MEAN UPPER-AIR DATA FOR SELECTED WORLD STATIONS

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ABSTRACT

Mean upper-air pressure heights, temperatures, and mixing ratios are presented for 48 radiosonde stations well distributed in longitude around the globe. Of the 48 stations whose means are given, a majority were selected from arid zones, equatorial regions, and from the Southern Hemisphere. This geographical distribution, plus the fact that humidity means are given, constitute the chief value of the data presented.

In recent years several series of mean upper-air charts have been published that present temperature and pressure-height normals. None of these, to my knowledge, has included upper-air mixing ratio means, and also none extends across the equatorial zone into the Southern Hemisphere. Hence, in a current study that involved analysis of mean precipitable water amounts for stations representative of several different climatic regions well distributed around the globe, it became necessary to compute such upper-air means from original data tabulations. Until such time as really extensive tabulations of upper-air climatic data become available, these data should have reference value, so they are briefly summarized here (table 1).

No data for United States stations were computed, since an excellent tabulation has recently been published by Ratner [1]. Data for Mexican stations were taken from individual issues of two U.S. Weather Bureau publications, *Monthly Weather Review* and *Climatological Data National Summary*. All other data have been extracted from *Monthly Climatic Data for the World*, a U.S. Weather Bureau compilation. A total of 48 stations was considered.

It is important to note that the original observations were made with a wide variety of aerological sounding equipment and under a variety of levels of control. Furthermore these published data have not been subjected to any quality control by the publishing agency. Hence, the means here presented must be recognized as being rather uneven in quality. Nevertheless they should be useful as provisional means for areas of the world for which almost no published averages are currently available.

Mean conditions at three standard pressure surfaces (850, 700, 500 mb.) and for the climatically extreme months of January and July were obtained. Heights (H) of the pressure surfaces in meters above sea level, temperatures (T) in degrees Celsius, and mixing ratios (X) in grams per kilogram were the quantities averaged. The last quantity was obtained from mean relative humidities or mean dew points (depending on the data source). Analysis showed that errors due to nonlinearity in the dependence of saturation mixing ratio upon temperature that are incurred by such a method of averaging are of the order of only a fraction of a percent. The number of calendar years of record varied, unavoidably, from station to station, with maximum lengths of 10 years. The longest records cover the period 1949–58, and all data fall somewhere within that decade. To indicate to the user of the tables the number of years of record for which each station's means have been calculated, I give under the heading "N" the number of years of record used in computing the mean 700-mb. data. (The latter level is uniformly used in order to avoid having to cite special cases where for station-altitude reasons there exist no 850-mb. data.)

The inevitable problem of missing humidity data at upper levels arises here, especially at the 500-mb. level. It has been handled as follows: If only one year had no humidity data reported for a given level and month, the omission was ignored in the sense that the mean was computed for just that series of years for which actual humidities were reported. If more than one humidity entry was missing, the mean temperature for the group of missing cases was determined, and the so-called "motorboating" mixing ratio based on U.S. Weather Bureau radiosonde experience was taken to correspond to the mean temperature for that group of cases. Then a weighted average of this motorboating value plus the mean of the actually reported humidities (converted to mixing ratios) was calculated and listed. It is clear that to use a U.S. Weather Bureau motorboating value for *foreign* stations' missing humidity data is far from satisfactory in view of differences in instrumental characteristics; but this procedure is still preferable to simple omis-

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TABLE 1.—*Mean upper-air data for selected world stations. H=height of pressure surface (meters, MSL); T=temperature (° C.); X=mixing ratio (gm./kg.); N=number of years record used in computing 700-mb. data*

Station	N	JANUARY									JULY								
		850 mb.			700 mb.			500 mb.			850 mb.			700 mb.			500 mb.		
		H	T	X	H	T	X	H	T	X	H	T	X	H	T	X	H	T	X
Jan Mayen Island	5	1286	−12.0	1.5	2750	−19.4	0.8	5176	−35.0	0.3	1418	1.3	4.1	2964	−5.2	2.5	5540	−20.2	0.9
Keflavik, Iceland	7	1261	−6.4	1.9	2748	−16.9	0.9	5199	−32.7	0.3	1401	2.7	2.9	2951	−5.3	2.8	5521	−20.3	0.8
Sodankyla, Finland	6	1289	−10.4	1.6	2760	−18.5	0.9	5194	−34.3	0.2	1440	6.7	5.1	3008	−1.9	3.2	5610	−17.0	1.1
Stockholm, Sweden	8	1368	−7.1	1.9	2858	−14.7	1.0	5326	−31.0	0.3	1457	6.8	5.1	3024	−2.0	3.1	5625	−17.4	1.1
Lerwick, Great Britain	8	1354	−4.2	2.5	2862	−12.2	1.0	5353	−28.8	0.3	1435	5.2	4.8	2995	−2.4	2.5	5596	−17.8	0.8
Casablanca, Morocco	3	1520	5.3	4.5	3056	−2.3	1.7	5671	−19.1	0.5	1550	21.1	5.5	3201	11.3	2.3	5901	−9.2	0.8
Ft. Trinquet, Morocco	6	1519	9.1	3.0	3112	−2.1	1.4	5756	−14.0	0.5	1534	27.4	5.7	3216	14.0	3.1	5934	−8.4	1.6
Algers, Algeria	9	1482	2.9	3.4	3031	−5.7	1.5	5589	−22.1	0.4	1537	21.0	5.4	3192	10.3	2.9	5888	−9.9	1.0
Colomb-Bechar, Algeria	9	1512	6.0	3.0	3070	−3.0	1.6	5630	−18.8	0.4	1543	28.8	5.5	3224	13.9	3.1	5942	−8 5	1.6
Aoulef, Algeria	8	1503	9.6	2.3	3092	1.4	1.2	5718	−14.7	0.5	1528	28.4	3.4	3207	13.8	2.6	5924	−7.8	1.2
Benina, Libya	8	1492	5.2	3.6	3057	−2.5	1.4	5640	−18.6	0.4	1528	19.7	3.6	3171	10.4	2.5	5874	−5.7	0.7
Tunis, Tunisia	4	1454	2.0	3.4	2998	−6.2	1.7	5573	−23.2	0.4	1556	19.3	6.4	3200	9.2	2.7	5866	−9.6	0.9
Cairo, Egypt	8	1506	5.9	3.4	3090	−1.3	2.2	5642	−16.6	0.6	1495	21.2	7.8	3153	12.6	3.8	5886	−3.4	1.4
Khartoum, Sudan	4	1506	18 4	4.4	3147	9.8	2.3	5848	−8.0	0.8	1506	22 4	10.9	3158	11.2	6.7	5870	−7.0	2.8
Dakar, Senegal	8	1506	18.2	3.8	3135	8.1	2.8	5690	−9.1	1.3	1517	19.0	10.1	3153	10.1	5.5	5844	−7.3	2.3
Niamey, French Nigeria	6	1514	18.0	2.7	3147	9.7	2.2	5850	−7.0	0.9	1525	20.1	10.2	3168	9.9	5.9	5873	−4.4	2.2
Lagos, Nigeria	3	1519	18.2	9.8	3150	9.1	5.3	5858	−5.9	1.6	1531	15.8	11.8	3161	8 3	7.2	5866	−6.5	2.7
Douala, Cameroons	3	1493	17.6	11.2	3132	8.6	4.0	5831	−5.7	0.8	1514	15.6	1.6	3146	7.8	6.1	5850	−6.5	2.1
Bangui, French Equatorial Africa	5	1496	20.5	8.2	3148	10.1	4.3	5859	−5.7	1.1	1511	18.1	11.5	3154	8 6	6.0	5860	−6.4	2.2
Nairobi, British East Africa	8				3160	9.7	6.2	5875	−5.6	1.6				3163	6.9	7.6	5868	−6.4	1.4
Ankara, Turkey	6	1463	−1.3	3.2	2979	−8 9	1.8	5515	−26.5	0.4	1489	16.9	7.2	3117	7.1	4.1	5801	−9.3	1.0
Habbaniya, Iraq	7	1493	4.3	3.2	3048	−4.4	1.4	5620	−21.8	0.4	1449	28 0	3.5	3138	14.2	2.3	5866	−2.6	0.6
Bahrein, Arabia	8	1515	9.6	3.9	3096	1.6	2.2	5739	−14.5	0.8	1440	29.5	5.0	3128	16.7	2.8	5867	−3.1	1 3
Aden, Arabia	8	1531	16.1	7.8	3168	9.5	3.2	5882	−6.1	0.7	1461	26.8	11.3	3136	14.4	6.4	5864	−7.0	2.6
Quetta, West Pakistan	4				3078	−1.4	4.1	5700	−17.4	(0.5)				3100	18 6	10.0	5873	−1.2	4.2
Karachi, West Pakistan	4	1508	12.8	5.7	3125	5.0	3.6	5788	−10.0	1.2	1422	23.5	14.2	3120	17.5	8.6	5866	1.0	2.9
New Delhi, India	10	1509	10.9	4.4	3100	0.8	2.8	5715	−16.7	(0.5)	1423	24.1	16.5	3085	13.2	11.0	5846	−1.3	5.6
Jodhpur, India	10	1514	11.4	4.1	3106	1.8	2.4	5678	−14.6	(0.6)	1425	23.4	15.4	3092	13.3	9.5	5842	−2.2	3.2
Nagpur, India	8	1519	16.3	6.1	3138	6.0	3.1	5824	−9.0	(0.9)	1434	21.4	15.0	3092	11.9	9.7	5839	−2.2	(1.4)
Trivandrum, India	9	1510	17.8	10.6	3151	10.2	4.8	5872	−5.3	(1.2)	1490	17.3	12.0	3130	9.7	7.6	5850	−5.5	(1.2)
Calcutta, India	10	1518	12.8	4.8	3122	5.1	2.2	5786	−10.8	(0.7)	1429	21.5	14.5	3089	12 7	9.7	5845	−1.5	4.7
Madras, India	8	1523	16.5	7.0	3158	10.3	2.8	5883	−5.1	(1.2)	1468	21.3	13.2	3122	10.4	8.8	5851	−4.2	(1.2)
Port Blair, Andaman Island	7	1517	17 1	10.3	3155	9.9	4.5	5873	−5.0	(1.2)	1488	18.9	12.6	3137	10.6	7.9	5860	−4.3	1.2
Cocos Island	4	1504	15.7	9.5	3142	8.3	4.4	5842	−6.6	1.4	1509	15.6	14.5	3142	8.8	5.1	5856	−5.7	1.7
Hong Kong	7	1545	10.2	6.4	3143	5.0	2 8	5786	−8.1	0.6	1474	18.9	14.3	3125	11 5	7.3	5862	−3.5	3.0
Wake Island	7	1528	14.0	8.2	3149	9.8	(2.7)	5868	−5.7	(1.2)	1536	17.2	11.1	3157	9.0	5.7	5880	−6.8	2.1
Canton Island	8	1479	17.7	10.5	3122	10.6	1.7	5849	−4 4	2 2	1492	17.6	10 3	3132	9.9	4.8	5851	−5.2	1.9
Darwin, Australia	8	1474	19.1	11.2	3116	9.4	6.2	5853	−5.2	2.9	1508	15.6	6.3	3137	9.6	2.8	5852	−5.9	1.5
Alice Springs, Australia	8	1514	23.4	5.4	3156	9.8	4.4	5860	−6.8	1.2	1538	7.7	3.3	3124	2.5	1.8	5775	−11.6	0.9
Cloncurry, Australia	9	1474	21.3	16.4	3111	9.1	6.3	5772	−4.6	2.1	1516	11.6	4.2	3121	5 8	2.5	5793	−8.3	1.3
Charleville, Australia	9	1494	19.7	7.1	3128	7.2	4.6	5815	−8.6	1.4	1521	6.9	3.2	3095	−0.1	1.7	5716	−15.2	0.8
Townsville, Australia	7	1481	17.7	10.5	3118	9.0	5.6	5833	−5.6	2.2	1520	11 5	6.2	3130	6.6	2.2	5818	−7.7	0.8
Macquarie Island	7	1290	−0.1	3.2	2838	−7.4	1.6	5357	−22.6	0.5	1340	−4.4	2.1	2839	−12.0	1.0	5329	−28.8	0.3
Mazatlan, Mexico	10	1518	16.3	4.9	3138	5.9	2.4	5808	−11.0	1.0	1515	20.0	12.7	3165	10.7	7.8	5884	−6.5	3.0
Cuidad Victoria, Mexico	6	1514	11.8	6.5	3248	5.4	3.6	5966	−11 6	1.0	1523	22.0	10.9	3167	9.0	6.1	5876	−6.5	2.0
Tacubaya, Mexico	10				3151	9.2	4.3	5835	−8.4	1.2				3157	10.1	8.5	5874	−6.7	3.4
Vera Cruz, Mexico	4	1538	14.0	7.5	3155	6.8	3.4	5849	−8.3	1.0	1524	18.5	11.1	3161	8 6	6.0	5870	−6.6	2.2
Merida, Mexico	10	1549	14.3	8.9	3170	7.5	3.3	5877	−8.3	1.0	1552	21.3	13.8	3190	8.0	6.1	5896	−6.9	2.5

sion of all cases of missing data since to compute an average on the basis of only *reported* humidities in records containing entries missing due to upper-air dryness or anomalous coldness will yield an erroneously high value. On the other hand, to treat missing cases as zeroes will almost always yield an underestimate, so the procedure used is the best available compromise. In all instances where this procedure has had to be used, the mean mixing ratio in question has been enclosed in parentheses. It will be seen that only a single 700-mb. mixing ratio out of a total of 96 cases depends on such a motorboating adjustment, but the 500-mb. data includes 12 such cases out of 96.

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REFERENCES

1. B. Ratner, "Upper-Air Climatology of the United States: Part I, Averages for Isobaric Surfaces," *Technical Paper No. 32*, U.S. Weather Bureau, Washington, D.C., 1957, 199 pp.