A new method to estimate the systematic biases of XBT

(improper fall-rate, pure temperature error and start-up transient)

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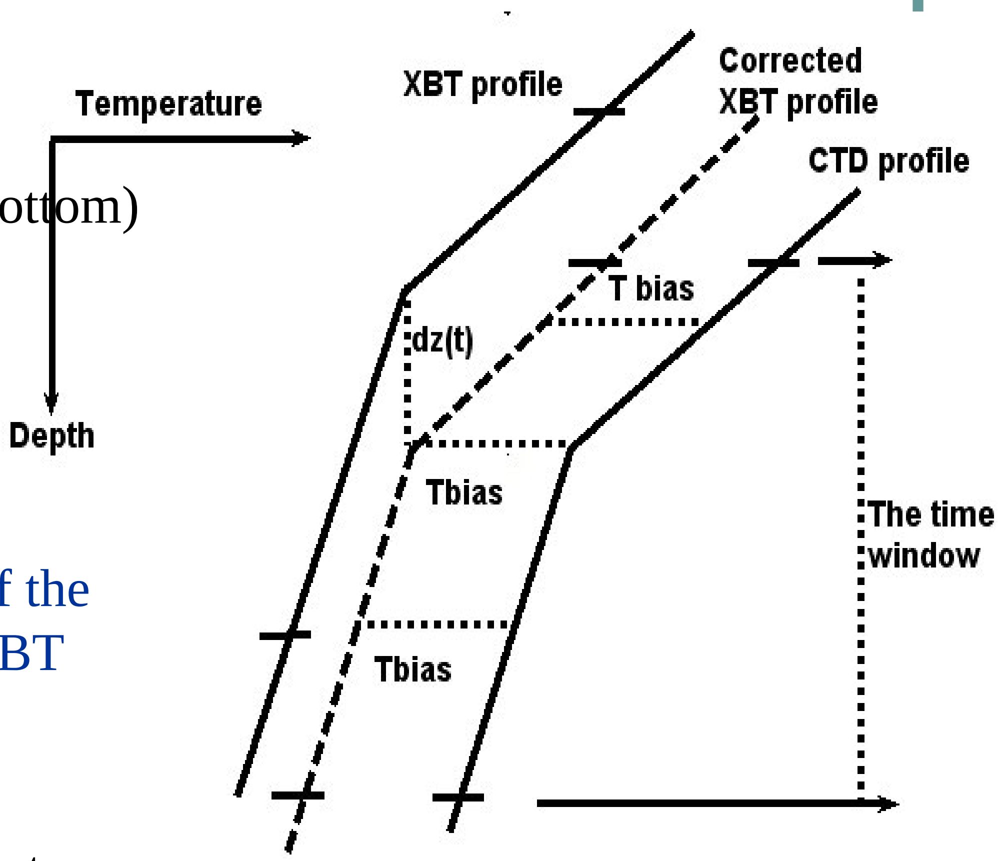
1. The new method: Introduction

- **Assumption:**
- The fall-rate equation:

$$Z(t) = At - Bt^2 - transient$$

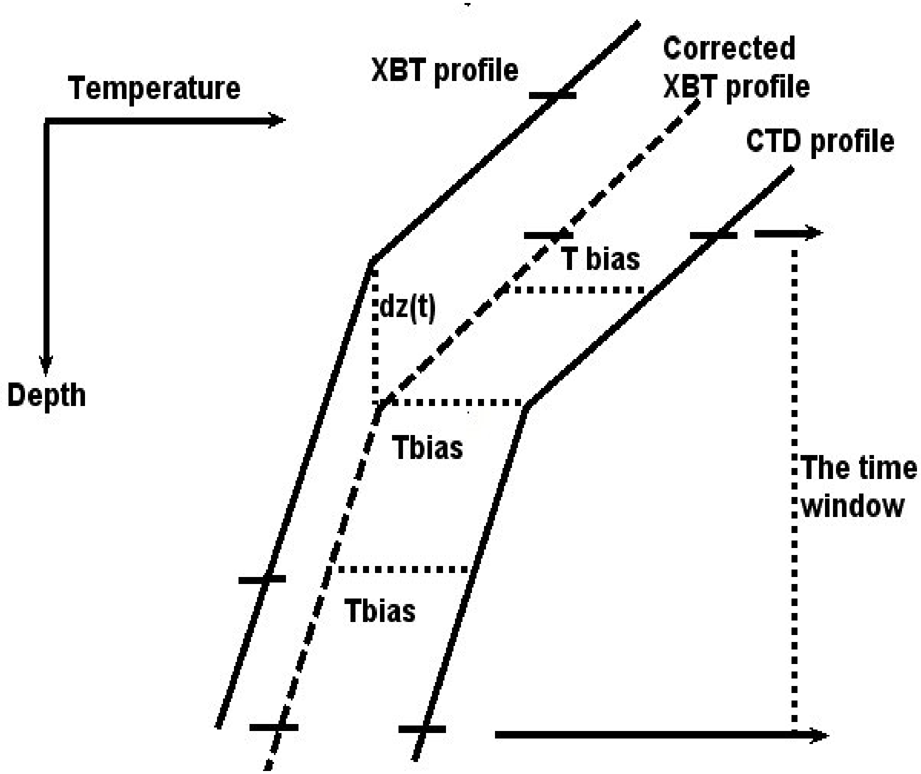
- The falling should be stable(20m-bottom)
- **Principle:**
- **Depth-error**
- Shift up and down – *transient*
- Stretch or shrink– *A, B*
- ---To minimize the std. deviation of the temperature differences between XBT and CTD profile.
- **Pure temperature error**
- Regression for the temperature offset after removing depth-error

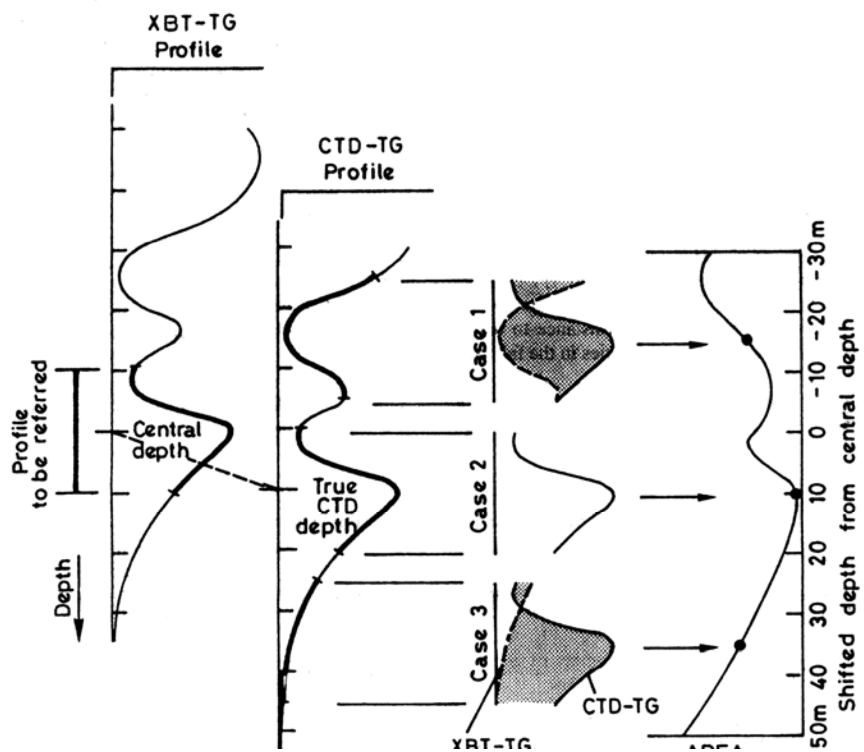


Time windows
---To reduce the impact of the inconstant pure temperature offset.

1. The new method: Introduction

Compared with the standard Hanawa et al. 1994,1995 method.





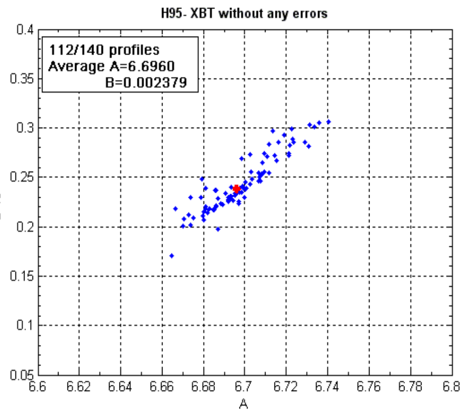
- **The new method focuses on temperature profile instead of temperature gradient profile.**
- **The new method introduces the correction for the error of start-up transient.**
- **Minimize the std. deviations instead of the temperature differences.**

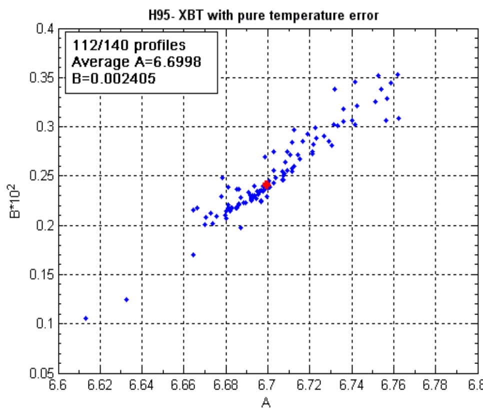
Theoretically, the new method is more noise-resistant because it uses the integral property instead of gradients

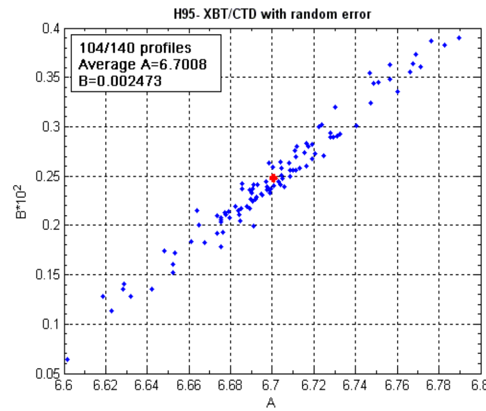
2. Test on simulated data

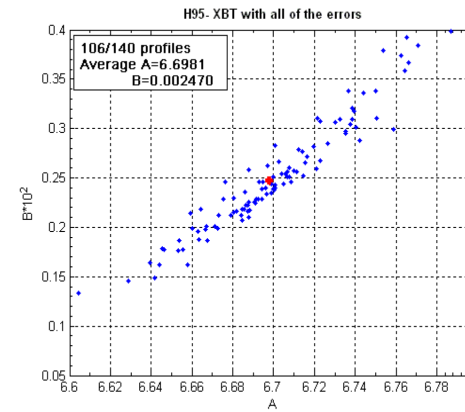
5.1 Comparison of Hanawa et al. 1995 (H95)vs. new method by computing simulated XBT vs. CTD profiles. Different XBT/CTD errors are added.

H95







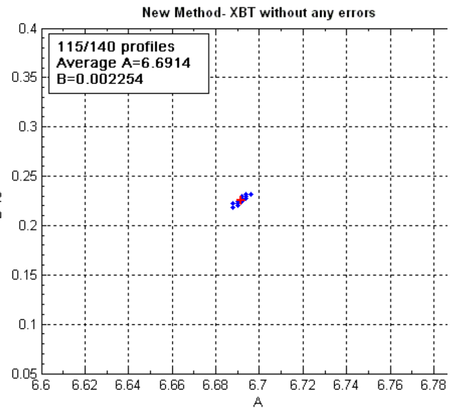


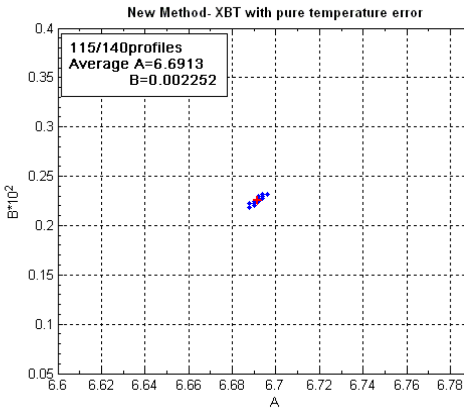
improper fall rate error

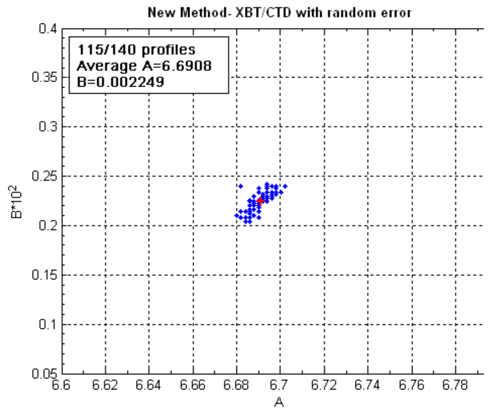
improper fall rate error
pure temperature error

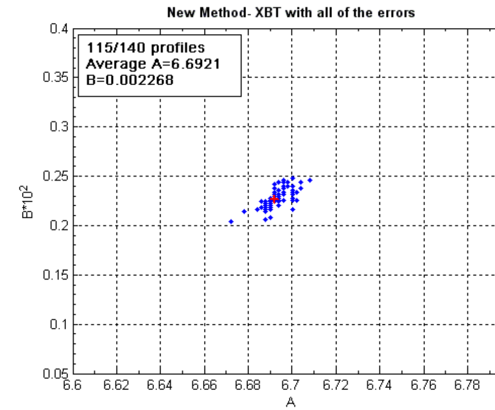
improper fall rate error
XBT/CTD random error

all of the error sources







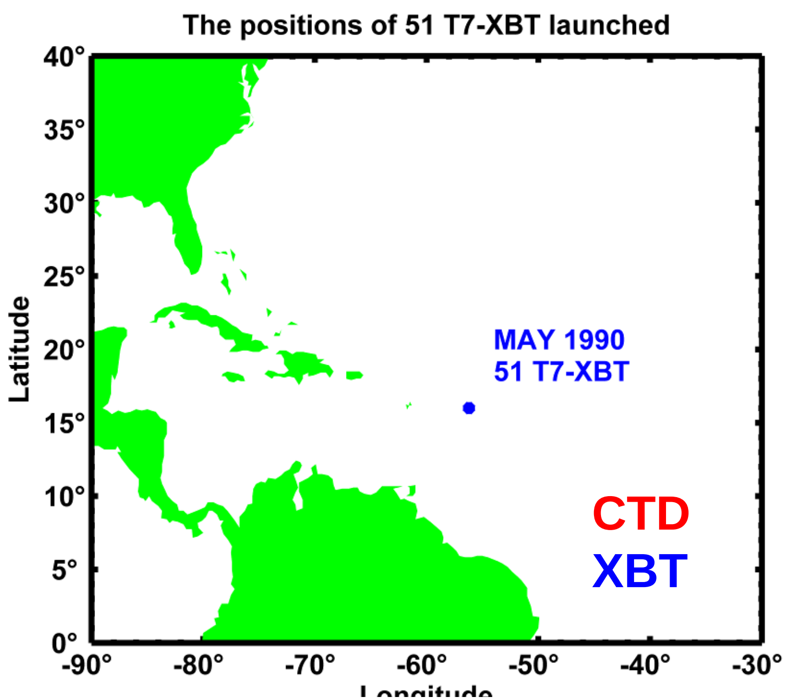


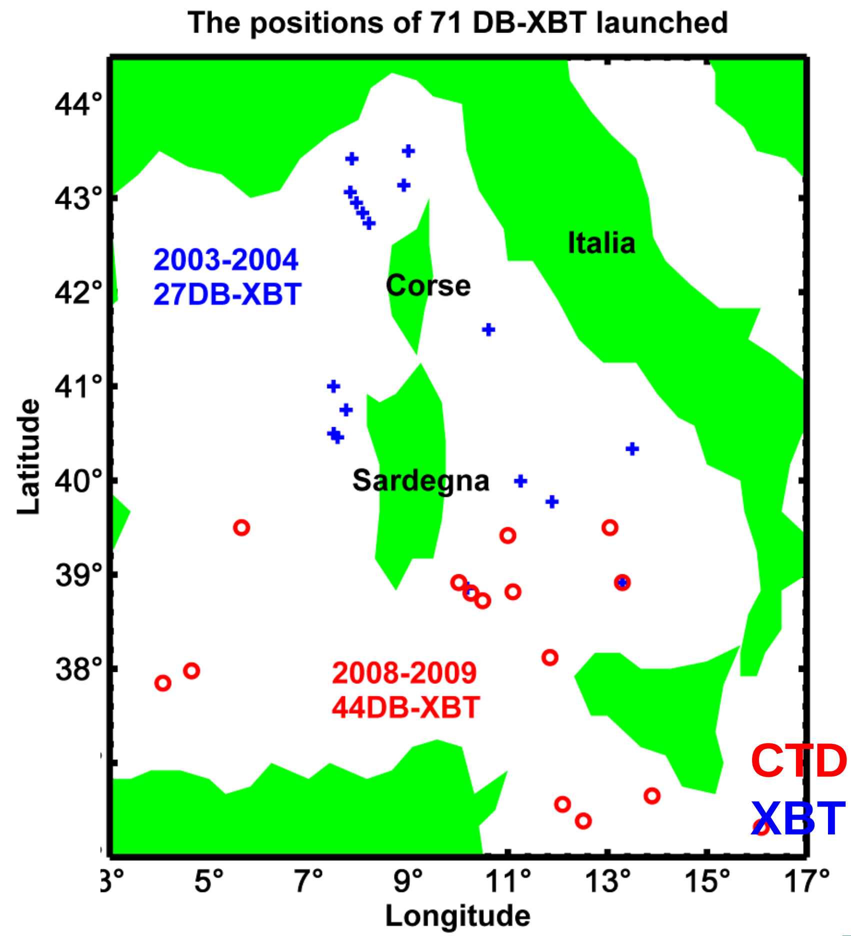
new method

The actual coefficients as our assumptions A=6.691m/s B=0.00225m/s^2

3.Application: XBT/CTD comparison experiments

3.1 Locations of the experiments





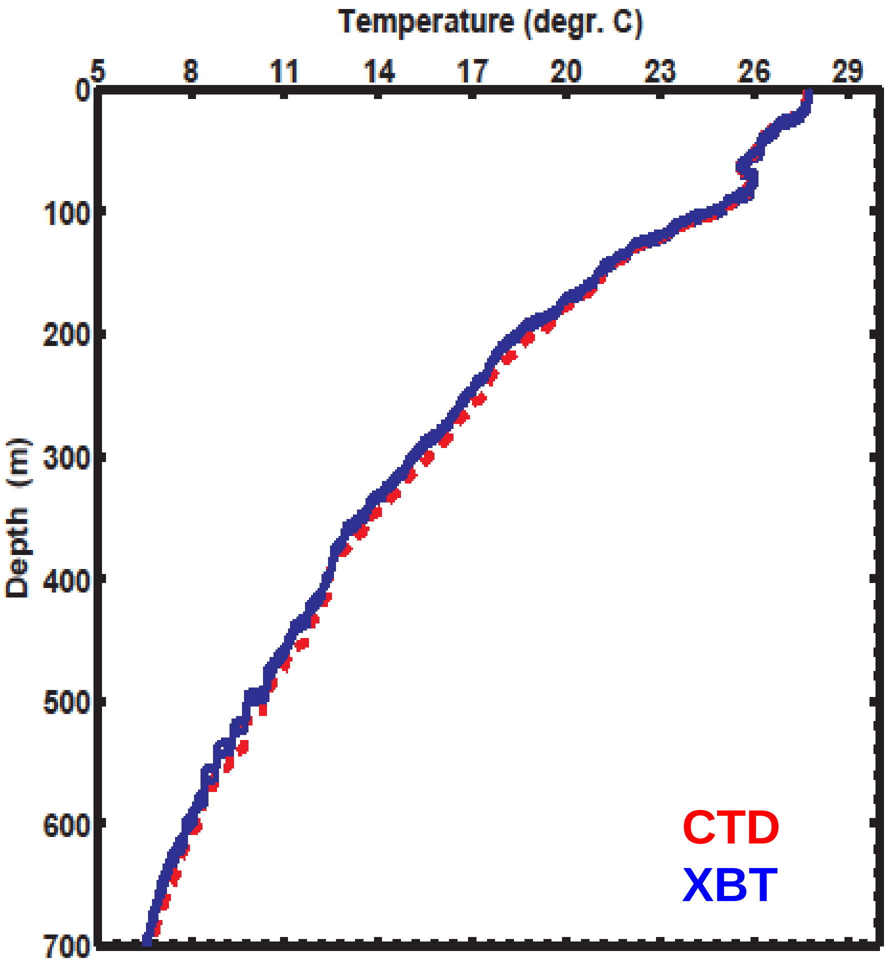
Group 1. Teague et al., 1990

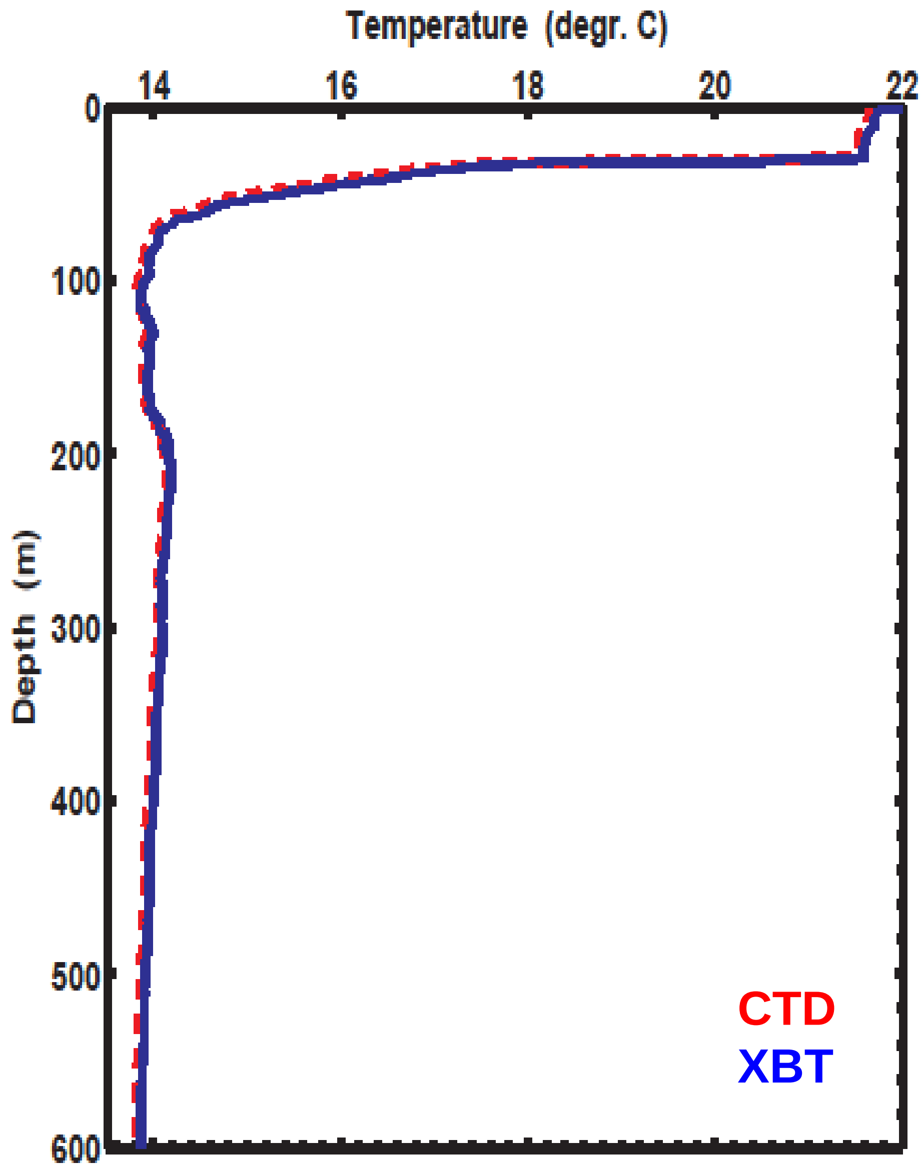
Hallock and Teague 1992

Group 2. subgroup1: 2003-2004

subgroup2: 2008-2009

Reseghetti et al. 2007





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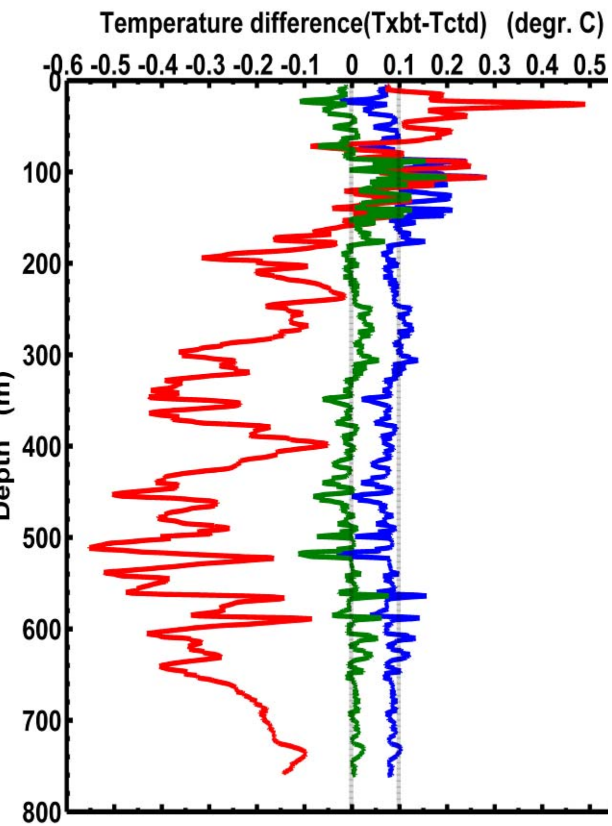
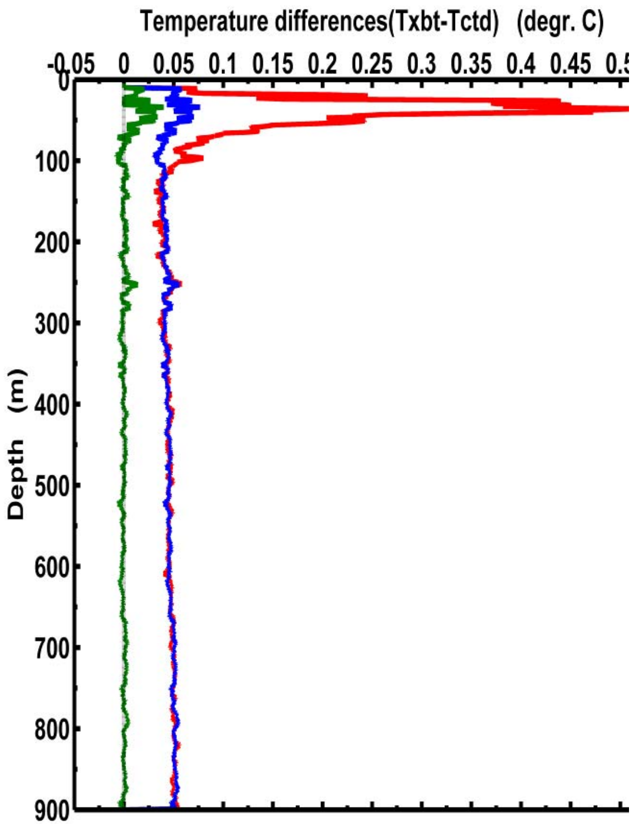
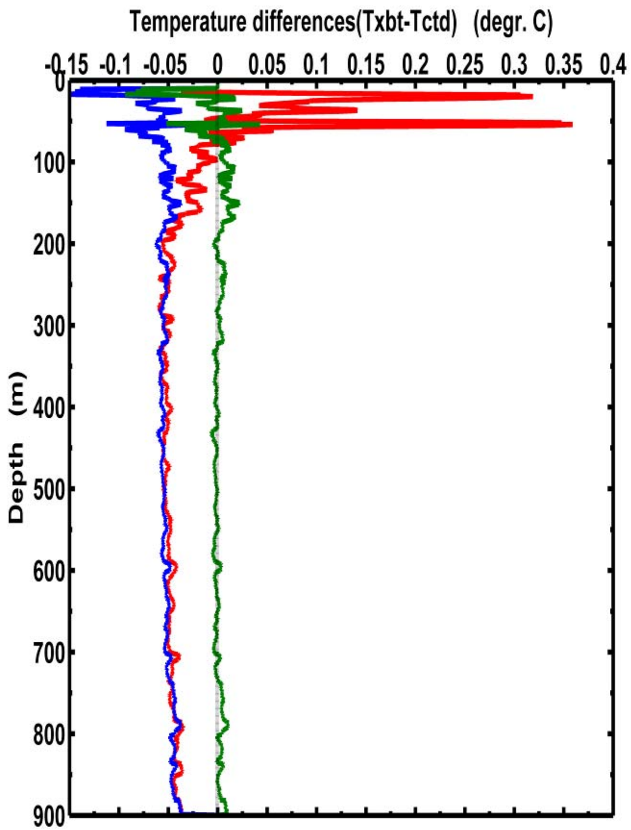
3.Application: XBT/CTD comparison experiments
3.2 individual corrections



Group1



Group2.1



Group2.2

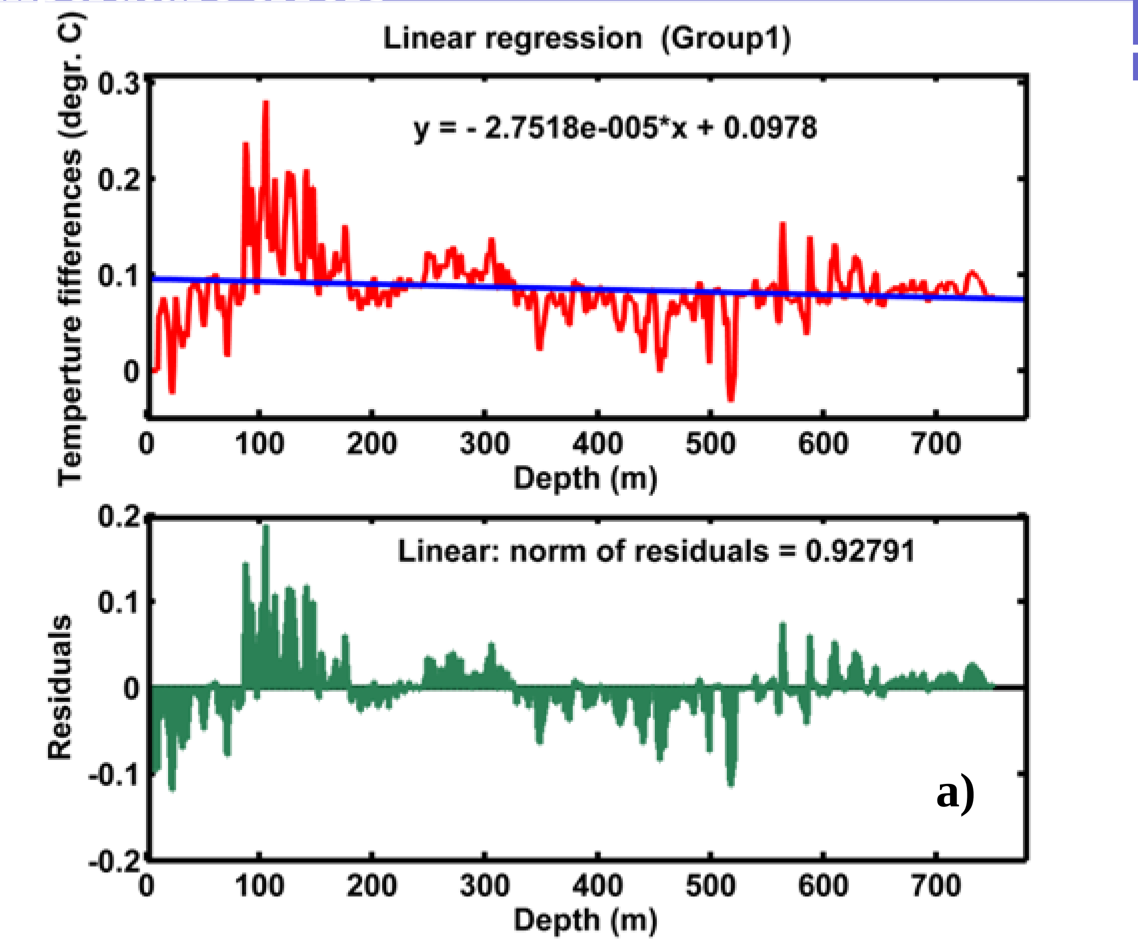
Red: Without any corrections

Blue: Remove depth-error

Deep green: Remove depth-error and pure temperature error

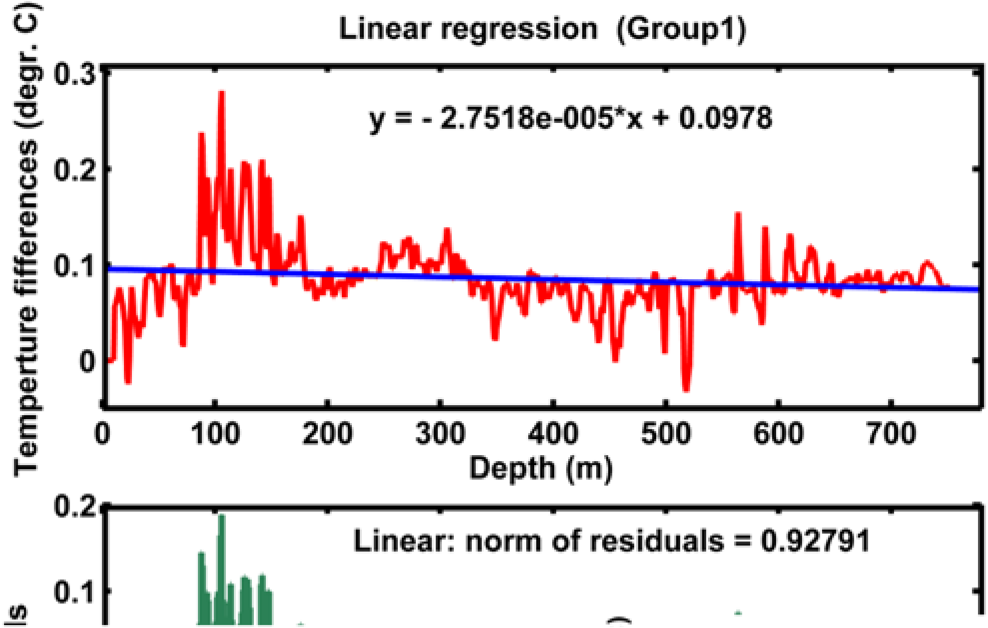
3.Application: XBT/CTD comparison experiments

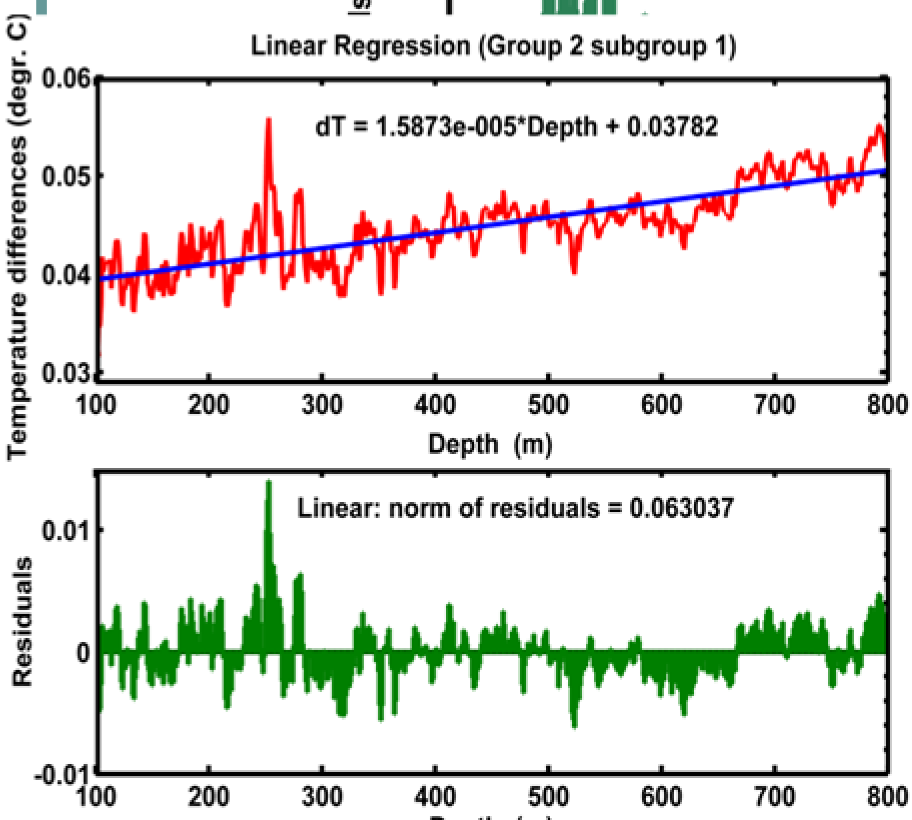
3.2 Pure temperature errors

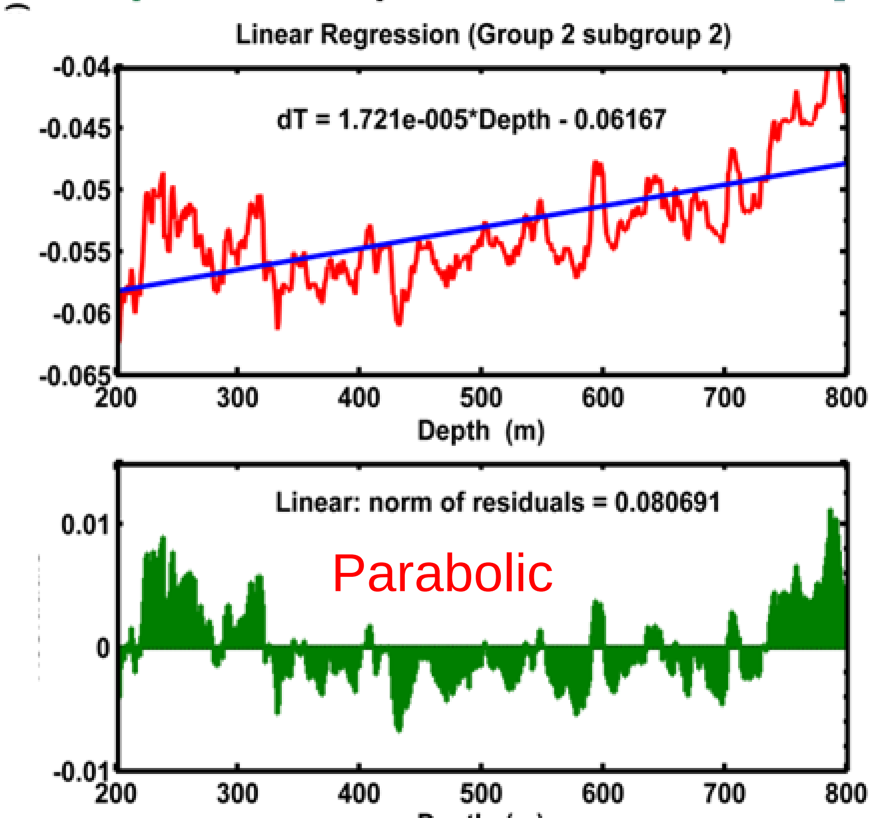


3.Applic iments

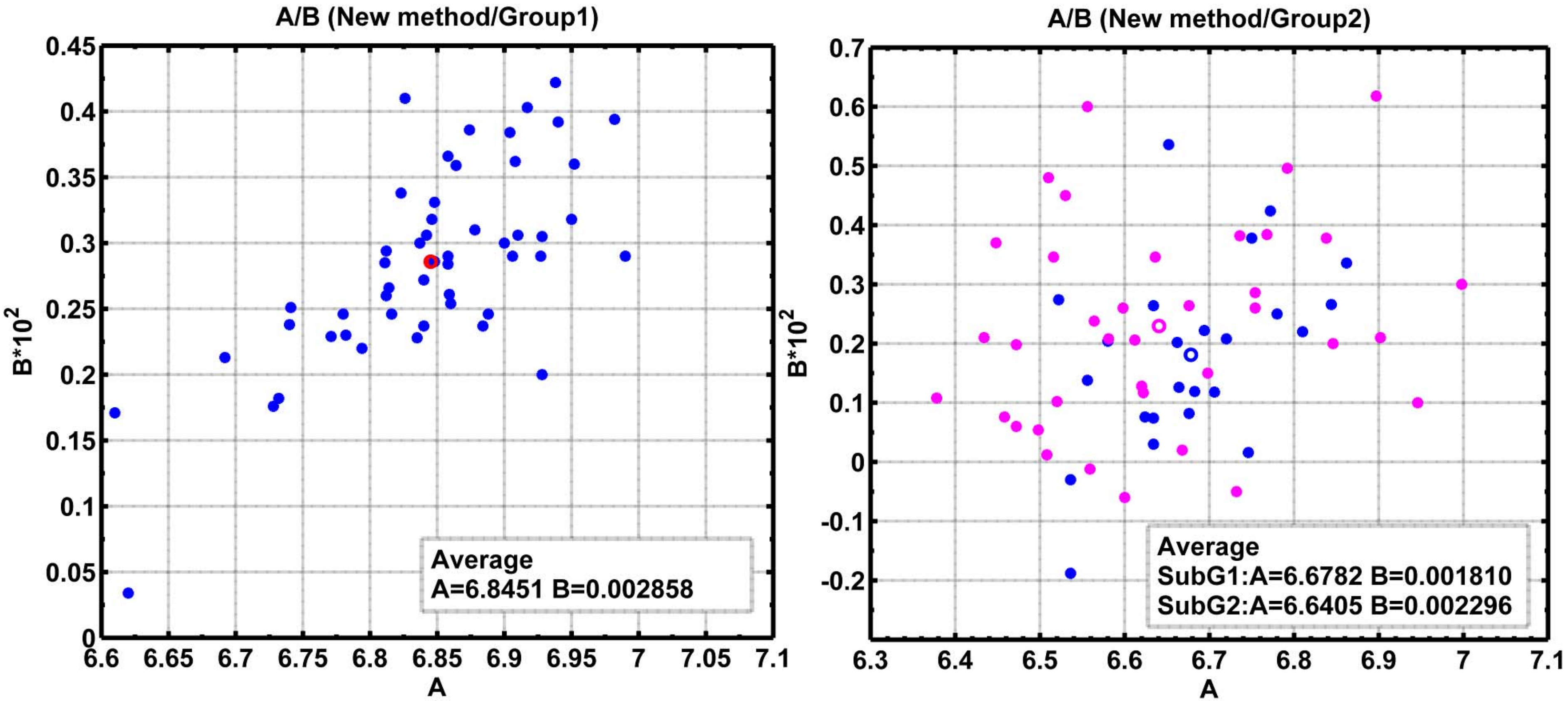
3.2 Pure ten





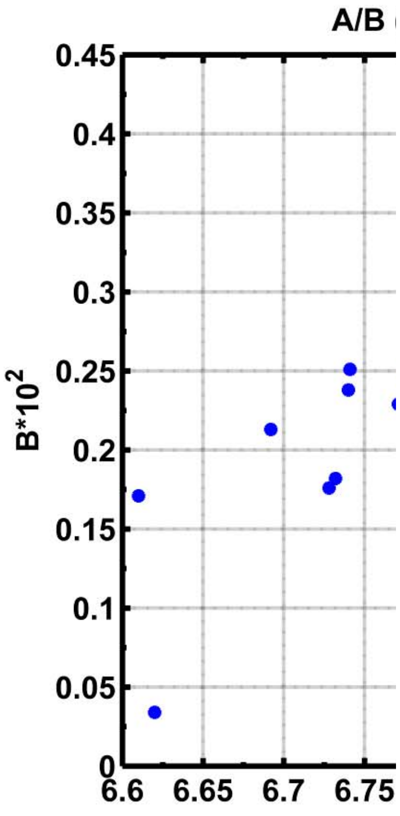


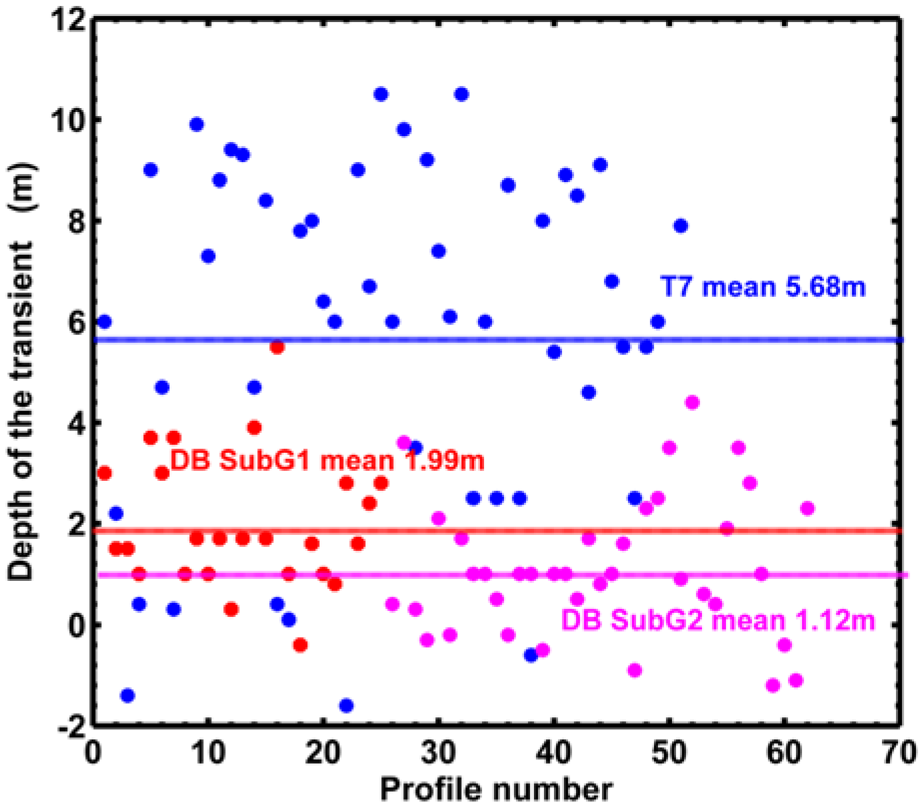
3.Application: XBT/CTD comparison experiments
3.2 individual corrections

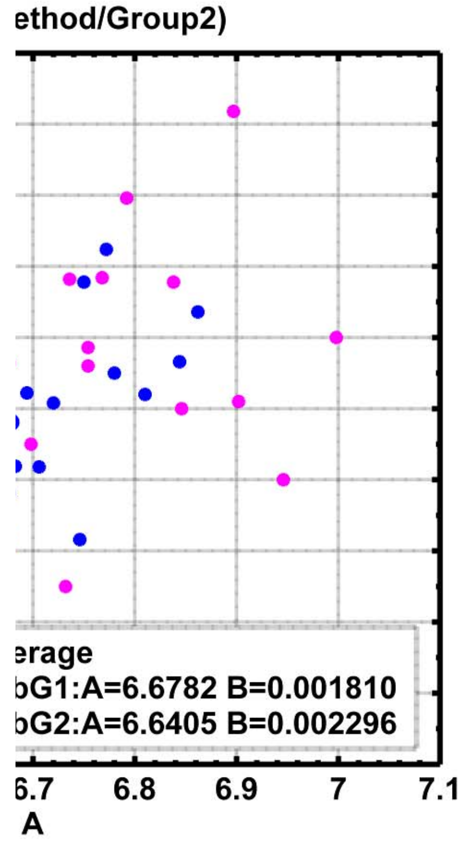


- **Group1:Z(t)=6.845t-0.00286t^2-Trasient ; Tbias=-0.0000275Depth+0.0957**
- **Group2.1: Z(t)=6.678t-0.00181t^2-Trasient; Tbias=0.0000159Depth+0.0378**
- **Group2.2: Z(t)=6.641t-0.00230t^2-Trasient; Tbias=0.0000172Depth-0.0618**

3.Application: XBT/CTD comparison experiments
3.2 individual corrections







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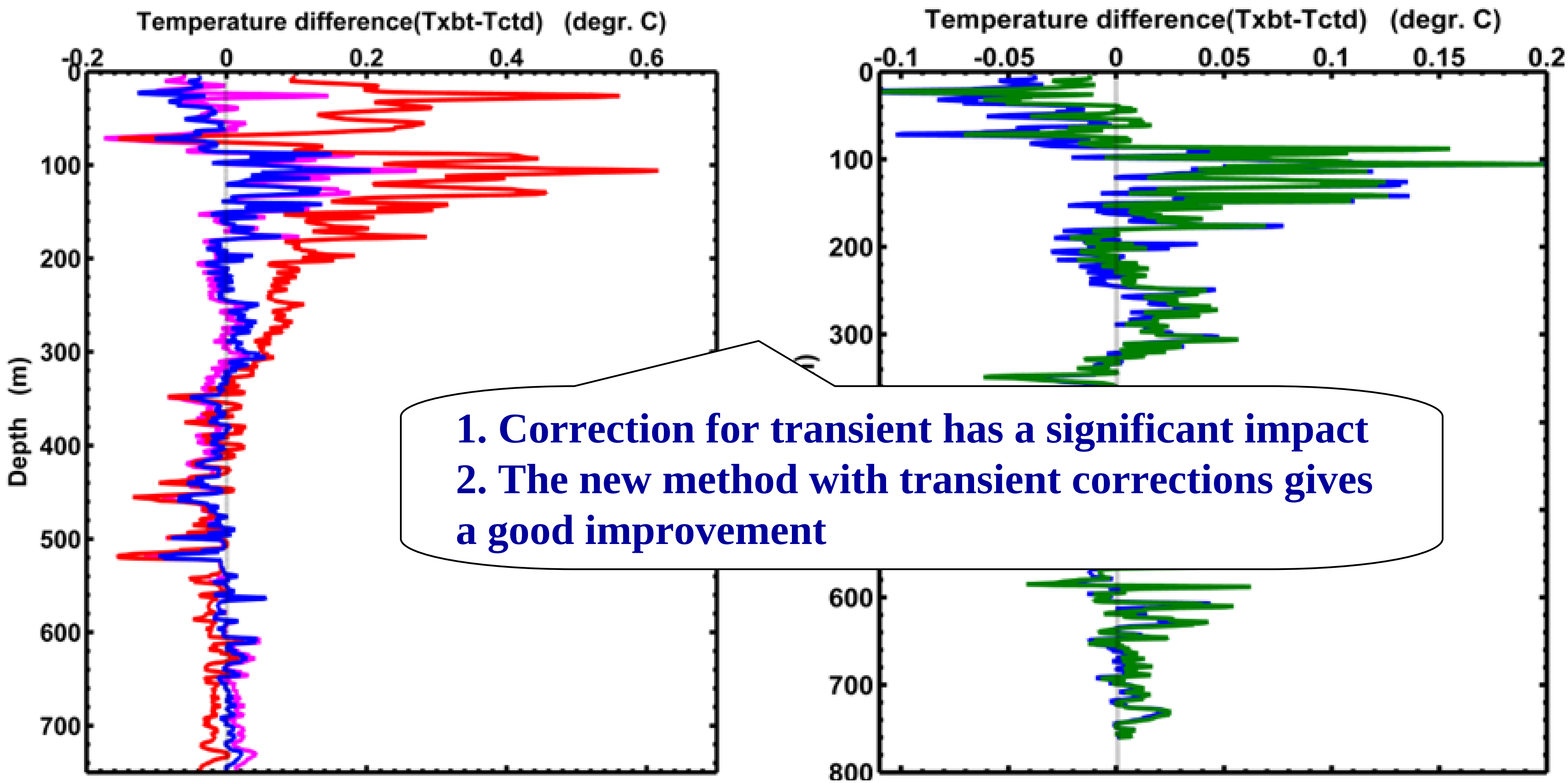
3.Application: XBT/CTD comparison experiments

3.3 Compared with Hanawa et al. 1994,1995, Group 1.

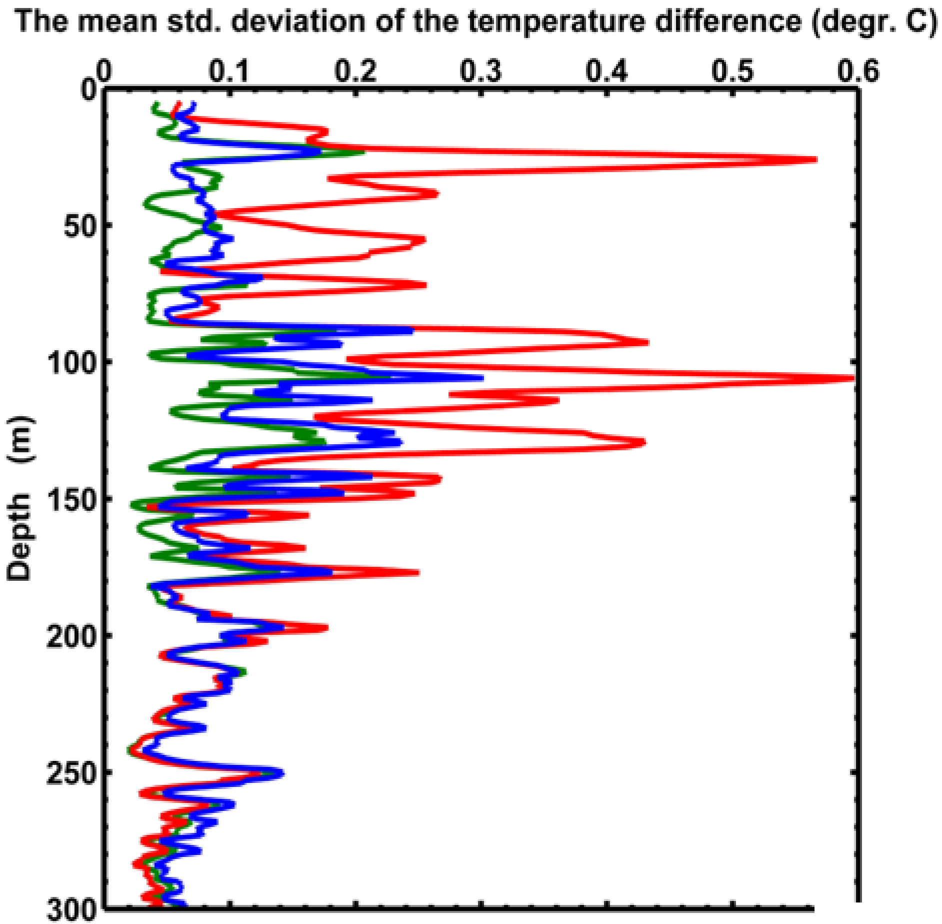


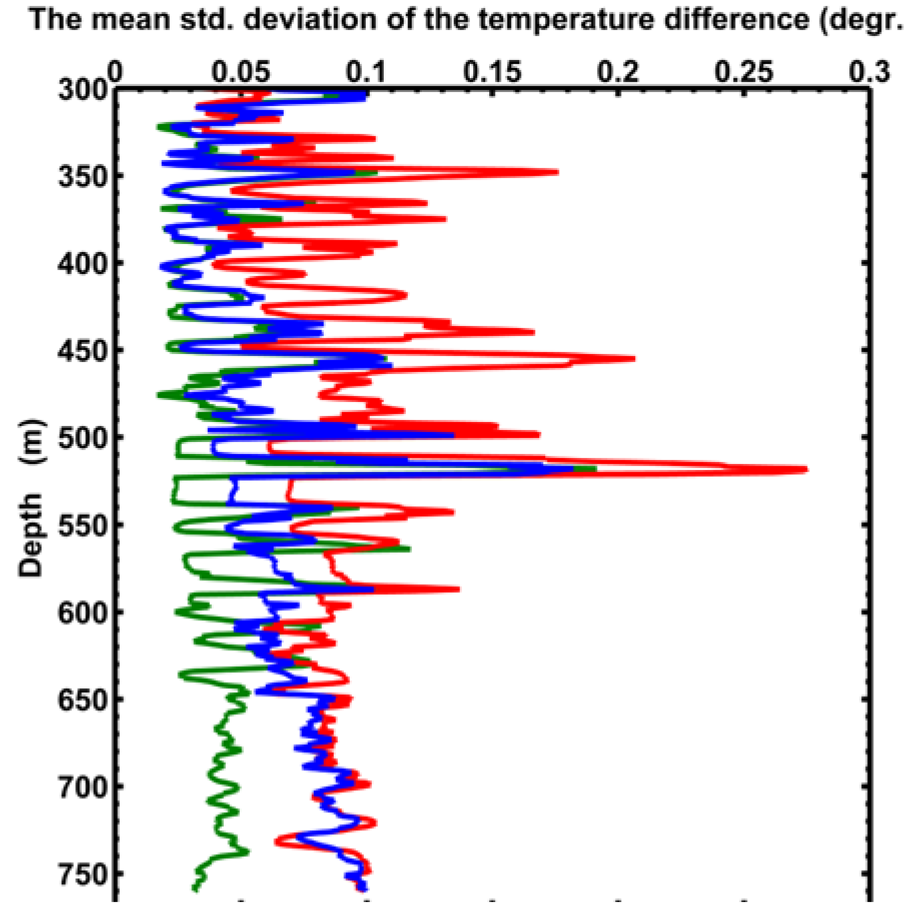
1. Correction for transient has a significant impact
2. The new method with transient corrections gives a good improvement

Red: H95
Blue: H95 with individual transient corrections
Pink: H95 with constant transient corrections (4.01m, Hallock et al., 1991)
Deep green: The new method with individual corrections

3.Application: XBT/CTD comparison experiments

3.3 Improvement of the standard deviation, Group 1.



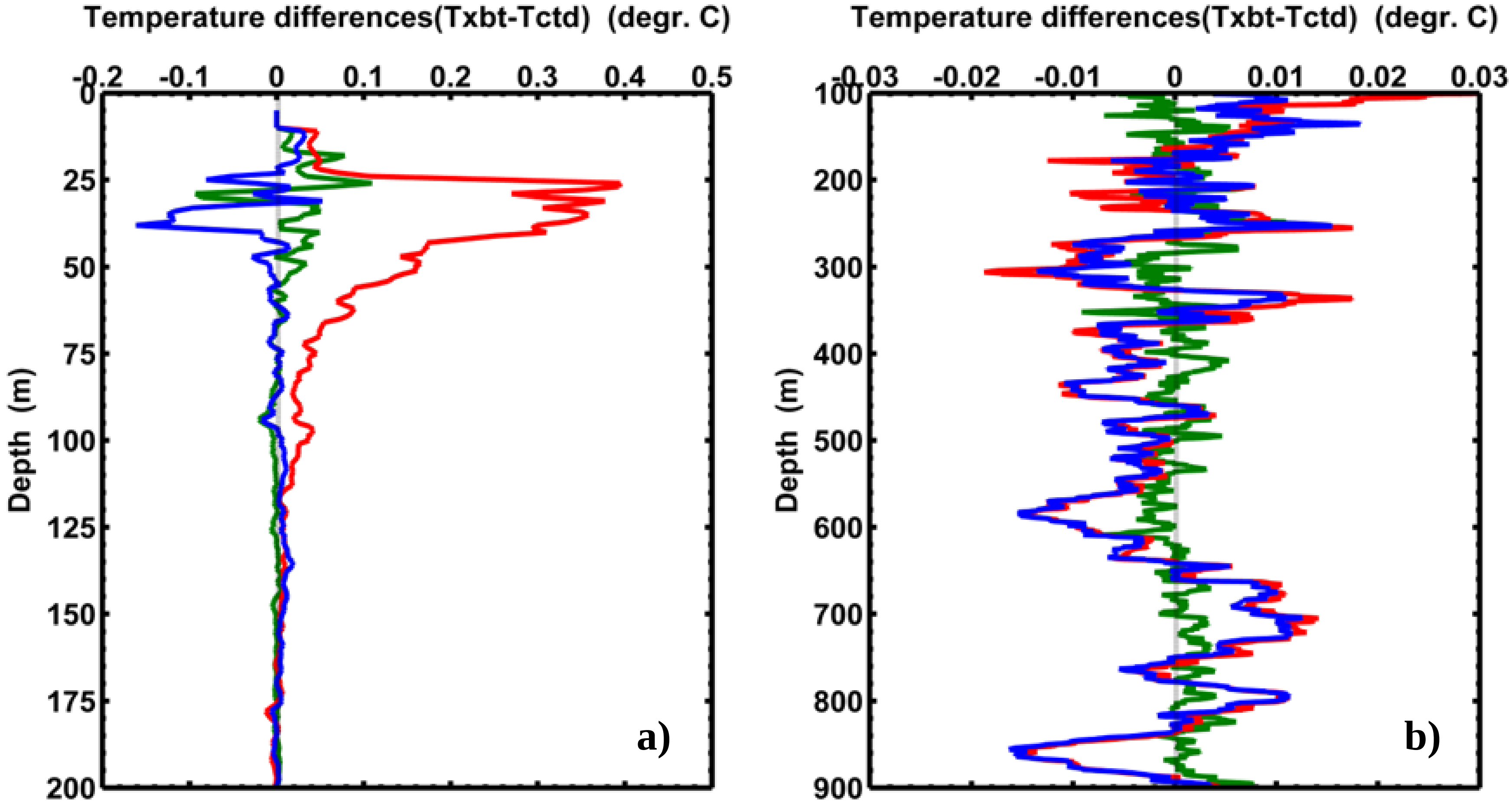


Red: H95
Blue: H95 with individual transient corrections
Deep green: the new method with individual corrections

The advantages of the new method are evident mainly in the thermocline (from the surface to 200 meters) and the small gradient regions (from 500m to 750m).

3.Application: XBT/CTD comparison experiments

3.4 Compared with Hanawa et al. 1994,1995, Group 2.

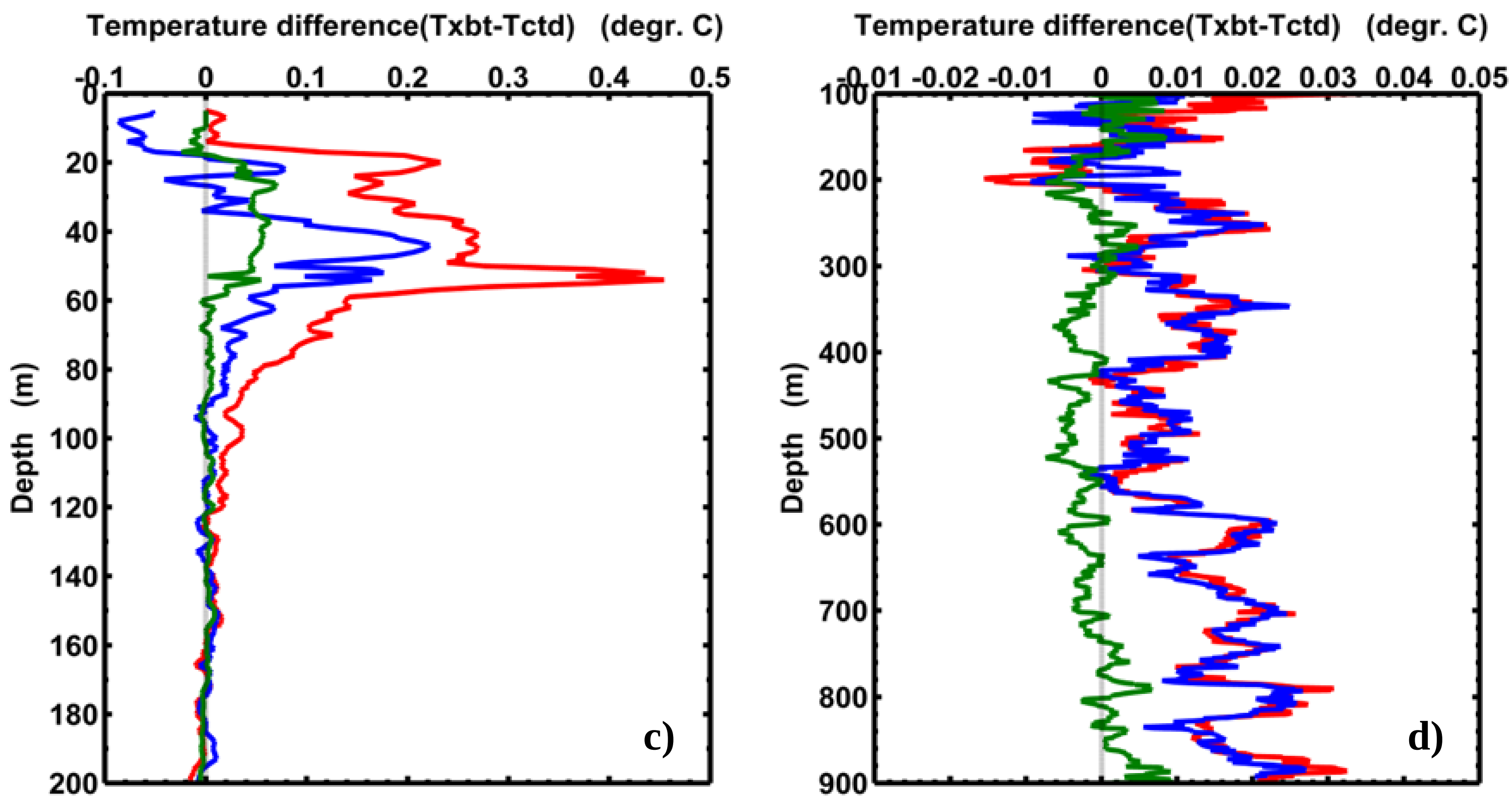


Red: H95
Blue: H95 with individual transient corrections
Deep green: the new method with individual correc...

The new method reduce the oscillation of the temperature differences.

3.Application: XBT/CTD comparison experiments

3.4 Compared with Hanawa et al. 1994,1995, Group 2.



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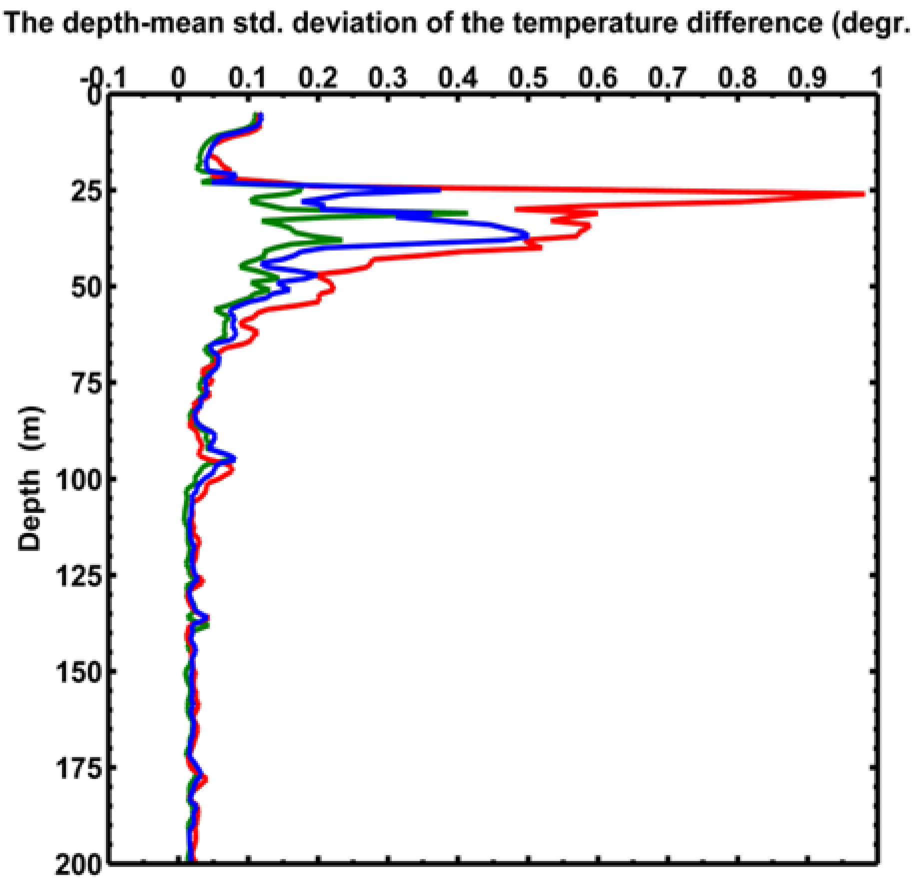
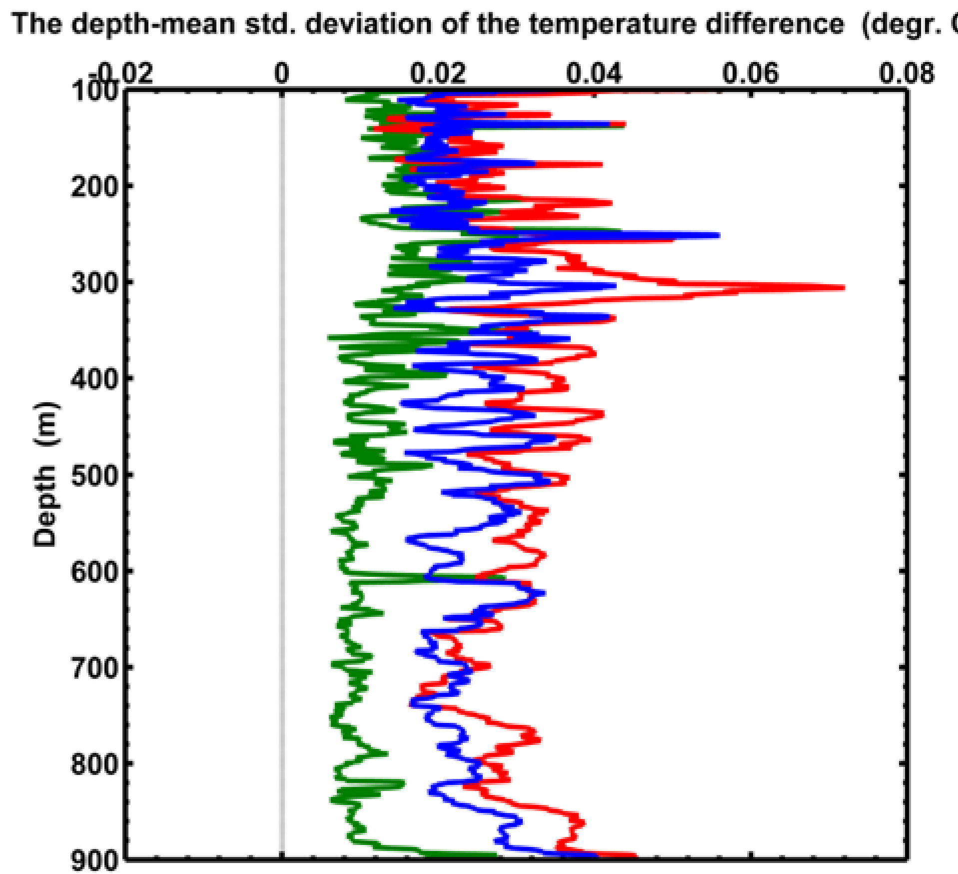
The new method reduce the oscillation of the temperature differences.

3.Application: XBT/CTD comparison experiments

3.4 Improvement of the standard deviation

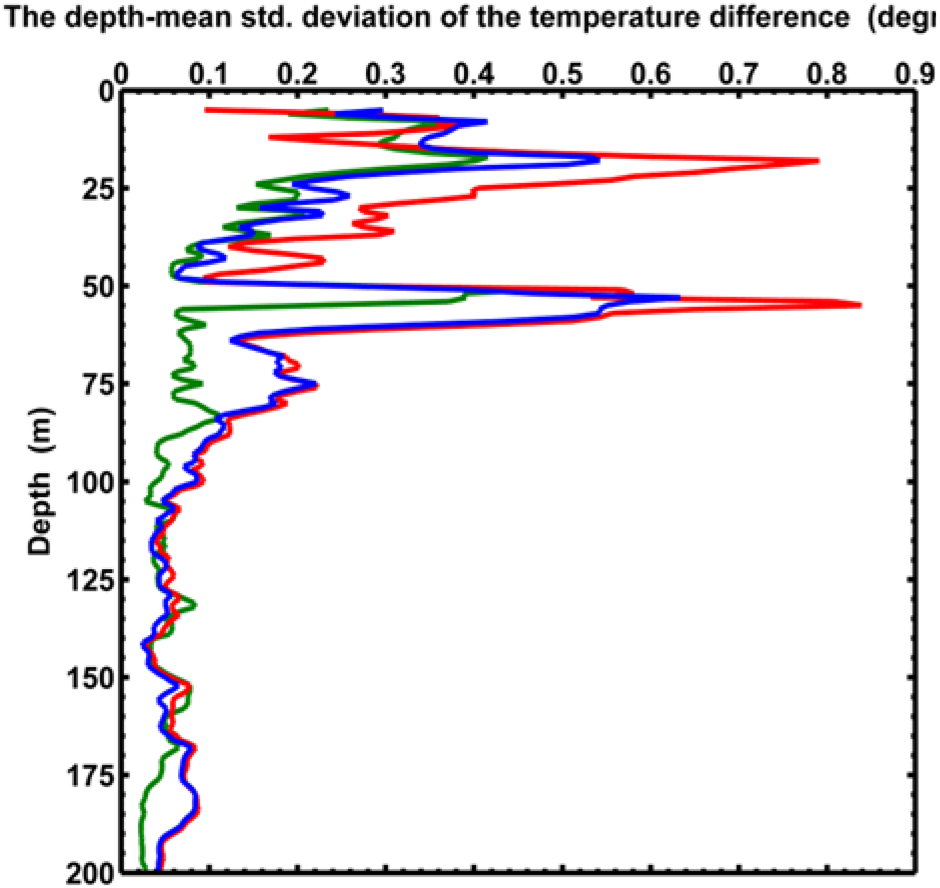


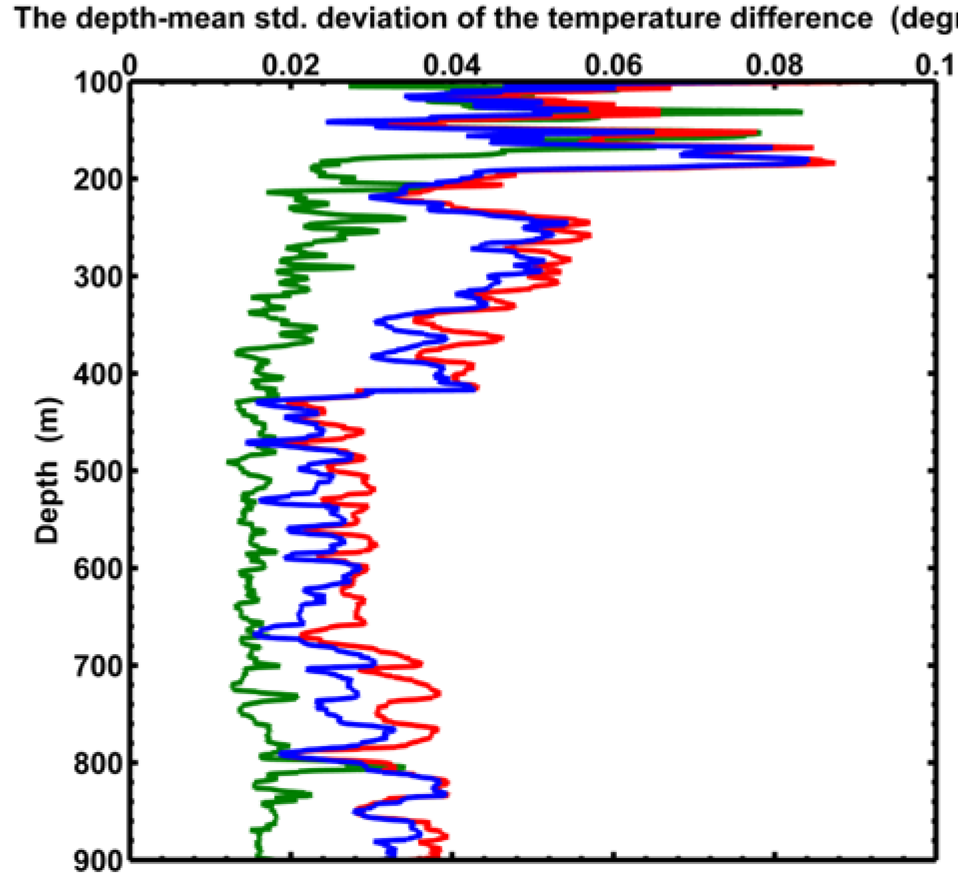


Red: H95
Blue: H95 with individual transient corrections
Deep green: the new method with individual corrections

3.Application: XBT/CTD comparison experiments

3.4 Improvement of the standard deviation





Red: H95

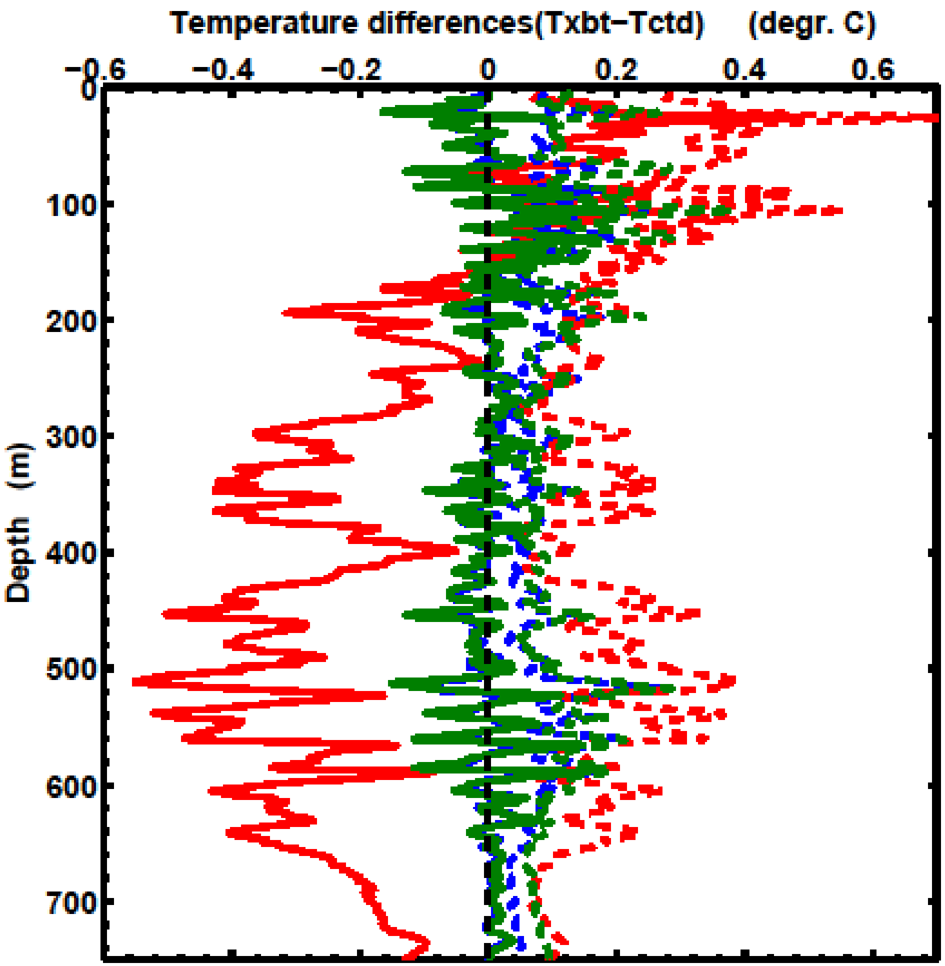
Blue: H95 with individual transient corrections

Deep green: the new method with individual corrections

The new method reduce the uncertainties.

3. Application: XBT/CTD comparison experiments

3.5 The overall corrections, by using mean fall-rate, mean transient, Group 1



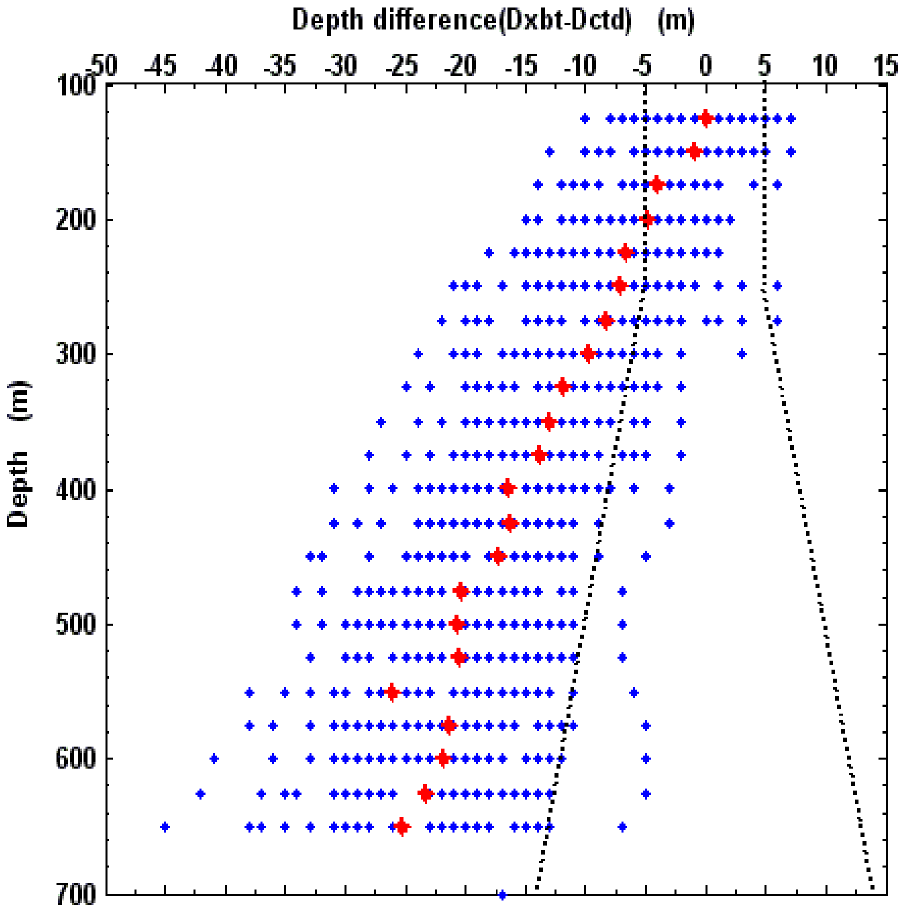
1. Good performance of the corrections determined by the new method. Temperature differences within 0.2℃.
2. There is not any significant difference between corrections by individual transient and that by the constant transient, though the standard deviation is a little larger when using the constant transient.

Red: Without any corrections
Blue: mean fall-rate coefficients (the new method), along with individual transient corrections
Deep green: mean fall-rate coefficients (the new method), with a constant transient corrections

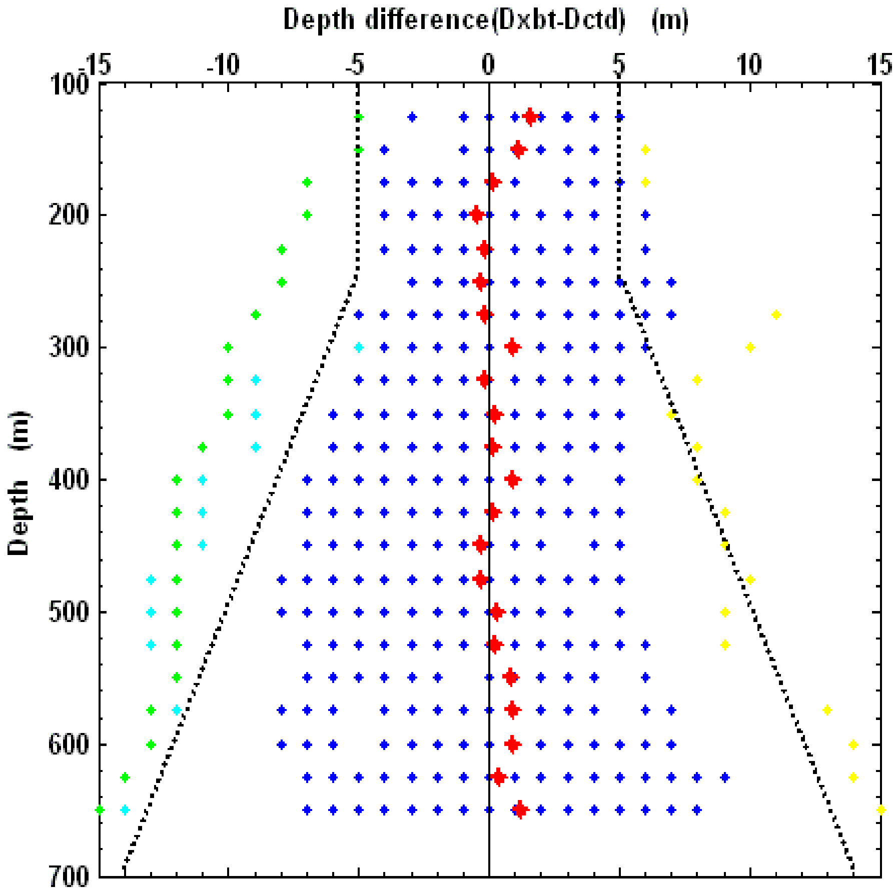
- **Group1:Z(t)=6.846t-0.00286t^2-5.68； Tbias=-0.0000275Depth+0.0957**

3.Application: XBT/CTD comparison experiments

3.5 The depth error, Group 1.



Before corrections

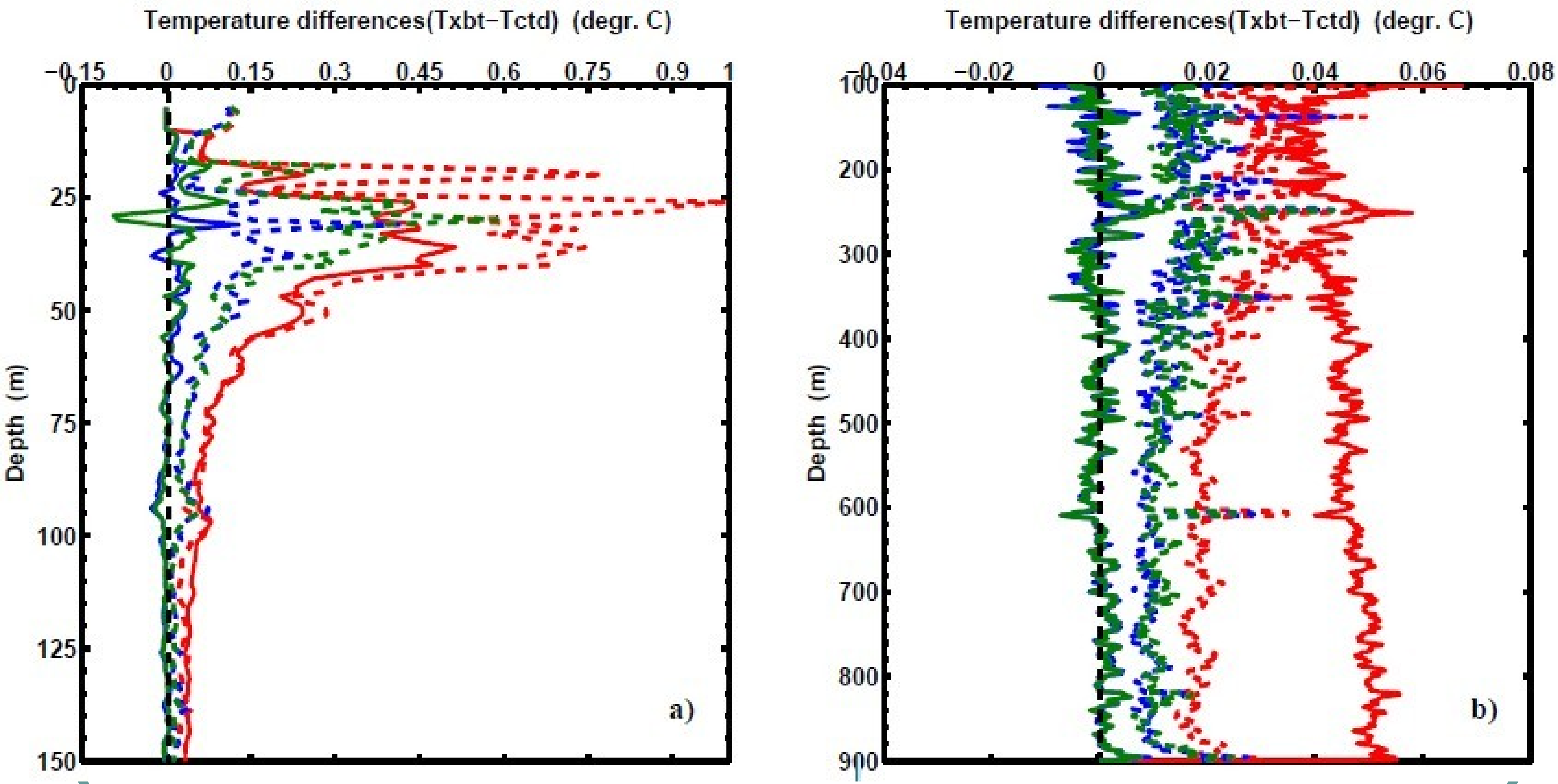


After corrections by Cheng et al.

The maximum depth difference within 7-8m at 700m(1.1%)

3. Application: XBT/CTD comparison experiments

3.5 The overall corrections, by using mean fall-rate, mean transient, Group 2

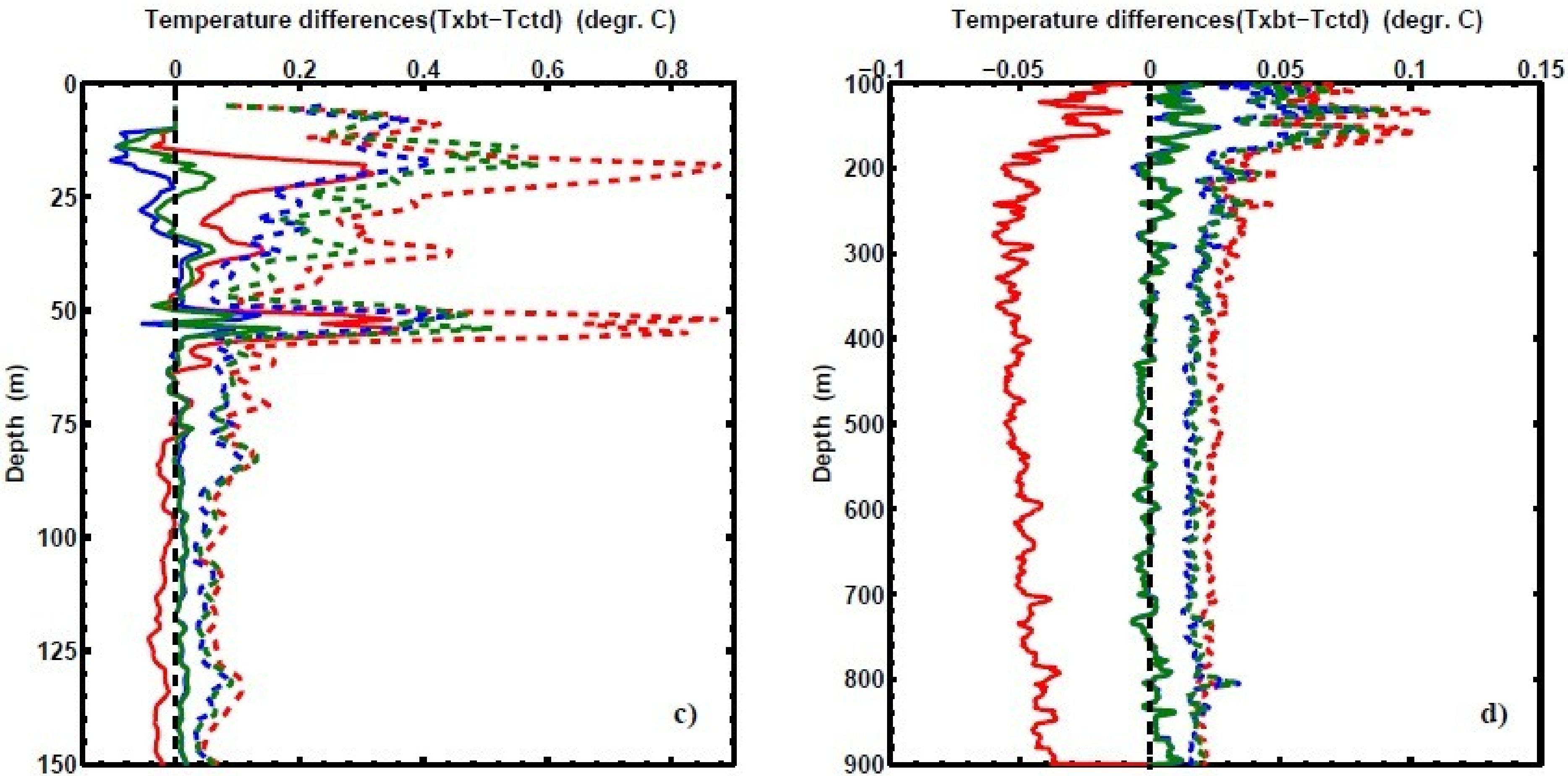


- Group2.1: Z(t)=6.678t-0.00181t^2-1.99; Tbias=0.0000159Depth+0.0378
- Group2.2: Z(t)=6.641t-0.00230T^2-1.12; Tbias=0.0000172Depth-0.0618

Temperature differences within 0.1℃, mostly within 0.05 ℃.

3. Application: XBT/CTD comparison experiments

3.5 The overall corrections, by using mean fall-rate, mean transient, Group 2



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Temperature differences within 0.1℃, mostly within 0.05 ℃.

Conclusions

- **By using the new method, the systematical errors including fall-rate error, pure temperature error, start-up transient can be estimated simply. And the corrections based on the new method dramatically reduce the discrepancy between XBTs and co-located CTDs.**
- **The method has a good performance on the water with high temperature homogeneity.**
- **The estimation and corrections for the start-up transient is essential to improve the quality of XBT data.**
- **Besides, the new method could be more automatic and simpler.**
- **Remarks**

  That means that the results mainly depend on the comparatively large gradient regions. The unpredictable uncertainties in the thermocline maybe lead to some bad results.

Further discussions

Different fall-rate of T7/DB at different waters

	Locations	XBT type, amount	A	B
Hallock et al., 1990	15° N, 55° W Atlantic	T7, 51	6.8458	0.2858
Reseghetti et al., 2003-2004	36 - 44° N, 3-17° E Mediterranean	DB, 27	6.6782	0.1810
Reseghetti et al., 2008-2009	36 - 44° N, 3-17° E Mediterranean	DB, 44	6.6405	0.2296
Thadathil et al., 2002	40-60° S, 145-150° E Antarctic	T7, 10	6.5968	0.2932
Sangra Inciarte Pablo, 2010	61-62° S, 56-62° W Antarctic	DB, 15	6.5745	0.3051

The velocity of the XBT probe trend to be decrease with latitude, We suppose that the viscosity of the water play an important role, thus the latitude-dependent XBT corrections should be taken into account!

Remarks

1. We've programmed a subscript of XBT corrections based on the new method, which is totally automatic, it will be available a few days later. It's my pleasure to share it with all.

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In the future

1. Collect the XBT/CTD pairs as much as possible!

2. Test the fall-rate variability with latitude, temperature, depth

3. More statistics on Start-up transient.

Thanks!