Boundary Tides in the Kattegat

In order to facilitate observations on the vertical movements of the boundary surface far from the shore a recording boundary gauge has been constructed. A commercial steel barrel of about 200 litres capacity used for kerosene was provided with an axial tube of two inches width running through the barrel and having its ends welded to the flat ends of the barrel. Thick glass rings inserted at both ends of the tube serve to reduce friction against a vertical guide, 25 metres in length, of phosphor-bronze wire rope, which runs straight through the tube. The wire rope has its upper end attached to a large buoy, which is kept five metres below the surface by means of a double anchorage[1], a heavy weight attached to the wire rope at its lower extremity keeping it vertical and well stretched. The barrel is thus free to move in a vertical direction between depths of 6 and 30 metres.

The barrel, filled partly with large spherical glass floats, partly with fresh water, was hermetically closed and finally balanced with the recording instrument and with an additional load, so as to be in equilibrium in sea-water of the density 1·022. This is the average density of the water at the boundary surface in the central Kattegat, where two or three such instruments were kept anchored during several weeks of the fall of 1932. By means of a precision pressure gauge attached to the barrel, its varying depth, which may be taken as equal to the depth of the boundary, is recorded on a large drum turned by clockwork, which runs for three weeks or more. An automatic record of the boundary waves is thus obtained, which it would otherwise require continuous hydrographic soundings from ships anchored at the points of observation to realise. Moreover, the boundary gauges also draw their records under weather conditions which would make observations from anchored ships impracticable.

The records prove that very considerable wave-like movements of the boundary round its average depth at about 17 metres were going on the whole time the instruments were working. The total depth at the anchored systems varied between 40 and 60 metres. Waves of a semidiurnal period between 11 and 13 hours from crest to crest, with a maximum height of about 6 metres, were conspicuous in the diagrams. These waves attained their largest amplitude about full moon and new moon, but there were also considerable variations in amplitude apparent over shorter intervals of time.

A harmonic analysis carried out on a fortnight's record gave an amplitude of the semidiurnal lunar tide in the boundary of $\pm$ 0·6 metres (the M_2–component tide), and of the semidiurnal solar tide $\pm$ 0·2 metres (the S_2–component tide). The surface tides in the Kattegat are much smaller; thus at Varberg the amplitude of M_2 in the surface is $\pm$ 0·038 metres and of S_2 $\pm$ 0·01 metres. The amplitudes of the tidal components in the boundary brought out by analysis, however, only account for a fraction of the maximum height of the boundary waves in our records.

Boundary waves of semi-diurnal period were first discovered in the Great Belt in 1907 by Otto Pettersson and have since then been recognised at other localities and also in the open sea by other observers. Local variations in the amplitude of the waves revealed by our records seem to support Zeilon's theory, that topographical features of the sea-bottom play an important part at the generation of the boundary waves.

It is of interest to note, that 'inertia currents' similar to those found from current measurements in the central Baltic (see the accompanying letter by Gustafson and Kullenberg), appear also to influence the boundary movements in the Kattegat. An analysis of one of our curves carried out with periods varied by steps from 13·9 to 14·5 hours gave a very distinct maximum of amplitude $\pm$ 0·3 metres for the sine curve with a period of 14·3 hours, which is equal to 12 pendulum hours at the latitude of the anchored systems : $\varphi = 57° 15'$ N. Analysing shorter fractions of 6 $\times$ 14·3 hours, the amplitude of the same sine curve occasionally rises to $\pm$ 0·7 metres, and the phase as well as the amplitude undergoes irregular variations, such as may be expected from waves set up by extraneous forces.

It is suggested that boundary gauges of the type here described suspended from ships, either drifting or at anchor, may be used for the study of such short period boundary waves, as were observed in the central Atlantic Ocean during the *Meteor* expedition.

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Feb. 8.

[1] Nature, 115, 639, May 2, 1925.

Inertia Currents in the Baltic

Theoretically, a particle moving without friction on the surface of a rotating planet should describe a circular path in the course of twelve 'pendulum hours', that is, with a period given by $T = \frac{\pi}{\omega \sin \varphi}$ where ω is the angular velocity of the rotation and φ is the latitude. It is generally assumed, that these movements are insignificant compared to the currents actually existing in the ocean.

In the course of Swedish investigations on the downward spread of the wind-current, carried out by means of recording current-meters suspended from large buoys, which were kept well below the surface by means of double anchorage, currents, apparently of the inertia type, were recorded near the surface in the central Baltic, lat. 56° 44′, long. 19° 37′, depth of observation 17 metres, total depth 136 metres. Beside a current of nearly steady direction set up by the wind, there was a current component turning clock-wise at the rate of 24° 6′ an hour. This rate remained practically constant for several days, so that altogether fifteen revolutions were made in about eight days. A strong wind blowing for some thirty hours in the middle of the observations produced a change of phase in the rotation, but the angular velocity before and after the break remained the same.

When the residual current was strong, the rotating current caused periodic variations in its velocity and direction, but when it was weaker than the rotating current, as was generally the case, the resultant current described spirals, which soon approached to an almost circular movement.

The period of the rotating current is on an average 14½ hours, whereas 12 pendulum hours at this latitude amount to a value slightly less or 14·3 hours. Measurements at different depths, from 11 to 22 metres, and at different points in the same locality, gave practically the same results.

A natural interpretation of these results would be,