THE POLAR FRONT IN THE INTERPRETATION AND PREDICTION of OKLAHOMA WEATHER*

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THE MOST important source of terrestrial heat is radiant energy from the sun, insolation. Because of the earth's shape, size, movements, and position in the solar system, annual insolation varies enormously with latitude. With the unit the average amount of insolation received at the equator during one day, the annual insolation at the equator amounts to 365.2 thermal days, while that at the poles is only 151.6 thermal days.

Earth temperature is not a function of insolation alone, but is rather a resultant of the action of two processes, insolation and outward radiation. Radiation of heat varies directly with temperature. A stable temperature obtains when dissipation of heat through radiation equals reception of heat through insolation. With a given regime of insolation, temperature will rise until outward radiation has increased to equal insolation. Stable temperatures corresponding to variations in distribution of insolation, would be high in equatorial latitudes and low at the poles, approximately 130°F. and —100° F. respectively.

In the polar regions loss of heat through outward radiation from the earth's surface is greater than insolation, and in the equatorial zone outward radiation is less than insolation. Equatorial temperatures are reduced and polar temperatures are raised by a transfer of heat through interzonal movements of air and water. Thus the actual annual equatorial and polar temperatures are approximately 80° F. and 0° F. respectively. This implies a reduction in temperature of 50° F. in the equatorial zone and an increase of 100° F. at the poles.

The excess of radiation over insolation in the polar region results in the development in high latitudes in both northern and southern hemispheres of caps of cold heavy air which are constantly receiving more cold air and are ever spreading equatorward along the earth's surface and are being "melted" back along their fronts. The excess of insolation over radiation in the equatorial region leads to the development there of a belt of warm light air, which too is constantly receiving additions, and thus tends to expand poleward along the surface of the earth beyond the trade wind belt. Where the polar and equatorial air masses come definitely together in middle latitudes, the warm air, being lighter is wedged up and flows over the cold air. The line of discontinuity between the cold and warm air is called the polar front.

In the summer season polar insolation increases, the excess of radiation over insolation is reduced, and the polar cap of cold heavy air shrinks causing the polar front to migrate far poleward. In the winter season with polar insolation reduced the polar cap expands and the polar front migrates again equatorward.

The polar front is extremely irregular in shape. Along it numerous lobes of cold polar air extend far down into tropical latitudes. the re-entrants between the cold lobes are occupied by warm tropical air. These

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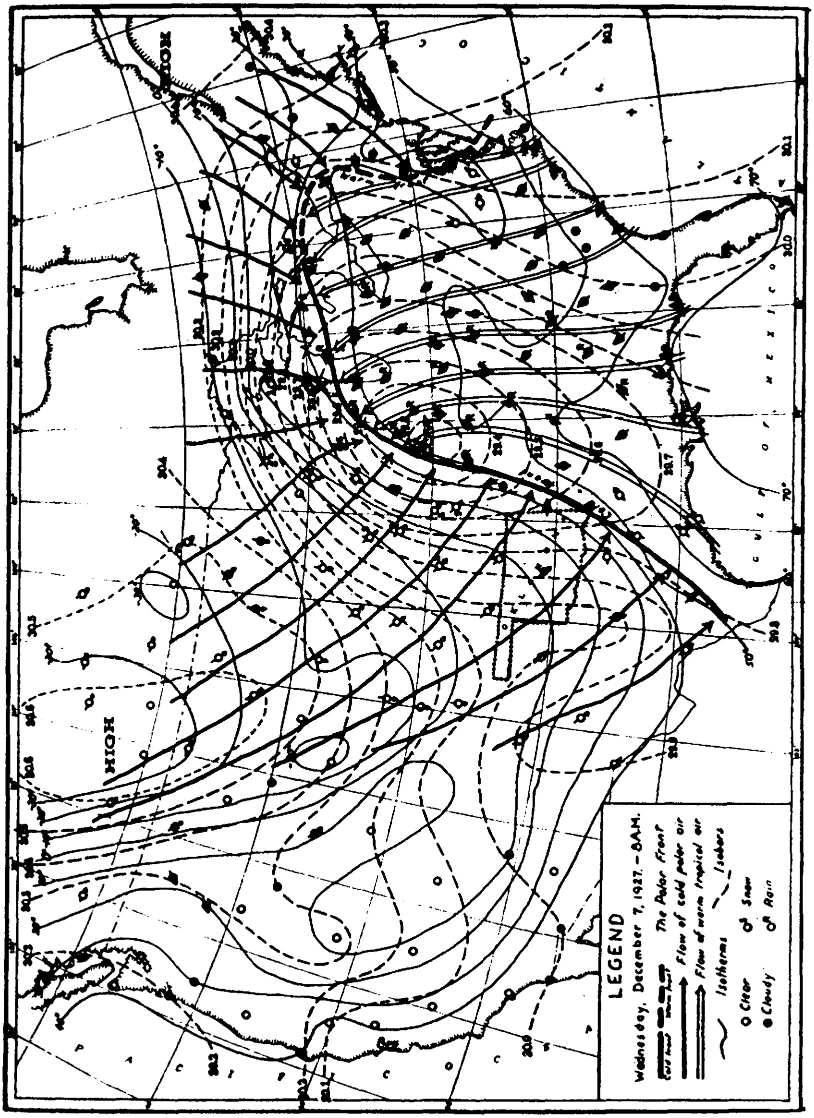

FIGURE 1. THE POLAR FRONT IN THE UNITED STATES, DECEMBER 7, 1927

Constructed from U. S. Weather Bureau's Official Map. Lines showing flow of polar and tropical air generalized from wind direction at individual stations. Note that Oklahoma lies entirely within the domain of the polar air. The conditions in the western mountain region were not taken into consideration because of the paucity of station records and the disturbing influence of local relief.

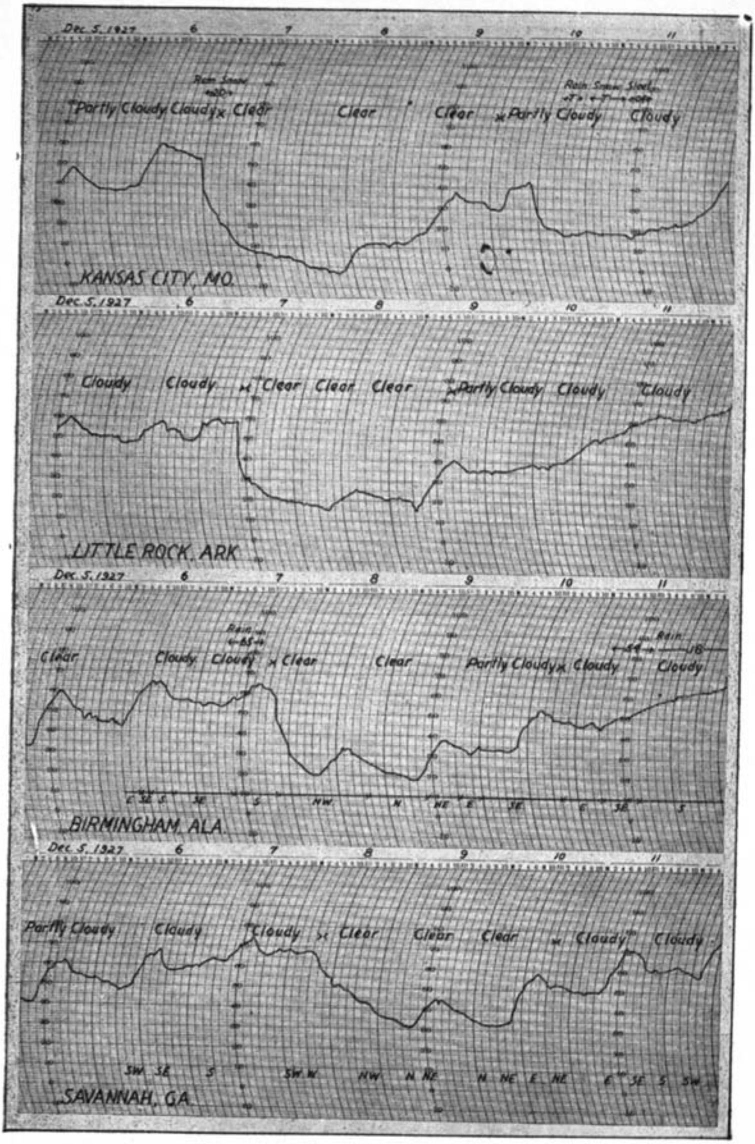

FIGURE 2. THERMOGRAPH CHARTS FROM FOUR TYPE STATIONS

Obtained through the courtesy of the meteorologists in charge of the stations. Wind change data were given for Birmingham and Savannah and precipitation data for Kansas City and Birmingham only. Precipitation is given in inches. Only trace of rain or snow is indicated by "T."

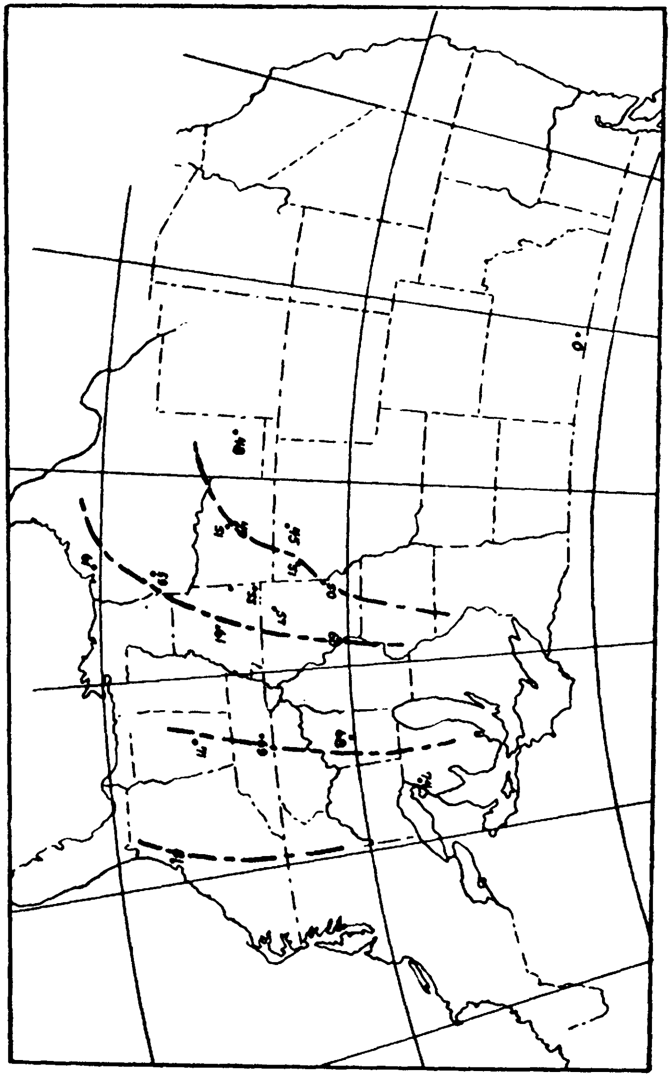

FIGURE 3. POSITION OF THE POLAR FRONT AT FOUR SUCCESSIVE PERIODS BETWEEN DECEMBER 4 AND 11

Figures refer to number of hours after polar front reached Havre, Montana. The four isochrones give the positions of the cold front after 50. 60. 70, and 80 hours.

lobes and reentrants in the edge of the polar cap move with a wavelike motion from west to east. The direction of movement of the cold heavy air within the polar cap and its lobes is in general from north and northwest to south and southeast in the northern hemisphere. That of the warm light air is from south to north. The association of warm light tropical air and cold heavy polar air along this line of discontinuity accounts for the development of many of the cyclones and anticyclones of middle latitudes. The advancing portion of the lobe of polar air is called the cold front, the retreating portion is called the warm front. The cold front is more distinctly marked than the warm front and is thus the best place to observe the line of discontinuity between the two bodies of air. For this study the "norther" of November 5 to 11, 1927, was selected. On the weather maps of the period the polar front can be traced with remarkable clarity (See figure 1). Thermograph records for the period were secured from key stations over the United States (Figure 2). In every instance the drop in temperature was sudden and was attended by a wind shift from south to north, and by an abrupt rise in atmospheric pressure. The following table summarizes the important facts embodied in the thermograph records:

TABLE I. PASSAGE OF THE "NORTHER" OF DECEMBER 5 to 11, 1927

Stations	time of passage of polar front	antecedent temperature degrees F.	subsequent temperature degrees F.	Temp. drop	drop in first two hours
Havre, Mont.	9pm, Dec 4	30	—30	60	--
Amarillo, Tex.	9pm, Dec 6	45	7	38	28
Oklahoma City	10pm, Dec 6	53	9	44	21
Iola, Kan.	10pm, Dec 6	56	6	50	31
Norman, Okla.	11pm, Dec 6	53	10	43	32
Kansas City	11pm, Dec 6	53	— 4	57	22
Palestine, Tex.	8am, Dec 7	52	20	32	12
Hannibal, Mo.	9am, Dec 7	51	3	48	18
Houston, Tex.	10am, Dec 7	59	26	33	8
Little Rock	10am, Dec 7	58	15	43	26
Indianapolis, Ind.	5pm, Dec 7	56	7	49	24
Nashville, Tenn.	6pm, Dec 7	64	15	49	25
Birmingham, Ala.	8pm, Dec 7	58	20	38	15
Savannah, Ga.	6am, Dec 8	67	30	37	6

Sixty-one hours elapsed from the time the polar front had passed Havre, Montana until it reached Savannah, Georgia. These stations are approximately 1800 miles apart so that average rate of its movement was about 22.2 miles per hour. The distance from Havre to Amarillo, one thousand miles, was traversed in just forty-eight hours, with a velocity averaging 20.2 miles per hour.

Figure 3 shows the time of arrival of the cold front at various stations in hours from Havre. The four isochronic lines give the positions of the cold front 50, 60, 70, and 80 hours after having passed Havre.

TABLE II. TEMPERATURE DROP AS RELATED TO LATITUDE

Station	Latitude	Temp. drop degrees F.	Drop in first two hours
Havre, Mont.	48° 35′ N.	60	--
Indianapolis	39° 44′ N.	49	24
Hannibal, Mo.	39° 35′ N.	48	18
Kansas City, Mo.	39° 15′ N.	57	22
Iola, Kan.	37° 50′ N.	50	31
Nashville, Tenn.	36° 10′ N.	49	25
Oklahoma City	35° 27′ N.	44	21
Amarillo, Tex.	35° 20′ N.	38	28
Little Rock, Ark.	34° 50′ N.	43	26
Birmingham, Ala.	33° 30′ N.	38	15
Savannah, Ga.	32° 04′ N.	37	7
Palestine, Tex.	31° 45′ N.	32	12
Houston, Tex.	29° 45′ N.	33	8

The above table demonstrates that the drop in temperature at the individual stations is correlated very closely with latitude, the higher the latitude the greater the temperature range. The drop in temperature during the first two hours seems to depend more on exposure than on latitude. Iola, Kansas, and Amarillo, Texas, on the Great Plains, had the greatest reduction and Savannah, Georgia, and Houston, Texas, had a very moderate decline.

The four selected thermograph records of figure 2 show the typical weather changes accompanying the movement of the polar front. The coldest temperatures of the nights following the return of warm tropical air, were in each case warmer than the highest temperatures recorded while under the domination of the cold polar air. The normal diurnal march of temperature is profoundly disturbed, by the passing of both the cold and warm fronts. At Kansas City all through December 7 the temperature dropped steadily. The sun had no effect on the temperature except to moderate slightly the rate of decline. At Little Rock December 10 and 11 the temperature rose steadily and was seventeen degrees higher at dawn on December 11 than it was at noon on December 10. At Birmingham during December 8 the diurnal temperature range was practically normal. There is considerable contrast between the moderate drop in temperature at Savannah and the very rapid drop in Little Rock.

Warm tropical air along the polar front brings cloudiness and usually rain. Cold polar air brings clear weather (See figures 1 and 2). The structure of a reentrant of tropical air is shown in cross section in figure 4. The warm air is shown flowing up over the cold air on the warm front (B) and being wedged up by the moving cold air on the cold front (A). In either case the warm moisture laden air is being cooled adiabatically and condensation and precipitation of moisture is the result. The various cloud types, cirrus, stratus, cumulus, nimbus and their varied combinations are shown in their relative positions along the zone of discontinuity. The normal sequence of clouds can readily be deduced by observing figure 4, knowing that the movement is from west to east.

During the winter season, during the months October to May, the polar front migrates back and forth across Oklahoma alternately cooling the region with polar air and heating it with tropical air and subjecting it to the normal sequences of weather which have been discussed above. A knowledge of this succession of weather types enables one to interpret the passing weather and to forecast it with a fair degree of accuracy. At least it permits one to discuss intelligently that most used topic of conversation, the weather.

BIBLIOGRAPHY

1. Bjerknes, J. On the structure of moving cyclones. Mo. Weather Rev., Vol. 47, 1919. Pp. 95-99.

2. Bjerknes, V. Weather forecasting. Mo. Weather Rev., Vol. 47, 1919. Pp. 90-95.

3. Beck, A. L. The earth's atmosphere as a circular vortex. Mo. Weather Rev., Vol. 50, 1922. Pp. 393-401.

4. Henry, A. J. J. Bjerknes and H. Solberg on meteorological conditions for the formation of rain. Mo. Weather Rev., Vol. 50, 1922. Pp. 402-404.

5. Henry, A. J. J. Bjerknes and H. Solberg on the life cycle of cyclones and the polar front theory of atmospheric circulation. Mo. Weather Rev., Vol. 50, 1922. Pp. 468-474.

6. Rossby, C. G. and Weightman, R. H. Application of the polar-front theory to a series of American weather maps. Mo. Weather Rev., Vol. 54, 1926. P. 485.

7. Henry, A. J. M. A. Giblett on line-squalls. Mo. Weather Rev. Vol. 56, 1928 Pp. 7-11.

8. Piippo, A. F. An analysis of the Madison, Wis., aerological data, with an application of the Bjerknes theory. Mo. Weather Rev., Vol. 56, 1928. Pp. 47-53.

9. Clayton, H. H. World Weather. New York, Macmillan, 1923.

10. Bollinger, C. J. and Thornthwaite, C. W. General Geography.