# *Zugspitze and Garmisch site news*

## NDACC & TCCON - Zugspitze (47.4 °N, 11.0 °E, 2964 m a.s.l.)

## TCCON - Garmisch (47.5 °N, 11.1 °E, 743 m a.s.l.)


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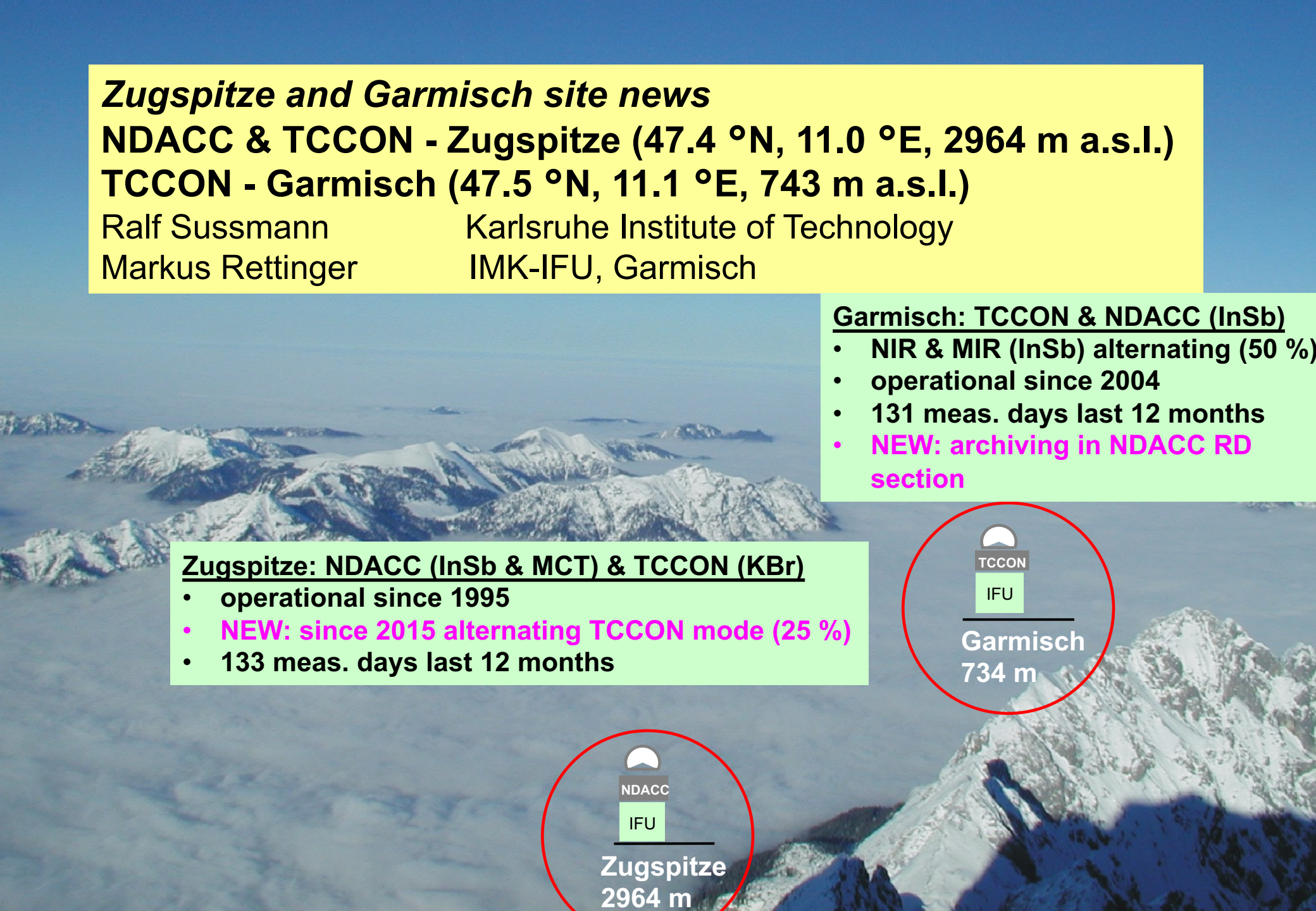
**Garmisch: TCCON & NDACC (InSb)**

- **NIR & MIR (InSb) alternating (50 %)**
- **operational since 2004**
- **131 meas. days last 12 months**
- **NEW: archiving in NDACC RD section**

**Zugspitze: NDACC (InSb & MCT) & TCCON (KBr)**

- **operational since 1995**
- **NEW: since 2015 alternating TCCON mode (25 %)**
- **133 meas. days last 12 months**



NDACC (MCT + InsB)
TCCON (InGAs, KBr)

(120 →) 125 HR,
4.18 m OPD

# Zugspitze Archiving

**Zugspitze NDACC archiving:**

| | |
|---|---|
| HNO3 | 7/1995 – 3/2018 |
| N2O | 8/1995 – 3/2019 |
| HCl | 3/1995 – 3/2018 |
| HF | 3/1995 – 3/2018 |
| HCN | 12/2015 – 3/2019 |
| CO | 7/1995 – 3/2019 |
| CH4 | 8/1995 – 3/2019 |
| C2H6 | 3/1995 – 3/2019 |
| H2CO | 3/1995 – 3/2019 |
| O3 | 3/1995 – 3/2019 |
| ClONO2 | 7/1995 – 3/2019 |
| OCS | 7/1995 – 3/2018 |

Planned next NDACC archiving: CO 3 monthly

**NEW: Zugspitze TCCON archiving:**

4/2015 – 4/2019

Planned next TCCON archiving: 3 monthly

# Garmisch TCCON site: 47.5 °N, 11.1 °E, 743 m a.s.l.

# Garmisch TCCON/NDACC FTIR system / archiving

**Submitted to TCCON Database:**
**GFIT-files 7/2007 – 4/2019**

125 HR, 2.50 m OPD

**NEW: Garmisch is no official NDACC instrument, BUT archiving now on RD section:**

| | |
|---|---|
| CO: | 06/2017 – 08/2018 |
| N2O: | 02/2004 – 09/2018 |
| CH4: | 02/2004 – 09/2018 |
| H2CO: | 02/2004 – 09/2018 |

# Papers 2018/19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Wunch, D., Jones, D. B. A., Toon, G. C., Deutscher, N. M., Hase, F., Notholt, J., Sussmann, R., Warneke, T., Kuenen, J., Denier van der Gon, H., Fisher, J. A., and Maasakkers, J. D.: Emissions of methane in Europe inferred by total column measurements, Atmos. Chem. Phys., 19, 3963-3980, doi:10.5194/acp-19-3963-2019, 2019.

Trieu, T. T. N., Morino, I., Ohyama, H., Uchino, O., Sussmann, R., Warneke, T., Petri, C., Kivi, R., Hase, F., Pollard, D. F., Deutscher, N. M., Velazco, V. A., Iraci, L. T., Podolske, J. R., Dubey, M. K.: Evaluation of Bias Correction Methods for GOSAT SWIR XH2O Using TCCON data, Remote Sens. 11, 290, doi:10.3390/rs11030290, 2019.

O'Dell, C. W., Eldering, A., Wennberg, P. O., Crisp, D., Gunson, M. R., Fisher, B., Frankenberg, C., Kiel, M., Lindqvist, H., Mandrake, L., Merrelli, A., Natraj, V., Nelson, R. R., Osterman, G. B., Payne, V. H., Taylor, T. E., Wunch, D., Drouin, B. J., Oyafuso, F., Chang, A., McDuffie, J., Smyth, M., Baker, D. F., Basu, S., Chevallier, F., Crowell, S. M. R., Feng, L., Palmer, P. I., Dubey, M., García, O. E., Griffith, D. W. T., Hase, F., Iraci, L. T., Kivi, R., Morino, I., Notholt, J., Ohyama, H., Petri, C., Roehl, C. M., Sha, M. K., Strong, K., Sussmann, R., Te, Y., Uchino, O., and Velazco, V. A.: Improved retrievals of carbon dioxide from Orbiting Carbon Observatory-2 with the version 8 ACOS algorithm, Atmos. Meas. Tech., 11, 6539-6576, doi:10.5194/amt-11-6539-2018, 2018.

# Papers 2018/19, contd.


Borsdorff, T., aan de Brugh, J., Hu, H., Hasekamp, O., Sussmann, R., Rettinger, M., Hase, F., Gross, J., Schneider, M., Garcia, O., Stremme, W., Grutter, M., Feist, D. G., Arnold, S. G., De Mazière, M., Kumar Sha, M., Pollard, D. F., Kiel, M., Roehl, C., Wennberg, P. O., Toon, G. C., and Landgraf, J.: Mapping carbon monoxide pollution from space down to city scales with daily global coverage, Atmos. Meas. Tech., 11, 5507-5518, doi:10.5194/amt-11-5507-2018, 2018.

Boynard, A., Hurtmans, D., Garane, K., Goutail, F., Hadji-Lazaro, J., Koukouli, M. E., Wespes, C., Vigouroux, C., Keppens, A., Pommereau, J.-P., Pazmino, A., Balis, D., Loyola, D., Valks, P., Sussmann, R., Smale, D., Coheur, P.-F., and Clerbaux, C.: Validation of the IASI FORLI/EUMETSAT ozone products using satellite (GOME-2), ground-based (Brewer–Dobson, SAOZ, FTIR) and ozonesonde measurements, Atmos. Meas. Tech., 11, 5125-5152, doi:10.5194/amt-11-5125-2018, 2018.

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Wu, L., Hasekamp, O., Hu, H., Landgraf, J., Butz, A., aan de Brugh, J., Aben, I., Pollard, D. F., Griffith, D. W. T., Feist, D. G., Koshelev, D., Hase, F., Toon, G. C., Ohyama, H., Morino, I., Notholt, J., Shiomi, K., Iraci, L., Schneider, M., de Mazière, M., Sussmann, R., Kivi, R., Warneke, T., Goo, T.-Y., and Té, Y.: Carbon dioxide retrieval from OCO-2 satellite observations using the RemoTeC algorithm and validation with TCCON measurements, Atmos. Meas. Tech., 11, 3111-3130, doi:10.5194/amt-11-3111-2018, 2018.

# Funding: Zugspitze & Garmisch

**Funding status (instrument and facility):**

- 80 % basic funding by Helmholtz Society of German Research Centers
- funded projects:

- DLR-project „S5P-Validation by NDACC and TCCON measurements“ (Partners: Bremen, Karlsruhe, Jena)
- ESA-project „Zugspitze FIRMOS validation campaign“ (Partners: CNR-INO Firenze, Jülich)

Karlsruhe Institute of Technology

KIT-Campus Alpin
IMK-IFU: Atmospheric Environmental Research

Universität Augsburg University

# Validation of TROPOMI CH4 and CO with TCCON: Reduction of intercomparison error via independent profile information

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## 1. Summary

Motivation: Find common a priori profiles, to reduce intercomparison errors, for validation of Sentinel-5P/TROPOMI $XCH_4$ with TCCON FTIR measurements

Current Status:

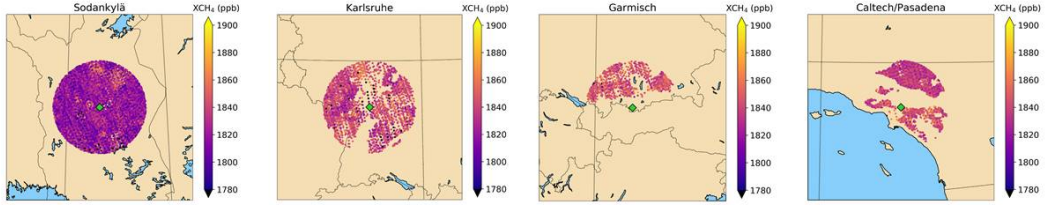
- Simple regression-based correction for ground altitude difference
- Sentinel-5P/TM5 $CH_4$ a priori profiles more in line with available in-situ measurements than TCCON a priori profiles.
- Correction of TCCON measurements to daily mean prior profile of coincident Sentinel-5P pixels
- Reduces Sentinel-5P vs. TCCON biases with altitude correction.
- Reduced biases with common prior correction only at some TCCON sites.

Outlook:

- Further investigate possible common priors
- Extend research to CO

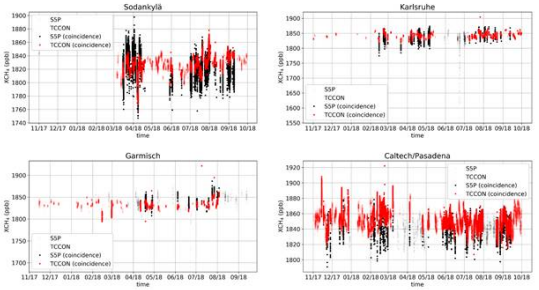
## 2. TCCON Sites and Coincidence Criteria

Sentinel-5P $XCH_4$ (Nov 2017 – Sep 2018) ; Spatial Coincidence : r < 100 km




**Full list of TCCON sites used**

| TCCON Site | Site Latitude (°N) | Site Longitude (°) | Site Altitude (m) |
|---|---|---|---|
| Eureka | 80.05 | -86.42 | 610 |
| Sodankylä | 67.37 | 26.63 | 188 |
| Bremen | 53.10 | 8.85 | 27 |
| Karlsruhe | 49.10 | 8.44 | 116 |
| Garmisch | 47.48 | 11.06 | 743 |
| Zugspitze | 47.42 | 10.98 | 2960 |
| Lamont | 36.60 | -97.49 | 320 |
| Caltech | 34.14 | 34.14 | 230 |




Temporal Coincidence: Same local day

# Project 1 (DLR/S5P): ESA-Living Planet Symposium Poster

Karlsruhe Institute of Technology

## *Correction S5P/TCCON for differing ground-pixel altitude and realistic common prior (model profiles):*

### 3. Regression-Based Altitude Correction

Correction of Sentinel 5P $XCH_4$ values for TCCON sites with heterogeneous surrounding orography ($\Delta z_{max}$ > 500 m):

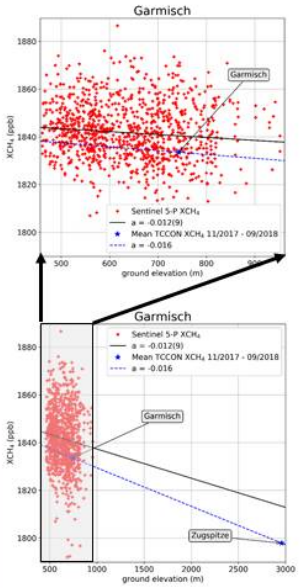
$$XCH_{4,corr} = XCH_4 + a \cdot (z_{TCCON} - z)$$

**Validation with Garmisch-Zugspitze TCCON $\Delta XCH_4$ (Nov 2017 – Sep 2018):**

| $\Delta XCH_4$ TCCON | $\Delta XCH_4$ Regression |
|---|---|
| 35.7 ppb | 31.5 ± 21.8 ppb |

**Regression slopes for selected sites**

| TCCON Site | Site Altitude (m) | Site Latitude (°N) | Regression Slope (ppb/m) |
|---|---|---|---|
| Eureka | 610 | 80.05 | -0.023(1) |
| Karlsruhe | 116 | 49.10 | -0.018(6) |
| Garmisch | 743 | 47.48 | -0.012(9) |
| Zugspitze | 2960 | 47.42 | -0.014(10 |
| Caltech | 230 | 34.14 | -0.012(1) |



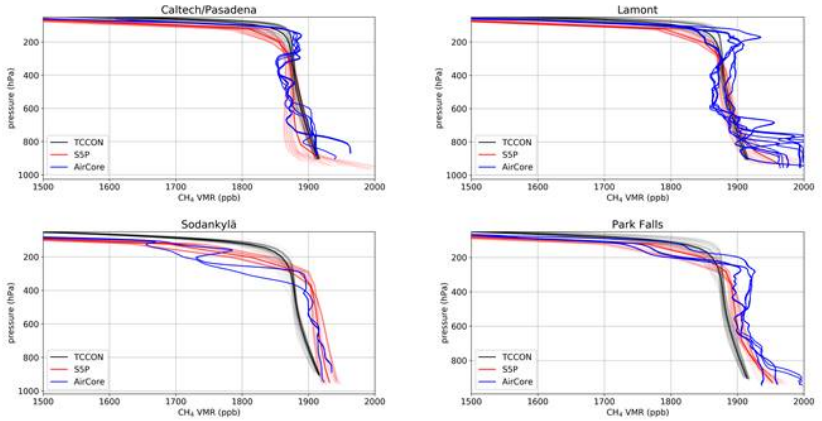

### 4. Correction to Common Prior

Correction of TCCON $XCH_4$ to daily-mean Sentinel-5P/TM5 prior:

$$XCH_{4,corrected} = XCH_4 + \frac{1}{p_0}\sum_l (1 - a^l)\left(x^l_{common} - x^l_{TCCON}\right)\Delta p^l$$

**Sentinel-5P/TM5 a-priori profile as common priors**

Sentinel-5P/TM5 a-priori profiles are more in line with AirCore in-situ measurements than TCCON priors. In particular, boundary layer, tropopause and stratosphere are better represented.



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## 5. Effect of Corrections to Sentinel-5P-TCCON $XCH_4$ Bias

**Monthly Bias:**
Differences of monthly means of co-inciding $XCH_4$ values from Sentinel-5P and TCCON with and without correction to common TM5 prior

**Mean monthly $XCH_4$ bias (ppb) Sentinel-5P-TCCON**

| TCCON Site | Original prior | Original prior Alt. correction | S5P/TM5 prior | S5P/TM5 prior Alt. correction |
|---|---|---|---|---|
| Eureka | 15.1 | 7.9 | 15.8 | 8.7 |
| Sodankylä | -13.5 | | -12.6 | |
| Bremen | 0.6 | | -4.9 | |
| Karlsruhe | -6.2 | -2.7 | -12.4 | -9.0 |
| Garmisch | 6.7 | 5.7 | 0.8 | -0.3 |
| Zugspitze | 43.9 | 11.3 | 39.5 | 6.9 |
| Lamont | -7.2 | | -11.5 | |
| Caltech | -14.1 | -8.0 | -16.7 | -10.6 |

- much smaller biases with altitude correction
- reduced biases with comon model prior für Sodankylä, Garmisch, Zugspitze
- larger biases with common model prior for all other sites: hidden by differing priors before

# Campaign at Zugspitze Summit

**Ancillary Intrumentation provided for the 2nd campaign**

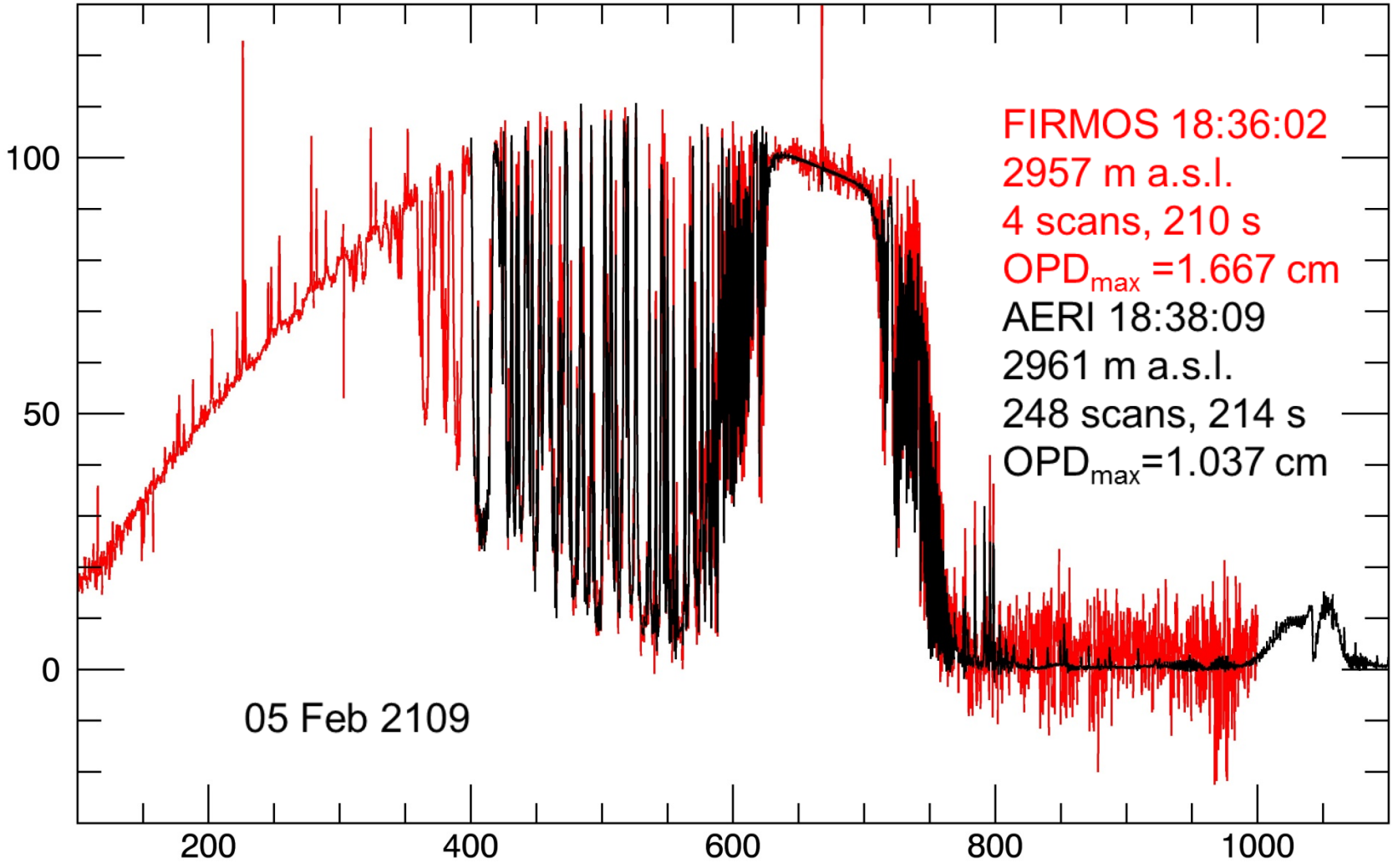
- ✔ AERI (3.3 - 25 micron) → Ralf Sussmann, KIT
- ✔ Backscatter & Water vapor lidars → Hannes Vogelmann, KIT
- ✔ Balloon launches → Christian Rolf, Forschungszentrum Jülich

FIRMOS

AERI

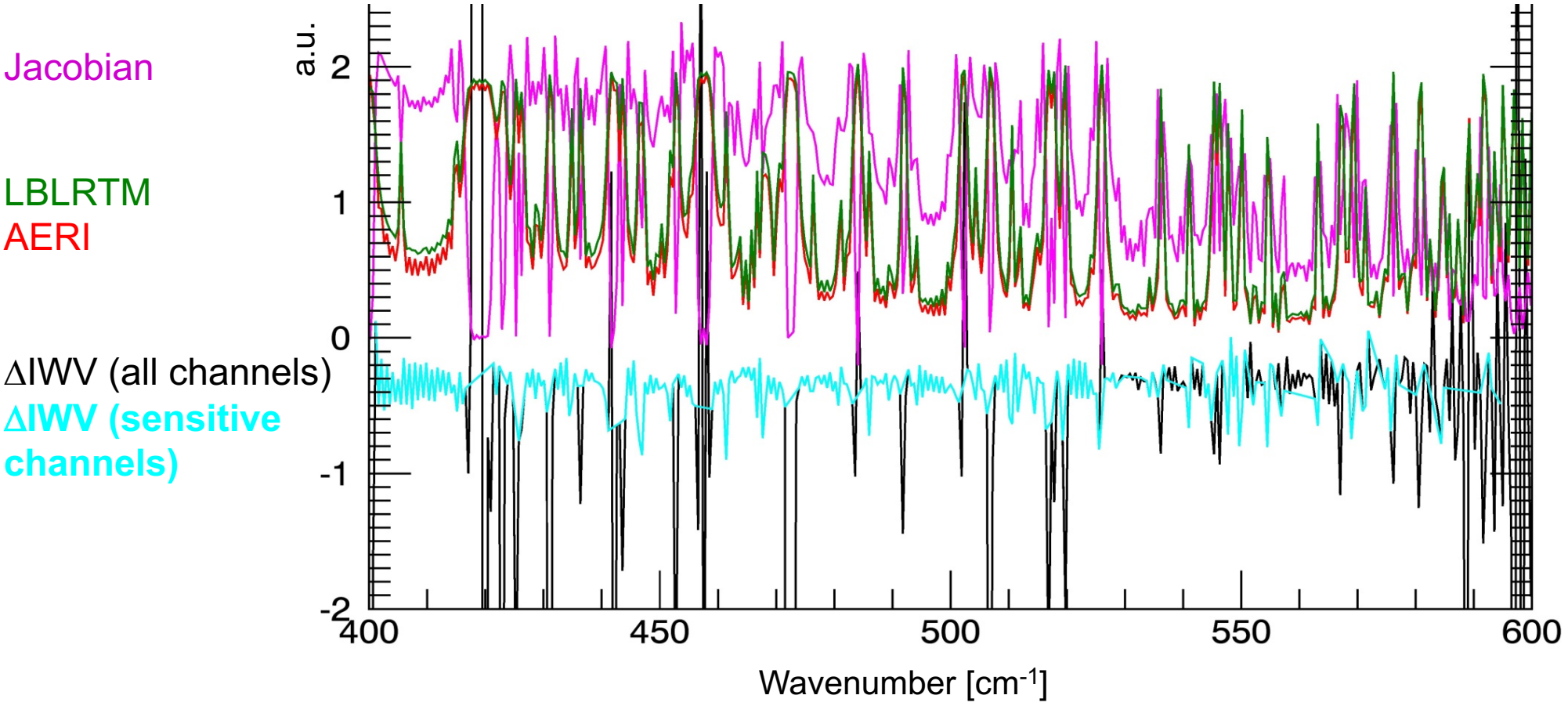
Earth & Atmospheric Spectroscopy Group

# Project 2 (Zugspitze ESA-FIRMOS Campaign): Far-IR Earth Explorer Prototype validated vs AERI



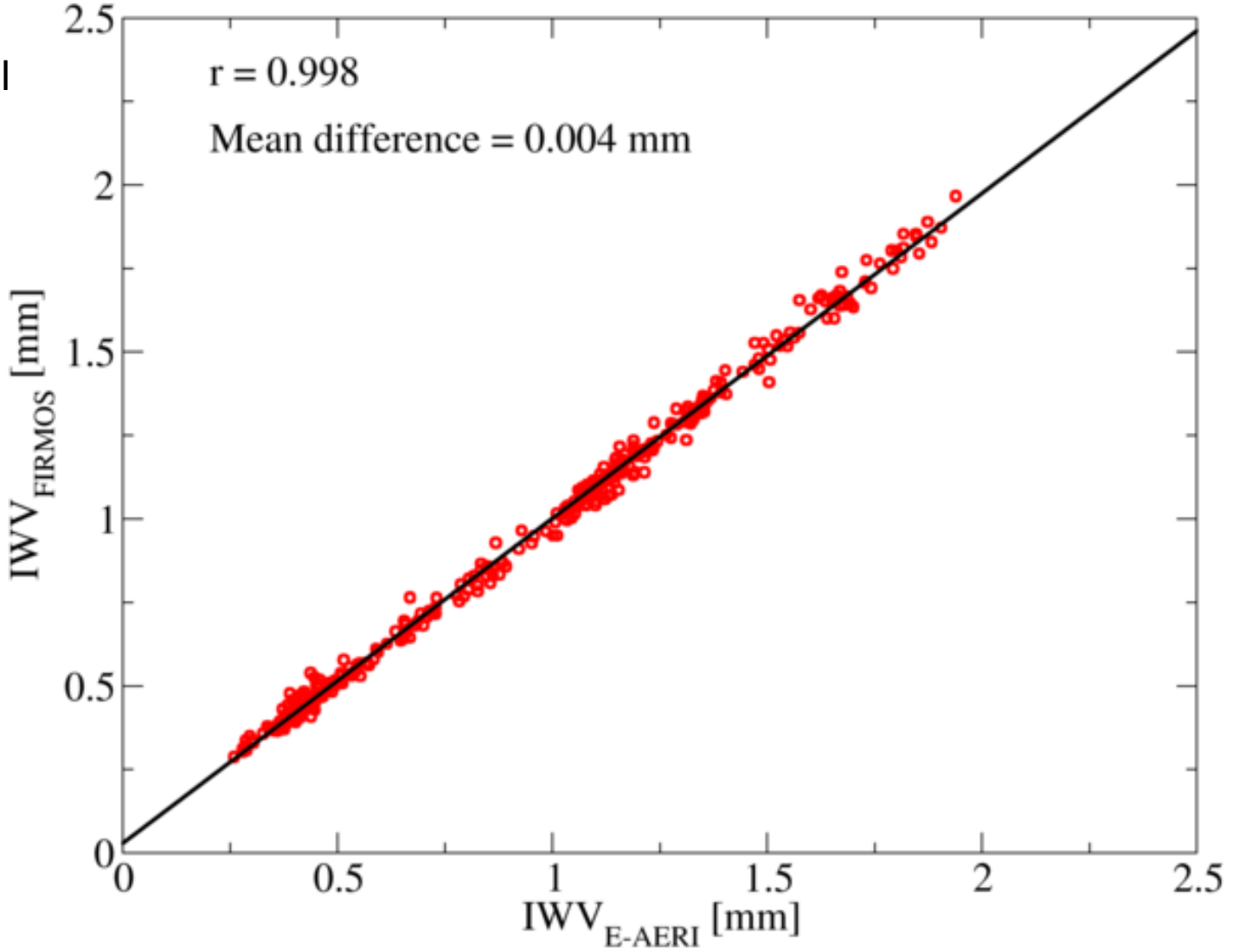
# Project 2 (Zugspitze ESA-FIRMOS Campaign): Set up IWV retrieval from far-IR downwelling emission spectra ….

- IWV retrieved by minimizing LBLRTM-AERI/FIRMOS spectral residuals
- Selected IWV sensitive windows using threshold for Jacobian



# Project 2 (Zugspitze ESA-FIRMOS Campaign): … to validate FIRMOS vs AERI

- very stable IWV retrieval possible in the far-IR
- perfect agreement AERI vs FIRMOS



Thank you and best regards!

Institute of Meteorology and Climate Research, IMK-IFU

## *IMK-IFU-Group "Atmospheric Variability and Trends"*

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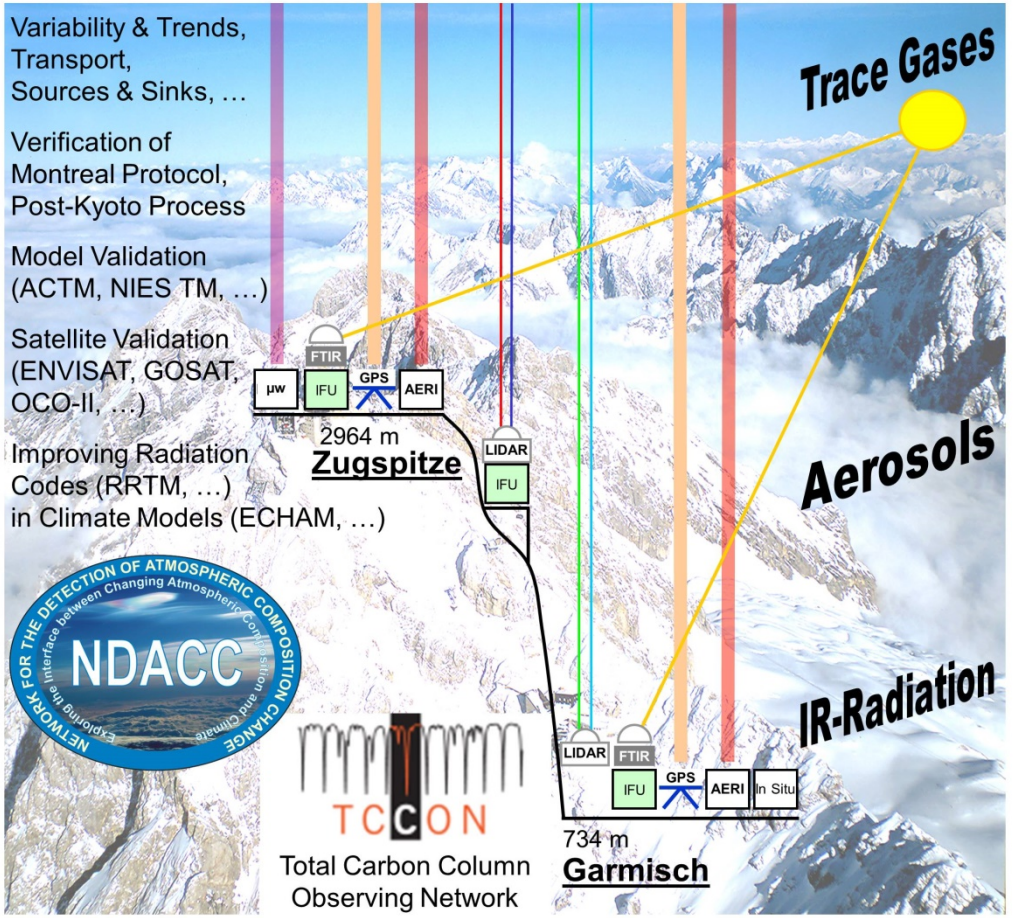


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