FS Meteor

Expedition M203 “BOWTIE”

10. August 2024 — 24. September 2024 | Mindelo — Bridgetown

7. Weekly report (16.09.2024 — 22.09.2024)

In our last week of the M203 expedition, we recovered our continuously measuring oceanographic instruments (ocean gliders and drifters) after transecting the ITCZ and started to steam towards Barbados. In this last weekly report, we introduce our drone measurements on M203, after going through all our other measurements in previous reports.

Soundings have been at the core of atmospheric measurements for more than a century, and there are no remote-sensing alternatives that can better report the state of the atmosphere, i.e. the pressure, humidity, temperature, and winds. The main objective of the TU Delft STRINQS contribution to M203 was to take soundings of the atmospheric boundary layer, sampling both horizontal and vertical gradients at scales of 1.5 km in the vertical and 2-5 km in the horizontal. STRINQS stands for Soundings & TuRbulent eddy measurements in the ITCZ with a Network of QuadcopterS. As the name suggests, the innovation here is that the campaign uses four meteorological drones. These are quadcopter flight-drones that are capable of handling strong weather conditions (heavy rain and strong winds), that most commercial drones are unable to. These drones are equipped with 2 sets of meteorological sensors to measure pressure, temperature, and humidity at 10 Hz sampling rate as well as a 1-meter arm above the drone carrying a sonic anemometer, capable of providing 3D winds at 40 Hz sampling rate. Therefore, each drone has the capability of providing horizontal transects of the boundary layer as well as vertical profiling. We planned to exploit the multiplicity of platforms at hand, and together with a network of 4 drones, aimed to cover a larger spatial region than would be possible with one drone, thus allowing for area-averaged measurements such as vertical velocity -- a notoriously difficult signal to observe. Apart from these ambitious objectives, the idea of flying such heavy-duty drones from a moving platform such as the FS METEOR is in and of itself a high-risk project. There have never been such drone flights attempted from a research vessel, let alone four simultaneous flights. Therefore, the STRINQS project is also a demonstration of the capability of carrying out such projects to obtain novel measurements of the atmospheric boundary layer.

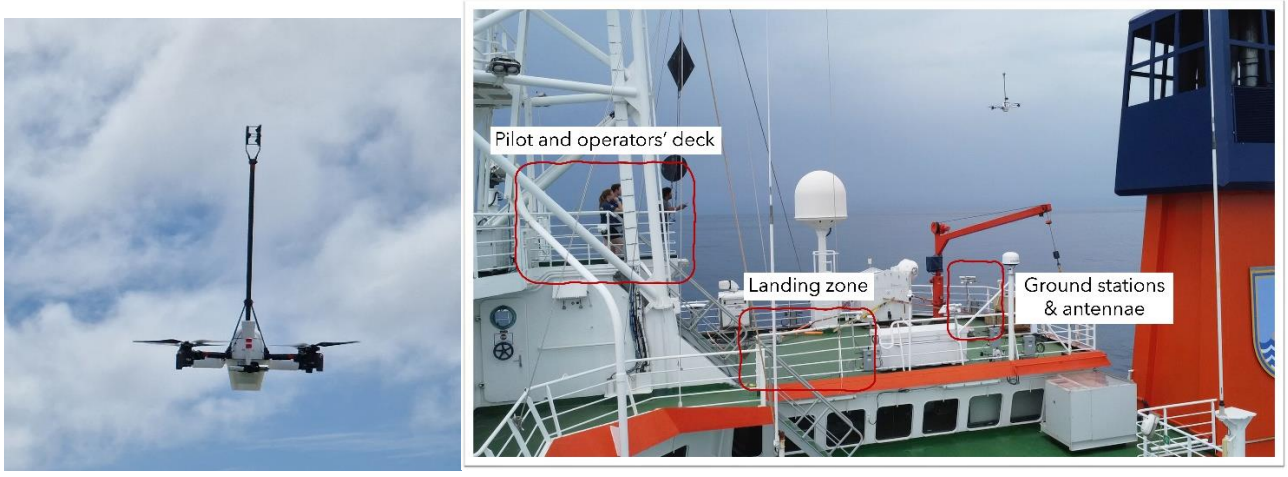

Figure 1: Drone in flight (left) and the drone operation setup for M203 on FS METEOR (right)

The STRINQS contribution to the campaign initially had a setback with the drones arriving to Mindelo very late due to unforeseen logistical issues and therefore had to disembark before FS METEOR left on August 16th, 2024. However, thanks to the support of the ship's team and the Leitstelle, the STRINQS team, with their drones, was able to rejoin from Praia around 12 days later. After two days of setting up the equipment and managing some hiccups with their batteries having been discharged during transport, the team finally made their first flights. In the beginning, the flights were mostly test flights to check communications of the drones with their corresponding ground control stations (see figure 1, systems mounted on the ship) and their remote controllers. After a few test flights, once confidence in the platform was built, the pilots started conducting measurements missions on 30th August with profiles first going up to 300 m, and then slowly building their way up to 1500 m profiles (example in figure2, the approved flight ceiling by the Dakar Oceanic Flight Information Region). The drones were also capable of carrying out horizontal transects in the shape of hexagons with 500 m sides each, thus transversing a total of more than 3000 m in the horizontal and reaching a maximum horizontal distance of around 1250 m from the ship. Such hexagons were flown at different altitudes (300 m, 600 m and 900 m being the common ones) multiple times. Two drones simultaneously flew these hexagons at the same latitude-longitudes but different altitudes for four different missions, whereas three drones achieved the same feat simultaneously once. The STRINQS team had also begun to train other scientists on board as pilots and these new trainees showed tremendous promise.

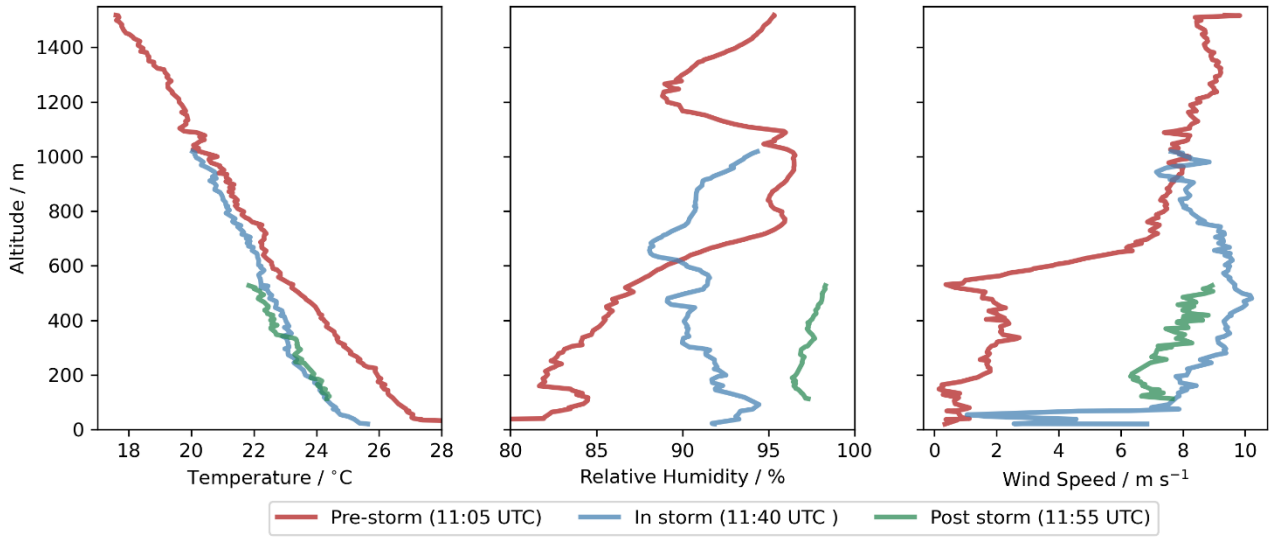

Figure 2: Atmospheric boundary layer profiles measured on the 8th of September 2024, before, during and after the passage of a gust front.

However, some unfortunate incidents occurred with the drones on the 3rd of September 2024. The team lost one of the drones to the ocean, with the reason still unclear. While the floats deployed, the drone detached from the floats and sank to the bottom of the ocean. A capacitor in one of the propellor arms of another drone immediately burnt after receiving power from the battery, putting that drone out of commission. With only two remaining drones, the team took 3 days to reassess the problems before continuing flights on 7th September. The team then performed mainly flights of vertical profiles up to 1500 m, with occasional hexagons for some flights. On the 9th of September, one of the drones lost the GPS signal immediately at takeoff and after 15-20 seconds of flight, gently landed into the ocean. This time the floats performed as expected, and FS METEOR was successful in retrieving the drone back on board. After this incident, the STRINQS team decided to cut their losses and ceased any remaining operations for the cruise.

In the end, the campaign obtained around 40 vertical profiles, and 10 hexagons, which are far less than its target of statistically sampling the ITCZ boundary layer under different wind regimes. However, the data collected still look good with some intriguing cases recorded, such as one where the boundary layer

profile was obtained before, during and after a squall line passing over a ship. In retrospect, measurement campaigns with novel strategies have always faced challenges, something the drone team experienced first-hand. Despite the challenges, what is encouraging is that forgiving some unforeseen incidents, the drones performed remarkably in distance and height endurance, as well as by sustaining flight in rainstorms where winds were greater than 30 kts. Such capabilities give hope for similar endeavors in the future, once the drones are made more reliable after repeated testing on land. For a campaign that demonstrated for the first time that a moving ship could be used as a launch pad for repeated boundary layer measurements by drones and signaling the first possibility of getting a rich spatial characterization of the boundary layer, the drone team takes its success in the (paraphrased) words of a crew member who was manning the deck during one of the missions, "You have turned Meteor into an aircraft carrier. One drone lands, the other takes off after an F1-style pit stop, and our bridge is happy to be your air traffic control center!"

Figure 3: Participants of M203 BOWTIE on FS METEOR in front of the East coast of Babados.

This afternoon we will be able to see Barbados, where our expedition will conclude. Before heading to the port of Bridgetown in Barbados, FS METEOR spend a day stationed in front of the Barbados Cloud Observatory (BCO), which is operated by Max Planck Institute for Meteorology in cooperation with Caribbean Institute for Meteorology and Hydrology (CIMH) since 2010. We will perform coordinated atmospheric measurements with the observatory and the German research aircraft HALO, which is currently stationed in Barbados as part of ORCESTRA, within which BOWTIE on FS METEOR is an important component.

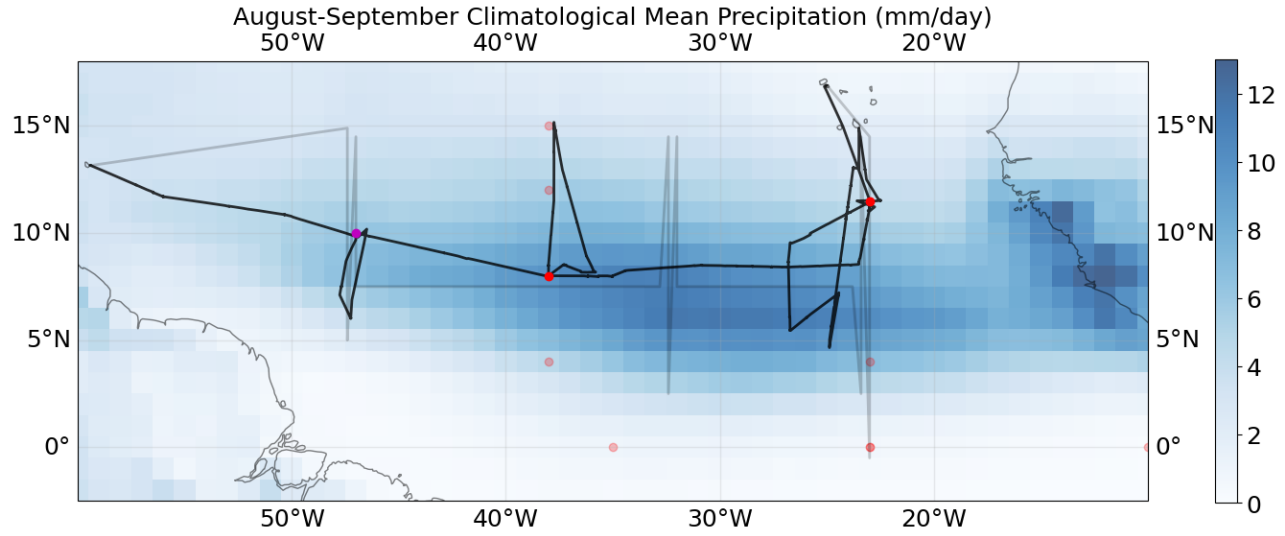

Figure 4: M203 expedition track plotted over the climatological precipitation of August-September.

The scientists of M203 are very grateful to Captain Korte and his crew. Without their professional support, this campaign would not have been possible, and they contributed enormously with their experience to making M203 a great success. The friendly and cooperative working atmosphere also made the M203 a fun and unforgettable experience. We wish everybody a safe trip home, or a successful onward journey and hope to meet again in the not-too-distant future.

Greetings from all participants of the M203 expedition from near the coast of Barbados.

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