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Rocket Ozone Sounding Network Data

Quarterly Report

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PREFACE

The objectives of the rocket ozone program are to: (1) determine seasonal and annual variations of ozone, above balloon altitudes, for use in atmospheric modeling; (2) provide calibration/validation data for satellite experiments; and (3) measure ozone changes associated with specific energy or momentum inputs to the atmosphere in conjunction with other experimenters on an expeditionary basis.

The launch vehicle configuration for the rocket ozonesonde is described as an unstable Super Loki with 2-1/8 inch diameter Dart and 7-1/2 foot starute. The combination of standard components provide the rocket ozonesonde with a nominal apogee of 70 km and the ability to measure ozone profiles to as high as 67 km.

The Super Loki booster burns for 1.8 seconds; at which time it separates by drag from the Dart which continues in its ballistic trajectory to apogee. At the time of booster burn out, the Super Loki vehicle (both Dart and booster) typically reaches 1.52 km and has a velocity of 1628 m/sec. The booster becomes completely unstable at drag separation and has an impact dispersion which, in some situations, is inappropriately large. In those situations where less impact dispersion is dictated, such as the standard requirement of water impact at Wallops Flight Center, and better control of impact, such as the restricted impact zone at Antigua, West Indies, 3.4 kg additional weight is added at the booster head cap. The result is the stable Super Loki which meets the requirements but lessens the rocket ozone apogee to approximately 58 km. The compromised performance proportionately reduces the upper altitude limit of the rocket ozone profiles. Therefore, the unstable Super Loki is used wherever possible.

The ozone rocket activities described in this report are a part of a cooperative effort between the Goddard Space Flight Center and Wallops Flight Center in support of Environmental Quality and Weather and Climate Program Discipline Objectives (Office of Applications). The efforts to date will form a strong data and operational planning base for correlative support for remote sensors to be flown in the near future on Nimbus-G and the AEM/SAGE satellite platforms. It is anticipated that the program will continue into the 1980's in support of Shuttle launched atmospheric research and monitoring satellites and sensor systems, and in the pursuit of unique research objectives not possible to achieve from satellite systems alone.

Quarterly reports are published to provide flight operations and reduced data records for the scientific community. Formal scientific reports will be published at less frequent intervals.

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ROCKET OZONE SOUNDING NETWORK DATA QUARTERLY REPORT

D. U. Wright, A. J. Krueger, and G. M. Foster

INTRODUCTION

Rocket ozone flights are scheduled for local apparent noon plus or minus one hour on World Days (December 22, 1976, January 19 and February 16, 1977) according to the International Geophysical Calendar. Back-up flights are scheduled for the same time period the following day or priority days the following week. During the period December 1976 through February 1977, eight (8) rocket ozonesondes were expended: two (2) provided calibration/validation data for the Backscatter Ultraviolet (BUV) instruments on Atmospheric Explorer 5 and Nimbus 4 satellites, and six (6) were normal Network/World Day launches--five (5) from Wallops Flight Center and one (1) from the Churchill Research Range. Of the six Network/World Day launches, four (4) were successful. In addition, two (2) test flights were launched for the purpose of confirming starute decelerator survivability due to added weight. The additional weight is a result of replacing Ag cells with Ni Cd batteries as a power source. The test flight results are discussed in the appendix.

This quarterly report contains discussions and tabulation sheets and plots for each rocket ozone flight plus all associated support data presented in sequence according to flight number. A chronologically ordered Flight/Data Log Summary, which identifies the flights, as well as all associated support data that are discussed and/or used in reducing the flight data for this reporting period, is presented in Table I. The discussions include a flight synopsis and the results of the data reduction processes. The synopsis gives a brief picture of the flight and its quality, as well as the atmospheric and dynamics environment encountered by the payload. The discussion of results presents a tabulation of the Solar Flux Values/Filter Characteristics where:

S_i is the filter I.D. $(i = 0, 1, 2, 3)$
λ is center of wavelength for the corresponding filter.
$\Delta\lambda$ is the full width at half the peak transmission (FWHM).
TM (volts) is the average signal level determined shortly after the starute stabilized.

A simplified version of the equation which forms the basis for the data reduction is

$$I(\lambda,h) = I(\lambda,\infty)\ \exp^{-[\alpha(\lambda)u(h) + \beta(\lambda)m(h)]} \qquad (1)$$

TABLE I.-FLIGHT/DATA LOG SUMMARY

Flight No.	T-0 (Z)	Date	Range Flight No.	Remarks
ANTIGUA	17.12°N	61.78°W		
	1035	12/ 4/76		RS
141	1253	12/ 4/76	TA1-8410	ATMOS EXP-5
	1405	12/ 4/76	2028	DS[1]
142	1410	12/ 6/76	TA1-8411	NIMBUS-4/MODIFIED INSTRUMENT
	1800	12/ 6/76	3955	DS
WFC	37.85°N	75.48°W		
	1918	12/13/76	T1-8412	STARUTE TEST
	2017	12/13/76	T1-8413	STARUTE TEST
	1515	12/22/76	T1-8599	DS
	1528/1727/1927	12/22/76		DOBSON
143	1604	12/22/76	T1-8408	WORLD DAY
	2038	12/22/76		RS/ECC[2]
	1357	1/19/77		RS/ECC
	1512/1722/1902	1/19/77		DOBSON
	1536	1/19/77	T1-8668	DS
144	1730	1/19/77	T1-8414	WORLD DAY
	1400	2/16/77		RS/ECC
	1514/1711/1937	2/16/77		DOBSON
	1546	2/16/77	T1-8691	DS
145	1732	2/16/77	T1-8415	WORLD DAY/TM FAILURE
147	1813	2/16/77	T1-8418	WORLD DAY/SYSTEM ANOMALY - NO DATA
	1350	2/23/77		RS/ECC
	1451/1639/1925	2/23/77		DOBSON
	1600	2/23/77	T1-8648	DS
148	1700	2/23/77	T1-8417	WORLD DAY + 7 DAYS
CRR	58.75°N	94.07°W		
146	1807	2/16/77	TH1-8708	WORLD DAY
	----	2/16/77		DS/SYSTEM ANOMALY - NO DATA
	1700	2/16/77		RS/MAST[3]
	----	2/16/77		DOBSON

[1]DS indicates a Super Loki Datasonde was used to collect the standard thermodynamic data.

[2]RS/ECC indicates a radiosonde balloon plus electrochemical concentration cell was used to collect lower altitude ozone profile data and "tie-in" pressure reference.

[3]RS/MAST is an instrument used by Canada for the same purposes as the RS/ECC.

where $I(\lambda,h)$ is the solar intensity at wavelength λ and height h

$I(\lambda,\infty)$ is the extraterrestrial solar intensity at wavelength λ

$(\alpha)_\lambda$ is the effective ozone absorption coefficient at wavelength λ

$u(h)$ is the slant path ozone from h to the top of the atmosphere

$\beta(\lambda)$ is the effective Rayleigh scattering coefficient at wavelength λ

$m(h)$ is the slant path air mass from h to the top of the atmosphere

The reference values of $I(\lambda,\infty)$ are derived from the work of Furukawa et al[1]; $\alpha(\lambda)$ is based on the values published by Vigroux[2], and Inn and Tanaka[3].

The Naval Weapons Center, China Lake, California, measures the transmission of each filter, as well as the other components of the system, computes the effective absorption coefficients, and reports the final result in the form of:

$$\alpha(u,m) = A_0 + A_1 u + A_2 u^2 + [B_1 m + B_2 m^2]$$

Which, because the bracketed term is trivial, reduces to:

$$\alpha(u) = A_0 + A_1 u + A_2 u^2 \qquad (2)$$

and, in a similar manner,:

$$\beta(u,m) = C_0 + [C_1 u + C_2 u^2 + D_1 m + D_2 m^2]$$

Since the bracketed term is essentially zero, it reduces to:

$$\beta(u,m) = C_0 \qquad (3)$$

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[1] P. M. Furukawa, P. L. Haagenson and M. J. Scharberg. Composite, High Resolution Solar Spectrum from 2080 to 3600 Å, NCAR Technical Note No. 26, February 1967.

[2] E. Vigroux. "Contribution a l'etude experimentale de l'absorption de l'ozone," Ann. Phys. 8 (1953) 709.

[3] E. C. Inn and Y. Tanaka. "Ozone Absorption Coefficients in the Visible and Ultraviolet Regions", in Ozone Chemistry and Technology, Advances in Chemistry Series No. 21 (1969) 263, American Chemistry Society.

The details of the processes involved in determining $\alpha(u)$ and $\beta(u)$ are to be found in the report by Hills and Flanagan[4]. The appropriate references for the theoretical basis of the rocket ozone technique are the work of Krueger et al[5,6,7]. The tabulation values of the filter characteristics listed in the discussion of results are the coefficients indicated in equations (2) and (3).

FOURTH QUARTER OPERATIONS

Flight No. 141 (Antigua/Atmosphere Explorer 5)

Synopsis.-Rocket ozone flight No. 141, launched at 1253Z on December 4, 1976, reached an apogee of 51.3 km at T+110 seconds. The sonde stabilized by T+132 seconds, approximately 26 seconds after ejection, and radar acquisition was at T+200 seconds. Flight data were recorded for 27 minutes.

The short term (seconds) noise in the UV signals (S_0, S_1, S_2, and S_3) at T+145 seconds was approximately 300 millivolts. The longer term (minutes) noise in the data, at approximately the same time, was slightly greater than 400 millivolts. The highest frequency component observable on the compensation signal (Channel 3) had a period of one-half seconds and is due to light reflected off the front surface of the filters. Longer period noise from modulation due to pendulation corresponded to a full angle of six degrees early in the flight. Toward the end of the flight, at approximately 15 km (T+47 minutes), the pendulation varied from full angles of 4 to 11 degrees. The extraterrestrial signal levels for the UV channels are shown in Table II. The S_0 signal exceeded the system dynamic range.

Flight Results.-The Solar Flux Values and Filter Characteristics are presented in Table II. The data were reduced on the HP 9810 and corrections for zero offset were applied to S_1, S_2, and S_3. The offset was 0.01 volts for S_1 and 0.02 volts for S_2 and S_3, however, no correction for diffuse light has been made. In the overlap region for S_2 and S_3 data, there was no statistically significant difference in the ozone densities;

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[4]M. E. Hills and C. A. Flanagan. Calculation of Effective Ozone Absorption Coefficients for a Rocketsonde Ozonesonde, NWC TP 5904, March 1977.

[5]A. J. Krueger and W. R. McBride. Rocket Ozonesonde (ROCOZ) Design and Development, NWC TP 4512 (1968).

[6]A. J. Krueger. Rocket Measurements of Ozone and Relative Solar Irradiance Profiles. Interagency Agreement DOT-AS-20056 (Final Report) May 1975.

[7]A. J. Krueger and R. A. Minzner. A Mid Latitude Model for the 1976 U.S. Standard Atmosphere, J. G. R. 81 (1976) 4477.

however, S_2 densities were 16 percent less than those of S_1 in their overlap region and is somewhat greater than observed in other flights.

TABLE II.-SOLAR FLUX VALUES/FILTER CHARACTERISTICS FOR FLIGHT NO. 141

TM CHANNEL (#/S/λ/$\Delta\lambda$)	TM (VOLTS)	I(∞)	OZONE PROFILE INTERVAL (km)
#1/S_0/3198.4/38.5	--	--	REFERENCE
#2/S_1/2992.7/33.5	9.10	58	20-42
#4/S_2/2877.3/33.4	7.35	36	36-48
#5/S_3/2656.9/105.2	7.90	23	43-50

POLYNOMIAL COEFFICIENTS FOR α AND β

S	A_0	A_1	A_2	C_0
S_0	0.633	-0.014	0.000	0.927
S_1	10.451	-1.874	0.503	1.156
S_2	49.67	-36.76	-23.3	1.5
S_3	233.4	-397.	-66300.	2.3

NOTE: λ and $\Delta\lambda$ are expressed in Å, I(∞) is expressed in $\mu W/cm^2/nm$.

The composite results are given in Table III. The analysis was carried out between 21 to 49 km. RS/ECC or Dobson data were not available for comparison with these results. The total ozone amount above 20.5 km was 0.192 atm-cm. This value has a large uncertainty due to the very low signal level below 24 km from the 2993 Å filter used in the payload. The ratio of this profile to the middle latitude model indicates an excess between 26 and 39 km, with a peak excess of 44 percent at 30 km. The ozone mixing ratio and partial pressure were computed using atmospheric temperatures and densities from a Datasonde launched at 1405Z.

TABLE III.-COMPOSITE RESULTS

Flight No 141 Location Antigua Rocket Total Ozone Above ______ km

Equals ______

Date 12/4/76 Experimenter A. Krueger Balloon Residual Ozone Below ______ km

Equals ______

GMT Time 1253Z Ser.No. Sensor/PCM/Starute 206/760629/512955 Total Ozone = ______

Sec Z = 1.8617

= 1.9188 Scale Height = 4.8 Dobson Total Ozone = ______

= 1.9493

Ht. km	Δx/Δh atm-cm/km	Probable Error, %	x(h) atm-cm	E(h) mol/cm³	Mixing Ratio ugm/gm	O_3 Partial Pressure umb	Air Temp. °C	Air Pressure mb	Ratio E(h) to Model
70									
69									
68									
67									
66									
65									
64									
63									
62									
61									
60									
59									
58									
57									
56									
55									
54									
53									
52									
51									
50			.00139						
49	.00029	09	.00168	7.80×10^{10}	5.4	2.78	-17.2	.849	
48	.00037	08	.00205	9.95	6.0	3.53	-18.3	.968	.97
47	.00045	07	.00250	1.21×10^{11}	6.4	4.29	-18.1	1.10	
46	.00055	07	.00305	1.48	6.8	5.25	-18.0	1.26	.88
45	.00068	06	.00373	1.83	7.5	6.55	-15.6	1.44	
44	.00084	07	.00457	2.26	8.1	8.08	-16.1	1.64	.82
43	.00114	09	.00571	3.06	9.5	10.8	-19.7	1.87	
42	.00142	08	.00713	3.82	10.3	13.3	-22.3	2.13	.96
41	.00176	08	.00889	4.73	11.2	16.6	-21.4	2.44	
40	.00211	06	.0110	5.67	11.4	19.3	-28.1	2.79	.93
39	.00269	06	.0137	7.23	12.2	23.9	-36.1	3.21	
38	.00347	05	.0172	9.33	13.7	30.9	-34.8	3.70	1.07
37	.00418	06	.0213	1.12×10^{12}	14.3	37.1	-36.1	4.26	
36	.00520	07	.0265	1.40	15.5	46.3	-35.0	4.91	1.15
35	.00581	07	.0324	1.56	15.1	52.0	-33.8	5.66	
34	.00685	06	.0392	1.84	15.6	61.7	-32.6	6.51	1.16
33	.00798	06	.0472	2.15	15.6	71.2	-34.6	7.49	
32	.00933	05	.0565	2.51	15.6	81.8	-38.7	8.64	1.24
31	.0113	05	.0678	3.04	16.0	97.2	-43.2	9.99	
30	.0135	05	.0813	3.63	16.3	115.	-46.1	11.6	1.44
29	.0153	06	.0967	4.11	15.2	124.	-55.9	13.5	
28	.0163	07	.113	4.38	14.3	136.	-49.4	15.7	1.35
27	.0167	09	.130	4.49	12.4	138.	-52.3	18.3	
26	.0151	12	.145	4.06	9.4	123.	-56.1	21.3	1.01
25	.0128	19	.158	3.44	6.8	103.	-57.9	25.0	
24	.0122	19	.170	3.28	5.5	97.9	-58.6	29.2	.72
23	.0106	27	.180	2.85	4.1	84.5	-60.2	34.2	
22	.00757	36	.188	2.03	2.5	60.8	-58.4	40.1	.42
21	.00380	71	.192	1.02	1.0	29.4	-66.6	47.1	
20									
19									
18									
17									
16									
15									

Used datasonde for Antigua AFS, West Indies on 12/ 76 at 1405Z.

Air Temp., Pressure Density, Data Source: ______

The ozone density profile is illustrated in Figure 1. The mean scale height* above

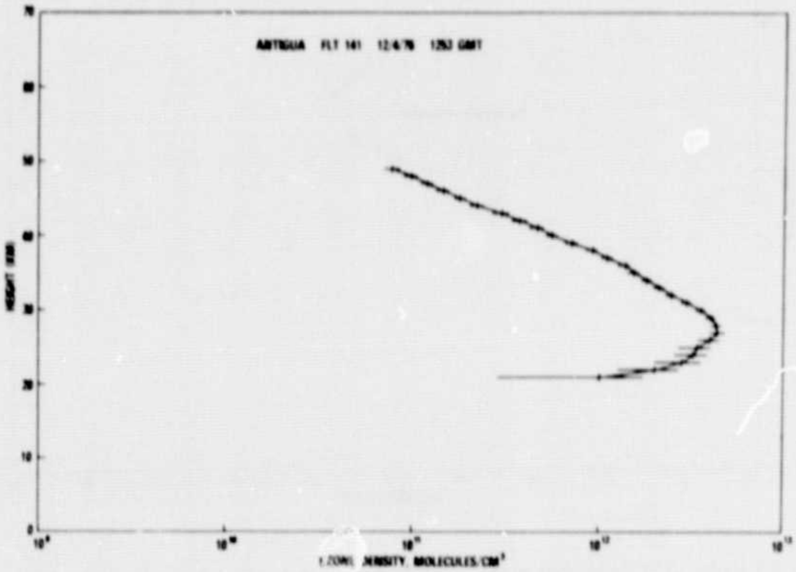

Figure 1.-Ozone density profile.

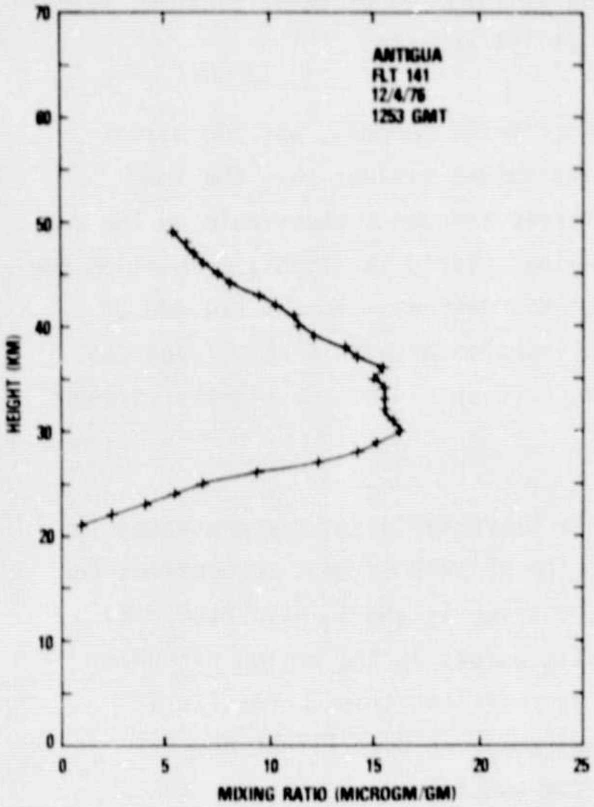

Figure 2.-Mixing ratio profile.

45 km was 4.8 km; the maximum density was 4.49×10^{12} cm^{-3} at 27 km. The mixing ratio profile (Figure 2) has a relatively broad peak, with little apparent structure, of 15.5 µgm/gm extending from about 29 to 36 km. The highest value is 16.3 at 30 km. The mixing ratio exceeds 10 µgm/gm between 26 and 42.5 km. The temperature profile from the support Datasonde is shown in Figure 3.

*The mean scale height is the altitude interval over which the signal is reduced by 1/e.

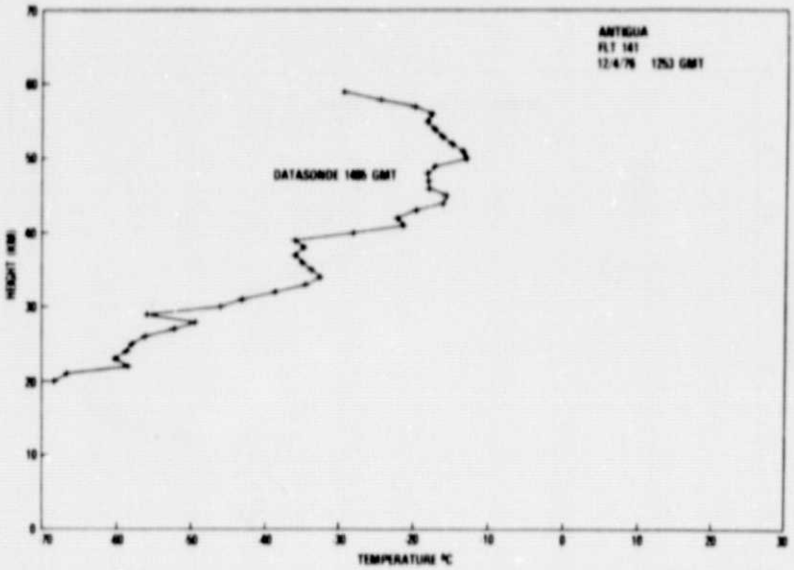

Figure 3.-Temperature profile from support Datasonde.

Flight No. 142 (Antiqua/Nimbus 4)

Synopsis.-Rocket ozone flight No. 142, launched at 1410Z on December 6, 1976, reached an apogee of 55.3 km at 108 seconds. Ejection was at 104 seconds.

The short term (seconds) noise in S_2 and S_3, at about T+180 seconds, was 200 millivolts. S_0 was utilized in noise measurements for instrument evaluation. The long term (minutes) UV noise was 300 millivolts. The highest frequency observable on the compensation signal was the typical one-half second period. Early in flight, modulation due to pendulation corresponded to a full angle of about six degrees. Toward the end of recorded flight, the pendulation corresponded to full angles between 6 and 17 degrees. The payload temperature ranged from 28°C at 47 km to 12°C at 21 km. S_1 signals exceeded the instrument dynamic range until T+5 minutes.

Flight Results.-The Solar Flux Values and Filter Characteristics are presented in Table IV. The flight data have been processed with the HP 9810 without corrections for diffuse light. Zero offsets of .025 V for S_1 and .05 V for S_2 and S_3 have been subtracted. No significant disagreement in ozone density exists in the region of redundant data from S_2 and S_3, but S_2 results are nine percent less than S_1 results at their overlap altitude interval which is small (2 km) compared with Flight No. 141 because of increased wavelength difference between the two filters for these channels.

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TABLE IV.-SOLAR FLUX VALUES/FILTER CHARACTERISTICS FOR FLIGHT NO. 142

TM CHANNEL (#/S/λ/$\Delta\lambda$)	TM (VOLTS)	I(∞)	OZONE PROFILE INTERVAL (km)
#1/S_0/3203.0/ 33.4	N.A.	--	
#2/S_1/3042.5/ 34.8	--	--	20-40
#4/S_2/2828.9/ 39.0	6.3	28	37-48
#5/S_3/2641.3/ 77.9	6.7	13	42-48

POLYNOMIAL COEFFICIENTS FOR α AND β

S	A_o	A_1	A_2	C_o
S_0	0.598	-0.011	0.000	0.927
S_1	5.276	-0.411	0.064	1.156
S_2	80.93	-47.94	45.	1.5
S_3	247.8	-755.	-161300.	2.3

NOTE: λ and $\Delta\lambda$ are expressed in Å I(∞) is expressed in μW/cm /nm.

The merged results are listed in Table V. No balloon ozonesonde or Dobson total ozone data are available for comparison. The integral ozone above 20.5 km is 0.221 atm-cm. This value is determined with less uncertainty than that from Flight No. 141 due to the use of a filter optimized for ozone measurement at lower altitudes in Channel 2.

Relative to the Mid-Latitude Ozone Model, this profile has an excess between 24 and 37 km with a maximum excess of 41 percent at 30 km. This is similar to the profile from Flight No. 141, taken two days earlier from Antigua. The ozone mixing ratios and partial pressures are derived from air density data obtained on December 4, 1976. The indicated temperatures, however, were measured on December 6, 1976, at 1800 GMT.

TABLE V.-COMPOSITE RESULTS

Flight No. 1?2 Location Antigua Rocket Total Ozone Above ____ km

Equals ____

Date 12/6/76 Experimenter A. Krueger Balloon Residual Ozone Below ____ km

Equals ____

GMT Time 1410Z Ser.No. Sensor/PCM/Starute 211/760833/512948 Total Ozone = ____

Sec Z = 1.4350

= 1.4655 Scale Height = 5.0 Dobson Total Ozone = ____

= 1.4655

Ht. km	Δx/Δh atm-cm/km	Probable Error, %	x(h) atm-cm	E(h) mol/cm³	Mixing Ratio ugm/gm	O_3 Partial Pressure umb	Air Temp. °C	Air Pressure mb	Ratio E(h) to Model
70									
69									
68									
67									
66									
65									
64									
63									
62									
61									
60									
59									
58									
57									
56									
55									
54									
53									
52									
51									
50									
49									
48			.00250						
47	.00050	09	.00300	1.34×10^{11}	7.1	4.76	-18.5	1.10	
46	.00061	09	.00361	1.64	7.6	5.89	-15.0	1.26	.97
45	.00076	07	.00437	2.04	8.4	7.39	-13.4	1.44	
44	.00096	07	.00533	2.58	9.3	9.20	-17.1	1.64	.94
43	.00110	07	.00643	2.96	9.2	10.4	-20.5	1.87	
42	.00142	09	.00785	3.82	10.3	13.4	-21.0	2.13	.96
41	.00181	07	.00966	4.87	11.5	17.0	-21.6	2.44	
40	.00207	08	.0117	5.56	11.2	19.2	-24.7	2.79	.92
39	.00248	08	.0142	6.67	11.3	22.9	-26.1	3.21	
38	.00293	08	.0171	7.88	11.6	26.7	-29.6	3.70	.90
37	.00397	26	.0211	1.07×10^{12}	13.6	35.5	-33.9	4.26	
36	.00496	20	.0261	1.33	14.8	44.3	-34.4	4.91	1.09
35	.00624	18	.0323	1.68	16.2	56.3	-32.0	5.66	
34	.00781	12	.0401	2.10	17.7	69.7	-34.7	6.51	1.33
33	.00916	12	.0439	2.46	17.9	80.2	-39.3	7.49	
32	.0105	09	.0598	2.82	17.5	90.3	-43.2	8.64	1.39
31	.0120	08	.0718	3.23	17.0	103.	-44.2	9.99	
30	.0132	07	.0850	3.55	15.9	111.	-47.5	11.6	1.41
29	.0146	06	.0996	3.92	14.5	123.	-47.2	13.5	
28	.0158	06	.115	4.25	13.8	130.	-52.5	15.7	1.31
27	.0171	06	.132	4.60	12.7	141.	-52.8	18.3	
26	.0184	06	.151	4.95	11.5	152.	-52.9	21.3	1.23
25	.0187	07	.170	5.03	9.9	151.	-56.7	25.0	
24	.0167	09	.186	4.49	7.5	138.	-52.0	29.2	.99
23	.0141	11	.200	3.79	5.4	112.	-61.0	34.2	
22	.0116	15	.212	3.12	3.8	91.	-62.5	40.1	.64
21	.00859	20	.221	2.31	2.3	65.9	-68.1	47.1	
20									
19									
18									
17									
16									
15									

Air Temp., Pressure Density, Data Source: For temp. used datasonde on 12/6/76 at 1800Z for Antigua, AFS, West Indies. For air pressure and density used datasonde on 12/4/76 at 1405Z for Antigua, AFS, West Indies.

NASA WI-1393 (3-77)

The ozone density profile is illustrated in Figure 4. The maximum density of 5.03×10^{12}

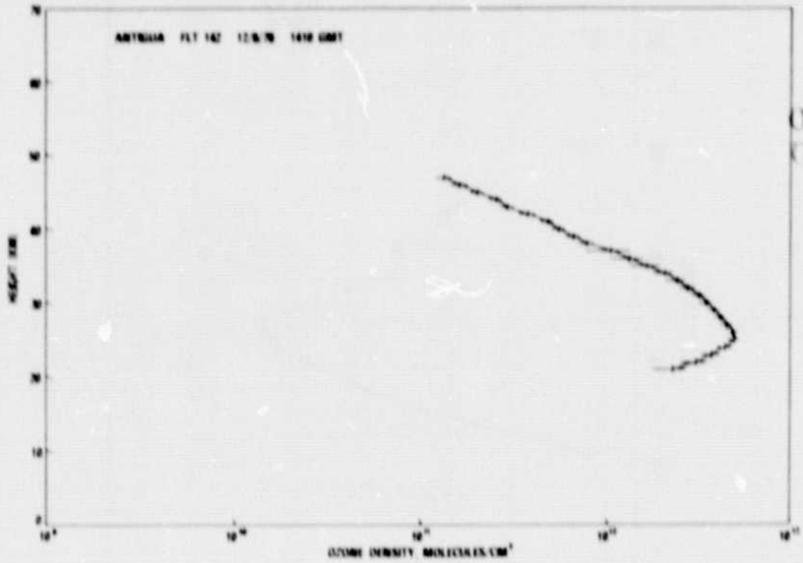


Figure 4.-Ozone density profile.

molecules/cm^3 was found at 25 km. The difference between the altitudes of the ozone maxima observed in Flights No. 141 and 142 is most likely due to the larger errors in Flight No. 141 data at these altitudes, as discussed above. At 27 km the two profiles agree within three percent. At the highest altitudes of flight No. 142 (above 42 km) the mean scale height is 5.0 km vs. 4.8 km for Flight No. 141.

The mixing ratio profile is shown in Figure 5. A rather peaked distribution is found with a maximum of 17.9 μgm/gm at 33 km. The mixing ratios exceed 10 μgm/gm between 25 and 42.5 km. Minor structure is present above the maximum; however, somewhat higher noise levels were present in the data above 33 km. The conjunctive Datasonde temperature profile is shown in Figure 6.

Flight No. 143 (Wallops Flight Center/World Day)

Synopsis.-Rocket ozone flight No. 143, launched at 1604Z on December 22, 1976, reached apogee at T+120 seconds. The decelerator stabilized at T+160 seconds, approximately 36 seconds after ejection. Telemetry and radar data were obtained after T+210 seconds and recorded until T+20 minutes. The battery voltage was abnormal; early in flight it was 5.2 volts but gradually increased to about 5.5 volts at T+12 minutes. It remained at this level until a minute before loss of signal.

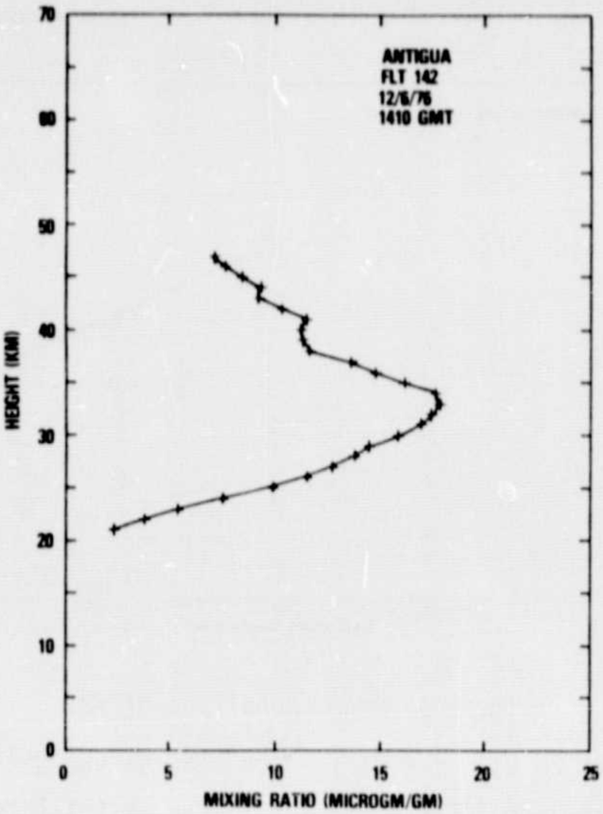


Figure 5.-Mixing ratio profile.

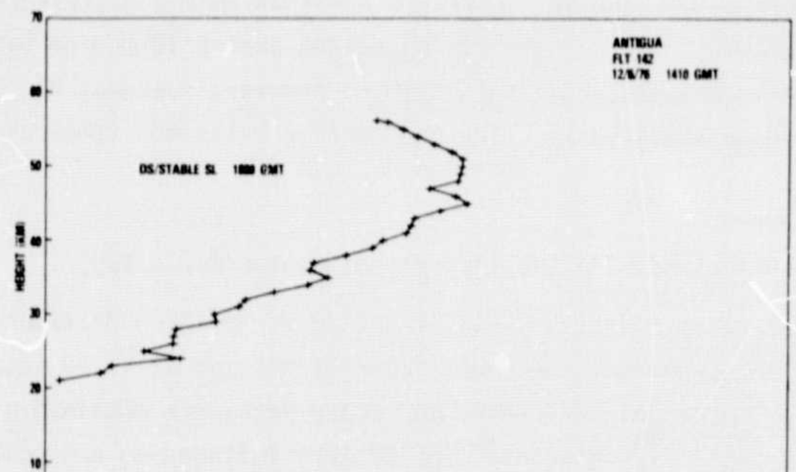


Figure 6.-Conjunctive Datasonde temperature profile.

The extraterrestrial UV signal levels are listed in TM volts in Table VI. Instrument

TABLE VI.-SOLAR FLUX VALUES/FILTER CHARACTERISTICS FOR FLIGHT NO. 143

TM CHANNEL (#/S/λ/$\Delta\lambda$)	TM (VOLTS)	I(∞)	OZONE PROFILE INTERVAL (km)
#1/S_o/3199.4/ 35.7	8.58	71	REFERENCE
#2/S_1/3041.3/ 35.0			25-40
#4/S_2/2829.4/ 39.1	6.00	22	38-49
#5/S_3/2567.5/ 91.7	3.65	9	43-53

POLYMONIAL COEFFICIENTS FOR α AND β

S	A_o	A_1	A_2	C_o
S_o	0.620	-0.012	0.000	0.927
S_1	5.360	-0.428	0.064	1.156
S_2	80.82	-47.90	-53.	1.56-
S_3	271.2	-1400.	-120500.	2.21-

NOTE: λ and $\Delta\lambda$ are expressed in Å I(∞) is expressed in $\mu W/cm^2/nm$.

sensitivity was satisfactory for S_0 and S_2. The S_1 signals were initially out of range and S_3 utilized 36% of the dynamic range. It should be noted that this was the initial flight with a 257 nm filter in S_3. The change from 264 nm improves ozone data precision at the highest altitudes. The compensation signal level varied between 3 and 4 volts. The modulation due to pendulation corresponded to a total coning angle of five degrees which remained constant throughout the flight. The payload temperature varied from 8.5°C at 55 km to a maximum of 12.4°C at 31 km, decreasing to 10.7°C at 26 km. Termination of the flight at 25 km was due to battery exhaustion.

Flight Results.-The Solar Flux Values and Filter Characteristics are presented in Table VI. This flight was analyzed using the standard HP 9810 program assuming only direct sunlight. The offsets for S_2 and S_3 were negligible at large optical depths. In the overlap region between S_2 and S_3 ozone data, the differences vary with optical depth. This is most likely due to near band leakage which is not accounted for in the effective absorption coefficient for the new S_3 filter. The S_1 and S_2 ozone data coincide only at one height level (39 km) where a 4 percent difference was found. The merged results are given in Table VII. The ozone densities are less than the Mid-

TABLE VII.-COMPOSITE RESULTS

Flight No. 143 Location Wallops Island Rocket Total Ozone Above 25.5 km Equals .115

Date 12/22/76 Experimenter A. Krueger Balloon Residual Ozone Below 25.5 km Equals .216

GMT Time 1604Z Ser.No. Sensor/PCM/Starute 213/760844/514846 Total Ozone = .331

Sec Z = 2.137
= 2.1542
= 2.1638

Scale Height = 3.85

Dobson Total Ozone = .311 @ 1528Z
.312 @ 1727Z
.310 @ 1927Z

Ht. km	Δx/Δh atm-cm/km	Probable Error, %	x(h) atm-cm	E(h) mol/cm³	Mixing Ratio ugr/gm	O_3 Partial Pressure umb	Air Temp. °C	Air Pressure mb	Ratio E(h) to Model
70									
69									
68									
67									
66									
65									
64									
63									
62									
61									
60									
59									
58									
57									
56			.00023						
55	.00006	.85	.00029	1.61×10^{10}	2.6	.589	-11	.365	
54	.00007	.49	.00036	1.88	2.8	.697	- 7	.415	.74
53	.00008	.59	.00044	2.15	2.8	.797	- 7	.470	
52	.00009	.56	.00053	2.42	2.7	.886	-10	.534	.63
51	.00012	.31	.00065	3.23	3.2	1.18	- 9	.607	
50	.00015	.32	.00080	4.03	3.6	1.49	- 7	.689	.61
49	.00021	.19	.00101	5.64	4.4	2.06	-10	.782	
48	.00027	.18	.00128	7.26	4.9	2.63	-12	.886	.70
47	.00036	.12	.00164	9.68	5.6	3.46	-16	1.01	
46	.00049	.11	.00213	1.32×10^{11}	6.7	4.73	-15	1.15	.78
45	.00063	.08	.00276	1.69	7.5	6.04	-17	1.32	
44	.00081	.10	.00357	2.18	8.7	7.92	-12	1.50	.80
43	.00106	.11	.00463	2.85	9.7	10.1	-18	1.71	
42	.00140	.11	.00603	3.76	11.1	13.2	-21	1.95	.94
41	.00180	.08	.00783	4.84	12.4	16.8	-23	2.23	
40	.00201	.08	.00984	5.40	12.1	18.8	-23	2.55	.89
39	.00233	.09	.0122	6.26	11.8	21.0	-32	2.93	
38	.00321	.40	.0154	8.63	13.9	28.5	-36	3.37	.99
37	.00390	.32	.0193	1.05×10^{12}	14.5	34.3	-38	3.89	
36	.00421	.27	.0235	1.13	13.4	36.7	-40	4.49	.93
35	.00495	.21	.0284	1.33	13.4	42.4	-44	5.20	
34	.00545	.15	.0339	1.46	12.6	46.3	-46	6.03	.92
33	.00598	.15	.0399	1.61	11.8	50.2	-49	7.00	
32	.00700	.13	.0469	1.88	11.7	58.2	-51	8.15	.93
31	.00781	.13	.0547	2.10	11.2	64.6	-52	9.50	
30	.00871	.10	.0634	2.34	10.5	72.7	-50	11.4	.93
29	.00995	.09	.0733	2.67	10.2	82.3	-52	13.2	
28	.0117	.07	.0850	3.14	10.3	96.4	-53	15.4	.97
27	.0139	.05	.0989	3.74	10.4	113.	-55	18.0	
26	.0159	.06	.115	4.27	10.1	129.	-56	21.0	1.06
25									
24									
23									
22									
21									
20									
19									
18									
17									
16									
15									

Air Temp., Pressure Density, Data Source: Used datasonde for 31-55 km on 12/22/77 at Wallops Is., VA at 1515Z for 26-30 km used statistical results for the years 1969-1975 inclusive at Wallops Is., VA.

Latitude Model at all altitudes greater than 26 km. The percentage difference is less than 10 percent below 40 km but increases to a maximum of 39 percent at 50 km. The integral ozone above 25.5 km is 0.115 atm-cm. Comparative data are available from an ECC balloon ozonesonde launched at 2038 GMT and periodic Dobson measurements of total ozone. The integral ozone below 25.5 km from the balloonsonde was 0.126 atm-cm which yields a combined rocket-balloon total ozone amount of 0.331 atm-cm. Throughout the day very little change in total ozone was found with the Dobson spectrophotometer. At 1727 GMT the reading was 0.312 atm-cm, approximately 6 percent less than the integral of the profiles.

The ozone mixing ratios and partial pressures at altitudes above 30 km are derived from temperatures and densities observed at 1515Z with a Datasonde. Monthly mean atmospheric data were used at lower altitudes.

The ozone density profile is shown in Figure 7. Because of the early termination of the rocket flight, the maximum ozone density (at approximately 24 km from ECC data) was not determined. The mean scale height at the higher altitudes was 3.8 km. Rather large error bars exist at the top of the sounding, extending to below 50 km. The increased errors below 38 km are due to the use of S_1 data at small optical depths.

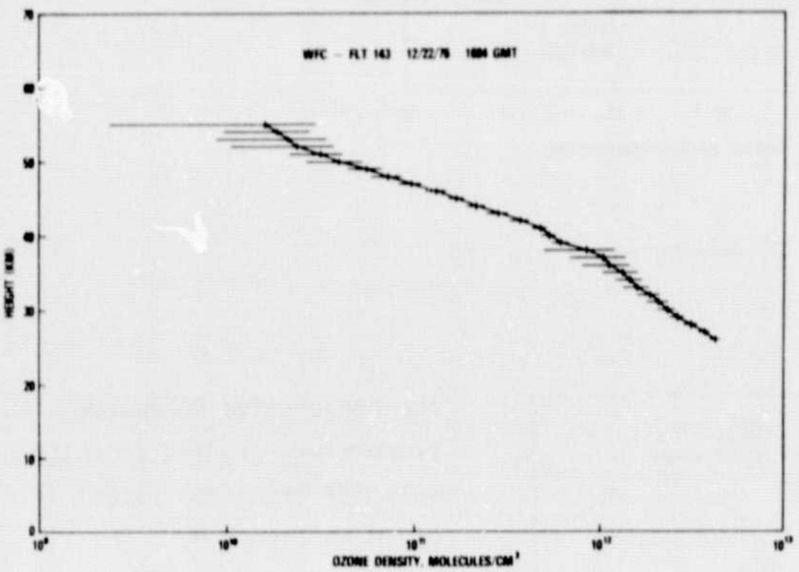


Figure 7.- Ozone density profile.

The mixing ratio profile (Figure 8) has a maximum of 14.5 μgm/gm at 37 km. This profile is similar to earlier soundings during the mid-latitude winter season. Compared with summer mixing ratio distributions, the peak is about 5 km higher in altitude. Some structure is evident near 40 km and below 30 km. The conjunctive balloon ozonesonde profile is also shown. In the overlap between 26 and 30 km, the balloon data are about 10 percent greater than the rocket data. From the composite profile, the mixing ratios are found to exceed 10 μgm/gm between 25 and 43 km.

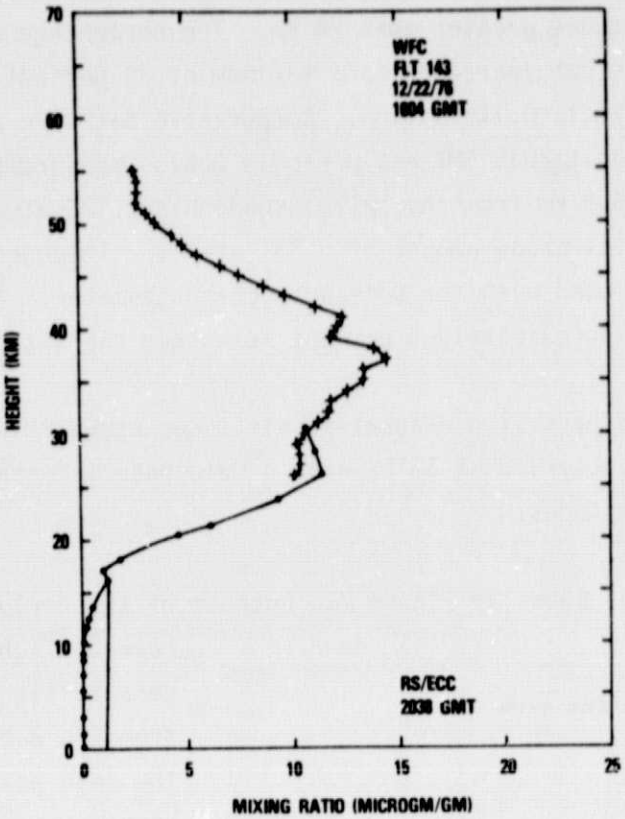
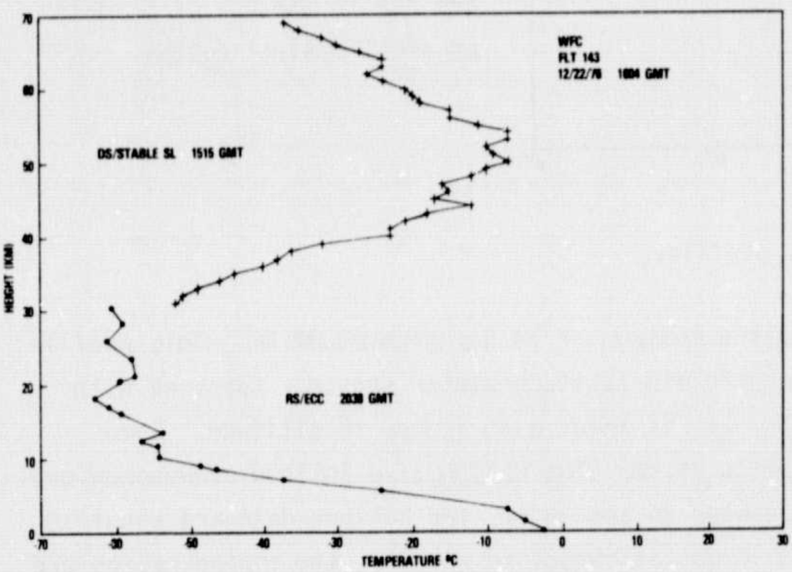


Figure 8.-Mixing ratio profile.



The conjunctive Datasonde temperature profile from the 1515 GMT Datasonde ascent is given in Figure 9.

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Figure 9.-Conjunctive Datasonde temperature profile.

Flight No. 144 (Wallops Flight Center/World Day)

Synopsis.-Rocket ozone flight No. 144, launched at 1730Z on January 19, 1977, reached an apogee of 71.3 km three seconds after ejection, at T+120 seconds. The decelerator stabilized at T+156 seconds and data were recorded until T+9 minutes plus 47 seconds. Payload operation was abnormal with periodic inversion of marker pulses and premature loss of telemetry. The short term (seconds) noise in the UV signals was initially 400 millivolts, but decreased to 300 millivolts after a few minutes. The longer term (minutes) noise was generally less than 500 millivolts.

Shortly after stabilization the modulation in the compensation signal due to pendulation was 3 to 4 volts peak-to-peak which corresponds to a full angle of 10 degrees. Near 36 km the signal modulation represented a full angle of 12 degrees.

After decelerator stabilization, all UV channels indicated reasonable signal levels. S_0 and S_1 had values of about 8-1/2 volts. The S_2 and S_3 signal levels were 5.3 and 5.8 volts, respectively.

The telemetry signal was reacquired approximately one minute after the initial loss of signal. During the remaining 2-1/2 minutes before final loss of signal, the payload performed erratically. The payload temperature at 60 km was about 7°C and increased to 11°C at 37 km.

Flight Results.-The Solar Flux Values and the Filter Characteristics are presented in Table VIII. Flight data were processed on the HP 9810 without corrections for diffuse light. The flight was relatively short due to loss of telemetry at 36 km. At that altitude, the S_2 signal had not been reduced to zero offset levels and, therefore, could not be used for that determination. No offset was observed in the S_3 signals, and consequently no correction was applied to the data.

The ozone densities computed from S_2 and S_3 in the redundant height interval from 44 to 49 km agree closely with no significant bias. In the small overlap between S_1 and S_2 ozone data (39-41 km), a difference of 22 percent is observed with S_2 giving the lower result, as is usual. Part of this difference is likely to be a result of the faulty payload operation. Rather large errors are present in the S_1 data because of noise.

TABLE VIII.-SOLAR FLUX VALUES/FILTER CHARACTERISTICS FOR FLIGHT NO. 144

TM CHANNEL (#/S/λ/$\Delta\lambda$)	TM (VOLTS)	I(∞)	OZONE PROFILE INTERVAL (km)
#1/S_o/3199.4/ 33.5	8.4	79	REFERENCE
#2/S_1/3041.1/ 34.9	8.5	64	36-42
#4/S_2/2830.8/ 39.8	5.3	22	38-50
#5/S_3/2578.6/123.5	5.8	12	43-59

POLYNOMIAL COEFFICIENTS FOR α AND β

S	A_o	A_1	A_2	C_o
S_o	0.624	-0.0124	0.000	0.927
S_1	5.368	-0.428	0.065	1.156
S_2	79.86	-49.85	-70.	1.56
S_3	266.247	-999.	-70866.	2.21

NOTE: λ and $\Delta\lambda$ are expressed in Å I(∞) is expressed in $\mu W/cm^2/nm$.

The merged results are given in Table IX. The analysis has been carried out between 37 and 60 km although it should be noted that the errors are large (>50%) above 50 km and uncertainty exists below 40 km because of the differences noted above.

TABLE IX.-COMPOSITE RESULTS

Flight No 144 Location Wallops Rocket Total Ozone Above ______ km

Date 1/19/77 Experimenter A. Krueger Equals ______

Balloon Residual Ozone Below ______ km

GMT Time 1730Z Ser.No. Sensor/PCM/Starute 216/760845/514861 Equals ______

Sec Z = 1.9181 Total Ozone = ______

= 1.9181

= 1.9143 Scale Height = 4.2 Dobson Total Ozone = .526

Ht. km	Δx/Δh atm-cm/km	Probable Error, %	x(h) atm-cm	E(h) mol/cm³	Mixing Ratio ug/gm	O_3 Partial Pressure umb	Air Temp. °C	Air Pressure mb	Ratio E(h) to Model
70									
69									
68									
67									
66									
65									
64									
63									
62									
61			.00009						
60	.000021	1.26	.00011	5.65×10^9	1.6	.190	-31	.196	.77
59	.000028	.83	.00014	7.53	1.9	.256	-29	.225	
58	.000032	.82	.00017	8.60	1.9	.296	-26	.258	.77
57	.000036	.67	.00021	9.68	1.9	.340	-21	.295	
56	.000043	.62	.00025	1.16×10^{10}	2.0	.411	-18	.336	.72
55	.000055	.46	.00031	1.48	2.3	.527	-17	.383	
54	.000070	.35	.00038	1.88	2.6	.676	-15	.437	.74
53	.000091	.27	.00047	2.45	2.9	.882	-14	.497	
52	.00011	.21	.00058	2.96	3.1	1.07	-14	.566	.77
51	.00014	.17	.00072	3.76	3.5	1.36	-13	.644	
50	.00019	.12	.00091	5.11	4.1	1.84	-15	.733	.77
49	.00026	.08	.00117	6.99	4.9	2.50	-16	.835	
48	.00034	.06	.00151	9.14	5.6	3.26	-17	.952	.89
47	.00040	.06	.00191	1.08×10^{11}	5.9	3.89	-13	1.11	
46	.00053	.05	.00244	1.42	6.9	5.16	-13	1.23	.84
45	.00069	.05	.00331	1.85	7.7	6.59	-18	1.41	
44	.00087	.06	.00418	2.34	8.5	8.34	-17	1.60	.85
43	.00114	.07	.00532	3.06	9.6	10.7	-22	1.83	
42	.00138	.07	.00670	3.71	10.3	13.1	-20	2.10	.93
41	.00170	.06	.00868	4.57	11.0	16.0	-22	2.39	
40	.00198	.07	.0110	5.32	11.3	18.8	-19	2.73	.88
39	.00234	.06	.0144	6.29	11.4	21.8	-24	3.13	
38	.00339	.15	.0180	9.11	13.9	30.5	-33	3.59	1.04
37	.00358	.14	.0216	9.62	12.8	32.0	-34	4.13	
36									
35									
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17									
16									
15									

Air Temp., Pressure Density, Data Source: Used datasonde for 1/19/77 at Wallops Is., VA on 1536Z

NASA WI 1360 (3-77)

The ozone density profile is shown in Figure 10. The mean scale height above 45 km is 4.2 km. This profile contains lower ozone densities than the Mid-Latitude Model at all altitudes above 38 km. The minimum value of the ratio is at 56 km where an 18 percent difference is found. Considering the large errors in the rocket profile at this altitude, the difference is not significant. However, at lower altitudes the errors decrease to about 6 percent, whereas the Mid-Latitude Model contains about 15 percent more ozone. Thus the differences are significant between 40 and 50 km.

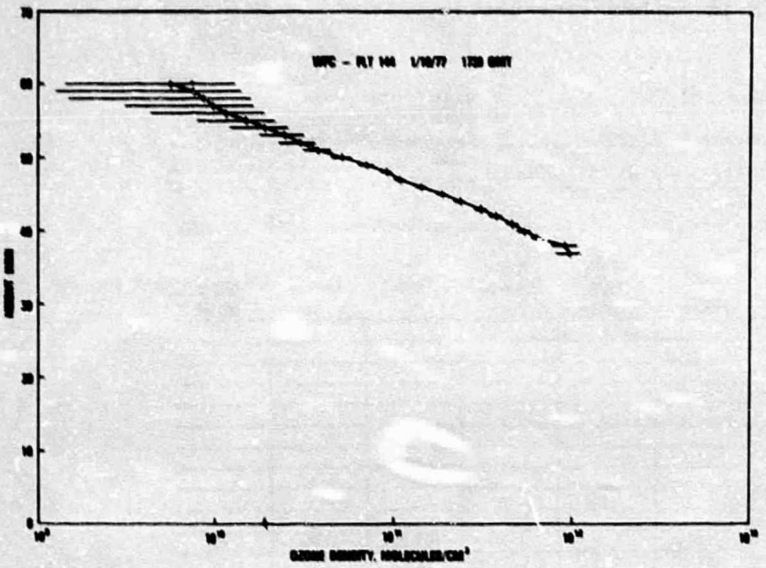

Figure 10.-Ozone density profile.

The mixing ratio profiles from the rocket and balloonsondes are given in Figure 11. No data are available between 29 and 37 km so that the peak mixing ratio was not determined. The composite curve exceeds 10 μgm/gm between 23 and 42.5 km. Compared with the December profiles, the mixing ratios are increased at all balloon altitudes. The strongest increase is at altitudes below 20 km where two- to four-fold changes appear. The mixing ratios of 14 μgm/gm just above 25 km are unusually high for other than midsummer at Wallops Flight Center. Because of the steep mixing ratio gradient with height, it is apparent that the increases at lower altitudes could come from relatively small vertical displacements of the air.

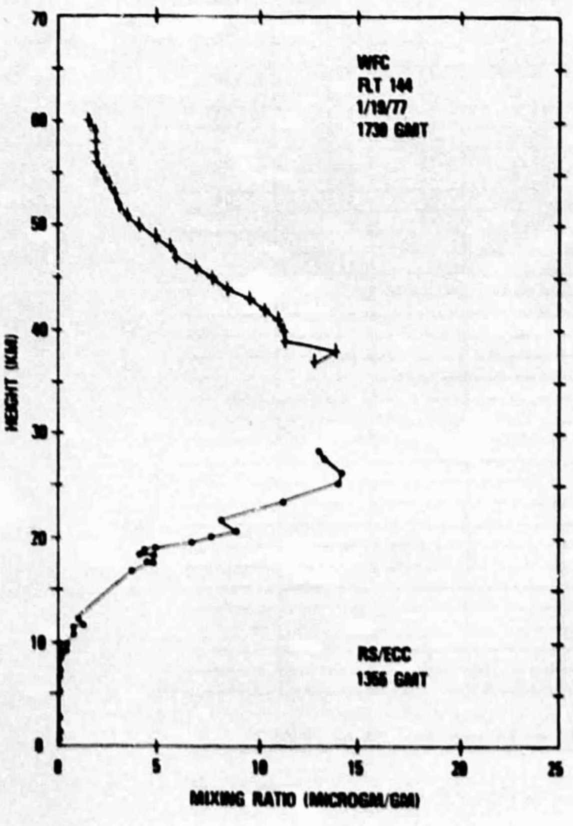

Figure 11.-Mixing ratio profile.

The total ozone was 0.526 atm-cm, a very large amount which was associated with a stratospheric warming which reached its maximum 17 days earlier at polar latitudes. The ozone mixing ratios above 40 km do not appear to be perturbed and are quite similar to those observed in December. Thus, at the stage of the warming on January 19, the only distinctive ozone changes are at balloon altitudes.

The temperature profile from the support Datasonde flight at 1730 GMT and conjunctive radiosonde at 1355 GMT is attached as Figure 12. The air temperature shows evidence late stages of the warming event. The stratopause temperature is 10°C colder on January 19 than it was on December 22, 1976 but the lower stratosphere temperatures are 15°C warmer at the altitudes where high mixing ratios were observed. The unusually large total ozone amount at the time of the soundings can be explained by ozone increases between 20 and 30 km.

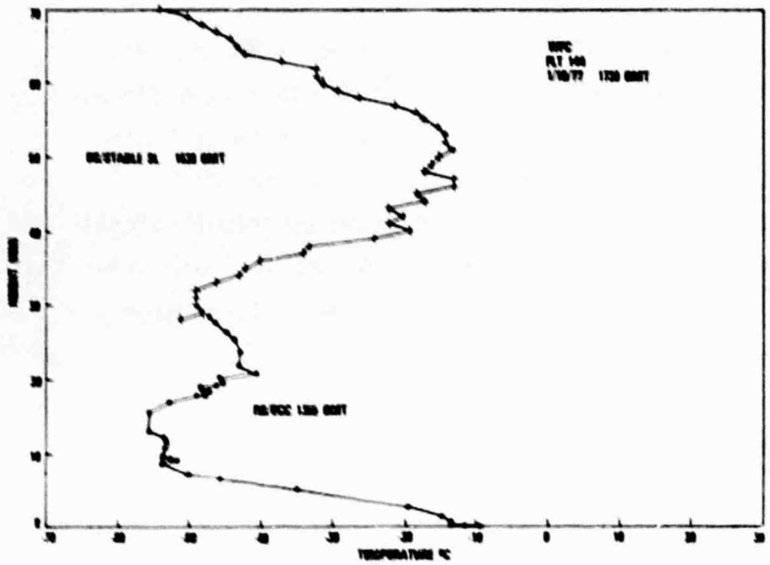

Figure 12.-Conjunctive Datasonde temperature profile.

Flight No. 145 (Wallops Flight Center/World Day)

Synopsis.-Rocket ozone flight No. 145 was launched at 1732 GMT on February 16, 1977 and reached an apogee of 72.5 km at T+122 seconds. Ejection occurred at T+123 seconds. The telemetry signal was nominal until ejection, where the PCM Decode Unit lost lock. No data were recovered.

Post Flight Analysis.-The post flight analysis indicated the PCM encoder section of the telemetry system malfunctioned at ejection and locked up on the Channel 6 word (battery voltage monitor). An analysis of the anomaly suggests a broken wire connection in the PCM encoder section.

Flight system serial numbers: Sensor/PCM/Starute 207/760848/S14839

Flight No. 146 (Churchill Research Range/World Day)

Synopsis.-Rocket ozone flight No. 146, launched at 1807Z on February 16, 1977, reached an apogee of 72.7 km at T+122 seconds. Ejection occurred at T+160, and data were recorded until 1854Z. Instrument #221 was equipped with an experimental wide angle diffuser plate as needed for large solar zenith angles at CRR during the winter.

The UV noise level in S_2 and S_3 was of the order of 400 millivolts at T+180 seconds. UV S_0 and S_1 were out of range until the sonde reached 40 km. The compensation signal initially was between 0 to 1 volt but increased after T+220 seconds to between 2 and 4 volts with an occasional deflection to 5 volts. A signal drop-out occurred at T+270 seconds and lasted until T+300 seconds. There were as many as seven additional signal drop-outs, but of brief duration. During the last 15 minutes of flight the modulation on the compensation channel increased due to wind shears. Similar modulations appear in the UV signals.

During the first seven minutes of flight, the payload temperature increased from 13 to 18°C and remained at that level for about three minutes. The temperature, beyond that point, decreased gradually until it reached -8°C at the end of the flight records.

Flight Results.-The Solar Flux Values and Filter Characteristics are shown in Table X.

Flight No. 146 is the first regular rocket ozone sounding launched at Churchill Research Range. It is particularly interesting because of this and because only three prior direct high altitude ozone soundings are known to exist at that site. The first, an optical ozonesonde, was launched July 19, 1968, and obtained data from 31 to 53 km (Krueger, 1973). The second and third flights were special photometers launched on November 2 and 4, 1969, to determine solar proton event effects on ozone, and to obtain data in the mesosphere (Weeks, Cuikay, and Corbin, 1972).

The ozone profile was determined between 21 and 63 km with best accuracy between 23 and 52 km from the HP 9810 data processing used for this flight. The merged data are given in

TABLE X.-SOLAR FLUX VALUES/FILTER CHARACTERISTICS FOR FLIGHT NO. 146

TM CHANNEL (#/S/λ/$\Delta\lambda$)	TM (VOLTS)	I (∞)	OZONE PROFILE INTERVAL (km)
#1/S_0/3199.9/ 33.7	--	--	REFERENCE
#2/S_1/3036.7/ 35.1	--	--	21-42
#4/S_2/2830.4/ 39.8	6.7	27	38-42
#5/S_3/2577.9/125.4	6.6	13	42-63

POLYNOMIAL COEFFICIENTS FOR α AND β

S	A_0	A_1	A_2	C_0
S_0	0.621	-0.012	0.000	0.927
S_1	5.663	-0.487	0.071	1.156
S_2	80.11	-48.58	-23.7	1.56
S_3	266.0	-991.	-63800.	2.21

NOTE: λ and $\Delta\lambda$(FWHM) are expressed in Å I(∞) is expressed in $\mu W/cm^2/nm$

Table XI. The average ozone densities from the S_2 and S_3 filters in the height interval from 45 to 53 km agree within 4 percent. In the single common altitude for S_1 and S_2 ozone data, the S_2 result is 7 percent less than the S_1 result.

The rocket profile had an integrated columnar ozone amount of 0.214 atm-cm above 20.5 km. This with the integrated balloon ozone below this level of 0.215 atm-cm yields a profile total ozone of 0.429 atm-cm. This is within 1 percent of the Dobson measurement of 0.426 atm-cm.

The February ozone density profile at Churchill Research Range, illustrated in Figure 13, is somewhat more complex than the February soundings at Wallops Flight Center which tends

TABLE XI.-COMPOSITE RESULTS

Flight No. 146   Location Ft. Churchill

Date 2/16/77   Experimenter A. Krueger

GMT Time 1807Z   Sensor/PCM/Starute Ser.No. 221/760834/514851

Sec Z = 3.106

= 3.1177

= 3.1177   Scale Height = 3.95

Rocket Total Ozone Above ______ km

Equals ______

Balloon Residual Ozone Below ______ km

Equals ______

Total Ozone = ______

Dobson Total Ozone = ______

Ht. km	Δx/Δh atm-cm/km	Probable Error, %	x(h) atm-cm	E(h) mol/cm³	Mixing Ratio ugm/gm	O_3 Partial Pressure umb	Air Temp. °C	Air Pressure mb	Ratio E(h) to Model
70									
69									
68									
67									
66									
65									
64									
63	.000019	1.24	.00008						
62	.000020	1.01	.00009	5.11×10^{9}	2.8	.182	-17.8	.105	
61	.000021	.87	.00011	5.38	2.6	.192	-16.8	.122	
60	.000022	.84	.00014	5.64	2.4	.202	-16.1	.138	
59	.000023	.68	.00016	5.91	2.2	.212	-15.4	.160	
58	.000023	.65	.00018	6.18	2.0	.222	-14.9	.183	
57	.000025	.59	.00020	6.18	1.7	.223	-14.5	.209	
56	.000031	.49	.00023	6.72	1.7	.242	-14.3	.239	
55	.000028	.54	.00026	8.33	1.8	.300	-14.3	.272	
54	.000029	.52	.00029	[illegible]	1.4	.271	-14.7	.311	
53	.000041	.34	.00032	7.80	1.3	.280	-15.3	.355	
52	.000049	.26	.00036	1.10×10^{10}	1.6	.396	-15.3	.403	
51	.000072	.17	.00041	1.32	1.7	.472	-15.6	.462	
50	.00012	.10	.00048	1.94	2.1	.693	-15.9	.527	
49	.00016	.07	.00060	3.23	3.1	1.15	-16.6	.600	
48	.00019	.07	.00076	4.3	3.7	1.53	-17.6	.683	
47	.00024	.05	.00095	5.11	3.8	1.81	-18.4	.783	
46	.00031	.06	.00119	6.45	4.1	2.28	-19.6	.894	
45	.00038	.05	.00150	8.33	4.6	2.91	-21.9	1.02	
44	.00063	.07	.00188	1.02×10^{11}	4.9	3.54	-24.5	1.17	
43	.00086	.06	.00251	1.69	7.1	5.81	-26.9	1.34	
42	.00117	.07	.00337	2.31	8.3	7.83	-29.7	1.54	
41	.00149	.08	.00454	3.14	9.6	10.5	-33.4	1.78	
40	.00188	.11	.00603	4.01	10.6	13.2	-36.0	2.04	
39	.00221	.13	.00791	5.05	11.4	16.5	-38.5	2.36	
38	.00294	.22	.0101	5.94	11.5	19.2	-41.0	2.74	
37	.00336	.16	.0131	7.90	13.1	25.2	-43.7	3.16	
36	.00378	.16	.0164	9.03	12.8	28.6	-45.8	3.67	
35	.00423	.12	.0202	1.02×10^{12}	12.3	32.0	-47.2	4.26	
34	.00448	.12	.0244	1.14	11.8	35.5	-48.8	4.96	
33	.00505	.11	.0289	1.20	10.6	37.3	-50.0	5.79	
32	.00584	.09	.0340	1.36	10.2	41.9	-51.6	6.72	
31	.00675	.08	.0398	1.57	10.1	48.1	-53.1	7.84	
30	.00786	.06	.0466	1.81	10.0	55.3	-54.1	9.15	
29	.00872	.06	.0544	2.11	9.8	64.2	-55.0	10.7	
28	.0103	.05	.0631	2.34	9.3	70.3	-57.7	12.5	
27	.0127	.06	.0734	2.77	9.4	83.5	-56.4	[illegible]	
26	.0146	.06	.0861	3.41	9.9	103.	-55.8	[illegible]	
25	.0169	.07	.101	3.92	9.7	119.	-55.8	[illegible]	
24	.0196	.09	.118	4.54	9.7	138.	-55.3	23.5	
23	.0231	.12	.137	5.27	9.6	160.	-55.0	27.5	
22	.0266	.16	.160	6.21	9.7	189.	-54.4	32.1	
21	.0275	.24	.187	7.15	9.6	218.	-54.2	37.3	
20			.214	7.39	8.5	226.	-53.4	43.5	
19									
18									
17									
16									
15									

Air Temp., Pressure Density, Data Source: Statistical results for Feb. for the years 1969-1976 inclusive at Ft. Churchill.

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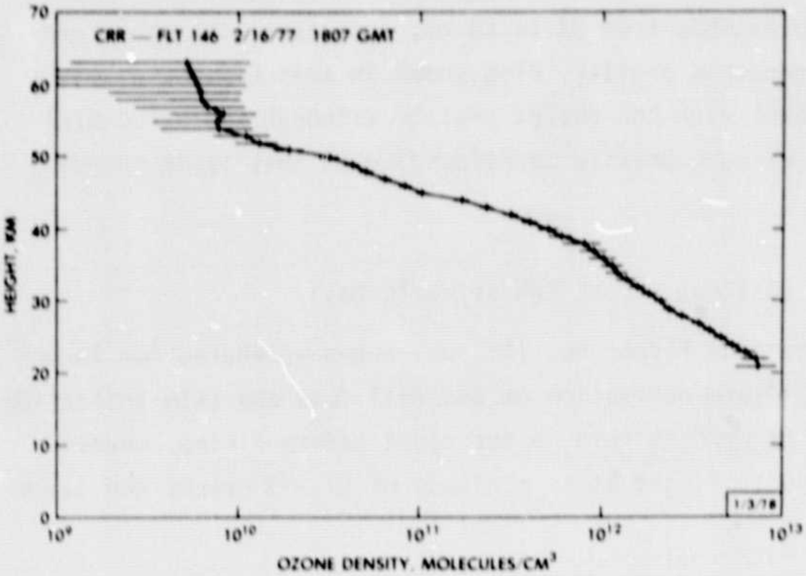

Figure 13.-Ozone density profile.

to have a rather constant scale height above 30 km. Excluding the region above 55 km where the errors are large, the Churchill Research Range ozone profile has distinctly different scale heights above and below 40 km and a slight hump between 35 and 45 km. The densities are significantly less in February at Churchill Research Range at all altitudes above 24 km compared with the February Wallops Flight Center sounding. The greatest differences are above 50 km, near 45 km and between 28 and 32 km where the Churchill Research Range densities are approximately half of the Wallops Flight Center densities. The structure in the Churchill Research Range profile is quite similar to the December 1976 sounding at Wallops Flight Center.

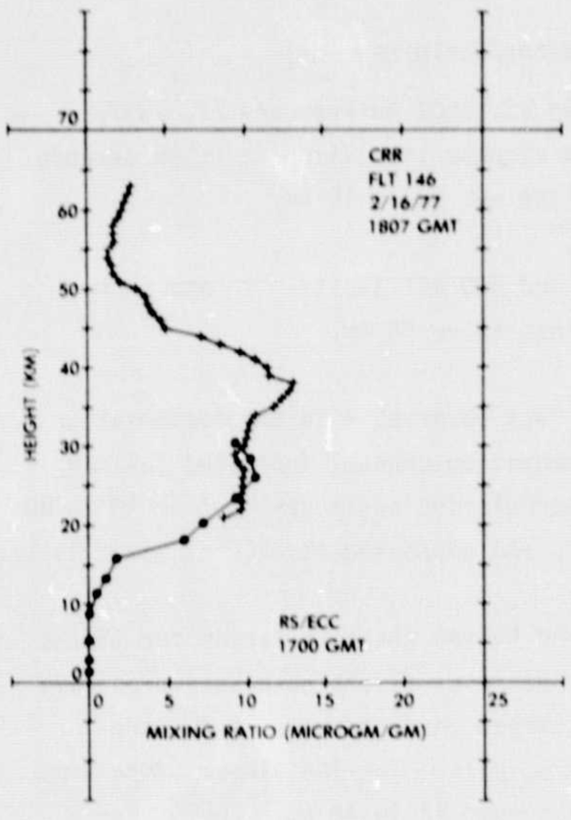

Figure 14.-Mixing ratio profile.

The ozone mixing ratio profile, Figure 14, has a well defined maximum of 13 μgm/gm (7.8 ppm) at 38 km, a common characteristic of winter satellite ozone soundings at high latitudes. Above this maximum, the mixing ratios fall rapidly with altitude, reaching a minimum of 1.3 μgm/gm (0.8 ppm) at 54 km. At higher altitudes, the mixing ratio increases to 2.8 μgm/gm (1.7 ppm) at the 63 km top of the soundings. This increase may only be apparent due to the rapid growth of errors at these altitudes.

Below the 38 km mixing ratio maximum, a broad region of constant mixing ratios near 10 μg/g (6 ppm) is found. This region extends from 33 to 22 km, just above the ozone density maximum. The Mast balloon ozonesonde profile, also shown in this Figure, displays excellent agreement in absolute amount with the rocket profile although the structural details differ. The Datasonde temperature profile corresponding to this ozone sounding is not available.

Flight No. 147 (Wallops Flight Center/World Day)

Synopsis.-No data were obtained from Flight No. 147, which was scheduled for launch on February 16, 1977 at 1812Z. Premature activation of the tail fuse and late initiation of the booster firing circuit, due to a short hold in the count before firing, caused early payload ejection at 55 seconds in flight at an altitude of 51,359 meters and subsequent starute failure.

Post Flight Analysis.-Modifications of the countdown procedures were made and the conduct of launch operations were reviewed.

Flight system serial numbers: Sensor/PCM/Starute 218/760841/S14838

Flight No. 148 (Wallops Flight Center/World Day + 7)

Synopsis.-Rocket ozone flight No. 148, launched at 1700Z on February 23, 1977, reached an apogee of 71.3 km at T+122 seconds. The starute stabilized at T+155 seconds, and data were recorded for 50 minutes when the payload was below 15 km.

The system noise in the UV signals was between 200 and 400 millivolts. S_1 and S_3 were initially out of range and no ozone data were obtained above 55 km.

The typical high frequency component of 1/2 second was observable in the compensation signal. Early in flight the modulation of the compensation channel indicated full angle pendulation from 5 to 8 degrees. Below 15 km the pendulation angle varied from 10 to 20 degrees. The payload temperature, at 54 km, was 7°C and decreased to -2°C at about 19 km.

Discussion of Results.-The Solar Flux Values and Filter Characteristics for flight No. 148 are shown in Table XII. The data from this February flight have been processed on the HP 9810 without diffuse light corrections. Offset corrections of 0.2V were required on S_2 and S_3 and 0.1 V was subtracted from S_0 data. The individual ozone profiles from S_2 and S_3 agree within 3% at their overlap from 43 to 46 km. The S_1 and S_2 data are common at only one altitude level (37 km), where the S_2 results are 7% higher.

TABLE XII.-SOLAR FLUX VALUES/FILTER CHARACTERISTICS FOR FLIGHT NO. 148

TM CHANNEL (#/S/λ/$\Delta\lambda$)	TM (VOLTS)	I(∞)	OZONE PROFILE INTERVAL (km)
#1/S_0/3199.7/ 33.9	8.1	113	REFERENCE
#2/S_1/3037.7/ 35.5			15-38
#4/S_2/2829.3/ 39.5	8.5	28	36-47
#5/S_3/2577.7/124.			42-53

POLYNOMIAL COEFFICIENTS FOR α AND β

S	A_0	A_1	A_2	C_0
S_0	0.622	-0.012	0.000	0.927
S_1	5.607	-0.482	0.073	1.156
S_2	80.76	-46.87	-22.	1.5
S_3	265.3	-1018.	-70000.	2.3

NOTE: λ and $\Delta\lambda$ are expressed in Å I(∞) is expressed in $\mu W/cm^2/nm$.

The merged data are given in Table XIII for altitudes from 16 to 54 km. Data from higher altitudes are missing due to saturation of S_3 signals. Air density data were not available for calculation of ozone mixing ratios and partial pressures below 20 km. Relative to the Mid-Latitude Model, this sounding has excess ozone below 39 km with a maximum difference of 32 percent at 32 km. Above 39 km, the relative ozone amount diminishes with altitude to a deficit of about 25 percent near 51 km.

The total ozone determined with the Dobson spectrophotometer was 0.372 atm-cm. The integral ozone obtained by merging the rocket profile with the conjunctive ECC balloon sonde profile at 19.5 km is 0.360 atm-cm, 3% less than the Dobson total.

TABLE XIII.-COMPOSITE RESULTS

Flight No. 148 | Location Wallops | Rocket Total Ozone Above 19.5 km Equals .273

Date 2/23/77 | Experimenter A. Krueger | Balloon Residual Ozone Below 19.5 km Equals .087

GMT Time 1700Z Ser. No. Sensor/PCM/Starute 222/760839/514854 | Total Ozone = .360

Sec Z = 1.4886
= 1.4893
= 1.4901

Scale Height = 3.5

Dobson Total Ozone = .372

Ht. km	Δx/Δh atm-cm/km	Probable Error, %	x(h) atm-cm	E(h) mol/cm³	Mixing Ratio ugm/gm	O_3 Partial Pressure umb	Air Temp. °C	Air Pressure mb	Ratio E(h) to Model
70									
69									
68									
67									
66									
65									
64									
63									
62									
61									
60									
59									
58									
57									
56									
55									
54	.00005	.71	.00018						
53	.00008	.49	.00023	1.34×10^{10}	1.8	.505	-3	.457	.53
52	.00011	.37	.00031	2.15	2.6	.815	-1	.518	
51	.00014	.26	.00042	2.96	3.1	1.11	-4	.586	.77
50	.00018	.19	.00056	3.76	3.5	1.39	-7	.664	
49	.00025	.13	.00074	4.84	3.9	1.81	-5	.753	.73
48	.00034	.09	.00099	6.72	4.8	2.48	-8	.854	
47	.00044	.08	.00133	9.14	5.7	3.37	-8	.970	.89
46	.00057	.06	.00177	1.18×10^{11}	6.3	4.23	-16	1.10	
45	.00075	.05	.00231	1.53	7.1	5.42	-19	1.26	.91
44	.00095	.05	.00306	2.02	8.1	7.08	-21	[illegible]	
43	.00113	.05	.00401	2.55	8.9	8.89	-23	[illegible]	.93
42	.00135	.07	.00514	3.04	9.4	10.8	-19	1.88	
41	.00169	.06	.00649	3.63	9.8	12.8	-20	2.15	.91
40	.00215	.05	.00818	4.54	11.0	16.4	-14	2.45	
39	.00273	.05	.0103	5.78	11.7	19.9	-26	2.80	.95
38	.00357	.06	.0131	7.34	12.9	25.3	-26	3.21	
37	.00437	.08	.0166	9.60	14.4	32.2	-32	3.68	1.10
36	.00492	.22	.0210	1.17×10^{12}	14.9	38.6	-37	4.24	
35	.00609	.16	.0259	1.32	14.4	42.9	-40	4.90	1.08
34	.00738	.16	.0320	1.64	15.4	53.1	-40	5.66	
33	.00813	.14	.0394	1.98	16.1	64.1	-41	6.55	1.25
32	.0100	.13	.0475	2.19	15.3	70.3	-42	7.57	
31	.0113	.11	.0575	2.69	16.1	86.1	-43	8.77	1.32
30	.0123	.08	.0688	3.04	15.6	96.9	-44	10.2	
29	.0142	.08	.0811	3.31	14.9	107.	-41	11.8	1.31
28	.0157	.08	.0953	3.82	14.8	123.	-41	13.6	
27	.0172	.06	.111	4.22	13.8	133.	-47	15.8	1.30
26	.0183	.08	.128	4.62	12.7	142.	-52	18.4	
25	.0190	.07	.147	4.92	11.6	151.	-53	21.4	1.22
24	.0200	.09	.166	5.12	10.3	156.	-54	25.0	
23	.0209	.08	.186	5.38	9.3	165.	-52	29.1	1.19
22	.0219	.10	.206	5.62	8.2	169.	-57	34.0	
21	.0222	.13	.228	5.89	7.2	175.	-60	39.8	1.21
20	.0222	.15	.251	5.97	6.2	177.	-60	46.7	
19			.273	5.97	5.2	174.	-64	54.8	1.25
18									
17									
16									
15									

Air Temp., Pressure Density, Data Source: Used datasonde for Wallops Is., VA on 2/23/77 at 1600Z

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The ozone density profile is shown in Figure 15. This maximum density is 5.69×10^{12} molecules/cm^3 at 21 km, a relatively low altitude which is typical of winter soundings. The upper tail of the profile decays uniformly with height. The scale height above the 45 km level is 3.5 km.

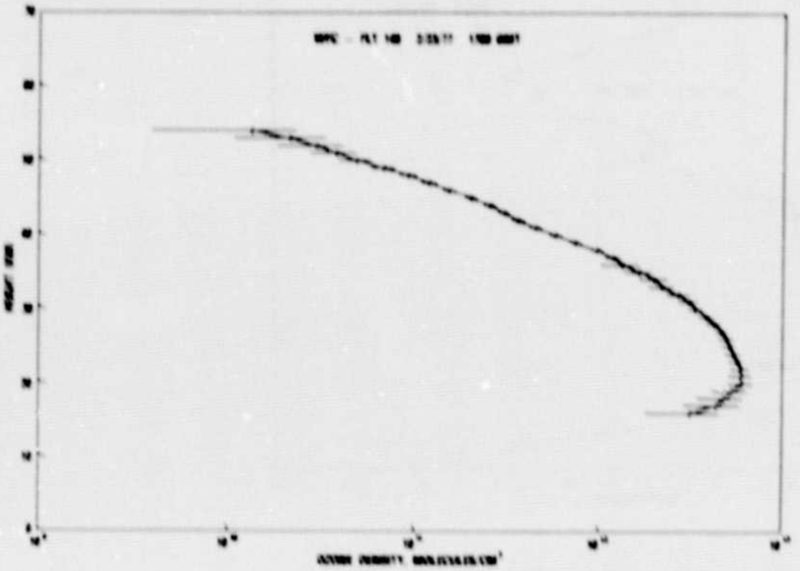

Figure 15.-Ozone density profile.

The corresponding mixing ratio profile is illustrated in Figure 16. Some structure appears at the maximum which is centered near 33 km. The structure is probably due to noise in the S_1 data. The region where the mixing ratios exceed 10 μgm/gm extends from 25 to 42 km. The balloon sonde mixing ratio curve is also shown. Good general agreement is found throughout the profiles, particularly between 20 and 25 km. Above 25 km the balloon mixing ratios are about 10 percent less than the rocket data.

The temperature profile, taken with a Datasonde at 1600 GMT is shown in Figure 17. Conjunctive radiosonde temperatures, taken at 1350 GMT are in good agreement.

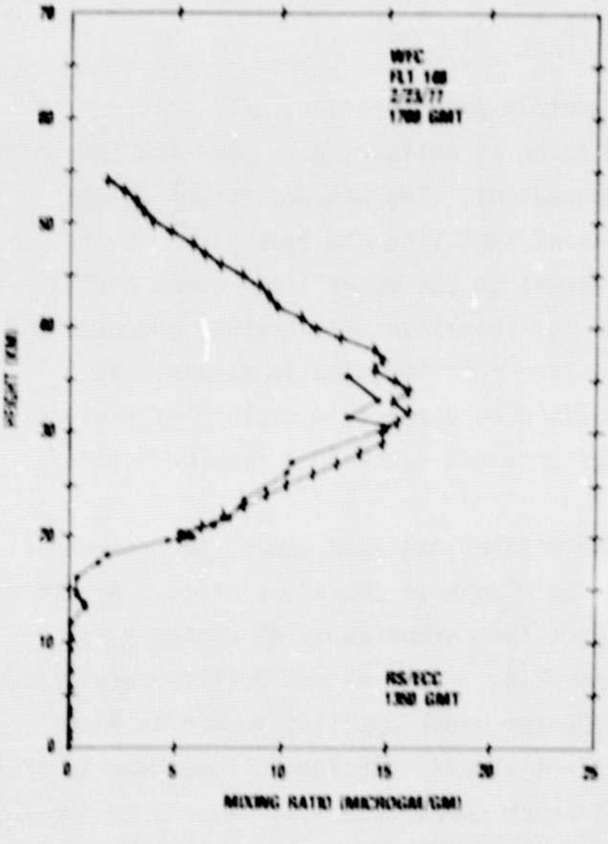

Figure 16.-Mixing ratio profile.

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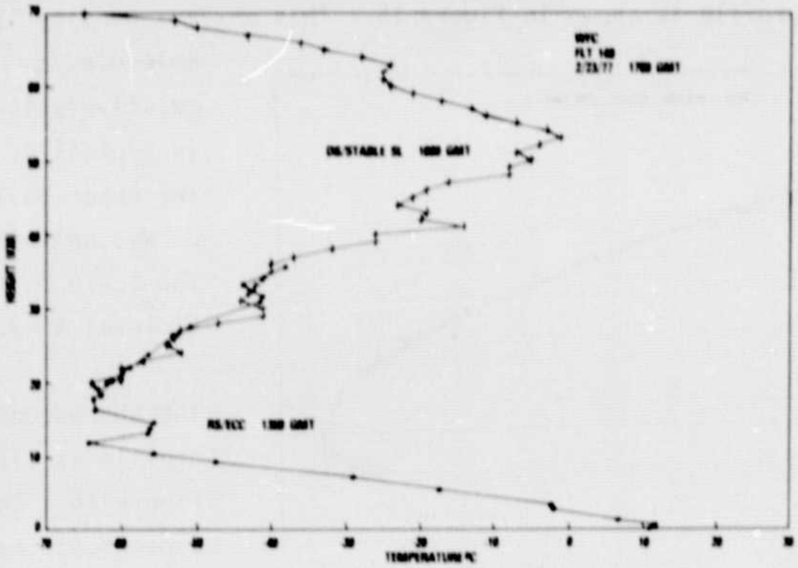

Figure 17.-Conjunctive Datasonde temperature profile.

SUMMARY

During this quarter of operations, three regular monthly ozone profiles were measured at Wallops Flight Center, two special soundings were taken at Antigua, W.I., and the Churchill Research Range was initiated in regular monthly operations. The Wallops Flight Center flights completed the first year of regular flights at that site and have given us the first high resolution vertical view of seasonal changes in the upper level ozone profile at mid-latitudes. The Antigua flights were needed for satellite verification purposes and increases the total number of successful soundings from that location to eleven. It should be noted, however, that it is still not possible to assemble a picture of seasonal ozone variations at Antigua because these soundings were not taken in a regular fashion.

The two Antigua soundings covered in this report were taken two days apart, on December 4 and 6, 1976. These profiles are quite similar in their general characteristics. Relative to the Mid-Latitude Model, both have about 10 percent less ozone above 40 km and a region of higher ozone concentrations between about 25 and 38 km. The maximum positive deviation (40%) is found at 30 km. Although Wallops Flight Center ozone profiles appear to have these same features during summer months, they are not simple functions of the mean solar zenith angle. The Wallops Flight Center soundings which correspond most closely to these December Antigua profiles were obtained in May and September 1976. On the other hand, the Antigua profiles are quite different from equatorial ozone distributions.

The Wallops Flight Center sounding in December has ozone densities less than the Mid-Latitude Model at all altitudes. In January and February, the ozone increased at altitudes below 40 km so that the ozone density became larger than the Model densities. The low December values are quite similar to those observed in November and represent the termination of a strong decreasing trend which was present for altitudes below 36 km during the late summer and fall months. It is because of these decreases that the height of the mixing ratio maximum was displaced from 32 km in July to 37 km in November and December. At higher altitudes the seasonal changes are relatively small. It is impossible to locate the height of the mixing ratio maximum in January because of missing data, but by February the profile resembled the summer regime with a maximum near 33 km. The statistical characteristics of the first year's data from WFC are under review and will be published in the open literature.

The data from the first sounding at Churchill Research Range has been compared with the earlier data from Churchill Research Range in Figure 18. The ozone density is lower at all altitudes than was found in July 1968. The greatest difference was near 50 km where the February 1977 densities were only 30 percent of the July 1968 densities. Part of this difference is due to seasonal air pressure changes. This is illustrated by a comparison of the mixing ratio profiles in Figure 19. Although the ozone densities are less, the February 1977 mixing ratios exceed the July 1968 values between 34 and 44 km.

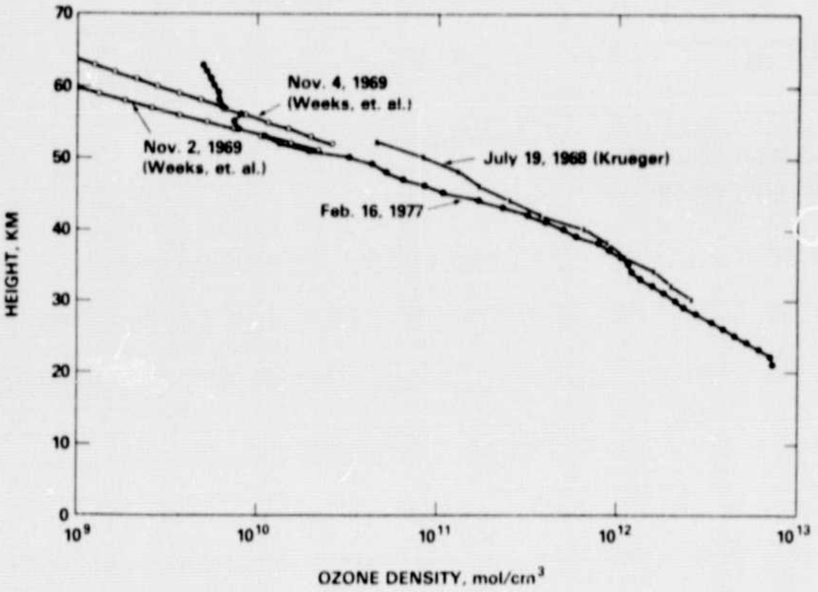

Figure 18.-Churchill Research Range ozone density profile of direct ozone measurements.

The November 1969 mesospheric ozone data are in closer agreement with the February 1977 sounding. The November 2, 1969, densities, taken under disturbed conditions, are within 10 percent from 51 to 54 km while the November 4, 1969, densities are about 70 percent higher. Neither of the November 1969 profiles show the increase in scale height which appears in the Feburary data above 55 km.

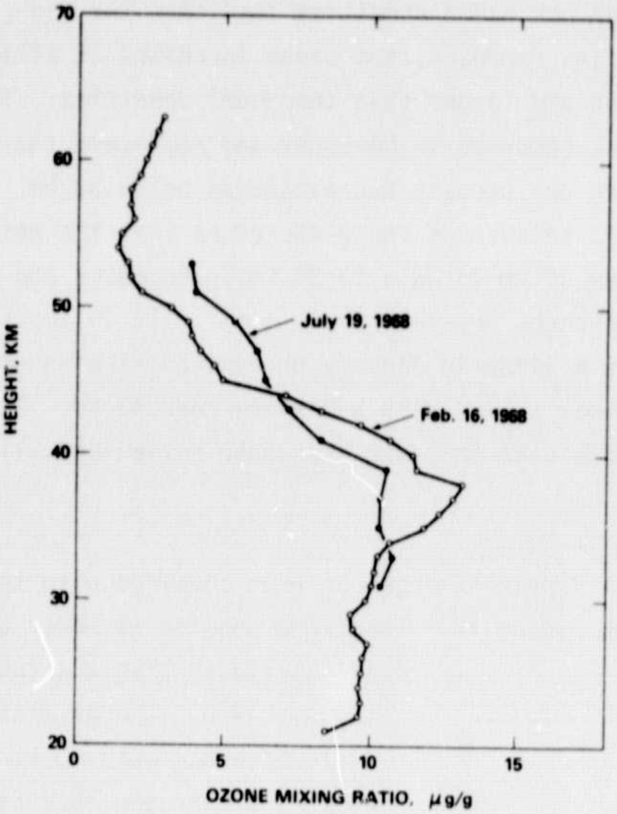

Figure 19.-Churchill Research Range comparison of ozone mixing ratio profiles in summer and winter.

These Churchill Research Range soundings, taken in toto, would indicate a much stronger seasonal variation of ozone near the stratopause than is found at Wallops Flight Center.

APPENDIX

Engineering Test of Flights

For many years the rocket ozone power packs were composed of Ag cells (HR-1's). These power packs have excellent power density, but require special handling and do not possess an adequate shelf life. Therefore, for network operations the latter two considerations, as well as cost, dictated that the Ag cells be replaced with Ni Cd batteries. The new power packs weighed 417 gms representing a 24 percent increase in sonde weight on the Starute. The Starute manufacturer estimated that, according to theoretical calculations, the added weight would not cause the Starute/suspension system or attachments to fail.

The decision was made to flight test the rocket ozonesonde configuration ballasted to the 70 percent level beyond what were "to date" standards in order to confirm the Starute survivability. Additional test objectives were 1) the duration of the useful life of the power packs and 2) the voltage history in the flight environment.

During this quarter two such test flights were launched:

Test Flight 1

Date and Time:	December 13, 1976 @ 1918Z
Vehicle No.:	T1-8412
Vehicle Type:	Super Loki (Unstable Booster)
Payload Type:	Weighted Dummy
Starute No.:	S 14858

Launched at Wallops Island, Virginia, to test Starute survivability.

Synopsis.-Test Flight 1 was launched at 1918Z and reached an apogee of 68 km at T +122 seconds. Ejection occurred at T +122 seconds. The horizontal velocity at ejection was 200 mps. The Starute performed nominally, inflating immediately after ejection and was tracked for 10 minutes with two precision radars. The test was successful.

Test Flight 2

Date and Time:	December 13, 1976 @ 2017Z
Vehicle No.:	T1-8413
Vehicle Type:	Super Loki (Unstable Booster)
Payload Type:	Weighted Dummy

Starute No.: S 14857

Launched at Wallops Island, Virginia to test Starute survivability.

Synopsis.-Test Flight 2 was launched at 2017Z and reached an apogee of 66.4 km at T +120 seconds. Ejection occurred at T +119 seconds. The horizontal velocity, at ejection, was 195 mps. The Starute performed nominally and became fully inflated immediately after ejection. Precision radars tracked for 20 minutes. The fall rate was normal and the mission was successful.