

IMK-IFU Working Group
„Variability and Trends“

Head

R. Sussmann (FTIR)

Scientists

H.E. Scheel (in situ)

T. Trickl (lidar)

H. Vogelmann (lidar)

P. Werle (UV)

Engineers

H. Giehl

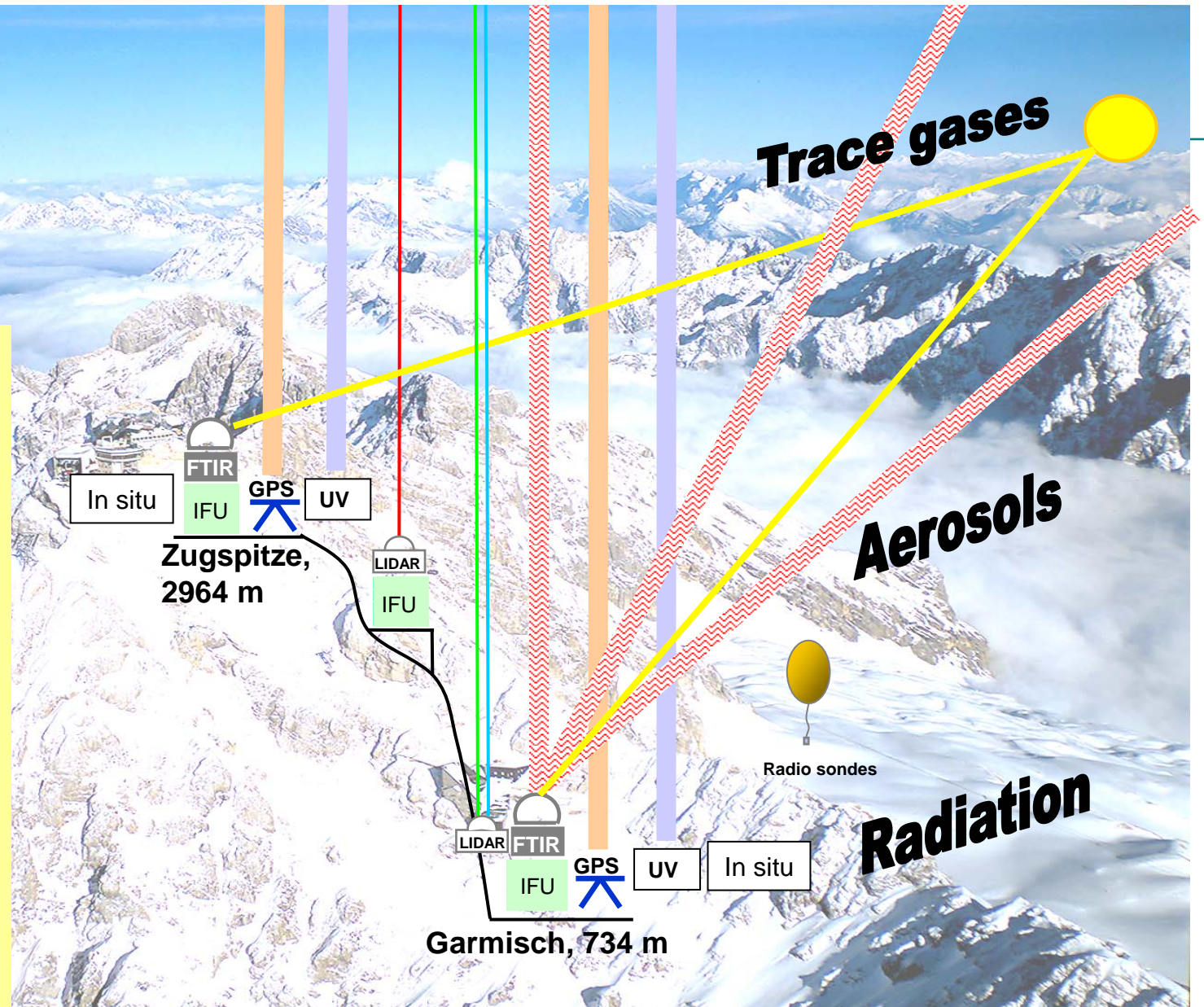
M. Rettinger

A. Rockmann

PhD students

W. Stremme

T. Borsdorff



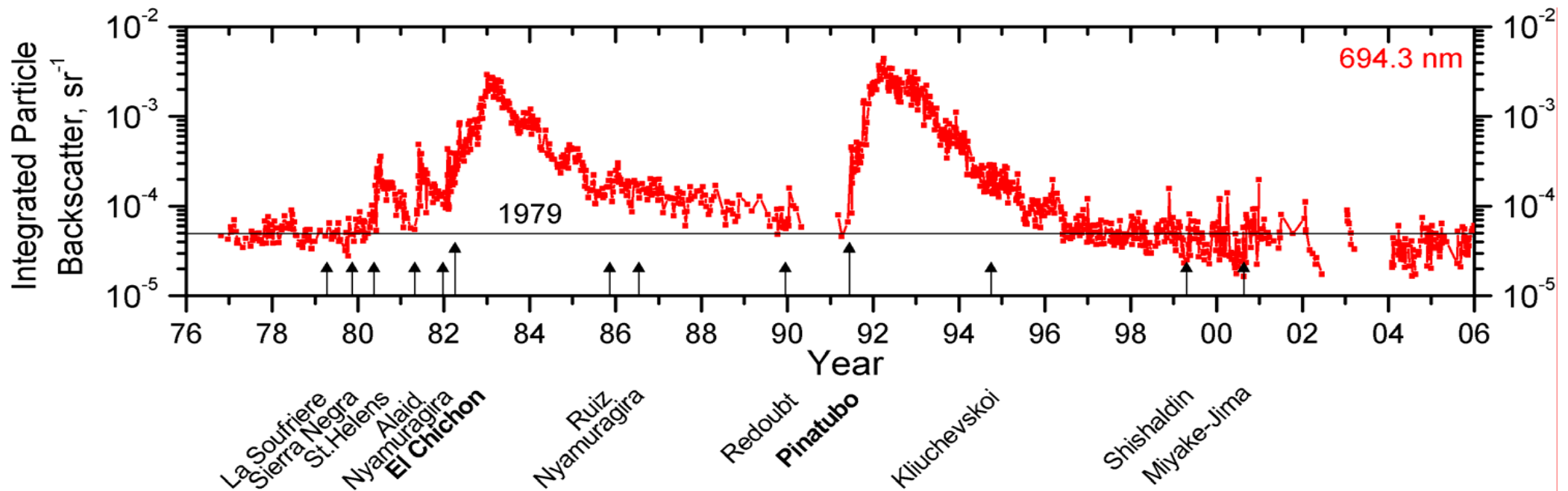
Research Center Karlsruhe

Ralf Sussmann

IMK-IFU Garmisch-Partenkirchen

Zugspitze/Garmisch Primary Site Report

Aerosol Lidar at Garmisch-Partenkirchen - Thomas Trickl (PI), Helmut Giehl (engineer)



Archiving status: Until 2005 complete

Research: 2 summary papers [Jäger, 2005; Deshler et al., 2006]

In preparation: publication(s) on the impact of strong forest fires in the lower stratosphere

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Zugspitze/Garmisch Primary Site Report

Measurement of solar UV radiation at the Zugspitze - Peter Werle, PI

NDACC-related target parameters measured routinely: Spectral UV irradiance (280-420 nm in 0.25 nm steps)

Data archiving at NDACC DHF:

- UV-A
- UV-B
- erythemat UV
- DNA-weighted UV
- generalized Plant

Main ancillary data measured:

- total irradiance,
- direct irradiance,
- erythemally weighted irradiance,
- Illuminance,
- temperature, humidity, ...
- sunshine indicator &
- cloud coverage from TSI system

(at 5 minutes sampling intervals)

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Institute for Meteorology and Climate Research

Radiation Measurements

NDSC Station Zugspitze

47,42° N / 10,98° E / 2964m asl

Online Data Running STOP

07:37:58 UTC 30.06.2006

09:37:58 local DST update in 0 sec

Realtime Data

2,6	MED/h	Robertson-Berger
89,2	kLux	Luxmeter
6,1	°C	Temperature ambient
71,7	%	rel. Humidity ambient
20,7	°C	Air Condition 20 ± 2 °C
31,8	%	rel. Humidity
0,0	V	Luxmeter @ Calibration
874	W/m ²	total global irradiance
373	W/m ²	Pyrheliometer (direct)
240	W/m ²	total direct irradiance
634	W/m ²	total diffuse irradiance
40	°	solar elevation > 5 °
99	°	solar azimuth
0,38	direct / diffuse	total irradiance
0,27	direct / global	<div style="width: 20px; height: 10px; background: linear-gradient(to right, blue, gray); border: 1px solid gray;"></div> %

Notify : Peter.Werle@imk.fzk.de

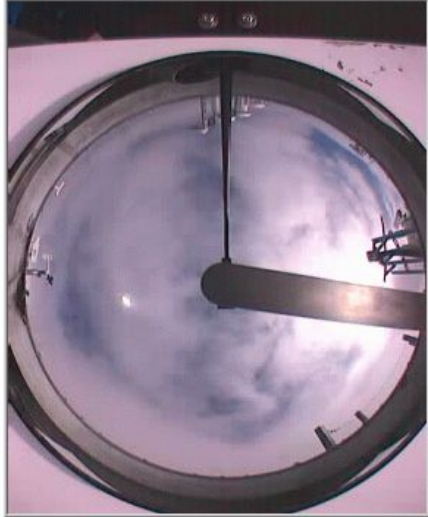
Data from Total Sky Imager

Locked	Cloud Camera	09:36:00
-119	sec offset	06/30/2006
100	%	cloud cover
100	%	opaque
0	%	thin
OK	Sunshine Indicator	
40	°	solar elevation
98	°	solar azimuth

Temperature Control / Air Condition

OK	Sensor global	
OK	Sensor direct	
OK	Fiber global	
OK	Fiber direct	
27,7	°C	Air Condition
24,7	°C	Spectra Module
32,4	°C	Bentham Electronics
24,1	°C	Computer Power Supply

ONLINE Sending 16



Log File START 22.06.06 12:06:24

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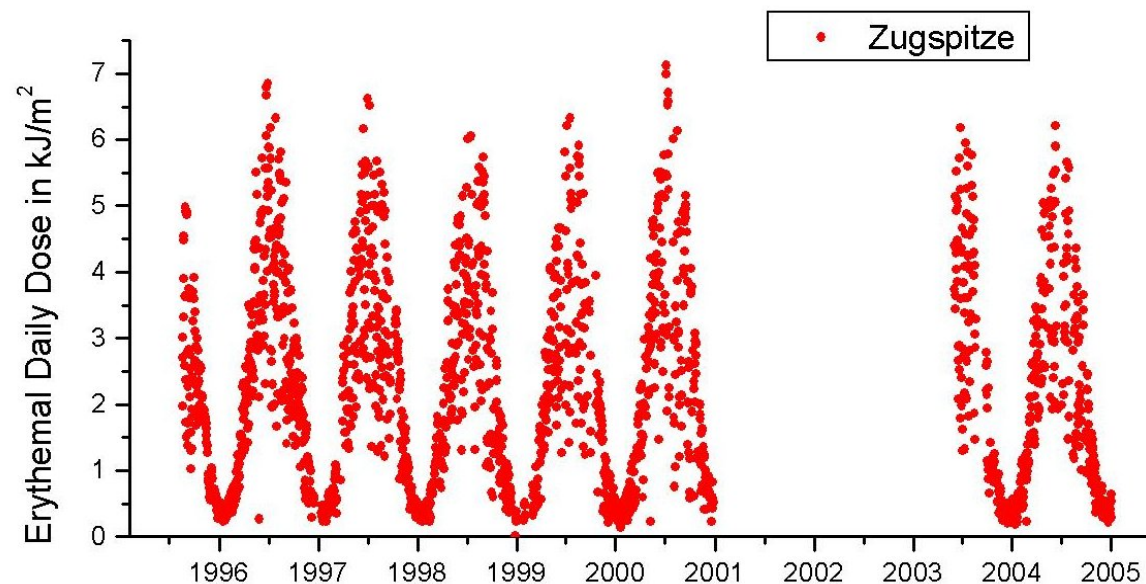
Zugspitze/Garmisch Primary Site Report

Measurement of solar UV radiation at the Zugspitze

Periods covered in data archiving at NDACC DHF: 1995 – 2001 & 2003 - 2004

Last archiving date: 10/2005

Erythemal
Daily Dose



Number of measurement days during past 12 months:

09/05 : 23; 10/05 : 24; 11/05 : 30; 12/05 : 31; 01/06 : 29; 02/06 : 28; 03/06 :
31; 04/06 : 30; 05/06 : 31; 06/06 : 26; 07/06 : 28; 08/06 : 28;

Next anticipated archiving date: IV/2006

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Zugspitze/Garmisch Primary Site Report

Zugspitze FTIR

Ralf Sussmann, PI

Markus Rettinger (engineer)

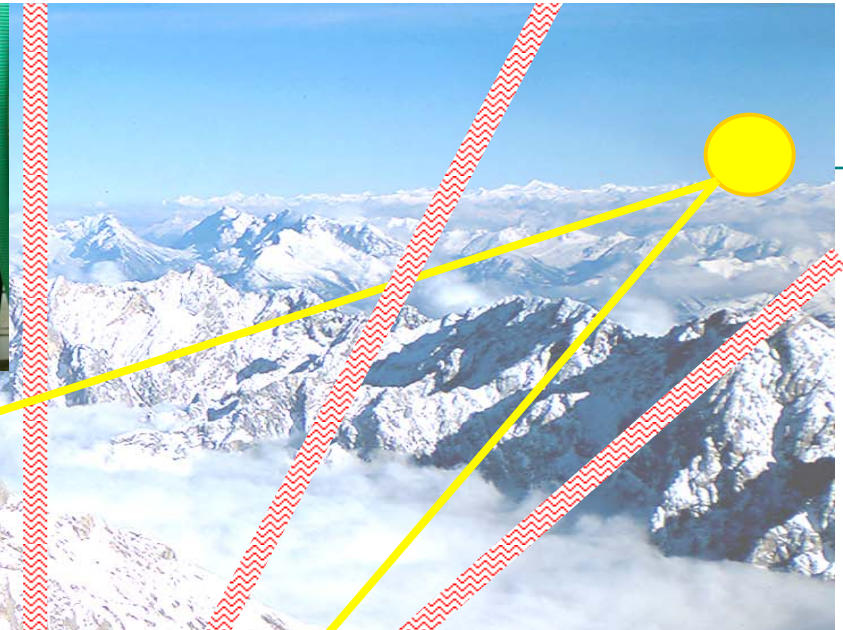
Alexander Rockmann (engineer)

Wolfgang Stremme (PhD student)

Tobias Borsdorff (PhD student)



FTIR



Zugspitze operational since 1995
typ. 130 measurement
days per year

O₃, ClONO₂, HCl, HF,
COF₂, HNO₃, NO₂,
CO, CH₄, N₂O, C₂H₆,
CFC-22, H₂O

FTIR
IFU

Zugspitze
2964 m

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

“Differential FTIR”
with Zugspitze:
O₃, CO, CH₄, N₂O,
C₂H₆, CFC-22, H₂O

CH₄/O₂, CO₂/O₂

FTIR
IFU

Garmisch
734 m



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Zugspitze/Garmisch

Primary Site Report: **Zugspitze FTIR**

Period(s) covered in data archiving at NDACC DHF: 1995-2005

HF columns: 03/1995 - 08/2005

HCl columns: 06/1995 - 11/2001

ClONO₂ columns: 07/1996 - 11/2001

O₃ columns: 07/1995 - 09/2004

N₂O columns: 07/1995 - 09/2004

CH₄ columns: 03/1995 - 09/2004

CO columns: 06/1995 - 08/2005

C₂H₆ columns: 06/1995 - 09/2004

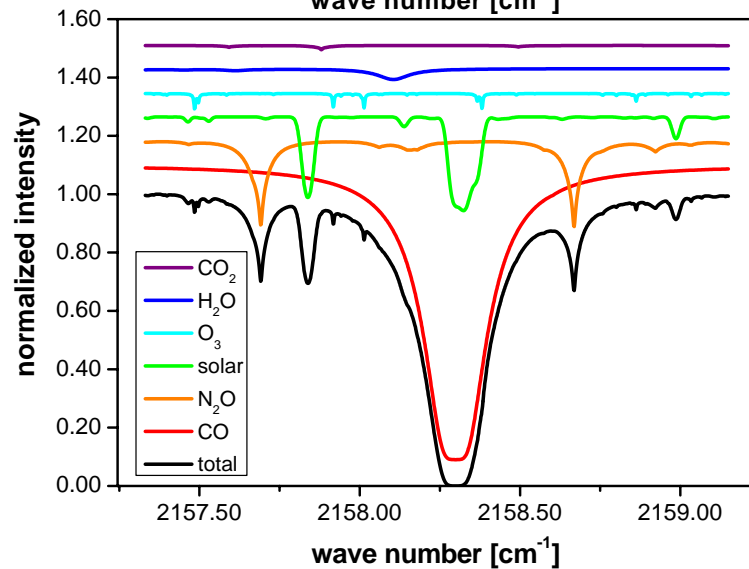
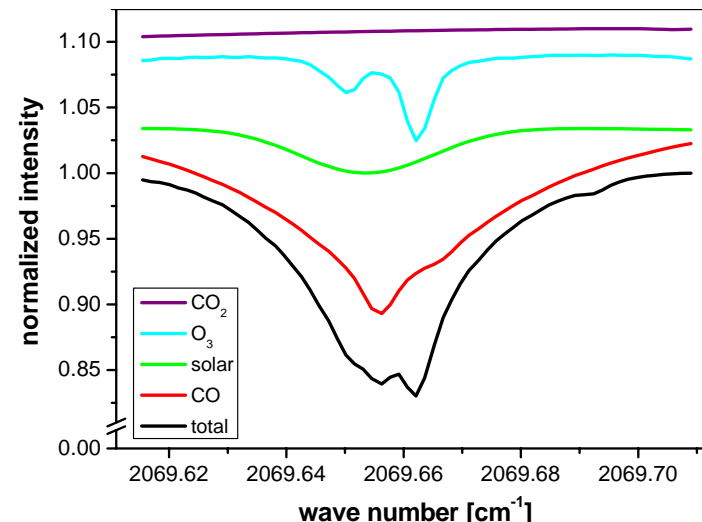
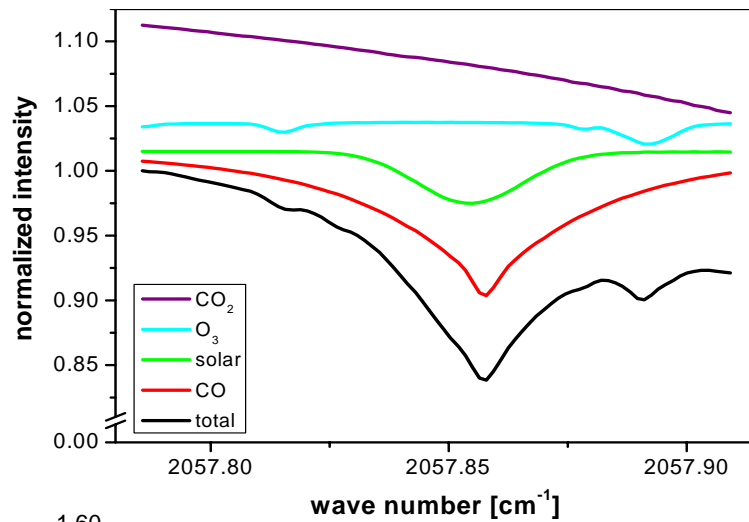
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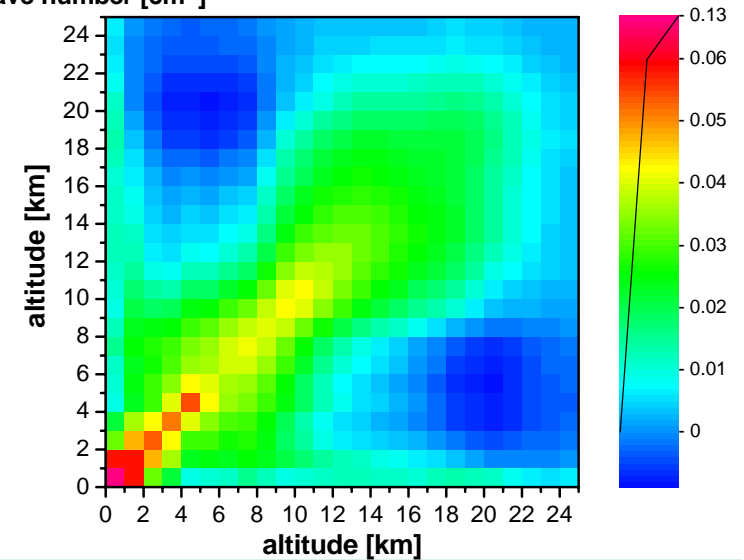
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Zugspitze/Garmisch Primary Site Report

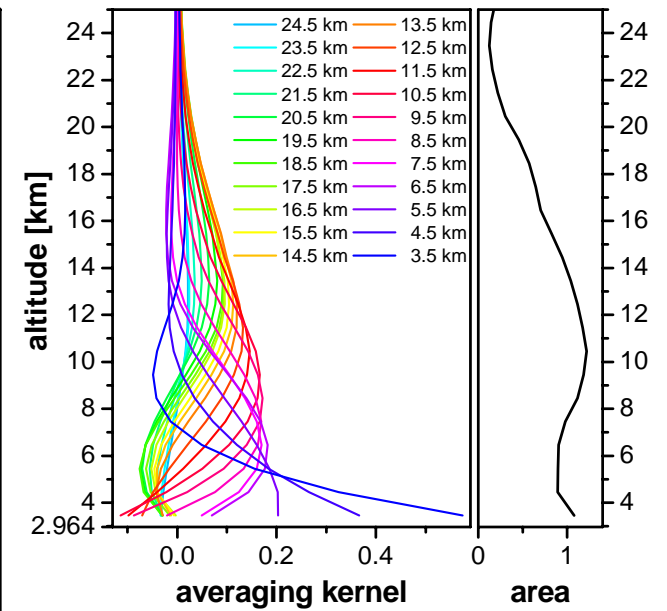
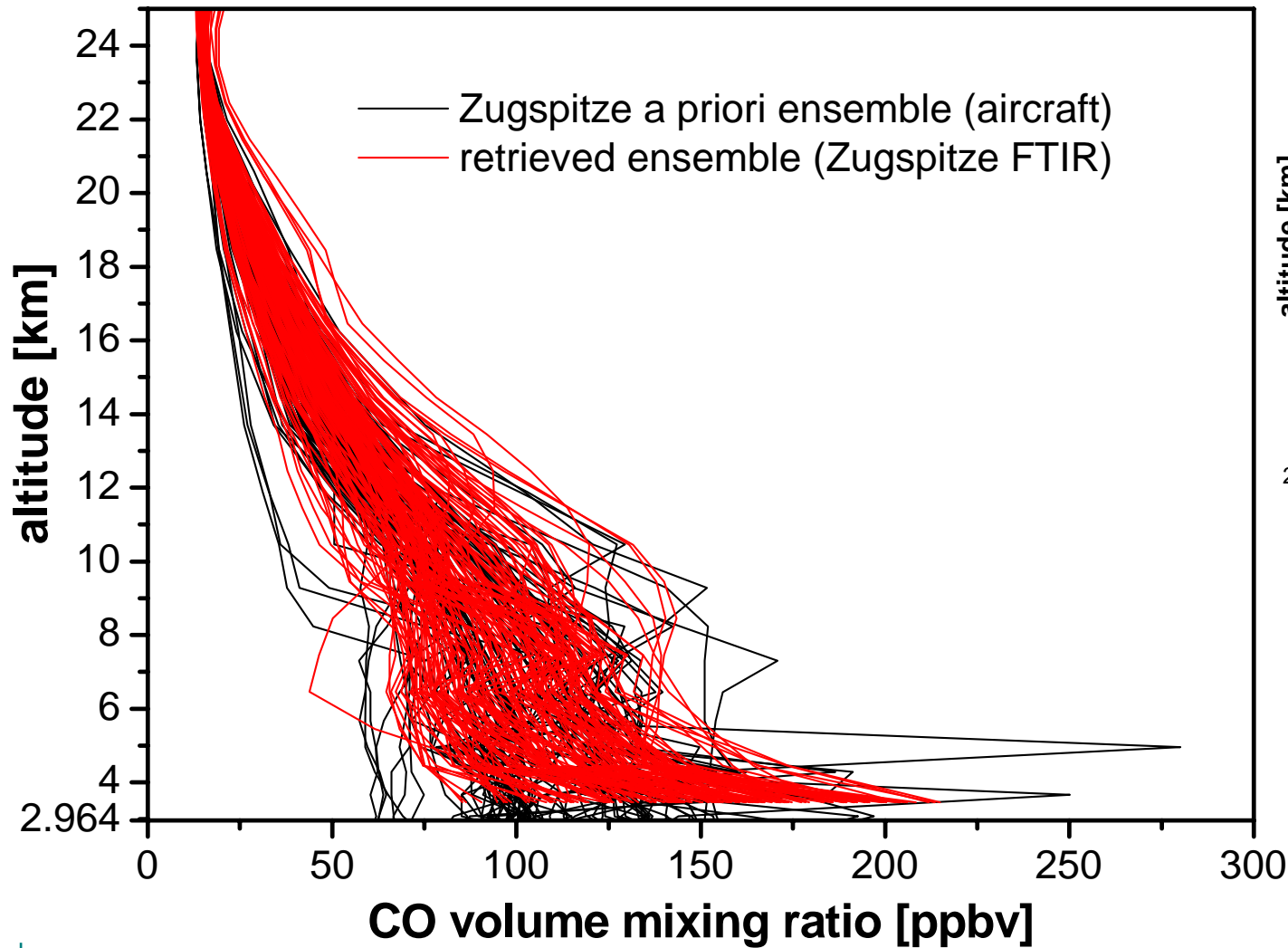
CO profiles/columns Zugspitze+Garmisch FTIR: retrieval



CO a priori covariance



CO profiles Zugspitze+Garmisch FTIR: retrieval



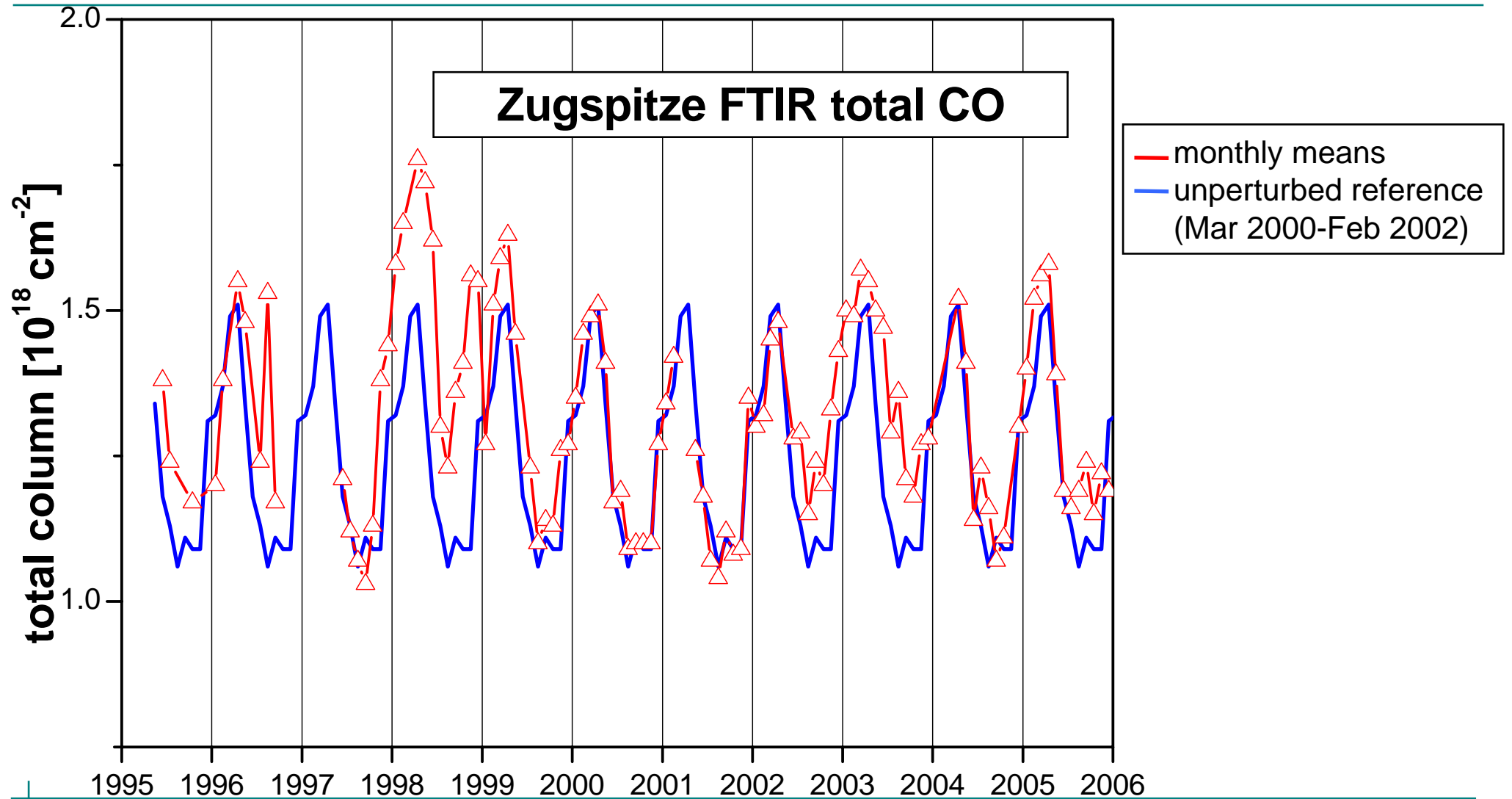
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Zugspitze/Garmisch Primary Site Report

FTIR-Archiving: e.g., Zugspitze CO series



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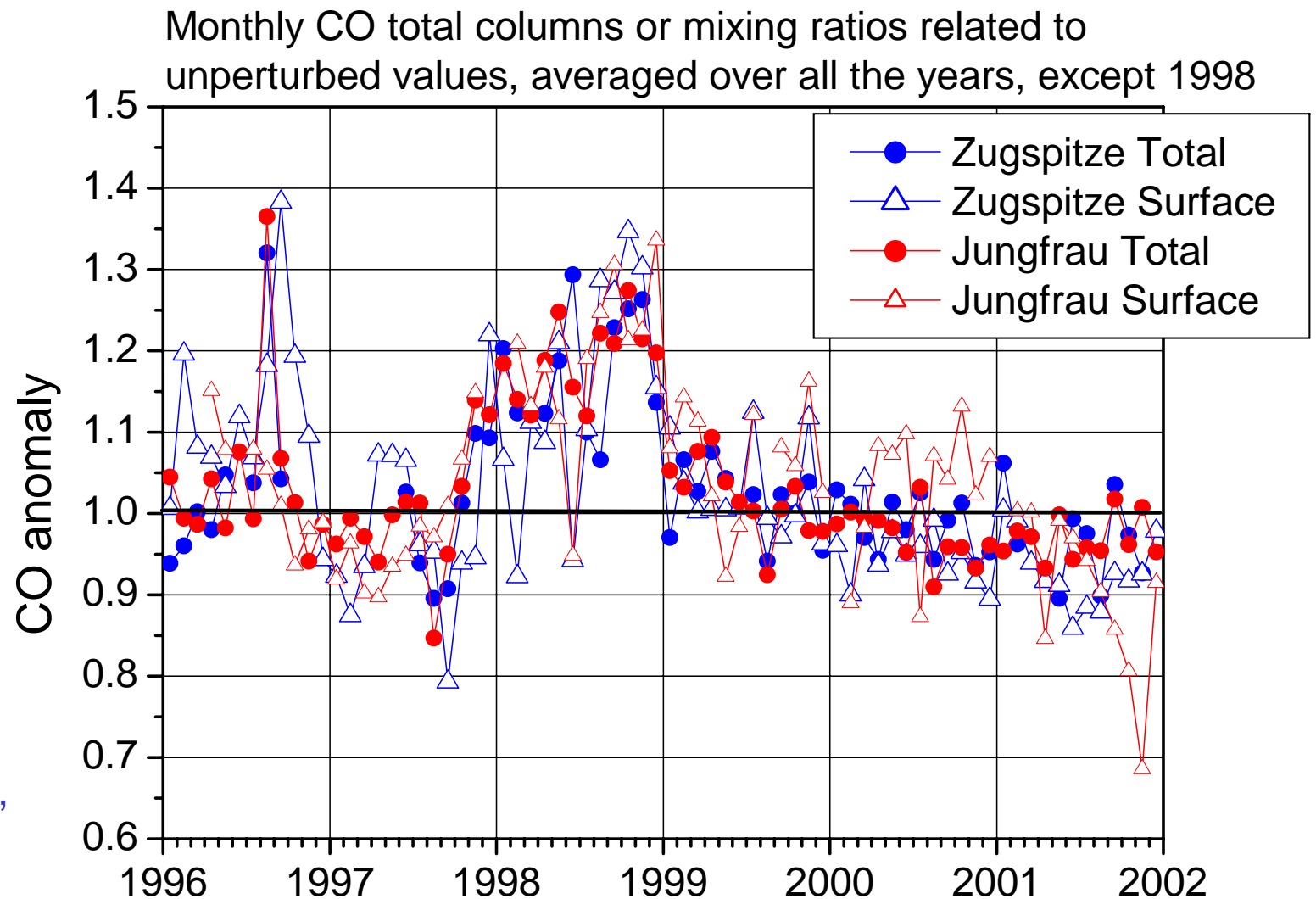
Zugspitze/Garmisch Primary Site Report

Primary Site Report: **Zugspitze FTIR**

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 ClONO₂, and comparison to the Jungfrauoch series; showed **very** good overall agreement!
- In 2002 we compared in preparation for ENVISAT Validation columns of N₂O, CO, CH₄, NO₂, O₃ to coincident Jungfrauoch data. E.g., N₂O 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!
- N₂O trop. columns trend (1995-2004): Zugspitze 0.18 %/yr, Jungfrauoch 0.23 %/yr
- ENVISAT validation: Learned much about precision of CO, CH₄, NO₂ as measured by FTIR!

Zugspitze + Jungfrauoch total and in situ CO: 1998 Hemispherical CO-Anomaly



Yurganov et al.,
Atmos. Chem.
Phys., 5, 563–573,
2005.

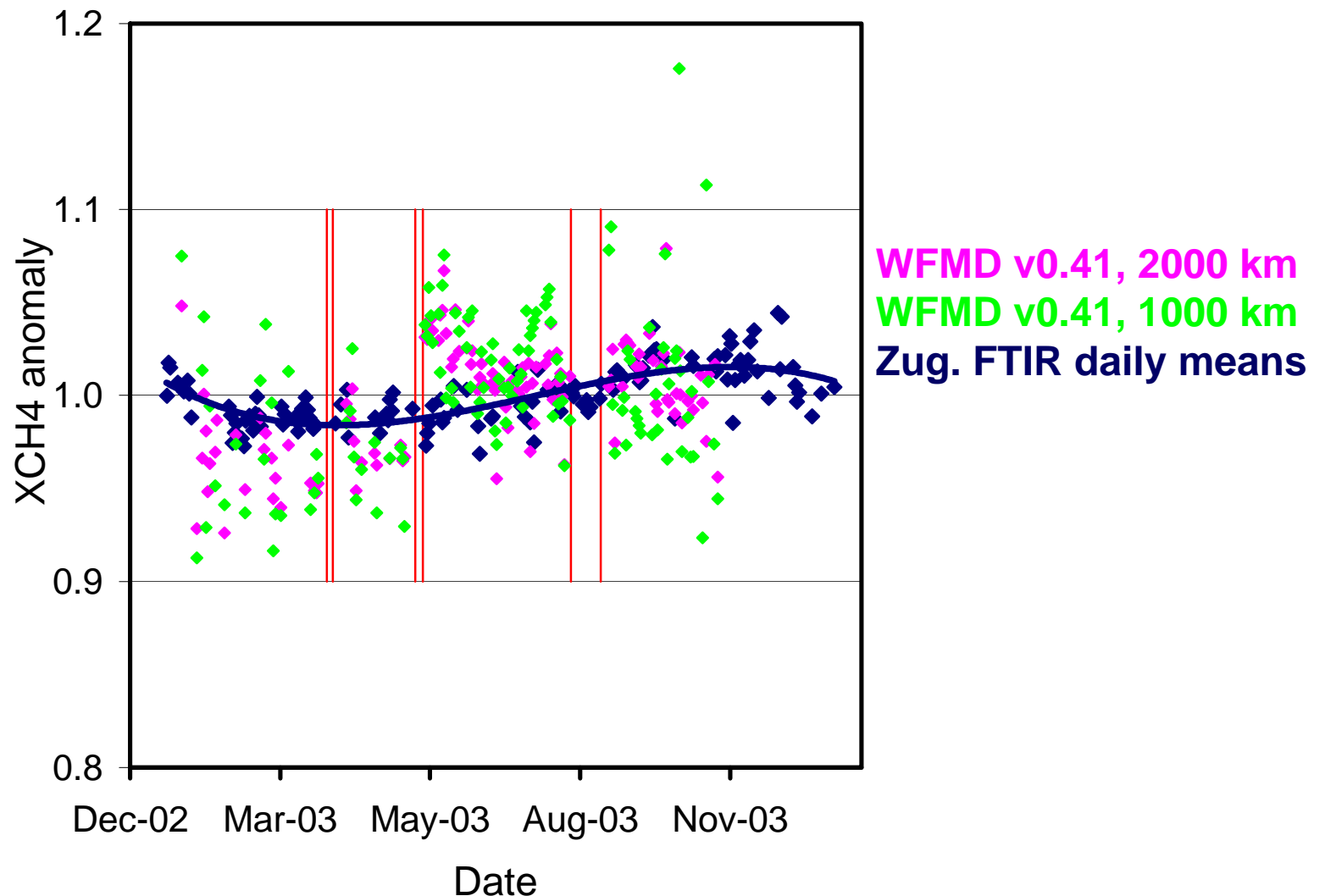
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Zugspitze/Garmisch Primary Site Report

Validation of SCIAMACHY XCH₄: Investigation of time-dependent bias v0.41



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

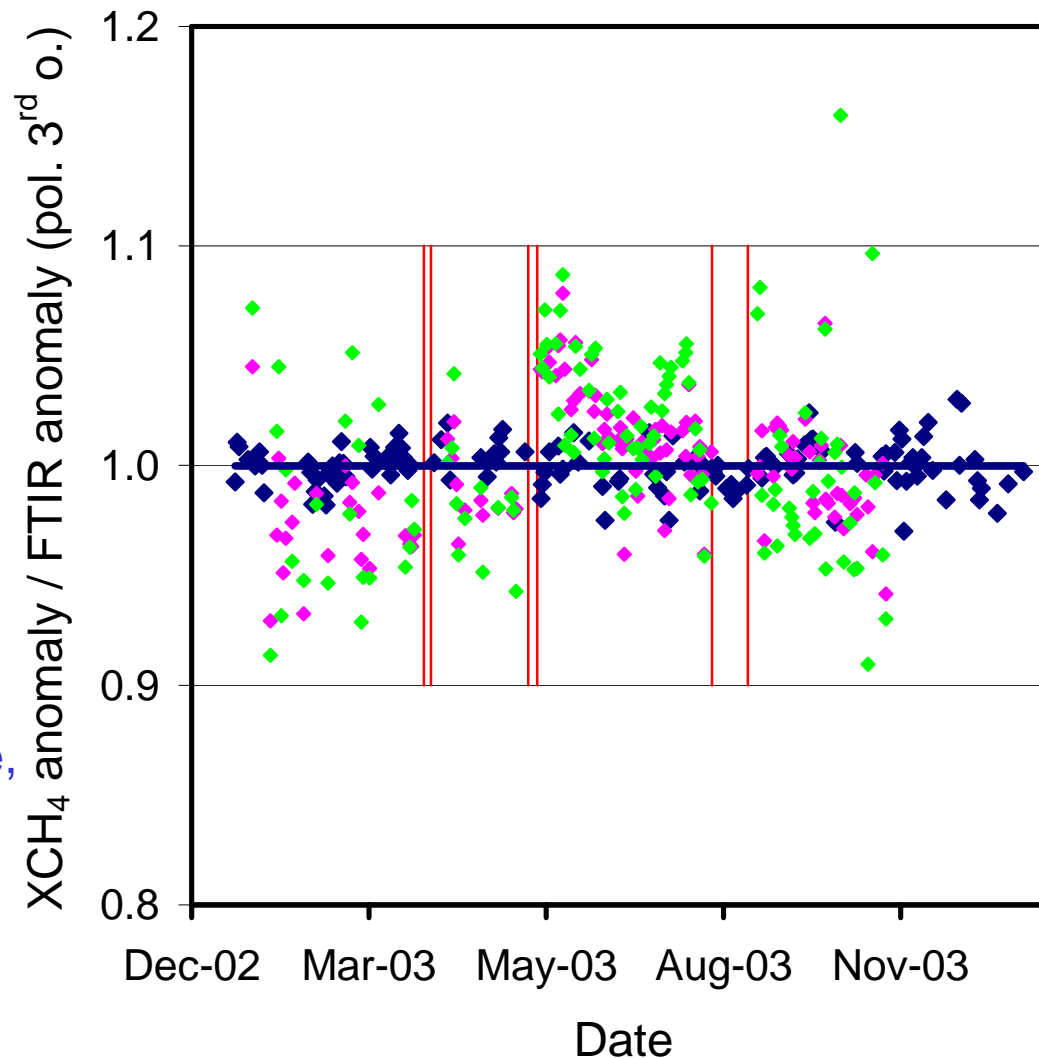
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Zugspitze/Garmisch Primary Site Report

Validation of SCIAMACHY XCH₄: 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.

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Zugspitze/Garmisch Primary Site Report

XCH₄ precisions FTIR versus SCIAMACHY: Single measurements, daily mean data

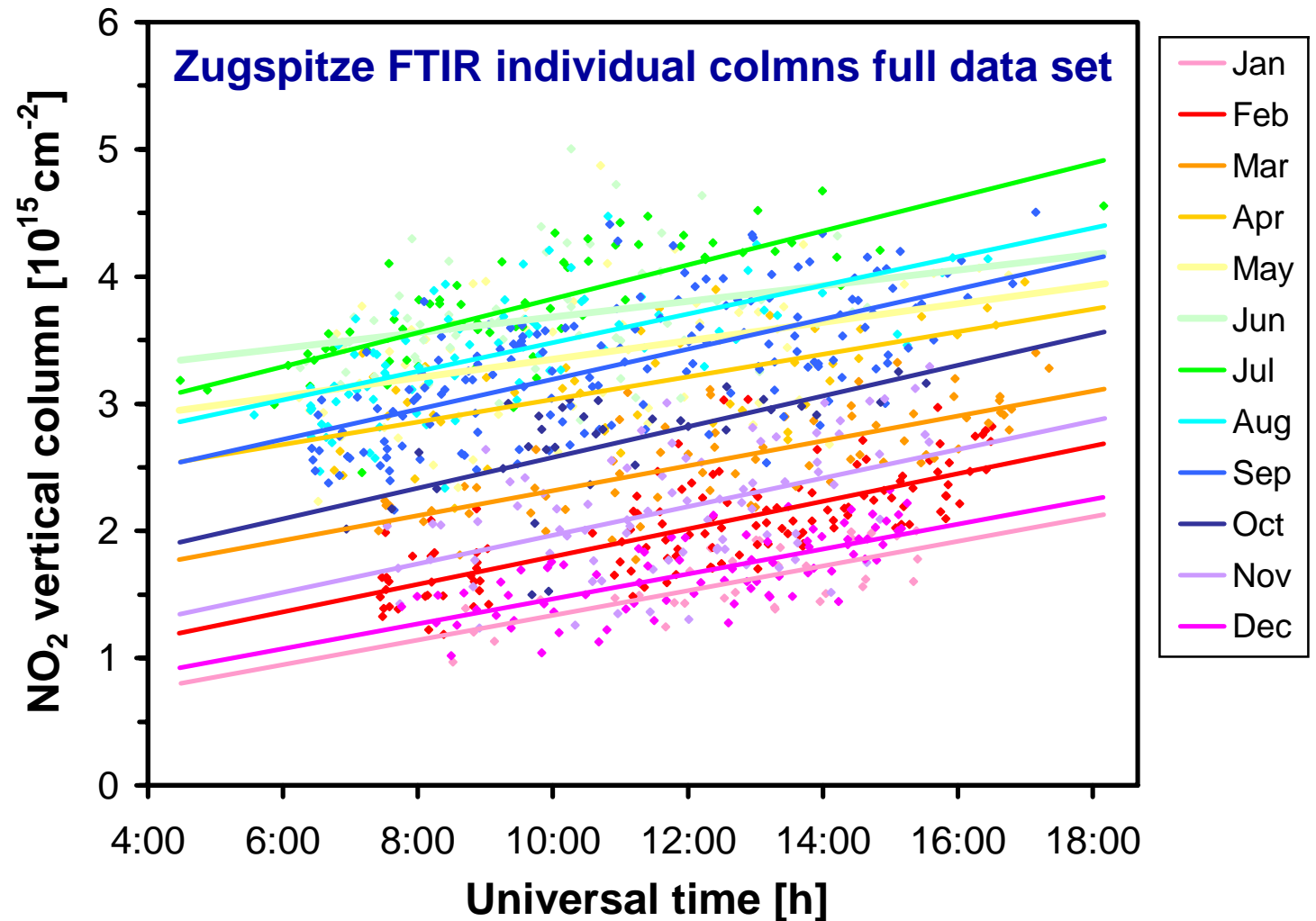
	$AV_i(n_i)$	$AV_i(\sigma_i)$	$AV_i(\sigma_i/\sqrt{n_i})$	σ of daily means corrected for ann. cycle
Zugspitze FTIR	12.3	1.3 %	0.4 %	1.0 %
SCIA 2000	249	5.2 %	0.3 %	2.4 %
SCIA 1000	85	5.4 %	0.6 %	2.7 %

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

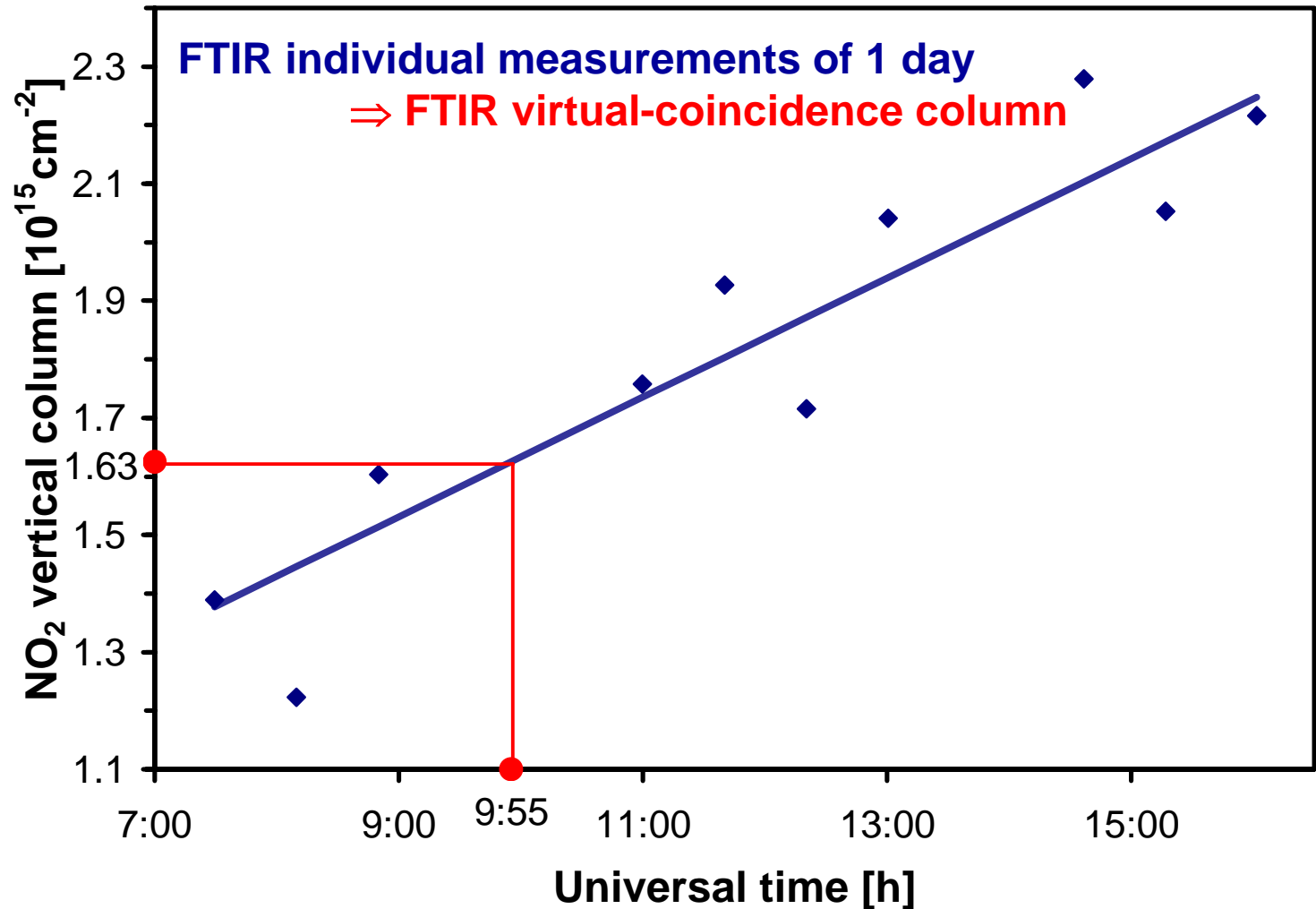
Total NO₂ diurnal increasing rate: ⇒ Coincidence issue for satellite validation

⇒ 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.



Matching FTIR to satellite overpasses: Concept of „virtual coincidences“



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

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Zugspitze/Garmisch Primary Site Report

NO₂ precisions FTIR versus SCIAMACHY: Single measurements, daily mean data

	$AV_i(n_i)$	$AV_i(\sigma_i)$	$AV_i(\sigma_i/\text{sqrt}(n_i))$	σ 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.

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Zugspitze/Garmisch Primary Site Report

Primary Site Report: **Zugspitze FTIR**

Funding status (instrument and facility): good

- Permanent 80 % basic funding by Helmholtz Society of German Research Centers
- plus several projects:
 1. UFTIR (EC, closed Jan 2005)
 2. HYMN (CH₄, N₂O, EC, new 2006)
 3. Sounding of the Atmosphere and Ground Truthing at Zugspitze/Schneefernerhaus (Bavarian Ministry of Economy, closed in 2005)
 4. Pole - Equator - Pole (PEP), Variability of atmospheric trace constituents along a North-South Transect (German Helmholtz Society 'Impuls und Vernetzungsfond' for the creation of a virtual institute, ongoing)
 5. TASTE (ENVISAT long-term validation, ESA-funded, new 2006)
 6. ESA/EUMETSAT project EPS/MetOp-IASI and -GOMEII validation, new, unfunded

Primary Site Report: **Zugspitze FTIR**

Matter(s) that need to be discussed during SC meeting: -

List of publications that appeared during the reporting period:

Yurganov, L.N., P. Duchatelet, A.V. Dzhola, D. P. Edwards, F. Hase, I. Kramer, E. Mahieu, J. Mellqvist, J. Notholt, P.C. Novelli, A. Rockmann, H.E. Scheel, M. Schneider, A. Schulz, A. Strandberg, R. Sussmann, H. Tanimoto, V. Velazco, J.R. Drummond, J.C. Gille:

Increased Northern Hemispheric carbon monoxide burden in the troposphere in 2002 and 2003 detected from the ground and from space,
Atmos. Chem. Phys., 5, 563–573, 2005.

Sussmann, R. and Buchwitz, M.:

Initial validation of ENVISAT/SCIAMACHY columnar CO by FTIR profile retrievals at the Ground-Truthing Station Zugspitze,
Atmos. Chem. Phys., 5, 1497–1503, 2005.

Sussmann, R., Stremme, W. Buchwitz, M., and de Beek, R.:

Validation of ENVISAT/SCIAMACHY columnar methane by solar FTIR spectrometry at the Ground-Truthing Station Zugspitze,
Atmos. Chem. Phys., 5, 2419–2429, 2005.

Sussmann, R., Stremme, W., Burrows, J.P., Richter, A., Seiler, W., and Rettinger, M.:

Stratospheric and tropospheric NO₂ variability on the diurnal and annual scale: a combined retrieval from ENVISAT/SCIAMACHY and solar FTIR at the Permanent Ground-Truthing Facility Zugspitze/Garmisch,
Atmos. Chem. Phys., 5, 2657–2677, 2005.

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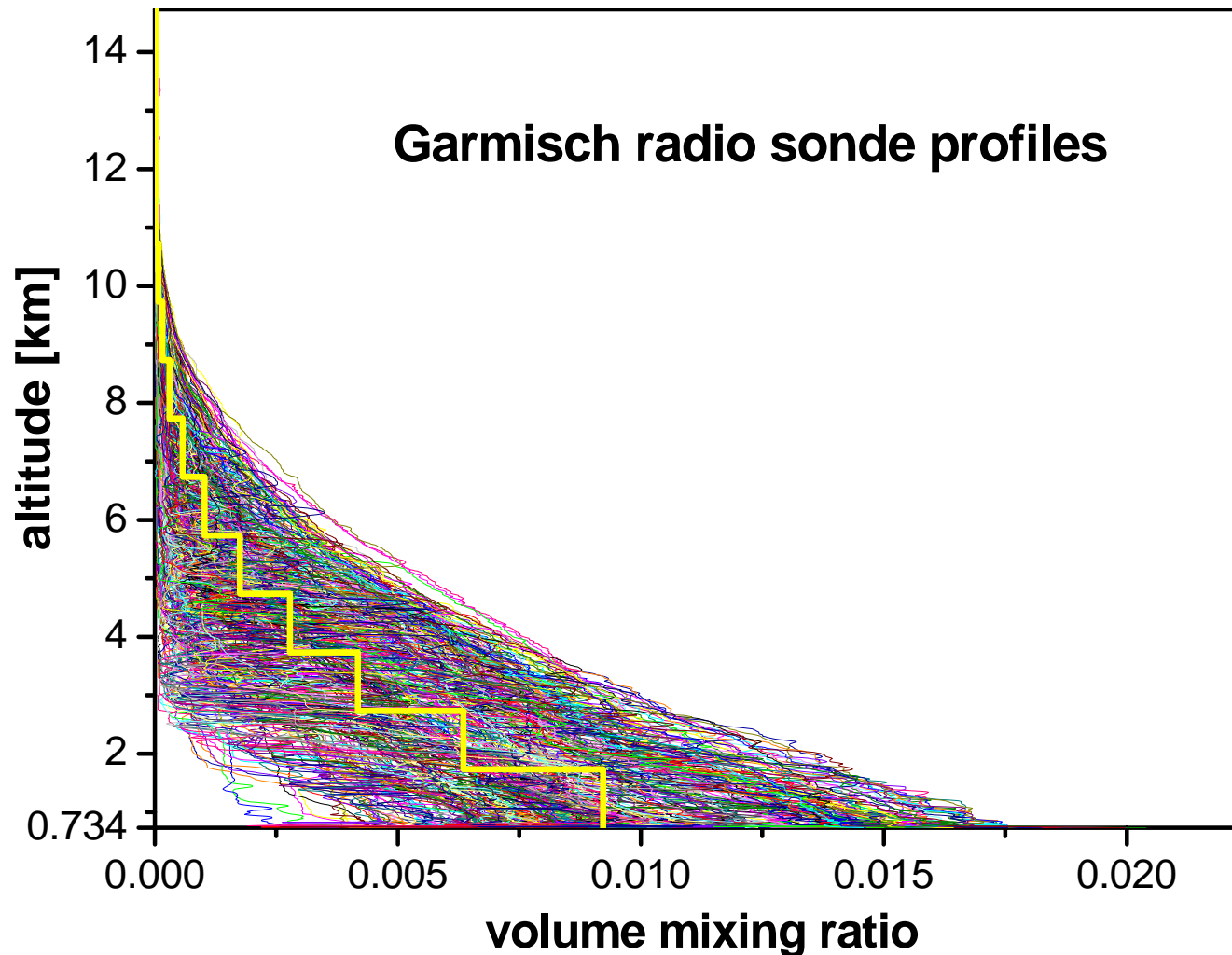
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Zugspitze/Garmisch Primary Site Report

Summary – Zugspitze FTIR Primary Instrument Report

- Zugspitze FTIR – recent electronics update, 134 measurements days/yr, archiving up to date, well funded, 4 papers.
- Intense ENVISAT/SCIAMACHY validation studies have helped to better understand quality of FTIR column measurements of CO, CH₄, and NO₂.
- Garmisch FTIR operational since 2004 for „differential FTIR“, CH₄/O₂ and CO₂/O₂ monitoring, and water vapor measurements.

Water vapor profiles with Zugspitze FTIR: A priori information used (I)



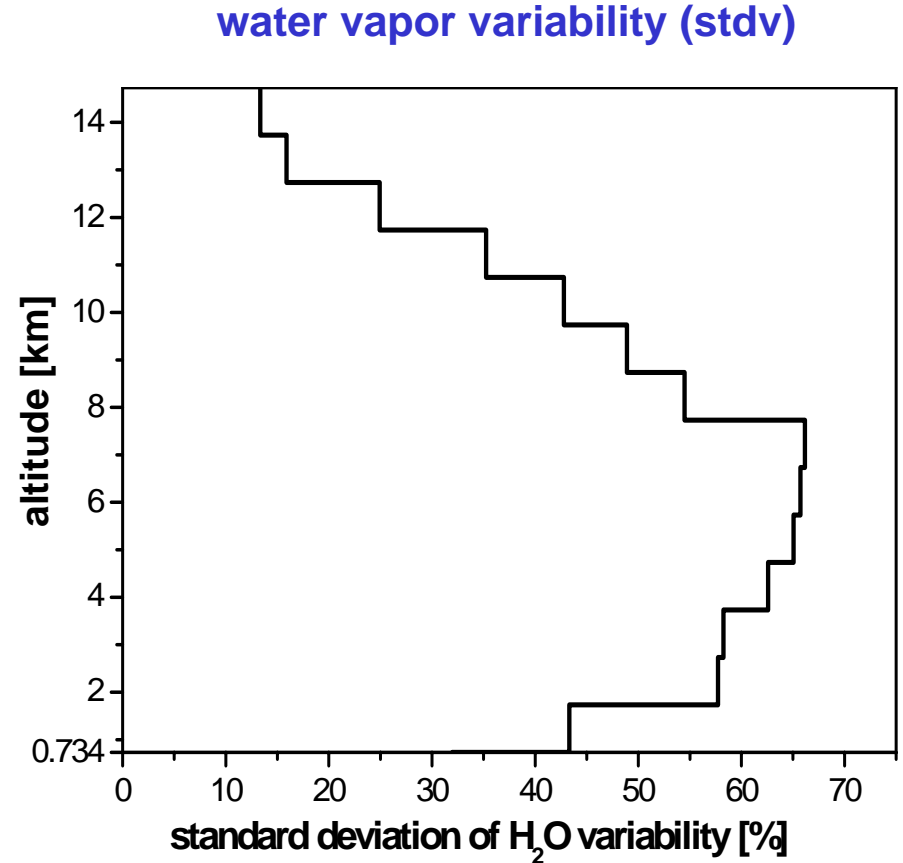
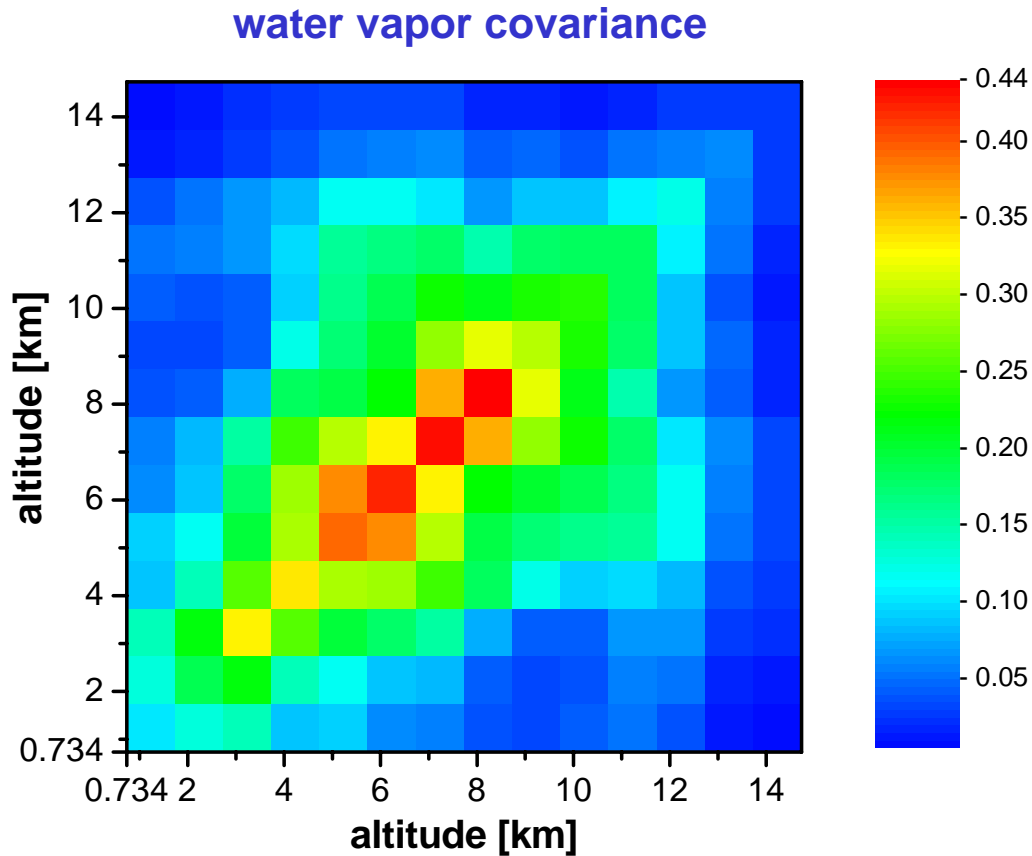
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Zugspitze/Garmisch Primary Site Report

Water vapor profiles with Zugspitze FTIR: A priori information used (II)



Unit: covariances of VMR-layer scaling factors

VMR

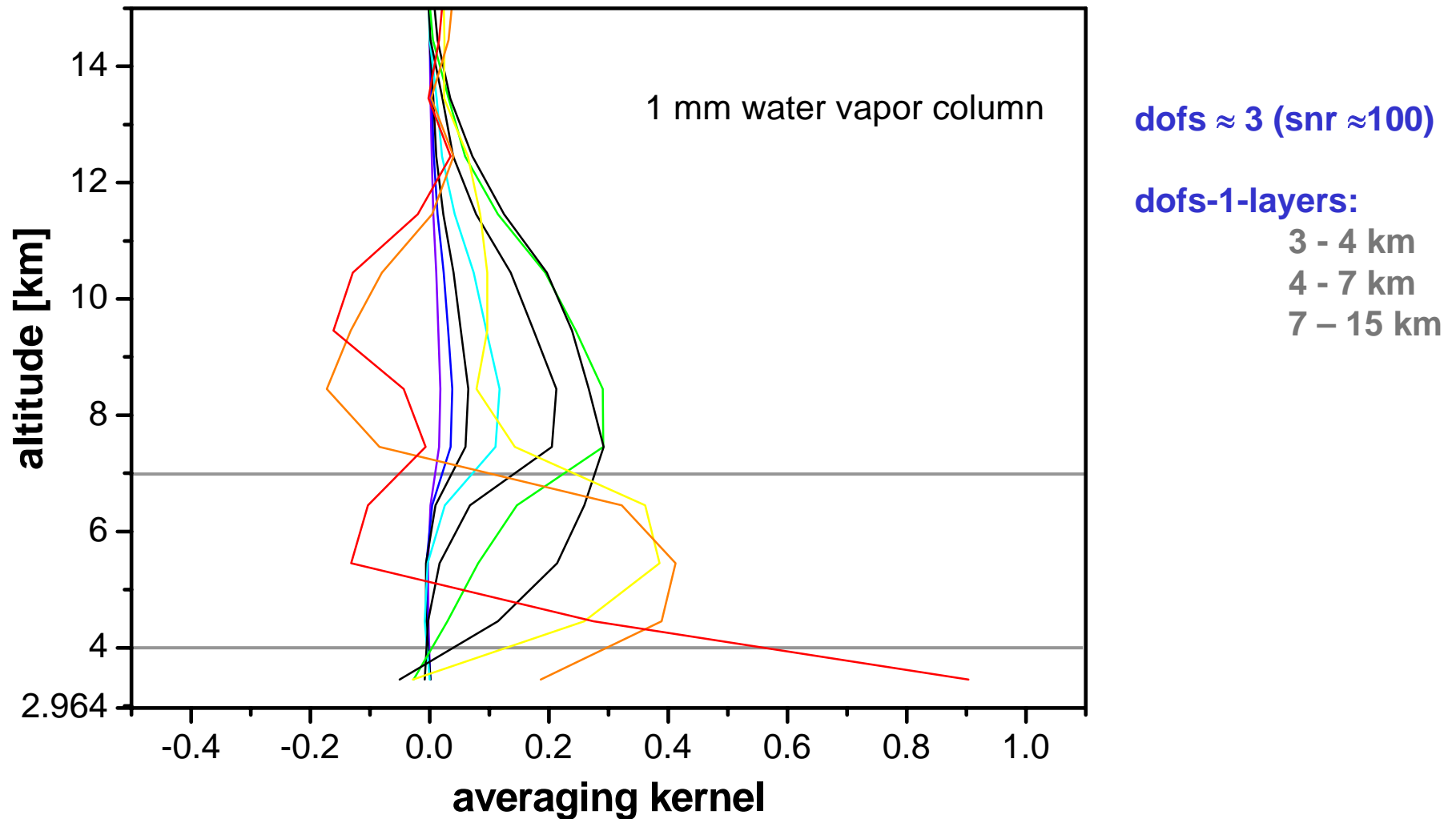
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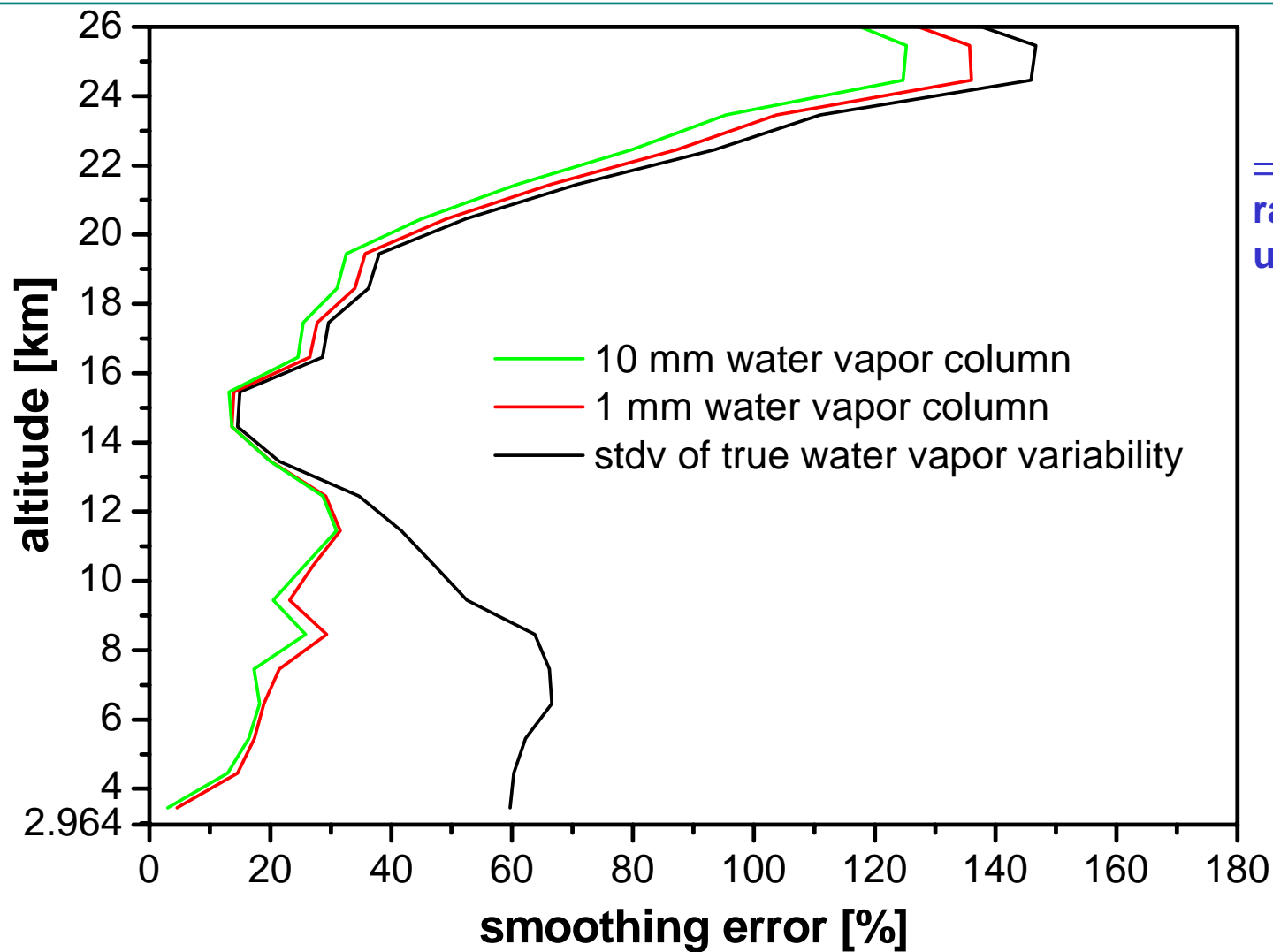
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Zugspitze/Garmisch Primary Site Report

Water vapor profiles with Zugspitze FTIR: Averaging kernels



Water vapor profiles with ZugspitzeFTIR: Smoothing error

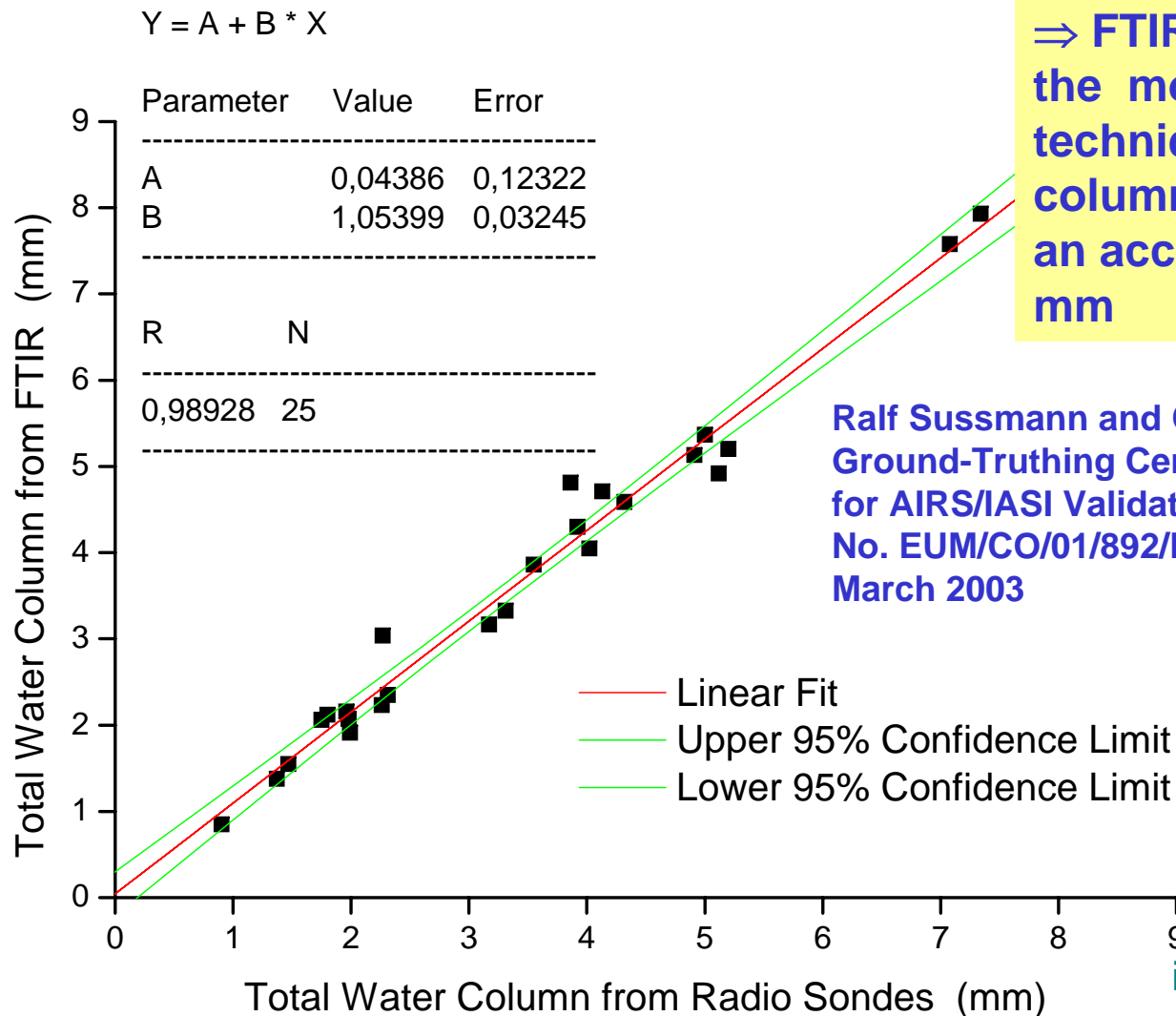


⇒ Smoothing error/altitude range does not depend upon absolute column level

Water vapor columns with Zugspitze FTIR: Validation of solar FTIR with sondes

Columns
above
Zugspitze,
2964 m

2-h-mean
values



⇒ FTIR is probably one of the most accurate techniques 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

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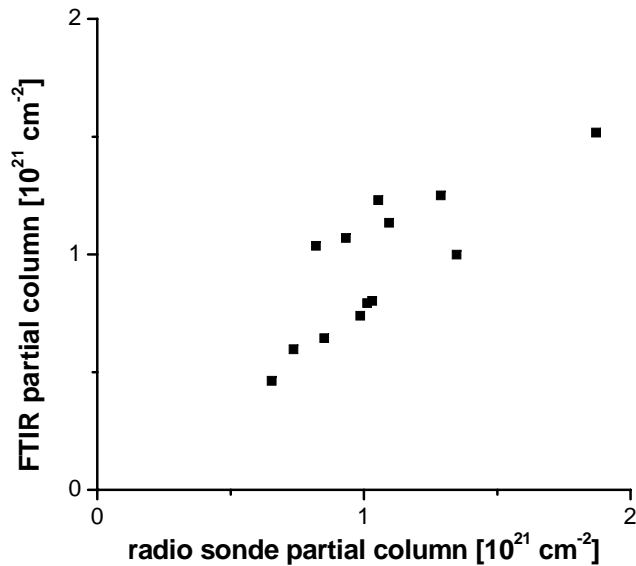
Ralf Sussmann

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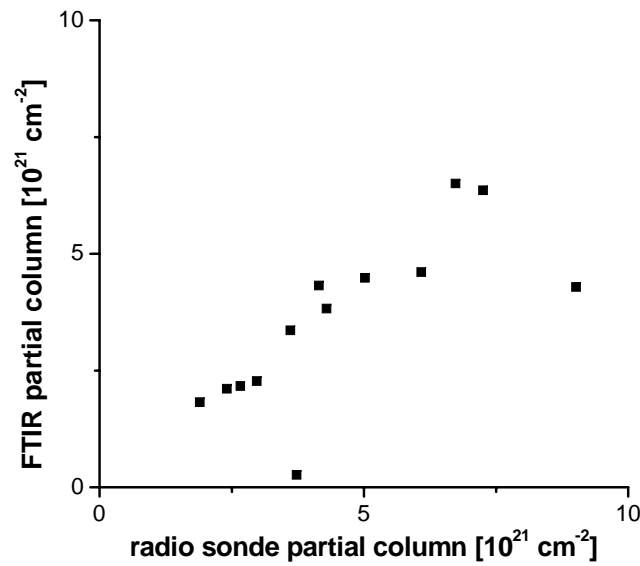
Zugspitze/Garmisch Primary Site Report

Water vapor profiles with Zugspitze FTIR: Retrieved profiles versus sondes

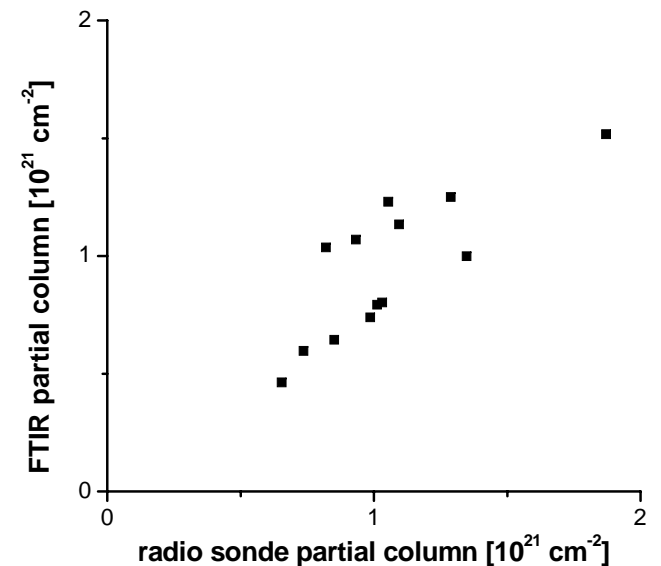
partial column 3 - 4 km



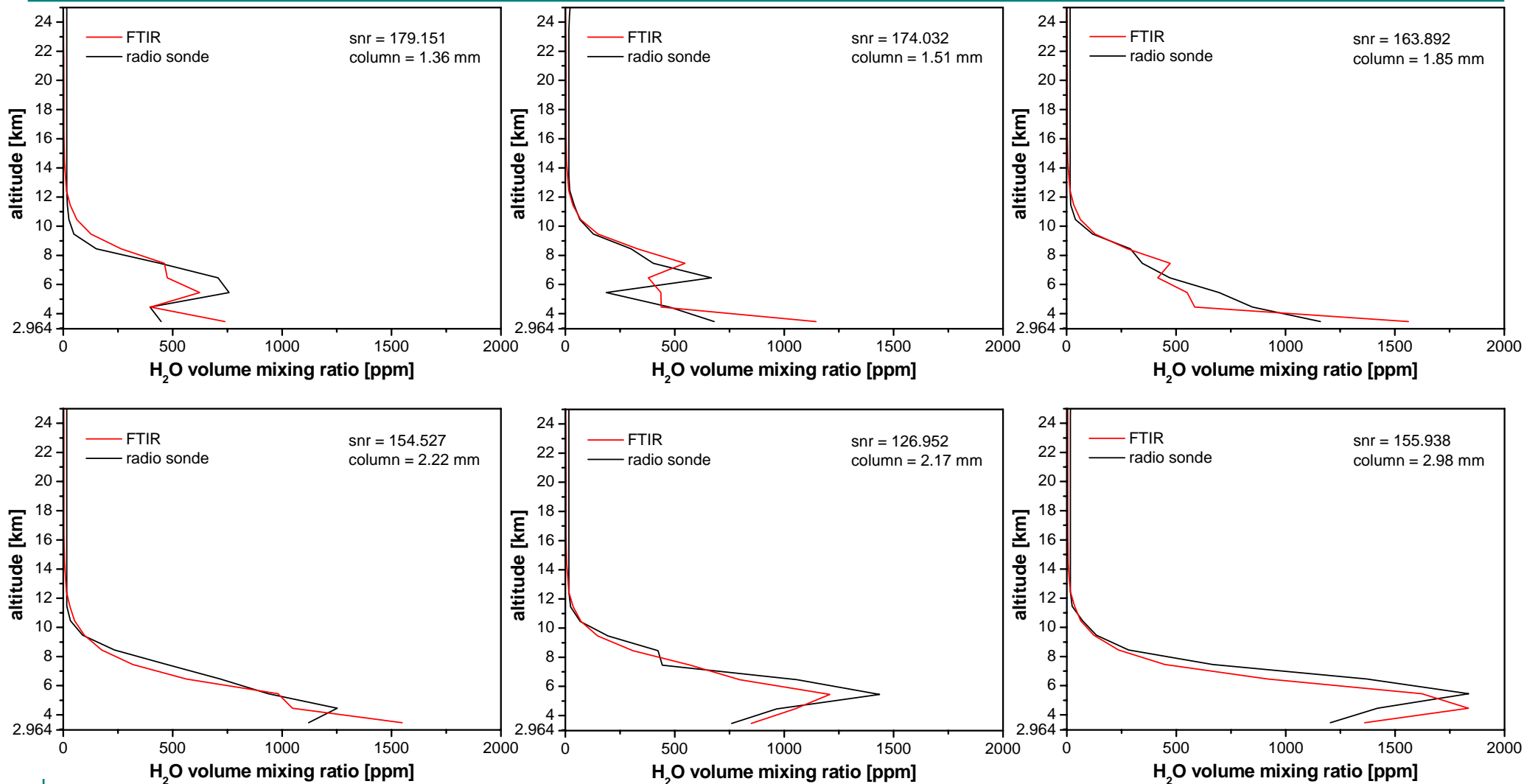
partial column 4 - 7 km



partial column 7 - 15 km



Water vapor profiles with Zugspitze FTIR: Retrieved profile versus sonde



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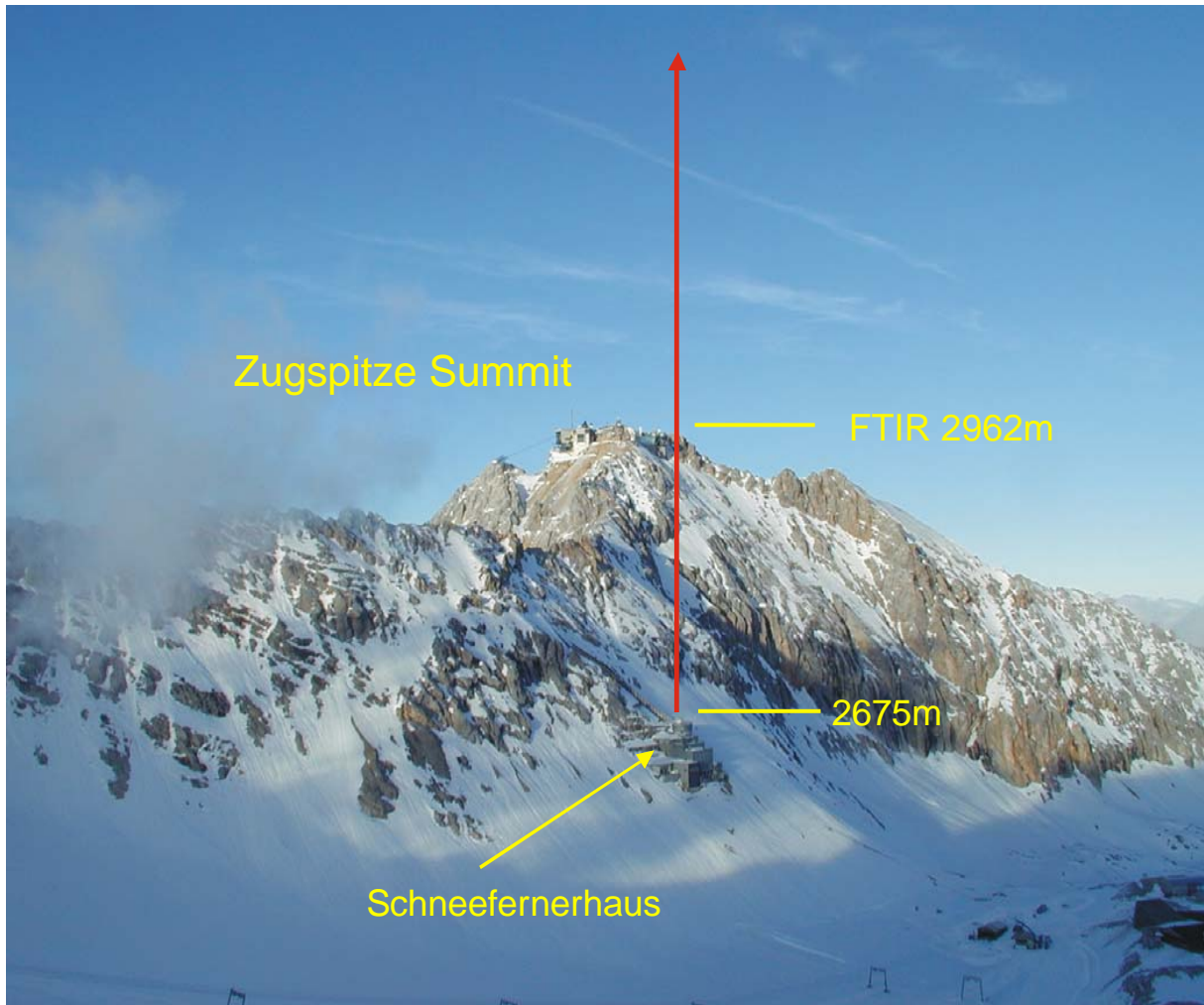
Zugspitze/Garmisch Primary Site Report

Summary/Outlook: FTIR water vapor retrievals at Zugspitze/Garmisch

- found interference-free micro-window set
- FTIR yields very very high accuracy total columns
- Zugspitze – Garmisch „differential FTIR“
- OE with climatological a priori covariance from sondes works fine
- dofs ≈ 3 , i.e., layers 3 - 4 km, 4 - 7 km, 7 – 15 km
- smooting error/altitude range does not significantly depend on absolute water column level
- validation against sondes good, given high quality spectra (snr > 120)



Zugspitze-Schneefernerhaus Water-Vapor LIDAR - H. Vogelmann, T. Trickl



Requirements:

- Range 12km asl. (Tropopause)
- Relative errors less than ca. 5%
- Vertical resolution ca. 50m to 300m
- Measurements at all daytimes

Method:

- Differential absorption LIDAR (DIAL)

Advantages versus Raman-Lidar:

- Daylight capability
- ⇒ capture intrusion events without daytime interruptions!
- Selfcalibrating technique
- ⇒ pre-requisite for trend measurements!

Major challenge:

- High power widely tunable narrow-band laser system had to be developed

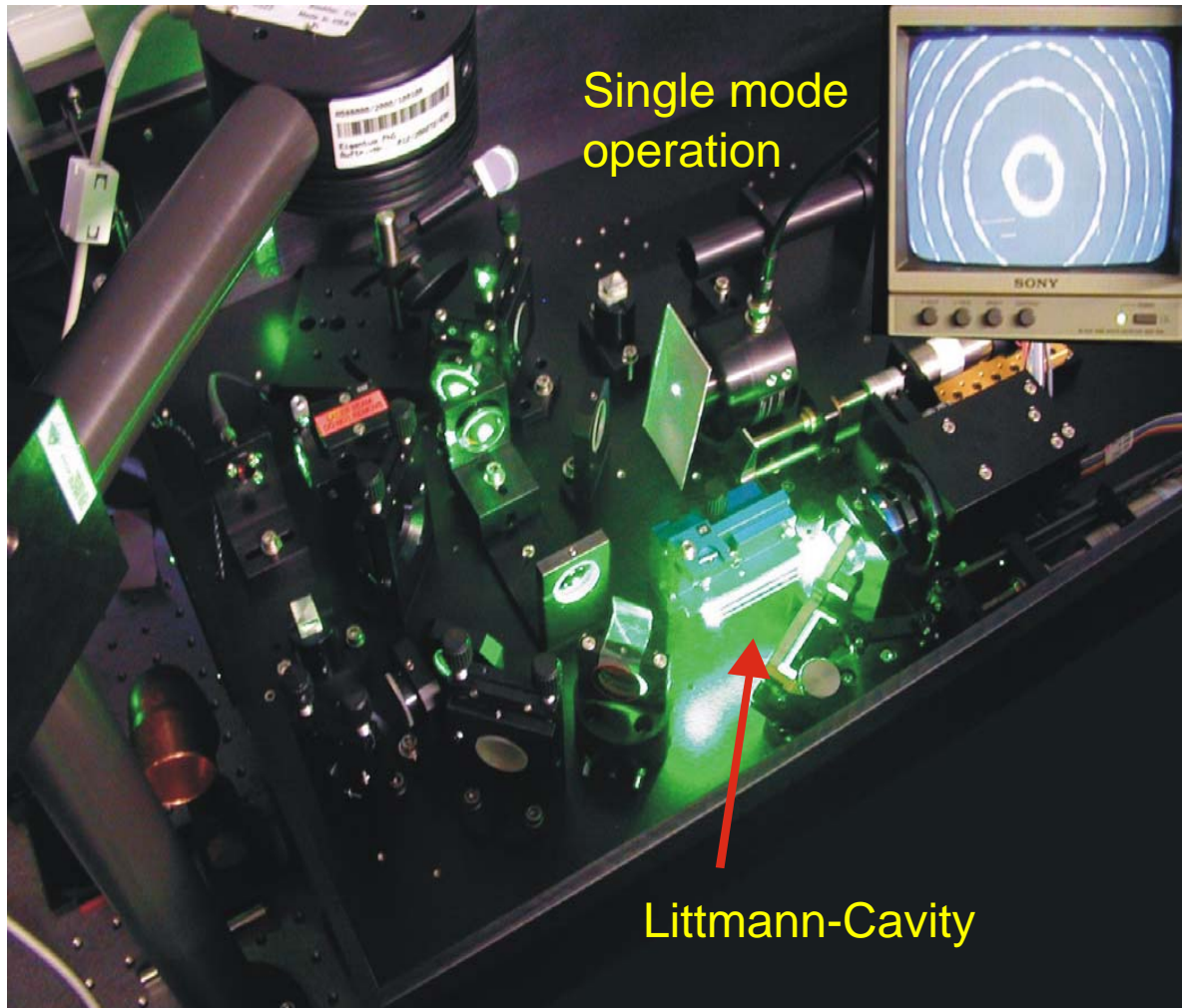
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Zugspitze/Garmisch Primary Site Report

DIAL-Laser System



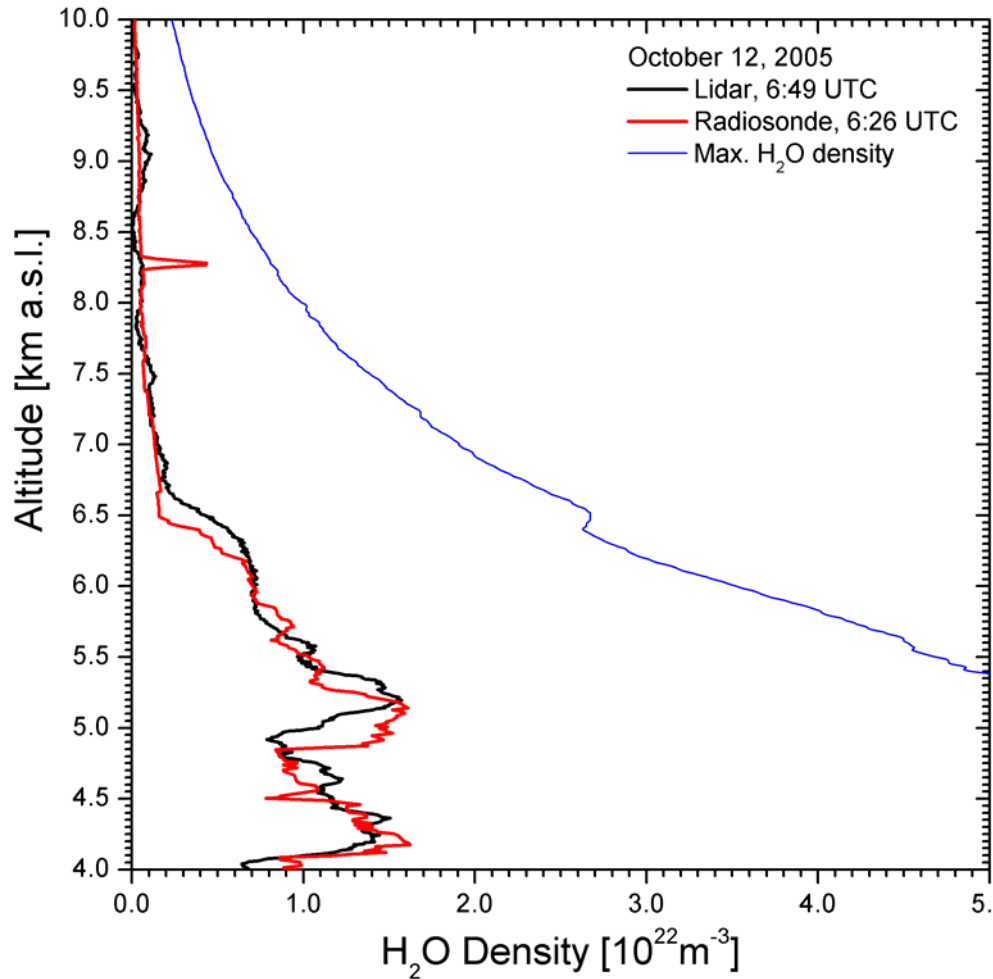
Specs:

- Widely tunable: 700nm – 950nm
- Narrow band: nearly Fourier-transform-limited, 130Mhz @ 4ns
- High output energy: 250mJ @ 800nm (700mJ estimated in future)
- Spectral purity: > 99.9%
- Repetition rate: 20Hz
- 2 Wavelength operation (alternating mode)

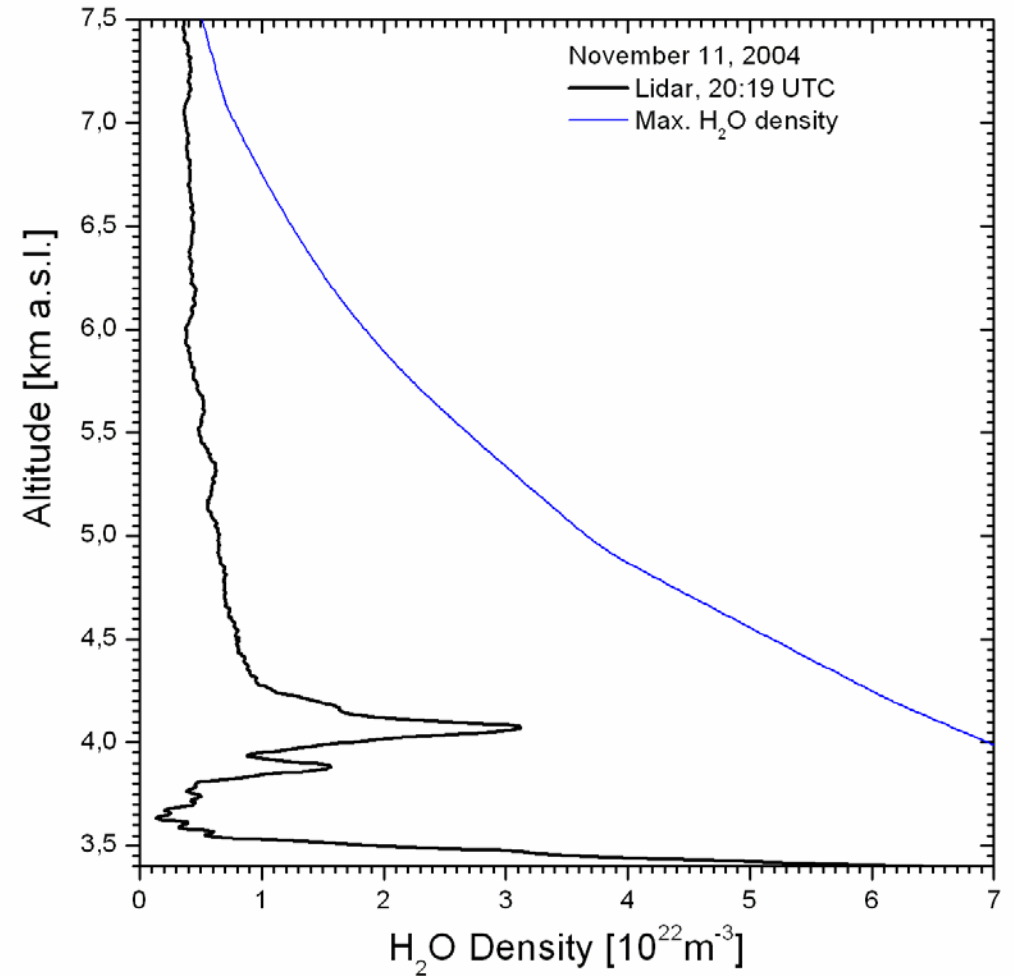
System:

- 2 optic parametric oscillators (OPO) pumped by a frequency doubled injection seeded flashlamp pumped Nd:YAG laser. Pulse amplification by one common flashlamp pumped Ti:Sapphire ring laser.

Instrument Validation



Measure Stratospheric Intrusions



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Zugspitze/Garmisch Primary Site Report

Zugspitze/Garmisch instrumentation for water vapor



e.g., EPS/MetOp-IASI
validation, ESA/EUMETSAT
RAO-project starting 2006

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Zugspitze/Garmisch Primary Site Report

Summary/Outlook: Zugspitze/Garmisch as a water vapor “super site“

- Zugspitze FTIR to reach high altitude + Garmisch FTIR to characterize boundary layer (profiles, very high column accuracy)
- GPS Zugspitze/Garmisch to get continuous guess for columns
- Zugspitze DIAL to get day calibration-free day- and nighttime measurements of profiles
- synergistic combination between with Zugspitze FTIR and Schneefernerhaus DIAL
- Zugspitze/Garmisch EPS-MetOp IASI validation campaign in 2007



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Zugspitze/Garmisch Primary Site Report