CONCERNING THE FLIGHT OF GULLS.

BY ALEXANDER FORBES.

MR. WILLIAM BREWSTER has recently published in this journal[1] a most interesting and important account of the soaring of gulls to windward. His account is especially valuable since his observations were made with such care and accuracy that no room is left for doubt that the birds soared for long distances horizontally against a strong wind in the neighborhood of a steamer, without the aid of wing beats. The phenomenon is of such interest from the standpoint of physics that it seems to me to warrant further discussion.

The essential features of his observations are briefly as follows:— The steamship on which Mr. Brewster travelled was steaming at a rate of about fifteen knots an hour, with a wind at first blowing at a rate of about twenty miles an hour from about two points off the port bow, and later freshening to a gale of about thirty-five miles an hour and shifting somewhat more nearly dead ahead. Under these conditions a large number of gulls accompanying the ship glided the greater part of the time on set wings; at first flapping their wings at fairly frequent intervals, but, as the wind freshened, less and less frequently until at the height of the gale most of the birds could be seen to glide "over distances certainly exceeding a mile, without a single wing beat." He says of them when gliding: "their respective positions in relation to each other and to the ship were so accurately and systematically maintained that whenever I got one of them in line with any fixed object on the deck I could often hold it there, without myself moving again, for several successive minutes." Thus it is clear that their motion was horizontal not downward, and that its continuance with unabated speed eliminates the possibility of explaining it as the result of momentum acquired in a previous downward swoop, or from previous wing beats.

The distribution of birds in relation to the ship was as follows:— "A few followed the creamy wake of the ship or poised directly over her just to the rear of her smoke-stack but the majority kept

[1] 'The Auk,' Jan., 1912, p. 85.

abreast of her to the windward side, the somewhat sheltered lee side being persistently avoided. On a level with her upper deck or a little above it, they were generally and rather evenly distributed — although more thickly in places than in others — all the way from her stern to amidships, some keeping within a yard or two of the rail, others thrice that distance off, still others fifty or more yards out over the water." He also occasionally saw "one of them leave the rest, and, going two feet to their one, forge ahead of them all perhaps to the bows of the steamer and beyond, yet without once beating its wings."

Mr. Brewster notes that when the birds soared during the height of the gale their wings were held back and with a "downward trend of the flight quills." He suggests that "the wind constantly fills the concave wings of the gliding gulls much as it does the sails of close-hauled vessels and with similar results but with this essential difference: that whereas its force is exerted for the most part laterally on the vessels' sails and opposed by the side thrust of their keels or centreboards in the water, it must have chiefly a lifting effect on the wings of the gulls and be counteracted by the weight of their bodies bearing downward. Hence we may infer that in the case of these birds forward movement is the resultant of two component forces, that of wind and of the attraction of gravitation." He then refers to an article by G. F. Tydeman in which by "extensive use of abstruse mathematical calculations" the phenomenon is analysed. Mr. Brewster then says that he dissents from Tydeman's conclusion "that birds gliding to windward depend for means of propulsion largely if not wholly on uplift afforded by powerful ascending currents of air such as must always rise above a vessel when heavy wind is striking against and deflected from, her sides." He says that for a time he favorably considered this view, adding:— "But I dismissed it altogether from my mind after repeatedly seeing birds hundreds of yards behind the steamer, or fifty or more yards to one side (always the windward one) of her, or even well in advance of her, gliding on set wings in precisely the same manner and quite as ceaselessly as those which hung about her flanks. It seems inconceivable that her presence or movement could have caused vertically rising currents of air to be regularly maintained at such distances from her as those just mentioned, or that they

could have been thus constantly and generally maintained by other influences when the ocean all about her was swept by a wind blowing over thirty-five miles an hour. I even doubt if they extended much above her upper deck for there I was lashed incessantly in the face by what seemed to be horizontally-racing wind, while several of the gulls were often sailing fifteen or twenty feet higher still, perhaps directly over me. On the other hand it must be admitted that I have never known any of these birds to glide far to windward except when accompanying a steamship, a fact which apparently lends some support to Mr. Tydeman's contention, although not necessarily having such significance since it may reasonably be interpreted in other ways."

With the data so thoroughly determined the problem resolves itself into one of comparatively elementary physics. I have not seen Tydeman's article, but I believe that without his abstruse calculations it is possible by reasoning which is within the reach of those untrained in higher mathematics to show that the phenomenon of horizontal gliding could not be produced in the way Mr. Brewster suggests.

Let us assume for the present that the wind is blowing horizontally and uniformly, that the air is an evenly moving mass without local distortions. Then to a bird surrounded by the moving mass it is as if the air were still and the earth's surface travelling by underneath. The bird will tend to drift freely with the wind and will feel no more pressure from it than from the surrounding air in a flat calm. The case of a bird in contact with only one medium moving uniformly is wholly different from that of a boat in contact with two media, air and water. The tendency of the water to prevent free drifting with the wind is the sole cause of the wind's pressure on the boat as long as the air moves uniformly. The bird can only feel pressure from the surrounding air in case of a sudden alteration in the speed or direction of the wind, or in case of motion through the air imparted by gravity or by the bird's own efforts.

The problem of gliding can best be considered by regarding the bird as in a calm and analysing its possible motions with respect to the surrounding air regardless of the earth beneath. After this analysis we may introduce the relative motion between air and

earth. Suppose, then, a bird in still air: in what directions can he glide without wing beats? Motion in any direction will be met by friction from the air. To overcome this, energy must be expended. This may be supplied by muscular action through the bird's wing beats, or by gravity. In the present case we have eliminated wing beats as we are dealing with gliding on set wings, and the only possible source of energy which remains to drive the bird is gravity. Gravity can only work effectively by inducing motion in a direction with a downward component; in a direction which satisfies its demands, so to speak, by bringing the object downward. The direction may deviate from the horizontal by ever so slight a slope, but it must have some downward component. For a bird with nothing but the resistance of his wing expanse to keep him from falling there must be a considerable downward component, especially if the gliding is to be rapid. The only case in which the energy imparted by gravity can carry a bird in still air in a direction without a downward component is when the bird soars for a short distance horizontally or even upwards with the momentum acquired in a previous downward swoop. This case is clearly ruled out of the present problem. Now the horizontal movement of the atmosphere in a wind without ascending currents or other irregularities does not alter the case of still air except in that the bird tends to be carried horizontally with the wind, and consequently must glide more rapidly through the air if going to windward in order to make headway over the earth's surface. In order to glide faster through the air the downward component of the direction of gliding must be increased.

When analysed in this way I think it is evident that no combination of the forces of a uniform horizontal wind and gravity can drive a soaring bird horizontally to windward. The fundamental difference between the close-hauled sailboat and the soaring bird with downward sloping flight quills may be considered in the following way. If a force is to do work the mass upon which it acts must move in such a way as to yield to the force. When a boat, close-hauled, sails to windward she moves in such a way that the sail is withdrawn from the wind's pressure (Fig. 1). When the gull soars with a horizontal wind bearing against the under surface of the downward sloping wing forward motion will not make the

wing withdraw from the wind's pressure but will do the reverse. The fallacy in the wind-gravity conception lies in likening gravity to a kite string which, unlike gravity, holds the kite from drifting to leeward.

The gull, being a very perfect gliding machine, can soar at a

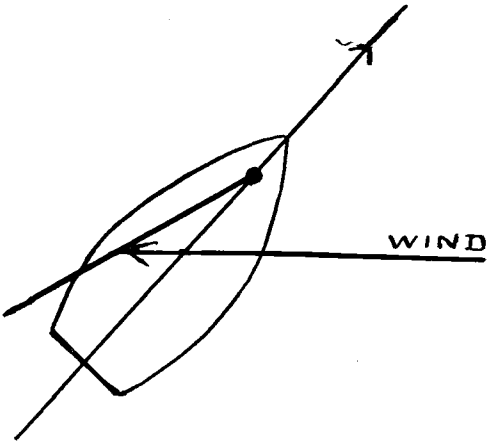

Fig. 1.

comparatively slight downward angle, and in this way can doubtless make head against a strong wind by soaring at a moderate incline. With an upward current of air the possibilities are wholly changed. Through such a current a bird might readily glide downward without descending at all in relation to the earth's surface. The downward motion through the air might suffice to render gravity an effective motive force and yet be so counterbalanced by the ascent of the air that the bird would remain at the same level above the earth. The air current need not rise vertically, but there must be some upward component in its direction, provided its motion be uniform, to make horizontal soaring possible.

The positions about the ship in which Mr. Brewster observed horizontal gliding present such a variety that at first sight it seems difficult to explain the presence of persistent ascending currents in all of them. And yet I believe that reasonable explanations are available in every case. The places noted were, (1) a short dis-

tance in front of the ship, (2) all along the windward side, (3) over the smoke-stack, (4) astern, directly over the wake.

Ascending currents of air must necessarily be produced by a ship steaming to windward, and two distinct causes will be concerned in their production. One is the diversion of the wind from its natural course, both laterally and upwards, by the great mass being forced through it. The other is the column of heated air and smoke rising from the smoke-stack which must cause to rise with it a considerable mass of the surrounding air.

Most of the diversion of the wind by the mass of the ship is probably lateral, but a fair proportion must be upwards. The point where the upward diversion would be most felt would presumably be just above the windward side of the diverting mass. But it would also extend a short distance to windward, for the ship must drive before it a sort of cushion of air suffering compression

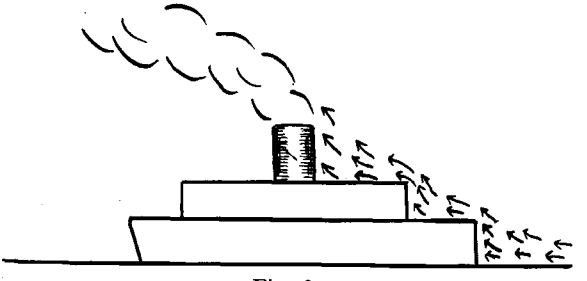

Fig. 2.

from the approaching obstruction. Although the point of maximum upward diversion is presumably just over the weather bow, there is probably an appreciable upward diversion from the propagated obstruction some distance in front and to windward of the ship (Fig. 2).

Mr. Brewster doubted the existence of rising currents where the birds were seen gliding fifteen or twenty feet above the upper deck on which the wind seemed to blow horizontally upon him. I think it is possible, and even probable, that while the wind swept the deck horizontally, it blew with an upward slant twenty feet higher; for in meeting the vertical forward end of the upper deck the air must have undergone some compression which reached a

maximum as the air rounded the corner, to be followed by expansion as it passed over the horizontal surface of the deck. The result of such expansion would be a divergent upward slant in that portion of the air which was at a slight distance from the deck.

On the leeward side of the ship the wind would probably cant downward to form an eddy. If this were so it would readily explain the avoidance of the lee side of the ship by the gulls.

Over the smoke-stack the ascending current must have been powerful, because of the heat. Its presence in the wake of the ship may be explained by the fact that the wind was not dead ahead but from a point and a half to two points off the port bow. As long as the volume of smoke and air poured from the funnel remained at a higher temperature than the surrounding air it must have continued to rise. And since such upward movement tends to be imparted to adjacent air it is probable that for a short distance to windward of the smoke an upward diversion of the wind occurred. With the wind blowing obliquely on the bow any given point in the wake must have been directly to windward of some point in the trail of smoke, namely, that portion of the smoke which was discharged when the boat was at the given point. The birds, although directly in the wake of the steamer, were directly to windward of a large mass of air and smoke, probably still warm and rising vigorously. They may well have been aided in this manner by rising currents for several hundred yards astern of the boat.

I do not claim that these suggestions cover all the factors involved in the explanation of the gliding Mr. Brewster describes. But I contend that the wind must have presented other than uniform horizontal motion to render the feat possible. Ascending currents caused in some of the ways I have suggested seem to me to present the easiest explanation that has occurred to me.

ADDENDUM.

Since writing this discussion my attention has been called to the papers on the subject by Lord Rayleigh, in which he discusses these points so clearly and concisely that my remarks seem almost

superfluous. In the first of these he says at the outset,— "I premise that if we know anything about mechanics it is certain that a bird *without working his wings* cannot, either in still air or in a uniform horizontal wind, maintain his level indefinitely."

This states concisely my main contention. Subsequently he names two possible conditions of continued soaring in other than a downward direction; (1) ascending currents and (2) variations in velocity or direction in different portions of the air. In his discussion he devotes more attention to the second condition, and cites an example of observed flight which seems to exemplify this principle. I scarcely mentioned the possibility of explanation by this latter principle of irregularities in the wind, for though it occurred to me as logically conceivable, it seemed too improbable in the case described by Mr. Brewster to be worth dwelling on.

The references to Lord Rayleigh's papers are as follows:— "The Soaring of Birds." Nature, Vol. XXVII, p. 534. 1883. (Collected Scientific Papers, No. 98, Vol. II, p. 194.)

"The Sailing Flight of the Albatross." Nature, XL, p. 34. 1889. (Coll. Sci. Papers, No. 159. Vol. III, p. 267.)

"The Mechanical Principles of Flight." Manchester Memoirs, Vol. XLIV, p. 1. 1900. (Coll. Sci. Papers, No. 257, Vol. IV, p. 462.)