Usage of differential absorption method in the thermal IR: a case study of quick estimate of clear-sky column water vapor

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Outline

- Motivation: the differential absorption method
  - UV and Visible
  - Thermal-IR?
- Algorithm
- Validations
- Conclusions
Motivation: the differential absorption method

Example 1: The Differential Optical Absorption Spectroscopy (DOAS) instrumentation, **visible and UV**

Example 2: Dobson spectrophotometer for ozone concentration, **UV**

Main point: double pairs of wavelengths are used to remove slowing varying component while retaining rapidly varying component

- Rapidly varying component
- Slowing varying component

\[ \Delta \nu_{AB} = \Delta \nu_{CD} \]
Motivation: the differential absorption method

Can we apply the concept to thermal IR?
A case study: clear-sky total column water vapor (CWV) retrieval from AIRS radiance
Algorithm

Flowchart for clear-sky CWV retrieval from AIRS radiance

1. AIRS radiance
2. Ts effect \((BT_E)\)
3. Lapse rate effect \((BT_E - BT_F)\)
4. Double difference
   \[ DDR = (R_D - R_C) - (R_B - R_A) \]
5. H\(_2\)O continuum is nearly canceled
6. H\(_2\)O line absorption contrast is highlighted
7. Look-up-table
8. Land or ocean?

Output: CWV
Datasets and model for training

- 6-hourly ECMWF ERA-Interim reanalysis
  Four months (Jan., Apr., Jul., Oct.) in 2005
- PCRTM (principal-component based radiative transfer model, Liu et al., 2006)

Datasets for validations

- 6-hourly ECMWF ERA-Interim reanalysis (diff. from the training data set)
  Four months (Jan., Apr., Jul., Oct.) in 2008
- Thermodynamic Initial Guess Retrieval (TIGR2000 v1.2)
  measured by real raidosondes, 1968-1989
- AIRS L2 cloud-cleared radiance in year of 2004
- AIRS L2 $\text{H}_2\text{O}$ retrievals: accuracy $\pm 10\%$, RMS 20-35%
Information on the selected AIRS channels

<table>
<thead>
<tr>
<th>ID</th>
<th>Channels (cm(^{-1}))</th>
<th>Peak of weighting function</th>
<th>Major absorption features</th>
<th>Surrogates</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>812.531</td>
<td>surface</td>
<td>H(_2)O continuum</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>814.029</td>
<td>80hPa above surface</td>
<td>H(_2)O weak line and continuum</td>
<td>DDR</td>
</tr>
<tr>
<td>C</td>
<td>827.747</td>
<td>80hPa above surface</td>
<td>H(_2)O weak line and continuum</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>829.299</td>
<td>surface</td>
<td>H(_2)O continuum</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>963.836</td>
<td>surface</td>
<td>H(_2)O continuum</td>
<td>(\Delta BT)(_{963.8-748.6}) for lapse rate</td>
</tr>
<tr>
<td>F</td>
<td>748.6</td>
<td>753.6 hPa</td>
<td>CO(_2)</td>
<td></td>
</tr>
</tbody>
</table>
Composites of log(CWV) as functions of DDR and BT\textsubscript{963.8} (proxy of $T\textsubscript{s}$)

Algorithm

Composites of log(CWV) as functions of DDR and BT\textsubscript{963.8} (proxy of $T\textsubscript{s}$)

DDR = Double difference radiance
Algorithm

Scatter plot of $\log(CWV)$ w.r.t. $\Delta BT_{963.8-748.6}$ (proxy of lapse rate)
Composites of CWV w.r.t. DDR, BT_{963.8}, \Delta BT_{963.8-748.6}\\
Ocean and land respectively\\
Denoted as CWV_{LUT} in following plots/validations
Validation I

(a) All
Slope $0.89\pm0.0110$
$R^2 0.82$
Mean: -0.07 cm;
RMS 34.8%

(b) Ocean
Slope $0.91\pm0.0119$
$R^2 0.89$
Mean: -0.06 cm;
RMS 31.7%

Validation I:
$CWV_{LUT}$ (y axis) VS. $CWV_{TIGR}$ (x axis)

Regression slope
1:1 line
Validation II: 

**CWV\textsubscript{LUT}** from real AIRSL2 cloud-cleared radiances **VS. CWV\textsubscript{AIRS}**

(a) CWV\textsubscript{AIRS}  
(b) CWV\textsubscript{LUT} - CWV\textsubscript{AIRS}  
(c) CWV\textsubscript{AIRS} - CWV\textsubscript{ERA}  
(d) STD of (CWV\textsubscript{LUT} - CWV\textsubscript{AIRS})

Mean is -0.05 cm
RMS is 33.8%.
Conclusions

- Differential absorption method is extended to the thermal-IR.
- CWV can be quickly estimated from look-up tables.
- The method is tested using multiple data sets. The mean bias is within $\pm0.07\text{cm}$ and the RMS fractional error is $\sim33\%$.
- It could be used as a first guess for other more sophisticated retrieval algorithms for CWV, or quick estimation of CWV for scene type classifications.

Thank you for attention!
Blue dots
298K < BT < 300K
0.02 < DDR < 0.02025 Wm$^{-2}$/sr/cm$^{-1}$

Red dots
288K < BT < 290K
0.01 < DDR < 0.01025 Wm$^{-2}$/sr/cm$^{-1}$