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Dobson Spectrophotometer Ozone Measurements during International Ozone Rocketsonde Intercomparison

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ABSTRACT

From October 20, 1979, to November 4, 1979, intensive measurements of the total ozone (O_3) content of the atmosphere were made with seven (7) ground-based instruments at a site near Wallops Island, Virginia. These were collected in support of the International Ozone Rocketsonde Intercomparison (IORI) conducted by NASA's Wallops Flight Center during this period. The total ozone amounts sensed by the ground instruments will serve as control values with which the rocketborne sensor data products can be compared. These products are profiles of O_3 concentration with altitude. By integrating over the range of altitudes from the surface to the rocket apogee and by appropriately estimating the residual ozone amount from apogee to the top of the atmosphere, a total ozone amount can be computed from the profiles that can be directly compared with the ground-based instrumentation results.

Because of the long history of testing, field usage, and data analysis associated with the Dobson spectrophotometer, one of the ground-based instruments, it is the device considered the standard in the field of ozonometry. Two such instruments were included in the complement of seven. This report contains preliminary data collected during the IORI from Dobson spectrophotometers 72 and 38. The agreement between the two and the variability of total ozone overburden through the experiment period are discussed. Final results from the other ground-based instruments will be published at a later date.

INTRODUCTION

This report contains preliminary Dobson spectrophotometer total ozone overburden (O_3) measurements collected at NASA Wallops Flight Center's Atmospheric Physics Measurement Laboratory during the International Ozone Rocketsonde Intercomparison (IORI). Its intent is to report these preliminary results to the experimenters participating in the IORI and to other interested parties in a timely fashion to facilitate the comparison of ground-based and in situ measurements.

Two Dobson instruments were utilized in the support of the IORI. Measurements were made on the direct sun, on the zenith, and on the moon during the sixteen (16) day extent of the experiment. Additionally, Umkehr profile data were taken with both instruments. The results from these various measurements contained in this document are preliminary only and are subject to refinement.

BACKGROUND

Part of the rationale for staging the International Rocket Ozonesonde Intercomparison at NASA's Wallops Flight Center (WFC) was the presence of an ongoing intercomparison of ground-based total ozone overburden instruments at the facility. Entitled the Total Ozone Photometer Intercomparison (TOPIC), this experiment consists of an evaluation for a period of at least one year of five different total ozone sensors. Its purpose is to determine the influence of environmental, atmospheric, and operational conditions on the performance of these instruments. The devices include the Dobson spectrophotometer, the Canadian Brewer Spectrophotometer, the University of Canterbury, New Zealand, filter photometer, the SenTran Company filter photometer, and the Soviet Union's M-83 ozonometer. Information gathered during the experiment will be used for two purposes. First, it will enable satellite ozone sensor scientists to reconcile historical data base differences between the Soviet Union's M-83 ozonometer network and the Dobson spectrophotometer network. Secondly, one of the instruments may emerge as a viable candidate for use as an alternative to the Dobson instrument. Long considered the standard in the field of ozonometry, the Dobson is expensive, quite bulky, and utilizes old technology. If one of the other TOPIC instruments consistently performs in acceptable agreement with the Dobson then it may be used to augment the existing Dobson network.

The TOPIC experiment was begun in April, but the intensive period of data collection began in early October with the arrival of the M-83 ozonometer. The standard for comparison in TOPIC is Dobson #72, a well-maintained instrument that has been operated at WFC since 1967. For several years, it has been known that the instrument produces erroneous answers for low sun elevation angles. Expressed in terms of a parameter called the air mass defined to be the secant of the solar zenith angle, Dobson #72 measurements have been found to be unreliable for an air mass of 2.5 or greater. This is normally not a problem because good direct sun measurements of total ozone overburden can be made for lower air mass values. In support of IORI, however, this was a deficiency.

To gather the most extensive data set possible, the IORI project team desired the acquisition of Umkehr profile data from the WFC Dobson. This inversion technique in its standard form requires the measurement of relative intensity at the zenith with the A, C, and D Dobson wavelength pairs of channels as the sun traverses between solar zenith angles of 60° and 90°. The Dobson #72 high air mass problem therefore cast doubts on the instrument's ability to collect the total measurement complement required by the IORI. To rectify this deficiency in the ground-based instrumentation ensemble, the Geophysical Monitoring for Climatic Change (GMCC) group within NOAA's Environmental Research Laboratories, Boulder, Colorado, sent their travelling unit, Dobson #38, to WFC to support the IORI.

It arrived on site on October 1 and was subsequently calibrated using standard lamp and mercury lamp tests and was ready for usage at the opening of the IORI window on October 20, 1979. This report contains only the data collected from the two Dobson instruments. This is for several reasons. First and foremost, the Dobson is recognized throughout the world as a reliable and accurate instrument usable operationally. The other TOPIC sensors are still in development and are subject to modification pending the results of TOPIC. At a later date, the measurements from them will be published in comparison with the Dobson values contained in this report. Additionally, only Dobson results are acceptable by the IORI experimenters as being the "real" values. Differences between the ground-based sensors should be and is the subject of TOPIC, and not of IORI.

DESCRIPTION OF DOBSON IORI SUPPORT OPERATIONS

IORI consisted of four segments each containing three different principle rocket types. On the Nike-Orion vehicle were the payloads from the countries of Japan, India, Australia, and Canada. The Super Loki rocket carried the optical ozonesonde package developed by Arlin Krueger of NASA's Goddard Space Flight Center (GSFC), and the chemiluminescent payload of Ernest Hilsenrath was launched by Super Arcas vehicles. These six *in situ* profiling instruments formed the nucleus of the IORI experiment. Electrochemical Concentration Cell (ECC) balloon-sonde flights and standard meteorological rocket flights were included to complement the ozone rocketsonde flights.

The four IORI segments were called the TRIAD experiment, the sunrise experiment, the sunset experiment, and the night-time experiment. The former was designed to include three sets of the three principle rocket/payload types. The sunrise experiment was designed to include two sets of the three types, the sunset experiment one set, and the night-time episode to include only the chemiluminescent payload and the Australian payload. The reader is referred to the IORI Project Planning Document dated October 1979 for more information concerning the design of the IORI experiments (contact the WFC Field Measurements Support Office for this document). Tables I, II, III, and IV contain the actual launch times of the balloon and rocket flights for each of the four experiments, respectively.

TABLE I. TRIAD EXPERIMENT SCHEDULE 10/21/79

Launch Time GMT	Vehicle/Payload
1034	Balloon/ECC Ozonesonde
1203	Balloon/ECC Ozonesonde
1430	Super Loki/Datasonde
1445	Super Loki/Sphere
1530	Nike Orion/International Ozonesondes
1537	Super Arcas/Chemiluminescent Ozonesonde
1548	Super Loki/Optical Ozonesonde
1625	Nike Orion/International Ozonesondes
1630	Super Arcas/Chemiluminescent Ozonesonde
1635	Super Loki/Optical Ozonesonde
1715	Super Arcas/Chemiluminescent Ozonesonde
1732	Super Loki/Optical Ozonesonde
1748	Nike Orion/International Ozonesondes
1829	Balloon/ECC Ozonesonde
1851	Super Loki/Sphere
1959	Balloon/ECC Ozonesonde
1621	NIMBUS-7 SBUV Orbit 5009 (.56° E of Wallops)

TABLE II. MORNING EXPERIMENT SCHEDULE 11/1/79

Launch Time GMT	Vehicle/Payload
0829	Balloon/ECC Ozonesonde
1001	Balloon/ECC Ozonesonde
1200	Super Loki/Datasonde
1300	Nike Orion/International Ozonesondes
1316	Super Loki/Optical Ozonesonde
1345	Nike Orion/International Ozonesondes
1355	Super Loki/Optical Ozonesonde
1505	Super Loki/Optical Ozonesonde
1515	Balloon/ECC Ozonesonde
1520	Super Loki/Datasonde
1621	NIMBUS-7 SBUV Orbit 5161 (.47°E of Wallops)

TABLE III. EVENING EXPERIMENT SCHEDULE 11/1/79

Launch Time GMT	Vehicle/Payload
1734	Balloon/ECC Ozonesonde
1900	Balloon/ECC Ozonesonde
2000	Super Loki/Sphere
2030	Super Loki/Optical Ozonesonde
2049	Super Loki/Optical Ozonesonde
2140	Nike Orion/International Ozonesondes
2202	Super Loki/Datasonde
2254	Balloon/ECC Ozonesonde
0052 (11/2/79)	Balloon/ECC Ozonesonde
2139	SAGE at tangent altitude 0 km

TABLE IV. NIGHT-TIME EXPERIMENT SCHEDULE 11/4/79

Launch Time GMT	Vehicle/Payload
0433	Balloon/ECC Ozonesonde
0625	Balloon/ECC Ozonesonde
0736	Super Loki/Datasonde
0850	Super Arcas/Chemiluminescent Ozonesonde
0925	Super Arcas/Chemiluminescent Ozonesonde
0930	Orion/3 Australian Ozonesondes
1000	Balloon/ECC Ozonesonde
1000	Super Arcas/Chemiluminescent Ozonesonde
1040	Super Loki/Datasonde
1054	Super Loki/Datasonde
1214	Balloon/ECC Ozonesonde
0245	DMSP Satellite 240 km from WFC

DOBSON SPECTROPHOTOMETER DATA

All four experiments were supported by the TOPIC instrumentation and the two Dobson spectrophotometers. Because of the time span separating the TRIAD experiments from the others, Dobson measurements were requested for the intervening days as well. All of the results from Dobson #72 are tabulated in Table V and those from #38 are found in Table VI. Asterisks connote observations on a cloudy zenith and the notation "m" indicates observations on the moon during the night-time experiment.

Tables VII and VIII contain Umkehr profiles of ozone partial pressure (P_3) collected on October 21 and November 1, respectively. On the former occasion, one profile was produced by both Dobson #72 and #38. These measurements were immediately sent to Carl Mateer of the Canadian Atmospheric Environment Service for processing. The algorithm used was the shortened version of the Umkehr method described by DeLuisi (1979) which has the distinct advantage that an Umkehr profile can be collected on the same afternoon or morning with direct sun observations. Only solar zenith angles of 80° to 90° are needed rather than the customary 60° to 90°. For the IORI sunrise and sunset experiments, a standard Umkehr would have eliminated the use of the Dobson for the more necessary total ozone measurements. For instrument #72, the residuals between successive iterations

TABLE V. DOBSON #72 DATA

10/20/79 GMT	μ	Ω(DU)
1500	1.699	290.0*
1640	1.494	286.0
1700	1.495	293.0
1736	1.533	285.0
1748	1.556	286.0
1754	1.570	282.0
1800	1.585	268.0
1806	1.601	285.0
1900	1.839	288.0
1924	2.015	290.0
2000	2.418	294.0

10/21/79 GMT	μ	Ω(DU)
1300	3.092	284.0
1330	2.488	288.0
1343	2.308	312.0
1354	2.178	286.0
1412	2.007	283.0
1425	1.908	285.0
1436	1.836	290.0
1442	1.801	283.0
1448	1.769	282.0
1500	1.711	283.0
1515	1.653	281.0
1524	1.622	283.0
1530	1.605	281.0
1536	1.588	281.0
1542	1.574	282.0
1548	1.561	281.0
1554	1.549	279.0
1600	1.539	280.0
1609	1.526	276.0
1619	1.515	281.0
1630	1.507	279.0
1636	1.504	278.0
1642	1.503	278.0
1651	1.503	280.0
1706	1.509	280.0
1713	1.515	281.0
1725	1.528	281.0
1730	1.535	280.0
1742	1.555	282.0
1748	1.568	280.0
1800	1.597	280.0
1812	1.632	278.0
1830	1.699	280.0
1842	1.754	279.0
1854	1.819	279.0
1900	1.855	279.0
1918	1.984	281.0
1930	2.089	282.0

10/22/79 GMT	μ	Ω(DU)
1315	2.778	274.0
1406	2.077	284.0
1500	1.724	281.0
1600	1.550	283.0
1700	1.516	283.0
1800	1.609	285.0
1900	1.872	289.0
2000	2.474	290.0

10/23/79 GMT	μ	Ω(DU)
1310	2.919	289.0
1402	2.133	289.0
1500	1.737	289.0
1600	1.56	285.0
1712	1.535	285.0
1806	1.639	290.0
1915	1.998	295.0

10/24/79 GMT	μ	Ω(DU)
1315	2.841	283.0
1400	2.172	308.0
1500	1.750	303.0
1554	1.582	303.0
1722	1.527	319.0*
1900	1.905	317.0*

10/25/79 GMT	μ	Ω(DU)
1354	2.256	301.0
1500	1.763	303.0
1618	1.559	309.0
1700	1.549	309.0
1807	1.667	316.0
1900	1.922	318.0

TABLE V. DOBSON # 72 DATA (continued)

10/26/79 GMT	μ	Ω(DU)	10/27/79 GMT	μ	Ω(DU)	10/28/79 GMT	μ	Ω(DU)
1333	2.566	349.0	1500	1.790	339.0	1500	1.804	291.0
1406	2.149	357.0	1700	1.571	325.0	1700	1.582	288.0
1500	1.776	353.0	1900	1.956	302.0	1900	1.973	264.0*
1604	1.588	351.0						
1700	1.560	353.0						
1803	1.668	354.0						
1856	1.912	363.0						
1944	2.357	362.0						

10/29/79 GMT	μ	Ω(DU)	10/30/79 GMT	μ	Ω(DU)	10/31/79 GMT	μ	Ω(DU)
1346	2.445	262.0	1354	2.363	256.0	1343	2.567	264.0
1500	1.818	256.0	1506	1.803	254.0	1457	1.861	267.0
1600	1.628	254.0	1606	1.630	254.0	1556	1.659	223.0*
1700	1.592	253.0	1730	1.638	261.0	1700	1.616	222.0*
1900	1.991	259.0	1800	1.710	261.0	1800	1.723	277.0*
2000	2.678	274.0	1900	2.008	263.0	1900	2.025	283.0*
2018	3.048	262.0	2000	2.709	265.0			

11/1/79 GMT	μ	Ω(DU)	11/2/79 GMT	μ	Ω(DU)
1330	2.782	264.0	1400	2.356	261.0
1348	2.489	275.0	1500	1.875	266.0
1400	2.334	274.0	1600	1.676	266.0
1412	2.205	274.0			
1424	2.096	279.5			
1436	2.004	273.0			
1448	1.926	271.0			
1500	1.860	271.0			
1503	1.846	272.0			
1524	1.758	271.0			
1536	1.720	271.0			
1550	1.683	272.0			
1600	1.664	273.0			
1700	1.628	276.0			
1800	1.736	282.0			
1824	1.828	277.0			
1836	1.888	278.0			
1842	1.922	277.0			
1854	1.999	277.0			
1912	2.142	280.0			
1926	2.281	280.0			
1936	2.399	280.0			
1948	2.567	280.0			
2000	2.770	279.0			

TABLE VI. DOBSON #38 DATA

10/20/79			10/21/79			10/23/79		
GMT	μ	Ω(DU)	GMT	μ	Ω(DU)	GMT	μ	Ω(DU)
1638	1.494	289.0	1330	2.488	289.0	1442	1.828	290.0
1700	1.495	294.0	1336	2.400	289.0	1512	1.687	291.0
1736	1.533	293.0	1354	2.178	290.0	1608	1.548	291.0
1742	1.544	289.0	1400	2.116	292.0	1712	1.535	291.0
1748	1.556	290.0	1412	2.007	289.0	1806	1.639	290.0*
1754	1.570	292.0	1424	1.915	287.0	1915	1.998	294.0
1806	1.601	286.0	1430	1.874	287.0			
			1436	1.836	286.0			
			1442	1.801	286.0			
			1448	1.769	288.0			
			1454	1.739	281.0			
			1500	1.711	282.0			
			1506	1.686	292.0			
			1512	1.663	280.0			
			1518	1.642	285.0			
			1524	1.622	284.0			
			1532	1.599	235.0			
			1536	1.588	285.0			
			1542	1.574	285.0			
			1548	1.561	285.0			
			1554	1.549	273.0			
			1600	1.539	294.0			
			1606	1.530	287.0			
			1618	1.516	283.0			
			1624	1.511	283.0			
			1630	1.507	283.0			
			1636	1.504	286.0			
			1642	1.503	283.0			
			1648	1.503	286.0			
			1654	1.504	285.0			
			1700	1.506	284.0			
			1706	1.509	285.0			
			1712	1.514	288.0			
			1718	1.519	284.0			
			1724	1.526	282.0			
			1730	1.535	282.0			
			1736	1.544	283.0			
			1742	1.555	284.0			
			1748	1.568	283.0			
			1754	1.581	284.0			
			1800	1.597	283.0			
			1806	1.614	287.0			
			1812	1.632	288.0			
			1818	1.653	285.0			
			1824	1.675	285.0			
			1830	1.699	284.0			
			1842	1.754	283.0			
			1848	1.785	282.0			
			1900	1.855	282.0			
			1912	1.938	282.0			
			1924	2.034	282.0			
			1930	2.089	282.0			

TABLE VI. DOBSON #38 DATA (continued)

10/25/79			10/26/79			10/29/79		
GMT	μ	Ω(DU)	GMT	μ	Ω(DU)	GMT	μ	Ω(DU)
1520	1.696	306.0	1406	2.149	357.0	1500	1.818	262.0
1708	1.554	317.0	1500	1.776	359.0	1659	1.594	259.0
1821	1.718	319.0	1628	1.562	358.0	1900	1.991	263.0
1854	1.916	321.0	1706	1.563	358.0	2000	2.678	263.0
			1807	1.670	362.0	2018	3.048	262.0

11/1/79			11/2/79			11/4/79		
GMT	μ	Ω(DU)	GMT	μ	Ω(DU)	GMT	μ	Ω(DU)
1306	3.351	268.0	1500	1.875	269.0	0339	1.175	264.0 m
1348	2.489	274.0	1600	1.676	268.0	0347	1.165	281.0 m
1400	2.334	273.0	1700	1.640	277.0	0355	1.156	301.0 m
1412	2.205	274.0	1800	1.749	278.0	0403	1.148	281.0 m
1424	2.096	275.0				0411	1.142	279.0 m
1436	2.004	275.0				0432	1.131	277.0 m
1448	1.926	274.0				0440	1.129	273.0 m
1500	1.860	274.0				0445	1.128	289.0 m
1512	1.805	275.0				0450	1.128	282.0 m
1524	1.758	272.0				0539	1.149	287.0 m
1536	1.720	277.0				0555	1.165	279.0 m
1550	1.683	276.0				0712	1.330	286.0 m
1600	1.664	277.0				0754	1.505	282.0 m
1700	1.628	278.0				0801	1.542	284.0 m
1800	1.736	278.0				1500	1.905	274.0
1812	1.778	281.0				1700	1.663	274.0
1824	1.828	281.0				1900	2.096	277.0
1836	1.888	281.0						
1848	1.959	282.0						
1900	2.043	281.0						
1912	2.142	281.0						
1924	2.259	282.0						
1936	2.399	281.0						
1948	2.567	280.0						
2002	2.806	285.0						
2012	3.018	280.0						
2024	3.328	279.0						
2036	3.721	274.0						

TABLE VII. 10/21/79 UMKEHR DISTRIBUTIONS

Layer Number	Pressure Range (mb)	Instrument #72 P_3(nb)	Instrument #38 P_3(nb)
16	1000-500	26.96	29.23
15	500-250	16.74	18.07
14	250-125	21.76	23.90
13	125-62.5	45.96	49.14
12	62.5-31.25	105.80	110.30
11	31.25-16.125	120.20	119.40
10	16.125-8.06	95.05	84.87
9	8.06-4.03	56.48	48.32
8	4.03-2.01	22.17	22.40
7	2.01-1.0	5.45	6.34
6	1.0-0.5	1.42	1.66
5	0.5-0.25	0.49	0.54
4	0.25-0.125	0.16	0.17
3	0.125-0.062	0.04	0.04
2	0.062-0.031	0.01	0.01
1	0.031-0.015	0.00	0.00
Solution Total Ozone		.2839 atm-cm	.2815 atm-cm

TABLE VIII. 11/1/79 UMKEHR DISTRIBUTIONS

Instrument #38

Layer Number	Pressure Range (mb)	Morning P_3(nb)	Evening P_3(nb)
16	1000-500	28.32	35.06
15	500-250	16.58	22.09
14	250-125	23.25	33.78
13	125-62.5	50.34	59.99
12	62.5-31.25	110.5	111.7
11	31.25-16.125	113.5	107.9
10	16.125-8.06	75.89	71.4
9	8.06-4.03	42.33	44.98
8	4.03-2.01	19.74	25.24
7	2.01-1.0	5.86	7.78
6	1.0-0.05	1.59	1.97
5	0.5-0.25	0.53	0.59
4	0.25-0.125	0.17	0.17
3	0.125-0.062	0.04	0.04
2	0.062-0.031	0.01	0.01
1	0.031-0.015	0.00	0.00
Solution Total Ozone		.2675 atm-cm	.2861 atm-cm

remained intolerably high, due to the aforementioned erroneous operation at air mass values in excess of 2.5. Hence, on November 1, only instrument #38 was used to gather both morning and evening Umkehr profiles.

The validity of these profiles in Table VIII is a subject of some concern. In accord with custom, the WFC observer team utilized monthly computer listings of solar air mass versus time to determine those times that the solar zenith angle corresponded to the values needed in the Umkehr data reduction algorithm. Unfortunately, a small error was present in the November printout that was not detected before its initial utilization on November 1, the date of the sunrise and sunset experiments. As a result, the data were collected at times between 3 and 6 minutes from the actual needed times. Interpolation between measurements to deduce the Dobson N-values at the correct zenith angles was difficult because measurements were only taken at the predicted times (private communication, Carl Mateer, December 1979). Measurements made at higher frequency as the solar zenith angle varied from 80° to 90° could have increased the quality of the interpolated N-values and correspondingly increased one's confidence in the resultant profiles. Nonetheless, the profiles are included in this report for completeness.

DISCUSSION

The item of paramount importance concerning the Dobson spectrophotometer is its accuracy. Therefore, with two units involved in the IORI support, it is only natural to intercompare their measurements. All Dobson instruments are calibrated monthly with their own standard and mercury lamps and should therefore always be in good agreement if they are maintained properly. For the recommended dual AD line pair combination, total ozone overburden is computed from the equation

$$\Omega_{AD} = \frac{0.7205\ (N_A - N_D)}{\mu} - 0.009\ \text{(atm-cm)}$$

where N_A and N_D are the N-values for the A and D wavelength pairs and μ is the air mass. If the N-value difference for one instrument is different than the difference for the other instrument by .01 N-value units, then the computed ozone amount will differ by at most .007 atm-cm or 7 Dobson units (D.U.).

The N-values for instruments #72 and #38 measured during this experiment have been intercompared with the following results. Figure 1 shows histograms of the difference between the $(N_A - N_D)$ values for instruments #38 and #72 for October 21, 1979, and November 1, 1979. The measurements with both were made simultaneously, and the difference

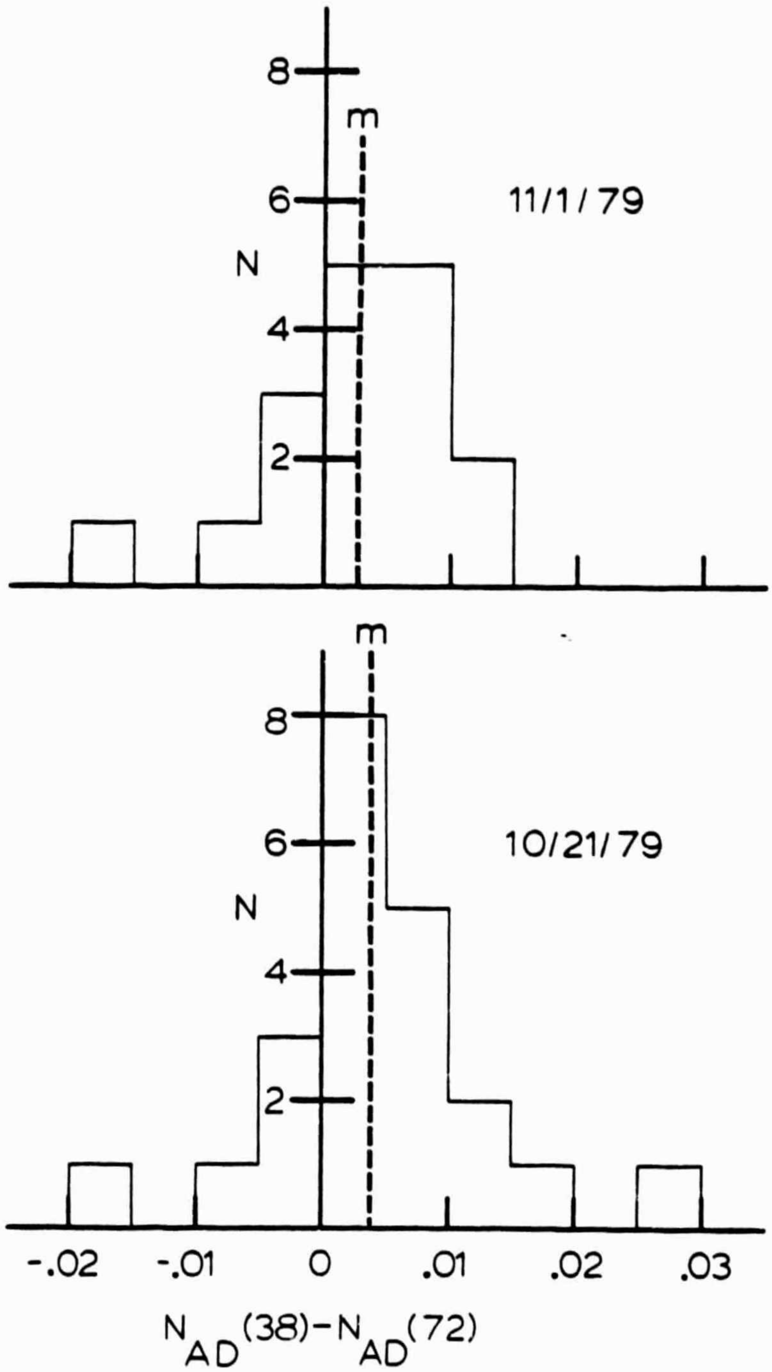

Figure 1. Histograms of the measured A-D line pair combination N-value differences between Dobson instruments 38 and 72 on October 21, 1979, and November 1, 1979. The ordinates are the number of joint coincidental measurements falling within the various bins, and m indicates the location of the distribution mean.

was taken so that a positive abscissa value indicates that $(N_A - N_D)$ for #38 exceeded the corresponding term for #72. The means and standard deviations were .0039 and .0087, respectively, for October 21, and .0026 and .0073, respectively, for November 1. A difference of .0039 N-value units corresponds to a maximum total ozone difference of 2.85 D.U. For a typical overburden value of 300 D.U. at WFC, this is an inter-instrument measurement difference of less than 1%. Therefore on the average it appears that instrument #38 measures an ozone amount about 1% in excess of that measured by #72. This difference is well below the 5% absolute accuracy level estimated by Thomas and Holland (1977) as representative of a well-maintained Dobson spectrophotometer. Finally, it should be stated that the data represented in the Figure 1 histograms were all taken at air masses at or below 2.5. Hence, the problem with Dobson #72 does not show in the illustration or the preceding discussion.

The reduction of the November 4, 1979, moon observations also merits some comment. These data were reduced following the procedures set forth by Komhyr (1962). The formula for calculating total ozone is the same as for direct sun observations. Of course, the air mass must be computed using valid moon ephemeris data and a horizontal parallax correction must be made. This effect is due to the relatively close proximity of the moon to the earth and the resultant inadequacy of the normal collimated light assumption. One other difference for the moon observation data subset is the increased scatter of the calculated ozone values caused by the much lower signal levels for the moon observations.

CONCLUSIONS

This report contains preliminary Dobson ozone spectrophotometer data collected at NASA's Wallops Flight Center in support of the International Ozone Rocketsonde Intercomparison (IORI). The ground-based data set contains measurements from two Dobson instruments, #72 and #38, during all four IORI experiments and is shown to be of high quality. The two instruments differed on the average by about 1% in terms of the total ozone amount measured.

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