Aerial Systems for Environmental Assessment

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SCIENTIFIC SESSION 4: DRONES & AI

Outline

- Overview and Motivation
- Automating GHG data collection
- Drone Architecture and Prototype
  - Current Results
  - AI and Embedded AI
- Current results & Discussion

Mission examples

Accurate evaluation of deforestation

- Unmanned airship

Accurate evaluation of environmental damage due to fire & Fire early warning

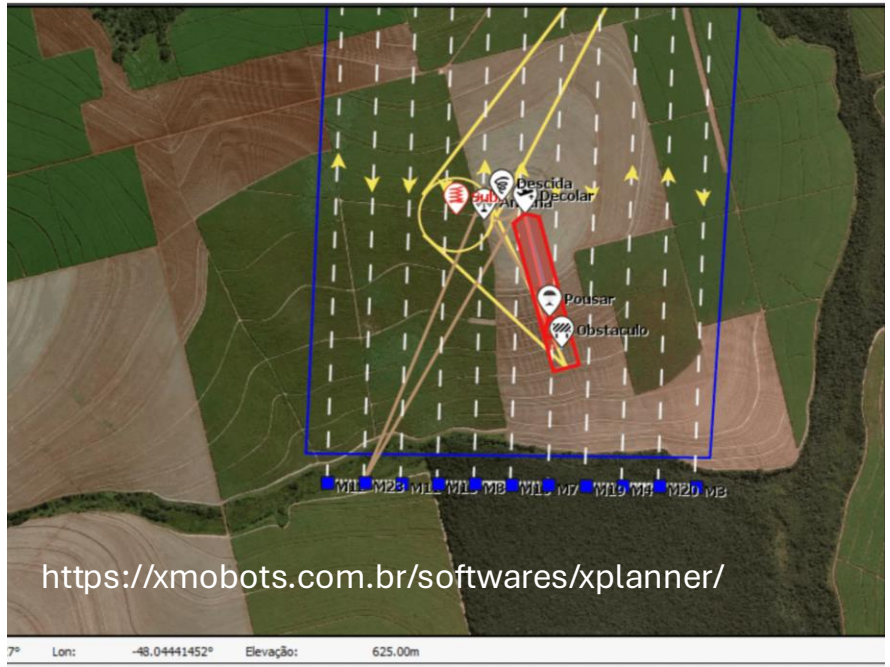
- Swarm drones
- High altitude drone

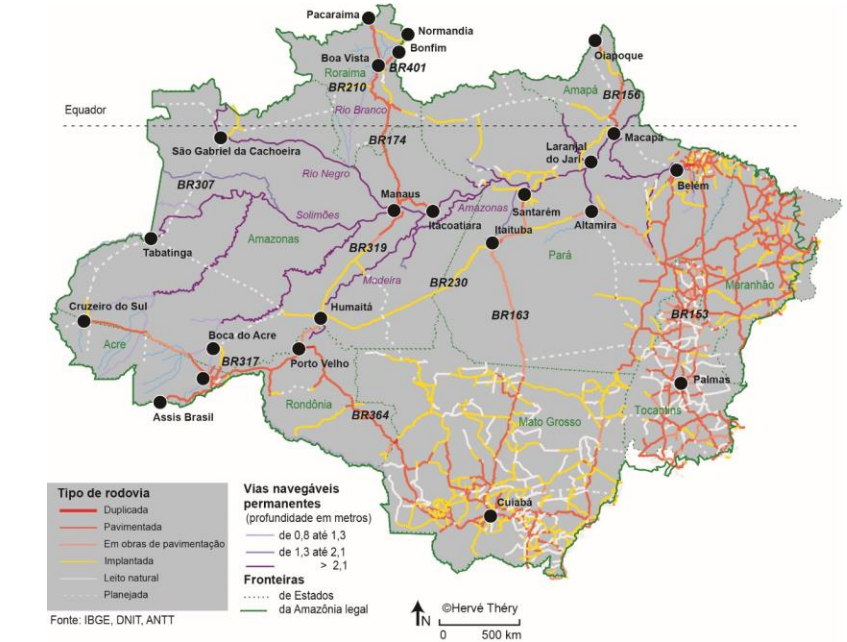
Water sample collecting & Improvement of Communication

- Unmanned Airship
- Ekranoplane

Continuous measurement of GHG concentrations from ground to 15 km

- UXV Ecosystem





https://journals.openedition.org/confins/docannexe/image/21176/img-1.jpg

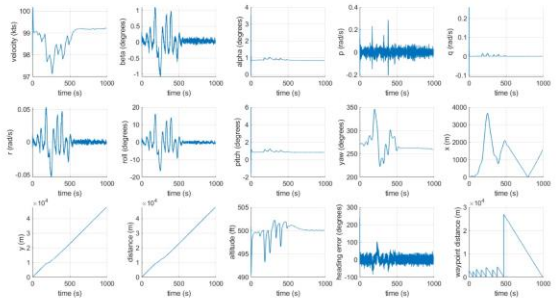


FAPESP France Week 2025

CCR ViaSul

ANTT
AGÊNCIA NACIONAL DE TRANSPORTES TERRESTRES

Resources for Technological Development
RDT



JSBSim
Open Source Flight Dynamics



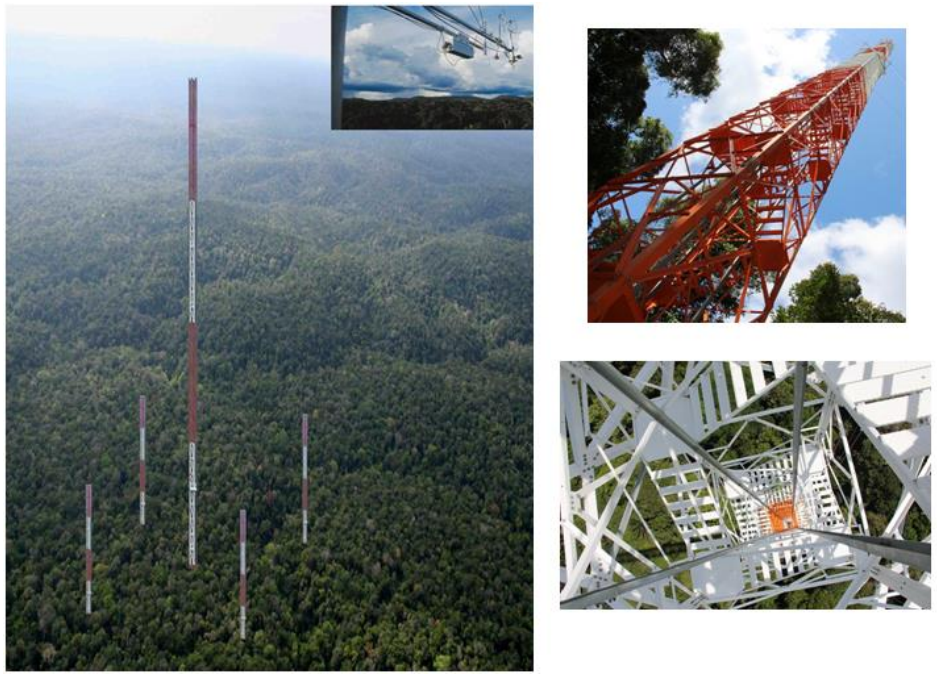
DRONES PERFORMANCE SIMULATION FOR ROAD INSPECTION - SIMD-I-ROD

ENGENHARIA AERONÁUTICA
USP · SÃO CARLOS

FAFQ Fundação de Apoio à Física e à Química

Automating GHG data collection

ATTO TOWER



https://pesquisa.inpa.gov.br/index.php/projetos-pesquisa/2016-07-28-14-46-53

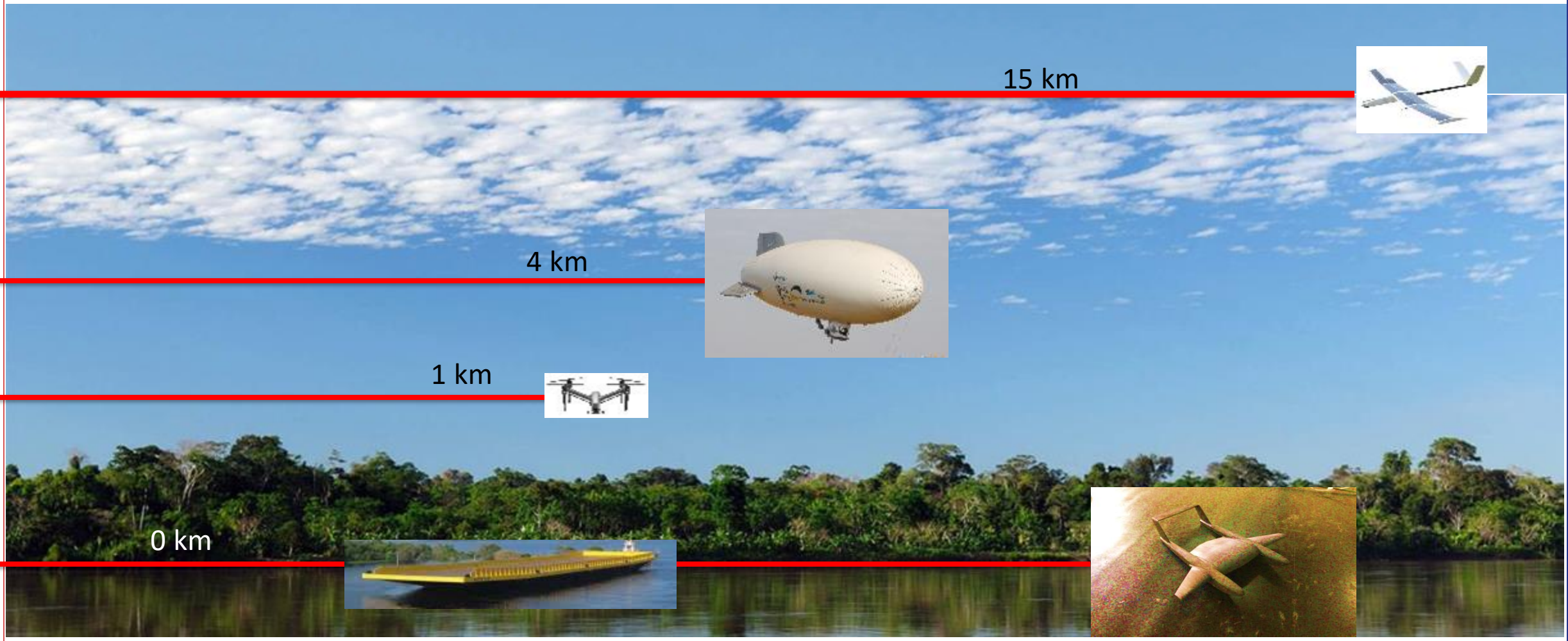
DLR HALO Research Aircraft



https://www.dlr.de/en/images/2019/4/research-aircraft-halo

Centro de Pesquisa e Inovação de Gases de Efeito Estufa – RCG2I
Process 20/15230-5
GHG Workstream 1: Sources, sinks and processes controlling process, monitoring and data integration

Ecosystem - Unmanned Autonomous and Semi-Autonomous Vehicles



CAURIN, G. A. P. ; DAUD FILHO, A. C. ; SILVA, J. R. . Unmanned Aerial Vehicle Cooperation for the Monitoring of Greenhouse Gases. Sustainable Aviation. 1ed.Cham: Springer Nature Switzerland, 2025, v. , p. 41-46.

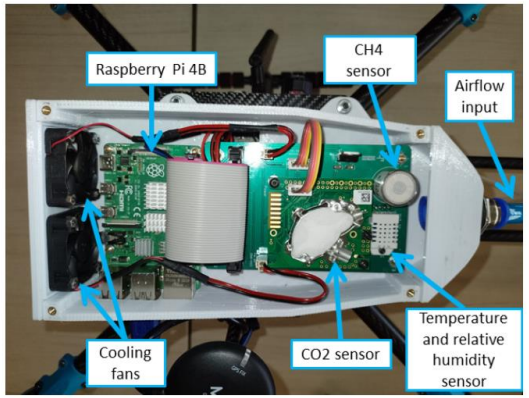
Drone Architecture and Prototype



(a)



(b)



(a)



(b)

Table 1: Low-cost drone specifications.

Drone frame	Holybro X500 V2
Onboard computer	Raspberry Pi 4B
Flight controller	Pixhawk 6C
Flight controller firmware	PX4
Battery	Lipo 4S 6500 mAh
Wifi-modem	4G LTE
Total weight	2.4 kg
Flight time	8.0 min
CO_2 sensor	Senseair K30 FR
CH_4 sensor	Winsen MH-441D NDIR
Relative humidity and temperature sensor	DHT22
Airspeed sensor	MS4525DO

Drone Architecture and Prototype

Table 2: GHG data low-cost sensors specifications.

Sensor	Measurement	Operating Principle	Measurement Range	Accuracy
SenseAir K30 FR	CO_2 (ppm)	NDIR	0 - 5000 ppm_{vol}	± 30 ± 3% of reading
Winsen MH-441D	CH_4 (ppm)	NDIR	0 - 50000 ppm_{vol}	± 100 ppm
DHT22	Temp. (^oC) and Rel. Hum. (%)	Polymer humidity capacitor	-40^{o}C - 80^{o}C ; 0 - 100%	Temp.: ± 0.5^{o}C; Rel. Hum.: ± 2%
MS5611	Atmospheric Pressure	Piezo-resistive pressure sensor	10 - 1200 mbar	± 1.5 mbar
MS4525DO	Pressure differential and Temp.	Air speed (m/s) from Pressure differential and Temp.	0 - 1.0 psi, ≈ 100 m/s	± 0.05 psi

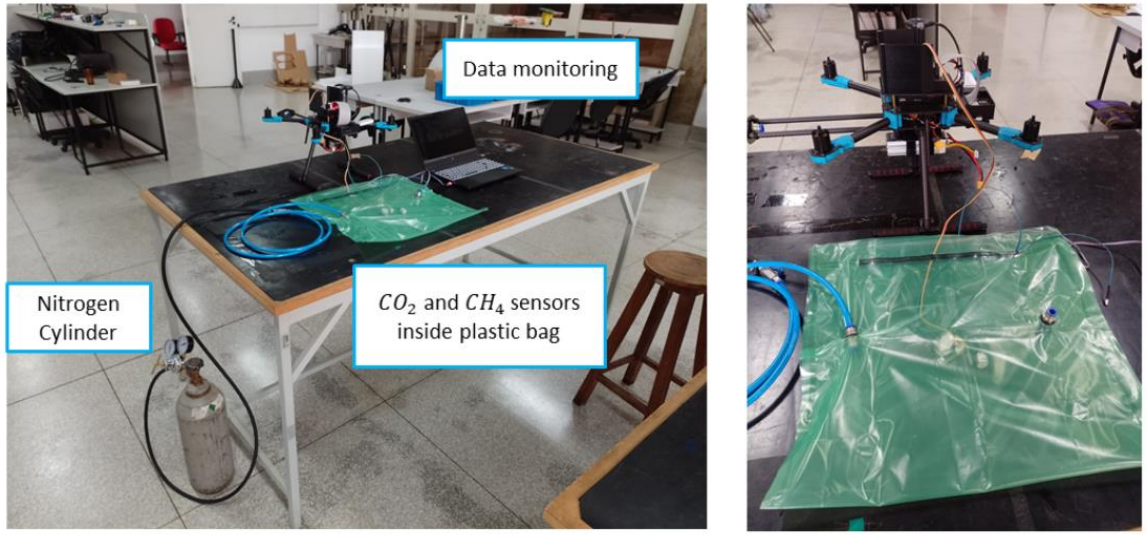


Figure 3: Trace gas sensors calibration.

Data Flow and Communication

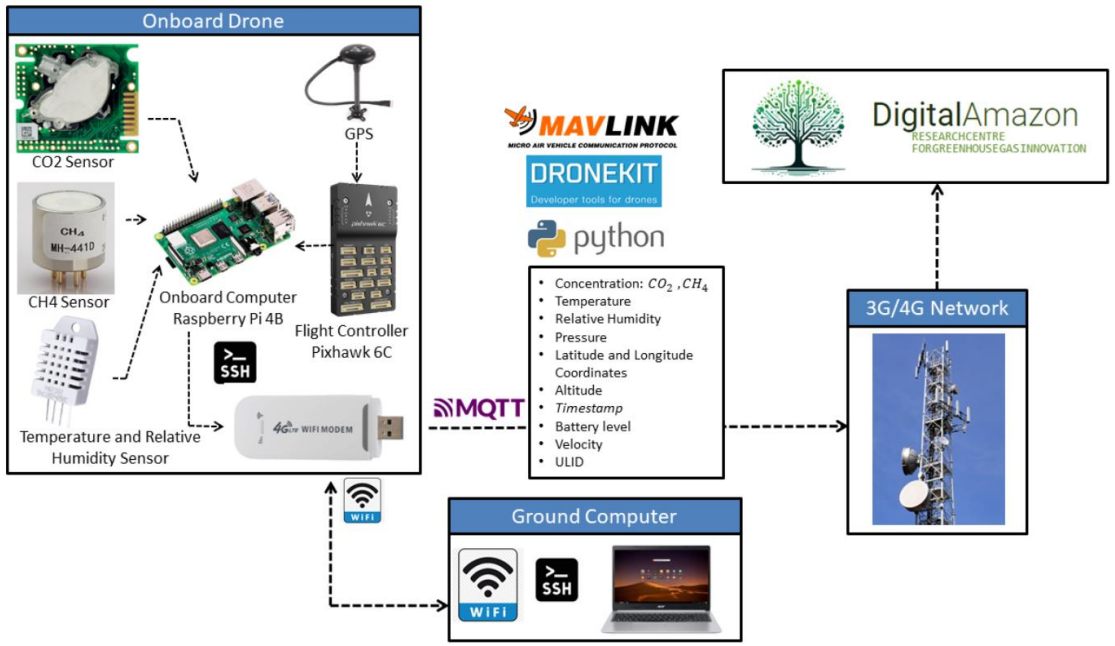


Figure 4: System architecture of the communication, data acquisition and transmission to Digital Amazon data repository.

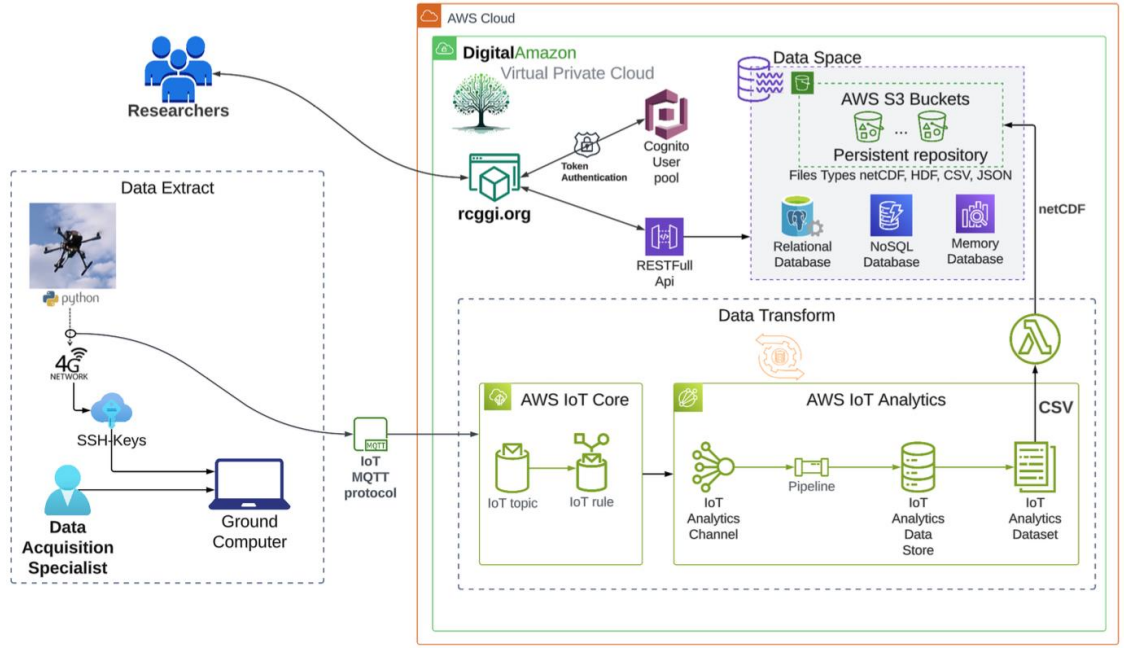


Figure 5: System architecture diagram for data transmission, storage, and analysis to the Digital Amazon in the AWS cloud using 4G network.

The drone flight path must fit the mission measuring objectives

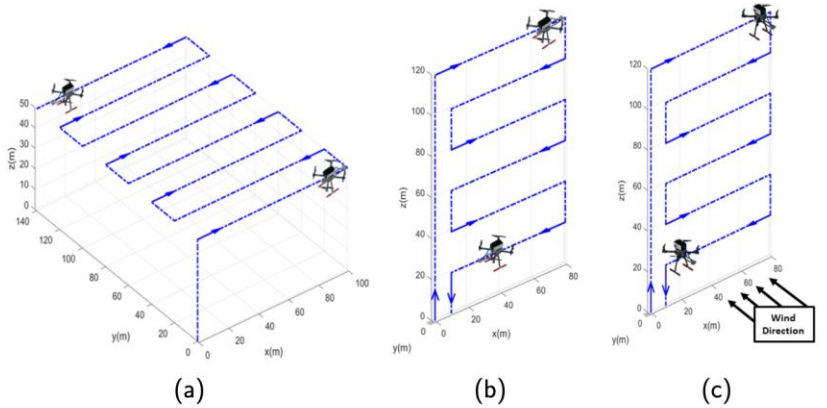


Figure 6: Drone flight path to perform: (**a**) GHG data mapping. (**b**) GHG data profile measurement along altitude. (**c**) Gas flux quantification across the vertical sampling plane.

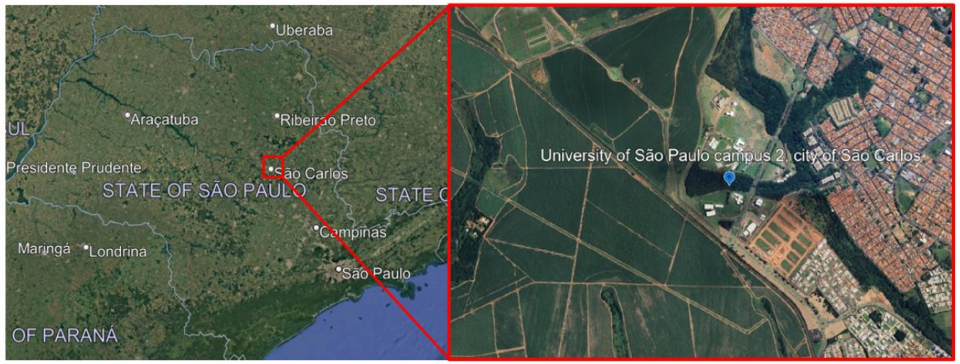


Figure 7: Experiments site at the University of São Paulo campus 2 in the city of São Carlos, state of São Paulo, Brazil (Longitude: -47.932853°, Latitude: -22.004291°).



Figure 8: Drone flight path to take measurements profile along altitude.

GHG data mapping

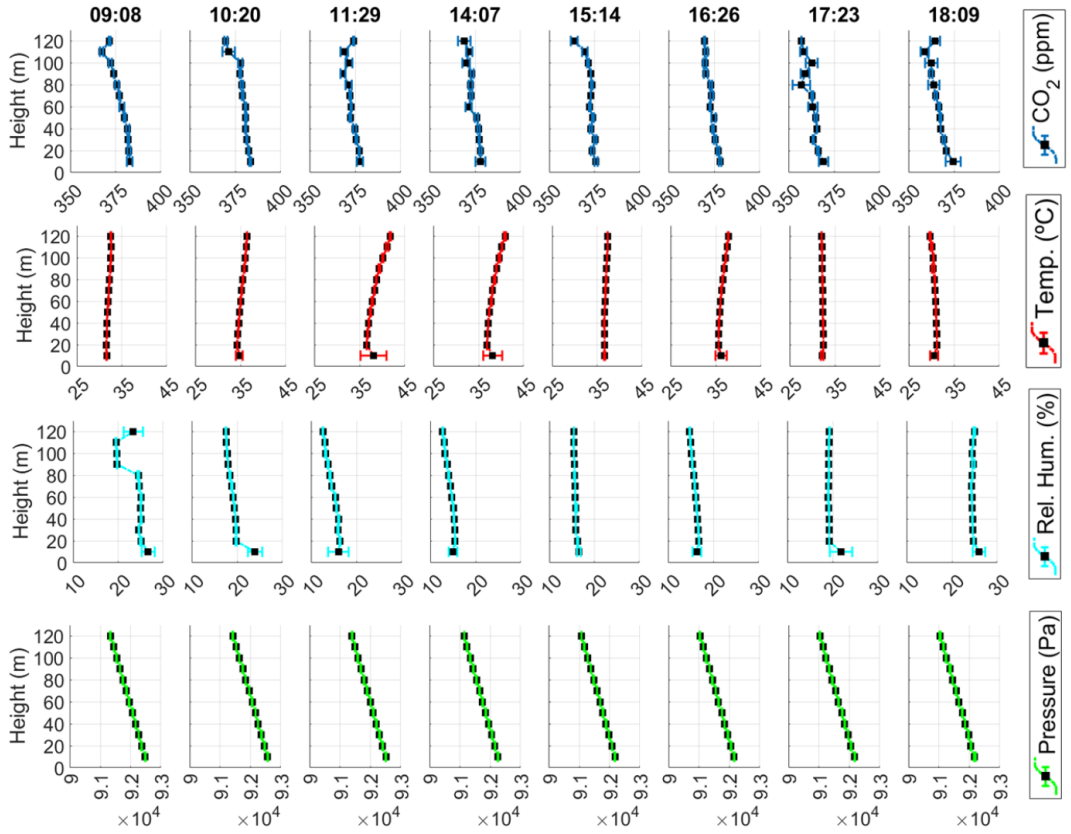


Figure 9: Results of average CO_2 concentration, temperature, relative humidity, and atmospheric pressure profile along altitude, throughout the day on August 20th, 2024, at the University of São Paulo campus 2 in the city of São Carlos, state of São Paulo, Brazil.

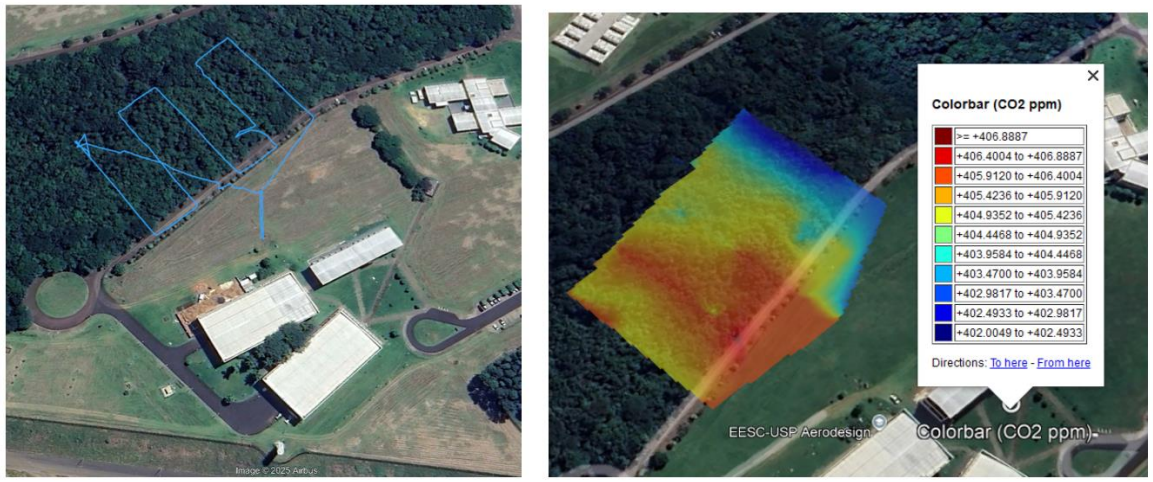


Figure 10: (**a**) Drone flight path to take GHG data measurements at a height of 50 meters. (**b**) Result of CO_2 concentration along the flight path for gas concentration mapping experiment.

GHG data mapping

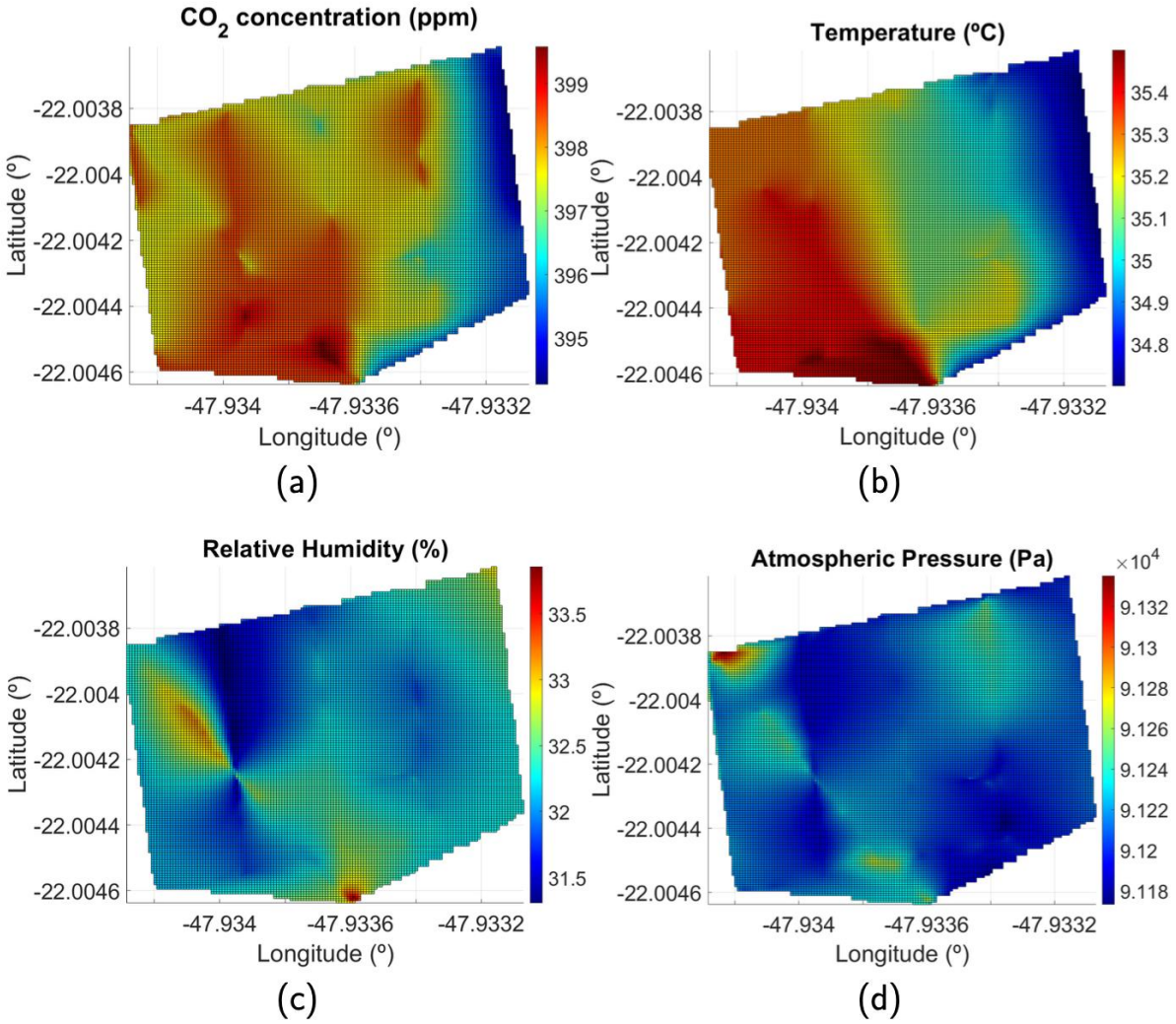
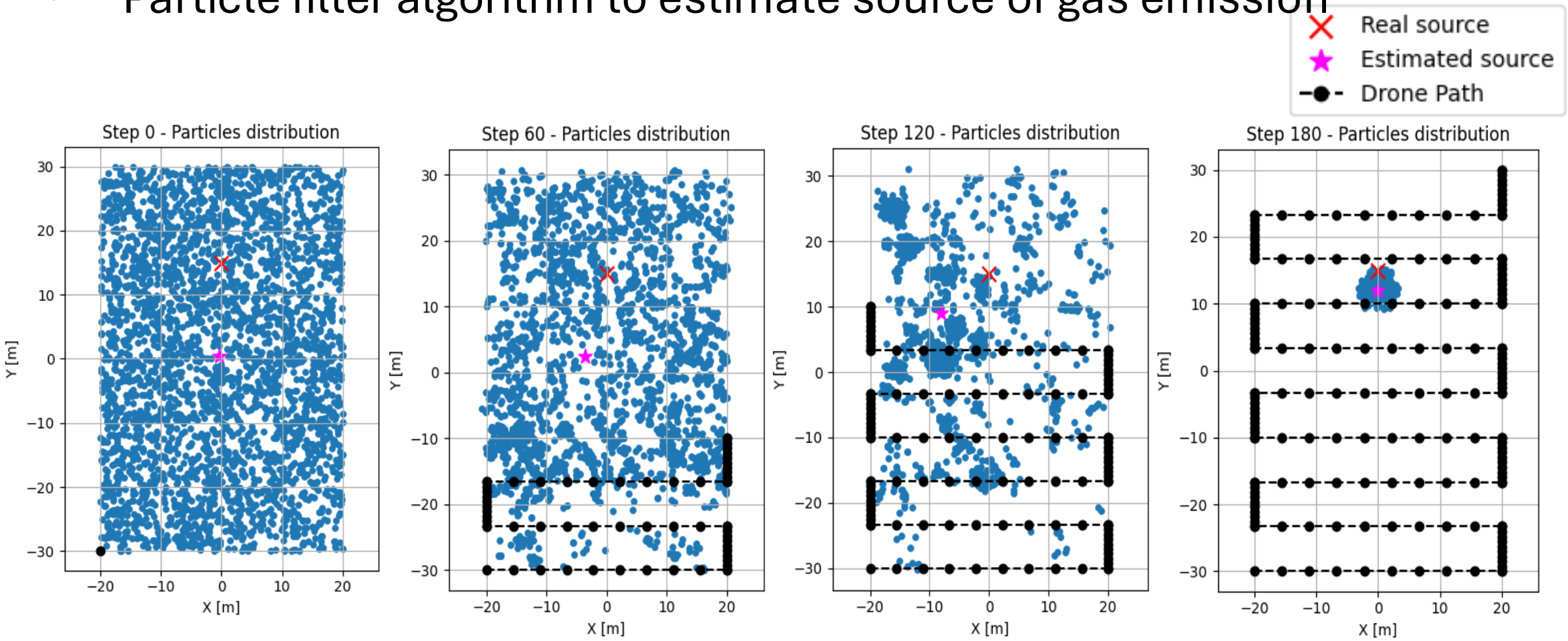


Figure 11: Result of two-dimensional linear interpolations of UAV measurements along flight path at a height of 50 meters. (**a**) CO_2 concentration mapping. (**b**) Temperature mapping. (**c**) Relative humidity mapping. (**d**) Atmospheric pressure mapping.

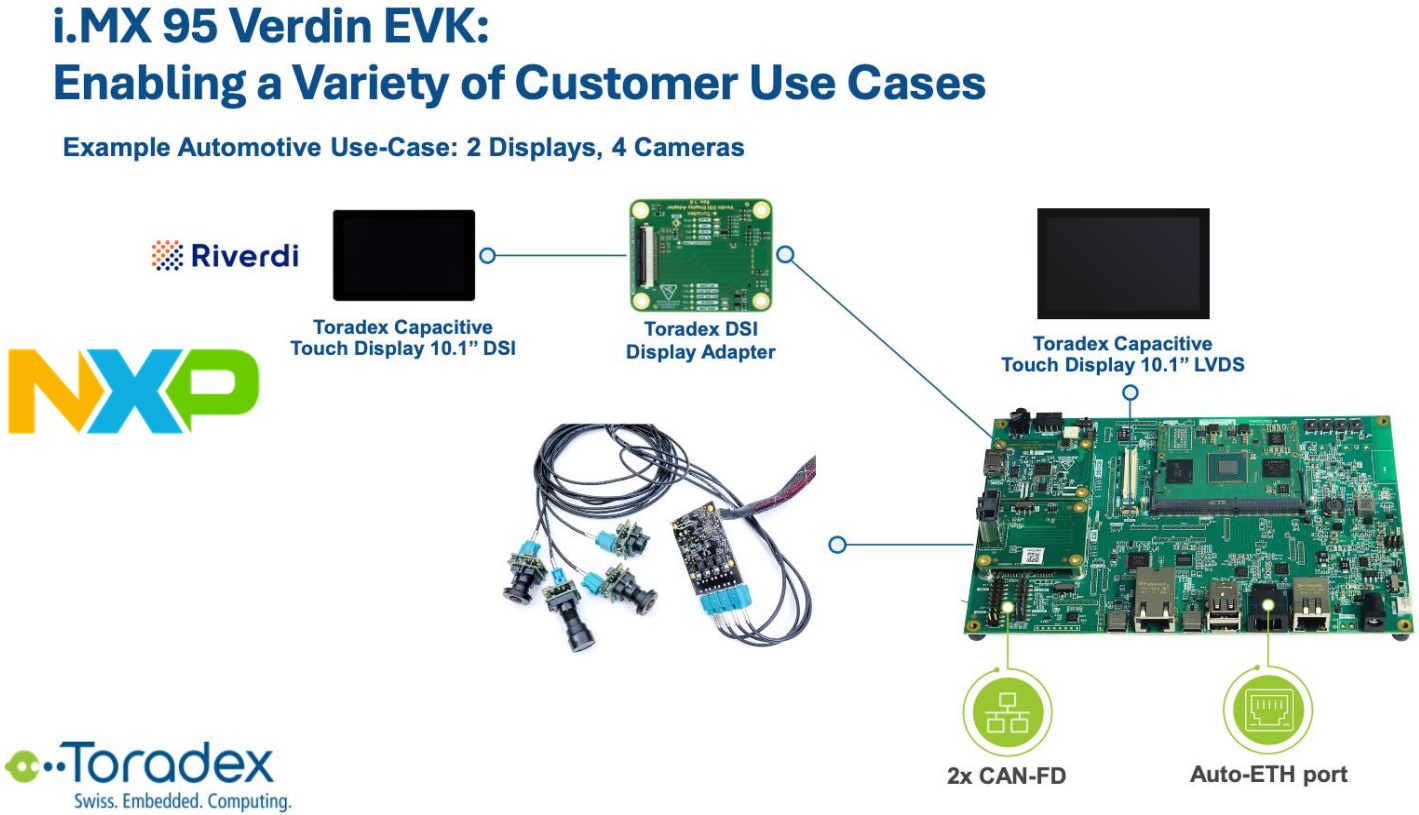
Gas Source Localization Using UAV

- Particle filter algorithm to estimate source of gas emission



Vision and Embedded AI

- One-note Samba ("Samba de uma nota só")

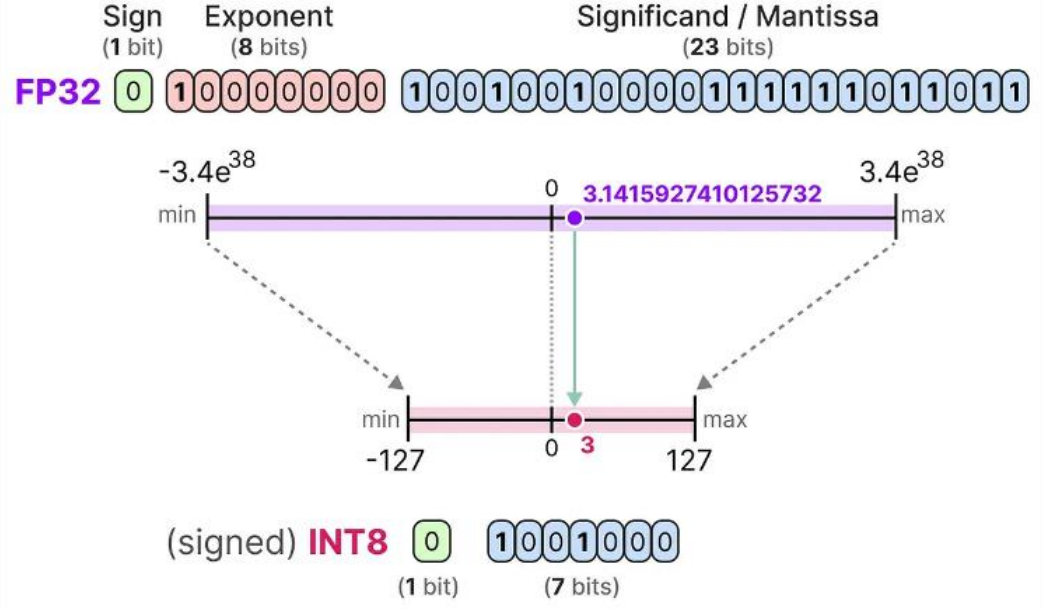




https://www.toradex.com/pt-br/webinars/deep-dive-into-the-imx95-apps-processor-npu-and-vision-pipeline

Quantized Model "Magic"

- Reduces model size: lower-precision data.
- Reduced Memory Bandwidth: move less data
- Can impact model accuracy slightly.
- Not just an shift and scale transformation.
- Quantization reduces the precision of the data representation
- Many-to-one: multiple float32 values map to the same int8 value (lossy, non invertibility).

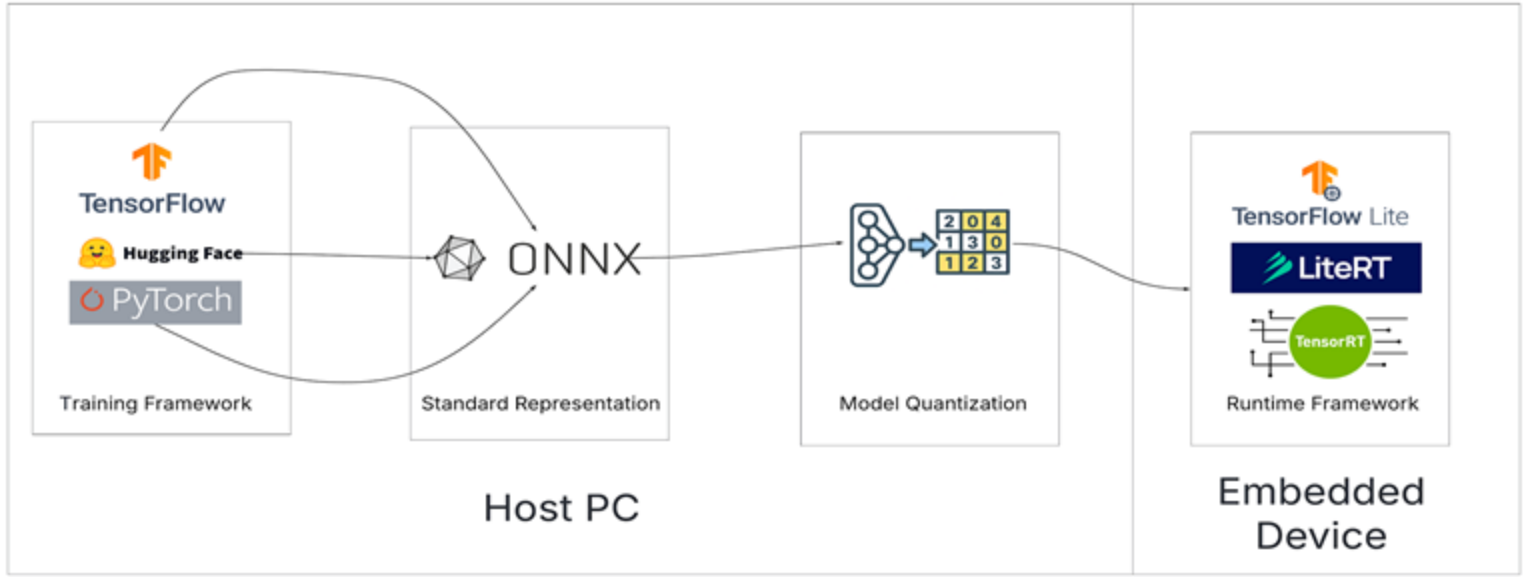


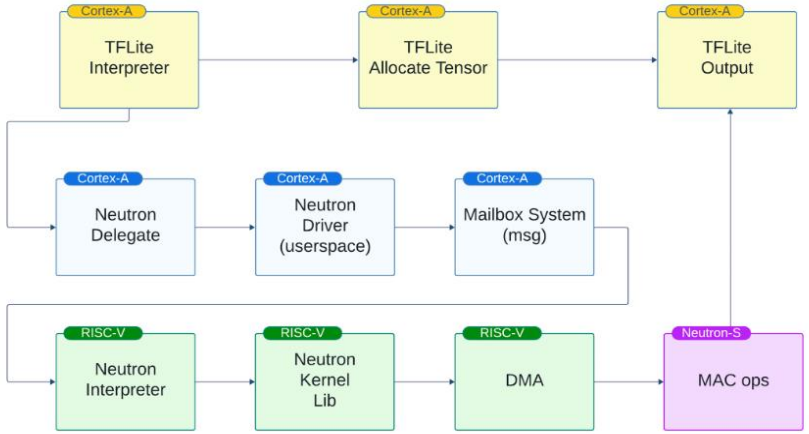
real_value = (int8_value − zero_point) × scale

https://newsletter.maartengrootendorst.com/p/a-visual-guide-to-quantization

Conversion in Practice

ONNX (Open Neural Network eXchange)





Runtime
NXP i.MX95 Neutron-S NPU

- Neutron computation core
- Neutron controller (RISC-V core)
- DMA like memory controller

https://www.nxp.com/design/design-center/training/TIP-DEEP-DIVE-INTO-IMX-95-NPU-AND-VISION-PIPELINE

Final remarks

- UAV-based platforms enable flexible, high-resolution data collection for GHG monitoring, filling critical gaps left by satellite observations.
- AI-driven data processing allows for accurate 3D environmental characterization, enhancing decision-making and climate modeling.
- The integration of autonomous flight and onboard sensing represents a scalable and cost-effective alternative for environmental monitoring.

TEAM





















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Thank you!

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