AN ALTERNATIVE FORM OF POTENTIAL VORTICITY

By H. ARAKAWA

[Central Meteorological Observatory, Tokyo, June 1941]

Potential vorticity ζ_0 is defined by C. G. Rossby [1] as the vorticity which a column of air between two isentropic surfaces would have if it were brought to an arbitrary "standard" latitude and then stretched or shrunk to an arbitrary "standard" thickness. If f is the Coriolis parameter $2\omega \sin \varphi$ at a given latitude φ, and ζ the actual vorticity of an air column of thickness D at its observed position, then from Rossby's vorticity theorem we have

$$\frac{f+\zeta}{D}=\frac{f_0+\zeta_0}{D_0}, \tag{1}$$

where ζ_0 is the vorticity which the air column would have if brought to a latitude where the Coriolis parameter has the value f_0, and to a thickness D_0. If f_0 and D_0 are the adopted standards of comparison, ζ_0 is the potential vorticity, a term chosen by analogy with potential temperature.

In a previous paper [2] the present author has presented results of an investigation in which a newly-defined type of potential temperature was employed. In that paper a potential vorticity of air *particles*, not of air *columns*, was introduced; it is defined as the vorticity which a particle of air would have if it were brought to an arbitrary "standard" latitude and to an arbitrary "standard" density. The author has shown that if ρ is the density.

$$\frac{f+\zeta}{\rho}=\frac{f_0+\zeta_0}{\rho_0}, \tag{2}$$

where ζ_0 is the potential vorticity which an air particle would have if brought to a standard latitude, and to a standard density ρ_0. This type of potential vorticity as a conservative element for identification purposes seems to be better than that of Rossby, because the analysis does not involve the concept of a column of air.

To apply this quantity to isentropic analysis, assuming isentropic flow, equation (2) may be written

$$\frac{f+\zeta}{p^{c_v/c_p}}=\frac{f_0+\zeta_0}{p_0^{c_v/c_p}}, \tag{3}$$

where c_p and c_v are the specific heat at constant pressure and the specific heat at constant volume, respectively. Thus f_0 and p_0 are the arbitrary standards on an isentropic surface to which all particles are brought for comparison and ζ_0 is the potential vorticity.

In view of the significance of Rossby's potential vorticity [3], the recognition of a simpler form is of fundamental importance in meteorology.

[1] C. G. Rossby: Planetary Flow Patterns in the Atmosphere, *Quarterly Journal of the Royal Meteorological Society*, *66*, Supplement, 1940, p. 72.

[2] H. Arakawa: Die Wirbelgleichungen mit Berücksichtigung der Erddrehung, *Meteorol. Zeitschr.*, 1941, Heft 2. Herein a slight misprint occurred; in example 2 and example 4, change "$\frac{\partial u}{\partial x}$ and $\frac{\partial v}{\partial y}$" to "$\frac{\partial w}{\partial x}$ and $\frac{\partial w}{\partial y}$".

[3] V. P. Starr and M. Neiburger: Potential Vorticity as a Conservative Property, *Journal of Marine Research*, Vol. III, No. 3, 1940; M. Neiburger: Vorticity Analysis of a Thunderstorm Situation, *Bull. Amer. Metl. Soc.*, *22*, 1, 1941.

METEOROLOGICAL AND CLIMATOLOGICAL DATA FOR JULY 1941

[Climate and Crop Weather Division, J. B. KINCER in charge]

AEROLOGICAL OBSERVATIONS

By EARL C. THOM

The mean surface temperatures for July were above normal over most of the country. Temperatures were slightly below normal, however, in a considerable part of the Southern Plateau region and at four scattered stations in the eastern half of the country. At all stations in other sections of the country temperatures were above normal, with values considerably above normal over the north-central and the northwestern areas, departures for the month being from +6° to +8° F. over parts of Washington and Oregon.

At 1,500 meters above sea level the 5 a. m. resultant winds for July were from directions to the north of normal over the extreme northeast, the upper Gulf region, and over parts of the central and northwestern sections, and from south of normal at this level over the rest of the country. At 3,000 meters the morning resultant winds for July were more northerly than normal over most of the northeast, over a considerable part of the Western Plains States, and over a strip of the Rocky Mountains along the Great Divide, and were more southerly than normal elsewhere. When the 5 p. m. resultant winds for the month at the 5,000 meter level are compared with the corresponding 5 a. m. normals it is noted that the late afternoon resultants were more southerly than the corresponding morning winds at about two-thirds of the stations for which these data could be compared.

At both the 1,500 m. and 3,000 m. levels the resultant velocities were below normal over most stations, being above normal over only eight pilot-balloon stations at each of these levels. At 5,000 meters, however, the 5. p. m. resultant velocities were generally higher than the corresponding 5 a. m. normals.

At 1,500 meters the 5 p. m. resultant winds were from more northerly directions than were the corresponding 5 a. m. winds over most of the Rocky Mountain and Plateau regions and over a considerable part of the Mississippi River Valley and the Gulf coast, while a turning to the southward during the day was noted at this level over the rest of the country. At 3,000 meters the resultants turned to the northward during the day over a considerable portion of the country. The opposite shift during the day was noted at this level over most stations along the Atlantic Coast, over the northern Plateau and Great Plains regions, and over two stations to the southward.

The 5 p. m. resultant velocities for the month were higher than the corresponding 5 a. m. velocities over the extreme west and over part of the extreme southeast and were lower at this level over most of other pilot-balloon stations of the country. At 3,000 meters the resultant velocities in the late evening were lower than those in the early morning over 10 widely scattered stations. An increase in resultant velocity occurred during the day at this level over all other stations.

The upper-air data discussed above are based on 5 a. m. (eastern standard time) pilot-balloon observations (charts VIII & IX) as well as on observations made at 5 p. m. (table 2 and charts X and XI).

Radiosonde and airplane stations located in the southern

part of the country recorded on the average the highest daily pressures at each of the several standard levels from 2,000 meters to 18,000 meters. The highest mean monthly pressure occurred over both San Antonio and Miami for the 2,000-meter level, over Miami for the 2,500-meter level, over San Antonio for the 3,000-meter level, and over Phoenix for the standard levels 4,000, 6,000, and 7,000 meters. The highest mean pressure for the month occurred over both Phoenix and San Antonio at 5,000 meters as well as at each of the standard levels from 8,000 meters to 15,000 meters, inclusive. At 16,000 meters the highest mean pressure, 114 mb., occurred over Phoenix, San Antonio and San Diego with San Diego recording the maximum pressure at the next two higher levels. The lowest mean monthly pressure occurred over Sault Ste. Marie for each of the standard levels from 2,000 meters to 6,000 and again at 8,000 meters and 16,000 meters. The corresponding minima occurred over Seattle at the 11000-, 12,000- and 13,000-meter levels, while these minima occurred over two or more northern stations at each of the other standard levels from 7,000 meters to 18,000 meters.

With but few scattered exceptions mean pressures for July were higher than those in June over all stations and at all levels up to and including 19,000 meters. This increase in pressure over that of last month was well marked in the western half of the country, especially in the extreme northwest, for example, at Medford the average increase in mean pressure from June to July was 11 mb. for the levels from 4,000 meters to 12,000 meters. The largest difference between the highest and the lowest mean pressures for the month was 11 mb. which was noted at each of the standard levels from 6,000 meters to 11,000 meters, inclusive. Pressure gradients were not as steep as in June over the northwestern part of the country. The steepest upper level pressure gradient, for July, occurred at the 8,000-meter and 9,000-meter levels between Buffalo, N. Y., and Washington, D. C. At these levels there was a change of 1 mb. pressure for each 53 miles of horizontal distance between these cities.

The mean temperatures for June were generally higher than those of last month from the surface up to and including 11,000 meters. The only exception to this increase in temperatures occurred at Pensacola and Brownsville at levels from 2,000 meters to 11,000 meters. At most of the standard levels from 12,000 meters to 19,000 meters temperatures were lower than last month over the western half of the country, while increases and decreases of temperatures were well distributed to the eastward. At only two stations, Sault Ste. Marie and Miami, were free-air temperatures higher than last month at all levels.

Comparison of the mean temperature charts for July 1941 with those for July 1940 show the temperatures this year to be the higher over a considerable portion of the country from the surface up to 11,000 meters. Temperatures at these levels were lower than last year along the Gulf Coast and over most of the Rocky Mountain and Southern Plateau regions. Above 11,000 meters temperatures were lower than last year at most levels over the northeast and were generally higher over the rest of the country.

The mean temperatures for July at 1,000 meters were somewhat above normal over most of the western half of the country and over all but one station in the northeast and were below normal elsewhere. At 3,000 meters temperatures were above normal generally over the eastern third of the country and over most of the extreme north-central and middle-plateau regions, and were generally below normal over other areas at this level. Temperatures at the 5,000 m. level were above normal over most stations in the eastern two-thirds of the country while they were below normal at this level over all stations to the westward.

The mean relative humidities for the month at the 1,000 m., 3,000 m., and 5,000 m., levels were normal or above over most of the country. Humidities were, however, below normal over the Southwest, at all three levels, over Sault Ste. Marie at the two lower levels and also below normal over the extreme Northwest at 1,000 meters.

The altitude at which the mean monthly temperature of 0° C. for July occurred, varied from the lowest (3,900 meters) over Seattle, Wash., to the highest (5,000 meters) over San Antonio, Tex. The level at which, on the average, freezing conditions occurred was higher than last month over all of the United States with the exception of Brownsville where it was slightly lower. This level was much higher than last month over the upper Pacific coast, being 1,500 meters higher over Medford, Oreg., and 1,200 meters higher over Seattle.

The lowest free-air temperature recorded during the month over United States was −79.9° C. (−111.8° F.). This temperature occurred over Brownsville, Tex., on the morning of July 7, at an altitude of 17,400 meters (about 10.8 miles) above sea level. (In this connection a temperature of −85.0° C. was reported as having been recorded over Phoenix on July 2, 1941. This minimum is not well supported by surrounding stations and has not been verified. It has not, therefore, been accepted as official). The lowest temperature for the month over San Juan was −81.4° C. (−114.5° F.) which was observed at 16,400 meters (about 10.2 miles) above sea level on the morning of July 24.

Table 3 shows the maximum free-air wind velocities and their directions for various sections of the United States during July as determined by pilot-balloon observations. The highest observed wind velocity for the month was 68 m. p. s. (152 miles per hour) observed over Evansville, Ind., on July 2. This wind was blowing from the southwest at an elevation of 4,170 meters (about 2.6 miles) above sea level.

The highest July wind velocity observed during the last 5 years in the free-air layer from the surface to 2,500 meters was 43.0 m. p. s. (96 miles per hour), observed on July 11, 1941, over Cheyenne, Wyo. (see table 3). The wind velocity of 68 m. p. s. over Evansville (reported in table 3 and in the previous paragraph) on July 2 this year was the highest observed in the layer from 2,500 meters to 5,000 meters while during this 5-year period a still higher wind velocity, 84.0 m. p. s. (188 miles per hour), was observed in July in the free-air above the 5,000-meter level. This wind was observed on July 6, 1939, over Redding, Calif., and was blowing from the west at an elevation of 19,710 meters (about 12.2 miles).

TABLE 1.—*Mean free-air barometric pressure in millibars, temperature in degrees Centigrade, and relative humidities in percent, obtained by airplanes and radiosondes during July 1941*

Stations with elevations in meters above sea level

Altitude (meters) m. s. l.	Albuquerque, N. Mex. (1,620 m.)				Atlanta, Ga. (300 m.)				Bismarck, N. Dak. (505 m.)				Boise, Idaho (864 m.)				Brownsville, Tex. (6 m.)				Buffalo, N. Y. (221 m.)				Charleston, S. C. (14 m.)			
	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity
Surface	30	841	21.6	52	31	982	23.1	91	31	955	19.7	73	25	915	21.5	49	31	1,014	26.5	89	31	989	19.7	78	31	1,015	24.4	94
500	----	----	----	----	31	960	23.2	85	----	----	----	----	----	----	----	----	31	959	24.8	82	31	958	20.6	70	31	960	23.9	86
1,000	----	----	----	----	31	907	21.4	81	31	903	23.3	60	25	901	24.7	44	31	906	22.5	71	31	904	18.2	70	31	907	21.2	80
1,500	----	----	----	----	31	856	18.5	78	31	852	20.4	61	25	851	23.2	36	31	855	19.9	64	31	852	14.8	74	31	856	18.3	77
2,000	30	805	20.6	49	31	807	15.6	76	31	804	16.9	63	25	803	19.2	37	31	806	17.0	58	31	803	11.7	68	31	807	15.1	75
2,500	30	759	17.2	50	31	761	12.8	73	31	758	13.4	63	25	757	15.1	39	31	760	14.2	54	31	756	9.1	61	31	761	12.1	72
3,000	30	716	13.4	53	31	717	9.9	71	31	714	10.2	62	25	713	11.0	42	31	716	11.2	50	31	711	6.1	58	31	716	9.2	70
4,000	30	635	5.6	62	31	635	4.2	69	31	632	3.8	56	25	632	3.0	50	31	635	5.4	48	31	629	0.6	50	30	634	3.8	63
5,000	29	561	−2.1	70	31	561	−1.1	62	31	558	−2.7	49	25	558	−4.1	53	31	562	−.7	48	31	555	−5.2	46	29	561	−1.9	60
6,000	29	494	−8.6	70	31	495	−6.7	57	30	492	−9.5	46	25	490	−11.1	51	30	495	−6.8	45	31	488	−11.5	43	29	494	−7.4	58
7,000	28	434	−14.5	65	31	435	−13.1	52	30	431	−16.6	44	25	430	−18.6	49	29	435	−13.5	44	31	428	−18.1	40	29	434	−13.4	55
8,000	28	380	−20.9	60	31	380	−19.9	51	30	377	−24.0	43	25	375	−26.0	47	29	380	−20.3	43	31	373	−25.1	39	29	380	−20.4	52
9,000	27	330	−28.1	56	31	332	−27.1	50	30	327	−31.6	42	23	326	−33.4	46	29	331	−27.4	42	31	324	−32.3	40	28	331	−27.6	50
10,000	27	287	−35.3	54	31	288	−34.9	48	29	284	−39.2	42	23	282	−41.0	----	29	288	−34.5	41	31	281	−40.0	----	27	288	−35.1	46
11,000	26	248	−42.7	----	31	249	−43.0	----	29	245	−46.6	----	22	243	−47.9	----	28	249	−42.3	----	30	242	−47.6	----	27	249	−43.0	----
12,000	26	214	−49.4	----	30	215	−50.8	----	29	210	−52.4	----	22	208	−54.0	----	27	215	−50.1	----	30	208	−54.4	----	27	214	−50.8	----
13,000	26	183	−56.0	----	30	184	−58.2	----	28	180	−55.3	----	22	178	−56.6	----	27	184	−57.6	----	30	177	−58.3	----	27	183	−58.5	----
14,000	26	156	−62.0	----	29	156	−64.1	----	27	154	−57.4	----	22	152	−56.9	----	27	156	−64.5	----	28	151	−60.3	----	27	156	−64.3	----
15,000	25	132	−66.7	----	29	132	−66.5	----	27	131	−58.3	----	20	130	−57.9	----	27	132	−69.6	----	26	129	−61.5	----	27	132	−67.4	----
16,000	24	112	−68.7	----	29	112	−67.4	----	26	112	−58.0	----	20	111	−58.5	----	27	112	−71.2	----	24	110	−61.5	----	27	112	−68.5	----
17,000	23	95	−66.7	----	26	95	−66.0	----	24	95	−57.6	----	18	94	−58.5	----	26	95	−69.5	----	20	93	−60.7	----	24	95	−66.6	----
18,000	20	81	−63.2	----	21	80	−63.6	----	21	81	−56.7	----	18	80	−58.0	----	22	80	−66.1	----	15	80	−59.2	----	21	80	−63.6	----
19,000	10	69	−60.5	----	15	69	−60.1	----	14	70	−55.6	----	15	69	−57.0	----	19	68	−62.5	----	----	----	----	----	10	68	−61.2	----
20,000	----	----	----	----	----	----	----	----	8	59	−54.6	----	6	58	−55.2	----	13	58	−59.6	----	----	----	----	----	----	----	----	----
21,000	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	5	49	−56.7	----	----	----	----	----	----	----	----	----

Stations with elevations in meters above sea level

Altitude (meters) m. s. l.	Denver, Col. (1616 m.)				El Paso, Tex. (1193 m.)				Ely, Nev. (1908 m.)				Great Falls, Mont. (1128 m.)				Huntington, W. Va. (172 m.)				Lakehurst, N. J.[1] (39 m.)				Medford, Ore. (401 m.)			
	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity
Surface	28	842	18.8	63	28	883	24.0	55	31	812	15.1	52	31	888	19.8	54	15	995	20.2	93	30	1,010	19.3	90	31	967	22.7	47
500	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	15	959	24.1	74	30	958	19.9	79	31	956	24.3	46
1,000	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	15	905	21.4	69	30	904	18.5	74	31	903	22.0	46
1,500	----	----	----	----	28	853	24.2	51	----	----	----	----	31	851	20.0	50	15	854	18.4	65	30	853	16.0	72	31	853	19.0	49
2,000	28	805	19.7	51	28	805	21.6	52	31	804	18.0	49	31	802	16.6	49	15	806	15.8	63	30	804	13.4	70	31	804	16.2	52
2,500	28	759	16.9	50	28	760	17.9	54	31	758	17.4	42	31	756	12.6	50	15	759	12.8	56	30	758	10.7	70	31	758	13.5	50
3,000	28	716	13.3	50	28	716	13.9	58	31	715	13.8	41	31	712	8.6	55	15	715	9.6	54	30	713	8.0	68	31	714	10.6	49
4,000	28	635	5.2	59	28	635	6.3	65	31	634	5.2	45	31	630	1.4	61	15	633	4.2	51	30	631	2.5	60	31	632	3.7	48
5,000	28	561	−2.6	68	28	562	−1.0	72	31	560	−3.0	52	31	556	−5.3	60	14	560	−1.0	46	29	558	−2.9	58	31	558	−2.4	43
6,000	27	494	−9.5	65	28	495	−7.2	70	31	492	−10.8	52	30	489	−11.6	58	14	493	−6.8	43	28	491	−8.2	51	31	492	−9.6	42
7,000	27	433	−16.2	57	28	435	−12.8	60	31	432	−17.5	50	30	428	−18.7	56	13	433	−13.1	41	27	432	−14.5	46	30	431	−17.2	42
8,000	25	378	−23.4	53	28	381	−19.3	54	31	377	−24.6	48	29	374	−26.5	55	13	379	−20.4	40	27	376	−21.4	48	30	376	−24.8	40
9,000	24	329	−30.9	52	28	332	−26.5	51	31	328	−32.3	47	29	325	−34.1	55	12	330	−27.7	39	27	327	−29.2	50	30	327	−32.5	39
10,000	24	286	−38.8	47	27	289	−33.8	50	30	284	−40.2	----	29	281	−41.9	----	12	287	−35.1	----	27	284	−36.9	51	30	284	−39.8	38
11,000	24	246	−46.7	----	27	250	−41.4	----	30	244	−47.7	----	29	242	−49.2	----	12	248	−43.0	----	27	245	−44.6	----	30	244	−47.1	----
12,000	22	211	−53.7	----	27	215	−49.0	----	30	210	−53.2	----	28	207	−54.5	----	12	214	−50.7	----	27	210	−52.3	----	30	210	−52.9	----
13,000	17	180	−57.9	----	27	184	−56.6	----	30	180	−56.9	----	28	177	−57.1	----	12	183	−57.4	----	27	180	−58.4	----	29	180	−55.0	----
14,000	17	154	−61.0	----	27	157	−63.6	----	30	153	−59.5	----	28	151	−58.0	----	12	156	−62.6	----	25	154	−62.0	----	29	153	−56.1	----
15,000	15	130	−63.0	----	27	133	−68.9	----	29	130	−62.0	----	26	129	−58.2	----	12	132	−64.3	----	22	131	−63.8	----	29	131	−57.5	----
16,000	14	111	−63.4	----	26	113	−70.9	----	29	111	−63.4	----	23	110	−58.4	----	11	112	−64.5	----	20	111	−64.2	----	27	112	−58.6	----
17,000	11	94	−62.7	----	25	95	−68.0	----	26	94	−62.5	----	22	94	−57.5	----	11	95	−62.8	----	17	94	−63.0	----	23	96	−58.4	----
18,000	5	80	−60.3	----	22	80	−64.2	----	19	80	−61.3	----	20	80	−56.8	----	10	81	−60.8	----	12	79	−60.9	----	14	81	−58.1	----
19,000	----	----	----	----	16	68	−60.7	----	9	68	−59.9	----	17	68	−55.9	----	7	69	−59.2	----	7	66	−58.3	----	7	69	−57.4	----
20,000	----	----	----	----	6	58	−57.3	----	----	----	----	----	8	58	−54.9	----	----	----	----	----	----	----	----	----	----	----	----	----

See footnotes at end of table.

TABLE 1.—*Mean free-air barometric pressure in millibars, temperature in degrees Centigrade, and relative humidities in percent, obtained by airplanes and radiosondes during July 1941*—Continued

Altitude (meters) m. s. l.	Miami, Fla. (4 m.)				Nashville, Tenn. (180 m.)				Norfolk, Va.[1 2] (10 m.)				Oakland, Calif. (2 m.)				Oklahoma City, Okla. (391 m.)				Omaha, Nebr. (301 m.)				Pensacola, Fla.[1] (24 m.)			
	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity
Surface	31	1,017	24.6	92	31	994	23.8	84	22	1,016	23.8	89	31	1,014	15.7	84	31	970	24.2	77	31	980	22.4	77	20	1,015	26.6	86
500	31	962	23.4	88	31	959	24.6	75	22	960	23.7	76	31	957	18.4	67	31	958	25.4	72	31	958	23.6	67	20	962	23.7	83
1,000	31	908	20.4	83	31	905	21.8	74	22	907	21.3	75	31	903	22.3	41	31	905	24.5	65	31	904	22.5	60	20	907	20.9	78
1,500	31	857	17.6	80	31	855	18.3	76	22	856	18.5	74	31	852	20.5	34	31	855	21.2	68	31	854	19.6	58	20	856	18.0	75
2,000	31	808	14.8	77	31	806	15.2	76	22	807	15.8	72	31	804	17.3	30	31	807	17.9	67	31	805	16.4	58	20	807	14.8	73
2,500	31	762	12.2	73	31	760	12.0	69	22	760	13.1	67	31	757	14.1	26	31	760	14.2	66	31	759	13.4	56	20	761	11.9	71
3,000	31	717	9.8	68	31	715	9.3	64	22	716	10.2	63	31	713	10.8	24	31	717	10.7	67	31	715	10.0	57	20	716	9.2	68
4,000	31	636	4.4	62	31	634	3.9	58	21	634	3.7	64	31	632	4.2	22	31	635	4.3	59	31	633	3.5	61	20	635	3.5	63
5,000	31	562	−1.5	64	29	560	−1.6	52	20	560	−2.7	60	31	558	−2.7	20	31	561	−1.5	55	31	560	−2.3	56	20	560	−2.4	60
6,000	30	495	−7.5	62	27	493	−7.5	48	----	----	----	----	31	491	−10.4	19	31	494	−7.1	48	31	493	−8.5	49	19	493	−8.5	58
7,000	30	434	−14.0	59	27	433	−13.9	45	----	----	----	----	30	431	−18.2	19	31	434	−13.4	47	30	433	−15.3	45	19	433	−14.7	58
8,000	30	380	−21.0	56	26	379	−20.9	44	----	----	----	----	30	376	−26.0	19	29	380	−20.2	43	30	378	−22.0	42	15	379	−21.7	55
9,000	30	331	−28.2	53	26	330	−28.2	43	----	----	----	----	30	326	−33.6	19	27	331	−27.4	41	29	329	−29.2	39	15	329	−29.3	54
10,000	30	287	−35.9	52	25	287	−35.7	42	----	----	----	----	30	283	−41.0	----	27	288	−34.8	39	29	286	−36.7	36	14	286	−37.1	----
11,000	30	248	−43.6	----	24	248	−43.5	----	----	----	----	----	30	243	−47.6	----	27	249	−42.6	----	28	247	−44.3	----	13	247	−45.8	----
12,000	30	214	−51.2	----	24	213	−51.2	----	----	----	----	----	30	209	−52.8	----	26	214	−49.7	----	28	212	−51.5	----	11	212	−54.5	----
13,000	30	183	−58.5	----	24	183	−58.1	----	----	----	----	----	30	178	−56.2	----	26	183	−56.2	----	28	182	−56.9	----	6	182	−61.6	----
14,000	30	155	−64.6	----	24	155	−64.0	----	----	----	----	----	30	152	−59.2	----	25	156	−61.8	----	28	155	−59.9	----	----	----	----	----
15,000	28	132	−68.0	----	24	132	−66.2	----	----	----	----	----	28	130	−61.4	----	24	133	−65.7	----	28	132	−62.0	----	----	----	----	----
16,000	28	112	−69.1	----	22	112	−66.7	----	----	----	----	----	26	110	−62.5	----	22	113	−67.0	----	26	112	−62.3	----	----	----	----	----
17,000	26	94	−68.3	----	19	95	−65.0	----	----	----	----	----	26	94	−61.9	----	21	95	−65.8	----	25	96	−60.9	----	----	----	----	----
18,000	23	79	−66.3	----	15	80	−62.3	----	----	----	----	----	23	79	−60.5	----	16	80	−62.8	----	18	81	−59.3	----	----	----	----	----
19,000	18	67	−63.6	----	7	68	−60.1	----	----	----	----	----	20	68	−58.8	----	13	69	−59.9	----	11	69	−57.7	----	----	----	----	----
20,000	11	57	−61.5	----	----	----	----	----	----	----	----	----	9	58	−57.2	----	6	58	−58.2	----	5	58	−55.4	----	----	----	----	----
21,000	5	48	−58.9	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----

Stations with elevations in meters above sea level

Altitude (meters) m. s. l.	Phoenix, Ariz. (339 m.)				Portland, Maine (19 m.)				St. Louis, Mo. (171 m.)				St. Paul, Minn. (225 m.)				San Diego, Calif.[1] (19 m.)				San Antonio, Tex. (174 m.)				S. S. Marie, Mich. (221 m.)			
	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity
Surface	31	970	29.1	44	31	1,011	15.9	91	31	995	24.0	70	31	987	21.2	79	30	1,010	19.1	86	31	995	25.4	83	31	988	15.2	89
500	31	953	33.6	35	31	957	18.8	76	31	958	24.3	66	31	956	22.3	70	30	956	20.0	71	31	960	25.5	80	31	956	18.2	74
1,000	31	902	31.9	33	31	902	16.4	70	31	905	21.7	68	31	903	20.7	61	30	902	23.0	41	31	906	24.1	73	31	902	17.0	66
1,500	31	852	28.4	34	31	851	13.4	70	31	854	18.3	73	31	852	17.8	63	30	851	22.5	35	31	856	21.4	71	31	850	14.1	63
2,000	31	805	24.3	37	31	802	10.5	68	31	805	15.2	74	31	804	14.6	63	30	803	20.5	33	31	808	18.4	66	31	801	11.0	61
2,500	31	760	20.0	40	31	755	7.7	64	31	759	11.9	71	31	757	11.5	62	30	757	17.2	34	31	761	15.5	59	31	754	8.1	58
3,000	31	717	15.6	45	31	710	5.1	60	31	715	9.1	64	31	713	8.3	60	30	714	13.8	35	31	718	12.8	52	31	710	5.2	57
4,000	31	637	7.8	50	31	628	0	58	31	633	3.3	57	31	631	2.5	55	30	633	6.3	32	31	636	6.3	51	31	628	0	55
5,000	31	563	.5	52	31	554	−5.2	50	31	559	−2.4	53	31	557	−2.9	51	30	560	−.2	32	31	563	.1	53	31	553	−6.0	51
6,000	31	497	−6.5	52	31	487	−11.3	45	30	492	−8.7	49	30	490	−9.2	47	30	493	−6.6	26	30	496	−6.1	50	30	486	−12.4	47
7,000	31	437	−12.8	46	31	427	−17.7	44	29	432	−15.0	45	30	430	−16.0	42	30	434	−13.0	22	30	436	−12.2	46	29	426	−19.1	43
8,000	30	382	−19.6	42	30	373	−24.6	43	29	378	−22.1	43	30	376	−23.1	40	26	379	−20.6	----	30	382	−18.6	44	29	371	−26.2	42
9,000	29	333	−26.8	40	29	324	−31.9	41	29	329	−29.1	44	30	326	−30.6	39	26	330	−28.2	----	30	333	−25.4	43	29	322	−33.7	40
10,000	29	290	−34.1	39	29	281	−39.1	----	29	286	−36.4	44	30	283	−38.0	38	26	287	−35.3	----	29	290	−32.7	43	29	279	−40.8	----
11,000	28	251	−41.2	----	29	242	−46.2	----	29	247	−43.8	----	30	244	−45.2	----	25	248	−41.7	----	29	251	−40.2	----	29	241	−46.9	----
12,000	28	216	−48.1	----	29	208	−52.5	----	29	212	−50.7	----	30	210	−51.2	----	24	213	−48.3	----	29	216	−47.6	----	29	207	−51.3	----
13,000	28	185	−54.9	----	28	178	−56.4	----	29	182	−57.0	----	30	180	−54.7	----	21	183	−54.3	----	29	185	−55.0	----	28	177	−54.1	----
14,000	26	158	−61.1	----	27	152	−58.1	----	26	155	−62.0	----	30	153	−56.8	----	21	157	−60.1	----	28	158	−62.1	----	27	151	−56.8	----
15,000	26	134	−66.5	----	23	129	−59.2	----	26	132	−64.4	----	28	131	−58.5	----	18	134	−64.5	----	28	134	−68.1	----	23	129	−57.9	----
16,000	26	114	−70.0	----	21	110	−58.2	----	25	112	−65.0	----	23	112	−58.8	----	17	114	−67.6	----	27	114	−70.4	----	19	109	−57.5	----
17,000	25	96	−68.7	----	19	94	−57.5	----	24	95	−64.2	----	21	95	−58.0	----	14	97	−67.6	----	27	96	−69.4	----	16	93	−56.2	----
18,000	22	81	−65.8	----	15	80	−56.1	----	21	81	−62.4	----	17	81	−56.7	----	11	82	−65.9	----	22	81	−65.9	----	11	79	−54.5	----
19,000	17	69	−62.7	----	8	69	−54.9	----	15	69	−59.9	----	10	69	−55.3	----	8	69	−63.8	----	12	69	−62.6	----	7	67	−52.9	----
20,000	6	58	−59.7	----	----	----	----	----	13	58	−57.5	----	7	59	−54.0	----	----	----	----	----	----	----	----	----	----	----	----	----
21,000	----	----	----	----	----	----	----	----	6	50	−55.8	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----

See footnotes at end of table.

TABLE 1.—*Mean free-air barometric pressure in millibars, temperature in degrees Centigrade, and relative humidities in percent, obtained by airplanes and radiosondes during July 1941*—Continued

Altitude (meters) m. s. l.	Stations with elevations in meters above sea level											
	Seattle, Wash., 1 (27 m.)				Spokane, Wash. (598 m.)				Washington, D. C. (5 m.)			
	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity
Surface	30	1,013	19.5	68	31	944	21.4	52	30	1,013	22.8	83
500	30	959	18.8	64	----	------	------	----	30	959	22.7	80
1,000	30	905	16.4	66	31	902	23.9	42	30	906	20.7	77
1,500	30	853	13.6	67	31	851	20.4	40	29	855	18.1	78
2,000	30	804	10.9	63	31	803	16.1	42	28	806	15.2	73
2,500	30	756	8.2	61	31	756	11.7	46	28	759	12.4	70
3,000	30	712	5.5	57	31	712	7.5	49	28	715	9.7	67
4,000	30	629	−.5	48	31	630	.5	52	26	634	3.8	67
5,000	30	554	−6.9	43	31	556	−5.9	50	26	560	−1.8	60
6,000	30	487	−13.3	46	30	488	−12.3	45	24	493	−7.7	54
7,000	30	426	−20.4	51	29	428	−19.5	43	24	433	−14.2	50
8,000	30	372	−27.9	53	28	373	−26.6	42	23	379	−21.4	49
9,000	30	322	−35.2	52	27	324	−34.0	42	22	330	−28.7	49
10,000	28	279	−42.3	----	27	280	−41.8	----	22	286	−36.4	50
11,000	28	240	−49.3	----	25	242	−49.4	----	22	247	−44.7	----
12,000	28	206	−54.4	----	23	207	−55.7	----	22	212	−51.5	----
13,000	27	176	−55.2	----	20	177	−56.7	----	19	182	−57.0	----
14,000	26	151	−55.8	----	18	151	−55.2	----	19	154	−60.1	----
15,000	26	130	−56.0	----	17	129	−55.2	----	19	132	−62.0	----
16,000	25	112	−56.1	----	17	111	−55.5	----	18	112	−61.6	----
17,000	23	96	−56.1	----	15	94	−55.6	----	15	95	−61.5	----
18,000	19	81	−55.7	----	14	81	−55.1	----	10	80	−59.3	----
19,000	14	69	−55.4	----	7	69	−54.9	----	6	68	−57.1	----
20,000	6	58	−55.6	----	----	------	------	----	----	------	------	----

Altitude (meters) m. s. l.	Stations with elevations in meters above sea level											
	Anchorage, Alaska (42 m.)				Atlantic Station No. 1[3] (3 m.)				Atlantic Station No. 2[4] (3 m.)			
	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity
Surface	31	1,008	15.0	69	30	1,020	25.0	84	27	1,026	23.8	85
500	31	954	11.7	69	30	964	21.2	89	27	969	20.5	86
1,000	31	899	8.1	72	30	910	18.5	84	27	915	18.2	83
1,500	30	846	4.4	78	30	858	15.9	79	27	863	16.0	77
2,000	29	796	1.1	84	30	809	13.7	73	27	813	14.2	66
2,500	28	747	−1.7	85	30	762	11.0	64	27	766	11.7	61
3,000	26	702	−4.2	82	26	718	8.2	61	27	721	8.8	61
4,000	26	617	−9.5	77	25	636	2.7	57	25	639	3.0	59
5,000	26	542	−15.6	71	26	561	−2.7	55	25	564	−2.9	58
6,000	26	474	−21.9	67	25	494	−8.3	50	25	496	−8.7	54
7,000	26	412	−29.1	65	22	434	−14.4	50	25	436	−15.0	48
8,000	27	358	−36.2	61	22	380	−21.2	48	25	381	−21.9	46
9,000	28	309	−43.0	----	20	330	−28.3	46	25	332	−29.4	45
10,000	28	266	−47.7	----	20	287	−35.8	45	25	288	−37.4	45
11,000	28	229	−48.0	----	20	248	−43.8	----	25	248	−45.8	----
12,000	28	197	−46.3	----	20	213	−51.5	----	25	213	−53.4	----
13,000	28	169	−44.5	----	20	182	−58.6	----	25	182	−59.0	----
14,000	27	146	−44.3	----	20	154	−63.0	----	21	155	−61.9	----
15,000	27	125	−44.5	----	20	131	−65.7	----	21	132	−62.4	----
16,000	27	108	−44.3	----	20	111	−66.8	----	21	112	−62.7	----
17,000	27	93	−44.4	----	19	94	−65.3	----	19	96	−61.9	----
18,000	26	80	−44.5	----	19	79	−62.3	----	16	81	−59.9	----
19,000	23	69	−44.6	----	17	67	−59.6	----	8	69	−57.9	----
20,000	22	59	−44.7	----	7	57	−57.0	----	----	------	------	----
21,000	15	51	−44.7	----	----	------	------	----	----	------	------	----
22,000	8	44	−44.9	----	----	------	------	----	----	------	------	----

Altitude (meters) m. s. l.	Stations with elevations in meters above sea level											
	Coco Solo, C. Z.[1 2] (15 m.)				Fairbanks, Alaska (156 m.)				Juneau, Alaska (49 m.)			
	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity
Surface	17	1,012	26.2	91	31	992	17.0	59	31	1,012	14.2	80
500	17	957	24.5	81	31	952	14.3	61	31	958	11.8	82
1,000	17	904	21.8	81	31	897	10.3	64	30	903	8.4	87
1,500	17	853	18.8	79	31	844	6.6	69	30	850	5.1	92
2,000	17	804	16.0	67	31	794	3.1	75	28	799	2.3	92
2,500	16	758	14.0	47	31	746	−.4	79	28	750	.7	83
3,000	14	715	11.5	40	31	701	−3.6	81	26	705	−1.7	76
4,000	9	633	4.0	56	31	617	−9.6	75	20	621	−7.0	64
5,000	----	------	------	----	31	541	−15.7	65	18	545	−13.1	60
6,000	----	------	------	----	31	473	−22.7	61	17	477	−19.8	57
7,000	----	------	------	----	30	412	−29.7	57	14	416	−26.9	53
8,000	----	------	------	----	30	358	−36.7	55	14	361	−34.8	52
9,000	----	------	------	----	30	309	−43.5	----	12	312	−41.1	----
10,000	----	------	------	----	30	266	−48.5	----	12	270	−47.1	----
11,000	----	------	------	----	30	229	−49.0	----	10	232	−50.9	----
12,000	----	------	------	----	29	196	−45.9	----	10	199	−48.4	----
13,000	----	------	------	----	29	169	−44.6	----	10	171	−46.1	----
14,000	----	------	------	----	29	145	−44.2	----	10	147	−45.8	----
15,000	----	------	------	----	29	125	−44.6	----	10	126	−45.7	----
16,000	----	------	------	----	28	108	−44.7	----	8	109	−45.1	----
17,000	----	------	------	----	27	93	−44.6	----	6	94	−45.1	----
18,000	----	------	------	----	26	80	−44.5	----	5	81	−45.1	----
19,000	----	------	------	----	22	69	−44.3	----	----	------	------	----
20,000	----	------	------	----	16	59	−44.2	----	----	------	------	----
21,000	----	------	------	----	7	51	−43.8	----	----	------	------	----
22,000	----	------	------	----	----	------	------	----	----	------	------	----

Altitude (meters) m. s. l.	Stations with elevations in meters above sea level							
	Ketchikan, Alaska (26 m.)							
	Number of observations	Pressure	Temperature	Relative humidity				
Surface	31	1,015	16.3	72				
500	31	959	13.2	78				
1,000	31	904	9.8	82				
1,500	31	851	7.2	81				
2,000	31	800	4.7	75				
2,500	30	752	2.5	67				
3,000	30	707	.3	63				
4,000	29	624	−5.1	58				
5,000	28	548	−11.2	54				
6,000	26	481	−17.9	51				
7,000	26	420	−24.7	48				
8,000	25	365	−32.2	47				
9,000	24	316	−39.3	47				
10,000	23	273	−45.2	----				
11,000	23	234	−50.2	----				
12,000	23	201	−51.5	----				
13,000	22	172	−49.9	----				
14,000	20	147	−49.4	----				
15,000	19	126	−48.8	----				
16,000	17	108	−48.8	----				
17,000	14	92	−48.3	----				
18,000	11	79	−48.1	----				
19,000	----	------	------	----				
20,000	----	------	------	----				
21,000	----	------	------	----				
22,000	----	------	------	----				

See footnotes at end of table.

TABLE 1.—*Mean free-air barometric pressure in millibars, temperature in degrees Centigrade, and relative humidities in percent, obtained by airplanes and radiosondes during July 1941*—Continued

Altitude (meters) m. s. l.	Stations with elevations in meters above sea level— Nome, Alaska (14 m.)				Pearl Harbor, T. H. (7 m.)[1]				St. Thomas, V. I. (8 m.)[1 2]				San Juan, P. R. (15 m.)			
	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity
Surface	30	1008	10.8	82	31	1016	24.2	76	31	1018	27.5	74	31	1016	25.4	89
500	30	951	8.4	82	31	960	20.6	80	31	963	23.3	91	31	962	23.7	87
1,000	30	896	6.5	79	31	906	17.4	84	31	908	20.1	81	31	908	20.6	84
1,500	30	842	4.1	76	31	854	15.0	77	31	858	16.8	76	31	858	17.6	80
2,000	30	792	1.6	76	31	805	14.2	54	31	809	14.8	68	31	808	14.9	71
2,500	30	744	−.8	74	31	758	12.4	38	31	763	12.7	61	31	761	12.4	61
3,000	30	698	−3.2	67	31	714	10.0	33	31	719	9.8	57	31	718	9.5	55
4,000	29	615	−8.9	58	31	632	4.3	25	31	637	4.7	47	31	636	4.4	49
5,000	29	540	−15.1	52	31	559	1.0	20	----	----	----	----	31	562	−.9	44
6,000	29	472	−21.9	50	29	492	−5.2	20	----	----	----	----	31	495	−6.8	40
7,000	29	411	−28.9	49	29	432	−11.6	18	----	----	----	----	31	435	−13.7	38
8,000	28	357	−36.2	48	16	378	−18.6	----	----	----	----	----	30	331	−20.0	37
9,000	28	308	−42.9	----	15	329	−26.1	----	----	----	----	----	30	331	−27.5	36
10,000	25	266	−47.3	----	14	286	−33.5	----	----	----	----	----	30	288	−35.4	35
11,000	23	228	−48.8	----	14	247	−41.0	----	----	----	----	----	30	249	−43.7	----
12,000	22	196	−45.9	----	13	213	−48.8	----	----	----	----	----	30	214	−51.7	----
13,000	22	169	−44.2	----	12	182	−55.6	----	----	----	----	----	30	182	−59.4	----
14,000	20	145	−44.1	----	11	155	−61.6	----	----	----	----	----	30	155	−65.6	----
15,000	20	125	−44.0	----	7	132	−65.6	----	----	----	----	----	30	131	−69.2	----
16,000	20	108	−43.9	----	7	112	−67.9	----	----	----	----	----	30	111	−71.7	----
17,000	18	93	−43.9	----	5	94	−67.5	----	----	----	----	----	29	94	−72.3	----
18,000	16	80	−43.8	----	----	----	----	----	----	----	----	----	27	79	−69.6	----
19,000	13	69	−43.8	----	----	----	----	----	----	----	----	----	24	67	−66.2	----
20,000	13	59	−43.7	----	----	----	----	----	----	----	----	----	16	57	−63.0	----
21,000	7	51	−43.4	----	----	----	----	----	----	----	----	----	10	48	−60.8	----
22,000	----	----	----	----	----	----	----	----	----	----	----	----	5	41	−58.8	----

LATE REPORT FOR JUNE 1941

Altitude (meters) m. s. l.	San Juan, P. R. (15 m.) Number of observations	Pressure	Temperature	Relative humidity	Altitude (meters) m. s. l.	San Juan, P. R. (15 m.) Number of observations	Pressure	Temperature	Relative humidity	Altitude (meters) m. s. l.	San Juan, P. R. (15 m.) Number of observations	Pressure	Temperature	Relative humidity	Altitude (meters) m. s. l.	San Juan, P. R. (15 m.) Number of observations	Pressure	Temperature	Relative humidity
Surface	29	1,016	25.5	87	3,000	28	717	10.3	53	9,000	27	331	−28.4	44	15,000	18	131	−73.6	----
500	29	961	23.6	88	4,000	28	636	4.2	50	10,000	26	288	−36.2	43	16,000	18	110	−75.1	----
1,000	29	908	20.8	86	5,000	28	562	−1.8	50	11,000	25	248	−44.4	----	17,000	17	93	−74.5	----
1,500	29	857	17.9	82	6,000	28	495	−7.8	49	12,000	23	213	−52.5	----	18,000	13	78	−69.8	----
2,000	29	808	15.3	70	7,000	28	434	−14.2	47	13,000	20	182	−60.3	----	19,000	8	66	−64.7	----
2,500	29	762	13.1	58	8,000	27	380	−21.3	46	14,000	18	155	−67.7	----					

[1] U. S. Navy.
[2] Airplane observations.
[3] Observations made on Coast Guard vessels in or near the 5° square: Lat. 35°00′ N. to 40°00′ N.; long. 55°00′ W. to 60°00′ W.
[4] Observations made on Coast Guard vessels in or near the 5° square: Lat. 35°00′ N. to 40°00′ N.; long. 45°00′ W. to 50°00′ W.

NOTE.—All observations taken at 12:30 a. m. 75th meridian time, except at Lakehurst, N. J., where they are taken near 5 a. m.; E. S. T.; at Norfolk, Va., where they are taken at about 6 a. m.; and at Pearl Harbor, T. H., at 7 a. m.

None of the means included in this table are based on less than 15 surface or 5 standard level observations.

Number of observations refers to pressure only as temperature and humidity data are missing for some observations at certain levels; also, the humidity data are not used in daily observations when the temperature is below −40.0° C.

TABLE 2.—*Free-air resultant winds based on pilot balloon observations made near 5 p. m. (75th meridian time) during July 1941. Directions given in degrees from North (N=360°, E=90°, S=180°, W=270°)—velocities in meters per second*

Altitude (meters) m. s. l.	Abilene, Tex. (537 m.) Observations	Direction	Velocity	Albuquerque, N. Mex. (1,630 m.) Observations	Direction	Velocity	Atlanta, Ga. (299 m.) Observations	Direction	Velocity	Billings, Mont. (1,095 m.) Observations	Direction	Velocity	Bismarck, N. Dak. (512 m.) Observations	Direction	Velocity	Boise, Idaho (866 m.) Observations	Direction	Velocity
Surface	31	134	1.7	31	227	1.3	30	196	2.0	31	312	0.6	31	249	1.4	31	316	4.3
500	----	----	----	----	----	----	30	217	2.8	----	----	----	----	----	----	----	----	----
1,000	31	147	3.2	----	----	----	30	234	3 3	----	----	----	31	296	.9	31	315	3.9
1,500	31	153	2.3	----	----	----	29	238	2.9	31	322	1.0	30	288	1.7	31	318	3.0
2,000	31	152	1.1	31	225	1.2	27	260	2.2	30	304	1.4	29	281	3.2	31	277	1.5
2,500	30	227	.7	31	246	1.1	24	265	2.1	30	274	2.4	27	274	4.0	31	249	2.8
3,000	29	244	.9	31	287	1.7	23	274	2.3	30	267	4.1	25	271	5.7	31	243	4.0
4,000	27	309	2.2	29	317	2.6	19	268	2.2	24	268	6.4	22	279	7.9	31	247	6.8
5,000	24	309	2.5	27	308	2.8	15	294	3.1	20	273	8.7	20	276	9.0	29	241	8.4
6,000	22	342	2.2	27	289	3.4	14	306	2.8	19	274	10.1	20	280	11.2	29	243	8.8
8,000	17	325	.9	23	264	6.2	11	190	.6	11	279	8.8	18	273	13.9	18	261	11.0
10,000	16	354	3.3	20	267	10.1	----	----	----	----	----	----	15	273	17.4	----	----	----
12,000	13	3	4.6	15	264	13.8	----	----	----	----	----	----	11	280	19.3	----	----	----
14,000	11	339	6.7	13	262	13.9	----	----	----	----	----	----	----	----	----	----	----	----

Altitude (meters) m. s. l.	Brownsville, Tex. (7 m.) Observations	Direction	Velocity	Buffalo, N. Y. (220 m.) Observations	Direction	Velocity	Burlington, Vt. (132 m.) Observations	Direction	Velocity	Charleston, S. C. (18 m.) Observations	Direction	Velocity	Chicago, Ill. (192 m.) Observations	Direction	Velocity	Cincinnati, Ohio (152 m.) Observations	Direction	Velocity	Denver, Colo. (1,627 m.) Observations	Direction	Velocity
Surface	31	145	6.1	31	265	3.2	31	208	1.3	31	174	2.5	31	316	0.9	30	246	0.7	31	23	1.5
500	31	149	7.2	31	260	3.5	31	205	2.6	31	191	5.7	31	343	1.1	30	249	1.8	----	----	----
1,000	30	160	6.2	29	263	4.0	30	238	2.7	30	201	5.4	31	287	2.4	30	253	2.6	----	----	----
1,500	29	167	5 1	29	261	4.4	30	270	4.2	27	211	4.7	30	274	4.0	29	261	3.0	----	----	----
2,000	24	168	4.2	26	276	5.2	26	275	4.8	26	213	3.3	29	274	4.6	29	278	3.8	31	43	2.6
2,500	23	161	3.2	25	278	5.7	25	283	5.7	24	230	3.3	28	285	5.8	28	289	4.0	31	42	2.4
3,000	21	161	3.3	24	279	7.1	20	274	6.4	23	235	3.0	26	294	6.1	27	294	4.6	31	19	2.1
4,000	17	156	3.2	17	300	8.8	16	285	7.1	22	220	3.1	25	295	7.9	23	284	5.5	30	323	3.1
5,000	16	166	2.9	13	295	8.9	----	----	----	16	255	1.0	21	291	10.0	21	288	7.3	25	304	4.0
6,000	16	167	2.2	12	304	9.2	----	----	----	13	64	.7	20	286	11.9	19	291	8.6	19	285	5.3
8,000	12	114	1.6	----	----	----	----	----	----	----	----	----	15	287	15.4	13	280	9.8	13	294	3.6
10,000	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	11	256	5.0
12,000	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	11	286	7.6
14,000	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----

TABLE 2.—*Free-air resultant winds based on pilot balloon observations made near 5 p. m. (74th meridian time) during July 1941. Directions given in degrees from North (N=360°, E=90°, S=180°, W=270°) —velocities in meters per second*—Continued

Altitude (meters) m. s. l.	El Paso, Tex. (1,196 m.)			Ely, Nev. (1,910 m.)			Grand Junction, Colo. (1,413 m.)			Greensboro, N. C. (271 m.)			Havre, Mont. (767 m.)			Jacksonville, Fla. (14 m.)			Las Vegas, Nev. (570 m.)			Little Rock, Ark. (79 m.)			Medford, Oreg. (410 m.)			Miami, Fla. (10 m.)			Minneapolis, Minn. (265 m.)			Mobile, Ala. (8 m.)			Nashville, Tenn. (194 m.)		
	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity
Surface	31	111	2.3	31	195	2.5	31	325	1.9	31	205	1.5	31	255	1.9	30	159	2.8	31	149	1.9	30	185	0.7	31	296	1.5	30	136	3.0	31	209	0.6	31	201	2.1	30	229	0.9
500										31	209	2.6				30	189	3.7				30	239	.7	31	306	2.1	30	149	4.7	31	205	1.1	31	218	4.4	30	201	1.4
1,000										31	219	3.5	31	271	2.4	30	209	4.7	31	163	2.7	28	261	1.6	31	311	1.8	30	158	3.8	31	234	1.5	29	248	3.0	30	247	1.6
1,500	31	124	2.2				31	325	2.6	29	245	3.2	31	265	2.0	28	216	4.9	31	187	2.7	28	275	2.2	31	290	1.3	29	154	1.8	28	244	2.6	27	269	1.6	30	271	1.5
2,000	31	152	1.3	31	196	2.8	31	319	2.9	25	260	4.2	31	277	2.3	27	229	4.5	30	196	3.7	27	275	2.5	30	236	1.8	28	139	1.5	25	264	3.2	23	310	1.7	29	280	2.3
2,500	31	105	.5	31	201	3.1	31	297	2.7	24	271	5.0	28	270	3.7	25	228	4.8	30	204	4.2	26	288	2.4	30	213	3.4	27	176	1.0	19	286	4.7	23	324	2.4	27	285	2.8
3,000	30	70	1.2	31	211	3.5	31	266	2.7	21	271	4.8	25	272	5.0	23	234	4.9	30	212	4.6	25	305	3.1	30	213	4.4	27	170	1.0	17	297	5.6	19	311	3.7	25	294	2.6
4,000	31	9	1.6	31	217	4.3	30	257	3.1	19	283	5.6	19	272	5.8	17	213	4.0	29	223	5.4	25	321	4.0	30	223	4.8	23	180	1.7	11	300	4.6	18	282	3.0	17	295	4.3
5,000	21	345	3.5	29	236	6.5	30	252	3.4	16	280	4.5	16	276	7.6	15	221	2.4	27	224	4.8	21	306	4.1	29	236	6.1	18	163	1.6				14	274	3.7	12	274	3.3
6,000	14	290	2.0	24	236	7.6	24	252	2.9	14	285	6.4				13	221	2.1	26	233	5.4	19	292	3.6	27	241	7.5	17	164	1.4									
8,000				18	241	9.2	15	244	4.2										22	256	6.6	12	250	4.9	24	238	10.0	11	110	2.9									
10,000				13	240	12.4													22	251	11.2				21	244	12.3	12	81	5.5									
12,000				13	238	16.4													20	252	16.2				17	245	12.0	10	72	10.6									
14,000				10	237	18.6													18	250	17.8				13	259	12.9												
16,000																			15	249	4.4																		
18,000																			10	173	1.9																		

Altitude (meters) m. s. l.	New York, N. Y. (15 m.)			Oakland, Calif. (8 m.)			Oklahoma City, Okla. (402 m.)			Omaha, Nebr. (306 m.)			Phoenix, Ariz. (338 m.)			Rapid City, S. Dak. (982 m.)			St. Louis, Mo. (181 m.)			San Antonio, Tex. (180 m.)			San Diego, Calif. (15 m.)			Sault Ste. Marie, Mich. (230 m.)			Seattle Wash. (14 m.)			Spokane, Wash. (603 m.)			Washington, D. C. (24 m.)		
	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity
Surface	30	177	3.0	31	283	4.9	31	174	2.2	31	143	1.5	31	269	1.4	30	16	2.0	31	351	0.7	31	122	3.1	30	293	4.6	28	285	3.1	31	298	2.2	31	217	1.7	29	177	2.6
500	30	229	3.7	31	260	3.5	31	170	2.6	31	138	2.0	31	270	1.5				31	340	1.3	31	127	4.0	30	302	2.6	28	291	4.7	31	309	1.4				29	210	2.6
1,000	29	261	4.8	30	220	3.0	31	173	2.7	31	167	1.2	31	273	2.1	30	21	2.0	30	303	1.5	31	144	3.6	28	271	1.3	28	292	4.7	30	295	1.4	31	222	1.8	26	250	2.9
1,500	27	277	5.0	29	196	2.9	31	190	2.5	31	229	.8	31	244	2.2	30	32	1.0	30	292	2.0	31	138	3.3	28	259	1.6	28	294	4.5	30	286	1.6	31	227	1.9	21	271	5.5
2,000	21	281	5.8	29	192	3.2	30	214	1.4	31	297	2.5	30	248	2.5	30	302	.6	28	290	3.5	30	145	2.4	27	250	1.7	28	294	4.9	28	247	1.4	31	227	2.6	19	283	7.2
2,500	14	292	5.6	29	184	3.4	30	263	1.2	29	294	5.6	30	238	2.2	30	274	2.7	28	287	4.9	26	172	2.0	27	218	3.2	25	304	5.3	27	225	2.2	31	224	3.4	17	289	7.1
3,000	12	294	5.0	29	177	3.2	28	310	1.7	29	297	6.8	30	246	2.2	27	279	5.2	24	294	6.6	20	179	1.5	27	219	3.7	21	314	7.4	27	223	2.8	31	230	4.2	12	290	9.5
4,000	12	307	6.7	29	192	3.5	25	315	2.9	26	301	8.6	30	239	2.7	27	279	7.0	22	296	7.1	15	288	1.3	25	203	4.5	18	317	8.4	26	227	4.5	28	248	7.2	11	294	11.8
5,000				29	204	3.5	23	303	2.9	23	305	8.2	27	240	1.6	24	285	7.9	19	297	7.1	13	250	.7	22	200	5.4	16	319	10.6	24	234	5.5	26	252	9.0			
6,000				29	217	3.6	22	297	3.5	21	305	9.3	27	254	2.8	20	282	8.0	16	293	9.1	10	274	1.8	14	204	2.7	11	319	10.9	22	239	6.9	24	253	10.1			
8,000				29	224	6.3	18	239	2.9	19	298	8.7	23	265	4.3	15	264	8.6	12	292	10.4										14	260	6.9	21	241	12.2			
10,000				29	228	10.1	10	269	3.4	13	289	10.0	22	275	9.6	11	278	8.5																17	243	14.4			
12,000				27	239	12.4							21	261	13.3																			13	233	11.3			
14,000				20	255	12.0							15	264	15.1																								
16,000				15	233	8.0							10	242	10.6																								

TABLE 3.—*Maximum free-air wind velocities (m. p. s.), for different sections of the United States based on pilot-balloon observations during July 1941*

Section	Surface to 2,500 meters (m. s. l.)					Between 2,500 and 5,000 meters (m. s. l.)					Above 5,000 meters (m. s. l.)				
	Maximum velocity	Direction	Altitude (m) m. s. l.	Date	Station	Maximum velocity	Direction	Altitude (m) m. s. l.	Date	Station	Maximum velocity	Direction	Altitude (m) m. s. l.	Date	Station
Northeast [1]	30.2	NW	2,260	28	Philadelphia, Pa.	38.1	WNW	5,000	3	Caribou, Maine	56.0	SW	9,460	21	Boston, Mass.
East-Central [2]	27.9	WSW	950	30	Cincinnati, Ohio	29.8	SSW	2,810	9	Chattanooga, Tenn.	40.8	W	12,640	15	Louisville, Ky.
Southeast [3]	21.2	SW	1,960	4	Spartanburg, S. C.	18.0	SW	2,500	4	Spartanburg, S. C.	30.1	SW	13,670	17	Atlanta, Ga.
North-Central [4]	27.5	S	1,000	20	Huron, S. Dak.	35.2	SSW	4,380	26	Bismarck, N. Dak.	54.4	NW	9,290	17	Fargo, N. Dak.
Central [5]	29.3	S	1,650	20	North Platte, Nebr.	68.0	SW	4,170	2	Evansville, Ind.	43.6	W	12,380	14	Chicago, Ill.
South-Central [6]	28.5	SSE	1,770	27	Big Spring, Tex.	18.4	NE	4,110	11	Big Spring, Tex.	28.4	NW	12,870	18	Waco, Tex.
Northwest [7]	26.6	NW	1,100	21	Ellensburg, Wash.	35.9	WSW	3,380	22	Great Falls, Mont.	49.6	W	11,450	8	Portland, Oreg.
West-Central [8]	43.0	SSE	2,290	11	Cheyenne, Wyo.	28.4	S	4,700	6	Ely, Nev.	48.8	WSW	12,000	31	Winnemucca, Nev.
Southwest [9]	21.4	E	1,850	13	Albuquerque, N. Mex.	25.5	ESE	3,030	15	Tucson, Ariz.	44.4	W	15,430	4	Las Vegas, Nev.

[1] Maine, Vermont, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, and northern Ohio.
[2] Delaware, Maryland, Virginia, West Virginia, southern Ohio, Kentucky, eastern Tennessee, and North Carolina.
[3] South Carolina, Georgia, Florida, and Alabama.
[4] Michigan, Wisconsin, Minnesota, North Dakota, and South Dakota.
[5] Indiana, Illinois, Iowa, Nebraska, Kansas, and Missouri.
[6] Mississippi, Arkansas, Louisiana, Oklahoma, Texas (except extreme west Texas), and western Tennessee.
[7] Montana, Idaho, Washington, and Oregon.
[8] Wyoming, Colorado, Utah, Northern Nevada, and northern California.
[9] Southern California, southern Nevada, Arizona, New Mexico, and extreme west Texas.