of the structure. If we could imagine the cyclone to be surrounded by a cylinder, and the *wall of the cylinder to act as an axis*, then the computation would proceed as in the case of a central axis, so far as the spacing of these lines is concerned.

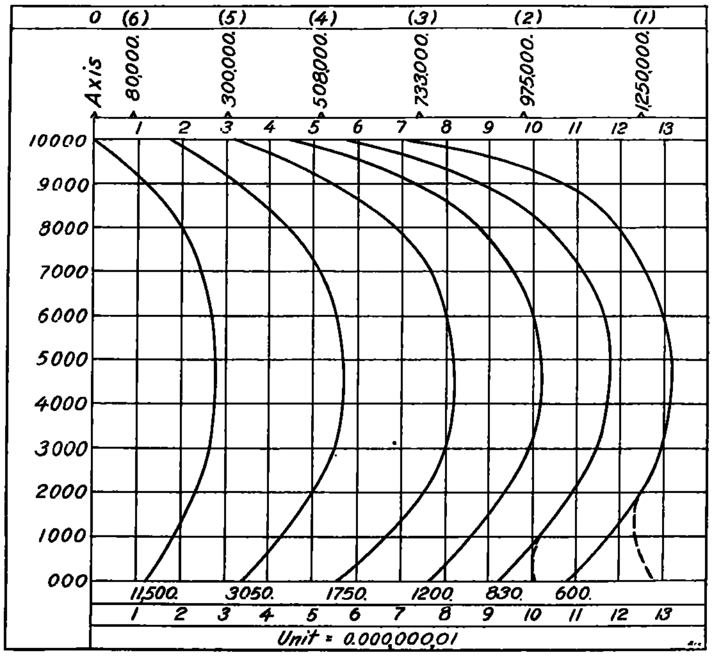

FIG. 19.—The computed vortex lines aA of the asymmetric land cyclone.

THE CONCAVE DUMB-BELL-SHAPED VORTEX.

The preceding discussion of the vortex lines, which involved the computation of the product of two constants $a\ A$, a being about 0.10 and A being a constant on each vortex line but having different values on the different lines, has resulted in a vortex system which suggests a convex dumb-bell-shaped vortex, where the lines are concave toward the axis instead of convex, as in the tornado and the hurricane. These two vortices satisfy the equations of motion as follows:

	Convex vortex.	Concave vortex.
Current function,	$\psi = A\varpi^2 \sin az.$	$\psi = A\varpi^2 \cos az.$
Radial velocity,	$u = -Aa\varpi \cos az.$	$u = +Aa\varpi \sin az.$
Tangential velocity,	$v = +Aa\varpi \sin az.$	$v = +Aa\varpi \cos az.$
Vertical velocity,	$w = +2A \sin az.$	$w = +2A \cos az.$

It is easy to trace out the relative differences by simply interpreting the trigonometrical signs. In the concave vortex the radial velocity is zero for $az = 0°$, increases outward to $az = 90°$, and returns to zero for $az = 0°$. The tangential velocity begins at a maximum for $az = 0°$, decreases to zero for $az = 90°$, and increases again to the maximum. The vertical velocity begins at a maximum for $az = 0°$, decreases to zero for $az = 90°$, and then increases to a maximum; v and w reverse direction at $az = 90°$. Whether this is a possible vortex in the atmosphere is a question which does not need to be considered in this connection for the following reasons. When one attempts to match the observed angles i of Table 84 III with the lines of fig. 19, as was done by some computations, it is readily seen that they do not in anywise agree in meeting the required conditions of the suggested concave vortex, and we must conclude that the suggested analogy is in fact fictitious and not very useful.

What we actually have in the cyclone is a convex dumb-bell-shaped vortex disturbed from normal conditions, and distorted almost beyond recognition by two fundamental circumstances. *The first is that the temperature distribution is entirely changed. In the hurricane the temperatures are stratified horizontally, but in the cyclone they are separated vertically, the warm and cold masses lying side by side, and the streams seeking to interpenetrate horizontally in the different levels by the action of gravitation. The second is the fact that the imperfect dumb-bell-shaped vortex which results from the preceding process attempts to lift its head into the rapidly flowing eastward drift which keeps stripping off the top layers and thus prevents the formation of the vortex in its natural proportions.* This process has been fully described in the MONTHLY WEATHER REVIEW, February, 1903, **31**, fig. 28, where the scheme of the isobars and wind vectors is developed. I therefore interpret fig. 19, above, to mean that it represents a convex dumb-bell-shaped vortex struggling to establish equilibrium between masses of different temperatures on the same levels, while the top layers are continuously stript away in the eastward drift. The inward radial velocity which properly belongs to the lower sections of a perfect dumb-bell-shaped vortex continues to prevail as long as there is any tangential velocity surviving, *because the lower half of the dumb-bell-shaped vortex is in fact never completed in this cyclonic circulation.* It is really a nameless survival of this typical vortex, and is a succession of hydrodynamic circulations more due to mutual reactions of warm and cold streams on the same horizontal plane, than to any total vortex structure involving mutual dependencies thru great depths. It is a question whether these cyclonic circulations can ever be analyzed as a vortex structure of any given type, as has always been assumed to be the case in the general discussions which prevail in meteorological literature. *Certainly there is no prospect of settling this problem until such accurate discussions of the observations of temperature, pressure, and wind vectors become available in all the levels as are given for the surface in fig. 18 of this paper.*

As a matter of fact it is exceedingly difficult to secure the correct values of the radial velocity u in the upper levels, as is abundantly testified by the work in the Cloud Report of 1896–97. In that place the motions of all sorts of cyclones, large and small, whether fully or incompletely developed, were united in one composite. Evidently for the study of this vortex problem in the upper levels only the strong cyclones should be used so that the data on the upper levels may be comparable with the data of fig. 18. In case the velocities of the Cloud Report, Table 126, adopted to extend the discussion above the surface, are not representatively correct the conclusions of this paper must be modified, but it is certain that no superficial treatment of the data of cyclones and anticyclones in the upper levels suffices to form the basis of our theoretical discussion. The cyclonic components u_2, v_2, must be fully separated from the eastward drift u_1, v_1, in all the levels, and a continuous campaign of observations with nephoscopes and theodolites, extending over several years, seems to be demanded by this branch of meteorological science.

DRY FARMING.

The expression "dry farming" has come into prominence during the last three years, and the "Third Trans-Missouri Dry-farming Congress," held at Cheyenne, Wyo., February 23–25, 1909, was the occasion of an enthusiastic presentation of the methods and the success attaching to this new departure. The term "dry farming" itself may be considered as an abbreviation of the expression "dry-land farming." The general idea of the method consists in giving up the attempt to raise a crop every year continuously on a given piece of land, and attempting instead of that to so conserve and utilize the moisture that the land receives from rain and snow as to secure a crop once every two or three years.

Few persons realize that the great success of the pioneers in a semiarid country depended upon their having the accumulated moisture stored up in the soil for many years upon which the first crops could feed. After a few years this accumulation is reduced below the ability of the annual precipitation to meet the demand made upon it, and either artificial irrigation must be resorted to or else the farmer suffers great loss in dry years and secures a good crop only in a wet year. Dry farming attains the same average results as ordinary farming without irrigation, but with the great advantage that the farmer's crops are fairly uniform thruout the successive years and he avoids the harrowing habit of worrying over frequent droughts and the necessity of borrowing money to tide him over the loss of crops.

The methods adopted in dry farming vary in every community with the climate, the soil, and the plant to be cultivated, and it is beyond our province to enter into the details of this side of the subject. On the other hand the climatic features that render dry farming possible and wise depend essentially upon the annual quantity rather than the seasonal distribution of precipitation and evaporation. This feature belongs to climatology proper.—*C. A.*

SOME CLIMATIC FEATURES OF WYOMING, AND THEIR RELATION TO DRY FARMING.[1]

By W. S. PALMER, Section Director. Dated Cheyenne, Wyo., February 24, 1909.

That portion of our country which is commonly spoken of as the semiarid region, and where so-called dry farming is practised, embraces a large territory which is included between the 95th and 125th degrees of longitude west of Greenwich. Within that belt of 30 degrees of longitude can be found a vast variety of climates; its topography is such that along its northern border winter temperatures of from 50° to 60° below zero may be experienced at times, while during the summer temperatures as high as 120° above zero may be recorded in the deserts of Arizona and southern California. There is, also, a great variation in the average annual precipitation of the various sections of this region, for in some of the mountain districts or along the Pacific coast the annual amounts may exceed 50 inches, while some of the desert regions have annual averages of less than 5 inches. On account of the broad area embraced within this region and the various climates that may be found therein, I wish to discuss in detail the climate of but a small portion of the semiarid region, so I shall confine my address to a discussion of some of the climatic features of Wyoming, a subject which has received my special study during the last ten years or more. While my remarks will be confined mostly to a discussion of the climate of Wyoming, they will, in general, apply to a large portion of the country which is now being cultivated by the so-called dry-farming method, Wyoming being located near the center of the dry-farming belt of the West.

During the last seventeen years a systematic collection of weather data has been made in Wyoming. In addition to the weather records which have been kept at the regular Weather Bureau stations where commissioned men are stationed, a large number of valuable records have been kept by persons who have been supplied with standard instruments by the Government and who have cooperated with the Weather Bureau in this work. The value of these records which have been voluntarily kept by the cooperative observers can not be overestimated, as they furnish data from the sections of the State where there are no regular Weather Bureau stations.

PRECIPITATION FOR WYOMING.

The most essential element in the success of dry farming is moisture, and I wish to present to you some Wyoming records regarding precipitation. From the monthly reports which have been compiled in the Cheyenne office from records kept at stations distributed over nearly all sections of the State, it has been determined that the average precipitation for the State as a whole during the last seventeen years has been 13.68 inches, or a trifle more than 13.50 inches. This average does not take into consideration the heavy precipitation which may fall in the high mountain districts where very few reliable records have ever been kept, but it is a fair average for that portion of the State below 8,000 feet, or for all of those districts where cultivation is possible. The precipitation herein spoken of includes rainfall and snowfall, the latter being reduced to its water equivalent.

Geographical distribution of the precipitation.

While the average amount for the State is 13.68 inches, there is a wide variation in the normal amounts received over the various sections of the State. There are portions of Big Horn and Sweetwater counties where the average annual precipitation is probably less than 5 inches, while over the extreme northeastern and the extreme northwestern portions of the State there may be a few sections where the annual average is nearly 20 inches. On a map which I have prepared to accompany this paper, see fig. 1, I have endeavored to show the geographical distribution of the annual rainfall thruout Wyoming; the peculiar and complicated topography of the State causing a wide variation over the various sections. The unshaded portions of the map show areas of the State where the average annual precipitation is less than 10 inches, and you will notice that those areas embrace only portions of Big Horn County and the Red Desert region, the aggregate of which is only a small percentage of the total area of the State. I believe that most of the dry-farming experts of to-day do not advise that dry farming be attempted in regions where the annual precipitation is less than 10 inches, so the unshaded portions of the map show regions where dry-farming attempts should not be made at the present day. The darkest shadings represent areas where the average annual precipitation is in excess of 15 inches, and here again you will notice that these areas represent only a small percentage of the total area of the State. It is probable that about 75 per cent of the total area of the State is embraced within the region which receives from 10 to 15 inches annually, such areas being represented on the map by a light shading. Thus you can see that a large proportion of this State receives an average annual rainfall sufficient, so we are told by the dry-farming experts, for the successful growth of certain crops where proper methods of cultivation are followed.

Seasonal distribution of rainfall.

From the large number of monthly records which have been compiled at the Cheyenne office, covering a period of seventeen years, I have computed the average monthly precipitation for each month of the year, and have shown the amounts graphically on the accompanying chart, fig. 2. It will be noticed that the monthly amount of precipitation increases from January to May, which has the highest average of any month of the year; a gradual decrease in the monthly amount is noted from May to November which shows the lowest average for the year. From fig. 2 it can readily be seen that in this section of the semiarid region the rain falls during that time of the year when it is most needed for the crops, that is, about 70 per cent of the total annual amount falls during the six months, March to August, inclusive. There is some variation in the average amounts for the different seasons in the different sections of the State. I give below for a number of selected stations, the percentage of the total annual averages which falls during the six months, March to August:

Station.	County.	Percentage which falls March to August.
Cheyenne	Laramie	75
Buffalo	Johnson	75
Fort Laramie	Laramie	73
Laramie	Albany	72
Sheridan	Sheridan	68
Lander	Fremont	66
Bedford	Uinta	55
Evanston	Uinta	54
Border	Uinta	54
Yellowstone Park	National Park	50

[1] Paper presented to Third Trans-Missouri Dry-farming Congress at Cheyenne, Wyo., February 24, 1909.