

Ocean heat content variations and its trends estimated from historical oceanographic observations

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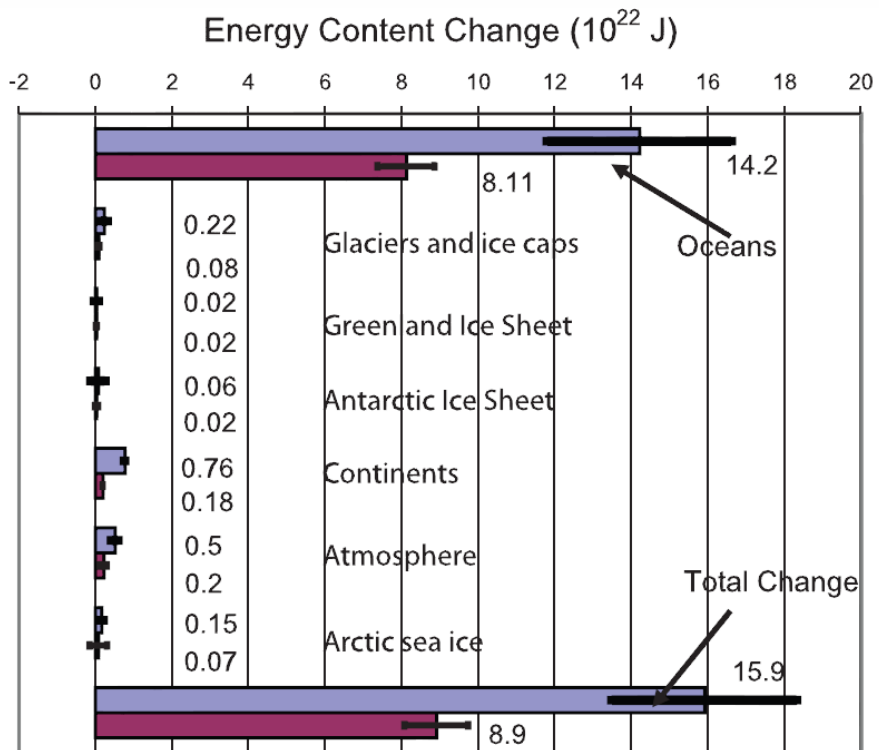
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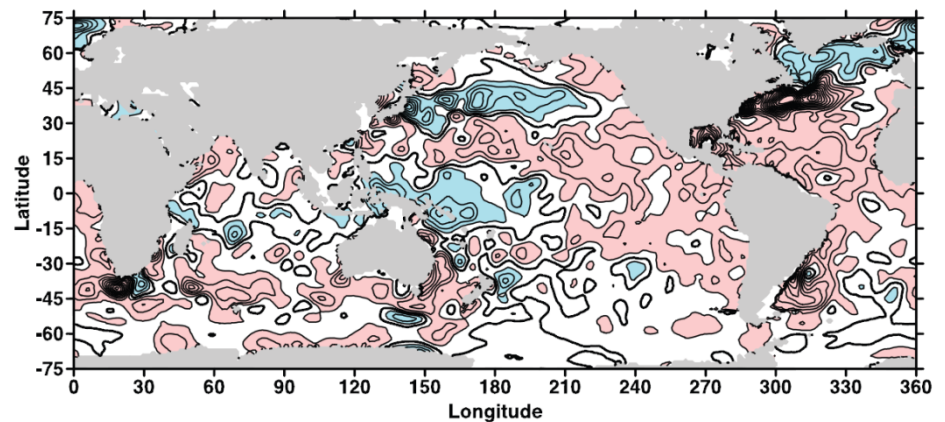
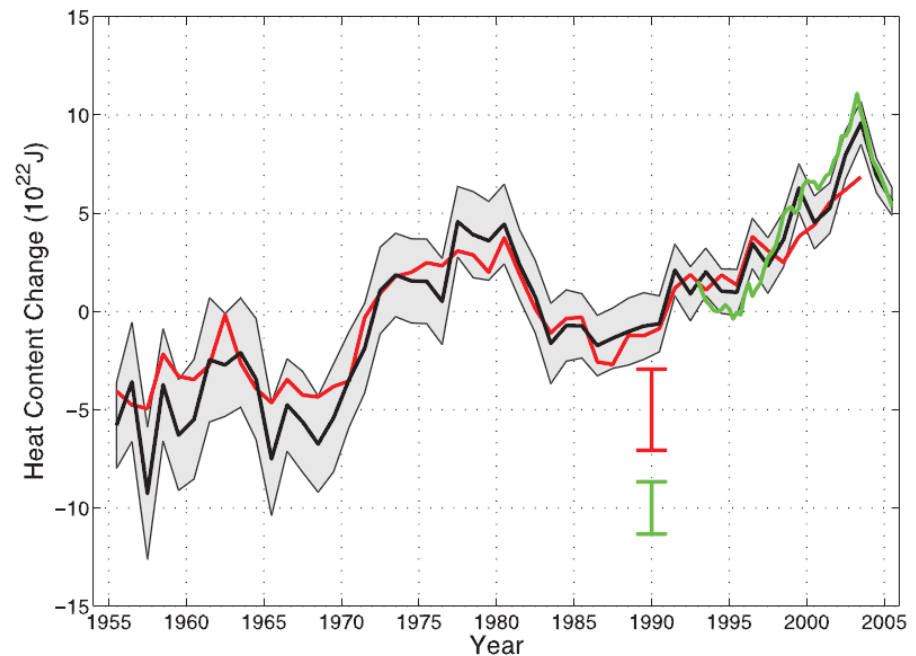


BACKGROUND

Ocean Heat Content

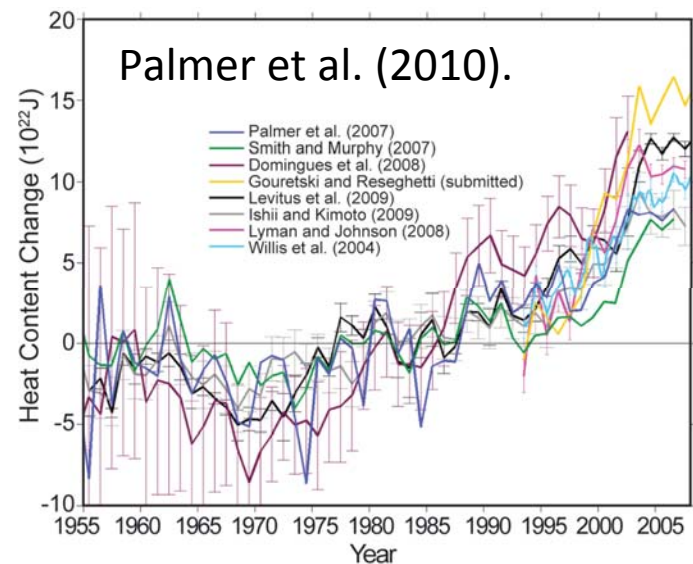
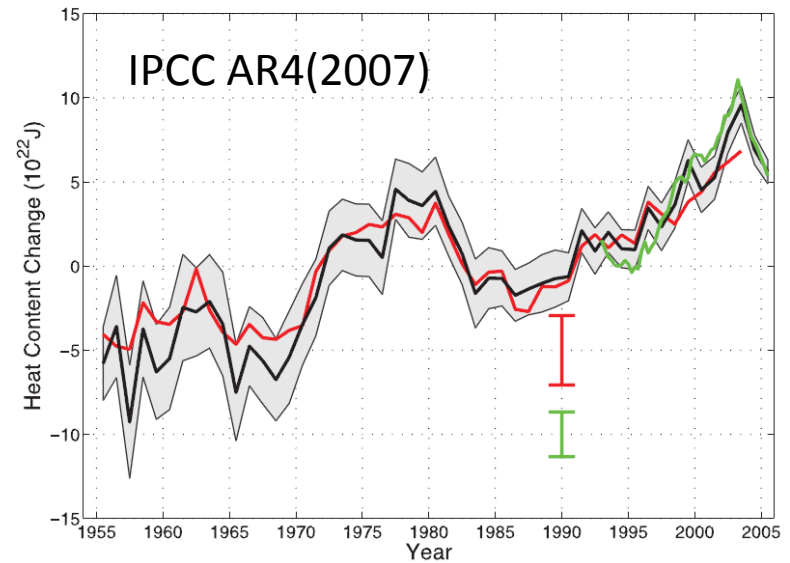
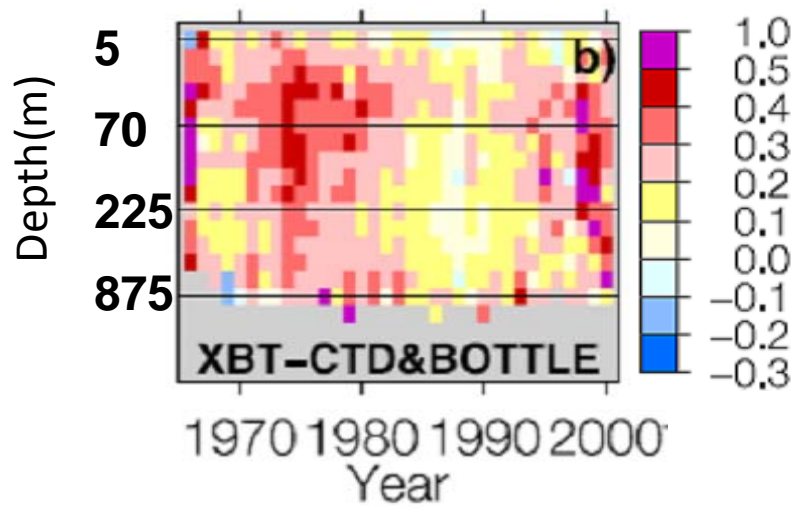


IPCC AR4



Historical XBT biases

Gouretski and Koltermann (2007)





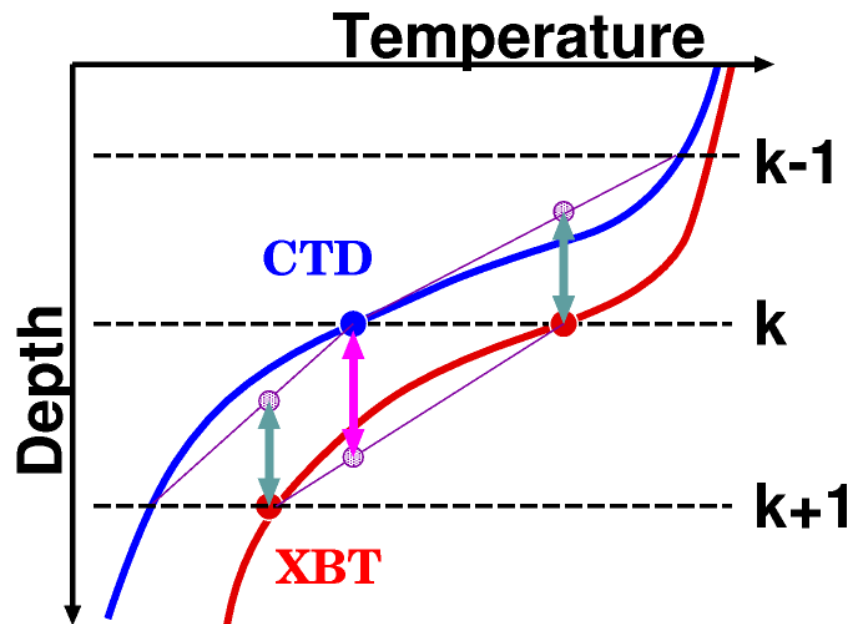
**ISHII AND KIMOTO, 2009
AND THE UPDATE**

Analysis Outline

- ❑ Objective analysis of monthly T & S by 3-dimensional variational minimization without a dynamical model
- ❑ 1 deg. X 1. deg., 28 levels above 3000 m depth, from 1945 to 2009.
- ❑ Observational data:
 - ❑ WOD09
 - ❑ GTSP
 - ❑ GDAC Argo data
 - ❑ XBT data compiled by Japan oceanographic Data Center (JODC)
- ❑ Climatology: WOA05
- ❑ MBT & XBT depth bias corrections updated

XBT/MBT bias correction

- **Box Averaging**; compute monthly box-averages individually for XBT and CTD-BOTTLE observations in WOD and GTSP. Argo data are not used.
 - The box size: global 1 deg. X 1 deg., 10 m in the vertical (0-900m)
 - Averaging observed anomalies (relative to WOA climatology) rather than full temperature values.
- **Sampling**; collect depth differences for the same temperature values of XBT and CTD+BOTTLE at the same position in the same month.



- ✓ Directly compared to CTD & BOTTLE
- ✓ Minimizing interpolation errors
- ✓ Minimizing sampling errors
- ✓ Accurate enough for practical uses.

- **Least squares fitting**; compute a coefficient of the linear bias model.

Probe-type-dependent Biases

Means over the whole period.

XBT

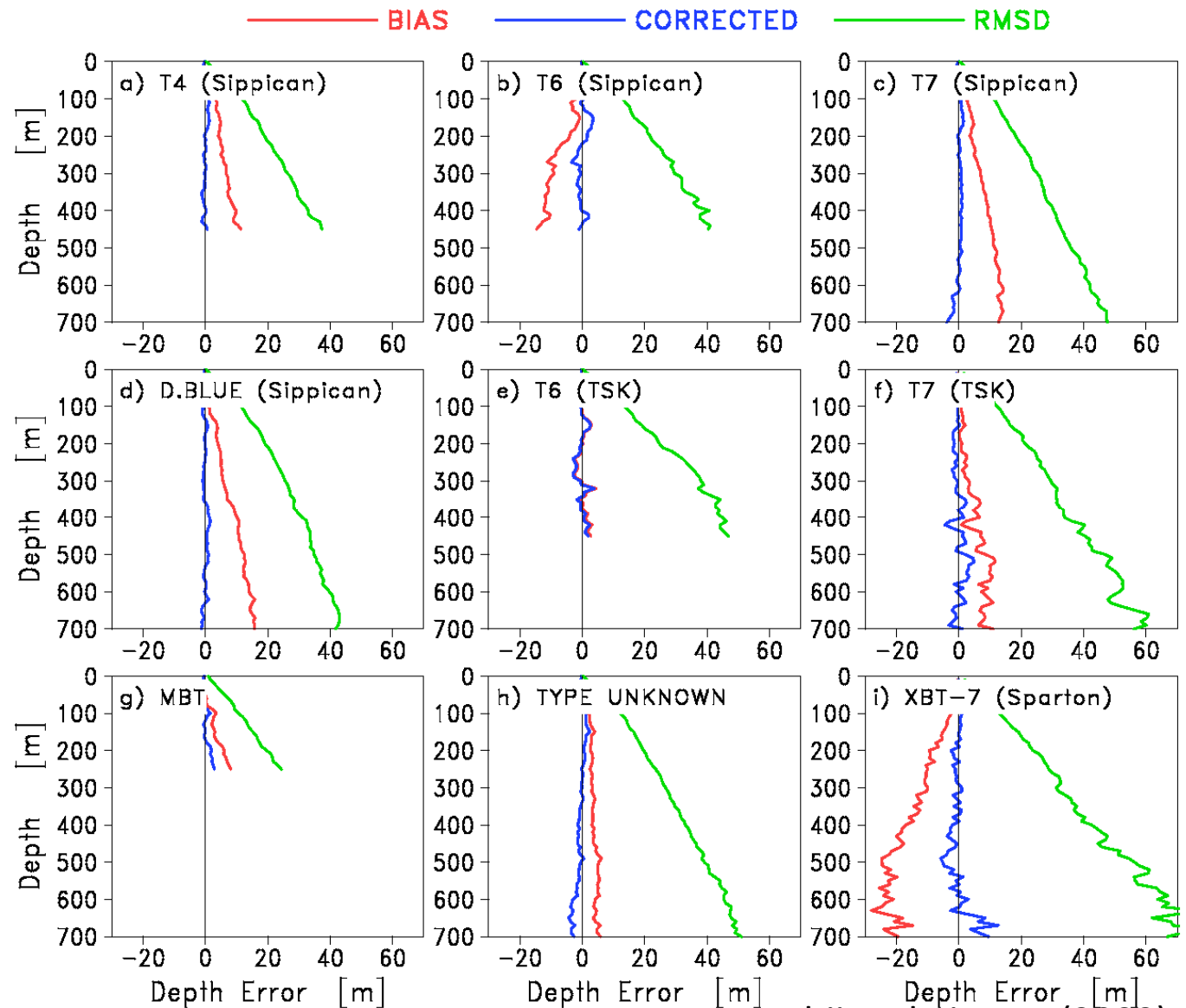
Manufacturer's dep.: Sippican, TSK, Sparton

Probe-type dep.: T4, T6, T7, Unknown

MBT

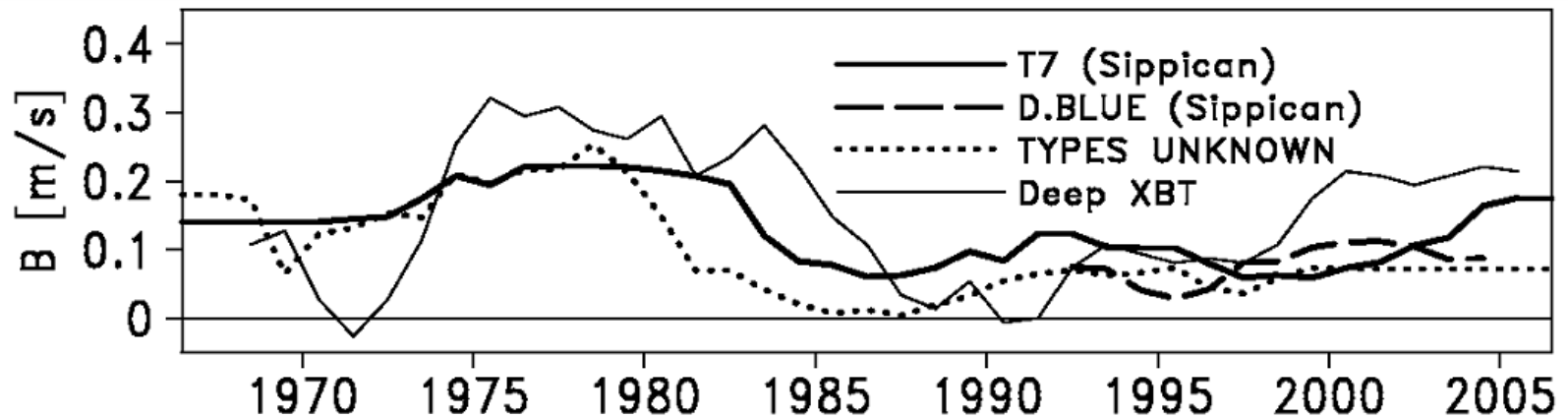
All profiles are adjusted to Hanawa et al (1995) corrections applied.

- Magnitudes of biases vary among types and manufacturer.
- Large RMSD, noisy
- The linear model is OK



Ishii and Kimoto (2009)

Temporal changes in Bias

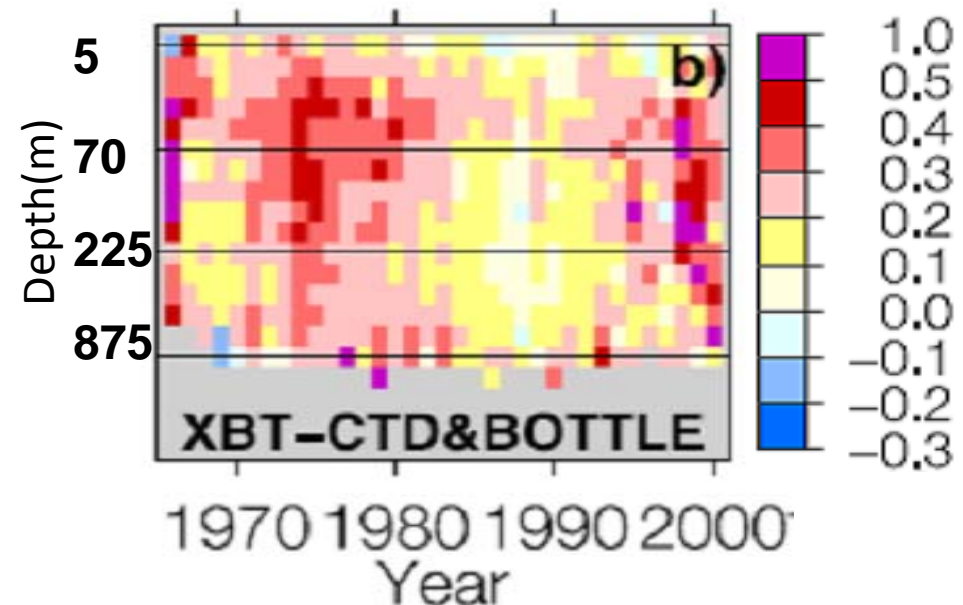


Ishii and Kimoto (2009)

Depth Bias Model:

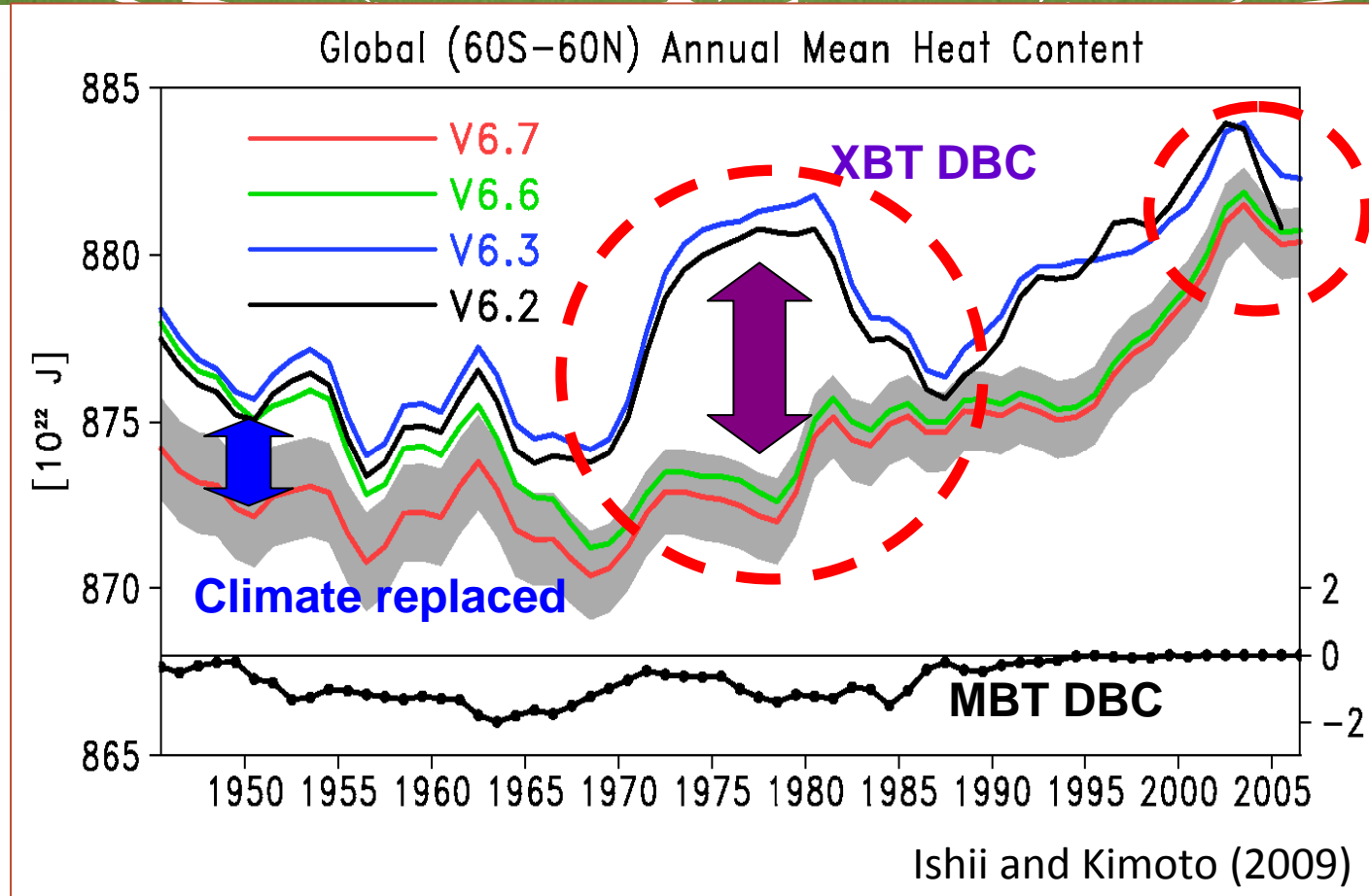
$$\delta d = Bt$$

- temporal changes
- agree with Wijffels et al. (2008)
- agree with G&K (2007)



Gouretski and Koltermann (2007, GRL)

Ocean heat content



V6.2: WOA01, WOD01, W/O XBT and MBT DBCs

V6.3: WOA05, WOD05, W/O XBT and MBT DBCs

V6.6: WOA05, WOD05, W/ XBT and MBT DBCs

V6.7: WOA05, WOD05, W/ XBT and MBT DBCs, W/ V6.6 CLIMATE

Recent OHC Changes Verified with Argo

- Recent Argo data may not be contaminated severe errors or biases.

w/ Argo vs. w/o Argo

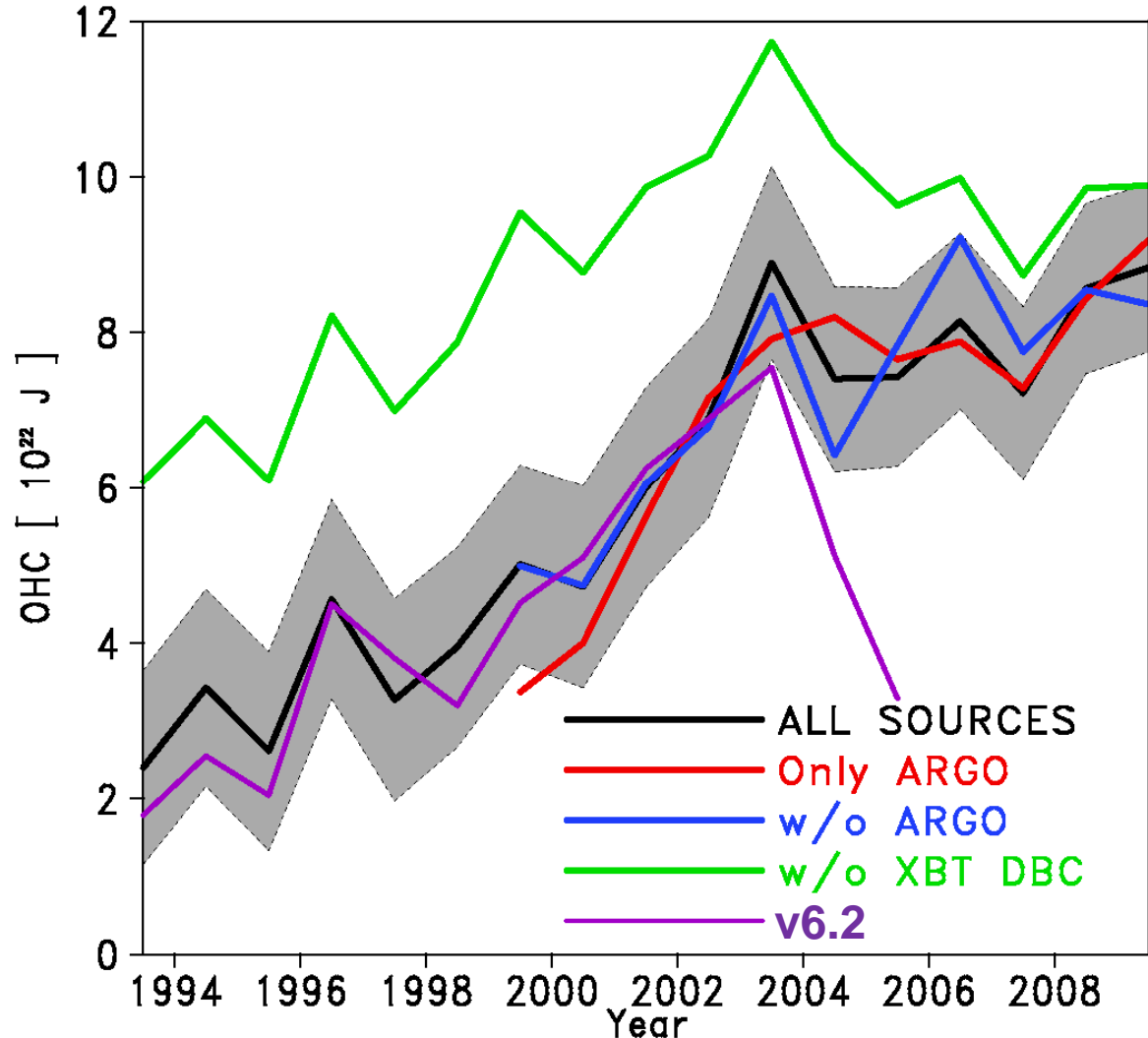
- XBT bias correction is very necessary for agreement with Argo data. Recall that Argo is not used in constructing XBT bias formula.

w/ DBC vs. w/o DBC
vs. only Argo

- XBT biases partly contributed artificial ocean cooling after 2003 (Ishii and Kimoto 2009).

w/o DBC vs. v6.2

Global Annual Mean OHC
relative to 1961–90 mean of ALL SOURCE

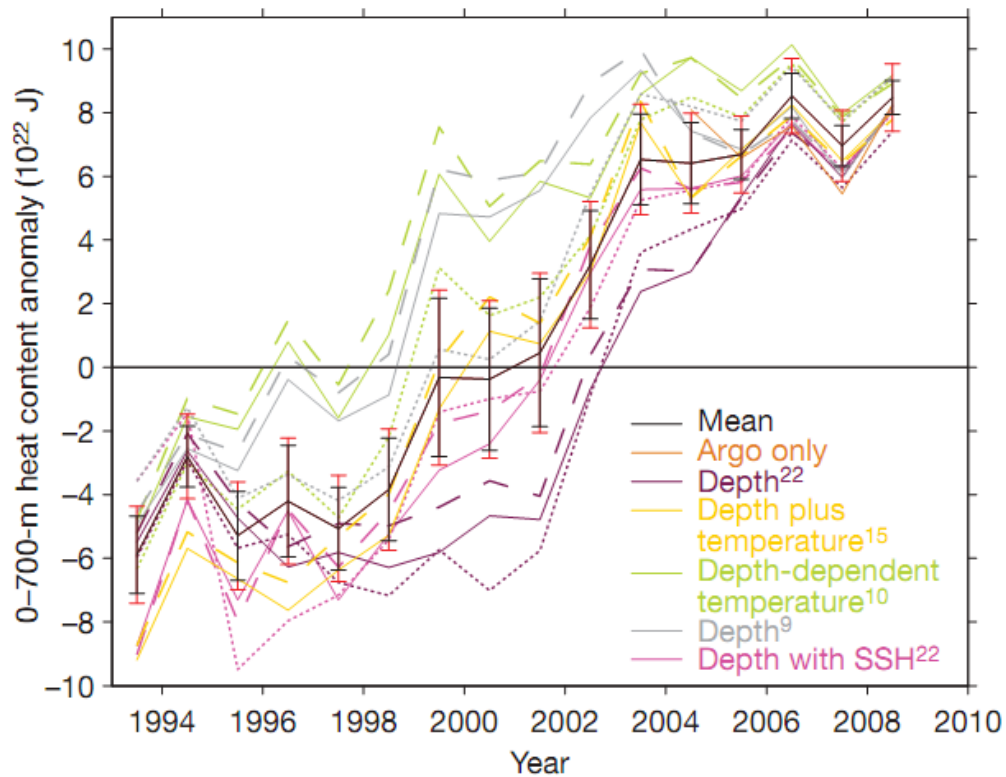


The importance of meta data



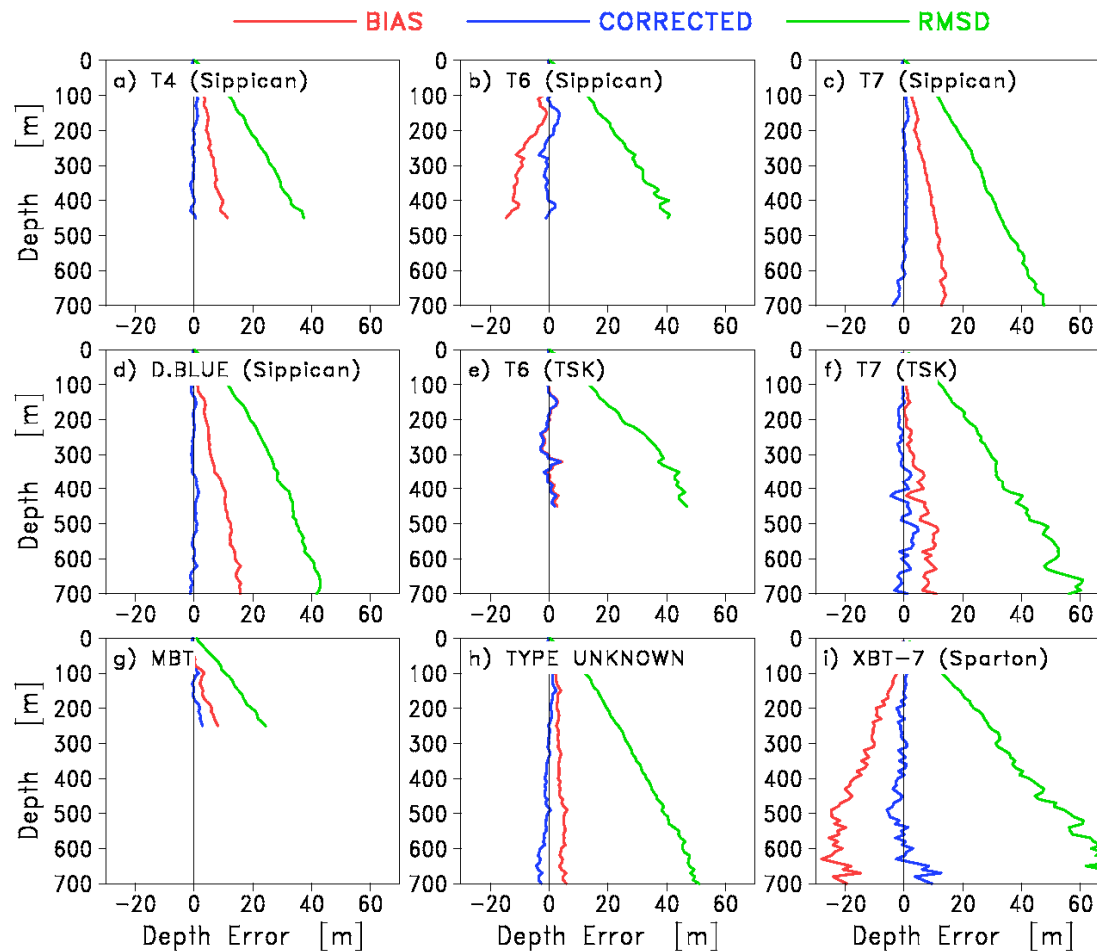
FOR THE NEXT STEP

What is the Problem.



XBT bias corrections of different centers are a major cause of large uncertainty in global mean ocean heat content. (Lyman et al. 2010)

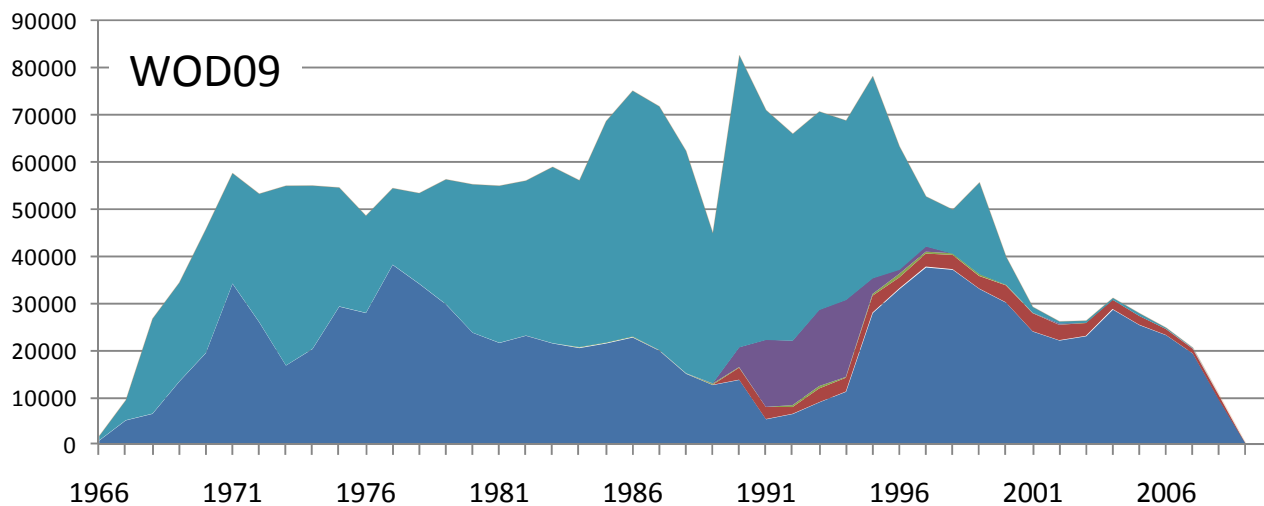
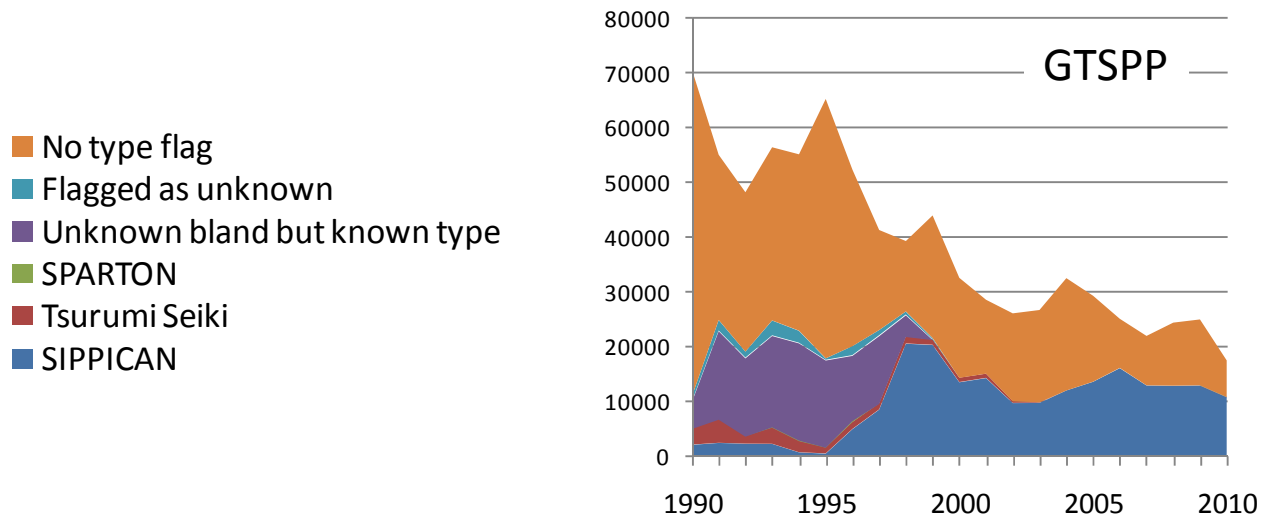
XBT fall rate bias correction



There are different amplitude of depth bias for each type and brand of XBT.

➔ Identification of XBT/MBT type and manufacturer is necessary

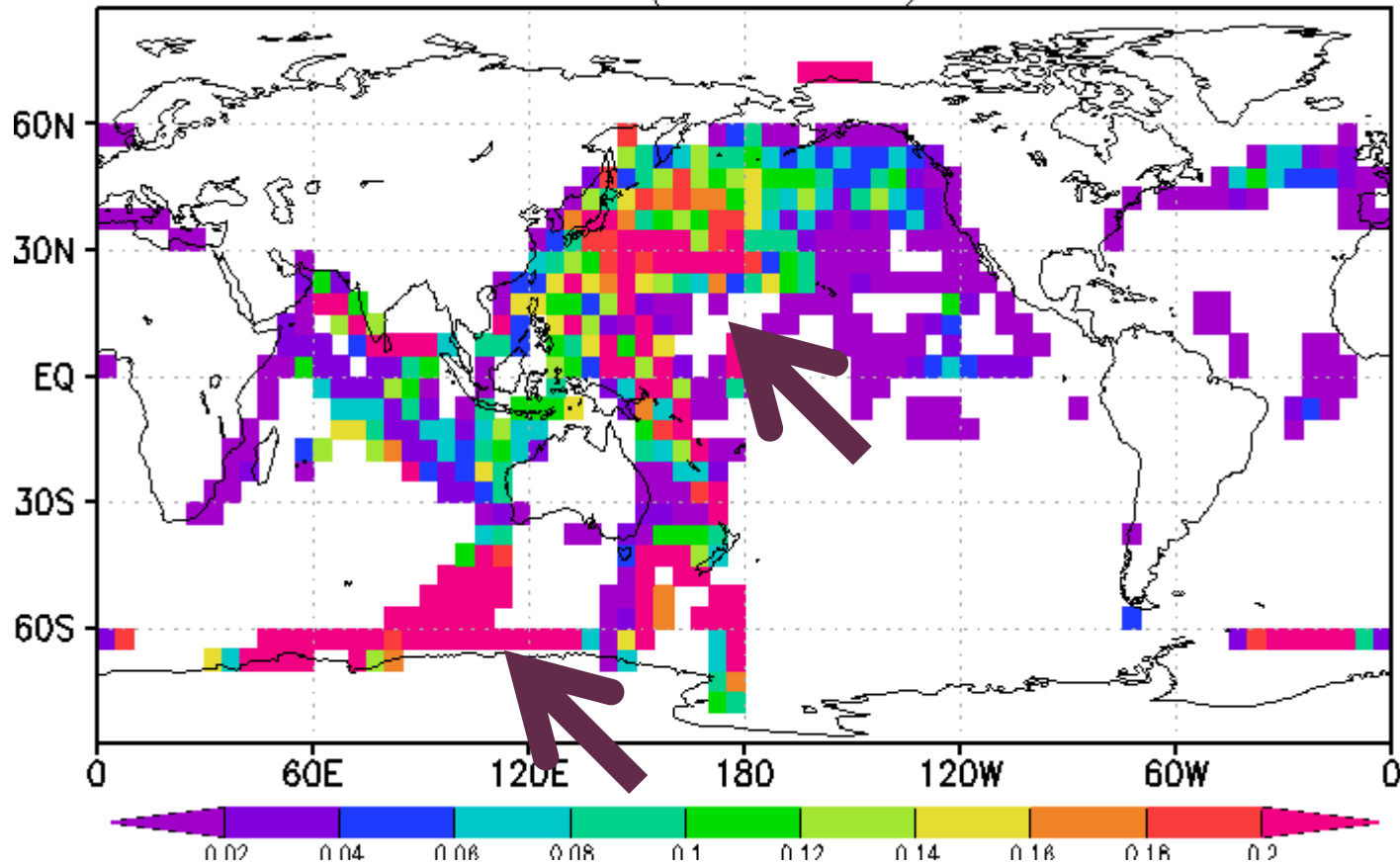
Manufacturer flag



- Actually, unknown flags are rarely used in GTSPP
- After 2000, almost all records in WOD09 are identified the types and manufacturers.
- Tsurumi Seiki(TSK) have been archived mainly since 1990.

Tsurumi Seiki XBT distribution

Proportion of TSK XBT observation to all XBT observation in WOD09 (1990-2008, 5deg. X 5deg.)



In the western North Pacific and a part of southern ocean, TSK XBT observations share more than 20% of all XBT observations.

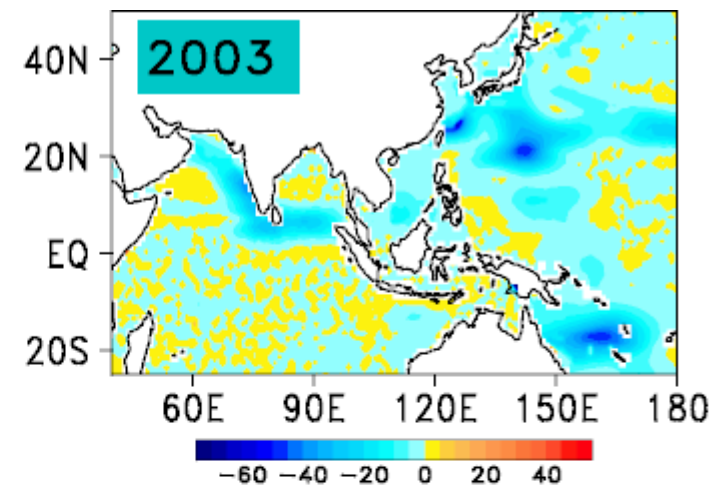
The impact of identification of manufacturer

Experiment:

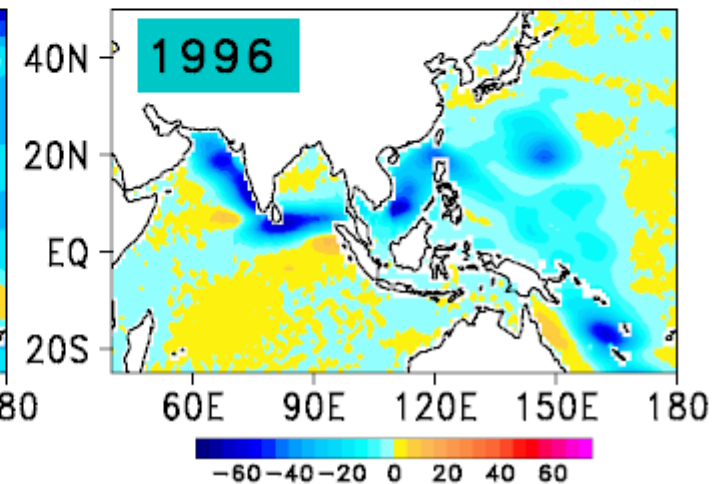
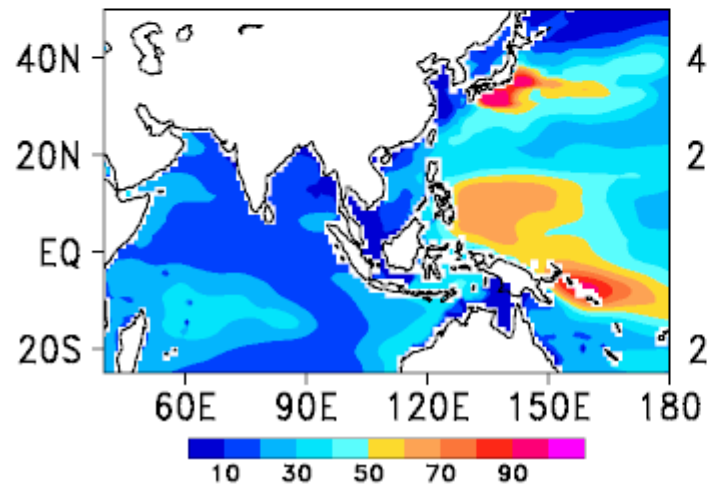
Applying SIPPICAN corrections to TSK XBT of WOD09.

- Along the ship roots, differences are comparable to standard deviation.
- In the north Indian Ocean with small standard deviations, the impact is significantly large.

Normalized thermosteric sea level differences to the original analysis

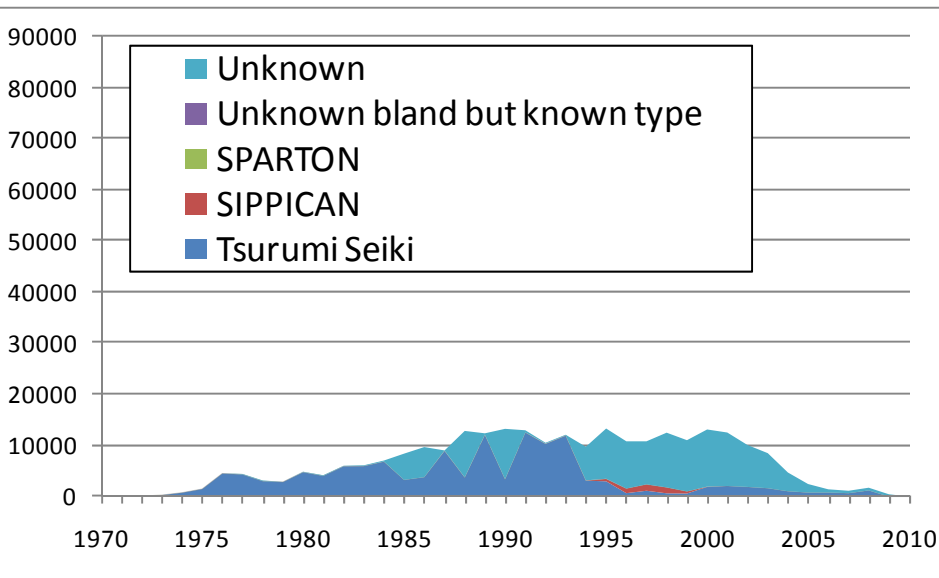


Therosteric sea level annual SD [mm]

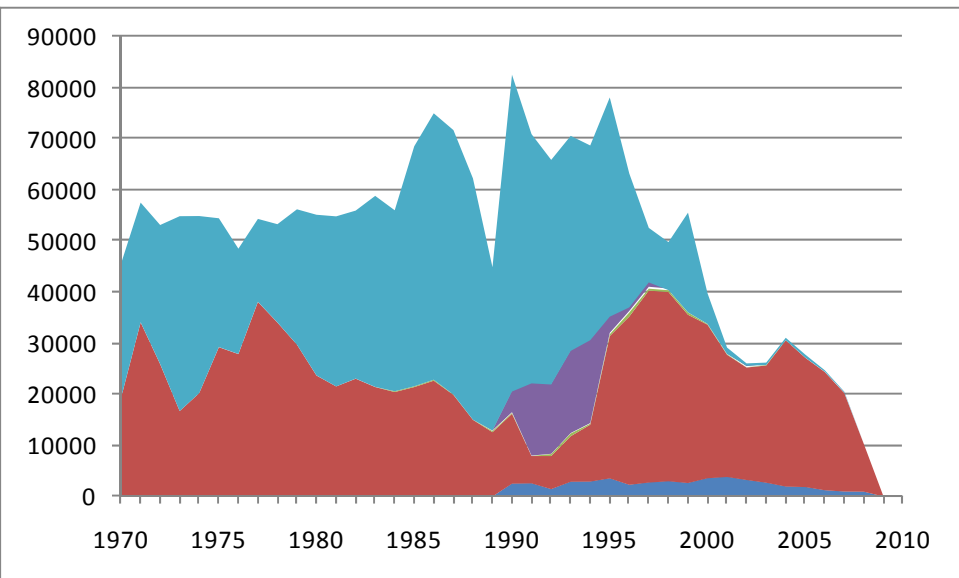


JODC archived data

Japanese data
archived in Japan Oceanographic Data Center

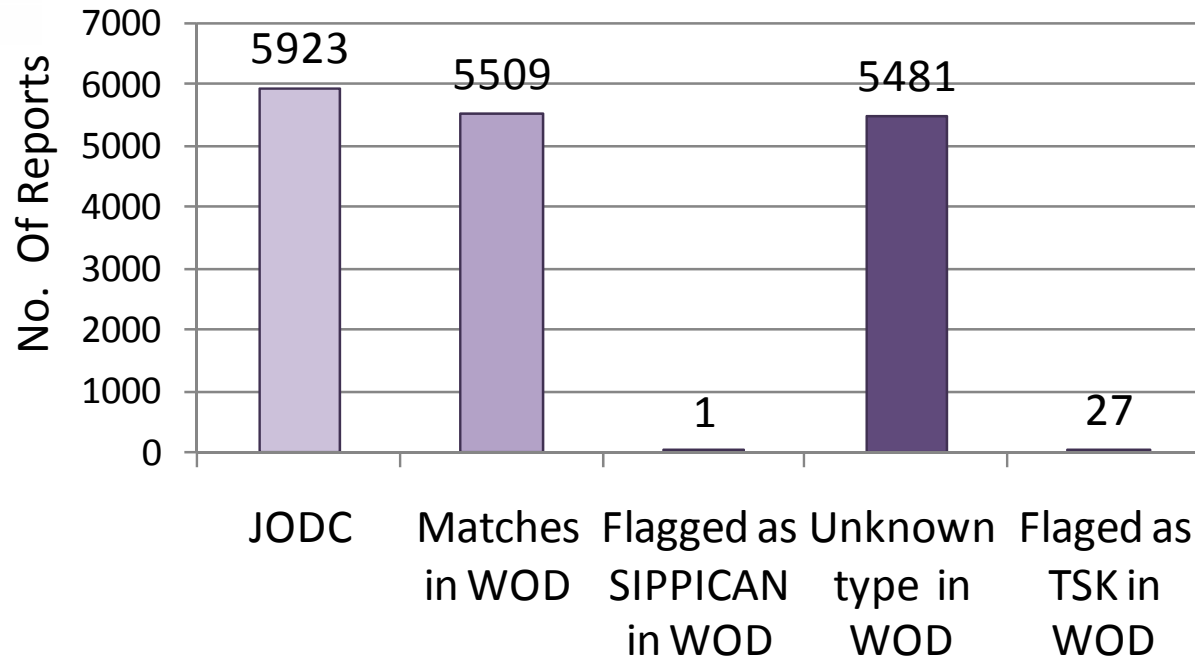


WOD09



- JODC archives many TSK observations even before 1990 although a few observations are flagged as “TSK” in WOD09.
- Many of Tsurumi Seiki data may be flagged as “Unknown” or “Unknown bland” or not be archived in WOD09 especially before 1990.

An example – 1982 case –



- 5923 Japanese XBT observations in 1982 are archived in JODC.
- In those 5923 observations,
 - 5509 observations are identified in WOD09 (the same location and time).
- In those 5509 observations,
 - 1 observation of “TSK” is flagged as “SIPPICAN”.
 - 5481 observations of “TSK” are flagged as “Unknown”.
 - Only the other 27 observations are flagged the correct type and manufacturer.

Summary

- ❑ For global and regional OHC monitoring, temperature biases in historical XBT observations cause large uncertainty since the 1970s, and still large even in recent years.
 - ❑ Global OHC differences between with/without the XBT bias correction are larger than the analysis errors.
- ❑ XBT probes of individual types and manufacturers should have different characteristics of bias among them.
 - ❑ We should correct XBT-probe dependent biases properly.
 - ❑ Meta data such as probe types, manufacturers, flags of correction are needed to reduce the uncertainty in OHC.
- ❑ There may be some meta data which are not archived in WOD.
- ❑ We are attempting to re-build the XBT data base of Japanese observations.