Reviewer comments in black, answers in blue and changed text passages in black/red

RC1 (18.04.2025)

Overall, I believe this manuscript suits well with the scope of AMT and is well-written, warranting publication after addressing two concerns and minor technical questions.

We appreciate the reviewer's positive evaluation of the manuscript and the valuable hints and recommendations provided.

1. The aluminum rail in this RoLi system. I don't see a detailed description and evaluation of the strength of this commercial rail system. The Authors stated that "...is ideal for RoLi" but according to Figures 1 and 2, the thickness of the aluminum rail is notably smaller than the supporting frame. Considering the pulling forces from the ~80kg instrument payload, it would be more convincing if the authors could add some evaluation results about the strength. I am sure some words from the manufacturer's specifications would strengthen this claim.

   Thanks for this comment. We have clarified the specifications of the rail in our response here and in the manuscript text. The aluminum rail is a commercial product provided by the company HighStep Systems AG (https://www.highstepsystems.com/en/climbing-system-and-fall-protection/highstep-rail/#technische-daten). According to the manufacturer's specifications, the rail has a stiffness rating of 5 tons per 6-meter segment. This rating ensures that the rail can safely support the dynamic and static loads associated with the RoLi system, including the ~80 kg instrument payload. Although the rail appears thinner than the supporting frame in Figures 1 and 2, it is specifically engineered to provide high strength-to-weight performance. We have included this information now in the revised manuscript to support our claim that the rail is indeed well-suited for the RoLi application.

   Line 95 to 98:

   ... The rail consists of 6 m sections, each secured to the tower structure every 3 m, and is engineered for high strength-to-weight performance. It has a stiffness rating of 5 tons per 6-meter segment, sufficient support both static and dynamic loads of the RoLi system, including the approximately 80 kg instrument payload. This commercial rail system is ideal for RoLi, as it has been easy to install and maintenance-free. ...

2. Potential contamination of the RoLi system. In this paper, the authors demonstrated the application of RoLi system in the research area related to aerosol profiles. I am sure with such a payload, this system can support measurement of other targets, even VOCs. It would be great if the authors could clarify whether lubricants, solvents, or maintenance materials could introduce interference. Such words would enhance the credibility for multi-purpose future applications.

   The reviewer points out an important topic: potential contaminations (of any kind) by the RoLi platform itself have been discussed and considered carefully during the development phase. Outgasing compounds, such as lubricants, have been avoided as far *as possible. No lubricant is for instance used on the rail itself. For some moving parts, however, lubrication was necessary, which could cause contaminations especially with measurements of volatile organic compounds (VOCs). Specifically, the RoLi system uses high-temperature grease on moving components, which could under certain conditions be a potential source of VOC contamination. For upcoming VOC measurements, targeted tests are planned to identify such potential interferences. Constructive changes on the system, such as a shielding of certain parts or relocation of the inlet, might be required. Alternative lubricants could be considered as well, if the currently used substances turn out to cause interferences.*

Line 450 to 455:

...Furthermore, none of the aerosol and ozone data show any measurement artifacts or interference from the tower or the RoLi platform, as no particles are generated and emitted during RoLi's operation. For upcoming VOC measurements, targeted tests are planned to identify potential interferences from the RoLi platform itself, such as emissions from lubricants or other construction materials. Modifications to the system, such as shielding of specific components or relocation of the inlet, might be required. Alternative lubricants, such as low-emission greases, could also be considered if the currently used substances are found to introduce contamination. ...

Below are some more specific comments:

1. Line 105: Insulation is crucial for the tower-based measurements. I am thinking the 100 kΩ resistance threshold for power supply reactivation described by the authors might lead to frequent restarts when the unstable resistance fluctuates around 100 kΩ. Maybe a higher restart resistance threshold would be better to prevent unnecessary power cycling and reduce hardware stress.

   We have indeed considered adjusting the insulation threshold to reduce the potential for frequent shutdowns due to transient fluctuations around the 100 kΩ value. However, regular cleaning of the algae and dirt buildup on the power rails has proven effective in maintaining sufficient insulation and preventing undesired power interruptions. While lowering the insulation threshold might reduce the number of shutdowns, it could compromise safety by weakening the ground fault protection. Since insulation-related power losses occur mainly during heavy rain events and remain rare overall, we have opted to retain the 100 kΩ threshold to ensure operational safety without introducing unnecessary risks.

2. Line 155: My experience with Raspberry Pi won't allow me to trust such a small processor. The connection between the RoLi system and the ground station is essential since the loss of connection would trigger the alarm. I don't know how frequently the connection check was scheduled (which should be mentioned), but I have double that this Raspberry Pi can handle such a burden of work.

   The connection monitoring system sends a keepalive signal once per second (info added to manuscript). This interval is configurable via software. During extended field operation, we have not experienced any false positives or missed detections. Given that RoLi's maximum movement speed is 0.3 m/s under normal conditions, any connection loss would be detected within approximately 30 cm of travel. It is also important to clarify that the connection to the ground station is primarily used for transmitting new positioning *commands and data transfers. All real-time positioning, movement execution, and monitoring are handled autonomously by the onboard Raspberry Pi in conjunction with the motor controllers. Furthermore, key safety functions, such as emergency stop and overspeed protection, are directly implemented on the motor controllers themselves, providing an additional layer of independent protection in the event of Raspberry Pi failure.*

3. Line 164: I understand that the selection of Cyberbajt YAGI 24-16-2.4 was well discussed by authors and technicians, but some descriptions would be great to show the capability of the effective range and signal strength, etc.

   The Cyberbajt YAGI 24-16-2.4 is a directional 2.4 GHz antenna with 16 dBi gain, well suited for outdoor point-to-point or point-to-multipoint communication over moderate distances. Supporting standard WiFi protocols (IEEE 802.11b/g/n) and built with weather-resistant materials, it ensures stable performance in harsh environments. Under ideal conditions with clear line of sight (which is the case between the RoLi ground station and RoLi on the tower), it can reach distances of up to ~7 km, making it a reliable option for wireless data transmission in field deployments (info added to manuscript).

   Line 172 to 175:

   … RoLi itself is equipped with a long-range Wi-Fi antenna (Cyberbajt YAGI 24-16 - 2.4 GHz Wi-Fi Directional Yagi Antenna, Cyberbajt, Młyńska 27, 22-400 Zamość, Poland) offering a reliable line-of-sight range of up to 7 km and ensuring stable communication and data transmission between the RoLi system and the ground station under outdoor field conditions (Figure 1). …

4. Line 221-226: When there is heavy wind with wind speed exceeding 15 m/s, the contingency plan is to send the RoLi system “go to home”, as stated by the authors. My point of view is that staying where it is would be safer. During situations with heavy wind or lost connection, either moving upward or downward is not safe, especially when the connection alarm is triggered, which would send the system home, but if there is something wrong with the rail lower than the current system location, the system is out of control to stop, leading to a dangerous situation. Please correct me if there are unmentioned advantages of the current plan.

   To ensure safe operation, the RoLi system is designed to return to the ground automatically in potentially hazardous conditions. If a wind or connection alarm is triggered, for example during sudden gusts, the system immediately begins a downward movement at maximum speed (0.33 m/s), minimizing the time spent at higher elevations where wind loads are greater. Keeping the system elevated during strong winds could cause the lift to swing, potentially placing mechanical stress on both the rail and the lift itself. The wind alarm is configured to trigger already under conditions that are still considered safe, acting as a preventive measure to avoid exposure to unsafe wind speeds.

   In addition to this automatic safeguard, an operator is always present during RoLi operations and continuously monitors weather conditions. If thunderstorms or strong winds are expected, the operator proactively lowers the system in advance.

   Even during automatic descent, RoLi’s built-in motor safety features remain active and take priority. If the system encounters any obstruction or abnormal mechanical load, it *stops immediately to prevent damage. In addition, an emergency power-off button is installed at the tower base next to the power supply. This allows the operator to immediately stop RoLi under any circumstances, providing an additional level of manual control, even when radio and WiFi connection to RoLi is lost. Finally, the rail system is regularly inspected to ensure its integrity, adding a further layer of operational safety. Taken together, we believe the current "go to home" procedure represents a safe and reliable strategy for handling adverse weather conditions. The manuscript text has been revised as follows:*

Line 222 to 248:

To further enhance safety during operation, especially when the lift is in automatic mode, several safety features have been implemented in the control software and on RoLi:

- ***Wind Alarm:** Wind data from the onboard weather station are continuously monitored to detect such situations. If the wind speed exceeds 15 m/s for more than five seconds, a wind warning is automatically triggered in the control software. This action stops any ongoing automatic operation, disables user inputs, and immediately issues the "go to home" command. The system then descends at a speed of 0.33 m/s, minimizing the time spent at higher elevations where wind loads are more severe. Keeping the system elevated during strong winds could cause the lift to swing, potentially placing mechanical stress on both the rail and the lift structure. The wind alarm is configured to activate already under conditions that are still considered safe, serving as a preventive measure to ensure RoLi is not operating at height during unsafe wind conditions. In addition to this automatic safeguard, an operator is always present during RoLi operations and continuously monitors the weather. If thunderstorms or strong winds are expected, the operator proactively lowers the system in advance, providing an additional level of safety and control.*
- ***Connection Alarm:** If the Wi-Fi connection to the ground station is lost, within one second a connection error is triggered and RoLi automatically drives to the home position at a speed of 0.05 m/s, and all user inputs, as well as automatic mode, are deactivated.*
- ***Temperature Alarm:** If the temperature of one of the motors or motor controllers exceeds 70 °C, a temperature warning is triggered. Above 60 °C, the cooling fans mounted on top of the motor control unit are activated to prevent further temperature increases. During normal operation, the temperatures of the motors and motor controllers always remained below 70 °C. If the temperature warning is triggered, the lift immediately stops all operations and locks in place, waiting for the motors to cool down.*

Even during automatic descent (during normal operation and in case an alarm is triggered), RoLi's built-in motor safety features remain active and take priority. If the system encounters an obstruction, such as dirt accumulation or an object blocking the rail, the onboard electronics detect the resulting increase in motor current and torque, immediately stop the movement, and disable user inputs to prevent damage. An emergency power-off button is also installed at the tower base next to the power supply. This allows the operator to stop RoLi immediately under any circumstances, providing an additional level of manual control, even when radio and Wi-Fi connection to the system is lost. Finally, the rail system is regularly inspected to ensure its integrity, adding a further layer of operational safety.

5. Line 242: Overheating inside the box is always painful. My recommendation is to use aluminum-coated foam wrapping around the box. It works great based on my experience.

   Many thanks for this suggestion. Aluminum-coated foam wrapping could indeed be an additional measure to prevent overheating. Our ventilation system, combined with a double-roof design, has proven to be sufficiently effective so far, even under hot and sunny conditions. In practice, the internal temperature of the box - with all instruments and pumps running - remained only about 5 °C above ambient temperature.

6. Line 299: It would be more informative if the authors could provide the list of instruments or the compounds being measured permanently at the top of the ATTO tower.

   We agree that providing more detail on the permanently installed instruments adds clarity and context. At different inlet heights along the ATTO tower, a range of atmospheric parameters has been continuously monitored. These parameters include aerosol number size distributions (measured with an SMPS, ~10–400 nm), aerosol mass concentrations (PM_2.5 and PM_{10}), black carbon (BC) mass, ozone (O_3), volatile organic compounds (VOCs), carbon dioxide (CO_2), and basic meteorological variables such as temperature, humidity, wind speed, and direction (specifications added to manuscript). This information is provided in the manuscript in the following sections:

   Line 41 to 45:

   ... To capture the vertical exchange and processing of gases and aerosols, measurements are typically conducted at multiple inlet heights. At ATTO, greenhouse gases are currently measured at six heights (4, 42, 81, 150, 273, 321 m), volatile organic compounds (VOCs) at four heights (i.e., 40, 80, 150, and 321 m; (Zannoni et al., 2020; Pfannerstill et al., 2021; Ringsdorf et al., 2024), reactive species such as ozone at eleven heights (i.e., 0.05, 0.5, 4, 12, 24, 36, 53, 79, 80, 150 and 320 m), and aerosols at two heights (i.e., 60, and 325 m, (Andreae et al., 2015; Franco et al., 2024; Machado et al., 2024)). ...

   Line 313 to 317:

   ... The 15-minute waiting time at the top of the tower allowed the motors to cool down and provided an opportunity to compare the RoLi instrument data with measurements from permanently installed instrumentation at the top of the ATTO tower. These include continuous measurements of aerosol number size distributions (approximately 10–400 nm, SMPS), aerosol number concentration, aerosol mass ($PM_{2.5}$ and PM_{10}), black carbon, ozone, VOCs, CO_2, and basic meteorological parameters, enabling effective intercomparison and calibration of the RoLi system. ...

7. Line 381-382: I am sure the authors had done that, but are there other parameters measured at the top of the ATTO tower that can help with the analysis?

   We are currently working on an in-depth analysis of all the data measured with RoLi over nearly two years, which will be presented in several follow-up studies. The main aim of this manuscript is to demonstrate the functionality and potential of the RoLi platform in detecting and characterizing transient features in the vertical aerosol profile.

8. Line 407-409: A small K-type thermocouple works great in the described situation. Lightweight and adaptable. So thin that it won't be bent by heavy wind. You can set it away from the box and the frame to avoid interference.

   A small K-type thermocouple is indeed a good option for this application due to its low weight, flexibility, and minimal wind resistance. Placing it slightly away from the box and supporting structures to avoid heat interference is a helpful idea and will be considered for future improvements of the setup. Many thanks for this suggestion.