Although most precipitation falls as rain and rain is usually of chief interest, other phases of precipitation have great importance at times. Examples are damage caused by hail and by freezing rain. Early winter snow cover helps insulate the underlying soil, but late melting of the snow retards spring plowing and planting. The Cooperative Snow Investigations of the Corps of Engineers and the Weather Bureau has improved our understanding of the physical properties of snow—how fast it melts under various weather conditions and how rain or snow is retained or transmitted. Studies of records of snowfall and accumulation have given builders and others yardsticks for measuring snow loads that buildings can carry and for designing and using equipment for melting and removing snow.

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*The history of every nation is eventually written in the way in which it cares for its soil.*—FRANKLIN D. ROOSEVELT

# Is Weather Subject to Cycles?

Ivan R. Tannehill

Droughts and floods often cause us to think about possible cycles, rhythms, and trends in the weather.

Daily and yearly changes in rainfall are obvious and were recognized long ago as caused by the motion of the sun and the consequent variations in temperature and wind. The first world travelers learned that in some places rain falls at about the same time almost every day. Then, too, in many regions dry and wet seasons or other variations in the rainfall are more or less regular every year. The knowledge of some of those phenomena has encouraged a search for cycles.

In most land areas the daily and seasonal variations in the rains are not very regular or dependable. (In this discussion rainfall includes snow and other forms of precipitation.) The dry and wet spells come at irregular intervals. In many regions a succession of years or seasons drier than normal followed by an extended period of wetter weather is common. Rainfall in the amounts adequate for agriculture usually is more dependable on the lands near the sea. As we go inland it becomes less regularly so, until we reach the deserts and arid regions. There are exceptions, however, for which the causes are obvious. The deserts of Peru, for instance, are close to the ocean, but the moist sea winds are relatively cool and stable and acquire no upward motion. Little or no rain results, for atmospheric processes are such that rain must come from air that is being cooled in one way or another. Mountainsides facing the sea, with moist winds blowing upward and becoming cooled, have plenty of rain, while on opposite slopes the air is warmed in descent and becomes dry even if it is not far from the ocean.

Thus for many reasons the daily and seasonal rhythms in rainfall are imperfect. At times they cease altogether. In this respect rainfall is more difficult to predict than temperature. Daily and yearly variations in temperature are fairly regular, although marked changes result occasionally from large horizontal motions of the atmosphere. As a rule, the temperature is high in the afternoons and low in the early mornings, lagging after the sun, but in middle and higher latitudes the temperature on any one night often is warmer than during the preceding or following day. Summers range from cool to hot and winters from mild to very cold, depending on broad-scale motions in the atmosphere. In more complicated ways and in greater frequency than temperature, rainfall departs widely from normal or average daily and seasonal patterns.

The great economic importance of variations in rainfall in some parts of the world has induced many investigators to look into cycles for an answer to long-term forecasting.

In a review of many claims, one British meteorologist counted more than 130 different cycles of which one or more investigators had found evidence in the weather records. Many more have been indicated by tree-ring measurements and other data. It is probable that no matter what happens in the rainfall it can be made to fit one or more of the numerous cycles.

Aside from the daily and annual periodicities, cycles can be divided into two classes. First are those derived from the records without any explanation of their causes. In this group are many that run for so long a term of years that no acceptable verification is possible at present. Others, derived from analyses of shorter periods, persist for a time and then fail altogether or are reversed in phase.

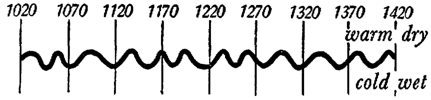
One of the most notable was the 35-year cycle named after its author, Eduard Brückner, a climatologist in Vienna. The cycle, based on rainfall records from 1815 to 1890, averaged 35 years but was quite variable within the limits of 20 to 50 years. He also showed evidence of such a cycle in the years 1020 to 1420, based mostly on records of severe European winters. Brückner's cycle became well known in later years, but the variation in rainfall is small and too irregular to be of definite value in prediction.

Nearly all persons who engage for a year or more in predicting weather from maps find now and then that the current map looks a good deal like some preceding map. If the forecaster has a file of back maps or an index to them he can refresh his memory. Sometimes, but not very often, the resemblance is good, and the development of the weather seems to have been much like that in the current case. The back map is called an analog.

For this purpose the maps over a long period must be cataloged so that the forecaster can classify the current map—much as a fingerprint is classified—and find similar maps at the same season in other years. In tests covering 40 years of maps, many analogs have been found, but only a few can be called excellent. The advantages of the method seldom justify the time required, and it has not been used as standard practice in many forecasting offices.

That points to the probability that there are no clear-cut cycles or rhythms in the weather. Nevertheless, at intervals, a surprisingly good forecast is made of an unusual development in the weather because of the forecaster's recollection of a similar case, sometimes many years before.

In the second group of cyclical variations are those for which a motivating force has been suggested but the processes in the atmosphere that lead from cause to effect cannot be explained. The moon, for example, appears to influence weather, but no one can explain how. Other forces of the same kind have been suggested (and some of them may possibly be real), but doubt centers around the lack of a satisfactory explanation.




*Eduard Brückner's weather cycle for the years from 1020 A. D. to 1420 A. D. It is based mostly on records of the severity of European winters. (After Gregory.)*

Another group of variations in the second class is attributed to solar changes. Attempts are made to show how the varying energy from the sun causes the changes in the temperature and the circulation of the atmosphere that seem to account for certain cyclical patterns in rainfall. While the solar hypothesis is more acceptable on a physical basis than many others, it suffers in two ways. For one, the circulation of the atmosphere and its variations are complex, and the effects of solar changes are extremely difficult to trace. In fact, no acceptable theory explains fully how solar effects are converted to changes in the weather.

In another respect, the usefulness of conclusions derived from the solar hypothesis has been questioned, for the changes in the sun are not regular.

THE SUNSPOT CYCLE, which averages approximately 11.3 years, has been as short as 7 years and as long as 17 years. We have yet no generally accepted method of predicting solar variations so that the resultant weather changes can be foreseen in any detail.

Through millions of years of geological time, unquestioned evidence appears of great oscillations in world climate, and several hypotheses have attempted to explain them. In the case of oscillations within historical times, however, the evidence points to two probable causes—the effect of dust thrown into the atmosphere by volcanic eruptions and the effect of the sun's radiation. Only the latter is cyclical in nature.

Weather has other rhythmic or recurrent features. The atmosphere over a hemisphere or a large part of it may exhibit a certain resonance. The change in temperature that comes with a single rotation of the earth on its axis may not be sufficient to start a large-scale motion in the atmosphere, but the accumulated effect of heating and cooling in a number of successive rotations may find a resonance in the atmosphere over a region and a periodic change may set in. That can result in rain every fifth day or every seventh day, or at some other interval, continue that way for a month, more or less, and then cease.

In large areas of the United States an interval of 4 or 5 days is the most common and persistent between rain-bearing disturbances. That fact is not very useful, however, unless the associated motions of the weather systems are watched on a map of the hemisphere or a large part of it.

Research in the upper air has shown a vast wavelike motion in the horizontal circulation of the atmosphere above the earth. Large-scale features of this circulation around the hemisphere change occasionally, but any given pattern tends to persist for a time, bringing a characteristic disturbance of rainfall to the lands below. The high-level winds over the United States in recent dry years, for instance, have some of the same characteristics as those in the dry years of the 1930's.

Some scientists believe there are vast oscillations between distant parts of the atmosphere whereby one may say, for example, that unusual weather in one world region in December may indicate or foreshadow dry weather somewhere else in the world the following month. Tremendous tasks in correlation of pressure, temperature, and rainfall for selected places around the world for succeeding months or seasons have been carried out, but they have not yielded much that is definitely useful. There has been more "cause-and-effect" weather forecasting by this type of foreshadowing, however, than by any other method. Nevertheless, the reasons advanced for the existence of the correlations are rather vague.

Other weather phenomena of the recurrent type are known as singularities. They are the spells of warmer or colder or wetter or drier weather than normal for the season that develop at certain times each year. The Northeastern States, for example, have their January thaw and Indian summer. Similar spells of weather are known in Europe. Winter storms in some parts of Europe tend to recur at the same time each year. Such spells and recurrences undoubtedly have a physical basis. Hurricanes occur mostly in the same months each year; therefore it must be true that the ocean heat, lagging behind the more rapid changes of temperature on the continents, is a major cause of hurricanes. But to the extent that that is true, hurricanes are merely a part of the annual cycle.

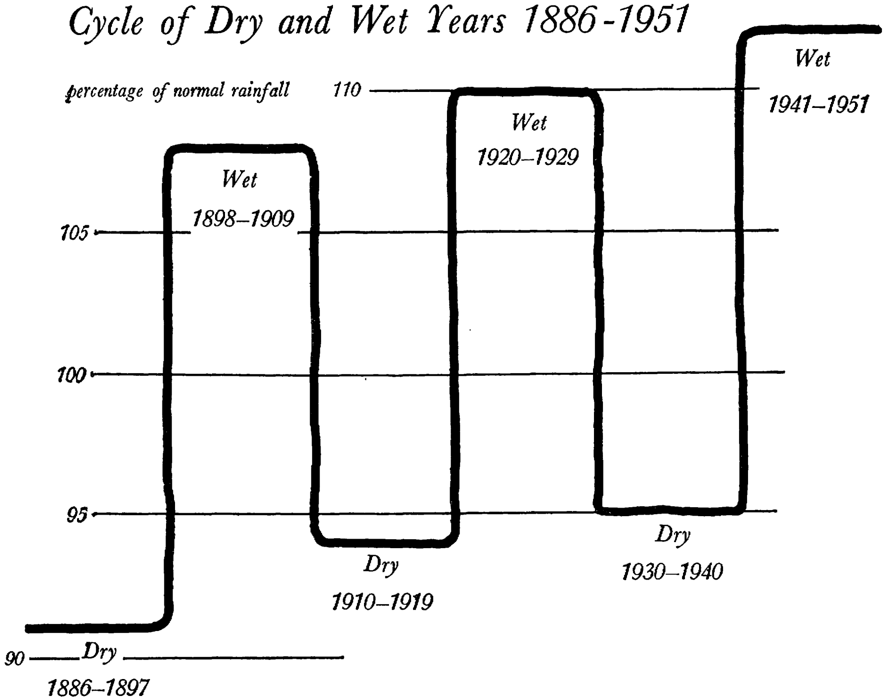
As we look through the literature at the amazing amount of work that has been done on so many phases of this question, we come to one definite conclusion—the problem is complex and any apparent cycles or rhythms that appear for a time in the rainfall records must be looked upon with suspicion.

Even if the so-called cycles or rhythms are demonstrated on a sound physical basis we are nevertheless, for another reason, forced to exercise a great deal of caution. There are long swings or trends in the weather, such as the rise of temperature in some parts of the world in the present century, recently so noticeable in winter in eastern and northern parts of this country and most pronounced in some Arctic regions. As this trend becomes dominant, a local rhythm or periodicity that depends in part on the recurrence of cold winters may gradually diminish and finally fade away or shift to higher latitudes. On the other hand, accurate weather records are generally too short to determine the nature and cause of the so-called trend or judge its future course. It is quite possible that long-term progressive changes in rainfall climates are cyclical or rhythmic, but of such long periods that our records do not reveal the facts.

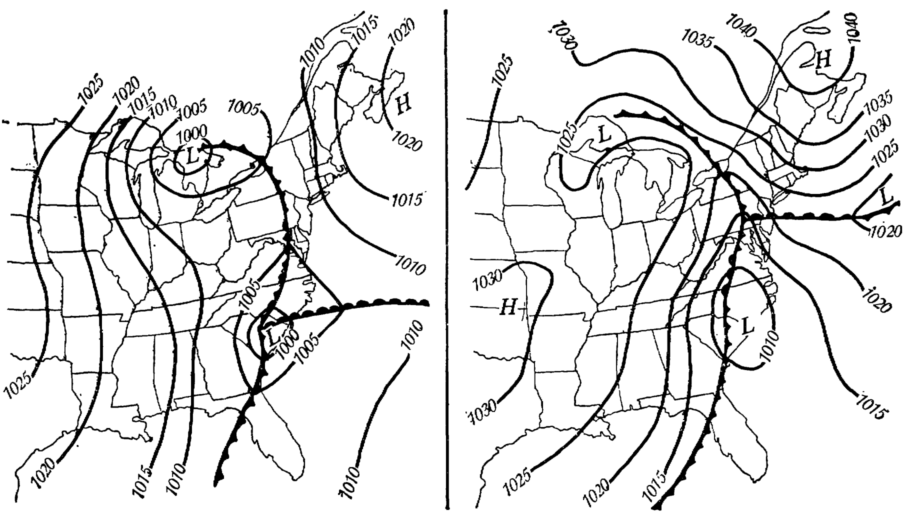
As world populations increase, some parts of the problem assume tremendous importance. In the United States the rainfall climates range from the superhumid in some Eastern and Southern States to the dry climates of large regions in the West and Southwest. We deal with the problems in various regions by irrigation, drainage, flood control, soil conservation, and similar practices. In a vast region, however, where rainfall normally is adequate for agriculture (though barely so in some marginal areas) it is so variable that frequently extremes cause minor or major disasters. In some degree, the situations are made more dangerous by man's actions, such as cultivation and denudation, which eliminate a part of Nature's stabilizing controls and contribute to disaster, at least in local areas.

THE METEOROLOGIST struggling with these questions adopts one or two general lines of attack, depending on his ability to understand what is going on or to extrapolate from the tendencies, trends, or rhythms apparent in the records. In neither case is he on very solid ground, but two phases of the work are definitely promising.

First, the broad-scale patterns of the atmospheric circulation tend to persist or to change slowly and to afford useful correlations with the main features of weather at the surface of the earth. In this work the meteorologist endeavors to extend his view more than 30 days into the future. He must have an intimate knowledge of the impact of change in one region on remote regions. For example, at certain critical times in the year, the patterns are apt to change, and a constant watchfulness sometimes yields deductions very useful for planning in agriculture and industry. Here the meteorologist has some background of experience because his predecessors, beginning in the latter part of the 19th century, originated the concept of "centers of action" as applied to surface weather conditions around the earth. They watched the




*Cyclical pattern in Oklahoma rainfall. The total rainfall for each group of years given within the diagram is shown in percentage of normal. Each group of years begins 3 years before sunspot minimum. The present group, presumably 1952–1962, is running very dry, in accordance with this large-scale cycle.*



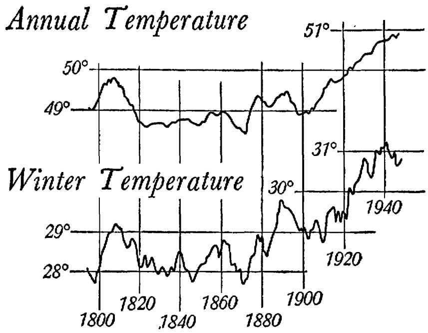
*The weather map on the left, for November 8, 1913 (after C. P. Mook) was used as an analog by Weather Bureau forecasters to make a correct prediction on November 25, 1950, from the map on the right (after C. D. Smith); it was followed by a destructive storm and heavy snow like those that had occurred 37 years earlier.*

centers (for example, the continental highs, the Aleutian and Icelandic lows, the oceanic high pressure cells) for hints as to future weather beyond the day-to-day predictions in certain regions. More recently the meteorologist has learned why the centers of action behave as they do in relating them to the upper planetary waves.

About 15 years ago meteorologists in the United States introduced the idea of the zonal index, a measure of the speed of the westerly winds in middle latitudes as a part of the general circulation. When the pressure increases from north to south in this belt, the index is "high"; when it diminishes from north to south in the same belt, the index is "low." More recently it has been shown that there is a variation in the index that is not regular; it is called the index cycle. The time interval is 4 to 6 weeks. The zonal index is related to the form of the general circulation of the atmosphere and especially to the position and development of the centers of action. In turn, the weather, including rainfall, is related to the changes in the index, but the cycle is irregular and, as in the case of most other so-called cycles in weather, the meteorologist has been unable to predict the changes in the index with satisfactory accuracy.

In the second phase, the meteorologist attempts to associate the weather with solar activity, to find an adequate measure of the variations in the latter, to trace their effects through the atmosphere, and to explain the results in terms of weather changes, including anomalies in rainfall. Here there is hope of further progress as man's understanding of solar changes increases and information regarding the atmosphere is improved through balloon soundings and rocket research.

There is some evidence of important effects, such as long-term, large-scale migrations of rainfall toward the interior of the United States that result from high solar radiation and migrations to coastal areas when radiation is low. The results are similar to the annual mi-

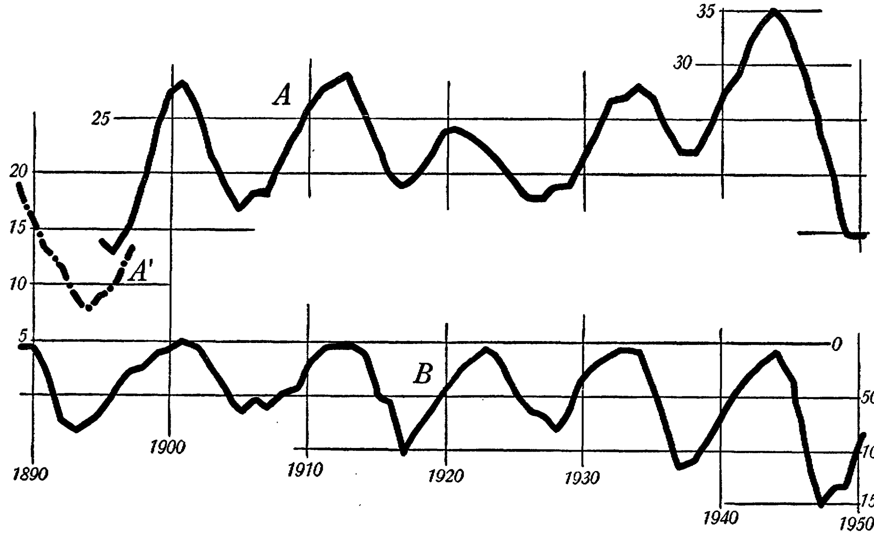



*Upward trend in temperatures at New Haven, Connecticut, shown by 20-year means ending at the dates given.*

grations that attend seasonal changes in insolation. Then, too, there are indications of shifts of rainfall from warmer months to colder and back again as radiation increases and decreases. The total evidence accumulated in the past 100 years to show important solar effects cannot be disregarded. Combinations of these rhythmic variations provide an index to long-term changes in rainfall, but at present it seems reasonable to conclude that the practical results in the immediate future will be limited to a very general indication for the few years ahead, useful for planning but not yet applicable in any detail to the prospects for a single season or even a single year. In this phase the work of the meteorologist will depend in a large degree on the ability of the astrophysicist to predict long-term and short-term changes in solar activity.

For the reasons given, it has not yet been possible to bridge the large gap between the projection of current atmospheric patterns into the future for 30 days, possibly more, and, on the other hand, the detail which can be derived from the analyses of the long-term effects of solar changes. But there is much hope that the meteorologist will be able to make more rapid progress as we accumulate more information about the upper air.

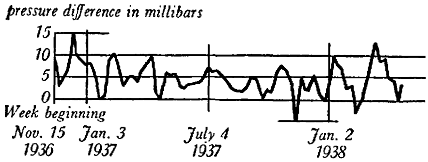
An enormous amount of work on cycles in rainfall and related problems




*A, Differences in yearly rainfall between Galveston and Amarillo, Texas (smoothed); A', Abilene rainfall is used for years prior to beginning of Amarillo record. Scale at left shows excess of Galveston rainfall over Amarillo's in whole inches. B, Annual sunspot numbers inverted by scale at lower right. This cycle shows migration of rainfall from coast to interior and back again.*

has been done, but in an unorganized fashion by men who were depending on some other activity for a livelihood.

The main reason is that years ago scientists reached a rather definite conclusion that there are no true cycles in rainfall. It is believed that there are only certain rhythmic variations which can and must be dealt with on a physical basis as soon as there is a much improved understanding of the complex changes that take place in the earth's atmosphere as a result of its own internal reactions and the impact of extraterrestrial forces. Some useful progress has been made toward an understanding of the physical processes involved rather than dependence on




*Examples of variations in weekly values of the zonal index—pressure differences between 35° and 55° latitude—in millibars, scale at left. The higher the value the stronger the westerly winds in middle latitudes.*

cycles or rhythms as such. And, in any case, whether the investigator depends on one or the other of these methods, it has become certain that he must use weather maps to get 3-dimensional views of the atmosphere for the time involved, whether they represent means for a week, a month, or for one or more years. On this basis the meteorologist is making slow but definite headway.

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