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Trial to check XBT fall rate and to develop simple numerical model

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We will try to directly check fall rate of XBT probes, currently used in our community, based on inter-comparison experiments between CTD and XBT, for three years from 2011 to 2013, under the research grant from MEXT.

The obtained inter-comparison data will also be used to develop a simple numerical model for XBT fall rate.

Systematic error sources of XBT data

Two findings on systematic error sources of XBT data

1. Temporal variability of XBT fall rate
2. Warm temperature bias

In order to solve these issues, many attempts have been made and now going on.

Several kinds of approach to solve to temporal variability of XBT fall rate:

1. Comparison between gridded (binned in space and time) data sets of XBT and other more accurate measuring methods such as CTD
   e.g., Gouretski and Koltermann (2007), Wijffels et al. (2008)
2. Comparison between bathymetry and probe bottom-hitting depth
   e.g., Gould et al. (1991), Good (2011)
3. Re-examination of inter-comparison experiment data
   e.g., Cheng et al. (2010)

Our contribution to this issue:

1. To monitor fall rate for XBT probes currently used in our community
2. To provide some suggestion to XBT manufacturers to stably keep present fall rate, based on numerical approach for fall rate

Our Project for XBT fall rate issue

Project name:

Development of numerical model for free-fall type sensors and its validation

PIs:

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Term of the project:

FY2011 to FY 2013; research fund is about 15 thousand US$/year

Purposes of the project:

1. **'Real time' check of fall rate of XBT probes, currently being in the circulation, provided from both TSK and LMS**
2. **Development of simple numerical model for XBT fall rate. The model is used to get some idea on shape and weight of probes, to reduce the scatter in XBT fall rate and stably keep the fall rate in time.**

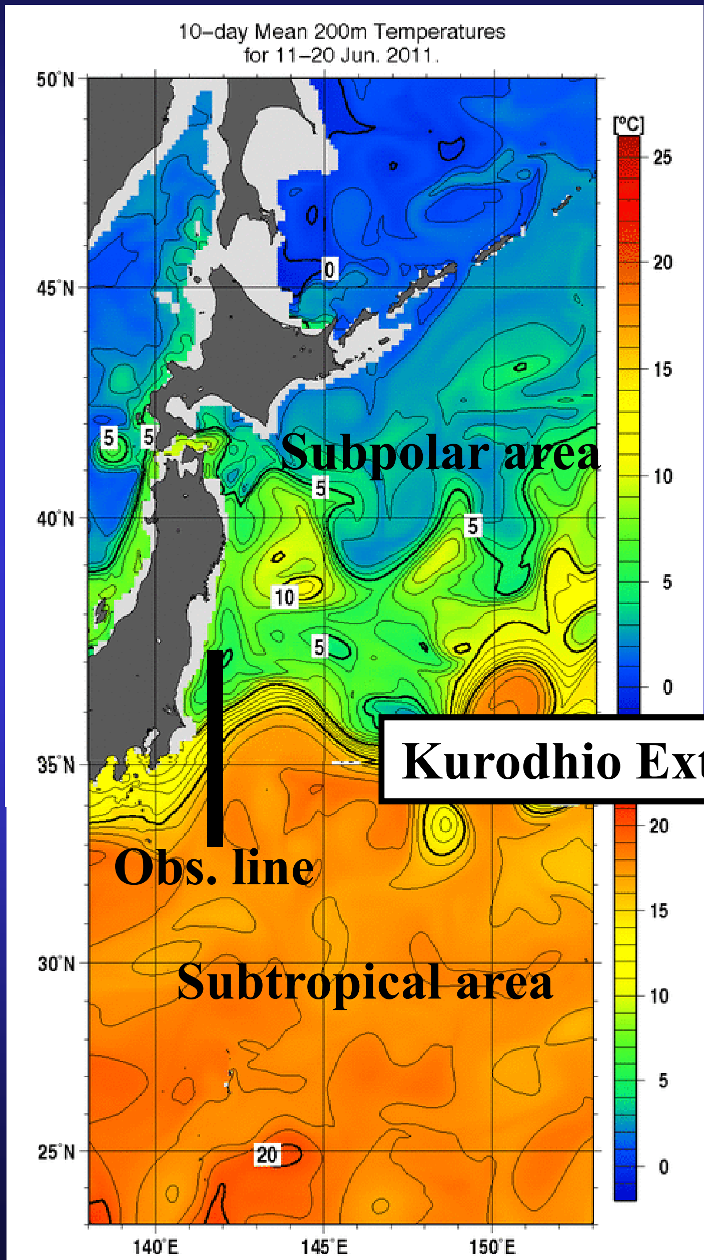
Objective probes: 5 types

TSK: T-6 and T-7; for purpose 1

Reduced-weight probes of (T-7) minus 10 and 20 g; for purpose 2

LMS: T-7; for purpose 1

Inter-comparison experiment in 2011



Shinyo-Maru Cruise:

August 6 to 10, 2011

7 stations along 142°E from 37°N to 33°N

Two CTD casts down to 1000db at each station

2 probes for each of 5 types of XBTs are to be dropped.

This kind of experiment will be done every year from this year to 2013, using Shinyo-Maru cruise.

Shinyo-Maru
Tokyo University of Marine Science and Technology

Scatter of XBT fall rate

Fall-rate equation for XBT probe: $z = at - bt^2$

z: depth of probe in meter
t: elapsed time from the hit at the sea surface in second
***a* and *b*: constants to be determined empirically**

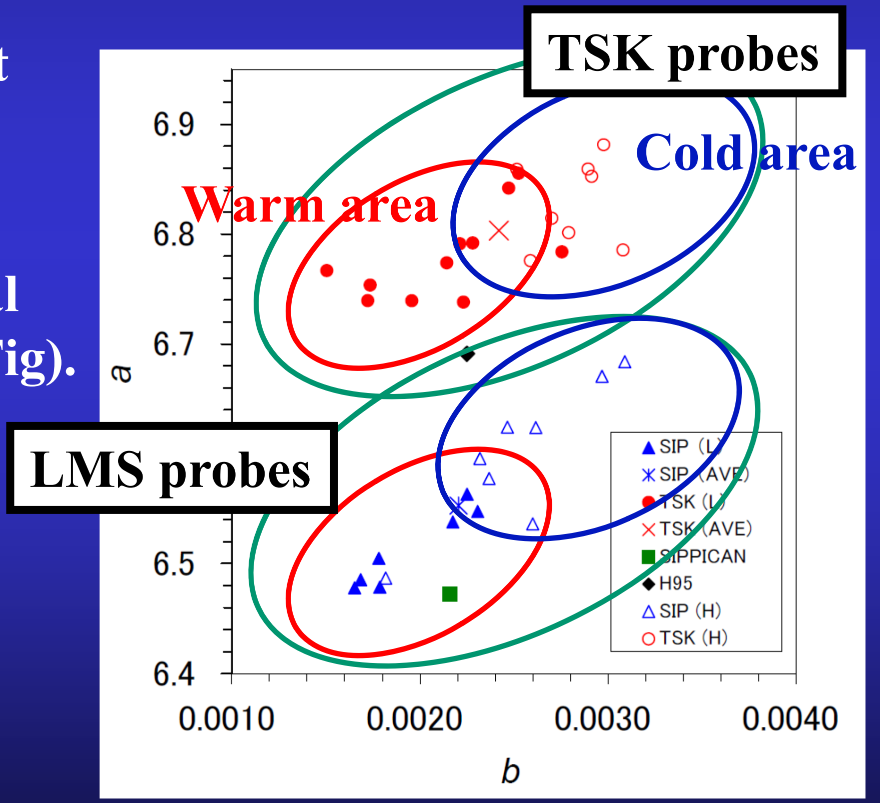
The results of inter-comparison experiment of XBT vs. CTD are plotted on the '*a-b*' plane.

In general, obtained *a-b* pairs for individual probe widely scatter on the *a-b* plane (see Fig).

What is the reason responsible for this scatter?

What kinds of caution should XBT manufacturer pay their attention in production of XBT probe?

In order to clarify these points, numerical model would be useful.



Kizu *et al.* (2011), Ocean Science

Model for free-fall type sensors

Basic equations for free-fall type sensors (so-called rocket launching model)

$$(M+m)\frac{d}{dt}s = \{(M+m) - \underbrace{\rho(V+v)}_{①}\}g - \underbrace{(k+dk)}_{②}s^2$$

equation of motion

$$\frac{d}{dt}(M+m) = s\frac{m}{L}$$

temporal change of probe weight

① buoyancy

② effect of drag

z (depth) should be inserted here.

M: weight of the probe except for wire (kg)
V: volume of the probe except for wire (m^3)
m: weight of the wire installed in probe (kg)
v: volume of the wire installed in probe (m^3)
L: initial length of the wire (m)
ρ: water density (kg/m^3)
s: free-fall velocity of the probe (m/s)
g: acceleration of gravity (m/s^2)

k and dk : unknown parameters to be determined

k: effective drag coefficient of the probe proportional to square of velocity (kg/m^4)

dk: variable component of k linearly depending on the probe depth (kg/m^3) reflecting temperature change in depth

Dependence on total weight of the probe

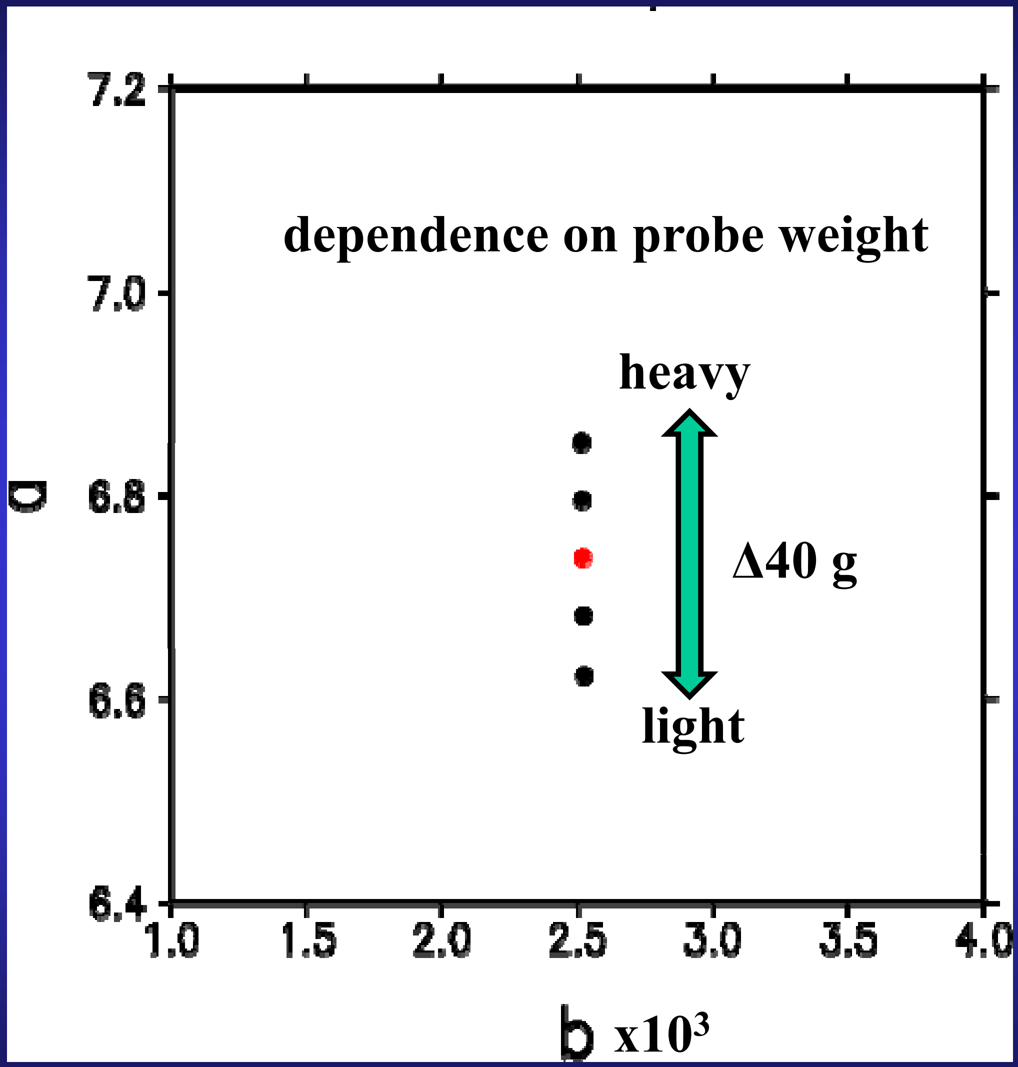
After we set the prototype fall-rate equation, we can estimate effects of each of various parameters.

First, we estimate effect of probe weight on *a-b* constants.

Figure shows *a-b* dependence on probe weight.

As weight increases, then *a* becomes larger, but *b* does not change.

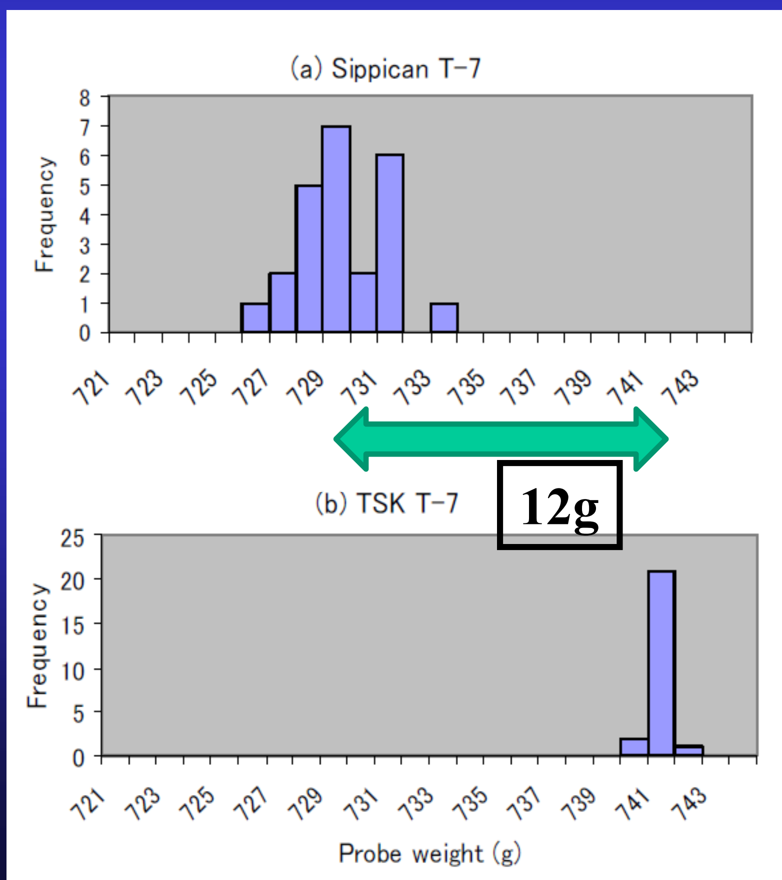
Roughly speaking , change of 10g in weight gives change of 0.06 in *a*.

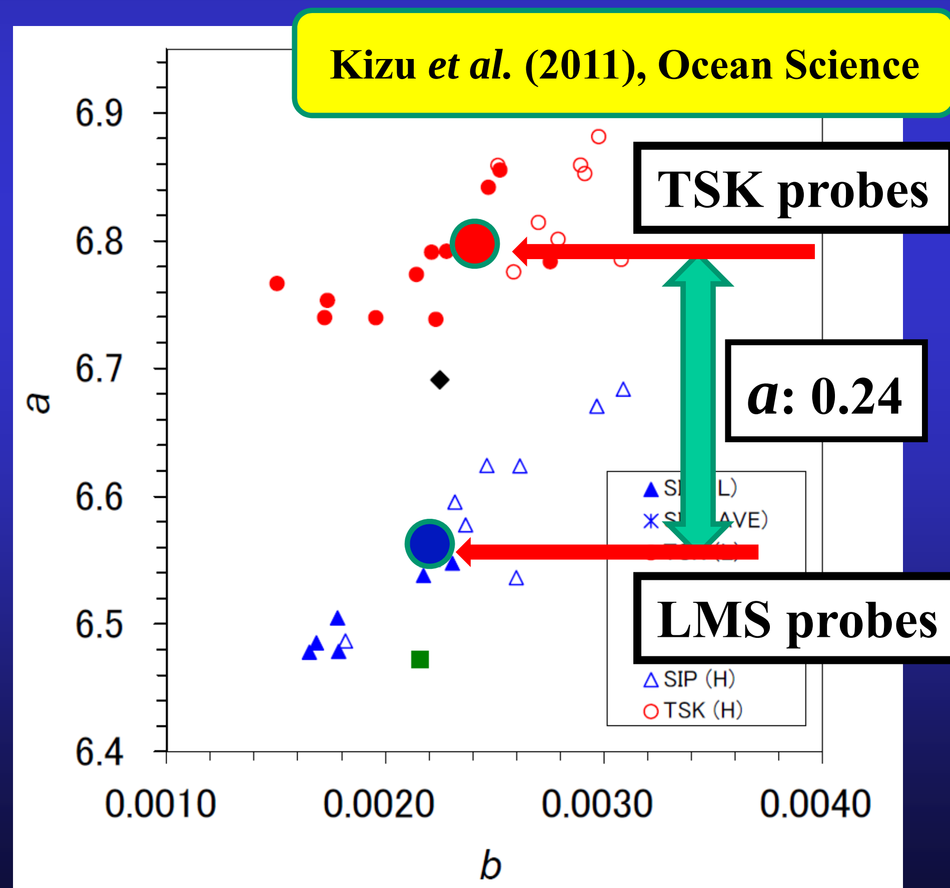


Weight = 560, 570, 580, 590, 600 g

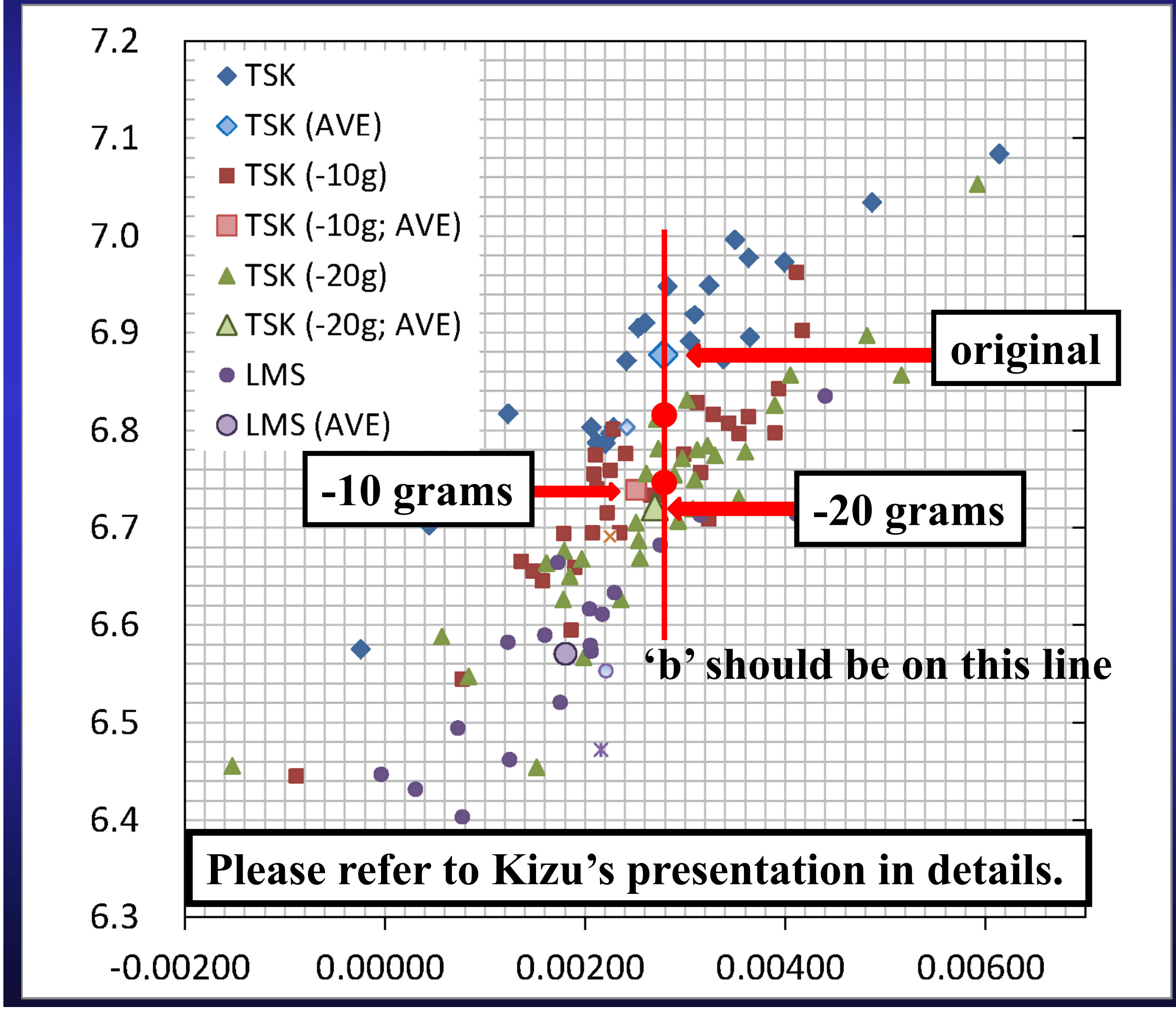
Interpretation of difference between Sippican (LMS) and TSK probes

Our model says that change of 10g in weight gives change of 0.06 in *a*.
So, difference of 0.24 in *a* cannot be explained by difference of weight only.
Other effect might influence on fall rate. We suppose the difference in shape causes difference effective drag coefficient (k) , and this different k gives different pairs of *a* and *b* between Sippican (LMS) and TSK probes,





Interpretation of difference in weight of TSK probes:
Preliminary result from Hakuho-Maru cruise (February, 2011)



	a	*b* (x10³)
TSK	6.877	2.78
-10g	6.739	2.51
-20g	6.721	2.70

Model predicts for '*a*'

-10g	6.817
-20g	6.757

Obs. result is not same as model prediction, but not so bad.

More data should be accumulated.

Remarks on numerical model

The developed numerical model is so simple, but I believe the model can provide some useful suggestion concerning the degrees of allowable scatter of XBT probes to XBT manufacturers.

e.g., scatter of the weight of XBT probe in the water should be within +/- 2 g.

scatter of the weight of wire in the water should be within +/- 0.000001 g/m.

the probe shape is critical one, since it drastically changes the magnitude of effective drag. The probe shape should be kept as it is absolutely.

etc.

I guess XBT probes (shape and weight etc.) have been changing in time, and therefore fall rate has been changing in time. We had better recommend to XBT manufacturers that XBT probes should not be changed from any kinds of viewpoints.

Summary

In the project granted by the MEXT

1. **We will check fall rate of T-6 and T-7 probes of TSK and T-7 probes of LMS, every year, for three years from 2011 to 2013, based on by in-situ inter-comparison experiment.**

2. **In inter-comparison experiment, we also deploy artificially reduced-weight probes, in order to check performance of numerical model to be developed in the project.**

3. **Based on the result of numerical model, we want to give some suggestion recommendation to XBT manufacturers on allowable scatter of probe specification such as probe weight and wire weight, etc.**