industrialized, the influence of these forces can be reduced to a minimum. At the same time we can raise the favorable conditions, leaning on a firm scientific basis. The main lines of the struggle are already marked out, and with intense research studies success is assured.

12. If realized, this should give a mighty impulse to the raising to a higher level the quantity of agricultural production, on a basis of broad industrialization and enlarged scale, with reconstruction on a strictly scientific basis.

WEATHER ABNORMALITIES IN UNITED STATES

551.577.3 (764) (766)

HEAVY RAINS IN TEXAS AND OKLAHOMA, MAY, 1929

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(FIFTH NOTE)

Ordinarily one thinks of the rainfall as being due primarily to the frequency and horizontal movement of cyclonic storms or simply shallow barometric depressions, and this idea has some basis of fact when applied to certain parts of the country. The preliminary study in the preparation of this paper showed, however, that a different conception is equally valid, as will appear in subsequent paragraphs.

In May, 1929, precipitation in Texas was 4.04 and in Oklahoma 3.30 inches above the State normals, respectively. In order to reach a conclusion as to the ideal conditions for heavy rains in the region considered, I have made a detailed examination of the total rainfall for the month of May from the beginning of state-wide distribution of rainfall stations in 1891 to date. I have selected for detailed examination those months which gave the greatest May precipitation of record. These are:

For Oklahoma, May, 1902: State average, 10.13 inches; departure, 5.72 inches.

For Texas, same month: State average, 3.93 inches; departure, 0.27 inches.

Greatest amount for Texas, May, 1929, 7.70 inches; departure, 4.04 inches.

Second greatest for Texas, May, 1914, 7.68 inches; departure, 4.02 inches.

For Oklahoma in May, 1929, 7.67 inches; departure, 3.30 inches.

For Oklahoma in May, 1914, 5.17 inches; departure, 0.80 inches.

Thus it is seen that the two States do not closely parallel each other in the distribution of heavy rains.

The details of the rains of May, 1929, are shown in Table 1 below:

TABLE 1.—*Monthly mean and extreme values of precipitation in Texas and Oklahoma, May, 1929*

Divisions	Number of stations	Precipitation (inches)			Monthly departure
		Average	Greatest		
			Monthly	24 hours	
Texas:					
Northwestern	51	4.37	8.85	6.30	+1.47
Northeastern	26	8.43	15.29	7.00	+3.80
Western	36	3.62	8.86	3.62	+1.13
Central	37	10.88	20.46	7.22	+6.19
Eastern	13	13.48	22.49	11.05	+8.63
Southwestern	47	8.62	17.18	6.16	+5.05
Coast	37	9.42	17.86	7.65	+5.17
Oklahoma:					
Eastern	27	9.15	16.25	4.70	+4.33
Central	26	8.98	12.90	6.50	+3.94
Western	31	5.20	14.78	7.86	+1.96

The detailed examination of the daily weather maps which gave the greatest monthly totals of precipitation for the region under consideration clearly show that the controlling pressure formations are (1) strong anticyclones with central pressure between 30.50 and 30.60 inches overspreading one of the northern tier of States from North Dakota to Michigan; (2) at the same time pressure should be low over the Great Basin, a depression with central pressure of 29.70 to 29.80 inches over Nevada or Utah.

The anticyclone tends to spread fan shaped to the southeast with a slow movement; the Utah depression has a somewhat uncertain movement and development. In most cases the southern end will in a day or so occupy New Mexico and part of west Texas as a shallow depression, or the northern end of the original trough may develop and move to the northeast as a going cyclone; in that case a secondary will usually develop over west Texas.

The circulation proper to the anticyclone as it spreads to the southeast is manifest by east to southeast winds on its southwest periphery, and these winds are mainly from the Gulf of Mexico. They are augmented in force by the presence of low pressure to the west over New Mexico and adjoining areas. When the anticyclone is of great magnitude it may persist for as long as a week before passing over the Atlantic. Meanwhile the southeast winds and rain, locally heavy because of long duration prevail, there being as many as three or four different periods of relatively long-continued rains in the States named. These may be classed as warm front rains.

Rains due to a cold front may vary the situation, but their occurrence is not so frequent as the first named. Cold front rains occur when a strong anticyclone advances southward from Montana into a trough of low pressure left over Texas as a residual from a northern cyclone that has passed to the eastward. A 4-day rain, due wholly to the northern anticyclone, is not uncommon.

Moderately heavy rains, especially in Oklahoma, occur when the number of secondary cyclones that originate in the spring months over the southern Plateau region and move east-northeast over northwest Texas and Oklahoma is fairly large, say, three or four in any one month. Dry weather is the rule when southern plateau cyclones do not develop and the cyclonic movement eastward is confined to the northern border States.

May is the month of greatest precipitation in Oklahoma, the State average being 4.37 inches, with a rather large number of stations having an average of 5 inches and slightly over. Although the State is not far from the center of the continent, its average May rainfall is not exceeded in any other part of the country. The greater rainfall of this month is doubtless due to the large opportunity that is present for vertical convection and also the overrunning and underrunning of air masses of different temperature and moisture content. These conditions are best developed in the months April–June.

The foregoing is, of course, rather broadly generalized; the details of pressure distribution will follow the plan outlined more or less closely, but there will be differences. As an example of the closeness of fit I give the detailed pressure distributions that were responsible for the heavy rains of May, 1929, in Texas and Oklahoma; these were grouped around four separate periods totaling 18 days as given below:

Rains of May 1–4, 1929.—These were cold front rains due to the southeastward advance of an anticyclone

from Wyoming to the Gulf of Mexico in three days in association with low pressure over Texas.

Rains of May 8–9, 1929.—A depression of the barometer moved from the southern plateau on the 7th to Texas on the 8th and dissipated over that State on the 9th, a strong anticyclone in the meantime having advanced from the western Canadian Provinces to the lake region.

Rains of May 16–18, 1929.—As in previous cases, a strong anticyclone and a pronounced fall in temperature was centered on the 15th in Montana, and there was a depression of the barometer over northern New Mexico. This anticyclone moved very rapidly to Iowa by the 16th and to the New Jersey coast in the next 24 hours. Meanwhile Texas and Oklahoma were occupied by a residual low; the winds were southerly and very general rains occurred on the dates named.

Rains of May 26–31, 1929.—The rains of these dates were not quite so general as those already mentioned, but the total for the six days was a very considerable amount at many stations.

On the morning of the 26th a shallow depression of the barometer occupied southeastern Wyoming and an anticyclone of wide extent was centered in the lake region. In the three days immediately following the depression was forced to the south-southeast and gradually dissipated over Texas. Meanwhile the pressure gradient over Texas and Oklahoma was for south to southeast winds, and these are rain winds for the States named.

Finally the dominating weather control being anticyclonic, the temperature will be several degrees below the seasonal average in months of heavy rainfall.

KITE OBSERVATIONS IN MAY, 1929

A brief study of the free-air observations made at the two kite stations of Broken Arrow, Okla., and Groesbeck, Tex., has been made. The geographical coordinates of the stations are as follows:

Broken Arrow, north latitude 36° 02″, west longitude 95° 49″; elevation, 765 feet. Groesbeck, north latitude 31° 30″, west longitude 96° 28″; elevation, 461 feet.

It so happened that barometric formations were favorable for rain in May, 1929, in Texas and Oklahoma on at least 16 different dates; and since the occurrence of precipitation is prejudicial to kite flying, it is not surprising that synchronous flights at both stations were obtained on but seven days and at a single station on four days. The amount of observational material is therefore less than we would wish.

No pretense was made to subject the observations to critical analysis. At most search was made for some obvious relation between the wind direction, the moisture content of the air and its temperature, and the occurrence of rain at the kite stations.

True, the kite observations reveal to a greater or less extent the structure of the immediate section of the atmosphere explored, depending upon the altitude reached. When, however, clouds are present both the temperature and moisture of the air is apt to be in a more or less stratified condition, thus making it difficult to draw inferences of value.

The circulation of the wind in cyclones and anticyclones is already well known so that the added information of the kite flight is of little or no avail.

The significant data afforded by the flights are changes in the decrease of temperature with increase in altitude, changes in the lapse rate, as it is now known, and also changes in the moisture content of air masses that can be identified as coming from higher latitudes (polar air) and from lower latitudes, respectively (equatorial air). Progress is being made toward showing such changes graphically, but the methods thus far in use have not as yet been applied to the kite observations here discussed. I am therefore under the necessity of closing my comment on the kite observations with the statement that they have not thrown additional light upon the physical processes involved in the heavy rains in both Texas and Oklahoma.

THE INFLUENCES THAT BRING ABOUT HEAVY RAINS IN TEXAS AND OKLAHOMA COMPARED

Oklahoma, being farther removed from the source of moisture than Texas, does not respond in the same degree to the influences that produce heavy rains in the last named. The chief cause of heavy rains in Texas and Oklahoma is the combination, low pressure over west Texas, New Mexico, or southeast Colorado, and high pressure to the east-southeast, as in May, 1929, and as may be inferred, the individual months may show slight variations from this general pattern.

It is axiomatic that whenever the progression of a cyclonic system or simply a shallow barometric depression in its northeastward course over the Plains States is blocked by high pressure centered over or to the north of the Great Lakes, especially in the months of May and June, the rains over the States named are heavy and in places of longer duration than usual. Since the movement of the anticyclone from the Great Lakes to the South Atlantic coast may consume three or four days, and since the relative geographic position of the two formations changes but slowly, the long continuance of the rains is thus explained. In further explanation it should be said that the anticyclonic air being relatively and absolutely cooler than the air in the cyclone, a mass movement of the cooler anticyclonic air toward the center of the cyclone or depression must bring about very generous rainfall.

A second cause of general rains in Oklahoma, and in a less degree in Texas, is the origin of secondary cyclones or simply barometric depressions over the southern plateau and their subsequent movement over Oklahoma and western Texas. In some months for reasons that are unknown there is an absence of secondaries in the region named; such disturbances have their origin far to the northward and pass eastward along the Canadian border too far north to give rain in Oklahoma. The problem of predicting the rains of the coming season is therefore an impracticable one at the present time.

The conclusion is reached that heavy rains, particularly in the Plains States, including Texas, are quite as likely to be due to the aberrant movement of cyclones and the resulting development of secondaries as to the frequency of fully organized cyclones that may pass over a given region in the space of a month or more.

It is also apparent that the development of strong anticyclones and their southeastward movement across the United States is an important factor in controlling the rainfall of the Plains States, the lower Missouri and the middle Mississippi Valleys.

Torrential rains in Texas may also be due to the advance inland over that State of a tropical disturbance from the Gulf of Mexico that expends its energy in heavy flood-producing rains.