Modifications of the Pisa Tube and Some Results from Observations off Cape Point[1]

C. P. Duncan

Division of Sea Fisheries
Cape Town, South Africa

ABSTRACT

Twelve stations were worked from 6 to 8 July 1965 aboard the R.S. SARDINOPS in a tight grid of three lines between Cape Town and the Cape of Good Hope, one line of four stations being worked each day. One subsurface current observation was made at each station with a Pisa Current Indicator (Carruthers Jelly Bottle). Results show three cyclonic eddies, with upwelling at each eddy. Surface flow, as shown by ship drift, bears no relationship to subsurface flow, possibly because of the strong thermocline throughout the area.

The current indicator consists of a low-density polythene Pisa Tube fitted with a Pyrex bottle containing a compass, gelatin, and castor oil. The tube floats at an angle from the vertical according to the strength of the current; the gelatine sets at the same angle and freezes the compass. The strength of the current is given by a calibration graph of tilt versus speed, and the direction is given by the compass. The equipment, designed by J. N. Carruthers of the National Institute of Oceanography in England, has been provided by that Institute; the apparatus is similar to that shown by Carruthers (1958: fig. 10). Previous cruises had given poor results because of the ease with which the cylindrical tubes rotated about their longitudinal axes. Two small (30 × 5 cm) vanes of neutrally buoyant polythene were therefore welded onto the tubes 120° apart to damp short-period oscillations (Fig. 1).

This modification was very successful. In the absence of a suitable flume, tests were made at sea to compare the indications of modified tubes with standard ones. At 0.22 kt there was no discernible difference in the readings. At a speed of 0.87 kt, as registered by the standard tube, the tube with vanes registered 0.97 kt. These tests, conducted aboard R. V. TRACHURUS, indicate that the percentage error increases with the speed of the current. Since the maximum speed considered in the present paper is 0.52 kt (using a finned

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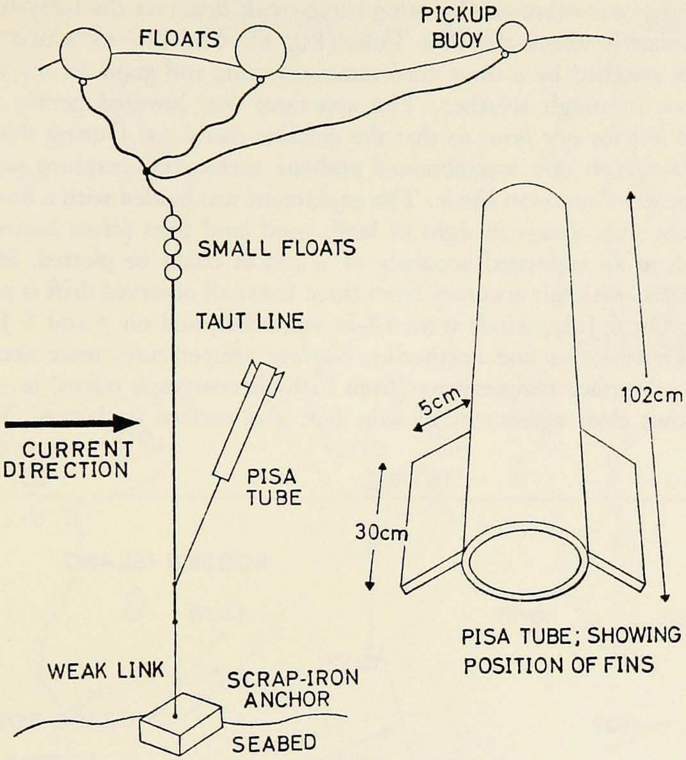

Figure 1. Stabilizing vanes on a Pisa Tube and manner of use.

tube), the error in this reading is certainly less than that at 0.87 kt—by linear interpolation, about 4.6°/₀ less. Drag on the vanes and consequent additional deflection will increase with the square of the current speed, and this figure of 4.6°/₀ error is therefore probably an overestimation. A difference of 5°/₀ is considered negligible in the results presented here. Direction in all comparisons was identical.

Each Pyrex "jelly bottle" was warmed in boiling water until the gelatin was liquid and the compass could orient itself freely. The Pisa Tube was filled with hot water to delay the setting of the gelatin, and the jelly bottle was then secured in position inside it. The station depth was determined with the echo-sounder, and a nylon line of the same length (breaking strength 230 kg) was rigged. An anchor of scrap iron was secured by means of trawl twine to the end of the line so that, if the weight fouled on the bottom, the trawl twine would break and the nylon line bearing the equipment could be recovered. The jerking on the line by the surface buoys had been found to cause gelatin to mix with the castor oil at the interface so that no reading could be obtained;

this difficulty was overcome by using three small floats on the buoy-to-anchor line immediately above the Pisa Tube (Fig. 1). The line to which the Pisa Tube was attached by a stout cord remained taut, and good results were obtained even in rough weather. The apparatus was lowered gently into the water and left for one hour so that the gelatine could set. During this time, a bathythermograph cast was obtained and the surface temperature was taken with a Nansen-Pettersson bottle. The equipment was hauled with a line hauler.

With the ship always in sight of land, good land fixes (cross bearings) and radar fixes to an estimated accuracy of ±400 m could be plotted. Ship drift was estimated with fair accuracy from these fixes; all observed drift is presented in Fig. 2. On 6 July, winds were 18-kt westerlies, and on 7 and 8 July, less than 10-kt westerlies and northerlies. Surface temperatures were accurate to ±.02°C, subsurface temperatures (from bathythermograph traces) to ±0.1°C. Fig. 2 shows close agreement of ship drift and surface isotherms. This was

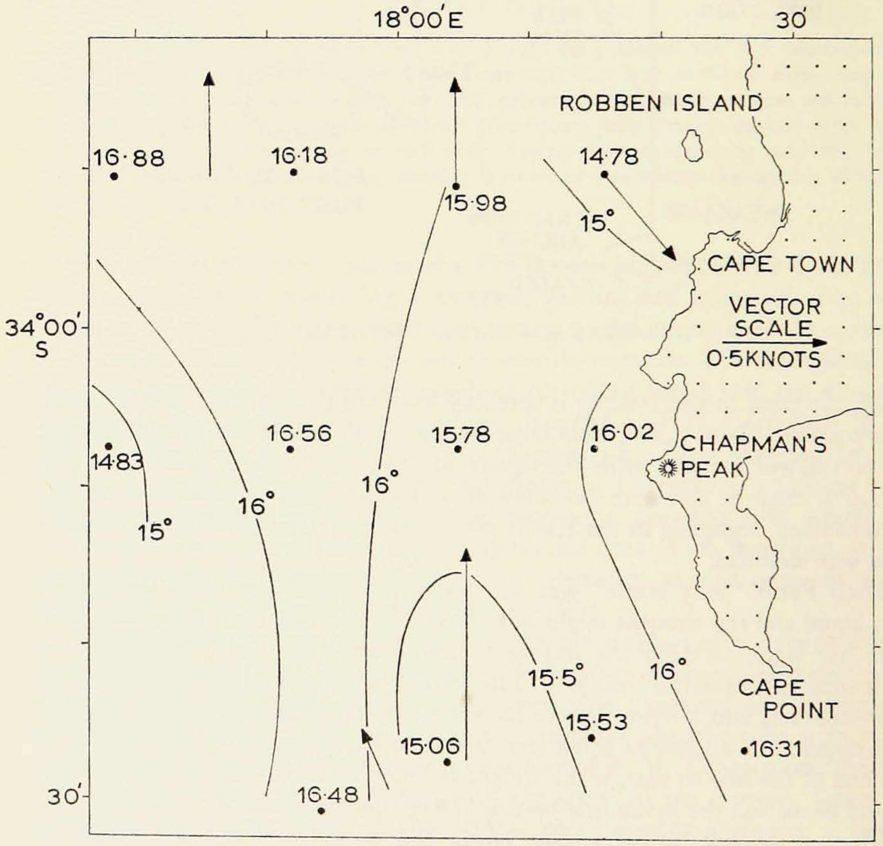

Figure 2. Surface isotherms and ship drift.

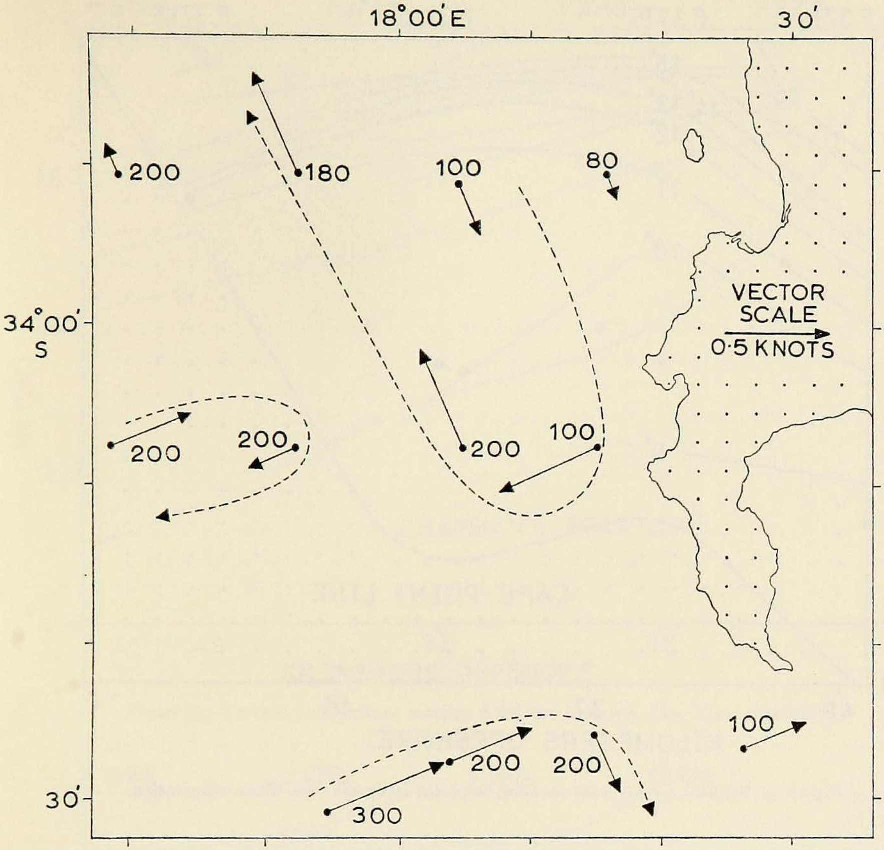

Figure 3. Subsurface currents. Figure next to a vector arrow indicates depth of observation in meters.

especially noticeable (i) 24 km west of Cape Point, where there was a one-knot intrusion of cool water northward, and (ii) west of Robben Island, where there was a half-knot set to the southeast. Fifty-six km west of Chapman's Peak there was an isolated cold patch (as shown by the ship's continuous thermograph) with the same temperature as the upwelled water at Robben Island. Good sights were obtained on this line, but no drift was noticed.

All observations of subsurface currents were made below the thermocline (Figs. 4, 5, and 6). LaFond (1960: 743) has illustrated how the thermocline can act as a layer separating opposed motion above and below it. Although this is a small-scale effect caused by a progressive internal wave, it has here been assumed that the currents above and below the thermocline could, on a larger scale, form two distinct and separate systems. It should be noted that winter is normally the season when thermoclines occur least frequently off

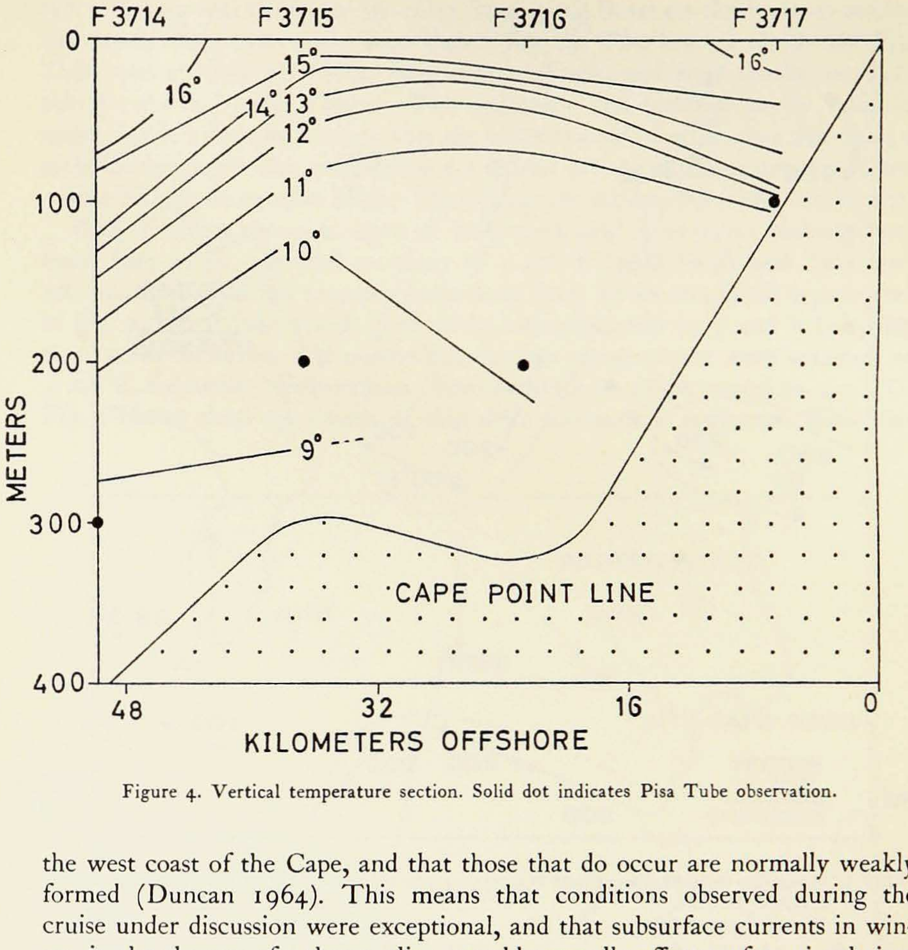

Figure 4. Vertical temperature section. Solid dot indicates Pisa Tube observation.

the west coast of the Cape, and that those that do occur are normally weakly formed (Duncan 1964). This means that conditions observed during the cruise under discussion were exceptional, and that subsurface currents in winter, in the absence of a thermocline, would normally affect surface circulation.

Comparison of Figs. 2 and 3 shows that the colder temperatures are always within one of the eddies indicated with a dashed line. A cyclonic eddy in the southern hemisphere will have the effect of raising cold water toward the surface, and vertical temperature profiles (Figs. 4, 5, and 6) were drawn to determine whether the cold surface temperatures were actually caused by the subsurface cyclonic movement.

Fig. 4 shows definite upwelling at the two middle stations; this agrees well with both the cyclonic current pattern and the surface temperatures. Fig. 5 shows upwelling from 8 to 20 km offshore, which agrees with the surface-temperature pattern and the cyclonic circulation shown in Fig. 3. If the isotherms (40 km offshore) are regarded as being equivalent to isopycnals, this configuration would indicate an anticyclonic cell with a warm center. This

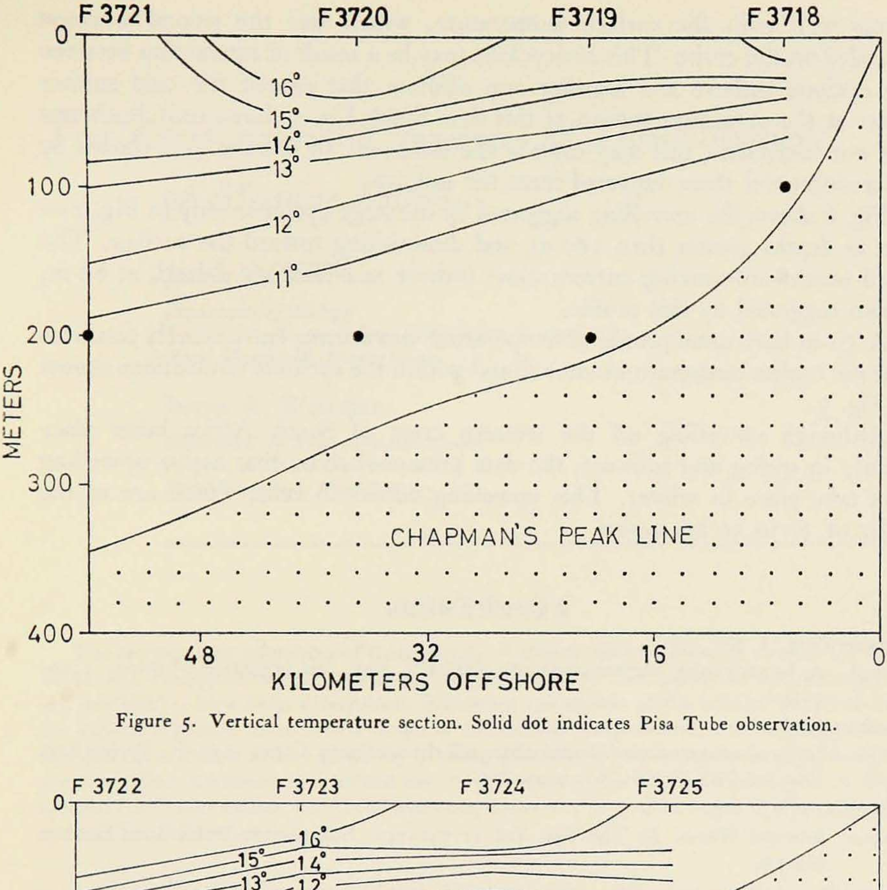

Figure 5. Vertical temperature section. Solid dot indicates Pisa Tube observation.

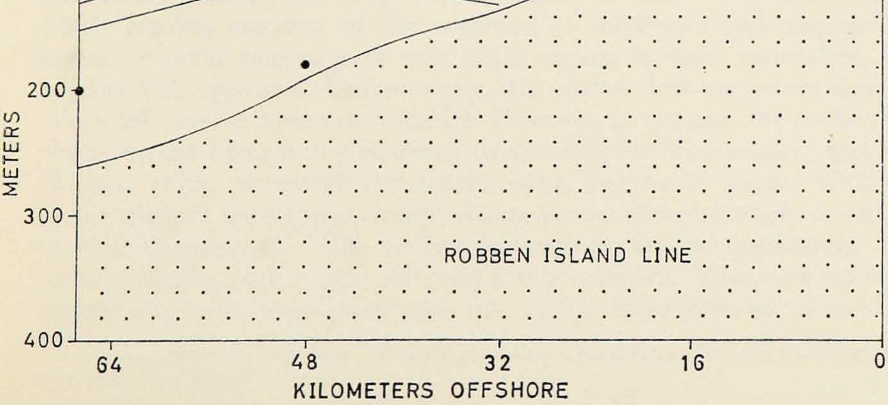

Figure 6. Vertical temperature section. Solid dot indicates Pisa Tube observation.

agrees well with the surface temperature, which was the second warmest recorded on the cruise. This anticyclone may be a result of interaction between the cyclone inshore and another one offshore that caused the cold surface water at the outermost station of this line. Since Fig. 5 shows only isotherms and not isopycnals, this may explain the difference in the currents shown by observation and those expected from the isolines.

Fig. 6 shows the upwelling suggested by the large cyclonic eddy in Fig. 2—best at depths greater than 100 m, and diminishing toward the surface. The small southward-moving current close inshore near Robben Island, at 80 m, is also suggested by this profile.

A 50-m horizontal profile of temperature was drawn, but it merely confirms that the coolest temperatures were found within the cyclonic circulations shown in Fig. 3.

Although upwelling off the western coast of South Africa takes place mainly in spring and summer, the data presented show that active upwelling does take place in winter. This upwelling occurs in cells, which are of the order of 30 to 50 km across.

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