Sippican T5 bias in side-by-side and global-scale datasets

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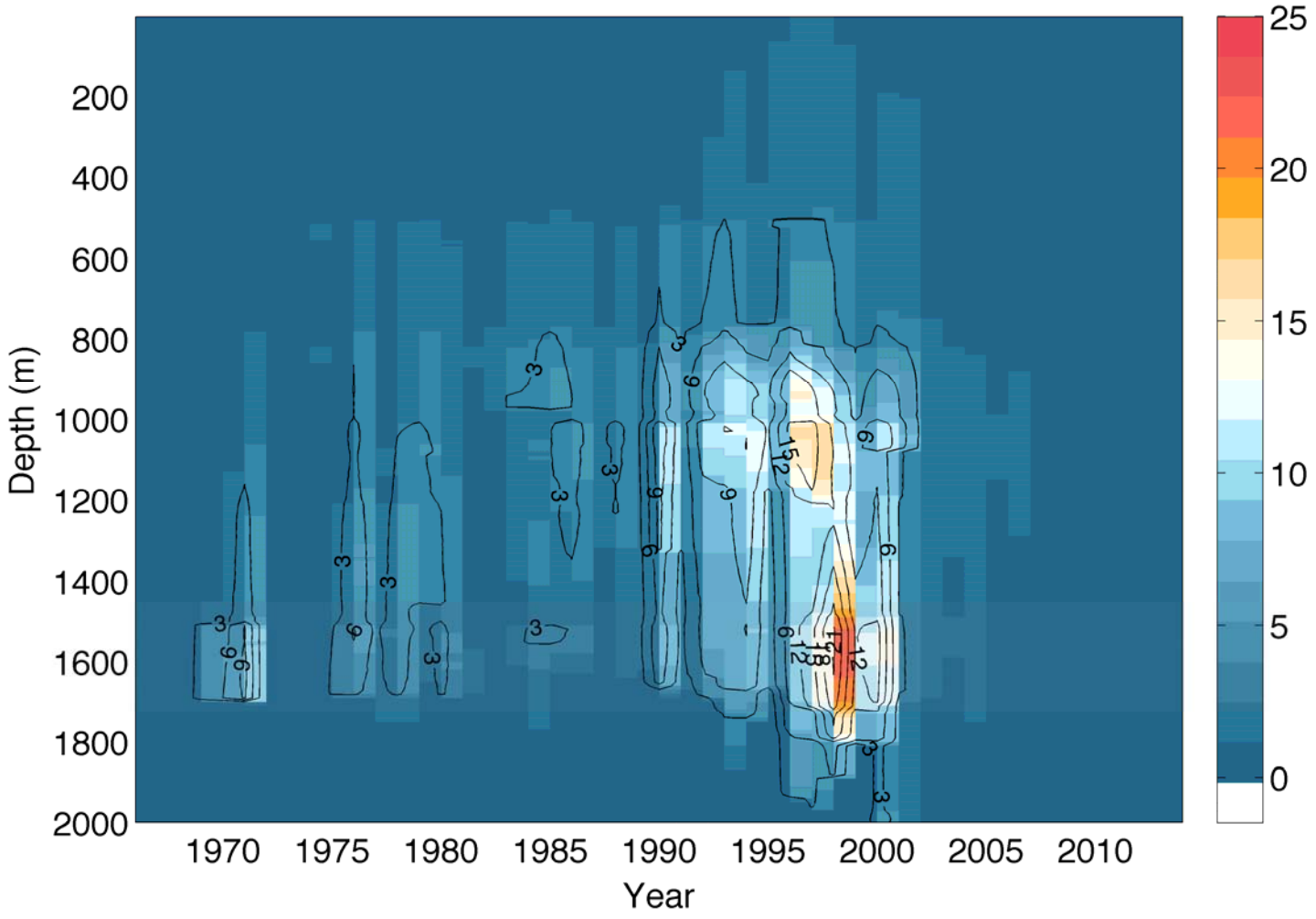
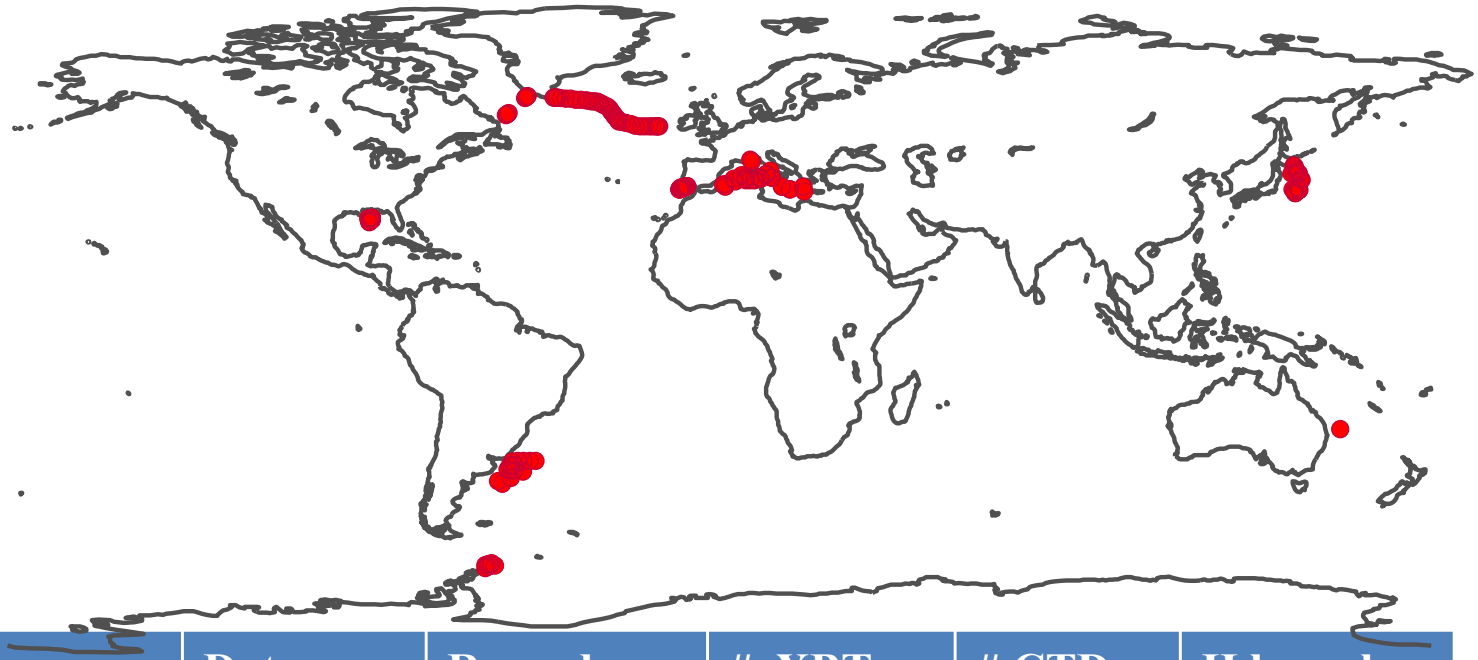
Are XBT-T5 data important?



Percentage of T5 data in World Ocean Database 2013 at each depth from 1966 to 2014

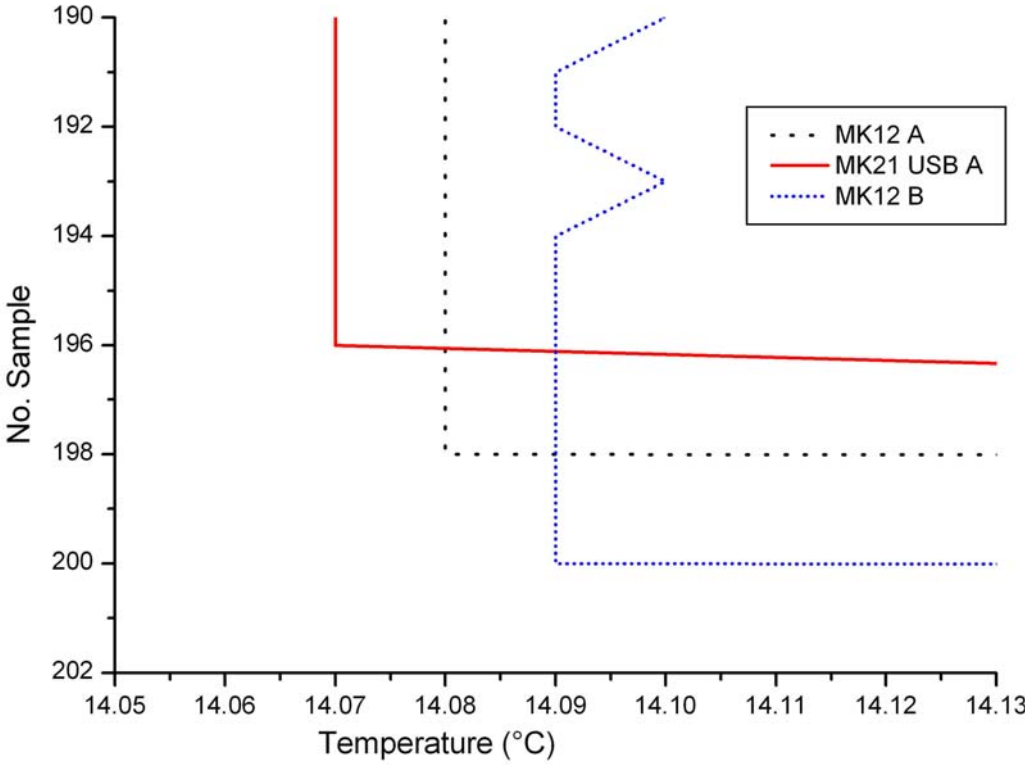
- T5 data contributes to up to 24% of data from 1990 to 2002 within 800-1800m (Important in monitoring deep ocean changes)

1. Side-by-side T5 data

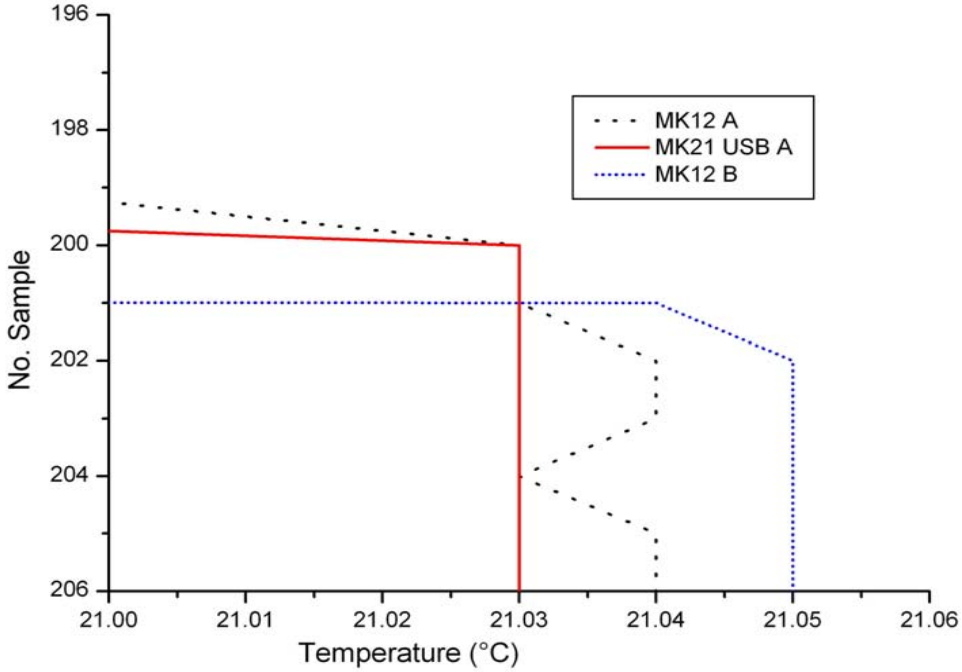


	Source	Data	Recorder	# XBT	# CTD	H launch
MED	Authors	2007/15	MK21	46	31	2.5-12.0
Breddies (Antarctic)	NOAA/NODC	2003	MK12	7	7	4.0-5.0
Gulf Mexico	NOAA/NODC	2006	MK21	7	7	2.5-3.0
Franklin (Au)	NOAA/NODC	1999	MK12	6	5	4.0-5.0
GO (Cadiz)	Prof. Hobbes	2007	MK21	59	23	4.0-5.0
Kizu (Japan)	Prof. Kizu	2003	MK-130	23	23	3.0-5.0
BSH(North Atlantic)	NOAA/NODC	1994	MK12	32	29	4.0-5.0
Argentina	Marcela Charo	1988	analogic	15	15	???

Tbias and delay from recording systems

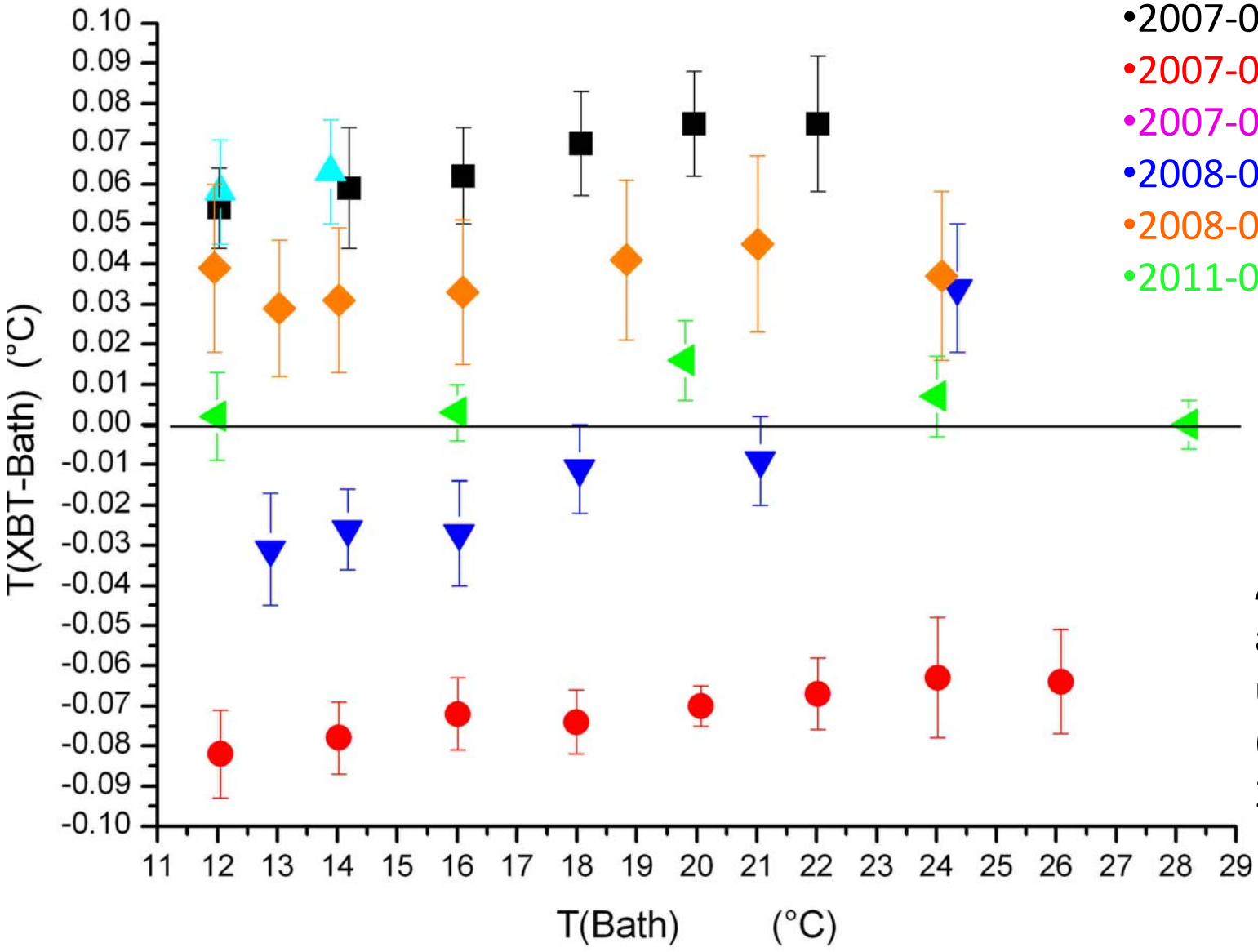


14°C-21°C



- **A CSIRO XBT system comparison timer has been used**
- **Positive temperature bias (0.02-0.1°C)**
- **The response time for MK21 is larger than the other two systems (0.4s, ~2.6m bias). MK12 requires two samplings (~1.3-1.4m bias)**

T5 and recorder calibration in bath



- 2007-06-11, 6 probes (black);
- 2007-08-06, 4 probes (red);
- 2007-09-19, 4 probes (cyan);
- 2008-02-04, 6 probes (blue);
- 2008-02-05, 6 probes (orange);
- 2011-04-13, 4 probes (green).

A MK21-USB digitizer and a laptop were always used as recording system (exception of the test 2008-02-05)

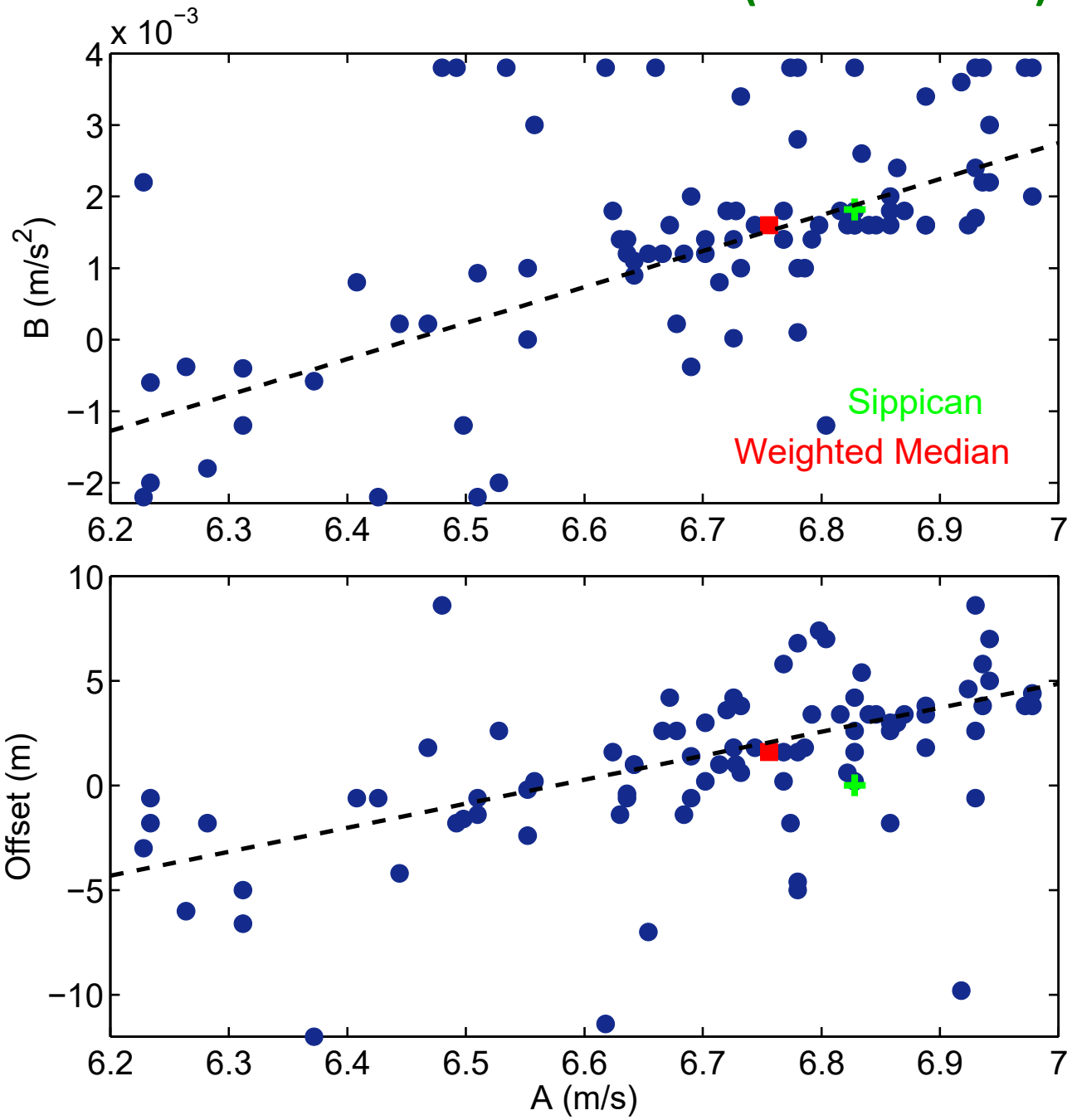
Dimensions of T5-T5/20: lab measurements

- **Copper wire**: the measured linear density is in the range 0.119-0.121 gm^{-1} (analytic scale resolution < 0.0005 g) without correlation with the year
- **Diameter** of the central hole: the measured values are in the range 1.060-1.085 cm (admitted range by Sippican is 1.062-1.087 cm), while the nose diameter is in the range 5.055-5.070 cm (admitted range 5.050-5.075 cm), without correlation with the year.
- **Probe weight in air**: see the Table. Nominal values: 998±5g in air, 680.5 g in water (LMSippican, personal communication).
- **Length of the plastic cylinder**: in the range 12.69-12.75 cm (resolution 0.005cm), with small correlation with the year.
- A certain lack of homogeneity has been observed in the insertion of this plastic in the zinc nose.

Type/year	2007	2008	2010	2014
T5	972.8 - 979.5 g	980.1 - 994.9 g	982.6 - 991.9 g	--
T5/20	--	973.9 - 988.1 g	--	983.7 - 992.4 g

2. Depth Error

1.1 Fall rate coefficients (CH11 method) $D=At-Bt^2-Offset$



Coefficients:

Weighted median ± 2 σ

A: 6.756 ± 0.0424

B: 0.0016 ± 0.00032

Offset: 1.6 ± 10.1372

(weighted by the maximum depth of each profile, in fact the length of the profiles is variable.)

A and B values are closer to Boyd-Linzell values than to LM Sippican ones.

Correlation:

B=0.0050*A-0.0325

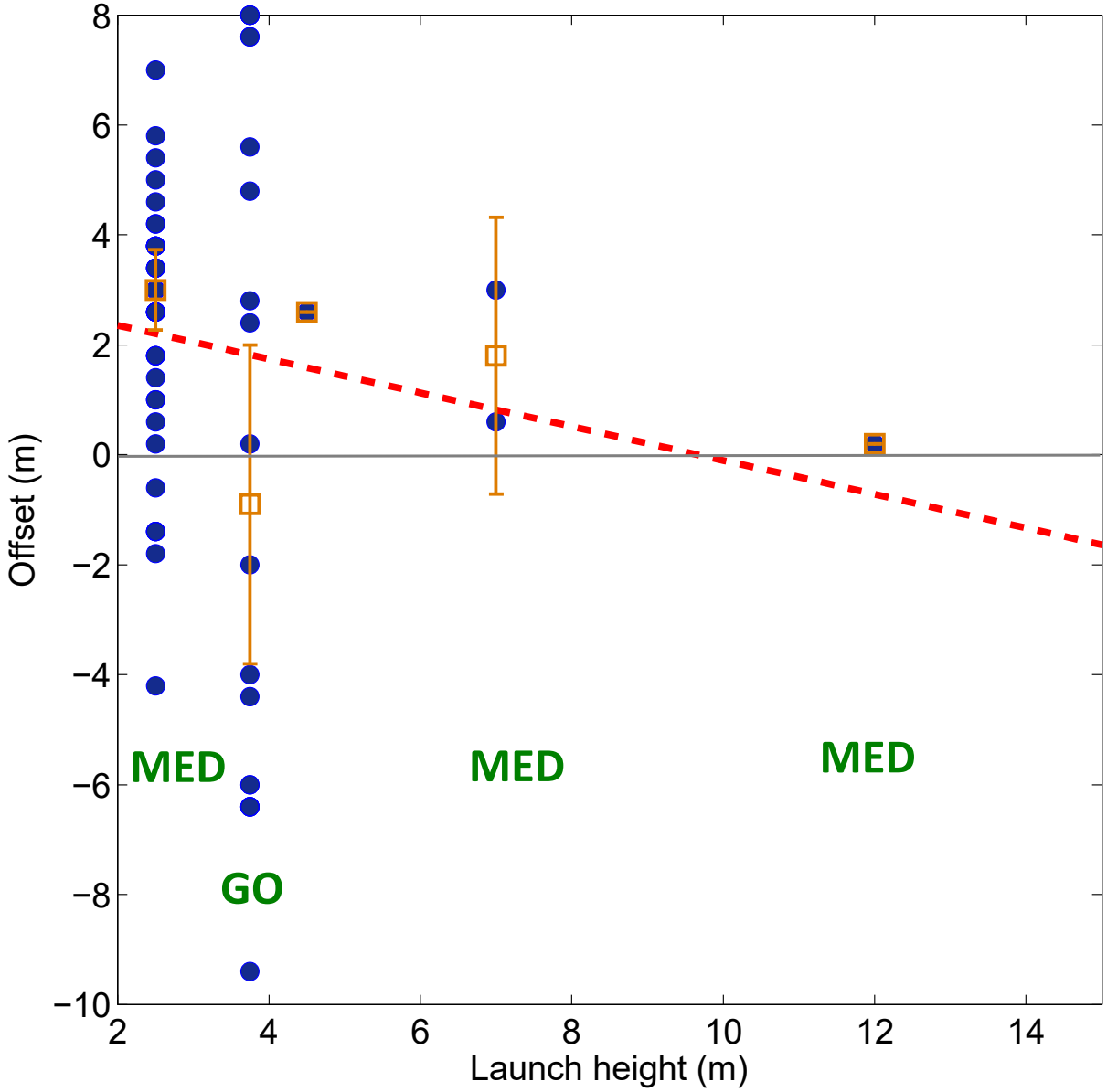
Offset=11.4599*A-75.3593

Coefficients of FRE for T5 - summary

Authors / FRE coefficients	A (ms^{-1})	B (ms^{-2})	C(ms^{-3})	D(m)
Sippican	6.828	0.00182		
quoted in Mied et al. 1981	6.640	0.00177		
Boyd - Linzell 1993	6.705	0.001619		
Boyd - Linzell 1993	6.795	0.002475	$2.148\ 10^{-6}$	-1.803
T5 TSK Kizu - Hanawa 2003	6.4751±0.2247	0.00175±0.0011 7		
T5 TSK Kizu et al. 2005	6.54071	0.0018691		
T5 TSK Miura et al. 2004	6.622	0.00230		
T4/T6/T7/DB Sippican	6.472	0.00216		
T4/T6/T7/DB IGOSS	6.691	0.00225		

2. Depth Error

1.2 Is Offset term influenced by launch height?



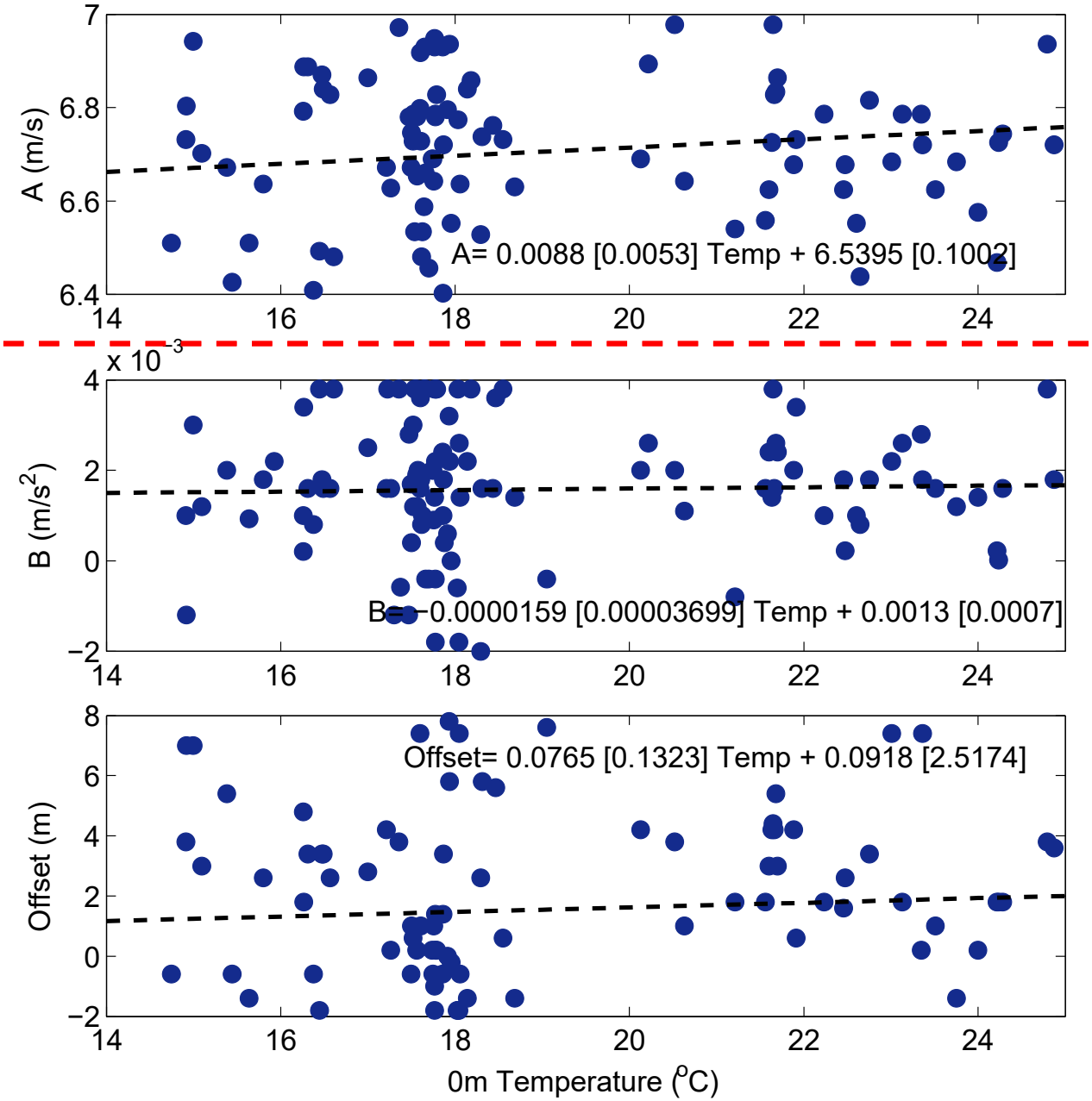
- **Significant** difference of Offset term for different launch height:
- Largest positive surface depth bias for 2.5m launch height.

Offset = -0.3073 Height +2.9711 m
(maybe linear is not a good assumption, consider Francis&Gustavo model)

2. Depth Error

1.3 Fall rate coefficient A vs. Ocean temperature

Significant



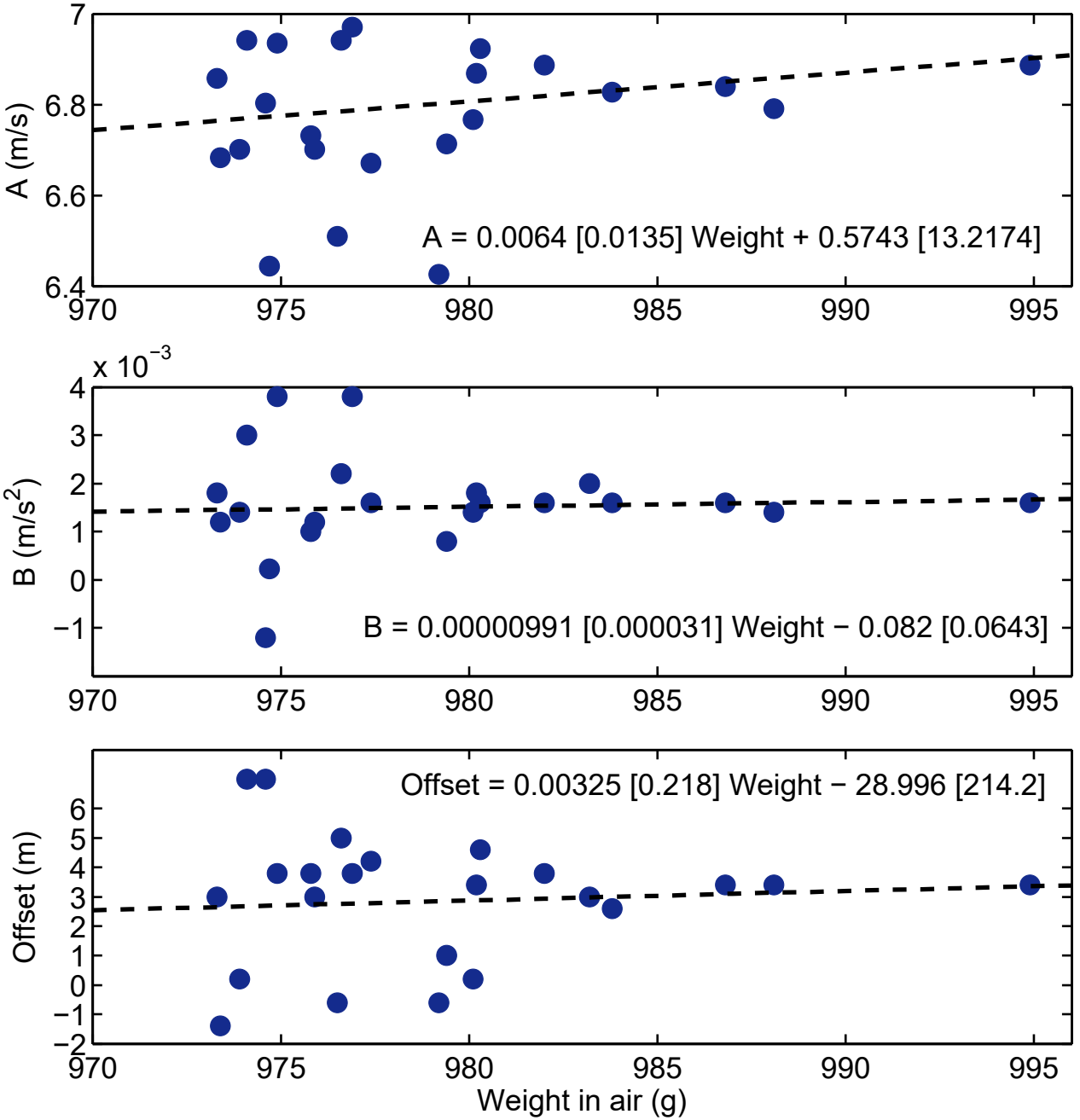
Increasing fall rate A with water temperature (Slope: 0.0088, stronger than T4/T6 (0.005) and T7/DB(0.0025))

2. Depth Error

1.4 Is XBT fall rate influenced by probe weight?

Only 24 XBT profiles, from MED dataset

- A increases with probe weight (but insignificant)
- It could make sense, heavier probe may have quicker fall rate.
- TSK T5 are heavier than LMS T5, but A is smaller. Other physical parameters are different (see Kizu et al. 2005)
- But it is statistically insignificant, it is likely that the uncertainty in FRE calculation is larger than the A/weight relationship



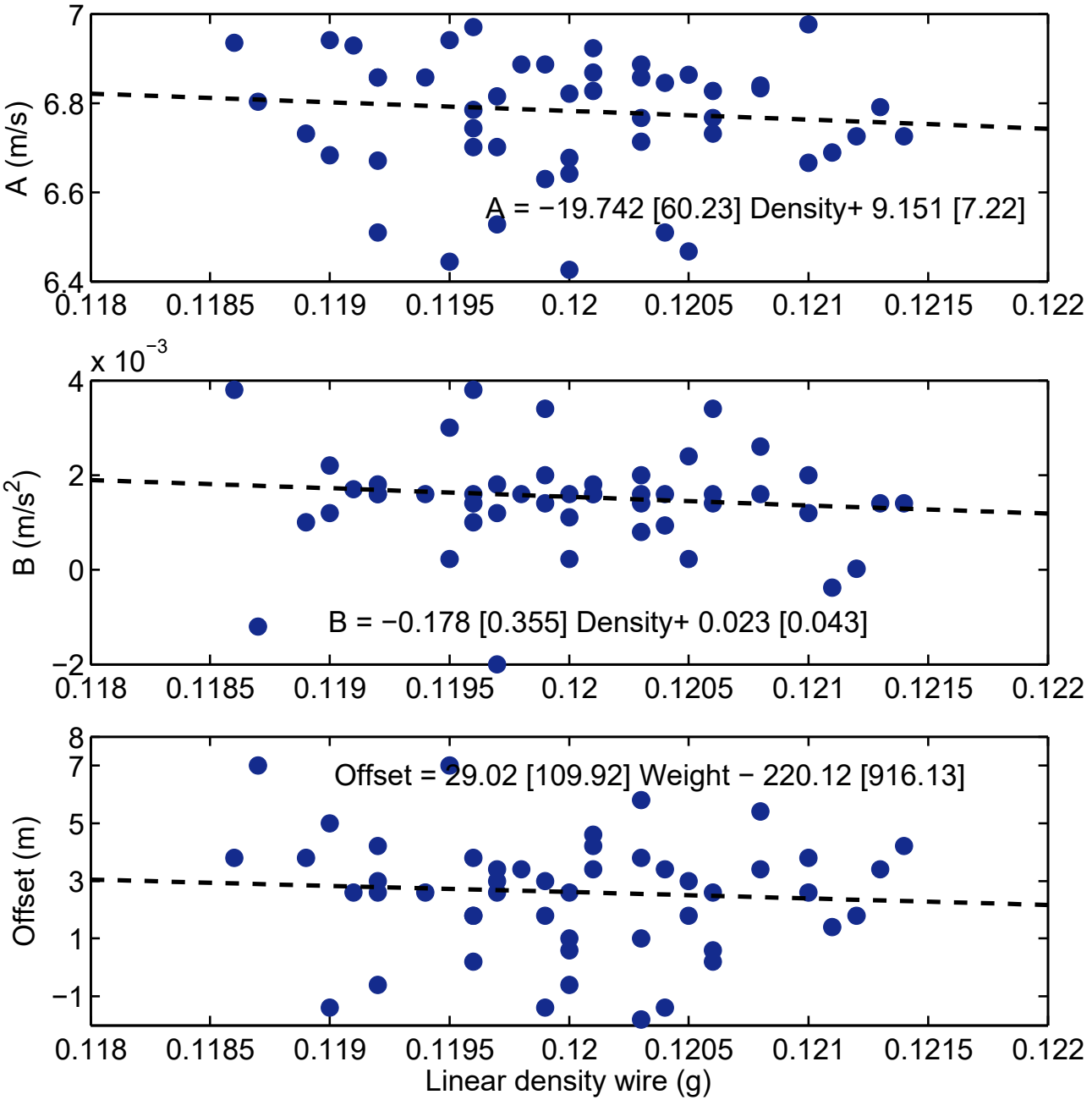
2. Depth Error

1.5 Is A influenced by wire density?

51 XBT profiles, from MED dataset

- **A/B/Offset decreases with wire density (insignificant)**

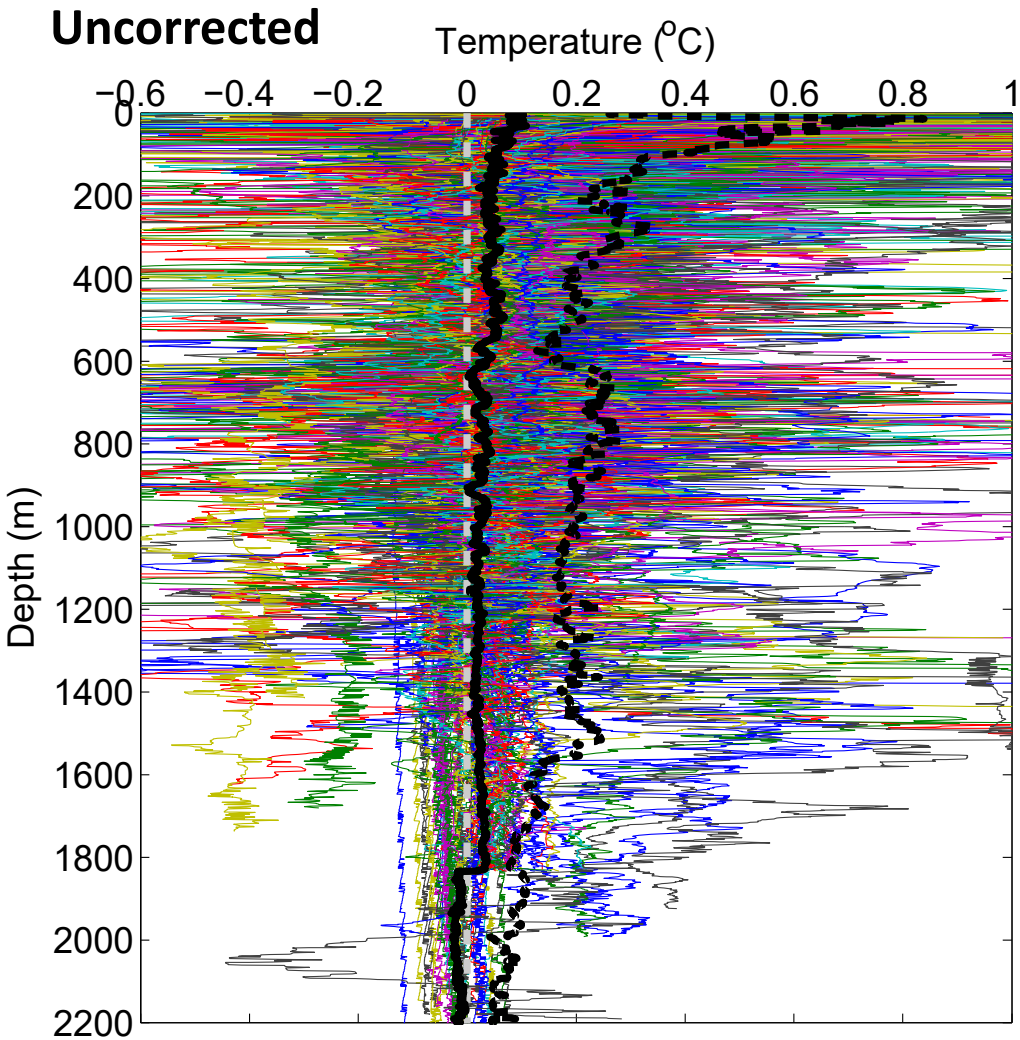
The linear density of the copper wire may influence the weight variation due to the wire dereeling

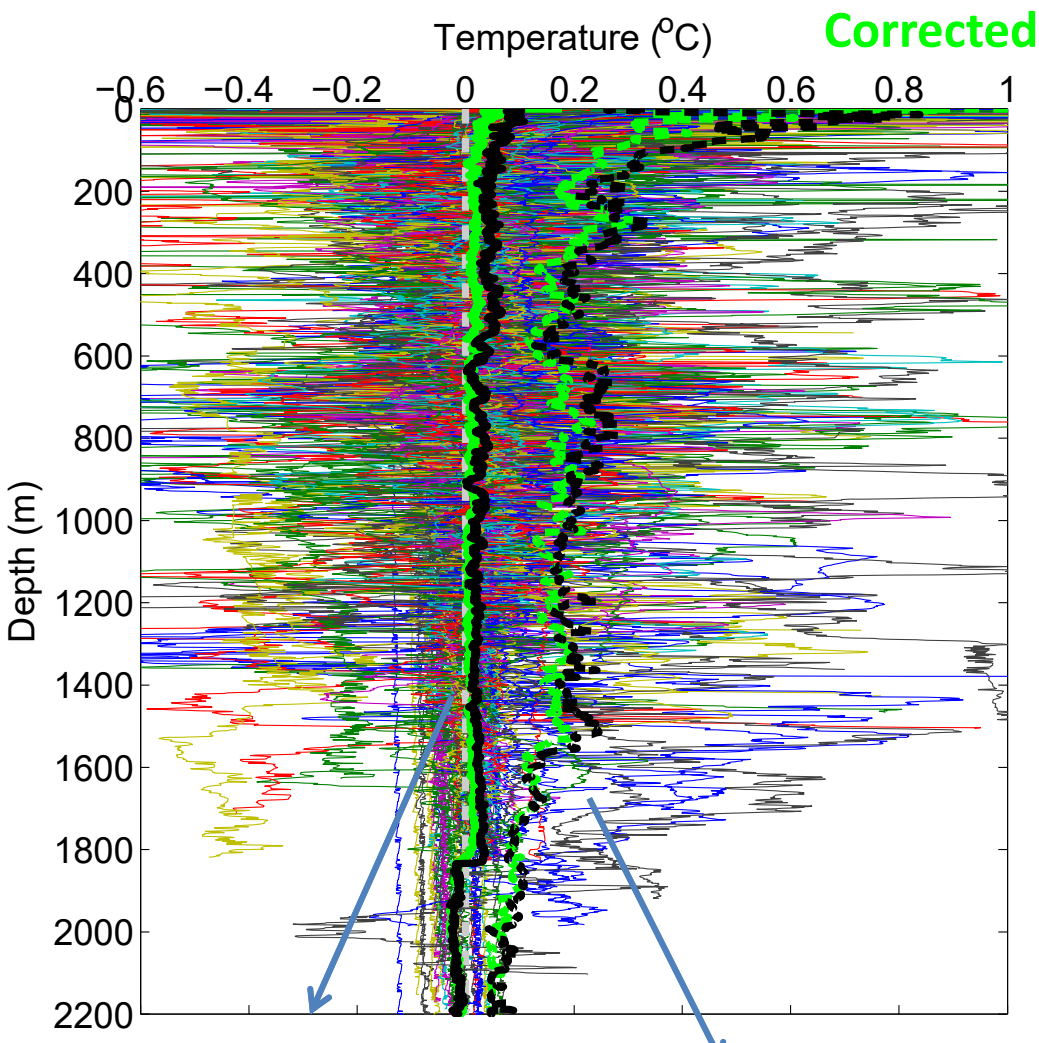


3. Pure temperature bias

3.1 Temperature bias defined as residuals after correcting depth bias

All 200 pairs (large uncertainty and positive bias on average)





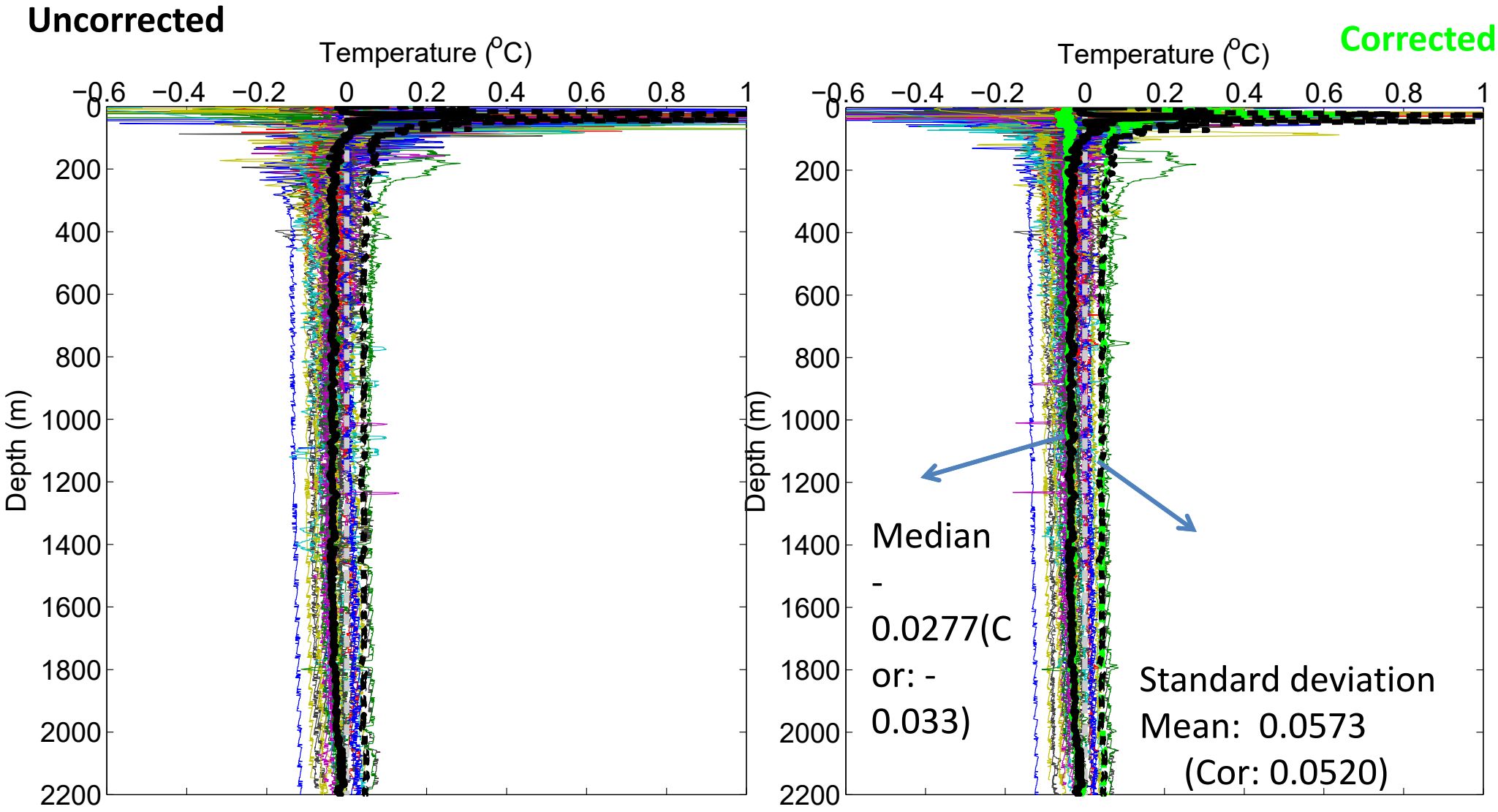
Median
0.0222 (Cor: 0.0082)

Standard deviation
Mean: 0.188 (Cor: 0.156)

3. Pure temperature bias

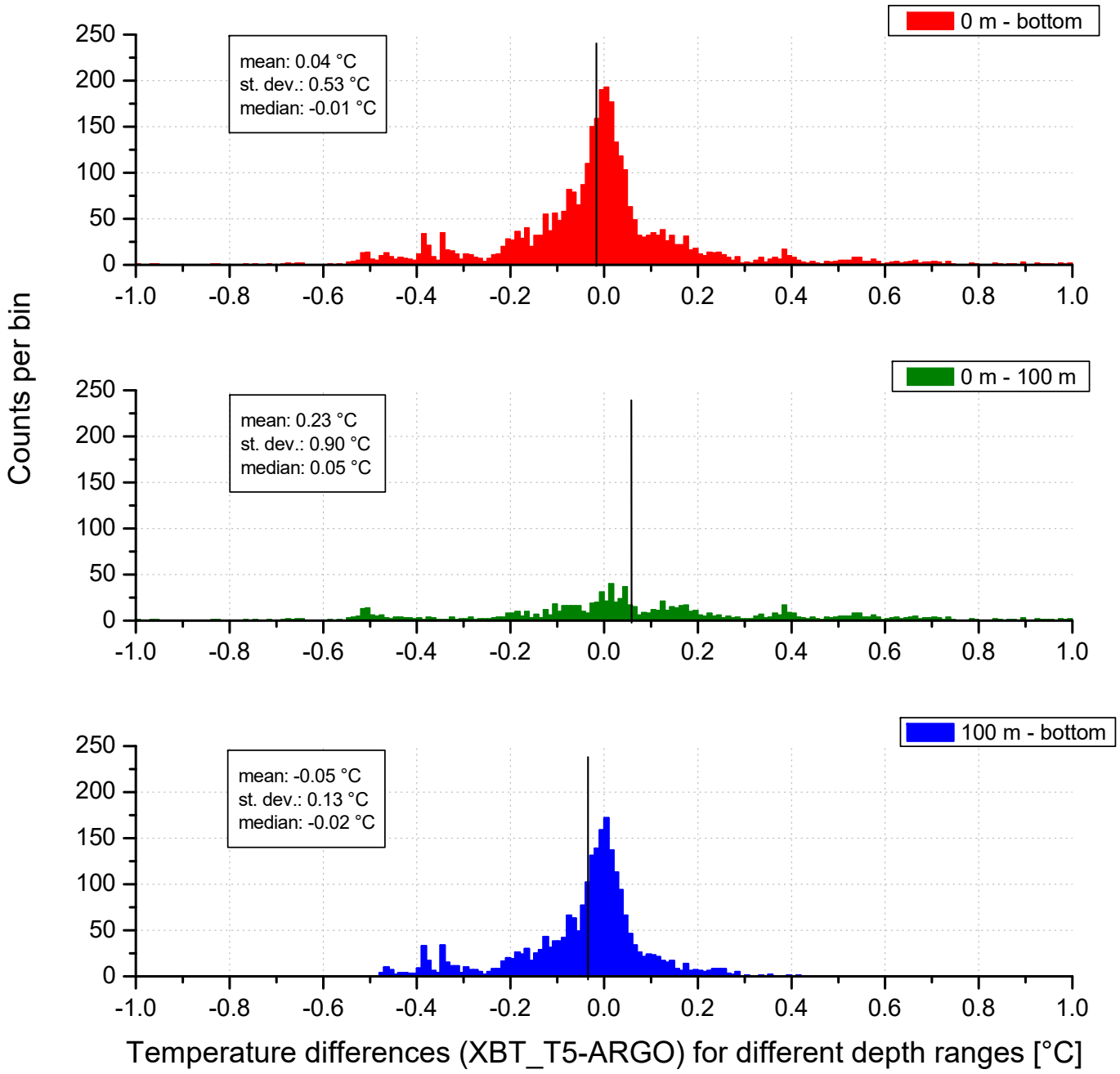
3.1 Temperature bias defined as residuals after correcting depth bias

Only Mediterranean Sea data (much smaller uncertainty and negative pure temperature bias on average)



T5/20 from SOOP vs. ARGO in the Med Sea

Matching conditions: Lat: ±0.10° / Lon: ±0.15° / time: ±7 dd

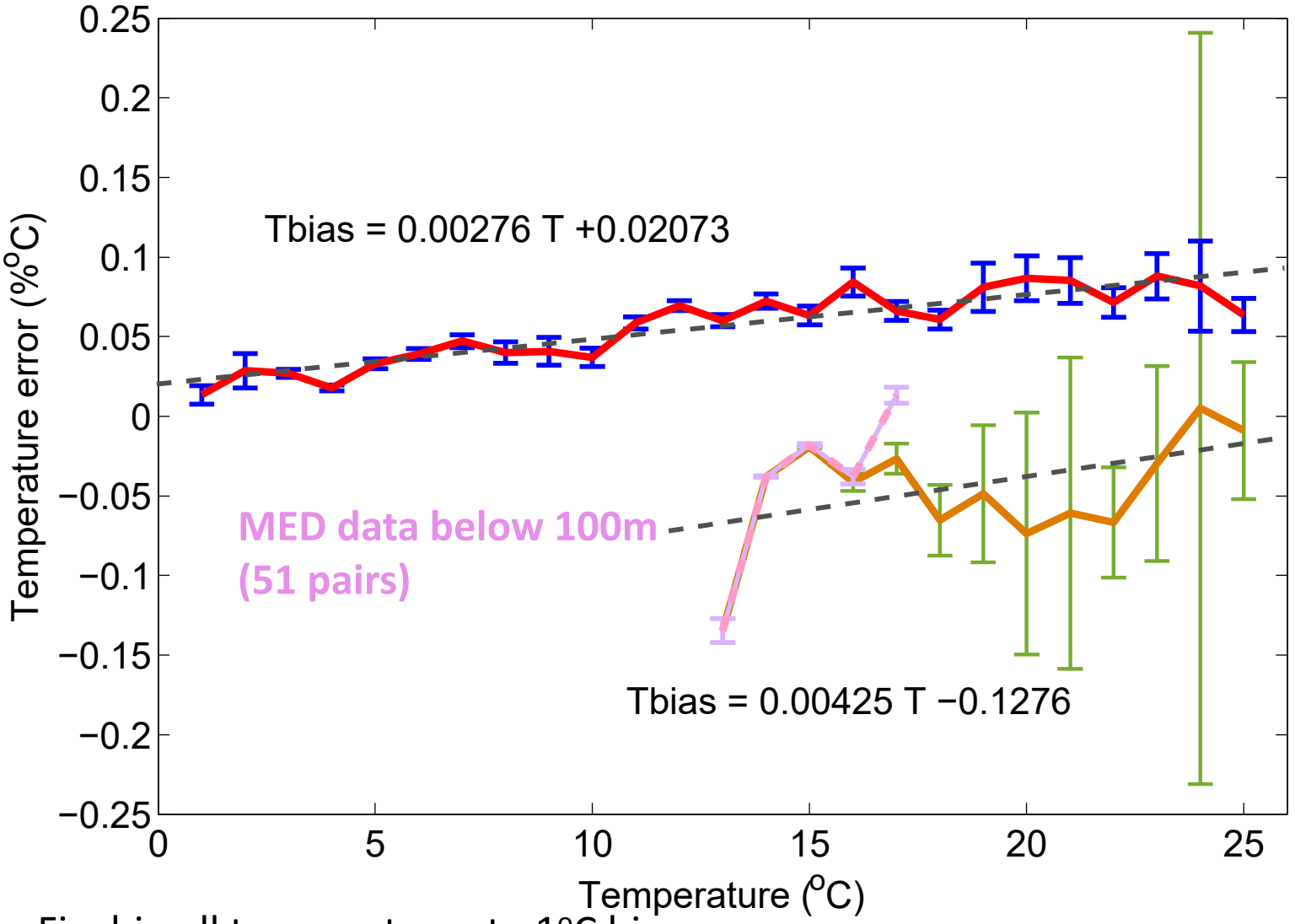


Comparison with Argo also shows **negative** temperature bias below 100m in MED.

3. Pure temperature bias

3.2 Pure temperature bias vs. Ocean Temperature

- **Significant increases of Tbias with temperature for other data except MED**
- **Below 100m, MED data also show an increase of Tbias with temperature**



Others (149 pairs)

MED data (51 pairs)

Stronger than T4/T6/T7/DB:
0.00140 (T4/T6)
0.00167 (T7/DB)

Fig. bin all temperatures to 1°C bins

4. Global-scale data

- **Use new A/B, A/Offset correlation, A(Temp), Tbias (Temp) for T5 based on Side-by-side dataset**
- **Update A(time), Tbias(time) for T5 based on WOD13-based Global-scale dataset**

A brief overview of CH14 scheme:

- **Side-by-side XBT/CTD data**

1. A(temperature), Tbias(temperature)
2. Correlation of FRE coefficients: B(A), Offset(A)

- **Global XBT/CTD comparison**

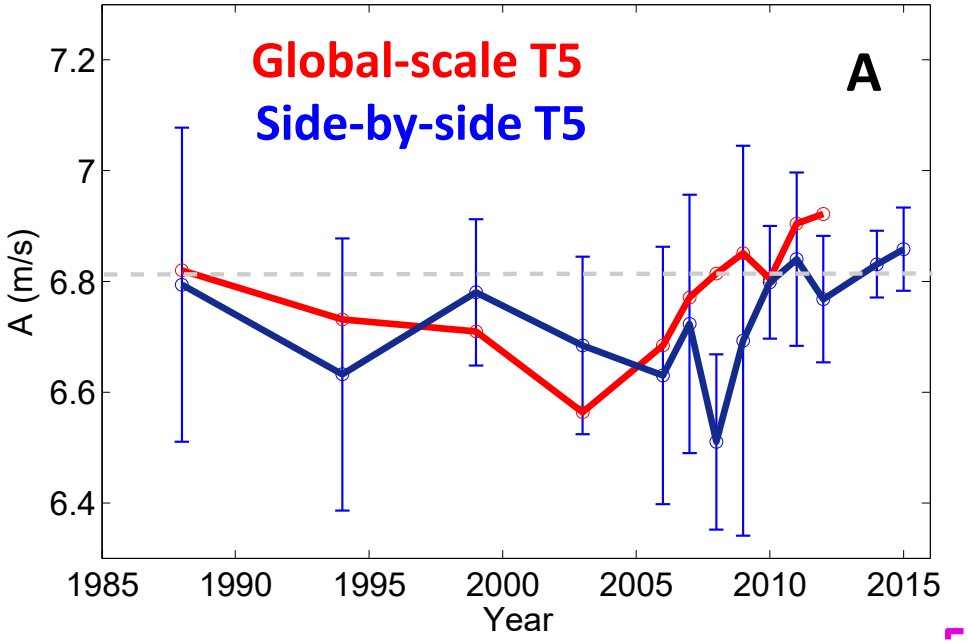
3. Tbias(year), A(year)

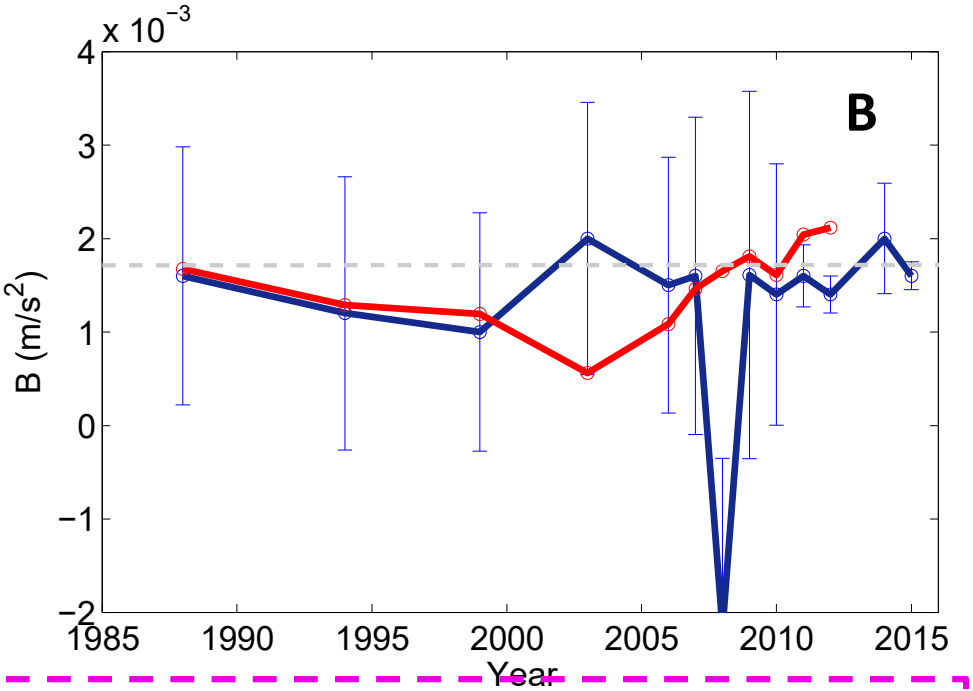
→→→

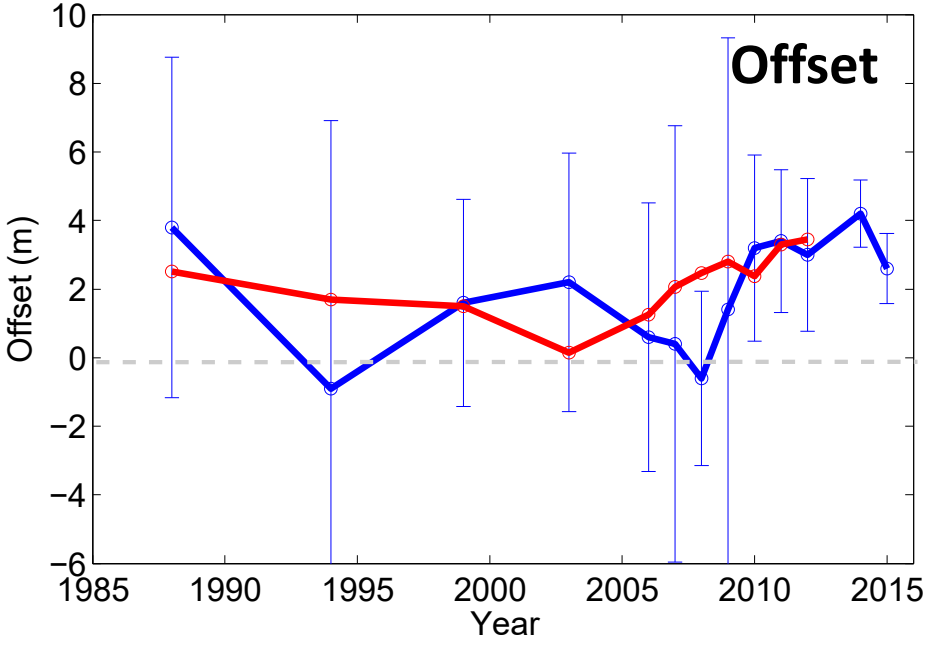
XBT Bias (year) = Tbias(year)
+ Tbias(temperature)
+ A(year)
+ A(temperature)
(+B(A) +Offset(A))

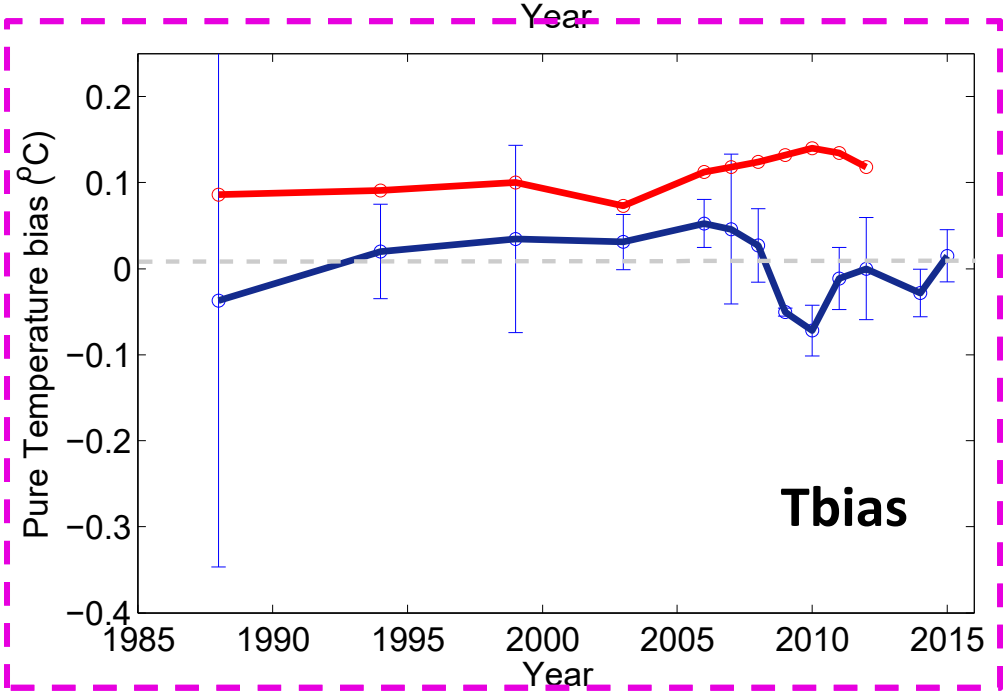
4. Time variation, compared with Global-scale data

Significant difference for pure temperature bias for side-by-side and global-scale data









5. Summary

- A large number of Side-by-side T5-XBT/CTD pairs are used in this analysis: 200 pairs !!!

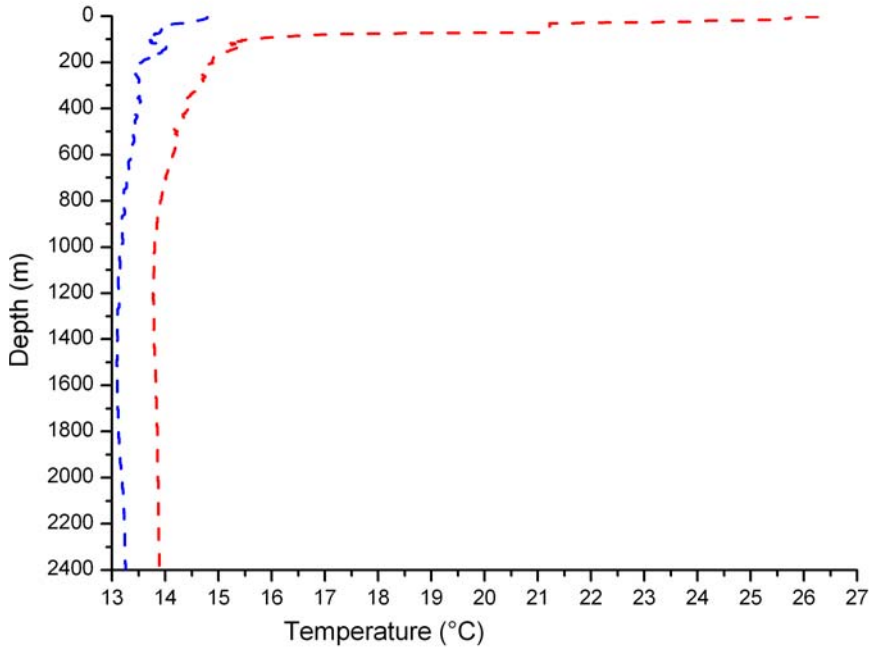
- Initial fall rate *A* is smaller than Sippican (larger than H95, but T5 has different shape&weight)
- Fall rate coefficient *A* increases with water temperature
- Significant impact of launching height
- Possible influence of probe weight on fall rate (A)

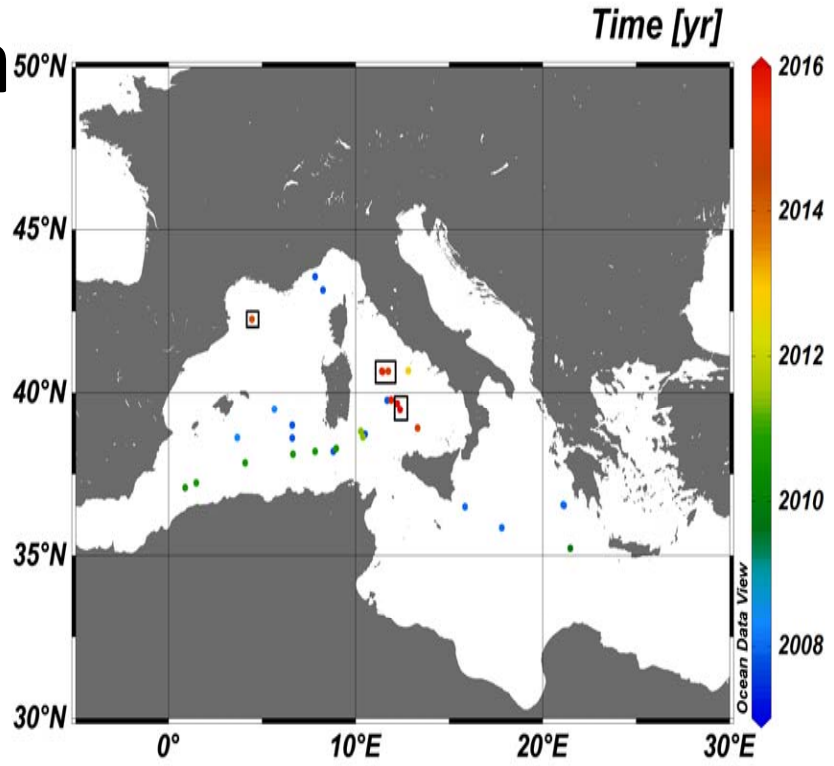
- Pure temperature bias contains large difference for different experiment: MED vs. others
- Pure temperature bias increases with water temperature

- Global-scale dataset shows similar fall rate coefficients with side-by-side data, but larger pure temperature error.

- T5 probes are popular and frequently used in geological surveys in the Oceans and in seismic/multibeam measurements.Therefore, it should be useful to contact geo-researchers to recover a lot of unpublished (or unavailable or unknown)T5 data ….

Characteristics of Med Sea





XBT_T5 vs CTD (dots) and vs ARGO (dots in squared box)-Period: 2007-2016