

# Zugspitze FTIR Site Report



FTIR

Ralf Sussmann

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47 °N, 11 °E, 2964 m a.s.l.

Research Center Karlsruhe  
IMK-IFU, Garmisch-Partenkirchen, Germany

# The NDACC duty No 1: Increase number of measurement days

**Zugspitze: NDACC**  
operational since 1995  
2008: 130 meas. days  
2009: 43 meas. days

O<sub>3</sub>, ClONO<sub>2</sub>, HCl, HF,  
COF<sub>2</sub>, HNO<sub>3</sub>, NO<sub>2</sub>,  
CO, CH<sub>4</sub>, N<sub>2</sub>O, C<sub>2</sub>H<sub>6</sub>,  
CFC-22, H<sub>2</sub>O

FTIR  
IFU  
**Zugspitze**  
2964 m

**Garmisch: TCCON**

2004: 94 meas. days, MIR  
2005: 147 meas. days, MIR  
2006: 136 meas. days, MIR  
2007: 140 meas. days, 50 % NIR  
2008: 129 meas. days, 50 % NIR  
2009: 49 meas. days, 50 % NIR

CH<sub>4</sub>/O<sub>2</sub>, CO<sub>2</sub>/O<sub>2</sub>

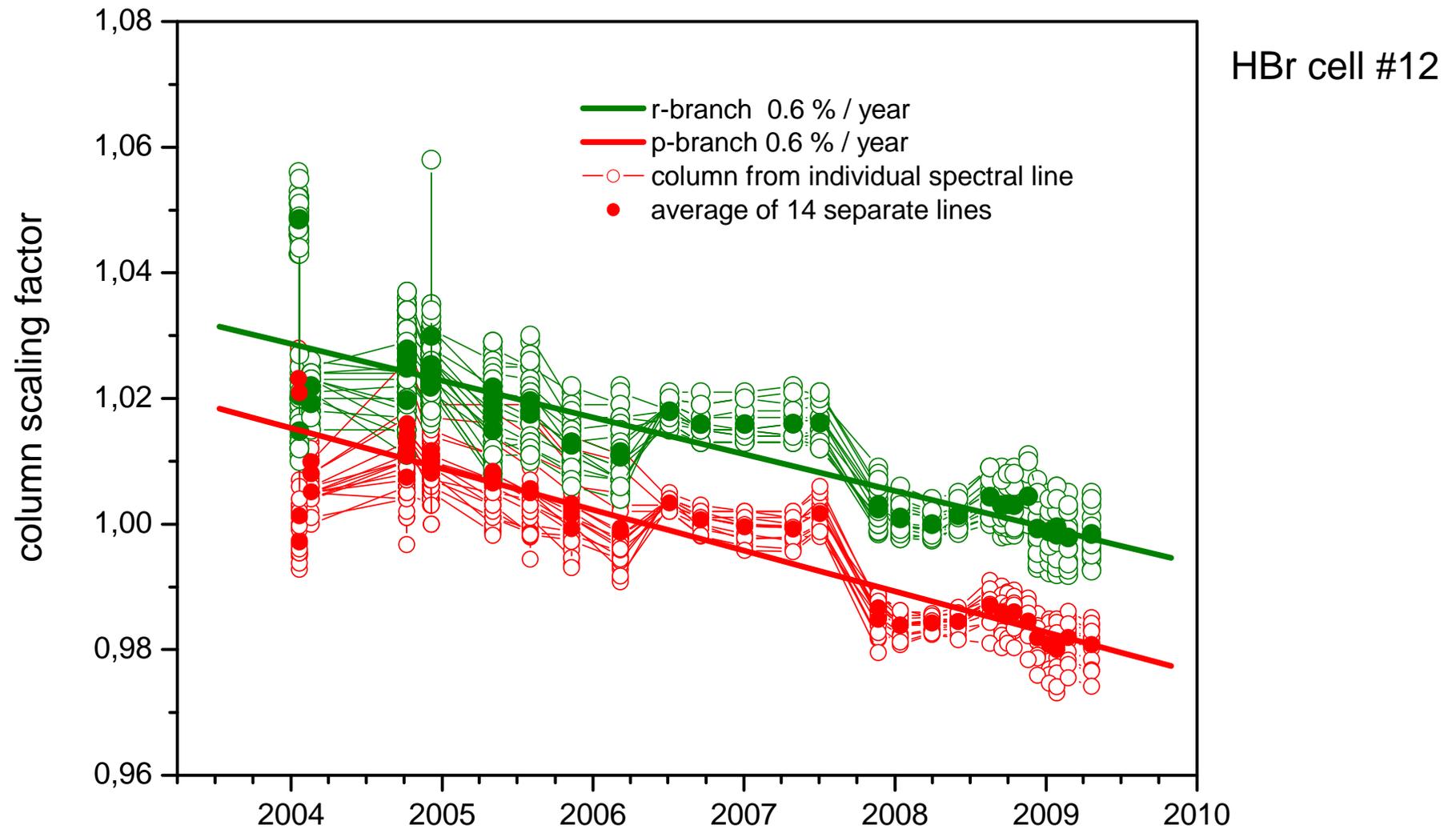
“Differential FTIR”  
with Zugspitze:  
O<sub>3</sub>, CO, CH<sub>4</sub>, N<sub>2</sub>O,  
C<sub>2</sub>H<sub>6</sub>, CFC-22,  
H<sub>2</sub>O

FTIR  
IFU  
**Garmisch**  
734 m

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# You forgot what NDACC duty No 2 was about? [Ask Frank and Mike](#) 😊



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## The NDACC duty No 3: Archiving

### Period(s) covered in data archiving at NDACC DHF:

recently updated full Zugspitze series (1995 up to now) for CO, O<sub>3</sub>, HF, COF<sub>2</sub>, HCl, ClONO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, and H<sub>2</sub>O

tried to archive in new NDACC HDF database, but

were stopped by a problem with ASC2HDF:

- after conversion of the input data the resulting HDF-File contains the variable "DATA\_START\_DATE" in the wrong format MJD2000.

- the NDACC database only accepts the ISO8601 format "yyyymmddThhmissZ".

- if the date is entered in the metadata in the right (ISO) format before conversion it is changed to (the wrong) MJD2000.

## Zugspitze FTIR Site Report: **Intercomparisons**

### **Name, date, and location of last intercomparison and/or validation:**

- 1996 intercomparison with Jungfrauoch: coincident measurements and blind independent analyses of HF, HCl. Agreement within 2 per cent
- In 2001 evaluation of the Zugspitze time series since 1995 of HCl and ClONO<sub>2</sub>, and comparison to the Jungfrauoch series; showed **very** good overall agreement!
- In 2002 we compared in preparation for ENVISAT Validation columns of N<sub>2</sub>O, CO, CH<sub>4</sub>, NO<sub>2</sub>, O<sub>3</sub> to coincident Jungfrauoch data. E.g., N<sub>2</sub>O agreed within 1 %!
- Intense 3 months water vapor validation campaign at Zugspitze (mid Aug – mid Nov 2002) with permanent FTIR water vapor measurements compared to 4 radio sondes launched on site daily and permanent GPS water column measurements on site. Very good agreement of FTIR to sonde columns within a few per cent! Detailed FTIR validation study also relative to GPS measurements performed.
- In spring 2003 comparison of the Zugspitze time series (1996-2002) of CO to the Jungfrauoch series; showed very good overall agreement!
- N<sub>2</sub>O trop. columns trend (1995-2004): Zugspitze 0.18 %/yr, Jungfrauoch 0.23 %/yr
- 2005: Initial SCIAMACHY validation: learned much about precision of CO, CH<sub>4</sub>, NO<sub>2</sub> measured by FTIR
- 2007: Comparison of Zugspitze HF, COF<sub>2</sub>, HCl and ClONO<sub>2</sub> to KASIMA model (issue of fall FTIR-ClONO<sub>2</sub> enhancements)
- 2007/08: Validation of matured SCIA CH<sub>4</sub> data: precision of MIR retrievals (prior impact, annual cycle issue)

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## Zugspitze FTIR Site Report: **Intercomparisons**

### Name, date, and location of last intercomparison and/or validation:

- Comparing Zugspitze CH<sub>4</sub> to Jungfraujoch: Perfect agreement of annual cycle
- 2008/09: first FTIR retrieval of a meso CO annual cycle above mid-latitudes: compared Zugspitze FTIR to Garmisch FTIR, to Bremen FTIR, and to WACCM model (⇒ Tobias' talk)
- 2008/09: Developed H<sub>2</sub>O column retrieval compared matched to coincident radiosondes (transferred retrieval to ISSJ in a harmonized way, analyzed ISSJ side-by-side intercomparison of H<sub>2</sub>O columns).
- Ongoing : Lead retrieval strategy/harmonization effort for CH<sub>4</sub> and N<sub>2</sub>O retrievals and perform global SCIA validation versus 13 participating g.-b. stations (2 SCIA algorithms)

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## Zugspitze FTIR Site Report: Publications

### List of conference contributions during the reporting period:

Ruhnke, R., Blumenstock, Th., Duchatelet, P., Hamann, K., Hase, F., Kouker, W., Kramer, I., Mahieu, E., Mikuteit, S., Notholt, J., Reddman, Th., Schneider, M., Sinnhuber, B.-M., Sussmann, R., Velazco, V., Warneke, T., Wiehle, M.: Measured and modelled **trends of stratospheric Cly and Fy** column amounts in the northern hemisphere, Abstracts of the Quadrennial Ozone Symposium, Tromsø, Norway, June 29 – July 5, 2008.

Sussmann, R., Borsdorff, T., Rettinger, M., Ruhnke, R.: **Variability and trends of total O3, Cly and Fy** in relation to the Montreal Protocol from long-term FTIR observations at the NDACC Primary Station Zugspitze, Abstracts of the Quadrennial Ozone Symposium, Tromsø, Norway, June 29 – July 5, 2008.

Borsdorff, T., Sussmann, R., and Rettinger, M.: First measurements of **stratospheric CO at midlatitudes** derived from ground-based FTIR measurements at Zugspitze and Garmisch-Partenkirchen, Verhandl. DPG (VI) 44, 2009, UP 2.4, <http://www.dpg-verhandlungen.de/2009/hamburg/up2.pdf>, (Poster).

Borsdorff, T., Sussmann, R., and Rettinger, M.: First detection of a seasonality of **stratospheric CO above mid-latitudes** via solar FTIR measurements. Analysis of one decade of observations at the NDACC Primary Station Zugspitze, Geophysical Research Abstracts, Vol. 11, EGU2009-5053-10, 2009, <http://meetingorganizer.copernicus.org/EGU2009/EGU2009-5053-10.pdf>, EGU General Assembly 2009 (Poster).

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## Zugspitze FTIR Site Report: Publications

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### List of conference contributions during the reporting period:

Sussmann, R., Borsdorff, T., Rettinger, M., Camy-Peyret, C., Demoulin, P., Duchatelet, P., and Mahieu, E.: New **multi-station and multi-decadal trend data on precipitable water**. Recipe to match FTIR retrievals from NDACC long-time records to radio sondes within 1 mm accuracy/precision, Geophysical Research Abstracts, Vol. 11, EGU2009-10617-2, 2009, <http://meetingorganizer.copernicus.org/EGU2009/EGU2009-10617-2.pdf>, EGU General Assembly 2009 (Poster).

Sussmann, R., Forster, F., Borsdorff, T., M. De Mazière, Dils, B., Vigouroux, C., Blumenstock, T., Buchwitz, M., Burrows, J.P., Demoulin, P., Duchatelet, P., Frankenberg, C., Hannigan, J., Hase, F., Jones, N., Klyft, J., Kramer, I., Mahieu, E., Mellqvist, J., Notholt, J., Petersen, K., Schneising, O., Strandberg, A., Strong, K., Taylor, J., Wood, S.: Satellite **validation of column-averaged methane on global scale**: ground-based data from 15 FTIR stations versus last generation ENVISAT/SCIAMACHY retrievals, IGAC 10th International Conference - Bridging the scales in Atmospheric Chemistry: Local to Global, Annecy, France, 7 to 12 September 2008 (Poster).

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## Zugspitze FTIR Site Report: Publications

### List of conference contributions during the reporting period:

Sussmann, R., F. Forster, T. Borsdorff, B. Dils, M. De Mazière, C. Vigouroux, T. Blumenstock, M. Buchwitz, J.P. Burrows, P. Duchatelet, C. Frankenberg, J. Hannigan, F. Hase, N. Jones, J. Klyft, E. Mahieu, J. Mellqvist, J. Notholt, K. Petersen, O. Schneising, K. Strong, J. Taylor, Satellite **validation of column-averaged methane on global scale**: Harmonized data from 13 FTIR ground stations versus last generation ENVISAT/SCIAMACHY retrievals, Verhandl. DPG (VI) 44, 2009, UP 10.5, <http://www.dpg-verhandlungen.de/2009/hamburg/up10.pdf> (Poster).

Sussmann, R., F. Forster, T. Borsdorff, B. Dils, M. De Mazière, C. Vigouroux, T. Blumenstock, M. Buchwitz, J.P. Burrows, P. Duchatelet, C. Frankenberg, J. Hannigan, F. Hase, N. Jones, J. Klyft, E. Mahieu, J. Mellqvist, J. Notholt, K. Petersen, O. Schneising, K. Strong, J. Taylor: A novel **Tikhonov-based approach for harmonized high-accuracy retrieval of methane columns and profiles** from NDACC FTIR network measurements. Application to global validation of ENVISAT/SCIAMACHY biases, Geophysical Research Abstracts, Vol. 11, EGU2009-7869-2, 2009, <http://meetingorganizer.copernicus.org/EGU2009/EGU2009-7869-2.pdf>, EGU General Assembly 2009 (Talk).

Sussmann, R., F. Forster, T. Borsdorff, B. Dils, M. De Mazière, C. Vigouroux, T. Blumenstock, M. Buchwitz, J.P. Burrows, P. Duchatelet, C. Frankenberg, J. Hannigan, F. Hase, N. Jones, J. Klyft, E. Mahieu, J. Mellqvist, J. Notholt, K. Petersen, O. Schneising, K. Strong, J. Taylor, Satellite **validation of column-averaged methane on global scale**: Harmonized data from 13 FTIR ground stations versus last generation ENVISAT/SCIAMACHY retrievals, Fifth International Symposium on Non-CO<sub>2</sub> Greenhouse Gases (NCGG-5) Science, Reduction Policy and Implementation, Wageningen, The Netherlands, June 30 - July 3, 2009 (**Lead Session Talk**).

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## Zugspitze FTIR Site Report: Publications

### List of peer review publications that appeared during the reporting period:

Clerbaux, C., George, M., Turquety, S., Walker, K. A., Barret, B., Bernath, P., Boone, C., Borsdorff, T., Cammas, J. P., Catoire, V., Coffey, M., Coheur, P.-F., Deeter, M., De Mazière, M., Drummond, J., Duchatelet, P., Dupuy, E., de Zafra, R., Eddounia, F., Edwards, D. P., Emmons, L., Funke, B., Gille, J., Griffith, D. W. T., Hannigan, J., Hase, F., Höpfner, M., Jones, N., Kagawa, A., Kasai, Y., Kramer, I., Le Flochmoën, E., Livesey, N. J., López-Puertas, M., Luo, M., Mahieu, E., Murtagh, D., Nédélec, P., Pazmino, A., Pumphrey, H., Ricaud, P., Rinsland, C. P., Robert, C., Schneider, M., Senten, C., Stiller, G., Strandberg, A., Strong, K., Sussmann, R., Thouret, V., Urban, J., and Wiacek, A.: **CO measurements from the ACE-FTS** satellite instrument: data analysis and **validation** using ground-based, airborne and spaceborne observations, *Atmos. Chem. Phys.*, 8, 2569-2594, 2008.

Gardiner, T., Forbes, A., de Mazière, M., Vigouroux, C., Mahieu, E., Demoulin, P., Velazco, V., Notholt, J., Blumenstock, T., Hase, F., Kramer, I., Sussmann, R., Stremme, W., Mellqvist, J., Strandberg, A., Ellingsen, K., and Gauss, M.: **Trend analysis of greenhouse gases** over Europe measured by a network of ground-based remote FTIR instruments, *Atmos. Chem. Phys.*, 8, 6719–6727, 2008.

Vigouroux, C., De Mazière, M., Demoulin, P., Servais, C., Hase, F., Blumenstock, T., Kramer, I., Schneider, M., Mellqvist, J., Strandberg, A., Velazco, V., Notholt, J., Sussmann, R., Stremme, W., Rockmann, A., Gardiner, T., Coleman, M., and Woods, P.: Evaluation of tropospheric and stratospheric **ozone trends** over Western Europe from ground-based FTIR network observations, *Atmos. Chem. Phys.*, 8, 6865-6886, 2008.

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## Zugspitze FTIR Site Report: Publications

### List of peer review publications that appeared during the reporting period:

Dupuy, E., Walker, K.A., Kar, J., Boone, C.D., McElroy, C.T., Bernath, P.F., Drummond, J.R., Skelton, R., McLeod, S.D., Hughes, R.C., Nowlan, C.R., Dufour, D.G., Zou, J., Nichitiu, F., Strong, K., Baron, P., Bevilacqua, R.M., Blumenstock, T., Bodeker, G.E., Borsdorff, T., Bourassa, A.E., Bovensmann, H., Boyd, I.S., Bracher, A., Brogniez, C., Burrows, J.P., Catoire, V., Ceccherini, S., Chabrillat, S., Christensen, T., Coffey, M.T., Cortesi, U., Davies, J., De Clercq, C., Degenstein, D.A., De Mazière, M., Demoulin, P., Dodion, J., Firanski, B., Fischer, H., Forbes, G., Froidevaux, L., Fussen, D., Gerard, P., Godin-Beekman, S., Goutail, F., Granville, J., Griffith, D., Haley, C.S., Hannigan, J.W., Höpfner, M., Jin, J.J., Jones, A., Jones, N.B., Jucks, K., Kagawa, A., Kasai, Y., Kerzenmacher, T.E., Kleinböhl, A., Klekociuk, A.R., Kramer, I., Küllmann, H., Kuttippurath, J., Kyrölä, E., Lambert, J.-C., Livesey, N.J., Llewellyn, E.J., Lloyd, N.D., Mahieu, E., Manney, G.L., Marshall, B.T., McConnell, J.C., McCormick, M.P., McDermid, I.S., McHugh, M., McLinden, C.A., Mellqvist, J., Mizutani, K., Murayama, Y., Murtagh, D.P., Oelhaf, H., Parrish, A., Petelina, S.V., Piccolo, C., Pommereau, J.-P., Randall, C.E., Robert, C., Roth, C., Schneider, M., Senten, C., Steck, T., Strandberg, A., Strawbridge, K.B., Sussmann, R., Swart, D.P.J., Tarasick, D.W., Taylor, J.R., Tétard, C., Thomason, L.W., Thompson, A.M., Tully, M.B., Urban, J., Vanhellefont, F., Vigouroux, C., von Clarmann, T., von der Gathen, P., von Savigny, C., Waters, J.W., Witte, J.C., Wolff, M., and Zawodny, J.M.: **Validation of ozone** measurements from the Atmospheric Chemistry Experiment (**ACE**), *Atmos. Chem. Phys.*, 9, 287–343, 2009.

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## Zugspitze FTIR Site Report: Publications

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List of ACPD open-peer-reviews that appeared during the reporting period:

Sussmann, R.: Interactive comment on “**Validation of ACE-FTS N<sub>2</sub>O** measurements” by K. Strong et al., Atmos. Chem. Phys. Discuss., 8, S1288–S1293, 2008.

Sussmann, R.: Interactive comment on “Simultaneous atmospheric measurements using **two Fourier transform** infrared spectrometers at the Polar Environment Atmospheric Research Laboratory during spring 2006, and **comparisons with the Atmospheric Chemistry Experiment-Fourier Transform Spectrometer**” by Fu et al., Atmos. Chem. Phys. Discuss., 8, S1834–S1841, 2008.

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## Zugspitze FTIR Site Report: **Publications**

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List of peer review publications accepted or submitted during the reporting period:

Sussmann, R., Borsdorff, T., Rettinger, M., Camy-Peyret, C., Demoulin, P., Duchatelet, P., Mahieu, E., and Servais, C.: New **trends in column-integrated atmospheric water vapor**. Method to harmonize and match long-term records from the FTIR network to radiosonde characteristics, Atmos. Chem. Phys. Discuss., 9, 2009.

Borsdorff, T. and Sussmann, R.: First detection of significant seasonality in **stratospheric CO** above mid-latitudes via solar FTIR spectrometry, submitted 2009.

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## Zugspitze FTIR Site Report: **Publications**

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### Peer review publication and book article in preparation:

Sussmann., R., Forster, F., Borsdorff, T., Dils, B., De Mazière, M., Vigouroux, C., Blumenstock, T., Buchwitz, M., Burrows, J.P., Duchatelet, P., Frankenberg, C., Hannigan, J., Hase, F., Jones, N., Klyft, J., Mahieu, E., Mellqvist, J., Notholt, J., Petersen, K., Schneising, O., Strong, K., Taylor, J.: **Satellite validation of column-averaged methane on global scale**: ground-based data from 13 FTIR stations versus last generation ENVISAT/SCHIAMACHY retrievals, Atmos. Meas. Tech. in preparation 2009.

Schneider, M., Notholt. J., and Sussmann R., and contributing authors: Fourier Transform Infrared Spectrometry, in: "**Sounding techniques for atmospheric water vapor monitoring**", Kämpfer, N. et al. eds., Book Series of International Science Space Institute (ISSI), Bern, Switzerland, in preparation 2009.

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## Zugspitze FTIR Site Report: **Publications**

List of conference contributions during the reporting period:

Duchatelet, P., E. Mahieu, R. Sussmann, F. Forster, T. Borsdorff, P.F. Bernath, C.D. Boone, K.A. Walker, M. De Mazière, and C. Vigouroux: Determination of **isotopic fractionation  $^{13}\text{C}$  of methane** from ground-based FTIR observations performed at the Jungfraujoch, Geophysical Research Abstracts, Vol. 11, EGU2009-9914-1, 2009, <http://meetingorganizer.copernicus.org/EGU2009/EGU2009-9914-1.pdf>, EGU General Assembly 2009 (Poster).

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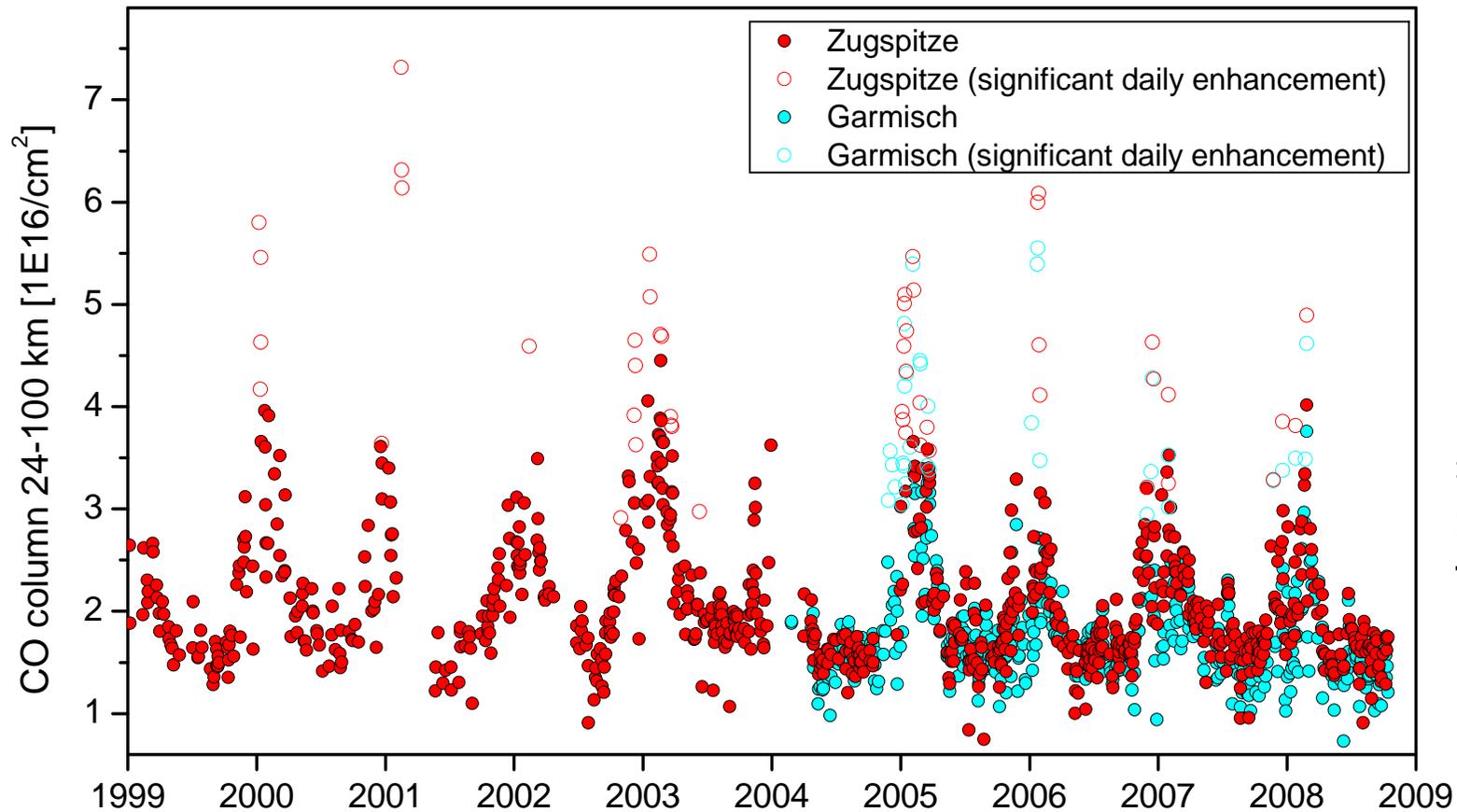
## Zugspitze FTIR Site Report: **Funding**

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

- Permanent 80 % basic funding by Helmholtz Society of German Research Centers
- plus funded projects:
  - EC-HYMN (CH<sub>4</sub>, N<sub>2</sub>O, since 2006, ongoing)
  - EC-GEOMON (Cl<sub>y</sub>, F<sub>y</sub>, since 2006, ongoing)
  - SATVAL-A (German Space Agency, SCIA Validation: CH<sub>4</sub>, ongoing)

# Stratomesospheric CO above Zugspitze and Garmisch: **New for mid-latitudes**



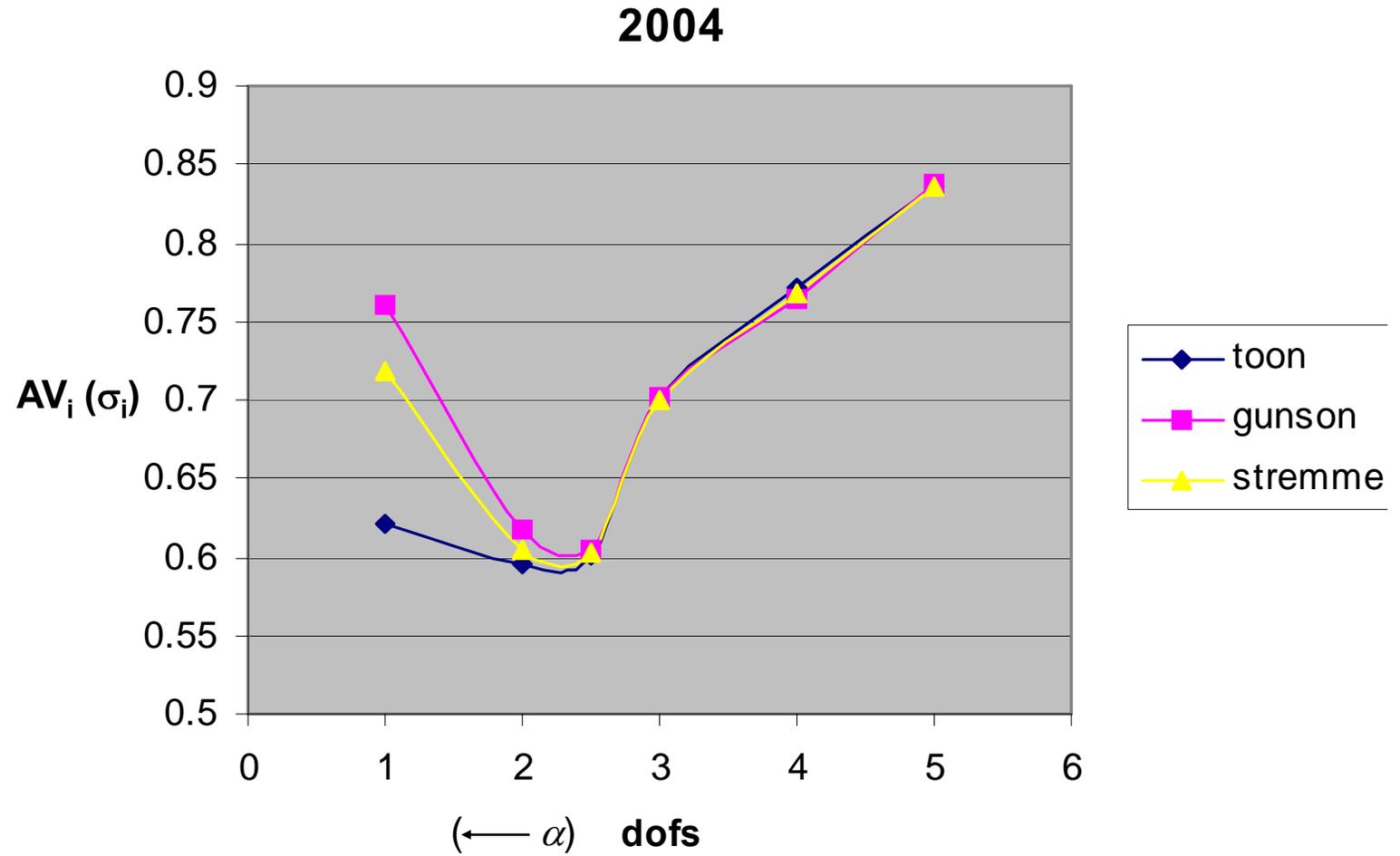
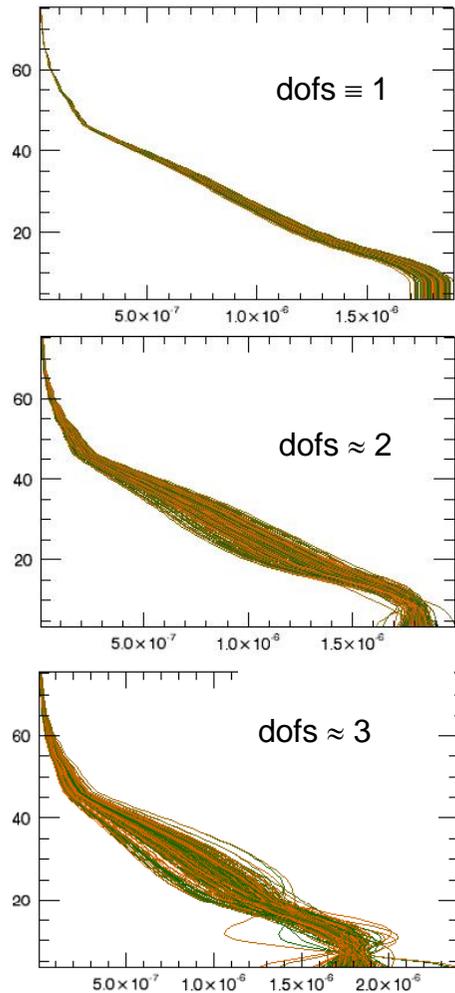
Borsdorff,  
Sussmann,  
submitted 2009

⇒  
Science talk by  
Tobias Borsdorff

Research Center Karlsruhe, IMK-IFU Garmisch-Partenkirchen

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Finally: **Tikhonov L1 on %-VMR scale** suggest ed at IRWG 2008 for CH4 ...



Finally: **Tikhonov L1 on %-VMR scale** has gotten many “babies 😊” last year ...

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## CH4 & N2O official HYMN strategy

It was decided in Oct 2008 at the Garmisch HYMN meeting that Tikhonov L1 on the %-VMR is adopted for both CH4 and N2O as the official strategy for revised NDACC time series within the EC-HYMN project

Sussmann et al., D4.4 document on HYMN retrieval strategy for CH4 and N2O  
[http://... type “HYMN” to google](#)

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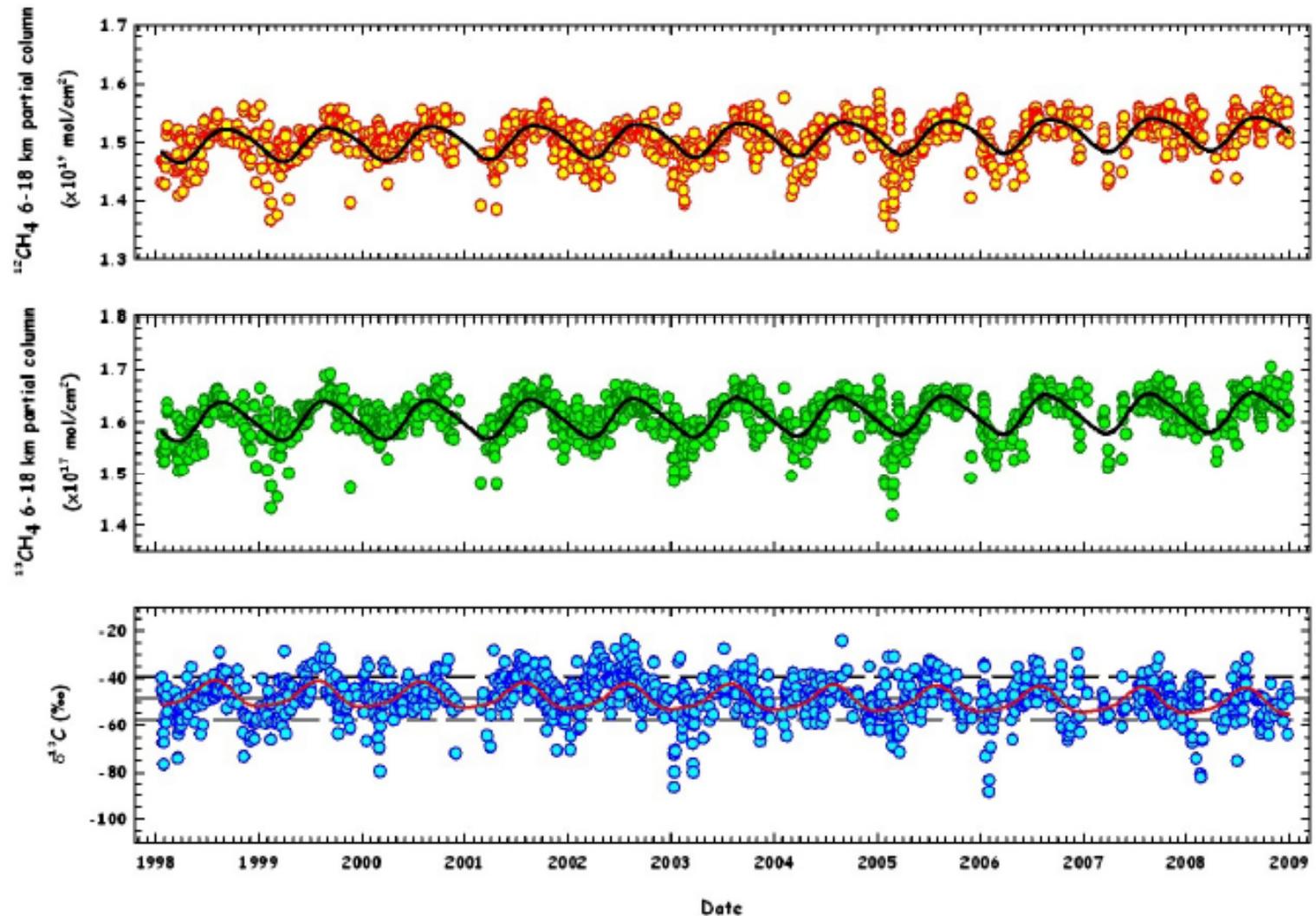
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Finally: **Tikhonov L1 on %-VMR scale** has gotten many “babies ☺” last year ...

$\delta^{13}\text{C}$

Duchatelet, P., E.  
Mahieu, R. Sussmann,  
F. Forster, T. Borsdorff,  
P.F. Bernath, C.D.  
Boone, K.A. Walker, M.  
De Mazière, and C.  
Vigouroux:  
Determination of  
**isotopic fractionation**  
 **$^{13}\text{C}$  of methane** from  
ground-based FTIR  
observations performed  
at the Jungfraujoch,  
Geophysical Research  
Abstracts, Vol. 11,  
EGU2009-9914-1, 2009



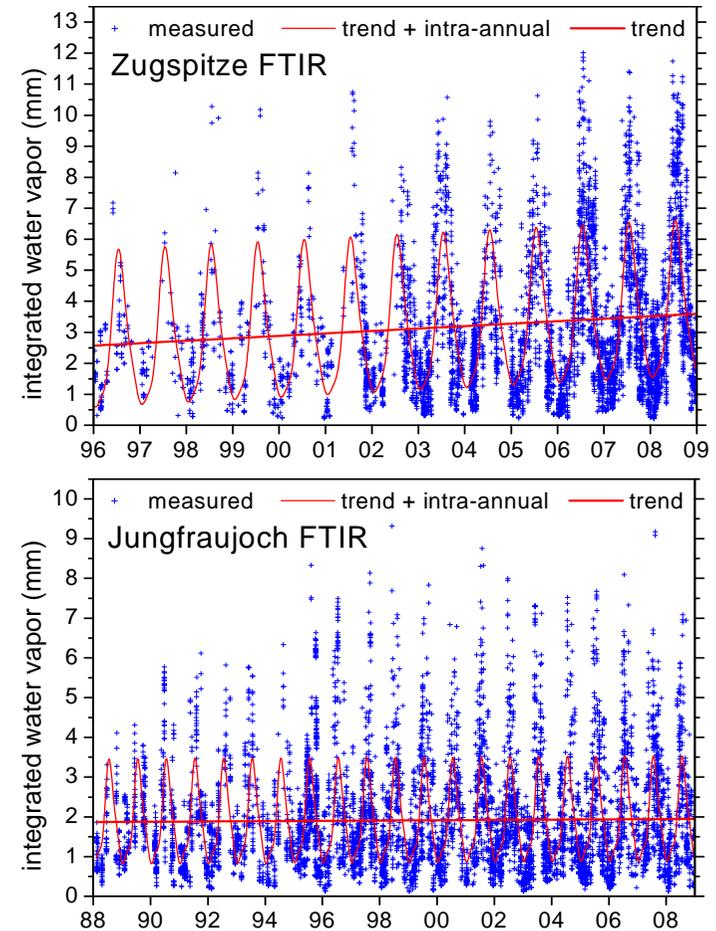
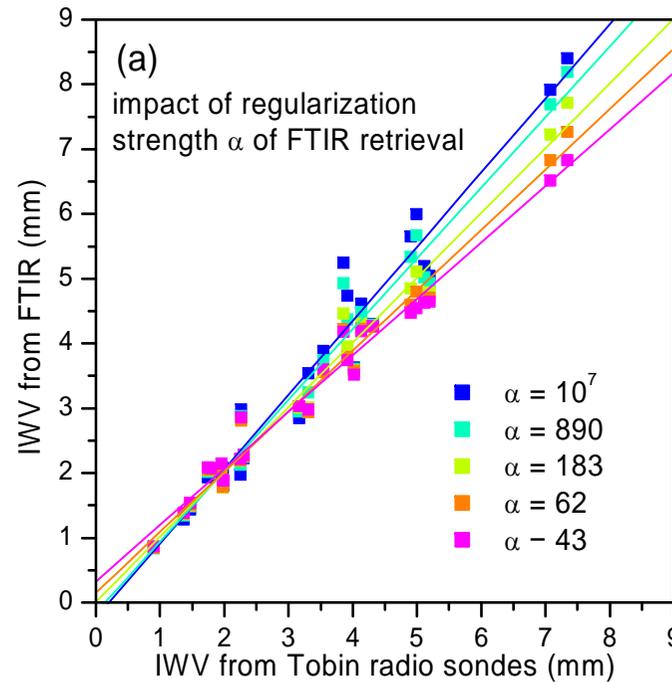
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Finally: **Tikhonov L1 on %-VMR scale** has gotten many “babies 😊” last year ...

- decadal trends in column-integrated water vapor

Sussmann, R., Borsdorff, T., Rettinger, M., Camy-Peyret, C., Demoulin, P., Duchatelet, P., Mahieu, E., and Servais, C.: New trends in column-integrated atmospheric water vapor. Method to harmonize and match long-term records from the FTIR network to radiosonde characteristics, Atmos. Chem. Phys. Discuss., 9, 2009.



Finally: **Tikhonov L1 on %-VMR scale** has gotten many “babies 😊” last year ...

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... i.e., was applied by various groups to various species

1) Liege group: 13CH<sub>4</sub> (EGU 2009, Duchatelet et al.)

2) IMK-IFU & Liege group: water vapor (ACPD, 9, 2009)

3) BIRA group: H<sub>2</sub>CO (science talk, paper in prep.)

4) BIRA group: IASI retrievals

**Seems that Tikhonov L1 on %-VMR scale is on its way to become a IRWG standard default / reference regularization approach (esp. for dofs ≈1-2 cases) ...**

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## Summary – Zugspitze FTIR Site Report

- 130 measurements days in 2008, well funded
- updated full Zugspitze series for CO, O<sub>3</sub>, HF, COF<sub>2</sub>, HCl, ClONO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O, H<sub>2</sub>O
- paper on stratomesospheric CO variability submitted  
⇒ science talk
- lead retrieval optimization/harmonization for CH<sub>4</sub> and N<sub>2</sub>O profile retrievals with 13 stations
- lead global validation of SCIAMACHY XCH<sub>4</sub> with 13 stations  
⇒ paper in preparation
- lead retrieval optimization/harmonization for columnar H<sub>2</sub>O at Zugspitze and ISSJ
- ACPD paper on water vapor trends ⇒ science talk
- Tikhonov-L1 on %-VMR scale demonstrated at IRWG 2008 for CH<sub>4</sub> has got babies: N<sub>2</sub>O, <sup>13</sup>CH<sub>4</sub>, H<sub>2</sub>O, H<sub>2</sub>CO, IASI retrieval, ...