Outline

• Zugspitze/Garmisch Instrumentation
• Interference errors and micro window selection
• Zugspitze FTIR profile retrieval
• Strategy for validation of FTIR total columns by sondes
• Optimized FTIR total column retrieval and its validation
• Summary and Outlook
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Water vapor retrieval from Zugspitze FTIR measurements

Triple NDACC Primary Station: FTIR, Aerosol, UV.

Permanent Ground-Truthing Facility Zugspitze/Garmisch according to the WMO requirements.

IMK-IFU Working Group „Variability and Trends“

Scientists
R. Sussmann
H.E. Scheel
T. Trickl
H. Vogelmann

Engineers
H. Giehl
M. Rettinger

PhD students
T. Borsdorff
F. Forster

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

Radio sondes

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Zugspitze/Garmisch instrumentation for water vapor columns/profiles

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Water vapor retrieval from Zugspitze FTIR measurements
Zugspitze operational since 1995
typ. 130-140 measurement
days per year

H₂O columns and profiles

Garmisch operational
since 2004
typ. 130-140 measurement
days per year

“Differential FTIR”
with Zugspitze:
H₂O columns and profiles

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Water vapor retrieval from Zugspitze FTIR measurements
Interference errors and micro window selection: Interference errors (I)

Example CO retrieval: interfering species O₃, N₂O, CO₂, H₂O

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Water vapor retrieval from Zugspitze FTIR measurements
Interference errors and micro window selection: Interference errors (II)

Example CO retrieval

taken from:
Sussmann, R. and Borsdorff, T:

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Water vapor retrieval from Zugspitze FTIR measurements
Zugspitze FTIR water vapor profile retrieval: Interference-free micro windows

HITRAN2000

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Water vapor retrieval from Zugspitze FTIR measurements
Zugspitze FTIR water vapor profile retrieval: A priori information used (I)

Garmisch radio sonde profiles

AIRS validation campaign
19 Aug 2002 - 17 Nov 2002
Zugspitze FTIR water vapor profile retrieval: A priori information used (II)

Water vapor covariance

Unit: covariances of VMR-layer scaling factors

Water vapor variability (stdv)

VMR
Zugspitze FTIR water vapor profile retrieval: Averaging kernels

1 mm water vapor column

dofs ≈ 3 (snr ≈ 100)
dofs-1-layers:
3 - 4 km
4 - 7 km
7 - 15 km

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Water vapor retrieval from Zugspitze FTIR measurements
Zugspitze FTIR water vapor profile retrieval: **Smoothing error**

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

- **10 mm water vapor column**
- **1 mm water vapor column**
- **stdv of true water vapor variability**

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Water vapor retrieval from Zugspitze FTIR measurements
Zugspitze FTIR water vapor profile retrieval: Retrieved profile versus sonde

⇒ profile retrieval works fine, given high quality spectra (snr > 120) and dry days (< 3 mm)
Strategy for validation of FTIR total water vapor columns by sondes: Tobin-Sondes

Sonde 1 launched 1h before overpass
Sonde 2 launched 5 min before overpass

AIRS validation campaign
19 Aug 2002 - 17 Nov 2002

Vaisala RS 80-30 G sondes
TOTEX-800-g balloons
2 x Digicora III (Marvin 21, SPS220G)

TOBIN-Inter-/Extrapolation between both soundings:

\[ q_{\text{Tobin}}(z, t_{op}) = q_{\text{sonde}}(z, t_0) + \left( \frac{dq(z)}{dt} \right) (t_{op} - t_0) \]


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Water vapor retrieval from Zugspitze FTIR measurements
Strategy for validation of FTIR total water vapor columns by sondes: Tobin-Sondes
Strategy for validation of FTIR total water vapor columns by sondes: Tobin-Sondes

![Graph showing water vapor concentration vs altitude for Sonde 1 and Sonde 2, along with Tobin-Interpolation line.](image)

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Water vapor retrieval from Zugspitze FTIR measurements
Water vapor retrieval from Zugspitze FTIR measurements

Columns above Zugspitze, 2964 m 2-h-mean values

\[ Y = A + B \times X \]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.00727</td>
<td>0.12393</td>
</tr>
<tr>
<td>B</td>
<td>1.01153</td>
<td>0.03263</td>
</tr>
</tbody>
</table>

\[ R = 0.98824 \]
\[ R^2 = 0.97662 \]
\[ SD = 0.27622 \]
\[ Bias = 0.04646 \]
\[ N = 25 \]

FTIR is one of the most accurate techniques to quantify columnar water vapor

Total Water Column from FTIR (mm)

Total Water Column from Radio Sondes (mm)
Optimized FTIR total water vapor column retrieval and its validation

Comparison between other instruments and TROWARA at Bern

- Bias
- Standard Deviation
- Intercept
- Slope

taken from:

Sussmann, Borsdorff, Camy-Peyret, Atmos. Chem. Phys., to be published

FTIR Zugspitze - Sonde
Summary

• found interference-free micro-window set
• profile retrieval
  • OE with climatological a priori covariance from sondes: dofs ≈ 3, i.e., layers 3 - 4 km, 4 - 7 km, 7 – 15 km
  • smoothing error/altitude range does not depend on absolute water column
  • FTIR profiles reproduce sonde fine struture well, given high quality spectra (snr > 120) and dry days (< 3 mm)
• FTIR is the most accurate technique for total columns (?): validation against sondes (Tobin): $R^2 = 0.98$, slope = 1.01, stdv < 0.3 mm, intercept < 0.01 mm, bias < 0.05 mm

Outlook

• validation against lidar / synergetic combination with lidar
• investigate “differential FTIR“ (Garmisch – Zugspitze column)