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On the calibration of the CTD data collected by "KNMI" during JASIN-78.

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Summary.

The calibration results of the KNMI CTD for the JASIN data set are presented. From these results and some intercomparison dips it is concluded that the absolute uncertainty in these CTD data is of the order of 0.02 in temperature and practical salinity.

Introduction.

During the JASIN experiment KNMI collected CTD data with a Guildline CTD Type 8700. The signals of the CTD were amplified and were provided with an offset. The signals were then fed into a 15 bit A/D converter. A PDP-8 computer subsequently took care of the data storage. The sampling was done at a rate of 20 cycles per second. A running mean of 8 cycles was computed and these where stored at a rate of 5 cycles per second.

To check the calibration of the instrument waterbottle samples and reversing thermometer readings were taken in the mixed layer about once every 10 hours. The results are given below. The amplifiers were checked several times during the cruise using a voltage standard as input.

Lost data.

At the beginning of the cruise the 7^{th} bit of the A/D converter was not connected to the PDP-8 computer. Because of the averaging procedure this error could not be corrected afterwards. The files 780101 to 780129 were lost because of this error. File 780135 was lost because of a computer defect.

The A/D converter failed to change channel property sometimes. This resulted in readily recognizable errors which have been removed in the clean data. The printed circuit causing this error has been repaired several times. The files 780206 to 780229 were completely lost, while the files 780501 to 780557 show data losses of 5 to 15%.

Fauling of a conductivity cell caused the loss of files 780601 and 780602.

Temperature.

The temperature sensor was calibrated at the Van Swinden Laboratorium in 1977 to an absolute accuracy of less than .01 K. Subsequent ice point checks and comparisons with reversing thermometers have not revealed any changes in calibration up till now. So the result of this calibration is used. After survey 2 it appeared that the amplifier was incorrectly tuned. This error was corrected but the incorrect values were not written down. The correction to the temperature of the first 2 surveys was found by indirect means using the temperature effect in the salinity calculation. We used the difference in salinity calibration in the surface layer and the difference in the T/S relation of the intercomparison dip with "Challenger" at the beginning of cruise 2.
The following formula were used.
$T = 0.00100518\ V_T - 2.1035$ °C for files 780101-780261
$T = 0.00100387\ V_T - 2.0714$ °C for files 780301-780880
where V_T is the binary result of the A/D conversion on the temperature signal.

The temperature was also corrected for the time constant of the temperature sensor with the formula:
corrected $T_i = T_i + 0.04\ (T_{i+1} - T_{i-1})/2\Delta t$
where Δt is the time step between cycles in seconds (=0.2).
The time constant used of 0.040 second was provided by the manufacturer. Comparison of T/S relations of up traces versus down traces showed that this gives a good correction.
Table I shows the comparison between the calibrated CTD temperature and the reversing thermometer data. Excluding obvious extremes we get the following results:

$T_{13998} - T_{2356} = -\ 0.013 \pm 0.014\ ^{o}C$

$T_{13998} - T_{2354} = -\ 0.004 \pm 0.012\ ^{o}C$

$T_{13998} - T_{6435} = -\ 0.006 \pm 0.013\ ^{o}C$

(the index shows the number of the reversing thermometer)

Thermometers - CTD = + 0.025 ± 0.012 for surveys 1 and 2
+ 0.017 ± 0.014 for surveys 3 and 4
+ 0.014 ± 0.019 for surveys 5 and 6
+ 0.005 ± 0.011 for surveys 7 and 8
+ 0.014 ± 0.016 for all surveys

These results did not warrant a correction to the official calibration.

Salinity.

The uncalibrated R_{CTD} was converted to R_T using the formulae A.S. Bennett (1976). The salinity was subsequently calculated with the formulae from the old Unesco tables. Comparison with the salinity of the samples provided us with the small calibration factor. At the beginning of survey 6 the original cell malfunctioned and was replaced by a spare cell. The calibration factor changed accordingly. The following formulae were used:

$R_{CTD} = 1.0004\ (2.54313 \times 10^{-5} \times V_c + 0.4999)$ for surveys 1 to 5

$R_{CTD} = 1.00025\ (2.54313 \times 10^{-5} \times V_c + 0.4999)$ for surveys 6 to 8

where R_{CTD} is the in situ conductivity ratio and V_c is the result up A/D conversion of the conductivity signal.

Table II shows the comparison between the calibrated salinity and the salinity of the waterbottle samples, as analyzed on board of the Tydeman with an Autolab salinometer. A number of duplicate samples were analyzed during the second phase on board of Shackleton also with an Autolab salinometer and, one day later, with a Guildline salinometer.

Excluding some obvious extremes the following results were obtained:

$Autolab_T - Autolab_S = -\ 0.005 \pm .008$

$Autolab_T - Guildline_S = -\ 0.011 \pm .008$

$Autolab_S - Guildline_S = -\ 0.006 \pm .003$

$Autolab_T$ - CTD = -.001 ± .003 surveys 1 and 2
+.000 ± .004 surveys 3,4 and 5
-.000 ± .005 surveys 6,7 and 8
-.000 ± .004 all surveys

Pressure.

For the pressure sensor the calibration of the manufacturer was used. The amplification was such that

$P = 10^{-1} V_p$

where V_p is the result of the A/D conversion of the pressure signal. No checks on the pressure calibration were made during JASIN. Results from other cruises have given us no reason to change this calibration.

Intercomparison with "Challenger" and "Meteor".

During JASIN 2 intercomparison dips were made with "Challenger" and 1 with "Meteor". In figures 1,2 and 3 the T/S curves for these stations are given. When we consider the main thermoclines, shifts in salinity of + 0.008 for "Challenger" and of - 0.02 for "Meteor" bring the T/S curves in line. Since we can not be sure which of the curves is the better one we can only conclude that an uncertainty in the salinity of the different ships of a few hundreds remains. This result is in accordance with comparison of asynoptic data of the different ships.
Note that the salinity differences between the watermasses during JASIN are an order of magnitude larger.

References.

Bennett, A.S., 1976: Conversion of in situ measurements of conductivity to salinity. Deep Sea Res. 23 p V.157-165.

TABLE 1.

Temperature calibration data

Dip	CTD calibrated T	Thermometers 2356	6435	13998	2354	Δ T
103		11.90		11.88		
108		12.08		12.08		
113		11.63		11.63		
118		11.88		11.86		
123		11.36		11.33		
129		11.43		11.41		
139	11.904	12.00		11.96		(.076)
144	11.457	12.48		12.47		.018
157	11.815	11.83		11.83		.015
162	11.733	11.77		11.77		.037
167	11.611	11.66		11.64		.039
201	11.842	11.86		11.87		.023
205	11.983		12.00		12.02	.027
210			11.70	11.70	11.70	
215			11.86	11.84	11.85	
220			12.25	12.24	12.25	
225			12.24	12.24	12.24	
230	12.176		12.20	12.21	12.23	.037
235	12.421		12.43	12.42	12.44	.009
248	12.386		12.39	12.40	12.41	.014
253	12.348		12.37	12.35	12.37	.015
259	12.838		12.89	12.87	12.88	.042
301	12.528		12.57	12.55	12.55	.029
304	12.769		12.80	12.80	12.81	.034
309	12.998		13.00	13.02	13.03	.019
314	13.123		13.18	13.16	13.17	.047
329	13.355		13.38	13.37	13.35	.012
334	13.696		13.71	13.70	13.71	.011
339	13.113		13.14	13.14	13.13	.024
344	13.228		13.23	13.27	13.27	.029
349	13.221		13.22	13.20	13.23	-.004
359	12.972		12.99	12.99	12.99	.018
404	13.040		13.06	13.04	13.03	.003
409	12.243					
413			13.07	13.07	13.07	
413	13.028		13.02	13.02	13.01	-.011
416	12.525			12.54	12.53	.010
421	12.814			12.83	12.85	.026
436	12.645		12.66	12.67	12.67	.022
442	12.953		12.98	12.87	12.87	.020
447	13.079		13.09	13.07	13.08	.001
452	13.110		13.12	13.12	13.11	.007
457	12.912		12.95	12.94	12.92	.025
503	12.569		12.57	12.57		.001
508	12.773		12.81	12.84		.052
513	12.723		12.75	12.74		.022
518	12.379		12.41	12.39		.021
520	12.436		12.44	12.45		.009
523	11.753		11.77	11.75		.007
533	12.288		12.29	12.28		-.003
539	12.410		12.41	12.41		.000
544	12.546		12.52	12.55		-.011
554	12.648		12.66	12.65		.007

Temperature calibration data

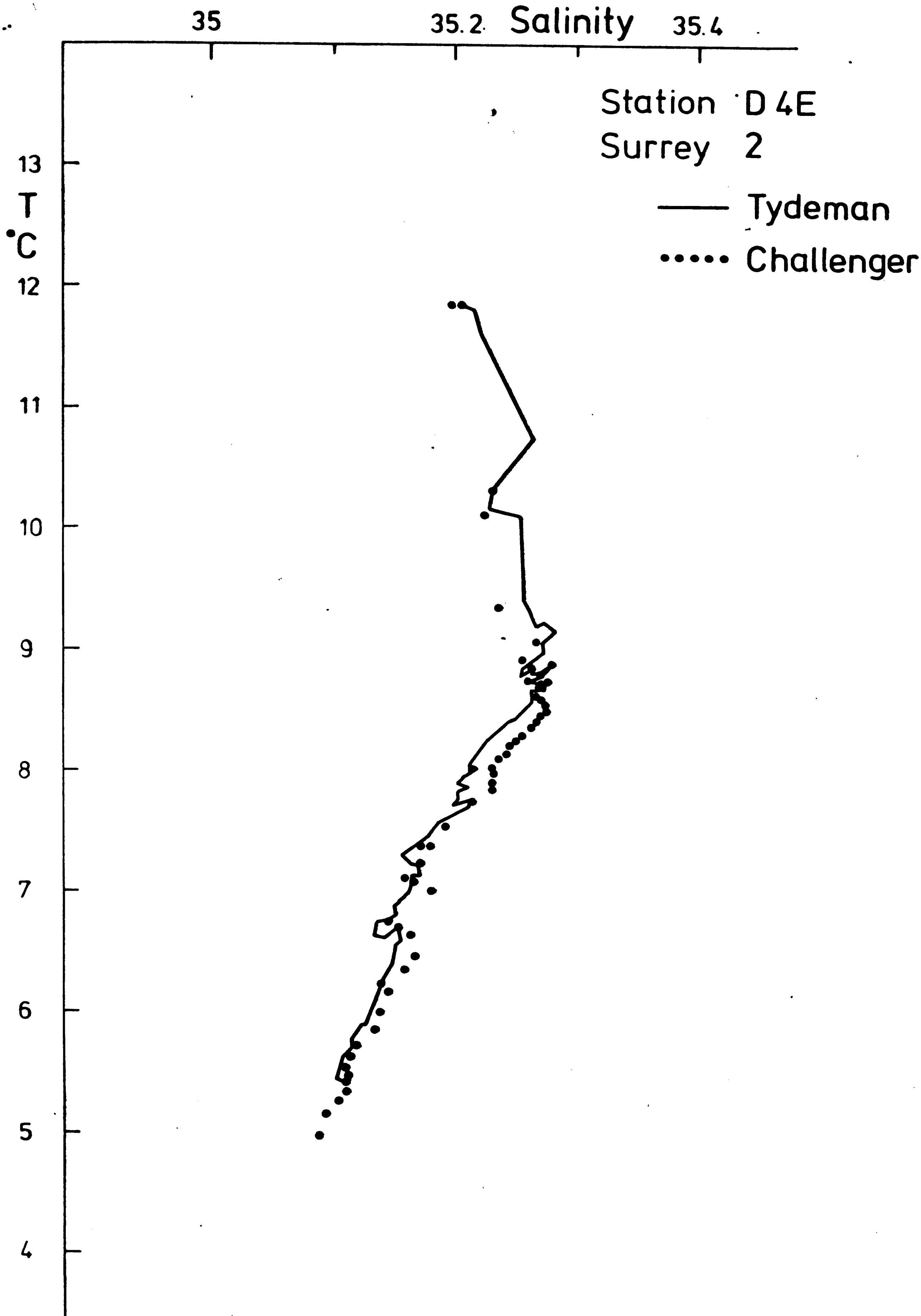
Dip	CTD calibrated T	Thermometers				Δ T
		2356	6435	13998	2354	
559	12.461		12.72	12.72		(.259)
564	12.347		12.39	12.40		.048
569	12.410		12.49	12.50		(.085)
601	12.511		12.79	12.79		(.279)
604	12.713		12.77	12.76		.052
610	12.145		12.15	12.15		.005
622	12.660		12.68	12.66		.010
636	13.214		13.24	13.23		.021
642	12.750		12.77	12.75		.010
647	12.879		12.87	12.85		-.019
652	12.833		12.86	12.83		.012
657	12.856		12.86	12.86		.004
664	13.003		13.02	13.04		.027
701	12.510					
704			13.42	13.41		
709	12.881		12.89	12.88		.004
714	12.709		12.74	12.74		.031
719	12.327		12.34	12.33		.008
724	12.467		12.47	12.47		.003
729	12.657		12.66	12.65		-.002
734	13.108		13.13	13.13		.022
743	12.838		12.86	12.85		.017
749	12.709		12.73	12.70		.006
812	12.299		12.32	12.31		.016
817	12.170		12.17	12.18		.005
822	12.406		12.40	12.40		-.006
832	12.344		12.36	12.34		.006
838	12.425		12.42	12.42		-.005
843	12.528		12.52	12.52		-.008
848	12.665		12.69	12.67		.015
853	12.915		12.91	12.89		-.015
859	13.004		13.00	13.00		-.004
869	12.619		12.62	12.62		.001
877	12.309		12.32	12.31		.006

Salinity calibration data

Dip	CTD calibrated S	Autolab Tydeman	Δ S	Autolab (Shackleton)	Guildline (Shackleton)
103		35.279		35.282	35.290
108		35.270		35.269	35.274
113		35.249		35.290	35.297
118		35.256			
123		35.167		35.168	
129		35.176		35.185	
139	35.246	35.249	.003	35.240	35.249
144	35.316	35.311	-.005	35.316	(35.348)
157	35.181	35.180	-.001	35.177	35.188
162	35.201	35.199	-.002	35.194	35.205
167	35.161	35.158	-.003	35.165	35.170
201	35.210	35.210	.000	35.226	35.231
205	35.213	35.209	-.004	35.235	35.244
210		35.195			
215		35.187		35.198	35.208
220		35.210		35.206	35.212
225		35.183		35.201	35.211
230	35.078	35.080	.002	(35.000	35.003)
235	35.249	35.250	.001	35.260	35.263
248	35.257	35.256	-.001	35.260	35.270
253	35.274	35.271	-.003	35.268	35.274
259	35.248	35.251	.003	35.251	35.257
301	35.227	35.231	.004	35.229	35.234
304	35.183	35.186	.003	35.193	35.198
309	35.175	35.172	-.003	35.174	35.182
314	35.142	35.149	.007	(35.195	35.206)
329	35.169	35.170	.001	35.170	35.176
334	35.110	35.114	.004	35.122	35.125
339	35.260	35.258	-.002	35.256	35.257
344	35.244	35.243	-.001	35.244	35.250
349	35.208	35.197	(-.011)	35.204	(35.223)
359	35.182	35.182	.000	35.184	35.184
404	35.156	35.158	.002	35.153	35.160
409	35.141	35.134	-.007	35.149	35.151
413		35.151		35.164	35.167
413	35.175	35.172	-.003	35.173	35.174
416	35.158	35.161	.003	35.178	35.184
421	35.126	35.122	-.004	(35.193	35.192)
436	35.173	35.175	.002		
442	35.255	35.253	-.002		
447	35.174	35.175	.001		
452	35.256	35.257	.001		
457	35.255	35.256	.001		
503	35.204	35.211	.007		
508	35.228	35.232	.004		
513	35.233	35.233	.000		
518	35.157	35.162	.005		
520	35.166	35.161	-.005		
523	35.180	35.175	-.005		
533	35.099	35.095	-.004		
539	35.147	35.145	-.002		
544	35.177	35.177	.000		
554		35.244			

Salinity calibration data

Dip	CTD calibrated S	Autolab / Tydeman	Δ S	Autolab / Shackleton	Guildline / Shackleton
559	35.158	35.175	(.017)		
564	35.182	35.176	-.005		
569	35.177	35.179	.002		
601		35.151			
604	35.012	35.101	(.089)		
610	35.150	35.169	(.019)		
622	35.080	35.160	(.080)		
636	35.248	35.210	(-.038)		
642	35.105	35.104	-.001		
647	35.216	35.218	.002		
652	35.179	35.185	.006		
657	35.211	35.208	-.003		
664		35.244			
701	35.108	35.113	.005		
704		35.184			
709	35.155	35.153	-.002		
714	35.182	35.189	.007		
719	35.145	35.138	-.007		
724	35.118	35.122	.004		
729	35.062	35.064	.002		
734	35.317	35.192	(-.125)		
743	35.199	35.197	-.002		
749	35.108	35.113	.005		
812	35.117	35.112	-.005		
817	35.095	35.091	-.004		
822	35.123	35.126	.003		
832	35.076	35.074	-.002		
838	35.081	35.075	-.006		
843	35.223	35.130	.007		
848	35.121	35.116	-.005		
853	35.110	35.113	.003		
859	35.141	35.142	.001		
869	35.198	35.197	-.001		
877	35.163	35.156	-.007		



35
35.2
Salinity
35.4
Station D 4E
Surrey 2
Tydeman
Challenger
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T
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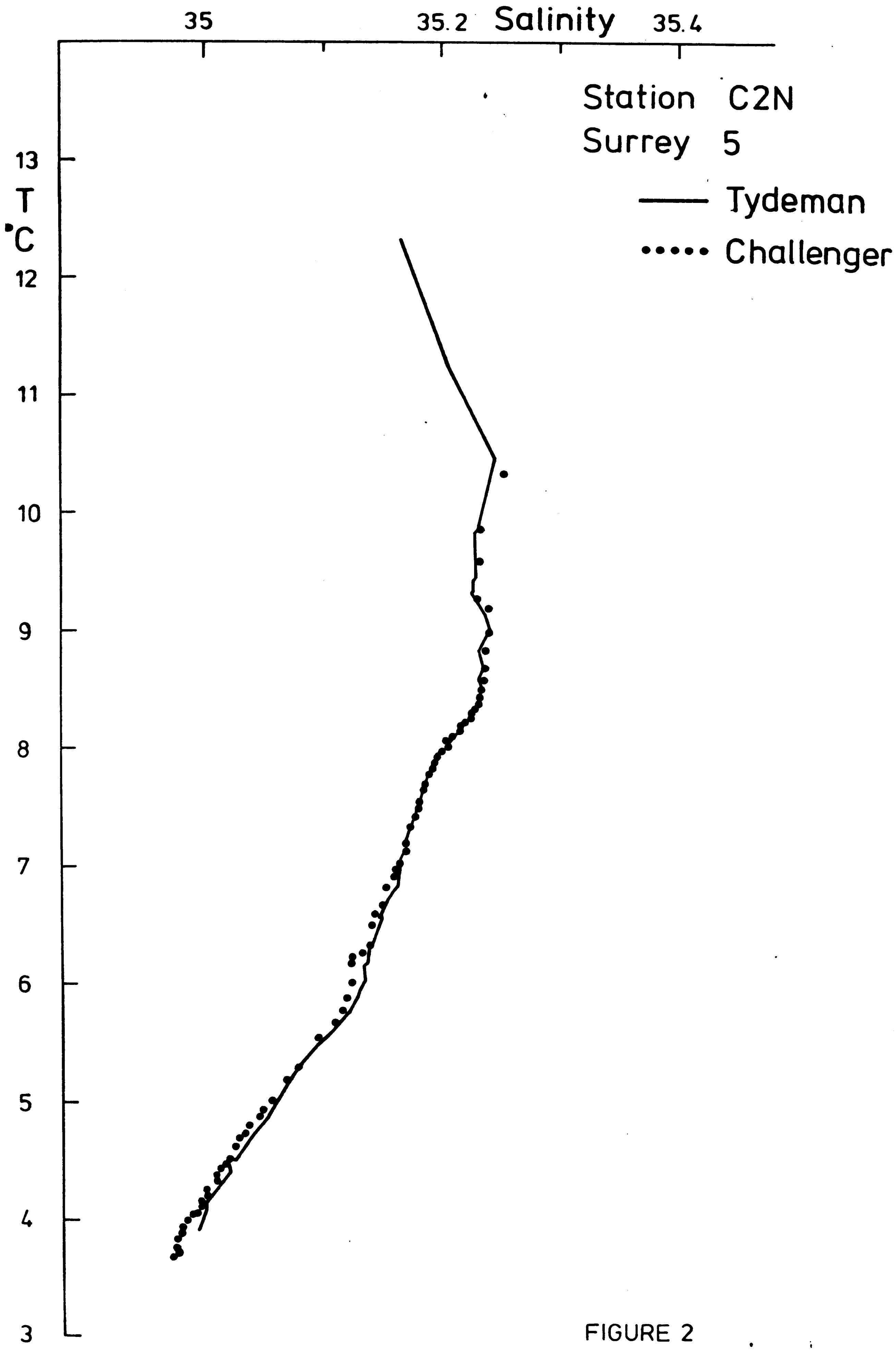
FIGURE 1



Salinity
35
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35.4
Station C2N
Surrey 5
Tydeman
Challenger
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°C
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12
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10
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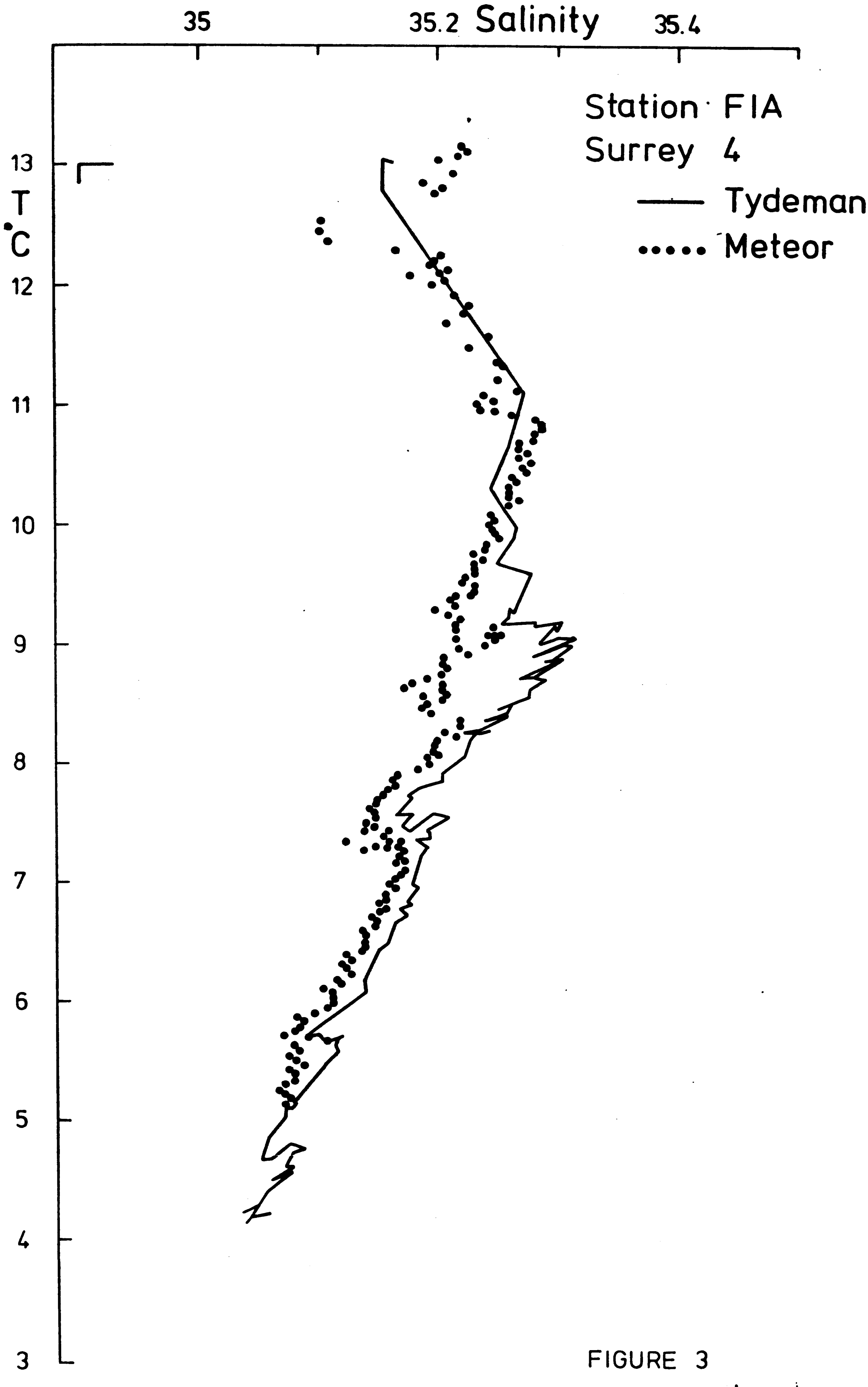
FIGURE 2


Salinity
35
35.2
35.4
Station FIA
Surrey 4
Tydeman
Meteor
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13
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FIGURE 3