CHAPTER I

THE INFLUENCE OF SUN AND SPACE

SOME PRELIMINARY FIGURES

Conditions of balance between solar and terrestrial radiation for a horizontal black surface and a perfectly transparent atmosphere.

Temperature (a) of a black horizontal surface ...	200	210	220	230	240	250	260	270	280	290	300
Sun's altitude for balance	$3\frac{1}{2}°$	$4\frac{1}{4}°$	5°	6°	$7\frac{1}{4}°$	$8\frac{1}{2}°$	10°	$11\frac{3}{4}°$	$13\frac{3}{4}°$	$15\frac{3}{4}°$	18°
Temperature (a) of a black horizontal surface ...	310	320	330	340	350	360	370	380	390	400	402
Sun's altitude for balance	$20\frac{3}{4}°$	$23\frac{3}{4}°$	27°	31°	$35\frac{1}{4}°$	40°	46°	$53\frac{1}{4}°$	$62\frac{1}{4}°$	$79\frac{1}{4}°$	90°

Temperature (a) = tercentesimal temperature (tt) + ·10 ± ·05 (*Dict. App. Phys.* vol. 1).

Mean solar constant 135 kilowatts per square dekametre, 1·93 gramme calories per square centimetre per minute.

Stefan's constant of radiation from unit area of a black body $5{\cdot}72 \times 10^{-9}$ kilowatts per square dekametre per degree of absolute temperature, or 82×10^{-12} gramme calories per square centimetre per minute.

Constant of gravitation $6{\cdot}6576 \times 10^{-8}$ $cm^3/(g.\ sec^2)$.
Mean distance of earth from sun 149,500,000 kilometres.
Minimum distance of earth from sun 146,700,000 kilometres.
Maximum distance of earth from sun 152,100,000 kilometres.

In the fifteen chapters of our historical introduction we have sketched the evolution of modern methods of obtaining current information about the condition of the atmosphere and the facilities for dealing with the information thus obtained. In the present volume we offer for the reader's consideration a representation of the structure of the atmosphere, and some indication of the general circulation which is based upon observations collected in the manner described.

The representation cannot pretend to take account of all the observations which are, in one way or other, pertinent to the subject under consideration. The author, when he was director of the Meteorological Office in London, endeavoured to bring together in compact form the information about the weather of the British Isles which was collected in the ordinary course of duty and found himself responsible for about 2000 maps and as many pages of tables, expressing the data for one year. This was exclusive of the work on the meteorology of the sea for which, strangely enough, the publication of current data remains without adequate organisation on an international basis. The number of "significant figures" on a page, many of which are themselves summaries, may run to 5000. A year's output on this scale is quite beyond the capacity of any human being to keep in mind. In ten years a corresponding output for 50 countries of similar meteorological importance would provide 1,000,000 pages and would occupy some 100 metres' run of a substantial book-shelf. In the common jargon of the geophysicist the number of data to be dealt with is of the order 10^{10} to 10^{12}. The publication of such a vast number of facts for the several countries can only be justified on the understanding that the data are available for a large variety of economic and scientific purposes apart from the special study of the atmosphere; the general solution of the atmospheric problem can only be approached by adopting some systematic plan of dealing with the vast accumulation of data.

By general consent the first step is to deal with "normals" for selected periods based upon the co-ordination of data extending over a long series of years. In accordance with international agreement, confirming a practice already established, the year and, wisely or unwisely, the calendar months are the selected periods.

Our first endeavour is therefore to represent the "normal" structure of the atmosphere for the month or the year and the normal circulation which corresponds therewith.

The atmosphere has thickness as well as length and breadth. The length and breadth at the surface constitute the base of the structure; and, for these, vast collections of data are available, though there are still many regions for which no adequate monthly data exist. For the thickness comparatively few data are available. We must therefore deal with the thickness in a much more sketchy manner than the base.

By the presentation month by month of the base of the normal structure and circulation, seasonal changes are disclosed which are the main features of climate all over the globe; and one of the primary problems of meteorology is to study these changes and if possible to ascertain their causes. On that account we have judged it necessary to represent the conditions month by month. In meteorological text-books, for purposes of illustration, it is often deemed sufficient to present the extremes of seasonal conditions as represented by the months of January and July. But for the purposes of study the transition months are indispensable because it is precisely the course and causes of transition that we seek.

When in this way the normal structure and the normal circulation have been briefly indicated, we shall endeavour to represent the data upon which we must rely for insight into the nature of those local deviations of the normal circulation which constitute the sequence of weather.

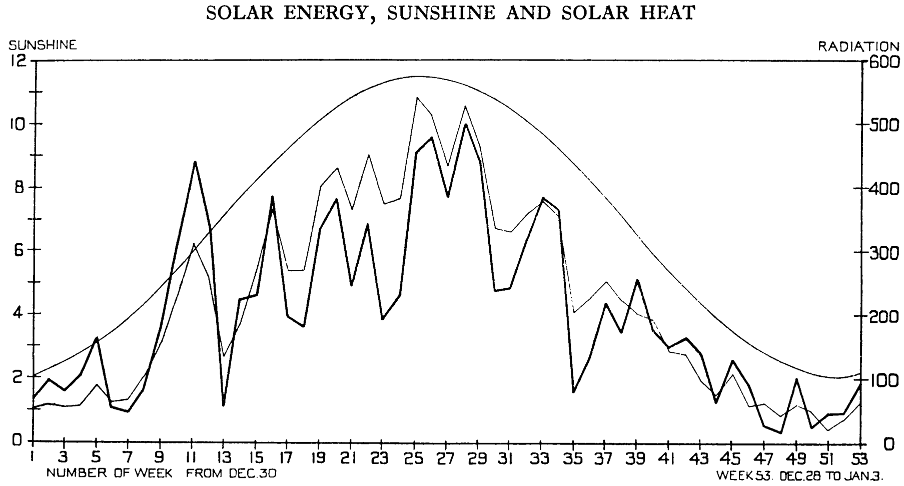
SOLAR RADIATION AND SUNSPOTS

While we set out here as clearly as we can the general features of the problem of the normal circulation of the atmosphere and its local variations, we must reserve for a subsequent volume the consideration of the progress that has been achieved in tracing the physical and dynamical relationships between the several features, and the contributions made thereby towards the explanation of the sequence of weather as the natural effects of ascertained physical causes.

The fundamental causes have to be sought in solar and terrestrial radiation. That aspect of meteorology we must consider in due course; but the details of the physical processes by which, for example, radiation is related quantitatively to temperature or its possible alternative vapour-pressure are still in the stage of development that belongs rather to the meteorological laboratory than to the normal observatory, and we must accordingly postpone the detailed consideration of the subject until we come to deal with our knowledge of the physical processes which are operative in the atmosphere.

Yet even here we think it desirable to enable our readers to keep in mind some of the information about the sun and its radiation, and about radiation from the earth into free space, the use of which may be called for at any time and does not require any expert knowledge of the details of the physical processes involved. The information includes, first, the distribution of solar energy over the different regions of the globe as computed by A. Angot[1] assuming a value for the "constant" of solar radiation, that is the amount of energy which would reach unit-area of receiving surface at right angles to the sun's rays at the outer limit of the atmosphere; we shall take a square dekametre as the unit area and in a table on pp. 4, 5 express the energy of radiation received by it in the ordinary unit of power, the kilowatt.

SOLAR ENERGY, SUNSHINE AND SOLAR HEAT



Week 1. Dec. 30 to Jan. 5. Week 2. Jan. 6 to Jan. 12, etc.

Fig. 1. Thick line —— mean daily duration of sunshine in hours per day. Thin line —— mean daily total of radiation received from sun and sky in kilowatt-hours per square dekametre of horizontal surface at Rothamsted week by week in 1924.

The smooth curve represents, on the same scale as that of radiation received, 50 per cent. of the solar radiation per square dekametre of horizontal surface.

The numbers for the smooth curve of solar energy in fig. 1 are the halves of those given in the column for 50° in the table of p. 4.

By way of comparison we have included in the same figure the amount of energy received by a Callendar recorder at Rothamsted in 1924 as daily averages for successive weeks; daily duration of sunshine for corresponding weeks is also shown. The latitude of Rothamsted is 51° 48′ N.

[1] *Ann. bur. cent. météor.*, Paris, 1883, part I (1885), pp. B. 121–169.

Cambridge University Press
978-1-107-47547-2 - Manual of Meteorology: Volume II: Comparative Meteorology
Sir Napier Shaw
Excerpt
More information

Energy, in kilowatt-hours, which would be received, if there were no atmosphere, upon a hundred square metres of horizontal surface by direct radiation from the sun with a solar constant of 135 kilowatts per square dekametre.

Totals for the middle day of successive weeks of the year.
Multiply by $3{\cdot}6 \times 10^{13}$ to express the result in ergs per sq. dekametre.
Multiply by $3{\cdot}6$ to express the result in joules per sq. centimetre.

NORTHERN HEMISPHERE

		Date	90°	80°	70°	60°	50°	40°	30°	20°	10°	0°
	22° 45′ S	Jan. 4	—	—	—	68	217	385	554	714	859	987
	21° 50′	„ 11	—	—	—	80	234	401	568	728	869	990
	20° 35′	„ 18	—	—	—	99	255	424	590	745	882	998
	19° 01′	„ 25	—	—	4	124	285	452	616	767	898	1006
	17° 10′	Feb. 1	—	—	19	155	320	487	647	791	915	1015
	15° 4′	„ 8	—	—	45	193	360	525	680	818	934	1023
	12° 45′	„ 15	—	—	78	238	406	568	717	846	952	1030
	10° 16′	„ 22	—	—	123	289	456	614	755	875	971	1037
	7° 40′	Mar. 1	—	20	174	344	509	660	794	903	987	1041
SPRING	4° 58′	„ 8	—	63	234	404	564	709	833	932	1002	1042
	2° 14′ S	„ 15	—	123	298	467	621	757	871	957	1014	1041
	† 0° 32′ N	„ 22	30	196	370	532	679	805	906	980	1025	1038
	3° 17′	„ 29	186	281	444	599	736	852	941	1002	1033	1033
	5° 59′	Apr. 5	338	377	524	667	792	896	973	1021	1038	1025
	8° 36′	„ 12	482	482	603	733	846	938	1002	1037	1041	1014
	11° 5′	„ 19	617	608	683	798	898	976	1027	1050	1041	1002
	13° 26′	„ 26	743	732	763	860	946	1013	1050	1061	1040	990
	15° 36′	May 3	857	844	841	918	991	1045	1072	1069	1038	977
	17° 33′	„ 10	957	944	915	971	1031	1072	1088	1076	1034	964
	19° 16′	„ 17	1045	1029	984	1018	1065	1096	1102	1080	1029	952
	20° 43′	„ 24	1116	1100	1050	1058	1095	1115	1112	1083	1025	940
	21° 53′	„ 31	1175	1157	1103	1092	1118	1131	1122	1084	1021	930
SUMMER	22° 44′	June 7	1215	1196	1142	1115	1134	1142	1127	1085	1017	923
	23° 15′	„ 14	1239	1220	1165	1130	1143	1148	1130	1085	1014	918
	*23° 27′	„ 21	1249	1229	1173	1135	1148	1150	1130	1085	1013	915
	23° 18′	„ 28	1239	1222	1165	1130	1143	1148	1129	1084	1013	917
	22° 49′	July 5	1215	1197	1142	1115	1133	1139	1125	1083	1014	919
	22° 01′	„ 12	1176	1157	1104	1091	1115	1127	1116	1080	1015	925
	20° 54′	„ 19	1119	1102	1052	1057	1091	1111	1107	1076	1018	933
	19° 30′	„ 26	1049	1033	987	1017	1062	1091	1095	1072	1021	942
	17° 50′	Aug. 2	964	949	918	971	1027	1067	1081	1067	1025	953
	15° 56′	„ 9	865	852	845	918	988	1040	1064	1060	1027	965
	13° 50′	„ 16	756	744	770	861	945	1007	1044	1050	1029	977
	11° 32′	„ 23	633	624	691	801	898	972	1021	1040	1029	988
	9° 6′	„ 30	504	500	612	737	846	934	995	1027	1029	999
AUTUMN	6° 33′	Sept. 6	365	393	533	672	794	894	967	1011	1026	1008
	3° 54′	„ 13	217	297	456	606	738	851	936	994	1021	1017
	† 1° 12′ N	„ 20	68	212	382	541	683	805	903	972	1013	1023
	1° 32′ S	„ 27	—	138	312	477	628	759	868	950	1004	1027
	4° 15′	Oct. 4	—	77	246	414	571	713	832	926	992	1029
	6° 56′	„ 11	—	30	186	355	517	666	794	899	979	1027
	9° 32′	„ 18	—	1	135	300	466	620	757	872	963	1025
	12° 1′	„ 25	—	—	90	250	416	575	720	845	946	1021
	14° 21′	Nov. 1	—	—	54	205	370	533	684	818	930	1015
	16° 30′	„ 8	—	—	27	166	329	494	651	792	913	1008
	18° 26′	„ 15	—	—	8	132	293	460	621	768	896	1000
	20° 05′	„ 22	—	—	—	107	263	431	594	747	882	994
	21° 27′	„ 29	—	—	—	85	239	406	572	729	868	987
WINTER	22° 28′	Dec. 6	—	—	—	72	221	387	556	716	859	981
	23° 8′	„ 13	—	—	—	62	209	377	545	706	853	979
	*23° 26′	„ 20	—	—	—	58	204	371	540	702	851	977
	23° 21′	„ 27	—	—	—	59	207	373	543	705	852	979
	23° 7′	„ 31	—	—	—	62	211	378	547	709	855	981

* Solstice. † Equinox.

The table shows the year divided into fifty-two weeks with one day, namely, December 31, over. The weeks are grouped in fours and fives. The groups of five introduce the seasons of the Farmers' year, spring, summer, autumn, winter, and are so chosen that their middle weeks contain the solstices and the equinoxes. The first days of the seasons would be March 5, June 4, September 3, December 3 respectively. Each group of five with a group of four before and after forms a quarter of the "May-year" which is arranged in accordance with the sun's declination, the dates of commencement being February 5, May 7, August 6 and

CAMBRIDGE

Cambridge University Press
978-1-107-47547-2 - Manual of Meteorology: Volume II: Comparative Meteorology
Sir Napier Shaw
Excerpt
More information

Energy, in kilowatt-hours, which would be received, if there were no atmosphere, upon a hundred square metres of horizontal surface by direct radiation from the sun with a solar constant of 135 *kilowatts per square dekametre.*

Totals for the middle day of successive weeks of the year.

Multiply by ·86 to express the result in gramme calories per square centimetre.

SOUTHERN HEMISPHERE

0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	Week of May-year		Orbit factor
987	1084	1157	1202	1218	1210	1189	1218	1277	1296	I	9	·9832
990	1085	1153	1192	1202	1188	1160	1170	1227	1246		10	·9834
998	1087	1148	1179	1180	1157	1118	1106	1158	1177		11	·9839
1006	1087	1138	1161	1153	1119	1067	1027	1072	1089		12	·9846
1015	1085	1127	1139	1121	1075	1008	945	969	984		13	·9855
1023	1084	1114	1114	1081	1023	944	857	852	865	II	1	·9866
1030	1079	1098	1083	1040	967	872	767	721	733		2	·9879
1037	1072	1077	1050	992	907	799	676	581	590		3	·9895
1041	1064	1054	1014	944	846	725	587	454	440		4	·9911
1042	1052	1029	975	892	783	651	501	344	285		5	·9929
1041	1037	1000	934	840	720	576	419	248	128		6	·9948
1038	1019	971	891	786	656	506	340	166	—		7	·9968†
1033	1000	938	848	732	594	437	270	97	—		8	·9988
1025	979	906	805	679	535	374	207	45	—		9	1·0008
1014	957	872	761	628	478	316	151	7	—		10	1·0028
1002	934	838	720	581	425	263	104	—	—		11	1·0048
990	911	806	679	535	378	216	65	—	—		12	1·0067
977	888	776	643	494	335	176	36	—	—		13	1·0084
964	868	748	609	456	297	142	15	—	—	III	1	1·0101
952	848	722	579	424	265	113	3	—	—		2	1·0116
940	832	701	555	398	239	92	—	—	—		3	1·0130
930	817	683	535	377	219	74	—	—	—		4	1·0141
923	806	670	520	360	204	63	—	—	—		5	1·0151
918	799	662	510	351	194	57	—	—	—		6	1·0158
915	797	657	506	347	192	54	—	—	—		7	1·0164*
917	797	660	509	350	193	56	—	—	—		8	1·0167
919	803	667	516	358	201	62	—	—	—		9	1·0167
925	811	678	529	373	215	73	—	—	—		10	1·0166
933	824	694	548	392	234	88	—	—	—		11	1·0162
942	838	714	571	417	259	109	1	—	—		12	1·0157
953	857	737	599	447	289	135	12	—	—		13	1·0149
965	876	764	630	482	325	167	31	—	—	IV	1	1·0137
977	898	792	666	521	366	207	59	—	—		2	1·0125
988	919	824	703	564	412	251	95	—	—		3	1·0110
999	941	855	744	612	462	301	139	4	—		4	1·0094
1008	963	887	784	660	516	356	192	35	—		5	1·0077
1017	983	918	826	710	572	417	251	82	—		6	1·0059
1023	1002	949	869	761	632	482	319	146	—		7	1·0040†
1027	1019	980	911	814	694	551	393	223	86		8	1·0020
1029	1034	1008	952	867	756	622	473	313	240		9	1·0000
1027	1046	1034	991	918	818	695	556	416	393		10	·9980
1025	1057	1058	1027	967	879	768	643	535	541		11	·9960
1021	1065	1079	1061	1014	938	841	732	672	683		12	·9941
1015	1072	1098	1092	1058	995	911	821	803	815		13	·9922
1008	1076	1114	1121	1098	1048	979	907	923	938	I	1	·9905
1000	1077	1126	1145	1133	1096	1040	992	1031	1048		2	·9889
994	1080	1137	1165	1164	1137	1095	1072	1123	1141		3	·9874
987	1080	1145	1181	1189	1172	1141	1145	1200	1219		4	·9861
981	1080	1152	1193	1208	1199	1176	1199	1257	1276		5	·9851
979	1081	1156	1203	1220	1216	1200	1235	1295	1314		6	·9843
977	1081	1158	1207	1227	1224	1211	1251	1311	1331		7	·9837*
979	1083	1158	1207	1227	1223	1210	1247	1308	1328		8	·9833
981	1083	1158	1204	1223	1218	1202	1237	1296	1316		x	·9832

* Solstice. † Equinox.

November 5, these comply with the specification given in chapter III of vol. I. In the table the groups of four and five weeks are shown by spaces between the lines. Large spaces separate the quarters of the May-year, the smaller spaces the seasons, or quarters of the Farmers' year. The quarters of the present kalendar year are somewhat deranged, each one of them being in its turn a week late, that is to say, a quarter begins with Jan. 8, April 9, July 9, October 8. There is no great disadvantage about this so far as statistical meteorology is concerned; indeed it leads us to a kalendar adjusted to the duration of daylight.

Secondly, we give a table of the accepted mean values of the solar "constant" during the period 1912–24 as determined by Dr C. G. Abbot and his colleagues of the Smithsonian Institution of Washington.

Mean values of the "solar constant" 1912–20[1]
in kilowatts per square dekametre.

Mount Wilson		$kw/(10\ m)^2$	Hump Mountain		$kw/(10\ m)^2$
1912	May to September	135·6	1917	June to December	133·7
1913	July to November	132·7	1918	January to March	134·3
1914	June to October	136·4			
1915	June to October	136·0			
1916	June to October	135·6			
1917	July to October	136·5		**Calama**	
1918	June to October	135·7	1918	July to December	135·7
1919	June to September	135·9	1919	January to December	135·7
1920	July to September	134·6	1920	January to July	136·0

For the period 1918–24 we give the following provisional values of the solar constant for each month at the three stations Calama, Harqua Hala and Montesuma[2]. A definitive table for Montesuma (1921–30) is given in chap. x.

Year	$kw/(10\ m)^2$	Ja	F	Mr	Ap	My	J	Jy	Au	Se	Oc	No	De
		Thousandths of gramme calories per square centimetre per minute											
1918	135·4	Calama					1900 +	21	54	44	39	41	62
1919	135·8	43	49	41	53	40	55	54	53	39	53	53	50
1920	136·0	64	56	45	52	53	39	45	—	—	—	—	—
Means	1900 + 48	54	53	43	53	47	47	40	54	42	46	47	56 g. cal./1000
	130 + 5·8	6·2	6·1	5·4	6·1	5·7	5·7	5·2	6·2	5·4	5·6	5·7	6·3 $kw/(10\ m)^2$
1920	135·8	Harqua Hala								1900 +	43	52	48
1921	135·7	64	49	44	48	54	35	39	37	43	44	58	48
1922	134·1	41	47	30	24	28	20	12	20	05	19	15	30
1923	134·0	26	17	18	17	23	18	—	—	25	33	26	25
1924	134·0	24	18	13	12	20	16	23	26	23	34	34	—
Means	1900 + 30	39	33	26	25	31	22	25	28	24	35	37	38 g. cal./1000
	130 + 4·5	5·1	4·7	4·2	4·2	4·6	4·0	4·2	4·4	4·1	4·9	5·0	5·1 $kw/(10\ m)^2$
1920	135·6	Montesuma						1900 +	30	47	44	48	57
1921	135·7	55	56	49	44	43	39	47	35	53	46	50	52
1922	134·2	47	42	37	30	24	13	11	18	22	26	28	14
1923	134·0	30	12	12	12	16	18	26	31	34	30	31	23
1924	134·1	31	22	19	17	22	29	22	18	20	29	30	—
Means	1900 + 31	41	33	29	26	26	25	27	26	35	35	37	37 g. cal./1000
	130 + 4·6	5·3	4·7	4·5	4·2	4·2	4·2	4·3	4·2	4·9	4·9	5·0	5·0 $kw/(10\ m)^2$

Thirdly, since there is at least some reason to consider that the intensity of solar radiation which reaches the earth is dependent upon the activity of the sun's surface as indicated by the spots to be noticed upon it, we give a table of mean annual frequency of sunspots during the past 185 years, estimated according to a regular plan devised at Zürich by Professor Wolf and now continued regularly by Professor Wolfer.

The mean period of frequency of spots is 11·1 years and anything with a period approximating to 11 years or a multiple or sub-multiple thereof, may suggest a connexion with sunspots. The most recent and most effective relation that has come to the knowledge of the Meteorological Office is the direct relation between the sunspot-number and the variation of level of the water in Lake Victoria at Port Florence. The correlation in this case is + ·8.

[1] *Annals of the Astrophysical Observatory of the Smithsonian Institution*, vol. IV, p. 193. Washington, 1922. The values at Hump Mountain are of inferior weight.
[2] *Smithsonian Misc. Coll.*, vol. LXXVII, No. 3. Washington, 1925.

Table of sunspot-numbers[1], 1750–1934.

Years	0	1	2	3	4	5	6	7	8	9
	n	n	n	n	n	n	n	n	n	n
175–	83	48	48	31	12	10	10	32	48	54
176–	63	86	61	45	36	21	11	38	70	106
177–	101	82	66	35	31	7	20	92	154	126
178–	85	68	38	23	10	24	83	132	131	118
179–	90	67	60	47	41	21	16	6	4	7
180–	14	34	45	43	48	42	28	10	8	2
181–	0	1	5	12	14	35	46	41	30	24
182–	16	7	4	2	8	17	39	50	62	67
183–	71	48	28	8	13	57	122	138	103	86
184–	63	37	24	11	15	40	62	98	124	96
185–	66	65	54	39	21	7	4	23	55	94
186–	96	77	59	44	47	30	16	7	37	74
187–	139	111	102	66	45	17	11	12	3	6
188–	32	54	60	64	64	52	25	13	7	6
189–	7	36	73	85	78	64	42	26	27	12
190–	10	3	5	24	42	64	54	62	49	44
191–	19	6	4	1	10	47	57	104	81	64
192–	38	26	14	6	17	44	64	69	78	65
193–	36	21	11	6	9	—	—	—	—	—

TERRESTRIAL RADIATION

Finally, we quote in advance, as "Stefan's law," the formula for the heat emitted by radiation from a square centimetre of surface at temperature t in a perfectly transparent medium as σT^4, where T is the absolute temperature for which the tercentesimal temperature *tt* can be substituted with sufficient accuracy for meteorological work. The symbol σ represents a "constant" independent of the temperature but dependent upon the nature of the surface. It is called Stefan's constant[2]. "According to Professor Millikan, who has recently reviewed the literature of the subject, the most probable value of σ is $5{\cdot}72 \times 10^{-12}$" watts per square centimetre.

Radiation from a square dekametre of black earth at various temperatures, computed according to the formula $\Sigma = \sigma t^4$.

$\sigma = 5{\cdot}72 \times 10^{-9}$ kw per square dekametre $= 82 \times 10^{-12}$ g. cal. per square cm per minute

tt	0	1	2	3	4	5	6	7	8	9
					kilowatts per square dekametre					
26–	26·1	26·5	27·0	27·4	27·8	28·2	28·6	29·1	29·5	30·0
27–	30·4	30·9	31·3	31·8	32·2	32·7	33·2	33·7	34·2	34·7
28–	35·2	35·7	36·2	36·7	37·2	37·7	38·3	38·8	39·4	39·9
29–	40·5	41·0	41·6	42·2	42·7	43·3	43·9	44·5	45·1	45·7
30–	46·3	47·0	47·6	48·2	48·8	49·5	50·2	50·8	51·5	52·1

It is almost needless here to say that no material medium is perfectly transparent, the atmosphere certainly not, and from that fact arises the necessity of considering in some detail the subject of radiation before we can bring it into the quantitative explanation of meteorological phenomena.

[1] *Meteorological Glossary*, p. 245, H.M.S.O. 1916. The table has been extended by the addition of data for the years 1915–34 published in the *Astronomische Mitteilungen*, Zürich.

[2] *Meteorological Glossary*, s.v. Radiation. A more recent value (National Research Council Washington) is 5·709 for absolute temperature, equivalent to 5·717 for tercentesimal.

THE RELATION OF SOLAR AND TERRESTRIAL RADIATION

In the heading to this chapter we have given a short table in order to indicate a relation between the intensities of solar and terrestrial radiation. The figures are really hypothetical because they assume that the atmosphere which intervenes between the sun and earth and between the earth and free space is perfectly transparent both to the solar and terrestrial radiation. With that gratuitous assumption the table indicates the altitude at which the sun would have to be in order to compensate for the loss of heat by radiation from a horizontal surface of "black" earth. The final figure of the table indicates that a black surface at the temperature of about 402 tt would be in balance with a vertical sun.

We are bold enough to introduce this table with its assumption of a transparent atmosphere for the simple reason that it is precisely the part which the atmosphere plays in affecting the incoming and outgoing radiation which is a matter of chief interest for the science of meteorology.

Actual observations of the conditions of balance between incoming radiation and outgoing radiation must be included in the facts upon which any effective physical theory of atmospheric changes is to be built. In considering this subject, on account of the lack of perfect transparency of the atmosphere, we have to deal with radiation not only from the sun and the solid earth or the sea but also from the atmosphere itself which for this purpose is called "the sky." Not much progress has yet been made in the effective study of the relation of terrestrial radiation to the radiation from sun and sky. The subject is however coming gradually into our knowledge through the efforts of Anders Ångström, C. Dorno and W. H. Dines. During the years 1921 to 1927 the last-mentioned compared the loss of energy from a grass meadow with that received from the whole sky near the time of sunset. We quote a summary of some figures given by the author in a kalendar for 1925 based on the figures published in the *Meteorological Magazine*. They are arranged according to the quarters of the May-year (see pp. 4, 5).

Summary of inward long-wave radiation from the sky, and outward radiation from a grass field on cloudless days near sunset at Benson in 1924.

		On cloudless days near sunset. Kilowatts per square dekametre		Total daily income from sun and sky. Rothamsted
		Gain from sky	Loss from field	kw-hr/(10 m)²
First quarter	May 6 to Aug. 5	30	37	423
Second quarter	Aug. 6 to Nov. 4	28	35	210
Third quarter	Nov. 5 to Dec. 31 Jan. 1 to Feb. 4	24	31	57
Fourth quarter	Feb. 5 to May 5	25	33	212

It appears that whatever may be the time of the year, with clear sky about sunset, the earth is losing heat at the rate of 7 kilowatts per square dekametre.

Further details of the physical aspects of the behaviour of radiation are given in chapters IV and V of volume III.

CHAPTER II

LAND, WATER AND ICE. OROGRAPHIC FEATURES AND OTHER GEOPHYSICAL AGENCIES

Continental masses and unknown seas.

Asia	44,680,000 square kilometres	Europe ...	9,710,000 square kilometres
Africa	29,840,000 ,,	Australia ...	7,633,000 ,,
North America ...	20,018,000 ,,	[Greenland]	2,142,000 ,,
Central and South America ...	18,461,000 ,,	Antarctic (summer)	14,170,000 ,,
		[,, (winter)	about 45,000,000] ,,

Unknown Sea: Arctic 3,445,000 square kilometres, Antarctic 2,200,000 square kilometres

after W. S. Bruce, *The Scottish Geographical Magazine*, July 1906.

Area of land-surface 145,000,000, water-surface 367,000,000 square kilometres
Equatorial diameter ... 12,755 kilometres. Polar diameter 12,712 kilometres
Volume of the earth ... 1,082,000,000,000 cubic kilometres
Mass of the earth ... $5{\cdot}98 \times 10^{21}$ metric tons
Mass of the atmosphere $5{\cdot}34 \times 10^{21}$ grammes
Acceleration of polar gravity 983·21, equatorial 978·03, lat. 45° 980·62 cm/sec^2

At this stage of our inquiry we have no wish to enter into details, our aim is to give a general idea of the structure and circulation, as accurate as circumstances permit, but always capable of improvement in detail. We conceive that, of the several schools of meteorology, each will have its own set of basic maps and diagrams corresponding with those in this volume but on a scale which is quite beyond the capacity of its modest page. The basic maps can be improved as detailed maps of the several countries and the several oceans are developed. They can be used as a kind of note-book into which new information can be incorporated from time to time by superposition.

Furthermore, for adequate conception of the actual behaviour of the atmosphere, the idea of circulation is fundamental, and circulation is related either to the earth's axis, which is permanent, and in that sense meteorologically normal, or to some local axis which is meteorologically speaking transitory. Every portion of an isobaric line on the earth's surface has what mathematicians call a centre of curvature, and air which moves along it has an "instantaneous axis of rotation." We have therefore chosen for the ground-plan of the great majority of our maps hemispheres in pairs, Northern and Southern. A simple geometrical representation of a hemisphere upon a plane surface by projection is an insoluble problem and the scheme which we have used cannot be said technically to be a projection, or even a map; it is a diagram or working picture, in which meridians are radii drawn through the poles, and lines of latitude are concentric circles at distances proportional to the co-latitude, that is, the angular distance from the pole. There is accordingly much exaggeration of the distance between the consecutive meridians at the equator compared with the polar regions, represented by a ratio of $\pi : 2$. Wind-directions, as represented on these charts, are not "true" in the sense that applies to winds on Mercator's projection, that is to say, an East wind is not always represented by a line drawn from right to left nor a West wind by a line from left to right; indeed the line for each wind has every direction in turn according to the position, on the map, of the point to which it refers; but, taken with due regard to the meridians which all pass through the pole of the chart, a true idea of convergence or divergence of direction is obtained which is more effective for many purposes than the idea that the directions of winds of the same name are everywhere parallel.

An obvious disadvantage of our charts is that the plan of computing the direction and velocity of the geostrophic wind from the separation of consecutive isobars with the aid of a common geostrophic scale is not applicable on account of the difference of scale along parallels from that along meridians. In the first edition of this volume we indicated a method of meeting that difficulty by means of scales which give separately the components of velocity along parallels of latitude and along meridians respectively.

But our maps are unsuitable for the study of the circulation in the equatorial regions, partly on account of the distortion and partly because of the separation at the equator. For subjects which are related especially to these regions we have accordingly used a special map drawn on Mercator's projection and extending from 30° N to 30° S of the equator. The division is appropriate for the region so specified because, as we shall see, the general idea of the normal atmospheric motion in the upper air near the equator is a circulation from East to West, whereas for middle latitudes the circulation is from West to East.

OROGRAPHIC FEATURES

We shall begin our representation of the atmospheric structure and circulation with maps of the main orographic features of the two hemispheres (figs. 2*a* and 2*b*) which are arranged to show: (1) the coast-lines together with the summer and winter boundaries of sea-ice in the two hemispheres, (2) the contour of 200 metres, and (3) the contour of 2000 metres. The contour of 200 metres is chosen because the orographic features below that level offer comparatively little obstruction to atmospheric currents and the contour may thus be regarded as a sort of secondary coast-line in considering such questions as the travel of cyclonic depressions, whatever may prove to be the final result of the analysis of the phenomena which are connoted by that term. The reader may be interested to notice that in this sense there is an atmospheric coast-line for North Western Europe which runs from the Pyrenees to the Ural Mountains and which circumscribes the great plain of Northern Europe enclosing the Baltic Sea and leaving the Scandinavian Peninsula as a huge island.

Even that line is broken through by a gap in Western Russia and by a large area between the Northern coast of Russia and the basins of the Caspian Sea and the Sea of Aral. There is also a large area under 200 metres in Siberia East of the Ural Mountains. Other notable areas under that level are marked by the valleys of the Nile, the Niger, the Indus, the Ganges, the Chinese rivers, the Mississippi and Hudson Bay in the Northern Hemisphere, by the