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MEASUREMENT OF 200-400 NM SOLAR UV FLUXES AT ALTITUDES UP TO 39--ETC(U)

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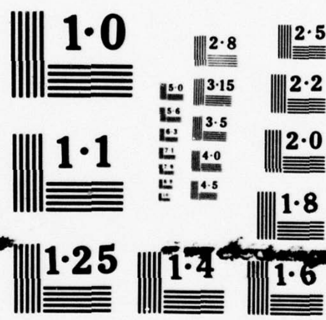

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MEASUREMENT OF 200-400 nm SOLAR UV FLUXES AT ALTITUDES UP TO 39 km ON THE STRATCOM VII-A BALLOON FLIGHT.

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Solar UV fluxes in the 200-400 nm range have been measured at up to 39 km altitude on the Stratcom VII-A balloon flight on 28-29 September, 1976. A filter-wheel UV Spectrophotometer was used to make measurements at ten wavelengths over this range. Flux vs solar zenith angle data were obtained for ascent, descent/sunset, sunrise and cut-down. Ascent, descent/sunset, and load cut-down gave vertical profiles of solar UV flux to below 10 km. The total ozone values derived from the UVS measured fluxes

next page

allow ozone densities to be calculated for ascent and descent on 28 September which are in good agreement with the measured local ozone densities. A good measurement of the 220 nm solar flux in the ozone-oxygen atmospheric window was made. The results is 3.27×10^{-6} W/(cm^2-nm), and together with other measurements indicates some dependence of the 220 nm solar flux on sunspot number and 2800 MHz solar flux.

.00000327 W/(sq cm.-nm)

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FOREWORD

The UV Spectrophotometer used in this work was fabricated for use in the Dept. of Transportation's Atmospheric Monitoring and Experiments Subprogram, managed by Mr. Samuel C. Coroniti, a major element of the Climatic Impact Assessment Program (CIAP). Funding was accomplished through the Office of Naval Research.

The modification and flight of the UVS, as reported herein, was carried out under Contract No. DAAD07-75-C-0124 with the Atmospheric Sciences Laboratory of White Sands Missile Range. The Contracting Officer's Technical Representative was Mr. Harold N. Ballard, whose guidance throughout the course f this work contributed significantly to the success achieved. The UVS was integrated into the Stratcom VI-A payload as a cooperative effort between Sandia Laboratories and White Sands Missile Range. The help of Mr. Miguel Izquierdo and his associates of the University of Texas at El Paso (UTEP) in the installation of the UVS and the data retrieval is appreciated.

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Introduction

The UV Spectrophotometer (UVS) flown on the Stratcom VII-A balloon payload was originally developed to measure high altitude solar UV fluxes from an aircraft as part of the Climatic Impact Assessment Program (CIAP) [1]. The UVS has previously flown on Stratcom VI-A in September, 1975 [2]. On both these balloon flights the UVS gave measurements of the solar UV flux in the 200-400 nm region at altitudes up to 40 km.

Of particular interest are the measurements at 220 nm, a window in the atmospheric transmission lying between the peak of the ozone absorption at 250 nm and the strong oxygen absorption below 180 nm. This wavelength region is extremely important for the photochemistry of the upper atmosphere, particularly the 15-45 km region. The photolysis of many important pollutants, the chlorofluoromethanes in particular [3], is due primarily to the solar UV in this 220 nm window. The UVS data from Stratcom VI-A, along with other solar flux measurements, suggest that the 220 nm solar flux varies with solar activity [2]. The 220 nm flux measured on Stratcom VII-A is consistent with the earlier picture.

The remaining nine solar UV flux measurements are used mostly to obtain information about the ozone layer and certain other photochemical reactions. The 280-330 nm region can be used to calculate the total ozone along the air path to the sun for very thin to very thick layers. The 330-400 nm measurements provide a check on UVS operation since the sun has a stable, well known output at these wavelengths, and they are not significantly affected by ozone. The UVS thus measures an important part of the solar spectrum, a part necessary to understand the upper atmosphere.

Instrument Description

The UVS is basically a narrow-band transmission filter photometer. A set of ten filters on a stepping wheel in front of a calibrated UV photomultiplier measures the solar irradiance over the range 200-400 nm. A conical diffuser in front of the filters provides response over a large range of solar zenith angles ($\simeq 20^{\circ}$ to $>90^{\circ}$) with only a vertical orientation requirement.

This is an improvement over the Stratcom VI-A flight where the flat diffuser required use of a sun-oriented platform. A more detailed description of the basic UV Spectrophotometer (UVS) is given in [1]. The wavelengths of the ten filter sets used are given in Table 1. To fly the UVS on a balloon for a prolonged period of time required several design changes to the basic instrument. They include increased thermal insulation, selection of the filter wheel sample rate by ground command, and the mounting configuration. A more detailed description of the UVS as it is operated on the Stratcom balloon flights is given in [2]. The only changes for Stratcom VII-A were the use of a conical diffuser with vertical pointing and an overhead shield to block sunlight reflected by the balloon, and modifying the temperature monitor to cover the range -50° to $+60^{\circ}$C.

UVS Calibration

The calibration procedure has been described in [1] and [4]. The response of the UVS to a calibrated Standard of Spectral Irradiance (SSI)* is measured and corrected for the difference in solar spectral shape. The result is a calibration constant in A/(W/(cm^2-nm)) for each filter set. The UVS was calibrated before and after the balloon flight with the internal temperature monitor at 25° to 30°C. Most filter sets showed only a few percent variation between the two calibrations. The average calibration is listed in Table 1, and this was used for the data reduction. Also listed are the single filter bandwidths and the number of filters used in each set. The 401.9 and 371.3 nm filters are both used with neutral density 4 filter.

The SSI is calibrated over the range 250 nm to 2500 nm. For calibration of the 220 nm (3 x 214.0 nm filters) set the SSI spectrum below 250 nm was calculated from a 3100°K blackbody spectrum normalized to the 250 nm calibration intensity. This extrapolated spectrum yields a calibration for the 220 nm filter set which is accurate to about 50%. To improve the 220 nm calibration accuracy the SSI relative spectrum was measured using the calibrated UV photomultiplier from the UVS and several broadband filters. This effectively

*A 200W tungsten-iodine quartz envelope lamp calibrated by EG&G Inc., Electro Optics Division, Salem, Mass. The calibration is traceable to the National Bureau of Standards.

Table 1

UVS Calibration Sensitivities
for the Stratcom VII-A Balloon Flight

Filter set average wavelength (nm)	Single filter bandwidth (nm)	Number of filters used	Solar Calibration Sensitivity (A/(W/(cm^2-nm)))
401.9	26	1	1.241×10^{-3}
371.3	28	1	7.946×10^{-4}
329.7	2.2	2	4.782×10^{-3}
322.4	2.0	2	8.901×10^{-3}
311.7	1.8	2	9.497×10^{-3}
307.0	2.0	2	1.512×10^{-2}
298*	3.0	2	2.101×10^{-2}
292.0	2.4	2	4.990×10^{-2}
287*	1.8	2	1.171×10^{-2}
220**	28	3	2.825×10^{-1}

*Original band-pass central wavelength. Upon remeasurement of the filter transmissions these two filter sets showed some deterioration and have since been replaced. Their data quality is not as good as that of the other sets, and data from these sets have thus not been included in this report.

**This is the effective wavelength at high altitudes.

transfers the UV photomultiplier calibration, which extends below 200 nm, to the SSI. Using this method the SSI intensity at 220 nm was found to be within 10% of the extrapolated blackbody spectrum. The 220 nm calibration is thus improved to about 20% absolute error. The errors in the other filter calibrations are less than 10%.

Analysis of Flight Operation

The scientific payload with the UVS on board was launched from Holloman AFB at about 0700 MST on 28 September 1976. The balloon reached 30 km at about 1030 MST and then began a slow descent to about 18 km at 1800 MST. During the night and following morning the balloon ascended to about 26 km. Cut-down occurred at about 0930 MST from 24 km. UVS solar flux data were thus obtained for a morning balloon ascent, a balloon descent during the afternoon and ending with sunset, a sunrise, and a morning cut-down.

The UVS heaters were turned on a few hours before sunrise to bring the instrument up to +20°C before sunrise data were taken. This worked reasonably well, with the UVS achieving about +10°C when the first sunrise data were taken. With the conical diffuser, good sunrise data were obtained, since there were no sun-seeking platform difficulties as with Stratcom VI-A. Cut-down data were also much improved with the elimination of the sun-seeking platform requirement. The UVS operated properly during its turn-on periods for the entire flight.

Data Reduction Procedure

The basic data reduction procedure for the UVS has been described in [1], [4], and [5]. For altitudes above about 20 km the effects of Rayleigh scattering become quite small, and so the analysis procedure is unaffected by the corrections for Rayleigh scattering. The major change from the earlier analysis procedure is the use of the angular response for the conical diffuser in place of that for the flat diffuser. The fluxes as derived by this procedure are the downward fluxes through a horizontal plane. The solar fluxes through a plane perpendicular to the sun-earth line, which are given in this report, are obtained by dividing the downward fluxes by cos θ_{sun}, θ_{sun} being the solar zenith angle. For altitudes above 15 km the Rayleigh scattered component is usually less than 10% (except for large solar zenith angles) so this procedure gives an accurate value for the direct solar flux. Below 15 km (and for somewhat higher altitudes at large solar zenith angles) the resulting flux values deviate increasingly from the direct solar flux. Between about 5 and 15 km the listed fluxes should be multiplied by cos θ_{sun} to obtain the correct downward fluxes through a horizontal plane. Since most interest is in the high altitude UVS data, all fluxes are listed as direct solar fluxes, with the understanding that the low altitude data really represent the total downward flux (after multiplication by cos θ_{sun}).

The UVS data for a complete cycle consist of 10 UV filter measurements for the wavelengths listed in Table 1, a dark current measurement, and two calibration points from the set (1,2), (3,4), (5, CALB), and (CALA, 0). The values 0, ---, 5 are nominal voltage calibrations to correct for any shifts that might be introduced in signal transmission and processing, while CALA and CALB are light calibration points to monitor the photomultiplier-log amplifier gain. For the Stratcom VII-A flight the complete data analysis procedure has been used, rather than the simplified form described in [2]. This allows the use of lower altitude data, down to about 5 km, with reasonable accuracy in the analysis results, especially the ozone thicknesses.

For some wavelengths the residual ozone above the balloon can be calculated from

$$t_{O_3}(\lambda) = \frac{-\cos\theta_{sun}}{\mu_{O_3}(\lambda)} \ln \left\{ \frac{F'_{meas}(\lambda)}{F'_{calc}(\lambda)} F_{tm} \right\} \qquad (1)$$

The result (1) is most accurate for values of the bracket between about 0.3 and 0.05. The factor F_{tm} in (1) is a normalization to the 401.9 and 371.3 nm flux measurements, and is additionally used for the 220 nm flux normalization. The solar zenith angle is θ_{sun} while the ozone absorption coefficient is $\mu_{O_3}(\lambda)$. $F'_{meas}(\lambda)$ is the measured downward flux obtained as described above, while

$F'_{calc}(\lambda)$ is the calculated downward flux with no ozone attenuation. These are the fluxes calculated by the procedures described in [1], [4], and [5], and are not the direct fluxes tabulated here, which are calculated from

$$F_{meas}(\lambda) = F'_{meas}(\lambda)/\cos\theta_{sun} \quad (2)$$

as described above.

Results

Stratcom VII-A was launched during the early morning on 28 September, 1976. During the entire flight the balloon was near latitude 33°N, longitude 106°W, although radar location data were used to obtain the precise balloon location for UVS data analysis. The UVS data can be conveniently divided into four groups: ascent during the morning on 28 September; slow descent combined with sunset data on 28 September; sunrise on 29 September; and cut-down on the morning of 29 September. Because no sun orientation was required the UVS data for on-periods is generally quite good, with only occasional dips when the diffuser cone is partially shaded by the payload support cables.

The solar flux data for the four periods listed above are given in Tables 2 to 5. Fluxes were calculated as described in the preceding section. All 220 nm fluxes have been normalized to the 401.9 and 371.3 nm measurements, which is the optimum procedure for high altitudes. The fluxes are for an area perpendicular to the sun-earth line, and include the downward going component of backscattered light from the lower atmosphere and the earth's surface. The sun-earth distance for September 28-29 is 1.0017 AU, so solar UV fluxes not attenuated by ozone or oxygen are effectively normalized to 1 AU. The uncertainty in the fluxes is ±10%, except for the 220 nm flux which is ±20%. Numbers in parentheses have larger uncertainties because of large corrections for leakage flux at longer wavelengths, or because of shading by the payload support cables. Blanks in the tables indicate fluxes too weak to measure with the UVS. The 298 and 287 nm filters have not been included because of the filter deterioration noted in Table 1.

Table 2

Stratcom VII-A
UVS Solar Flux Data for Ascent on 28 September 1976

MST (hrs-min)	Altitude (km)	Solar zenith angle (deg)	Flux ($W/(cm^2$-nm)) at wavelength λ(nm), on an area normal to the sun-earth line*							
			401.9	371.3	329.7	322.4	311.7	307.0	292.0	220.0
0745	6.22	68.4	1.44-4	1.00-4	7.28-5	3.98-5	8.44-6	(1.41-6)	-	-
0800	11.23	65.2	1.55-4	1.16-4	8.95-5	5.56-5	1.39-5	(3.39-6)	-	-
0815	15.48	62.0	1.60-4	1.31-4	1.19-4	6.08-5	1.85-5	5.79-6	(1.47-7)	-
0830	18.94	59.2	1.65-4	1.29-4	1.10-4	6.53-5	2.54-5	9.03-6	(3.35-7)	4.44-9
0845	22.64	56.4	1.65-4	1.37-4	1.33-4	6.32-5	3.27-5	1.63-5	(3.65-7)	6.00-9
0900	26.36	53.8	1.74-4	1.36-4	1.26-4	8.12-5	4.74-5	2.63-5	(8.72-7)	9.67-9
0910	28.96	52.0	1.64-4	1.27-4	1.13-4	8.76-5	5.17-5	3.80-5	1.52-6	3.80-8
0915	30.36	51.2	1.71-4	1.27-4	1.17-4	7.63-5	5.59-5	4.22-5	3.71-6	5.87-8
0920	31.65	50.3	1.76-4	1.44-4	1.39-4	8.82-5	6.47-5	5.42-5	5.50-6	1.09-7
0928	33.79	49.0	1.67-4	1.40-4	1.39-4	8.74-5	6.97-5	6.25-5	1.12-5	2.29-7
0932	34.71	48.3	1.34-4	1.10-4	1.13-4	8.69-5	6.26-5	5.70-5	1.36-5	4.33-7
0943	36.71	46.6	1.52-4	1.26-4	1.30-4	8.47-5	6.75-5	6.51-5	2.45-5	6.49-7
0954	38.25	45.0	1.66-4	1.24-4	1.10-4	9.39-5	7.26-5	6.50-5	3.22-5	9.35-7
1001	38.55	44.0	1.71-4	1.29-4	1.14-4	9.46-5	7.88-5	6.98-5	4.18-5	(8.88-7)
1032	38.80	39.9	1.66-4	1.25-4	1.10-4	9.72-5	7.31-5	6.65-5	3.74-5	1.25-6

*Read N-n as $Nx10^{-n}$. Numbers in parentheses are for measurements where the leakage flux is greater than 25% of the solar flux measurement and so have increased uncertainty, or where shadowing by the payload support cables occurred.
Blanks indicate no data because leakage flux formed most of the signal.

Table 3

Stratcom VII-A
UVS Solar Flux Data for Slow Descent and Sunset on 28 September 1976

MST (hrs-min)	Altitude (km)	Solar zenith angle (deg)	Flux ($W/(cm^2$-nm)) at wavelength λ(nm), on an area normal to the sun-earth line*							
			401.9	371.3	329.7	322.4	311.7	307.0	292.0	220.0
1103	38.09	36.9	1.60-4	1.26-4	1.20-4	9.25-5	7.15-5	6.85-5	3.57-5	1.09-6
1203	35.84	34.7	1.74-4	1.35-4	1.33-4	9.76-5	8.21-5	7.41-5	3.45-5	5.91-7
1232	33.45	34.8	1.60-4	1.26-4	1.20-4	9.47-5	6.39-5	6.05-5	1.54-5	3.58-7
1303	32.43	38.3	1.75-4	1.46-4	1.48-4	9.83-5	7.99-5	6.95-5	1.33-5	2.34-7
1332	31.83	41.8	1.70-4	1.38-4	1.35-4	8.93-5	7.46-5	6.29-5	8.74-6	1.74-7
1403	30.84	46.3	1.78-4	1.39-4	1.35-4	1.01-4	7.25-5	5.90-5	6.11-6	1.02-7
1432	29.38	51.0	1.90-4	1.41-4	1.26-4	1.05-4	7.81-5	5.05-5	2.54-6	3.13-8
1501	26.71	56.1	1.95-4	1.57-4	1.52-4	1.01-4	6.23-5	3.97-5	(9.12-7)	1.23-8
1534	24.31	62.2	1.86-4	1.44-4	1.29-4	9.03-5	4.26-5	2.07-5	(4.81-7)	5.67-9
1602	21.84	67.7	1.78-4	1.35-4	1.16-4	8.24-5	2.71-5	9.38-6	(2.78-7)	(4.70-9)
1618	20.91	71.0	1.77-4	1.29-4	1.08-4	7.20-5	1.89-5	5.05-6	(2.48-7)	-
1631	20.26	73.5	1.82-4	1.37-4	1.19-4	6.49-5	1.57-5	(3.03-6)	(1.94-7)	-
1642	19.88	75.9	1.54-4	1.28-4	1.23-4	5.68-5	1.04-5	(1.59-6)	-	-
1651	19.65	77.7	1.67-4	1.32-4	1.07-4	5.10-5	7.36-6	(6.01-7)	-	-
1658	19.50	79.1	1.74-4	1.28-4	1.03-4	4.86-5	5.72-6	-	-	-
1731	18.94	86.1	1.38-4	1.10-4	8.49-5	1.99-5	-	-	-	-

*See footnote for Table 2.

Table 4

Stratcom VII-A
UVS Solar Flux Data for Sunrise on 29 September 1976

MST (hrs-min)	Altitude (km)	Solar zenith angle (deg)	Flux ($W/(cm^2$-nm)) at wavelength λ(nm), on an area normal to the sun-earth line*							
			401.9	371.3	329.7	322.4	311.7	307.0	292.0	220.0
0616	22.90	86.5	1.47-4	1.07-4	5.75-5	2.00-5	-	-	-	-
0631	23.07	83.4	1.38-4	1.12-4	8.53-5	2.92-5	(1.41-6)	-	-	-
0702	23.47	77.1	1.44-4	1.20-4	1.06-4	5.03-5	9.50-6	(1.58-6)	-	-
0731	24.28	71.4	1.72-4	1.30-4	1.09-4	6.50-5	2.20-5	6.78-6	(2.86-7)	-
0801	24.91	65.3	1.63-4	1.26-4	1.05-4	7.85-5	3.09-5	1.30-5	(3.00-7)	(4.01-9)
0833	25.55	59.3	1.67-4	1.31-4	1.21-4	8.12-5	3.90-5	2.08-5	(4.80-7)	6.34-9
0842	25.72	57.7	1.77-4	1.37-4	1.25-4	8.25-5	4.37-5	2.34-5	(5.91-7)	6.37-9
0901	25.86	54.3	1.71-4	1.38-4	1.30-4	8.37-5	4.66-5	2.73-5	(6.33-7)	8.38-9
0915	24.93	51.9	1.79-4	1.42-4	1.29-4	8.33-5	4.64-5	2.65-5	(7.38-7)	9.11-9
0930	24.07	49.4	1.69-4	1.44-4	1.41-4	8.02-5	4.35-5	2.63-5	(5.82-7)	8.23-9

*See footnote for Table 2.

Table 5

Stratcom VII-A
UVS Solar Flux Data for Cut-Down on 29 September 1976

MST (hrs-min)	Altitude (km)	Solar zenith angle (deg)	Flux ($W/(cm^2$-nm)) at wavelength λ(nm) on an area normal to the sun-earth line*							
			401.9	371.3	329.7	322.4	311.7	307.0	292.0	220.0
0933	20.93	49.0	1.74-4	1.16-4	1.12-4	8.00-5	3.77-5	1.94-5	(5.13-7)	(4.19-9)
0935	18.19	48.6	1.49-4	9.99-5	9.97-5	8.96-5	4.19-5	1.41-5	(3.68-7)	-
0937	16.33	48.2	1.57-4	1.56-4	1.47-4	8.39-5	2.70-5	9.78-6	(2.68-7)	-
0940	14.33	47.7	1.63-4	1.33-4	1.17-4	7.93-5	2.82-5	1.20-5	(3.01-7)	-
0943	12.82	47.3	1.64-4	1.21-4	1.03-4	7.55-5	3.14-5	1.34-5	(4.19-7)	-
0945	11.47	46.9	1.60-4	1.37-4	1.16-4	6.99-5	2.80-5	1.23-5	(4.06-7)	-
0948	10.19	46.5	1.29-4	1.09-4	1.04-4	7.17-5	2.97-5	1.26-5	(3.67-7)	-
0950	9.00	46.1	1.42-4	1.25-4	1.13-4	6.76-5	2.74-5	1.20-5	(2.97-7)	-
0953	7.90	45.7	1.48-4	1.23-4	1.14-4	6.55-5	2.72-5	1.21-5	(1.97-7)	-
0955	6.89	45.3	1.53-4	1.22-4	1.10-4	6.07-5	2.31-5	1.12-5	-	-

*See footnote for Table 2.

Plots of the solar flux at four wavelengths vs altitude for the balloon ascent on 28 September are given in Fig. 1. Also shown is the solar zenith angle, which decreases from 68^{o} to 40^{o} during the ascent. Most of the change at the shorter wavelengths is caused by penetration of the ozone layer. Similar plots for the descent/sunset data on 28 September are given in Fig. 2, with the solar zenith angle making one axis and the altitude being plotted. The variations in Fig. 2 are from a combination of increasing ozone because of the descent and the increasing solar zenith angle. Sunrise data from 29 September are plotted in Fig. 3. Only three wavelengths are plotted, as the comparatively low altitude of 23-26 km puts the balloon below most of the ozone layer, and so only marginally measurable fluxes are observed at 292 nm (see Table 4). Plots of solar flux measured during descent after cut-down (24 km) resulted in no useful 292 nm flux measurements and only moderate variations in the other fluxes, since the payload was already below most of the ozone layer.

The ascent and descent of Stratcom VII-A on 28 September allow the UVS derived total ozone above the balloon to be used to calculate average ozone densitites. The results are given in Tables 6 and 7. Some of the total ozone values listed are averages over a number of the measurements listed in Tables 2 and 3. Such averaging reduces the statistical error in the ozone measurements, and it results in altitude increments sufficiently large to provide meaningful ozone densities. The total ozone values are estimated to be accurate to 5-10%, while the densities are accurate to 20%, neglecting transport effects.

The measured local ozone densities [6] showed significant differences between ascent and descent, with an apparent rise of about 6 km in the ozone layer during the day. The local ozone densities and UVS derived ozone densities are plotted in Fig. 5. The ascent data agree quite well, but the descent data disagree at the lowest altitudes. This can be explained by vertical air motion during the balloon descent. From the Stratcom VII-A descent velocity data [7] it appears that this velocity changed by about 1 m/sec several times during descent, so vertical air mass velocities of this magnitude may have occurred during 28 September. If the 6 km rise in the ozone density "knee" at 15-20 km took place over the maximum possible time of 8 hours, this would give an average vertical velocity of 0.2 m/sec as a minimum. Since the rise most likely took place over a much shorter time period, a 1 m/sec vertical air mass velocity is quite possible. While horizontal transport of a different ozone profile may be possible, it would be difficult without also producing large horizontal balloon motions, so some form of mostly vertical air motion, as suggested in [8], is most likely.

The descent ozone densities derived from the UVS total ozone values can be corrected approximately for vertical air motion. If it is assumed that air with 30×10^{17} mol/m^3 of ozone is transported vertically with 1 m/sec velocity, then the additional amount of ozone transported past the balloon can be calculated and subtracted from the measured total ozone differences. This has been done for the three lowest altitude density values in Table 7, and the "corrected" values are also plotted in Fig. 5. This "correction" is obviously crude, but the reasonable agreement this gives with the locally measured ozone densities shows that such vertical air mass motions can readily explain the UVS total ozone observations. The locally measured ozone densities and UVS derived total ozone values thus show excellent agreement for the 28 September data, when vertical air motion effects are taken into account.

The high altitude data can be used to obtain an absolute value for the solar flux at 220 nm. This is done by plotting the measured intensities against the attenuation path length on a semilog plot and extrapolating to zero path length. The attenuation path length should be proportional to the local atmospheric pressure divided by the cosine of the solar zenith angle, provided that the oxygen/ozone ratio remains constant. Because of the observed ozone profile changes on 28 September only the Stratcom VII-A ascent data are likely to be useful for a valid 220 nm flux determination. Both the ascent and descent 220 nm data are plotted in Fig. 6. The five highest altitude points for the ascent data, acquired over about one hour, give a best fit to the unattenuated solar flux at 220 nm of 3.27×10^{-6} W/(cm^2-nm). Comparable descent data required more than 2-1/2 hours to acquire, and thus are more likely to be affected by the vertical air motions discussed earlier.

The UVS 220 nm solar flux responses have been recalculated using the 170 to 280 nm solar spectrum of [9]. This changes the calibration slightly, with the Stratcom VI-A 220 nm results reported in [2] being increased by about 9% to 4.19×10^{-6} W/(cm^2-nm). The 220 nm solar fluxes measured with the UVS on Stratcom VII-A and Stratcom VI-A (as corrected here) are compared in Table 8, with four additional measurements from [10], [11], and [12], as originally reported in [2]. The solar activity as measured by Zürich sunspot number and 2800 MHz flux measured at Ottawa, both obtained from [13], are also listed. It is interesting to note that the Stratcom VII-A 220 nm flux is about 22% lower than the Stratcom VI-A flux, with the sunspot number being higher, but the 2800 MHz flux being lower. The two Stratcom UVS 220 nm flux measurements are thus consistent with each other, and give this flux level for minimum solar activity. The possible variation of the 220 nm flux with solar activity (sunspot number, 2800 MHz flux level) suggested in [2] is supported by the addition of the 28 September 1976 results, and additional measurements over the next several years as solar maximum is reached should be most interesting.

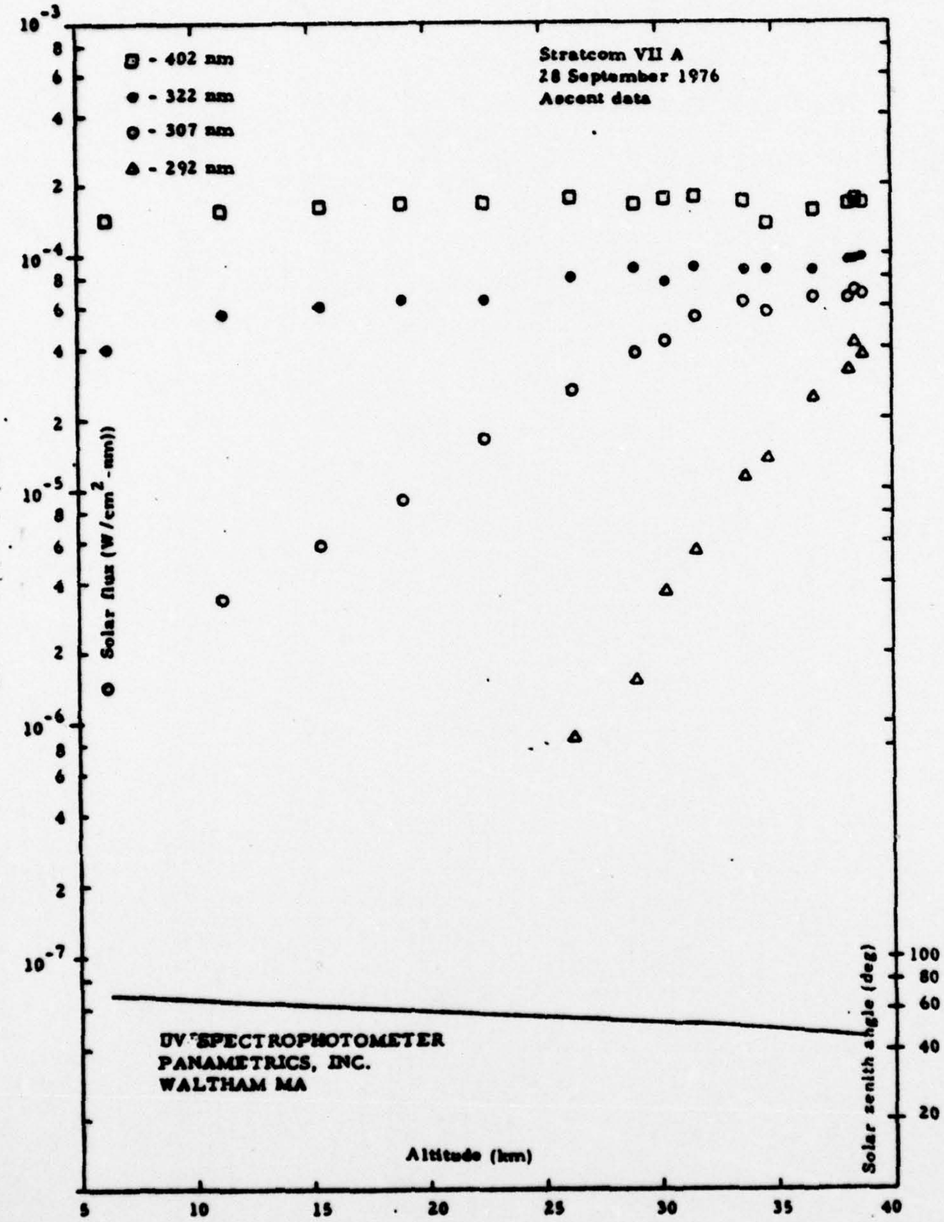

Fig. 1. Plots of Solar Flux at Four Wavelengths vs Altitude for Ascent of Stratcom VII-A on 28 September 1976.

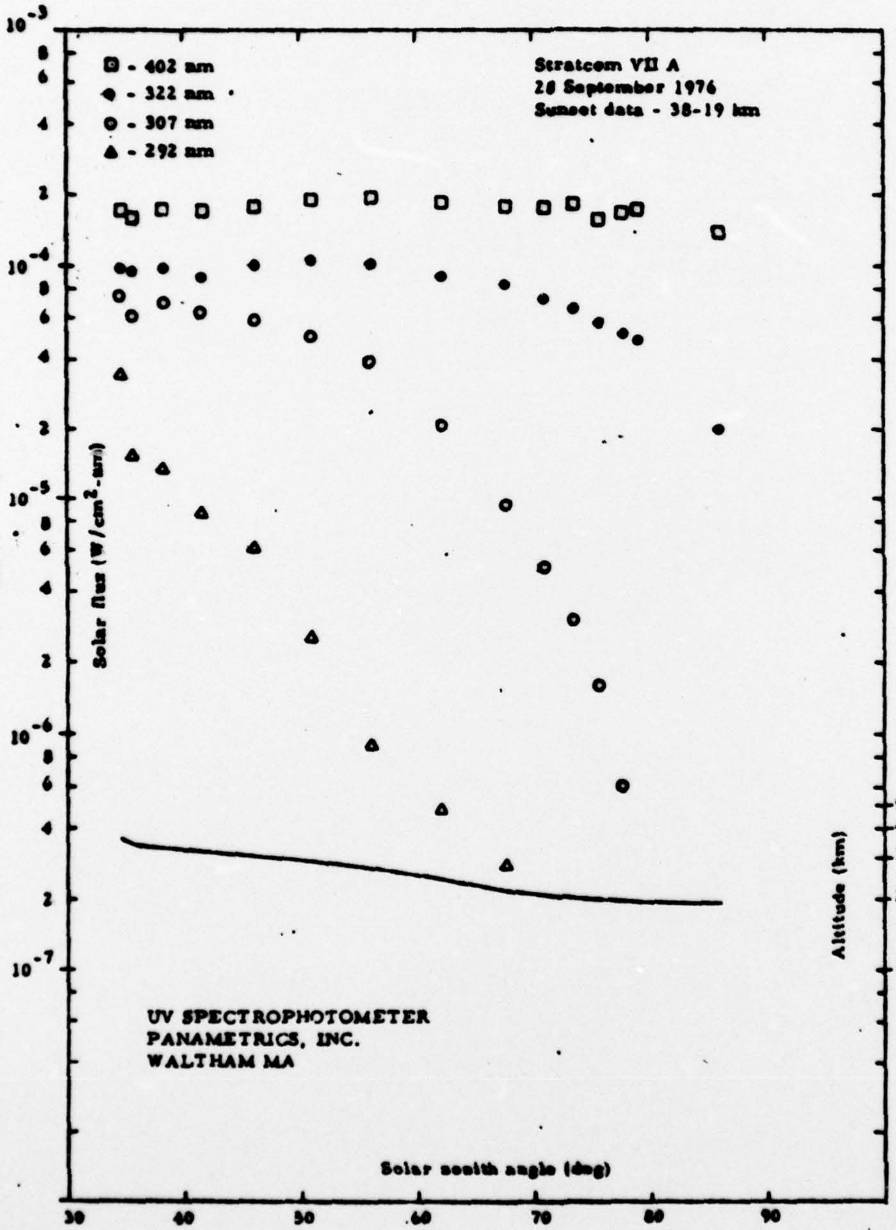

Fig. 2. Plots of Solar Flux at Four Wavelengths vs Solar Zenith Angle for Descent/Sunset of Stratcom VII-A on 28 September 1976.

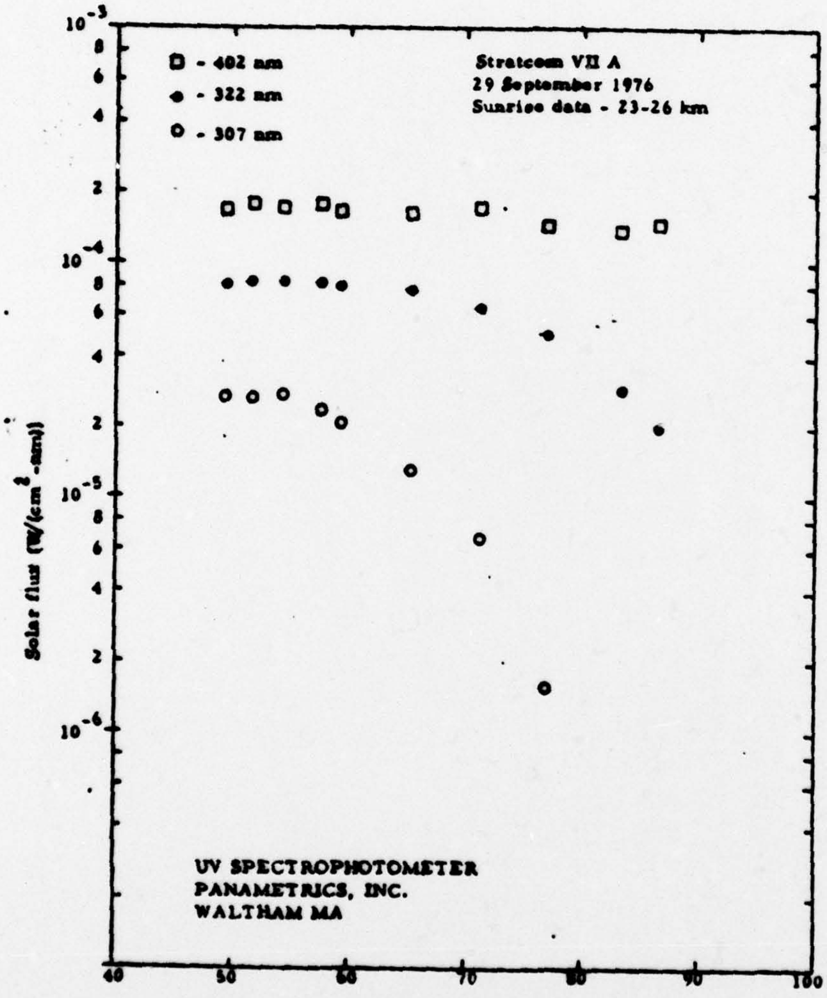

Fig. 3. Plots of Solar Flux at Three Wavelengths vs Solar Zenith Angle for Sunrise on 29 September 1976.

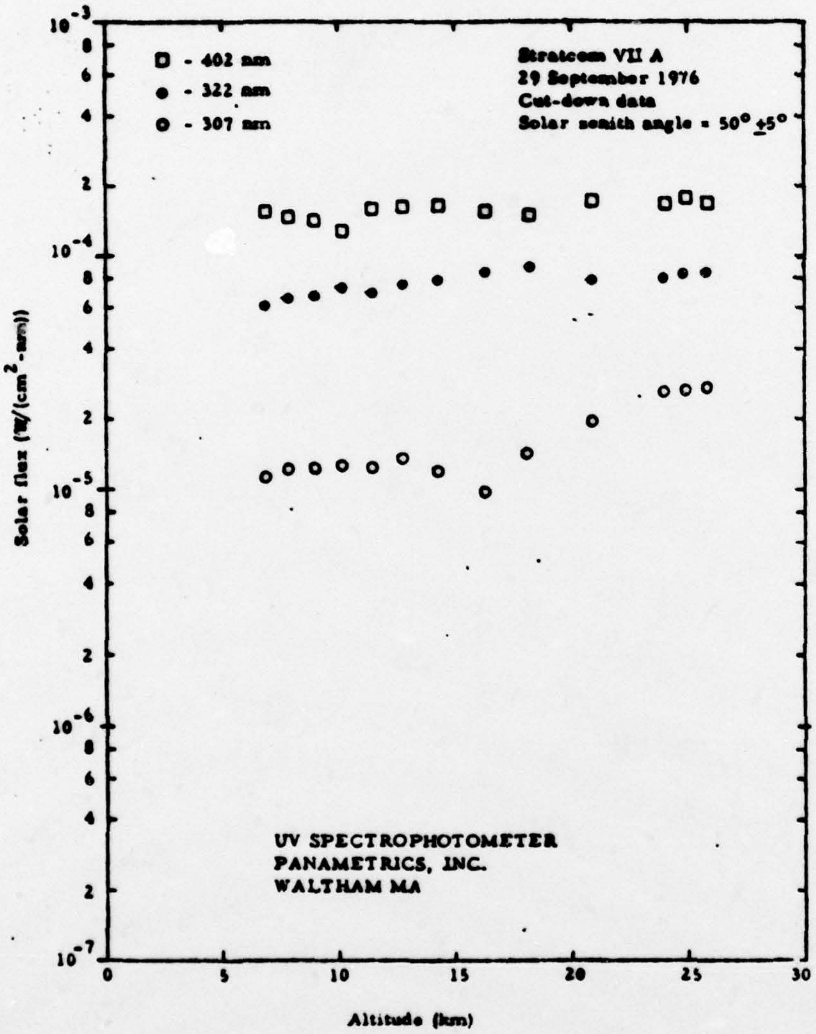

Fig. 4. Plots of Solar Flux at Three Wavelengths vs Altitude for Stratcom VII-A Cut-Down on 29 September 1976.

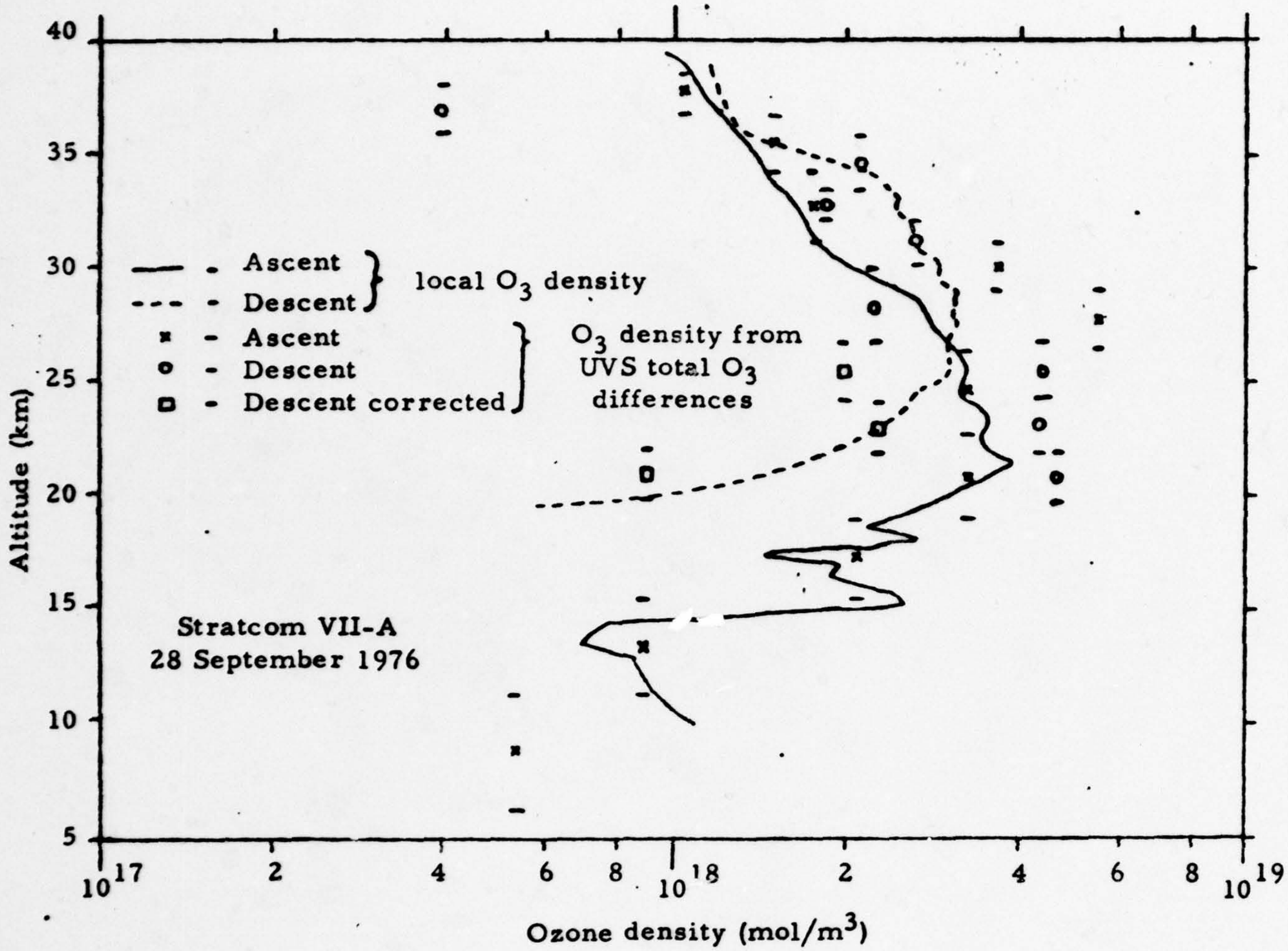

Fig. 5. Plots of Vertical Ozone Density Profiles Measured on Strat com VII-A on 28 September 1976.

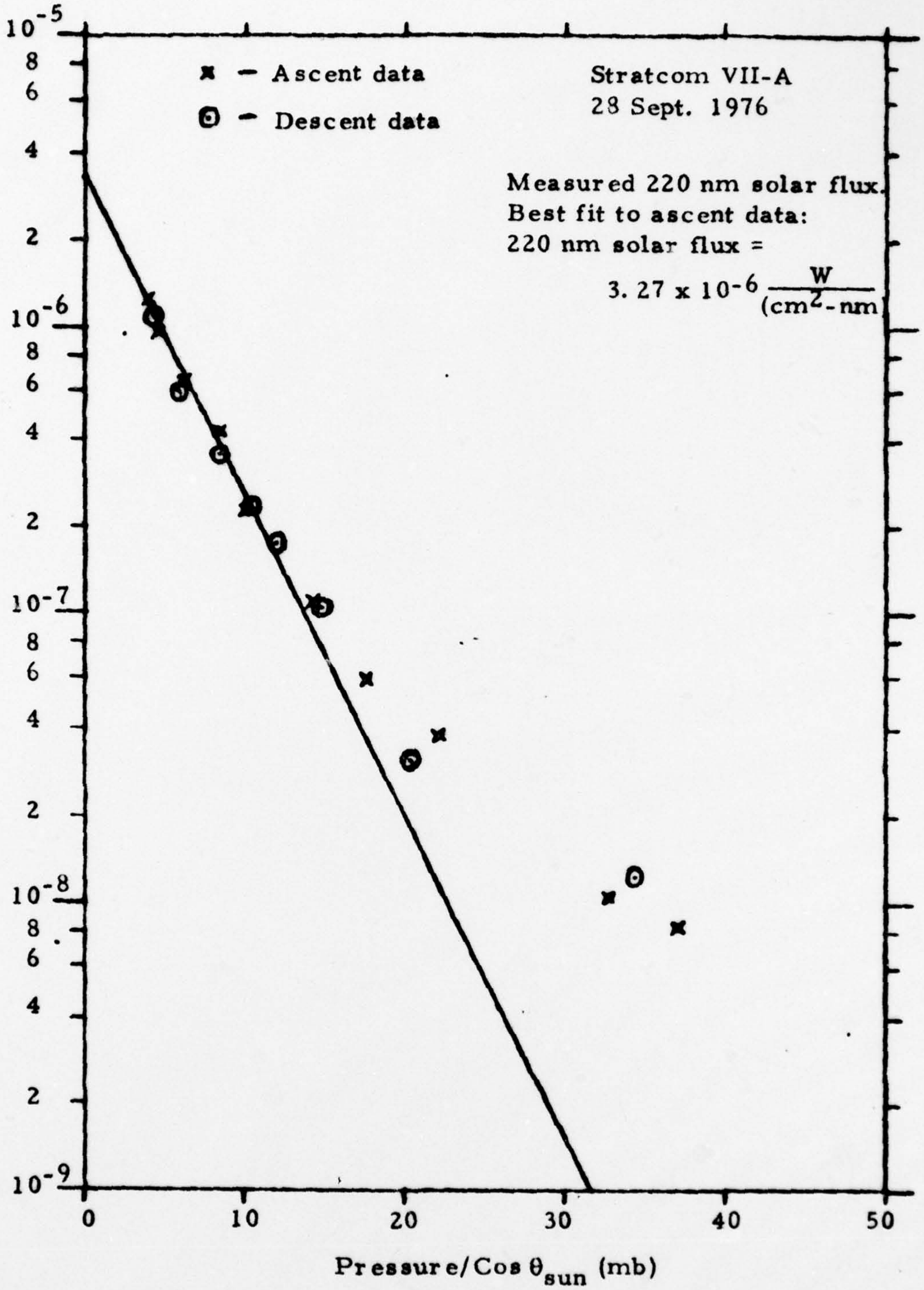

Fig. 6. Plot of UVS Measured 220 nm Solar Flux vs Attenuation Pathlength in Atmosphere.

Table 6

Ozone Densities Derived from UVS Measured Ozone Thicknesses During Ascent on 28 September 1976

MST (hrs-min)	Solar zenith angle (deg)	Total ozone above the balloon (atm-cm)	Altitude (km)	Average altitude (km)	Altitude interval (km)	Average ozone density for alt. int. (10^{17} mol/m^3)
0745	68.4	0.276	6.22			
				8.73	5.01	5.4
0800	65.2	0.266	11.23			
				13.36	4.25	8.9
0815	62.0	0.252	15.48			
				17.21	3.46	21.0
0830	59.2	0.225	18.94			
				20.79	3.70	32.7
0845	56.4	0.180	22.64			
				24.50	3.72	32.5
0900	53.8	0.135	26.36			
				27.66	2.60	55.4
0910	52.0	0.0814	28.96			
				30.05	2.17	37.8
0918	50.7	0.0517	31.13			
				32.69	3.12	17.7
0930	48.7	0.0312	34.25			
				35.48	2.46	15.1
0943	46.6	0.0174	36.71			
				37.62	1.82	10.9
1009	43.0	0.0100	38.53			

Table 7

Ozone Densities Derived from UVS Measured
Ozone Thicknesses During Descent on 28 September 1976

MST (hrs-min)	Solar zenith angle (deg)	Total ozone above the balloon (atm-cm)	Altitude (km)	Average altitude (km)	Altitude interval (km)	Average ozone density for alt. int. (10^{17} mol/m^3)	Ozone density corrected for vertical air motion* (10^{17} mol/m^3)
1103	36.9	0.0111	38.09				
				36.97	2.25	3.9	-
1203	34.7	0.0144	35.84				
				34.65	2.39	21.1	-
1232	34.8	0.0332	33.45				
				32.79	1.32	18.5	-
1318	40.1	0.0423	32.13				
				31.12	2.02	26.6	-
1418	48.7	0.0623	30.11				
				28.41	3.40	22.7	-
1501	56.1	0.0910	26.71				
				25.51	2.40	44.7	19.9
1534	62.2	0.1309	24.31				
				23.08	2.47	43.3	22.8
1602	67.7	0.1707	21.84				
				20.98	1.72	46.7	9.1
1638	75.0	0.2006	20.12				

*The correction is made by assuming air containing 30×10^{17} mol/m^3 of ozone moves vertically upward past the balloon at 1 m/sec. The amount of ozone transported above the balloon during the measurement time interval is then subtracted from the measured ozone thickness difference to calculate a corrected ozone density. This approximate correction is calculated for only the three lowest altitude densities.

Table 8

Solar Flux at 220 nm vs Solar Activity

Solar Flux at 220 nm ($\pm$5 nm) (W/(cm^2-nm))	Zürich Sunspot Number	Ottawa 2800 MHz Solar Flux (10^{-22} W/(m^2-Hz))	Date of measurement DD/MM/YY	Data source and comments
3.27×10^{-6}	18	73.6	28/9/76	Present results
4.19×10^{-6}	0	76.8	24-25/9/75	[2], as corrected here
4.39×10^{-6}	33	89.5	16/5/73	[10] - average separated
4.91×10^{-6}	65	125.2	23/9/72	
9.16×10^{-6}	115	139.5	10/5/68, 19/4/69, 3/10/69	[11] - averages for all three dates
5.78×10^{-6}	168	209.2	15/6/70	[12]

Conclusions

The UV Spectrophotometer operated properly at all times on the Stratcom VII-A balloon flight. Use of the conical diffuser and vertical orientation significantly improved data collection by eliminating problems associated with the sun-pointing platform. Vertical profiles of solar UV fluxes were measured on ascent and descent/sunset on 28 September 1976, and after cut-down on 29 September. Solar flux vs solar zenith angle was measured for sunrise at 24-26 km on 29 September.

The ascent and descent total ozone values derived from the UVS measured fluxes on 28 September allow the calculation of ozone densities which are in good agreement with the locally measured densities, after correction for assumed vertical air motions during the balloon descent period. While more complex explanations might be possible, this simple assumption of a vertical air rise is also consistent with other Stratcom VII measurements. The ascent data on 28 September give a 220 nm solar flux of 3.27×10^{-6} W/(cm^2-nm), in reasonable agreement with the corrected Stratcom VI-A measurement of 4.19×10^{-6} W/(cm^2-nm). Comparison with other 220 nm flux measurements shows possible dependence on solar activity as measured by sunspot number or 2800 MHz flux.

References

1. F. A. Hanser, B. Sellers and J. L. Hunerwadel, Design, Fabrication and Flight of a UV Spectrophotometer Aboard a WB57F High Altitude Aircraft for the CIAP Flight Series, Report PANA-UVS-7, Summary Report for Contract No. N00014-73-C-0316 (December, 1975).

2. B. Sellers, F. A. Hanser, and J. L. Hunerwadel, Stratcom VI-A UV Flux and 30-65 km Low-Background Betasonde Air Density Measurements, Report PANA-AIR-1, Final Report for Contract No. DAAD07-75-C-0124 (July, 1976).

3. F. S. Rowland and M. J. Molina, Chlorofluoromethanes in the Environment, Rev. Geophys. Space Phys. 13, 1-35 (1975).

4. B. Sellers, F. A. Hanser, and J. L. Hunerwadel, Design, Fabrication and Flight of an Ultraviolet Interference-Filter Spectrophotometer Aboard a WB57F High Altitude Aircraft, Report PANA-UVS-1, Annual Report for Contract No. N00014-73-C-0316 (October, 1973).

5. F. A. Hanser and B. Sellers, Solar UV Fluxes and Ozone Overburdens Obtained from UVS Measurements on the CIAP Airstream Flight Series of June 1973, September 1973, November 1973, and January 1974, Report PANA-UVS-4, Annual Report for Contract No. N00014-73-C-0316 (August, 1974).

6. J. Randhawa, M. Izquierdo, Z. Salpeter, and C. McDonald, Stratospheric Ozone Density as Measured by Chemiluminescent Sensors During the Stratcom VII-A Flight, EOS, Trans. Am. Geophys. Union 58, 452 (1977).

7. H. Carrasco, and G. Cordoba, Vertical Velocities of the Stratcom VII-A Balloon Calculated from Radar Data, EOS, Trans. Am. Geophys. Union 58, 451 (1977).

8. M. Izquierdo, H. Ballard, and J. Randhawa, A Qualitative Interpretation of the Ozone Number Density and Temperature Profiles Measured Aboard Stratcom VII-A as Related to Indicated Atmospheric Vertical Transport, EOS, Trans. Am. Geophys. Union 58, 452 (1977).

9. M. Ackerman, Ultraviolet Solar Radiation Related to Mesospheric Processes, in G. Fiocco, ed., Mesopheric Models and Related Experiments, 149, Reidel, Holland (1971).

References (cont'd)

10. P. Simon, Balloon Measurements of Solar Fluxes between 1960Å and 2300Å, in Proceedings of the Third Conference on the Climatic Impact Assessment Program, A. J. Broderick and T. M. Hard, Editors, DOT-TSC-OST-74-15, 137 (November 1974).

11. M. Ackerman, D. Frimount, and R. Pastiels, New Ultraviolet Solar Flux Measurements at 2000Å using a Balloon Borne Instrument, in New Techniques in Space Astronomy, Labuhn and Lust, Eds., 251, Reidel, Dordrecht, Holland (1971).

12. A. L. Broadfoot, The Solar Spectrum 2100-3200Å, in Astrophys. J. 173, 681-9 (1972).

13. Solar-Geophysical Data, issued monthly by U.S. Dept. of Commerce, NOAA, Environmental Data Service, Boulder, Colorado.