Temperature-Salinity Curves in the Pacific and their Application to Dynamic Height Computation[1]

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ABSTRACT

Mean temperature-salinity (*TS*) curves are computed from all available hydrographic data for 10° quadrangles in the Pacific between 20°S and 40°N. These curves together with temperature profiles from hydrographic stations are used to compute a quantity called *TS* dynamic height. The rms differences between dynamic and *TS* dynamic height indicate where mean *TS* curves may be reliably used to compute dynamic height from temperature profiles.

1. Introduction

The use of mean temperature-salinity (*TS*) relations to compute dynamic height from temperature profiles has received increased attention from investigators recently. In the Mid Ocean Dynamics Experiment (MODE-1) a mean *TS* relation was used to calculate dynamic height at stations having good temperature data but no salinity information. This use of a *TS* curve was justified by the small scatter of the *TS* relation and by comparisons that showed dynamic height computed from a *TS* curve to be a good measure of "true" dynamic height (Richard Scarlet, personal communication).

In an earlier paper, Emery (1975) made similar comparisons at three ocean weather stations in the North Pacific. He concluded that at two of the three locations studied, dynamic height computed from temperature profiles and a mean *TS* curve (called *TS* dynamic height) was a reliable substitute for dynamic height. Since *TS* dynamic height had a large uncertainty at one of the three locations, the question is raised as to where in the Pacific *TS* dynamic height can be used as a reliable measure of dynamic height.

As a first step toward answering this question, mean *TS* curves were computed from hydrographic data for 10° quadrangles between 20°S and 40°N. The mean curves were computed by averaging salinities over temperature intervals of 0.1°C and were then smoothed four times with a 9-point moving average to reduce small irregularities in the curves without changing their shape. All of the curves were cut off at 1.5 and 25°C. A more detailed description of how these curves were computed can be found in a report by Emery and Wert (1976). This report also contains plots of each *TS* curve along with the corresponding scatter points and the envelope of the standard deviation in salinity.

The mean *TS* curves are presented in Fig. 1. This figure provides information about water mass distribution in more detail than is found in traditional discussions of mean *TS* curves (Sverdrup *et al.*, 1942; Dietrich, 1964; Mamayev, 1975). This paper is not intended to examine water masses; therefore, it discusses only briefly the main water mass features seen in Fig. 1.

The presence of the same deep water over the entire area of study is evidenced by the almost uniform value of salinity at 1.5°C in all the curves. At slightly higher temperatures the differences in the north and south salinity minima indicate the presence of Subarctic Intermediate Water and Antarctic Intermediate Water. A transition zone between these two intermediate waters is found in the latitude band between 10° and 20°N; however, the expression of this transition region in the mean *TS* curves is complicated by the additional presence of an intermediate water formed off California and advected into this latitude band (Cooksa and Mikhailichenko, 1975). A transition zone is also found between upper waters in the latitude band between 0° and 10°N. A more complete description of the water mass distribution as seen in Fig. 1 is given in Emery and Wert (1976).

2. *TS* dynamic height

The mean *TS* curves in Fig. 1 were used to compute *TS* dynamic height (0/500 m) for individual hydrographic stations. The 500 m reference level was chosen because expendable bathythermographs (XBT's), a primary source of temperature profiles, only go as deep as 500 m. Temperature and salinity values from the

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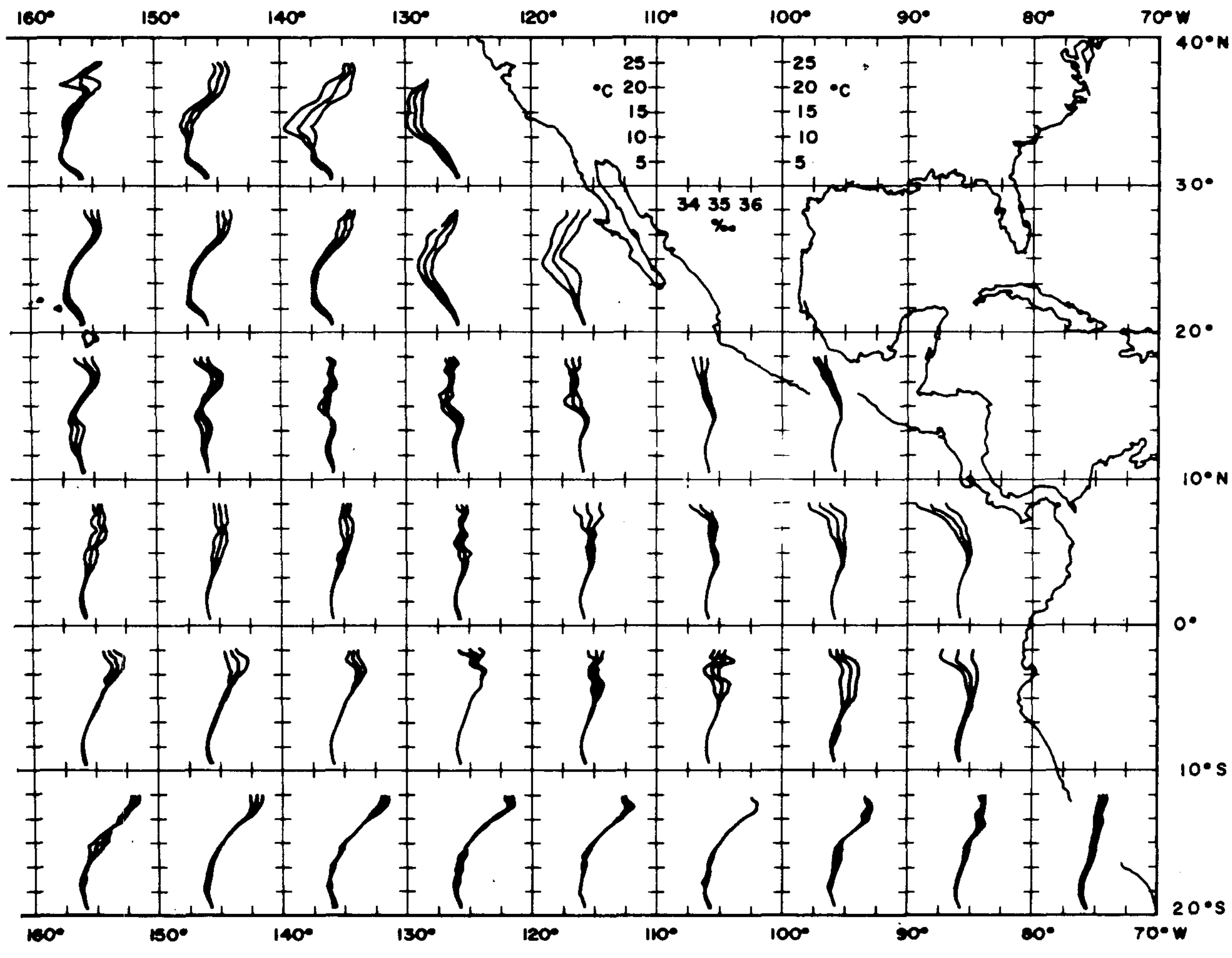
same hydrographic stations were then used to compute dynamic height (also 0/500 m), and the differences between the corresponding dynamic and *TS* dynamic heights were formed. The rms values of these differences are given in Fig. 2 along with the number of stations used in the computation of each average.

The rms differences are an estimate of the uncertainty in using *TS* dynamic height as a measure of dynamic height. Interestingly, the regions of large rms differences coincide with areas where there is a boundary between water masses, with the largest differences occurring in the transition region off California (Roden, 1971) and at the boundary between upper waters between 0° and 10°N all across the Pacific.

Before we can use Fig. 2, we must determine at what level of uncertainty we can consider the use of *TS* dynamic height reliable. The answer to this problem lies in the way *TS* dynamic height is to be used. If an exact replacement for dynamic height is required, the replacement must have an uncertainty no greater than the uncertainty inherent in a traditional dynamic height calculation. Emery (1975) reviewed the various estimates of this uncertainty and concluded that it was about 4.0 dyn-cm. About three-fourths of the squares in Fig. 2 have rms differences smaller than this value.

More commonly, *TS* dynamic height would be used as a measure of the large-scale temporal and spatial variations in dynamic height. For this purpose *TS* dynamic height need not be an exact substitute for dynamic height. Instead, the uncertainty in using *TS* dynamic height must be less than the changes in dynamic height. In other words, the signal of dynamic height changes must be larger than the noise introduced by using *TS* dynamic height. Taking the standard deviation in dynamic height as an estimate of this signal, a comparison between Fig. 2 in this paper and



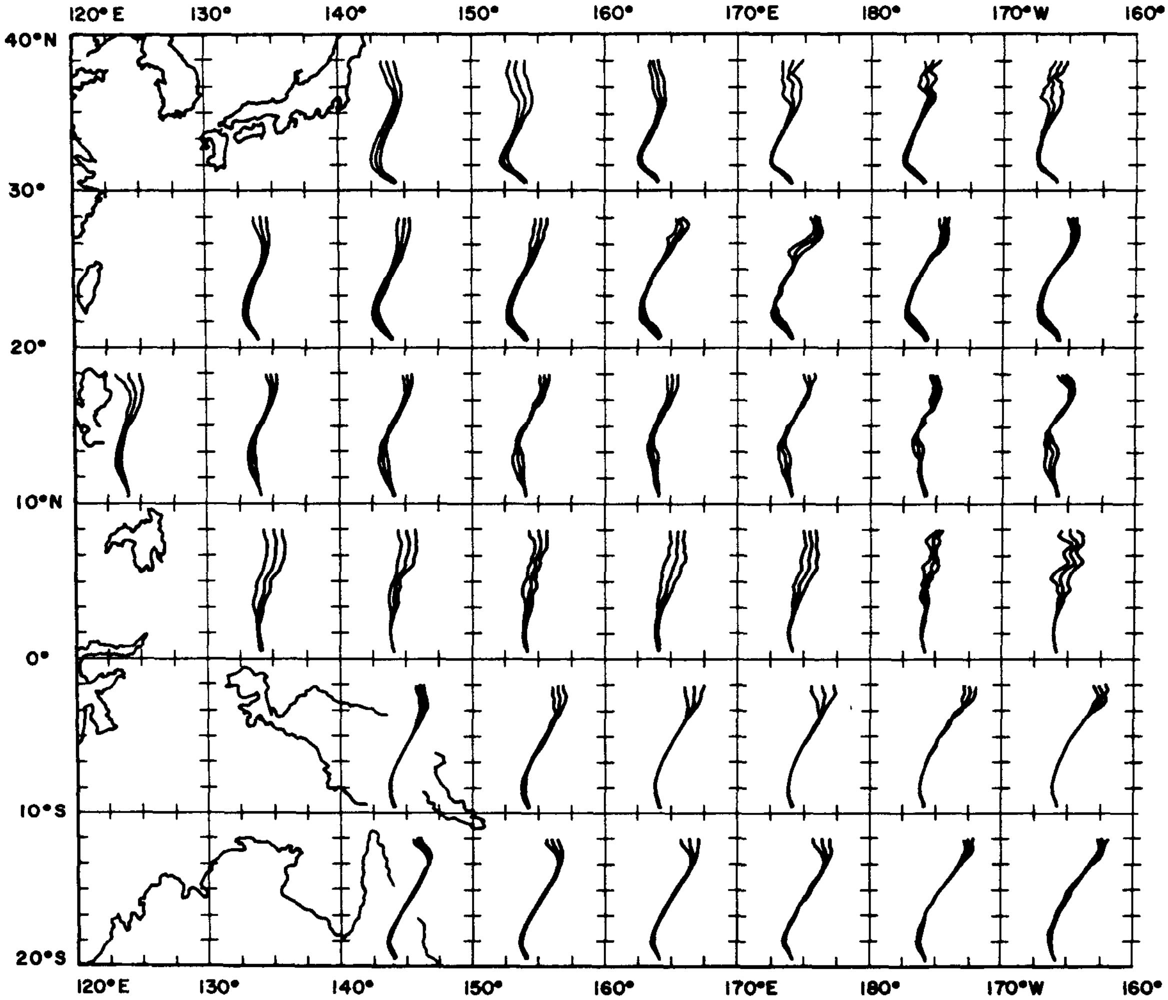


FIG. 1. Mean *TS* curves in 10° quadrangles. The center lines are the mean curves and the bracketing lines represent the standard deviations in salinity. (a) 70°W to 160°W, (b) 160°W to 120°E.

Fig. 19 of Wyrtki (1975) shows that almost everywhere *TS* dynamic height uncertainty is smaller than the standard deviation in dynamic height. This is especially true in the western Pacific where strong changes in the thermal structure cause large changes in dynamic height. The relatively smaller values of *TS* dynamic height uncertainty mean that the variations in dynamic height can be identified using *TS* dynamic height. Consequently, information about dynamic topography and its changes can be gathered with low-cost XBT's.

One final consideration is the possible reduction of the rms differences in Fig. 2 if mean *TS* curves were computed for different space or time scales. It is likely that averaging over smaller quadrangles would help to separate the water masses in the important boundary regions, which should reduce the rms differences. Perhaps more detailed studies of these important regions of transition between water masses will provide new insights into better ways to compute *TS* dynamic height.

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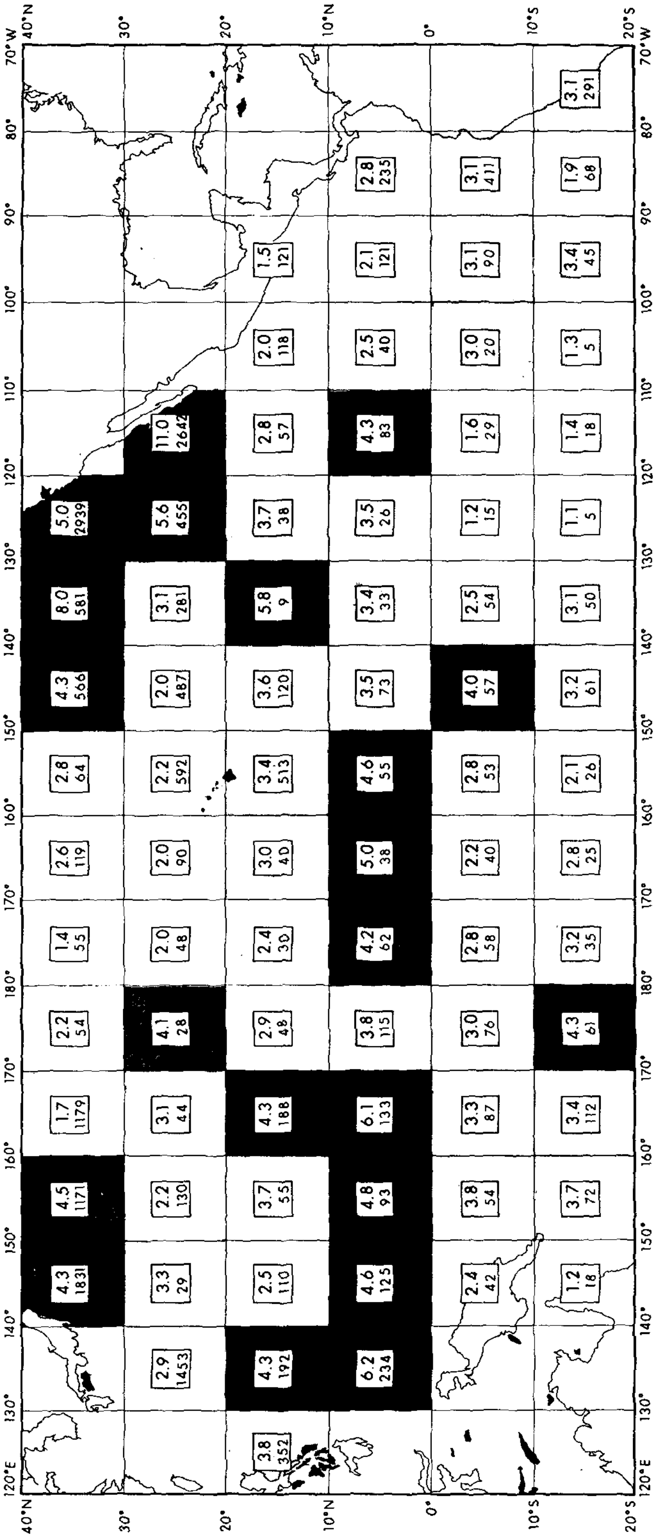

FIG. 2. Root-mean-square difference between dynamic and *TS* dynamic heights (dyn-cm) for the 500 m reference level. The number of *hydrostations* used in the computation of each difference is also shown.

REFERENCES

Cooksa, V. I., and Y. G. Mikhailichenko, 1975: On some pecularities of formation and distribution of the Pacific Ocean intermediate water masses. Report for the 13th Pacific Science Congress, Nauka Publishing House, Moscow.

Dietrich, G., 1964: *General Oceanography*. Wiley, 588 pp.

Emery, W. J., 1975: Dynamic height from temperature profiles. *J. Phys. Oceangr.*, **5**, 369–375.

——, and R. T. Wert, 1976: Mean *TS* curves in the Pacific Ocean and their application to dynamic height computations. SIO Ref. Ser., Scripps Institution of Oceanography, 76–6.

Mamayev, O. I., 1975: *Temperature-Salinity Analysis of World Ocean Waters*. Elsevier, 374 pp.

Roden, G. I., 1971: Aspects of the transition zone in the northeastern Pacific. *J. Geophys. Res.*, **76**, 3462–3475.

Sverdrup, H. U., M. W. Johnson and R. H. Fleming, 1942: *The Oceans, Their Physics, Chemistry and General Biology*. Prentice Hall, 1087 pp.

Wyrtki, K., 1975: The dynamic topography of the Pacific Ocean and its fluctuations. Hawaii Institute of Geophysics, HIG-74-5, Honolulu.