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THE ILLUSTRATION OF OCEANIC DATA

(I) : SCALARS

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SUMMARY

Although a wide variety of illustrations is used to illustrate scalar quantities, there are underlying simplicities which (once recognised) can be used to represent data simply and clearly and to label it unambiguously. An extension of the same principles is of some use even when the illustrator tries to put more than one idea in a single diagram.

INTRODUCTION

There are very many illustrations of oceanic data (RICHARDSON, 1975), and it is a little surprising to find that with the limits imposed by a two-dimensional page, there are only three basic ways of drawing line diagrams. We have a choice of five axes when illustrating a scalar. These are the three spatial co-ordinates, x, y and z, time, and the range of values of the parameter itself. Fortunately, some of these will probably be constant or nearly so, and are not required in the drawing. Geological features, for example, seldom require time as an axis, and bathymetric features are further simplified by the use of a single axis for depth-of-the-seabed.

In general, if we consider a scalar P to vary with position and time we can write it :

$$P = P\,(x, y, z, t)$$

This is a brief way of listing our five variables. The notation is useful. It enables us to find all possible ways of illustrating the scalar, *because the axes P, x, y, z and t are equivalent in a drawing.*

Case 1 — No dimensions vary

If P is measured at a particular place at one given time, then all dimensions are constant, and

$$P = P\,(c, c, c, c)$$

This is a simple number only. For example, the sea surface temperature at 17°37. 2′ N, 67°00′ W at 1600 GMT on 8 June 1971 was 27.77°C (SHANLEY & DUNCAN, 1973).

Case 2 — One dimension varies

For P to vary, at least one dimension must vary. A typical example of this case is the record of surface temperature at a fixed point (fig. 1). Then x, y and z are constant and are described in the caption. This leaves only t to vary, and P with it, and they are used as axes. In my notation,

$$P = P(c, c, c, t)$$

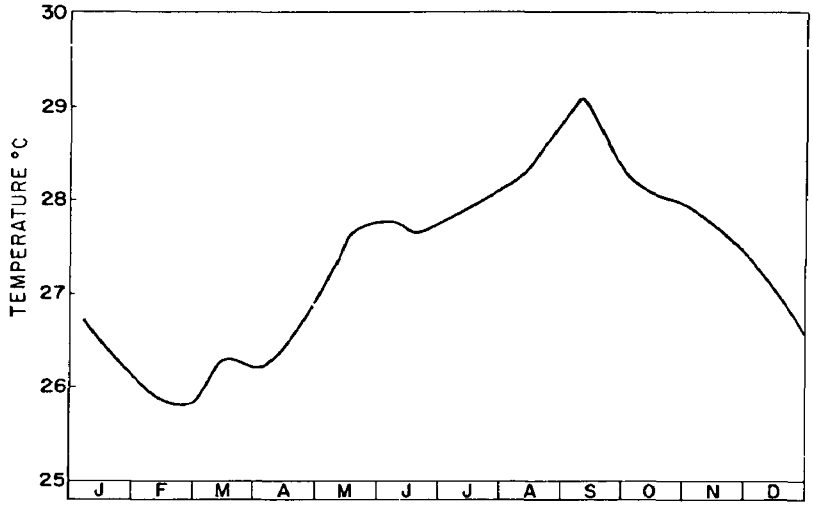

FIG. 1. — Sea surface temperature (°C) at 17°38′ N, 67°00′ W as it varied in 1971.

This is exactly the same *kind* of drawing as a bathythermograph slide, where x and y are constant, t is assumed to be constant, i.e. $P = P(c, c, z, c)$. With a change of P, this is illustrated in figure 2 for the variation of

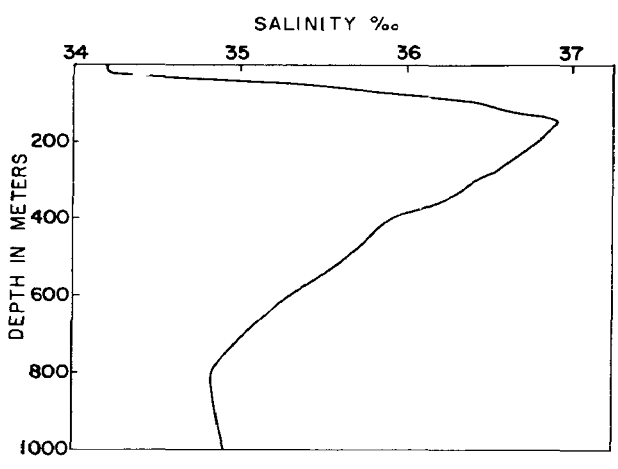

FIG. 2. — Salinity (‰) profile at 17°38′ N, 67°00′ W on 5 October 1971.

salinity with depth at a given point and time. Similar diagrams result whenever we hold three dimensions constant and vary P with the fourth. They are merely simple graphs, not necessarily on Cartesian axes, and one need only follow the editor's "Instructions to Authors" to produce lucid and acceptable diagrams.

Unfortunately most real-life diagrams are more complex, because the author very often wishes to show more than one variable. Commonly he adds points to show the location of data points, and perhaps mensuration error bars as well. If the curve is a mean, he wishes to show the range and the standard deviation, and the problem becomes how to illustrate three parameters rather than one. These are considered "Compound Diagrams". The most common illustration — over 50 % — in an issue of *Deep Sea Research* and one of the *Journal of Geophysical Research*, picked at random, was the simple graph and its Compound Diagram relative.

Case 3 — Two dimensions vary

The most common cases of two dimensions varying are maps and sections, but six possibilities exist :

(a) $P\ (x, y, c, c)$ e. g. Map
(b) $P\ (x, c, z, c)$ e. g. Section
(c) $P\ (x, c, c, t)$ e. g. Metachronic map
(d) $P\ (c, y, z, c)$ e. g. Section
(e) $P\ (c, y, c, t)$ e. g. Metachronic map
(f) $P\ (c, c, z, t)$ e. g. Time section

(a) *Maps*

Conceptually the easiest kind of maps to understand are the high altitude or satellite photographs which are appearing more frequently in the journals. Beautiful color examples, up to 22 cm square, appear in *Photogrammetric Engineering* (e.g. SMITH (1963), MAIRS (1970)). One-column black and white half tones are more common and have been used to good effect (e.g. KUHN *et al.*, 1975). The limits here are the patience of the author in selecting the photo which best illustrates what he has to say, and the budget of the editor.

Strictly speaking a map does not represent two dimensions only, but is usually represented so. Figure 3 is an example to complete our illustrations.

(b) *Sections*

Sections are essentially the same, whether x or y or t varies, the more so since oceanographers occasionally upset their own conventions and merely regard the x-direction as the one they wish to discuss. Depth, though, is almost invariably down the page (fig. 4, drawn from data in Table I). The example of a time section (fig. 5) shows the essential similarity.

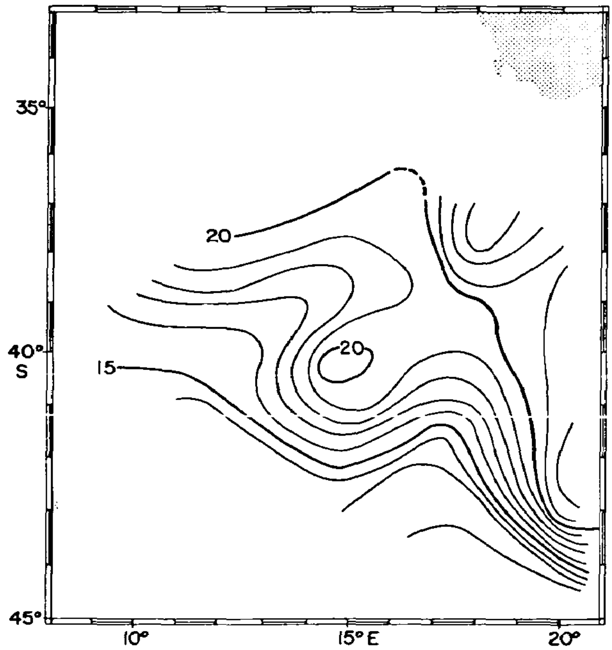

FIG. 3. — Sea surface temperature (°C) south-east of Africa, March 1964.

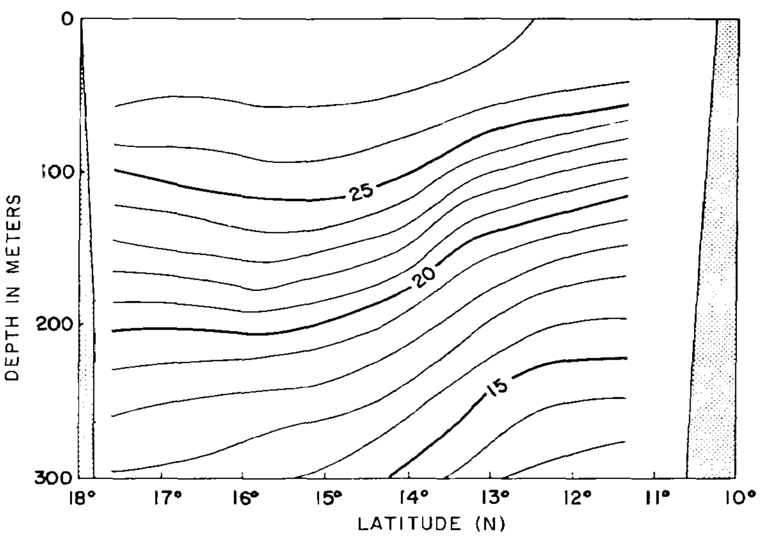

FIG. 4. — Mean temperature (°C) section to 300 meters along 67° W.

(c) *Metachronic Maps*

A metachronic map is partly a map and partly a time series, and more easily shown than discussed. An example of $P(c,y,c,t)$ is given in figure 6. The January strip by itself may be considered as a very thin map of the Red Sea. The twelve monthly strips together show the variation over the Sea during the year. Examples of $P(x,c,c,t)$ are more rare, but can easily be constructed.

TABLE I

Mean temperatures (°C) along 67° W

North Latitude	17°38′	16°42′	15°50′	14°53′	13°18′	12°22′	11°21′
Depth (meters)							
0	27.42	27.23	27.19	27.37	27.22	26.93	26.87
50	27.15	27.00	27.11	27.15	26.55	25.92	25.33
100	24.92	25.36	25.68	25.61	23.41	22.18	21.27
150	22.71	23.09	23.45	22.98	19.81	18.62	17.93
200	20.22	20.21	20.37	19.65	17.38	16.10	15.85
250	18.23	17.95	17.73	17.35	15.28	14.16	13.97
300	16.87	16.70	16.12	15.55	13.41	12.44	12.27

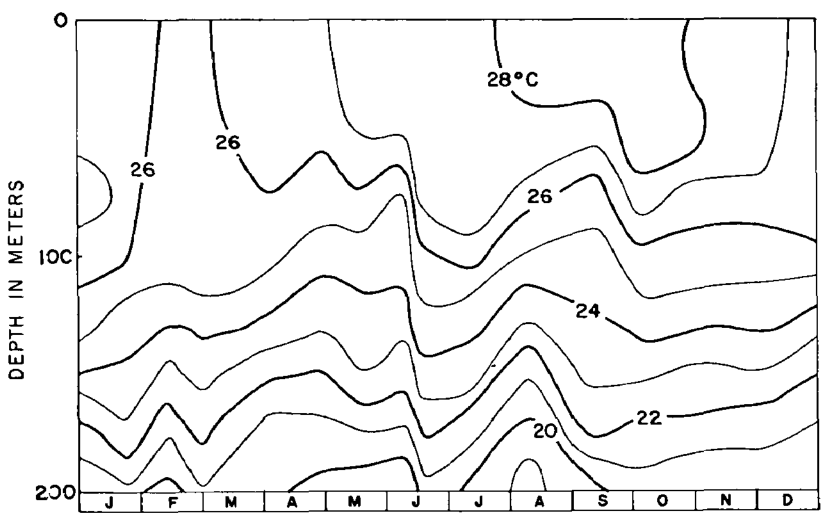

FIG. 5. — Temperature (°C) variation with time and depth during 1971 at 17°38′ N, 67° W.

In all the preceding illustrations there is little call for originality, and, provided the oceanographer has a clear idea of what he wants to display, the draughtsman is very often used as a simple tracer who need only consider proportions, reduction percentage, pen width and letter sizes. In the next section we begin to meet problems requiring ingenuity.

Case 4 — Three dimensions vary

Holding one dimension constant and letting the three others vary, one is faced with the problem of representing a three-dimensional surface on a two-dimensional page. The draughtsman's way out of this is to draw a perspective or perhaps an isometric representation, shading his drawing for greater clarity. LA FOND (1964) has excellent examples, and from time to time similar drawings appear in the literature, but they are rare for many

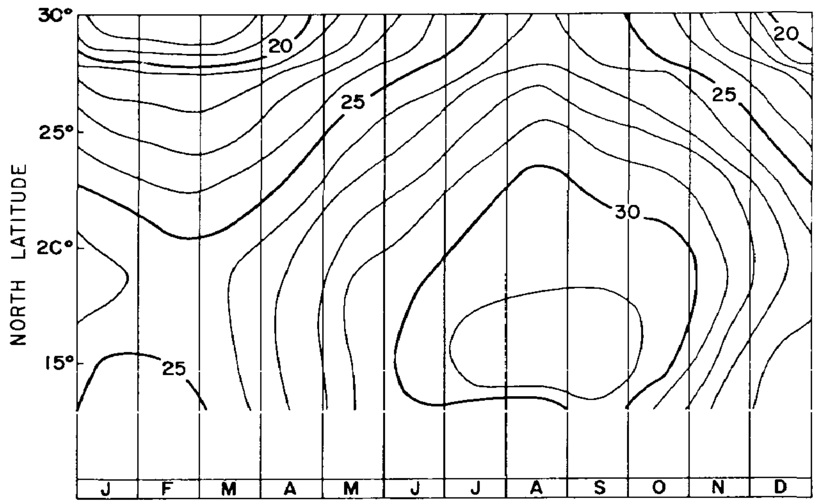

FIG. 6. — Metachronic map of mean sea surface temperature (°C) along the axis of the Red Sea.

reasons : they are expensive, not many people visualise things in 3-D, and even fewer can adequately shade a perspective drawing of any complexity.

In general, when one is faced with the problem of illustrating *P* (x,y,z,c) or *P* (x,y,c,t), one has the following choices:

(1) Investigate very seriously the *need* for drawing in 3-D, i.e., can the drawing be reduced to two dimensions? Perhaps a contoured section or map will be as good. For example, the isometric figure (fig. 7).

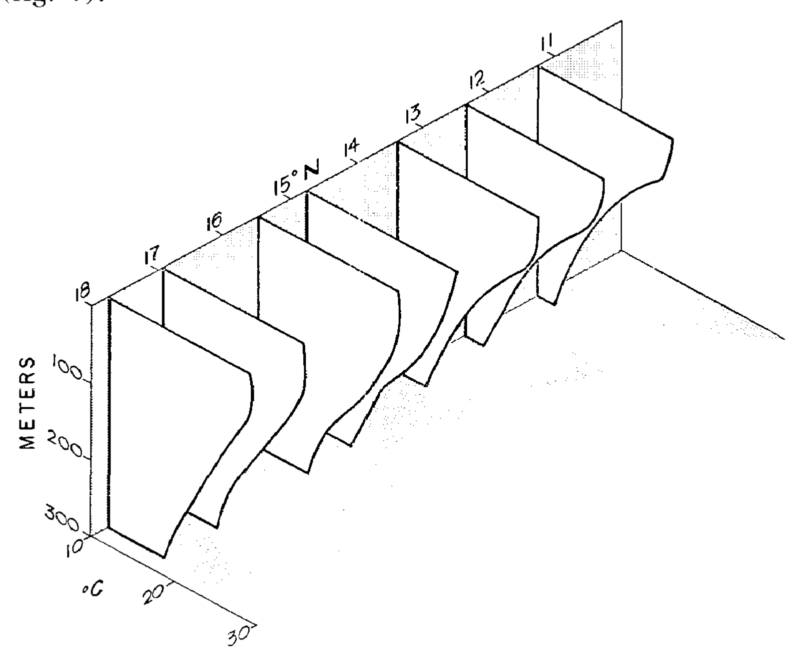

FIG. 7. — Isometric representation of figure 4; mean temperature (°C) section to 300 meters along 67° W.

was drawn from the same data as the vertical section in figure 4 to little advantage, and a perspective view of the same data would not be worth drawing. My example of a map, above, could have been drawn as a shaded 3-D surface similar to LA FOND's, but it would not have repaid the labor.

(2) Consider carefully what the axes will be. LA FOND's choice was almost forced upon him, but figure 7 was drawn many ways in rough. A lot of time can be saved by the right choice the first time.

(3) Even more time can be saved by correctly choosing the point of view for a perspective drawing before one starts work. Perspective graph paper *can* be a waste of time, and a perspective ruler is a better aid.

(4) Computer-drawn 3-D plots are becoming more and more common, but unless one has a large organization with a computer-graphics section, they are almost certainly a bad choice. For one-off or even ten-off jobs, it is cheaper to draw by hand.

Captions

Given even one numerical value for a single piece of oceanic data, we need to know where and when the value was observed and what parameter it describes. An adequate description of "where" is usually given by latitude, longitude and depth, although any defined three-dimensional system of axes can be used. "When" is time referred to a datum point, and "what" is usually a well-known name such as temperature, but may be a less well-known quantity such as "oxyty" or "biological oxygen demand", in which case a separate definition is needed. To make sense of our numerical value, then, we need five labels, each label having its own dimensions; ten things which need to be known for an adequate description of a single value. This seems very unlikely for a scalar quantity, and outside our normal experience, but a glance at a published illustration will show that unless the ten are present, the diagram is ambiguous. This is partly because we still have not yet reached international accord about the units we use. The U.S. Navy until recently published temperature maps in degrees Fahrenheit, and vertical sections in degrees Fahrenheit and feet. More recently they use degrees Celsius and feet.

Many of the ten items are present in an abbreviated form. Latitude and longitude and their units, for example, may be subsumed under a place name, reducing four items to one. Oceanographers commonly give unique "station numbers" to a set of samples taken at a particular spot at a particular time, and if there is no need for further detail, this number may be used as acceptable shorthand for six items because there is no ambiguity. In one form or another, though, the ten are necessary for complete identification.

COMPOUND DIAGRAMS

The illustrations discussed above are very simple, and have been deliberately made so by omitting everything that was not pertinent to the point being made. In oceanographic reality they would most likely have been cluttered with other data, becoming "compound diagrams". In figures 1 and 2 dots might have been used to indicate point measurements, error bars added to show the quality of the data, and double scales used to enable the graphs to be read in different units. An entirely different parameter could have been added. The map of surface temperatures would normally have at least dots to indicate sampling positions, and perhaps station numbers as well. So long as the additions help to clarify the author's intentions they are welcome, but they can easily go over the edge to confusion, and deter the reader. Figure 8 started as a simple graph of

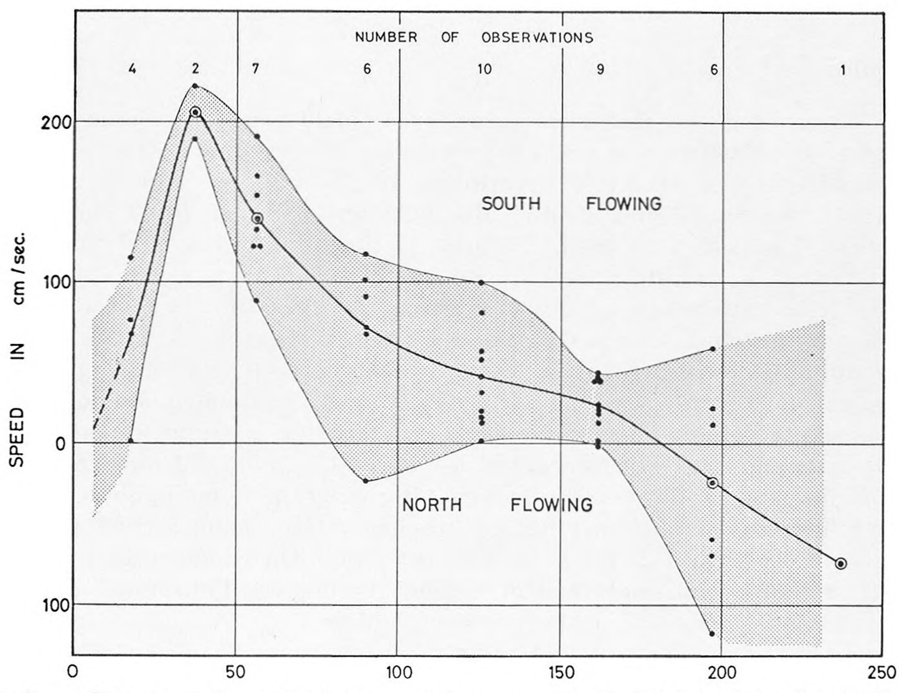

FIG. 8. — Compound diagram of mean surface current speed (cm/sec) in the Agulhas Current as it varied with distance (km) offshore from East London.

mean current speed as a function of distance offshore in the Agulhas Current. Then the individual data points were added, and the envelope of observations shaded. There are, therefore, really three parameters shown rather than one, and if one counts "speed north" as different to "speed south", then we have four. The "table of number of observations" is another parameter still, but is sufficiently far removed to be innocuous. The grid is for the convenience of the user in taking off values, but comes close to being too much detail.

Great care should be taken in putting two parameters on the same axes unless it is a very simple diagram, or unless the technique is known to the reader. (An Elsasser diagram, for example, is lucid only to meteorologists). Figure 8 is about as crowded as it can be without being repellent. The general principle for clarity seems to be that (in my notation) the brackets for what is illustrated must be the same, in this case (x,y,c,c), and that if a different parameter is added it must be related to the first or to the frame. This general rule would enable one to draw the bottom topography in a vertical section of salinity, for example (same bracket), or to add sample positions as dots (related to location and parameter). A salinity minimum or maximum in the same drawing could be shaded without incongruity.

A complementary article on the illustration of vectors is in preparation and will show some of the techniques used in the literature.

ACKNOWLEDGEMENTS

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Data sources

Figures 1, 2 and 5 were drawn from data in SHANLEY and DUNCAN (1973). Figure 3 illustrates data collected by the author from R.S. *Africana II* in 1964 and available from NODC, Washington, D.C. Figure 4 appeared in DUNCAN *et al.* (1976) and was based on a work-sheet which appears here as Table I. Figure 7 is an isometric drawing of the same data. Figure 6 was drawn from data in the K.N.M.I. atlas of the Red Sea and Gulf of Aden. The South African Navy is thanked for permission to use the data which appears here as figure 8 (Ref. No. HVS/502/3/4).

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