FS METEOR

Expedition M203 "BOWTIE"

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

5 . Weekly Report (02. - 08.09.2024)

In the fifth week of our expedition, we reached our working area in the central Atlantic at 38°W. On our way west, we conducted another coordinated measurement with the EarthCare satellite (on September 3rd) and the research aircraft HALO, as well as an overflight by HALO on September 6th, when the aircraft relocated its base from Cape Verde to Barbados. At 8°N and 38°W, we deployed three ocean gliders and two drifting buoys, which will be measuring in this area while we survey the ITCZ in a north-south direction with the research vessel METEOR. The equipment will be retrieved after approximately six days before we move our working area further west.

Since August 15, 2024, we have conducted 188 radiosonde launches from the FS METEOR as part of the BOWTIE project (as of September 8, 2024). We are using Vaisala RS41-SGPE sondes, which ascend into the stratosphere to heights of approximately 25 km, carried by helium-filled weather balloons. Due to the balloon's expansion in low-pressure environments, it eventually bursts, and the sonde descends back to the ocean surface, slowed by a small parachute. This allows for the collection of two atmospheric measurement profiles per sonde launch. The sonde is equipped with sensors for temperature and relative humidity. Additionally, GPS data is used to derive wind information from the balloon's drift. The measurements are transmitted every second via radio waves to receivers on board the FS METEOR.

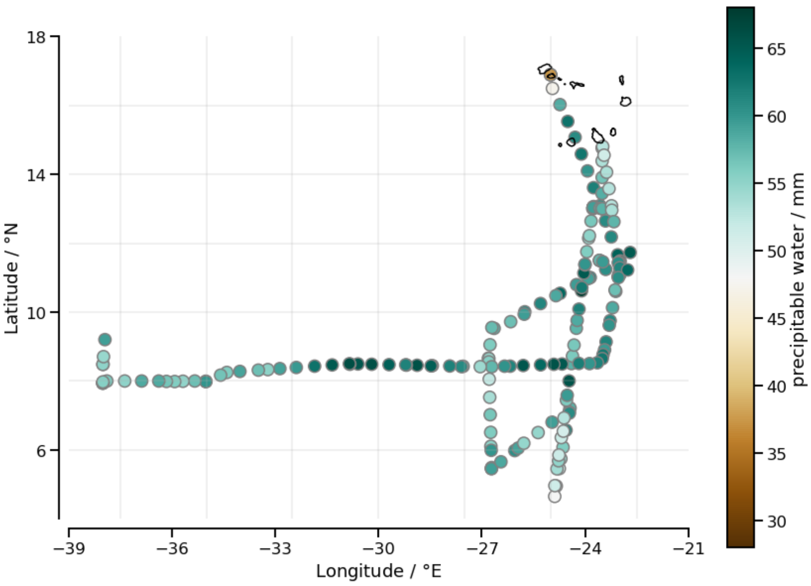

Figure 1: Launch of a radiosonde from the FS METEOR on September 4, 2024, at 10:50 UTC (left). The points on the right-hand graphic indicate the locations of previous radiosonde launches from the RV METEOR. The color shading represents the water vapor content of the atmospheric column, calculated from the radiosonde measurements.

Radiosonde launches remain indispensable for obtaining vertical profiles of essential atmospheric parameters, despite advances in remote sensing. Globally, there are about 800 stations where radiosondes are launched daily—often multiple times a day—primarily to gather data for initializing weather forecasting models. As part of the BOWTIE project, vertical profiles of atmospheric moisture, temperature, and winds are also collected from the FS METEOR using remote sensing instruments such as LIDAR (see Figure 4) and radiometer devices, which have the advantage of providing continuous measurements. However, radiosonde launches offer measurements with much finer vertical resolution and are crucial for evaluating both the remote sensing instruments aboard the FS METEOR and the retrievals from the EarthCARE satellite.

Typically, eight radiosonde launches are conducted daily, with the sondes reaching the 100 hPa pressure level (approximately 19 km altitude) at 00 UTC and then every three hours. Additional sondes may be launched during overflights to compare with observations from the HALO aircraft and the EarthCARE satellite. One of the daily launches is carried out by Martin Stelzner, a technician from the German Weather Service (DWD) on board the RV METEOR. Martin's cooperation, along with the use of both the receivers from the Max Planck Institute for Meteorology (MPI-Met) in Hamburg and the DWD's equipment on board, enables the high frequency of radiosonde launches in the BOWTIE project. Data from every second launch is transmitted in real-time to the radiosonde database of the World Meteorological Organization (WMO) and is available for weather forecasting. Positive feedback from U.S. colleagues has already confirmed the value of this data from a region that is central but poorly observed for tropical storm forecasting.

Figure 1 shows a balloon launched on September 4, 2024, at 10:50 UTC. On the map on the right, the

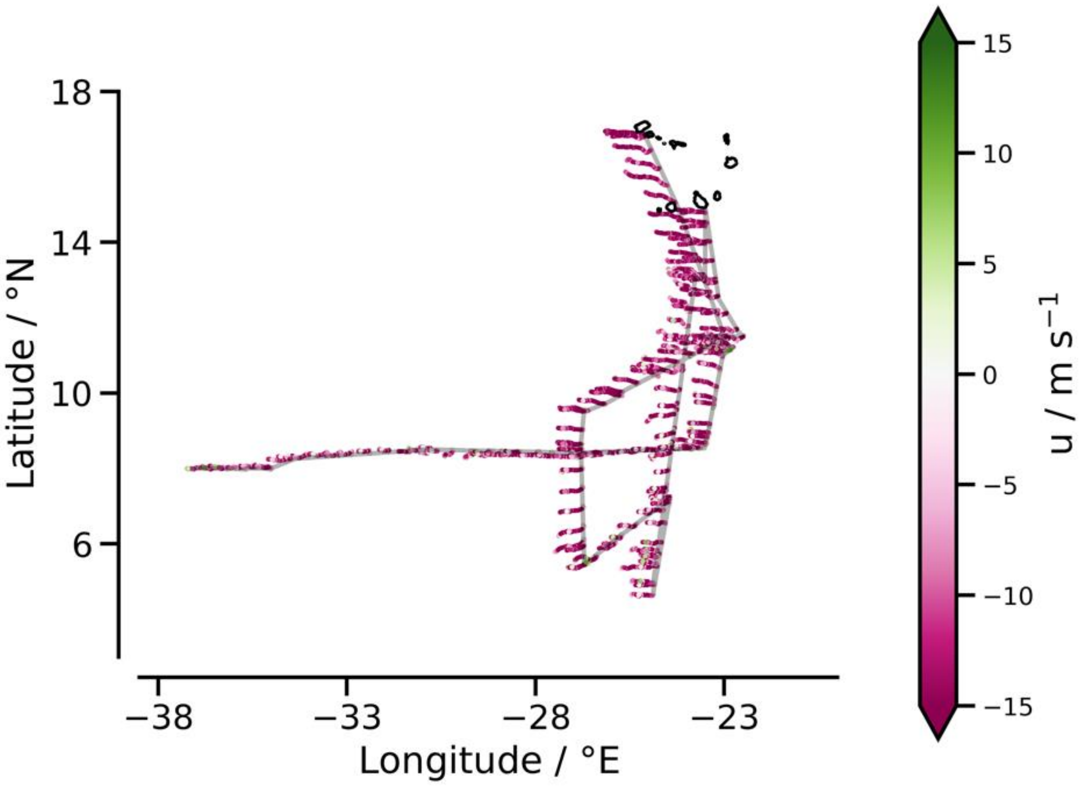

Figure 2: Trajectories of all radiosondes launched from the RV METEOR up to September 5, 2024. The color shading indicates the zonal wind at various points of the ascent. The predominant pink shading represents the relatively strong easterly winds that prevailed above the middle troposphere in all the launches.

locations of all radiosonde launches from the BOWTIE campaign up to September 7, 2024, are marked. The color shading represents the vertically integrated water vapor content of the atmosphere, which was calculated from the radiosonde measurements. To ensure comparability between the individual launches, the vertical integration is uniformly conducted from the surface up to the 100 hPa pressure level (approximately 19 km). The water vapor content of the atmospheric layers above this is usually less than 1 mm and can be neglected. Measurements exceeding 48 mm are characteristic of the Intertropical Convergence Zone (ITCZ), the region where the convergence of the trade winds triggers convection. A better understanding of this zone is a key goal of the ORCESTRA campaign, to which BOWTIE contributes ship-based measurements. Only the first measurements, which were launched in the port of Mindelo (Cape Verde), show values well below 48 mm, indicating a location clearly outside the ITCZ. On August 23, 2024, we reached the southern edge of this zone at approximately 4.5°N/25°E. Figure 2 shows the trajectories of all radiosondes launched up to September 5, 2024. All the radiosondes drifted westward, although monsoon winds from the west prevailed in the planetary boundary layer and sometimes up to altitudes of about 6 km until around September 2, 2024. However, over the entire series of launches, these winds were dominated by the prevailing easterly winds in the higher layers.

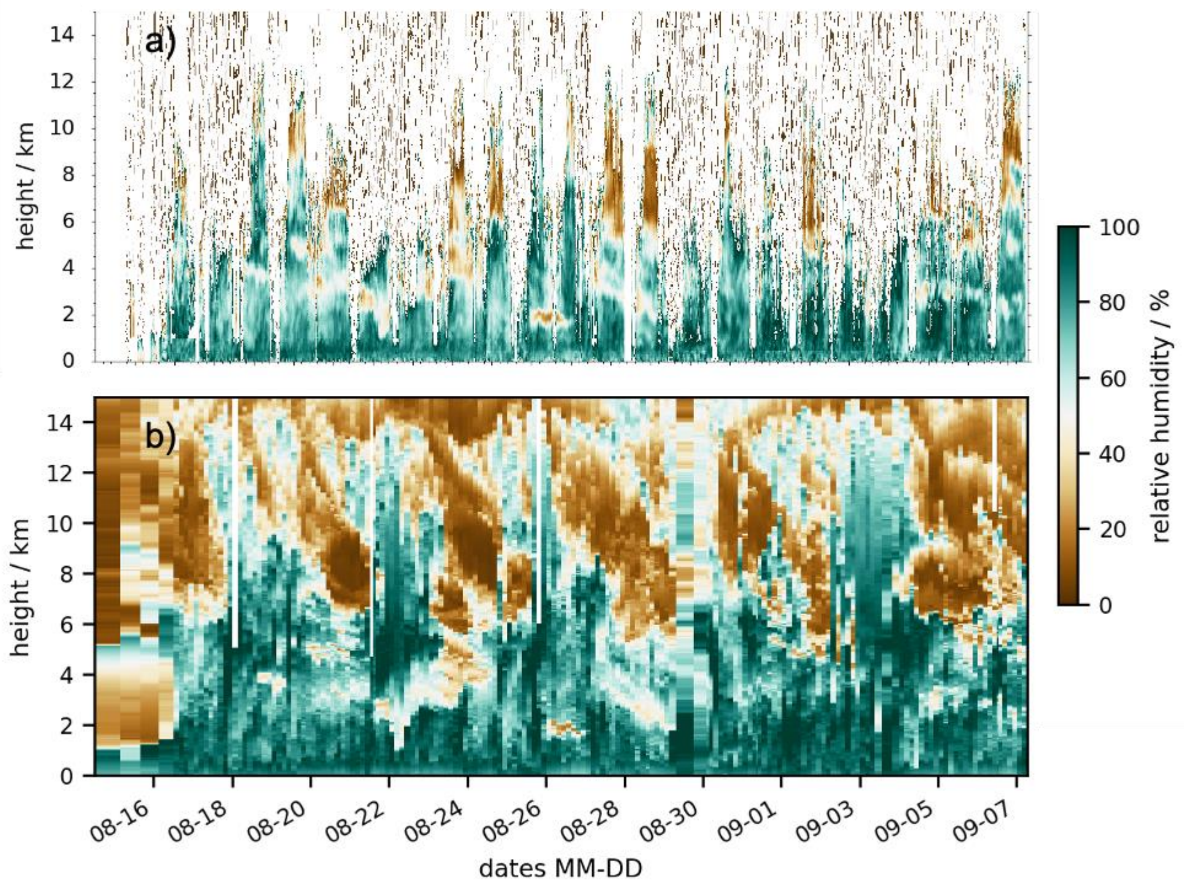

Figure 3: Vertical profiles of relative humidity (with respect to liquid water) from a) measurements with the LICHT lidar and b) radiosonde launches from the RV METEOR in the tropical Atlantic between August 15 and September 7, 2024.

Figure 3 highlights the vertical distribution of relative humidity, measured using two methods: the Raman Lidar LICHT ("Lidar for Cloud, Humidity, and Temperature profiling") from the MPI-Met, and the radiosondes. LICHT is operated on board the RV METEOR in collaboration with a colleague from the National Observatory of Athens, Greece. The Lidar system is capable of continuous measurement (the data in the figure is based on hourly averages) and provides a true vertical profile (see Figure 3). However, the water vapor content of the atmosphere can only be measured below clouds and not during strong sunlight with a small zenith angle. For the periods when data from both systems are available, a good agreement is observed.

Figure 3 is not only an example of the evaluation of remote sensing instruments using radiosonde launches, but also of meteorological interest. The alternating sequence of relatively moist and dry atmospheric conditions, particularly between about 6 and 14 km in height, with a periodicity of around four days, is due to so-called "African Easterly Waves." These westward-propagating, convectively coupled equatorial Rossby waves travel with phase speeds typically between 5 and 10 m/s from the African continent across the tropical Atlantic. They are of particular interest because tropical depressions and occasionally hurricanes can develop from them.

The analysis of the vertical structure of these waves over the ocean has, until now, been primarily based on model data. The high-frequency vertical profiles of the atmosphere obtained during the BOWTIE campaign provide an additional source of information to better understand these waves. The data collected so far show that the structure of the ITCZ, at least in the eastern Atlantic, is strongly influenced by these waves.

In the coming week, we will continue surveying the ITCZ in the central Atlantic. Before shifting our work area further west. We will retrieve the oceanographic instruments at 8°N and 38°W, and use the remaining two weeks to measure transects of the ITCZ in the western Atlantic.

Greetings from all participants of the M203 expedition in the central tropical Atlantic.

Daniel Klocke[1] (Chief scientist, M203) und Hauke Schmidt[1] (Scientist, M203)
[1]Max-Planck-Institute for Meteorology, Hamburg, Deutschland