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Royal Belgian Institute for Space Aeronomy (BIRA-IASB)

Institut royal d'Aéronomie Spatiale de Belgique (IASB)

Koninklijk Belgisch Instituut voor Ruimte-Aeronomie (BIRA)

First results of the ESA AO project TCCON4S5P focusing on the validation of the Sentinel-5P Methane and Carbon Monoxide using TCCON data

Validation team

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Support team members of the network

TCCON sites in the NH (20)

- Anmyeondo – Tae-Young Goo
- Bialystok – Justus Notholt / Thorsten Warneke
- Bremen – Justus Notholt / Thorsten Warneke
- Burgos – Isamu Morino / Voltaire Velazco
- Pasadena/JPL – Paul Wennberg
- Edwards/Dryden – Laura Iraci
- East Trout Lake – Debra Wunch
- Eureka – Kimberly Strong
- Garmisch – Ralf Sussmann
- Izana – Matthias Schneider
- Karlsruhe – Frank Hase
- Lamont – Paul Wennberg
- Orleans – Justus Notholt / Thorsten Warneke
- Park Falls – Paul Wennberg
- Paris – Yao Té
- Rikubetsu – Isamu Morino
- Saga – Kei Shiomi
- Sodankyla – Rigel Kivi
- Spitsbergen / Ny Alesund – Justus Notholt
- Tsukuba – Isamu Morino

TCCON sites in the SH (5)

- Ascension Island – Dietrich Feist
- Darwin – David Griffith / Voltaire Velazco
- Lauder – Dave Pollard
- Reunion Island – Martine de Mazière
- Wollongong – David Griffith / Nicholas Deutscher

Upcoming TCCON sites (3)

- Los Alamos – Manvendra Dubey
- Harwell – Damien Weidmann
- Hefei – Cheng Liu

+ contribution from Coleen Roehl, Matthäus Kiel and Geoffrey Toon and other members of TCCON

Overview of the proposed activity

- Geophysical validation of S5P Methane (CH4) and Carbon Monoxide (CO) total column products using coinciding data of the Total Carbon Column Observing Network (TCCON)
  - → Phase E1 (12 months): Initial validation with rapid delivery data (every 3 months)
  - → Phase E2 (7 years): Improvement of ongoing validation strategy, long term validation during the life time of the satellite, revalidation using future versions of TCCON and S5P data products
- Reduction of intercomparison error by using independent profile information as a common prior for satellite and ground based soundings
- Validation with TCCON-constrained global XCH4 fields
  - → Available global XCH4 fields for S5P
    - → ECMWF/Copernicus CAMS project (near real-time)
    - → new MPI for Biogeochemistry Jena CH4 inversion (yearly)
  - → Both inversion systems provide global CH4 fields constrained by S5P-independent observations (in-situ, satellite, TCCON)
  - → MPI-BGC inversion can be run TCCON-only constrained to extend TCCON observations to the global scale

The TCCON has been specially created with satellite validation in mind

- → Highly homogenized network, global coverage (80° N – 45° S)
- → High accuracy / precision (0.2% / 0.3% for CH4 and 2% / 1% for CO)
- → Data is used to validate satellite measurement from GOSAT (TANSO-FTS), ENVISAT (SCIAMACHY) and OCO-2
- → TCCON and TROPOMI measure CO and CH4 in the same spectral region

Sentinel-5 Precursor

- TROPOMI has unprecedented resolution and capabilities: global daily coverage with 7x7 km^2 pixel size and 2600 km swath width.
- TROPOMI observes the CO global abundance in the 2.3 μm (2305-2385 nm) spectral range in the SWIR spectral region. TROPOMI clear-sky observations provide CO total columns with sensitivity to the tropospheric boundary layer.
- TROPOMI will use the absorption information from the Oxygen-A Band (757-774 nm) and the SWIR spectral channel (2305-2385 nm) to retrieve the CH4 global abundance in the Earth's atmosphere.

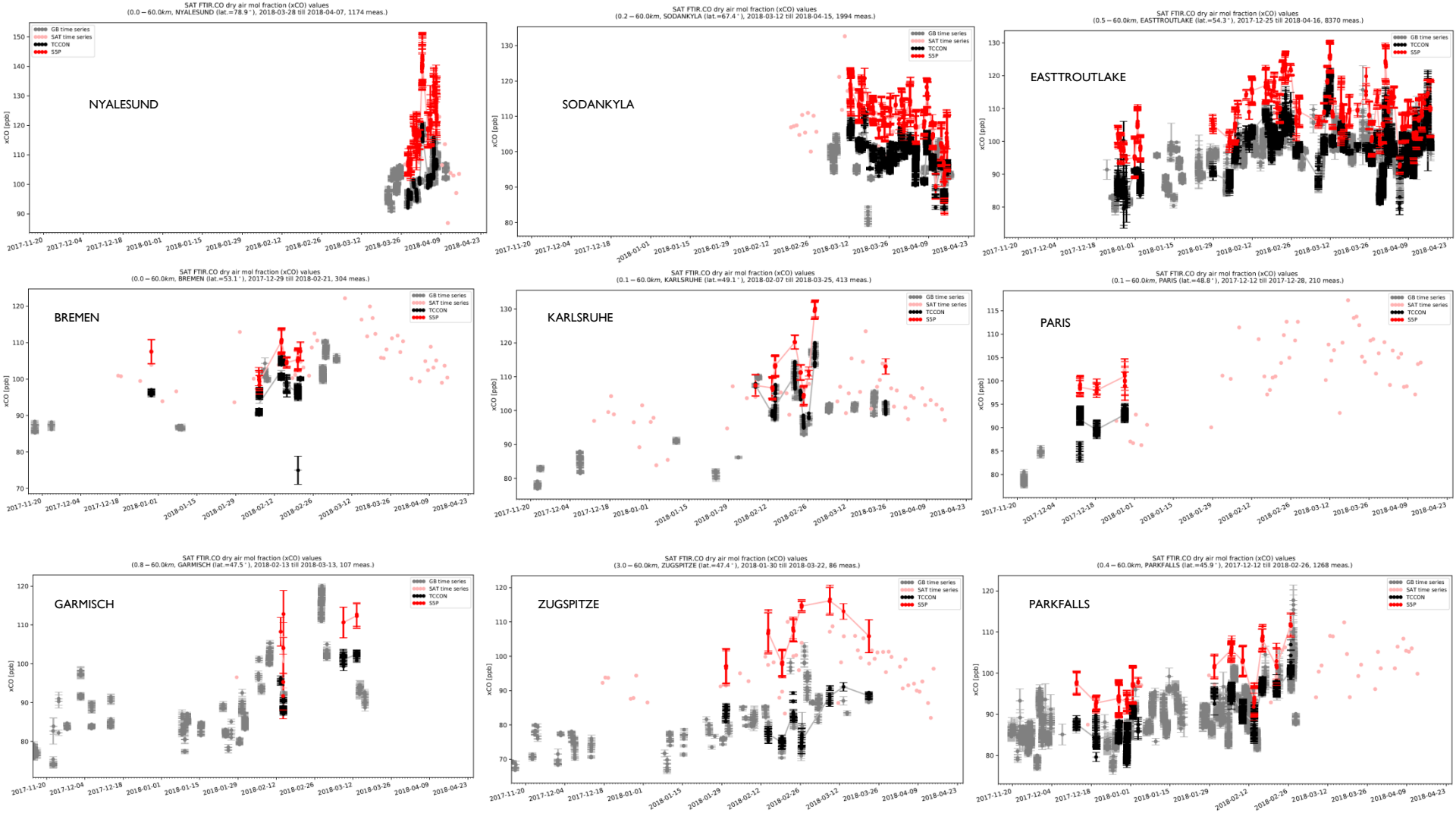
Table 1 – Sentinel-5P TROPOMI mandatory atmospheric composition data products addressed by this project

Parameter	Data Product	Vertical resolution	Systematic Uncertainty Requirement	Random Uncertainty Requirement
Carbon Monoxide (CO)	Total CO	Total column	15%	<10%
Methane (CH4)	Total CH4	Total column	1.5%	1%

Validation during S5P phase E1

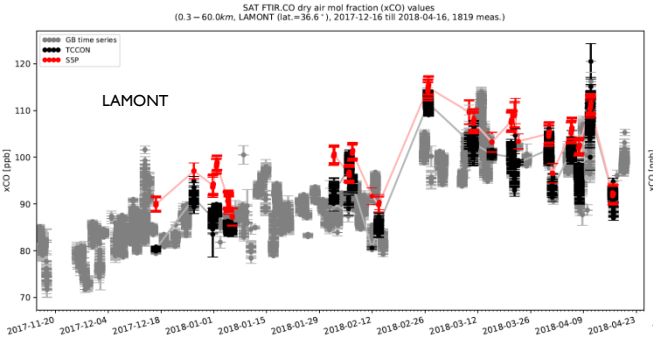
- Period of study: 17 November 2017 – 25 April 2018
- TCCON data provided by 20 stations (fast data delivery).
  Missing stations: mostly have instrumental problems or not yet ready with fast data delivery.
- S5P data from Mission Performance Centre (MPC) provided by the Payload Data Ground Segment (PDGS) at DLR (Preliminary data for Phase E1).
- Coincidence criteria for CO and CH4: Time delta = 3 hours; sensitive on the LOS = 5 km; Geo-distance delta = 30 km from the effective location on LOS. Filtering: SZA < 80; VAA > 0; VZA < 65; From the coincident and filtered satellite measurements an average of all pixels is taken for each TCCON measurements.
- Validation for CO: S5P CO a priori is substituted with the TCCON CO a priori (Rodgers, 2003)
- Validation for CH4: direct comparison of the total column CH4 of S5P and TCCON.

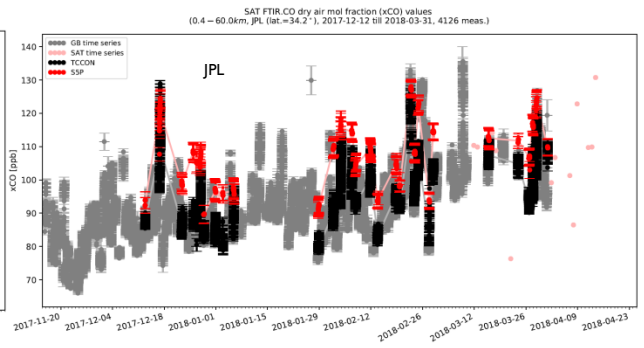
Validation plots for CO

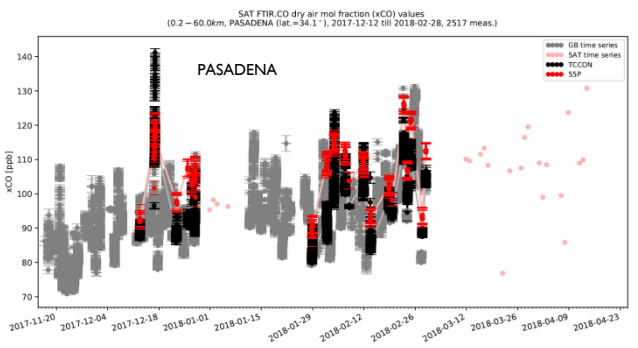


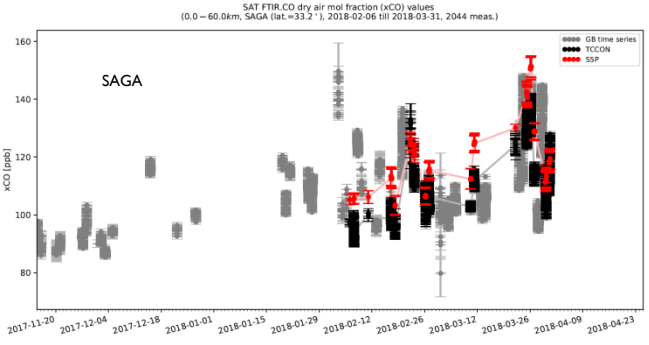
GB time series (grey): all TCCON measurements; SAT time series (light red): mean of all SAT measurements which pass the coincidence criteria; TCCON (black): coincidence TCCON measurements; SAT (red): coincidence TCCON S5P measurements.

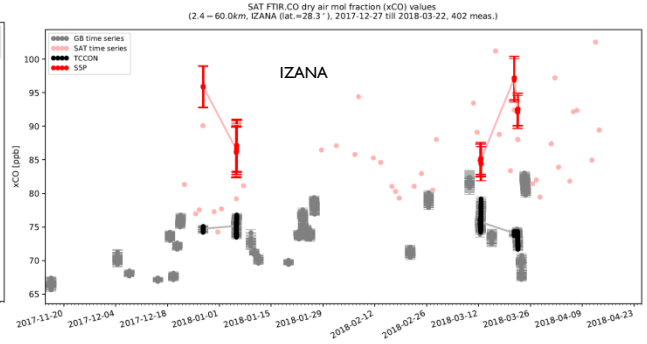
Validation plots for CO

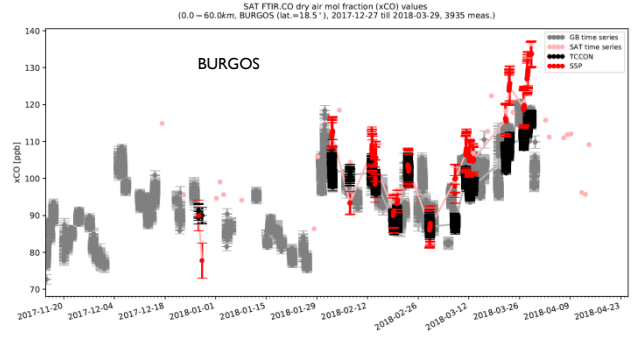




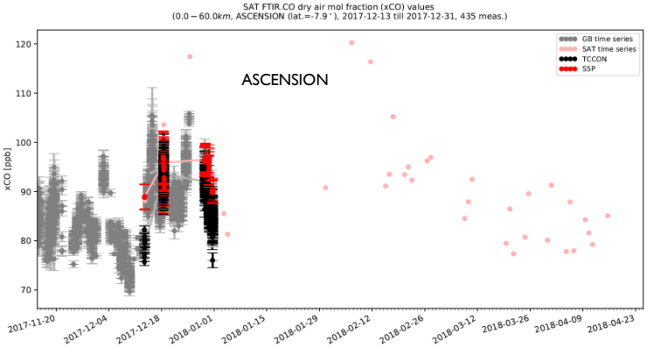


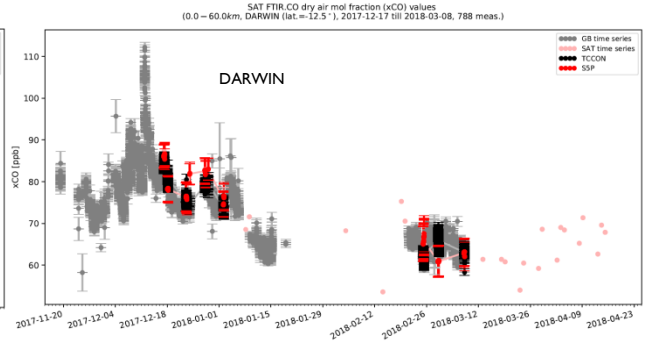


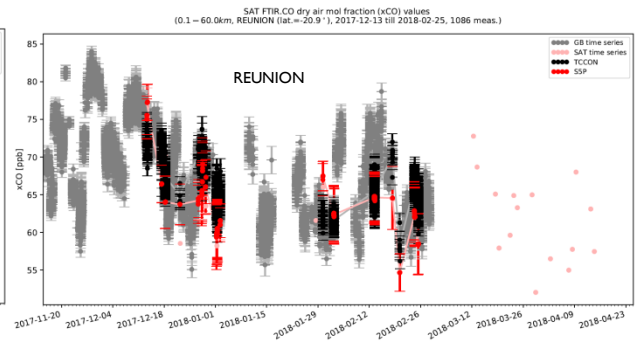


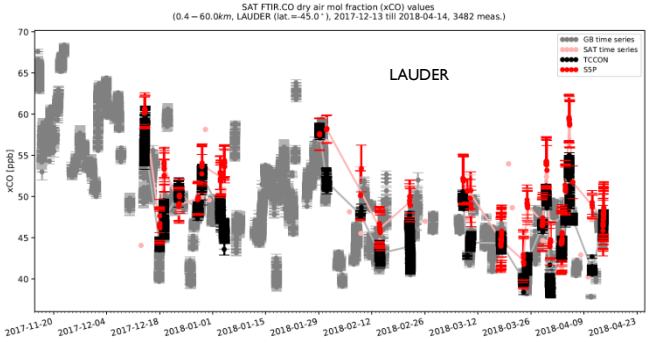


Validation plots for CO

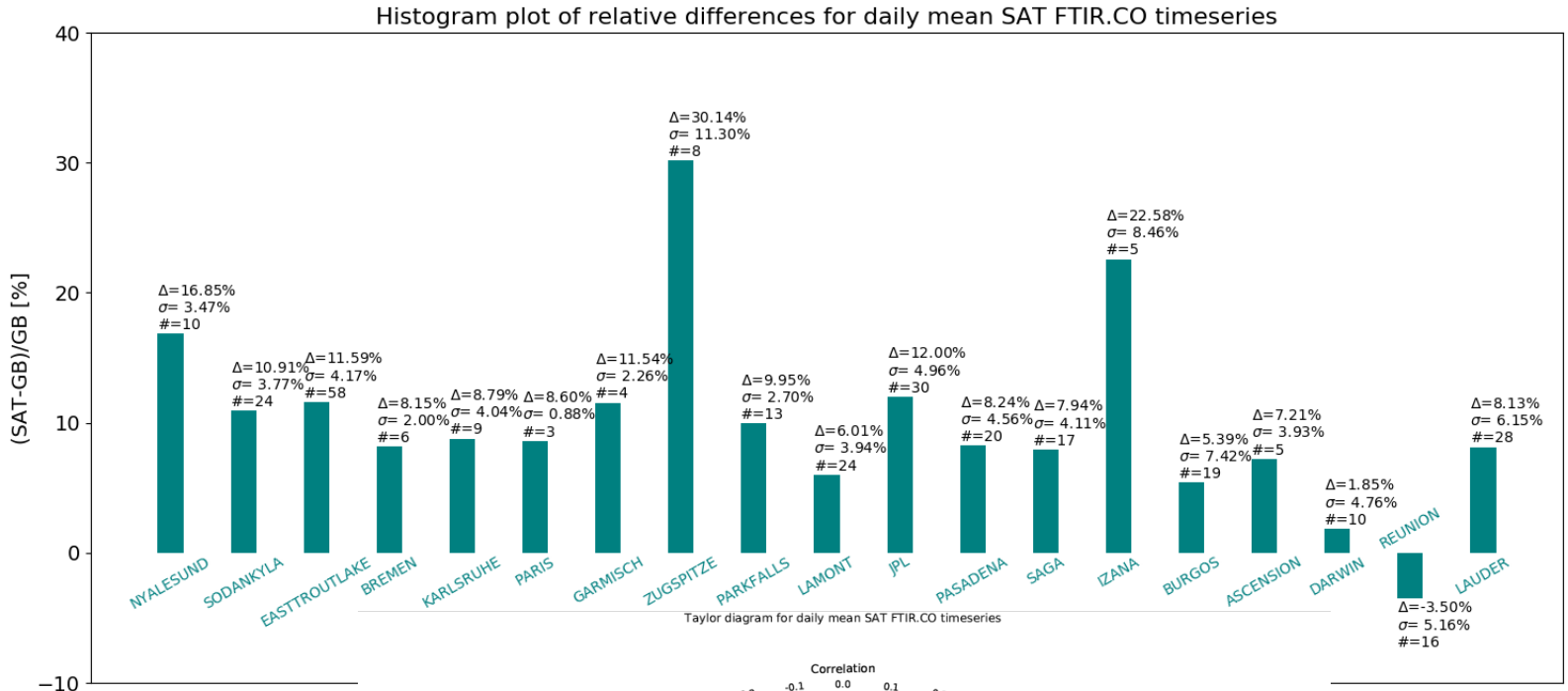


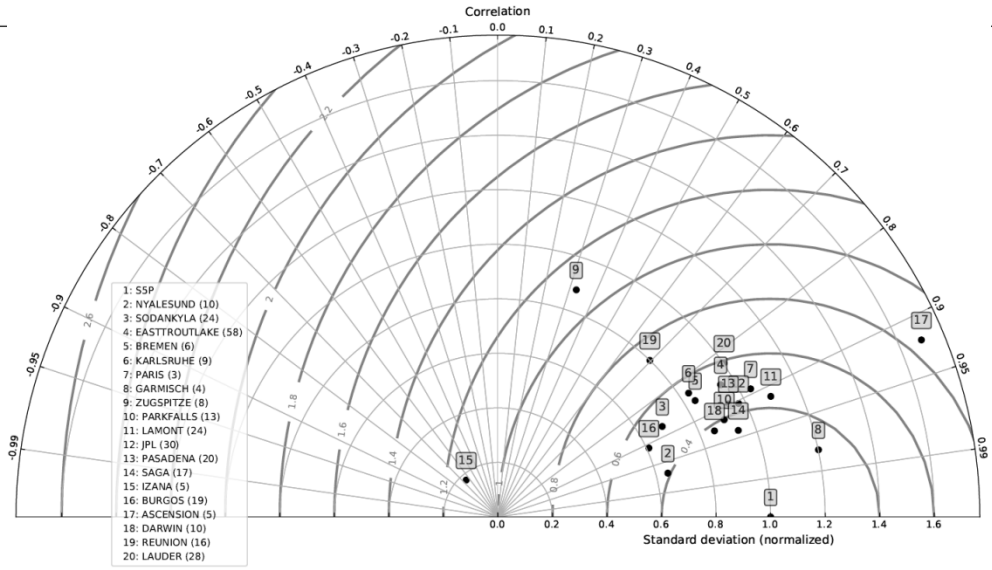




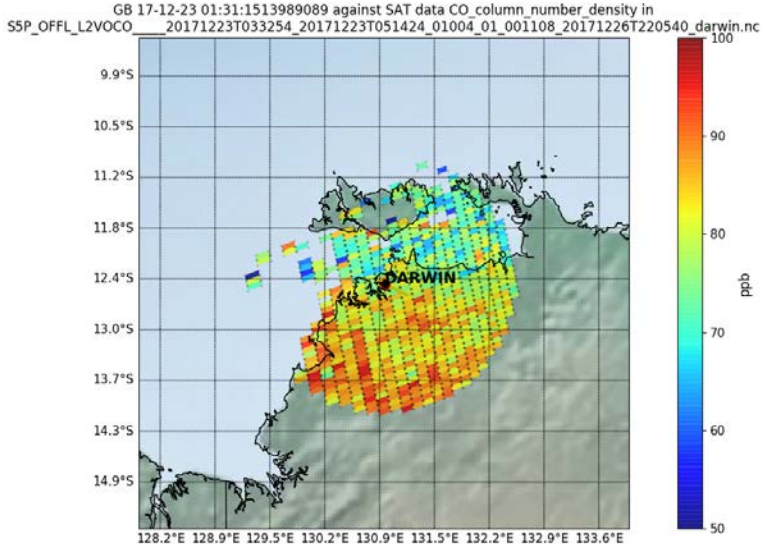


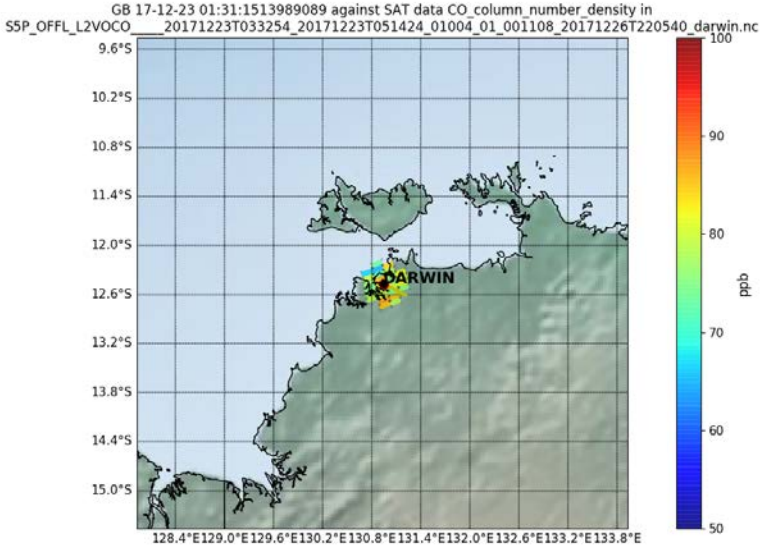
Validation plots for CO

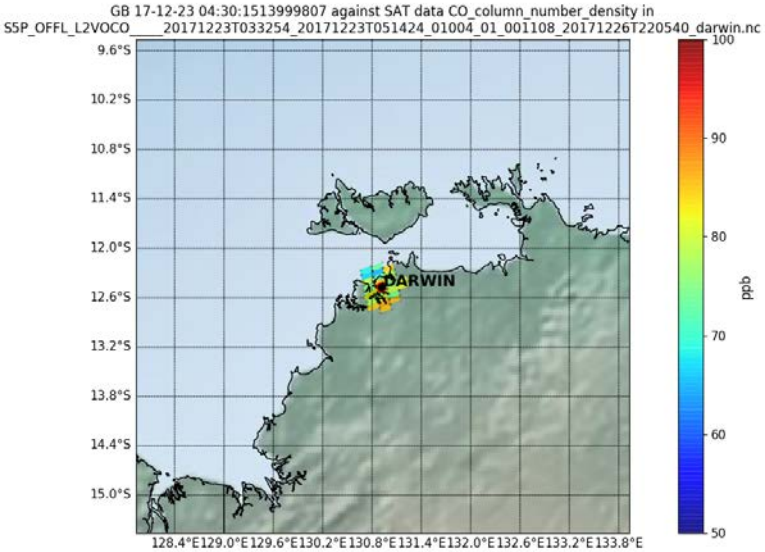


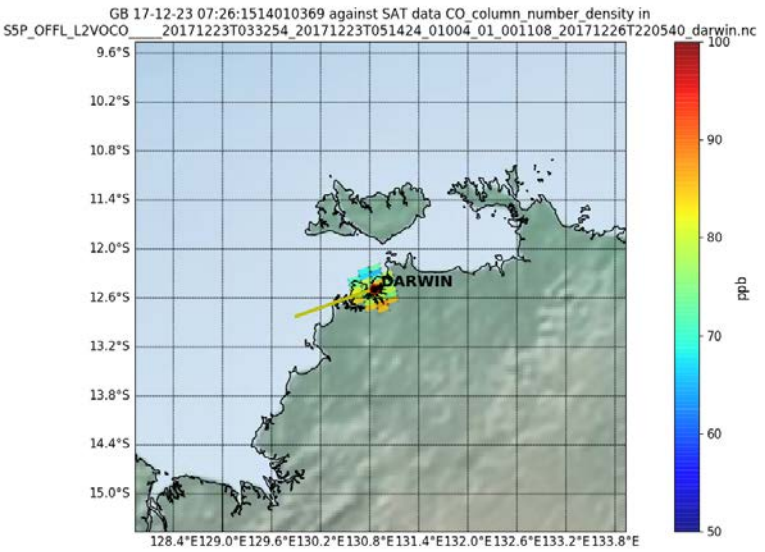


Validation plots for CO – Darwin (40 m)

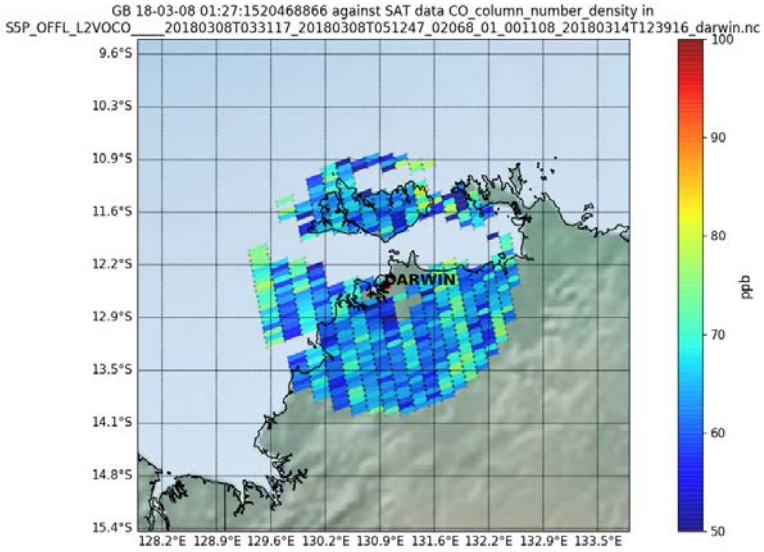


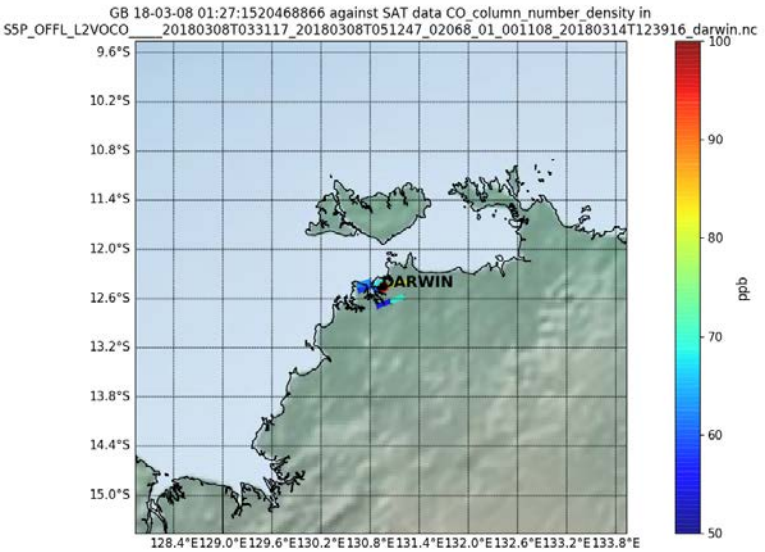


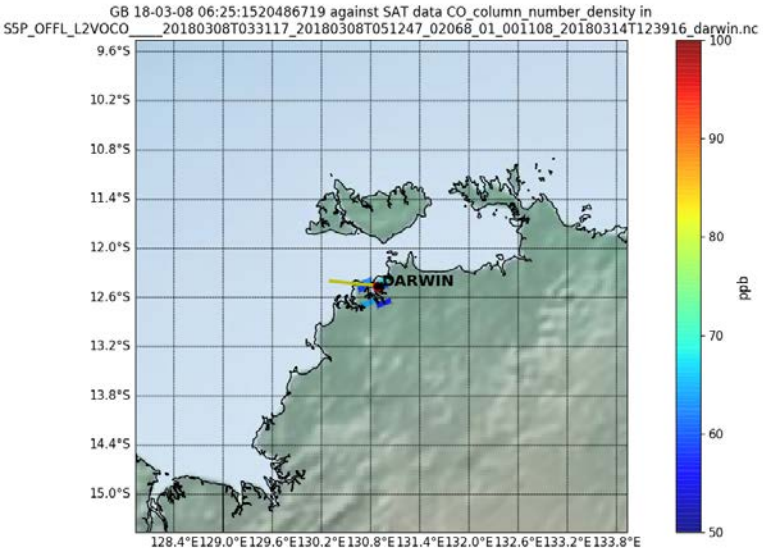


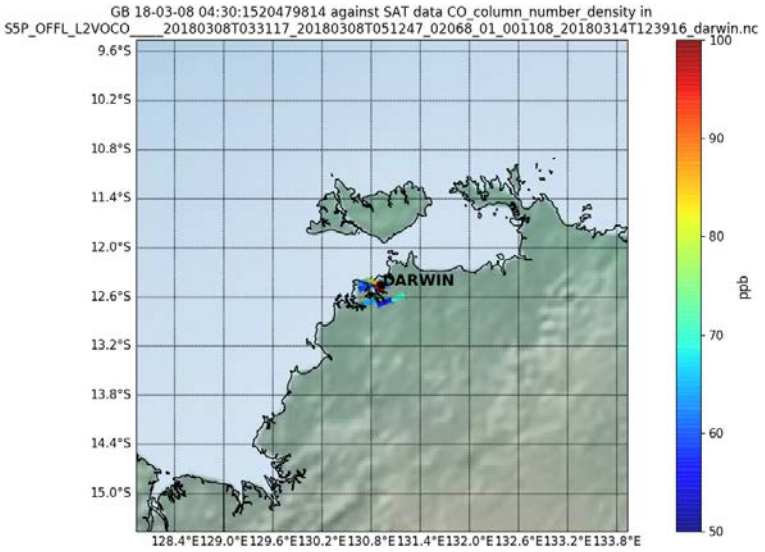


Validation plots for CO – Darwin (40 m)

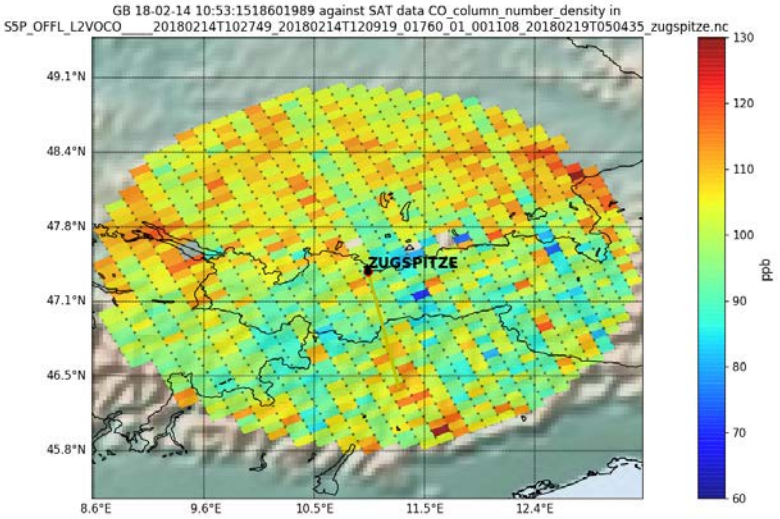




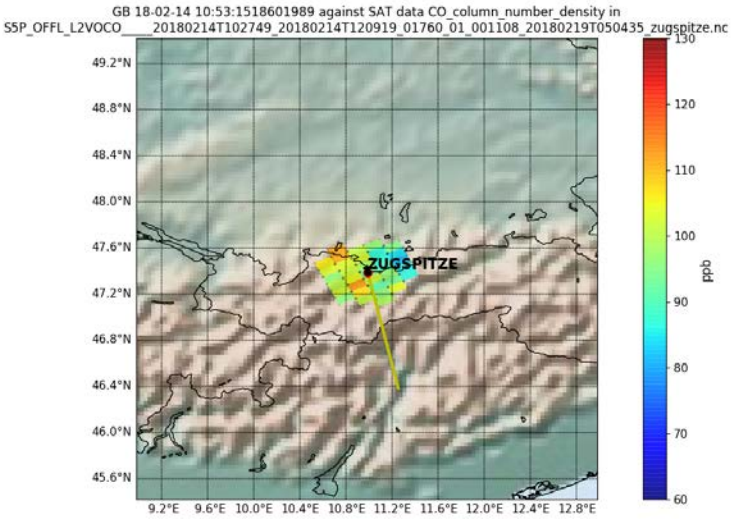


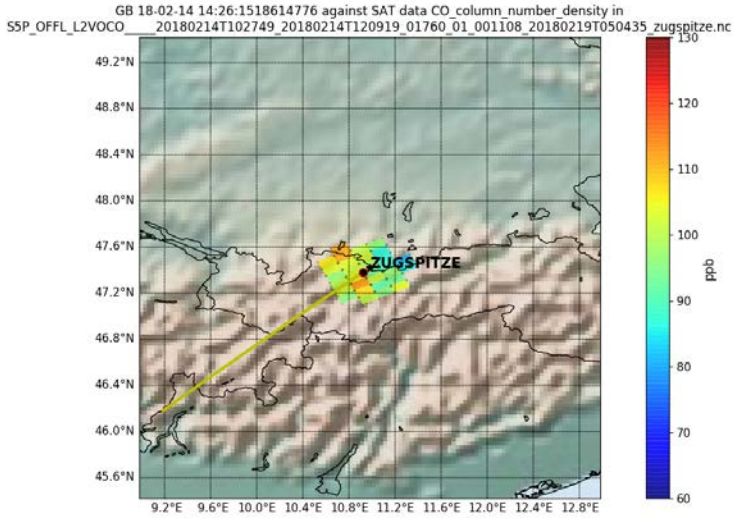


Validation plots for CO – Zugspitze (2960 m)

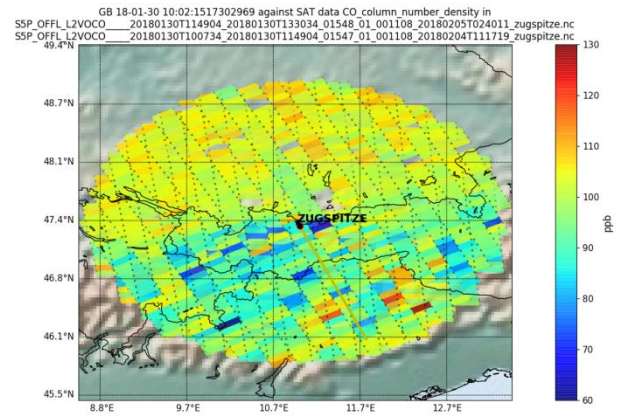


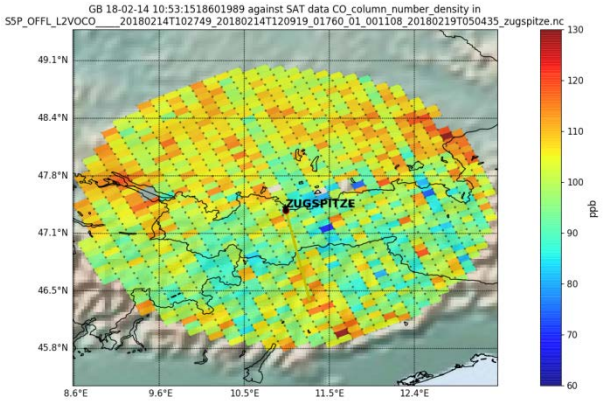
SZA variation for 6 hrs coincidence criterion

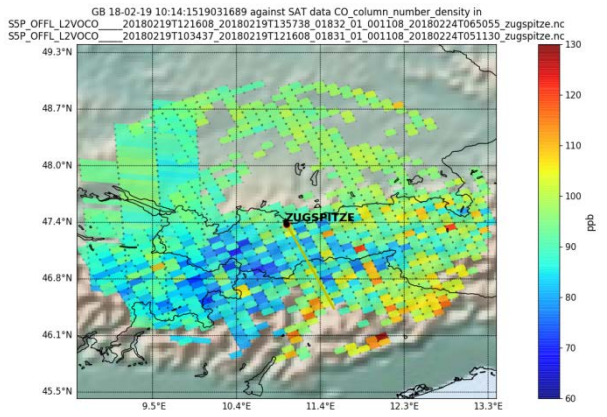


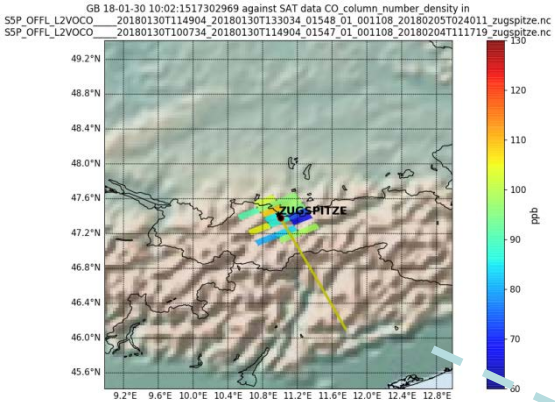


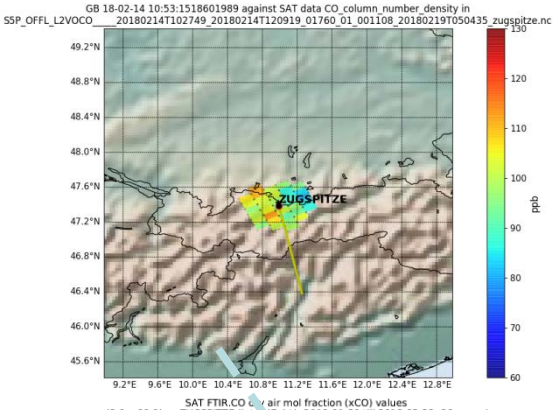
Validation plots for CO – Zugspitze (2960 m)

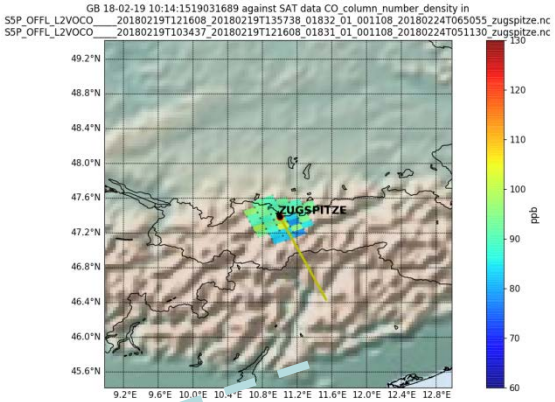


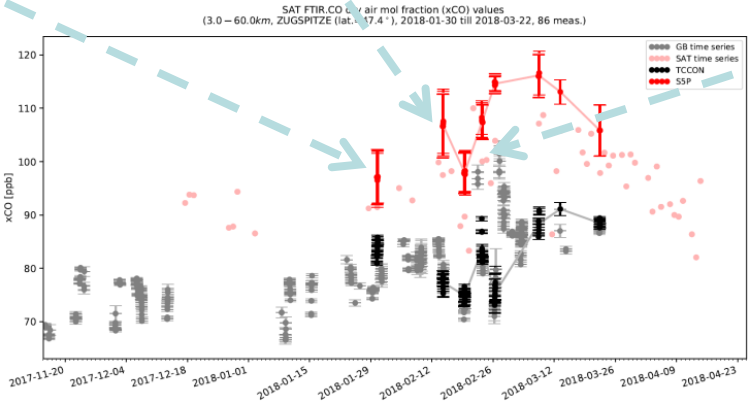




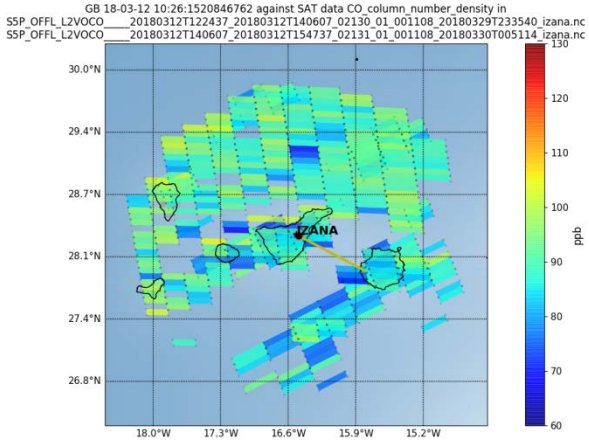


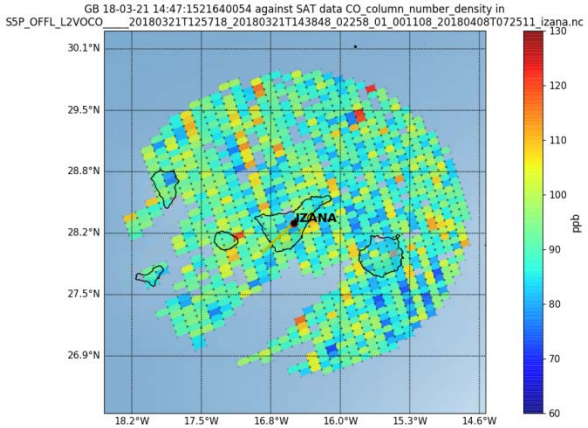


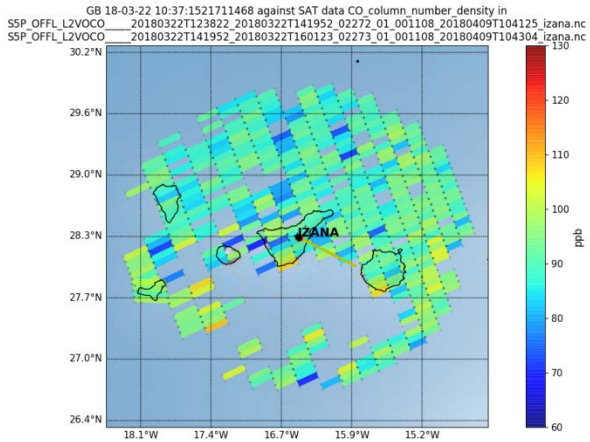


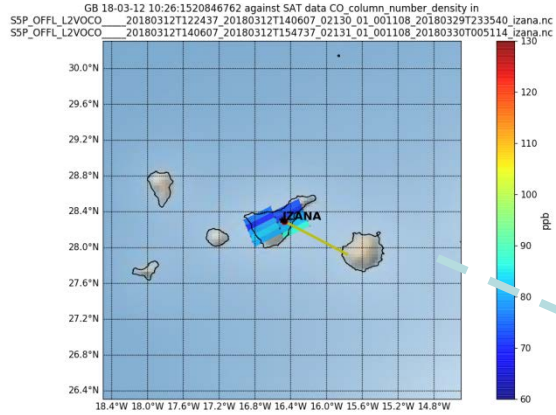


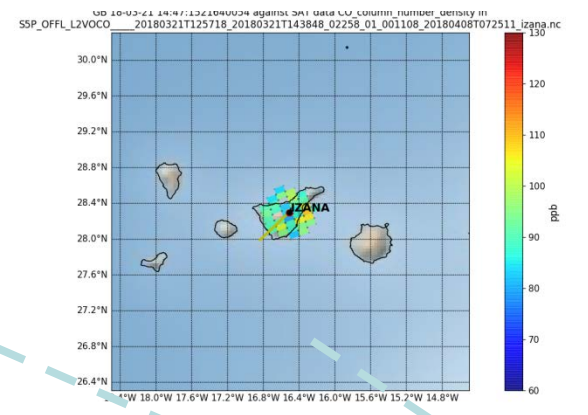
Validation plots for CO – Izana (2370 m)

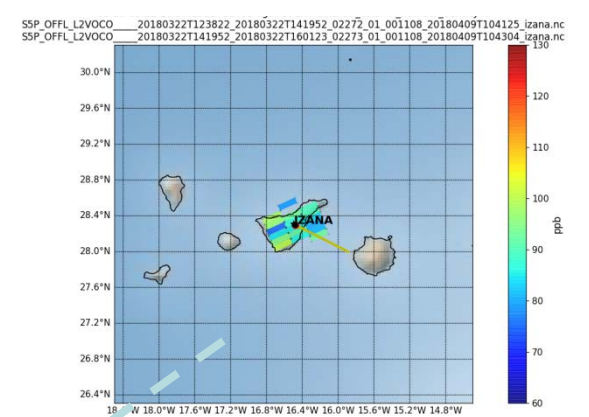


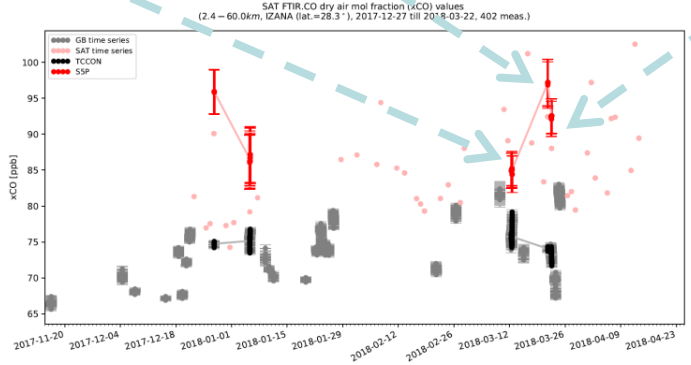




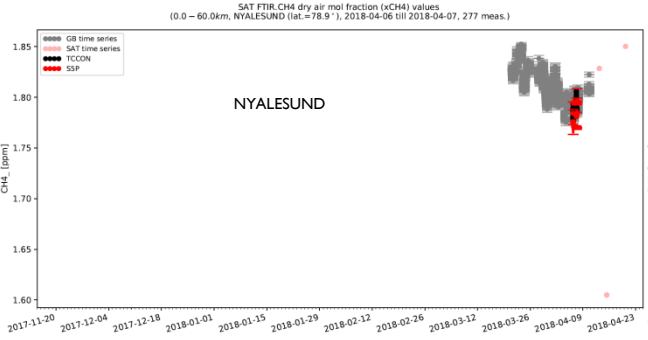


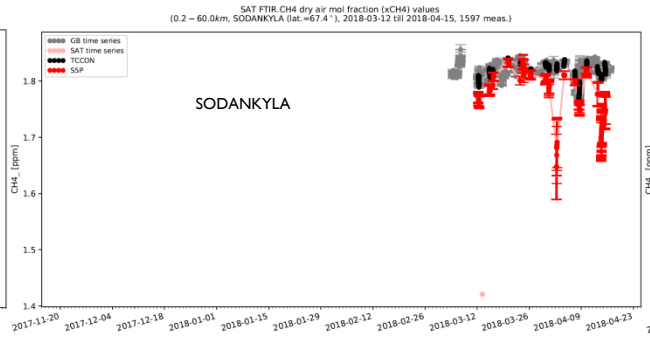


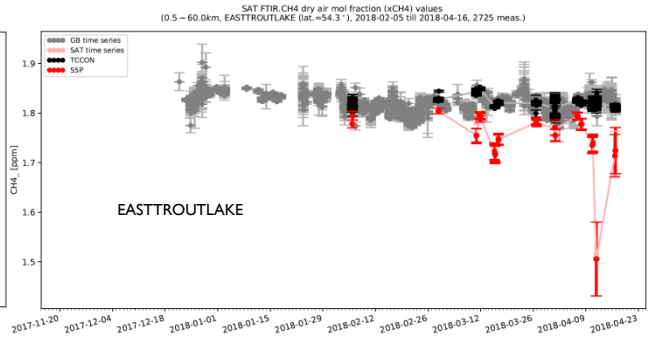


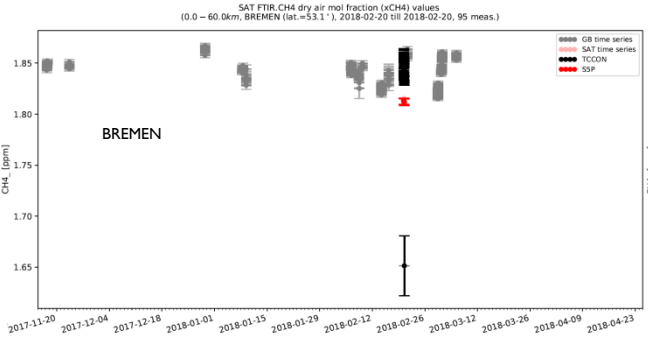


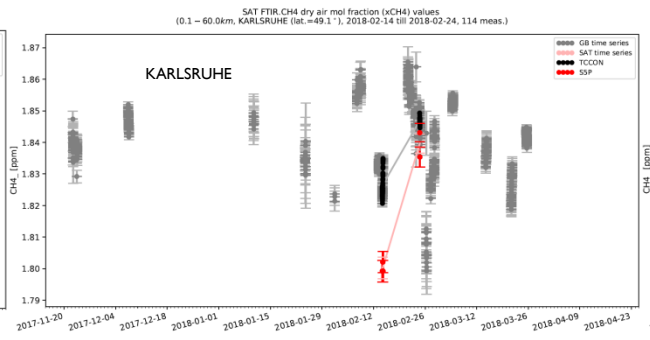
Validation plots for CH4

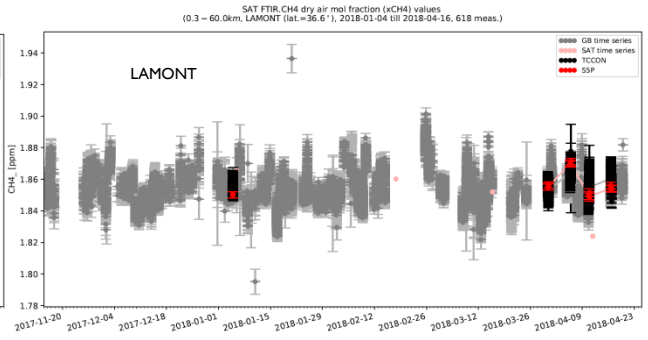


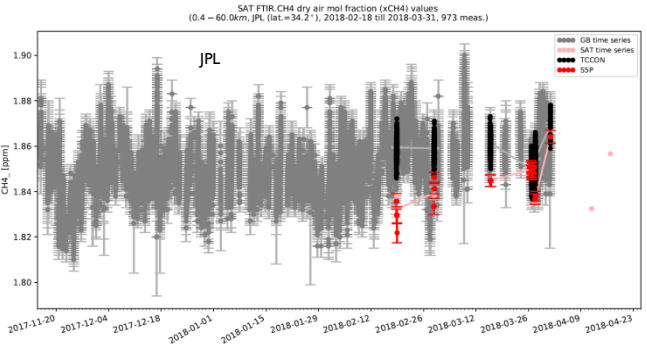


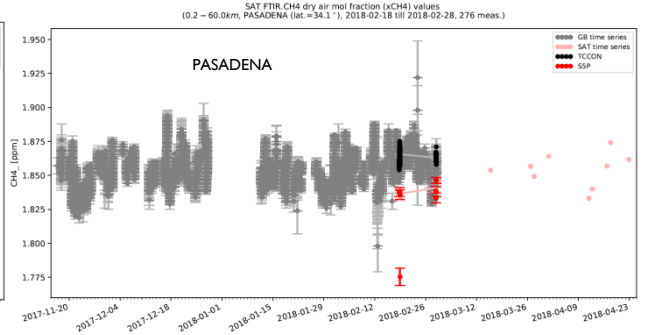


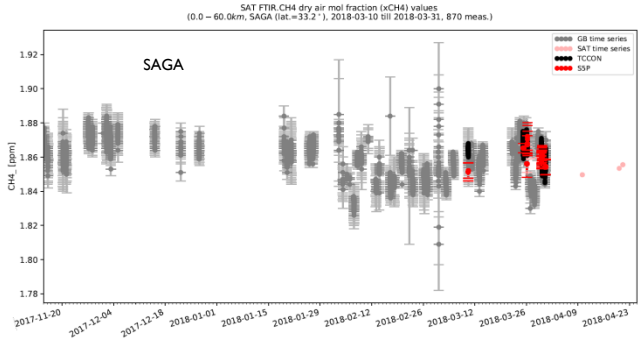




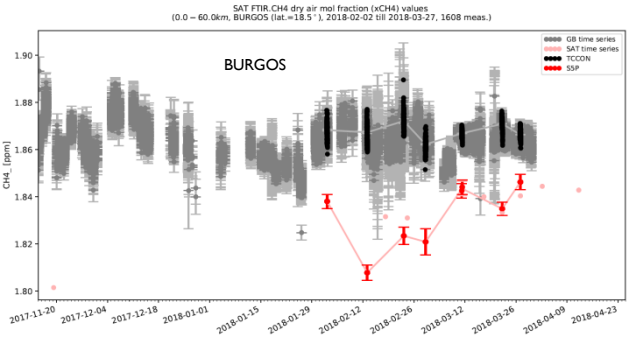


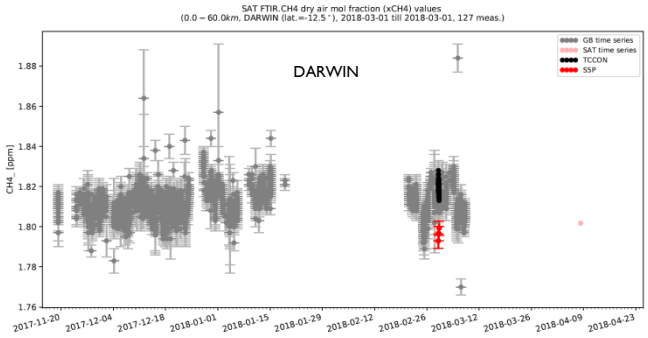


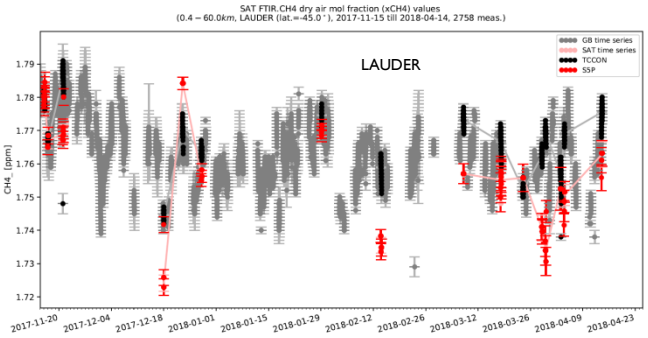




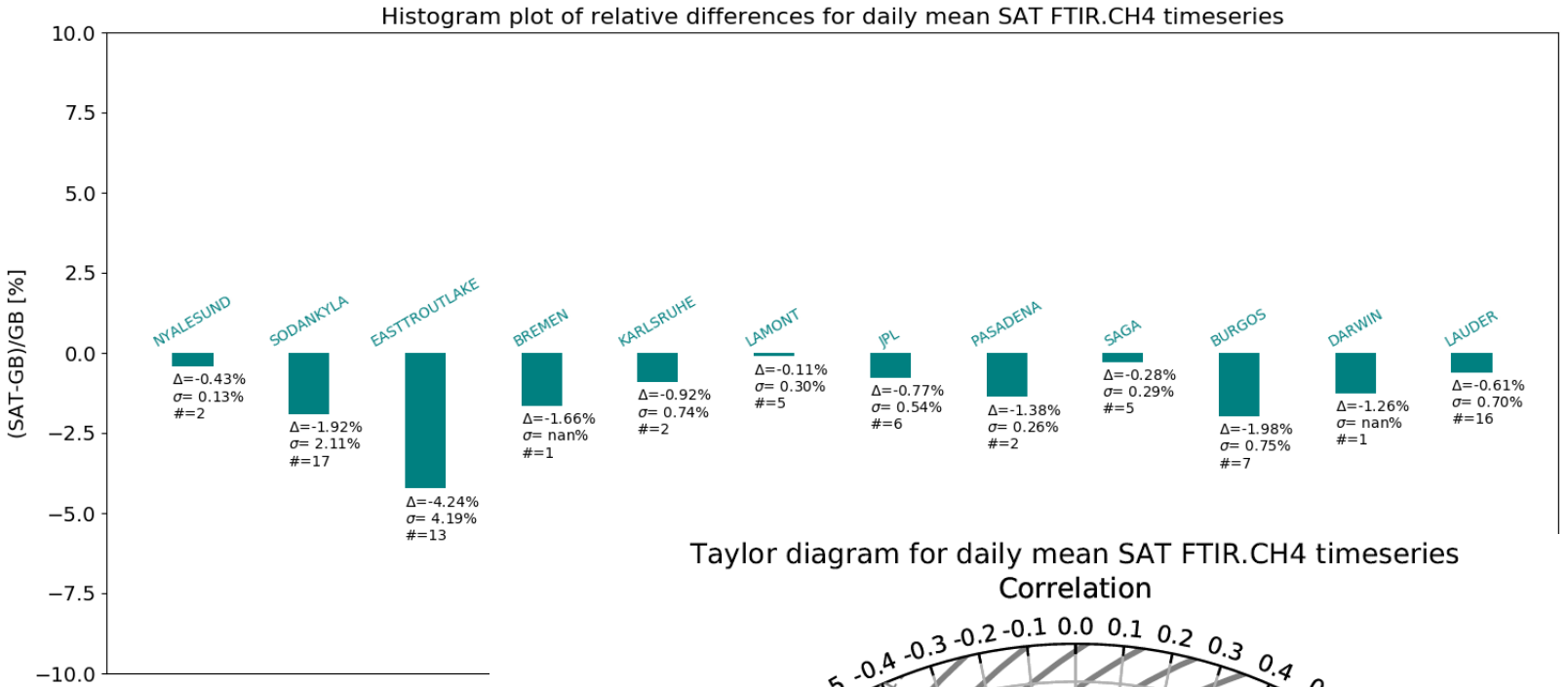
Validation plots for CH4

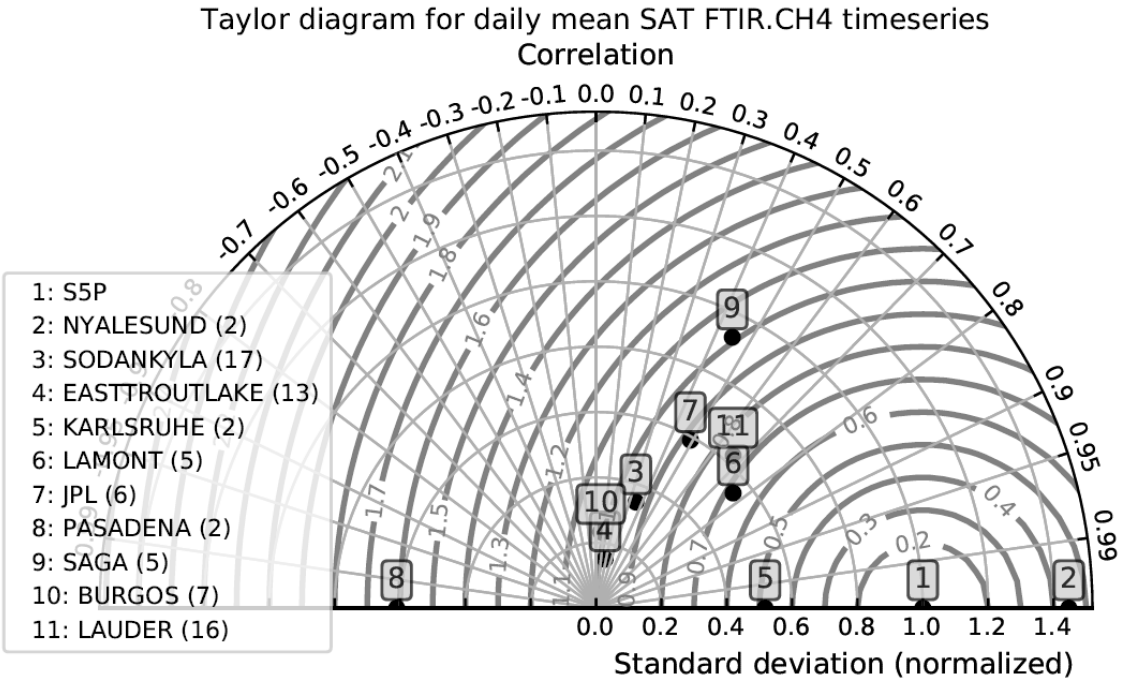






Validation plots for CH4





Summary and outlook

- Preliminary data with very few coincidences for several sites.
- CO: positive bias for all stations except Réunion; mean bias (systematic uncertainty) and scatter (random uncertainty) except for 2 mountain stations (comparison need improvement and more data for these sites) are already complaint with mission requirements.
- CH4: not enough S5P data – processing undergoing; so far negative bias for all stations; measurement during mostly NH winter season → under polar vortex conditions; high bias for high latitude stations; other stations which have good coincidences show the bias and scatter within the mission requirements.

- More TCCON data will be added when we will have the new TROPOMI data and re-processing of the existing data.
- Validation studies comparing seasonal cycles with improved coincidence criteria.

Notes

Disclaimer: The presented work has been performed in the frame of the Sentinel-5 Precursor Validation Team (S5PVT) or Level 1/Level 2 Product Working Group activities. Results are based on preliminary (not fully calibrated/validated) Sentinel-5 Precursor data that will still change.

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Thank you for your attention!