NOTES ON DETERMINING THE DEPTHS OF SAMPLING IN SERIAL OCEANOGRAPHIC OBSERVATIONS

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ABSTRACT

In order to interpolate between thermometrically determined depths of sampling in serial oceanographic observations it has been customary to plot a curve of depth to wire length ratio against wire length. It is shown that a simpler and probably more accurate method consists of plotting wire length minus depth against wire length. In this method the surface wire angle is converted into a line of tangency to the curve which always terminates at the zero point of the graph. Furthermore, the limiting slope of this curve is more readily defined and utilized.

In oceanographic serial observations the determination of depth by means of an unprotected reversing thermometer is a completely standardized technique which requires no further elaboration. On the other hand, when only two or three unprotected thermometers are used on a deep cast, the interpolation for the depths of intervening Nansen bottle samples and temperatures presents a problem of somewhat greater complexity. This problem has become especially pertinent since the end of the war because of the limited supply of reliable unprotected reversing thermometers now available in this country. Closely related to it is the problem of extrapolation beyond the lowest thermometrically determined depth on exceptionally deep casts. The depth limit of an unprotected thermometer having a scale range of 60° C. and a pressure coefficient of 0.01° C. per meter is about 5,500 meters. Only an occasional thermometer has a pressure coefficient sufficiently small to permit the direct measurements of depths as great as 7,000 meters.

The procedure now generally used for calculating depths of sampling will be called the depth ratio method. This consists of plotting the ratio of thermometer depth to wire length (D/W) against wire length (W) and drawing a smooth curve through these points. The cosine of the surface wire angle is used as an additional point at the surface. Intermediate depths are obtained by multiplying the wire length by its corresponding ratio on the curve.[2]

[1] Contribution No. 488 from the Woods Hole Oceanographic Institution.

[2] Sverdrup, H. U., Determination of depths at which temperatures were measured and water samples collected, in, Scientific results of Cruise VII of the CARNEGIE during 1928–1929; Oceanography—1-A, Observations and results in physical oceanography. Publl. Carneg. Inst., No. 545: 15–18 (1944).

A different procedure, used by the writer in working up a number of ATLANTIS stations, involves less computation than the depth ratio method and is believed to be at least as accurate. Instead of the depth ratio (D/W), the depth difference $(W - D)$ is plotted against wire length for the thermometrically determined points and a smooth curve is drawn through them. This curve must terminate at the zero point of the graph, thus, in effect, adding an inerrant point towards its construction. The surface wire angle is utilized by converting it to a line to which the curve becomes tangent at the surface. This is done in the following manner. Supposing the wire angle to have a cosine of 0.870, the line of surface tangency is drawn from the origin through a point with co-ordinates $W = 100$ and $W\text{-}D = 100 - 87 = 13$, or $W = 1000$ and $W\text{-}D = 1000 - 870 = 130$. Intermediate depths are found by interpolation along the curve and by the subtraction of the depth difference from the corresponding wire length.

A comparison of the two methods is best illustrated by the example shown in Fig. 1: the depth ratio and depth difference curves for a deep ATLANTIS station on which nine Nansen bottles were distributed between wire depths of 2,300 and 7,200 meters. Only two unprotected thermometers were available, each attached near its maximum depth. Since the wire angle is apt to be a crude measurement, the cosines and lines of surface tangency for angles 5° on either side of it were also plotted on the graphs.

These supplementary surface values bring out one of the major distinctions between the two systems. An error in the surface wire angle would radically change the depth ratio curve and would throw suspicion on the validity of the two thermometric points. On the other hand, even though the slope of the depth difference curve would be altered near the surface, the three points used for its construction would remain unchanged and only the accuracy of the wire angle would become open to question.

Another important difference between the two methods is found in the limiting slopes of the curves. The slope (λ) will be defined as equal to 0 when it is parallel to the vertical axis of the graph. For the depth ratio curve,

$$\lambda = \frac{d\left(\dfrac{D}{W}\right)}{dW} = \frac{WdD\text{-}DdW}{W^2 dW},$$

while for the depth difference curve,

$$\lambda = \frac{d\,(W\text{-}D)}{dW} = \frac{dW\text{-}dD}{dW}.$$

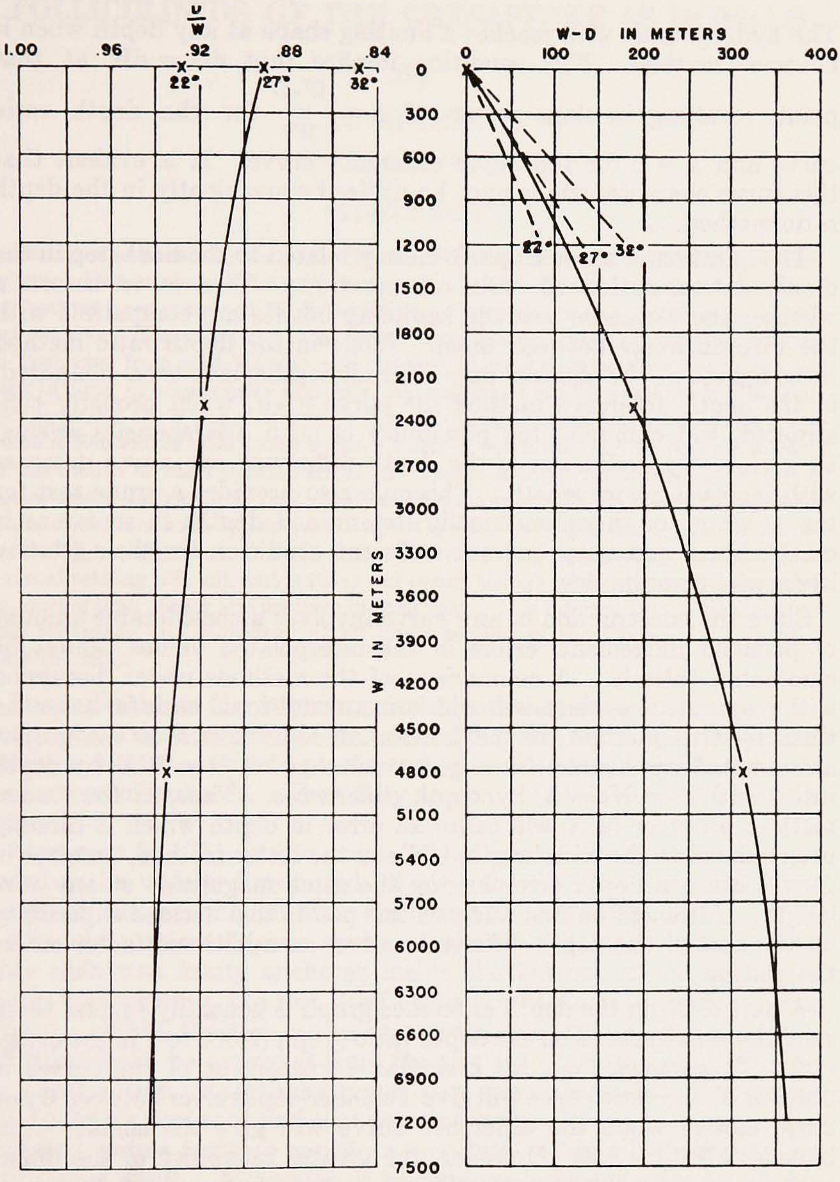

Figure 1. Depth ratio and depth difference curves for a deep Atlantis station.

The hydrographic wire reaches a limiting shape at any depth when it becomes vertical. This condition implies that $dD = dW$ at that point, resulting in slope values of $\lambda = \frac{W\text{-}D}{W^2}$ for the depth ratio curve and $\lambda = 0$ for the depth difference curve. It is evident that this curve characteristic cannot be utilized conveniently in the depth ratio method.

The question of curve slopes is closely related to the final step in the depth determination of serial observations. This is to ascertain whether the distances between sampling bottles are compatible with the wire distances between them. While in the depth ratio method these figures can be checked only after all depths have been computed, in the depth difference method the curve itself, when properly constructed, will eliminate the possibility of such discrepancies arising. In a correctly drawn curve the depth difference can never decrease with increasing wire length. This rule also provides a crude test for the accuracy of thermometrically determined depths in so far as it establishes a necessary but not sufficient condition for their relative horizontal co-ordinates.

Since the construction of any curve involves a considerable amount of personal judgement, errors in the interpolated values cannot be eliminated entirely. A comparison of the methods under discussion with respect to these errors should form an additional basis for assessing their relative merits. If the horizontal co-ordinates of the graphs are denoted by X, then for a given value of W, $D = WX$ by depth ratios and $D = W - X$ by depth differences. Thus, in the former method, an error in X will cause an error in depth which is directly proportional to the wire length, while in the latter method, an error in X will cause a depth error having the same magnitude at any wire length. Although on first analysis this points to a decided superiority on the part of the depth difference curve, an additional factor enters the picture.

A unit of X on the depth difference graph is generally several thousand times as great as on the depth ratio graph (2,500 to 1 in the example). This means that, for a similar displacement of the curves in units of X, the ratio curve will give a smaller depth error between 0 and 2,500 meters while the difference curve will give the smaller error beyond 2,500 meters. However, the greater reliability of the difference curve near the surface will compensate to some extent for its development of large errors in that range. Furthermore, the depth to which the ratio curve is superior will vary with the scale ratio of the two graphs and may be considerably less than in the example cited.