STREAKS ON NATURAL WATER SURFACES

Contribution No. 538 from the Woods Hole Oceanographic Institution

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I was very much interested to see Mr. A. K. Totton's photographs of markings on the water (in the August 1950 issue of *Weather*, Pl. IV) because recently I have been trying to collect as much information about such phenomena as possible. I enclose two photographs which may interest the readers of *Weather*; one, showing ' venous streaks ' on the surface of the Great Salt Lake of Utah, was kindly given to me by Prof. A. J. Eardley of the University of Utah (Plate 9); the other, a picture of the Banana River in Florida, shows a remarkable development of ' parallel streaks ', which was taken by Mr. Alfred Woodcock, of Woods Hole (Plate 9, lower).

Most natural bodies of water have a streaky appearance which results from a natural process, although artificial streaks (due to the passage of a ship, for example) are also frequently observed. There has been quite a difference of opinion in the literature as to the nature of the process which produces streaks. I am personally inclined to admit that under certain circumstances any one of the processes suggested may account for them ; to attribute all streaks to the same mechanism would be a great mistake. I should like, therefore, to review briefly what little material there is in the literature about these streaks on the surface of natural bodies of water.

The streaks themselves may consist of accumulations of floating objects, such as Gulf-weed (Woodcock 1950), pine needles or bubbles of foam, all of which are visible because of their colour. Others are local concentrations of an oil film (presumably of planktonic origin) which damp the tiny wind-raised capillary waves. These are visible because of the marked difference in reflectivity of sky light between ruffled and slick areas.

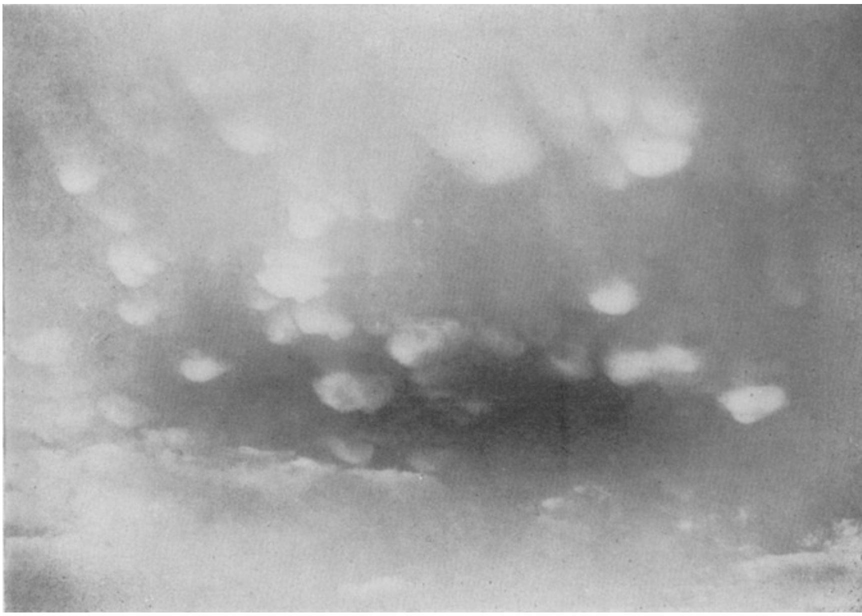
SINGLE STREAKS

Single long streaks are often observed in harbours. They may stream out from a single continuous source of contamination, and run downwind with the surface water, or follow tidal or other currents. For convenience they may be called ' trail-streaks '. Single long streaks may also develop from an initially localized concentration of surface contamination in regions of strong horizontal shear by a simple stretching of elements of water in the shear zone. These ' shear-streaks ' occur on the edges of strong tidal currents and in rivers. A third kind of commonly observed single streak is seen to remain parallel to a coast-line a hundred feet or so offshore, most frequently with an onshore wind. The cause of these ' shore-streaks ' is not known, but I venture to suggest that they are due to the horizontal convergence and sinking of surface water which is driven toward the shore by the wind, sinking somewhere off-shore, where the water is reasonably deep, rather than at the vanishingly small depths at the very water's edge.

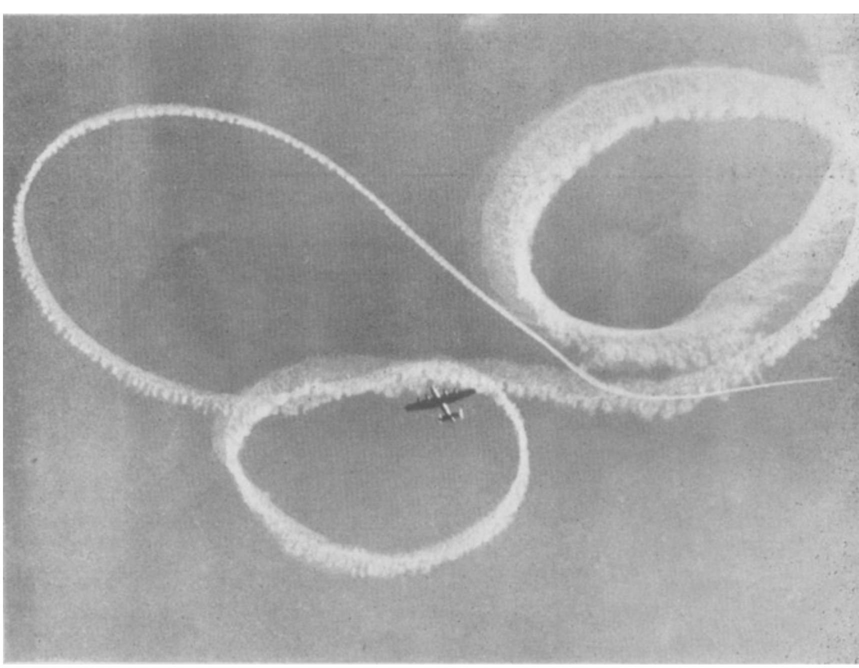
'Venous streaks' on the Great Salt Lakes of Utah

' Parallel streaks' on the Banana River

PLATE 9



Mammato-cumulus



Condensation trails

Photographs by [*M. Hubbard*

PLATE 10

MULTIPLE STREAKS

The kinds of single streaks mentioned above are described in order to avoid confusion with other kinds which are really more interesting. I am referring to the large numbers of streaks often arranged in geometric patterns over large areas of a lake or ocean. Although it may be dangerous to draw a sharp distinction, these multiple streaks usually appear either in long parallel lines or with a vein-like pattern. I find it convenient to call them 'parallel' and 'venous' streaks respectively.

Parallel and venous streaks are plentiful in nature. Windrows of Gulf-weed in the deep ocean (Woodcock 1944, 1950) are conspicuous examples of parallel streaks. Unfortunately there are no good photographs of these lines of weed. I have tried to photograph them on several occasions, as have others at this institution, and so far we have had no success. Similar streaks are observed on lakes, and have been carefully studied (Langmuir 1938).

AIR- AND WATER-CELL THEORIES

A large proportion of the parallel and venous streaks are aligned up- and down-wind. Two possible mechanisms have been suggested. One is the air-cell theory, which maintains that there is a cellular structure of the wind, which sweeps the surface water into lines. Langmuir (1938) on the other hand has reported that cellular motions exist in the water and that the streaks are located along lines of surface convergence and sinking water, a mechanism which may be called the water-cell theory. He has suggested that the cellular motion extends down to the thermocline, and indeed that it plays an important rôle in the formation of the thermocline. If this idea be true it certainly deserves further investigation, because the lack of an adequate theory of the thermocline is one of the most glaring lacunæ in oceanography and limnology. Langmuir believes the water-cells are mechanically driven by the wind, although in just what manner is obscure. Woodcock (1944) indicated the presence of films of colder water on the surfaces of lakes and ocean waters and suggested that the water-cells are thermally driven convection-cells similar to those observed in the laboratory (Stommel, 1946). I do not think the results of these laboratory studies are directly applicable to lake and ocean processes without further investigation.

Ewing (1950) has observed other parallel streaks whose orientation bears no obvious relation to the direction of the wind. He attributes them to alternate contractions and dilatations of the surface film due to progressive internal waves travelling along at some distance beneath the surface.

CINEMATOGRAPHIC STUDIES

During June and July of last year I made a number of cinematographic studies of streaks on small ponds on Cape Cod, Massachusetts. They were of the venous and parallel types, and consisted of oil-slicks and lines of foam. The steadier the wind direction, the more nearly parallel they seemed. Upon showing the pictures at some 80 times their normal speed interesting features, which otherwise escaped the eye, were visible : the structure of the wind was so gusty and turbulent that it was obvious that no permanent structure in the air maintained the streaks ; these were so quickly re-oriented after a shift of wind (only 1 or 2 minutes was necessary) that deep motions such as those reported by Langmuir did not seem likely. Thermal convection seemed also unlikely because the streaks occurred at times of intense heating of the ponds and with a very stable *epilimnion* ($0{\cdot}1\ ^{\circ}\mathrm{C.\,m}^{-1}$). Although surface convergence into the lines was confirmed, using Woodcock's ballasted-bottle technique, cellular motions were not observed at depths of one foot or deeper. The indications were that these streaks were due to a process confined to the top few inches at most, and did not play a rôle in the formation of the deep thermocline, which in this instance was at a depth of about thirty feet. It seems, therefore, that they were due to yet another process, perhaps associated with differences of wind-stress in and out of streaks, but which I must admit I do not understand. It would be misleading to conclude that this classification of various types of surface marking is complete. For example, Woodcock and Wyman (1946) have published photographs of mysterious bands on the surface of the ocean which may be due to some still undiscovered process.

If any of your readers have in their possession further data and pictures on these things, I should be most grateful to hear from them.

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WANTED