improvement was noticed in the condition of June corn, although this crop suffered along river bottom lands. Rice, sugar cane, and all minor crops made satisfactory advancement.—*Edward H. Bowie.*

Utah.—A remarkably cool spell prevailed during the first decade. Freezing temperatures and heavy frosts occurred in the elevated valleys of the State on several mornings between the 2d and 9th, badly damaging potatoes and other tender vines, and slightly damaged corn, wheat, and alfalfa in places. Irrigation water became very short before the close of the month, but on the whole growing crops did fairly well.—*L. H. Murdoch.*

Virginia.—During the first half of the month fairly favorable weather prevailed over the State and crop growth was, in the main, satisfactory, but the latter half was quite droughty and vegetation suffered considerably, especially early corn, pastures, and tobacco. Opportunities for field work were almost uninterrupted, and at the close of the month all crops were clean. Hay making, thrashing and housing of wheat, and cutting and stacking of oats were vigorously prosecuted.—*Edward A. Evans.*

Washington.—Long drought broken by heavy rains beginning on 1st, and lasting three to six days, averting danger to and causing great improvement in crops. In parts of the eastern section it was the heaviest July rainfall known. With the exception of the first week it was a splendid month for haying. Fall wheat harvest progressed during the last week; the yield was fair to good. Oats were in need of rain. The potato crop promises to be excellent.—*S. N. Salisbury.*

West Virginia.—The weather conditions during the month were generally favorable for crop growth and also for harvesting. By the end of the first week wheat was mostly in shock and some was being thrashed, with light yield. Meadows continued to thicken and improve, so that haying was not in full progress until the last week, when hay was secured in good condition, with about half a crop. Oat harvest was in progress during the last week, with a good yield, and early potatoes were made, with a good crop. Corn made excellent growth during the month, and the prospects were for a fairly good crop. Some fall plowing was being done during the latter part of the month. Apples continued to fall during the month, and the prospects were for about half a crop; peaches and plums were scarce, but grapes were quite promising.—*E. C. Vose.*

Wisconsin.—Crops generally in a very promising condition, although frequent and heavy rains damaged grains and hay in most sections and delayed the harvest. Killing frosts occurred the first of the month in the extreme northern counties and considerable damage resulted; light frost occurred in the middle section, but no damage resulted. The first of the month was exceptionally cool and retarded the advancement of corn, but later it showed a gradual and thrifty growth. Rain was materially deficient the greater portion of the month in the northeast counties. Hail did material damage in some localities, especially in St. Croix County on the 22d.—*J. W. Schaeffer.*

Wyoming.—The weather was unseasonably cool during the first half of the month and retarded crop growth some, but was warm and favorable for good crop growth during the latter half. Precipitation was sufficient in most sections of the State, except parts of Big Horn County, where some crop failures resulted. At the end of the month haying was in general progress, and the second crop of alfalfa was being secured in several sections. Gardens and grain were backward, but doing well. Ranges had become generally dry, but stock was in good condition. Prospects for winter feed were poor in sections. As a whole the month was favorable for agricultural interests.—*W. S. Palmer.*

SPECIAL CONTRIBUTIONS.

STUDIES ON THE STATICS AND KINEMATICS OF THE ATMOSPHERE IN THE UNITED STATES.

No. VII. A CONTRIBUTION TO COSMICAL METEOROLOGY.

By Prof. FRANK H. BIGELOW, dated August 12, 1902.

GENERAL REMARKS.

I have already published the results of certain computations and discussions on the subject of the direct connections between the variations of the solar output of energy, and the corresponding synchronisms in the meteorological elements of the earth's atmosphere. These are in particular, Solar and Terrestrial Magnetism, Weather Bureau Bulletin No. 21, 1898, and Eclipse Meteorology and Allied Problems, Weather Bureau Bulletin I, 1902, which include the substance of other minor papers related to this subject. The purpose of these studies has been, (1) to establish the fact that a synchronous connection does exist between the solar and the terrestrial forces, and (2) to derive the operation of these periodic movements so as to ultimately lead meteorology to a scientific understanding of the terrestrial seasonal climatic changes, and to a true basis for forecasts of weather conditions, at least one year in advance.

The difficulty of reaching a correct solution of this problem is well understood by those who have worked upon it, to reside in the unsteadiness of the solar output itself, and the numerous subordinate transformations of the energy, through the radiation, the general and local cyclonic circulations, till it culminates in a season having certain characteristics. The material for the study consists in the variations of the pressures, temperatures, and vapor tensions at many stations in different portions of the earth, in the fluctuations of the terrestrial magnetic field, in the changes of the spectrum energy of the solar and the aqueous vapor curves, and in the variations of the sun spots, the prominences, and the solar faculæ. The magnitude of the task involved in handling this material is such as to limit the attempt to deal with it to a few institutions having these subjects specially in charge. Among them the United States Weather Bureau has been able to make some contributions from time to time.

SUMMARY OF THE DISCUSSION OF 1898.

On pages 121–130, Bulletin No. 21, is given a brief account of an extensive discussion of the data then at hand, and the result was such as to show that there is a marked synchronism between the solar and terrestrial variations of energy. Fig. 24 serves to recall this fact and it shows that in the sun-spot period, 1878–1893, there was a true synchronism in the variation of the sun-spot areas, the European magnetic force, which is the resultant of the two components measured on a horizontal plane, and the American meteorological system. The latter includes a variation of temperature at 25 stations in the northwestern portions of the United States, the pressure at 10 stations, the variable mean movements of the storms in latitude and longitude, and the movement of the tracks of the cold waves in latitude. Each of the two latter elements was derived from an exhaustive compilation of the coordinate positions of the cyclonic centers for the interval of fifteen years ending with 1893. It led me to the following summary:

The increase of solar magnetic intensity is synchronous with a diminution of temperature but with an increase of pressure, and this function persists throughout every phase of the research.

In spite of some irregularity, there is a distinct conformity in the general sweep of these curves, and also in the tendency to describe crests during the same years. Indeed, the occurrence of four subordinate crests in the 11-year period suggests strongly that a $2\frac{3}{4}$-year period is superposed upon the long sweep of that periodic curve. Apparently this minor period is the basis of these seasonal variations of the weather conditions of the United States more than anything else, so that in long-range forecasting this period must be very carefully considered.

It was for the purpose of carrying this subject one step further forward that the discussion of the data summarized in this present paper was undertaken. There has been considerable delay in completing the work on account of many other important duties.

It is evident that the terrestrial magnetic field affords the data which is most available for studying the fundamental periods in this solar-terrestrial synchronism. An exact quantitative computation for the several elements involves a very large amount of labor, and therefore it is important as an alternative to derive the periods by *methods which shall give reliable proportional variations* of the elements. The ideal treatment is to compute the total deflecting force of the magnetic field, by using the means of 24-hourly observations of the horizontal force, the declination, and the vertical force, taking out their daily component variations in rectangular coordinates

(dx, dy, dz,) and combining them into polar coordinates s, α, β.

The next simpler method is to omit the vertical component, as one is tempted to do in consequence of the unreliable action of the Lloyd's balance, and turn the horizontal components, dx, dy, into polar coordinates σ, β, on the horizontal plane. Since it has been proved by computation that the east-west component, dy, derived from variations of the declination, practically disappears, as it should do by theory, we may adopt the variations of the horizontal component, dx, along the magnetic meridians, as the best single component for computation. This is all the more satisfactory because the bifilar horizontal magnet is the most efficient instrument in use in the magnetic observatories, and is generally free from objectionable features in its operations. I have, therefore, in this discussion, adopted the variations of the horizontal force, as shown by the 24-hourly means, on the ground that they are proportional to the total variations of the magnetic field and quite free from instrumental errors.

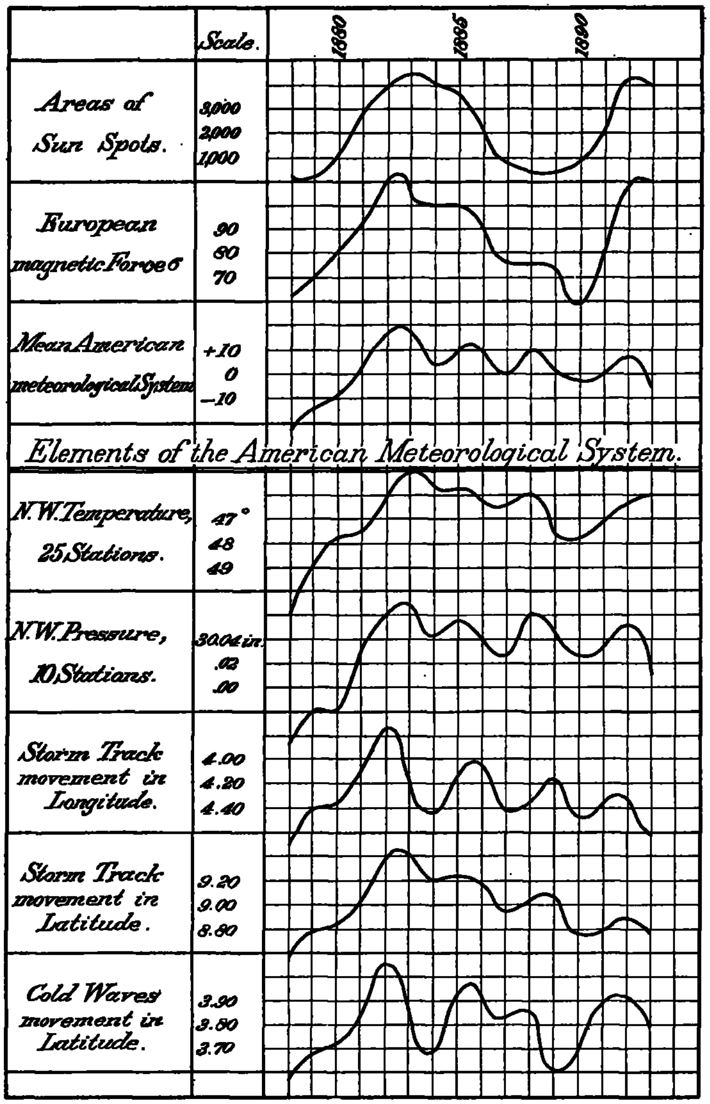

Fig. 24.

THE MAGNETIC OBSERVATIONS 1841–1899.

Accordingly, the magnetic horizontal force for the interval 1841–1899 has been submitted to a discussion, the result of which is summarized in this section. The synchronous action of the solar energy, as exhibited in the variation of the sun spots, the terrestrial aurora, the magnetic field, and several other phenomena, has been frequently developed, so that the general fact is admitted by all students, but it is now important to trace out this sympathetic movement in these cosmical forces more in detail, especially as they relate to the annual and seasonal variations in the earth's atmosphere. In the Proceedings of the Royal Society, volume 63, Mr. William Ellis, F. R. S., has exhibited this synchronism between Wolf's sun-spot numbers and the declination and horizontal force at the Greenwich Observatory for the interval 1841–1896. (Compare Bulletin I, 1902, page 105.) In his diagram not only do the curves present the same large sweeps, but also the minor variations appear simultaneously in the three curves. It is for the purpose of developing yet more distinctly these minor fluctuations that the compilation of the following magnetic observations was executed.

Instead of confining the study to a single observatory, it has been extended so as to practically include the entire earth, at least sufficiently to demonstrate that the variations are common to the whole terrestrial magnetic field. Thus, for different years we studied the records at the following stations:

1841–44. Toronto, St. Helena, Hobarton.[1]

1845. Greenwich, Toronto, Singapore, St. Helena, Cape of Good Hope, Hobarton.

1846–47. Toronto, St. Helena, Hobarton.

1848. Toronto, Greenwich, Hobarton.

1849–1870. Whatever was available, as Greenwich, Toronto, Madras, Batavia, Pavlosk, some of the data being unsatisfactory.

1871–77. Greenwich, Pavlosk.

1878–1885. Greenwich, Pavlosk, Vienna, Prague, Tiflis.

1886–1887. Los Angeles, Toronto, Greenwich, Paris, Pola, Prague, Pavlosk, Tiflis, Zi-ka-wei, Batavia.

1888. Greenwich, Prague, Pavlosk.

1889–90. Greenwich, Washington, Pavlosk.

1891. Greenwich, Prague, Pavlosk.

1892–99. Paris, Pola, Pavlosk.

By thus changing the stations it becomes impossible that the peculiar action of any set of instruments, should such exist, can impose a bias upon the final result. It seems to me that it makes no difference what three stations are chosen to represent the cosmical variation of the magnetic field, as indicated by the horizontal force which is proportional to the total force. Three stations are desirable in order to eliminate the local impulses of the field, and if they had been available I should have used the same three stations throughout, all reduced to the C. G. S. system of units, for the sake of having rigorous quantitative results. The data of this paper limit it to showing relative synchronisms, but these are quite sufficient for our purposes in the present stage of meteorology.

The horizontal force, as given by the means of twenty-four successive hourly ordinates, or by a smaller number of selected hours in some cases, was considered, and the *daily variation from the normal horizontal force* was computed either numerically or graphically. (Compare the methods of Bulletins Nos. 2 and 21.) In some of the years the normal force was found by drawing a mean line through the monthly trace of the curve, as plotted from the daily means; in other years the daily variation was computed from the numerical data contained in the published reports. In all years from 1841–99 the horizontal trace was graphically transferred to curves and distributed in the period of 26.68 days, whose epoch is June 13.72, 1887; the exact adopted period was 26.67928 days, as given in the January Ephemeris. (See Bulletin No. 21, page 120.) Therefore throughout this interval the several curves, generally three in number, are plotted on the sheets, so that the irregularities as well as the agreements are open to inspection. On examining this long series of curves in succession, it is evident that a decided change occurs in the amplitudes of the variable curve with regard to the normal base line which was superposed upon each of them. In some years the curves are flat and

[1] Now called Hobart Town, or Hobart, Tasmania.

quiet, so that the ordinates are small, and the curves are free from violent or spasmodic impulses. In other years, on the contrary, the curves sway about roughly and are much disturbed, great irregularities being superposed upon them. My procedure was to measure, at least proportionally, the area which is inclosed between the variable curve and the average base line and to integrate these areas in the 26.68-day period, the 11-year period, and throughout the interval 1841–99. This was accomplished by measuring these ordinates from day to day, taking the mean of those stations selected for the given day, usually three in number, and transferring these mean ordinates with their plus and minus signs to the Ephemeris Tables. For by taking the ordinates from day to day, that is to say, at frequent intervals along the curve, their *sum is proportional to the area developed between the bounding curve and the base line.* If the actual area had been read off by means of a planimeter, the relative variation between different epochs would have been the same. These relative numbers were transferred to tables, showing the direct type curves in black ink and the inverse type curves in red ink, which can not be reproduced in this connection. These figures were now summed together by the year, the direct type and the inverse type separately, but no account is given here of this summation. Also the figures were summed across each period, without regard to their signs, so that the total divergence of amplitude might appear as a sort of integral. In each year there are thirteen or fourteen periods, but when the successive years are placed in the 11-year period, and five or six of these in the final summary, then the mean dates of the total ephemeris can be restored by simply applying 26.68 days to the mean of the January dates, that is to January 15.44, as on page 106, of Bulletin No. 21.

Table 22, "Total variations of the horizontal force for the earth generally, arranged in 26.68-day periods," contains an exhibit of these integral sums of the included areas for each 26-day period within the limits of the computation; the sums are also given for each year for five successive 11-year cycles, and for the general mean; and, finally, the differences between the annual sums for each successive year and also the average

TABLE 22.—*Total variations of the horizontal magnetic force for the earth generally, arranged in 26.68-day periods.*

11-YEAR PERIOD, 1841-1851.

26-day period.	1841.	1842.	1843.	1844.	1845.	1846.	1847.	1848.	1849.	1850.	1851.	Means.
1	171	142	130	155	177	101	193	282	152	204	141	168
2	170	181	159	153	139	100	200	272	160	225	112	169
3	204	168	130	151	111	238	289	277	170	137	104	180
4	254	165	126	134	102	231	220	223	362	147	153	193
5	226	209	178	135	122	229	196	161	170	200	164	181
6	134	175	109	96	142	155	137	199	114	261	155	153
7	134	260	75	132	82	110	155	105	130	317	140	149
8	169	93	138	118	79	127	130	216	144	217	162	145
9	143	89	119	113	85	155	164	196	129	178	279	150
10	145	160	96	182	99	220	296	120	161	80	250	164
11	219	136	84	242	108	208	231	85	188	160	187	168
12	197	176	58	147	97	139	257	152	121	183	159	153
13	211	240	68	142	62	131	320	106	182	111	191	160
14	239	107	130	......	126	95	......	76	206	184	......	160
Sums	2,516	2,301	1,600	1,900	1,631	2,239	2,788	2,470	2,389	2,604	2,197	2,293
Differences	......	−215	−701	+300	−269	+608	+549	−318	−81	+215	−407	333

11-YEAR PERIOD, 1852-1862.

26-day period.	1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.	Means.
1	225	118	175	86	183	105	281	162	174	281	231	183
2	248	138	134	124	134	117	186	239	224	169	182	172
3	146	138	179	126	157	125	241	150	269	208	199	176
4	258	182	170	146	142	171	262	206	273	207	194	196
5	189	168	116	107	151	188	324	225	161	131	144	173
6	153	162	100	81	128	90	190	139	168	233	171	147
7	128	139	126	90	95	125	177	225	272	202	194	161
8	133	118	91	141	111	114	163	150	305	176	208	155
9	107	163	125	112	163	192	134	271	230	212	169	171
10	154	189	127	100	165	143	194	221	168	267	253	180
11	137	122	79	131	124	213	199	379	115	187	281	179
12	152	161	104	106	92	231	205	168	148	289	166	166
13	167	148	72	93	124	282	196	330	256	259	187	192
14	129	117	......	151	168	......	174	151	......	240	170	179
Sums	2,315	2,015	1,558	1,594	1,937	2,096	2,926	3,016	2,763	3,061	2,749	2,430
Differences	+118	−300	−457	+36	+343	+159	+830	+90	−253	+298	−312	291

TABLE NO. 22.—Continued.

11-YEAR PERIOD, 1863-1873.

26-day period.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	Means.
1	163	120	89	135	85	80	183	166	120	149	137	130
2	140	99	121	195	80	117	82	204	196	282	181	150
3	159	117	94	96	80	159	91	184	165	167	118	130
4	128	102	85	105	93	129	143	201	161	210	144	136
5	116	103	78	68	115	139	217	272	137	175	126	141
6	113	121	147	84	73	111	150	209	222	202	139	143
7	99	105	98	149	125	94	111	173	151	227	95	130
8	122	151	156	140	67	90	129	250	144	196	101	141
9	133	138	113	135	69	90	159	230	160	215	125	142
10	131	133	89	150	118	159	150	290	141	193	107	151
11	115	176	126	124	58	178	99	319	111	225	130	151
12	123	146	122	66	65	128	131	263	163	228	142	143
13	66	93	69	98	71	101	189	251	100	144	120	118
14	......	95	171	98	......	98	281	......	186	199	......	177
Sums	1,608	1,699	1,558	1,643	1,099	1,673	2,123	3,012	2,157	2,762	1,665	1,983
Differences	−1,141	+91	−141	+85	−544	+574	+450	+889	−855	+605	−1,097	616

11-YEAR PERIOD, 1874-1884.

26-day period.	1874.	1875.	1876.	1877.	1878.	1879.	1880.	1881.	1882.	1883.	1884.	Means.
1	120	108	114	112	172	160	134	302	224	230	235	174
2	239	212	146	82	146	97	194	251	165	241	223	181
3	199	125	109	95	151	127	135	171	144	283	196	158
4	202	132	83	64	141	120	171	182	421	223	233	179
5	152	114	93	108	152	162	215	145	215	210	251	163
6	159	128	57	107	191	187	173	235	264	192	203	172
7	106	97	85	148	168	161	160	220	256	224	296	175
8	159	82	73	113	135	177	310	187	295	197	184	174
9	115	75	79	118	103	156	250	157	183	356	255	168
10	112	139	92	90	141	204	221	264	344	194	242	186
11	184	100	105	92	116	159	278	149	281	229	218	174
12	132	105	110	98	187	182	176	238	486	287	264	206
13	115	91	120	128	176	194	219	219	290	186	267	182
14	97	79	......	70	180	172	......	160	141	......	244	157
Sums	2,091	1,587	1,266	1,425	2,165	2,257	2,636	2,880	3,809	3,052	3,311	2,449
Differences	+426	−504	−321	+159	+740	+92	+379	+244	+929	−757	+259	437

11-YEAR PERIOD, 1885-1895.

26-day period.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	Means.
1	265	136	161	177	128	101	158	261	279	143	182	181
2	223	224	162	160	153	116	174	286	200	389	156	204
3	194	276	136	222	143	126	164	298	220	205	186	197
4	197	225	172	218	147	102	182	409	207	254	191	210
5	324	198	163	223	131	94	287	278	209	210	200	211
6	183	156	130	161	130	102	139	301	223	189	156	170
7	273	174	172	140	137	115	140	330	230	147	181	185
8	141	207	178	149	138	123	157	245	302	250	232	193
9	177	263	190	157	189	115	178	211	212	295	191	198
10	247	272	208	171	184	131	302	174	229	269	170	214
11	171	242	179	184	225	164	162	255	312	128	247	206
12	201	209	149	205	251	140	191	179	191	295	256	209
13	221	127	197	139	136	117	214	231	247	176	164	179
14	257	......	194	127	......	110	178	150	......	135	216	188
Sums	3,074	2,709	2,391	2,533	2,092	1,656	2,626	3,608	3,061	3,135	2,728	2,745
Differences	−237	−365	−318	+142	−441	−436	+970	+982	−547	+74	−407	447

1896-1899.

26-day period.	1896.	1897.	1898.	1899.	Means.	Average for the whole interval, 1841-1899.
1	152	165	152	172	161	166
2	220	169	179	151	180	176
3	177	169	260	249	214	176
4	254	188	178	190	203	186
5	273	203	153	157	197	178
6	194	195	190	166	186	162
7	205	203	121	134	191	165
8	185	144	128	109	142	158
9	209	100	208	103	155	164
10	229	115	169	132	161	176
11	227	124	190	145	172	175
12	248	113	148	109	155	172
13	261	178	166	102	177	168
14	....	218	127	....	173	172
Sums	2,834	2,285	2,369	1,920	2,467	....
Differences	+106	−549	+84	−449	....	....

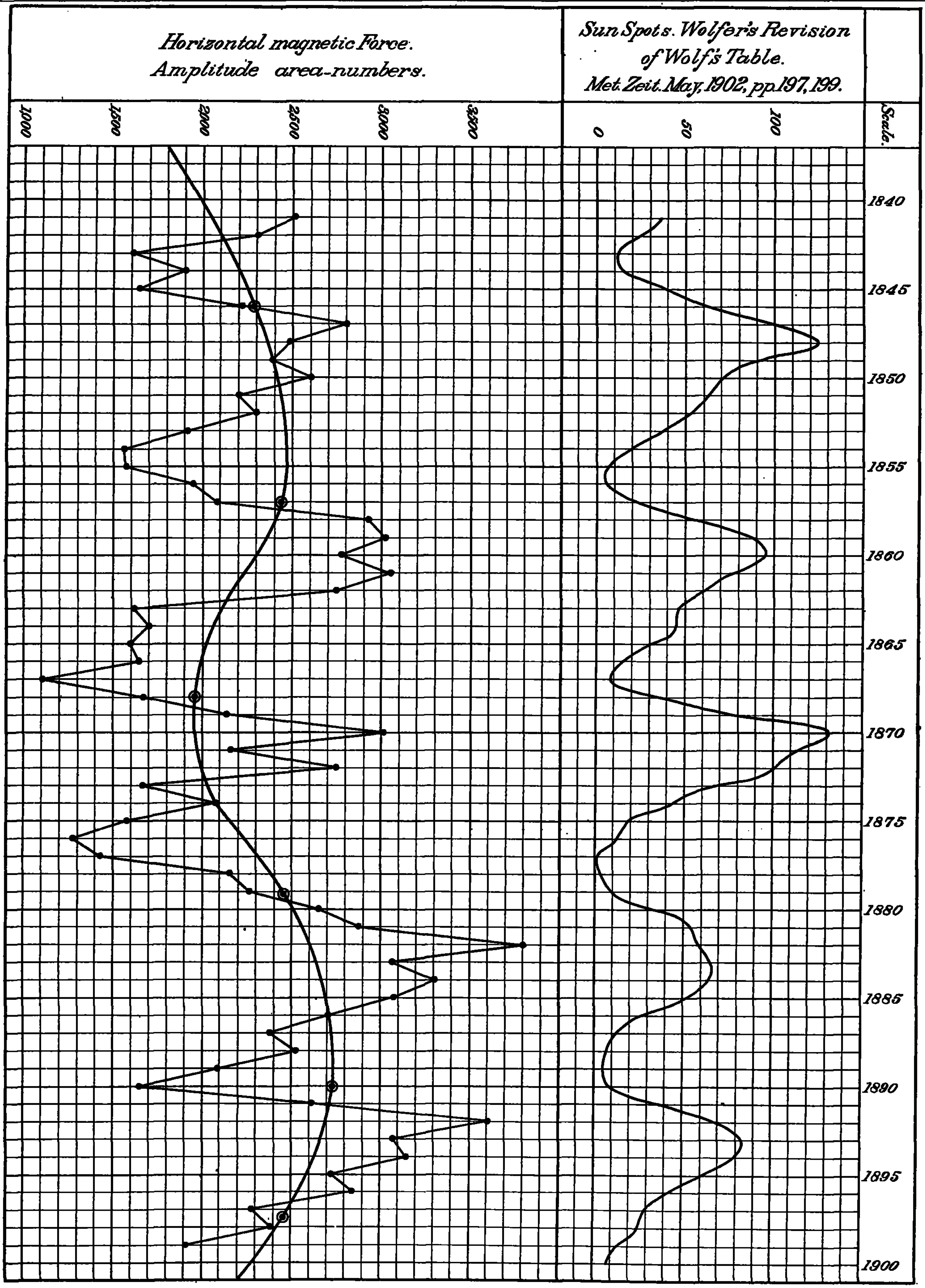

FIG. 25.—Variation of the sun-spot numbers and the amplitude area numbers.

annual variation. In taking the mean of each bottom row of periods, the mean of the numbers visible, usually 7 or 8, was increased proportionally to 11, in order to make it comparable with the other 13 periods; the action of the ephemeris causes the periodic skip in the 14th period. There was one other place in which an arbitrary change was introduced, namely, wherever the disturbance in the negative direction, at a few of the largest perturbations, exceeded —0.00040 C. G. S. units, the disturbance ordinate was computed at this value. There are only a few excessive disturbances of the horizontal force above this limit, and I did not wish to distort the average annual numbers with these great abnormalities.

The revised Wolf's table of the sun-spot numbers, by Prof. A. Wolfer, Meteorologische Zeitschrift, May 1902, page 197,[2] has been used to give the curve of the sun-spot variations, it being unimportant for this discussion whether the observed or smoothed numbers are employed.

The result of this computation, "Variation of the sun-spot numbers and the amplitude area numbers," is shown in fig. 25, the figures of Table 22 being transferred thereto. The annual sums were plotted so as to give the horizontal force curve, and the mean sums for the successive 11-year periods were plotted for the mean curve. This curve brings out three variations with extraordinary clearness: (1) The 35-year period, with maxima in 1855 and 1890, a minimum at about 1868, another probable minimum at about 1833, and one more at about 1903. After this exhibit there can be little doubt of the existence of this long period variation, discussed by Lockyer and others, and it is certain that a continuation of this method of computation will eventually fix the characteristics of this period with exactness. The fall from maximum to minimum seems to occupy thirteen years, and the rise from minimum to maximum requires a longer time, probably twenty-two years. (2) The 11-year period is seen to be in exact synchronism throughout the interval 1841–1899 with the sun spots and the horizontal force taking the curve as a whole, but there are superposed upon it a series of abrupt minor variations, which, as stated above, it is chiefly desirable to obtain for comparison with our meteorological data. (3) These subordinate crests of energy indicate that in the rise and fall of the 11-year period there is a series of spasmodic impulses, generally one in ascending the curve and two in descending, which, added to the maximum crest itself, makes four minor crests to be superposed upon the mean 11-year curve, as mentioned in the opening paragraphs, and shown in fig. 24. In the ascending branch the successive annual changes are not equal to the mean value, and this branch must evidently be considered as produced by a secondary system of crests, even though the 11-year line is not deeply indented. The discussion of this $2\frac{3}{4}$-year period will be resumed in a later section of this paper.

If the mean values of the fourteen periods as collected in the 11-year periods and indicated in Table 22 be plotted successively, the result is as shown in fig. 26. We find that there is a distinct semiannual period in the horizontal force areas, with maxima at March 22 and September 22, and minima at June 22 and December 22, thus indicating that it depends upon the orbital relations of the earth to the sun. But, furthermore, it is noted that the same 35-year period is indicated within this semiannual period, since there is a distinct minimum in the period 1874–1884, and maxima in the 1852–1862 and 1896–1900 periods, as measured by their amplitudes. Also, there is, apparently, a tendency for the spring maximum to surpass the autumn maximum, whenever they are strongest within the 35-year period. We have here indicated a field of research of importance in mechanical astronomy, since it implies that another force besides simple Newtonion gravitation is binding the sun and the earth together. It becomes an interesting problem to discover whether these magnetic forces are capable of fulfilling the outstanding theoretical requirements involved in the orbital perturbations of the earth and the other planets. It becomes, also, a further argument, in addition to those presented in my bulletins, Solar and Terres-

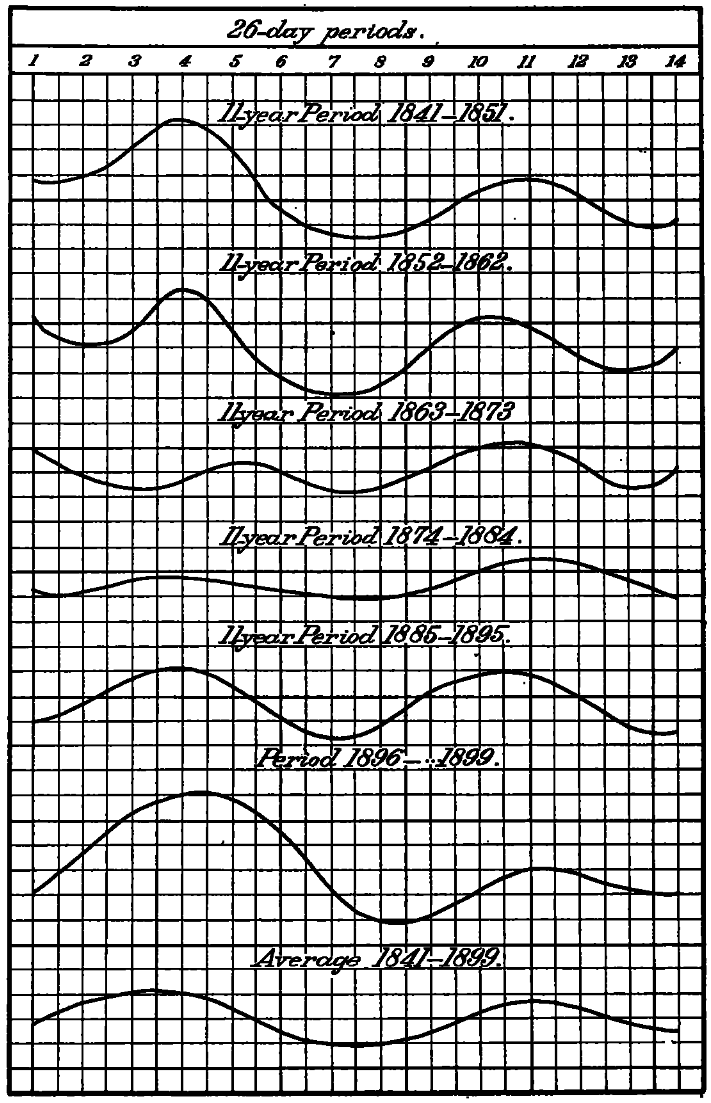

FIG. 26.—Semiannual period in the horizontal force of the terrestrial magnetic field, arranged for six successive 11-year periods.

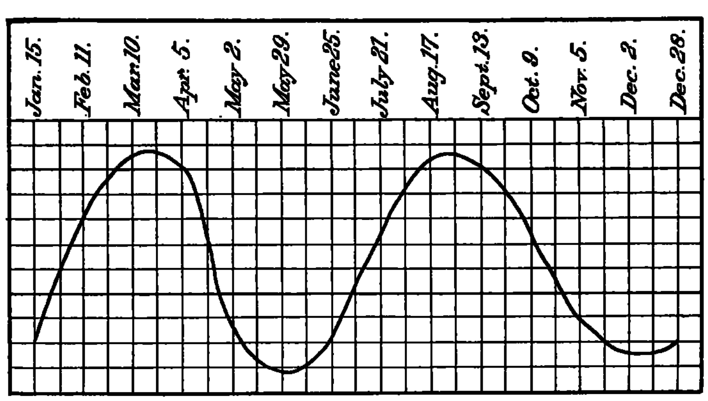

FIG. 27.

[2] This table had been originally communicated to the Monthly Weather Review and the proof sheets sent to Professor Wolfer for revision, so that as published in the Monthly Weather Review, April, 1902, page 175, the figures have the full authority of Professor Wolfer, and it is believed no typographical error exists therein.—ED.

trial Magnetism, and Eclipse Meteorology and Allied Problems, to show that the sun is a great magnetised sphere, in whose external field the earth is immersed. On fig. 27 I have copied Chart No. 19, page 106, of Bulletin No. 21, which shows the curve of the frequency of the direct type in the 26.68-day period. Its crests regularly precede those in the semiannual orbital period by a small interval, and there must be a physical reason for this divergence, such as explained in my other papers.

COMPARISON OF THE VARIATIONS OF THE SOLAR PROMINENCES WITH THOSE OF THE TERRESTRIAL HORIZONTAL MAGNETIC FORCE FOR THE INTERVAL 1874–1900.

It is well understood that the variations of the sun-spot frequency constitute only one of the manifestations of the changes in the output of the solar energy; the frequency of the hydrogen prominences, or of the faculæ, and of the extensions of the solar corona are other forms of the display of this variable force. Indeed, there is reason to believe that the sun spots are a somewhat sluggish type of the variable impulses, although the first to be studied, on account of the ease with which the spots are observed. Since scientific processes of observation have improved of late years, it has become possible to measure the frequency of the prominences and of the faculæ with precision, so that a continuous record is now being made of these types of solar energy. The prominences have been observed by Tacchini since 1873 and the faculæ by Hale and others for several years, so that it is now possible to add to the sun-spot record that of each of these two phenomena. The prominences are distributed all over the surface of the sun, and the relative frequency has been determined in 10-degree zones between latitudes $\pm 90°$ annually since 1873, so that we possess a prominence curve of relative frequency extending through more than two 11-year cycles. Through the courtesy of Sir Norman Lockyer, of the Solar Physics Observatory, South Kensington, London, I have had an opportunity to see some advance copies of different sets of curves of a very valuable character prepared by him for a paper published by the Royal Society, in which this subject is discussed, It is gratifying to note that his work confirms my curves of 1898 and is in agreement with those presented in this paper. I reproduce the Lockyer-Tacchini prominence curve, which represents the mean frequency ni all latitudes for the years 1874–1900. It is found at the head of fig. 28. It shows a large curvature synchronous with the sun-spot frequency in the 11-year cycle, and also a series of minor crests of a characteristic nature. Underneath this curve is placed the series of minor variations which were found in the horizontal magnetic force, as shown in fig. 25, after the 11-year cycle curve has been eliminated. The remarkable synchronism between these curves can not escape recognition, except after the year 1894, when an extra minor crest is developed in the horizontal force. If these two curves are compared with the 15-year systems exhibited on fig. 24, it is evident that my paper of 1898 had detected the same synchronism, not only throughout the curve of sun-spot frequency, but also throughout the whole European magnetic field and the entire American meteorological system.

THE VARIATIONS OF ATMOSPHERIC PRESSURE OVER THE ENTIRE EARTH.

In the course of my studies into this set of phenomena, including the solar and terrestrial magnetic fields and the meteorological elements, it became evident that in cosmical problems we should be compelled to deal with the variations of small quantities in meteorology, such as a few hundredths of an inch of pressure and a few degrees of temperature. It was, therefore, necessary to carefully exclude all possible sources of error due to the imperfect methods of observation and reduction, in order that variations arising from such causes might not be falsely attributed to cosmical forces. The result of such a discussion of the barometric pressures

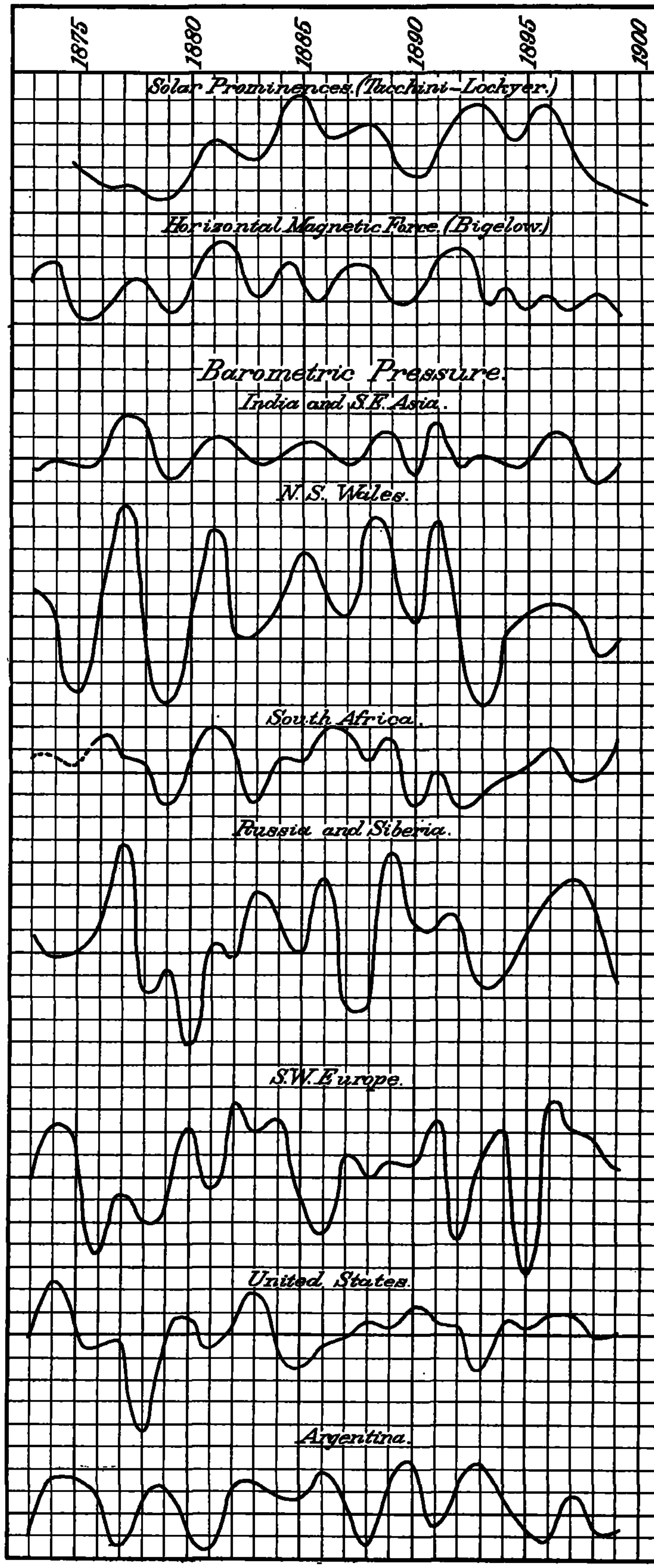

FIG. 28.—Comparison of the solar prominence variations with those of the terrestrial horizontal magnetic force and the atmospheric pressures over the entire earth.

for the United States will be found in Report of the Chief of the United States Weather Bureau for 1901, Volume II. A similar rediscussion of the temperature and the vapor tension will be executed as soon as practicable. It is important that comparable rigorously homogeneous systems should be prepared by other weather services which possess continuous long series of records of the meteorological elements. Pending the preparation of such revised systems, I have collected together a considerable number of sets or series of barometric pressures, taken in different parts of the earth, and have reduced them to a homogeneous basis, as well as I could, from a study of the published data. There are still annoying discontinuities at many stations, due to changes in the elevations of the barometers. It is also probable that the instrumental errors and the methods of reduction employed still need to be thoroughly examined.

Table 23, "The variations of the annual atmospheric pressure in many districts of the earth," serves to indicate, at least approximately, the relations of the annual barometric pressure variations to the changes in the solar output. It contains a summary of the results in the several countries where long series of barometric observations exist. It is arranged in an order which will bring out a remarkable feature of the pressure variations, as will be briefly indicated. The table gives the mean data for comparatively large districts; it is divided into groups and the mean pressures for these groups are transferred to fig. 28, which has been already mentioned. The following catalogue shows the stations that were employed in the discussion:

Northeast China.—Zi-ka-wei, Pekin, Vladivostok.
Japan.—Tokio, Nagasaki, Hieroshima, Osaka, Kioto.
North India.—Leh, Murree, Simla.
Central India.—Darjeeling, Lahore, Lucknow, Calcutta.
South India.—Pachmari, Bangalore, Nagpur, Bombay, Madras.
Batavia and Mauritius.
North New South Wales.—Albury, Bathurst, Deniliquin.
South New South Wales.—Goulburn, Newcastle, Sidney.
Kimberley.—Kimberley, Bloemfontein.
Inland Cape Colony.—Grahamtown, Lovedale, Aliwal North.
Coast Cape Colony.—Cape Town, Port Elizabeth, East London, Mossel Bay.
North Russia.—Archangel, St. Petersburg.
East Russia.—Moscow, Katharinenburg.
Russia and Southwestern Siberia.—Odessa, Tiflis, Baku.
Central Siberia.—Tomsk, Barnaul, Irkutsk.
France.—Paris.
Spain.—Madrid, Lisbon, San Fernando, Coimbra.
South Europe.—Pola, Budapest, Kalocsa, O'Gyalla, Vienna.
United States.—Pacific coast States, 20 stations; northern Plateau, 33 stations; southern Plateau, 19 stations; Lake region, 31 stations; west Gulf States, 41 stations; North Atlantic States; 26 stations; South Atlantic States, 32 stations; total number of United States stations, 202.
North Argentina.—Villa Formosa, Corrientes, Salta, Tucuman, Santiago, Goya, Hernandarias.
Central Argentina.—Cordoba, San Juan, Parana, Rosario, Carcaraña, Estancia San Juan, Buenos Ayres, Chacra de Matanzas, Bahia Blanca, Colonia Chabut.

In all cases the mean annual pressures were extracted from the observatory reports; these were reduced to the same elevation of the barometer, usually that for 1899, and all known corrections were applied. The mean for the homogeneous series was computed and then the variation of each year from this mean, the result being always changed, if necessary, into units of 0.001 inch in the English system. These annual variations were plotted as curves on sheets for the several countries, so that the several districts could be studied for their characteristic types. The stations were finally grouped as indicated in the the catalogue, and the larger district means, including about all the region having the same type of curve, were transferred to fig 28. It was very interesting to study these local curves, and to note that the same pressure variations in fact prevail over very large districts of the earth, though varying from one region to another. The variations were also transferred to charts of the earth, one for each year, and it was found that while there is an irregularity from year to year, it was possible to discover some very suggestive features. I regret that these charts can not be reproduced in this connection. Some years

TABLE NO. 23.—*The variations of the annual mean atmospheric pressures in many districts of the earth, in units of 0.001 inch.*

Stations.	1873.	1874.	1875.	1876.	1877.	1878.	1879.	1880.	1881.	1882.	1883.	1884.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.
Northeast China	− 8	− 8	+ 4	−16	+12	+32	−20	−32	− 4	+24	+24	+12	+24	+20	− 4	+ 4	+24	− 8	+ 4	− 4	+ 4	+12	−12	− 4	+24	−12	−12
Japan	0	+ 8	+ 4	0	+ 4	+12	−12	+ 4	+ 8	+12	+ 8	+ 4	+ 8	+16	− 8	−12	0	−24	+ 8	− 8	+ 8	+16	− 8	+12	+16	− 8	− 8
North India	.....	.....	+ 6	− 1	+ 7	+18	− 9	− 3	+11	−13	−16	+ 1	+ 3	− 5	− 3	+ 7	+13	− 9	+20	+ 6	−14	−10	+13	+18	+ 7	− 1	+14
Central India	.....	.....	− 8	− 2	+35	+16	− 6	0	+ 3	− 9	− 4	+12	+16	+ 7	− 3	+ 8	+ 9	−11	+16	+24	+ 6	− 8	+ 3	+ 5	− 1	−16	− 3
South India	.....	.....	−10	− 8	+31	− 6	−14	0	+ 7	− 9	− 5	+11	+20	− 1	+ 2	+19	+ 8	− 3	+17	− 9	− 6	−10	+ 2	+ 5	− 7	−15	+12
Batavia	− 4	+ 4	− 8	+ 8	+43	+ 4	−20	+ 8	+16	0	−16	−24	−20	− 8	− 8	−20	+12	+ 4	+24	−12	− 4	+ 4	0	+20	+ 8	−12	+12
Mauritius	0	− 6	− 3	+ 8	+ 7	+ 3	+16	+24	+22	+16	− 7	−12	0	+ 8	+12	+12	+17	+ 2	+14	−16	+10	−22	−13	+14	0	−13	.....
Means	− 3	0	− 2	− 2	+20	+11	− 9	0	+ 9	+ 3	− 2	+ 1	+ 7	+ 5	− 2	+ 3	+12	− 7	+15	− 4	+ 1	− 3	− 1	+10	+ 7	−11	− 2
North New South Wales	+17	+ 9	−32	− 1	+55	−13	−39	−21	+46	− 3	−12	− 4	+12	+15	0	+42	+26	− 1	+54	− 6	−36	− 9	+ 7	+ 7	+ 5	−21	.....
South New South Wales	+ 7	− 2	−38	− 7	+40	−35	−37	− 4	+31	−18	− 5	+ 5	+43	+11	− 2	+44	+30	− 7	+27	−23	−47	− 3	− 3	− 2	+ 1	−13	.....
Means	+12	+ 4	−35	− 4	+50	−24	−38	−13	+39	−11	− 9	+ 1	+28	+13	− 1	+43	+28	− 4	+41	−15	−42	− 6	+ 2	+ 3	+ 3	−17	.....
Kimberly	.....	.....	.....	+ 5	− 2	+ 1	−25	+ 2	+16	+10	−14	− 4	+11	+38	+12	+34	+ 7	−23	−14	−15	− 3	− 5	+ 3	+12	− 4	− 9	+ 4
Inland Cape Colony	.....	.....	.....	+14	+ 9	+ 5	−16	− 7	+25	+17	− 5	+ 5	− 8	+11	+29	+ 4	+27	− 5	+ 3	−11	−11	+ 2	− 3	+ 3	−11	− 2	+19
Coast Cape Colony	.....	.....	.....	+30	+ 8	+ 4	− 3	+17	+18	+ 4	−26	+25	+17	+11	+14	−18	+ 2	−15	+ 5	−24	−13	− 2	+ 3	+15	+ 5	+ 2	+18
Means	.....	.....	.....	+16	+ 5	+ 3	−15	+ 4	+20	+10	−15	+ 9	+ 7	+20	+18	+ 7	+12	−14	− 2	−17	− 9	− 2	+ 1	+10	− 3	− 3	+14
North Russia	.....	−24	+55	+39	+35	−75	+20	−71	+16	+24	+43	+55	+ 4	+55	−35	− 8	+79	+47	+20	− 8	−47	−16	+24	+59	+63	+20	−43
East Russia	.....	−20	−12	+ 8	+63	−16	−12	−67	− 4	−32	+32	−12	−20	+24	−47	−55	+51	+20	0	+36	−16	− 8	−12	+36	+39	+16	−24
Southwest Siberia	.....	+28	−20	+ 8	+32	−24	−12	− 8	+ 8	+16	+20	+20	+ 4	+16	+ 8	−16	+ 8	+28	+36	−12	−16	+12	−24	+12	+ 4	+24	−20
Central Siberia	.....	0	−12	−24	+67	+40	−32	−16	− 4	−12	+ 8	0	+ 8	+28	−32	−24	+43	−39	−20	+43	+16	−20	+20	− 8	+24	− 4	+24
Means	.....	− 3	+ 3	+ 8	+49	−19	− 9	−41	+ 4	− 1	+26	+16	− 1	+31	−27	−26	+45	+14	+ 9	+15	−16	− 8	+ 2	+25	+33	+14	−16
Paris	0	+39	+24	−43	−28	−24	−12	+20	0	+ 8	+20	+35	+12	−43	+39	0	+12	+16	+24	−32	+20	+16	−43	+51	+20	+32	.....
Spain	−12	+20	+12	−28	+16	0	−12	+16	−32	+55	+32	+ 4	−32	−20	−28	− 8	+20	−16	+12	−39	− 4	+20	−47	+35	+24	0	− 8
South Europe	+12	+12	+ 4	−24	−12	−35	−28	+32	+16	+32	+12	+39	−12	−16	+20	+12	−12	+16	+35	−16	+12	+28	−43	+16	+16	+12	+16
Means	0	+24	+13	−32	− 8	−20	−17	+23	− 5	+32	+21	+26	−11	−26	+10	+ 1	+ 7	+ 5	+25	−29	+ 9	+21	−44	+34	+20	+15	+ 4
Pacific coast	+15	+ 3	+22	0	−12	−31	− 4	+19	− 1	+ 7	+16	−27	−15	− 2	+ 1	−16	−15	+16	+ 3	+ 6	+ 9	+ 8	+ 8	− 4	+ 7	− 1	+ 1
North Plateau	.....	.....	.....	−20	− 8	−28	−24	− 7	− 4	− 4	+18	− 7	− 5	0	− 6	+11	+16	+14	− 7	+ 8	−18	− 5	+10	+ 5	+12	+12	− 4
South Plateau	.....	.....	.....	+ 3	− 9	−25	− 9	− 8	−13	− 1	+11	− 5	+ 8	+ 5	− 1	+ 4	+22	+20	− 5	+ 2	−12	+14	+12	+ 8	+ 6	+ 1	− 3
Lake region	−15	+28	0	−12	+11	−51	+10	− 6	+ 2	+ 7	+15	+ 2	−20	0	+ 1	+24	+ 8	+12	+ 7	+20	−32	−12	−10	+ 6	+11	−11	+ 2
West Gulf States	− 1	+19	+ 8	+ 7	+ 2	−49	+ 7	+13	−15	+ 1	+15	− 6	−12	− 9	− 5	+ 8	+ 6	+11	+ 1	+ 4	−21	+12	+ 6	+ 9	0	− 3	0
North Atlantic States	−10	+34	+ 4	−20	+ 5	−67	+10	+21	− 8	+20	+31	− 1	−33	− 6	− 1	− 1	−11	− 1	+15	− 8	−16	+17	− 8	+10	+ 8	− 3	+11
South Atlantic States	− 1	+31	+ 9	− 2	−10	−58	+17	+25	−14	+13	+18	− 8	−31	−13	− 2	+ 4	−12	+12	+ 6	+ 6	−19	+ 9	− 7	+15	+ 2	− 1	+ 4
Means	− 2	+23	+ 9	− 6	− 3	−44	+ 1	+ 8	− 8	+ 6	+18	− 7	−15	− 4	− 2	+ 5	+ 2	+12	+ 3	+ 5	−16	+ 6	+ 2	+ 7	+ 7	− 1	+ 2
North Argentina	− 4	+12	+ 8	+ 8	−20	+ 4	+ 8	− 4	−12	+20	+16	+16	+16	+16	− 8	−20	+ 8	+20	− 8	+ 8	+24	0	− 4	.....	.....	.....	.....
Central Argentina	−16	+20	+20	+12	−12	+16	+16	−12	−20	+ 4	+ 4	0	− 4	+20	+12	− 8	+12	+28	− 4	+ 8	+24	+16	− 8	−12	+ 8	− 8	.....
Means	−10	+16	+14	+10	−16	+10	+12	− 8	−16	+12	+10	+ 8	+ 6	+18	+ 2	−14	+10	+24	− 6	+ 8	+24	+ 8	− 6	−12	+ 8	− 8	.....

show that in North America and South America the annual pressure prevails in excess, or that the variation is positive, as 1874, 1875, 1883, 1890, 1892, 1897. Others show that the entire Northern Hemisphere is in defect as a whole, as 1876, 1878, 1879, 1885, 1887, 1893. Others show the Northern Hemisphere to be in excess, as 1883, 1896, 1897. Other years are more irregular. I have the impression that there is a westward movement of the defect in pressure, or of the negative residuals; and that there are similar groups separated by intervals of seven or eight years. This subject will require an exhaustive study by meteorologists in the future, and much valuable information will be extracted from it.

If the positive values of the pressure variations be added together for each year, and also the negative values by themselves, the result may be indicated as it is plotted in the curves of fig. 29' The upper curve is for the positive and the lower for the negative summation, but these curves show, since they rise and fall together, that these values do not cancel each other. The curves match fairly well with the prominence curve, and I take it to mean that *some external force is at work to raise and lower the total atmospheric pressure by a small amount from year to year.* It is probable that a more rigorous discussion would eliminate certain distortions of this curve, and show that it synchronizes very closely with the curve of the variations of solar energy. If this proves to be so, it raises some exceedingly interesting questions in cosmical meteorology.

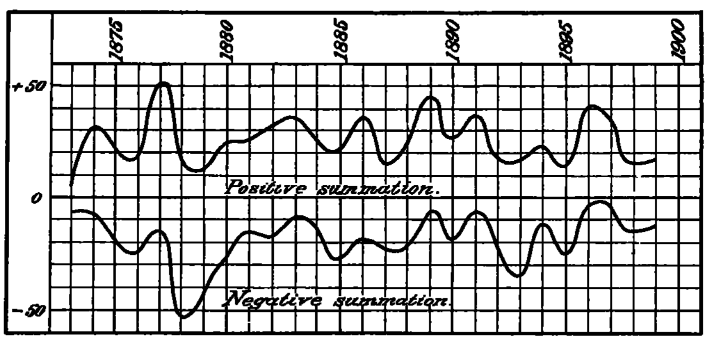

FIG. 29.—Positive and negative pressure variations over the earth as a whole for successive years, on a scale of relative numbers.

It is interesting to compare the results of this series of annual variations, 1873–1899, with those of the series, 1874–1884, studied by H. H. Hildebrandsson,[3] the latter, however, extending the details to the monthly values. The data of the Barometry Report make it possible to do this readily for the United States with little additional labor.

Returning to fig. 28, if we compare the successive pressure groups with the prominence curve, it will be seen that India and southeastern Asia are in very close synchronous agreement. This synchronism extends also to New South Wales, the Indian Ocean, and even to south Africa. In Siberia and Russia the synchronism begins to break a little and seems to be transferred somewhat toward the right, although this may be due in part to defective data. In Europe and in the United States, while the same curve is developed as to the number of the maxima and minima, the synchronism becomes more irregular. In South America, on the other hand, the synchronism is resumed very distinctly, but the *entire curve is reversed as referred to India and the Eastern Hemisphere.* Thus we perceive that around the Indian Ocean the synchronism is clearly developed; it weakens in Europe and North America, and it becomes a distinct reversal in South America. I presume that this remarkable phenomenon is due to the fact that the Pacific-Indian Ocean is quite free from frequent cyclonic disturbances, as is also South America, and that the atmospheric pressure surges back and forth between these two central or southern hemispheres, or else slowly rotates about the entire earth, probably from east to west. In North America and Europe, while the type curve reappears less perfectly, it still exists, and the disturbance may be due to the turbulent cyclonic circulation, which prevails over this region of the earth in marked contrast with the quiescent circulation of the other regions. It is, however, of much importance to have shown that changes in the annual atmospheric pressure of the earth synchronize approximately with the typical output of solar energy.

From this rapid survey of the cosmical meteorological problem, it is obvious that meteorology has large interests in solar and terrestrial magnetism. The annual reports of magnetic observatories are usually published several years after the records are made, hence, if meteorology is to insure any progress in seasonal forecasting, it evidently must possess its own magnetic apparatus, so that the state of the solar-terrestrial field may be known in connection with current meteorological phenomena. It must be conceded that considerable scientific skill will be required to bring this system of cosmical forces into control for the benefit of mankind, but I do not see how it can be doubted that the true pathway of research is already open before us. It is to be hoped that meteorologists generally will take up these cosmical problems, and compute the necessary homogeneous systems, so that it may become possible to advance promptly to practical results.

[3] Quelques recherches sur les centres d'action de l'atmosphère, par H. H. Hildebrandsson, Stockholm, 1897.

HAWAIIAN CLIMATOLOGICAL DATA.

By CURTIS J. LYONS, Territorial Meteorologist.

Rainfall data for July, 1902.

Stations.	Elevation.	Amount.
HAWAII.		
HILO, e. and ne.	*Feet.*	*Inches.*
Waiakea	50	12.82
Kaumana	1,250	13.80
Pepeekeo	100	11.75
Hakalau	200	11.88
Honohina	300	9.03
Puuohua	1,050	13.73
Laupahoehoe	500	9.72
Ookala	400	4.48
HAMAKUA, ne.		
Kukaiau	250	2.69
Paauhau (Mill)	300	1.49
Honokaa (Muir)	425	1.22
Kukuihaele	700	2.22
KOHALA, n.		
Niulii	200	3.44
Kohala (Mission)	521	3.13
Kohala (Sugar Co.)	235	2.42
Hawi Mill	......	3.70
Puuhue Ranch	1,847	1.65
Waimea,	2,720	1.04
KONA, w.		
Holualoa	1,350	11.97
Kealakekua	1,580	13.23
Napoopoo	25	5.16
KAU, se.		
Kahuku Ranch	1,680	3.09
Pahala	850	0.49
PUNA, e.		
Volcano House	4,000	3.79
Olaa, Mountain View	1,700	16.80
MAUI.		
Waiopae Ranch, s	700	0.00
Kaupo (Mokulau), s.	285	5.42
Kipahulu, s	300	8.41
Nahiku, ne	1,600	22.75
Nahiku, ne	850	14.36
Haiku, n	700	2.98
Kula (Erehwon), n	4,500	5.02
Puuomalei, n	1,400	2.40
Kula (Waiakoa), n	2,700	3.49
Paia, n	180	1.32
Haleakala Ranch, n	2,000	1.84
MAUI—*Continued.*	*Feet.*	*Inches.*
Wailuku, ne	200	0.04
OAHU.		
Punahou (W. B.), sw	47	2.87
Kulaokahua, sw	50	1.76
Makiki Reservoir	120	2.99
U. S. Naval Station, sw	6	0.88
Kapiolani Park, sw	10	0.33
Manoa (Woodlawn Dairy), c.	285	10.49
School street (Bishop), sw	50	2.27
Insane Asylum, sw	30	2.32
Kalihi-Uka, sw	260	8.76
Nuuanu (W. W. Hall), sw	50	2.45
Nuuanu (Wyllie street), sw	250	5.15
Nuuanu (Elec. Station), sw	405	4.05
Nuuanu (Luakaha), c	850	12.66
Waimanalo, ne	25	1.68
Maunawili, ne	300	6.13
Ahuimanu, ne	350	6.56
Ewa Plantation, s	60	0.25
Waipahu, s	200	0.00
Moanalua, sw	15	2.02
Rhodes gardens (Manoa)	300	13.05
Nahuina (Castle)	1,150	10.21
Tantalus Heights (Frear)	1,360	10.95
KAUAI.		
Lihue (Grove Farm), e	200	2.38
Lihue (Molokoa), e	300	2.29
Lihue (Kukaua), e	1,000	6.68
Kealia, e	15	1.14
Kilauea, ne	325	4.85
Hanalei, n	10	6.55
Eleele, s	200	0.25
Wahiawa Mountain, s	2,100	12.85
McBryde (Residence)	850	4.15
Lawai	450	4.96
East Lawai	800	3.49
West Lawai	200	1.68
Delayed June reports.		
Waimanalo	......	7.45
Kailua (Hawaii)	......	5.78
Nuuanu (Wyllie street), sw	......	1.87
Wahiawa (Oahu)	......	3.07

NOTE.—The letters n, s, e, w, and c show the exposure of the station relative to the winds.