ZANASCA

to : URD 19.07.94

: AOG

: P.M. POULAIN

: OED

: E. McCARTHY

: C. MONTANARI

from : P. ZANASCA

subj. : On board XBTs calibration.

The accuracy, in temperature, of the XBTs is commonly specified to be +/- 0.15 deg.

This is not sufficient for the Oceanographics applications.

We calibrated the XBTs to improve the accuracy considerably, on board of the 'ALLIANCE', during the cruise GIN 93 (see relevant CRUISE REPORT, pag. 6).

The individual XBT temperature offsets are determined by using two stirred calibration baths, at two different temperature, and a stable accurate reference platinum thermometer.

Other comparison were done reading the SST from water buckets and profiles from CTDs.

A few considerations were done on the depth errors.

XBT CALIBRATION

The calibration was done between two points using two different baths at sea water and different temperatures; the temperature values was respectively: 2.66 (+/- 0.82) and 8.60 (+/- 1.35) deg. (fig.1).

Out of 390 XBTs, 364 were calibrated at the low temperature, 357 were also calibrated at the higher temperature. The rest were not calibrated due to broken XBTs or unstable calibration conditions.

The average errors between XBT and calibration BATH temperature readings were:

- *bath 1 (low temp.) : -0.006 +/- 0.063 deg.*
- *bath 2 (higher temp.) : -0.024 +/- 0.060 deg.*
- *bath 1+2 (all temp.) : -0.015 +/- 0.062 deg.*

The following equation is the best-fit of all points:

$$T(xbt) = T(bath) * 0.99731 - 0.000058$$

with an error of +/- 0.061 deg. and a linear correlation coefficient of 0.999812 (fig.2).

If we consider only XBTs within a maximum error of +/- 0.1 deg. (92% of the XBTs for both temperature) we have the following results:

- *bath 1 : -0.011 +/- 0.042 deg.*
- *bath 2 : -0.014 +/- 0.038 deg.*
- *bath 1+2 : -0.013 +/- 0.040 deg.*

and within a maximum error of +/- 0.08 deg. (85% and 89% of XBTs) we have the following results:

> *bath 1*	: *-0.011 +/- 0.035*	*deg.*
> *bath 2*	: *-0.012 +/- 0.035*	*deg.*
> *bath 1+2*	: *-0.011 +/- 0.035*	*deg.*

Doing again the best-fit with all points (2 temp. and max. error +/- 0.08 deg.) we arrive to the following equation:

$$T(xbt) = T(bath) * 0.999992 - 0.011$$

with an error of +/- 0.035 deg. and a linear correlation coefficient of 0.99993837.

We can note that at least 85% of XBTs have a good stability and accuracy. A further improvement of the on-board calibration could be made, i.e. we could record the bath temperatures to calculate the averaged value, (during the measurement period time) instead of transcribing a personal interpretation of the value; to ensure the homogeneity of the water temperature; to control the measurement stability both from the bath temperature and from XBT temperature having the two systems great differences in time constant (1). It also important that, prior to launch, the XBT might remains in an environment with a temperature very similar to that expected in the sea surface.

This is because the temperature of the XBT nose has a significant effect on the sensor (2).

BUCKET COMPARISON

Althouth no longer recommended (2), a bucket of salt water has been taken to measure sea surface temperature. An IDRONAUT thermometer, calibrated before the cruise, has been used with a stability reference of -0.02 deg. measured after two months.

These temperatures have been compared with the XBTs data, assuming first manually edited value and selecting five different depth ranges:

1 - < 1 m
2 - 1 , 3.5 m
3 - 3.5, 5.5 m
4 - 5.5, 8.5 m
5 - > 8.5 m

Comparisons have been repeated after having calibrated the individual XBT, by means of the calibration baths installed on board for this purpose.

The following results have been determined (XBT temp. minus BUCKET temp.):

\ range	1	2	3	4	5	XBTs
aver.	-0.13	-0.08	-0.04	-0.01	-0.05	without calib.
st.dev.	0.28	0.21	0.27	0.23	0.32	
aver.	-0.11	-0.06	-0.02	0.01	-0.03	with calib.
st.dev.	0.27	0.23	0.28	0.23	0.31	

****

CTD COMPARISON

Temperature

We chose some well defined points from the profiles of an XBT (T7) and a CTD cast, deployed at the same time, to compare the temperature and the depth (fig.3,4,5,6). This comparison was done two times:

	XBT cast #	CTD cast #
Comparison 1)	261	20
Comparison 2)	286	30

The depth, for the XBTs, was calculated with the SIPPICAN algorithm:

$$z = -0.00216*t^2 + 6.472*t$$

The equations relating the temperatures were found to be:

$$1)\quad T(xbt) = T(ctd)*1.0234 - 0.004$$

(eq.1)

$$2)\quad T(xbt) = T(ctd)*0.9929 + 0.11$$

and the errors were found to be : +/- 0.023 and +/- 0.029 deg.

The following bath calibration algorithms were applied:

$$1)\quad T(xbt) = T(bath)*1.0026 - 0.01$$

(eq.2)

$$2)\quad T(xbt) = T(bath)*0.9860 + 0.17$$

Finally the new equations calculated were found to be:

$$1)\quad T(xbt) = T(ctd)*1.0207 + 0.006$$

(eq.3)

$$2)\quad T(xbt) = T(ctd)*1.0070 - 0.06$$

and the errors were : +/- 0.023 and +/- 0.03 deg.

The relevant characteristics of each comparison are:

comparison 1):

- *14 temperature and depth values are used,*
- *the profiles do not present very clear points to compare;*

comparison 2):

- *the temperature points are 15 and the depth points are 14 (in order not to force the surface depth difference),*
- *the points are very well defined,*
- *the XBT broke at about 120 meters, then the results might be used with caution.*

The preliminary conclusions could be the following for the two cases:

1) - the difference between the comparisons XBT-BATH and XBT-CTD (eq.1 and eq.2) is not very well-defined because:

a) in the bath control the XBT was good with errors of: -0.01 and +0.01 deg. at the two temperatures,

b) the bath-calibration does not produce great effect on data (eq.1 and eq.3),

c) the XBT calibration via CTD comparison give an error lower than mean total errors calculated from other comparisons,

d) the items a) and c) seem in contrast;

2) - a good correlation between the calibration methods (eq.1 and eq.2) (the mean error is -0.01 deg.),

- the good linearity between XBT calibrated data and CTD (eq.3) with an error inside the global errors range.

Depth

The equations that connect the XBTs and the CTDs were:

1) $z = -0.00258 * t^2 + 6.342 * t - 6.342$ *(14 points)*

2) $z = -0.05112 * t^2 + 5.825 * t - 8.131$ *(14 points)*

the equation 2) was calculated only until about 120 m.

Apart from the known limit of the SIPPICAN algorithm (3), the depths calculated present a shift of 6.342 and 8.131 m that corresponds approx. to the part of the profile with errors.

Looking to the temperature gradient (fig.7,8) this shift is evident.

Also from the bucket comparison we have indication to the same direction.

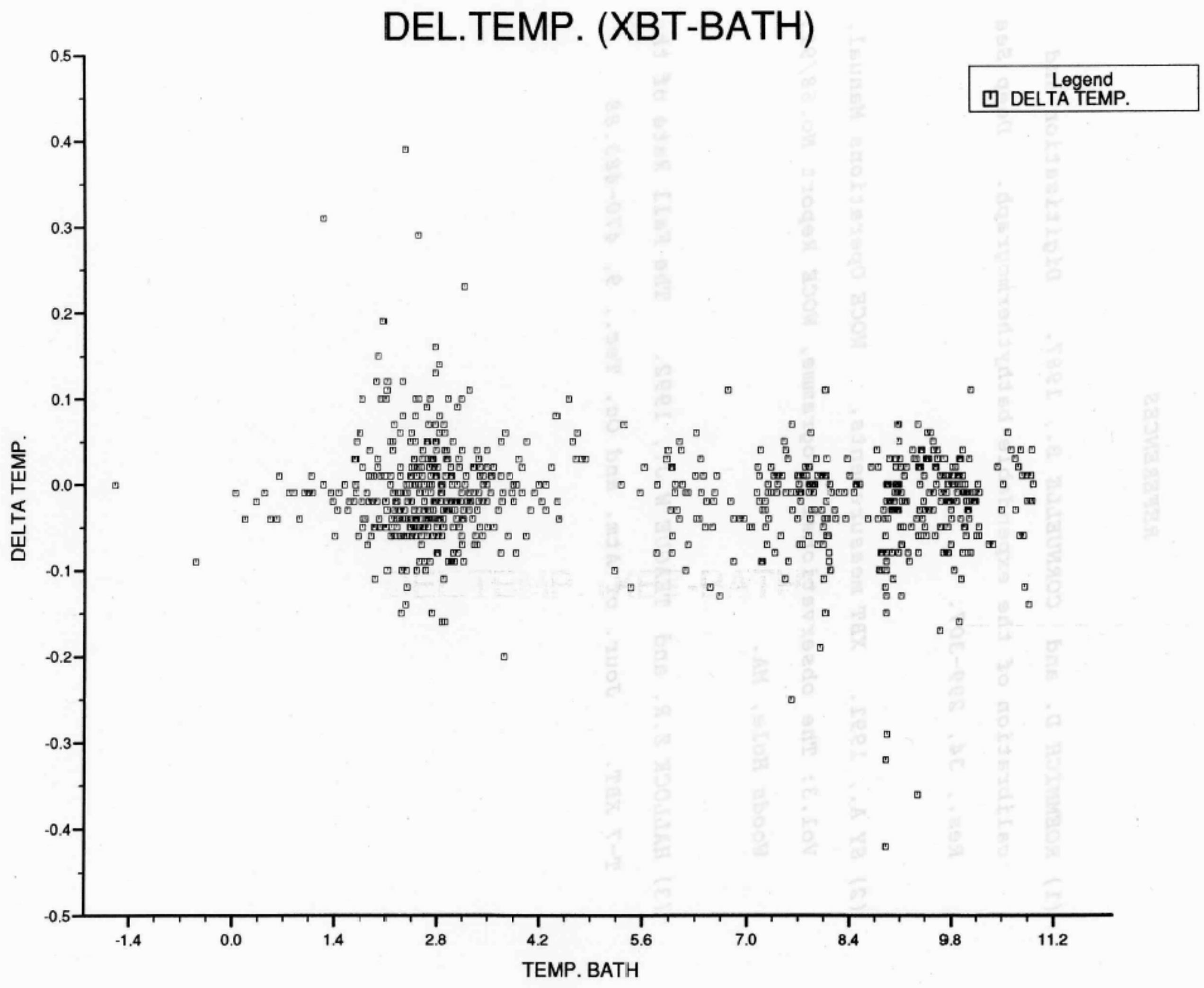
DEL.TEMP. (XBT-BATH)
Legend
DELTA TEMP.
DELTA TEMP.
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-1.4
0.0
1.4
2.8
4.2
5.6
7.0
8.4
9.8
11.2
TEMP. BATH

fig. 1

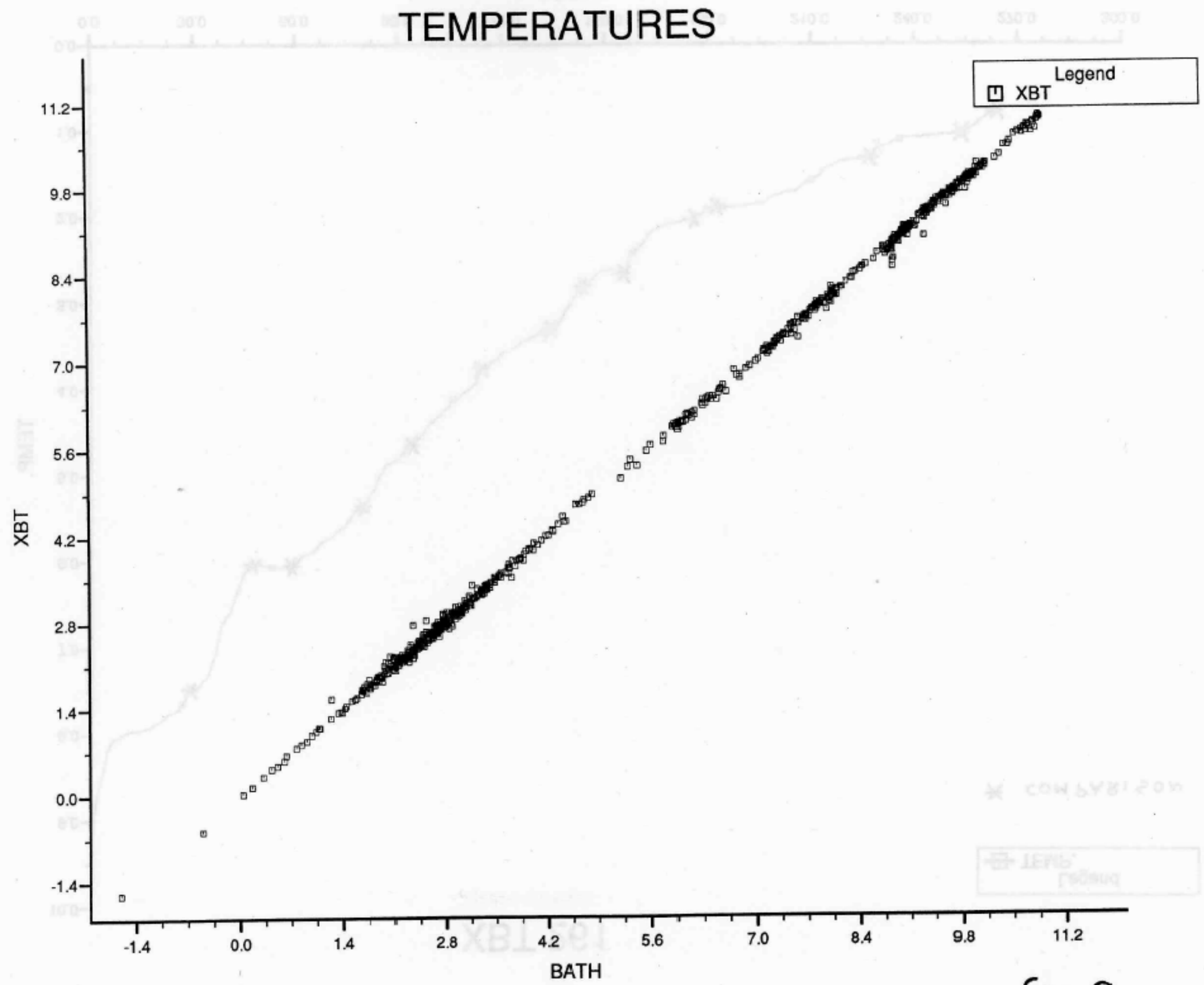

fig. 2

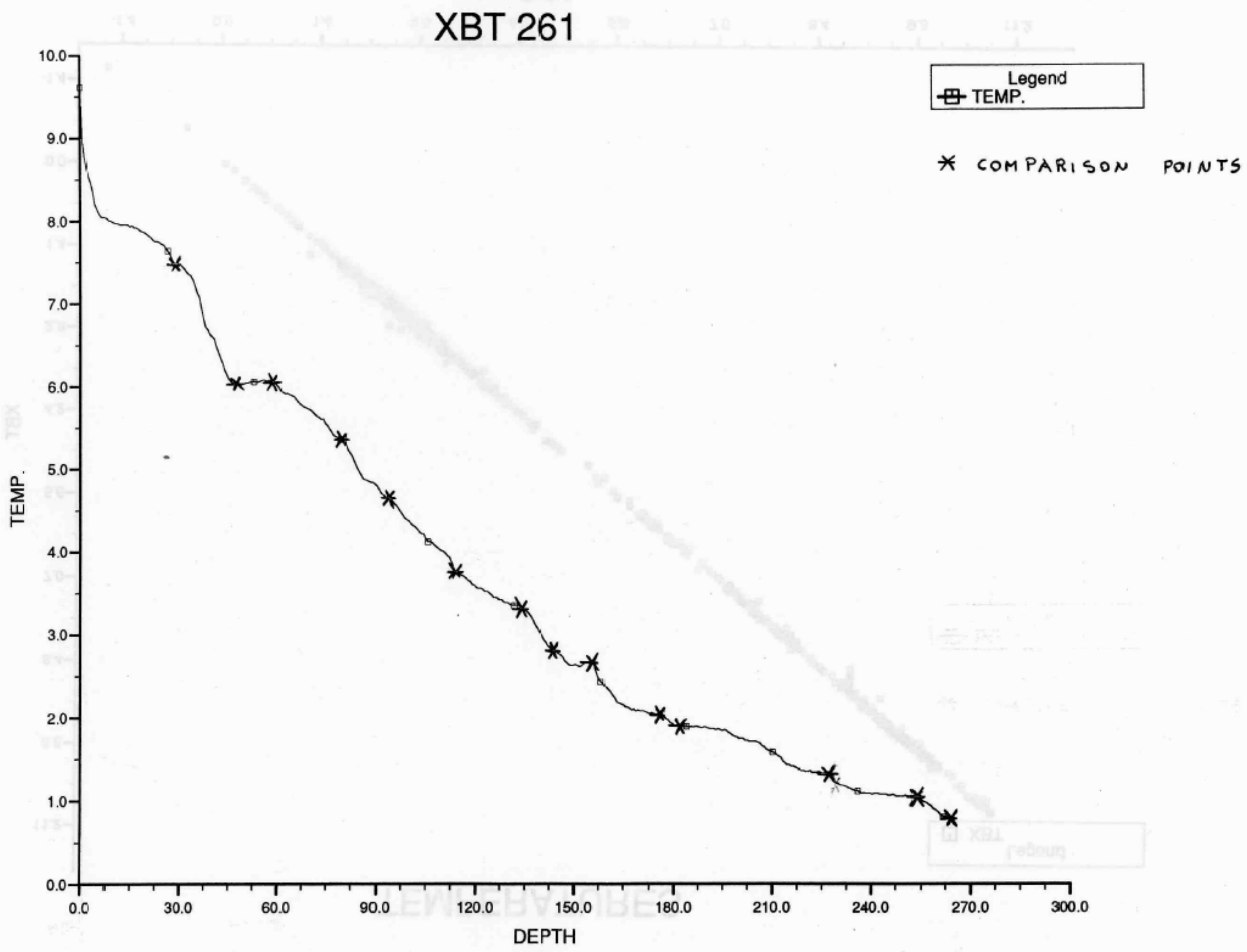
XBT 261
Legend
TEMP.
COMPARISON POINTS
TEMP.
DEPTH
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
30.0
60.0
90.0
120.0
150.0
180.0
210.0
240.0
270.0
300.0

fig. 3

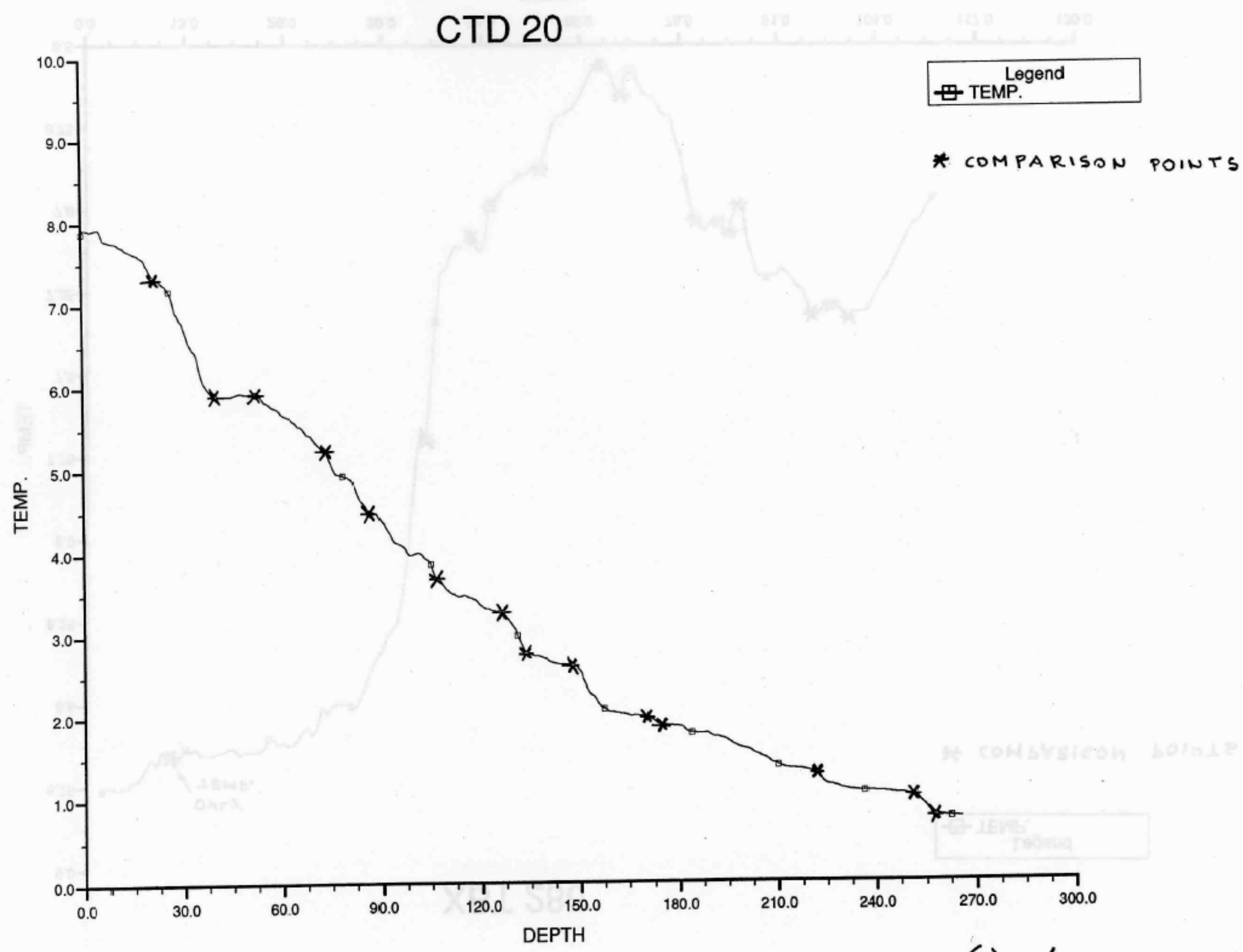
CTD 20
Legend
TEMP.
* COMPARISON POINTS
TEMP.
DEPTH
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0.0
30.0
60.0
90.0
120.0
150.0
180.0
210.0
240.0
270.0
300.0

fig. 4

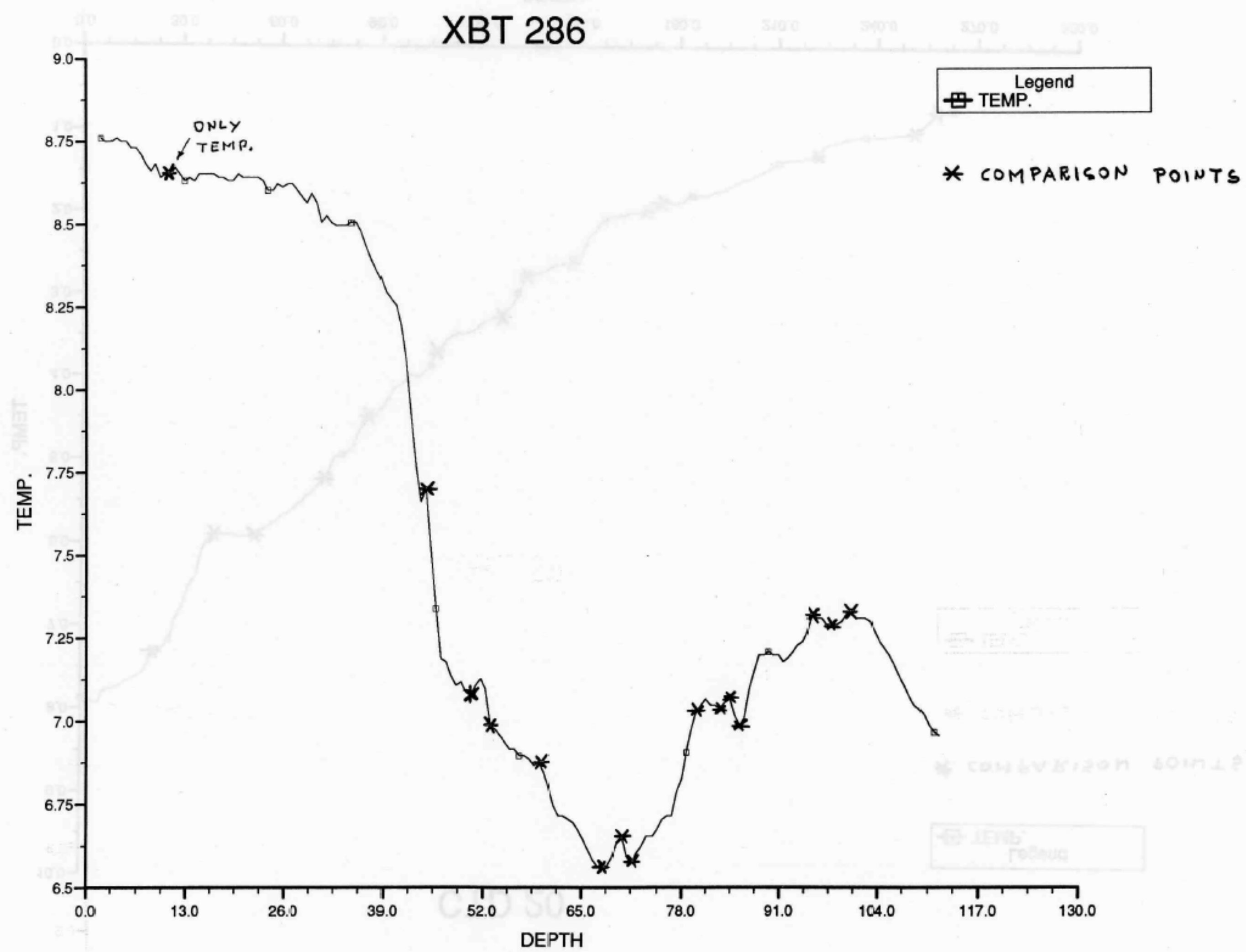
XBT 286
Legend
TEMP.
* COMPARISON POINTS
ONLY TEMP.
TEMP.
9.0
8.75
8.5
8.25
8.0
7.75
7.5
7.25
7.0
6.75
6.5
0.0
13.0
26.0
39.0
52.0
65.0
78.0
91.0
104.0
117.0
130.0
DEPTH

fig. 5

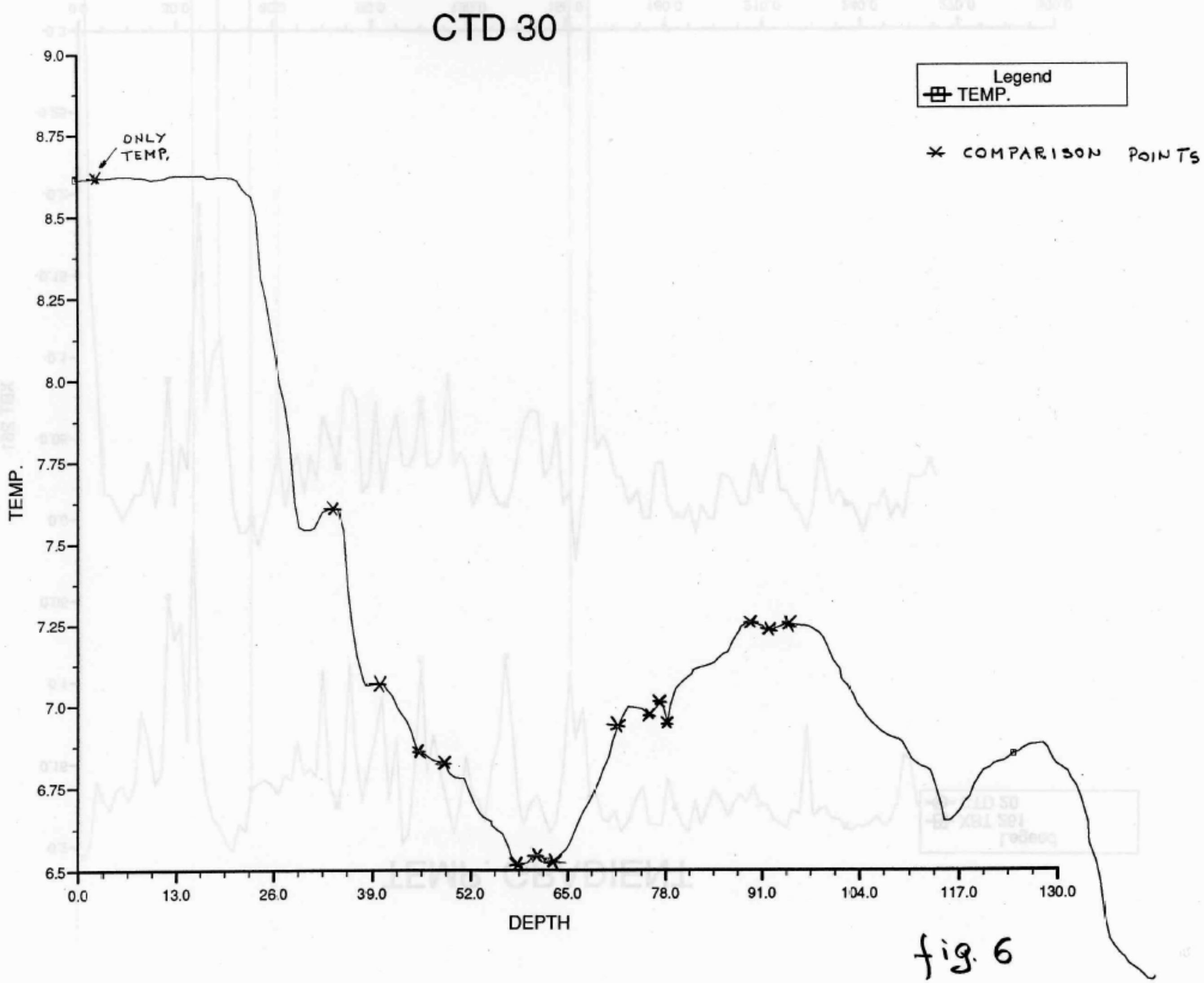
CTD 30
Legend
TEMP.
* COMPARISON POINTS
ONLY TEMP.
TEMP.
DEPTH
9.0
8.75
8.5
8.25
8.0
7.75
7.5
7.25
7.0
6.75
6.5
0.0
13.0
26.0
39.0
52.0
65.0
78.0
91.0
104.0
117.0
130.0

fig. 6

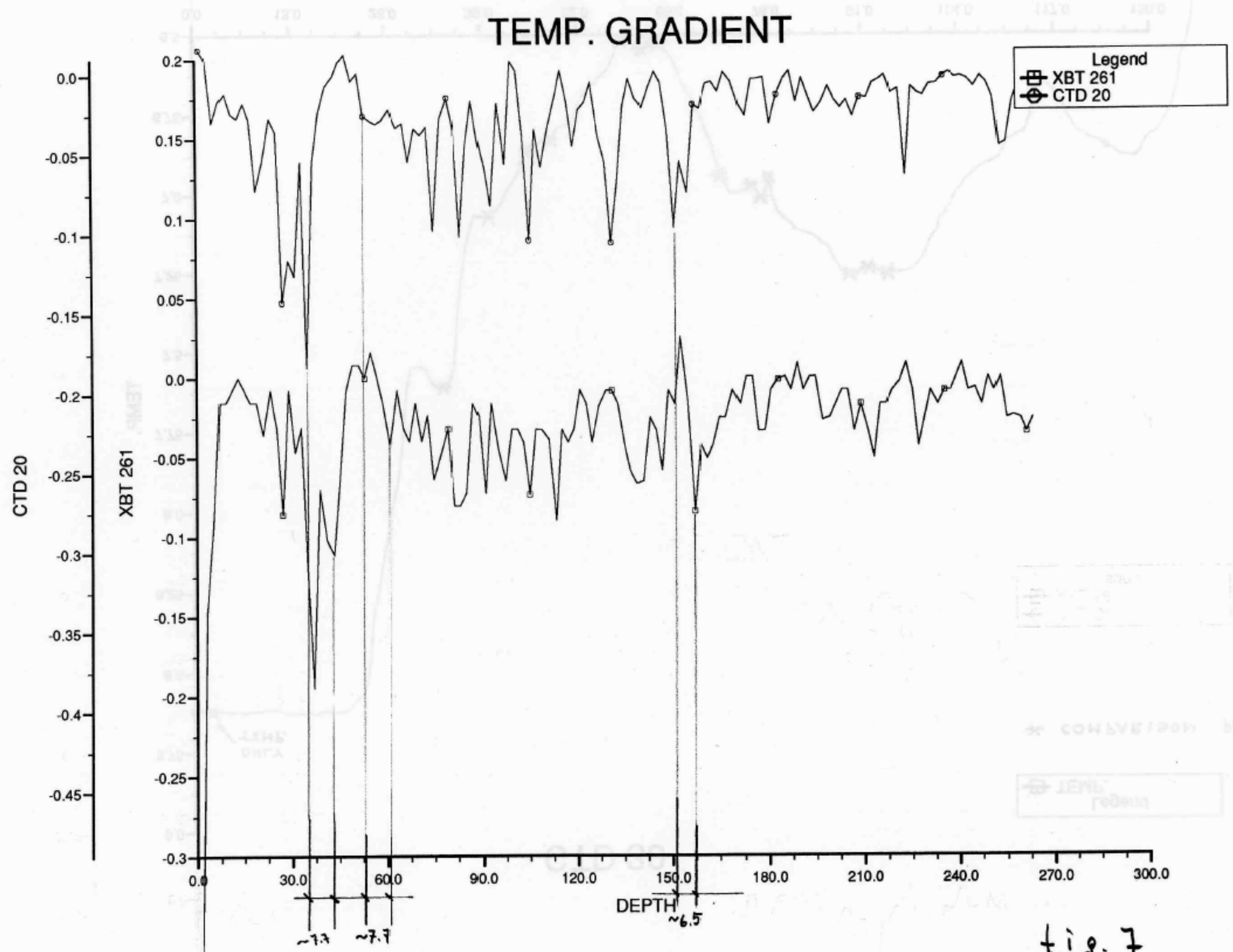
TEMP. GRADIENT
Legend
XBT 261
CTD 20
CTD 20
XBT 261
DEPTH
~7.7
~7.7
~6.5

fig. 7

TEMP. GRADIENT

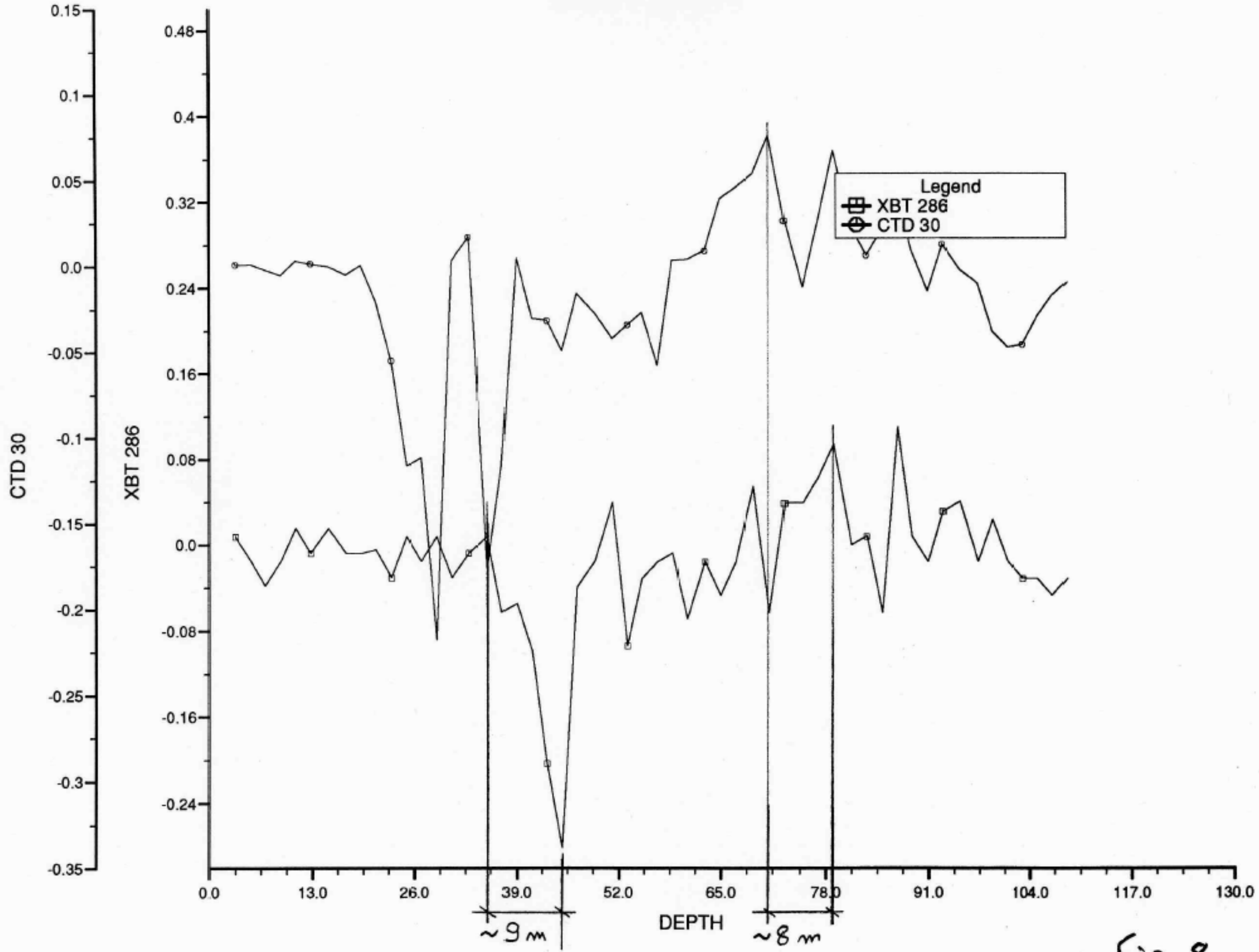

fig. 8