FAA-EQ-77-2

LEVEL II

13

B.S

SUMMARY OF UPPER ATMOSPHERIC DATA

N. Sundararaman

October 1976

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
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16. Abstract

Simultaneously observed concentrations of Cl and ClO; NO, NO_2, and HNO_3; and NO_2, HNO_3, and H_2O are reported. Also included are mixing ratios of HCl, CF_2Cl_2, $CFCl_3$ and N_2O, and photoabsorption cross sections for CCl_2F_2, CCl_3F, $ClONO_2$, and NO_2.

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Introduction

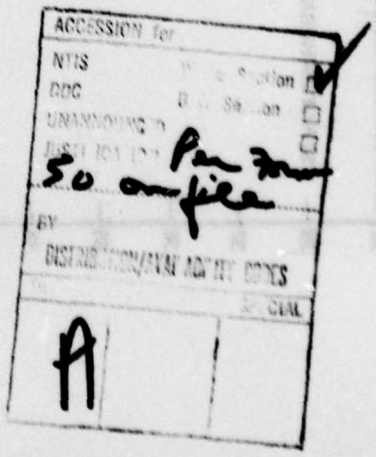
The following data related to the upper atmosphere are presented in this report:

1. Concentrations of $O(^3P)$, OH
2. Concentrations of Cl and ClO observed simultaneously
3. Volume and mass mixing ratios of HCl
4. Volume mixing ratios of CF_2Cl_3, $CFCl_2$ and N_2O
5. Concentrations, simultaneously observed, of NO, NO_2 and HNO_3; and of NO_2, HNO_3 and H_2O
6. Photoabsorption cross sections, and their temperature dependences, for CCl_2F_2 and CCl_3F
7. Photoabsorption cross sections of $ClONO_2$ and of NO_2.

The data are displayed in graphical form, and, if readily available, in tabular form. Some comments have been included regarding the observational technique, date, time and location of the experiment and the associated uncertainty. Lists of references are appended immediately after these comments or after the data.

In the "Initial Summary of Upper Atmospheric Data," disseminated in April 1976, two errors have been noted: one, in the improper labeling of the abscissae in the HCl absorption cross section diagram, and the other in the wrong copying of the table of values for the 5 Å - average solar flux values for quiet sun conditions in the 1750-2100 Å region. Both of these oversights have been corrected and the corrected diagram (Figure 17) and table (Table 10) are included in this report.

It is quite likely that the author of this report has missed some of the data; he would be grateful if such data are brought to his attention.



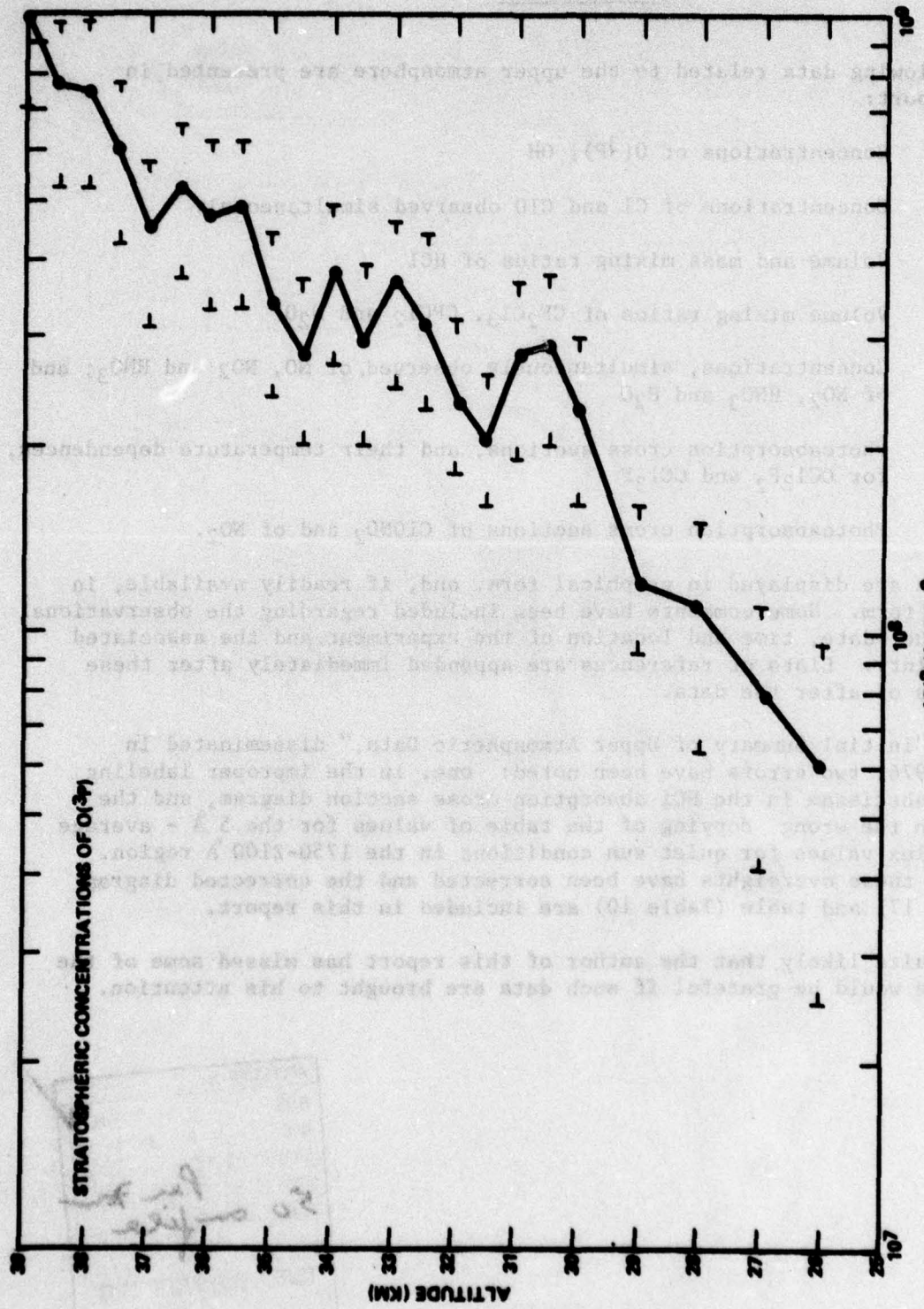


Figure 1: Stratospheric $O(^3P)$ Concentrations
(Source: Anderson, 1975)

TABLE 1: Stratospheric Concentration of $O(^3P)$
(Values read off published graph)

Altitude	$O(^3P)$ Concentration:		
	Observed	Experimental[a] Uncertainty	
km	cm^{-3}	cm^{-3}	cm^{-3}
39	1.0(9)[b]	7.0(8) -	1.3(9)
38.5	7.5(8)	5.2(8) -	9.7(8)
38.0	7.5(8)	5.2(8) -	9.7(8)
37.5	6.1(8)	4.2(8) -	7.7(8)
37.0	4.4(8)	3.1(8) -	5.7(8)
36.5	5.2(8)	3.7(8) -	6.6(8)
36.0	4.6(8)	3.3(8) -	6.2(8)
35.5	4.9(8)	3.3(8) -	6.2(8)
35.0	3.4(8)	2.4(8) -	4.4(8)
34.5	2.8(8)	2.0(8) -	3.7(8)
34.0	3.9(8)	2.7(8) -	4.9(8)
33.5	2.9(8)	2.0(8) -	3.9(8)
33.0	3.7(8)	2.5(8) -	4.6(8)
32.5	3.1(8)	2.3(8) -	4.4(8)
32.0	2.4(8)	1.8(8) -	3.2(8)
31.5	2.0(8)	1.6(8) -	2.6(8)
31.0	2.8(8)	1.9(8) -	3.7(8)
30.5	2.9(8)	2.0(8) -	3.8(8)
30	2.3(8)	1.6(8) -	3.0(8)
29	1.2(8)	9.2(7) -	1.6(8)
28	1.1(8)	6.4(7) -	1.5(8)
27	8.1(7)	4.1(7) -	1.1(8)
26	6.0(7)	2.5(7) -	9.5(7)

(Source: Anderson, 1975)

[a] Experimenter's uncertainty
[b] 1.0(9) refers to 1.0×10^9

Stratospheric Concentrations of $O(^3P)$

Technique:	Atomic resonance fluorescence of $O(^3P)$ at 1304 Å
Date:	25 November 1974
Time:	10:30 a.m. CST
Solar Zenith Angle:	56°
Location:	Palestine, Texas (32° N)
Experimental Uncertainty:	±30% from 40 km to 29 km increasing to ±60% at 27 km.
Comments:	Structure evident in the profile is statistically significant above 30 km. Profile measured from 40 to 26 km integrated over 500 m intervals above 30 km and over 1 km intervals below 30 km.

Anderson, T. G., The Absolute Concentration of $O(^3P)$ in the Earth's Stratosphere, Geophys. Res. Lett., 2, 231-234, 1975

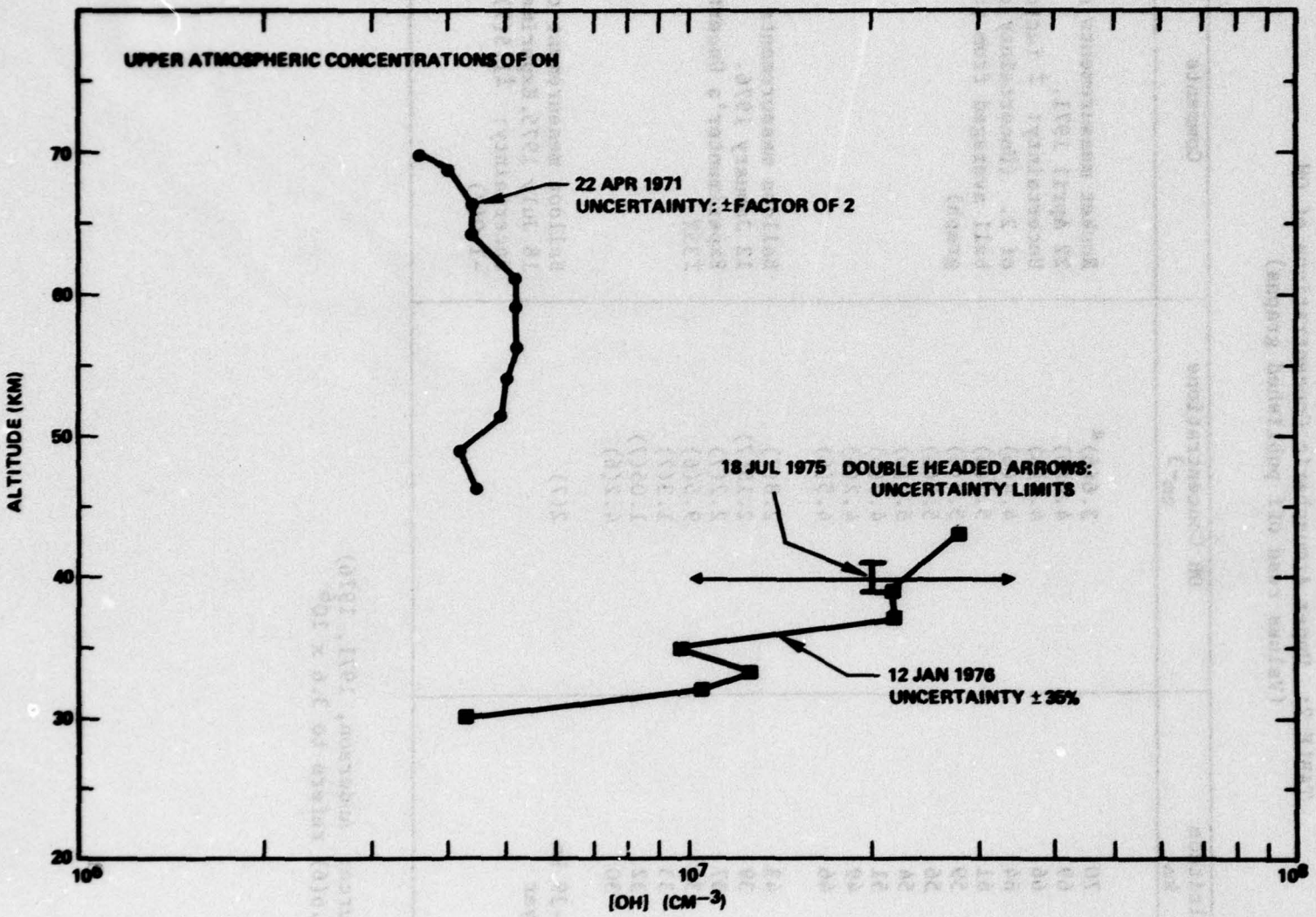


Figure 2: Upper Atmospheric OH Concentrations
(Source: Anderson, 1971, 1976)

TABLE 2: Upper Atmospheric Concentrations of OH
(Values read off published graphs)

Altitude km	OH Concentrations cm^{-3}	Comments
70	3.6(6)[a]	Rocket measurements on 22 April 1971. Uncertainty: ± factor of 2. (Uncertainty eyeball averaged from published graph)
69	4.0(6)	
66	4.4(6)	
64	4.4(6)	
61	5.2(6)	
59	5.2(6)	
56	5.2(6)	
54	5.0(6)	
51	4.9(6)	
49	4.2(6)	
46	4.5(6)	
43	2.8(7)	Balloon measurements on 12 January 1976. Experimenter's Uncertainty: ±35%
39	2.15(7)	
37	2.2(7)	
35	9.5(6)	
33	1.3(7)	
32	1.05(7)	
30	4.2(6)	
41-39 km layer	2(7)	Balloon measurement on 18 July 1975. Experiment's Uncertainty: ±1.5(7) to -1.0(7)

(Source: Anderson, 1971, 1976)
[a] 3.6(6) refers to 3.6×10^6

Upper Atmospheric Concentrations of OH

Technique: Resonance fluorescence of OH in the wavelength region 3064-3120 Å

22 April 1971

Platform: Rocket (Nike-Apache sounding rocket)

Time: 1816 MST

Solar Zenith Angle: 86° 13'

Location: White Sands, New Mexico

Vertical Region Sampled: 70 to 45 km

Uncertainty: ± Factor of 2 obtained as an eye-ball average from published graph.

18 July 1975

Platform: Balloon

Time: Local noon (at launch)

Solar Zenith Angle: 80° (during measurement)

Location: Palestine, Texas (32° N)

Vertical Region Sampled: 41 to 39 km

Uncertainty: $+1.5 \times 10^7$ to -1.0×10^7 cm^{-3} (Experimenter's uncertainty)

12 January 1976

Platform: Balloon

Time: Local noon (at launch)

Solar Zenith Angle: 80° (during measurement)

Location: Palestine, Texas (32° N)

Vertical Region Sampled: 43 to 29 km

Uncertainty: ±35% (Experimenter's uncertainty)

Anderson, J. G., Rocket Measurements of OH in the Mesosphere, J. Geophys. Res., 76, 7820-7824, 1971

Anderson, J. G., The Absolute Concentration of OH ($X^2\Pi$) in the Earth's Stratosphere, Geophys. Res. Lett., 3, 165-168, 1976

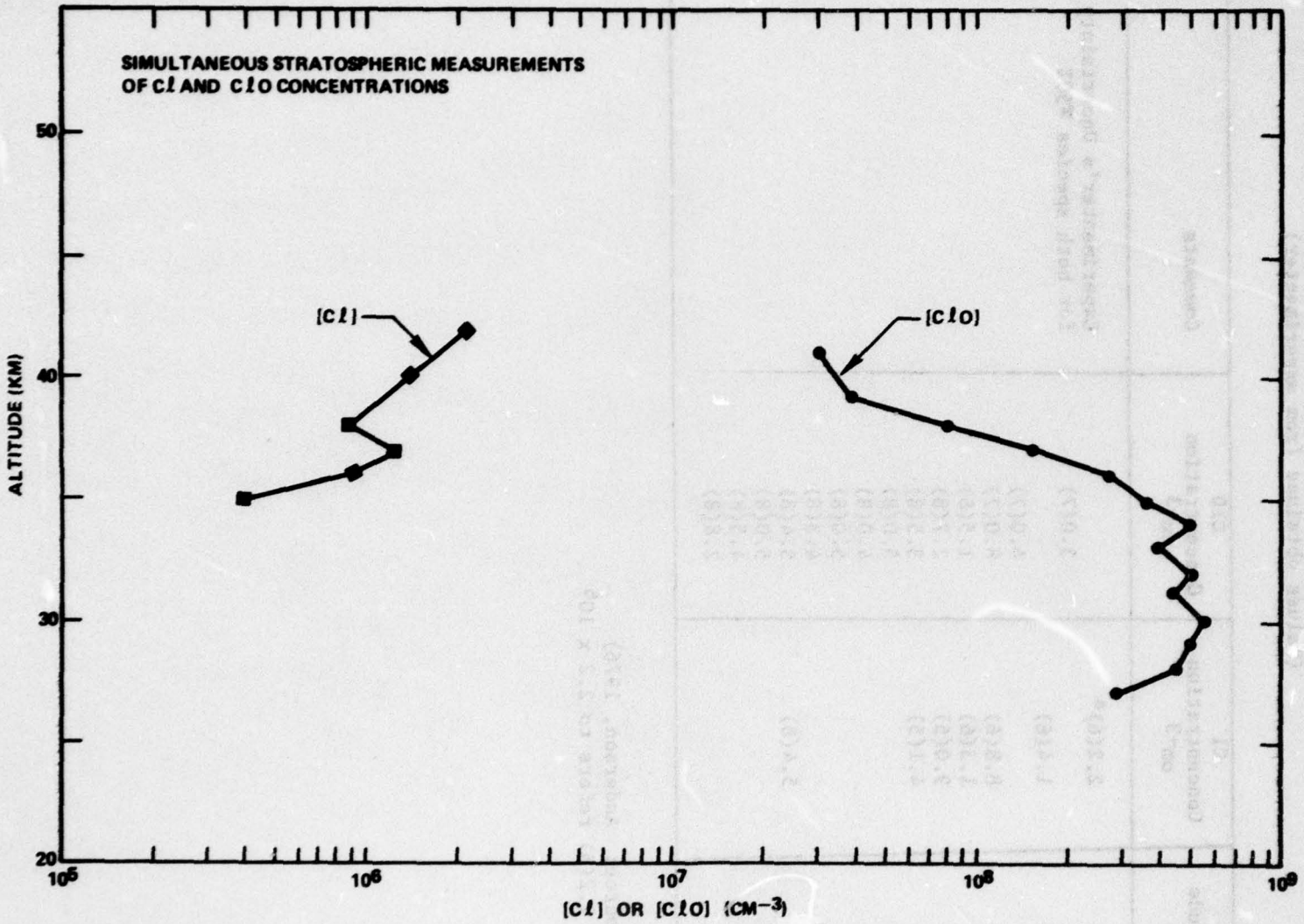


Figure 3: Simultaneous Observations of Stratospheric Cl and ClO Concentrations
(Source: Anderson, 1976)

TABLE 3: Stratospheric Concentrations of Cl and ClO Simultaneously Observed (Values obtained from experimenter)

Altitude km	Cl Concentration cm^{-3}	ClO Concentration cm^{-3}	Comments
42	2.2(6)[a]		Experimenter's Uncertainty for both species ±50%
41		3.0(7)	
40	1.4(6)		
39		4.0(7)	
38	8.8(6)	8.0(7)	
37	1.3(6)	1.5(8)	
36	9.0(5)	2.7(8)	
35	4.1(5)	3.5(8)	
34		5.0(8)	
33		4.0(8)	
32		5.0(8)	
31		4.3(8)	
30	5.4(8)	5.4(8)	
29		5.0(8)	
28		4.5(8)	
27		2.8(8)	

(Source: Anderson, 1976)

[a] 2.2(6) refers to 2.2×10^6

Simultaneous Stratospheric Measurements of Cl and ClO Concentrations

Technique:	Resonance fluorescence (ClO does not fluoresce; hence it is converted to Cl by adding NO: $ClO + NO \rightarrow Cl + NO_2$, and resulting Cl detected at 1188 Å)
Platform:	Balloon Two instruments, one for Cl and the other for ClO, launched simultaneously on the same balloon
Date:	28 July 1976
Time:	12 Noon CDT
Solar Zenith Angle:	16^{o}
Location:	Palestine, Texas (32^{o}N)
Uncertainty:	$\pm$50% for both species (Experimenter's uncertainty)

Anderson, J. G., A Simultaneous Measurement of Cl and ClO in the Earth's Stratosphere, Paper presented at the International Conference on the Stratosphere and Related Problems, Logan, Utah, September 15-17, 1976.

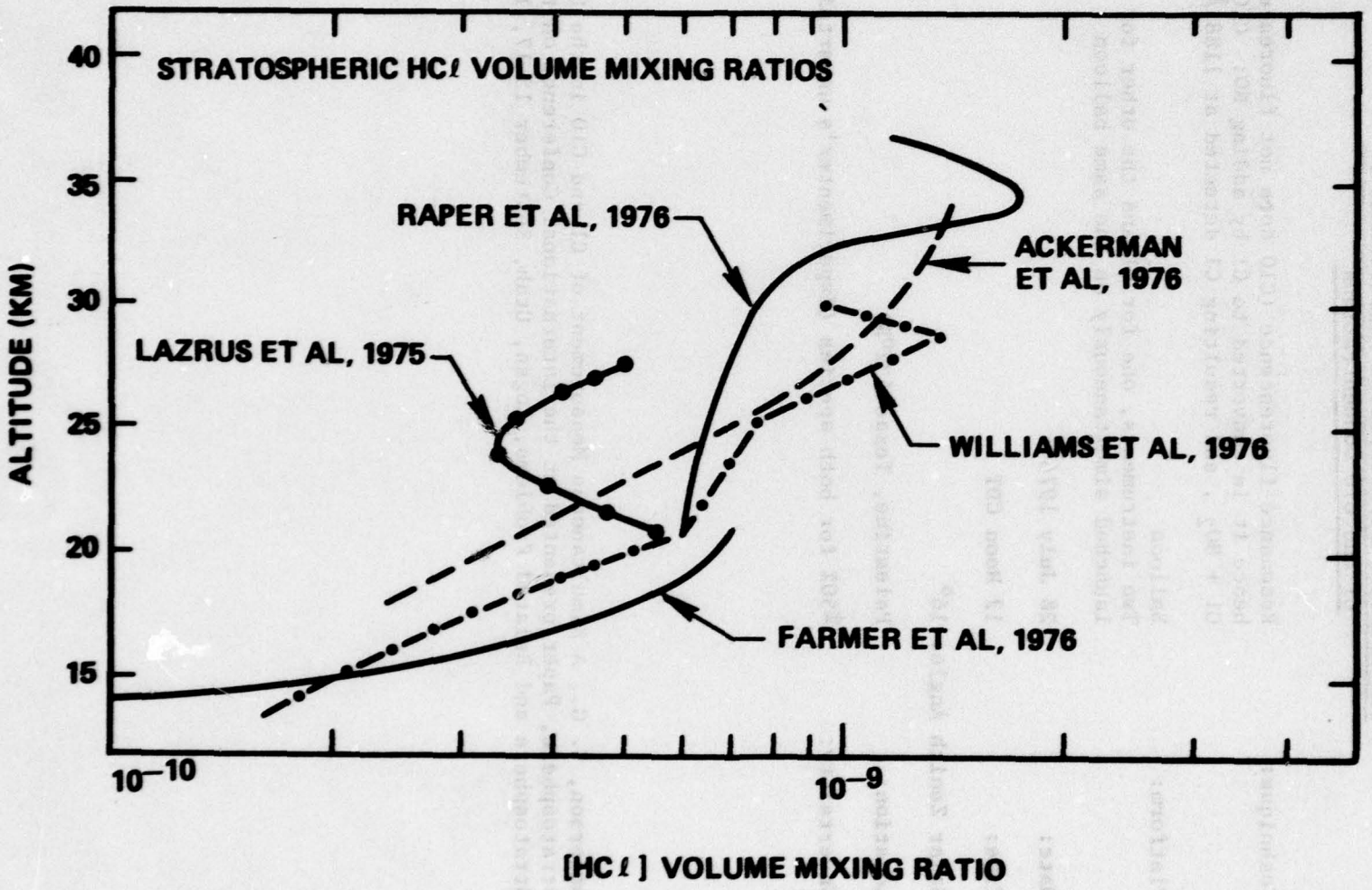


Figure 4: Stratospheric HCl Volume Mixing Ratios

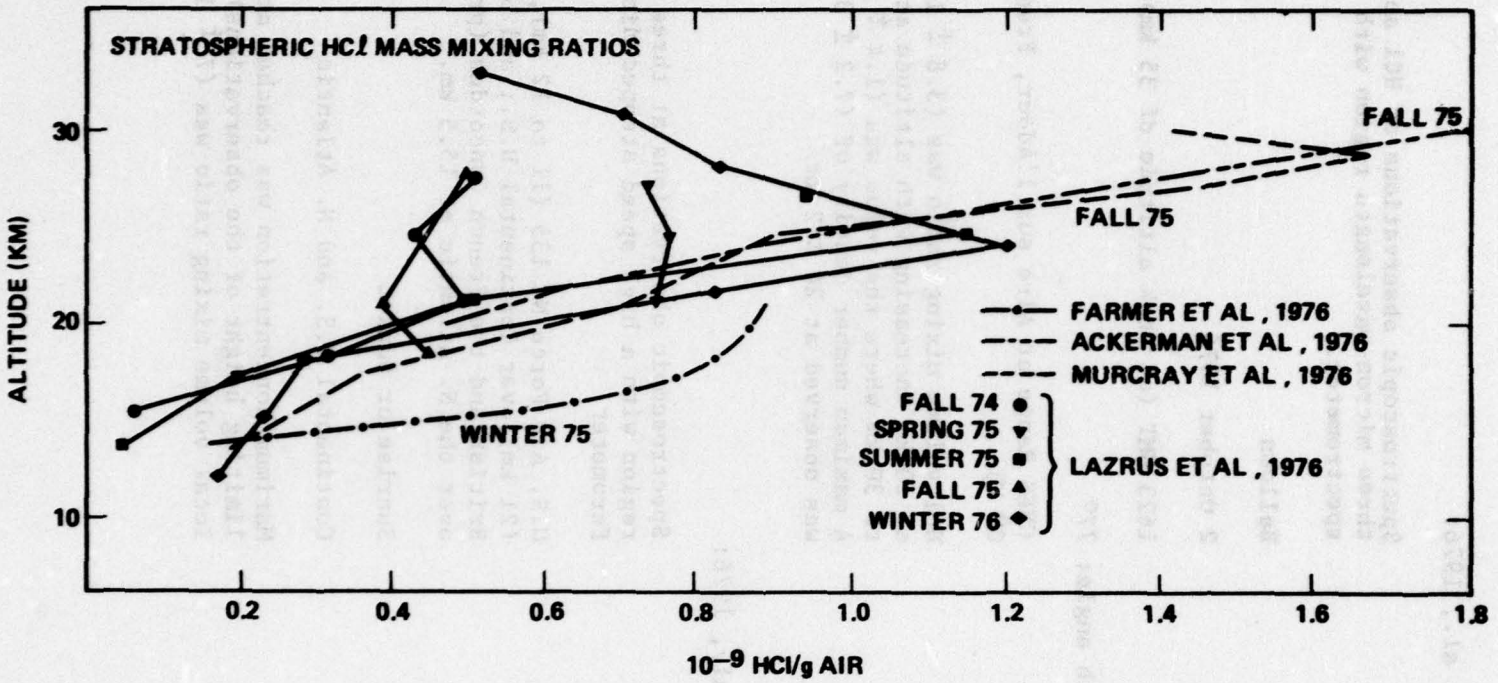


Figure 5: Stratospheric HCl Mass Mixing Ratios

Stratospheric HCl Mixing Ratios

1. Ackerman et al., 1976:

Technique:	Spectroscopic observations of HCl absorption at three micron-wavelength region with a grille spectrometer.
Platform:	Balloon
Date:	2 October 1975
Time:	1623 GMT (at peak altitude of 35 km)
Solar zenith angle:	77°
Location:	CNES Range at Aire sur l'Adour, France (44° N, 0° W)
Comments:	HCl volume mixing ratio was $(3.8 \pm 1.5) \times 10^{-10}$ at 20 km increasing with altitude at least up to 30 km where the value was $(1.4 \pm 0.6) \times 10^{-9}$. A maximum number density of $(7.2 \pm 3) \times 10^{8}$ cm^{-3} was observed at 24 ± 2 km.

2. Farmer et al., 1976:

Technique:	Spectroscopic observations at three micron-wavelength region with a high speed stepped Michelson interferometer
Platform:	U.S. Air Force NC 135 (11 to 12 km), NASA U2 (21 km) over Continental U.S.; and both the British and the French Concordes (prototypes) over the N. Atlantic at 15.5 km.
Time:	Sunrise or Sunset
Location:	Continental U.S. and N. Atlantic
Comments:	Maximum concentration was reached at 21 km (the limiting height of the observations) where the local volume mixing ratio was $(7 \pm 1) \times 10^{-10}$.

Stratospheric HCl Mixing Ratios (cont'd)

3. **Lazrus et al., 1975:**

Technique:	In situ sampling using filter capture.
Platform:	Balloon
Time:	Fall 1974, generally in early morning.
Location:	Hollomon Air Force Base, New Mexico
Comments:	The volume mixing ratios were 5.5×10^{-10} at 21 km, 3.4×10^{-10} at 24 km, 5.1×10^{-10} at 26.4 km and 4.0×10^{-10} at 27.5 km.

4. **Lazrus et al., 1976:**

See Lazrus et al., 1975. The times of experiments are given in the figure.

5. **Raper et al., 1976:**

Technique:	See Farmer et al., 1976
Platform:	Balloon
Date:	September 1975 and May 1976
Location:	Palestine, Texas (32° N)
Comments:	The HCl volume mixing ratio increased from about 6×10^{-10} at 20 km to a maximum of about 1.7×10^{-9} at 34-35 km and fell off rapidly thereafter to less than 4×10^{-10} at 40 km.

6. **Williams et al., 1976:**

Technique:	Spectroscopic observations at three micron-wavelength region with a grating spectrometer at float altitude, 30 km.
Platform:	Balloon
Date:	16 December 1975

Stratospheric HCl Mixing Ratios (cont'd)

Time:	**Sunset**
Location:	**Hollomon Air Force Base, New Mexico**
Comments;	**The volume mixing ratio increased from 1.5×10^{-10} to 1.2×10^{-9} in the 13.4 to 27 km altitude range.**

Ackerman, M., D. Frimout, A. Girard, M. Gottignies, and C. Muller, Stratospheric HCl From Infrared Spectra, Geophys. Res. Lett., 3, 81-83, 1976.

Farmer, C. B., O. F. Raper, and R. H. Norton, Spectroscopic Detection and Vertical Distribution of HCl in the Troposphere and Stratosphere, Geophys. Res. Lett., 3, 13-16, 1976.

Lazrus, A. L., B. W. Gandrud, R. N. Woodard, and W. A. Sedlacek, Stratospheric Halogen Measurements, Geophys. Res. Lett., 2, 439-441, 1975, as quoted in "The Effect of Fluorocarbons on the Concentration of Atmospheric Ozone" by the Technical Panel on Fluorocarbon Research, Manufacturing Chemists Association, 1825 Connecticut Ave., N.W., Washington, D.C. 20009, 1 March, 1976.

Lazrus, A. L., B. W. Gandrud, R. N. Woodard, and W. A. Sedlacek, Variability of Stratospheric Hydrogen Chloride, Private Communication, 1976.

McCarthy, R., An Industry View of the Scientific Aspect of the Fluorocarbon/Ozone Issue, Paper presented at the International Conference on the Stratosphere and Related Problems, Logan, Utah, September 15-17, 1976.

Raper, O. F., C. B. Farmer, and R. A. Toth, The Vertical Distribution of HCl in the 20-40 km Region of the Stratosphere, Paper presented at the International Conference on the Stratosphere and Related Problems, Logan, Utah, September 15-17, 1976.

Williams, W. J., J. J. Kosters, A. Goldman, and D. G. Murcray, Measurement of the Stratospheric Mixing Ratio of HCl using Infrared Absorption Technique, Geophys. Res. Lett., 3, 383-385, 1976.

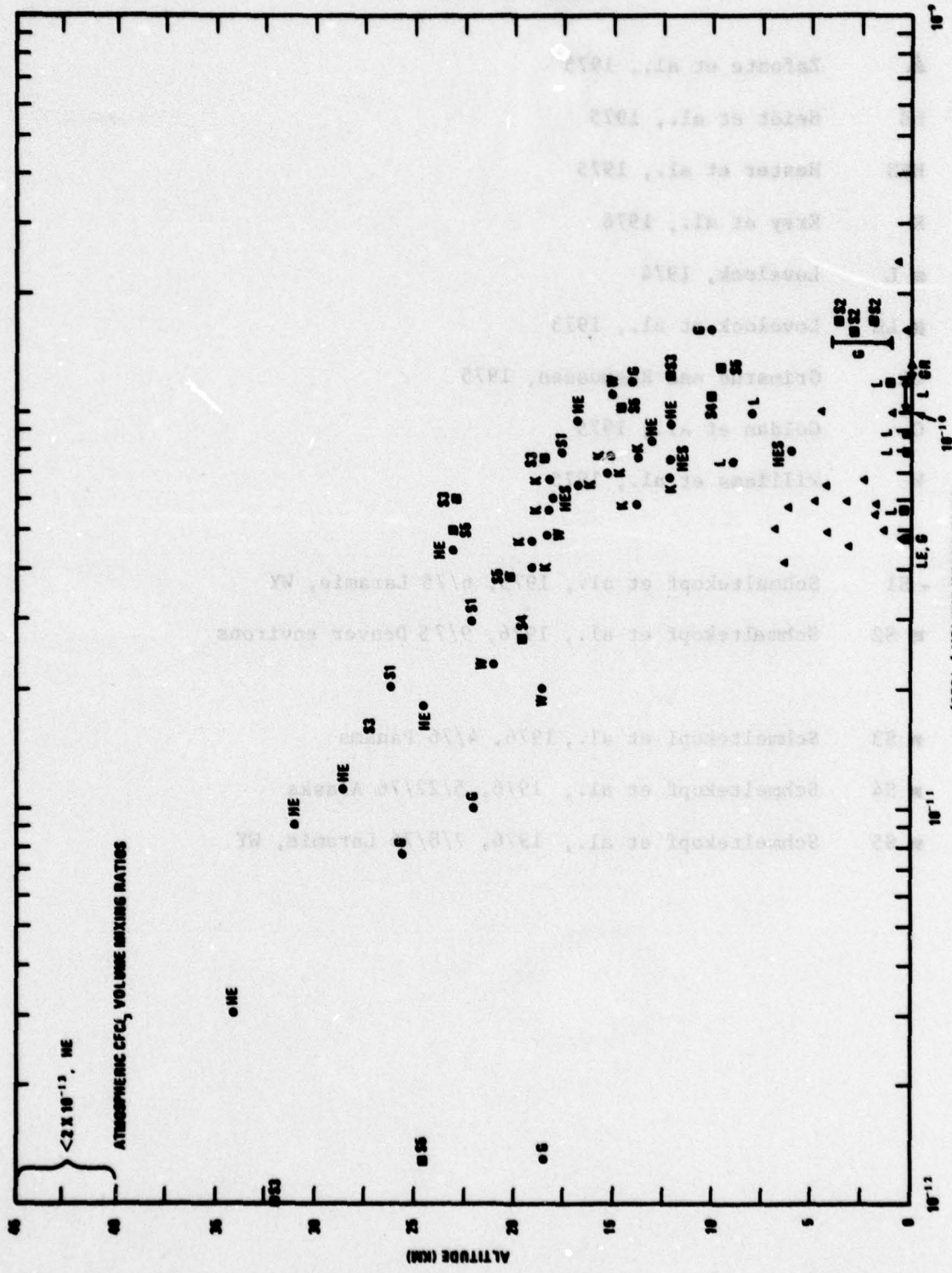
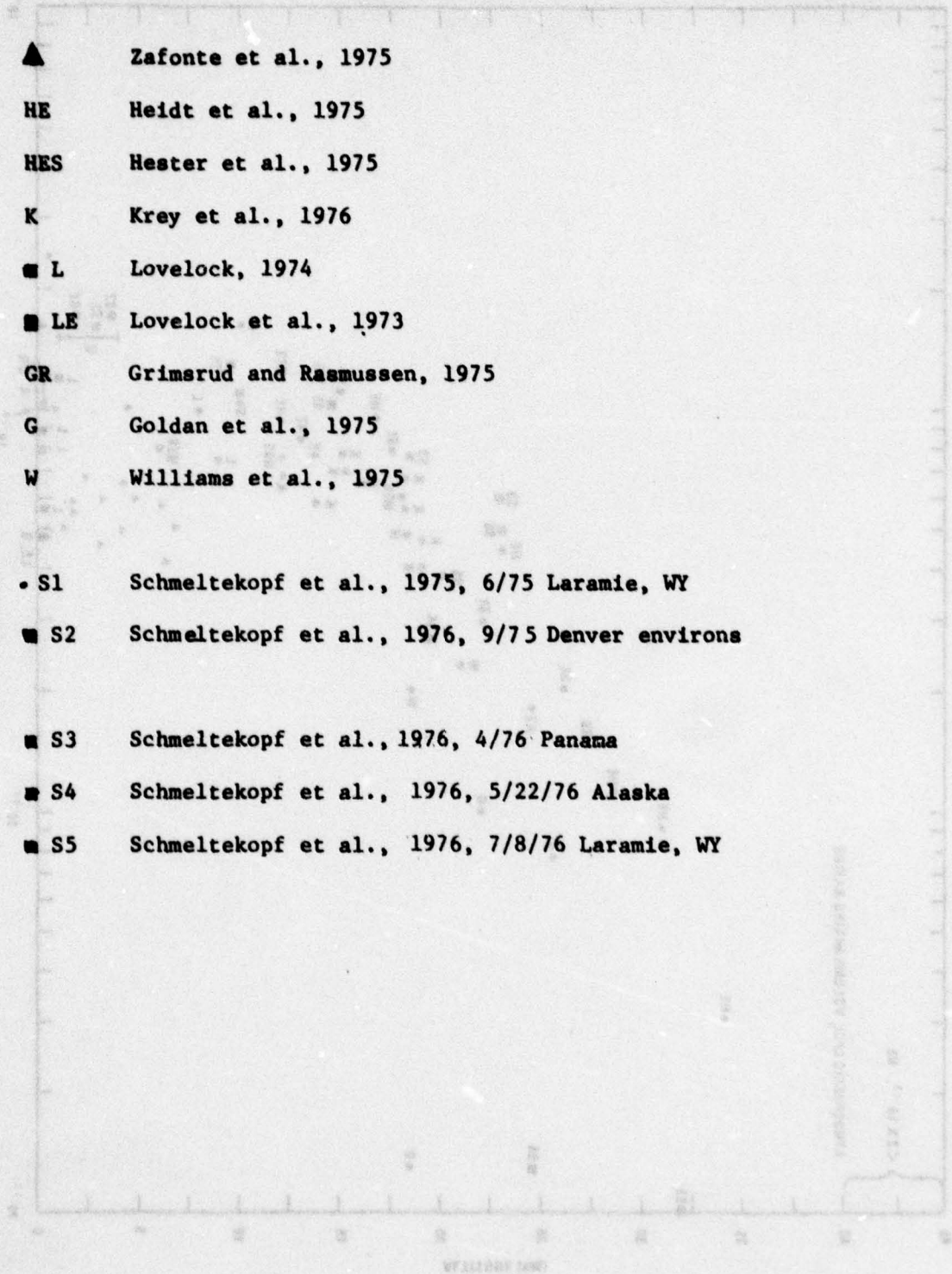


Figure 6: Atmospheric $CFCl_3$ Volume Mixing Ratios

Legend to Figure 6



▲ Zafonte et al., 1975

HE Heidt et al., 1975

HES Hester et al., 1975

K Krey et al., 1976

■ L Lovelock, 1974

■ LE Lovelock et al., 1973

GR Grimsrud and Rasmussen, 1975

G Goldan et al., 1975

W Williams et al., 1975

• S1 Schmeltekopf et al., 1975, 6/75 Laramie, WY

■ S2 Schmeltekopf et al., 1976, 9/75 Denver environs

■ S3 Schmeltekopf et al., 1976, 4/76 Panama

■ S4 Schmeltekopf et al., 1976, 5/22/76 Alaska

■ S5 Schmeltekopf et al., 1976, 7/8/76 Laramie, WY

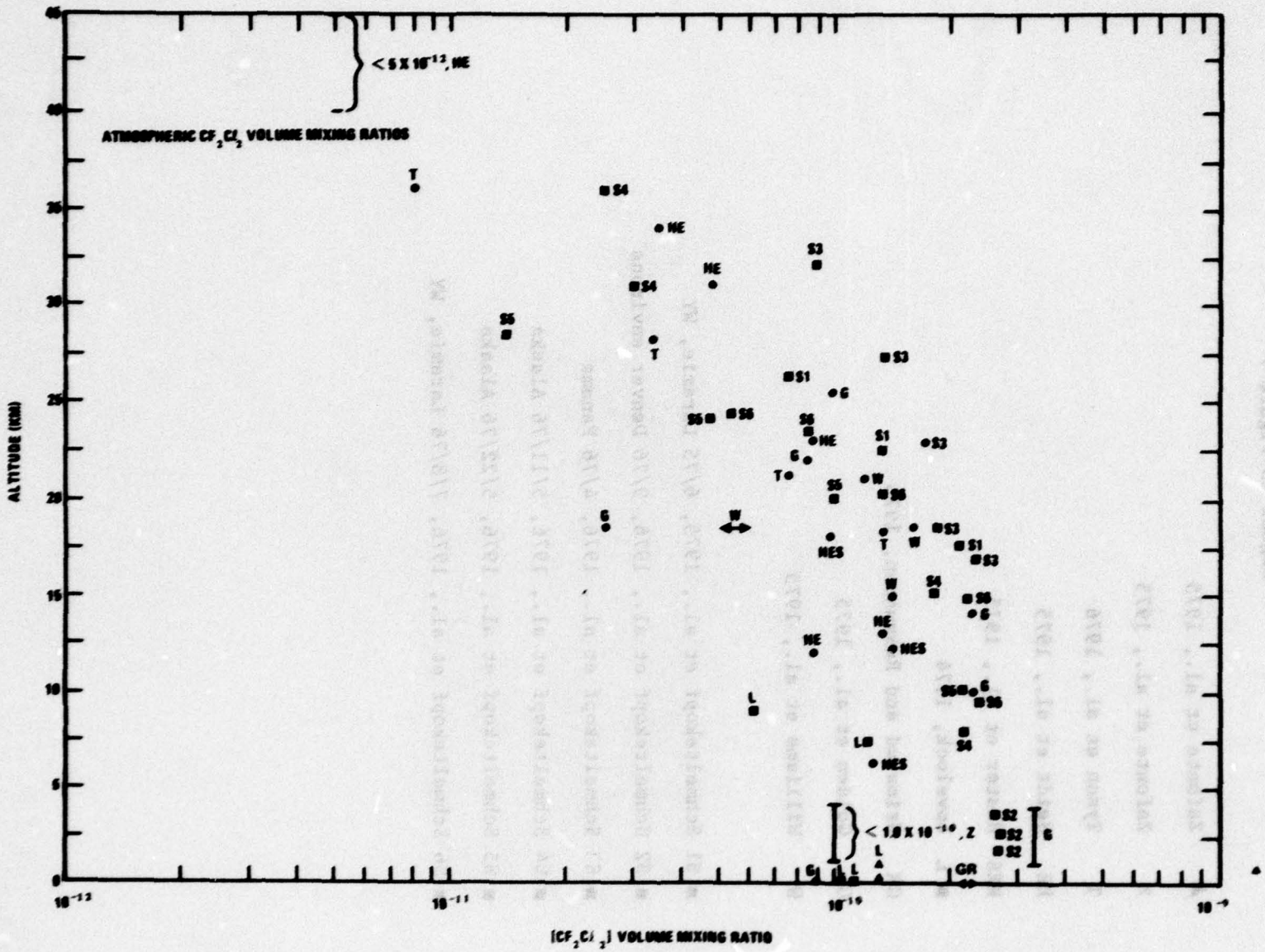
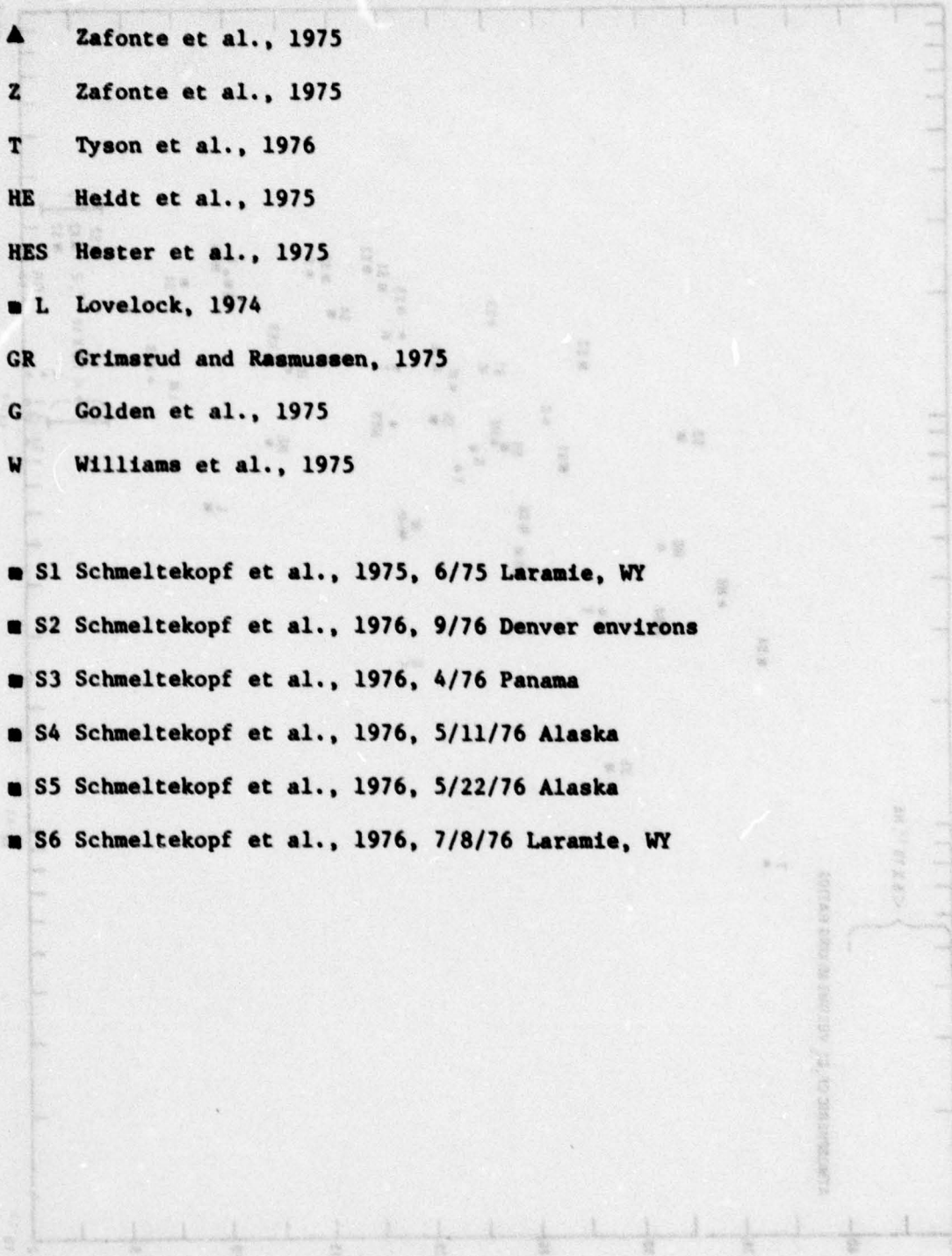


Figure 7: Atmospheric CF_2Cl_2 Volume Mixing Ratios

Legend to Figure 7



▲ Zafonte et al., 1975

Z Zafonte et al., 1975

T Tyson et al., 1976

HE Heidt et al., 1975

HES Hester et al., 1975

■ L Lovelock, 1974

GR Grimsrud and Rasmussen, 1975

G Golden et al., 1975

W Williams et al., 1975

■ S1 Schmeltekopf et al., 1975, 6/75 Laramie, WY

■ S2 Schmeltekopf et al., 1976, 9/76 Denver environs

■ S3 Schmeltekopf et al., 1976, 4/76 Panama

■ S4 Schmeltekopf et al., 1976, 5/11/76 Alaska

■ S5 Schmeltekopf et al., 1976, 5/22/76 Alaska

■ S6 Schmeltekopf et al., 1976, 7/8/76 Laramie, WY

TABLE 4: MEASUREMENTS OF FLUOROCARBON VOLUME MIXING RATIOS
UNITS: pptv (10^{-12}v/v)

Author	Altitude, km	F-11 ($CFCl_3$)	F-12 (CF_2Cl_2)	Date & Location	Comments
Heidt et al., 1975	40-45	< 0.2	< 5	5/23/73	Rocket-integrated air sampling between 40 and 50 km (Ehhalt et al., 1975)
	34.0	3	35	5/7/74	Balloon-borne cryogenic sampling; gas chromatography with an electron capture detector
	31.0	9	48	5/7/74	
	28.6	11	--	6/2/75	
	24.5	18	--	6/2/75	
	23.0	45	86	9/9/73	
	16.9	95	--	6/2/75	
	13.0	83	133	9/9/73	Tropopause: 15km (1973)
	12.0	94	78	9/9/73 Palestine, TX (32°N)	16.19km (1975)
Hester et al., 1975	18.3 (18)	60 ± 4 (57)	98 ± 18 (110)	5/23/74 36.15 -39.30 Lat. 106.17-106.45 Long.	Average value from 2 flights
	12.2 (12)	75 (75)	140 (140)	5/23/74 33.10 -34.14 Lat. 104.30-105.10 Long.	Tropopause: 13 km

Author	Altitude, km	F-11 ($CFCl_3$)	F-12 (CF_2Cl_2)	Date & Location	Comments
	6.4 (6)	80 ± 3 (82)	125 ± 7 (120)	5/23/74 34.45 -33.50 Lat. 106.20-105.00 Long.	Values in parentheses quoted by Heidt et al., 1975
Krey et al., 1976	13.7	59		4/74 60°N-37°S	
	15.2	70			
	16.8	65			
	18.3	57			
	19.2	47			Compressed air sample Gas chromatography analysis
	12.2	69		10/74 75°N-10°S	
	13.7	77			
	15.3	77			Mean concentration averaged over latitude interval of sampling
	16.8	66			
	18.3	67			
	19.2	41			
Lovelock, 1974	Surface	79.8	101.7	6/74, 7/74 W. Ireland	Gas chromatography
		88.6	115.2	10/73 N. Atlantic	
		101-119		6/74 Central England	
		57		9/74 Capetown, S. Africa	

Author	Altitude, km	F-11 ($CFCl_3$)	F-12 (CF_2Cl_2)	Date & Location	Comments
	9	75	60		Tropopause between 7.5 and 9 km
	7.5	100	122		
	1	118	128		
Lovelock et al., 1973	Surface	49		11/71, 12/71 50°N-60°S	Oceanographic cruise of Shackleton Latitude
					Aerial concentration averaged over 50°N-60°S. Concentration ranges from 70 pptv at 50°N to 38 pptv at 60°S.
Schmeltekopf et al., 1975	26.2 ± 1	20	75 ± 5	6/75 Laramie, WY	Balloon-borne stainless steel grab samplers
	22.3 ± 0.7	30+3 -6	135 ± 10		Electron capture detector/gas chromatography
	17.7 ± 0.5	80 ± 10	210 ± 10		
Grimsrud and Rasmussen, 1975	Surface	120-130	210-230	May 1975	Gas chromatography/ mass spectrometry Values as quoted by Sze and Wu, 1976
Goldan et al., 1975	Surface	48 ± 5	90 ± 10	8/75	
	1-4	150	330	9/75	Values as quoted by Sze and Wu, 1976.
	10	160 ± 15	230 ± 30	8/75	
	14	120 ± 15	225 ± 30	8/75	

Author	Altitude, km	F-11 ($CFCl_3$)	F-12 (CF_2Cl_2)	Date & Location	Comments
	18.5	$1.3 + 0.7 - 0.3$	25 ± 3	8/75 Saskatchewan	
	22	10 ± 1	84 ± 8	8/75	
	25.5	7.6 ± 1	100 ± 10	8/75	
Williams et al., 1975	21	23	120	9/26/75	See Williams et al., 1975.
	18.5	49	160	9/26/75	
	18.5	20	50-60	8/12/68	
	15	110	140	9/26/75	
Schmeltekopf et al., 1976	1.75	170	270	9/75	Electron capture detector/gas chromatography
	2.5	160	270	Denver	
	3.5	170	260	Environs	(Values read off the graphs provided by the experimenters)

Author	Altitude km	F-11 ($CFCl_3$)	F-12 (CF_2Cl_2)	Date and Location	Comments
Schmeltekopf et al., 1976	12	125	230	4/76	Electron capture detector/gas chromatography
	18.5	77	185	Panama	
	23	60	175		
	27	15	135		(Values read off the graphs provided by the experimenters)
	32	1	90		
	8		220	5/11/76	" "
	15		180	Alaska	
	31		30		
	36		25		
	10	110	220	5/22/76	" "
	19.5	27	100	Alaska	
	24		47		
	28.5		14		

Author	Altitude km	F-11 ($CFCl_3$)	F-12 (CF_2Cl_2)	Date and Location	Comments
Schmeltekopf et al., 1976	9.5	130	240	7/8/76	Electron capture detector/gas chromatography
	14.5	100	220	Laramie, WY	
	20.3	39	135		
	23.3	5	84		(Values read off the graphs provided by the experimenters)
	24.5	1.3	54		
Tyson et al., 1976	18.3		132 ± 3	3/23/76, Oregon 42° 08'N, 117° 15'W	Cryogenic Sampling by U-2 aircraft at 18.3 and 21.3 km and by balloon at 28.3 and 35.9 km.
	21.3		84 ± 1	3/23/76, Oregon 42° 13'N, 117° 20'W	
	21.3		73 ± 1	2/20/76, Calif. 37° 45'N, 120° 08'W	
	21.3		73 ± 2	3/11/76, Calif. 36° 54'N, 119° 38'W	
	21.3		74 ± 10	5/14/76, Canada 55° 50'N, 67° 45'W	
	21.3		76 ± 2	5/14/76, Canada 61° 00'N, 68° 35'W	
	Mean at: 21.3		76 ± 3		
	28.3		34 ± 3	1/23/76, Texas 32° 08'N, 92° 26'W	
	35.9		8 ± 2	1/23/76, Texas 31° 26'N, 94° 05'W	

Author	Altitude km	F-11 ($CFCl_3$)	F-12 (CF_2Cl_2)	Date and Location	Comments
Zafonte et al., 1975	0.426	160	130	2/23/73, Riverside	Whole air samples by twin-engined aircraft
	0.610	240	1300	Calif., Rialto	
	0.914	100	130	Rialto	
	1.372	150	< 100	Rialto	
	1.829	58	< 100	Rialto	
	2.348	67	< 100	Rialto	
	3.048	59	< 100	Rialto	
	4.267	65	< 100	Rialto	
	0.457	48	< 100	3/7/73,	Whole air samples by twin-engined aircraft.
	1.372	49	< 100	Rialto, Calif.	
	1.829	55	< 100		From these data tropospheric background levels of F-11 and F-12 were determined to be 60 and 90 pptv, respectively.
	3.048	46	< 100		
	4.268	50	< 100		
	4.877	60	< 100		
	6.096	58	< 100		
	6.248	42	< 100		
	6.706	51	< 100		

Ehhalt, D. H., L. E. Heidt, R. A. Lueb, and E. A. Martell, "Concentrations of CH_4, CO, CO_2, H_2, H_2O and N_2O in the Upper Atmosphere," J. Atm. Sci., 32, 163-169, 1975.

Heidt, L. E., R. Lueb, W. Pollock, and D. H. Ehhalt, "Stratospheric Profiles of CCl_3F and CCl_2F_2," Geophys. Res. Lett., 2, 445-447, 1975.

Hester, N. E., E. R. Stephens, and O. C. Taylor, "Fluorocarbon Air Pollutants," III, Environ. Sci. and Technol., 9, 875-876, 1975.

Krey, P. W., R. J. Lagomarsino, and J. J. Frey, "Stratospheric Concentrations of CCl_3F in 1974," J. Geophys. Res., 81, 1557-1560, 1976.

Lovelock, J. E., "Atmospheric Halocarbons and Stratospheric Ozone," Nature, 252, 292-294, 1974.

Lovelock, J. E., R. J. Maggs, and R. J. Wade, "Halogenated Hydrocarbons in and over the Atlantic," Nature, 241, 194ff, 1973.

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Schmeltekopf, A. L., et al., Private Communication, 1976.

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Williams, W. J., J. J. Kosters, A. Goldman, and D. G. Murcray, "Simultaneous Stratospheric Measurements," Paper presented at the fall AGU Meeting, San Francisco, December 1975.

Zafonte, L., N. E. Hester, E. R. Stephens, and O. C. Taylor, "Background and Vertical Atmospheric Measurements of Fluorocarbon-11 and Fluorocarbon-12 over Southern California," Atm. Environ., 9, 1007-1009, 1975.

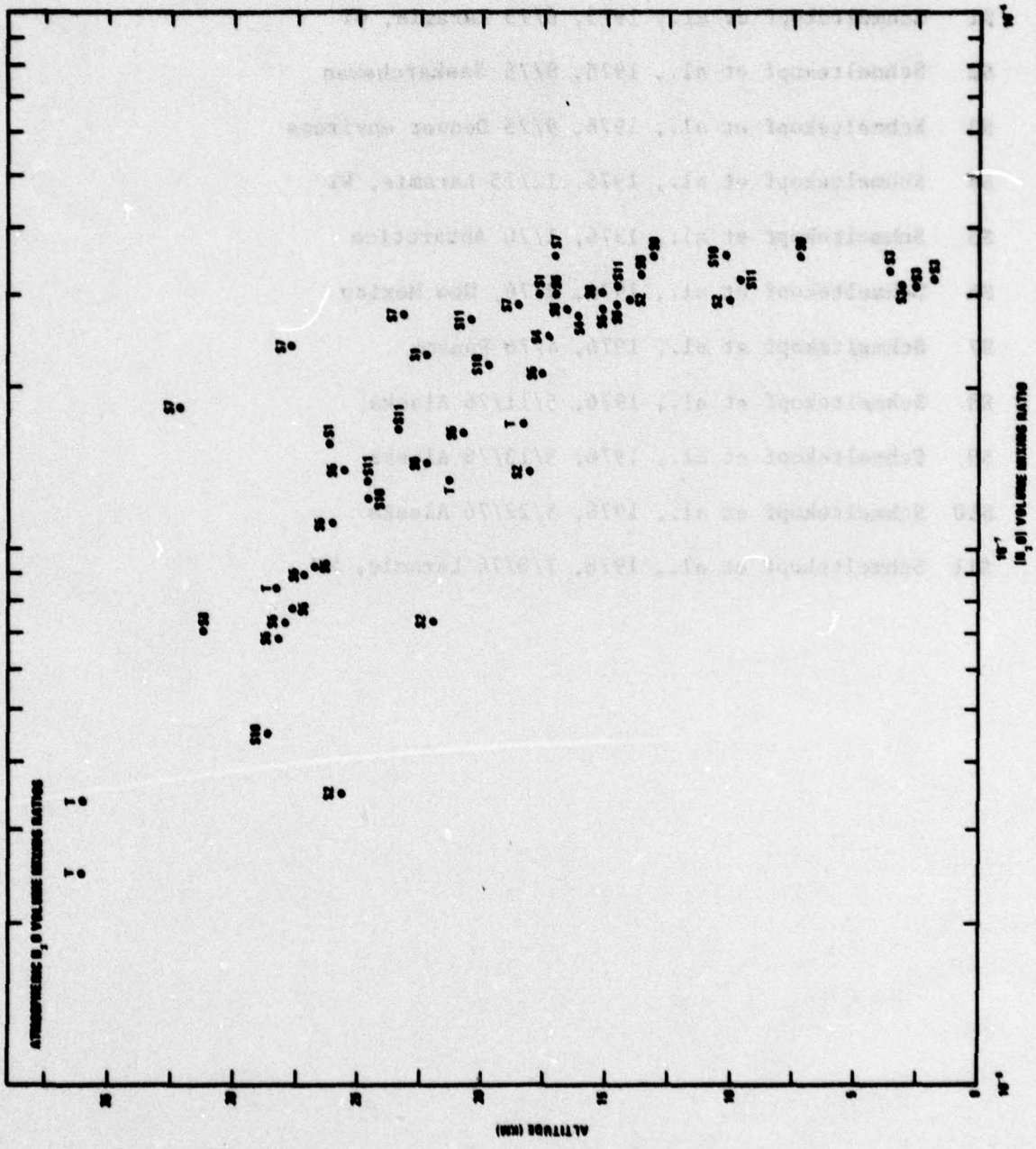

Figure 8: Atmospheric H_2O Volume Mixing Ratios

Legend to Figure 8

T Tyson et al., 1976

S1 Schmeltekopf et al., 1975, 6/75 Laramie, WY

S2 Schmeltekopf et al., 1976, 8/75 Saskatchewan

S3 Schmeltekopf et al., 1976, 9/75 Denver environs

S4 Schmeltekopf et al., 1976, 12/75 Laramie, WY

S5 Schmeltekopf et al., 1976, 1/76 Antarctica

S6 Schmeltekopf et al., 1976, 2/76, New Mexico

S7 Schmeltekopf et al., 1976, 4/76 Panama

S8 Schmeltekopf et al., 1976, 5/11/76 Alaska

S9 Schmeltekopf et al., 1976, 5/13/76 Alaska

S10 Schmeltekopf et al., 1976, 5/22/76 Alaska

S11 Schmeltekopf et al., 1976, 7/8/76 Laramie, WY

TABLE 5: ATMOSPHERIC N_2O VOLUME MIXING RATIOS
Units: ppbv (10^{-9} v/v)

Author	Altitude km	(N_2O) ppbv	Date & Location	Comments
Schmeltekopf et al., 1975	17.7 ± 0.5 22.3 ± 0.7 26.2 ± 0.1	300 ± 20 230 ± 20 160 ± 20	6/75 Laramie, WY	Balloon-borne grab sampling; electron capture detector/gas chromatography. Values published by experimenters
Schmeltekopf et al., 1976	10	290	8/75	
	14	290	Saskatchewan	
	18	140		" "
	22	74		
	25.5	35		
	1.75	320	9/75	" "
	2.5	310	Denver	
	3	310	Environs	
	3.5	330		
				" "
	16	270	12/75	
	17.25	250	Laramie, WY	
	15	280	1/76	" "
	17.5	215	Antarctica	
	20.5	165		
	25.5	140		
	26	113		
	26.5	93		
	27	90		
	27.5	78		
	27.75	73		
	28	68		
				" "
	17	300	2/76	
	22	145	New Mexico	

Author	Altitude km	(N_2O) ppbv	Date & Location	Comments
Schmeltekopf et al., 1976	17	340	4/76	Balloon-borne grab sampling; electron capture detector/gas chromatography. Values published by experimenters
	18.5	290	Panama	
	23	270		
	27.5	238		
	32	185		
	7.5	350	5/11/76	" "
	15	300	Alaska	
	31	70		
	36	25		
	13	350	5/13/76	" "
	13.5	330	Alaska	
	14.5	290		
	16.5	280		
	10	350	5/22/76	" "
	19.5	220	Alaska	
	24.5	125		
	28.5	45		
	9.5	320	7/8/76	" "
	14.5	310	Laramie, WY	
	20.25	265		
	23.25	168		
	24.50	135		
Tyson et al., 1976	18.3	171 ± 12	3/23/76, Oregon 42° 08'N, 117° 15'W	Cryogenic Sampling by U-2 aircraft at 18.3 and 21.3 km and by balloon at 28.3 and 35.9 km. Values provided by experimenters
	21.3	122 ± 7	3/23/76, Oregon 42° 13'N, 117° 20'W	
	21.3	117 ± 4	2/20/76, Calif. 37° 45'N, 120° 08'W	

Author	Altitude km	(N_2O) ppbv	Date & Location	Comments
Tyson et al., 1976	21.3	129 ± 5	3/11/76, Calif. 36° 54'N, 119° 38'W	Cryogenic Sampling by U-2 aircraft at 18.3 and 21.3 km and by balloon at 28.3 and 35.9 km. Values provided by experimenters.
	21.3	143 ± 11	5/14/76, Canada 54° 50'N, 67° 45'W	
	21.3	159 ± 9	5/14/76, Canada 61° 00'N, 68° 35'W	
	Mean at 21.3	134 ± 7		
	28.3	85 ± 1	1/23/76, Texas 32° 08'N, 92° 26'W	
	35.9	34 ± 2	1/23/76, Texas 31° 26'N, 94° 05'W	

Schmeltekopf, A. L., P. D. Goldan, W. R. Henderson, W. J. Harrop, T. L. Thompson, F. C. Fehsenfeld, H. I. Schiff, P. J. Crutzen, I. S. S. Isaksen, and E. E. Ferguson, "Measurement of Stratospheric $CFCl_3$, CF_2Cl_2 and N_2O," Geophys. Res. Lett., 2, 393-396, 1975.

Schmeltekopf, A. L., et al., Private Communication, 1976.

Tyson, B. T., R. B. Brewer, J. A. Arveson, and J. F. Vedder, "Concentrations of Freon 12 and Nitrous Oxide in the Stratosphere," Paper presented at the International Conference on the Stratosphere and Related Problems, Logan, Utah, September 15-17, 1976.

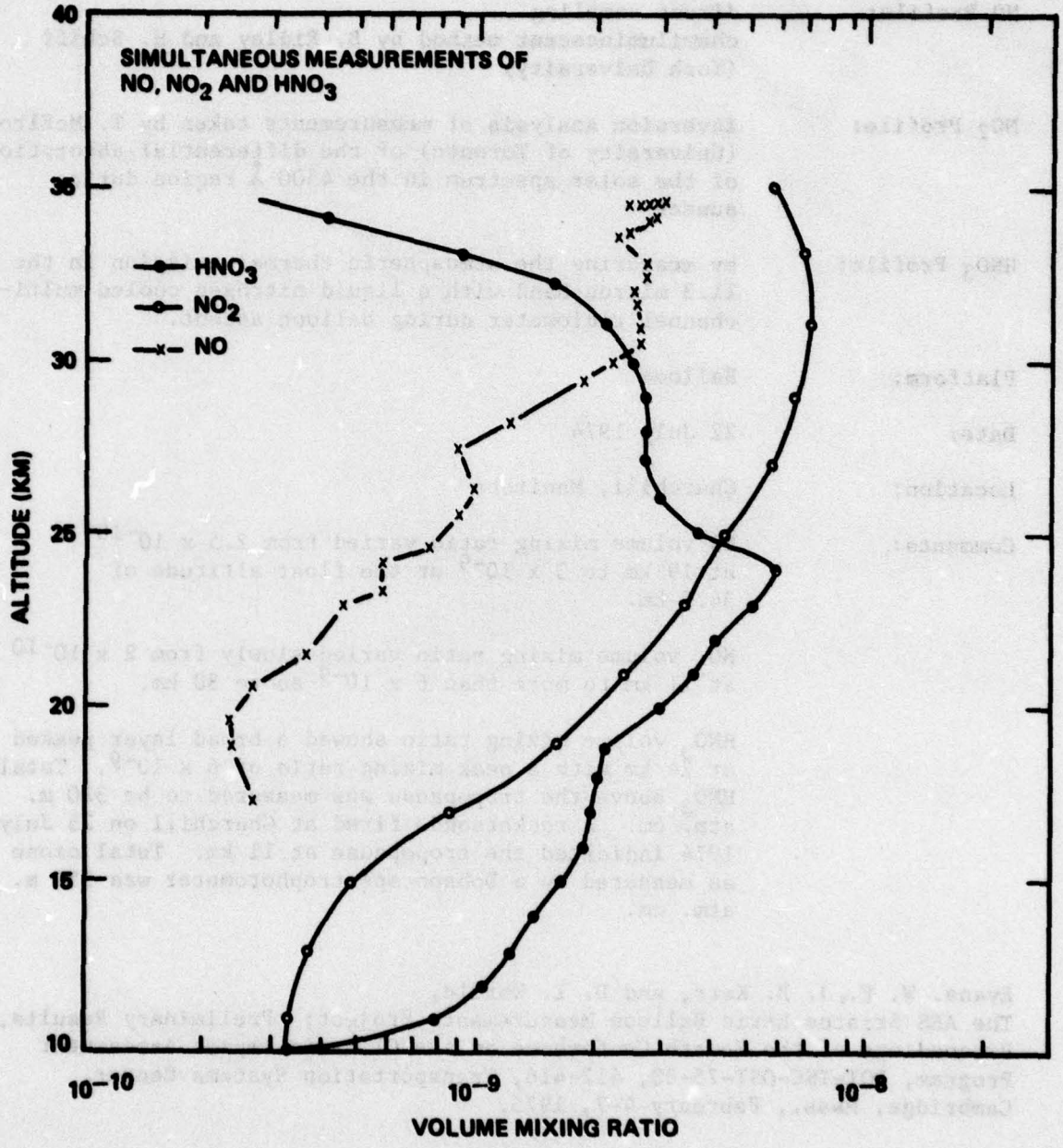

Figure 9: Simultaneous Measurements of NO, NO_2 and HNO_3 in the Stratosphere
(Source: Evans et al., 1975)

Simultaneous Observations of NO, NO_2 and HNO_3

Technique:

NO Profile:	direct sampling chemiluminescent method by B. Ridley and H. Schiff (York University)
NO_2 Profile:	inversion analysis of measurements taken by T. McElroy (University of Toronto) of the differential absorption of the solar spectrum in the 4500 Å region during sunset
HNO_3 Profile:	by measuring the atmospheric thermal emission in the 11.3 micron band with a liquid nitrogen cooled multi-channel radiometer during balloon ascent.
Platform:	Balloon
Date:	22 July 1974
Location:	Churchill, Manitoba
Comments:	NO volume mixing ratio varied from 2.5×10^{-10} at 19 km to 3×10^{-9} at the float altitude of 34.5 km. NO_2 volume mixing ratio varied slowly from 2×10^{-10} at 11 km to more than 6×10^{-9} above 30 km. HNO_3 volume mixing ratio showed a broad layer peaked at 24 km with a peak mixing ratio of 6×10^{-9}. Total HNO_3 above the tropopause was measured to be 320 m. atm. cm. A rocketsonde fired at Churchill on 23 July 1974 indicated the tropopause at 11 km. Total ozone as measured by a Dobson spectrophotometer was 350 m. atm. cm.

Evans, W. F., J. B. Kerr, and D. I. Wardle,
The AES Stratospheric Balloon Measurements Project: Preliminary Results, Proceedings of the Fourth Conference on the Climatic Impact Assessment Program, DOT-TSC-OST-75-38, 412-416, Transportation Systems Center, Cambridge, Mass., February 4-7, 1975.

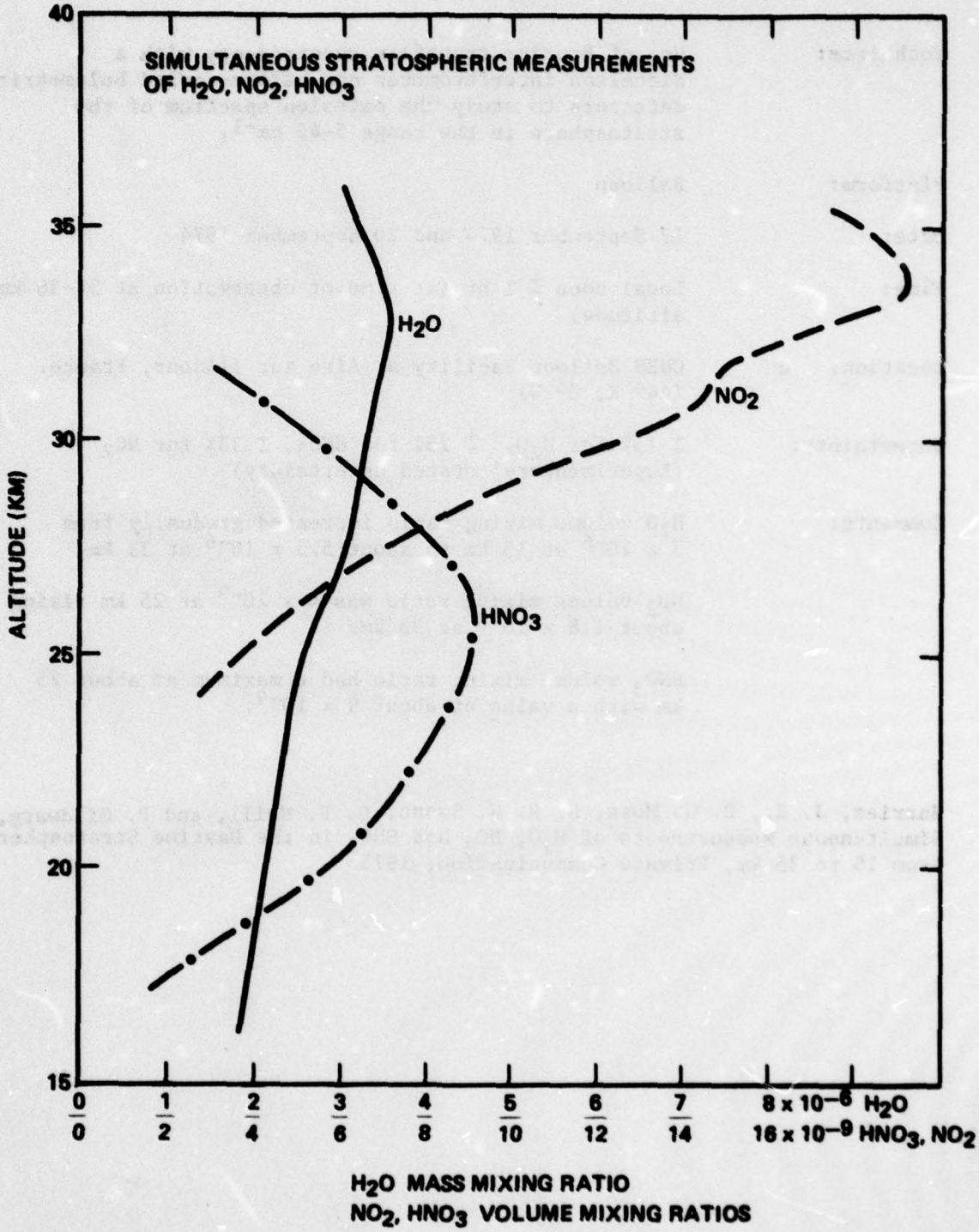

Figure 10: Simultaneous Measurements of NO_2, HNO_3 and H_2O in the Stratosphere
(Source: Harries et al., 1975)

Simultaneous Measurements of H_2O, NO_2 and HNO_3

Technique:	Use of Fourier transform spectroscopy with a Michelson interferometer and helium-cooled bolometric detectors to study the emission spectrum of the stratosphere in the range 5-45 cm^{-1}.
Platform:	Balloon
Date:	12 September 1974 and 20 September 1974
Time:	Local noon $\pm$ 1 hr (at time of observation at 34-36 km altitude)
Location: c	CNES Balloon Facility at Aire sur l'Adour, France. (44° N, 0° W)
Uncertainty:	$\pm$ 15% for H_2O, $\pm$ 25% for HNO_3, $\pm$ 35% for NO_2 (Experimenters' stated uncertainty)
Comments:	H_2O volume mixing ratio increased gradually from 3×10^{-6} at 15 km to about 5.5×10^{-6} at 33 km. NO_2 volume mixing ratio was 4×10^{-9} at 25 km rising to about 1.8×10^{-8} at 33 km. HNO_3 volume mixing ratio had a maximum at about 25 km with a value of about 9×10^{-9}.

Harries, J. E., D. G. Moss, N. R. W. Swann, G. F. Neill, and P. Gildwarg, Simultaneous Measurements of H_2O, NO_2 and HNO_3 in the Daytime Stratosphere from 15 to 35 km, Private Communication, 1975

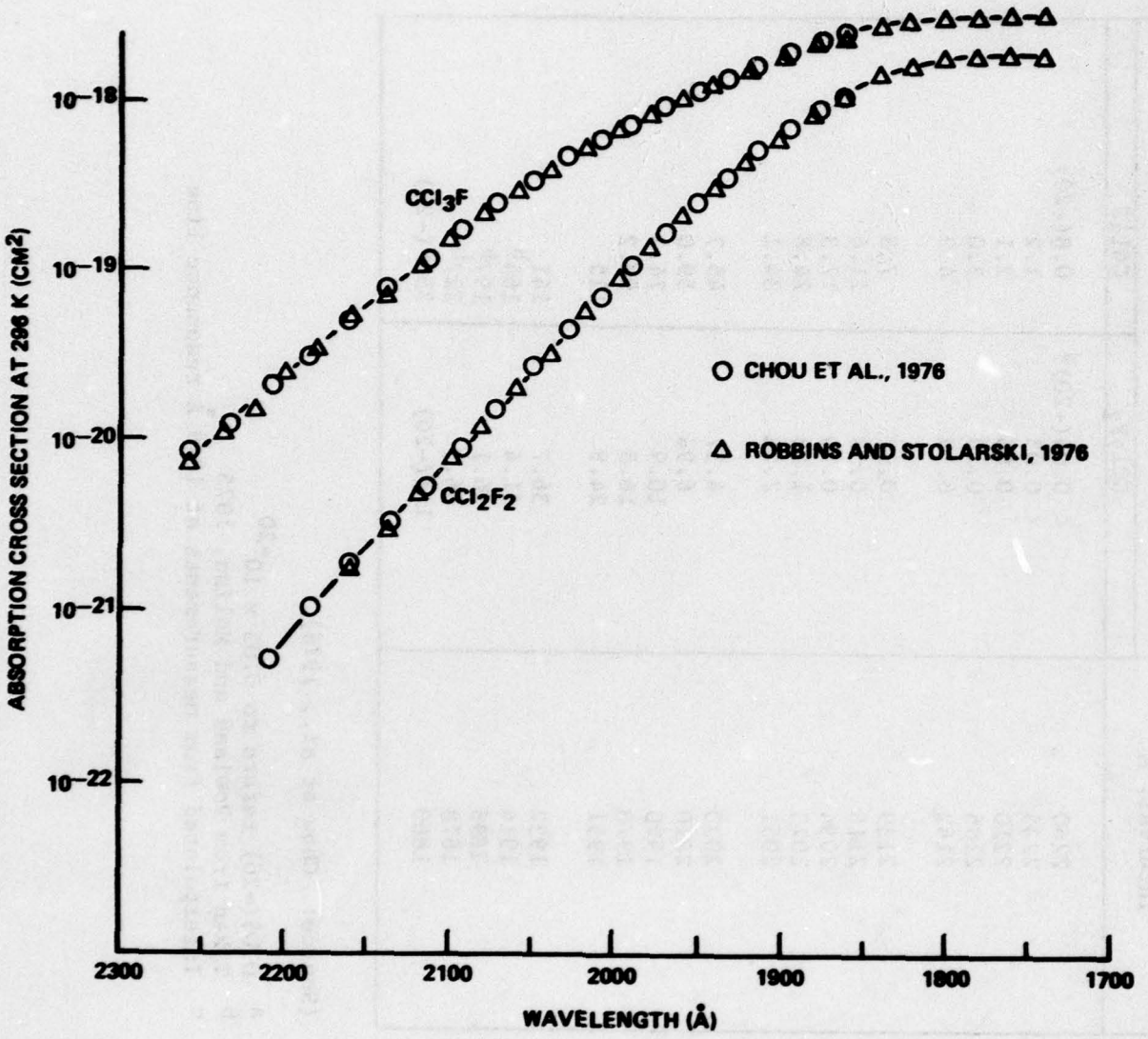

Figure 11: Absorption Cross Sections of CCl_3F and CCl_2F_2 at 296K
(Source: Chou et al., 1976)

TABLE 6: Absorption Cross Sections for CCl_2F_2 and CCl_3F in the Wavelength Range 1850-2272Å at 296K (Values obtained from the experimenters)

Midpoint of the Wavelength Interval, Å	Absorption Cross Section, cm^2	
	CCl_2F_2	CCl_3F
2260	< 0.05(-20)[a]	0.8(-20)
2235	< 0.05	1.2
2210	0.05	2.1
2186	0.10	3.0
2162	0.19	4.9
2139	0.32	7.8
2116	0.53	11.6
2094	0.90	17.3
2073	1.53	24.8
2051	2.66	34.1
2030	4.37	45.7
2010	6.96	59.0
1990	10.9	74.3
1970	16.8	93.2
1951	24.9	115
1932	36.7	141
1914	51.4	164[b]
1896	66.1	197[b]
1878	86.5	227[b]
1860	105(-20)	255[c](-20)

(Source: Chou et al., 1976)

[a] 0.05(-20) refers to 0.05×10^{-20}
[b] Taken from Rowland and Molina, 1975
[c] Interpolated from measurements at 1849 Å resonance line

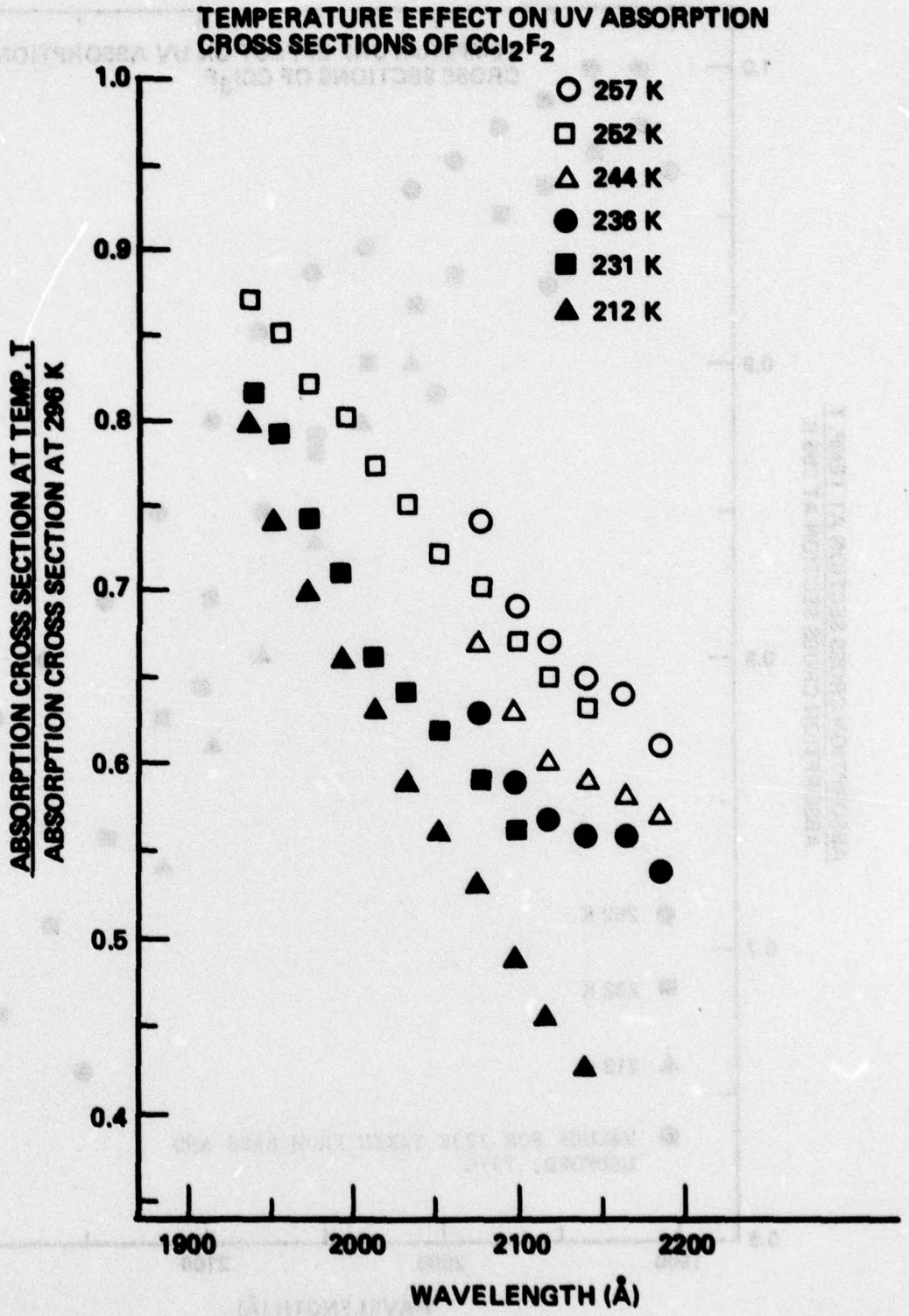

Figure 12: Ratio of the Absorption Cross Section of CCl_2F_2 at Temperature T to that at 296K. (T= 257, 252, 244, 236, 231, 212K)
(Source: Chou et al., 1976)

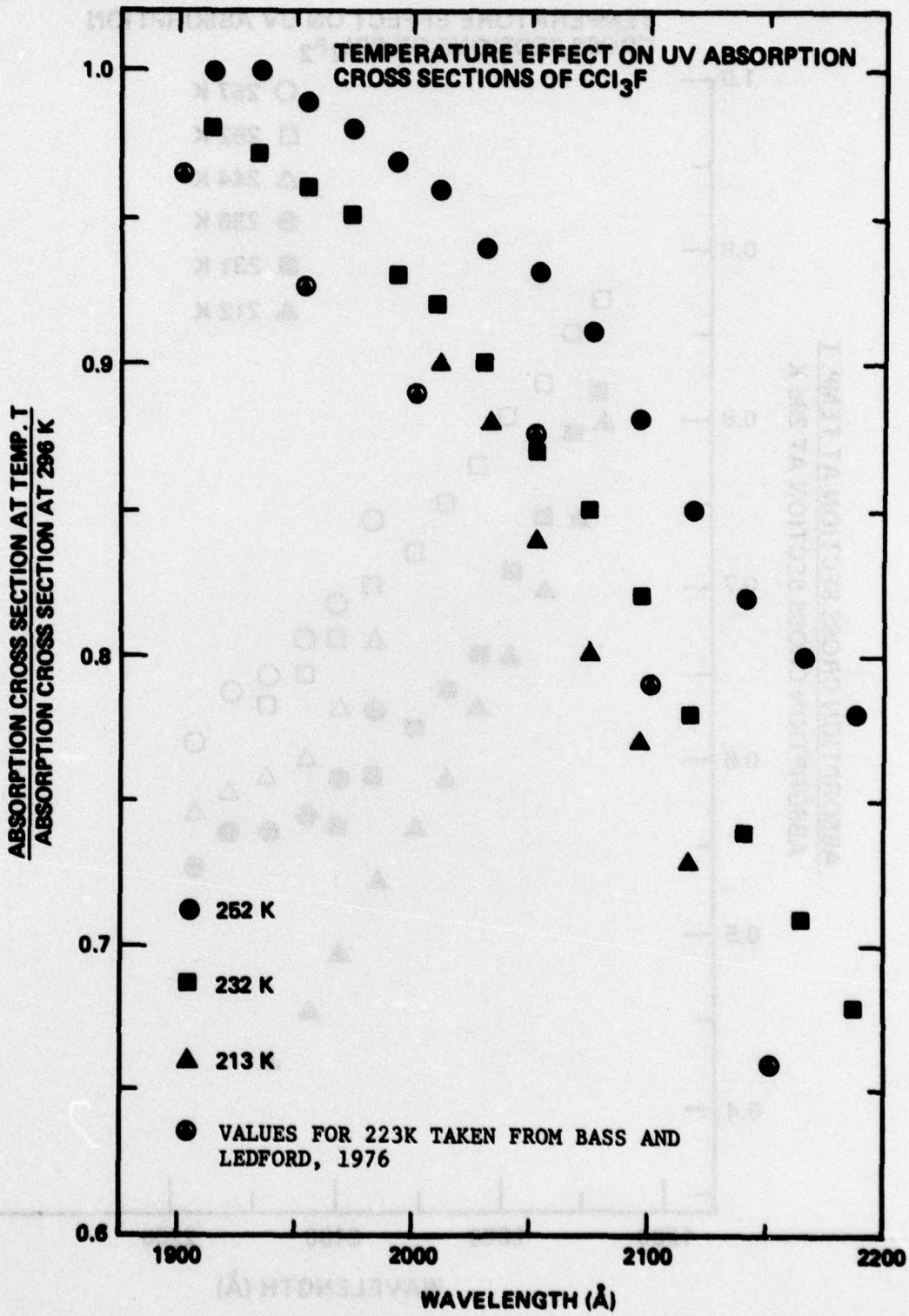

Figure 13: Ratio of the Absorption Cross Section of CCl_3F at Temperature T to that at 296K. (T=252, 232, 213K)
(Source: Chou et al., 1976)

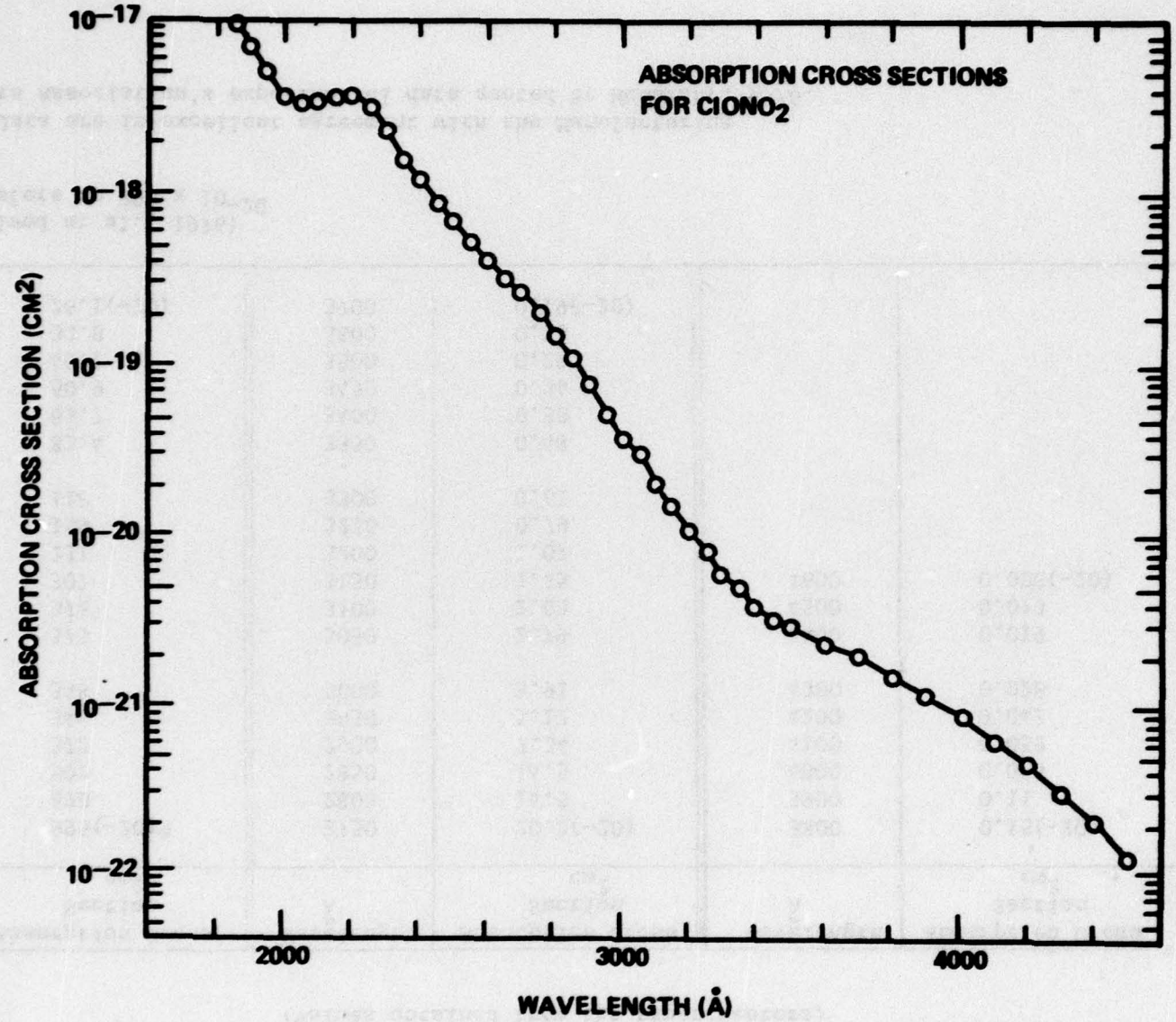

Figure 14: Absorption Cross Sections of $ClONO_2$
(Source: Rowland et al., 1976)

TABLE 7: Absorption Cross Sections for Chlorine Nitrate ($ClONO_2$)
(Values obtained from the experimenters)

Wavelength Å	Absorption Cross Section cm^2	Wavelength Å	Absorption Cross Section cm^2	Wavelength Å	Absorption Cross Section cm^2
1860	995(-20)[a]	2750	20.2(-20)	3800	0.15(-20)
1900	690	2800	14.5	3900	0.11
1950	502	2850	14.5	4000	0.085
2000	372	2900	7.34	4100	0.059
2050	344	2950	5.12	4200	0.042
2100	348	3000	3.91	4300	0.028
2150	375	3050	2.79	4400	0.019
2200	376	3100	2.03	4500	0.013
2250	307	3150	1.45	4600	0.008(-20)
2300	231	3200	1.07		
2350	159	3250	0.79		
2400	118	3300	0.61		
2450	85.4	3350	0.48		
2500	65.7	3400	0.38		
2550	50.9	3450	0.34		
2600	40.7	3500	0.29		
2650	32.8	3600	0.23		
2700	26.1(-20)	3700	0.19(-20)		

(Source: Rowland et al., 1976)
[a] 995(-20) refers to 995×10^{-20}

Note: These data are in excellent agreement with the Manufacturing Chemists Association's experimental data quoted by McCarthy, 1976.

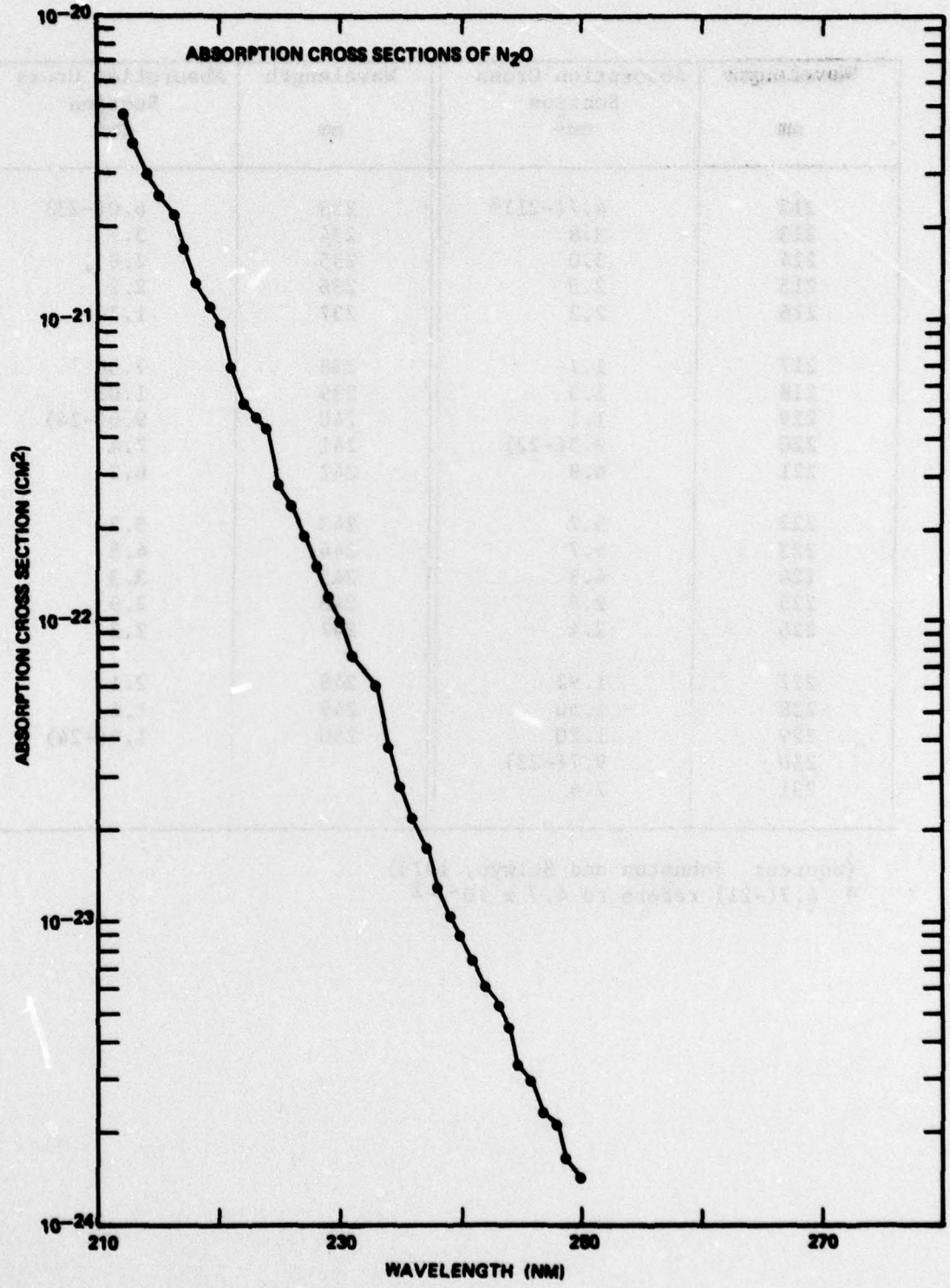

Figure 15: Absorption Cross Sections of N_2O
(Source: Johnston and Selwyn, 1975)

TABLE 8: Absorption Cross Sections of N_2O
(Values obtained from the experimenters)

Wavelength nm	Absorption Cross Section cm^2	Wavelength nm	Absorption Cross Section cm^2
212	4.7(-21)[a]	233	6.0(-23)
213	3.8	234	3.7
214	3.0	235	2.8
215	2.5	236	2.2
216	2.2	237	1.74
217	1.7	238	1.36
218	1.3	239	1.08
219	1.1	240	9.0(-24)
220	9.5(-22)	241	7.4
221	6.9	242	6.2
222	5.2	243	5.2
223	4.7	244	4.5
224	4.3	245	3.3
225	2.8	246	2.9
226	2.4	247	2.3
227	1.92	248	2.1
228	1.50	249	1.6
229	1.20	250	1.4(-24)
230	9.7(-23)		
231	7.4		

(Source: Johnston and Selwyn, 1975)
[a] 4.7(-21) refers to 4.7×10^{-21}

Bass, A. M., and A. E. Ledford, Jr.,
Ultraviolet Photoabsorption Cross Sections of CF_2Cl_2 and $CFCl_3$ as a Function of Temperature, Paper presented at the 12th Informal Conference on Photochemistry, National Bureau of Standards, Gaithersburg, MD, June 28-July 1, 1976, as quoted in Chou et. al., 1976.

Chou, C. C., W. S. Smith, H. Vera Ruiz, K. Moe, G. Crescentini, M. J. Molina and F. S. Rowland,
The Temperature Dependences of the Ultraviolet Absorption Cross Sections of CCl_2F_2 and CCl_3F, and Their Stratospheric Significance, Private Communication, 1976.

McCarthy, R., An Industry View of the Scientific Aspect of the Fluorocarbon/Ozone Issue, Paper presented at the International Conference of the Stratosphere and Related Problems, Logan, Utah, September 15-17, 1976.

Robbins, D., and R. Stolarski,as quoted by Chou et. al., 1976.

Rowland, F. S., and M. J. Molina,
Chlorofluoromethanes in the Environment, Rev. of Geophys. Sp. Phys., 13, 1-36, 1975.

Rowland, F. S., J. E. Spencer, and M. J. Molina,
Stratospheric Formation and Photolysis of Chlorine Nitrate, $ClONO_2$, Private Communication, 1976.

Johnston, H. S. and G. S. Selwyn,
New Cross Sections for the Absorption of Near Ultraviolet Radiation by Nitrous Oxide (N_2O), Geophys. Res. Lett., 2, 549-551, 1975.

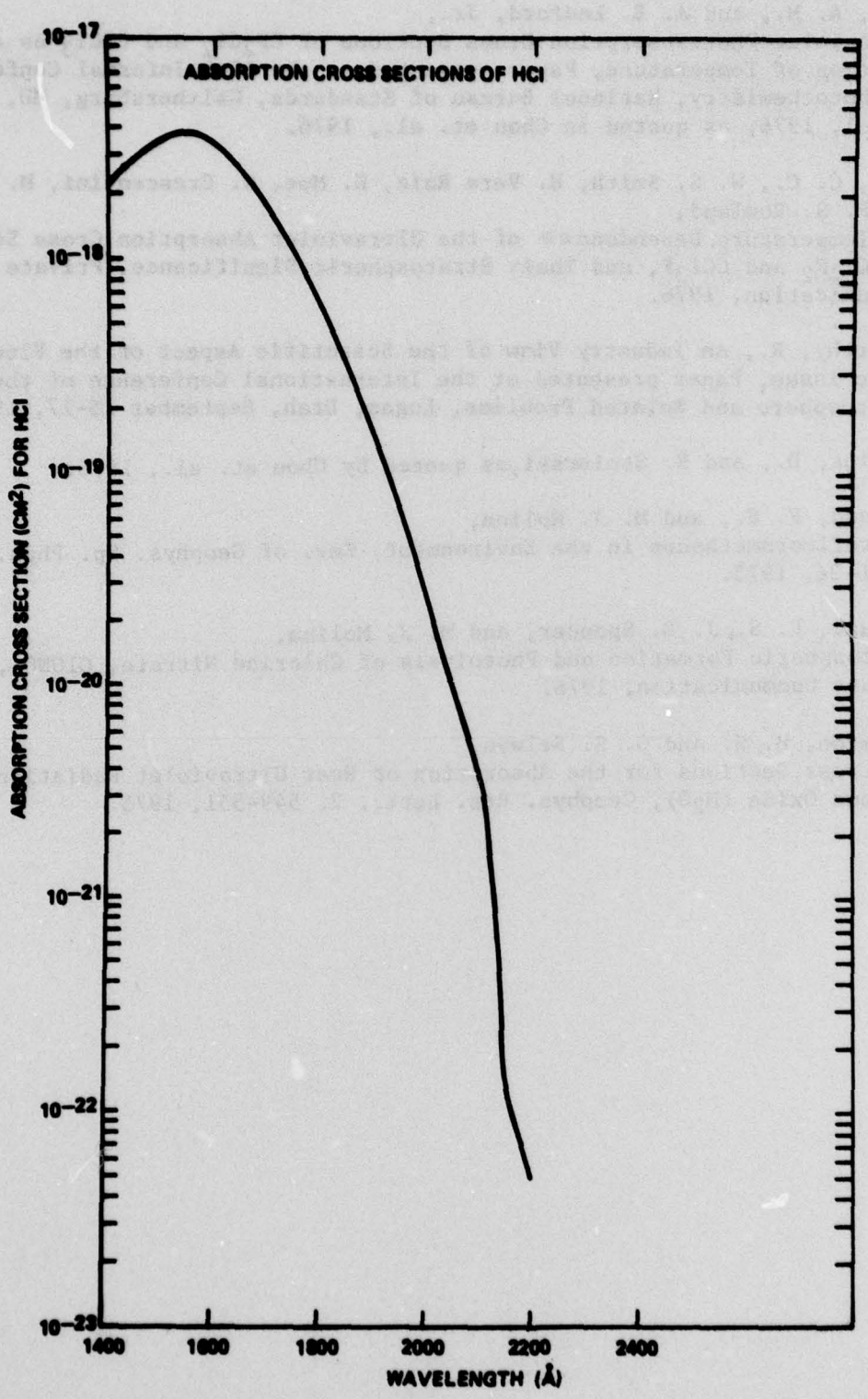

Figure 16: Absorption Cross Sections of HCl
(Source: Inn, 1975)

TABLE 9: ABSORPTION COEFFICIENTS OF HCl IN THE CONTINUUM 1400-2200 Å

(Source: Inn, 1975)

λ (Å)	α (cm^{-1} atm^{-1})	σ ($x10^{18} cm^2$)	λ (Å)	α (cm^{-1} atm^{-1})	σ ($x10^{18} cm^2$)
1400	56.8	2.11	1775	21.7	0.808
1425	67.4	2.51	1800	15.8	0.588
1450	75.6	2.81	1825	11.6	0.432
1475	87.0	3.24	1850	8.41	0.313
1500	92.7	3.45	1875	5.79	0.215
1525	100.0	3.72	1900	3.90	0.145
1550	102.5	3.82	1950	1.66	0.0618
1575	93.3	3.47	2000	0.688	0.0256
1600	89.1	3.32	2050	0.264	0.00983
1625	79.9	2.97	2100	0.106	0.00395
1650	66.7	2.48	2150	0.0369	0.000137
1675	54.9	2.04	2200	0.0129	0.0000480
1700	43.7	1.63			
1725	35.1	1.31			
1750	29.3	1.09			

α, the absorption coefficient, is defined by

$$I/I_o = \exp.\left[-(\alpha\, p T_o l)/(p_o T)\right]$$

where I and I_o are the transmitted and incident intensity, respectively, p the pressure, T the temperature in K, p_o = 1 atmosphere, T_o = 273.15K and l is the absorption path length.

σ, the absorption cross section, is defined by

$$\sigma = \alpha/N_o$$

where $N_o = 2.687 \times 10^{19}$ cm^{-3} is the Loschmidt's number.

λ is the wavelength.

Inn, E. C. Y., Absorption Coefficients for HCl in the Region 1400 to 2200 Å, J. Atm. Sci., 32, 2375-2377, 1975.

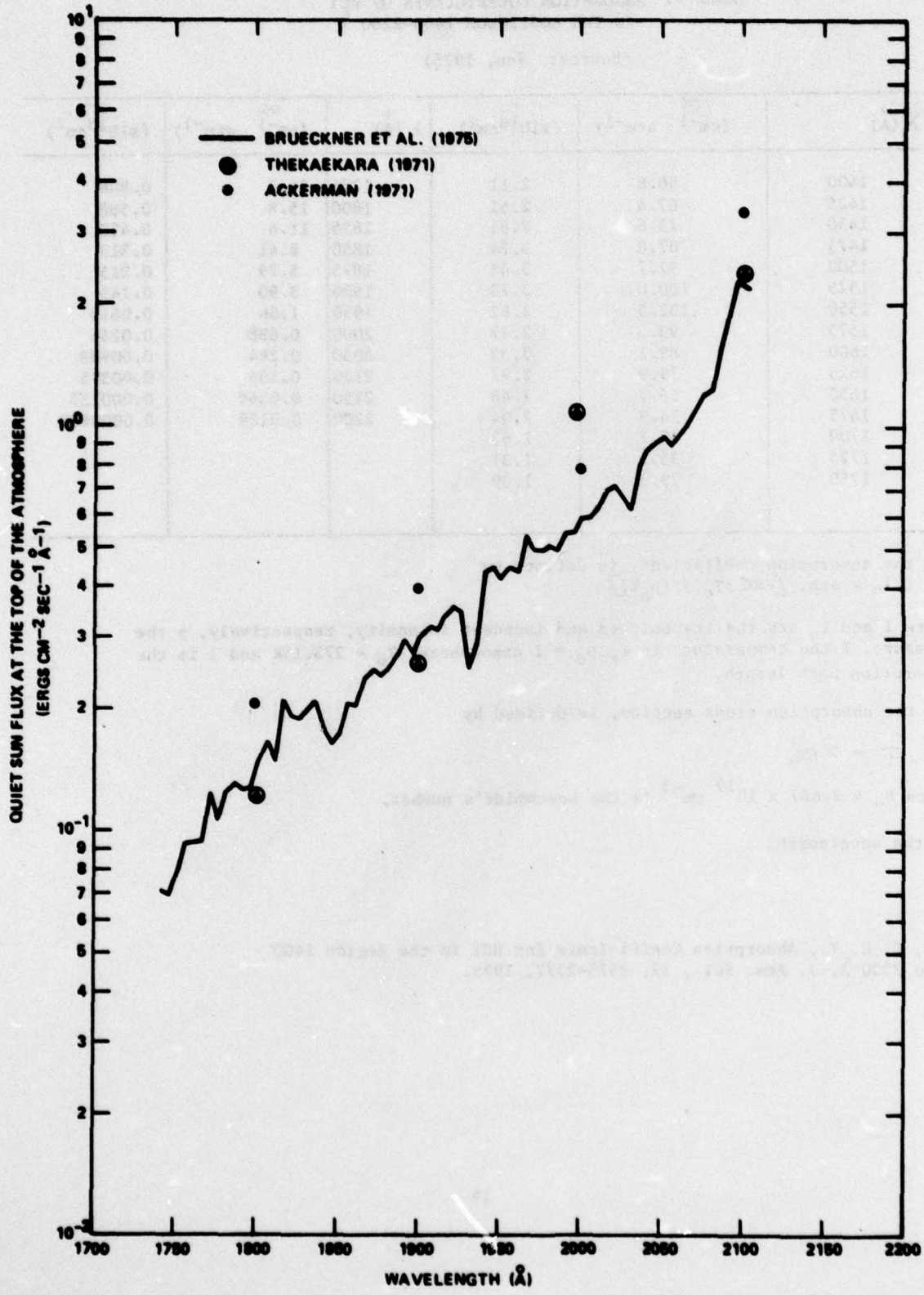

Figure 17: 5 Å - Average Solar Fluxes in the 1750-2100 Å Range

TABLE 10: 5 Å - AVERAGE SOLAR FLUXES FOR QUIET SUN CONDITIONS
(Values provided by Brueckner et al., 1975)

Mid-point of Wavelength interval, (Å)	FLUX (ergs $cm^{-2}s^{-1}Å^{-1}$)	Mid-point of Wavelength interval, (Å)	FLUX (ergs $cm^{-2}s^{-1}Å^{-1}$)
1742.5	7.05(-2)[a]	1927.5	3.49(-1)
47.5	6.89	32.5	2.50
		37.5	2.88
1752.5	8.01	42.5	4.34
57.5	9.18	47.5	4.52
62.5	9.28		
67.5	9.40	1952.5	4.18
72.5	1.23(-1)	57.5	4.46
		62.5	4.36
1777.5	1.06	67.5	5.33
82.5	1.25	72.5	4.93
87.5	1.31		
92.5	1.26	1977.5	4.90
97.5	1.27	82.5	5.06
		87.5	5.90
1802.5	1.46	92.5	5.44
07.5	1.66	97.5	5.47
12.5	1.47		
17.5	2.08	2002.5	5.89
22.5	1.88	07.5	5.94
		12.5	6.36
1827.5	1.83	17.5	6.96
32.5	1.96	22.5	7.13
37.5	2.03		
42.5	1.75	2027.5	6.69
47.5	1.62	32.5	6.23
		37.5	8.13
1852.5	1.74	42.5	8.77
57.5	2.03	47.5	9.16
62.5	2.02		
67.5	2.37	2052.5	9.40
72.5	2.51	57.5	8.96
		62.5	9.50
1877.5	2.40	67.5	1.01(0)
82.5	2.51	72.5	1.10
87.5	2.69		
92.5	2.93	2077.5	1.19
97.5	2.70	82.5	1.23
		87.5	1.55
1902.5	2.97	92.5	1.89
07.5	3.17	97.5	2.27
12.5	3.10		
17.5	3.39	2102.5	2.25(0)
22.5	3.59		

(Source: Brueckner et al., 1975)

[a] 7.05(-2) refers to 7.05×10^{-2}

5 Å - Average Solar Fluxes in the 1750-2100 Å Range

Date of Experiment:	September 4, 1973
Agency:	Naval Research Laboratory
Platform:	Rocket (Black Brant VC Rocket)
Instrument:	Double Dispersion Spectrograph
Calibration:	Preflight, ground calibration against a secondary standard deuterium lamp, (continuous emission for $\lambda > 1680$ Å) which was calibrated against NBS absolute standard, a high-power hydrogen arc.
Spectral Resolution:	0.07 Å
Accuracy:	R. M. S. total error ±20% (down from a factor of 2 or 3 over past measurements).
Method:	Intensity measurements over selected, inactive areas of the solar disk.
Comments:	A few representative values of the solar fluxes reported by Ackerman (1971) and Thekaekara (1971) have been included in the figure for comparison purposes.

Ackerman, M., Ultraviolet Solar Radiation Related to Mesospheric Processes, in Mesopheric Models and Related Experiments, G. Fiocco (Ed.), 149-159, D. Reidel, Dordrecht, Holland, 1971.

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