Some Observed Effects of Certain Atmospheric Variations

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The series of severe and devastating droughts that have affected much of the United States, Canada, and some other parts of the world during the last decade has emphasized the need of a better understanding of the conditions which make such calamities possible. Man can hardly hope that he will ever be able to prevent the actual occurrence of such abnormalities of the weather, but, if he can gain a better understanding of their causes and of the conditions necessary for their recurrence, he may possibly be able to recognize their approach in time to make some preparations for rendering their effects a little less severe.

This possibility has prompted the writer to make an intensive study of the atmospheric conditions which prevail during such periods of abnormal weather. Daily observations of atmospheric conditions were made during a period of more than six years, and these observations were compared with the weather charts published daily by the United States Weather Bureau. Observations made by others were also checked with the daily weather charts. Some knowledge has been gained. Some observations were made that were not altogether in agreement with good meteorological theory. In such cases the observations were carefully checked and rechecked in order to make sure that there were no mistakes due to faulty observation. When these unusual conditions occurred again, they were carefully observed and the resulting weather noted. This practice eventually resulted in certain interpretations and conclusions which the writer believes to be new and of possible value in weather forecasting.

It is the purpose of this paper to call attention to some of the observations that have been made, to explain the interpretations that have been given, to state the conclusions reached, and to show how these interpretations and conclusions, if accurate, may be of considerable value in determining the long range weather trends.

Those desiring a more complete knowledge of the many and various effects of certain atmospheric conditions and variations are referred to Dexter[1], Huntington[2], and others who have discussed various phases of the matter. This discussion will be confined to variations in the velocity of the general circulation, their effects, and certain observations connected therewith.

That variations in the velocity of the general circulation actually occur is clearly indicated by the irregular variation in the speed of the migratory pressure formations as they are carried along by the general air movements. Irregular variations have been observed ranging from a low value of 2 miles per hour to a high value of 66 miles per hour during January, and values ranging upward to 39 miles per hour in

[1] Dexter, Edwin G., 1904. Weather influences. New York.
[2] Huntington, Ellsworth, 1915. Civilization and climate. New Haven.

July[3]. These movements show that the general circulation is usually more active and moves more rapidly in winter than in summer. The more rapid winter movement is usually attributed to the increase in the poleward temperature gradient resulting from the lower winter temperatures in middle and lower latitudes. That explanation, however, is probably not the true one because the winter variations are very irregular, and the observed variations do not correspond to the changes in temperature required by the theory. In other words, the more rapid circulation does not occur when temperatures are lowest in middle and lower latitudes, nor does the more sluggish circulation occur when the temperatures are higher, but just the opposite. The writer has also observed that the general air movements may be very sluggish during the winter months and then become more active as summer approaches. These irregular variations in velocity seem to have a peculiar effect upon the form and the direction of movement of the migratory pressure formations and a somewhat similar effect upon the stationary pressure areas.

It was first observed that the great masses of cold air which form during the winter months at points near or above the Arctic Circle sometimes follow a northern route which leads southeastward and eastward toward Hudson's Bay. Sometimes they follow what may be called a middle route which leads southeastward across the Lake Region and into the Ohio Valley, and thence eastward to the coast. At other times the masses of cold air follow a western track southward over the Rocky Mountains and Great Plains toward Mexico and the Gulf Coast. Further observations showed that the northern route was usually followed during periods when the pressure formations were moving rapidly eastward. The middle route was followed during periods when the pressure formations were moving more slowly eastward, and the western track was followed when the atmospheric movements were usually very sluggish. These observations seem to indicate that there may be a very close relationship between the velocity of the general circulation and the tracks which are followed by Arctic air masses.

This relationship can be more easily understood if consideration is given to the fundamental principle which causes all moving masses that are not rigid to become elongated in the direction of their most rapid motion. The truth of this principle is very evident even in the case of semi-rigid masses, such as glaciers, or ice sheets, the moving masses of ice becoming elongated in the direction of their most rapid motion.

All masses of moving air must conform to this fundamental principle. If a mass of cold air appears over Alaska or northern Canada, it may possibly suffer a slight development westward toward a region of low pressure, but it cannot be carried westward against the planetary wind system. The air mass may follow any one of three courses. It may move eastward with the movements of the general circulation, or it may move southward, or it may move in a direction that is some combination of these two movements. If the eastward drift of the atmosphere is very rapid at the time, the air mass may be expected

[3] Milham, W. I., 1912. Meteorology. New York.

to develop in the direction of its most rapid motion; that is, the air mass will probably follow the northern route eastward toward Hudson's Bay. If the general atmosphere is moving less rapidly eastward, the air mass may be able to move southward just about as easily as it can move eastward. In such cases the actual movement is usually a combination of the two movements; that is, the air mass moves southeastward and follows the middle route. However, if the eastward drift of the atmosphere is very sluggish, the air mass can develop southward more easily than it can move eastward. The mass obeys the fundamental principle and extends its long axis in the direction of its most rapid motion; that is, it develops southward along the western track toward Mexico and the Gulf Coast.

This suggestion, that the tracks of Arctic air masses may be determined largely by the velocity of the general circulation at the time of movement, is believed to be new. The writer has endeavored to put it to the hardest test that can possibly be given, that of actually forecasting the particular region to be affected by the cold wave, even before the cold air mass has left the Arctic Circle. The results have been very encouraging. Some errors have been made. The greatest errors occurred during periods when the circulation was subject to irregular variations of short period, and the greatest successes have occurred during periods when the short period variations were absent.

The irregular variations of short period may cause the cold air mass to shift from one track to another during the forecast period. Two common examples have been observed quite frequently. If the general eastward movement of the atmosphere is moderately rapid, the cold air mass may be expected to move eastward along the northern route, but if the eastward movement should be retarded during the forecast period, the air mass will obey the fundamental principle and develop southeastward or southward, bringing severe temperatures to a region that might have escaped had the same rapid movement continued for a day or two longer. If the eastward drift is sluggish at the time when the forecast is made, the forecaster may have the reasonable assurance that the mass of cold air will follow the western track southward; but, if the eastward movement should become more rapid during the forecast period, the air mass will develop more rapidly eastward and thus cause the forecast to be more or less in error.

These variations of short period cause the work of the forecaster to become especially difficult, but, if the variations are absent, the circulation may move at a fairly uniform velocity for periods ranging upward to several months. Such long periods with little fluctuation have made it possible for the effects of velocity upon the form and direction of pressure formations to be detected and traced.

Charts of world pressures show areas of high atmospheric pressure over the oceans during the summer months. Pressure charts for the months of January and July may be found in physical geographies, while Bartholomew's Meteorological Atlas[4] shows pressure conditions for each month of the year. It should be understood that these charts show only mean, or average pressures. They do not show pressure

[4] Bartholomew, J. G., and Herbertson, A. J., 1899. Bartholomew's Physical Atlas. Volume 3. Edinburgh.

conditions when the circulation is very rapid nor when it is very sluggish. However, a study of oceanic pressures during extended periods of both rapid and sluggish circulation shows that the velocity of the general circulation seems to affect these stationary areas in practically the same way that it affects the migratory pressure formations; that is, the pressure areas develop in the direction of their most rapid motion.

Changes in the velocity of the general circulation seem to cause certain changes in the form and position of the oceanic anticyclones. These changes are illustrated in Figure 1. The anticyclone *A* represents the form and position of the oceanic pressure area during periods of moderately sluggish circulation. Note that the major axis of the anticyclone lies in a southwest to northeast direction. This is due to the fact that the general air movement is from west to east in the higher latitudes, and from east to west in the lower latitudes, in accordance with the planetary wind system. A full discussion of the planetary winds may be found in most of the general discussions of meterology. These winds cause the anticyclone to develop toward the east in the higher latitudes and toward the west in the lower latitudes. Hence its major axis lies in a southwest to northeast direction.

A moderate increase in the velocity of the general circulation causes the anticyclone to develop more rapidly toward the east in the higher latitudes and toward the west in the lower latitudes. This seems to cause some change in the form and position of the anticyclone, the major axis of the pressure area becoming extended in the direction of its most rapid motion. This change is shown in the anticyclone marked *B* in the illustration. A further increase in the velocity of the general circulation causes a further rapid development eastward in the higher latitudes and westward in the lower latitudes. This causes a further change in the form and position of the anticyclone, as shown in formation *C* in the illustration. Note particularly how the anticyclone tends to assume a horizontal position as the circulation increases in velocity. When these stationary anticyclones lie more nearly in a horizontal position they appear on the pressure charts as belts of increased pressure that completely encircle the earth.

Clockwise winds prevail around an anticyclone in the northern hemisphere. This wind movement is shown in the illustration by the arrows which accompany each formation. Note particularly the changes in the direction of the prevailing winds as the anticyclone changes in form and position. Similar changes in the direction of the prevailing winds that have continued throughout an extended period have been observed and reported by Ray. Certain changes in the direction of the trade winds over the North Atlantic Ocean are shown in percentages in the following table[5].

	Northeast	East	Southeast	South
1905-1920	20	35	26	10
1921-1929	6	55	16	15

Note particularly the change from northeast, in the period from 1905 to 1920, to east in the period from 1921 to 1929. Ray also states that similar changes occurred in the direction of the trade winds over

[5] Ray, C. L., 1933. The North Atlantic trade winds. Mo. Wea. Rev. 61:261-264.

the Pacific Ocean at approximately the same time. The fact that similar changes occurred over both oceans at approximately the same time suggests that the cause must be found in some factor that affects the general circulation. Ray reaches the conclusion that the change may be due to a northward displacement of the oceanic anticyclone. That conclusion is probably correct. The writer suggests that the northward displacement of the anticyclone may be due to an increase in the velocity of the general circulation. Such a displacement is shown in Figure 1. Particular attention should be given to the fact that the southern part of the anticyclone is gradually displaced into the higher latitudes as the circulation increases in velocity. It should also be noted that a similar displacement into the lower latitudes occurs as the circulation decreases in velocity. These changes in the form and position of the oceanic anticyclones are of the greatest importance because of their influence upon summer weather conditions over continental areas.

A further study of the three formations shown in Figure 1 reveals the fact that the major axis of the anticyclone shifts, or rotates in a clockwise direction as the circulation increases in velocity, and in an opposite, or anticlockwise direction as the circulation decreases in velocity. A question may be raised regarding the actuality of this movement. Do the major axes really rotate in the manner suggested? Strong evidence which seems to indicate an actual rotation of the axes of anticyclonic areas is found in the tracks followed by cyclonic storms. These cyclonic areas, or lows, move around the anticyclone rather than through it. The low cannot pass through the high pressure area unless a break or gap occurs in the pressure ridge. Therefore the direction taken by the moving cyclone is determined largely by the major axis of the adjoining anticyclonic area. If the major axis lies in an east-west direction, any cyclone forming west or north of the anticyclonic area will move rather rapidly in a west to east direction along the northern side of the elongated anticyclonic area. Any tropical cyclones which form on its southern side must either break through some weak spot in the pressure ridge or be carried around its western end. They are usually carried westward by the prevailing winds, some of them curving toward the northeast at points far west of the normal position, while others blow themselves out over land areas without changing their course to any considerable extent. If the circulation is sluggish and the major axis of the anticyclonic lies more nearly in a southwest to northeast, or a south to north direction, the cyclones which move around it must also move more nearly in a south to north direction. The tropical cyclones or hurricanes may very easily pass around the anticyclonic area without causing destructive winds over any part of the continent. This condition prevailed during the hurricane season of 1937 when the storms moved more generally in a south to north direction. The movements from east to west without recurving were observed quite frequently during the hurricane season of 1936.

These observed movements of cyclonic storms seem to indicate that the major axes of the oceanic anticyclonic areas actually rotate in the manner described. When the matter becomes more fully understood, and accurate data on the velocity of the general circulation have been obtained, weather forecasters should be able to determine the probable tracks of tropical cyclones even before the hurricane season begins. If the circulation is sluggish, the forecaster may have the reasonable assurance that the cyclones will move toward the north or northeast without striking the continent. If the circulation is rapid to very rapid, some storms of considerable intensity are practically certain to pass over the mainland and may cause much destruction. These hurricane tracks may be more clearly understood if careful study is given to the formations shown in Figure 1.

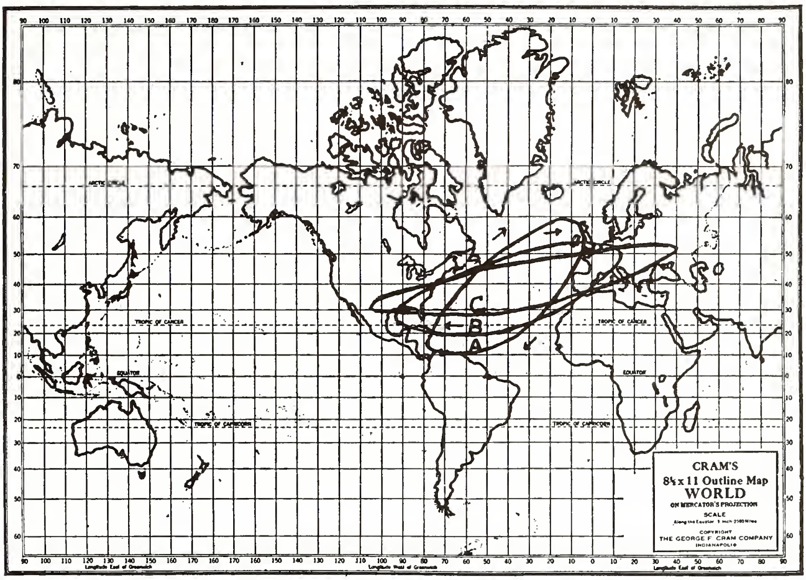

Fig. 1. Changes in the form and position of the pressure area as the circulation varies in velocity. The arrows show the wind direction in some parts of the pressure area.

When the atmosphere is moving eastward at or near its normal velocity for this particular age of the earth's history, the western end of the Atlantic anticyclone extends inland over the southeastern states. This inland extension is shown in all pressure charts of average conditions. These charts may be found in many physical geographies and in Bartholomew's Meteorological Atlas, which has been cited earlier in this discussion. The normal extension of the anticyclone over the southeastern states is shown in Figure 2. An increase in the velocity of the general circulation causes this anticyclone to shift its position slightly and causes it to become more elongated in an east-west direction. The normal inland extension of the oceanic pressure area develops farther inland and forms a ridge of increased pressure over the southern states and the Gulf of Mexico, which effectually prevents all inflow of moist air from the Gulf. This pressure condition is illustrated in formation *C* of Figure 1.

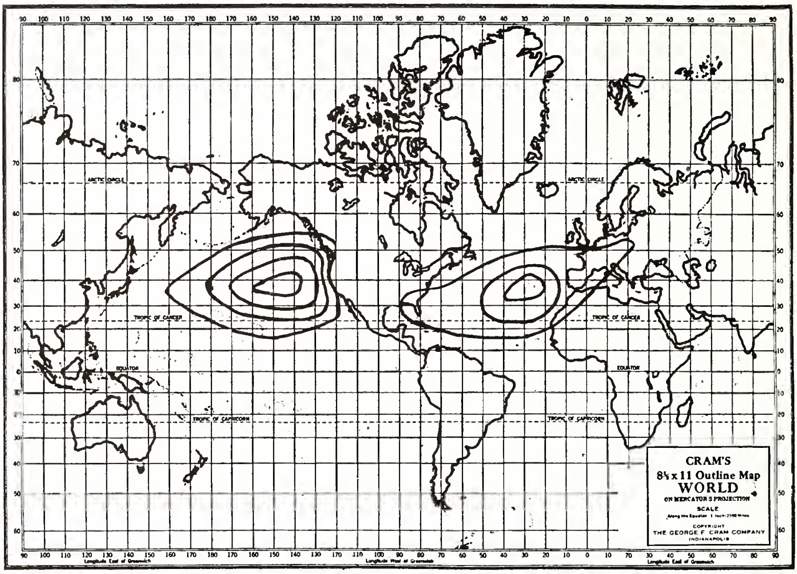

Fig. 2. The average position of the oceanic areas of increased pressure, as they are shown on the average pressure charts.

The same rapid circulation which causes the east-west elongation of the Atlantic anticyclone also causes a similar elongation of the Pacific pressure area, which forms an extension eastward across the mountains. This inland extension is not shown on the pressure charts, due to high temperatures and reductions to sea level, but its existence is revealed by the stagnant low pressure trough in midwestern sections, and by the tracks of cyclones which move around the inland extension on its northern side. The inland extensions of the two pressure areas tend to unite in the formation of a pressure ridge across the United States, with a shallow pressure trough somewhere in the interior between the inland extensions of the two pressure areas.

This particular type of pressure conditions causes the most severe drought to prevail over widely extended areas in the United States, with the formation of a heated area in the region affected by the pressure trough. This pressure type continued with little change for several weeks during the summer of 1936, and abnormally high temperatures were recorded at some midwestern stations that lay in the region affected by the pressure trough.

The general movement of air in an east-west direction causes the interior valleys of the United States to become covered by an accumulation of warm air, which acts as a blanket in preventing the escape of heat. Convection currents rise with difficulty, owing to the increased pressure resulting from the excess air that has been carried into the interior. When clouds do form and spread out at higher levels, the temperature of the air at the cloud level is too high to permit rapid condensation. Consequently, little precipitation occurs, and the little that does fall often evaporates before it reaches the ground. The air may contain a considerable percentage of moisture, yet drought continues and crops suffer because condensation does not occur. Condensation cannot occur under such conditions until the heat becomes so intense that convection currents finally break through the heated layer of air near the earth's surface and escape upward into a region of lower temperature which lies at greater altitudes. This results in violent thunderstorms with destructive winds and heavy precipitation over limited areas, while only a mile or so away there may be not even a trace of precipitation. This type of thunderstorm is characteristic of an arid climate.

If this abnormal condition is really due to the east-west elongation of the oceanic pressure areas, as the writer suggests, no decided change in the abnormal weather can occur until there is some change in the pressure areas. No great change in the pressure areas can occur while the general circulation continues to move at the same uniform velocity. But if the circulation should begin to move at a lesser velocity decided changes in the weather may confidently be expected.

These changes seem to occur approximately in the following manner. A decrease in the velocity of the general circulation causes, first, a decrease in pressure in the interior, due to the fact that the elongated pressure areas do not extend so far inland; second, a change in the position of the pressure trough with its attendant movement toward the south and east, due to the fact that the major axes of the pressure areas are shifting in an anticlockwise direction; third, a flow of moist

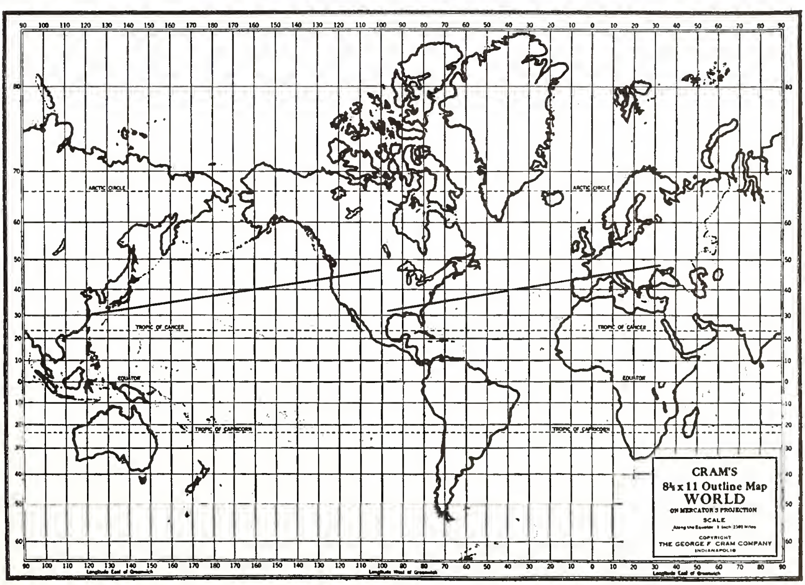

Fig. 3. The black lines show the approximate positions of the long axes of the oceanic pressure areas during periods of very rapid circulation. Note that the pressure ridge prevents all inflow of moist air from the Gulf.

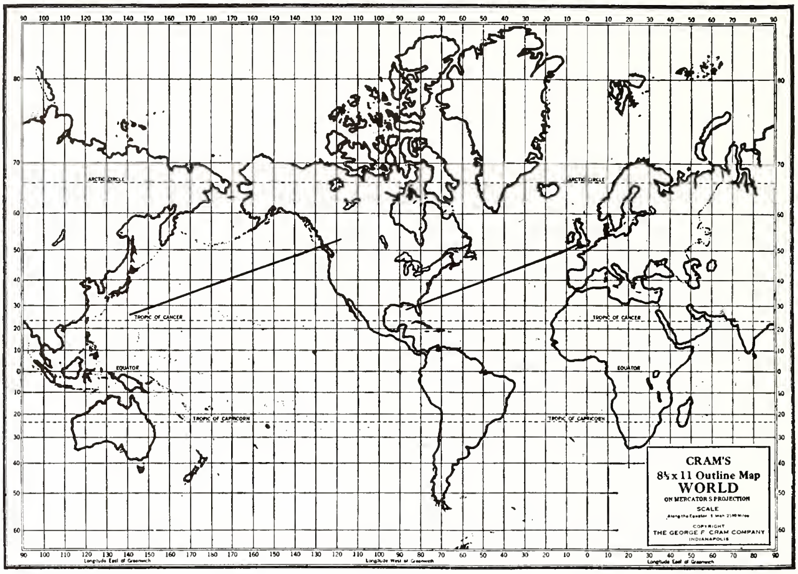

Fig. 4. The lines show the positions of the major axes when the circulation is less rapid. Note that the axes are shifting with an anticlockwise movement.

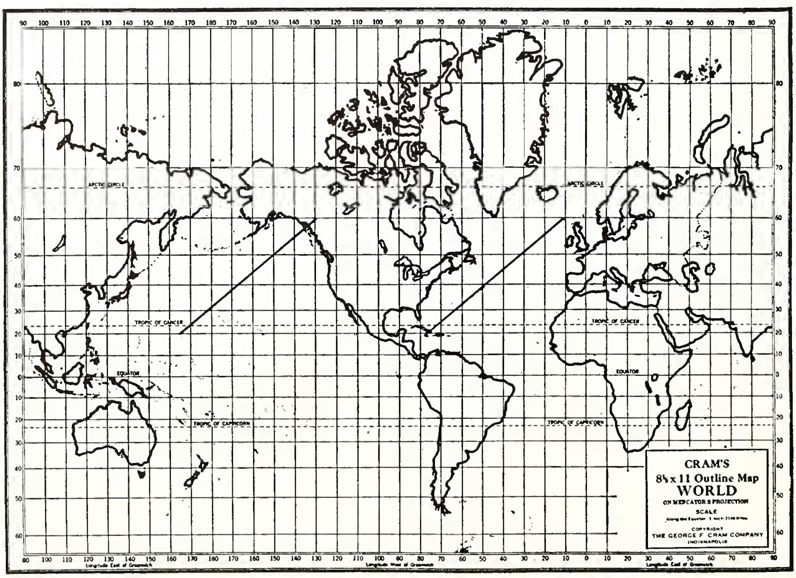

Fig. 5. A more sluggish condition of the atmosphere. The position of the major axes allows moist air to flow in from the Gulf, while cool air masses move down from the northwest.

air from the Gulf of Mexico into the interior, resulting from the breaking up and removal of the pressure ridge that extended across the southern states; and, fourth, a movement of cooler air from the northwest, due to the fact that the eastern end of the Pacific anticyclone has shifted into the higher latitudes.

These changes are illustrated in Figures 3, 4, and 5. The lines in each illustration represent the position of the major axes of the oceanic anticyclones. It should be remembered that a change to a more sluggish circulation causes, or permits, the major axes of the anticyclonic areas to shift or rotate in an anticlockwise direction, while a change toward a more rapid movement causes them to shift in a clockwise direction. Figure 3 shows the approximate position of the major axes during periods of rapid circulation during the summer season. Note the position of the pressure trough between the inland extensions of the two pressure areas. Clockwise winds blow around these major axes, and, as the winds move generally in an east-west direction, severe drought and abnormal heat prevails over widely extended areas. Figure 4 shows the shifting of the major axes which permit the pressure trough with its attendant heat wave to move eastward as the western extremity of the Atlantic anticyclone shifts eastward and southward over the Gulf. Figure 5 shows the further shifting of the major axes. This movement opens the way for an inflow of moist air from the Gulf, while clockwise winds moving around the Pacific anticyclone carry cool air southward to meet the warm moist air that is moving northward from the Gulf. When these air masses meet, the cool air acts as a condenser, showers develop along the cool front, and the earth is refreshed by much-needed rain. The showers may be expected to continue at frequent intervals as long as the circulation continues to move at the same decreased velocity.

Particular attention should be given to the fact that east-west movements are the predominating movements during periods of rapid circulation, but these movements weaken, and north-south movements become predominant as the circulation becomes more sluggish. Any assertion that westerly winds must always prevail in temperate latitudes may be somewhat misleading. Such an assertion is true only when the circulation is rapid. At other times the longitudinal movement eastward tends to develop into a latitudinal movement from some northerly or from some southerly direction. These latitudinal movements in a general north-south direction are responsible for the intermingling and the intermixing of air masses of different temperatures which results in a general instability of atmospheric conditions with an overturning of air masses and increasing precipitation.

If the same rapid circulation continues throughout the winter months, all continental and oceanic anticyclonic areas tend to unite in the form of a belt of increased pressure that extends across both land and sea. This seems to be due to the fact that all pressure formations must become elongated in the direction of their most rapid motion. Cyclonic storms move rapidly eastward along the northern side of this belt of increased pressure. Reed, in describing this type of weather on the Pacific coast, says:

> Self evidently, with the general trend of air currents from west to east as prescribed by the lay of the isobars, cyclones would be required to travel eastward. Their speed of travel, too, consistent with this type of atmospheric circulation, needs no labored explanation . . . Northern districts may get almost continuous unsettled, rainy weather, with only a brief intermission between one storm and the next, whereas in southern districts the rainy regimes are relatively short and separated by well-marked periods of bright weather concurrent with shifts in the wind from southerly to northerly quarters and conspicuous fluctuations of temperature in conformity therewith. In other words, while northern districts are almost continuously in the belt of low pressure and its eastward-moving depressions, southern districts are almost continuously in the belt of high pressure which suffers inflections of varying degree as the traveling depressions pass along it on the northern side.[6]

Reed's description may be applied equally well to the weather in the interior, except that the unsettled, rainy weather does not pass over the mountains. The weather in the interior is usually mild with generally fair to partly cloudy conditions accompanied by subnormal precipitation and winds blowing generally from the south or southwest. The observed wind movement is due to the fact that the belt of high pressure extends across the United States while the pressure north of the international boundary is almost continuously low. Severe temperatures from above the Arctic Circle are carried southward by the anticlockwise circulation about the lows that move rapidly eastward across Canada, but these severe temperatures affect only the extreme northeastern parts of the United States. The lows move so rapidly, and changes in the temperature follow so swiftly, that residents of the New England states feel that a cold wave occurs "almost every night." Moderate to mild winter temperatures prevail over widely extended areas in the United States and western Canada at the same time. These mild conditions are characteristic of periods of rapid circulation.

These observations reveal another fact of primary importance which may be stated as follows: Unseasonably mild winter temperatures prevail over widely extended areas in the United States and Canada during periods of rapid circulation. These mild periods apparently are caused by the rapid circulation.

When the rapid eastward drift of the atmosphere in temperate latitudes becomes more sluggish, great changes occur in the direction of air movements. The broad belt of high pressure, which had extended from west to east across both land and sea, begins to break up into centers of action. The major axes of the anticyclonic centers shift in an anticlockwise direction. The former rapid movement from west to east becomes more sluggish, while the currents move more nearly in a southwest to northeast direction. This direction of air-flow can be easily recognized and traced on the weather charts published by the United States Weather Bureau. The San Francisco station prepares charts showing atmospheric conditions for some distance out over the Pacific Ocean. The data on oceanic conditions are gathered by ships at sea and reported to the mainland by radio. These charts show that the main air-flow during periods of rather sluggish circulation is from southwest to northeast over the ocean and from northwest

[6] Reed, Thomas R., 1932. Weather types of the northeast Pacific ocean as related to the weather of the north Pacific coast. Mo. Wea. Rev. 60:246-252.

to southeast after the air-flow has crossed the mountains. In other words, the main air-flow follows a path that may be likened to a very wide, inverted V with its apex pointing toward Alaska and the two sides being somewhat crescent-shaped. This type of air-flow permits the cold air masses from Alaska and northern Canada to move southeastward along the middle route, which leads across the lake region and into the Ohio Valley, and thence eastward toward the coast. It brings abnormally low temperatures to all of the region affected.

A further decrease in the velocity of the general circulation seems to cause a further development of the north-south movements. The air currents over the northeast Pacific Ocean flow more nearly in a south to north direction while the flow immediately east of the mountains is more nearly from north to south. The cold air masses then follow the western track southward toward Mexico and the Gulf Coast.

These observations suggest another fact of major importance. The lowest temperatures are carried farthest into the lower latitudes during periods of sluggish circulation. The low temperatures apparently occur in the lower latitudes as a result of the sluggish circulation.

According to good meteorological theory, low temperatures over widely extended areas in middle and lower latitudes should tend to increase the poleward temperature gradient and thus tend to speed up the circulation. According to careful observations which have been checked and rechecked many times, the lowest temperatures in middle and lower latitudes occur during the periods of most sluggish circulation. If these low temperatures have any effect in speeding up the circulation, that effect is so small that it has not yet been observed Again, according to accepted theory, mild temperatures in middle and higher latitudes should tend to decrease the poleward temperature gradient and thus cause the general circulation to become more sluggish. According to observation, the mild temperatures in middle and higher latitudes occur when the circulation is most rapid. If the mild temperatures have any effect in causing the circulation to become more sluggish, that effect is so small that it has not yet been observed. In other words, the observed movements are in direct opposition to good meteorological theory.

The accepted theory holds that the change in temperature comes first, and the change in circulation follows as a result of the change in temperature. The observations seem to indicate that the change in circulation comes first, and the change in temperature follows as a result of the change in circulation. In other words, the temperature changes apparently have no effect upon the circulation, but changes in the circulation have a very great effect upon the temperatures. This suggests that the difference in temperature between the equator and the poles may not be the primary factor in producing the general circulation of the atmosphere, as so many now believe. The general circulation may not be a convectional circulation. Can this possibly be true?

Reed has suggested that "weather types are essentially air-flow types, and the persistence of a weather type is consequent upon the persistence of an air-flow type."[7] If the observations made by the writer

[7] Reed, Thomas R., 1933. Some aspects of the free air winds in the far west. Mo. Wea. Rev. 61:42-43.

have been interpreted correctly, the persistence of any given type of air-flow is determined by the velocity of the general circulation. It seems, then, that a given type of weather will persist as long as the general circulation continues to move at the same uniform velocity. If these conclusions are correct, will it not be possible to forecast future weather trends for several weeks or months in advance when accurate data on the velocity of the general circulation have been obtained? This may not be as difficult as it seems. The normal movement is toward a more rapid circulation in winter and a more sluggish circulation during the summer. If the circulation becomes more active as summer approaches, can the weather observer be safe in predicting drought? If the trend toward sluggishness is greater than normal, will he not be able to predict timely rains and an abundant harvest? If a more complete knowledge of certain atmospheric variations will enable scientific men to foresee impending abnormalities in the weather, should they not give the matter the most careful study and earnest consideration?

This study of certain atmospheric variations has led the writer to the following definite conclusions.

1. All major weather changes in the United States, and possibly in all other parts of the world, seem to be due to changes in the form and position of the world pressure areas. These changes in the form and position of the world pressure areas apparently are due to variations in the velocity of the general circulation.

2. The longitudinal movement of the air, eastward in temperate latitudes, may not be a permanent feature of a planetary wind system. It may be replaced by a latitudinal movement from some northerly or from some southerly direction.

3. Temperature apparently does not affect the circulation in just the way that is generally believed, but the circulation has decided effects upon the temperature.

4. A more complete knowledge of the variations in the velocity of the general circulation may be of decided advantage in forecasting future weather trends.