# Cruise Report

# Sonne 172

## Meridional Overturning Variability Experiment

## CLIVAR

**Pointe a Pitre - Pointe a Pitre**
**13 June 2003 - 01 July 2003**

Chief Scientist Uwe Send

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# 1 Summary

The SONNE cruise S172 took place in the framework of the German CLIVAR project MOVE. Its main purpose was the servicing of moorings along a section along approx. 16N, which had been maintained there for 3.5 years at the time of the cruise. Thus most of the work consisted of the recovery of the third deployment period and deployment of the moorings for the fourth time. The cruise lasted from 13 June until 1 July 2003 with 16 participants, mainly from IfM Kiel. Five moorings were recovered, with a total of 58 microcats, 16 T/D loggers, 3 PIES and 3 bottom pressure recorders, and 23 RCM current meters. The re-deployments included an extra mooring for carrying a tomography source. Also surface telemetry units were added again to two of the moorings, for transmitting in realtime microcat data from down to approx. 1000m. Nine CTD stations were occupied for calibrating mooring sensors and for obtaining reference profiles near the mooring. Underway data were collected with an Ocean Surveyor ADCP and thermosalinograph. This report provides details about the operations and first data results, as well as a short diary in the appendix.

# 2 Participants

| Name | Function | Institution |
|---|---|---|
| Uwe Send | Chief Scientist | IfMK[1] |
| Tom Avsic | Tomography, Surveys, Moorings | IfMK |
| Christian Begler | Moorings, CTD, Plots | IfMK |
| Johannes Homuth | RCM, CTD, Moorings | IfMK |
| Torsten Kanzow | PIES, Mooringdesign, MicroCATS | IfMK |
| Johannes Karstensen | ADCP, DVS, Moorings | IfMK |
| Rudolph Link | Tomography, PIES, Moorings | IfMK |
| Steve Mack | Pressure Sensors | POL[2] |
| Helmut Möller | Pressure Sensors | SIO[3] |
| Gerd Niehus | Moorings, RCM, Releaser | IfMK |
| Andreas Pinck | Telemetry, WatchDogs, Moorings | IfMK |
| Christopher Smarz | CTD, MicroCat, Moorings | IfMK |
| Martin Scharffenberg | MicroCATS, Moorings | IfMK |
| Hauke Schmidt | ADCP, CTD, Moorings | IfMK |
| Sunke Schmidt | CTD, Moorings, DVS | IfMK |
| Pierre Testor | Salinometer, Database, Moorings | IfMK |

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[c]Scripps Institution of Oceanography

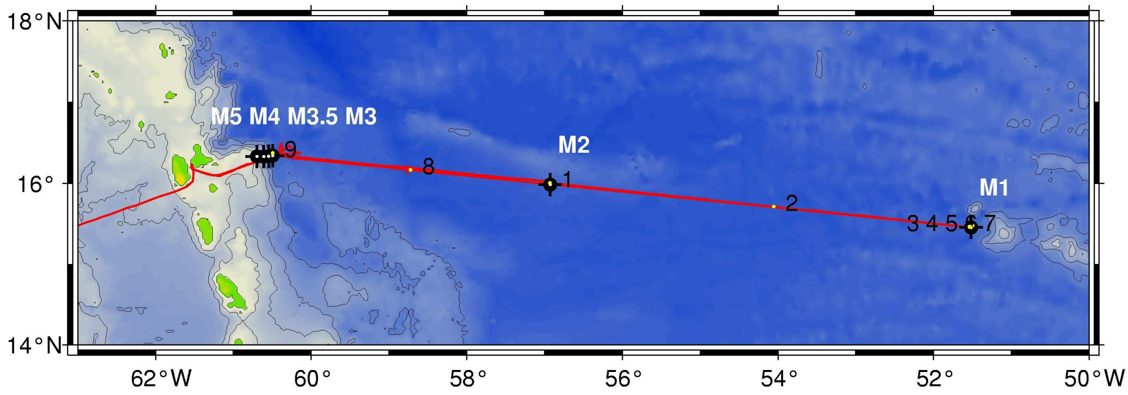


Figure 1: Cruise track, CTD station and mooring locations.

# 3 Moorings

The basic idea of MOVE is to determine the variability of the deep meridional mass transport across 16°N in the western basin of the North Atlantic as a part of the meridional overturning circulation. In the interior an array of three "geostrophic" moorings (M1-M3) is maintained which captures the meridional flow with a combination of dynamic height and bottom pressure measurements. East of this array, in the triangle over the continental slope, direct current measurements are applied (M3-M5) to capture that part of the deep flow, which passes inshore of M3 (for details see figure 2). Furthermore acoustic tomography is used to determine deep integrated temperature fluctuations between M2 and M3.

Five moorings were recovered and six deployed on the cruise. Three recoveries were started on the first day of the cruise (M4, M5, M3). M4's upper 30m (including an Aanderaa RCM and a Mini-TD Logger) had torn of one month before and had already been recovered by Pierre Gervain. The recovery work was carried out successfully over the stern as for the second one (M5). However, the third mooring (M3) broke at a splice after 1600m at 19:30 local time. The releaser could be ranged acoustically with a hull-mounted transducer. Therefore it was decided to maneuver the ship to stay close by and to wait until next morning. The contact was lost at 02:00. Attempts to locate mooring acoustically from various best-guess locations (assuming the prior currents of over 1kn had ceased since 2am according to ship displacement and bridge doppler data) were without success. Analysis of vmADCP data showed large currents all night long and displacement since 23:00 of 12nm. A grid search pattern was started at 9:00, around most likely displaced position. By 12:00 M3 had been relocated and recovery was started at

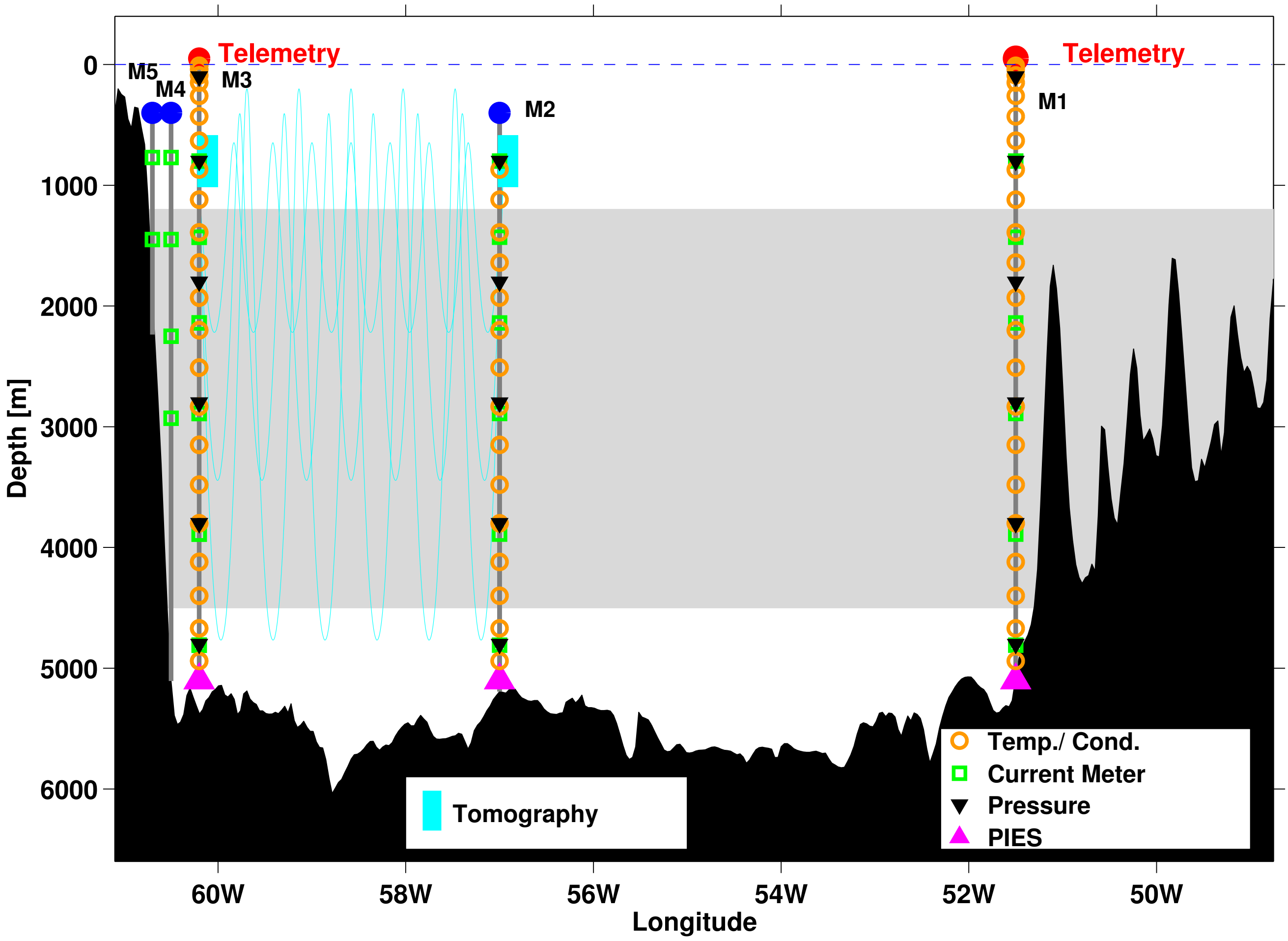


Figure 2: MOVE mooring design at 16°N.

13:00, this time over the side to reduce the strain on the corroded splices.

Due to the experiences made with M3, the moorings M2 and M1 were also recovered over the side, however parts of them were knotted together so that occasionally up to three wires had to be recovered at the same time.

All deployments were carried out over the stern with the mooring winch which working without mechanical problems. Heating problems during the M3.5 deployment were solved by cooling the heat exchanger with water. Due to corrosion of splices, all splices were treated with "wollfett" before deployment. The MicroCAT markers on the wire appeared in wrong order, since wires had been respooled in Kiel. In doing so the order of wires had been reversed in shop but not their orientation. Therefore most markers had to be re-measured by metering wheel which started to fail during last MicroCAT deployment (M3). Apart from this, all deployments were carried out successfully and the reported problems will not affect the system's overall performance.

| mooring | deployment | latitude | longitude | water depth | date set | date recovered |
|---|---|---|---|---|---|---|
| M1 | 2002-2003 | 15N 27.00 | 52W 31.50 | 4984m | 01/02/02 | 19/06/03 |
| M1 | 2003-2004 | 15N 27.00 | 51W 31.50 | 4984m | 23/06/03 | |
| M2 | 2002-2003 | 15N 59.20 | 56W 55.60 | 4985m | 04/02/02 | 17/06/03 |
| M2 | 2002-2003 | 15N 59.20 | 56W 55.60 | 4985m | 25/06/03 | |
| M3 | 2002-2003 | 16N 20.30 | 60W 30.30 | 4960m | 08/02/02 | 15/06/03 |
| M3 | 2003-2004 | 16N 20.30 | 60W 30.30 | 4960m | 27/06/03 | |
| M3.5 | 2003-2004 | 16N 20.20 | 60W 32.80 | 4100m | 30/06/03 | |
| M4 | 2002-2003 | 16N 20.00 | 60W 36.45 | 3030m | 05/02/02 | 15/06/03 |
| M4 | 2003-2004 | 16N 20.00 | 60W 36.45 | 3010m | 27/06/03 | |
| M5 | 2002-2003 | 16N 19.94 | 60W 42.17 | 1600m | 05/02/02 | 16/06/03 |
| M5 | 2003-2004 | 16N 20.01 | 60W 41.75 | 1600m | 28/06/03 | |

# 4 MicroCATs

All of the 58 MicroCATs in the moorings M1, M2 and M3 were recovered and had acquired temperature and conductivity (and 2 instruments also pressure) data throughout the deployment period. Except in one case (#1520), where in the last third of the time series the conductivity appears to be noisy and jumpy, all other instruments have work without any problems. In M1 and M3 the topmost MicroCATs (at 10m nominal depth) fell to about 300 m depth due to the loss of the telemetry buoys in March 2002. After that the measurements closest to the surface took place in 40 m depth in either case. After the data transfer all of the instruments were exposed to in situ calibration casts with the CTD, as during the cruises before, to allow for a drift correction. Here again, all of the instruments had acquired data. Finally, 59 MicroCATs were redeployed with the moorings M1, M2 and M3 (with #1520 being replaced) and are to be recovered in February 2004. Preliminary temperature anomaly timeseries above and below 1000m can be seen in the figures 3 and 4.

# 5 MiniTD Logger

All of the 16 MTD logger in the moorings M1, M2, M3 and M4 were recovered and all had acquired temperature and pressure data throughout the duration of the deployment. The data appears to be of good quality except for two instruments: #46 shows a linear decrease in pressure in the last 50 days of the measurement period and #22 displays a 10 dbar jump in pressure at day 22 and then gradually recovers to the original values. In the following in situ calibration casts no substancial differences showed up relative to the CTD pressure measurement. Thus, all of the MTD logger were again redeployed in the moorings M1,M2,M3 and M4.

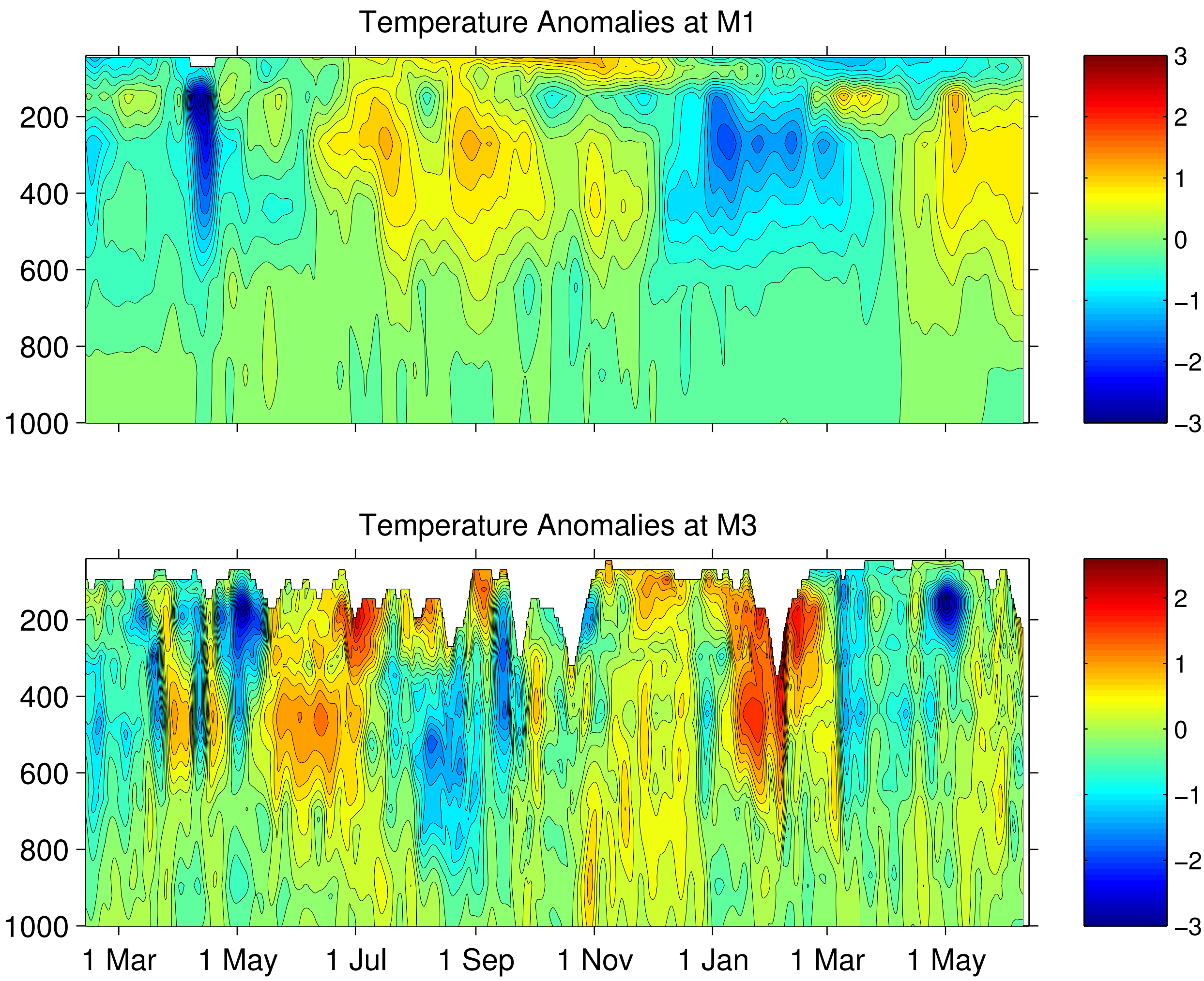


Figure 3: Timeseries of temperature anomalies at M1 and M3 above 1000m

# 6 Pressure Inverted Echo Sounder PIES

The three PIES (#001, #002, #012) that had been deployed close to the moorings M1, M2 and M3 (see figure 2 ) were successfuly recovered and had acquired pressure, traveltime and temperature data throughout their mission. After the release of PIES #001 no acoustic signal could be heard with the Benthos deckunit and only weak ones with the EdgeTech. At the surface no USW signals were received. Upon recovery 2 cm of water as present in the glass sphere and thin glass parts, originating from the sphere were visible. The electronics was covered with salt and even after a treatment with destilled water the PIES could not be switch on again and thus had to be replaced for the redeployment. In PIES #002 glass parts were present as well upon recovery and as was the case with #012 the USW unit turn out to be rather weak and unreliable. Nevertheless, the data of all 3 PIES is of good quality. For the new deployment period PIES #057 / #002 / #012 were deployed at M1 / M2 / M3.

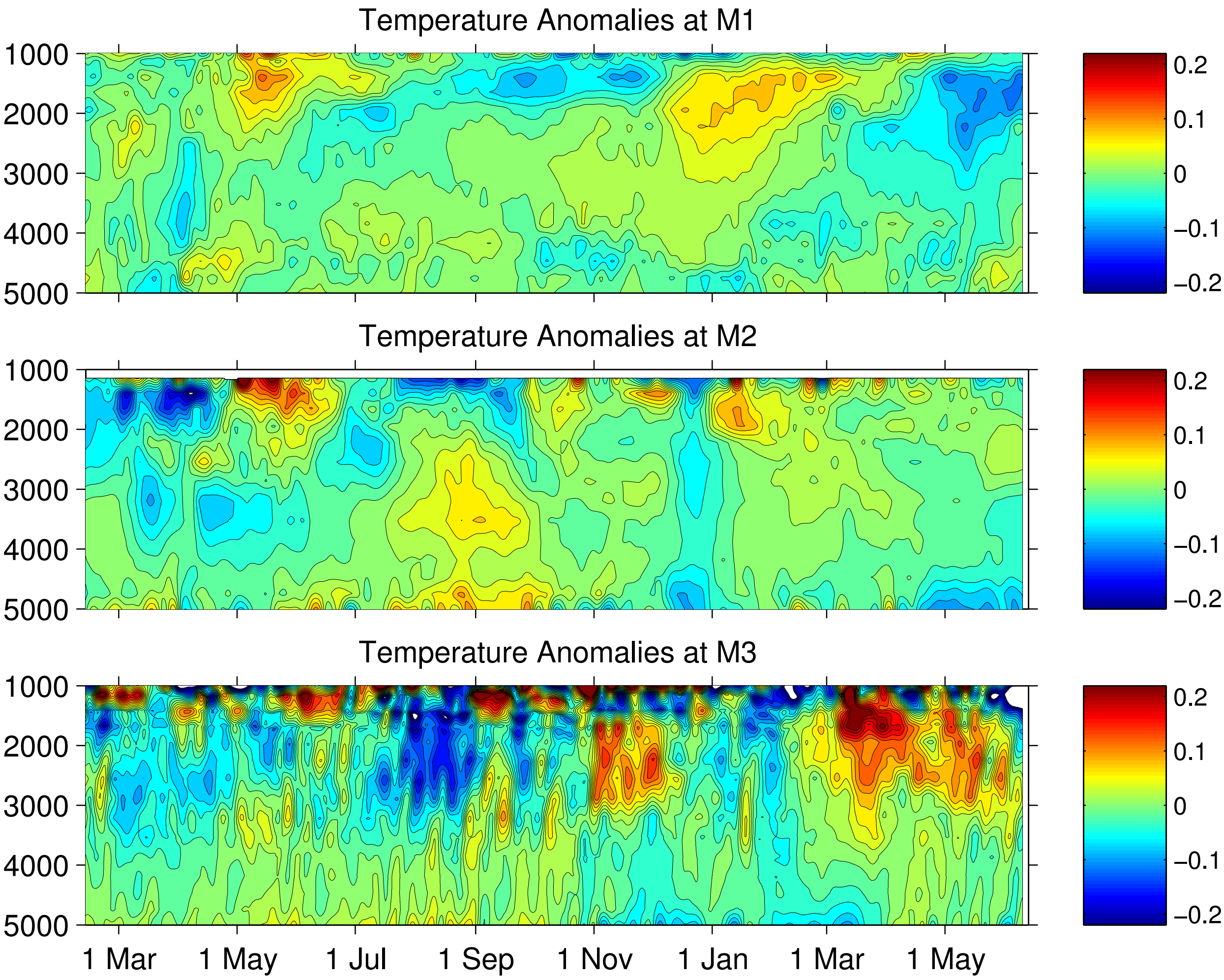


Figure 4: Timeseries of temperature anomalies at M1 M2 and M3 below 1000m

PIES #057 has the capability to transmit data to the surface via acoustic telemetry. This system, recently implemented by Randy Watts, is still in a test phase and we are the first group to operate it in a scientific experiment. First tests of the "Burst" mode (transmits data from the most recent measurement with reduced accuracy) as well as of the "File" mode (transmission of daily averages after de-tiding) were technically successful, with one exception: The transmitted data (time, pressure, acoustic travel time) are encoded as temporal delays of acoustic pulses relativ to a marker puls. As the distance from the receiver to the PIES changes permanently due to vessel motion, the delay times are changed. This results in error in pressure fluctuations of a few centimeters, whereas we would need a millimeter accuracy. We are not interested in absolute pressure and travel times and have therefore proposed R. Watts to change the firmware such that the user himself can select the measurement range to be transmitted. For our purpose a range of 0.5 dbar would be more than sufficient and would compared to the now built in range of 50 dbar increase the accuracy of the transmission by 2 order of magnitudes. Futhermore we want to test to which degree the transmited data can be corrected for vessel motion, making use of RV SONNE's built-in accelerometer.

Likewise successfully recovered were the two bourdon tube type bottom pressure sensors made available by A. Chave (WHOI) and operated by H. Möller (SIO). Both sensors, #3 (near M1) and #12 (near M3), yielded data of good quality and were redeployed again.

From the two bottom pressure sensors made available by P. Foden (POL) and operated by S. Mack (POL) only one (near M3) was recovered and yielded good data. It was redeployed again. Upon release the second one (near M1) had switched into the release mode but failed to leave the bottom for reasons unknown. And intense search with the vessel's lowered OFOS camera system combined with acoustic positioning failed. In february 2004 aboard RV METEOR a new rescue mission shall be carried out and till then further possibilities of recovery will be thought about.

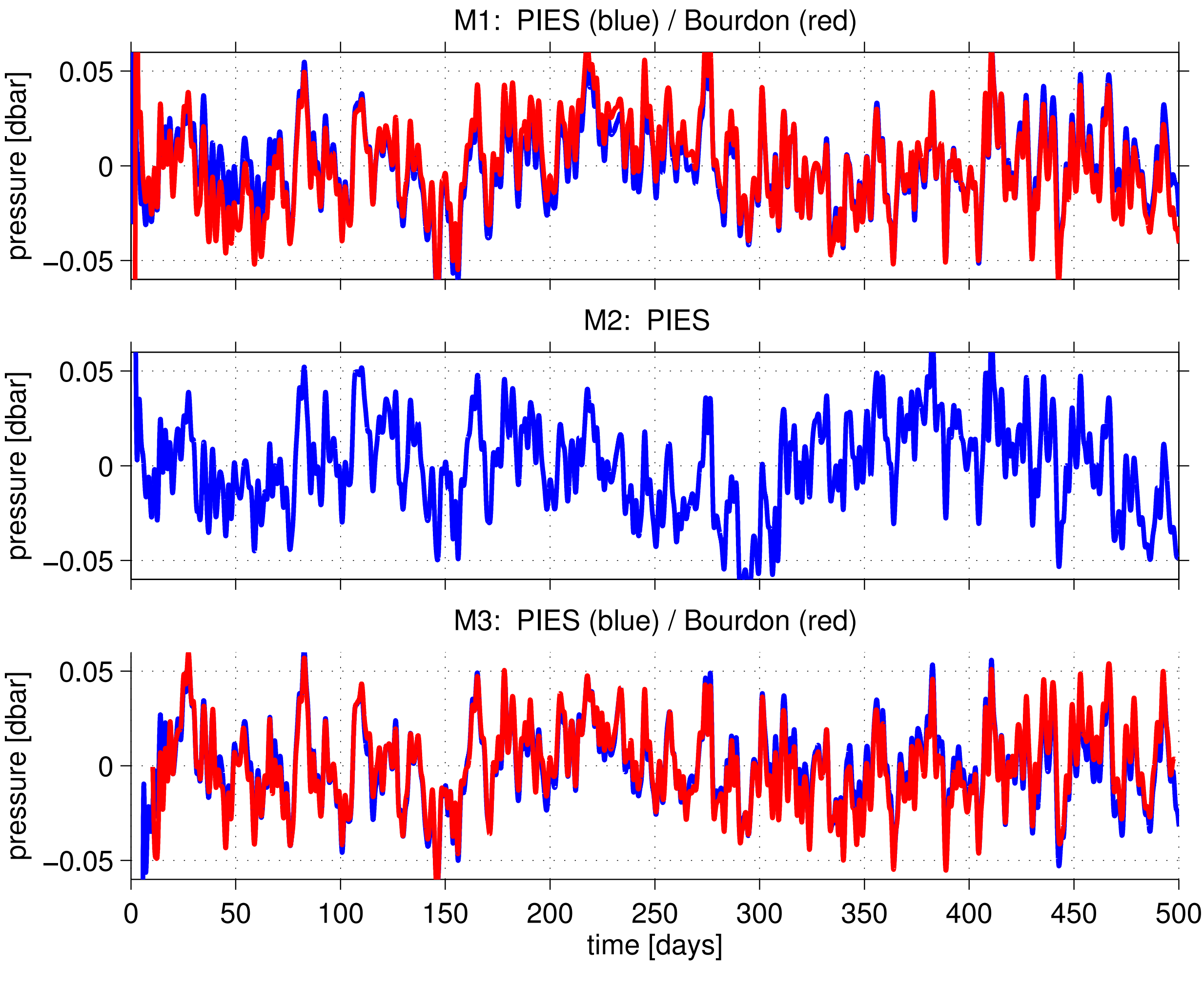


Figure 5: Timeseries of detrended and 48h low-pass filtered bottom pressure at M1 M2 M3.

# 7 Tomography

Last year a new tomographic source was deployed on our L'Atalante cruise and recovered on the Meteor cruise by Monika Rhein half a year later. The instruments measure the travel time of different acoustic rays (eigenrays) between them (see figure 6). The data showed that neither the source nor the modified receiver worked properly. Both were again modified by their manufacturers and tested together with Rudolph Link to be prepared for the next deployment. Both instruments seemed to be in order and ready to deploy.

The receiver was moored together with the other instruments at the M2 location. It was programmed to receive the 200-300Hz sweep signal four times a day. The final test of the source however showed that the system reset itself just at the time starting to send its second signal. Andrey K. Morozov (Webb Research), who designed the instrument, explained that this could be related to the low power in-air test signals. However, disconnecting the instrument from the SAIL loop would cause it not to reset but to work further in its task. A test-task was run with one transmission every 10 minutes. To check the high power possibility also an in-water test was planed, however, the actuator controlling the resonance frequency stopped working. One resistor was burned inside the electronics. Connecting the electronics to the SAIL loop without the end-cap, like it can be done with other instruments from the same manufacturer, destroyed the SAIL interface of the source as well. More than eight hours were needed to repair this. Thereafter several tests, including one in-water test, still showed a malfunction of the sleeve electronics, burning again the same resistor. Finally an incorrect ground connection of one transistor could be located as the main failure. Further tests were positive. Finally a mid-power in water test, where the signal could be heard clearly in the bilge of the ship, triggered the decision to finally deploy the sound source (mooring M3.5) .

Among this also six TR6000 transponders for mooring navigation (three at both moorings) were recovered and redeployed. All six instruments released after having been deployed for one and a half year. The burning time of the release wire was about 10 min, which is 5 to 10 min shorter than for a one year deployment. The ascending time was between 60min and 75min. Due to the damaged hydrophone of the ship, the transponder survey was done by stopping the ship at seven to ten locations measuring with a hydrophone over the side. See the following table for transponder positions.

| | | rx [kHz] | tx [kHz] | rel.code | latitude | longitude | depth | error |
|---|---|---|---|---|---|---|---|---|
| M2 | XP-1 | 10.0 | 11.5 | A | 15°N 58.436 | 056°W 56.894 | 5006m | ± 6.4m |
| M2 | XP-2 | 10.0 | 12.0 | D | 15°N 58.424 | 056°W 54.194 | 5004m | ± 7.8m |
| M2 | XP-3 | 10.0 | 12.5 | F | 16°N 00.831 | 056°W 55.615 | 4960m | ± 12.3m |
| M3.5 | XP-1 | 10.0 | 11.5 | A | 16°N 19.255 | 060°W 34.140 | 3575m | ± 10.0m |
| M3.5 | XP-2 | 10.0 | 12.0 | B | 16°N 19.108 | 060°W 31.344 | 4563m | ± 4.0m |
| M3.5 | XP-3 | 10.0 | 12.5 | F | 16°N 21.477 | 060°W 32.657 | 4211m | ± 7.3m |

The source and the receiver were both equipped with the new ORCA clocks. These clocks calibrate themselves with a built-in rubidium quartz every 24h in this experiment. They were kept as long as possible at 5.4°C in a thermal chamber of the ship to let them calibrate to similar conditions as in water.

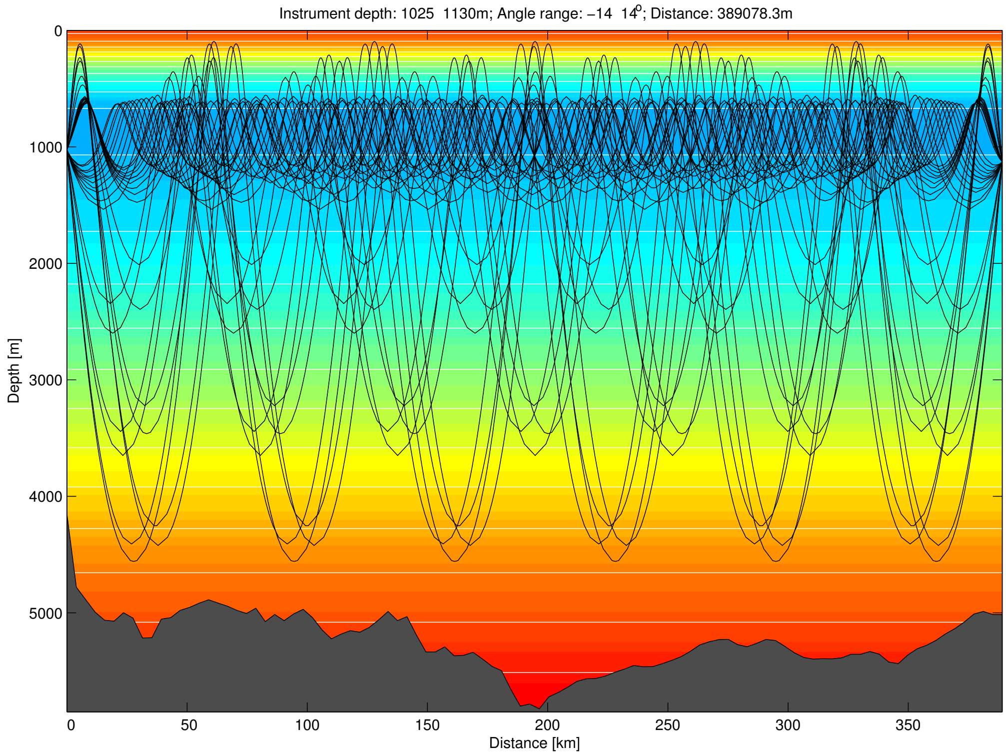


Figure 6: Acoustic Eigenrays between M3.5 and M2.

## 8 RCM

The moorings M1-M5 deployed in 2002 had been equipped with a total of 23 Anderaa RCM 8 current meters. While the RCMs in M3-M5 are used to determine that part of the deep flow, which passes the 16 N section inshore of the dynamic heigth array (M1-M3), those in M1-M3 are employed to reference the geostrophic transports. Only one instrument in mooring M4 had some problems and recorded only until November 2002. All other instruments worked properly and recorded data over the whole deployment period. The data has been corrected for compass deviation and saved in common rodb format. A list of all current meters is shown below. In addition to the recovered instruments one more RCM 8 and two RCM 9 current meters were redeployed, mainly to extend the measurements into the Antarctic Intermediate Water. The RCM 9 current meters are no longer rotor current meters, instead they measure the flow acoustically via frequency doppler shift. All time current time series of the recovered instruments can be seen in the figures 31 to 35.

Table 1: Summary of Anderaa current meters used in mooring M1 (v404_3).

| type | serial # | depth (m) | start date | start time | end date | end time | filename |
|---|---|---|---|---|---|---|---|
| RCM 8 | 9831 | 789 | 2002/02/01 | 12:28 | 2003/06/19 | 16:29 | V404_3_001.rcm |
| RCM 8 | 10662 | 1438 | 2002/02/01 | 12:28 | 2003/06/19 | 16:29 | V404_3_002.rcm |
| RCM 8 | 4570 | 2139 | 2002/02/01 | 12:28 | 2003/06/19 | 16:29 | V404_3_003.rcm |
| RCM 8 | 11621 | 2889 | 2002/02/01 | 12:28 | 2003/06/19 | 16:29 | V404_3_004.rcm |
| RCM 8 | 9727 | 3888 | 2002/02/01 | 12:28 | 2003/06/19 | 16:29 | V404_3_005.rcm |
| RCM 8 | 9344 | 4930 | 2002/02/01 | 12:28 | 2003/06/19 | 16:29 | V404_3_006.rcm |

Table 2: Summary of Anderaa current meters used in mooring M2 (v405_3).

| type | serial # | depth (m) | start date | start time | end date | end time | filename |
|---|---|---|---|---|---|---|---|
| RCM 8 | 10075 | 799 | 2002/02/04 | 12:28 | 2003/06/17 | 16:29 | V405_3_001.rcm |
| RCM 8 | 9345 | 1449 | 2002/02/04 | 12:28 | 2003/06/17 | 16:29 | V405_3_002.rcm |
| RCM 8 | 9728 | 2149 | 2002/02/04 | 12:28 | 2003/06/17 | 16:29 | V405_3_003.rcm |
| RCM 8 | 9732 | 2899 | 2002/02/04 | 12:28 | 2003/06/17 | 16:29 | V405_3_004.rcm |
| RCM 8 | 94 | 3998 | 2002/02/04 | 12:28 | 2003/06/17 | 16:29 | V405_3_005.rcm |
| RCM 8 | 11618 | 4940 | 2002/02/04 | 12:28 | 2003/06/17 | 16:29 | V405_3_006.rcm |

# 9 Meridional Transports

From the moored dynamic height data (based on the MicroCAT und MTD Logger measurments) from mooring M1, M2 and M3, baroclinic geostrophic mass transports are derived. Therefore first of all time series of the time varying MicroCAT sensor depths have to be generated. In the case of small mooring subduction (M1, M2) this can be done by simply vertically interpolating between the MTD pressure sensors. During strong current events (M3), the static mooring simulation programme IMP is used to additionally determine the mooring curvature in order to derive MicroCAT depths of the required accuracy (a few meters). Now the conductivities can be converted into salinities. Finally temperatures and salinities are interpolated onto a regular depth grid and meridional baroclinic geostrophic transports are calculated. Figure 7 (top) shows the results below 1200 dbar (rel. bottom) for the mooring pairs M1-M3 (total section), M1-M2 (east) and M2-M3 (west). Fluctuations of the east and west sections are anti-correlated which can be explained in terms of westward propagating baroclinic rossby waves (and eddies). The amplitude of this variability is in the order of 10-20 Sv on time scales of about 3 months, which compares well with the results from the preceding years. The time mean vertical shear in figure 7 (bottom) however is slightly reduced compared to the preceding deployment period (year 2001), with the vertical positions of the deep cores (1800 and 4000 dbar) being unchanged. These results are preliminary and still require a careful sensor calibration.

Another important issue is the southward flow of that part of the Deep Western Boundary Current (DWBC) which passes inshore of the M1-M3 array over the continental slope and therefore cannot be observed by dynamic height. In this “triangle” direct current measurements are applied (M3-M5). A preliminary time mean of 4.7 Sv southward flow is obtained, which is about twice as large as during the previous deployment periods (Fig. 8). Whether the slightly weaker baroclinic shear in the interior (M1-M3) is somewhat compensated by this near boundary

Table 3: Summary of Anderaa current meters used in mooring M3 (v406_3).

| type | serial # | depth (m) | start date | start time | end date | end time | filename |
|---|---|---|---|---|---|---|---|
| RCM 8 | 8411 | 1439 | 2002/02/08 | 01:00 | 2003/06/15 | 10:58 | V406_3_001.rcm |
| RCM 8 | 10663 | 2139 | 2002/02/08 | 01:00 | 2003/06/15 | 10:58 | V406_3_002.rcm |
| RCM 8 | 4562 | 2889 | 2002/02/08 | 01:00 | 2003/06/15 | 10:58 | V406_3_003.rcm |
| RCM 8 | 8365 | 3889 | 2002/02/08 | 01:00 | 2003/06/15 | 10:58 | V406_3_004.rcm |
| RCM 8 | 8349 | 4905 | 2002/02/08 | 01:00 | 2003/06/15 | 10:58 | V406_3_005.rcm |

Table 4: Summary of Anderaa current meters used in mooring M4 (v407_3).

| type | serial # | depth (m) | start date | start time | end date | end time | filename |
|---|---|---|---|---|---|---|---|
| RCM 8 | 10813 | 771 | 2002/02/05 | 19:18 | 2003/06/15 | 13:18 | V407_3_001.rcm |
| RCM 8 | 10815 | 1449 | 2002/02/05 | 19:18 | 2003/06/15 | 13:18 | V407_3_002.rcm |
| RCM 8 | 9820 | 2254 | 2002/02/05 | 19:18 | 2003/06/15 | 13:18 | V407_3_003.rcm |
| RCM 8 | 11617 | 2930 | 2002/02/05 | 19:18 | 2003/06/15 | 13:18 | V407_3_004.rcm |

increase is one of the issues that have to be checked.

# 10 CTD

The purpose of the CTD casts carried out during the cruise was to in situ calibrate the MicroCAT and MTD logger prior to their redeployment. Thus, a certain number of those instrument was attached to the CTD frame. Then, the CTD was lowered to the sea floor (or to maximum tolerated depth of the instrument to be calibrated). During the upcast, the CTD was stopped at certain depth intervalls (bottle-stops) - each time for about 8 minutes each. This long time is needed for the (older) MicroCAT conductivity sensors to adjust to the surrounding values. Temperature, conductivity and pressure differences between the CTD and the other instruments during those stops are then used for the calibration - a technique that has proven to work well during the previous cruises.

## 10.1 Calibration and data quality of CTD measurements

The CTD-system used during the cruise SO172 was a Seabird Electronics Inc. of Bellevue, Washington, USA (SBE) 9 plus. It is the IfM SBE2 with serial number 09p24785-0612. Connected were a pressure sensor (ser. no. 80024, last laboratory calibration February 2003), a temperature sensor (ser. no. 2826, last laboratory calibration February 2003) and a conductivity sensor (ser. no. 2512). The oxygen sensor used is a Seabird SBE-43 sensor (ser. no. 430215), recording oxygen current but no oxygen temperature, as it was the case in former Beckman oxygen sensors.

There were no malfunctions of the CTD throughout the cruise and the quality for all nine profiles was good. The Seabird bottle release unit used with the rosette and the Seabird instrument

Table 5: Summary of Anderaa current meters used in mooring M5 (v427_1).

| type | serial # | depth (m) | start date | start time | end date | end time | filename |
|---|---|---|---|---|---|---|---|
| RCM 8 | 10077 | 803 | 2002/02/06 | 01:39 | 2003/06/15 | 17:38 | V427_1_001.rcm |
| RCM 8 | 6160 | 1449 | 2002/02/06 | 01:39 | 2003/06/15 | 17:38 | V427_1_002.rcm |

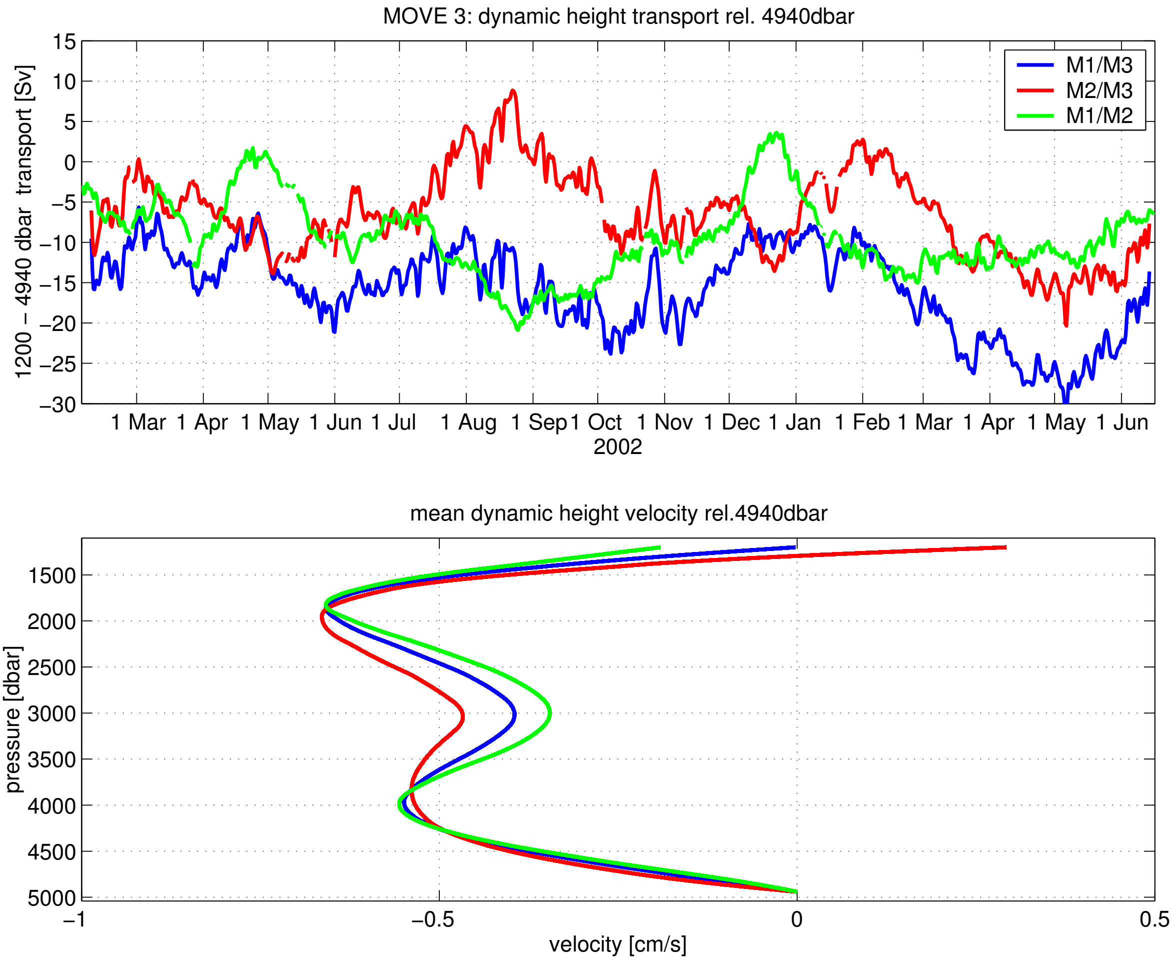


Figure 7: Top: Time series of meridional baroclinic geostrophic transports in the 1200-4940 dbar range (rel. 4940 dbar) for the mooring pairs M1-M3, M2-M3 and M1-M2. Bottom: Time mean vertical shear profiles of the three above cases.

worked well. Only at the first CTD-profile one Niskin bottle was not closed. As this bottle should have closed at the same depth as three other Niskin bottles for sampling substandard water for salinity calibration, no data was lost. Water samples from Niskin bottles were only used for salinity calibration of the SBE2 CTD. Oxygen calibration was not carried out.

During most of the CTD casts MicroCATs and/or MTD recorders were attached to the rosette for calibration purposes. This reduced the possible amount of water samples per calibration profile to five. At all stations water samples were taken in different depths from the rosette bottles. Because of the limitation to five water samples, the depths were chosen mainly in homogeneous layers to get most possible accuracy for salinity calibration. Bottle salinities were determined

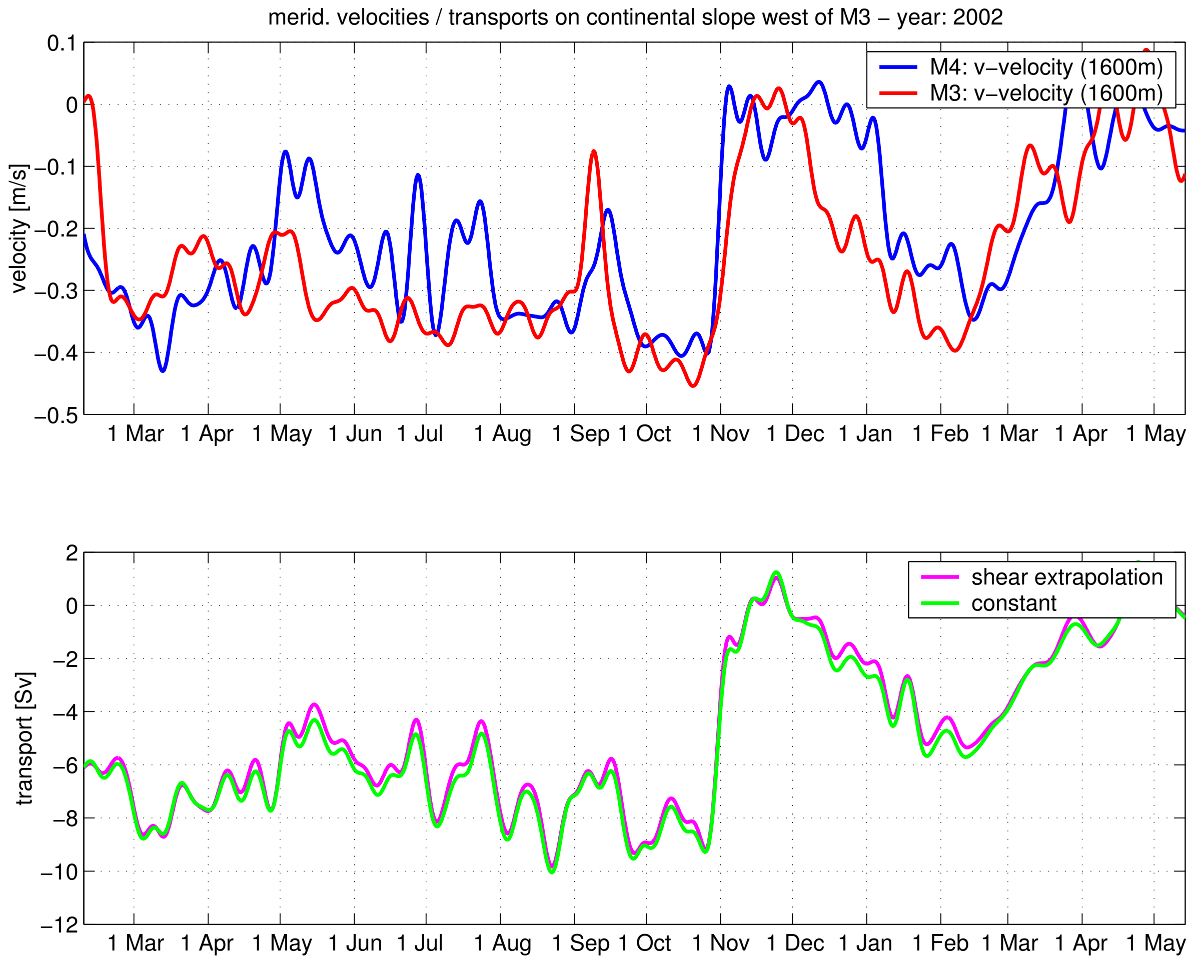


Figure 8: Top: Time series of meridional velocities in 1600 m measured at moorings M3 and M4. Bottom: Meridional transports over the continental slope below 1200 m east of M3.

with a Guidline (Guidline Instruments Inc., Smith Falls, Canada) Autosal salinometer (Kiel AS 8). Calibration of the SBE2 CTD salinity was carried out with a total amount of 55 water samples. Data was marked as erroneous and was rejected when exceeding 2.5 times the standard deviation of the salinity differences. Beforehand manually four samples were rejected because of obvious errors (these four values increased the rms differences by a factor 15), leaving a rms difference between the bottle and CTD salinity samples of 0.0025 psu. This criterion includes 91% of the calibration data. After correcting the salinity with respect to itself, temperature and pressure the rms differences between bottle and CTD salinities samples were 0.0011 psu. For data deeper than 1000 m the rms difference of salinity was even as low as 0.00107 psu.

## 10.2 CTD stations

A total of nine CTD stations were carried out. These are marked on the overview map in figure 1. One CTD cast was taken at each mooring cite, and a couple on the way between the moorings along the connecting section. One CTD station (cast 5) only went down to 1000m, since MicroCAT recorders with shallow pressure sensors had to be calibrated. One other station (cast 6) only went to 4000m because MTD logger with pressure sensors had to be calibrated. A list of CTD stations is given in the first table below, whereas the second table contains the MicroCATs and MTD logger attached to the CTD frame during the calibration casts. A flat and a deep salinity section can be seen in figure 9 and temperature CTD section can be seen in figure 10.

| **Sonne 172** | | **CTD Stations** | | | | | |
|---|---|---|---|---|---|---|---|
| Profile | Station | Date | Time | Latitude | Longitude | Water Depth | Profile Depth |
| 1 | 13 | 2003/06/18 | 04:12 | 16° 00.49' N | 56° 55.81' W | 4968 | 5043 |
| 2 | 16 | 2003/06/18 | 23:03 | 15° 42.93' N | 54° 03.21' W | 5454 | 5550 |
| 3 | 20 | 2003/06/20 | 13:35 | 15° 28.11' N | 51° 31.75' W | 4951 | 5040 |
| 4 | 23 | 2003/06/20 | 20:42 | 15° 29.03' N | 51° 28.28' W | 4897 | 4969 |
| 5 | 28 | 2003/06/21 | 19:04 | 15° 27.84' N | 51° 32.65' W | 4942 | 995 |
| 6 | 30 | 2003/06/22 | 19:20 | 15° 27.70' N | 51° 31.85' W | 4953 | 4000 |
| 7 | 31 | 2003/06/22 | 22:55 | 15° 27.67' N | 51° 31.82' W | 4958 | 5046 |
| 8 | 39 | 2003/06/25 | 19:00 | 16° 10.06' N | 58° 43.35' W | 5691 | 5816 |
| 9 | 44 | 2003/06/27 | 02:36 | 16° 22.59' N | 60° 29.68' W | 4936 | 5055 |

| Profile | Micocat / MTD Logger |
|---|---|
| 1 | – |
| 2 | MicoCAT: 940 941 942 946 952 957 1270 1276 1317 1318 1320 1321 1322 1323 1550 1719 |
| 3 | MicoCAT: 935 937 944 950 954 958 959 963 1162 1271 1272 1273 1275 1319 1722 |
| 4 | MicoCAT: 960 961 1520 1720 1723 939 929 1316 934 MTD: 39 56 57 58 59 |
| 5 | MicoCAT: 1717 1716 |
| 6 | MTD: 19 20 22 23 29 30 33 46 47 48 52 55 |
| 7 | MicoCAT: 1268 1269 1274 1277 1279 1280 1520 1718 1721 1724 933 945 949 953 962 |
| 8 | MicoCAT: 910 948 1278 1288 |
| 9 | – |

MicroCATs and MTD Logger lowered with the CTD during calibration casts.

The results of a typical calibration cast in terms of temperature and conductivity differences between MicroCATs and the CTD is shown in figure 11. The MicroCAT temperature have a positive Offset of about 0.004 °C relative to the CTD, which had already been observed during the previous cruises. It also becomes clear that due to the stratification only conductivity samples from below 2000 m should be used for calibration.

# 11 Acoustic Doppler Current Profiles (ADCP)

## 11.1 Vessel mounted ADCP

The upper ocean velocity field during SO 172 was observed with an Ocean Surveyor 75kHz (OS75) system that was generously provided by RD Instruments (San Diego, USA). The system

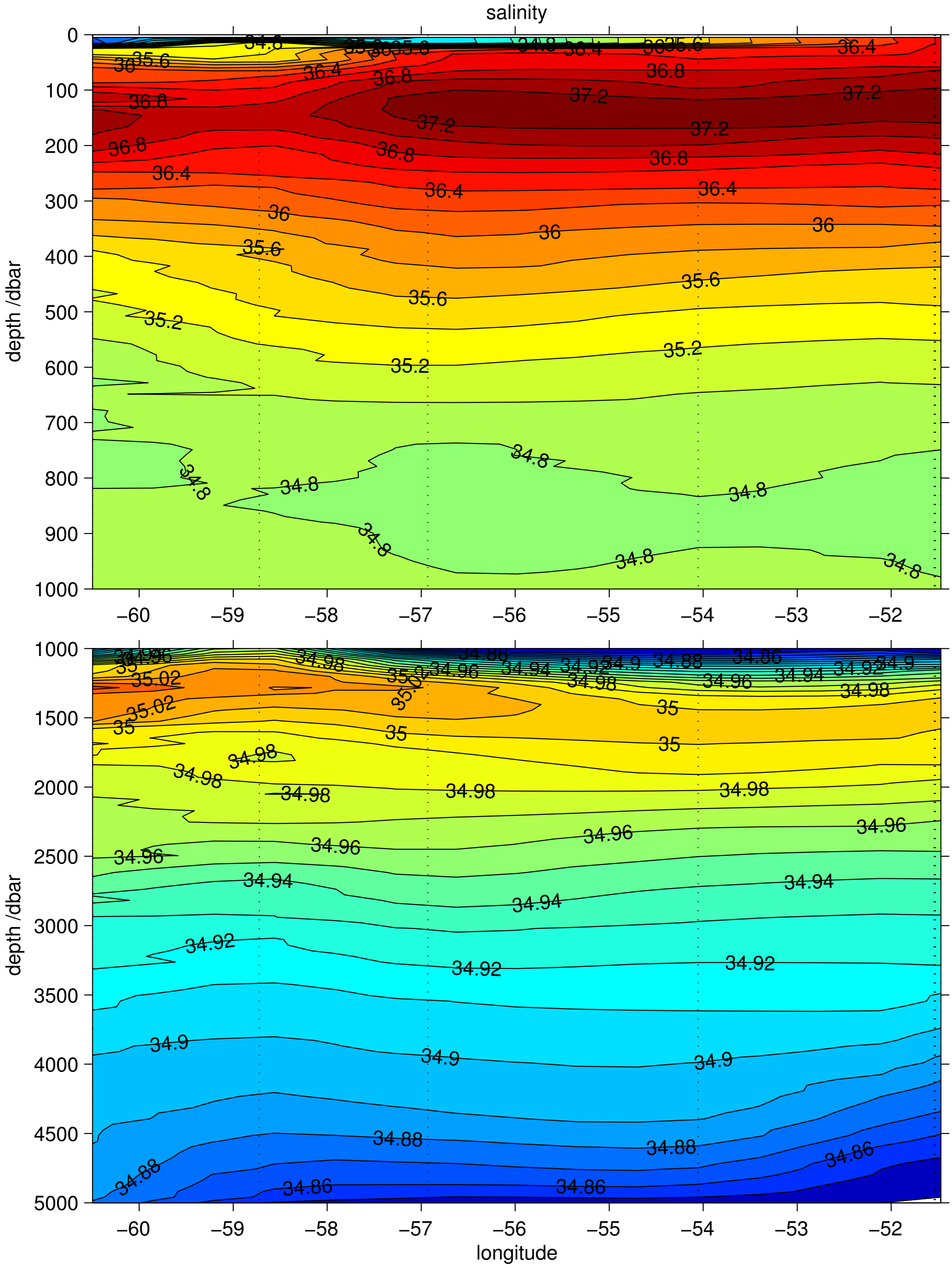


Figure 9: Salinity CTD section. The dotted lines indicate the position of stations. The section is divided in an upper part and a lower part.

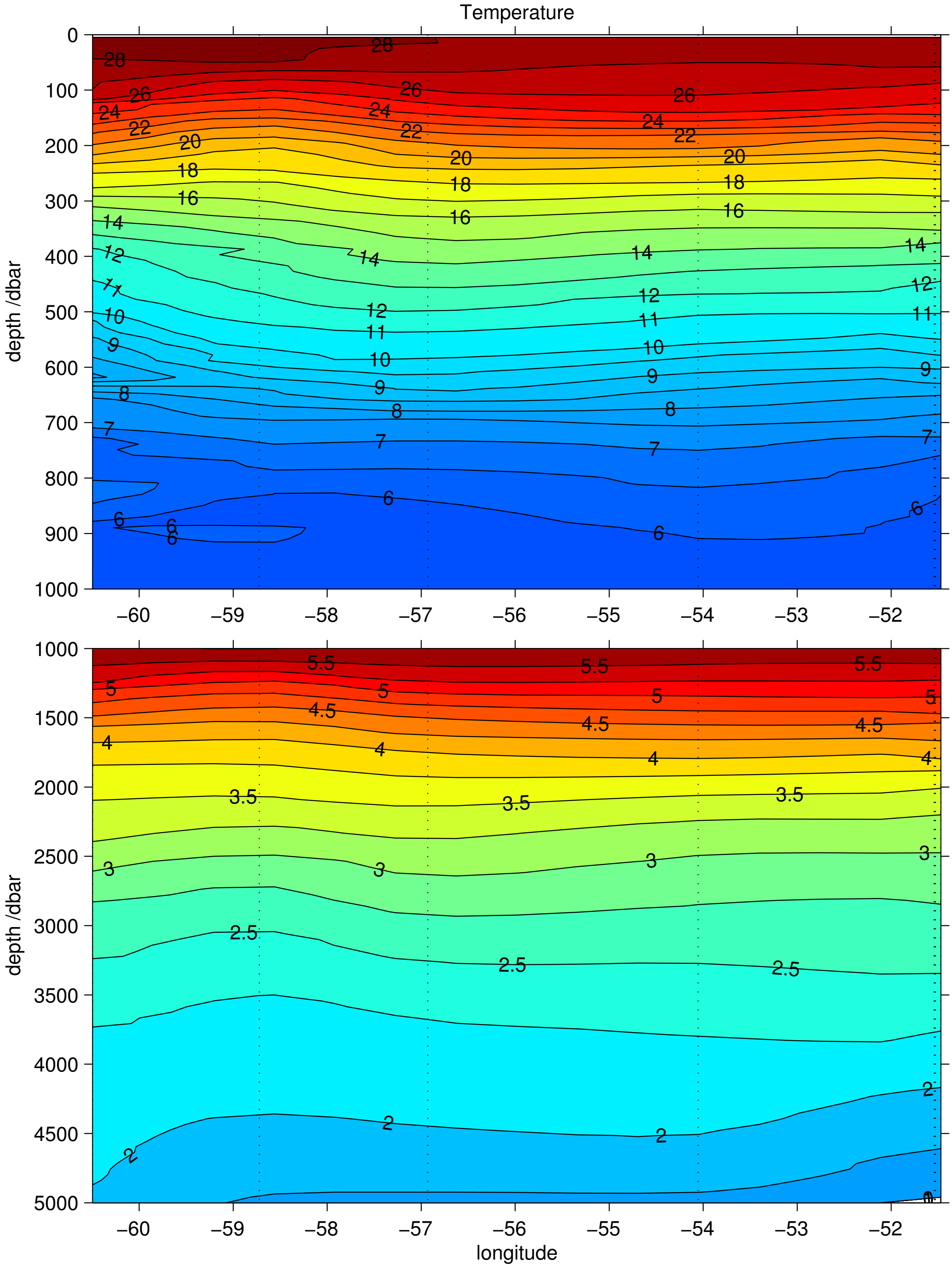


Figure 10: Temperature CTD section. The dotted lines indicate the position of stations. The section is divided in an upper part and a lower part.

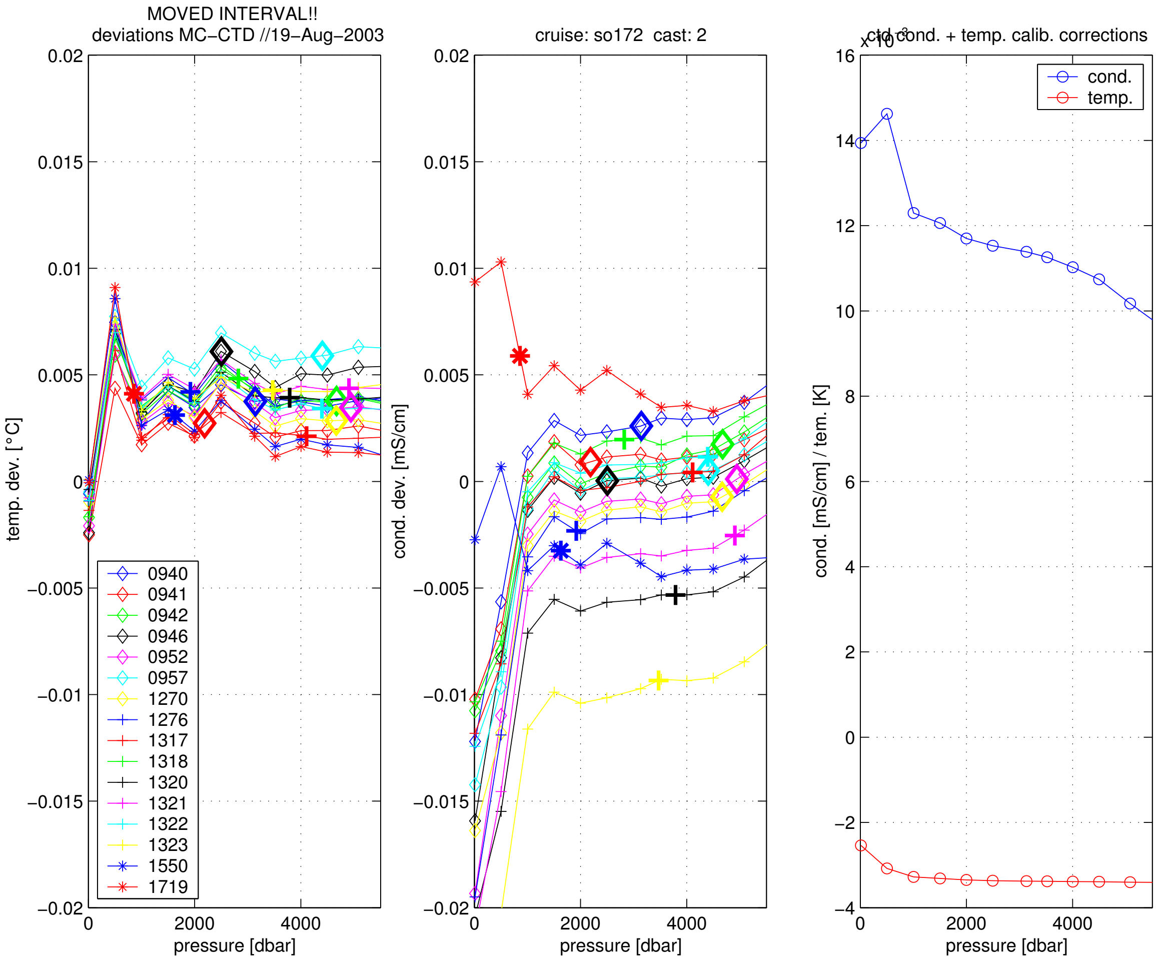


Figure 11: Diffences MicroCAT-CTD in temperature (left) and conductivity (center) during cast 2. Right: The following corrections from the pre-cruise temperature laboratory calibration and from the salinometry have already been applied to the CTD .

was mounted and setup on 29.4.2003 (20:43 UTC) during cruise SO 170 (F. Schott, 23.4.2003-21.5.2003) and quasi continuously recorded during the following two SONNE cruise (SO171, M. Rhein and SO172, U. Send). About once a day the OS75 was stopped for a short period of time to retrieve the data. In addition at port stops the system was switched off for some days period. The OS75 system (instrument, deck unit, cable, supply) was shipped back to RDI from SO 172 Guadeloupe port stop on 30.6.2003 by the vessel's agent.

Data acquisition on SO 172 with OS75 started in international waters on 15.6.2003 03:00 UTC. The OS75 was configured to record with 60 bins with 16m bin depth and 8m blank using 2 sec ping rate and 2 ping ensemble averaging. The recording strategy was adopted from the earlier cruises and resulted in velocity profiles for a depth range from 25m up to about 900m. Data was recorded in 'beam coordinates' and transformed into earth coordinates (north/east) velocity data in a number of processing steps using navigational information (heading, ship velocity). Most of the processing software was provided through the physical oceanography I group of IfM

Kiel (F. Schott).

The final data was averaged in 10min intervals and stored in MAT files. The raw data is stored in a set of files associated with a recording segment, for example, the 71 segment with filenames ADCP071_000*.*. The segments are in general about 24h. Data is retrieved using RDI's VMdas program which writes for segment 71 about 30 raw data files:

- *.ENX, *.ENR, *.ENS are binary raw files with the beam coordinate data (note *.ENX is used for processing),
- *.N1R, *.N2R are ASCII files with navigation information as ASHTECH heading, pitch, roll, ADCP ping number, DGPS date, lat, long, etc.,
- *.LOG is the logging of ADCP startup/down,
- *.STA, *.LTA are binary files

The final processed data is stored in structures in MAT files
ADCP000_000000_71_hc.mat → here 'hc' means heading correction
Sub processing files are:
ADCP000_000000_71.mat → in earth coordinates but not corrected for heading/ship speed
Subfiles for the different types of navigational information (heading, position, time, etc.)
ADCP071_000000_ATT.mat → all data of 71
ADCP071_000000d_ATT.mat ... ADCP071_000006d_ATT.mat → individual subfiles

Some minor problems occurred with the navigational data provided by the DVS on RV SONNE. In particular the Ashtech 3D GPS receiver which records the ship's heading, and pitch and roll, did not work totally stable and had to be rebooted some time. The worst case was a loss of about one day of Ashtech data. However, all navigational information necessary to process the data was still available from other instruments (with only little lower final data quality). During these occasions, ship's heading was retrieved from the gyro compass but corrected with a rather constant offset between Ashtech and gyro of about -0.78°(figure 12).

From past usage of the OS75 it was found that considering pitch and roll information in the data processing procedures does not improve the data accuracy, but the overall quality depends on the sea state [2]. The instrument's miss-alignment angle, which is first of all related to the mounting was found to be -45.27°(Amplitude 1.003) in agreement with the two earlier cruises.

A good indicator for the performance of the system depending on the environmental conditions is the 'percent good' (PG) indicating the number of reasonable pings per ensemble (range from 0 to 100%). One factor for the PG value is the availability of backscatter. The 75kHz sound-wave has a wavelength of about 2 cm (using 1500 ms sound-speed) which means that objects up to about 5mm will reflect the sound while smaller ones will scatter it. During SO 172 a pronounced change in PG can be seen below about 450m (figure 13).

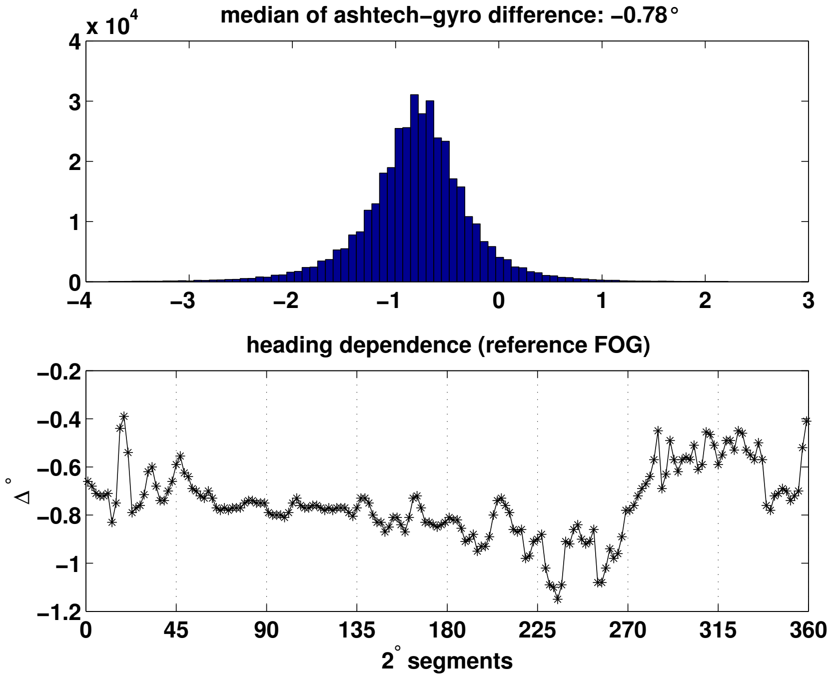


Figure 12: *Statistics on heading from ASHTECH 3D and gyro.*

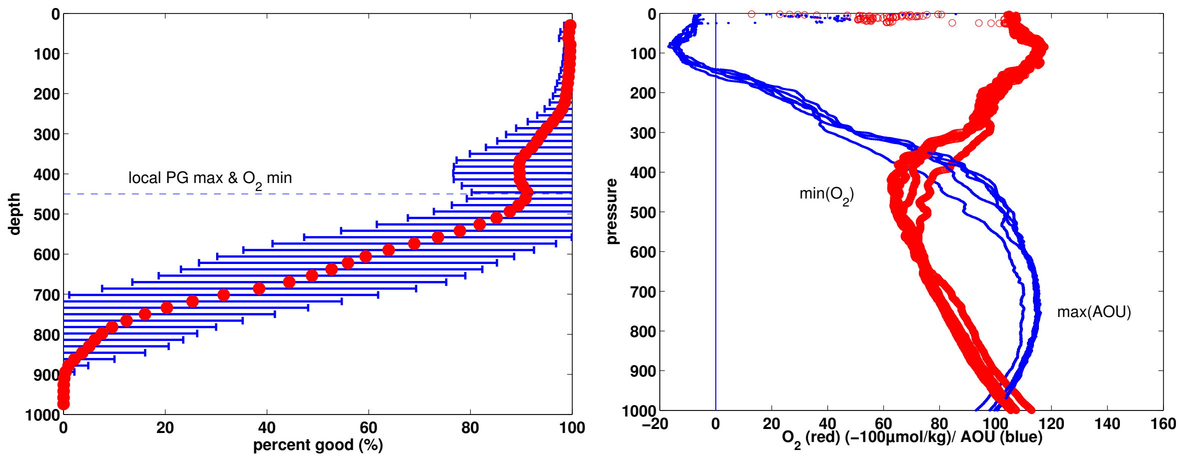


Figure 13: *(left) Overall average and standard deviation of 'percent good' and (right) distribution of oxygen (-100μ*molkg$^{-1}$*) as well as 'apparent oxygen utilization (AOU).*

Using data from the CTD's oxygen sensor (not calibrated during the cruise) one finds depths around 50m to be associated with a local minimum in oxygen. However, considering the temperature effect on the oxygen content of the water by calculating the apparent oxygen utilization (the difference between oxygen saturation [4] and the observed oxygen) indicates the largest oxygen consumption on a large scale occurred at about 700 to 800m depth, associated with water at the deep thermocline level but above the salinity minimum of the Antarctic Intermediate Water with its core (salinity minimum) at 850 to 900m depth. The local minimum at 450m should have a different, locally formed origin and may be related to the interplay between local

consumption, sinking and size of material, and ventilation.
One may note that the salinity maximum at about 100m depth is related to the Ekman driven formation of high salinity subtropical Underwater in the region of negative wind stress curl. However, our CTD data indicates that highest salinities are located deeper in the water column than the oxygen maximum. Hence, at 16°N the most recently ventilated water is fresher.

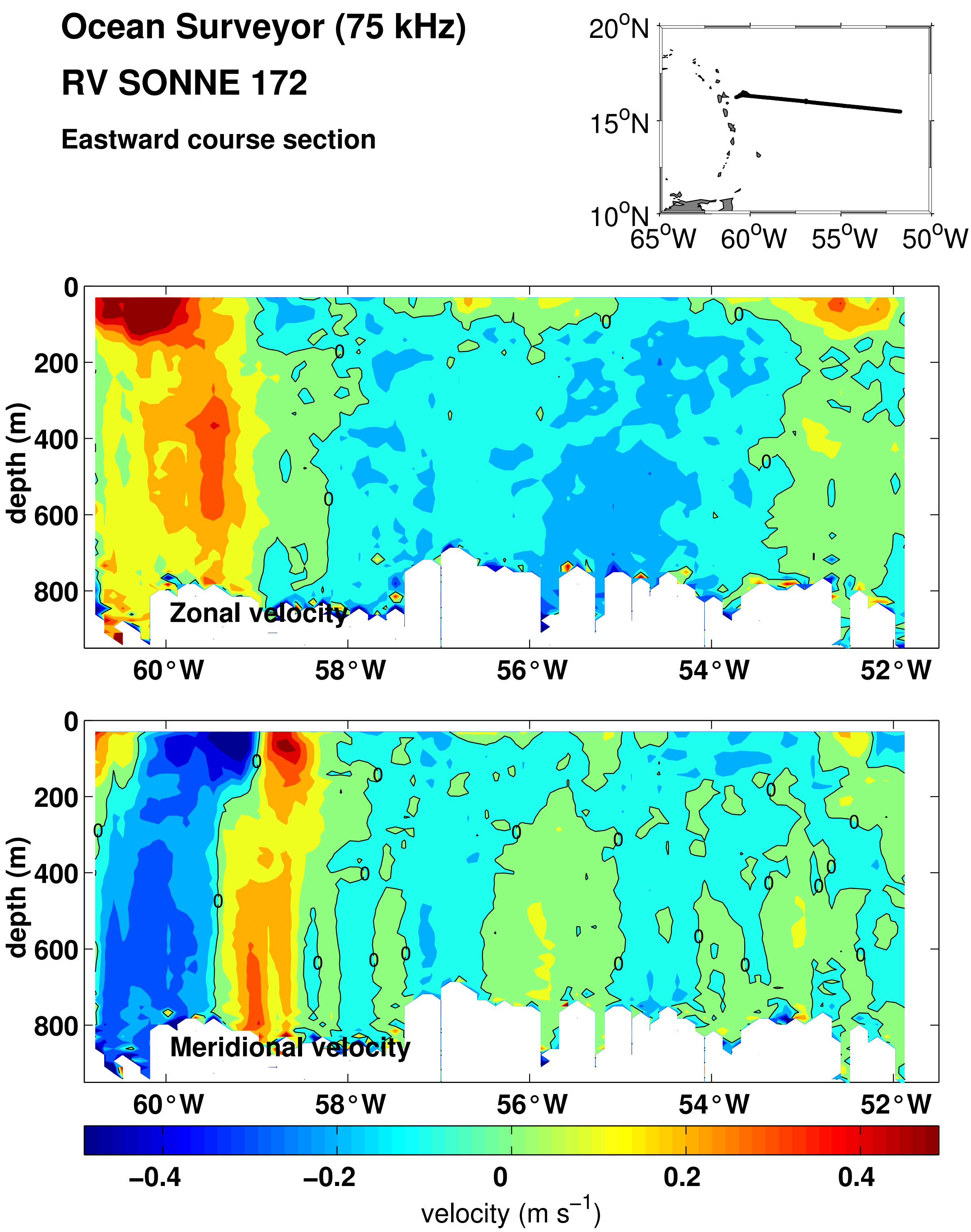


Figure 14: *Zonal and meridional velocity sections on the eastward course (about 14.6.2003 to 19.6.2003).*

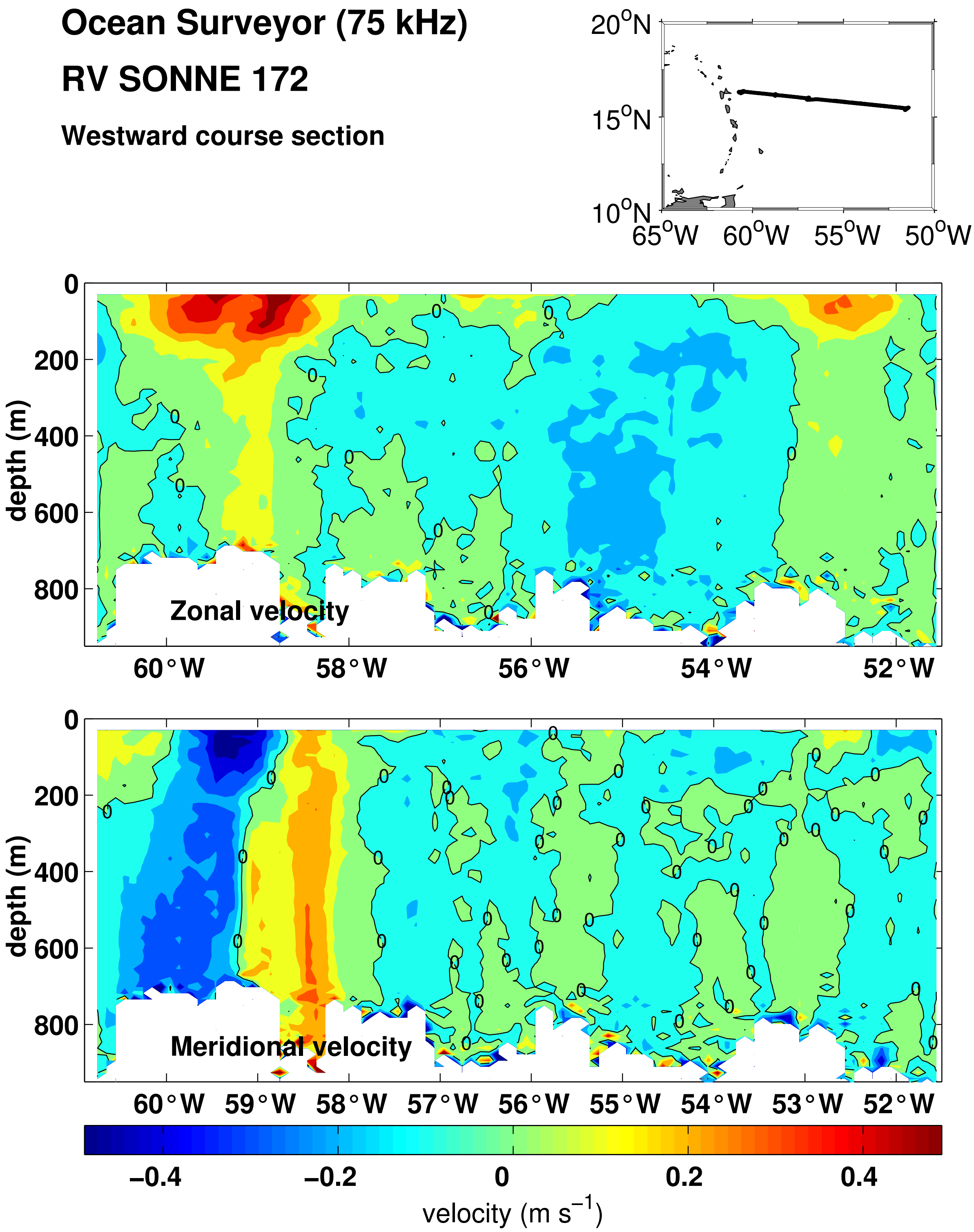


Figure 15: *Zonal and meridional velocity sections on the westward course (about 21.6.2003 to 26.6.2003).*

The OS75 data recorded during steaming of the ship was essentially a repeat zonal section from about 60°W to 52°W at about 16°N. The velocity structure along both sections are quite similar as they were acquired only about one to two weeks apart. The most striking feature is a near shore eddy (figure 14) which does not only appear in our sections but also in the 16°N section sampled during the SO 171 cruise (M. Rhein). Unfortunately, because of ship time limitations during SO 172 only one CTD/lADCP station was sampled in the eddy, but it showed that the eddy's core is composed of generally less saline water (about 0.4 psu in the core of the high salinity Subtropical Underwater at about 150m depth) and accompanied with lower oxygen values. As the high salinity Subtropical Underwater is formed in the region it indicates that the water in the eddy has to have its origin at a different place. Using again the apparent oxygen utilization (AOU) one finds the eddy about 4 times higher in AOU, which indicates, assuming constant oxygen consumption over time in and outside of the eddy, a life time (which is the time since leaving his region of origin) four times longer than the surrounding waters at 16°N.

During station work (CTD/lADCP casts, OFOS usage) some performance indicator for the OS75 (and for the lADCP system as will be shown below) can be derived. Assuming a constant flow field the variability of the measured velocity can be viewed as a measure of accuracy of the data. The general 'on station' profiles showed quite low deviations, order 2 to 3 cms$^{-1}$ (figure 16) which confirms other studies [2].

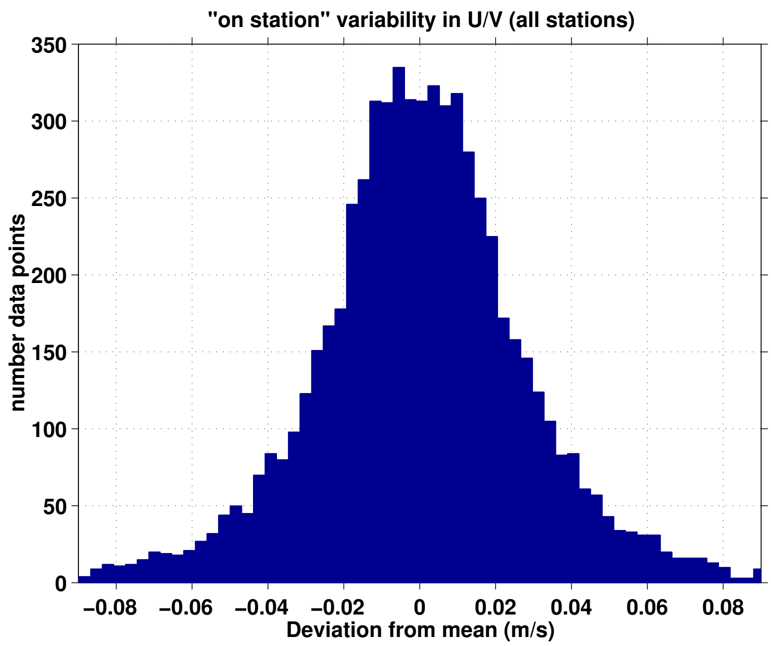


Figure 16: *Distribution of the difference of all u/v components from there mean during station work.*

## 11.2 Lowered ADCP

In addition to the OS75 vessel mounted system two Broad-Band 300kHz (BB300) work horse ADCP have been mounted to the CTD rosette and lowered to resolve the full depth current structure. The system was set up in a master(serial #839, downward)/slave (serial #876, upward) configuration. First a well-proven set of configuration files, provided by M. Visbeck (LDEO, Palisades, USA), was used while slight modification have been made during the cruise to test the systems performance, see table 7.

The script file used to control the master was:

```
; LADCP *.CMD file by Martin Visbeck
;
;Modified for So172, 25.06.03 by Hauke Schmidt

;CR1 retrieving parameter
CR1
;ED0000  Depth of transducer
ED0000
;ES35 salinity
ES35
;EX11111   coordinate transformation
;earth coordinates
EX11111
;TE00:00:02.50 time per ensemble
TE00:00:02.50
;TP00:00.40     time between pings s
TP00:00.40
;EZ0011111  sensor source
; defaults to manual depth setting, uses internal heading,pitch,roll
;EC1500 set speed of sound to 1500m/s
EC1500
;EA00000   heading alignment correction = 0
EA00000
;EB00000   heading bias correction = 0
EB00000
;CF11101   flow control, serial output disabled
CF11101
;----------  SPECIAL LADCP commands  ----------
;LD111100000  data out (vel,corr,intensity,%good,status...)log only vel,corr,ea,%good
LD111100000
;LF0500 blank after transmit (0-9999cm) this should be half the bin length
LF0500
;LP00003  3 pings per ensemble 1 ping per ensemble for anslope
LP00003
;LJ1 receiver gain
LJ1
;LN025 number of depth cells 250 m range covered by 25 bins * 10 m
LN025
; LS1000 bin length (cm)  = 10m
LS1000
; LV250 correlation velocity (cm/s radial)
LV250
; LW1  band width
LW1
;LZ30,220 Amplitude, Correlation Thresholds
LZ30,220
; SI0  master waits 1 ensemble before sending sync pulse
SI0
; SM1 set this instrument to master
```

```
SM1
; SA011 master sends pulse before ensemble
SA011
; SW5500 synchronization delay the master waits .5500 s after sending sync pulse
SW5500
;  ---------- END of LADCP commands ---------------
; CK keep parameters as user defaults
CK
; CS start pinging
CS
```

As the lADCP system did not work properly in the past the SO172 cruise was indented to serve as a test field for the instrument. Data of a full depth lADCP section along 16°N using a 150kHz ADCP should have been acquired during SO 171 and in a later stage intersecting stations should have been used for comparison. But due to an instrument failure and the limitation in pressure (only 5000 dbar) of the old ADCP no intersecting lADCP stations are available.

As the main purpose of the SO172 cruise was recovery and deployment of moorings of the MOVE array only few CTD casts have been performed mainly to calibrate instruments mounted on the rosette (MicroCat, MTD logger). However, when possible a full CTD/lADCP cast to the bottom was performed. Full water depth recordings are essential for an improved lADCP processing. A summary of lADCP stations is given in the table 6. Note CTD stations #5 and 6 are only down to 1000m depth and no lADCP profile was recorded.

Table 6: Summary of lADCP cast during So 172.

| station # | CTD st. # | latitude | longitude | depth (m) |
|---|---|---|---|---|
| 13 | 1 | 16°00.50' N | 56°55.81' W | 4968 |
| 16 | 2 | 15°42.94' N | 54°03.22' W | 5550 |
| 20 | 3 | 15°28.14' N | 51°31.72' W | 5042 |
| 23 | 4 | 15°29.06' N | 51°28.25' W | 4897 |
| 31 | 7 | 15°27.65' N | 51°31.82' W | 4956 |
| 39 | 8 | 16°10.07' N | 58°43.35' W | 5676 |
| 44 | 9 | 16°22.59' N | 60°29.67' W | 4924 |

Table 7: Summary of lADCP parameters during So 172.

| station # | CTD st. # | bin length (m) | depth cells | time between pings (s) |
|---|---|---|---|---|
| 13 | 1 | 10 | 25 | 0.7 |
| 16 | 2 | 10 | 25 | 0.7 |
| 20 | 3 | 10 | 25 | 0.7 |
| 23 | 4 | 10 | 25 | 0.7 |
| 31 | 7 | 15 | 15 | 0.7 |
| 39 | 8 | 10 | 25 | 0.4 |
| 44 | 9 | 10 | 25 | 0.4 |

It has been reported earlier (D. Symonds, pers. communication) that work horse based lADCP performance is low in comparison to 'traditional' 150kHz devices and only 1 to 2 bin resolution has been observed. However, during our cruise the instruments performed somewhat better with 2 to 4 bin resolution which is however, at the limit of what can be expected. As it is a hardware problem, an improvement of the instrument would be required. Using the BB300 in lADCP mode, switches the downward looking one automatically into a bottom track mode. This allows for improved data processing as it yields another contraint at the bottom for the inversion solution of the full depth velocity profile [3].

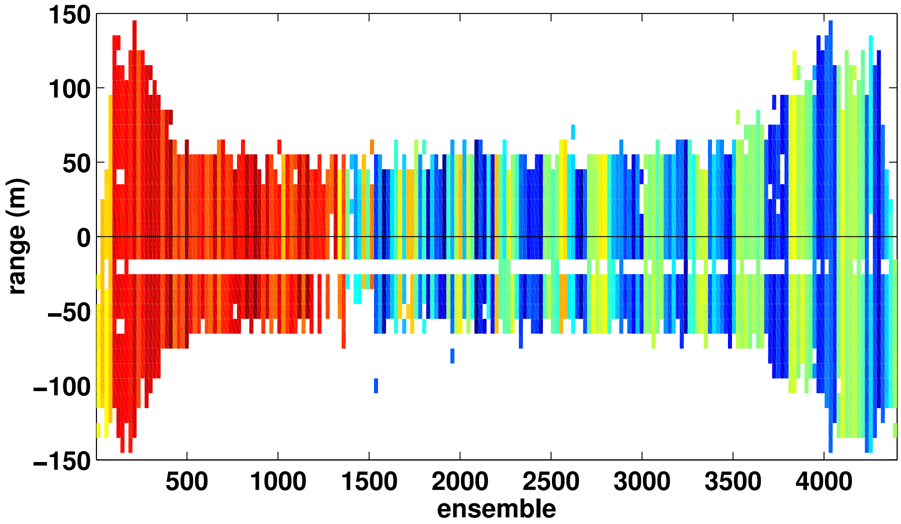


Figure 17: *Typical depth ranges of upward and downward looking BB300 during lADCP cast (here station # 16).*

Some idea about the quality of the data, at least in a relative sense, is obtained by comparing 'on station' OS75 and lACDCP data. Three different solutions are compared in the upper layer with the OS75 (figure 18): The shear based velocity (SB), the inverse based without upper ocean constraint (IB0) and the inverse based with the OS75 as constraint (IB75).

The velocity profiles of the three different solutions are shown in figures 19,20,21. The largest differences are found between the shear and the inverse solutions while the inverse solutions with or without OS75 constraint do not differ as much. In summary, from the comparison to the OS75 data one should favor the inverse solution. But due to the limited range of the BB300 ADCPs, the rms differences (0.012 $ms^{-1}$) between the OS75 'on station' profiles and the IB0 solution from the lADCP are as twice as large as reported earlier for the 150kHz Narrow-Band lADCP ([2]).

Because heading information is crucial for lADCP processing, we have done some quality check for the two fluxgate compasses in the WH-ADCPs. The results are shown in the following figures 22, 23. The mean difference between the two instruments over all seven stations of the SO 172 cruise is estimatet to 119.2°with a standard deviation of 0.39°. The difference does not vary systematically with depth, but shows some systematic variation with heading. We also analysed the tilt differences between the two ADCPs, which almost show a normal distribution (lower panels of figures 22, 23). The final data is available as a matlab structure array or in common RODB[4] format (one file per station). The matlab files contain the following structure arrays:

[4]Regionale Ozeanographie Datenbank

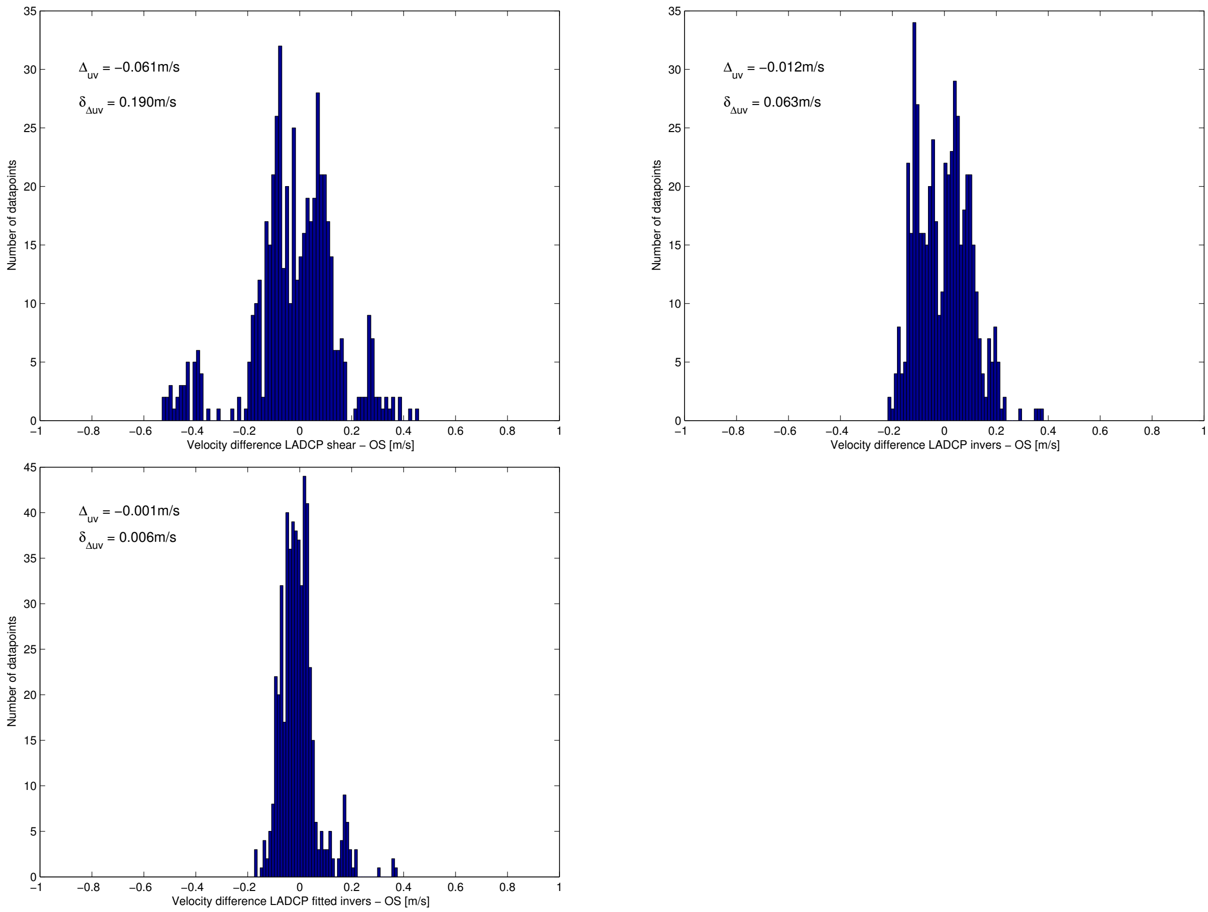


Figure 18: *Statistical comparison of three different lADCP solutions for the upper 700m with 'on station' OS75 velocities.*

- dr: all ladcp profile data including ships navigation, shear and inverse solution
- p: profil and station parameters including position, time, serial numbers etc.
- ps: processing parameters
- f: names of all data files used during processing

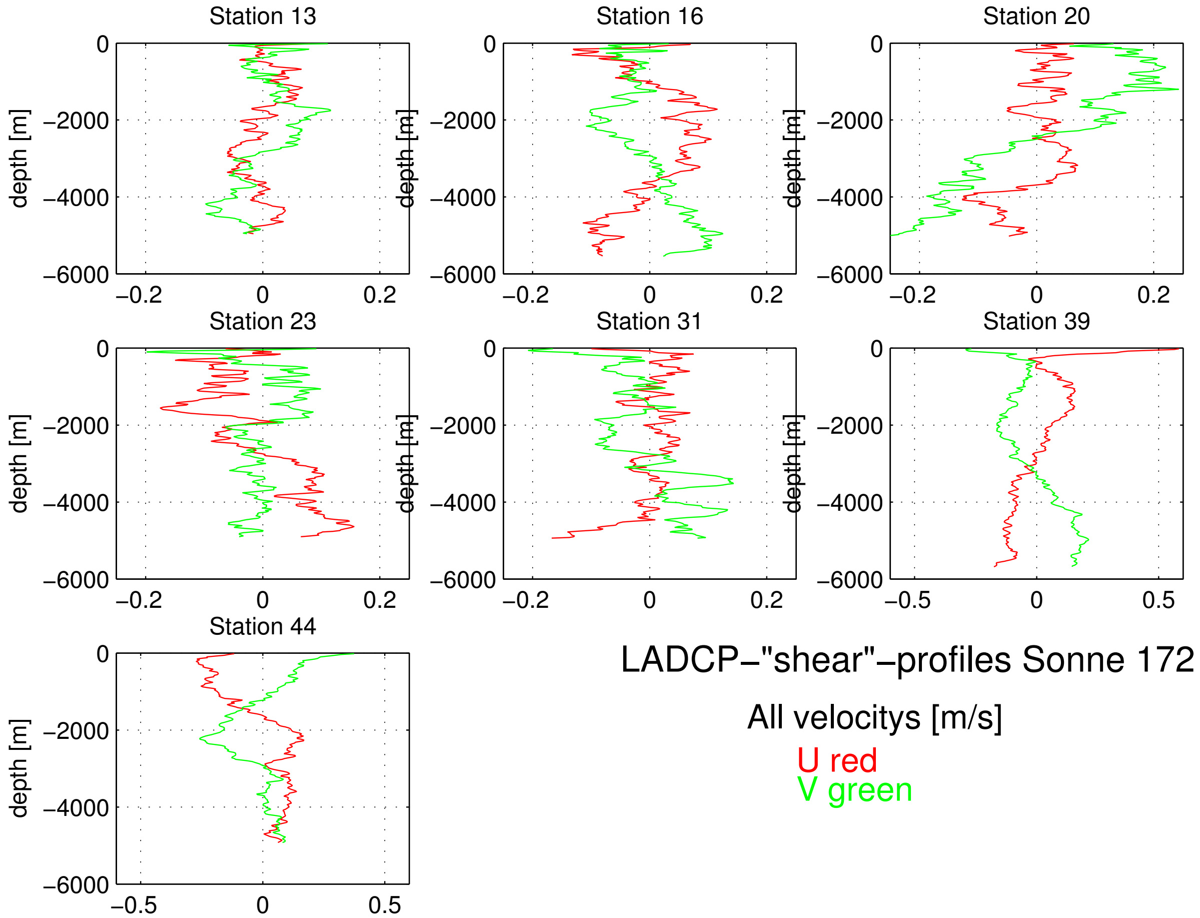


Figure 19: *lADCP shear solutions for the upper 700m (for quality comparison with OS see figure 18).*

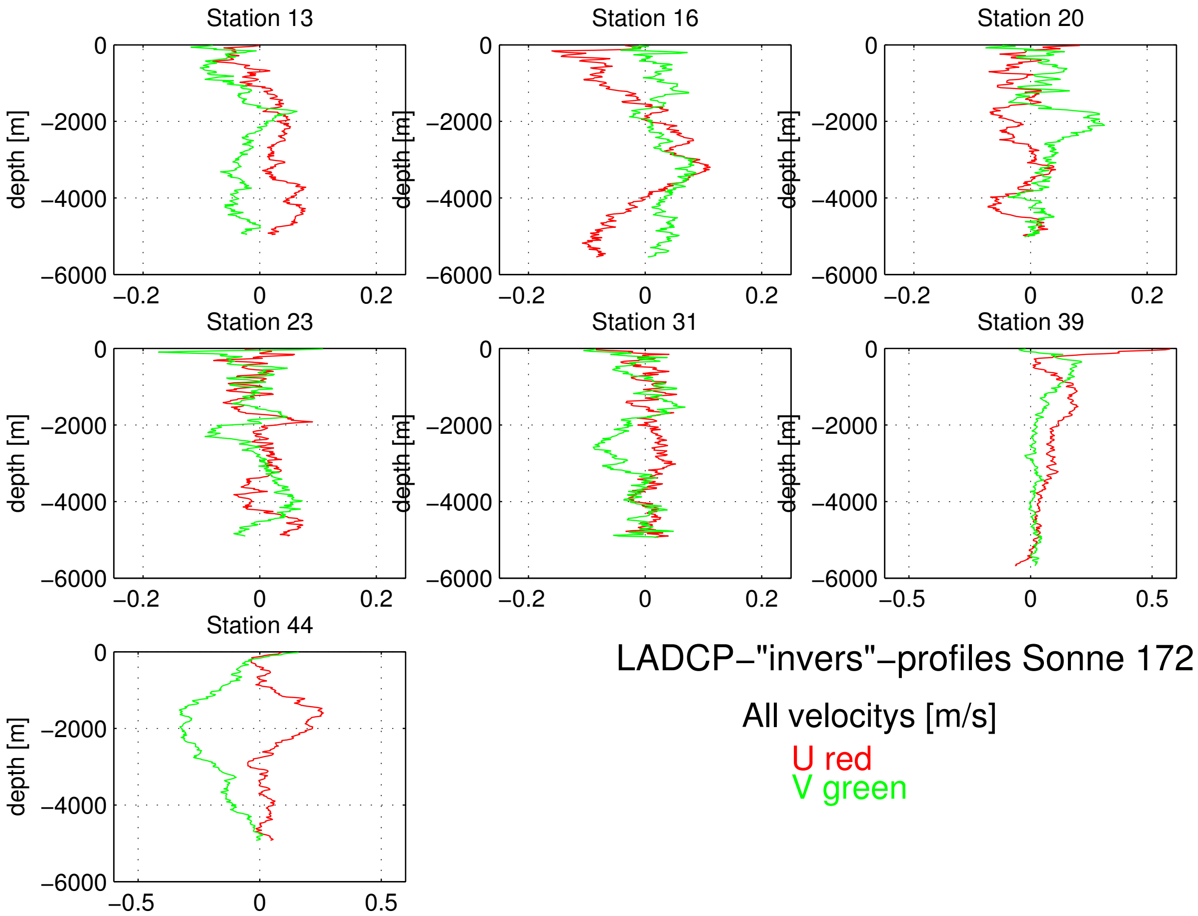


Figure 20: *lADCP inverse solutions for the upper 700m (for quality comparsion with OS see figure 18).*

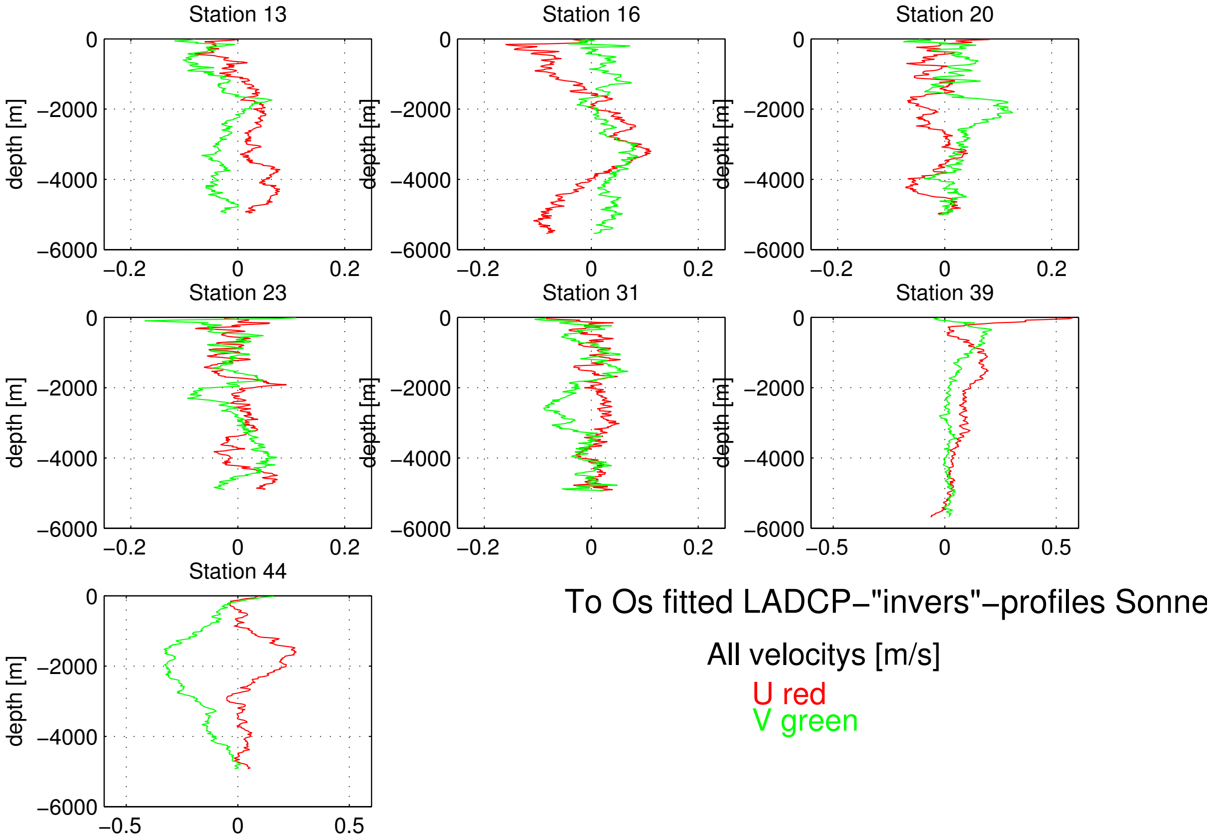


Figure 21: *To OS fitted lADCP inverse solutions for the upper 700m (for quality comparsion with OS see figure 18).*

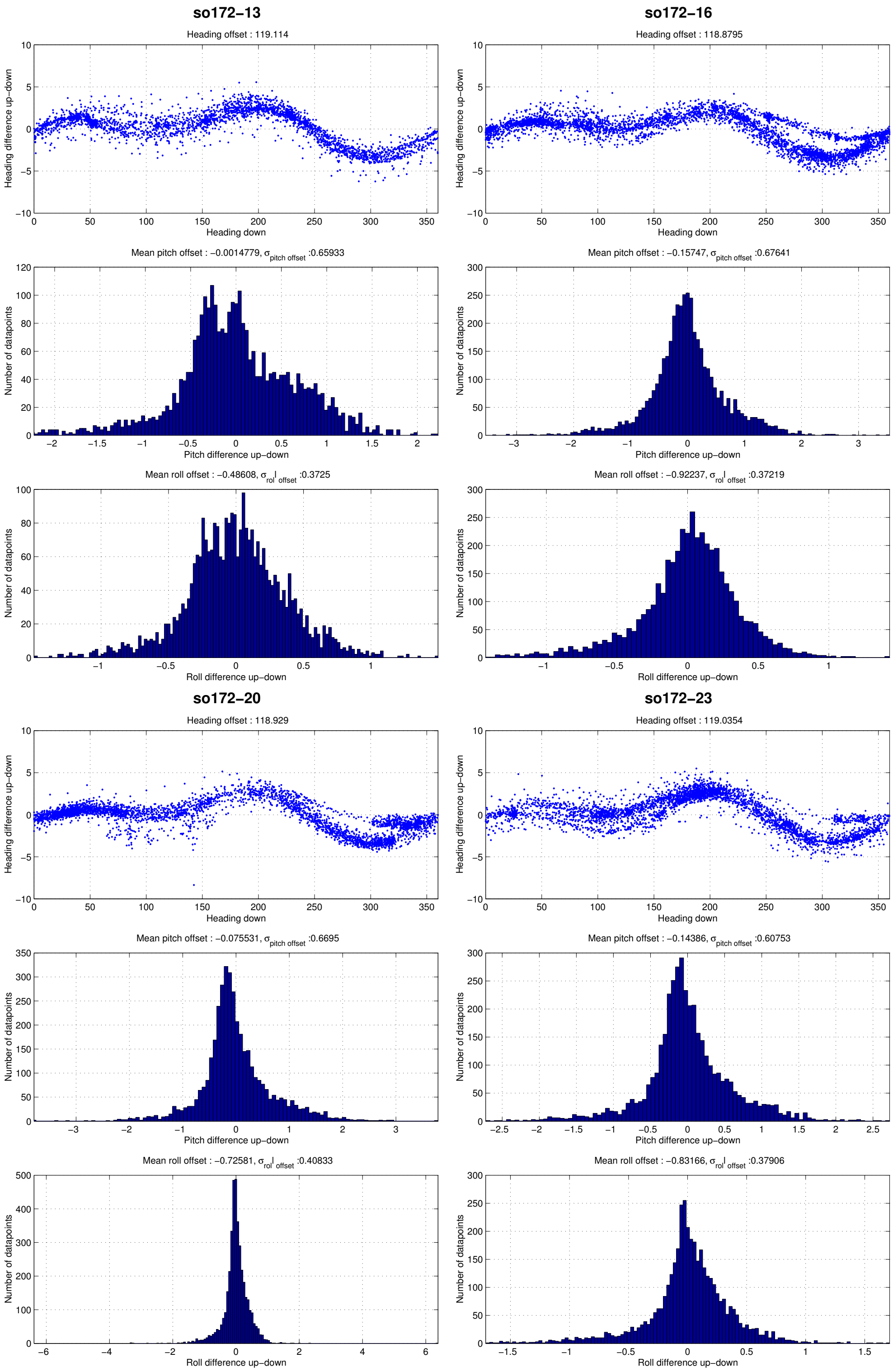


Figure 22: *Heading, Pitch and Roll comparison Stations 16 - 23.*

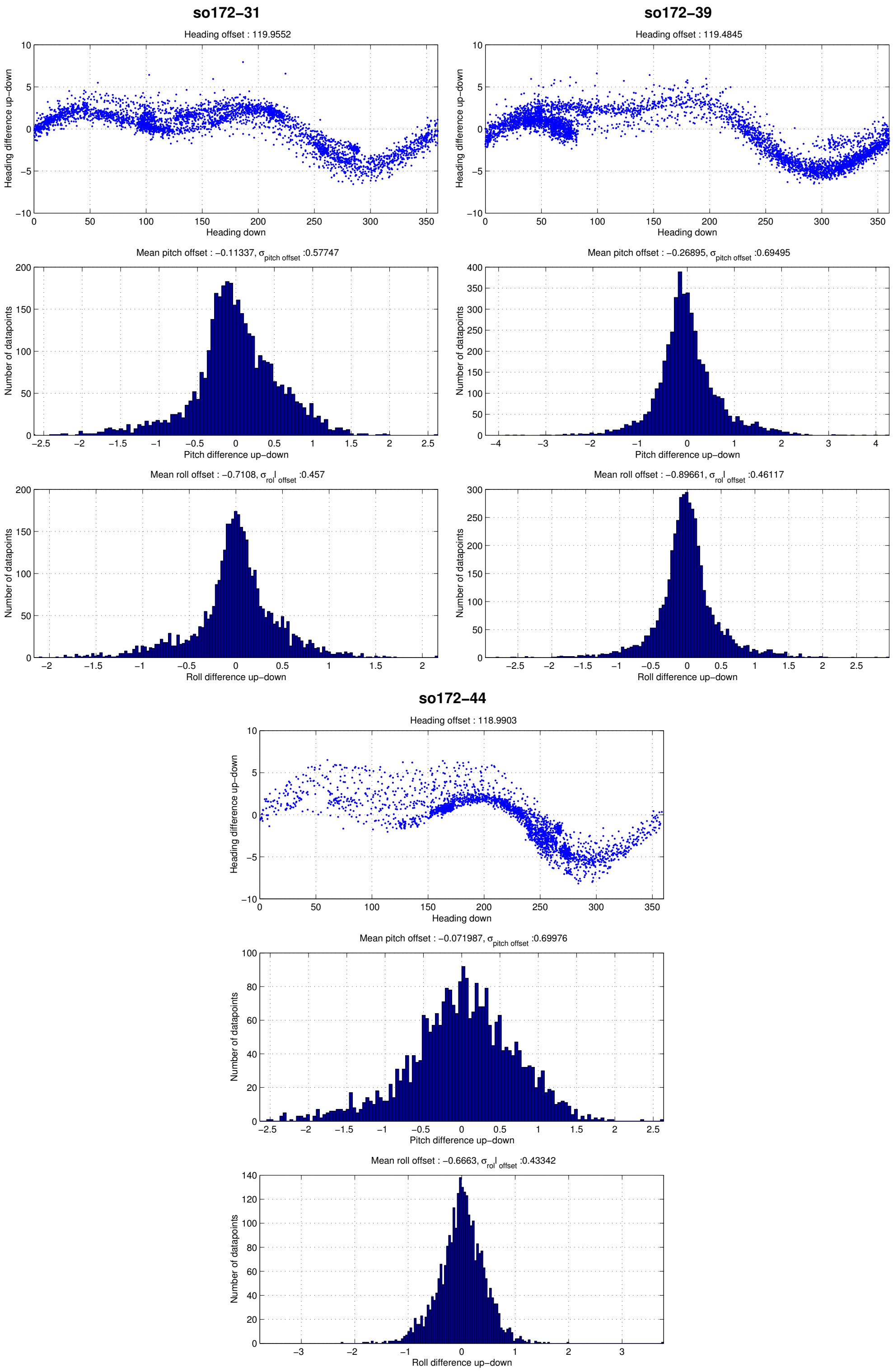


Figure 23: *Heading, Pitch and Roll comparison Stations 16 - 44.*

## 12 DVS Data

Data collected via the DVS (Datenverteilung system) include the following parameters:

| Label | Format | NoValue/ErrorValue |
|---|---|---|
| Date | %s | **:**:** |
| Time | %s | **:**:** |
| Latitude | %+010.6f | -99 |
| Longitude | %+011.6f | -999 |
| Course.o.Ground | %05.1f | 999 |
| Speed.o.Ground | %05.2f | 999 |
| Hydrosweep.Depth | %05.0f | 99999 |
| True.Wind.Speed | %05.2f | 99 |
| True.Wind.Direction | %06.2f | 999 |
| Rel.Wind.Speed | %04.1f | 99 |
| Rel.Wind.Direction | %05.1f | 999 |
| Air.Temperature | %+05.1f | 99 |
| Humidity | %05.1f | 999 |
| Air.Pressure | %06.1f | 9999 |
| Water.Temperature | %+06.2f | 99 |
| Water.Salinity | %05.2f | 99 |

Data was made available in minutes and seconds recording intervals from the computing staff on bord SONNE and once a day copied to the main ship server from where it was available for download. Time and positions are provided from a differential GPS system which was also used in deeper water to calculate the course and speed over ground. The other parameters are either available from the meteorological sensors or the thermosalinograph (TSG). All meteorological parameters are recorded in 20 to 21 meter height above the mean sea level (depends on the loading of tanks etc.). There is not much calibration one can do with the DVS data. During the cruise bottles samples where collected at the TSG tab to calibrate the sensor. During SO170 and SO171 the calibration of TSG salinity against CTD surface values resulted in a rather constant bias of 0.15 psu (TSG lower). This was confirmed from our measurements.

TSG salinity was surprisingly low (down to about 31) but reached nearly 36.5 at the most eastern part of the section. This was much lower then climatological values(figure 24). It is unclear at this stage if this is related to stronger then normal precipitation which might be associated with the current La Nina state in the western Pacific.

Time series of a number of DVS parameters is given in figures 25 and 26. Parameters as shown here are not corrected for the daily cycle.

Air temperatures getting colder towards the open Atlantic with average of 26.55°C, the maximum was reached on the 25.6.2003 with more than 30°C. The air temperature maximum can be seen in a number of parameters and coincide with the higher air pressure and low humidity. Winds

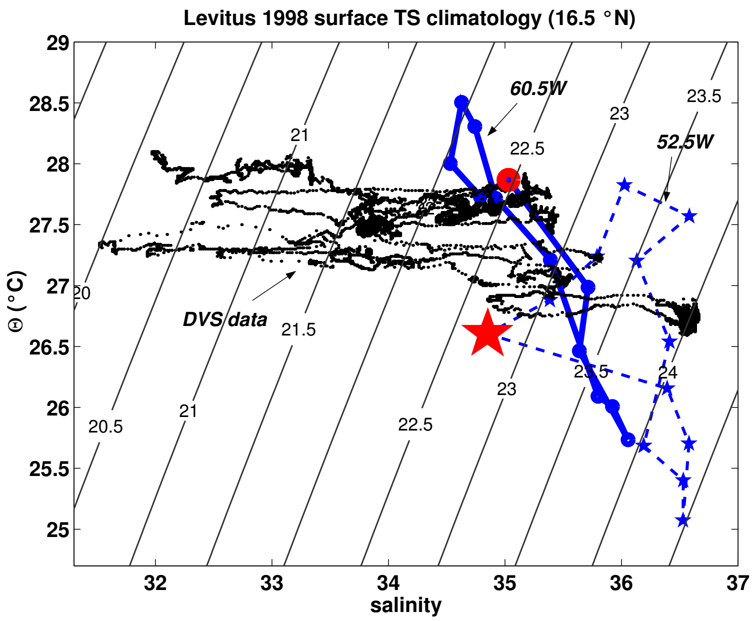


Figure 24: *Levitus 1998 monthly climatology TS-time diagram for 16.5° N/60.5° W (solid) and 52.5° W /(broken). The dots are the DVS temperature/salinity (corrected with bottle samples) values between 17.6. to 28.6.2003. The red marks indicate Levitus June values.*

have been, as expected in the trade wind zone, from the northeast with an average of about 9 ms$^{-1}$. The TSG data shows as a general trend of a decrease in temperature and an increase in salinity from west to east.

Because of its large variability the salinity plays the important role on the surface density along the section (figure 27). Besides density, other parameters which describe the air/sea exchange of heat and momentum can be derived from the DVS data (see figure 27): the sensible and latent heat fluxes (using bulk formulas, [1]) and the wind stress. As SONNE does not have radiation sensors to determine short/long wave radiation, no net air/sea flux could be estimated. Along the cruise track the ocean looses on average sensible and latent heat to the atmosphere as expected in the trade wind region. Some sensible heat gain occurred during the time of very high air temperature, in parallel latent heat loss of the ocean was diminished as the weather was calm.

All the anomalies during the 25.6. to 26.6.2003 coincide with the second transit through the above mentioned eddy (compare first bin (29m) meridional velocity component from the OS75 lowest panel on figure 27). As such a change was not as obvious during the eastward course (first transit) it is at this stage unclear if there is an air/sea feedback because of surface anomalies transported through the eddy. However, the eddy is associated with higher salinity (and maybe temperatures) then its surroundings.

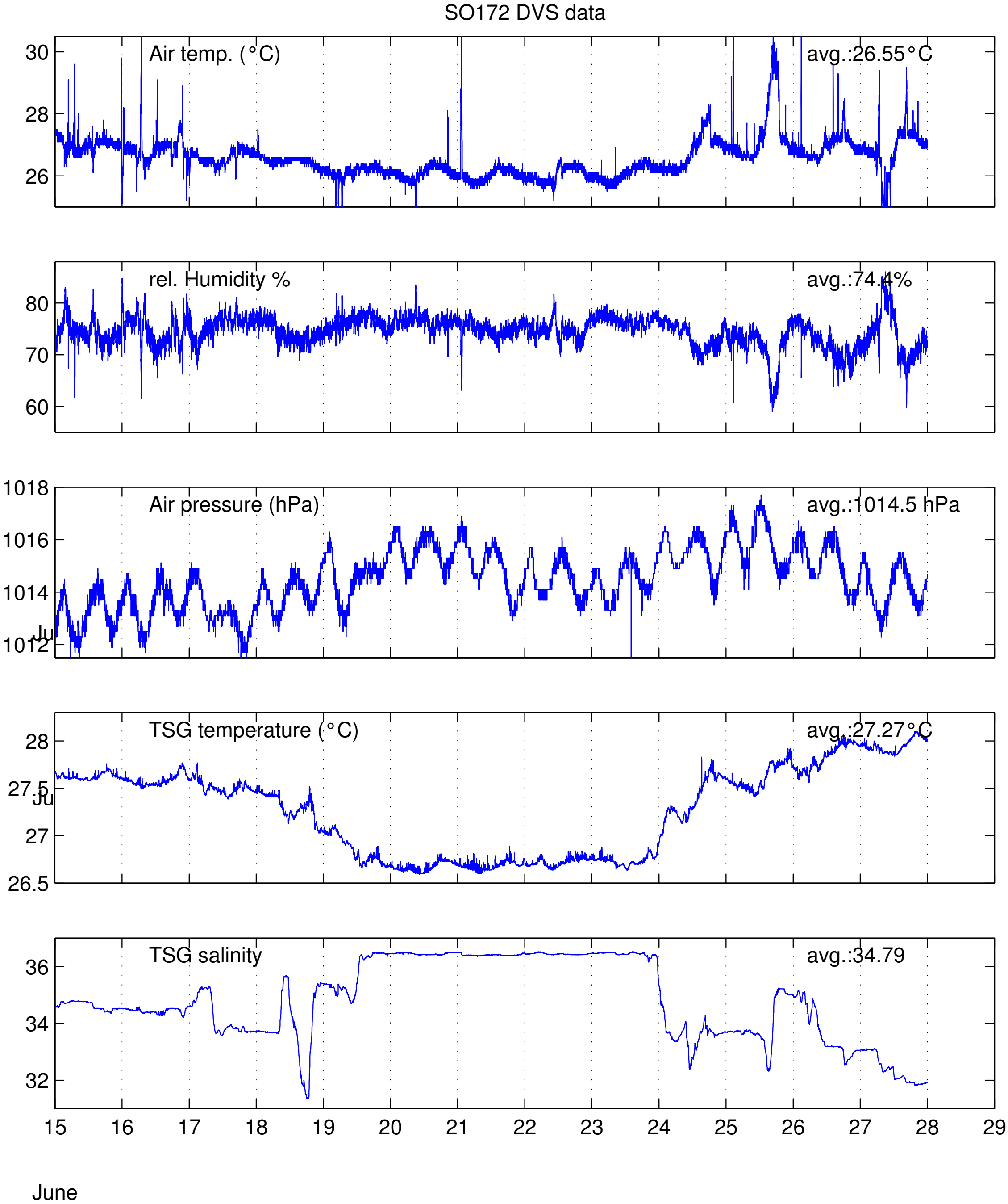


Figure 25: *SO 172 DVS data as labeled in the upper right corner of each panel. The time average of the parameter is given in each panel at the upper right.*

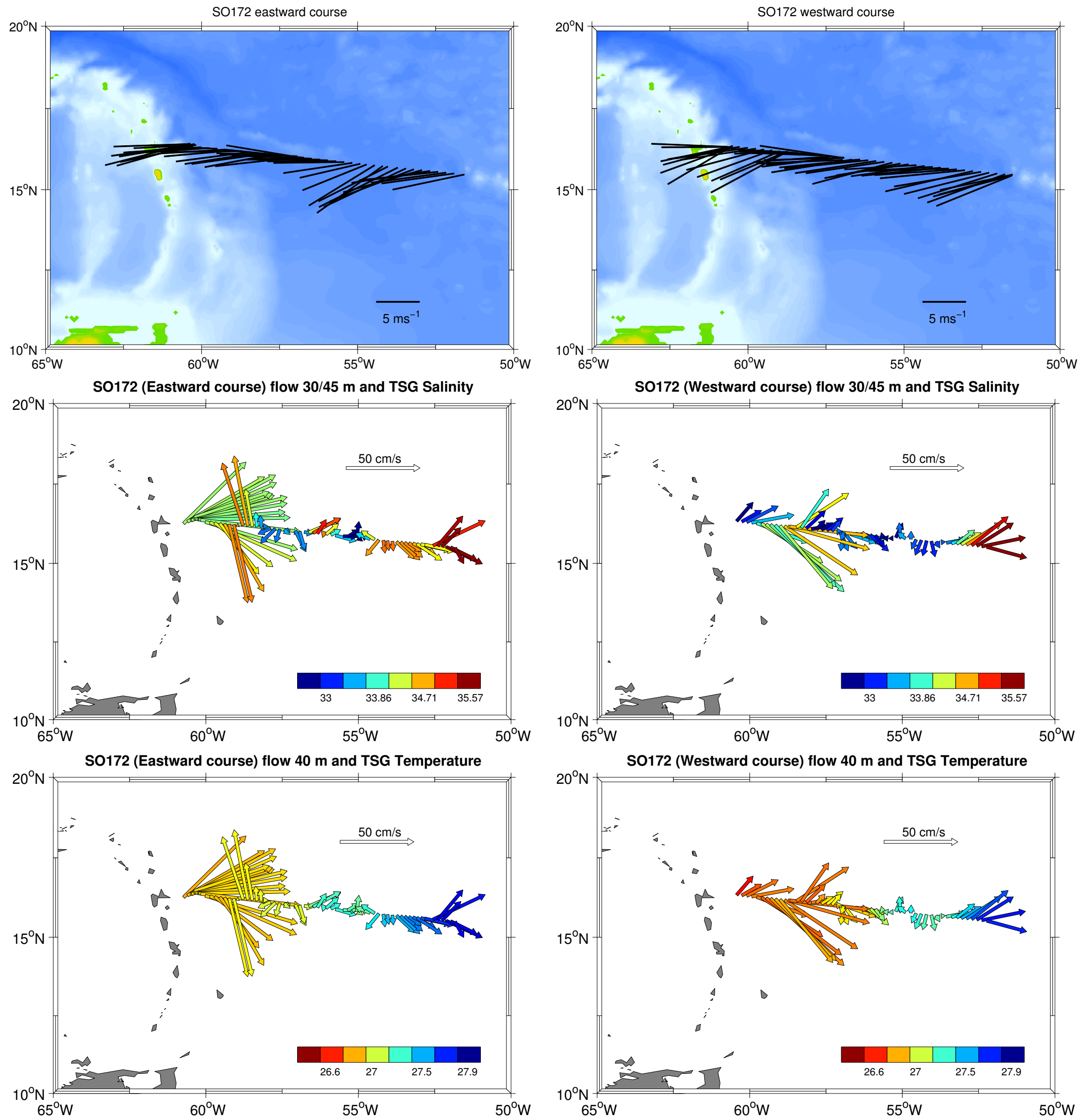


Figure 26: *True wind (upper), TSG temperature (middle), and TSG salinity (lower) measurements on eastward course (left) and westward course (right). For temperature and salinity the upper layer (25/40m) OS75 velocity vectors are color coded.*

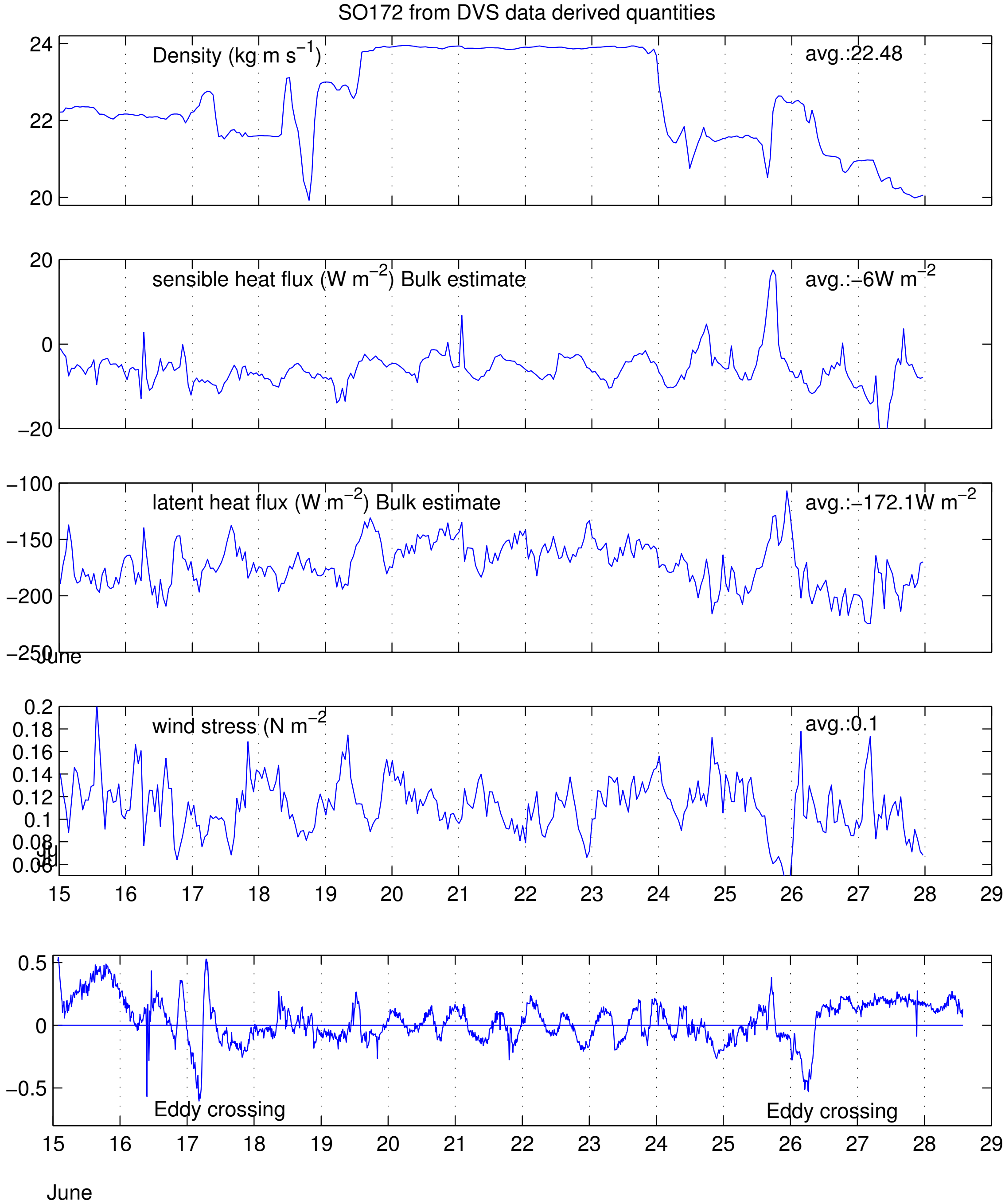


Figure 27: *From DVS data derived quantities as labelled in the upper left corner of the figures. Note values are not corrected for the instruments height of 20m. Lowest panel is the meridional velocity record in the first bin of the vmADCP (OS75).*

## References

[1] Fairall, C.W., et al., 1996: Bulk parameterization of air-sea fluxes for Tropical Ocean-Global Atmosphere Coupled-Ocean Atmosphere Response Experiment, J. Geophys. Res., 101: 1295-1308

[2] Fischer, J., et al., 2003: Surveying the upper ocean with the Ocean Surveyor: A new phased array doppler current profiler, J. Atmos. Ocean Tech., 20: 742 - 751.

[3] Visbeck, M.,2002:Deep Velocity Profiling using Lowered Acoustic Doppler Current Profiler: Bottom Track and Inverse Solutions, J.Atmos. Ocean Tech.,19: 794-807.

[4] Weiss, R.F., 1970: The solubility of nitrogen, oxygen and argon in water and seawater. Deep-Sea Res., 17:721-735.

# 13 Diary (all times local)

| | |
|---|---|
| SAT 14.6. | |
| 16:00 | safety maneuver outside PTP harbour |
| 18:00 | depart |
| SUN 15.6. | |
| 00:00 | checked PIES3 (ser.#12), alive and answering ok (using hull-mounted transducer with DS7000 with URI codes) |
| 01:00 | release bottom pressure sensor SIO3 (ser.#12) |
| 02:30 | SIO3 on surface and recovered (problem finding instrument since FM direction finder of ship not working; located flashing light and recovered over 1nm from nominal position) |
| 04:00 | recover 3 acoustic transponders (until 08:00) (ascent speed 1.2-1.3m/s for large TR6000, worked well with hull-mounted ship hydrophone, burn-wire released after few minutes, burning confirmed with beacon-mode pings every 3sec approx.) |
| 10:30 | recover mooring M4 (until 13:00) over stern, upper 30m had been recovered by P.Gervain previously, |
| 14:30 | recover mooring M5 (until 16:00), over stern |
| 17:00 | start mooring M3 recovery over stern. |
| 19:30 | mooring wire breaks after 1600m, at a weak/corroded splice, since dark ship cannot go back and search. Located acoustic release from 1300m finally, also with hull-mounted transducer, so could maneuver ship to stay closeby. Start this with changing staff around 22:00. |
| MON 16.6. | |
| 04:00 | chief scientist woken up since had mooring lost acoustically for 1-2 hours, before that acoustics got worse and worse and distance had increased to 2km. Attempts to locate mooring acoustically from various best-guess locations (assuming the prior currents of over 1kn had ceased since 2am according to ship displacement and bridge doppler data). Until 09:00. No success. |
| 09:00 | Analysis of vmADCP data showed large currents all night long and displacement since 23:00 of 12nm. Started grid search pattern, 6x7nm around most likely displaced position already 14nm away (by 11am). Located mooring at 12:00. |
| 13:00 | start recovery of remaining M3 mooring part (3400m) (until 15:30) this time over side since less tension on wire. |
| 17:45 | deploy bottom pressure sensor SIO3 (ser.#12) |
| 18:00 | start steaming 19h for site M2 (207nm at 10.5kn against wind) |
| TUE 17.6. | |
| | ship's FM direction finder was repaired (1 antenna broken off) |
| 12:00 | recover 3 transponders at site M2 (until 15:30), 10mins to burn wire each time, ascent 1h5min to 1h15min |
| 16:00 | recover mooring M2 (until 20:30) |
| 21:30 | release PIES2, after confirming release command no more replies received from instrument; normally takes 1h45min to surface (incl about 15min for burning) but even after 2h30min no surface contact (radio or flash). By chance, it was then located near the ship with a night vision binocular and recovered (24:00). Had water inside (200-300ml) and wet/crusted electronics. Data recovered from PC card were ok. |

| WED 18.6. | |
|---|---|
| 00:00 | CTD #1 (until 03:30) |
| steam 30h | (313nm @10.5kn against wind) |
| 14:00 | stop to check FM direction finder with boat circling the ship, combined with man-overboard maneuver |
| 19:00 | continue stop for CTD #2 with microcats (until 23:30), making long stops for mCats |
| 23:30 | continue steaming |
| THU 19.6. | |
| 13:40 | deploy telemetry PIES (ser.#56) at M1 site, at bottom 15:30 test data telemetry in burst mode - works, but fluctations in traveltime of 1-2ms (data are encoded to 0.1ms accuracy !!!) - problems turns out to be ship motion - have to correct this somehow. |
| 16:30 | release mooring M1/V404-2, 16:45 start recovery, done 20:30, recovery done over the side to avoid too much tension on weak wire/splices |
| 21:00 | acoustic reading of PIES1 telemetry data in burst mode (no ship motion compensation yet) |
| FRI 20.6. | |
| 07:00 | recover bottom pressure sensor SIO1 (ser.#3) start temperature calibrations for SIO1 |
| 09:30 | CTD/lADCP #3 with microcats |
| 14:00 | test of mooring winch with wire/weight over stern |
| 16:40 | CTD/lADCP #4 with microcats |
| 20:00 | acoustic reading of PIES telemetry data (all night) in burst mode, recording ship motion with SIMRAD accelerometer |
| SAT 21.6. | |
| 07:00 | release bottom pressure sensor POL1; even after many tries and confirmed commands the sensors stays on the bottom (range from transpond pings constant) |
| 08:30 | release PIES1(ser.#2) |
| 10:30 | PIES1 on surface, 15min later on deck |
| 12:00 | acoustic releaser tests |
| 15:00 | CTD/lADCP#5 with microcats to 1000m |
| 16:00-22:00 | preparations for OFOS camera system, in meantime acoustic survey of POL1 to determine location to a few meters |
| 22:00 | OFOS search for bottom pressure sensor POL1 for this had modified a small transponder to reply at 11kHz which then triggers the POL1 to reply at 12kHz. Difference between 11 and 12kHz signal is measure for distance between OFOS and POL1 (make sure 10m or more above POL1 due to ray bending). With that could navigate OFOS to stay within 30m or so POL1 during whole search, but the 2m field of view and hooks and line below OFOS never found POL1 in 8hrs search at bottom, impossible to maneuver OFOS from above and know its position below/behind ship, even though ship moved slowly with 10m accuracy all the time. |

| | |
|---|---|
| SUN 22.6. | |
| 10:30-14:30 | sort out problems about mooring deployments after dark (had wanted to do CTD for required calibrations and then mooring deployment around 15:00) |
| 15:30 | CTD/lADCP#6 with TD-loggers to 4000m |
| 19:00 | CTD/lADCP#7 with microcats |
| 23:00 | deploy bottom pressure sensor SIO1 |
| MON 23.6. | |
| 01:00 | acoustic reading of 3 days of PIES1(ser.#57) data in file mode, recording ship motion data with SIMRAD accelerometer |
| 04:00 | drift test for mooring M1 |
| 05:15 | deploy mooring M1/V404-4 with telemetry (until 13:15) |
| 14:00 | depart for site M2, steam 25h (313nm @12.5kn) |
| TUE 24.6. | |
| 14:00 | release tests |
| 15:30 | drift test for mooring M2 |
| 16:15 | deploy mooring M2/V405-3 with tomography receiver (until 21:20) |
| 22:45 | deploy acoustic transponders for M2tomo |
| WED 25.6. | |
| 00:30 | deploy inverted echosounder PIES2 (ser.#2), recovery line got wrapped around a leg of the tripod - may lead to entangling when trying to recover; decision not to release during descent since may have got twisted and after release command it goes into beacon mode until batteries dead. This way can still locate it in transpond mode, get measurements, and try to find it next year (get ROV or something...) |
| 02:00 | survey acoustic transponders for M2tomo and PIES2, since built-in ship transducer not working, had to do 10 stops and use hydrophone over the side; high accuracy wanted in case have to search for PIES next year |
| 07:00 | steam 17h (207nm @12.5kn) for site M4 |
| 14:00 | stop for acoustic release tests |
| 15:00 | continue stop for CTD #8 with microcats |
| 20:00 | continue stop for hydrosweep calibration course (4 hours) |
| THU 26.6. | |
| 08:05 | release PIES3 (ser.#12), pings very hard to see |
| 09:50 | PIES at surface, FM transmitter received but irregular |
| 10:50 | release bottom pressure sensor POL3 |
| 11:30 | drift test for mooring M3 |
| 13:00 | bottom pressure sensor POL3 on surface (radio signal), recovered at 13:30 |
| 14:30 | deploy mooring M3/V406-4 with telemetry (until 20:30), ADCP float down at 21:10 according to ARGOS watchdog. This mooring was modified to have only 1 instead 2 ADCP floats, instead 3 clamp-on plus more glass balls, giving safer anchor weight and launch tension but slightly higher subduction (500m instead of 350m for strong event). Telemetry later gave depth for 40m microcat of 120-160m due to currents, and position near 16 20.0N 60 29.7W. |
| 21:30 | acoustic release tests |
| 22:30 | CTD/lADCP#9 (no microcats) |

| | |
|---|---|
| FRI 27.6. | |
| all day | build new frame and bottom weight for POL3 sensor, since it had not been planned to re-deploy this one. |
| 07:00 | drift test for mooring M4 |
| 08:45 | deploy mooring M4 (until 11:30) |
| 15:00 | drift test for mooring M5 |
| 15:30 | start mooring M5 deployment |
| 16:00 | stop deployment since ARGOS watchdog stopped working, pull mooring in again |
| until night | repairs of several IfM watchdogs, all new ones brought from Kiel had intermittent reset problems; rebatterying of old ones (which were recovered and had worked) yielded similar problems in lab and in water; modifications to make power supply electronics less sensitive to HF radiation; tests in water; then watchdogs available for deployments next day |
| SAT 28.6. | |
| 07:15 | drift test for mooring M5 |
| 08:15 | deploy mooring M5 (until 09:30) |
| 10:30 | fire exercise |
| 14:00 | wanted to test tomo projector, but actuator for sleeve not moving; diagnosis shows various damaged electronics parts, possible due to obstructed movement of sleeve while being handled on deck, resistor in motor drive burnt, but also sail loop damaged. |
| all night | repairs of projector electronics |
| 19:00 | deployment of bottom pressure sensor POL3 at site M3 |
| 20:10 | deployment of PIES3 (ser.#12) |
| SUN 29.6. | |
| all day | trouble shooting, tests, repairs of tomography projector |
| 18:00 | in-water tests (until 20:00), with projector lowered vertically (with sail cable connected) to 20m depth. There, all functions were verified, phase tracking correct, and transmissions (at power level 80) were heard clearly in bilge of ship. |
| 22:00 | deploy transponders for mooring M3-tomo, survey transponders |
| MON 30.6. | |
| 06:00 | drift test for mooring M3.5-tomo |
| 07:45 | deployment of mooring M3.5-tomo (until 12:15) |
| 13:00 | depart for PTP |
| | arrive PTP 18:00 |
| TUE 1.7. | |
| 08:00 | unload ship |
| 12:00 | depart PAP for Balboa |

# 14 Appendix

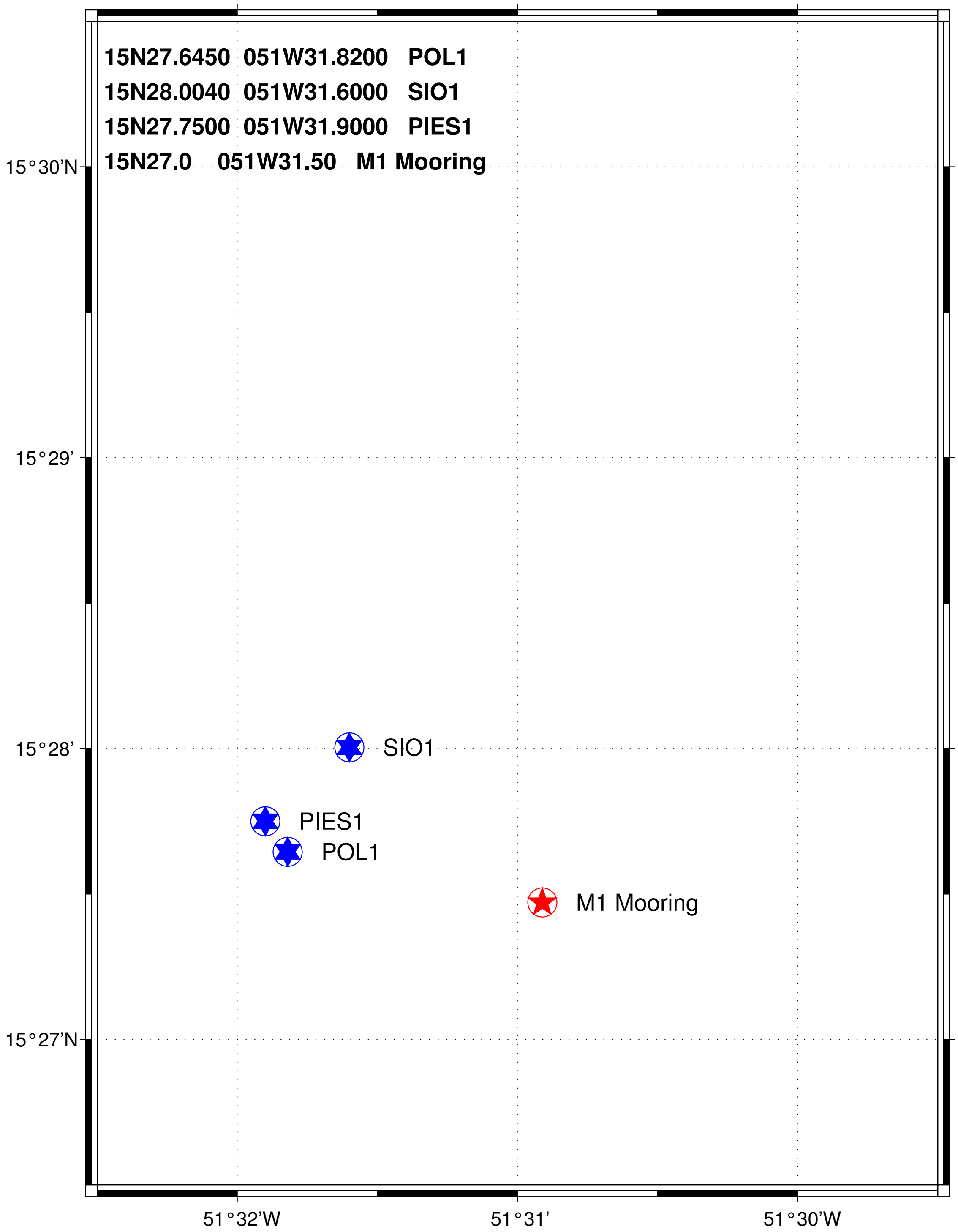


Figure 28: *Position of M1 Mooring and Bottom Pressure Sensors.*

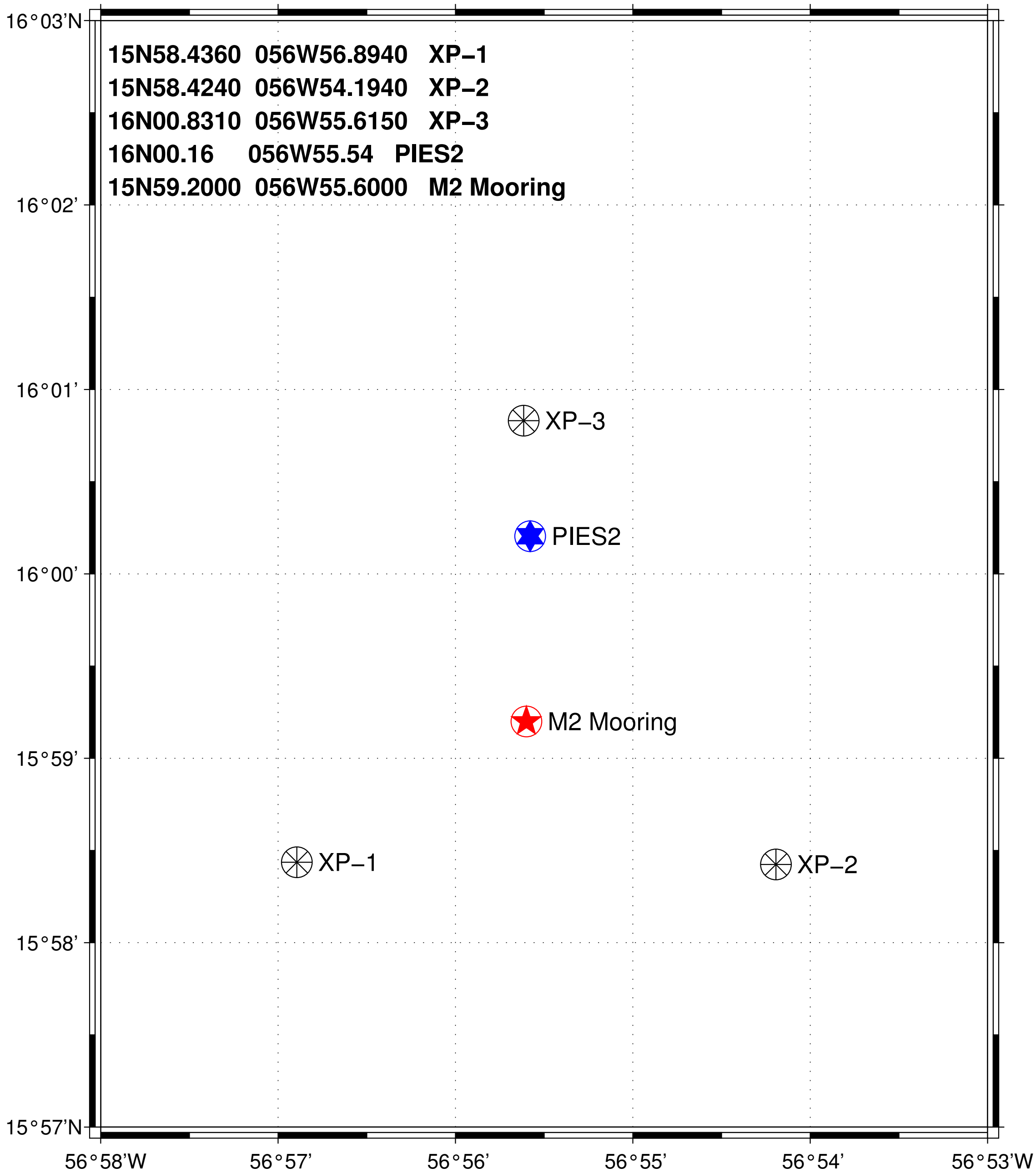


Figure 29: *Position of M2 Mooring, Bottom Pressure Sensors and Transponders.*

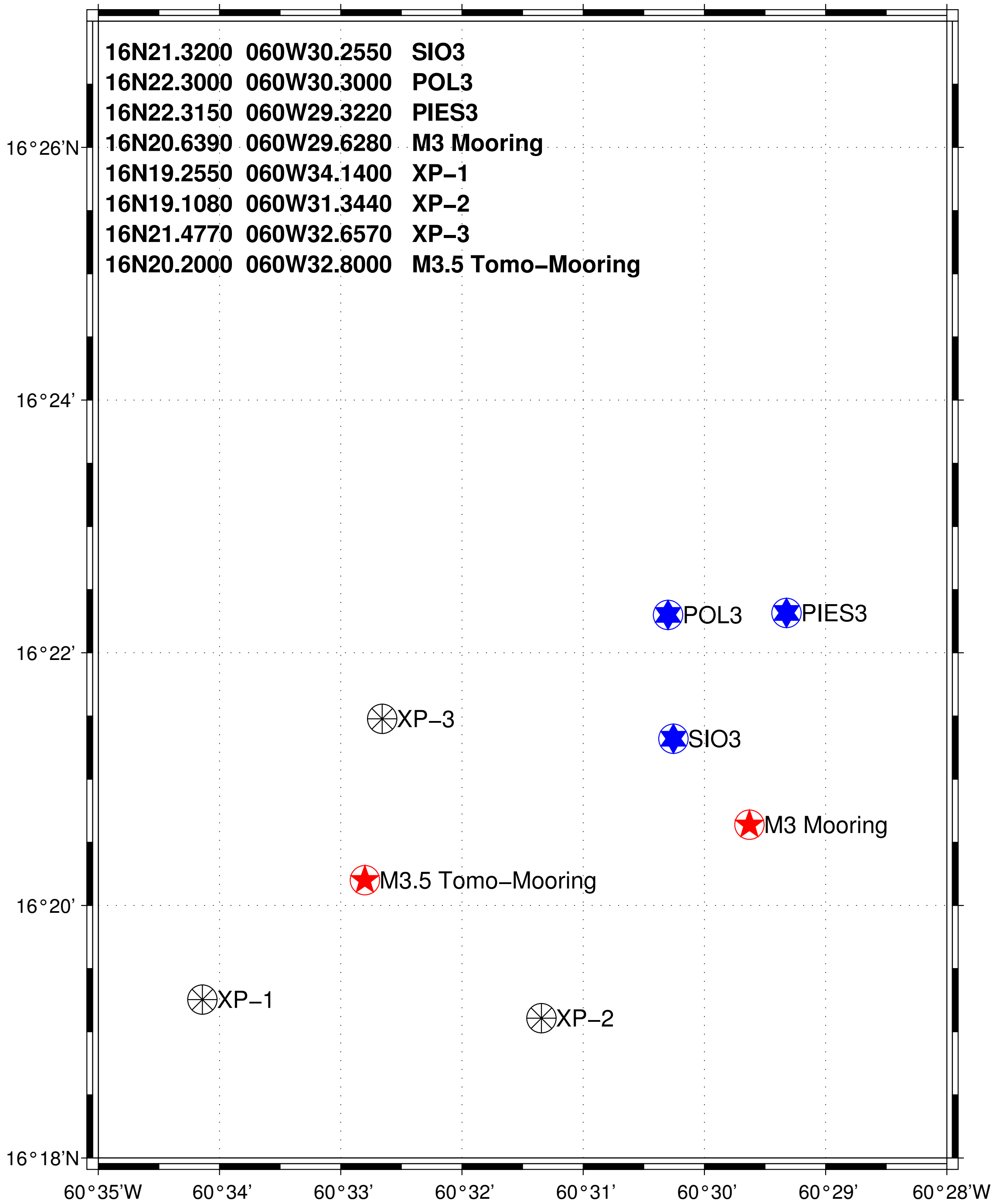


Figure 30: *Position of M3 Mooring, Bottom Pressure Sensors and Transponders.*

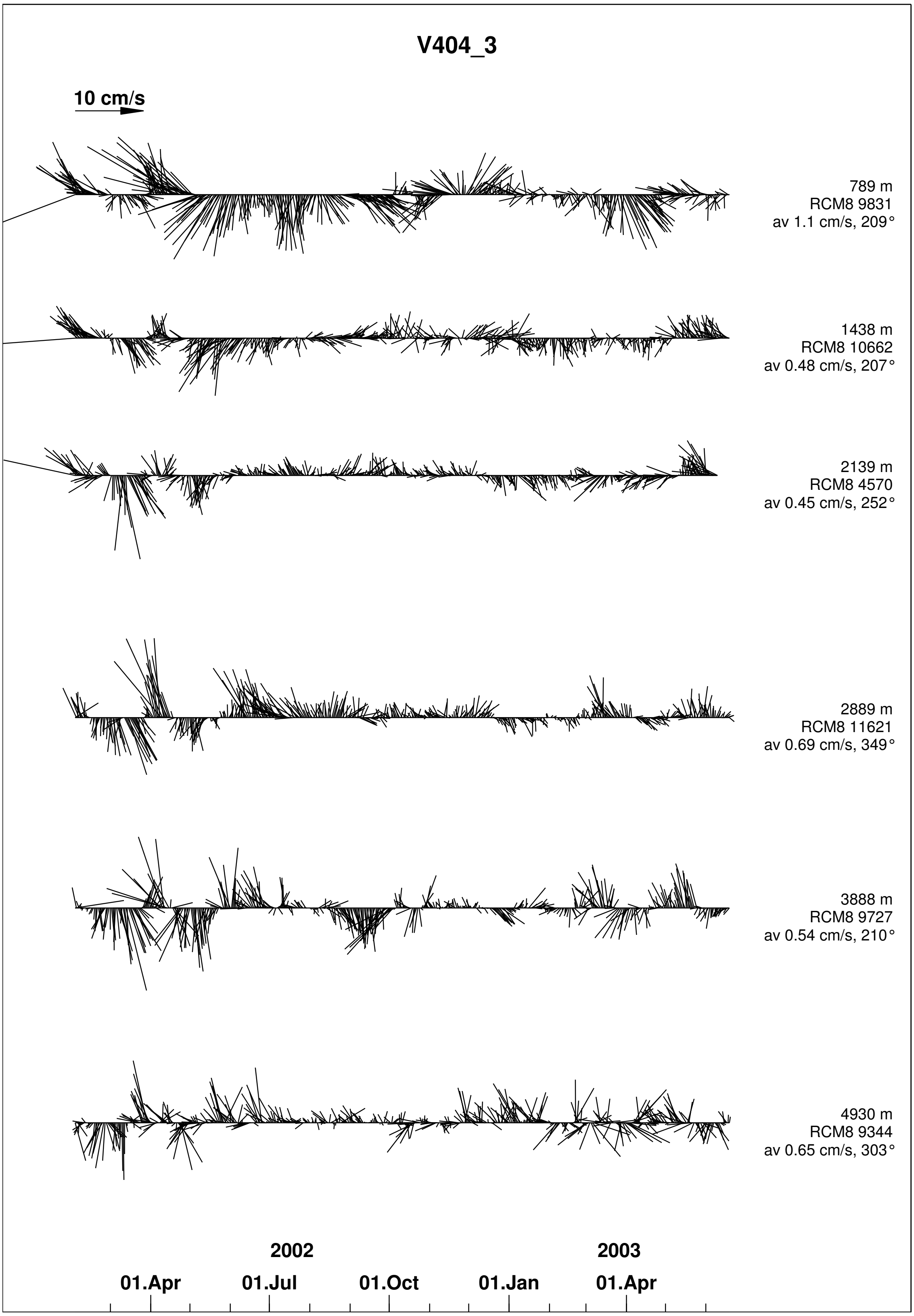


Figure 31: *Time series of vector plots from mooring M1 (v404_3)*

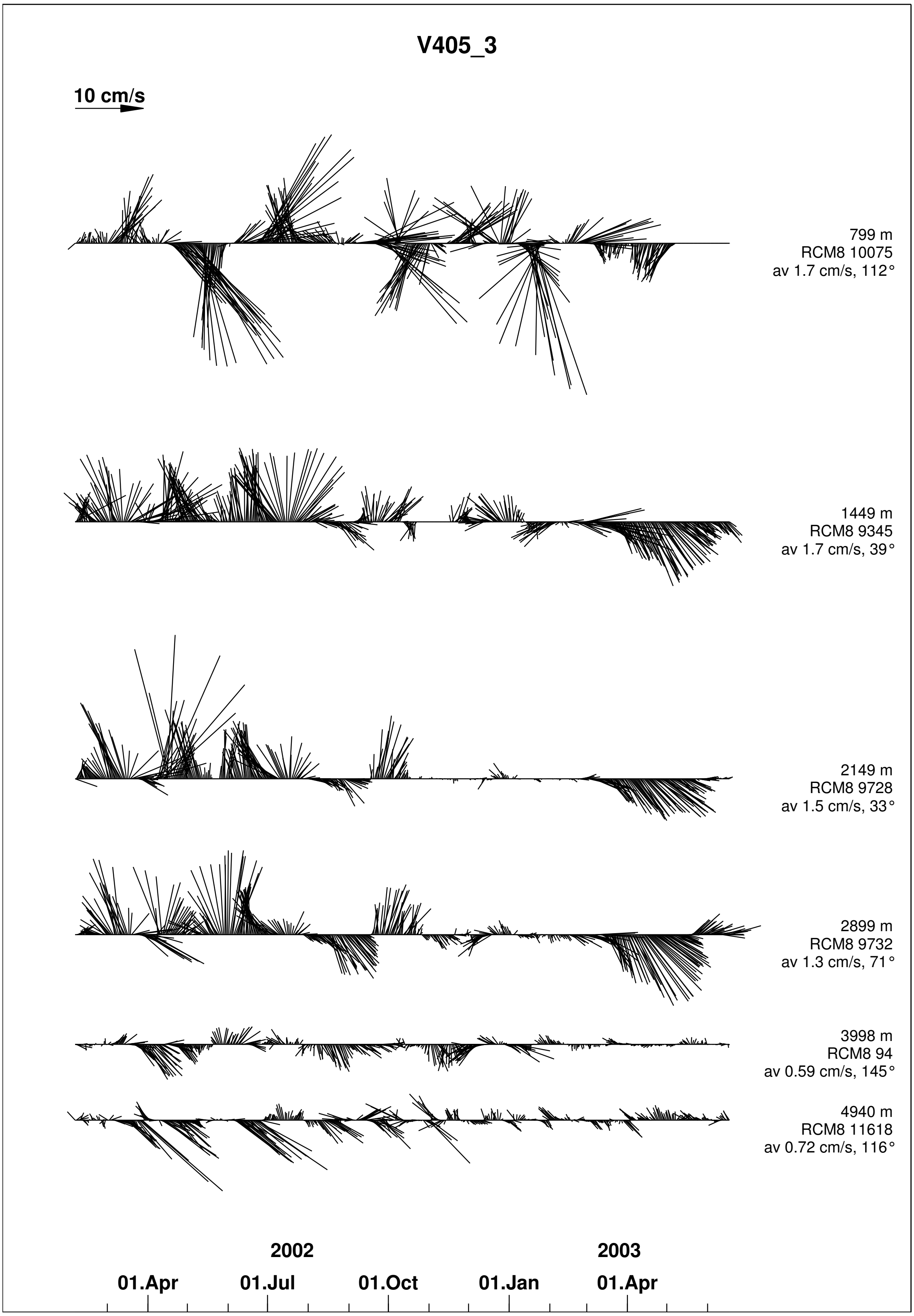


Figure 32: *Time series of vector plots from mooring M2 (v405_3)*

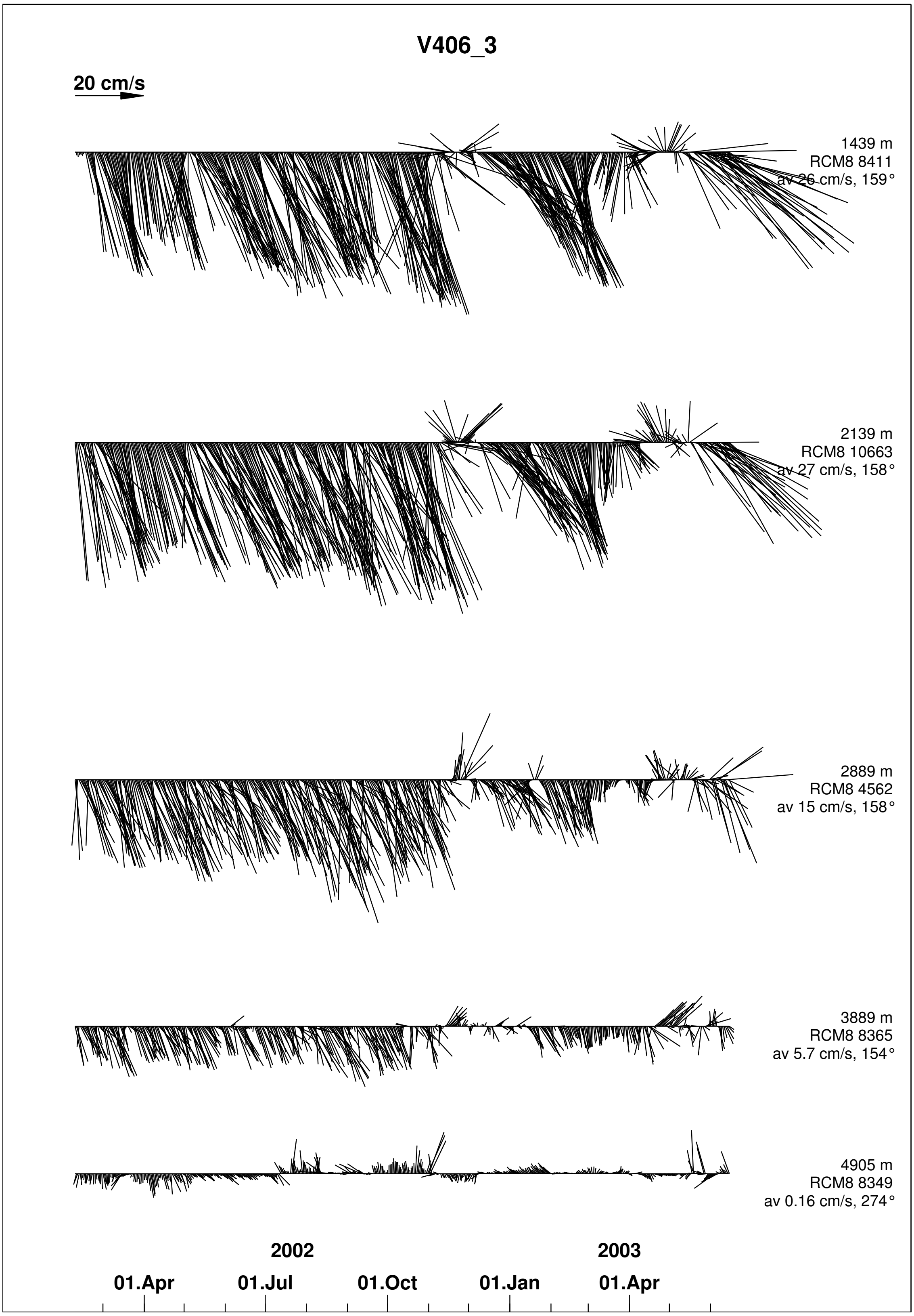


Figure 33: *Time series of vector plots from mooring M3 (v406_3).*

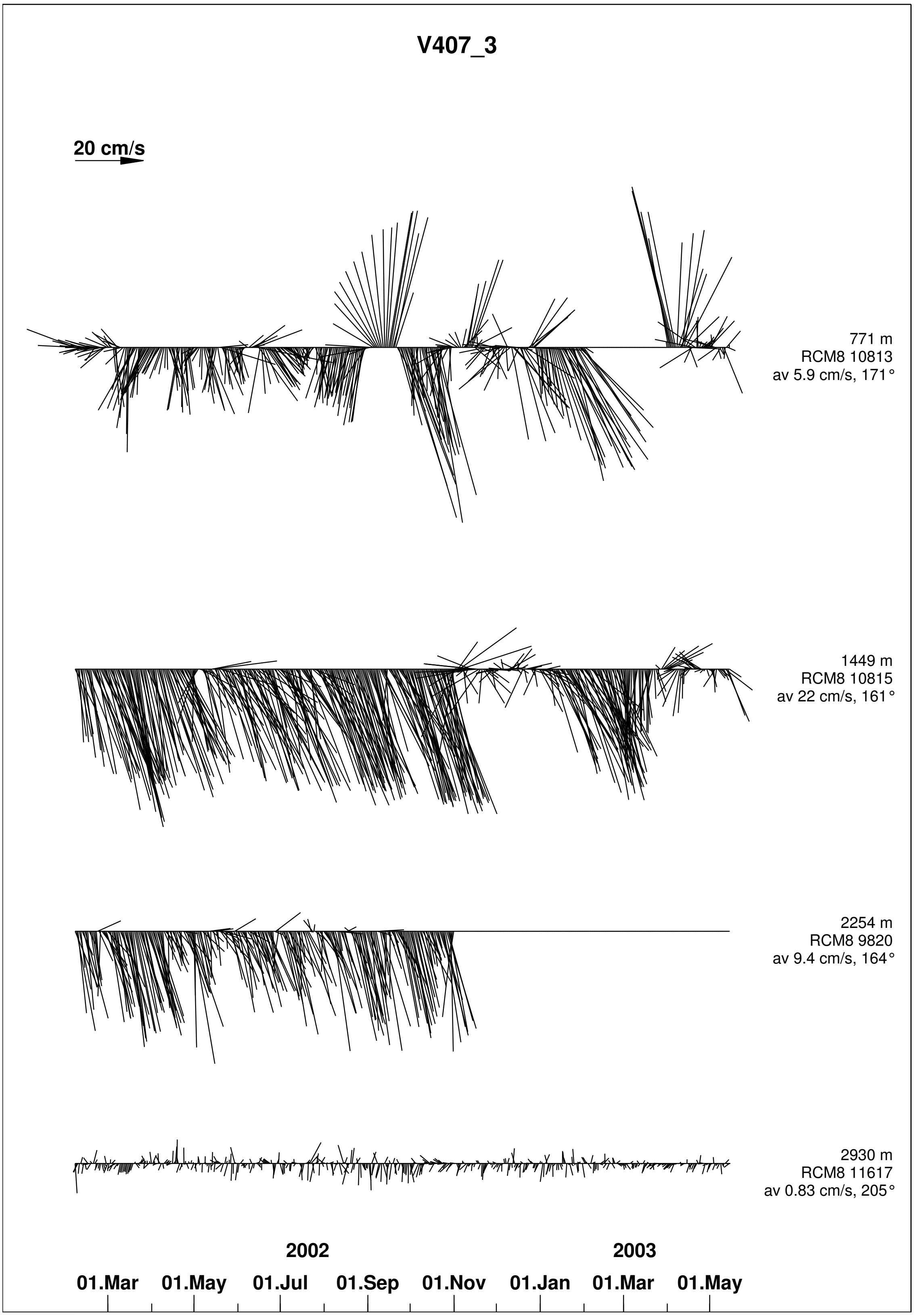


Figure 34: *Time series of vector plots from mooring M4 (v407_3).*

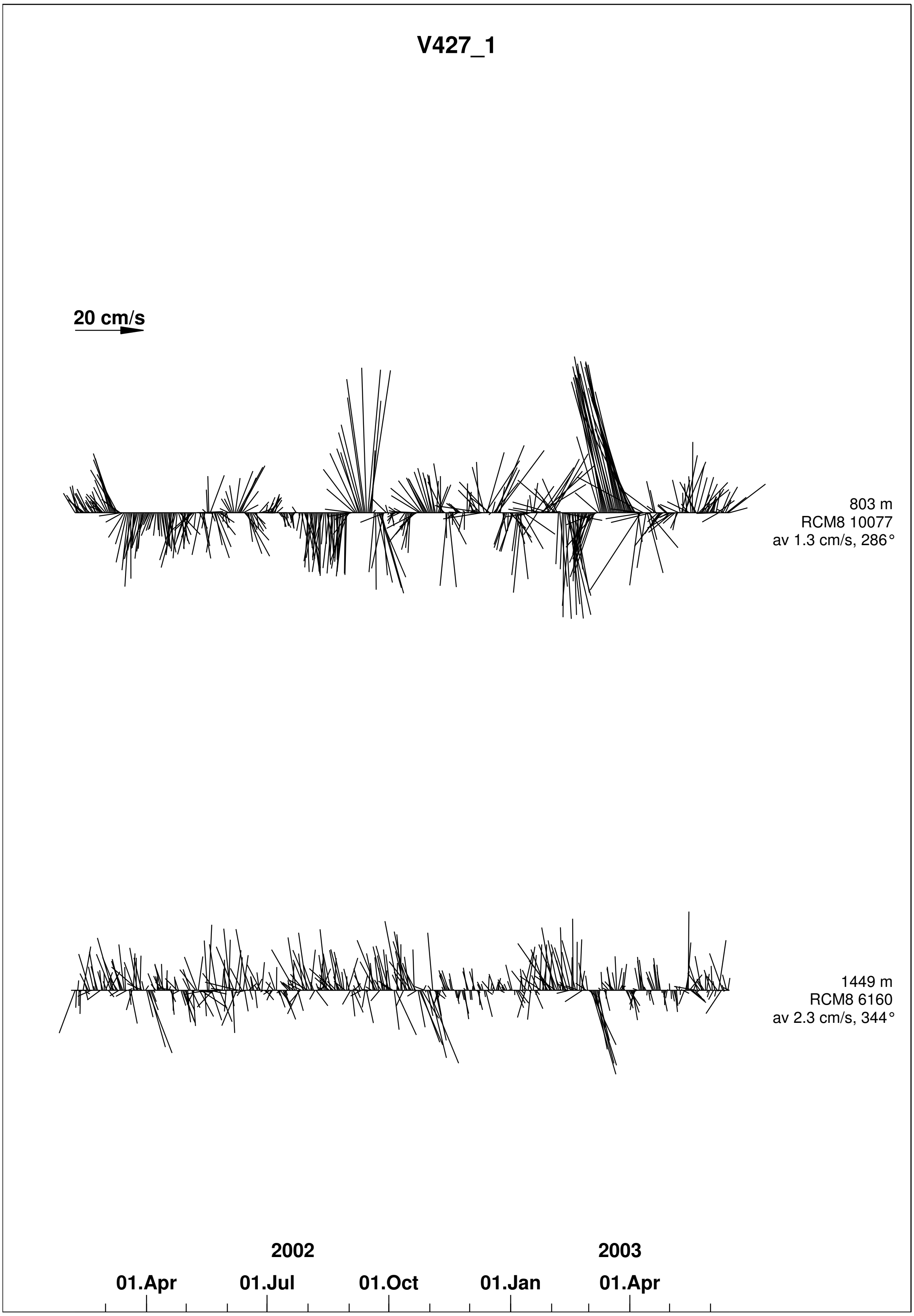


Figure 35: *Time series of vector plots from mooring M5 (v427_1)*