X-621-68-159
PREPRINT

NASA TM X- 63264

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GPO PRICE $ ______

CFSTI PRICE(S) $ ______

Hard copy (HC) 3.00

Microfiche (MF) .65

ff 653 July 65

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MAY 1968

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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David T. Pelz

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Greenbelt, Maryland

*Presented at the 49th Annual Meeting of the American Geophysical Union, Washington, D. C., April 10, 1968

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George P. Newton and David T. Pelz

ABSTRACT

In-situ atmospheric density measurements from the Explorer 32 density gauges for the time period May through October 1966 reveal latitudinal density structure in the neutral thermosphere during geomagnetically undisturbed times. At altitudes between 400 and 700 km the densities at northern geographic latitudes (> 55°) are at least 1.5 times the equatorial densities during the daytime, and greater at night. The northern auroral zone atmospheric densities have been observed to be as much as a factor of five greater than the equatorial densities at altitudes between 450 and 600 kilometers, even on geomagnetically quiet days. These results suggest that auroral zone and high latitude heating is a permanent feature of the summer thermosphere.

CONTENTS

ILLUSTRATIONS

LATITUDINAL VARIATIONS IN THE NEUTRAL ATMOSPHERIC DENSITY

INTRODUCTION

Early conclusions regarding the latitudinal variation of the neutral thermospheric density were based on atmospheric densities derived from variations in the orbital periods of satellites. These conclusions and conclusions from previous density gauge measurement results are presented and summarized in the following paragraphs.

Lidov (1958) reported that near 225 km altitude the northern values of $\zeta_0 \sqrt{H}$ (product of density and square root of the density scale height) were roughly 1.5 times the southern values. Schilling and Whitney (1959) reported data obtained during July to November 1958 in the altitude range 257 to 270 km, and concluded that there was no appreciable variation of average density between latitudes 49°N and S. At about 50°N and S latitudes however, they observed a sharp discontinuity in the density with the northern hemisphere value about twice the southern hemisphere value, and assuming the phenomenon to be real interpreted the result to be a variation of density with latitude or time. Champion and Minzner (1959) reported preliminary results which suggested that the density in the altitude range 170 to 230 km may be lower in the summer than in the winter. Groves (1961), for altitudes below 300 km, concluded that the atmospheric density varied less than 20% with latitude except for a possible 60% increase in density near the winter pole. King-Hele and Walker (1961) concluded that there was no systematic latitudinal density variation exceeding a factor of 1.5 at heights between 200 and 600 km between latitudes 50°N to 50°S. Paetzold and Zschörner (1961) stated that a weak dependency of density on latitude and season exists such that in summer at 200 km height the polar region density is 15% higher than at lower latitudes, while in winter the density decreases by 10% towards the pole. May (1963) reported that the diurnal density variation at 205 km altitude was smaller at higher latitudes. In a later paper (May, 1964) he concluded that there was a decrease in density of approximately 30% with increasing latitudes at 1400 hours local time for altitudes below 300 km. Roemer (1966) found a latitude-dependent seasonal density variation of ±25% at 39° latitude and 690 km altitude with the greater density in the winter hemisphere. More recent findings (Keating and Prior, 1967), (Jacchia and Slowey, 1967) from satellite drag observations of satellites with perigees above 500 km, were that a winter helium bulge existed at these altitudes. Jacobs (1967) observed a daily periodicity in the accelerations of low perigee satellites (below 250 km altitude) which he attributed to an earth fixed density bulge at high latitudes.

From Explorer 17 in-situ density gauge measurements, Newton et al. (1965) concluded that between 35° and 55° northern geographic latitude the average latitude dependence of the atmospheric density has an amplitude of less than a factor of two. In a later paper (Newton, 1967) he concluded that the density at 350 km altitude was a factor of two greater at 55°N (summer 1963) than at the equator.

If consideration of the differences in solar activity due to different times in the solar cycle corresponding to the observations are neglected, the earlier conclusions may be summarized as follows. There is general agreement that the latitudinal density variation for midlatitudes is less than a factor of two, although it is uncertain what the variation is. There is disagreement as to whether the density at higher latitudes is greater than the equatorial density in summer or in winter. The magnitudes of the density variations with latitude appear to be variable and may be a function of altitude. The reasons for the differences in the observations are as yet unexplained.

Current atmospheric models describe the latitudinal density variation as that resulting essentially from a subsolar bulge with the density at a given altitude decreasing as the distance from the subsolar point increases.

We present new direct measurements from the Explorer 32 density gauges which show increased density at high northern latitudes in May to October 1966 contrary to the model atmosphere density behavior. This high latitude enhancement is believed to reflect an important source of heating of the high latitude and auroral zone thermosphere that may be a permanent feature at least in the summer hemisphere.

DENSITY EXPERIMENT AND DATA ANALYSIS

Direct, in-situ density measurements from the Explorer 32 atmospheric density experiment have been utilized in this analysis. Newton et al. (1968) have described the experiment and the density gauge response characteristics have also been reported (Pelz and Newton, 1967).

The data we have considered are shown in Table 1 and were selected for days (1) which were geomagnetically quiet or undisturbed, and (2) for which density measurements at different latitudes at common altitudes were obtained. The data cover the time period May through October 1966 and approximately one-half of the days meeting the above criteria were used in the analysis. However, the data reported are generally representative of the total data available during this time period.

Figure 1 shows the measured atmospheric density versus altitude for 8 June 1966, and is an example of a selected days data. It should be noted that turn-ons 185 through 188 all occurred within 23 minutes of real-time, a time duration short compared to expected time lapses required for atmospheric density changes.

An individual display similar to Figure 1 was constructed for the analysis of the data corresponding to each day. For the altitude ranges in which both equatorial latitude data (between ±16° geographic latitudes) and higher northern latitude data existed, the ratio of northern latitude density to equatorial density at a selected altitude was calculated. This ratio was then multiplied by a density ratio computed from the Jacchia (1964) model (0° latitude, $A_p = 3$, $F_{10.7} = 100$ units) as follows: For the selected altitude the model density corresponding to the local time of the equatorial data was divided by the model density corresponding to the local time of the northern latitude data. This procedure adjusted the equatorial data to correspond to the local time of the northern latitude data.

ACCURACY

The accuracy of the density ratios is believed to be influenced primarily by the experiment precision. The agreement between the densities measured on turn-ons 188 and 193, as seen in Figure 1, is believed to be representative of the repeatability (>90%) of the density measurements. It should be noted that these turn-ons have a region of common altitudes, latitudes and local times. Neglecting any relative composition changes in the atmosphere as a function of latitude, the density ratio error is less than 20%.

Density gauge measurement interpretation has some dependence on the atmosphere composition. The density values in Table 1 and those shown in Figure 1 were obtained by interpreting the data in terms of an atomic oxygen atmosphere, making appropriate recombination assumptions as previously discussed (Newton et al. 1965). The calculated possible impact of compositional corrections is summarized in Table 2.

Appropriate composition corrections will be applied to the data at a later date when final analysis of the Explorer 32 and other mass spectrometer results has been completed. Errors in the density ratios due to incorrect atmospheric composition assumptions could be important for altitudes above 600 km, since this altitude may be near the transition level for atomic oxygen and helium and the transition altitude may vary with latitude. However, we believe the effect of composition corrections on the conclusions of this paper are small since most of the data considered are below 600 km.

RESULTS

The local time corrected density ratios have been separated into three ten degree wide latitude bands according to the geographic latitude of the northern hemisphere data, and are shown in Figures 2-4 as a function of altitude. If the data are separated into comparable bands of geomagnetic latitude and plotted as a function of altitude, there is only a small change in the appearances of Figures 2-4. Local times corresponding to the high latitude data are coded by symbols. It should be remembered that these data cover the time period May through October 1966, during which time the monthly average $F_{10.7}$ was 100 ±22 units, and correspond to geomagnetically undisturbed times.

From Figure 2, it is seen that the low midlatitude density can be 20% greater than the equatorial density during the day for altitudes between 300 km and 400 km.

The data in Figure 3 show that the density at midlatitudes is generally greater than the equatorial density over the altitude range 300 km to 500 km. The average density ratio is near 1.3 for these altitudes.

The data in Figure 4 show the high northern latitude (55° N - 65° N geographic) density to be greater than the equatorial density. Although during the day the average density ratio is near 1.4 to 1.5 and increases at night to be near a factor of two for altitudes between 370 km and 600 km, it can, as shown, be as large as a factor of 10. Generally, the higher density ratios (greater than two) correspond to locations near the auroral zone. In particular, all density ratios greater than three correspond to the high northern latitude measurements at locations in or near the auroral zone. In two instances these larger ratios correspond to the same geomagnetically quiet day.

CONCLUSIONS AND DISCUSSIONS

Our conclusions from the above analysis are:

(1) There is a latitudinal variation greater than 30% in the neutral atmospheric density at altitudes between 300 km and 700 km for latitudes greater than 45° N geographic, with the summer northern latitude densities being greater than the equatorial densities.

(2) The northern high latitude (>55°) to equatorial latitude density ratio is smallest during the day (near 1.3) and increases at night to values greater than two.

(3) Large density ratios (>3) are observed only near or in the auroral zone. These ratios are observed even on geomagnetically quiet days.

These results are in agreement with those obtained from analysis of Explorer 17 data and reported previously (Newton et al., 1965, 1967). The early preliminary Explorer 32 data analysis conclusions (Newton, 1967) were invalidated by errors in the preliminary satellite world map which was used. Our conclusions are consistent with those of Schilling and Whitney (1959) and Paetzold and Zschörner (1961) in that the northern summer hemisphere density is greater than the equatorial density. Our observations are also in accord with the results of Jacobs (1967), although the relationship between the densities at 500 km and 200 km altitude at these latitudes is not clear.

We have not yet determined the role, if any, of a seasonal variation in these results. We are currently analyzing additional Explorer 32 data covering the time period October 1966 to January 1967, in an attempt to determine the seasonal variation of the atmospheric density. It is clear, however, that the variations observed and reported here are generally much larger in magnitude than and opposite in direction to the latitudinal behavior of the neutral thermosphere density predicted by current atmospheric models (Jacchia, 1965) (Friedman, 1967).

A possible explanation for the observed latitudinal density structure requires a general heating of the high latitude summer thermosphere even during geomagnetically quiet times. This heating is supported by a preliminary analysis (to be reported later) of the density scale heights provided by the same experiment covering the same time period. Such heating is estimated to be a significant fraction of the solar EUV heating on the basis of a comparison of the magnitude of the latitude density variation with the magnitude of the diurnal density variation. It may also be relevant to consider the latitudinal variation of the neutral thermosphere density as related to the observed light ion depletion and heavy ion abundance at high latitudes reported by Taylor, et al., (1968).

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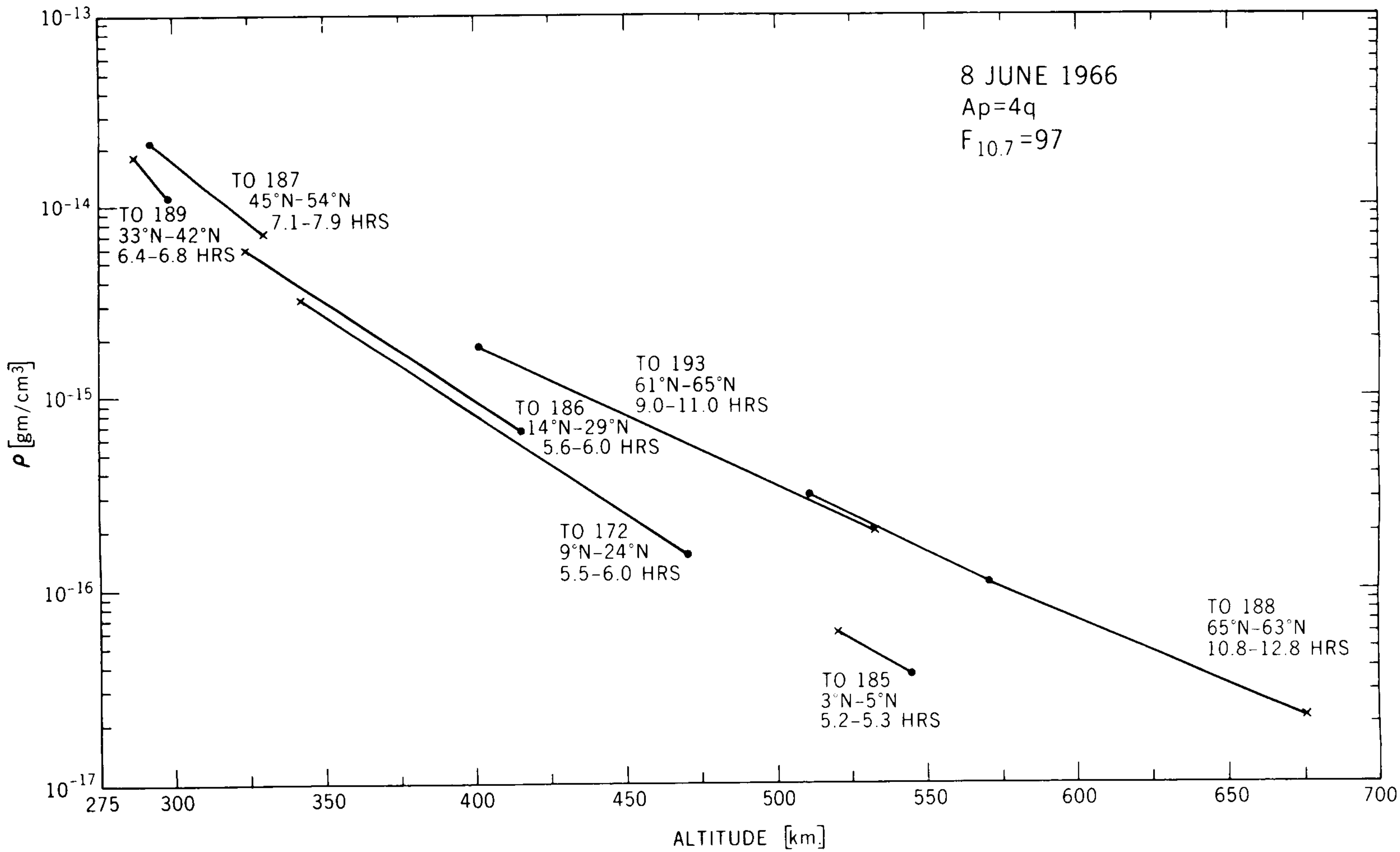

Figure 1. Atmospheric density versus altitude measured on June 8, 1966. Each line represents nearly one hundred density measurements. The turn-on number, latitude and local time ranges covered during the pass are shown beside the line. The start and end of each turn-on are represented by the circle and cross, respectively. The $F_{10.7}$ was 97 units and the A_p was 4 q.

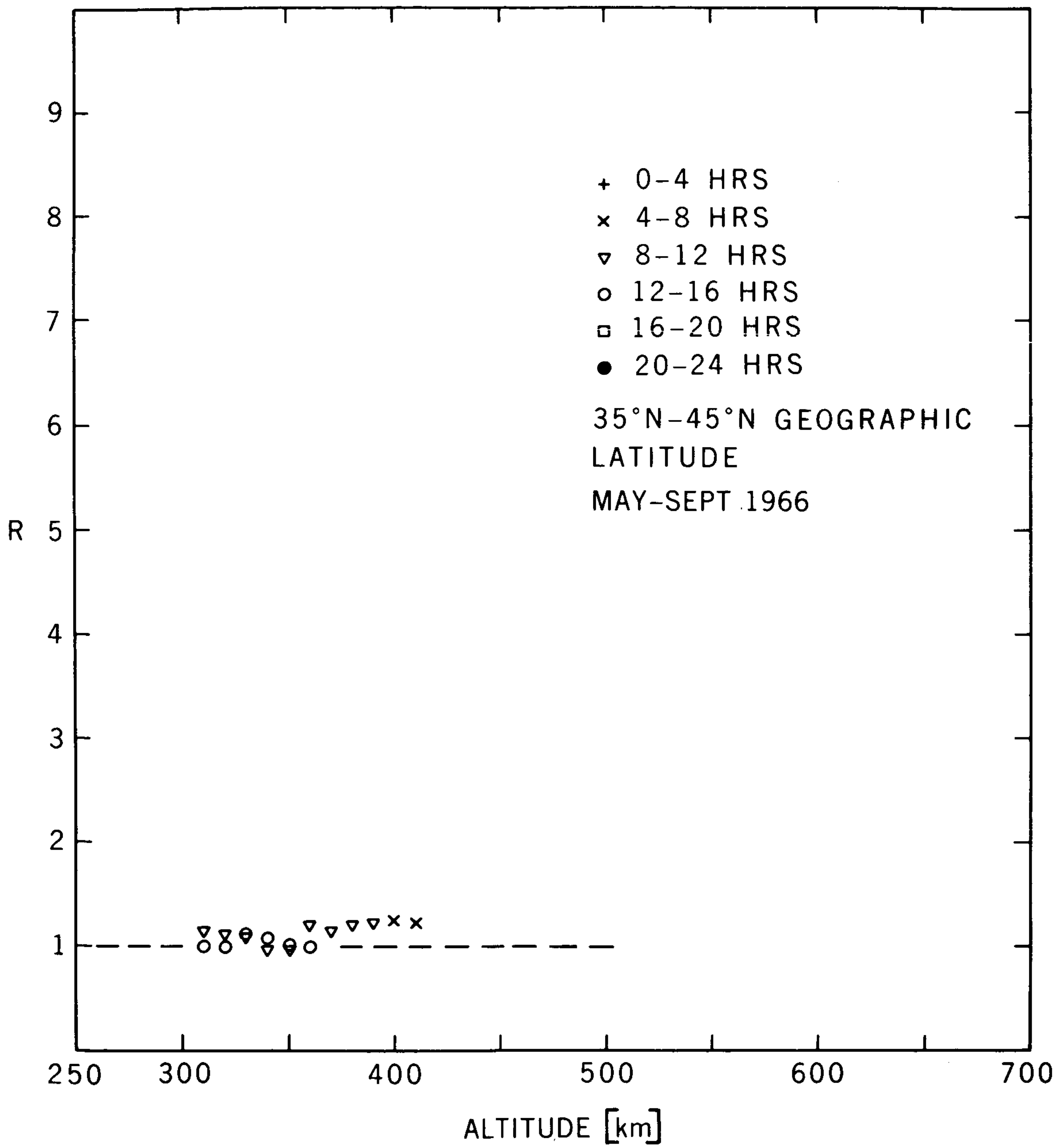

Figure 2. Ratios of the 35°N - 45°N geographic latitude densities to the equatorial densities versus the altitudes at which the ratios were determined. The ratios have been corrected for local time differences in the two density measurements. Local times corresponding to the higher latitude data are coded by symbols.

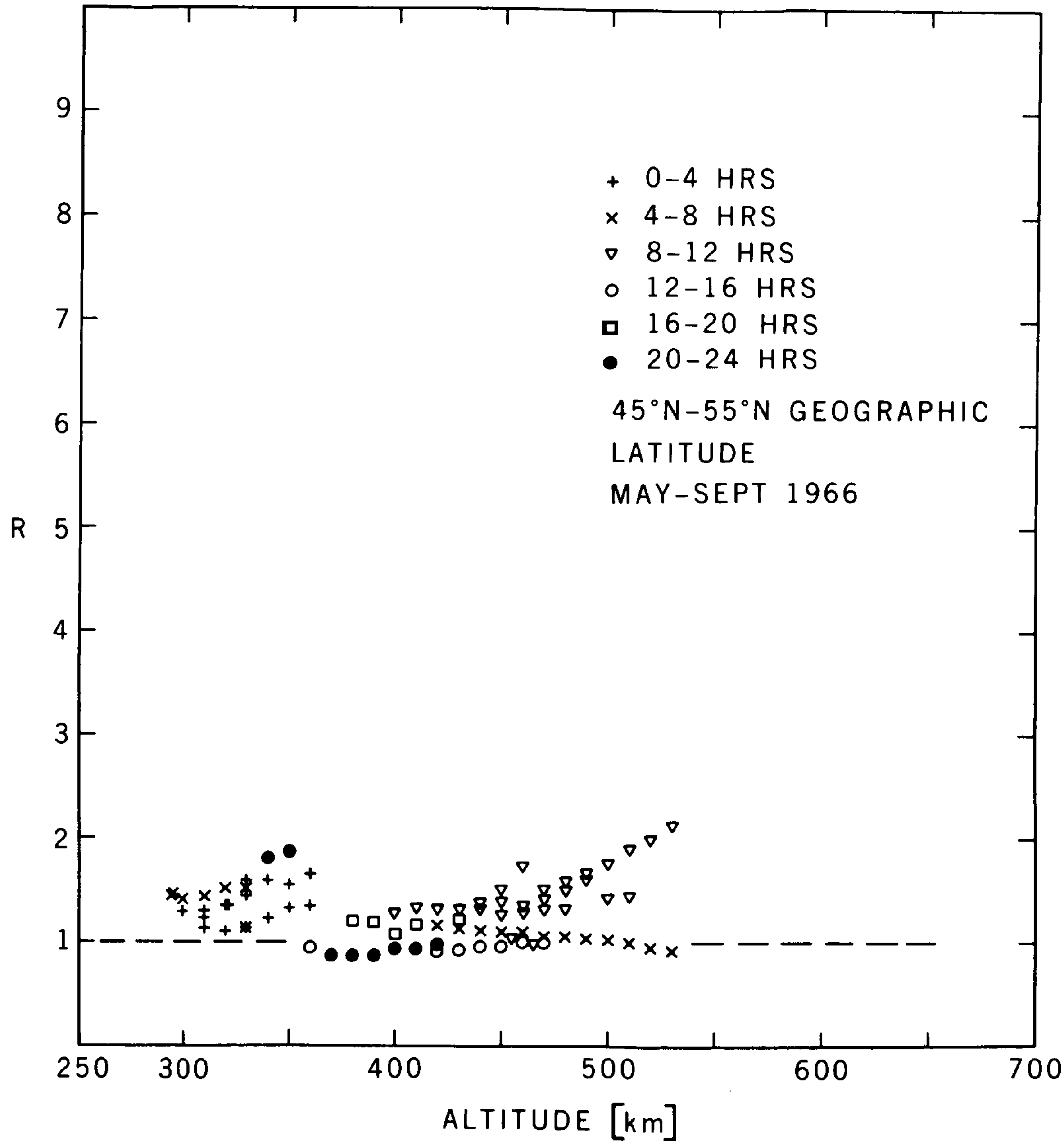

Figure 3. Ratios of the 45°N - 55°N geographic latitude densities to the equatorial densities versus the altitudes at which the ratios were determined. Local time corrections and symbols are explained in Figure 2.

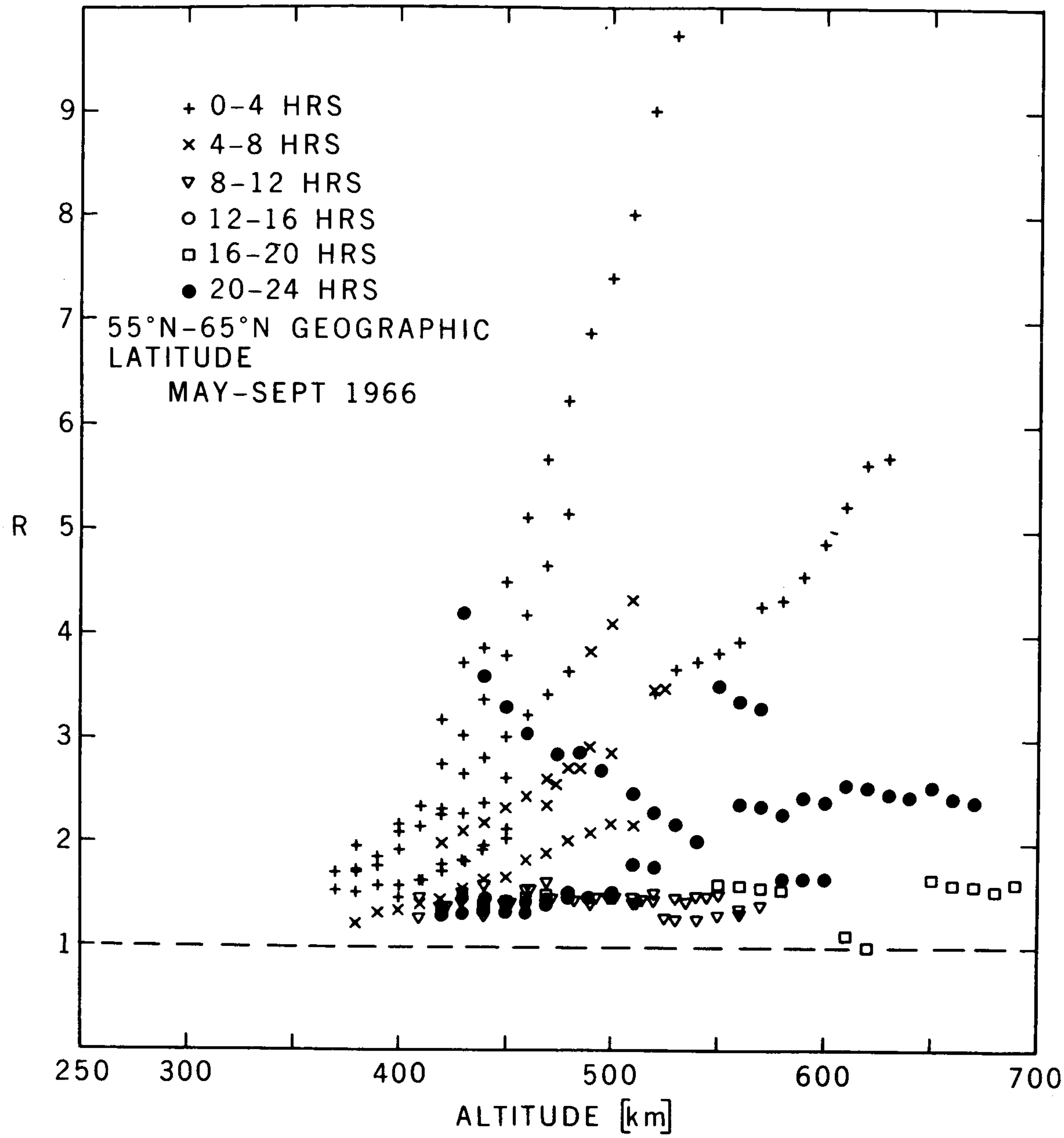

Figure 4. Ratios of the 55°N - 65°N geographic latitude densities to the equatorial densities versus the altitudes at which the ratios were determined. Local time corrections and symbols are explained in Figure 2.

Table 1

Table 1 is a listing of the Explorer 32 density measurements used to obtain the results presented in this paper.

Col. 1 is the station code for the minitrack stations recording the data or the remote location identification in the case of tape recorded data.

Col. 2 is the orbit number corresponding to the data.

Col. 3 is the turn-on number corresponding to the data.

Col. 4 is the date the data were obtained.

Col. 5 is the average GMT corresponding to the data.

Col. 6 is the daily $F_{10.7}$ in units of 10^{-22}W./m^{2}c/s corresponding to the date indicated.

Col. 7 is the daily A_p corresponding to the date indicated.

Col. 8-12 are a listing of the values of the geographic latitude, longitude, local solar time, altitude and density respectively.

STA	ORBIT	PASS	DATE	GMT	F10.7	AP	LAT	LONG	LST	ALT.	DENSITY
KNO	131	132	6/05/66	5:13:19.3	99.	5	11.0	4.6	5.97	530.	4.30E-17
							10.6	13.5	6.16	460.	1.00E-16
							15.5	15.6	6.33	410.	7.20E-16
ULA	139	139	6/05/66	19:02:44.7	99.	5	60.4	-143.6	9.47	386.	2.80E-15
							62.8	-133.3	10.18	430.	1.20E-15
							64.6	-115.3	11.42	511.	3.10E-16
RAI	167	172	6/08/66	:56:07.9	97.	4	9.1	68.8	5.53	470.	1.50E-16
							23.6	75.4	6.03	342.	3.20E-15
QUI	171	185	6/08/66	10:31:44.7	97.	4	2.8	-80.0	5.24	544.	3.60E-17
							4.7	-79.3	5.30	521.	6.00E-17
FTM	171	186	6/08/66	10:37:43.4	97.	4	14.4	-75.2	5.62	415.	6.60E-16
							26.9	-69.1	6.08	324.	5.90E-15
NFL	172	187	6/08/66	10:46:13.6	97.	4	45.5	-55.4	7.08	292.	2.10E-14
							54.5	-43.5	7.92	330.	7.20E-15
WNK	172	188	6/08/66	10:54:42.8	97.	4	64.5	-2.3	10.76	511.	3.10E-16
							64.5	9.5	11.57	570.	1.10E-16
							62.6	26.9	12.76	676.	2.20E-17
ROS	173	189	6/08/66	12:38:56.9	97.	4	33.5	-94.5	6.35	298.	1.10E-14
							41.7	-88.4	6.80	287.	1.80E-14
ULA	176	193	6/08/66	18:35:54.1	97.	4	61.1	-143.6	9.02	401.	1.80E-15
							64.6	-115.0	10.99	532.	2.00E-16
QUI	208	236	6/11/66	10:05:44.7	93.	3	6.3	-81.1	4.73	495.	6.00E-17
							9.1	-79.9	4.83	462.	1.30E-16
FTM	209	237	6/11/66	10:10:44.6	93.	3	16.5	-76.7	5.07	391.	6.90E-16
							27.9	-71.0	5.50	317.	4.80E-15
NFL	209	238	6/11/66	10:18:42.5	93.	3	44.8	-58.7	6.40	291.	1.40E-14
							55.2	-44.5	7.40	338.	5.00E-15
WNK	209	239	6/11/66	10:27:42.4	93.	3	64.6	-2.3	10.31	530.	1.50E-16
							63.4	19.3	11.79	650.	2.60E-17

ROS	210	240	6/11/66	12:11:39.7	93.	3	33.6	-96.8	5.74	296.	8.20E-15
							41.2	-91.2	6.15	287.	1.25E-14
RO2	214	246	6/11/66	19:52:07.0	93.	3	20.0	138.6	5.11	363.	1.30E-15
							35.0	147.1	5.74	293.	9.20E-15
LIM	343	542	6/22/66	7:05:30.1	93.	3	-1.8	-73.8	2.21	570.	9.40E-18
							2.0	72.3	2.33	519.	2.70E-17
NFL	344	543	6/22/66	7:19:29.4	93.	3	40.8	-51.7	3.88	287.	1.25E-14
							52.5	-38.7	4.81	329.	4.30E-15
ULA	348	552	6/22/66	15:09:45.2	93.	3	59.4	-141.3	5.74	396.	1.15E-15
							64.4	-114.5	7.58	528.	1.10E-16
KNO	402	686	6/27/66	1:13:44.8	97.	4	2.5	2.0	1.36	592.	7.90E-17
							15.1	7.3	1.77	377.	1.50E-15
QUI	405	691	6/27/66	6:59:31.7	97.	4	1.3	-86.3	1.27	516.	6.00E-17
							7.4	-83.8	1.47	447.	2.90E-16
FTM	406	692	6/27/66	7:05:45.2	97.	4	17.3	-79.5	1.80	360.	1.90E-15
							23.5	-76.5	2.02	322.	5.50E-15
							29.8	-73.1	2.28	297.	9.40E-15
NFL	406	693	6/27/66	7:13:43.5	97.	4	48.4	-57.9	3.38	310.	7.80E-15
							56.9	-44.2	4.34	374.	1.85E-15
ULA	410	702	6/27/66	15:01:44.7	97.	4	58.3	-158.0	4.49	390.	1.30E-15
							64.0	-132.1	6.28	520.	1.30E-16
RO1	412	707	6/27/66	18:51:35.1	97.	4	52.3	131.8	3.65	333.	4.40E-15
							60.5	150.2	4.93	424.	7.00E-16
ROI	413	711	6/27/66	20:34:08.1	97.	4	4.3	70.2	1.25	480.	7.50E-17
							18.7	76.4	1.73	349.	1.70E-15
KNO	414	715	6/28/66	:25:43.6	98.	5	2.2	10.8	1.15	503.	7.10E-17
							14.9	16.2	1.56	377.	1.20E-15
QUI	418	721	6/28/66	6:14:43.4	98.	5	5.8	-75.4	1.22	461.	1.60E-16
							16.5	-70.9	1.57	364.	1.70E-15
NFL	418	722	6/28/66	6:24:43.9	98.	5	42.8	-54.7	2.76	291.	1.30E-14
							53.9	-41.1	3.73	346.	3.00E-15

MOJ	420	727	6/28/66	10:13:45.9	98.	5	37.5	-117.6	2.41	285.	1.30E-14
							44.3	-111.8	2.83	295.	1.15E-14
ULA	422	734	6/28/66	14:14:40.1	98.	5	60.2	-143.4	4.69	420.	8.60E-15
							64.6	-115.1	6.63	565.	6.90E-17
RO2	423	737	6/28/66	15:59:33.9	98.	5	23.8	146.4	1.75	319.	4.70E-15
							35.8	153.5	2.28	286.	1.20E-15
WNK	478	860	7/03/66	2:25:56.8	96.	4	46.5	-6.2	2.02	305.	8.80E-15
							56.7	9.1	3.09	381.	1.50E-15
FTM	480	864	7/03/66	6:10:45.3	96.	4	20.3	-82.7	0.66	333.	3.40E-15
							33.0	-75.8	1.18	287.	1.30E-14
NFL	480	865	7/03/66	6:22:48.5	96.	4	60.5	-39.0	3.78	434.	5.30E-16
							63.8	-22.5	4.92	519.	1.10E-16
ULA	484	875	7/03/66	14:06:45.1	96.	4	60.3	-156.9	3.65	430.	4.60E-16
							64.5	-130.0	5.50	570.	3.60E-17
RO1	486	880	7/03/66	17:56:07.0	96.	4	53.7	129.3	2.56	350.	2.60E-15
							62.6	154.3	4.29	480.	2.30E-16
KNO	488	886	7/03/66	23:29:44.3	96.	4	8.8	8.9	0.12	420.	5.20E-16
							14.2	11.2	0.30	373.	1.30E-15
							1.8	6.0	23.90	494.	8.00E-17
WNK	503	921	7/05/66	2:47:31.7	102.	5	51.6	-11.1	2.05	336.	4.60E-15
							58.8	3.0	3.03	410.	9.10E-16
							60.9	9.5	3.49	444.	5.20E-16
LIM	503	923	7/05/66	4:24:44.7	96.	4	-8.6	-77.0	23.32	630.	6.40E-18
							-4.2	-75.2	23.46	567.	2.40E-17
NFL	504	924	7/05/66	4:40:44.2	102.	5	42.4	-50.8	1.29	292.	1.30E-14
							53.5	-37.4	2.24	351.	3.10E-15
RO5	506	926	7/05/66	8:36:26.1	102.	5	54.3	-94.5	2.30	358.	2.80E-15
							63.1	-68.0	4.14	498.	4.50E-16
ULA	508	932	7/05/66	12:29:44.4	102.	5	57.8	-145.8	2.77	397.	1.30E-15
							63.8	-120.8	4.50	529.	1.40E-16
RO3	409	935	7/05/66	14:08:23.4	102.	5	0.2	140.3	23.51	510.	6.10E-17
							11.7	145.1	23.88	390.	9.00E-16
RO1	511	943	7/05/66	18:10:08.1	102.	5	2.7	82.8	23.56	480.	1.15E-16
							14.2	87.7	23.93	370.	1.80E-15

KNO	513	949	7/05/66	23:51:43.8	102.	5	21.8	3.4	0.15	321.	4.40E-15
							9.1	-2.3	23.71	413.	5.70E-16
QUI	614	1241	7/14/66	3:03:44.2	97.	4	-2.3	-81.2	21.66	520.	3.30E-17
							8.8	-76.6	22.01	400.	7.20E-16
NFL	615	1242	7/14/66	3:16:44.8	97.	4	55.2	-41.2	0.59	379.	1.10E-15
							44.5	-55.5	23.58	304.	7.90E-15
RO1	621	1252	7/14/66	14:54:04.6	97.	4	54.3	141.6	0.37	370.	1.60E-15
							60.2	155.8	1.35	450.	2.90E-16
							49.3	134.3	23.86	330.	4.80E-15
WNK	626	1266	7/15/66	:34:44.3	98.	8	56.0	-1.2	0.52	390.	1.20E-15
							60.3	9.8	1.29	453.	3.80E-16
							51.4	-9.2	23.97	345.	3.40E-15
ROS	627	1274	7/15/66	4:20:18.7	98.	8	29.1	-87.1	22.53	289.	1.20E-14
							34.2	-84.0	22.76	284.	1.50E-14
							42.8	-77.3	23.25	298.	9.90E-15
ULA	631	1281	7/15/66	10:16:44.8	98.	8	57.2	-145.0	0.61	405.	8.70E-16
							63.6	-120.8	2.28	541.	5.90E-17
ROI	634	1290	7/15/66	15:49:08.1	98.	8	2.3	85.0	21.48	463.	1.90E-16
							17.3	91.4	21.98	335.	3.00E-15
WNK	638	1299	7/15/66	23:45:43.2	98.	8	58.4	13.1	0.69	422.	7.20E-16
							49.7	-2.5	23.60	333.	4.90E-15
WNK	663	1365	7/18/66	:06:19.8	98.	4	57.3	-0.7	0.09	410.	1.10E-15
							61.1	10.5	0.87	475.	3.10E-16
							51.5	-11.2	23.36	349.	4.80E-15
QUI	663	1368	7/18/66	1:46:43.5	98.	4	-3.9	-75.0	20.78	530.	5.00E-17
							1.1	-73.0	20.94	470.	1.70E-16
							7.3	-70.5	21.14	407.	8.30E-16
ROS	665	1370	7/18/66	3:52:46.0	98.	4	33.6	-86.6	22.11	283.	2.00E-14
							44.5	-78.0	22.74	306.	8.90E-15
ROS	666	1372	7/18/66	5:55:30.4	98.	4	59.2	-83.5	0.39	439.	9.00E-16
							63.4	-65.6	1.62	540.	2.20E-16
							55.0	-93.2	23.71	383.	2.60E-15

R07	666	1375	7/18/66	7:35:05.1	98.	4	-3.1	-162.4	20.76	519. 7.70E-17
							10.4	-156.9	21.19	380. 1.40E-15
ULA	668	1377	7/18/66	9:49:16.7	98.	4	59.5	-141.1	0.42	445. 6.10E-16
							64.0	-119.2	1.92	568. 5.00E-17
WNK	675	1392	7/18/66	23:17:43.8	98.	4	59.4	13.8	0.27	444. 4.30E-16
							50.3	-3.8	23.04	341. 4.00E-15
							52.6	-0.5	23.28	360. 2.30E-15
LIM	725	1545	7/23/66	1:34:53.4	111.	6	-15.1	-93.0	19.38	677. 8.10E-18
							-3.0	-88.0	19.77	507. 1.40E-16
FTM	726	1547	7/23/66	1:44:43.5	111.	6	20.9	-77.8	20.56	309. 1.05E-14
							28.3	-73.9	20.85	287. 2.15E-14
NFL	726	1548	7/23/66	1:52:43.3	111.	6	49.8	-56.1	22.14	342. 6.00E-15
							59.1	-38.6	23.36	447. 6.70E-16
ULA	730	1562	7/23/66	9:40:46.2	111.	6	62.5	-143.2	0.15	520. 1.80E-16
							64.6	-123.7	1.49	633. 4.00E-17
							60.6	-151.0	23.61	474. 4.70E-16
QUI	799	1761	7/29/66	:40:42.9	129.	5	-2.5	-92.0	18.55	488. 5.80E-16
							3.3	-89.6	18.73	424. 1.60E-15
							10.0	-86.9	18.94	367. 5.20E-15
WNK	810	1796	7/29/66	20:13:45.1	129.	5	46.4	3.2	20.44	326. 9.80E-15
							52.6	11.2	21.01	375. 3.00E-15
							56.5	18.3	21.51	422. 1.10E-15
WNK	812	1808	7/30/66	:12:45.2	124.	6	64.5	7.9	0.79	713. 1.00E-17
							63.6	-14.4	23.25	577. 7.20E-17
							64.3	-6.8	23.77	620. 3.40E-17
R07	813	1815	7/30/66	3:43:21.3	124.	6	-6.1	-142.9	18.20	530. 1.90E-16
							8.8	-136.8	18.67	374. 3.10E-15
WNK	823	1836	7/30/66	21:23:43.4	124.	6	56.4	-2.2	21.26	420. 1.20E-15
							61.8	13.7	22.36	520. 1.90E-16
LIM	823	1838	7/30/66	22:59:43.7	124.	6	-11.7	-77.6	17.85	604. 7.20E-17
							-5.9	-75.2	18.04	524. 3.00E-16
NFL	824	1840	7/30/66	23:16:23.7	124.	6	43.3	-49.2	19.99	310. 2.20E-14
							46.1	-46.5	20.19	325. 1.25E-14
							55.1	-33.9	21.07	404. 1.70E-15

ULA	853	1918	8/02/66	7:25:45.4	116.	1	61.0	-146.7	21.65	504.	4.10E-16
							62.2	-141.6	22.00	535.	2.00E-16
							64.6	-119.4	23.52	671.	1.90E-17
LIM	860	1946	8/02/66	22:29:44.6	116.	1	-19.6	-83.1	16.96	720.	1.10E-17
							-8.8	-78.4	17.32	552.	1.50E-16
QUI	860	1947	8/02/66	22:34:43.9	116.	1	-3.1	-76.1	17.51	483.	5.50E-16
							9.6	-70.9	17.91	362.	4.10E-15
ROS	900	2071	8/06/66	2:14:20.0	103.	6	59.7	-85.4	20.56	488.	1.00E-15
							64.1	-62.5	22.14	629.	4.30E-17
ULA	902	2082	8/06/66	6:07:44.8	103.	6	60.6	-141.0	20.73	505.	4.80E-16
							63.2	-128.9	21.56	580.	1.00E-16
							64.6	-113.8	22.60	673.	2.60E-17
WNK	909	2101	8/06/66	19:36:44.4	103.	6	54.6	-0.5	19.58	410.	7.80E-15
							57.3	5.1	19.97	447.	2.20E-15
							61.9	19.4	20.96	540.	1.90E-16
LIM	909	2107	8/06/66	21:14:44.2	103.	6	-10.9	-72.2	16.43	572.	1.10E-16
							0.8	-67.4	16.81	432.	1.30E-15
JOB	1041	2504	8/17/66	12:16:43.6	94.	2	-14.9	26.5	14.09	600.	6.90E-17
							-11.3	28.1	14.21	550.	1.50E-16
KNO	1042	2505	8/17/66	14:20:24.7	94.	2	4.7	5.4	14.70	378.	3.50E-15
							11.3	8.1	14.91	332.	8.10E-15
							18.7	11.5	15.17	298.	2.00E-14
WNK	1044	2510	8/17/66	16:27:44.6	94.	2	46.8	1.3	16.55	350.	6.10E-15
							56.2	15.3	17.54	452.	6.60E-16
LIM	1045	2515	8/17/66	20:01:43.4	94.	2	-15.7	-90.8	13.99	610.	5.20E-17
							-6.9	-87.0	14.28	493.	3.70E-16
QUI	1045	2516	8/17/66	20:06:42.9	94.	2	-1.0	-84.6	14.47	429.	1.10E-15
							11.7	-79.4	14.89	330.	8.20E-15
WNK	1057	2543	8/18/66	17:37:44.5	95.	10	55.3	-6.6	17.19	440.	1.25E-15
							62.4	14.5	18.65	585.	8.60E-17

LIM	1057	2545	8/18/66	19:11:24.6	95.	10	-16.7	-82.0	13.76	623.	4.70E-17
							-11.8	-79.9	13.92	552.	1.50E-16
QUI	1057	2546	8/18/66	19:16:43.5	95.	10	-5.6	-77.3	14.12	476.	5.30E-16
							6.6	-72.4	14.51	362.	4.80E-15
KNO	1091	2633	8/21/66	13:01:43.6	100.	5	5.9	13.4	13.92	363.	5.30E-15
							12.7	16.2	14.14	320.	1.20E-14
							18.8	18.9	14.35	294.	2.40E-14
NFL	1095	2638	8/21/66	18:59:22.1	100.	5	42.8	-53.7	15.41	327.	1.20E-14
							44.8	-51.7	15.55	340.	8.20E-15
							54.5	-39.0	16.45	435.	1.15E-15
QUI	1180	2862	8/28/66	16:55:44.2	130.	4	-7.0	-73.7	12.02	470.	9.00E-16
							5.1	-68.7	12.40	358.	7.20E-15
ROS	1182	2864	8/28/66	19:02:45.2	130.	4	34.9	-83.1	13.51	295.	3.10E-14
							46.2	-73.5	14.20	360.	7.10E-15
NFL	1182	2865	8/28/66	19:07:44.9	130.	4	51.6	-66.8	14.67	413.	2.60E-15
							60.2	-48.6	15.95	550.	2.70E-16
NFL	1182	2866	8/28/66	19:12:27.9	130.	4	62.6	-38.8	16.62	618.	8.20E-17
							64.6	-14.6	18.29	780.	7.60E-18
ULA	1185	2872	8/29/66	:58:43.5	127.	13	59.9	-137.1	15.84	544.	2.70E-16
							64.3	-112.6	17.52	710.	2.30E-17
KNO	1190	2884	8/29/66	12:19:44.1	127.	13	11.0	1.4	12.43	320.	1.65E-14
							23.7	7.3	12.87	282.	4.00E-14
SNT	1192	2888	8/29/66	15:59:44.8	127.	13	-23.5	-71.8	11.25	700.	1.70E-17
							-20.3	-70.3	11.37	648.	3.30E-17
FTM	1194	2889	8/29/66	18:09:29.7	127.	13	18.7	-82.8	12.64	290.	3.20E-14
							26.0	-79.2	12.91	281.	4.08E-14
							32.1	-75.6	13.18	288.	3.50E-14
ROS	1194	2890	8/29/66	18:14:46.4	127.	13	38.4	-71.3	13.49	310.	2.20E-14
							47.5	-62.9	14.10	372.	5.40E-15
NFL	1194	2891	8/29/66	18:19:45.2	127.	13	54.6	-52.8	14.81	452.	1.30E-15
							62.0	-32.3	16.23	601.	8.90E-17

WNK	1414	3509	9/16/66	11:16:44.4	123.	10	54.2	-3.2	11.06	484.	5.80E-16
							61.8	16.9	12.46	645.	3.90E-17
LIM	1414	3512	9/16/66	12:52:17.4	123.	10	-14.4	-75.6	7.85	517.	1.00E-16
							-5.5	-71.9	8.14	418.	9.60E-16
NFL	1416	3515	9/16/66	15:08:45.1	123.	10	56.4	-57.3	11.34	521.	3.05E-16
							61.9	-40.9	12.47	650.	2.80E-17
MOJ	1417	3517	9/16/66	16:56:47.0	123.	10	28.8	-114.9	9.29	289.	2.80E-14
							42.2	-105.5	9.98	354.	5.30E-15
ULA	1419	3524	9/16/66	20:57:43.1	123.	10	58.2	-140.9	11.57	556.	1.60E-16
							63.0	-123.2	12.79	690.	2.55E-17
WNK	1476	3677	9/21/66	11:01:14.9	136.	10	54.8	-13.7	10.11	533.	5.60E-16
							62.1	6.5	11.51	670.	4.40E-17
LIM	1476	3678	9/21/66	12:35:27.1	136.	10	-18.9	-89.3	6.66	565.	6.00E-17
							-13.9	-87.1	6.83	500.	2.00E-16
							-10.1	-85.4	6.96	456.	6.00E-17
QUI	1476	3679	9/21/66	12:40:44.0	136.	10	-4.1	-82.9	7.15	397.	1.80E-15
							8.8	-77.7	7.56	311.	1.30E-14
NFL	1477	3680	9/21/66	12:52:17.7	136.	10	39.6	-60.8	8.82	341.	9.00E-15
							52.1	-47.4	9.77	465.	9.10E-16
NFL	1478	3682	9/21/66	14:52:44.9	136.	10	55.7	-70.5	10.19	520.	4.20E-16
							58.3	-64.7	10.59	570.	1.70E-16
							61.7	-53.5	11.37	657.	4.90E-17
MOJ	1479	3684	9/21/66	16:41:14.6	136.	10	29.4	-126.2	8.27	292.	2.70E-14
							41.4	-117.8	8.89	354.	5.70E-15
ULA	1481	3689	9/11/66	20:41:45.5	95.	7	57.8	-153.6	10.46	560.	1.60E-16
							62.6	-137.0	11.61	690.	2.45E-17
WNK	1488	3707	9/22/66	10:09:19.1	131.	6	47.8	-14.5	9.19	415.	2.20E-15
							58.2	3.0	10.42	572.	1.40E-16
LIM	1488	3712	9/22/66	11:46:42.9	131.	6	-19.4	-80.2	6.44	570.	4.10E-17
							-13.2	-77.4	6.65	490.	1.90E-16
							-8.3	-75.3	6.81	435.	7.00E-16
NFL	1490	3716	9/22/66	14:01:34.0	131.	6	50.0	-70.2	9.35	442.	1.30E-15
							59.0	-53.4	10.52	590.	1.10E-16

MDJ	1491	3719	9/22/66	15:50:32.2	131.	6	25.1	-119.2	7.89	285.	2.80E-14
							32.3	-115.1	8.20	304.	1.60E-14
							38.2	-111.1	8.50	335.	7.80E-15
ULA	1493	3724	9/22/66	19:51:43.2	131.	6	57.7	-144.4	10.24	562.	1.70E-16
							62.6	-127.4	11.42	695.	2.60E-17
ULA	1494	3727	9/22/66	21:47:46.0	131.	6	57.6	-173.8	10.21	561.	1.30E-16
							60.2	-166.5	10.72	620.	5.00E-17
							61.9	-160.3	11.15	668.	2.60E-17
WNK	1525	3808	9/25/66	9:35:43.4	118.	13	45.9	-17.6	8.42	400.	2.60E-15
							55.7	-3.7	9.40	532.	2.60E-16
QUI	1525	3811	9/25/66	11:15:44.2	118.	13	-13.2	-78.5	6.03	483.	2.50E-16
							-5.7	-75.4	6.27	405.	1.30E-15
							-0.7	-73.3	6.43	364.	3.70E-15
NFL	1527	3814	9/25/66	13:27:43.9	118.	13	46.6	-75.3	8.44	408.	2.00E-15
							56.4	-60.7	9.47	544.	2.20E-16
MOJ	1528	3816	9/25/66	15:16:45.1	118.	13	22.6	-121.6	7.18	282.	2.80E-14
							36.6	-113.3	7.79	327.	8.90E-15
ULA	1530	3820	9/25/66	19:18:45.2	118.	13	57.5	-145.9	9.59	566.	1.40E-16
							62.6	-128.7	10.78	702.	2.20E-17
WNK	1562	3903	9/28/66	9:33:44.6	97.	22	49.4	-14.7	8.08	444.	9.60E-16
							58.4	1.3	9.20	590.	8.80E-17
LIM	1562	3907	9/28/66	10:40:44.3	97.	22	-17.5	-81.4	5.26	530.	6.30E-17
							-7.8	-77.2	5.59	420.	8.00E-16
ULA	1567	3915	9/28/66	18:44:13.3	97.	22	52.9	-155.8	8.35	492.	5.30E-16
							56.3	-149.6	8.78	550.	1.80E-16
							60.9	-137.1	9.56	657.	3.80E-17
LIM	1747	4312	10/13/66	7:51:49.9	123.	8	-22.9	-88.5	1.96	560.	8.70E-17
							-9.3	-82.4	2.44	401.	1.60E-15
NFL	1748	4314	10/13/66	8:09:16.6	123.	8	43.4	-54.9	4.50	400.	2.00E-15
							53.4	-42.6	5.37	530.	1.40E-16

Table 2 gives the multiplicative correction factors to be applied to the densities given in Table 1 for several relative atmospheric compositions.

Table 2

Relative Atmospheric Composition	Multiplicative Correction Factor for the Density Values in Table 1
100% N_2	0.7
100% O	1.0
50% O 50% He	1.3
100% He	2.1