Results of the first phase of the FRM4GHG project

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Project objectives & implementation

Are small, mobile, and cheap instruments able to measure GHGs (CO_2, CH_4, CO) with sufficient precision?

Perform an intercomparison of GHGs using several different portable low-cost spectrometric instruments at a TCCON site

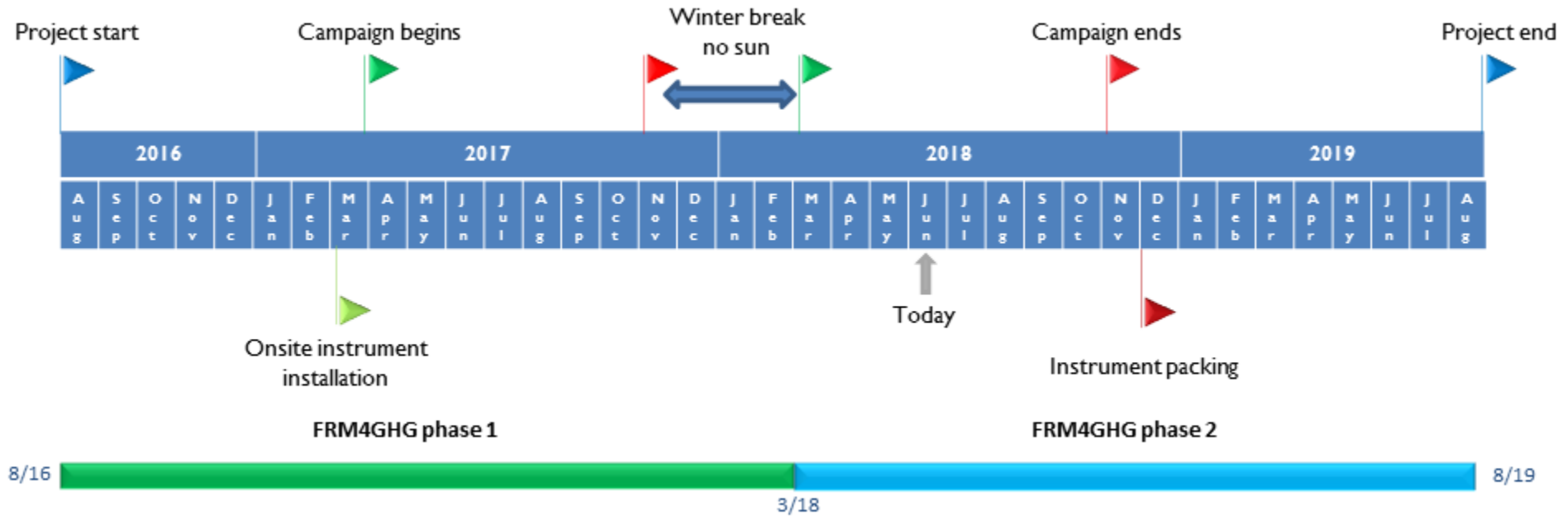
- TCCON site Sodankylä @ 67.37°N, 26.63°E

- simultaneous measurements

- spring/summer/autumn 2017

- regular Aircore launches

Project timeline

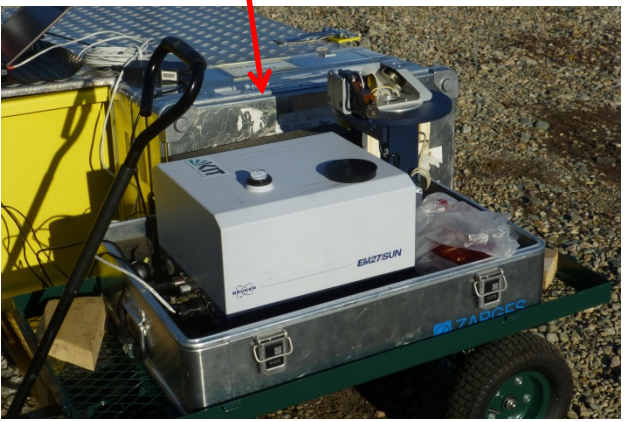


Measurements start in March 2017

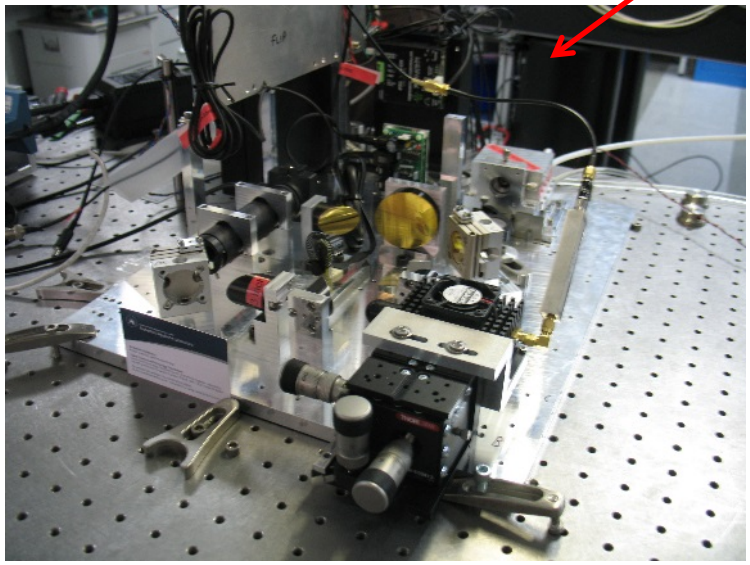
Instruments overview

Instrument	Institute	Spectral range	Resolution	Main GHGs
Bruker IFS 125HR	FMI	1800 — 15000 cm^{-1}	0.004 cm^{-1}	XCO_2, XCH_4, XCO @ 0.02 cm^{-1}
Bruker Vertex 70	Uni Bremen BIRA-IASB	2500 — 15000 cm^{-1}	0.16 cm^{-1}	XCO_2, XCH_4, XCO @ 0.2 cm^{-1}
Bruker EM27/SUN	KIT	4000 — 9000 cm^{-1}	0.5 cm^{-1}	XCO_2, XCH_4, XCO
Bruker IR Cube	Uni Wollongong	4500—15000 cm^{-1}	0.5 cm^{-1}	XCO_2, XCH_4
LHR (Laser Heterodyne Radiometer)	RAL	954—960 cm^{-1}	0.002 and 0.02 cm^{-1}	CO_2
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

Vertex 70

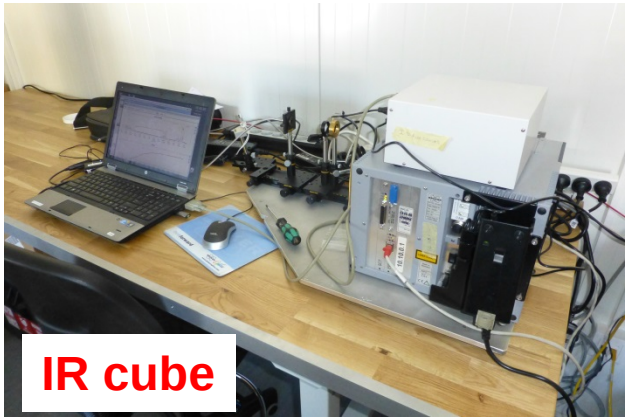


EM27/SUN w/ suntracker



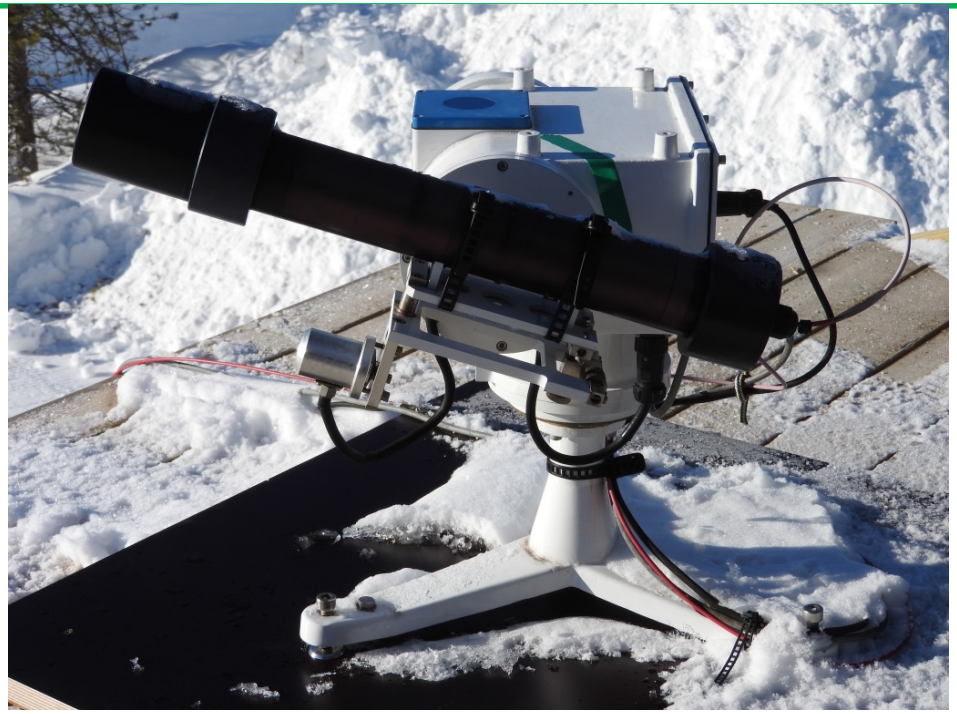
LHR optical breadboard

AirCore launch



IR cube

Suntrackers



Eko suntracker with 50 mm telescope, fiber-coupled to IRcube

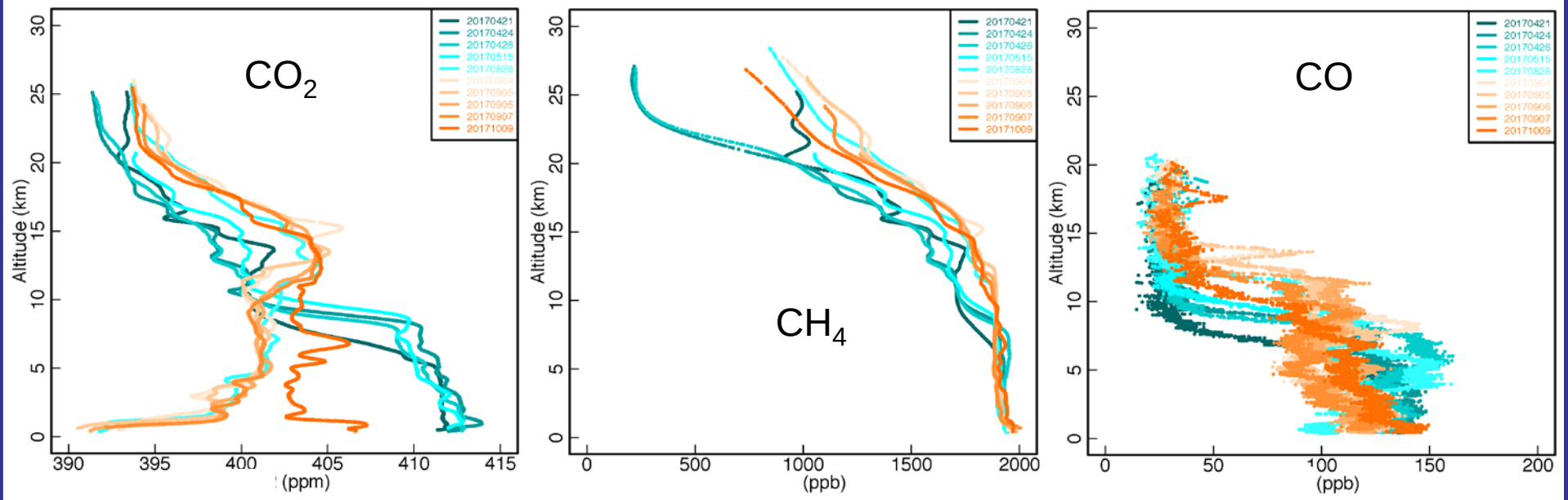
BIRA suntracker- coupled to Vertex 70 and LHR

Aircore (NOAA, Karion et al., 2010)

Principle:

1. Long tube, filled with 'fill gas', open at one end, is launched in the air with a carrier (typically a balloon, up to 25 km altitude).

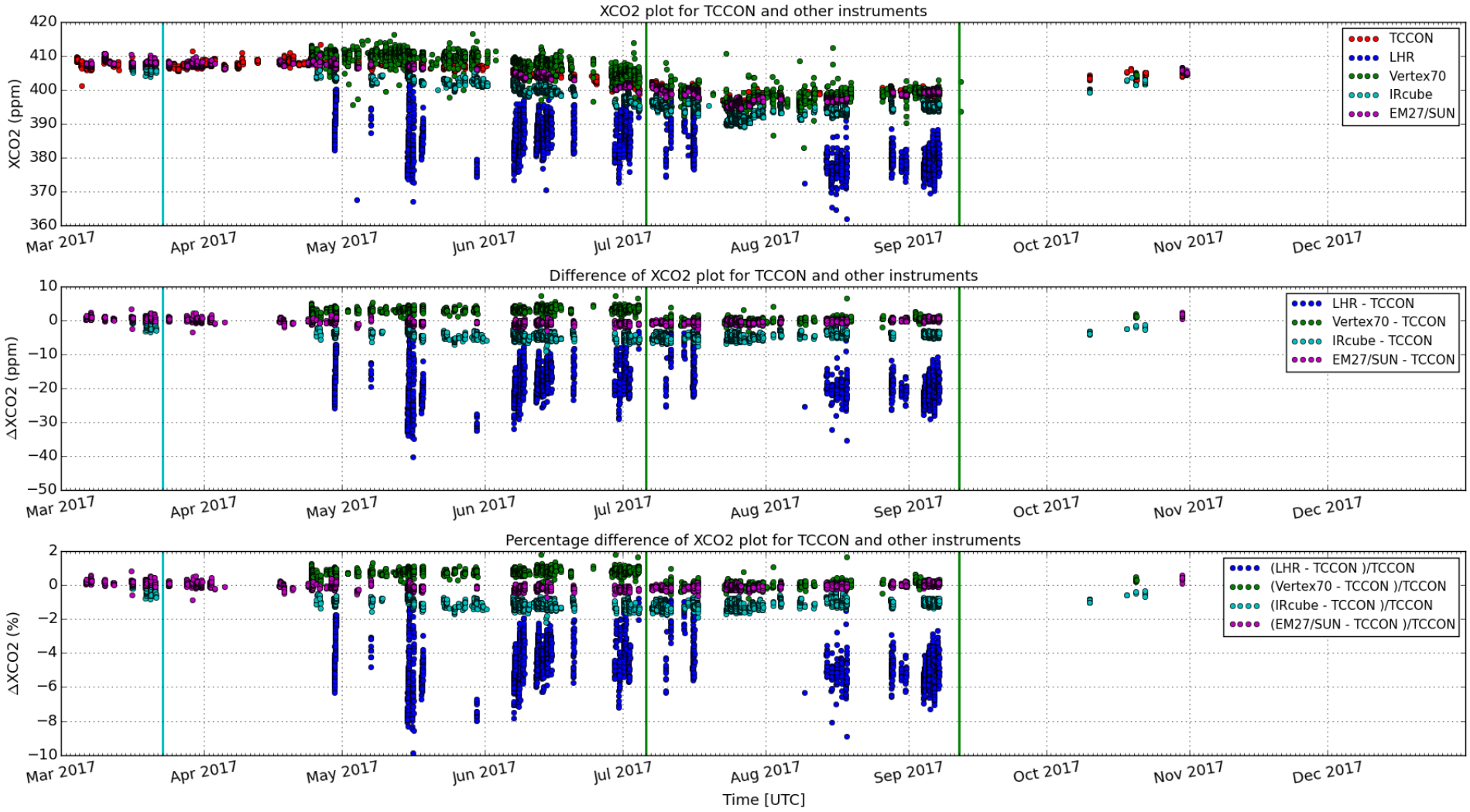
April – October 2017



Results

Comparing other instruments with TCCON

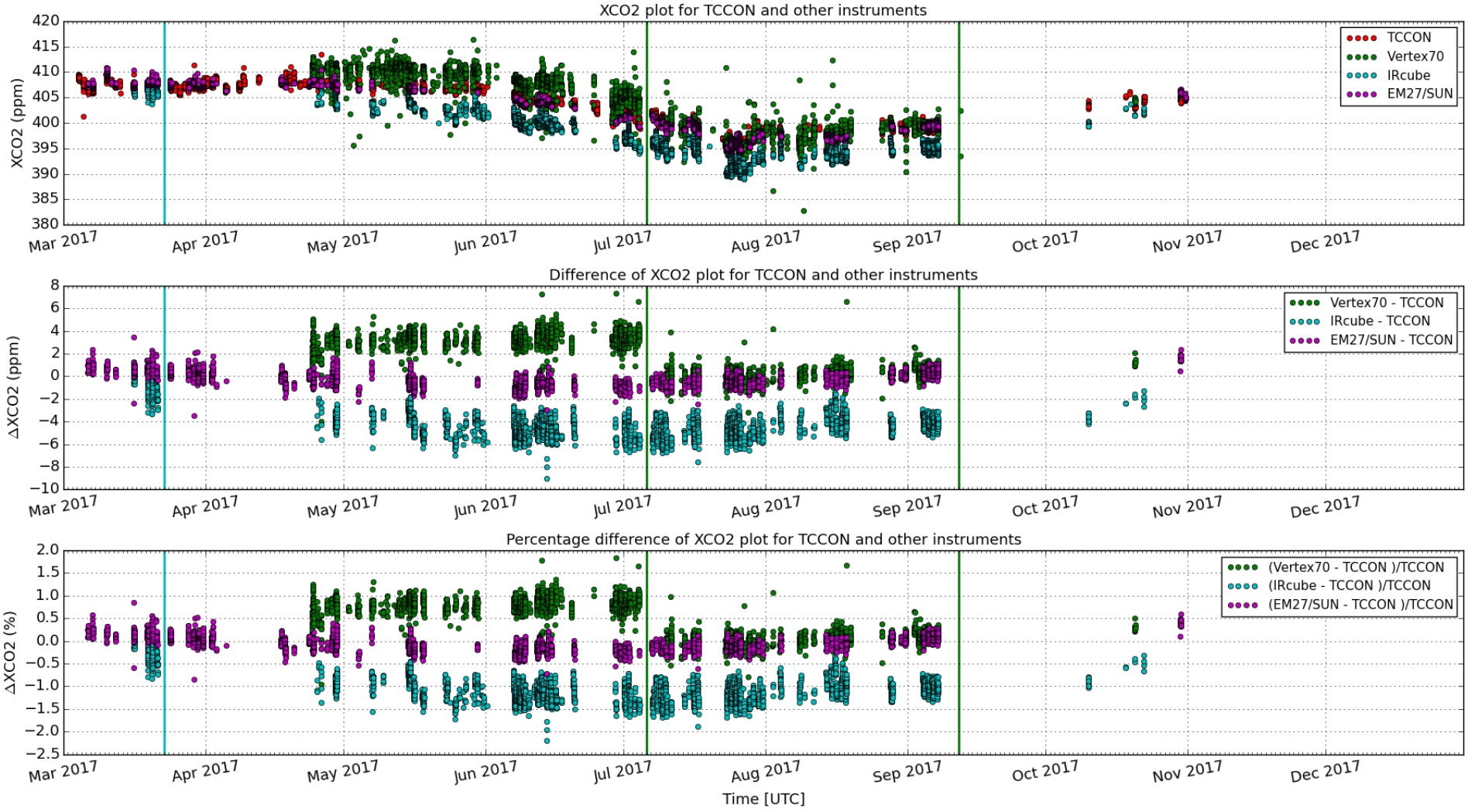
Other instruments vs TCCON – XCO2



IRcube: new fiber cable installed for the solar tracker

Vertex 70: installation of additional aperture in the parallel beam exiting the interferometer (20 mm in July; 8-9 mm in Sept)

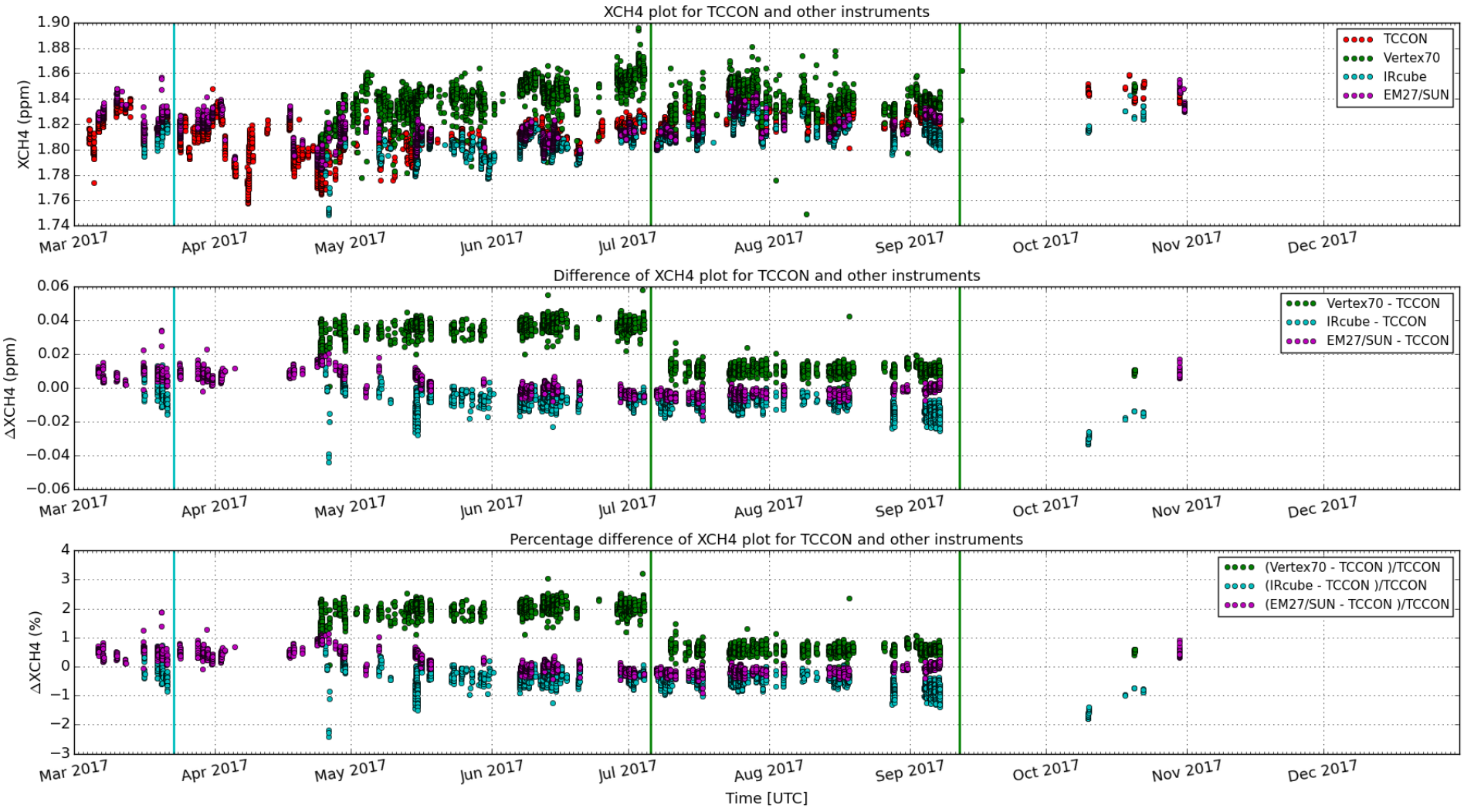
Other instruments vs TCCON – XCO2



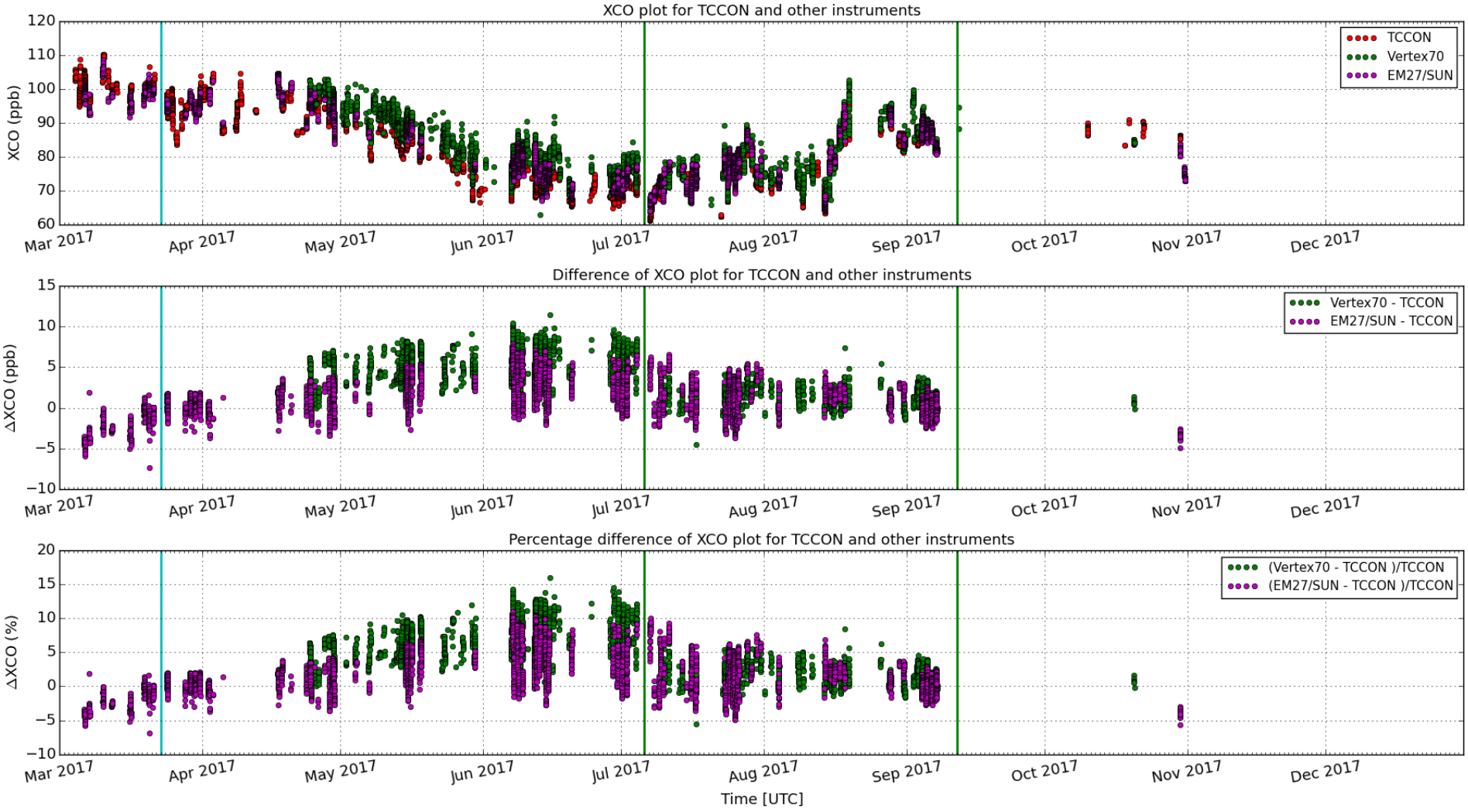
IRcube: new fiber cable installed for the solar tracker

Vertex 70: installation of additional aperture in the parallel beam after the interferometer

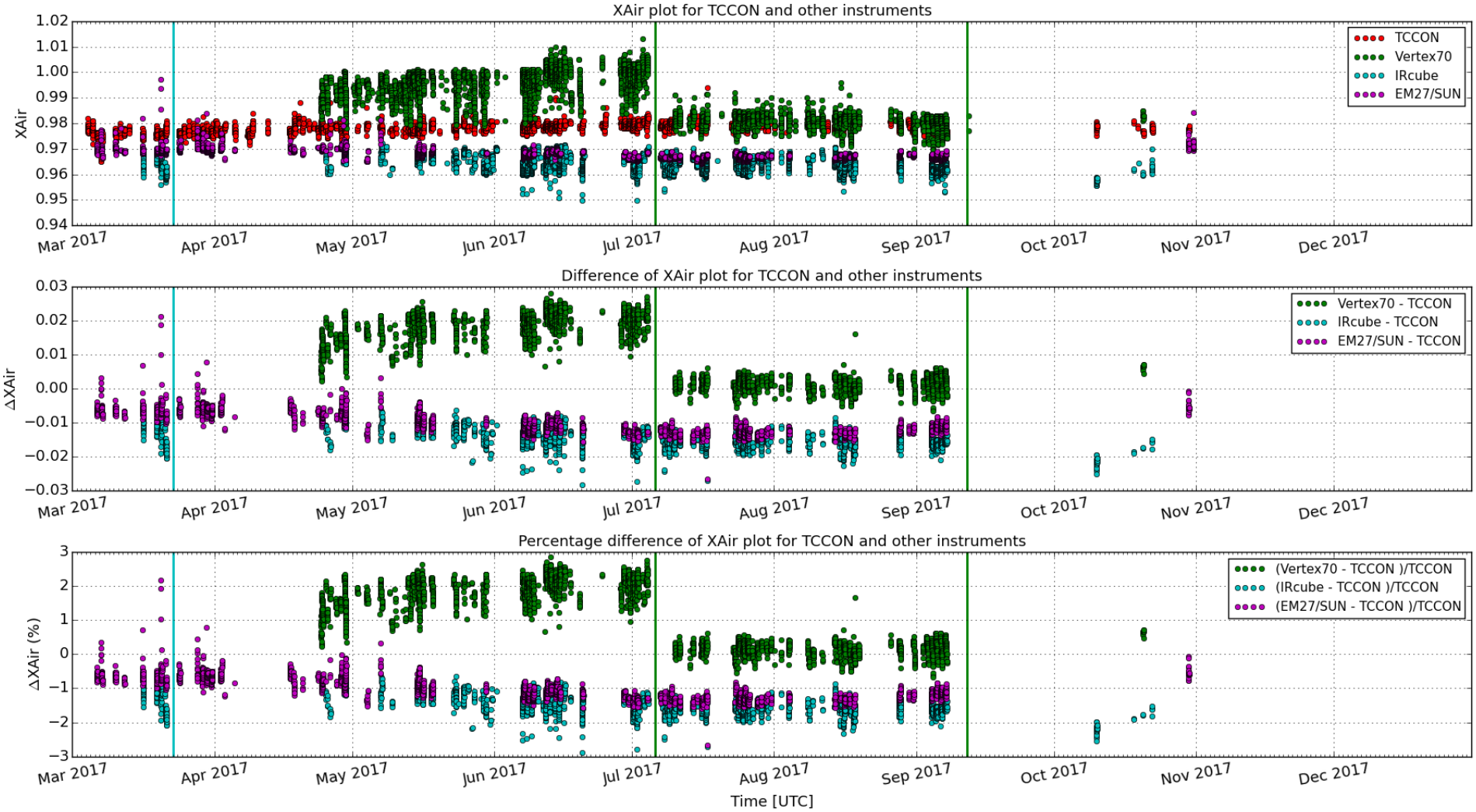
Other instruments vs TCCON – XCH4



Other instruments vs TCCON – XCO



Other instruments vs TCCON– XAir

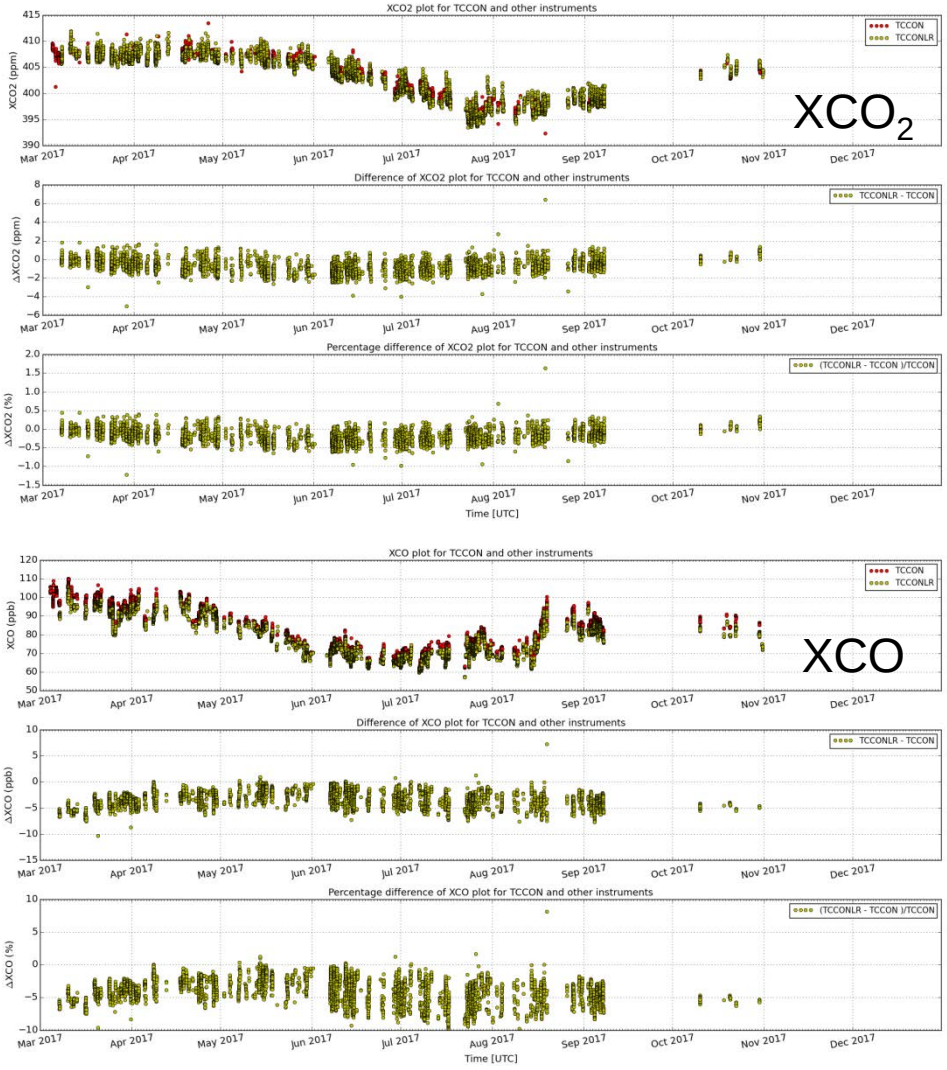


Xair is a measure of the instrument performance and is calculated from the O2 total column and ground pressure measured independently.The deviation of Xair value (~0.98) from unity is mostly due to spectroscopic errors. Vertex 70 shows much better match after instrument modification. IRcube and EM27/SUN have lower Xair (~ 0.96 – 0.97) – known for EM27/SUN

Comparing TCCONLR with TCCON measurements

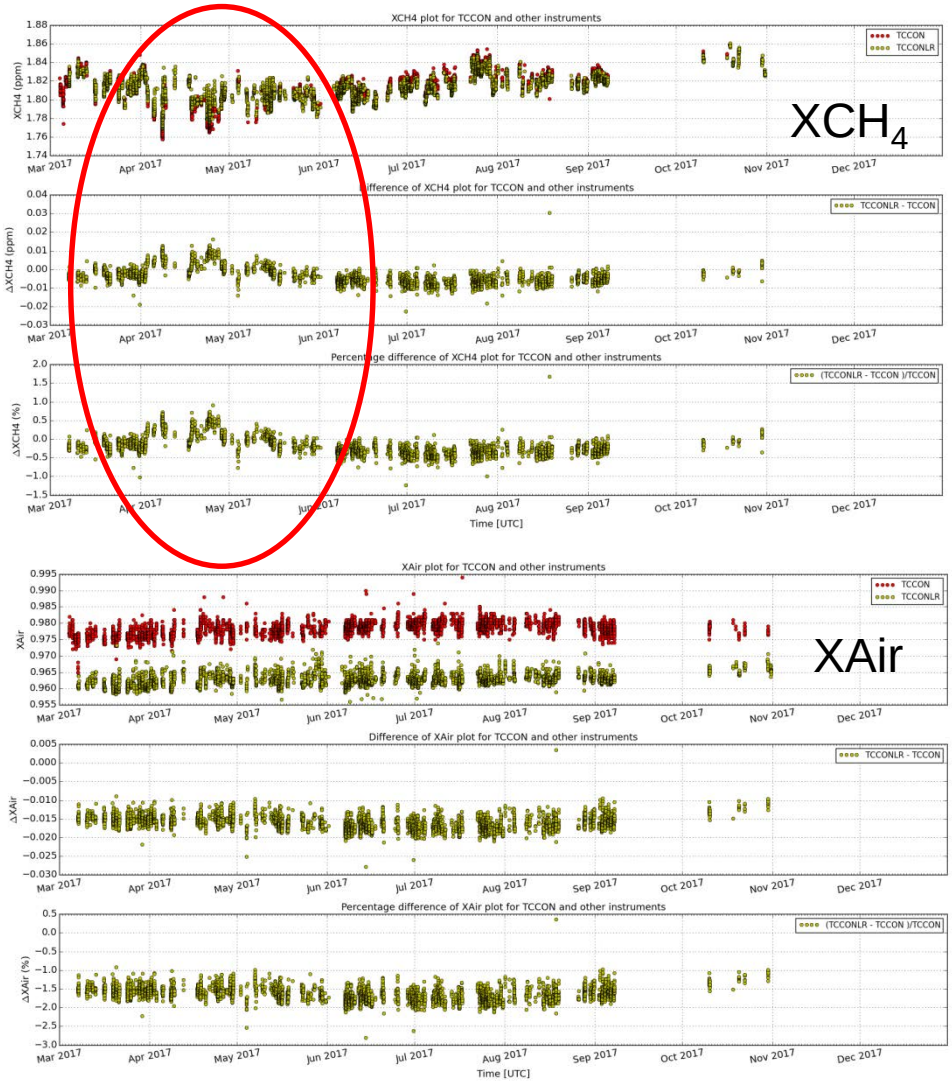
(TCCONLR processed with PROFFIT)

Comparison results – TCCONLR vs TCCON



XCO_2

XCO



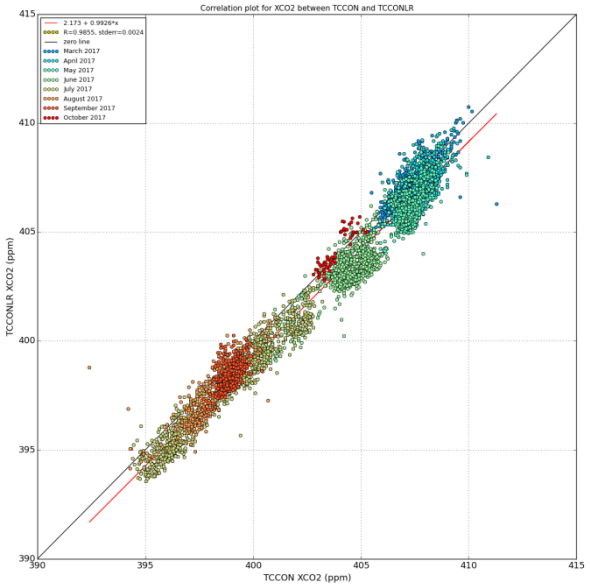
XCH_4

XAir

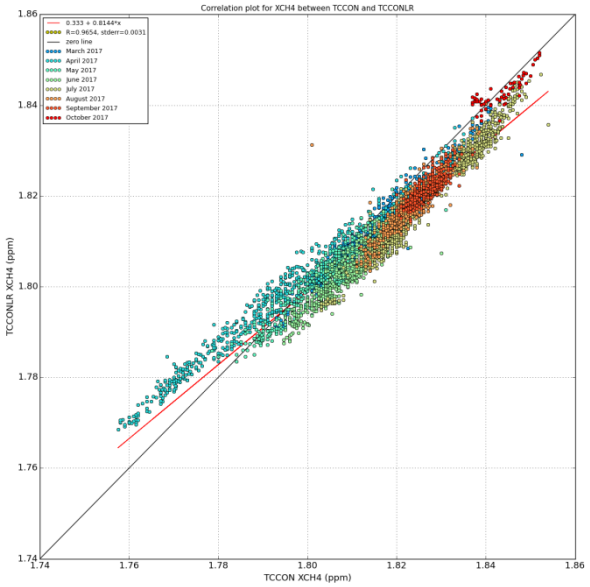
Slight seasonal dependences in biases

Xair for TCCONLR lower : ~ 0.96 – 0.965

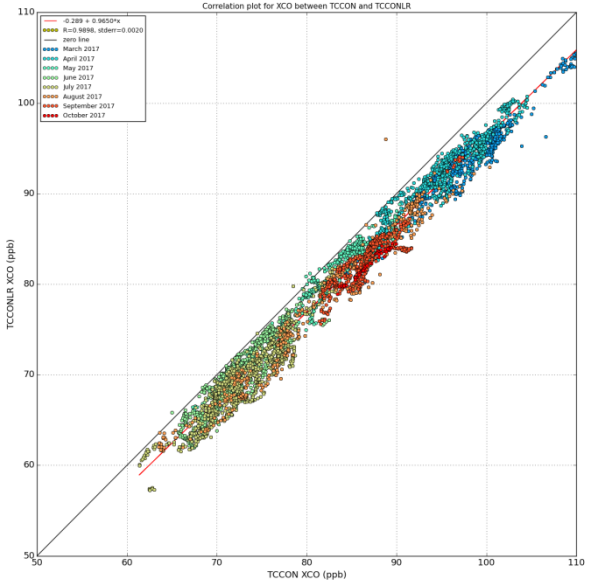
Comparison results – TCCONLR vs TCCON



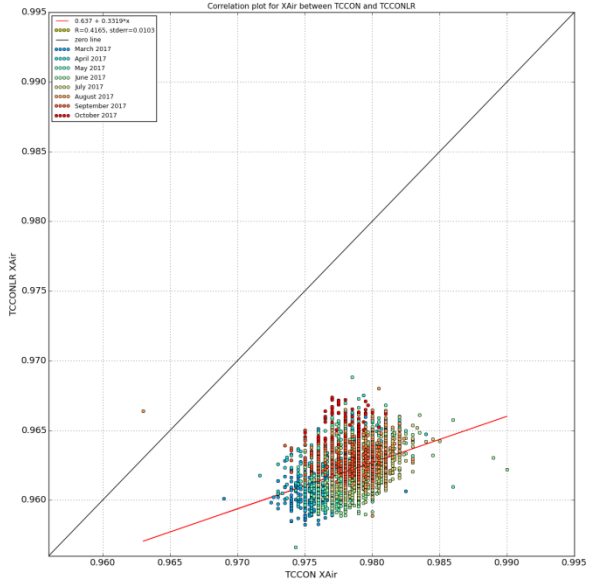
XCO_2



XCH_4



XCO



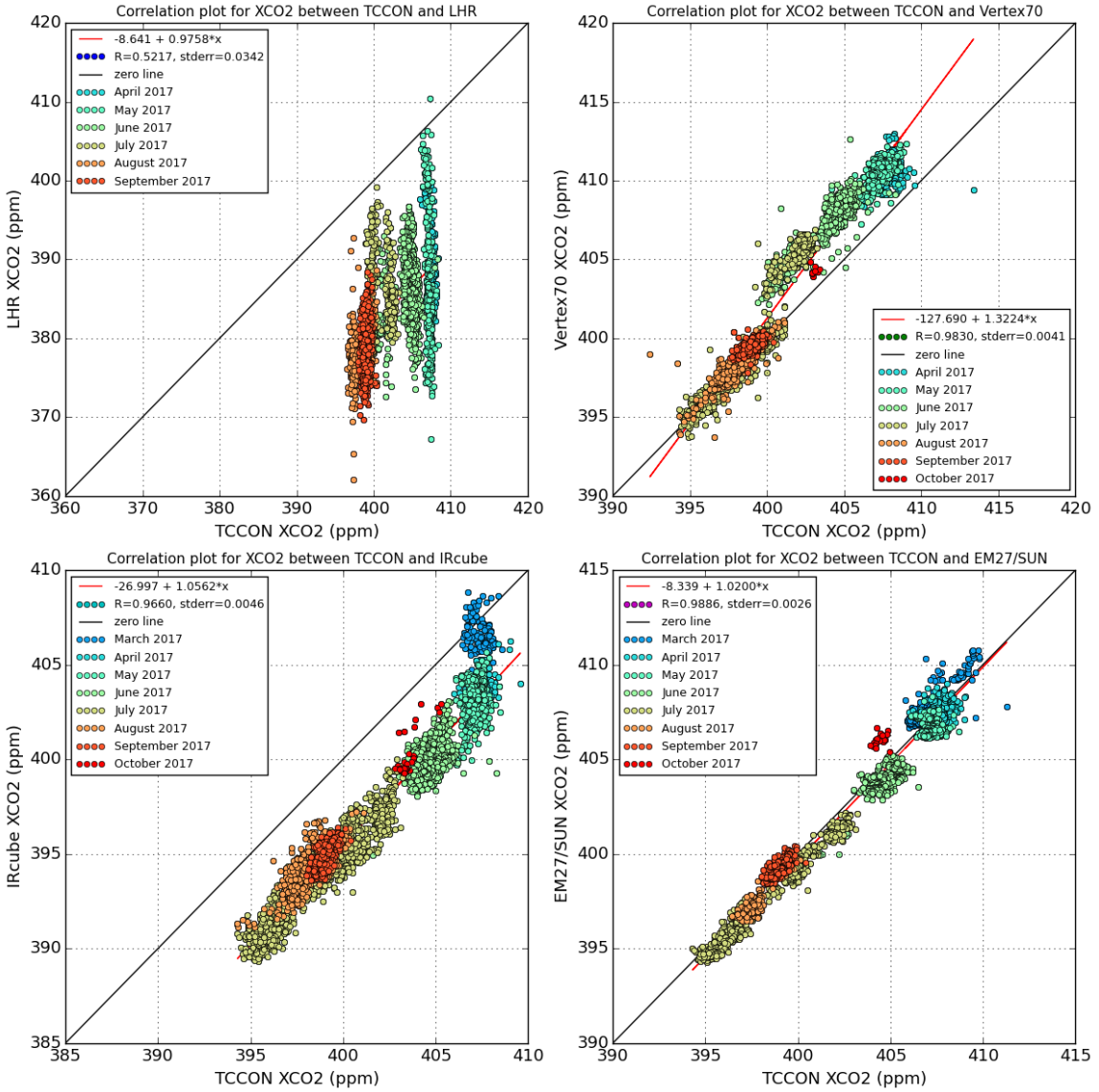
XAir

Comparing other instruments with TCCON(LR)

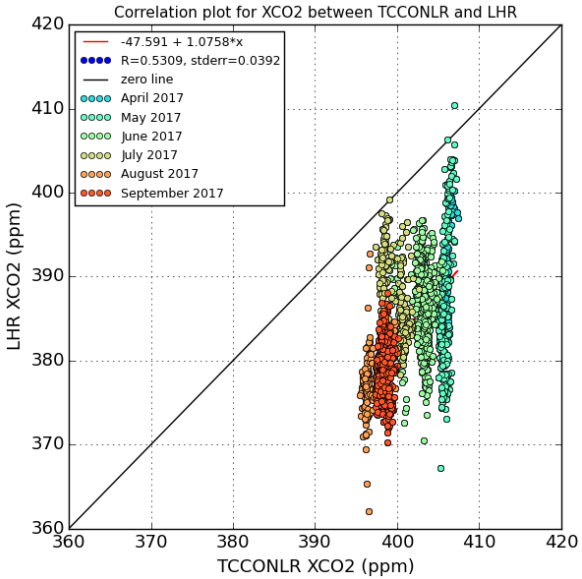
Comparing other instruments with TCCON(LR)

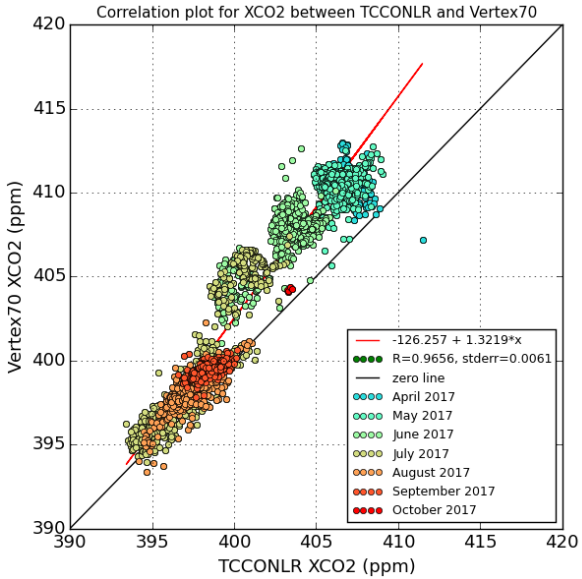
CO2

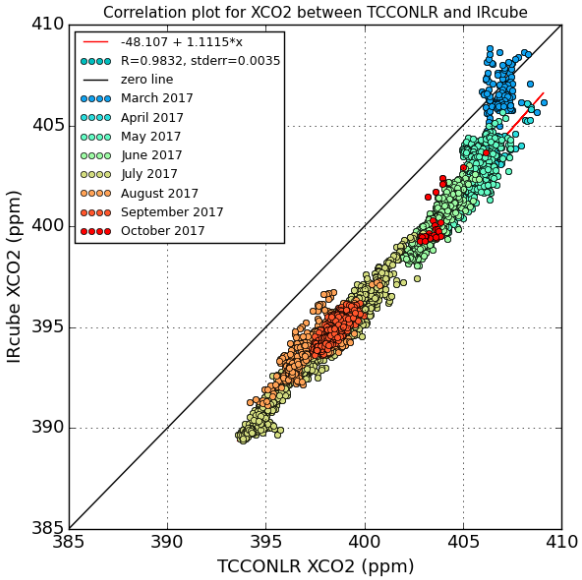
Other instruments vs TCCON - XCO2

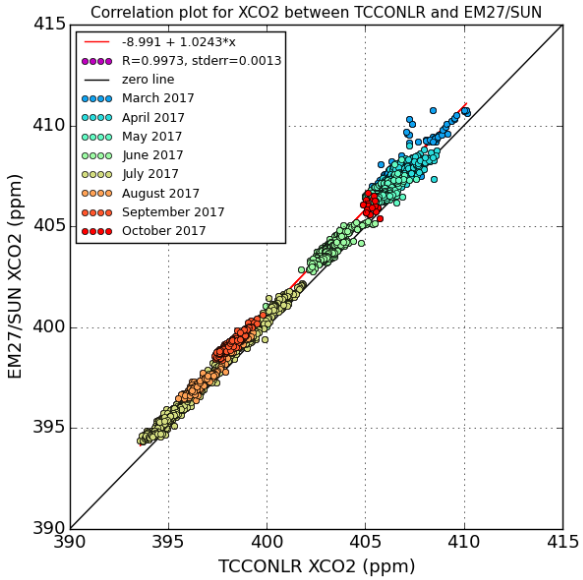


Other instruments vs TCCONLR – XCO2

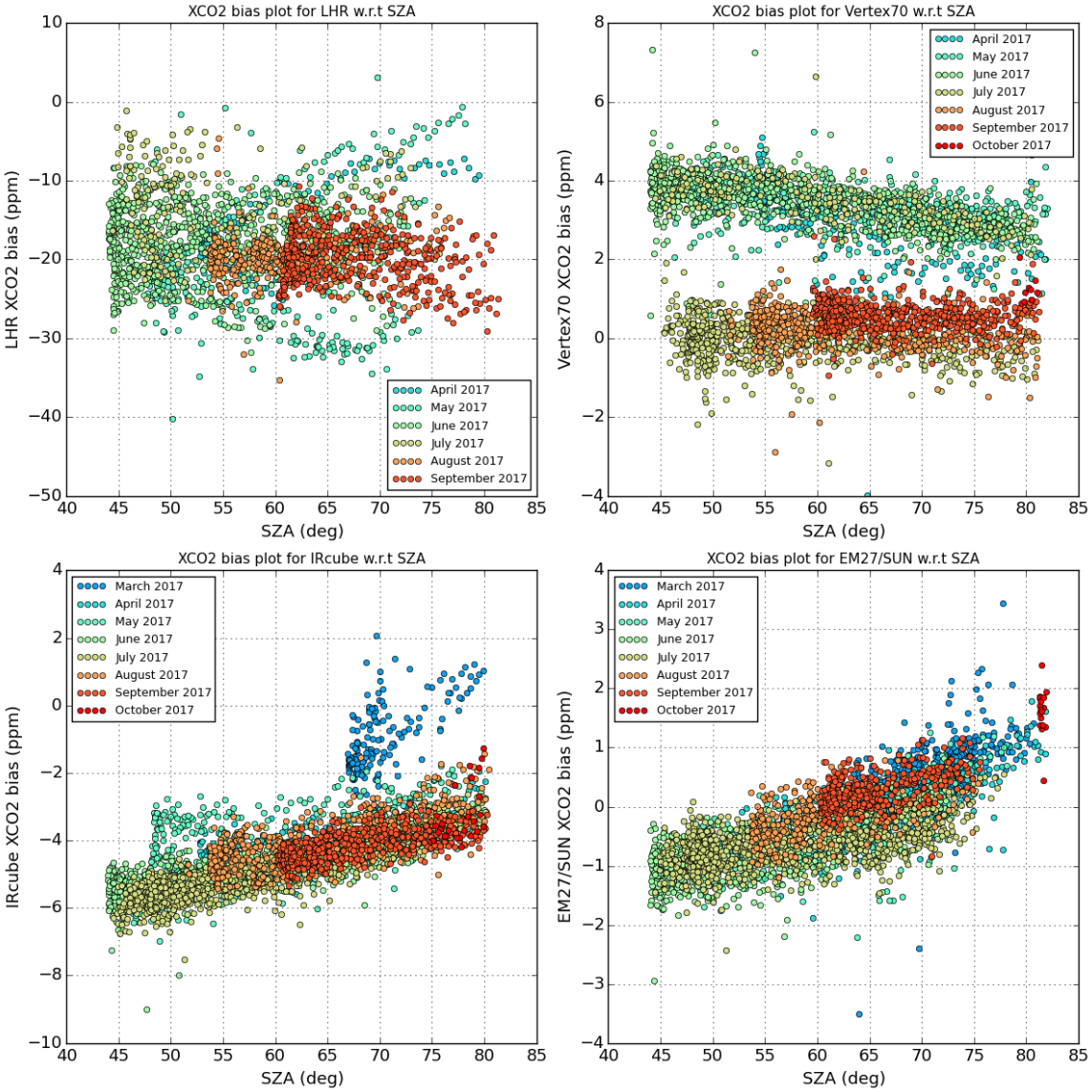




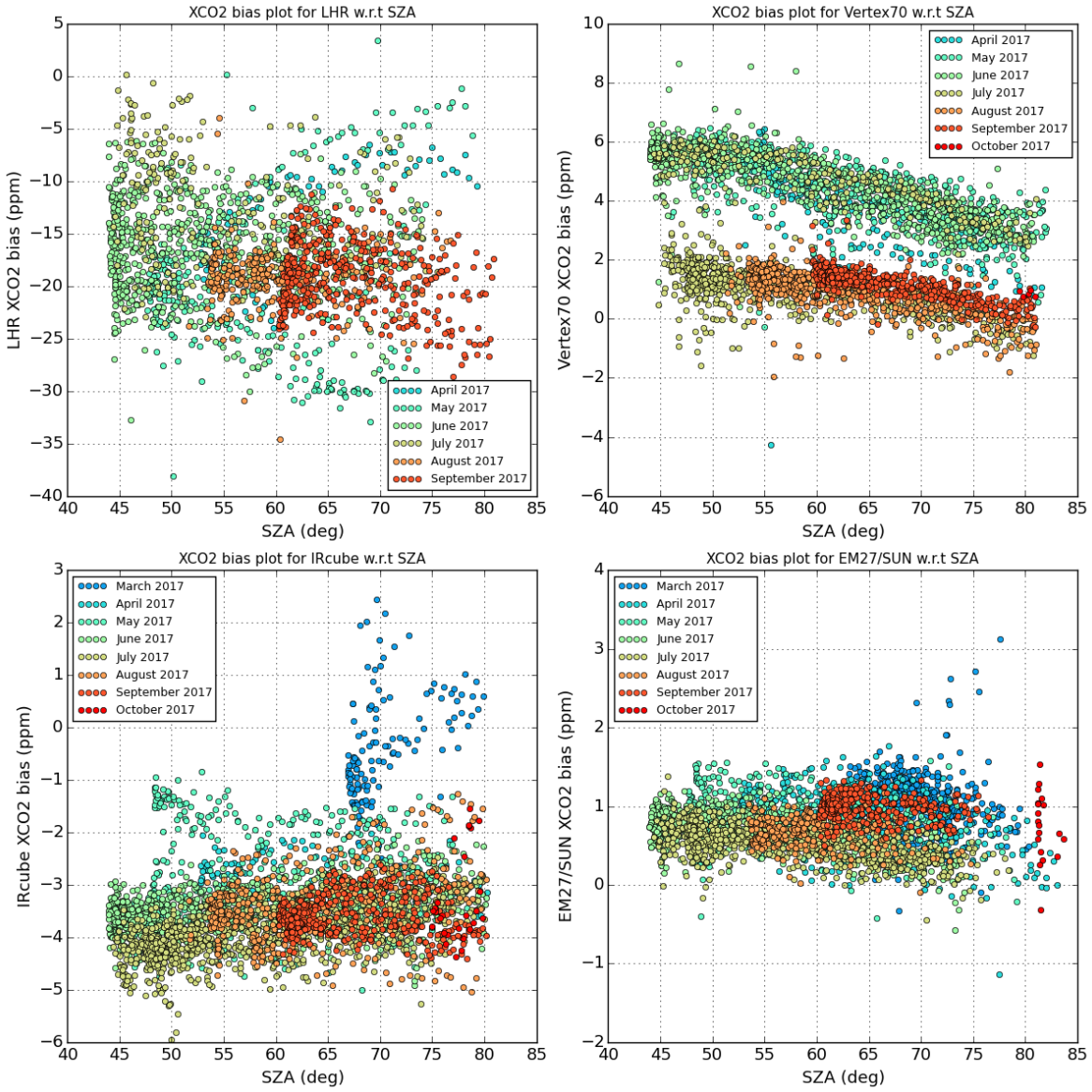




Other instruments vs TCCON - XCO2 bias vs SZA



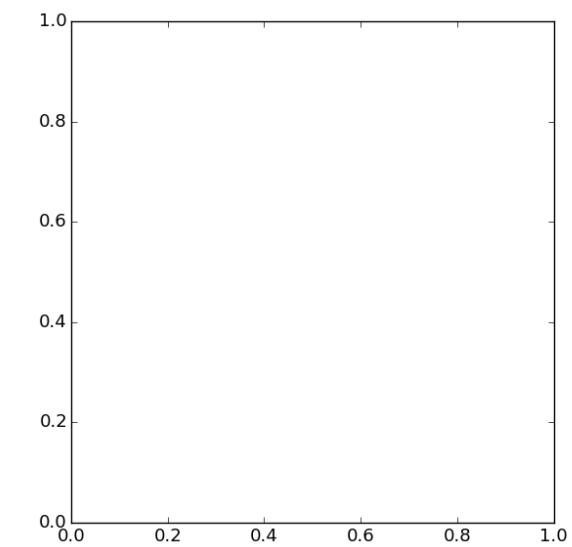
Other instruments vs TCCONLR – XCO2 bias vs SZA

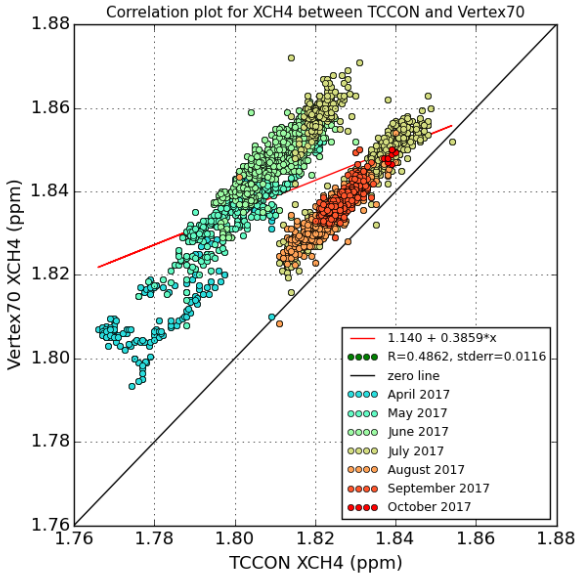


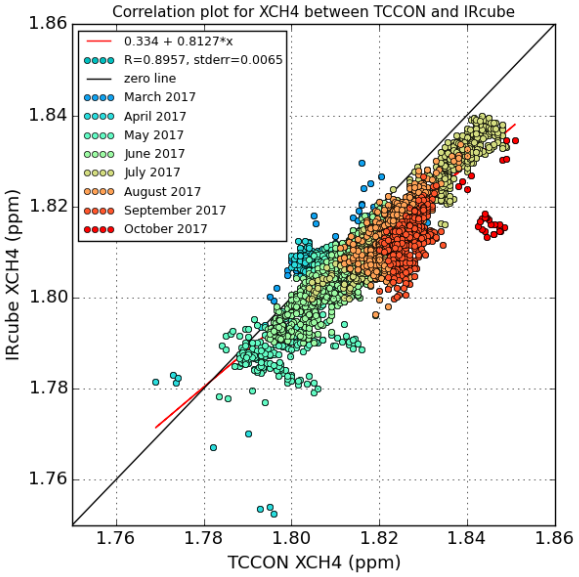
Comparing other instruments with TCCON(LR)

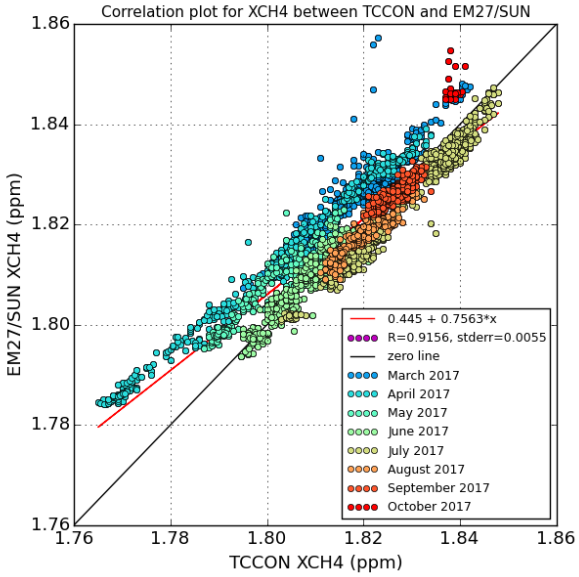
CH4

Other instruments vs TCCON – XCH4

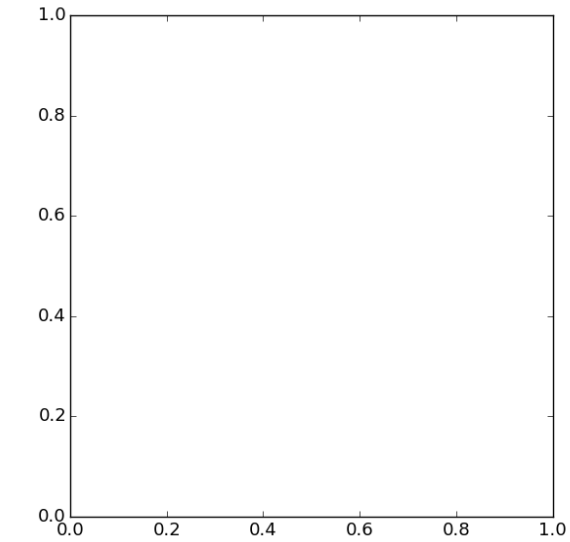


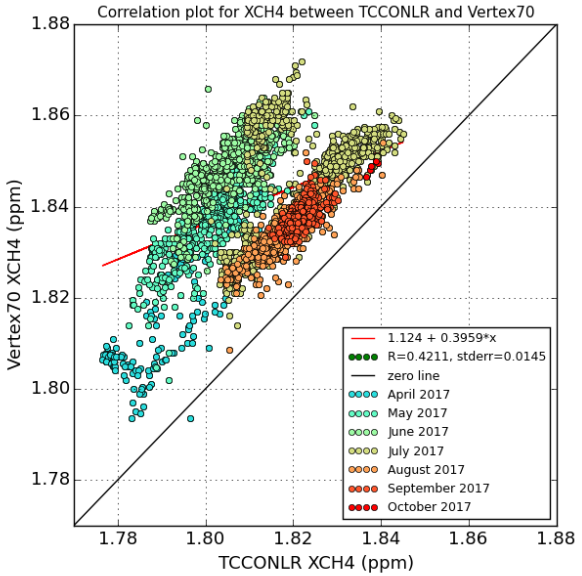


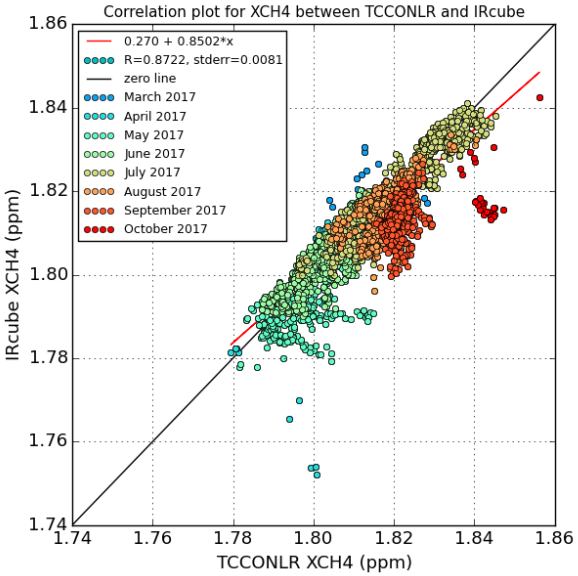


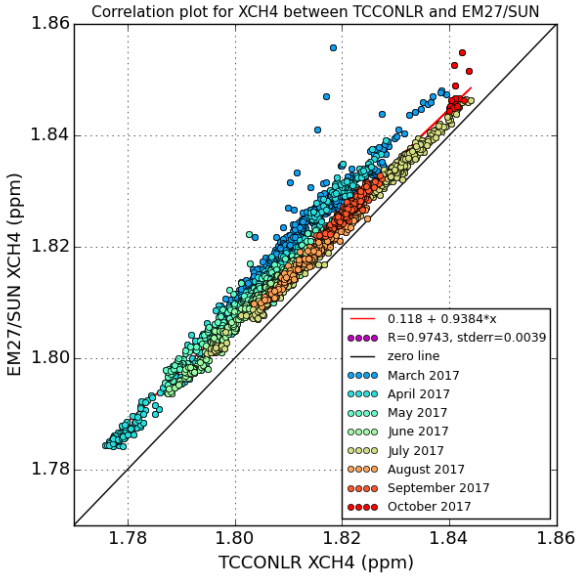


Other instruments vs TCCONLR - XCH4

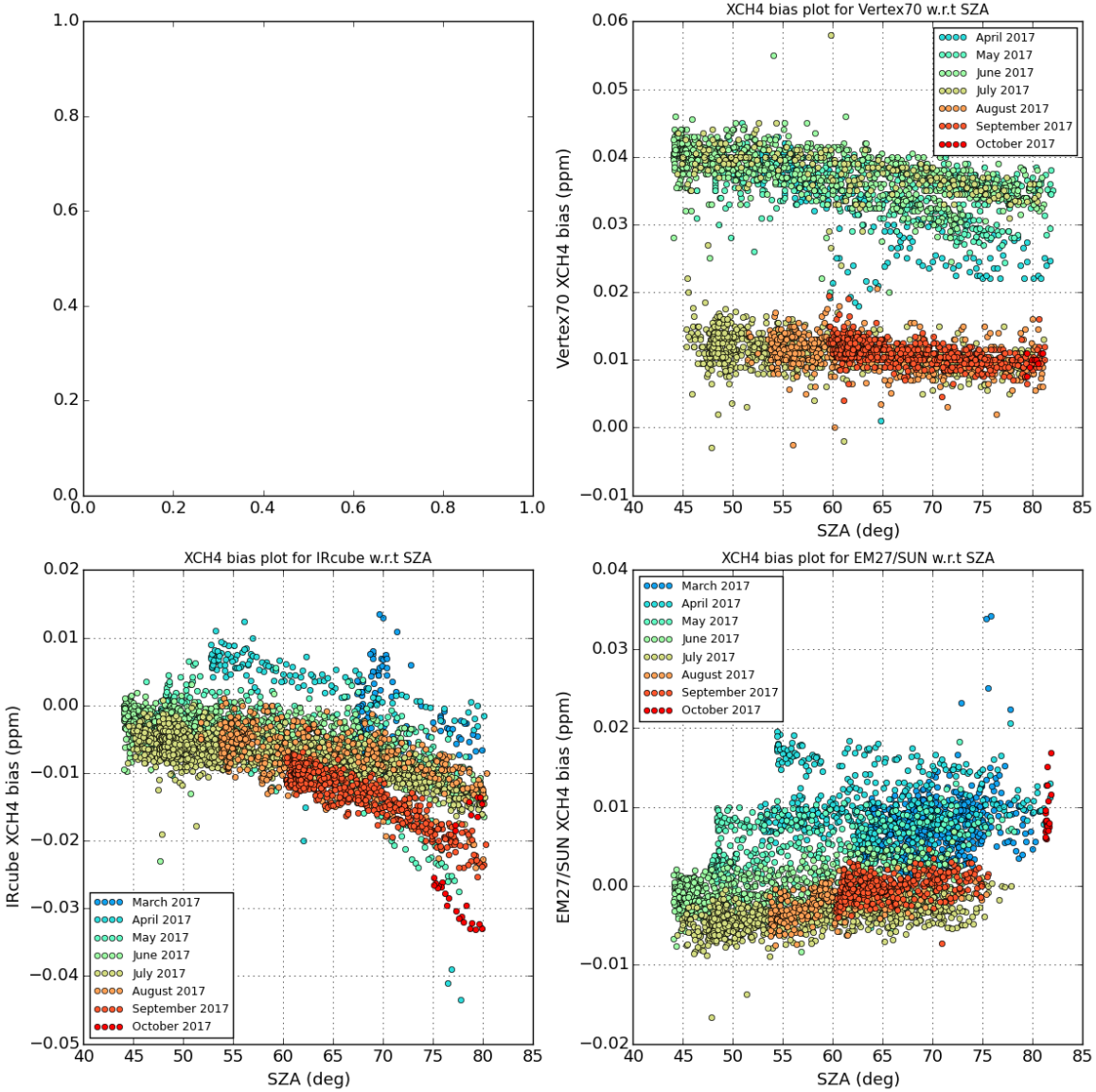




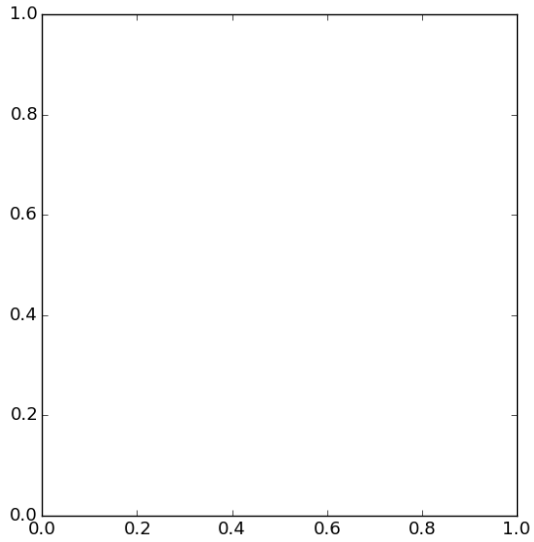


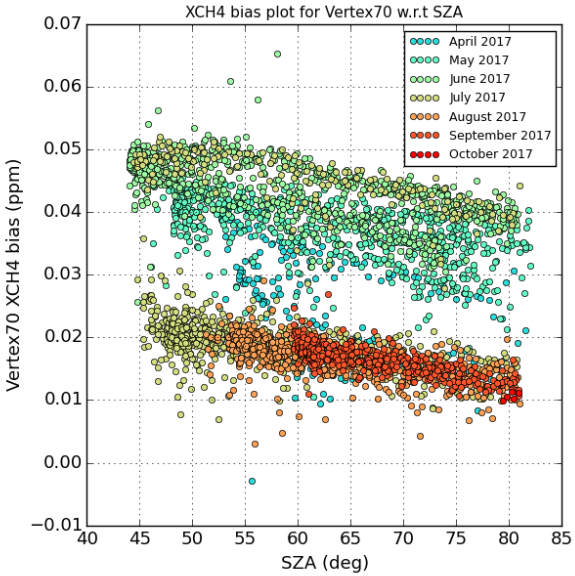


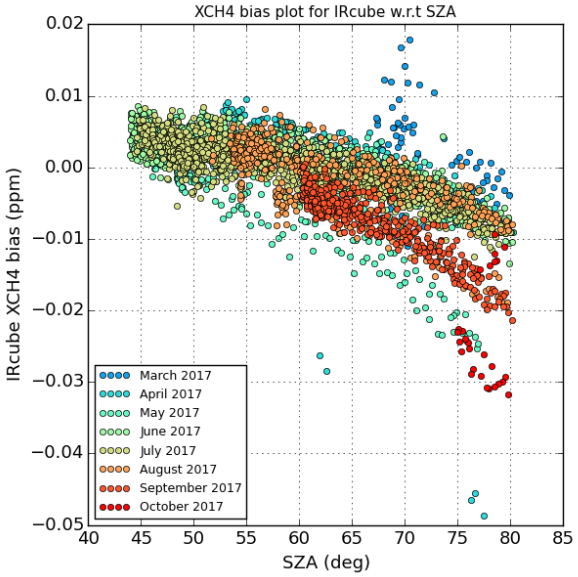
Other instruments vs TCCON – XCH4 bias vs SZA

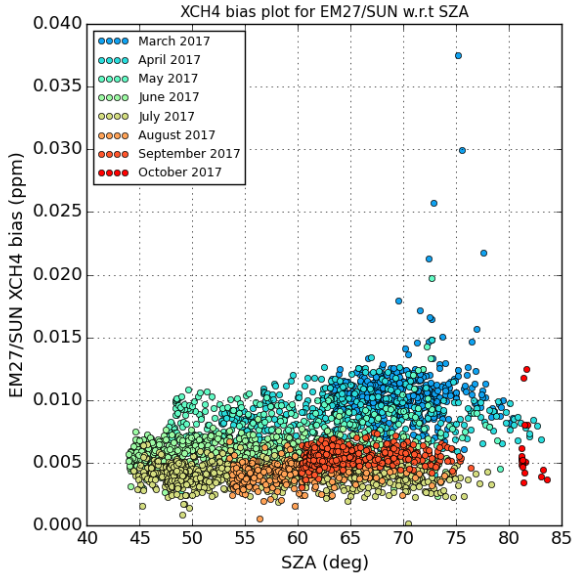


Other instruments vs TCCONLR – XCH4 bias vs SZA





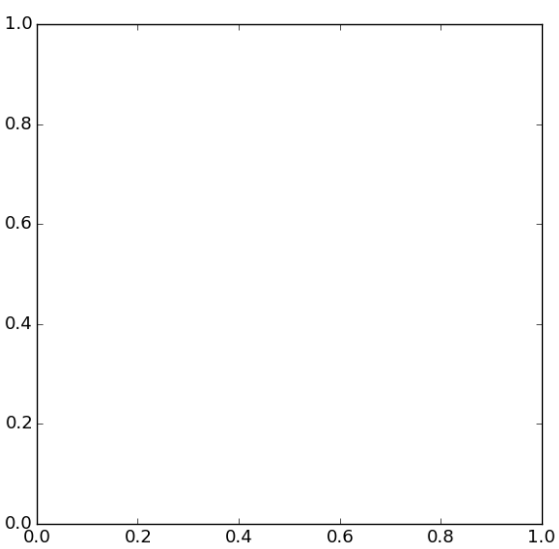


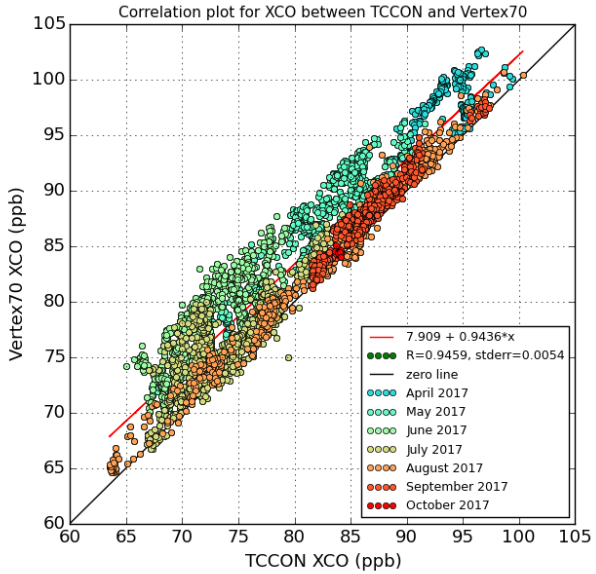


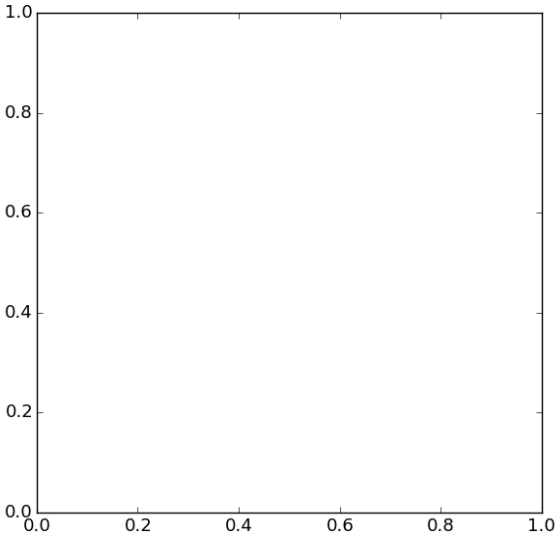
Comparing other instruments with TCCON(LR)

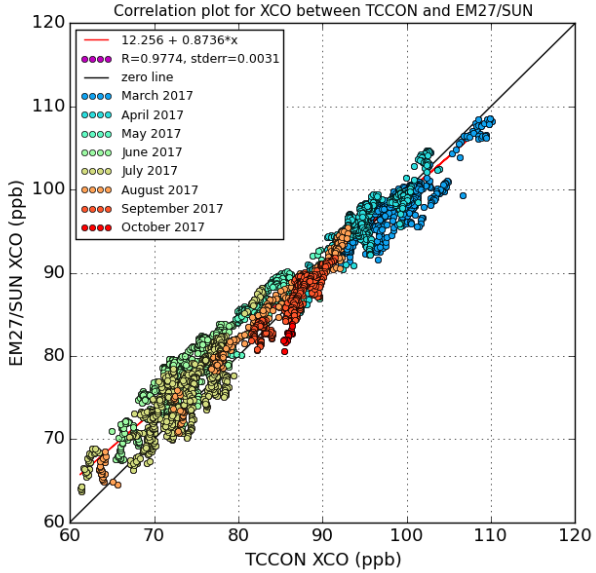
CO

Other instruments vs TCCON – XCO

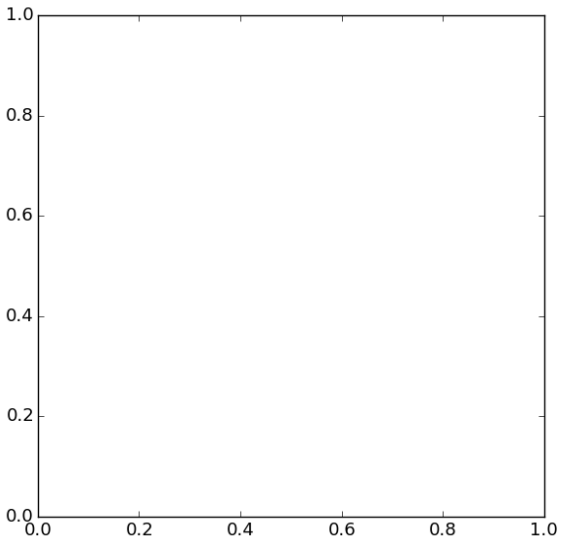


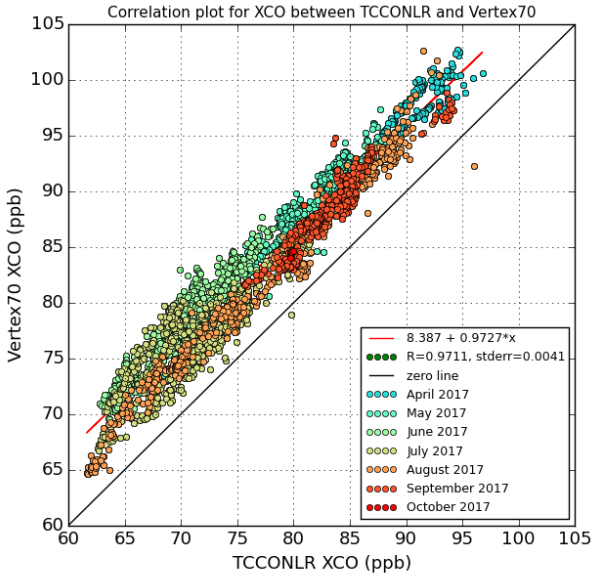


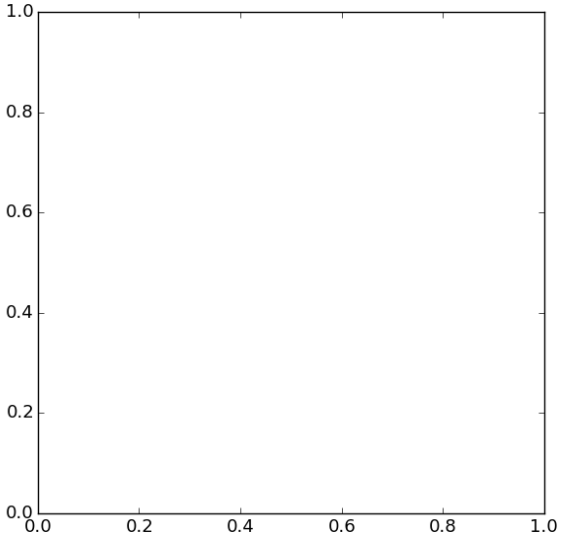


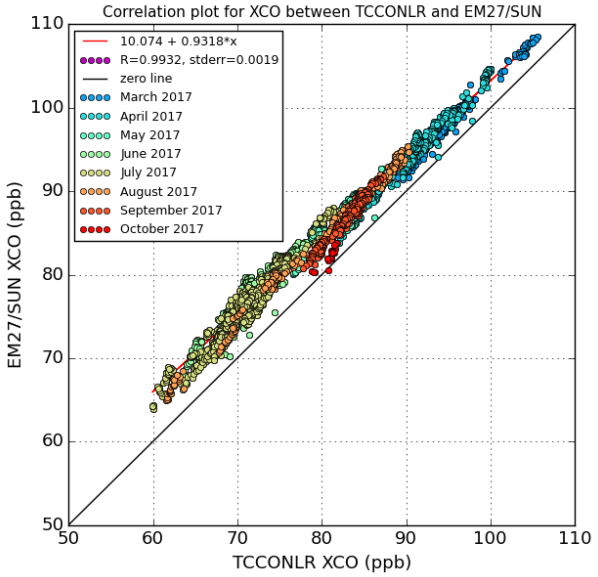


Other instruments vs TCCONLR – XCO

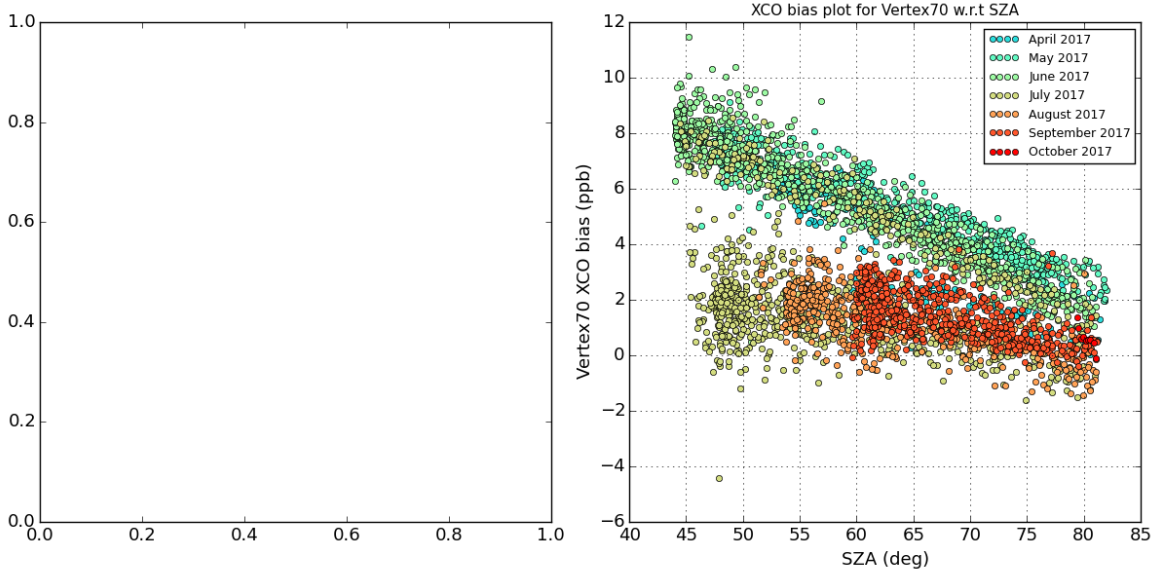


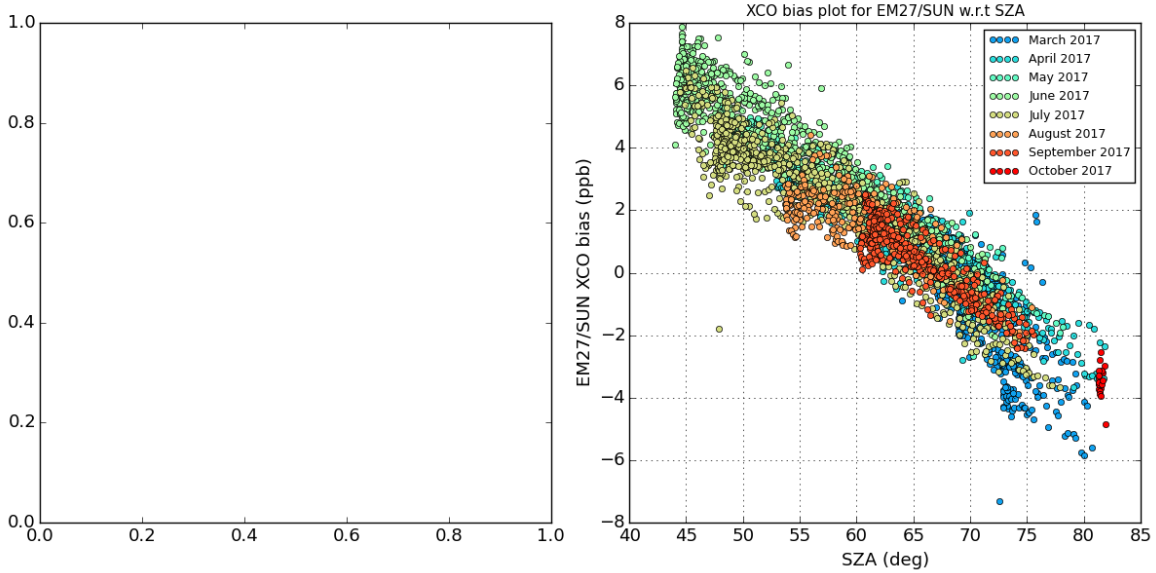




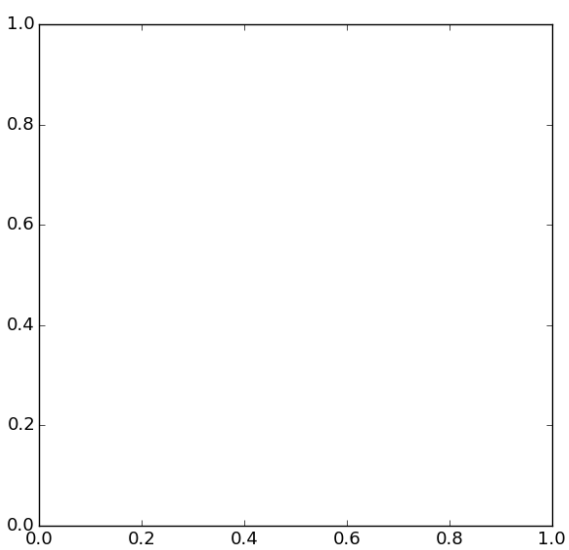


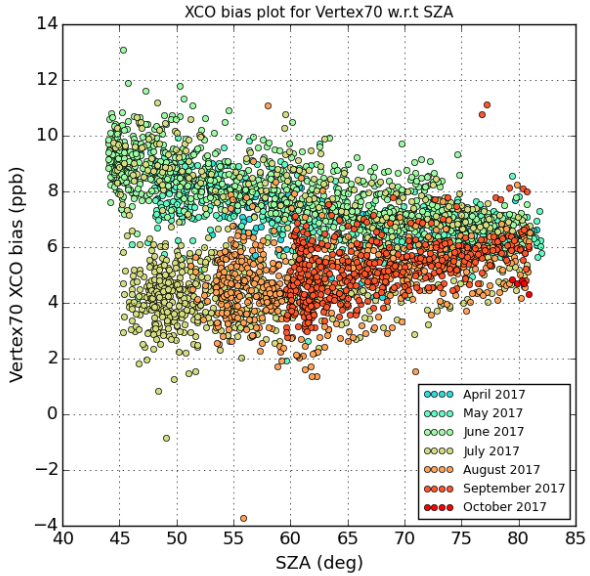
Other instruments vs TCCON – XCO bias vs SZA

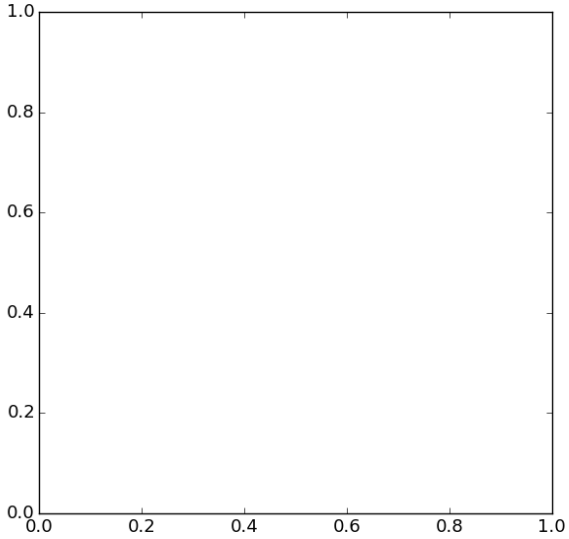


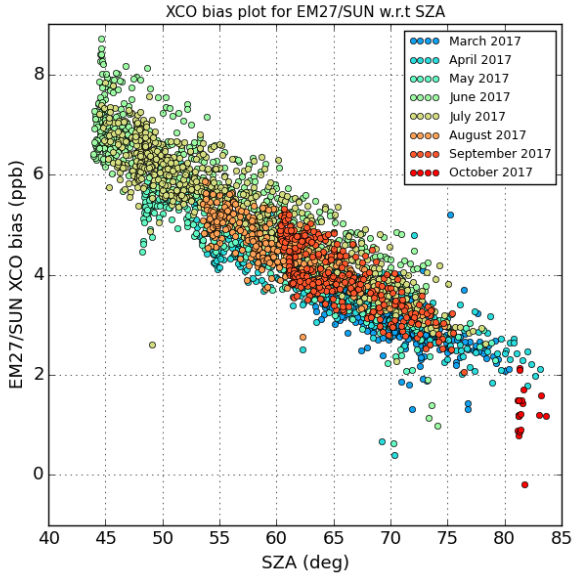


Other instruments vs TCCONLR – XCO bias vs SZA



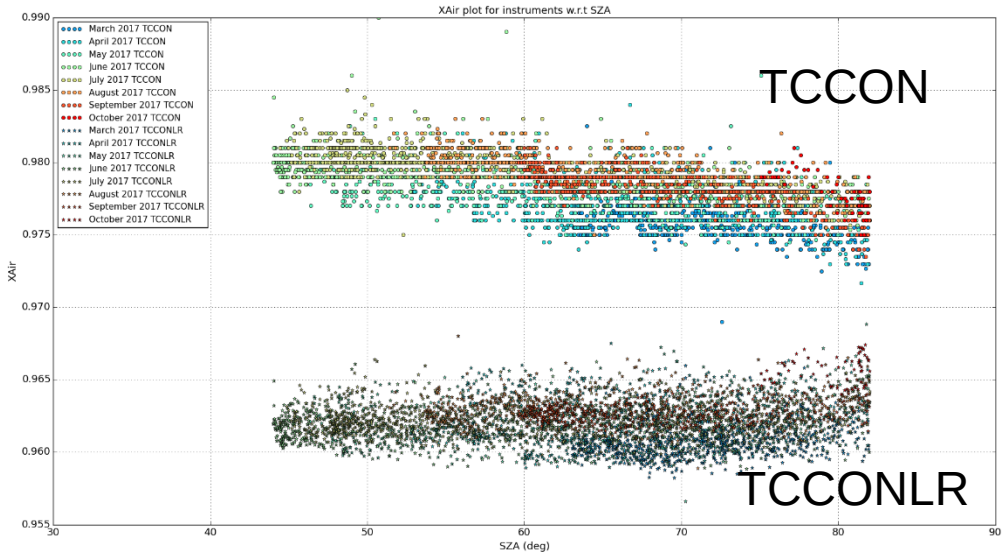


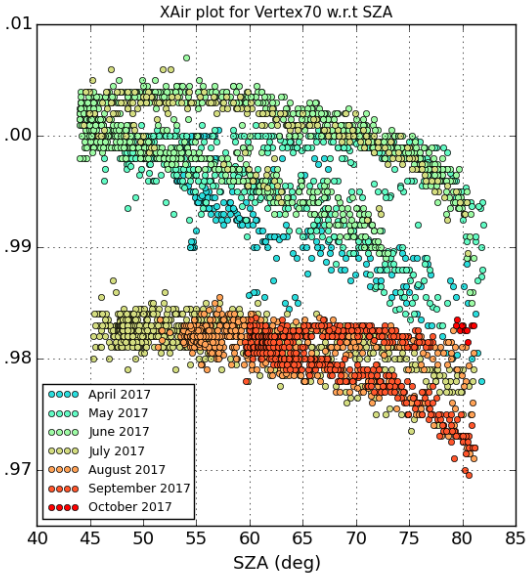


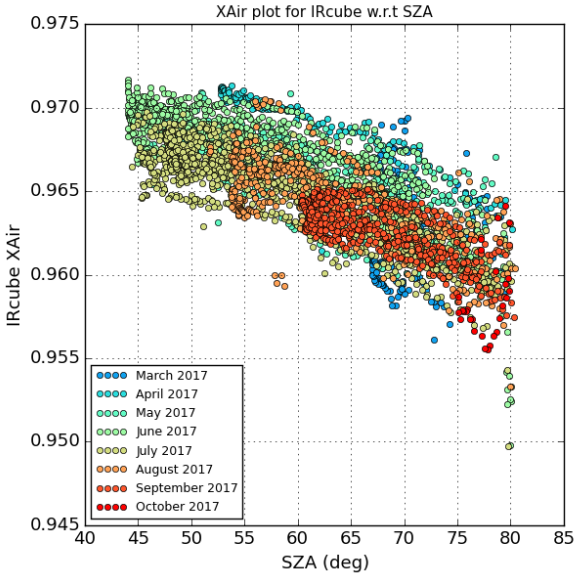


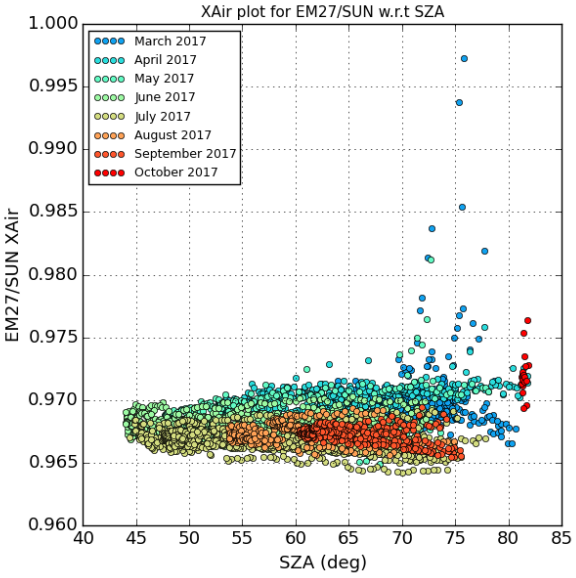
Dependence of Xair on SZA

Xair vs SZA


XAir plot for instruments w.r.t SZA
March 2017 TCCON
April 2017 TCCON
May 2017 TCCON
June 2017 TCCON
July 2017 TCCON
August 2017 TCCON
September 2017 TCCON
October 2017 TCCON
March 2017 TCCONLR
April 2017 TCCONLR
May 2017 TCCONLR
June 2017 TCCONLR
July 2017 TCCONLR
August 2017 TCCONLR
September 2017 TCCONLR
October 2017 TCCONLR
TCCON
TCCONLR
XAir
SZA (deg)

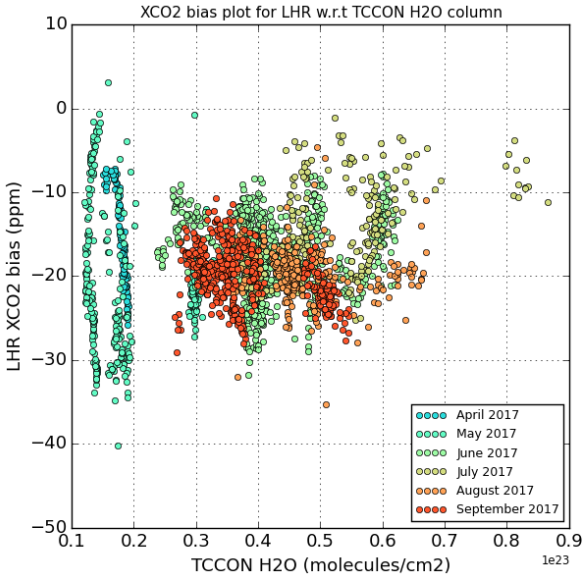

XAir plot for Vertex70 w.r.t SZA
April 2017
May 2017
June 2017
July 2017
August 2017
September 2017
October 2017
SZA (deg)

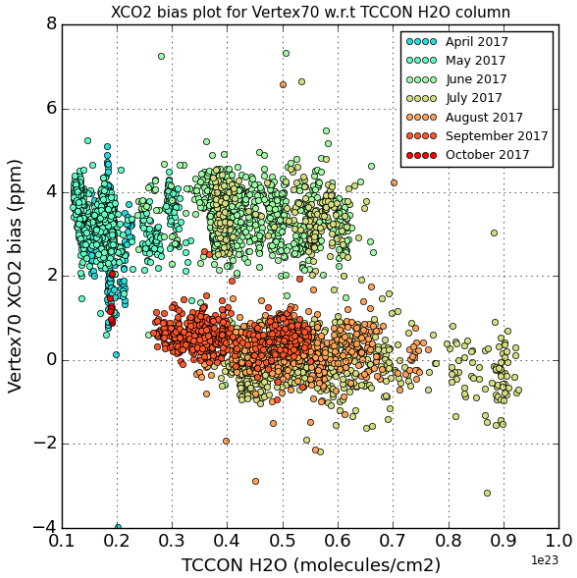

XAir plot for IRcube w.r.t SZA
March 2017
April 2017
May 2017
June 2017
July 2017
August 2017
September 2017
October 2017
IRcube XAir
SZA (deg)

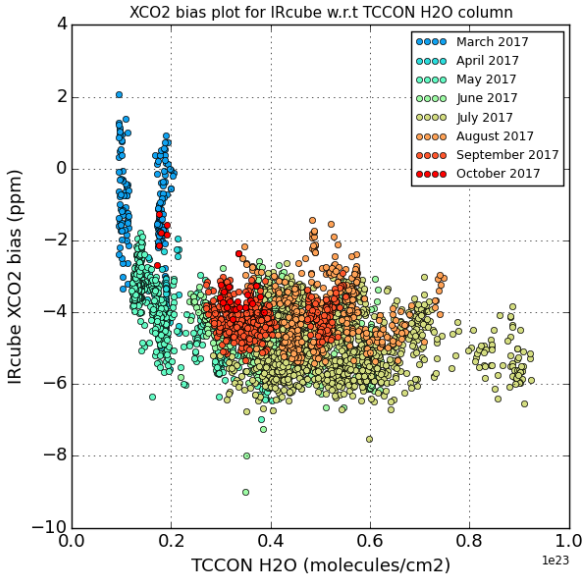

XAir plot for EM27/SUN w.r.t SZA
March 2017
April 2017
May 2017
June 2017
July 2017
August 2017
September 2017
October 2017
EM27/SUN XAir
SZA (deg)

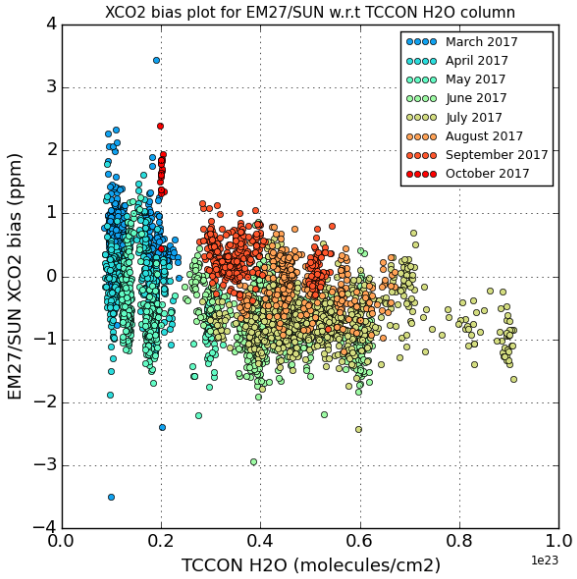
Dependence of biases wrt TCCON on H2O (H2O measured by TCCON)

XCO2 bias dependence on H2O

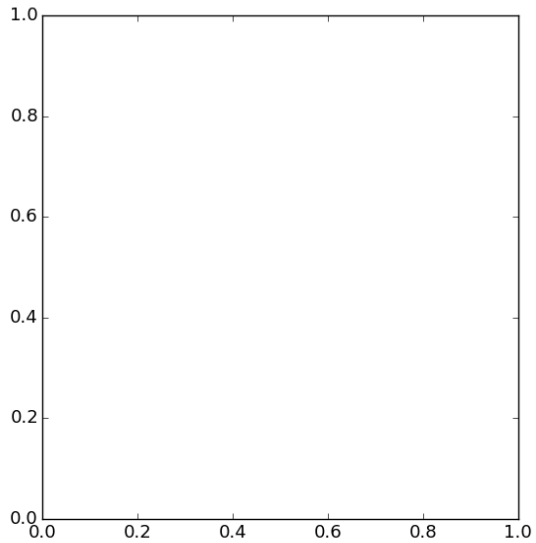


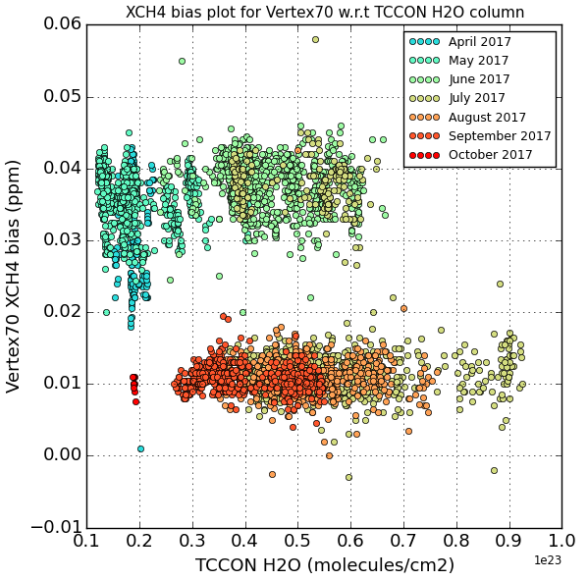


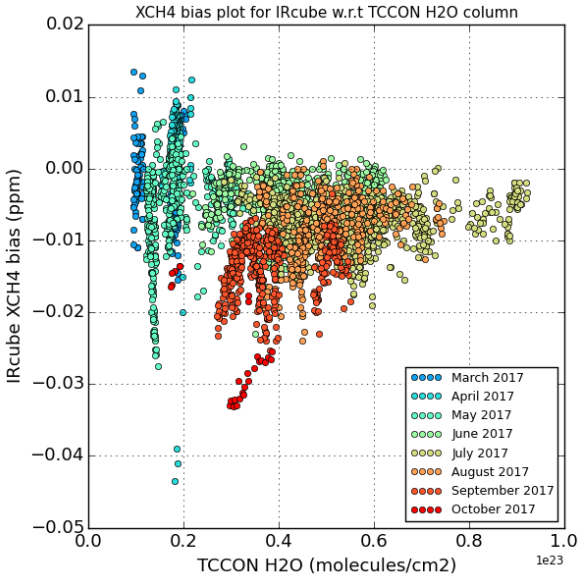


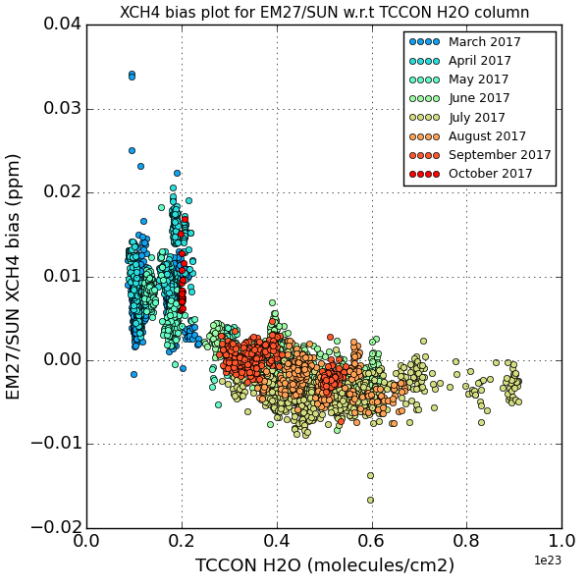


XCH4 bias dependence on H2O

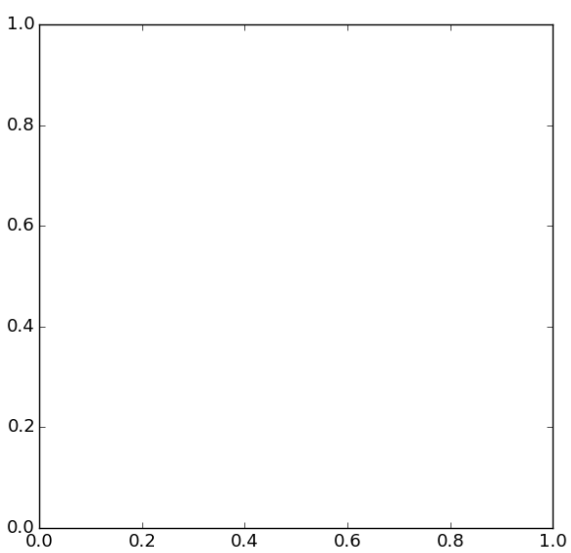


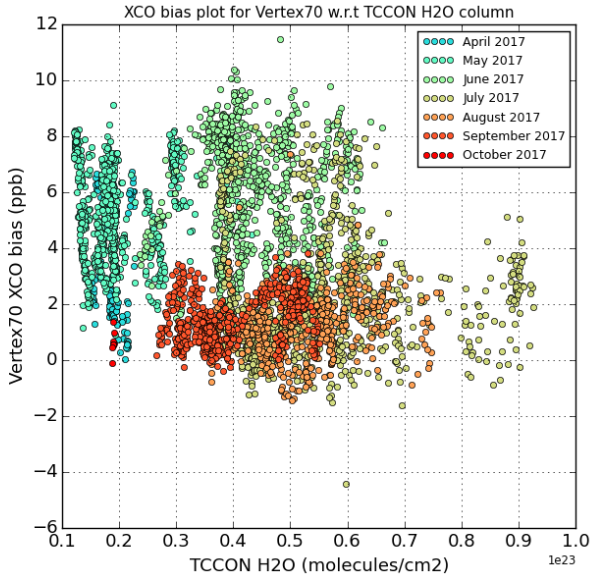


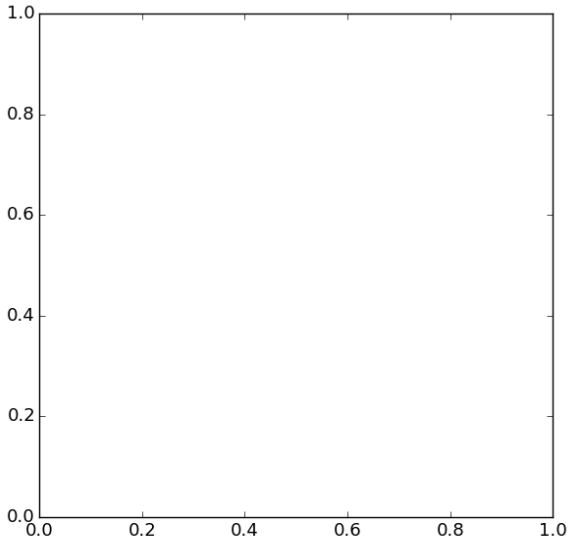


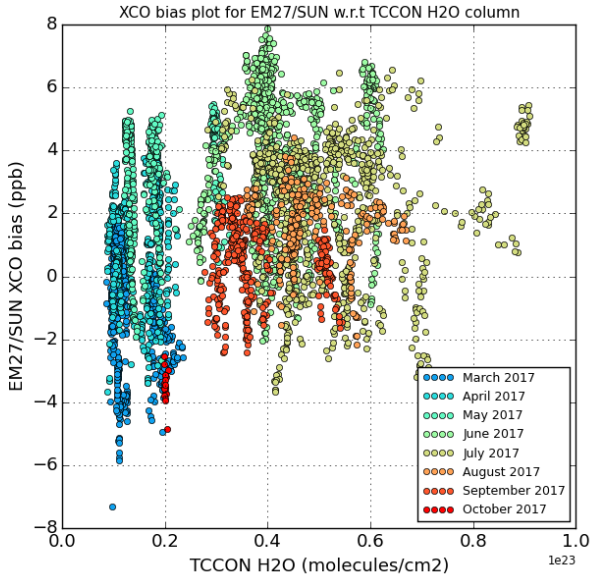


XCO bias dependence on H2O

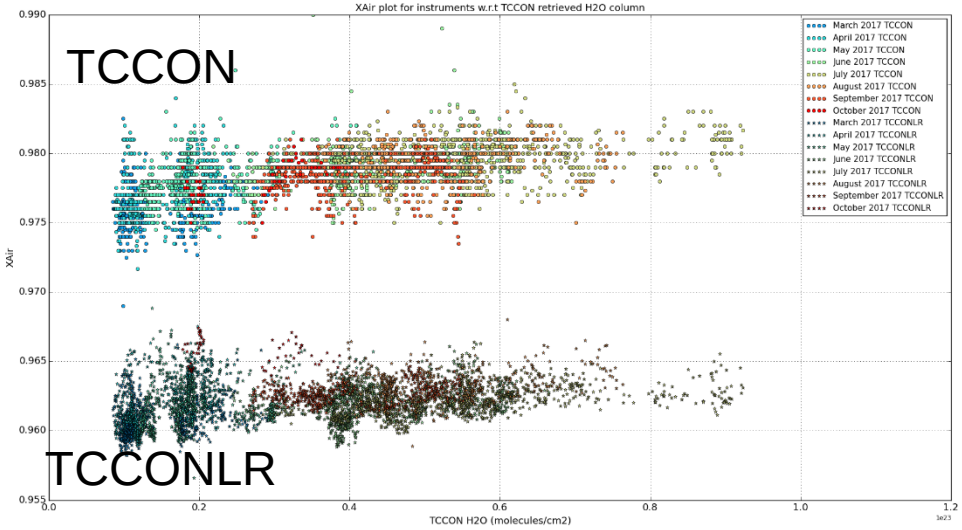


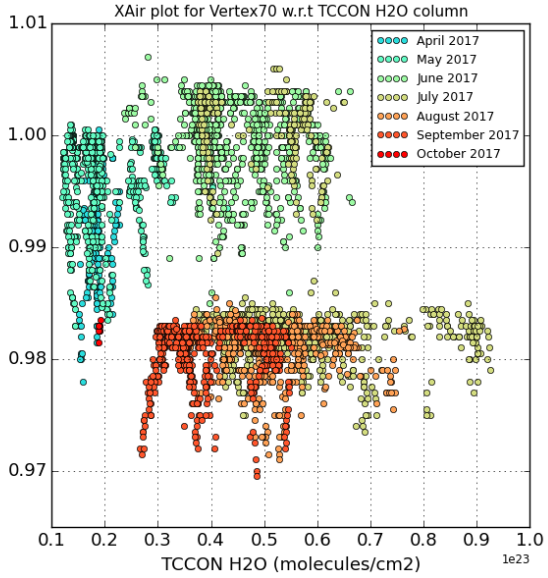


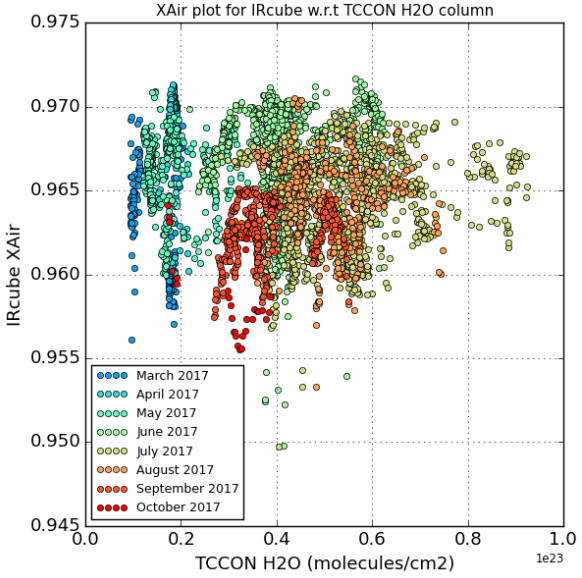


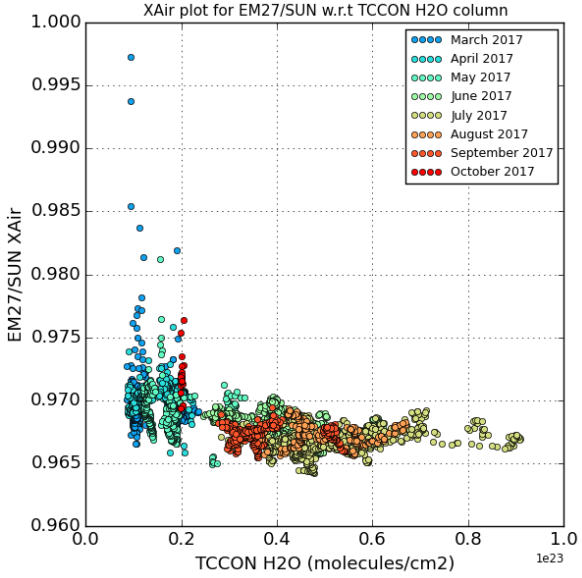


Xair dependence on H2O









Comparison results – summary

- The EM27/SUN has been running in a single stable configuration during the whole campaign (cf. its history), whereas the other LR instruments needed optimisation, therefore quantitative comparative statistics are difficult to make;
- The instruments behave better after the changes
- All instruments capture the annual summer drawdown in CO2
- CH4 annual cycle is consistent for TCCON, IRcube and EM27/SUN; we see a bias change (0.01 ppm) between TCCON and others in March-to-May period. Accounting for the configuration change in the Vertex, it seems to also capture the annual cycle (TBC).
- All instruments capture the CO seasonal cyle
- The variation of Xair with SZA is smallest for EM27/SUN; IRcube and Vertex have Xair decreasing with SZA. The deviation of Xair of EM27/SUN is understood.
- The differences between the comparisons with TCCON and TCCONLR highlight the impact of the different spectral resolutions and processing codes, with the Vertex resolution being closest to the TCCON resolution.
- The comparisons with TCCONLR are most sensitive to instrument problems

Conclusions

The ESA-funded project – FRM4GHG - to intercompare several low-resolution instruments besides TCCON instrument in Sodankyla/Finland, complemented with regular Aircore launches,

has delivered very interesting and new results.

It has allowed to improve the setup of LR instruments like the Vertex 70, and has provided insight in the operation of the LHR instrument.

Some more specific issues need further investigation:

- Corrections for non-linearity
- Impact of a priori vertical profile -> under study using the measured AirCore profiles
- LHR issues

Phase 2 of FRM4GHG to:

- continue and extend the measurements
- perform a full year of measurements in stable operational conditions
- contribute to S5P/Tropomi validation

Next steps

- Ongoing extension of the campaign at Sodankylä in 2018
- Perform more low resolution measurements with TCCON instrument
- Exchange spectra and do a round-robin intercomparison

  Cf. use of PROFFIT and GFIT14 and GFIT16
- Identify sources, understand, and correct the biases observed with the instruments
- Add InSb species … in particular HCHO
- Add retrieval of CH_4 in the 2.3 µm band, cf. S5P
- Provide a significant dataset of GHG measurements which will be used for satellite validation purposes
- Provide a guideline for further development of new observation sites to complement the TCCON network and provide better support for the validation of existing and future satellite missions

Access to information, data and results

http://frm4ghg.aeronomie.be

Twitter: #frm4ghg