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Mean Temperature-Salinity relationships and their application to Computing Steric Height in Australian Waters

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MEAN TEMPERATURE-SALINITY RELATIONSHIPS AND THEIR APPLICATION TO COMPUTING STERIC HEIGHT IN AUSTRALIAN WATERS

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Abstract

Mean temperature-salinity (TS) relationships are computed for a spatial network of 2.5° x 5° bins within the range of 5°-45°S and 105°-160°E. They consist of a series of mean salinities obtained at 2.5°C intervals between 5° and 27.5°C. Results are compared with other mean TS relationships obtained previously in the south-east Indian Ocean and the Tasman Sea and satisfactory agreement is found.

A comparison of steric height from (observed T and S) and TS steric height (from observed T and S obtained from the mean TS curves) indicates that the latter may be substituted for the former over most of the region when instrumental and computational errors are considered. The TS method should, however, be applied with care in the north-west (between 15° and 25°S) as the above errors are of similar magnitude.

Introduction

In ocean regions with "tight" temperature-salinity (TS) relationships, steric height may be computed directly from expendable bathythermograph (XBT) temperature profiles. The use of mean TS relationships to obtain salinities -- and hence the density distribution -- from temperature data was first suggested by Stommel (1947). He applied this technique to data from the North Atlantic and obtained satisfactory results in some areas.

The TS method was investigated more recently by Emery (1975), who determined that it can be applied to areas where the TS distribution is sufficiently well defined below the seasonally variable layer. The results of a comprehensive application of the TS method to the North Atlantic and North Pacific are given in Emery and Wert (1976) and Emery and Dewar (1982).

In Australian waters, Andrews (1976) and Pearce (1983) demonstrated that the TS properties in the south-east Indian Ocean and in the Tasman Sea are such that TS methods can be used to generate steric height from temperature profiles alone.

A more comprehensive examination of the applicability of these TS methods in Australian waters is attempted in this report. Mean TS relationships are obtained within a network of regional divisions around Australia. Tables of mean salinity as a function of temperature at 2.5°C intervals are presented. A detailed discussion of the water masses in the region, as inferred from these TS relationships, is given in Ridgway and Loch (1985).

The performance of the TS method in determining steric height (from the mean TS relationships) is assessed by comparing the error induced using TS steric height with the uncertainty inherent in computing steric height.

Data and Methods

All of the hydrology data for the region 5°-45°S and 105°-160°E between the years 1950 and 1980 were obtained from the data archive at the CSIRO Division of Oceanography. Fig. 1 gives the spatial distribution of this data set. In

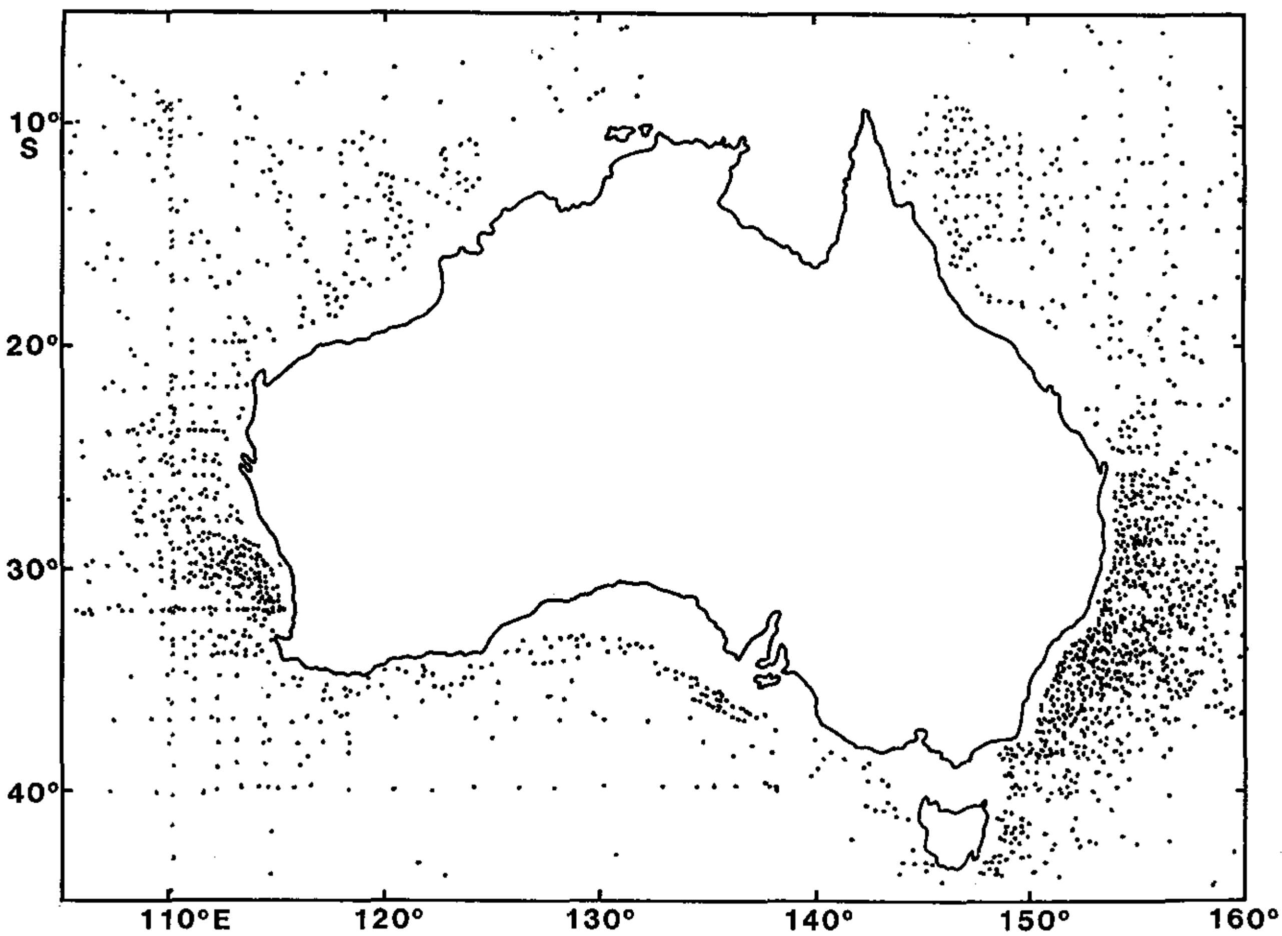

Figure 1 Spatial distribution of hydrology data. Each dot represents at least one station.

calculating TS curves, only stations deeper than 200 m were included to avoid the influence of low salinity continental shelf water. Data stations with digitising errors were removed at the first stage of analysis. Errors included: temperature and salinity values not recorded; mastercards omitted; obviously faulty data entries (salinities greater than 40); surface temperatures omitted; and casts with decreasing depth values.

Derivation of Mean TS Relationships

As a compromise between the competing requirements of minimising the geographic variations of TS properties within a region and maximising the hydrology data within it, the area considered was divided into a network of 2.5° (latitude) x 5° (longitude) bins, as the greater variation occurs zonally.

Initial attempts at fitting algebraic polynomials to the raw data in each bin were abandoned and a numerical procedure was adopted to cope with the varying degree of scatter occurring throughout the region of study. The computation procedure is summarised in the following steps:

1. Salinity is estimated for each cast within a bin by linear interpolation at a series of standard temperatures (i.e. $T°C = 5.0 + (\underline{n}-1) * 2.5$, $\underline{n} = 1,2,...10$). Mean and standard deviations of salinity are then computed at each of the 10 temperatures. The process is repeated for all bins within the region.

2. The standard deviations are smoothed once in both the temperature and spatial dimensions.

3. Using the smoothed standard deviations, salinities with TS pairs falling outside the range (mean ± 4 standard deviations from the mean) are removed from the file. Any station with two or more such values is rejected.

4. The mean and standard deviations of salinity are recalculated from the 'cleaned up' file.

5. Within the distribution of bins, gaps in the mean TS relationships at any standard temperature are filled by interpolating from adjacent salinities in both spatial and temperature dimensions. This procedure is applied whenever there are fewer than three TS pairs at a standard temperature.

The Reliability of TS Steric Height

The reliability of TS steric height computed from observed temperature data and salinities inferred from the mean TS relationships obtained in the previous section was established by the procedure detailed below, which is essentially the same as that used by Emery (1975) and Emery and Wert (1976).

For this purpose, all steric heights are surface values relative to the 450 db surface, and all hydrology stations of at least 450 m depths were used (the 450 db level was chosen because most XBTs stop near that depth).

(1) Within each bin, steric height is computed from TS observations at each hydrology station (H) and an overall mean is obtained.

(2) The salinity distribution for that station is then ignored and TS steric height (H') is calculated from each temperature profile with the corresponding salinity distribution deduced from the mean TS relationship for the bin. A mean TS steric height is then obtained for the bin.

(3) As a measure of the total uncertainty associated with a steric height calculation, the standard deviation of steric height (ΔH) is obtained for each bin.

(4) The rms differences between steric height and TS steric height (ΔH') is, according to Emery (1975), an estimate of the uncertainty in using TS steric height as a measure of steric height. Hence the rms difference corresponding to each bin is generated.

Results

Mean salinity within each 5° x 2.5° bin is presented at each standard temperature in Tables 1-10. The blanks in bins towards the south at temperatures above 12.5°C indicate that the maximum temperatures observed in those bins are lower than the particular standard temperature.

To save space we do not reproduce tables of standard deviations or graphs of the mean TS relationships; they are available in Ridgway (1982) and Ridgway and Loch (1985) respectively. However, a brief summary of the standard deviation may be of interest.

In eastern waters the standard deviations of salinity associated with temperature below 22.5°C (the variable surface layer) are much less than 0.1. Even above this temperature they are not high, being of order 0.1, except for between 25 and 27.5°S at 27.5°C, which has a large salinity range.

The waters to the west of Australia in contrast, show considerable divergence of salinity occurring at temperatures as low as 12.5°C, sometimes with standard deviations greater than 0.1. This behaviour is confined mainly to the latitude range 10°-27.5°S, but spreads north and south at temperatures above 20°C. Despite this increased variation, the standard deviations are of the order 0.2 below the surface layer.

The data set was essentially unchanged by the filtering procedures described in the previous section and therefore could have been omitted.

Comparison with other Results

Previous TS relationships obtained in coincident regions and from essentially identical data sets provide a useful check on the reliability of the present segmented TS curves. Andrews (1976) derived mean TS curves in the form of algebraic polynomials in the south-east Indian Ocean, and Pearce (1981) obtained four curves in the latitude band 25°-45°S in the western Tasman Sea (using methods after Emery (1975)). Despite their using different bin sizes and depth criteria (4° x 4° and 75-500 m for Andrews and 5° x 5° and greater than 300 m for Pearce), it is still worthwhile to compare the respective polynomials with segmented curves in appropriate bins.

The segmented curves agree in all essentials with the polynomials, especially in the linear portion of the distributions (see Figs 2 and 3). At turning points (upper salinity maximum and lower salinity minimum) the segmented curves exhibit some zonal variation in salinity, providing a finer scale resolution of TS properties due to the smaller bin spacing. The polynomials naturally show a smoother representation of the same features, as the segmented curves are limited by the size of the 2.5°C temperature interval. A spline fit through the salinities at standard temperatures might slightly improve the agreement with Pearce's and Andrews' results, below about 6°C. This was not done, however, because our purpose was to obtain steric heights from XBTs to 450 m, and such XBTs very seldom reach water of 6°C or less.

Of note is the divergence of the segmented curves from the polynomials between 8° and 15°C in the 35-40°S band and in the section from 10°-15°C in the range 37.5°-40°S (off eastern Australia), i.e. Figs 3c and 3d. The former variation is related to the presence of North Bass Strait water in the Tasman Sea, which tends to increase the mean salinity in this temperature range. This influence on the TS curves is described in detail in Pearce (1981). Curve a, which is derived from the majority of stations in Pearce's region, fits the polynomial closely. However, curves a and c, which are based on far fewer stations, show some divergence in this temperature range. It would appear that the polynomial is dominated by the TS properties existing in the area represented by curve a. The divergence between 10° and 15°C has been attributed by Wyrtki (1962) to the influence of the Subtropical Convergence. This temperature range revealed similar aberrations in Pearce's original once-smoothed curve; the subsequent process of fitting a polynomial to the curve seems to have removed the irregularities in his results.

A mean TS curve in the form of an algebraic polynomial has been derived for the Coral Sea by Church and Golding (1983). This curve is based on data obtained during a series of cruises between 1980 and 1981. Although this data set is considerably larger than that available for the Coral Sea at the time of the present study, a preliminary comparison between the above polynomial and the appropriate 'segmented' TS curves revealed no noticeable difference.

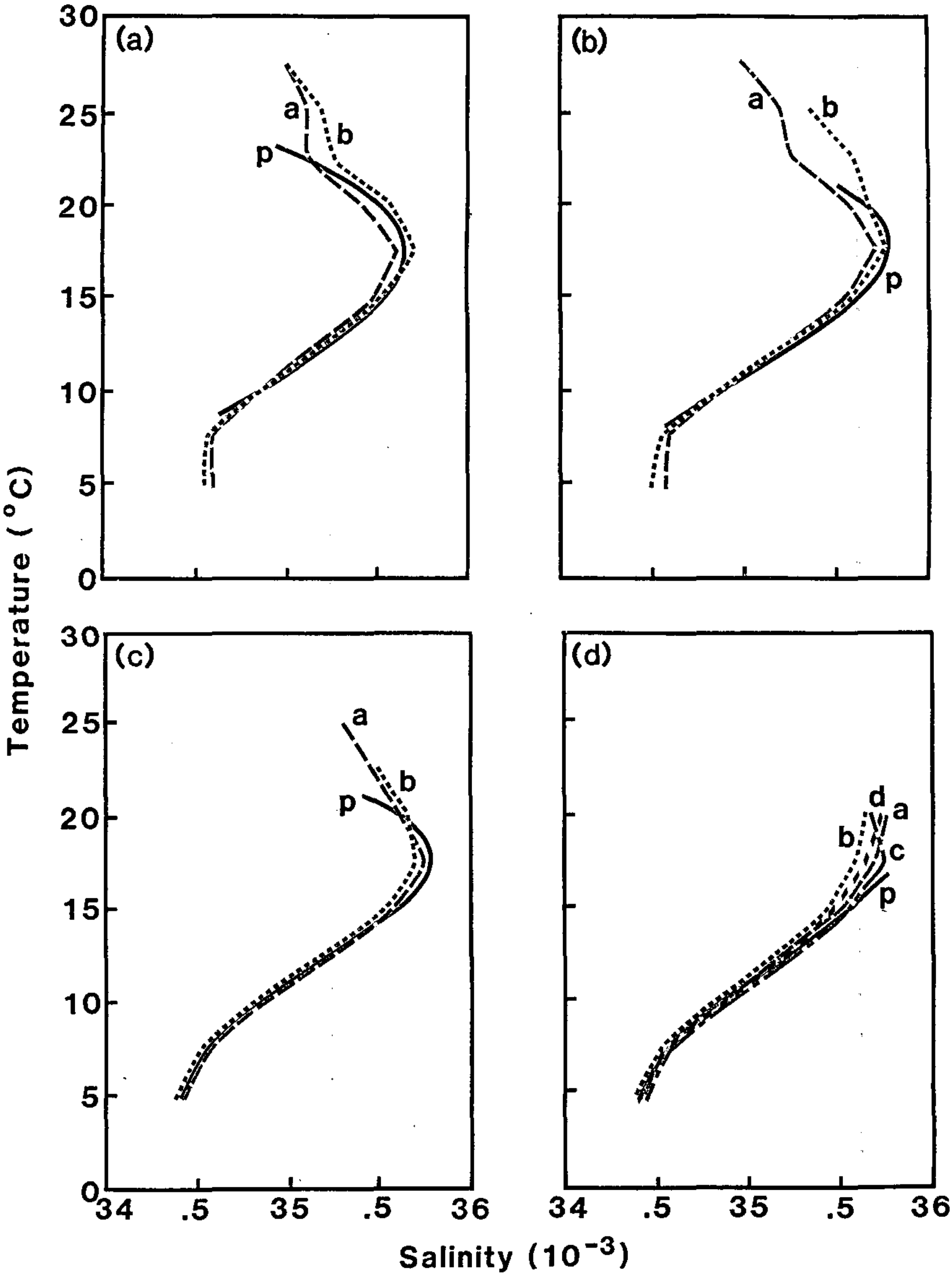

Figure 2 Comparison of polynomials (p) after Andrews (1976) with segmented curves (a, b, c, d) from the present analysis (c, d only in Fig. 2d).

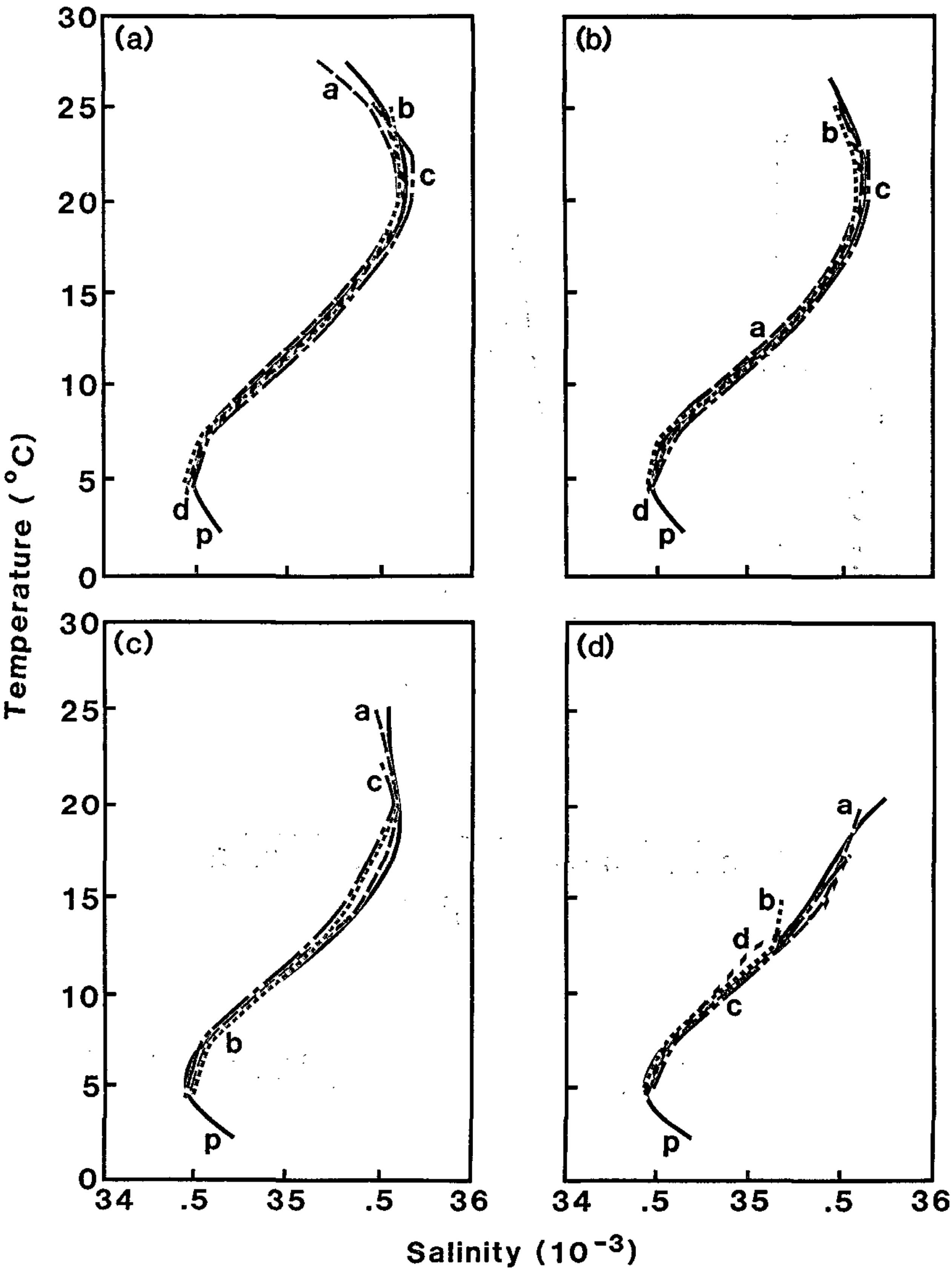

Figure 3 Comparison of polynomials (p) after Pearce (1981) with segmented curves (a, b, c, d) the present analysis (d not in Fig. 3c). The segmented curves in Fig. 3b are so similar that the individual curves cannot be separated. In Fig. 3d, curve c cannot be distinguished from the other curves.

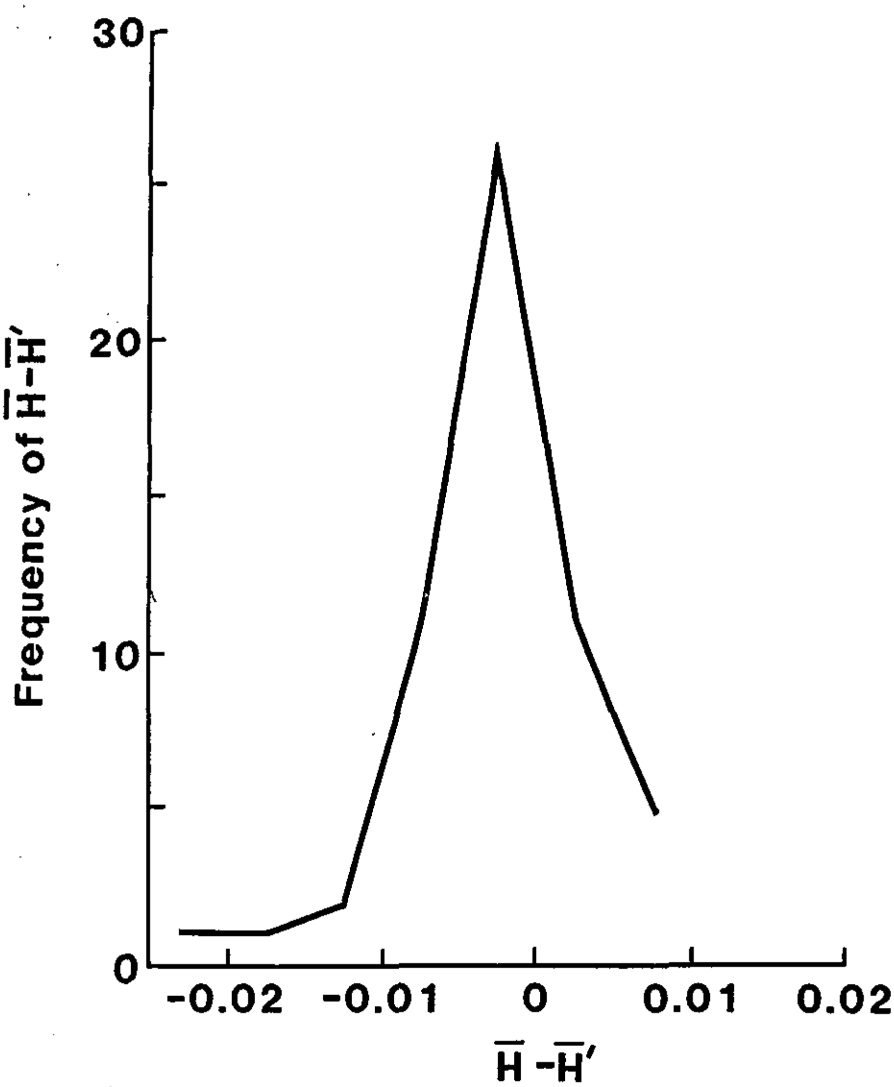

Figure 4 Frequency distribution of $\overline{H}-\overline{H}'$ (the difference between mean steric height and mean TS steric height in each bin with at least 10 stations).

Comparison of Steric Height and TS Steric Height

Steric height ($\bar{H}$) and TS steric height ($\bar{H}'$) obtained within each bin are displayed in Table 11. Excellent agreement between the two values may be observed (within 0.01 m in most bins). One obvious exception is located in the north-west corner, where the ($\bar{H}$) value is 1.14, the ($\bar{H}'$) value 1.25 m. This bin, which contains only one station, differs substantially from the associated mean TS curve, which was obtained by linear extrapolation from neighbouring 2.5° x 5° bins.

The existence of a systematic variation between ($\bar{H}$) and ($\bar{H}'$) values is observed in the frequency distribution of $\bar{H}-\bar{H}'$ for bins containing 10 or more stations (Fig. 4). The slight negative bias in the curves indicates that TS steric height is, on average, marginally greater than steric height. The origin of this bias is not clear, but it may be related to the interpolation procedures used to calculate the TS curves and to infer salinity from the same curves.

For bins with three or more observations, all $\Delta H'$except *two along* 45°C are below ΔH (see Table 12). In fact, where there are more than ten stations in a bin, $\Delta H'$ as low as 10% of ΔH are common. Apart from several bins in the north-west between about 10° and 25°S, all other $\Delta H'$ are less than 0.04 m, being of the order 0.02 m. These exceptional bins are contained within the transition zone where a rapid meridional variation in TS properties occurs; hence the result is not surprising. Even in this region, however, the $\Delta H'$ are seldom larger than the instrumental error and are still lower than the corresponding ΔH values.

These results indicate that TS steric height may be used as a replacement for steric height with some confidence in most of the region considered apart from a transition zone in the north-west (between 12.5° and 25°S) where the method should be applied with caution. This is, of course, only if the thermal structure of the cast or casts does not differ greatly from the norm for the location.

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TABLES 1 - 12

110°E 120° 130° 140° 150° 160°

	34.65†	34.64†	34.61†	34.60†	34.60*	34.60†	########	########	34.50†	34.52*	34.56*	
	34.66	34.63	34.59*	34.58*	34.60	34.60†	########	########	34.47*	34.51*	34.51*	
10°	34.63	34.59	34.60	34.60	34.60	########	########	34.46*	34.47	34.47	34.48*	10°S
	34.63	34.61	34.60	34.61	########	########	########	34.47*	34.48	34.47	34.48	
	34.65	34.64	34.62	34.61†	########	########	########	########	34.47	34.46*	34.48*	
	34.64	34.63	34.64*	34.62†	########	########	########	########	34.46*	34.47	34.47	
20°	34.62	34.62	########	########	########	########	########	########	########	34.47*	34.48	20°
	34.55	34.57	########	########	########	########	########	########	########	34.48	34.48	
	34.49	34.49	########	########	########	########	########	########	########	34.48	34.48	
	34.44	34.44	########	########	########	########	########	########	########	34.48	34.48	
30°	34.41	34.42	34.43†	########	########	########	########	########	########	34.48	34.49	30°
	34.41*	34.41	34.42†	34.41†	34.42*	34.42†	########	########	########	34.48	34.49	
	34.43*	34.41	34.40	34.42*	34.41*	34.42	34.43	########	########	34.48	34.49	
	34.40*	34.40	34.40*	34.40†	34.42†	34.42†	34.44*	34.41*	34.46	34.48	34.48†	
40°	34.41*	34.41*	34.39*	34.42*	34.42*	34.42*	34.42*	34.42*	34.47	34.46	34.47†	40°
	34.40†	34.39†	34.40†	34.40†	34.41†	34.42†	34.42†	34.43*	34.44	34.44*	34.43*	

Table 1 Mean salinity at 5°C within each 2.5° * 5° bin.

* = salinity obtained from fewer than 10 TS pairs

† = salinity obtained from fewer than 3 TS pairs

	34.71†	34.68†	34.60†	34.56†	34.58*	34.58†	########	########	34.57†	34.58*	34.59*	
	34.71	34.69	34.54*	34.52*	34.57	34.58†	########	########	34.55*	34.57*	34.58*	
10°	34.66	34.63	34.60	34.57*	34.58†	########	########	34.54*	34.55	34.55	34.55*	10°S
	34.65	34.64	34.62	34.61	########	########	########	34.56*	34.55	34.55	34.55	
	34.66	34.66	34.65	34.63†	########	########	########	########	34.54	34.55*	34.55*	
	34.64	34.63	34.66*	34.65†	########	########	########	########	34.56	34.56	34.56	
20°	34.61	34.60	########	########	########	########	########	########	########	34.56*	34.59*	20°
	34.58	34.58	########	########	########	########	########	########	########	34.56	34.55	
	34.56	34.56	########	########	########	########	########	########	########	34.56	34.57	
	34.55	34.55	########	########	########	########	########	########	########	34.56	34.56	
30°	34.54	34.54	34.54†	########	########	########	########	########	########	34.56	34.58	30°
	34.54*	34.54	34.54†	34.50*	34.54*	34.53*	########	########	########	34.56	34.56	
	34.55*	34.54	34.52	34.53*	34.52*	34.53	34.54	########	########	34.57	34.57	
	34.53*	34.53	34.51*	34.52†	34.53†	34.53†	34.54*	34.51*	34.57	34.57	34.58*	
40°	34.57*	34.55*	34.52*	34.54*	34.52*	34.52*	34.52*	34.52*	34.57	34.54	34.56†	40°
	34.55†	34.54†	34.54†	34.52†	34.52†	34.52†	34.52†	34.53*	34.55	34.55	34.51*	

110° 120° 130° 140° 150° 160°

Table 2 Mean salinity at 7.5°C within each 2.5° * 5° bin.

		110°E		120°		130°		140°		150°	160°	
	34.74†	34.72†	34.64†	34.54†	34.56*	34.57†	################	################	34.76†	34.77*	34.77*	
10°	34.75	34.71	34.50*	34.49*	34.56	34.56†	################	################	34.76*	34.76*	34.77*	10°S
	34.68	34.66	34.57	34.56*	34.58†	################	################	34.75†	34.75	34.75	34.75*	
	34.73	34.77	34.68	34.62	################	################	################	34.75†	34.75	34.74	34.74	
	34.84	34.83	34.79	34.65*	################	################	################	################	34.75	34.75*	34.75*	
20°	34.87	34.86	34.83*	34.78†	################	################	################	################	34.76*	34.78	34.78	20°
	34.85	34.85	################	################	################	################	################	################	################	34.78*	34.82*	
	34.86	34.85	################	################	################	################	################	################	################	34.79	34.79	
	34.84	34.84	################	################	################	################	################	################	################	34.80	34.81	
30°	34.84	34.84	################	################	################	################	################	################	################	34.81	34.81	30°
	34.83	34.83	34.83*	################	################	################	################	################	################	34.81	34.82	
	34.83*	34.83	34.83†	34.81*	34.83*	34.85*	################	################	################	34.82	34.82	
	34.83*	34.82	34.81	34.82*	34.83*	34.85	34.85	################	################	34.84	34.82	
40°	34.82†	34.81	34.80*	34.81†	34.84†	34.84†	34.85*	34.83*	34.83	34.83	34.84*	40°
	34.85*	34.82	34.79*	34.78*	34.74*	34.81*	34.83*	34.82*	34.86	34.82	34.83†	
	34.83†	34.82†	34.80†	34.76†	34.76†	34.79†	34.81†	34.82*	34.83	34.82	34.78*	

Table 3 Mean salinity at 10°C within each 2.5° • 5° bin.

* = salinity obtained from fewer than 10 TS pairs

† = salinity obtained from fewer than 3 TS pairs

	34.62†	34.61†	34.57†	34.54†	34.57*	34.58†	################	################	34.98†	34.97*	34.96*	
10°	34.62	34.60	34.51*	34.50*	34.57	34.60*	################	################	34.99*	34.97*	34.96*	10°S
	34.63	34.61	34.55	34.55*	34.58†	################	################	34.99†	34.99	34.98*	34.96*	
	34.73	34.80	34.72	34.61	################	################	################	34.99†	34.98	34.98*	34.98	
	35.05	35.01	34.88	34.70*	################	################	################	################	34.98*	35.00*	35.00*	
20°	35.16	35.13	34.89*	34.84†	################	################	################	################	35.01*	35.03	35.02	20°
	35.18*	35.18	################	################	################	################	################	################	################	35.03*	35.08	
	35.24*	35.24*	################	################	################	################	################	################	################	35.04	35.06*	
	35.25	35.24	################	################	################	################	################	################	################	35.06	35.09	
30°	35.24	35.23	################	################	################	################	################	################	################	35.09	35.10	30°
	35.22	35.23	35.20*	################	################	################	################	################	################	35.11	35.12	
	35.22*	35.21	35.22†	35.20*	35.18	35.20	################	################	################	35.13	35.12	
	35.22*	35.20	35.15	35.18	35.15*	35.21	35.26	################	################	35.18	35.13	
40°	35.16†	35.15	35.15*	35.12†	35.16†	35.21†	35.17*	35.20	35.17	35.16	35.17*	40°
	35.10†	35.06*	35.00*	34.90*	34.84*	34.97*	35.16*	35.04	35.19	35.18	35.14†	
	35.01†	35.00†	35.00†	34.89†	34.85†	35.00†	35.04†	35.15†	35.13	35.06*	34.89*	
		110°		120°		130°		140°		150°	160°	

Table 4 Mean salinity at 12.5°C within each 2.5° • 5° bin.

	110°E		120°		130°		140°		150°		160°	
	34.60†	34.59†	34.57†	34.55†	34.58*	34.58*	################		35.21†	35.20*	35.19*	
	34.61	34.59	34.51*	34.55†	34.57	34.61*	################		35.24*	35.19*	35.19*	
10°	34.63	34.62	34.54*	34.56*	34.58†	################		35.23†	35.23	35.21*	35.20*	10°S
	34.71	34.73	34.73	34.59	#########################			35.23†	35.24	35.22	35.21	
	35.18	35.09	34.94	34.74*	##################################				35.23	35.26*	35.25*	
	35.40	35.35	34.98*	34.90†	##################################				35.25*	35.27	35.26	
20°	35.49	35.49	##							35.27*	35.34	20°
	35.57	35.57	##							35.28	35.27*	
	35.59	35.58	##							35.30	35.34	
	35.60	35.58	##							35.32	35.34	
30°	35.57	35.58	35.56*	##						35.34	35.36	30°
	35.57*	35.53	35.56†	35.50	35.46	35.44	##########################			35.37	35.37	
	35.54*	35.46	35.46	35.45	35.34*	35.35	35.44	################		35.42	35.39	
	35.43†	35.38	35.37*	35.41†			35.19*	35.22*	35.36	35.37	35.43*	
40°		35.26*	35.34†			35.18†	35.19*	35.04*	35.37	35.35	35.36†	40°
									35.17	35.41†	35.32†	

Table 5 Mean salinity at 15°C within each 2.5° * 5° bin.

* = salinity obtained from fewer than 10 TS pairs

† = salinity obtained from fewer than 3 TS pairs

	110°E		120°		130°		140°		150°		160°	
	34.58†	34.57†	34.54†	34.54†	34.59*	34.58†	################		35.44	35.44*	35.44*	
	34.60	34.56	34.49*	34.55†	34.56	34.61*	################		35.45*	35.43*	35.44*	
10°	34.63	34.56	34.57	34.56*	34.58†	################		35.45†	35.45	35.45	35.44*	10°S
	34.70	34.69	34.73*	34.60	#########################			35.45†	35.45	35.44	35.44	
	35.14	35.09	34.92	34.78*	##################################				35.46	35.47*	35.47*	
	35.35	35.40	35.16	34.97†	##################################				35.50*	35.49	35.50	
20°	35.55	35.62	##							35.48*	35.54	20°
	35.72	35.72	##							35.49	35.54	
	35.80	35.78	##							35.51	35.55	
	35.80	35.77	##							35.52	35.54	
30°	35.76	35.76	35.73	##						35.52	35.54	30°
	35.76*	35.69	35.75†	35.73	35.71	35.63*	##########################			35.53	35.53	
	35.70*	35.61	35.65	35.67*	35.49*	35.57	35.64	################		35.55	35.51	
	35.61†	35.58*	35.59*				35.32*	35.54†	35.49	35.49	35.54†	
40°		35.49*	35.56†						35.50	35.54*		40°
										35.52†		

Table 6 Mean salinity at 17.5°C within each 2.5° * 5° bin.

	110°E		120°		130°		140°		150°		160°	
	34.56†	34.55†	34.51†	34.51†	34.57*	34.55†	########	########	35.62†	35.65*	35.68*	
	34.57	34.53	34.45*	34.49*	34.52	34.59*	########	########	35.59*	35.66*	35.64*	
10°	34.63	34.53	34.53	34.52*	34.55†	########	########	35.61†	35.60	35.61	35.67*	10°S
	34.67	34.70	34.76	34.59	########	########	########	35.61†	35.62	35.63	35.65	
	35.06	35.02	34.85	34.76*	########	########	########	########	35.62	35.64*	35.63*	
	35.14	35.20	34.92	34.86†	########	########	########	########	35.61*	35.62	35.63	
20°	35.38	35.43	########	########	########	########	########	########	########	35.61*	35.65	20°
	35.60	35.58	########	########	########	########	########	########	########	35.61	35.67	
	35.72	35.67	########	########	########	########	########	########	########	35.63	35.67	
	35.77	35.64	########	########	########	########	########	########	########	35.62	35.65	
30°	35.81	35.67	35.68*	########	########	########	########	########	########	35.62	35.64	30°
	35.68†	35.75	35.68†	35.80†	36.00*	35.92†	########	########	########	35.60	35.60	
	35.73†	35.64*	35.72*	35.87†	35.92†	35.92†		########	########	35.62	35.57	
									35.61	35.60		
40°									35.60*			40°

Table 7 Mean salinity at 20°C within each 2.5° • 5° bin.

* = salinity obtained from fewer than 10 TS pairs

† = salinity obtained from fewer than 3 TS pairs

	110°E		120°		130°		140°		150°		160°	
	34.48†	34.47†	34.42†	34.42†	34.51*	34.48*	########	########	35.68†	35.76*	35.84*	
	34.50	34.46	34.32*	34.34*	34.46	34.53*	########	########	35.60*	35.79*	35.76*	
10°	34.56	34.47	34.44	34.44*	34.49†	########	########	35.64*	35.63	35.62	35.80*	10°S
	34.61	34.63	34.71	34.54	########	########	########	35.59*	35.67	35.67	35.72	
	34.96	34.92	34.77	34.69*	########	########	########	########	35.66	35.64	35.55*	
	35.01	35.05	34.86	34.79†	########	########	########	########	35.61	35.60	35.53	
20°	35.11	35.11	########	########	########	########	########	########	########	35.51*	35.55	20°
	35.26	35.26	########	########	########	########	########	########	########	35.58	35.60	
	35.62	35.59	########	########	########	########	########	########	########	35.58	35.67	
	35.66	35.48	########	########	########	########	########	########	########	35.63	35.63	
30°		35.49	35.48†	########	########	########	########	########	########	35.63	35.63	30°
							########	########	########	35.58	35.59	
								########	########	35.53	35.54	
										35.50*		
40°												40°

Table 8 Mean salinity at 22.5°C within each 2.5° • 5° bin.

		110°E		120°		130°		140°		150°	160°	
	34.41†	34.38†	34.32†	34.27†	34.36*	34.36†	########	########	35.48†	35.54*	35.75*	
	34.41	34.41	34.20*	34.13*	34.33	34.45*	########	########	35.39*	35.59*	35.62*	
10°												10°S
	34.47	34.43	34.43	34.37*	34.40†	########	########	35.48*	35.36	35.41	35.68*	
	34.46	34.52	34.55	34.49	########	########	########	35.38†	35.38	35.46	35.50	
	34.70	34.72	34.70	34.65*	########	########	########	########	35.39	35.40*	35.35*	
	34.85	34.87	34.85*	34.71†	########	########	########	########	35.47*	35.38	35.30*	
20°												20°
	34.99*	35.12	########	########	########	########	########	########	########	35.42*	35.40*	
	35.20*	35.20*	########	########	########	########	########	########	########	35.40	35.36	
	35.24†	35.36*	########	########	########	########	########	########	########	35.46	35.49	
		35.31†	########	########	########	########	########	########	########	35.56	35.50*	
30°												30°
				########	########	########	########	########	########	35.49	35.49*	
							########	########	########	35.50	35.47*	
								########	########	35.49†		
40°												40°

Table 9   Mean salinity at 25°C within each 2.5° * 5° bin.

* = salinity obtained from fewer than 10 TS pairs

† = salinity obtained from fewer than 3 TS pairs

		110°		120°		130°		140°		150°	160°	
	34.22†	34.18†	34.04†	34.00†	34.10†	34.21†	########	########	35.11†	35.22*	35.31*	
	34.23	34.19	34.20†	34.20†	34.22*	34.21†	########	########	34.81*	35.18*	35.29*	
10°												10°S
	34.35	34.24	34.45	34.37*	34.27†	########	########	35.29*	35.18	35.00*	35.18*	
	34.31	34.41	34.50*	34.49*	########	########	########	35.23†	35.23*	35.04*	35.21*	
	34.72*	34.67	34.65	34.51*	########	########	########	########	35.32*	35.21*	35.13†	
	34.88*	34.89*	34.74†	34.64†	########	########	########	########	35.30†	35.24†	35.14†	
20°												20°
	34.94*	35.01*	########	########	########	########	########	########	########	35.17†	35.12†	
	34.99†	34.99†	########	########	########	########	########	########	########	35.19*	35.17†	
			########	########	########	########	########	########	########	35.17†		
			########	########	########	########	########	########	########			
30°												30°
				########	########	########	########	########	########			
							########	########	########			
40°												40°

Table 10 Mean salinity at 27.5°C within each 2.5° * 5° bin.

110°E 120° 130° 140° 150° 160°

	1.14 1.25	---------- ----------	---------- ----------	1.26 1.25	1.28 1.29	1.27 1.28	********** **********	********** **********	1.38 1.36	1.31 1.31	1.28 1.28
	1.16 1.16	1.16 1.16	1.27 1.23	1.22 1.20	1.30 1.30	1.27 1.26	********** **********	********** **********	1.29 1.29	1.31 1.30	1.41 1.40
10°											
	1.24 1.24	1.18 1.19	1.25 1.25	1.31 1.30	********** **********	********** **********	********** **********	1.34 1.34	1.27 1.26	1.28 1.29	1.30 1.30
	1.35 1.36	1.35 1.35	1.34 1.34	1.29 1.29	********** **********	********** **********	********** **********	1.29 1.30	1.31 1.31	1.31 1.30	1.35 1.34
	1.23 1.24	1.25 1.25	1.28 1.28	1.30 1.30	********** **********	********** **********	********** **********	********** **********	1.34 1.34	1.35 1.34	1.28 1.28
	1.22 1.22	1.22 1.23	1.25 1.28	********** **********	********** **********	********** **********	********** **********	********** **********	1.32 1.31	1.34 1.34	1.32 1.31
20°											
	1.11 1.14	1.16 1.17	********** **********	********** **********	********** **********	********** **********	********** **********	********** **********	********** **********	1.31 1.30	1.22 1.23
	1.03 1.03	1.04 1.04	********** **********	********** **********	********** **********	********** **********	********** **********	********** **********	********** **********	1.24 1.25	1.24 1.24
	0.90 0.91	0.96 0.96	********** **********	********** **********	********** **********	********** **********	********** **********	********** **********	********** **********	1.15 1.15	1.19 1.19
	0.82 0.83	0.88 0.89	********** **********	********** **********	********** **********	********** **********	********** **********	********** **********	********** **********	1.06 1.06	1.07 1.08
30°											
	0.75 0.75	0.84 0.84	0.87 0.89	********** **********	********** **********	********** **********	********** **********	********** **********	********** **********	1.05 1.06	1.04 1.05
	0.68 0.69	0.73 0.73	********** **********	0.71 0.70	0.72 0.71	0.74 0.74	********** **********	********** **********	********** **********	0.91 0.92	0.93 0.94
	0.69 0.70	0.73 0.74	0.73 0.73	0.71 0.70	0.70 0.70	0.70 0.70	0.69 0.68	********** **********	********** **********	0.79 0.79	0.81 0.81
	0.67 0.69	0.69 0.69	0.70 0.70	0.64 0.63	---------- ----------	0.63 0.64	0.66 0.67	0.68 0.67	0.73 0.73	0.76 0.77	0.70 0.71
40°											
	0.59 0.59	0.62 0.62	0.63 0.63	0.66 0.66	0.65 0.65	0.65 0.65	0.64 0.63	0.64 0.64	0.66 0.66	0.66 0.67	0.69 0.68
	0.57 0.55	0.61 0.59	---------- ----------	0.62 0.60	---------- ----------	0.62 0.58	---------- ----------	0.62 0.60	0.63 0.63	0.62 0.63	0.63 0.63

110° 120° 130° 140° 150° 160°

Table 11 Comparison of dynamic height (upper entry) and TS dynamic height (lower entry) in each 5° * 2.5° bin and within 5° to 45°S and 105° to 160°E.

	110°E		120°		130°		140°		150°		160°
	0.00	----	----	0.08	0.11	0.07	****	****	0.05	0.15	0.04
	0.11	----	----	0.01	0.01	0.02	****	****	0.02	0.01	0.01
	0.09	0.12	0.15	0.08	0.06	0.00	****	****	0.04	0.14	0.18
	0.02	0.02	0.05	0.03	0.01	0.01	****	****	0.02	0.01	0.02
10°											
	0.09	0.09	0.08	0.05	****	****	****	0.02	0.07	0.05	0.07
	0.02	0.03	0.01	0.01	****	****	****	0.00	0.03	0.02	0.02
	0.09	0.08	0.06	0.06	****	****	****	0.00	0.06	0.08	0.05
	0.03	0.03	0.04	0.03	****	****	****	0.02	0.02	0.01	0.02
	0.07	0.08	0.04	0.05	****	****	****	****	0.06	0.09	0.05
	0.04	0.04	0.03	0.00	****	****	****	****	0.02	0.01	0.01
	0.06	0.06	0.04	****	****	****	****	****	0.08	0.06	0.04
	0.03	0.03	0.04	****	****	****	****	****	0.01	0.01	0.01
20°											
	0.07	0.08	****	****	****	****	****	****	****	0.03	0.06
	0.04	0.02	****	****	****	****	****	****	****	0.01	0.02
	0.11	0.08	****	****	****	****	****	****	****	0.08	0.09
	0.02	0.02	****	****	****	****	****	****	****	0.01	0.01
	0.07	0.08	****	****	****	****	****	****	****	0.13	0.12
	0.01	0.01	****	****	****	****	****	****	****	0.01	0.02
	0.07	0.11	****	****	****	****	****	****	****	0.12	0.12
	0.01	0.02	****	****	****	****	****	****	****	0.01	0.02
30°											
	0.07	0.11	0.07	****	****	****	****	****	****	0.17	0.13
	0.01	0.02	0.02	****	****	****	****	****	****	0.01	0.02
	0.06	0.06	****	0.02	0.03	0.03	****	****	****	0.17	0.17
	0.01	0.01	****	0.01	0.01	0.01	****	****	****	0.02	0.02
	0.05	0.05	0.07	0.03	0.03	0.03	0.03	****	****	0.11	0.09
	0.01	0.01	0.01	0.02	0.02	0.01	0.01	****	****	0.02	0.01
	0.05	0.04	0.06	0.00	----	0.00	0.03	0.02	0.08	0.11	0.03
	0.02	0.02	0.01	0.01	----	0.01	0.01	0.01	0.02	0.02	0.03
40°											
	0.03	0.03	0.01	0.01	0.01	0.01	0.02	0.03	0.04	0.06	0.00
	0.01	0.02	0.01	0.03	0.01	0.00	0.01	0.02	0.02	0.03	0.02
	0.01	0.00	----	0.00	----	0.00	----	0.02	0.03	0.05	0.01
	0.02	0.02	----	0.02	----	0.04	----	0.02	0.02	0.03	0.02
	110°		120°		130°		140°		150°		160°

Table 12 Standard deviations of dynamic height, and rms differences between dynamic height and TS dynamic height, the upper and lower left entries repectively.

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