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## Introduction

In 1949, the Naval Research Establishment, in co-operation with the Atlantic Oceanographic Group, expanded observations of temperature conditions in the water column at the Sambro Lightship off Halifax, N. S. This expansion consisted chiefly of making BT casts twice daily to obtain the detailed vertical temperature distribution in the water column. The responsibility of analysing these data has been assumed by the Naval Research Establishment, and this report deals with observed water replacements, which have recently been discussed and presented for publication by Messrs. Longard and Banks in more detailed form (in press).

For convenience, currents in the ocean are divided into three groups:

- (1) Convection or slope currents associated with the distribution of density and pressure;
- (2) Currents associated with the tides; and
- (3) Drift currents initiated and maintained by the frictional drag of winds on the surface.

It is the application of this latter phenomena to the Scotian Shelf which will here be considered. Illustrations of water movements and replacements have been furnished in earlier papers (Hachey, 1934,1937). However, while the resultant movements and replacements can be observed, it is difficult

to evaluate the components arising from the various factors.

Work primarily done in this area used observational data taken at weekly or greater intervals, and usually only in Halifax Harbour, which meant that many short term fluctuations went unobserved, and, in any case, the extent of any water replacement was not definitely known. At Sambro Lightship, located about eight miles offshore, twice daily observations of the water column, as well as observations of atmospheric conditions, have been recorded since 1949. During October, 1949, water column observations indicated that the colder bottom waters were completely replaced. These replacements were associated with a tropical cyclone, and it is of interest to analyse the relationship between the two phenomena.

#### Ekman's Theory

A successful theory of wind driven currents was developed by Ekman (Sverdrup et al, P. 489-507) from a number of type problems which he solved by ordinary hydrodynamical methods. A particular problem was concerned with a steady and uniform wind blowing in a constant and uniform direction outside and parallel to a straight and infinitely long coast, where the sea is considered to be of uniform depth. In such a case, a slope of the surface will be developed perpendicular to the coast, and gradually increase until the total flow, perpendicular to the coast, due to wind and pressure gradient, is zero.

If the depth of the wind current be represented by  $D$ , and that of the sea, by  $d$ , then three currents will exist, provided

d > 2D:

- (a) a surface drift current deflected to the right of the winds direction,
- (b) a mid-water current parallel to the coast, and in the winds direction, and,
- (c) a bottom current moving more or less in a direction at right-angles to the coast.

General Case for South Coast of N. S.

A north-east or south-west wind along the Scotian coast, should, according to Ekman's theory, cause on-shore or off-shore movement of surface water. The surface currents initiated by a north-east wind veer off to the right, with the result that surface waters tend to pile up along the coast, with consequent offshore movement of the deeper waters.

Observations at Sambro Lightship

Observations made at Sambro Lightship during the cyclone of October, 1949, indicate a complete replacement of deeper and colder waters by warmer surface water. With reference to Figure 1, the replacement, which began about October 17th, is clearly indicated. The period before October 17th indicates a normal structure with a temperature difference between top and bottom of 20° F, and a 50 ft. surface layer of an approximate temperature of 56° F. During the 18th and 19th, the surface layer is rapidly thickening, and by the 22nd it extends nearly to the bottom, with a temperature difference between top and bottom of about 2° F, and an average temperature of about 55° F.

It is the 25th before the colder bottom water begins to re-appear, and by the 28th normal conditions have returned. During this period wind directions correlate exceedingly well, as one would expect from Ekman's theory, with the resulting replacement. For about a week previous to the 22nd, the wind was from a direction between east and north - a direction ideal for piling warmer surface waters along the coast and eventually to replace the colder sub-surface water. By the 23rd the wind has changed direction to the southwest, and thence forward remains in a general westerly direction. This, results in the cessation of surface replacement and colder bottom waters return to the water column. By the 28th, water conditions are again normal, being similar to that of the 17th, except that the surface layer is slightly thicker.

It is interesting to note that while during the 27th, 28th and 29th, winds from the west and north-west, attained velocities up to 30 m.p.h., the water structure underwent no appreciable change. According to theory, with which these observations agree, winds from the north-west would tend to produce movement parallel to the coast with little on-shore or off-shore movements and hence little change in water column structure.

#### Summary

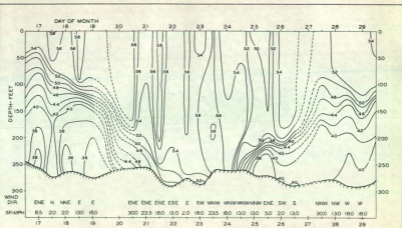
Drift currents initiated and maintained by the wind are capable of causing widespread replacement of coastal waters. The effect of a northeast wind along the Scotian Coast is to pile surface water along the coast and ultimately to replace the colder bottom water. In the course of this discussion, the

effect of pressure in producing this replacement has been neglected. While the atmospheric pressure gradient during this period, were, in all probability, tending to produce the same result, it is fairly safe to assume that the role played by this factor is a relatively minor one.

The direction, strength and duration of the wind are factors which enter into this phenomenon of water replacements, demonstrated by the observations in the water column at the Sambre Lightship. Further observations are required to elucidate the relative importance of the three factors.

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