The Hadley Centre
Global Ocean Analysis (HadGOA)

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INTRODUCTION

We report on progress toward new subsurface observational analyses of ocean heat content (OHC) and temperature diagnostics relative to fixed-depths and fixed-isotherms, including error estimates. The analyses are constructed using quality controlled temperature profiles developed as part of the ENSEMBLES EU project. We find that temperature diagnostics computed relative to isotherms provide a useful addition to the more traditional fixed-depth analyses in aiding the interpretation of ocean heat content changes. In particular, the fixed-isotherm analyses allow us to better separate the influence of changes in air-sea heat fluxes and ocean circulation by considering both changes in isotherm depth and mean temperature above the isotherm. Consequently, our new analyses provide a more sophisticated approach to evaluating ocean and coupled ocean-atmosphere model performance.

DATA

Our analyses are based on 9.5 million quality controlled ocean temperature profiles over the period 1950–2006 from the Met Office EN3 data set (Ingleby and Huddleston, [2007] http://www.metoffice.gov.uk/hadobs). This is an updated data set to that used by Palmer et al. [2007] and includes XBT bias corrections (see below) approximately 7.9 million profiles come from the World Ocean Database 2005 (WOD05) [Johnson et al., 2006]. Additional data sources include: the World Ocean Circulation Experiment (WOCE); the Bureau of Meteorology Research Centre (BMRC, Australia); the Commonwealth Scientific and Industrial Research Organisation (CSIRO, Australia); the Pacific Marine Environmental Laboratory (PMEL, USA); the Global Temperature-Salinity Profile Program (GTSPP, Australia, Canada, France, Germany, Japan, Russia); and the Argo profiling array [Davis et al., 2001]. In the early 1990s GTSPP adds about 5% to the number of profiles used relative to WOD05, rising to about 10% in the late 1990s. Unlike WOD05, EN3 uses a time-evolving background field for the statistical background check, which is particularly useful for quality control of data in the tropical Pacific.

METHOD

Following Palmer et al. [2007], each temperature profile for a given month is assigned to a 2°×2° latitude-longitude grid box and averages are formed from the profiles to produce 588 monthly gridded fields of: (i) the mean temperature of the water warmer than 14 °C, (ii) the depth of the 14 °C isotherm, and (iii) the mean temperature of each profile down to 220 m. We choose the 14 °C isotherm because it provides good coverage of the upper water column, at low to mid-latitudes, throughout the historical record, and 220 m because it is the time-mean depth of the 14 °C isotherm in low and mid-latitudes. We produce a 12 month climatology based on the period 1956-2004 and construct gridded anomaly fields to remove the seasonal cycle. Volume-weighted mean temperature anomalies are computed to produce time series.

XBT BIAS CORRECTIONS

It was recently discovered that expendable bathy-thermograph (XBT) data have a time-varying warm bias, which introduces spurious decadal variability into observational time series [Gouretski and Koltermann, 2007]. Wijffels et al. [submitted] suggest that the warm bias is mostly the result of incorrect fall-rate equations and have developed corrections to remove this effect (Figure 1). We include here an additional analysis with these fall-rate corrections applied to investigate the impact on the time series of ocean warming.

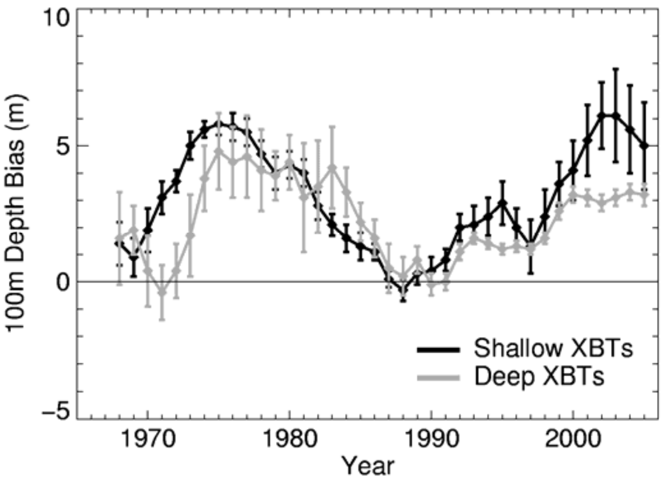

Figure 1: Diagnosed depth errors for shallow (≤ 550m) and deep (> 550m) XBTs at 100m depth from Wijffels et al. [submitted].

TIME SERIES

With the original EN3 data set there is a marked reduction in the high frequency variability of the 14 °C mean temperature analyses over all ocean basins compared to the 220 m analyses (Figure 2a-d). Also at lower frequencies there is a reduction in multi-annual to decadal variability for the 14 °C analyses. This can be seen in the reduced amplitude of the warm anomaly in the 1970s and 1980s in the Pacific and Global time series and the reduced multi-annual variability for the Atlantic time series throughout. The long-term trends for the 14 °C analyses are more similar between basins than those of the 220 m analyses [see Palmer et al. 2007, for further discussion].

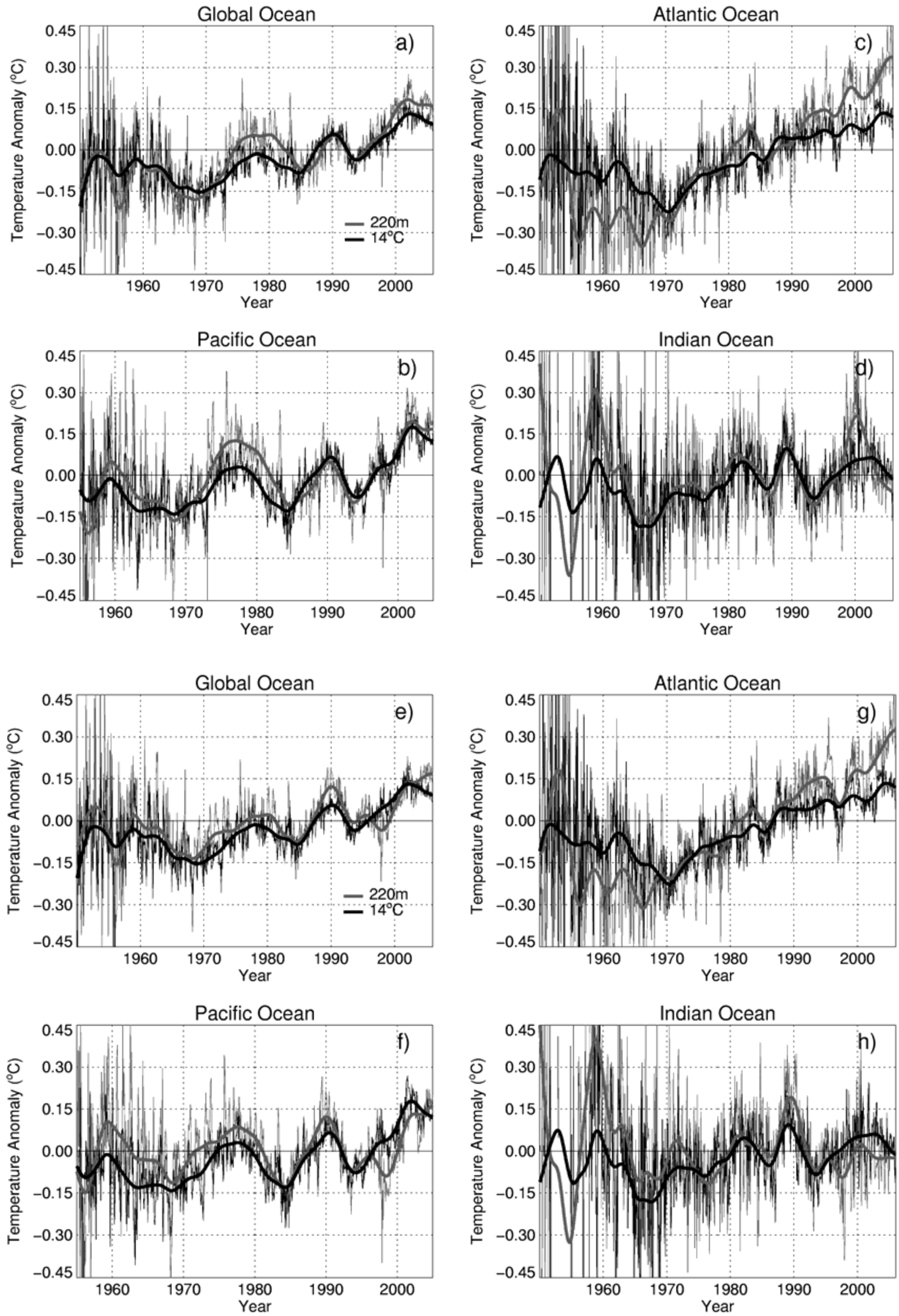

Figure 2: Time series of monthly mean temperature anomaly above the 14 °C isotherm (black) and 220 m (grey). Panels a-d show results for the standard EN3 data and panels e-h show results for the XBT bias-corrected EN3 data. The thick lines are the data after a 5-year low-pass filter has been applied. Grid boxes for each month are selected to make sure that 14 °C and 220 m analyses have identical geographical coverage.

IMPACT OF XBT BIAS CORRECTIONS

The XBT corrections make very little impact on the 14 °C analyses, (Figure 2e-h). This result is consistent with the argument put forward by Palmer et al. [2007] that the mean temperature above an isotherm should be insensitive to fall rate corrections whilst still giving a good detector of upper ocean warming from air-sea fluxes. For the 220 m analyses the impact of the XBT bias corrections is most noticeable in the Pacific and Global Ocean as a reduction in the amplitude of the 1970s and 1980s warm anomaly. There is also evidence that the overall warming trend in these basins is reduced, as it is in the Atlantic time series to a lesser extent. However, the XBT corrections also appear to amplify some interannual variability, e.g. the positive temperature anomalies around 1990 and dip in temperature anomaly around 1998.

CONCLUSIONS AND FUTURE WORK

We have implemented the XBT bias corrections developed by Wijffels et al. [submitted] in the EN3 data base. Our results for the 14 °C analyses confirm that temperature above an isotherm is insensitive to XBT fall-rate errors. For the 220 m analyses, the bias corrections lead to a reduction in the 1970s-1980s warm anomaly and reduce the long-term warming trend. However, the bias corrections also lead to some amplification of interannual variability later in the time series. We are currently working towards producing sampling/coverage uncertainties for our analyses, following a similar method to that documented by Brohan et al. [2006]. These uncertainties will be combined with uncertainty estimates for the bias-corrected time series. Our fixed-depth and isotherm analyses will be the basis for evaluation of ocean warming in Met Office Hadley Centre coupled climate models.

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