SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 103, NUMBER 10
(End of Volume)

Roebling Fund

A REMARKABLE REVERSAL IN THE DISTRIBUTION OF STORM FREQUENCY IN THE UNITED STATES IN DOUBLE HALE SOLAR CYCLES, OF INTEREST IN LONG-RANGE FORECASTING

BY
C. J. KULLMER

(PUBLICATION 3729)

CITY OF WASHINGTON
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The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

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By C. J. KULLMER[1]

We have for the United States the only long fairly uniform series of maps of tracks of barometric depressions. These have been published in the Monthly Weather Review for each month from 1874 to the present. Dunwoody assembled the material for the 10-year international period, 1878-87, in storm-frequency maps for the whole Northern Hemisphere. Dunwoody's method was to divide the maps into 5° squares and record the number of centers of barometric depressions that crossed each square. In 1911 I remade the maps of storm frequency in the United States for 1899-1908 according to Dunwoody's plan of 5° squares.[2] In the interval of 21 years a slight but definite southerly and westerly shift had taken place. But 5° in latitude, about 345 miles, is evidently unnecessarily large if we wish to test latitude shifts. I wished to ascertain whether there is any correspondence between the latitude shifts of sunspots and the latitude of the vortexes in our own atmosphere. Accordingly, I cut Dunwoody's square in half, making the unit 5° in longitude and 2½° in latitude, and made in 1913 a series of year maps from 1874 to 1912, furnishing comparison material for three solar cycles. Since that time three more solar cycles have become available. The results for the five cycles, with a series of year maps, 1883-1930, appeared in 1933 in a Smithsonian publication.[3] I shall now present the results for the last solar cycle.

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[1] Published posthumously; Dr. Kullmer, formerly of Syracuse University, died in 1942.

[2] The shift of the storm track. Chap. 16 *in* Huntington, The climatic factor, Carnegie Inst. Publ. 192, 1914.

[3] Kullmer, C. J., The latitude shift of the storm track in the 11-year solar period, Smithsonian Misc. Coll., vol. 89, No. 2, 1933. Preliminary publication of parts of the study appeared in Huntington, The solar hypothesis of climatic changes, Bull. Geol. Soc. Amer., vol. 25, pp. 477-590, 1914. See also Huntington, Earth and Sun, Yale Univ. Press, 1923.

For comparison, the most powerful method of attack seemed to be to add together 3-year maps at solar minimum and 3-year maps at solar maximum and compare them with each other. This was done for five solar cycles, with the result that a uniform pattern appeared. In figure 1 I present one such cycle, perhaps the most typical of the five. Plus figures indicate the excess in years of solar maximum over years of solar minimum; minus figures, the reverse. In the north there was a strong increase along the main storm track, but also a southerly projection. I have drawn a heavy dotted line through the main area of excess at times of maximum and also through the projection; at both sides of the projection there are areas of decrease, i.e., more storms at years of minimum than at maximum. In figure 2 I have assembled the dotted lines through the area of excess and the projection. It will be noted that in the fifth period there was an unexpected move to the south and that the southerly projection had shifted even farther west than in the second period. Because of a certain orderly progression in the shifts of the southerly projection I ventured a hypothetical position for the sixth solar cycle, and was correct in assuming an easterly motion of the southerly projection. I now present in figure 3 the results for the last solar cycle, showing an unexpected still greater shift to the south of the main area of excess at solar maximum. There was some doubt as to the year of maximum, 1937 or 1938, and consequently I made the maps for both periods, figure 4. Except for slight variation in figures, the maps are identical.

Now what does the continued southerly shift of the pattern signify, with the large increases at minimum in western Canada? The interpretation of a relation between sunspot latitudes and latitudes of earthly storms seemed to be justified by the first four periods, but contradicted by the fifth and sixth periods. There remained one way to test the relationship. In figure 5, taken from Clayton's "World Weather," we have Maunder's chart of sunspot latitudes. All these years I have been comparing 3 years at solar minimum with 3 years at solar maximum, but evidently the latitude effect would be intensified if I compared 3 years at the beginning of the cycle with 3 years at the end of the cycle. There is a noticeable overlapping of the new cycle with the old; in order to avoid this source of error I would eliminate by inspection the year of maximum overlapping, as indicated in the chart, and proceed to test the latitude effect by comparing 3 years at the beginning of a cycle with 3 years at the end of a cycle. I began with the first cycle available, figure 6, and the results were a succession of surprises. Gone was all thought of a relation to sunspot latitudes. Gone entirely was the pattern with the southerly projection, which I had found consistently for six solar cycles. This pattern still remains an enigma, the result of some solar relationship, the difference between years of maximum solar activity and those of minimum activity. Instead I discovered a solar relationship of possibly great significance.

The first period, figure 6, shows three horizontal bands. Plus figures indicate more storms at the beginning of the cycle; minus figures, more storms at the end of the cycle than at the beginning. The following period, figure 7, shows a map of an entirely different character—a plus band in the north, and curving down the Atlantic coast and across the south a minus area, forming a script T pattern. The succeeding period, figure 8, returns to the pattern of the first, three horizontal bands, but in reversed order, with a pronounced minus area between the plus bands. The succeeding map, figure 9, was the greatest surprise of all—a return to the almost identical script T pattern of the second period, but in reverse, with a minus area in the north and curving down the Atlantic coast, and across the south a plus area. And now with the fifth period, figure 10, we return to the three horizontal bands, but again in reverse, with a plus area between two still widened minus areas. These complicated relationships will appear more simple in a table, figure 11. Because of the appearance of three bands in the first and third period and the strange script T pattern in the second and fourth periods, we may divide the first four periods into two Hale solar cycles. But whatever the solar influence may be that determines the location of storms on earth, that influence was completely reversed in the two Hale cycles. The evidence of a reversal is further supported by the return in the fifth period to the conditions found in the first.

A crucial test will be offered by the coming sixth solar cycle, which will have to show the script T pattern with a plus area in the north and the long curved minus area in the south. Fortunately we are able to look somewhat into the future. I have combined the maps for 1935-1937, and they show the highest known figures for the eastern Canadian region. It might be considered that this shows merely the increase in the network of northern Canadian recording stations. But I present the evidence of the two squares in Quebec, north of the Gaspé. Figure 12 shows the number of barometric depressions that crossed these two squares from 1883 to 1940. This diagram is another evidence that tends to confirm my confidence in the early records of tracks of storms. The early years show approximately the same high frequency as the later years; the year 1894 with 56 barometric depressions almost equals the high of 1937 with 57 storms. We note that in 1895 there was a sudden drop from 56 to 17 and in a few years to 2. Furthermore, we notice that in 1940 there was a sudden drop from a high of 57 to 29 and that the interval between the two sudden drops was 45 years, exactly four solar cycles. I think there can be little question that the years of minimum, 1941-43, will show a decrease in eastern Canada. With the plus area in eastern Canada assured, we shall have to wait 3 or 4 years for the possible completion of the lower part of the script T pattern.

How shall we interpret these findings? We naturally first think of the alternations in solar activity as shown in the accompanying table, figure 13, and of Clayton's northerly shift of the centers of action with increased solar activity, but the figures resist attempts at correlation with the observed reversal. It seems, therefore, necessary to consider the theory that solar activity may possibly be completed in four cycles, of which the third and fourth are in some mysterious way the exact reversal of the first and second. We have become accustomed to the idea of a reversal of solar activity through Hale's discovery of a reversal of magnetic polarity with each new solar cycle. But in what way could such a Hale cycle itself be reversed?

Finally a word concerning the years selected for comparison. It will be remembered that for the first three and a half periods I selected by inspection from Maunder's chart of sunspot latitudes the years of maximum overlapping and used 3 years on either side of such a year. Maunder's chart does not include the minima of 1923 and 1933; consequently I selected these years as boundaries. Figure 14 summarizes the official years of minimum and maximum solar activity, together with my periods selected as described. I would call attention to the fact that the first and third periods begin 2 years after the official minimum; the second period, 1 year after minimum, and the fourth period begins with the minimum. There are very slight differences in the Wolfer sunspot numbers which determine the solar minimum, and it seemed worth while to test the matter by making a series of maps using the official minimum year as the boundary; for the fifth test period, which was originally so bounded, I included the minimum year and have already presented it as the superior map. In figure 15 I present the first period. The central plus band is strengthened, but the southern minus band is weakened. My original period seems to be the best for the three-banded effect. In the second period, figure 16, the plus band in the north is weakened, uncovering, as it were, a narrow band of minus which crosses the map. Also the southern curved minus area is weakened. Again my original period is the best. In the third period, figure 17, the northern plus band is weakened; otherwise, there is little choice. The fourth period, figure 18, shows the greatest discrepancy, with a great weakening of the northern minus band and the introduction with the year 1916 of a new strong plus band. There is also a weakening of the southern plus curve. It is evident that for the solar influence presented in this paper my original period is far the superior. The last period, figure 19, shows a widening and strengthening of the northern minus band and I have consequently chosen it as the best representative of the three-banded effect. Why, with this one exception, my original periods best bring out the solar effect here presented I cannot venture an opinion; it is, however, of interest, that with the exception of the fourth period, a shift of 1 year, and in one case, of 2 years does not vitiate the results.

These, then, are my findings, and I offer them to those more competent than I am for interpretation.

I append the year maps of storm frequency for 1931-1940, forming a series of 58 year maps, made with care according to a uniform technique, to which can be added the years 1874-1882, now in manuscript.

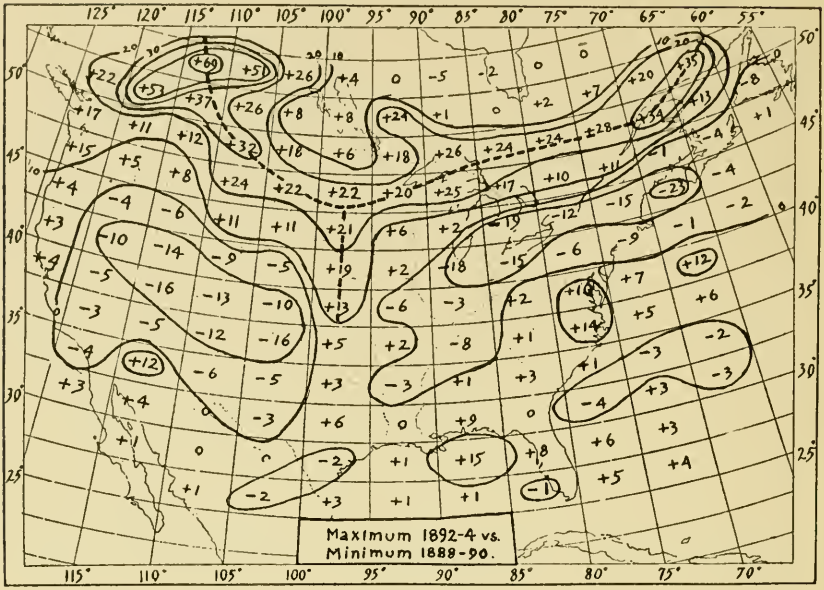

Maximum 1892-4 vs.
Minimum 1888-90.

FIG. 1.

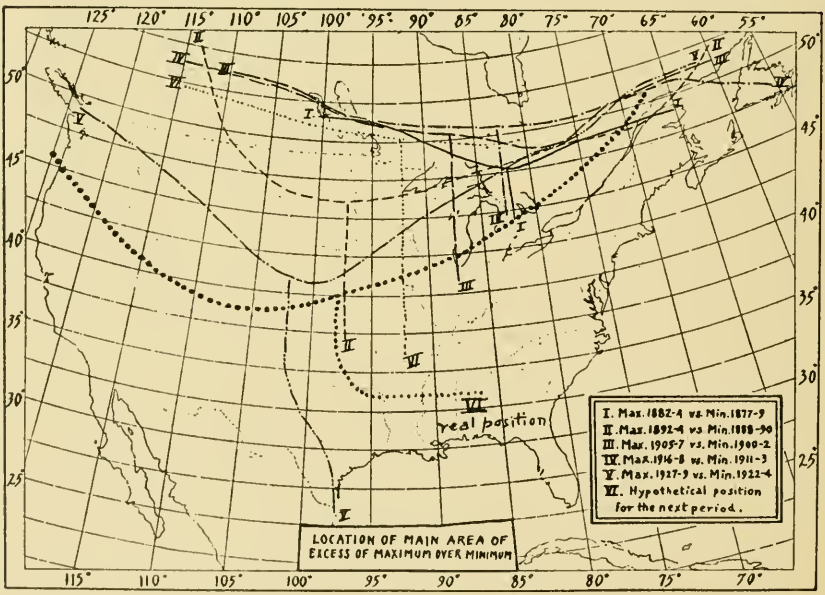

real position
I. Max. 1882-4 vs. Min. 1877-9
II. Max. 1892-4 vs Min. 1888-90
III. Max. 1905-7 vs. Min. 1900-2
IV. Max. 1916-8 vs. Min. 1911-3
V. Max. 1927-9 vs. Min. 1922-4
VI. Hypothetical position for the next period.
LOCATION OF MAIN AREA OF EXCESS OF MAXIMUM OVER MINIMUM

FIG. 2.

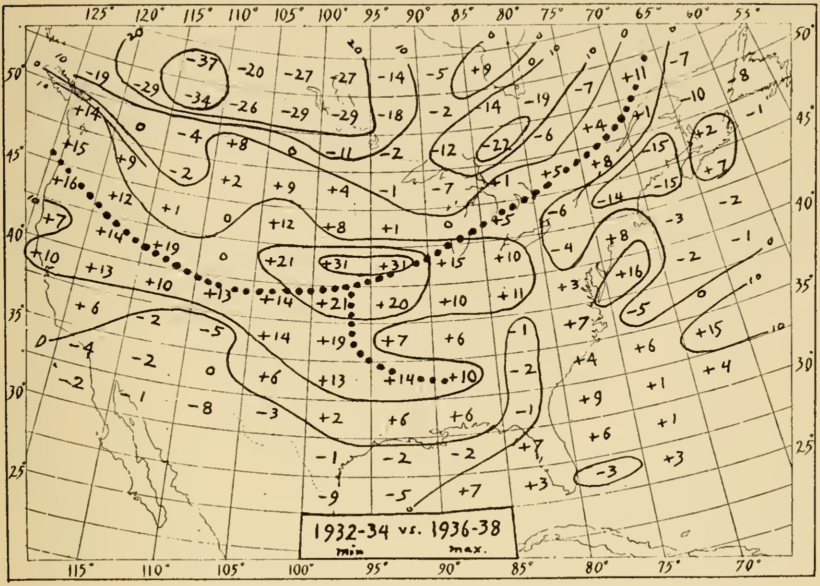


FIG. 3.

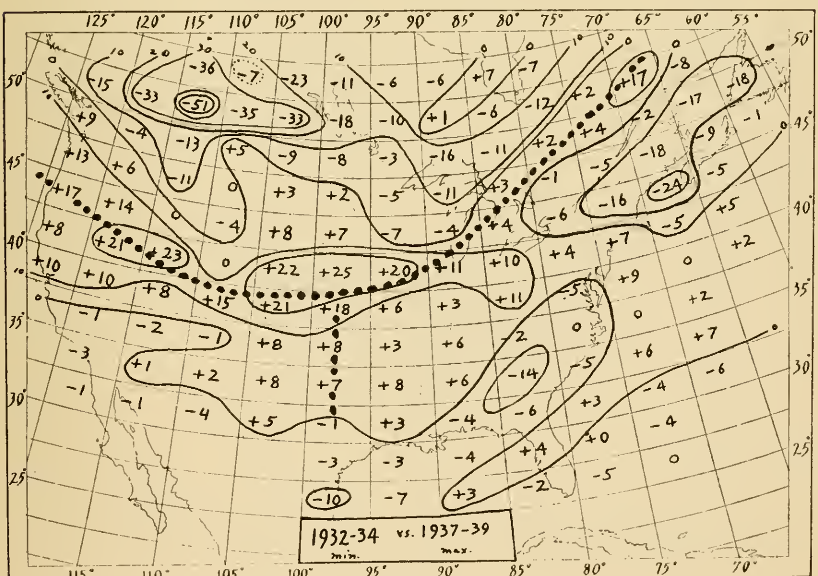


FIG. 4.

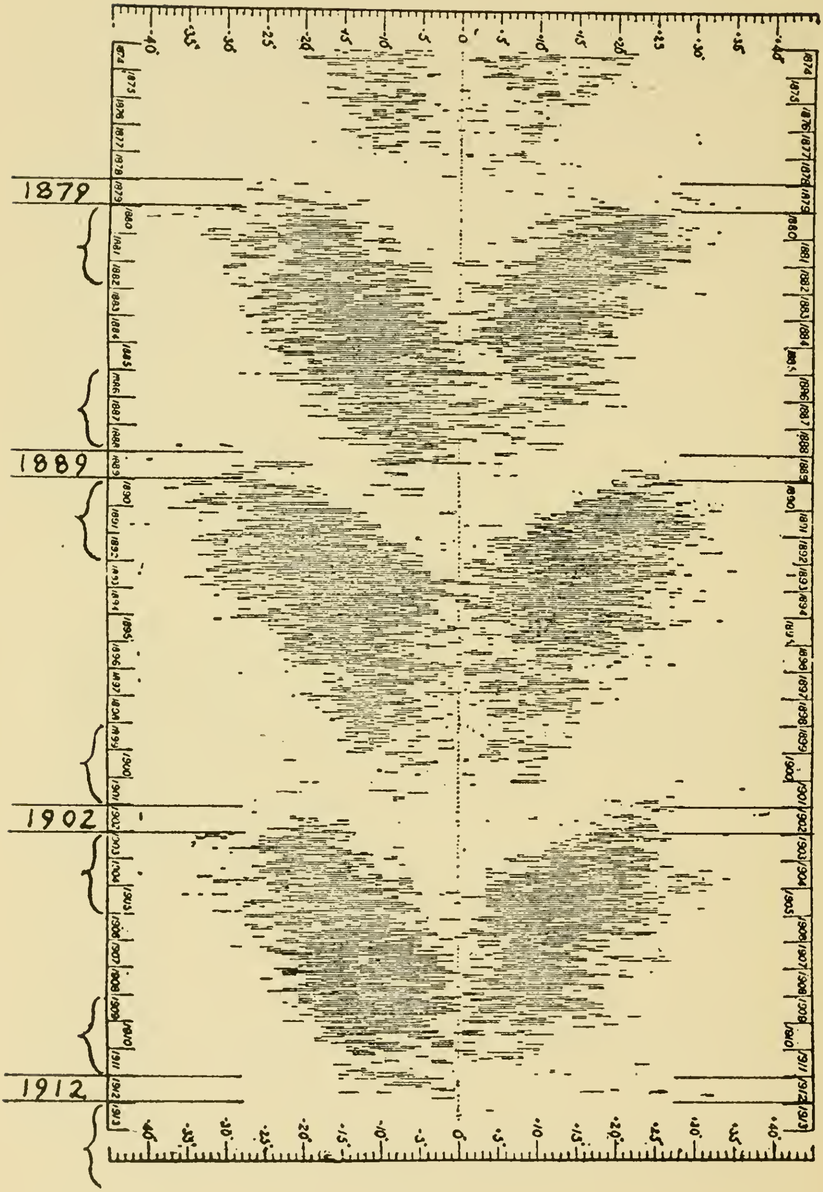


Fig. 5.

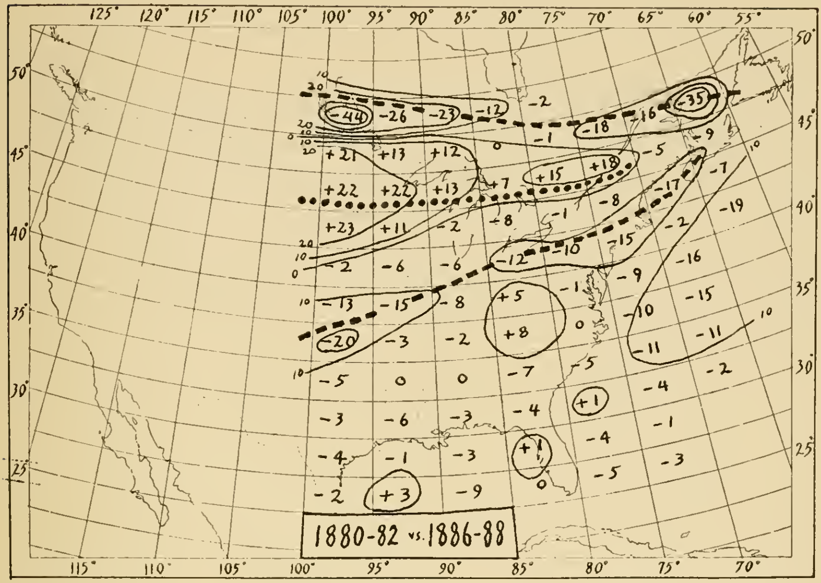


FIG. 6.

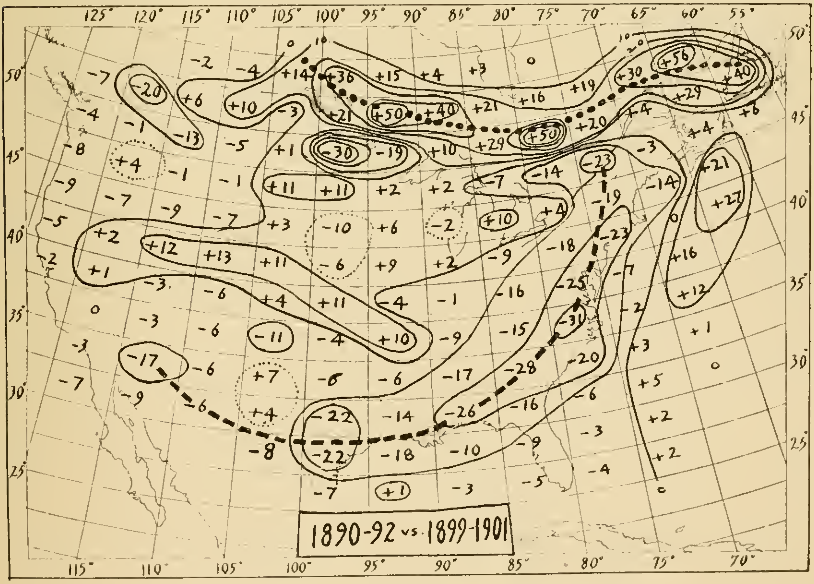


FIG. 7.

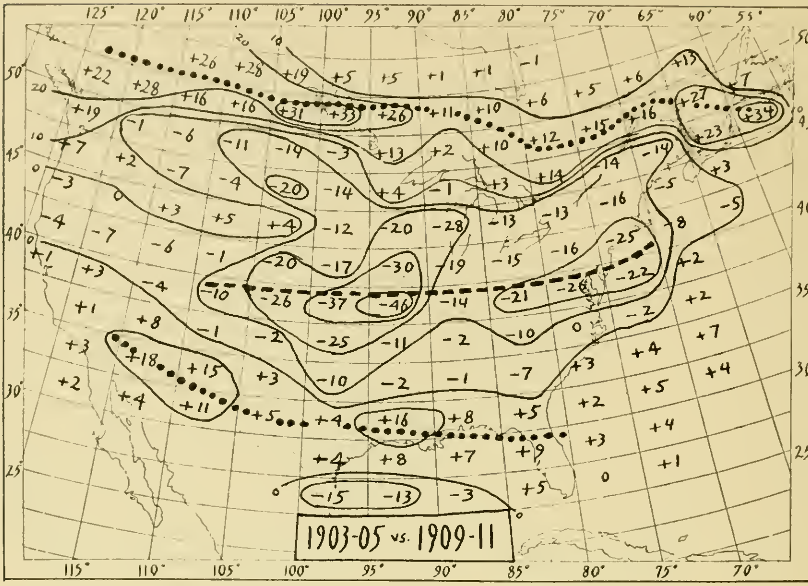


FIG. 8.

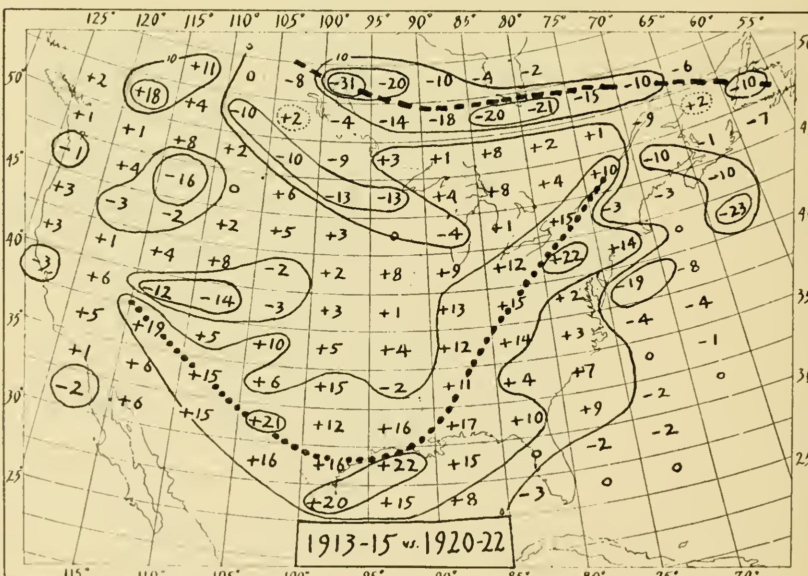


FIG. 9.

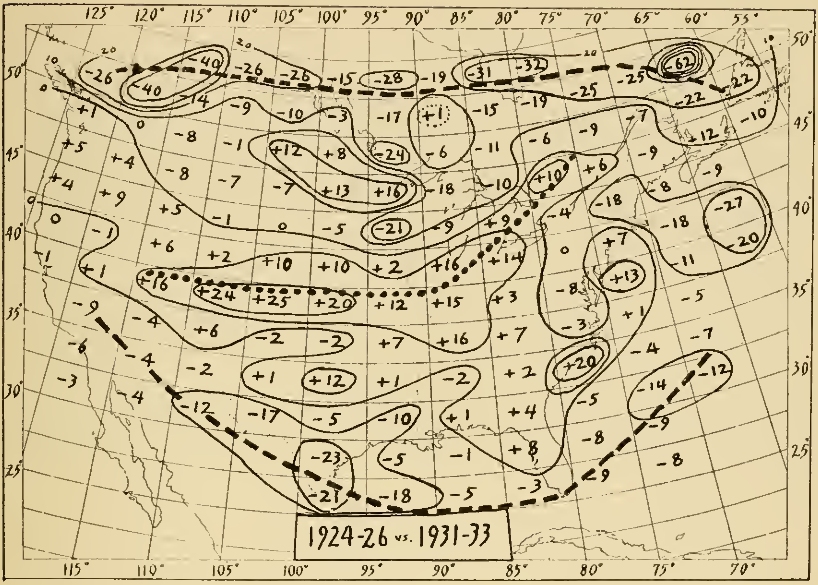


FIG. 10.

1880-82	1890-92	1903-05	1913-15	1924-26	1935-37
vs.	vs.	vs.	vs.	vs.	vs.
1886-88	1899-01	1909-11	1920-22	1931-33	1941-43?
Three bands	Two bands in a ℐ pattern	Three bands	Two bands in a ℐ pattern	Three bands	?
minus	plus	plus	minus	minus	plus
plus	—	minus	—	plus	?
minus	minus	plus	plus	minus	

FIG. 11.

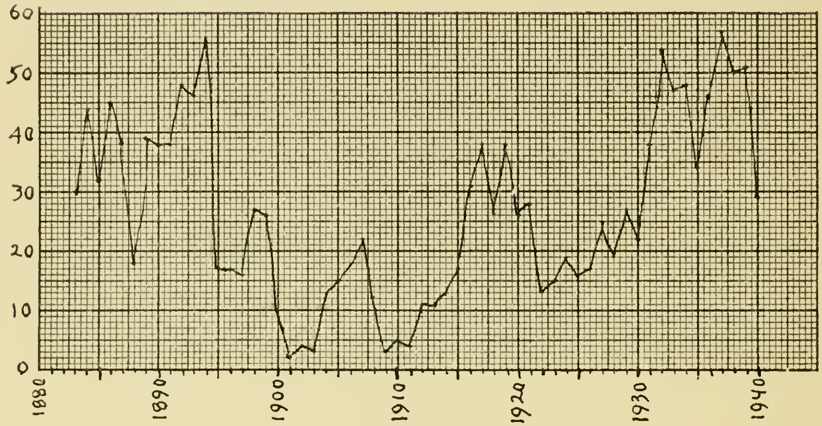


FIG. 12.

1870	Max.	**139.1**	
1883	Max.	63.7	Three Bands
1893	Max.	**84.9**	ꟻ Pattern
1905	Max.	63.5	Three Bands
1917	Max.	**103.9**	ꟻ Pattern
1928	Max.	77.8	Three Bands
1937	Max.	**137.0**	? ꟻ Pattern

FIG. 13.

Years selected	Min.	Max.	Test years
1880-82 vs. 1886-88	1878	1883	1879-81 vs. 1886-88
1890-92 vs. 1899-01	1889	1893	1890-92 vs. 1898-00
1903-05 vs. 1909-11	1901	1905	1902-04 vs. 1910-12
1913-15 vs. 1920-22	1913	1917	1914-16 vs. 1920-22
1924-26 vs. 1930-32	1923	1928	1924-26 vs. 1931-33
	1933	1937	

Fig. 14.

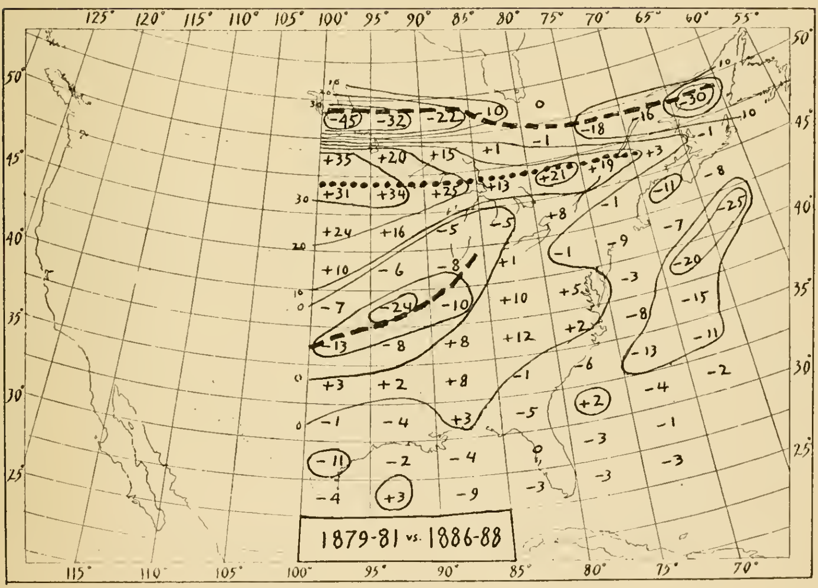


Fig. 15.

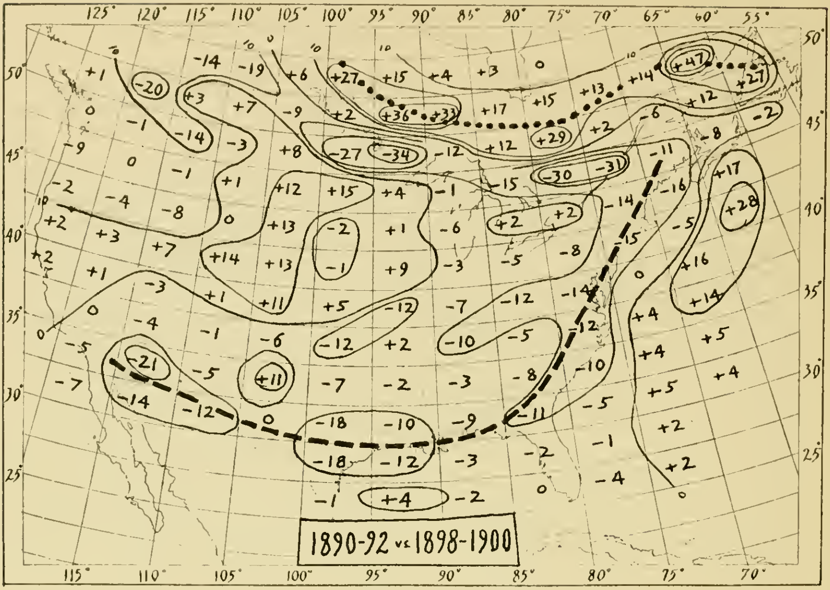


FIG. 16.

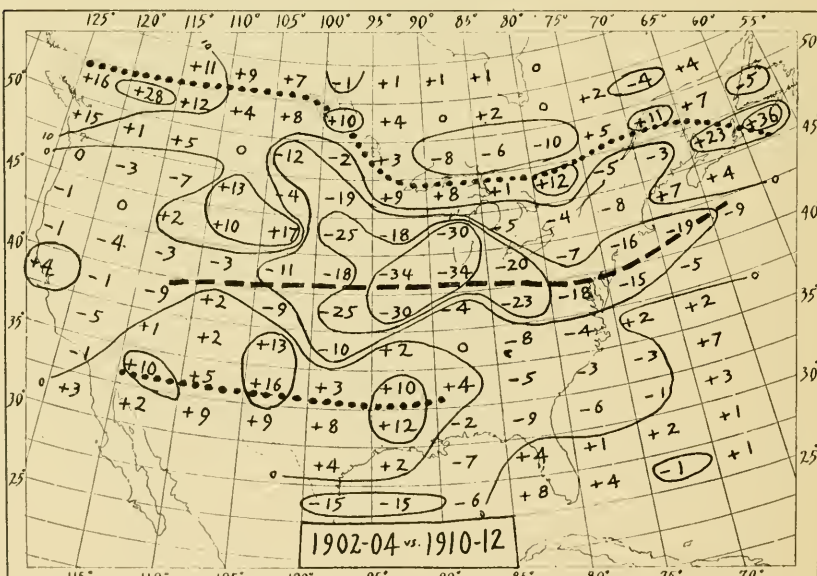


FIG. 17.

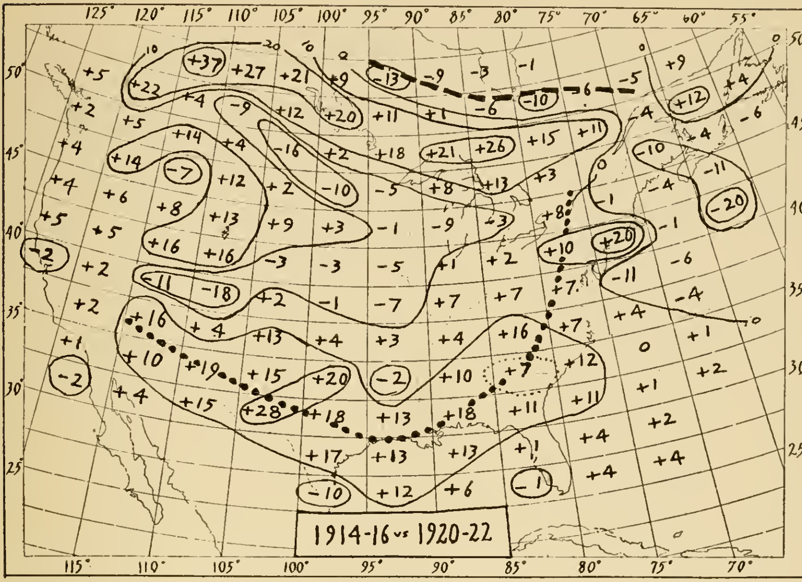


FIG. 18.

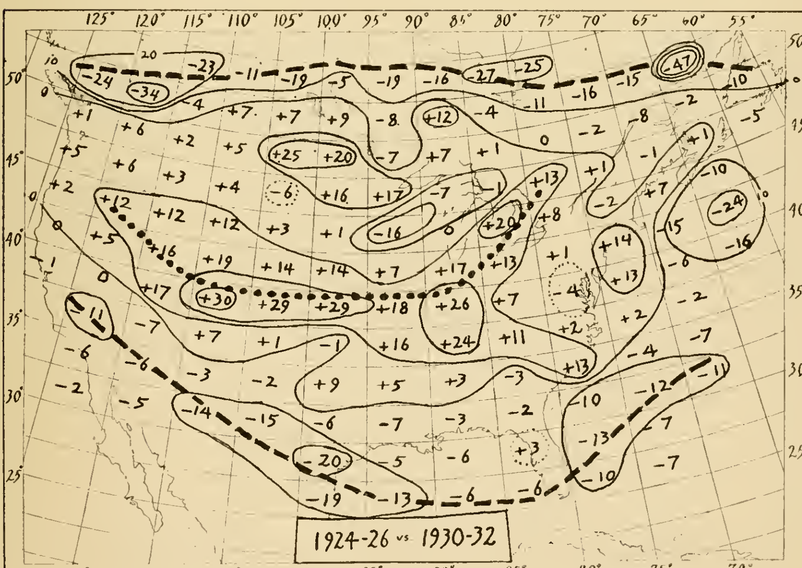
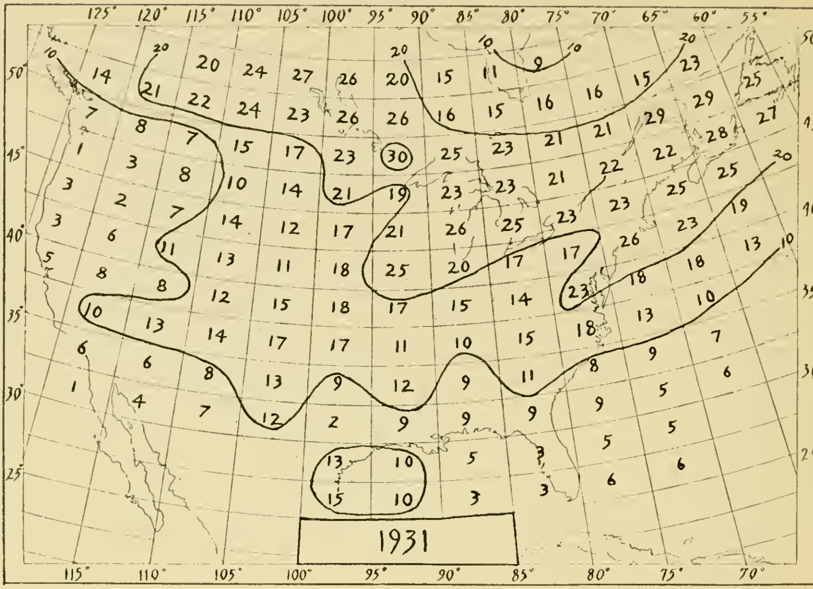
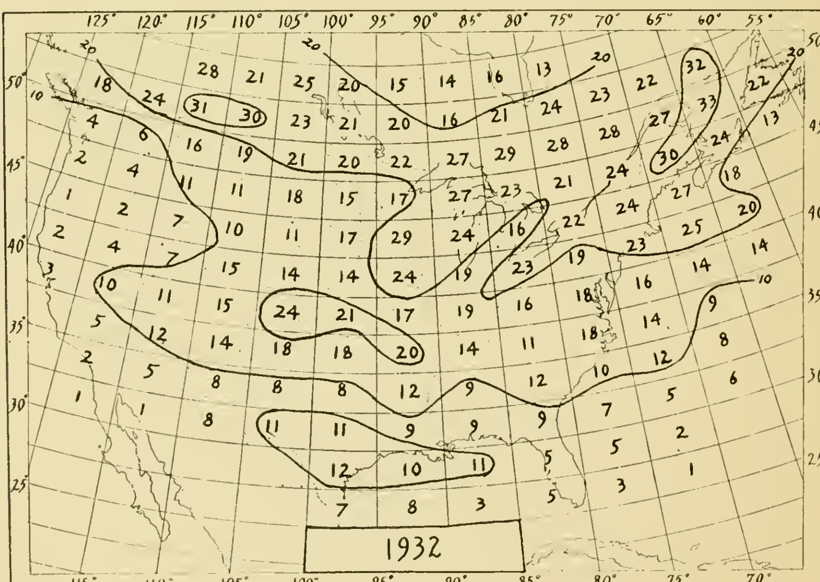


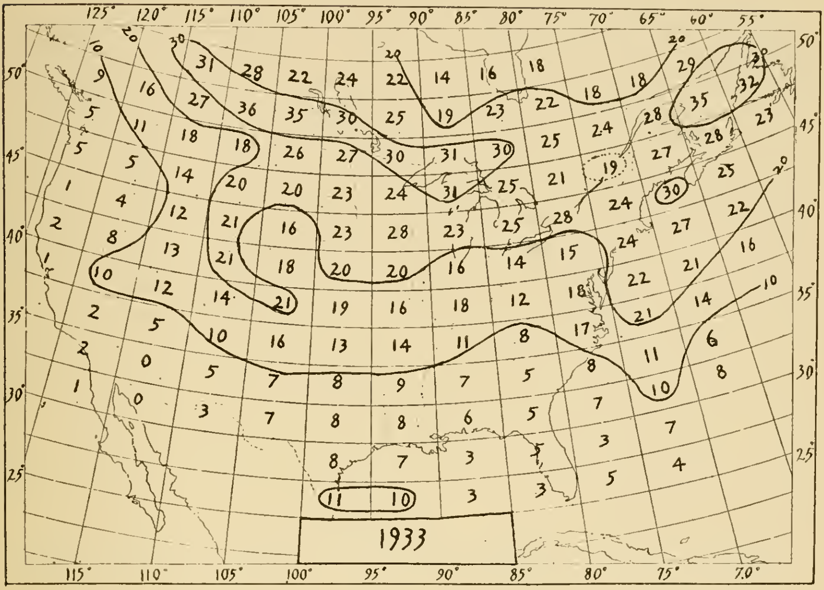
FIG. 19.

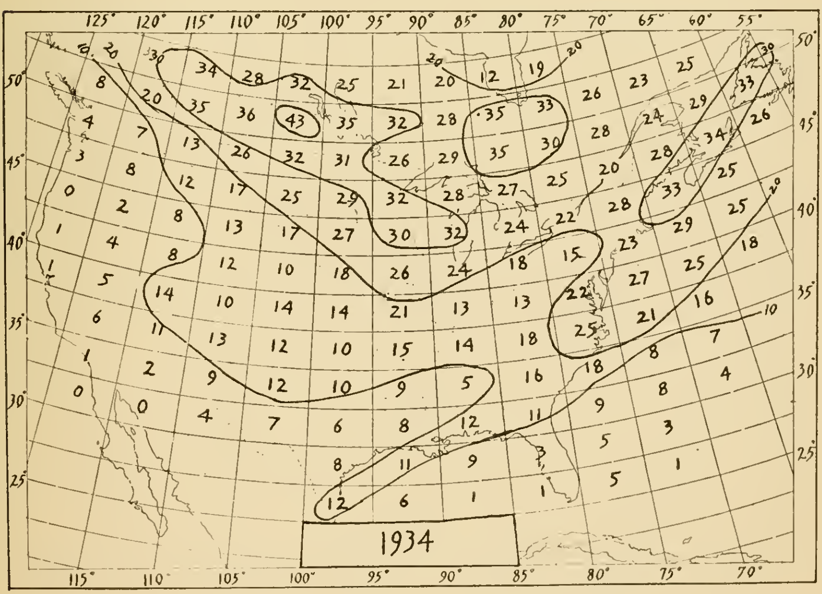
1931 and 1932



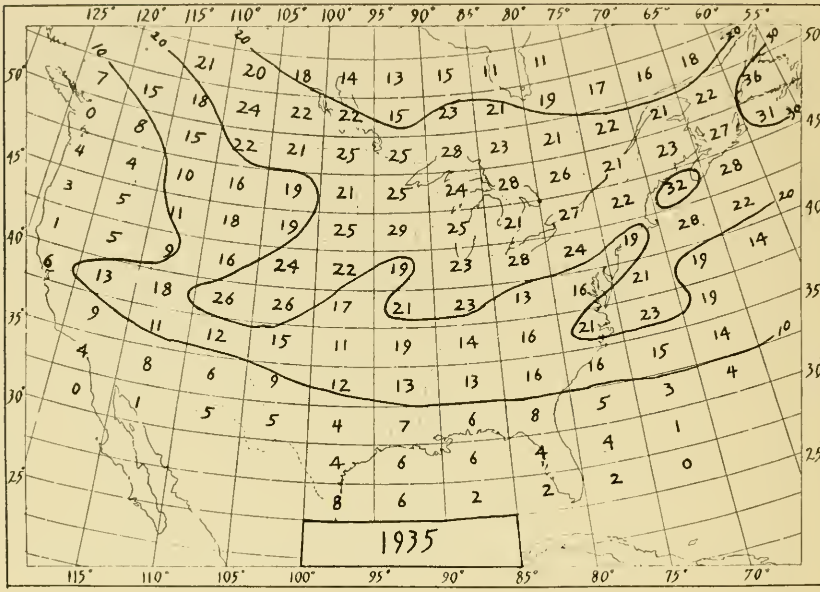


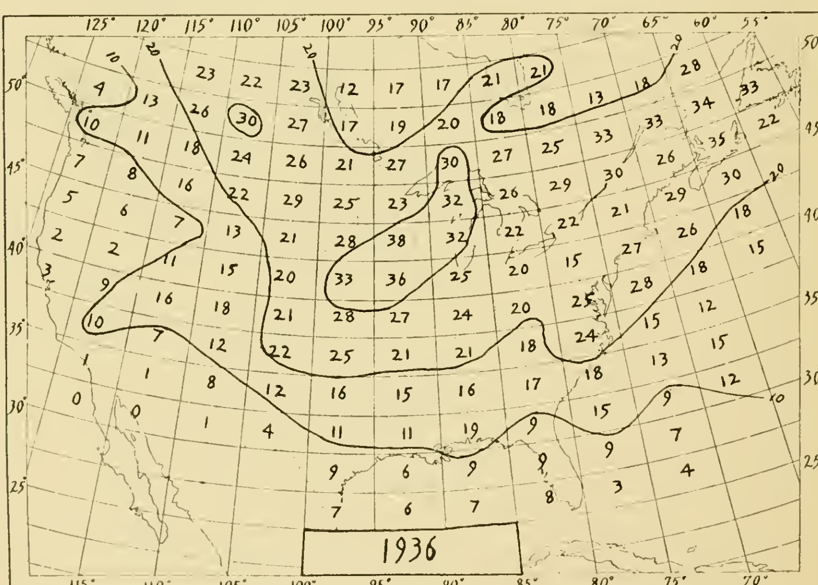
1933 and 1934



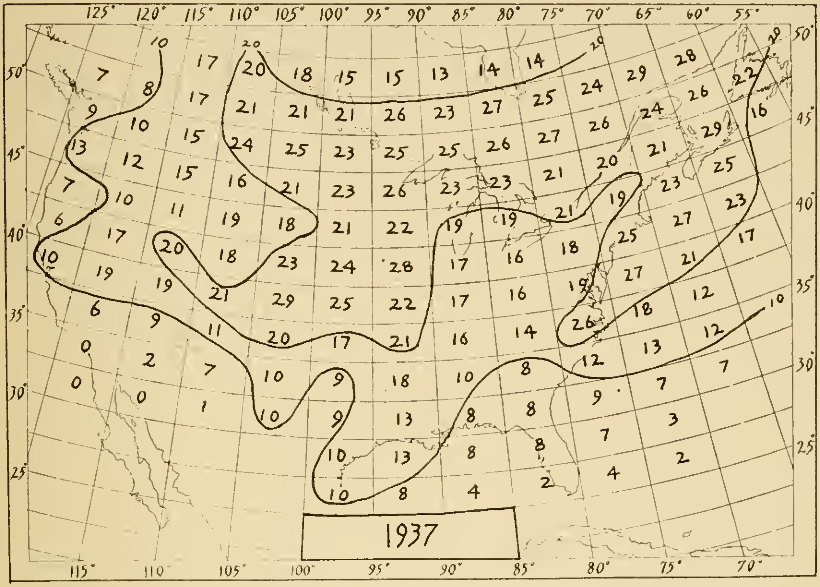


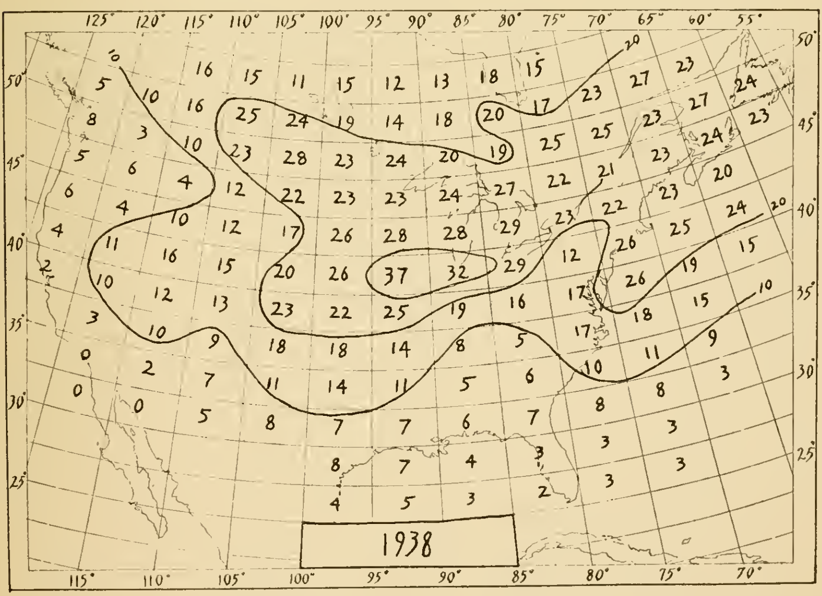
1935 and 1936





1937 and 1938





1939 and 1940