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Short Cruise Report
M141-2

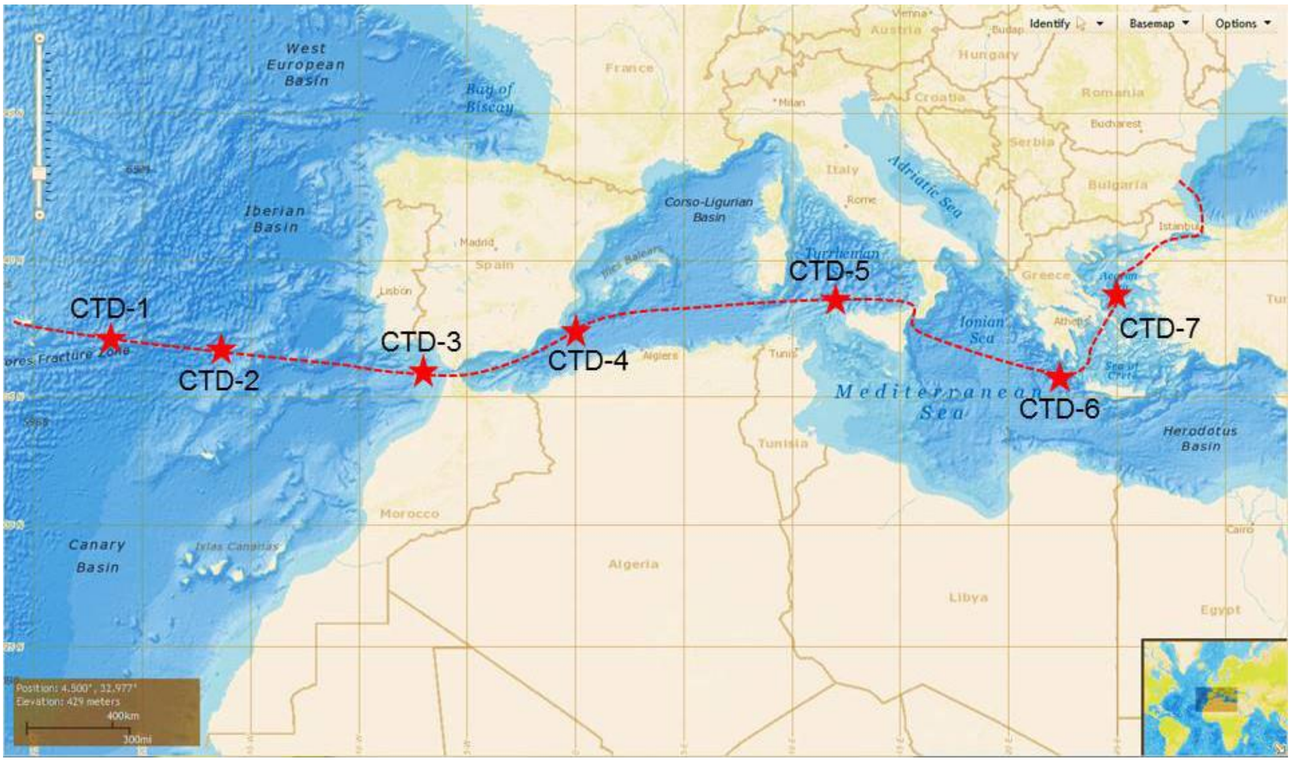
- UFO -
U-Isotope Fingerprinting of Mediterranean Outflow Water

Ponta Delgada (Portugal) - Varna (Bulgaria)

October 5 - 19, 2017

Chief Scientist: Norbert Frank

Captain: Detlef Korte



CTD-1
CTD-2
CTD-3
CTD-4
CTD-5
CTD-6
CTD-7
West European Basin
Bay of Biscay
Iberian Basin
Canary Basin
Islas Canarias
Corso-Ligurian Basin
Adriatic Sea
Ionian Sea
Mediterranean Sea
Herodotus Basin
France
Spain
Italy
Morocco
Algeria
Tunisia
Libya
Egypt
Greece
Hungary
Romania
Bulgaria
Serbia
Croatia
Austria
Madrid
Lisbon
Rome
Milan
Algiers
Tunis
Athens
Istanbul
Bucharest
Vienna
Cairo
Identify
Basemap
Options
400km
300mi

Rational / Objectives

Riverine, groundwater and aeolian inputs influence the natural seawater isotopic composition of U, here its $^{234}U/^{238}U$ ratio. It has been shown that the salt-like element U may be considered as being in stationary condition leading to a weakly salt dependent [U] concentration of 3.3 µ/l and a significant but globally constant excess of ^{234}U (or by definition a positive deviation from radioactive equilibrium given in ‰ as $\delta^{234}U$). However, it is also known that this marine U budget contains very large uncertainties, i.e. regarding the unknown sources of U and excess ^{234}U from groundwater and also the difficulty to properly assess the global depositional fluxes. Recent high precision measurements (‰-level) of Atlantic, Pacific and Indian Ocean water $\delta^{234}U$ further highlighted the conservative nature of U. Improvements of U-series techniques beyond the ‰ precision limit yield evidence of small but systematic $\delta^{234}U$ differences to the global mean value in semi-closed ocean basins such as the Arctic Ocean. Such variations are likely indicative of major freshwater-derived U fluxes that can be traced throughout the basin. Changes of those fluxes may be related to variable freshwater discharge but also variable isotopic compositions of U in the source region. Consequently, seawater $\delta^{234}U$ may be a novel indicator of global changes of the relative rate of continental weathering. The Mediterranean Sea is a basin of 3.75 Million km^3 volume, with a strong influx of Atlantic water due to the evaporation of water in the Mediterranean Sea. This cycle drives the production of Mediterranean warm and salty deep water leaving the Mediterranean Sea via the Strait of Gibraltar. We have recently found evidence that even though the residence time of water in the Mediterranean Sea is solely some 100 years, its U-isotopic composition differs notably from the one of the Atlantic Ocean. To conduct high precision U isotope measurements of the evolving Mediterranean Sea water this scientific cruise has the major objective to collect seawater along the transit through the Mediterranean Sea, which can subsequently be studied for its U isotopic composition as well as other geochemical trace isotopes fingerprinting water masses. A second goal of the research cruise is to provide measures of the suns attenuation through marine aerosols. As part of the global MAN (Marine Aerosol Network) it is intended to collect spectral data of aerosols informing on their abundance and type along the 3000 nautical miles transect through the Mediterranean Sea, which can be used to validate remote sensing data from satellites.

Narrative

To meet the goals of this project it was planned to collect seawater along the 3020 nm transit from the Atlantic (Ponta Delgada) to the Black Sea (Varna) that would ensure the ship's tied scheduling towards the shipyard of Varna. Initially, 8 CTD stations (3 in the Atlantic and 5 in the different basins of the Mediterranean Sea and Black Sea) were thus planned in order to determine physical water mass properties and to collect large volume filtered seawater samples for geochemical analysis in the host laboratory at Heidelberg University. The selected depth range was spanning from 0 m to as deep as 3500 m, to cover a wide range of water masses in the Atlantic as well as in the Mediterranean Sea basins. Due to the fact that no permissions were granted by the Turkish authorities to sample seawater in the Sea of Marmara and the Black Sea, 7 CTD casts remained in our program and were performed, with one now placed in the shallow Aegean Sea to obtain water outflowing the Sea of Marmara and Black Sea. In addition, we planned to collect surface water samples (filtered and unfiltered) along the transect on a daily basis using the seawater pump in the forefront of the Meteor, while running temperature and salinity calibration sampling as long as permissions from Spain, Italy and Greece were available. In addition to the water sampling, our small science team has made use of the shipboard acoustic measurements along the transit, to study the water flow path and direction in the upper 1500 m of the Northeast Atlantic and Mediterranean Sea using the ships ADCP (75kHz). Moreover, using the EM122 echo-sounder the seafloor topography was mapped along those sections of the transit for which diplomatic permissions were granted. While water current measurements are an important help to better understand the flow of water, which was sampled for geochemical analysis, mapping was conducted to supply data to the bathymetry services and to train students. Seawater sampling was conducted using nucleopore 0.45 µm particle filters and samples were subsequently acidified to pH 2 to keep the relevant particle reactive metal ions, including U, in solution. Samples were labeled and stored for shipping to Heidelberg University. Regarding the second goal of this transit cruise the observation of the solar attenuation due to marine aerosols, we used a handheld MICROTOPS photo spectrometer whenever the sun was uncovered. The solar attenuation data were sent immediately to NASA via satellite internet connection to provide them to the larger science community and to the public.

Our first station was ca. 280 nm east of the Azores (37° 4.4'N, 19° 47.15'W), where the presence of Mediterranean Sea Water (MSW) was traced between 700 and 1500 m through the salinity maximum of 35.8 psu. ADCP indicates slow and variable current speed (~ 0.2m/s) and water mostly from eastern direction around 1000 m depth. About 200 nm further east we reached the second station just prior to a seamount of which its flank was subsequently mapped to reach up to 700 m water depth from the mean basin depth of 3500 to 4000 m. Here, the salinity maximum of MSW at 36.08 psu indicates a two fold increase of the MSW contribution (10% at CTD-1 to ~20% at CTD-2) at 1090 m. Due to a technical failure station 3 near the Strait of Gibraltar was cancelled to repair the system before reaching station 4 in the Alboran Sea (37° 15.53' N and 0° 10,09' E). There, the MSW was present below a shallow North Atlantic inflow layer of 40 m depth with outflow characteristics of 38.5 psu and 13.12° C. Two more CTD stations followed to represent the southern edge of the Tyrrhenian Sea (38° 25,95'N; 12° 5,25' E; 1550 m) and the Ionian Sea (35° 59.15‘ N; 021° 03.62‘ E, 3500 m). Overall a clear increase in salinity of the core intermediate waters of the Mediterranean Sea was noticeable (as expected) with salinity increasing to 38.83 psu and temperatures increasing by 0.8°C to 13.95° C in the Ionian Sea. Each time we sampled in roughly >15 depth layers to obtain multiple samples from key Mediterranean and Atlantic water masses. Our last station was placed in the Center of the Aegean Sea to possibly capture the outflow and inflow to the Marmara and Black Sea (38° 11.65‘ N; 024° 47.62‘ E, 550 m). Regarding the other sensor data a clear oxygen decrease is visible in the Mediterranean Sea compared to the Atlantic water masses and the light transmission sensors reveal a peak of biological activity typically around 20 to 50 m depth. In addition to the large volume water sampling using the shipboard CTD-Rosette, the TSG calibration pump provided 2 unfiltered and 10 filtered large volume surface water samples along the transect. In total 1200 l of seawater were collected, filtered, acidified to pH 2, and stored for further geochemical analysis. Echo-sounder and ADCP was collected over a total distance of 1465.5 nm with numerous interesting observations of canyons in the Aegean Sea and Seamounts (near Josephine Seamount) in the Atlantic. The ADCP highlighted the strong current dynamic towards the Strait of Gibraltar, but further data evaluation, i.e. flagging of outliers etc. must be conducted. All raw sensor data was submitted to the BSH databases. Regarding our second scientific objective the detection of the solar attenuation from marine aerosols, the excellent weather has helped to provide a large amount of novel data. Along the 3000 nm transit roughly 1500 individual measurements have been obtained which show a strong longitudinal variability of solar attenuation. Highest aerosol optical depth (at 440nm) was observed near the Strait of Gibraltar at 6-5° W. All data will be available on NASA MAN website in due time. Overall, we have had mostly sunny and calm weather intercepted by a short occurrence of higher winds in the eastern Mediterranean Sea, which however lasted only for one day. The following figures highlight some of the results and the work on board RV Meteor M141-2. We have been very successful with our research program and thanks to the perfect weather conditions and the rapid transit through the Bosporus and the Dardanelles, we completed the program and transit one day in advance and reached Varna on the 18th October 2017.

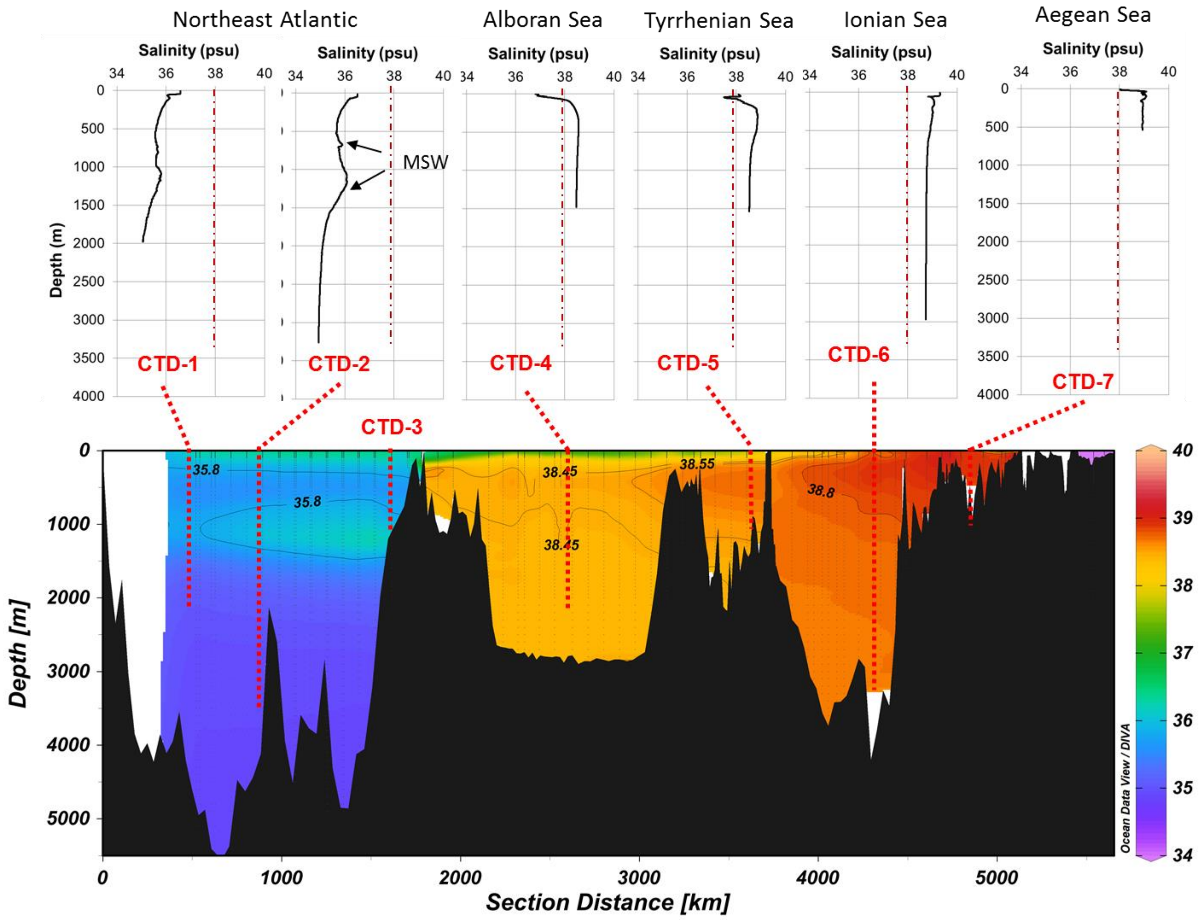


Figure 1: Evolution of the salt content along the transect sampled during M141-2. Roughly 12-24 depth intervals were sampled at each CTD station providing together with several surface water samples about 1200 l of water for geochemical studies of the U isotopes and other trace elements (salt map created with the ocean data view program odv 4.7.6)

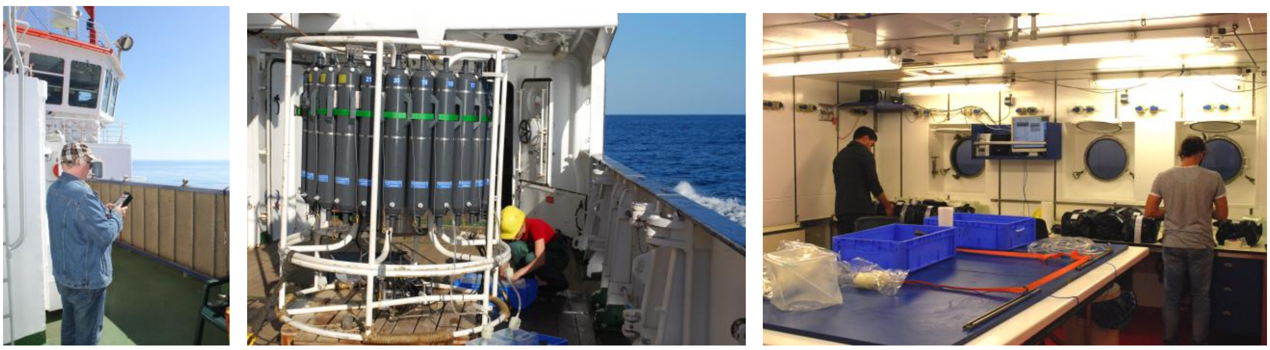


Figure 2: Left: Alexander Smirnov measuring the solar attenuation with the Microtops hand-held spectrometer. Middle: Collecting large volume seawater samples using the shipboard CTD, and left, preparation of the water samples for shipping and further laboratory work.

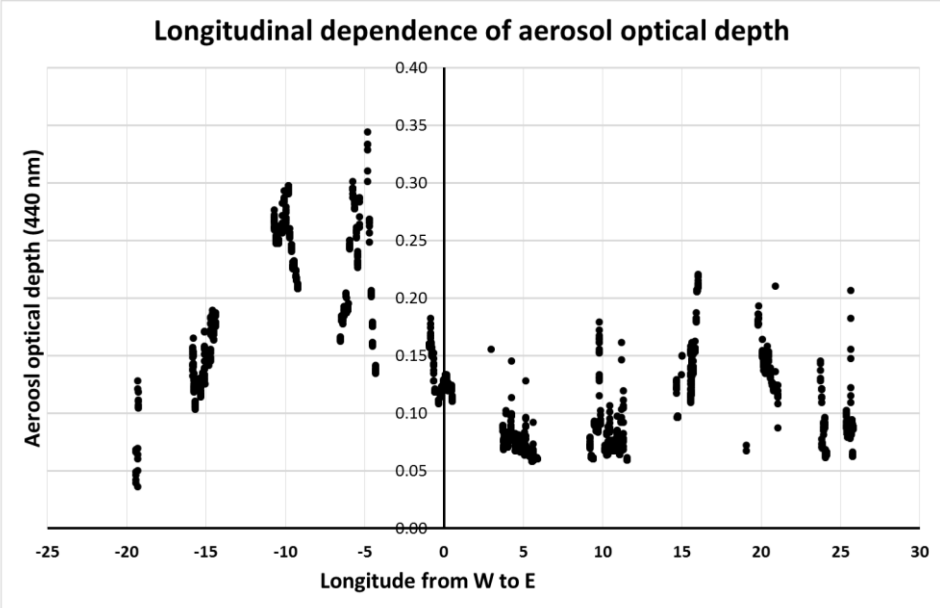


Figure 3: Results of the Microtops solar attenuation measurement spanning the studied longitudinal range. Highest solar attenuation is observed in the northeastern Atlantic near the Strait of Gibraltar.

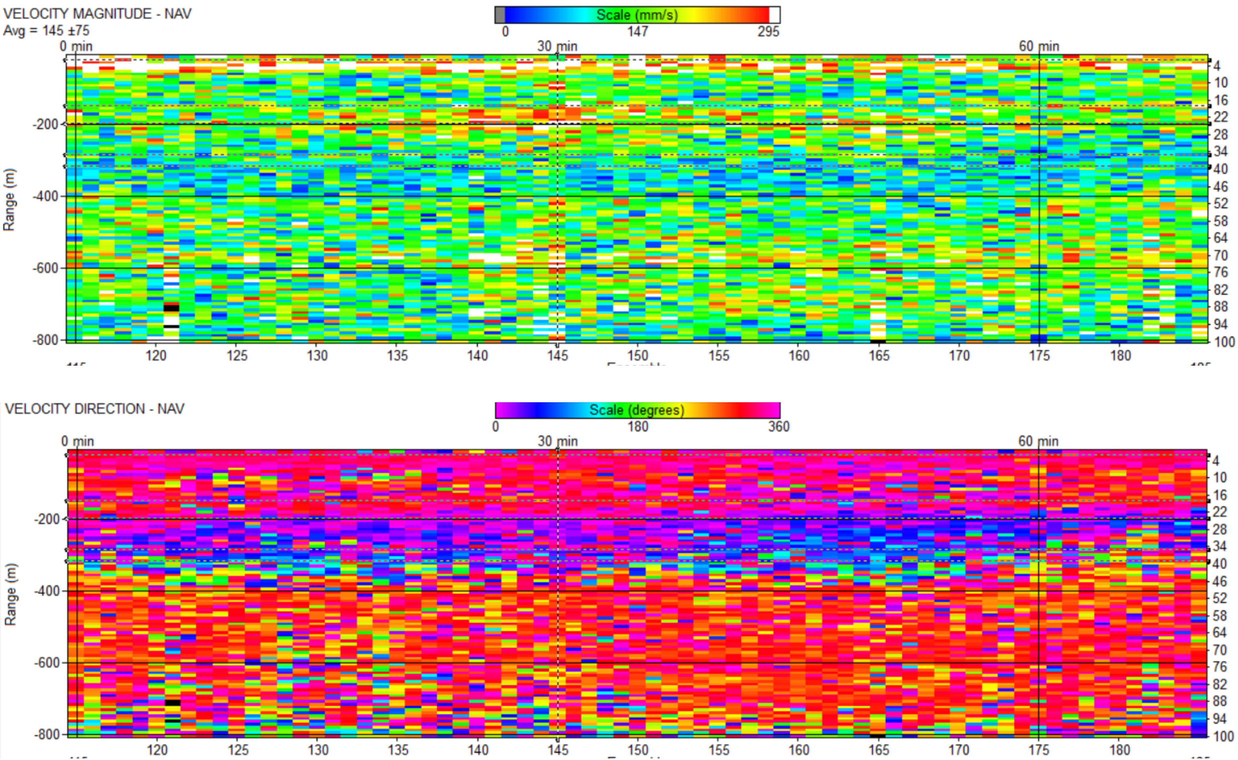


Figure 4: ADCP profile near the Strait of Gibraltar (CTD station 3), which demonstrates the presence of Mediterranean outflow water leaving the Strait in predominantly westward direction.

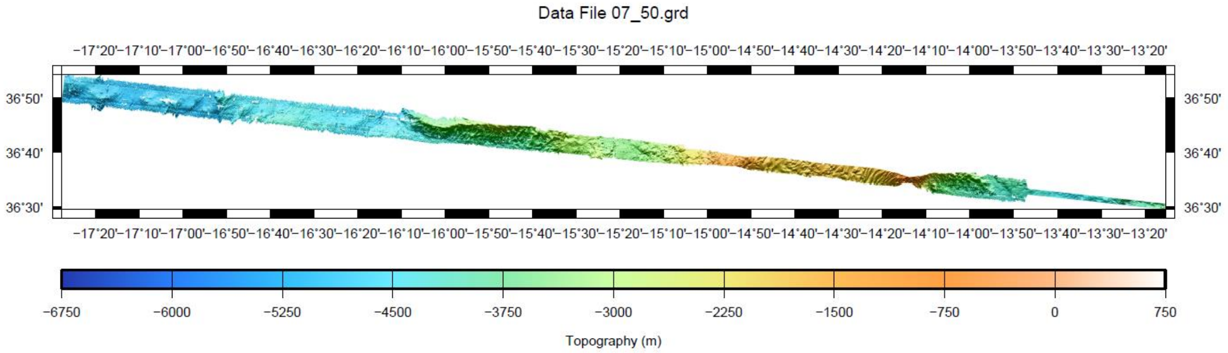


Figure 5: Example map of Echosounding obtained near the Josephine Seamounts chain. The small seamount traced reaches up to water depth of 700 m from a mean seafloor depth of 3500 m in the vicinity.

Acknowledgements

We greatly acknowledge the outstanding work of the captain and his crew of RV Meteor. We are grateful to the diplomatic representatives of Spain, Greece, Italy who granted us on short notice the possibility to sample seawater in their national waters. We are thankful to Andrea Schröder-Ritzrau who helped prepare this mission, as well as to Klaus Bohn from LPL Hamburg for prompt and rapid logistics and advice. Last but not least we acknowledge the DFG sea commission who has been rapidly following on our demands and of course the 'Deutsche Forschungsschiff Leitstelle' in Hamburg who was an invaluable help in preparing for this mission.

Teilnehmerliste

1.	Norbert Frank	Fahrtleiter / *Chief Scientist*	IUP-Heidelberg
2.	Patrick Blaser	Marine Geochemistry	GEOW-Heidelberg
3.	Evan Cooper Border	Marine Geochemistry	IUP-Heidelberg
4.	Marleen Lausecker	Marine Geochemistry	IUP Heidelberg
5.	Alexander Smirnov	Aerosol Measurements	NASA - GSFC
6.	Andreas Raeke	Bordwetterwarte	DWD
7.	Hartmut Sonnabend	Bordwetterwarte	DWD

IUP-Heidelberg	Institute für Umweltphysik, Universität Heidelberg
GEOW-Heidelberg	Institut für Geowissenschaften, Universität Heidelberg
NASA-GSFC	NASA Goddard Space Flight Center
DWD	Deutscher Wetter Dienst

Stationsliste

Station	Station label	Date	Time UTC	Position Lat (°N)	Position Lon (°W,°E)	Gear	125/250ml bottle	cubitainer (11l)	PhyPara (T,S,P)	LightTran / Oxygen	Comment
ME 141-2/1257-1	M141-2 CTD-1	06.10.2017	12:00	37° 04.40' N	019° 47.15' W	CTD//RO*			x	x	
ME 141-2/1257-1	M141-2 CTD-1	06.10.2017	12:38	37° 04.50' N	019° 47.17' W	CTD//RO*	12	12	x	x	
ME 141-2/1257-1		06.10.2017	13:27	37° 04.59' N	019° 47.19' W	CTD//RO*			x	x	
ME 141-2/1258-1	M141-2 CTD-2	07.10.2017	07:00	36° 43.98' N	016° 01.23' W	CTD//RO*			x	x	
ME 141-2/1258-1	M141-2 CTD-2	07.10.2017	08:04	36° 43.99' N	016° 01.19' W	CTD//RO*	24	24	x	x	
ME 141-2/1258-1		07.10.2017	09:04	36° 44.00' N	016° 01.55' W	CTD//RO*			x	x	
ME 141-2/1259-1		07.10.2017	10:31	36° 42.87' N	015° 45.27' W	EB#			x	x	
en route	M141-2 S1	08.10.2017	18:30	36° 08,20' N	08° 52,08' W	TSG pumb		1	x	x	UF**
ME 141-2/1260-1	M141-2 CTD-3	09.10.2017	02:55	35° 58.93' N	007° 05.71' W	CTD//RO*	-	-	x	x	TP***
ME 141-2/1260-1	M141-2 CTD-3	09.10.2017	03:55	35° 58.93' N	007° 05.71' W	CTD//RO*			x	x	
en route	M141-2 S1	09.10.2017	07:05	35° 55.77' N	06° 35.24' W	TSG pumb		1	x	x	UF**
en route	M141-2 S2	09.10.2017	11:28	35° 55.22' N	05° 38.78' W	TSG pumb		1	x	x	
en route	M141-2 S3	09.10.2017	16:56	36° 06.40' N	04° 16.47' W	TSG pumb		1	x	x	
en route	M141-2 S4	10.10.2017	09:28	36° 58.12' N	00° 37.67' W	TSG pumb		1	x	x	
ME 141-2/1261-1	M141-2 CTD-4	10.10.2017	13:26	37° 15.53' N	000° 10.09' E	CTD//RO*			x	x	
ME 141-2/1261-1	M141-2 CTD-4	10.10.2017	14:28	37° 15.53' N	000° 10.08' E	CTD//RO*	19	19	x	x	
en route	M141-2 S5	10.10.2017	17:00	37° 20.07' N	00° 42.45 ' E	TSG pumb		1	x	x	
en route	M141-2 S6	11.10.2017	10:00	37° 46.54' N	04° 29.17' E	TSG pumb		1	x	x	
en route	M141-2 S7	12.10.2017	06:05	38° 16,93' N	09° 13,10' E	TSG pumb		1	x	x	
en route	M141-2 S8	12.10.2017	17:00	38° 26.38' N	11° 48.37' E	TSG pumb		1	x	x	
ME 141-2/1262-1	M141-2 CTD-5	12.10.2017	18:28	38° 25.99' N	012° 06.03' E	CTD//RO*			x	x	
ME 141-2/1262-1	M141-2 CTD-5	12.10.2017	19:33	38° 26.00' N	012° 06.00' E	CTD//RO*	19	19	x	x	
en route	M141-2 S9	13.10.2017	06:05	38° 19,99' N	14° 35,79' E	TSG pumb		1	x	x	
en route	M141-2 S10	14.10.2017	06:15	36° 37.49' N	19° 16.82' E	TSG pumb		1	x	x	
en route	M141-2 S11	14.10.2017	14:07	36° 02.43' N	20° 55.78' E	TSG pumb		1	x	x	
ME 141-2/1263-1	M141-2 CTD-6	14.10.2017	14:58	35° 59.17' N	021° 03.63' E	CTD//RO*			x	x	
ME 141-2/1263-1	M141-2 CTD-6	14.10.2017	16:42	35° 59.13' N	021° 03.79' E	CTD//RO*	18	18	x	x	
en route	M141-2 S12	15.10.2017	20:37	38° 07.77' N	24° 45.04' E	TSG pumb		1	x	x	
ME 141-2/1264-1	M141-2 CTD-7	15.10.2017	21:21	38° 12.57' N	024° 48.30' E	CTD//RO*			x	x	
ME 141-2/1264-1	M141-2 CTD-7	15.10.2017	22:00	38° 12.57' N	024° 48.30' E	CTD//RO*	23	11	x	x	

EB	Expendable bathythermograph
CTD/RO	CTD/ rosette water sampler
UF	unfiltered
TP	Technical Problems
PhyPar	Physical parameters (temperature, salinity, pressure)
LightTrans	Transmissivity