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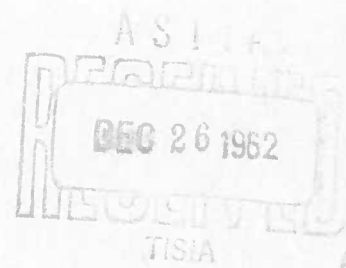
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Research Note

Supplemental Atmospheres

A. COURT
A. J. KANTOR
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Research Note

Supplemental Atmospheres

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A. J. KANTOR
A. E. COLE**

METEOROLOGICAL DEVELOPMENT LABORATORY PROJECT 8624

AIR FORCE CAMBRIDGE RESEARCH LABORATORIES, OFFICE OF AEROSPACE RESEARCH, UNITED STATES AIR FORCE, L.G. HANSCOM FIELD, MASS.

Abstract

Atmospheres typical of the tropics (15°N), sub-tropics (30°N), and mid-latitudes (45°N) have been prepared as members of a family of atmospheres supplemental to the 1962 U. S. Standard Atmosphere; they provide information on latitudinal and seasonal changes in atmospheric structure up to 90 km.

Temperature gradients for various segments are linear with geopotential height. Humidity is incorporated into the lowermost 10 km of each atmosphere. Figures and tables depict temperature, relative humidity, pressure, and density.

The atmospheres are mutually consistent; zonal wind profiles computed from the geostrophic wind equation at selected pressure heights compare favorably with existing rawinsonde and Meteorological Rocket Network wind observations.

The tropical atmosphere has a surface temperature of 26.5°C and a trade-wind inversion, 250 m thick, of 0.8°C at 2250 m, and a sharp tropopause inversion at 16.5 km with a minimum temperature of -80°C; it has isothermal regions at -3°C from 47 to 51 km and at -89°C from 80 to 90 km.

Subtropical winter and summer temperature-height profiles have surface temperatures of 14°C and 28°C, respectively, and three isothermal layers: -70°C at 17 to 18 km in winter and 15 to 16 km in summer; -4°C in winter and -0.5°C in summer, both at 47 to 51 km; -82°C in winter and -94.5°C in summer, both at 80 to 90 km.

Mid-latitude winter and summer profiles begin with surface temperature of -1°C and 21°C, respectively, and contain three isothermal regions: -58°C at 19 to 27 km in winter and -57.5°C at 13 to 17 km in summer; -7.5°C and 2.5°C at 47 to 52 km; and -79.5°C and -99°C at 80 to 90 km in winter and summer, respectively.

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Foreword

The revised "U. S. Standard Atmosphere, 1962," extending to 700 km was adopted on 15 March 1962 by the U. S. Committee on Extension to the Standard Atmosphere (COESA), representing 29 U. S. scientific and engineering organizations. The Atmosphere is intended to permit estimation of the effects of the atmosphere on certain design and performance criteria of objects traveling through it, as well as to serve as a mid-latitude reference against which new measurements of atmospheric properties can be compared.

To satisfy the many requests for description of latitudinal and seasonal changes to a height of at least 90 km, not distinguished in a single Standard, an attempt has been made to incorporate systematically the relatively few observations available above 30 km into an internally consistent family of atmospheric models. Although much less detailed than the U. S. Standard Atmosphere, 1962, these models combined into a north-south vertical cross section serve to illustrate latitudinal and winter-summer atmospheric variations.

The Tropical, Subtropical and Mid-latitude Atmospheres described in this report were reviewed at a COESA working group meeting in June, 1962. A task group was appointed to investigate new data, and to revise and extend these models to the subarctic and arctic so that eventually a complete series of supplemental atmospheres can be adopted by COESA and published as an appendix to the U. S. Standard Atmosphere through the Government Printing Office.

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June 1962

Supplemental Atmospheres

1 INTRODUCTION

A mean annual Tropical (15°N) Atmosphere and summer and winter Subtropical (30°N) and Mid-latitude (45°N) Atmospheres described in this report define atmospheric structure typical of tropical, subtropical and middle latitudes in the Northern Hemisphere. These atmospheres belong to a family of nine atmospheres which are being constructed at 15° latitude intervals from 15° through 75°N to supplement the U. S. Standard Atmosphere, 1962. They reflect the seasonal and latitudinal variability of density, temperature and pressure, thus amplifying the description provided by the U. S. Standard. As in the Standard, the latest internationally adopted values of the various thermodynamic and physical constants have been used in all equations for computing atmospheric properties (Cole et al, 1961). Each supplemental atmosphere retains the value for the acceleration due to gravity corresponding to its latitude decreasing with height according to Lambert's (1951) formula:

Tropical:	978.381	cm/sec ²
Subtropical:	979.324	cm/sec ²
Mid-latitude:	980.665	cm/sec ²

The defining parameter up to at least 80 km is atmospheric temperature with linear gradients in geopotential meters exact to tenths of a Celsius degree. Humidity has been specified at appropriate levels in all five atmospheres. Mean values of relative humidity, ambient temperature, and resulting virtual temperatures for the lowermost 10 km of each atmosphere are shown

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in Table 4. Above 10 km the differences between virtual and ambient temperatures are insignificant since relative humidity less than 30 percent produces a negligible virtual temperature increment at the colder temperatures.

The derived virtual temperature gradients depart from linearity so slightly that errors in pressure, assuming linearity, are insignificant over 1- and 2-km layers. Vertical pressure and density distributions were calculated for each atmosphere according to its assumed moisture content from the hydrostatic equation and the equation of state (Cole and Kantor, 1962; Kantor and Cole, 1962).

2 DATA

Data available for constructing the various atmospheres consisted of: (1) summaries of radiosonde observations at stations within a few degrees of latitudes 15°, 30°, and 45°N; (2) density measurements from searchlight observations in New Mexico; and (3) observations made from rockets and instruments released by rockets fired at ranges in California, Florida, New Mexico, Virginia, and Guam (all between 13° and 38°N), at Churchill, Canada (59°N), in Australia (33°S), at the equator, and aboard ships. Data sources are given in the Appendix.

Below 30 km realistic mean January and July temperatures for latitudes 30° and 45°N and mean annual temperatures for 15°N were obtained by giving equal weight to radiosonde observations and interpolated data over both land and ocean areas at each ten degrees of longitude. Above 30 km the temperature-height profiles were based on mean seasonal latitudinal temperature-height cross sections between 15° and 60°N (Fig.1), prepared from all available rocket and searchlight observations of temperature, pressure, and density between 30 and 90 km. Winter and summer temperatures for 60°N are preliminary and appear on the cross section solely for comparison with the proposed 15°, 30°, and 45°N structure. Additional research is underway in order to determine more accurately the vertical temperature distribution and variability at latitude 60°N and 75°N, particularly during the winter months.

Sea-level pressures for each atmosphere were estimated from monthly normal sea-level charts for the Northern Hemisphere (USWB, 1952) based upon a 40-year period of record, and from 5-day normal sea-level charts (Lahey et al, 1958) based upon a 20-year period of record. Mean hemispheric sea-level pressures selected for the various atmospheres are shown in Tables 1, 2, and 3.

3 DESCRIPTION

A mean annual atmosphere rather than seasonal atmospheres was adopted for 15°N since the temperature-height structure in the tropics remains relatively constant throughout the year. The largest seasonal variability in temperature (3° - 5°) occurs near the tropopause which is about 1 km higher in January than in July. Routine averaging by height of available data indicates an isothermal layer about 2 km thick from 16 to 18 km; averaging of tropopause height and temperature, and of conditions above and below it, however, depicts a sharp inversion. As a result, the mean annual profile has a tropopause, 16.5 geopotential km, more typical of actual conditions.

Latitude 15°N lies in the heart of the trade-wind belt characterized by a trade-wind inversion through most of the year. To represent the average height and magnitude of this inversion, the mean annual temperature-height profile has a 0.8°C temperature inversion between 2250 and 2500 meters. The Tropical Atmosphere is considered representative of the entire region between the equator and 15°N because differences in mean temperature between 15°N and the equator are no larger than between various longitudes along 15°N.

The temperature-height profiles for 30° and 45°N atmospheres are compared with the mean annual 15°N atmosphere in Figure 2 for winter and summer. In Figure 3 each atmosphere is shown with the U. S. Standard, and in addition the tropical atmosphere is compared to temperature-height curves for three other atmospheres:

1. MIL-STD 210A, Tropical Atmosphere (DOD, 1957)
2. Tropical Atmosphere, proposed by Pisharoty (1959)
3. A Low-latitude Atmosphere, prepared by Nordberg and Stroud (1961).

All four low-latitude profiles are in close agreement reflecting the homogeneity of the tropical climate.

4 DENSITIES

Densities for the proposed Tropical, Subtropical, and Mid-latitude Atmospheres are shown in Figure 4, as percent departures from the 1962

U. S. Standard. Also depicted with the 15°N atmosphere are density departures for the MIL-STD 210A Tropical Atmosphere.

Comparisons for both 15° and 30°N are based on densities at even geopotential altitudes. However, geometric height of a given geopotential surface decreases with increasing latitude: the 50 geopotential km surface at latitudes 15° and 30°N occurs at 50.480 and 50.432 geometric km, respectively. The percentage departures shown in Figure 4 at geopotential heights are therefore slightly different than those at geometric heights. The differences at 90 km, the altitude at which the largest discrepancy exists, is roughly 2 to 3 percent.

Based on rocket and searchlight observations, estimates of the day-to-day (inter-diurnal) variability exceeded less than 5 percent of the time above 30 km are shown in Figure 4 for 30°N (horizontal arrows). Minimum seasonal and inter-diurnal variability at 8 km represents the isopycnic level where density remains relatively constant throughout the year regardless of location. A second isopycnic level may exist near 90 km, at which seasonal density profiles at all latitudes appear to approach or cross the Standard (Cole, 1961); the limited number of observations at this altitude also indicates a decrease in inter-diurnal variability.

At 45°N densities are not symmetric about the Standard at most heights: the summertime departures are larger than those of winter, particularly above 8 km. Below 30 km, where data are plentiful, mean annual densities based on all months (or four seasons) approach the Standard, whereas those averaged for winter and summer values do not. Since similar conditions probably exist between 30 and 90 km, the annual variation of density, to at least 90 km, is not linear at 45°N.

5 VALIDITY

January and July geostrophic zonal wind components were estimated between 25° and 30°N, and 30° and 45°N, using latitudinal pressure gradients computed from the Tropical, Subtropical and Mid-latitude Atmospheres. These estimates are compared in Figure 5 with appropriate Meteorological Rocket Network zonal wind observations (Bruch and Morgan, 1961, USASMSA, 1959-1961) above 30 km, and with serially complete tabulations of rawinsonde observations for the period 1951-1956 (Charles, 1956) below 30 km.

For further comparison geostrophic winds were also computed between 25°

and 30°N (Fig. 5), using seasonal tropical data. The slightly better agreement of computed and observed winds using seasonally computed pressure-heights at 15°N in contrast to that using mean annual values at 15°N does not warrant development of seasonal atmospheres at 15°N at this time.

The five supplemental atmospheres are mutually consistent. Temperatures, pressures, and densities versus geopotential and geometric altitudes are provided for each atmosphere at heights up to 90 km (Tables 1, 2, and 3).

The Tropical Atmosphere represents mean annual conditions at 15°N, a region with little seasonal variability; the Subtropical and Mid-Latitude Atmospheres depict mean winter and summer conditions at 30° and 45°N, respectively. At latitude 45°N, however, and to some extent 30°N, longitudinal variations in mean winter and summer temperatures are significant up to heights of about 15 km, reflecting hemispheric continental and maritime influences. Winter temperatures over continents can be as much as 50°C lower than that over oceans at the surface, and 10°C near 15 km. Thus, suitability of mean seasonal atmospheric structure in the lower most 15 km must be carefully determined when used for specified location and/or purposes.

Table 1. Properties to 90 Km of Mid-Latitude (45°N) Atmosphere,
Winter and Summer.

Kilometers		Temp. Grad.		Temp. (K)		Pressure (mbs)		Density (g / m ³)	
Geomet	Geopot	Win	Sum	Win	Sum	Win	Sum *	Win	Sum *
90.000	88.743	0.0	0.0	204.15	174.15	1.9472	1.7975 -3	3.3229	3.5957 -3
89.235	88.000	0.0	0.0	204.15	174.15	2.2051	2.0796	3.7628	4.1600
87.179	86.000	0.0	0.0	204.15	174.15	3.0816	3.0787	5.2586	6.1587
85.125	84.000	0.0	0.0	204.15	174.15	4.3066	4.5579	7.3490	9.1177 -3
83.072	82.000	0.0	0.0	204.15	174.15	6.0184	6.7478	1.0270	1.3498 -2
81.020	80.000	0.0	0.0	204.15	174.15	8.4108	9.9898 -3	1.4353	1.9984
79.994	79.000	xxx	xxx	204.15	174.15	0.9943	1.2155 -2	1.6967	2.4315
78.969	78.000	-2.5	-4.5	206.65	178.65	1.1742	1.4753	1.9795	2.8769
76.920	76.000	-2.5	-4.5	211.65	186.65	1.6279	2.1426	2.6795	3.9777
74.872	74.000	-2.5	-4.5	216.65	196.65	2.2398	3.0577	3.6016	5.4168
72.825	72.000	-2.5	-4.5	221.65	205.65	3.0593	4.2948	4.8084	7.2754
70.779	70.000	-2.5	-4.5	226.65	214.65	4.1497	5.9453	6.3783	9.6491 -2
68.735	68.000	-2.5	-4.5	231.65	223.65	5.5913	8.1207 -2	0.8409	1.2649 -1
66.692	66.000	-2.5	-4.5	236.65	232.65	0.7486	1.0931 -1	1.1020	1.6368
64.651	64.000	xxx	-4.5	241.65	241.65	0.9962	1.4616	1.4361	2.1071
62.611	62.000	-2.0	xxx	245.65	250.65	1.3187	1.9292	1.8701	2.6813
60.572	60.000	-2.0	-2.5	249.65	255.65	1.7376	2.5270	2.4247	3.4435
58.534	58.000	-2.0	-2.5	253.65	260.65	2.2797	3.2928	3.1310	4.4010
56.498	56.000	-2.0	-2.5	257.65	265.65	2.9782	4.2690	4.0269	5.5983
54.463	54.000	-2.0	-2.5	261.65	270.65	3.8747	5.5080	5.1589	7.0897
52.429	52.000	xxx	xxx	265.65	275.65	5.0210	7.0735	6.5845	8.9396 -1
50.396	50.000	0.0	0.0	265.65	275.65	6.4938	9.0632 -1	0.8516	1.1454 +0
48.365	48.000	0.0	0.0	265.65	275.65	9.8399	1.1613 +0	1.1014	1.4677
47.350	47.000	xxx	xxx	265.65	275.65	0.9551	1.3145	1.2525	1.6613
46.335	46.000	+3.1	+2.5	262.55	273.15	1.0870	1.4888	1.4423	1.8988
44.307	44.000	+3.1	+2.5	256.35	268.15	1.4145	1.9164	1.9223	2.4897
42.279	42.000	+3.1	+2.5	250.15	263.15	1.8526	2.4785	2.5800	3.2812
40.253	40.000	+3.1	+2.5	243.95	258.15	2.4429	3.2214	3.4886	4.3472
38.229	38.000	+3.1	+2.5	237.75	253.15	3.2443	4.2084	4.7538	5.7914
36.205	36.000	+3.1	+2.5	231.55	248.15	4.3410	5.5722	6.5311	7.8227 +0
34.183	34.000	+3.1	+2.5	225.35	243.15	5.8545	7.2998	0.9051	1.0459 +1
32.162	32.000	xxx	xxx	219.15	238.15	7.9616	9.6966 +0	1.2656	1.4184
30.142	30.000	+0.8	+2.1	217.55	233.95	1.0887	1.2952 +1	1.7434	1.9287
28.124	28.000	+0.8	+2.1	215.95	229.75	1.4921	1.7391	2.4071	2.6370
27.115	27.000	xxx	xxx	215.15	227.65	1.7484	2.0193	2.8310	3.0901
26.107	26.000	0.0	+1.2	215.15	226.45	2.0493	2.3472	3.3182	3.6109
24.091	24.000	0.0	+1.2	215.15	224.05	2.8153	3.1790	4.5584	4.9430
22.076	22.000	0.0	+1.2	215.15	221.65	3.8677	4.3197	6.2627	6.7893
20.063	20.000	0.0	+1.2	215.15	219.25	5.3134	5.8892	8.6034	9.3575 +1
19.057	19.000	xxx	+1.2	215.15	218.05	6.2278	6.8852	1.0084	1.1000 +2
18.051	18.000	-0.5	+1.2	215.65	216.85	7.2981	8.0565	1.1790	1.2943
17.046	17.000	-0.5	xxx	216.15	215.65	8.5492	9.4353 +1	1.3779	1.5242
16.040	16.000	-0.5	0.0	216.65	215.65	1.0011	1.1055 +2	1.6098	1.7859
14.031	14.000	-0.5	0.0	217.65	215.65	1.3713	1.5176	2.1949	2.4516
13.027	13.000	-0.5	xxx	218.15	215.65	1.6041	1.7781	2.5616	2.8724
12.023	12.000	-0.5	-6.5	213.65	222.15	1.8757	2.0784	2.9885	3.2593
10.016	10.000	xxx	-6.5	219.65	235.15	2.5620	2.8025	4.0634	4.1515
8.010	8.000	-6.0	-6.5	231.65	248.15	3.4682	3.7184	5.2155	5.2189
6.006	6.000	-6.0	xxx	243.65	261.15	4.6236	4.8625	6.6096	6.4828
4.003	4.000	-6.0	-6.0	255.65	273.15	6.0789	6.2782	8.2797	7.9955
3.001	3.000	xxx	-6.0	261.65	279.15	6.9367	7.1034	9.2287	8.8451 +2
2.001	2.000	-3.5	xxx	265.15	285.15	7.8964	8.0150 +2	1.0364	9.7560 +3
0.000	0.000	-3.5	-4.5	272.15	294.15	1.0180	1.0135 +3	1.3010	1.1920 +3

* Power of ten by which preceding figures should be multiplied.

Table 2. Properties to 90 km of Subtropical (30°N) Atmosphere,
Winter and Summer

Kilometers		Temp. Grad.		Temp. (K)		Pressure (mbs)			Density (g / m ³)	
Geomet	Geopot	Win	Sum	Win	Sum	Win	Sum	*	Win	Sum *
90.000	88.680	0.0	0.0	191.15	178.65	1.8916	1.7297	-3	3.4474	3.3729 -3
89.301	88.000	0.0	0.0	191.15	178.65	2.1357	1.9695		3.8923	3.8411
87.244	86.000	0.0	0.0	191.15	178.65	3.0518	2.8856		5.5619	5.6270
85.188	84.000	0.0	0.0	191.15	178.65	4.3608	4.2277		7.9476	8.2441 -3
83.133	82.000	0.0	0.0	191.15	178.65	6.2314	6.1941		1.1357	1.2079 -2
81.078	80.000	0.0	0.0	191.15	178.65	8.9044	9.0752	-3	1.6228	1.7697
80.053	79.000	xxx	xxx	191.15	178.65	1.0644	1.0985	-2	1.9399	2.1421
79.028	78.000	-3.1	-3.7	194.25	182.35	1.2705	1.3270		2.2785	2.2352
76.978	76.000	-3.1	-3.7	200.45	189.15	1.7954	1.9151		3.1203	3.5160
74.928	74.000	-3.1	-3.7	206.65	197.15	2.5104	2.7251		4.2320	4.8153
72.879	72.000	-3.1	-3.7	212.85	204.55	3.4757	3.8277		5.6887	6.5190
70.830	70.000	-3.1	-3.7	219.05	211.95	4.7673	5.3120		7.5818	8.7311 -2
68.786	68.000	-3.1	-3.7	225.25	219.35	6.4815	7.2892		1.0024	1.1577 -1
66.742	66.000	-3.1	-3.7	231.45	226.75	8.7389	9.8981	-2	1.3154	1.5207
64.699	64.000	-3.1	-3.7	237.65	234.15	1.1689	1.3309	-1	1.7135	1.9801
62.657	62.000	-3.1	-3.7	243.85	241.55	1.5520	1.7732		2.2172	2.5574
60.615	60.000	-3.1	-3.7	250.05	248.95	2.0460	2.3420		2.8505	3.2773
59.596	59.000	xxx	xxx	253.15	252.65	2.3431	2.6833		3.2244	3.6999
58.578	58.000	-2.0	-2.5	255.15	255.15	2.6798	3.0692		3.6589	4.1906
56.541	56.000	-2.0	-2.5	259.15	260.15	3.4941	3.9998		4.6971	5.3562
54.504	54.000	-2.0	-2.5	263.15	265.15	4.5374	5.1865		6.0068	6.8144
52.468	52.000	-2.0	-2.5	267.15	270.15	5.8691	6.6926		7.6535	8.6304
51.450	51.000	xxx	xxx	269.15	272.65	6.6654	7.5890		8.6273	9.6966 -1
50.432	50.000	0.0	0.0	269.15	272.65	7.5661	8.6006	-1	0.9793	1.0989 +0
48.401	48.000	0.0	0.0	269.15	272.65	0.9749	1.1046	+0	1.2619	1.4114
47.385	47.000	xxx	xxx	269.15	272.65	1.1067	1.2519		1.4324	1.5996
46.370	46.000	+2.4	+2.4	266.75	270.25	1.2570	1.4195		1.6416	1.8298
44.340	44.000	+2.4	+2.4	261.95	265.45	1.6271	1.8314		2.1639	2.4035
42.311	42.000	+2.4	+2.4	257.15	260.65	2.1164	2.3738		2.8672	3.1727
40.282	40.000	+2.4	+2.4	252.35	255.85	2.7665	3.0916		3.8192	4.2096
38.258	38.000	+2.4	+2.4	247.55	251.05	3.6348	4.0468		5.1152	5.6156
36.233	36.000	+2.4	+2.4	242.75	246.25	4.8014	5.3246		6.8905	7.5327 +0
34.209	34.000	+2.4	+2.4	237.95	241.45	6.3777	7.0440		0.9337	1.0163 +1
32.186	32.000	xxx	xxx	233.15	236.65	8.5207	9.3710	+0	1.2732	1.3795
30.163	30.000	+2.0	+2.0	229.15	232.65	1.1447	1.2534	+1	1.7403	1.8768
28.144	28.000	+2.0	+2.0	225.15	228.65	1.5458	1.6848		2.3918	2.5670
26.125	26.000	+2.0	+2.0	221.15	224.65	2.0986	2.2767		3.3059	3.5306
24.108	24.000	+2.0	+2.0	217.15	220.65	2.8652	3.0932		4.5966	4.8836
22.092	22.000	xxx	+2.0	213.15	216.65	3.9346	4.2261		6.4307	6.7955
21.084	21.000	+2.5	xxx	210.65	214.65	4.6219	4.9505		7.6437	8.0345
20.077	20.000	+2.5	+2.3	208.15	212.35	5.4398	5.8083		9.1043	9.5287 +1
18.064	18.000	xxx	+2.3	203.15	207.75	7.5803	8.0377		1.2999	1.3478 +2
17.057	17.000	xxx	+2.3	203.15	205.45	8.9665	9.4809	+1	1.5376	1.6076
16.052	16.000	-2.6	xxx	205.75	203.15	1.0595	1.1204	+2	1.7939	1.9213
15.046	15.000	-2.6	xxx	208.35	203.15	1.2493	1.3253		2.0889	2.2727
14.041	14.000	-2.6	-7.0	210.95	210.15	1.4700	1.5632		2.4276	2.5914
12.031	12.000	xxx	-7.0	216.15	224.15	2.0235	2.1405		3.2613	3.3267
10.023	10.000	-6.5	-7.0	229.15	238.15	2.7494	2.8758		4.1798	4.2062
8.016	8.000	-6.5	-7.0	242.15	252.15	3.6728	3.7987		5.2830	5.2458
6.010	6.000	-6.5	xxx	255.15	266.15	4.8326	4.9422		6.5961	6.4619
4.005	4.000	-6.5	-5.5	268.15	277.15	6.2717	6.3508		8.1407	7.9634
2.002	2.000	xxx	-5.5	281.15	288.15	8.0375	8.0778		9.9341	9.7192 +2
1.001	1.000	-3.0	xxx	284.15	293.65	9.0652	9.0770	+2	1.1072	1.0698 +3
0.000	0.000	-3.0	-7.5	287.15	301.15	1.0210	1.0170	+3	1.2328	1.1632 +3

*Power of ten by which preceding figures should be multiplied.

Table 3. Properties to 90 km of Tropical (15°N) Atmosphere

Kilometers		Temperature		Pressure	Density
Geomet	Geopot	Grad.	Kelvin	mbs *	g / m ³ *
90.000	88.597	0.0	184.15	1.8620 -3	3.5224 -3
89.388	88.000	0.0	184.15	2.0796	3.9342
87.330	86.000	0.0	184.15	3.0113	5.6965
85.272	84.000	0.0	184.15	4.3603	8.2487 -3
83.214	82.000	0.0	184.15	6.3137	1.1944 -2
81.156	80.000	0.0	184.15	9.1422 -3	1.7295
80.130	79.000	xxx	184.15	1.1001 -2	2.0811
79.104	78.000	-3.5	187.65	1.3215	2.4534
77.052	76.000	-3.5	194.65	1.8878	3.3786
75.000	74.000	-3.5	201.65	2.6630	4.6006
72.949	72.000	-3.5	208.65	3.7128	6.1989
70.898	70.000	-3.5	215.65	5.1199	8.2710 -2
68.852	68.000	-3.5	222.65	6.9881	1.0934 -1
66.806	66.000	-3.5	229.65	9.4466 -2	1.4330
64.761	64.000	-3.5	236.65	1.2655 -1	1.8629
62.717	62.000	-3.5	243.65	1.6809	2.4033
60.673	60.000	-3.5	250.65	2.2148	3.0783
59.652	59.000	xxx	254.15	2.5351	3.4749
58.634	58.000	-2.0	256.15	2.8974	3.9404
56.595	56.000	-2.0	260.15	3.7730	5.0524
54.556	54.000	-2.0	264.15	4.8935	6.4536
52.518	52.000	-2.0	268.15	6.3221	8.2135
51.498	51.000	xxx	270.15	7.1756	9.2534 -1
50.480	50.000	0.0	270.15	8.1405 -1	1.0497 0
48.448	48.000	0.0	270.15	1.0477 0	1.3511
47.432	47.000	xxx	270.15	1.1886	1.5328
46.416	46.000	+2.2	267.95	1.3492	1.7542
44.384	44.000	+2.2	263.55	1.7437	2.3049
42.352	42.000	+2.2	259.15	2.2633	3.0425
40.320	40.000	+2.2	254.75	2.9510	4.0355
38.293	38.000	+2.2	250.35	3.8654	5.3788
36.267	36.000	+2.2	245.95	5.0874	7.2061
34.242	34.000	+2.2	241.55	6.7291	9.7049 0
32.217	32.000	+2.2	237.15	8.9464 0	1.3142 +1
30.192	30.000	+2.2	232.75	1.1958 +1	1.7898
28.171	28.000	+2.2	228.35	1.6072	2.4519
26.150	26.000	+2.2	223.95	2.1726	3.3797
24.131	24.000	+2.2	219.55	2.9546	4.6884
22.113	22.000	xxx	215.15	4.0430	6.5466
20.096	20.000	+4.0	207.15	5.5838	9.3903 +1
18.081	18.000	+4.0	199.15	7.8106 +1	1.3663 +2
16.570	16.500	xxx	193.15	1.0137 +2	1.8284
16.067	16.000	-6.7	196.50	1.1063	1.9613
14.054	14.000	-6.7	209.90	1.5474	2.5682
12.043	12.000	-6.7	223.30	2.1200	3.3074
10.032	10.000	-6.7	236.70	2.8516	4.1965
8.023	8.000	-6.7	250.10	3.7733	5.2545
6.016	6.000	-6.7	263.50	4.9201	6.4996
4.009	4.000	-6.7	276.90	6.3303	7.9509
2.505	2.500	xxx	286.95	7.5861	9.1845
2.254	2.250	(+3.2)	286.15	7.8133	9.4604
2.004	2.000	-6.0	287.65	8.0475	9.6896 +2
1.002	1.000	-6.0	293.65	9.0417	1.0645 +3
0.000	0.000	-6.0	299.65	10.1325 +2	1.1666 +3

*Power of 10 by which preceding figures should be multiplied.

Table 4. Moisture Properties to 10 Km of the Supplemental Atmospheres

Table 4a. Mid-Latitude (45°N) Atmospheres, Winter and Summer

Kilometers		Temp Grad		Temp (K)		Virtual Temp(K)		Rel Hum(%)		Pressure (mb)		Density(g/m ³)	
Geomet	Geopot	Win	Sum	Win	Sum	Win	Sum	Win	Sum	Win	Sum	Win	Sum
10.016	10.000	xxx	-6.5	219.65	235.15	219.654	235.172	30 = 30		256.20	280.25	406.34	415.15
8.010	8.000	-6.0	-6.5	231.65	248.15	231.664	248.211	35 30		346.82	371.84	521.55	521.89
6.005	6.000	-6.0	xxx	243.65	261.15	243.698	261.299	45 30		462.36	486.25	660.96	648.28
4.003	4.000	-6.0 =	-6.0	255.65	273.15	255.774	273.552	50 40		607.89	627.82	827.97	799.55
3.001	3.000	xxx	-6.0	261.65	279.15	261.850	279.777	55 45		693.67	710.34	922.87	884.51
2.001	2.000	-3.5	xxx	265.15	285.15	265.427	286.192	65 55		789.64	801.50	1036.40	975.65
1.000	1.000	-3.5	-4.5	268.65	289.65	268.998	291.142	70 65		897.34	902.20	1162.13	1079.53
0.000	0.000	-3.5	-4.5	272.15	294.15	272.594	296.216	77 75		1018.00	1013.50	1300.99	1191.95

Table 4b. Subtropical (30°N) Atmospheres, Winter and Summer

Kilometers		Temp Grad		Temp (K)		Virtual Temp(K)		Rel Hum(%)		Pressure (mb)		Density(g/m ³)	
Geomet	Geopot	Win	Sum	Win	Sum	Win	Sum	Win	Sum	Win	Sum	Win	Sum
10.023	10.000	-6.5	-7.0	229.15	238.15	229.162	238.179	30 = 30		274.94	287.58	417.98	420.62
8.016	8.000	-6.5	-7.0	242.15	252.15	242.185	252.266	30 40		367.28	379.87	528.30	524.58
6.010	6.000	-6.5	xxx	255.15	266.15	255.239	266.445	30 40		483.26	494.22	659.61	646.19
4.005	4.000	-6.5	-5.5	268.15	277.15	268.389	277.823	35 50		627.17	635.08	814.07	796.34
3.003	3.000	-6.5	-5.5	274.65	282.65	275.098	283.716	45 60		711.07	717.13	900.47	880.54
2.002	2.000	xxx	-5.5	281.15	288.15	281.862	289.536	50 60		803.75	807.78	993.41	971.92
1.001	1.000	-3.0	xxx	284.15	293.65	285.244	295.580	70 65		906.52	907.70	1107.16	1069.81
0.000	0.000	-3.0	-7.5	287.15	301.15	288.519	304.583	80 = 80		1021.00	1017.00	1232.80	1163.21

Table 4c. Tropical (15°N) Atmosphere

Kilometers		Temp Grad		Temp (K)		Virtual Temp(K)		Rel Hum(%)		Pressure (mb)		Density(g/m ³)	
Geomet	Geopot												
10.032	10.000	-6.7		236.70		236.717		20		285.16		419.65	
8.023	8.000	-6.7		250.10		250.172		30		377.33		525.45	
6.016	6.000	-6.7		263.50		263.709		35		492.01		649.96	
4.009	4.000	-6.7		276.90		277.363		35		633.03		795.09	
2.505	2.500	xxx		286.95		287.743		35		758.61		918.45	
		+3.2											
2.254	2.250	xxx		286.15		287.717		75		781.33		946.04	
2.004	2.000	-6.0		287.65		289.336		75		804.75		968.96	
1.002	1.000	-6.0		293.65		295.893		75		904.17		1064.53	
0.000	0.000	-6.0		299.65		302.588		75		1013.25		1166.56	

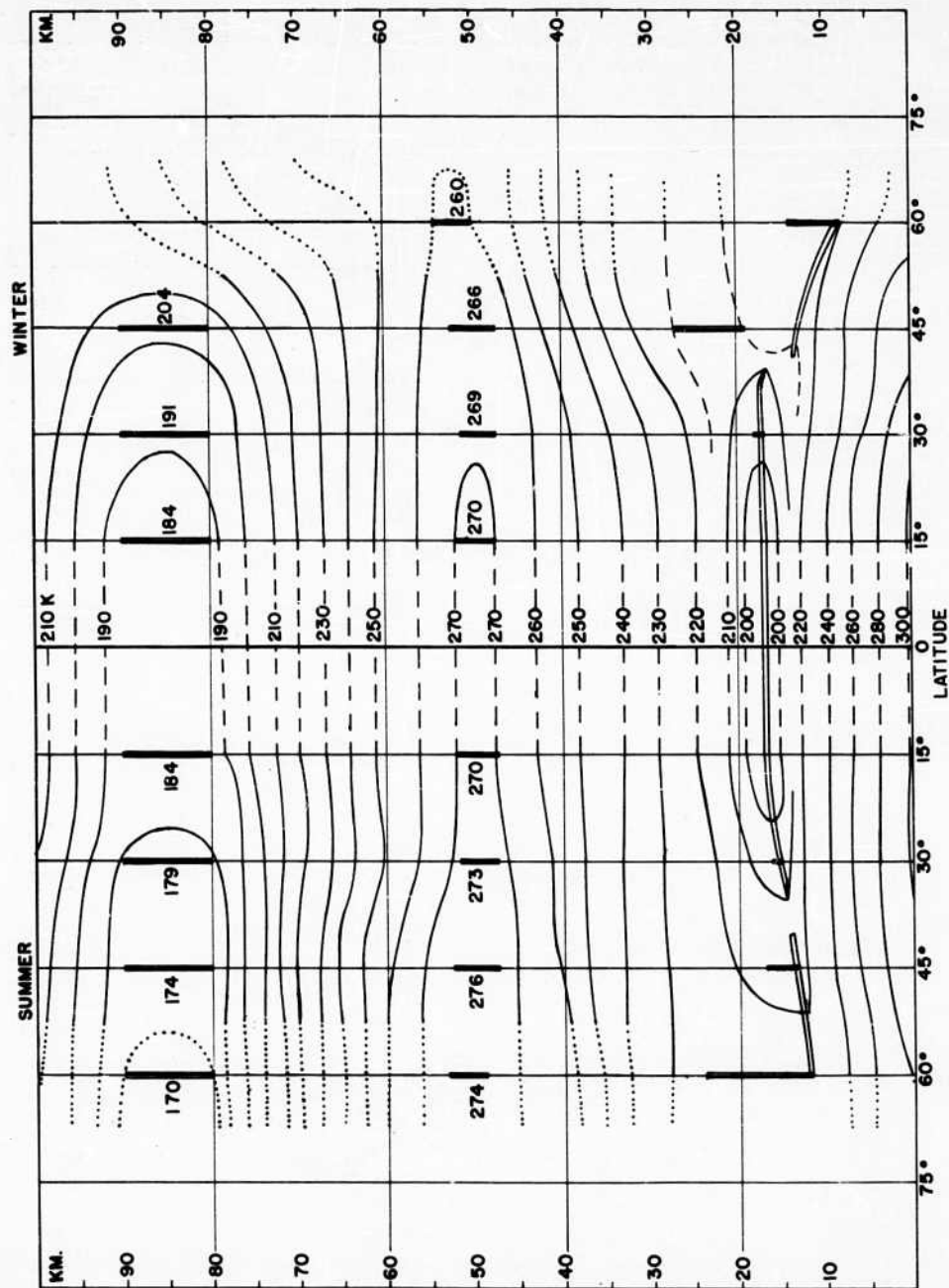


Figure 1. Latitudinal temperature-height cross section of the Supplemental Atmospheres (60°N tentative) winter (right) and summer (left). Double vertical lines, isothermal; double horizontal line, tropopause.

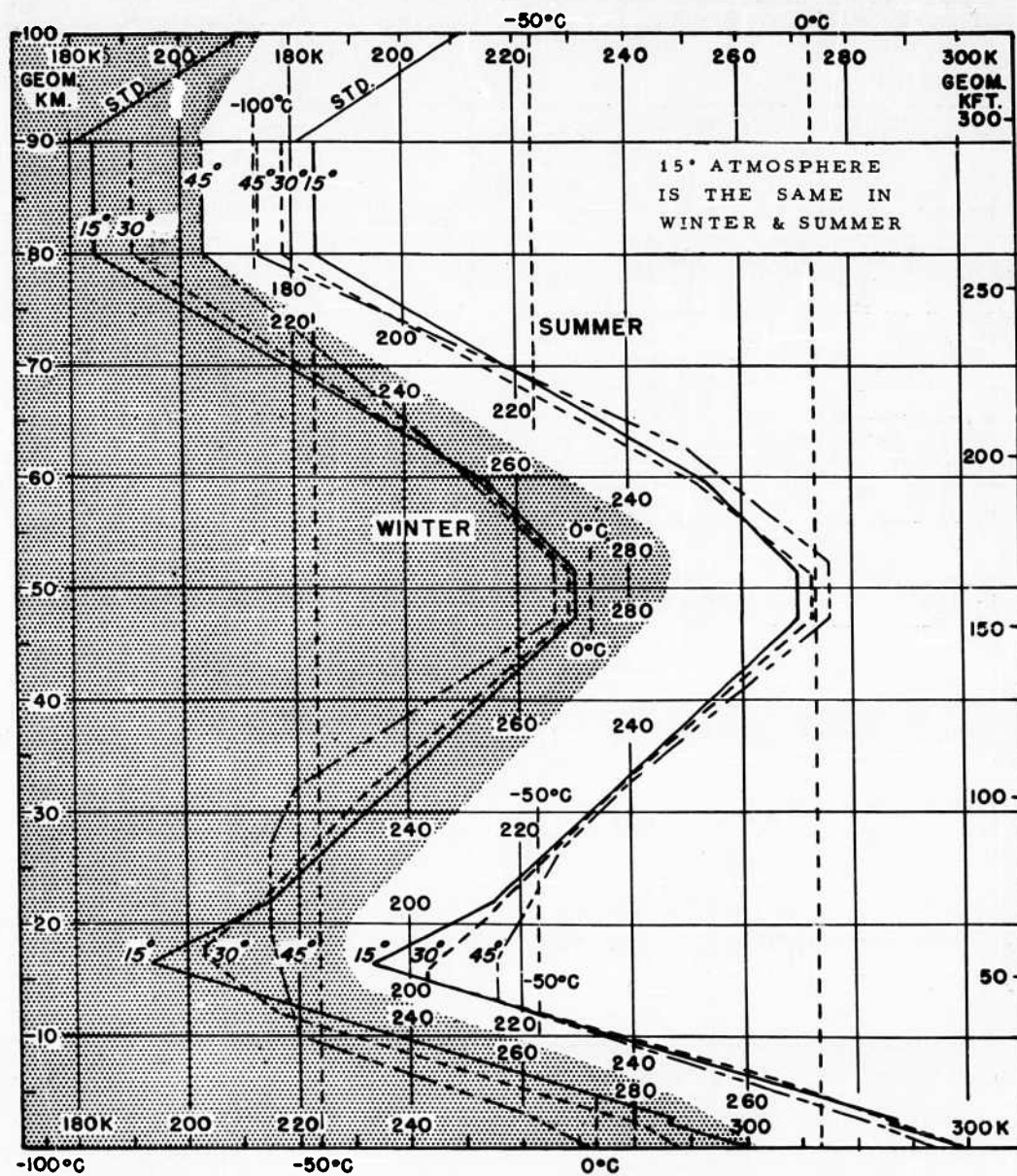


Figure 2. Temperature-height profiles of Supplemental Atmospheres, winter (left) and summer (right).

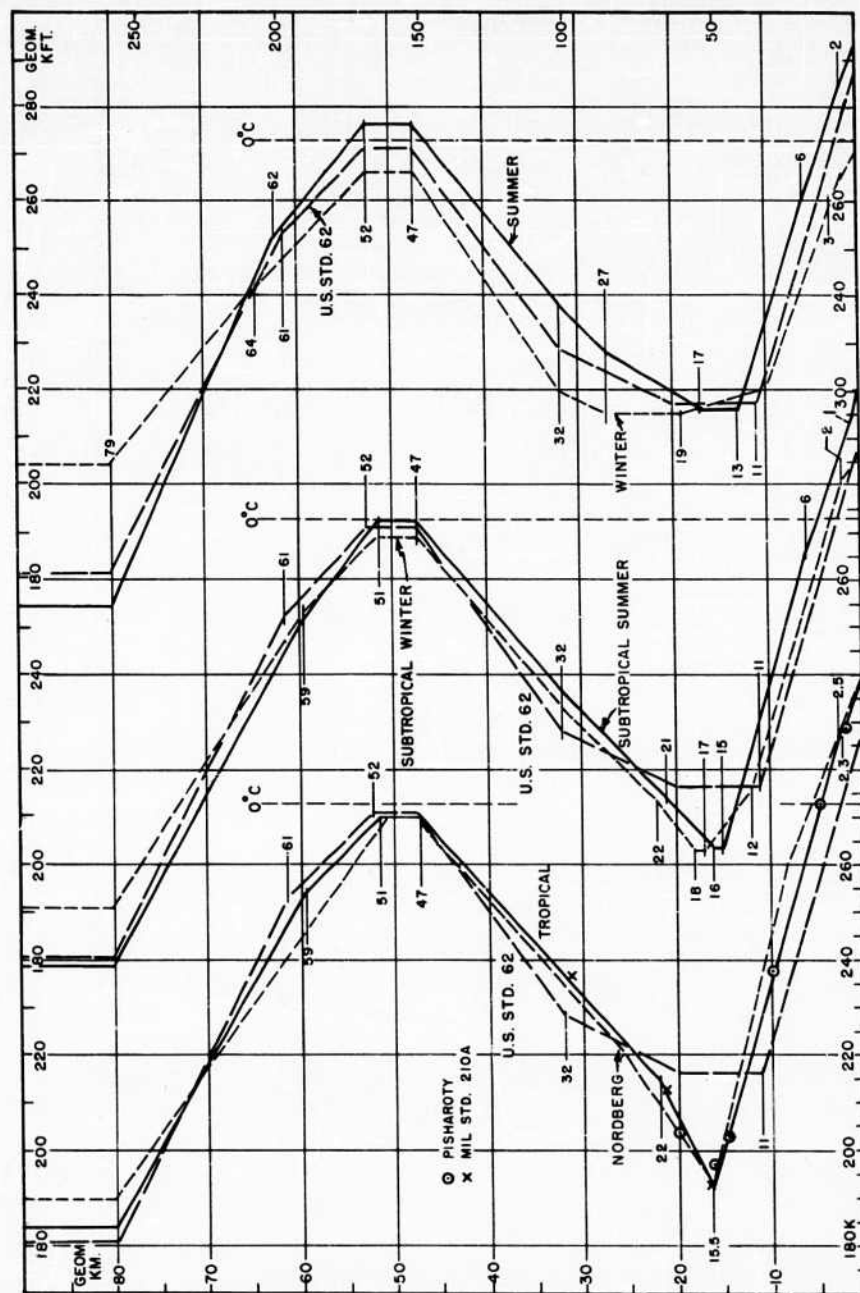


Figure 3. Supplemental Atmospheres compared with the U. S. Standard Atmosphere, 1962, and other atmospheres: (left), mean annual Tropical (15°N) temperature-height profile and three low-latitude Model Atmospheres; (center), Subtropical (30°N) temperature-height profiles, winter and summer.

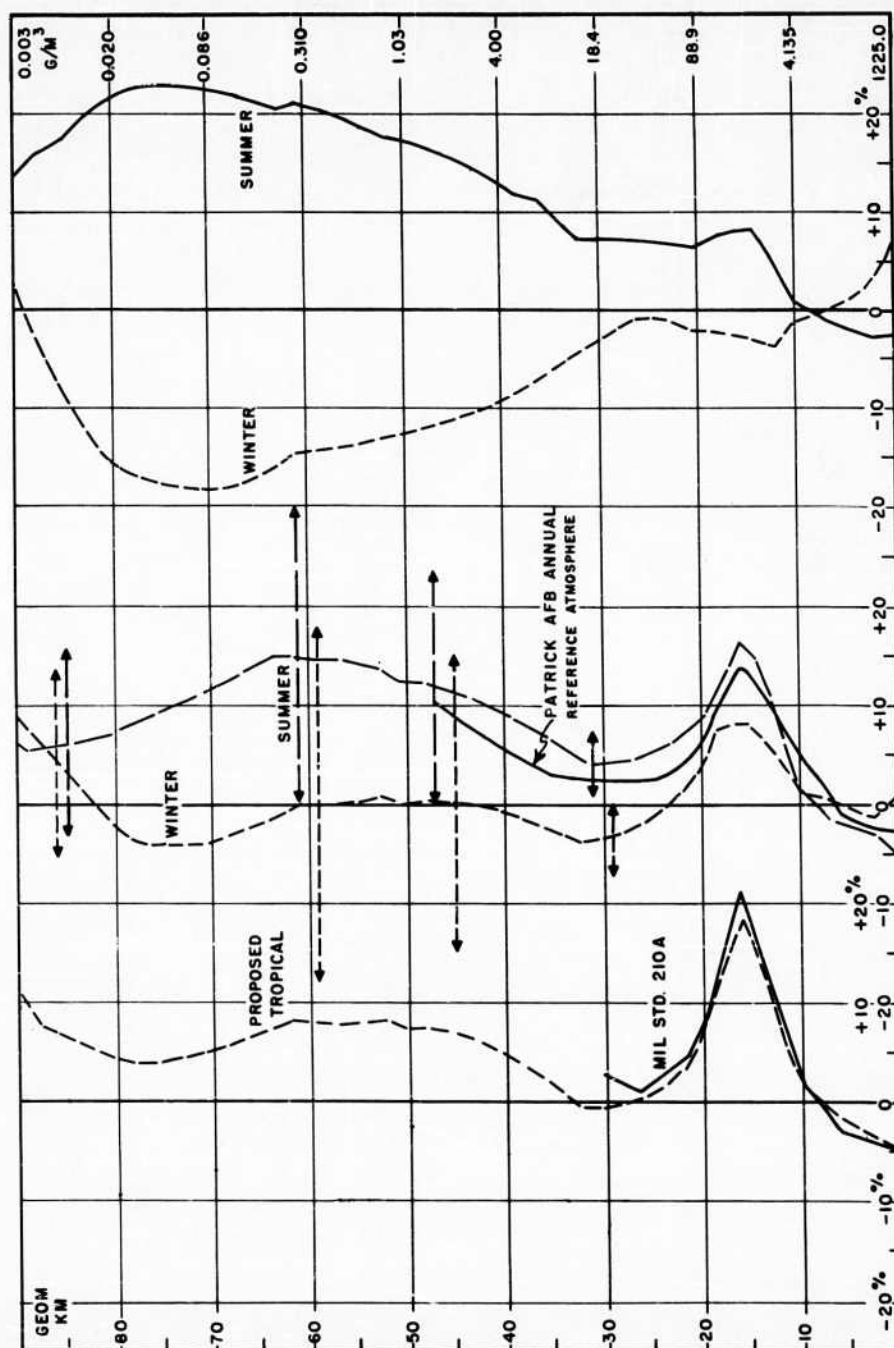


Figure 4. Density departures (percent) of Supplemental Atmospheres from the U. S. Standard Atmosphere, 1962: (left), Tropical (15°N), MIL-STD 210A Tropical, and Nordberg's Low-Latitude Atmospheres; (center), Subtropical (30°N) Atmospheres, winter and summer and Patrick AFB Annual Reference Atmosphere; (right), Mid-Latitude (45°N) Atmospheres, winter and summer.

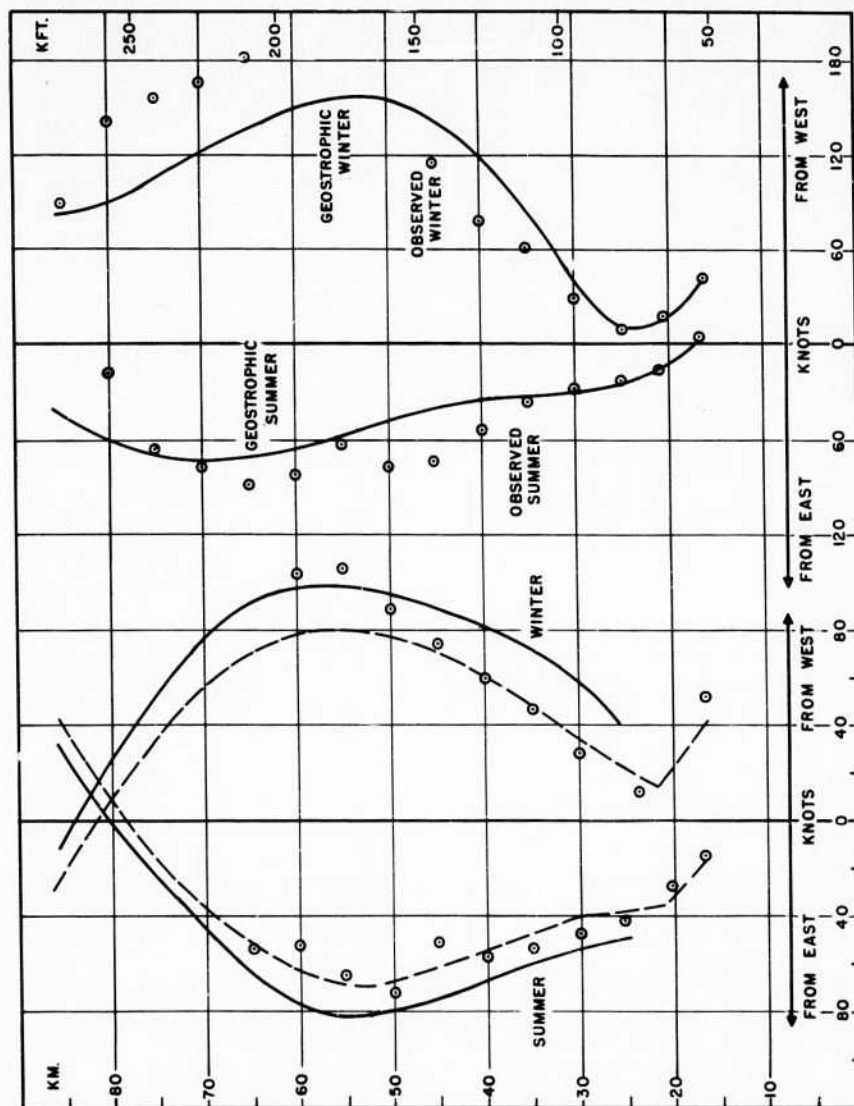


Figure 5. Zonal wind components. Left, between 25° and 30°N, geostrophic components computed (solid lines) from Tropical (annual) and Subtropical (seasonal) atmospheres, and (dashed lines) from seasonal data at both 15°N and 30°N; circles show observed mean seasonal components at Patrick AFB. Right, between 30° and 45°N, winter and summer geostrophic components computed from Subtropical and Mid-latitude atmospheres, with observed winter and summer components at 38°N (circles).

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Appendix

DATA SOURCES

1. Radiosonde temperature-height summaries:
 - a. Caribbean and U. S. (Jordan, 1958, Ratner, 1957, USWB, 1956-61).
 - b. Atlantic and Pacific Oceans, Europe, Africa, and Asia (Borden, 1960, Goldie et al, 1958, Faust and Attmannspacher, 1959, McDonald, 1959, Pisharoty, 1959, U. S. Navy, 1955-56, USWB, 1956-61, Wege, 1958).
2. Rocket and searchlight observations of temperature, pressure and density:
 - a. Rocket-grenade measurements: 12 at White Sands; 10 at Ft. Churchill (Stroud et al, 1956, 1960); 9 at Guam (Nordberg and Stroud, 1961); 4 at Woomera, Australia (Boyd and Groves, 1961).
 - b. Pressure-gage flights: 7 at White Sands and Holloman AFB; 15 at Ft. Churchill; 1 at the equator (Ainsworth et al, 1961; Dow and Spencer, 1953; Havens et al, 1952; LaGow and Ainsworth, 1956; Newell, 1960; Ripley, 1960; Sicinski et al, 1954; Spencer et al, 1958).
 - c. Falling-sphere flights: 4 at White Sands; 2 at Wallops Island; 3 in the North Atlantic; 4 at Ft. Churchill (Jones and Peterson, 1961).
 - d. Searchlight probes: 18 density profiles for New Mexico (Elterman, 1954).
 - e. Meteorological rocket flights: several dozen from the eight stations in the Meteorological Rocket Network (USASMSA, 1959-61).
 - f. Atmospheric density: Summary of observations between 30 and 80 km (Quiroz, 1961, Thiele, 1961).

AF Cambridge Research Laboratories, Bedford, Mass. Geophysics Research Directorate SUPPLEMENTAL ATMOSPHERES, by A. Court, A.J. Kantor, and A.E. Cole. September 1962. 21 pp.incl.illus.tables. AFCRL-62-899 Unclassified report Atmospheres typical of the tropics, subtropics, and mid-latitudes are prepared as part of a family supplemental to the 1962 U.S.Standard Atmosphere; they provide information on latitudinal and seasonal changes in atmospheric structure up to 90 km. Temperature gradients for various segments are linear with geopotential height. Humidity is incorporated into the lowermost 10 km of each atmosphere. Figures and tables depict temperature, relative humidity, pressure, and density. The atmospheres are mutually consistent; zonal wind profiles computed from the geostrophic wind equation at selected pressure heights compare favorably with existing rawinsonde and Meteorological Rocket Network wind observations.	UNCLASSIFIED 1. Atmosphere model 2. Meteorology I. Court, A. II. Kantor, A.J. III. Cole, A.E.	AF Cambridge Research Laboratories, Bedford, Mass. Geophysics Research Directorate SUPPLEMENTAL ATMOSPHERES, by A. Court, A.J. Kantor, and A.E. Cole. September 1962. 21 pp.incl.illus.tables. AFCRL-62-899 Unclassified report Atmospheres typical of the tropics, subtropics, and mid-latitudes are prepared as part of a family supplemental to the 1962 U.S.Standard Atmosphere; they provide information on latitudinal and seasonal changes in atmospheric structure up to 90 km. Temperature gradients for various segments are linear with geopotential height. Humidity is incorporated into the lowermost 10 km of each atmosphere. Figures and tables depict temperature, relative humidity, pressure, and density. The atmospheres are mutually consistent; zonal wind profiles computed from the geostrophic wind equation at selected pressure heights compare favorably with existing rawinsonde and Meteorological Rocket Network wind observations.	UNCLASSIFIED 1. Atmosphere model 2. Meteorology I. Court, A. II. Kantor, A.J. III. Cole, A.E.
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