Sea tests of XCTDs
- How are they different from XBTs? -

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About the notation of FRE (a small complaint)

Traditional

$$Depth(t) = at - bt^2$$

COMMON CODE TABLE C–3: ***Instrument make and type for water temperature profile measurement with fall rate equation coefficients***

Common Code table
- Code table 1770 – $I_XI_XI_X$ (Instrument type for XBT, with fall rate equation coefficients) – for alphanumeric codes
- Code table 0 22 067 (Instrument type for water temperature salinity profile measurement) in BUFR

Code figure for $I_XI_XI_X$	Code figure for BUFR (Code table 022 067)	Meaning		
		Instrument make and type	Equation coefficients	
			a	*b*
001	1	Sippican T-4	6.472	–2.16
002	2	Sippican T-4	6.691	–2.25
011	11	Sippican T-5	6.828	–1.82
021	21	Sippican Fast Deep	6.346	–1.82

$$Depth(t) = at + bt^2$$

Some of you

$$Depth(t) = at^2 + bt + c$$

eXpendable Conductivity-Temperature-Depth profiler

XBT/XCTD System

- eXpendable BathyThermographs
- eXpendable Conductivity, Temperature & Depth
- Data Acquisition and Processing Equipment

XBTおよびXCTDシステムは海象・海況条件に制約を受けること無く船舶の航行中にプローブを投下し、水温あるいは、水温および電気伝導度を計測するシステムです。XBTは最大水深1,830mまでの深度/水温を、XCTDは最大水深1,850mまでの深度/電気伝導度および水温を、高精度かつ高い信頼性の基に、リアルタイムに計測します。水深は、XBTおよびXCTDプローブの形状と重量から決定される降下式に基づき着水後の経過時間から自動的に演算されます。

The TSK expendable profiling systems allow the collection of highly accurate oceanographic data from moving platforms. They produce cost effective profiles of ocean conditions from ships, airplanes, and submarines.
For all the expendable models, depth is calculated from the well known drop rate of the hydrodynamically shaped probes.

From TSK’s catalog

XCTD probe types

XCTDプローブ　XCTD Probes

型式 Type	深度(m) Measuring Depth(m)	船速(ノット) Ship Speed(knots)	計測時間(秒) Measuring Time(sec.)
XCTD-1	1,000	12	300
XCTD-2	1,850	3.5	600
XCTD-3	1,000	20	200
XCTD-4	1,850	6	537

XBTプローブ
XBT Probe

Ring hood

XCTDプローブ
XCTD Probe

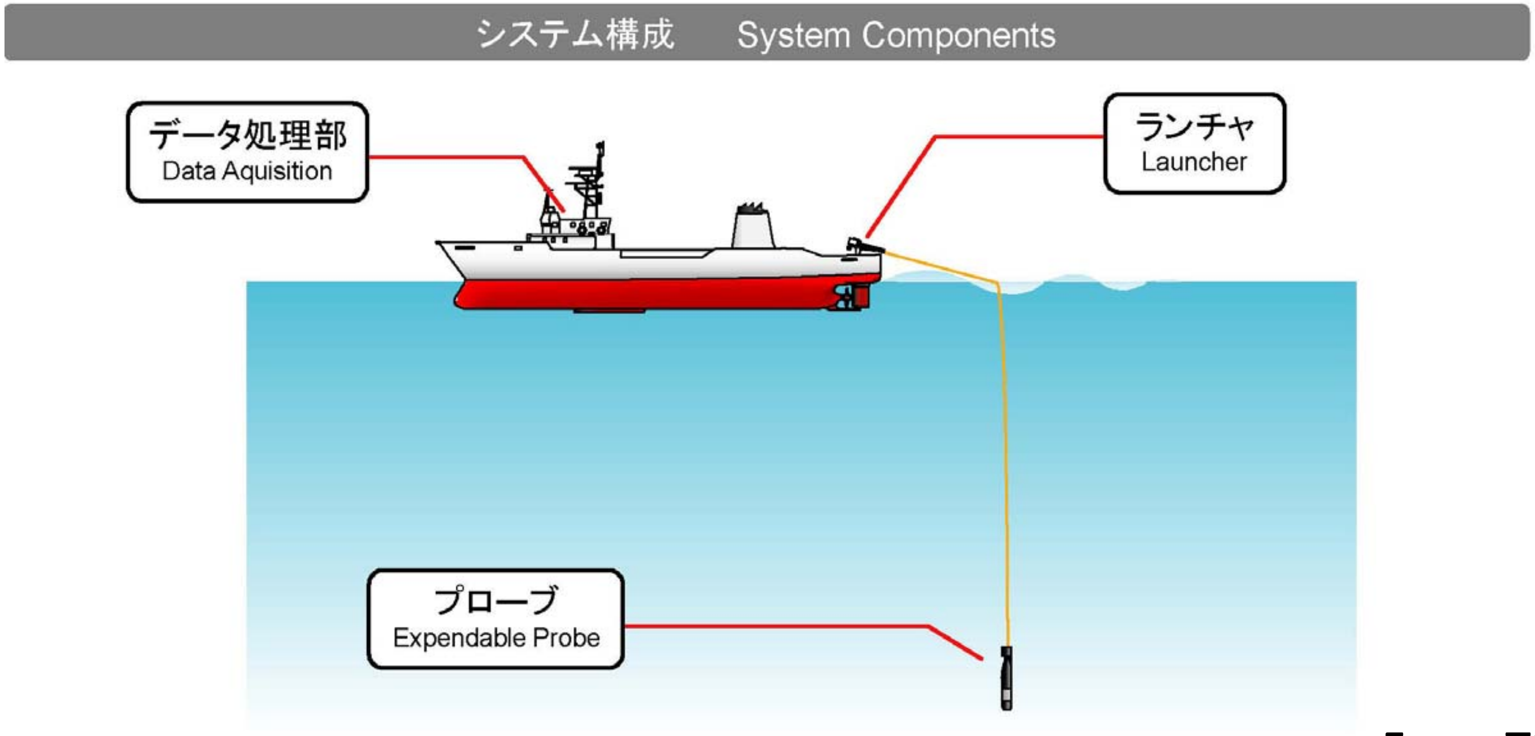
Similarity to XBT

- Expendable
- Double reels

    Decouple measurement from the cruising of the ship

- Absence of pressure sensor

    Need for FRE



From TSK's catalog

Difference from XBT

- Role of wires

XBT

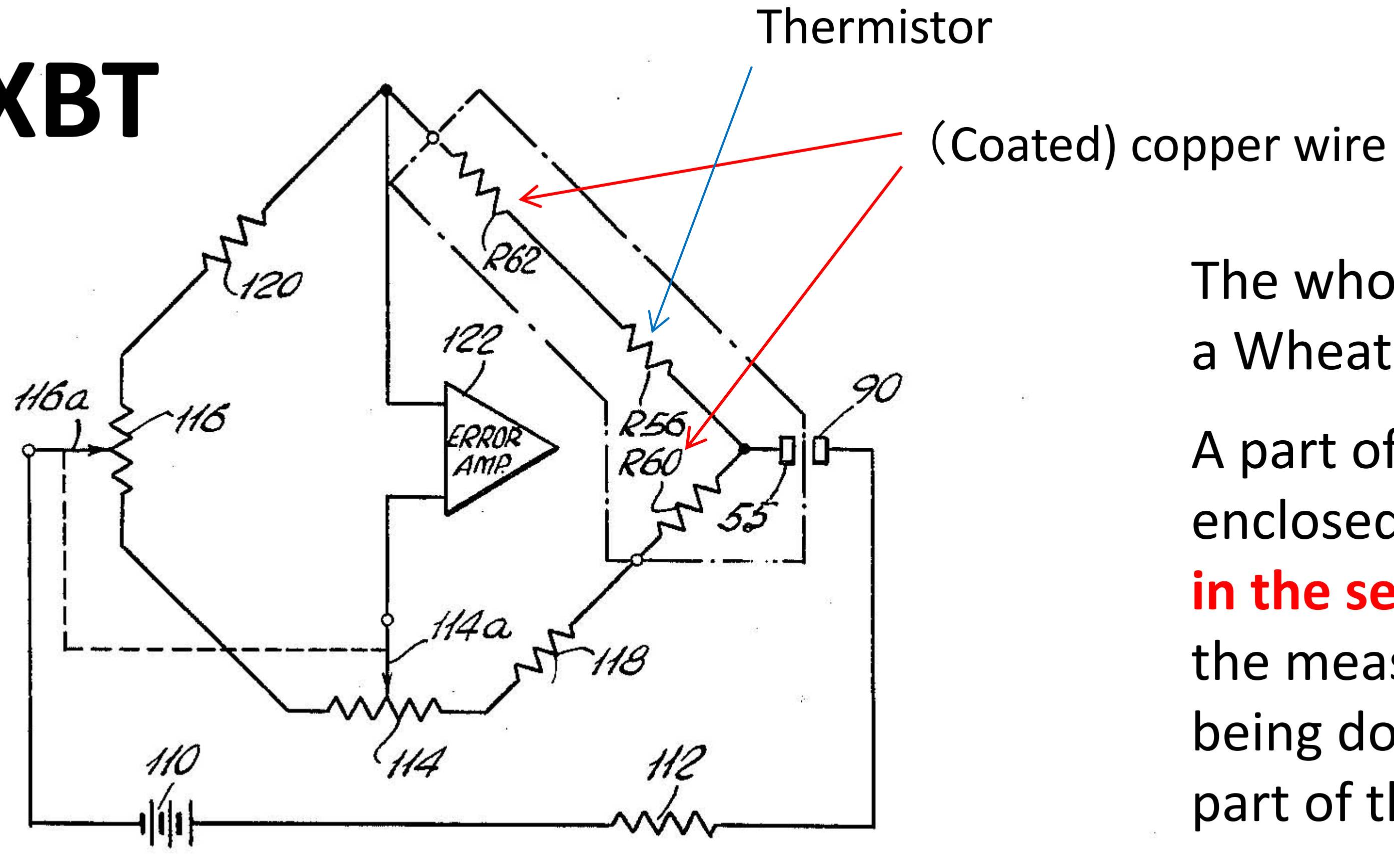


Fig. 8.

INVENTORS
WALTER G. CAMPBELL
WILLIAM VAN ALAN CLARK, JR.
COURTLAND B. CONVERSE
BY Nolte & Nolte
ATTORNEYS

The whole system is like a Wheatstone bridge.

A part of the circuit (the enclosed part) is soaked **in the seawater** when the measurement is being done. Wires are part of the circuit.

Difference from XBT

- Role of wires

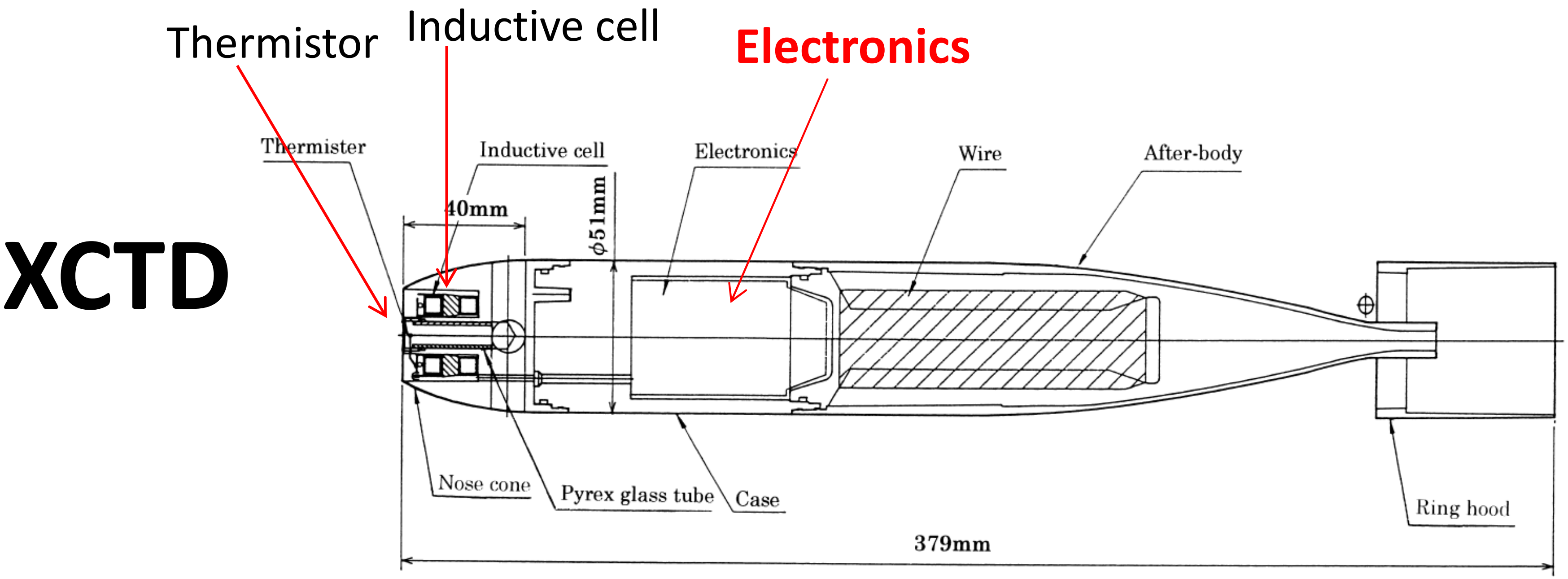


Fig. 1. Sketch of XCTD probe.

Mizuno and Watanabe (1998)

The measurement is **completed in the probe**.

The wires **only work for data transmission**.

This allows addition of a pressure sensor in XCTD, at least mechanically.

(TSK is trying some prototype.)

Difference from XBT

➢ Calibration

白河工場
Shirakawa Plant

XCTDプローブ校正装置
XCTD Calibration Bath

	水温 Temperature			電気伝導度 Conductivity		
	測定範囲 Range	精度 Accuracy	分解能 Resolution	測定範囲 Range	精度 Accuracy	分解能 Resolution
XBT	−2～35℃	±0.2℃	0.01℃			
XCTD	−2～35℃	±0.02℃	0.01℃	0～60mS/cm	±0.03mS/cm	0.015mS/cm

The temperature sensor is a thermistor of the same brand, but much **higher accuracy is achieved by probe-wise calibration** in the factory.

Difference from XBT

- Outer shape of the probe

XBTプローブ
XBT Probe

XCTDプローブ
XCTD Probe

The nose of XBT is more like streamlined body. The XCTD has **flat front** and **ring hood** around the tail fins (except XCTD-3). For these differences, XBT falls much quickly than XCTD, and the former works on faster ships.

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Instruments and Methods

Evaluation of the fall rates of the present and developmental XCTDs

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Table 1
Specifications of the TSK XCTDs that are currently available or under development

Model	Speed (kt)	Range (m)	Probe weight (g)	Wire length (m)	Wire diameter (mm)	Ring hood	Manufacturer's a	Manufacturer's b
XCTD-1	12	1000	688	1025	0.09	Yes	3.42543	4.7×10^{-4}
XCTD-2	3.5	1850	682	1954	0.07	Yes	3.43898[a]	3.1×10^{-4}[a]
XCTD-2F	8	1850	682	1954	0.07	Yes	3.43898	3.1×10^{-4}
XCTD-3	20	1000	687	1025	0.09	No	5.07598	7.2×10^{-4}
XCTD-5	8	1850	773	1915	0.09	No	N/A	N/A

Speed allowance, profiling range, initial probe weight in fresh water, the length and diameter of probe wire, and the coefficients of the manufacturer's fall-rate equations installed in the TS-MK-130 XCTD system. The XCTD-2F is for Japan Coast Guard only.

[a]For probes with serial numbers smaller than 05011071 and not 04120989 nor 04120990, the coefficients are $a = 3.3997$ and $b = 3.0 \times 10^{-4}$.

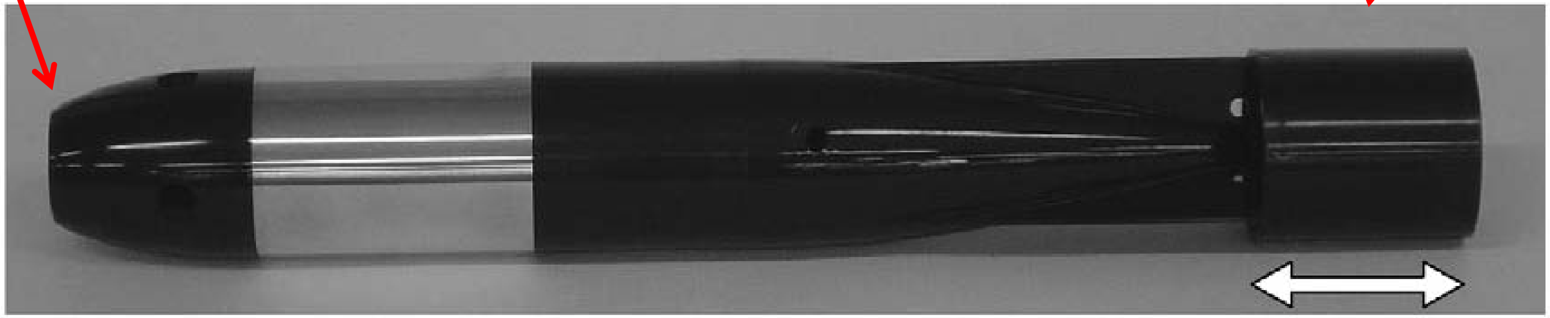
Kizu, Onishi, Suga, Hanawa, Watanabe, Iwamiya (2008)

Stability in the fall

Corner

Ring hood

XCTD-1
XCTD-2



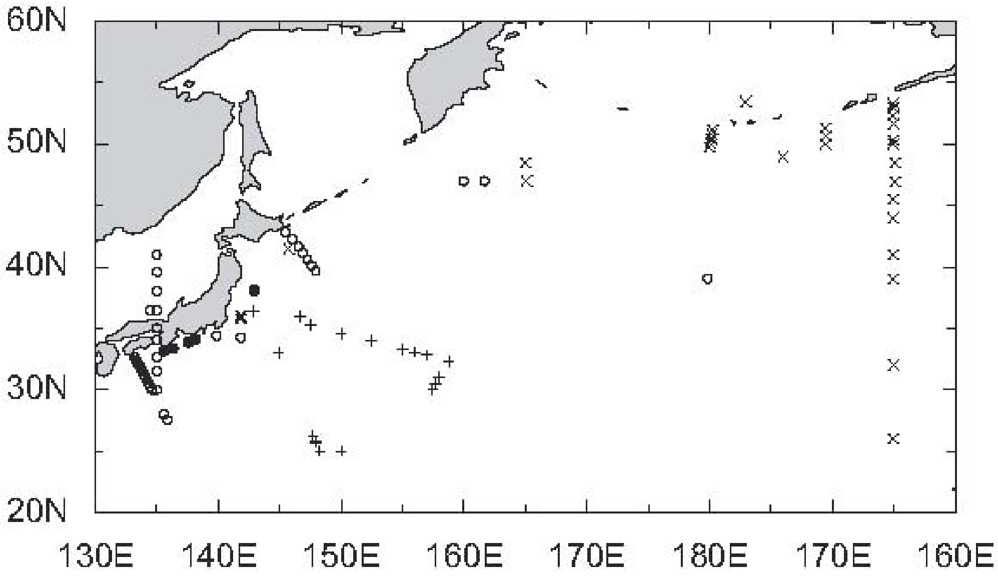
XCTD-3

Round

T-7 (TSK)

Kizu, Onishi, Suga, Hanawa, Watanabe, Iwamiya (2008)

XCTD/CTD comparisons



x Subset A (Hokkaido Univ)
+ Subset B (KH06-1)
o Subset C (Japan Coast Guard)

Table 3
The mean and standard deviation of the a and b coefficients for the XCTD-1 and the XCTD-2/2F in Groups A–C

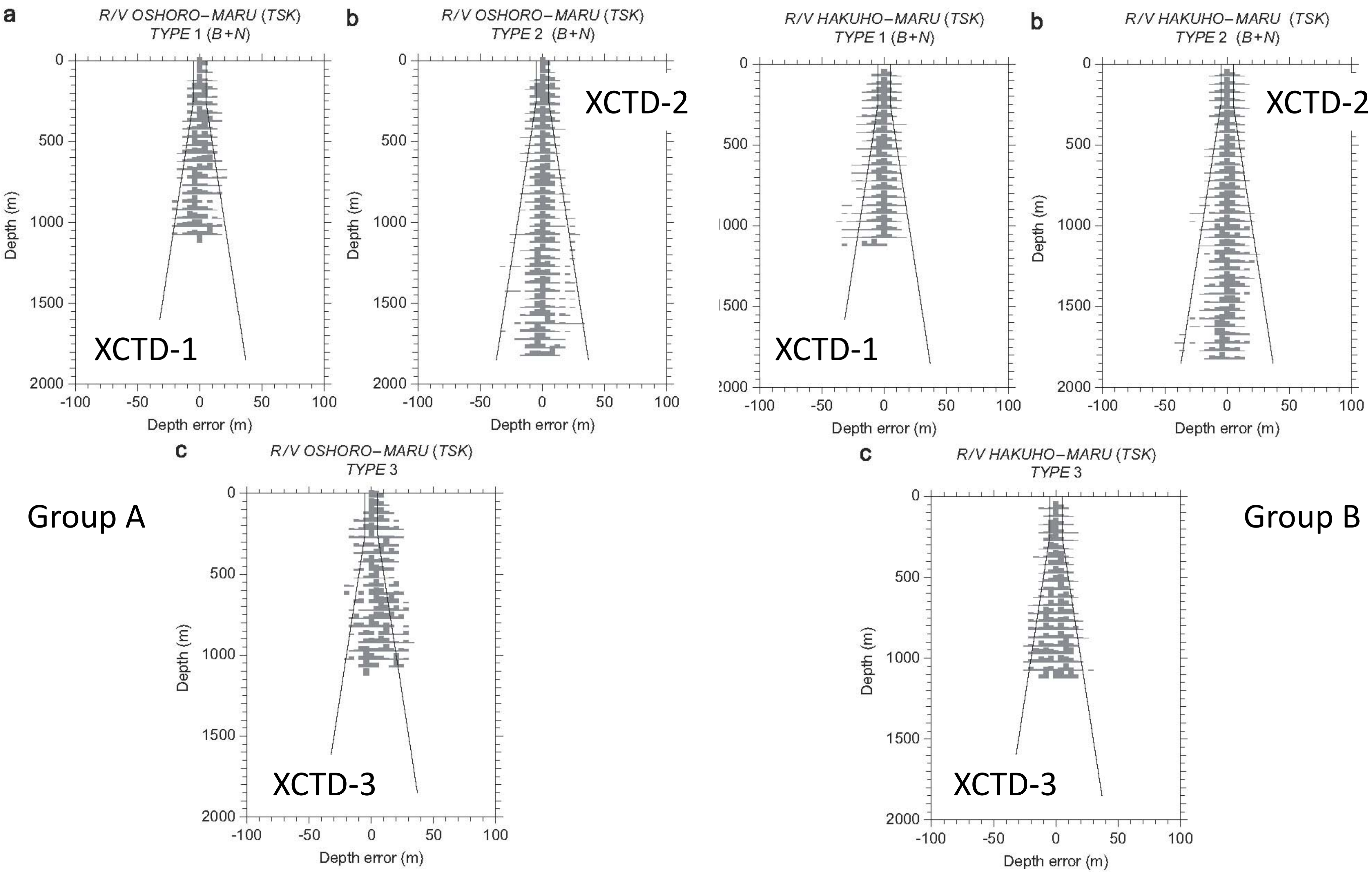
	XCTD-1		XCTD-2/2F		
	Group A	Group B	Group A	Group B	Group C
a (ave.)	3.4018	3.4392	3.4293	3.4329	3.4345
b (ave.)	2.95E−4	4.96E−4	2.85E−4	3.04E−4	2.93E−4
a (std.)	0.0589	0.0291	0.0280	0.0267	0.0195
b (std.)	4.74E−4	1.05E−4	6.77E−5	7.34E−5	5.99E−5
N	25	28	40	27	36

N is the sample size.

Table 4
Same as Table 3 but for the XCTD-3 and the XCTD-5

	XCTD-3		XCTD-5	
	Group A	Group B	Group A	Group B
a (ave.)	4.9724	5.0644	5.0318	5.0621
b (ave.)	4.04E−4	6.54E−4	4.38E−4	4.57E−4
a (std.)	0.1213	0.0513	0.0863	0.0550
b (std.)	5.22E−4	2.92E−4	3.22E−4	2.82E−4
N	17	18	18	17

Depth error statistics



Kizu, Onishi, Suga, Hanawa, Watanabe, Iwamiya (2008)

FRE coefficients vs. Water temperature

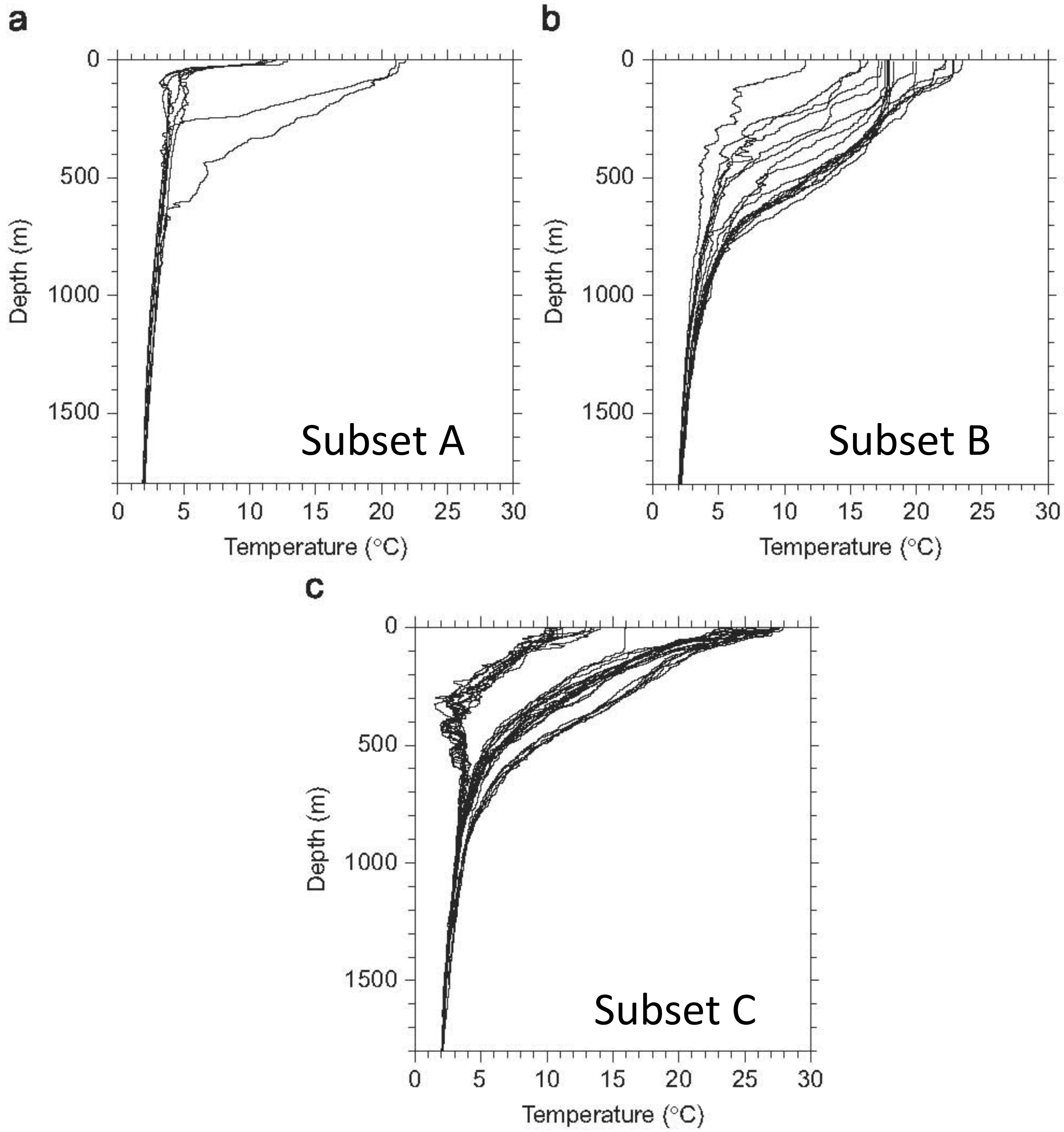
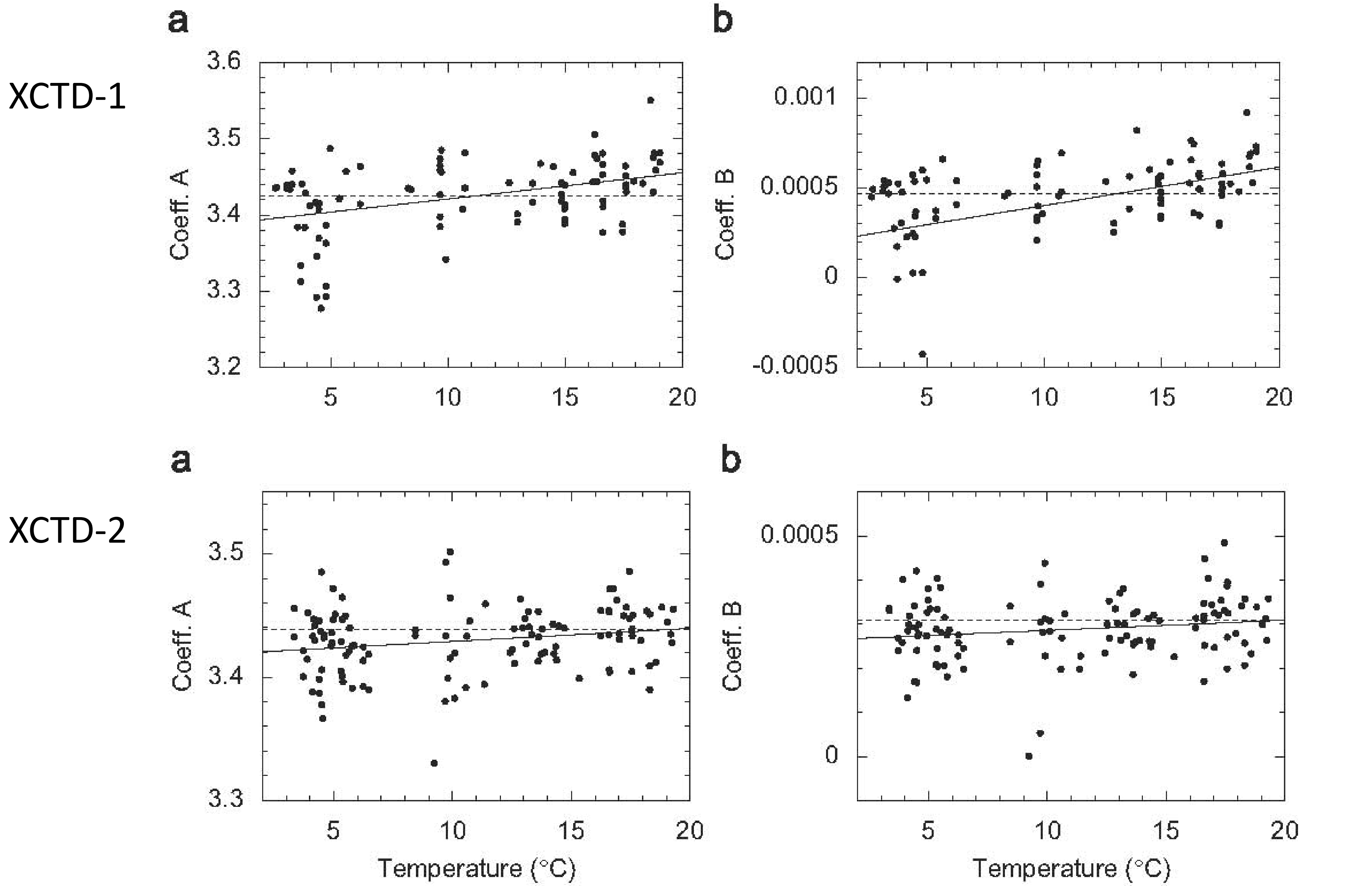


Fig. 3. CTD temperature profiles obtained from (a) Group A, (b) Group B and (c) Group C.

Kizu, Onishi, Suga, Hanawa, Watanabe, Iwamiya (2008)

FRE coefficients vs. $T_{AVG\ (0\text{-}500m)}$



Kizu, Onishi, Suga, Hanawa, Watanabe, Iwamiya (2008)

Temperature-dependence of fall-rates (T5) *Kizu and Hanawa (2005b)*

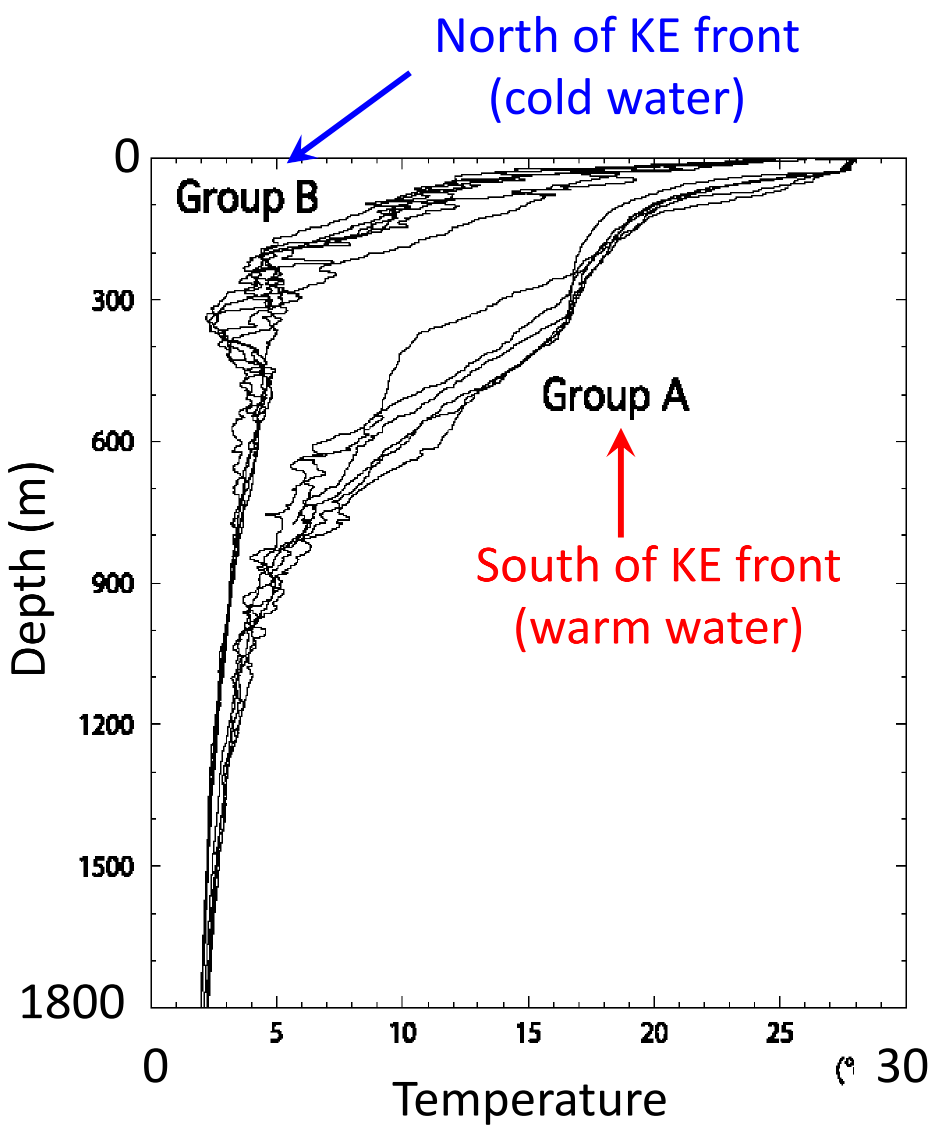
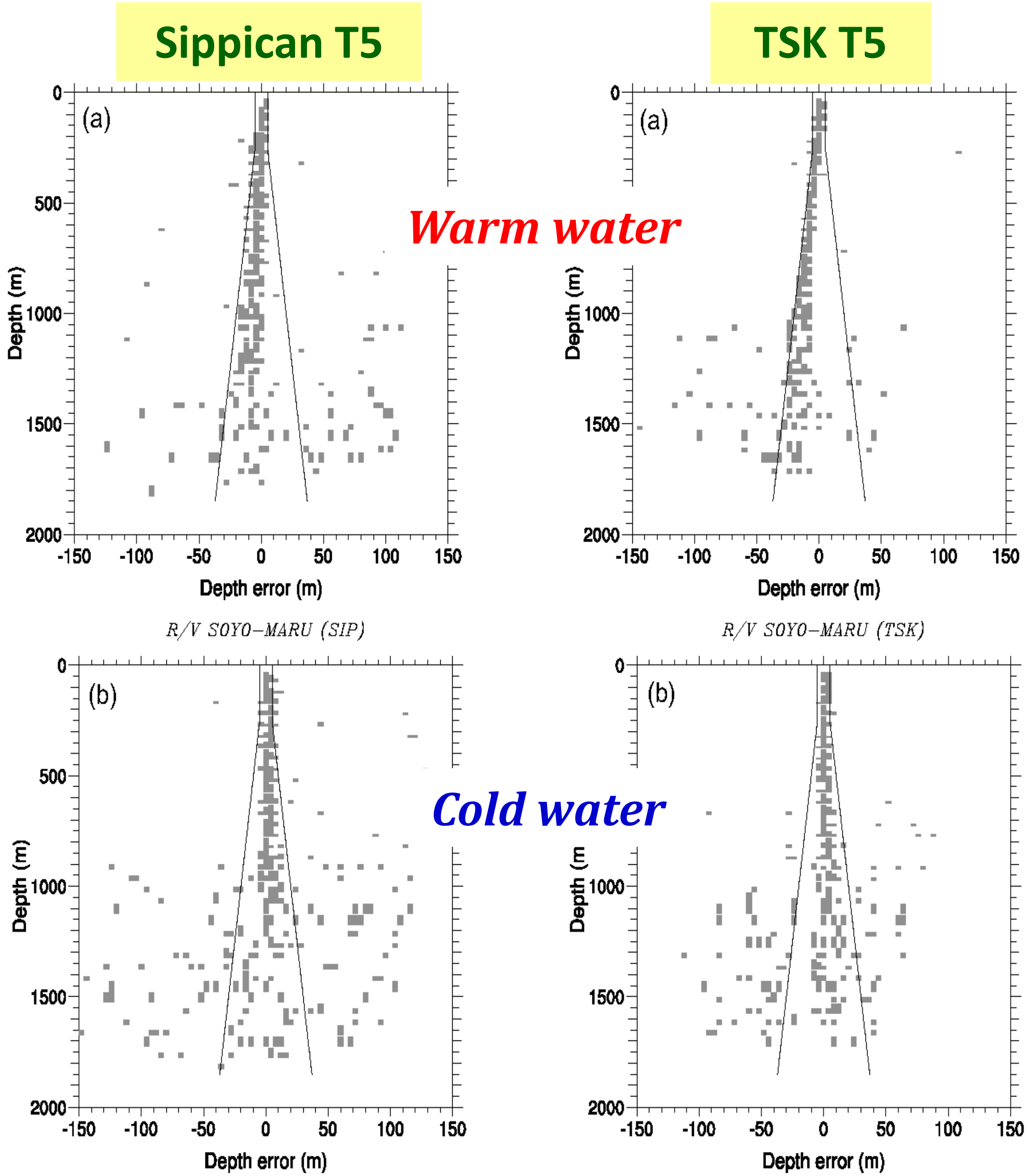


Fig. 7. All temperature profiles obtained by CTD profilers during the *R/V Soyo-Maru* cruise. Group A from warm water region and Group B from cold water region.

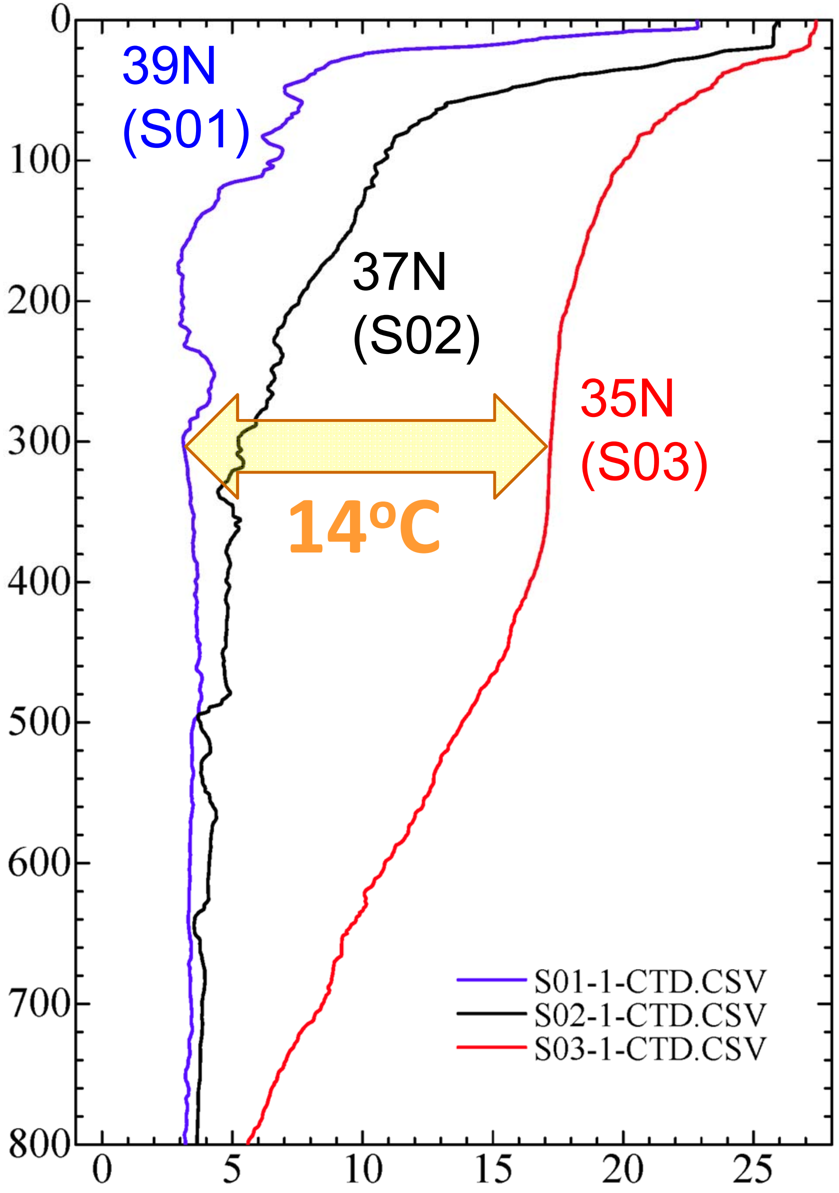


TSK T5 showed larger temperature dependence than Sippican T5.

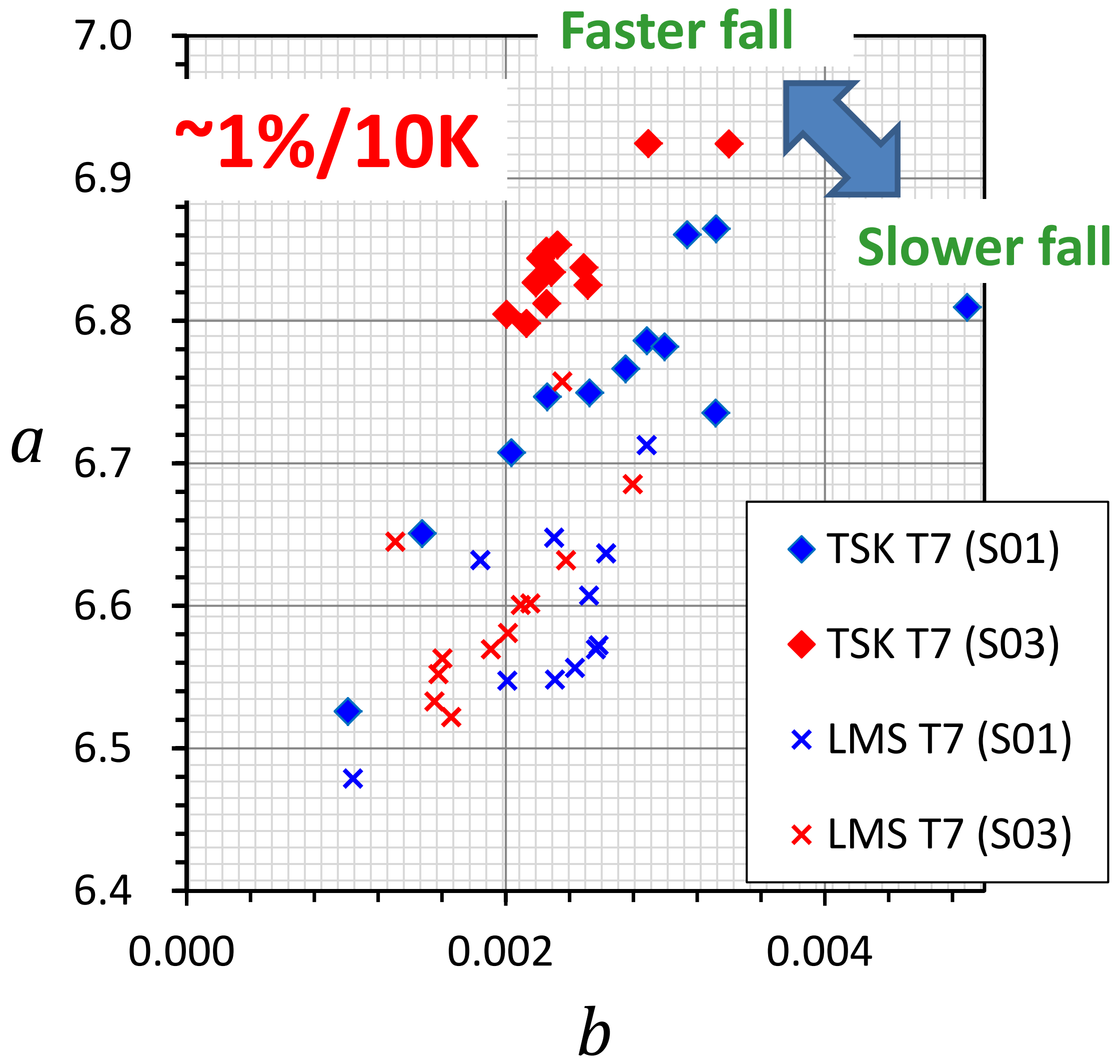
Temperature-dependence of fall-rates (T7)

A test off Honshu (143E)

(Kizu and Hanawa, to be published)



XBT "feels" change of water viscosity.



FRE coefficients vs. Water temperature

Table 5
Temperature dependency of the fall rate of each XCTD type, estimated by linear regression

Type	a_0	a_1 (K^{-1})	b_0	b_1 (K^{-1})	N_p
XCTD-1	3.387	3.4e−3	1.87e−4	2.14e−5	93
XCTD-2	3.418	1.1e−3	2.63e−4	2.31e−6	119
XCTD-3	4.938	8.0e−3	3.42e−4	1.85e−5	35
XCTD-5	5.005	4.1e−3	3.83e−4	6.27e−6	35

The constants a_0 and b_0 are the values of a and b at 0 °C. The sensitivity of a and b coefficients to water temperature is given as a_1 and b_1. The number of profiles used in the regression (the number of points in Figs. 9–12) is shown as N_p for each type.

T-dependence of linear coefficient: ~<1% for 10K (in T_{AVG}), suggesting more turbulent?

T-dependence of quadratic coefficient: >0, perhaps due to stratification (quicker T change)

Kizu, Onishi, Suga, Hanawa, Watanabe, Iwamiya (2008)