A Quality-Control Procedure for Surface Temperature and Surface Layer Inversion in the XBT Data Archive from the Indian Ocean*

PANKAJAKSHAN THADATHIL, ARAVIND K. GHOSH, JAYDEEP PATTANAIK, AND LASITHA RATNAKARAN

National Institute of Oceanography, Dona Paula, Goa, India

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Expendable bathythermograph (XBT) depth error associated with the probe's fall rate has been reported in many earlier studies. Hanawa et al. (1995) made a comprehensive evaluation of the fall rate problem and suggested a global algorithm to correct the XBT depth, though the applicability of the algorithm in waters of extreme temperature is yet to be resolved. The other two potential sources of error in XBT data are the sea surface temperature (SST) and surface layer inversion (SLI). A quality-control procedure has been developed to address these sources of error in SST and SLI of XBT data from Indian Ocean, archived at Responsible National Oceanographic Data Centre for Indian Ocean region (RNODC-INDO).

The surface temperature error due to start-up transient in the digitizer electronics was reported by Roemmich and Cornuelle (1987). They observed that the magnitude, sign, and duration of this transient vary from instrument to instrument and even from cast to cast. One way to overcome the start-up transient problem is to flag the data up to the transient depth for poor quality (Bailey et al. 1993). The other alternative is to correct the surface temperature by bucket temperature, measured prior to the launch of an XBT probe. In the former case, SST, a prominent parameter required in general circulation models (GCMs) and other major environmental applications, will be missing from the prodigious XBT coverage over the global ocean. The procedure of correcting XBT surface temperature (XST) with bucket temperature sounds good. However, in many cases such corrections were not possible as the bucket temperatures were not reported along with the XBT data. Even when reported, the values need not be accurate enough as it is individually dependent and chances for intrusion of error in manual reading and coding cannot be ruled out. Such uncertainty in bucket temperature is figured out by comparing CTD surface temperature (CST) and bucket temperatures, having the same locations and time from RNODC CTD and surface meteorological databases, respectively. Figure 1 depicts the scatterplot between CTD surface and bucket temperatures. Since both the observations are from the same locations and times, if the bucket temperatures are correctly reported, then the scatter would have been minimum. At some stations the bucket temperature differs from CTD surface temperature by 2°–3°C, depicting the large uncertainty in the bucket temperature. Correction of XST with such erroneous bucket temperatures results in poor-quality data.

As an alternative, we examined the validity of taking 5-m XBT temperature as an extrapolation for XST. From the dataset of Thadathil et al. (1998) we compared XST with CST and the results are given in Fig. 2a. In many cases, XSTs are found to be significantly different from CSTs, showing the large uncertainty in the former. Using the same dataset we plotted the 5-m XBT temperature (5-XT) with the CSTs (Fig. 2b). The linear relation without any bias shows that 5-XT can be considered as a valid extrapolation for XSTs. However, while applying such extrapolation for XBT data from regions of strong upwelling and also of mixed layer depth shallower than 5 m, care should be taken. In such regions we recommend taking two observations of bucket temperature before the launch of XBT to confirm the validity of bucket temperature from the concurrent values.

Surface layer temperature inversion in an XBT profile may be a real one or due to wire stretch or pinhole leak in the cable (Bailey et al. 1993). Inversion-like features may also appear in the surface layer due to some unknown reasons. In certain regions, especially in frontal zones where the warm water meets cold water, such as the Kuroshio and Oyashio, temperature inversions are not unusual features (Nagata 1979). Though such strong thermal fronts were not reported from the Indian Ocean, temperature inversions were reported in many earlier

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Corresponding author address: Mr. Pankajakshan Thadathil, Indian Oceanographic Data Centre (RNODC-INDO), National Institute of Oceanography, Dona Paula, Goa 403 004, India.
E-mail: panka@csnio.ren.nic.in

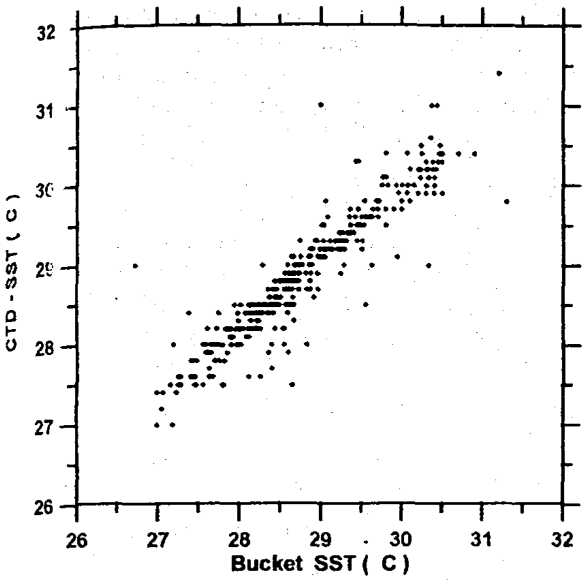
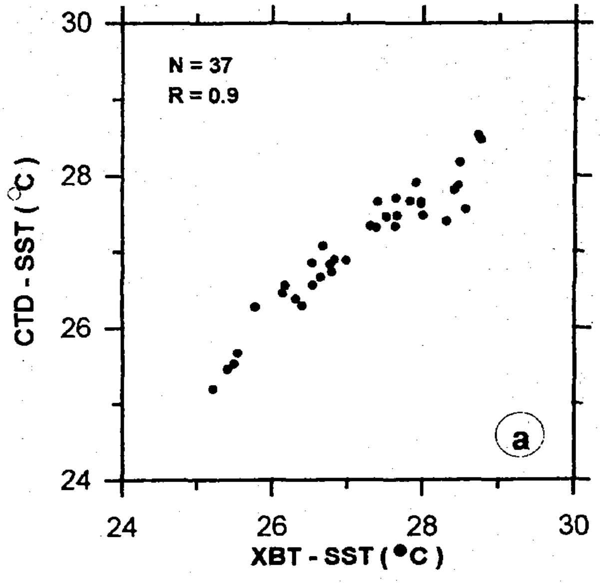


FIG. 1. Scatterplot between CTD and bucket temperature from different stations having the same location and time.



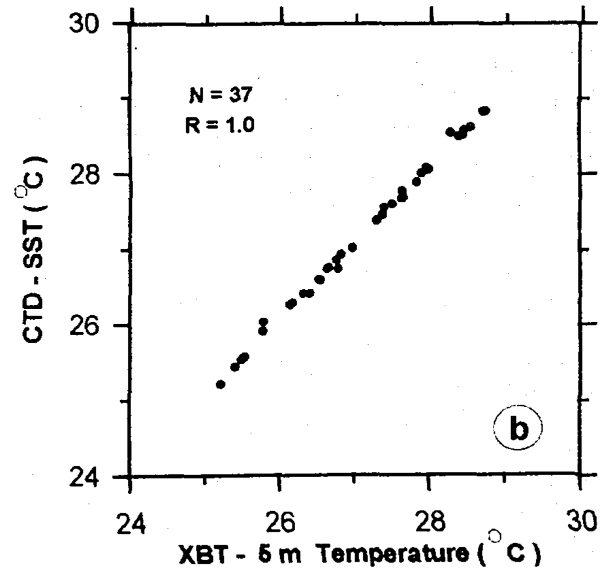


FIG. 2. (a) Scatterplot between CTD surface temperature and XBT surface temperature from controlled CTD–XBT dataset of Thadathil et al. 1998. (b) Same as in (a) except between CTD surface and 5-m XBT temperature.

studies (Panakala and Sastry 1981; Rao et al. 1983; Prabhakara Rao et al. 1987; Thadathil et al. 1992). In order to find out an inversion filter applicable for XBT data, the characteristics of surface layer temperature inversions from the CTD data archive have been analyzed. Though mechanical bathythermograph (MBT) and XBT data archive could be used, temperature inversions only from CTD data have been chosen due to the availability of density data and to use only genuine inversions (filtered out based on stability criteria) in this quality-control procedure. The results obtained from this analysis are used for proposing an inversion filter for XBT temperature inversions.

Since the purpose of this study is to figure out dubious inversions and flag them accordingly, we analyzed the general characteristics (temperature gradient and thickness of the inversion layer, starting and ending depth of inversion, etc.) of inversions. Figure 3 shows the scatter diagram between the inversion layer thickness and sea surface temperature. For computing the inversion layer thickness, the criteria adopted by Thadathil et al. 1992 has been used. Only those inversions having a temperature gradient (of the entire inversion layer) >0.5°C and a layer thickness >15 m have been considered. These lower limits were applied to sort out only those inversion layers that might cause significant errors in the XBT data. Another reason is that most of the XBT data in the RNODC XBT archive is of delayed mode and the depth resolution is 5 m. To capture an inversion-like feature from this delayed mode XBT profile, three consecutive data points corresponding to 15 m are required. The layer thickness (D) shows significant correlation (0.7) with the SST and the linear relation is $D = (-\mathrm{SST} + 23.4)/0.05$. The rms error ($\sigma$) between the observed and model D is 13 m. The layer thickness increases as SST decreases and vice versa. This empirical relation is considered as a filter for XBT inversion and to flag the dubious inversions within the tolerance of $\pm 2\sigma$.

The quality check for XST is robust, except in regions where thermocline outcrops to surface or mixed layer depth is less than 5 m. In such regions we have to depend on the reliability of bucket temperature by taking two concurrent observations, as we recommended, in the case of the inversion filter, though the layer-thickness–

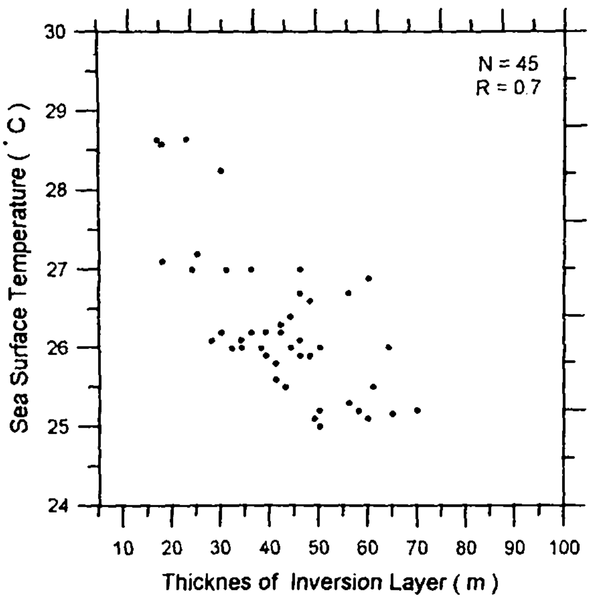


FIG. 3. Scatterplot between inversion layer thickness and sea surface temperature.

SST relation is statistically significant, care should be taken while flagging the inversions. For example, if a particular inversion is found to be falling out of the 2σ threshold, instead of labeling it "erroneous inversion" it is desirable to call it "doubtful inversion" and flag accordingly. Since we need not depend on any other datasets (like simultaneous CTD or climatology), the implementation of the quality check discussed here is more practical and simple and can be done either by the data originators or the data managers.

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