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Sea Surface Temperature: a Comparison between Ship Reports from Marine Decks and Ship-of-Opportunity Subsurface Data in the Tropical Atlantic Ocean

Marine reports from merchant ships in marine decks are routinely used to analyze the large-scale seasonal variability of the sea surface temperature (SST). Marine reports, together with other *in-situ* data, are also used (Reynolds, 1988) to correct possible biases in SST retrieved from satellite-borne radiometers (McClain *et al.*, 1985; Strong and McClain, 1984). Whether these data are of sufficient quality for this purpose is a major concern. Indeed, the noise level of the marine reports is large (reported to be of the order of 1°C), and is assessed by Reynolds (1988) to be a significant source of uncertainty in his large-scale monthly SST analysis.

Here, specifically, it is the systematic biases which we discuss for recent years. The background question is whether the marine reports should be incorporated in analyses of SST for TOGA. Since the early 1950s, the marine decks have primarily incorporated estimates made in two different ways which can differ noticeably: the temperature of water collected at the sea surface in an insulated bucket, or a measurement in the ship-intake conduct close to the ship hull. The differences between the two measurements is expected to be a few tenths of a degree, but it is not clear which one is the more accurate (Parker, 1988). The comparison by Tabata (1978) between the mechanical bathythermographs of station *Papa* in the southern Gulf of Alaska, and nearby ship reports transmitted in real time, suggested that ship-intake measurements could have a positive bias of 0.2°C. As air-sea temperature differences in the marine decks has not evolved during the last 30 years (Folland *et al.*, 1984; Barnett, 1986; Wright, 1986), it is expected that, recently, no major change in the biases of the SST from marine decks has taken place. Many reports in national marine decks lack the code for the SST estimation technique, and it is often only feasible to consider the data as a whole.

Comparisons between the marine decks have been done with other *in-situ* measurements, including drifting buoy measurements (as in the satellite calibration attempts presented in Reynolds [1988]), hydrographic station data, or moored instruments (see, for example, the studies on the climatological mean field by Reynolds [1983] and Levitus [1987], or, for recent years, a comparison in Barnett [1984]). These comparisons are often difficult to interpret, as data are not simultaneous in time and space.

Recently, in the tropics, data from expendable bathythermographs (XBTs) have been collected for TOGA by ships-of-opportunity. Usually, these ships run along well-sampled routes where a large number of marine reports are available, and there is a larger chance of getting significant results. XBTs are not frequently used, and sampling errors will be a significant constraint. Also, XBTs are not very accurate instruments (measurements in a laboratory show that the sensor uncertainty is of the order of 0.05°C [Roemmich and Cornuelle, 1987], but there are also recording errors, and they do not correctly measure the temperature in the upper 3 meters). SST is usually obtained from a subsurface depth, and this may vary with the recording instrument (sometimes, it is also hand digitized). Although laboratory experiments do not show a mean bias (Roemmich and Cornuelle, 1987), positive bi-

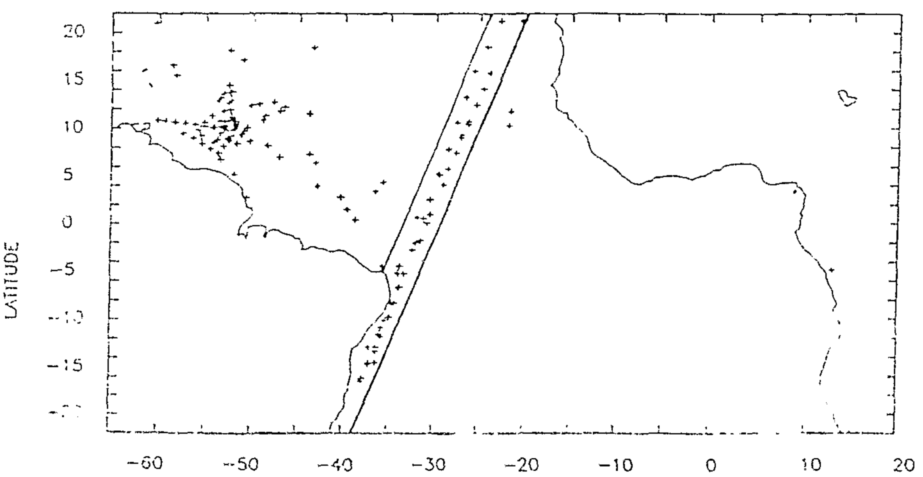


FIGURE 1 (*Reverdin, et al.)*
Subsurface temperature data for December, 1981. The XBT line selected for the analysis is outlined on a monthly distribution of subsurface profiles in December, 1981.

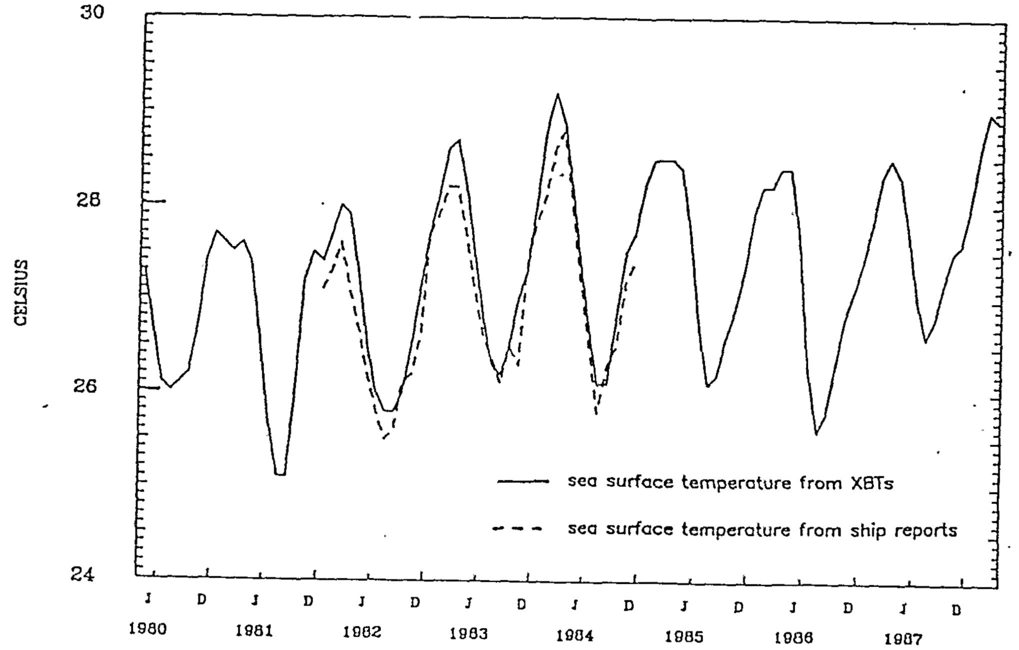
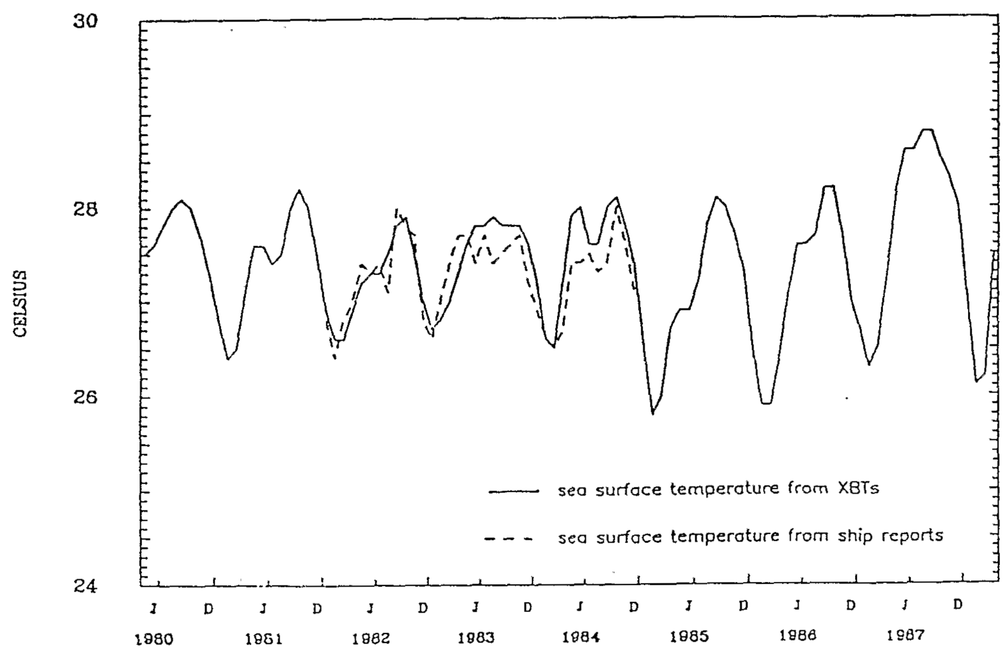
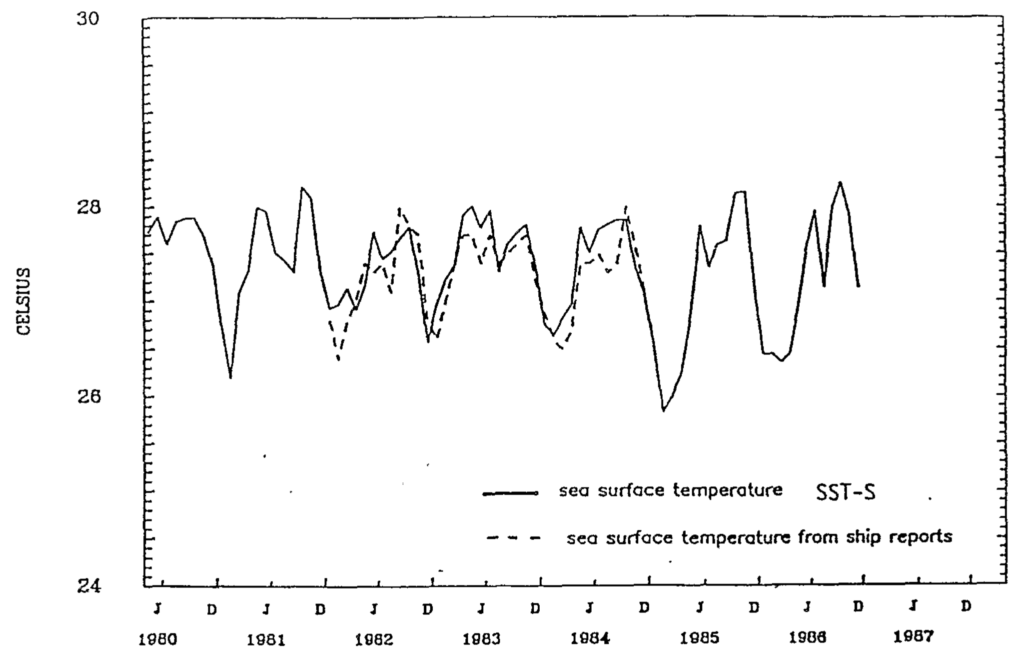


FIGURE 2 *(Reverdin, et al.)*
Comparisons between time series of SST. Figure 2a is for a bin centered at 10.5°S and containing 212 XBT profiles (rms deviation with the analysis is 0.24°C). Figures 2b and 2c are for the bin centered at 6°N. There are 324 XBT profiles (rms deviation with the analysis of 0.25°C).



ases are expected according to earlier *in-situ* studies (Heinmiller, *et al.* [1983] report a 0.19°C bias for the T4 type, and a 0.13°C bias for the T7 type).

Here, we investigate one of the best sampled lines. Located in the tropical Atlantic, it runs along the NE-SW axis between Cape Verde Islands and Brazil (Fig. 1), and has been regularly sampled since mid-1980 by two ship-of-opportunity programs (managed respectively by the French agency ORSTOM and by the German agency DHD). These ships sample the SST approximately every 1.5° of latitude and, north of the Cape Verde Islands, the ship routes are distributed over 5° of longitude; the analysis bins will be 1.5° in latitude and 5° in longitude. In 1983-1984, we have complemented the data-set with subsurface profiles collected for the French-American cooperative program FOCAL-SEQUAL. Except for a few interruptions (particularly in late 1982-early 1983), this well samples the low-frequency variability, with a monthly average of three reports per bin within 6°S-10°N, and two reports farther poleward. In each bin, individual data depart from an analysis of the low frequencies with an rms deviation



smaller than 0.3°C, and sampling uncertainties on monthly time scales are often no more than 0.15°C.

In the same bins, we gathered marine reports for 1982-1984 from a marine deck compiled at the *Deutsches SeeWetter Amt* and the TDF-11 compiled at the American National Meteorological Center. The latest significant update for these years was carried out during July, 1988. After eliminating most duplicates and reports with unexpected values (a too-large wind or air-sea temperature difference), we are left with a monthly average number of reports of the order of 50 by a 1.5° latitude bin between 10°N and 4°S, and 80 reports along the Brazil coast. The lower number of reports to the north is the unexpected result of the shift to the east of the XBT line from the line sampled in the marine decks (the French vessels often travel closer to Africa than the vessels selected in the German program). Monthly rms standard deviations range between 1.0°C south of 5°S or north of 10°N to 0.8°C closer to the equator. As these are much larger than the ones in the XBT files, we can expect them to result from random noise, and the resulting uncertainty in the monthly mean is less than 0.15°C within 10°S-10°N.

Two examples of bin time-series are presented. For the first one at 10.5°S (Fig. 2a), SST experiences a moderate seasonal cycle which has a similar amplitude every year, superimposed to lower frequencies. On the second one at 6°N (Fig. 2b), a latitude with no sharp spatial gradient in the sea surface temperature, SST has a smaller seasonal cycle, with a maximum SST in September-October when the eastward-flowing North Equatorial Countercurrent is well established. At both locations, the XBT analysis and the ship reports suggest similar characteristics of the seasonal variability. The rms deviation between the two monthly analyses, which is less than 0.30°C between 6°S and 10°N, has a magnitude comparable to the expected rms uncertainties due to sampling of the two analyses.

However, in the two cases presented, temperatures from ship reports are colder than the XBT analysis in most months. This happens at most latitudes, except between 10°N and 14°N, and between 3°N and 1.5°S, where there is a larger zonal gradient, with colder waters where the XBT line runs to the east of the routes most heavily sampled in the marine decks. Elsewhere, the mean bias is of the order of -0.20°C. This bias has the sign opposite to the one which we expected, assuming that it was the positive bias from the ship intake measurements which would dominate the error. We eliminated the possibility of a different sampling of the diurnal cycle in the XBT program and the ship reports, as in both of them there is the same excess of daily reports over night reports (10% more reports during the day time). We also separated day and night measurements in the analysis of the ship reports, and found that the day-night difference averaged 0.49°C, with little latitudinal or seasonal dependence (there was also a daily cycle in reported wind stress, assuming a constant drag coefficient, with day-time wind stresses exceeding night-time wind stresses by 12%). The XBT analysis, which is an estimate of the temperature below a 3-meter depth, has a much smaller amplitude, and if it was the day-time SST in ship reports which was too warm, we would expect the SST analysis from the marine decks to be overestimated.

We then considered another SST product: SST-S, derived from marine decks available earlier and containing less ship reports than in our ship-report analysis (Servain *et al.*, 1987) for data up to 1984; an update to 1987 has been compiled later). Random monthly differences between SST-S and the XBT-based analysis of SST are larger (rms of the order of 0.40°C), and random differences with the more recent ship report analysis have an rms of the order of 0.30°C; SST-S is also warmer (Fig. 2c) than the SST from the more recent ship report analysis, and in most places it is even warmer than the XBT analysis (the mean difference is 0.11°C). We have no explanation for these systematic differences. However, even at 6°N where the interannual variability is small, the seasonal variability is portrayed similarly in the different analyses (Fig. 2b, 2c): there, in the different records up to 1986, there are more year-to-year differences in the minimum temperatures than in the maximum temperatures. The similarities in the low frequencies are widespread, and there is hope that interannual variability is well portrayed by the ship reports along well-sampled lines.

The systematic differences between the two SST analyses from ship reports and the

XBT analyses were found along a ship line which is particularly well sampled. We did not comprehend what caused the biases, but processing of the ship reports is a likely source of biases. This suggests that it may be difficult to merge ship reports with the variety of other SST measurements envisioned in TOGA to produce accurate, large-scale SST fields. Although the XBTs yield less noisy estimates of temperature at a depth of 3 meters and are easier to control, their absolute accuracy should be monitored closely as instruments and recording systems evolve.

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News of the International Tropical Ocean Global Atmosphere Programme

TOGA, the Tropical Ocean and Global Atmosphere programme, is an international research experiment designed to improve the understanding of events in the tropical oceans and global atmosphere that significantly influence the predictability of seasonal to interannual variations in the Earth's climate. TOGA is a component of the World Climate Research Programme (WCRP), which was established by WMO and ICSU, and is carried out in association with IOC and SCOR. The scientific planning and development of TOGA is under the guidance of the JSC/CCCO Scientific Steering Group for TOGA, assisted by the International TOGA Project Office. JSC and CCCO are the main bodies of WMO-ICSU and IOC-SCOR, respectively for formulating overall WCRP scientific concepts. TOGA's intergovernmental coordination is undertaken jointly by WMO and IOC. The following items were prepared by or for the International TOGA Programme office to communicate developments of importance to the TOGA program:

NEWS FROM THE INTERNATIONAL TOGA PROJECT OFFICE

Undoubtedly the most significant recent event for the ITPO was the successful site survey that was carried out in Gan in September by Mr. Peter Budgen of the U.K. Meteorological Office. In a separate article Valery Lee explains the details of this project which will lead to upper winds from Gan being reported on the Global Telecommunication System.

The growing support for the proposed TOGA Coupled Ocean Atmosphere Response Experiment (COARE) in the warm pool in the western Pacific has been monitored with keen interest. Two future events that will be important for the development of TOGA COARE are the presentation by the United States to the second session of the Inter-governmental TOGA Board in December 1988 and the International Workshop that will be sponsored by France, the USA and the ITPO in Noumea, 24-30 May 1989. An announcement about this Workshop appears separately in this issue.

To follow up the recent meeting of the TOGA Scientific Steering Group (reported in TO-AN 46) the TOGA XBT Operations and Management Committee has been insti-