Empirical correction on XBT fall rate and its impact on heat content analysis

Hamon M., Le Traon P.Y., Reverdin G.

presented by Guinehut S.

Introduction

- Expendable BathyThermograph (XBT) system does not measure directly the depth of the probe, it uses a fall rate to estimate it

- Is there a correct depth equation for correcting temperature as a function of depth from XBT that could be applied to the global datasets ?

- Gouretski and Koltermann (2007) used a CTD climatology to identify a positive temperature bias of XBT

- Wijffels et al (2008) proposed a yearly correction which is a linear function of the depth

- Levitus et al (2009) used a simpler temperature correction to estimate the ocean heat content

Introduction

- The W08 correction is a reference for the treatment of XBT, but how does this correction vary with the method of comparison of XBT and CTD profiles ?

- Correcting individually each type of XBT cannot be envisionned but can we refine the W08 correction including regional correction ?

- What is the impact of such a correction on the calculation of the ocean heat content ?

Data and method

- We used WOD05 profiles, interpolated to standard levels
  - CTD and OSD are our reference profiles
  - XBT have been processed when identification was possible with the Hanawa correction (Hanawa et al 1995)

- Rather than to use climatologies as W08, we used a collocation method (1°lat*2°lon*15 days)
  - For each individual XBT profile, we calculated the median of all CTD/OSD selected in the collocation area, to obtain a single reference profile
  - Using the median is preferred for this kind of data distribution, it reduces influence of outliers
  - Every XBT profile less deep than 200-m have been removed
  - Large influence to oceanographic cruises where CTD/XBT jointly deployed

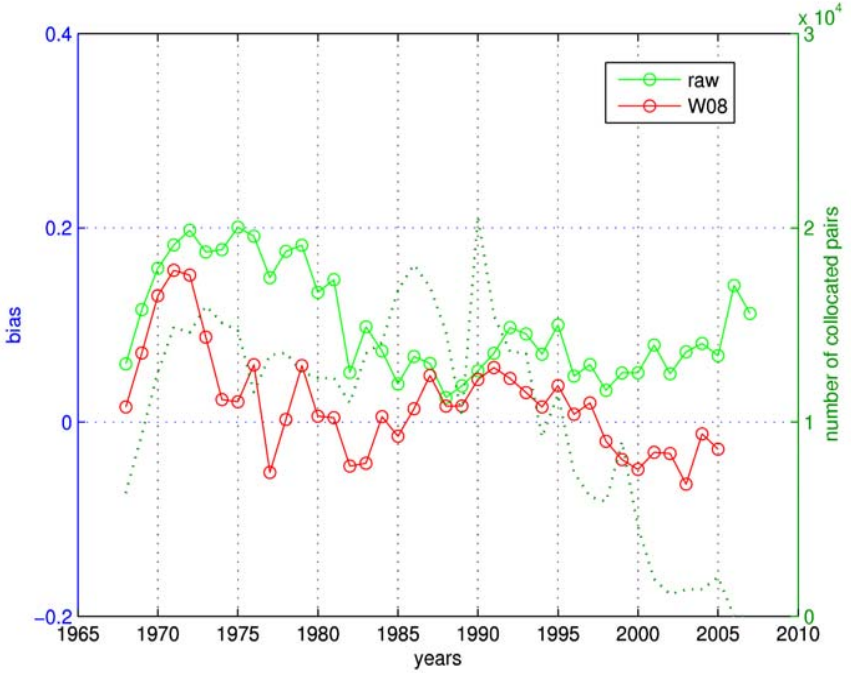
- This method allows us to capture about 10^4 XBT profiles per year between 1967 and 2008. 10% of XBT profiles associated to a reference profile

Test of the W08 correction

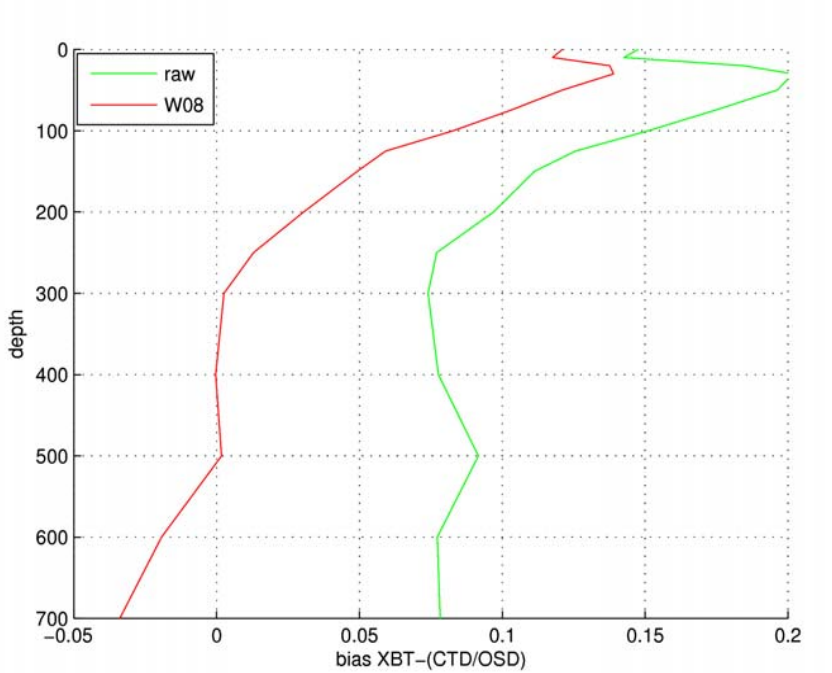
- The W08 is a linear annual correction on depth. It separates XBTS (shallow) and XBTD (deep):

$$Z_{true} = Z(1 - r)$$

- The W08 corrections have been applied to our collocated profiles



XBT-CTD median bias = original depth eq. (green) and corrected by W08 (red) integrated between 0 and 700m.



Median bias = original depth eq. (green) and corrected by W08 (red) function of depth on average over the study period.

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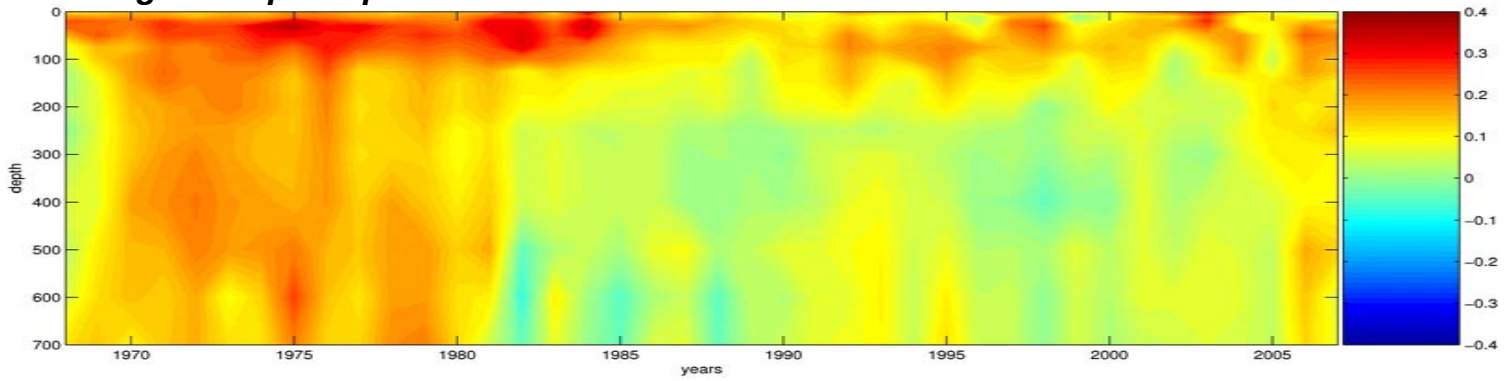
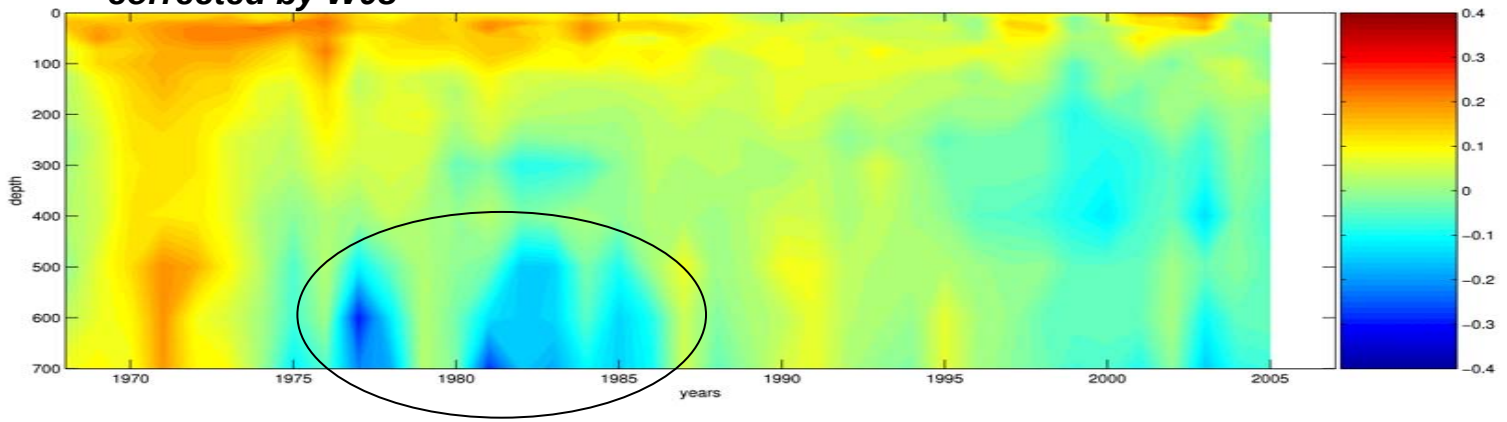
Test of the W08 correction

original depth eq.



corrected by W08



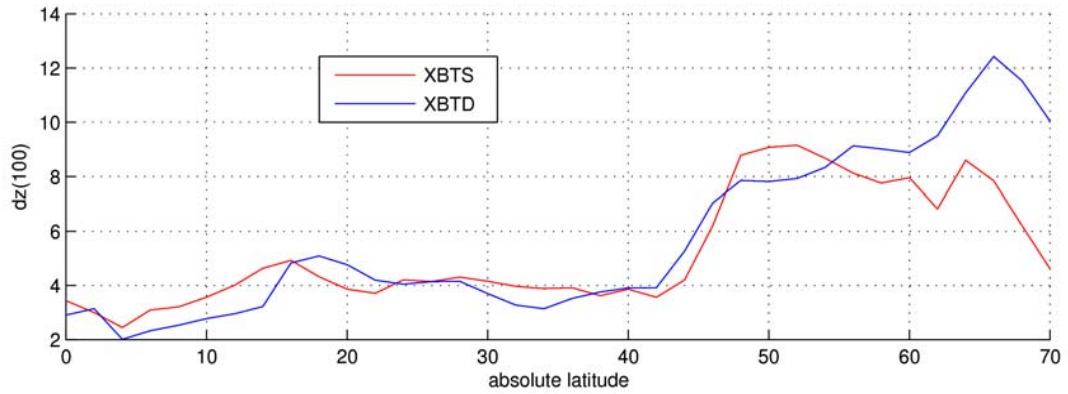
Evolution of the median bias as a function of depth and years

- The linear correction is not always performing well (with our collocation method) especially between 1975 and 1985. It provides too strong correction below 500m depth and a too small correction for surface layers.

A new correction

Second order correction

- Annual median depth correction computed using: $$dZ = (T_{CTD} - T_{XBT}) \frac{\delta Z}{\delta T_{CTD}}$$
- The difference between collocated profiles do not seem to indicate a linear function for depth correction, but rather a second order function with an offset,
- Between the surface and 30m, the bias doesn't follow a parabolic behavior because of high variability noise due to the surface mixed layer.
- Correlation between depth correction term and the deployment latitude.

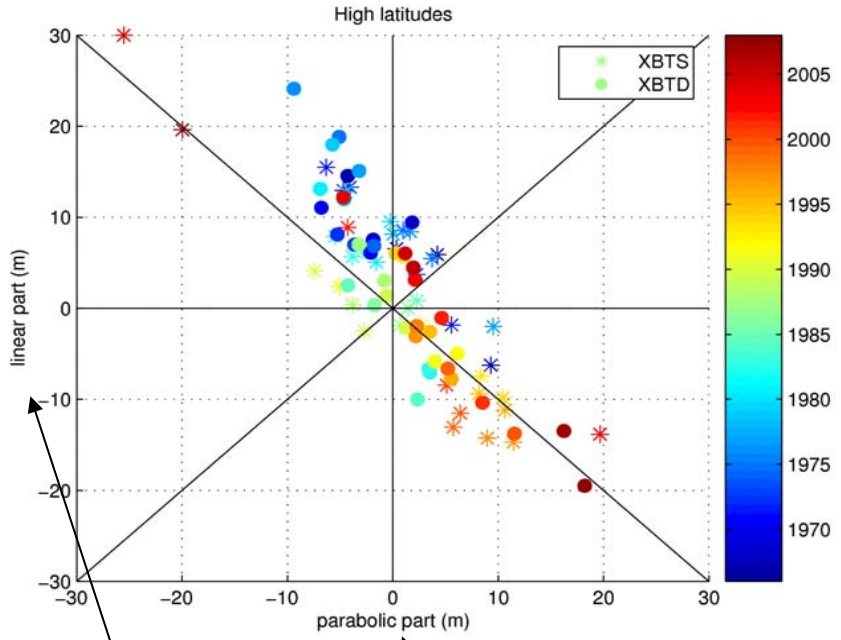


We can't distinguish XBTS to XBTD comparing depth correction at a given depth.

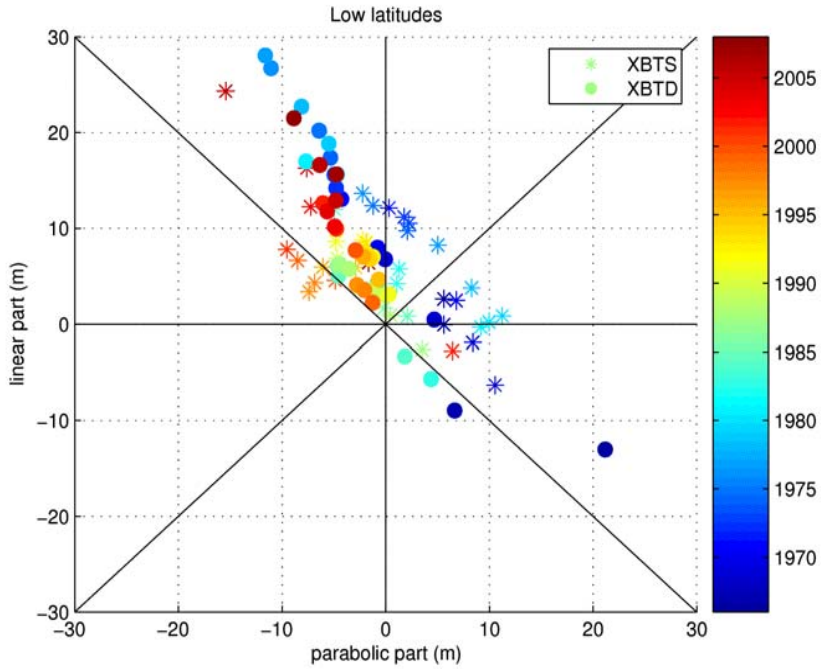
Median XBT-CTD depth bias at 100m function of absolute latitude for XBTS (red) and XBTD (blue)

A new correction

Second order correction



Linear part function of parabolic part and years in meters, at 400m for XBTS (stars) and XBTD (filled circles).



$$Corr = A(t,xbt,lat)z + B(t,xbt,lat)z^2 + OFFSET(t,xbt,lat)$$

➔ **Separation of XBT into 4 classes:**

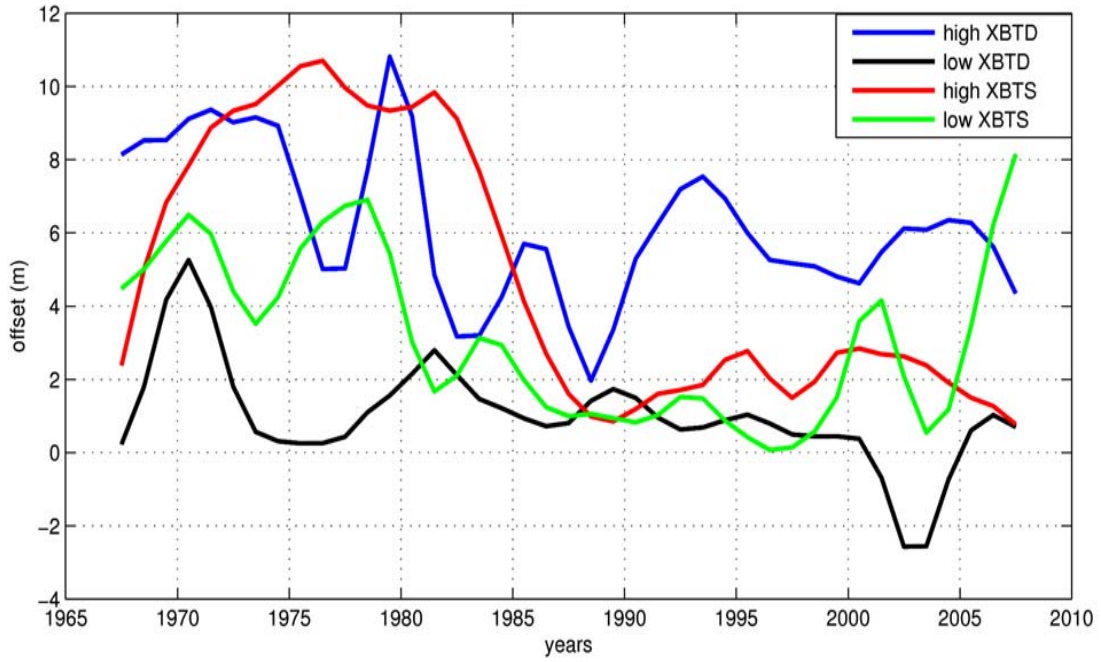
- XBTS and XBTD
- Low and high latitudes (40°N/S)

➔ **Different behaviors between the 4 classes**

A new correction

Offset

- An offset is necessary and is computed in an empirical fashion.
- An offset could be justified by human mishandling (drop height in board, probe can touch the surface not vertically...) and environmental factors (swell, waves...).
- It's calculated to minimize the temperature bias on the profile between 30m and 200m.

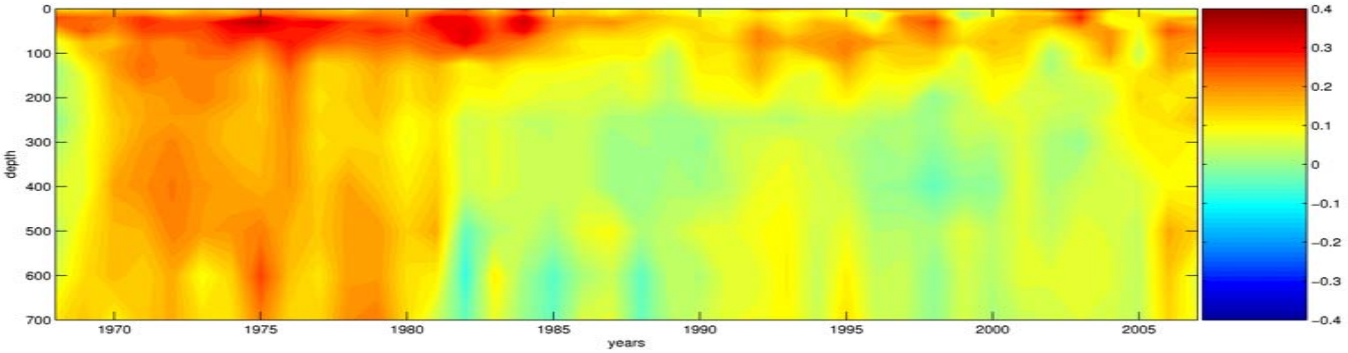


➔ Maximum of the offset between 1970 and 1985.

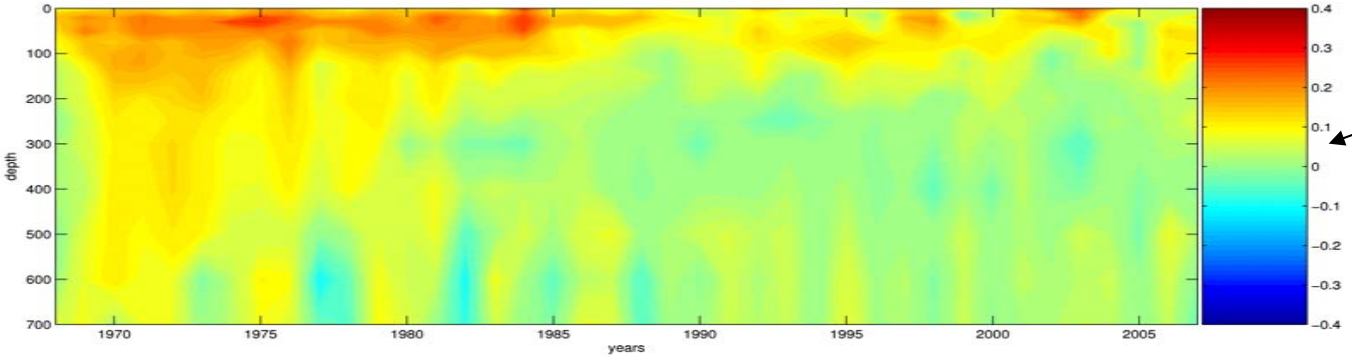
Offset in meters calculated for XBTD deployed in high/low latitudes (blue/black) and XBTS deployed in high/low latitudes (red/green) function of years.

Results

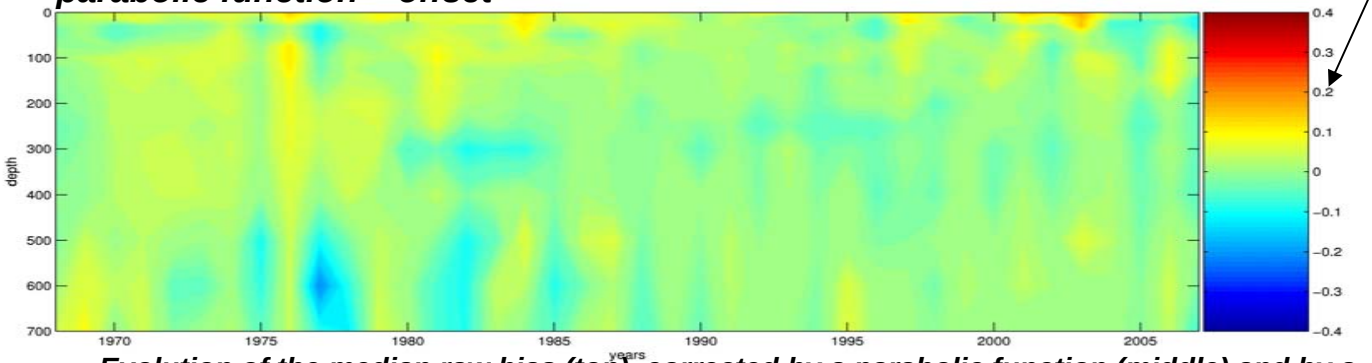
original depth eq.



parabolic function



parabolic function + offset



Evolution of the median raw bias (top), corrected by a parabolic function (middle) and by a parabolic function added an offset (below) funtion of depth and years.

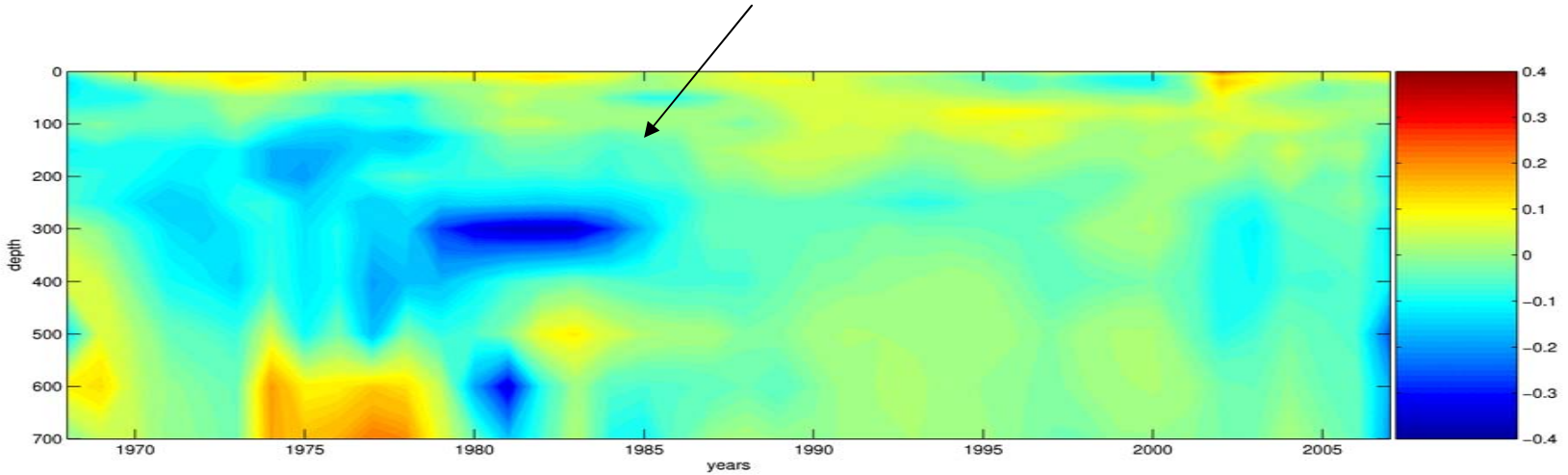
The correction reduces the median temperature bias.

Contribution of the offset is significant.

A new correction

Specific case

- A strong negative temperature bias is found in the western Pacific (from 0 to 60°N, West of 180°W) after the global correction.
- It is predominantly located at 300m between 1970 and 1985.

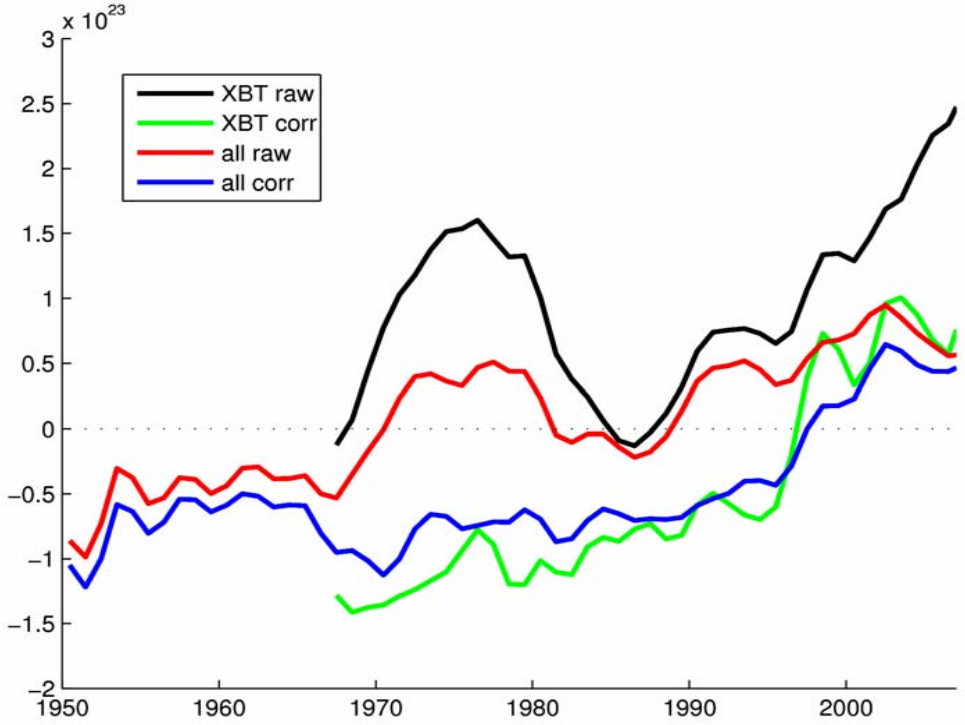


Evolution of XBT-CTD median globally corrected bias for XBT deployed in western Pacific, function of depth and years

➔ A regional correction is available

➔ These profiles (years 1968 to 1985) have been separated from the global dataset

Heat content analysis



Evolution of [0-700] m ocean heat content calculated from only WOD05 XBT (black), corrected XBT (green),all data from WOD05 (red) and all corrected data (blue)

- The calculation of the ocean heat content confirms that on average XBT temperature data are now closer to CTD temperature data.
- Using the same methodology, we corrected MBT (second order correction and an offset, latitude classes).
- We finally found a heat content linear trend of $0{,}4.10^{22} J/yr$ between 1970 and 2008.

Conclusion

- According to W08, XBT are subject to a depth bias varying with the year of deployment.
- However, our collocation method reveals that this bias should be better corrected with a second order function added to an offset.
- Behavior of XBTS and XBTD are quite different and depends on the latitude of deployment.
- We confirm that the maximum of heat content during the 70's in early papers can be explained by the XBT bias.
- In addition, a linear trend of $0{,}4.10^{22}$ *J*/yr is apparent between 1970 and 2008 (identical to Levitus et al, 2009).
- We have now available a corrected database and we are now working on field reconstruction using a EOF method (DINEOF, Beckers et al , 2003).
- We can provide the correction table (contact: **mathieu.hamon@ifremer.fr**).