

be used in devices having practical applications.

Articles identified in this way may be depicted as interconnected elements on a citation map. Replotting of the maps periodically enables the growth, decay and changing interrelationships of specialities to be studied. It seems likely that this will provide an overview of the ramifications of science for the benefit of science policy makers and others.

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Great Plains weather

Sir,—A number of authors have pointed out the periodicity or quasi-periodicity of 20 to 22 years in the recurrence of droughts in the Great Plains of North America, the region between the Rocky Mountains and the Mississippi River. Perhaps most notable of these droughts was the "Dust Bowl" era in the 1930s which retarded the Great Plains agriculture and economy for a full decade. Most authors have also pointed out that the mid-years of the droughts coincide fairly well with every other sunspot minimum, specifically the minimum in which the polarity of the leading spots in the Sun's northern hemisphere is changing from north-seeking to south-seeking.

Since we are now approaching another solar minimum of the type mentioned, the question of the reality of the sunspot drought relationship is of great interest. The dates of the four most recent solar minima of this kind, and the central year of the four most widespread droughts in the Great Plains, were as follows:

| Sunspot minima | Mid-years of droughts |
|----------------|-----------------------|
| 1889 | 1892 |
| 1912 | 1912 |
| 1933 | 1934 |
| 1954 | 1953 |

The causes of these droughts are not well understood. J. R. Borchert has pointed out that some of these in the table were associated with greater than normal zonal circulation of the atmosphere, and some with increased meridional flow, evaluated on a hemispheric basis. The common element in drought situations seems to be stability in the type of weather pattern, that is, drought tends to be associated with a highly persistent pattern, either meridional or zonal.

I. R. Tannehill points out that drought in the Great Plains is associated with higher than normal pressure in the eastern Pacific area, whereas others find that droughts in western Kansas tend to occur simultaneously with positive height anomalies at 700 millibars over the eastern Pacific between latitudes 30° and 40° N and with negative surface temperature anomalies

over the eastern tropical Pacific.

In the spring and summer of 1974 there was evidence for the beginning of another drought in the Great Plains. If the situation is the same in most of the next several years, we may well conclude that the periodicity of 20 to 22 years is recurring. A sunspot minimum of the type mentioned; is expected in, perhaps, 1976.

In the spring the drought was confined to the western and southern parts of the Great Plains (Fig. 1). Most of the Great Plains region was actually suffering from too much rainfall, with serious delays to the starting of the spring planting in large areas. Meteorologically, the region was affected by greater than normal westerly wind flow. Thus the drought in the area just east of the Rockies may perhaps best be described as primarily a rain-shadow effect.

By mid-June and extending through July (Fig. 2), the situation had changed to a more meridional flow, with a stable high pressure cell over the Mississippi Valley in the upper atmosphere. This created an extended period of low precipitation and abnormally high surface temperatures just at the time when

certain crops, such as corn and soy beans, were reaching the maturing stage. For instance, Grand Island, in central Nebraska, reported no precipitation from June 15 until July 22, the longest rain-free period ever recorded at that station. The resulting damage to crops in such states as Iowa, Kansas, Nebraska, Oklahoma and adjoining states approached \$10,000 million dollars. This loss was caused mainly to the extreme but short summer drought, but also in part by the spring drought in western Oklahoma and northern Texas.

A mere coincidence in timing between the droughts and the double sunspot cycle will not, of course, constitute proof of a physical relationship. If, however, the drought of the 1970s does materialise, over the next several years, we will have a very strong incentive to search for physical mechanisms to explain the linkage or to provide other reasons for the recurrence.

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