# Geophysical validation of EPS/MetOp vertical profiles/columns of water vapor, temperature, and trace gases at the Ground-Truthing Center Zugspitze/Garmisch, Germany


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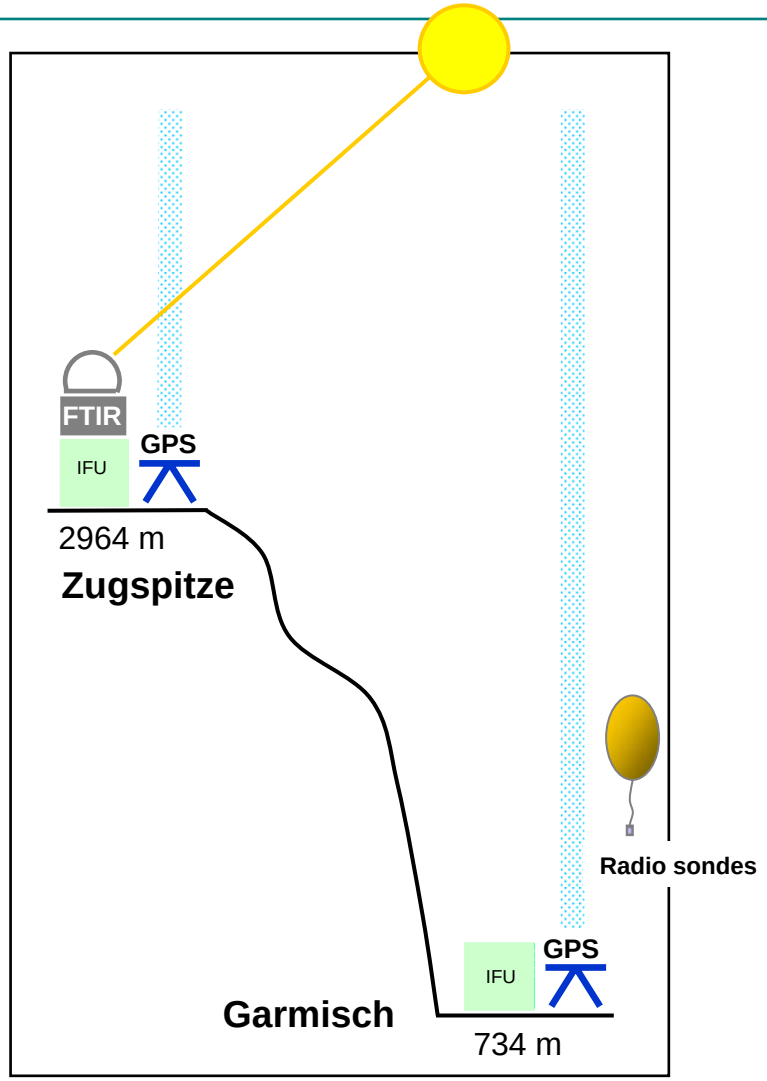
Co-I: C. Camy-Peyret

**Contents**

- Ground instrumentation / data products for IASI + GOME II validation
- Ongoing developments relevant for IASI validation
- Results from SCIAMACHY validation
- Possible validation activities (unfunded versus funded options)

# Heritage: EUMETSAT-funded AIRS validation campaign 2002

**47.4 °N, 11.0 °E**




**Ralf Sussmann and Claude Camy-Peyret, Ground-Truthing Center Zugspitze, Germany for AIRS/IASI Validation, EUMETSAT Contract No. EUM/CO/01/892/PS, Phase I Report, 17 April 2002**

**Ralf Sussmann and Claude Camy-Peyret, Ground-Truthing Center Zugspitze, Germany for AIRS/IASI Validation, EUMETSAT Contract No. EUM/CO/01/892/PS, Phase II Report, 28 March 2003**

## Heritage: EUMETSAT-funded AIRS validation campaign 2002

Campaign duration:
3 Months (19 Aug 2002 - 17 Nov 2002)

**Data delivery: within 12 h for both day and night overpasses**

Validation measurements:
7 days a week,
2-hours-period around each overpass delivered,
for 2 EOS-Aqua overpasses per day

- Radio Sondes (Garmisch): 4 sondes a day (two per overpass)
- GPS Garmisch+ Zugspitze, permanent operation, half hourly mean values
- Zugspitze FTIR: clear sky operation, typically, 20-min-integration intervals
- In-Situ Met Data (Garmisch + Zugspitze): 1-min-values
- Cloud/weather information (Zugspitze: hourly; Garmisch: 1 fish eye image per overpass)

**Permanent Ground-Truthing Facility Zugspitze/Garmisch according to the WMO requirements.**
***Validation and Synergistic use with Satellite Measurements***

**IMK-IFU Working Group „Variability and Trends“**

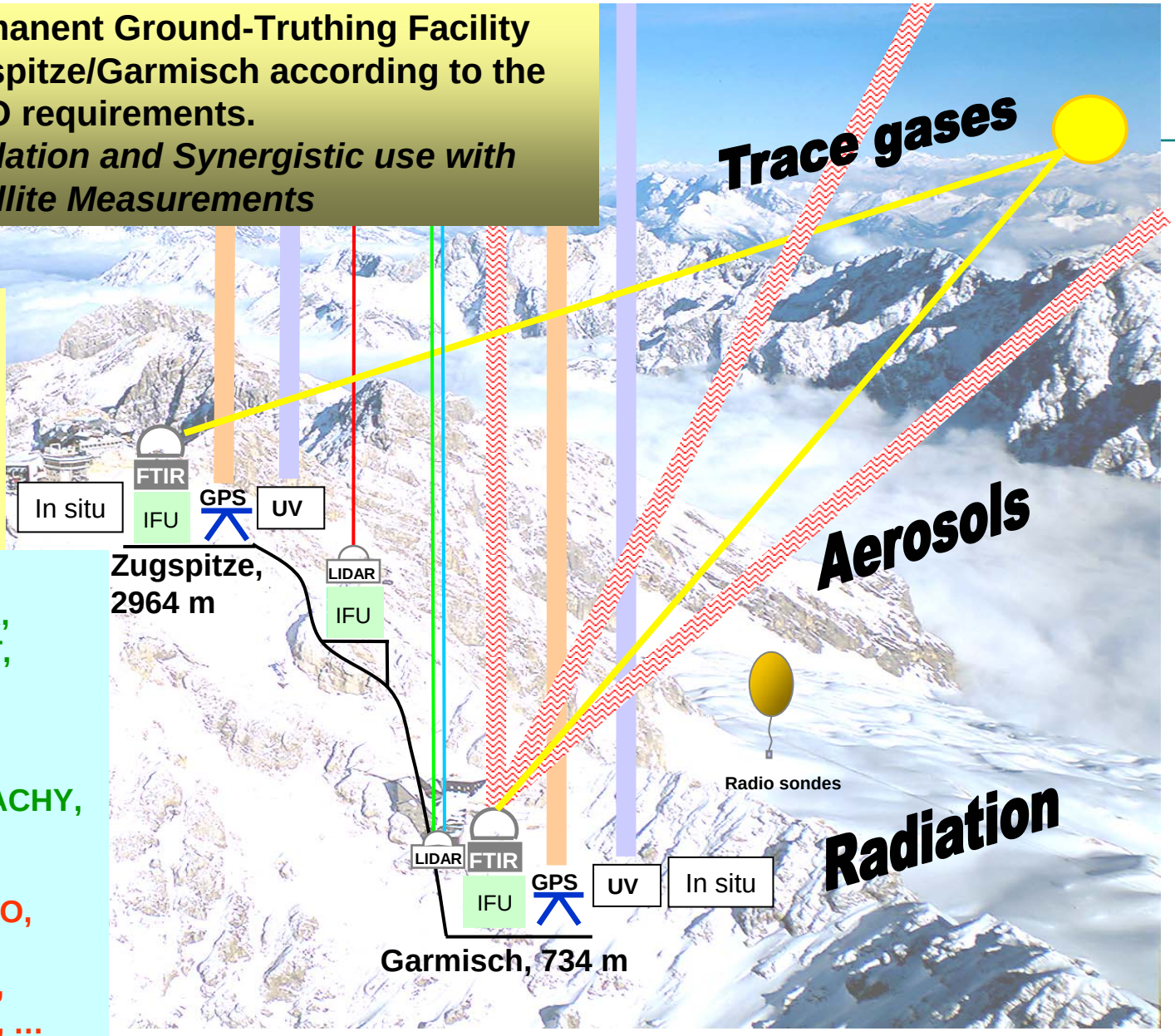
**Head**
- R. Sussmann

**Scientists**
- W. Junkermann
- H.E. Scheel
- T. Trickl
- H. Vogelmann
- P. Werle

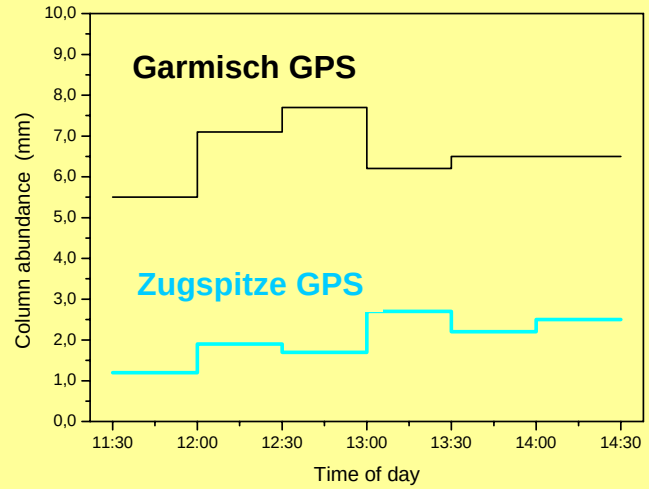
**Engineers**
- H. Giehl
- M. Rettinger
- A. Rockmann

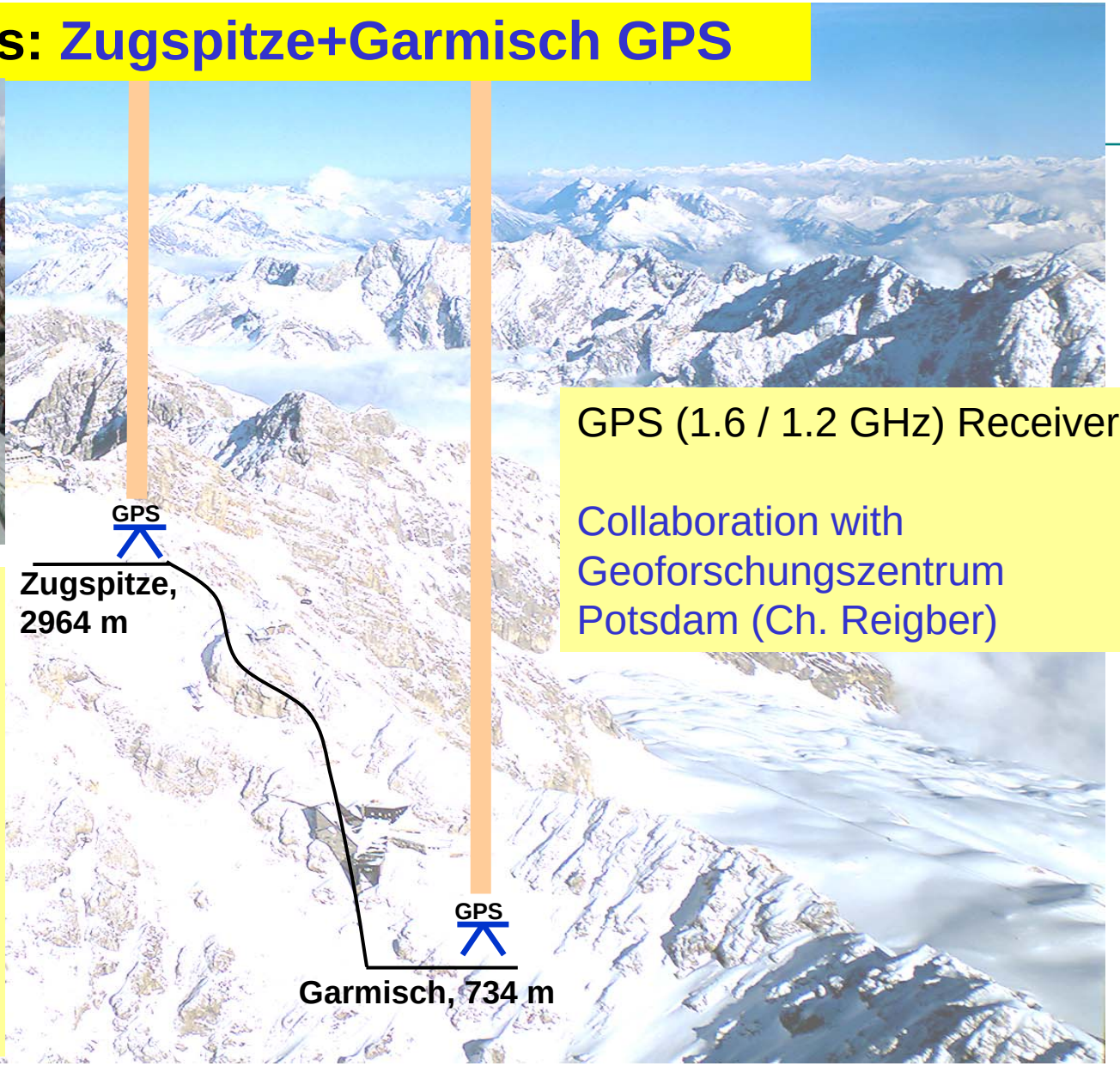
**PhD students**
- W. Stremme
- T. Borsdorff

**MAPS, CRISTA, MOPITT, SAGE, GOME, AIRS, SCIAMACHY, ACE, IASI, CALIPSO, OCO, TCCON, GOSAT, ...**



# Water vapor columns: Zugspitze+Garmisch GPS




GPS (1.6 / 1.2 GHz) Receivers

Collaboration with
Geoforschungszentrum
Potsdam (Ch. Reigber)

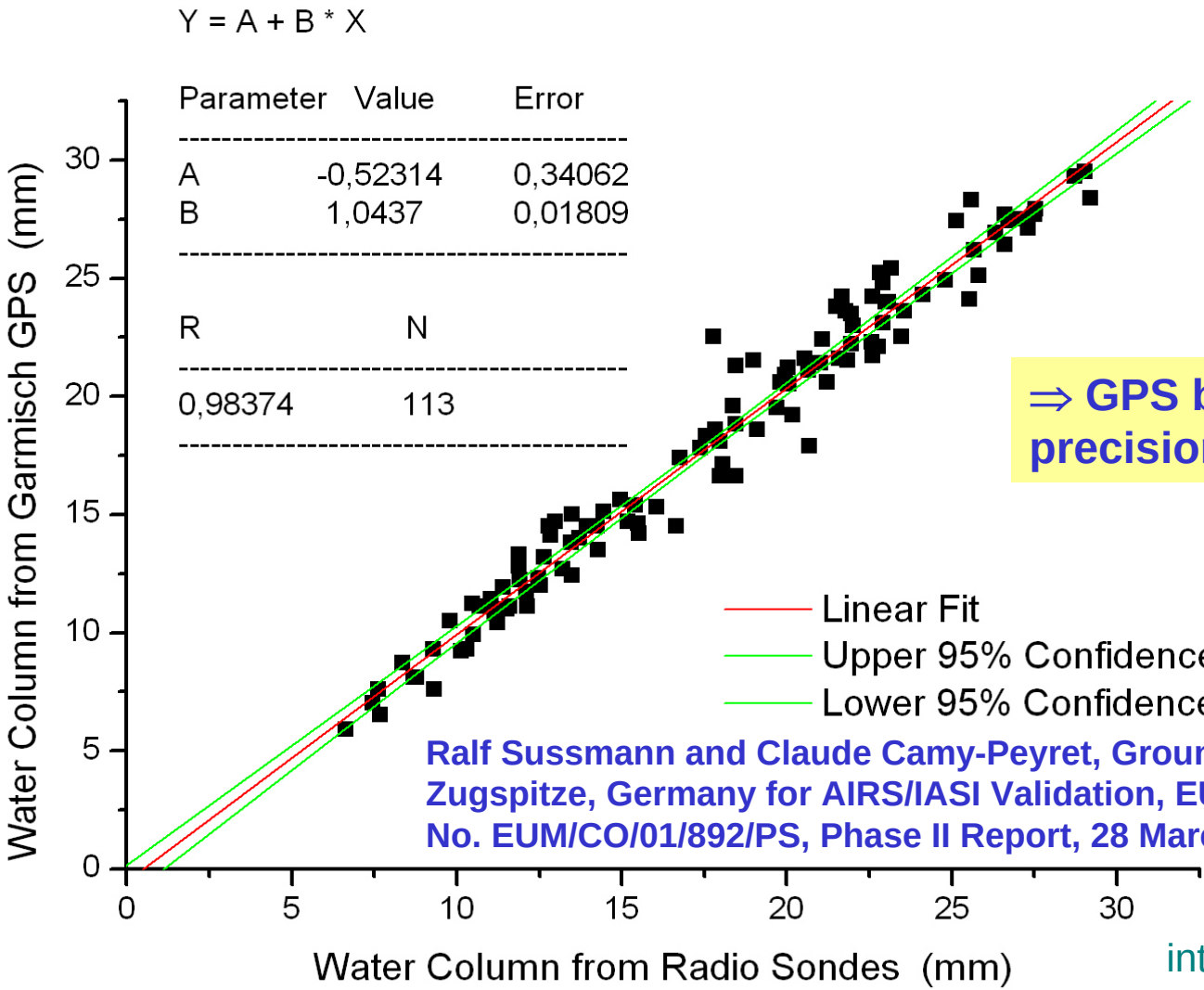
**IMK-IFU, Research Center Karlsruhe, Garmisch-Partenkirchen, Ralf Sussmann**

EPS/MetOp validation at Ground-Truthing Center Zugspitze/Garmisch

# Water vapor columns: Validation of Garmisch GPS with radio sondes

Columns above Garmisch, 734 m

2-h-mean values




**⇒ GPS bias 1-2 mm, precision 1 mm**

**Ralf Sussmann and Claude Camy-Peyret, Ground-Truthing Center Zugspitze, Germany for AIRS/IASI Validation, EUMETSAT Contract No. EUM/CO/01/892/PS, Phase II Report, 28 March 2003**

integrated Tobin-profiles

**Zugspitze operational since 1995**
**typ. 130 measurement days per year**

**$H_2O$ columns and profiles**

FTIR
IFU

**Zugspitze 2964 m**

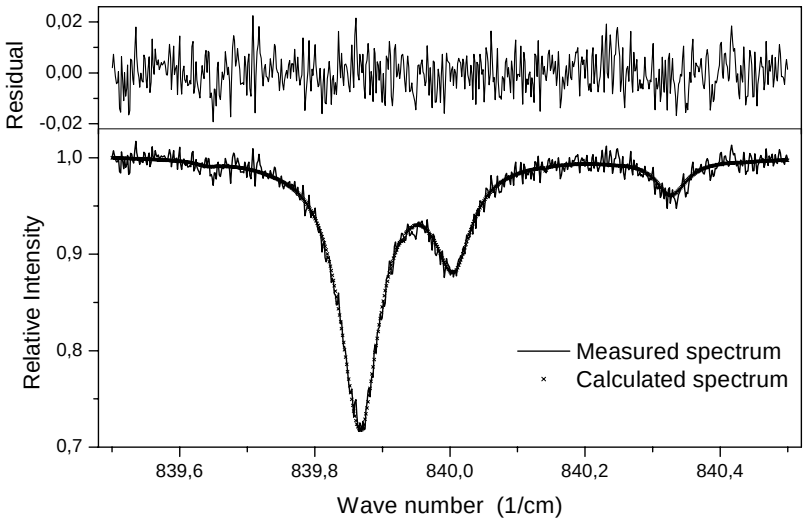
**Garmisch operational since 2004**
**94 measurement days in 2004**
**147 measurement days in 2005**

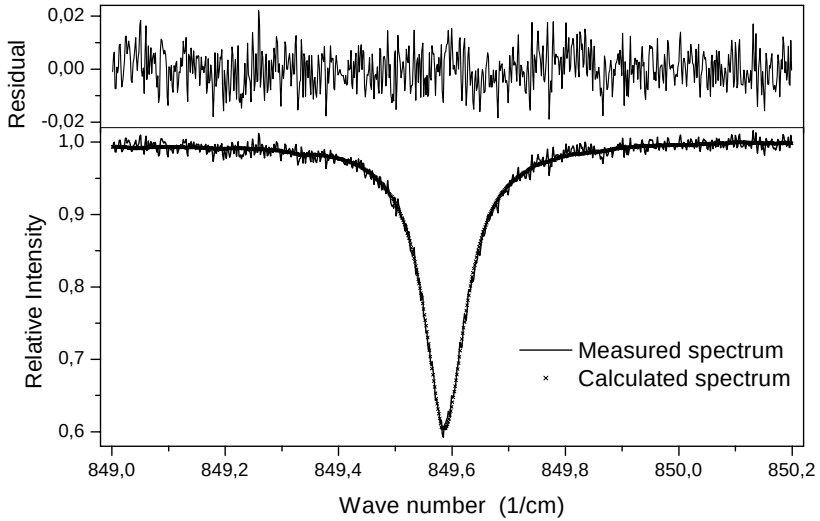
**"Differential FTIR" with Zugspitze: $H_2O$ columns and profiles**

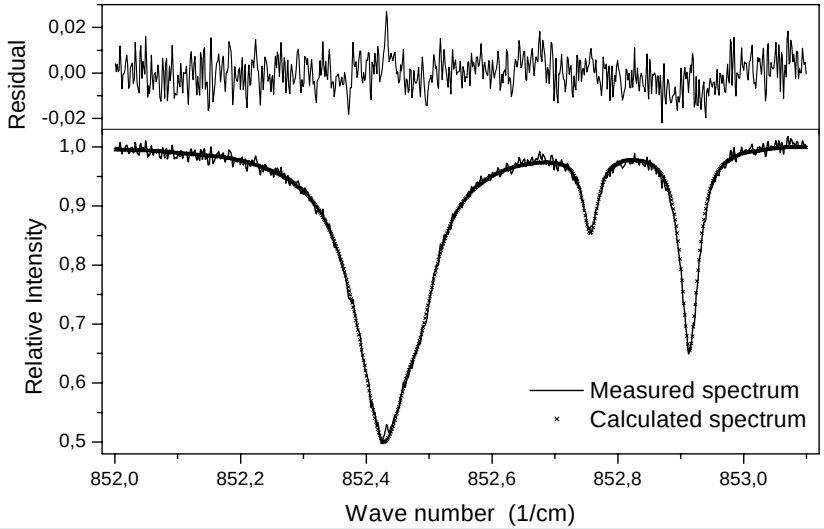
FTIR
IFU

**Garmisch 734 m**

# Water vapor columns/profiles: Solar FTIR retrieval



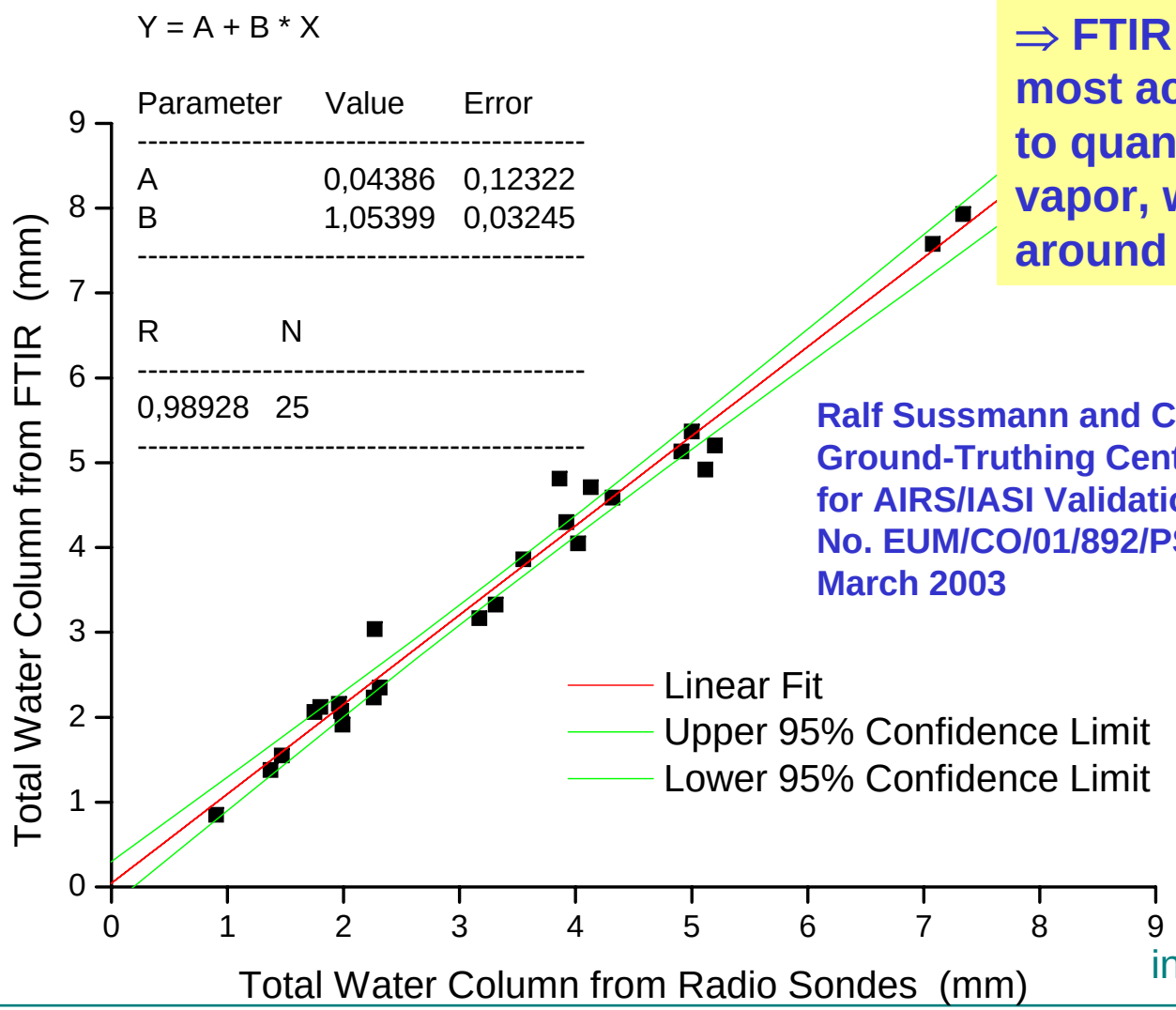



# Water vapor columns Zugspitze/Garmisch: Validation of solar FTIR with sondes

Columns above Zugspitze, 2964 m

2-h-mean values



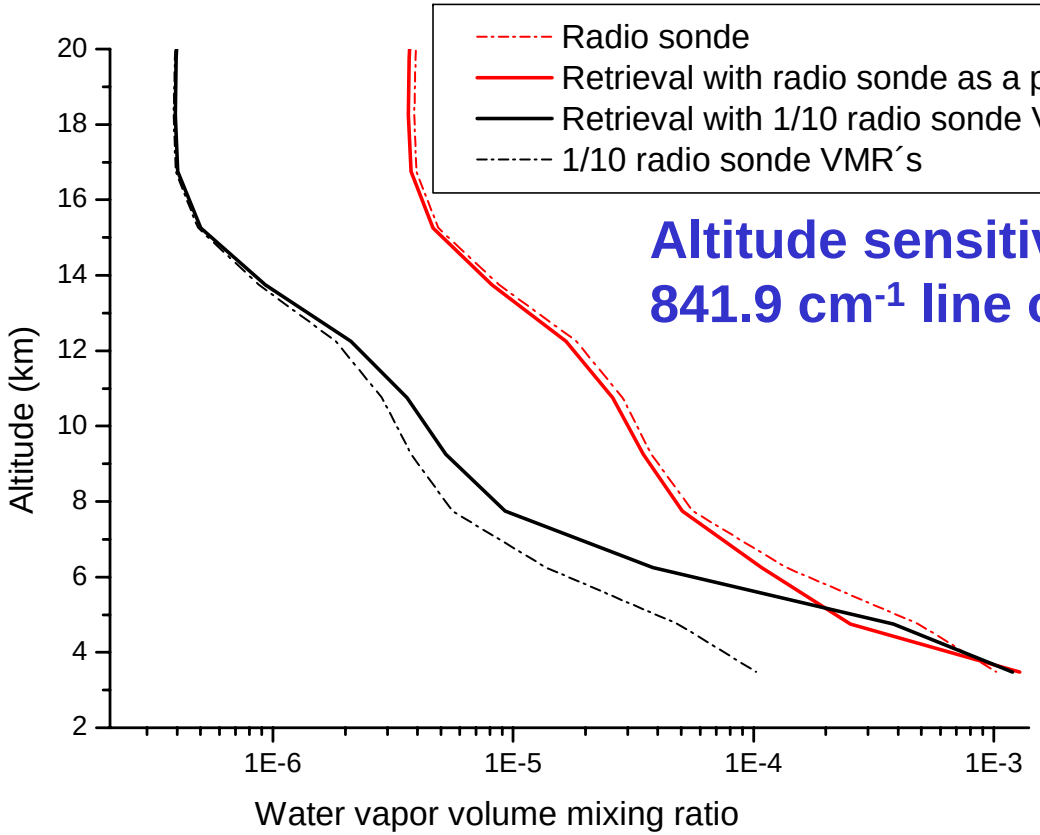

integrated Tobin-profiles

**⇒ FTIR is probably the most accurate technique to quantify columnar water vapor, with an accuracy around 0.1 mm**

**Ralf Sussmann and Claude Camy-Peyret, Ground-Truthing Center Zugspitze, Germany for AIRS/IASI Validation, EUMETSAT Contract No. EUM/CO/01/892/PS, Phase II Report, 28 March 2003**

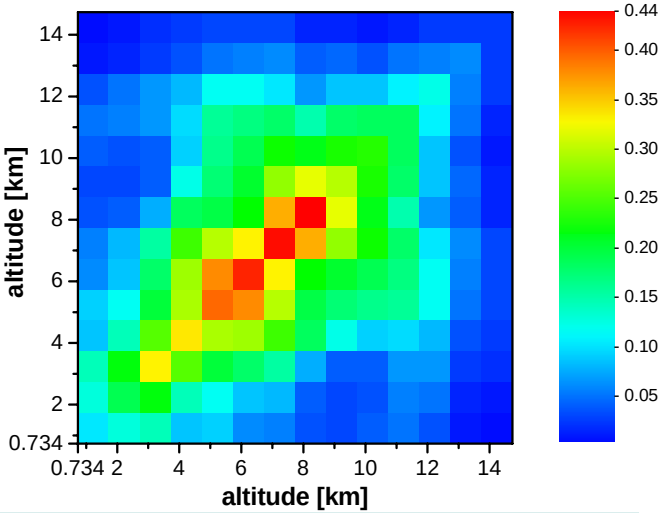
# Water vapor profiles: from Zugspitze/Garmisch solar FTIR

**altitude range (high-altitude site): 12-14 km, depending on humidity**
**degrees of freedom of signal: 3-4**
**vertical resolution: decreasing with altitude, e.g, 1 km, 2 km, 4 km, 7 km**




**Altitude sensitivity test with single weak 841.9 $cm^{-1}$ line of the pure rotation band**

$H_2O$ a priori covariance



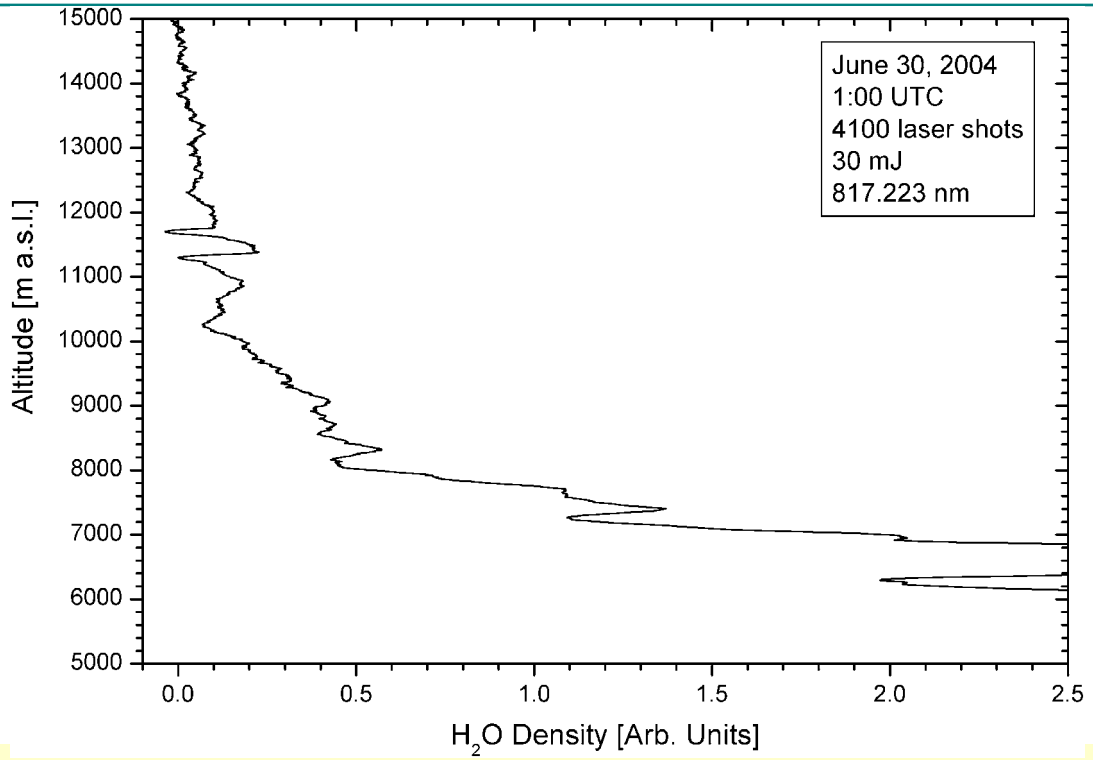
**Schneefernerhaus**

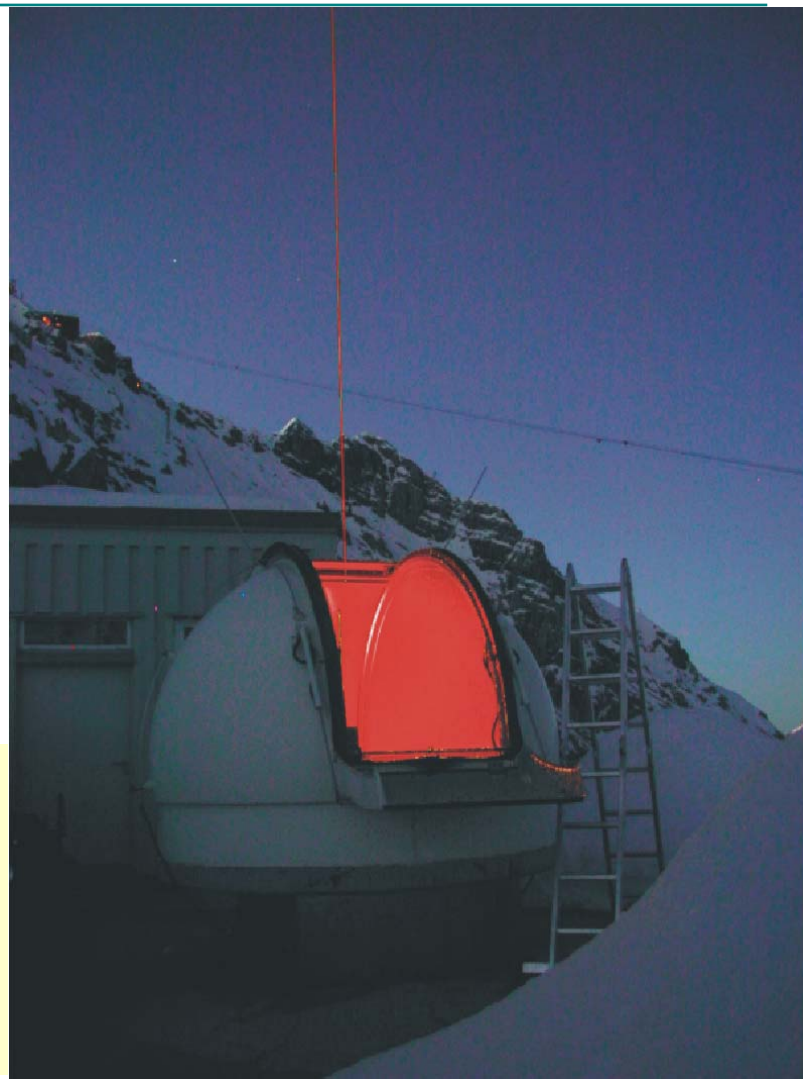
2675 m asl.

water vapor

differential absorption lidar

# Water vapor profiles at Zugspitze: Differential-absorption lidar at the Zugspitze



- measurement range up to >12 km
- vertical resolution 50 m (near field) to 250 m (far field)
- accuracy 5% (near field) to 10% (far field), depending on humidity
- 10-min-integration

**IMK-IFU, Research Center Karlsruhe, Garmisch-Partenkirchen, Ralf Sussmann**

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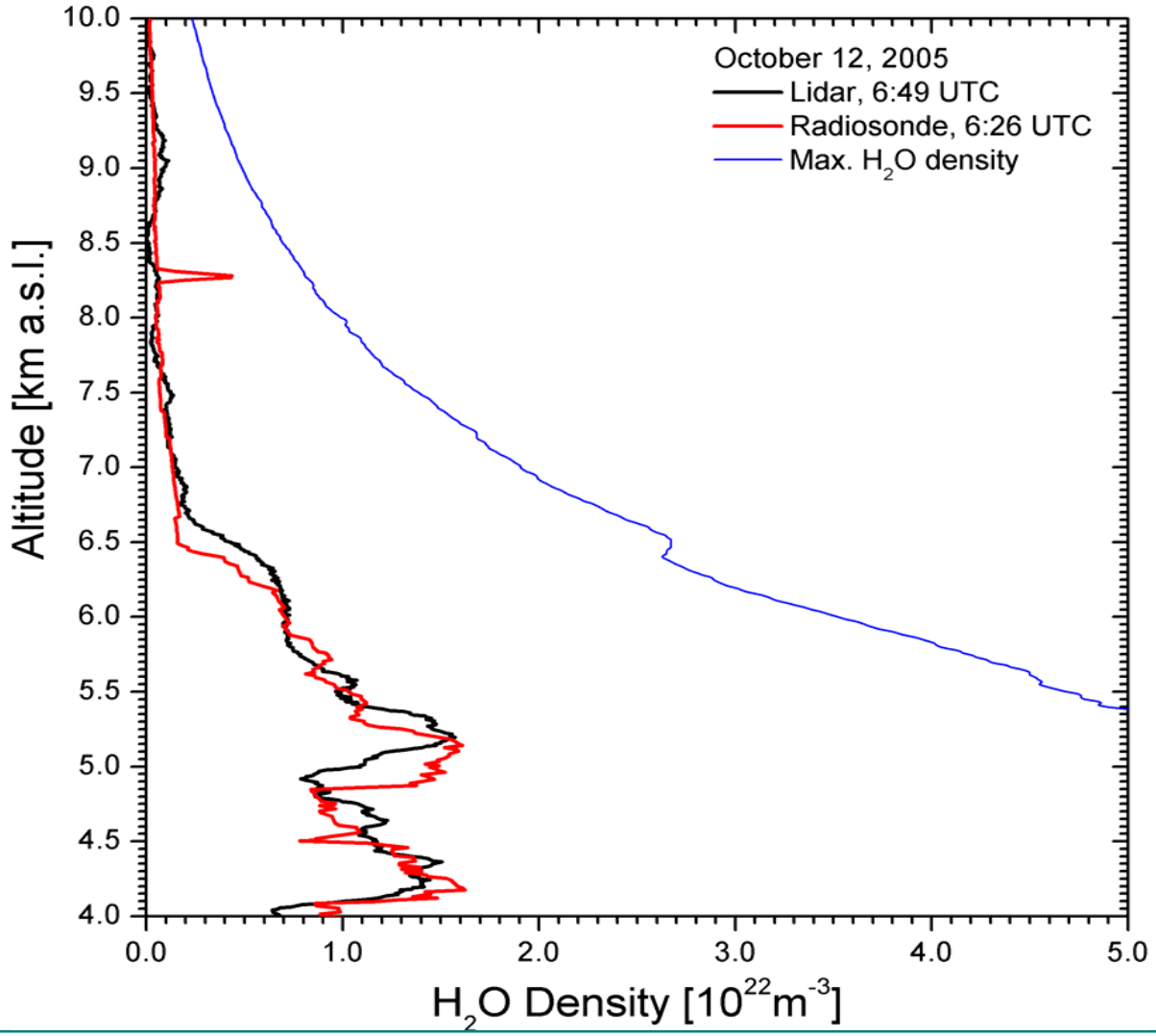
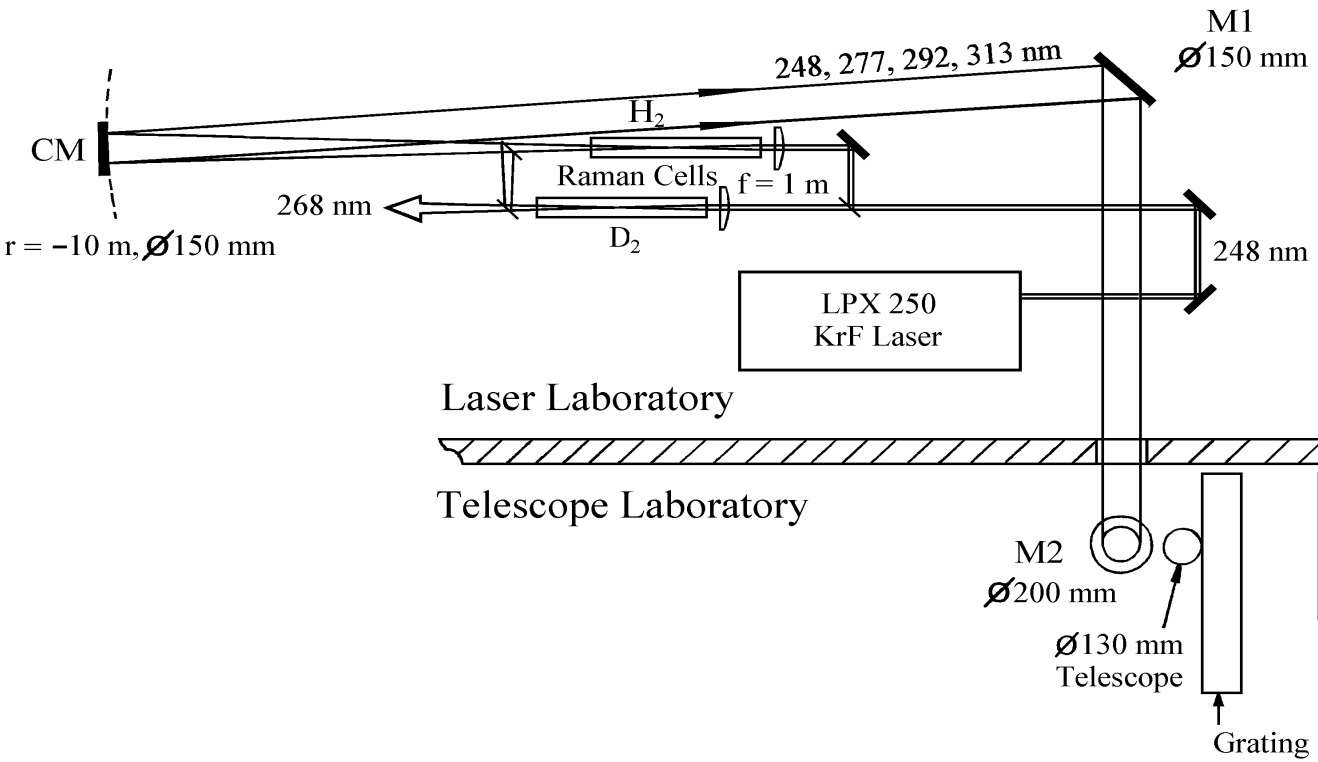
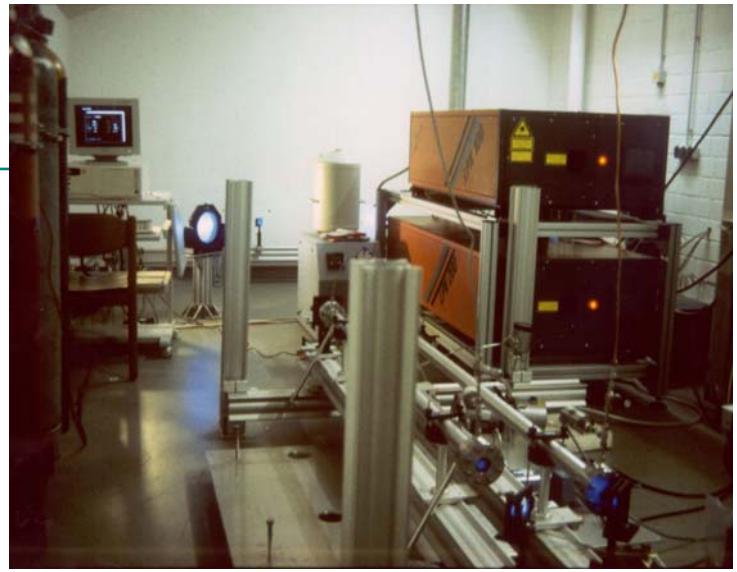
## Water profiles Zugspitze: Validation of lidar with radio sondes




Slight vertical displacement above 4.8 km due to orographic effects

# $O_3$ profiles at Garmisch: Tropospheric $O_3$ lidar



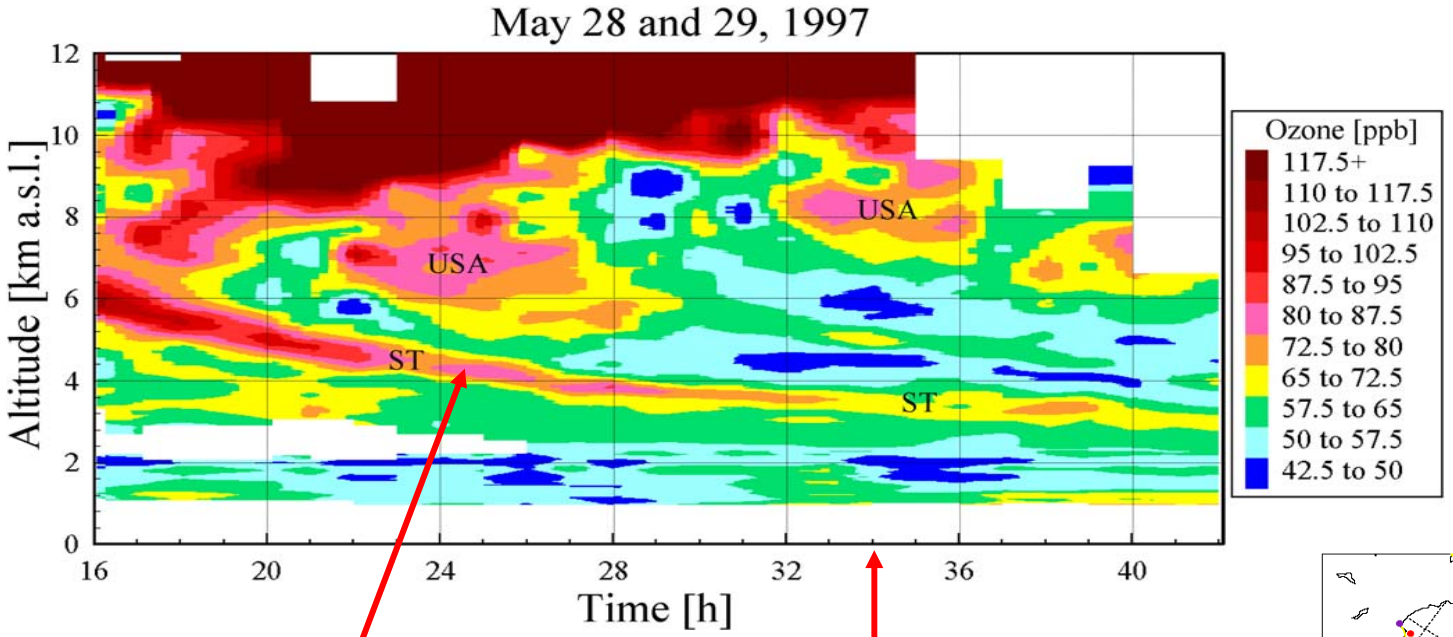
Detectors:
Hamamatsu
H5783P-06
PMTs

Optimized for tropospheric profiling: range up to 16 km

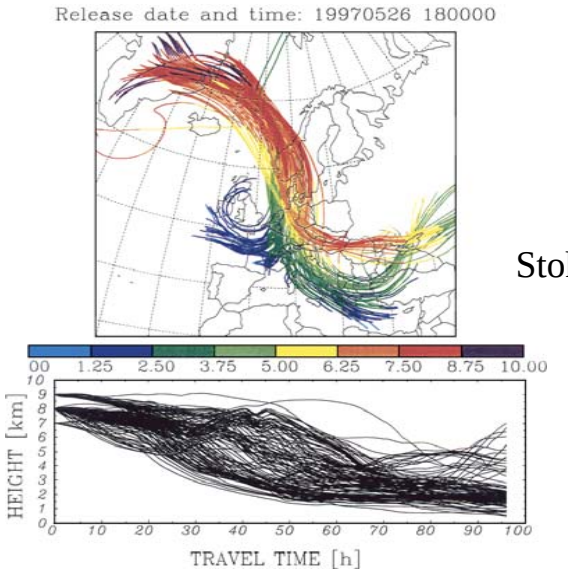
Near-field telescope: 3 analog channels

Far-field telescope: 3 analog channels, 2 photon-counting channels (700 MHz)

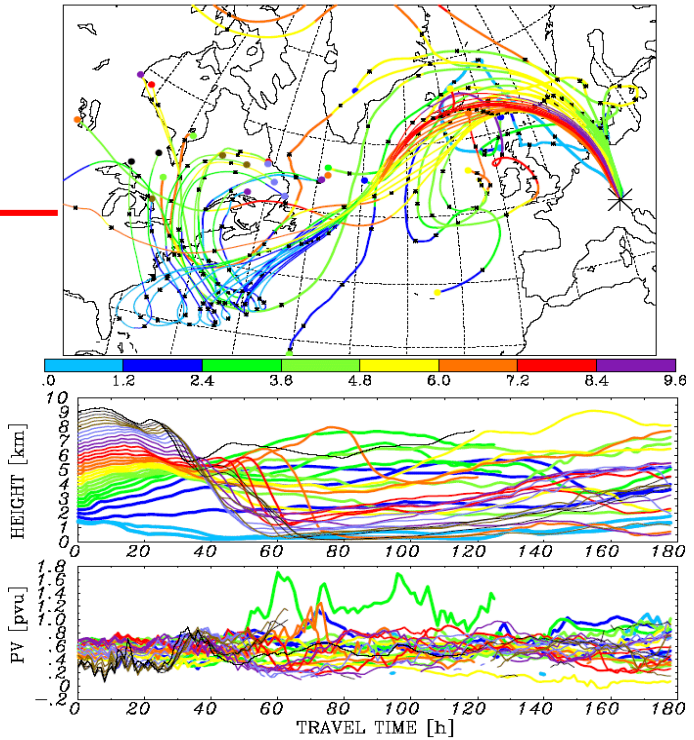
# $O_3$ lidar profiles Garmisch: Stratospere-troposphere and Transatlantic Transport



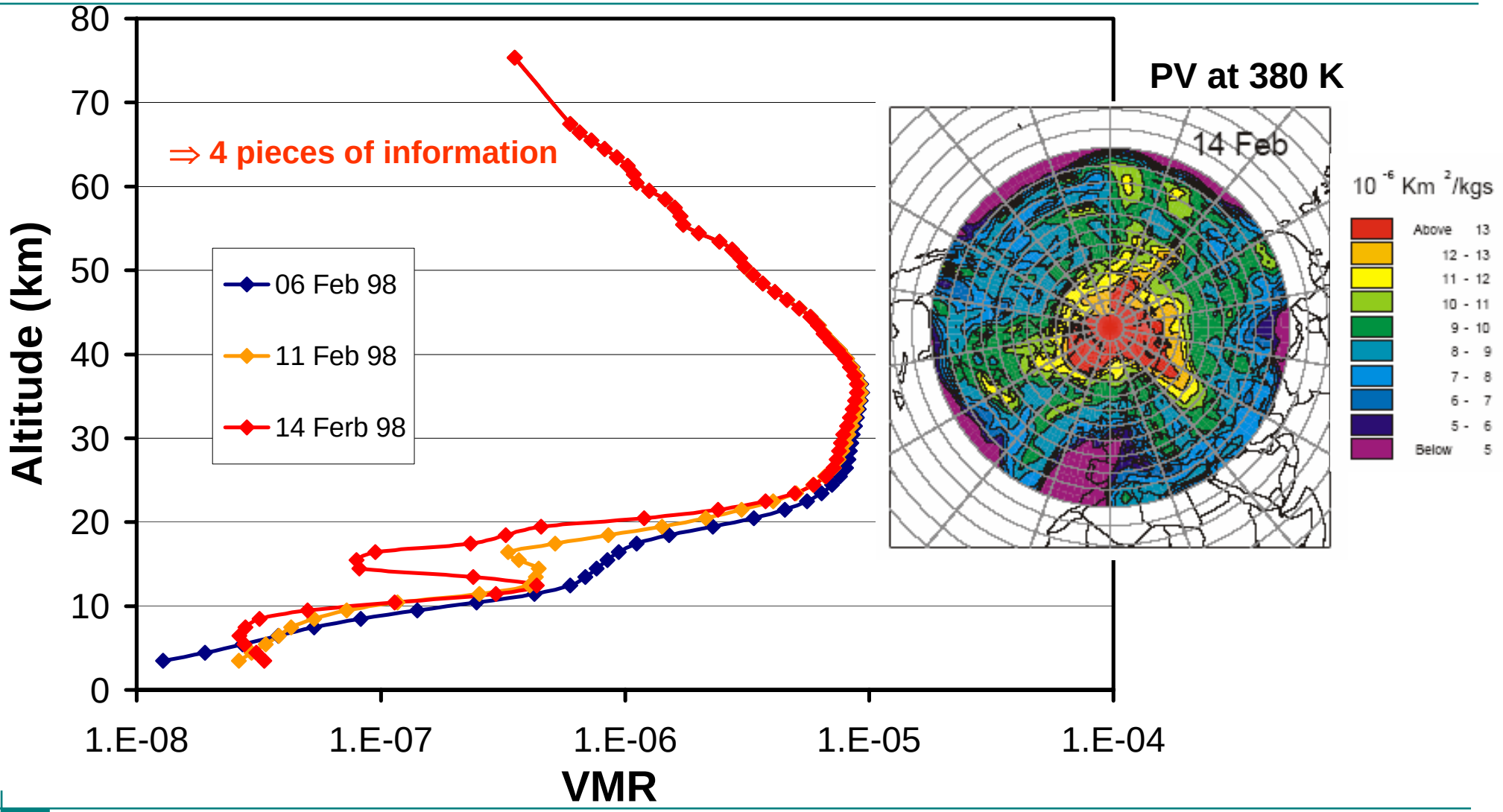

Time series up to four days




Stohl and Trickl, J. Geophys. Res. 1999



# $O_3$ columns/profiles (Zugspitze+Garmisch FTIR): Subtropical intrusion Feb 1998

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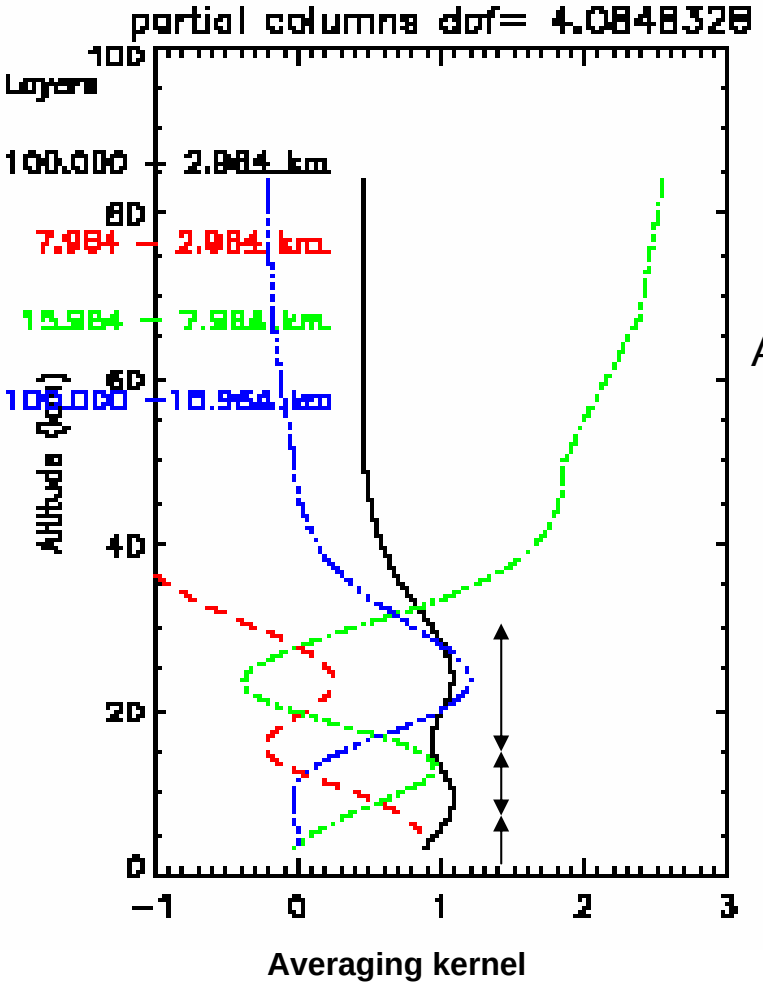
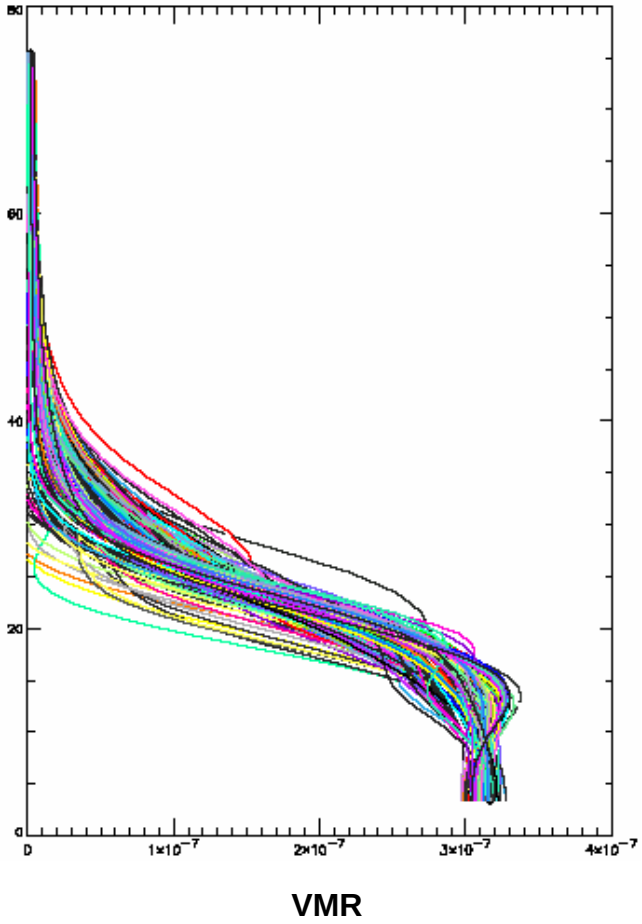
EPS/MetOp validation at Ground-Truthing Center Zugspitze/Garmisch

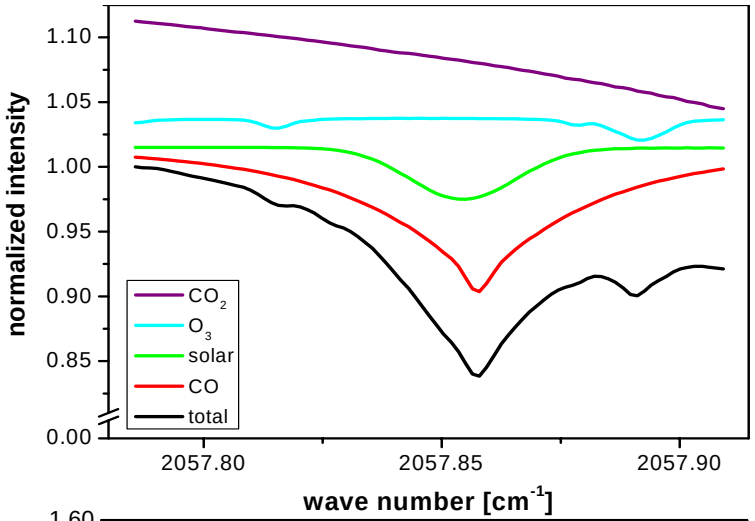
# $N_2O$ profiles Zugspitze+Garmisch FTIR: retrieval

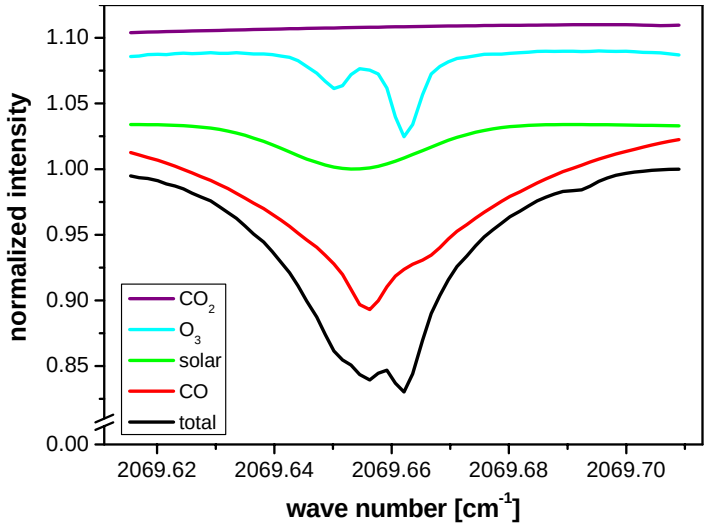


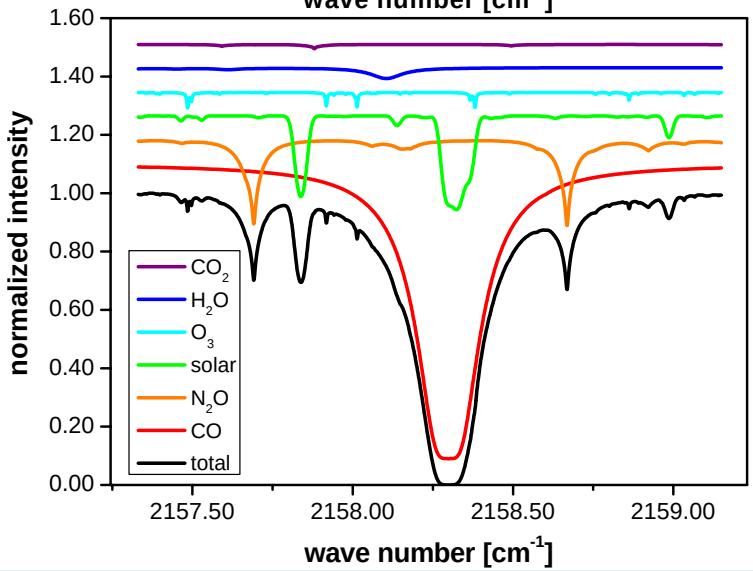

| Altitude: | Dofs: |
|---|---|
| 8.96 km | 1.0598609 |
| 16.96 km | 2.1855644 |
| 25.96 km | 3.2838593 |



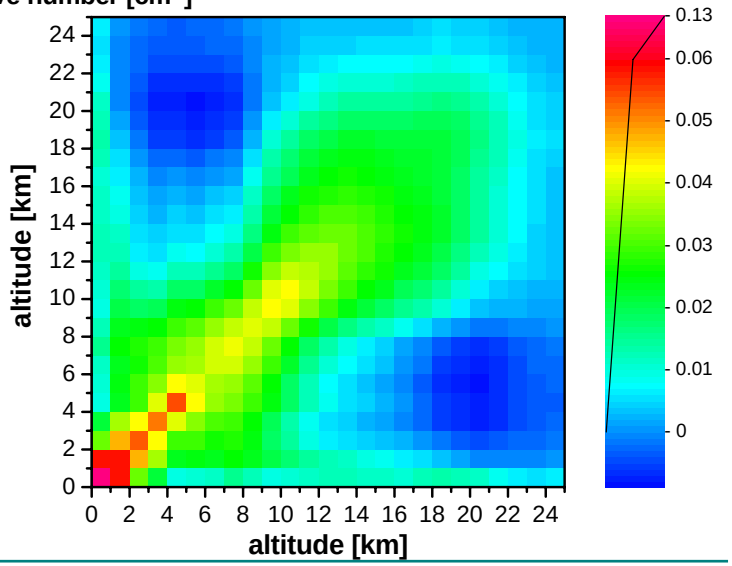
# CO profiles/columns Zugspitze+Garmisch FTIR: retrieval



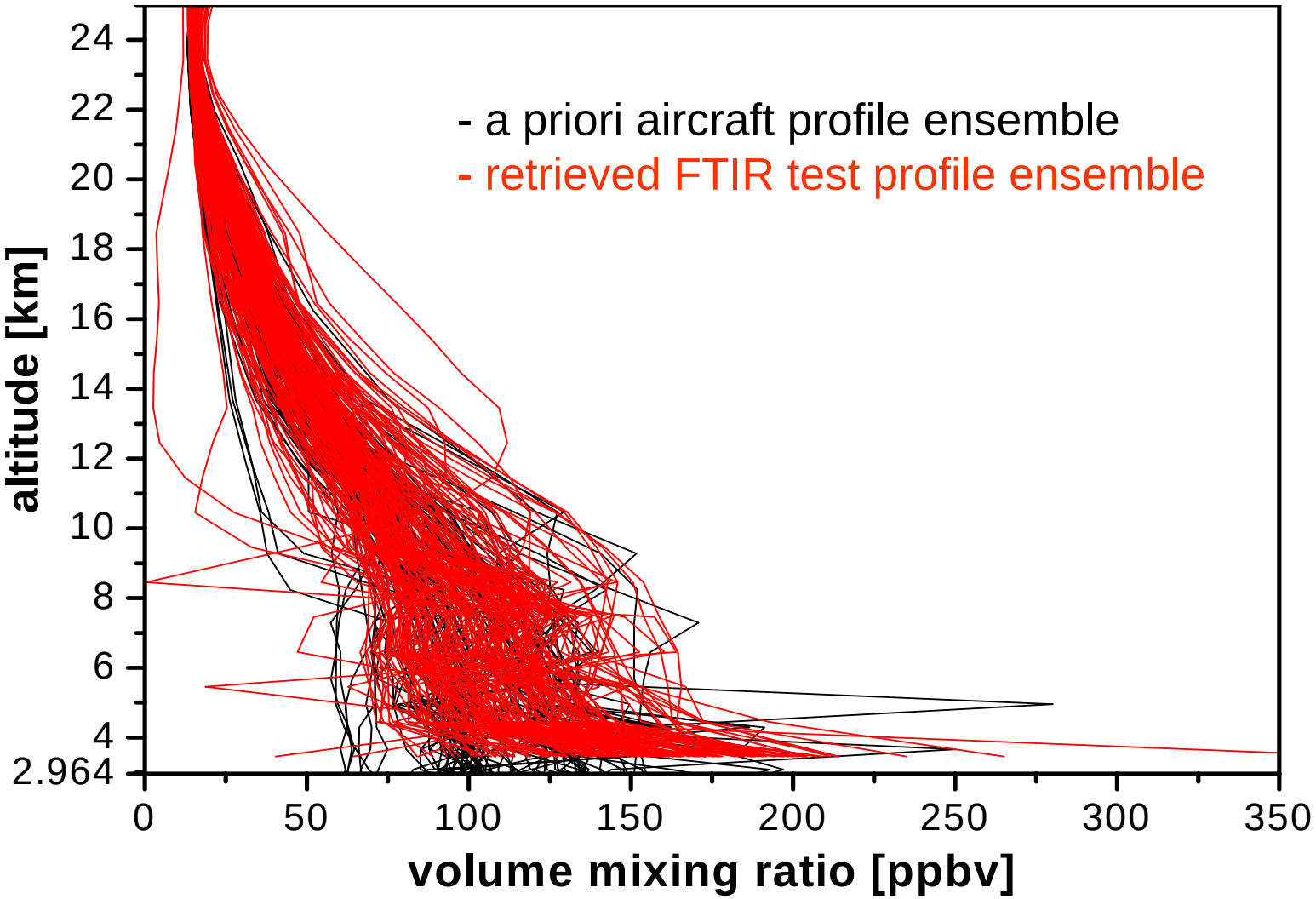

CO a priori covariance



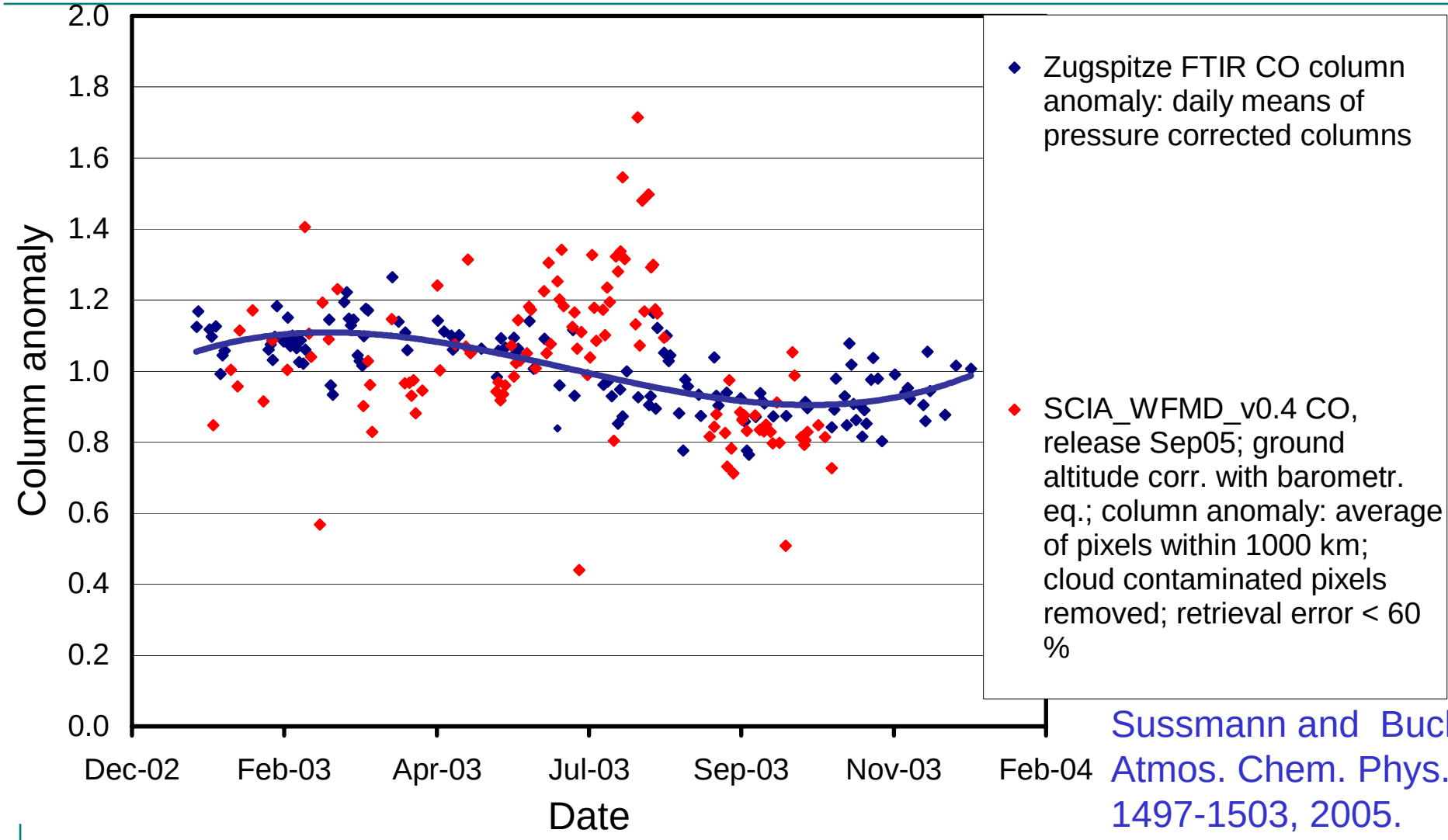

**IMK-IFU, Research Center Karlsruhe, Garmisch-Partenkirchen, Ralf Sussmann**

EPS/MetOp validation at Ground-Truthing Center Zugspitze/Garmisch

## CO profiles Zugspitze+Garmisch FTIR: retrieval



# CO SCIAMACHY validation: by Zugspitze FTIR

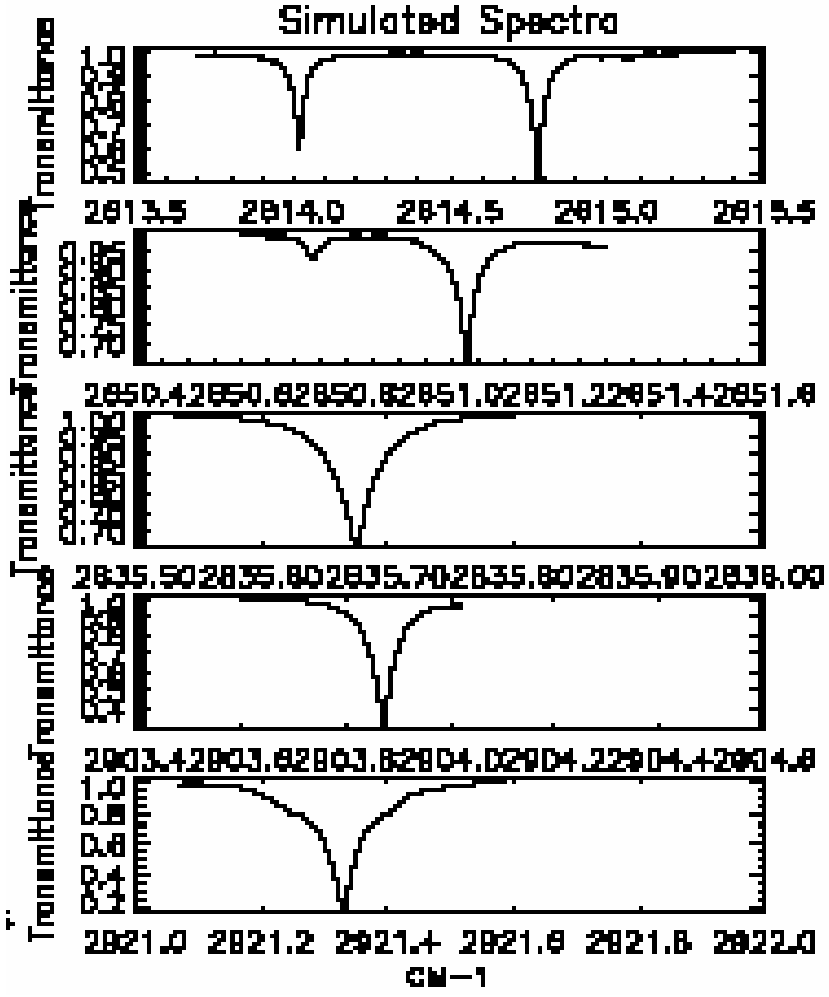


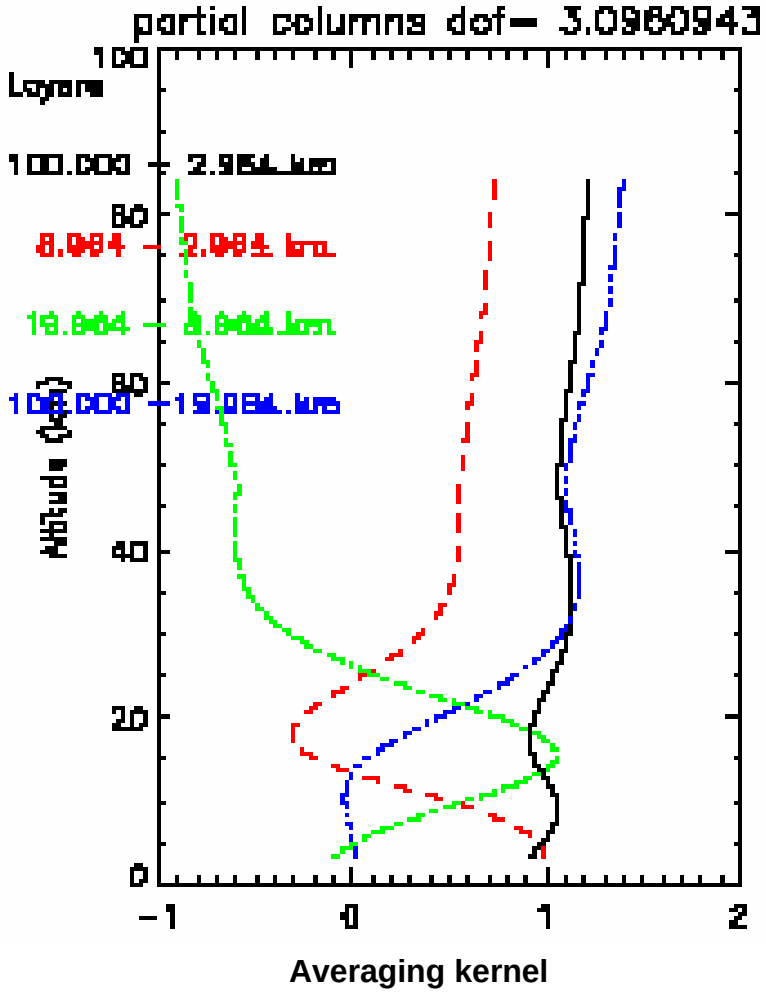

Sussmann and Buchwitz, Atmos. Chem. Phys., 5, 1497-1503, 2005.

**IMK-IFU, Research Center Karlsruhe, Garmisch-Partenkirchen, Ralf Sussmann**

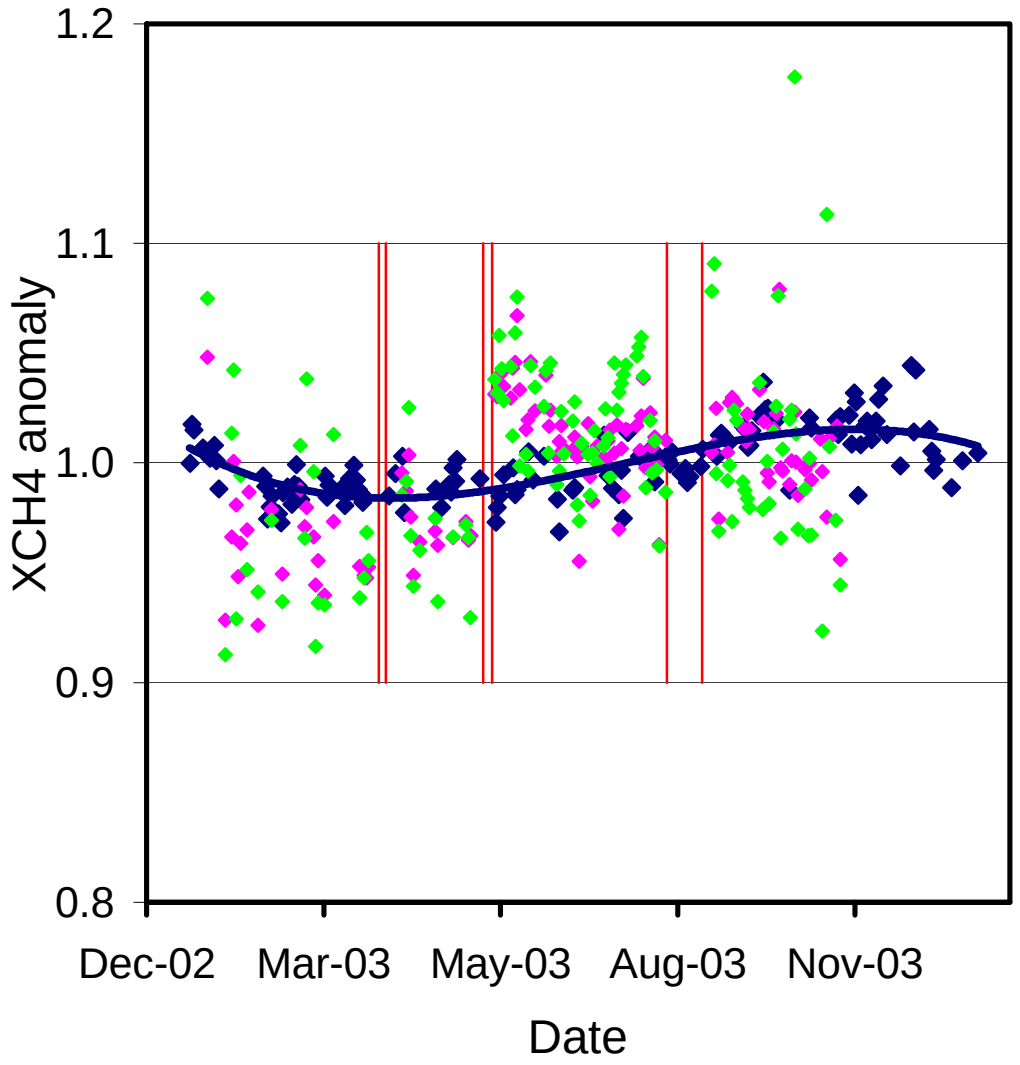
EPS/MetOp validation at Ground-Truthing Center Zugspitze/Garmisch

# $CH_4$ profiles Zugspitze+Garmisch FTIR: retrieval



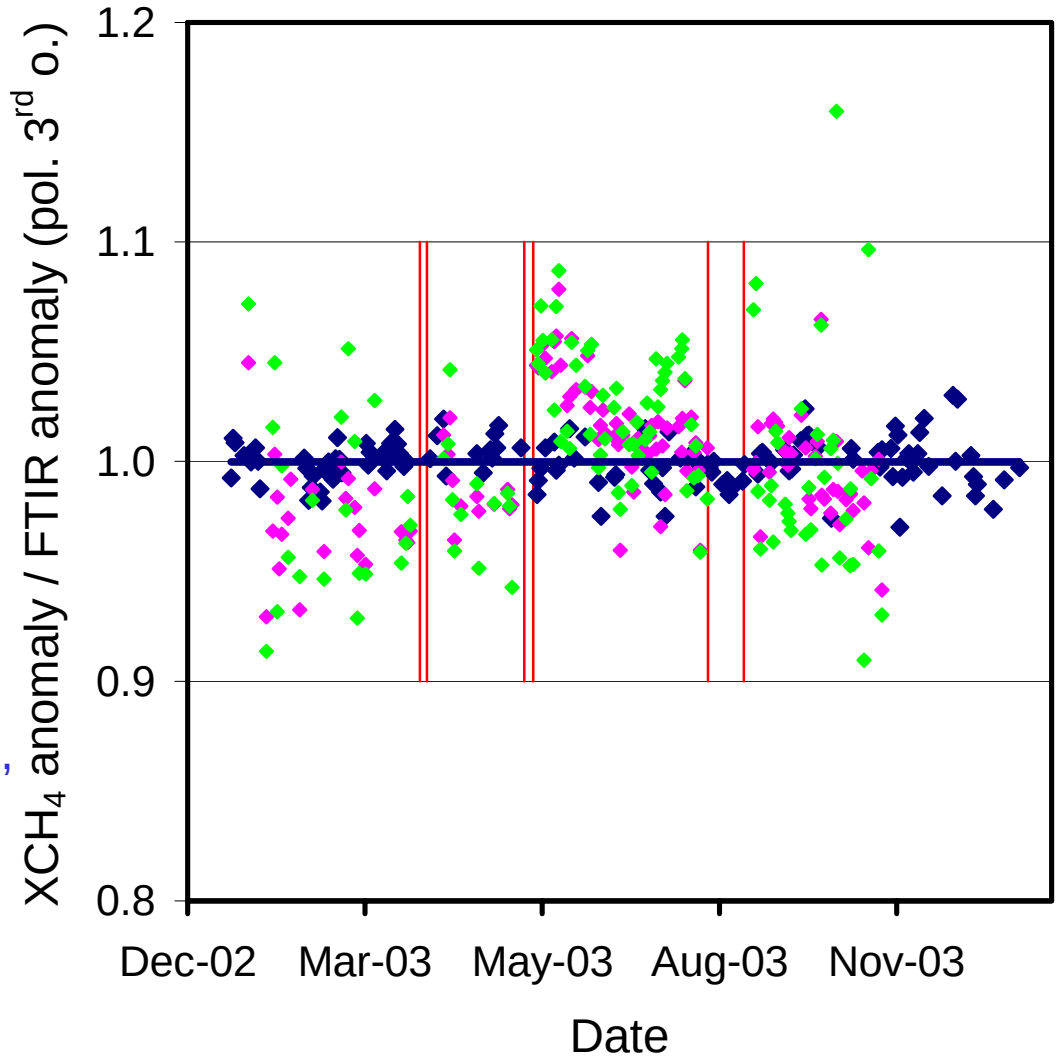
# Validation of SCIAMACHY $XCH_4$: Investigation of time-dependent bias v0.41




**WFMD v0.41, 2000 km**
**WFMD v0.41, 1000 km**
**Zug. FTIR daily means**

Sussmann, Stremme, Buchwitz, de Beek, Atmos. Chem. Phys., 5, 2419-2429, 2005.

# Validation of SCIAMACHY $XCH_4$: Investigation of time-dependent bias v0.41




WFMD v0.41, 2000 km
WFMD v0.41, 1000 km
Zug. FTIR daily means

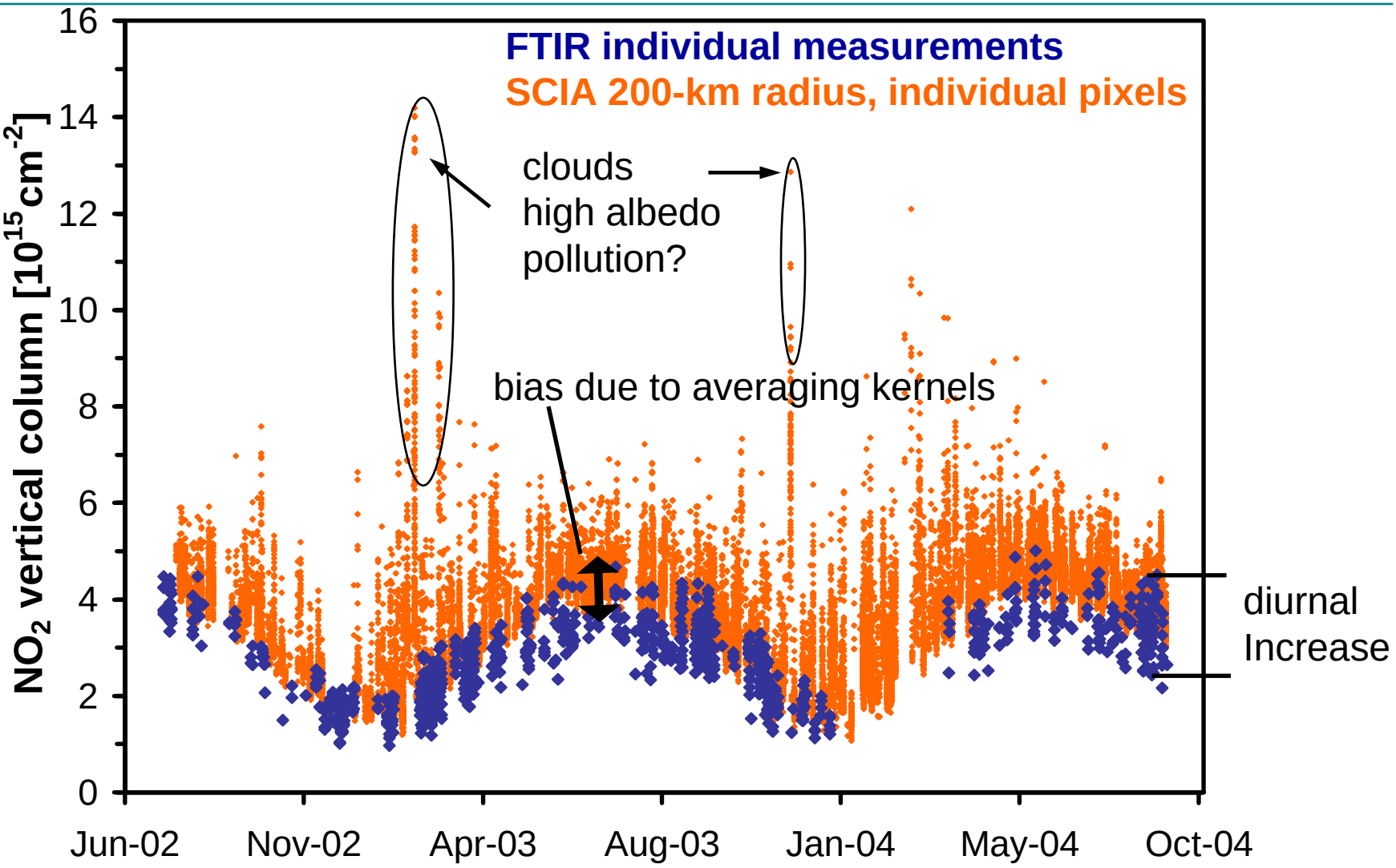
Sussmann, Stremme, Buchwitz, de Beek, Atmos. Chem. Phys., 5, 2419-2429, 2005.

## $XCH_4$ precisions FTIR versus SCIAMACHY: Single measurements, daily mean data

| | $AV_i(n_i)$ | $AV_i(\sigma_i)$ | $AV_i(\sigma_i/sqrt(n_i))$ | $\sigma$ of daily means corrected for ann. cycle |
|---|---|---|---|---|
| Zugspitze FTIR | 12.3 | 1.3 % | 0.4 % | 1.0 % |
| SCIA 2000 | 249 | 5.2 % | 0.3 % | 2.4 % |
| SCIA 1000 | 85 | 5.4 % | 0.6 % | 2.7 % |

Sussmann, Stremme, Buchwitz, de Beek,
Atmos. Chem. Phys., 5, 2419-2429, 2005.

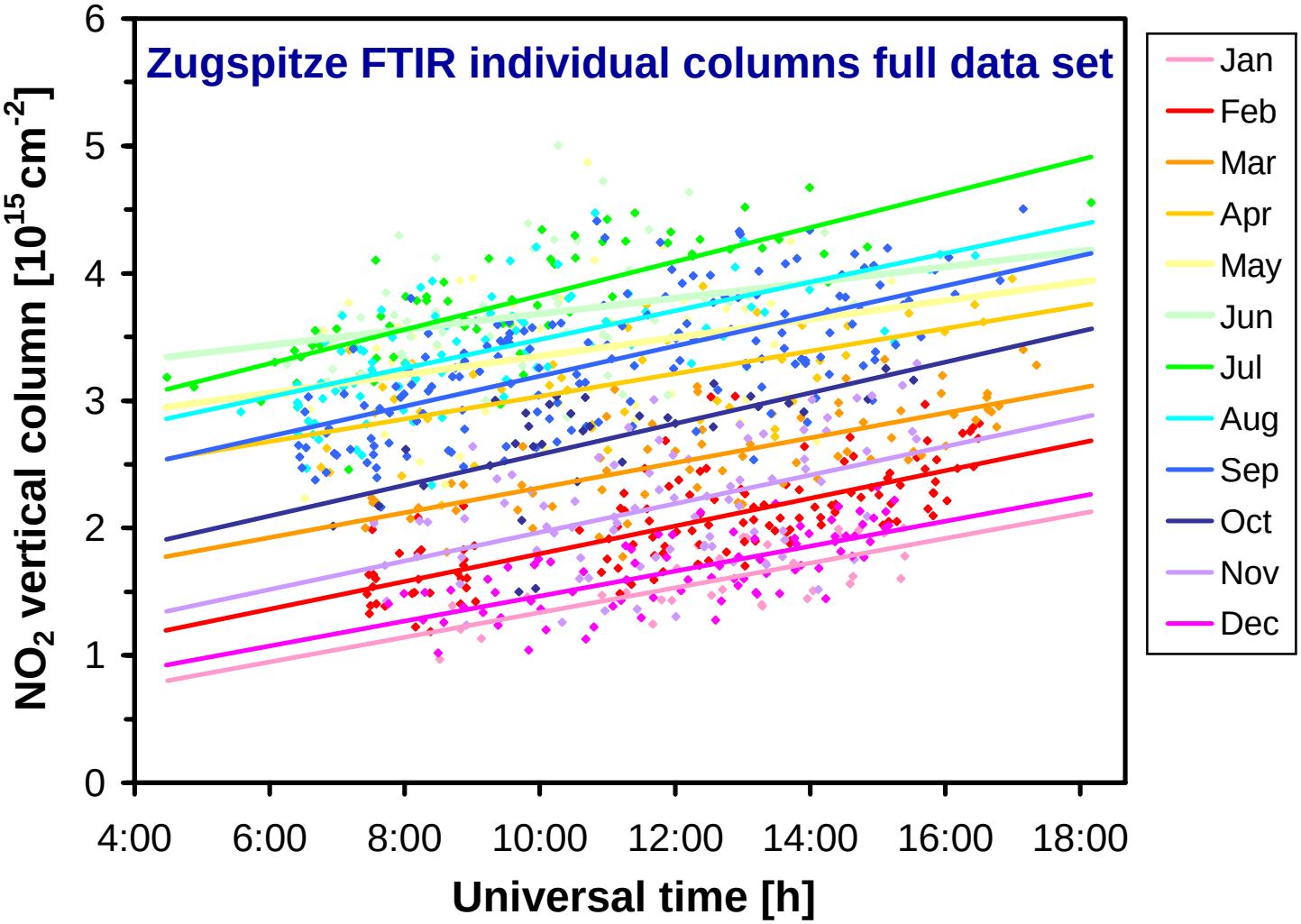
# Total $NO_2$: Validation of SCIAMACHY versus Zugspitze FTIR



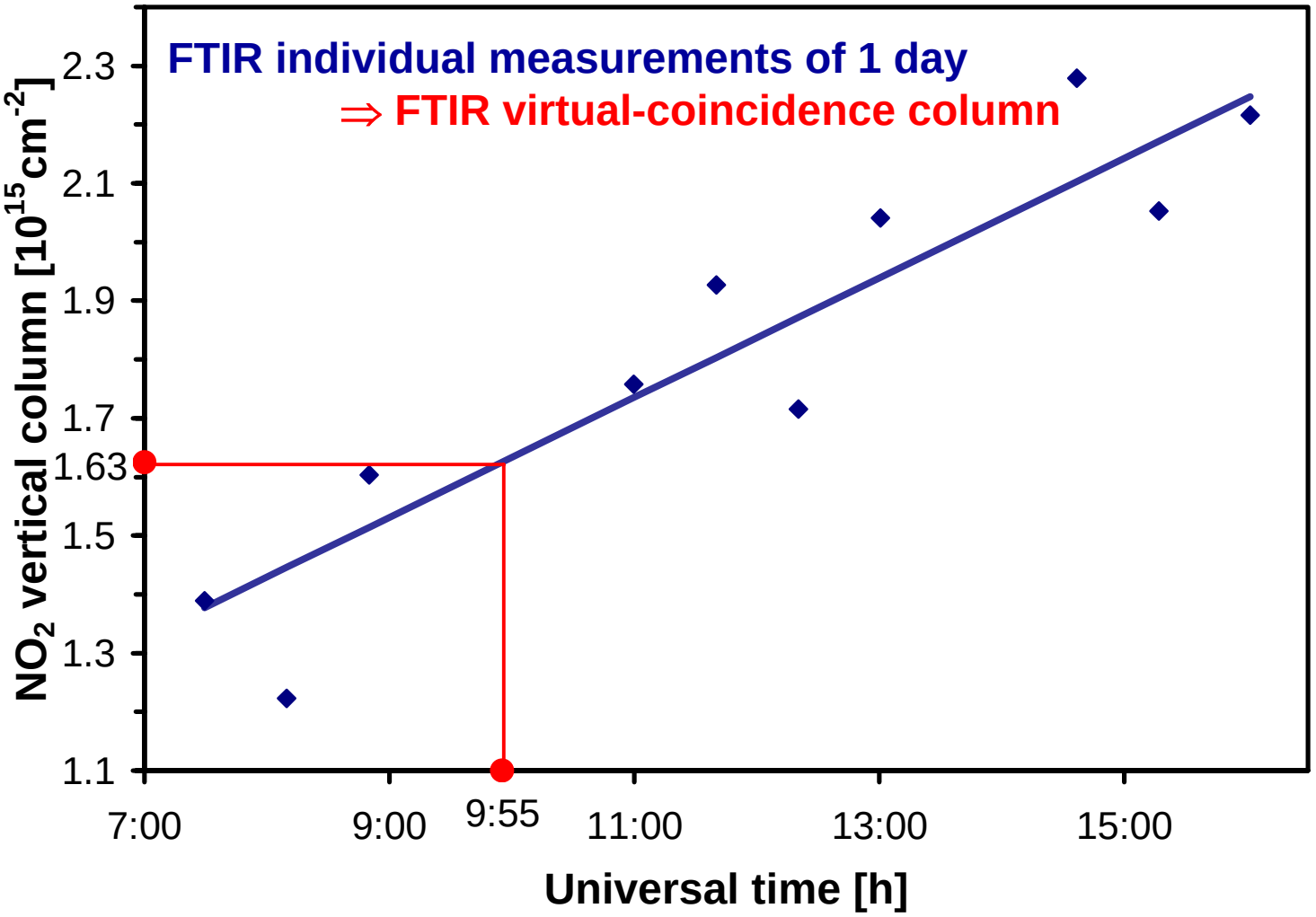
# Total $NO_2$: Matching FTIR to satellite overpasses - diurnal increasing rate

**⇒ Mean diurnal increasing rate for mid-latitudes = + 1.02(6)E+14 $cm^{-2}/h$**

**Sussmann, Stremme, Burrows, Richter, Seiler, and Rettinger, Atmos. Chem. Phys., 5, 2657-2677, 2005.**



## Total $NO_2$: Matching FTIR to satellite - concept of „virtual coincidences“




Sussmann, Stremme, Burrows, Richter, Seiler, and Rettinger, Atmos. Chem. Phys., 5, 2657-2677, 2005.

## $NO_2$ pecisions FTIR versus SCIAMACHY: Single measurements, daily mean data

| | $AV_i(n_i)$ | $AV_i(\sigma_i)$ | $AV_i(\sigma_i/sqrt(n_i))$ | $\sigma$ of daily means corrected for annual cycle |
|---|---|---|---|---|
| Zugspitze FTIR | 4.6 | 8.8 % | 4.3 % | 9.2 % |
| SCIAMACHY (200 km, poll. corr.) | 22 | 6.8 % | 1.9 % | 6.5 % |

**Sussmann, Stremme, Burrows, Richter, Seiler, and Rettinger, Atmos. Chem. Phys., 5, 2657-2677, 2005.**

## Summary/Outlook (I): IASI and GOME II validation at Zugspitze/Garmisch

Profiles

$H_2O$, $O_3$, CO, $N_2O$, $CH_4$

Columns

$H_2O$, $O_3$, $NO_2$, $N_2O$, CO, $CO_2$, $CH_4$

Special options

- „higher order“ products for $H_2O$, $O_3$: both optimum profile+column information via coincident lidar+FTIR
- Garmisch-Zugspitze „differential FTIR“
- trop. mixing ratios via NIR $CH_4/O_2$ and $CO_2/O_2$ monitoring

## Summary/Outlook (II): IASI and GOME II validation at Zugspitze/Garmisch

Activities with own funding:

- available routine measurements (science oriented)
- selected validation case studies (science-interest driven)

Funded option: operational 6 months + 1 year campaign?

- dedicated correlative measurements (overpass ± 2h)
- providing formatted correlative data to database
- systematic validation studies for all species

⇒ Remote sounding:

12 PM (Scientist)

⇒ Optional PTU-soundings:

230 soundings

rent/buy dual sonde receiver

12 PM (Engineer)