BRIEF COMMUNICATIONS

EFFECT OF TIDAL FLOWS ON THE POSITION OF THE UPPER BOUNDARY OF THE THERMOCLINE

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The position and structure of the thermocline is determined by a number of factors, including the effects of wind, the presence of surface and body waves, convection, turbulence, topography of sea bottom, etc. The influence of these factors on thermocline dynamics has been extensively investigated (see, for example, [1-6]).

In this paper, we report an attempt to establish the dependence of the position and structure of the thermocline on tidal flows in the sea.

The vertical temperature distribution T(z) was measured in the Kandalakshskii Bay of the White Sea in July, 1975. A dc bridge was used for the continuous recording of T(z). The sensitive element was the MT-54 thermistor. The results were recorded on the N-39 strip-chart recorder. In the temperature range $5° \leq T \leq 20°C$, the measuring channel had a characteristic that was linear to better than 5%. The rate at which the vertical scan could be carried out was restricted by the thermal inertia of the probe and did not exceed 50 cm/sec. The corresponding spatial resolution was about 25 cm. The temperature was measured within 0.1°C.

The vertical temperature profiles were carried out in the absence of appreciable wave motion or wind so that these factors could be ignored thereafter.

The distributions were recorded at high and low tide at two stations.

Station 1 was located to the west of the White Sea biological station of the Moscow State University, at a distance of about 250 m from the shore, at a depth of 15 m. Continuous vertical temperature scanning was carried out for 1.5 h and a total of 35 profiles was obtained.

Figures 1a-c show the vertical temperature distributions measured just before the beginning of low tide (16:45 h). It is clear from Fig. 1 that the temperature profiles have a complicated shape with locally reversive variations of temperature with depth.

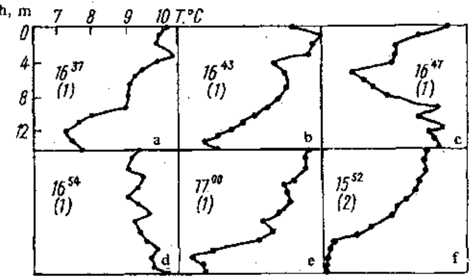

Fig. 1. Vertical temperature distribution: a-e) station 1; f) station 2.

Comparison of the curves in Fig. 1b,c and values of the correlation coefficient between them ($R_{12} = 0.11$) show that the temperature profiles are subject to rapid time variations at the end of the high tide and the beginning of the low tide. Thus, at 16:37 h the temperature fell with depth and an inversion was present at z = 12 m. The correlation between (a, b) was R = 0.82. At 16:47 h (c), the temperature was found to increase with z beginning with z = 5 m, and the temperature at sea bottom was found to be equal to the surface temperature.

The next two temperature profiles, measured at 16:50 and 16:52 h, repeat the previous profile (c), and this is indicated by the high correlation coefficient (R = 0.7).

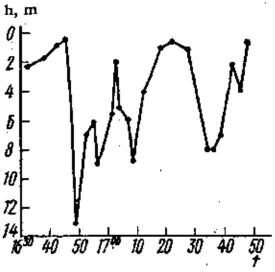

Fig. 2. Position of the upper boundary of thermocline (station 1).

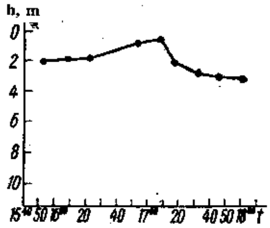

Fig. 3. Position of the upper boundary of thermocline (station 2).

At 16:54 h, there is again a considerable change in T(z) and the correlation between adjacent profiles is only R = 0.1 (Fig. 1d). In contrast to the preceding temperature distributions, here the situation is quasi-isothermal in most of the high tide flow, and the temperature exceeds the surface value only at the bottom (by 0.1°C).

However, after a further 5 min, the temperature distribution (e) becomes similar to (b) with correlation coefficient R = 0.84, i.e., the profile observed before low tide, which persists for 40 min, is again observed. The picture is then repeated but in somewhat modified form.

The temperature distribution data have been used to determine the position of the upper boundary of the thermocline. It is clear from Fig. 2 that the data for station 1 are characterized by a rise in the upper boundary of the thermocline at the end of high tide (between 16:35 and 16:54 h) and a sharp increase in its depth at the beginning of low tide (between 16:45 and 16:50 h). The rate at which the thermocline descended was calculated from the formula $v = \Delta h/\Delta t$ and was found to be 5.4 cm/sec (Δh is the change in the depth of the thermocline in the time Δt).

As the low tide continued, the position of the thermocline was found to fluctuate sharply, and the interval between these motions increased from 7 min to 25 min while the velocity with which this occurred varied between 0.3 and 3.4 cm/sec.

It is clear from Fig. 2 that there was a certain trend in the position of the upper boundary of the thermocline. The reason for this variation in the thickness of the upper isothermal layer must be sought in the dynamics of tidal motion in bays. Station 2 was located at a distance of 500 m from the shore at a depth of about 15 m, in the region between Kendamys and the biological station. The meteorological conditions remained practically the same at the two stations, but the data obtained at station 2 were different from those at station 1. At station 2, the surface temperature remained constant whereas at station 1 it varied within broad limits. The vertical temperature profiles obtained at station 2 were smoother and the thermocline was better defined (Fig. 1f). The upper boundary of the thermocline was found to rise smoothly up to the point where rising tide was replaced by falling tide (17:07 h, Fig. 3). At this time, there were no rapid variations in the T(z) profiles of the kind observed at station 1 (Fig. 1c). The variations at station 1 were observed immediately after the beginning of falling tide, determined by calculation. After the beginning of the falling tide, the thermocline was found to descend, but this was only slight and occurred with v = 0.3 cm/sec.

The relatively small changes in the position of the thermocline recorded at station 2 were probably due to the fact that the measurements were performed further out at sea, at a wider part of the bay, where the rate of flow of water during rising and falling tides was much smaller.

We note in conclusion that the thickness of the isothermal layer at stations 1 and 2 near the end of the rising tide was smaller, and this was probably connected with the fact that the measurements were performed in the coastal zone at a depth of 15 m where friction against the bottom affected the entire flow and this in turn produced considerable variations in the flow velocity as a function of depth. Moreover, the flow of water in the coastal zone at a time of rising tide occurs toward smaller depths, so that advective transport under these conditions leads to a reduction in the thickness of the isothermal layer.

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