METEOROLOGY

Noctilucent Clouds in Alaska during 1962

Since the first reported sightings of noctilucent clouds in 1885, there have been many subsequent observations of them from latitudes ranging between 45° and 63·3°. The majority of these observations have been made from north-western Europe and the U.S.S.R. There appear to be only three previously reported observations of noctilucent clouds from the North American continent: two of these from Canada and one from Alaska. Vestine's observation[1] of the clouds from Meanook, Alberta (54° 37′ N., 113° 20′ W.), on July 20–21, 1933, was the first reported sighting from North America. The second reported sighting from Canada[2] was made on the night of July 23–24, 1961, from Saskatoon, Saskatchewan (52° 08′ N., 106° 38′ W.). The one reported Alaskan sighting[3] was made from Anchorage (61° 10′ N., 149° 59′ W.) on July 27–28, 1957. The lack of noctilucent cloud observations at latitudes higher than 63·3° (the latitude of Torsta, Sweden) was attributed by Ludlam[4] to the lack of keen observers at these latitudes.

Following a suggestion by Prof. Sydney Chapman, a watch for noctilucent clouds was kept this summer here (64° 53′ N., 148° 03′ W.) to determine whether the clouds could be seen at higher latitudes than previously observed. On the night of August 13–14, 1962, a noctilucent cloud display was observed from College by four independent observers. The clouds were first seen at approximately 2330 A.S.T. (Alaskan Standard Time, 150° W. Meridian Time) on August 13, and were observed until 0030 A.S.T. on August 14. The display, exhibiting the characteristic billow structure, was most intense shortly after midnight at which time the clouds extended in elevation up to 11° with the azimuthal extent of the clouds being approximately 25° west to 25° east of true north. A photograph of the display seen on that night is shown in Fig. 1. This picture was taken by Mr. Yngvar Gotaas on Kodochrome film at an exposure of 90 sec at f 5·6. Two subsequent noctilucent cloud displays, faintly visible through the cloud cover, were seen and photographed from College, Alaska, on the nights of August 14–15 and August 16–17. The display on August 14–15 was also observed at Ft. Yukon[5] (66° 34′ N., 145° 18′ W.), and the display on August 16–17 was seen from Galena[6] (64° 46′ N., 156° 54′ W.).

Noctilucent cloud displays were also observed by the Weather Bureau personnel at Anchorage on two occasions this year[7]. Their first sighting was on May 6–7, 1962, 0005–0050 A.S.T. This display was visible up to 7° above the horizon. At the beginning of the display the azimuth extent of the clouds was 303°–009°, and toward the end of the display the azimuthal extent of the clouds was 021°–071°. Their second sighting was on the night of August 11–12, 1962. This display was first seen at approximately 2300 A.S.T. and lasted until 0115 A.S.T. The elevation angle of the upper border of the display was about 10°, and the clouds extended from north-north-west to north-north-east, approximately. According to Mr. John Gardey[7] of the Anchorage Weather Bureau, the clouds are seen at least once every year from Anchorage.

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[1] Vestine, E. H., *J. Roy. Astro. Soc. Canad.*, **28**, 249 (1934).
[2] Baker, K. D., and Currie, B. W., *Canad. J. Phys.*, **39**, 1515 (1961).
[3] Lindley, W. B., *Monthly Weather Rev.*, **85**, 272 (1957).
[4] Ludlam, F. H., *Tellus*, **9**, 341 (1957).
[5] Young, J. (private communication).
[6] Private communication from the F.A.A. observer in Galena.
[7] Gardey, J. (private communication).

PHYSICS

Bath-Tub Vortex

Perennially one hears controversy regarding the direction of the vortex in the drain of the bath-tub or the kitchen sink. Some claim that the direction of swirl is always the same in the northern hemisphere, and that in the southern hemisphere it is always opposite to that for the northern hemisphere. Others claim that there is no unique direction of swirl in either hemisphere.

Both schools of thought are in some sense correct. For the everyday observations of the kitchen sink and bath-tub variety, the direction of the vortex seems to vary in an unpredictable manner with the date, the time of day, and the particular household or experimenter. But under well-controlled conditions of experimentation, the observer looking downward at a drain in the northern hemisphere will always see a counter-clockwise vortex, while one in the southern hemisphere will always see a clockwise vortex.

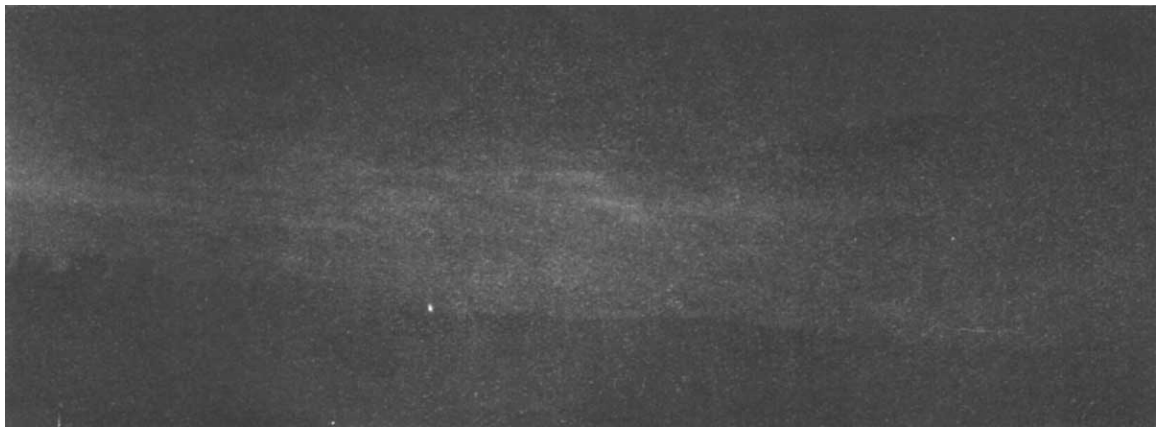

Fig. 1. Photograph of noctilucent clouds taken from College, Alaska, at 00 : 06 : 30 A.S.T. on August 14, 1962

In a properly designed experiment, the vortex is produced by Coriolis forces, which are counter-clockwise in the northern hemisphere and clockwise in the southern hemisphere.

There are two reasons for the apparent haphazard results of the everyday observations. The effective rim speed of a tank 2 ft. in diameter rotating with the Earth at Boston, Massachusetts, is only about 0·04 in./min. This tiny Earth-induced motion may be much less than other motions too small to be perceived by ordinary observation. Unless the water in the vessel is allowed to settle for many hours, for example, the residual motions from the filling of the vessel may far exceed the foregoing figure. Moreover, the very act of pulling the plug from the bottom of the vessel may inadvertently create substantial velocities. Even if many hours are allowed for settling, air currents in the room or thermal currents associated with non-uniform temperatures around the vessel may easily cause water velocities larger than that due to the Earth's rotation. All these difficulties are quite real; this was amply proved by early experiments with the apparatus described later.

The second source of confusion in the casual everyday observations is that the Coriolis forces due to the Earth's rotation may in fact be much smaller than other forces normally present. For a speed of 0·1 in./sec toward the drain, the Coriolis force at latitude 42° north is about $3(10)^{-7}$ times the force of gravity. If the vessel is not perfectly symmetrical about the axis of the drain, the asymmetrical viscous forces at the side walls and at the bottom of the vessel may produce torques larger than that due to the Coriolis force; the direction of this asymmetrical torque would, of course, vary from vessel to vessel. Even the extremely small forces of surface tension at the free surface may, owing to non-uniformities in temperature or chemical impurity, lead to torques.

A meaningful experimental demonstration of 'the bath-tub vortex' must be designed to cope with the difficulties mentioned here. Such an apparatus was made and operated near Boston for an educational motion picture entitled *Vorticity*. The tank is circular, 6 ft. in diameter and 6 in. high, with a flat bottom. The drain hole, 3/8 in. in diameter, is centrally located and flush with the bottom. A length of hose some 20 ft. long leads the water from the drain to a sump. A 'vorticity float' makes the vortex visible. This is a cross made of two slivers of wood, each about 1 in. long, pinned together with a fine wire through the centre of each. The cross floats in a horizontal plane just below the surface of the water, and a small length of wire extending above the surface of the water provides the necessary floating stability.

Before starting the experiment the end of the long hose is closed with a plug. The tank is then filled nearly to the brim with water swirling clockwise. This direction is deliberately chosen to test whether sufficient time has elapsed for adequate decay of the original motion, so that one may be confident that the swirl seen in the experiment really arises from Coriolis forces rather than from initial swirl not yet sufficiently dissipated. After filling, the tank is covered with a plastic sheet to eliminate the effect of air currents, and the room is maintained at nearly uniform temperature. About 24 h are required for settling of the motion to a degree where the residual motions are unimportant compared with those due to the Earth's rotation. The plug is then pulled from the end of the long hose and the vorticity float is delicately inserted above the drain hole. About 20 min are required for the tank to drain completely. During the first 12–15 min no rotation of the float is perceptible to the eye. At about 15 min, however, the counter-clockwise rotation of the vorticity float becomes distinctly perceptible, and gradually increases. Near the end of the experiment, when the vessel is almost completely drained, the vorticity cross turns one revolution in about three or four seconds. This is about 30,000 times greater than the effective speed of rotation of the Earth at latitude 42° N. It agrees in order of magnitude with what one would calculate theoretically on the assumption that the rotation of the float is indeed due to the Coriolis forces of the Earth.

When all the precautions described were taken, the vortex was invariably in the counter-clockwise direction.

If the plug were pulled after only about 1–2 h, the vorticity cross would begin to spin clockwise within 1–2 min after the plug was pulled, and would reach a rate much greater than the rate of counter-clockwise spin for the correct experiment. This was because the angular velocity remaining from the clockwise filling action, although not readily perceptible, was nevertheless greater than that of the Earth.

In one experiment the original clockwise swirl was allowed to settle for four or five hours before pulling the plug. An unusual result was observed. During the first two-thirds of the draining period, the vorticity float turned in the clockwise direction owing to the angular momentum of the initial swirl. After having reached a large clockwise angular velocity, the float began to slow down, ultimately came to rest, and then proceeded to accelerate in the counter-clockwise direction. This may be explained as follows. The water acquires the rotational velocity of the Earth through the diffusion of a viscous shear layer, mainly from the bottom of the tank. This viscous boundary layer on the bottom, in which the water has acquired the counter-clockwise angular velocity of the Earth, grows thicker with time. Above this boundary layer the water still retains the clockwise angular velocity associated with the initial swirl. When the vorticity float sinks to the appropriate level, it tends to reverse direction.

I am prepared to provide precise particulars of my apparatus to anyone in the southern hemisphere who wishes to perform an identical experiment for the sake of convincing any remaining doubters.

Incidentally, those who claim to have seen the direction of swirl change as a ship crosses the equator are surely pressing the case too far. At the equator the Coriolis forces vanish, and it would be virtually impossible to perform a valid experiment a short distance from the equator.

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Solution of Boundary Value Problems in Plane Strain

This method replaces direct solutions of the Airy relation by, in effect, linear combinations of solutions of this equation for the edge dislocation. So far its use has been investigated only in connexion with the stress fields of dislocations in finite bodies; it may well be that it is useful in other connexions as well.

This technique is limited to two-dimensional representation and is as follows: the finite body is