Validation of forecast cloud parameters from multispectral
AIRS radiances

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

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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…)
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 CO$_2$- 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**

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<tr>
<th>Channel #</th>
<th>Wavenumber</th>
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<tbody>
<tr>
<td>204</td>
<td>707.770</td>
</tr>
<tr>
<td>221</td>
<td>712.661</td>
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<tr>
<td>232</td>
<td>715.862</td>
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<td>252</td>
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<td>310</td>
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<td>355</td>
<td>752.970</td>
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<td>362</td>
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<td>475</td>
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<td>Reference channel</td>
<td></td>
</tr>
<tr>
<td>528</td>
<td>820.731</td>
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</tbody>
</table>

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

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

<table>
<thead>
<tr>
<th>Pair #</th>
<th>Channel A #</th>
<th>cm⁻¹</th>
<th>Channel B #</th>
<th>cm⁻¹</th>
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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

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

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

$\text{N} =$ 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**

\[
Y = 1.133 \cdot X \\
\text{Standard deviation} = 0.724 \\
R^2 = 0.969
\]

**CALIPSO CTH vs retrieved CTH from real AIRS radiances**

\[
Y = 1.159 \cdot X \\
\text{Standard deviation} = 1.460 \\
R^2 = 0.885
\]

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.

2008/07/14

Daily values for July 2008
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 $e \leq 1$

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
Cloud fraction (N) comparisons

Excellent agreement between AIRS-CMC and MODIS Model has maximum Cloudiness next to Antarctic coast, not supported by observations.

Source: MODIS science team
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.