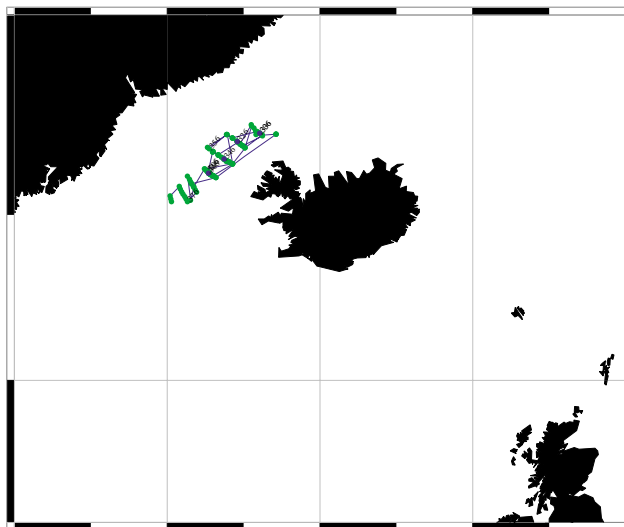


**A. Cruise Narrative: AR18**  
 (NORDIC WOCE - OVERFLOW THROUGH THE DENMARK STRAIT)



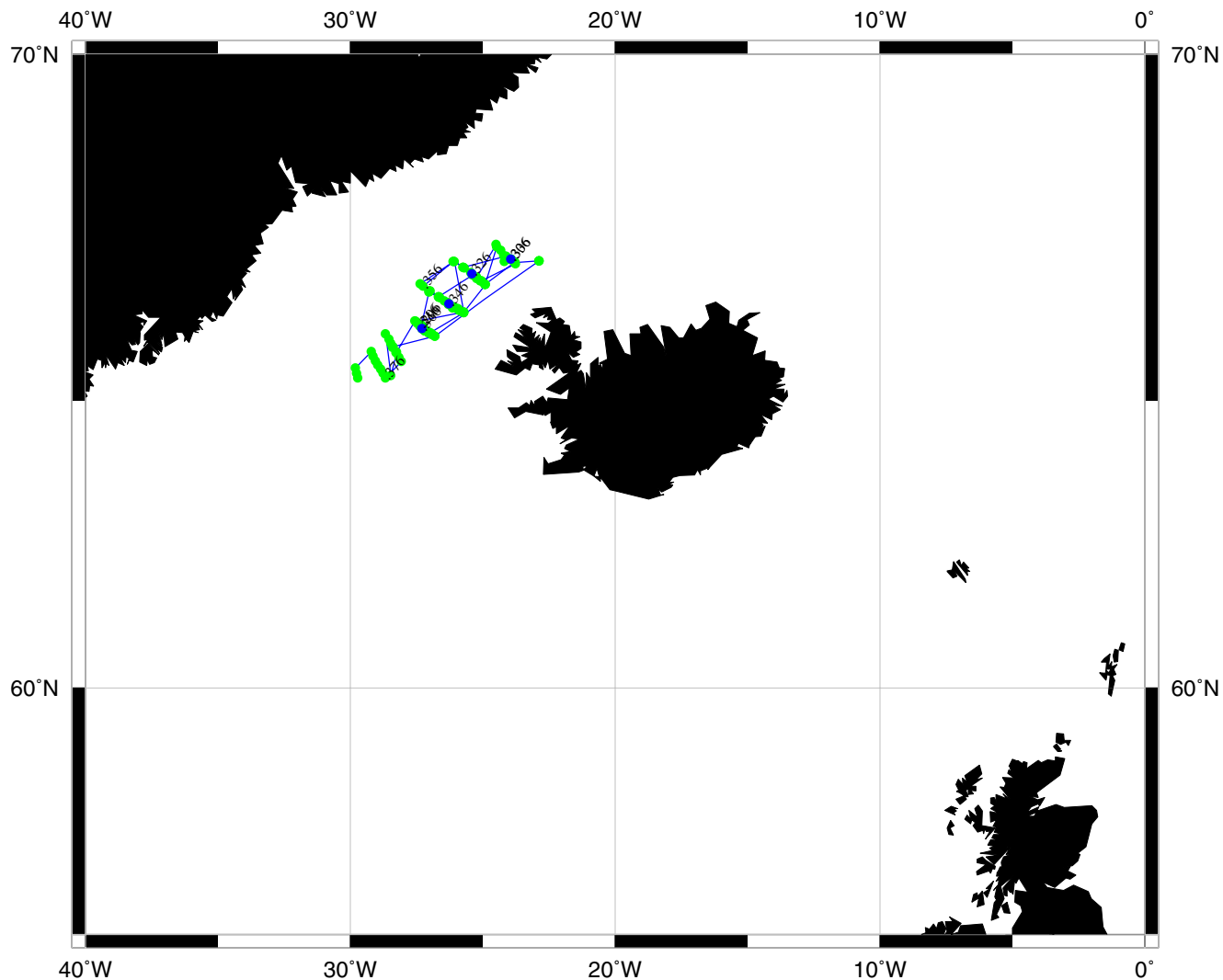
**A.1. Highlights**

**WHP Cruise Summary Information**

WOCE section designation	<b>AR18</b>
Expedition designation (EXPOCODE)	Leg 1 <b>34AR10_1</b>
	Leg 2 <b>34AR10_2</b>
Chief Scientist(s) and their affiliation	<b>Jouko Launiainen*</b>
Dates	Leg 1 1993.AUG.16 to 1993.SEP.10
	Leg 2 1993.SEP.11 to 1993.OCT.05
Ship	R/V ARANDA
Ports of call	Leg 1 Gothenburg, Sweden to
	Reykjavik, Iceland to
	Isafjoudur Island
	Leg 2 Isafjoudur Island to
	Reykjavik, Iceland to
	Helsinki, Finland
Number of stations	99
Geographic boundaries of the stations	67° 23.16' N 29° 47.53' W 22° 52.02' W 65° 22.08' N
Floats and drifters deployed	two Argos drifters
Moorings deployed or recovered	0
* Chief Scientist	Jouko Launiainen
Phone +358-0-331-044	Finnish Institute of Marine Research
FAX +358-0-331-376	3 Lyypekinkukja
Telex 125731 imr sf	P.O. Box 33
Email jouko.launi@fimr.fi	FIN-00931 Helsinki, Finland



# Station locations for AR18: LAUNIAINEN, 1993



## A.2. CRUISE SUMMARY

Exchange of water and heat between the Atlantic Ocean and the polar seas is one of the key problems in the oceanographic, climatological and environmental change. As a contribution to the WOCE, the Nordic Countries study the question, especially the exchange of water, heat and salt through the Denmark Strait and the Iceland-Faeroe Ridge as the NORDIC WOCE. After a Norwegian pilot expedition in 1992, the Icelandic research vessel Bjarni Saemundsson and the Finnish R/V Aranda (of ice class 1A Super) started in autumn 1993 a set of NORDIC WOCE expeditions. R/V Aranda made in the Denmark Strait Area a CTD and ADCP survey, took samples for tracer studies (freons), released Argos drifters, monitored flow- through surface salinity and fluorescence and, made marine meteorological studies and balloon soundings.

The ice conditions in the Denmark Strait were during the late summer and autumn 1993 quite difficult and exceptional. Opposite to the normal situation in this time of the year time, when approximately a fourth of the strait should be covered by ice on the Greenland side, during late August and September on might meet sea ice, growlers and ice bergs on the Icelandic side of the Strait, up to 25 to 30 nautical miles from the coast. During the R/V Aranda expedition some 100 to 150 growlers and ice bergs were seen in the area (Fig.1) and as a top curiosity one might report that 30 nautical miles from north-western Iceland a grounded (at  $66^{\circ} 44' N$ ,  $29^{\circ} 24' W$ ) iceberg was seen the over water part of which was 95 to 100 m high! The thermal front between the Polar and Atlantic water was shifted eastwards as well.

In spite of rather difficult navigation and measuring conditions, fog and currents and high winds during the later expedition, in addition to the ice difficulties, a successful CTD-network of 99 station was implemented in the Denmark Strait. Seven transversal sections were taken, four of which were repeated three times during the four weeks (Fig. 1). The data is of high quality and meets the "WOCE" standards. In Fig. 2 is given the density and salinity structure and its time history for one section, the overall structure indicating the northward flow of warm Atlantic water on the eastern side and polar outflow in the west. In each of the sections, both a ship mounted and a CTD mounted acoustic doppler current profiler, ADCP, was used. Although especially the latter techniques turned out to be rather demanding and suffered technical faults, the measurements offer an interesting situation for a methodological comparison study, in addition to getting more insight to the on-site oceanographic processes. Additionally, two Argos drifters were deployed on 28 August 1993 (Fig. 3). The one, having a sail in the depth of 75 m, was deployed on the eastern warm Atlantic water side of the front. The other, having the sail in 10 m, was deployed on the western cold polar water side, 20 nautical miles from the eastern one. The drifters are still active (15 Nov. 1993) and their trajectories showed the front later to have been shifted back towards the Greenland. Generally, the drift was rather irregular having e.g. tidal and inertial scales of motions. During the first and a half month the eastern buoy showed a net drift of 3 to 4 cm/s northwards in the Irminger Current. The western one drifted a slightly longer distance towards south-southwest, in the East Greenland current, towards which also the eastern drifter turned, finally.

For tracer studies, samples for four fluorocarbons (CFCl<sub>3</sub>, CF<sub>2</sub>Cl<sub>2</sub>, CCl<sub>2</sub>FCClF<sub>2</sub>) were taken both from water and air samples during the first three weeks of the cruise. Water samples were taken from rosette mounted 10 l Niskin bottles and analysed using a purge-and-trap sample work-up technique based on gas chromatographic separation and very sensitive electron capture detection. A total of 672 water samples from the CTD casts were analysed. Additionally, a continuous flow-through monitoring of surface salinity and fluorescence was implemented. Especially in the thermal frontal areas, intensive marine meteorological near surface measurements were made from the research vessel for studies of air-sea interaction. These were completed by over 40 aerological balloon soundings (by Vaisala DigiCora). Those give data e.g. for estimating the aerial atmospheric forcing as well as for studies of air - sea exchange during the exceptional ice conditions prevailed.

### RESEARCH GROUP

The institutions involved in the expedition, co-ordinated and financially supported by the NORDIC WOCE read:

FIMR	Finnish Institute of Marine Research
HU	University of Helsinki, Department of Geophysics, Finland
GU/OI	University of Gothenburg, Oceanographic Institute, Sweden
GU/CUT	Univ. of Gothenburg and Chalmers Univ. of Technol., Department of Anal. and Mar. Chem., Sweden

### Responsible investigators:

P. Lundberg/GU/OI	CTD
J. Vainio/FIMR	CTD
R. Hietala/FIMR	ADCP - ship mounted
B. Liljeblad/GU/OI	ADCP - CTD mounted
J. Launiainen/FIMR	Drifters
T. Vihma/HU	Drifters
E. Fogelqvist/GU/CUT	Chem. tracers
J. Launiainen/FIMR	Air-sea
T. Vihma/HU	Air-sea

## EXPEDITION PARTICIPANTS:

Name	Institution		Leg(s)	
Launiainen, Jouko	FIMR	Chief scientist	I	
Grönvall, Hannu	FIMR	Chief scientist		II
Hietala, Riikka	FIMR		I	
Kalliosaari, Simo	FIMR		I	II
Purokoski, Tero	FIMR		I	II
Söderman, Henry	FIMR		I	II
Vainio, Jouni	FIMR		I	
Vuori, Hannu	FIMR		I	II
Vihma, Timo	HU		I	
Lundberg, Peter	GU/OI		I	II
Fristedt, Tim	GU/OI			II
Liljeblad, Bengt	GU/OI		I	
Lindblad, Klas	GU/OI		I	II
Fogelqvist, Elisabet	GU/CUT		I	
Krysell, Mikael	GU/CUT		I	
Tanhua, Toste	GU/CUT		I	
Bastürk, Özden	GU/CUT/Turkey		I	

## CTD MEASUREMENTS

### EQUIPMENT AND CALIBRATIONS

The CTD equipment used on R/V Aranda's cruise was the property of FIMR. The following equipment was deployed on the CTD/multisampler underwater frame:

1. Neil Brown Mk-III CTD, Serial No. 22-1007.
2. General Oceanics 24 bottle rosette, model 1015, with 24 12 liter Niskin-bottles.
3. RD Instruments 600kHz ADCP. Property of University of Gothenburg.

The shipboard equipment consisted of system for collecting, displaying and post-processing the CTD data as well as controlling the rosette multisampler. The system included the following units:

1. EG&G deck-unit. Model 1401.
2. 386PC system connecting to network for archiving data to DAT-tape.
3. General Oceanics' rosette firing module.

Calibration of the Mk-III CTD temperature and pressure sensors and conductivity cell was carried out at the IOS calibration facility.

CTD temperature calibration	IOSDL CT0001	13 July 1993	Temperature was calibrated in the ITS <sub>90</sub> scale at five temperatures ranging from -2°C to 32°C with uncertainty better than ±0.3m°C.
CTD pressure calibration	IOSDL CP0001	9 July 1993	Pressure was calibrated at five pressures ranging from 0 to 5000 dbar with uncertainty better than ±0.3dbar.
CTD conductivity calibration	IOSDL 90233	15 July 1993	Conductivity was calibrated at five points ranging from 10 to 40 in salinity.

No post-cruise laboratory calibration is available due to bottom-contact of the equipment during return-cruise in the Baltic Sea.

### SAMPLE SALINITY MEASUREMENTS

On R/V Aranda cruise 10/1993 (NordicWOCE cruise) the salinity analysis of collected samples was carried out after cruise in University of Gothenburg, Sweden.

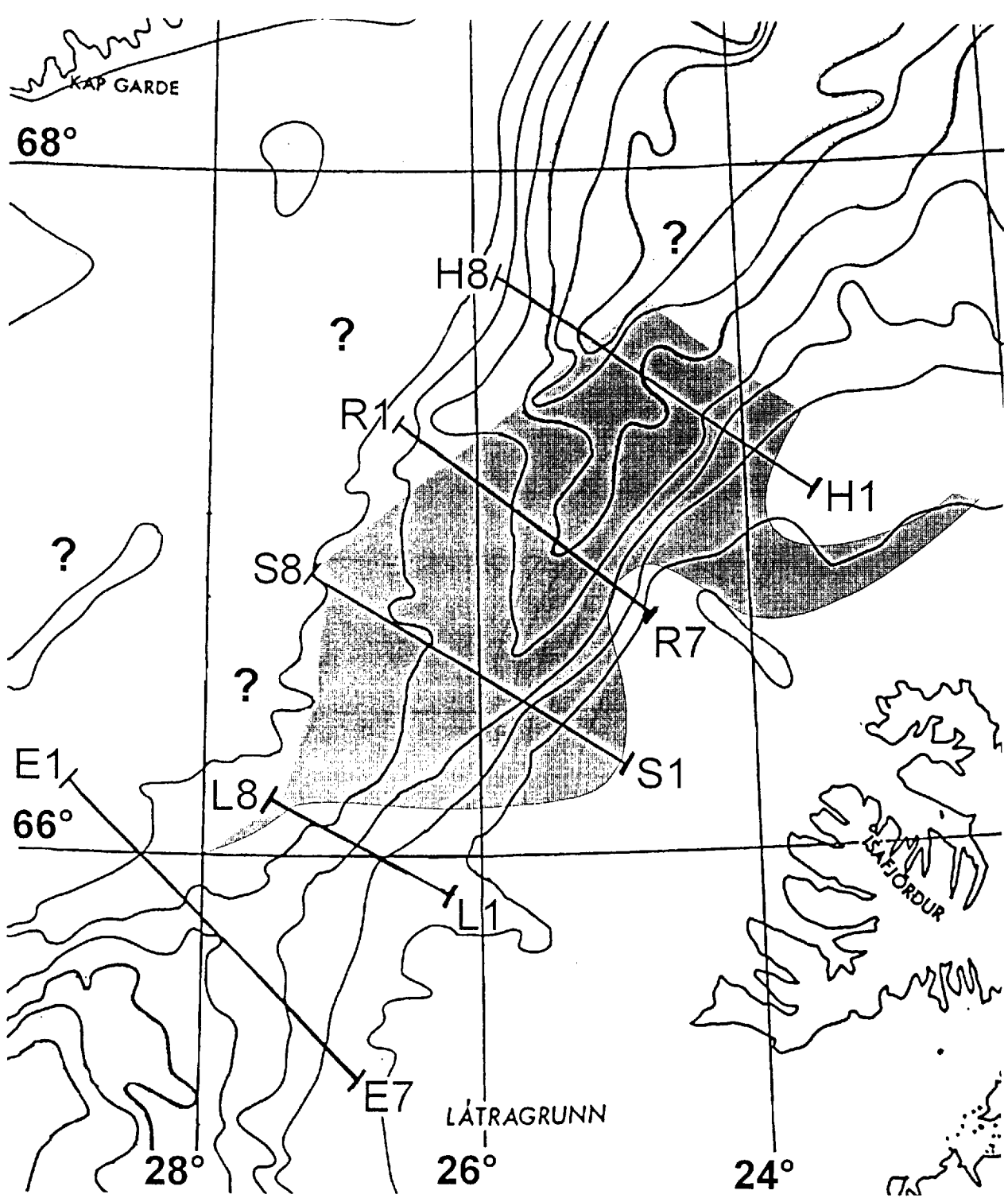
**Table 1**

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288	WOCE-E3	24-AUG-1993	16:03	65:54:48	-28:27:39	494
289	WOCE-E4	24-AUG-1993	19:57	65:46:22	-28:15:14	796
290	WOCE-E3A	24-AUG-1993	22:22	65:50:46	-28:21:43	583
291	WOCE-L1	25-AUG-1993	06:11	66:01:00	-26:48:01	438
292	WOCE-L2	25-AUG-1993	08:11	66:03:02	-26:55:07	571
293	WOCE-L3	25-AUG-1993	10:04	66:05:02	-27:03:11	645
294	WOCE-L4	25-AUG-1993	12:34	66:06:58	-27:09:18	604
295	WOCE-L5A	25-AUG-1993	14:41	66:09:23	-27:13:08	523
296	WOCE-L6A	25-AUG-1993	16:31	66:11:06	-27:17:45	481
297	WOCE-S7	25-AUG-1993	21:15	66:42:06	-27:00:10	445
298	WOCE-S6	26-AUG-1993	05:29	66:37:02	-26:38:04	541
299	WOCE-S5	26-AUG-1993	09:14	66:30:53	-26:15:31	634
300	WOCE-S4	26-AUG-1993	11:20	66:28:00	-26:04:16	652
301	WOCE-S3	26-AUG-1993	13:39	66:25:55	-25:53:15	626
302	WOCE-S2	26-AUG-1993	15:43	66:23:00	-25:42:04	441
303	WOCE-R1	26-AUG-1993	22:50	67:08:08	-26:02:58	753
304	WOCE-R2	27-AUG-1993	02:54	67:03:05	-25:45:04	866
305	WOCE-H4	28-AUG-1993	03:32	67:13:42	-24:05:30	647
306	WOCE-H3	28-AUG-1993	05:57	67:10:29	-23:55:36	457
307	WOCE-H2	28-AUG-1993	08:05	67:07:14	-23:46:22	290

Idx	Station name	Date	UTC	Latitude	Longitude	Depth
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309	WOCE-BENGT	28-AUG-1993	14:41	67:09:00	-22:52:02	256
310	WOCE-BENGT	28-AUG-1993	16:25	67:09:00	-22:52:05	256
311	WOCE-L1	30-AUG-1993	09:10	66:00:59	-26:48:05	440
312	WOCE-L2	30-AUG-1993	11:15	66:02:57	-26:55:25	571
313	WOCE-L3	30-AUG-1993	13:06	66:05:00	-27:02:53	642
314	WOCE-L4	30-AUG-1993	15:03	66:06:52	-27:09:08	607
315	WOCE-L5	30-AUG-1993	16:58	66:08:04	-27:15:02	526
316	WOCE-L6	30-AUG-1993	18:44	66:11:01	-27:21:09	481
317	WOCE-L8	30-AUG-1993	21:17	66:14:58	-27:32:40	483
318	WOCE-S2	31-AUG-1993	08:25	66:22:58	-25:42:18	447
319	WOCE-S3	31-AUG-1993	10:10	66:25:59	-25:53:30	635
320	WOCE-S5A	31-AUG-1993	14:17	66:33:27	-26:24:41	557
321	WOCE-S6	31-AUG-1993	16:57	66:37:04	-26:38:05	541
322	WOCE-S7A	31-AUG-1993	20:02	66:41:31	-27:01:52	442
323	WOCE-S8	31-AUG-1993	22:20	66:48:05	-27:21:46	365
324	WOCE-R1	01-SEP-1993	13:43	67:08:43	-26:05:56	732
325	WOCE-R2	01-SEP-1993	17:01	67:03:02	-25:44:59	864
326	WOCE-R3	01-SEP-1993	19:33	66:57:12	-25:24:40	1032
327	WOCE-R4	01-SEP-1993	22:15	66:54:16	-25:14:16	969
328	WOCE-H6A	02-SEP-1993	09:27	67:22:32	-24:32:06	1135
329	WOCE-H5A	02-SEP-1993	12:34	67:18:37	-24:20:21	941
330	WOCE-H4A	02-SEP-1993	17:25	67:10:01	-24:09:31	634
331	WOCE-H3	02-SEP-1993	20:55	67:10:37	-23:55:38	462
332	WOCE-H2A	02-SEP-1993	22:40	67:07:50	-23:47:19	317
333	WOCE-R6	03-SEP-1993	09:14	66:48:09	-24:53:20	575
334	WOCE-R5	03-SEP-1993	12:25	66:50:59	-25:02:40	808
335	WOCE-H2A	07-SEP-1993	08:58	67:07:40	-23:47:32	320
336	WOCE-H3	07-SEP-1993	12:06	67:10:31	-23:55:35	459
337	WOCE-H4A	07-SEP-1993	16:01	67:13:05	-24:06:37	654
338	WOCE-H5A	07-SEP-1993	19:42	67:15:13	-24:11:55	776
339	WOCE-H6B	08-SEP-1993	12:07	67:21:25	-24:29:01	1077
340	WOCE-R6	09-SEP-1993	09:05	66:48:19	-24:53:50	585
341	WOCE-R5	09-SEP-1993	10:58	66:51:16	-25:04:11	832
342	WOCE-R4	09-SEP-1993	13:07	66:54:11	-25:13:38	965
343	WOCE-R3	09-SEP-1993	15:53	66:57:10	-25:23:35	1038
344	WOCE-S6A	10-SEP-1993	04:33	66:36:41	-26:39:40	540
345	WOCE-S7	10-SEP-1993	07:28	66:42:05	-27:00:07	445
346	WOCE-S5	10-SEP-1993	11:08	66:30:52	-26:15:17	636
347	WOCE-S4	10-SEP-1993	13:36	66:28:05	-26:04:54	659
348	WOCE-S3	10-SEP-1993	16:37	66:26:02	-25:53:07	636
349	WOCE-S2	10-SEP-1993	18:28	66:22:57	-25:42:04	440

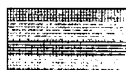


Idx	Station name	Date	UTC	Latitude	Longitude	Depth
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352	WOCE-R4A	13-SEP-1993	22:54	66:53:56	-25:13:02	956
353	WOCE-R3B	14-SEP-1993	06:07	66:58:10	-25:27:35	1015
354	WOCE-R2A	14-SEP-1993	09:48	67:02:37	-25:43:12	886
355	WOCE-R1	14-SEP-1993	13:39	67:08:53	-26:05:59	732
356	WOCE-S8A	14-SEP-1993	21:53	66:46:40	-27:15:39	371
357	WOCE-S7	15-SEP-1993	00:07	66:42:07	-27:00:33	446
358	WOCE-S6	15-SEP-1993	02:50	66:37:07	-26:38:40	538
359	WOCE-S5A	15-SEP-1993	05:47	66:31:38	-26:18:01	622
360	WOCE-S4	15-SEP-1993	11:00	66:27:58	-26:04:02	658
361	WOCE-S3B	15-SEP-1993	14:21	66:25:02	-25:50:13	601
362	WOCE-S2	15-SEP-1993	15:51	66:23:03	-25:42:32	455
363	WOCE-L2A	16-SEP-1993	11:18	66:05:08	-26:59:30	637
364	WOCE-L3	16-SEP-1993	13:08	66:05:00	-27:03:02	651
365	WOCE-L4	16-SEP-1993	14:45	66:07:02	-27:09:18	605
366	WOCE-L5	16-SEP-1993	16:16	66:08:58	-27:15:07	520
367	WOCE-L6	16-SEP-1993	17:34	66:11:02	-27:21:07	484
368	WOCE-L7	16-SEP-1993	18:39	66:13:00	-27:26:26	486
369	WOCE-L8	16-SEP-1993	19:47	66:15:05	-27:32:43	486
370	WOCE-E4	17-SEP-1993	04:58	65:46:14	-28:15:01	802
371	WOCE-E3A	17-SEP-1993	07:02	65:50:41	-28:22:05	615
372	WOCE-E3	17-SEP-1993	08:30	65:54:57	-28:28:10	493
373	WOCE-E2A	17-SEP-1993	09:46	65:59:00	-28:32:33	444
374	WOCE-E4A	17-SEP-1993	12:53	65:41:59	-28:08:56	882
375	WOCE-E5	17-SEP-1993	14:59	65:37:40	-28:02:36	805
376	WOCE-F7	17-SEP-1993	18:34	65:22:12	-28:40:10	1244
377	WOCE-F6	17-SEP-1993	20:56	65:26:21	-28:45:14	1222
378	WOCE-F5	17-SEP-1993	23:59	65:30:20	-28:50:40	1181
379	WOCE-F4	18-SEP-1993	03:33	65:34:33	-28:56:11	1088
380	WOCE-F3	18-SEP-1993	05:52	65:38:37	-29:01:18	931
381	WOCE-F2	18-SEP-1993	08:40	65:42:52	-29:06:50	733
382	WOCE-F1	18-SEP-1993	10:37	65:47:01	-29:12:06	441
383	WOCE-G1	18-SEP-1993	14:23	65:31:59	-29:47:14	414
384	WOCE-G2	18-SEP-1993	16:00	65:27:20	-29:44:04	834
385	WOCE-G3	18-SEP-1993	17:48	65:22:30	-29:40:52	1147



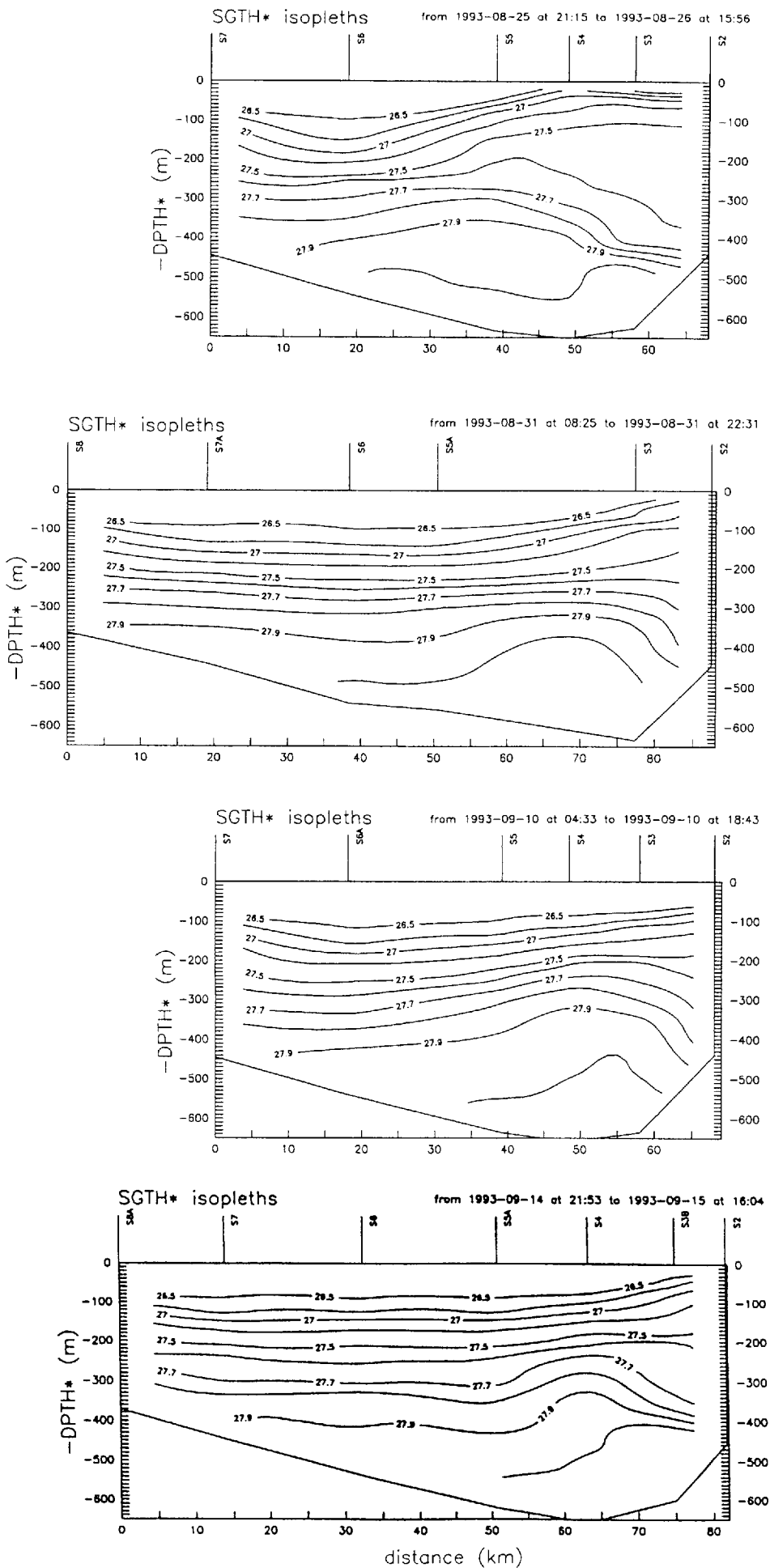
Ice situation in 30.8. - 3.9.1993

? Ice situation unknown

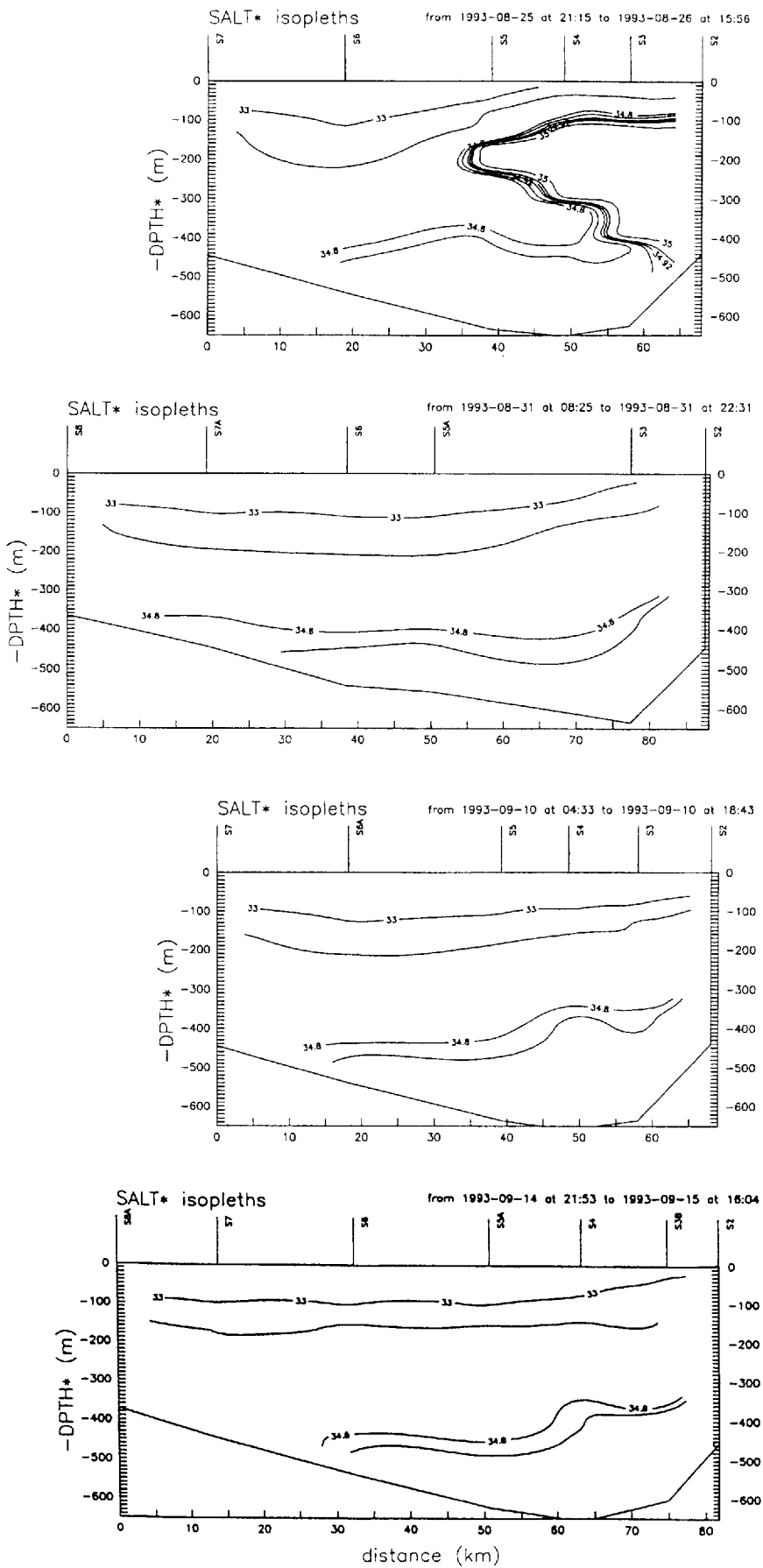


Drift ice, growlers, ice bergs

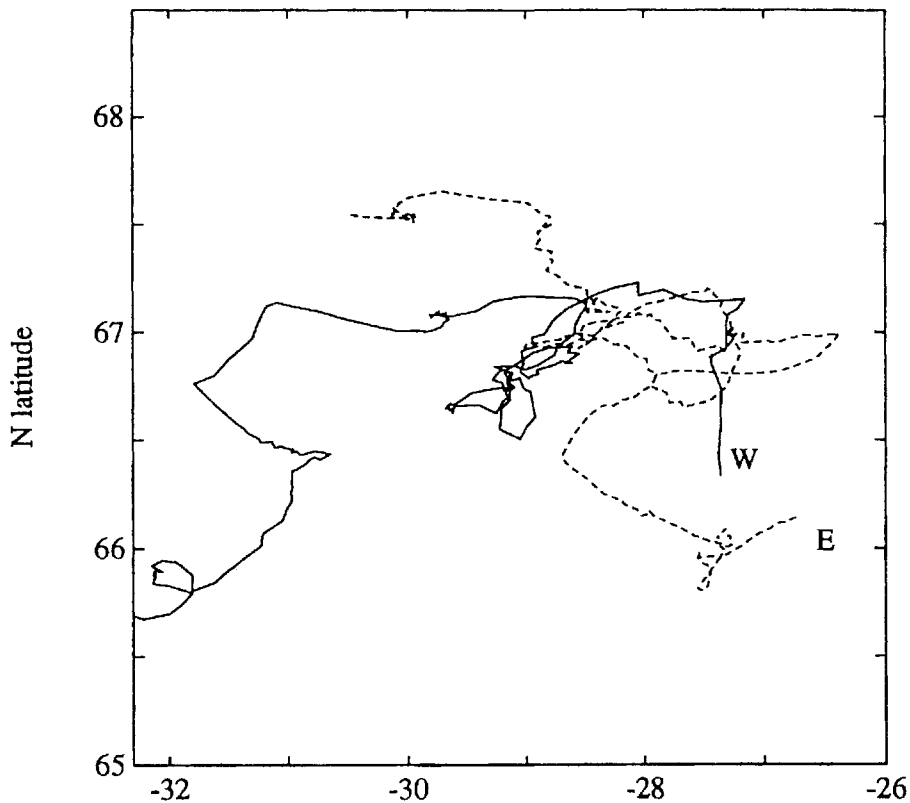
**Figure 1:** NORDIC WOCE / R/V Aranda research sections and ice conditions during 30. August to 3. September 1993 in the Denmark Strait.



**Figure 2.a:** Density structure in the section S during four consecutive weeks during 23. August to 15. September 1993.



**Figure 2.b:** Salinity structure in the section S during four consecutive weeks during 23. August to 15. September 1993.



NWOCE buoy drift 18055(W)---, Buoy 1 8057(E)--

**Figure 3:** Drift trajectories of the Argos buoys during 29 August to 20 October 1993. Six hours positions. W = buoy deployed in the cold polar water side of the NE-SW directional thermal front. E = trajectory of the buoy deployed in the warm water Atlantic side of the front.

## Data Processing Notes

Date	Contact	Data Type	Data Status Summary	
09/24/99	Buck	CTD/SUM/DOC	Website Updated	Files added to website
09/30/99	Bartolacci	SUM	Update Needed	SUM file errors listed below: This sumfile AR18 34AR10_1 had the following errors from sumchk: .SUM header was missing: BOTTOMHT WHEEL_MT sumun1: hour or minute bad = 0 91 main: warning on rec = 53 sumun1: hour or minute bad = 0 83 main: warning on rec = 175 sumun1: hour or minute bad = 0 84 main: warning on rec = 193
10/01/99	Anderson	SUM	Data Reformatted	I reformatted the AR18 .sum file to conform with the "standard" WHP format and put it in my ftp area in the subdir AR18. Error in the time: Sta. 311 the BE was input as 0091. Since this was a 400+ meter cast and the EN time was 0954 I assumed the BE should have been 0910. Sta. 372 the BE was input as 0083 and the EN was 0859. Since this was a shallow cast I assumed the BE should have been 0830. Sta. 381 the BE was input as 0084 and the EN was 0922. Since this was a shallow cast I assumed the BE should have been 0840. If possible these should be checked with the originator. I would guess that the last digit in the minutes should not always be 0. Sta. 331 the EN had 462 for UNC DEPTH, 446 for COR DEPTH and 4440 for WIRE OUT. I changed the WIRE OUT to 444 which is much more reasonable.
10/04/99	Launiainen	SUM	Data Update	Corrections OK'd
12/11/00	Uribe	DOC	Submitted	File contained here is a CRUISE SUMMARY and NOT sumfile. Documentation is online. Files were found in incoming directory under whp_reports. This directory was zipped, files were separated and placed under proper cruise. All of them are sum files. Received 1997 August 15th.
03/26/01	Uribe	CTD	Website (Expocodes) Updated	Expocodes in all ctd files have been edited to match the underscored expocode in the sum file. New files were zipped and replaced existing ctd files online. Old files were moved to original directory.
05/01/02	Bartolacci	CTD/BTL	Update Needed	BOT still with PI CTD needs WOCE frmtnng. CTD is NONPUB still. Cruise not linking to table. Email PI for BOT and PUB status. Find out why cruise isn't linking!
07/15/02	Kappa	DOC	Doc Update:	pdf, txt versions compiled Added sections on CTD measurements, Salinity measurements, this List of Data Processing Updates, and cruise participants list. Also added a pdf version of this cruise report which includes everything in the text document as well as figures and links between the table of contents, figures and tables and relevant text passages.