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Ocean Science Discussions

Interactive comment on "Comparing historical and modern methods of Sea Surface Temperature measurement – Part 2: Field comparison in the Central Tropical Pacific" *by* J. B. R. Matthews and J. B. Matthews

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We thank AR2 for their comments.

>"This paper gives an overview of some methods for measuring SST and does an analysis of data from an experiment in the tropics. The results from field experiments are useful for improving models of SST bias from different measurement methods. My major concern is that the authors suggestion of broad conclusions from a study over a brief period in the tropics only. Others such as Kent and coworkers and Folland and Parker

and coworkers have done more extensive studies of the problem. Where this more limited study shows findings inconsistent with more extensive studies, comparisons should be made and it is possible that some improvement in the more comprehensive understanding of bias could be made using these results. But this study on its own is not sufficient evidence for changing bias estimation models."

No rigorous global-scale field assessment of shipboard SST measurement methods of the type we report has ever been conducted. We took hourly measurements with several types of bucket over a period of several weeks, contemporaneously measured a suite of meteorological variables and crucially also analysed the vertical near-surface temperature structure. We focused on the tropical Pacific in part since our study was inspired by Vecchi et al. (2008) who had found large discrepancies between SST records for this region.

The conclusions to which AR2 refers are that bucket adjustments should not be applied to historical SST datasets and that intake temperatures should be excluded. These conclusions were not reached solely based on the results of our field experiment. For one, we think it inappropriate to correct bucket temperatures using uncertain, poorly verified and complex adjustments. Rather we argue for exclusion of data suspected to be of particularly low accuracy. As an additional argument for removal of EITs, we note that the extent to which subsurface temperatures can be assumed equivalent to bucket temperatures is unclear. We observed strong temperature gradients across the upper 3m both day and night (average temperature difference of 0.4 ± 0.2C between 0 and 3m) in the central tropical Pacific, independent of wind speed. The prevalence of vertical gradients exceeding 0.05Cm-1 in the upper 10m is poorly known on large spatial scales (Argo floats typically record few temperatures in this depth range). However, strong vertical near-surface gradients are thought ubiquitous under weak winds and strong insolation, as noted in studies by KN Federov and coworkers from the 1980s onwards. Thus we think this line of reasoning applicable to regions outside the tropics. Some additional discussion of field observations of near-surface temperature structure

will be provided in the revised manuscript.

The studies referred to by AR2 are of quite different nature to the one under discussion. Kent and coworkers have used statistical approaches to assess systematic errors in bucket and intake temperatures (e.g. Kent and Kaplan, 2006). Note, however, that Kent and Kaplan (2006) focused only on reports from the North Atlantic obtained between 20 and 50N and that the paired bucket and intake measurements used were only approximately spatially collocated (within 100km of each other). The results of such correlation-based approaches require confirmation by rigorous field experiments of the type we present. This is also true of the bucket models devised by Folland and Parker, the results of which have not been thoroughly evaluated on large spatial scales. Nor have the parameterisations they employ for turbulent heat fluxes been experimentally verified on a moving vessel.

>"Some particular concerns: 1. Limitations in the record: May-June 2008 for a small region of the tropical Pacific. This region is not typical of the global oceans, and a short period may not be representative of tropical air-sea interactions. It's good to do studies and necessary to limit them. But it's also good to be aware of the limitations and not suggest too general a conclusion. More data are needed for the development of models."

Our results from the tropics are of wider significance given that particularly strong bucket cooling is predicted for this region. By way of loose comparison, we note the FP95 adjustments reach ∼0.4-0.7C in the central tropical Pacific by 1940. Thus the fact we found consistent average inter-bucket temperature differences of zero there suggests the FP95 models could be overestimating bucket cooling, at least for measurements from sailing vessels.

We argue that bucket measurement exposure times were generally short (1-2 minutes) such that when bucket cooling did occur, it would generally have been of fairly small magnitude (0.05-0.2C assuming cooling rates of 0.05-0.1Cmin-1). We agree that fur-

ther field experiments should be conducted in other ocean regions, seasons and with different types of vessel. Sampling should be organised so as to cover complete diel cycles.

>"2. Ship intake biases are noisy, but when averaged give a bias of about 0.1C (Reynolds et al. 2002, J. Clim, 15, 1609-1625). In the tropics where SSTs are already warm the bias would likely be less, but that does not mean that intake temperatures are unbiased."

We are a little unclear as to what is being suggested by AR2 here. While our engine intake warming model demonstrates that intake temperatures are unlikely to be strongly biased by warming of the intake seawater, we are certainly not suggesting EITs are generally unbiased. Indeed, we are citing the fact that several studies have found them to be in large systematic warm error (>0.5C, e.g. Tauber, 1969) as a reason for their removal from SST datasets. Crucially, however, subsurface temperatures have never been shown to be generally equivalent to temperatures in the upper few 10s of centimeters on large spatial scales. Such an assumption certainly appears to be invalid in the tropical Pacific, where we found temperature differences of up to 1C across the upper 3m. Note that sampling depth for EIT measurements is largely unknown prior to 1995 and only poorly known thereafter.

>"3. All in situ SST measurements tend to be noisy due to observing practices and small ship location errors. It's not just a problem with intake temperatures. It's especially a problem with historical measurements. Proper analysis techniques can account for the noise and properly use the observations."

We are proposing a new approach in which there is a more critical selection process over the data used to construct SST records in order to limit systematic and random errors. In terms of observing changes in heat content due to anthropogenic global warming, higher accuracy is required for SST measurements than marine air temperatures given that seawater has a much larger volumetric heat capacity than air (∼3000

times larger). We do not see how to reliably improve the accuracy of historical SST data collected by uninterested mariners using inaccurate, low-resolution instruments. Thus while we suggest that all (supposed) intake data be excluded, we are not implying that all the remaining bucket data be used in historical datasets. For instance, it may be reasonable to assume bucket temperatures reported to higher resolution are of greater accuracy and precision and thus only use those reported to 0.1C. That bucket temperatures, like intake temperatures can be noisy (random rather than systematic error) will be made clearer in the revised manuscript.

>"3. HadISST-ERSST differences in NINO3.4 have two main causes. One is the different bias adjustment as noted. The other is the different analysis methods for the long-period variations (Smith et al. 2008). Differences in the analysis methods are at least as important as the tropical bias differences."

That different analysis methods can also be important will be noted in the revised manuscript.

Interactive comment on Ocean Sci. Discuss., 9, 2975, 2012.