

The Sun Spot Cycle and Temperature Departures at Indianapolis, Indiana, 1872-1936

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Since the discovery of the periodicity of sun spots by Heinrich Samuel Schwabe, who published his findings in 1843, there has accumulated an enormous volume of literature dealing with investigations of possible relationships between the solar cycle and terrestrial phenomena. Weather variations, climatic changes, plant growth, crop yields, floods, earth magnetism, and human health and behavior have been correlated with the sun spot cycle. The works of Stetson (1) and Clough (2) may be cited as examples of such studies.

The possible effect of sun spots on weather, particularly temperature, has been a popular field of investigation. These investigations seek to establish a definite periodicity in weather variations which will correspond with those of the sun spots. The conclusions of these studies are conflicting. The negative attitude may be illustrated by the following quotation (3): "It is certainly impressive to the thoughtful mind to realize that there is even a slight connection between solar and terrestrial phenomena but the delicacy of this connection is such that it still remains true that the study of meteorology is essentially the study of the earth's atmosphere as acted upon by a constant source of heat, the sun. None of these astrophysical studies should tempt the meteorologist to wander far from the study of the dynamics of the earth's atmosphere and the effect of the oceans and the continents that diversify the earth's surface." The following (4) illustrates the positive attitude. "The principal departures from normal climates which comprise weather are due primarily to a group of periodic variations of the sun's radiations rather than to terrestrial complexities, as has been generally supposed. Sun spots are associated with important modifications of weather not hitherto recognized."

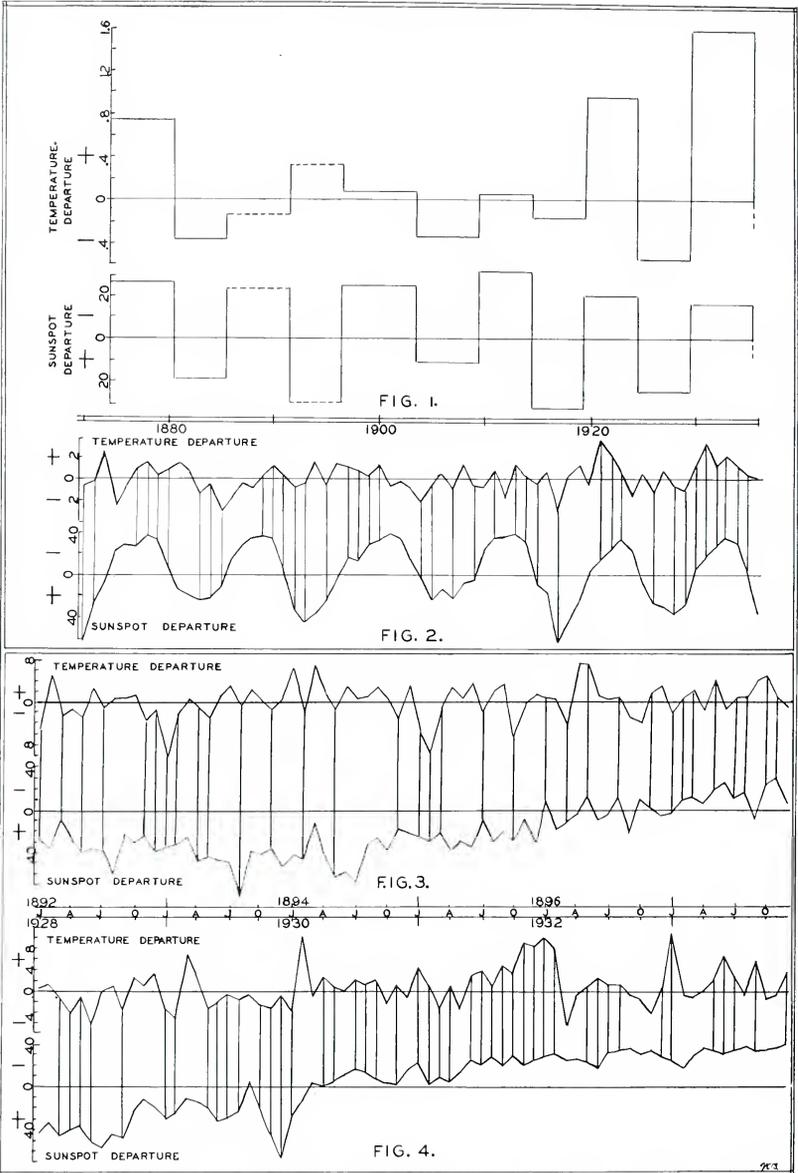
Among those meteorologists and astrophysicists who hold that there is a measurable relationship between sun spot activity and weather variations, there is disagreement as to the nature of the relationship. With regard to temperature, some believe the relationship to be inverse, *i.e.*, an increase in sun spot activity results in decreased temperatures, and a decrease in sunspot activity brings about an increase in temperature. This viewpoint can probably be traced to the works of Köppen and Mielke (5) and has had a more recent application in the work of Henry (6).

This paper investigates the relationships between temperatures for Indianapolis, Indiana, as recorded by the United States Weather Bureau (7) and the Wolf sun spot index numbers (8). These data are plotted to check the assumption that the solar and terrestrial relationship is inverse.

In figure 1 the sun spot index numbers are averaged for the epochs

in which the solar activity was above or below normal. The departures above or below normal are plotted along a base line which represents the average annual sun spot number.

Between 1875 and 1937 there were six epochs in which sun spot



Figs. 1-4.

activity was below average. The longest period of minimum sun spots, seven years, included the years 1897 to 1903. Two periods, 1910 to 1914 and 1920 to 1924, were but five years each. The epochs of maximum sun spots between 1875 and 1937 were five in number. One epoch, 1904 to 1909, lasted six years. The other four epochs had a length of five years each.

The temperatures plotted in figure 1 are the average of departures from normal for the years included in the epochs of maximum and minimum sun spot activity. For the years 1875 to 1880 the average temperature departure was above normal, and the sun spot activity was below normal. Thus, for this epoch an inverse agreement is established.

For the eleven epochs of maximum and minimum sun spot activity shown in figure 1, there is an inverse agreement between temperature and sun spot departures from normal in nine cases. The two exceptions occurred in the epochs of 1886 to 1891 and 1892 to 1896. This establishes, for Indianapolis temperature departures, an inverse agreement in about 82% of the sun spot epochs studied.

In figure 2 sun spot and temperature departures from average are plotted by years. According to the original assumption, a plus sun spot departure should be associated with a minus temperature departure, and a minus sun spot departure should be associated with a plus temperature departure. Where such agreement occurs in figure 2, vertical lines connect the points of agreement.

In the 65 years between 1872 and 1937, 40 years agreed inversely in temperature and sun spot departures. This is an agreement of about 62%.

It is possible that an increase or decrease in solar activity might affect temperature departures inversely but not sufficiently to bring them above or below average. Thus, there might be an agreement in trend which would not be represented by the vertical lines in figure 2. Such a situation is illustrated in the years 1875 to 1876. Agreement in trend is apparent in 37 of the 65 years charted. This is an agreement of about 60%.

Figure 3 and figure 4 represent sun spot and temperature departures from the monthly averages. They are sections from the chart covering the 780 months between 1872 and 1937. Figure 3 shows the 72 months in the period 1892 to 1897, and figure 4 the 72 months in the years 1928 to 1933. In figure 3 inverse agreement occurs in 34 of the months concerned for an agreement of about 47%. In figure 4 inverse agreement is found in 44 months, an agreement of about 62%.

For the full chart there is agreement for 396 of the 780 months considered. This is an agreement of 51% or only slightly better than might be expected from the operation of the law of chance. The highest agreement occurs in the years 1921 and 1929. Ten of the 12 months in each of these years had temperature departures varying inversely with the sun spot departures. The lowest agreement occurred in 1875 when only two of the 12 months were in agreement.

Agreement in trend between sun spot and temperature departures as revealed by the monthly chart shows that form of agreement in 378 of the 780 months or in about 49% of the cases considered.

Solar activity in any given month might be reflected in temperature departures not for that month but in some subsequent month. The possibility of a lag in agreement was investigated on the monthly chart. Allowing a time interval of one month, it was found that 370 of the 780 months considered agreed inversely for a percentage of about 48. Increasing the lag interval beyond one month did not consistently increase the percentage of agreement.

The following conclusions may be drawn from the above discussion:

1. Temperature departures from the average are most likely to agree inversely with sun spot departures when the period used is the epoch of maximum and minimum sun spot activity. Over a 62-year period at Indianapolis, which covered 11 epochs, there was an agreement of 82%.
2. With shorter time intervals, the year or the month, the agreement becomes less pronounced, that for the year being 62% and that for the month 51%. The monthly agreement is about what might be expected from the operation of the law of chance.
3. Agreement in trend seems to be less significant than the actual agreement in departure from the average.
4. There is no evidence that a lag interval of one month or more increases the percentage of agreement.

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