Wetland emission and atmospheric distribution of methane: Results and lessons learned from the MAGIC2021 international campaign in Scandinavia

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→ THE EUROPEAN SPACE AGENCY

The MAGIC2021 campaign

- **Scientific objectives:**
  - **CH_4 and CO_2 emissions at high-latitude (~68°N)**
    - High northern latitudes are a major yet poorly known contributor to the global methane budget.
    - Natural and anthropogenic emissions.
  - **Validation of space missions in this difficult environment.**
    - Passive space missions (TROPOMI/S5P, IASI): difficulties due to specific obs conditions (high solar zenith angle, surface and thermodynamics conditions) and lack of validation.
    - Active space missions (Merlin): an opportunity to bring new high-quality measurements.

- **Date and location:**
  - 14-27 August 2021
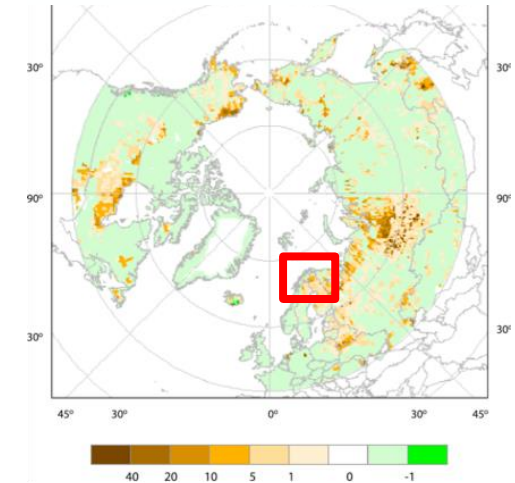 - Lapland (bases of operation: Esrange SSC station and Kiruna airport)

- **Team:** 70 participants, 17 teams, 7 countries

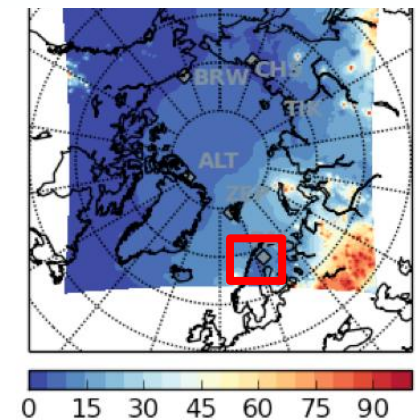- **Funding:** CNES, CNRS, DLR, EUMETSAT, ESA MAGIC4AMPAC

Wetland CH_4 emissions

O' Connor et al., 2010

Anthropogenic CH_4 emissions

Thonat et al., 2018

The MAGIC2021 campaign

Research aircrafts

© T. Vergoz

BAS Twin Otter
- HyTES

DLR Cessna
- Picarros
- Probes

SAFIRE ATR42
- Picarros
- SPIRIT
- Lidars (CH_4, wind)

ATR42
ZPD balloon
Cessna
TwinOtter
FTS
© P. Jezeck

FTIR

EM27/SUN   CHRIS (TIR-SWIR)

→ **Weighted columns of CO_2, CH_4, CO**

Weather and ZPD balloons
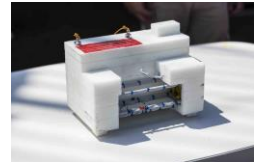
AirCore-light   Amulse

→ **0-30 km profiles of CO_2, CH_4, CO, H_2O, T, wind**

The MAGIC2021 campaign
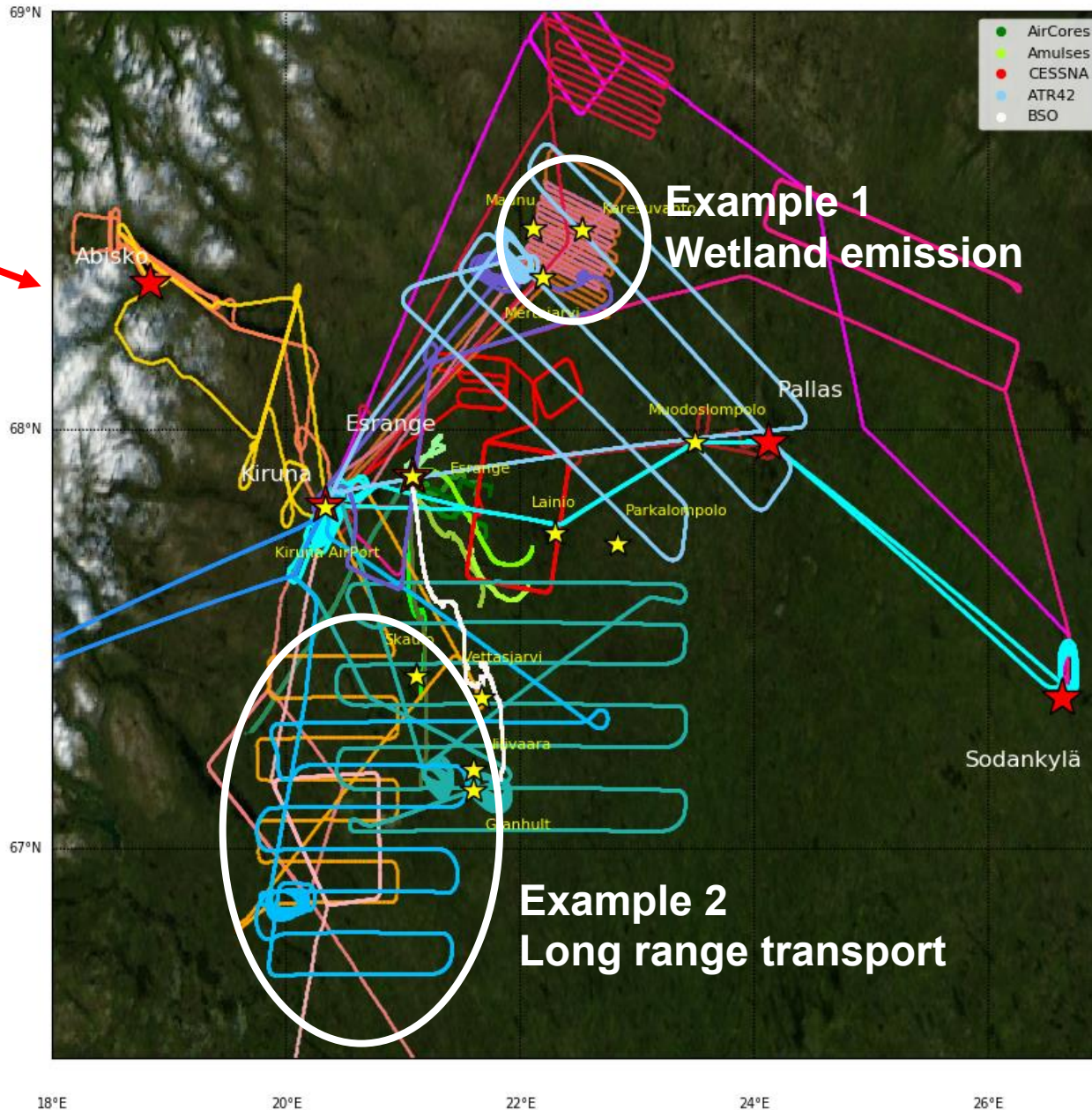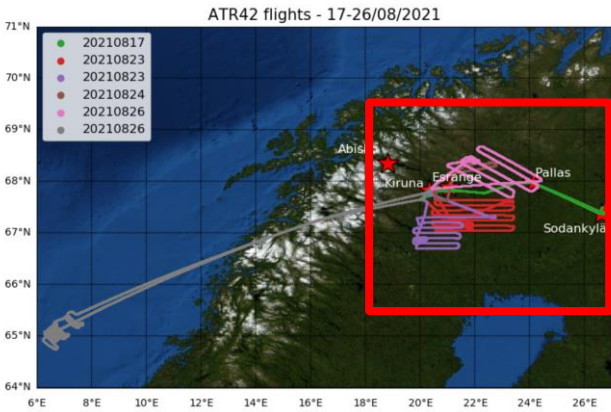
Example 1. Wetland emission

1. Signal selection

CH$_4$ mixing ratio

Distinguish signal & background
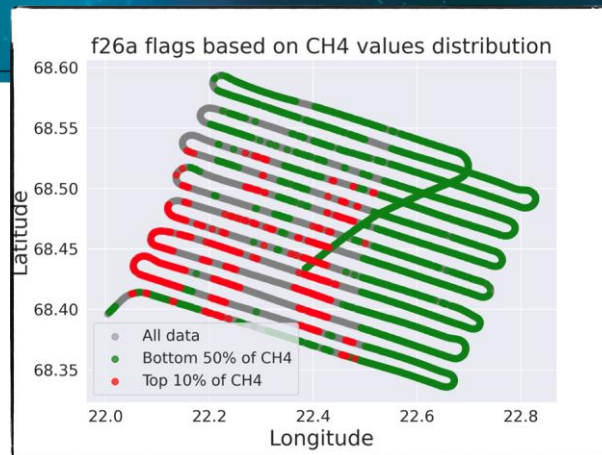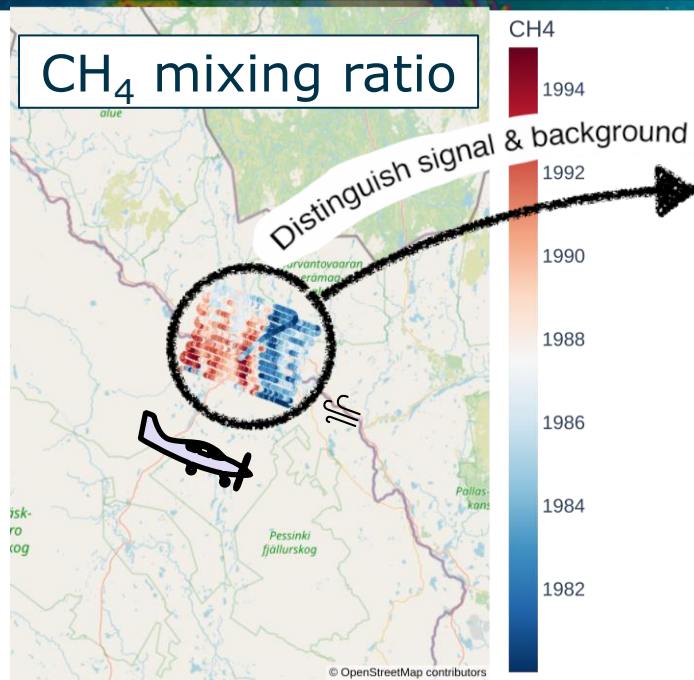
2. Link to source via backtrajectories

Footprints
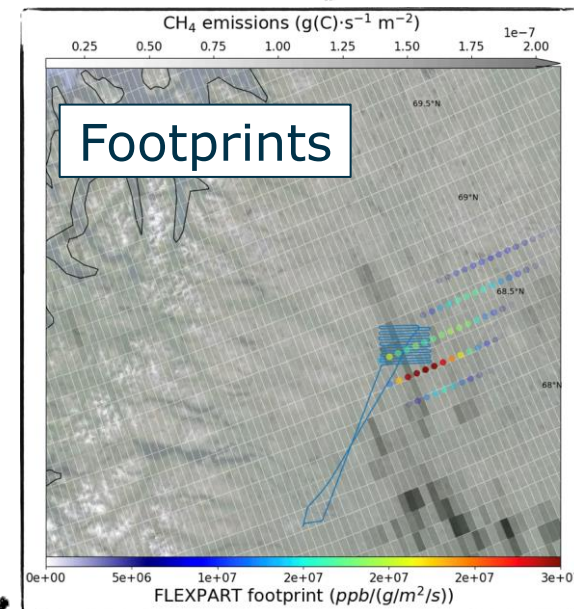
Flux estimates and comparison to inventories
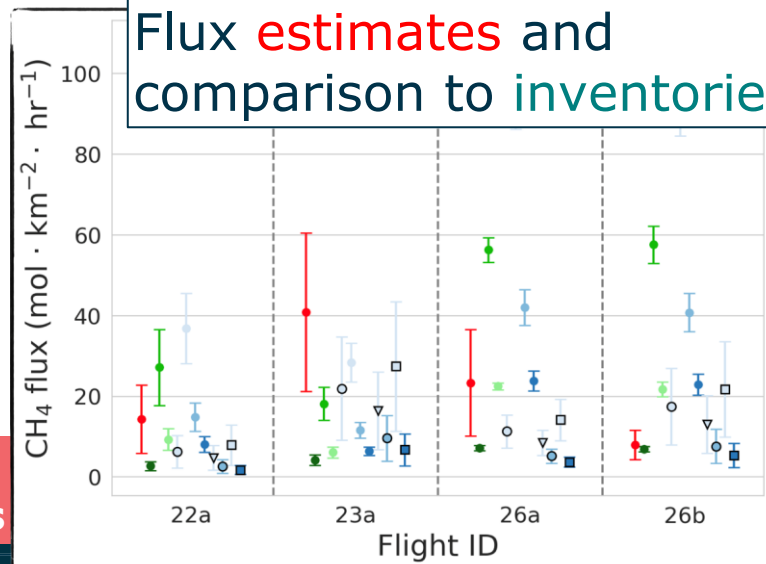
3. Flux computation

Inventory rankings

JSBACH-HIMMELI

Wetcharts-GLWD

4. Assess inventories

Langot et al., in prep.

Methane profile

50 ppb enhancement
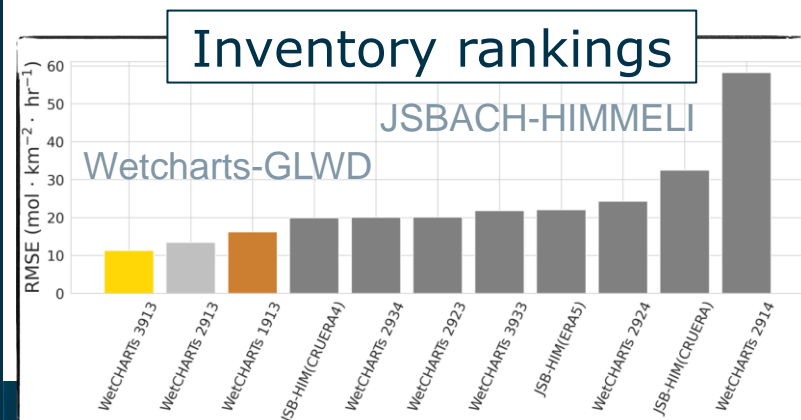
15 ppb enhancement
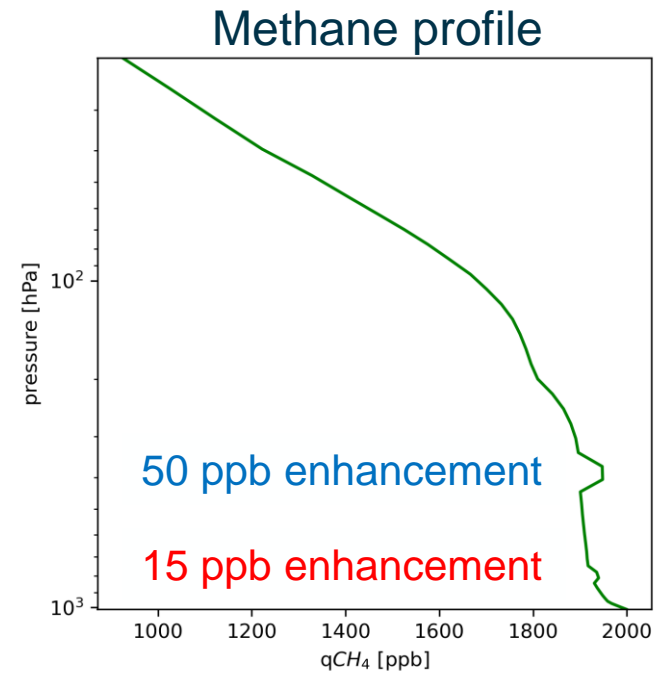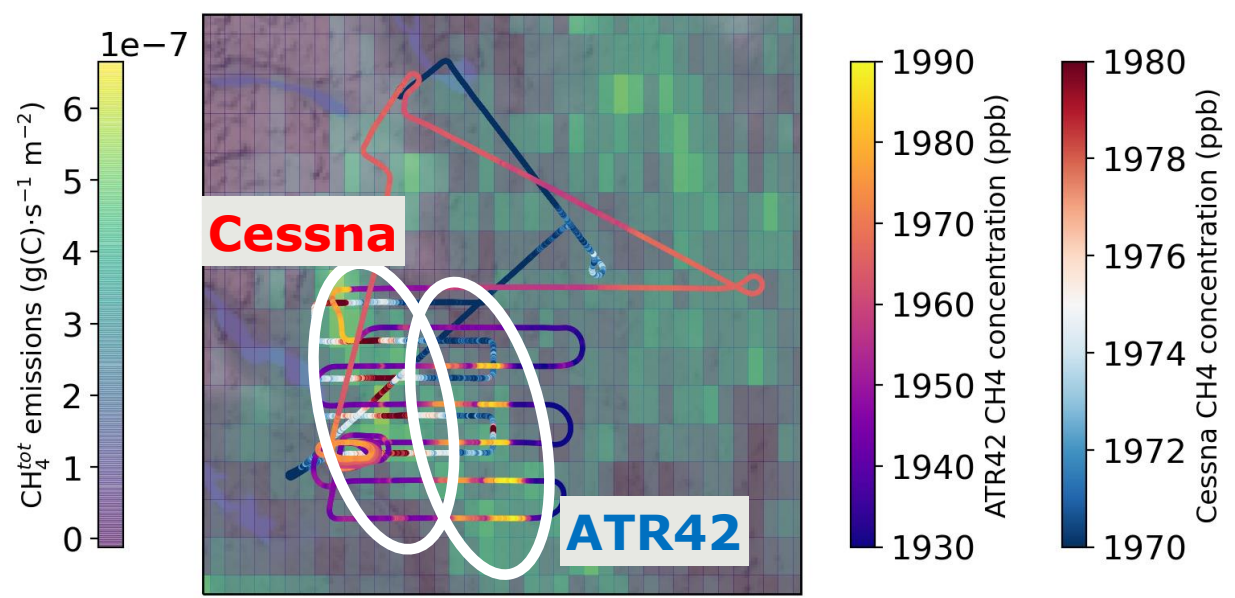
Two superimposed CH$_4$ plumes on the same day:

- **At 2km**, DLR Cessna detects a CH$_4$ plume of ~15ppb
  → local wetland emissions.

- **At 6km**, SAFIRE ATR42 detects a plume of ~50ppb associated to a CO plume
  →transported fire emissions from Canada and Siberia (verified through backtrajectory

Impact on columns retrieved from space

Plume height	Only 2 km	Only 6 km	Both 2 and 6
ΔMT-CH4 (IASI)	0.15 ppb	7.05 ppb	7.20 ppb
ΔXCH4 (S5P)	0.53 ppb	1.77 ppb	2.30 ppb

→ **Implication for flux inversion, also highlighting the potential of joined TIR/SWIR obs**

Satellite validation

Plans to validate TROPOMI/S5P XCH4 and IASI MT-CH4

BUT... almost 10 days of clouds/rain !

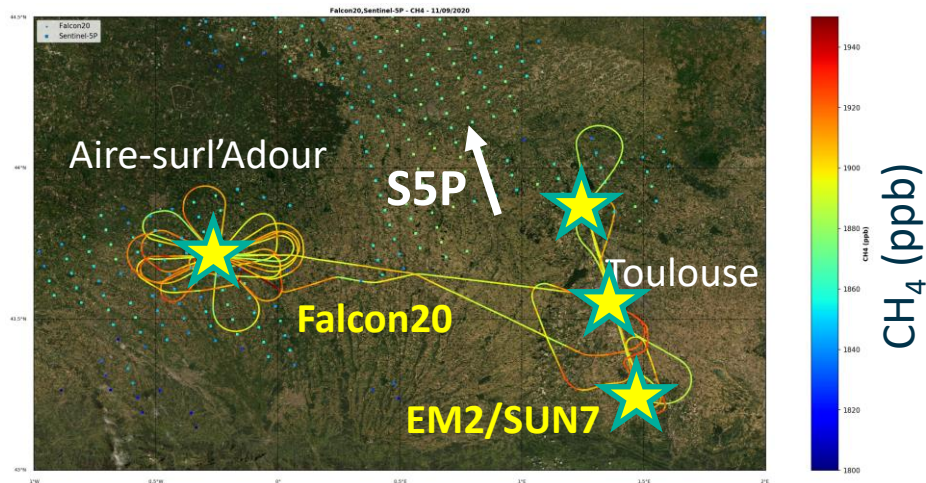First day of MAGIC2021 .... Following days. .... First day after campaign end
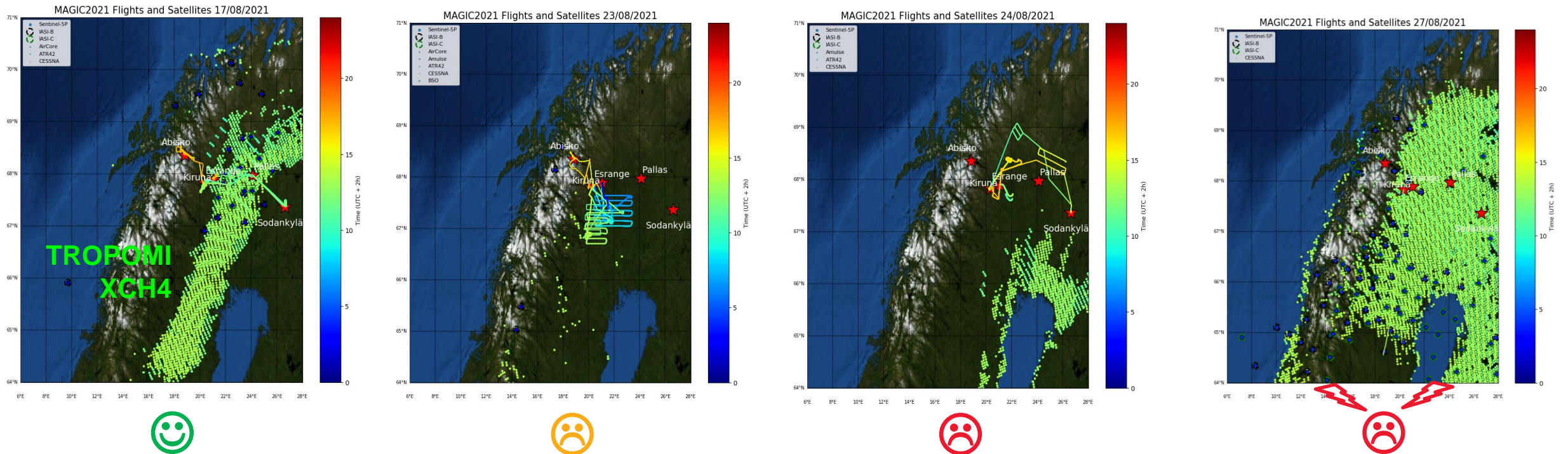
# What could have been done… a look at MAGIC2020 and AirCore-Fr

Validation of TROPOMI/Sentinel-5P 11 June 2020 – SW of France

Deployement of 4 EM27/SUN, SAFIRE Falcon20 and AirCores from Aire-sur-l'Adour along Sentinel5-P track

$XCH_4^{S5P/OPER} - XCH_4^{EM27} = -4.6 \pm 19.7$ ppb

Validation with AirCore from French network (3 sites with monthly launches)

CH$_4$ profiles

Vertical sensitivity of GHG missions

IASI   S5P   OCO-2
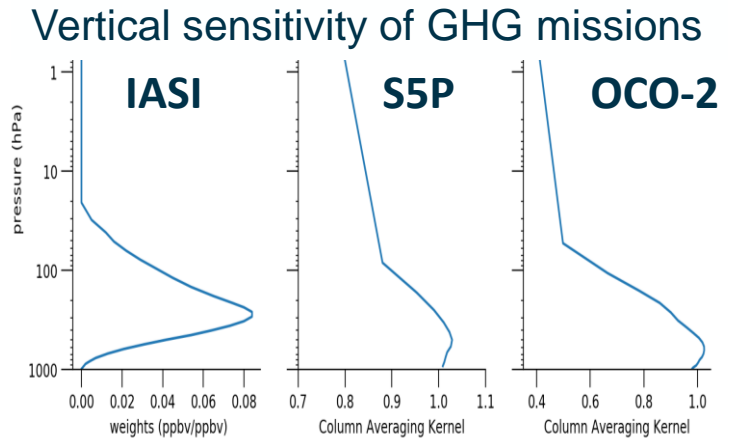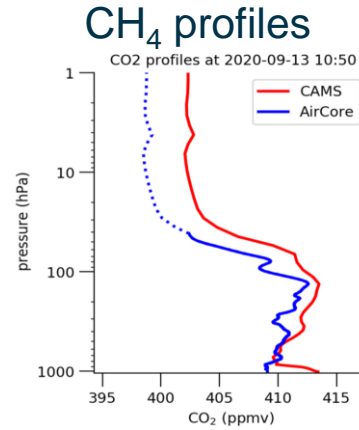
Satellite	Version	Gas	mean ± stdv (AirCore-Satellite)	#FOVs	#AirCore
IASI	v10.2	CH$_4$	0.1 ± 13.0 ppb	3037	35
TROPOMI	L2 OPER	CH$_4$	-9.5 ± 11.9 ppb	8472	33
OCO-2	LtCO2 B10206 Ar	CO$_2$	0.99 ± 0.93 ppm	5212	11

AirCore-Fr data from https://aircore.aeris-data.fr

Lessons learned from MAGIC

- Large field (short) campaigns complement networks by:
  - targeting **specific objectives**: e.g. surface/atm conditions, remote locations, network gaps
  - offering **high density measurements** for spatial representativity
  - enabling the **combination of several instruments** that complement each other ('what is a column?')
- AirCore is extremely valuable to link together various kind of products (profiles vs. weighted columns)

  → **Large-scale campaigns should target at least one-month duration** to cope with bad weather.
  → **Regular AirCore launches in coordination with sat overpass** (such as done in AirCore-Fr program) **and increase in spatial coverage (e.g. high latitudes, tropics) are strongly recommended.**
  → **Need to validate L2 but also to establish a robust relationship between concentrations and fluxes**: Data to support the evaluation and improvement of transport models should be included in campaigns.
  → **Funding not only the instrument part but also data exploitation**.

- Large field campaigns require huge efforts in terms of preparation, logistics, human resources and budget.
  → It is strongly recommended **to combine validation of several space missions and scientific objectives**.
  → A **joined framework between agencies** (CNES, ESA, EUMETSAT, DLR) would strongly help with campaign ambition and administrative aspect (budget gathering, reporting, etc.)

Next campaign: MAGIC-Tropics 2026
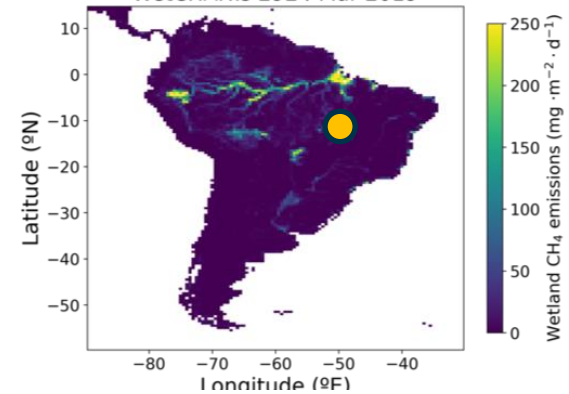
- **Objectives:**
  - **Study of natural GHG emissions:**
    - CH_4 emissions from wetlands and pastures
    - Biomass burning (arc of deforestation)
  - **Satellite validation of flying satellites and specific Cal/Val for:**
    - MicroCarb (launch: March 2025 TBC)
    - IASI-NG/Metop-SG (launch October 2025 TBC)
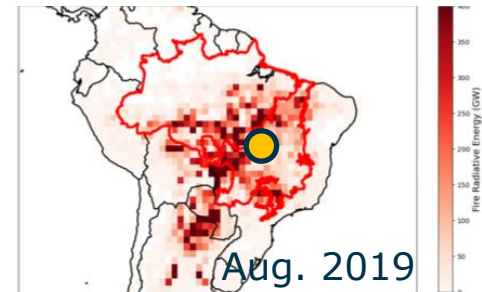
- **Date and locations:**
  - Summer 2026 (6 weeks in June-August) combined with CoMet3.0 DLR campaign
  - Campaign-HQ: Palmas, Tocantins region ●

- **If interested in joining the already 14 teams involved, please contact cyril.crevoisier@lmd.ipsl.fr**

https://magic.aeris-data.fr

Wetland CH_4 emissions

GOES **Fire** Rad. Energy

Aug. 2019