NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
UNITED STATES DEPARTMENT OF COMMERCE

Global Ocean Heat Content 1955-2007 in Light of Recently Revealed Instrumentation Problems

Syd Levitus, John Antonov, Tim Boyer

National Oceanographic Data Center- NOAA
Ocean Climate Laboratory

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Preamble

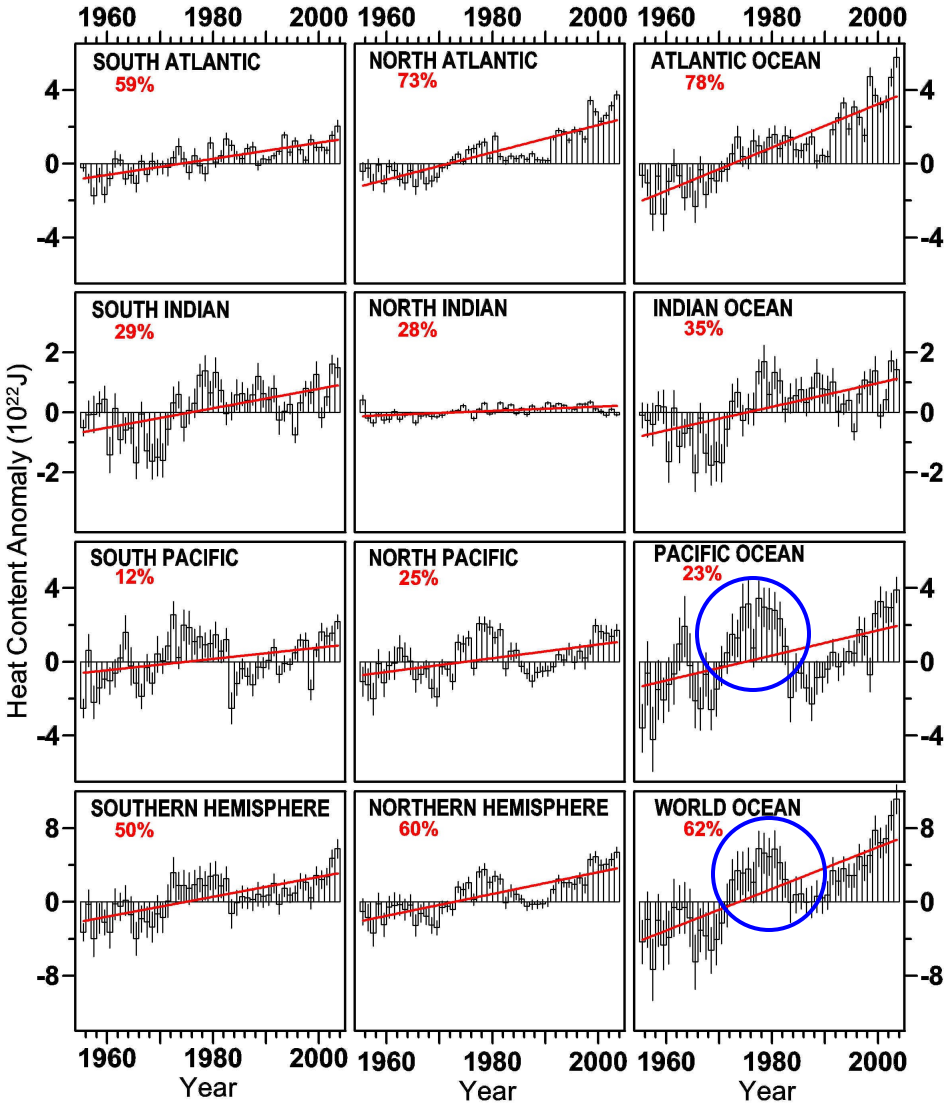
- Following recent assessment of ocean heat content trends (e.g., *Levitus et al.*, 2000, 2005; *Ishii et al.*, 2006; *Willis et al.*, 2004), it was pointed out by *Gouretski & Koltermann*, 2007 that there is an systematic **warm**, **time-varying** bias with XBT data;

- Corrections for this XBT bias were suggested to improve previous ocean heat content calculations;

- There was a concern that instrumental bias corrections might have affected the **long-term** trend (1955-2007) in ocean heat content that we previously reported. It will be demonstrated that, although some small corrections are indeed necessary, the instrument bias corrections do not affect the previously reported **long-term** trend in ocean heat content.

Note. XBT = Expendable Bathythermograph

Yearly heat content by ocean basins in the upper 700 m



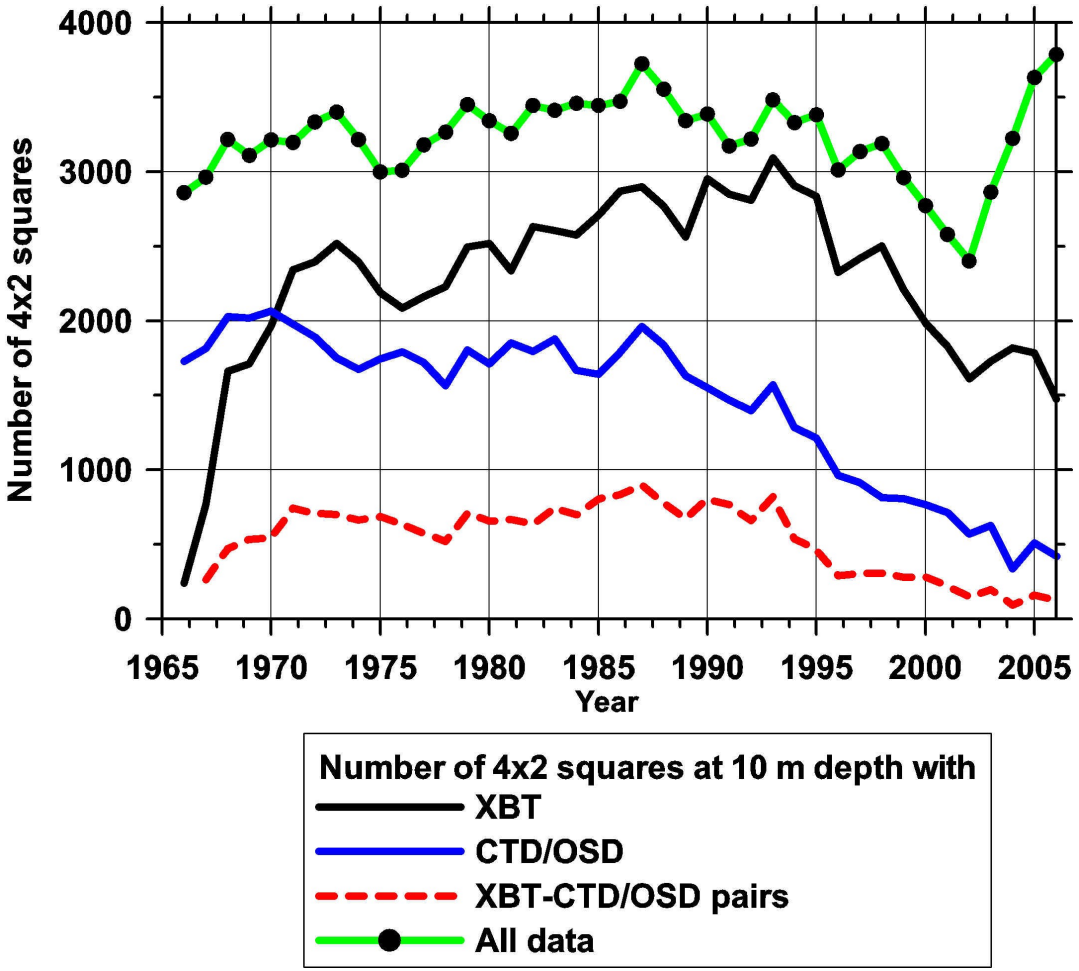
After: *Levitus et al.*, *Geophys. Res. Letters*, 2005

Procedure for XBT Corrections

- Temperature observations were interpolated to standard depth levels;
- The effect of seasonal signal was reduced by subtracting the monthly climatology from observations;
- These differences between observations and mean climatology were averaged within 4°x 2° squares at standard depth levels for each year to produce yearly mean XBT and CTD/OSD anomalies;
- The **median** of the differences between XBT and CTD/OSD anomalies were computed for each year at each standard depth level for all 4°x 2° squares with contained both XBT and CTD/OSD observations.

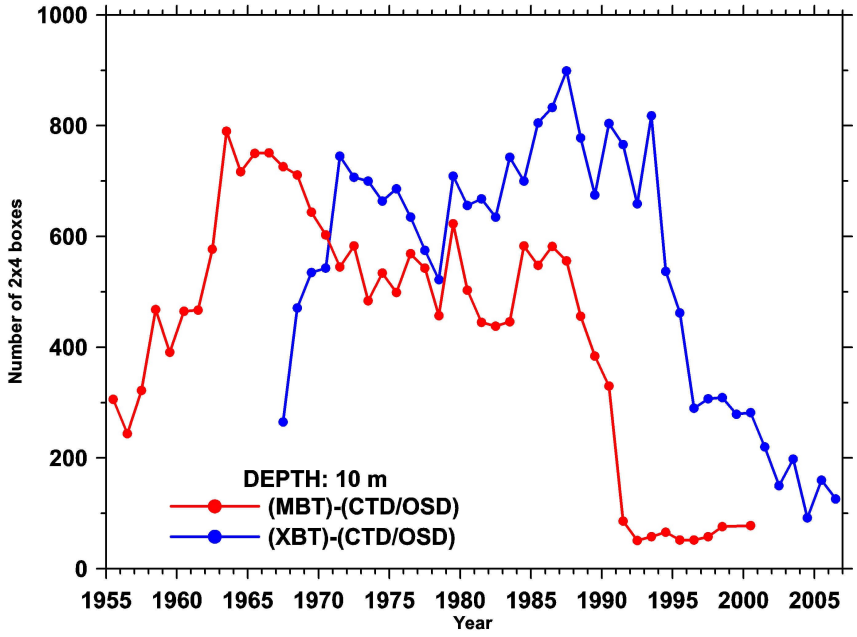
Note. CTD = **C**onductivity, **T**emperature, and **D**epth; OSD = **O**cean **S**tation **D**ata (bottles)

Data Availability



Note. PFL = **P**rofiling **F**loats

Possible Source of Error in Previous Estimates Using MBT

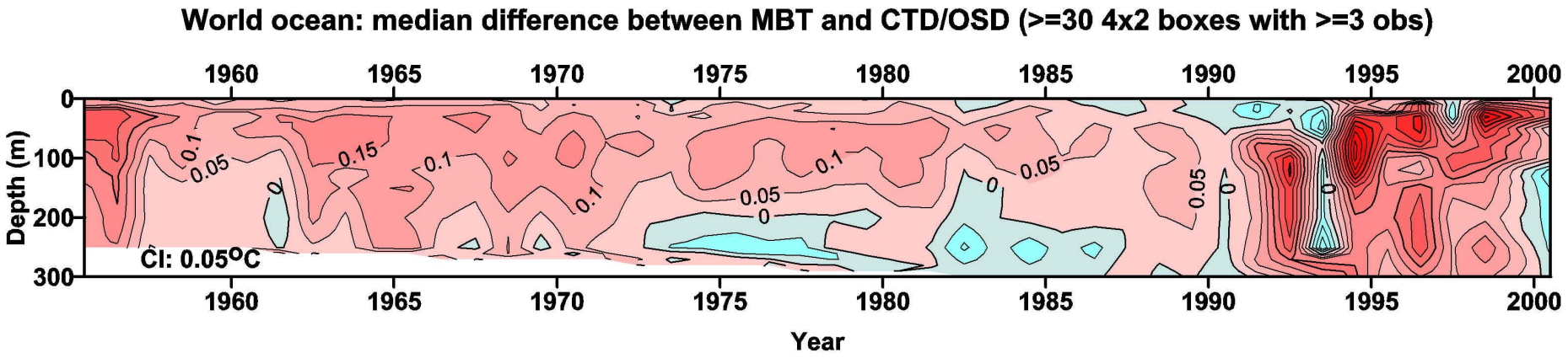


The number of 4x2 boxes that meet the observation criteria as a function of time for both MBT and XBT comparisons based on computations from WOD data.

Note. MBT = **M**echanical **B**athythermograph; WOD = **W**orld **O**cean **D**atabase

World Ocean: Median Difference Between MBT & CTD/OSD

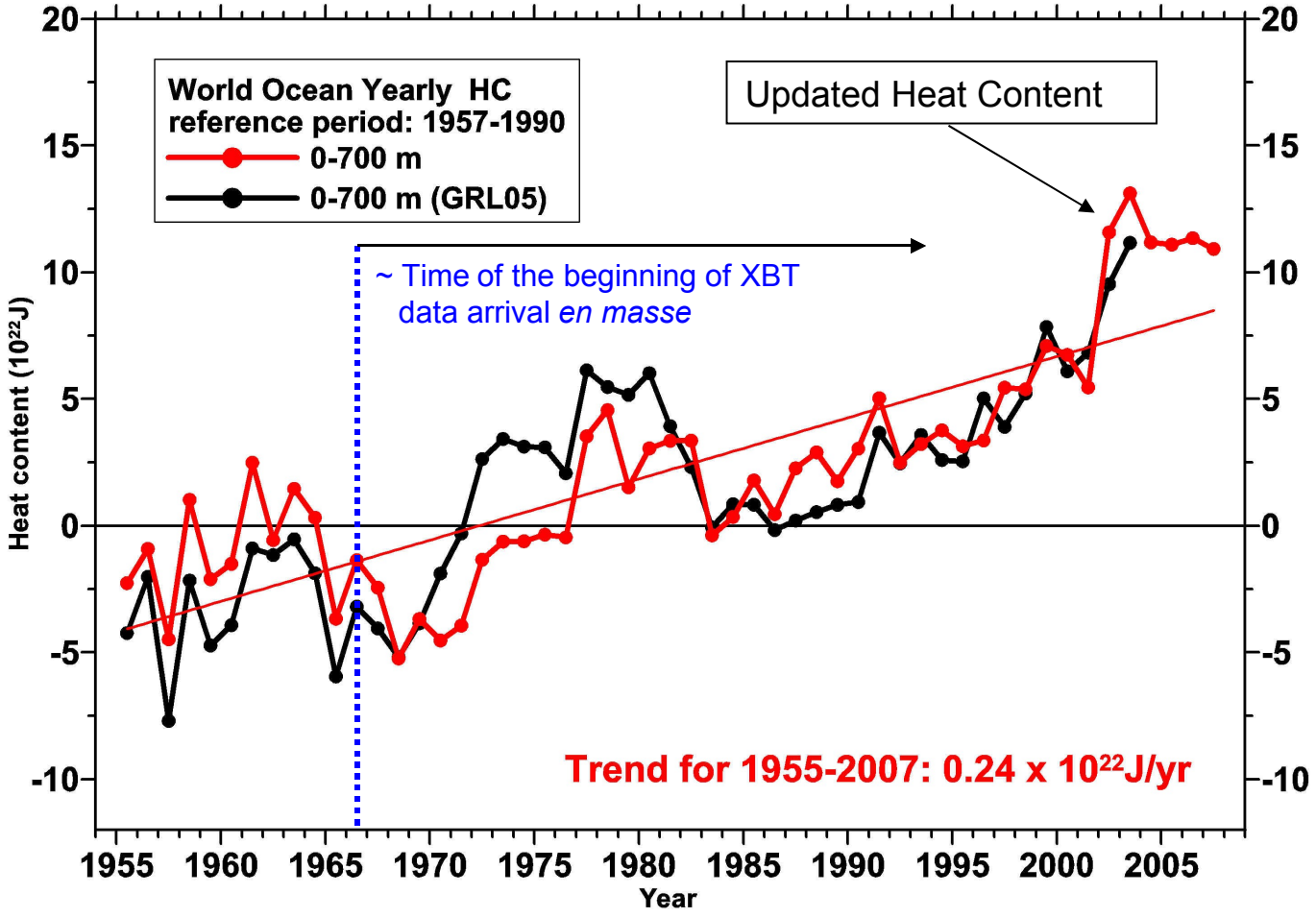
(In area with more than 4°x2° boxes with ≥3 observations in a box)



There are very few MBT-CTD/OSD pairs after 1990. Therefore, MBT data after 1990 were excluded from our new ocean heat content estimates.

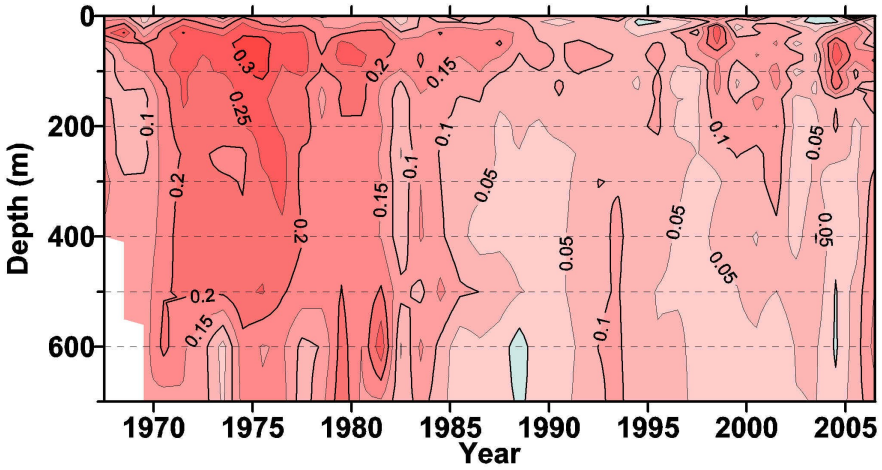
The shallow subsurface maximum in the difference field suggests that either MBT thermistor and/or pressure sensing elements caused the bias toward CTD and reversing thermometer observations.

Updated Ocean Heat Content for 0-700m layer



Note. GRL05 = *Levitus et al., Geophys. Res. Letters*, 2005.

XBT Correction Comparison

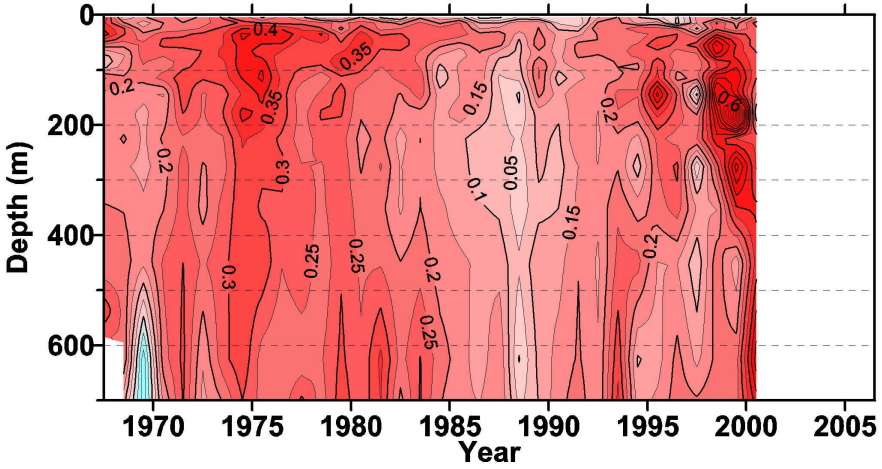


Median of differences

XBT minus CTD/OSD

CI: 0.05 ^{o}C

(4x2 boxes with >=3 obs)



Gouretski and Koltermann (2007)

Mean of differences

XBT minus CTD/OSD

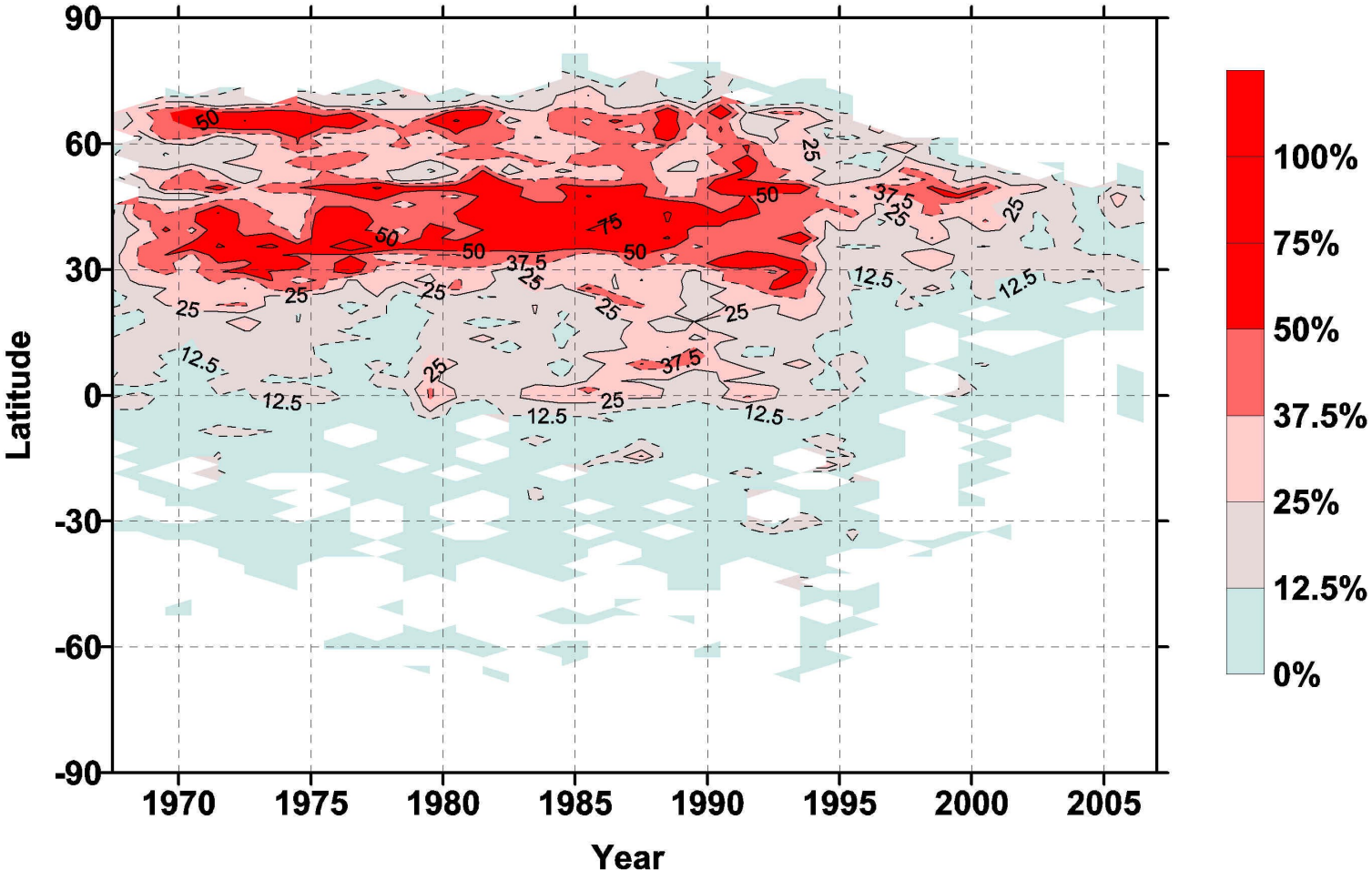
CI: 0.05 ^{o}C

(4x2 boxes with >=3 obs)

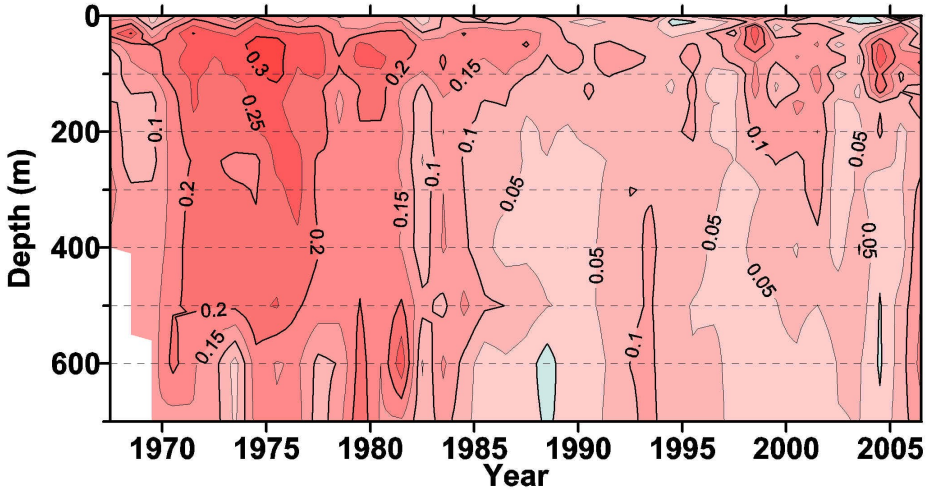
Note. Only 20% of all XBT observations were used for computing the bias

Geographical Bias of the Corrections

Percent ocean area of 2-degree zonal belts with 4°x2° differences between XBT and CTD/OSD pairs at 50 m depth



XBT Corrections in Reanalysis

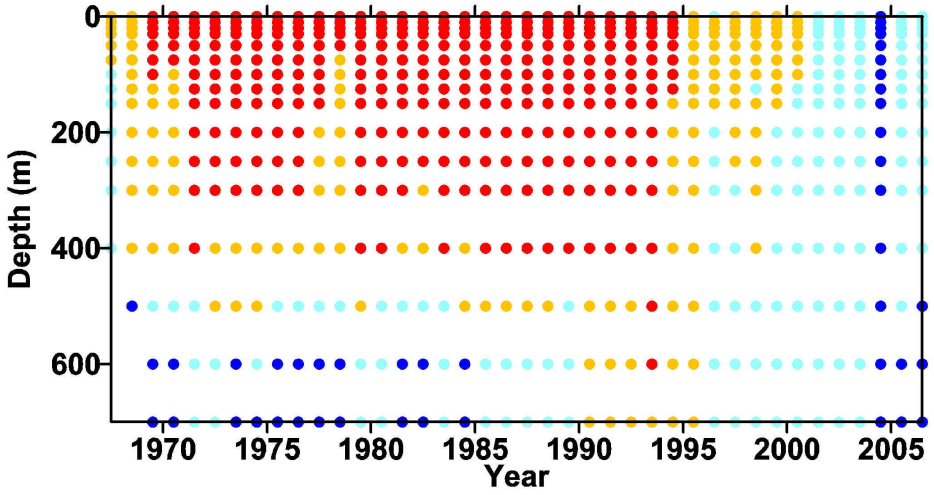


Median of differences

XBT minus CTD/OSD

CI: 0.05 ^{O}C

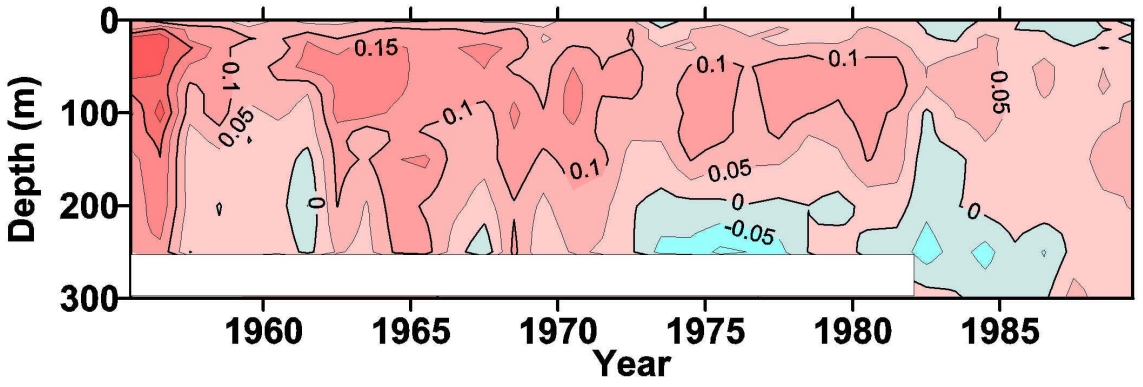
(4x2 boxes with >=3 obs)



Number of 4x2 differences

- 30 to 100
- 100 to 250
- 250 to 500
- 500 to 1000

MBT Corrections in Reanalysis

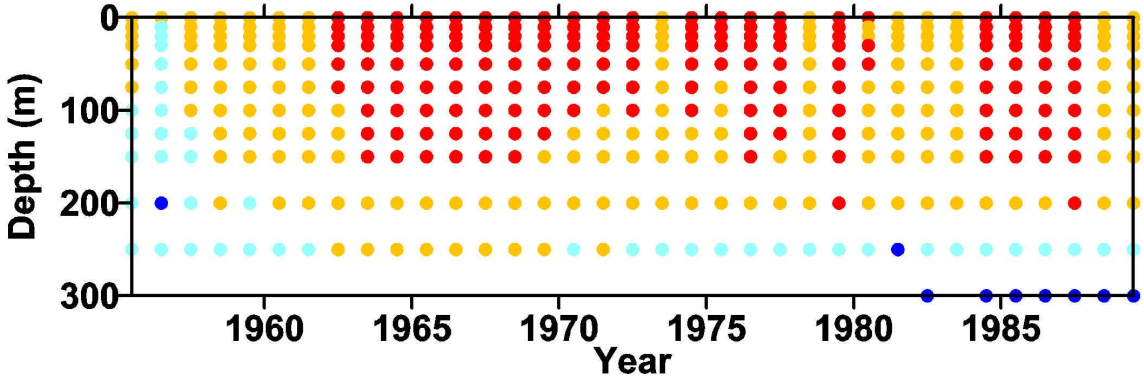


Median of differences

MBT minus CTD/OSD

CI: 0.05 ^{o}C

(4x2 boxes with >= 3 obs)



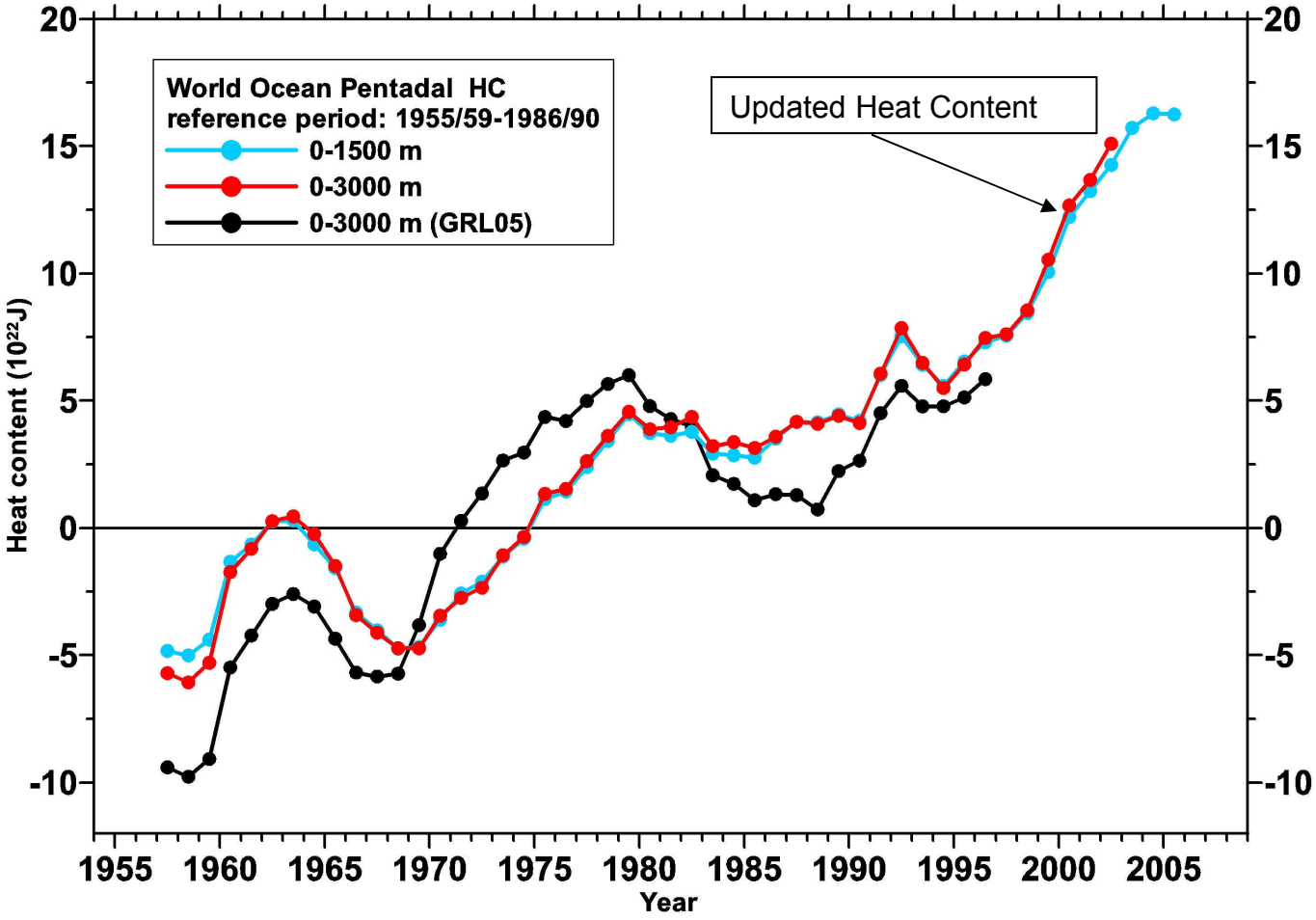
Number of 4x2 differences

- 32 to 100
- 100 to 250
- 250 to 500
- 500 to 782.1

Reanalysis

- XBT and MBT observations were bias corrected on standard levels
- XBT data below 700 m depth were excluded (except for T5 XBT profiles)
- MBT data after year 1990 were excluded
- Subset of PFL data with **pressure offset problem** was excluded
- All instrumental types of data were used to compute the objectively analyzed climatology and temperature anomaly fields

Updated Heat Content



Note. GRL05 = *Levitus et al., Geophys. Res. Letters*, 2005.

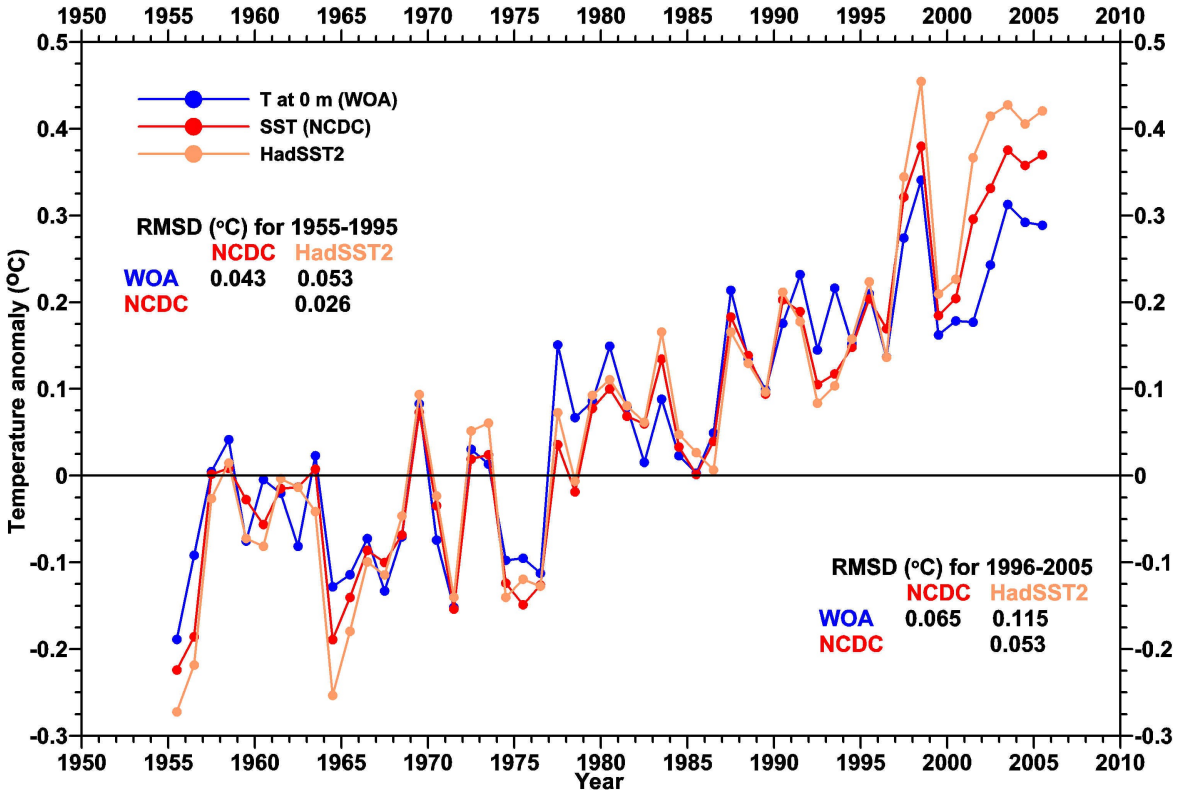
Linear trend estimates of World Ocean Warming (10^{22} J/year)

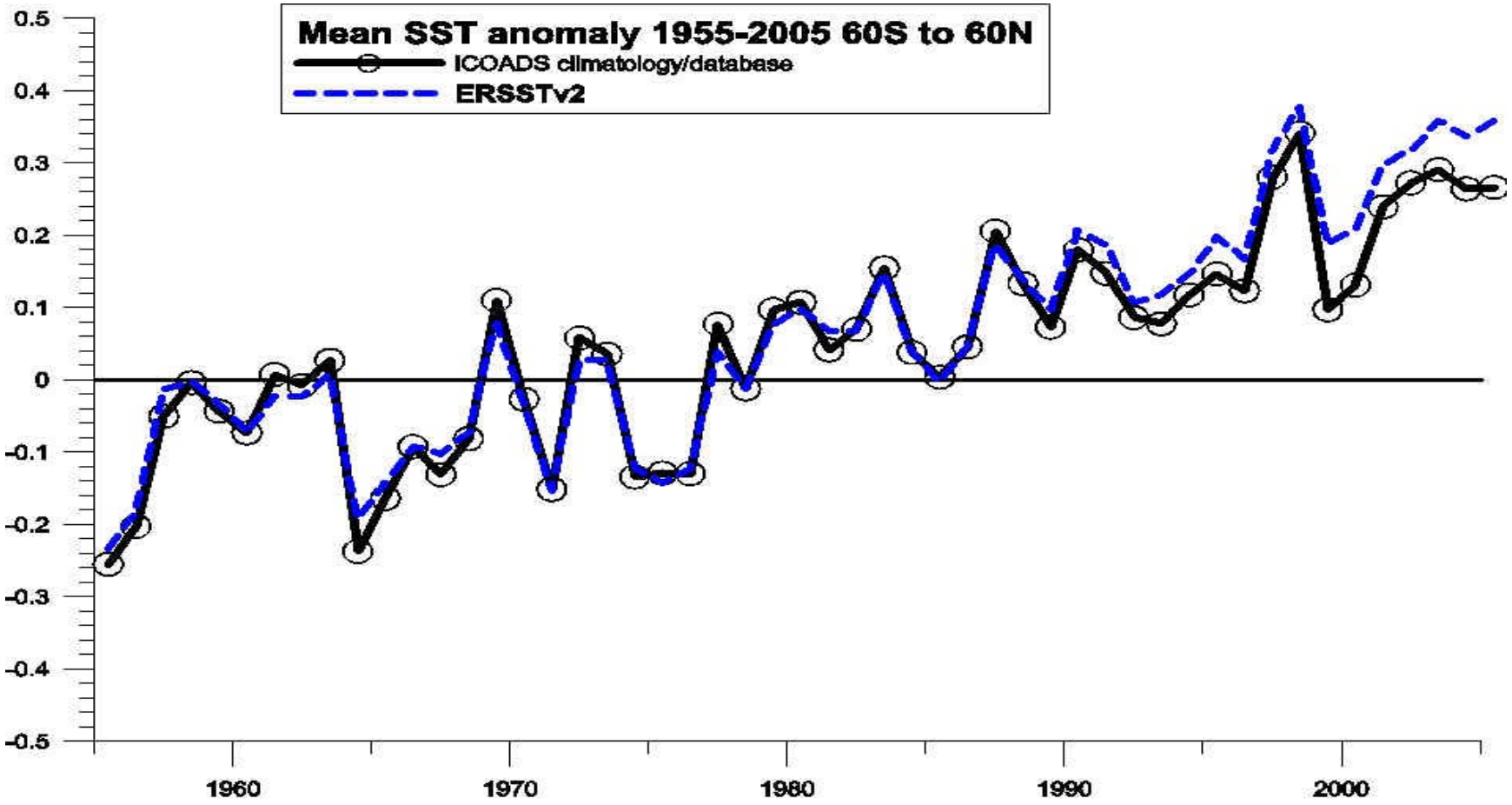
	New estimates	*Levitus et al.* (2005)
0-700 m layer		
1955-2003:	**0.21**	**0.23**
1955-2007:	**0.24**	
1968-2007:	**0.35**	
1993-2007:	**0.73**	
0-1500 m layer		
1955/59-2003/07:	**0.38**	
1968/72-2003/07:	**0.46**	
1993/97-2003/07:	**1.13**	
0-3000 m layer		
1955/59-1994/98:	**0.31**	**0.33**

Comparison of Three Different SST Climatologies

Is there enough data to produce reasonable estimates of upper ocean heat content?

The global SST time series from NCDC and the UKMO Hadley Centre based on ICOADS and the global SST time series based on WOD05 (over 7.9 million SST observations) show excellent agreement. Historical and new data are being added to reduce ambiguity of the forthcoming estimates.




Mean SST anomaly 1955-2005 60S to 60N
ICOADS climatology/database
ERSSTv2
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
1960
1970
1980
1990
2000

Recommendations

Based on our re-analysis of the ocean heat content, and because the XBT "bias" correction depends on the number of CTD/XBT pairs, we propose the following steps in order to better address the instrument bias in future:

- No changes should me made to original XBT data;
- The corrections which investigators apply to the raw XBT data in their research should be made available along with the publication of any scientific work using those data. There will be a new page at NODC web site for this purpose;
- Acquiring additional historical as well as modern CTD, OSD, and PFL data is critical for improving the estimates of time dependent XBT biases;
- For improving corrections, XBT-CTD comparisons should be continued in future until a better remedy is found

Conclusions

1) We concur with the recent studies that there is a systematic time-varying bias with XBT data;

2) We concur that the introduction of corrections for this XBT bias reduces the amplitude of the interdecadal variability observed in our previous ocean heat content results;

5) However, the XBT bias corrections do not seriously affect our previously reported long-term (1955–2007) trend in ocean heat content.

Thank you!