



Technical Note

No. 5

TABLES OF MEDIAN HOURLY VALUES OF THE COSINE OF THE SOLAR ZENITH ANGLE (α) FOR THIRTY-FIVE LOCATIONS

by R. E. McDuffie



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Tables of Median Hourly Values of the Cosine of the
Solar Zenith Angle (χ) for Thirty-five Locations

Many parameters of the lower ionosphere, notably D and E region maximum electron densities and D region absorption, vary as a simple function of the cosine of the zenith angle (χ) of the sun. It is convenient, therefore, to have tabulations of cosine χ for the locations at which ionospheric vertical soundings are being made. This report consists of tables of hourly values of cosine χ from sunrise to sunset for the 15th day of each month appropriate to thirty-five vertical incidence ionospheric stations associated with the National Bureau of Standards, including fourteen new stations established for IGY (see Table 1). The tables were prepared in response to the recommendation by the U.R.S.I. Mixed Commission on the Ionosphere (see Proc. Mixed Comm. on the Ionosphere, p. 77 Resolution 2, Brussels, 1954).

The calculations were made in compliance with the suggestions of W. J. G. Beynon and G. M. Brown, expressed in a paper entitled "On the calculation of solar zenith angle" published in U.R.S.I. Information Bulletin, No. 97. In addition to a comprehensive discussion of the merits and accuracy of their method of computation they list a table of values of solar declination δ and equation of time ϵ for the 15th day of each month that are considered to be the best compromise values which allow for the year-to-year variations. Since the period of the International Geophysical Year (1957-1958) falls midway between the times of extreme variations of δ and ϵ , i.e., midway between consecutive leap years, the values given will be quite adequate for the determination of $\cos \chi$ at all stations.

The basic equation is:

$$\cos X = \sin \varphi \cdot \sin \delta + \cos \varphi \cdot \cos \delta \cdot \cos (h_m + \epsilon + \beta)$$

where

φ is latitude

δ is solar declination

h_m is the hour angle of the mean sun from noon, reckoned positive westwards

ϵ is the correction applied to h_m due to the Equation of Time, reckoned positive when the true sun is ahead of the mean sun

β is the local time correction, reckoned positive when the time meridian is west of the station.

Since the values of δ and ϵ for the 15th day of a month are close to the monthly median values, it is legitimate to employ the resulting $\cos X$ values in conjunction with monthly median ionospheric parameters. Interpolation between stations is not correct because of the time correction for distance from the standard meridians.

TABLE 1

Location	Geographic		Time	Page
	Lat.	Long.		
Adak, Alaska	N51 ^o 54'	W176 ^o 36'	180 ^o W	4
Amundsen-Scott (Pole), Antarctica	S90 00	-- --	GCT	5
Anchorage, Alaska	N61 14	W149 53	150 W	6
Baguio, Philippines	N16 25	E120 35	120 E	7
Barrow, Alaska	N71 20	W156 46	150 W	8
Belvoir, Virginia	N38 44	W 77 08	75 W	9
Bogota, Colombia	N 4 32	W 74 15	75 W	10
Byrd Base, Antarctica	S80 00	W120 00	120 W	11
Cape Canaveral, Florida	N28 24	W 80 36	75 W	12
Cape Hallett (Adare), Antarctica	S72 25	E170 55	165 E	13
Chiclayo, Peru	S 6 48	W 79 49	75 W	14
Chimbote, Peru	S 9 04	W 78 35	75 W	15
College-Fairbanks, Alaska	N64 54	W147 48	150 W	16
Concepcion, Chile	S36 35	W 72 59	75 W	17
Ellsworth, Antarctica	S77 43	W 41 07	45 W	18
Ft. Monmouth, New Jersey	N40 18	W 74 12	75 W	19
Godhavn, Greenland	N69 15	W 53 33	45 W	20
Grand Bahama Island	N26 36	W 78 15	75 W	21
Guam, Mariana Islands	N13 27	E144 45	150 E	22
Huancayo, Peru	S12 03	W 75 20	75 W	23
La Paz, Bolivia	S16 29	W 68 03	75 W	24
Little America, Antarctica	S78 17	W162 15	165 W	25
Maui, T. of Hawaii	N20 48	W156 30	150 W	26
Narsarssuak, Greenland	N61 09	W 45 22	45 W	27
Okinawa, Ryukyu Islands	N26 19	E127 47	135 E	28
Panama, Canal Zone	N 9 24	W 79 54	75 W	29
Puerto Rico, W. Indies	N18 30	W 67 10	60 W	30
Reykjavik, Iceland	N64 08	W 21 47	15 W	31
San Francisco, California	N37 24	W122 10	120 W	32
San Salvador, Bahama Islands	N24 05	W 74 30	75 W	33
St. John's, Newfoundland	N47 37	W 52 42	60 W	34
Talara, Peru	S 4 38	W 81 18	75 W	35
Thule, Greenland	N76 33	W 68 50	75 W	36
White Sands, New Mexico	N32 18	W106 30	105 W	37
Wilkes, Antarctica	S66 15	E110 35	105 E	38

Amundsen-Scott (Pole Station), Antarctica (90.0°S, --) Time: GCT

Hourly values of cos X for 15th day of each month

GCT	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
00	.363	.225	.042							.144	.315	.394
01	.363	.224	.041							.144	.314	.394
02	.363	.224	.041							.145	.314	.394
03	.363	.224	.041							.145	.314	.394
04	.362	.224	.040							.145	.314	.394
05	.362	.224	.040							.146	.314	.395
06	.362	.223	.040							.146	.313	.395
07	.362	.223	.040							.146	.313	.395
08	.362	.223	.039							.146	.313	.395
09	.362	.223	.039							.146	.313	.395
10	.362	.222	.039							.147	.313	.395
11	.362	.222	.038							.147	.313	.395
12	.362	.222	.038							.147	.312	.395
13	.361	.222	.038							.148	.312	.395
14	.361	.221	.037							.148	.312	.395
15	.361	.221	.037							.148	.312	.395
16	.361	.221	.037							.148	.312	.395
17	.361	.221	.036							.149	.312	.395
18	.361	.220	.036							.149	.312	.395
19	.361	.220	.036							.149	.311	.395
20	.361	.220	.036							.149	.311	.395
21	.360	.220	.035							.150	.311	.395
22	.360	.220	.035							.150	.311	.395
23	.360	.219	.035							.150	.311	.396

Barrow, Alaska (71.3°N, 156.8°W) Time: 150°W

Hourly values of cos X for 15th day of each month

LST	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
00					.002	.083	.055					
01					.005	.083	.054					
02					.028	.104	.073					
03					.070	.143	.111					
04					.127	.198	.165	.042				
05				.041	.197	.266	.231	.112				
06				.121	.274	.340	.306	.189	.021			
07				.204	.353	.417	.384	.270	.104			
08			.077	.283	.429	.490	.459	.349	.184	.004		
09			.151	.354	.497	.556	.526	.419	.255	.072		
10	.027	.212	.412	.551	.610	.582	.476	.311	.126			
11	.072	.256	.453	.589	.648	.622	.517	.350	.161			
12	.097	.280	.473	.607	.667	.643	.538	.369	.177	.008		
13	.101	.282	.472	.605	.666	.644	.539	.366	.170	.001		
14	.084	.263	.450	.582	.645	.624	.518	.342	.143			
15	.047	.224	.408	.541	.606	.586	.478	.297	.096			
16		.166	.350	.484	.551	.532	.421	.236	.033			
17		.095	.259	.414	.485	.465	.351	.166				
18		.016	.198	.337	.410	.390	.272	.080				
19			.116	.289	.334	.312	.191					
20				.183	.260	.237	.112					
21				.116	.194	.169	.041					
22				.062	.140	.113						
23				.024	.103	.073						

Byrd Base, Antarctica (80.0°S, 120.0°W) Time: 120°W

Hourly values of cos X for 15th day of each month

LST	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
00	.196	.052									.145	.229
01	.200	.055									.154	.235
02	.214	.069									.173	.252
03	.238	.094								.029	.201	.278
04	.270	.127								.066	.237	.312
05	.309	.166								.109	.277	.351
06	.350	.209	.032							.154	.320	.392
07	.392	.253	.077							.198	.362	.433
08	.432	.295	.119					.036	.239	.400	.472	
09	.466	.331	.156					.071	.273	.432	.504	
10	.493	.360	.185					.098	.298	.456	.529	
11	.511	.379	.204					.115	.313	.470	.544	
12	.518	.387	.211	.005				.120	.316	.472	.549	
13	.514	.384	.206					.114	.308	.464	.542	
14	.499	.370	.191					.096	.289	.444	.525	
15	.475	.345	.164					.068	.260	.416	.499	
16	.442	.311	.129					.031	.223	.380	.466	
17	.404	.271	.088						.181	.339	.427	
18	.362	.228	.043						.136	.296	.386	
19	.320	.183							.092	.253	.345	
20	.280	.141							.052	.215	.307	
21	.245	.104							.019	.182	.274	
22	.218	.075								.158	.250	
23	.200	.055								.144	.235	

Cape Hallett(Adare), Antarctica (72.4°S, 170.9°E) Time: 165°E

Hourly values of cos χ for 15th day of each month

LST	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
00	.065										.017	.101
01	.079										.039	.119
02	.111										.079	.155
03	.160	.014									.134	.206
04	.220	.077								.033	.200	.268
05	.290	.149								.110	.273	.339
06	.363	.225	.057							.188	.348	.411
07	.435	.300	.134						.061	.263	.419	.481
08	.501	.370	.205	.011					.129	.329	.482	.544
09	.556	.429	.264	.071					.186	.383	.533	.596
10	.597	.473	.307	.111				.032	.226	.420	.567	.633
11	.621	.499	.333	.133				.056	.247	.437	.584	.651
12	.626	.506	.338	.136				.060	.248	.435	.581	.652
13	.612	.492	.322	.117				.043	.228	.413	.558	.634
14	.579	.460	.287	.080				.009	.190	.372	.518	.598
15	.531	.410	.235	.026					.135	.315	.463	.547
16	.470	.347	.169						.067	.246	.397	.484
17	.400	.276	.094							.171	.323	.414
18	.327	.198	.015							.093	.248	.342
19	.254	.122								.018	.177	.272
20	.188	.052									.113	.209
21	.132										.062	.158
22	.091										.027	.121
23	.067										.010	.102

Godhavn, Greenland (69.2°N, 53.5°W) Time: 45°W

Hourly values of cos X for 15th day of each month

LST	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
00						.048	.020					
01						.046	.017					
02						.067	.035					
03					.034	.108	.075					
04					.096	.167	.133	.010				
05				.016	.172	.240	.205	.086				
06				.104	.256	.321	.285	.171	.006			
07				.196	.344	.406	.373	.261	.098			
08			.080	.284	.429	.489	.457	.348	.187	.011		
09			.162	.364	.505	.563	.533	.427	.267	.088		
10	.048	.232	.430	.567	.624	.596	.493	.332	.150			
11	.100	.283	.478	.611	.668	.642	.540	.378	.192	.024		
12	.130	.312	.503	.634	.692	.668	.567	.401	.211	.043		
13	.138	.318	.505	.635	.693	.672	.570	.401	.207	.039		
14	.122	.299	.483	.612	.673	.653	.550	.377	.179	.012		
15	.083	.258	.439	.569	.632	.613	.508	.330	.130			
16	.025	.197	.376	.507	.573	.555	.446	.264	.062			
17		.120	.298	.431	.501	.482	.370	.188				
18		.032	.211	.347	.419	.400	.284	.094				
19			.120	.260	.334	.314	.194	.002				
20			.032	.175	.252	.230	.107					
21				.100	.177	.154	.027					
22				.038	.116	.090						
23					.073	.043						

Little America, Antarctica (78.3°S, 162.2°W) Time: 165⁰⁰W

Hourly values of cos X for 15th day of each month

LST	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
00	.165	.021									.115	.199
01	.172	.026									.127	.209
02	.191	.045									.152	.230
03	.221	.076								.015	.187	.263
04	.261	.117								.061	.230	.304
05	.307	.165								.112	.279	.351
06	.356	.216	.041							.165	.329	.400
07	.405	.267	.093						.012	.216	.378	.448
08	.451	.315	.142						.060	.263	.422	.492
09	.490	.357	.184						.100	.301	.458	.528
10	.520	.389	.216	.015					.130	.328	.485	.555
11	.539	.409	.235	.032					.147	.344	.498	.571
12	.545	.417	.242	.036					.151	.345	.499	.574
13	.538	.410	.234	.027					.140	.333	.486	.564
14	.518	.391	.213	.004					.117	.307	.461	.542
15	.487	.360	.180						.082	.271	.426	.510
16	.448	.318	.137						.038	.227	.382	.469
17	.401	.270	.087							.176	.333	.423
18	.352	.219	.034							.124	.283	.374
19	.302	.167								.072	.233	.326
20	.256	.118								.026	.189	.282
21	.216	.076									.152	.245
22	.189	.044									.126	.218
23	.168	.023									.112	.203

Thule, Greenland (76.6°N, 68.8°W) Time: 75°W

Hourly values of cos X for 15th day of each month

LST	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
00					.094	.172	.143	.015				
01					.108	.185	.155	.027				
02					.137	.212	.181	.055				
03				.018	.177	.250	.218	.094				
04				.069	.227	.298	.266	.143				
05				.127	.283	.352	.319	.199	.023			
06				.187	.340	.407	.376	.258	.083			
07			.037	.246	.396	.462	.431	.315	.142			
08			.092	.299	.446	.511	.481	.367	.194	.005		
09			.138	.342	.487	.551	.522	.410	.237	.045		
10			.171	.374	.517	.580	.553	.442	.267	.073		
11		.006	.191	.390	.532	.596	.570	.459	.283	.086		
12		.011	.195	.392	.533	.597	.573	.462	.283	.083		
13		.001	.183	.378	.518	.584	.561	.449	.267	.065		
14			.157	.350	.490	.558	.535	.421	.236	.033		
15			.117	.309	.450	.519	.497	.381	.193			
16			.067	.258	.400	.472	.449	.331	.145			
17			.009	.201	.345	.418	.395	.275	.082			
18				.141	.288	.363	.339	.216	.021			
19				.083	.232	.308	.284	.158				
20				.031	.183	.259	.233	.105				
21					.142	.219	.191	.062				
22					.113	.190	.160	.030				
23					.094	.173	.146	.018				

