Reference:
van Haren, H., 2013. Cruise report KM3NeT13: R/V Pelagia cruise 64PE367, 02-15 April 2013, NIOZ, 25 pp.

Cruise Report

KM3NeT13

R/V Pelagia cruise 64PE367

02 – 15 April 2013
Motril (Spain) – Lisbon (Portugal)

Hans van Haren
(with contributions from participants)

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

0. Contents

1. Summary of R/V Pelagia KM3NeT13 cruise

In March/April 2013 R/V Pelagia (Royal NIOZ, the Netherlands) sailed to the Alboran Sea (Western Mediterranean Sea; south of Spain), to perform several tests for the future cubic kilometer neutrino telescope KM3NeT. The research cruise was commissioned by Nikhef, the Dutch National Institute for Subatomic physics, Amsterdam. Nikhef is the main contributor to European Project KM3NeT in the Netherlands, with minor contributors NIOZ and KVI (Groningen University). The Dutch contribution to KM3NeT is funded via a large investment program in the realm of ESFRI by NWO, the Netherlands Organization for the advancement of scientific research.

As a follow-up of unrolling tests of a compacted mooring-string in December 2009 and February 2011 in the Ionian Sea, further tests were performed 20 miles south of Motril (E) during 10 days. This Launcher of Optical Modules (LOM), a 2.02 m diameter sphere holding 35 glass spheres of 17″-diameter, unrolled a string of two 690-m long, 0.004 m diameter Dyneema lines with 18 glass spheres in between. The LOM surfaces freely after emptying its contents (the string). The entire deployment was tested five times. Reloading the LOM took two days and mooring deployment and recovery more than a full day, including ROV underwater video inspection. With respect to previous tests, a full data cable was used running along the lines, including glass-sphere penetrators and optic fiber during the fifth attempt.

As support information five Conductivity Temperature Depth (CTD)-profiles were obtained, as well as some current measurements and a small Multibeam-bottom-mapping survey around the mooring site.

The cruise was quite successful, despite the moderately favourable weather conditions. The LOM unrolled smoothly and set-up the entire string during all five attempts. Not all deployments were equally successful, resulting in a considerable amount of suggestions for future improvement.

2. General research aim.

KM3NeT

KM3NeT, a European deep-sea research infrastructure, will host a neutrino telescope ('NeT') with a volume of at least one cubic kilometer ('KM3') at the bottom of the Mediterranean Sea that will open a new window on the Universe. The telescope will search for neutrinos from distant astrophysical sources like gamma ray bursters, supernovae or colliding stars and will be a powerful tool in the search for dark matter in the Universe. An array of thousands of optical sensors will detect the faint light in the deep sea from charged particles originating from collisions of the neutrinos and the Earth. The facility will also house instrumentation from Earth and marine sciences for long term and on-line monitoring of the deep sea environment and the sea bottom at depths of several kilometers. Recently, an EU-funded prepatory phase ended to design the KM3NeT structure. Presently, about 40 MEuro is available from various national funds to start construction. Eventually, 150-250 MEuro is needed to build the entire telescope. To compliment the IceCube-telescope in Antarctica, proposed KM3NeT-sites are in the Northern Hemisphere. The sites are all in the Mediterranean Sea where sufficiently deep (below 1500 m) waters are found within several tens of kilometers from coasts. This facilitates the huge data transport to shore. Three sites are selected: ANTARES near Toulon (F), NEMO east of Sicily (I), NESTOR west of Peloponessos (Gr).

KM3NeT-Esfri

The NWO investment programme for large European Structures has granted Nikhef-Amsterdam, NIOZ-Texel and KVI-Groningen 8.8 MEuro to set-up the dutch part of KM3NeT. This national funding was followed by funds from France, Romania and Italy (with a present-day total sum of about 40 MEuro). Hopefully, many more funds will be brought in soon within the KM3NeT-consortium.

KM3NeT13 cruise a/b oceanographic research vessel Pelagia

The construction of a cubic kilometer telescope at great depths demands special mooring techniques. Standard single line oceanographic taut-wire moorings, consisting of an anchor, acoustic release and instrumented cable, all below a sub-surface buoy, cannot be used easily in a construction with, say, 600 detection units (DU), each 700 m high and 100 m apart horizontally. Deploying standard moorings with optical sensors in unprotected glass spheres, 'optical modules (OMs)', requires extreme precision in handling. Furthermore, the entire telescope needs to be operational within 4 years after the start of production. Thus, it is proposed to use compacted moorings that unfold upon acoustic command. The new techniques have the advantage that they can be prepared in the laboratory prior to going to sea.

One of the compacted mooring techniques proposed by KM3NeT during the technical design study is the ‘Tower’. It consists of 6 m long aluminum frames (bars) holding 4 OMs. Twenty of such bars will be placed under a 1500 kg buoy (the whole structure weighing about 7000 kg). In March 2013, a successful deployment of an 8-bar test-tower was done near Capo Passero, Sicily (I).

Another proposed compacted mooring technique is the ‘String’, with two 4 mm diameter Dyneema lines holding 18-20 OMs between them under a 125 kg buoy. This low-drag single mooring is wound-up in a re-usable 2-m diameter aluminum sphere, the Launcher of Optical Modules (LOM). The loaded LOM weighs about 1200 kg, its anchor 900 kg. It could be mounted on a 1-km ground-line, to become deployed as a multiple (~10) string deployment.

The purpose of the KM3NeT13 cruise in the Alboran Sea was to perform multiple technical test-deployments of a single string using the LOM holding 17 OMs and one optical fan-out module (OFM) with data communication cable. Each deployment test was to be followed by visual under-water inspection of the mooring by ROV, before recovery. This mooring-recovery considerably complicates the test-set-up; it will not be required during telescope construction. Some environmental conditions measurements on temperature and current variations were to be conducted simultaneously for proper interpretation of the mooring tests.

3. KM3NeT13 overview.

The main working area of the R/V Pelagia was approximately two hours sailing south of the harbour of Motril (E), around the position of 36°24´N, -3°30´W, ~900m water depth (Figure 1). The location has a relatively flat, muddy bottom. This facilitates the use of a U-shaped mooring (Appendix A) to be deployed and recovered. During every other night, the sea floor of part of the working area was mapped using Pelagia's Multibeam system. For hydrographic- and calibration-purposes several Conductivity-Temperature-Depth (CTD) profiles were made locally.

The second site planned to be visited for mooring deployment was 1 mile East of the ANTARES neutrino telescope, about 50 km Southeast of Toulon (F). Unfortunately this was cancelled four days before the planned operation.

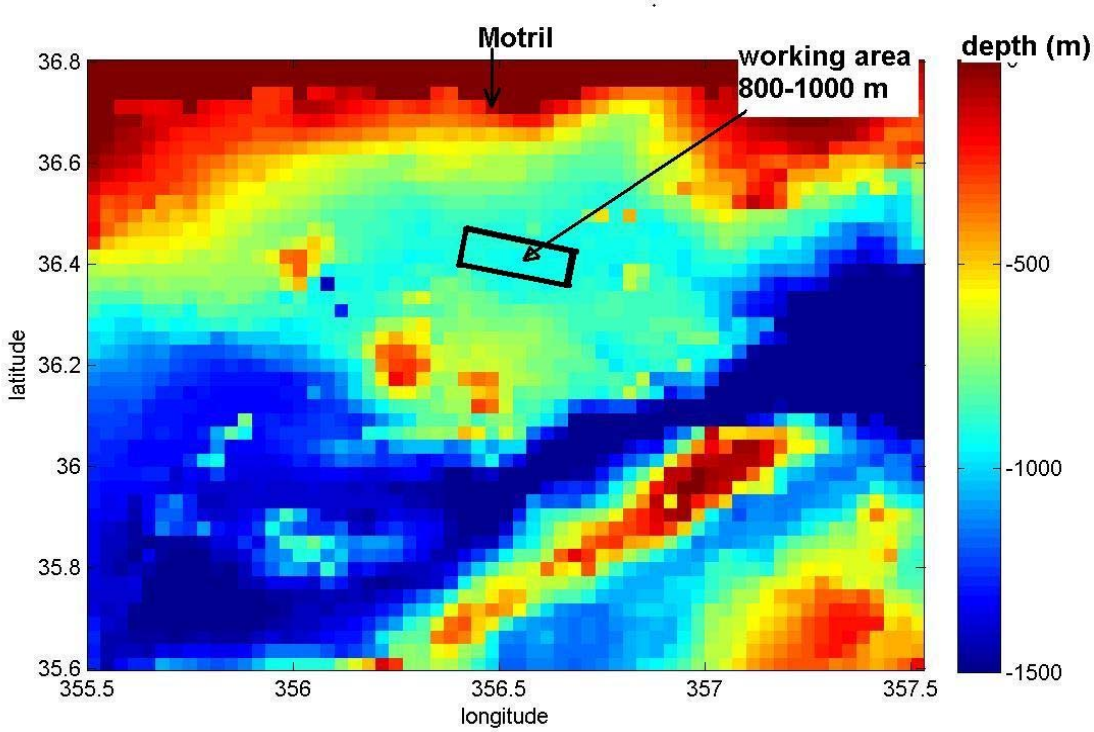


Fig. 1. Map of the Alboran Sea, with LOM-testing site ('working area') indicated.

4. Participants.

Pelagia Texel-Motril 26 March – 02 April 2013

	Institute	Name	Nationality
1	NIOZ	Hans van Haren	Dutch
2	NIOZ	Martin Laan	Dutch
3	NIOZ	Leon Wuis	Dutch
4	ECL	Louis Gostiaux	French

Pelagia Motril-Motril 02 – 03 April 2013

1	NIOZ	Hans van Haren	Dutch
2	NIOZ	Martin Laan	Dutch
3	NIOZ	Lorendz Boom	Dutch
4	NIOZ	Yvo Witte	Dutch
5	ECL	Louis Gostiaux	French
6	NIOZ	Ruud Groenewegen	Dutch
7	VLIZ	Wim Versteeg	Dutch
8	VLIZ	Michiel T'Jampens	Belgian
9	Nikhef	Paul Kooijman	Dutch
10	Nikhef	Dimitri John	Dutch
11	NIOZ	Johan van Heerwaarden	Dutch
12	NIOZ	Roel Bakker	Dutch
13	NIOZ	Leon Wuis	Dutch
14	NIOZ	Barry Boersen	Dutch

Pelagia Motril-Motril 03 – 05 April 2013

	Institute	Name	Nationality
1	NIOZ	Hans van Haren	Dutch
2	NIOZ	Martin Laan	Dutch
3	NIOZ	Lorendz Boom	Dutch
4	NIOZ	Yvo Witte	Dutch
5	ECL	Louis Gostiaux	French
6	NIOZ	Ruud Groenewegen	Dutch
7	VLIZ	Wim Versteeg	Dutch
8	VLIZ	Michiel T'Jampens	Belgian
9	Nikhef	Paul Kooijman	Dutch
10	Nikhef	Erno Roeland	Dutch

Pelagia Motril-Motril 05 – 07 April 2013

	Institute	Name	Nationality
1	NIOZ	Hans van Haren	Dutch
2	NIOZ	Martin Laan	Dutch
3	NIOZ	Lorendz Boom	Dutch
4	NIOZ	Yvo Witte	Dutch
5	NIOZ	Ruud Groenewegen	Dutch
6	VLIZ	Wim Versteeg	Dutch
7	VLIZ	Michiel T'Jampens	Belgian
8	Nikhef	Erno Roeland	Dutch
9	Foselev Marine	Adrien Combe	French

Pelagia Motril-Motril 07 – 08 April 2013

	Institute	Name	Nationality
1	NIOZ	Hans van Haren	Dutch
2	NIOZ	Martin Laan	Dutch
3	NIOZ	Lorendz Boom	Dutch
4	NIOZ	Yvo Witte	Dutch
5	ECL	Louis Gostiaux	French
6	NIOZ	Ruud Groenewegen	Dutch
7	VLIZ	Wim Versteeg	Dutch
8	VLIZ	Michiel T'Jampens	Belgian
10	Nikhef	Dimitri John	Dutch

Pelagia Motril-Motril 08 – 09 April 2013

	Institute	Name	Nationality
1	NIOZ	Hans van Haren	Dutch
2	NIOZ	Martin Laan	Dutch
3	NIOZ	Lorendz Boom	Dutch
4	NIOZ	Yvo Witte	Dutch
5	ECL	Louis Gostiaux	French
6	NIOZ	Ruud Groenewegen	Dutch
7	VLIZ	Wim Versteeg	Dutch
8	VLIZ	Michiel T'Jampens	Belgian
9	Nikhef	Paul Kooijman	Dutch
10	Nikhef	Dimitri John	Dutch
11	CPPM	Sylvain Henry	French
12	CPPM	Alain Cosquer	French

Pelagia Motril-Motril 09 – 10 April 2013

	Institute	Name	Nationality
1	NIOZ	Hans van Haren	Dutch
2	NIOZ	Martin Laan	Dutch
3	NIOZ	Lorendz Boom	Dutch
4	NIOZ	Yvo Witte	Dutch
5	NIOZ	Leon Wuis	Dutch
6	NIOZ	Barry Boersen	Dutch
7	ECL	Louis Gostiaux	French
8	NIOZ	Ruud Groenewegen	Dutch
9	VLIZ	Wim Versteeg	Dutch
10	VLIZ	Michiel T'Jampens	Belgian
11	Nikhef	Paul Kooijman	Dutch
12	Nikhef	Dimitri John	Dutch
13	CPPM	Sylvain Henry	French
14	CPPM	Alain Cosquer	French

Pelagia Motril-Motril 10 – 11 April 2013

	Institute	Name	Nationality
1	NIOZ	Hans van Haren	Dutch
2	NIOZ	Martin Laan	Dutch
3	NIOZ	Lorendz Boom	Dutch
4	NIOZ	Yvo Witte	Dutch
5	NIOZ	Leon Wuis	Dutch
6	NIOZ	Barry Boersen	Dutch
7	ECL	Louis Gostiaux	French
8	NIOZ	Ruud Groenewegen	Dutch
9	VLIZ	Wim Versteeg	Dutch
10	VLIZ	Michiel T'Jampens	Belgian
11	Nikhef	Paul Kooijman	Dutch
12	Nikhef	Dimitri John	Dutch

Pelagia Motril-Lisbon 12 – 15 April 2013

	Institute	Name	Nationality
1	NIOZ	Hans van Haren	Dutch
2	NIOZ	Martin Laan	Dutch
3	NIOZ	Leon Wuis	Dutch

Landbased Motril 02 – 11 April 2013

	Institute	Name	Nationality
1	NIOZ	Johan van Heerwaarden	Dutch
2	NIOZ	Roel Bakker	Dutch
3	NIOZ	Leon Wuis	Dutch
4	NIOZ	Barry Boersen	Dutch
5	Nikhef	Edward Berbee	Dutch
6	Nikhef	Dimitri John/Erno Roeland	Dutch

Nikhef	National institute fro subatomic physics, Amsterdam (NL)
CPPM	Centre de Physique des Particules de Marseille (F)
INFN	Istituto Nazionale di Fisica Nucleare (I)
ECL	École Centrale de Lyon (F)
VLIZ	Vlaams Instituut voor de Zee (B)

5. Data acquisition and instrumentation (see Appendix A for mooring diagram).

a. Launcher Optical Module (LOM) compact mooring test

The key-purpose of this cruise was to further perform in-situ tests of a compacted string-mooring launcher, this time with operational data-communication cables.

For the KM3NeT13 cruise a test-DU has been developed with various test monitoring sensors. Instead of PMTs and electronics, OMs hold a concrete dummy weight, except for two test-instrumented ones and the OFM. The single string proposed DU has two 4-mm 690 m long Dyneema lines for support and a 6 mm tube, the Vertical Electrical Optical Cable (VEOC), holding all power and data communication cabling. The VEOC is a pressure-balanced oil-filled cable in which optical fibers and copper conductors operate under the ambient hydrostatic pressure which is much reduced with respect to the in situ under-water pressure. As no tensile loading is allowed on the VEOC, it is made 10% longer than the Dyneema lines accounting for a maximum of 5% stretch of the latter (between tensionless new, after pre-stretching, mounting and submerged, aged mooring-tension). This stretch has been inferred from half-year long tests at NIOZ. A string will hold eighteen 17″ glass spheres and about 65 anti-torsion sticks. The sticks also function as cross-over for extra length of the VEOC. Eventually, each glass sphere will hold 30 small Photo Multiplier Tubes for optical sensing.

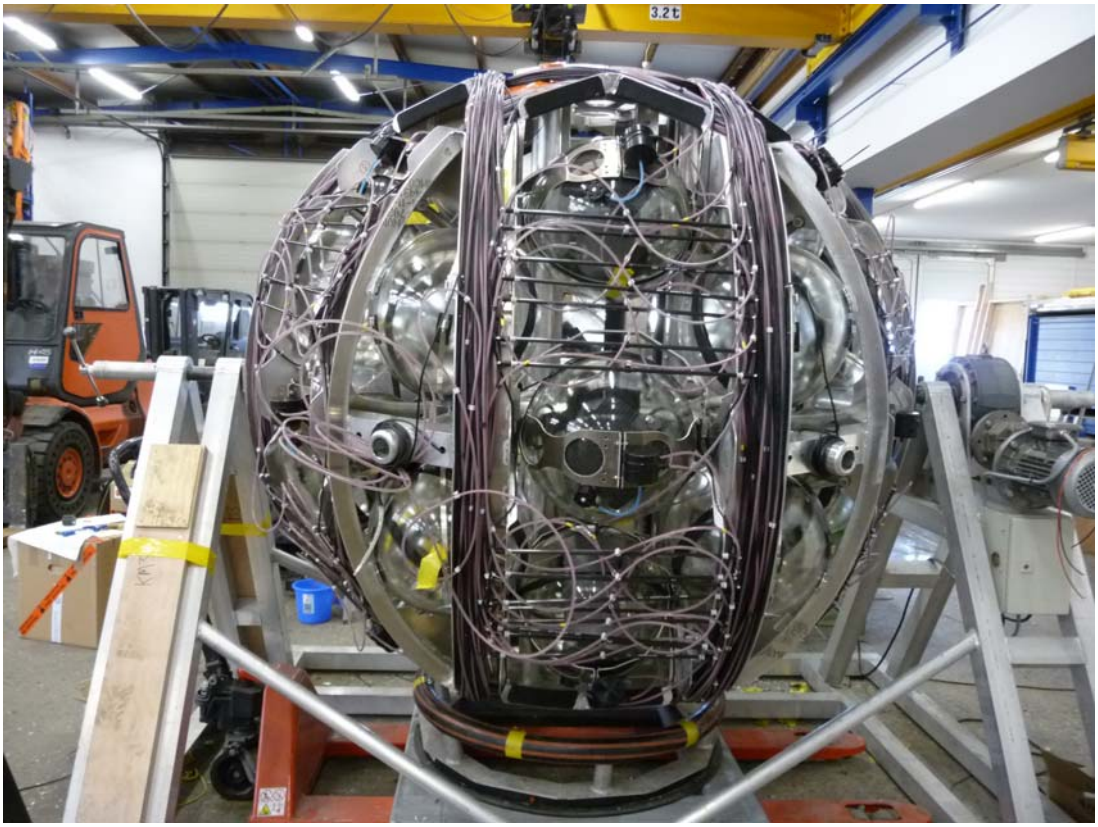


Fig. 2. Launcher of Optical Modules (LOM) in its winding 'rotator', with Dyneema lines (black) and data cable (white-purple). Most OMs are loaded with dummy weights.

Seventeen OMs are separated by approximately 36 m each. Halfway the string, an OFM, also held in a 17″ glass sphere, splits the VEOC in two. For the present tests, the upper, lower OM and the OFM contain data-communication equipment with which the data cable is tested (Figure 3).

Fig. 3. Upper OM with data cable test-equipment inside held in custom-made arms on a pallet-carrier. The 'ear'-mounting of the aluminum OM-support-ring on the black Dyneema line is clearly visible.

The OMs are mounted 'naked' in between the two lines, except for a aluminum support-ring to keep it tight-closed. This ring supports the data-communication splitter or Break-Out Box (BOB). At each BOB one bidirectional fibre and two power conductors are branched out to a Break-out Electro-Optical Cable (BEOC) connector. The BEOC is connected to the OM via a penetrator (glass feed-through). As the string is disassembled on board during recovery, no fibres or Cu wires are going into the OM during this test, except for the upper and lower OMs and the OFM.

For compacted mooring deployment, the entire 690 m string and top-buoyancy are mounted in and on a 1.9 m inner-diameter (2.1 m outer-diameter) aluminum sphere, the LOM, see Fig. 2. This LOM is placed directly above a bottom-weight. Upon release it unrolls its lines and releases the OMs and the OFM due to its positive buoyancy. After releasing the 132 kg buoyancy syntactic foam top-buoy (Figure 4) it detaches itself and surface freely. Its acoustic release-buoy surfaces separately.

Fig.4. Syntactic foam topbuoy inside the (empty) LOM (left; side-view). Top-buoy mechanical release mechanism (right; top-view).

Attached to the support ring of the OMs, next to the BOB, two test-instruments are mounted. The test-instruments are modified NIOZ4-thermistors, which only output their compass-tilt (acceleration) data, at 10 Hz. Using two sensors that are started 120 s apart at each OM ensures data continuation during data storage (0.3 s every 180 s). Three such sensors are also mounted inside the LOM. The anchor holds a video system and five OMs were equipped with cameras.

A remotely operated vehicle (ROV; see further under c.) is launched for visual inspection of the entire string once deployed and unrolled.

The above string-mooring (**KM3NeT13_LOM_#, #=1,2**…) is deployed in water around 900 m deep. Several test-deployments are performed, with different configurations of VEOC: one with only copper, another with copper and pressure sensing, a final one with copper and optical fiber. As the mooring is recovered to read the stand-alone sensors, it is deployed in a U-shape (see Appendix A), with a 1.4 km long steel ground-line and separate surface marker. The fully equipped LOM with bottom anchor and release weighs about 2.2 tonnes in air. Prior to and after deployment CTD-data are collected for reference temperature profile across the entire water depth.

In order to accomplish multiple test-deployments in only 10 days, two complete LOM-DUs have been manufactured. Except during the first and the last (10^{th}) day, the first LOM is deployed and recovered the next day at sea by the Pelagia, while the second LOM is remounted with the DU at the quay-side in the harbour of Motril. The remounting procedure takes 2 days. Every night the Pelagia entered Motril-harbour to either exchange personel or equipment plus empty LOM-I and loaded LOM-II, and vice versa.

Deployment is done from the stern, separate surface marker going out first, followed by spooling out the 14 mm ground cable before the LOM package is lowered all the way to the bottom by the stern-winch. The LOM-package includes the separate acoustic release in a

beacon above the LOM (Fig. 5) and another acoustic release for detaching the winch-cable once bottom is hit (Appendix A). To move the winch-cable away from the LOM two glass spheres are attached to it, 20 m above the release. The entire deployment takes 3-4 hours.

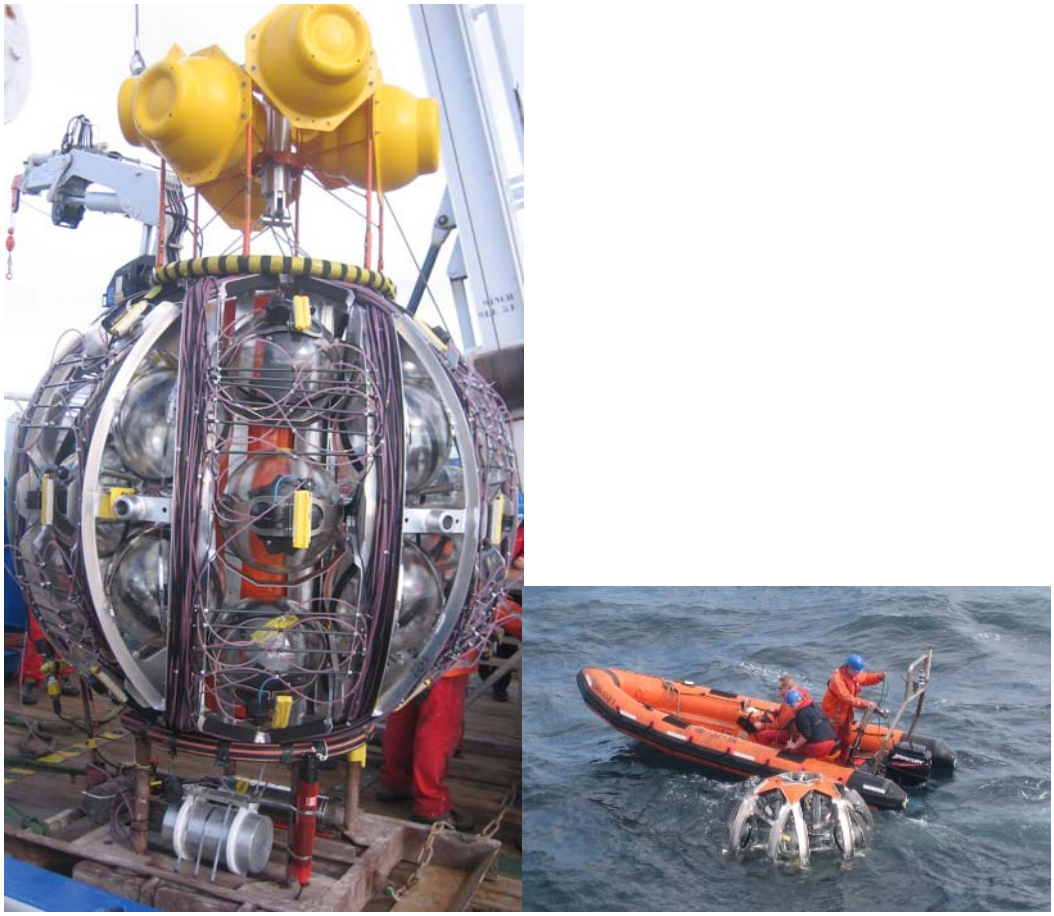


Fig. 5. (left): Fully equipped LOM just before being put in the water. Below the LOM the bottom weight and video camera (to the left) are visible. Above it, its own acoustic release is in between six plastic-capped glass spheres. (right): picking up empty LOM after surfacing.

Empty LOM and release-buoy are recovered with assistance of the MOB-boat (Fig. 5). The recovery of the U-shaped mooring starts again with the surface buoy. Once the DU-anchor is off the bottom, Pelagia moves forward at minimum speed with continued winching to stretch the string at the surface, which prevents the glass spheres from colliding into each other. On deck, OMs, Dyneema lines and VEOC are separated and stored for rewinding (Fig. 6). The entire recovery takes about 4 hours. The remounting of the LOM is done on land, as the ship-motions make rotating the process too difficult.

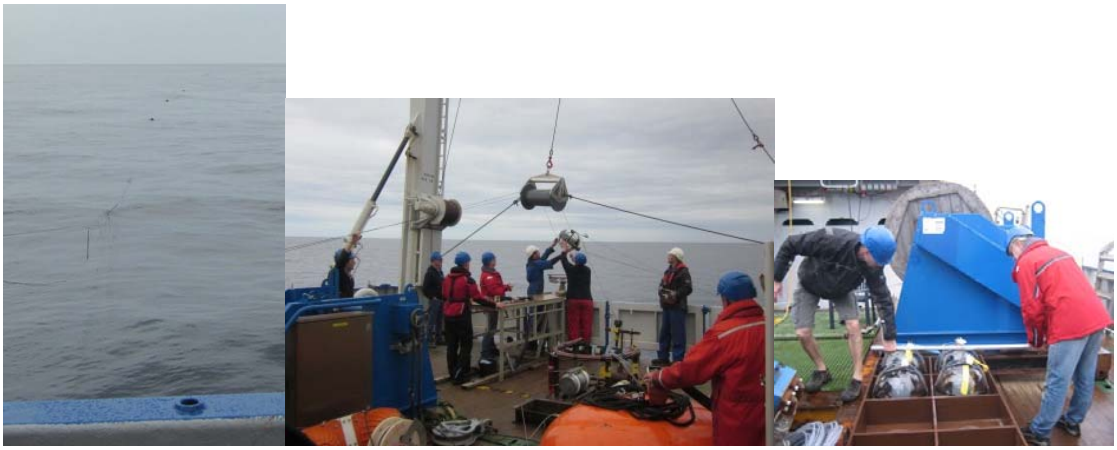


Fig. 6. (left): A sea-strait of glass spheres. (middle): detaching the OM-glass spheres from the black mooring lines which are hauled in over the special 'KM3' pulley-block (right): special tool for lifting an OM-glass sphere dates back to Dutch cheese-makers times.

b. Short-term mooring

A free-falling mooring 120 m long is deployed during the cruise to monitor the environmental conditions (temperature and current variations) at the LOM test-site.

c. Shipborne sampling

The NIOZ CTD/Rosette system contains a Seabird 911 Conductivity Temperature Depth sensor. The CTD samples at a rate of 24 Hz. Its data are used to calibrate the Pelagia Multibeam system and the NIOZ4 temperature sensors. It also provides information on the environmental conditions for LOM-tests.

The Kongsberg EM-302 Multibeam system in the hull of the Pelagia is used to map the seafloor in detail around the test-site. Especially the bottom flatness is important for deploying the 1.4 km long U-shaped mooring.

ROV "Genesis" (Fig. 7), a 1500 m depth-rated ROV Cherokee manufactured by SubAtlantic and operated by VLIZ (B), is deployed every LOM launch. It is used for visual (video) inspection of the OM-mooring.

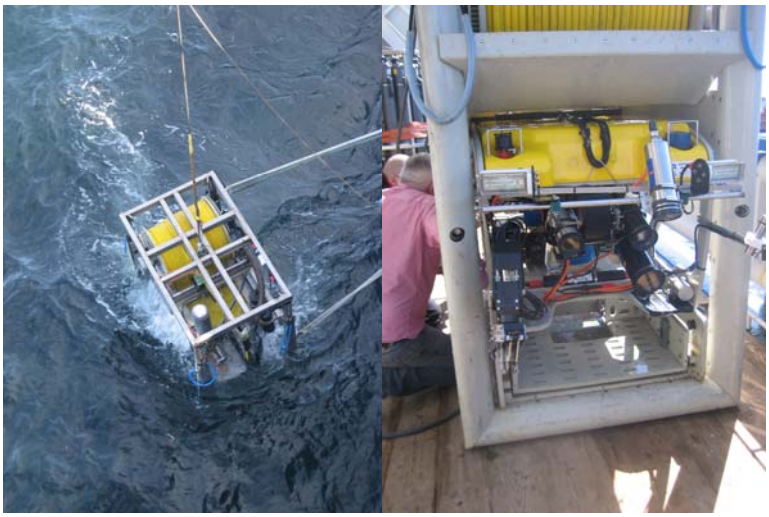


Fig. 7. ROV Genesis (VLIZ).

6. Daily summary of KM3NeT13.

(Transit

Tuesday 26 March

16:30 LT (15:30 UTC). Pelagia leaves the completely ice-covered NIOZ-harbour (Texel, NL). ENE6, feels freezing cold. During the one week transit software is prepared for reading and interpreting accelerometer data)

Tuesday 02 April

W6-2var. 06:30 UTC CTD in the Alboran Sea test-area; 07:30 deployment current meter mooring. 12:40 UTC arrival in Motril harbour, docked along new quay at the end of the breakwater because first assignment was quite dusty. Lots of shifting of materials; construction of NIOZ/Nikhef shore station in which LOMs will be reloaded. 21:15 UTC departure to Alboran Sea. During the night Multibeam mapping.

Wednesday 03 April

E3. 06 UTC First LOM-deployment in the Alboran Sea (LOM1). Smooth operation. Normal surfacing of empty LOM and release beacon; during recovery line, accompanied by common dolphins, not very stretched initially, absolutely no tension on the lines. Quite a number (7) of twists between the two Dyneema lines (due to imperfect unrolling). Data cable fully recovered successfully. No ROV- and no first hour of bottom-weight video due to technical problems. All other sensors worked flawlessly. 19:30 UTC return in Motril; exchange materials; 21:15 UTC departure from Motril. This was too long a day, already

without ROV. Change program to deployment every two days. During the night Multibeam mapping.

Thursday 04 April

W5. 06 UTC deployment LOM2. Normal surfacing of release beacon (after 11 minutes) and empty LOM (14 minutes). 11 UTC CTD. 12:15 UTC ROV in water; after some winch repair: bottom reached at low visibility (~5 m). Some difficulties in sighting mooring; complete mooring video, showing it to stand upright, no twist and glass spheres well mounted. About a third of the tension-bars are broken loose. 15:45 UTC ROV out of water. During the night guarding of surface buoy.

Friday 05 April

NW4, rain. 06 UTC recovery LOM2. Not a single twist in the lines, mooring surfacing in a nearly straight line, accompanied by dolphins very close to the ship. All sensors worked, bottom weight video too. 10 UTC CTD. 13 UTC arrival Motril; exchange of materials; 20:05 UTC departure from Motril. During the night Multibeam mapping.

Saturday 06 April

W7, windy! 06 UTC successful deployment LOM3. Cable tension reaching 3 tonnes during lowering. Despite the windy conditions, a very smooth operation. Too rough for MOB-boat launch, so no release of LOM (waiting at the bottom). 09 UTC CTD. 12 UTC delivery of package to Motril. Afternoon and night guarding surface buoy.

Sunday 07 April

WNW5-var2. 06:15 UTC MOB-pick-up of empty LOM. 07:20 UTC ROV. 11:15-14:30 UTC recovery LOM3. Quite some damage due to deployment under too windy conditions previous day. All damages repaired within a day. 17-20 UTC Motril for exchange materials; during the night Multibeam mapping.

Monday 08 April

WNW4-5. 06-09 UTC deployment of LOM4, including the pick-up of the empty LOM and release beacon by MOB-boat. 09 UTC CTD, followed by ROV (11-15 UTC). 17-17:20 UTC Motril for pick-up people.

Tuesday 09 April

W6. 06:20-09:50 UTC recovery LOM4, somewhat difficult with ship moving backwards in relatively strong winds. From 17-20 UTC Motril for exchange materials; during the night continued Multibeam mapping.

Wednesday 10 April

W5. 06-09 UTC deployment of **LOM5**, including the pick-up of the empty LOM and release beacon by MOB-boat. 09:30 UTC CTD, followed by ROV (11:15-15:15 UTC). 17-17:15 Motril for sign-off people. Receive unfriendly and unhelpful e-mail message from ANTARES regarding planned mooring deployment near Toulon (F).

Thursday 11 April

W3-4. Decision made to cancel planned mooring operation near ANTARES site. 06:15-09:40 UTC recovery **LOM5**. 11:10 UTC recovery of current meter mooring. 13:30 UTC arrival Motril for pick-up land-base materials and re-packing.

Friday 12 April

WSW4-5. 09:15 UTC Leave Motril and head for Atlantic Ocean.

(Transit

Monday 15 April

18 UTC. Arrival Lisbon (P) for disembarkment last participants.

Sunday 21 April

09 UTC. Arrival Pelagia at Texel for unloading.)

7. Scientific summary and preliminary results

Test-mooring **KM3NeT13_LOM** was deployed in about 900 m on a smooth muddy and flat bottom just south of Motril. The bottom texture turned out perfect, a clean silt bottom without large rocks, as is interpreted from video camera observations and residue at the bottom-weights after recovery. The clarity of water was less good: 5-10 m visibility. The overboard operation of the U-shaped mooring was generally handled well, even in Bf7 winds. It is learned from the multiple deployments that Bf5 winds are in principle the working limit, and that the ground-cable should be kept tight during deployment and made loose during recovery. The 1400 m long ground-line was long enough for the ship to move gently away from the surface marker/ADCP and allow ample time to transfer this cable from the stern to the LOM-anchor. When the ground-cable was not tight during the lowering, the underwater weight of some 200 kg was only just about enough in the calm seas. In the future, the LOM weight is better increased by ~200 kg, for quicker lowering.

The multiple testing of LOM-deployment was successful, in so far that many improvements worked well, including the top-buoy improvement, entire smooth unrolling and mounting of OM-spheres, and that quite a few flaws came to light. The accelerometer sensors all worked flawlessly, unfortunately one sensor was lost, being torn off by the data cable, and another one damaged during the last deployment. Video systems worked during all, except the first (LOM1) deployment. Visibility was rather poor though: 5-7 m. Cameras inside OM-spheres all suffered battery problems. During LOM2 and LOM4 the string stood upright exactly as planned, During LOM1,3,5 it had 5-10 twists and many bars broken.

Fig. 8. Underwater video stills of LOM2 just prior and after its release.

The main process of unwinding went rapid and smooth (Fig. 8), no glass spheres were damaged and the new surface buoy worked excellent, not hampering the LOM to surface. The unrolling worked always and took 8.5±0.2 minutes for a 690 m string (Fig. 9; an average unrolling speed of 1.3 m/s). The slack in the data cable was more than sufficient to keep up with the stretch in the Dyneema; the slack could have been slightly differently distributed. BOBs worked well in principle, but some connection with VEOC can be slightly improved to

restrict bending. When the LOM had started with more or less equal tension on the two cables (LOM2 and LOM4), the string stood perfectly upright (Fig. 10) with the spheres barely tilted all more or less in the same direction (Fig. 11). Unfortunately, the tilt sensors were mounted in holdings that regularly got caught by the slack data cable, thereby becoming disoriented thus hampering analysis. When too many bars were broken, as in the uneven LOMs, slightly faster precession and eventually some line-twisting occurred. The more sturdy attachment of bars to the Dyneema line will prevent this from happening.

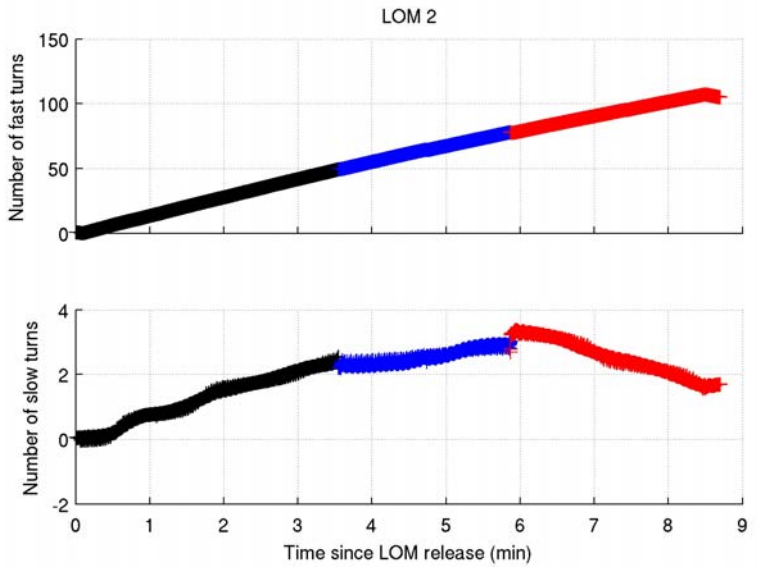


Fig. 9. Unrolling of LOM2 as a function of time (in minutes): (upper panel) number of 6 m (LOM circumference) turns, (lower panel) number of precession turns: due to bar-tension the LOM rotates back after 6 minutes from its start.

After release, the mooring remained at the bottom for at least 3 hours before retrieval. Relative current speeds were measured up to about 0.15 m s^{-1} over the string-range (Fig. 12). This barely affected the string-tilt (Fig. 11). In a thin surface layer currents were considerably larger: 0.7 m s^{-1}, which slightly hampered overboard operations, although not as much as the windconditions (on average Bf5).

Fig. 10. ROV underwater video stills of upright LOM2. The white line is the data cable, which switches between the barely visible black Dyneema lines every bar (left), but goes in and out the same side of an OM glass sphere (right).

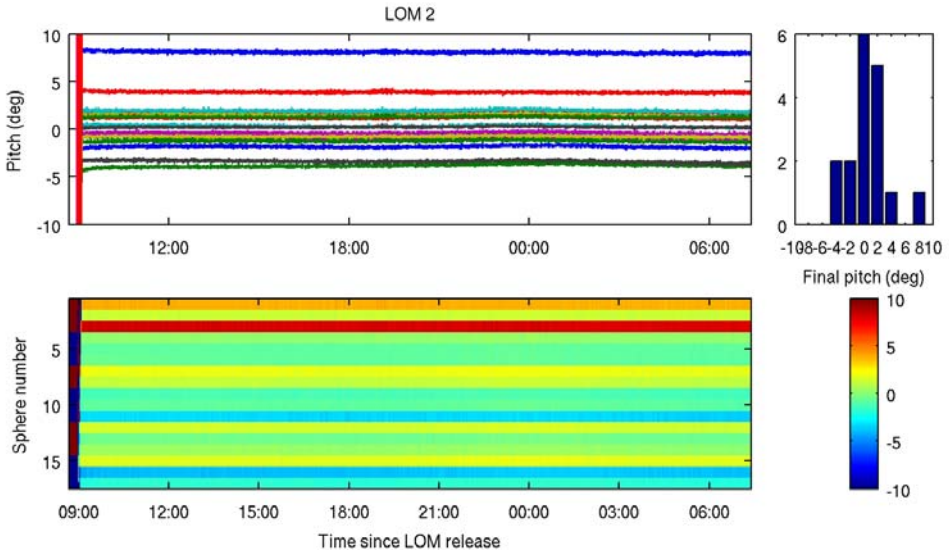


Fig. 11. Pitch of LOM2 OM-glass spheres after unrolling, when the string is upright.

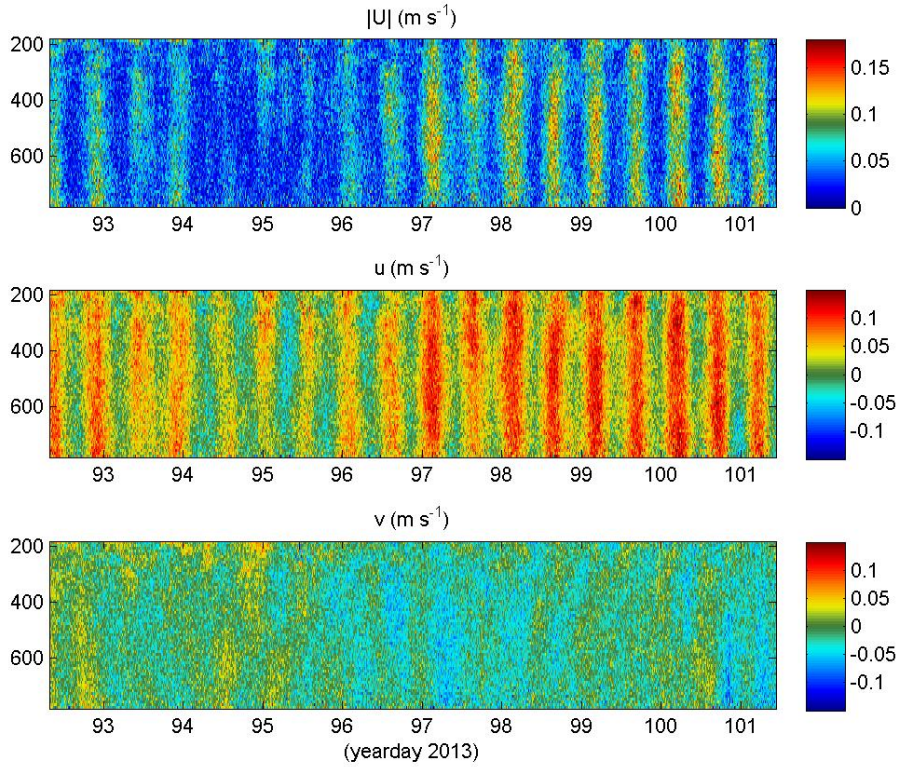


Fig. 12. ADCP-current data as a function of time (yeardays) and depth (in m) of: (upper panel) total current amplitude, (middle panel) East-West component, (lo wer panel) North-South component. Tidal variation with time is dominant.

8. Achnowledgments

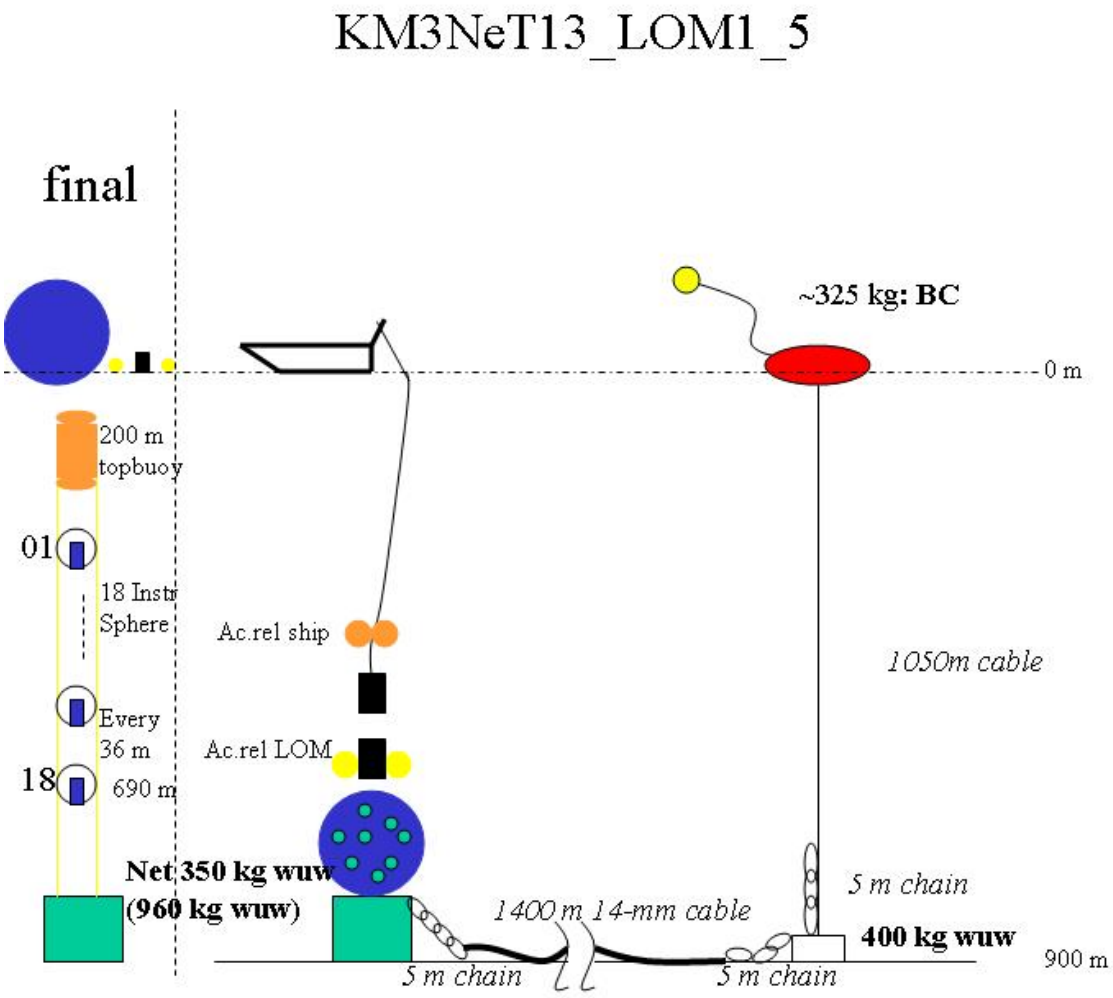
On behalf of all participants, I would like to thank captain John Ellen and the crew of R/V Pelagia for the very pleasant cooperation. Funding by the Netherlands Organization for the advancement of Scientific Research is gratefully acknowledged.

April/May 2013,

Hans van Haren

Appendix A Mooring diagram KM3NeT13

U-shape mooring



Appendix B Cruise summary of stations (activities) of KM3NeT13

Station _cast	Device	Action	Date	Heure (UTC)	Latitude (deg. min.milli)	Longitude (deg. min.milli)	EA600 Depth (m)
	Multibeam	Begin	02/04/2013	21:32:11	N 36° 24.0489'	W 3° 32.50326'	888.35
	Multibeam	Begin	02/04/2013	21:32:24	N 36° 24.0492'	W 3° 32.4702'	888.42
	Multibeam	Course Change	02/04/2013	22:35:33	N 36° 24.07986'	W 3° 24.93888'	909.1
	Multibeam	Course Change	03/04/2013	00:09:47	N 36° 22.94304'	W 3° 32.41272'	888.2
	Multibeam	Course Change	03/04/2013	01:32:51	N 36° 21.5043'	W 3° 24.83184'	903.5
	Multibeam	End	03/04/2013	02:56:44	N 36° 20.23992'	W 3° 32.52'	846.74
1_1	LOM1	Deployment	03/04/2013	07:01:21	N 36° 23.96934'	W 3° 26.59926'	909.71
1_1	LOM1	Recovery	03/04/2013	17:06:03	N 36° 24.52896'	W 3° 22.251'	907.71
	Multibeam	Begin	03/04/2013	21:47:12	N 36° 25.57428'	W 3° 31.91724'	883.24
	Multibeam	Course Change	03/04/2013	22:45:47	N 36° 25.57206'	W 3° 24.68808'	907.17
	Multibeam	Course Change	04/04/2013	00:16:48	N 36° 26.78286'	W 3° 32.49636'	874.66
	Multibeam	Course Change	04/04/2013	01:29:02	N 36° 27.9963'	W 3° 25.00698'	850.97
	Multibeam	End	04/04/2013	02:46:51	N 36° 29.21622'	W 3° 32.51568'	830.46
2_1	LOM2	Deployment	04/04/2013	06:32:24	N 36° 24.23028'	W 3° 25.22796'	907
3_1	CTD	Begin	04/04/2013	11:03:50	N 36° 24.13464'	W 3° 27.5007'	907.49
3_1	CTD	Bottom	04/04/2013	11:24:42	N 36° 24.13188'	W 3° 27.50292'	907.69
3_1	CTD	End	04/04/2013	11:44:07	N 36° 24.13746'	W 3° 27.49578'	908.06
4_1	ROV	Deployment	04/04/2013	12:17:21	N 36° 24.18564'	W 3° 25.11606'	909.11
4_1	ROV	Recovery	04/04/2013	12:35:12	N 36° 24.17424'	W 3° 25.11402'	908.46
4_2	ROV	Deployment	04/04/2013	12:44:31	N 36° 24.17652'	W 3° 25.1109'	908.87
4_2	ROV	Recovery	04/04/2013	15:58:07	N 36° 24.2082'	W 3° 25.13508'	908.68
2_1	LOM2	Recovery	05/04/2013	07:50:13	N 36° 27.47772'	W 3° 20.18256'	887.06
5_1	CTD	Begin	05/04/2013	10:06:46	N 36° 27.80712'	W 3° 19.71732'	885.41
5_1	CTD	Bottom	05/04/2013	10:27:23	N 36° 27.80904'	W 3° 19.73394'	885.69
5_1	CTD	End	05/04/2013	10:47:31	N 36° 27.81072'	W 3° 19.72956'	885.07
	Multibeam	Begin	05/04/2013	19:59:12	N 36° 29.19816'	W 3° 25.1874'	817.71
	Multibeam	Course Change	05/04/2013	21:00:34	N 36° 29.25894'	W 3° 17.1789'	885.52
	Multibeam	Course Change	05/04/2013	22:18:14	N 36° 27.94512'	W 3° 25.16166'	853.28
	Multibeam	Course Change	05/04/2013	23:30:18	N 36° 26.85876'	W 3° 17.72826'	898.41
	Multibeam	Course Change	06/04/2013	00:47:39	N 36° 25.63806'	W 3° 24.97542'	904.12
	Multibeam	Course Change	06/04/2013	01:51:42	N 36° 24.49638'	W 3° 17.72778'	905.81
	Multibeam	End	06/04/2013	03:29:21	N 36° 23.25474'	W 3° 25.01232'	907
6_1	LOM3	Deployment	06/04/2013	06:35:13	N 36° 24.38196'	W 3° 25.04796'	909.04
7_1	CTD	Begin	06/04/2013	09:00:58	N 36° 24.39702'	W 3° 25.17426'	909.28
7_1	CTD	Bottom	06/04/2013	09:19:03	N 36° 24.47622'	W 3° 25.26294'	908.84
7_1	CTD	End	06/04/2013	09:36:17	N 36° 24.63'	W 3° 25.30332'	908.71
	LOM3	Release (MOB)	07/04/2013	06:15:30	N 36° 24.36438'	W 3° 24.85728'	909
	ROV	Deployment	07/04/2013	07:23:30	N 36° 24.36438'	W 3° 24.85728'	909
	ROV	Recovery	07/04/2013	09:50:22	N 36° 24.30162'	W 3° 24.87954'	909
6_1	LOM3	Recovery	07/04/2013	15:43:19	N 36° 42.95292'	W 3° 31.15296'	909
	Multibeam	Begin	07/04/2013	19:55:17	N 36° 29.17488'	W 3° 32.22636'	829.94
	Multibeam	Course Change	07/04/2013	20:58:32	N 36° 29.1204'	W 3° 39.69786'	851.35
	Multibeam	Course Change	07/04/2013	22:16:50	N 36° 27.76866'	W 3° 32.38812'	863.18
	Multibeam	Course Change	07/04/2013	23:30:30	N 36° 26.62368'	W 3° 39.64746'	885.58
	Multibeam	Course Change	08/04/2013	00:50:12	N 36° 25.18968'	W 3° 32.07078'	884.64
	Multibeam	Course Change	08/04/2013	02:10:30	N 36° 23.83188'	W 3° 39.57228'	891.03
	Multibeam	End	08/04/2013	03:17:20	N 36° 22.46448'	W 3° 32.27964'	888.78
9_1	LOM4	Deployment	08/04/2013	06:07:32	N 36° 24.12336'	W 3° 23.82324'	908
10_1	CTD	Begin	08/04/2013	09:10:59	N 36° 24.18954'	W 3° 23.3727'	908

10_1	CTD	Bottom	08/04/2013	09:30:16	N 36° 24.15156'	W 3° 23.5107'	908
10_1	CTD	End	08/04/2013	09:49:07	N 36° 24.13404'	W 3° 23.619'	908.39
	ROV	Deployment	08/04/2013	11:12:01	N 36° 24.09432'	W 3° 23.84754'	908.94
	ROV	Recovery	08/04/2013	13:40:37	N 36° 24.13002'	W 3° 23.7486'	908.52
9_1	LOM4	Recovery	09/04/2013	07:43:39	N 36° 24.40002'	W 3° 22.69122'	905.17
	Multibeam	Begin	09/04/2013	21:08:52	N 36° 20.2359'	W 3° 32.41362'	848.74
	Multibeam	Course Change	09/04/2013	22:06:45	N 36° 20.20158'	W 3° 39.54858'	769.35
	Multibeam	Course Change	09/04/2013	23:58:34	N 36° 21.84072'	W 3° 25.14816'	899.87
	Multibeam	Course Change	10/04/2013	00:54:08	N 36° 21.91254'	W 3° 17.7336'	898.66
	Multibeam	End	10/04/2013	02:15:06	N 36° 20.58786'	W 3° 24.97482'	896.93
10_1	LOM5	Deployment	10/04/2013	06:31:06	N 36° 23.92584'	W 3° 24.54222'	907
12_1	CTD	Begin	10/04/2013	09:45:34	N 36° 24.40674'	W 3° 23.59062'	907
12_1	CTD	Bottom	10/04/2013	10:04:58	N 36° 24.23868'	W 3° 23.4867'	907
12_1	CTD	End	10/04/2013	10:25:55	N 36° 24.10614'	W 3° 23.39682'	907
	ROV	Deployment	10/04/2013	11:17:44	N 36° 23.9553'	W 3° 24.39012'	907
	ROV	Recovery	10/04/2013	13:13:58	N 36° 23.94234'	W 3° 24.4056'	909.16
10_1	LOM5	Recovery	11/04/2013	07:44:01	N 36° 24.3483'	W 3° 23.57424'	908.15

Appendix C Accelerometer sensor mounting

Sensors always mounted in pairs, started 120 s apart, to cover disk-write data-gap.

OM-sphere (numbering from top-string)	**NIOZ4-sensors (10 Hz sampling rate)**
1	281, 301
2	282, 302
3	283, 303
4	284, 304
5	285, 305
6	286, 306
7	287, 307
8	288, 308
9 (OFM)	
10	299, 310
11	271, 291
12	272, 292
13	273, 293
14	274, 294
15	275, 295
16	276, 296
17	277, 297
18	278, 298
LOM(8→17)	251, 279[a] axis red lane
LOM(17→2)	252, 280[a] axis blue lane
LOM(2→11)	253, 290[a,b] axis black lane
weight	289[b,c], 309[c]

a: Only on LOM3,4,5 (second sensor on LOM)
b: Sensor 290 switched with 289 on LOM3 (so, w.r. to table: 290 on weight and 289 on black lane)
c: Not on LOM1 (no sensor on weight)