RV SONNE Cruise SO244-II

Antofagasta – Antofagasta

27.11.15 – 13.12.15

1. Weekly Report

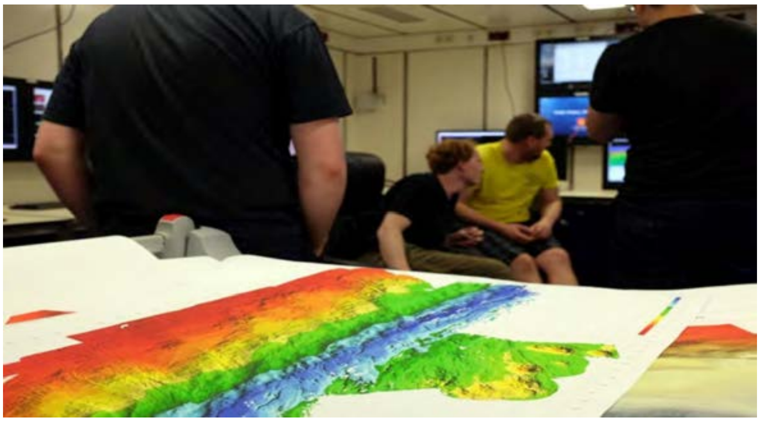
We left the port of Antofagasta and its beautiful setting against the coastal cordillera on Friday, November 27 at 9:30 a.m. The previous days in port were used to prepare and assemble our scientific gear. A total of 24 scientists from Chile, Germany and Great Britain will sail on SONNE to install the seafloor geodetic array GeoSEA. GeoSEA (**G**eodetic **E**arthquake **O**bservatory on the **SEA**floor) will be deployed in water depth between 2000 m and 6000 m on the continental margin and the oceanic plate offshore Chile to measure seafloor deformation at a sub-centimeter scale. The measured seafloor parameters contain crucial information on the strain build-up prior and during an earthquake and hence are important to improve our understanding of earthquake physics and hazard mitigation in the area. The network contains 23

RV SONNE leaves the port of Antofagasta.

transponder benchmarks, which are installed on steel tripods on the seafloor where they autonomously measure the deformation pattern.

The 20-hour transit to our first working area was used to define locations for the network based on AUV data acquired during Leg I of SO244. The scientific crew of Leg I mapped four areas on the continental slope as well as an additional area on the outer rise seaward of the trench at 2 m resolution. From these maps we identified three areas, which are ideal for the installation of three GeoSEA sub-arrays to survey their diverse tectonics.

Our first working area is located at water depth ranging from 2500 m to 2800 m and thus is the most shallow of the target areas. It is characterized by four fault zones trending in a N-S direction parallel to the trench showing indications for active deformation.

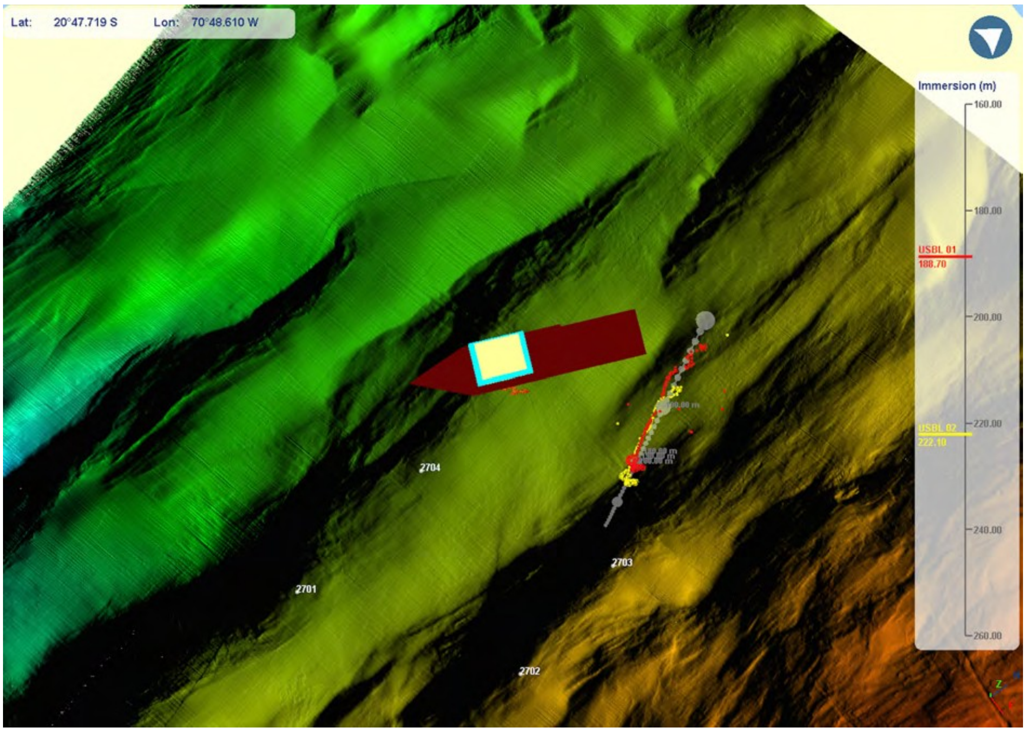


Analysis of bathymetric maps to define the network configuration.

On Nov. 28 at 6:00 we started with the preparation of the first deployment of GeoSEA station A101. The steel tripod is approximately 4 m high and was assembled on the large working deck of RV SONNE. Deployment was conducted using the deep-sea cable to which the tripod as well as two floats and a train wheel (as weight) were attached to stabilize the cable tension. In addition, two USBL Posidonia transponders were attached to the cable to indicate touch down on the seafloor.

GeoSEA Tripod on the aft working deck (Height app. 4 m without transponder beacon).

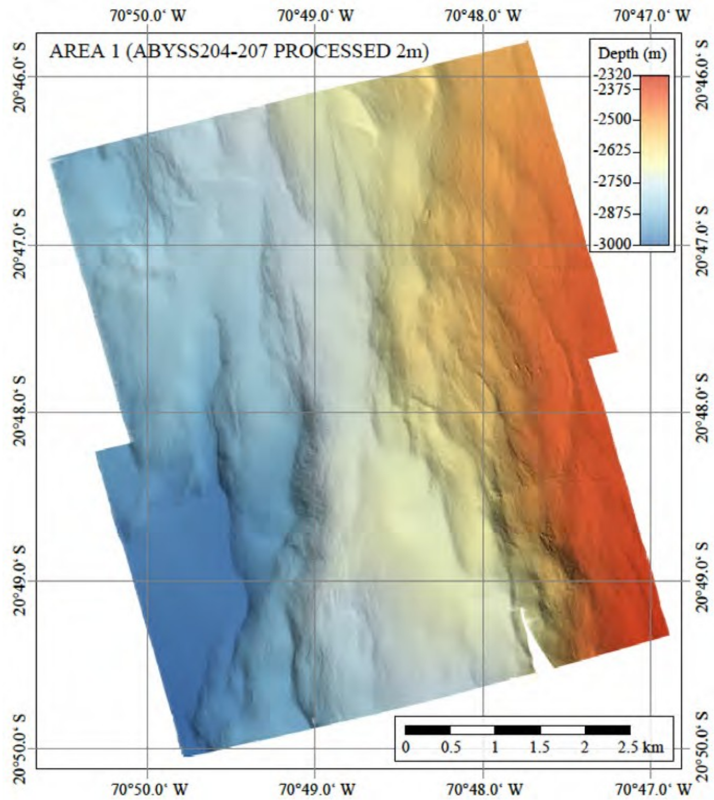
The deployment went smoothly until 200 water depth, when the winch was put on halt to deploy a dunker modem over the starboard side of RV SONNE. While on hold, suddenly the distance between the two USBL transponders rose significantly, indicating that the tripod was in a free fall mode towards the seafloor at 2500 m water depth.



USBL-Tracker monitoring the distance between two Posidonia transponders (red and yellow) to survey the seafloor deployment – and the yanking off of the tripod. White dots on the seafloor AUV map indicate planned positions of the GeoSEA network.

Due to the quick response of the deck's crew and scientific crew the hook of the heavy weight releaser could be released and the instrument as well as the floats were rescued.

With the additional modem on the starboard side we could monitor the fall and touch down of the tripod on the seafloor. As the barycenter of the tripod is located at its base, the instrument landed upside down and could be pinged immediately. It landed approximately 12 m away from its planned position and can be included in the network as a full-scale node.



AUV map of the first working area on the middle continental slope offshore northern Chile (2 m resolution). A total of 8 GeoSEA transponders will be deployed in a network on the seafloor.

Heave of the deep-sea cable brought the train wheel back on the deck: The eyelet where the cable had been attached was broken. The weight was modified to compensate for this.

On November 28 at 16:00 station A102 was deployed and installed on the seafloor. Both beacons respond and communicate with each other.

On November 29 we continued to deploy stations A103, A104, and A105 at water depths ranging from 2620 m to 2865 m. All five stations respond properly. Based on the acoustic travel times between the instruments we calculate the distance between the nodes and monitor the tectonic deformation between the stations in the following years.

In the meantime the deck's crew and scientific crew have reached some routine in deploying these new instruments and hence we look forward to our remaining time on board. Our special thanks go to the crew and officers of RV SONNE who make difficult deployments like ours possible in the first place.

The weather up to now has bee very good and everybody on board is doing fine and enjoys the Pacific swell.

Kind greetings to everybody back home,

Heidrun Kopp

At sea, 20°47'S / 70°49'W

FS SONNE Reise SO244-II

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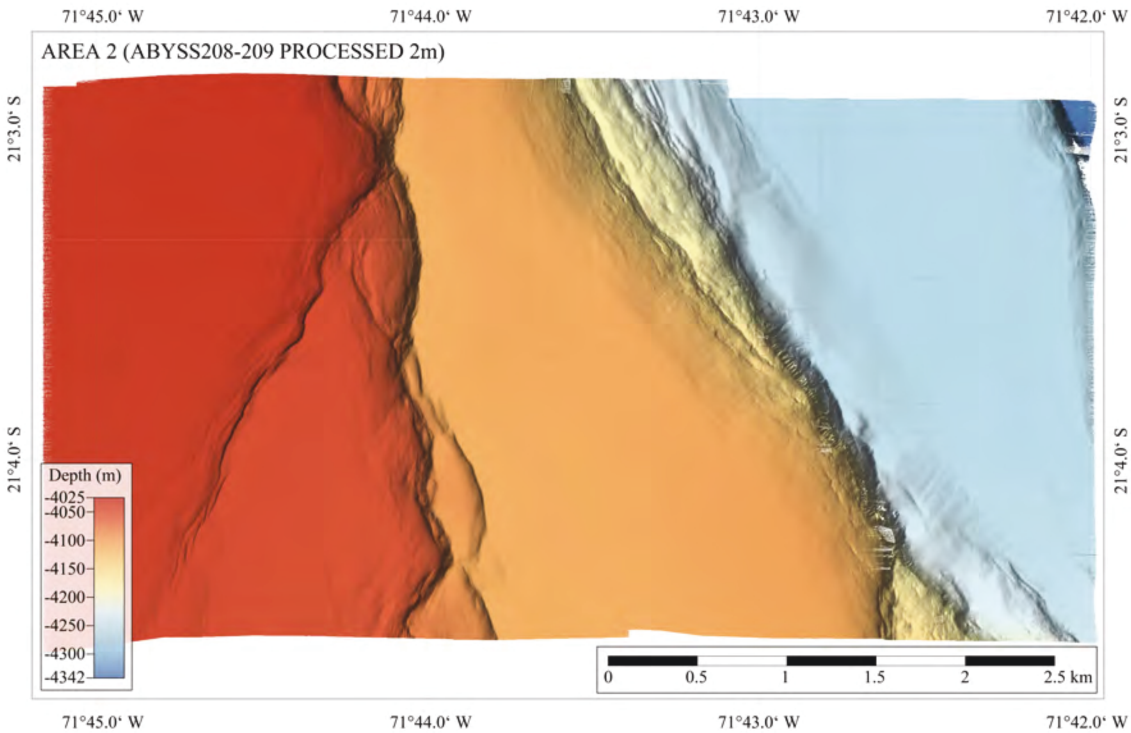
2. Weekly Report, Dec. 6, 2015

Our second week on RV SONNE started with the deployment of the GeoSEA array in our westernmost working area on the outer rise of the oceanic Nazca plate. This region on the downthrusting plate is characterized by a distinct topography inherited from seafloor spreading. In addition to volcanic structures such as cones and calderas the original seafloor spreading fabric is recognized. These inherited structures in the vicinity of the deep sea trench is overprinted by recent plate-bending related normal faulting which trend parallel to the trench.



AUV map of working area 2 in water depth exceeding 4000 m. An approximately 100 m high scarp is recognized to the right trending in a NW-SE direction. This structure originates from the original seafloor spreading. The structures on the left near 71°44'W are active fault zones trending parallel to the deep sea trench. The deformation focused on these faults is the target of the second GeoSEA sub array.

The monitoring of extensional processes across these outer rise bending faults will yield an improved understanding of the fault processes and degree of extension as well as the physical properties of the fault zone and elastic parameters of the lithosphere. Furthermore, the occurrence of earthquake doublets around the globe indicates a strain transfer from the outer rise to the forearc (e.g. Samoa-Doublet, 2009) or vice versa (e.g. Kuriles Doublet, 2006/7).

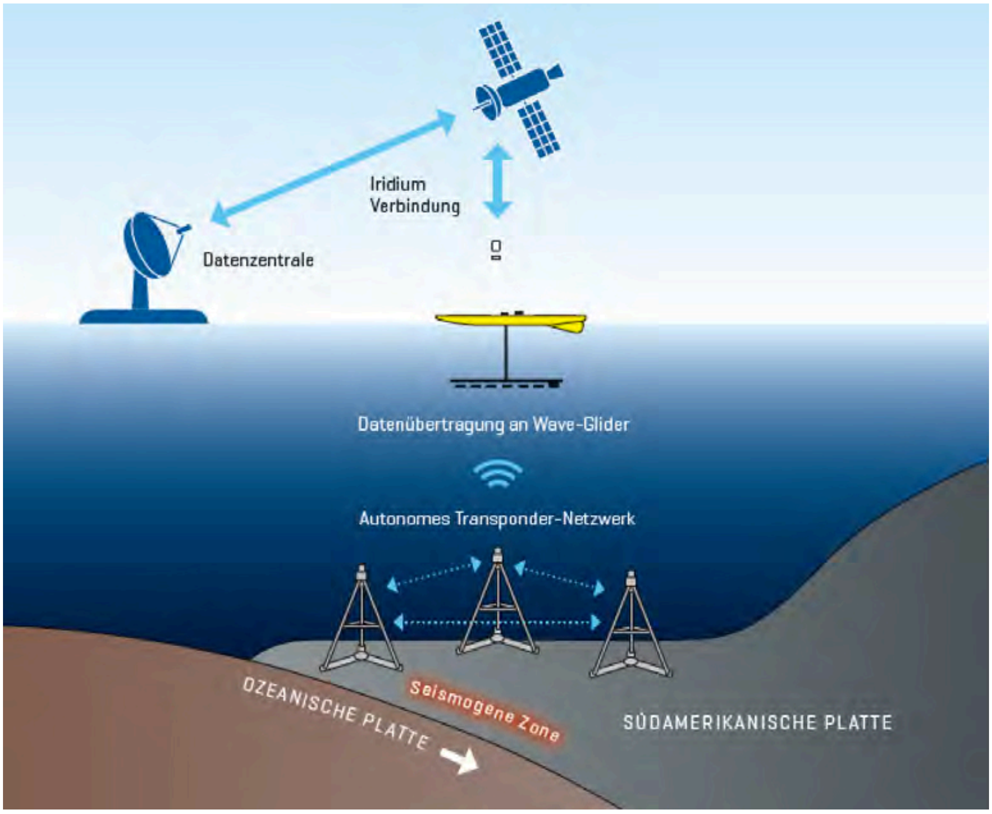
A total of five GeoSEA tripods (stations A201-A205) were installed in working area 2 between Nov. 30 and Dec. 1, 2015 in water depth ranging from 4034 m to 4105 m. Communication with the transponders proved very stable whereas the release of the tripod turned out to be troublesome. For the first two stations, the release unit did not respond and only after heaving the tripod we could recognize that the station indeed remained on the seafloor. The third station A203 however had to be heaved back to the deck of RV SONNE after not responding at all. After exchanging the release unit, this station was lowered to the seafloor again and could finally be released on its deployment position.

Simulatenously we deployed GeoSURF, a wave glider, which navigates autonomously above the installed stations at depth to retrieve data from the seafloor to the sea surface where it connects to a satellite and sends the data to our lab at GEOMAR.

Wave glider GeoSURF ready for deployment on the deck of RV SONNE.

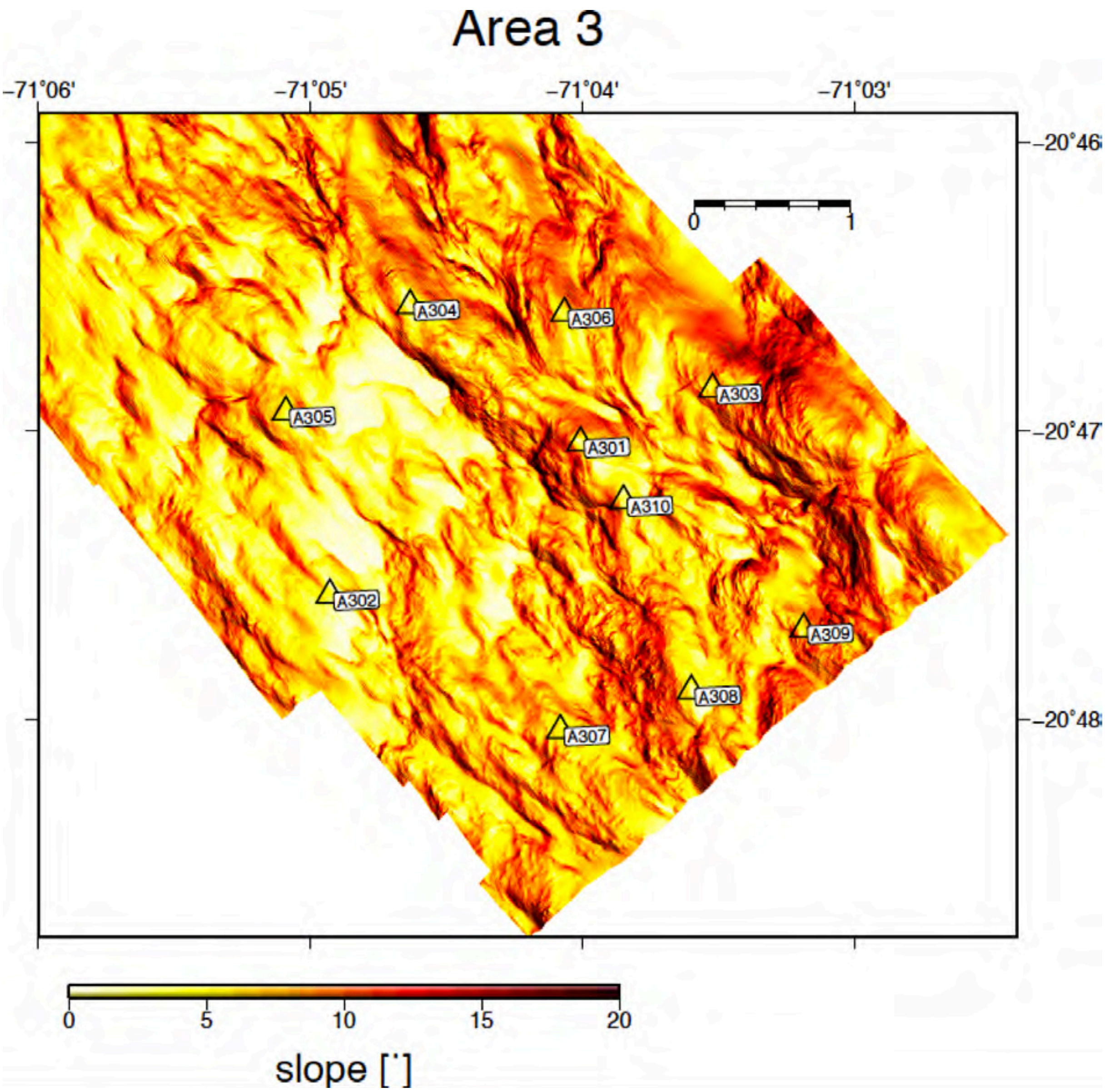
The deployment of GeoSURF started at 7:30 and lasted until 19:30 when we had to recover GeoSURF using the rescue boat of RV SONNE. The successful test of navigation as well as data upload leaves us confident to use GeoSURF in the future to autonomously monitor system health and retrieve the data (see sketch below).

Recovery of GeoSURF using RV SONNE's rescue boat.



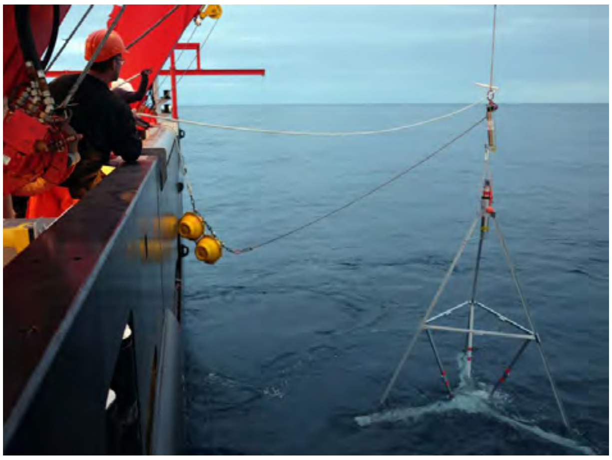
Sketch of the array set-up: The GeoSEA array installed on the seafloor communicates with GeoSURF, the wave glider at the surface that transfers the data via satellite to the lab (C. Kersten).

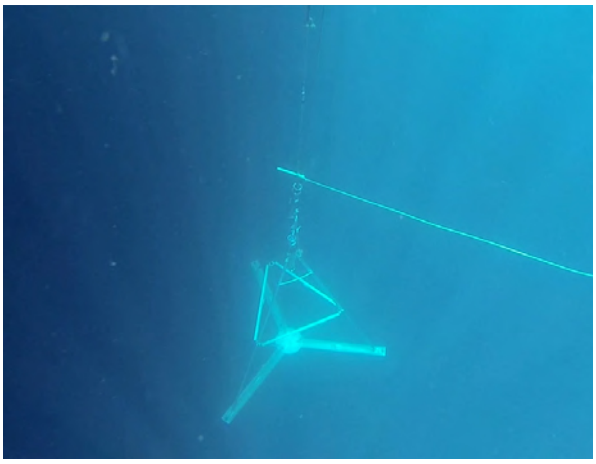
On December 2 we reached our third working area where a total of 10 stations was to be deployed in water depth between 5087 m and 5368 m. The working area is located on the lower slope of the continental margin about 10 km east of the deep sea trench and covers a region of 35 km^2. A suite of ridges and active fault zones with relative heights of up to 500 m dominates the region, which is overall characterized by steep slopes.



Slope map of working area 3 in water depth > 5000 m. The distinct steep slopes are challenging for the installation of the GeoSEA tripods. A total of 10 GeoSEA stations was successfully installed on the seafloor to measure the diffuse strain build up in this region.

The tectonically complex region with its steep slopes and narrow ridge crests poses a particular challenge for the deployment of the instruments regarding line-of-sight. Based on our previous experiences with deep-water deployment sites we modified the tripod installation by adding a floatation above the tripod as well as on the connecting line between the releaser and the train wheel. Furthermore, we added about 15 m to the connecting line to ensure that there is enough tension between the tripod and the Benthos floatation spheres as any point of time. All 10 stations could be deployed successfully until December 5. Line-of-sight between the stations was better than anticipated and the number of measured and retrieved baselines was accordingly higher than modeled or expected. Monitoring of the area in the upcoming years is targeted to measure the tectonic strain build-up. This information is crucial to understand the coupling between the downthrusting Nazca plate and South America and to better understand earthquake initiation and rupture.



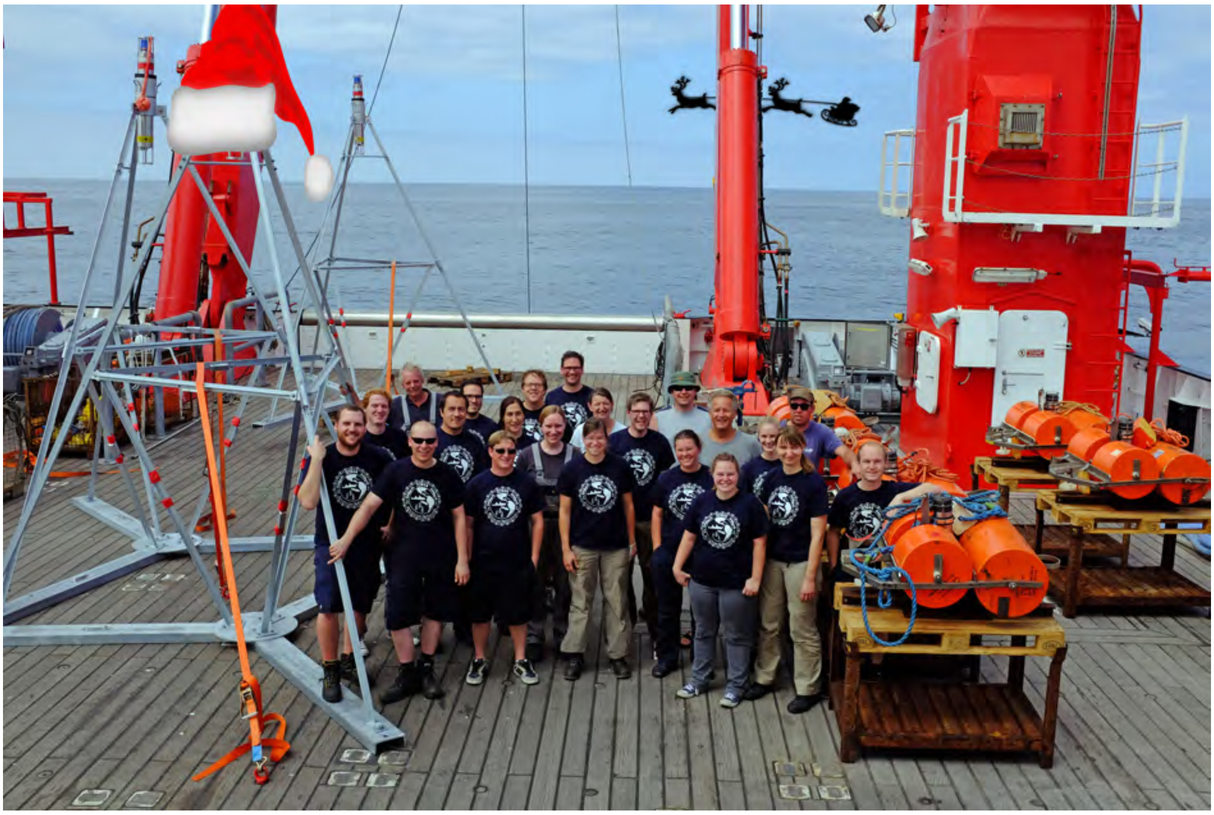


GeoSEA station A308 on the deep sea cable of RV SONNE: above and below the ocean surface....

During recovery of the releaser and train while of station A310 on the eve of December 5 the connecting line ripped apart above the Benthos spheres. Both floatation spheres as well as the heavy weight release unit got entangled in the portside propeller of RV SONNE, as could be verified by video. RV SONNE turned off the propellers as night fell and drifted slowly northwards carried by the Humboldt current.

On the morning of December 6 in the daylight we tried to free the propeller from the entangled material, however we did not succeed. We commenced our 12 nm long transit back to working area 1 to install the first of the remaining three stations (A106). This station immediately responded to the pings from the five stations already deployed in the network as well as to RV SONNE. This success was a vague consolation for the fact that one or both of the Benthos spheres must have imploded during transit. Fortunately the heavy-weight release unit pulled both spheres as well as the remaining line to depth, setting the portside propeller free so that it could be utilized unconditionally. In the afternoon of December 6 we successfully deployed station A107 and now look forward to the beginning of the upcoming week when we will hopefully complete the installation of the last of our 23 GeoSEA stations.

The weather as well as the Pacific swell prove very stable and everybody on board is doing well and enjoying the regular ‘visits’ by dolphins, whales, seals, Mahi Mahis and Humboldt squids to the vessel.



Kind greetings to everybody back home !

Heidrun Kopp

Heidrun Kopp

At sea, 20°47’S / 70°49’W

FS SONNE Reise SO244

Antofagasta – Antofagasta

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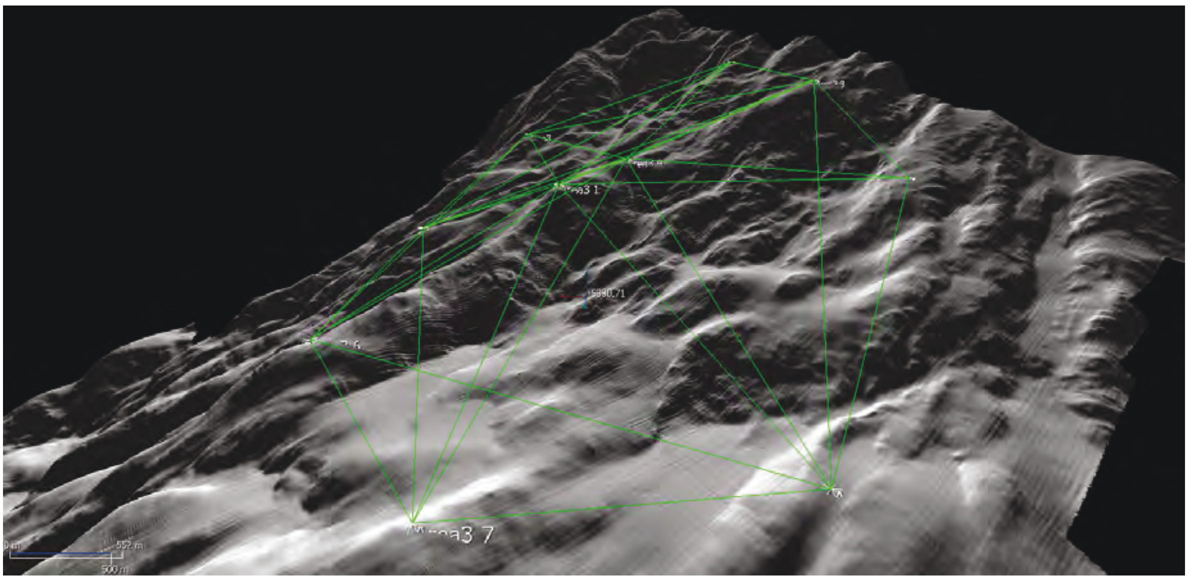
3. Weekly Report, 13. Dez. 2015

Our third and final week in the Pacific offshore Chile began with a pleasant start: we deployed our final GeoSEA station in working area 1 and are now excited to have three fully functioning geodesy arrays on the continental margin, which is the site of recurring earthquakes that pose a hazard to the coastal region. This installation is unique, as is the deployment method on the de-coupled deep-sea cable in water depth of more than 5000 m, obviating the use of a remotely operated vehicle (ROV). All stations on the seafloor are operating and communicating, yielding a 100% functionality of the networks. The technical hurdles we had to take in the past days especially in greater water depth did in the end not pose too great a challenge – this is mainly due to the efficient cooperation between vessel's crew and the scientific crew. Special thanks thus go to the officers and the crew of RV SONNE, particularly also to the crew working in the engine room, who make our work possible in the first place.



Array configuration for area 3: A total of 10 stations have been deployed here and surround two central stations. The green lines depict all measured baselines between the stations.

The figure above depicts the large number of baselines that we are able to measure in the tectonically and morphologically complex working area 3.

In the early afternoon of December 7 we deployed our first ocean bottom seismometer (OBS) in the study region. Another 13 OBS were deployed in the following days to register the seismic activity. These instruments will be recovered by RV Langseth in the spring/summer of 2016.

Ocean bottom seismometers are being prepared on the main deck of RV SONNE. The instruments will record the seismic activity along the Chilean plate boundary for a period of 6 months.

We deployed 12 OBS until December 8, when we returned to our first working area to deploy GeoSURF. The wave glider navigated autonomously above our installed stations until the next morning and successfully uploaded and saved the geodesy data.

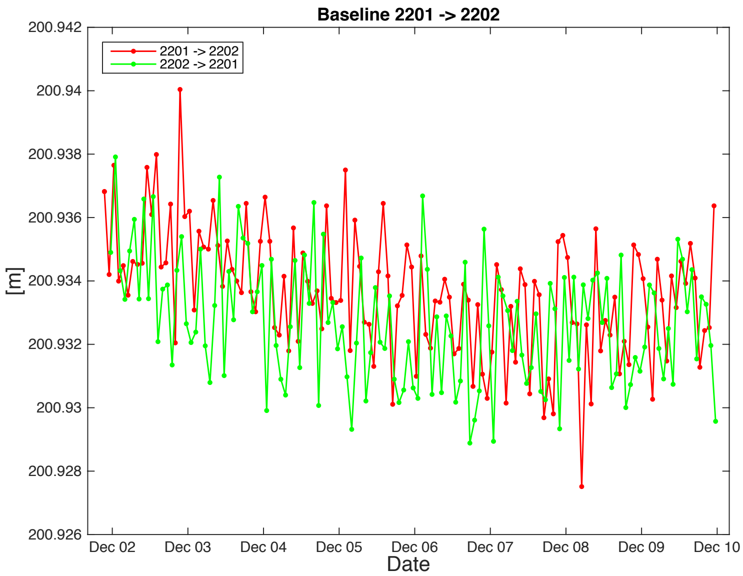
GeoSURF with RV SONNE in the background. The wave glider navigated autonomously over night to upload the seafloor data and transfer it via satellite.

We returned to area 3 in the early afternoon of the following day for a final check of the network functionality and for data upload. We will only be able to return in about 6 months time and hence want to make sure that the system configuration is optimal for our purposes. This is also true for our westernmost area, where we again deployed GeoSURF so that RV SONNE could leave the area to map previously uncharted areas of the seafloor seaward of the deep-sea trench.

While GeoSURF navigated to upload the data in area 2, RV SONNE left to map unknown parts of the seafloor seaward of the trench.

The mapping activities lasted for the following two days and nights after we had recovered GeoSURF and terminated our work in the western area 2. The figure below shows an example for a baseline between two stations spaced approximately 200 m apart. These yet uncorrected and unprocessed data suggest a repeatability precision of < 4mm.

Data example from working area 2 located in water depth of more than 4000 m. The baselines between two seafloor transponders are shown: the red line 'looks' from station A201 to A202 while the green line is 'looking back' from A202 to A201. The data have not been corrected yet using additional physical parameters of the water column. Processed data will have a precision of ±2 mm on average.



On December 12 at 0:00h we started our transit toward the port of Antofagasta. On the way we deployed the last OBS south of the aftershock region of the Iquique earthquake, which hit the coastal area on April 1, 2014 with a magnitude 8.1.

The good weather remains stable with air temperatures around 22°C and moderate winds. Everybody on board is thrilled with the successful deployment of the GeoSEA array and excited about the data that it will generate in the years to come. We hence disembark today with mixed feelings: We are looking forward to our loved ones back home while at the same time hope for a soon return to RV SONNE. We thank Captain Lutz Mallon and his entire crew for the professional and efficient work and for the shared days on board!

Kind greetings to everybody back home!

Heidrun Kopp

Heidrun Kopp

Port of Antofagasta, 23°39’S / 70°24’W