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

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July 8, 2011

[originally 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.

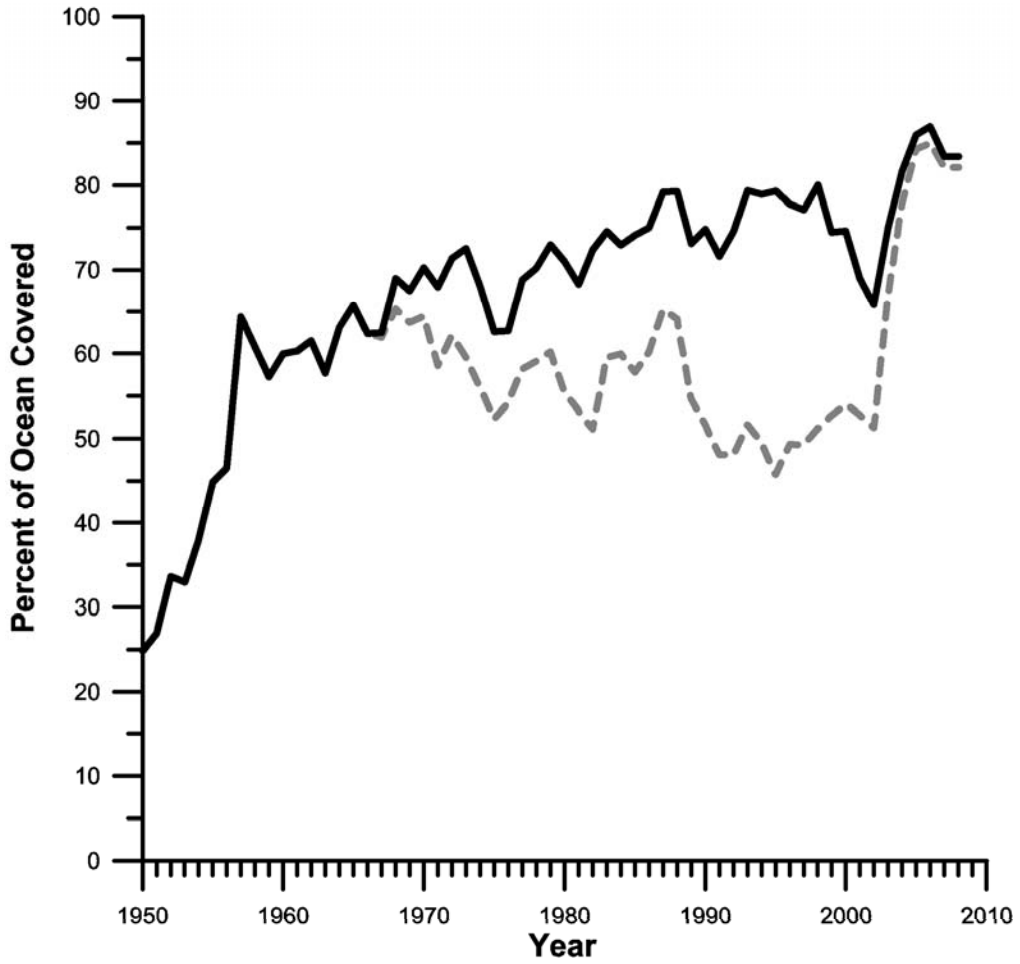
Main Questions

- 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.

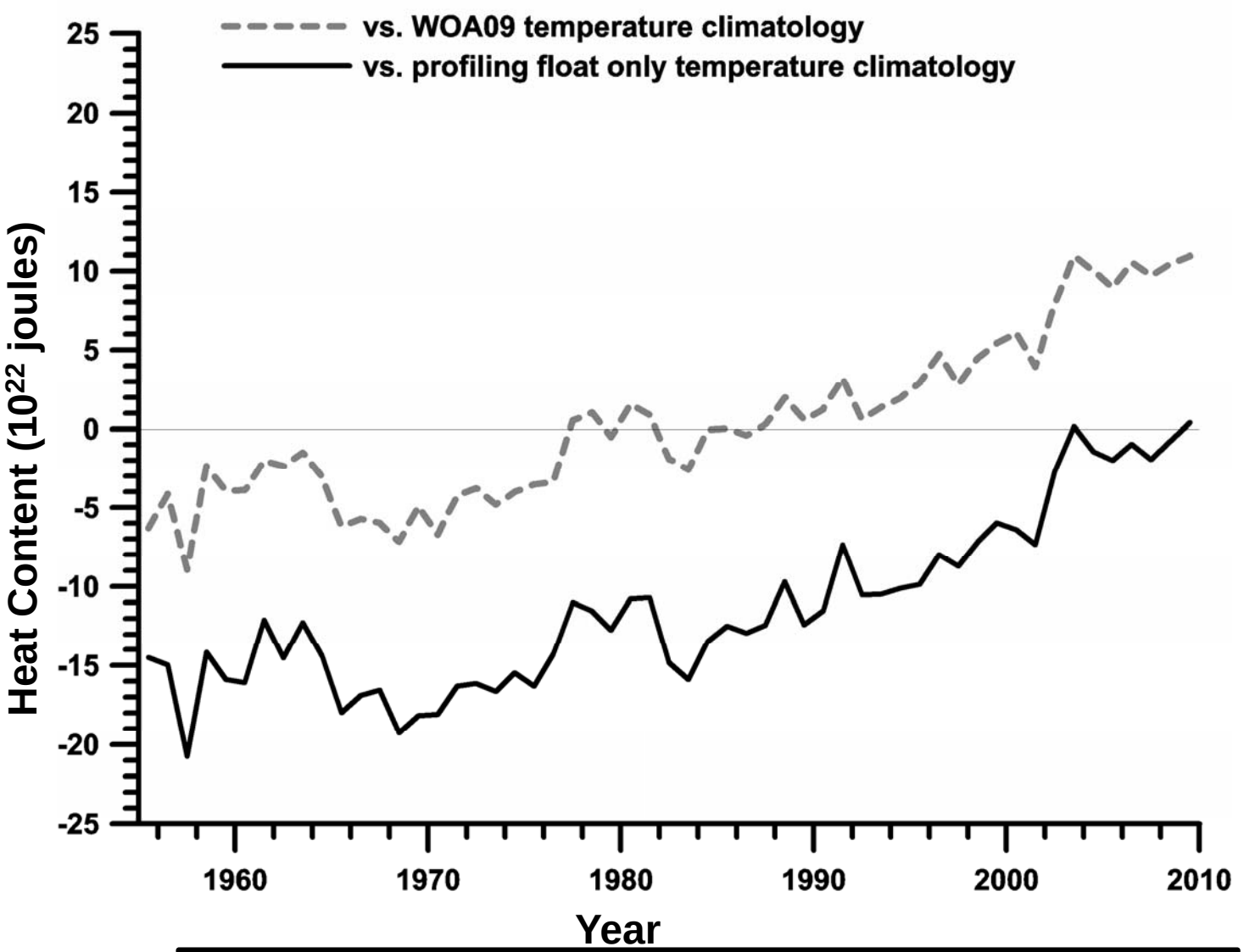
Comparison of XBT Correction Methods

- Use same data set (WOD) , same quality control

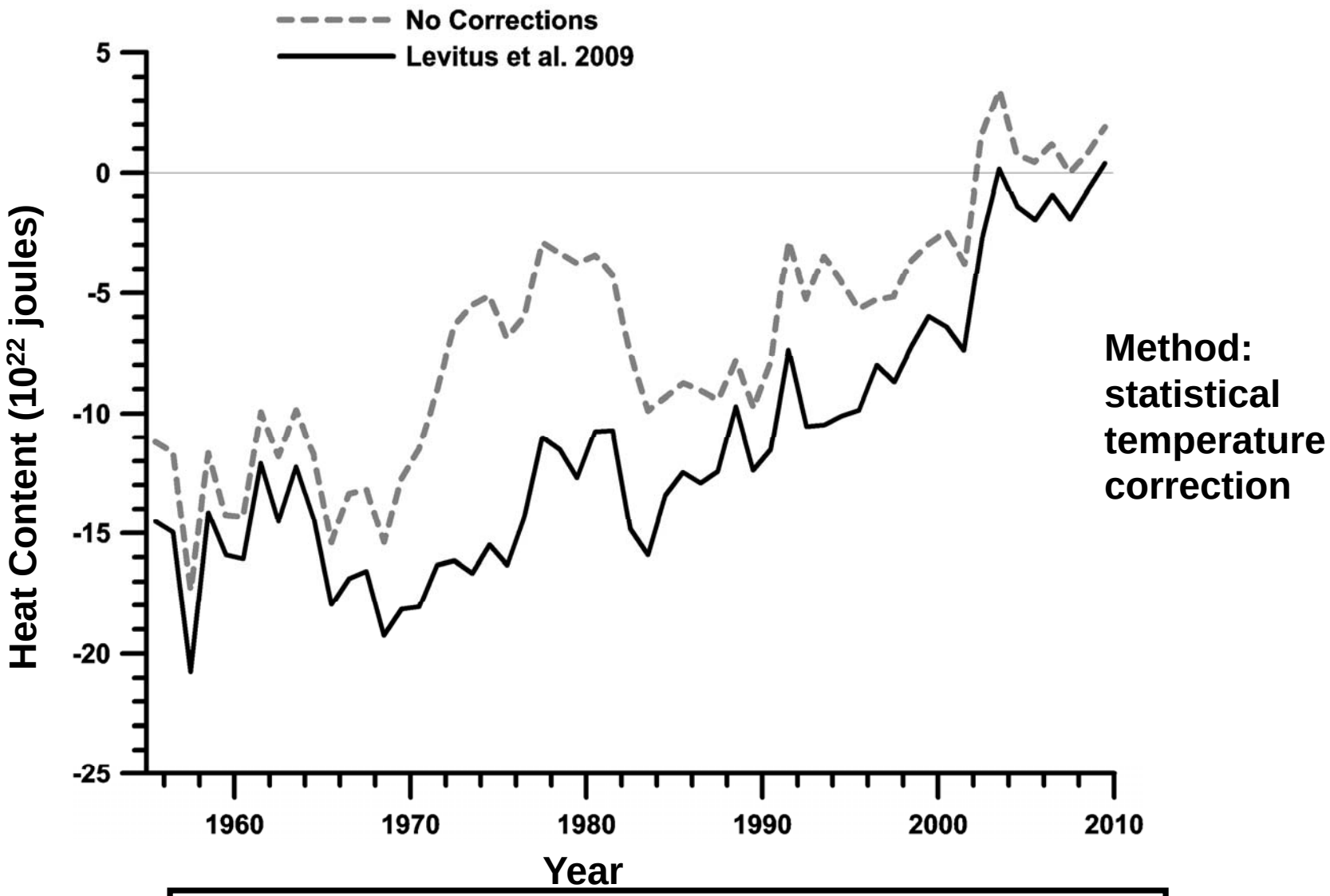
- Apply XBT corrections, calculate ocean heat content anomaly integrals using same method.

- 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

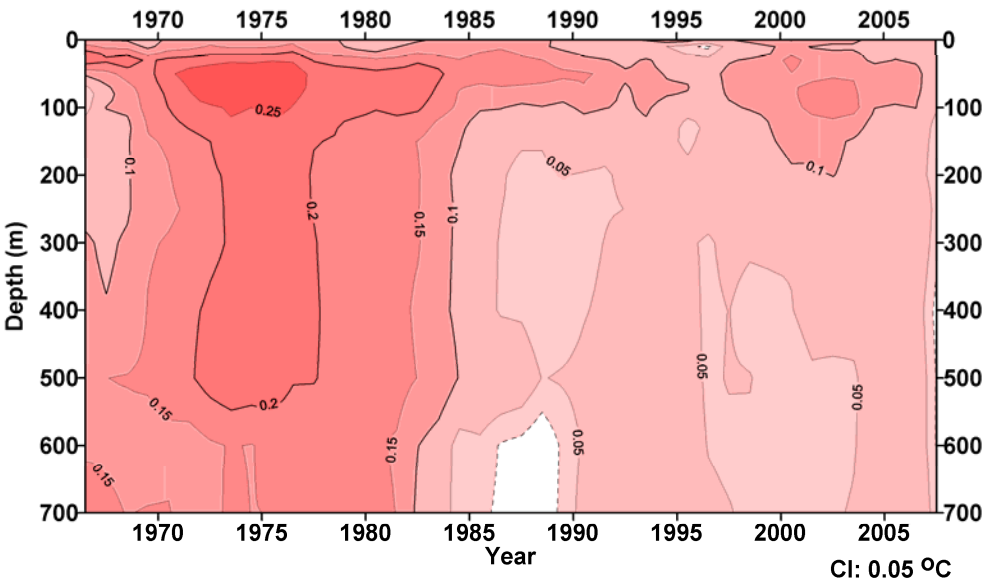
- **Compare XBT vs. CTD/bottle temperature anomaly means at standard depths, 4°X2° lat/lon boxes, 5-year running means (similar to Gouretski and Koltermann, 2007).**

- **Relatively easy to compute, understand.**

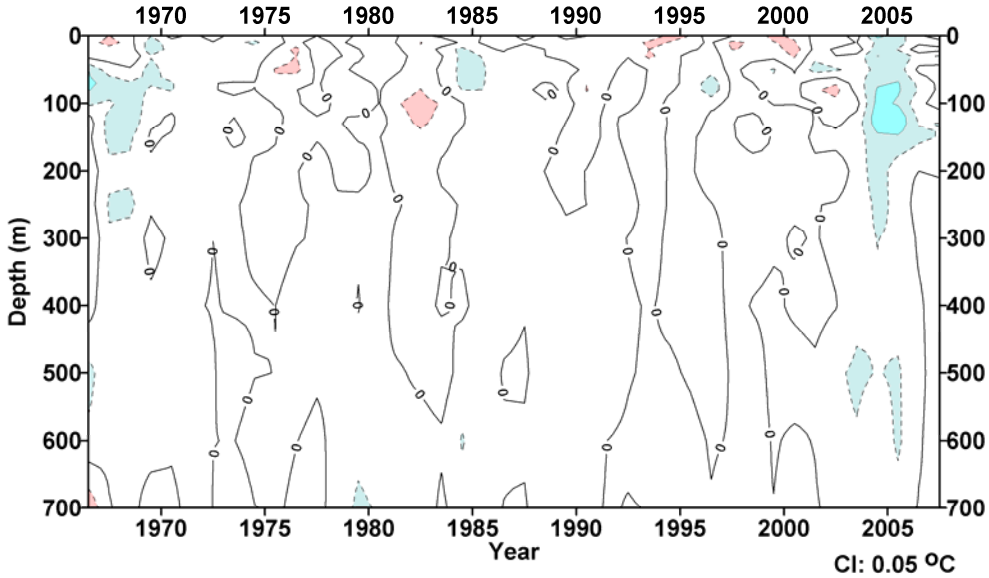
- **Limited metric: Only works in time periods, areas where there are sufficient data (what is sufficient data?).**

- **Can also compare temperature bins, latitude bins (see Gouretski and Reseghetti).**

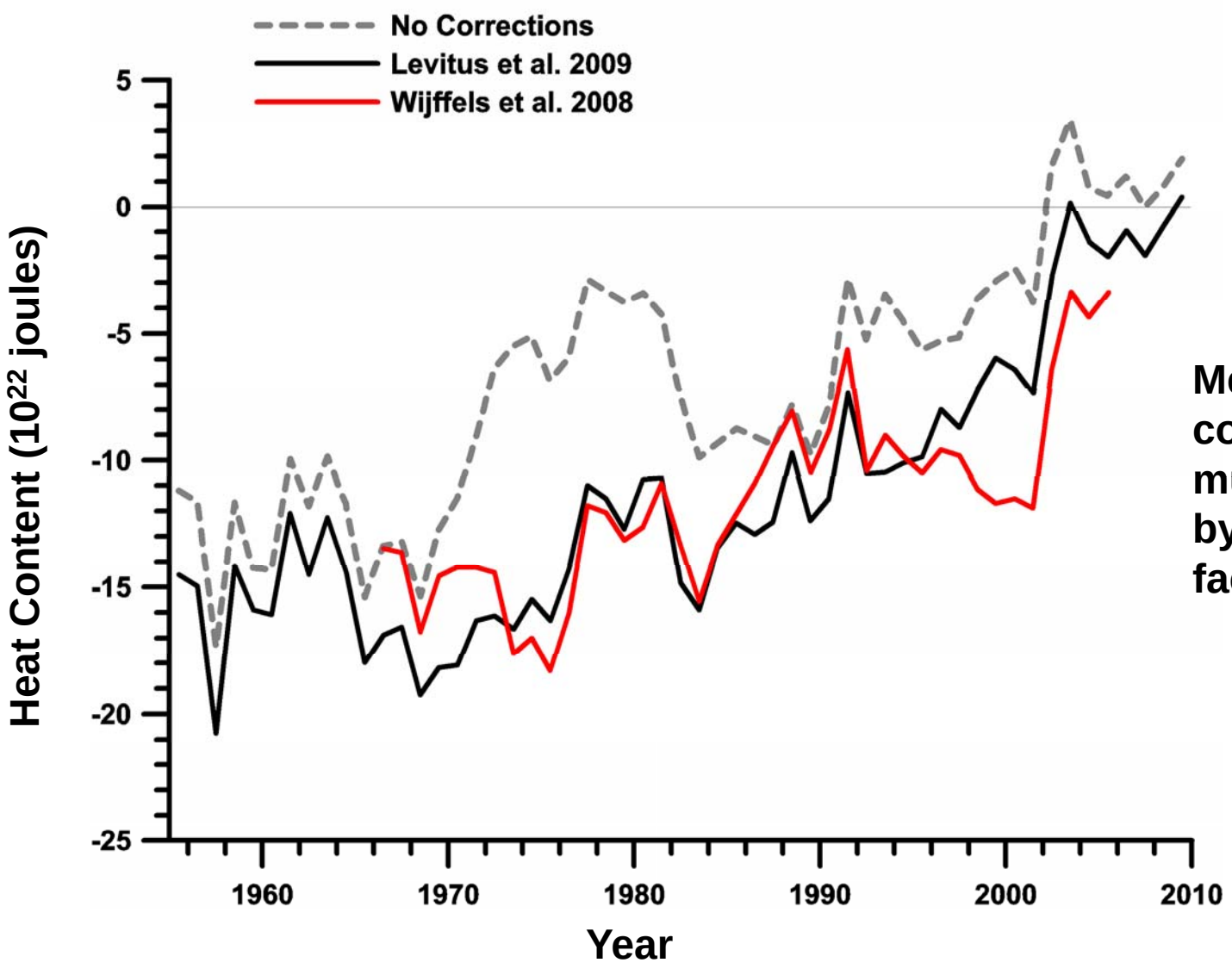
XBT minus CTD temperature means Red=positive, Blue=Negative



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

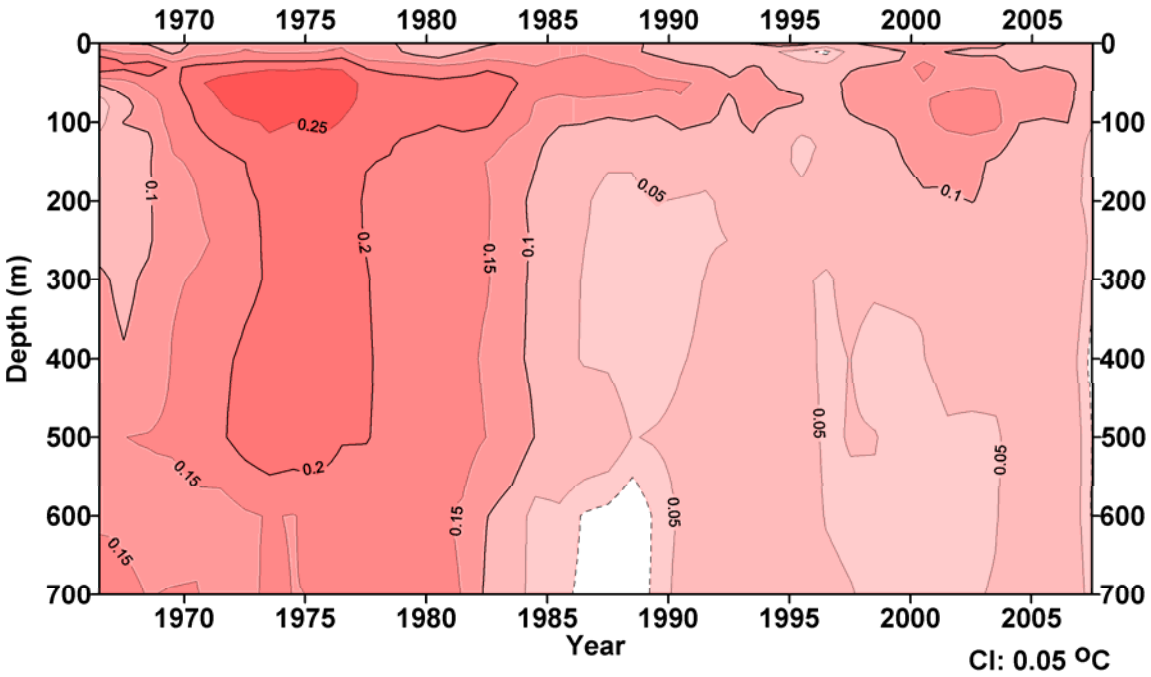


Levitus et al., 2009 simply subtracts bias from each standard level. Since comparison is run on subset of XBT, no guarantee it will work globally.



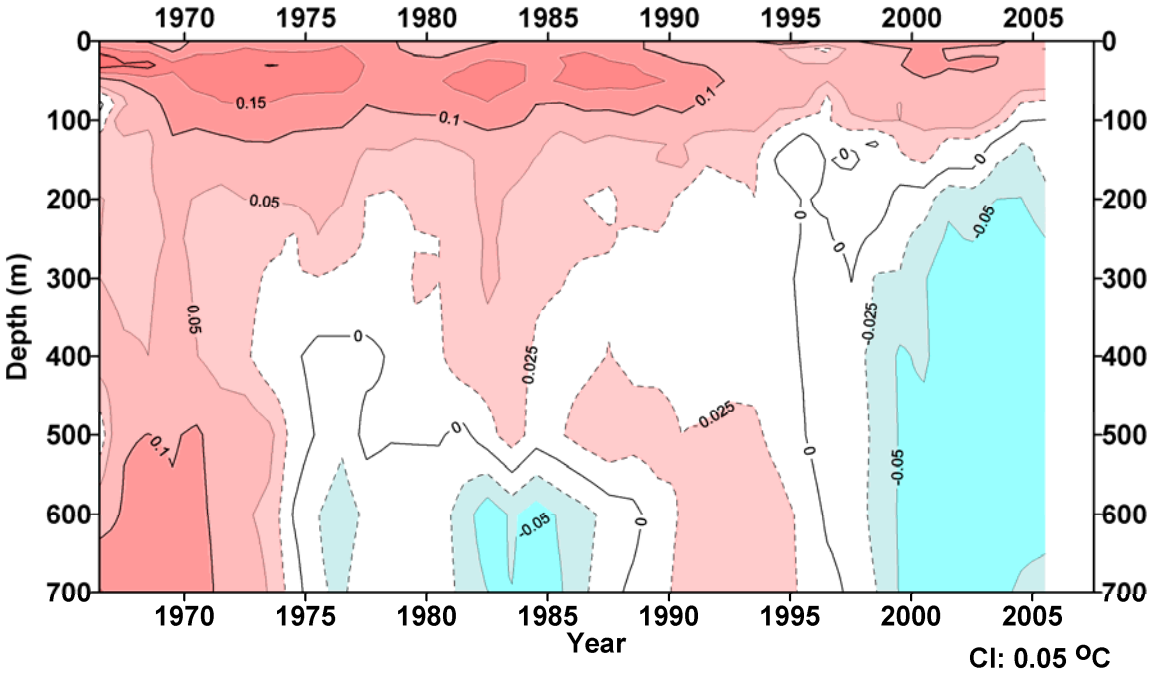
Method: depth correction – multiply depth by adjustment factor

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



XBT minus CTD temperature means

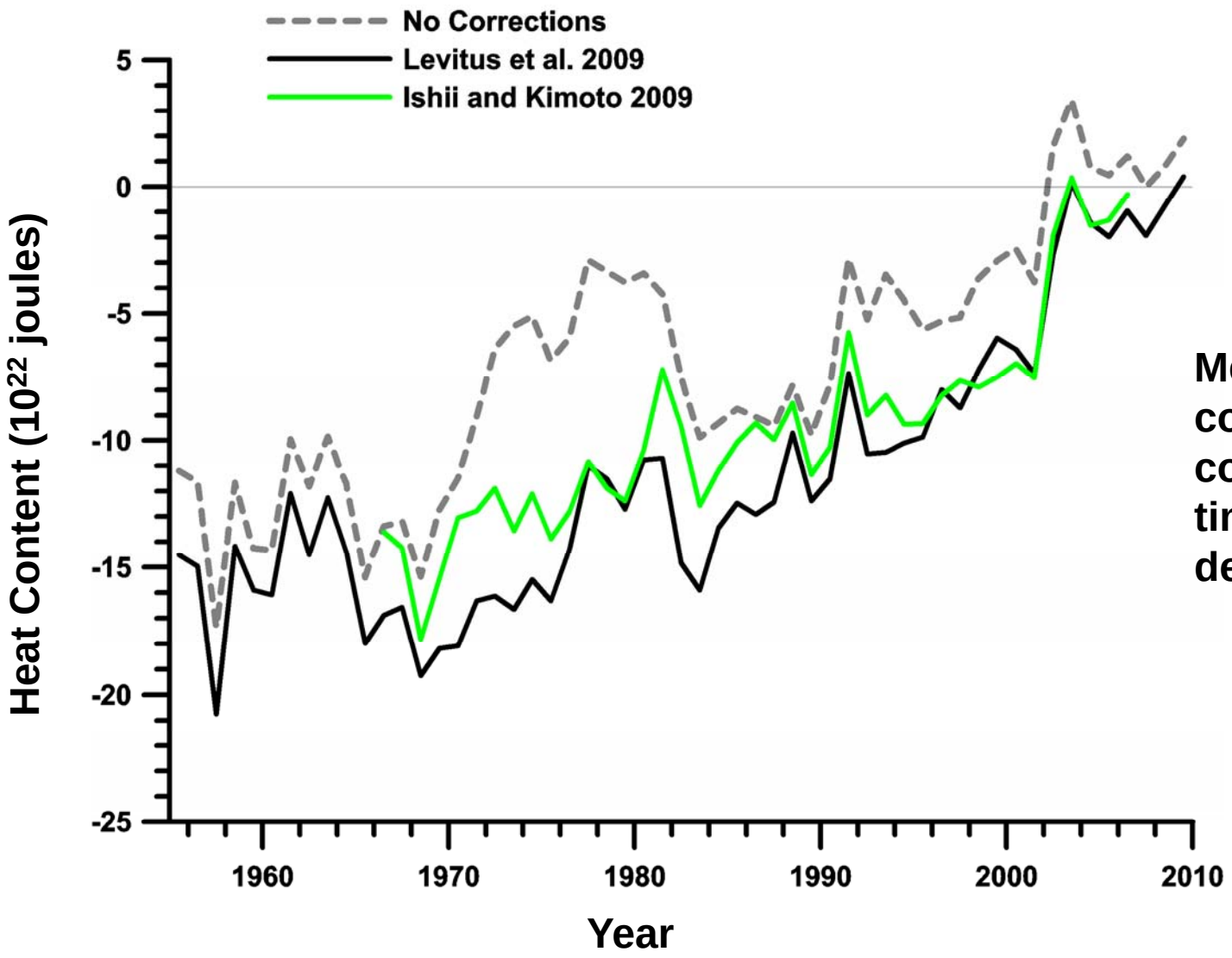
No XBT Corrections



XBT minus CTD temperature means

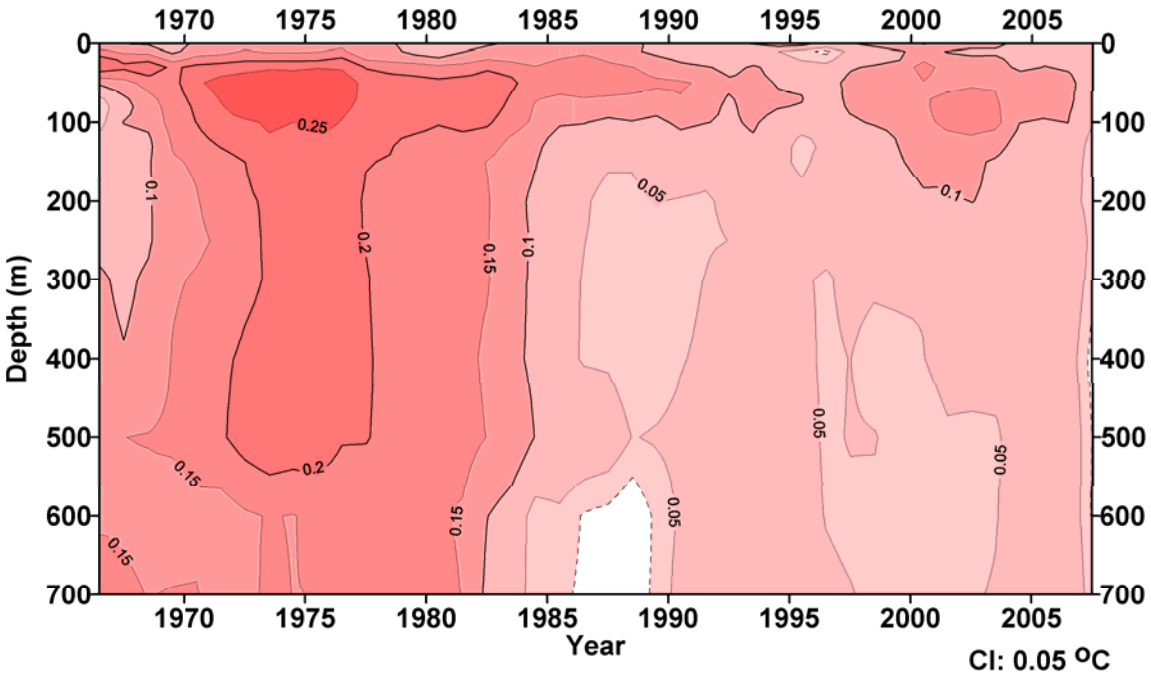
Wijffels et al. 2008 corrections applied

Red=positive, Blue=Negative



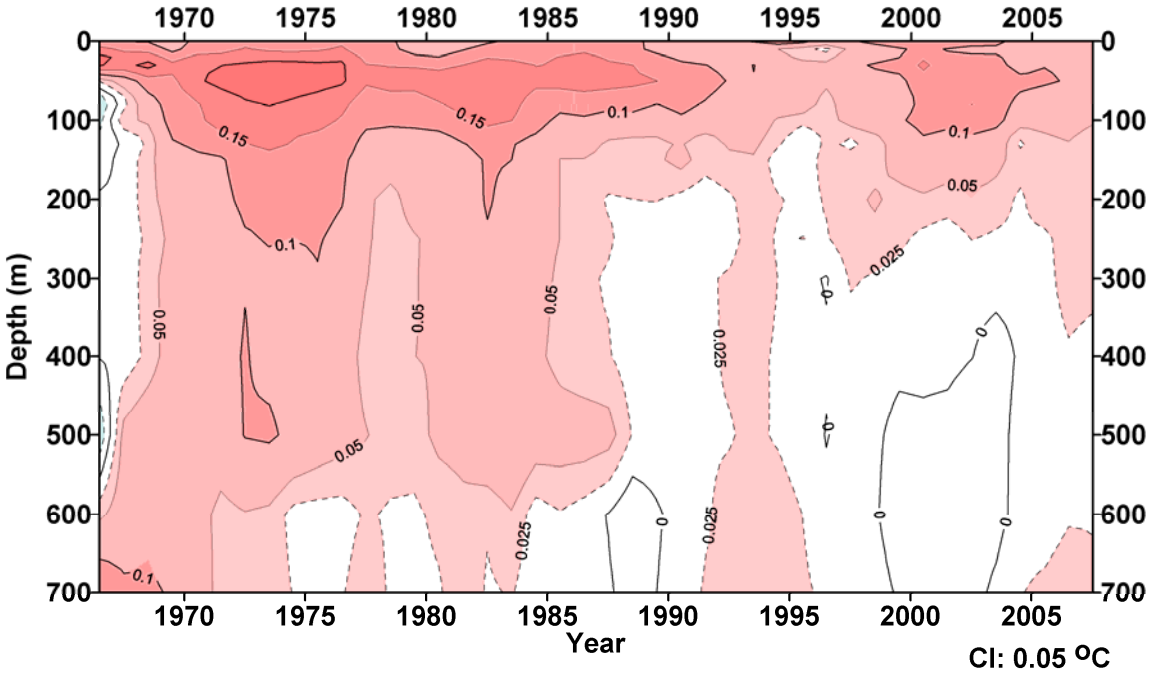
Method: depth correction - compute elapsed time, then adjust depth

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



XBT minus CTD temperature means

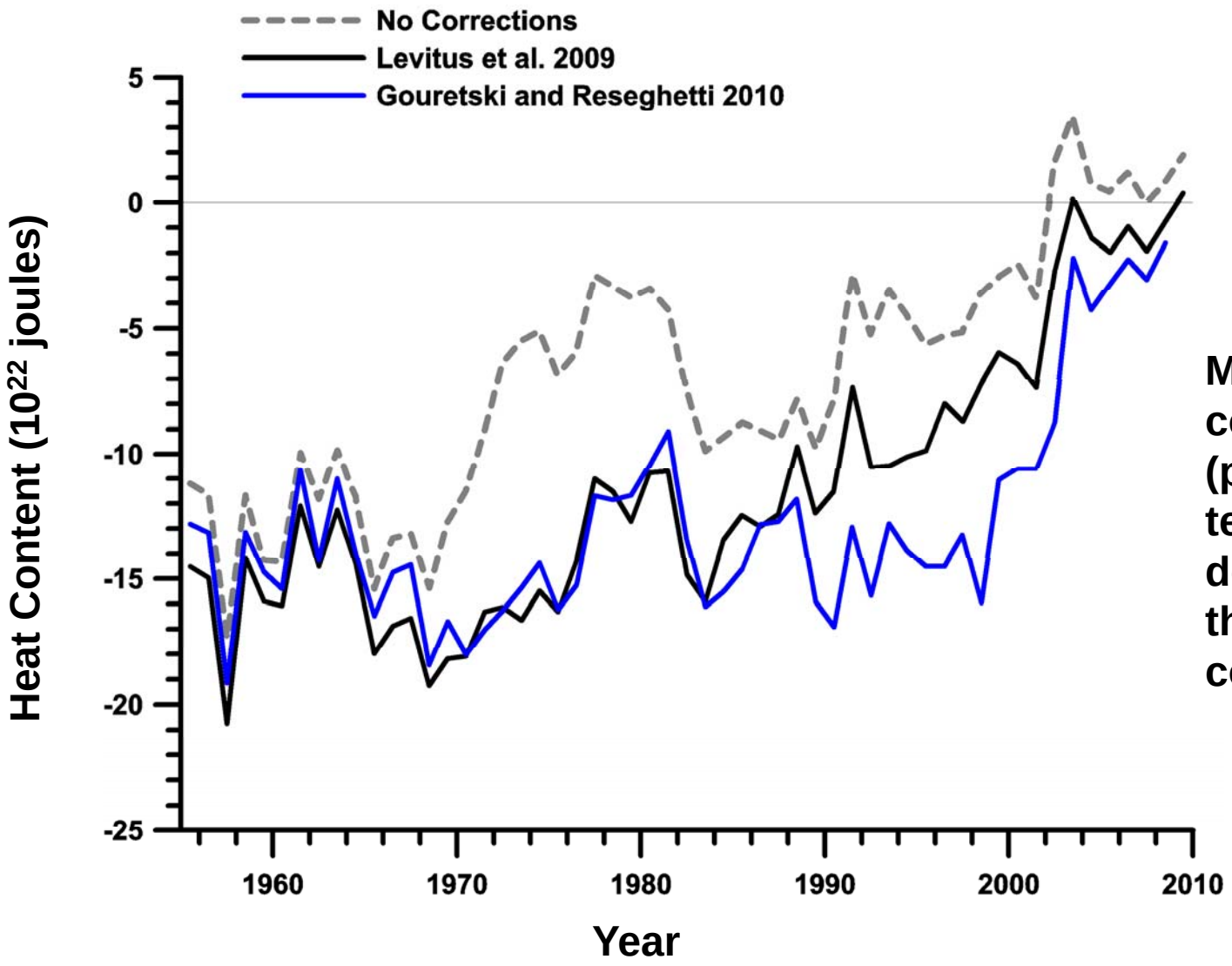
No XBT Corrections



XBT minus CTD temperature means

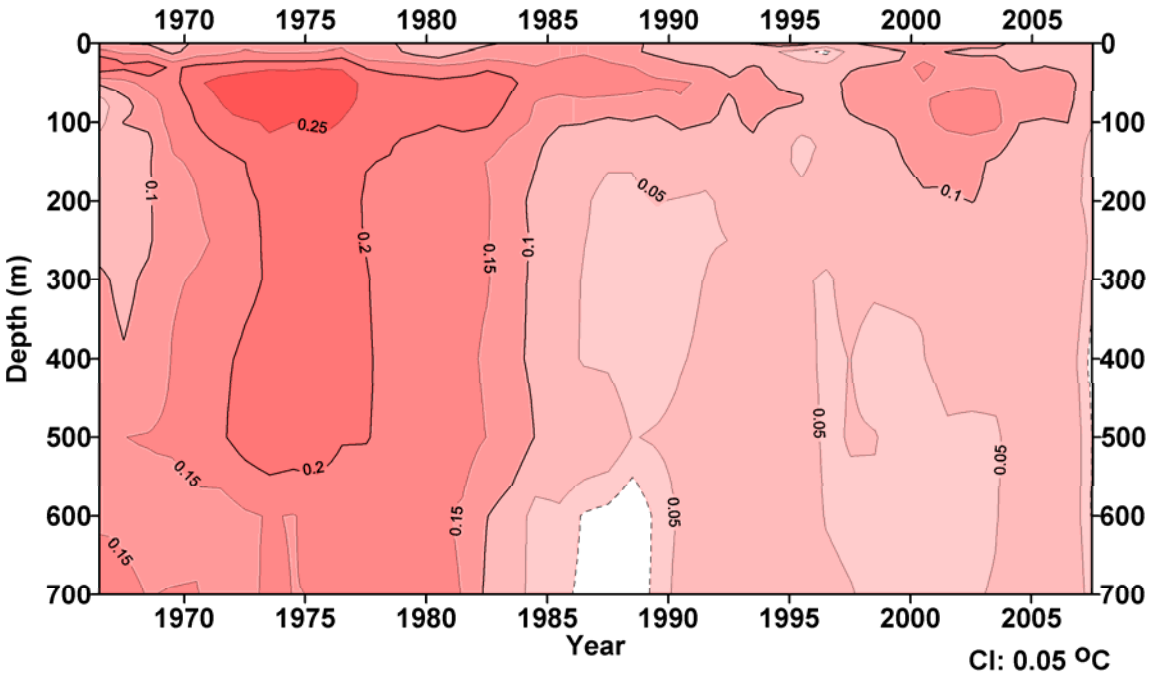
Ishii and Kimoto 2009 corrections applied

Red=positive, Blue=Negative



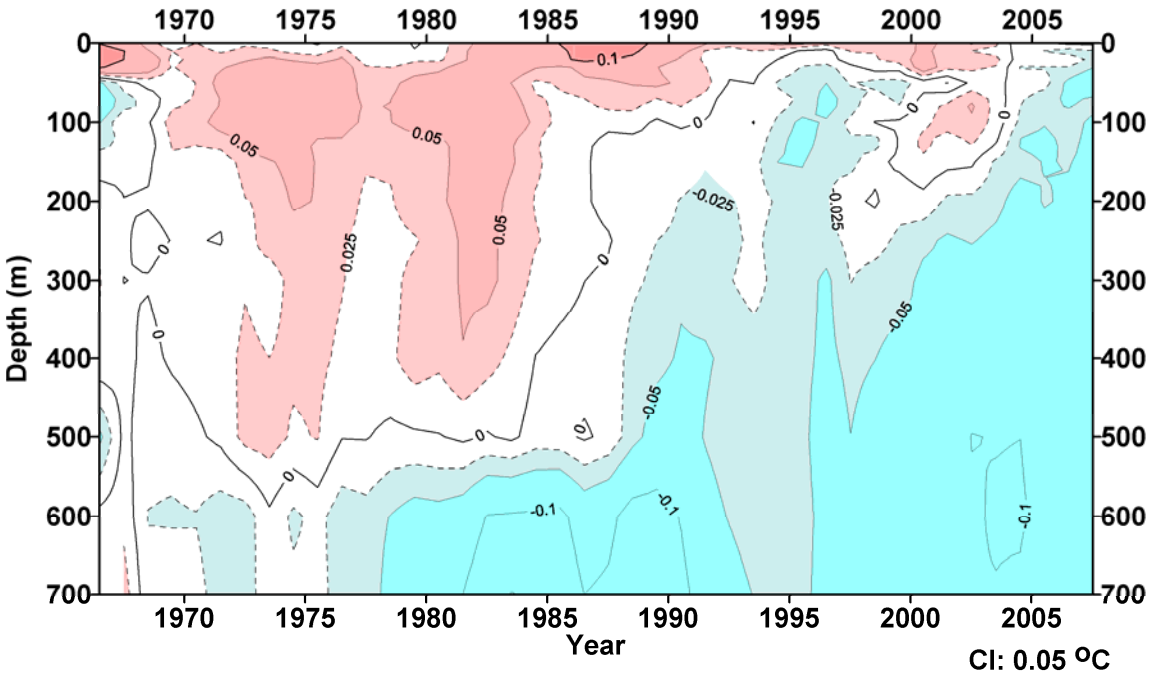
Method: depth correction (partially temperature dependent) + thermal bias correction

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



XBT minus CTD temperature means

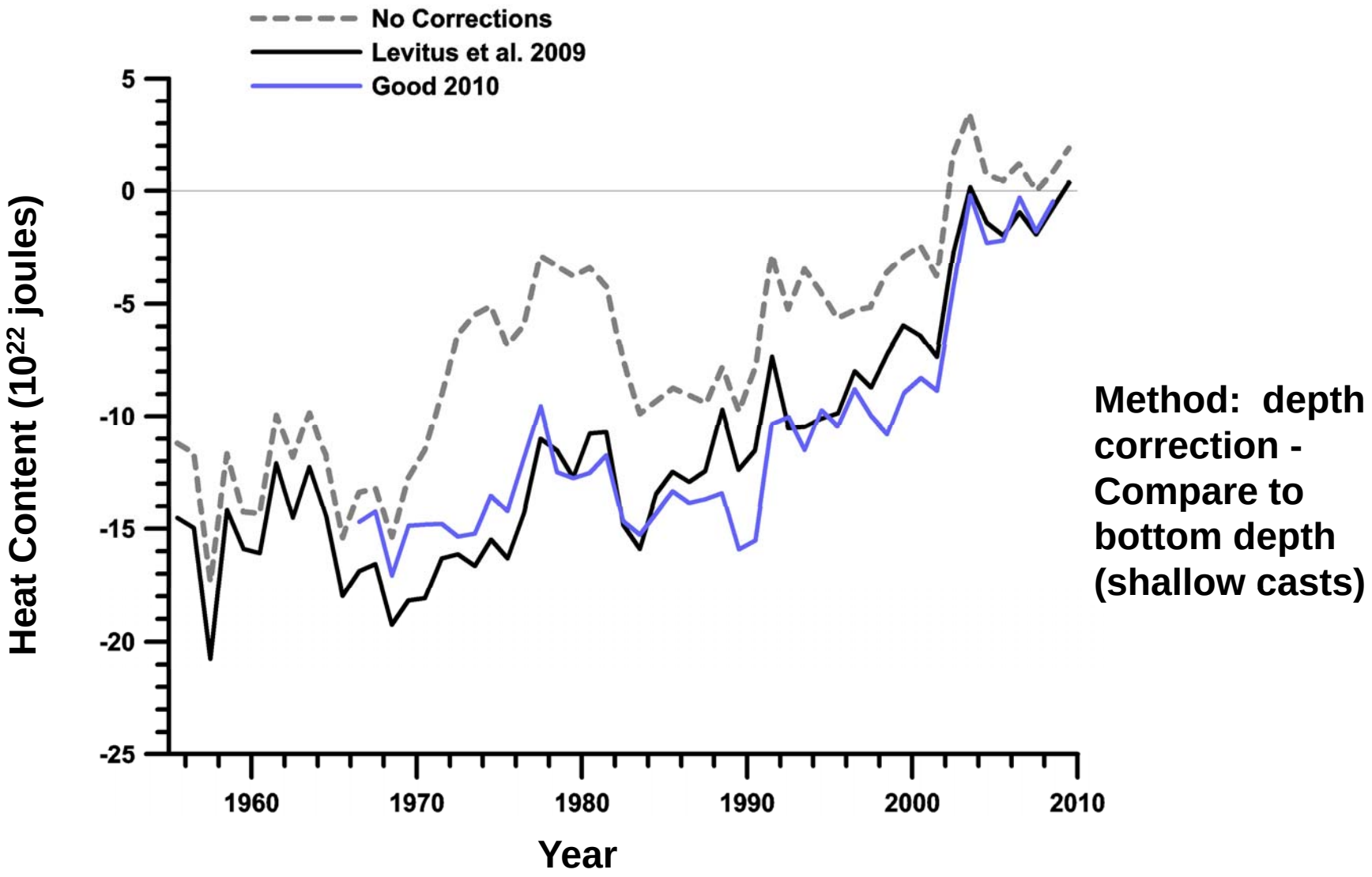
No XBT Corrections



XBT minus CTD temperature means

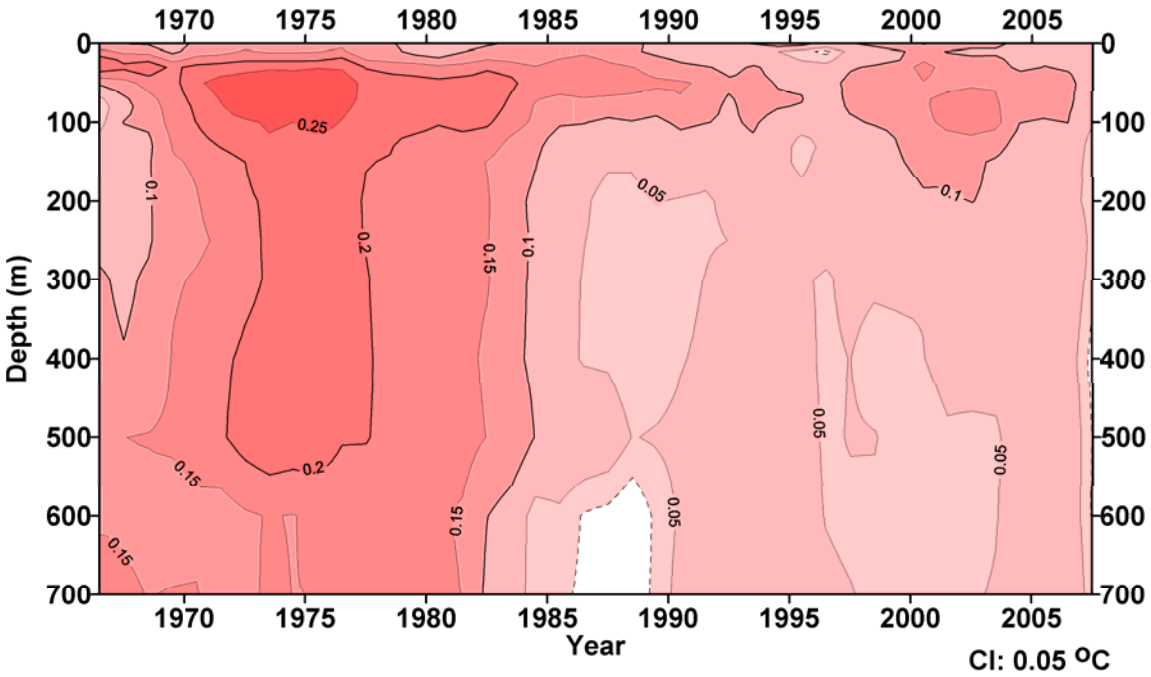
Gouretski and Reseghetti, 2010 corrections applied

Red=positive, Blue=Negative



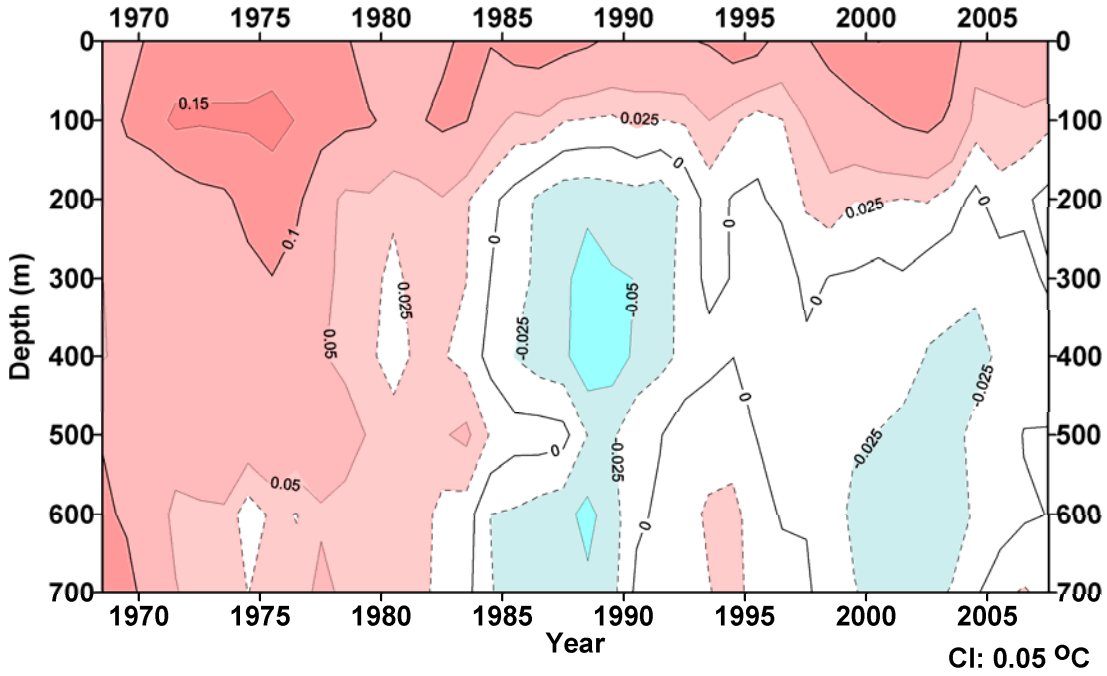
Method: depth correction - Compare to bottom depth (shallow casts)

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



XBT minus CTD temperature means

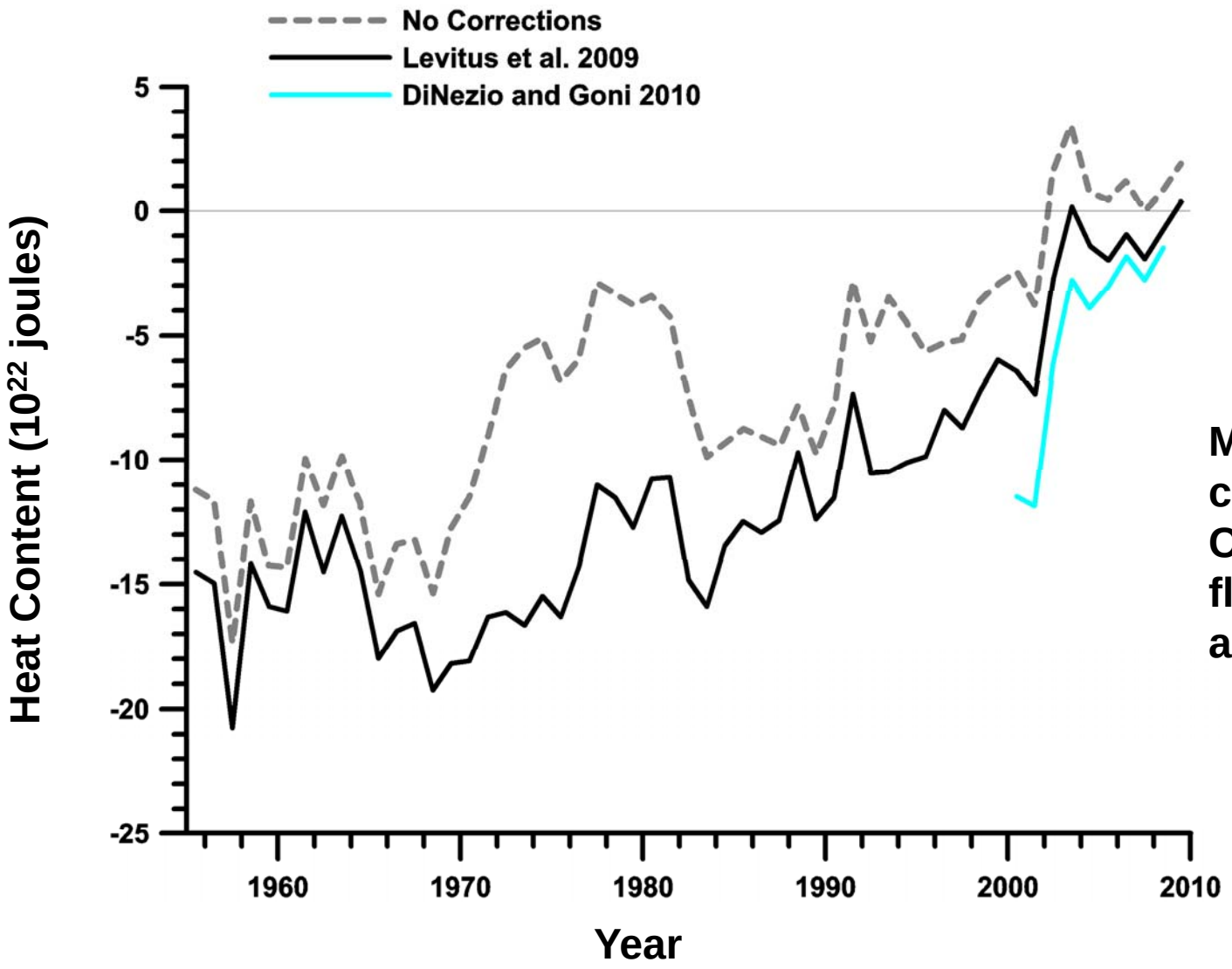
No XBT Corrections



XBT minus CTD temperature means

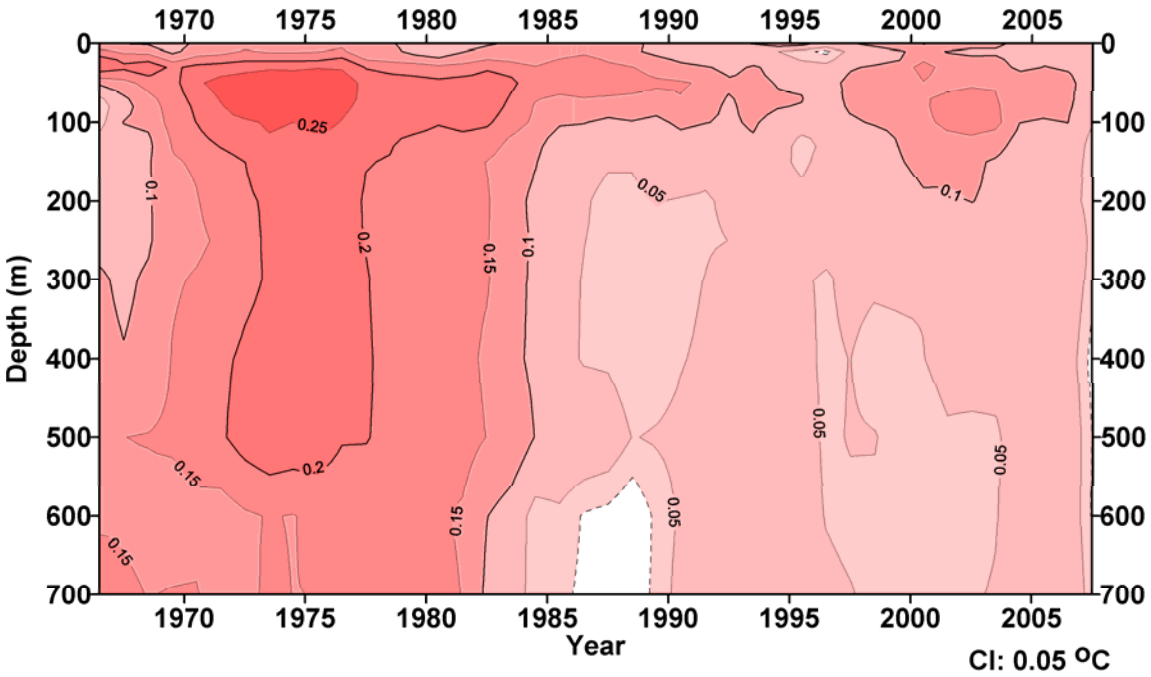
Good, 2010 corrections applied

Red=positive, Blue=Negative



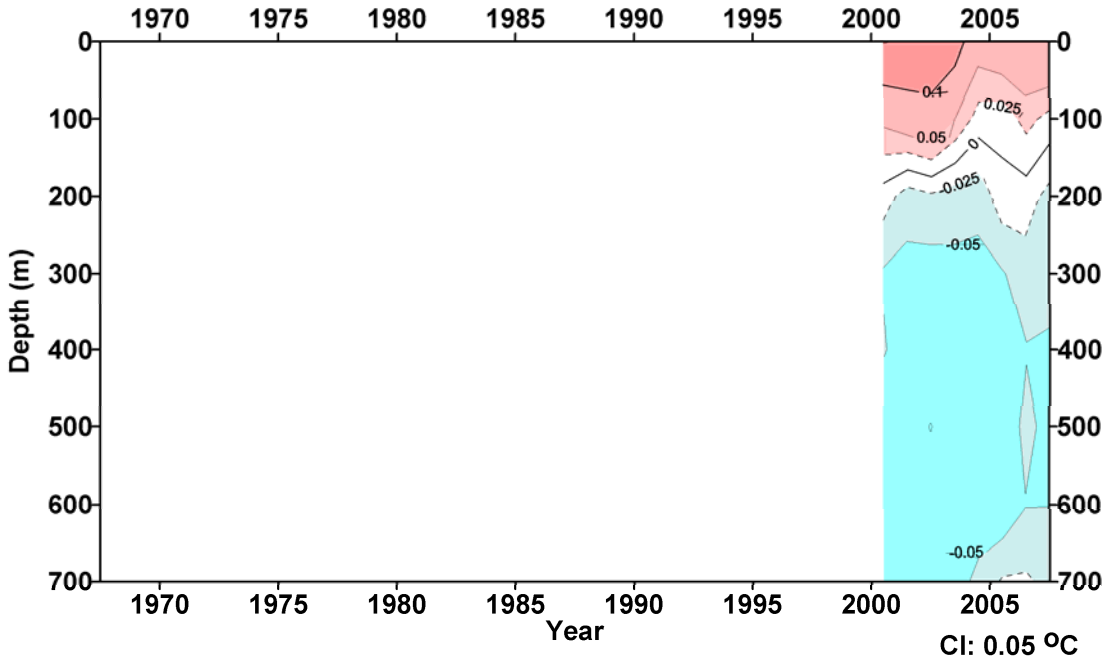
Method: depth correction - Compare to Argo floats, satellite altimetry

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



XBT minus CTD temperature means

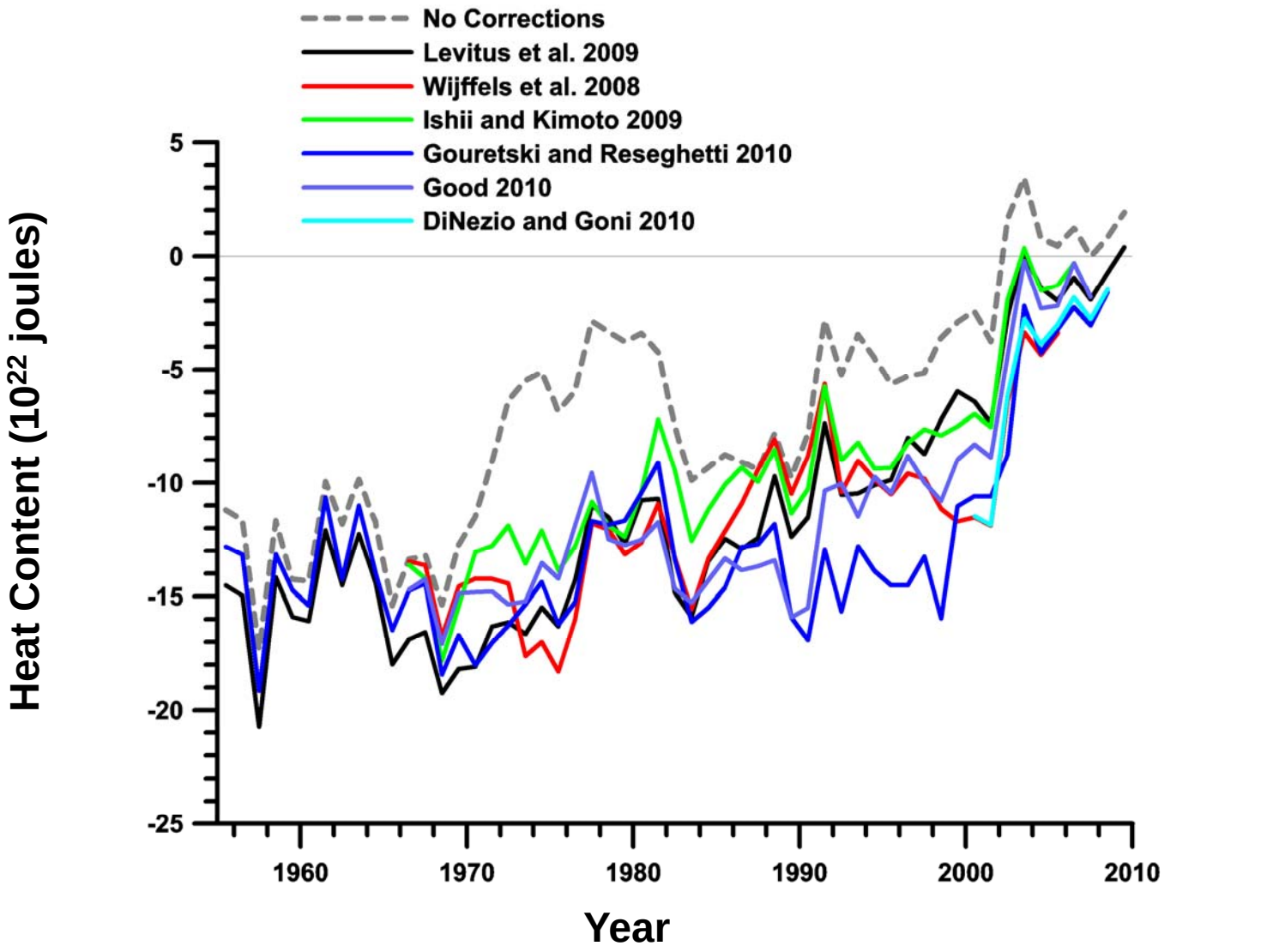
No XBT Corrections



XBT minus CTD temperature means

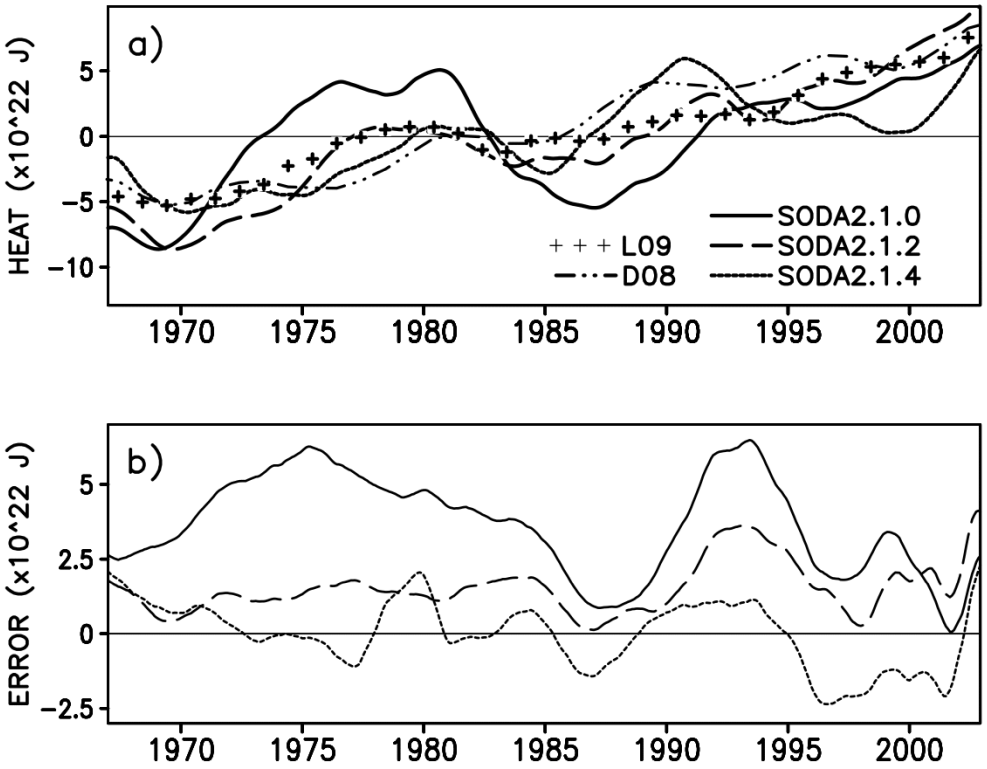
DiNezio and Goni, 2010 corrections applied

Red=positive, Blue=Negative



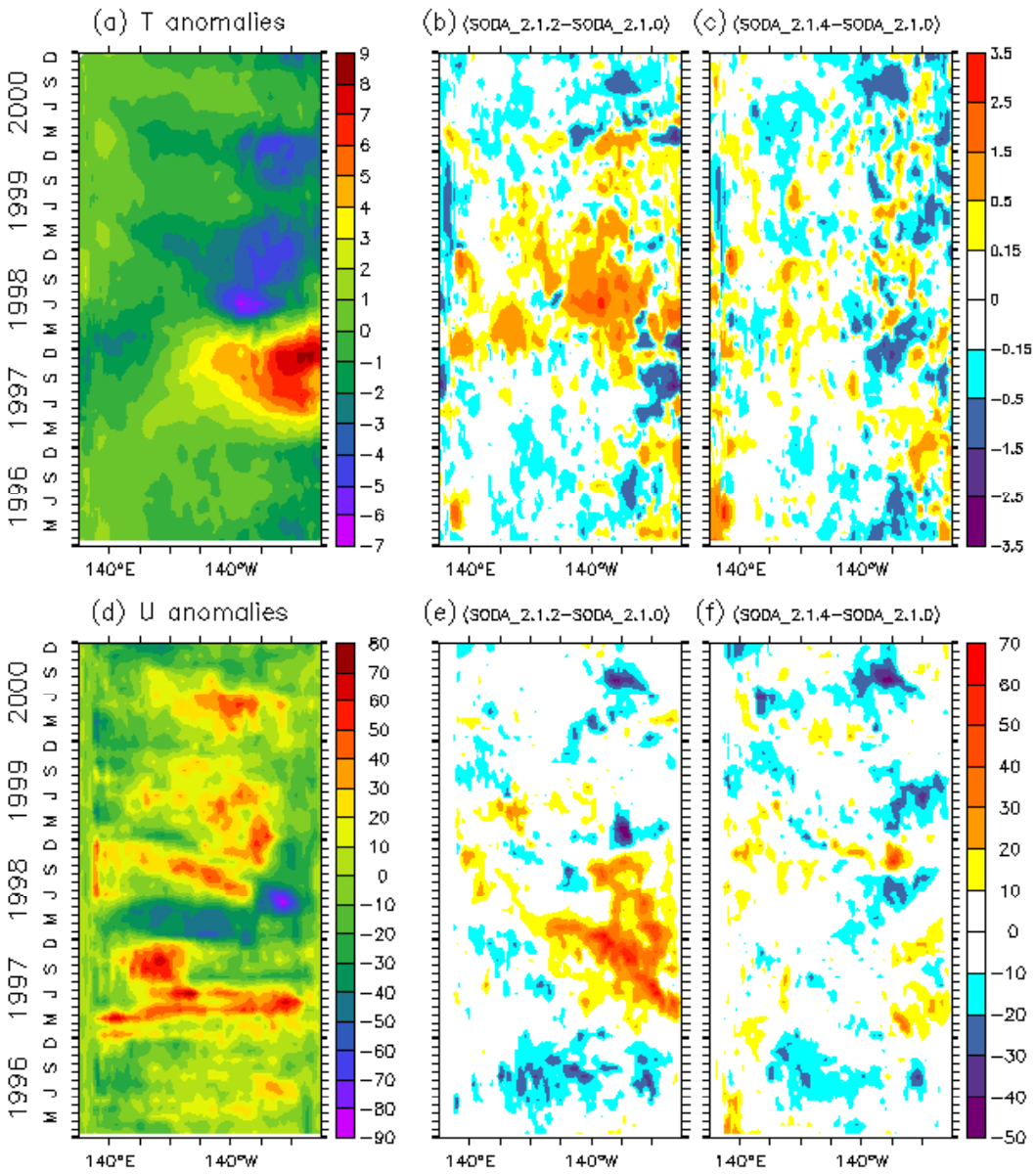
Integrated Ocean Heat Content Anomaly 0-700 m

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.**

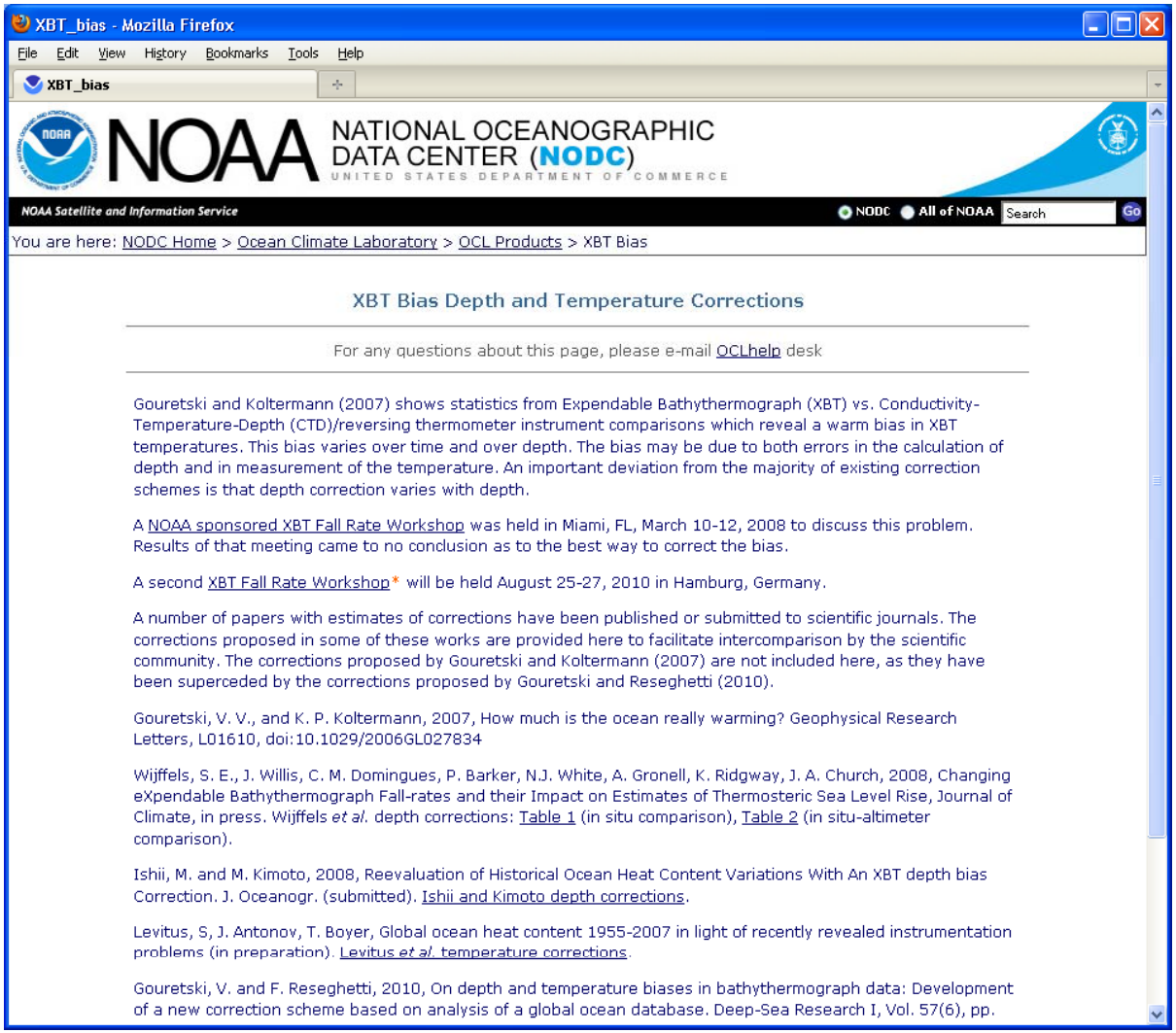
- **Make XBT data readily available with corrections. Make sure these data are updated regularly as XBTs are added to global database**

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**.



US NODC XBT Bias Page

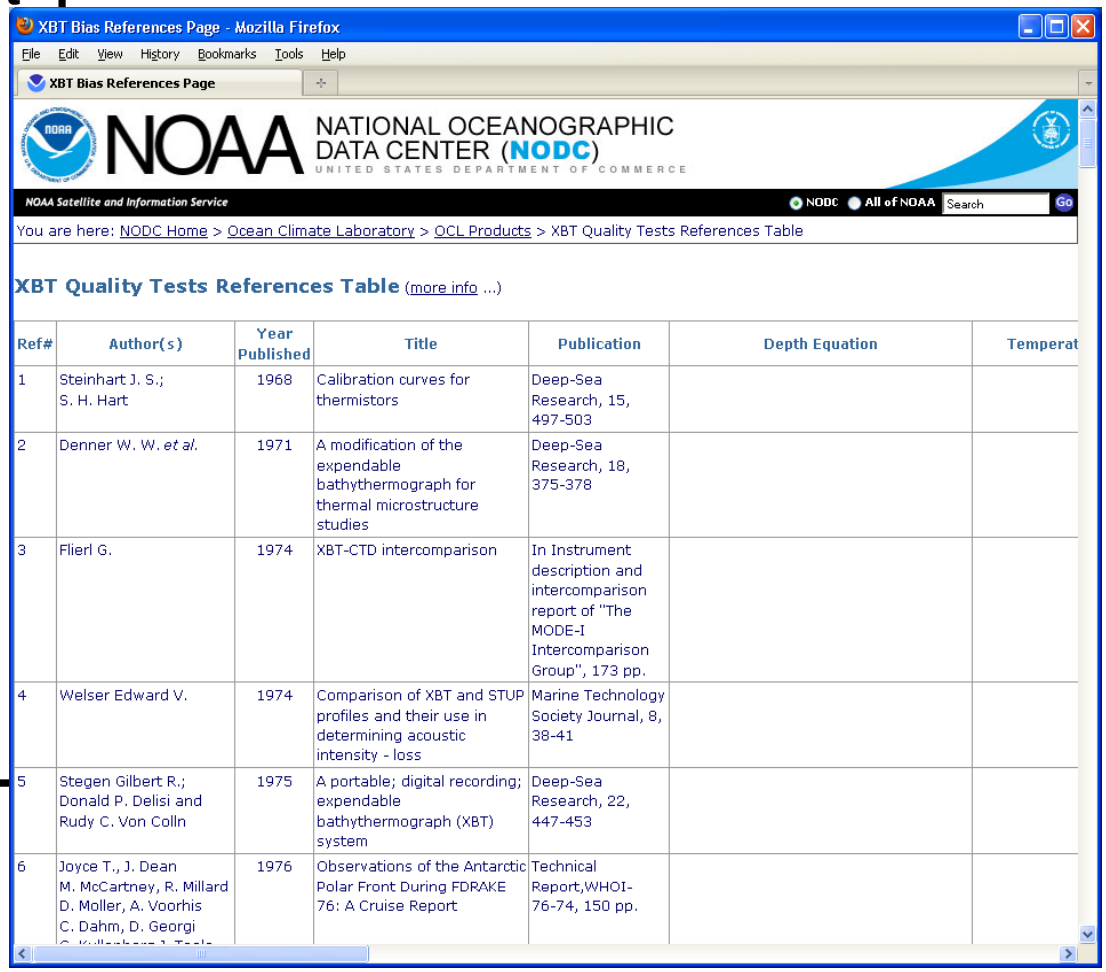
Currently: contains various XBT corrections methods and tables. Can Continue in this capacity

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

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

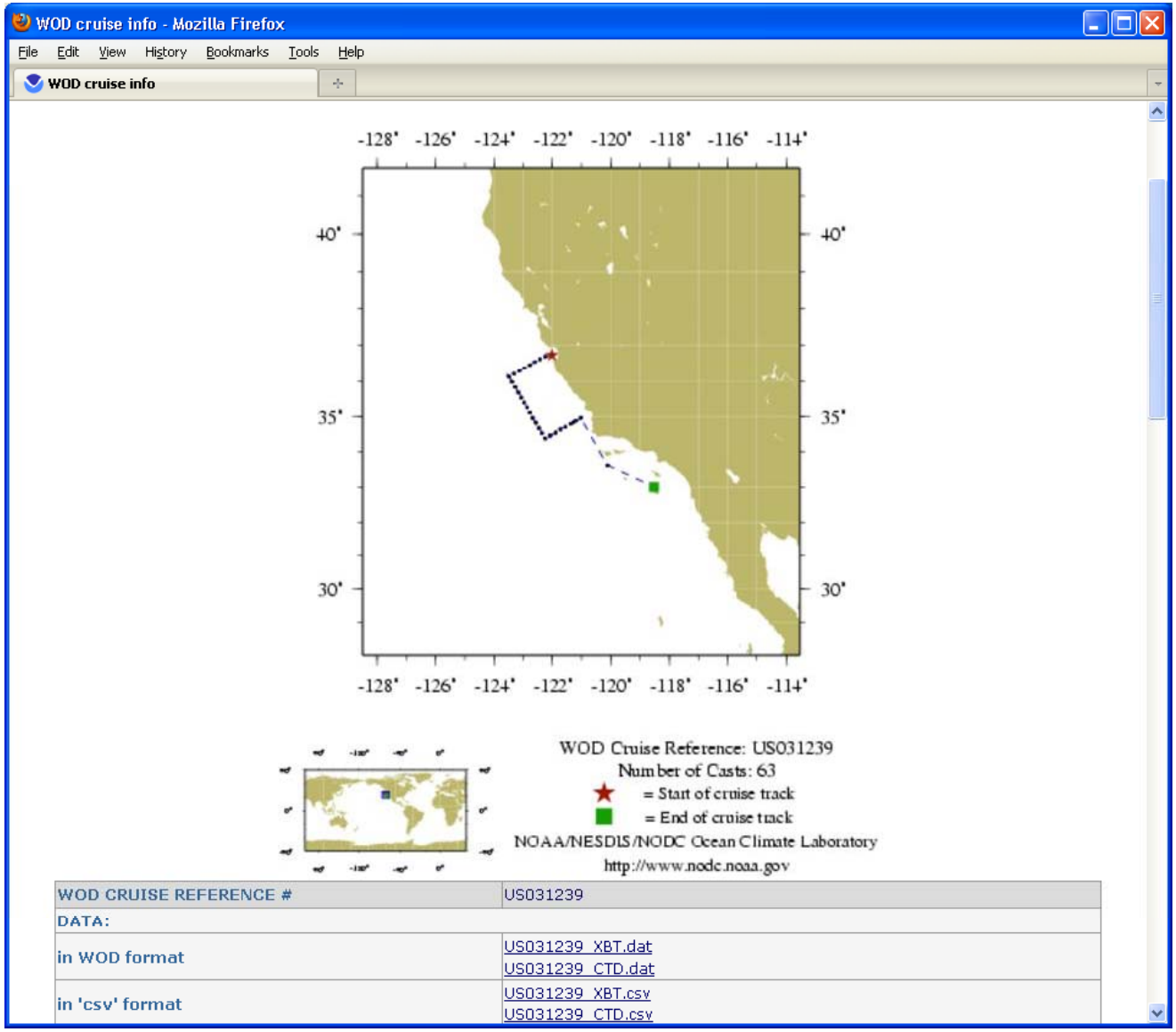
NODC XBT Quality Tests Reference Table

- **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.**



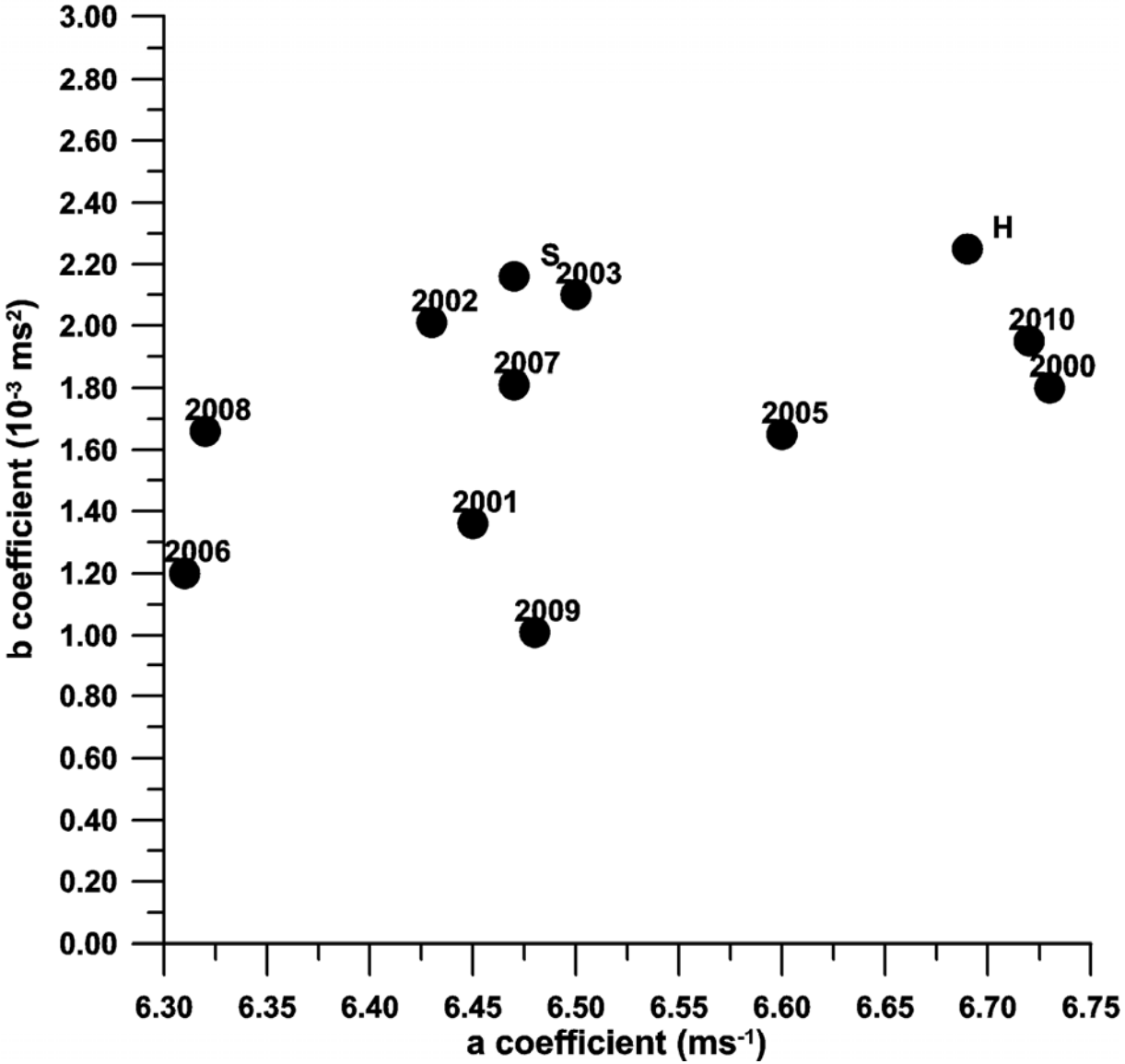
Ref#	Author(s)	Year Published	Title	Publication	Depth Equation	Temperat
1	Steinhart J. S.; S. H. Hart	1968	Calibration curves for thermistors	Deep-Sea Research, 15, 497-503		
2	Denner W. W. *et al.*	1971	A modification of the expendable bathythermograph for thermal microstructure studies	Deep-Sea Research, 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.

Hamburg Outcomes

- **Realization that XBT correction includes both drop-rate correction and temperature correction**

- **Standardize best practices for future drops (G. Pezzoli)**

- **Explore pressure sensor on XBT (G. Goni)**

- **Get timeline of manufacture changes from Sippican (G. Goni)**

- **Make available XBT datasets using different corrections (T. Boyer/NODC)**

- **More work to be done**

Thank You