Low-resolution FTIR Spectrometers Supplementing TCCON for the Validation of Space-borne Observations of Greenhouse Gases (CO_2, CH_4) and CO

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http://frm4ghg.aeronomie.be/

FRM4GHG campaign

Objective – perform an intercomparison of simultaneously measured total column amounts of CO_2, CH_4 and CO using several different portable low-cost spectrometric instruments under different atmospheric conditions in comparison to the TCCON instrument. These instruments can then be used to complement the existing TCCON network.

Description – perform side-by-side low-resolution measurements using test instruments next to a TCCON station.

Location – TCCON site at Sodankylä, Finland (67.37 N, 26.63 E, 188 m.a.s.l); possibilities of AirCore launches at the site

Duration – 2017 – 2019 (solar measurements during spring-summer-autumn period)

Table 1. List of instruments participating in the FRM4GHG campaign in 2018 and their properties.

Instrument	Institute	Spectral range	Resolution	Main species	Retrieval code
Bruker IFS 125HR (TCCON)	FMI	1800 – 15000 cm^{-1}	0.004 cm^{-1}	XCO_2, XCH_4, XCO @ 0.02 cm^{-1}	GFIT 2014, TCCON standard
Bruker EM27/SUN (COCCON)	KIT	4000 – 9000 cm^{-1}	0.5 cm^{-1}	XCO_2, XCH_4, XCO	PROFFAST
Bruker IRcube	Uni Wollongong	4500 – 15000 cm^{-1}	0.5 cm^{-1}	XCO_2, XCH_4	GFIT 2016
Bruker Vertex70	Uni Bremen & BIRA-IASB	2500 – 15000 cm^{-1}	0.16 cm^{-1}	XCO_2, XCH_4, XCO @ 0.2 cm^{-1}	GFIT 2014, TCCON standard
Bruker IFS 125HR (HR125LR)	FMI & KIT	1800 – 15000 cm^{-1}	0.004 cm^{-1}	XCO_2, XCH_4, XCO @ 0.5 cm^{-1}	PROFFAST
LHR (Laser Heterodyne Radiometer)	RAL	954 – 960 cm^{-1} 1233.5 cm^{-1}	0.002 and 0.02 cm^{-1}	CO_2, H_2O CH_4, H_2O	own code, optimal estimation
AirCore	Uni Groningen & FMI	In-situ sampling	13.4 mbar (Amb.P. > 232 mbar) 3.9 mbar (Amb.P. < 232 mbar)	CO_2, CH_4, CO vertical profiles calibrated to WMO standards	

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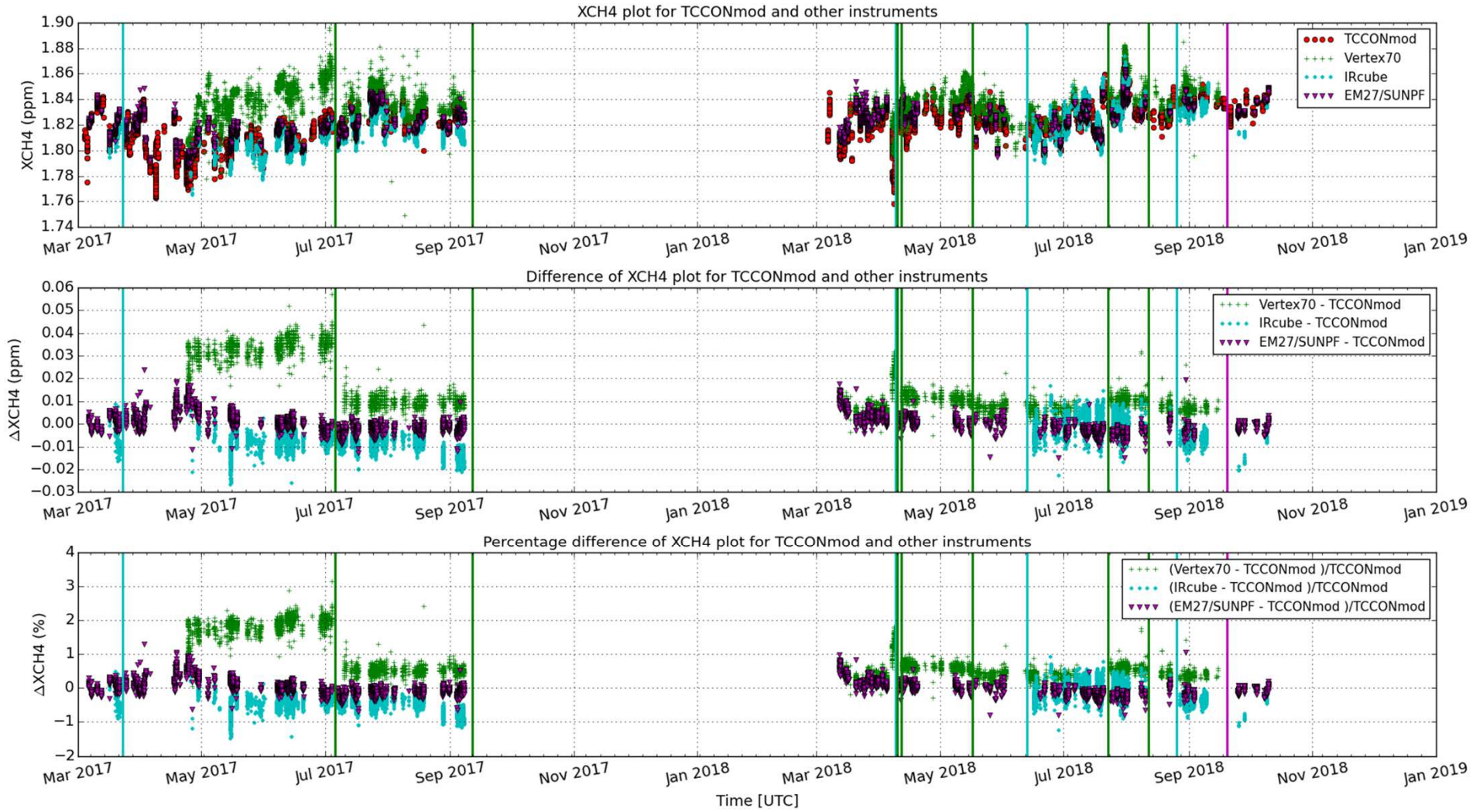
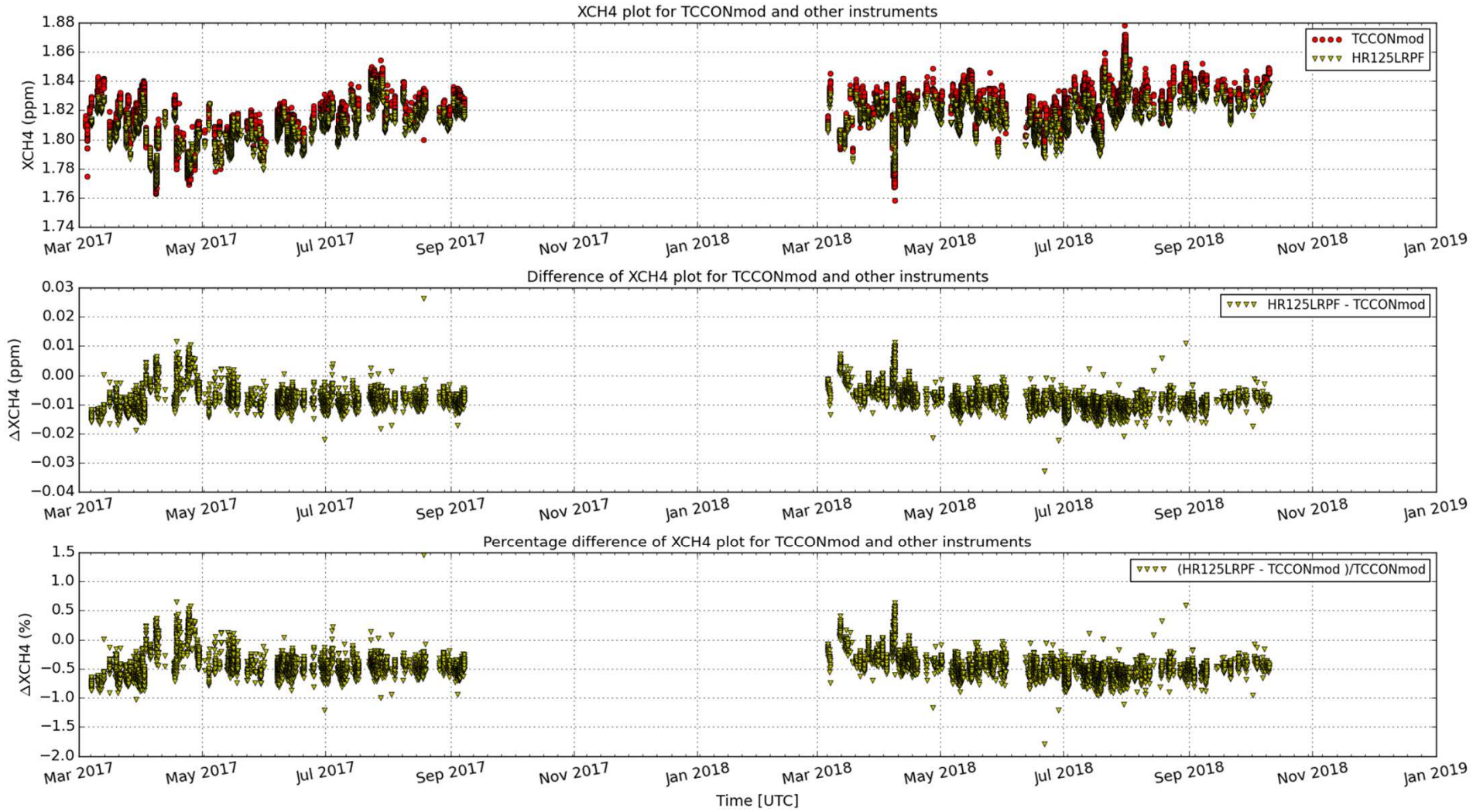
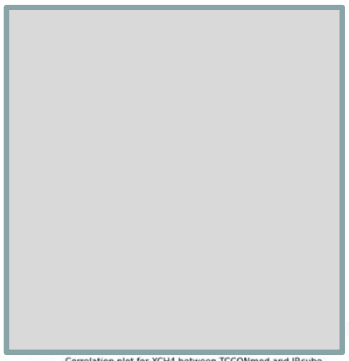
3 instruments vs TCCONmod – XCH4

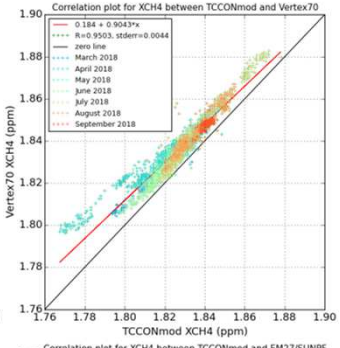


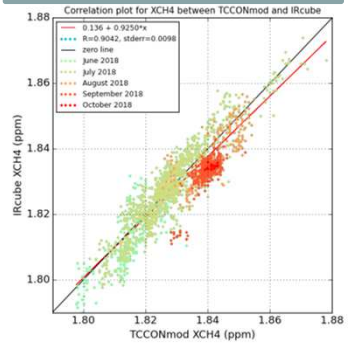
HR125LR vs TCCONmod – XCH4

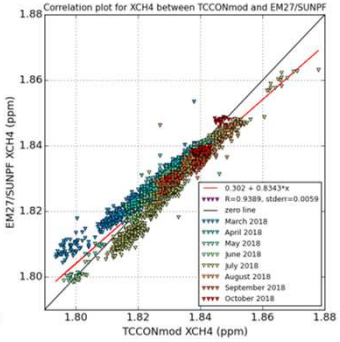


Correlation – XCH4 for 2018

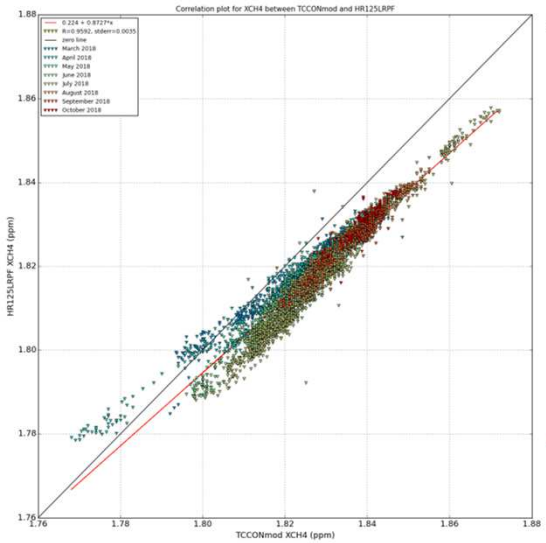




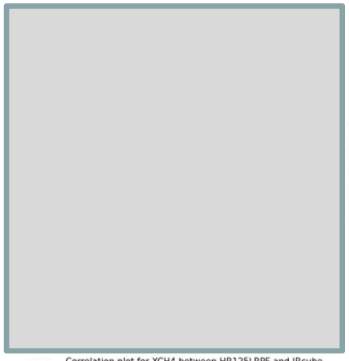


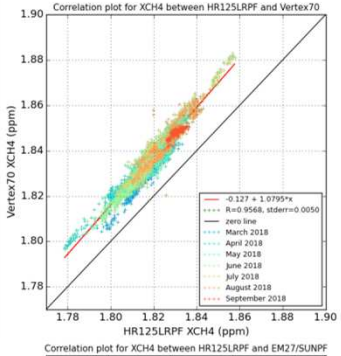


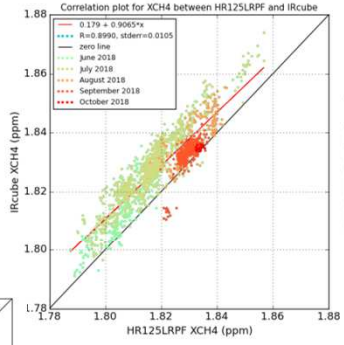
TCCONmod comparison

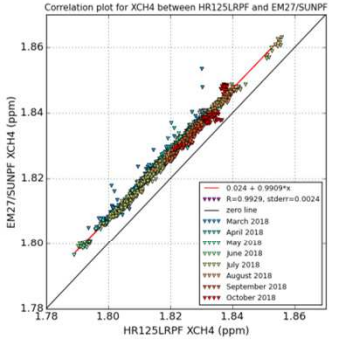


TCCONmod vs HR125LR









HR125LR comparison

Coincidence criteria for validation study

- Period of study: 01 March 2018 – 31 October 2018.
- S5P data from Mission Performance Centre (MPC) provided by the Payload Data Ground Segment (PDGS) at DLR.

- Coincidence criteria for CH4: Time delta = 1 hours; Geo-distance delta = 100 km radius. QA filtering: qa_value > 50; bias corrected S5P-CH4 product used for the study. From the coincident and filtered satellite measurements an average of all pixels is taken for each ground-based reference measurements.

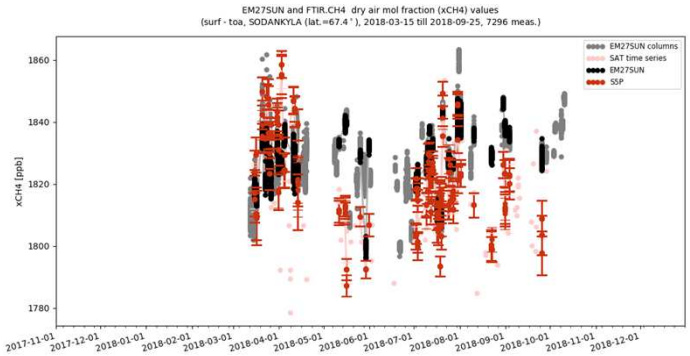
- S-5P requirements for CH4 total column: target bias = 1.5 %; target precision : < 1 %

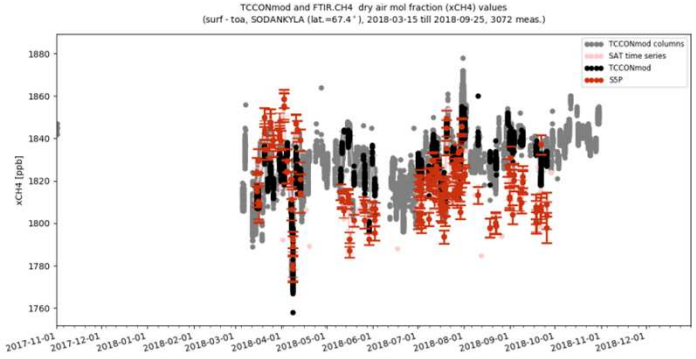
- Coincidence criteria for CO: Time delta = 1 hours; Geo-distance delta = 50 km radius. QA filtering: qa_value > 50;. From the coincident and filtered satellite measurements an average of all pixels is taken for each ground-based reference measurements.

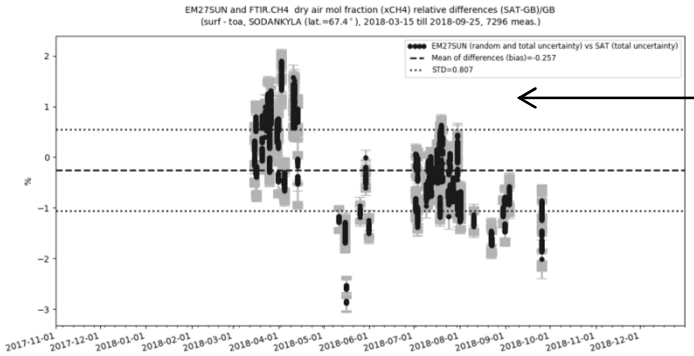
- S-5P requirements for CO total column: target bias = 15 %; target precision : < 10 %

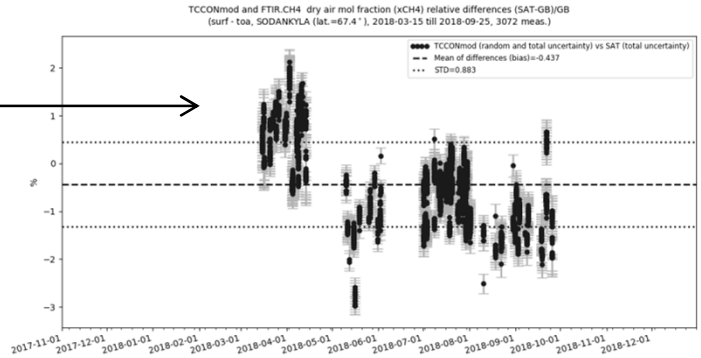
S5P-XCH4 bias corrected product vs EM27/SUN

(COCCON network instrument)



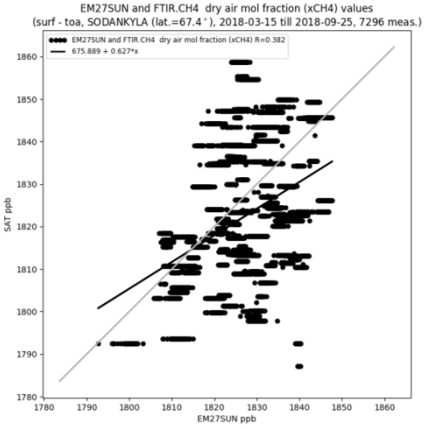






Note: different number of measurements

EM27/SUN data scaled to WMO via TCCON



S5P vs TCCONmod

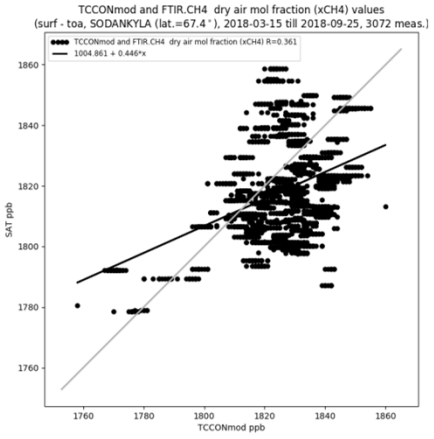
Mean bias = -0.44%, STD = 0.88%, R = 0.36

S5P vs EM27/SUN

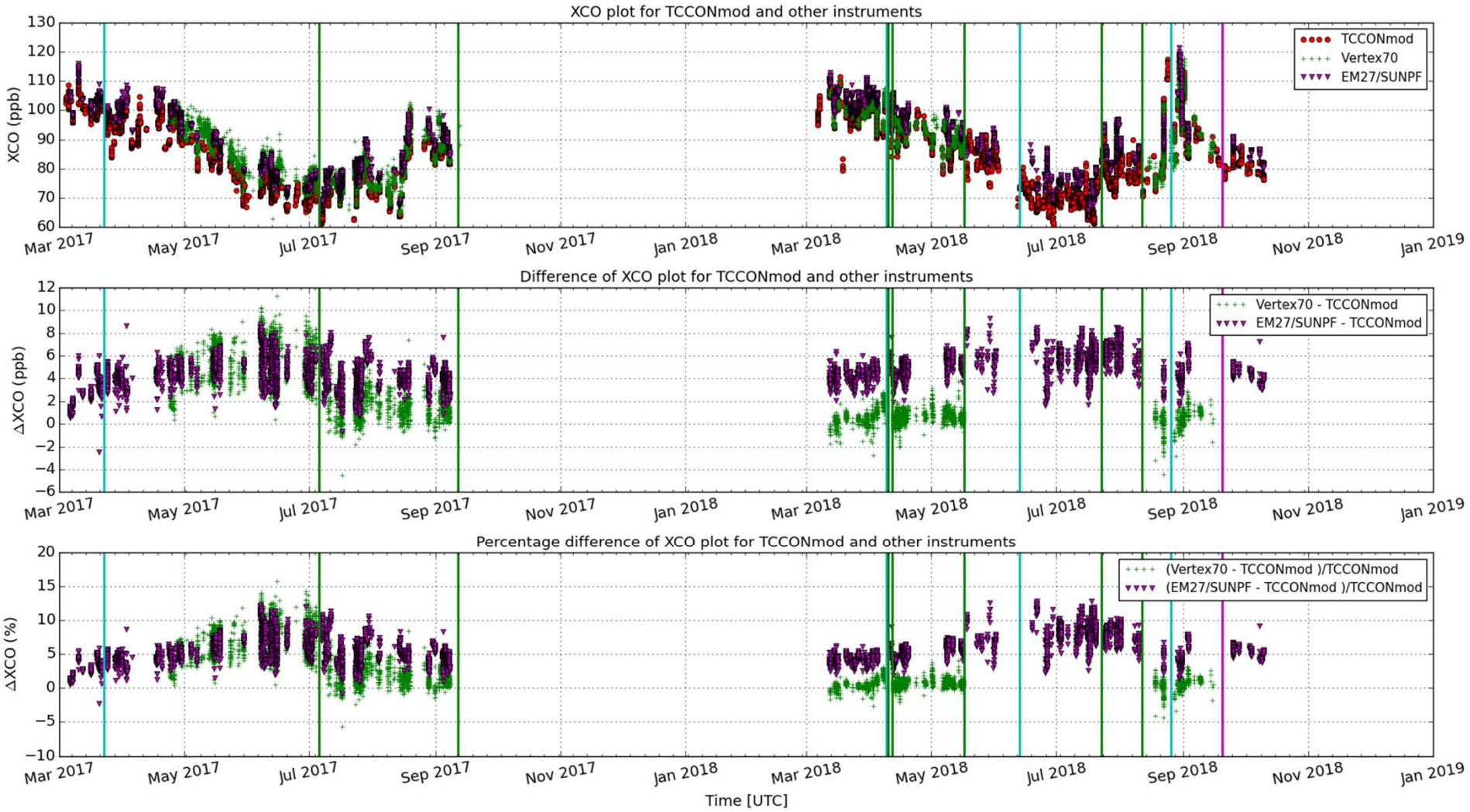
Mean bias = -0.26%, STD = 0.81%, R = 0.38

EM27/SUN vs TCCONmod

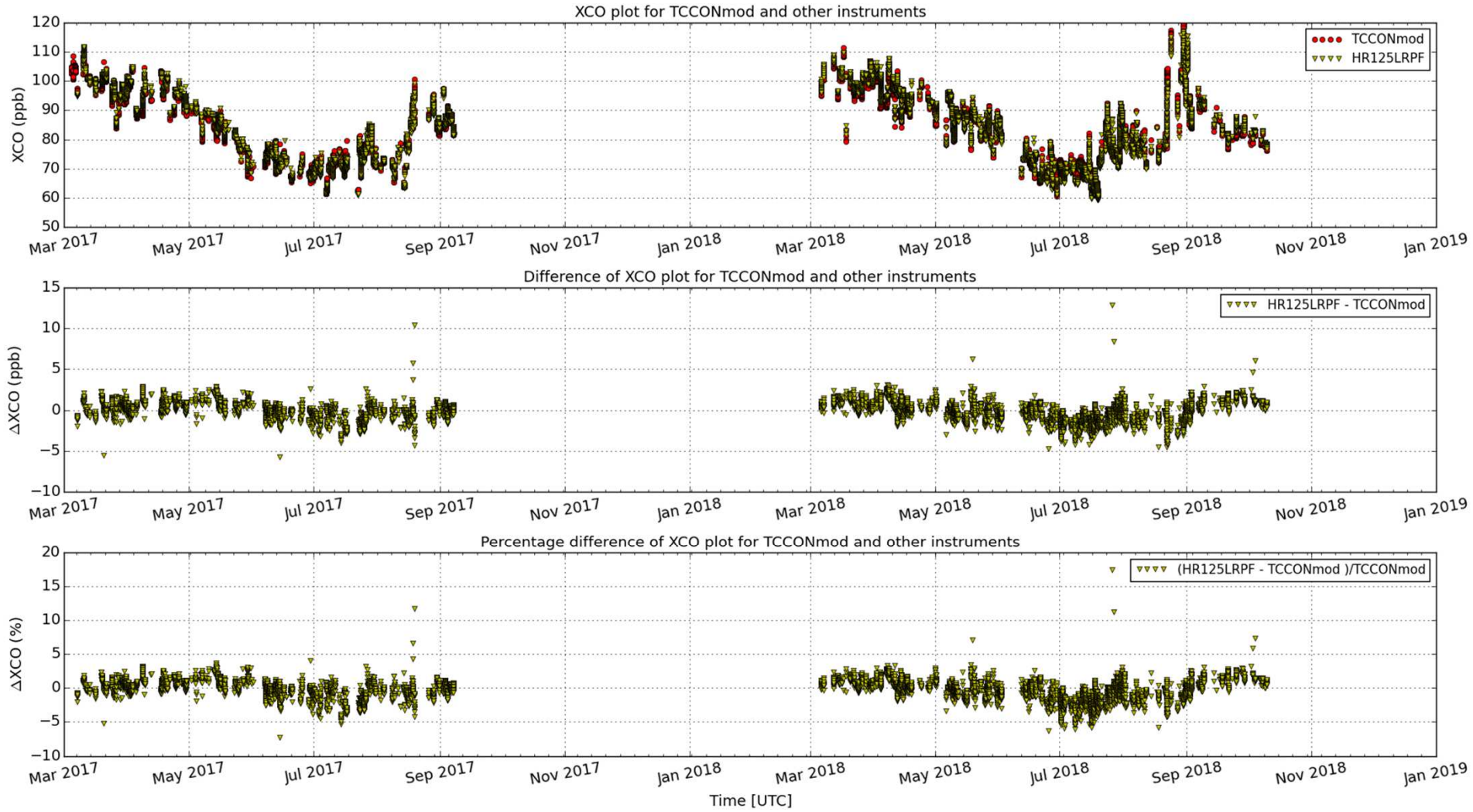
Mean bias = -0.05% (-1 ppb), STD = 0.22% (4 ppb), R = 0.94



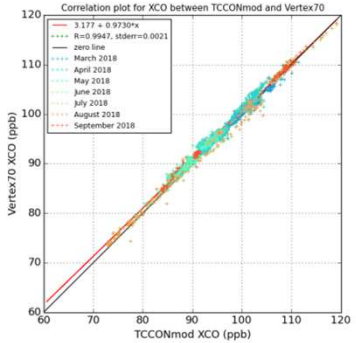
EM27SUN, VERTEX70 vs TCCONmod – XCO

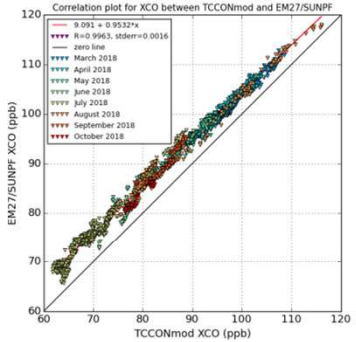


HR125LR vs TCCONmod – XCO

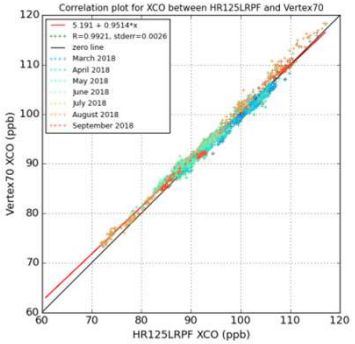


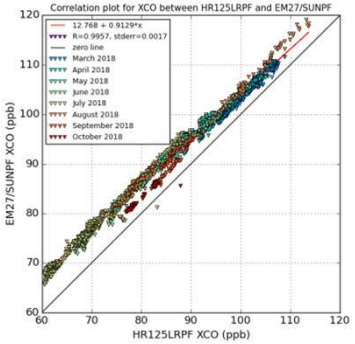
Correlation – XCO for 2018



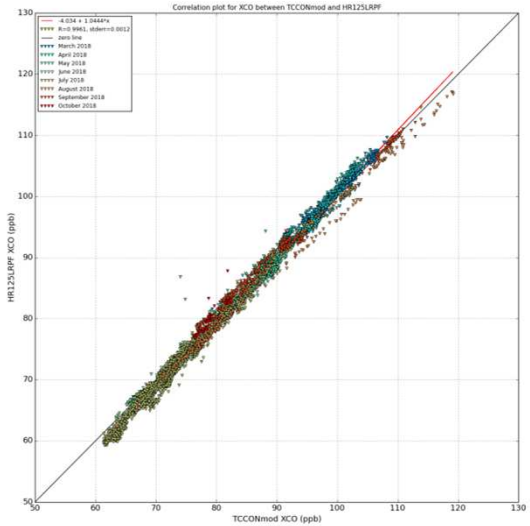


TCCONmod comparison





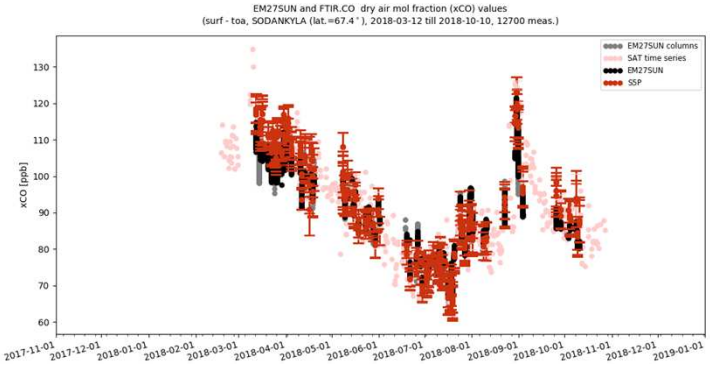
HR125LR comparison

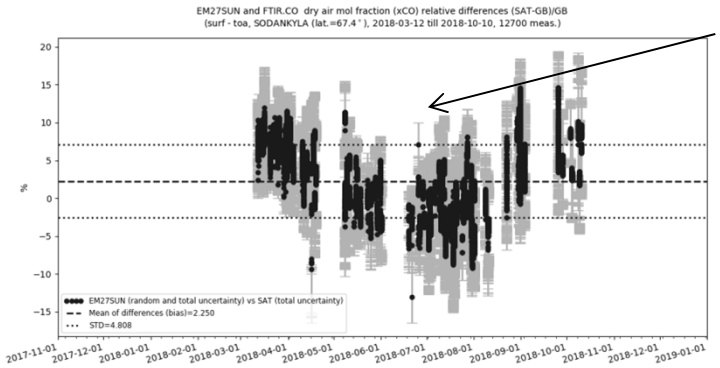


TCCONmod vs HR125LR

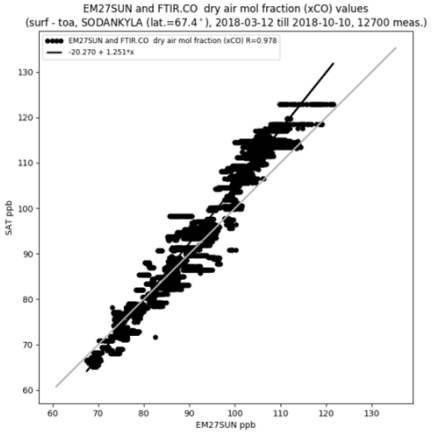
S5P-CO validation results using EM27/SUN

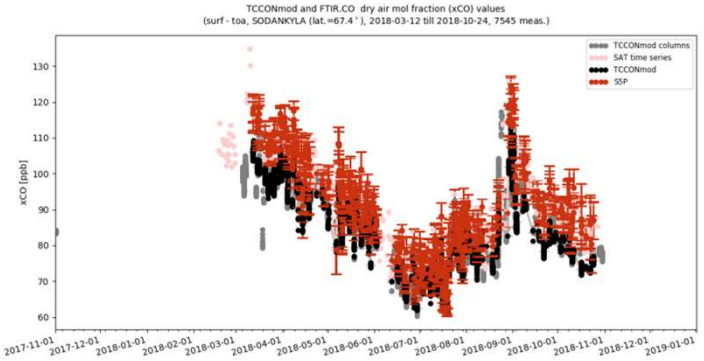
(COCCON network instrument)

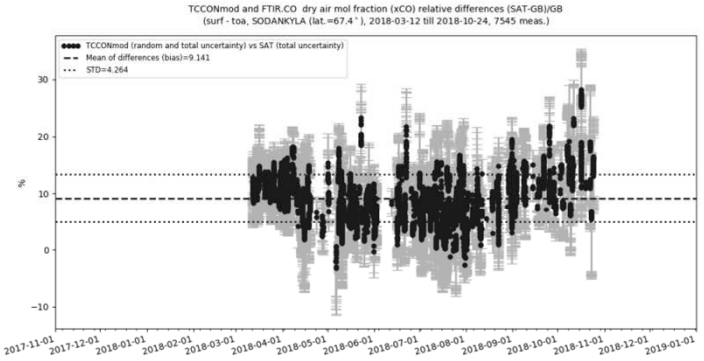




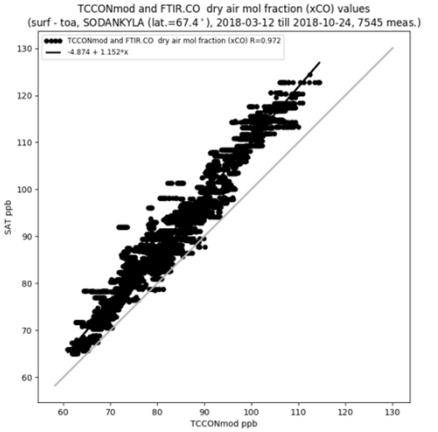
Note:
EM27SUN data not yet corrected for spectroscopic errors







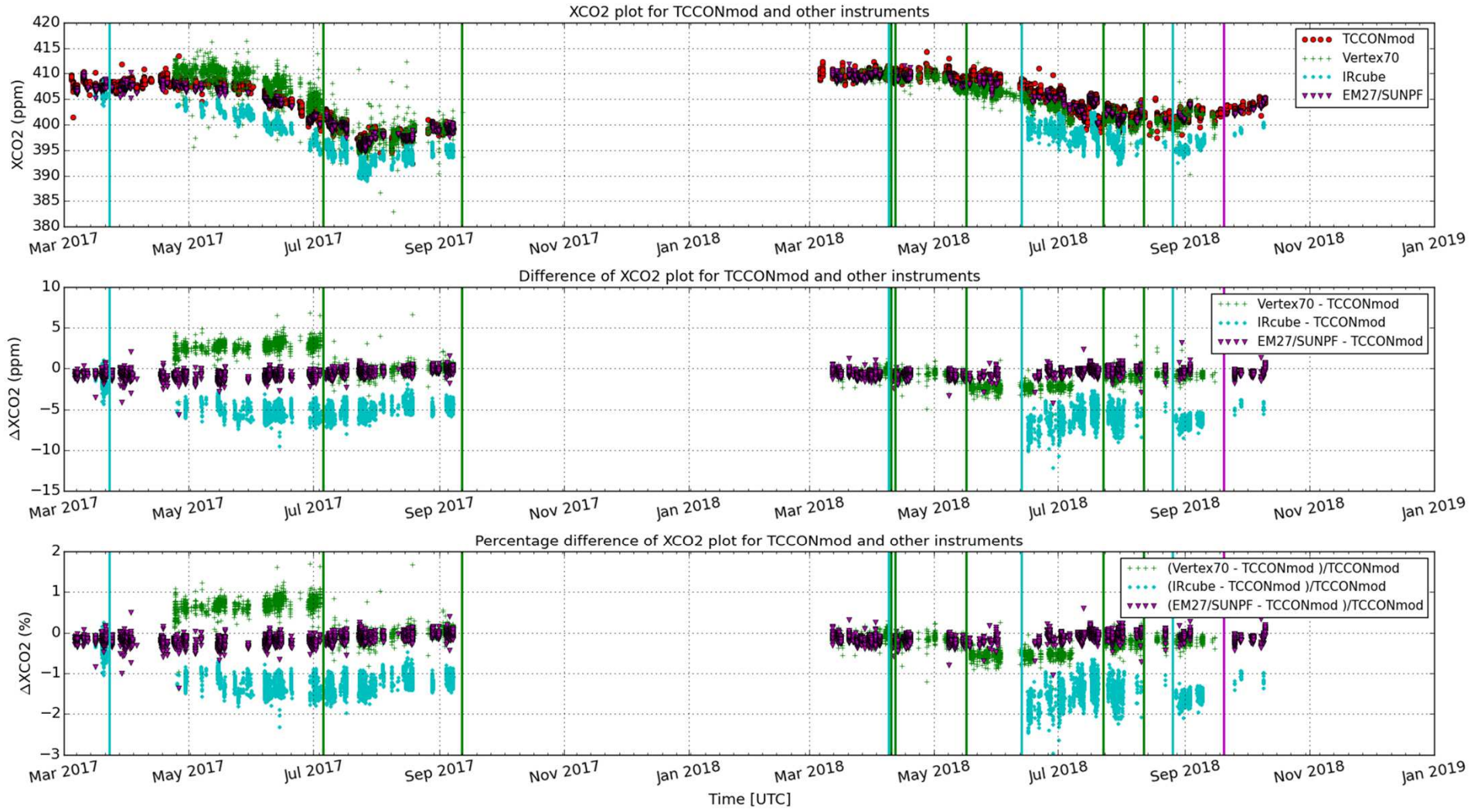
S5P vs TCCONmod
Mean bias = 9.14%, STD = 4.26%, R = 0.972



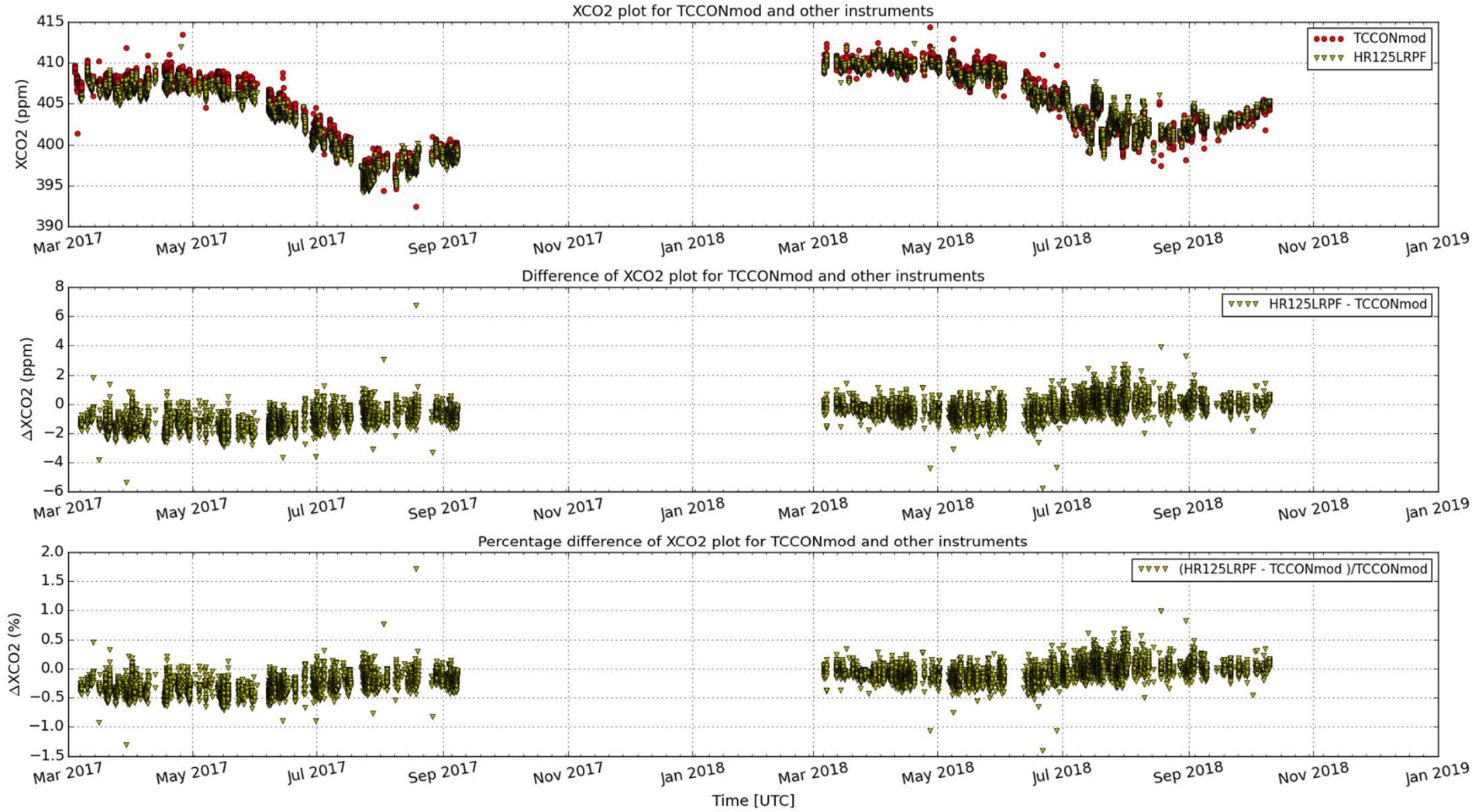
S5P vs EM27SUN
Mean bias = 2.25%, STD = 4.81%, R = 0.978

EM27/SUN vs TCCONmod
Mean bias = 5.66% (5.09 ppb), STD = 1.37% (1.23 ppb), R = 0.996

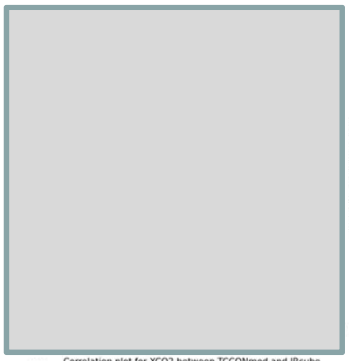
3 instruments vs TCCONmod – XCO2

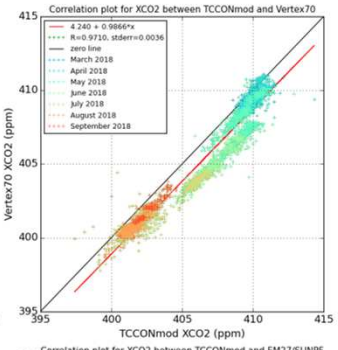


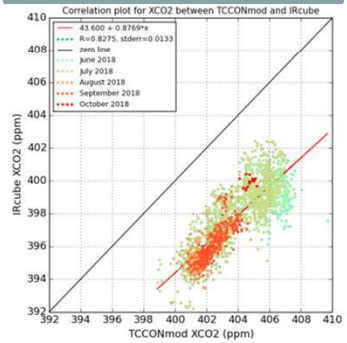
HR125LR vs TCCONmod – XCO2

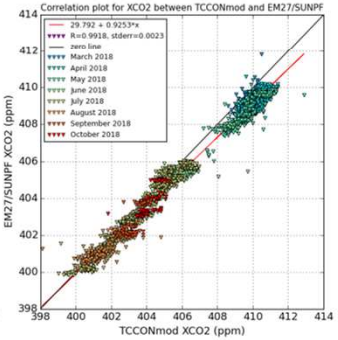


Correlation – XCO2 for 2018

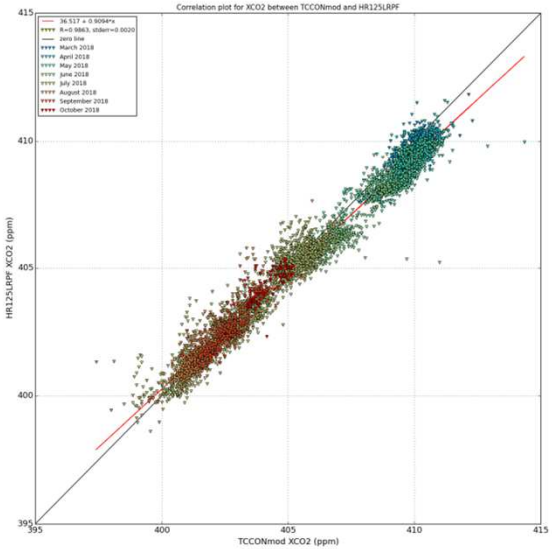




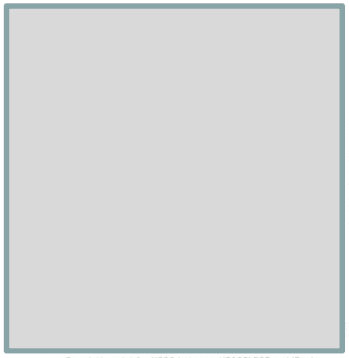


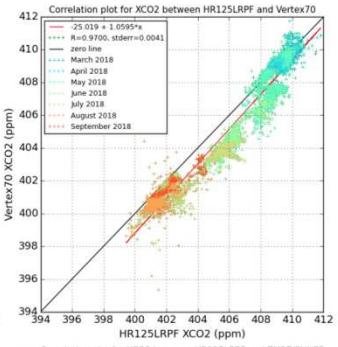


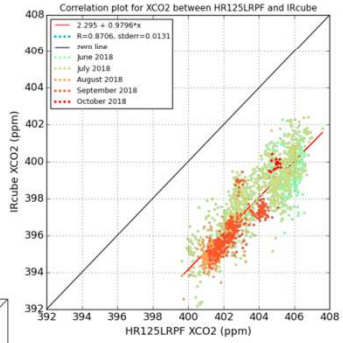
TCCONmod comparison

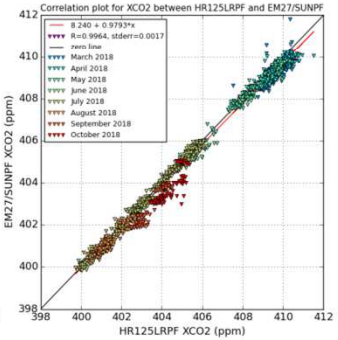


TCCONmod vs HR125LRPF









HR125LRPF comparison

Coincidence criteria for CO2 validation study

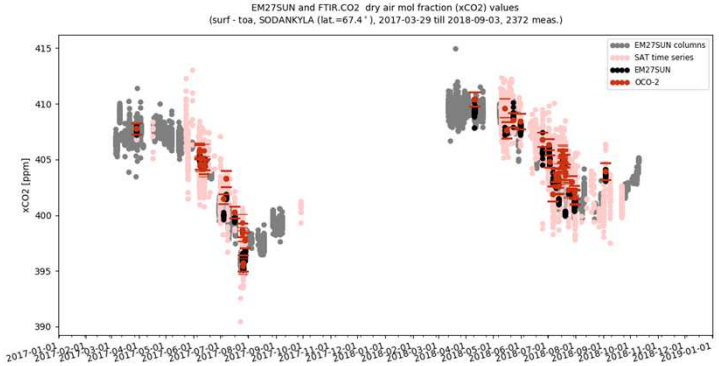
- Period of study: 01 March 2017 – 31 October 2018.
- OCO-2 data OCO2_L2_Lite_FP: OCO-2 Science Team/Michael Gunson, Annmarie Eldering (2018), OCO-2 Level 2 bias-corrected XCO2 and other select fields from the full-physics retrieval aggregated as daily files, Retrospective processing V9r, Greenbelt, MD, USA, Goddard Earth Sciences Data and Information Services Center (GES DISC), Accessed: 08/04/2019, 10.5067/W8QGIYNKS3JC

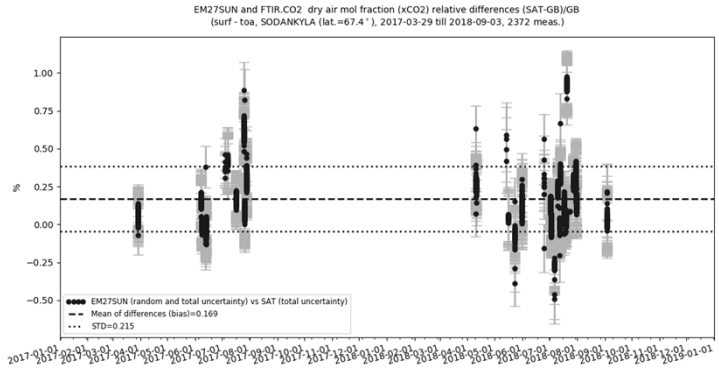
- OCO-2 spatial coverage: -180, -90, 180, 90; Spatial resolution: 2.25 km x 1.29 km; Temporal: 16 days

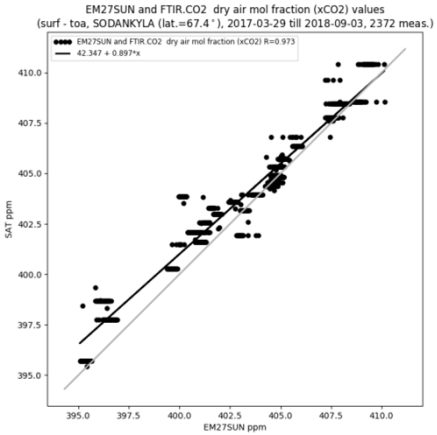
- Coincidence criteria for CO2: Time delta = 1 hours; Geo-distance delta = ± 5° lon, ± 2.5° lat. xco2_quality_flag = 0. From the coincident satellite measurements an average of all pixels is taken for each ground-based reference measurements.

OCO-2 CO2 validation results using EM27/SUN

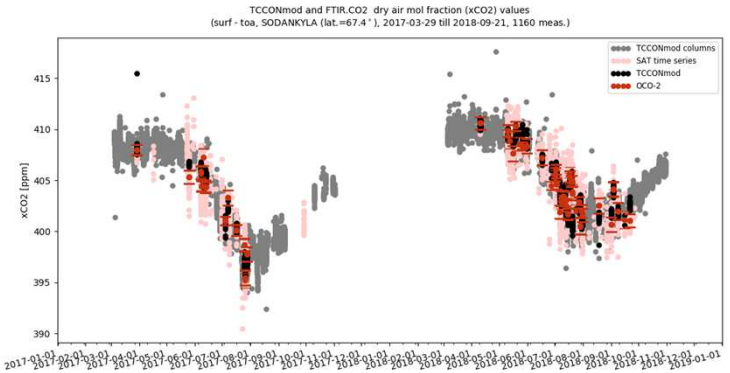
Year: 2018 (COCCON network instrument)

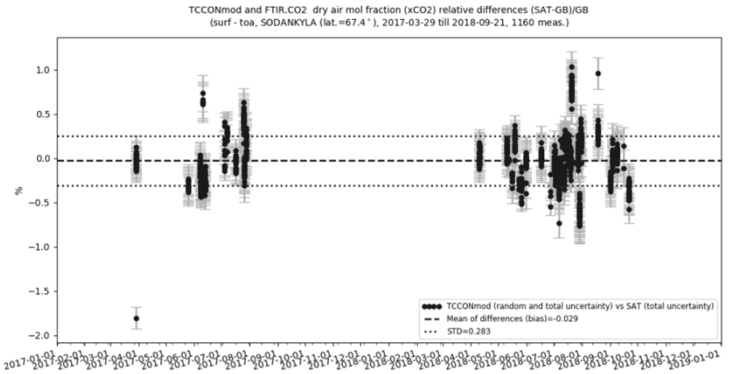




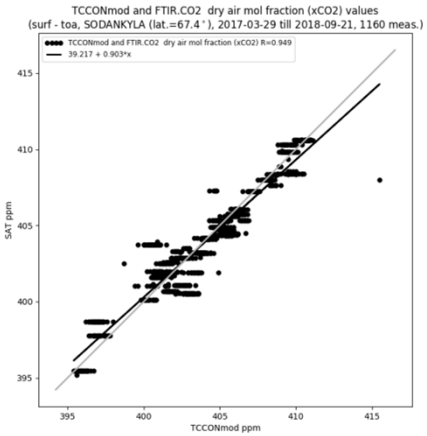


EM27/SUN data scaled to WMO via TCCON





OCO-2 vs TCCONmod
Mean bias = -0.029%, STD = 0.283%, R = 0.949



OCO-2 vs EM27/SUN
Mean bias = 0.169%, STD = 0.215%, R = 0.973

EM27/SUN vs TCCONmod
Mean bias = -0.164% (-0.666 ppm), STD = 0.120% (0.486 ppm), R = 0.995

Conclusion

- The low-resolution datasets are able to capture the seasonal cycle of CO2, CH4 and CO as seen by the TCCON.
- A small bias in CH4 is observed during spring due to the high difference between the prior relative to the true atmospheric state, the column averaging kernel at high solar zenith angles and the retrieval sensitivities.
- The difference seen in the CH4 intercomparison with respect to the TCCON and the HR125LR highlights the impact of the different spectral resolutions. The scatter of the intercomparison results are within the limit of the TCCON precision (0.5%) with a high correlation between the two datasets.
- The bias seen in the CO intercomparison is because the low-resolution instruments are not yet scaled to the WMO reference.
- Validation results of CH4 and CO from S-5P and CO2 from OCO-2 using low resolution instruments show comparable scatter and correlation similar to the TCCON.

➔ **EM27/SUN (COCCON network instrument), IRCube, and Vertex70 can complement the TCCON network and can be considered suitable reference networks / instruments for the satellite validation of CO2, CH4 and CO products.**

Notes

Disclaimer: The presented work has been performed in the frame of the FRM4GHG project. 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!