Validation of forecast cloud parameters from multispectral AIRS radiances

Louis Garand, Ovidiu Pancrati, Sylvain Heilliette
Environment Canada
Data Assimilation and Satellite Meteorology Research Section

17th TOVS Study Conference
Monterey, CA
April 14-21, 2010
Motivation

• Provide to modelers a reliable methodology to validate cloud height and amount distributions in forecasts
• Improve cloud parameter retrievals, with applications to model validation, data assimilation and climate studies
• Use hyperspectral sounders to do this in a general framework (applicability to AIRS, IASI, Cris…)

Typical 6-h AIRS coverage
Basic idea

Assumption: Comparing directly model output cloud parameters with retrievals subject to ambiguous results due to limitations of the retrieval technique

Therefore:

• Retrieve effective cloud height and amount from CO₂-slicing technique using observed AIRS radiances
• Retrieve same parameters from calculated AIRS radiances using forecast output at real observation locations

Eliminates ambiguity of definition between retrieved and model values of cloud parameters: comparing apples with apples. This also allows to understand and minimize limitations of the retrieval technique.
**Data, RTM**

**INPUT:**

**Collected data:** AIRS 281-channel set reduced to center pixel in 3X3 "golf ball" (in assimilation warmest, but this is not suitable for climatology of cloud parameters)

**Forecast model:** EC global model, 600 X 800 grid (~35 km), interpolated at the location of observation, 6 h forecast (valid interval 3-9h) and 12h forecast (valid interval 9-15h) at 45 min intervals. Entire month of July 2008 used (31 days times 4 forecasts/day).

**Radiative transfer model:** modified RTTOV 8.7 version

**Cloud optical properties:** cloud overlap scheme [Räisänen, 1998], fixed liquid particle size (10 µm radius over land and 13 µm radius over ocean), ice particle size parameterization [McFarquhar et al. 2003]
Revision/adaptation of CO$_2$-slicing technique

following this study

- 13 radiance pairs used, all in narrow range 13.2-14.1 µm
- Median value of height retained with corresponding effective amount

before

- Original implementation for AIRS in 2004 used 12 pairs with channel 528 (12.2 µm) used in all pairs. Mean was retained.
**CO₂-slicing technique: new selection**

**Initial configuration:** 12 channels coupled with a reference channel

<table>
<thead>
<tr>
<th>Channel #</th>
<th>Wavenumber</th>
</tr>
</thead>
<tbody>
<tr>
<td>204</td>
<td>707.770</td>
</tr>
<tr>
<td>221</td>
<td>712.661</td>
</tr>
<tr>
<td>232</td>
<td>715.862</td>
</tr>
<tr>
<td>252</td>
<td>721.758</td>
</tr>
<tr>
<td>262</td>
<td>724.742</td>
</tr>
<tr>
<td>272</td>
<td>727.752</td>
</tr>
<tr>
<td>299</td>
<td>735.298</td>
</tr>
<tr>
<td>305</td>
<td>737.152</td>
</tr>
<tr>
<td>310</td>
<td>738.704</td>
</tr>
<tr>
<td>355</td>
<td>752.970</td>
</tr>
<tr>
<td>362</td>
<td>755.237</td>
</tr>
<tr>
<td>475</td>
<td>801.001</td>
</tr>
<tr>
<td><strong>Reference channel</strong></td>
<td><strong>528</strong></td>
</tr>
</tbody>
</table>

**Chosen configuration:** 13 pairs of coupled channels in narrow limited range

<table>
<thead>
<tr>
<th>Pair #</th>
<th>Channel A</th>
<th>Channel B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>#</td>
<td>cm⁻¹</td>
</tr>
<tr>
<td>1</td>
<td>204</td>
<td>707.770</td>
</tr>
<tr>
<td>2</td>
<td>221</td>
<td>712.661</td>
</tr>
<tr>
<td>3</td>
<td>232</td>
<td>715.862</td>
</tr>
<tr>
<td>4</td>
<td>252</td>
<td>721.758</td>
</tr>
<tr>
<td>5</td>
<td>262</td>
<td>724.742</td>
</tr>
<tr>
<td>6</td>
<td>272</td>
<td>727.752</td>
</tr>
<tr>
<td>7</td>
<td>299</td>
<td>735.298</td>
</tr>
<tr>
<td>8</td>
<td>305</td>
<td>737.152</td>
</tr>
<tr>
<td>9</td>
<td>310</td>
<td>738.704</td>
</tr>
<tr>
<td>10</td>
<td>355</td>
<td>752.970</td>
</tr>
<tr>
<td>11</td>
<td>362</td>
<td>755.237</td>
</tr>
<tr>
<td>12</td>
<td>375</td>
<td>759.485</td>
</tr>
<tr>
<td>13</td>
<td>375</td>
<td>759.485</td>
</tr>
</tbody>
</table>
Assimilation impact test on CO2-slicing channel selection: 120 h forecast vs observations

Global

Southern Hemisphere

Ref channel AIRS-528 (820 cm\(^{-1}\)), mean of 13 pairs
All pairs in range 797-760 cm\(^{-1}\), median of 13 pairs

Positive impact in Southern hemisphere
Definition of model cloud parameters

Based on cloud transmittance $\tau_{\text{cloud}} (I, \text{TOA})$ in a window channel, considering cloud emissivity and overlap assumptions

$\textbf{CTH} = \text{effective Cloud Top Height} = \text{level} \ I \ \text{where} \ \tau_{\text{cloud}} = 0.9$

$\textbf{Ne} = \text{effective cloud fraction} = 1 - \tau_{\text{cloud}}$

$\textbf{N} = \text{cloud fraction, same definition, but assuming cloud emissivity of unity: cloud mask}$
Understanding CO$_2$-slicing

Direct model output CTH vs retrieved CTH

- Bias increases with height except for low Ne
- Underestimation of retrieved overcast cases
Validation results: cloud top height bias

Model CTH vs retrieved CTH from simulated AIRS radiances

Global data

Model CTH vs retrieved CTH from simulated AIRS radiances

CALIPSO CTH vs retrieved CTH from real AIRS radiances

Remarkable similitude in dynamic range and bias attributed to CO₂ slicing technique. Implies definition of model height OK.
Validation results: cloud top height bias

Model CTH vs retrieved CTH from simulated AIRS radiances

65°S – 40°S

Model CTH vs retrieved CTH from simulated AIRS radiances

CALIPSO CTH vs retrieved CTH from real AIRS radiances
Validation results: cloud top height bias

Model CTH vs retrieved CTH from simulated AIRS radiances

40°N – 65°N

Model CTH vs retrieved CTH from simulated AIRS radiances

CALIPSO CTH vs retrieved CTH from real AIRS radiances
Validation results: cloud top height bias

Model CTH vs retrieved CTH from simulated AIRS radiances

Arctic: 65°N – 90°N

Model CTH vs retrieved CTH from simulated AIRS radiances

CALIPSO CTH vs retrieved CTH from real AIRS radiances
Validation results: cloud top height bias

The bias model vs retrieved is quite stable. Only cloud amounts superior to 0.5 were considered.
Importance of CTH bias correction

CO₂ slicing from simulated BTs
Raw
Unbiased

CTH directly from Model output

15-S to 15 S CTH distribution
Tool to the modeler: cloud height distributions. Here global for 15 June 2008

Real data Co2-slicing

Simulated data CO2-slicing

Direct model output (e<=1)

Direct model output (e=1)
CTH distributions 15S=15N

Real data Co2-slicing

Simulated data CO2-slicing

Direct model output (e<=1)

Direct model output (e=1)
CTH distributions 65-90 N

Real data Co2-slicing

Simulated data CO2-slicing

Direct model output (e<=1)

Direct model output (e=1)
CTH distributions 65-90 S

Real data Co2-slicing

Simulated data CO2-slicing

Direct model output (e<=1)

Direct model output (e=1)
Ne global distributions

real retrievals

simulated retrievals

Direct output e<=1
direct output e=1
Effective cloud amount Ne monthly results

Observed Ne AIRS-CMC

Model 3-9-h Ne simulated BTs

Observed Ne AIRS-JPL

Ne from direct 3-9h model output
Excellent agreement between AIRS-CMC and MODIS Model has maximum Cloudiness next to Antartic coast, not supported by observations.
Monthly cloud height results

- Observed AIRS-CMC
- Model 3-9h forecasts CO2-slicing
- Observed MODIS
- Model 9-15h forecasts CO2-slicing
- Observed AIRS-JPL
- Direct model output 3-9h forecasts
Conclusions

- A model validation methodology for basic cloud parameters was presented based on the following principle: Apply the same retrieval technique to real and simulated radiances.
- Robust definitions of model effective height and amount are proposed.
- The method is designed for hyperspectral sounders and relies on well established Co2-slicing method.
- CO₂-slicing technique was revised. It is suggested to use ~13 independent pairs in range 13.2-14.1 mm range. Retain median CTH and corresponding Ne.
- A simple CTH bias correction is proposed based on simulated retrievals with remarkable similarity to real retrievals compared to CALIPSO heights.
- Vertical distributions of CTH is the main output to the modeler to adjust cloud and radiation parameterizations.
- Monthly products compare well with independent sources such as AIRS-JPL and MODIS. Differences are attributed to different retrieval methodology.