About the quality of water vapour profiles retrieved from ground-based FTIR measurements

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Our group operates currently two FTIR spectrometers within NDACC

Since several years we are working on ground based FTIR H$_2$O profile retrieval, first results were published in:

ACP, 6, 811-830, 2006
ACP, 6, 4705-4722, 2006
Ground-based FTIR measurements within NDACC for long term validation of IASI H$_2$O products

**NDACC Sites**

BUT: First we have to prove the quality of the ground based FTIR data!!!
A ground-based FTIR experiment
A typical mid-infrared measurement

Information content of solar absorption spectra:
1. Envelope of the calibrated spectrum: aerosols (PSCs, mineral dust, cirrus, …)
2. Line area: column amounts
3. Line shape: profiles
Example of H$_2$O signatures

2. Line area: column amounts

3. Line shape: profiles: the Jacobian is a singular matrix, so we cannot determine the profile unambiguously ...
Optimal Estimation (OE) of vertical profiles

... but estimate the most probable state for the given measurement (OE). This leads to a minimisation problem of the cost function:

$$\sigma^{-2}(y - \frac{\partial y}{\partial x} x)^T(y - \frac{\partial y}{\partial x} x) + (x - x_a)^TS_a^{-1}(x - x_a)$$

$y, x, x_a, S_a$ : spectral-, state-, a priori state-vectors, a priori covariance-matrix

$\frac{\partial y}{\partial x}$ : Jacobians (sensitivity of spectra wrt absorber)

Advantages of FTIR technique:
- measures many trace gases
- for extended time periods, nearly continuously
- good precision
- provides information about vertical distribution
- different isotopologues produce different absorption signatures
- enables to measure the isotopic composition of the atmosphere
Ground-based remote sensing of vertical H$_2$O distributions: a real challenge

- The first 2 km contain already 60% of all atmospheric H$_2$O.

- The first 5 km more than 90%.

- Above 10 km there is only 1% of all atmospheric H$_2$O.
Optimising the H$_2$O retrieval

(1) retrieval on a logarithmic scale (Hase et al., 2004; Schneider et al. 2006; Deeter et al., 2007):

(2) simultaneous retrieval of temperature profile (Schneider et al. 2006; 2007):

temperature from CO$_2$ lines
Optimising the H$_2$O retrieval

(3) reduce inconsistencies in spectroscopic line parameters:
Optimising the H$_2$O retrieval

Investigating inconsistencies between HITRAN parameters and our FTIR measurements:

Idea: use the residuals to 'remove' inconsistencies in HITRAN parameters.

→ we make an optimal estimation of the HITRAN parameters taking the residuals as measurement.
Optimising the H$_2$O retrieval

Adapting HITRAN parameters to our measurements:

the required changes are within the given HITRAN uncertainties:

- $< 0.002$ cm$^{-1}$ for line positions
- $< 3$ % for line intensities
- $< 4$ % for pressure broadening coefficients
Averaging kernels for ground based FTIR H$_2$O mixing ratios

DOF: 2.8 – 3.5

→ we can retrieve between 3 and 4 independent layers:
  - surface layer: 1$^{st}$ km
  - mid troposphere: e.g. 3.3 km-5.3 km
  - upper troposphere: e.g. 5.3 km-10 km
  - tropopause: above 10 km
Estimated FTIR H$_2$O errors

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<th>error source</th>
<th>total</th>
<th>2.3–3.3 km</th>
<th>4.3–6.4 km</th>
<th>7.6–10.0 km</th>
<th>8.8–11.2 km</th>
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<tr>
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<td>22</td>
<td>24</td>
<td>49</td>
<td>42</td>
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</table>

from ACP, 6, 811-830, 2006
Example of Vaisala RS92 vs. FTIR profiles

15. March 2006
(measured between 11:20 and 11:50 GMT)

11:50 GMT

RS92
FTIR a-priori (climatology)
FTIR retrieved
(measured between 11:30 and 11:40 GMT)
Theoretical FTIR performance (2.37 km−15 km+)

*more than 99.9% of total column amount*
RS92* vs. FTIR (2.37 km–15 km+)

*corrected according to Vömel et al. (2006)
*more than 99.9% of total column amount
Theoretical FTIR performance (1st km; 2.37 km–3.3 km+)

*typically 36% of total column amount
Vaisala RS92* vs. FTIR (1st km; 2.37 km-3.3 km+)


* typically 36% of total column amount
Theoretical FTIR performance (3.3 km-5.3 km⁺)

* typically 40% of total column amount
Vaisala RS92* vs. FTIR (3.3 km-5.3 km)

Theoretical FTIR performance (5.3 km–10 km+)

*typically 22% of total column amount*
Vaisala RS92* vs. FTIR (5.3 km–10 km)

Theoretical FTIR performance (10 km–15 km$^+$)

*typically 1% of total column amount*
Vaisala RS92* vs. FTIR (10 km-15 km)

The ground based FTIR system can distinguish the 1% of H₂O above 10 km from the 99% below 10 km !!!

Vaisala RS92* vs. FTIR (10 km-15 km)

for retrieval on a linear scale:
Vaisala RS92* vs. FTIR (10 km–15 km)

with original HITRAN 2006 data:
FTIR $H_2O^*$ time series above Tenerife ($1^{st}$ km)

*preliminary (no temperature and phase error fit)
FTIR $\text{H}_2\text{O}^*$ time series (3.3 km-5.3 km)

*preliminary (no temperature and phase error fit)
FTIR H$_2$O* time series (5.3 km-10 km)

H2O 5.3 - 10 km

*preliminary (no temperature and phase error fit)
FTIR H$_2$O* time series (above 10 km)

*preliminary (no temperature and phase error fit)

upper tropical troposphere ???

stratosphere ???
FTIR HDO/H$_2$O time series

Absolute radiances [W/(cm$^2$ sterad cm$^{-1}$)]

Wavenumber [cm$^{-1}$]

δD [°/00]

Middle/upper troposphere (5.3-8.8km)

Lower troposphere (2.3-5.3km)

Higher latitude or strongly descending airmasses

Tropical airmasses

From ACP, 6, 4705, 2006
Summary

(1) We confirm the good performance of the Vaisala RS92 system

(2) NDACC FTIRs are suited to measure the H$_2$O (and HDO/H$_2$O) distribution from the ground to 15 km

(3) Our retrieval is 'nearly operational'

→ NDACC FTIRs can contribute to a long term QC of IASI H$_2$O products

Thank You!