Karlsruhe Institute of Technology

CO_2 CCON
Collaborative Carbon Column Observing Network

Instrumental calibration of COCCON EM27/SUN spectrometers as a prerequisite for the detection of Berlin CO_2 emissions

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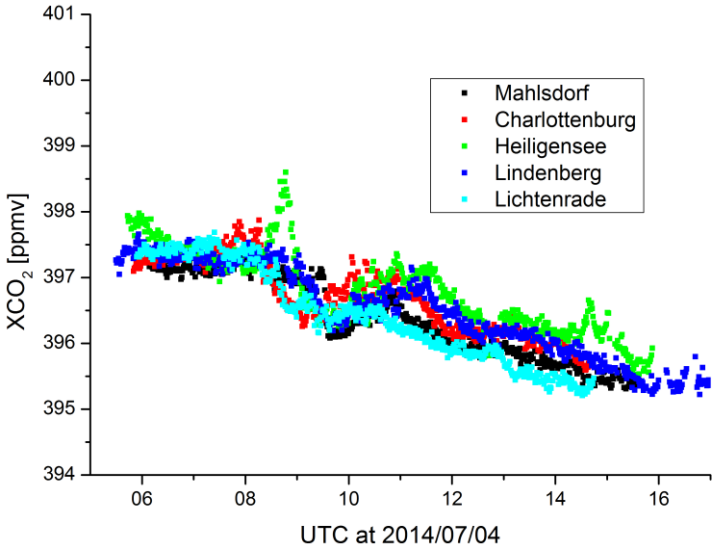
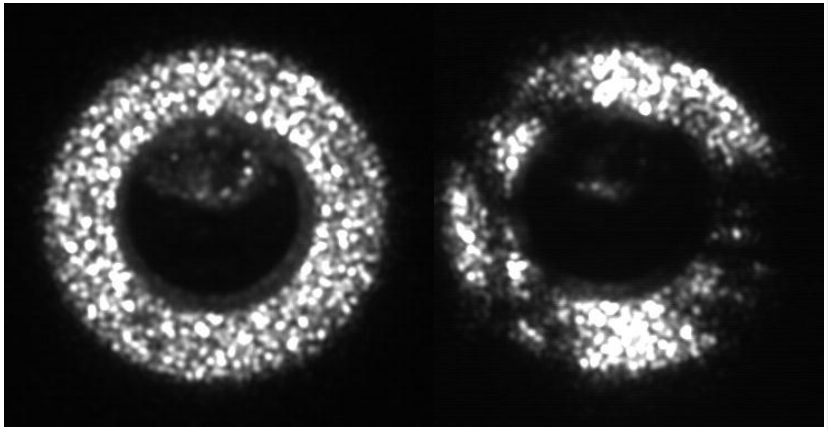


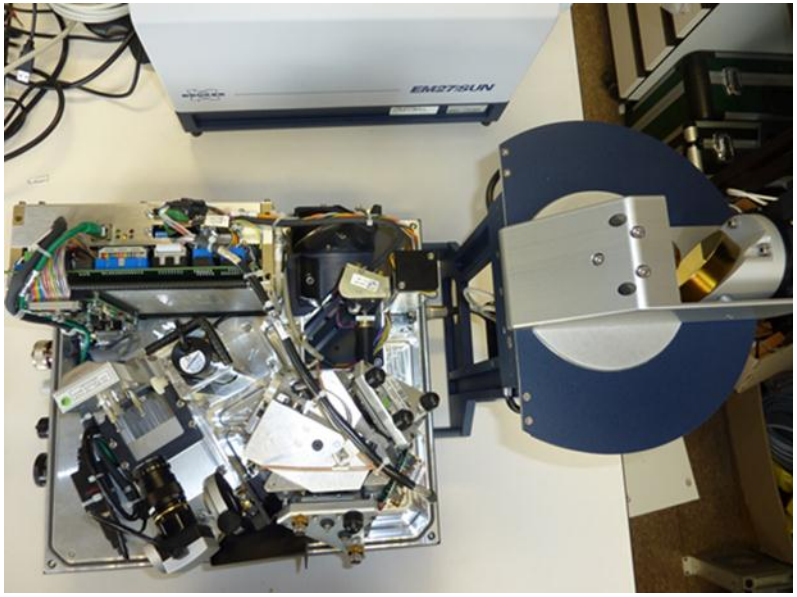
Outline

- Instrumentation
- Instrumental line shape characterisation
- Calibration procedure
- Summary and outlook

Instrument overview EM27/SUN

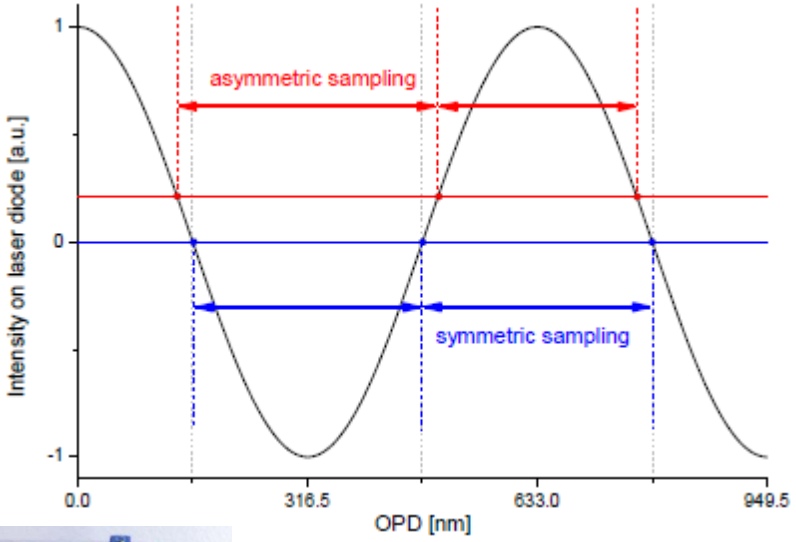
- Rock Solid™ pendulum interferometer
  - 2 cube corners
  - CaF_2 beamsplitter
- MOPD: 1,8 cm; resolution: 0,5 cm^{-1}
- Double sided interferograms
- InGaAs detector
  - Spectral range: 5000 cm^{-1} – 11000 cm^{-1}
- SemiFOV: 2.36 mrad
- Standard non frequency-stabilized HeNe reference laser
- Dimensions: 35 x 40 x 27 cm
- Mass: ~25 kg with tracker
- Tracker unit including tracking software developed by M. Gisi

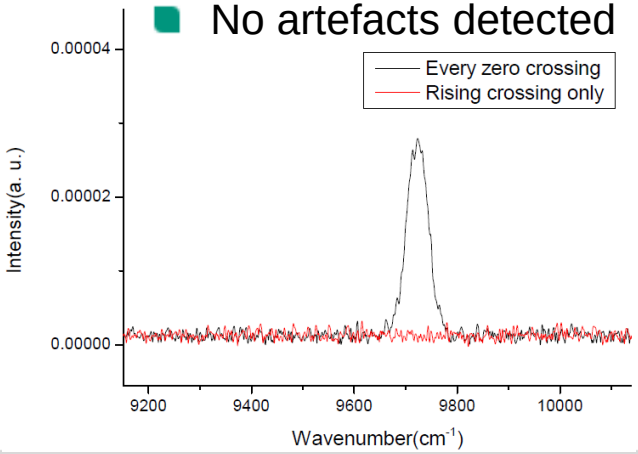


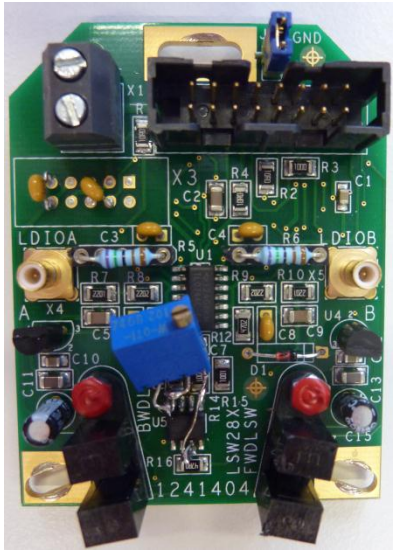


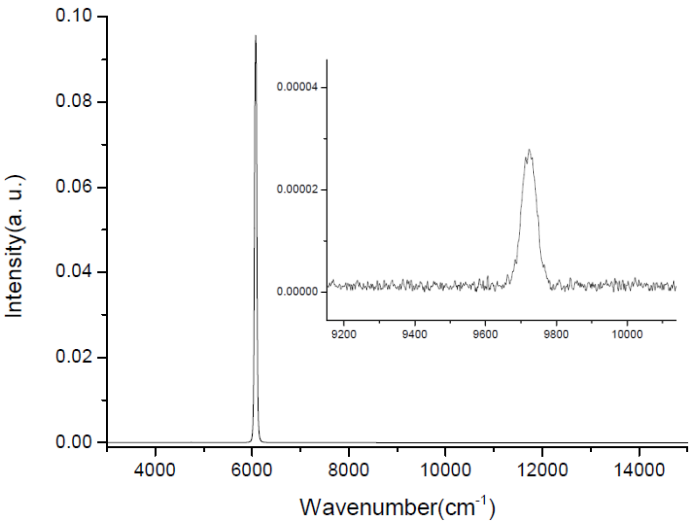
Instrument characterisation

- Sampling errors („Ghosts“)
- GPR (Ghost to parent ratio)
  - ~3 x 10^{-4}
- Correction:
  - Laser board update by J. Gross
    - Temperature dependency
  - Temporal linear interpolation
    - Released by Bruker
    - Ghosts vanish
    - No artefacts detected









Instrumental line shape (ILS) characterisation

- Accurate ILS knowledge of utmost Importance
  - 1 % Δ MEA at MPD → 0.15 % Δ XCO_2
- Minimalistic approach: Use shape of lab air water vapor lines
  - No gas cell
  - Only external source needed
    - 50 W light bulb
    - Aspherical collimation lens
  - Water column inside spectrometer is not negligible

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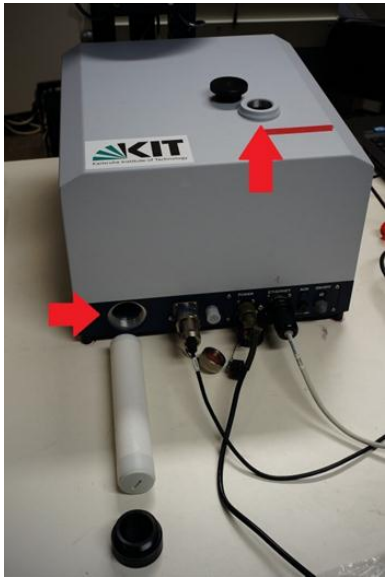
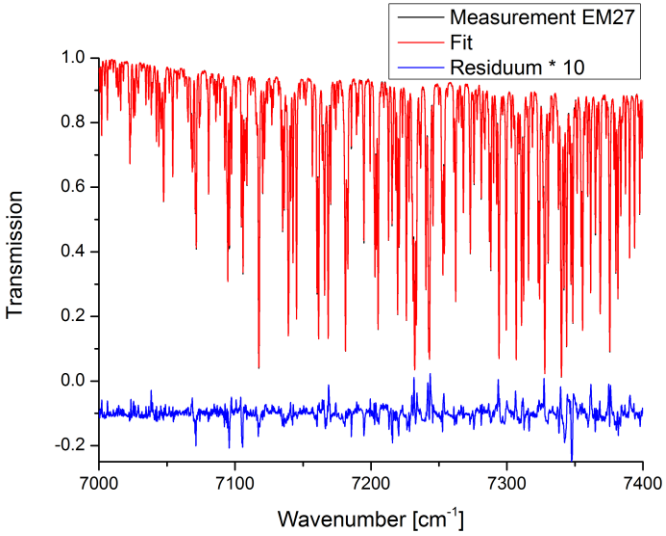
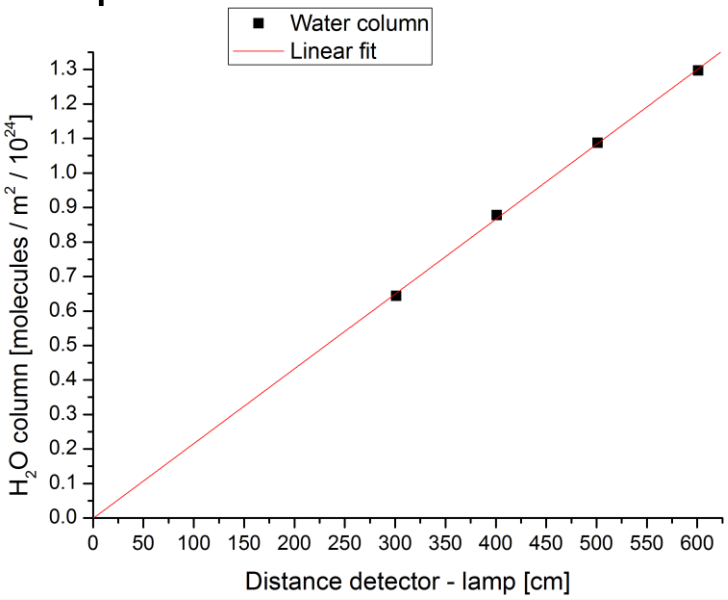
Vent instrument for uniform water vapor mixing ratio

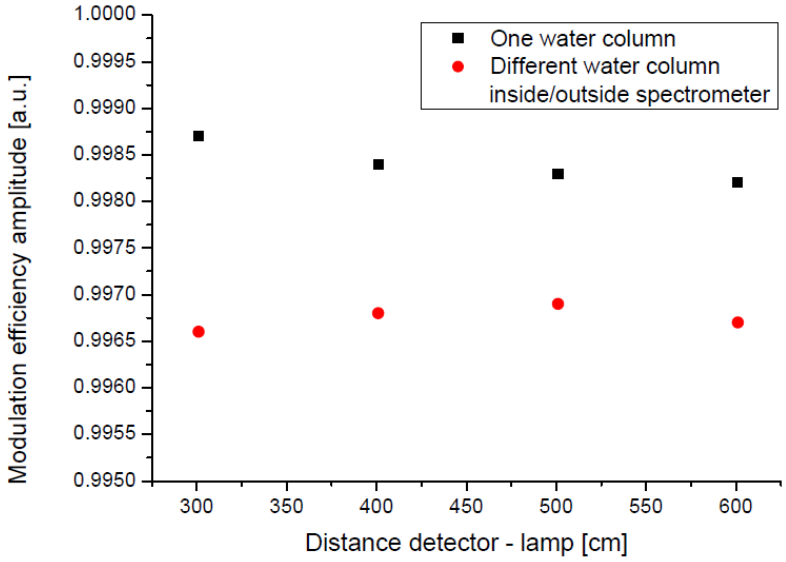


Instrumental line shape (ILS) characterisation

- Retrieval with LINEFIT ver. 14
- H_2O linelist: HIT09mod (minor adjustments introduced by TCCON + ad hoc)
- Strong H_2O lines in 7000 – 7400 cm^{-1} region
- Input parameters: Temperature, pressure, distance lamp – detector, partial water vapor pressure







ILS parameter

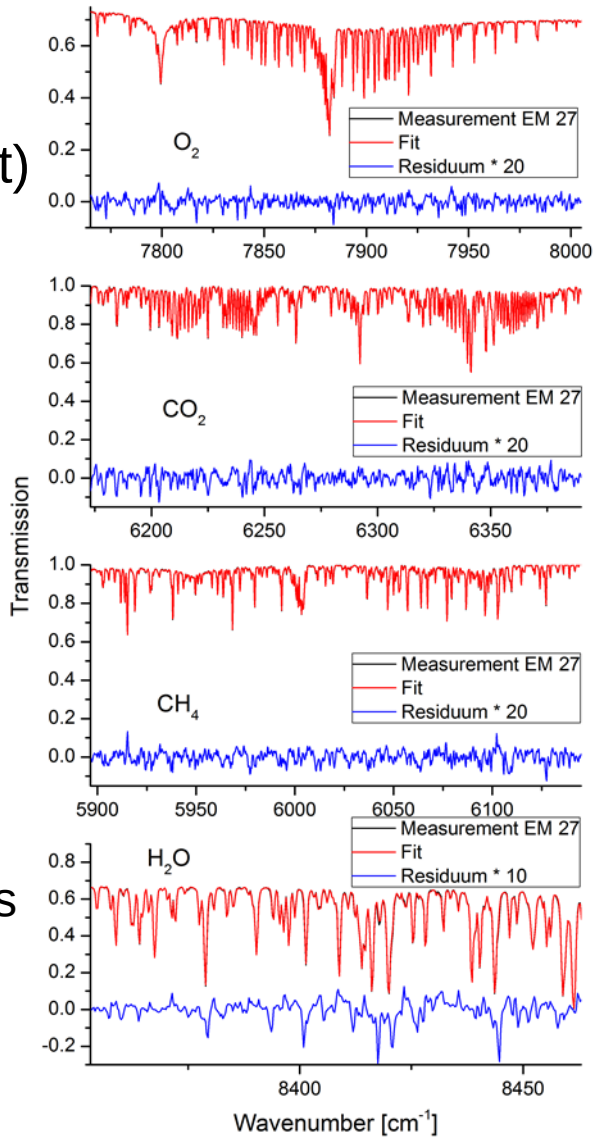
Instrument	03.06.	15.07.
1	0.9979	0.9996
2	0.9914	0.9938
3	0.9971	0.9997
4	1.0010	1.0020
5	0.9959	0.9963

Setup EM27 measurements

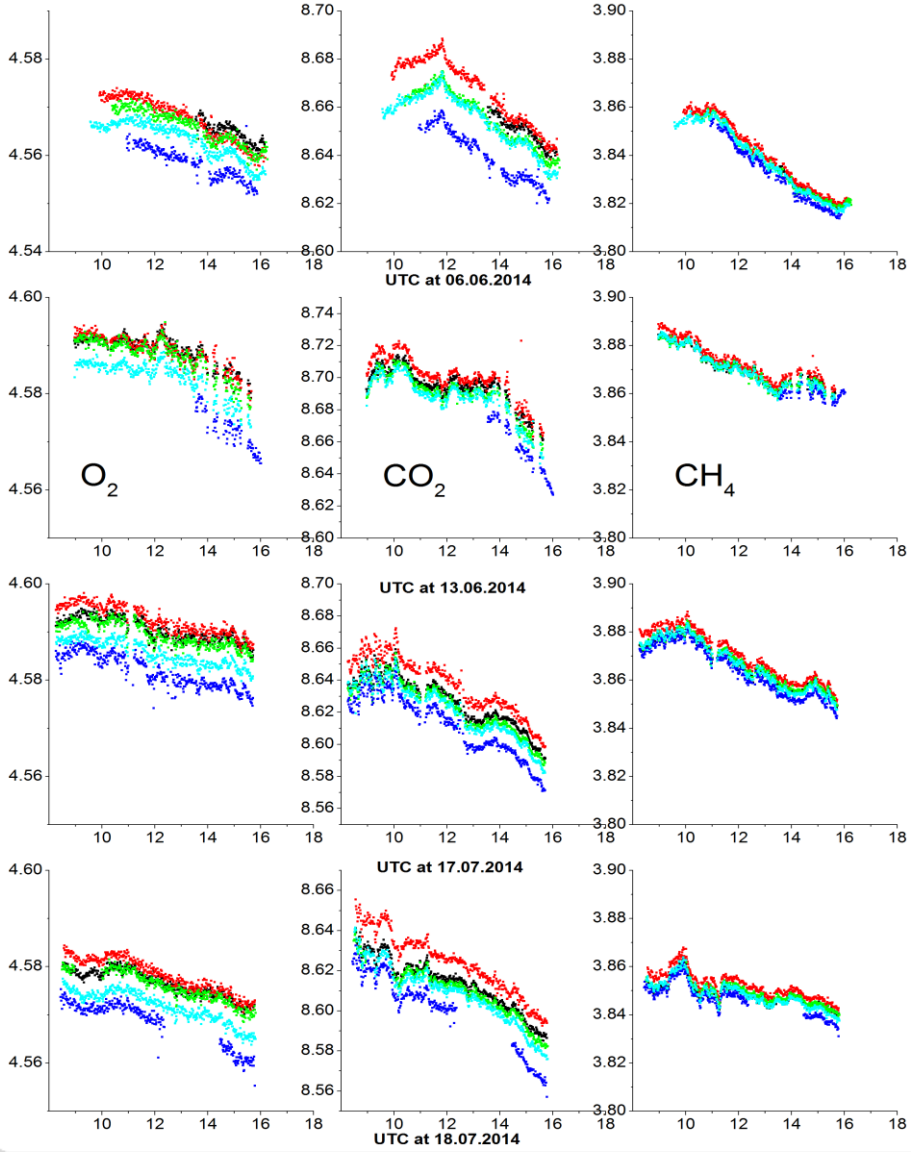
- Aim: Measure differences in campaigns for lee and luv instruments
- Requirement: Calibration of instruments to common scale
- Calibration measurements performed before and after campaign at IMK-ASF office building
  - 0.5 cm^{-1} resolution
  - 10 scans
  - 10 khz scanner velocity
  - ~ 1 min
- GPS receiver for precise time recording
- Additional pressure and temperature on site from tall tower measurements

Retrieval of EM27/SUN solar spectra

- Preprocessing: Python tool (DC-correction, quality filter, generate PROFFIT spectrum format) maintained by M. Kiel
- PT profiles including intraday variability
  - Karlsruhe:
    - Tall tower data
    - MERRA model
  - Berlin:
    - NCEP model
    - Sonde data
    - On site PT logger data
- Linelists
  - HITRAN 2008 O_2, CO_2, CH_4 linelist + adjustments
  - HIT09mod H_2O linelist
- WACCM ver. 6 climatology as apriori
- Scaling retrieval



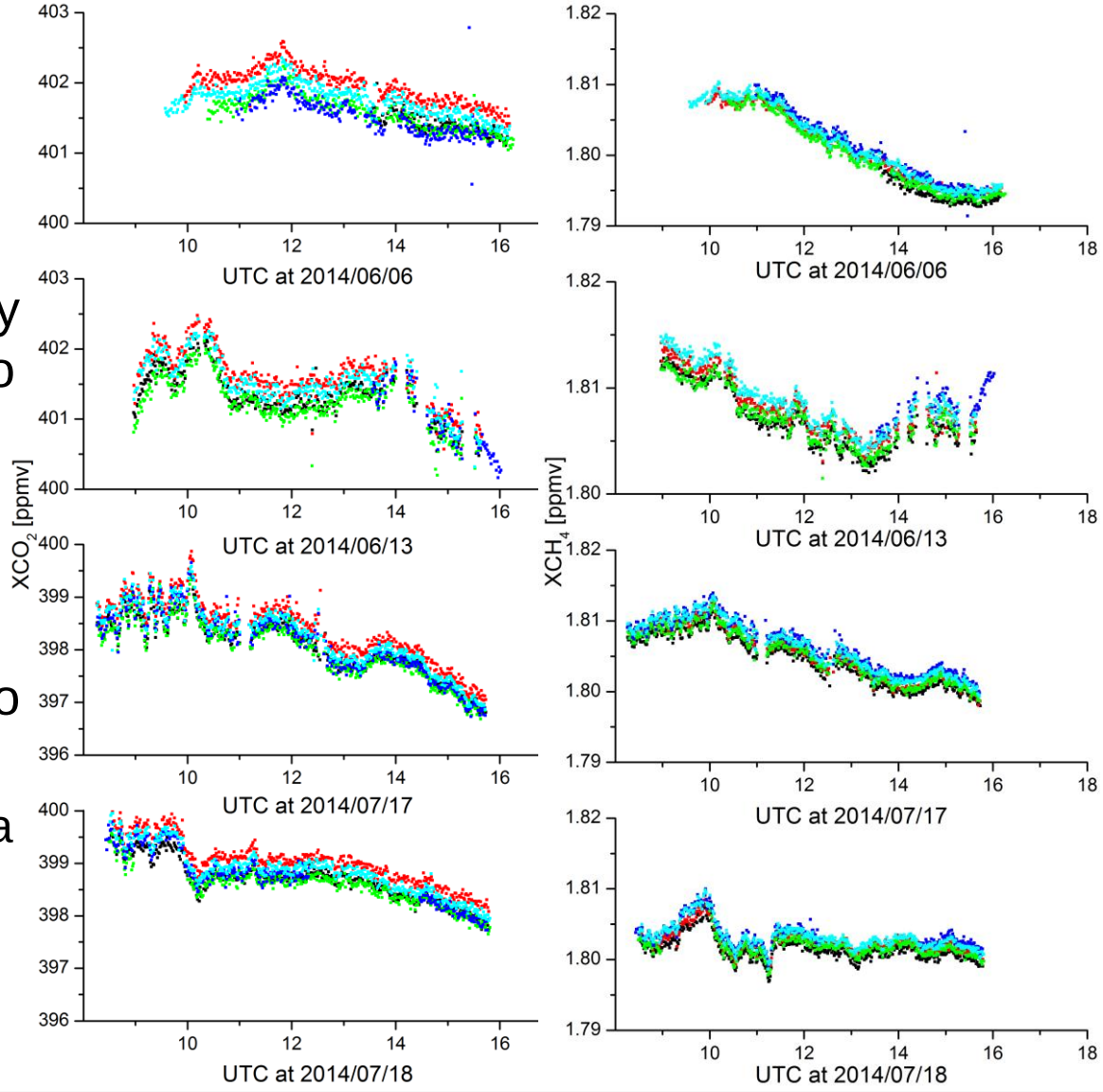
Total columns calibration measurements



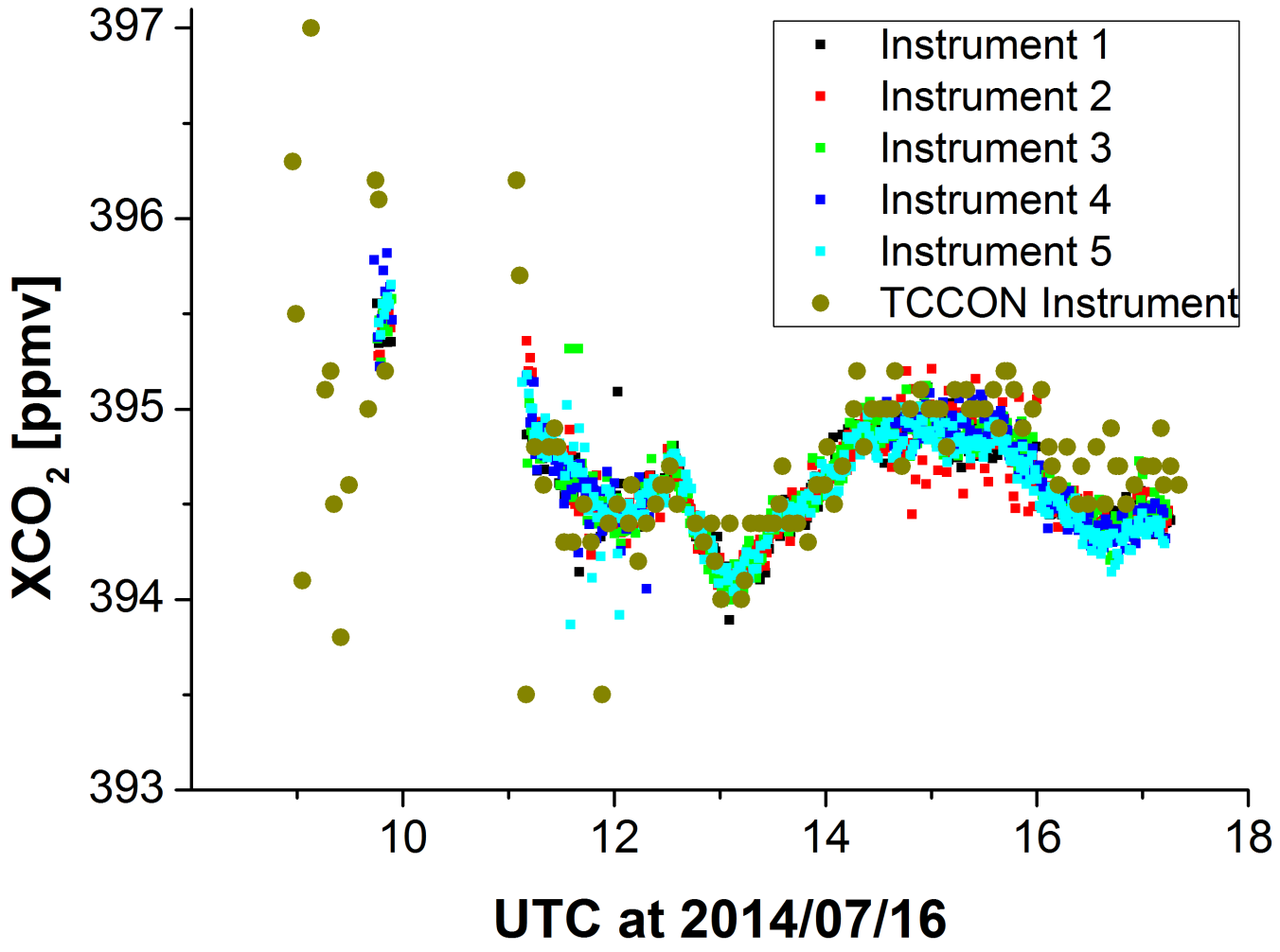
Instrument number	O_2 column sc. factor before campaign	O_2 column sc. factor after campaign
1	1.0000	1.0000
2	1.0001	0.9997
3	1.0004	1.0002
4	1.0024	1.0020
5	1.0012	1.0011

XCO2 and XCH4 calibration

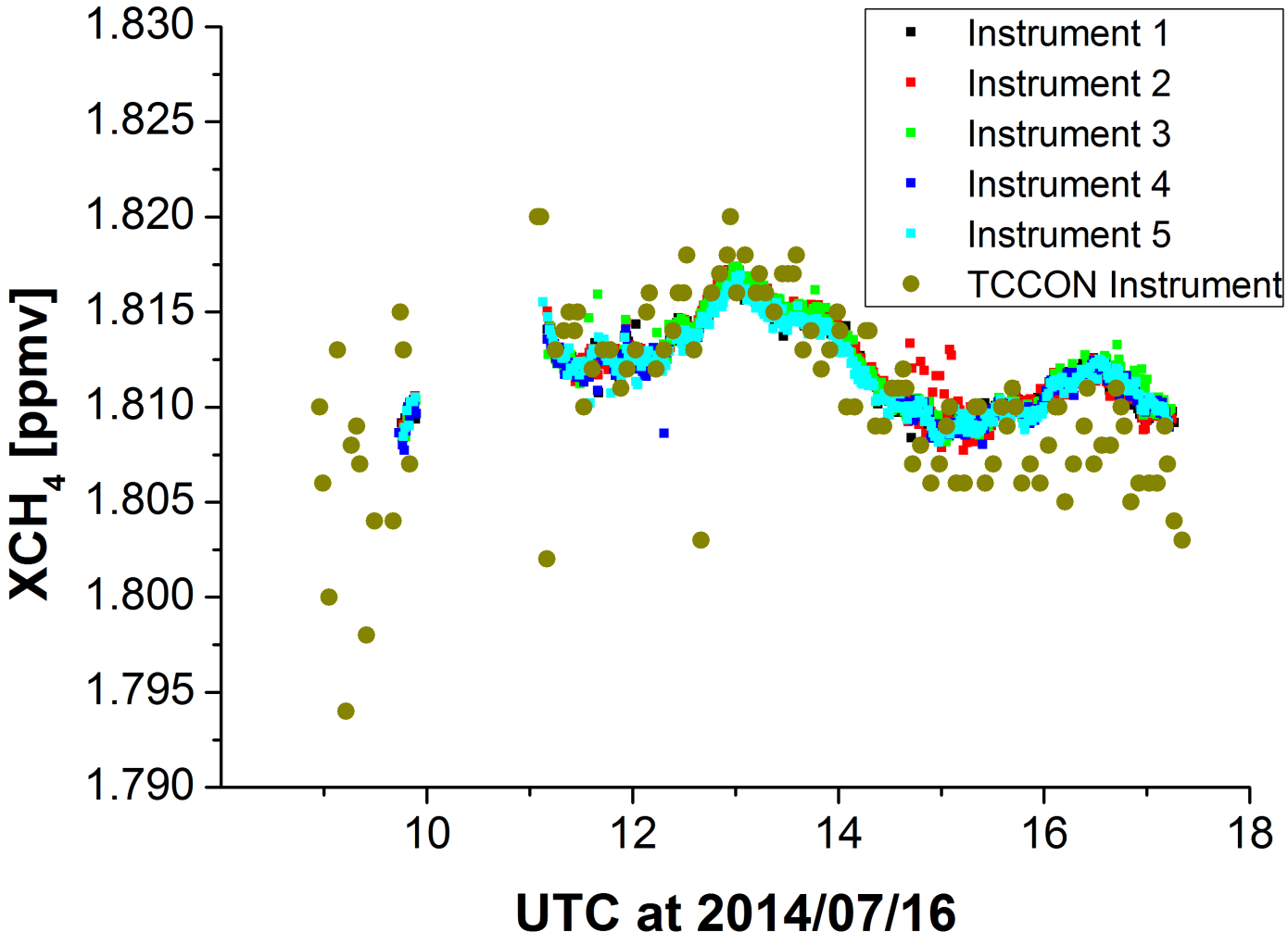
- Systematic errors tend to cancel out
- Very good agreement
- No post calibration, only individual ILS taken into account
- In principle ready for campaign
- For external comparison, SZA has to be dealt with
  - Research vessel data
    - No temporal variability of target gases



Intercalibrated and TCCON scaled XCO_2



Intercalibrated and TCCON scaled XCH_4



XCO_2 Calibration factors

Instrument number	Intercalibration factor before campaign	Intercalibration factor after campaign
1	1.00000	1.00000
2	0.99924	0.99921
3	1.00015	1.00016
4	0.99987	0.99987
5	0.99960	0.99962

- Excellent agreement before and after campaign!
- Drifts below 0.005%(XCH_4 0.035%)
- Calibration factor against WMO scale 0.9951

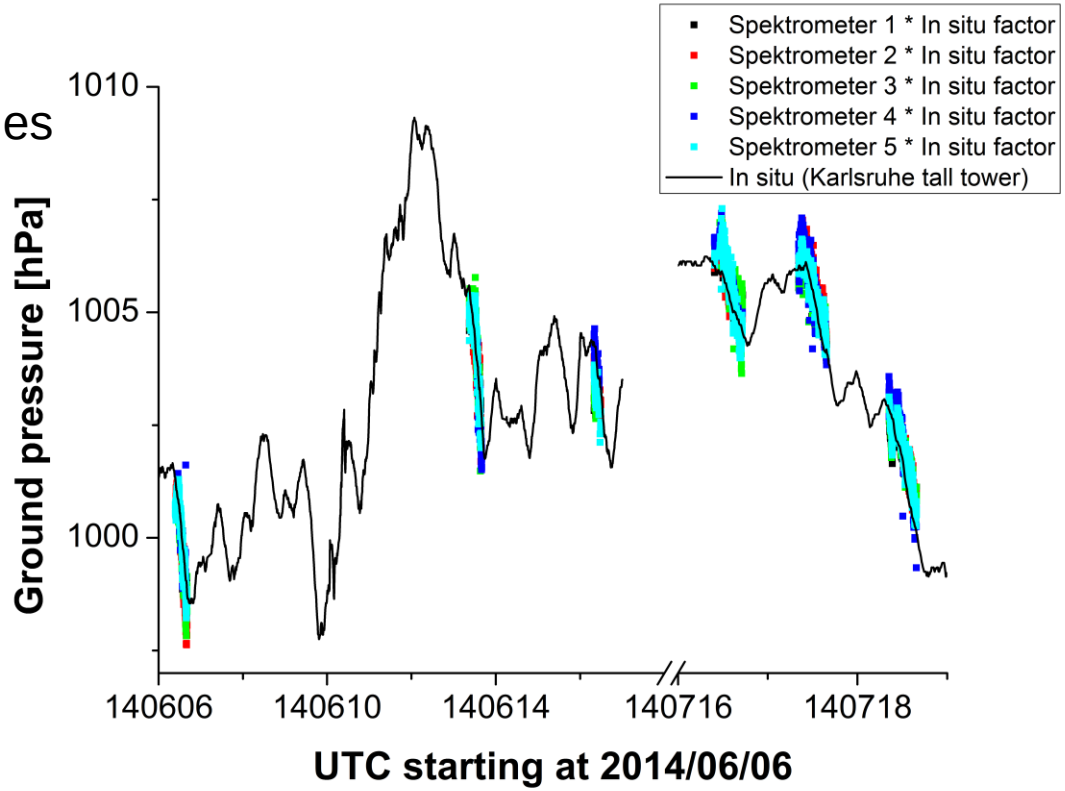
Summary and outlook

- Thorough analysis of the performance of a set of EM27/SUN spectrometers
- Presentation of a method for accurate ILS characterisation from open path measurements
- Only small drifts in the modulation efficiency amplitudes
- Implementation of calibration procedure for multiple EM27/SUN
- High instrumental stability found
  - Drifts within 0.005 % for XCO_2, 0.035 % for XCH_4 (not shown)
- Unambigious detection of XCO_2 in the sub-ppm is possible, prerequisite for possible network applications as well as campaigns
  - ➢ Talk Mahesh Kumar Sha on detection of CO_2 emitted by the megacity Berlin

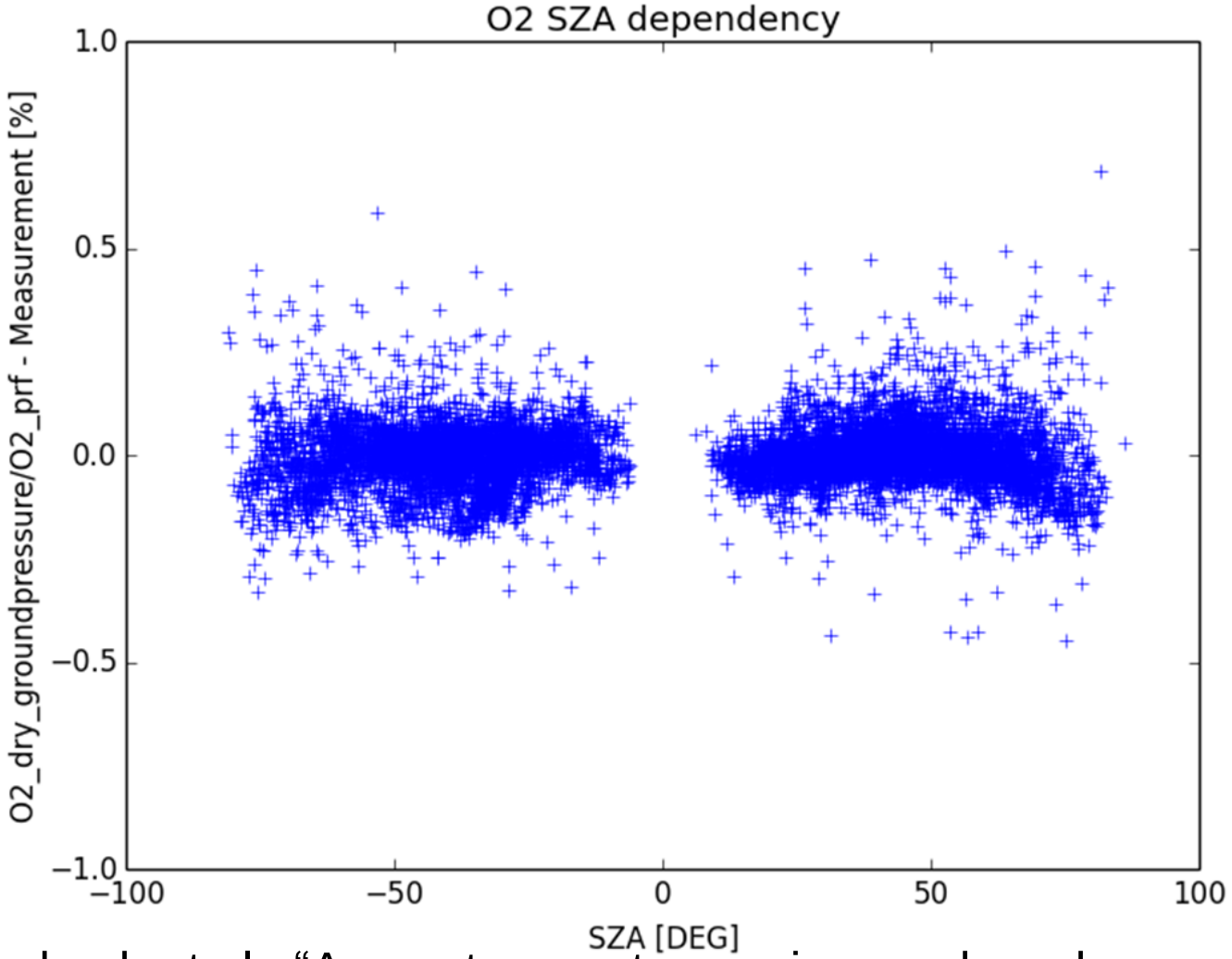
Extra slides

O_2 column as indicator of instrumental stability

- $P_S = \left(H_2O_{Column} \times \mu_{H_2O} \times g + O_{2\,Column} \div 0.2095 \times \bar{\mu} \times g\right) \times \exp\left(\frac{\Delta h}{h_S}\right) \times In\ situ\ factor$
- Data scaled to 133 m a. s. l.
- In situ factor ~ 3 %
  - Spectroscopic uncertainties
  - Commonly observed
- Column data fits barometric records



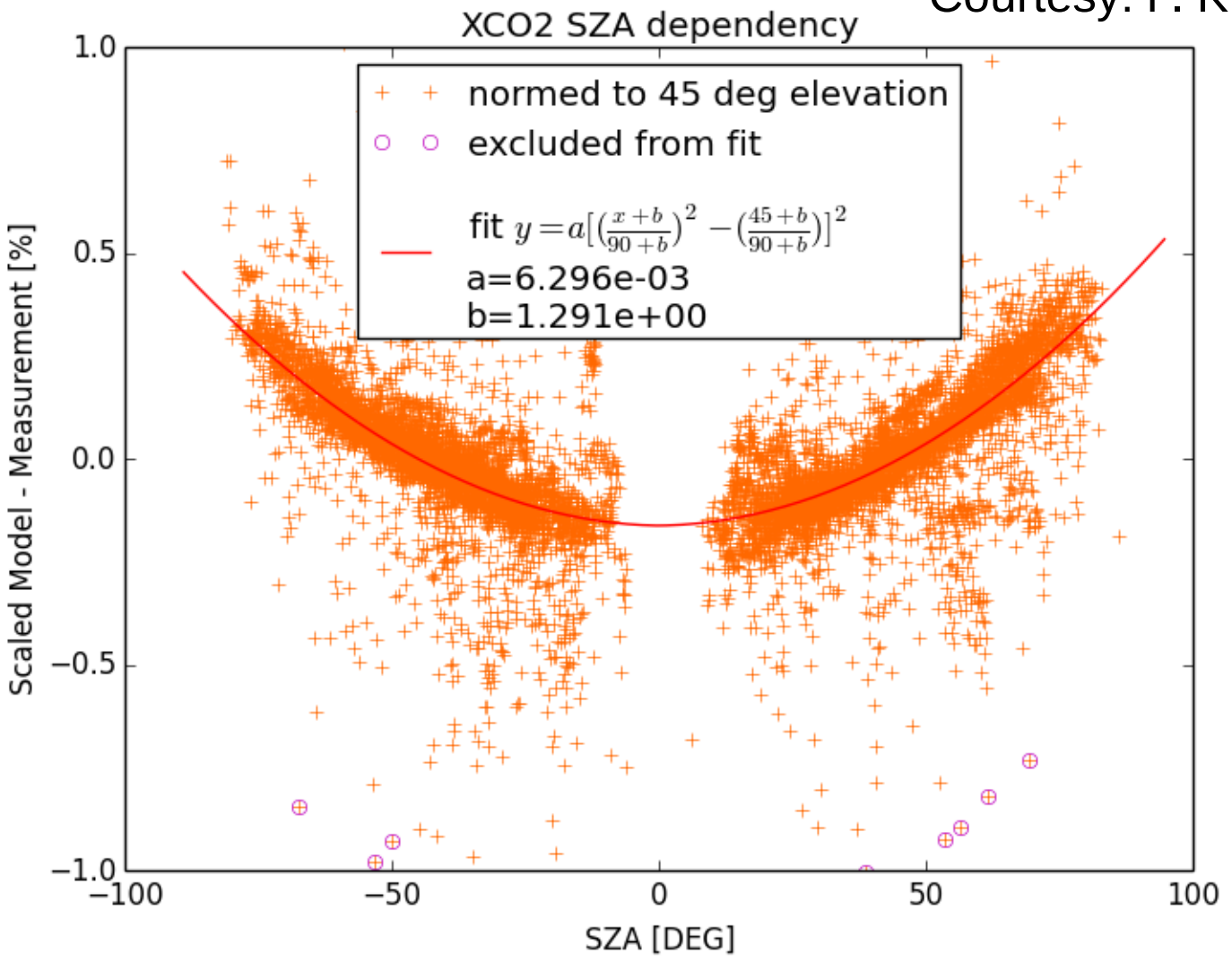
SZA correction research vessel



Klappenbach et al., “Accurate remote sensing … aboard a research vessel“, AMTD, submitted

SZA correction research vessel

Courtesy: F. Klappenbach



SZA correction research vessel

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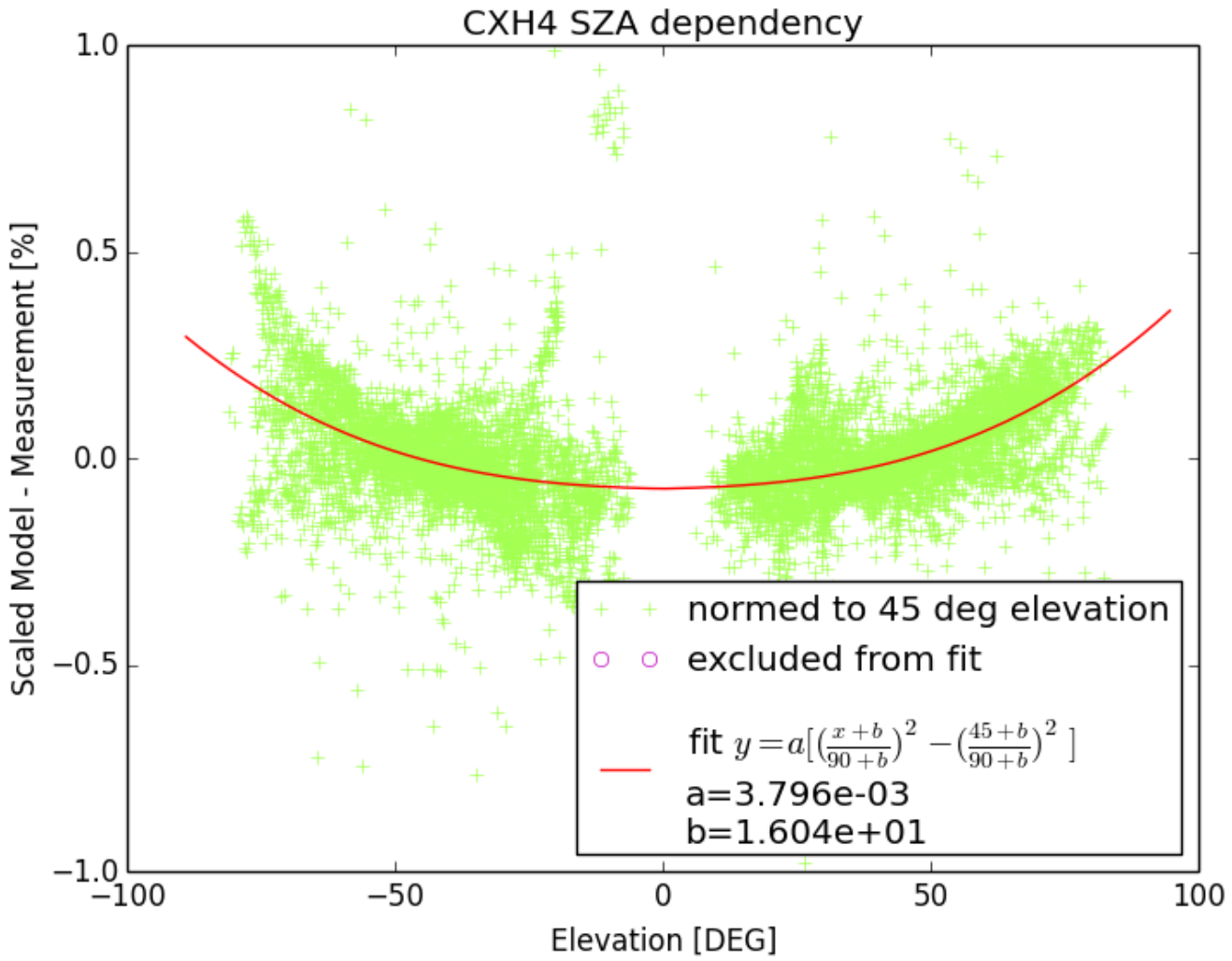
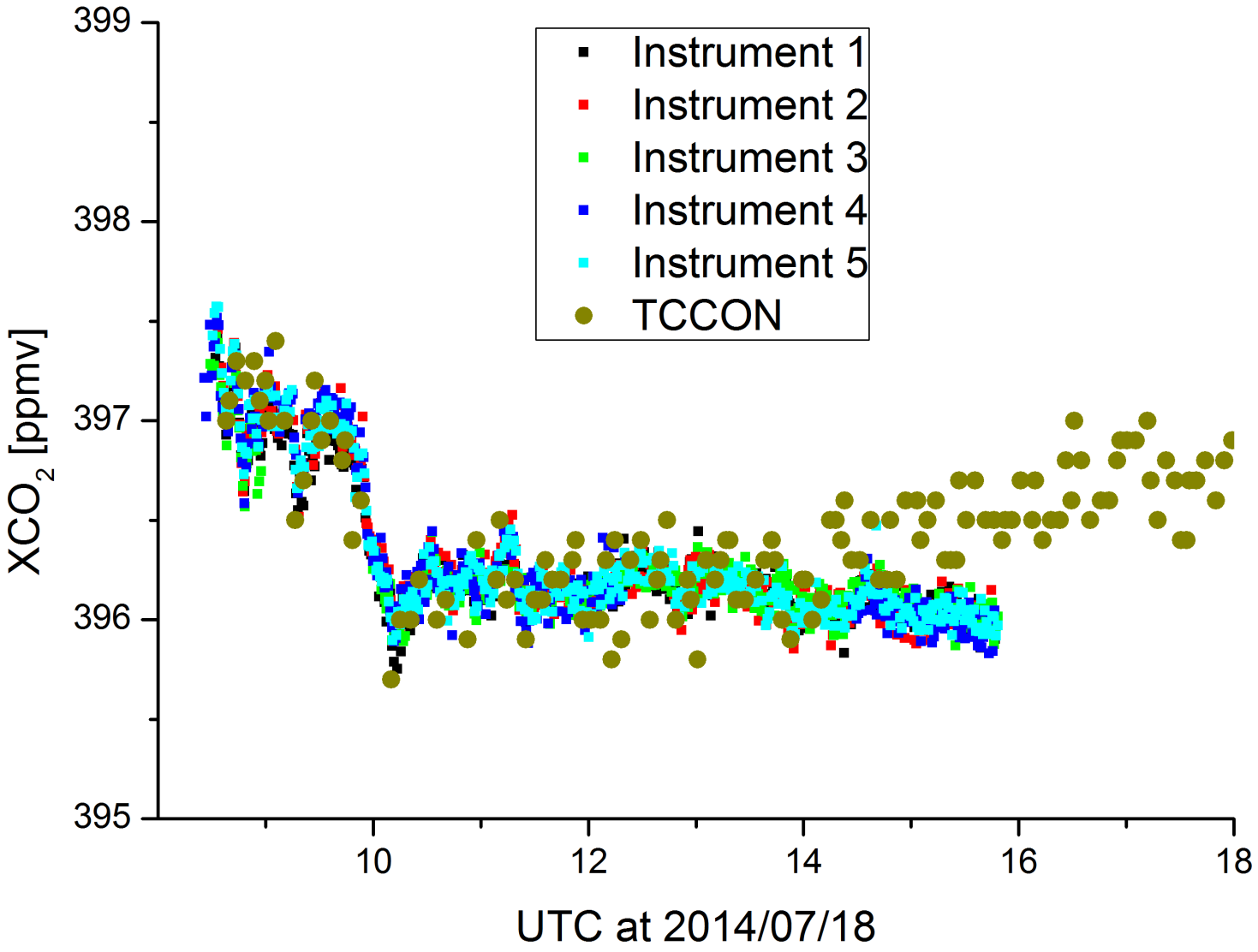
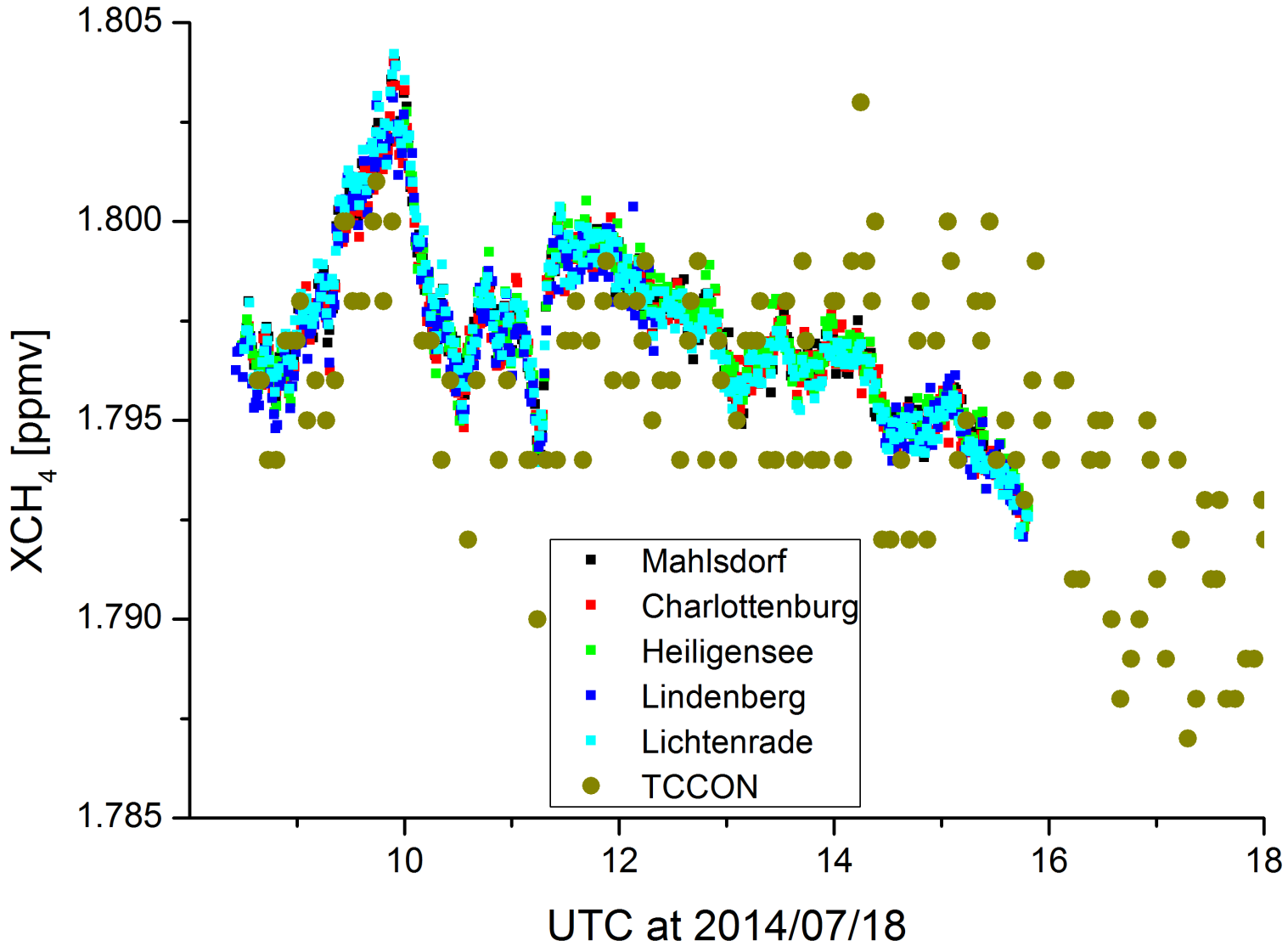


Intercalibrated and in situ scaled XCO_2




1.805
1.800
1.795
1.790
1.785
XCH4 [ppmv]
10
12
14
16
18
UTC at 2014/07/18
Mahlsdorf
Charlottenburg
Heiligensee
Lindenberg
Lichtenrade
TCCON