Cruise Report
and preliminary results

Mediterranean geodesy and Saharan dust

Cruise No. 64PE443

9 – 13 August 2018
Catania, Sicily (Italy) – Heraklion, Crete (Greece)

Jan-Berend W. Stuut, Ernst Flüh, Florian Petersen,
Patrick Schröder, Morelia Urlaub, Leon Wuis

1. Summary

RV Pelagia cruise 64PE443 was dedicated to the recovery of five Acoustic Monitoring Transponders (AMTs) from the eastern submarine flank of Mount Etna and to service a moored sediment trap in between Sicily and Crete.

The five AMTs are part of a longer-term geodetic study with the overall aim to monitor movements of the Mediterranean Seafloor as a result of movements of the volcano Mount Etna.
The moored sediment trap "MedDust" is also part of a longer-term monitoring project of modern Saharan-dust deposition in the Mediterranean. Since 2013, a sediment trap has been deployed at ~35°N/18°E, collecting sediments (next to Saharan dust, also marine organic matter and fossil remains of plankton) settling towards the seafloor. Using so-called "ships of opportunity", this sediment trap is serviced on an irregular basis.

Table 1.1: key data of sediment-trap mooring "MedDust", recovered / (re-)deployed during 64PE433

Series	Start date	Lat (° 'N)	Lon (° 'E)	End date	Nr cups	Interval
MedDust2017	14 Apr 2017	34°57.826'	18°2.155'	19 May 2018	40	10 days
MedDust2018	13 Aug 2018	34°57.749'	18°01.788'	19 Sep 2019	40	10 days

2. Participants

Table 2.1: Participants of cruise 64PE433

Name, title	Discipline	Affiliation
Jan-Berend Stuut, Dr	Marine Geology, chief scientist	NIOZ & VU
Ernst Flüh, Prof. Dr.	Marine Geodesy	GEOMAR
Florian Petersen	Marine Geodesy	GEOMAR
Patrick Schröder	Marine Geodesy	GEOMAR
Morelia Urlaub, Dr.	Marine Geodesy	GEOMAR
Leon Wuis	Marine Technology	NIOZ

NIOZ – Royal Netherlands Institute for Sea Research, and Utrecht University, Texel, the Netherlands
VU – Vrije Universiteit Amsterdam, the Netherlands
GEOMAR – Helmholtz Centre for Ocean Research, Kiel, Germany

3. Research program

The purpose of cruise 64PE433 was two-fold:

1) Five Acoustic Monitoring Transponders that had been deployed in 2016 on the eastern flank of Mount Etna were to be recovered;
2) The moored sediment-trap station "MedDust" was to be recovered and re-deployed.

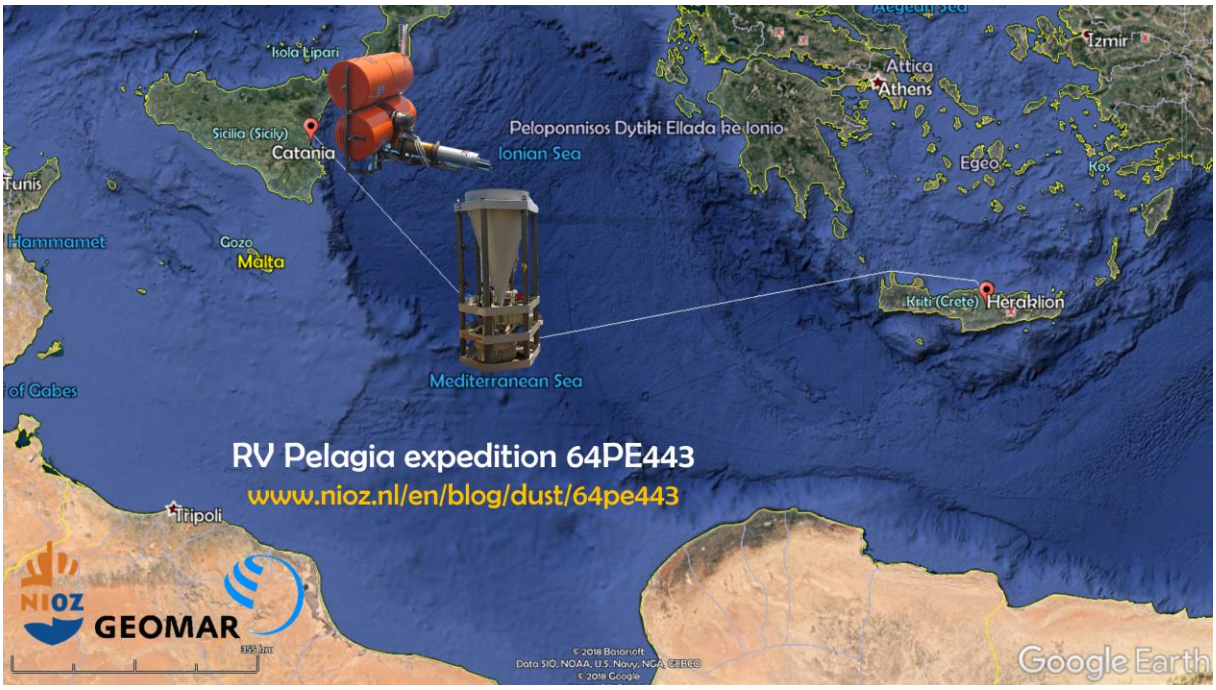

Figure 3.1: Track of RV Pelagia cruise 64PE433.


Geodesy station off Catania, Sicily;


Sediment-trap mooring MedDust

3.1 Mediterranean Geodesy

The south-eastern flank of Etna volcano slides into the Ionian Sea at rates of centimeters per year (Fig. 3.1.1). Numerous hypotheses have been proposed explaining flank sliding, which can broadly be classified into those related to the magmatic plumbing system and those induced by gravity. It is, however, crucial to understand which mechanism is driving flank instability as the two mechanisms have fundamentally different hazard implications. While magma dynamics can trigger slope failures near the magma pathways, large-scale gravitational deformation can precede catastrophic collapses. Uncertainties regarding the causes of flank sliding originate from the lack of information on the dynamics of the submarine part of the volcano. While onshore geodetic measurements document large-scale continuous seaward motion at an average rate of 3-5 cm per year with highest rates at the coast since the early 1980's (e.g. Puglisi & Bonforte 2004), no information on the movement of the submarine part of the flank existed prior to this project.

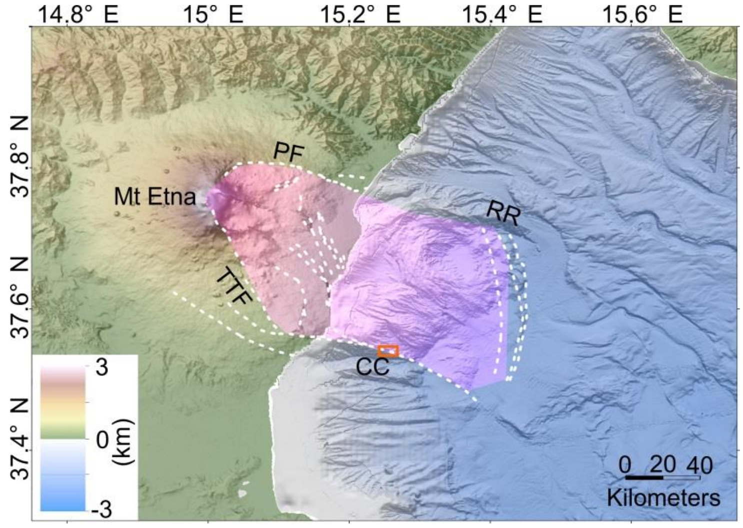

Figure 3.1.1: Morphology of Mount Etna and its on- and offshore surroundings in greenish and blueish colours, respectively. Purple transparent polygon shows the outline of the unstable sector. The orange rectangle marks the working area. Dashed white lines mark major fault systems. PF=Pernicana Fault, TTF=Tremestieri-Trecastagni Fault, CC=Catania Canyon, RR=Riposto Ridge.

Established satellite-based geodetic tools are not adaptable for the marine environment due to the opacity of seawater to electromagnetic waves. Underwater, distances can be estimated using sound speed of water and travel time measurements between transponders on the seafloor. Periodic back-and-forth acoustic interrogations between several transponders equipped with absolute pressure sensors and arranged in a network allow continuous determination of seafloor displacement in horizontal and vertical directions within the network. In April 2016 a network of five such Acoustic Monitoring Transponders (AMT) was installed on both sides of the submerged southern boundary of Etna's unstable flank (Fig. 3.1.2, Krastel et al. 2016). Changes in distance between AMTs across the fault indicate movement of the presumed unstable flank relative to the stable surrounding. This seafloor network is part of GEOMAR's Geodetic Earthquake Observatory on the Seafloor (GeoSEA) array and it is the first to monitor deformation of a submerged volcanic flank sub-centimetre resolution. About 15 months of data were downloaded via an acoustic link in July 2017. These data indicate successful and stable measurements and yield the first ever slow slip event monitored in three dimensions (Urlaub et al., in press).

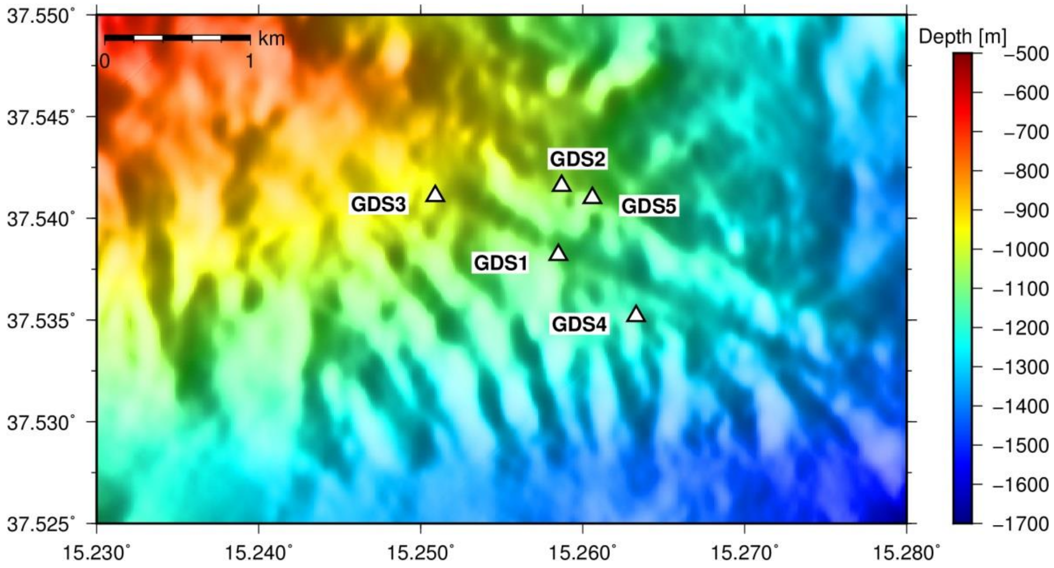

Figure 3.1.2: Seafloor geodetic network

3.2 Saharan dust collected in the Mediterranean

Every year, about 180 Million Ton dust is leaving the north African west coast to be deposited into the Atlantic Ocean (Yu et al., 2015). Although the western trajectory is the main dust path, considerable amounts Saharan dust are also blown in a northern direction (Stuut et al., 2009). Many experiments have been carried out in the western Mediterranean Sea to study the marine environmental effects of Saharan-dust deposition (e.g., Guieu et al., 2002; 2014; Ridame and Guieu 2002), but little is known about the amounts and characteristics of Saharan dust deposited into the central Mediterranean Sea, or its marine environmental effects. Since 1991, there have been sediment traps collecting Saharan-dust deposition in the Mediterranean between Sicily and Crete by scientists from Utrecht University, the Netherlands (e.g., Rutten et al., 2002). This sediment-trap time series was terminated in 2012 and then continued by scientists from NIOZ.

References

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Yu, H., Chin, M., Bian, H., Yuan, T., Prospero, J.M., Omar, A.H., Remer, L.A., Winker, D.M., Yang, Y., Zhang, Y., Zhang, Z. (2015) Quantification of trans-Atlantic dust transport from seven-year (2007–2013) record of CALIPSO lidar measurements. *Remote Sensing of Environment* 159, 232-249.

4. Narrative of the cruise

RV Pelagia left the port of Catania on Friday 10 August 2018 under very pleasant weather conditions (sunny skies and calm seas). The clock was immediately adjusted from Italian (UTC +2) to Greek time (UTC +3). The first waypoint was the seafloor geodetic network consisting of five stations sitting at the seafloor. After a very short transit we reached the working area. At 9:55 an acoustic modem was lowered to 50 m below sea level. Using the modem, contact was made to station GDS1 and data were successfully downloaded. As all attempts to contact the other stations were unsuccessful due to low batteries of the AMTs the modem was recovered at $10.^{20}$. Station GDS1 was acoustically released at $10.^{26}$. It was first seen from the bridge at $11.^{02}$ floating at the sea surface. Thereupon, the dinghy was deployed and two members of the crew (Inno and Wim Jan) and one scientist (Ernst or Florian) set out to approach the floating instrument. As the RV Pelagia reached the instrument, it was manually hooked to the crane by the dinghy crew. In order to prevent loss of the instrument or parts of it, a 10 m x 5 m safety net was lowered to the water with the short side fixed to the vessel. The opposite short side, equipped with weights and two long ropes with flotation, sank down and was pulled away from the vessel underneath the instruments by the dinghy. The crane then lifted the instrument (Fig. 4.1). At 11.^{24} the station GDS1 was on deck. The dinghy was lifted out of the water. The recovery procedure was repeated for the remaining four stations. At 15.^{00} pm the last station was safely recovered and the transit to the next waypoint began. All five stations were recovered without losses. This is a great success as this was the first recovery of a GeoSEA array. Handling of the stations was done in a very professional way by the crew.

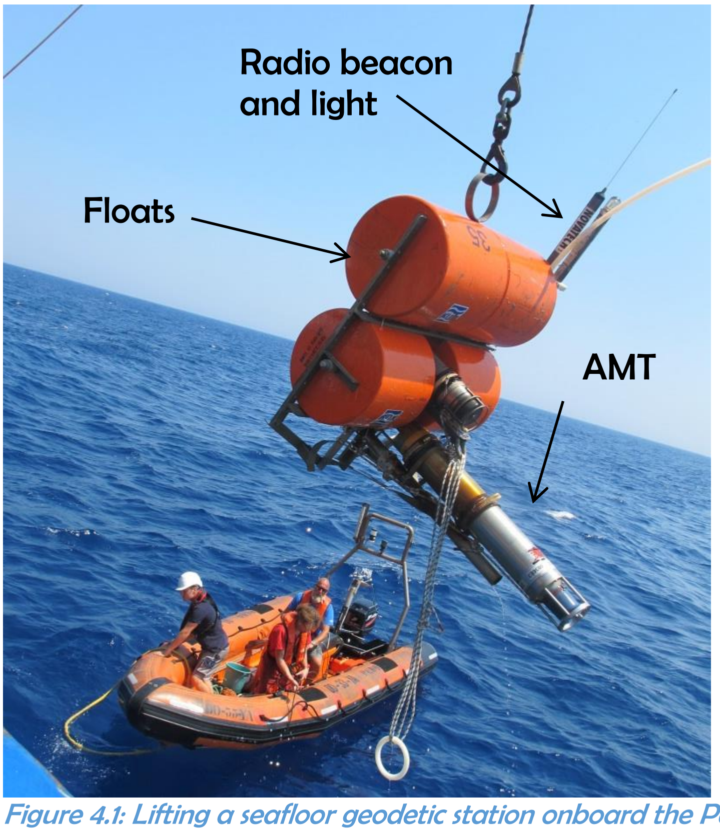

Figure 4.1: Lifting a seafloor geodetic station onboard the Pelagia

The transit towards the MedDust sediment-trap site took us ~210 nm in southeasterly direction, a distance that was covered in about 23 hours. During this transit, we also collected dust from the atmosphere, using two dust collectors that had been installed on the upper deck above the bridge. Unfortunately, there was not much dust around, and only a slight greyish colouration could be discerned on the filters.

Just after lunch on Saturday 10 August contact was made with the acoustic modem to release the mooring. At a dazzling speed of 100m / minute she came to the surface and popped up about 200m from the ship. The recovery then went very smooth and fast; at 15.^{30} the mooring was on deck and at 18.^{00} the anchor was re-deployed again! In these 2½ hours the batteries were replaced, all samples (N=40) were harvested and new bottles installed in the two carrousels. All mechanical parts like shackles, lines and floats were checked and –where necessary—fixed or replaced. Obviously, this quick handling of the mooring relied heavily on the collaboration between John, Len and Peter on the bridge and Leon, Norberto, Roel, Wim Jan and Jan-Berend on deck,

After launching the anchor, the ship set course towards Heraklion, Crete, which took us ~360nm in easterly direction. We arrived safely in the harbour of Heraklion on Monday 13 August at 8.^{00}.

Figure 4.2: The sediment trap is gently put on deck by (L2R) Norberto, Leon, Wim Jan and Roel

5. Preliminary results

5.1 Geodetic measurements

Except for GDS1 all instruments ran out of battery power before recovery (last logs of GDS 2 and GDS3 in May 2018, GDS4 in March 2018, and GDS5 in January 2018). The time series from deployment in April 2016 until July 2017 was known previously thanks to previous data download in July 2017. Preliminary analysis of the new data recovered during this cruise (from July 2017 onwards) do not show significant length changes in any baselines (see Figure 5.1.1 for a data example). All baselines show a particular scatter starting from January 2018, which is indicative of a fault in the sound velocity.

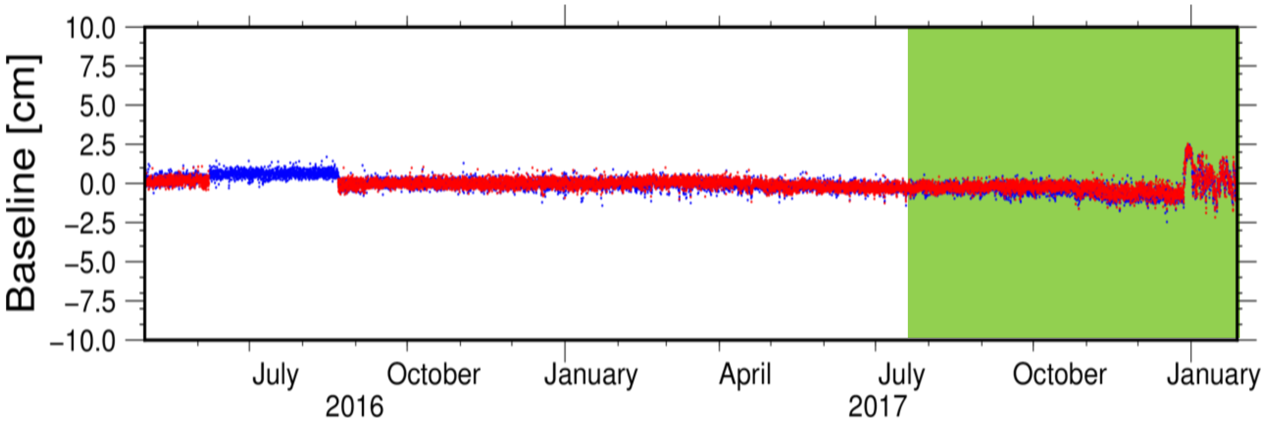

Figure 5.1.1: Relative distance changes between GDS2 and GDS5 (compare Fig. 3.1.2) for the entire observation period. Green background marks the new data obtained during this cruise.

5.2 *Saharan dust collection*

As could clearly be seen from the clear blue skies, there was not a lot of Saharan dust around during the transit between Sicily and Crete. Nevertheless, the filters we collected showed some light greyish colouration (Figure 5.2.1 and Table 5.2.1).

Two types of filters were used: 1) Cellulose Acetate (Whatman 41) for inorganic analyses like particle-size and -composition, and 2) Ashed (organic-matter free) Glass fibre (GFF) filters for organic geochemical analyses. The Cellulose Acetate filters were stored at room temperature, the GFF filters were frozen at -80°C.

Figure 5.2.1: GFF filter #1 collected between Catania and the MedDust site (see Table 5.1)

Table 5.2.1: Details of the dust filters (both GFF and CA) collected during 64PE433

Start lat(N)/lon(E)	End lat(N)/lon(E)	Sampling time (min)	Sampled air (m^3; GFF,CA)
37°29.21' / 15°18.92'	35°0.48' / 17°58.49'	988	858, 1118
35°0.48' / 17°58.49'	35°27.33' / 21°46.96'	1337	1163, 1513
35°27.33' / 21°46.96'	35°26.76'/ 25°0.44'	805	703, 915

Since 2013 there had been some issues with the KUM-type sediment traps with two carrousels; never before had they functioned 100%. NIOZ technician Bob Koster found out that actually there was a mistake in the design, preventing the required amount of power being transferred from the batteries towards the motors, so that they jammed easily. The problem was solved by Bob and KUM acknowledged the mistake and replaced some electronic boards in the traps. The MedDust trap was the first to work with the improved set-up and it has proved its worth; the two carrousels had rotated flawlessly and in all bottles (N=40) there was some material to be seen, collected over 10 days per bottle. See Table 1.1 for start- and end dates of the collected series as well as the appendix for the event table of the MedDust2017 program and the new schedule that was programmed for MedDust2018.

6 *Acknowledgements*

Our sincere thanks go to Master John Ellen and his crew for the friendly cooperative atmosphere during the entire cruise as well as their competent technical assistance during all operations. You made us all really feel at home!

This expedition was funded both by the German Helmholtz Association through GEOMAR and by the Dutch National Science Foundation (NWO) through NIOZ.

Appendix 1: event table of MedDust2017 (14 April 2017 – 19 May 2018)

'K.U.M. Schedule Events																	
'For support: K.U.M Umwelt- und Meerestechnik Kiel GmbH																	
'TEL 431-72092-20																	
'FAX 431-72092-44																	
'WEB www.kum-kiel.de																	
'MAIL info@kum-kiel.de																	
EVENTS	1	1	0	0	L/B Pulses	543	523	0	0	0	0	0	0	0	0	0	0
EVENTS	2	1	0	0	L/B Pulses	545	517	0	0	0	0	0	0	0	0	0	0
EVENTS	3	1	0	0	L/B Pulses	545	520	0	0	0	0	0	0	0	0	0	0
EVENTS	4	1	0	0	L/B Pulses	545	515	0	0	0	0	0	0	0	0	0	0
EVENTS	5	1	0	0	L/B Pulses	545	514	0	0	0	0	0	0	0	0	0	0
EVENTS	6	1	0	0	L/B Pulses	545	520	0	0	0	0	0	0	0	0	0	0
EVENTS	7	1	0	0	L/B Pulses	545	511	0	0	0	0	0	0	0	0	0	0
EVENTS	8	1	0	0	L/B Pulses	545	515	0	0	0	0	0	0	0	0	0	0
EVENTS	9	1	0	0	L/B Pulses	545	513	0	0	0	0	0	0	0	0	0	0
EVENTS	10	1	0	0	L/B Pulses	544	510	0	0	0	0	0	0	0	0	0	0
EVENTS	11	1	0	0	L/B Pulses	544	508	0	0	0	0	0	0	0	0	0	0
EVENTS	12	1	0	0	L/B Pulses	544	513	0	0	0	0	0	0	0	0	0	0
EVENTS	13	1	0	0	L/B Pulses	544	514	0	0	0	0	0	0	0	0	0	0
EVENTS	14	1	0	0	L/B Pulses	544	513	0	0	0	0	0	0	0	0	0	0
EVENTS	15	1	0	0	L/B Pulses	544	508	0	0	0	0	0	0	0	0	0	0
EVENTS	16	1	0	0	L/B Pulses	543	509	0	0	0	0	0	0	0	0	0	0
EVENTS	17	1	0	0	L/B Pulses	543	509	0	0	0	0	0	0	0	0	0	0
EVENTS	18	1	0	0	L/B Pulses	543	505	0	0	0	0	0	0	0	0	0	0
EVENTS	19	1	0	0	L/B Pulses	543	509	0	0	0	0	0	0	0	0	0	0
EVENTS	20	1	0	0	L/B Pulses	543	511	0	0	0	0	0	0	0	0	0	0
EVENTS	21	1	0	0	L/B Pulses	543	509	0	0	0	0	0	0	0	0	0	0
EVENTS	22	1	0	0	L/B Pulses	545	517	0	0	0	0	0	0	0	0	0	0
EVENTS	23	1	0	0	L/B Pulses	542	520	0	0	0	0	0	0	0	0	0	0
EVENTS	24	1	0	0	L/B Pulses	542	515	0	0	0	0	0	0	0	0	0	0
EVENTS	25	1	0	0	L/B Pulses	542	519	0	0	0	0	0	0	0	0	0	0
EVENTS	26	1	0	0	L/B Pulses	542	510	0	0	0	0	0	0	0	0	0	0
EVENTS	27	1	0	0	L/B Pulses	542	520	0	0	0	0	0	0	0	0	0	0
EVENTS	28	1	0	0	L/B Pulses	542	517	0	0	0	0	0	0	0	0	0	0
EVENTS	29	1	0	0	L/B Pulses	541	514	0	0	0	0	0	0	0	0	0	0
EVENTS	30	1	0	0	L/B Pulses	541	514	0	0	0	0	0	0	0	0	0	0
EVENTS	31	1	0	0	L/B Pulses	541	513	0	0	0	0	0	0	0	0	0	0
EVENTS	32	1	0	0	L/B Pulses	541	514	0	0	0	0	0	0	0	0	0	0
EVENTS	33	1	0	0	L/B Pulses	541	514	0	0	0	0	0	0	0	0	0	0
EVENTS	34	1	0	0	L/B Pulses	541	515	0	0	0	0	0	0	0	0	0	0
EVENTS	35	1	0	0	L/B Pulses	540	516	0	0	0	0	0	0	0	0	0	0
EVENTS	36	1	0	0	L/B Pulses	540	510	0	0	0	0	0	0	0	0	0	0
EVENTS	37	1	0	0	L/B Pulses	540	515	0	0	0	0	0	0	0	0	0	0
EVENTS	38	1	0	0	L/B Pulses	540	508	0	0	0	0	0	0	0	0	0	0
EVENTS	39	1	0	0	L/B Pulses	540	514	0	0	0	0	0	0	0	0	0	0
EVENTS	40	1	0	0	L/B Pulses	540	507	0	0	0	0	0	0	0	0	0	0
EVENTS	41	1	0	0	L/B Pulses	540	511	0	0	0	0	0	0	0	0	0	0
EVENTS	42	1	0	0	L/B Pulses	539	506	0	0	0	0	0	0	0	0	0	0

Appendix 2: schedule of MedDust2018 (13 August 2018 – 19 September 2019)

Time	Table	Page:	1					
Date/Time	Action	Group/Motor	Group/Pulses	L/B	Group/Pulses	SW	TimeOut[d:hh:mm]	Remarks
13-08-2018/01:00:00	1	1/ON	1/1	1/1	00:00:20	Next	Bottom	Bottle
23-08-2018/01:00:00	1	1/ON	1/1	1/1	00:00:20	Next	Bottom	Bottle
02-09-2018/01:00:00	1	1/ON	1/1	1/1	00:00:20	Next	Bottom	Bottle
12-09-2018/01:00:00	1	1/ON	1/1	1/1	00:00:20	Next	Bottom	Bottle
22-09-2018/01:00:00	1	1/ON	1/1	1/1	00:00:20	Next	Bottom	Bottle
02-10-2018/01:00:00	1	1/ON	1/1	1/1	00:00:20	Next	Bottom	Bottle
12-10-2018/01:00:00	1	1/ON	1/1	1/1	00:00:20	Next	Bottom	Bottle
22-10-2018/01:00:00	1	1/ON	1/1	1/1	00:00:20	Next	Bottom	Bottle
01-11-2018/01:00:00	1	1/ON	1/1	1/1	00:00:20	Next	Bottom	Bottle
11-11-2018/01:00:00	1	1/ON	1/1	1/1	00:00:20	Next	Bottom	Bottle
21-11-2018/01:00:00	1	1/ON	1/1	1/1	00:00:20	Next	Bottom	Bottle
01-12-2018/01:00:00	1	1/ON	1/1	1/1	00:00:20	Next	Bottom	Bottle
11-12-2018/01:00:00	1	1/ON	1/1	1/1	00:00:20	Next	Bottom	Bottle
21-12-2018/01:00:00	1	1/ON	1/1	1/1	00:00:20	Next	Bottom	Bottle
31-12-2018/01:00:00	1	1/ON	1/1	1/1	00:00:20	Next	Bottom	Bottle
10-01-2019/01:00:00	1	1/ON	1/1	1/1	00:00:20	Next	Bottom	Bottle
20-01-2019/01:00:00	1	1/ON	1/1	1/1	00:00:20	Next	Bottom	Bottle
30-01-2019/01:00:00	1	1/ON	1/1	1/1	00:00:20	Next	Bottom	Bottle
09-02-2019/01:00:00	1	1/ON	1/1	1/1	00:00:20	Next	Bottom	Bottle
19-02-2019/01:00:00	1	1/ON	1/1	1/1	00:00:20	Next	Bottom	Bottle
01-03-2019/01:00:00	1	1/ON	1/1	1/1	00:00:20	Next	Bottom	Bottle
01-03-2019/01:10:00	2	2/ON	2/1	2/1	00:00:20	Next	Upper	Bottle
11-03-2019/01:10:00	2	2/ON	2/1	2/1	00:00:20	Next	Upper	Bottle
21-03-2019/01:10:00	2	2/ON	2/1	2/1	00:00:20	Next	Upper	Bottle
31-03-2019/01:10:00	2	2/ON	2/1	2/1	00:00:20	Next	Upper	Bottle
10-04-2019/01:10:00	2	2/ON	2/1	2/1	00:00:20	Next	Upper	Bottle
20-04-2019/01:10:00	2	2/ON	2/1	2/1	00:00:20	Next	Upper	Bottle
30-04-2019/01:10:00	2	2/ON	2/1	2/1	00:00:20	Next	Upper	Bottle
10-05-2019/01:10:00	2	2/ON	2/1	2/1	00:00:20	Next	Upper	Bottle
20-05-2019/01:10:00	2	2/ON	2/1	2/1	00:00:20	Next	Upper	Bottle
30-05-2019/01:10:00	2	2/ON	2/1	2/1	00:00:20	Next	Upper	Bottle
09-06-2019/01:10:00	2	2/ON	2/1	2/1	00:00:20	Next	Upper	Bottle
19-06-2019/01:10:00	2	2/ON	2/1	2/1	00:00:20	Next	Upper	Bottle
29-06-2019/01:10:00	2	2/ON	2/1	2/1	00:00:20	Next	Upper	Bottle
09-07-2019/01:10:00	2	2/ON	2/1	2/1	00:00:20	Next	Upper	Bottle
19-07-2019/01:10:00	2	2/ON	2/1	2/1	00:00:20	Next	Upper	Bottle
29-07-2019/01:10:00	2	2/ON	2/1	2/1	00:00:20	Next	Upper	Bottle
08-08-2019/01:10:00	2	2/ON	2/1	2/1	00:00:20	Next	Upper	Bottle
18-08-2019/01:10:00	2	2/ON	2/1	2/1	00:00:20	Next	Upper	Bottle
28-08-2019/01:10:00	2	2/ON	2/1	2/1	00:00:20	Next	Upper	Bottle
07-09-2019/01:10:00	2	2/ON	2/1	2/1	00:00:20	Next	Upper	Bottle
17-09-2019/01:10:00	2	2/ON	2/1	2/1	00:00:20	Next	Upper	Bottle

Appendix 3: sketch of mooring MedDust2018