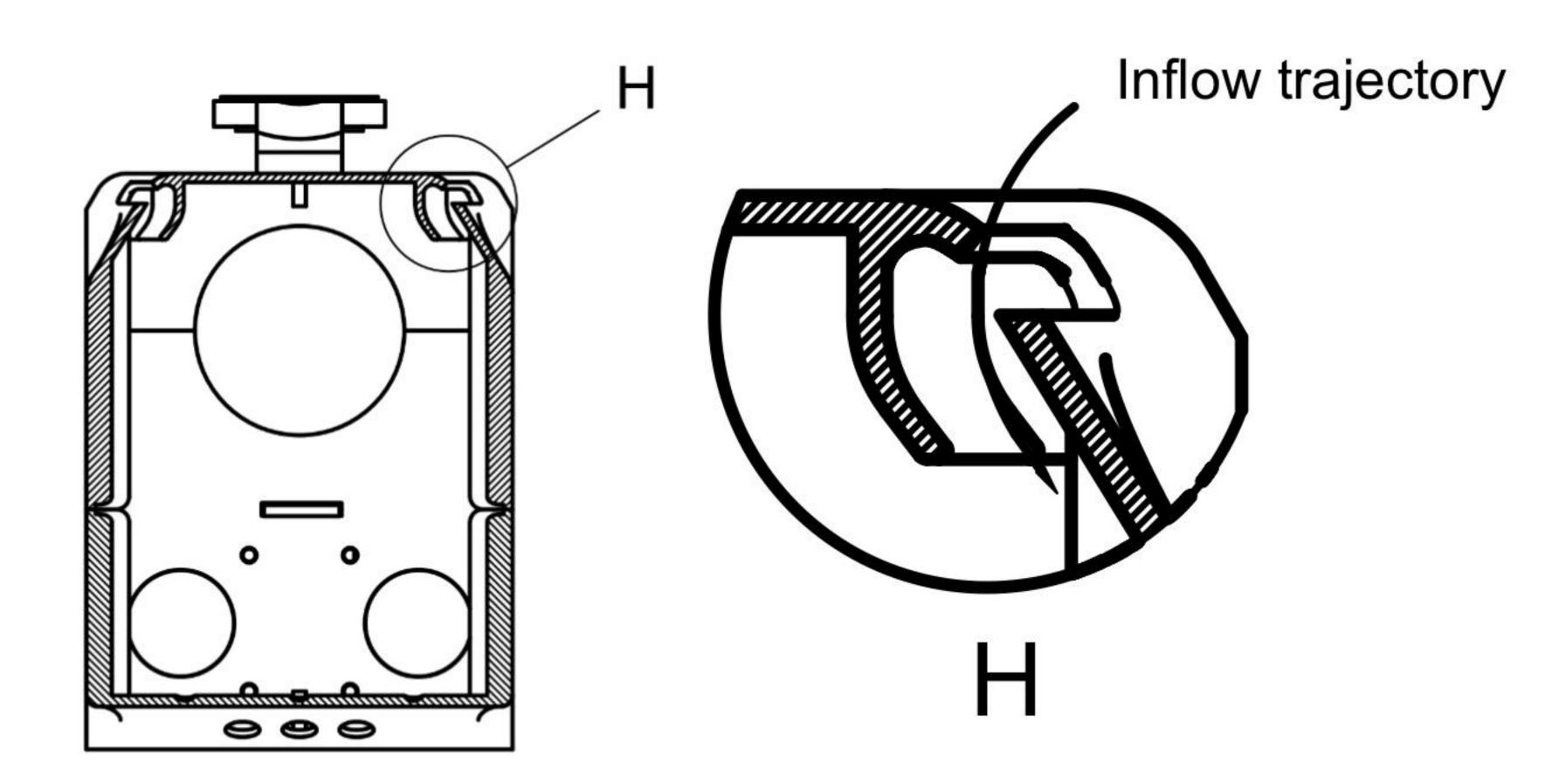
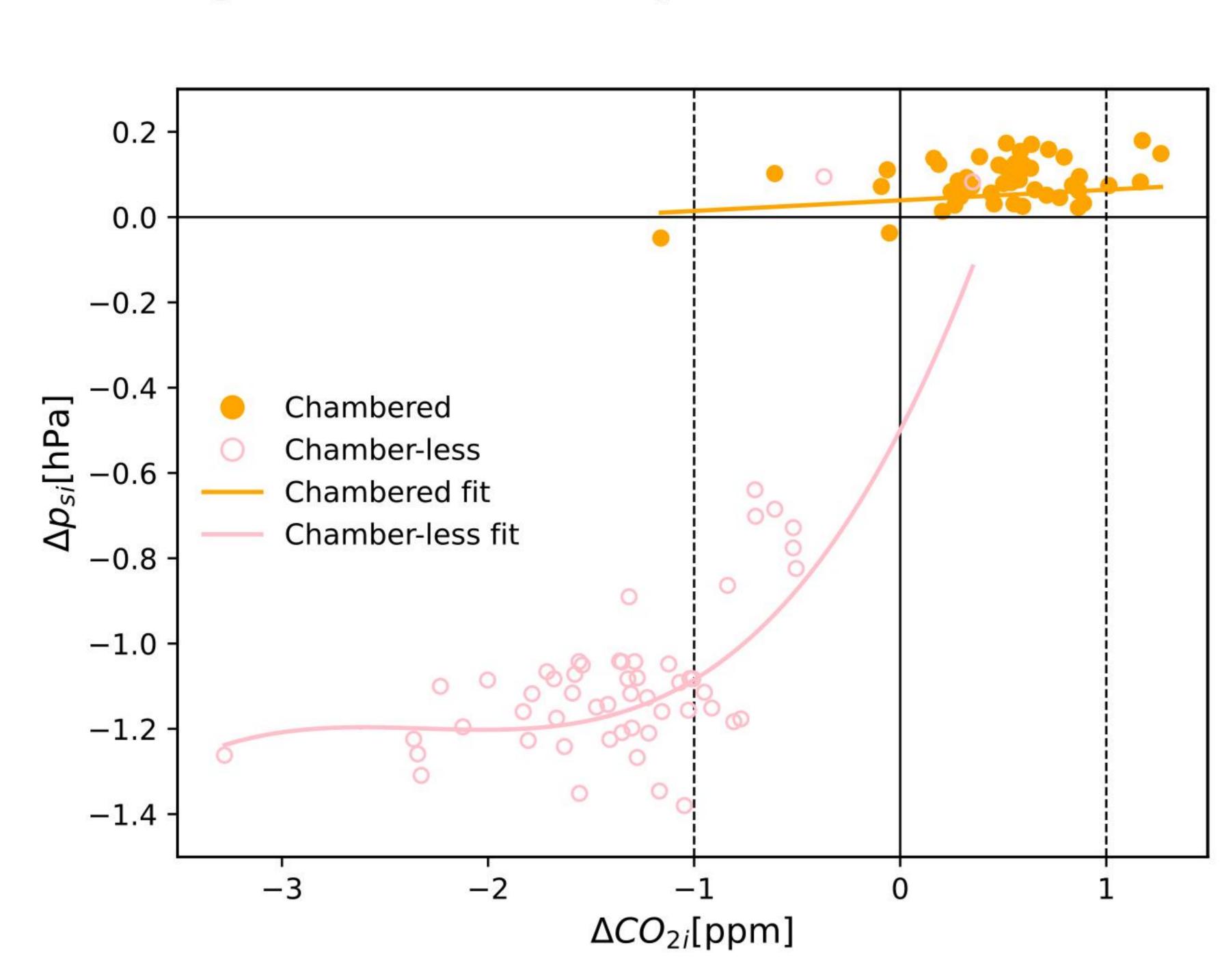
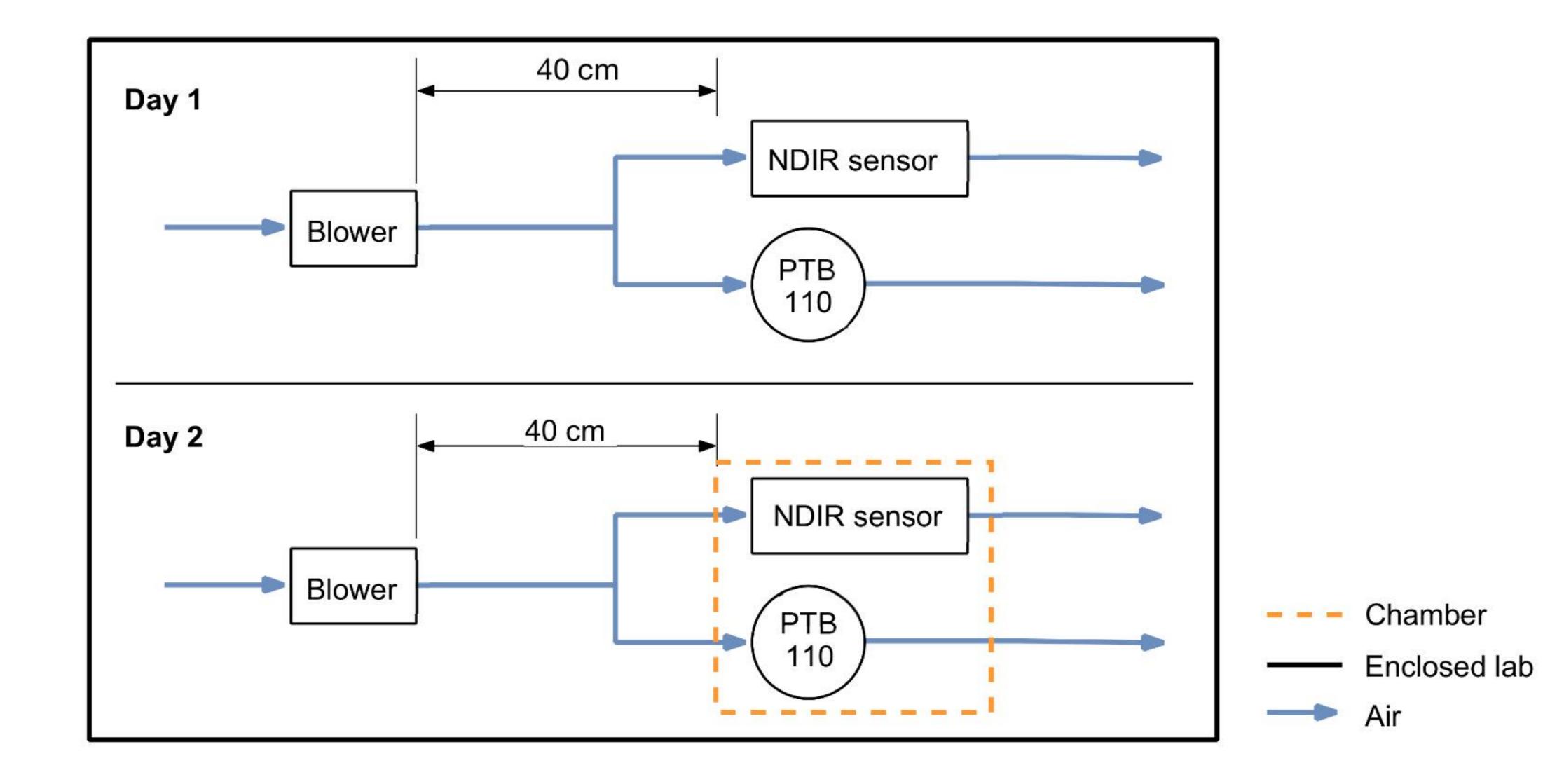


↑ We developed and tested a lightweight UAV (unmanned aerial vehicle) payload enclosure integrating a non-dispersive diffusion infrared (NDIR) spectrometer and two electrochemical sensors for measurements of carbon dioxide (CO₂), carbon monoxide (CO) and nitrogen dioxide (NO₂). To achieve higher response times and maintain measurement qualities, we designed a custom air inlet on the rotor-facing side of the enclosure to reduce measurement fluctuations caused by rotor downwash airflow. To validate the payload design, we conducted a controlled test for comparing chambered and chamber-less NDIR spectrometer measurements. From the test we observed a reduction of 0.48 hPa in terms of standard deviation of pressure measurements and minimised downwash-flow-induced anomalous biases (+0.49 ppm and +0.08 hpa for chambered compared to −1.33 ppm and −1.05 hpa for chamber-less as shown in the bottom left figure). We also conducted an outdoor in-situ measurement test with multiple flights reaching 500 m above ground level (ABGL). The test yielded high resolution results representing vertical distributions of mole fraction concentrations of three types of gases via two types of flight trajectory planning methods (bottom right figure). Therefore, we provide an alternative UAV payload integration method for NDIR spectrometer CO₂ measurements that complement existing airborne GHG observation methodologies. Additionally, we also introduced an aerodynamic approach in reducing measurement noises and biases for a low response time sensor configuration.



The frontal sectional view of the measurement chamber and zoomed-in view (H) of the **downwash flow spoiler** responsible for adjustments of flow velocity and direction.





↑ Chambered and chamber-less comparative measurement test setups illustrated with a simplified diagram. The blower is optimally placed and configured to acclerate airflow for producing simulated rotor downwash flow. The indoor environment is relatively enclosed, with no known source or sink of CO₂ and no source of extra airflow.

 \leftarrow Distribution of mean CO₂ concentration anomalous biases (ΔCO_{2i}) with respect to mean air pressure anomalous biases (Δp_{si}) of individual test iterations for the chambered and chamberless setups.

$$\Delta CO_{2i} = \overline{\textbf{\textit{CO}}_{2i}^{on}} - \overline{\textbf{\textit{CO}}_{2i}^{off}}, i \in \{1, \dots, n\}$$

$$\Delta p_{s_i} = \overline{\boldsymbol{p_{s_i}}^{on}} - \overline{\boldsymbol{p_{s_i}}^{off}}, i \in \{1, \dots, n\}$$

Development of an Integrated Lightweight Multi-Rotor UAV Payload for Atmospheric Carbon Dioxide Mole Fraction Measurements

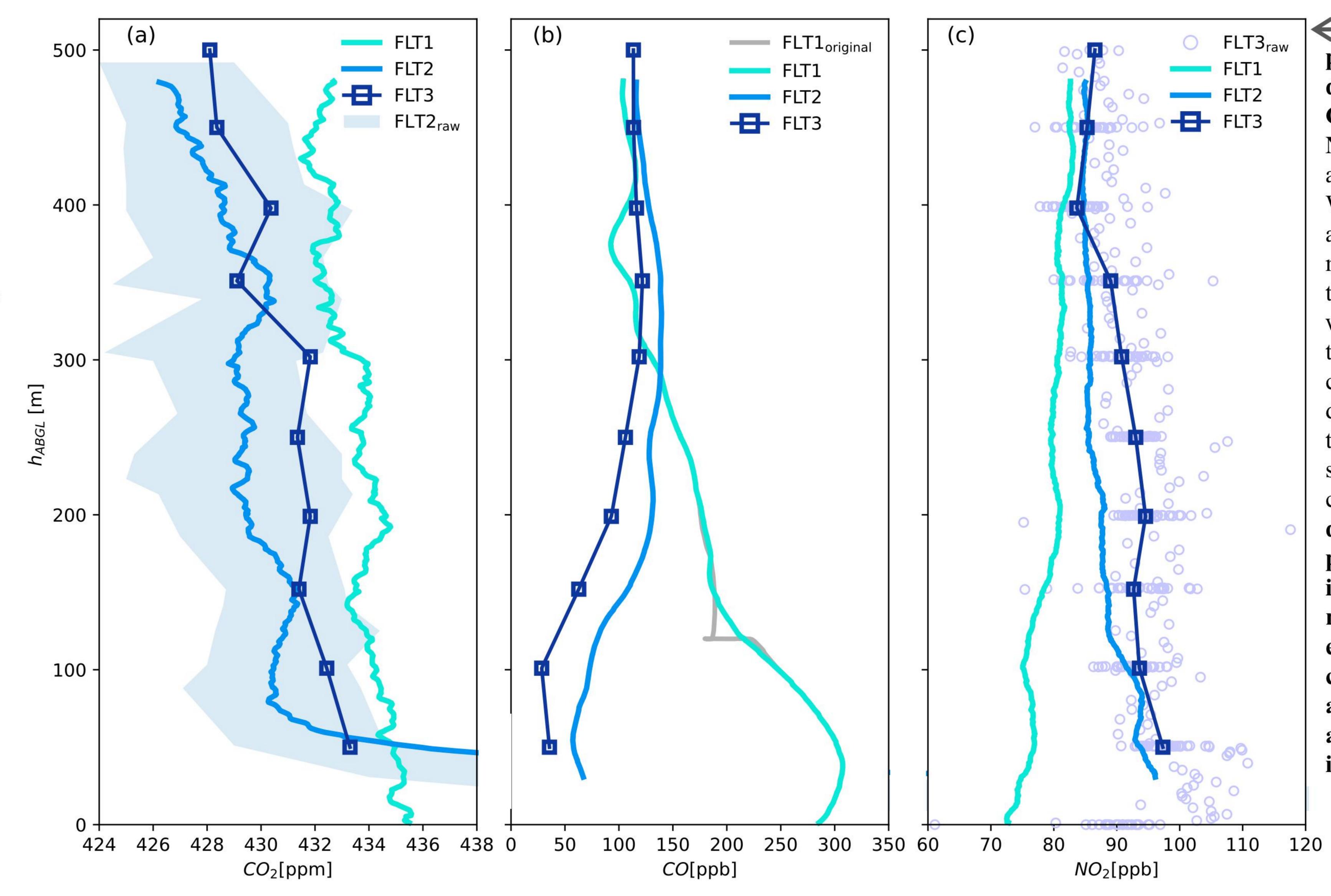
Tonghui Zhao, Dongxu Yang, and Yi Liu | Carbon Neutrality Research Centre, IAP, CAS



	Flight 1	Flight 2	Flight 3
Method	Continuous	Continuous	Level hover
	Ascent	Ascent	Ascent
Take-off time	16:06:38	19:08:23 1	20:09:36
Reached 500 m at	16:20:20	19:20:12	20:17:08
Landing time	16:32:46	19:24:24	20:21:43
Vertical speed	<1 m/s	<1m/s	N/A

The ascent and descent of the first two flights were conducted with constant and lowest possible velocity (0.5 m/s), while the ascent of the last flight was based on half-minute hovering at height levels that are 50 m apart.

Take-off location, rural area near a village in northern Beijing.



Vertical atmospheric profile of mole fraction density distributions for CO_2 (a), CO (b) and NO₂ (c) during ascent of all three test flights. While the moving averages of measurements of the first two flights are plotted with continuous lines, the third flight is exhibited in connected dots due to its distinctive flight trajectory. The three subplots respectively contain information of different data processing methods including simple moving averages of every 60s; ascent cessation smoothening and variance-filtered arithmetic mean for individual height levels.