Recent Improvements on CH₄ Retrieval Using CrIS FSR Data -- suggestion for AIRS-V7

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Outline

- Requirement for CH$_4$ Product in J-1
  - The major sensitivity in mid-upper troposphere requires a good CH$_4$ firstguess in the lower troposphere
  - Recent increase of CH$_4$ and N$_2$O also calls for an update of CH$_4$ and N$_2$O firstguess

- Recent Improvements—Test Study Based on NUCAPS
  - Update of firstguess: comparison with model and ATom aircraft measurements
  - Other Improvements: Channel selection, re-tuning and Quality control (CH$_4$QC);

- Assessment of the Improved Retrievals
  - Comparison with model, AIRS, TCCON and ATom data;

- Summary and Future works
# Requirements of Trace Gases Products from CrIS

<table>
<thead>
<tr>
<th>EDR Attribute</th>
<th>CO</th>
<th>CO₂</th>
<th>CH₄</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Coverage</td>
<td>Total Column</td>
<td>Total Column</td>
<td>Total Column</td>
</tr>
<tr>
<td>Horizontal Resolution</td>
<td>100 km</td>
<td>100 km</td>
<td>100 km</td>
</tr>
<tr>
<td>Mapping Uncertainty, 3 sigma</td>
<td>25 km</td>
<td>25 km</td>
<td>25 km</td>
</tr>
<tr>
<td>Measurement Range</td>
<td>0 – 200 ppbv</td>
<td>300 – 500 ppmv</td>
<td>1100 – 2250 ppbv</td>
</tr>
<tr>
<td>Measurement Precision</td>
<td>15%</td>
<td>0.5% (2 ppmv)</td>
<td>1% (~20 ppbv)</td>
</tr>
<tr>
<td>Measurement Accuracy</td>
<td>±5%</td>
<td>±1% (4 ppmv)</td>
<td>±4% (~80 ppbv)</td>
</tr>
<tr>
<td>Refresh</td>
<td>24 h</td>
<td>24 h</td>
<td>24 h</td>
</tr>
</tbody>
</table>

**Note**
Sensitivity of CrIS to Atmospheric CH$_4$

- Major sensitivities are in the mid-upper troposphere – not near the surface where the variation is impacted by emissions;

- Sensitivities in the polar are lower than in tropics and mid-latitude
Simple Estimate of the CH$_4$ Total Amount Error
assuming 5% error of CH$_4$ profile in lower troposphere (below 800 hPa)

Assuming 5% error of CH$_4$ profile in lower troposphere (below 800 hPa), the error in total amount is about 1.2%.

- to meet the requirement of total amount in 1% (precision) is hard if without a good a priori, particularly in the lower troposphere.
Significant Increase of CH$_4$ in the past 10 years

We built a fixed firstguess in AIRS-V6 in about 10 years ago → it helps us to check the possibility to monitor the trend.

Downloaded from https://www.esrl.noaa.gov/gmd/ccgg/trends_ch4/
Annual Increase Rate of CH$_4$ from AIRS-V6 and its Comparison with NOAA Ground-based Measurements

Nearly Linear Increase of N$_2$O

AIRS can be used to monitor the N$_2$O trend (with a fixed first-guess)

+ 0.26%/yr

Questions

Even though we have some capability to monitor the CH$_4$ trend using AIRS data (with a fixed first-guess), should we include the trend in the AIRS-V7 to reprocess the data, so that we can have a better product, esp. the total amount?

Similarly for N$_2$O ....

Even we do not want to add the trend for future retrieval, at least for CrIS we need to update CH$_4$ and N$_2$O firstguess to be consistent with current observation
Update of CH$_4$ First-guess – based on JAMSTEC Model

--- Old fg is the one used in AIRS-V6 and NOAA IASI system

($\sim 2.5\%$)
Examples of selection of flight lags

2016-07-29 ATom

Pressure (hPa)

Time (seconds)

CH₄ (ppb)
Comparison of CH$_4$ firstguess with ATom Aircraft Measurements

More improvement to the CH$_4$ firstguess in the southern hemisphere is needed.
Comparison of $\text{N}_2\text{O}$ firstguess with ATom Aircraft Measurements

$+4.5 \text{ ppb}$
Simple Estimate of the Impact of N₂O firstguess to CH₄ Retrievals

Adding 4.5ppn in N₂Ofg and compared the difference of the retrieved CH₄;
Used one day data on 2/17/2015;

- An update N₂O from AIRS-V6 is necessary for improving CH₄ retrieval
Other Optimizations(1): Channel Selection

Due to the spectral resolution of CrIS (0.625 cm⁻¹), our option is not many; not only consider the information content, I also checked the fitting error and removed some channels with strong N₂O and HNO₃ absorption; 70 channels (red) are selected (it was 84 in NUCAPS V2.0.5.4, Blue).
Comparison of Jacobian

Upper left is V2.0.5.4
Lower right is the recent one
The existence of uncertainty of CH$_4$ absorption (line-mixing) near 1306 cm$^{-1}$ (Xiong et al., 2008, JGR; Xiong et al., 2015, AGU talk);

Cloud-clearing is a good thing to increase the yield of retrievals, but it also contaminate trace gases products; Also CH$_4$ is very sensitive to upstream water vapor products. So a re-tuning using the upstream T, q retrievals products and cloud-clear radiance has been made.
Comparison of CH$_4$ from AIRS, IASI and CrIS (20160508, @515hPa) – NO QC to CrIS CH$_4$ products
Other Optimizations(3): Quality Control (CH$_4$QC)

- For two granules
- Left panels: red lines are from version V2.0.5.4 (delivered in July) and black lines are from updated retrievals;
- Right panels: Profiles from updated retrieval and using CH$_4$QC (=0,1)
Example of CH$_4$ map after Preliminary CH$_4$ QC

Preliminary CH$_4$ QC is tailored to CH$_4$ products based on the DOF, surface temperature, chisq etc.
# Yields after using CH$_4$QC

<table>
<thead>
<tr>
<th>Descending</th>
<th>Yield (%)</th>
<th>Percentage relative to NO CH$_4$QC (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>QC=0 (best)</td>
<td>37.4</td>
<td>45.0</td>
</tr>
<tr>
<td>QC=1 (good)</td>
<td>13.4</td>
<td>16.0</td>
</tr>
<tr>
<td>QC=2 (bad)</td>
<td>49.2</td>
<td></td>
</tr>
</tbody>
</table>

50.8%

<table>
<thead>
<tr>
<th>Ascending</th>
<th>Yield (%)</th>
<th>Percentage relative to NO CH$_4$QC (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>QC=0</td>
<td>43.6</td>
<td>52.0</td>
</tr>
<tr>
<td>QC=1</td>
<td>11.1</td>
<td>13.2</td>
</tr>
<tr>
<td>QC=2</td>
<td>45.2</td>
<td></td>
</tr>
</tbody>
</table>

54.7%
Assessment

- Comparison with AIRS (515 hPa)
- Comparison with MODEL (4 different layers and total column amount)
- Comparison with TCCON (total column amount)
- Comparison with ATom (300-600 hPa)
Comparison of CH$_4$ at 500 hPa with AIRS

Upper left is V2.0.5.4
Lower right is the recent one
Comparison of CH$_4$ with Model at Four Layers (260, 515, 706 and 852 hPa)

Upper left is V2.0.5.4
Lower right is the recent one
Comparison of CH$_4$ Total Amount with Model

2/17/2016

Upper left is V2.0.5.4
Lower right is the recent one

2/17/2015

0.087546830 (2.7251925) (%)
Comparison of CrIS xCO/xCO$_2$/xCH$_4$ with TCCON Measurements

- Data of 10 days is used;
- This is a simple comparison by averaging TCCON data within 1 hour of satellite overpass and satellite data within 200 km over the ground site;
- Better agreement can be achieved if using averaging kernels
Comparison with ATom data (Preliminary)

No averaging Kernels
No QC tailored to trace gases

Within 200 KM

We need QC!
Summary and Future Works

1. The major sensitivity of CrIS is in the mid-upper troposphere. In order to meet the requirement in total amount, a good firstguess is really needed.

2. Rapid increase of CH$_4$ since 2007 and almost linear increase of N$_2$O request an update to CH$_4$ and N$_2$O firstguess in AIRS-V6;

3. Recent test of improvements (firstguess, channel selection, tuning ) are promising, but more works need to be done …

4. Cloud-clearing is a major part in AIRS and NUCAPS retrieval systems, but we should be very careful to set QC for all trace gases.

A question is: should we add the increase trend in the firstguess of CH$_4$ and N$_2$O in AIRS-V7?

I vote “YES” , as it impacts other products, i.e. q