XBT Measurements of Thermal Gradients in the MODE Eddy

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ABSTRACT

Estimates of the repeatability and accuracy of XBT measurements were made using XBT data taken during MODE. The XBT observations of the depth of isotherms had systematic errors of up to 15 decibars (by comparison to simultaneous CTD drops) as well as random errors on the order of 8 decibars. Maps of these observations show small-scale thermal structure which would imply sizeable increases in geostrophic shears.

An XBT survey was taken during the MODE-I experiment to evaluate the use and accuracy of the XBT in examining the mesoscale eddy field and to investigate the presence of smaller scale features within the mesoscale eddies. These results can be useful to those planning XBT observations of the mesoscale.

The Sippican Corporation 750 m T7 XBT was evaluated under calm sea conditions by comparisons with simultaneous CTD stations. The recorder's calibration was checked frequently with the calibration XBT tube and the surface temperature of each drop was com-

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TABLE 1

Repeatability of the depth of an isotherm

Temperature (°C)	Standard deviation of the difference of the data from the mean of the appropriate group. (decibars)	Degrees of freedom
17.5	5.5	10
10	3.8	9

Accuracy of the XBT depth of an isotherm

Temperature (°C)	Mean $p_{\mathrm{XBT}}-p_{\mathrm{CTD}}$ (decibars)	Standard deviation (decibars)	Degrees of freedom
17.5	3.9	6.2	14
10	−14.4	4.1	13

pared with a bucket reading. There was a 20% failure rate—most occurred while steaming at 12 kt. Six stations were used, four with two XBT drops during the CTD station, one with four XBT's, and one with a pair of XBT's one of which failed before reaching the 10°C isotherm. The repeatability of XBT measurements was estimated by comparing the results of the multiple drops; the absolute accuracy by comparison with the CTD. (CTD pressures in decibars and XBT depths in meters were converted using $p=1.008d+2\times10^{-6}d^2$ or $d=0.992p-2\times10^{-6}p^2$.) Table 1 shows the repeatability and accuracy estimates for the depths of the 17.5° and 10°C isotherms. From 15 repeated CTD Stations at the central mooring over a 3-day period, the high-frequency noise appears to be about 7 and 5 decibars in these depths; use of the XBT would increase noise

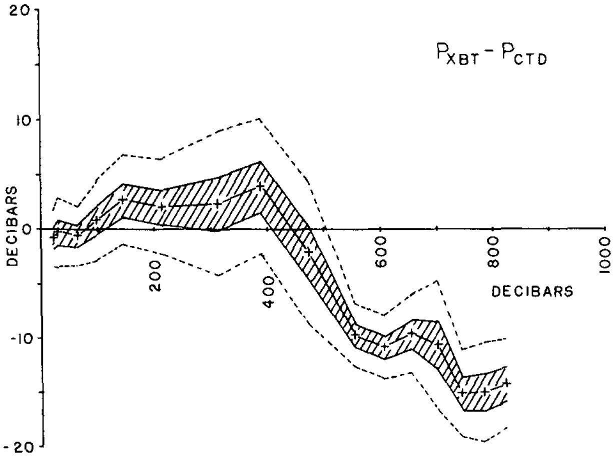

FIG. 1. Comparison of the XBT and CTD. The crosses show the mean value of $p_{\mathrm{XBT}}-p_{\mathrm{CTD}}$ (12–14 degrees of freedom); the shaded area shows 80% confidence limits on the mean value. The dotted lines are mean ±1 standard deviation and represent the 67% probability boundary for the error of an individual drop. They are plotted as a function of the mean CTD depth of the isotherm.

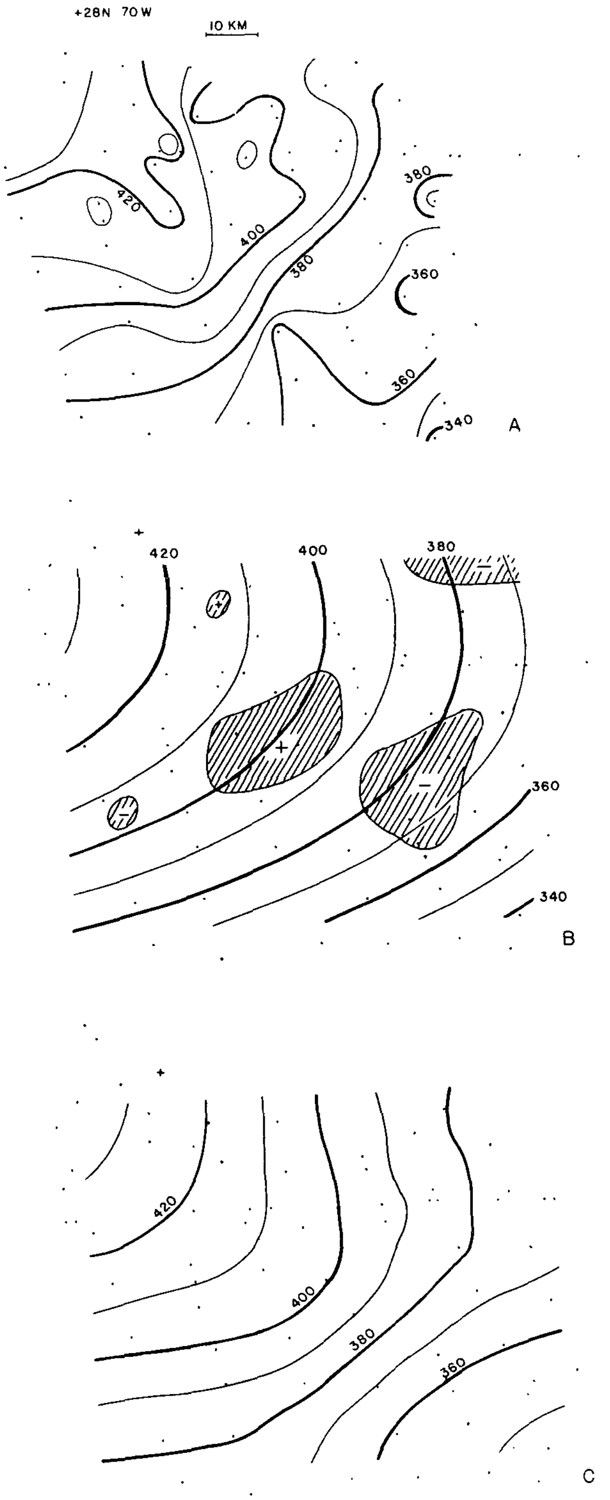

FIG. 2. Contour maps of the pressure (decibars) of the 17.5°C isotherm showing the subjective contouring (A), a quadratic surface fit to the data with the shaded regions showing where the average (over 20 km radius) deviation of the data from the surface is more than 80% significant (B), and an objectively smoothed and contoured map of the data (C). The standard deviation of the data from the field shown in Fig. 2C is 8.5 decibars.

figures to 9 and 6 decibars (in addition to a calibration shift). Compared to a mesoscale signal level of order 40 decibars rms, this is not a significant degradation for qualitative work. Fig. 1 shows the mean difference $p_{\mathrm{XBT}}-p_{\mathrm{CTD}}$ as a function of the mean depth of the isotherm, the 80% (t test) confidence limits of the mean, and the standard deviation of the $p_{\mathrm{XBT}}-p_{\mathrm{CTD}}$ values. It should be emphasized that these indicate only the errors in our specific data set; other recorders, XBT batches or operating conditions may alter the calibration and accuracy.

The error does not seem to be a simple vertical shift of a profile—the correlation between the 17.5 and 10°C errors is only 0.3. Although the error is largest deep, it does not seem to increase strikingly below the nominal 750 m depth rating.

Fig. 2A shows contours of the depth (in decibars) of the 17.5°C isotherm. The reliability of small-scale features has been evaluated by computing quadratic surface least squares fits (Fig. 2B) and the residuals. The residual noise 8.8 (7.7 decibars for 10.5°C) agrees with the high-frequency noise estimates from the CTD's above reasonably well; however, the noise is not uniformly distributed over the map, but rather has patches (shown shaded on Fig. 2B) in which the mean deviation of the XBT's within a 20 km radius circle is more than 80% significant. The central (+) anomaly (a patch of water in which the actual surface topography appears to be deeper than the quadratic surface) and the southeast (−) region combine to give the protusion of the isotherms to the southeast and the sharpening of the gradient shown on the objectively contoured and smoothed map of Fig. 2C. [The method used is that of Cressman (1959).] This sharpening gives small regions with 30–50% increase in the geostrophic shear.

In summary, the XBT appears to give sufficient accuracy for investigation of mesoscale phenomena, and, with relatively dense and repeated sampling, even of small-scale features; however, this is somewhat optimistic, being based on a single recorder and XBT batch, and optimal sea conditions. The presence of small-scale O(20 km) features corresponding to perhaps a 50% increase in geostrophic shears embedded in the MODE eddy is supported by this data, though the level of significance is probably low.

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REFERENCE

G. P. Cressman, 1959: An operational objective analysis system. *Mon. Wea. Rev.*, 87, 367–374.