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Cruise report

PAC16

R/V Sally Ride cruise SR1916
31 October – 04 November 2019 Palau-Guam

Hans van Haren

Royal Netherlands Institute for Sea Research (NIOZ), P.O. Box 59, 1790 AB Den Burg, the Netherlands
hans.van.haren@nioz.nl

Early November 2019 research vessel Sally Ride (Scripps Institution of Oceanography, San Diego, CA, USA) sailed to the Challenger Deep, Mariana Trench. The single purpose of the cruise was to recover a 7 km long mooring line (diagram in Appendix A) owned by the NIOZ Royal Netherlands Institute for Research. Special tools had to be designed for this recovery as the originally planned recovery failed because of zero acoustic contact with the nearly 11 km deep releases using standard deck-units in November 2018. With the aid of a deep pinger lowered via a Sally Ride winch the mooring was successfully recovered in the night of 02 November 2019.

The purpose of the physical oceanographic study was to characterize the unknown internal wave motions and turbulent exchange in a deep-ocean trench, *i.c.* near the deepest point on Earth. Since life like large crustaceans has been found near the floor of the Challenger Deep, the hypothesis is that waters cannot be stagnant but require a certain level of turbulent motions for sufficient replenishment of oxygen and nutrients to sustain life. For this study shipborne Conductivity Temperature Depth CTD-profiles and a specific long-term mooring have been deployed from R/V Sonne in November 2016. Additionally, Sonne's advanced EM122 Multibeam echosounder system allowed unprecedented accurate sea floor mapping, supported by a local very deep sound velocity profile from the CTD-data.

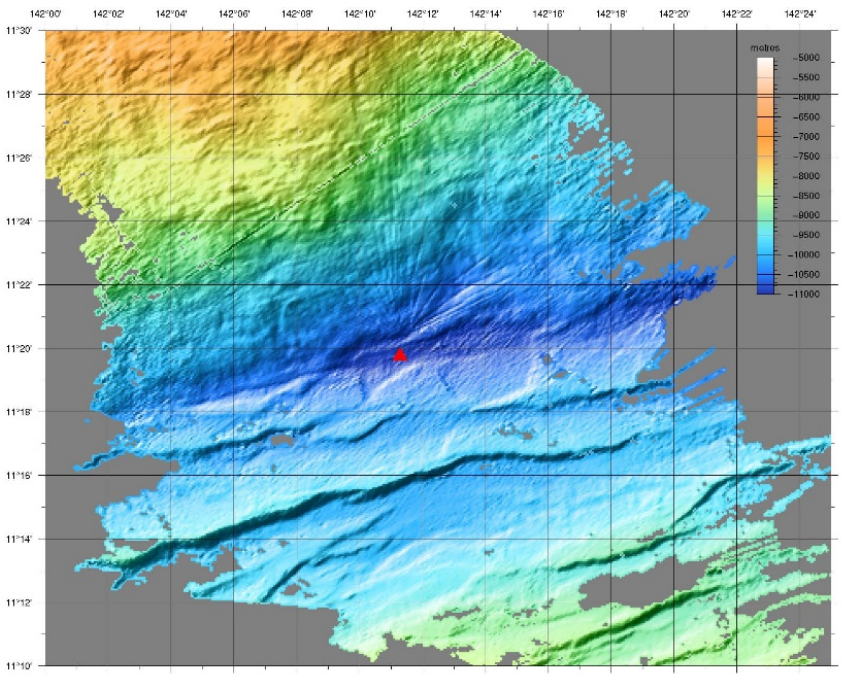


Figure 1. Challenger Deep, Mariana Trench, as determined from R/V Sonne's Multibeam system. The present working area is indicated by the red triangle.

The 7 km long mooring line (Appendix A) consisted of top-floatation with radio-beacon and Iridium satellite beacon around 4 km depth, two sections of 0.006 m diameter Dyneema neutrally buoyant line, two Benthos R12K acoustic releases and two sections of self-contained instrumentation. Around 6 km depth two single-point Nortek AquaDopp current meters were mounted below a 200 m long array of 100 standard high-resolution NIOZ temperature sensors (van Haren, 2018). In the lower 600 m above the trench-floor 295 specially designed NIOZ high-resolution temperature sensors were mounted. Sensors were taped at 2 m intervals. The lowest sensor was at 8 m above the trench floor. The specially designed instruments were built and tested to withstand 1400 Bar of static pressure (Figure 2).

The current meters sampled at a rate of once per 150 s, the temperature sensors at a rate of once per 2 s. Both sections of temperature sensors are synchronized every 4 hours so that the 200 and 600 m ranges are sampled within 0.02 s. The <0.1 mK noise level of the sensors is designed to study breaking internal wave motions and associated turbulent overturning.

Figure 2. Custom-made titanium pressure container to test 7 nigh-resolution temperature sensors at 1400 Bar by applying about 40 Tons for at least 4 hours.

Mooring deployment was smoothly performed from the German R/V Sonne in November 2016. The moored instrumentation was meant to remain in the Challenger Deep for 1 to 1.5 years, but eventually remained under water for nearly 3 years. As the Benthos acoustic releases can withstand an ambient pressure of 1200 Bar, it was thought that their acoustic performance would be capable to cover 11 km ranges, sufficient to be reached using a deck-unit from the surface vessel. Unfortunately, this turned out not to be the case from the R/V Sonne in November 2018. No acoustic contact could be established with the releases from the deck-unit, recovery failed and the reason for failure was totally unknown. At NIOZ it was decided to attempt a second recovery cruise with particular salvage materials.

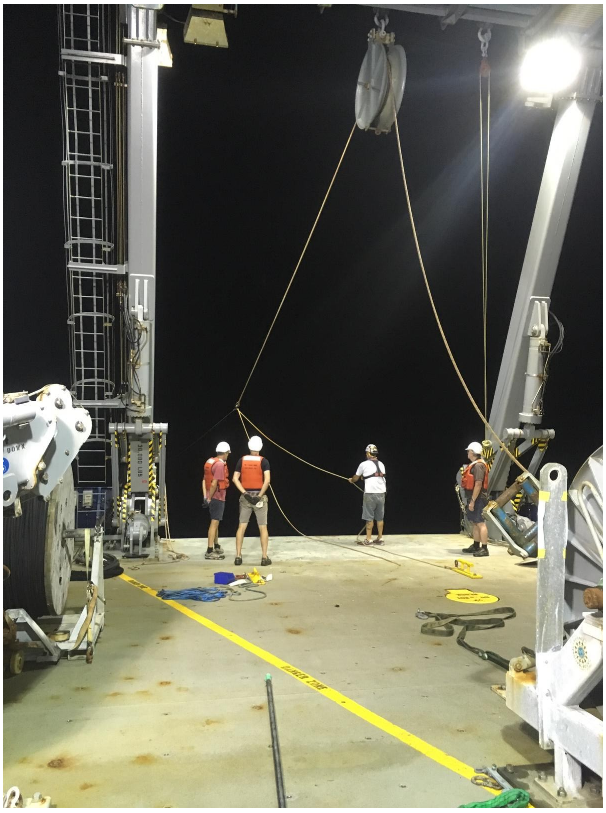
Second recovery cruise preparations.

Several methods were discussed to salvage long and deep mooring from the Challenger Deep. A rescue operation was proposed to dive an ROV. This method was considered very costly and least desirable, therefore abandoned. As the anchor was too deep for dredging, a top-buoy fishing method was adapted from a similar salvage method employed by Japanese colleagues from JAMSTEC. The method ('Plan B') consisted of lowering a heavy weight, in this case down to 5 km, that would tow neutrally buoyant thick line with hooks. As the location of the mooring was known to within 500 m the thick line was 1200 m in length. Because the thin Dyneema mooring line is vulnerable to cutting by any sharp object, the hooks were custom-made and very smooth.

Desired Plan A consisted of a 'deep pinger'. As such apparatus is not available on the market, it was custom-designed by NIOZ electro-technicians by remodeling an existing Benthos acoustic release to a hydrophone that could be lowered into the deep from a ship. The deep pinger is capable of repeatedly every 120 s calling two release commands for 10 s, up to 5 hours after being switched on.

Sally Ride SR1916 cruise participants.

Hans van Haren	PI/chief scientist	NIOZ
Martin Laan	electro-technician	NIOZ
Yvo Witte	mooring technician	NIOZ
Joshua Manger	mooring technician	Scripps IO
Mary Huey	computer technician	Scripps IO



Mooring recovery narrative.

R/V Sally Ride arrived above the Challenger Deep on 02 November 2019 at 17:30 LT. Sally Ride parked into dynamic positioning about 2 km East of the approximate mooring location. All ship acoustics are switched off. The deep pinger was attached with a small weight to one of RV Sally Ride's sidewinch-cables. It was lowered at a speed of about 1 m/s. After half an hour a Benthos deck-unit was calling the deep releases every 10 minutes for first sign of potential release of the anchor. No deep acoustic response was received, just noise. British colleagues have now confirmed that a ship in dynamic positioning spoils the faint return signal from deep acoustic beacons. Presumably because of large amounts of turbulent eddies whirling underneath the ship. It is recommended for future use to have the ship manually drifting when listening to deep acoustic beacons.

Just before 19 LT a radio-signal is received at the bridge of Sally Ride. At 19:10 LT a first Iridium signal is received, followed at 19:14 LT by a first position: about 300 m SW from the aimed position. Subsequent plotting of satellite positioning messages demonstrates a mooring displacement in WWNW direction at a speed of about 250 m/h. The expected upward floating speed was about 1 m/s. The mooring turned out to be located about 200 m south from the 2016-CTD location (Fig. 3).

In hindsight, the deep pinger managed to contact the near-bottom releases after 15 to 20 minutes of lowering, i.e. around 1000 m or at a distance of approximately 10 km. Although during nighttime, once released from the bottom-anchor the mooring-line recovery went very smoothly, due to radio beacons, Iridium satellite beacon and swift manoeuvring with searchlights on. The mooring was designed to have only pick-up float and –line, main float and 3 smaller floats at the surface. The rest was suspended vertically downward. At 02:30 LT on 03 November 2019 after some 6 hours of spooling the entire line and all instrumentation were on board.

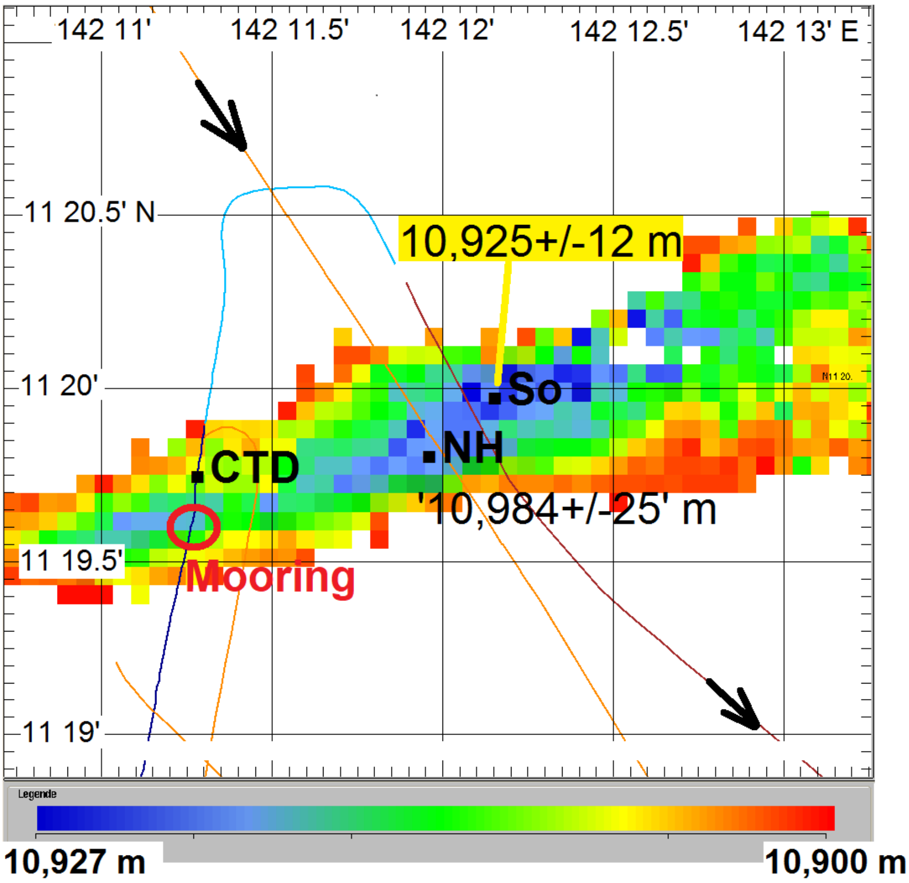


Figure 3. Detail of Sonne's Multibeam map of the deepest area in the western Challenger Deep, with depths only coloured when greater than 10,900 m. The red circle indicates the most probable location of the free-fall mooring, recovered deployed in 2016 by R/V Sonne and recovered in November 2019 during SR1916. CTD indicates the shipborne profile during R/V Sonne cruise in 2016. NH indicates the deepest point incorrectly established because of too shallow (<700 m) sound velocity profiling by Gardner et al. (2014). So indicates the deepest point in this map, and probably the deepest point on Earth (van Haren et al., 2017).

Instrument performance.

Originally, the mooring was intended and designed to stay underwater for 1 to 1.5 years. It turned out to be twice as long, also because of some difficulties in finding a ship of opportunity in the rather remote West-Pacific waters. The data outcome benefitted from the prolonged duration, better than expected given several battery issues in the past.

The special pressure testing up to 1400 Bars for at least 4 hours paid off very well. Only 15 of the 395 sensors had mechanical problems. Between 1.5 and 2 years of useful temperature data were obtained, which is more than expected. Current meters gave more 2.25 years of data. Electro-technically, between 10 and 20% of the temperature sensors showed problems like too high noise, reduced battery life, detuning.

First results.

Preliminary analysis demonstrates that the mooring was less stiff than expected for about a third of the mooring period, when vertical motions at the upper current meter exceeded the 2 m interval between the temperature sensors (Fig. 4). The mooring motions do not correspond to the locally measured current speeds. This suggests that at other depth levels currents are stronger than the ones observed at about z = -6200 m. Presumably currents above the Mariana Trench are stronger, around the depth of the larger drag-force elements the top-buoys. Indirectly, this suggests a distinct difference between inner-trench motions and the surrounding deep open-ocean above. The larger mooring motions occur a few times per year and last a week or two. It is to be investigated whether there is a connection between these motions and passing atmospheric disturbances, for example.

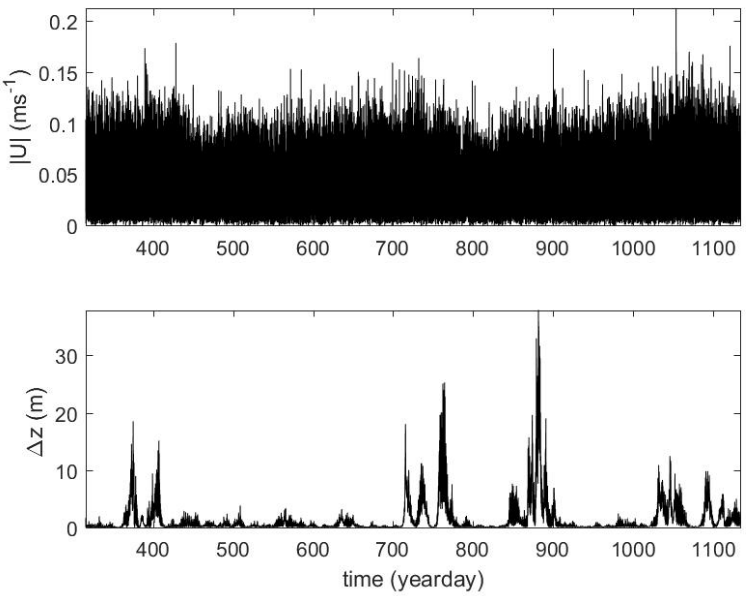


Figure 4. Current meter data from z ≈ -6200 m, with speed in upper panel and vertical displacement in the lower panel.

Although direct influences by atmospheric disturbances do not seem to affect the observed currents at z = -6200 m that are dominated by tidal and yearly periodicities (Fig. 4), it remains to be investigated whether they affect internal waves and specifically at their lowest, inertial frequency. A first snapshot of observations is presented in Fig. 5. It demonstrates weak temperature variations, with all dynamical variations in the 1 mK range around 6 km depth and in the 0.1 mK range around 10.5 km depth. In the latter case, post-processing even had to take into account the second order correction for pressure compressibility effects. In this great depth range freely propagating internal waves cannot exist having periods of half a day and shorter, because of the very weak vertical density stratification.

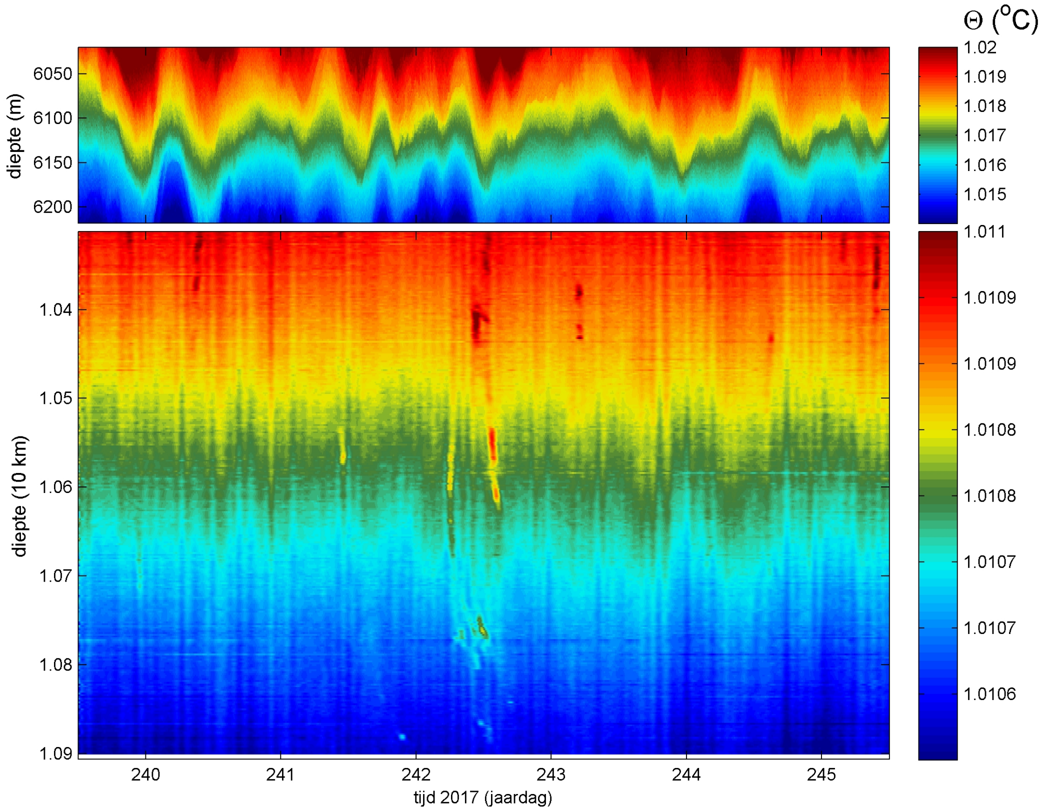


Figure 5. Six days of high-resolution temperature data end of September/early October 2017 when mooring motion was negligible. The two panels are separated by 4100 m in the vertical, the upper has a pressure-corrected Conservative Temperature range of 7 mK, the lower a range of 0.4 mK. The vertical scale is the same per 100 m in both panels.

Internal waves with typically 50 m amplitude crest-trough are found abundant around 6 km. The waves may influence the very weak stratification around 10.5 km depth by pushing convective type turbulent pulses of 1 to 2 hours duration obliquely from above, roughly a few times a day. Episodically the pulses extend over hundreds of meters. While the mean turbulence is weak, about 10 times less than in the open ocean, the observed phenomenon of pushed convection is capable of generating short-term turbulent pulses having 10 to 30 times higher. Mean turbulence levels are consistently higher than found around 6 km. Further analyses are aimed to establish the source of the dominant internal waves pushing and the potential variations with background conditions such as passing atmospheric storms.

Resuming, the data return was more than reasonable. The current meter worked well for 29 months. The upper set of temperature sensors returned >90% of good data for at least 1.5 years. The deep lower set of temperature sensors returned more than 80% of good data for at least 1.5 years.

Cited Literature:

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Appendix A Sketch of the 7 km long mooring with current meters and high-resolution temperature sensors.