Jungfraujoch and supplements have been added to the Photometric Atlas of the Solar Spectrum from 3000-10,000 Angstroms. The spectral domain covered by the Atlas now extends from 4,006-7,994 Angstroms. In addition to the extension of the solar atlas, measurements made near 2.5 and 3.3 micrometers have been used for deducing trace atmospheric species such as hydrofluoric and hydrochloric acid. A fourier transform spectrometer has been used to record high accuracy

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solar spectra in the atmospheric windows between 1.1 and 2.5 micrometers. Stratospheric balloon instrumentation has been flown on two occasions to obtain solar spectra in selected intervals between 1.8 and 8.1 micrometers. The object here is to measure trace atmospheric species in spectral regions of significant atmospheric absorption by other species.

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FINAL SCIENTIFIC REPORT

Period : 1 March 1976 - 28 February 1979

HIGH RESOLUTION TRANSMISSION MEASUREMENTS OF THE ATMOSPHERE IN THE INFRARED

prepared by R. ZANDER

Contracting Representative
and Supervisor

M. MIGEOTTE
Professor
University of Liège, Belgium

Principal Investigator

L. DELBOUILLE
Professor
University of Liège, Belgium

The period : 1 March 1976 - 28 February 1977 of the present contract has been covered by an Interim Scientific Report dated May 31, 1977.

The period : 1 March 1977 - 28 February 1978 of the same contract has been covered by an Interim Scientific Report dated April 28, 1978.

This Final Report summarizes informations presented in the Interim Reports mentioned above and includes new results obtained during the period 1 March 1978 - 28 February 1979.

TABLE OF CONTENTS

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I. SUMMARY

During the period covered by this contract (1 March 1976 to 28 February 1979), two experimental facilities have been operated in order to obtain either new or improved atmospheric transmission spectra in the infrared :

- The Solar Laboratory of the International Scientific Station of the Jungfraujoch, where :
  - A.- the 7.5 meters focal length prism-grating spectrometer has been used to further record solar spectra as supplement to the "Photometric Atlas of the Solar Spectrum from λ 3,000 to λ 10,000 Å ".
  - B.- various series of solar observations were made near 2.5 and 3.3 microns as part of an atmospheric monitoring program of telluric species such as hydrofluoric and hydrochloric acids.
  - C.- a one-meter optical path difference Fourier transform spectrometer has been used to record high accuracy solar spectra in the atmospheric windows between 1.1 and 2.5 microns.

- The stratospheric balloon instrumentation which was flown in 1976 and in 1978; it has provided solar spectra in selected intervals located between 1.8 and 8.1 microns which have been investigated in relation to the study of the stratospheric concentration of species such as HF, HCl, CH_4, ...

II. JUNGFRAUJOCH OBSERVATIONS

A.- Observations in the λ 3,000 to λ 10,000 Å

Observations related to the "Photometric Atlas of the Solar Spectrum from λ 3,000 to λ 10,000 Å" have been pursued by L. Delbouille, G. Roland and L. Neven {1}.

The first part of that Atlas, covering the region from 4,300 to 6,200 Å, was issued in 1973. Since that time, supplements have been added progressively : the region from 6,200 to 6,850 Å was published in 1974; that one from 4,006 to 4,300 Å in 1975; the supplement issued in 1977 ranged from 6,850 to 7,498 Å and, in 1978, the region from 7,498 to 7,994 Å was released. The spectral domain covered by the Atlas extends now from 4,006 Å to 7,994 Å. Dr. G. Roland is responsible for the reduction of these data and for their final presentation.

Observations covering the regions from 3,600 to 4,006 Å have been made during 1977 and 1978; they are currently under reduction. The domain from 8,000 to 10,000 Å has also been recorded during the last years, but some specific intervals need to be reobserved under more favorable dryness conditions at the Jungfraujoch; this should be achieved during 1979.

The above mentioned Atlas has been distributed worldwide; more than 350 subscriptions are currently on the mailing list for that publication. The data are also available in digital form on magnetic tapes.

B.- Jungfraujoch atmospheric monitorings

Hydrofluoric acid

In 1976, after hydrofluoric acid had been detected for the first time in the earth's stratosphere {2}, L. Delbouille and G. Roland attempted and succeeded in measuring that species from the Jungfraujoch; observations were carried out in the vicinity of 2.5 microns {3}. The following HF lines :

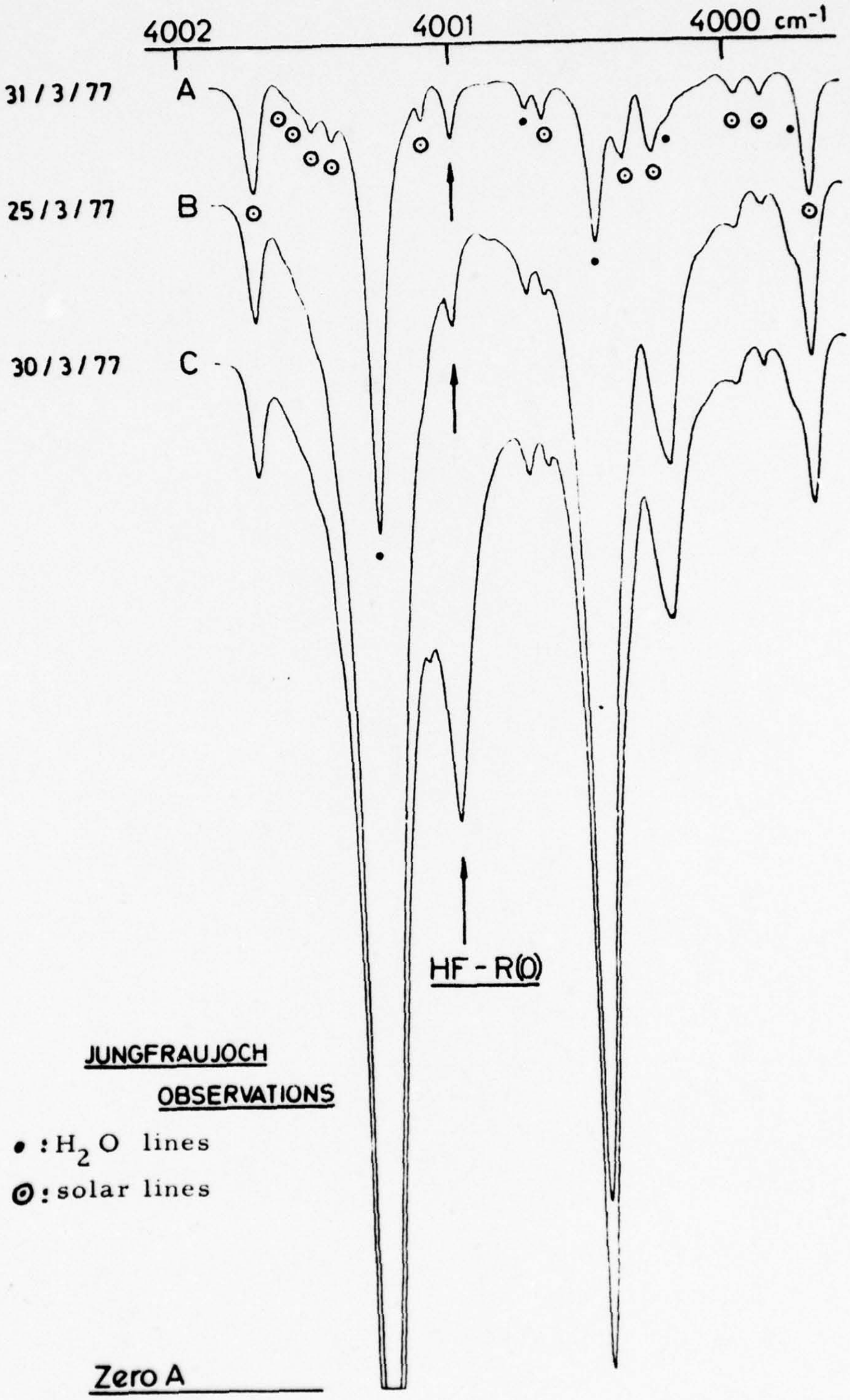
R(0) at 4,000.985 cm^{-1}
R(1) at 4,038.972 cm^{-1}
R(2) at 4,075.301 cm^{-1}
and R(3) at 4,109.945 cm^{-1}

of the 1-0 band are observable on solar spectra obtained under spectral resolutions of about 0.02 cm^{-1}. Among these lines, only R(0) and R(1) can be considered as isolated and easily measurable despite of being located in the wings of strong H_2O lines; R(1) being the strongest HF line, it is that feature which is normally used for our ground monitorings.

Figures 1 and 2 show typical sample spectra near the R(0) and R(1) lines of HF. Trace C of Fig.1 corresponds to the recorded solar spectrum with small amounts of gaseous HF having been added in front of the entrance slit of the spectrometer; this "enhancement" procedure allows an unambiguous identification of the HF feature indicated by an arrow; air masses are 1.53 for Trace A and 1.92 for Trace B.

Figure 2 represents three sample spectra without any "enhancement" effect. On both Fig.1 and 2, the Traces A show sample spectra taken under exceptionally dry conditions.

Since 1976, we have analysed a series of ground observations in order to establish any long term variation of the telluric HF contents above Switzerland; the results deduced till now are given hereafter.



4002
4001
4000 cm-1
31 / 3 / 77
A
25 / 3 / 77
B
30 / 3 / 77
C
HF - R(0)
JUNGFRAUJOCH
OBSERVATIONS
• : H_2O lines
⊙ : solar lines
Zero A

FIGURE 1

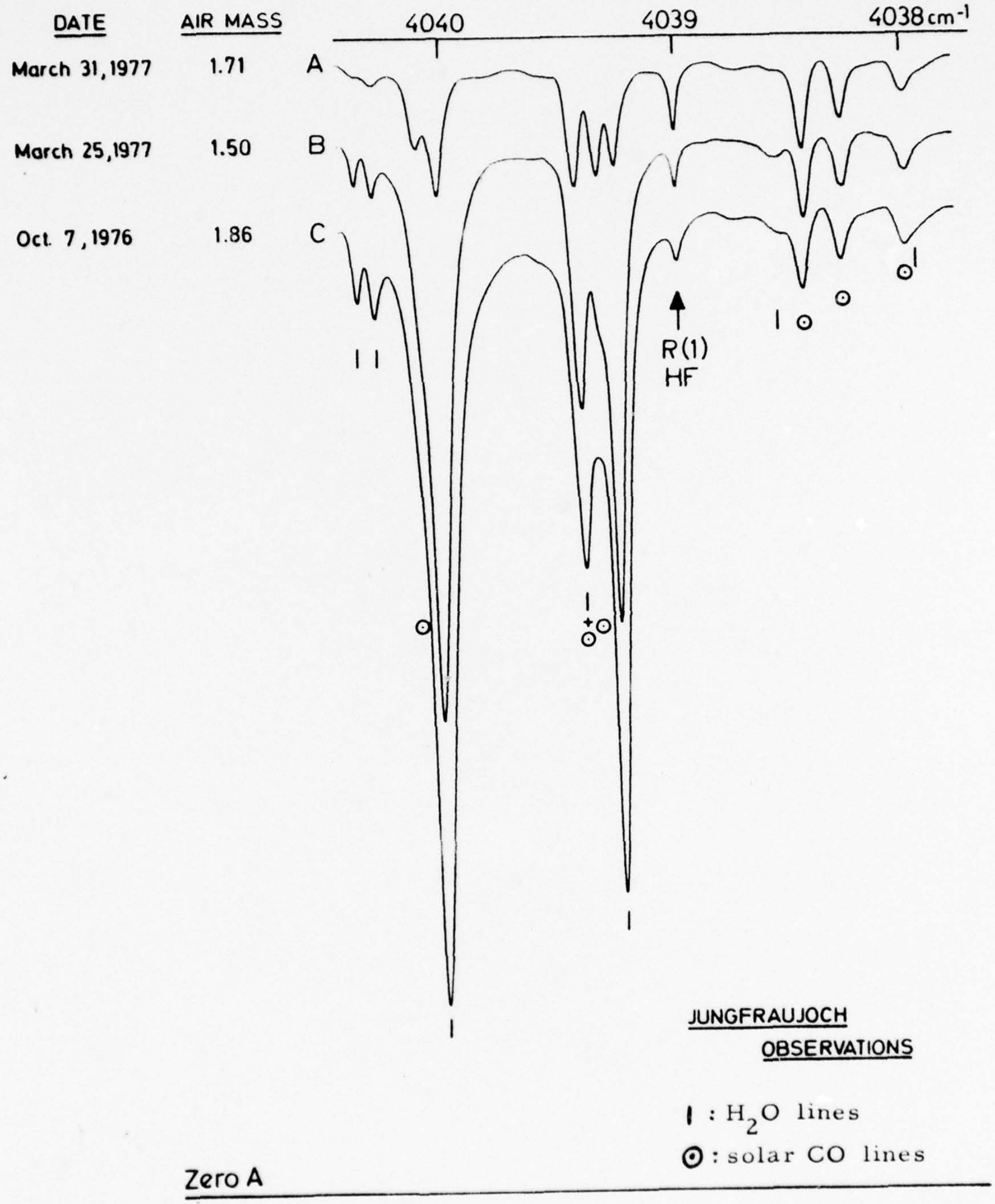

DATE
AIR MASS
4040
4039
4038 cm-1
March 31, 1977
1.71
A
March 25, 1977
1.50
B
Oct. 7, 1976
1.86
C
R(1)
HF
JUNGFRAUJOCH
OBSERVATIONS
: H2O lines
: solar CO lines
Zero A

FIGURE 2

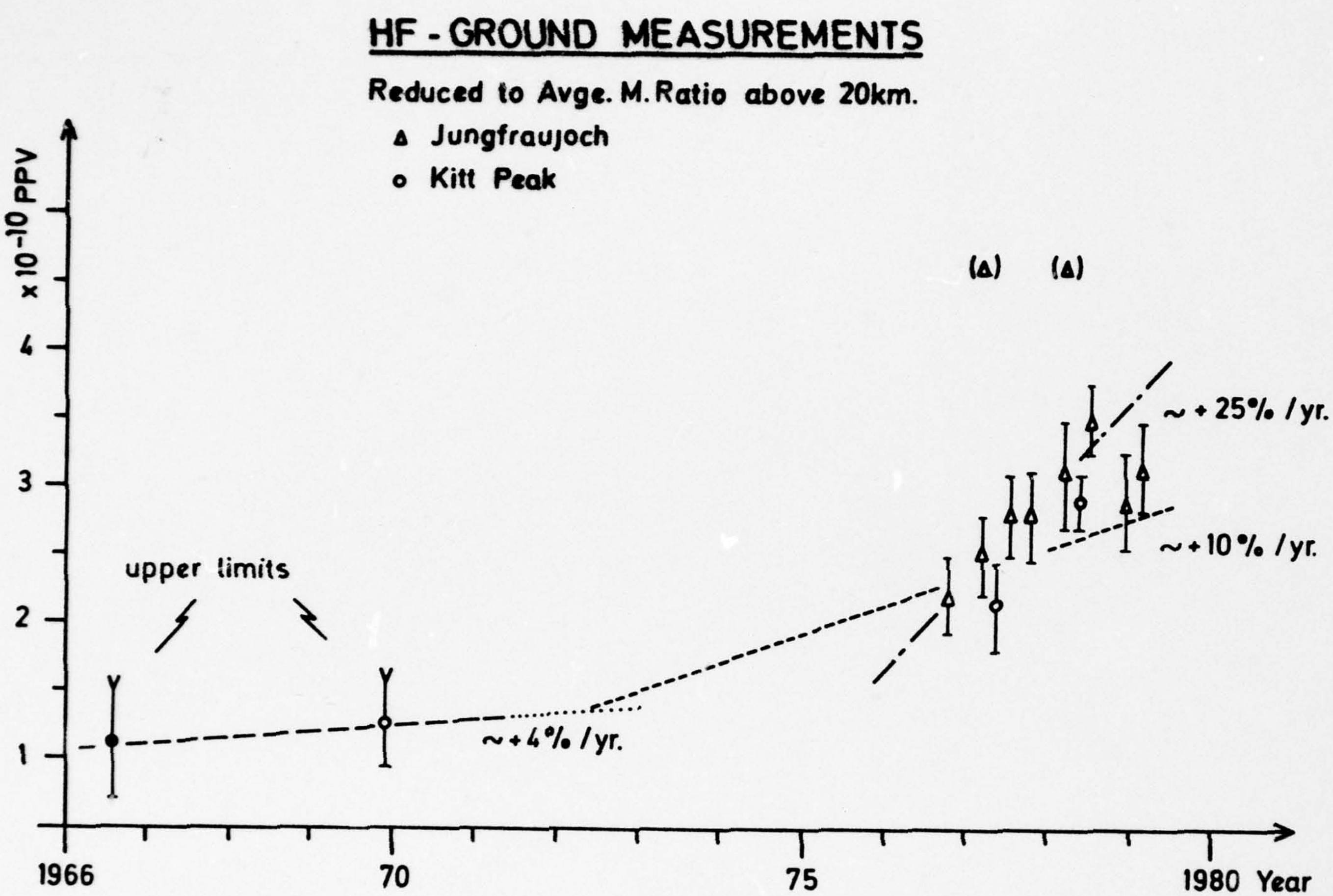
Date		Mixing ratio	
Oct. 1976	average above 20 Km	$(2.2 \pm .4) \times 10^{-10}$ ppv	
March 77	"	$2.5 \pm .3$	
"	"	$4.6 \pm .5$	Max.
July 77	"	$2.8 \pm .3$	
Oct. 77	"	$2.8 \pm .3$	
March 78	"	$3.1 \pm .4$	
"	"	$4.6 \pm .4$	Max.
July 78	"	$3.5 \pm .3$	
Dec. 78	"	$2.9 \pm .3$	
Febr. 79	"	$3.2 \pm .3$	

These results have been obtained by considering a line strength for R(1), equal to 74.2 cm^{-2} Am^{-1} at 225°K.

Figure 3 is a graphical representation of all our ground bound mixing ratios, including two upper limits obtained from earlier recordings as well as two measurements made in May 1977 and May 1978 at the Kitt Peak Observatory, Tucson (Arizona), by L. Delbouille and G. Roland. The dotted straight lines are only indicative of some increasing trends not yet significant. Indeed, the slight tendency to an increase which seems to show up from our measurements has to be taken with caution because of the short period covered by the observations which, furthermore, show significant changes among recent results (e.g. Dec. 1978).

The high values of $(4.6 \pm .4) \times 10^{-10}$ ppv (indicated by triangles between parentheses on Fig.3) observed occasionally, e.g. on March 31, 1977 and on March 7, 1978 have been explained by invoking the transport of HF-loaded stratospheric polar air towards lower latitudes and lower altitudes; that conclusion was drawn from similar variations observed on ozone soundings recorded over Switzerland by the Swiss Meteorological Office, Zurich.

The mixing ratios given here imply that all hydrofluoric acid is located above 20 Km altitude. This subjective presentation was adopted here because of the fact that the major source of HF is definitely the photodissociation, in the upper stratosphere, of



HF - GROUND MEASUREMENTS
Reduced to Avge. M. Ratio above 20km.
Δ Jungfraujoch
o Kitt Peak
x10-10 PPV
4
3
2
1
upper limits
(Δ)
(Δ)
~ + 25% /yr.
~ + 10% /yr.
~ + 4% /yr.
1966
70
75
1980 Year

FIGURE 3

various chlorofluorocarbon species, especially $CFCl_3$ ("Freon-11") and CF_2Cl_2 ("Freon-12"); furthermore, balloon observations have indicated that the HF concentration is indeed important above 20 Km altitude, decreasing rapidly below (we shall come back to that problem, later in this report).

Hydrochloric acid

Despite a poor efficiency of the grating installed in the 7.5 meters focal length spectrometer for observations in the 3.5 microns region (off-blaze operation), it has been possible to obtain very good solar spectra around the R(1), R(2) and R(3) lines of the fundamental band of HCl. R(1), located at 2925.895 cm^{-1}, was retained for our ground monitorings because of blending effects by either H_2O or CH_4 lines on R(2) and R(3).

Figure 4, Trace A, shows a typical solar spectrum recorded near 2926 cm^{-1}; Trace B of that Figure was recorded with some gaseous hydrochloric acid placed in front of the entrance slit of the spectrometer; here again the "enhancement" procedure allows to locate unambiguously the HCl features.

The following Table summarizes the Jungfraujoch average mixing ratios of HCl, deduced till now; Figure 5 represents them graphically. Also indicated on Fig.5 are upper limits for 1951 and 1969 (note the discontinuity of the abcissa scale) as well as values deduced from 1977 and 1978 Kitt Peak observations.

Date		Mixing ratio
April 1951	average above Joch	$(1.4 \pm .4) \times 10^{-10}$ ppv
March 77	"	$2.3 \pm .3$
July 77	"	$2.2 \pm .3$
Oct. 77	"	$2.3 \pm .3$
March 78	"	$2.6 \pm .3$
July 78	"	$3.1 \pm .3$
Dec. 78	"	$2.0 \pm .4$
Febr. 79	"	$2.3 \pm .4$

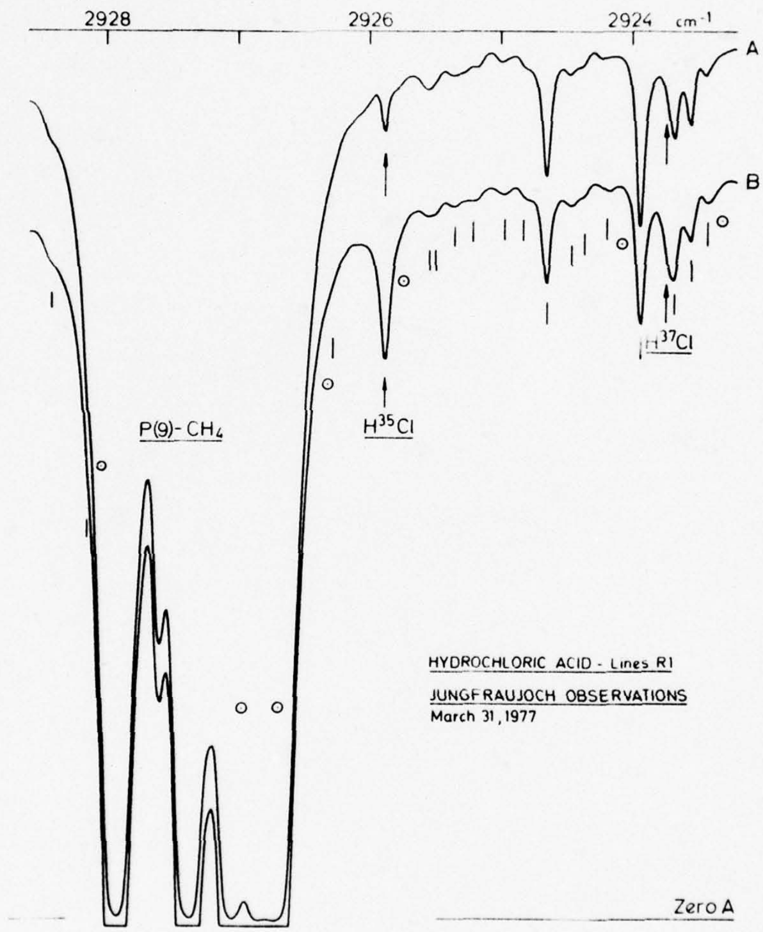
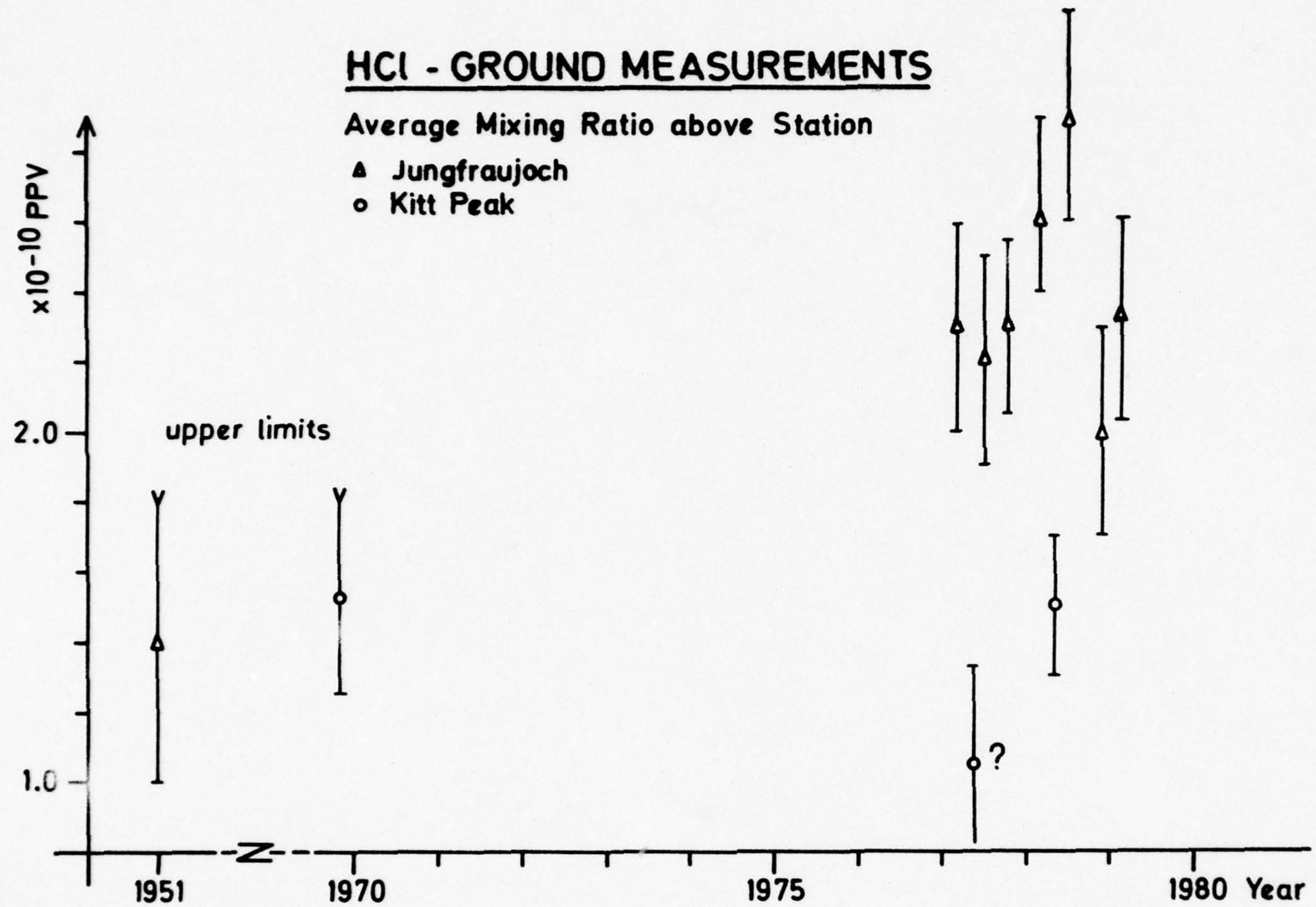

2928
2926
2924 cm-1
A
B
P(9)- CH4
H35Cl
H37Cl
HYDROCHLORIC ACID - Lines R1
JUNGFRAUJOCH OBSERVATIONS
March 31, 1977
Zero A

FIGURE 4



HCl - GROUND MEASUREMENTS
Average Mixing Ratio above Station
▲ Jungfraujoch
o Kitt Peak
x10-10 PPV
2.0
1.0
upper limits
?
1951
1970
1975
1980 Year

FIGURE 5

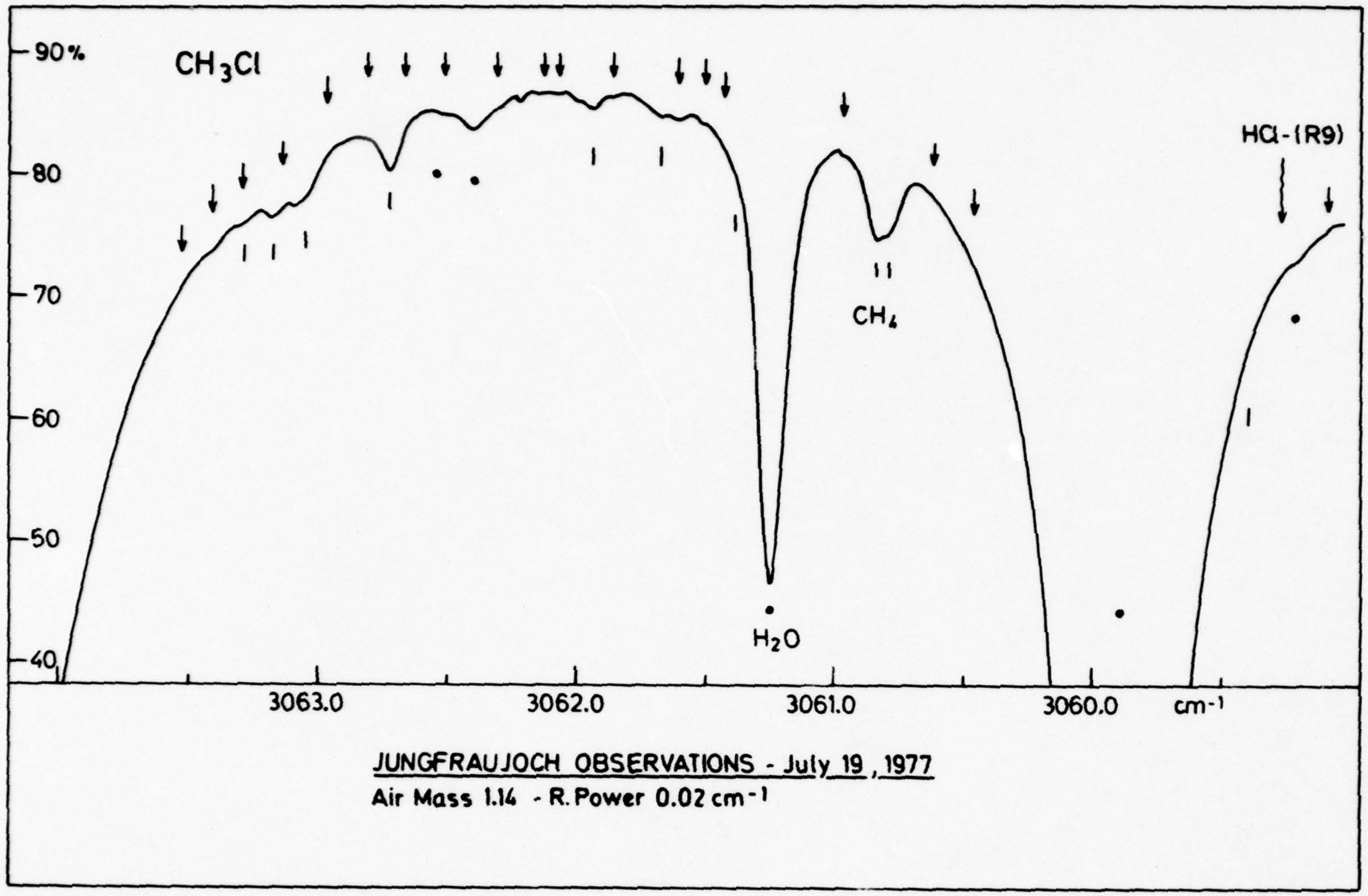
The results presented here have been deduced by considering a R(1) line strength equal to 10.75 cm^{-2} atm^{-1} at 240°K and assuming an uniform mixing ratio above the sites of observation.

It is known that the atmospheric distribution of HCl versus altitude shows a decrease from the ground to about 12-15 Km altitude, followed by an increase up to at least 35 Km; however, we have not attempted to interprete the observations in order to derive the respective contributions from the troposphere and from the stratosphere (this should be envisaged with observations of a few .001 cm^{-1} spectral resolution made over a series of HCl lines having different temperature dependences). The set of data accumulated till now does not allow any conclusion regarding the temporal evolution of the telluric hydrochloric acid contents; the large scatter in the results and the lower values deduced for Kitt Peak tend to support the fact that most of the HCl variability occurs in the troposphere, also that a sort of background effect is different at various geographic locations.

Methyl chloride

Attemps have also been made in order to detect and monitor the atmospheric contents of CH_3Cl.

Figure 6 shows one sample spectrum between 3059 and 3064 cm^{-1}, where many weak absorption lines belonging to the ν_4 band of CH_3Cl are present (their positions are indicated by arrows). The observations have not yet been analysed systematically but the few average mixing ratios available for 1977 and 1978 range from 1.1 to 1.8 x 10^{-9} ppv.



90%
80
70
60
50
40
CH_3Cl
HCl-(R9)
CH_4
H_2O
3063.0
3062.0
3061.0
3060.0
cm-1
JUNGFRAUJOCH OBSERVATIONS - July 19, 1977
Air Mass 1.14 - R. Power 0.02 cm-1

FIGURE 6

C.- Fourier transform spectrometry

In 1974, Dr. R. Malbrouck has installed, at the Coudé focus of the 76 cm telescope of the Jungfraujoch, a one meter optical path difference interferometer of the Connes type; its theoretical spectral resolution limit is 0.01 cm^{-1} and its absolute wavelength accuracy is better than 0.001 cm^{-1}.

This instrument was used in 1975 and 1976 for recording various spectral intervals indicated in the following Table.

Spectral region cm^{-1}	Spectral resolution cm^{-1}
4058 - 4450	.0154
4300 - 4800	.0145
4470 - 4890	.014
4900 - 5200	.025
5820 - 6144	.0172
5930 - 6400	.0159
6150 - 6650	.0167
7610 - 8150	.0131
8150 - 8590	.0223

Figures 7 and 8 show two sample spectra obtained with the Fourier instrument and reproduced from Dr. Malbrouck's Ph.D. Thesis {4} (with an abcissa scale as in the two last Figures, all spectra indicated in the previous Table would extend over more than 60 meters). The lines indicated by a vertical bar are those for which accurate wavelength positions have been deduced. Reference 4 contains tables and wavelengths for all the lines observed and having central depression to noise ratios equal or larger than 10; the given wavelengths have been corrected for instrumental effects, for air index and for Doppler effects due to relative earth-sun motions. The final accuracy of the wavelengths provided in the tables is about 1.2×10^{-4} cm^{-1}; they can be used as references for interpolations of other weak absorption features present on the spectra.

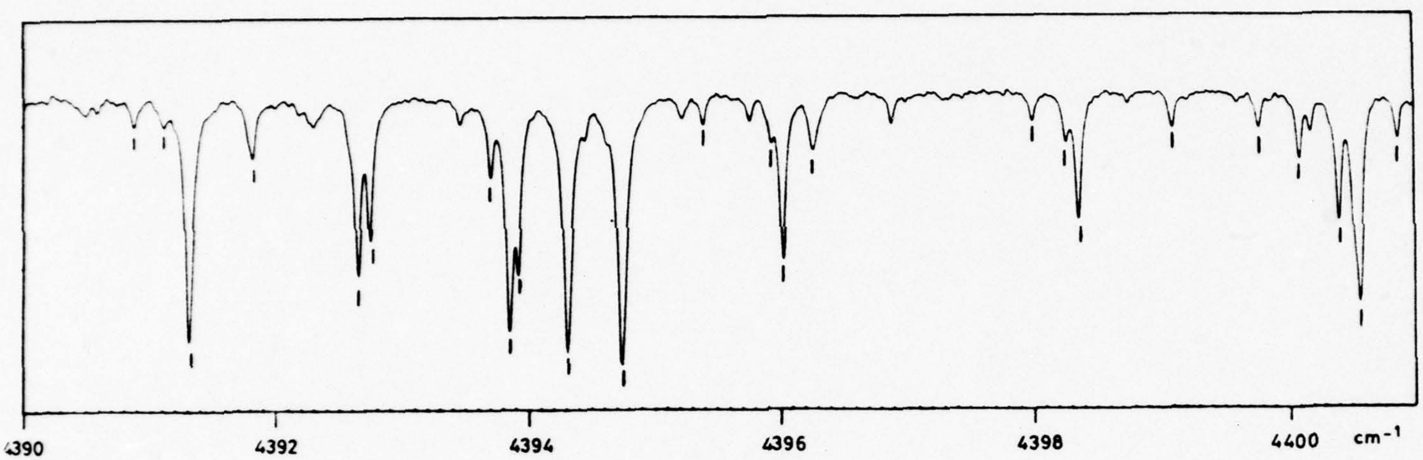


PLANCHE 1

FIGURE 7

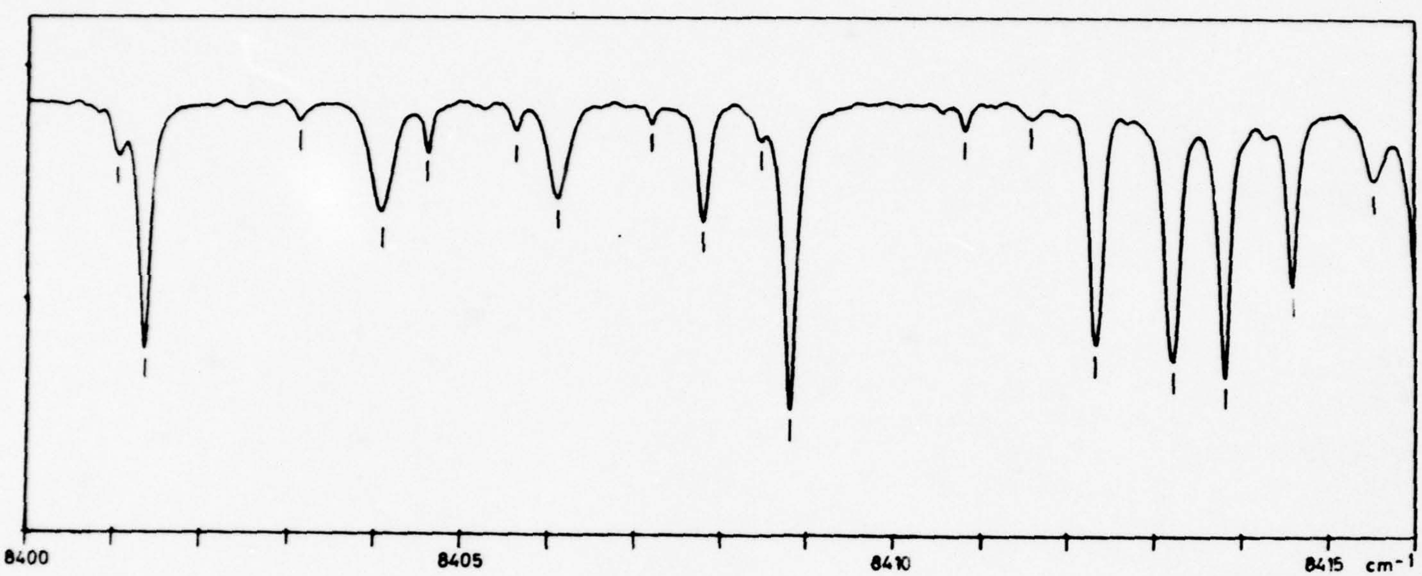


PLANCHE 11

FIGURE 8

Part of the data accumulated by FTS have been analysed by R. Malbrouck. For instance, he has investigated the center to limb variations of the profiles of CO lines observed in the 4500 to 4000 cm^{-1} region; he has also updated the identifications of solar Fe I lines in the regions 4050 to 4800 cm^{-1}, 5821 to 6650 cm^{-1} and 7600 to 8600 cm^{-1}.

Furthermore, the abundance of telluric methane above the Jungfraujoch has been determined from the analysis of the $2\nu_3$ band of CH_4 near 1.6 microns {5}; the average mixing ratio deduced is equal to 1.48×10^{-6} ppv.

The CO_2 mixing ratio deduced from the analysis of lines belonging to the $5\nu_2 + \nu_3 - \nu_2$ band near 2.08 microns is equal to (322 $\pm$ 12) ppmv.

Finally, it is worth mentioning the work on standard half-widths variations versus the quantum number J, obtained for :

- the R branch of the $2\nu_3$ band of CH_4 $(0<J<9)$ {6}.
- the P and R branches of the two CO_2 bands $\nu_1 + 4\nu_2 + \nu_3$ (near 1.6 microns) and $2\nu_1 + 2\nu_2 + \nu_3$ (near 1.57 microns) {4}.

III. STRATOSPHERIC BALLOON OBSERVATIONS

During the period covered by this report, our stratospheric balloon program was pursued with two flights carried out during the spring of 1976 and two others made in the fall of 1978; all flights were conducted from the National Scientific Balloon Facility, Palestine (Texas).

Till 1974, most of the observational time at float altitude had been devoted to the recording of solar spectra extending over intervals as wide as possible (e.g. the 1.85 microns H_2O band; the 2.65 microns H_2O and CO_2 absorption region), in order to fill the gaps remaining in the ground-recorded solar atlases. By 1976, however, it became necessary to reorientate the prime objective of our flights and to spend as much time as possible to the study of the chemical composition of the upper stratosphere; therefore the recording of narrow spectral intervals into which as many telluric species as possible were supposed to show characteristic absorption lines was more appropriate here; in an attempt to establish concentrations versus altitude, it became necessary to repeat certain observations along various slant paths corresponding to different solar elevation angles and to take a maximum advantage of the curvature of the various atmospheric layers.

For these last purposes, the instrument, especially the guidance system, needed to be adapted to very low, even sub-horizontal solar observations during sunrise and sunset.

A.- The 1976-balloon observations

The interim reports of May 31, 1977 and of April 28, 1978 contain most of the scientific informations deduced from our two balloon flights made on April 22 (flight ULG-10) and on May 10 (ULG-11), 1976.

Flight ULG-10 was still devoted to near infrared solar observations, using PbS detectors for single- and for double pass solar recordings. The following spectral intervals were recorded with a spectral resolution of about 0.035 cm^{-1} in double pass and 0.08 cm^{-1} in single pass : 5757.1-5685.1 cm^{-1}; 5523.4-5465.1 cm^{-1}; 5438.0-5415.9 cm^{-1}; 5366.2-5227.3 cm^{-1}; 4879.1-4845.2 cm^{-1}; 4626.2-4607.04 cm^{-1}; 4061.6-4036.0 cm^{-1}.

For the flight ULG-11, the spectrometer was equipped with a gallium-doped germanium bolometer; solar observations were made with a 0.04 cm^{-1} resolution over the following spectral regions : 3024-3007 cm^{-1}; 2937-2965 cm^{-1}; 1849-1830 cm^{-1}; 1620-1593 cm^{-1}; 1325-1259 cm^{-1}. That flight ended prematurely due to a leakage at the top fitting of the balloon and dramatically as the gondola came down in lake O'The Pine, Texas; it suffered very heavy damages.

Some stratospheric constituents having absorption characteristics in the various spectral regions mentioned above, are H_2O, CO_2, CH_4, CO, N_2O, NO, NO_2, HF, HCl, CH_3Cl.

Among the results reported earlier, it is worth recalling that the 1976 observations confirmed the presence of HF above 27.9 Km altitude, the average mixing ratio being equal to $(3.6 \pm .6) \times 10^{-10}$ ppv {3}.

Unexpectedly the concentrations of CH_4 and N_2O in the upper stratosphere showed large variations between the October 1974 and the May 1976 flights; this seems to confirm the existence of large scale dynamical processes above 25 Km altitude and raises the question about eventual seasonal variations of the contents, in the stratosphere, of supposedly well known minor constituents.

The 1976 observations have also allowed to identify, for the first time, a series of photospheric lines lying above 5 microns, out to 8 microns {7-8}.

B.- The 1978-balloon observations

Following its splash-down, the balloon instrumentation demanded a large amount of work and of money for being repaired and be reflown with good chances of success.

The 1978 campaign, initially planned to take place during the spring of 1978, had to be delayed by 4 months because of late delivery of the set of 5 metal mirrors, constituting the basic optics of the instrument, which had to be recoated by canigean deposits then polished and vacuum aluminized.

The complete balloon instrumentation, also the check-out and maintainance material (21 boxes; total weight ∿ 3,200 Kgs) was delivered to the Rhein-Main Air Force Base in Frankfurt (F.R.G.) on July 12, 1978; it arrived at the NSBF, Palestine (Texas), on August 8, 1978.

In accordance with the various sponsors and collaborators of our 1978 campaign, it was decided to undertake observations in the 2 to 5 microns region, using InSb detectors cooled down to liquid nitrogen temperatures.

The following Table (see next page) gives a number of molecules observable in the InSb-sensitive region; a selection was made among these for setting the scientific priority program. HOCl was also retained because of its importance raised recently in relation with the study of the chlorine budget in the upper stratosphere.

Figure 9 shows the Liège gondola ready for ground testings prior to its balloon launch.

Constituent	Band Center (cm^{-1})	Approx. Band Intensity ($cm^{-2}atm^{-1}$)	Expected Range of Stratospheric Volume Concentration
HF	3962	325	$10^{-10}-10^{-9}$
HCl	2886	150	10^{-9}
O_3	2110 3042	32 3	$10^{-6}-10^{-5}$
NO_2	2910	60	$10^{-9}-10^{-8}$
NO	1876	110	$10^{-9}-10^{-8}$
HNO_3	3550	moderate	$10^{-9}-10^{-8}$
N_2O	2224 2563	1300 40	10^{-7}
CH_4	3019	300	10^{-6}
CO	2143	230	10^{-7}
CO_2	2349 3613 3715	2000 30 40	$3x10^{-4}$

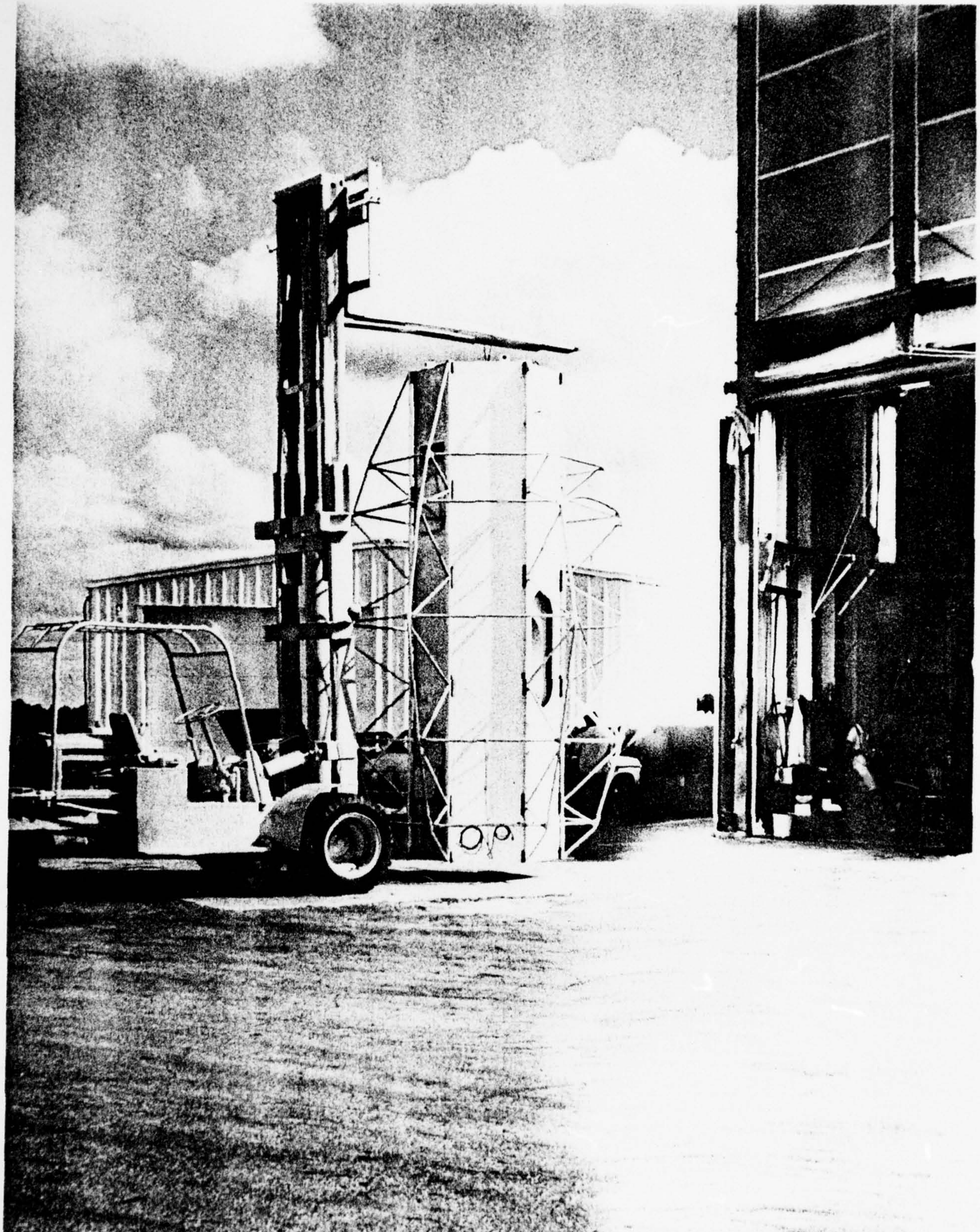


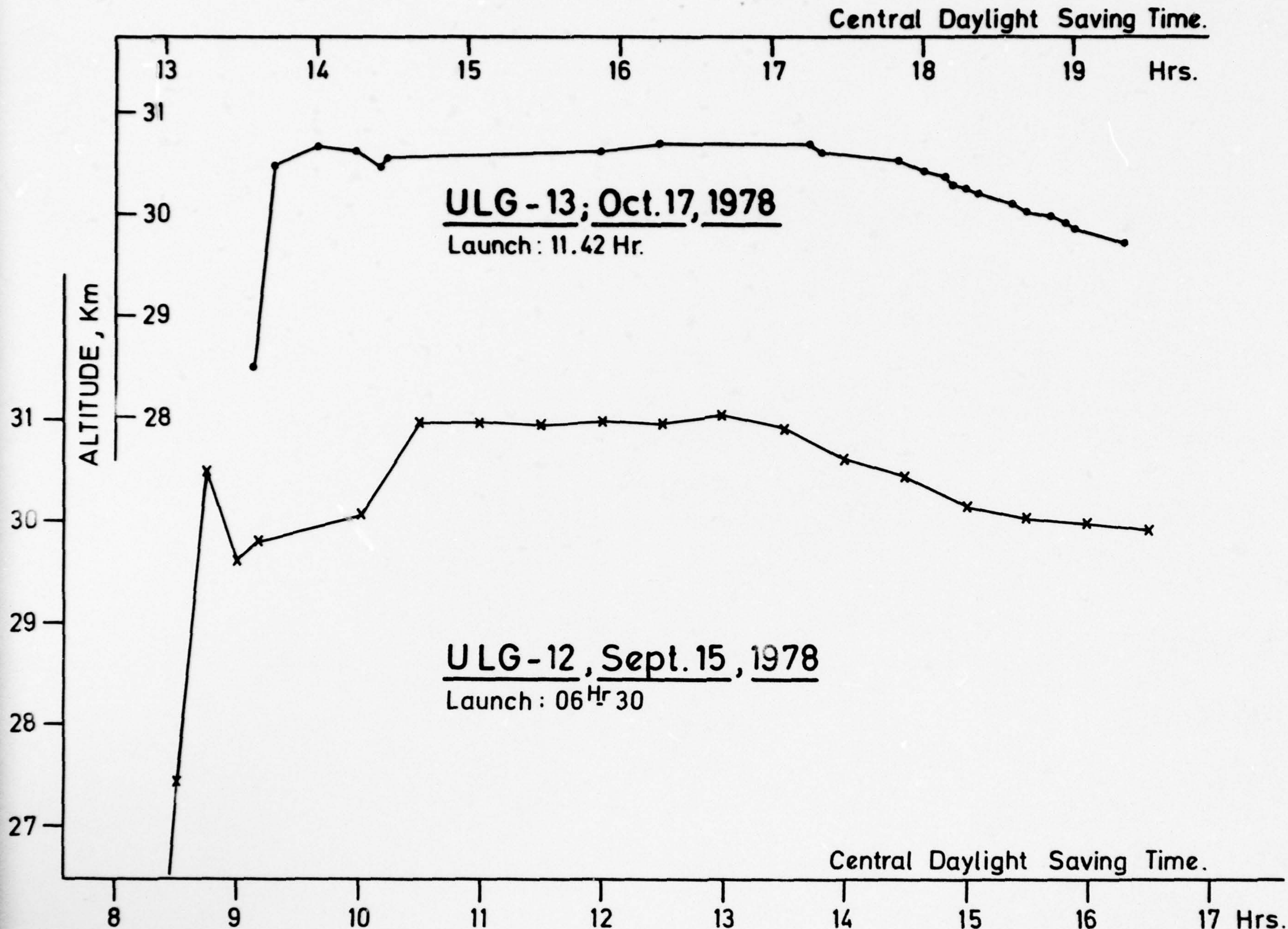
FIGURE 9

Flight ULG-12, which took place on September 15, was only a 30% success experiment because of a defectuous functioning of the optical chopper (tuning fork) which forced us to record data at very slow scanning speeds of the grating. Furthermore, a deficiency in the guidance system became excessive during the afternoon and prevented us from making observations during sunset.

Flight ULG-13 started on October 17, at 11Hr.30 CDST, because of poor low level winds earlier in the morning; observations were made till sunset, under excellent conditions.

Figure 10 shows the float profiles of the 1978 flights. The next Table gives a summary of the measurements carried out during the two flights.

Flight	Spectral Region (microns)	Number of Recordings	Expected Molecules Absorptions
ULG-12	∿1.78 ; ∿1.85	4	H_2O; calibration and telluric
	∿2.48	4	HF, H_2O
	∿2.66	4	HOCl, CO_2, H_2O
	∿3.40	2	HCl, CH_4, CH_3Cl
	∿4.63	2	CO, N_2O
ULG-13	∿1.85	2	H_2O; calibration
	∿2.48	20	HF, H_2O
	∿2.66	15	HOCl, CO_2, H_2O
	∿3.40	9	CH_4, HCl, CH_3Cl
	∿4.20	7	CO_2
	∿4.63	4	CO, N_2O
	∿4.70	2	O_3, CO, ...



Central Daylight Saving Time.
13
14
15
16
17
18
19
Hrs.
31
30
29
28
ALTITUDE, Km
ULG-13; Oct. 17, 1978
Launch: 11.42 Hr.
31
30
29
28
27
ULG-12, Sept. 15, 1978
Launch: 06 Hr 30
Central Daylight Saving Time.
8
9
10
11
12
13
14
15
16
17 Hrs.

FIGURE 10

Preliminary results

Figures 11, 12 and 13 show a few sample spectra recorded in the vicinity of, respectively :

- the R(2) line of $H^{35}Cl$, at 2,944.915 cm^{-1}
- the R(1) line of HF, at 4,038.972 cm^{-1}
- the $R(Q_4)$ branch of the ν_1 band of HOCl.

Note that the samples shown on Fig.11 have not yet been filtered numerically for "removing" the high frequency noise present on the tracings.

From the 1978 balloon observations, we have already deduced informations regarding species which were given some observational priority, e.g. HF, HCl, CH_4, CO, HOCl; these are summarized hereafter.

HF. The average mixing ratio above 30.9 Km deduced from ULG-12 is $(5.2 \pm .6) \times 10^{-10}$ ppv. On ULG-13, a more accurate value, equal to $(4.8 \pm .2) \times 10^{-10}$ ppv prevailed above 30.3 Km. A summary of all past balloon results is given in the following Table.

Date	Float Altitude (Km)	Average Mixing Ratio $\times 10^{-10}$ ppv
April, 71	27.8	$3.2 \pm .7$
Oct., 74	27.4	$4.8 \pm .8$
April, 76	27.9	$3.6 \pm .6$
Sept., 78	30.9	$5.2 \pm .6$
Oct., 78	30.3	$4.8 \pm .2$

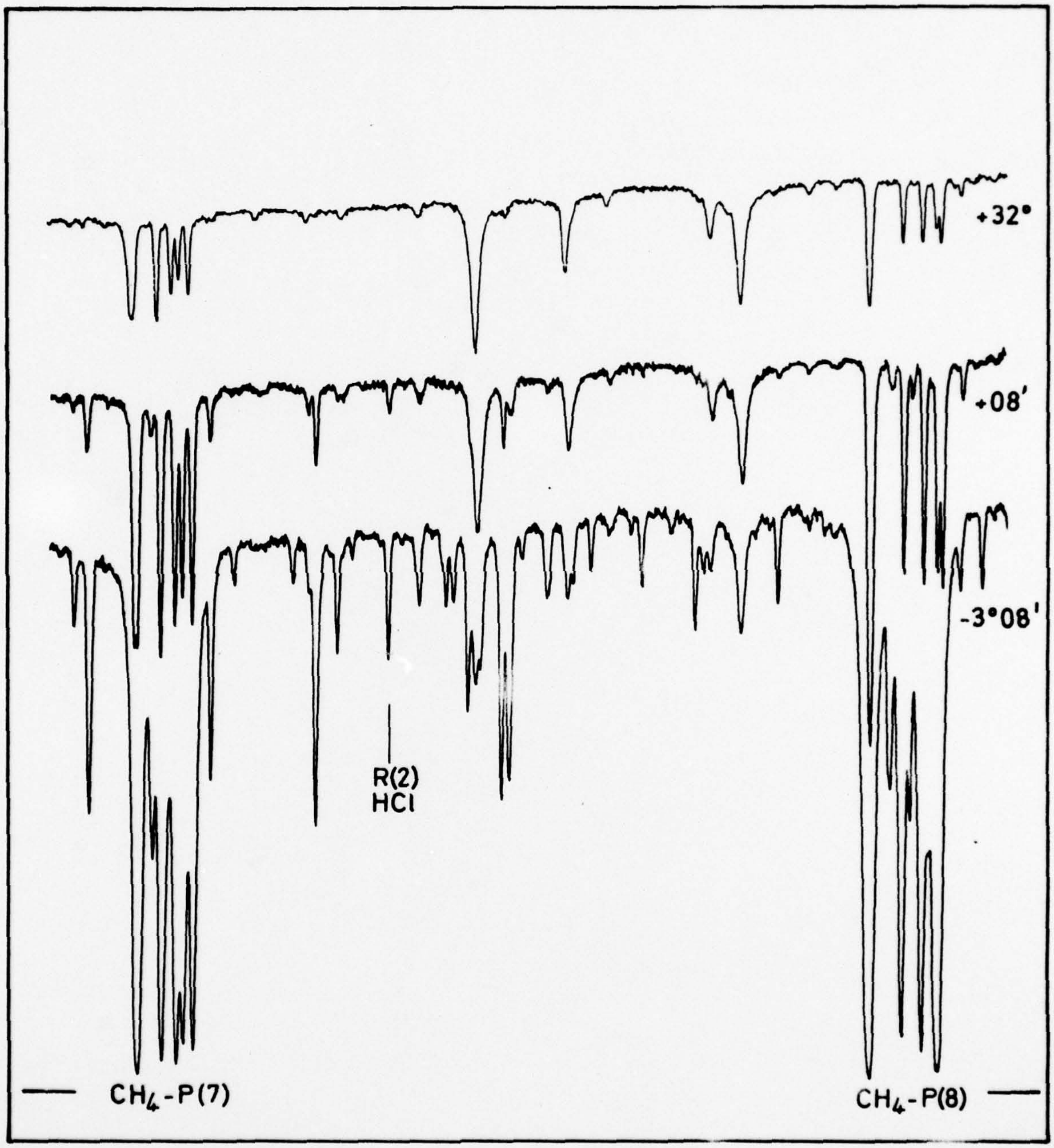


FIGURE 11

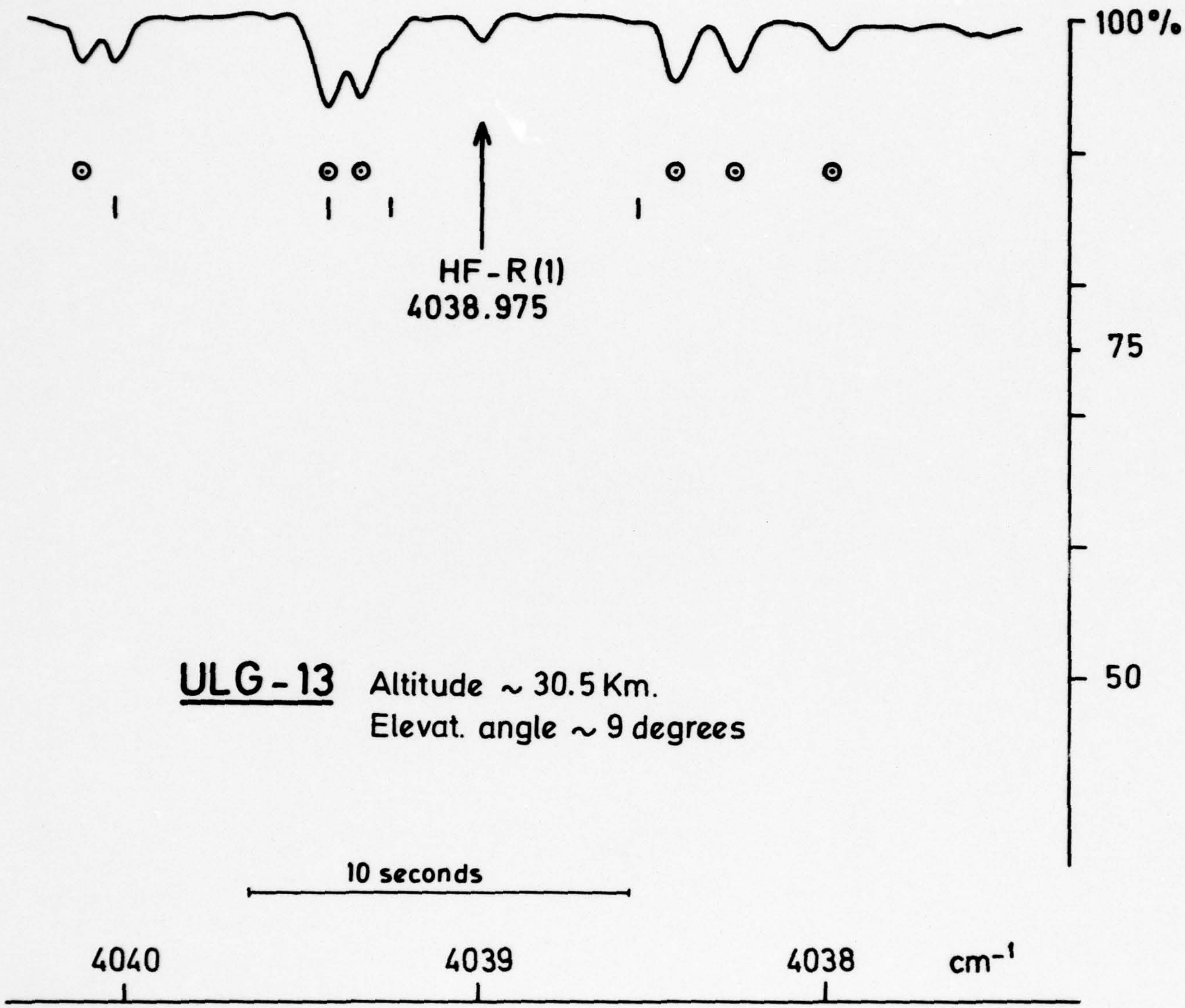

100%
75
50
HF-R(1)
4038.975
ULG-13
Altitude ~ 30.5 Km.
Elevat. angle ~ 9 degrees
10 seconds
4040
4039
4038
cm-1

FIGURE 12

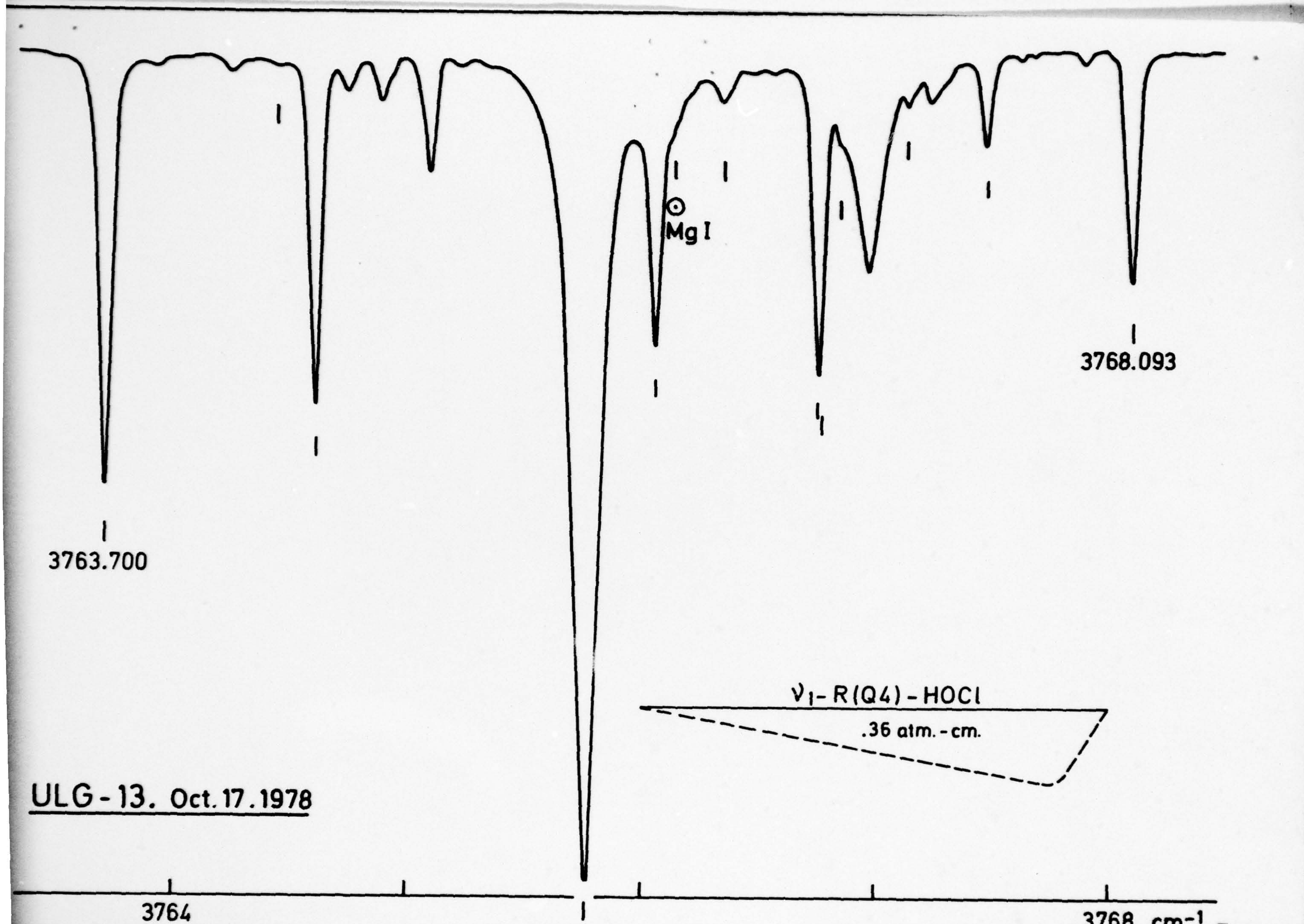

3763.700
Mg I
3768.093
ν_1 - R(Q4) - HOCl
.36 atm.-cm.
ULG-13. Oct. 17. 1978
3764
3765.760
3768 cm^{-1}
Zero

FIGURE 13

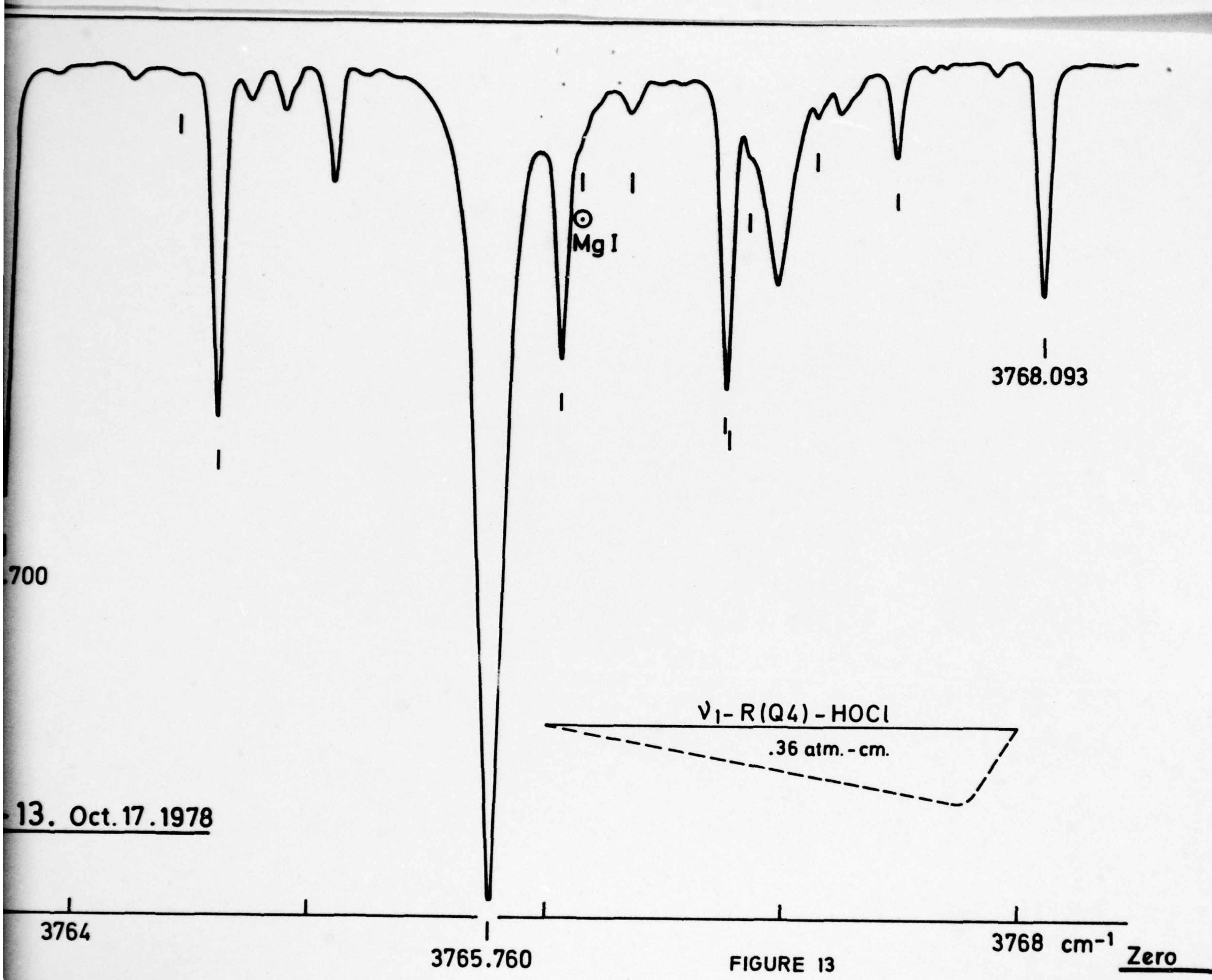
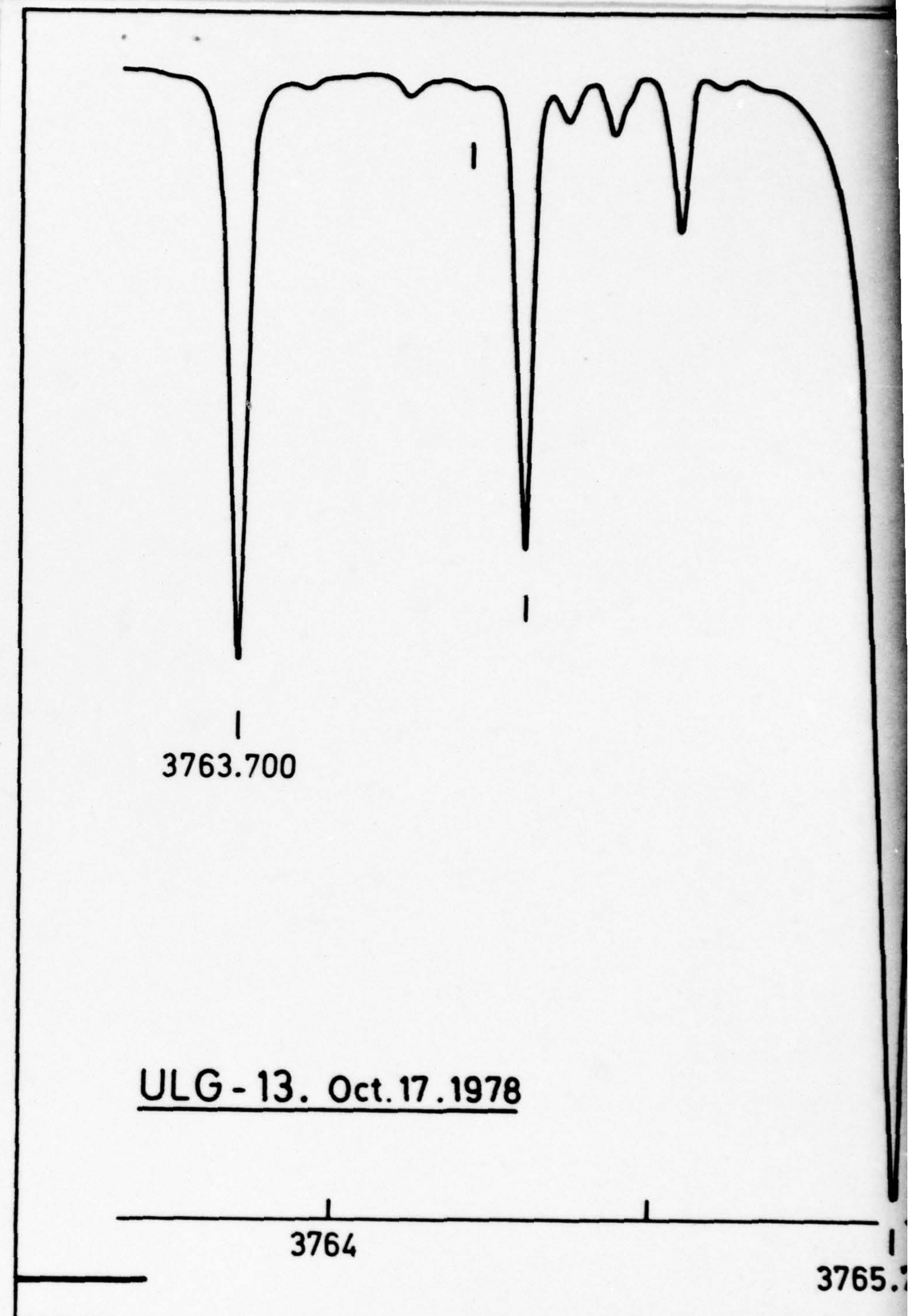

3768.093
Mg I
.700
ν1- R(Q4) - HOCl
.36 atm.-cm.
-13. Oct. 17. 1978
3764
3765.760
3768 cm-1
Zero

FIGURE 13


3763.700
ULG - 13. Oct. 17. 1978
3764
3765.

It is worth noting here that the consideration of our ground and balloon data about HF has allowed us to establish a 3-steps HF profile between 15 and 45 Km altitude with the following mixing ratios for 1978.

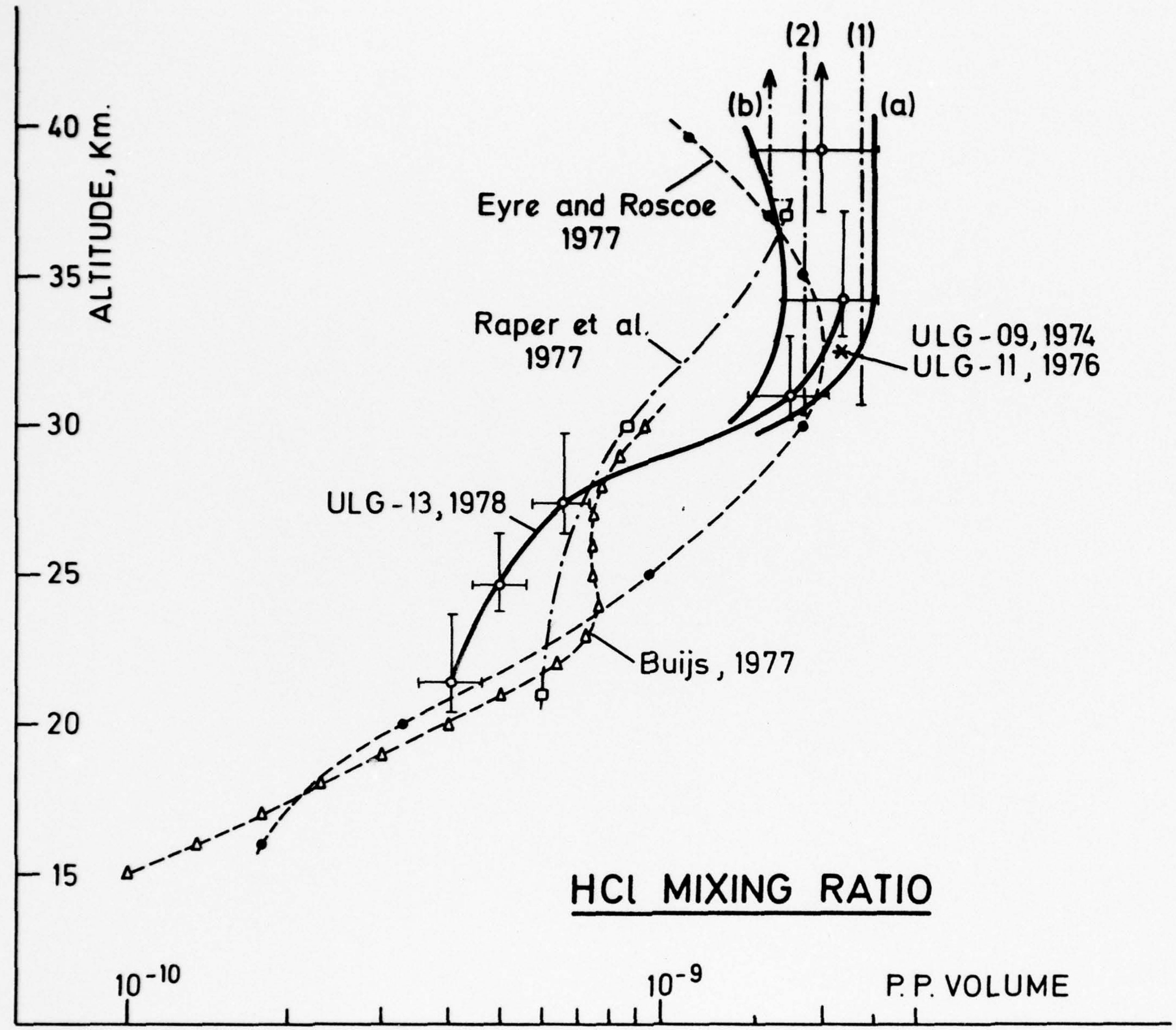
Altitude Range (Km)	Mixing Ratio (x 10^{-10} ppv)
15-20	(1.05 $\pm$ .2)
20-30	(2.5 $\pm$ .3)
30-45	(5.0 $\pm$ .3)

This simplified profile is in good agreement with theoretical calculations by Sze {9}.

HCl. Figure 14 (full curve) shows the average profile deduced on October 1978; a few other profiles are drawn for comparison. Above 30 Km, our results indicate a decrease of the HCl average mixing ratio from a value indicated by the straight line noted (1) to that corresponding to the line (2), for observations made respectively above +1 degree and between +1 and 0 degree solar elevation; the full curves (a) and (b) are the corresponding modeled extremes.

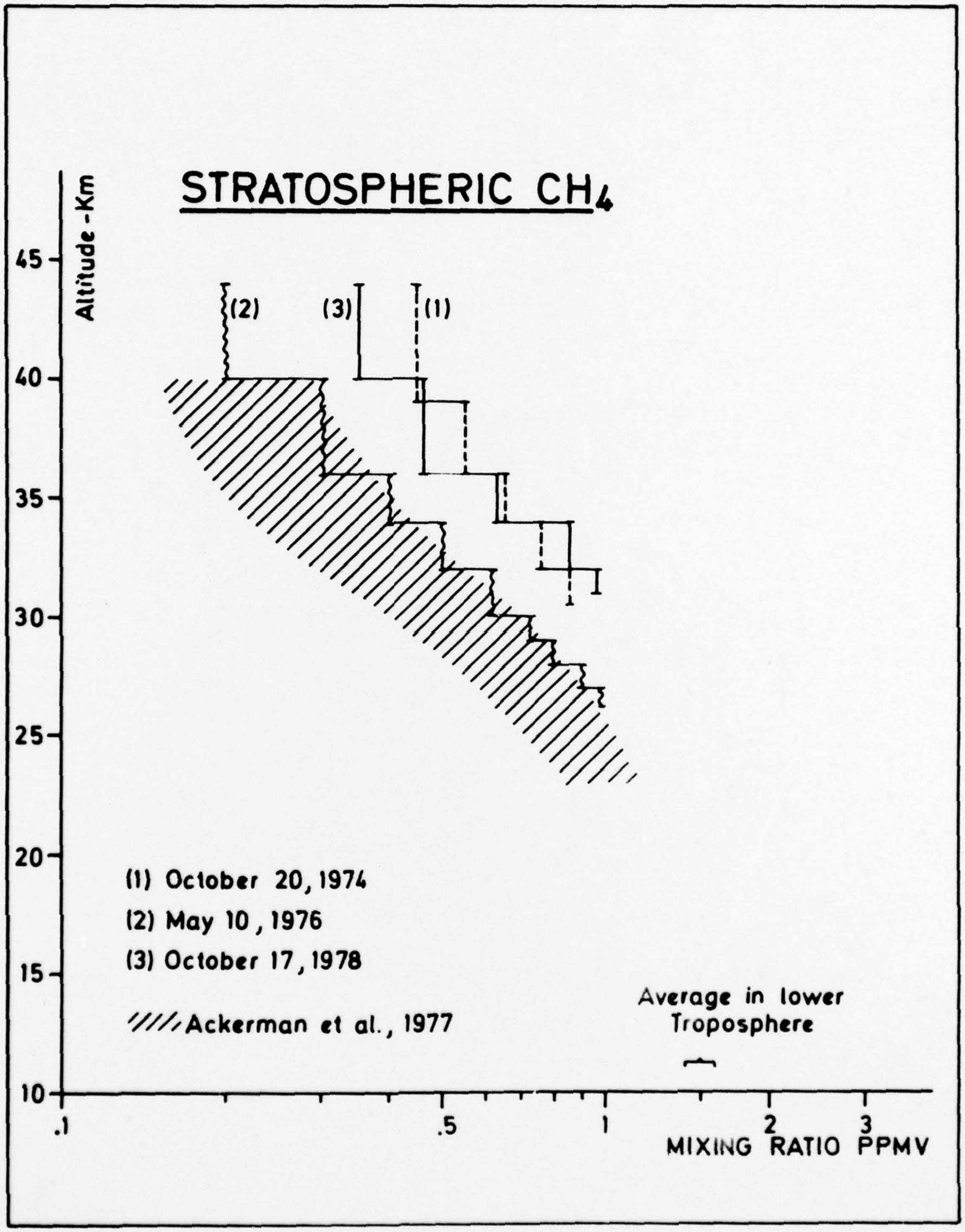
CH_4. Figure 15 represents three CH_4 profiles deduced from balloon observations made during the last years. Our results indicate the existence of important variations of methane above 30 Km altitude, likely to be associated with stratospheric dynamical processes; they do not confirm the low values deduced by Ackerman (shaded area).

CO. After having corrected the observed absorption lines for the CO photospheric contribution, we have deduced an average telluric CO mixing ratio above 30.6 Km, equal to (1.6 $\pm$ .25) x 10^{-8} ppv ; this result is definitely lower than most of the values obtained by cryogenic sampling techniques (e.g. Ehhalt et al.).



ALTITUDE, Km.
40
35
30
25
20
15
(2)
(1)
(b)
(a)
Eyre and Roscoe
1977
Raper et al.
1977
ULG-09, 1974
ULG-11, 1976
ULG-13, 1978
Buijs, 1977
HCl MIXING RATIO
10^-10
10^-9
P.P. VOLUME

FIGURE 14



STRATOSPHERIC CH4
Altitude - Km
45
40
35
30
25
20
15
10
(2)
(3)
(1)
(1) October 20, 1974
(2) May 10, 1976
(3) October 17, 1978
Ackerman et al., 1977
Average in lower
Troposphere
.1
.5
1
2
3
MIXING RATIO PPMV

FIGURE 15

HOCl. After having received further informations from the NBS (Dr. R.L. Sams), we can conclude that HOCl can not be measured on our spectra taken near 2.66 microns. If that chlorine species is present with a concentration in the 10^{-10} ppv range at 25-30 Km altitude, it should be investigated along almost horizontal slant paths from about 28 Km altitude (larger air masses will not necessarily be more favorable because of increasing blending by H_2O and CO_2 absorption features). On a future trial, we shall envisage such optimum geometrical conditions for HOCl detection.

Remarks

1.- Data from our 1978 balloon flights are subject to further analysis refinements which, however, should not modify appreciably the results already deduced.

2.- CO_2, CH_3Cl, N_2O and O_3 will be investigated in a near future.

3.- Among prime objectives of our 1979 balloon campaign, we shall attempt to measure the total chlorine contents in the stratosphere, e.g. HCl, ClO, $ClONO_2$, HOCl, CH_3Cl.

IV. CONCLUSIONS

This final report presents an ensemble of informations related to efforts made by Professor Migeotte's group, in order to obtain new high resolution transmission spectra of the atmosphere in the infrared. Till now, some of these efforts have been restricted in their spectral coverage, because of very specific requirements, e.g. repeated scannings of narrow intervals around selected absorption lines of particular telluric species. However, they have shown the feasibility and the quality of recordings towards longer wavelengths and have necessitated experimental optimizations which have had the virtue of rendering both the Jungfraujoch and the balloon equipments ready for more systematic solar observations in the infrared.

A great deal of observations available have not yet been fully reduced and published; this is particularly true for balloon data and it is due to lack of time and absence of personnel support; we hope that a solution can be found to that situation in 1980.

While the regular monitoring of atmospheric species will have to be maintained as part of the observational programs, we also hope that soon, the recording of a new "Migeotte's Atlas", out to 25 microns, can be undertaken systematically.

Observations related here have revealed the usefulness of coordinations between airborne and ground measurements; the complementarity of these two observational methods, while desirable for pollution monitorings, will become essential for a full coverage of the solar spectrum out to 25 microns.

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All scientific, technical and administrative people from the "Migeotte's group" have been involved in the efforts summarized in this report; we thank them here for their various contributions.

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