

*Effects of different XBT corrections
on historic and recent ocean heat
content calculations*

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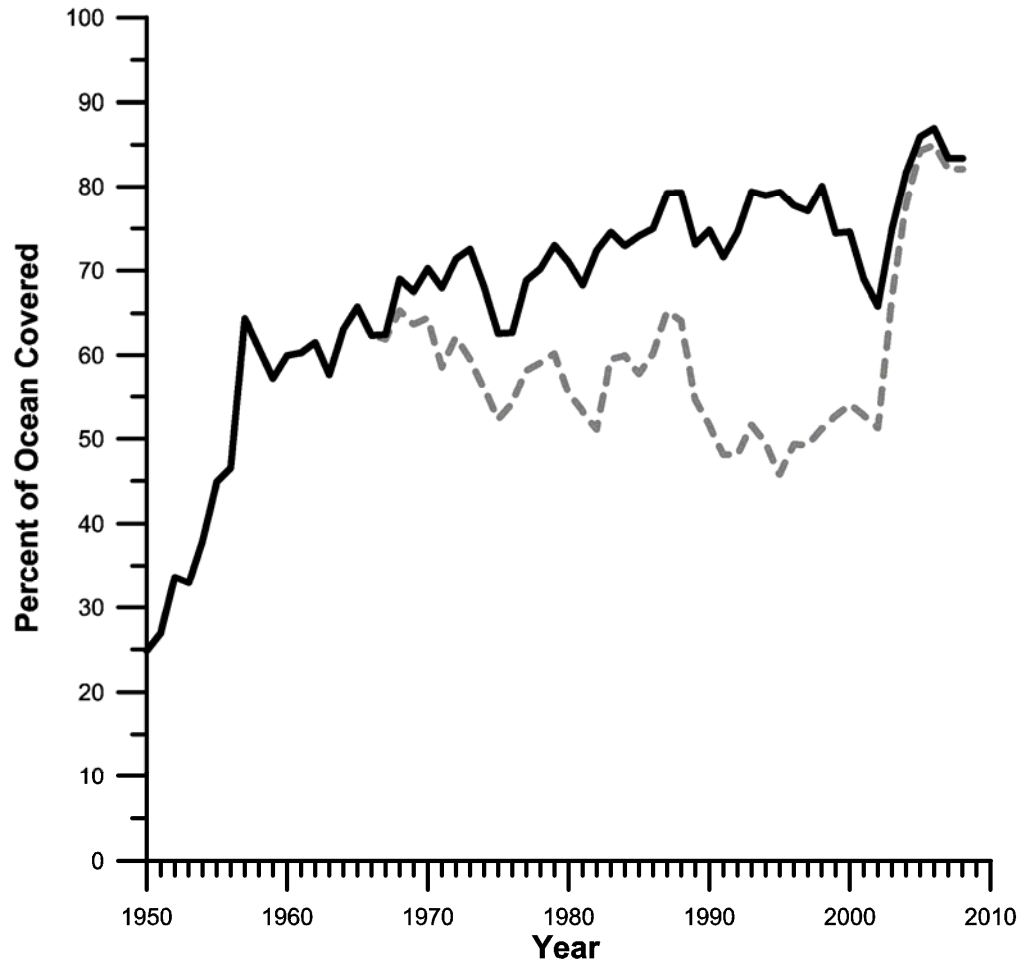
August, 2010

Our Antagonist

The **XBT** with its time-varying, depth-varying, temperature-varying drop-rate, variable equipment, variable manufacture, variable deployment technique and conditions, temperature bias, and lack of meta-data.

Main Questions

- Do we need XBTs for ocean heat content integrals (historical and in the future)?
- How similar are different corrections with respect to ocean heat content integrals?
- How do we measure how good are the corrections?
- Should we (oceanographers) settle on one method for XBT correction, and if so, how do we disseminate correction information/data?



Percent of 1° ocean squares globally with adequate coverage using all instrument types (solid line) and using all instrument types except XBTs (dashed line). A 1°-square is considered to have adequate coverage if there are at least 3 1°-squares with at least 1 temperature profile within a 440 km radius of the center of the 1°-square. Criteria is as used for climatologies in Levitus *et al.* (2009).

Into the Future

Number of temperature profiles in the World Ocean Database (WOD) by instrument: 2009

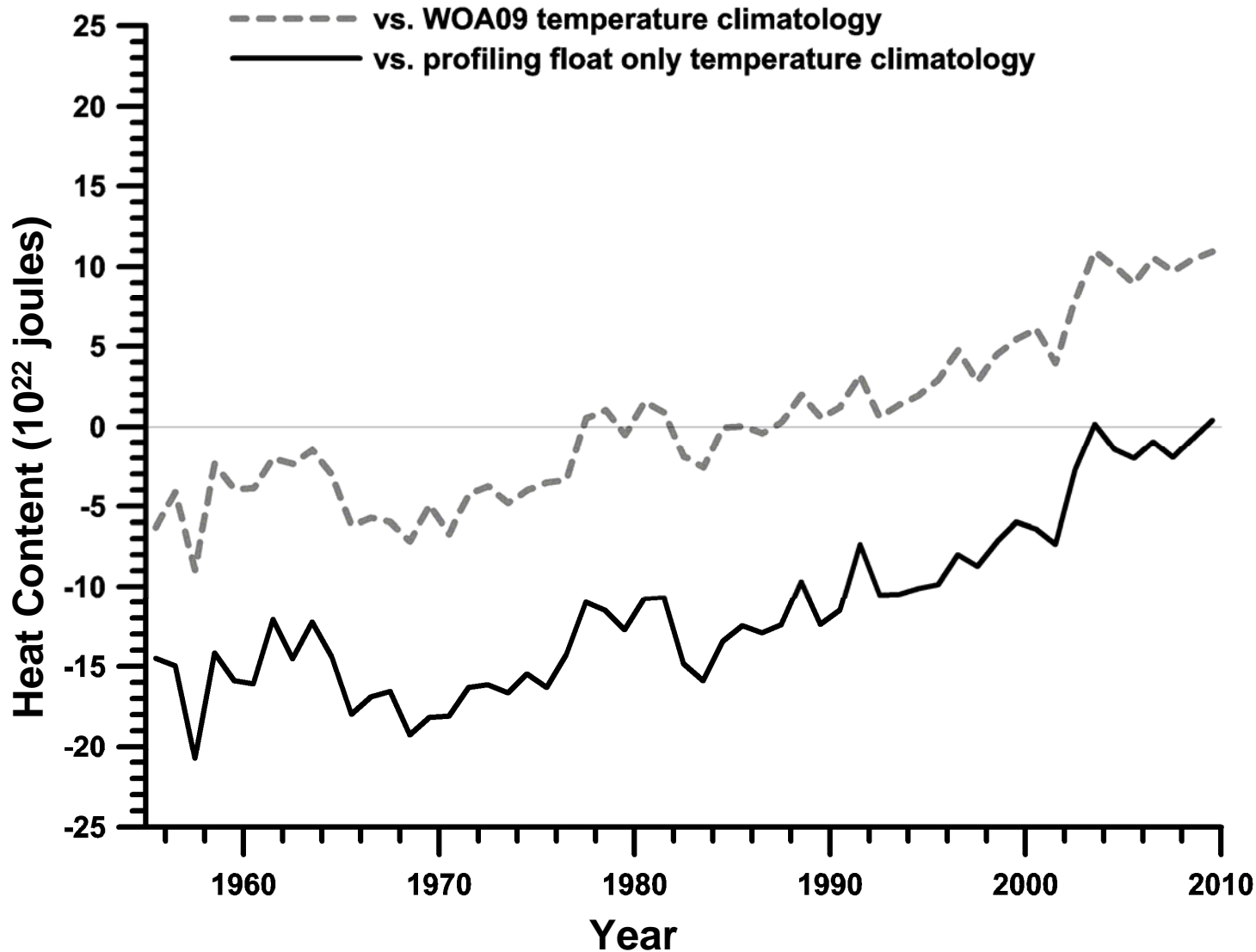
- **profiling floats** **118,988**
- **XBT** **20,173**
- **ship-based CTD** **13,504**

- **tropical moored buoys** **32,222**
- **elephant seal** **41,069**
- **glider** **877**

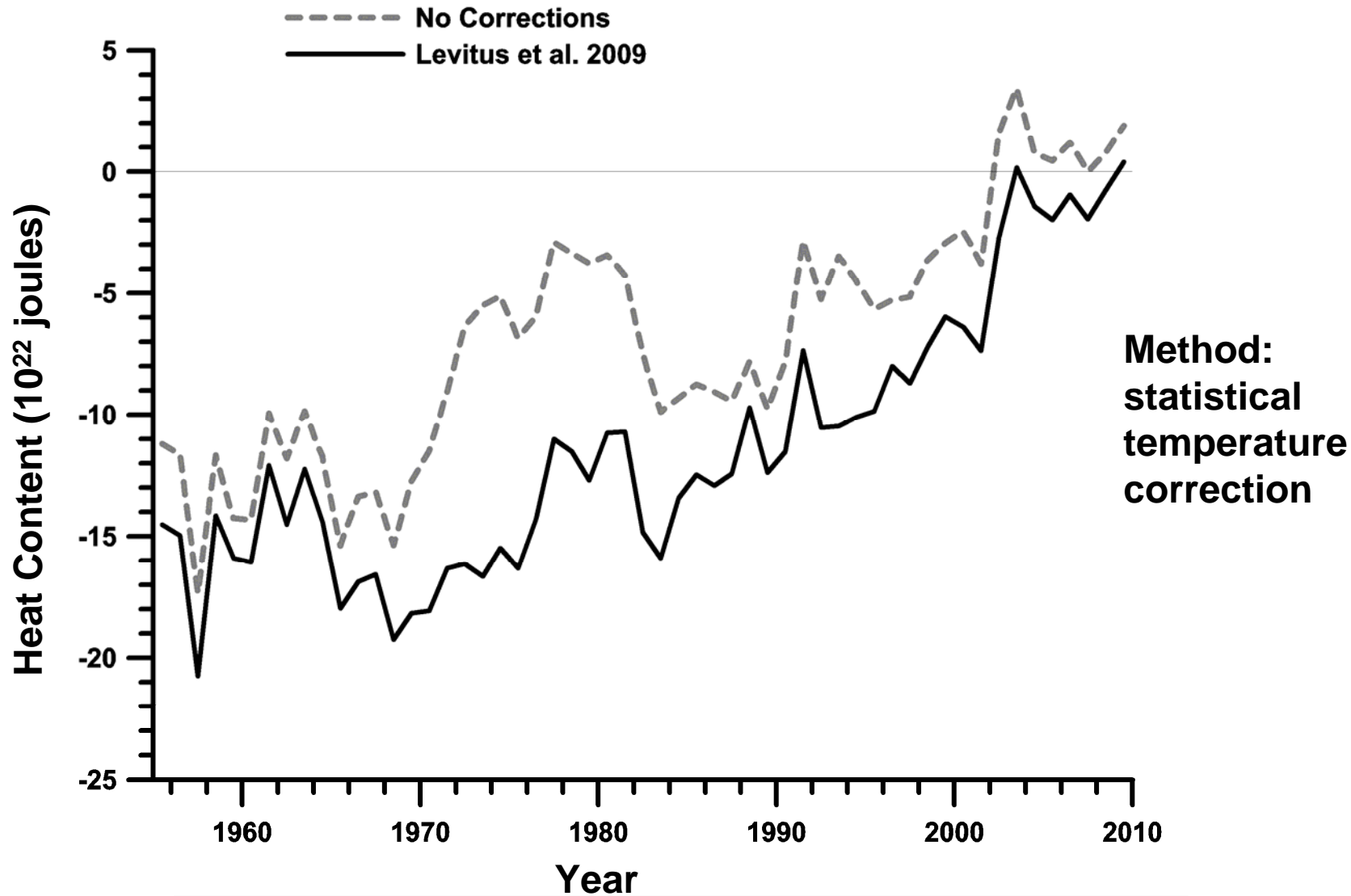
XBTs were ~9% of all global coverage, widely extant instruments
XBTs were ~6% of all temperature profiles.

Comparison of XBT Correction Methods

- Use same data set (WOD) , same quality control
- **Apply XBT corrections, calculate ocean heat content anomaly integrals using same method.**
- **Use same base mean ocean temperature field. In this case, a profiling float only climatology.**
- **Compare heat content integrals: How similar are results from different methods?**



Integrated Ocean Heat Content Anomaly 0-700 m
depth profiling float only climatology used for the
present experiment.

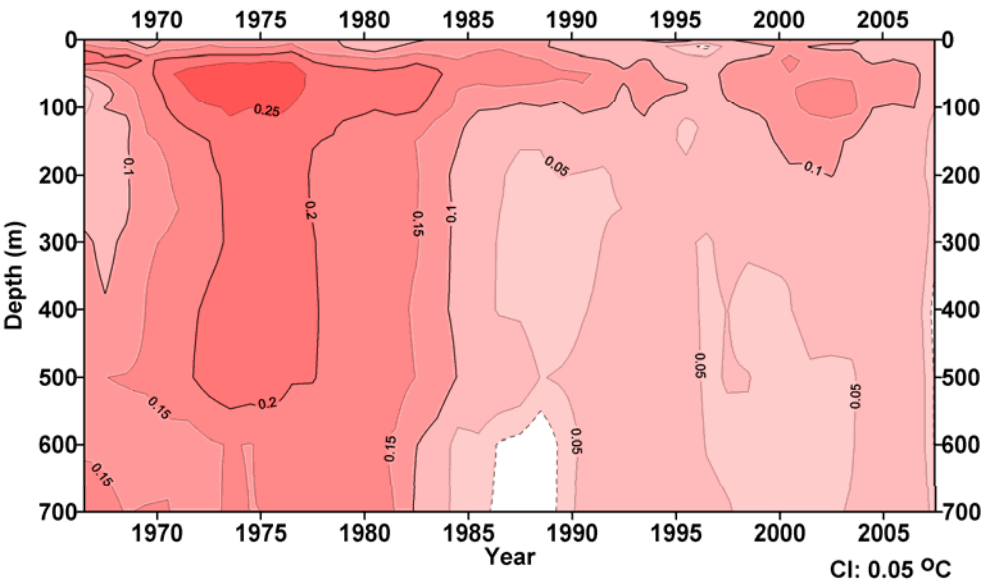


**Integrated Ocean Heat Content Anomaly 0-700 m
Levitus et al. 2009 corrections.**

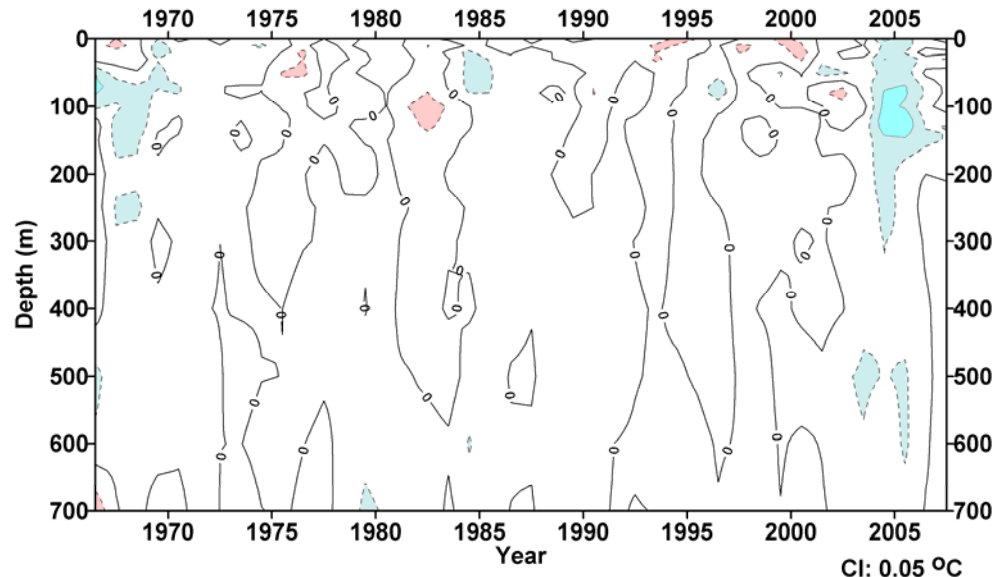
Performance Metric

- Compare XBT vs. CTD/bottle temperature anomaly means at standard depths, $4^{\circ} \times 2^{\circ}$ lat/lon boxes, 5-year running means (similar to Gouretski and Koltermann, 2007).
- Relatively easy to compute, understand.
- Limited metric: Only works in time periods, areas where there are sufficient data (what is sufficient data?).
- Can also compare temperature bins, latitude bins (see Gouretski and Reseghetti).

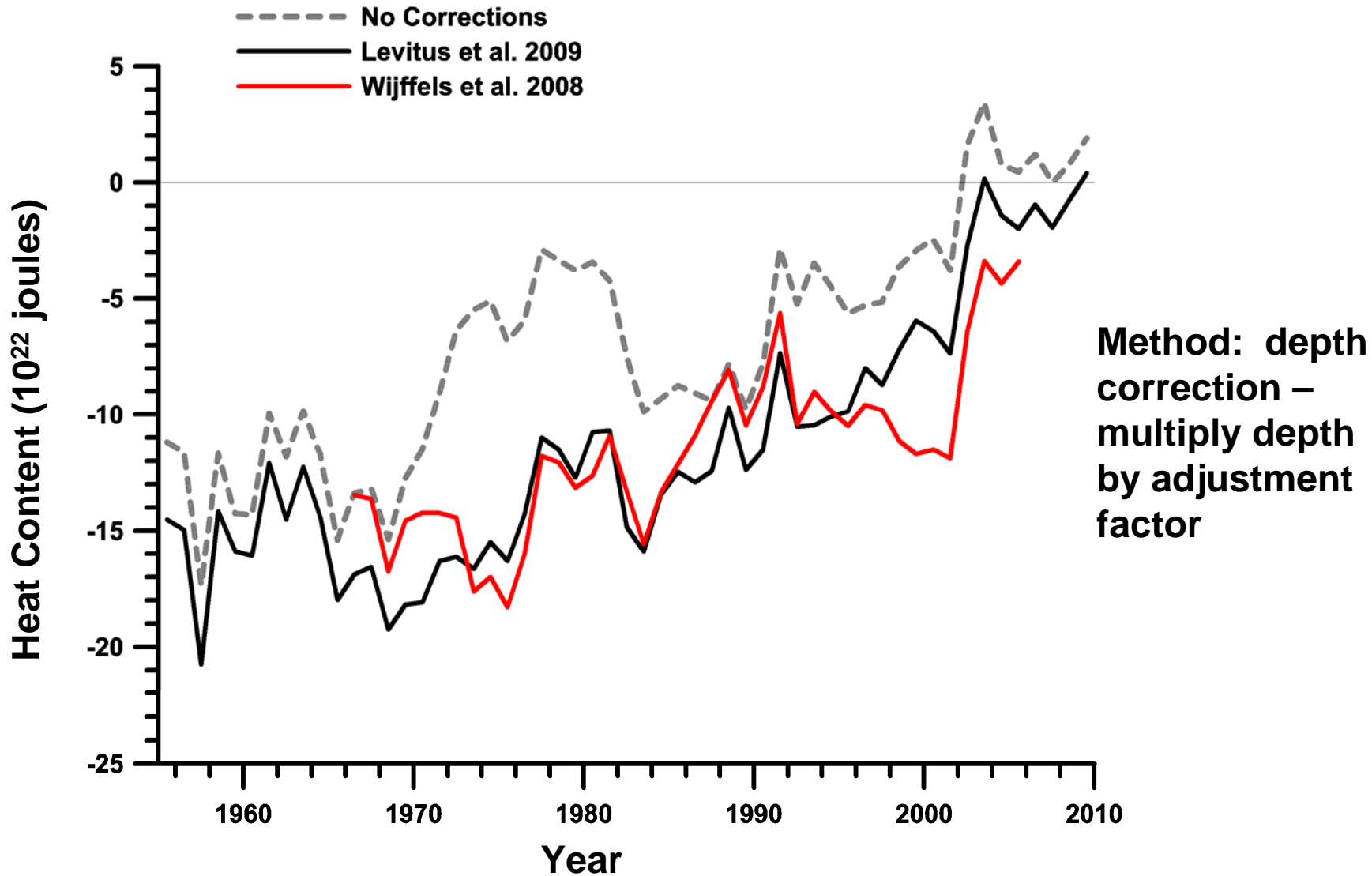
XBT minus CTD temperature means **Red=positive**, **Blue=Negative**



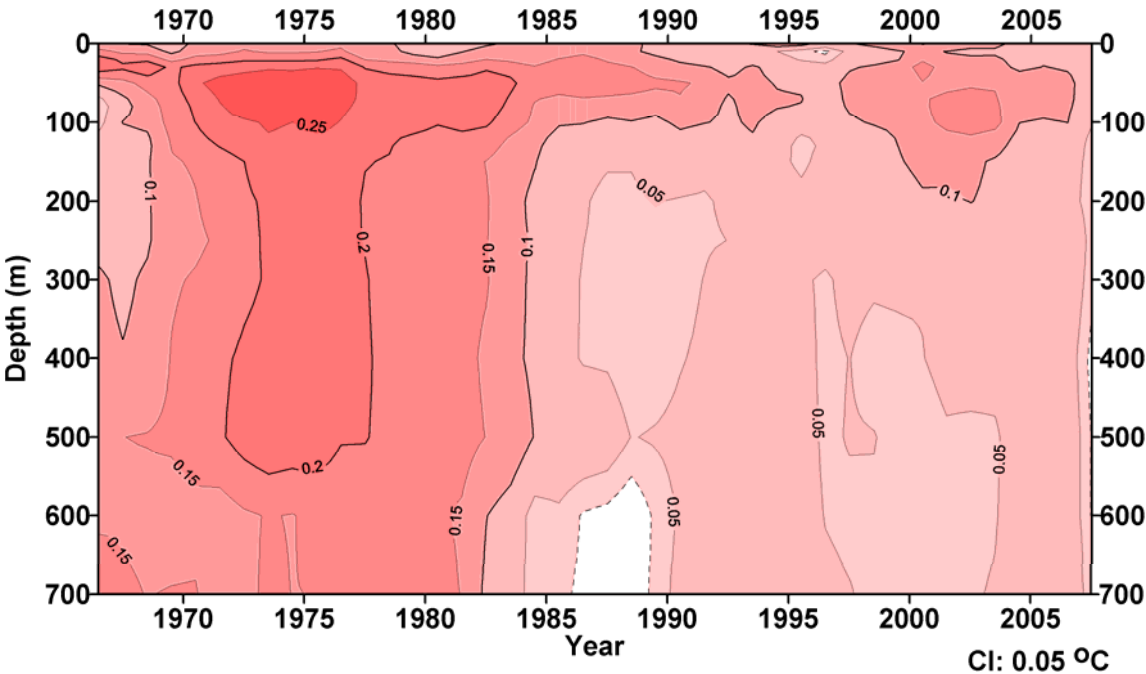
Initial XBT bias vs. CTD/Bottle warm everywhere, time/depth variant. This is how variable bias was first identified (Gouretski and Koltermann, 2007)



Levitus et al., 2009
simply subtracts bias from each standard level. Since comparison is run on subset of XBT, no guarantee it will work globally.

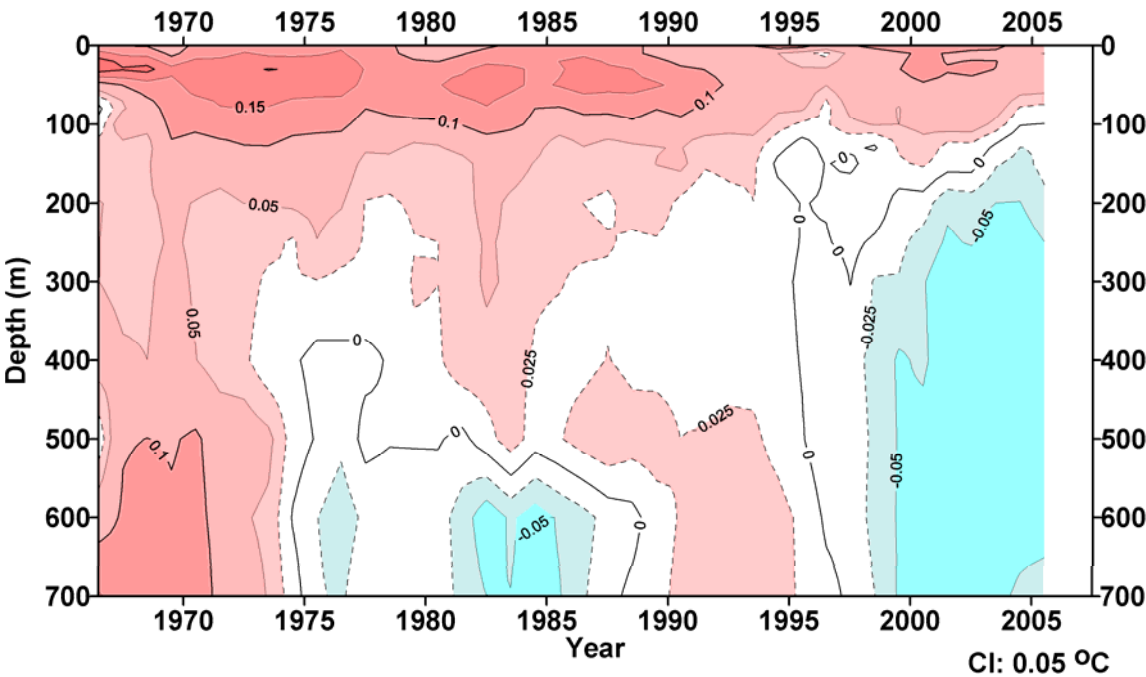


Integrated Ocean Heat Content Anomaly 0-700 m
Wijffels et al. 2009 corrections



**XBT minus CTD
temperature means**

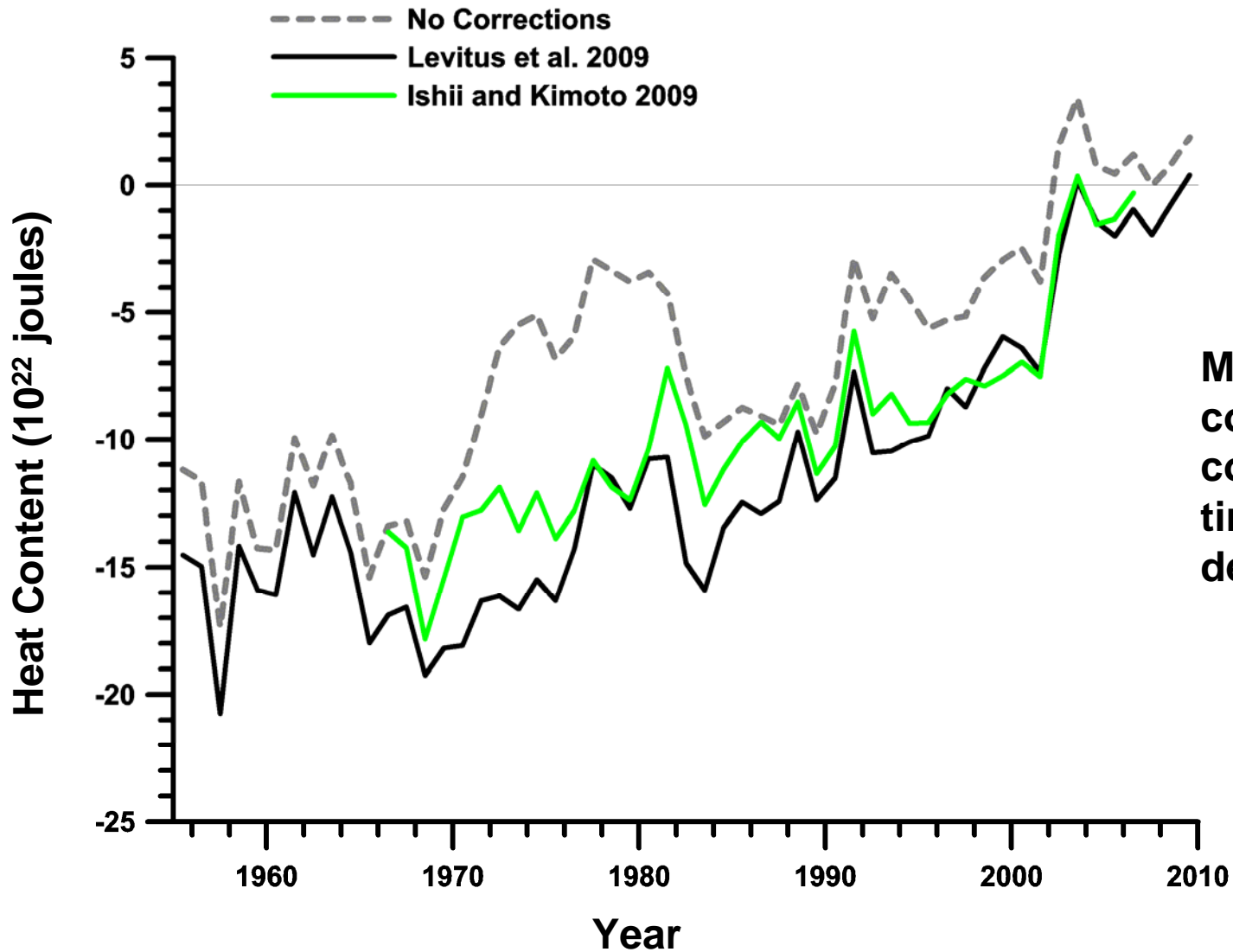
No XBT Corrections



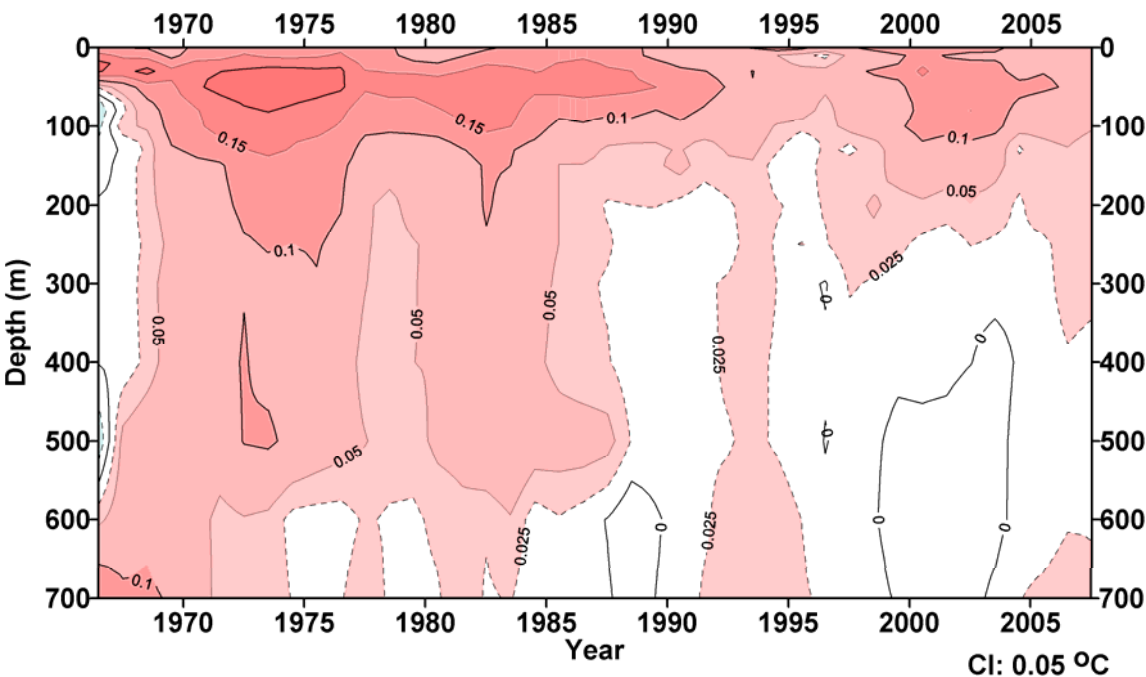
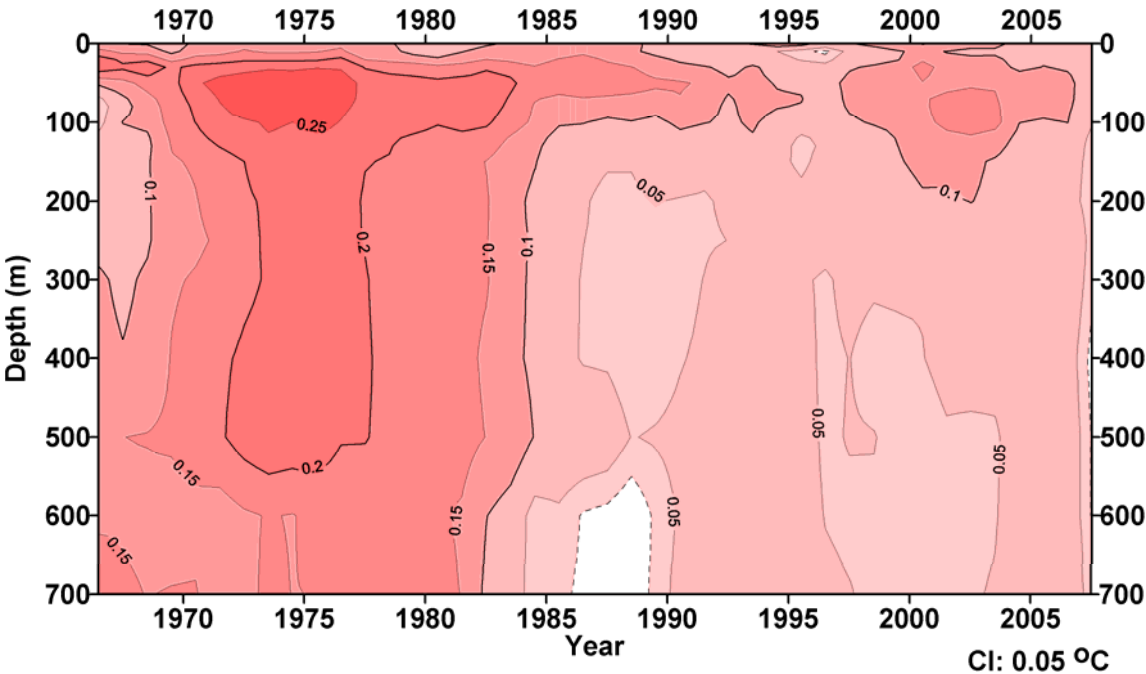
**XBT minus CTD
temperature means**

**Wijffels et al. 2008
corrections applied**

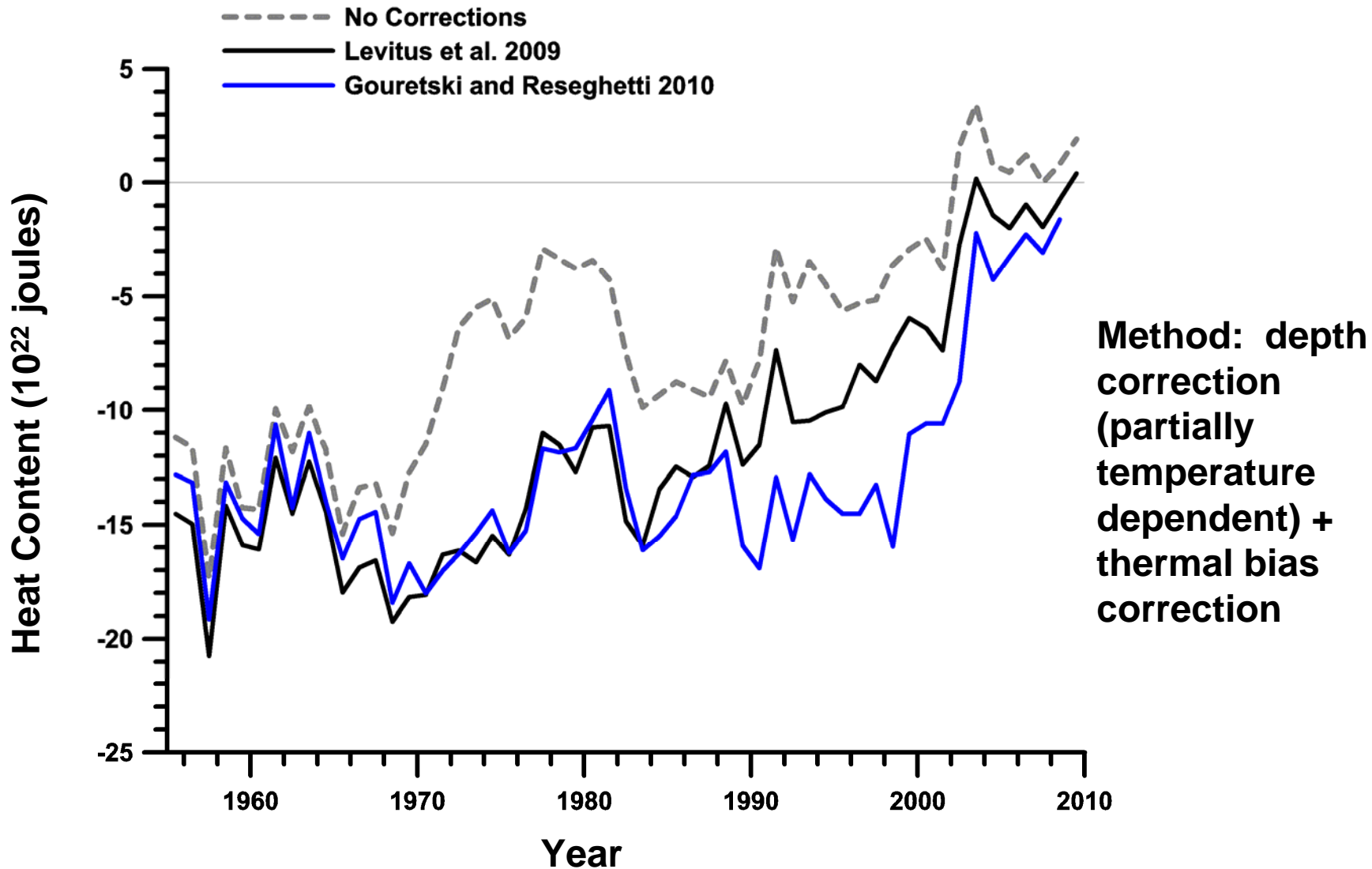
Red=positive, Blue=Negative



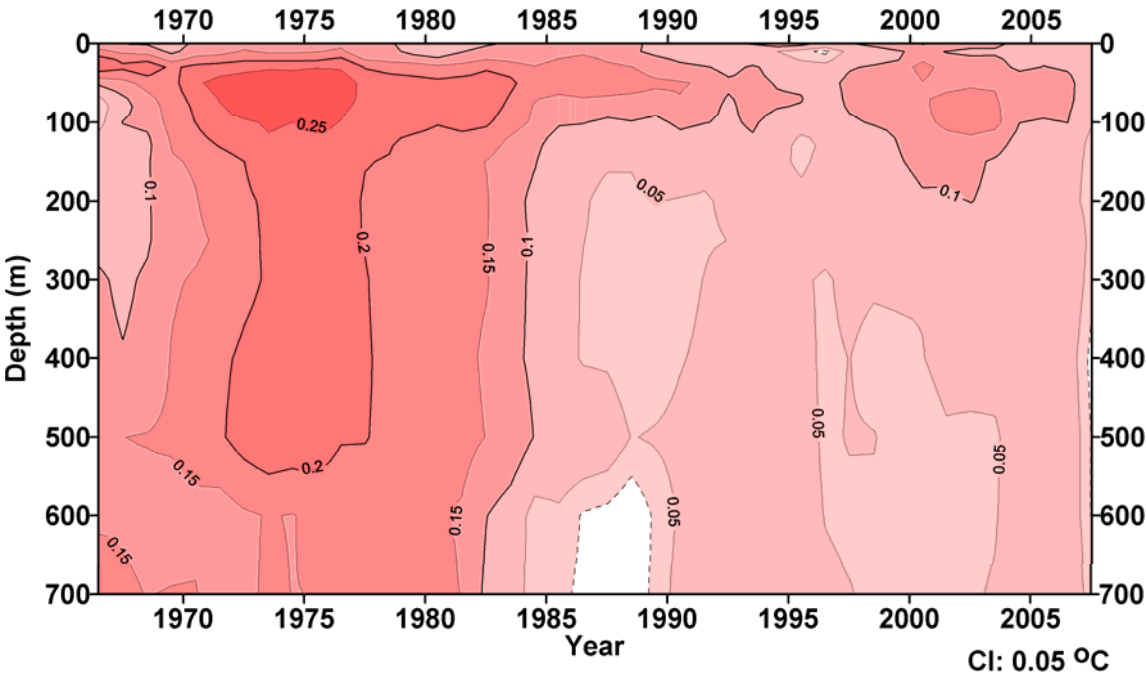
Integrated Ocean Heat Content Anomaly 0-700 m
Ishii and Kimoto, 2009 corrections



Red=positive, Blue=Negative

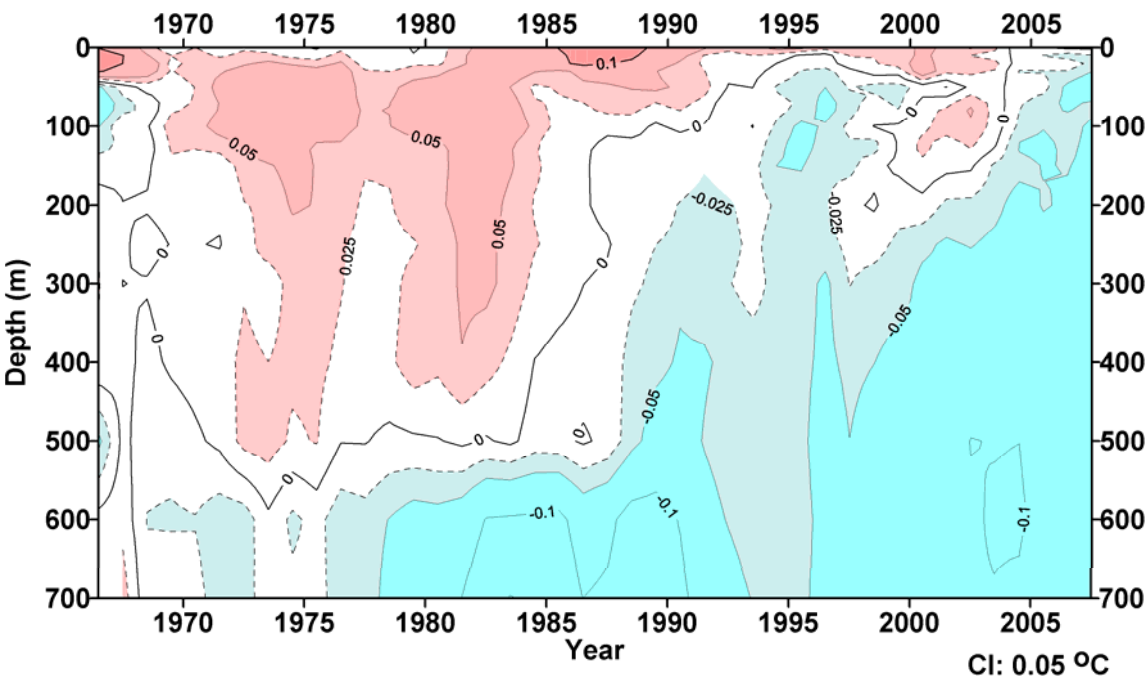


Integrated Ocean Heat Content Anomaly 0-700 m
Gouretski and Reseghetti, 2010 corrections



**XBT minus CTD
temperature means**

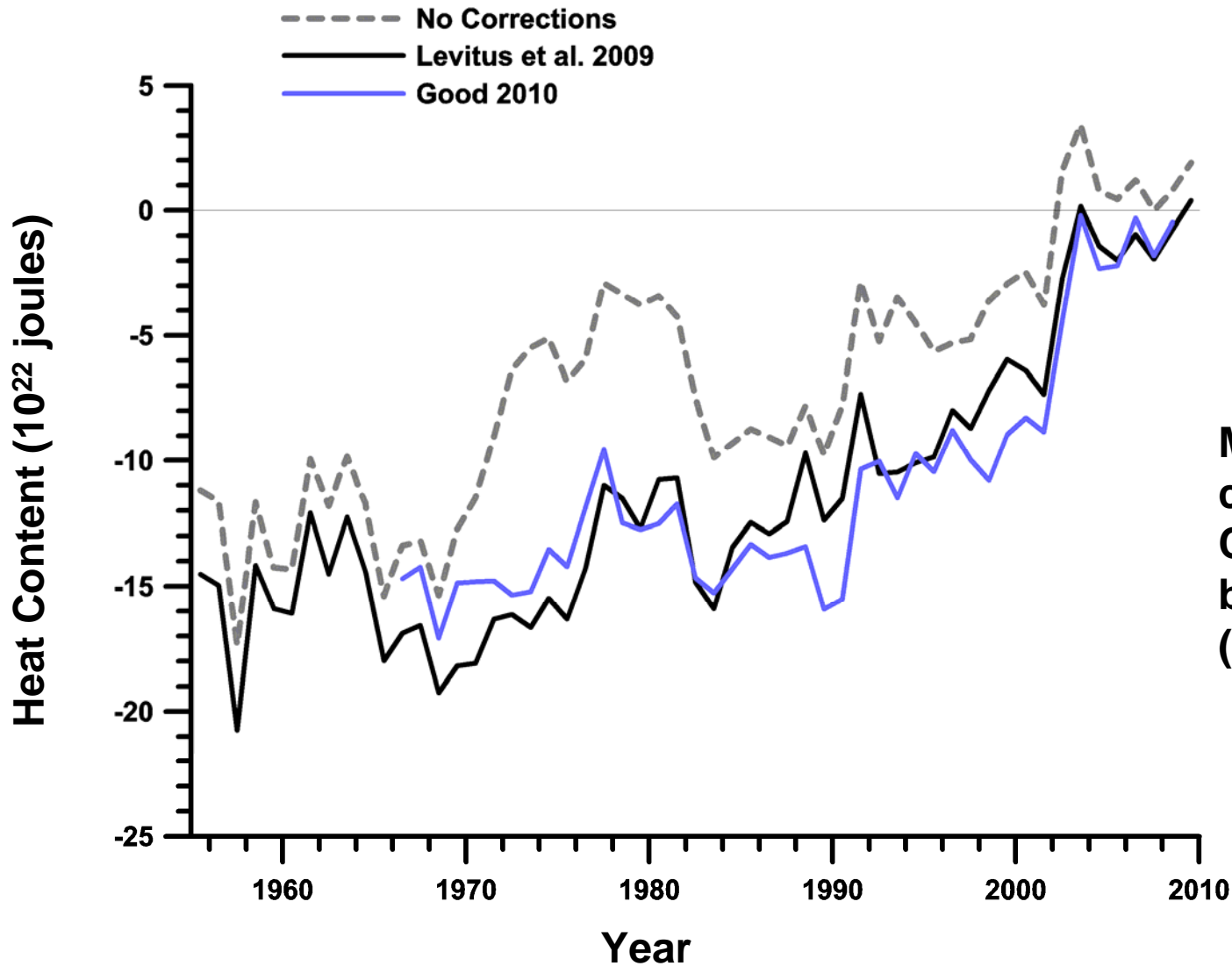
No XBT Corrections



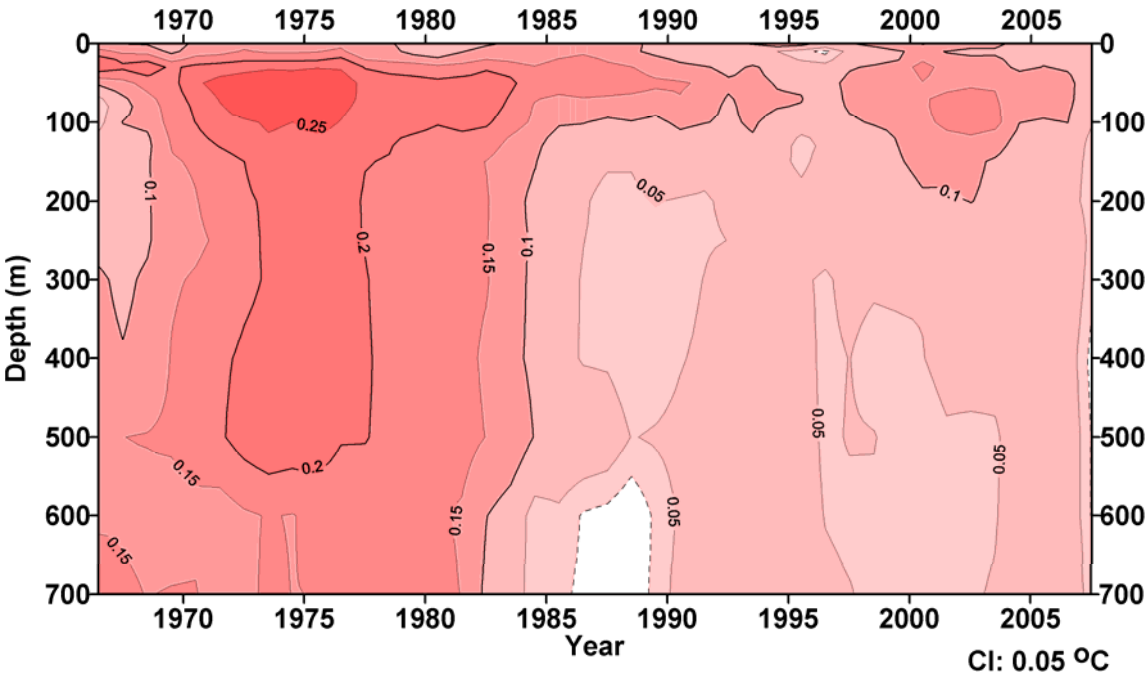
**XBT minus CTD
temperature means**

**Gouretski and
Reseghetti, 2010
corrections applied**

Red=positive, Blue=Negative

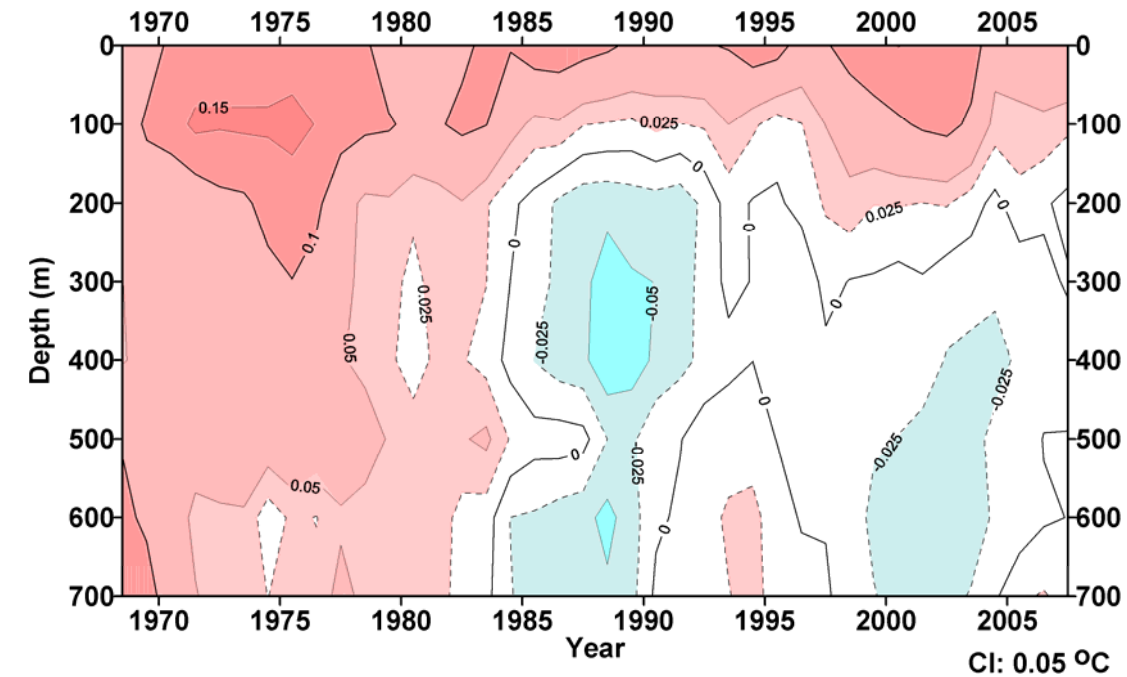


**Integrated Ocean Heat Content Anomaly 0-700 m
Good, 2010 corrections**



**XBT minus CTD
temperature means**

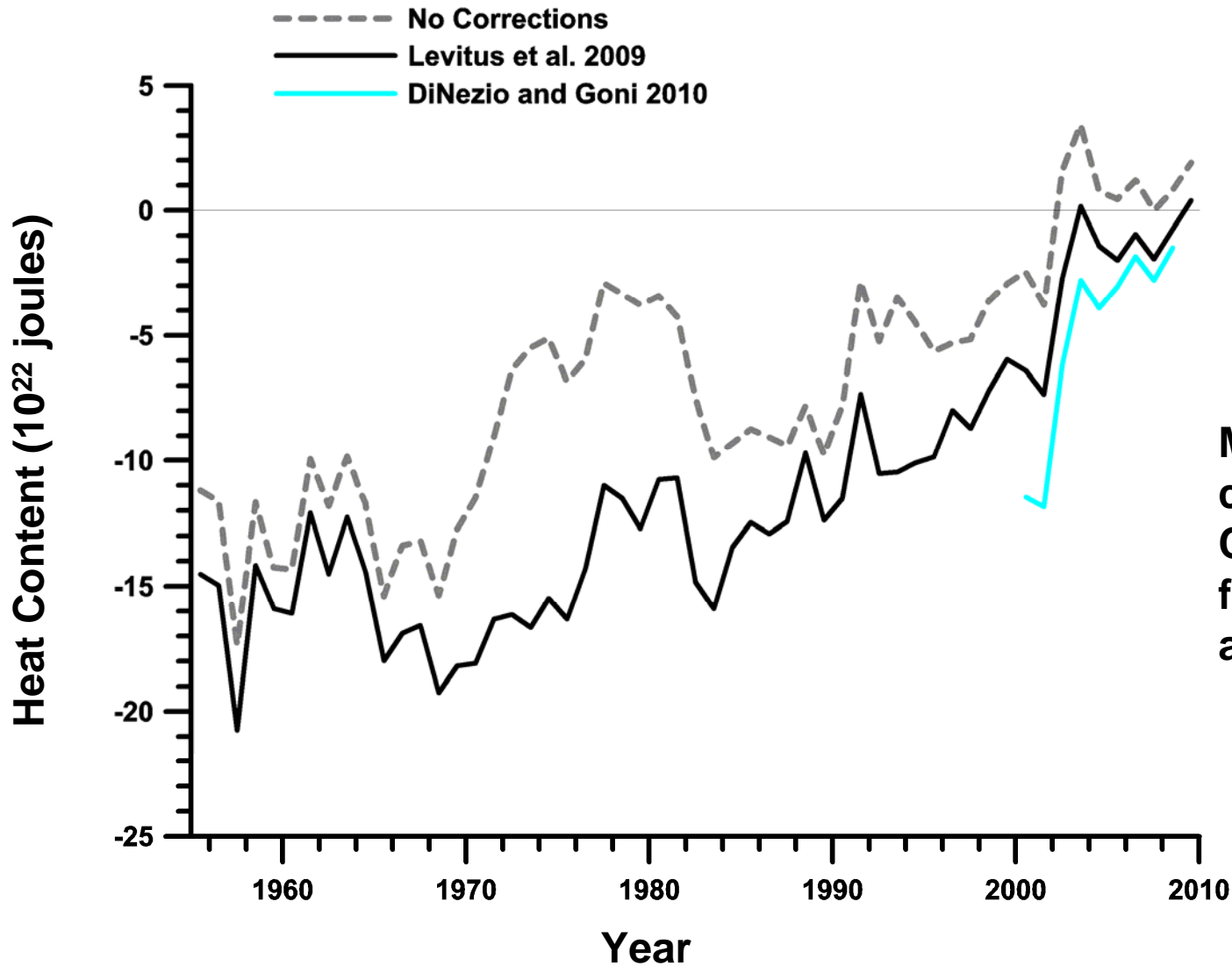
No XBT Corrections



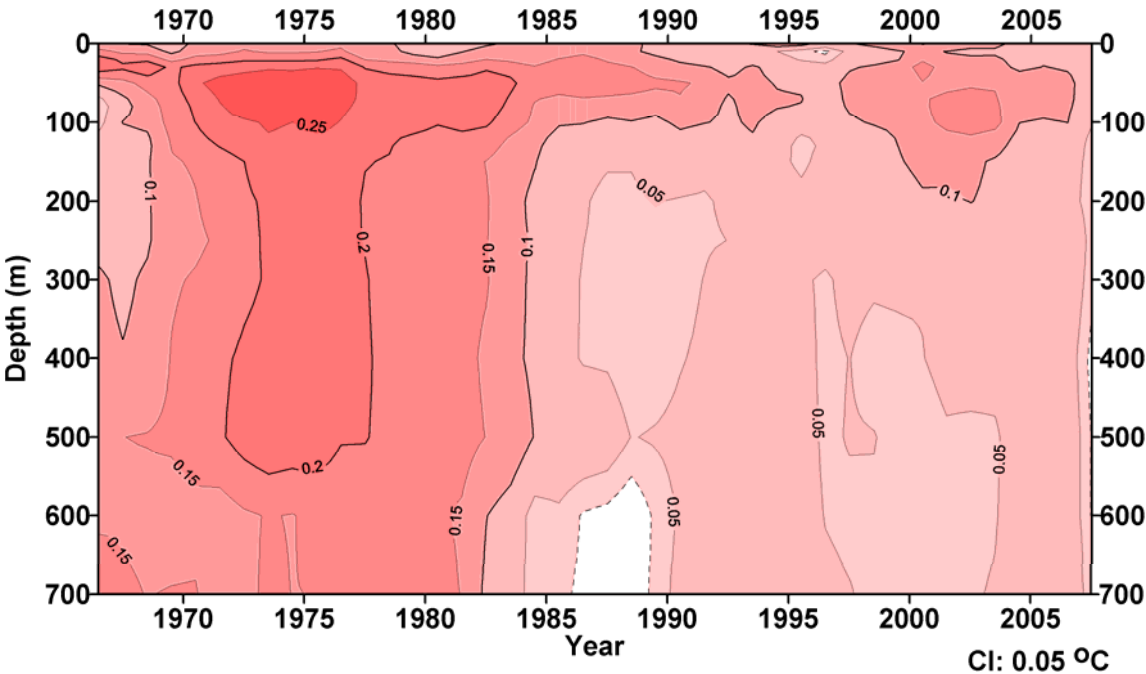
**XBT minus CTD
temperature means**

**Good, 2010
corrections applied**

Red=positive, Blue=Negative

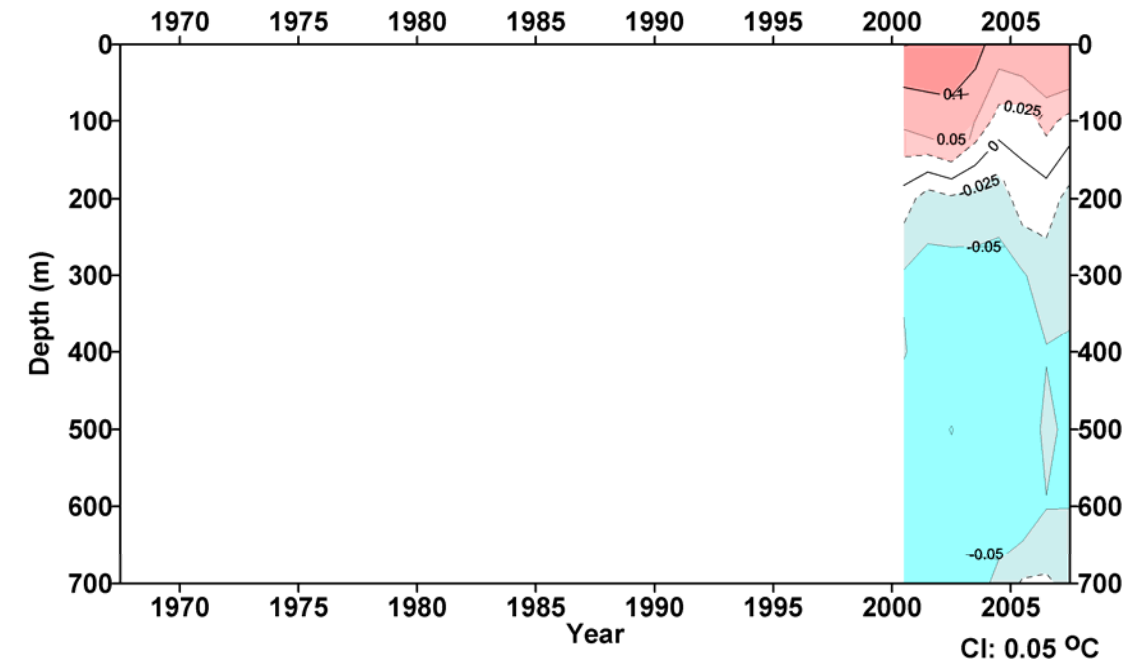


Integrated Ocean Heat Content Anomaly 0-700 m
DiNezio and Goni, 2010 corrections



**XBT minus CTD
temperature means**

No XBT Corrections

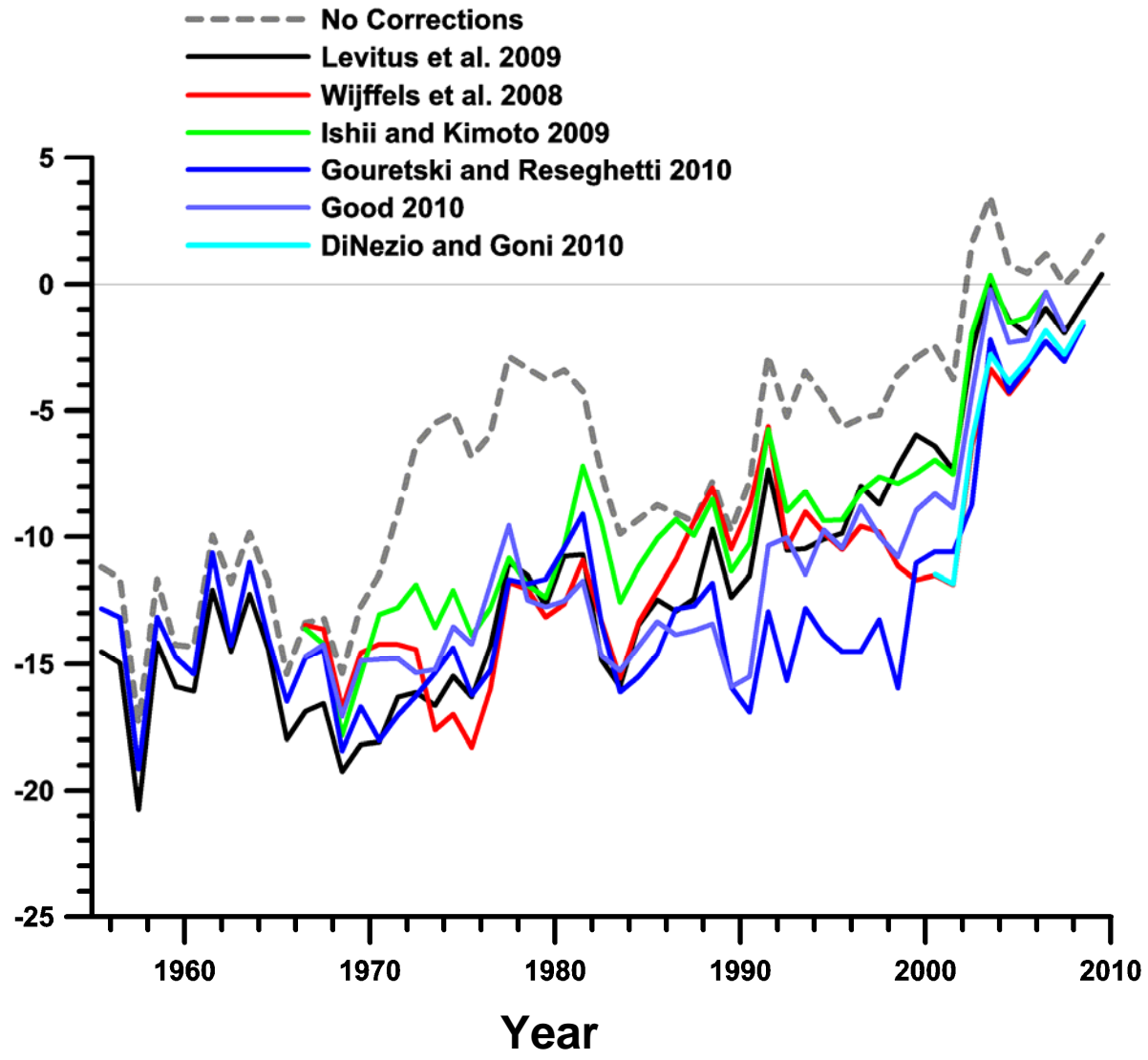


**XBT minus CTD
temperature means**

**DiNezio and Goni,
2010 corrections
applied**

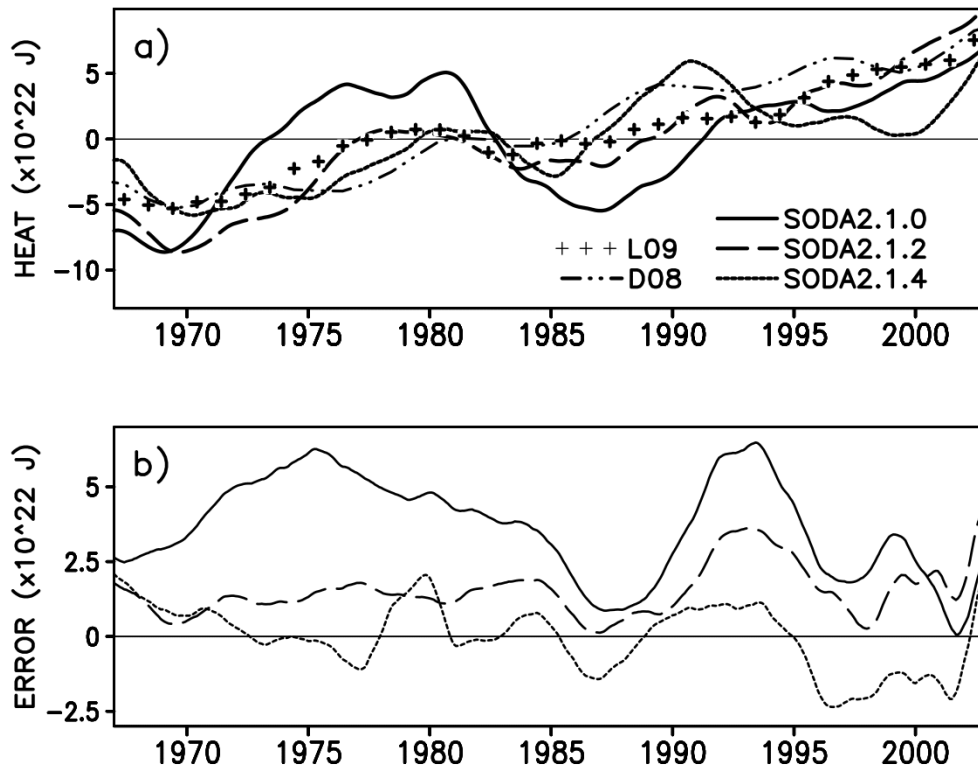
Red=positive, Blue=Negative

Heat Content (10^{22} joules)



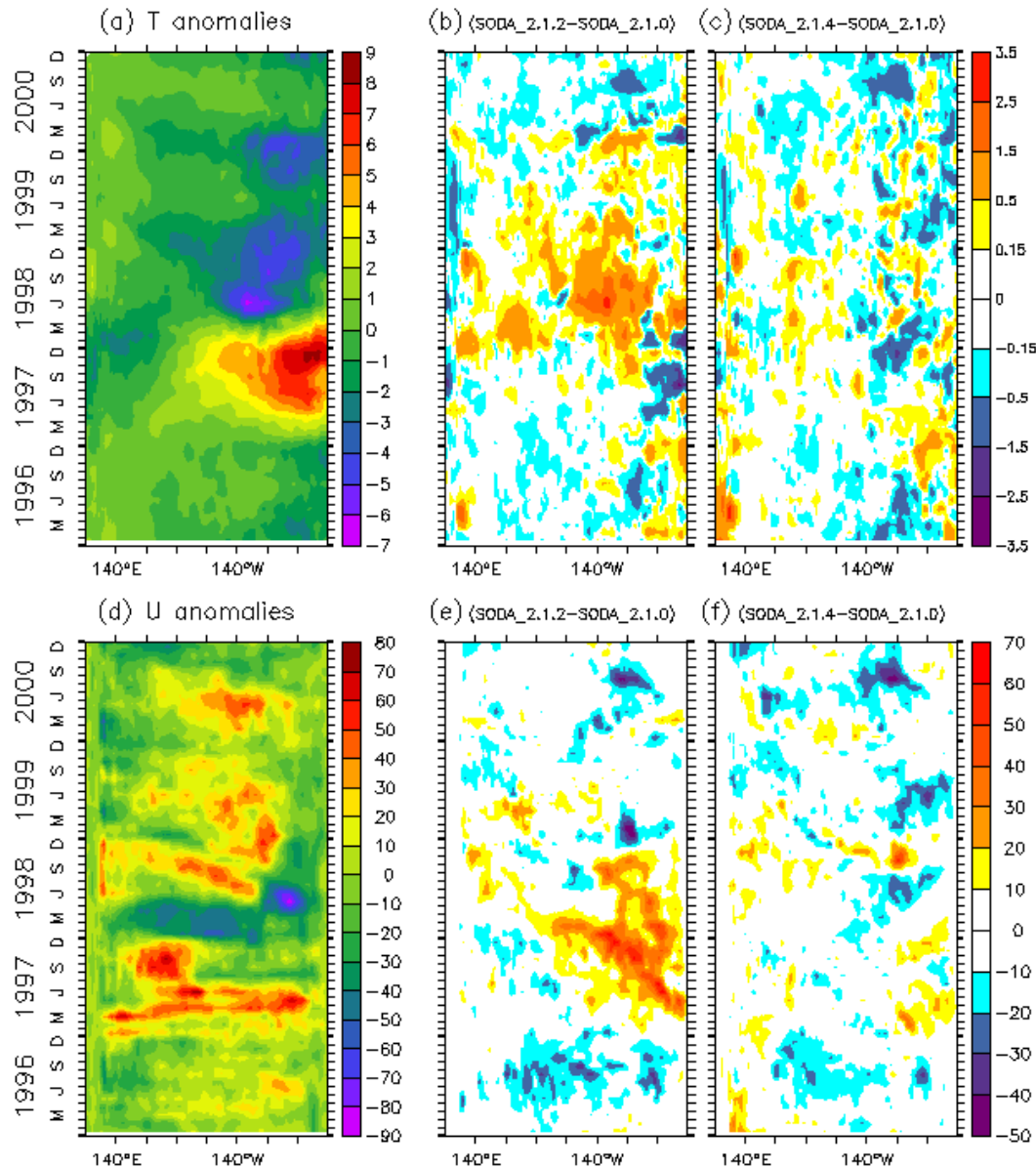
Integrated Ocean Heat Content Anomaly 0-700 m

How do XBT corrections affect assimilation models?



Examined in submitted Journal of Climate paper: "Impact of Bathythermograph Temperature Bias Models on an Ocean Reanalysis", Giese *et al.*

XBT corrections :Wijffels *et al.* (2008, W08) , Levitus *et al.* (2009, L09) significantly reduce errors in heat content in SODA model.



Giese et al. continued:

Instant impact of corrections can be large. 1997/98 El Niño/La Niña temperatures and currents changed significantly

rms error for current speed* between ADCP and

| | |
|-----------------|------------------------|
| Uncorrected run | 40.7 cms^{-2} |
| L09 run | 30.8 cms^{-2} |
| W08 run | 48.4 cms^{-2} |

*5-day average zonal current at 50 m

Conclusions

- **Many XBT corrections, all improve heat content calculations over uncorrected data.**
- **Corrections are not consistent with each other, causing inconsistencies in heat content calculations.**
- **Not new conclusions (Lyman *et al.* 2010)**

WHAT TO DO ABOUT IT?

- **There is a need to decide on a recommended method for XBT correction.**
- **Cannot force researchers to use one method. However, researchers can be encouraged to present results (or alternate results as the case may be) using recommended corrections.**
- **Make XBT data readily available with corrections. Make sure these data are updated regularly as XBTs are added to global database**

Criteria for Recommended XBT correction method

- **Should be able to successfully meet a performance criteria: such as being able correct 95% of all depths to within 0.025°C vs. CTD in statistical tests.**
- **Should be relatively easy to implement, fully documented, extendable into future.**
- **Should cover all XBT types, all observation depths, all time periods.**

XBT_bias - Mozilla Firefox

File Edit View History Bookmarks Tools Help

XBT_bias

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XBT Bias Depth and Temperature Corrections

For any questions about this page, please e-mail [OCLhelp](#) desk

Gouretski and Koltermann (2007) shows statistics from Expendable Bathothermograph (XBT) vs. Conductivity-Temperature-Depth (CTD)/reversing thermometer instrument comparisons which reveal a warm bias in XBT temperatures. This bias varies over time and over depth. The bias may be due to both errors in the calculation of depth and in measurement of the temperature. An important deviation from the majority of existing correction schemes is that depth correction varies with depth.

A NOAA sponsored [XBT Fall Rate Workshop](#) was held in Miami, FL, March 10-12, 2008 to discuss this problem. Results of that meeting came to no conclusion as to the best way to correct the bias.

A second [XBT Fall Rate Workshop](#) will be held August 25-27, 2010 in Hamburg, Germany.

A number of papers with estimates of corrections have been published or submitted to scientific journals. The corrections proposed in some of these works are provided here to facilitate intercomparison by the scientific community. The corrections proposed by Gouretski and Koltermann (2007) are not included here, as they have been superseded by the corrections proposed by Gouretski and Reseghetti (2010).

Gouretski, V. V., and K. P. Koltermann, 2007, How much is the ocean really warming? *Geophysical Research Letters*, L01610, doi:10.1029/2006GL027834

Wijffels, S. E., J. Willis, C. M. Domingues, P. Barker, N.J. White, A. Gronell, K. Ridgway, J. A. Church, 2008, Changing expendable Bathothermograph Fall-rates and their Impact on Estimates of Thermosteric Sea Level Rise, *Journal of Climate*, in press. Wijffels *et al.* depth corrections: [Table 1](#) (in situ comparison), [Table 2](#) (in situ-altimeter comparison).

Ishii, M. and M. Kimoto, 2008, Reevaluation of Historical Ocean Heat Content Variations With An XBT depth bias Correction. *J. Oceanogr.* (submitted). [Ishii and Kimoto depth corrections](#).

Levitus, S, J. Antonov, T. Boyer, Global ocean heat content 1955-2007 in light of recently revealed instrumentation problems (in preparation). [Levitus et al. temperature corrections](#).

Gouretski, V. and F. Reseghetti, 2010, On depth and temperature biases in bathythermograph data: Development of a new correction scheme based on analysis of a global ocean database. *Deep-Sea Research I*, Vol. 57(6), pp.

US NODC XBT Bias Page

Currently: contains various XBT corrections methods and tables. Can Continue in this capacity

Future: Can contain information on recommended method, corrected XBT dataset (independent of GTSP, WOD) updated periodically (monthly?)

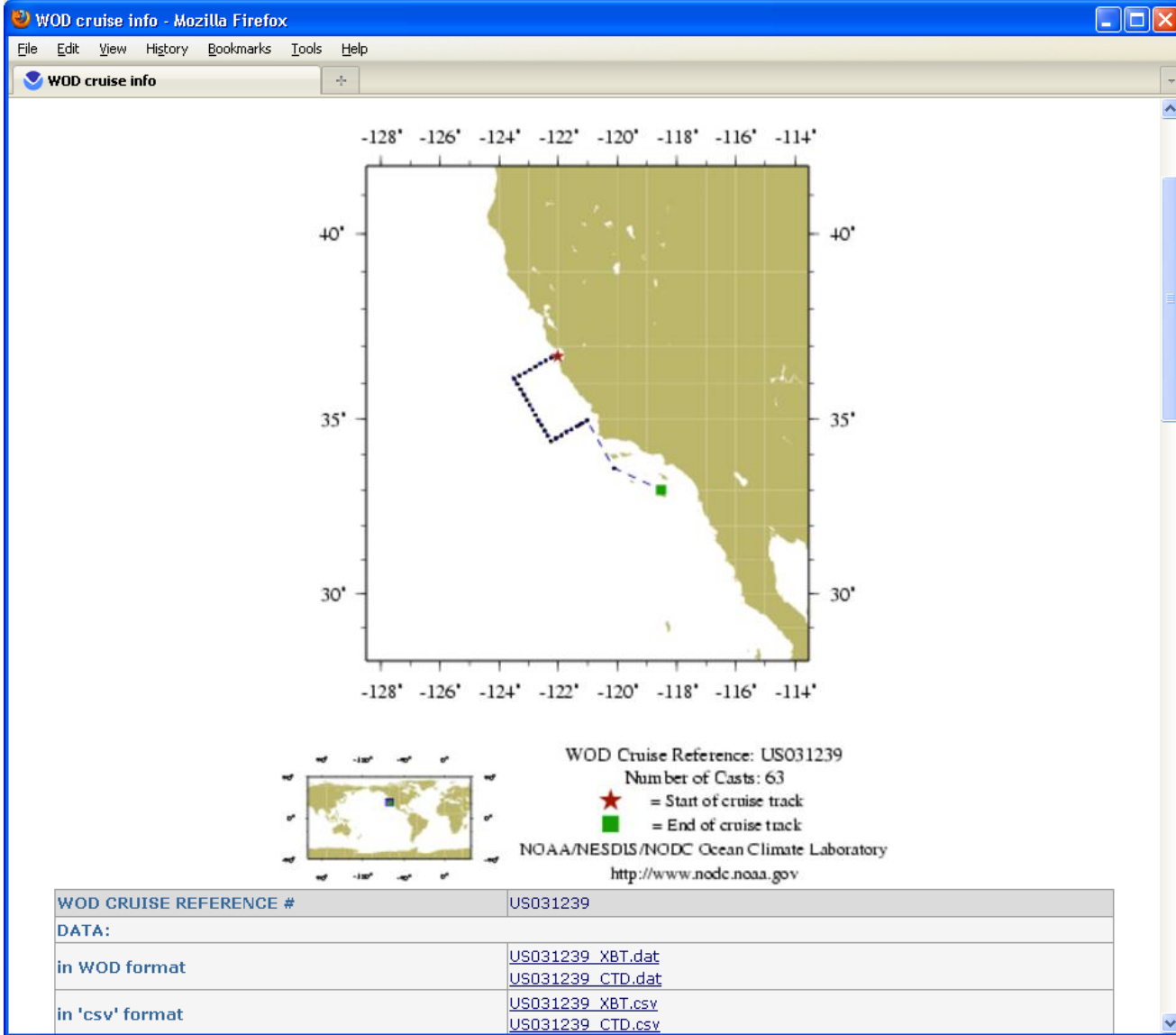
http://www.nodc.noaa.gov/OC5/XBT_BIAS/xbt_bias.html

NODC XBT Quality Tests Reference Table

- Deciding on one method does not mean the end to investigation
- XBT/CTD comparison test references and data can still be posted, downloaded.
- Very important to adjust recommended method (or change altogether) based on future knowledge.
- Nature of XBT correction, variability still changing.

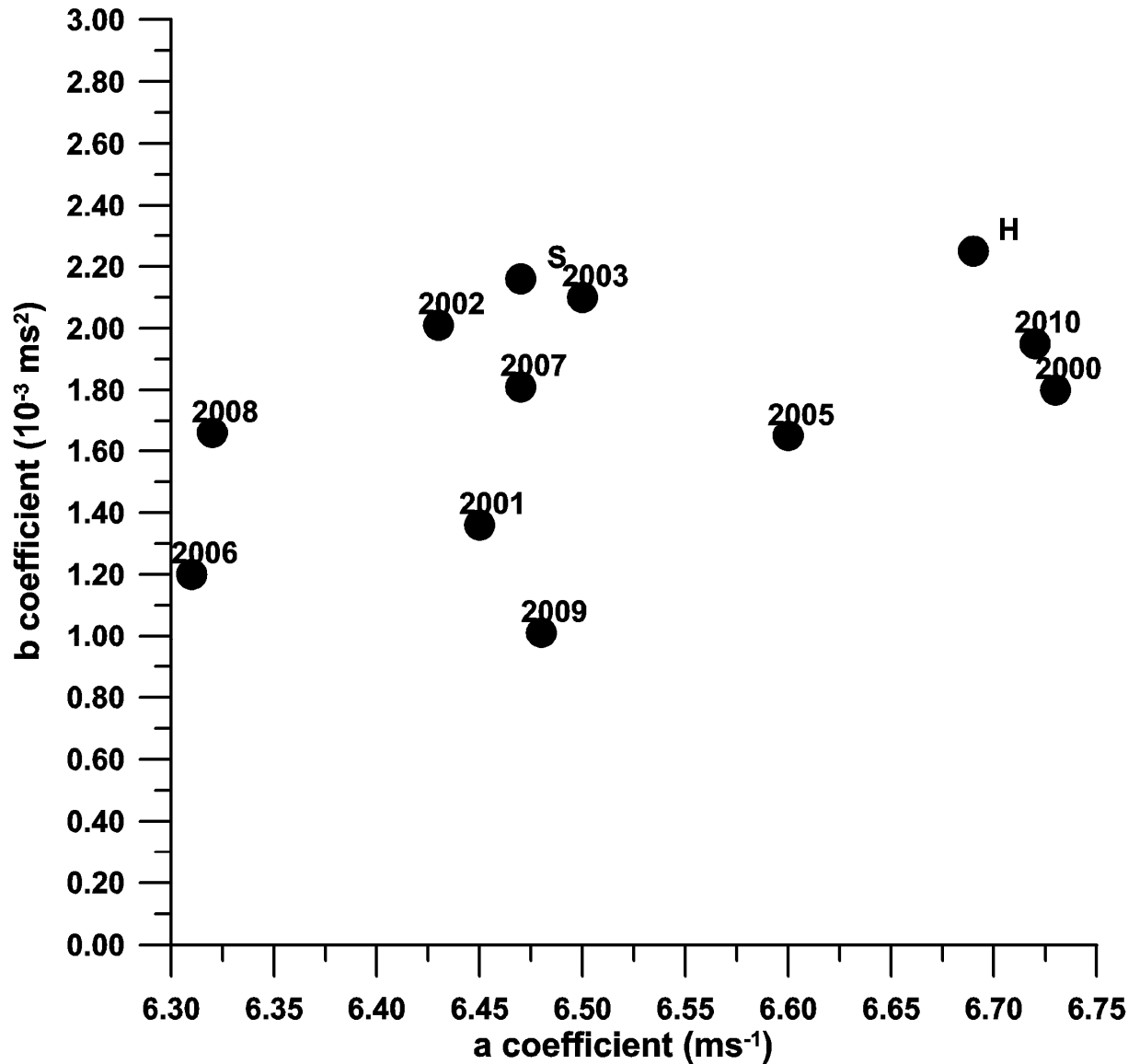
| Ref# | Author(s) | Year Published | Title | Publication | Depth Equation | Temperature |
|------|--|----------------|--|---|----------------|-------------|
| 1 | Steinhart J. S.; S. H. Hart | 1968 | Calibration curves for thermistors | Deep-Sea Research, 15, 497-503 | | |
| 2 | Denner W. W. <i>et al.</i> | 1971 | A modification of the expendable bathythermograph for thermal microstructure studies | Deep-Sea Research, 18, 375-378 | | |
| 3 | Flierl G. | 1974 | XBT-CTD intercomparison | In Instrument description and intercomparison report of "The MODE-I Intercomparison Group", 173 pp. | | |
| 4 | Welser Edward V. | 1974 | Comparison of XBT and STUP profiles and their use in determining acoustic intensity - loss | Marine Technology Society Journal, 8, 38-41 | | |
| 5 | Stegen Gilbert R.; Donald P. Delisi and Rudy C. Von Colln | 1975 | A portable; digital recording; expendable bathythermograph (XBT) system | Deep-Sea Research, 22, 447-453 | | |
| 6 | Joyce T., J. Dean M. McCartney, R. Millard D. Moller, A. Voorhis C. Dahm, D. Georgi | 1976 | Observations of the Antarctic Polar Front During FDRAKE 76: A Cruise Report | Technical Report, WHOI-76-74, 150 pp. | | |

http://www.nodc.noaa.gov/OC5/XBT_BIAS/xbt_bibliography.html



Possibility?:
 Future
 Calibrations of
 XBT corrections:
 cruises in **Pacific**
(NPS), **Atlantic**
(AOML), Indian,
 Southern Ocean
(CSIRO)

Dr. Collins Naval Postgraduate School, Monterey, CA. Student cruises XBT/CTD tests every year 1999-2010. 18 cruises available for research



Very preliminary results from NPS cruises. Variable drop rates 2000-2010, many very near Sippican (S) values, a few higher than Hanawa (H). Year of cruise next to each a,b coefficient pair.

Thank You