**SFB 754**

METEOR -Berichte

# *Oxygen in the Tropical Pacific*
# *POSTRE II First Tracer Survey*

Cruise No. M135

March 01 – April 08, 2017
Valparaiso (Chile) – Callao (Peru)
POSTRE-III


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2017

**Table of Content**

# 1 Cruise Summary

## 1.1 Summary

Cruise M135 was a contribution to the DFG Collaborative Research Project (SFB) 754: "Climate-Biogeochemistry Interactions in the Tropical Ocean" with the main goal to better understand the the role of diffusive and advective pathways connecting water within the bottom boundary layer (i.e. the water directly affected by sediment processes) to the pelagic and surface ocean. To achieve this, we have injected a conservative tracer ($CF_3SF_5$) within the bottom boundary layer at three different sites along the Peruvian coast at a depth of about 300 m in October 2015 that was mapped during M135. Tracer sampling was carried out by measuring water samples from the CTD-rosette water bottles. In total 144 CTD casts were carried out. From 132 CTD profiles 2828 samples for $CF_3CF_5$ investigations were gained and on most stations the tracer could be found. In addition 48 trace metal CTD's were recorded and trace metal and chemical samples taken from the rosette bottles. On 166 of the CTD profiles oxygen samples were taken and on 94 CTD profiles nutrient samples were collected. Microstructure measurements were made on 24 stations and 2 gliders were deployed. For geological investigations at 5 locations multicorer and long gravity cores were taken. Continuous underway measurements of $CO_2$,$N_2O$ and CO as well as continuous ADCP and thermosalinograph recording was made on 37 days.

The cruise M135 was very successful; most systems on METEOR worked well and all planned objectives were reached.

## 1.2 Zusammenfassung

Die Reise M135 war ein Beitrag zum DFG Sonderforschungsbereich 754: „Klima-Biogeochemische Wechselwirkungen im Tropischen Ozean“. Ein Hauptziel der Fahrt war es die Rolle der diffusiven und advektiven Pfade von der Bodengrenzschicht (d.h. das Wasser das direkt von den Sedimentprozessen beeinflusst wird) in den pelagischen und Oberflächenozean zu quantifizieren. Um dies zu bestimmen, wurde ein konservativer Tracer ($CF_3CF_5$) an drei verschiedenen Positionen in der Bodengrenzschicht entlang der peruanischen Küste in einer Tiefe von ca. 300 m im Oktober 2015 ausgebracht, der auf M135 vermessen wurde. Tracer Messungen wurden aus Wasserproben, die aus den CTD-Rosetten Schöpfern genommen wurden durchgeführt. Insgesamt wurden 144 CTD Profile gewonnen. Von 132 CTD-Profilen wurden 2828 Proben für $CF_3CF_5$ Untersuchungen genommen und in den meisten Profilen konnte der Tracer nachgewiesen werden. Zusätzlich wurden 48 Spurenmetall-CTD Profile aufgezeichnet und Spurenmetall-und chemische Parameterproben aus den Schöpfern entnommen. Auf 166 der CTD Profile wurden Sauerstoffproben genommen und auf 94 CTD Profilen Nährstoffproben gesammelt. Mikrostruktur Messungen wurden auf 24 Stationen durchgeführt, sowie 2 Glider ausgesetzt. Bei den geologischen Arbeiten wurden auf 5 Stationen Multicorer und Schwerelot-Kerne gezogen. Kontinuierliche Messungen während der Fahrt wurden für $CO_2$, $N_2O$ und CO sowie für das Schiffs-ADCP und den Thermosalinograph an 37 Tagen durchgeführt.

Die Reise M135 wahr sehr erfolgreich, die meisten Systeme der METEOR liefen gut und fast alle geplanten Ziele konnten erreicht werden.

## 2 Participants

| Name | Position/Discipline | Institute |
|---|---|---|
| 1. Visbeck, Martin, Prof. Dr. | Chief Scientist | GEOMAR |
| 2. Tanhua, Toste, Dr. | Tracer | GEOMAR |
| 3. Schmitdko, Sunke, Dr. | CTD | GEOMAR |
| 4. Begler, Christian (technician) | CTD | GEOMAR |
| 5. Klenz, Thilo (student) | ADCP/CTD | GEOMAR |
| 6. Stramma, Lothar, Dr. | CTD/Salinometer | GEOMAR |
| 7. Link, Rudolf (technician) | CTD | GEOMAR |
| 8. Evers, Florian (technician) | CTD/ TM winch | GEOMAR |
| 9. Lüdecke, Nils (student) | $O_2$ and nutrients | GEOMAR |
| 10. Mutzberg, Andre (technician) | $O_2$ and nutrients | GEOMAR |
| 11. Eroglu, Sümeyya, Dr. | $O_2$ and nutrients | CAU |
| 12. Bogner, Boie (technician) | Tracer | GEOMAR |
| 13. Freund, Madeleine (PhD student) | Tracer | GEOMAR |
| 14. L'Esperance, Chris (PhD student) | Tracer | DAL |
| 15. Ketelhake, Sandra (student) | Tracer | GEOMAR |
| 16. Lange, Nico (student) | Tracer | GEOMAR |
| 17. Liu, Mian (PhD student) | Tracer | GEOMAR |
| 18. Hopwood, Mark, Dr. | Trace metals | GEOMAR |
| 19. Chu, Keshen (PhD student) | Trace metals | GEOMAR |
| 20. Nehir, Münevver (PhD student) | Trace metals | GEOMAR |
| 21. Langmaack, Jannis (student) | CTD | GEOMAR |
| 22. Steinig, Sebastian (student) | Geological sampling | CAU |
| 23. Salvatteci, Renato, Dr. | Geological sampling | CAU |
| 24. Groß, Felix, Dr. | Geological sampling | CAU |
| 25. Velazco, Federico, Dr. | Geological sampling | IMARPE |
| 26. Ortiz-Cortes, Joaquin (student) | N2-fix | GEOMAR |
| 27. Lorca Luna, Alejandra | Observer Chile | PUCV |
| 28. Raeke, Andreas | Weather Technician | DWD |
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**Fig. 2.1** Scientific party of M135

## 3 Research Program

The primary goal of M135 was to quantify the role of diffusive and advective pathways connecting water within the bottom boundary layer (i.e. the water directly affected by sediment processes) to the pelagic and surface ocean. This exchange can be a consequence of either enhanced mixing close to the bottom or advective processes. To achieve this, we have injected a conservative tracer ($CF_3SF_5$) in October 2015 within the bottom boundary layer at three different sites along the Peruvian coast at a depth of about 300 m that was surveyed for the first time. One goal was the quantification of the strength of mesoscale and submesoscale transports and their influence on the ventilation of the OMZ, and quantification of the flux of oxygen, nutrients and other biogeochemicaly relevant compounds from the bottom boundary layer and the surface and interior ocean. We will also aim for determination of diapycnal mixing coefficients by additional ship and glider based turbulence measurements. The observed spreading rates will allow for assessment of the realism of models such as ROMS and to give some ground truth testing to parameterization of exchange rates for other types of models. Ship-based observations of horizontal velocities (from the ADCP) will provide information on the strengths and horizontal scales of the local circulation and thus estimates of horizontal and vertical shear as the prime mixing agents. The coarsely spaced CTD stations will give some indication of the horizontal water mass and tracer correlation and hence additional information relevant for stirring and mixing. Deployment of the Underwater Vision Profiles on all CTD casts during the cruise will extend the dataset that will be gathered during the accompanying cruises within SFB754 towards regions with higher OMZ core oxygen concentrations (off Chile) and further into the open ocean. This data will be valuable to test the hypothesis that particle characteristics and particle flux are correlated with zooplankton abundance and their oxygen tolerance.

In addition we were able to perform a substantial mapping of the South Pacific oxygen minimum zone (OMZ) south of 12°S. Observational and experimental work addressed the fluxes of N, P and Fe and the behavior of Fe in the water column. Fluxes of N, P and Fe from the bottom boundary layer to surface waters, and from the shelf-slope region to off shore oceanic waters, will be quantified using observations of N, P and Fe species in association with geochemical tracers (radium), physical observations (advective and turbulent mixing) and modelling efforts, in strong collaboration with the tracer release observations and physical oceanographic and modelling efforts in the SFB754 project. We will investigate the stabilization of Fe by organic iron binding ligands and formation of Fe nanoparticles under varying redox conditions. We will investigate the distribution of Fe(II) in the water column away from the sediments, with special emphasis on the oxidation kinetics controlled by oxygen and reactive oxygen species, and the potential stabilization of Fe(II) by ligands. We will use radium, cobalt and manganese as tracers of benthic P and Fe release, and the I-/IO3- pair as a sensitive indicator of suboxic conditions. This combination of elements will act as additional tracers of shelf inputs, and redox/recycling processes on the Peruvian shelf. A range of trace elements (Al, Ba, Cd, Cr, Cu, Co, Mo, Ni, Pb, Ti, U, Zn) will be analyzed as part of our routine analytical protocol to assist us and other subprojects with data interpretation. We will assess the changes in semi-labile DOP and DON with distance away from the OMZ using the tracers phosphomonoesters and total amino acids.

The paleoceanographic studies focused on the retrieval of sediment cores for the reconstruction of centennial to millennial scale climate change and low-latitude oxygen minimum conditions off Peru: How have past surface and subsurface ocean conditions within the Peru-Chile Current changed with respect to temperature (salinity), thermocline structure, productivity, and OMZ conditions south of the central Peruvian upwelling area during the last 25 ka BP? The cores should link the existing paleoceanographic records off central and northern Peru obtained during former cruise with RV METEOR in 2008 (M77-2) with new records to be established for the transition zone of the Peru-Chile Current between the upwelling zones off Peru and Chile, that is characterized by large extent of oxygen depletion in subsurface waters along the margin.

Thus the main objectives were:

- Map the conservative tracer along the Humboldt-Current System
- Map the water mass properties with regards to temperature, salinity, oxygen, nutrients, transient tracer and trace elements
- Map the boundary current and eddy velocity and density fields
- Determine the diapycnal mixing along the Peruvian shelf region.
- Observe the $pCO_2$ fluxes and sea surface temperature and salinity conditions
- Map the particle abundance using an Underwater Vision Profiler
- Perform biological sampling and incubation experiments
- Execute an acoustic sediment survey
- Recover sediment cores
- Deploy two gliders for the subsequent M136 leg

The cruise was very successful and most objectives were reached and the measurements were roughly carried out as planned.

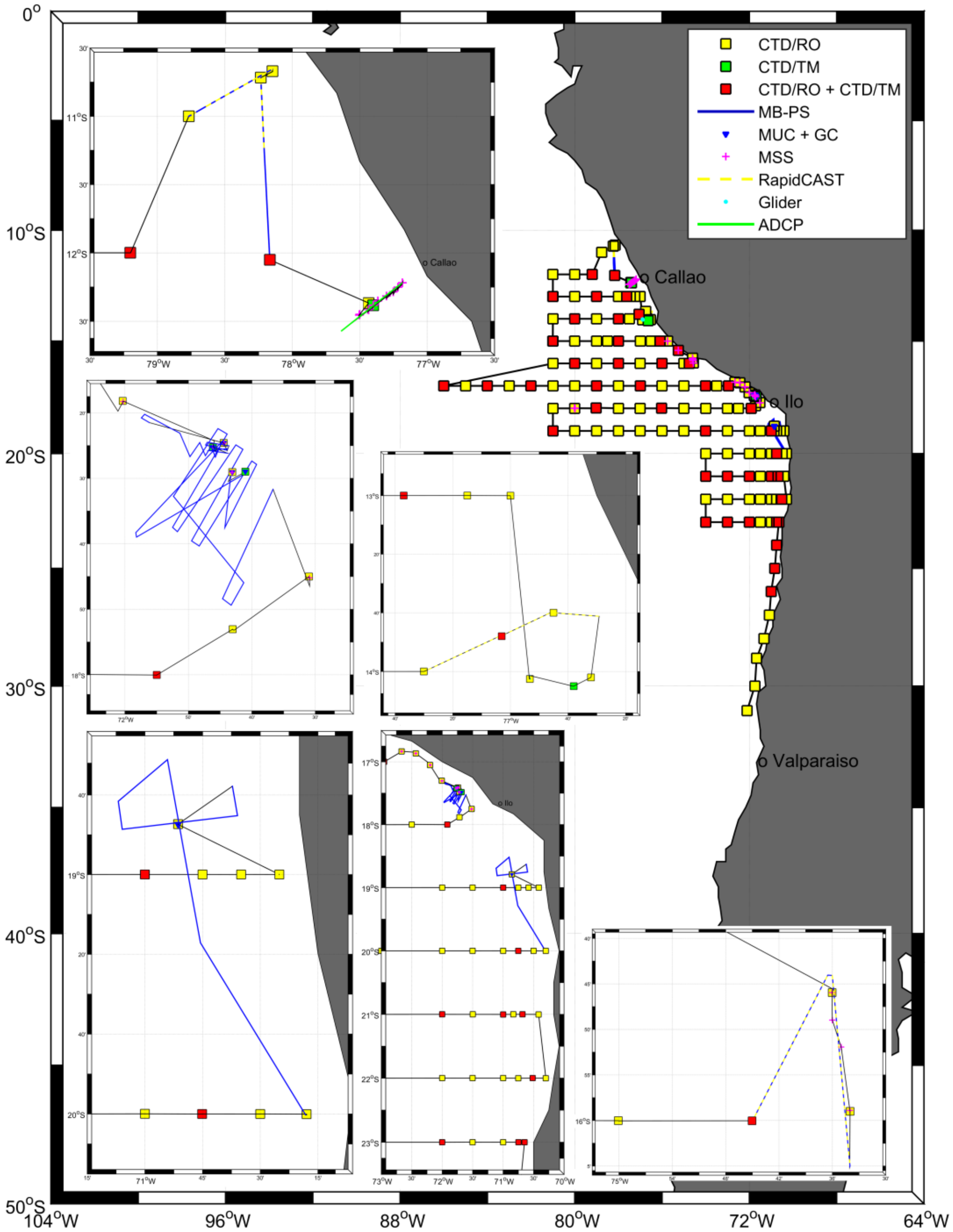


**Fig. 3.1** Cruise track of METEOR cruise M135 with locations of stations.

## 4 Narrative of the Cruise

R/V METEOR departed from Valparaiso, Chile in the evening of March 1 2017 an began a transect along the 2000m isobath northward with the first CTD-station at 31°S with a station every 1° until 23°S. On March 5 we performed the first zonal section along 23°S west until 74°W and returning along 22°S back to the shelf. The pattern was repeated along 21° and 20°S until the afternoon of March 10 when an acoustic survey of Chilean shelf between 71°W and 70°20’W and 18°48’S and 18°30’S was performed and a core war recovered at 18°47’S and 70°51’W. On March 11 afternoon the CTD survey resumed from the coast of Chile along 19°S. On March 12 lunch time we crossed into the economic zone of Peru. At 74°W we returned to the coast along 18°S and made a brief stop near Ilo on March 18 to remove an entangled drifting fisher net from the ships hull. The next two days were spent with acoustic surveys and coring operation that yielded five 4-9m long cores near 17°28’S and 71°43’W. On March 21 we began a westward survey along 17°S and reached the western most station at 86°W on March 25. On March 29 we returned to the coast after a section along 16°S and completed two shelf break surveys with echo sounder, underway CTD sections and micro structure profiles. The next CTD survey went westward along 15°S and reached 81°W on March 31 and returned to the coast along 14°S. On April 3 two gliders were deployed at 14° 2’S and 76° 53’W near the position of the last tracer release site. The next section went west along 13°S and on April 5 the final section east along 12°S started at 81°W. On April 6 a short dog leg brought us to the shelf at 10° 40’S the location of the first tracer release position. On April 7 we finished the 12°S section and moved slightly south with a last CTD at the second tracer release site. The expedition finished with a micro structure transect onto the shelf south of 12°S.

METEOR reached the port of Callao, Peru on April 8, 2017.

# 5 Preliminary Results

In the following report, a detailed account of the types of observations, the methods and instruments used as well as some of the early results are given.

## 5.1 CTD System and Calibration

(PI: Sunke Schmidtko, Lothar Stramma, Rudolf Link)

### *5.1.1 CTD-Rosette Systems*

During M135 two different CTD-Rosette systems were used. One was designated for acquiring sampling water for the tracemetal analysis, hereinafter CTD-TM, as described in section 5.5. The other CTD-Rosette System, herein after CTD, was used primarily for the physical and chemical water analysis. Combined a total of 192 CTD-profiles and 3169 water samples were collected. For the CTD, the rosette system was installed in a Seabird Rosette System frame for 24 bottles. See Table 5.1.1 for sensor details. Depth profiles were performed up to a maximum pressure of 4832 dbar, along the shelf break section reached up to 2000 dbar and in the open ocean for the majority of stations only the top 1000m of the water column was sampled. Similar sampling procedure was performed on the CTD-TM.

Data acquisition on the CTD was done using Seabird Seasave software version 7.23.2; pre processing was done with SBE Data Processing 7.23.2. The CTD-TM used Seabird Seasave software version 7.26.6.26; pre processing was done with SBE Data Processing 7.26.6.28.

The first CTD profile was collected at instrument test station #179. It was determined that all parameters, except pressure showed suspicious behavior and the cast was canceled. A check of the wire required a new termination of the ships winch equipment. The successive cast at station #180 showed similar behavior. After detailed analysis of the sensors the fault was assumed to be the connector to the CDOM sensor. Though as station #181, cast 3, revealed, this did not solve the issue, the complete sensor CTD system #3 was replaced and CTD system SBE#5 was used thereafter from station #182, cast 4, onwards.

Data from casts 1–3 are flagged as probably bad, will not be calibrated and not published, since all sensors showed suspicious behavior and good data could not be separated from spikes and interferences.

The conductivity cell # 2537 of sensor pair #1 was replaced with cell # 2512 after the first cast with the CTD system SBE#5, profile 4 – station #182, since it showed an erratic behavior in the upper part of the profile. The cause could not be determined.

The altimeter was swapped from 42099 to 41839 after CTD cast 3, since it showed unreliable behavior.

The oxygen probes were shipped via airfreight and did not accompany the CTD system in the container for safety reasons, after the experiences with extreme temperature exposures of oxygen sensors in a container in a previous cruise (METEOR 105). The oxygen sensors provided reliable high quality data throughout the cruise, despite increased noise at greater depth (>2000dbar), a detailed analysis showed that the quality of the median filtered data were still excellent. From the current experience it is suggested to continue the practice of shipping the oxygen sensors separate from the CTD system via airfreight.

No further problems were recorded with the sensors or sampling system of the CTD system. The CTD system worked without problems for all profiles since profile 4.

The first CTD-TM profile was collected at station #184-1. Calibration of the CTD-TM was done with samples from cast 21 onwards, since the first 20 cast had a failure of the Niskin bottle closure, resulting in no defined depth for each bottle. All sensors on the CTD-TM showed good data from cast 21 onwards. The first 20 casts of the CTD-TM are not used and raw data are possibly of poor quality.

The exact instrument configuration of the CTD systems can be found in Table 5.1.1. Additionally a self-recording, self-powered Underwater Video Planktonrecorder, UVP, was attached to the CTD water sampler. It is described separately in section 5.13.

Processed preliminary CTD data, 5-dbar binned, was sent in near real time to the Coriolis Data Centre in Brest, France, (via email: codata@ifremer.fr) for integration in the databases to be used for operational oceanography applications and the WMO supported GTS/TESAC system.

**Table 5.1.1** Summary of CTD system SBE #3 and SBE #5 configuration used during M135, only data from SBE #5 were used. The 3 profiles with SBE #3 discarded.

| | CTD system SBE#3 (cast 1-3) | CTD system SBE#5 (cast 4) | CTD system SBE#5 (cast 5-XX) | CTD-TM system |
|---|---|---|---|---|
| Pressure sensor | # 0615 | # 1162 | # 1162 | # 1086 |
| T primary | # 4547 | # 4051 | # 4051 | # 5562 |
| T secondary | # 4867 | # 2120 | # 2120 | # 5661 |
| C primary | # 3379 | # 2537 | # 2512 | # 4064 |
| C secondary | # 2512 | # 3374 | # 3374 | # 4084 |
| O2 primary | SBE 43 # 0194 | SBE 43 # 2669 | SBE 43 # 2669 | SBE 43 # 2336 |
| O2 secondary | SBE 43 # 0145 | SBE 43 # 0992 | SBE 43 # 0992 | SBE 43 # 2337 |
| Altimeter | # 42299 | # 42099 | # 41839 | # 53899 |
| WET Labs ECO-AFL/FL & ECO-NTU | # FLNTURTD-2928 | # FLNTURTD-2928 | # FLNTURTD-2928 | - |
| WET Labs ECO CDOM | # 2687 | - | - | - |

### *5.1.2 CTD-Conductivity Calibration*

Overall 583 calibration points were obtained by sampling for salinity, used were 389 for the CTD and 66 for CTD-TM. Salinity samples were taken by the CTD watch in recycled 'Flensburger' beer bottles, which proved to be ideal for storing salt samples over a prolonged time, as used by the institute since several decades. The results and description of the salt measurements are found in section 5.1.4. Due to the large amount of samples, a simple outlier removal method was applied that discharged the largest 33% deviations between CTD and bottle samples prior to calibration. The projection from the bottle closure depth of the up- to the downcast was done by searching for similar potential temperatures within 50dbar pressure internal around similar pressure horizons between up- and downcast. For the critical loop edit velocity, 0.01m/s were used. The final CTD data set is composed from the secondary set of sensors for all profiles, though the differences between sensor pairs were marginal. The conductivity calibration of the downcast data was performed using a 1$^{st}$ order linear fit with respect to temperature, pressure and conductivity. Successive calibrations during the cruise indicated a slow conductivity drift of the primary sensor. Since this drift was small and linear in time, it was not replaced. A linear correction in time was added to the calibration of the primary sensor.

The CTD calibration results in a salinity RMS-misfit for the downcast of order 0.0011107 psu for the primary and 0.00098406 for the secondary sensor. The up-cast calibration succeeds these excellent values with and RMS-misfit of 0.00096273 for the primary and 0.00080682 for the secondary sensor. For details please see Table 5.1.2.

The CTD-TM was calibrated only preliminary, since there are insufficient amount of samples. Since the identical system will be used in the following cruise M136. It is suggested to make a final CTD-TM calibration after more samples have been taken. For the preliminary calibration please see Table 5.1.3.

**Table 5.1.2** End of cruise salinity and pressure summary of downcast calibration information for the two CTD systems used during M135.

| | CTD system SBE#5 (profile 4 to 143) | CTD system SBE#5 (profile 3 to 143) |
|---|---|---|
| Sensor pair | primary | secondary |
| RMS misfit after calibration - salinity | 0.0011107 | 0.00098406 |
| Polynomial coefficients - conductivity | Offset: -0.0091142<br>P1: -1.8035e-07<br>T1: -0.00032864<br>C1: +0.0033129<br>t1: +1.5784e-05 | Offset: -0.00053308<br>P1: -2.2829e-08<br>T1: -3.5451e-05<br>C1: +0.00019797 |
| Pressure sensor correction (decks-offset) | 0.88 | 0.88 |

**Table 5.1.3** End of cruise salinity and pressure summary of downcast calibration information for the two CTD-TM systems used during M135.

| | CTD-TM system (profile 22 to 48) | CTD-TM system (profile 22 to 48) |
|---|---|---|
| Sensor pair | primary | secondary |
| RMS misfit after calibration - salinity | 0.002834 | 0.0029249 |
| Polynomial coefficients - conductivity | Offset: -0.022786<br>P1: 1.8491e-06<br>T1: -0.00070944<br>C1: 0.0074651<br>t1: +1.5784e-05 | Offset: -0.0048485<br>P1: +2.7279e-06<br>T1: +1.1112e-05<br>C1: +0.00093391 |
| Pressure sensor correction (decks-offset) | 0.69 | 0.69 |

### *5.1.3 Oxygen Calibration:*

The CTD oxygen downcast for CTD systems was calibrated by using the best two thirds of the joint data pairs between downcast CTD sensor value and titrated oxygen on samples taken during the upcast (Section 5.2). For the calibration, a linear correction polynomial depending on pressure, temperature and the actual oxygen value as well as the cubed pressure correction was fitted. Despite the very accurate titration and stable oxygen data no temporal drift was detected. A total of 559 oxygen data points for CTD system SBE#7 were recorded, which results in an RMS-misfit for the downcast on the order of 0.49 µmol $kg^{-1}$ for the primary SBE43 and 0.51 µmol $kg^{-1}$ for the secondary SBE43.  The up-cast calibration matched these very good values with an RMS-misfit of 0.48896 µmol $kg^{-1}$ for the primary SBE43 and 0.51 µmol $kg^{-1}$ for the secondary SBE43 (Table 5.1.4)..

The CTD-TM was calibrated only preliminary, since there are insufficient amounts of samples. Since the identical system will be used in the following cruise M136. It is suggested to make a final CTD-TM calibration after more samples have been taken. For the preliminary calibration please see Table 5.1.5.

**Table 5.1.4** End of cruise downcast oxygen summary of calibration information for the CTD system SBE#5 used during M135.

| | Oxygen Sensor #2669 | Oxygen Sensor #0992 |
|---|---|---|
| Sensor pair | primary | secondary |
| RMS misfit after calibration – oxygen | 0.49868 | 0.51289 |
| Polynomial coefficients – oxygen | Offset: -5.4691<br>P1: +0.0036941<br>P2: -1.7349e-07<br>T1: +0.27519<br>O1: +0.040228 | Offset: -5.1484<br>P1: +0.0043271<br>P2: -2.4182e-07<br>T1: 0.25917<br>O1: 0.023999 |

**Table 5.1.5** End of cruise downcast oxygen summary of calibration information for the CTD-TM system SBE#5 used during M135.

| | Oxygen Sensor #2336 | Oxygen Sensor #2337 |
|---|---|---|
| Sensor pair | primary | secondary |
| RMS misfit after calibration - oxygen | 0.59627 | 0.6042 |
| Polynomial coefficients - oxygen | Offset: -8.0397<br>P1: 0.0072935<br>T1: +0.52075<br>O1: -0.0013626 | Offset: -3.1471<br>P1: 0.0021206<br>T1: 0.12805<br>O1: 0.047796 |

### *5.1.4 Salinometer Measurements*

On board were three GEOMAR instruments: Guildline Autosal salinometer, #7 (Model 8400B, AS7), Guildline Autosal salinometer, #5 (Model 8400A, AS5) and Guildline Autosal salinometer, #8 (Model 8400A, AS8). Throughout the cruise, mainly the Guildline Autosal salinometer #8 was used, except for 24 samples from the CTD-TM which were used for testing the AS7.

The instrument has a manufacturer given absolute accuracy in salinity of ±0.002 psu, with a slightly higher relative accuracy. In total, a number of 555 samples were measured from *163* CTD and CTD-TM stations. CTD casts on the shelf, shallower than 1500m, were omitted, to prevent contamination of the salinometer with particles, which usually occur in large quantities in shallow waters and near coasts.

The bath temperature of AS#8 was constant throughout the cruise with 24°C in a temperated room of 22.5°C. A standardisation of the instrument was performed at the beginning of each measurement day using IAPSO standard sea water (batch: P159, K15: 0.99988) with a respective salinity of 34.99953. Starting March 24$^{th}$, CTD station 83 the batch P157 (K15:099985, Salinity 34.9941) was used till the end of the cruise. That value was set by adjusting a resistance to get the required conductivity measurement (potentiometer).

Substandard was taken from a deep CTD cast >1000m and renewed twice during the cruise. Substandard measurements showed that no drift occurred during each measurement session.

Successive standard measurements with IAPSO standard sea water indicated stable behavior of the instrument.

During the cruise the cell was cleaned with Mucasol and TritonX-100 to prevent small arbitrary jumps, likely due to particles in the bottles. We avoided to sample salinity near the coast in the upper water column. Upper ocean samples were taken seawards of the 1000m isobath.

Salinity samples from the M135 CTD profiles and M135 and previous cruise (M134) underway METEOR TS recorder (thermosalinograph) were analyzed and the calibration procedures are described in section 5.1.2 for CTD and 5.8 for the thermosalinograph.

### *5.1.5 Exemplary Results*

The sampling strategy of M135 data allowed detailed analysis of upper ocean tropical South East Pacific water masses (Fig. 5.1.1).

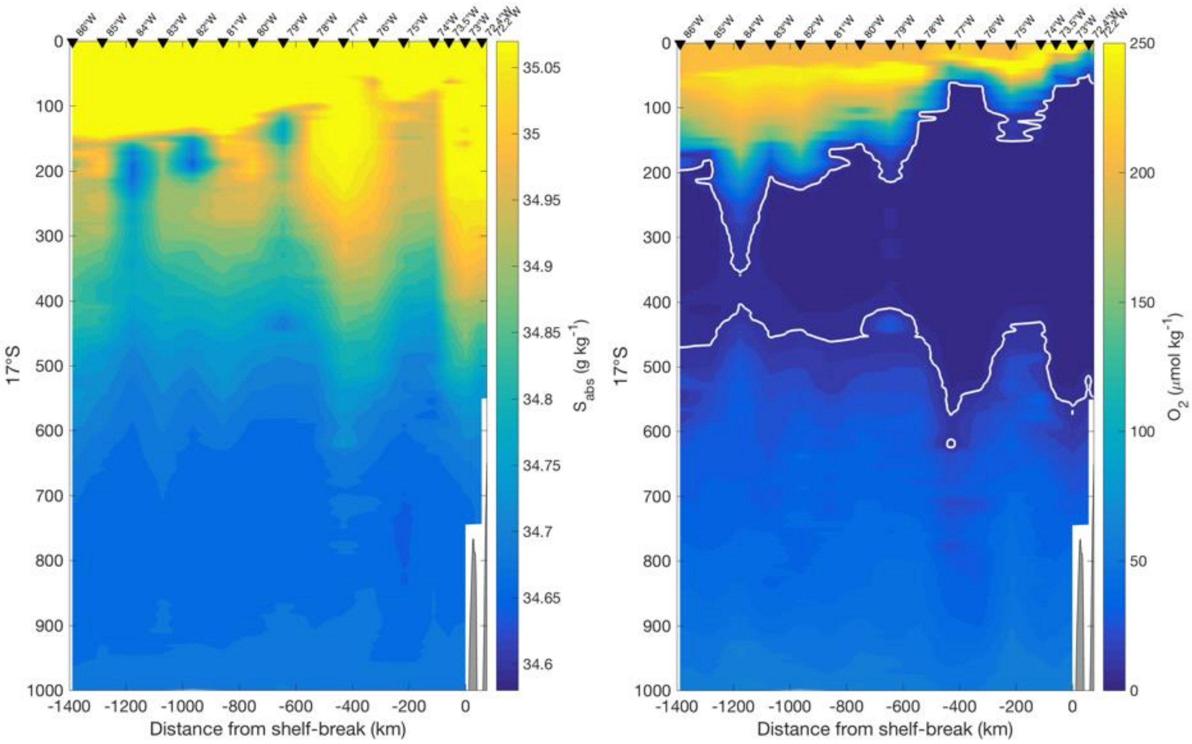


**Fig. 5.1.1** Top 1000dbar salinity and oxygen section along 17°S.

## 5.2 Measurements of Dissolved Oxygen

(Sümeyya Eroglu, Nils Lüdecke, Sebastian Steinig, PI: Toste Tanhua)

Observing and understanding the concentration of dissolved oxygen in the ocean is one of the key objectives of the SFB754. While the CTD system is capable of measuring dissolved oxygen in the ocean at high vertical resolution, the sensors need to be carefully calibrated. Thus high quality reference observations are essential.

<u>Oxygen measurements</u>

A total amount of 1487 discrete water samples successfully measured for its oxygen concentration by Winkler titration at 42 CTD-TM casts and at 124 for CTD/RO casts. Samples were taken with 100 ml wide necked WOCE glass bottles with well-defined volumes (calibrated flasks: matched pair of flask and stopper) in order to calibrate the SBE43 oxygen sensor attached to the CTD. Oxygen samples were taken immediately after the CTD cast was finished and always directly after the Tracer sampling was finished. It was ensured that the sample bottles were flushed with at least 3 times its volume and the samples were free of air-bubbles. Immediately after sampling, the seawater samples were spiked from the bottom with the fixation solution (NaOH/NaI and $MnCl_2$) and shook vigorously for at least 30 seconds.

Most of the samples were taken as duplicates or triplicates in order to quantify sampling and titration uncertainties.

Oxygen was determined by Winkler titration within a minimum of 40 minutes and a maximum of 16 hours after sampling following standard protocols (Langdon, 2010). The concentration values were reported in µmol $kg^{-1}$. The precision of the Winkler-titrated oxygen measurements is calculated as the average of the standard deviation of replicate measurements. The precision calculated this way is 0.96 µmol $kg^{-1}$, or 6.1%. The highest relative values are found in the oxygen minimum zone with values close to 0. The highest absolute values occurred in the strong near-surface gradients and weakly developed mixed layers, while the precision is considerably better for replicate measurements below the OMZ.

Standard measurements for the determination of the thiosulfate factor (f in equation 1) were carried out every day. Additionally, the total reagent blank ($a_r$ in equation 1) was determined every day. This step is necessary to account for small impurities in the fixation reagents (e.g higher oxidation states of manganese or traces of iodine). The reagent blank determination follows the procedure described in Langdon (2010). 1 ml of each of the 50% sulphuric acid, the alkaline iodide solution and the manganese chloride were added to about 50 ml of demineralised water and mixed after each step. 1 ml of the iodate standard was added and titrated while adding 1 ml of the starch solution. After reaching the equivalence point another 1 ml of the iodate standard was added and titrated again until reaching the equivalence point. The reagent blank was determined as the difference between the first and second titration volume. The arithmetic mean over all blank measurements was calculated and subtracted from the titration value of each water sample.

The amount of dissolved oxygen contained in the fixing reagents ($DO_r$ in equation 1) was subtracted from the calculated oxygen content of each water sample. The oxygen content of the 2 ml reagents was assumed as 0.0759 µmol (Langdon, 2010). Please note that the cited value in “Methods of Seawater Analysis” is too high by a factor of 2.

The resulting equation used for calculation of the dissolved oxygen concentration in µmol/L of the water samples is given as:

$$C_{OX} = \frac{f*(a-a_r)*5000-(DO_{r*}*1000)}{V-2} \qquad (1)$$

with:

- f: thiosulfate factor
- a: titrated volume of sample
- $a_r$: reagent blank volume
- $DO_r$: dissolved oxygen content of reagents
- V: volume of WOCE bottle

Measurement setup

All titrations were performed according to GO-SHIP standard operating procedures (Langdon, 2010). The following reagents were used during this cruise:

- Sulfuric acid (50%)

- Zinc iodide starch solution (500 mL, Merck KGaA)
- Stock solution, pre-weighted: sodium thiosulfate pentahydrate (49,5 g · $L^{-1}$); stock solution was diluted by a factor of 10 to create the working solution (0.02 mol · $L^{-1}$)
- Fixation solution, all pre-weighted: manganese(II)chloride (600 g · $L^{-1}$), sodium iodide (600 g · $L^{-1}$) and sodium hydroxide (320 g · $L^{-1}$)
- Standard solution, pre-weighted: potassium hydrogen diiodate (0,325 g · $L^{-1}$)

Titrations were performed within the WOCE bottles using a 20 mL Piston Burette (No. 00692888) TITRONIC universal from SI Analytics GmbH. Dosing accuracy reported by the company is 0.15%, referred to the nominal volume, indicated as a measurement uncertainty with a confidence level of 95%. The iodate standard was added with a 50 mL Piston Burette (No. 00692869) TITRONIC universal SI Analytics GmbH. 1 mL of the fixation solutions (NaI/NaOH and $MnCl_2$) were dispensed with a high precision bottle-top dispenser (0.4 - 2.0 mL, Ceramus classic, Hirschmann).

Titration procedure

The titration procedure for each measurement was the following:

1) Switch on Piston Burettes and clear the system (dosing tubes) from air bubbles
2) Determine factor of the thiosulfate working solution by titrating the homemade standard between 3 to 5 times on a daily basis
3) Measure the reagent blank
4) Measure the actual Winkler samples

A small number of oxygen samples were rejected due to possible sampling (air bubble entry during fixation), storing (air bubble) and measuring errors. Results derived from those measurements were not considered in the final data evaluation.

Sampling blank correction

Since this cruise focused on the largest oxygen minimum zone on the planet with large areas with zero or near-zero oxygen concentrations, we took particular care to eliminate biases in the measurement procedure. This was done in three steps, the two are described above as compensating for impurities in the reagents and oxygen in the fixation solution.

As a third step that is arguably somewhat subjective, we took the median of all samples well within the OMZ and considered this to be the sampling blank, i.e. contamination from air during sampling and fixation, and outgassing from the PVC Niskin bottles. The sampling blank was determined to be 1.45 µmol $L^{-1}$. This value was deduced from the values from the winkler titration assuming a linear relation between saturation and sampling blank, i.e. samples with 100% saturation was assumed not to be affected by sampling blank whereas samples with no oxygen was assumed to be affected by the full offset.

## 5.3 Measurements of Nutrients

(Andre Mutzberg, PI: Toste Tanhua)

Nutrients were measured on-board with a QuAAtro auto-analyzer from SEAL Analytical, (Serial number: 8003836) and a SEAL XY-2 Autosampler (Serial number: 5002A15014). The following methods from SEAL Analytical were used:

Nitrite and Nitrate – Q-068-05 Rev 11; the nitrate is determined as nitrite after reduction on a cadmium coil. The nitrite is determined with a colorimetric metric method where sulphanilamide is forming a diazo compound.

Nitrite – Q-070-05 Rev 6; the nitrite is determined with a colorimetric metric method where sulphanilamide is forming a diazo compound.

Phosphate – Q-064-05 Rev 8; this is the colorimetric method based on reaction with molybdate and antimony ions.

Silicate – Q-066-05 Rev 5; this is the colorimetric method where a silico-molybdate complex is reduced to molybdenum blue.

All together 1937 nutrient samples from 54 CTD/RO casts and 40 CTD-TM casts were successfully measured during the cruise, of which 322 samples were replicate measurements (several measurements from the same sample). The 14 mL polyethylene sampling tubes and the respective caps were rinsed at least three times with the sampling water before the final sample was taken. In most cases the samples were measured directly after sampling with a delay of one hour or less. If the start of measurement was delayed for more than one hour, the samples were stored in the fridge prior to analysis.

The precision of the nutrient measurements were calculated as the average of standard deviation from the replicate measurements of samples and are listed in Table 5.3.1.

**Table 5.3.1** Precision of nutrient measurements during M135

| | Precision (absolute,µmol $kg^{-1}$) | Precision (relative, %) |
|---|---|---|
| Nitrite ($NO_2$) | 0.01 | 10 |
| Nitrate ($NO_3$) | 0.10 | 0.39 |
| Phosphate ($PO_4$) | 0.008 | 0.57 |
| Silicate (Si) | 0.16 | 0.42 |

In addition to the CTD samples, 34 bottles of Reference Material for Nutrients in Seawater (RMNS) from the General Environmental Technos (KANSO) Co., Ltd., Osaka/Japan were used. This batch of CRMs was provided by Japan Agency for Marine-Earth Science and Technology (JAMSTEC) at a reduced price in collaboration with the SCOR WG#147 "Towards comparability of global oceanic nutrient data ( COMPONUT ) ". All CRMs were from lot CG (middle concentration is pacific Ocean Matrix) with the following preliminary certified values:

$NO_3$ 23.7, ± 0.2; $NO_2$ 0.06 ± 0.03; Si 56.4 ± 0.5; $PO_4$ 1.70 ± 0.02, all units in µmol $kg^{-1}$. The manufacturer of the CRMs caution that these preliminary certified values might change slightly after measurement by JAMSTEC is conducted in April 2017.

CRMs were measured as triplicates at least in every sample run, see Fig. 5.3.1. From run 14 a new batch of artificial seawater (ASW) was used that was made of higher purity salts. This changed the offset vs. phosphate and nitrite vs. certified values in particular. Since impurities in the ASW were the obvious reason for offset in $NO_2$, this offset was compensated for as an additive adjustment. This corrected nitrite value was deduced from the $NO_2$+$NO_3$ values, and a multiplicative adjustment for $NO_3$ was applied. Multiplicative adjustments were applied for silicate and phosphate as well. All adjustments were applied on a run-by-run basis.
For phosphate these corrections were always within 1%, for nitrate the adjustments were mostly a positive adjustment of up to 2% whereas for silicate a positive adjustment of up to 4% was applied.

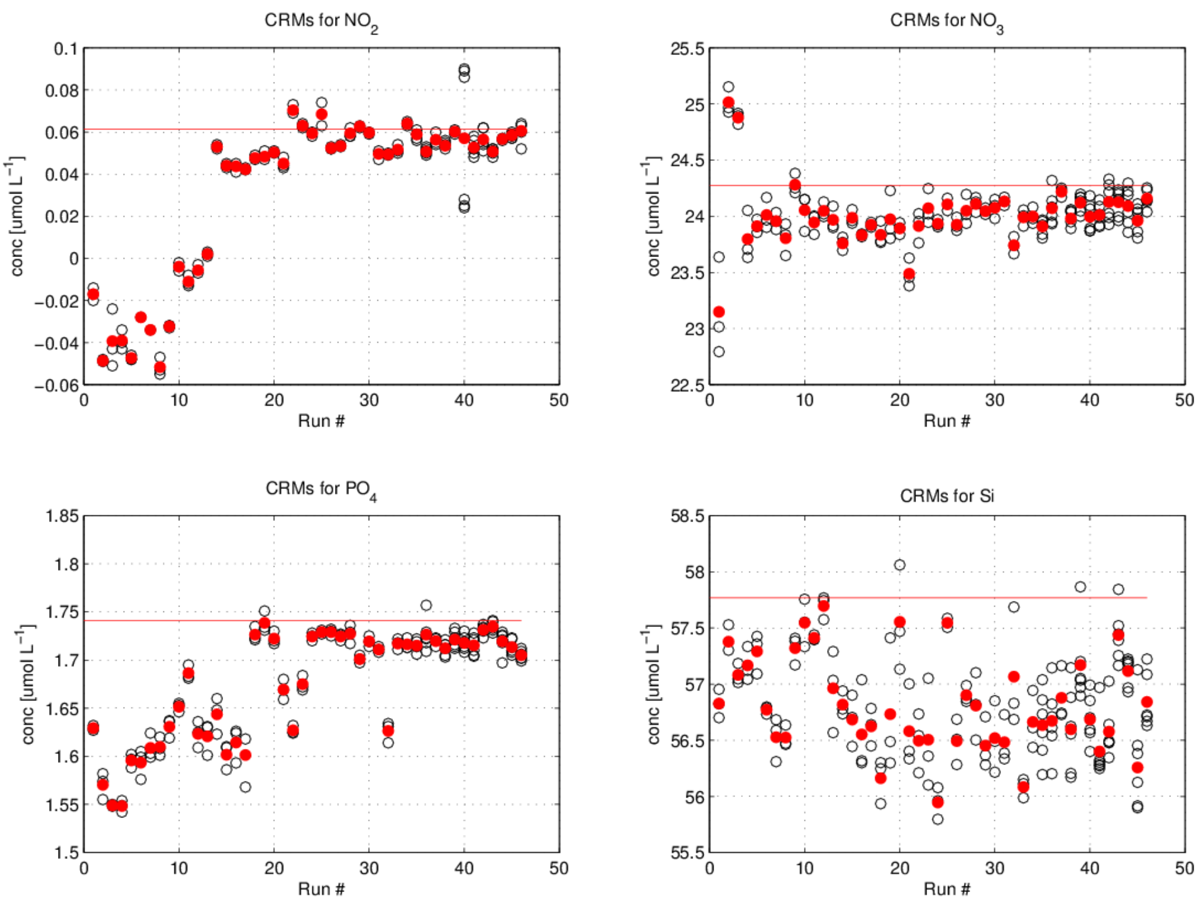


**Fig. 5.3.1** Measurements of CRMs during M135; for each run replicate measurements of CRMs were measured (open circles) and the average of those (red dots) were used for adjustment of measured values of seawater concentrations.

## 5.4 Measurements of CFC-12, $SF_6$ and $CF_3SF_5$

(Boie Bogner, Madeleine Freund, PI: Toste Tanhua)

### *5.4.1 Analysis System Setup:*

During the cruise, two GAS CHROMATOGRAPH / PURGE-AND-TRAP (GC/PT) systems (PT3 and PT4) were used for the measurements of the transient tracers CFC-12, $SF_6$ and the deliberately released tracer $CF_3SF_5$. The systems are modified versions of the set-up normally used for the analysis of CFCs (Bullister and Weiss, 1988).

The traps for both systems consisted of 100 cm 1/16" tubing packed with 70cm Heysep D kept at temperatures between -60 and -70°C during trapping. The traps were desorbed by heating to 120°C and passed onto the pre-colummn. For PT3, the pre-column consisted of 20 cm Porasil C followed by 20 cm Molsieve 5A in a 1/8" stainless steel column. For PT4, the pre-column consisted of 10 cm Porasil C and 20cm Molsieve 5A in a 1/8" stainless steel column. Both systems used a 1/8" packed main column consisting of 180 cm Carbograph 1AC (60-80 mesh) and a 50 cm Molsieve 5A post-column. All columns were kept isothermal at 50°C (PT4) or 60°C (PT3). Detection was performed on an Electron Capture Detector (ECD). This set-up allowed efficient analysis of CFC-12, $SF_6$ and $CF_3SF_5$ on both PT systems.

All samples were collected in 250 mL ground glass syringes, of which an aliquot about 200 mL was injected to the purge-and-trap system.

Standardization was performed by injecting small volumes of gaseous standard containing $SF_6$, $SF_5$ and CFC-12. This working standard was prepared by the company Dueste-Steiniger (Germany). The CFC-12 and $SF_6$concentrations in the working-standard has been calibrated vs. a reference standard obtained from R.F Weiss group at SIO, and the CFC-12 data are reported on the SIO98 scale. Calibration curves were measured roughly once a week in order to characterize the non-linearity of the system, depending on workload and system performance. Point calibrations were always performed between stations to determine the short-term drift in the detector. Replicate measurements were taken except for near coastal stations due to high workload. We measured 165 samples on both instruments to estimate the inter-system precision, 80 replicates samples were run on PT3 and 63 replicate samples were run on PT4. In total we successfully measured 2828 samples on 132 stations for transient tracers and $CF_3SF_5$.

The determined values for precision and limit of detection are listed in Table 5.4.1.

**Table 5.4.1** Precision of tracer measurements determined from replicate measurements and approximate limit of detection.

| Compound | PT3 precision | PT4 precision | Intersystem precision | Limit of Detection |
|---|---|---|---|---|
| $SF_6$ | 0.04 fmol $kg^{-1}$<br>4.9 % | 0.04 fmol $kg^{-1}$<br>5.3 % | 0.06 fmol $kg^{-1}$<br>8.5 % | |
| $CF_3SF_5$ | 0.05 fmol $kg^{-1}$<br>11.0 % | 0.06 fmol $kg^{-1}$<br>9.6 % | 0.11 fmol $kg^{-1}$<br>16 % | |
| CFC-12 | 0.006 pmol $kg^{-1}$<br>0.56 % | 0.008 pmol $kg^{-1}$<br>0.77 % | 0.018 pmol $kg^{-1}$<br>2.1 % | 0.006 pmol $kg^{-1}$ |

### *5.4.2 Preliminary Results:*

*Deliberately released tracer ($CF_3SF_5$)*

During RV Sonne cruise 243 in 2015, a total of 68.5 kg of an inert tracer, $CF_3SF_5$, was injected on three locations along the Peruvian shelf (10°S, 12°S, and 14°S, Figure 5.4.1) at a depth of about 250 meters, about one meter above the sediment surface. The density of the tracer injection varied somewhat but was centered around density anomaly ~26.3 kg $m^{-3}$. A main objective of cruise M135 was to map the distribution of the tracer in both vertical and horizontal directions. This objective largely directed our cruise track, which, in turn, was designed based on regional ocean model (ROMS) output. The concentration of the tracer was measured with high vertical resolution (typically 10-30 m). Most of the tracer found was found in water of lighter density than the release density. Figure 5.4.1 show the vertical integrated concentration of the tracer along the cruise track.

We can see that the tracer has a maximum extent of at least 2000 km to the south, as we found small concentrations of the tracer at our first station at 30°S along the shelf break. The tracer is relatively homogenous distributed but clearly influenced by eddy activity, most prominent between 19°S to 16°S. It shows significant gradients offshore from the South American coast. The highest column integrals of tracer were found 18-24°S within a few hundred miles from shore. Overall the tracer was found on lighter isopycnals compared to the release indication substantial mixing and transfer.

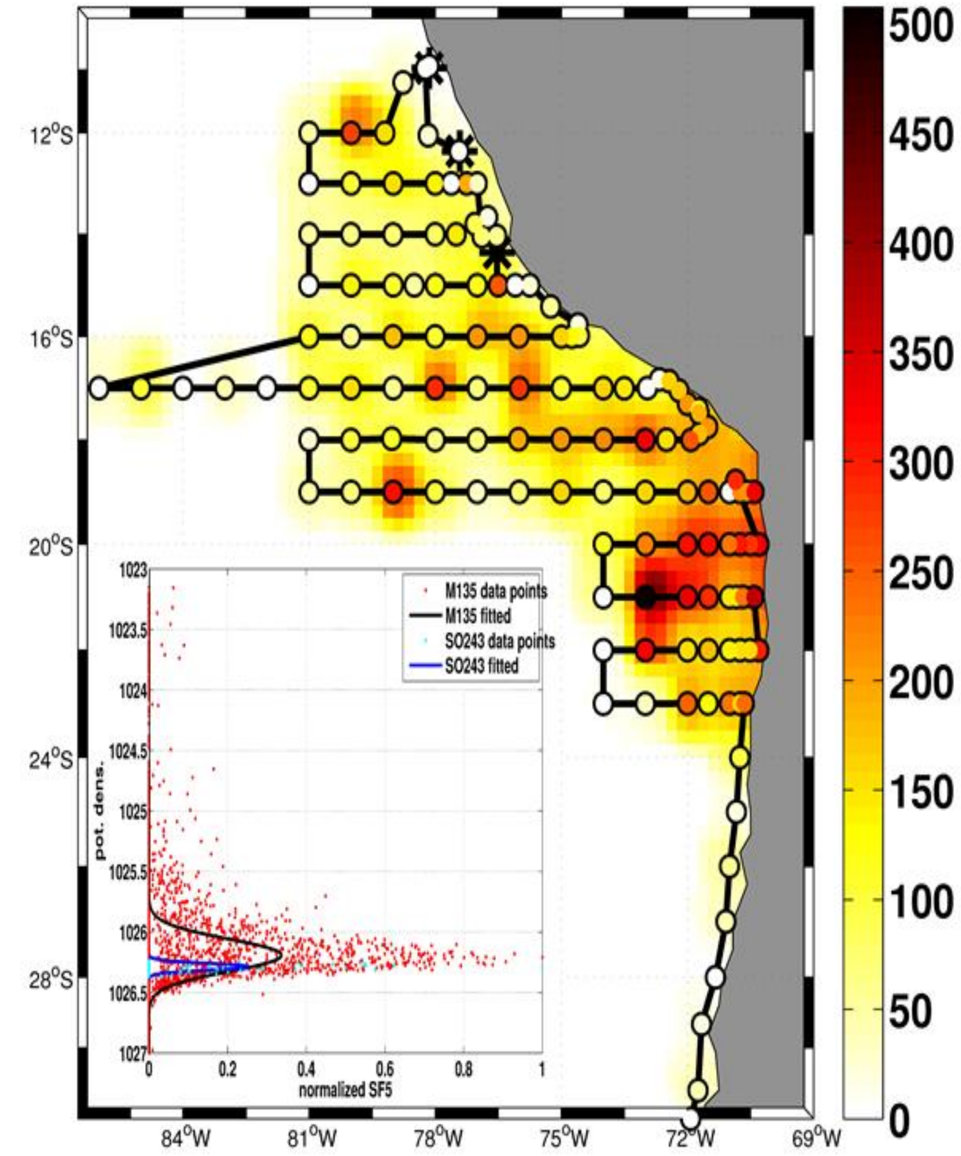


**Fig. 5.4.1** The objectively mapped horizontal distribution of the column integral of the deliberately released tracer $CF_3SF_5$ from the POSTRE experiment. The circles show the values for the individual stations. The units are $10^{-12}$mol $m^{-2}$. The black stars indicate the positions of the tracer release in 2015, and the line the cruise track. Insert all $CF_3SF_5$ concentrations normalized by the maximum of the survey and Gaussian fits. Blue indicate injection values.

## 5.5 Trace Metal Sampling

(Mark Hopwood, PI: Eric Achterberg)

A trace metal clean sampling rosette and winch were operated from METEORr’s A-frame with the winch container mounted in the central position at the stern of the ship. A pre-fabricated lab container with in-built air filtration was positioned forward and starboard of this. The trace metal clean sampling rosette was equipped with GO-FLO bottles which were stored in the trace metal clean lab container when not in use. Before trace metal (CTD-TM) stations, GO-Flo bottles were covered with protective plastic caps, bottoms and gloves over the spigots inside the clean container. They were then carried onto deck and mounted onto the trace metal sampling rosette. Immediately (maximum 5 minutes) before deployment the protective plastic was removed. Upon return to deck, gloves were immediately added to the spigots and then the GO-FLO bottles returned to the clean laboratory for sampling.

Sampling for contamination-sensitive parameters (trace metals, particles for elemental analysis, DOP, $H_2O_2$) was undertaken inside the clean container. Positive air pressure was maintained in the container via a continuous inward air flow, with dust particles in this air flow removed by a HEPA filter. Inside the laboratory, clean suits were worn and all labware was free from exposed metal components. $N_2$ gas was used to overpressure (0.2 atm) all Go-Flo bottles except 1-6 at every station which were maintained without $N_2$ and used for only $O_2$ collection to calibrate the CTD data. $O_2$ samples were collected immediately after bottles were in the clean container. Sampling then proceeded around the Go-Flo bottles in the order trace metals, Si isotopes, DOP, $H_2O_2$, nutrients, salinity.

The sampling focus for trace metals focused on second part of the cruise and began with station #254-1. Overall 26 stations were sampled with 520 trace metal samples collected and acidified for analysis in Kiel.

CTD-TM stations typically focused only on the surface 1000 m in order to sample the OMZ at high resolution (normally 18 Go-Flo bottles for trace metal analysis per profile). Exceptions were 6 stations at the 2000 m contour where full deopth profiles were conducted in order to compare benthic and OMZ trace metal distributions, and 3 shallow stations in waters >1000 m where full depth profiles were also conducted. 3 stations on the northern most W-E section (12°S) were selected to match a US-Geotraces section.

Multi-coring on-board recovered a number of cores with an undisturbed, intact sediment-bottom water interface at every multicore station. Bottom water was sub-sampled for nutrients and trace metals (ulfitered i.e. total dissolvable) upon collection of the cores on deck from the first 3 cores at every multicoring location (M135-MC-001 – M135-MC-005).

### *5.5.1 Trace Elements:*

Samples were collected in acid washed 125 mL LDPE sample bottles for dissolved (0.2 µm filter capsule) trace metal concentrations (metals: Fe, Zn, Mn, Mg, Cu, Co, Cd, Al). Samples were acidified with 180 µL concentrated (10 M) Optima grade hydrochloric acid, in batches and under a laminar flow hood, within 2 days of collection. These samples will be measured on return to GEOMAR via pre-concentration on a SeaFAST system (Thermo scientific) and subsequent analysis on an Element 2 ICP-MS following the method of Milne et al. (2010).

### *5.5.2 Major Nutrients and DOP:*

Samples were collected for dissolved macronutrients and dissolved organic phosphate (DOP) concentration analyses at nano-molar level. 20 mL samples were collected Falcon tubes for macronutrient concentrations. 30 mL samples for DOP analysis were collected separately in acid washed HDPE bottles. DOP samples were then frozen immediately in a -20°C freezer. These samples will be analysed on return to GEOMAR using a custom-built analyser following the method of Patey et al. (2008). Macronutrients were stored refrigerated and measured onboard within 1 day of collection.

### *5.5.3 Particles*

For approximately 10 depths at every CTD-TM station, 4 L of seawater as filtered through satorius 0.2 µm filters to collect sufficient particles for elemental analysis in Kiel (this volume was reduced to 2 L at coastal stations with high suspended sediment loads). Filters were mounted on plastic, acid cleaned, filter holders and attached directly to Go-Flo bottles (still under $N_2$) and then allowed to drain for approximately 2-3 hours. Filters were then rinsed with de-ionized water (10 mL) and frozen in a -20°C freezer. They will be digested and analysed via ICP-MS in Kiel.

### *5.5.4 $H_2O_2$*

Hydrogen peroxide samples were collected in acid cleaned 125 mL opaque HDPE bottles which were filled to overflowing and then stored in the dark. Analysis commenced within 1 hour of sample collection. A flow injection system was assembled in the isotope container using luminol chemiluminescence. A total of 177 samples were analysed abroad consisting of a complete W-E section at 17°S (event 254-1 at 77°W until 273-1 at 86°W) with 10 depths analysed at each station, and surface (towfish) data for the 4 W-E transects 17°S, 16°S and 15°S.

### *5.5.5 Si Isotopes*

Samples were collected in acid washed 125 mL LDPE (for coastal waters) or 500 mL LDPE (for offshore waters) for dissolved (0.2 µm filter capsule) Si isotopic analysis. These samples were then stored sealed in plastic bags without addition of any preserving agent and will be analysed upon return to Kiel. A total of 145 samples were kept for Si isotopes, collected along four W-E transects: 12°S, 14°S, 16°S and 17°S.

## 5.6 Underway Measurements Vessel Mounted ADCP

(Thilo Klenz, PI: Martin Visbeck)

Underway measurements of water column velocities were performed continuously throughout the whole cruise using two vessel mounted Acoustic Doppler Current Profilers (VMADCP).

### *5.6.1 System Setup*

RV METEOR is equipped with a 75 kHz RDI Ocean Surveyor (OS75), mounted in the ship's hull, and a 38 kHz RDI Ocean Surveyor (OS38) placed in the moon pool. Both systems were turned on after leaving the 3nm zone of Chile on March 1$^{st}$ 2017. Both instruments worked reliably for the duration of the cruise.

VmDAS software version 1.46 was used to configure the VMADCPs as well as record the raw data and the ship's navigational data on a central PC. Both units were run in narrowband (NB) mode, the OS38/OS75 configured to record 55/100 32m/8m bins at 16m/4m blanking distance. Both were set to ping every second.

Good quality data was recorded down to 700m depth for the OS75 and 1200m for the OS38. Depending on the amount of backscatterers in the water column, the OS75 was missing data in the depth range of the oxygen minimum zone on the northern sections.

During the entire cruise the SEAPATH navigation data was of high quality. A major source of interference, especially for the 75kHz unit, was the vessel's thruster mounted in the bow of the ship and used primarily when on station. The 38kHz was not affected by this, however, the Parasound system, with a frequency of 40kHz, did lead to noticeable interference during geological surveys and whenever else it was turned on. However, the effect on the quality of the acquired velocity data was minimal. On April 4$^{th}$ 2017 both systems stopped recording for 5 hours, due to a server update, that resulted in data loss of 25nm. Further, the systems were turned of before entering the 3nm zone of Peru on March 18$^{th}$ and April 2$^{nd}$ 2017.

The data were processed on board and a preliminary data set was used for a number of near real time velocity products.

Both the OS38 and the OS75 are mounted at an angle of zero and 45 degree, respectively, towards the ship's heading to reduce the amount of interference between the two instruments. However, small deviations from these angles are expected. Hence, a primary motivation of the data processing is to correct the misalignment angle of the instruments to get the most accurate estimates of north- and southward velocities. Raw data was processed in MATLAB using the OSSI toolbox v. 1.9A, last updated by T. Fischer (GEOMAR) on June 23$^{rd}$ 2016. Heading misalignment correction resulted in a mean misalignment angle for the OS38/OS75 of -0.5722/1.0543 with a standard deviation of 0.5848/0.5977. Amplitude correction resulted in a mean amplitude factor of 1.0008/1.0046, standard deviation 0.0095/0.0102, respectively (as of April 6$^{th}$, 2017).

### *5.6.2 Exemplary Results*

Preliminary data processing shows a turbulent and eddy rich flow through out the whole cruise. To illustrate that, Figure 5.6.1 shows a zonal section along 18°S displaying mesoscale activity in the form of two cyclonic eddies. These eddies are particularly interesting due to their effect on the lateral spreading of the tracer, as well as transport of water masses from the shelf region into the open ocean. The map in figure 5.6.2 shows the mean velocity between 80 m and 150 m depth, which roughly corresponds to the depth range of the maximum measured tracer concentrations.

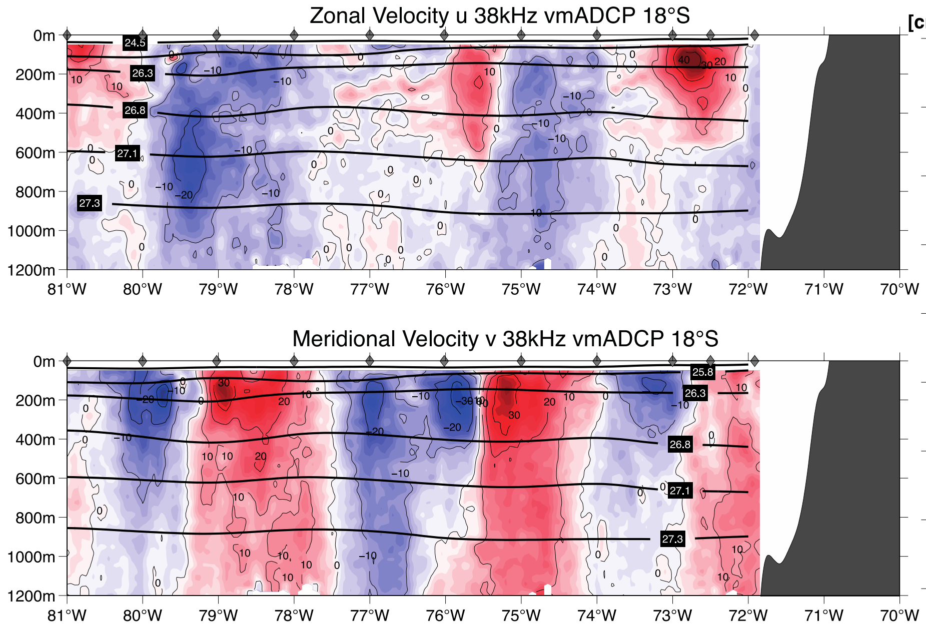


**Fig. 5.6.1** Zonal (top) and meridional (bottom) velocities ([$cms^{-1}$]) along the 18°S transect from the 38 kHz vmADCP. Potential density ([$kgm^{-3}$]) isolines from CTD stations (grey diamonds) are overlaid in black. The effect of mesoscale eddies on the potential density field is visible in the sloping of isopycnals in the presence of strong alternating north- and southward velocities (indicating cyclonic rotation) centered at 75.5°W and 79.5°W.

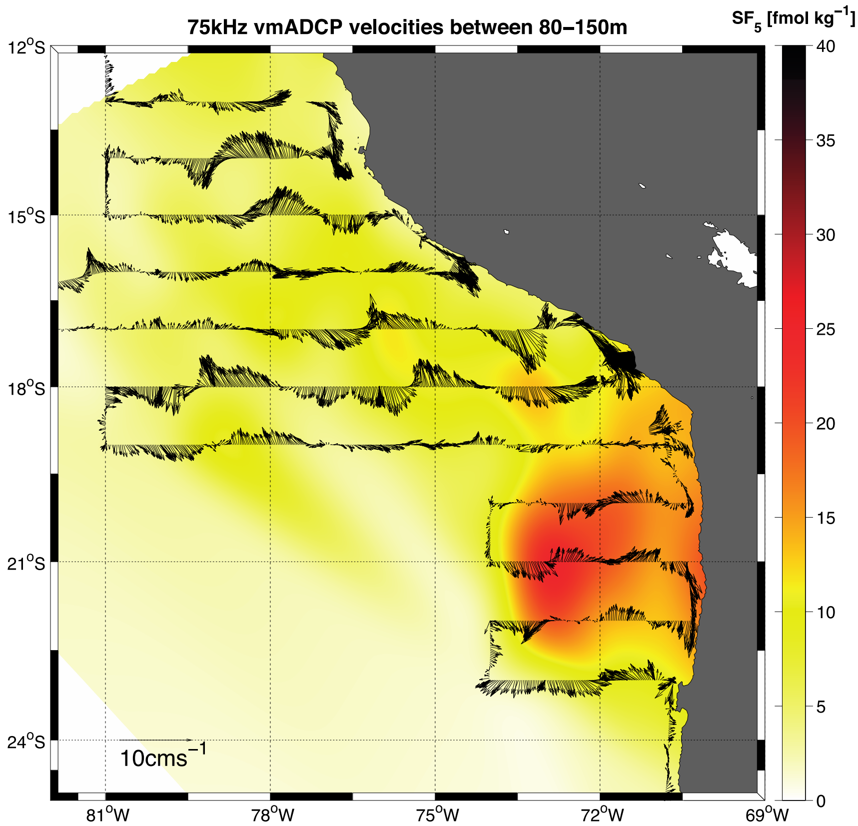


**Fig. 5.6.2** Sum of measured tracer concentrations in the water column (colors) and mean velocities from the 75kHz vmADCP between 80-150m water depth.

## 5.7 Underway CTD System

(PI: Sunke Schmitdko, Rudolph Link)

A Teledyne Oceanscience rapidCast system #0098 was used during the cruise to make measurements of upper ocean temperature and salinity while underway. The system consists of a CTD probe with a tail spool, which is not spooled with rope during this type of deployment. The probe falls through the water column, sampling temperature, conductivity and pressure at about 15.95 Hz during a pre-set time interval. Deployment and recovery of the probe are done using a winch and small davit that form part of the rapid cast CTD system. Data are recorded internally and uploaded via Bluetooth connection.

Two probes, SN 045 (probe-1) and SN 155 (probe-2), were used alternatingly on the rapid cast CTD transects, each a few hours at a time; while one probe was in use, the other had its memory read and battery re-charged.

A total of 202 rapid cast CTD casts were completed during the cruise in 7 deployments. Most of the profiles were done to a target depth of 135 m. The depth reached by the probe varied but was generally within about 10 m of the target depth.

Initial processing of rapidCast data was done using SBE Data Processing, Version 7.21 k, following a procedure used during an earlier METEOR cruise (M99). This basic processing included adjusting for sensor delay between temperature (T) and conductivity (C) sensors relative to pressure (P). The value by which to advance T or C in order to align parameters in time was explored experimentally and an adjustment of +0.08 s for T was selected (based on one cast). Salinity, potential temperature and density were then derived from the measured variables. Data were then averaged into 1 dbar bins. Only data from the down casts were included. Further processing, done in Matlab, involved matching the time stamp of the start of the cast, as recorded by the instrument, with the DAVIS Ship-data record to get the position of the cast.

During the cruise two calibration casts, CTD cast #101 and #132, were performed with the rapidCast CTD probes attached to the rosette during a regular CTD cast to 1000 m depth. The data will be used to obtain a final calibration of the system.

## 5.8 Underway Measurements Thermosalinograph

(Yannis Langmark, PI: Sunke Schmidtko, Martin Visbeck)

Underway temperature and salinity measurements were made with two SEABIRD Thermosalinographs SBE21 (Serial Number: 3388 & 3394, see also METEOR Handbuch) installed in the ship’s port well about 4 to 4.5 m below sea surface. The instrument measures seawater conductivity and temperature continuously. From those salinity is calculated. For calibration purposes of the conductivity sensor, all calibrated CTD station data was used.

### *5.8.1 M135 Performance*

During the entire cruise M135 (March 1st to April 8th), CTD measurements were performed in the tropical and subtropical east Pacific. We expected elevated surface temperatures and salinity further away from the shore and colder and fresher surface waters close to the coast, which was confirmed by the thermosalinograph (TSG) measurement. Sea surface temperatures (SST) ranged from 16.4°C to 27.1°C and typical sea surface salinity (SSS) characteristics ranged from 34.3 to 35.8 (Fig 5.8.1).

Good agreement was found between the reference measurements and the TSG data for the first weeks of the cruise and towards the end, shown in Fig. 5.8.1. Solid lines indicate measurements from the ship's TSG, red circles denote preliminary calibrated CTD-data that was averaged over 4 to 6 dbar of the profiles. After reaching the second geophysical survey area on March 18th, due to dirty and potentially chemically contaminated water close to the coast, the conductivity sensor of the thermosalinograph got contaminated by particles, which was only resolved after cleaning the system on April 4th (around 18:30 UTC). Also during this time the maintenance of the pump of the thermosalinograph was done on March 27th. After removing the mean the remaining variance between TSG-data and CTD-data is 0.241°C, since especially at stations at the shelf there are some big outliers with offsets of 2°C or more (Fig. 5.8.1). SSS measurements show a slightly decreasing trend until March 10th, followed be a steeper decrease until March 18th. For these two time-spans and the period after cleaning the thermosalinograph the mean offsets and variances are calculated separately and written in Table 5.8.1.

Additionally, for each of these three periods a linear fit for SSS is applied with corresponding slopes of -0.0003, -0.0032 and -0.0010 and intersections of 0.0254, 0.0204 and 0.0986 as plotted in Fig. 5.8.1 (black dashed line). The resulting mean offsets and variances are also shown in Table 5.8.1.

Comparison of these quantities shows that practical TSG-salinity is on average a little higher relative to CTD-measurements, however the problems concerning big deviations from these reference measurements for about half of the duration of the cruise makes it hard to analyze the SSS timeseries as a whole. TSG-temperature wasn't affected by this and is on average higher than CTD-surface temperatures by 0.14°C (Table 5.8.1).

**Table 5.8.1** Surface temperature and salinity offsets and standard deviation calibrated against high accurate CTD data.

| | SST (°C) | SSS (cast 4-40) | SSS (cast 42-69) | SSS (cast 126-139) |
|---|---|---|---|---|
| Mean Offset | 0.14 | 0.0191 | -0.0257 | 0.0910 |
| Variance | 0.241 | 0.00004 | 0.00072 | 0.00006 |
| Mean Offset (detrended) | | $8.4*10^{-14}$ | $8.8*10^{-12}$ | $2.0*10^{-12}$ |
| Variance (detrended) | | 0.00003 | 0.00002 | 0.00003 |

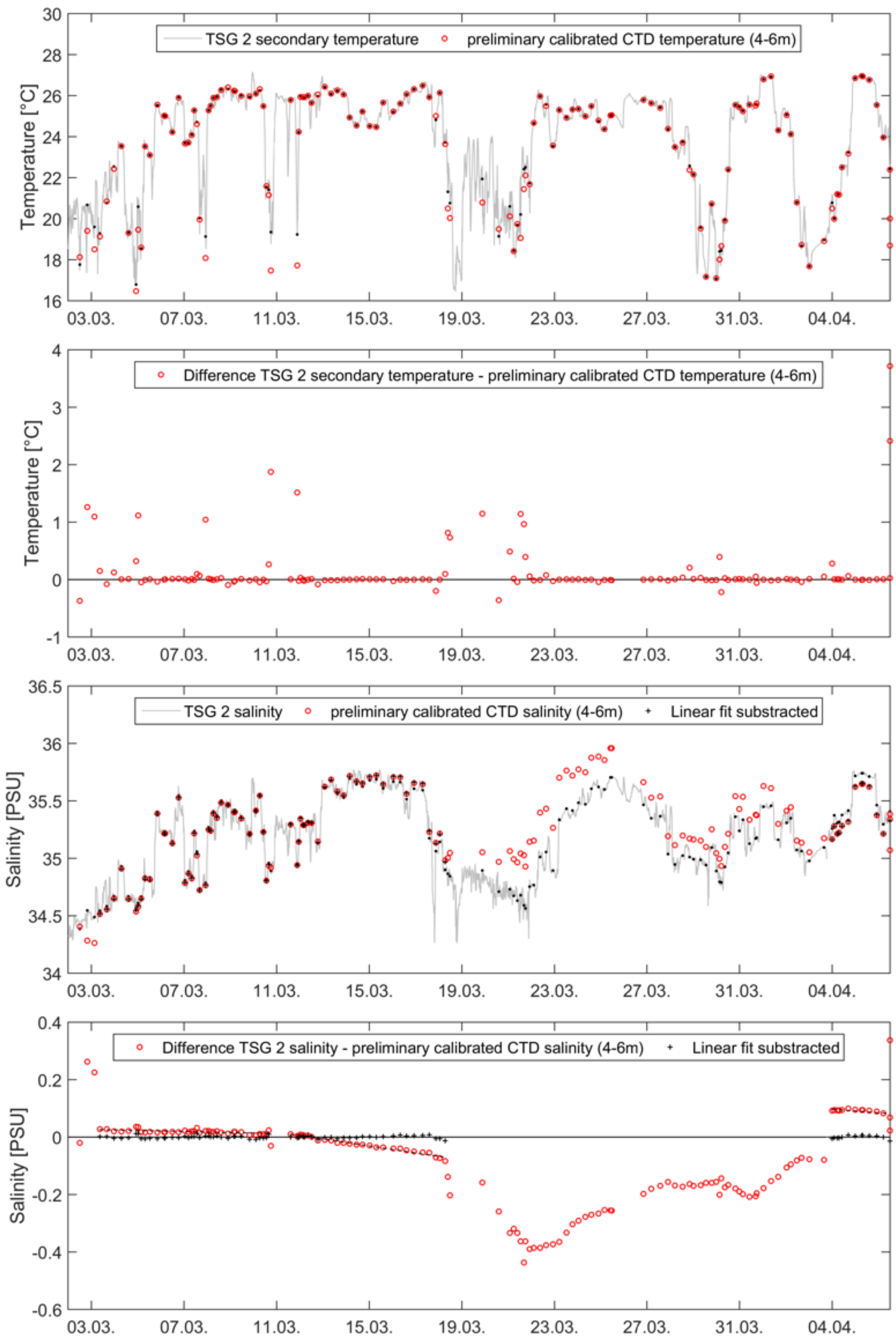


**Fig. 5.8.1** Sea Surface Temperature (top), temperature difference between TSG minus CTD, Sea Surface Salinity and salinity difference between TSG minus CTD (bottom). SSTs and SSSs from the ships Thermosalinograph (TSG) were compared to surface measurements of the CTD preliminary profiles (average between 4 and 6 dbar). TSG-measurements are denoted by solid grey lines, TSG-measurements used for comparison with CTD-data by black dots, CTD-measurements by red circles and detrended TSG-measurements by black crosses.

### 5.8.2 Experience from previous cruises

Furthermore, we measured the salinity of TSG samples from earlier cruises, starting with samples from the previous cruise M134. Those samples were taken with helpful support of the crew and previous cruise participants. All TSG samples that had the required plastic cap and lid were sampled. The data was recorded, stored and distributed to Martin Scharfenberg, Hamburg.

## 5.9 Underway $CO_2$, $N_2O$ and CO Measurements

(Damian L. Arévalo-Martínez, Tobias Steinhoff, PIs: A. Körtzinger, H.W. Bange)

Underway (UW) measurements of partial pressure of $CO_2$, $N_2O$ and CO in seawater were carried out by means of an autonomous equilibrator head-space setup (GO-System; General Oceanics, Inc.) coupled to an off-axis integrated cavity output spectroscopy analyzer (model DLT-100, Los Gatos Research, Inc.). The combined setup is shown in Fig 5.9.1. Water was drawn into the system at ca. 3 L $min^{-1}$ by using a LOWARA submersible pump installed in the ship's moon pool at about 6 m depth . In order to correct for potential warming of the seawater between intake and equilibrator, the water temperature at the equilibrator was constantly monitored by means of a high accuracy digital thermometer (Fluke) and at the intake by a Seabird SBE38 thermometer. Ambient air measurements were accomplished by drawing air into the system from a suction point located at the ships mast at about 30 m high. Control measurements and calibration procedures were performed every ~6 and 24 h respectively, by means of 3 standard gas mixtures (Deuste Steininger GmbH) bracketing the expected concentrations in this area.

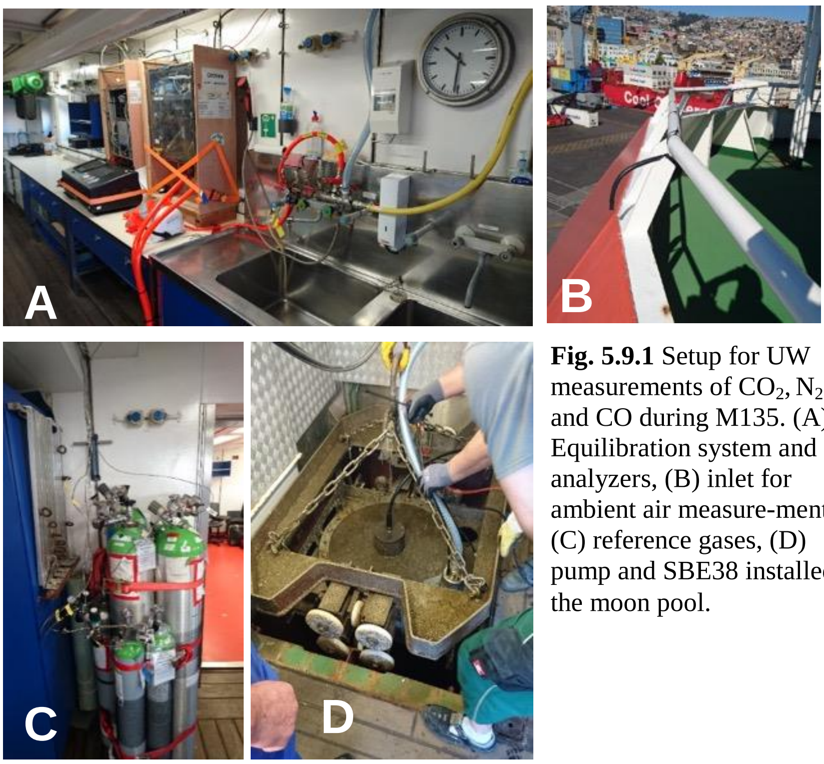


**Fig. 5.9.1** Setup for UW measurements of $CO_2$, $N_2O$, and CO during M135. (A) Equilibration system and gas analyzers, (B) inlet for ambient air measure-ments, (C) reference gases, (D) pump and SBE38 installed in the moon pool.

The UW measurements started on March 2$^{nd}$ at 17:00 am and stopped on April 7th, 2017, at 24:00 (both UTC). Preliminary results of along a cross-shelf section at about 17°S are shown in

Fig 5.9.2. As can be seen, a marked decrease in sea surface temperature (SST) coincides with an enhanced outgassing of $N_2O$ and a dramatic decrease in $CO_2$ outgassing to the atmosphere. Although previous observations in this area (and under the occurrence of upwelling) have provided evidence that the distribution of both gases is often similar in the shelf area, the fact that $CO_2$ diverges from this pattern suggests a strong biological drawdown, which in turn would drive partial pressures of $CO_2$ below atmospheric equilibrium. Since there is not such a biological sink for $N_2O$ in surface waters, the solubility effect seemed to be dominant across this section.

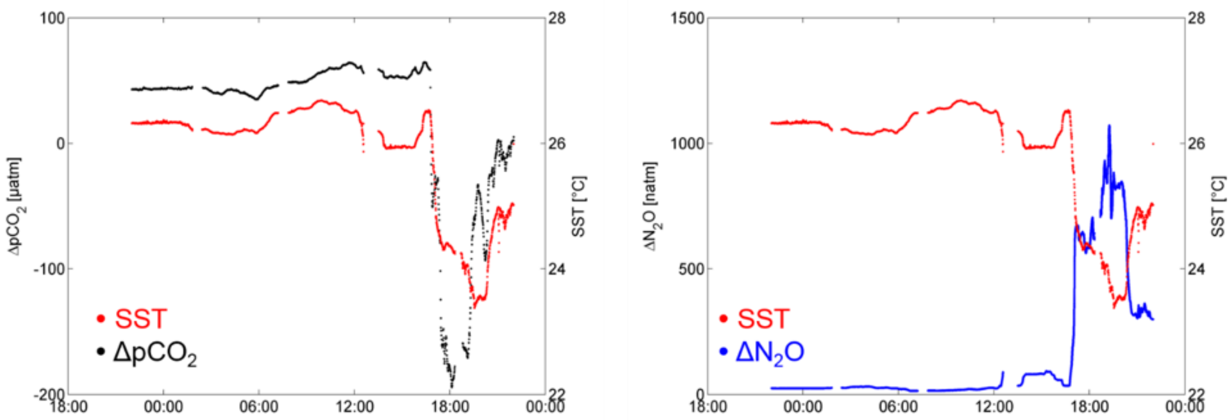


**Fig. 5.9.2** Cross-shelf section of $\Delta pCO_2$ ($pCO_{2\ seawater} - pCO_{2\ air}$; left) and $\Delta N_2O$ ($N_2O_{\ seawater} - N_2O_{\ air}$; right) at about 17°S. Positive values indicate that seawater is oversaturated with respect to the atmosphere (i.e. the ocean acts as a source for these gases). Along-track SST is displayed in red in both panels.

## 5.10 Experimental Underway Measurements SF5

(Chris L'Esperance PIs: Toste Tanhua and Douglas Wallace, DAL, Canada)

A new sampling device for dissolved gases was tried in experimental mode and is described in the following

Sampling approach

Dissolved gases were sampled from a continuous seawater stream distributed to METEOR's Geology / General Purpose Laboratory. A submersible pump (Lowara) mounted in METEOR's moon pool delivered seawater for the underway systems (including the $pCO_2$ and $N_2O$ instruments) at a flow of approximately 30 L/min to a stainless steel manifold. A secondary flow of approximately 1.2 L/min was filtered with a 5 um cartridge filter and delivered to a Liquicel (3M) membrane contactor which serves as a rapid gas exchange device/equilibrator. A compressed gas (helium 5.0, flow rate ~45 mL/min) was used as a sweep gas. Water vapor-laden effluent from the membrane contactor was pre-conditioned with a Nafion dryer (Perma-Pure) fed with helium counter flow at ~80 mL/min.

Description of Equipment and Technique

Dissolved gases were analyzed using a novel, underway gas chromatograph (GC) being developed at the Canada Excellence Research Chair Ocean Science & Technology Laboratory at Dalhousie University. The system consists of two alternately back-flushed, 15 m, GS-gaspro electrically heated capillary columns with low thermal mass, enabling fast gas chromatography. Known volumes (ranging from 25 uL to 1000 uL) of carrier, standard or sample gas was introduced into the analytical circuit via a standard 10-port, two-position valve and sample loop arrangement. The detector used was a pulsed-discharge detector operated in electron capture (ECD) mode (Vici Valco Instruments Inc.) operated at 50° C. The system is fully automated by a LabVIEW software application that allows for alternating frequency of blanks, standards, and samples.

Data acquisition/Coverage

Data acquisition began on the Eastward transect along 11°S and continued until the end of the cruise. Individual samples were acquired with an approximate sampling period of 8 min. The system was periodically taken offline for software/method development, mainly during on-station periods. A typical sequence consisted of duplicate blanks and triplicate, or greater, standard runs followed by a sequence of samples. The frequency of blanks and standards was reduced during the final days of the cruise in order to acquire the environmental signal with higher frequency.

Data Processing

Chromatographic peaks deemed meeting a certain signal to noise ratio threshold were integrated. A few compounds observed in the sample, yet absent from the standard could not be identified during the cruise; subsequent analyses and validation experiments will be carried out to identify these compounds.

## 5.11 Underway Tow Fish Measurements

(Mark Hopwood, PI: Eric Achterberg)

Surface (~2-3 m depth) seawater was sampled from a custom-built towed-fish via acid washed 1 cm diameter tubing with suction provided by a peristaltic pump. Water was pumped directly into the purpose-built clean air laboratory container.

100 Samples collected from 15.03.2017 until 06.04.2017 were for dissolved macronutrient (nitrate, nitrite, phosphate, silicate) concentrations, trace element concentrations, and (for select sections only) hydrogen peroxide ($H_2O_2$). Sample collection for this suite of measurements was carried out every ~3-5 hours of steaming time between CTD-TM stations (except when maintenance work was being conducted on the lower decks of the ship to avoid the risk of dirt intake into the towfish tubing) with a preference for sampling just before or after (~10-15 minutes) a CTD-TM station. Sampling was done for trace metals, Si isotopes, DOP, $H_2O_2$ and nutrients following the procedures outlined in section 5.5.

## 5.12 Biological Incubation Experiments

(Joaquin Ortiz-Cortes, PI: Ulf Riebesell and Allanah Paul)

24-hour duration on-deck incubation experiments were carried out in 4,5 liter Nalgene bottles, as well as immediate filtrations of 2l water samples in 3 to 4 different depths per station (Table 5.12.1). Depths included surface water, water from the center of the oxycline and deep water samples from the anoxic layer. Seawater was collected from CTD casts on 15 stations between 23°S and 13°S. Filling time was approximately 40-45 minutes for a total of 62,5l for 3 depths. Direct filtrations required 2l per depth and incubations required 18l per depth, as measurements were done in triplicates (3 x 4,5l) and one additional blank (4,5l).

The immediate filtrations were used for analysis of particulate organic matter (POM) to assess the initial isotopic composition of the samples as well as total particulate C and N. The incubations (N-fix) were meant to analyze the final isotopic composition of the samples.

Beforehand 2,5l of surface water were filtered and degassed using a peristaltic pump (Thermo Scientific Manostat Vera), a 0,2µm filter capsule (Whatman Polycap 36AS) and a degassing membrane (3M MiniModule G 541).

Incubation samples were treated with 13C (from prepared falcon tubes with 240mg of 13C (Isotec, Aldrich) to be dissolved in 10ml of MilliQ), as well as 15N2 gas (Cambridge Isotope Laboratories, Inc., 3000ml, 98% 15N2). From the 13C-solution 500µl were added to each sample of 4,5l. The 15N2 gas was previously injected into Tedlar bags (SKC, Restek) filled with degassed and filtered seawater (10ml 15N2 per 1l of water). The same was done with ambient air for the blanks. Once the gas was dissolved in the water, 60ml were added to each sample of 4,5l. Blanks were treated with 60ml of the ambient air/water mixture instead of 15N-solution and no 13C-solution.

Bottles were placed in on-deck incubators connected to the ships underway flow-through system to continuously maintain temperatures at that of sea surface waters. Incubators were screened with Blue Lagoon screening, which maintained irradiance at ~75% of that of the surface. After 24-hour incubation, experiments were taken down and all samples were filtered under following conditions: For each depth, POM and N-fix samples were filtered on two different filter sizes: 0,7µm (GF/F) and 0,3µm (GF75). Amounts filtered ranged from 500ml to 1000ml, depending on the amount of dissolved matter in the samples and therefore the duration of the filtration. The filters were then dried for 12 hours at 60°C and packed into Cryovials for shipping.

Filters will subsequently be taken to GEOMAR for analysis of 15N and 13C uptake rates via GC-MS (EuroEA Elemental Analyzer).

**Table 5.12.1** Sampling stations:

| Latitude (°S) | Longitude (°W) | CTD Station # | Sampling depth [m] |
|---|---|---|---|
| 23 | 70,38 | 187 | 10/50/200 |
| 23 | 74 | 193 | 10/70/200 |
| 21 | 70,41 | 203 | 10/50/200 |
| 21 | 74 | 209 | 10/95/200 |
| 19 | 71 | 223 | 10/55/200 |
| 19 | 74 | 227 | 10/100/200 |

| | | | |
|---|---|---|---|
| 19 | 81 | 234 | 10/160/250 |
| 17 | 72,50 | 259 | 10/30/200 |
| 17 | 76 | 264 | 7/60/200 |
| 17 | 82 | 269 | 10/180/300 |
| 17 | 86 | 273 | 10/150/280 |
| 15 | 76 | 290 | 9/32/80 |
| 15 | 81 | 297 | 10/120/230/1000 |
| 13 | 77,37 | 310 | 10/80/140 |
| 13 | 81 | 314 | 10/85/150 |

## 5.13 Ecological Studies

(Sunke Schmidtko, PIs: Rainer Kiko)

The ecological investigations focused on fine-scale vertical profiles of particle and zooplankton distribution were obtained by an Underwater Vision profiler (UVP).

### 5.13.1 Particle and Zooplankton observations with the Underwater Vision Profiler

An Underwater Vision Profiler 5 (UVP), serial number 10, was mounted on the CTD-rosette.

The UVP consists of a down facing high resolution camera and two red LED light arrays, which illuminate a defined water volume. During the downcast of a CTD-deployment, the UVP takes 3 to 11 images per second of the illuminated field. For each image, particles larger than ~60 µm are sized and counted. Furthermore, images of particles larger than 500 µm are saved as separate “vignettes” - small cut-outs of the original image – which allow for later, computer and Citizen Science (https://planktonid.geomar.de) assisted identification of these particles into different particle, phyto- and zooplankton classes.

In total 143 UVP profiles were taken on 143 CTD-stations during M135. The UVP was run autonomously and a specific depth routine was carried out to start it: the CTD was lowered to 10 dbar to enable the power up, then to >20dbar to start the camera and begin image acquisition, prior to lifting the CTD to the surface to start the cast. All measurements were taken with the same configuration settings of the UVP; the most relevant ones are shown in Table 5.13.1. A well-defined distance of 37.5 cm was set between the camera and the lights.

**Table 5.13.1** Main parameter setting for the UVP 5 system.

| | | | | | | |
|---|---|---|---|---|---|---|
| Camera info | Camera | Focale | Iris | Shutter | ISO | neutral Filter |
| | LUMIX G2 | 14 mm | F16 | 2.5" | 100 | 0.9 |
| Lens info | lens model | lens focal | | | | |
| | tamron | 8 | | | | |
| Lights info | light_1 | light_2 | flash frequency | flash duration | | |
| | h046a | h047a | 10 Hz | 100 µs | | |
| Calibration info | aa calib | exp calib | lighted Volume | Pixel size | | |
| | 0.0036 | 1.36 | 0.9933 L | 149 µm | | |

## 5.14 Geophysical Survey

(Felix Gross, PI: Ralph Schneider)

### 5.14.1 Bathymetric Survey

The EM122 system allows an accurate bathymetric mapping down to full ocean depth. Basic components of the system are two linear transducer arrays in a Mills cross configuration with separate units for transmitting and receiving. The nominal sonar frequency is 12 kHz with an angular coverage sector of up to 150° and 864 soundings per ping. Compared with the EM 120 the EM 122 has up to four times the resolution in terms of sounding density through inclusion of multiping capability and more than twice the number of detections per swath. In typical ocean depths, a sounding spacing of about 50 m across and along is achievable. The achievable swath width on a flat bottom will normally be up to six times the water depth dependent of the roughness of the seafloor. The angular coverage sector and beam pointing angles may be set to vary automatically with depth according to achievable coverage. This maximizes the number of usable beams. The beam spacing is normally equidistant, but an equiangular mode is also available. Using the detected two-way-travel-time and the beam angle known for each beam, and taking into account the ray bending due to refraction in the water column due to sound speed variations, depths are calculated for each beam. A combination of amplitude (for the central beams) and phase (slant beams) is used to provide a measurement accuracy practically independent of the beam pointing angle. Beside the depth values, the EM122 provides also backscatter information and pseudo-sidescan images. A real-time display for water-column backscatter is available for the EM122, when water column imaging is enabled.

The EM 710 multibeam echo sounder is a high to very high resolution seabed mapping system. The minimum acquisition depth is from less than 3 m below its transducers, and the maximum acquisition depth is specified down to 2000 m. However, during the cruise it turned out that the quality of the data degrades in water depths deeper than 900 m. The acrosstrack coverage (swath width) can reach 5.5 times the water depth. During the cruise, the swath width was set to 130°. The EM 710 operates at sonar frequencies in the 70 to 100 kHz range. The transmit fan is divided into three sectors to maximize range capability but also to suppress interference from multiples of strong bottom echoes. The sectors are transmitted sequentially within each ping, and uses distinct frequencies or waveforms. The alongtrack beamwidth of the system installed on RV METEOR is 1 degree. A ping rate of up to 25 per second is possible. The transmit fan is electronically stabilized for roll, pitch and yaw. The EM 710 on RV METEOR has a reception beamwidth of 1 degree as well. The number of beams is 256 or 400 (high resolution mode). The beamspacing may be set to equiangular or equidistant. The receive beams are electronically roll stabilized. A combination of phase and amplitude bottom detection algorithms is used in order to provide soundings with the best possible accuracy. Additionally, an integrated seabed acoustical imaging capability is included as standard. A real time display window for water column backscatter is also available.

During Cruise M135, the Kongsberg Simrad systems EM122 and EM710 were used for bathymetric mapping. The deep water system EM122 was operated continuously during the entire cruise. The shallow water system EM 710 was used in water depths less than 1000 m during site evaluation for geological sampling. All data was stored in the raw *.all file format and were nor further processed onboard. The EM122 worked reliable during the entire cruise.

Sound velocity profiles for multi-beam acquisition were generated from CTD casts by using the Kongsberg Sound Velocity Editor.

### 5.14.2 Sediment Echo Sounding

Since March 2006, the PARASOUND system P70 is installed on RV METEOR. The system uses the parametric effect, which occurs when very high (finite) amplitude sound waves are generated. If two waves of similar frequencies are generated simultaneously, also the sum and the difference of the two primary frequencies are emitted. For the PARASOUND System, 18 kHz is one fixed primary frequency, which distributes energy within a beam of 4.5° for a transducer of ~1 m length. The second primary frequency can be varied between 18.5 and 24 kHz, resulting in difference frequencies from 0.5 to 6.0 kHz. This signal travels within the narrow 18 kHz beam, which is much narrower than e.g. a 4 kHz signal, emitted from the same transducer directly (30°). Therefore, a higher lateral resolution can be achieved, and imaging of small scale structures on the sea floor is superior to conventional systems. As another consequence, the signal bandwidth is also increased, and much shorter signals can be generated with improved vertical resolution. However, due to the very narrow beam, it is necessary to control beam direction to compensate the ship's movement and to send the energy vertically downwards. The system treats three signals separately: the primary high frequency signal (18 kHz; PHF), the secondary low frequency signal (selectable 0.5 to 6.0 kHz; SLF) and the secondary high frequency (selectable 36.5 to 42 kHz; SHF). All three signals are recorded separately. Alternatively, also exclusively a low frequency signal (PLF; 3 or 12 kHz) can be emitted at much lower energy levels, where sound emission energy levels have to be limited (e.g. for mammal protection).

The PARASOUND system uses minimum three different computer systems. Two of them control realtime signal generation and data acquisition through a Linux and a Windows XP system. The third PC is available for the operator. This Operator-PC hosts the Hydromap Database Server, the Hydromap Control Software and the ParaStore 3 Software. The Hydromap Control Software is responsible for all systems settings and for communication with the realtime computers. For visualization, online processing and storage, the ParaStore Software Package is used. Data can be stored in the PARASOUND own ASD format, but also in the more common PS3 or SEG-Y Format. Several windows can be opened to display different signals (PHF, SLF, SHF) with different scaling and/or processing parameters. This allows optimizing the windows for specific purposes, as e.g. imaging of the upper 20 m of sediments to select optimal coring locations, to choose a full penetration plot, which also allows coverage of the topography, or to study the complete water column.

The system can be used in the single pulse mode, when a single pulse is emitted and the water column and sediment response are recorded before the next pulse is sent, or in the pulse train or quasi equidistant mode, by which the two-way travel time of the signal in the water column is used to emit more signal. Then, the signal density can be increased by as much as a factor of 16, if the time interval between pings and water depths allow.

Before M135, the PARSOUND P70 was inspected by a Teledyne technician in the port of Valparaiso. Nevertheless, alike during M133 and M134, the PARASOUND P70 showed major malfunctions and system crashes, which prohibited a continuous surveying. The system errors seemed to be a result of the crashing SPM and CM modules. During the reboot of the system, a synchronization of the SPM and CM often failed and the process had to be started again. The malfunction in between the SPM and the CM was indicated by a high latency with the Hydromap Control, manifesting in data set ages of more than 3 s. The error messages, set by the System were logged and forwarded to Teledyne Atlas Hydrographic. After the WTD replaced the power supply units of the HVPM (High Voltage Power Module) and the LVPM (Low Voltage Power Module) within the DEU (Digital Electronic Unit) on the 18.03.2017, the system was suddenly working fine without any malfunctions for the entire cruise. A remote maintenance by a Teledyne Technician on the 19.03.2017, did not show any further problems with the system. It is still unclear, if the change of the power supplies solved all these problems on a long-term perspective, which are known on RV METEOR for a long time.

As the 38 kHz ADCP was from major importance to the cruise's objectives, the interfering PARASOUND system was only turned on for dedicated surveys. These survey include the hydro-acoustic surveys for sediment sampling site evaluation and special surveys during rapid CTD casts. The system was mostly operated in single pulse mode, as the previous cruises indicated that the quasi-equidistant mode is more unreliable and led to more system crashes. From 01.04.2017 01:44 UTC - 02.04.2017 19:22 UTC, a continuous transect was recorded by using the quasi-equidistant mode. During this transect, the system performed well without any malfunctions.

All data were converted to the SEG-Y format during the cruise by using the software package

ps32sgy (Hanno Keil, University Bremen). The software allows generation of one SEG-Y file for longer time periods, by converting and compiling ps3 data. The PARASOUND data were loaded into the seismic interpretation software IHS Kingdom Suite 2016.1. This approach allowed us to obtain a first impression of sea floor morphology variations, sediment coverage and sedimentation patterns along the ship's track.

### 5.14.3 Preliminary Results

With the help of the parametric echo-sounder PARASOUND P70, we were able to identify and evaluate potential geological sampling locations. The objective during this cruise was to find undisturbed and well-stratified sedimentary systems, which indicate undisturbed sedimentary sequences (Fig. 5.14.1). As the entire working area at the shelf and the continental margin off Peru and Chile are well known for an intense overprint by erosive processes like submarine canyon incision, landslides and contouritic erosion and re-deposition, we concentrated on unmapped areas, and located within water depths of 250-1500 m. The data show a high abundance of submarine canyons and erosive sedimentary structures, indicated by unconformities, outcropping at the seafloor (Fig. 5.14.2).

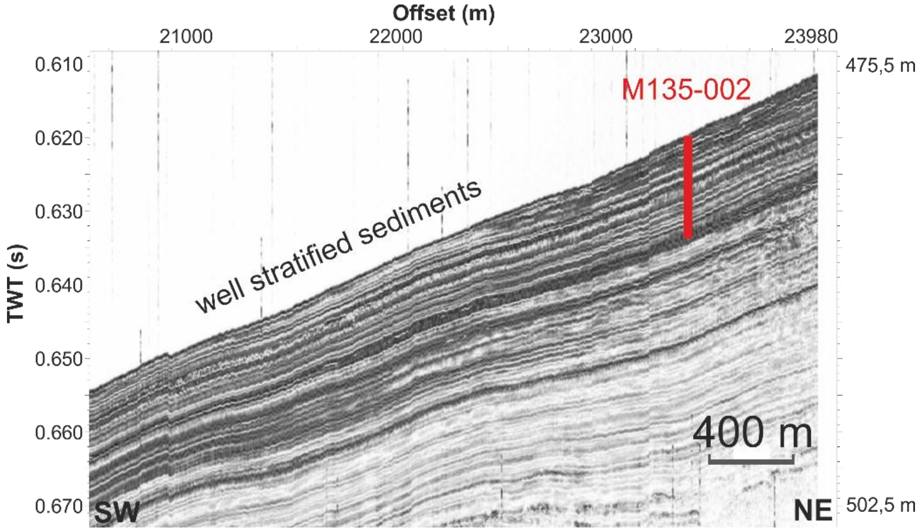


**Fig. 5.14.1** PARASOUND SLF echogram showing undisturbed sedimentary sequence offshore Peru.

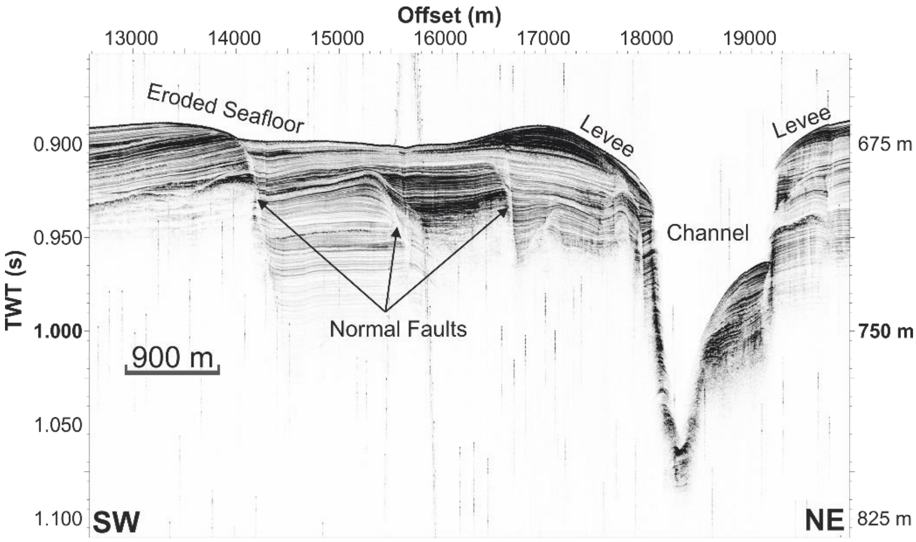


**Fig. 5.14.2** PARASOUND SLF echogram showing a channel levee system, normal faults and indications for seafloor erosion offshore Peru.

Next to conventional sediment echo-soundings, the PARASOUND system was also used to gather 2D water column information in water depths less than 1000 m. This method is enabled by using the Primary High Frequency (PHF) of the system, which images the entire water column but does not show a significant seafloor penetration. With the help of this method, it was possible to show major elements within the water column, like the mixed layer close to the surface and potential bio-activity caused by diurnal plankton and crill migration (Fig. 5.14.3).

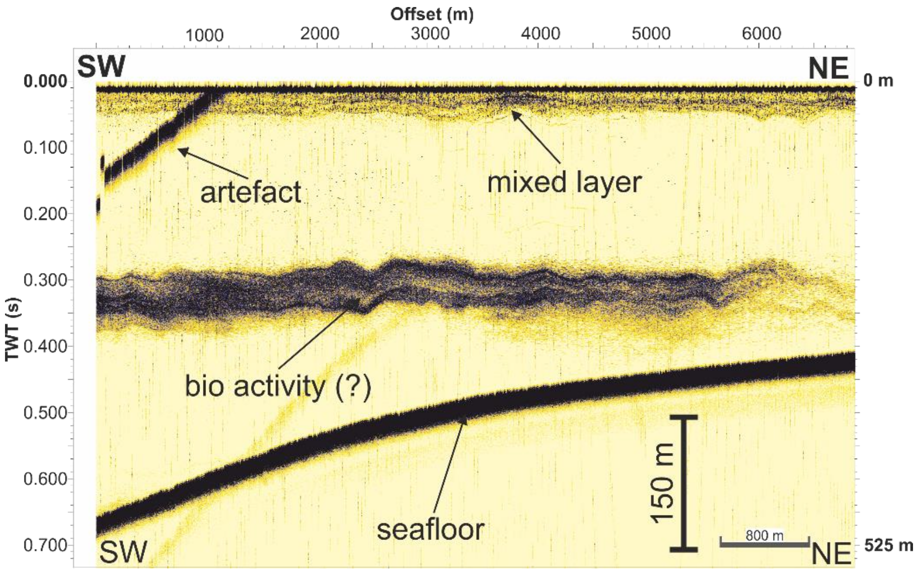


**Fig. 5.14.3** PARASOUND PHF echogram showing the water column offshore Paracas. In order to see potential interaction of processes within the water column and sedimentary systems, PARASOUND data were also acquired during rapid CTD casts during M135.

## 5.15 Geological Coring

(Renato Salvatteci, Federico Velazco, Felix Gross, Sümeyya Eroglu, Sebastian Steinig, PI: Ralph Schneider)

### 5.15.1 Area of Operation

The coring operation was done in Arica Basin (off Chile) and in the East Arequipa Basin (off Ilo, Peru; Fig. 5.15.1). The exact coring locations were determined using detailed Parasound profiles. One coring station was selected in the Arica Basin while four stations were selected in the East Arequipa Basin. In the Arequipa Basin two cores were retrieved at shallow depths and two at relatively deeper depths in order to evaluate changes in the vertical extent of the Oxygen Minimum Zone in the past. At each station a CTD, a multicorer and long gravity core were deployed, the only exception is station M135-002 where two gravity cores were collected.

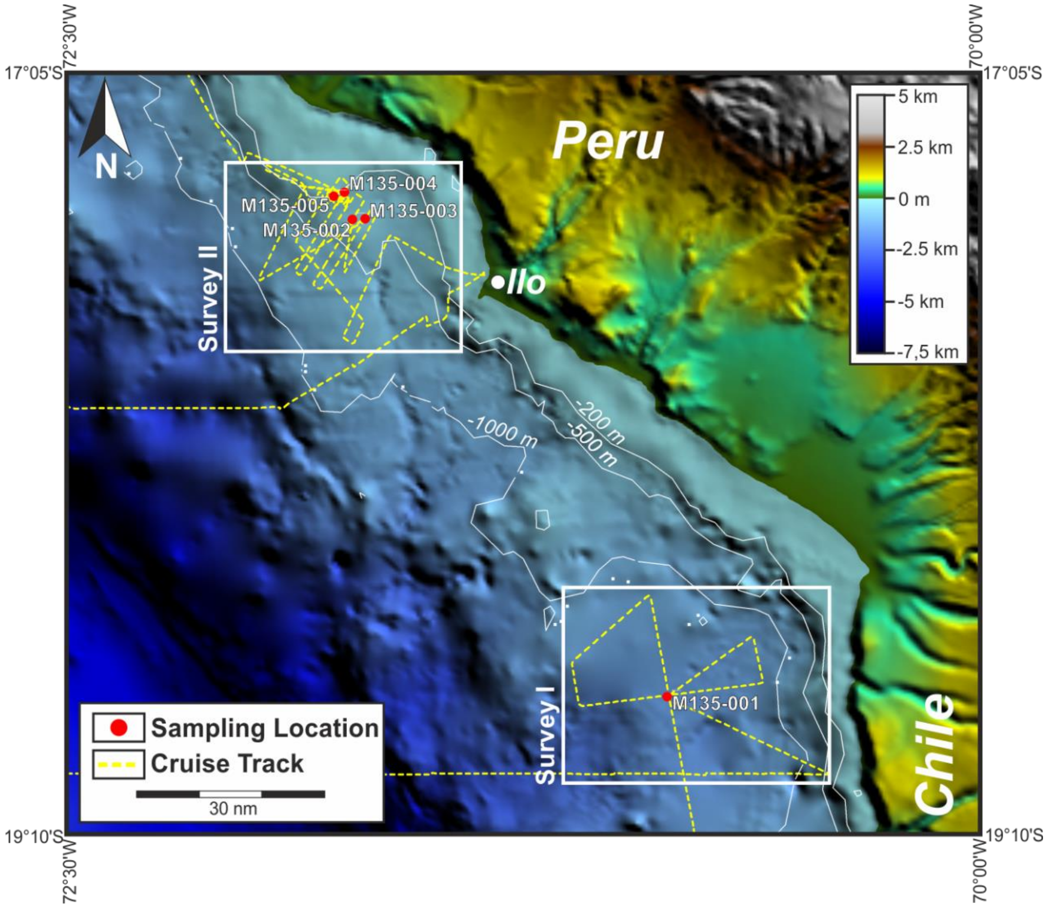


**Fig. 5.15.1** Map of southern Peru- northern Chile showing the location of the cores collected during M135. The discontinuous yellow lines indicate the cruise track.

### 5.15.2 Gravity Cores Sampling

During the M-135 cruise six sediment cores were recovered using a gravity corer (Table 5.15.1). The gravity corer device (l0 meter length that can be extended to 15 m; 12.5 cm inner diameter and a head weight of 1.5 tonnes) was successfully used to recover six sediment cores containing hemipelagic sediments. Once the core was placed on the deck, the 5 meters long core liners were cut into 1 m segments, closed with caps at both ends and labelled according to the scheme applied in the Geosciences Department, University Kiel.

A total length of 36.5 meters from 6 sediment cores was recovered during M-135. The core recovery was very good with average recoveries of ~6 m of sediment (see Table 5.15.1). The 1 meter long segments were cut along-core in two half pieces: one archive-half and one work-half. The archive halves were used for sedimentological description including photographs. The sedimentological description was based on macroscopic visual description including thee lithology (i.e. grain size), the color according to the MUNSELL soil color chart, and the sedimentary structure (i.e. presence of laminated sediments or slumps).

**Table 5.15.1** Gravity core samples retrieved during cruise M-135

| Station | Date | Latitude | Longitude | Water depth (m) | Recovery (m) |
|---|---|---|---|---|---|
| M135-001-3 | 11.03.2017 | 18°47.394'S | 70°51.387'W | 1412 | 5.8 |
| M135-002-3 | 19.03.2017 | 17°29.05'S | 71°43.088'W | 466 | 4.2 |
| M135-002-4 | 19.03.2017 | 17°29.054'S | 71°43.090'W | 465 | 4.3 |
| M135-003-3 | 19.03.2017 | 17°28.963'S | 71°41.012'W | 470 | 5.6 |
| M135-004-3 | 20.03.2017 | 17°24.598'S | 71°44.416'W | 229 | 7.5 |
| M135-005-3 | 20.03.2017 | 17°25.228'S | 71°46.139'W | 197 | 9.2 |

#### 5.15.2.1 M135-001-3

Core M135-001-3 retrieved in the Arica Basin is mainly composed of two massive-homogeneous sedimentary units, one from 0 – 320.5 cm and the other from 320.5 to the bottom (576 cm). These units are separated by irregular/erosional contacts. The color of the upper section of both units is very dark grayish brown to dark olive brown, and both units have slightly less silt content in the upper compared to the bottom section. Also in the two units the water content appears to be higher in the upper section compared to the bottom section. The color of the bottom section of both units is olive brown (lighter than the upper section) and the silt content increases toward the base. Additionally, the presence of very fine sand/sandy layers and isolated sand-sized calcareous shell fragments were observed.

#### 5.15.2.2 M135-002-3

Core M135-002-3 retrieved in the Arequipa Basin at 465.6 meters depth contains hemipelagic clayey-silt sediments characterized by sulfidic odor. The length of the core is 4.09 meters. The first 4 cm is composed by a homogeneous silty-clay, dark olive brown layers and the contact between this sedimentary unit and the next one is irregular. From 4 to 165.4 cm depth, clayey-silt, homogeneous, very dark grayish brown sediment can be observed, some sandy mud layers (thickness up to 4.5 cm) are also observed. At 99.5 cm depth, a dark gray silt layer (4.5 cm thick) with irregular contact at the base is observed. From 165.4 to 213 cm, sediments are composed by sandy mud with several darker, silty-clay layers. From 213 to 331 cm olive clayey-silt bands, bioturbated sections, and a package (287-301 cm) of laminated sediments (1 to 2 mm thick) are observed. Below this sedimentary unit, a slump is observed from 301 to 303.5 cm. From 331 to 409 cm clayey-silt with several olive light and dark bands (0.5 to 3.5 cm) with a prominent layer black to dark grayish brown from 380 to 382.5 cm depth.

#### 5.15.2.3 M135-002-4

Core M135-002-4 retrieved in the Arequipa Basin at 465 meters depth contains hemipelagic clayey-silt sediments characterized by sulfidic odor. The length of the core is 4.3 meters. The first 12 cm is composed by a homogeneous silty-clay, dark olive brown layer and the contact between this sedimentary unit and the next one is irregular. From 12 to 290 cm depth homogeneous layers are interspersed with sequences of banded sediments. The homogeneous layers are composed of very dark grayish brown clayey-silt sediments. The homogeneous sections present some sandy mud layers and lenses, also some dispersed sand-sized foraminifers are present. The color of the banded sections ranges between very dark grayish brown to dark olive brown. From 290 to 316 cm depth laminated sediments (1 to 5 mm thick) can be observed. The last sedimentary unit (342-429 cm depth) also contains clayey-silt, homogeneous sediments but the color (olive) is slightly lighter than the previous sections.

#### 5.15.2.4 M135-003-3

Core M135-003-3 retrieved in the Arequipa Basin at 470 meters depth is mainly composed of silty-clay hemipelagic sediments characterized by sulfidic odor. The length of the core is 5.6 meters. The first 55 cm is composed by two homogeneous layers separated at 6 cm by an irregular contact. Both layers are composed of silty-clay sediments, but the uppermost layer is very dark grayish brown while the bottom layer is slightly lighter. From 58 to 276 cm an alternation of homogeneous/banded clayey-silt with banded silty-clay sediments can be observed. The colors of both types of sedimentary structures vary between very dark grayish brown to dark grayish brown. From 276 to the bottom of the core laminated clayey-silt sediment sequences can be observed. The thickness of some of these laminae is lower than 1 mm. The laminated sequences are separated by irregular contacts (281, 454, 545 cm depth) and a slump (from 371 to 380 cm).

5.15.2.5 M135-004-3

Core M135-004-3 retrieved in the Arequipa Basin at 229 meters depth is mainly composed of silty-clay, hemipelagic sediments (Figure 5.15.2) characterized by strong sulfidic odor. The length of the core is 746 cm. From the top to 60 cm depth, laminated (0.5-3 mm thick) silty-clay sediments sequences are interspersed with bands (up to 1 cm thick) composed of clayey-silt sediments. The colors of the laminae vary from dark olive brown to very dark grayish brown, while the bands are dark gray. From 60 to 76 cm depth a prominent slump and a sandy silt lens on top of the slump can be observed. From 76 to 371 cm depth packages of laminated, silty-clay sediment sequences are interspersed with banded sequences. At 371 cm depth a prominent, dense and hard, olive, silty with sand grains band, is observed. On the top and the bottom of this band (2 cm thick) irregular contacts are observed. Below this hard silt layer, from 373.5 to the bottom (746 cm) silty-clay, laminated, dark olive brown to very dark grayish brown laminae are interspersed with bands. In this sedimentary unit bands are common than laminae and laminae are not that visible as compared to the first 2 meters. More silty sediments are observed toward the base of the core (646-746 cm depth). At 546, 610 and 713 cm depth dense, olive, clayey-silt bands (1 – 1.5 cm thick) are observed, some of these bands contain sand grains. These bands are hard and dense, but the hardness of each band is different.

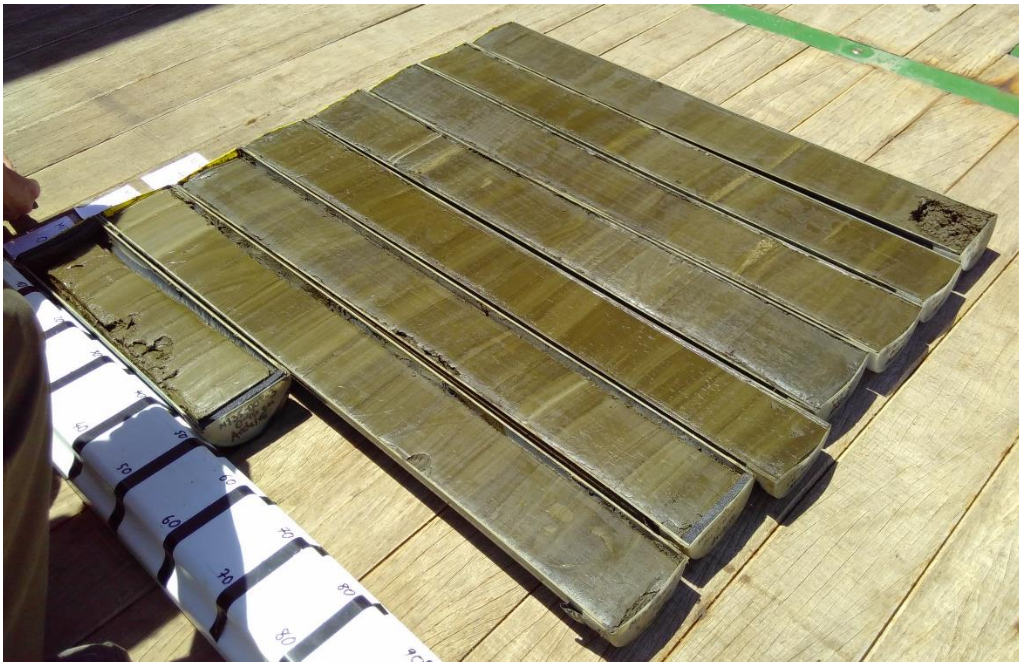

**Fig. 5.15.2** Photograph of core M135-004-3 showing finely laminated sequences.

### 5.15.2.6 M135-005-3

Core M135-005-3 retrieved in the Arequipa Basin at 197 meters depth is mainly composed of silty-clay, hemipelagic sediments characterized by strong sulfidic odor. The length of the core is 916 cm. The first sedimentary unit (top to 22.5 cm depth) is composed of silty-clay sediments, in this unit bands are observed as well as some light laminae. From 22.5 to 38 cm depth sediments are coarser (clayey-silt) and lighter than the previous section (dark gray) and some laminae of 0.5 to 3 mm thick are observed. From 38 to 375 cm laminated sequences composed of clayey-silt sediments are interspersed with bands and homogeneous sequences. In this unit, color varies from very dark grayish brown to dark olive brown. A slump is observed from 375 to 388.5 cm depth. At 388.5 cm a light gray band is overlying an erosional contact. From 388.5 to 440 cm silty-clay sediments with some lenses of muddy sand are observed. From 440 to 525.5 cm isolated laminations (less than 1 to 3 mm thick), bands and homogeneous sections (up to 10 cm) are observed. From 525.5 to 732 cm homogeneous sections with few very discrete laminae and sandy layers are observed. An indurated layer of 3.5 cm thick with clayey-silt, olive sediments is observed at 690 cm depth. From 732 to 916 cm laminae packages (1 – 3 mm thick) are interspersed with bands. There are some sand lenses and layers towards the bottom of the core (e.g. 831, 841 and 859.5 cm depth).

### 5.15.3 Multicore Sampling

Undisturbed sediment surface samples were collected using a multi-corer equipped with 8 tubes (60 cm length; 10 cm in diameter). The multicorer was deployed on the same locations where gravity or piston cores were taken (Table 5.15.1). On average at each station 7 to 8 tubes were recovered containing well preserved water-sediment interface. The average sediment recovery was 32.6 cm in the Arica Basin and the two deepest stations in the Arequipa Basin, while in the two shallower stations the average was 51.5 cm. Benthic fauna (Polychaeta sp., crustacean) was present in the sediments from the Arica basin. In the sediments from the Arequipa basin small mats or isolated filaments of giant bacteria (Thioploca sp.,), foraminifers, Polychaeta sp and rests of Munidae sp. characterized the top centimeters of the sediment cores. The presence of strong sulfidic odor characterized the sediments from the Arequipa basin. The general distribution of samples was as follow: 1 tube for foraminifera and fish scales assemblage determination, 1 for trace metals and organic carbon, 1 for biomarkers and radioisotopes determination, and at each station at least 2 tubes were kept refrigerated for further analyses that will be done in Kiel University and IMARPE. The sediment cores were then sliced in 1-cm intervals and placed into Petri dishes. All the samples were kept at 4°C in the cooling room. Multicores retrieved at station M135-004-3 presents finely laminated sequences as observed in Figure 5.15.3.

**Fig. 5.15.3.** Photograph of one of the cores collected with the multicorer in station M135-004-2, showing finely laminated sediments in the upper sedimentary column and the presence of filamentous bacteria.

## 5.16 Micro Strukture Sonde

(Thilo Klenz; PI: Marcus Dengler)

Measurements of finescale turbulence beneath the mixed layer and in the water column were performed using a vertical microstrucutre profiler (VMP) at several stations along the slope and shelf region of Chile and Peru throughout the cruise.

### 5.16.1 System Setup

During M135 a total of 97 microstructure profiles were taken at 24 stations using a Sea & Sun Technology VMP (sn 26). The VMP was equipped with three shear sensors (sh1: sn 130, sh2: sn 044, sh3: sn 120), a fast thermistor (NTC) and standard conductivity, pressure and temperature (CTD) sensors. A winch mounted at aft, portside allowed to deploy the VMP at free fall, ballasted with 17 thin and 6 thick rings leading to a sinking velocity of around 0.55m/s. During profiling the vessel was going between 1-1.5kn. During the first station the winch's motor malfunctioned and was replaced by a backup motor. The replaced motor worked throughout the rest of the cruise. The winch was connected to a Sea & Sun Technology deck unit (sn 020) and data recorded on a laptop connected to the deck unit using SSDA software v. 1.86.

Main objective of these microstructure measurements is the quantification of microscale (O(10-2m)) turbulent processes. Turbulence in the study region is favored by high shear in the depth range of the Peru-Chile Undercurrent and in the presence of internal waves, forced by the diurnal and semidiurnal tides impinging on the shelf break, traveling shoreward over the shelf. An example of enhanced turbulent kinetic energy dissipation in the presence of strong velocity shear is given in Figure 5.16.1. Here the presence of the poleward flowing Peru Chile Undercurrent leads to enhanced vertical velocity shear, which, in combination with weaker stratification at depth, leads to enhanced mixing between 200-250m water depth.

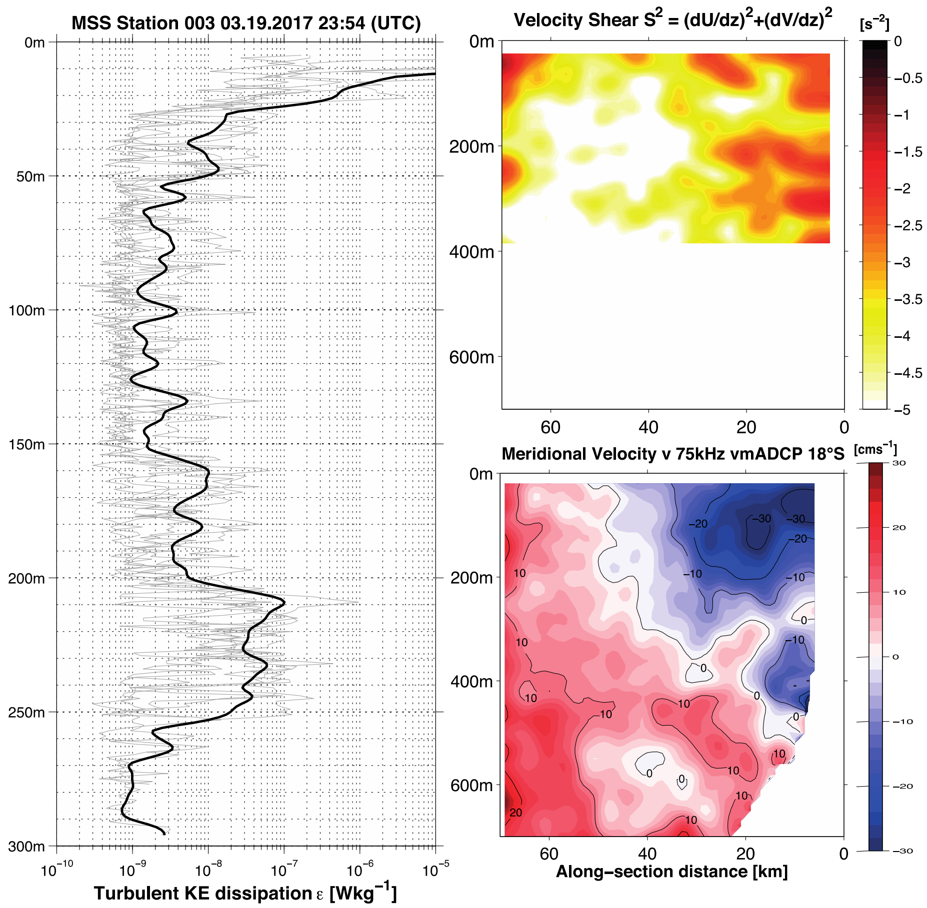


**Fig. 5.16.1** Individual profiles (thin, grey lines) and mean (thick black line) of turbulent kinetic energy dissipation (left) as well as logarithmic velocity shear (top right) and meridional velocity (bottom right) along 18°S. Regions of enhanced vertical shear in the water column are characterized by enhanced TKE dissipation (MSS st. 3 at about 30km along-section distance).

## 5.17 Glider Operations

(Christian Begler; PI: Gerd Krahmann and Marcus Dengler)

During the cruise M135 two SLOCUM ocean gliders #IFM09 and #IFM12 were deployed. #IFM09 was deployed at 14°01.28'S 76°53.31'W and #IFM12: 14°02.41'S 76°53.23'W within a few hours of each other on April 3rd, 14:30UTC and 16:12UTC. A zodiac operation deployed the gliders swiftly despite significant swell (1.5 m hight) and wind (8 m/s). Prior deployment ordinary cosmetic zinc-crème was used to cover most of the glider surface as biofouling protection, this proofed to be a good anti-fouling measure. The oxygen optodes of the gliders were attached with a logger to the CTD - casts 101, 111, 113 and 116 - in the days prior deployment. 7 stops with 4 minute wait times were made during the up-cast to allow a better CTD-sensor – optode comparison, paying tribute to the slow response time of the optical oxygen sensor.

# 6 Weather conditions during M135

(Harald Rentsch and Andreas Raeke, Meteorological Office RV METEOR)

RV METEOR left port Valparaiso in the evening on March 1st 2017 for its voyage M135. The ship sailed on the edge of a dynamical high pressure system nearby 35°S/100°W in a southerly wind flow of 5 Beaufort (Bft). When the ship reached open waters the wave heights prevailed around 2 m, during the night to 2nd of March we got a southwesterly swell of around 3.5 m with a period of 12 seconds. This happened all together with sunshine and weak southerly winds. Hours later during daytime a swell of nearly 4 m were observed. One other day later swell weakened to values below 3 m, also wind speed decreased from 5 Bft to 4 Bft. Due to the attenuation of the central steering high pressure system, located southwesterly of our research area and its movement towards northeast the wind came from south-southwesterly, wind speed was measured at 3 to 4 Bft (only for a short time 5 Bft in the evening). The cloudiness changed often, probably caused by a variable strength and height of inversion of temperature.

Until the end of the week the swell prevailed between 1.5 m and 2.5 m. A first radio-sounding on 5th of March showed a strong free inversion of temperature within a weak surface-trough, this was a clear evidence for the often seen changeable stratification of clouds over the working areas at this time and the days before.

From 6th of March onward due to a nearly stationary subtropical high pressure system 1023 hPa nearby 33°S 81°W weak southerly trade winds (around 4 Bft) and a calmed sea keep prevailed. Wave heights of 1 to 2 m from southerly directions and a steadily change of cloudiness were observed for some days. At the end of the week the sea increased a little and the southwesterly swell reached 2.5 m without to disturb the good research conditions significantly.

Also during the third week on sea **(**03/13/ - 03/19/2017) research were done in a stable trade-wind zone. On Monday, 13th of March, southeasterly winds around 5 Bft and a sea of 2 to 2.5 m minted the sea-conditions on the ships track. In addition, mostly broken, partly multilayered clouds situated in lower levels, were observed. Occasionally, mostly at night and in the hours of the morning, small amounts of drizzle or rain were measured, but sunny spells followed often in the afternoon. Variable sea surface temperatures (SST) between 16.5°C and 26°C were registered, depending on the distance to the coast, air temperatures reached maximal 25°C and minimal 22°C a time accommodated to SST.

Between the middle of the week and March 19th the ship sailed eastward crossing the continental shelf, which caused a more calmed sea (wave heights below 2 m), the probability of precipitation was smaller than the days before and the southeasterly trade winds decreased to below 4 Bft. On 18th of March, local effects of Sea Breeze evoked wind speed up to 6 Bft off the coast of Ilo (Peru) between noon and late afternoon. Air temperatures varied during this time between 20 and 23°C.

From 20th of March onward weak south-easterly trade winds of 3 to 4 Bft, at times up to 5 Bft, and a sea of around 2 m were the dominant features of sea-weather during following three days. Below an inversion of temperature broken cumulus- and stratocumulus clouds were observed, also some tops of cumulonimbus clouds were visited in the vicinity of coastal mountains of Peru. This was in accordance with given satellite pictures of the weather service of Peru for that period.

Already on 18th of March media worldwide reported of extreme floods and landslides in and nearby Lima (Peru) and various mountain regions in northern- and middle of Peru. This precipitation-issue was forecasted by rain-sum charts, which showed values of 20 to 50 mm per 12h for this time-period. The German weather service published a paper to this phenomenon and associated all this as a coastal "El Nino"- event.

After 22nd of March CTD water samplings were carried out along 17°S until 85°W. At the same time we measured a rising SST (around 26°C), which rose evaporation followed by convective clouds and isolated showers. Turbulence often acted upon an averaged wind speed of 5 to 6 wind-forces from Southeast during the second half of the day. The most precipitation during the whole expedition fell on 27th of March: around 1 mm as total rain-sum per 6 hours was registered.

On Monday, 27th of March, steadily south-easterly to easterly trade winds of around 5 Bft were measured, and the significant wave-heights did not exceed 2 m. Convective clouds were the dominant features on the sky, which were stopped rising by a strong, rising inversion of temperature nearby 2000 m. That's why isolated showers were rather seldom. The air temperature rose up to a value of 23°C.

Between Tuesday 28th and Wednesday 29th of March research were done very close to the Peruvian coast, a current of cold water (SST: 17-20°C) caused air temperatures below 21°C. Typically the pressure gradient produced a gradient wind of around 5 Bft, and additional in the evening, when the winds came from the cooling landside, we got around 6 Bft. The southerly swell reached at times 2.5 m there.

After the 31st of March the sea calmed a bit, 2 m was the highest value for the swell then.

On 2nd of April was planned to deploy some ocean gliders taken by a rubber dinghy. But a forecasted strong pressure gradient forced by land-sea effects produced wind forces of around 7 Bft, gusts 9 Bft (42 kt), and a wind-sea of nearly 2 m (5 s - period), too much for save working at sea. But more than one day later gliders were deployed successfully.

Right at beginning of the last week of our voyage, on 3rd of April, a weakening subtropical high caused decreasing winds of 5-6 Bft (sea < 2.5 m) and consequently a decreasing wind-sea of below 1 m. This slowly down-going trend of wind and waves continued during rest of the expedition. On 7th of April we had the last CTD cast nearby the Peruvian coast and unchanged good weather- and working conditions attended that.

On Saturday, April 8th 2017, RV METEOR reached the port of Callao.

# 7 Station List M135

**Station List:** of R/V METEOR cruise M135.

| Station M135 | Type | Num | Date (2017) | Time UTC | Latitude | Longitude | max. depth [m] | Parameters |
|---|---|---|---|---|---|---|---|---|
| 179-1 | CTD/RO | 1 | 02/03 | 11:56 | 31° 01' S | 72° 06' W | 724 | T,S,P,O2,Fl |
| 180-1 | CTD/RO | 2 | 02/03 | 19:46 | 30° 00' S | 71° 45' W | 763 | T,S,P,O2,Fl,nuts, tracer |
| 181-1 | CTD/RO | 3 | 03/03 | 02:59 | 28° 49' S | 71° 40' W | 655 | T,S,P,O2,Fl,nuts, tracer |
| 182-1 | CTD/RO | 4 | 03/03 | 08:37 | 28° 00' S | 71° 19' W | 1664 | T,S,P,O2,Fl,nuts, tracer |
| 183-1 | CTD/RO | 5 | 03/03 | 15:47 | 27° 00' S | 71° 04' W | 1437 | T,S,P,O2,Fl,nuts, tracer |
| 184-1 | CTD-TM | 1 | 03/03 | 22:40 | 26° 00' S | 71° 00' W | 500 | T,S,P,O2,Fl,TM |
| 184-2 | CTD/RO | 6 | 03/03 | 23:19 | 26° 00' S | 71° 00' W | 1990 | T,S,P,O2,Fl,nuts, tracer |
| 185-1 | CTD-TM | 2 | 04/03 | 06:38 | 25° 00' S | 70° 49' W | 505 | T,S,P,O2,Fl,TM |
| 185-2 | CTD/RO | 7 | 04/03 | 07:12 | 25° 00' S | 70° 49' W | 1653 | T,S,P,O2,Fl,nuts, tracer |
| 186-1 | CTD-TM | 3 | 04/03 | 14:00 | 24° 00' S | 70° 45' W | 500 | T,S,P,O2,Fl,TM |
| 186-2 | CTD/RO | 8 | 04/03 | 14:32 | 24° 00' S | 70° 45' W | 2312 | T,S,P,O2,Fl,nuts, tracer |
| 187-1 | CTD-TM | 4 | 04/03 | 21:47 | 23° 00' S | 70° 39' W | 502 | T,S,P,O2,Fl,TM |
| 187-2 | CTD/RO | 9 | 04/03 | 22:24 | 23° 00' S | 70° 39' W | 526 | T,S,P,O2,Fl,CDOM, tracer,bio |
| 188-1 | CTD-TM | 5 | 04/03 | 23:42 | 23° 00' S | 70° 45' W | 1010 | T,S,P,O2,Fl,TM |
| 188-2 | CTD/RO | 10 | 05/03 | 00:31 | 23° 00' S | 70° 45' W | 2075 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 189-1 | CTD/RO | 11 | 05/03 | 03:26 | 23° 00' S | 71° 00' W | 2008 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 190-1 | CTD/RO | 12 | 05/03 | 07:30 | 23° 00' S | 71° 30' W | 2002 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 191-1 | CTD-TM | 6 | 05/03 | 11:40 | 23° 00' S | 72° 00' W | 1009 | T,S,P,O2,Fl,TM |
| 191-2 | CTD/RO | 13 | 05/03 | 12:28 | 23° 00' S | 72° 00' W | 2024 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 192-1 | CTD-TM | 7 | 05/03 | 19:35 | 23° 00' S | 73° 00' W | 1008 | T,S,P,O2,Fl,TM |
| 192-2 | CTD/RO | 14 | 05/03 | 20:25 | 23° 00' S | 73° 00' W | 2001 | T,S,P,O2,Fl,nuts, tracer |
| 193-1 | CTD/RO | 15 | 06/03 | 03:22 | 23° 00' S | 74° 00' W | 206 | T,S,P,O2,Fl,bio |
| 193-2 | CTD-TM | 8 | 06/03 | 03:47 | 23° 00' S | 74° 00' W | 1001 | T,S,P,O2,Fl,TM |
| 193-3 | CTD/RO | 16 | 06/03 | 04:31 | 23° 00' S | 74° 00' W | 2000 | T,S,P,O2,Fl,nuts, tracer |
| 194-1 | CTD/RO | 17 | 06/03 | 11:48 | 22° 00' S | 74° 00' W | 1014 | T,S,P,O2,Fl, tracer |
| 195-1 | CTD/RO | 18 | 06/03 | 18:24 | 22° 00' S | 73° 00' W | 1002 | T,S,P,O2,Fl, tracer |
| 196-1 | CTD/RO | 19 | 07/03 | 00:48 | 22° 00' S | 72° 00' W | 1012 | T,S,P,O2,Fl, tracer |
| 197-1 | CTD/RO | 20 | 07/03 | 04:29 | 22° 00' S | 71° 30' W | 1001 | T,S,P,O2,Fl, tracer |
| 198-1 | CTD/RO | 21 | 07/03 | 08:04 | 22° 00' S | 71° 00' W | 1011 | T,S,P,O2,Fl, tracer |
| 199-1 | CTD/RO | 22 | 07/03 | 10:20 | 22° 00' S | 70° 45' W | 1012 | T,S,P,O2,Fl, tracer |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 200-1 | CTD-TM | 9 | 07/03 | 12:32 | 22° 00' S | 70° 31' W | 1008 | T,S,P,O2,Fl,TM |
| 200-2 | CTD/RO | 23 | 07/03 | 13:24 | 22° 00' S | 70° 31' W | 1746 | T,S,P,O2,Fl, tracer |
| 201-1 | CTD/RO | 24 | 07/03 | 16:02 | 22° 00' S | 70° 18' W | 606 | T,S,P,O2,Fl, tracer |
| 202-1 | CTD/RO | 25 | 07/03 | 22:18 | 21° 00' S | 70° 25' W | 523 | T,S,P,O2,Fl, tracer |
| 203-1 | CTD-TM | 10 | 08/03 | 00:27 | 21° 00' S | 70° 40' W | 1009 | T,S,P,O2,Fl,TM |
| 203-2 | CTD/RO | 26 | 08/03 | 01:14 | 21° 00' S | 70° 40' W | 2139 | T,S,P,O2,Fl,nuts, tracer,bio |
| 204-1 | CTD/RO | 27 | 08/03 | 03:41 | 21° 00' S | 70° 49' W | 1001 | T,S,P,O2,Fl,nuts, tracer |
| 205-1 | CTD-TM | 11 | 08/03 | 05:32 | 21° 00' S | 71° 00' W | 1000 | T,S,P,O2,Fl,TM |
| 205-2 | CTD/RO | 28 | 08/03 | 06:19 | 21° 00' S | 71° 00' W | 1004 | T,S,P,O2,Fl, tracer |
| 206-1 | CTD/RO | 29 | 08/03 | 09:57 | 21° 00' S | 71° 30' W | 1005 | T,S,P,O2,Fl,nuts, tracer |
| 207-1 | CTD-TM | 12 | 08/03 | 13:40 | 21° 00' S | 72° 00' W | 1012 | T,S,P,O2,Fl,TM |
| 207-2 | CTD/RO | 30 | 08/03 | 14:27 | 21° 00' S | 72° 00' W | 1013 | T,S,P,O2,Fl, tracer |
| 208-1 | CTD-TM | 13 | 08/03 | 20:42 | 21° 00' S | 73° 00' W | 1002 | T,S,P,O2,Fl,TM |
| 208-2 | CTD/RO | 31 | 08/03 | 21:28 | 21° 00' S | 73° 00' W | 1006 | T,S,P,O2,Fl, tracer |
| 209-1 | CTD/RO | 32 | 09/03 | 03:38 | 21° 00' S | 74° 00' W | 201 | T,S,P,O2,Fl,bio |
| 209-2 | CTD-TM | 14 | 09/03 | 04:04 | 21° 00' S | 74° 00' W | 989 | T,S,P,O2,Fl,TM |
| 209-3 | CTD/RO | 33 | 09/03 | 04:48 | 21° 00' S | 74° 00' W | 1003 | T,S,P,O2,Fl, tracer |
| 210-1 | CTD/RO | 34 | 09/03 | 11:16 | 20° 00' S | 74° 00' W | 4775 | T,S,P,O2,Fl,nuts, tracer |
| 211-1 | CTD/RO | 35 | 09/03 | 19:59 | 20° 00' S | 73° 00' W | 1002 | T,S,P,O2,Fl, tracer |
| 212-1 | CTD/RO | 36 | 10/03 | 02:34 | 20° 00' S | 72° 00' W | 1017 | T,S,P,O2,Fl, tracer |
| 213-1 | CTD/RO | 37 | 10/03 | 06:24 | 20° 00' S | 71° 30' W | 1004 | T,S,P,O2,Fl, tracer |
| 214-1 | CTD/RO | 38 | 10/03 | 10:06 | 20° 00' S | 71° 00' W | 1003 | T,S,P,O2,Fl, tracer |
| 215-1 | CTD-TM | 15 | 10/03 | 12:31 | 20° 00' S | 70° 45' W | 1009 | T,S,P,O2,Fl,TM |
| 215-2 | CTD/RO | 39 | 10/03 | 13:18 | 20° 00' S | 70° 45' W | 1276 | T,S,P,O2,Fl,nuts, tracer |
| 216-1 | CTD/RO | 40 | 10/03 | 15:50 | 20° 00' S | 70° 30' W | 1189 | T,S,P,O2,Fl, tracer |
| 217-1 | CTD/RO | 41 | 10/03 | 17:56 | 20° 00' S | 70° 18' W | 996 | T,S,P,O2,Fl, tracer |
| 218-1 | MB-PS | 1 | 10/03 | 18:45 | 20° 00' S | 70° 18' W | | acoustic survey |
| 218-1 | MB-PS | 1 | 11/03 | 12:30 | 18° 37' S | 70° 37' W | | acoustic survey |
| 219-1 | CTD/RO | 42 | 11/03 | 14:23 | 18° 47' S | 70° 51' W | 1417 | T,S,P,O2,Fl,nuts, tracer |
| 219-2 | MUC | 1 | 11/03 | 15:31 | 18° 47' S | 70° 51' W | 1417 | sediment probes |
| 219-3 | GC | 1 | 11/03 | 16:51 | 18° 47' S | 70° 51' W | 1416 | sediment core |
| 220-1 | CTD/RO | 43 | 11/03 | 21:15 | 19° 00' S | 70° 25' W | 514 | T,S,P,O2,Fl, tracer |
| 221-1 | CTD/RO | 44 | 11/03 | 22:48 | 19° 00' S | 70° 34' W | 1196 | T,S,P,O2,Fl, tracer |
| 222-1 | CTD/RO | 45 | 12/03 | 00:44 | 19° 00' S | 70° 45' W | 1532 | T,S,P,O2,Fl, tracer |
| 223-1 | CTD/RO | 46 | 12/03 | 03:24 | 19° 00' S | 71° 00' W | 199 | T,S,P,O2,Fl,bio |
| 223-2 | CTD-TM | 16 | 12/03 | 03:46 | 19° 00' S | 71° 00' W | 995 | T,S,P,O2,Fl,TM |
| 223-3 | CTD/RO | 47 | 12/03 | 04:29 | 19° 00' S | 71° 00' W | 1772 | T,S,P,O2,Fl,nuts, tracer |
| 224-1 | CTD/RO | 48 | 12/03 | 08:36 | 19° 00' S | 71° 30' W | 1007 | T,S,P,O2,Fl, tracer |
| 225-1 | CTD/RO | 49 | 12/03 | 12:17 | 19° 00' S | 72° 00' W | 1005 | T,S,P,O2,Fl, tracer |
| 226-1 | CTD/RO | 50 | 12/03 | 18:37 | 19° 00' S | 73° 00' W | 1004 | T,S,P,O2,Fl, tracer |
| 227-1 | CTD-TM | 17 | 13/03 | 00:54 | 19° 00' S | 74° 00' W | 1010 | T,S,P,O2,Fl,TM |
| 227-2 | CTD/RO | 51 | 13/03 | 01:54 | 19° 00' S | 74° 00' W | 1002 | T,S,P,O2,Fl,CDOM, tracer,bio |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 228-1 | CTD/RO | 52 | 13/03 | 08:20 | 19° 00' S | 75° 00' W | 1004 | T,S,P,O2,Fl,CDOM, tracer |
| 229-1 | CTD/RO | 53 | 13/03 | 14:51 | 19° 00' S | 76° 00' W | 1011 | T,S,P,O2,Fl,CDOM, tracer |
| 230-1 | CTD/RO | 54 | 13/03 | 21:22 | 19° 00' S | 77° 00' W | 1005 | T,S,P,O2,Fl,CDOM, tracer |
| 231-1 | CTD/RO | 55 | 14/03 | 03:43 | 19° 00' S | 78° 00' W | 1003 | T,S,P,O2,Fl,CDOM, tracer |
| 232-1 | CTD/RO | 56 | 14/03 | 10:34 | 19° 00' S | 79° 00' W | 1004 | T,S,P,O2,Fl,CDOM, tracer |
| 233-1 | CTD/RO | 57 | 14/03 | 16:56 | 19° 00' S | 80° 00' W | 1003 | T,S,P,O2,Fl,CDOM, tracer |
| 234-1 | CTD-TM | 18 | 14/03 | 23:22 | 19° 00' S | 81° 00' W | 1000 | T,S,P,O2,Fl,TM |
| 234-2 | CTD/RO | 58 | 15/03 | 00:17 | 19° 00' S | 81° 00' W | 1012 | T,S,P,O2,Fl,CDOM, tracer,bio |
| 235-1 | CTD/RO | 59 | 15/03 | 07:16 | 18° 00' S | 81° 00' W | 1007 | T,S,P,O2,Fl,CDOM, tracer |
| 236-1 | CTD/RO | 60 | 15/03 | 14:13 | 18° 00' S | 80° 00' W | 1008 | T,S,P,O2,Fl,CDOM, tracer |
| 236-2 | MSS | 1 | 15/03 | 15:54 | 18° 00' S | 80° 00' W | 225 | T,S,P,velocity shear |
| 236-3 | MSS | 2 | 15/03 | 16:31 | 18° 00' S | 79° 59' W | 252 | T,S,P,velocity shear |
| 237-1 | CTD-TM | 19 | 15/03 | 23:50 | 18° 00' S | 79° 00' W | 1000 | T,S,P,O2,Fl,TM |
| 237-2 | CTD/RO | 61 | 16/03 | 00:47 | 17° 59' S | 79° 01' W | 1062 | T,S,P,O2,Fl,CDOM, tracer |
| 238-1 | CTD/RO | 62 | 16/03 | 08:01 | 18° 00' S | 78° 00' W | 1005 | T,S,P,O2,Fl,CDOM, tracer |
| 239-1 | CTD/RO | 63 | 16/03 | 14:40 | 18° 00' S | 77° 00' W | 1005 | T,S,P,O2,Fl,CDOM, tracer |
| 240-1 | CTD-TM | 20 | 16/03 | 21:36 | 18° 00' S | 76° 00' W | 1000 | T,S,P,O2,Fl,TM |
| 240-2 | CTD/RO | 64 | 16/03 | 22:28 | 18° 00' S | 76° 01' W | 4507 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 241-1 | CTD/RO | 65 | 17/03 | 07:22 | 18° 00' S | 75° 00' W | 1007 | T,S,P,O2,Fl,CDOM, tracer |
| 242-1 | CTD/RO | 66 | 17/03 | 14:11 | 18° 00' S | 74° 00' W | 1007 | T,S,P,O2,Fl,CDOM, tracer |
| 243-1 | CTD/RO | 67 | 17/03 | 21:05 | 18° 00' S | 73° 00' W | 1006 | T,S,P,O2,Fl,CDOM, tracer |
| 244-1 | CTD/RO | 68 | 18/03 | 00:57 | 18° 00' S | 72° 30' W | 1014 | T,S,P,O2,Fl,CDOM, tracer |
| 245-1 | CTD-TM | 21 | 18/03 | 05:16 | 18° 00' S | 71° 55' W | 1960 | T,S,P,O2,Fl,TM |
| 245-2 | CTD/RO | 69 | 18/03 | 06:34 | 18° 00' S | 71° 55' W | 2005 | T,S,P,O2,Fl,CDOM, tracer |
| 246-1 | CTD/RO | 70 | 18/03 | 09:18 | 17° 52' S | 71° 43' W | 792 | T,S,P,O2,Fl,CDOM, tracer |
| 247-1 | CTD/RO | 71 | 18/03 | 11:35 | 17° 45' S | 71° 31' W | 561 | T,S,P,O2,Fl,CDOM, tracer |
| 247-2 | MSS | 3 | 18/03 | 12:15 | 17° 45' S | 71° 31' W | 335 | T,S,P,velocity shear |
| 248-1 | MB-PS | 2 | 19/03 | 01:24 | 17° 31' S | 71° 36' W | | acoustic survey |
| 248-1 | MB-PS | 2 | 19/03 | 21:00 | 17° 28' S | 71° 43' W | | acoustic survey |
| 249-1 | CTD/RO | 72 | 19/03 | 21:08 | 17° 28' S | 71° 43' W | 458 | T,S,P,O2,Fl,CDOM, tracer |

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| 249-2 | MUC | 2 | 19/03 | 21:40 | 17° 28' S | 71° 43' W | 466 | sediment probes |
| 249-3 | GC | 2 | 19/03 | 22:28 | 17° 28' S | 71° 43' W | 469 | sediment core |
| 249-4 | GC | 3 | 19/03 | 23:14 | 17° 28' S | 71° 43' W | 469 | sediment core |
| 249-5 | MSS | 4 | 19/03 | 23:52 | 17° 28' S | 71° 43' W | 298 | T,S,P,velocity shear |
| 250-1 | CTD-TM | 22 | 20/03 | 02:05 | 17° 28' S | 71° 40' W | 460 | T,S,P,O2,Fl,TM |
| 250-2 | MUC | 3 | 20/03 | 02:37 | 17° 28' S | 71° 40' W | 473 | sediment probes |
| 250-3 | GC | 4 | 20/03 | 03:25 | 17° 28' S | 71° 40' W | 473 | sediment core |
| 251-1 | MB-PS | 3 | 20/03 | 04:13 | 17° 29' S | 71° 41' W | | acoustic survey |
| 251-1 | MB-PS | 3 | 20/03 | 12:41 | 17° 21' S | 71° 56' W | | acoustic survey |
| 252-1 | CTD/RO | 73 | 20/03 | 14:03 | 17° 24' S | 71° 44' W | 218 | T,S,P,O2,Fl,CDOM, tracer |
| 252-2 | MUC | 4 | 20/03 | 14:20 | 17° 24' S | 71° 44' W | 233 | sediment probes |
| 252-3 | GC | 5 | 20/03 | 15:02 | 17° 24' S | 71° 44' W | 234 | sediment core |
| 252-4 | MSS | 5 | 20/03 | 15:36 | 17° 24' S | 71° 44' W | 323 | T,S,P,velocity shear |
| 253-1 | MB-PS | 4 | 20/03 | 18:52 | 17° 25' S | 71° 43' W | | acoustic survey |
| 253-1 | MB-PS | 4 | 20/03 | 20:36 | 17° 26' S | 71° 43' W | | acoustic survey |
| 254-1 | CTD-TM | 23 | 20/03 | 21:01 | 17° 25' S | 71° 46' W | 189 | T,S,P,O2,Fl,TM |
| 254-2 | MUC | 5 | 20/03 | 21:24 | 17° 25' S | 71° 46' W | 192 | sediment probes |
| 254-3 | GC | 6 | 20/03 | 22:03 | 17° 25' S | 71° 46' W | 195 | sediment core |
| 254-4 | MSS | 6 | 20/03 | 22:24 | 17° 25' S | 71° 46' W | 162 | T,S,P,velocity shear |
| 255-1 | CTD/RO | 74 | 21/03 | 01:42 | 17° 18' S | 72° 00' W | 410 | T,S,P,O2,Fl,CDOM, tracer |
| 255-2 | MSS | 7 | 21/03 | 02:13 | 17° 18' S | 72° 00' W | 339 | T,S,P,velocity shear |
| 256-1 | CTD/RO | 75 | 21/03 | 05:34 | 17° 03' S | 72° 12' W | 550 | T,S,P,O2,Fl,CDOM, tracer |
| 256-2 | MSS | 8 | 21/03 | 06:12 | 17° 03' S | 72° 12' W | 351 | T,S,P,velocity shear |
| 257-1 | CTD/RO | 76 | 21/03 | 09:19 | 16° 52' S | 72° 25' W | 743 | T,S,P,O2,Fl,CDOM, tracer |
| 257-2 | MSS | 9 | 21/03 | 10:03 | 16° 52' S | 72° 25' W | 327 | T,S,P,velocity shear |
| 258-1 | CTD/RO | 77 | 21/03 | 12:47 | 16° 49' S | 72° 40' W | 115 | T,S,P,O2,Fl,CDOM, tracer |
| 258-2 | MSS | 10 | 21/03 | 13:09 | 16° 49' S | 72° 40' W | 119 | T,S,P,velocity shear |
| 259-1 | CTD/RO | 78 | 21/03 | 16:06 | 17° 00' S | 72° 57' W | 205 | T,S,P,O2,Fl,CDOM, bio |
| 259-2 | CTD-TM | 24 | 21/03 | 16:30 | 17° 00' S | 72° 57' W | 1741 | T,S,P,O2,Fl,TM |
| 259-3 | CTD/RO | 79 | 21/03 | 17:44 | 17° 00' S | 72° 57' W | 1750 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 260-1 | CTD/RO | 80 | 21/03 | 22:00 | 17° 00' S | 73° 30' W | 1008 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 261-1 | CTD-TM | 25 | 22/03 | 01:42 | 17° 00' S | 74° 00' W | 1004 | T,S,P,O2,Fl,TM |
| 261-2 | CTD/RO | 81 | 22/03 | 02:28 | 17° 00' S | 74° 00' W | 1006 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 262-1 | CTD/RO | 82 | 22/03 | 08:51 | 17° 00' S | 75° 00' W | 1005 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 263-1 | CTD/RO | 83 | 22/03 | 15:18 | 17° 00' S | 76° 00' W | 1007 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 264-1 | CTD-TM | 26 | 22/03 | 21:43 | 17° 00' S | 77° 00' W | 1009 | T,S,P,O2,Fl,TM |
| 264-2 | CTD/RO | 84 | 22/03 | 22:28 | 17° 00' S | 77° 00' W | 1005 | T,S,P,O2,Fl,CDOM, nuts, tracer,bio |
| 265-1 | CTD/RO | 85 | 23/03 | 04:57 | 17° 00' S | 78° 00' W | 1007 | T,S,P,O2,Fl,CDOM, |

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| | | | | | | | | nuts, tracer |
| 266-1 | CTD-TM | 27 | 23/03 | 11:21 | 17° 00' S | 79° 00' W | 1003 | T,S,P,O2,Fl,TM |
| 266-2 | CTD/RO | 86 | 23/03 | 12:08 | 17° 00' S | 79° 00' W | 1008 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 267-1 | CTD/RO | 87 | 23/03 | 18:35 | 17° 00' S | 80° 00' W | 1007 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 268-1 | CTD/RO | 88 | 24/03 | 00:49 | 17° 00' S | 81° 00' W | 1007 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 269-1 | CTD-TM | 28 | 24/03 | 07:12 | 17° 00' S | 82° 00' W | 1002 | T,S,P,O2,Fl,TM |
| 269-2 | CTD/RO | 89 | 24/03 | 07:58 | 17° 00' S | 82° 00' W | 1007 | T,S,P,O2,Fl,CDOM, nuts, tracer,bio |
| 270-1 | CTD/RO | 90 | 24/03 | 14:12 | 17° 00' S | 83° 00' W | 1007 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 271-1 | CTD-TM | 29 | 24/03 | 20:42 | 17° 00' S | 84° 00' W | 1003 | T,S,P,O2,Fl,TM |
| 271-2 | CTD/RO | 91 | 24/03 | 21:28 | 17° 00' S | 84° 00' W | 1005 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 272-1 | CTD/RO | 92 | 25/03 | 03:43 | 17° 00' S | 85° 00' W | 1009 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 273-1 | CTD/RO | 93 | 25/03 | 10:05 | 17° 00' S | 86° 00' W | 282 | T,S,P,O2,Fl,CDOM, bio |
| 273-2 | CTD-TM | 30 | 25/03 | 10:35 | 17° 00' S | 86° 00' W | 1005 | T,S,P,O2,Fl,TM |
| 273-3 | CTD/RO | 94 | 25/03 | 11:18 | 17° 00' S | 86° 00' W | 4495 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 274-1 | CTD/RO | 95 | 26/03 | 20:22 | 16° 00' S | 81° 00' W | 1002 | T,S,P,O2,Fl,CDOM, tracer |
| 275-1 | CTD-TM | 31 | 27/03 | 03:32 | 16° 00' S | 80° 00' W | 1007 | T,S,P,O2,Fl,TM |
| 275-2 | CTD/RO | 96 | 27/03 | 04:23 | 16° 00' S | 80° 00' W | 4802 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 276-1 | CTD/RO | 97 | 27/03 | 13:51 | 16° 00' S | 79° 00' W | 1012 | T,S,P,O2,Fl,CDOM, tracer |
| 277-1 | CTD-TM | 32 | 27/03 | 21:00 | 16° 00' S | 78° 00' W | 1003 | T,S,P,O2,Fl,TM |
| 277-2 | CTD/RO | 98 | 27/03 | 21:45 | 16° 00' S | 78° 00' W | 1004 | T,S,P,O2,Fl,CDOM, tracer |
| 278-1 | CTD/RO | 99 | 28/03 | 04:59 | 16° 00' S | 77° 00' W | 1008 | T,S,P,O2,Fl,CDOM, tracer |
| 279-1 | CTD-TM | 33 | 28/03 | 12:08 | 16° 00' S | 76° 00' W | 1003 | T,S,P,O2,Fl,TM |
| 279-2 | CTD/RO | 100 | 28/03 | 12:56 | 16° 00' S | 76° 00' W | 1003 | T,S,P,O2,Fl,CDOM, tracer |
| 280-1 | CTD/RO | 101 | 28/03 | 20:05 | 16° 00' S | 75° 00' W | 1006 | T,S,P,O2,Fl,CDOM, tracer |
| 281-1 | CTD-TM | 34 | 28/03 | 22:44 | 16° 00' S | 74° 45' W | 2126 | T,S,P,O2,Fl,TM |
| 281-2 | CTD/RO | 102 | 29/03 | 00:10 | 16° 00' S | 74° 45' W | 2127 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 282-1 | MB-PS | 5 | 29/03 | 01:43 | 16° 00' S | 74° 45' W | | acoustic survey |
| 282-2 | RapidCAST | 1 | 29/03 | 01:48 | 15° 59' S | 74° 45' W | ~125 | T,S,P |
| 282-2 | RapidCAST | 2 | 29/03 | 04:07 | 15° 43' S | 74° 36' W | ~125 | T,S,P |
| 282-1 | MB-PS | 5 | 29/03 | 06:47 | 16° 05' S | 74° 34' W | | acoustic survey |
| 283-1 | CTD/RO | 103 | 29/03 | 07:30 | 15° 58' S | 74° 34' W | 817 | T,S,P,O2,Fl,CDOM, tracer |

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| 284-1 | MSS | 11 | 29/03 | 08:19 | 15° 58' S | 74° 34' W | 285 | T,S,P,velocity shear |
| 285-1 | MSS | 12 | 29/03 | 10:21 | 15° 52' S | 74° 34' W | 318 | T,S,P,velocity shear |
| 286-1 | MSS | 13 | 29/03 | 12:01 | 15° 49' S | 74° 36' W | 223 | T,S,P,velocity shear |
| 287-1 | CTD/RO | 104 | 29/03 | 13:18 | 15° 46' S | 74° 36' W | 123 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 287-2 | MSS | 14 | 29/03 | 13:43 | 15° 46' S | 74° 36' W | 122 | T,S,P,velocity shear |
| 288-1 | CTD-TM | 35 | 29/03 | 18:49 | 15° 25' S | 75° 15' W | 275 | T,S,P,O2,Fl,TM |
| 288-2 | CTD/RO | 105 | 29/03 | 19:09 | 15° 25' S | 75° 15' W | 295 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 288-3 | MSS | 15 | 29/03 | 19:38 | 15° 24' S | 75° 15' W | 219 | T,S,P,velocity shear |
| 289-1 | CTD/RO | 106 | 29/03 | 23:57 | 15° 00' S | 75° 45' W | 170 | T,S,P,O2,Fl,CDOM, tracer |
| 289-2 | MSS | 16 | 30/03 | 00:21 | 15° 00' S | 75° 45' W | 250 | T,S,P,velocity shear |
| 290-1 | CTD/RO | 107 | 30/03 | 03:17 | 15° 00' S | 76° 05' W | 143 | T,S,P,O2,Fl,CDOM, bio |
| 290-2 | CTD-TM | 36 | 30/03 | 03:41 | 15° 00' S | 76° 05' W | 2030 | T,S,P,O2,Fl,TM |
| 290-3 | CTD/RO | 108 | 30/03 | 05:04 | 15° 00' S | 76° 06' W | 2045 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 291-1 | CTD/RO | 109 | 30/03 | 08:40 | 15° 00' S | 76° 30' W | 1003 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 292-1 | CTD/RO | 110 | 30/03 | 12:17 | 15° 00' S | 77° 00' W | 1005 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 293-1 | CTD-TM | 37 | 30/03 | 18:53 | 15° 00' S | 78° 00' W | 999 | T,S,P,O2,Fl,TM |
| 293-2 | CTD/RO | 111 | 30/03 | 19:39 | 15° 00' S | 78° 00' W | 1012 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 294-1 | CTD/RO | 112 | 30/03 | 23:39 | 15° 00' S | 78° 30' W | 1007 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 295-1 | CTD/RO | 113 | 31/03 | 03:24 | 15° 00' S | 79° 00' W | 1009 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 296-1 | CTD/RO | 114 | 31/03 | 10:15 | 15° 00' S | 80° 00' W | 1004 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 297-1 | CTD/RO | 115 | 31/03 | 16:40 | 15° 00' S | 81° 00' W | 238 | T,S,P,O2,Fl,CDOM, bio |
| 297-2 | CTD-TM | 38 | 31/03 | 17:02 | 15° 00' S | 81° 00' W | 1001 | T,S,P,O2,Fl,TM |
| 297-3 | CTD/RO | 116 | 31/03 | 17:48 | 15° 00' S | 81° 00' W | 1003 | T,S,P,O2,Fl,CDOM, nuts, tracer,bio |
| 298-1 | CTD/RO | 117 | 01/04 | 00:46 | 14° 00' S | 81° 00' W | 1009 | T,S,P,O2,Fl,CDOM, tracer |
| 299-1 | CTD-TM | 39 | 01/04 | 07:53 | 14° 00' S | 80° 00' W | 1005 | T,S,P,O2,Fl,TM |
| 299-2 | CTD/RO | 118 | 01/04 | 08:40 | 14° 00' S | 80° 00' W | 1004 | T,S,P,O2,Fl,CDOM, tracer |
| 300-1 | CTD/RO | 119 | 01/04 | 16:02 | 14° 00' S | 79° 00' W | 1003 | T,S,P,O2,Fl,CDOM, tracer |
| 301-1 | CTD-TM | 40 | 01/04 | 23:58 | 14° 00' S | 78° 00' W | 1000 | T,S,P,O2,Fl,TM |
| 301-2 | CTD/RO | 120 | 02/04 | 00:49 | 14° 00' S | 78° 00' W | 1005 | T,S,P,O2,Fl,CDOM, tracer |
| 302-1 | CTD/RO | 121 | 02/04 | 05:12 | 14° 00' S | 77° 30' W | 1002 | T,S,P,O2,Fl,CDOM, tracer |
| 302-2 | RapidCA ST | 3 | 02/04 | 06:12 | 13° 59' S | 77° 28' W | ~125 | T,S,P |
| 303-1 | CTD-TM | 41 | 02/04 | 09:46 | 13° 48' S | 77° 03' W | 2028 | T,S,P,O2,Fl,TM |

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| 303-2 | CTD/RO | 122 | 02/04 | 11:08 | 13° 48' S | 77° 03' W | 2031 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 304-1 | RapidCAST | 4 | 02/04 | 12:42 | 13° 47' S | 77° 02' W | ~125 | T,S,P |
| 305-1 | CTD/RO | 123 | 02/04 | 16:19 | 13° 40' S | 76° 45' W | 284 | T,S,P,O2,Fl,CDOM, tracer |
| 306-1 | RapidCAST | 5 | 02/04 | 16:47 | 13° 40' S | 76° 45' W | ~125 | T,S,P |
| 306-1 | RapidCAST | 6 | 02/04 | 17:42 | 13° 40' S | 76° 44' W | ~125 | T,S,P |
| 307-1 | CTD/RO | 124 | 03/04 | 00:24 | 14° 01' S | 76° 31' W | 257 | T,S,P,O2,Fl,CDOM, tracer |
| 308-1 | CTD-TM | 42 | 03/04 | 01:40 | 14° 04' S | 76° 37' W | 602 | T,S,P,O2,Fl,TM |
| 309-1 | Glider | 1 | 03/04 | 14:30 | 14° 01' S | 76° 53' W | | T,S,P,O2,Fl,CDOM, Nitrate |
| 310-1 | CTD/RO | 125 | 03/04 | 15:24 | 14° 02' S | 76° 53' W | 1006 | T,S,P,O2,Fl,CDOM, tracer |
| 310-2 | Glider | 2 | 03/04 | 16:12 | 14° 02' S | 76° 53' W | | T,S,P,O2,Fl,velocity shear |
| 311-1 | CTD/RO | 126 | 04/04 | 00:03 | 13° 00' S | 77° 00' W | 415 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 312-1 | CTD/RO | 127 | 04/04 | 02:04 | 13° 00' S | 77° 15' W | 1239 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 313-1 | CTD/RO | 128 | 04/04 | 05:11 | 13° 00' S | 77° 37' W | 146 | T,S,P,O2,Fl,CDOM, bio |
| 313-2 | CTD-TM | 43 | 04/04 | 05:34 | 13° 00' S | 77° 37' W | 2042 | T,S,P,O2,Fl,TM |
| 313-3 | CTD/RO | 129 | 04/04 | 06:54 | 13° 00' S | 77° 37' W | 120 | T,S,P,O2,Fl,CDOM |
| 313-3 | CTD/RO | 130 | 04/04 | 07:07 | 13° 00' S | 77° 37' W | 1001 | T,S,P,O2,Fl,CDOM, tracer |
| 314-1 | CTD/RO | 131 | 04/04 | 10:10 | 13° 00' S | 78° 00' W | 1010 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 315-1 | CTD/RO | 132 | 04/04 | 16:43 | 13° 00' S | 79° 00' W | 1002 | T,S,P,O2,Fl,CDOM, tracer |
| 315-2 | CTD-TM | 44 | 04/04 | 17:32 | 13° 00' S | 79° 00' W | 1004 | T,S,P,O2,Fl,TM |
| 316-1 | CTD/RO | 133 | 04/04 | 23:56 | 13° 00' S | 80° 00' W | 1003 | T,S,P,O2,Fl,CDOM, bio |
| 317-1 | CTD/RO | 134 | 05/04 | 06:42 | 13° 00' S | 81° 00' W | 159 | T,S,P,O2,Fl,CDOM |
| 317-2 | CTD-TM | 45 | 05/04 | 06:58 | 13° 00' S | 81° 00' W | 1004 | T,S,P,O2,Fl,TM |
| 317-3 | CTD/RO | 135 | 05/04 | 07:40 | 13° 00' S | 81° 00' W | 1006 | T,S,P,O2,Fl,CDOM, tracer |
| 318-1 | CTD/RO | 136 | 05/04 | 14:30 | 12° 00' S | 81° 00' W | 1001 | T,S,P,O2,Fl,CDOM, tracer |
| 319-1 | CTD/RO | 137 | 05/04 | 22:10 | 12° 00' S | 80° 00' W | 1006 | T,S,P,O2,Fl,CDOM, tracer |
| 320-1 | CTD-TM | 46 | 06/04 | 04:13 | 12° 00' S | 79° 12' W | 1008 | T,S,P,O2,Fl,TM |
| 320-2 | CTD/RO | 138 | 06/04 | 04:59 | 12° 00' S | 79° 12' W | 1003 | T,S,P,O2,Fl,CDOM, tracer |
| 321-1 | CTD/RO | 139 | 06/04 | 12:00 | 11° 00' S | 78° 46' W | 2121 | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 321-2 | MB-PS | 6 | 06/04 | 13:28 | 11° 00' S | 78° 46' W | | acoustic survey |
| 321-3 | RapidCA | 7 | 06/04 | 13:46 | 10° 59' S | 78° 44' W | ~125 | T,S,P |

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| 321-3 | RapidCA ST | 8 | 06/04 | 14:29 | 10° 55' S | 78° 38' W | ~125 | T,S,P |
| 321-2 | MB-PS | 6 | 06/04 | 17:45 | 10° 39' S | 78° 09' W | | acoustic survey |
| 322-1 | CTD/RO | 140 | 06/04 | 17:58 | 10° 40' S | 78° 09' W | 166 | T,S,P,O2,Fl,CDOM, tracer |
| 323-1 | CTD/RO | 141 | 06/04 | 18:58 | 10° 43' S | 78° 13' W | 250 | T,S,P,O2,Fl,CDOM, tracer |
| 323-1 | CTD/RO | 142 | 06/04 | 19:05 | 10° 43' S | 78° 13' W | | T,S,P,O2,Fl,CDOM, nuts, tracer |
| 322-2 | MB-PS | 7 | 06/04 | 19:16 | 10° 43' S | 78° 13' W | | acoustic survey |
| 322-3 | RapidCA ST | 9 | 06/04 | 19:22 | 10° 43' S | 78° 13' W | ~125 | T,S,P |
| 322-2 | MB-PS | 7 | 07/04 | 03:28 | 12° 02' S | 78° 10' W | | acoustic survey |
| 324-1 | CTD/RO | 143 | 07/04 | 03:36 | 12° 03' S | 78° 10' W | 2092 | T,S,P,O2,Fl,CDOM, tracer |
| 324-2 | CTD-TM | 47 | 07/04 | 05:04 | 12° 03' S | 78° 10' W | 2095 | T,S,P,O2,Fl,TM |
| 325-1 | CTD/RO | 144 | 07/04 | 11:16 | 12° 22' S | 77° 25' W | 248 | T,S,P,O2,Fl,CDOM, tracer |
| 326-1 | MSS | 17 | 07/04 | 12:26 | 12° 27' S | 77° 30' W | 250 | T,S,P,velocity shear |
| 327-1 | MSS | 18 | 07/04 | 14:42 | 12° 25' S | 77° 25' W | 250 | T,S,P,velocity shear |
| 328-1 | CTD-TM | 48 | 07/04 | 16:31 | 12° 22' S | 77° 24' W | 233 | T,S,P,O2,Fl,TM |
| 328-2 | MSS | 19 | 07/04 | 16:56 | 12° 22' S | 77° 24' W | 250 | T,S,P,velocity shear |
| 329-1 | MSS | 20 | 07/04 | 18:38 | 12° 21' S | 77° 22' W | 250 | T,S,P,velocity shear |
| 330-1 | MSS | 21 | 07/04 | 20:18 | 12° 19' S | 77° 18' W | 250 | T,S,P,velocity shear |
| 331-1 | MSS | 22 | 07/04 | 21:52 | 12° 16' S | 77° 15' W | 250 | T,S,P,velocity shear |
| 332-1 | MSS | 23 | 07/04 | 23:24 | 12° 15' S | 77° 13' W | 250 | T,S,P,velocity shear |
| 333-1 | MSS | 24 | 08/04 | 01:00 | 12° 13' S | 77° 10' W | 250 | T,S,P,velocity shear |
| 334-1 | ADCP | 1 | 08/04 | 05:08 | 12° 34' S | 77° 37' W | | velocity |

# 8 Data and Sample Storage and Availability

In Kiel a joint Data-management-Team is active, which stores the data from various projects and cruises in a web-based multi-user-system. Data gathered during M135 are stored at the Kiel data portal, and is proprietary for the PIs of the cruise and for members of SFB754. All data will be submitted to PANGAEA within 3 years, i.e. by March 2020. Preliminary CTD data were submitted to CORIOLIS during the cruise for real time oceanographic analysis and Argo calibration. The chemistry data from the water sampling will be submitted to CDIAC for inclusion in the GLODAP data product on interior ocean carbon data.

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During the cruise we followed the guidelines recently developed by the GO-SHIP group, particularly did we consider the guides for best practices:

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