Wv-retrievals from gb-FTIR measurements: Focus on isotopologues

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AGACC: Advanced exploitation of Ground-based measurements for Atmospheric Chemistry and Climate applications.

- Science for a sustainable development (2005-2009), Belgian Science Policy
- Further exploration of the capabilities of ground-based measurement systems at NDACC sites for retrieving atmospheric composition parameters that impact chemical climate and air quality, with laboratory support.

- New or improved time series and trends for tropospheric aerosol, \( \text{H}_2\text{O}, \text{CH}_4, \text{CO} \) and isotopologues, \( \text{H}_2\text{CO}, \text{HCN} \)
- More precise UV index predictions at Uccle
- Feasibility of detecting new HCFC/HFC, \( \text{OH}, \text{C}_2\text{H}_4 \)
- New laboratory spectroscopic parameters, supporting field observations and submitted to HITRAN, GEISA,…
- Interacts with the satellite community, atmospheric modelers (European ACCENT, SCOUT-O3), NDACC…
Outline

- **What?**
  - ✓ H$_2^{16}$O, H$_2^{17}$O, H$_2^{18}$O, HDO retrievals
    - Based on LBLRTModel & uses OEM (inverse method)
    - A priori = ECMWF or ACE-FTS (@ ISSJ) for H$_2$O, NCEP for P & T
  - ✓ Laboratory measurements of line parameters

- **Outcomes?**
  - ✓ Total columns, partial columns, vertical profiles
    - → 1. Results @ Uccle
      + characterizations (vertical sensitivity & error budgets)
    - → 2a. Vertical information @ Reunion Island
  - ✓ Intercomparison with other instruments
    - → IWV comparison with sondes, GPS, CIMEL @ Uccle
  - ✓ Isotopic ratios → transport processes & the tropospheric dynamics
    - → 2b. $\delta_D$ from IASI/MetOp @ Reunion Island
  - ✓ Time series & trends @ ISSJ
    - → FTIR spectra: 1974-1976 & 1984-now (> 27000 spectra)
    - → Grating spectrometers measurements: 1968-1989
  - ✓ Spectroscopic linelists
    - → 4. Overview of measurements @ Reims, France
Uccle, Brussels (50.5°N, 4°E) - Profiles

- July ‘06 to April ‘07
- All:
  - 900 spe, 37 sunny days
  - 20 noon PTU soundings
- Chosen µw
  - 62 spe, 12 days
  - 37 spe, 8 days with sonde
- Strictly noon coinc.
  - 11 spe, 4 days

→ Good agreement with the sonde for the 0-15 km layer
→ Some vertical trends reproduced by the retrievals
→ But match with sonde less good above 8-10 km
→ Difference FTIR-smoothed sonde = larger for 1-3 km.
Uccle, Brussels (50.5°N, 4°E) – Partial columns

- Investigation of the systematic bias of IWV between FTIR & sondes

- Layers are chosen from characterization (kernels, eigenvalues, errors) = “resolvable” vertical structures

- Bias mainly comes from the first layer, close to the ground
- Agreement is reasonable or even very good for the other layers.
- Confirms the difference in the vertical profiles
- Related to the greatest variability of wv concentrations near the ground
- But exact reasons ??
Reunion Island (21°S, 55°E) - Setup

- 3 campaigns:
  - Maïdo summit & St-Denis: Oct. ’02
  - St-Denis Aug.-Oct. ’04
  - St-Denis May-Dec. ’07
Reunion Island (21°S, 55°E) – Case study on 25 May ‘07 - HDO averaging kernels

**GROUND-BASED**

DOFS = 3.01

- Independent pieces of information: 3
- Prominent averaging kernels: 3
- Peaking at: 0.5, 2, 4 (6) km
- Information up to: 12 km

**IASI: nadir viewing IR Atm. Sounding IF**

DOFS = 3.65

- Independent pieces of information: ~4
- Prominent averaging kernels: 4
- Peaking at: 0.5, 2, 4, 6 (8) km
- Information up to: 14 km

→ gb-FTIR: better sensitivity in the 0-1 km layer
→ Complementarity between the 2 → Joint retrieval?
\[ \delta_D = \left[ \frac{R}{R_{SMOW}} - 1 \right] \times 1000 \]

in %

\[ R = \frac{\text{HDO}}{\text{H}_2\text{O}^{16}} \]

SMOW = Standard Mean Ocean Value

\[ R_{SMOW} = 0.31152.10^{-3} \]

→ Depleted values comprised between -700‰ and 0

= Compatible with the theoretical distillation curve up to 10 km

→ Positive trend > 10 km

= Uplift of cold air (less dehydrated, less depleted) from the cold point?

→ Large variability & error bars, but consistent among a series of spectra and with values reported in the literature [Herbin et al., ACP7, 3957-3968, 2007].
ISSJ (46.5°N, 8°E) - Site

- Measurements since 1984
ISSJ (46.5°N, 8°E) – Total columns

1999-2006
1300 data

Column abundance (mol/cm²)

Mean diff = -3.54% (RMS=11.45%), slope=0.92, intercept ~ 0, R=0.98
→ Good agreement
Higher diff. at low conc. & oscillation of the diff., period > 12 months
→ possibly due to poor photometer quality at low wv quantity [R. Peter, B. Schmid]
Laboratory measurements of line parameters - Setup

- **H$_2^{16}$O, H$_2^{17}$O, H$_2^{18}$O, HDO**
- Several campaigns
- 26000-2000 cm$^{-1}$
- Abs. path: 30 cm to 1800 m
- Doppler limited resolution
- $\neq$ WV pressures + dry air or N$_2$
- Room $T^\circ$
- $+$ Low res & 330K $\rightarrow$ continuum
Laboratory measurements of line parameters – Overview of measurements

- GaP diode
  - Xe arc lamp

- Si diode
  - Xe arc lamp
  - W lamp

- Si diode
  - W lamp

- InSb
  - W lamp

- MCT
  - W lamp

Intensity (arb. units)

Wavenumber (cm$^{-1}$)

26000 24000 22000 20000 18000 16000 14000 12000 10000 8000 6000 4000 2000
**Laboratory measurements of line parameters – Summary & publications**

- **Linelists of wvnb, intensities, $\gamma_{self}$, $\gamma_{air}$, $\delta_{self}$, $\delta_{air}$, assignments**
  - Comprehensive dataset
  - Ongoing work: 6600-8800 cm$^{-1}$ (congested!), assignments, continuum, ...
  - Partially included in HITRAN & GEISA
  - > 10 publications since 1999

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<tr>
<th>26000-13000 cm$^{-1}$</th>
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<td><strong>H$_2^{16}$O</strong></td>
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<td>- Carleer M. et al., JCP111(6), 1-7, 1999</td>
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<td>- Zobov N.F. et al., JCP113, 1546-1552, 2000</td>
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<td>- Coheur P.-F. et al., JQSRT74, 493-510, 2002</td>
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<td>Tolchenov R.N. et al., JMS233(1), 68-76, 2005</td>
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<td><strong>IN PROGRESS</strong></td>
<td>Mérienne MF et al., JQSRT82, 99-117, 2003</td>
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<td>Partial results presented at conferences</td>
<td>Jenouvrier A. et al., JQSRT1065, 326-355, 2007</td>
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<td>(+ H$_2^{17}$O, H$_2^{18}$O)</td>
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<td><strong>HDO</strong></td>
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<td>- Voronin B.A. et al., JMS244, 90-104, 2007</td>
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<td>- Jenouvrier A. et al., JMS, 209, 165-168, 2001</td>
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<td>Naumenko O.V. et al., JMS238(1), 79-90 2006 in a narrower region 9250-8800 cm$^{-1}$</td>
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<td><strong>HDO &amp; D$_2$O</strong></td>
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<td>&gt; 25000 lines measured &amp; assigned</td>
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Conclusions

✓ 1st analysis of H₂¹⁶O @ Uccle, Reunion Island & ISSJ
✓ Successful retrievals of vertical profiles for H₂¹⁶O
  between 0 (3.6 @ ISSJ) & 14 km
  with 3 to 4 levels of independent information
  with a maximal sensitivity in the layers:
  0-4km @Uccle & Reunion I., 4-6km for IASI, 3.6-10km @ISSJ
  with a corresponding uncertainty <30%, <20%, 25%
✓ 1st analysis of H₂O isotopologues @ Reunion Island
✓ Very good results obtained with IASI down to the ground
✓ Complementarity of both datasets is demonstrated
✓ First results of isotopic ratios from IASI spectra

Perspectives

✓ Optimize the retrieval strategy
✓ Exploit 2007 Reunion Island campaign, incl. isotopic ratios & IASI comparisons
✓ Joint FTIR-IASI retrievals @ Reunion Island ?
✓ Preparation of the future permanent Ile de La Réunion observatory
✓ Temporal series over the previous years @ ISSJ
✓ Comparisons with GPS, Payerne soundings, Bern microwave radiometer @ ISSJ
✓ …
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http://www.ucl.ac.be/cpm/
http://girpas.astro.ulg.ac.be
http://www.meteo.be/meteo
THANK YOU FOR YOUR ATTENTION!