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Soon after the discovery of the 11-year period in sunspots, about 1850, the question was raised as to a possible relation between solar changes and the earth's weather. It was supposed that if these spot changes produce any change on the earth, its influence would be felt over the entire earth in the same manner. If the sun became warmer the entire earth would become warmer; if the sun became colder the entire earth would become colder. The exhaustive research of Köppen seemed to confirm this view. Using all available published records, which were mostly from land areas in middle and low latitudes, Köppen[1] found that the mean temperature of the earth was slightly lower at sunspot maximum than at sunspot minimum. When measurements at the Smithsonian Astrophysical Observatory indicated a greater heat radiation from the sun at sunspot maximum than at sunspot minimum, it was thought to be an anomaly, and even now writers frequently refer to the anomaly of a hotter sun and a colder earth.

However, other researches indicate that the relation of solar changes to terrestrial weather is far more complex than this simple theory suggests. Blanford[2] showed that at sunspot maxima there were opposing oscillations in pressure between Russia and India, and Lockyer[3] found opposing pressure oscillations between the region of the Indian Ocean and a region centered around Santiago, Chile. Hildebandsson and Weickmann added many examples of these opposing oscillations that exist in temperature and rainfall as well as in pressure, although they did not connect them with solar changes. That these opposing oscillations exist throughout the earth becomes evident to

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[1] Köppen, W., Lufttemperaturen, Sonnenflecken und Vulkan ausbrücke. Meteor. Zeitschr., July 1914, pp. 305-308.

[2] Blanford, H. F., On the barometric see saw between Russia and India in the sun-spot cycle. Nature, vol. 20, pp. 477-482, Mar. 18, 1880.

[3] Lockyer, Norman, Simultaneous solar and terrestrial changes. Nature, vol. 69, pp. 351-357, 1902; Lockyer, William, A world-wide barometric see-saw. Nature, vol. 70, p. 177, June 23, 1904.

anyone who makes a plot of pressure and temperature changes over any large portion of the earth's surface. Figure 1 shows a plot of the monthly departures from normal temperature at Helena, Mont., and at New Haven, Conn., during the 10 years from 1930-1939, covering

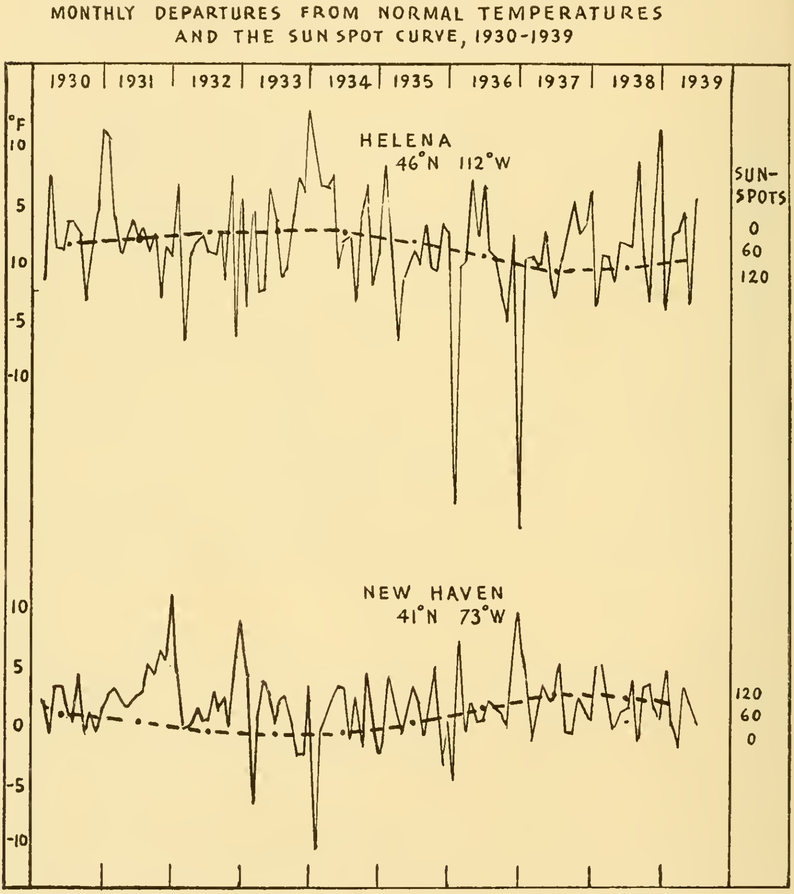

FIG. 1.—Monthly departures from normal temperature in western and eastern parts of United States compared with annual sunspot numbers.

most of the last sunspot period. A curve connecting the annual relative sunspot numbers is drawn through this plot of monthly temperature departures, but the numbers are inverted in the upper curve.

The curve for Helena fairly represents the temperature changes that took place between the Mississippi Valley and the Pacific Coast during the decade, and the curve for New Haven fairly represents the changes which took place in the Atlantic Coast States from

Maine to Florida. The curve for Helena shows that the greatest excess of temperature occurred at sunspot minimum in 1934 and the greatest cold occurred at sunspot maximum in 1937, whereas exactly opposite conditions prevailed in New Haven—the greatest cold occurred in 1934, and the greatest excess of temperature above normal after 1932 occurred in 1937. The mean difference in temperature between the years ending in August 1934 and 1937 at Helena was 6.5° F. and between the same years at New Haven was 2.3° F. with signs reversed. That is, there was a change of about 9 degrees in the temperature gradient between the two stations in the interval from the sunspot minimum of 1934 and the sunspot maximum of 1937. The extremely cold month, January 1937, shows a mean temperature difference between Helena and New Haven nearly 30° F. greater than the normal difference.

The early discoverers of these seesaw oscillations thought that the centers of oscillation were permanent in position. It followed that the sunspot effect, if any, would remain alike at each place and repeat itself in the same phase with each recurrent sunspot period. My investigations have disclosed that this conclusion is not justified.

In the American Meteorological Journal of 1884, vol. 1, pp. 130 and 528, I pointed out that an opposing oscillation of pressure and temperature in the United States having a period of about 25 months did not remain fixed in positions, but the centers of oscillation had a slow progressive motion. Later investigations have shown that this progressive motion is true for oscillations of all lengths, although the centers appear to re-form in certain favored locations.

Oscillations of pressure connected with the sunspot period show this progressive motion clearly.

In my recent paper on the sunspot period[4] it was shown that areas of excess pressure observed over the oceans in middle latitudes at the time of moderate solar activity move northward as solar activity increases. As a consequence, the phase of the sunspot period in atmospheric pressure inverts in all latitudes. (See fig. 2.) In 1906, with moderate solar activity the maximum excess of pressure was near latitude 40° N.; in 1893, with higher solar activity, it was near latitude 50° N.; and in 1917, with high solar activity, it was about latitude 60° N. The higher the solar activity the higher the latitude in which the areas of excess pressures are found. There is evidence that this is true both north and south of the Equator.

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[4] Clayton, H. Helm, The sunspot period, Smithsonian Misc. Coll., vol. 98, No. 2, 1939.

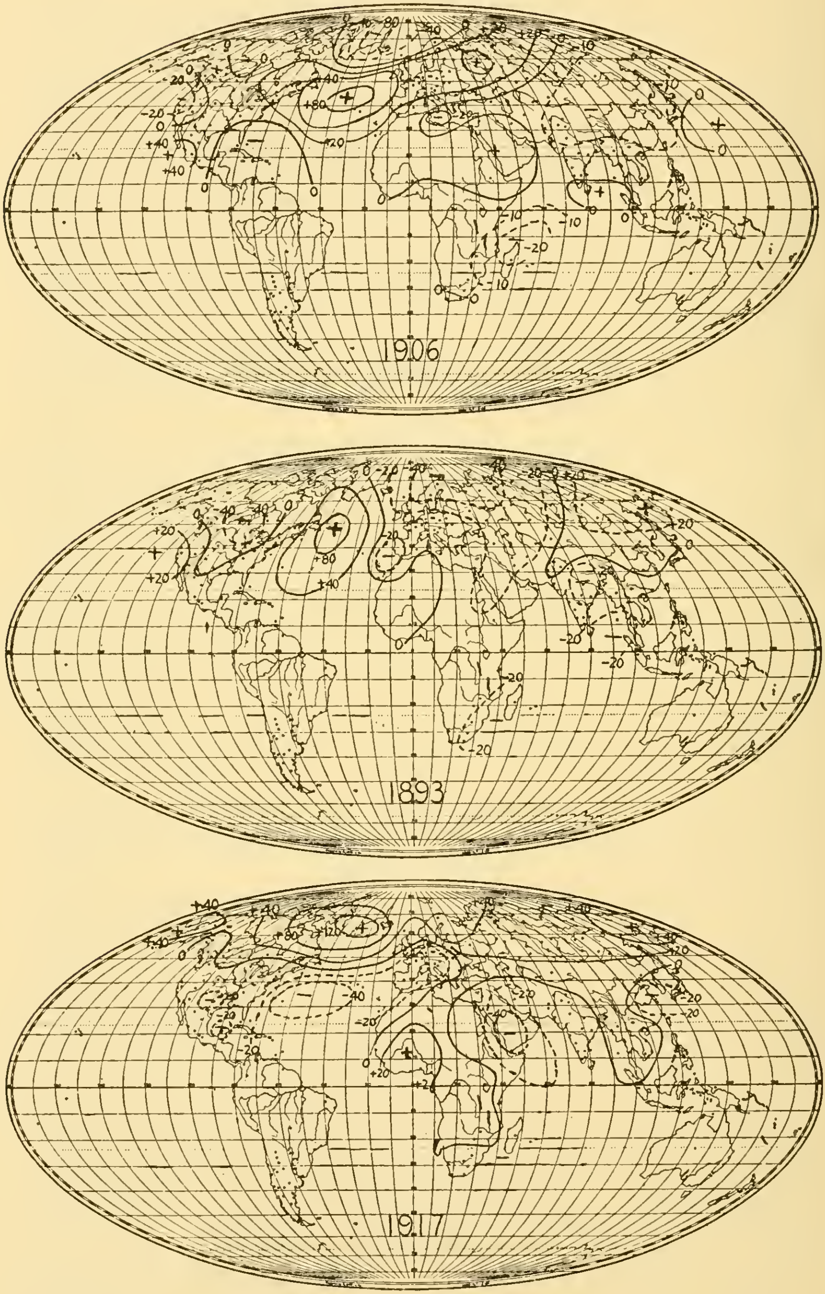

FIG. 2.—Atmospheric pressure at maxima of sunspots, 1906, 1893, 1917. (Unit 0.01 mm.)

Figure 3 shows oscillations of the annual means of pressure in the Tropics freed from a long-time trend. It also shows 5-year averages by a dotted curve. These curves are compared with the inverted sunspot curve. It is seen from the diagram that the 5-year means of pressure from 1890 to 1925 in the Tropics oscillated inversely to the sunspot curve. However, there is evidence that even in the Tropics the sunspot influence is intermittent and occasionally inverts in phase. Oscillations in the level of Lake Victoria Nyanza, situated in central Africa directly under the Equator, oscillated in phase with the sunspots from about 1890 to 1923.[5] After that time a tendency to invert in phase showed itself. Broken observations about 1870 also indicate a reversal of phase in regard to the sunspot period about 1870. Sydney M. Wood has recently shown[6] that low levels of the Nile show oscillations similar to the variations of Lake Victoria Nyanza (see fig. 4). These variations were probably produced mainly by an increased rainfall in the tropical belt which my investigations show existed during the same period.[7] The variation in evaporation was a contributory influence.

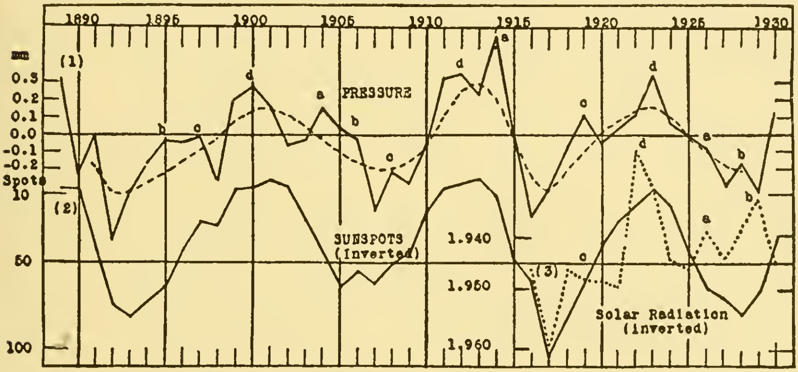

Fig. 3.—Comparison of mean pressures in the Tropics with sunspots and solar radiation. (1) Mean annual pressures at Quixeramobim and Antananarivo, corrected for trend. (2) Mean annual number of sunspots, inverted. (3) Mean annual values of solar radiation, in calories per minute, inverted.

With very high sunspot activity at the time of sunspot maxima an excess of pressure over normal (baroplion) is found at stations

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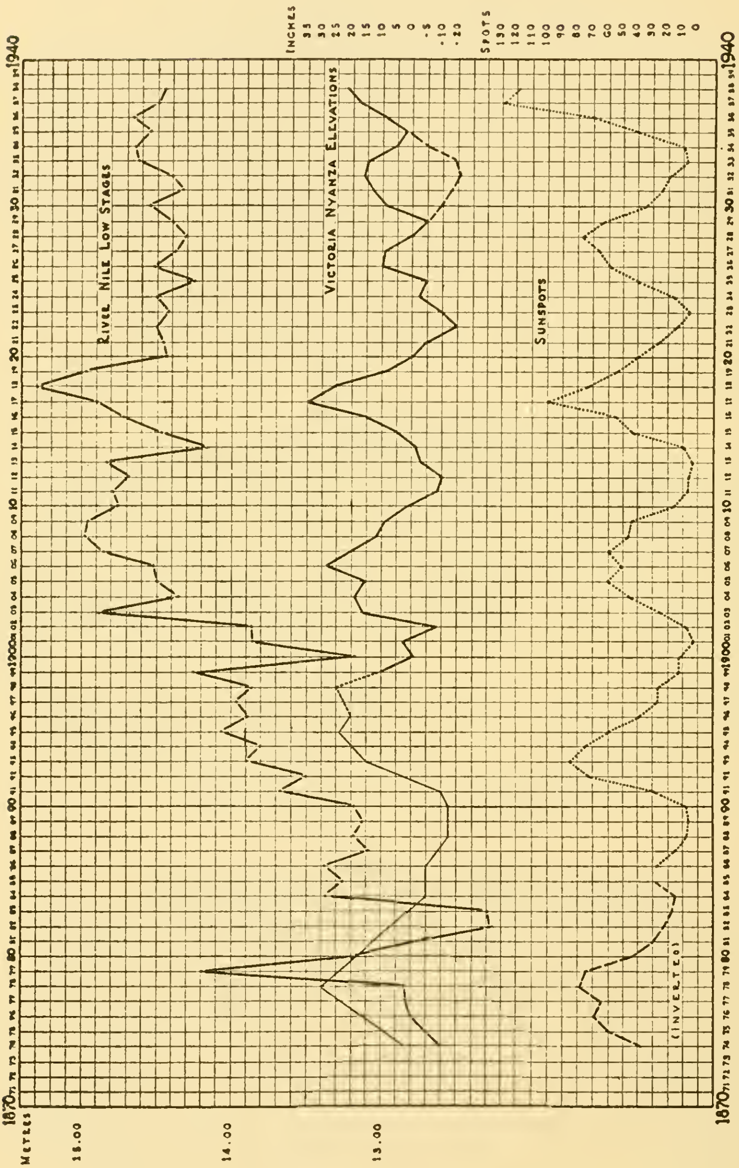
[5] Brooks, C. E. P., Variations in the levels of the central African lakes, Victoria and Albert, Geophys. Mem., No. 20, London, 1923.

[6] Wood, Sydney M., 31st Ann. Rep. Engineering Soc. Wisconsin, Inc., p. 102, 1939.

[7] Clayton, H. H., World weather, p. 264. Macmillan Co., New York, 1923.



River Nile Low Stages, with the Victoria Nyanza Elevations & Sunspot Frequencies 1874-1938

Fig. 4.—A reverse relationship between Nyanza and sunspots took place in the period near 1878 (shown with spots in reverse) and following 1929 (Nyanza curve shown in reverse). Illustration in reverse was made at the suggestion of H. H. Clayton.—(After Sydney Makepeace Wood.)

in both hemispheres in high latitudes, whereas with moderate sunspot activity at the time of sunspot maximum the excess of pressure is found near 40° latitude.[8] When the excess of pressure is found in high latitudes, as in 1870, 1917, and 1937, not only is there a widening of the belt of low pressure near the Poles, but centers of lower than normal pressure (baromions) develop about latitude 30° north and south of the Equator. As a result, indraught of air toward the Equator is lessened or reversed.

During the last century each alternate period of solar activity has been greater than the intermediate one, so that a period of 22 to 23 years was engendered which has been investigated by Dr. C. G. Abbot.[9] It is evident, if this finding is correct, that the centers of excess and defect of pressure are in constant movement and do not repeat themselves in the same manner at the same place at each sunspot maximum unless the solar intensities at successive sunspot maxima are nearly the same, and that rarely happens.

Such moving centers of oscillation have been found by me for every period of solar activity so far investigated, even to periods of only a few days in length. In addition Professor Turner, of Oxford, Dr. Abbot, Secretary of the Smithsonian Institution, and K. F. Wasserfalls, of Bergen, Norway, have advocated changes of phase in meteorological periods; but apparently the idea seems fantastic to most meteorologists, who either believe there are no meteorological periods or else are seeking periods that do not change in phase and intensity.

However, there are certain general regions where during the sunspot period areas of excess or defect of pressure tend to form. As shown in the preceding pages, areas of excess pressure tend to form in high latitudes with high solar activity. They tend to form over continents in winter and over oceans in summer, thus reversing the effect with the seasons.[10]

By dealing only with the summer rainfall (June—August), W. A. Thorn, of the Canadian Meteorological Office, was able to show a relation of the Toronto rainfall to the sunspot variations (see fig. 5) extending from 1848 to 1931.

Recently I have had under way investigations in regard to the period of solar rotation of about 27 days. Spot groups not infre-

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[8] Clayton, H. H. World weather and solar activity, Smithsonian Misc. Coll., vol. 89, No. 15, pp. 10-11, 1934.

[9] Abbot, C. G., Solar radiation and weather studies, Smithsonian Misc. Coll., vol. 94, No. 10, 1935.

[10] Clayton, H. H., World weather, p. 303. Macmillan Co., New York, 1923.

quently form in some definite longitude on the sun and continue to return opposite the earth for many solar rotations. Oscillations in the number of sunspots approximating a period of 27 days were observed in the latter part of 1936 and in the first half of 1937 and have been under investigation in regard to their meteorological relations. For this purpose, some pressure data prepared by Jean Gallenne for publication in World Weather Records were used. Owing to a gift from John A. Roebling to the Smithsonian Institution, it has been possible to obtain the pressure from daily weather maps at the intersections of each 10° of latitude and longitude over most of the northern hemisphere. These barometric pressures when plotted in curves are compared with sunspots plotted in the same manner as shown in figures 6 and 7. The continuous curves connect day to day pressures, and the dotted curves show the daily sunspot numbers as prepared at Zurich. During the winter and spring there is an evident direct relation between the sunspots and pressure in the North Pacific and North Atlantic Oceans near latitude 60°. At 30° latitude the relation tends to be inverted. This relation is of the same nature as that found for the sunspot period of 11 years.

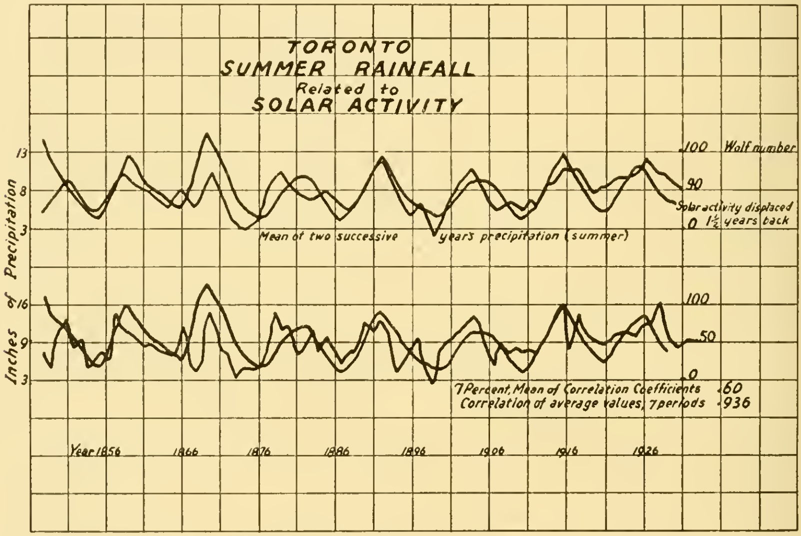

FIG. 5.—Comparison of summer rainfall at Toronto with sunspot numbers. In the upper curve the monthly rainfalls are smoothed by the formula $\frac{a + 2b + c}{4}$. In the lower curve the unsmoothed rainfalls are given.—(After W. A. Thorn.)

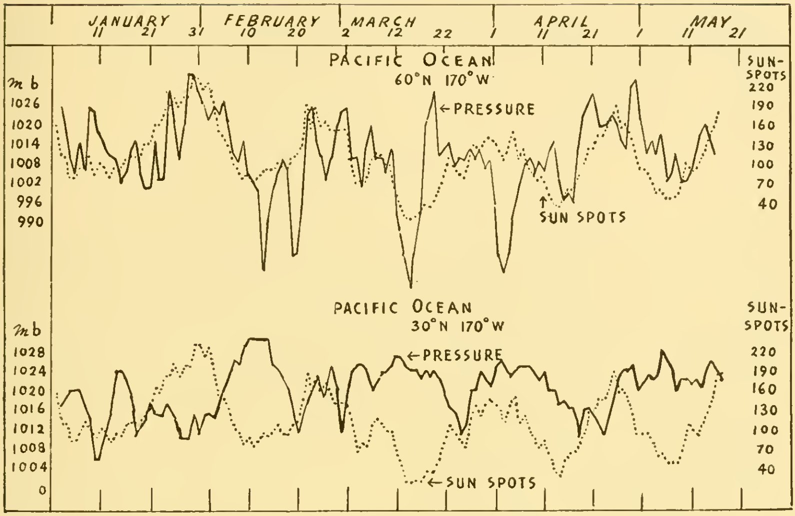

Fig. 6.—Daily sunspot numbers compared with atmospheric pressure over the Pacific.

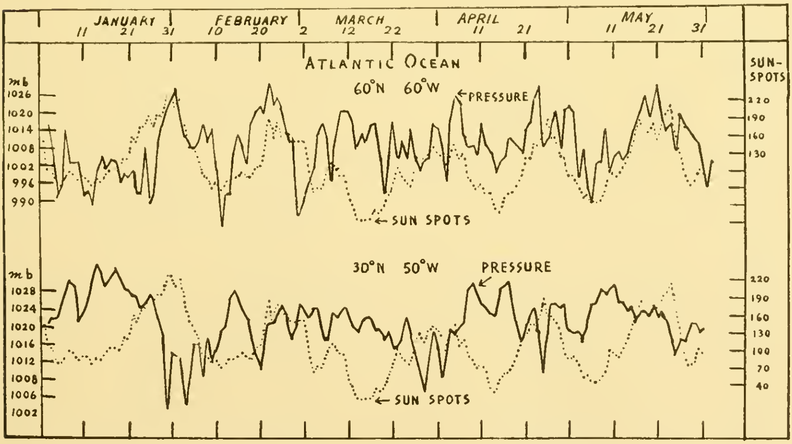

Fig. 7.—Daily sunspot numbers compared with atmospheric pressure over the Atlantic.

In order to determine quantitatively the relation between daily sunspot numbers and atmospheric pressures at different latitudes and longitudes in the northern hemisphere of the earth, the sunspot numbers were correlated with the pressure read from weather maps at the intersections of the 10° lines of latitude and longitude, using the accepted formula:

$$r = \frac{\Sigma ps}{\sqrt{\Sigma p^2 \cdot \Sigma s^2}}$$

in which p represents departures from the mean pressure for 27-day intervals and s represents departures from the mean of the sunspots for the same intervals. There were 173 values of the pressure each day at intersections distributed over the oceans and lands of the Northern Hemisphere between 20° and 70° N. The correlations were computed for twelve 27-day intervals beginning with October 12, 1936, and ending with August 31, 1937. Table 1 shows the correlations for the interval December 5-31, 1936.

The correlations for each interval of 27 days were plotted on maps of the Northern Hemisphere. Each of these maps shows many centers of plus and minus correlation. Figure 8 shows the correlations for the interval December 5-31, 1936, plotted on a map.[11] There are 12 major centers of plus and minus correlations. The plus area near Alaska gives three values exceeding .80, and the negative area at 30° N., 175° E. gives two values of −.83 and −.87. Maps for other periods of 27 days show areas of correlation exceeding .70; but the positions of the centers vary from period to period, showing the complex nature of the forces causing these areas of plus and minus correlation.

In the means of several periods, however, there emerge certain definite relations. The first of these is the latitude relationship. The time covered by the investigation was at the high point of the great solar activity of 1936-1937, and in accord with the results indicated by figure 2, the pressure was higher than normal in high latitudes with each recurrent maximum of sunspots in the 27-day period. This is illustrated by figure 9. From October 12, 1936, to June 12, 1937, the mean of all the correlations at 70° latitude was positive for each period of 27 days and increased as the mean sunspot number increased.

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[11] The base map is an equal area map of the Good series used by permission of the University of Chicago Press.

TABLE 1.—*Correlations of daily sunspot numbers with the atmospheric pressure (in percent), December 5-31, 1936.*

Long. E. Lat.	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
70° N.	..	..	..	10	..	..	17	..	−19	..	−25	..	08	..	−67	..	−75	..
60°	63	54	17	−09	−29	−36	−39	−44	−47	−55	−57	−52	−55	−70	−72	−65	−85	−70
50°	60	44	23	−36	−77	−76	−75	−51	−43	−40	−40	−48	−72	−79	−84	−77	−78	−70
40°	41	29	21	−24	−59	−84	..	..	..	..	−41	−41	−59	..	−81	−65	−57	−77
30°	29	47	62	25	−22	..	..	−40	38	49	−07	−08	−19	..	−48	−63	−72	−88
20°	..	..	..	50	..	..	..	29	13	−17	16	−36	..	−55	−17	−31	−40	−56
10°	..	..	..	..	..	..	..	..	−11	..	−22	..	..	..	..	..	..	..

Long W. Lat.	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	10
70° N.	..	..	24	..	44	..	61	..	55	..	11	..	..	13	..	38	..	..
60°	−41	−13	49	82	87	76	69	68	62	49	39	07	16	07	10	47	40	60
50°	−43	−21	77	81	62	08	−09	28	11	−06	10	30	30	−20	04	24	44	57
40°	−56	−35	25	53	40	−33	−70	−69	−57	−27	25	..	41	12	03	06	25	47
30°	−83	−69	−37	20	41	27	07	−66	−67	−12	..	68	59	−08	−35	−38	−23	37
20°	−65	−69	..	−52	−38	17	17	−11	..	..	..	44	−13	−20	−31	−05	−11	..

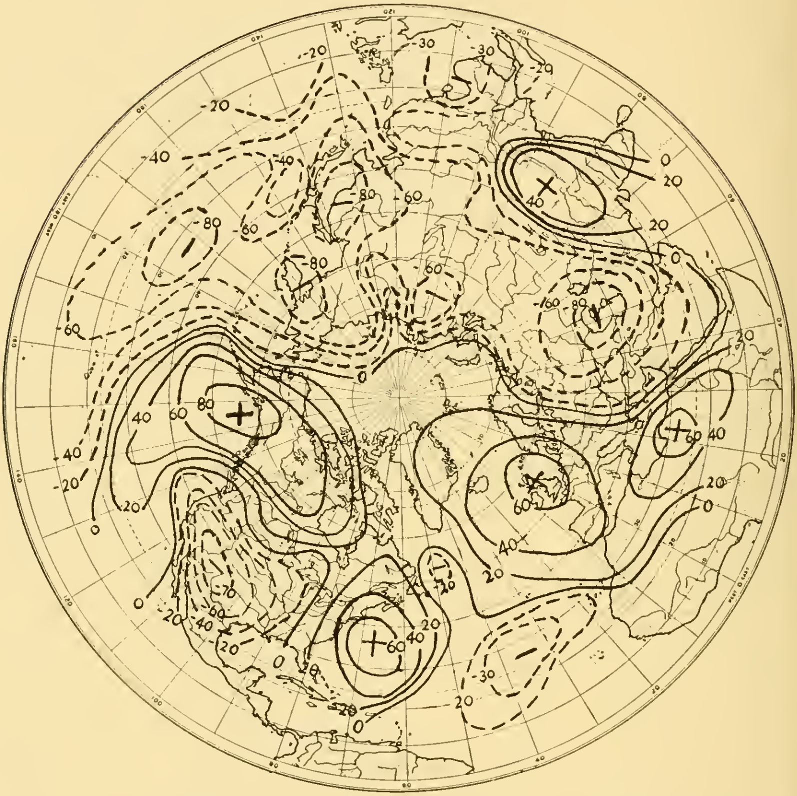

Fig. 8.—Correlations of daily sunspots and atmospheric pressure, December 5-31, 1936.

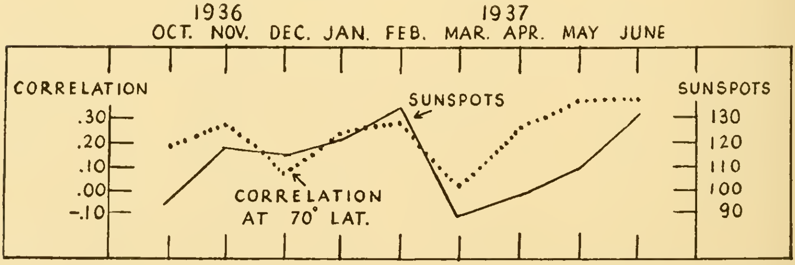

Fig. 9.—Mean correlations at 70° latitude of daily sunspots with atmospheric pressure from October 12, 1936, to June 11, 1937, for each 27-day interval compared with absolute number of sunspots.

At high latitudes in all seasons the average correlation was positive, whereas in latitudes below 50° it was negative. This fact is shown by table 2.

TABLE 2.—*Mean correlations of sunspots and pressure at different seasons*

Lat.	Autumn Oct. 12–Dec. 4	Winter Dec. 5–Feb. 13	Spring Feb. 24–May 15	Summer May 16–Aug. 31	Year
70°	.17	.19	.15	.11	.16
60°	.04	.10	.10	.04	.07
50°	.02	−.03	.01	−.05	−.01
40°	−.01	−.16	−.05	−.05	−.07
30°	−.05	−.13	−.05	.04	−.05
20°	−.10	−.06	.00	.05	−.02

The correlations in table 2 are the mean of about 350 values at each latitude. Although the averages are not high, the results are remarkably consistent in indicating an increased pressure in high latitudes at all seasons with increased sunspots in the short-period oscillations of about 27 days. There is no seasonal difference except in intensity, the correlations being greater in winter when the temperature difference between Pole and Equator is greater. The mean correlations for the year for each latitude are plotted in figure 10.

When the mean correlations for 12 consecutive periods of 27 days at each intersection of 10° lines of latitude and longitude are plotted on a map of the Northern Hemisphere and lines of equal correlation drawn, figure 11 is obtained. It is evident from this figure that there is a mean distribution of positive and negative areas of correlation depending on different conditions at the earth's surface. In the polar region there are positive correlations in all longitudes. In middle latitudes there are negative correlations over the land surfaces of the United States, northern Africa, and southern Asia.

There are also negative correlations over the warm waters of the Gulf Stream from the northern coast of South America to Norway and over the warm waters of the western Pacific from latitude 20° N. to 60° N.; whereas over the colder waters of the Pacific at about longitude 130° to 140°, and over the colder waters of the Atlantic near the coast of Africa, there are positive correlations.

Sir G. C. Simpson disclosed in his studies of the heat balance of the atmosphere that over the land surfaces south of latitude 45° there is an excess of insolation over radiation from the earth in the mean for the year, whereas north of latitude 45° radiation from the earth is in excess of insolation. This condition tends to bring about

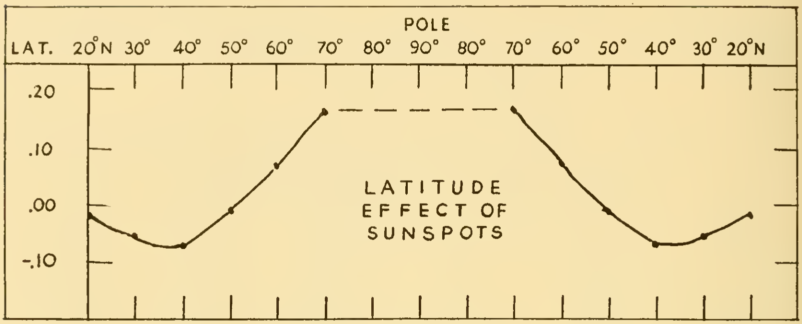

FIG. 10.—Mean correlations of daily sunspots with atmospheric pressure at different latitudes for 12 periods of 27 days, October 12, 1936, to August 31, 1937.

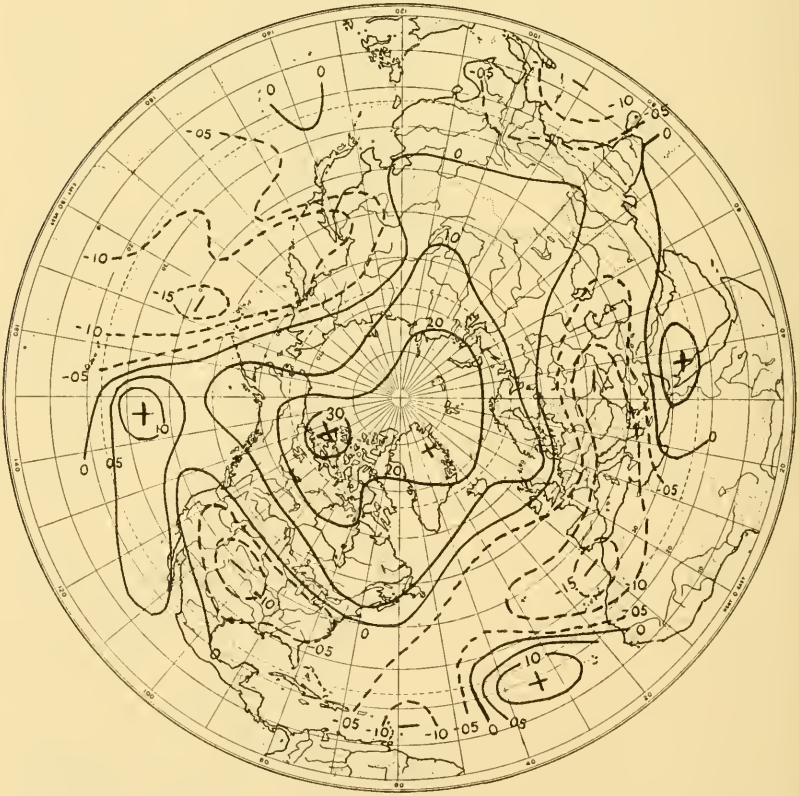

FIG. 11.—Mean correlations of daily sunspots with atmospheric pressure for 12 periods of 27 days, October 12, 1936, to August 31, 1937.

a fall of pressure in latitudes south of 45° and a rise of pressure north of 45° with an increase of solar radiation. Such an increase accompanies increased solar activity. The air flows from the heated areas of southern land surfaces and from the warmer waters of the ocean toward the north, and also toward the colder waters of the oceans in the same latitude, thus offering an explanation of the areas of positive correlation near the west coast of southern California and the west coast of North Africa.

This factor depending on the composition of the earth's surface is subject to a marked seasonal change. The region where outgoing radiation from the earth exceeds incoming radiation from the sun is separated by a line which moves north and south with the seasons. Hence, there are large areas of the earth's surface between 22° N. and 68° N. where the effect of increased solar radiation on pressure is inverted between summer and winter.

This inversion is evident from figure 12. The 12 periods of 27 days between October 12, 1936, and August 31, 1937, were divided into two intervals of six periods, one from October 12 to March 22, called the winter half year, and the other from March 23 to August 31, called the summer half year. A plot of the average correlations for each latitude and longitude is shown in figure 12. The continuous line at each latitude gives a plot of the winter half year, and the dotted line gives a plot of the summer half year. The curve for the winter half year shows two general maxima, one extending from about 0° to 120° E. longitude north of 50° latitude and covering the northern part of the continent, Euro-Asia, and a second extending from 180° to 80° W. covering the western part of the Pacific and North American continent north of 40° latitude. Why this second maximum should be larger than the first is not evident. At 20° N. and 30° N. the position of the positive and negative correlations are more complex, but at each latitude from 20° N. to 70° N. the maxima and minima in the curves for summer tend to be opposite to those for winter.

Even the harmonics of the 27-day solar rotation period show marked relationships to weather changes in the United States and Canada. The half period of 13.5 days, the third harmonic of 9.0 days, the fourth of about 6.8 days, and the sixth and eighth of 4.5 and 3.4 days show a relation to solar changes when the sunspot numbers are analyzed by harmonic analysis.

A plot of analyzed data is shown in figure 13, giving the analyzed values of the daily sunspot numbers and of the daily pressures observed at 8 a.m. each day at certain stations in the United States and Canada during the early part of 1939. The method of analysis is described in my paper on "The Sunspot Period" in the Smithsonian

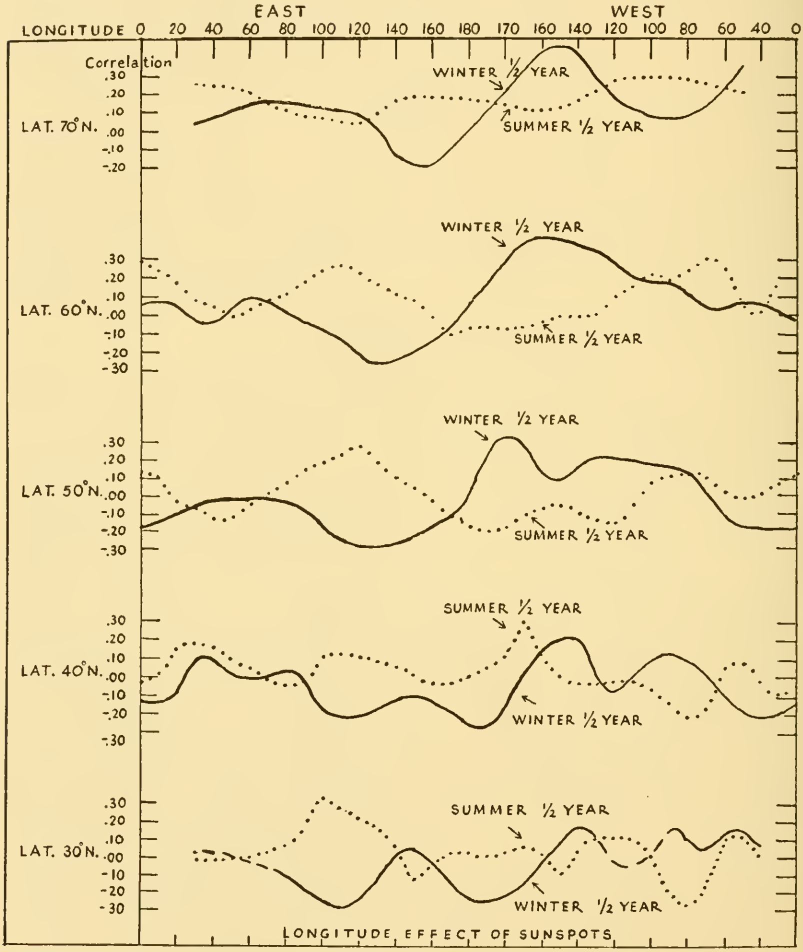

Fig. 12.—Correlation of daily sunspot numbers with atmospheric pressure for summer and winter half years.

Miscellaneous Collections, vol. 94, No. 10, pp. 1-5. In the plot the analyzed results for sunspots are shown by dotted curves and for pressure by continuous curves. The plots were made for stations showing the highest plus or minus correlations between sunspots and pressure. Means of three periods were used for the 13.5-day and

9-day periods, and means of nine periods were used for the 4.5-day period. The curves show that at stations like Nottingham, Churchill, and Cochrain in the Hudson Bay region the pressure oscillated mostly in phase opposed to that of sunspots, whereas at stations like Flagstaff, Galveston, and Tonopah in the southwestern United States they oscillated in the same manner as the sunspots.

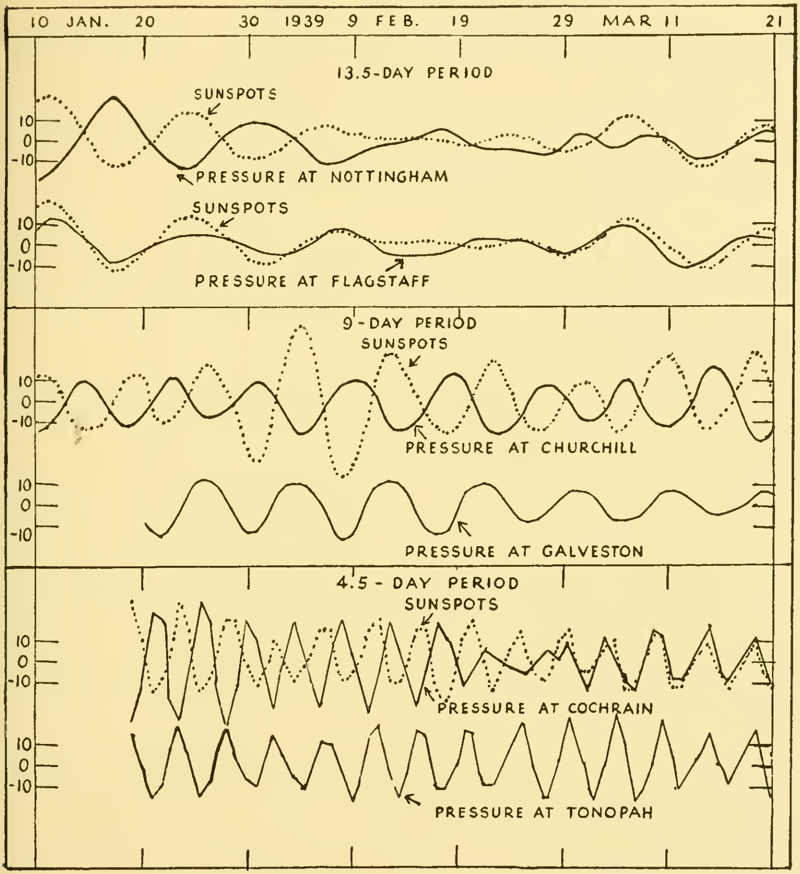

FIG. 13.—Harmonics of the solar rotation period of 27 days in sunspots and in atmospheric pressure.

In the 13.5-day period at Nottingham and the 4.5-day period at Cochrain there was a reversal of phase in March 1939. As mentioned before, this change of phase occurs for periods of all length and is due to the fact that when centers of oscillation are formed they assume the form of a wave and progress with a velocity inversely proportional to the wave length.[12]

Dr. C. G. Rosby has found an explanation for this differential motion in the effect of the earth's rotation on air at different latitudes moving along convex and concave isobaric gradients.[13] However, these movements are undoubtedly modified by atmospheric drift due to differences of temperature and pressure over large areas. This drift tends to carry the system of isobars and winds along with it and is variable in velocity. It is this drift combined with the drift due to the earth's rotation that makes the problem of forecasting difficult, but with sufficient observations and sufficient knowledge it can no doubt be computed.

This investigation of the 27-day period discloses that there are three distinct factors affecting the earth's atmosphere with increased solar activity as shown by sunspot numbers.

1. An increased flow of air from low latitudes to high latitudes acting throughout the year.

2. An increased flow of air from ocean to continent in winter and from continent to ocean in summer, which thus reverses with the season.

3. The formation of systems of circulating winds or waves that drift with velocities proportional to the wave length.

The meteorological changes accompanying sunspot changes of short period are even larger than those accompanying the 11-year sunspot period. It is evident from this fact that it is not sunspot changes that are the direct influence in causing weather, but something associated with them. Various possible relations have been suggested such as electrons coming from the sun, clouds of absorbing matter between the sun and the earth, changes in solar radiation, etc. I have examined several of these suggestions carefully, and my studies convince me that the variations of solar radiation which are being observed by the Smithsonian Institution are the primary causes of weather changes. These observations of solar radiation are made under great difficulties owing to the turbidity of our atmosphere, so that errors of observation have been nearly as large as the real variation of radiation, but when measures of solar radiation at two widely separated stations are compared, the values at each

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[12] Clayton, H. H., Monthly Weather Rev., vol. 48, No. 3, p. 127, March 1920.

[13] Rosby, C. G., Relation between variation in the intensity of the zonal circulation of the atmosphere and the displacements of the semi-permanent centers of action. Sears Foundation, Journ. Marine Res., vol. 11, No. 1, pp. 38-55, June 21, 1939.

station increase step by step with each other and show distribution curves of the observation in each step which are very similar. Furthermore, each distribution curve indicates a probable error in individual observation of about ±.005 calorie over a range of measurements six times as large as the probable error.[14]

Such a condition might be brought about by an interrelation of the observations; or else, by some absorption in our atmosphere, or in space, occurring simultaneously at the two stations. Both of these suggestions have been advanced. Hence, it is desirable to see whether the measurements of solar radiation are related to visible changes on the sun. If so they must be solar and not terrestrial relationships. The observations of faculae observed at Greenwich were first used as a test. These faculae are visible only on the east and west sides of the sun near the rim and are known to be due to heated matter brought up from the interior of the sun and much hotter than the other parts of the outer surface. Using four years of observation, 1918-1921, means were obtained by the solar radiation measured by the Smithsonian Institution for the day on which the faculae were observed and for the days before and after.[15] The results indicate clearly that the radiation was greatest when faculae were present. This difference was especially striking from September to April, when the solar measurements were best. The measurements of solar radiation were next compared with sunspots crossing the central meridian of the sun, taking 6½ days before and 6½ days after the crossing as representing the side of the sun facing the earth. The average solar radiation on each day indicates that there is a diminution of radiation when the spots are crossing the center of the sun and a marked increase of radiation when the spots are near the eastern and western rim of the sun.[16]

The same effect was even more marked when averages of radiation were computed for clouds of flocculi crossing the sun. The data were obtained from the Ebro Observatory.[17] These comparisons and similar comparisons by Dr. Abbot and Mr. Fowle, are convincing evidence that the Smithsonian Astrophysical Observatory was measuring real solar changes.

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[14] Clayton, H. H., The atmosphere and the sun. Smithsonian Misc. Coll., vol. 82, No. 7, p. 2, June 9, 1930. See also vol. 79, No. 4, pp. 50-53.

[15] Clayton, H. H., Solar radiation and weather. Smithsonian Misc. Coll., vol. 77, No. 6, pp. 53-54, June 20, 1925.

[16] Idem, p. 49.

[17] Clayton, H. H., The atmosphere and the sun. Smithsonian Misc. Coll., vol. 82, No. 7, p. 3, June 9, 1930.

Changes in solar radiation affect the atmospheric pressure in the same way as do changes in the number of sunspots. This similarity will be seen by comparing the results described in preceding pages for the 27-day period in sunspots with those found for solar radiation changes in my paper on "The Atmosphere and the Sun," Smithsonian Miscellaneous Collections, vol. 82, No. 7, pp. 5-11, and 30-31, 1930.

Since the effects of increased solar radiation depend in part on the composition of the earth's surface, it is evident that temporary changes at the earth's surface must play a part in the result. When the earth is covered with snow or the waters of the ocean are warmer than usual the effect must be altered. The most recent studies on the influence of changes in water temperatures and of snow covers are those of Sir Gilbert Walker, Dr. C. F. Brooks, and I. I. Schell. However, the present data are too scanty to enable me to get quantitative estimates of the influence of these temporary conditions when solar radiation increases.

A study of short-period climatic changes published in the Bulletin of the American Meteorological Society for February 1940 arrived as this paper was on the point of being sent to the printer. In this study Prof. Raymond H. Wheeler describes world-wide temporary changes in climate since 1800. Since 1900 there are sufficient data to connect these changes with the areas of excess and deficiency in pressure accompanying sunspot changes. In 1900 to 1904 when sunspots were at a minimum, the areas of excess pressure (baroplions) were in low latitudes, whereas the pressure was below normal in high latitudes. There resulted a warm-wet period in middle and high latitudes. This condition was repeated in the sunspot minimum of 1913-1915 and again in the sunspot minimum of 1920-1925. On the other hand a cold-dry period occurred in 1917-1920 with high sunspot activity when there were areas of excess pressure in high latitudes having a southward trend of motion. A warm-dry period occurred from 1925-1930 when the areas of excess pressure were being displaced from low latitudes to high latitudes. In this study by Professor Wheeler seasonal changes and changes due to progressive movements of areas of high and low pressures in longitude are not considered, but only general changes occurring simultaneously, mostly over the United States, Asia, Europe, and North Africa.