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SEASONAL AND LATITUDINAL VARIATIONS OF AIR DENSITY IN THE MESOSPHERE (30 TO 80 KILOMETERS)

By

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PREFACE

Air-density data for the upper atmosphere are expected to become increasingly important as certain military missile programs get further under way. Their value should also increase as meteorologists undertake further investigations of relationships of synoptic processes in the troposphere and the stratosphere to disturbances in the upper atmosphere. The substantial amount of observational data obtained by various agencies in the past decade has been only partially assimilated in the scientific literature. A critical and comprehensive account of upper atmosphere density data for different latitudes and times of the year has not been generally available to researchers and designers requiring such data.

In January 1961, the Air Weather Service published a report [1] containing the complete density data for 65 soundings of the mesosphere (30 to 80 km), as well as several soundings reaching to higher levels. [The lower limit of the mesosphere has been variously defined; in this report we have arbitrarily used the term merely to identify the layer from 30 to 80 km.] The results of a statistical analysis of these mesosphere data, together with four other soundings recently made available, are given in the present report.

Mean and extreme densities at every 2 km from 30 to 80 km are presented in tables and graphs, for the summer and winter half-years, for the entire data sample, and for three latitude bands. An analysis of the probable errors in the observations is given and the values of the standard deviation of air density are presented for every 10 km.

Seasonal and latitudinal variations in the means are discussed at length, and a model of the seasonal variation from near the ground to a height of 200 km is presented. Diurnal and day-to-day variations and latitudinal gradients of density are discussed briefly.

I wish to thank Dr. Adam Kochanski, Major Alvan Bruch, and other members of the Climatic Center for their helpful comments. Special acknowlegment is made of unpublished data provided by Mr. N. W. Spencer and Mr. D. R. Taeusch which were processed at the University of Michigan (Space Physics Research Laboratory) under sponsorship of AFCRC GRD and the National Science Foundation. These consisted of four new rocket soundings at Fort Churchill and revised data for three of the soundings included in [1].

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1 March 1961

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CONTENTS

TABLES

ILLUSTRATIONS

SEASONAL AND LATITUDINAL VARIATIONS OF AIR DENSITY IN THE MESOSPHERE (30 TO 80 KILOMETERS)

SECTION I – DATA PREPARATION

In an earlier report [1], the principal methods for measuring density in the mesosphere (approximately 30 to 80 km) were described, and the complete density data for 65 soundings obtained by these methods were presented. An estimate of the inherent observational error was given with each sounding. The soundings were taken at latitudes from the equator to 75°N, during 1947 to 1958. To these data we have added four rocket soundings not previously available (AM 6.39, 15 Jul 58; AM 4.12, 15 Oct 58; ABM 6.207, 20 Oct 58; and AA 6.16, 23 Nov 58), and have substituted revised data for AM 2.21, 23 Oct 56; AM 6.37, 24 Feb 58; and AM 6.38, 24 Mar 58; all at Fort Churchill. The total distribution of soundings is shown in Table 1.

The data have been plotted on semi-log graph paper and values of density have been derived for each sounding for even whole kilometers from 30 to 80 km. From an inspection of the curves for some of the more detailed soundings (e.g., the falling sphere data), it appeared that interpolation or extrapolation of data points lying between whole kilometers could be made without misrepresenting the true curves if the process were confined to layers approximately 2

TABLE 1. DISTRIBUTION OF AIR-DENSITY SOUNDINGS

Location	Latitude	Longitude	Number of Soundings and Method of Observation*
Equator	00°11'N	161°25'W	1(‡)
Guam, M.I.	13°37'N	144°51'E	7(*)
White Sands, N.M.	32°24'N	106°20'W	2(‡), 4(o)
Holloman AFB, N.M.	32°54'N	106°05'W	3(‡)
Albuquerque, N.M.	~35°10'N	~106°30'W	18(†)
Wallops I., Va.	37°50'N	75°20'W	2(o)
Ft. Churchill, Can.	58°46'N	94°10'W	11(‡), 10(*), 4(o)
Shipboard	49°-75°N	46°-94°W	4(‡), 3(o)
Total			69

* Observational methods: (‡) Rocket with pressure gages, (*) Rocket grenade, (o) Rocket and falling sphere, (†) Searchlight.

NOTE: Five rocket soundings at White Sands and four at Ft. Churchill which do not include data below 80 km are not reflected in this table.

km in thickness. Thus, in almost all cases, extrapolated values are removed from the original data points by not more than 2 km. The majority of the extrapolations were through height intervals smaller than 1 km (for example, to obtain a density at 58.0 km when the nearest reported value was at 57.6 km). Many of the data were originally reported at even kilometers and thus did not require modification.

The complete data sample thus obtained is on file in the Climatic Center, USAF. A few doubtful data points were eliminated and these were shown by an "X" in the tabulation. A large observational error, *per se*, was not a sufficient basis for eliminating data. In the falling-sphere soundings of 11 Dec 52 and 23 Apr 53, erratic fluctuations in the density curves, combined with a large observational error (>20%), were deemed a sufficient basis for eliminating the high-level data. Also omitted were the completed data for falling-sphere sounding of 27 Jan 58, 1249 CST (Churchill), owing to an apparent disparity with the radiosonde data and with rocket grenade densities obtained in the same rocket firing. For this date and time, the grenade sounding was used.

Revised unpublished data for several falling-sphere flights[1] were received from the University of Michigan High Altitude Engineering Laboratory in early February 1961, after the data on hand has been completely processed. A comparison with the earlier data for these flights indicated that the changes were nominal, except possibly in the upper reaches of the sounding. At the 70 and 80 km levels, the average change amounted to 7% and 12%, respectively. With respect to the total data sample, the effect is considered negligible. With respect to the winter densities in arctic latitudes, the effect is to lower the average density by 3% at 70 km, and 5% at 80 km. In view of the large seasonal variation of density at these latitudes (discussed in Section IV), this effect is considered unimportant; thus, no change in the data sample was made.

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[1] Wallops I., 6 Jul 56; Shipboard, 2, 4, and 10 Nov 56; Ft. Churchill, 25, 27, and 29 Jan 58, and 4 Mar 58. The revised data for these flights, together with the data of five earlier falling-sphere flights, making a total of 13 in the period 1952 to 1958, were published subsequently by Jones and Peterson [14].

SECTION II — ERROR ANALYSIS

On the basis of observational error estimates cited in Reference [1], an estimate of the probable error was assigned to each sounding at the levels 30, 40, ..., 80 km. The distribution of these probable errors is shown in Table 2. Since precise information on the error components and the degree of their independence was lacking for many soundings, the probable errors in Table 2 should not be taken in a rigorous statistical sense (i.e., 0.67 times the standard deviation, for a normal distribution), but merely as an approximation of the true error.

TABLE 2. FREQUENCY DISTRIBUTION OF PROBABLE ERRORS

Height (km)	Error in Reported Density Value 2-5%	6-10%	11-20%	Unknown	Total Cases	Mean Error*
30	42	7	1	0	50	5%
40	47	5	5	0	57	6%
50	49	5	0	0	54	5%
60	52	5	2	1	60	5%
70	27	2	3	1	33	6%
80	15	8	2	0	25	8%

* Computed from data for individual soundings. Mean errors obtained from multiplying the frequencies by mid-cell values may differ by about 1%.

SECTION III — MEAN AND EXTREME DENSITIES

The computed means and the observed extreme densities are shown in Table 3. Station Group I, representing tropical latitudes, includes Guam and the shipboard location at 161°W, near the equator. Station Group II, in middle latitudes, includes White Sands, Hollman AFB, Albuquerque (all in New Mexico), and Wallops I., Va. Station Group III, representing arctic and subarctic latitudes, includes Fort Churchill, Canada and seven shipboard locations in latitudes 49° to 75°N. Winter and summer refer to the winter and summer half-year, October-March and April-September, respectively.

In addition to the seasonal data by latitude groups, annual means and extremes are shown in Table 3d for all latitudes combined. Finally, the standard deviations of density for latitude groups II and III, and for selected heights are given in Table 4.

Graphs of the data in Table 3 are shown in Figures 1 to 3. From Figure 1, it may be seen that the overall mean density at 70 to 80 km is about 20% less than the corresponding densities in the U. S. Extension to the Standard Atmosphere [2]. Below 70 km, the departure becomes smaller with decreasing height.

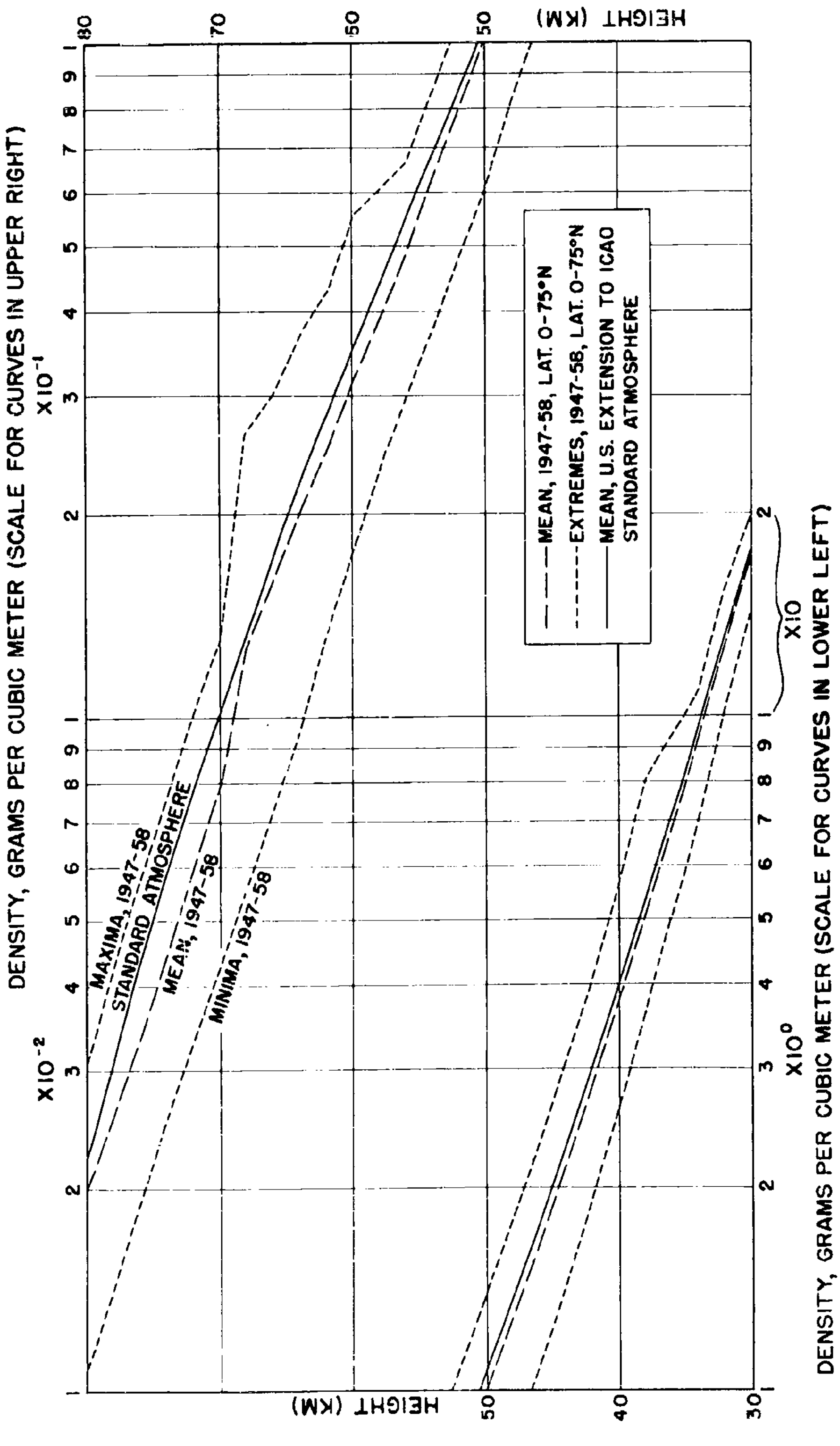

Figure 1 - Mean and Extreme Densities Compared to Standard Atmosphere.

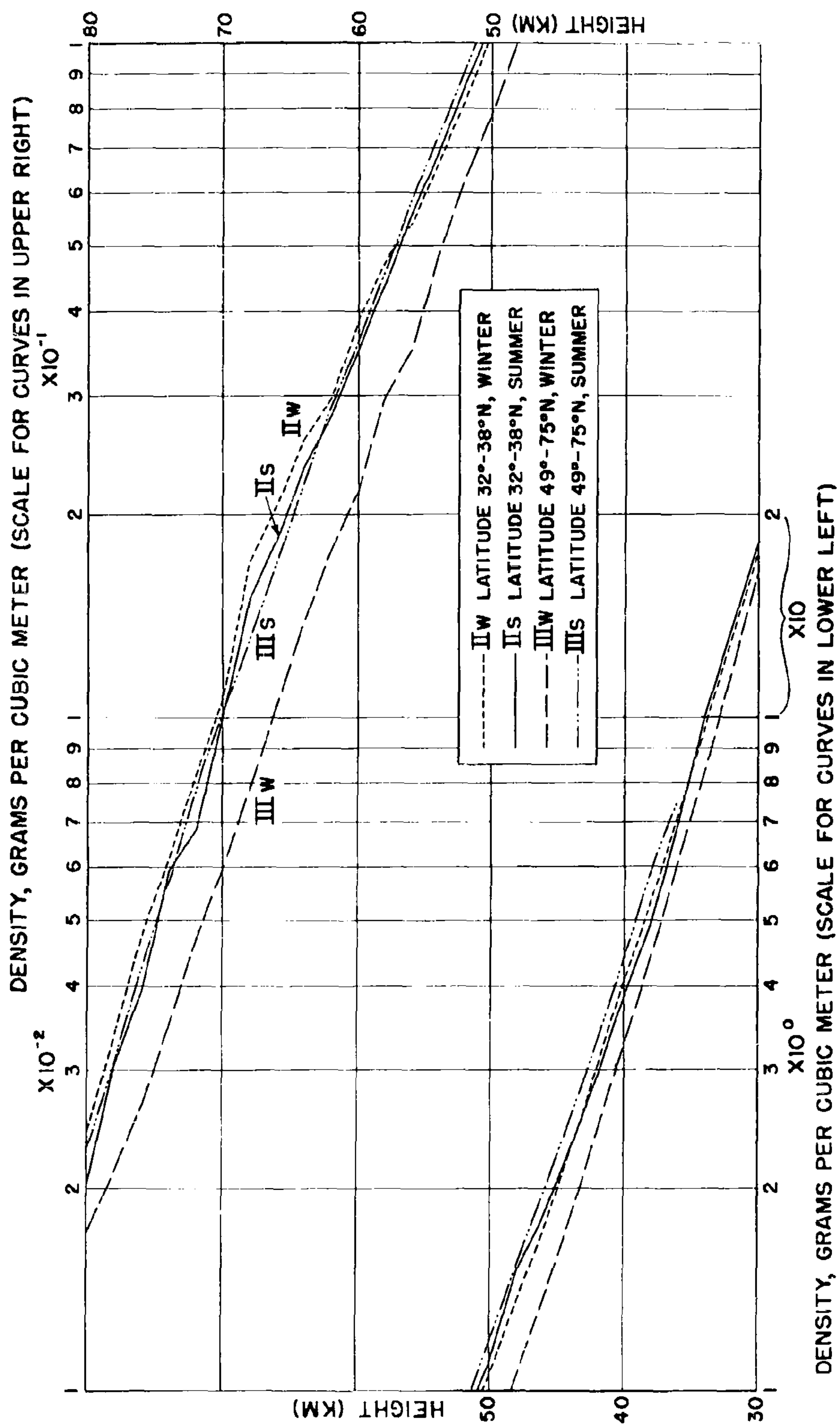

Figure 2 - Mean Densities, 1947 to 1958, Arctic and Middle Latitudes.

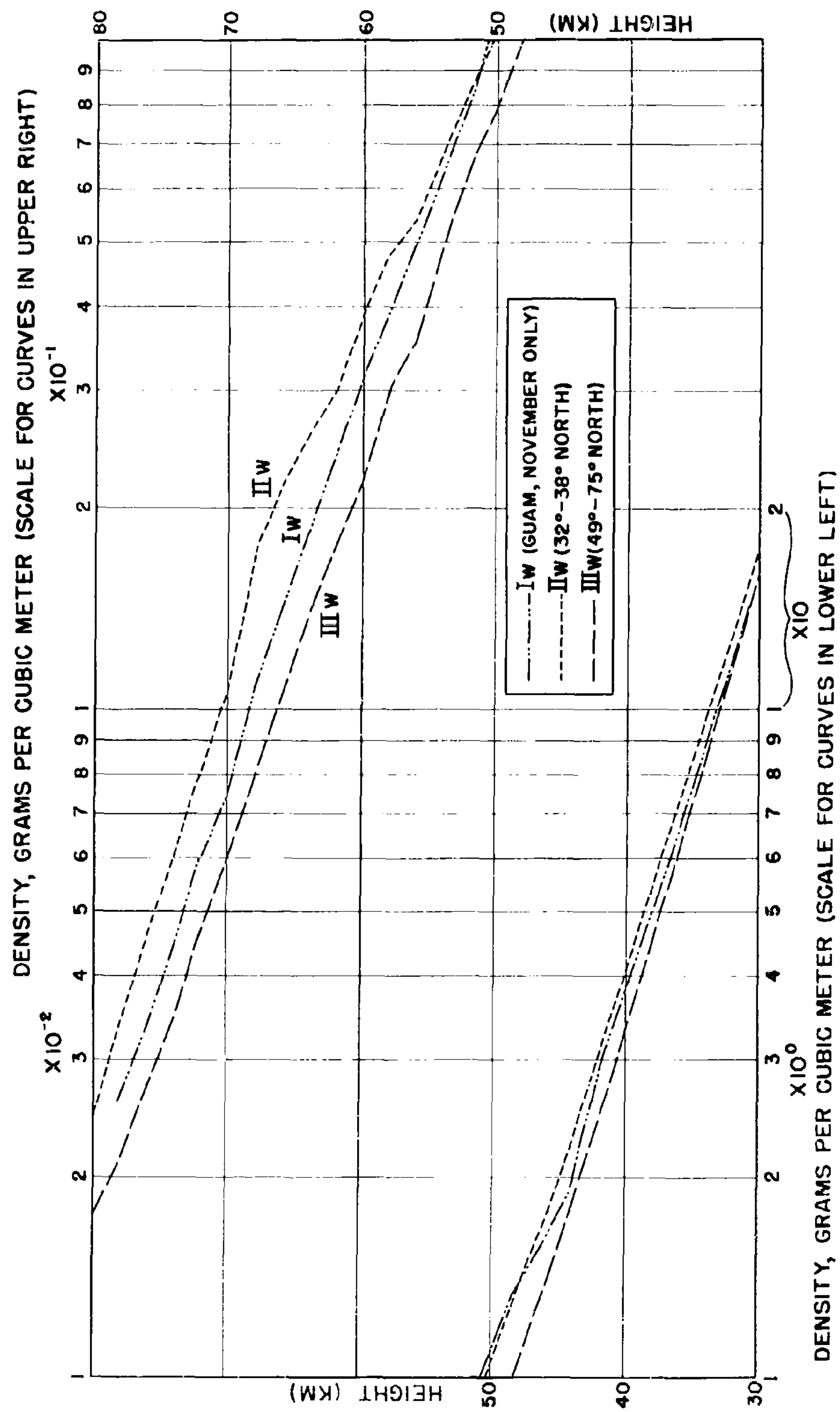

Figure 3 - Latitudinal Variation of Winter Mean Density.

Table 3a. Mean and Extreme Densities (gm m^{-3}), Station Group I (0-14°N)

Height (km)	Winter n	Winter $\bar{\rho}$	Winter Minimum	Winter Maximum	Summer n	Summer $\bar{\rho}$	Summer Minimum	Summer Maximum
30	7	16.4	15.0	17.5				
32	7	12.1	11.5	12.2				
34	7	8.97	8.9	9.1				
36	7	6.70	6.6	6.9				
38	7	5.00	4.9	5.3	1	7.5	7.5	7.5
40	7	3.80	3.7	4.1	1	4.7	4.7	4.7
42	7	2.91	2.8	3.3	1	3.1	3.1	3.1
44	7	1.93	2.1	2.5	1	2.3	2.3	2.3
46	7	1.73	1.63	1.94	1	2.0	2.0	2.0
48	7	1.33	1.26	1.44				
50	7	1.05	1.00	1.15				
52	7	.821	.78	.88				
54	7	.641	.61	.69				
56	7	.487	.48	.55				
58	7	.391	.38	.43				
60	7	.310	.30	.34				
62	5	.236	.23	.25				
64	5	.182	.175	.195				
66	4	.141	.135	.150	1	.20	.20	.20
68	4	.106	.103	.112				
70	3	.0741	.078	.083				
72	2	.0600	.060	.060				
74	2	.0445	.043	.046				
76	2	.033	.031	.035				
78	1	.026	.026	.026				
80								

Table 3b. Mean and Extreme Densities (gm m^{-3}), Station Group II (32-38°N)

Height (km)	Winter n	Winter $\bar{\rho}$	Winter Minimum	Winter Maximum	Summer n	Summer $\bar{\rho}$	Summer Minimum	Summer Maximum
30	7	17.63	17.0	18.0	15	17.85	16.5	19.5
32	7	13.01	12.5	13.5	15	13.13	10.9	15.2
34	8	9.73	9.2	10.2	15	9.49	8.3	10.4
36	8	7.20	6.8	7.7	16	6.94	5.7	7.6
38	8	5.36	5.0	5.9	16	4.91	4.2	5.7
40	8	4.03	3.7	4.5	16	3.89	3.1	4.4
42	8	3.03	2.7	3.4	16	2.98	2.1	3.5
44	9	2.26	1.85	2.5	16	2.27	1.95	2.5
46	9	1.71	1.45	1.90	16	1.78	1.55	2.1
48	1*	1.35	1.35	1.35	6*	1.50	1.32	1.60
50	9	1.04	.86	1.20	17	1.08	.94	1.29
52	9	.838	.71	.97	18	.869	.74	1.00
54	9	.667	.51	.80	18	.677	.41	.80
56	9	.539	.41	.66	17	.542	.45	.66
58	9	.469	.36	.60	17	.435	.37	.52
60	9	.388	.28	.55	18	.348	.26	.44
62	9	.296	.22	.42	17	.278	.21	.35
64	8	.256	.178	.35	17	.235	.157	.36
66	8	.207	.137	.30	16	.182	.120	.25
68	9	.170	.107	.26	16	.151	.082	.22
70	2	.106	.082	.129	4	.0990	.078	.117
72	2	.0810	.062	.100	3	.0680	.056	.085
74	2	.0605	.046	.075	2	.0590	.050	.068
76	2	.0460	.035	.057	2	.0390	.031	.047
78	2	.0340	.026	.042	2	.0305	.028	.033
80	2	.0243	.0195	.029	2	.0200	.0190	.021

* Value for n is correct as stated. The sudden reduction in sample size at 48 km is due to a lack of suitable searchlight data. Although data are relatively plentiful below about 45 km and above 50 km, it was felt that interpolation across this gap to obtain values at 48 km would lead to serious inaccuracies.

Table 3c. Mean and Extreme Densities (gm m^{-3}), Station Group III (49-75°N)

Height (km)	Winter n	Winter $\bar{\rho}$	Winter Minimum	Winter Maximum	Summer n	Summer $\bar{\rho}$	Summer Minimum	Summer Maximum
30	14	16.53	14.3	18.5	7	18.47	17.5	19.8
32	14	11.80	10.0	13.6	9	13.73	13.0	14.7
34	14	8.46	7.0	10.1	10	10.02	9.6	10.9
36	14	6.17	5.0	7.7	10	7.45	7.1	8.0
38	14	4.46	3.6	5.7	11	5.84	5.3	8.0
40	14	3.27	2.6	4.2	11	4.38	4.0	5.6
42	14	2.41	1.93	3.1	10	3.29	3.0	4.1
44	14	1.82	1.43	2.3	10	2.53	2.3	3.1
46	14	1.36	1.08	1.75	9	1.94	1.75	2.3
48	14	1.03	.81	1.37	7	1.51	1.36	1.77
50	14	.789	.61	1.10	7	1.19	1.07	1.38
52	16	.636	.48	.85	7	.919	.81	1.08
54	16	.486	.37	.66	7	.723	.63	.84
56	17	.352	.29	.52	7	.574	.50	.66
58	18	.297	.23	.40	7	.456	.39	.53
60	18	.216	.175	.30	8	.365	.31	.41
62	17	.175	.130	.24	8	.285	.23	.33
64	17	.137	.094	.195	8	.221	.188	.25
66	16	.103	.071	.145	8	.170	.146	.190
68	16	.0784	.055	.105	7	.133	.116	.150
70	16	.0596	.042	.083	8	.101	.088	.120
72	16	.0468	.033	.068	8	.0773	.066	.093
74	14	.0344	.025	.055	7	.0579	.048	.070
76	15	.0267	.0180	.044	7	.0429	.035	.053
78	14	.0211	.0141	.036	7	.0310	.025	.039
80	14	.0173	.0106	.030	7	.0229	.0178	.030

Table 3d. Mean and Extreme Densities (gm m^{-3}), Station Groups I, II & III

Height (km)	n	Annual $\bar{\rho}$	Minimum	Maximum
30	50	17.33	14.3	19.8
32	52	12.72	10.0	15.2
34	54	9.29	7.0	10.9
36	55	6.85	5.0	8.0
38	57	5.10	3.6	8.0
40	57	3.85	2.6	5.6
42	56	2.89	1.93	4.1
44	57	2.16	1.43	3.1
46	56	1.69	1.08	2.3
48	35	1.28	.81	1.77
50	54	1.01	.61	1.38
52	57	.799	.48	1.08
54	57	.623	.37	.84
56	57	.482	.29	.66
58	58	.394	.23	.60
60	60	.312	.175	.55
62	56	.246	.130	.42
64	55	.201	.094	.36
66	54	.158	.071	.30
68	52	.126	.055	.26
70	33	.0790	.042	.129
72	31	.0598	.033	.100
74	27	.0450	.025	.075
76	28	.0334	.0180	.057
78	26	.0257	.0141	.042
80	25	.0196	.0106	.030

SECTION IV — VARIABILITY OF DENSITY

In 1952, Jacchia [3] compared densities derived from the deceleration of meteors over New Mexico and Massachusetts and found a seasonal variation at heights 65 to 85 km which was more than twice as large over Massachusetts as over New Mexico. Later sources [4][5], based on limited series of rocket observations, have provided further evidence for a large seasonal variation of the order of 10% to 40%, in the arctic mesosphere. These sources have also indicated an appreciable latitudinal gradient in the winter densities. These and other aspects of the variation of density will be discussed in the sections that follow.

Variations in the Means.

The most interesting features in the data for 1947 to 1958 are the low winter densities at arctic latitudes (Curve IIIw, Figure 2) and the large variability in the vicinity of 60 to 70 km. At these levels, the mean arctic density in winter is 60% of the summer value and is one-half of the winter value for mid-latitudes (IIw). Below the *mesopeak* (the temperature maximum at about 50 km), the seasonal variation diminishes greatly with decreasing height.

The seasonal variation in mid-latitudes amounts to only a few percent near the base of the mesosphere and is greatest at 66 km (13%). At 70 to 80 km the data sample is too small to determine the amount of variation with certainty. A general decrease from the value at 66 km is indicated, possibly leading to a reversal in the sign of the variation at around 80 km. Unlike conditions in the arctic, the season of minimum density is not constant with height in the mesosphere. Our data indicate reversals in the sign of the variation at around 33, 44, and 57 km.

A tentative model of the seasonal variation of mean density for the atmosphere from near the ground surface to a height of 200 km is shown in Figure 4. In this figure, the percent departures from the annual mean densities at levels below 30 km are based on radiosonde data for geometric heights presented in Reference [6]. Data for St. Paul Island, Alaska (57°N) and Thule, Greenland (77°N) were used for arctic latitudes, and data for Washington, D. C. (39°N) were used for mid-latitudes. Data published by Wege and others [7] in the form of seasonal isoline maps of mean density over the Northern Hemisphere are constant-pressure data (200 mb to 20 mb) and are not directly comparable. To illustrate, the mean height of the 50-mb surface at 60°N, 90°W varies from approximately 24.4 km in summer to 23.3 km in winter. The normal variation in density corresponding to this variation in height is about twice the seasonal variation at constant height; thus, Wege's data show a winter density at 50 mb which is higher than the summer density, in contrast to the variation shown by the data in Reference [6].

For 30 to 80 km, the curves in Figure 4 are based on the means in Table 2.

In the region 100 to 200 km, the values shown are based on limited data obtained from rocket soundings and are essentially consistent with theoretical curves deduced for the atmosphere from 100 to 500 km by Nosenzo and Slezak [8].

In interpreting Figure 4, it is useful to note that a percent departure of 33% from the annual mean corresponds to a seasonal variation by a factor of 2 (at around 180 km the artic summer density is twice the arctic winter density), a percent departure of 20% corresponds to a variation by a factor of 1.5, and so on.[2]

[2] For example, consider the numbers 1 and 2. The second value is twice the first. Their average is 1.5, and the departure of either value from the average is only 0.5/1.5, or 33%.

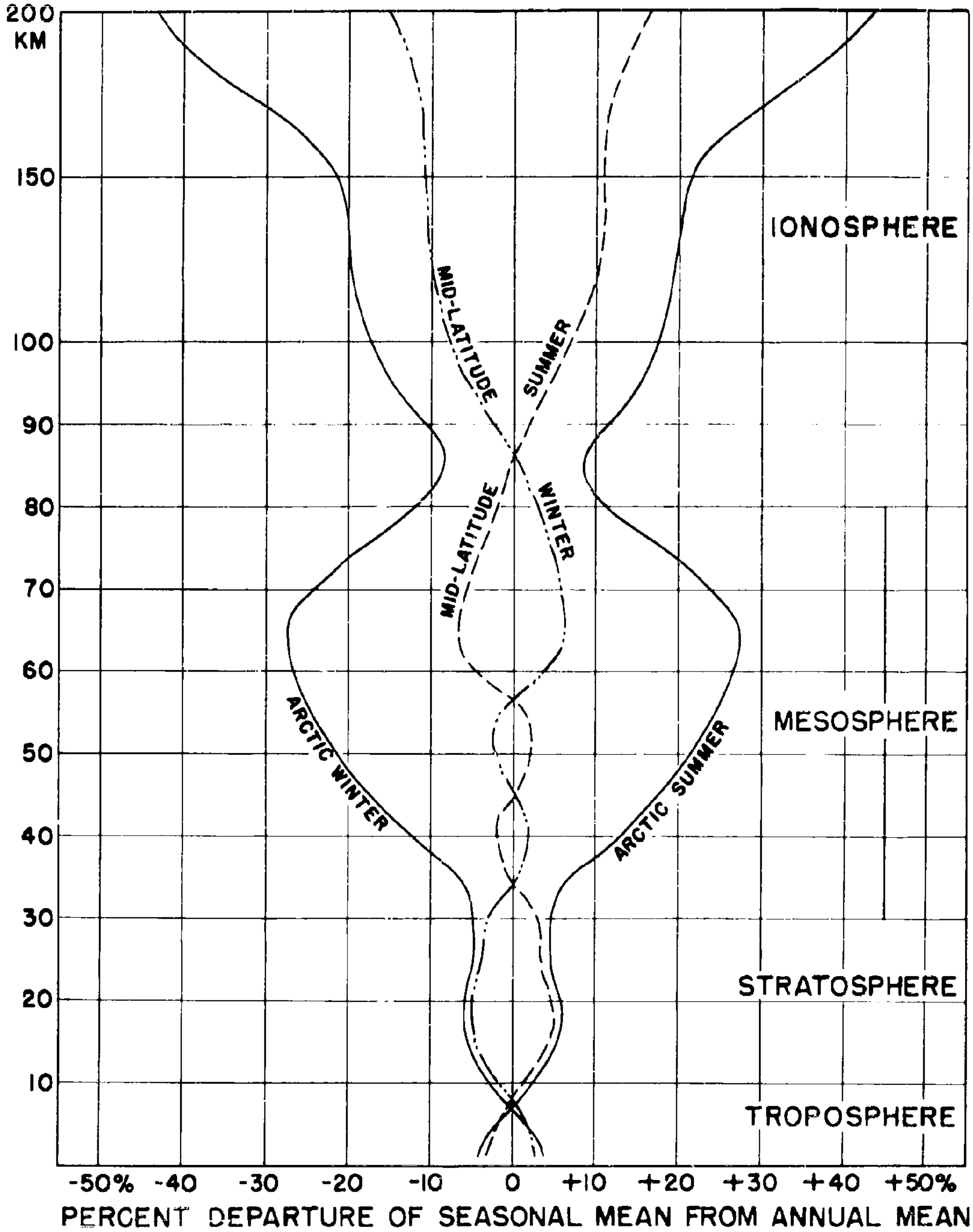

Figure 4 - Model of the Seasonal Variation of Mean Density to 200 km.

It should be emphasized that above 100 km, where the observational error for much of the rocket data is of the order of a factor of 2 or more, there are as yet insufficient data to define accurately the seasonal variation of density. Densities deduced from satellite orbital data fail to clarify the picture. Accordingly to King-Hele [9], satellite densities at 200 to 300 km do not fall into a consistent pattern, either seasonally or latitudinally. At these heights solar disturbances, which give rise to density variations of 20% with a periodicity of about 28 days, appear to be the main factor influencing the air density. King-Hele has further concluded that at heights near 220 km, at latitudes from 80°N to 65°S, the air density does not vary from its average value by a factor of more than 1.5; i.e., 50% of the annual average. This value is in good agreement with the percent departure which would be inferred by extrapolating the artic curves in Figure 1 to a height of 220 km.

The Anomaly at 60-70 Kilometers.

The curious bulge above the mesopeak in Curves IIw and IIs (Figure 2), centered at 60 to 70 km, is of special interest. A straight-edge placed along Curve IIIs clearly shows this feature to be present also during the arctic summer, although it is less pronounced.

Some of the bulging appears to be related to the peculiar temperature regime above the mesopeak. Below the mesopeak, temperature increases and pressure decreases with height, and in accordance with the equation of state, temperature and pressure operate jointly to produce a fall in density. Above the mesopeak a general decrease in both temperature and pressure results in a reduced rate of fall in density. Furthermore, the curvilinear shape of the density profile appears to be an imperfect reverse reflection of the curvilinear temperature structure above the mesopeak present in some of the soundings for mid-latitudes and for the artic summer. The shape of these soundings resembles a flattened "S" stretched along a straight line connecting 50 and 80 km, ascending diagonally to the left.

The temperature regime at 50 to 80 km above Fort Churchill differs radically from summer to winter. Rocket grenade experiments [10] have shown steep temperature lapse rates in summer, while winter, on the other hand, is characterized by stable lapse rates, with frequent inversions occurring above about 60 km. This seasonal variation may account for the different structure in density Curves IIIw and IIIs.

While the general shape of Curves IIs, IIw, and IIIs (Figure 2) is consistent with respect to the temperature distribution, the marked degree of bulging is not readily explained. A detailed examination of temperatures and pressures in individual soundings, and their effect on the density, appears necessary. Other factors, for example air motion, merit consideration. Upper-atmosphere wind data obtained in recent years point to the probability of very strong currents near 60 km; it is therefore reasonable to hypothesize that advective processes may strongly influence the density distribution above the mesopeak.

Latitudinal Gradient of Mean Density.

The winter mean density curves for Guam (14°N), Latitude Group 32° to 38°N, and Latitude Group 49° to 75°N, have been plotted in Figure 3. Throughout most of the mesosphere, the maximum density in winter occurs in mid-latitudes. In the vicinity of 65 km, where the largest gradient is found, the density decreases northward from mid-latitudes at the rate of 2% of the mid-latitude density per degree of latitude; equatorward, the density decreases at the rate of about 1 1/2% per degree of latitude. The only evidence for a gradient equatorward consists of rocket-grenade densities for Guam for November 1958. The one summertime sounding at 161°W, near the equator (see Table 3d), does not offer conclusive evidence regarding conditions in summer. When equatorial data at other longitudes and for other times of the year become available, it will be possible to learn more about the variation between densities in mid-latitudes and densities in the tropics.

Standard Deviation of Density.
Standard deviations about the annual mean densities were computed from the density values in the individual soundings. A comparison of the standard deviations given in Table 4 with the probable error data of Table 2 indicates that the standard deviations, being only partially masked by the observational errors, should be expected to have statistical significance. At the base of the mesosphere, the small values of the standard devistions, expressed as percentages of the mean annual densities, are consistent with values based on radiosonde data reported by Sissenwine and other [6], and in [11]. The increase with height through the mesosphere is consistent with the wide spread of the means at higher levels. In arctic latitudes (Station Group III) the standard deviation reaches a maximum near 60 km, then falls off slightly in the upper reaches of the mesosphere. The general increase through the mesosphere is consistent with the large variability reported at ionospheric levels on the basis of densities deduced from high-altitude rocket flights and from satellite observations [12].

TABLE 4. STANDARD DEVIATION OF DENSITY (gm m^{-3})

Height (km)	Station Group II n	σ	$\sigma/\bar{\rho}$ (%)	Station Group III n	σ	$\sigma/\bar{\rho}$ (%)
30	22	.77	4%	21	1.97	11%
40	24	.33	8%	25	.71	19%
50	26	.11	10%	21	.28	30%
60	27	.066	18%	26	.10	39%
70	6	.021	21%	24	.24	33%
80	4	.0047	21%	21	.0059	31%

Diurnal and Interdiurnal Variations.
There is probably, as yet, insufficient observational material to establish the magnitude of diurnal and interdiurnal variations in density.

On the basis of rocket-grenade firings at Guam on several dates in November 1958, Nordberg and Stroud [13] have reported significant day-to-day variations in temperature above the mesopeak, and a difference of 10°K between temperatures measured in two firings, seven hours apart. A variation in temperature of 10°K, assuming the pressure is constant, results in a density variation of about 4% at 60 km.

At Fort Churchill, a large variation in density over a period of several days in late January and early February 1958, at 45 and 65 km, has been reported by Jones and others [4]. For the New Mexico area, an analysis of the searchlight observations for May to October 1952 (several pairs of which were spaced one day apart) shows occasional day-to-day density changes exceeding 5% in the vicinity of 40 to 50 km, and several cases of more than 10% at 60 km. Even if one assumes that the sign of the observational error varies, a significant interdiurnal variation remains after subtracting the error component. These data suggest that in mid-latitudes the interdiurnal variation is at least as important as the seasonal variation.

SECTION V – SUMMARY

In an earlier report [1], the original density data for 65 soundings in the mesosphere were presented. From these data, together with data for four additional soundings not previously available, values for even whole kilometers from 30 to 80 km were obtained. An error analysis indicates that the mean probable error varies from 5% at 30 km to 8% at 80 km.

Means and extremes for the entire data sample, and seasonal means and extremes for three latitude groups, are presented in tables and graphs. Standard deviations were computed for every 10 km. Some conclusions reached are:

a. The lowest densities are found in winter in arctic latitudes. At 65 km, the mean winter density is 60% of the mean summer density.

b. The seasonal variation in mid-latitudes is relatively small, amounting to less than 5% below 50 km, with a maximum of 13% at 66 km.

c. The latitudinal gradient is greatest in winter and greatest at around 65 km. The gradient is directed northward from mid-latitudes, in the amount of 2% per degree of latitude (at 65 km), and there is a smaller gradient directed equatorward from mid-latitudes.

d. At mid-latitudes, the standard deviation of density varies from 4% (of the mean density) at 30 km to about 20% near 60 km, remaining nearly constant up to the top of the mesosphere. In arctic latitudes, the standard deviation varies from 11% at 30 km to a maximum of about 40% near 60 km, decreasing to about 30% at 80 km.

e. Although there are indications of significant diurnal and interdiurnal variations in density, the necessary observational material to establish the magnitude of these variations in the mesosphere is not yet available.

While these conclusions are based on the best data available at the end of 1960, it is recognized that the statistical sample is still wanting in several respects, particularly above 70 km and in tropical latitudes. The initiation of the North American rocketsonde network in 1959 is an important step toward providing sufficient data to obtain a definitive climatology of the mesosphere. Some temperature soundings, in addition to numerous wind soundings, have already been taken. A falling-sphere arrangement to measure densities directly is contemplated. When the observational errors are fully evaluated, it will be possible to obtain temperature-derived and sphere densities which can be used to test the results presented in this report.

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