ALKOR -Berichte

Monitoring and Mapping Active Deformation offshore Etna

Cruise No. AL532

29.01.2020 – 02.02.2020
Catania (Italy) – Catania (Italy)
MAPACT-ETNA

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2020

Table of Contents

1 Cruise Summary

1.1 Summary in English

The vessel left the port of Catania with a delay of seven days owing to bad weather conditions during the transit to Catania. The four-days long cruise with five scientists took place with excellent weather conditions without exception. The main purpose of the cruise was to collect high-resolution seafloor bathymetric data with an Autonomous Underwater Vehicle (AUV) and a ship-based multibeam echosounder. Deployment and recovery of the AUV Abyss with the Launch-and-recovery-system (LARS) was a premiere onboard RV ALKOR. Abyss did four dives, out of which two provided important data. In addition, about 250 km of ship-based echosounder tracks were sailed and three Conductivity-Temperature-Depth (CTD) profiles were taken.

1.2 Zusammenfassung

Aufgrund von schlechtem Wetter auf dem Transit nach Catania verließ die ALKOR den Hafen von Catania mit sieben Tagen Verspätung und fünf Wissenschaftlern an Bord. Während der gesamten Fahrt waren die Wetterbedingungen optimal. Das Hauptziel war, hochauflösende bathymetrische Karten des Meeresbodens mithilfe eines Autonomen Unterwasserfahrzeug (AUV) zu erstellen. Das Aussetzen und Einholen des AUV Abyss mit dem Launch-and-recovery-system (LARS) wurde zum ersten Mal auf der ALKOR durchgeführt. Abyss wurde vier Mal zu Wasser gelassen und zwei Tauchgänge lieferten wichtige Daten. Darüber hinaus wurden etwa 250 km Bathymetriedaten mit dem schiffsbasierten Multibeam Echolot gesammelt und drei vertikale Wasserschallgeschwindigkeitsprofile genommen.

2 Participants

2.1 Principal Investigators

Name	Institution
Urlaub, Morelia, Dr.	GEOMAR

2.2 Scientific Party

Name	Discipline	Institution
Urlaub, Morelia, Dr.	Hydroacoustics / Chief Scientist	GEOMAR
Kurbjuhn, Torge	AUV Team / Technician	GEOMAR
Steinführer, Anja	AUV Team / Technician	GEOMAR
Wenzlaff, Emanuel	AUV Team / Technician	GEOMAR
Bonforte, Alessandro, Dr.	Hydroacoustics / Scientist	INGV-CT

2.3 Participating Institutions

GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel
INGV-CT Istituto Nazionale di Geofisica e Vulcanologia Catania

3 Research Program

3.1 Aims of the Cruise

Mount Etna at the east coast of Sicily is Europe’s largest and most active volcano. Satellite-based ground deformation observations (GPS, Interferometric SAR) show that the volcano’s south-eastern flank slides seawards at a rate of 2-3 cm per year (Fig. 3.1). Recent seafloor geodetic measurements suggest that also the submerged part of the flank is sliding at a similar rate (Urlaub et al. 2018). However, this observation is spatially limited to one point along the fault that represents the boundary between the stable and unstable volcano flanks. The aim of this research cruise is to map this fault system at the best possible resolution. We use a multibeam echosounder carried by the AUV Abyss of GEOMAR. In addition we collect hydroacoustic data with ship-based multibeam echosounder. With the microbathymetric maps of the seafloor we will be able to identify the width and length of the fault system that hosted deformation measured by the seafloor geodetic network and to establish a potential link to larger regional tectonic structures.

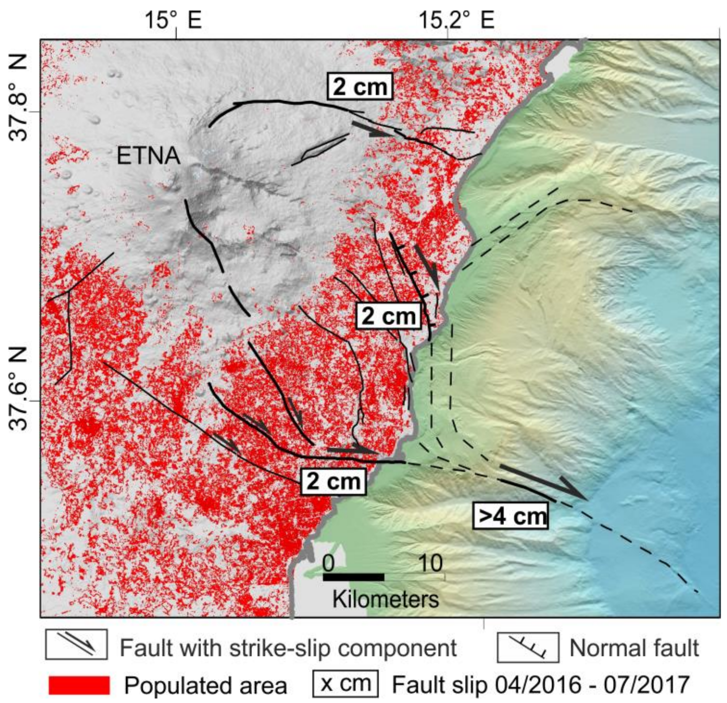


Fig. 3.1 Shoreline-crossing fault slip representation of Mount Etna’s south-eastern flank movement (Urlaub et al. 2018). Populated areas are obtained from a Landsat-8 classification on a 30 x 30 m grid (Landsat-8 image courtesy of the U.S. Geological Survey). Bold lines represent main active features during the observation period May 2016 – July 2017.

3.2 Agenda of the Cruise

RV ALKOR reached the port of Catania on the morning of the 27 January 2020 with a delay of eight days. On the same day, the scientific team embarked and we started to load and assemble the scientific instrumentation. We left the port on Wednesday and started the cruise AL532 seven days after the original schedule. After a short transit from the port to the working area, AUV Abyss was deployed for a three-hour test dive. In the meantime, we deployed two transponders to improve the AUV's navigation. No major problems were identified from the test dive so we could re-deploy the AUV before dinner for its first science dive. We used the night to perform a survey near the coast with the ship-based multibeam. The following two days had roughly the same schedule: Recovery of AUV Abyss in the morning, CTD station, ship-based multibeam survey, deployment of AUV Abyss before dusk, ship-based multibeam survey. Unfortunately, AUV Abyss sent an error message a couple of hours after its fourth deployment and had to be recovered in the night from Friday to Saturday. It was not possible to fix the error on board the vessel. Therefore, we used the remaining time to recover two transponders and conduct two surveys with the ship-based multibeam. The science program ended on Sunday at 9:15. After a short transit we arrived at the port of Catania.

3.3 Description of the Work Area

Being located in the direct vicinity of the Calabrian Arc Subduction Complex, where the oceanic lithosphere of the Ionian Sea is subducted under the Calabrian Arc, Eastern Sicily and the Western Ionian Sea are geohazard hot spots. Within historical and modern times, the area has experienced several severe earthquakes, volcanic eruptions, and marine as well as terrestrial landslides. Moreover, six large tsunamis have struck Eastern Sicily in historic times, likely triggered by either of these events. Today, the coastal belt near Catania is the most densely populated area in Sicily with about 1 million inhabitants, home to important infrastructure, industry, tourism, and several UNESCO world heritage sites. The working area of this cruise was the underwater continuation of Mount Etna's southeastern flank that reaches well over 20 km into the Ionian offshore. The AUV work concentrated near the foot of the flank about 20 km off the coast, while the ship-based multibeam surveys focused on the nearshore area between the villages of Aci Castello and Pozillo (Fig. 3.2).

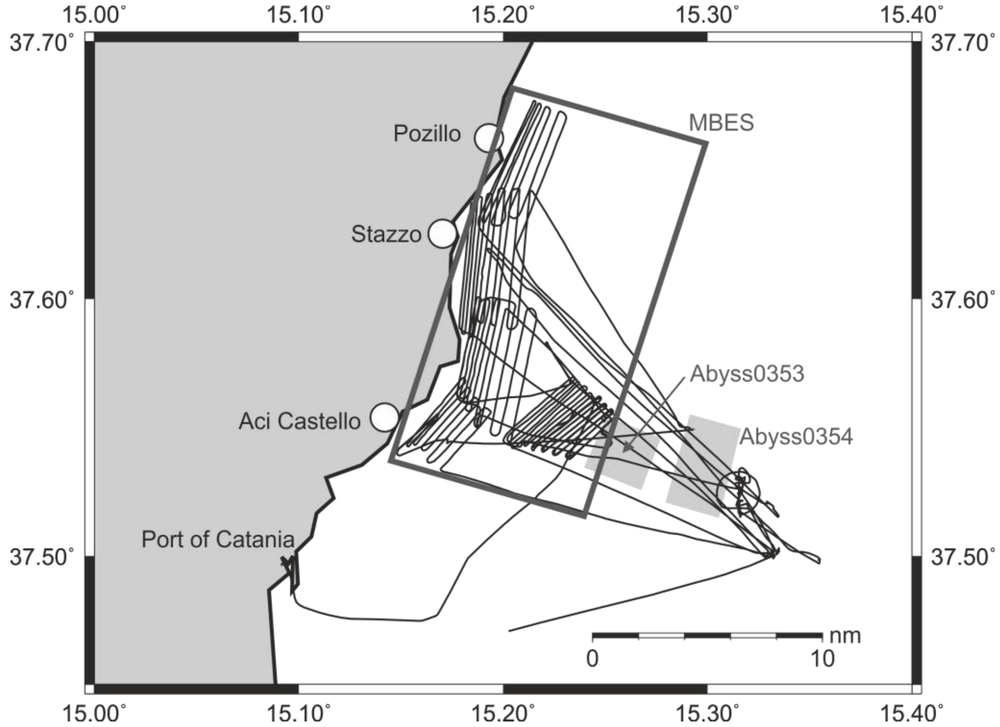


Fig. 3.2 Track chart of R/V ALKOR Cruise AL532 with the locations of the two scientific AUV surveys and the multibeam echosounder (MBES) working area.

4 Narrative of the Cruise

On **27 January 2020** four scientists boarded RV ALKOR at 10:00 in the port of Catania. Three containers at the pier were opened under surveillance of customs officers. An external crane lifted one container (Ops Van) and the LARS onboard, while scientists together with port workers manually unloaded two containers that remained in the port until the end of the cruise. The rest of the day and the following day were used to set up the LARS on the back deck, the portable multibeam system in the moonpool and the associated infrastructure on deck and in the dry laboratory. With the pilot onboard the vessel left the port of Catania on **29 January 2020** 8:00. The pilot left at 8:15 and RV ALKOR sailed in sunny weather and light winds to the AUV launch area. The first deployment of the AUV Abyss with the LARS went smoothly before lunchtime. It was the first time that AUV Abyss was deployed from RV ALKOR. AUV Abyss set off for a three hours test and calibration dive. This time was used to deploy two mooring-type transponders (20 m above seafloor) in about 1800 m water depth and to determine their exact locations. The AUV was recovered again using the LARS in the early afternoon and re-deployed at 6pm. The multibeam echosounder was lowered in the moonpool and the first multibeam survey close to the coast of Acireale began at 9pm and lasted until the early morning of the **30 January 2020**. AUV Abyss reached the sea surface at 5:00 and was located soon after in very calm weather conditions. The vessel remained at its side until recovery at 8:00. At 9:30 a CTD was lowered to 230 m. With the CTD back on deck the vessel continued to collect four multibeam calibration profiles before heading back to the AUV launch point. At 16:00 AUV Abyss was deployed for its third dive of this cruise again in very calm sea conditions. After a transit towards the coast the second multibeam echosounder survey off Santa Tecla was performed. The suvey lasted from 21:00 until the morning of the following day (**31 January**

2020). The vessel left the survey area to meet AUV Abyss who reached the sea surface at 8:30 and was recovered thereupon. The vessel returned to shallower waters to take one CTD down to 190 m at 9:30. This was followed by three multibeam calibration profiles and one survey near the coastal town of Acitrezza. During surveying AUV Abyss was already put into the LARS using the ship’s crane. RV ALKOR left the survey area in the late afternoon to reach the AUV launch area at 20:00. AUV Abyss was deployed for its fourth dive. The sea had a minor swell. The vessel was on transit to perform a multibeam survey when AUV Abyss sent emergency messages and came up to the sea surface at 23:00. RV ALKOR immediately returned to the given position. The AUV was located and recovered at 1:30 on the **1 February 2020**. Thereupon the vessel transited again to the multibeam survey area offshore of the city of Stazzo. The survey lasted from 4:30 until 13:00. The vessel then moved to the AUV working area and the AUV crew acoustically released the two transponders. The crew spotted both transponders quickly and recovered them to the vessel in the afternoon. After a short transit a CTD was lowered down to 580 m wire length. Shortly after the last multibeam survey initiated that continued until the morning of the 2 February 2020. After finishing the survey the multibeam was lifted from the moonpool at 8:00 and the vessel steamed towards the port of Catania.

5 Preliminary Results

5.1 AUV microbathymetry

(Torge Kurbjuhn[1], Anja Steinführer[1], Emanuel Wenzlaff[1])
[1]GEOMAR

5.1.1 System Overview

The Autonomous Underwater Vehicle (AUV) „ABYSS“ is a modular AUV designed to survey the ocean combining geophysical studies of the seafloor with oceanographic investigations of the overlying water column. The basic mission of ABYSS is deep-sea exploration, specifically in volcanically and tectonically active parts, such as mid-ocean ridges. With a maximum mission depth of 6000 meters, the AUV uses several technologies to map the seafloor accurately and determine its geological structure with applications from geology to biology to mineral exploration (Linke and Lackschewitz, 2016).

The system built by HYDROID Inc. comprises the AUV itself, a control and workshop container, and a mobile Launch and Recovery System (LARS) with a deployment frame that was installed at the afterdeck of RV ALKOR (Fig. 5.1). The self-contained LARS was developed by Woods Hole Oceanographic Institute (WHOI) to support ship-based operations so that no Zodiac or crane is required for launch and recovery. The LARS is mounted on steel plates, which are screwed to the deck of the ship. The LARS is configured in a way that the AUV can be deployed over the stern or port/starboard side of the German medium and ocean-going research vessels. The AUV Abyss can be launched and recovered at weather conditions with a swell up to 2.5 m and wind speeds of up to 6 Beaufort. For the recovery the nose float pops off when triggered through an acoustic command. The float and the ca. 17 m recovery line drift away from the vehicle so that a grapnel hook can snag the line. The line is then connected to the LARS winch, and the vehicle is pulled up. Finally, the AUV is brought up on deck and secured in the LARS.

Figure 5.1 AUV Abyss ready for launch at the afterdeck of RV ALKOR.

Depending on scientific needs different sensors can be used, following are part of the standard configuration: Reson SeaBat T50 multibeam echosounder, Edgetech 2200-MP sidescan sonar, Seabird SBE 49 FastCat and Wet Labs ECO FLNTU fluorometer and turbidity sensor. Optional instead of the multibeam echosounder the Edgetech 2200-MP sub-bottom profiler or the electronic still camera (Canon 6D) can be installed, the REDOX potential sensor by Ko-ichi Nakamura on request. A general description of the used sensors during this cruise AL532 is located below in section 5.1.3 Sensor Description.

The navigation of Abyss is mainly based on the Kearfott Inertial Navigation System (INS). The INS is capable to determine acceleration and angular velocity in 3-dimensional space and it usually requires an initial position by GPS to dead reckon its own position. Since the dead reckoning based navigation is associated with an increasing error, the Long Base Line Positioning (LBL) has been used successfully to aid. The LBL concept makes use of acoustic transponders moored to the seabed. The transponder positions are known from a preceding calibration from the surface vessel. The AUV position is computed from range measurements to the transponders. The downward looking doppler velocity log (DVL) stabilizes continuously the INS navigation by exact ground velocity values. The AUV depth is determined by a separate pressure sensor (Paroscientific 8B7000). The above mentioned DVL (Teledyne RDI Workhorse Navigator) provide the altitude (height above seabed), too. Once the AUV is surfaced and is within the WIFI range, it can be controlled from the ship. The vehicle can detect obstacles in its pre-field and escape upwards.

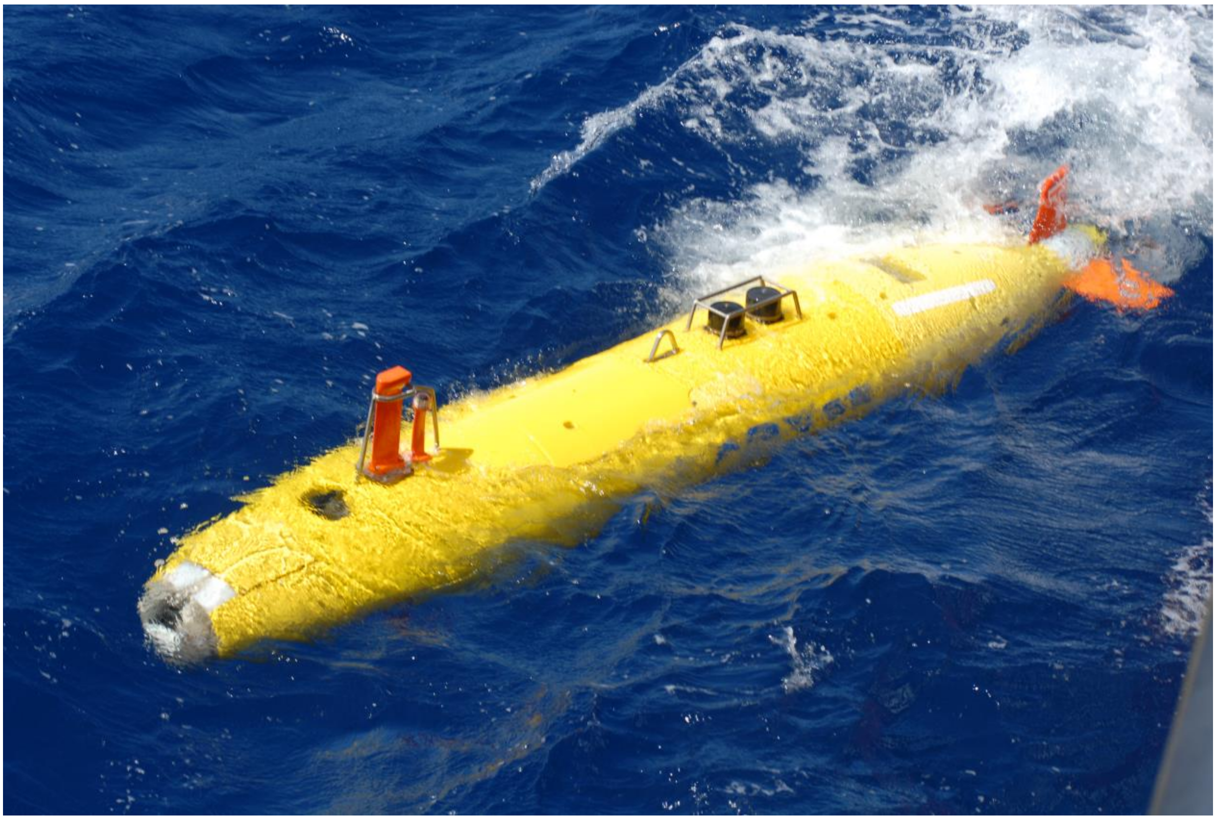


Fig. 5.2 AUV Abyss in the water (Credit: Peter Linke).

5.1.2 System Mission Summaries

During cruise AL532, three dives by the AUV were completed using the multibeam echosounder 200 kHz (MB200). One additional mission was aborted immediately after reaching the transponder (Table 5.1). Abyss 352 was a test dive including the multibeam calibration. The missions were planned based on ships bathymetrie. The sidescan sonar and subbottom-profiler were not used.

Table 5.1 AUV Mission Statistics for cruise AL532, Mission time = time including descent, survey and ascent phase; Distance travelled = total distance during mission; MB200 = Multibeam Echo Sounder 200 kHz.

Station	Area	Dive	Date	Mission time	Distance travelled	Sensors (Comments)
1	37N31.2 / 15E19.9	352	29.01.2020	02:38	13.509	MB200, calibration
5	37N31.6 / 15E15.6	353	29.01.2020	12:04	66.823	MB200,watercolumn
17	37N32.1 / 15E17.7	354	30.01.2020	16:20	87.600	MB200
	37N30.7 / 15E19.7	355	31.01.2020	00:19	00.000	MB200, aborted
			Total:	**31.21 h**	**167.932 km**	

Fig. 5.3 Overview of AUV missions and transponder positions.

Long Base Line Positioning (LBL)

As mentioned above the AUV Abyss uses Long Base Line Positioning to adjust the navigation at the seafloor. Upon arrival in the area two LBL- transponders were deployed and an acoustic survey was performed to determine position and depth of their landing spot on the bottom of the ocean. During the missions Abyss 353 and Abyss 354 the AUV repositioned itself successfully after the descent phase. The acoustic navigation is only used as an initial start position for the dead reckoning navigation during the survey. Table 5.2 shows surveyed positions and dates of deployment and recovery.

Table 5.2 LBL Positioning

Transponder	Type	Position	Transducer depth (m)	Deployment	Released	Recovered
1A	DT4A-LF	37° 31.706’ N 15° 18.991’ E	1820	29.01.2020 10:10 UTC	01.02.2020 14:16 UTC	01.02.2020 15:03 UTC
2C	DT4C-LF	37° 31.113’ N 15° 19.004’ E	1800	29.01.2020 10:10 UTC	01.02.2020 13:40 UTC	01.02.2020 14:21 UTC

Abyss 0352

Mission 0352 (Fig. 5.4) was supposed to check the vehicle for high resolution bathymetry data and to calibrate the multibeam system. Figure 5.5 shows the calibration procedure. The vehicle dived with an altitude of 80 meters in depths between 1746 and 1769 meters.

Fig. 5.4 Abyss 0352 mean value

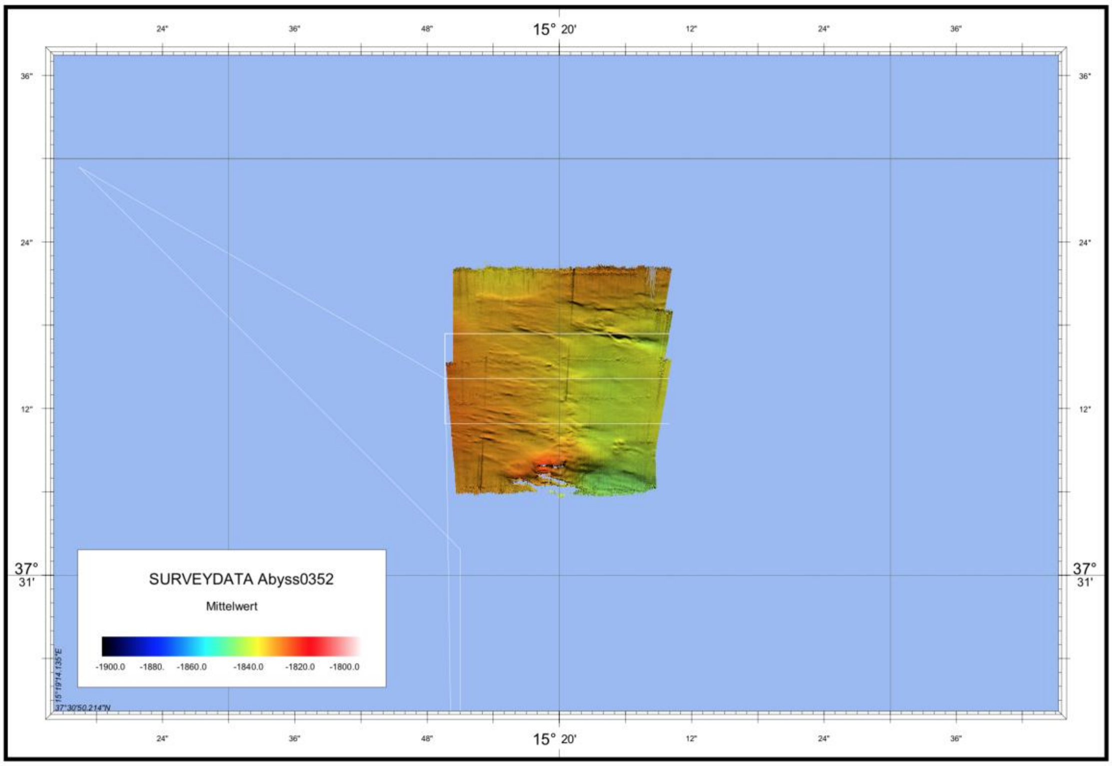
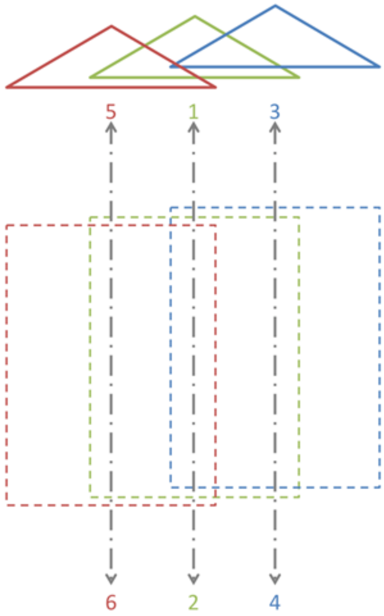


Fig. 5.5 Calibration procedure used for Abyss0352 (Credit: Jörg Brunken, jbr@macartney.com).



Abyss 0353

Mission 0353 (Fig. 5.6) was done in multibeam 200 kHz configuration including watercolumn record.

The RESON 7k Data Format, a record based protocol, includes all auxiliary sensors and information needed to completely describe data logged during a survey (see RESON DATA FORMAT DEFINITION DOCUMENT). During Abyss0353 data were collected using the records 7008, 7018 and 7042.

Record 7008 (7k Generic Water Column Data) is not operational anymore, it's superseded by 7018 beamformed data and 7028 snippet data. It exists for the backwards compatibility only. The 7018 record contains the sonar beam magnitude and phase data and contributes the largest part to the data size (~95%).

The Compressed Water Column record 7042 is a down sampled data set and allows the reduction in record data size.

The raw s7k files of Abyss0353 contain record 7008, 7018 and 7042. 7008 and 7018 were removed afterwards using the RESON utility *7kRecordExtractor.exe* to reduce the file size. They were renamed accordingly to *_extracted.s7k*

The large number of individual files, due to the splitting of the files after 250MB, were combined into seperate legs using *7KFileMerge.exe*. The files are named accordingly to the data files they're containing. For example: *20200129_185252-191902_extracted.s7k* is the first leg of the survey and contains all raw *.s7k files from *20200129_185252.s7k* to *20200129_191902.s7k*

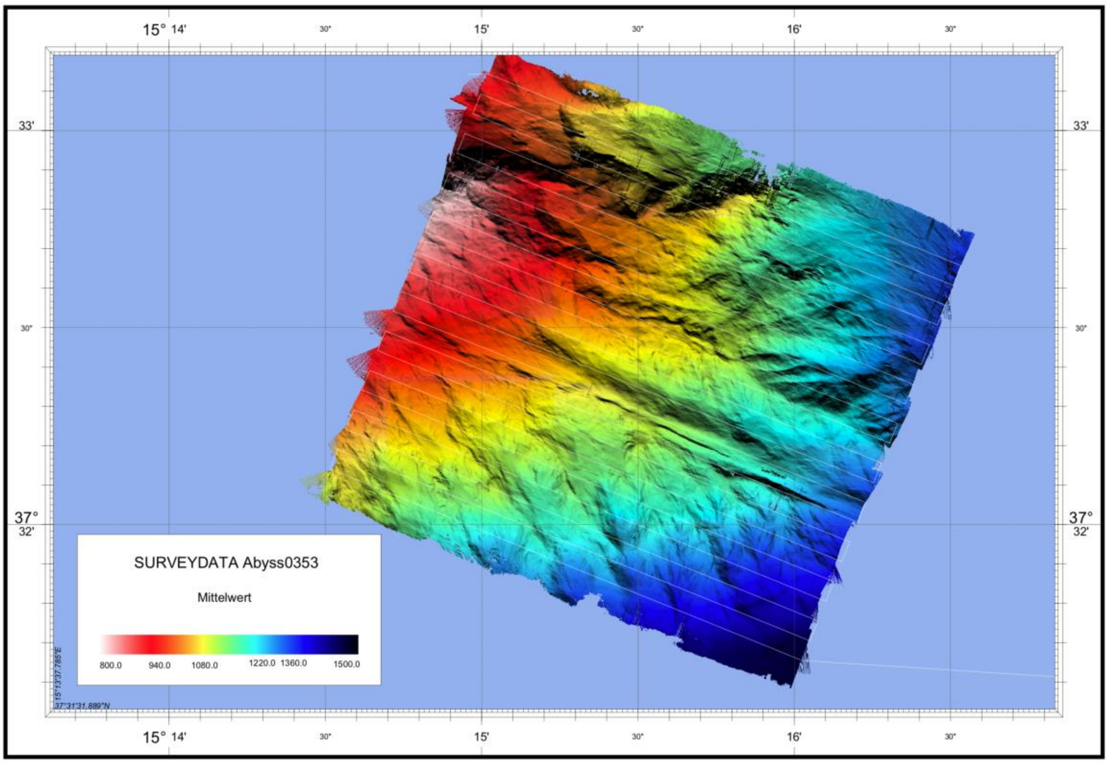


Fig. 5.6 Abyss 0353 mean value. Note that depth values are positive and thus inverted.

Abyss 0354

Mission 0354 (Fig. 5.7) was successfully done in multibeam 200 kHz configuration. There were no special occurrences.

Abyss 0355

Mission 0355 was planned as a 200 kHz multibeam survey including watercolumn but aborted by the AUV itself due to a leak in the main electronics housing.

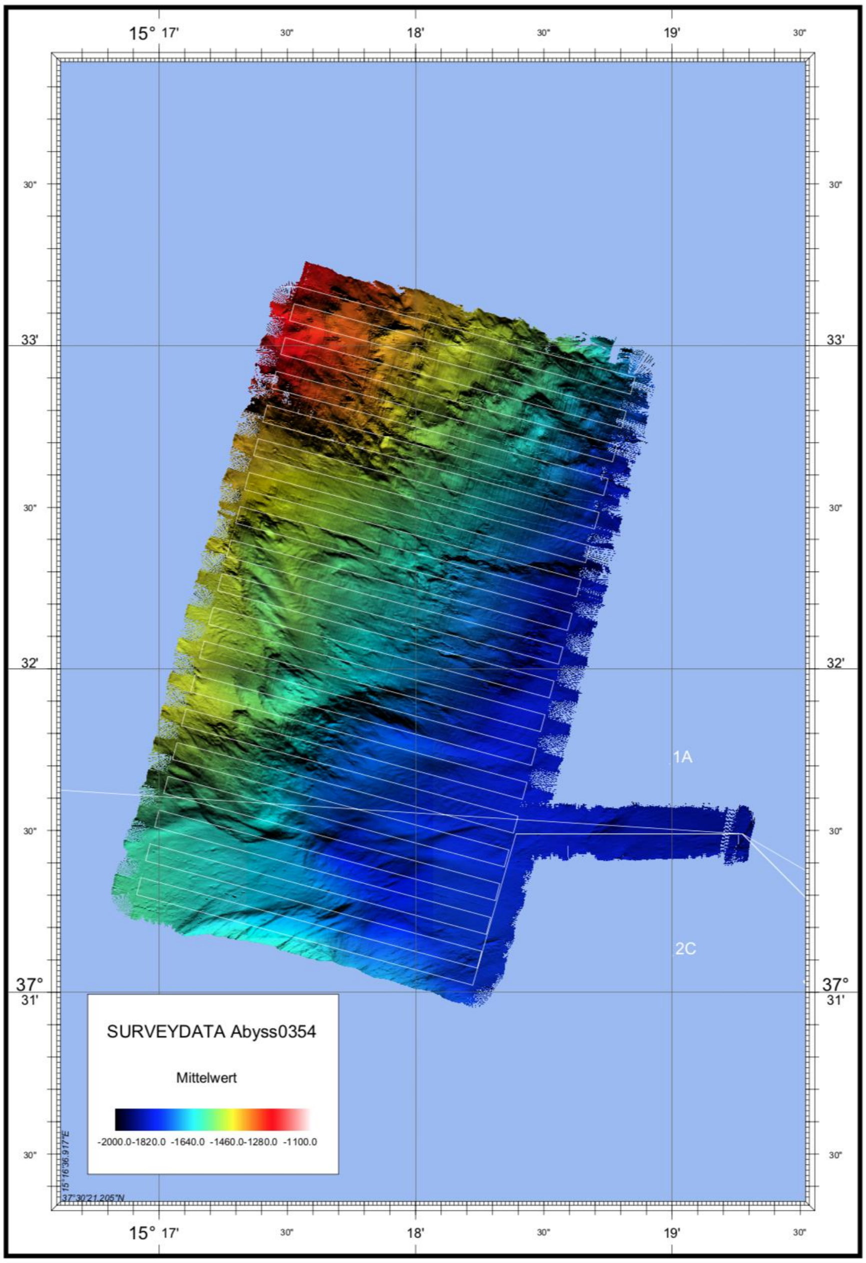


Fig. 5.7 Abyss 0354 mean value.

5.1.3 Sensor Description

Multibeam

Vendor	Reson
Typ	SeaBat T50-S Receiver EM7218-1 PN:85002538 SN:5018030 Projector TC2160 PN: 85000328 SN: 2218086 Projector TC2163 PN: 85000327 SN: 2214842
Last calibration	-
Exported data	*.s7k
Unit	-
Notes	The following specifications are taken from the general datasheet
Frequency	200kHz (400kHz available on request)
Along-track transmit beamwidth	2° at 200 kHz / 1°at 400 kHz
Across-track receive beamwidth	1° at 200 kHz / 0.5° at 400 kHz
Ping rate (range dependent)	Up to 50 pings/s
50 Hz (± 1 Hz)	33 µsec to 300 µsec
Number of beams (up to)	Min 10, Max 512
Swath coverage (up to)	150° Equi distance 165° Equi angle
Depth resolution	6mm
	Bathymetry, sidescan & snippets 7K data format Gbit Ethernet

Camera

Vendor	Canon
Typ	6D
Lens	CANON EF 8-15mm f/4L Fisheye USM
Exported data	*.jpeg
Frequency	Max 1Hz

ADCP

Vendor	RDI Teledyne
Typ	Model WHN300 S/N
Serial number	11436
Last calibration	
Exported data contains	- Latitude (degrees) - Longitude (degrees) - Altitude (meters) - Depth (meters) - Forward velocity over the bottom (meters/sec) - Starboard velocity over the bottom (meters/sec) - Error velocity - Temperature (degrees C) - Ensemble number - Heading (in degrees) - Stbd water velocity in mm/sec - Forward water velocity in mm/sec - Water velocity away from the transducer face (mm/sec) - Coordinate transform mode. The MSB (0x80) of this value indicates whether the water velocities are from the upward (set) or downward (cleared) looking beams.
Sample rate	

CTD

Vendor	Seabird
Typ	SBE 49 FastCAT
Serial number- [CTD1] or [CTD2]	4955482-[0198] or [0168]
Last calibration	03.07.2017
Exported data contains	latitude, longitude, mission_time, depth, conductivity, temperature, salinity, sound_speed
Unit	[deg],[deg],[HH.MM.SS.F],[m],[S/m],[°C],[psu],[m/s]
Sample rate	4Hz

ECO (Combination Fluorometer and Turbidity Sensor)

Vendor	Wetlabs
Typ	FLNTU / 0712017
Serial number	FLNTURTD-939
Last calibration	-
Exported data contains	latitude, longitude, mission_time, depth, version, chl_ref(lambda), chl_sig, chlorophyll_a, turbidity_ref, turbidity_raw, turbidity
Unit	[deg],[deg],[HH.MM.SS.F],[m],[],[nm],[count],[µg/l],[nm],[count],[NTU]
Sample rate	1Hz

Pressure/Depth

Vendor	Paroscientific
Typ	Digiquartz Intelligent Depth Sensor
Model	8BT7000-I
Range	7000m
PN	1537-001-0
Serial number	109773
Last calibration	-
Exported data contains	
Unit	
Sample rate	1Hz

5.1.4 Preliminary Results

Two high-resolution bathymetry maps provide an insight into tectonic and sedimentary processes at the offshore southern boundary of Etna's unstable flank. The first map covers a fraction of the area termed the "Lineament north of Catania Canyon" (Abyss0353, Fig. 5.6, Gross et al. 2016). It is the same area, where the GeoSEA geodesy network recorded 4 cm of fault slip during an 8-day slow slip event in May 2017 (Urlaub et al. 2018). The second map covers what has been interpreted as the toe of the volcano flank (Abyss0354, Fig. 5.7) in water depth of 1200 - 1800 m. Although only 2 km apart from each other, the surface expressions of faults in the two maps are very different. At the lineament, we observe a narrow and sharp lineament in NW-SE direction that is very prominent and easy to identify. Further downslope there is no such prominent structure. We observer several horseshoe-shaped scarps that we interpret as landslides. High sediment input through Catania Canyon and deposition at the slope break following its mouth to the south of the mapped area may mask clear evidence for tectonic activity.

5.2 Ship-based swath bathymetry

(M. Urlaub[1], A. Bonforte[2])
[1]GEOMAR, [2]INGV-CT

5.2.1 System Overview and Processing

We installed a mobile 50 kHz swath system, the ELAC SeaBeam 1050, in the moonpool of RV ALKOR to perform swath bathymetry mapping of the seafloor and of the signal amplitude (sidescan backscatter). This multibeam echosounder (MBES) is a mid-water system and operates with a frequency of 50 kHz, a constant opening angle of 150° and a maximum beam number of 126. The beam resolution is 1.5°. An OCTANS 3000 motion sensor compensated the system's motion. A Valeport miniSVS sound velocity sensor continuously measured sound velocity at the transducers. The ELAC Hydrostar software managed data acquisition under consideration of the ship's GPS data (GPS 150). Fig. 5.8 and Table 5.3 show the detailed installation configuration and offsets for cruise AL532. The roll offset was calculated in the HPPost Software based on two calibration profiles. The transponders remained inside the moonpool for the entire cruise.

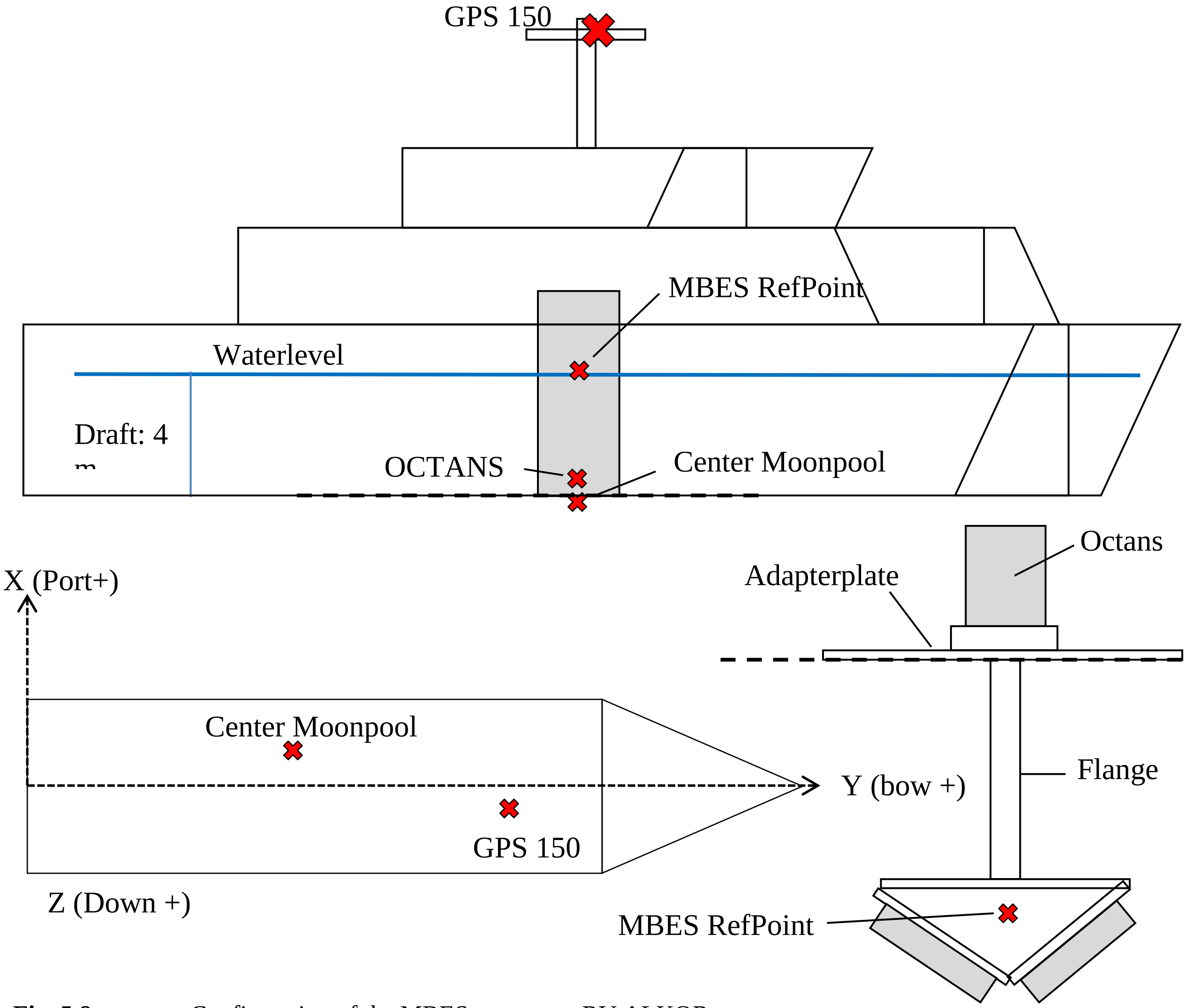


Fig. 5.8 Configuration of the MBES system on RV ALKOR.

Table 5.3 Configuration offsets during cruise AL532. Abbreviations according to the Hydrostar software.

#	Item	X (Port+) [m]	Y (bow+) [m]	Z (down+) [m]
Coordinate system as defined in Ship parameter file				
1	**TXPOS_P_X/Y/Z** (MBES RefPoint (at waterlevel) to Transducer Port)	0.0	0.18	4.5
2	**TXPOS_S_X/Y/Z** (MBES RefPoint (at waterlevel) to Transducer Stbd)	0.0	-0.18	4.7
3	**HRPOS_X/Y/Z** (MBES RefPoint to Octans)	0.0	0.0	- 0.6
4	**TROFF_P / _S** (values derived from patchtest)	2.04° / -2.37°		
5	**NAVPOS_X/Y/Z** (MBES RefPoint to GPS150)	-2.88	8.29	-23.84
6	*Draft: MBES RefPoint to waterlevel**	*0*	*0*	*+ 4.00 (Draft)*

For assessing vertical profiles of sound velocity we used a multisensor CTD 75M manufactured by Sea & Sun Technology. It is a self-sustaining probe, which is powered by batteries and can operate down to a depth of 1000 m. Three of the eight channels were equipped with a pressure, conductivity, and temperature sensor. The probe recorded at 1 dbar intervals. From the data, we derived the sound velocity (Fig. 5.9), which was loaded into the Hydrostar Software.

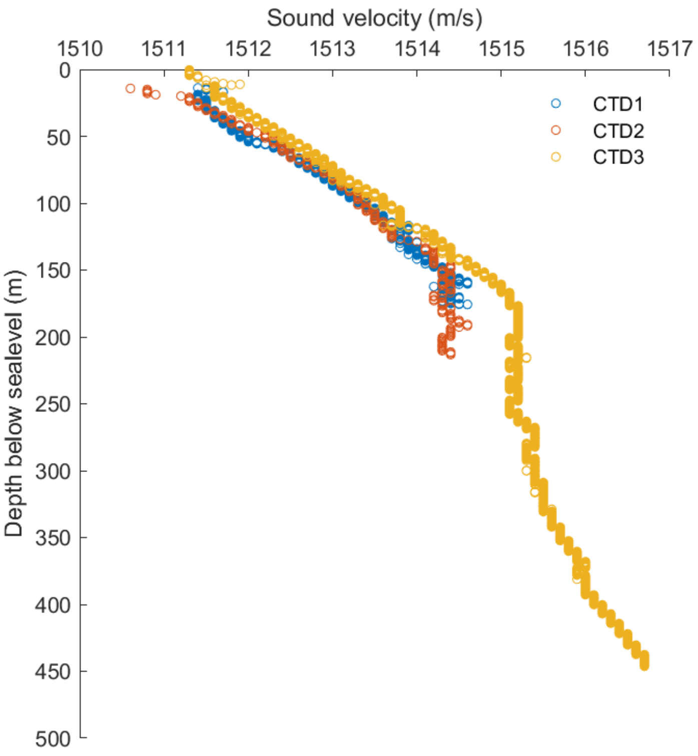


Fig. 5.9 Sound velocity profiles taken in the survey areas.

The bathymetric data were recorded in the ELAC proprietary xse format (known by MBSystem as MBIO Data Format ID: 94; Format name: MBF_L3XSERAW). Recording was halted during turns, so that each file presents one profile. The data were routinely renamed (xse file ending replaced by mb94), analyzed, and cleaned from outliers with the help of the MBSystem tools mbinfo, mbclean and mbprocess (Caress and Chayes, 1996).

5.2.2 Surveys and preliminary results

We ran four surveys close to the coast (offshore off the villages Aci Castello, Acitrezza, Santa Tecla, and Stazzo) in water depths of 40 – 400 m and one survey in greater depth (400 – 1200 m). Profile tracks were sailed at 4 knots. The MBES system worked very reliable and delivered satisfactory data (Fig. 5.10).

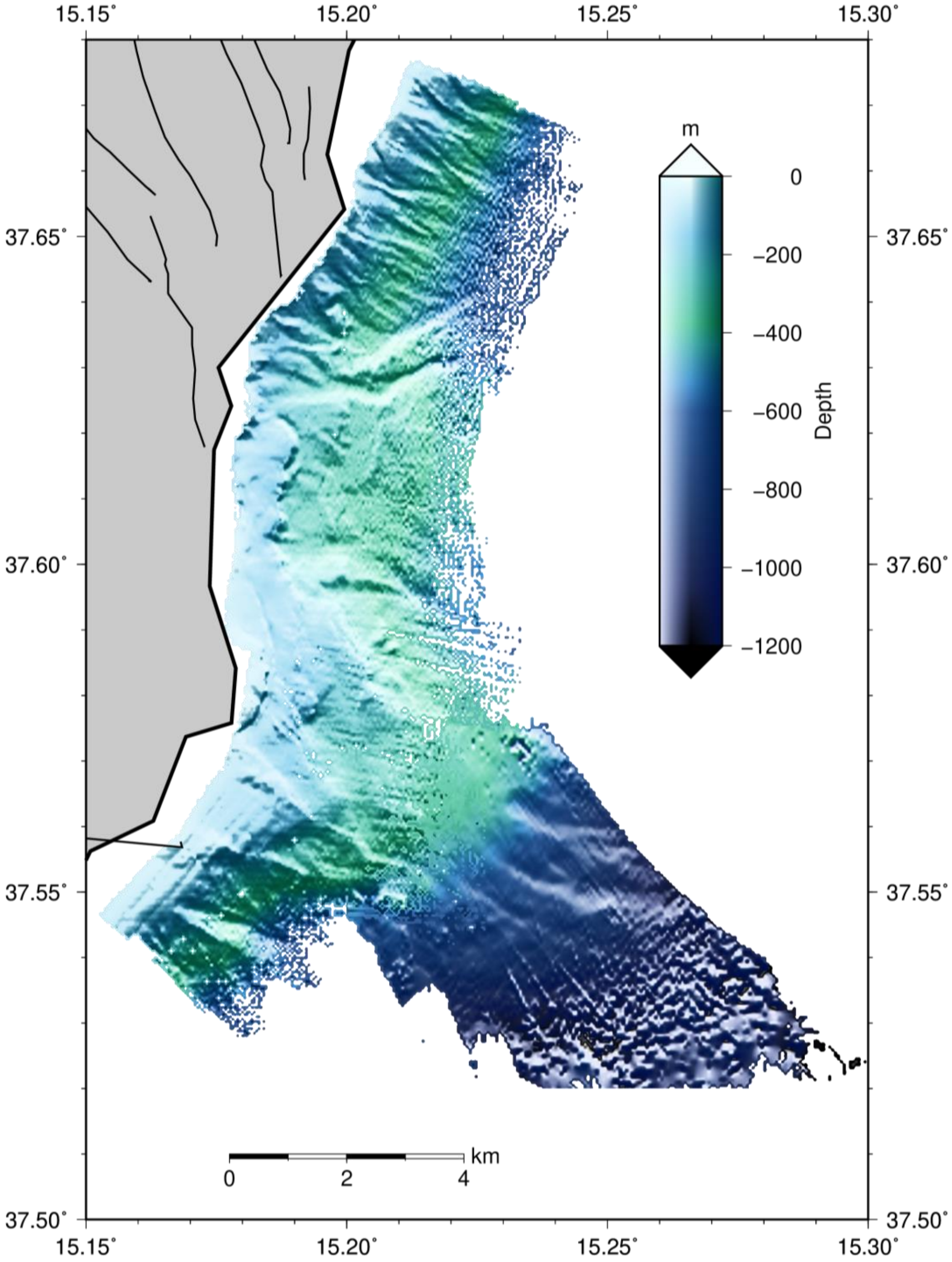


Fig. 5.10 Map with the ship-based multibeam data collected during AL532. Land is coloured grey. Black lines indicate faults. The data is gridded at 40 m spacing, which is appropriate for the shallower parts of the area.

The aim of the surveys was to detect changes in seafloor morphology caused by volcanic, tectonic, or sedimentological activity. Comparing this new data set to the existing data set (Chiocci and Ridente 2011) we are not able to depict any changes by visual inspection. We expect the grid quality to improve through dedicated editing and processing at a later stage.

6 Station List AL532

Station No.	Date	Gear	Time	Latitude	Longitude	Water Depth	Remarks/Recovery
ALKOR	2020		[UTC]	[°N]	[°E]	[m]	
AL532_1-1	01-29	AUV	09:26:08	37° 30.073'	015° 20.023'	1788	In water
AL532_2-1	01-29	Mooring	10:10:47	37° 31.165'	015° 18.905'	1800	Deployed
AL532_3-1	01-29	Mooring	10:32:20	37° 31.781'	015° 18.893'	1828	Deployed
AL532_1-1	01-29	AUV	13:02:11	37° 29.901'	015° 21.295'	1817	On deck
AL532_4-1	01-29	AUV	16:43:33	37° 30.047'	015° 19.869'	1792	In water
AL532_5-1	01-29	MBES	16:55:46	37° 30.004'	015° 19.746’	1798	In moonpool
AL532_5-1	01-29	MBES	18:35:12	37° 34.152'	015° 13.946’	440	Profile start
AL532_5-1	01-29	MBES	20:02:03	37° 34.167'	015° 13.937’	440	Profile end
AL532_5-1	01-29	MBES	20:47:37	37° 33.732'	015° 10.655’	89	Profile start
AL532_5-1	01-30	MBES	03:04:44	37° 35.696'	015° 12.050’	307	Profile end
AL532_4-1	01-30	AUV	04:45:08	37° 33.303'	015° 15.027’	866	At surface
AL532_4-1	01-30	AUV	06:59:53	37° 32.802'	015° 15.066’	859	On deck
AL532_6-1	01-30	CTD	08:14:54	37° 33.161'	015° 11.243’	307	In water
AL532_6-1	01-30	CTD	08:35:45	37° 33.064'	015° 11.242’	364	On deck
AL532_7-1	01-30	MBES	09:01:36	37° 33.780'	015° 10.644’	86	Profile start
AL532_7-1	01-30	MBES	13:06:38	37° 32.673'	015° 12.225’	624	Profile end
AL532_8-1	01-30	AUV	15:21:32	37° 30.090'	015° 19.867’	1790	In water
AL532_9-1	01-30	MBES	17:44:12	37° 35.234'	015° 10.855’	43	Profile start
AL532_9-1	01-31	MBES	05:36:54	37° 38.412'	015° 12.775’	410	Profile end
AL532_8-1	01-31	AUV	07:32:08	37° 33.009'	015° 17.291’	1205	At surface
AL532_8-1	01-31	AUV	07:43:00	37° 32.943'	015° 17.526’	1257	On deck
AL532_10-1	01-31	CTD	09:22:29	37° 32.621'	015° 10.355’	243	In water
AL532_10-1	01-31	CTD	09:40:16	37° 32.709'	015° 10.366’	229	On deck
AL532_11-1	01-31	MBES	10:07:04	37° 32.493'	015° 08.932’	67	Profile start
AL532_11-1	01-31	MBES	11:40:00	37° 33.094'	015° 09.901’	65	Profile end
AL532_12-1	01-31	MBES	12:00:58	37° 32.794'	015° 09.371’	65	Profile start
AL532_12-1	01-31	MBES	17:07:01	37° 32.107'	015° 10.250’	430	Profile end
AL532_13-1	01-31	AUV	19:14:22	37° 30.035'	015° 19.832’	1793	In water
AL532_13-1	02-01	AUV	00:32:12	37° 31.073'	015° 19.961’	1793	On deck
AL532_14-1	02-01	MBES	03:30:47	37° 37.854'	015° 11.280’	175	Profile start
AL532_14-1	02-01	MBES	11:47:20	37° 37.289'	015° 12.418’	283	Profile end
AL532_15-1	02-01	Mooring	13:45:22	37° 31.333'	015° 18.892’	1807	Released
AL532_16-1	02-01	Mooring	14:15:16	37° 31.182'	015° 18.934’	1804	Released
AL532_15-1	02-01	Mooring	14:15:46	37° 31.162'	015° 18.938’	1804	At surface
AL532_15-1	02-01	Mooring	14:27:59	37° 30.934'	015° 18.955’	1792	On deck
AL532_16-1	02-01	Mooring	14:49:12	37° 31.295'	015° 18.904’	1806	At surface
AL532_16-1	02-01	Mooring	14:56:13	37° 31.589'	015° 18.987’	1825	On deck
AL532_17-1	02-01	CTD	16:32:14	37° 32.678'	015° 12.636’	612	In water
AL532_17-1	02-01	CTD	17:11:57	37° 32.585'	015° 12.538’	600	On deck
AL532_18-1	02-01	MBES	17:28:38	37° 32.793'	015° 12.057’	510	Profile start
AL532_18-1	02-02	MBES	08:10:03	37° 33.729'	015° 14.575’	712	Profile end

7 Data and Sample Storage and Availability

All metadata has been entered into the Ocean Science Information System (OSIS), a central information and data sharing utility maintained by the Kiel Data Management Team. The view of all information in OSIS is open to the public. The ship-based bathymetry raw data and sound velocity profiles have been uploaded to PANGAEA. The AUV gridded bathymetry will be made available on PANGAEA following publication and within two years of the cruise.

Table 7.1 Overview of data availability

Type	Database	Available	Free Access	Contact
Metadata ship-based and AUV bathymetry	OSIS	April 2020	April 2020	murlaub@geomar.de
Bathymetry raw data, CTD	PANGAEA	May 2020	May 2020	murlaub@geomar.de
AUV bathymetry	PANGAEA	TBD	TBD	murlaub@geomar.de

8 Acknowledgements

Our sincere thanks go to captain Hero Nansen and the entire crew of RV ALKOR for their excellent support and hospitality during the cruise. MU also thanks Mareike Kampmeier, Iason Gazis, and Ingo Klaucke for their help with the MBES system. This cruise was funded by GEOMAR Helmholtz Centre for Ocean Science Kiel.

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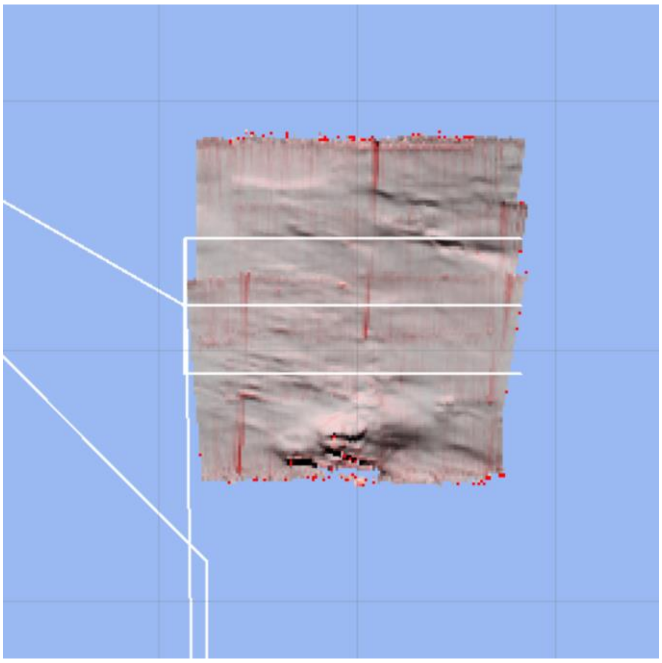
10 Abbreviations

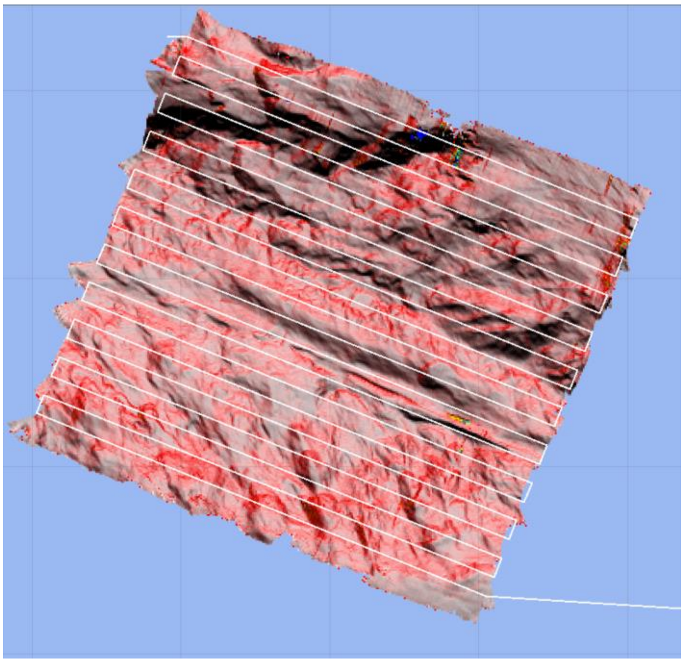
AUV	Autonomous Underwater Vehicle
CTD	Conductivity Temperature Depth
DVL	Doppler Velocity Log
INS	Inertial Navigation System
LARS	Launch And Recovery System
LBL	Long Baseline positioning
MBES	Multibeam echosounder
OSIS	Ocean Science and Information System

11 Appendices

11.1 AUV Abyss mission details

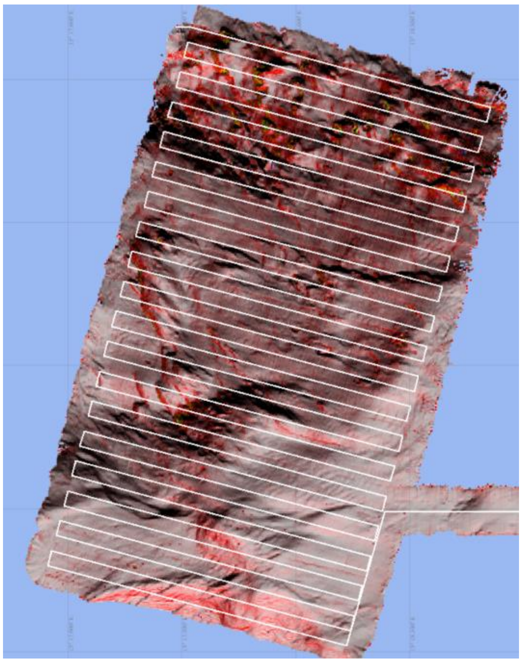
Station	**AL532**	Day (UTC)	**29.01.2020**
Dive	**Abyss0352**		
		Mission goal:	Multibeam (200kHz) test and calibration
		Times (UTC)	
		Launch	09:25 (29.01.2020)
		Mission start	09:31
		Mission finished	12:13
		Recovery	12:57
		Distance travelled	13.51 km
		Mission comments	
Depth / Altitude	- survey depths between 1825.56–1848.79 m - altitude: 80 m		
Sensor	RESON SeaBat T50 200 kHz Multibeam Echosounder		
Total raw files	9 files (*.s7k) / 1.25GB	First file	20200129_090720.s7k
		Last file:	20200129_105355.s7k
Sensor	Eh / REDOX Sensor (Koichi Nakamura)		
Total raw files		File name	Abyss0352_REDOX.txt
Comments			
Sensor	SeaBird SBE49 FastCAT CTD (S/N: 4948793-0168)		
Total raw files		File name	Abyss0352_CTD.txt
Comments			
Sensor	Wetlabs ECO FLNTU (Chlorophyll / Turbidity) (S/N: FLNTURTD-939)		
Total raw files		File name	Abyss0352_ECO.txt
Comments			
Comments	- Sensor data positions are not shifted to the corrected vehicle track		

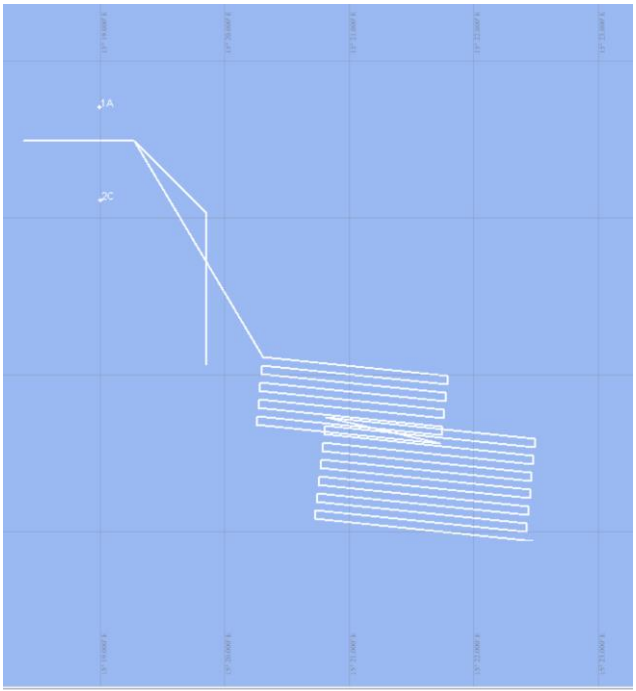
Station	**AL532**	Day (UTC)	**29.01.2020**
Dive	**Abyss0353**		



Mission goal:	multibeam survey with watercolumn data
Times (UTC)	
Launch	16:35 (29.01.2020)
Mission start	16:45
Mission finished	04:53 (30.01.2020)
Recovery	06:56
Distance travelled	91.58 km
Mission comments	– FM, Tracker, adaptive gates – line spacing 100m

Depth / Altitude	- survey depths between 813.95 – 1458.93 m - altitude: 80 m		
Sensor	RESON SeaBat T50 200 kHz Multibeam Echosounder		
Total raw files	19,469 files (5.49TB)	First file	20200129_163559.s7k
	survey area covered: 5.5 km²	Last file:	20200130_042836.s7k
Sensor	Eh / REDOX Sensor (Koichi Nakamura)		
Total raw files		File name	Abyss0353_REDOX.txt
Comments			
Sensor	SeaBird SBE49 FastCAT CTD (S/N: 4948793-0168)		
Total raw files		File name	Abyss0353_CTD.txt
Comments			
Sensor	Wetlabs ECO FLNTU (Chlorophyll / Turbidity) (S/N: FLNTURTD-939)		
Total raw files		File name	Abyss0353_ECO.txt
Comments			
Comments	- Sensor data positions are not shifted to the corrected vehicle track		

Station	**AL532**	Day (UTC)	**30.01.2020**
Dive	**Abyss0354**		
		Mission goal:	
		multibeam survey	
		Times (UTC)	
		Launch	15:15 (30.01.20)
		Mission start	15:23
		Mission finished	07:17 (31.01.20)
		Recovery	07:40
		Distance travelled	87.60 km
		Mission comments	
Depth / Altitude	- survey depths between 1249.35 – 1869.70 m - altitude: 80 m		
Sensor	RESON SeaBat T50 200 kHz Multibeam Echosounder		
Total raw files	100 files (26,04GB)	First file	20200130_151402.s7k
	survey area covered: 8.7 km²	Last file:	20200131_063746.s7k
Sensor	Eh / REDOX Sensor (Koichi Nakamura)		
Total raw files		File name	Abyss0354_REDOX.txt
Comments			
Sensor	SeaBird SBE49 FastCAT CTD (S/N: 4948793-0168)		
Total raw files		File name	Abyss0354_CTD.txt
Comments			
Sensor	Wetlabs ECO FLNTU (Chlorophyll / Turbidity) (S/N: FLNTURTD-939)		
Total raw files		File name	Abyss0354_ECO.txt
Comments			
Comments	- sensor data positions are not shifted to the corrected vehicle track		

Station	**AL532**	GEOMAR	Day (UTC)	**01.02.2020**
Dive	**Abyss0355**			
			Mission goal:	
			multibeam survey, watercolumn	
			Times (UTC)	
			Launch	19:10
			Mission start	19:18
			Mission finished	20:11
			Recovery	23:30
			Distance travelled	4.44 km
			Mission comments	
			– intentional mission stop	
Depth	1780 m			
Sensor	RESON SeaBat T50 200 kHz Multibeam Echosounder			
Comments	– water leak detected, the mission immediately stops and the vehicle floats to the surface			

11.2 Selected Pictures of Shipboard Operations

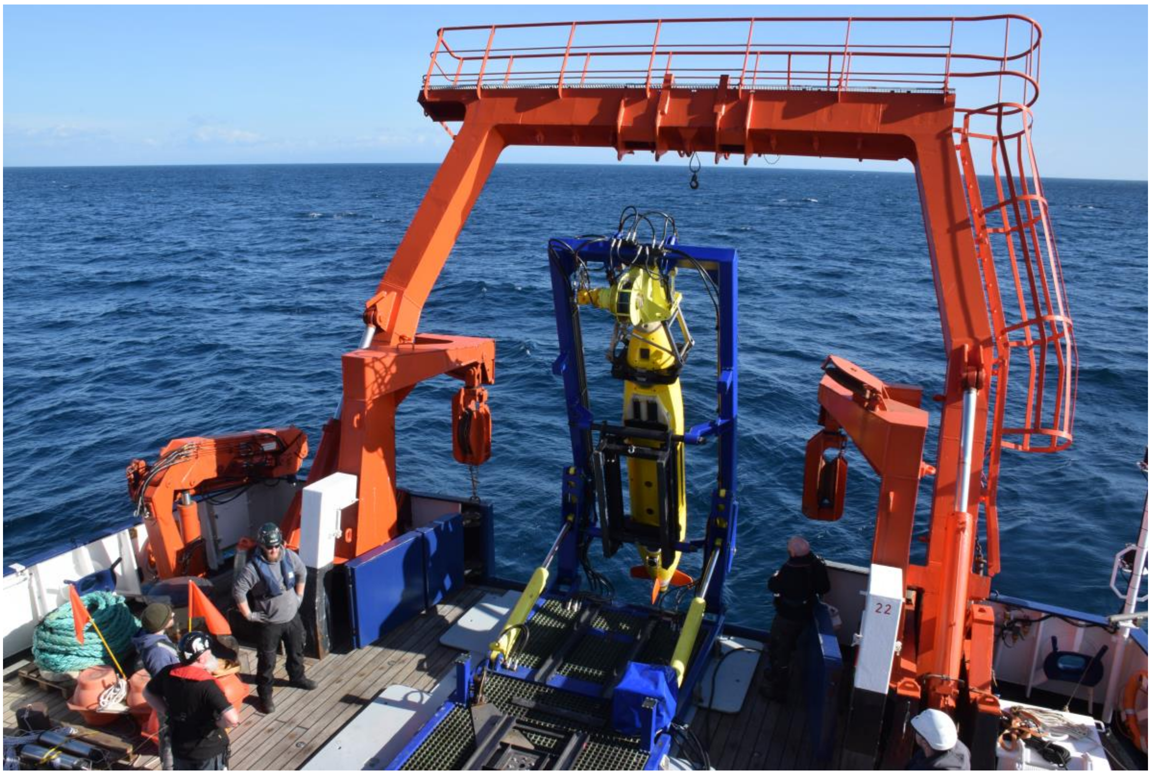


Fig. 11.1 AUV Abyss being lowered into the water by the LARS.

Fig. 11.2 Configuration of the multibeam system above ALKOR's moonpool.