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Evaluation of GHG satellite observations at high Northern latitudes

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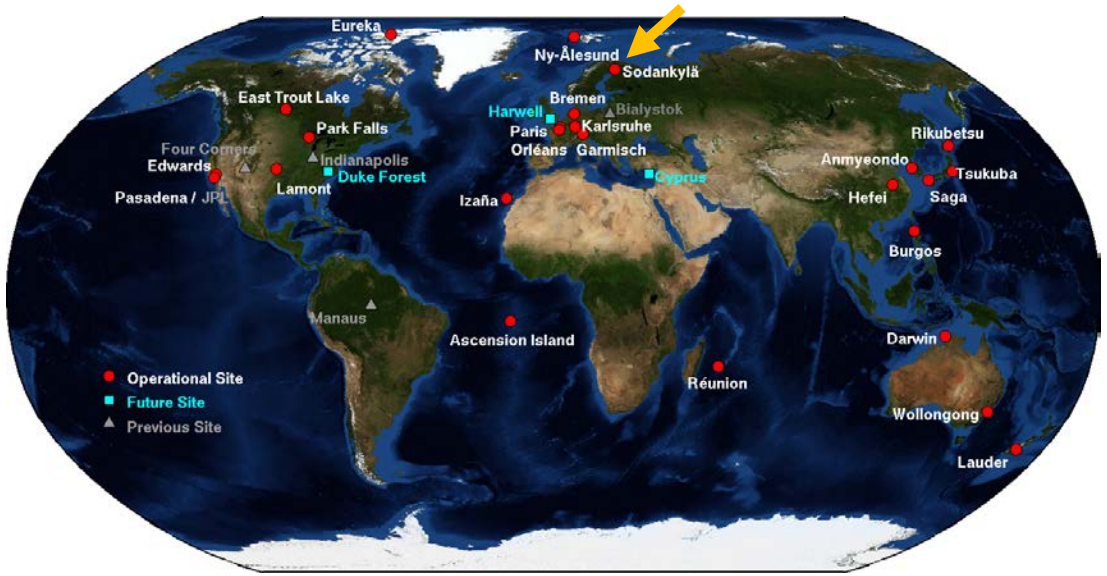
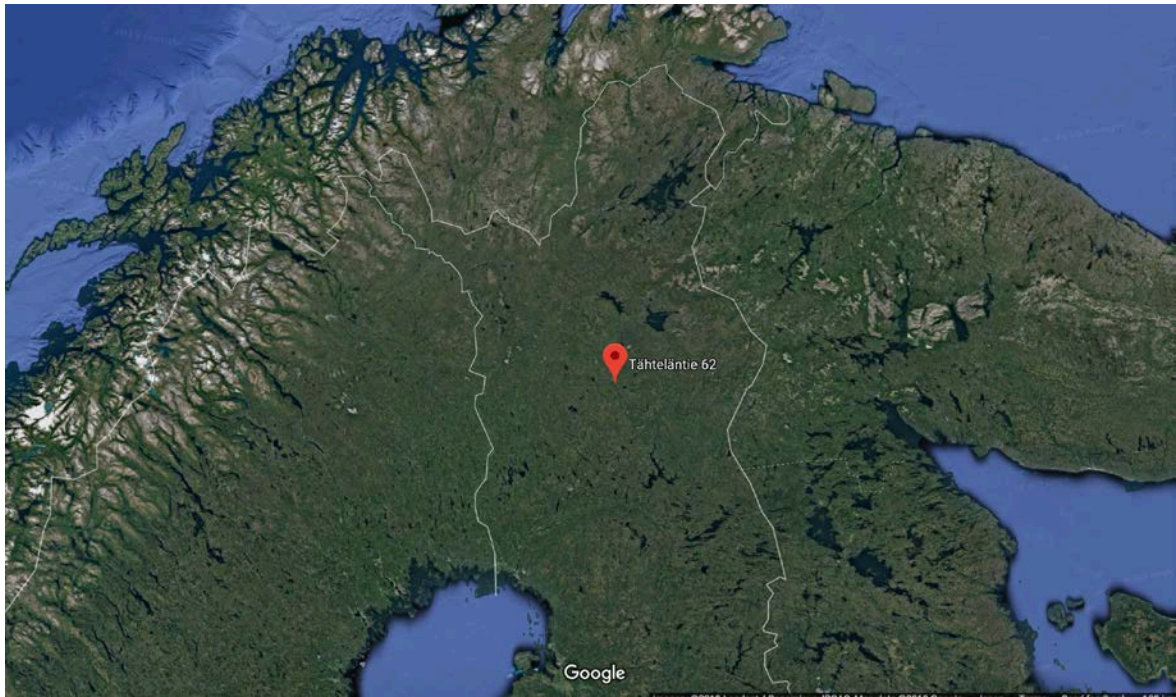
28.6.2019 **IWGGMS-15**

Quantifying changes in the carbon cycle at high Northern latitudes

- Integrated view on the soil-snow-vegetation-atmosphere processes using satellite and in-situ data together with modelling.
- Using diverse satellite data at high latitudes allows a seasonal view on soil/vegetation processes relevant to
  - carbon exchange
  - annual carbon balance
- Example approach: Snow melt derived from space-borne microwave radiometry as a proxy to estimate spring recovery of photosynthesis with the help of in-situ CO_2 flux observations (Pulliainen et al., *PNAS*, 2017)
- Ground-based reference measurements to help develop satellite retrieval algorithms accounting for high-latitude challenges
- Ground-based evaluation of greenhouse gas satellite data but also mapping of snow and soil characteristics and their relation to carbon cycle → Sodankylä supersite for high-latitude validation.

FMI Arctic Space Centre in Sodankylä, Finland





- 67.367 °N, 26.629 °E, 179 m
- Snow on the ground Oct – May
- Scots pine forest, peatlands, no significant anthropogenic GHG sources nearby
- Sub-arctic climate

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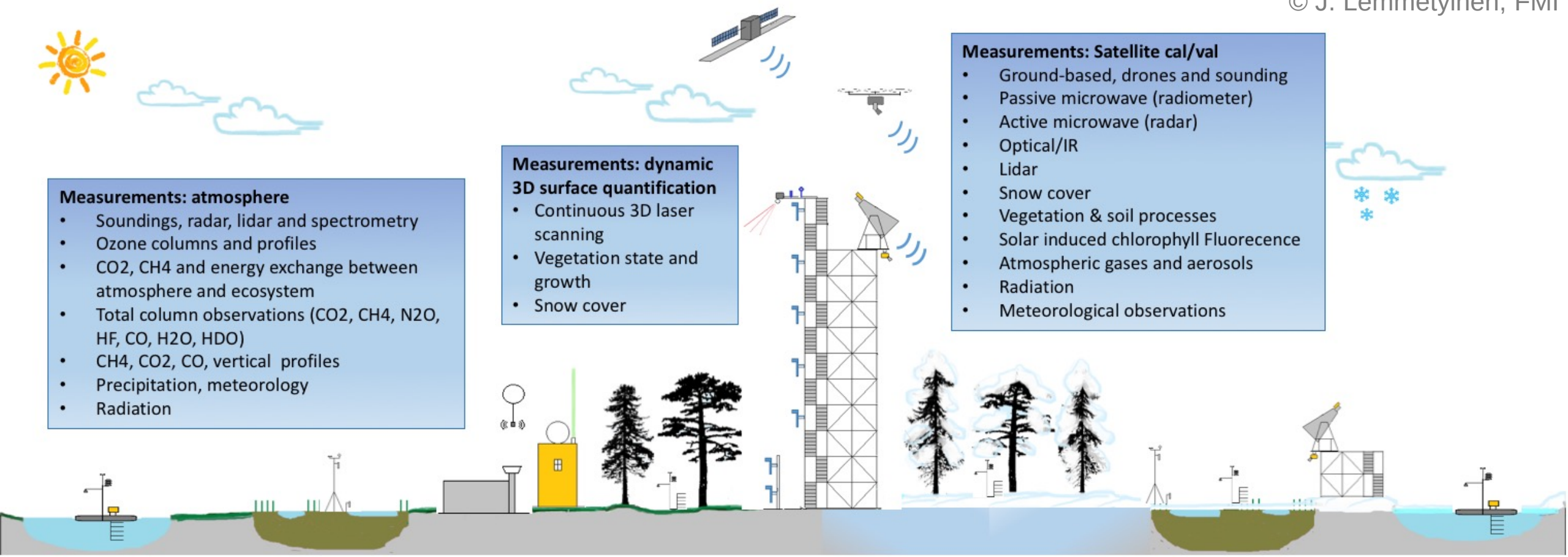


Measurements: atmosphere
- Soundings, radar, lidar and spectrometry
- Ozone columns and profiles
- CO2, CH4 and energy exchange between atmosphere and ecosystem
- Total column observations (CO2, CH4, N2O, HF, CO, H2O, HDO)
- CH4, CO2, CO, vertical profiles
- Precipitation, meteorology
- Radiation

Measurements: dynamic 3D surface quantification
- Continuous 3D laser scanning
- Vegetation state and growth
- Snow cover

Measurements: Satellite cal/val
- Ground-based, drones and sounding
- Passive microwave (radiometer)
- Active microwave (radar)
- Optical/IR
- Lidar
- Snow cover
- Vegetation & soil processes
- Solar induced chlorophyll Fluorecence
- Atmospheric gases and aerosols
- Radiation
- Meteorological observations

Ecosystem processes (summer)

Water bodies (lake/river)
- CO_2 / CH_4 exchange
- Water level
- Surface temperature
- Sensible and latent heat exchange

Wetland
- CO_2 /CH_4 exchange
- Long-term greening
- Plant phenology
- Water level
- Sensible and latent heat exchange

Forest
- CO_2 exchange
- Long-term greening
- Plant phenology
- Soil humidity
- Sensible and latent heat exchange

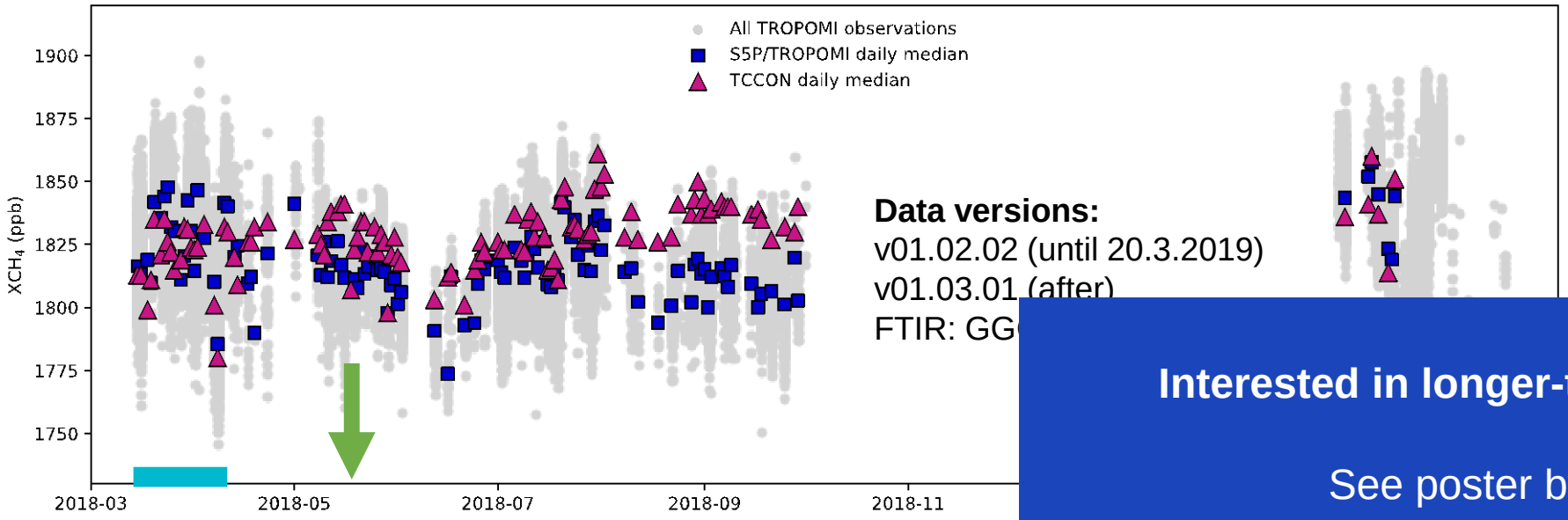
Ecosystem processes (winter)

Forest
- Snow - soil – forest interactions
- Snow Water Equivalent
- Soil freezing

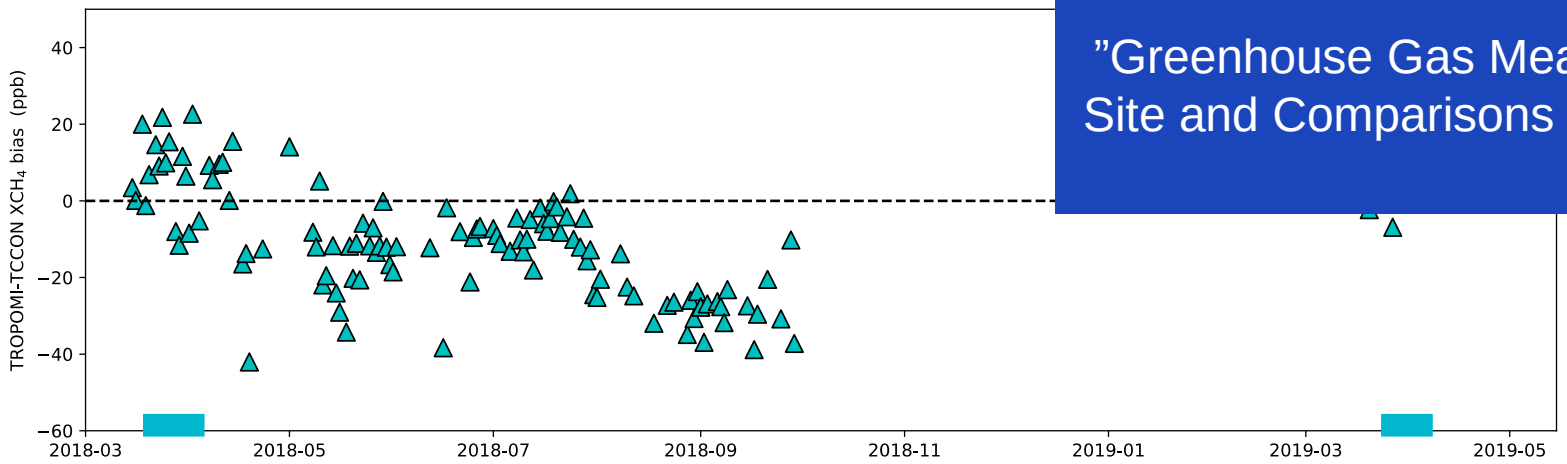
Wetland
- Snow – soil - vegetation interactions
- Snow Water Equivalent
- Soil freezing

Water bodies (lake/river)
- Snow - ice interactions
- Freezing

S5P/TROPOMI XCH_4 validation at Sodankylä



Data versions:
v01.02.02 (until 20.3.2019)
v01.03.01 (after)
FTIR: GG



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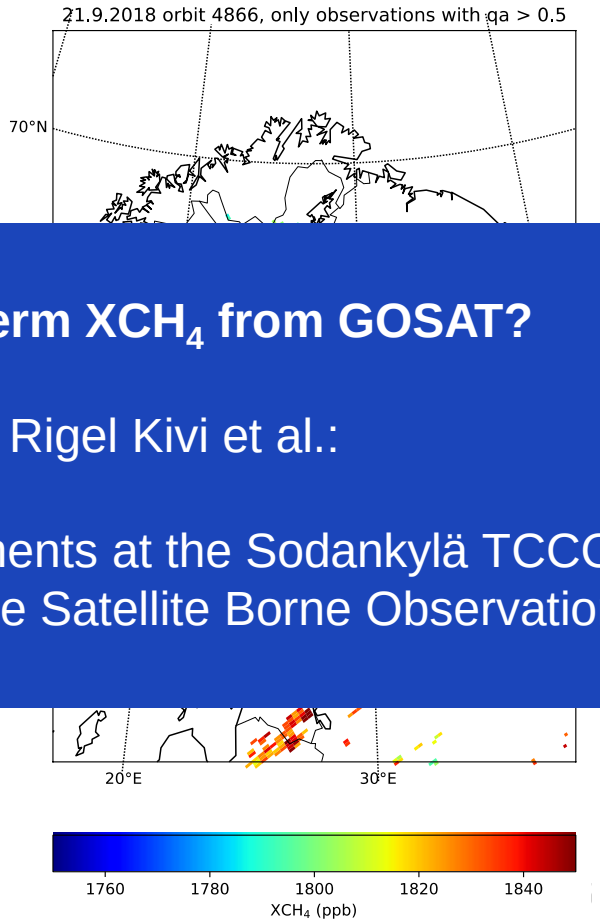
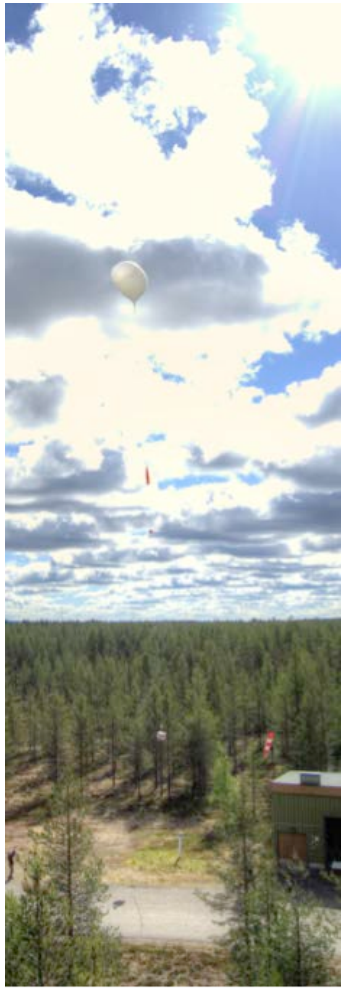


Interested in longer-term XCH_4 from GOSAT?

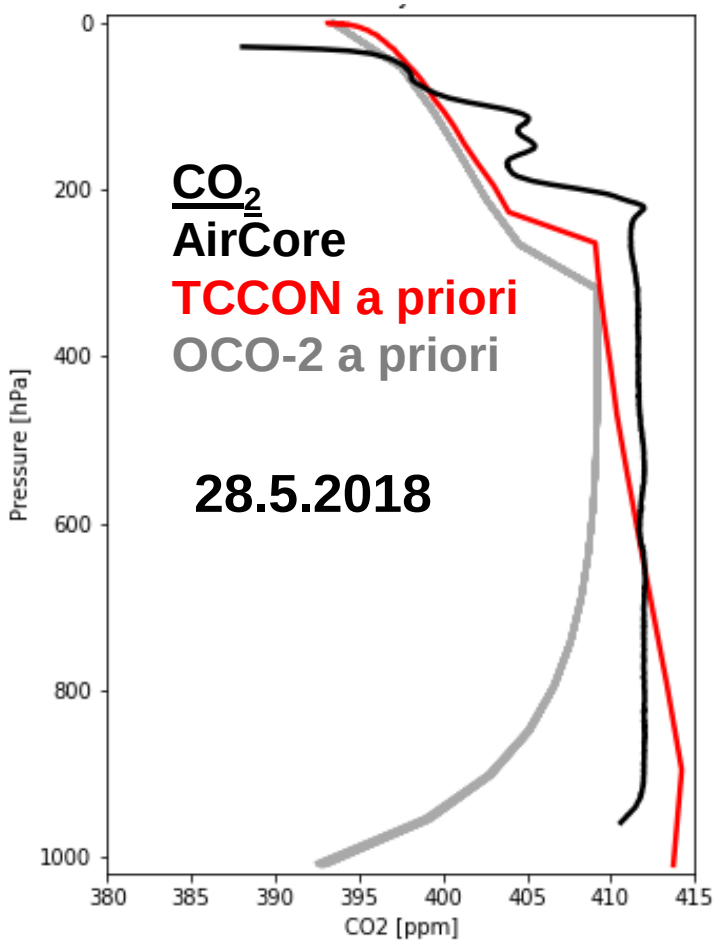
See poster by Rigel Kivi et al.:

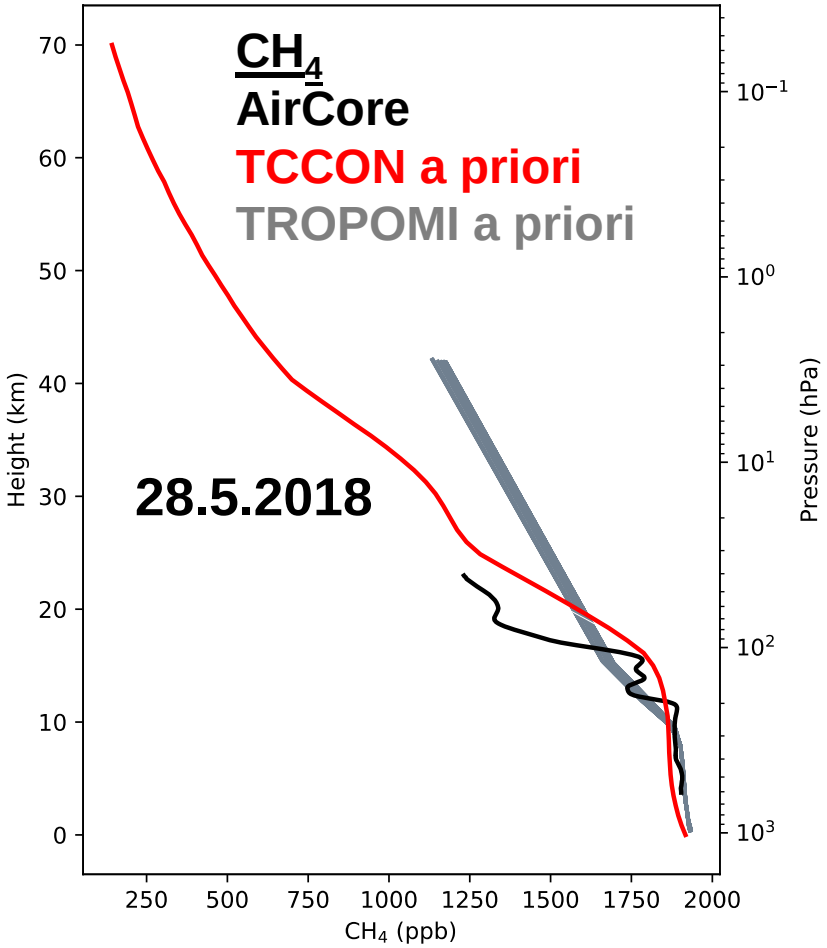
”Greenhouse Gas Measurements at the Sodankylä TCCON Site and Comparisons with the Satellite Borne Observations”

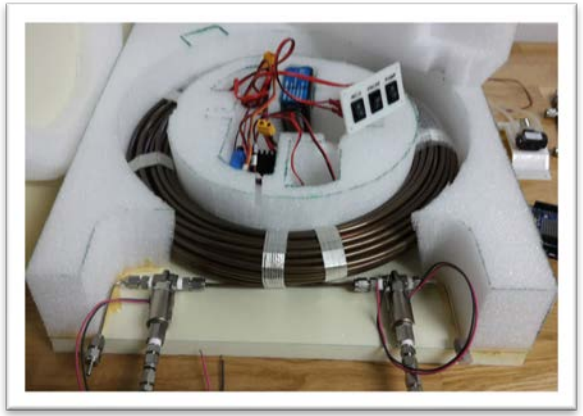
Atmospheric profile measurements



- Can be used to assess satellite retrieval priors.
- CO_2: some differences in the tropopause height and close to the surface
- CH_4: profiles may differ especially during polar vortex → CH_4 profile retrieval for FTIR (SWIRLAB)







- AirCore is an atmospheric sampling system where a stainless steel tube is lifted to the stratosphere using a meteorological balloon
- Monthly AirCore measurements planned during summer 2019; clear-sky days

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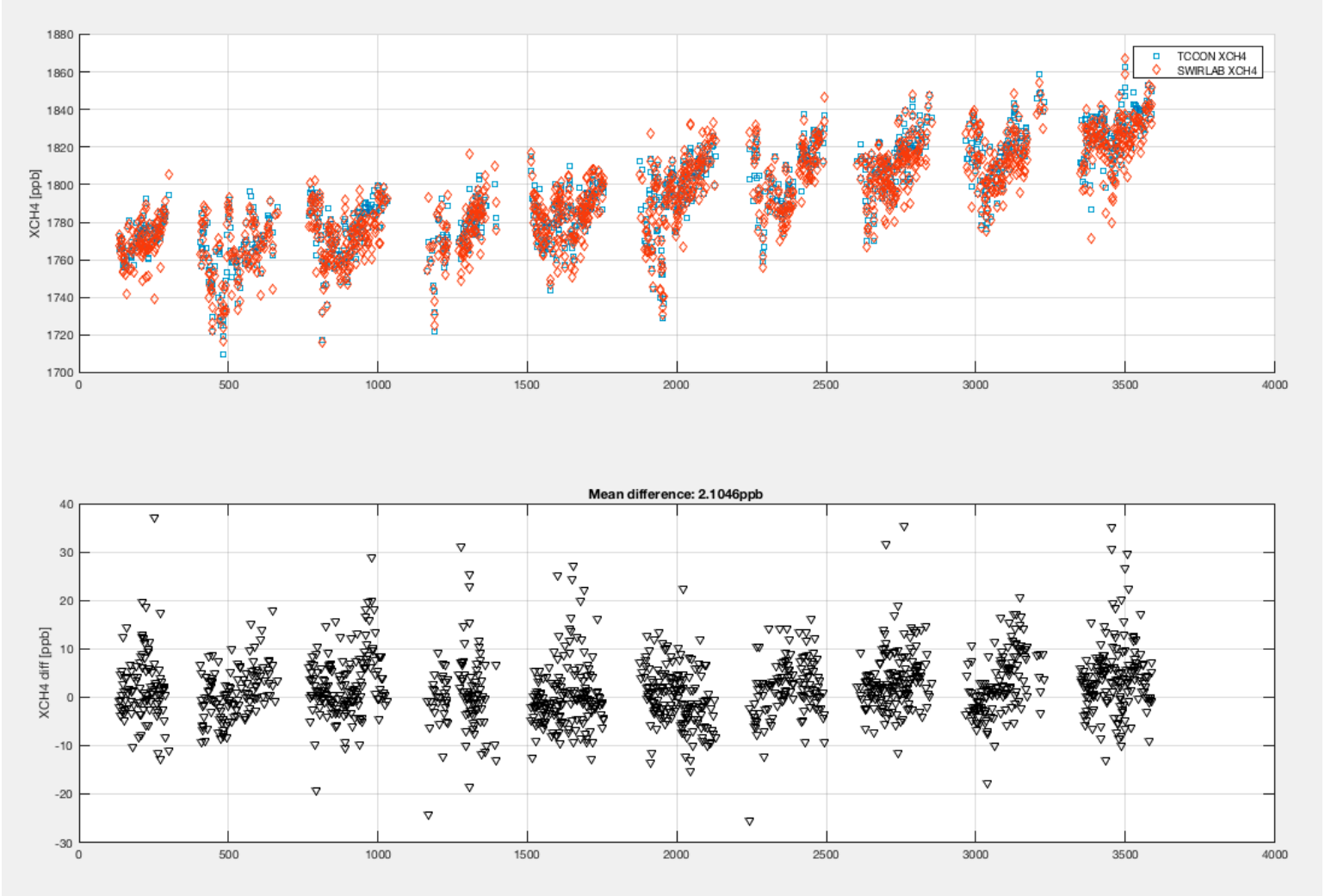
CH_4 profile retrieval for FTIR: XCH_4 comparison to GGG2014

- CH_4 profile retrieval for FTIR using dimension reduction and MCMC (Tukiainen et al., *JGR*, 2016)
- Further developed by Karppinen, Lamminpää et al.
  - Time series analysis for different layers
- XCH_4 agrees well with GGG2014.

Preliminary results – work in progress! (Karppinen et al., to be submitted)



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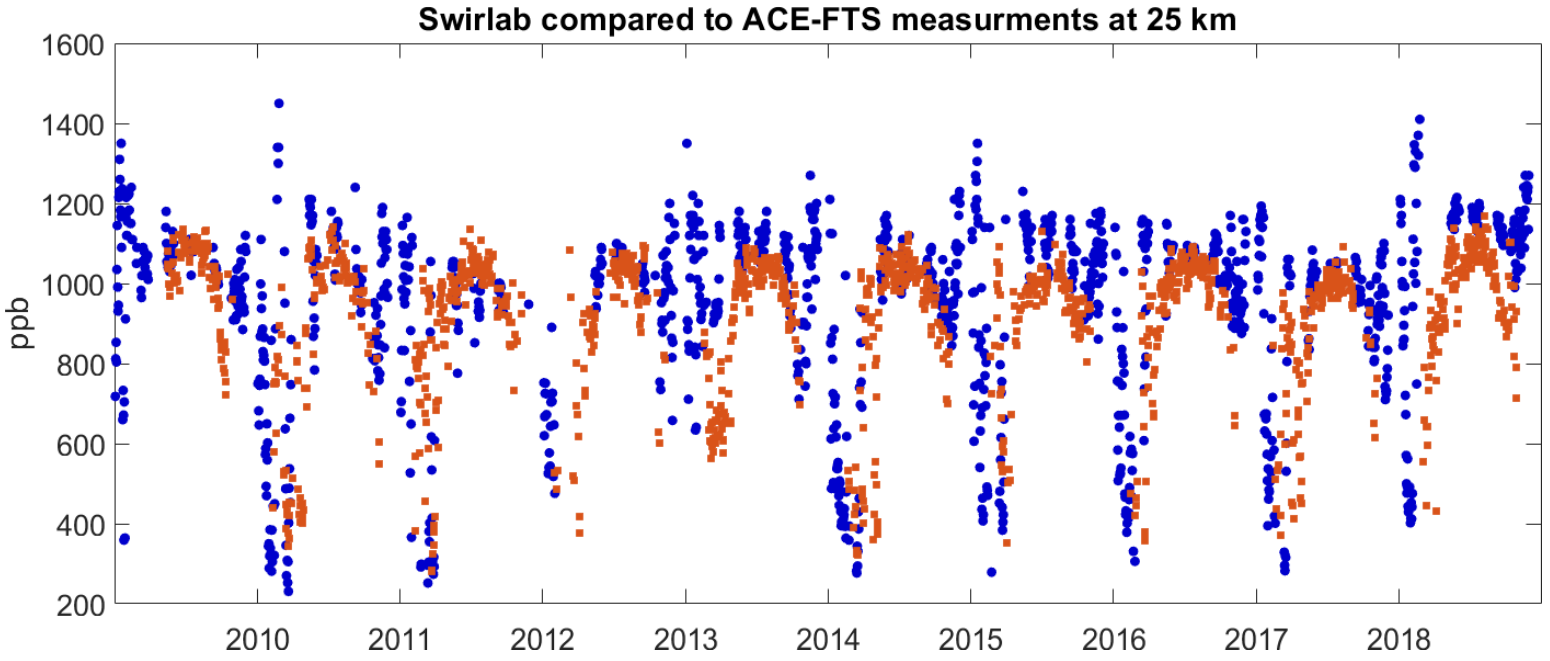
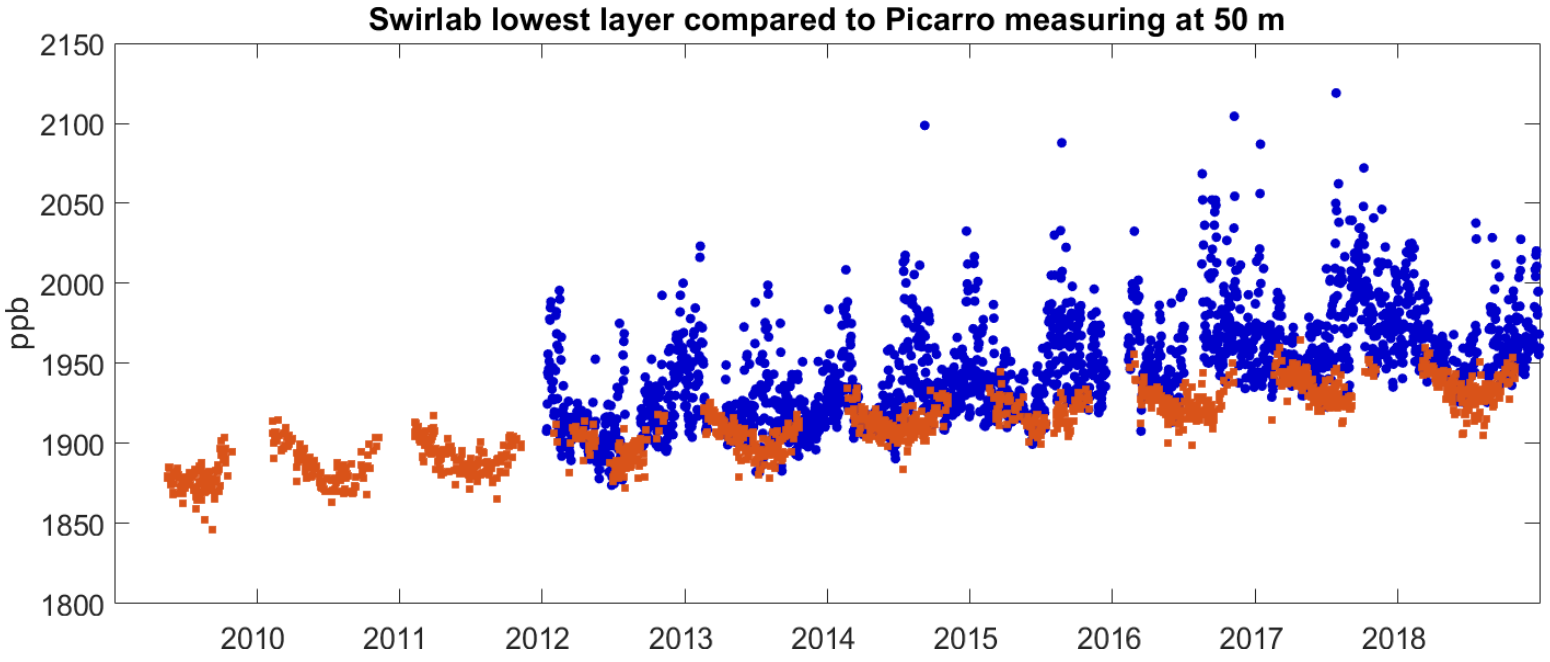


CH4 profile retrieval for FTIR:

Comparison to ACE-FTS at 25 km



Comparison to in-situ at ground level

Preliminary results – work in progress!
(Karppinen et al., to be submitted)

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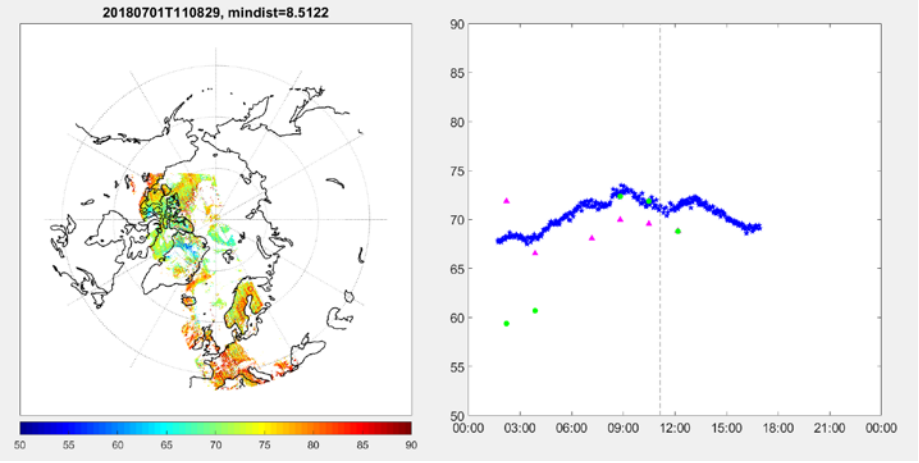
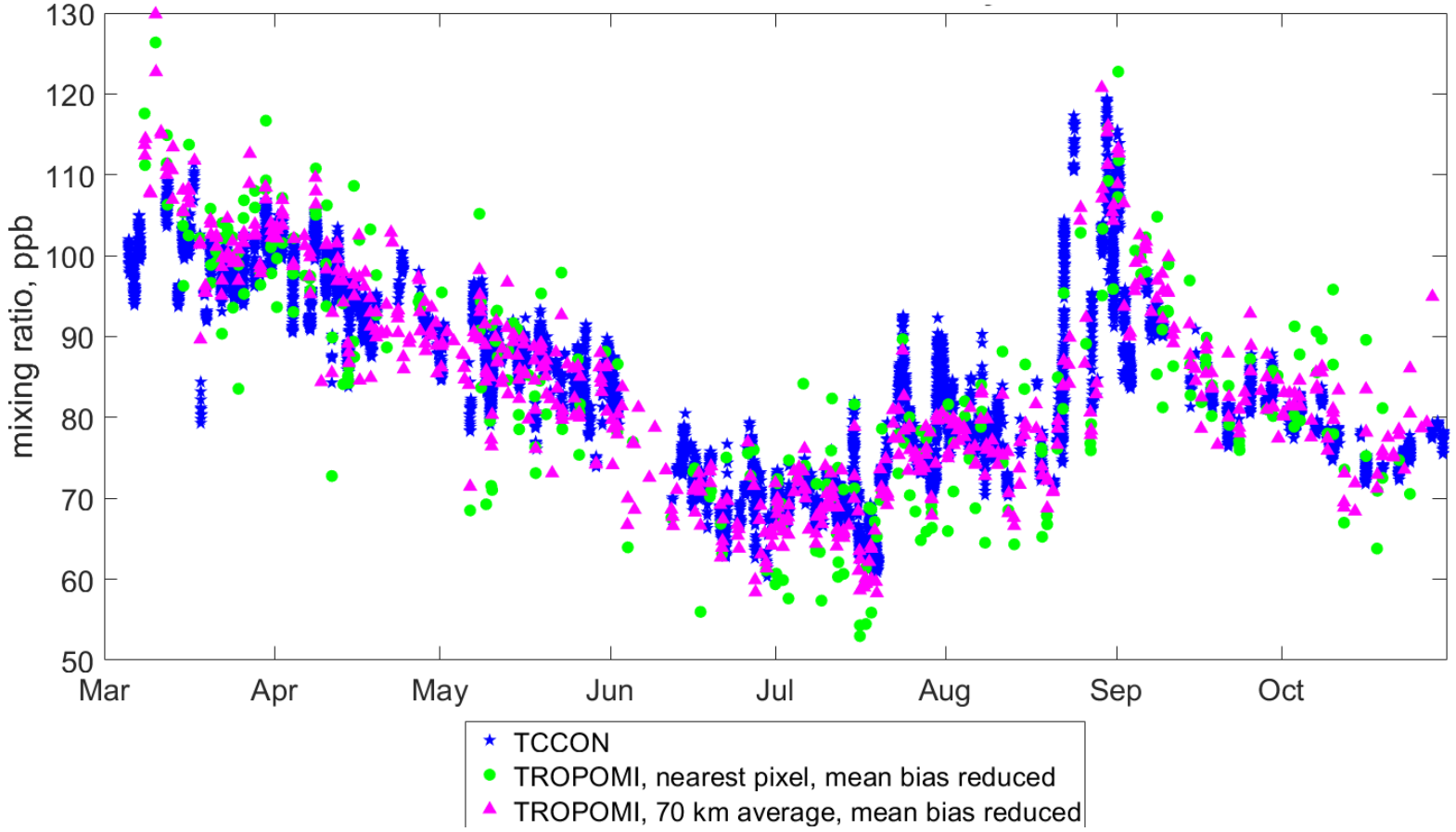
Diurnal variability at high latitudes with TROPOMI?

During NH summer, up to six TROPOMI overpasses per day at Sodankylä

→ Can TROPOMI detect diurnal variability of XCO reliably at high latitudes?





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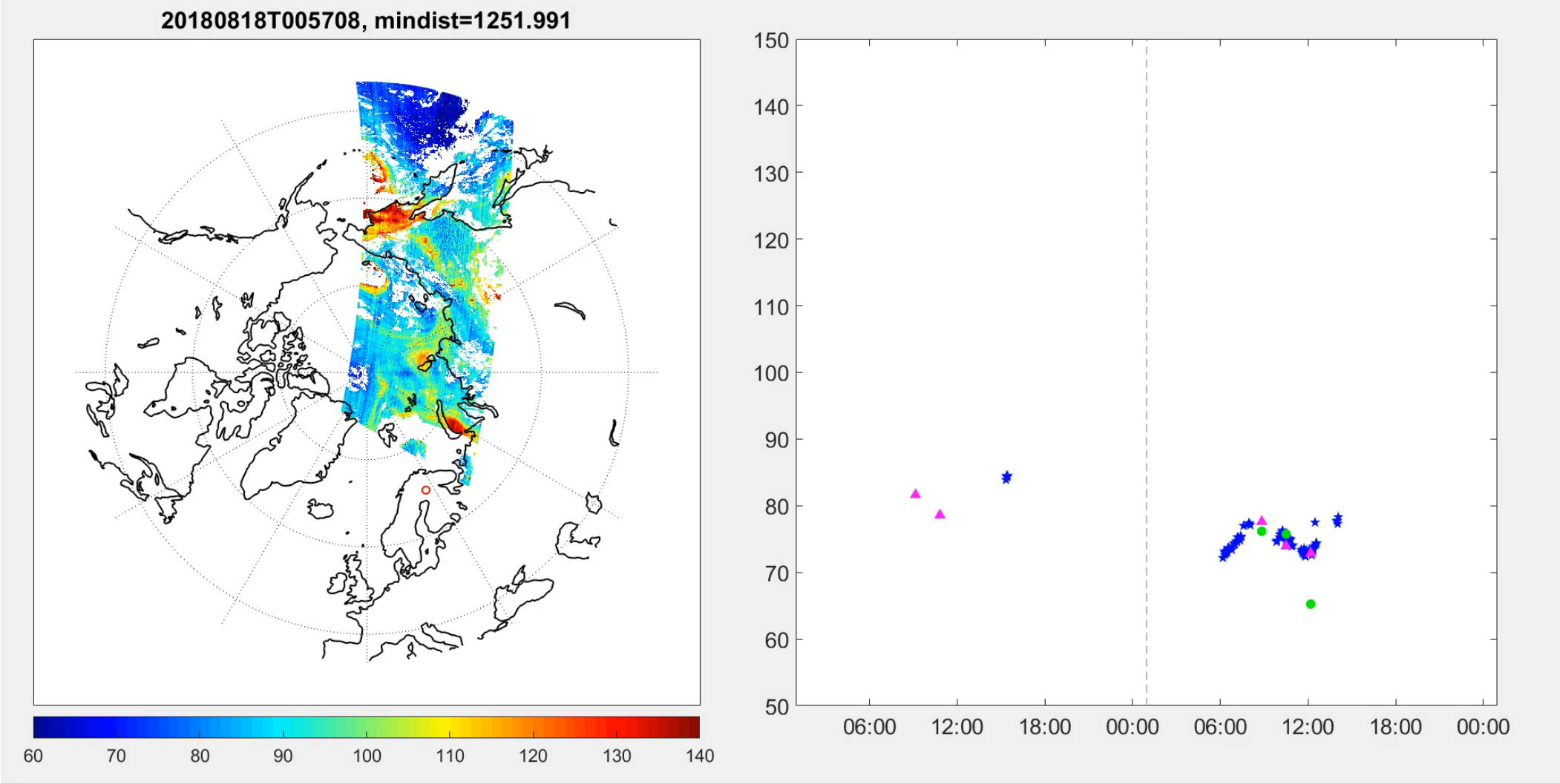
Canadian wildfires and CO transportation



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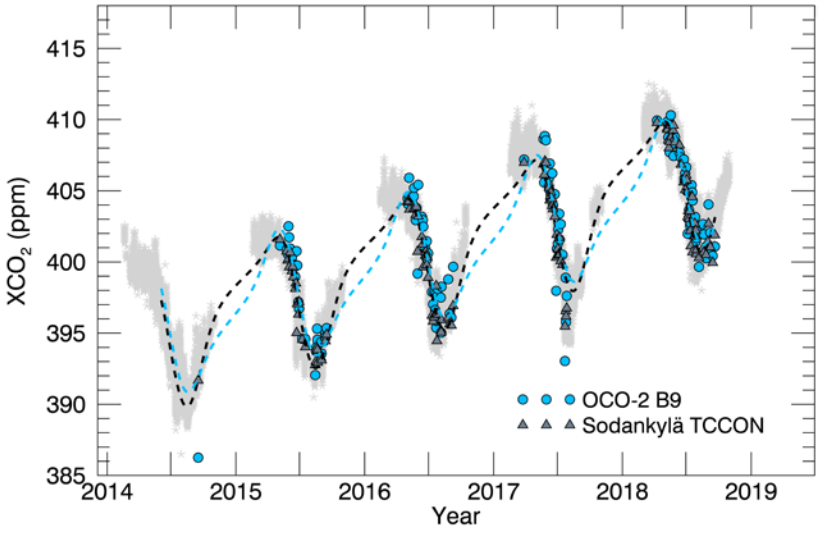
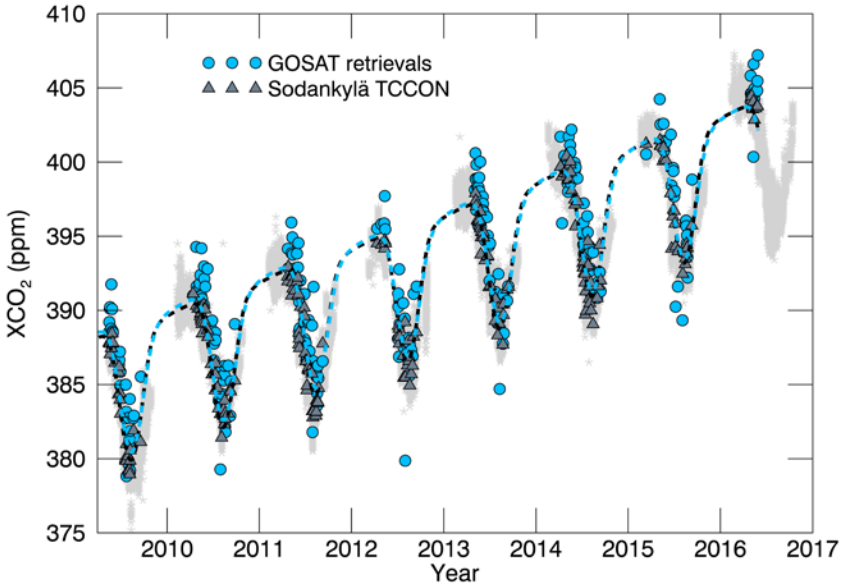
Evaluation of XCO_2 and XCH_4 seasonal cycles at Sodankylä

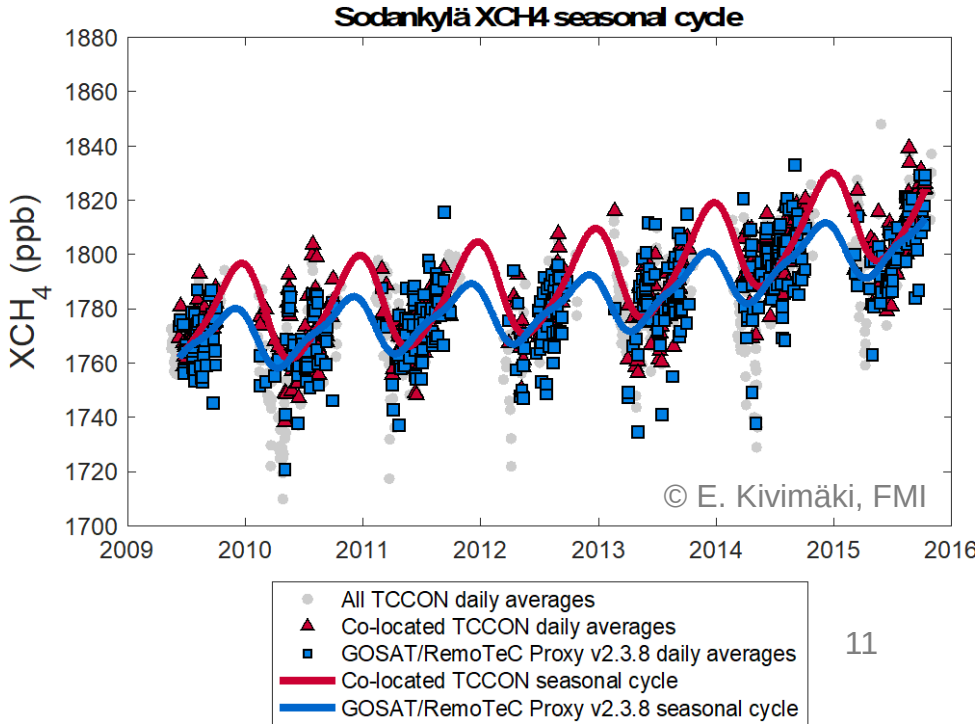




- XCO_2 average seasonal cycle amplitude from OCO-2 and ACOS GOSAT agree well with the TCCON (applied from Lindqvist et al., *ACP*, 2015)

TCCON (co-l. with OCO-2)	OCO-2	TCCON (co-l. with GOSAT)	ACOS GOSAT
10.0 ± 0.3 ppm	9.7 ± 0.4 ppm	9.1 ± 0.4 ppm	8.9 ± 0.4 ppm

- XCH_4 seasonal cycle amplitude from GOSAT (NIES, RemoTeC, RemoTeC proxy) does not correspond to TCCON (maximum during winter gap); however, the nonlinear trend is captured (Kivimäki et al., *Remote Sens.,* 2019)



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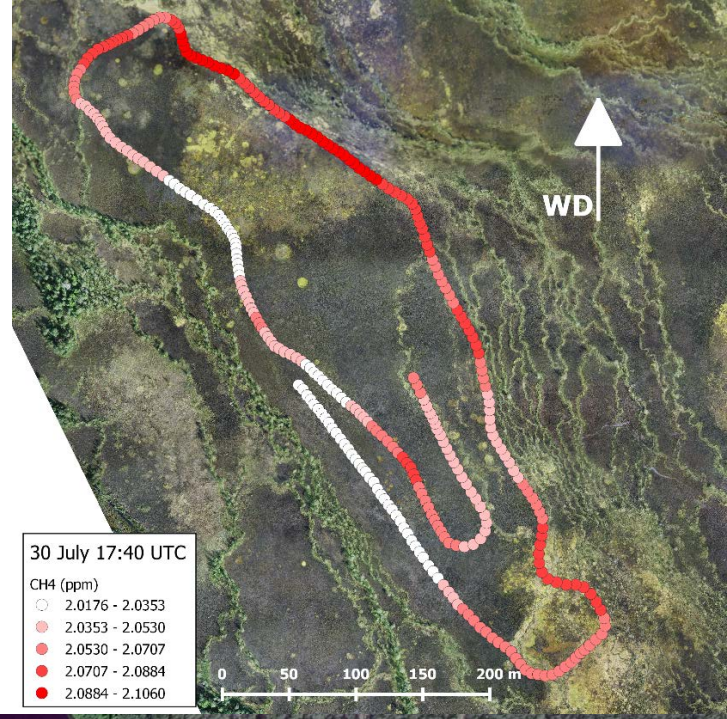
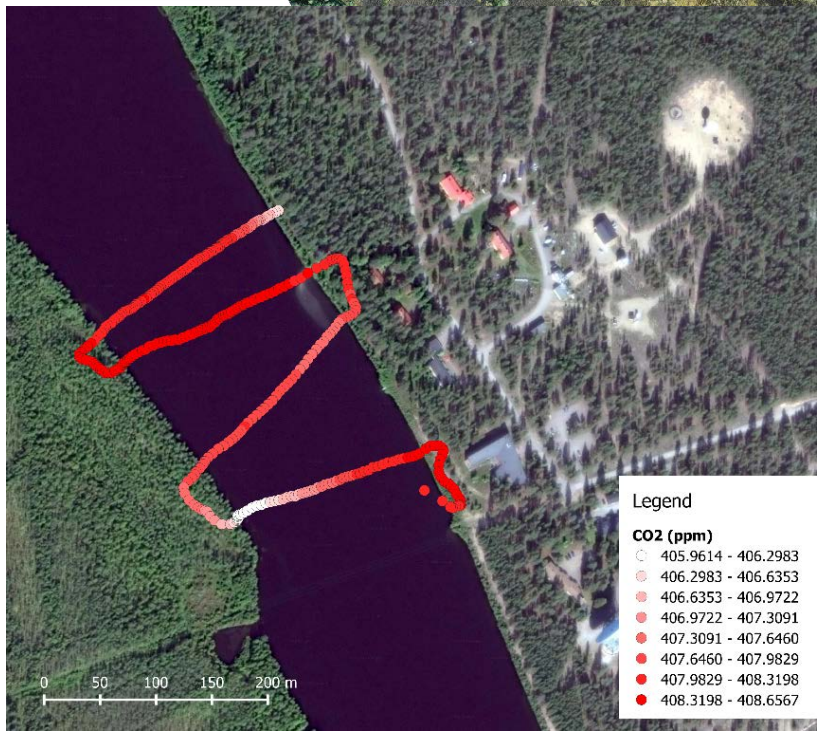
UAV-based measurements

- Initiated during summer 2018. GHG test measurements over wetlands and river Kitinen after spring thaw.
- DJI Matrice 600 for load-bearing, DJI Mavic Pro for aerial photography and mapping.
- Load:
  - 30 m ¼” AirCore
  - Rikola hyperspectral camera
- This summer: SIF measurements



Possibilities:

- Satellite pixel-level variability
- Lowest troposphere (difficult for balloon AirCore)
- Natural and anthropogenic emissions



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Summary and next developments

- Evaluation of satellite seasonal biases → investigate the root causes
- Regular GHG profile measurements important for the evaluation of retrieval priors and new FTIR profile retrieval algorithm.
- Diurnal XCO variability from TROPOMI during NH summer: first results promising but requires more research (next also XCH_4 and SIF).
- High-latitude seasonal cycle of XCO_2 reliably from OCO-2 and GOSAT.
- In summer–fall 2019: added focus on vegetation monitoring
  - SIF measurements on the ICOS tower (NIES collaboration) and onboard UAV
  - 3D laser scanning of trees planned

- Carbon cycle links to the changing cryosphere at high Northern latitudes → Quantifying high-latitude wetland methane exchange using SMOS soil freeze and thaw data: see poster by Lindqvist, Tsuruta et al.: ”Solving Methane Fluxes at Northern Latitudes using Atmospheric and Soil Earth Observations Data”