Radiosonde cluster launch experiment

CISM, Udine, Italy, June 19 2024

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1 Experiment setup and packet statistics

The experiment was set up with the following instruments:

- A cluster of 10 radioprobes suspended from disposable Mater-Bi balloons filled with helium.
- Three ground stations to receive data packets from the radiosondes: a **fixed station** at the launch site and **two mobile stations** mounted on vehicles.

Merged dataset from all ground stations			
probe	**number of packets**	**duration [hh:mm:ss]**	**sample rate [1/s]**
1	-	-	-
2	842	00:55:53	0.25
3	625	01:21:42	0.13
4	903	01:18:13	0.19
5	792	01:09:21	0.19
6	986	01:22:56	0.20
7	793	01:19:53	0.17
8	1357	01:30:09	0.25
9	1074	01:16:23	0.23
10	1032	01:24:32	0.20
Average number of packets per second			**0.20**

Table 1: Statistics of radiosonde packets received during the experiment. Communication with probe 1 was lost after launch (16:40 UTC, June 19, 2024, Udine, Italy). The expected packet transmission rate was approximately 1 every 4-5 seconds.

2 Trajectories and raw measurements

Current version of the radioprobe comprises a set of components, such as (Paredes Quintanilla et al. [2021], Abdunabiev et al. [2024]):

- Radio transmission module;
- GNSS (Global Navigation Satellite System) sensor;
- IMU (Inertial Measurement Unit) including accelerometer, gyroscope; and magenometer sensors
- PHT (Pressure, Humidity, Temperature) sensor.

Each radioprobe transmits a data packet to the receiver station with proprietary LoRa based transmission protocol. The data packet is uniquely identified with the pair of radioprobe id and data packet counter values.

Radiosondes traveled along the wind direction towards the north-east as also predicted by ARPA-FVG (Figure 1). Only at the end, they changed the direction towards north-west while they were descending to lower altitudes (Figure 2).

[1] See sensor datasheet.

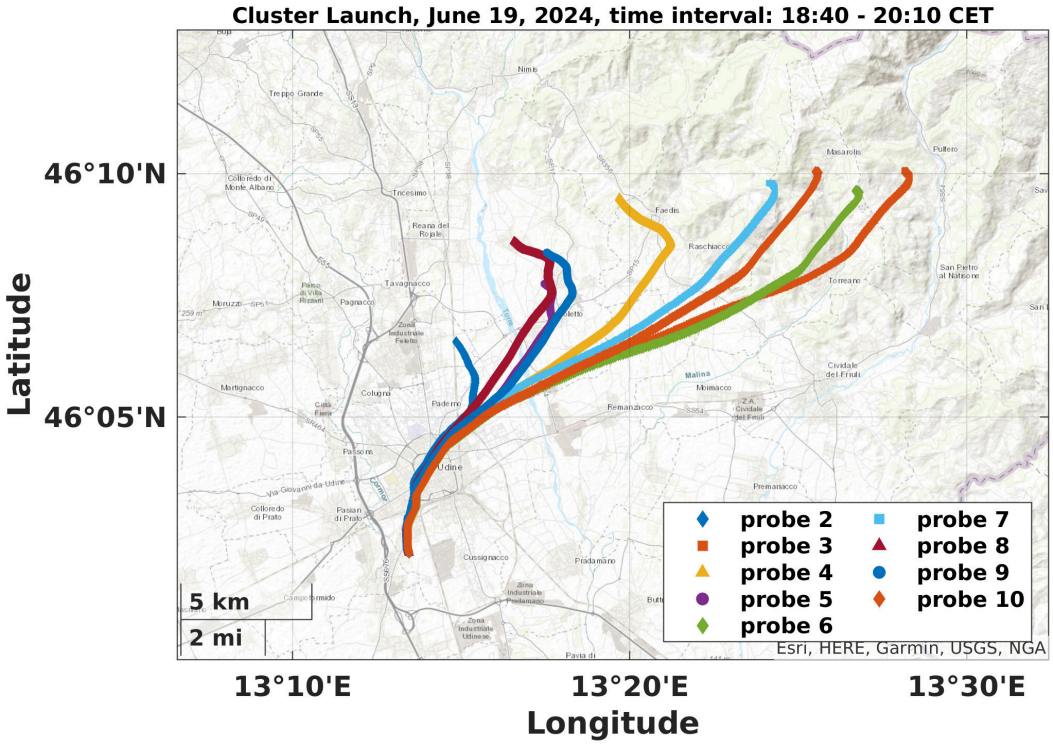


Figure 1: Radiosonde Trajectories (Launch: 16:40 UTC, June 19, 2024, Udine, Italy). Reference position: Longitude 13.2237°, Latitude 46.0366°, Altitude 92 m.

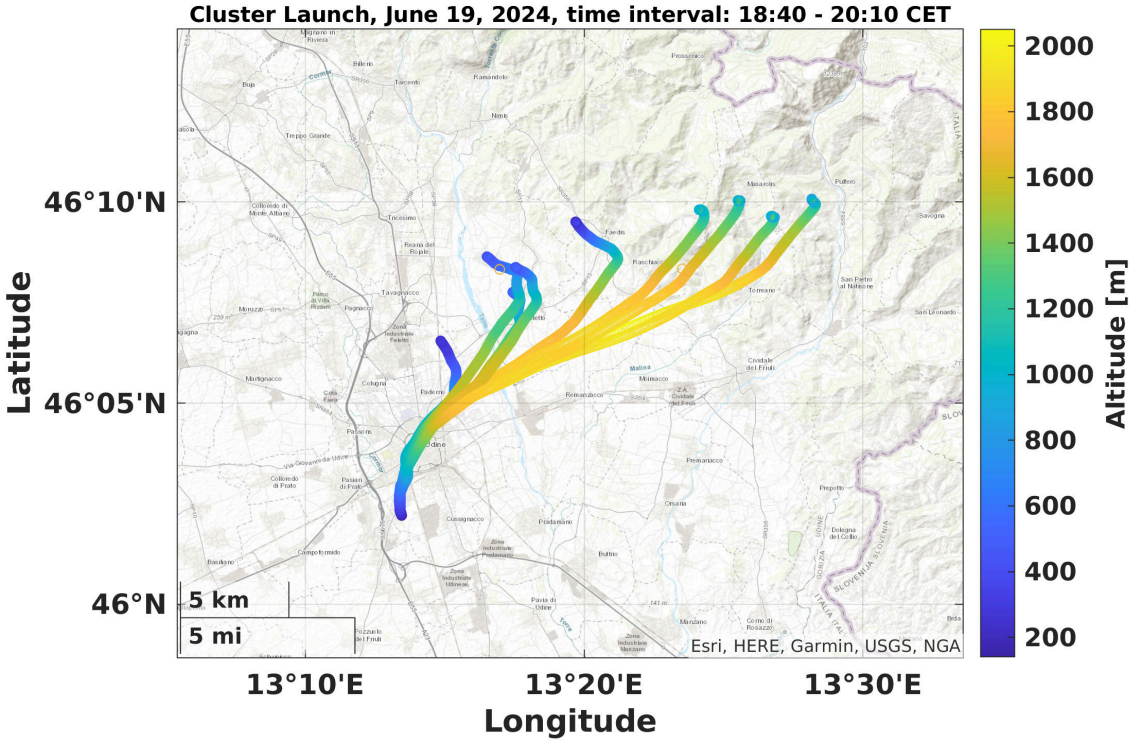
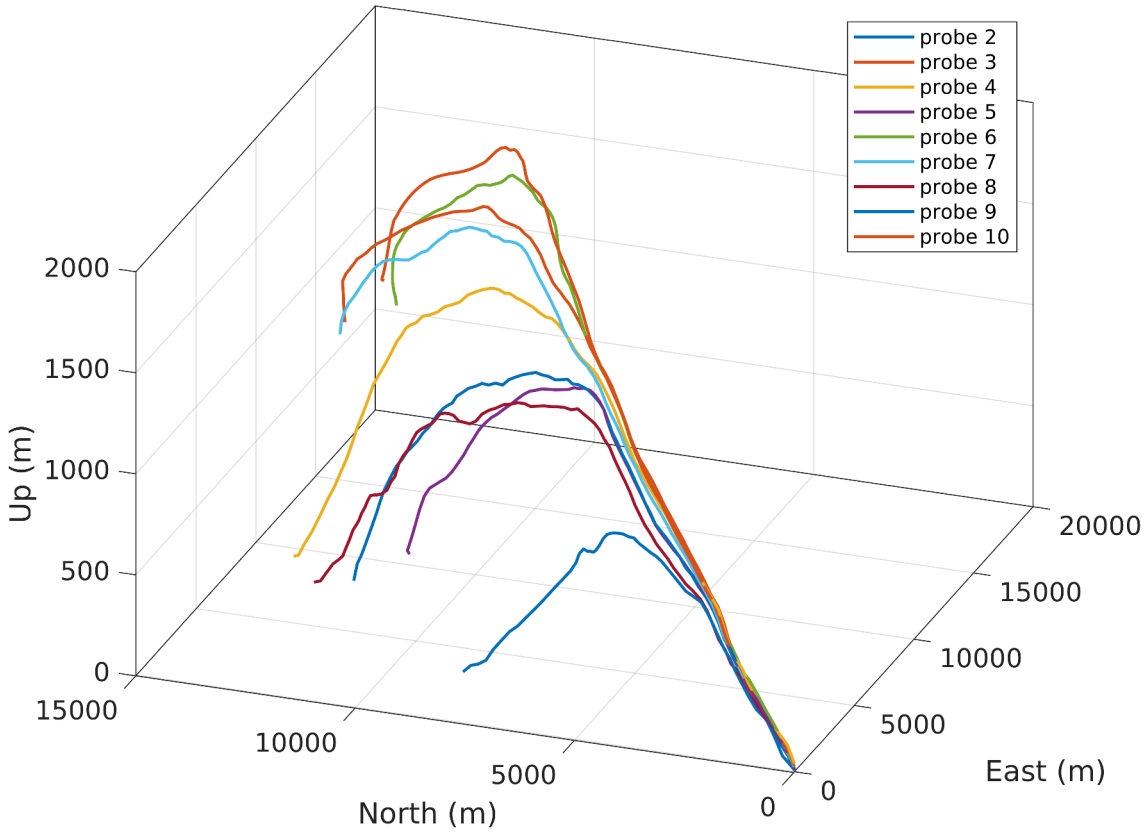
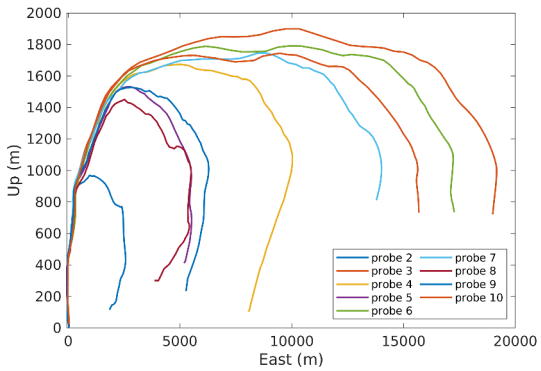


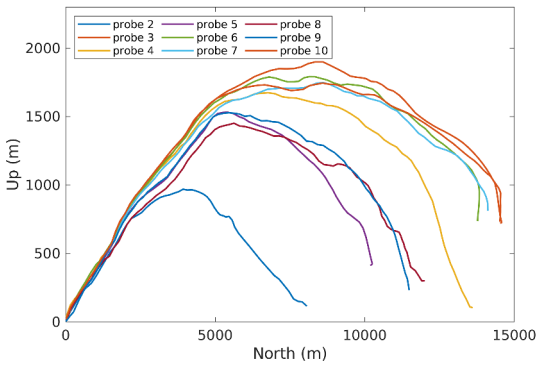
Figure 2: Radiosonde Trajectories (Launch: 16:40 UTC, June 19, 2024, Udine, Italy). Reference position: Longitude 13.2237°, Latitude 46.0366°, Altitude 92 m. Additional Information: Colorbar indicates the altitude reached by the radiosondes.



(a) 3D trajectories



(b) 2D, east-up plane



(c) 2D, north-up plane

Figure 3: Radiosonde Trajectories (Launch: 16:40 UTC, June 19, 2024, Udine, Italy). This figure shows the trajectories of radioprobes in East (X), North (Y), and Up (Z) directions relative to the launch location (Longitude 13.2237°, Latitude 46.0366°, Altitude 92 m). Panel (a) displays the 3D trajectory, while panels (b) and (c) present the 2D trajectories in the East-Up (X-Z) and North-Up (Y-Z) planes, respectively.

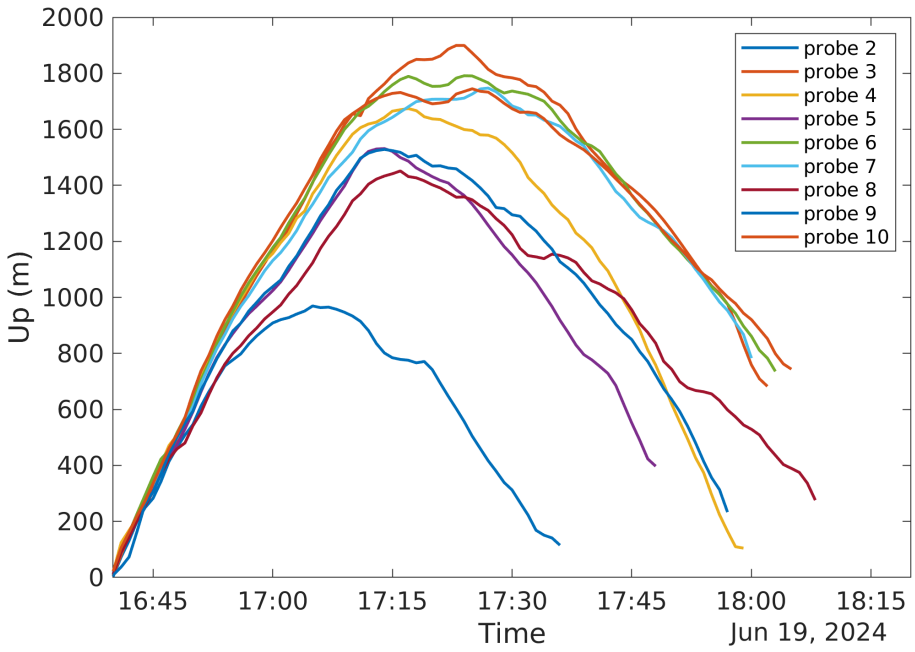


Figure 4: Radiosonde altitude readings (Launch: 16:40 UTC, June 19, 2024, Udine, Italy). This figure shows the trajectories of radioprobes in Up (Z) direction relative to the launch location (Longitude 13.2237°, Latitude 46.0366°, Altitude 92 m).

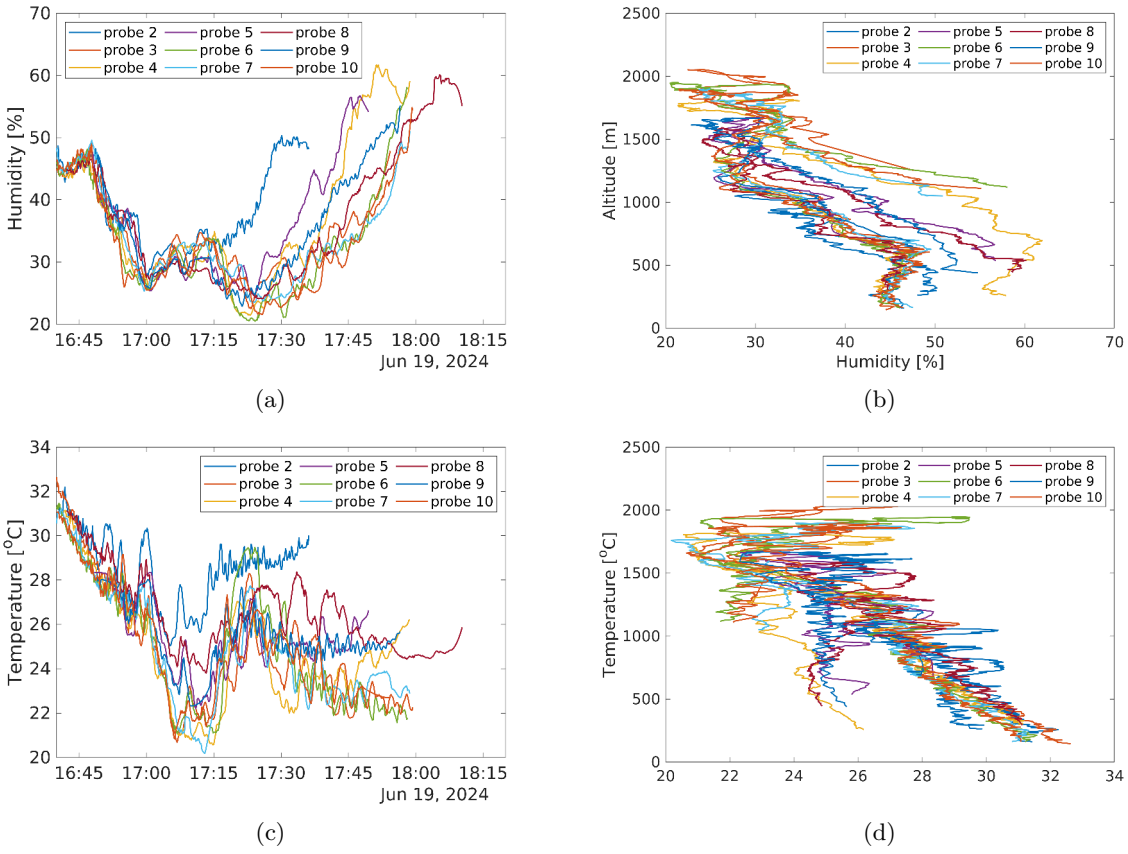


Figure 5: Humidity and Temperature Readings. This figure depicts variations in humidity and temperature as functions of time and altitude for the radiosonde measurements. The launch time was 16:40 UTC on June 19, 2024, from a reference position of longitude 13.2237°, latitude 46.0366°, and altitude 92 meters.

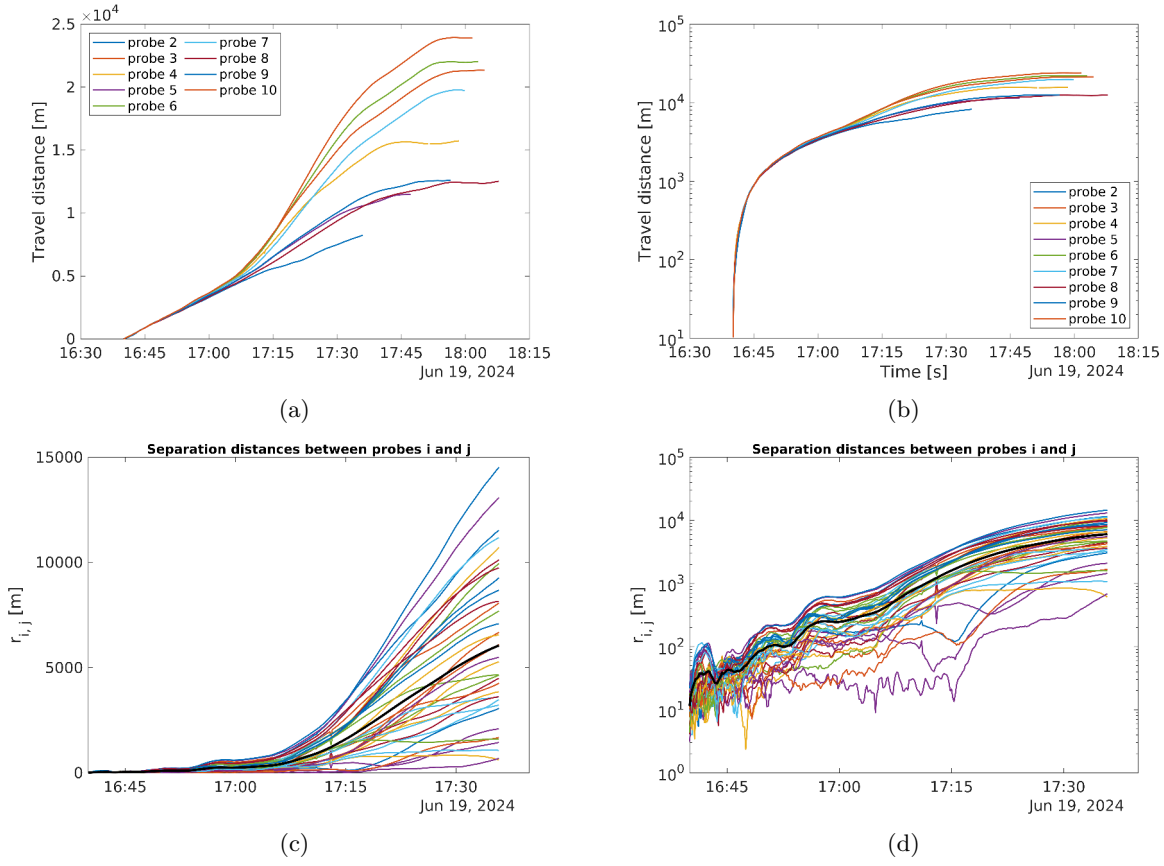


Figure 6: Travel and separation distances during the flight (Launch: 16:40 UTC, June 19, 2024, Udine, Italy). Panels (a) and (b) show the travel distances of the radiosonde probes during the flight, displayed in both normal and logarithmic scales, respectively. Panels (c) and (d) illustrate the separation distances between all pairs of probes throughout the flight. The solid black line represents the mean separation distance.

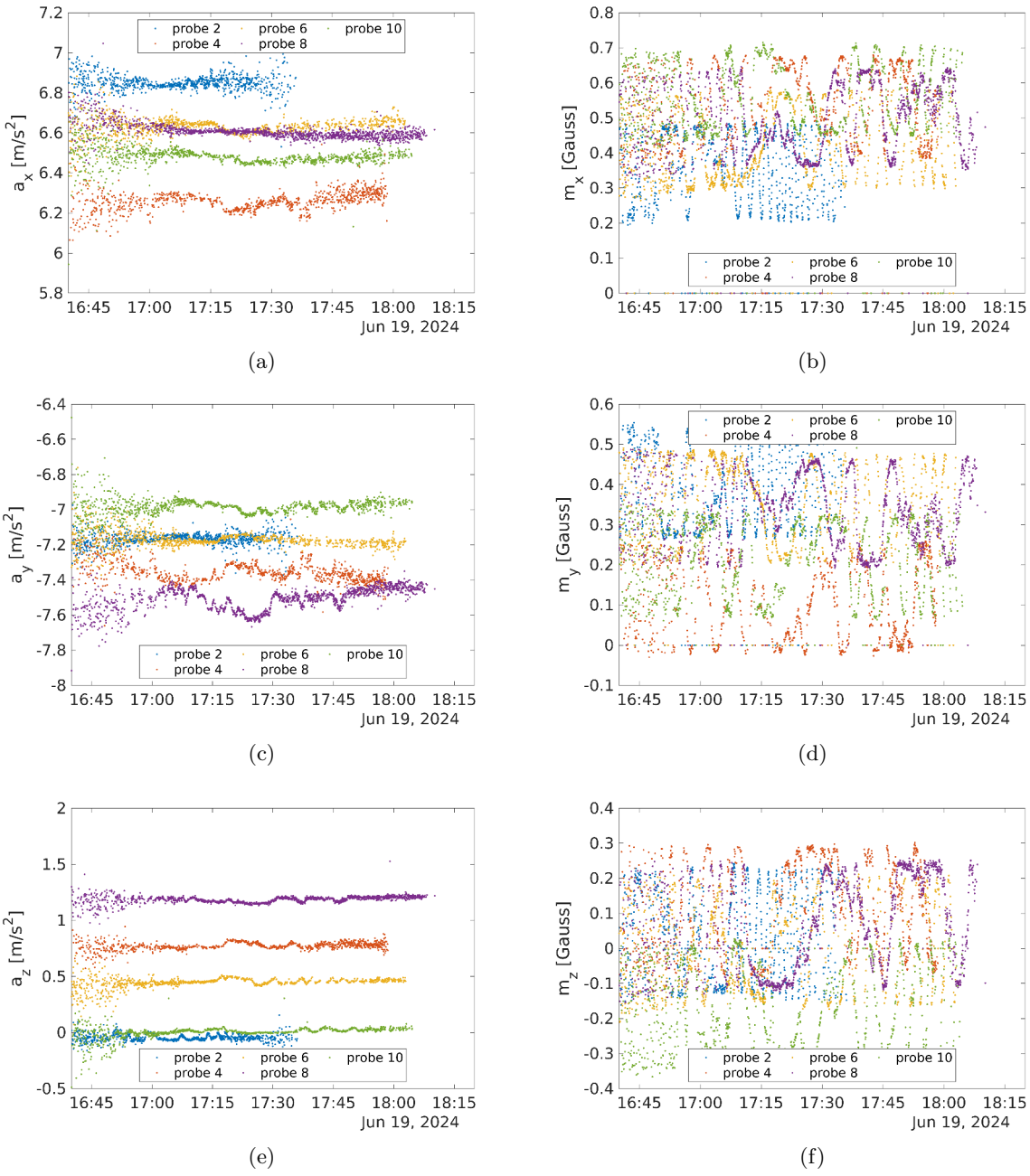


Figure 7: Raw acceleration and magnetic field strength readings from IMU (Inertial Measurement Unit). Panels (a, b, c) show the acceleration along x, y, z directions of probe coordinate frame[1]. Panels (c) and (d) illustrate the separation distances between all pairs of probes throughout the flight. The solid black line represents the mean separation distance.

3 Dataset availability

The radiosonde cluster dataset, along with other datasets from the Philofluid research group, are archived within the COMPLETE-CINECA data repository: `https://complete.cineca.it`. You can access them directly using this handle: `https://hdl.handle.net/11100/8b356298-e89b-11eb-9b8f-e41f13eb41b2`.

Datasets are available in two formats:

- CSV: Comma-separated values files, one per radiosonde in the cluster, containing the readings. A readme file is included to explain data types and file structure.
- NETCDF4: A single file containing all readings with embedded metadata and data type information.

3.1 Data usage policy

We ask any published work which uses this dataset (journal papers, conference proceedings, technical reports, thesis) will cite the following papers describing the dataset and some of the principal scientific results obtained by using it:

1. Abdunabiev, Shahbozbek, Chiara Musacchio, Andrea Merlone, Miryam Paredes, Eros Pasero, and Daniela Tordella. "Validation and traceability of miniaturized multi-parameter cluster radiosondes used for atmospheric observations." Measurement 224 (January 1, 2024): 113879. `https://doi.org/10.1016/j.measurement.2023.113879`.
2. Paredes Quintanilla, Miryam E., Shahbozbek Abdunabiev, Marco Allegretti, Andrea Merlone, Chiara Musacchio, EROS GIAN ALESSANDRO Pasero, Daniela Tordella, and Flavio Canavero. "Innovative Mini Ultralight Radioprobes to Track Lagrangian Turbulence Fluctuations within Warm Clouds: Electronic Design." SENSORS 21, no. 4 (2021). `https://doi.org/10.3390/s21041351`.

References

S. Abdunabiev, C. Musacchio, A. Merlone, M. Paredes, E. Pasero, and D. Tordella. Validation and traceability of miniaturized multi-parameter cluster radiosondes used for atmospheric observations. *Measurement*, 224:113879, Jan. 2024. ISSN 0263-2241. doi: 10.1016/j.measurement.2023.113879. URL `https://www.sciencedirect.com/science/article/pii/S0263224123014434`.

M. E. Paredes Quintanilla, S. Abdunabiev, M. Allegretti, A. Merlone, C. Musacchio, E. G. A. Pasero, D. Tordella, and F. Canavero. Innovative Mini Ultralight Radioprobes to Track Lagrangian Turbulence Fluctuations within Warm Clouds: Electronic Design. *SENSORS*, 21(4), 2021. doi: 10.3390/s21041351. URL `https://www.mdpi.com/1424-8220/21/4/1351`. Publisher: MDPI.