TABLE 1.—*Solar constant, atmospheric transmission, and atmospheric moisture values, measured at Calama, Chile, July, 1918, to January, 1919, inclusive*—Continued.

Date, A. M. or P. M.	Solar constant.	Grade.	Transmission coefficient at 0.5 micron.	Humidity (Air mass=3).			Remarks.
				ρ/ρ_{sc}	V. P. cm.	Rel. hum. %.	
Jan. 6, A. M.	1.890	VG+	.840	.270	.48	45	
8, A. M.	1.899	VG+	.845	.336	.39	39	Cirri all around horizon.
11, A. M.	1.941	E−	.855	.425	.41	43	
12, A. M.	1.888	E	.870	.568	.38	38	Some cirri in east and north
14, A. M.	1.963	VG−	.868	.637	.26	32	Considerable cirrus in east and south.
16, A. M.	1.948	E−	.841	.371	.45	50	Considerable cirrus in east and north, with large patches in west.
17, P. M.	1.939	VG−	.851	.423	.39	16	Considerable cirrus in east, but disappearing.
Jan. 18, A. M.	1.978	VG−	.858	.495	.31	32	Streaks of cirrus low in west.
19, A. M.	1.952	E−	.873	.630	.23	28	
20, A. M.	1.960	VG+	.874	.445	.48	51	
21, A. M.	1.932	VG+	.854	.430	.39	42	
22, A. M.	1.939	E−	.852	.384	.38	40	Thin cirri on north and cumuli at horizon in east.
23, A. M.	1.930	E−	.847	.344	.39	38	Patch of cirrus in southeast
24, A. M.	1.906	E−	.836	.305	.40	48	
25, A. M.	1.969	VG+	.822	.311	.58	61	Cirrus low in west.
29, A. M.	1.926	E−	.857	.387	.51	51	Small patch of cirrus near horizon in east.

THE DIRECTION OF ROTATION OF CYCLONIC DEPRESSIONS.

By J. S. DINES, Meteorological Office, London.

[Dated: Jan. 16, 1919.]

In a recent number of Nature (Dec. 12, 1918) I called attention to the fact that there is no dynamical reason why cyclonic circulation should not take place in the opposite direction to that commonly experienced. That is, clockwise circulation round a low pressure center may theoretically occur in the Northern Hemisphere and counter clockwise in the Southern. This result is apparent on consideration of the gradient wind equation connecting the velocity V with the pressure gradient γ.

The equation is

$$\frac{\gamma}{D} = 2\omega . V. \sin \lambda + V^2. \cot \rho / R$$

where D is density, ω angular velocity of the earth, λ latitude, R radius of the earth and ρ angular radius of curvature of the air path.

This equation being a quadratic in V has two roots, a positive one which corresponds with the normal circulation and a numerically larger one of negative sign corresponding with reversed circulation. Both these roots represent a stable state and therefore the only reason which appears to exist to prevent the reversed cyclone is that it can not get started, the rotation of the earth inevitably causing counter clockwise rotation to be set up in the Northern Hemisphere immediately any low pressure center is formed.

In a circular cyclone of the reversed type if the pressure gradient remain constant with increasing distance from the center the wind velocity will become very great in the outer regions, where ρ is large. It seems to follow that in such a cyclone the pressure gradient must fall off rapidly from the center and the steep gradient often found over large areas in normal cyclones could not occur in the reversed type.

In the case of circulation round a high pressure center the positive sign in the above equation is replaced by a minus sign. Two roots for V again appear, but in this case both are of the same sign and therefore both correspond with clockwise rotation in the Northern Hemisphere.

It seems possible that the reversed cyclone may be formed on a small scale by accidental causes such as an eddy set up round a precipitous headland, and perhaps under favorable conditions such a whirl might develop into a tornado, retaining its clockwise rotation. Little attention seems to have been devoted to the direction of rotation of tornados and evidence on the point is sometimes conflicting. Thus in the MONTHLY WEATHER REVIEW for April, 1918, a whirlwind at Pasadena, Calif., was described and Prof. E. Ellerman, of Mount Wilson Solar Observatory, recorded his impression that the rotation was clockwise.

The author of the paper apparently did not consider this evidence conclusive and the question remains open. One would like to impress strongly on observers of such phenomena the importance of taking careful note of the direction of rotation. A study of the damage along the storm track should afford conclusive evidence in the majority of cases. In this respect observers in the United States are in a much more favorable position than those in this country, owing to the extreme rarity of such phenomena in Europe.

An interesting fact which emerges from a study of the roots of the equation is that whereas in the case of a large depression the velocity in the reversed cyclone is decidedly greater than in the normal type for any given gradient, in small whirls of the tornado type it is almost the same in either direction. There is thus no reason to think that with a given decrease of barometric pressure at the center the reversed tornado would be appreciably more or less destructive than the counterclockwise type.

It has probably been generally recognized that a small whirl can rotate in either direction, but the fact that the same principle applies to a large cyclonic depression appears to have escaped attention.

DISCUSSION.

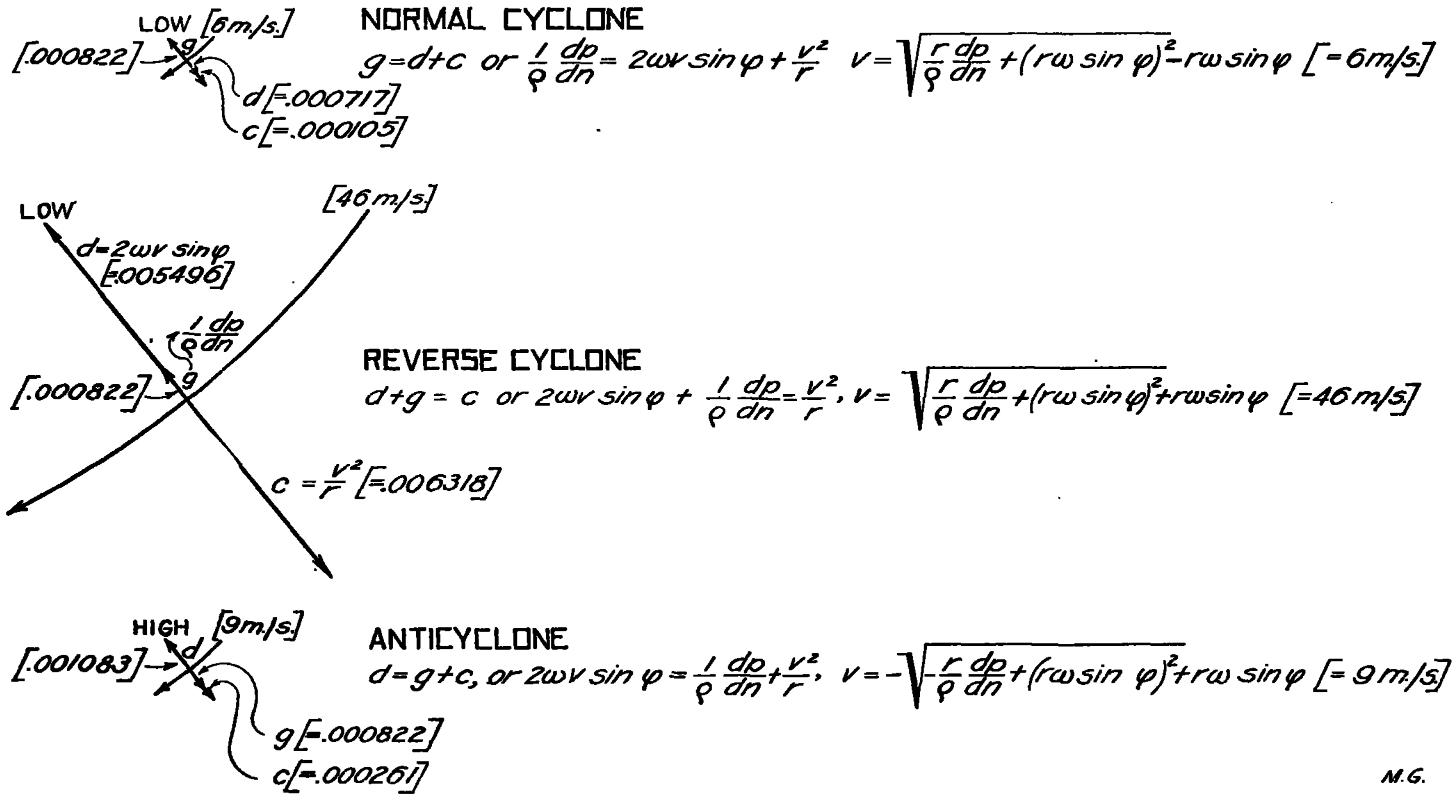
While the main point of Mr. Dines's paper is the proof of the dynamic possibility and a call for observations of reverse cyclones, the results of a further discussion of this matter in the Central Office of the Weather Bureau may be of interest.

A "gradient wind," by definition, flows in a direction perpendicular to the gradient and at such a velocity that two of the three forces, (1) gradient, (2) deflective effect of the earth's rotation, and (3) centrifugal force, acting

in one direction are numerically equal to the third, acting in the opposite direction. Taking symbols used in the United States [and assigning to each a value used by Dines (Nature, Dec. 12, 1918, p. 284)], namely,
ρ for air density [1,217 gm. per cu. m.],
dp/dn pressure gradient [1 mb. per 100 km.],
ω velocity of angular rotation of the earth [.00007292],
v wind velocity [to be determined],
ϕ latitude [55° N.],
and r radius of curvature of the wind path as projected horizontally on a plane tangent to the earth's surface at the center of wind-path curvature [334 km.],
the gradient force, g, is $\frac{1}{\rho}\frac{dp}{dn}$, [.000822],
the deflective effect of the earth's rotation, d, is $2\omega v \sin.\phi$ [.0001195v],
and the centrifugal force, c, is v^2/r [.000003v^2].

their interferences, thus, would be more likely to make counterclockwise whirls than the reverse.

What is the condition of relatively weak clockwise whirls? The reverse cyclone has the deflective and gradient forces toward the inside of the curve equal numerically to the very large centrifugal force toward the outside ($d+g=c$; see fig.); and it is only at high velocities that this centrifugal force can be large enough to equal both the deflective force and the gradient. At smaller velocities the centrifugal force is always less than the deflecting force, and so, to maintain the equation, the centrifugal force must have the gradient force acting with it to keep the wind on a given curved path ($d=c+g$; see fig.). In other words, there would have to be a high instead of a low pressure center on the inside of the curve. Weak clockwise impulses would, therefore, be associated with anticyclones instead of cyclones.—*C. F. Brooks.*



Let us consider these in the normal cyclone (counterclockwise in the Northern Hemisphere), the reverse cyclone (clockwise in the Northern Hemisphere), and the anticyclone, using, for illustration, diagrams drawn to correspond numerically to the values assigned above.

The given latitude, gradient, and radius of curvature in Dines's example would thus require a wind of 6 m./s. in the counterclockwise cyclone and one of 46 m./s. in the clockwise. Even if the gradient should approach zero the velocity requisite to keep the clockwise cyclone going would not fall below 40 m./s.

Since with ordinary gradients and radii of curvature the velocity necessary to maintain a clockwise cyclone is so high, it is obvious why such a reverse cyclone does not get started on a scale larger than a dust whirl or possibly a tornado. Tornadoes are so generally counterclockwise (1) because the necessary initial impulse does not need to be so great to start one in this direction as in the other, and (2) because in tornado regions there is the south wind on the east and the north wind on the west;

ADDITIONAL NOTE ON CLOCKWISE AND COUNTERCLOCKWISE CYCLONIC MOTIONS WITH APPLICATION TO THE FLIGHT OF AIRCRAFT.

Meteorologists easily perceive the slight possibilities that the clockwise motions, shown in Mr. Dines's note to be dynamically possible, can actually get agoing and be sustained on any considerable scale in nature. Nevertheless, no such limitations arise in the case of the flight of airplanes, and with a trifling alteration in one term the equations for the atmospheric motions become fully applicable to the flight of birds and aircraft. It may, therefore, be interesting to examine the results to which these considerations lead.

The basic equation governing all motions of bodies moving horizontally at a uniform velocity in curved paths over the earth's surface is:

$$\frac{mv^2}{r} = Fm \pm fm \qquad (1)$$

in which m is the mass of the body; v its velocity; r the