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SHORT CRUISE REPORT

M211

Nice (France) - Ponta Delgada (Portugal)

13.06.2025 – 28.07.2025

Chief Scientist: Prof. Dr. Oliver Wurl

Captain: Rainer Hammacher

Cruise Track

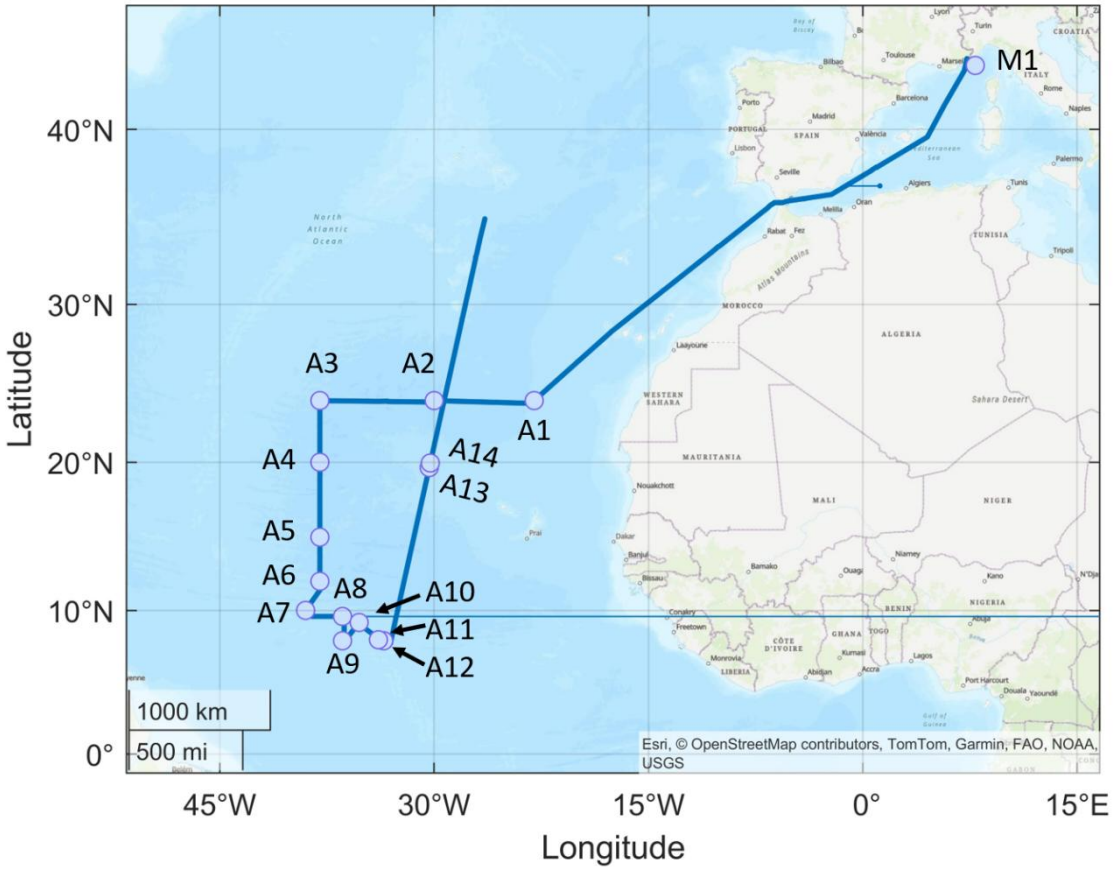

Figure 1: Cruise track of RV Meteor during M211

Objectives

At the global level, 85% of evaporation (E) and 77% of precipitation (P) occur over the oceans, clearly demonstrating that the oceanic water cycle is a key element of the global water cycle. Changes in the global water cycle due to climate change have significant societal impact, especially in areas affected by water scarcity and devasting floods However, difficulties in observing freshwater flux (i.e., evaporation rates minus precipitation rates, or E-P) limit the current understanding of the oceanic water cycle. However, difficulties in observing freshwater flux (i.e., evaporation rates minus precipitation rates, or E-P) limit the current understanding of the oceanic water cycle.

The overall goal of M211 has been to provide observational data of skin (upper 1 mm of the ocean) and near-surface salinity and temperature, and to gain mechanistic understanding of the dynamics of their anomalies. With this knowledge, we aim to understand how the skin and near-surface thermohaline field data can be used to integrate dynamic E-P fluxes in the subtropical (dominated by evaporation) and tropical Atlantic (dominated by precipitation). Interaction with atmospheric and

oceanic forcing (e.g. near-surface humidity and air temperature, biogenic surfactants films and turbulent mixing) influence the anomalies in the skin layer and needs to be quantified.

During M211, the autonomous surface vehicle (ASV) HALOBATES was deployed at 11 stations with operational time ranging from 6 to 24 hours for in situ observation of the skin layer and near-surface layer (NSL). To quantify the freshwater flux, a wide range of shipboard and airborne meteorological measurements were performed, including a disdrometer to characterize precipitation, an evaporation balance, short- and longwave radiometers, and vertical temperature, humidity and wind profiles with drones and weather ballons. Regime shifts were targeted in the form of cold pools at the most southern stations. In addition, the wide spread occurrence of floating Sargassum fields has been used to investigate thermohaline features within these fields. In addition, the sampled oceanic skin layer has been investigated on biochemical and microbiological features to study their influence on evaporative fluxes. Hydrographical features of the mixed layer depth were assessed by regular CTD profiles down to 600 meter and underway measurements. Current fields have been assessed with Lagrangian drifters equipped with additional temperature and conductivity sensors, and the operation of Acoustic Doppler Current Profiler (ADCP). In addition, an underway system has been operated for trace gas analysis (N_20, CH_4, CO_2).

Narratives

On 14 June 2025, the RV METEOR departed from Nice, France, bound for Station M1, which is located approximately 30 nautical miles off the coast. The RV METEOR remained at this station for three days. A film crew was on board to accompany our work. All equipment, including meteorological equipment, vehicles, CTD, underway systems, had been set up. Preparations for the ASV HALOBATES began at 04:30. At around 07:00, the ASV was deployed at calm sea conditions (Figure 2) and later recovered on deck before returning to the sea for afternoon sampling. First set of samples for chemical (nutrients and surfactants), bio-optical and microbiological analysis were collected. During the day, CTD profiles down to 200 metres were completed, as well one profile with a bio-optical profiler (BOP). Drone flights retrieved vertical profiles in the upper 120 metres. The following day, surface slicks were observed, and the ASV HALOBATES crossed the slicks to assess the thermohaline conditions and collect samples. As on the previous day, CTD and BOP profiles were taken, as well as drone flights. On 17 June, an ARGO float was deployed in the morning. HALOBATES was retrieved earlier than planned due to rougher seas. At around 10:00 UTC, the ship set course for Nice to change four members of the science team. During the longer transit to station A1, HALOBATES was fitted with a new set of infrared radiometers and the remotely operated vehicle GLAUCUS ATLANTICUS was prepared. In the evenings, a series of science talks were given.

On 26 June 2025, the RV METEOR reached Station A1 (24°N, 23°W) to conduct an east-west transect of the subtropical Atlantic, characterized by a maximum in surface salinity. Deployments and operations started at station A1 in the morning with HALOBATES, followed by drone flights for about an hour, CTD casts every two hours, and a BOP cast at noon. Five drifters, each equipped with a CTD and temperature sensors, were deployed alongside HALOBATES in a cluster and were later recovered in the afternoon. HALOBATES was recovered in the next morning for the first overnight operation. By evening, work at station A1 was complete. Stations A2 (29–30 June; 24°N, 30°W) and A3 (2–4 July; 24°N, 38°W) followed a similar deployment scheme. However, HALOBATES was deployed for more than 24 hours, with a recovery period of about two hours to change the battery packs and check all systems. Both in situ measurements and discrete

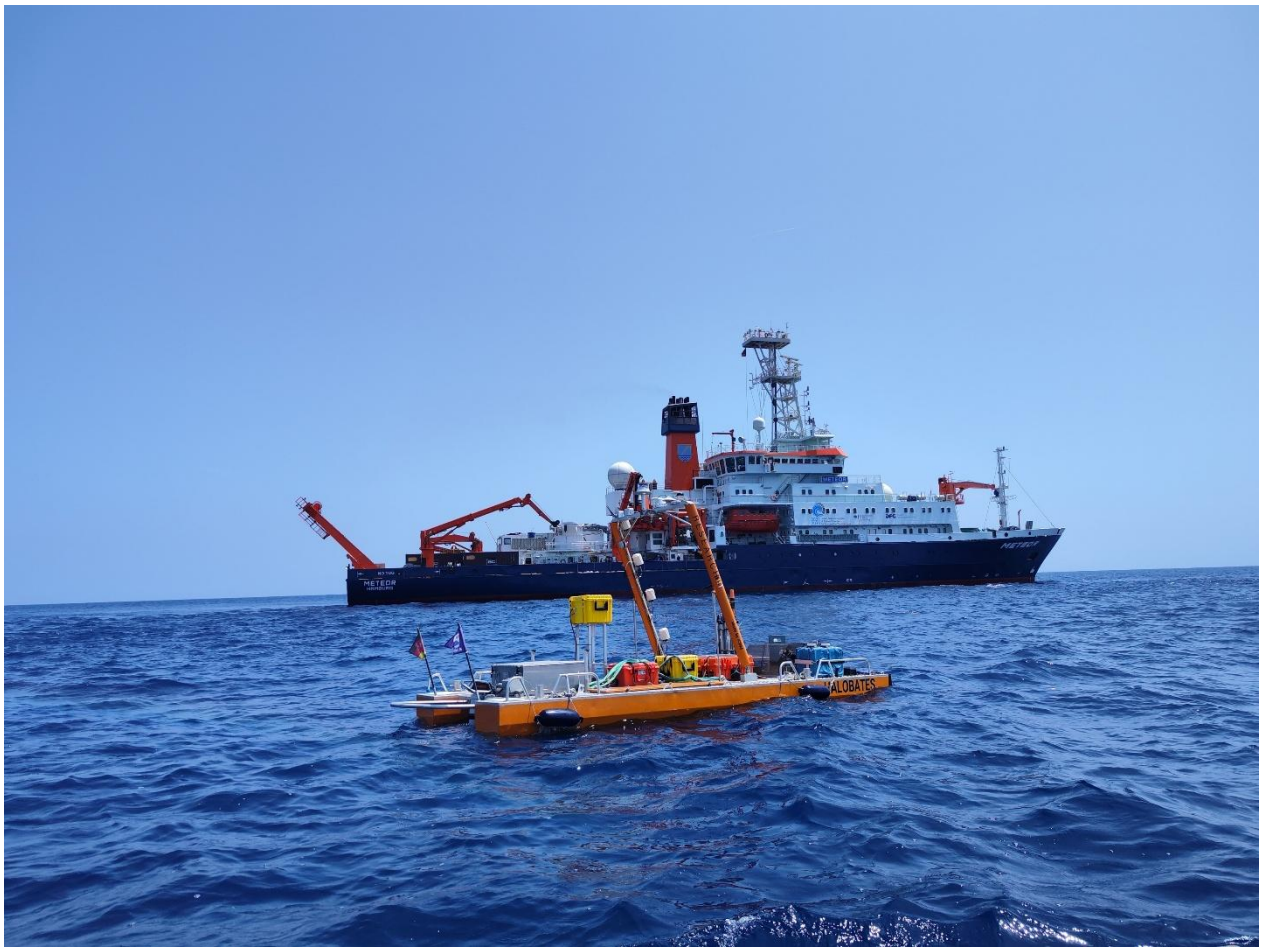

Figure 2: ASV HALOBATES operating on Station M1.

water sampling were carried out successfully. The drone team successfully completed several flights for meteorological measurements and aerosol collection. The underway system for trace gas measurements was slightly modified and tested to pump water from the CTD bottles for depth profiling. It was decided to continue trace gas sampling from the CTD on the remaining stations. Additionally, discrete samples were taken from the CTD profiles to analyse a range of microbiological parameters, bio-optics and nutrients. At station A3, deployments began in cloudy and rainy conditions, with the first sightings of Sargassum reported. The second surface vehicle, GLAUCUS ATLANTICUS, was deployed to assess pCO_2 and pH near the surface. Nearby GLAUCUS A. and from a small boat, science team collected discrete water samples from the upper two metres using a Van Dorn bottle for alkalinity and dissolved inorganic carbon (DIC) analysis. Additional alkalinity and DIC samples were taken from the skin via GLAUCUS A.'s flow-through system outlet. The science team conducted near-surface CTD casts (upper 10 metres) by hand from the small boat, and adopted this method for the following stations to retrieve casts in the morning and evening. Glaucus A. was recovered in the afternoon, while HALOBATES operated throughout the night after exchange of a broken outboarder. The following morning (4 July), data recorded by HALOBATES showed an air temperature drop of about 2°C within a few minutes. The science team identified this as the first cold pool. The data confirmed an immediate thermohaline response in the skin. Unfortunately, the drone could not fly due to darkness. In the morning of 4 July, after the first drone flights and CTD casts, GLAUCUS A. was deployed a second

time to survey pCO_2 and pH. In the afternoon, light drizzle appeared before the recovery of GLAUCUS A., the drifters and HALOBATES, completing station A3.

After station A3, the RV METEOR followed a north-south transect with stations A4 (6 July; 20°N, 38°W), A5 (8 July; 15°N, 38°W) and A6 (9–10 July; 12°N, 38°W), where there were regular sightings of Sargassum. Deployments followed the previous stations, with HALOBATES and a drifter being used for 8-24 hour operations. There were morning, afternoon and evening flights of the drones. Typically CTD casts were carried out every two hours and a daily BOP cast around noon. At station A4, deployment began in rainy conditions with intermittent showers throughout the morning. Short-term rain events were detectable in the thermohaline data obtained from the skin and NSL. At around 14:00 UTC, the team observed a second cold pool. This time, the drones were successfully deployed to study the phenomenon. At station A6, two hours of rainfall occurred in the afternoon while the HALOBATES and drifters were in the water. Another cold pool was observed around 20:00 UTC, accompanied by increasing winds. A drone and a weather balloon were launched for observation. The transit time between stations was used for downloading data, carrying out system checks and preparing for the next station. At station A6, the ladder used to attach the sensors on the HALOBATES was damaged and needed to be replaced. At station 5, one of the HALOBATES's rotating glass discs broke, but the team decided not to replace it, as the remaining five discs were able to collect a sufficient amount of skin to flush the onboard CTDs and collect discrete water samples.

At station A7 (10°N, 39°W; 11 July), the RV METEOR entered the ITCZ and it began to rain shortly before the regular deployments (drones, CTD, BOP, drifters and HALOBATES). Water samples and hand-held CTD casts from the small boat were taken during and after the rainfall. The drifters and HALOBATES were recovered before 18:00 UTC in order to finish the work at station A7. Similar daily operations continued at the following stations (A8 on 12 July, A9 on 13 July, A10 on 14 July and A11 on 15 July) with rain fronts and cold pools encountered. The science team collected data and discrete water samples whenever possible before, during and after rainfall. At station A10, Glaucus. A was deployed and operated in parallel with HALOBATES. On 15 July, crossing swells prevented the deployment of HALOBATES and the small boat. Furthermore, as it was not possible to make a clear prediction of atmospheric convection and therefore the appearance of cold pools from satellite images, the science team decided to transit to a new working area further north-east.

However, on the transit during the night of 15 July, the RV METEOR crossed a large Sargassum front (Figure 3), measuring at least 8 kilometres in length based on a wave radar (AG Jochen Horstmann, HEREON). The science team decided to set up the final station, A12, around this front and the RV METEOR remained close to it for the night. The following morning, the RV METEOR moved further to the northern end of the front to deploy equipment. HALOBATES was deployed at around 09:00 UTC, followed shortly by the GLAUCUS A. Both vehicles took samples from slicks associated with the Sargassum front, and several manual CTD profiles were recorded. Drifters were deployed both within and outside the front, as well as distinct sampling with HALOBATES both inside and outside the front for microbiological and bio-optical analysis. At 10:12 UTC, a cold pool passed through, scattering the Sargassum band. Drone flights and weather balloons were launched in time. GLAUCUS A. was recovered at 13:10, while HALOBATES continued to drift. In the evening, HALOBATES was recovered, prepared and redeployed for overnight measurements. The following morning, calm and rainy weather prevailed with scattered Sargassum patches. HALOBATES was recovered for sampling in the afternoon and redeployed at around 18:00 to drift overnight. On 18 July, HALOBATES encountered rain in the morning and, soon after sunrise,

drone flights and CTD casts followed. Additional samples were taken from the skin and NSL before and after the rain for comparison. The drifters were recovered in the afternoon. Shortly afterwards, the RV METEOR encountered a newly formed Sargassum front. HALOBATES was navigated across the front in order to characterize its thermohaline structure. Meanwhile, two rain fronts appeared from different directions, bringing very heavy rainfall. At 18:00 UTC, HALOBATES was recovered in preparation for the transit to Ponta Delgada. On 21 July, stations A13 and A14 were completed with two CTD casts for trace gas analysis. The transit time was used to pack the scientific equipment and to hold the last film nights, a farewell party and a table tennis tournament. RV METEOR arrived in Ponta Delgada for unloading on 27 July.

Figure 3: Sargassum front at Station A12

Acknowledgements

The scientific success would not have been possible without the excellent cooperation with captain Rainer Hammacher, the officers and the entire crew. Short-term changes to station plans and course changes due to the dynamic behavior of cold pools and slicks were accepted with great understanding by the bridge, the bosun, and the deck crew. Long missions led to the need for repairs, which were carried out promptly with the support of the scientific technical service, the electrician, and the deck mechanic, so that no missions had to be canceled. The food was excellent throughout, and the social gatherings organized by the stewards for the crew and scientists also contributed to the excellent cooperation. A big thank you also goes to the engineers and technicians in the engine room for the smooth completion of the journey. We thank Carola Lehners for the support in logistics.

Participant list

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Station List

Station no	Date 2025	Gear	Latitude	Longitude	Depth [m]	Days at station
M1	15.06.	HALOBATES, boat, CTD, drones - unmanned Aerial Vehicle, secchi disk, bio-optical platform, floater	N 43° 20.8685	E 007° 52.3510	-	3
A1	26.06.	HALOBATES, boat, CTD, drones - unmanned Aerial Vehicle, secchi disk, bio-optical platform, drifter	N 24° 00.0000	W 23° 00.0000	4139	2
A2	29.06.	HALOBATES, boat, CTD, drones - Unmanned Aerial Vehicle, secchi disk, bio-optical platform	N 24° 00.0000	W 30° 00.0000	5814	2
A3	02.07.	HALOBATES, GLAUCUS ATLANTICUS, boat, CTD, drones - unmanned Aerial Vehicle, secchi disk, bio-optical platform, drifter	N 24° 00.0000	W 38° 00.0000	5334	3
A4	06.07.	HALOBATES, boat, CTD, drones - Unmanned Aerial Vehicle, secchi disk, bio-optical platform, drifter	N 20° 00.0000	W 38° 00.0000	6607	1
A5	08.07.	HALOBATES, boat, CTD, drones - unmanned Aerial Vehicle, drifter	N 15° 00.0000	W 38° 00.0000	5935	1

A6	09.07.	HALOBATES, boat, CTD, drones - unmanned Aerial Vehicle, secchi disk, bio-optical platform, drifter	N 12° 00.0000	W 38° 00.0000	4210	2
A7	11.07.	HALOBATES, boat, CTD, drones - unmanned Aerial Vehicle, secchi disk	N 10° 00.0000	W 39° 00.0000	4510	1
A8	12.07.	HALOBATES, GLAUCUS ATLANTICUS, boat, CTD, drones - unmanned Aerial Vehicle, secchi disk, bio-optical platform, drifter	N 09° 35.0000	W 36° 25.0000	4208	1
A9	13.07.	HALOBATES, boat, CTD, drones - unmanned Aerial Vehicle, bio-optical platform, drifter	N 07° 54.0000	W 36° 25.0000	3841	1
A10	14.07.	HALOBATES, GLAUCUS ATLANTICUS, boat, CTD, drones - unmanned Aerial Vehicle, bio-optical platform, drifter	N 09° 10.0000	W 35° 15.0000	4772	1
A11	15.07.	CTD, drones - unmanned Aerial Vehicle, bio-optical platform,	N 07° 54.0000	W 33° 32.0000	4253	1

A12	16.07.	HALOBATES, GLAUCUS ATLANTICUS, boat, CTD, drones - unmanned Aerial Vehicle, secchi disk, bio-optical platform, drifter	N 07° 58.2985	W 33° 54.1156	6418	3
A13	21.07.	CTD	N 19° 39.1920	W 30° 20.6880	4515	-
A14	21.07.	CTD	N 19° 56.9070	W 30° 16.1940	4486	-