

**Leibniz-Institut für Meereswissenschaften
IFM-GEOMAR
KIEL, Germany**

Date: 20.07.2008

Cruise Report

Compiled by: Thomas J. Müller

F.S. Poseidon

Cruise No.: P321

Dates of Cruise: from 02.05.2005 to 11.05.2005

Port of sailing: Las Palmas de Gran Canaria, Spain

Port of berthing: Funchal, Madeira, Portugal

Port Calls: No

Areas of Research: Physical, chemical, and biological oceanography

Institute: Leibniz-Institut für Meereswissenschaften, IFM-GEOMAR, Kiel, Germany

Chief Scientist: Dr. Thomas J. Müller

Number of Scientists: 8

Projects:

- Time series stations ESTOC and KIEL276 in the Northeast Atlantic
- Azores Front studies

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1. Scientific crew

Name	Given name	Function	Institute
Müller	Thomas	Principal scientist	IFM-GEOMAR
Hemleben	Christoph	Marine geology	UT
Bayer	Margret	technician	UT
Sprenger	Dennis	technician	UT
Bourbonnais	Annie	Biological oceanography	UQUAM
Hehl	Uwe	Technician	IOW
Friedrich	Tobias	Student	IFM-GEOMAR
Smarz	Christopher	Technician	IFM-GEOMAR

IFM-GEOMAR	Leibniz-Institut für Meereswissenschaften, Kiel
IOW	Institut für Ostseeforschung Warnemünde, Rostock
UT	Institut für Geologie, Universität Tübingen
UQUAM	University of Quebec, Canada

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2. Research programme

The main objectives of POSEIDON cruise P321 were to investigate long-term variability of hydrographic and flow conditions and vertical particle fluxes at the time series stations KIEL276/L1 (Madeira Abyssal Plain) by

- Exchanging current meters and particle traps at site KIEL276 with additional CTD/rosette casts across the Azores Front.
- to study the origin and quality of organic particles using water bottles and pump systems
- to study pelagic and benthic communities by plankton nets, and bottom grabs

3. Narrative of cruise with technical details

2nd May, 2005

09:00 UTC, sail from Las Palmas at 09:00 under fair weather conditions towards the ESTOC time series station 60 nm north of Gran Canaria and Tenerife;

13:00 UTC, outside territorial waters of Spain, switch on underway data sampling system (nav data logging; weather station; vessel mounted ADCP; thermosalinograph)

14:50 UTC, CTD cast with SBE3 at ESTC down close to the bottom

3rd May

07:28 UTC, station 172, test with a minicorer (MC) attached to the CTD/rosette SBE4X, 797 m, steam towards 31°N, 023°W; on the way at

09:29 UTC, station 173, test two acoustic releasers, 1000 m

10:14 UTC, station 174, multi-closing plankton net (MCN)

4th May

07:23 UTC, station 175 and 176, CTD SBE4X with MC, to the bottom, 4907 m, followed by MCN, 500 m

23:46 UTC, reach 31°N, 023°W, station 177, start section across the Azores Front, CTD SBE3, 2000 m, continue section

5th May

09:39 UTC, station 178, CTD SBE3 2000 m, continue section

11:53 UTC, station 179, MCN 500 m, continue section

6th May

07:16 UTC, long-term mooring position K276 at 33°N, 022°W, station 180, recover mooring V276-24 without any problems

14:08 UTC, station 181 MCN at KIEL276, 500 m, continue cross frontal section

22:17 UTC, station 182, CTD SBE3, 2000 m, continue cross frontal section

7th May

07:09 UTC, station 183, MCN, 500 m, continue cross frontal section

13:09 UTC, reach northern end of section at 35°30'N, 020°15'W

station 184, CTD SBE3, 2000 m, and station 185, MCN, 500 m

steam towards position K276

8th May

13:25 UTC, position KIEL276 at 33°N, 022°W, station 186, deploy mooring V287-25

17:46 UTC, at KIEL276, station 187, CTD SBE3 close to bottom, 5217 m, course towards towards Madeira

9th May

12:38 UTC, station 188, CTD SBE4X with MC, 3549 m

10th May

07:00 UTC, station 189, CTD SBE4X with MC, 3172 m

11:22 UTC, station 190, CTD SBE4X with MC, 252 m

18:00 UTC, switch off underway logging system outside territorial waters of Portugal

11th May

09:05 UTC, berth in Funchal, Madeira, Portugal

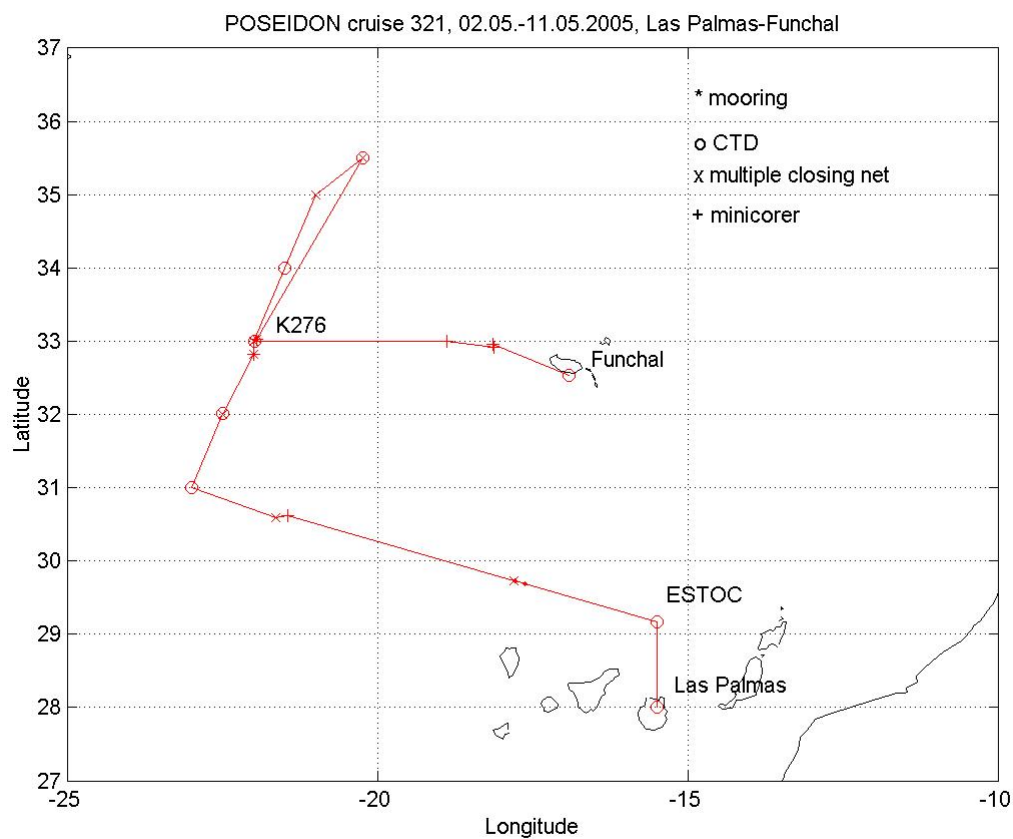


Fig. 3.1: POSEIDON cruise P321, 02nd May – 11th May, 2005, Las Palmas – Funchal, cruise track with Stations; symbols see legend in figure; positions of the time series station ESTOC and the long-term mooring KIEL276 are indicated.

4. Physical Oceanography of the Azores frontal zone

4.1 Long term variability

Since 1980 a current meter mooring KIEL276 is maintained by IFM-GEOMAR at 33°N, 022°W in the northern Canary Basin. With two year-long interruptions, currents were measured at at least 6 depths between 200 m and 50 m above the bottom. The measurements from March 2004 to May 2005 are displayed in Figures 4.1 and in table 4.1. They show weak average southwesterly currents of few cm/s with high variability and low directional stability in the North Atlantic Central Water (NACW, 217 m, 523 m), the North Atlantic Deep Water (1594 m, 2999 m) and 50 m above the bottom. The record in the Mediterranean Water level is short. Also the fluxes of momentum and temperature are weak.

The flow variability (Fig. 4.1) has time scales of up to several months. It is baroclinic as the amplitudes change with depth; however, some events have a barotropic component in the as the flow does not change sign with depth.

Table 4.1: Basic statistics from current and temperature measurements at KIEL276, March 2004 to May 2005

Mooring V276240: statistics from low pass filtered daily averages															
z	days	SPD	DIR	s	Mean Std			its			Fluxes				
					<u>	<v>	<T>	u	v	T	<u'v'>	<u'v'> _d	<u'T'>	<v'T'>	
217	411	3.3	248	0.37	-3.1 5.0	-1.2 8.3	16.7 0.7	9	21	35	6	7	0.5	0.1	
523	411	2.4	255	0.40	-2.4 3.1	-0.6 5.5	12.6 0.3	16	24	25	0	1	0.2	0.1	
1038	60	1.9	317	0.53	-1.3 2.3	1.4 2.6	9.0 0.3	8	8	7	3	39	0.0	0.4	
1594	411	1.0	255	0.36	-1.0 2.3	-0.3 2.1	5.8 0.3	14	13	25	-1	-51	0.2	0.1	
2999	411	0.8	272	0.33	-0.8 2.0	0.0 1.6	2.8 0.0	15	15	23	-1	-63	-0.0	-0.0	
5239	411	0.6	288	0.24	-0.6 2.4	0.2 1.7	2.3 0.0	15	15	48	-1	-72	0.0	0.0	

Legend:
z/m : nominal instrumental depth
days : length of record
SPD, DIR: mean speed/cm/s) and direction
s : directional stability of flow (mean vector speed / mean scalar speed)
u, v : East and North component of flow, cm/s
T : temperature
its : integral time scale (first zero crossing of autocorrelation function)
<> : average
' : deviation from average
<u'v'>_d : momentum flux direction

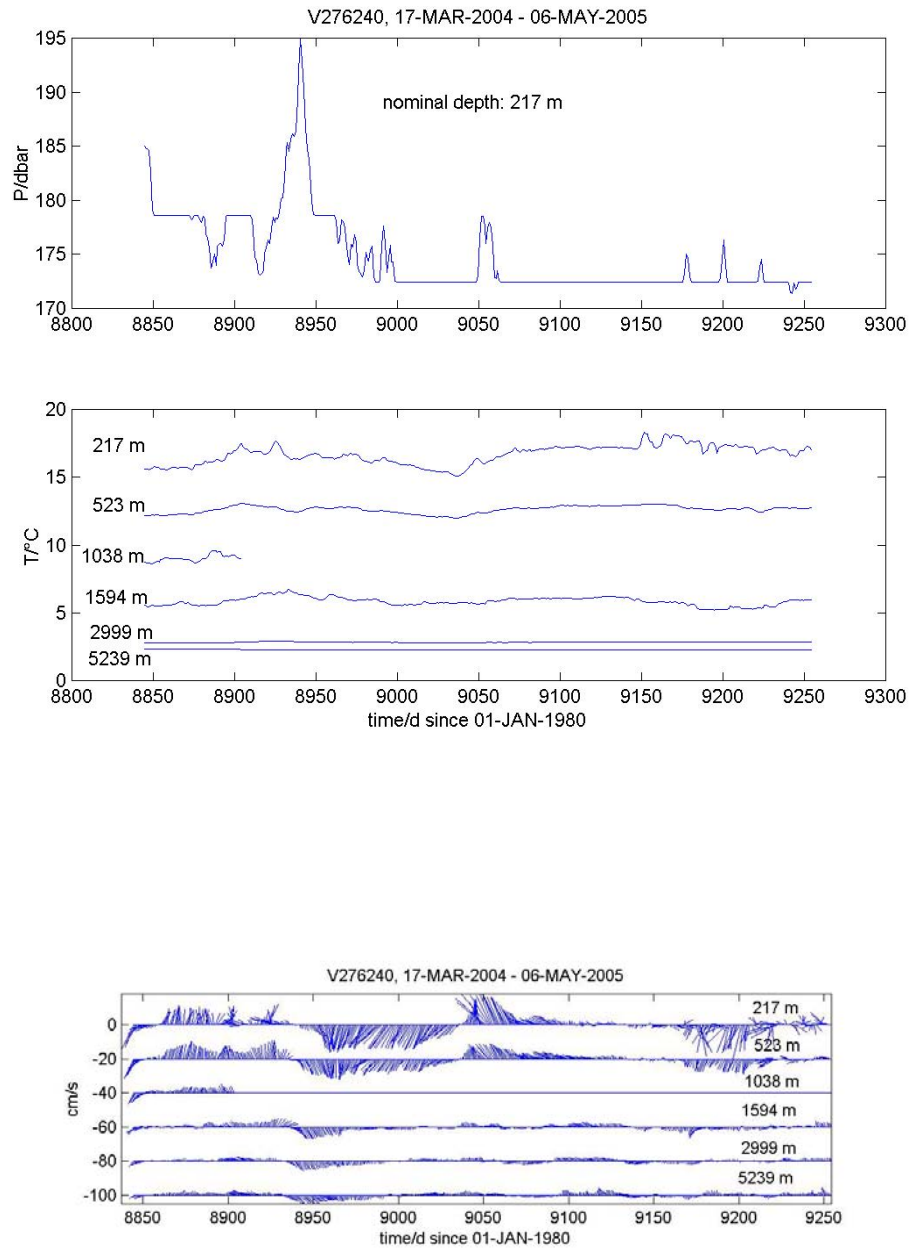


Figure 4.1: Current and temperature measurements at 33°N, 022°W from March 2004 to May 2005 at 217 m, 532 m, 1038 m (short record only), 1594 m, 2999 m and 5239 m nominal depths; low pass filtered daily averages. From top to bottom: pressure record of the uppermost instrument, temperature records and vector time series with North direction up.

4.2 A quasi-synoptic view

The upper ocean flow during the cruise is shown in figure 4.2.1, vertically integrated between 50 m and 300 m. The flow is highly variable on eddy scales with amplitudes of up to 20 cm/s and no clear signal of the Azores Current can be identified; only the northern most part at 35.5°N, 20°W this eastward current is hit.

The current field with depth along the section from the Southeast, 31°N, 023°W to the Northwest, 35.5°N, 020°W, is shown in figure 4.2.2 together with available surface temperature and salinity data. The clear decrease in surface salinity between 33°N and 34°N is associated with southwesterly flow, the increase between 34.5°N and 35°N with northward flow transporting salty water northwards. At the northern tip of the section, both temperature and salinity drop rapidly while the flow strongly increases eastwards thus indicating the Azores Current. Unfortunately, weather conditions and time did not allow for crossing the front completely.

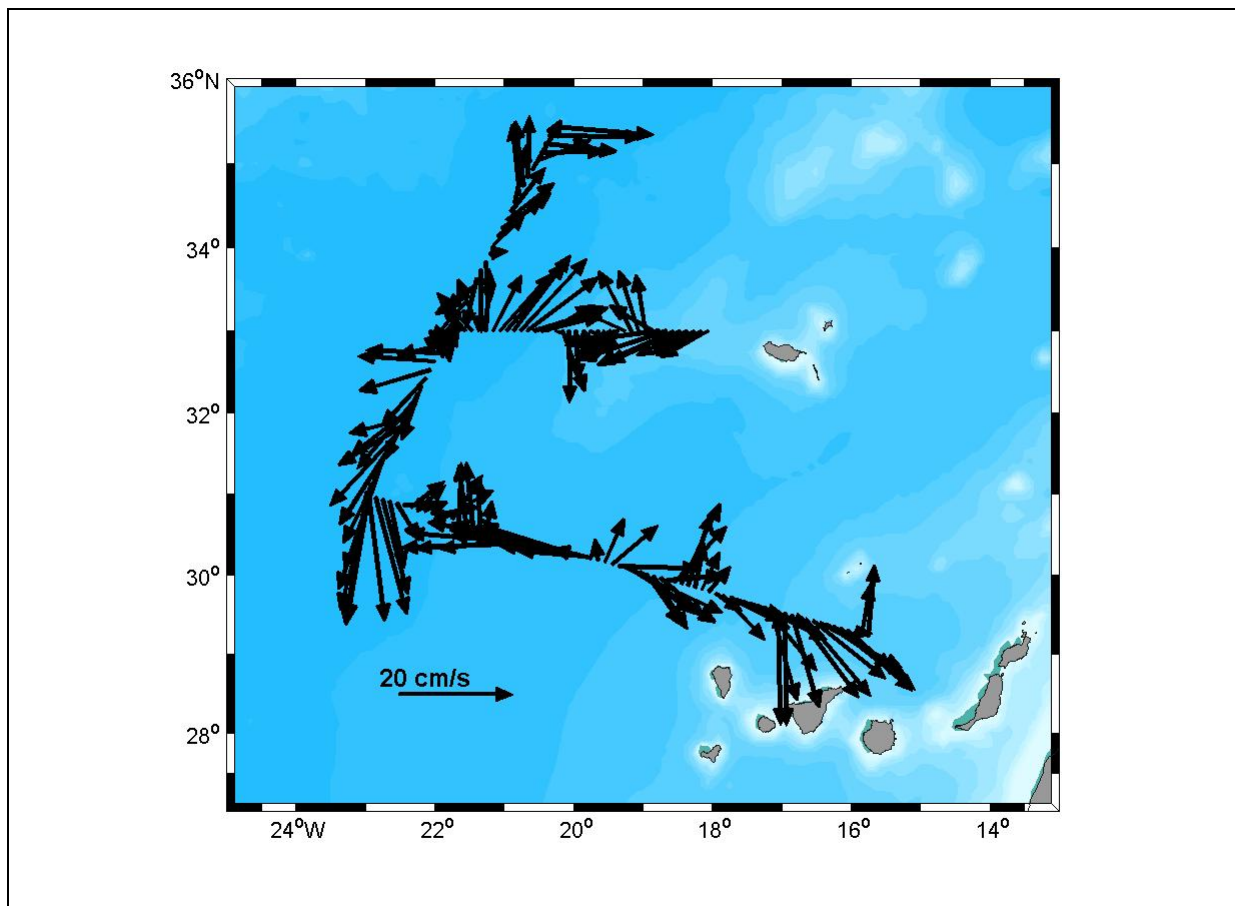


Figure 4.2.1: Currents in the layer 50 m to 300 m

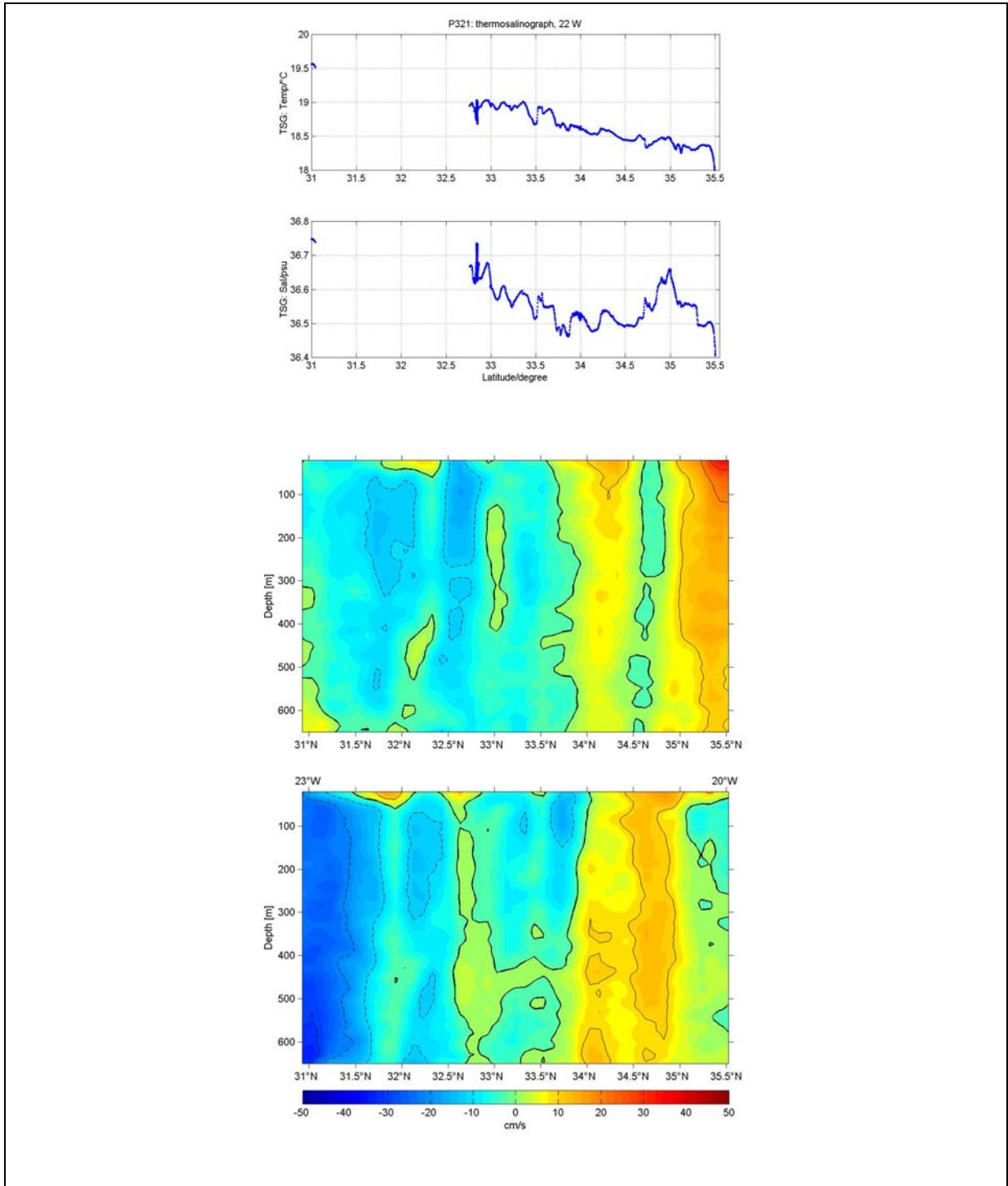


Figure 4.2.2: Section from SE, 31°N, 023°W to NW, 35.5°N, 020.2°W . From top to bottom: surface temperature and salinity, and East and North components of current.

5. Scientific equipment

5.1 Moorings

During Poseidon 321, the long term mooring K276/L1 was recovered (V276-24) and launched in a similar configuration and at the same location (V276-25). See Table 5.1.1 for dates, location and instrumentation and Table 5.1.2 for performance of recovered instruments.

Table 5.1.1: Poseidon 321 moorings recovered (R) and launched (L), Aandearaa RCM9/8 current meters, and particle traps

Site	Date	Position	Water Depth/m	ID	Instruments, nominal depth/m	Remarks
Kiel276/L1	06 th May 2005	32°49.65'N 022°00.20'W	5209	V276-24	RCM8: 270, 500, 1000, 1600, 3000, 5185 Traps: 2000 (2), 3050	R
	08 th May 2005	33°01.39'N 021°56.85'W	5325	V276-25	RCM8: 270, 500, 1000, 1600, 3000, 5185 Traps: 2000, 3050	L

Table 5.1.2: Instrumental configuration and data return of mooring V276-24

Mooring information						

General						

Mooring ID	:	V276-24				
Deployed	:	Date: 17-MAR-2004	Ship / Cruise:	Poseidon 308		
Recovered	:	Date: 06-MAY-2005	Ship / Cruise:	Poseidon 321		
Latitude N	:	32.818				
Longitude E	:	-022.000				
Water depth	:	5215 m (sounding with 1500 m/s)				
Magn. Anom.	:	-09 deg (W)				
Project	:	KIEL276 time series station				
PI, institute:	:	T.J. Mueller, IFM-GEOMAR				
Instrument						

Depth	Moor_ID	Type	S/N	Sampling	Sensor	Remarks

217	2762401	RCM8	10554	7200 s	REF	344, e-board 2595, DSU 3690
					T_LR	from day 340 on noisy
					PRES	ok, median 172 dbar, 6300 dbar linear range calibration
					DIR	from day 340 on noisy
					SPD	ok
523	2762402	RCM8	10581	7200 s	REF	301, e-board 2592, DSU 7097
					T_LR	ok
					DIR	ok
					SPD	ok
1038	2762403	RCM8	10578	7200 s	REF	342, e-board 2624, DSU 3644
					T_LR	ok
					DIR	ok
					SPD	ok
						short record of 61 d only; self check DSU ok
1594	2762404	RCM8	10558	7200 s	REF	257, e-board 2589, DSU 3689
					T_LR	ok
					PRES	ok, median 1582 dbar, 6300 dbar linear range calibration
					DIR	ok
					SPD	ok
1997	2762405a	PT	SE 001			particle trap
	2762405b	DL	1112	7200 s		inclination meter
					REF	711
					ch 2	inclination
					ch 3	constant
2999	2762406	RCM8	10555	7200 s	REF	414, e-board 2601, DSU 3392
					T_LR	ok
					DIR	ok
					SPD	ok
3068	2762407	PT	SE 002			particle trap
5239	2762408	RCM8	10550	7200 s	REF	258, e-board 2590, DSU 5937
					T_LR	ok
					DIR	ok
					SPD	ok
General remarks						

All temperatures & pressures still to be compared to CTD.						
All pressure records to be post calibrated.						
Data at sampling rates in RCM*.DAT.						
Low pass filtered daily averages in V276240.mat.						
Compiled by: T.J. Mueller				Date: 12-SEP-2005		

5.2 CTD/rosette

5.2.1 CTD configurations

For the CTD-measurements, two SeaBird 911 systems (internal IFM-GEOMAR codes SBE3 and SBE4X) were used (see Tab. 5.2.1). SBE3 with sensors for temperature, pressure, dissolved oxygen and fluorescence was mounted below a 12x10 l rosette. SBE4X had temperature, conductivity and oxygen sensors from IFM-GEOMAR CTD SBE4, and an underwater unit with pressure sensor on loan from SeaBird. SBE4X had no rosette sampler and instead carried the minicorer.

Table 5.2.1: CTD sensors during P321 according to *.CNV and *.CON files

Cast	SBE ID	T-sensor S/N	C-sensor S/N	P-sensor S/N	O2-sensor S/N	Fluorescence
001	SBE3	034051	042537	82991	631	yes
002	SBE4X	4234	2995	57437	735	no
003	SBE3	034051	042537	82991	631	yes
004	SBE3	034051	042537	82991	631	yes
005	SBE3	034051	042537	82991	631	yes
006	SBE3	034051	042537	82991	631	yes
007	SBE3	034051	042537	82991	631	yes
008	SBE4X	4234	2995	57437	735	no
009	SBE4X	4234	2995	57437	735	no
010	SBE4X	4234	2995	57437	735	no

5.2.2. CTD pressure, temperature and salinity calibration:

General

All sensors but fluorescence have a basic calibration by SeaBird, and in addition pre-cruise laboratory calibration and for some sensors post-cruise IFM-GEOMAR calibrations as well. CTD salinity for SBE3 has an in-situ calibration using some bottle data while no samples could be taken for SBE4X because the minicorer attached to it had replaced the rosette sampler.

The calibration procedures for pressure, temperature and conductivity sensors including data processing are described in Müller (1999). Basic SeaBird calibration is used to convert frequency measurements to physical data. Then, after cleaning, pre- and if available, post-cruise laboratory calibrations are applied to temperature and pressure sensors. Next, *in-situ* calibration is applied to conductivity values and salinity is re-calculated.

CTD bottom pressure check

Check of pressure sensor bottom values (Tab. 5.2.2) for SBE4X at all 4 casts with echo-sounding derived bottom pressures showed no significant differences. The same holds for the two deep SBE3 casts at locations ESTOC and K276. The differences are of the order of 10 dbar, i.e. 0.2% at 5000 dbar

Table 5.2.2: POSEIDON cruise P321: CTD pressure sensor calibration check: compare measured CTD bottom pressure (bottom alarm) with bottom pressure derived from corrected water depth of 12 kHz echosounder; sounding corrected for transducer depth of 4 m.

Cast	12 kHz echosounder			CTD	
	sounding	corrected	pressure	P-bottom	difference
<i>SBE4x</i>	m	m	dbar	dbar	dbar
002	4907	4959	5053	5043	10
008	3550	3571	3629	3641	-12
009	3169	3186	3221	3223	-2
010	2956	2971	3014	3023	-9
<i>SBE3</i>					
001	3614	3633	3689	3681	8
007	5214	5272	5376	5371	5

SBE3: in-situ salinity calibration

In-situ salinity is estimated from bottle samples where available and converted to *in-situ* conductivity using calibrated temperature and pressure values at bottle closures. Next, CTD conductivities at bottle closures are calibrated to *in-situ* conductivity; all calibrations are applied to full casts, and calibrated salinity is derived. After calibration, deep CTD casts are compared with the Saunders relation of potential temperature and salinity in the deep North East Atlantic (Saunders, 1986).

Bottle salinities were measured 3 months after the cruise in July 2005 at IFM-GEOMAR laboratory. SSW batch used: P143 with K15=0.99989, S=34.9957. Salinometer offset is less 0.0002; no drift. according to substandard. Offset corrected salinities S (Tab. 5.2.3).

Table 5.2.3: P321 bottle salinities; all bottles for SBE3; S is offset corrected salinity.

P321 Bottle salinities						
Salinometer used: Guildline Autosol (IFM-GEOMAR ID is AS6)						
Operator: H.-J. Langhof						
Batch P143: K15=0.99989, S=34.9957						
Measured 3 months after the cruise, July 2005						
STA	CAST	BNO	SAMP	2xRt	S_sali	S
Sub	-9	-9	-9	-9	33.9261	33.9263 % 14.07.2005, 09:05
Std	-9	-9	-9	-9	34.9955	34.9957 % 14.07.2005, 09:40
171	1	301	1305	1.9960	34.9215	34.9217
177	3	311	1295	2.0898	36.7736	36.7738
187	7	301	1317	1.9947	34.8957	34.8959
171	1	303	1306	1.9979	34.9579	34.9581
177	3	301	1301	2.0062	35.1217	35.1219
187	7	312	1298	2.0802	36.5834	36.5836
178	4	301	1297	2.0035	35.0681	35.0683
182	5	301	1303	2.0036	35.0713	35.0715
184	6	301	1309	2.0016	35.0321	35.0323
182	5	312	1304	2.0763	36.5060	36.5062
Sub	-9	-9	-9	-9	33.9261	33.9263 % 14.07.2005 15:00

For casts, 1, 3, 4, 5, 6, 7, apply calibration coefficients from pre- and post-cruise calibrated PRES and TEMP, and together with bottle salinity derive *in-situ* conductivity. Compare with measured CTD conductivity to get calibration coefficients in CONDRES*. Calibrate all casts. The correction $S_{CORR}=S-S_{CTD}$ is consistent at a median of 0.015 with an error of less 0.002 at pot. temp. < 3°C, and at a median of 0.014 with standard deviation 0.004 for all 10

comparisons (Tab. 5.2.4).

Tab.5.2.4 : SBE3, casts with salinity samples S ; correction is $S_{CORR} = S - S_{CTD}$

Cast	Bottle	Pres dbar	Potemp IPTS68	S_{CTD}	S IPSS78	$S - S_{CTD}$
1.000	1	3601.370	2.236	34.907	34.922	0.015
1.000	3	2998.750	2.588	34.941	34.958	0.017
3.000	1	2004.310	4.150	35.105	35.122	0.017
3.000	11	10.900	19.629	36.760	36.774	0.014
4.000	1	2004.350	3.850	35.053	35.068	0.015
5.000	1	2003.070	3.995	35.062	35.072	0.010
5.000	12	9.170	18.610	36.497	36.506	0.010
6.000	6	2000.820	3.680	35.026	35.032	0.006
7.000	1	5360.880	1.963	34.880	34.896	0.016
7.000	12	8.930	19.070	36.570	36.584	0.013

SBE4X salinity calibration check

None of the casts with SBE4X, 2, 8, 9, 10, has bottle salinity data. The deep casts meet exactly the Saunders (1986) theta/S relation for $\theta < 3^{\circ}\text{C}$. No salinity corrections for SBE4x necessary nor applied (Fig. 5.2.1).

Discussion of salinity calibration

After correction, SBE3 including deep casts 1 at ESTOC and 7 at K276 reads salinity by 0.004 higher in the deep sea than SBE4x which without salinity comparisons meets well the Saunders (1986) relation. On the level of double the standard deviation, however the casts are well within the Saunders (1986) relation (Fig. 5.2.1). Being consistently high, it may be noted that bottle salinities (for SBE3) were measured only 3 months after the cruise. Bottle salinity therefore are marked 'questionable' in the bottle file. Comparison of casts 2 (SBE4X), and cast 7 (SBE3, calibrated) with a calibrated cast taken one month later in June 2005 from POLARSTERN during cruise ANTXXII-5 at K276 shows that all data in the deep sea are within the 2xrms error of the Saunders (1986) relation.(Fig. 5.2.1).

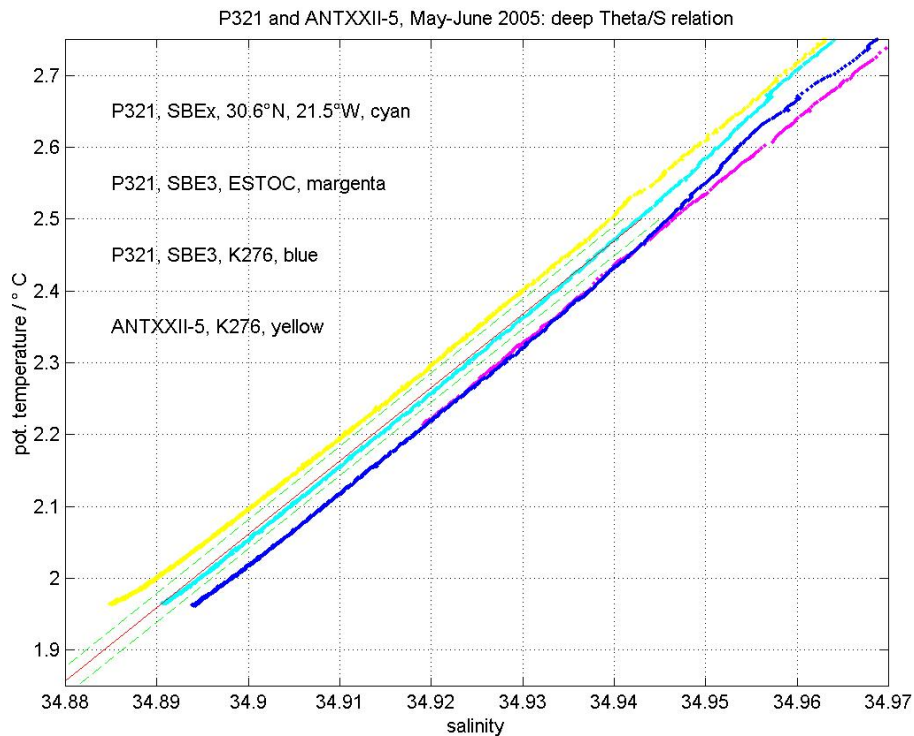


Fig. 5.2.1: relation of potential temperature and salinity from deep casts in the North East Atlantic in May (POSEIDON cruise P321) and June 2005 (POLARSTERN cruise ANTII-5). All data meet the Saunders' (1986) relation (red line) within its 2xrms limits (single rms is broken green)

CTD oxygen sensor adjustment to historic data

For dissolved oxygen, only the basic calibration is available. Therefore, 'historic' data (CDIAC GLODAP Data Set) from the region and later 1990 were used for comparison and adjustment. Both, the SBE3 and SBE4X sensors showed large offsets from the historic data in three selected of 1°x1° regional boxes (Fig. 5.2.2):

- ca. 31°N, 023°W, also representative for ESTOC (29°10'N, 015°30'W) within NADW and NACW
- ca. 33°N, 022°W Azores Front including location KIEL276
- ca. 36°N, 020°W, north of the Azores Front

Linear adjustments were performed at the central temperatures of North Atlantic Deep Water (NADW, 4°C) and North Atlantic Central Water (NACW, 14°C) to meet the historic data (Tab. 5.2.5, straight lines in Fig. 5.2.2).

SBE3 fluorescence sensor

No *in-situ* calibration values are available to convert raw data to chlorophyll 'a'. Therefore, only raw data are stored to identify maxima and minima in a cast.

Table 5.2.5: linear CTD oxygen sensor corrections at $\theta=4^{\circ}\text{C}$ (NADW) and $\theta=14^{\circ}\text{C}$ (NACW)

POSEIDON cruise P321
Oxygen sensor linear adaption to NADW and NACW.

Historic data at 04°C (North Atlantic Deep Water, NADW) and 14°C (North Atlantic Central Water, NACW) potential temperature.

Correction for dissolved oxygen sensor data: $O_{\text{COR}} = a + b \cdot (\theta - \theta_{\text{ref}})$

where

O_{cor} is the correction to sensor value $OX/(\mu\text{mol/kg})$

A: offset at 4°C potential temperature (NADW)

$B = (O_{\text{COR}14} - A) / (\theta - \theta_{\text{ref}})$; θ is surface referenced potential temperature

$\theta_{\text{ref}} = 4^{\circ}\text{C}$.

$O_{\text{cor}14}$ is estimated correction at $\theta = 14^{\circ}\text{C}$.

cast	A	B	remark
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SBE3

001	92	-2.6	ESTOC
003	85	-2.0	Azores Front
004	85	-2.0	Azores Front
005	85	-2.0	Azores Front
006	80	-1.0	at 36°N
007	85	-2.5	K276

SBE4X

002	15	-0.4	
008	30	-0.9	Azores Front
009	30	-0.9	Azores Front
010	30	-0.9	Azores Front

CTD calibration summary

Calibrations with corrections to basic calibrations for the CTD's from the following calibrations were used:

SBE3

temperature	pre-cruise: 2005-JAN-24, IFM-GEOMAR, better 0.001 K post-cruise: sensor exchanged, no calibration available
pressure	pre-cruise: 2003-APR-15, IFM-GEOMAR, better 2 dbar, pre-cruise post-cruise: 2006-MAR-15, IFM-GEOMAR, better 2 dbar
conductivity	in-situ, cruise P321, IFM-GEOMAR, better 0.003 mS/cm.
salinity	derived, 0.002 higher than Saunders' deep ($<3^{\circ}\text{C}$) theta-S relation
oxygen	pre-cruise SeaBird calibration 31-Jan-2004, better 0.1 ml/l no in-situ calibration available; adjustment better 5 $\mu\text{mol/kg}$
fluorescence	no in-situ calibration available;

SBE4X

temperature	pre-cruise: 2004_SEP-15, SeaBird basic calibration post-cruise: 2005-OCT-15, IFM-GEOMAR, better 0.002 K
pressure	pre-cruise: SeaBird basic calibration, better 2 dbar
conductivity	no samples, no <i>in-situ</i> calibration possible
salinity:	deep sea theta-S relation, cast #2 values at potential temperature $< 3^{\circ}\text{C}$ meet well Saunders' (1986) relation within 0.002 psu; no salinity correction.
oxygen	pre-cruise, SeaBird basic calibration, 21-Sep-2004, better 0.02 ml/l; no in-situ calibration available; adjustment better 5 $\mu\text{mol/kg}$

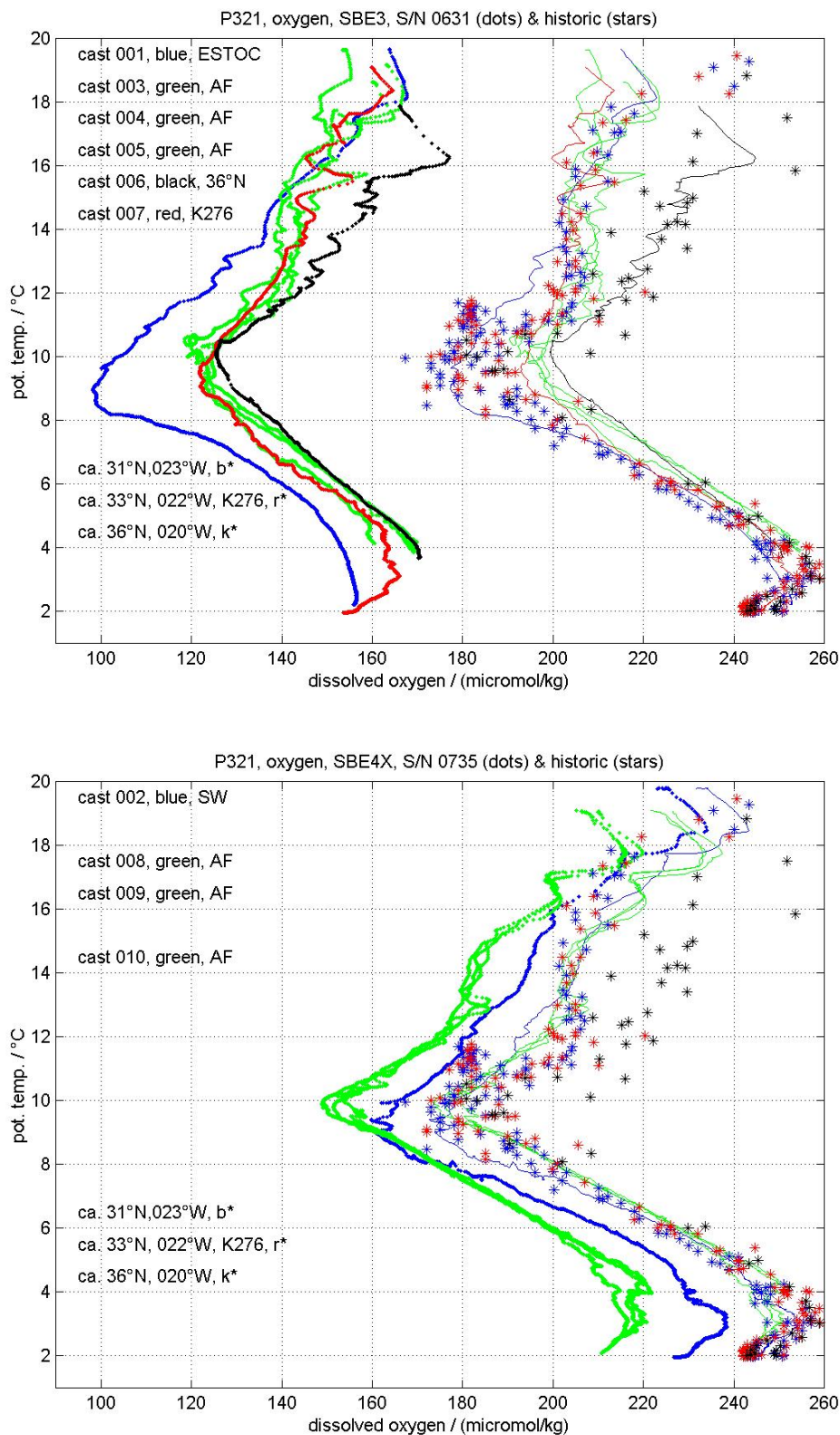


Fig. 5.2.2: CTD oxygen sensor casts with historic data comparisons; SBE3 sensor (upper panel) and SBE4X sensor (lower panel); casts (dots) and historic data(stars); lines show linear adjustments to historic data at potential temperatures 4°C (North Atlantic Deep Water, NADW) and 14°C (North Atlantic Central Water, NACW); for coefficients used, see Tab. 5.2.5. Note, NACW at 36°N (cast 006) has higher oxygen than at those at lower latitudes.

5.3 Organic particle sampling

5.3.1 Minicorer

A minicorer was attached below the SBE4X CTD for the first time to sample sediment probes from the deep sea; designed for shallow waters, it turned out that sediment if any was caught was lost on its more than 4 km long way up to the surface. Thus, no samples are available from this sampling device.

5.3.2 Plankton net

A multiple closing plankton net, 100 micron mesh, 5 nets, 50 cm diameter, 261 cm length, was used on five stations (see map in Fig. Xx, cruise log in App. 7.2) down to 100 m (3 casts) and 500 m (2 casts). Data are still under investigation at the University of Tübingen.

5.3.3 Water column and surface water sampling

The biologist's intention during this cruise was to study the origin and quality of organic particles using water bottles and pump systems. Analysis in turn of a Phd thesis is still going on at the University of Quebec, Canada.

Nutrient samples

Nutrient samples were taken from closed rosette bottles and analyzed onboard by UQUAM. Closing depths of bottles were often uncertain due to technical problems with the rosette sampler. However, also some nutrient measurements turned out to be uncertain although parallel samples of salinity from the same rosette bottle were consistent with CTD salinity thus excluding mis-closure of the rosette bottle. In the rosette data file, all nutrient data that do not meet the historic relation of nutrients and potential temperature are marked questionable.

5.4 Underway measurements

5.4.1 PC-Log

A PC-based programme package, PC-Log, is used to log consecutively the data streams from navigational units, the ship's meteorological automated weather station, the deep sea echosounder and from the thermosalinograph. Standard output format is binary, but ASCII transformation is an option. Data were recorded at 10 s intervals.

Processing removed spikes in all data by a median criterion or a graphical editor. Bad data were replaced by dummies.

From the date and time columns new columns were related with year, month, day, hour, minute, second and decimal yearday (with a resolution of 10 s) of 2005. Yearday=0 corresponds to 01-Jan-2005, 00:00:00 UTC. These new columns were right hand added to the original data matrix.

The gyro compass daughter data, the heading from the 4-antenna GPS ADU2 and from the thermosalinograph needed calibration; see sections below for details. After editing and calibration, the Excel readable file *p321_underwaydata.csv* (ASCII with decimal points, and commas as separators, -999 as dummies for non-existing or bad data) is the final output for underway measurements.

Details of sensor check, processing and calibration as follows:

Navigational data

The PC-Log file provides the following navigational information:

- combined GPS-GLONASS date (UTC), time (UTC), and position (WGS84) from the GG24 system (Ashtech) at 10 s sampling rate
- heading of the gyro's daughter digital output in the dry laboratory; 10 s sampling rate; this output needs offset adjustment to main compass which usually is performed at the beginning of a cruise while still in port without changes in compass readings.
- UTC time (no data), pitch, roll and ship's course from a 4-antenna ADU2 GPS system (Ashtech); 10 s sampling rate; quality of all three data depend on careful alignment of the 4-antenna system to ship's keel.

The combined GPS-GLONASS signal showed good data quality which needed no 'cleaning' (Fig. 5.4.1).

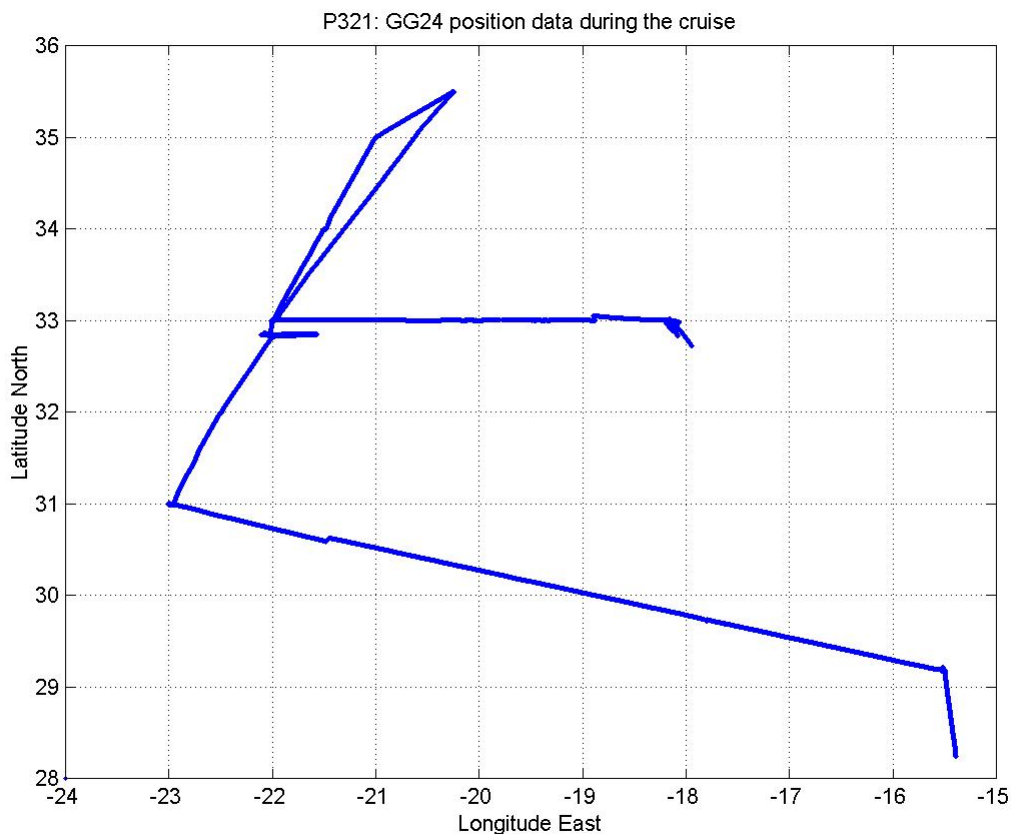


Fig. 5.4.1: position data from the GG24 ASTECH navigational system, 10 s rate.

To process e.g. ADPC data, it is essential to know with high resolution in time not only accurately the ship's position, but also the ship's course over ground (COG) and the ship's keel's course (heading or STN) relative to true North. COG is measured by the ship's gyro compass, at least over quite long distances at constant course at no currents and wind effects. In case of POSEIDON, the compass' daughter in the dry laboratory provides the COG relative to an electronic *switch-on offset*.

Usually, this offset is corrected for by comparison with the compass' mother reading on the bridge at the very beginning of a cruise, and is less than a degree. To check the offset correction of the gyro's daughter, one can compare COG as calculated at rather large speeds from 'long' distances end point and time differences with the gyro's readings. Over a whole cruise with different courses, winds and currents, the differences should be constant, ideally should read zero. At speeds larger 8 kn, over time intervals of 5 minutes and over almost the whole range of courses, the median correction of the gyro's daughter reading referenced to overall COG estimates is 2.72° with standard deviation 1.35° (Fig. 5.4.2). Ensemble medians differ less than a degree from the overall median correction.

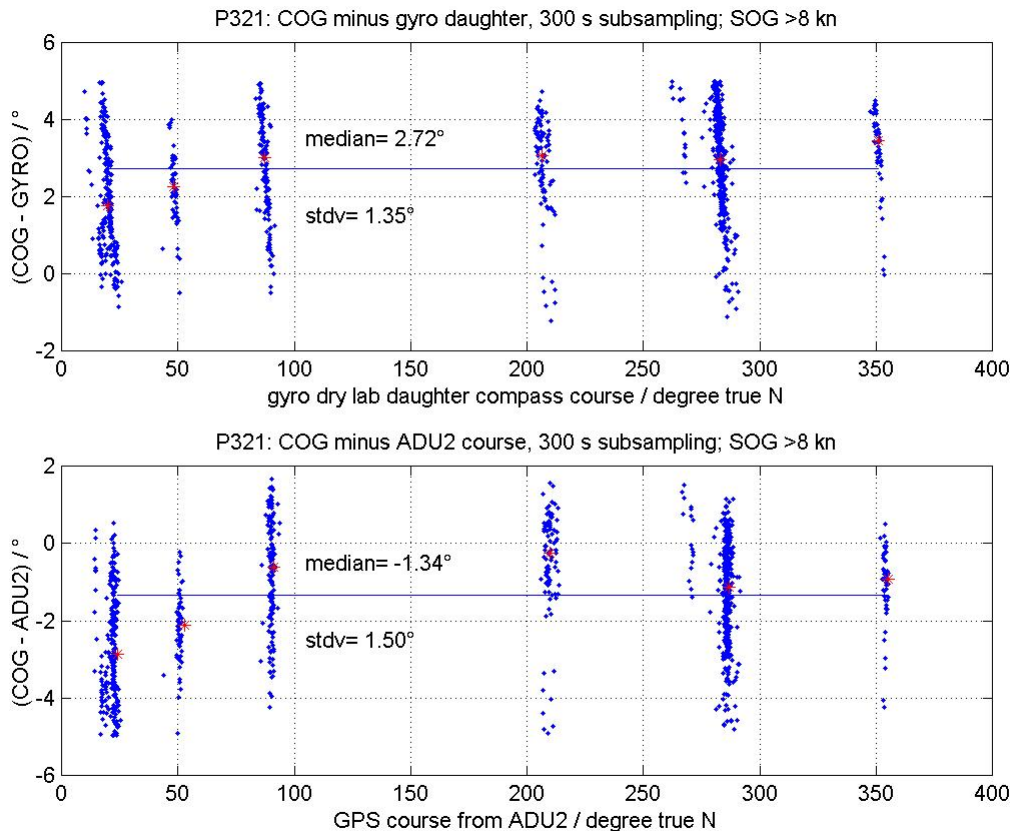


Fig. 5.4.2: Comparison of the ship's course over ground (COG) at speeds larger 8 kn with the gyro's daughter digital output (upper panel) and the ADU2 ASTECH 4-antenna GPS course (lower panel). Overall median corrections and standard deviations indicated; red stars indicate median correction within ensembles

STN is measured by the 4-antenna system of the ADU2 Ashtech GPS, provided the 4-antenna system is calibrated relatively to the ship's keel. Well calibrated, and with no currents and wind effects, it's readings over long distances should be the same as COG. Applying the same method as for the gyro's daughter correction, the STN overall correction is -1.34° with standard deviation 1.50° . Ensemble medians differ less than a degree from the overall correction.

Following the above discussion, the gyro's daughter digital output and the ADU2 heading were corrected (Tab. 5.4.1) using the above median correction; note however, that slight non-linearity in both corrections remains.

Tab. 5.4.1: Corrections of the gyro's daughter readings and of the ADU2 heading readings from comparisons with course over ground (COG) from 5 minute interval end point differences at 'large' speeds (>8 kn)

Correction to meet COG	Overall offset median correction	Standard deviation	Difference to ensemble median deviation
Gyro's daughter, dry lab	2.72°	1.35°	< 1°
ADU2 ASHTEC 4-antenna GPS	-1.34°	1.5°	< 1°

Automated Weather Station

The station is operated and serviced on an annual basis by the German Weather Service (DWD). Sensors for wind direction and speed, air temperature, humidity, air pressure and water temperature are implemented. Measurements of relative wind is converted to absolute wind using ship's speed as estimated from differential positions and heading from the gyro compass. Output of 15 s averages to the log system every 60 s, and directly to the *Global Telecommunication System* (GTS) via satellite METOSAT every 2 hours. The below plots show the data after cleaning.

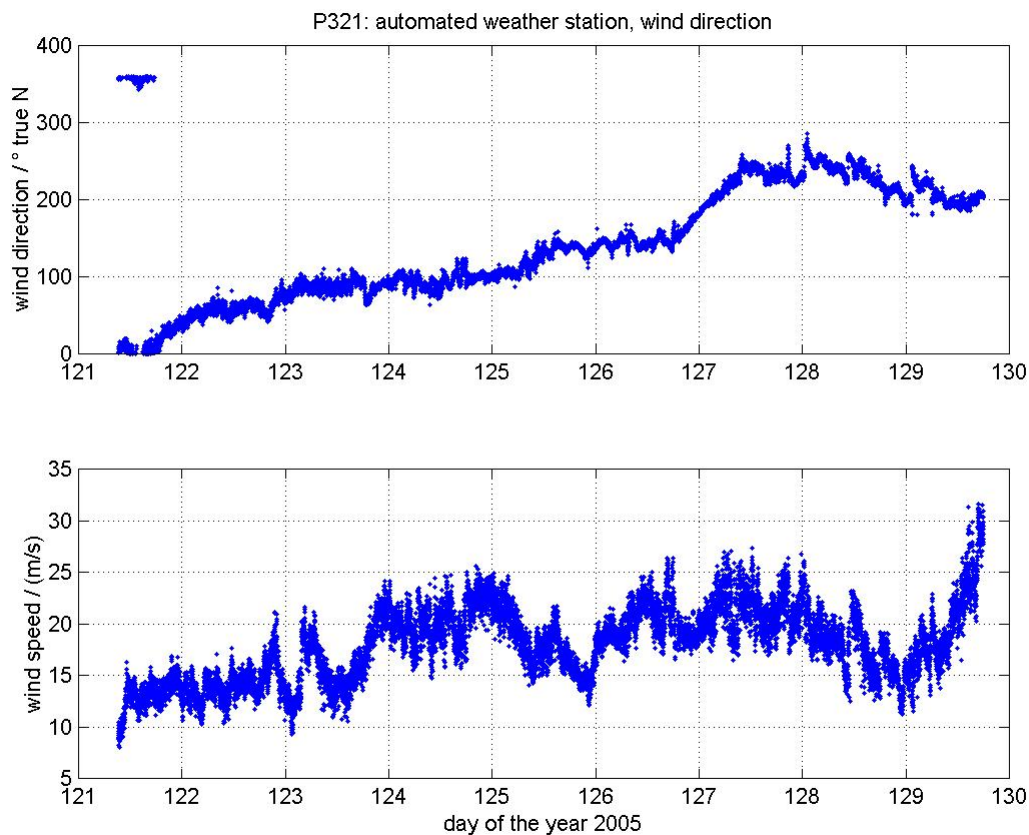


Fig. 5.4.3: Automated weather station, absolute wind direction and speed

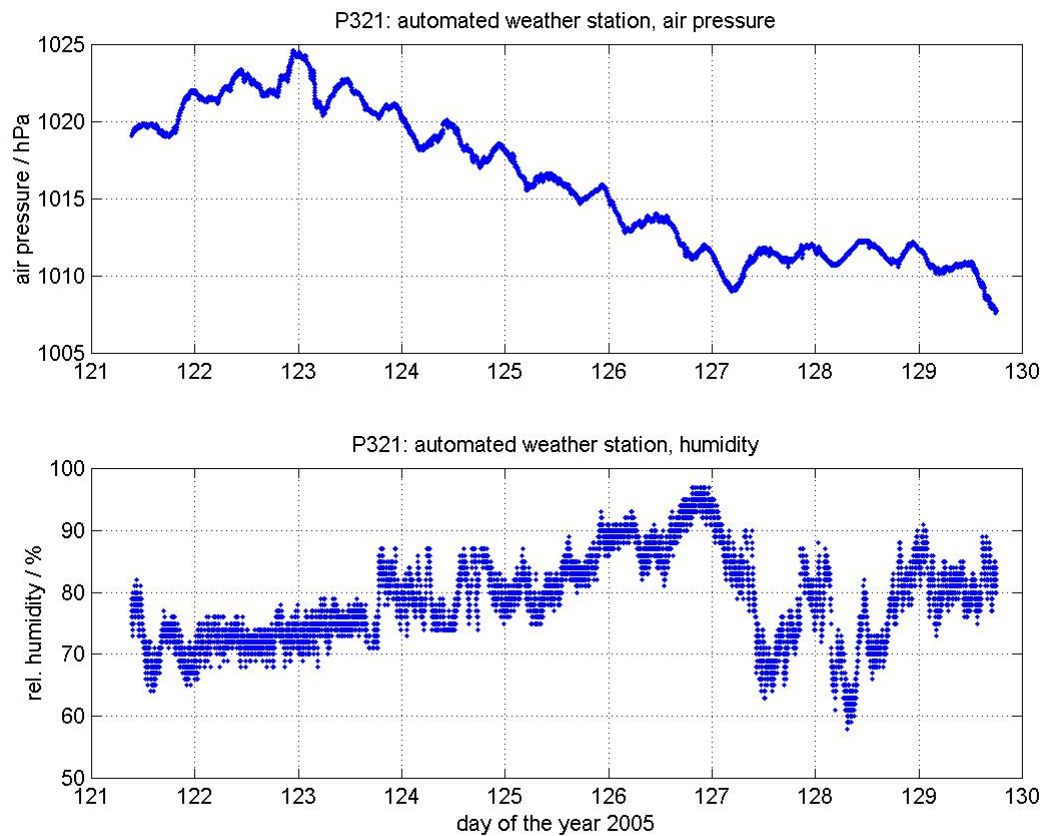


Fig. 5.4.4: Automated weather station, air pressure and relative humidity

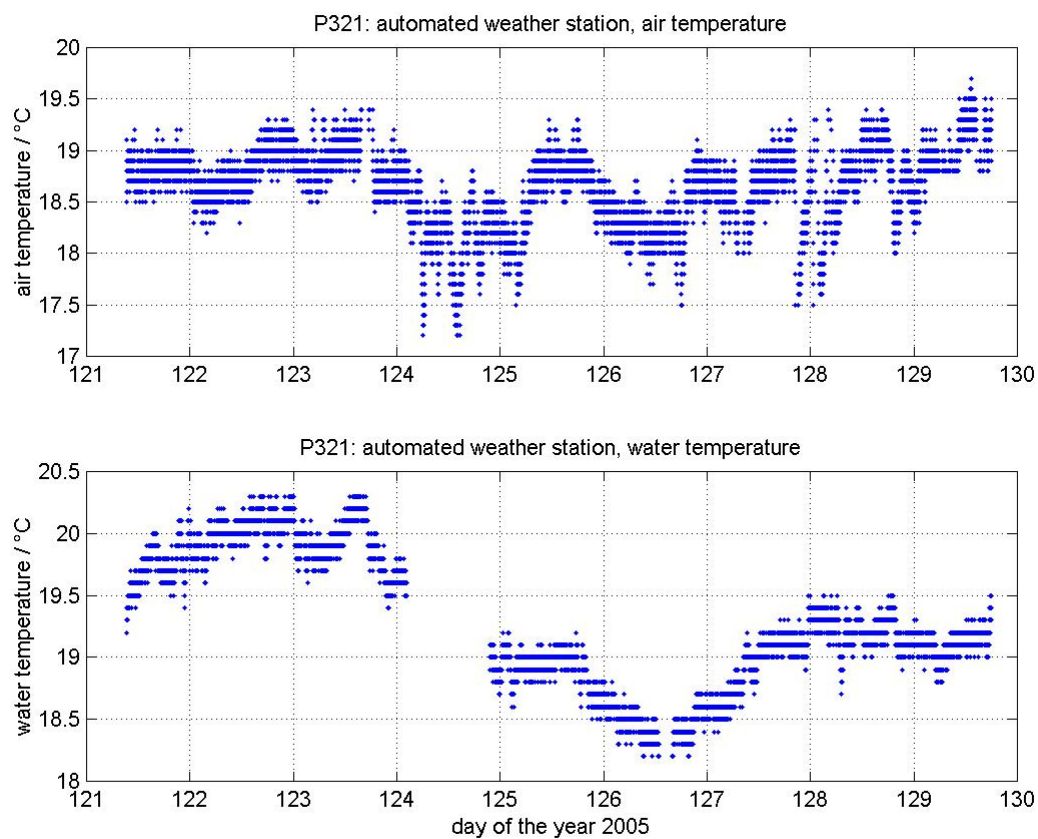


Fig. 5.4.5: Automated weather station, air and water temperature

Deep sea echosounder

A 12 kHz echosounder made by ELAC provides depth information, both as standard graph and as digital output. The sound velocity to convert travel times to sounding depths was 1500 m/s. Sensor depth offset of 4.5 m was applied to correct transducer depth to surface. The digital output was input to the PC-Log system.

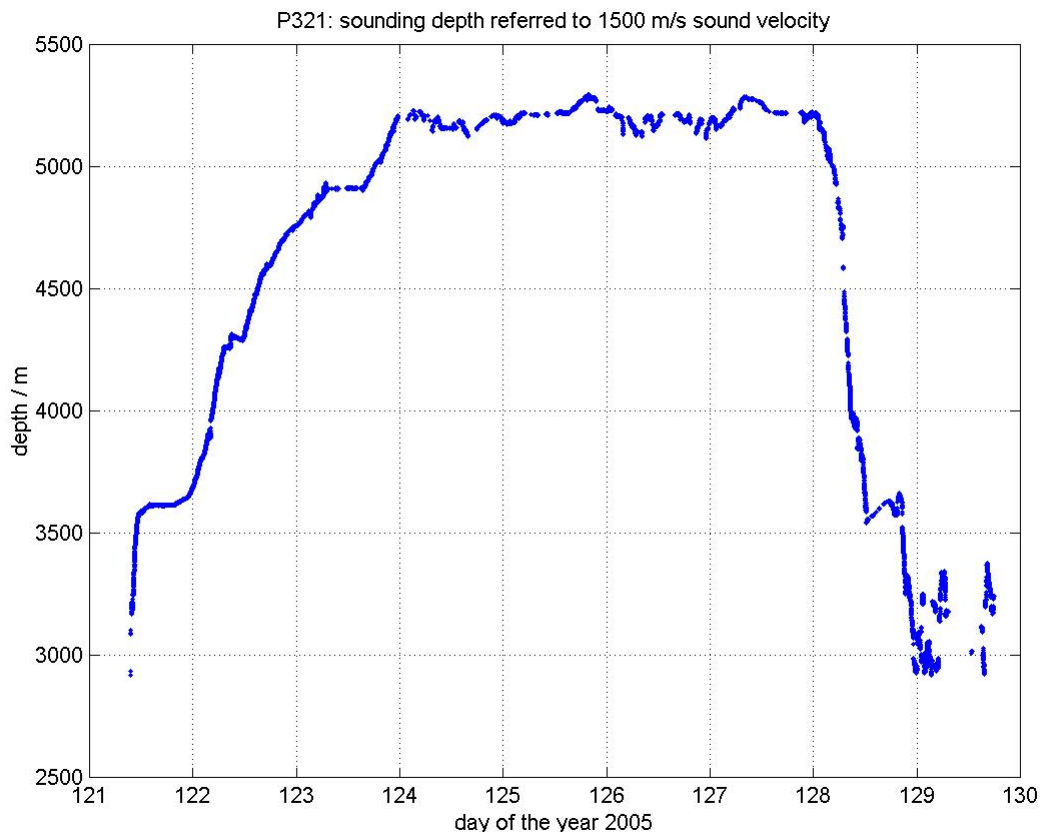


Fig. 5.4.6: 12 kHz sounding depth .reference sound velocity was 1500 m/s; offset of transducer depth below the keel is 4.5 m and is corrected for.

Thermosalinograph

The digital output of the thermosalinograph raw data is transferred to the PC-Log system where it is converted to physical units for temperature and conductivity. Salinity is calculated according to the International Practical Salinity Scale (IPSS78, UNESCO, 1983), and surface density anomaly according to the International Equation of State for seawater (EOS80, UNESCO, 1983). The accuracy is 0.1 K and 0.2 for temperature and salinity, respectively. Delayed-mode offset corrections, with near surface CTD data from 8 casts improve the accuracy estimates to 0.02 K and 0.02 psu for temperature and salinity, respectively (Fig. 5.3x; Tab. 5.4.2).

Tab. 5.4.2: Corrections applied to the thermosalinograph readings from comparisons with near-surface CTD values.

Median correction to meet CTD near-surface data	Overall offset median correction	Standard deviation of correction
Temperature	0.013 K	0.012
Salinity	0.201	0.15

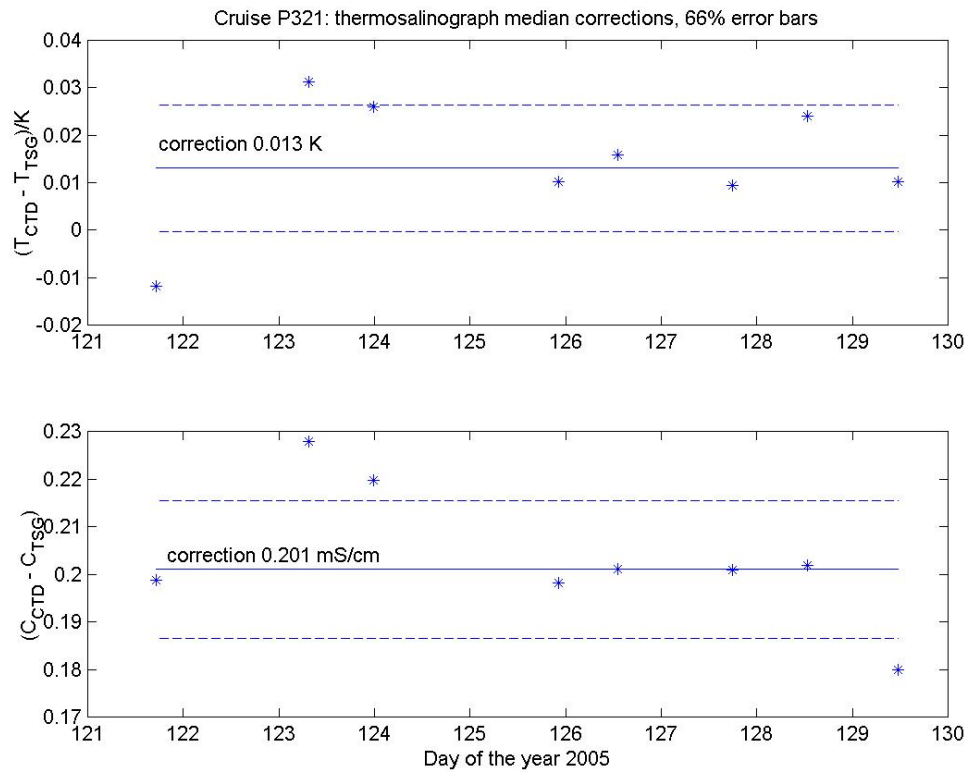


Fig. 5.4.7: Corrections for thermosalinograph data using near surface data from 8 CTD casts. Offset correction values from median differences and standard deviations (66% confidence) are indicated.

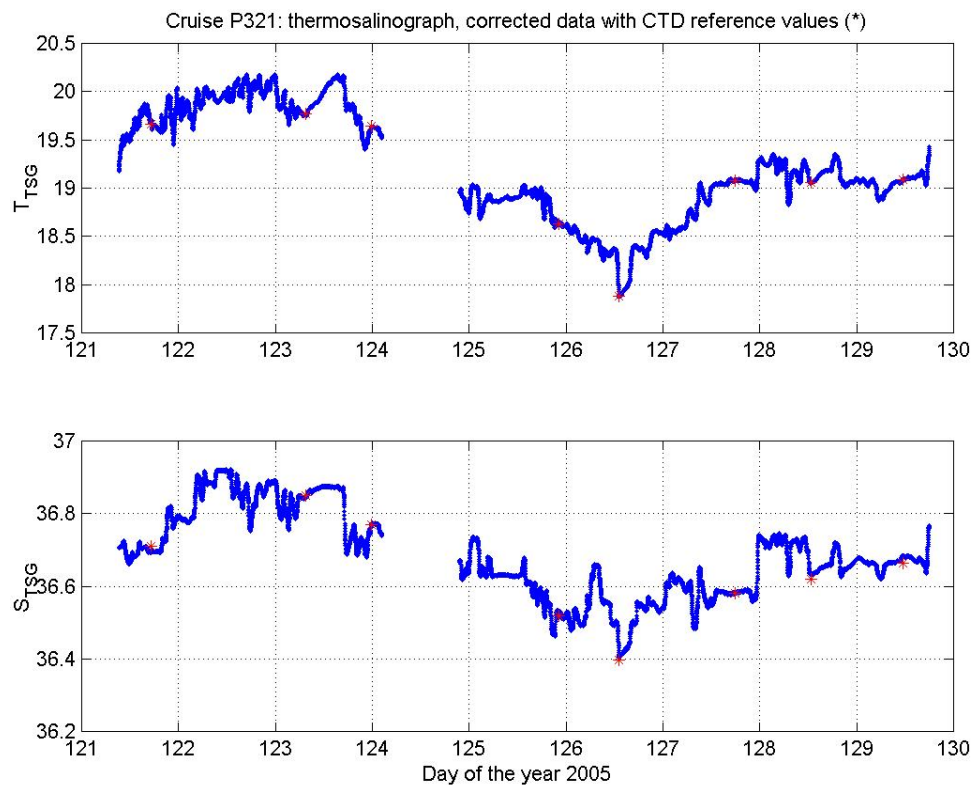


Fig. 5.4.8: Corrected temperature and salinity from the thermosalinograph; red stars indicate near surface calibration values from 8 CTD casts.

5.5 Vessel mounted current profiler (ADCP)

A 75 kHz Ocean Surveyor made by RDI, California, was mounted in the ship's moonpool to measure current profiles down to 700 m maximum throughout the cruise. Data were recorded by VMDAS provided by the manufacturer. Data were processed using the institute's programme library (Fischer et al., 2003). This library allows to despiked the data, to detect low response depth bins, to detide the data with a tidal model and to correct for misalignment of the transducer with the ship's keel (Fig. 5.5.1).

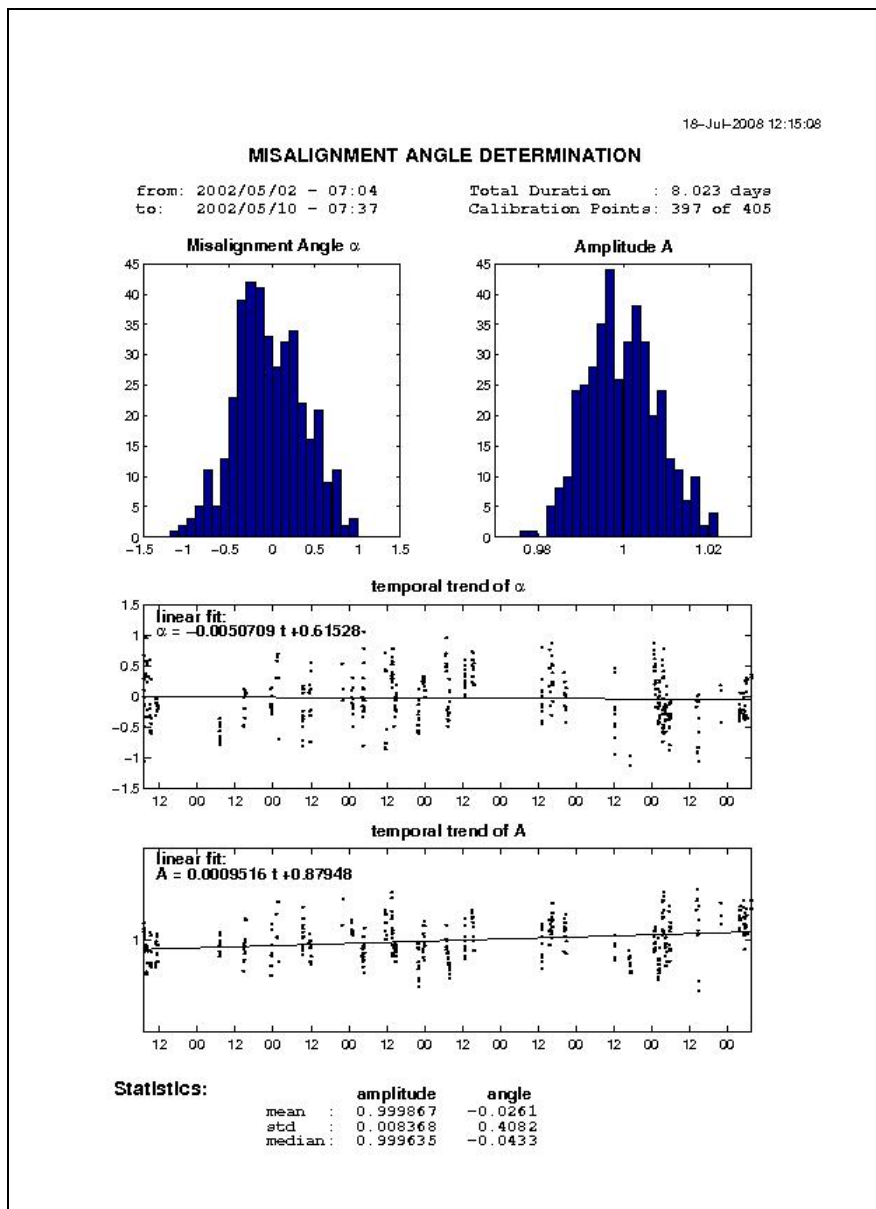


Figure 5.5.1: Statistics of misalignment correction errors; time range between 03rd May, 12:00 UTC to 10th May, 24:00. Both, the amplitude's and the angle's residual correction errors are about 10% of the corresponding standard deviations and thus are not significant; trend corrections are small and have not been applied.

Resulting East and North velocity components at 10 minute averages as a function of time are displayed in figure 5.5.2. Covered depths generally range from 50 m to 600 m. Few dark blue areas denote low signals. Overall data quality is good.

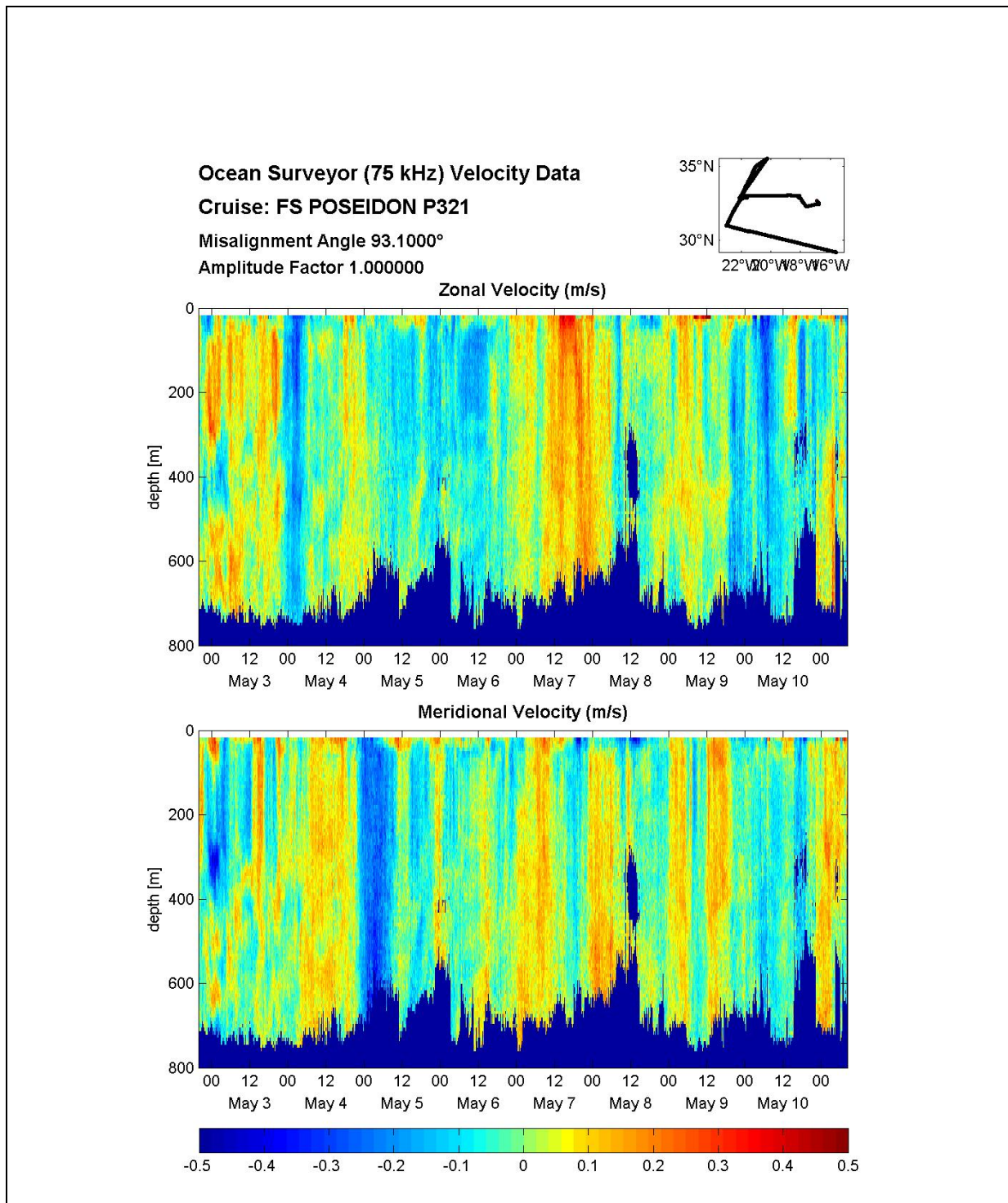


Fig. 5.5.2: 75 kHz ADCP velocity data at 10 minute average, 50 m to 800 m depth; upper panel East component, lower panel North component. Dark blue denotes no signal areas.

6. Acknowledgements

The ship's master Michael Schneider and his crew efficiently supported and advised the science party during this cruise. Thanks also to Jens Schafstall who processed the vmADCP data and provided the section plots.

7. Appendices

7.1 References

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Müller, T.J., 1999: Determination of Salinity. In: *Methods of Seawater Analysis*, Grasshoff, K., K. Kremling, M. Ehrhardt (editors), Wiley, 600 pp.

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UNESCO, 1983: Algorithms for computation of fundamental properties of seawater, *UNESCO technical papers in marine science*, **44**

7.2 List of CTD casts

Table 7.2.1: POSEIDON cruise P321, list of CTD casts; start dates and start times given (UTC); depth is sounding depth based on 1500 m/s average sound velocity

Stat	Cast	Date			Time		Latitude		Longitude		Depth		P _{max} dbar	CTD
		YYYY	MM	DD	hh	mm	N		E		m			
171	1	2005	5	2	17	14	29.1663		-15.5003		3609		3668	SBE3
175	2	2005	5	4	7	35	30.6218		-21.4506		4900		5042	SBE4X
177	3	2005	5	4	23	47	31.0009		-23.0010		5203		2004	SBE3
178	4	2005	5	5	9	42	32.0049		-22.4959		5153		2002	SBE3
182	5	2005	5	6	22	19	34.0000		-21.4984		5230		2002	SBE3
184	6	2005	5	7	13	11	35.4993		-20.2464		5207		2000	SBE3
187	7	2005	5	8	17	49	33.0007		-21.9814		5214		5358	SBE3
188	8	2005	5	9	12	44	33.0009		-18.8878		3550		3640	SBE4X
189	9	2005	5	10	7	7	32.9115		-18.1257		3335		3222	SBE4X
190	10	2005	5	10	11	22	32.9599		-18.1485		2952		3022	SBE4X

7.3 R/V POSEIDON, 02.05.2005-10.05.2005, Las Palmas - Funchal

Cruise -Log

Principal Scientist Dr. T.J. Müller

Acronyms

SBE3 : SeaBird CTD & oxygen sensor & fluorescence sensor, attached to 12x10 l rosette sampler

SBE4x: SeaBird CTD, C & T sensors from IFM-GEOMAR CTD SBE4, P sensor on loan from SeaBird

MC : minicorer, below SBE4X

MCN : multiple closing plankton net, 100 micron mesh, 5 nets, 50 cm diameter, 261 cm length

WD : sounding depth/m, 1500 m/s sound speed assumed

Pmax : for CTD max pressure/dbar, max depth/m else

SYM : symbol no. for plot

Status: 22.05.2005

Station	Cast	Date	Time	LAT	LONG	WD	Pmax	Sym	remarks
	CTD	DD MM YYYY	hh mm dd mm.mm	ddd mm.mm m	dbar				
-9	-9	02 05 2005	09 00 28 00.00	-015 -30.00 -9	-9	2			Las Palmas, sail
-9	-9	02 05 2005	13 00 -99 -99	-999 -99 -9	4	4			PC-log, vADCP, TSG on
171	1	02 05 2005	14 50 29 10.14	-015 -30.15 3608	3669	2			CTD SBE3, rosette, ESTOC
172	-9	03 05 2005	07 28 29 41.68	-017 -37.72 4347	797	4			test MC
173	-9	03 05 2005	09 29 29 43.91	-017 -47.90 4297	1000	4			test 3 acoustic releasers
174	-9	03 05 2005	10 14 29 43.54	-017 -47.97 4295	100	5			MCN
175	2	04 05 2005	07 23 30 37.37	-021 -26.98 4907	5030	3			CTD SBE4x, MC
176	-9	04 05 2005	14 57 30 35.20	-021 -39.09 -99	100	5			MCN
177	3	04 05 2005	23 46 30 59.88	-023 -00.08 5203	2004	2			CTD SBE3, rosette
178	4	05 05 2005	09 39 32 00.92	-022 -29.75 5153	2002	2			CTD SBE3, rosette
179	-9	05 05 2005	11 53 31 59.62	-022 -29.87 5126	100	5			MCN
180	-9	06 06 2005	07 16 32 49.20	-022 -00.46 5209	-9	1			mooring V276-24 recovery
181	-9	06 05 2005	14 08 33 00.05	-021 -59.99 5216	500	5			MCN
182	5	06 05 2005	22 17 34 00.00	-021 -29.91 5225	2002	2			CTD SBE3, rosette
183	-9	07 05 2005	07 09 35 00.05	-021 -00.03 5233	500	5			MCN
184	6	07 05 2005	13 09 35 29.96	-020 -14.79 5207	2001	2			CTD SBE3, rosette
185	-9	07 05 2005	15 05 35 30.03	-020 -14.68 5149	500	5			MCN
186	-9	08 05 2005	13 25 33 01.39	-021 -56.85 5325	-9	1			mooring V276-25 deploy
187	7	08 05 2005	17 46 33 00.04	-021 -58.87 5217	5359	2			CTD SBE3, rosette, KIEL276
188	8	09 05 2005	12 38 33 00.07	-018 -53.26 3549	3700	3			CTD SBE4x, MC
189	9	10 05 2005	07 00 32 54.67	-018 -07.41 3172	3224	3			CTD SBE4x, MC
190	10	10 05 2005	11 22 32 57.65	-018 -08.92 2952	3022	3			CTD SBE4x, MC
-9	-9	10 05 2005	18 00 -99 -99	-999 -99 -9	4	4			PC-log, vADCP, TSG off
-9	-9	11 05 2005	09 05 32 32.00	-016 -55.00 -9	-9	2			Funchal, call port