Inter-comparison and Assessment of AIRS Version-5 and Version-6 Temperature, Water Vapor, Surface Emissivity, and Cloud Products

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NASA GSFC Sounder Research Team (SRT)

AIRS Sounder Science Team Meeting
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Comparisons of V6.07, V6.07 AO, and V5.0

Two types of evaluation

- 9 focus days, September 6, 2002 through September 14, 2012, validated against ECMWF truth
  Evaluated $T_s^*$, surface spectral emissivity $\varepsilon_v^*$, $T(p)^*$, $q(p)^*$
  Mean* and trends** of yields, RMS differences, and biases

- 12 monthly means for 4 different months in 3 different years
  Evaluated biases as well as trends of V6.07 $T_{500}$, $q_{500}$, $W_A$, $\alpha \varepsilon$, OLR and OLR$_{CLR}$ compared to V.5

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Surface Skin Temperature Difference
9-Day Average    Daytime and Nighttime combined
50 N to 50 S    Non-Frozen Ocean

<table>
<thead>
<tr>
<th>Version</th>
<th>QC=0, 1</th>
<th>Mean</th>
<th>STD</th>
<th>% Cases</th>
<th>Percent greater than [3] from mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version-6.07</td>
<td>-0.32</td>
<td>0.95</td>
<td>53.39</td>
<td>0.40</td>
<td></td>
</tr>
<tr>
<td>Version-6.07</td>
<td>-0.27</td>
<td>0.84</td>
<td>41.59</td>
<td>0.60</td>
<td></td>
</tr>
<tr>
<td>Version-6.07 Airs Only</td>
<td>-0.34</td>
<td>0.95</td>
<td>50.18</td>
<td>1.49</td>
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<tr>
<td>Version-6.07 Airs Only</td>
<td>-0.30</td>
<td>0.87</td>
<td>41.54</td>
<td>0.76</td>
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<tr>
<td>Version-5</td>
<td>-0.58</td>
<td>0.63</td>
<td>20.19</td>
<td>1.25</td>
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</tr>
<tr>
<td>Version-5</td>
<td>-0.49</td>
<td>0.56</td>
<td>10.20</td>
<td>0.50</td>
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</tr>
</tbody>
</table>

NASA
Version-6 accepts many more cases than Version-5, especially at moderate to high cloud fraction. RMS errors of both Version-5 and Version-6 SST grow slowly with increasing cloud fraction.
Version-6 Level-3 SST product has much better accuracy and spatial coverage than Version-5
Ocean Surface Emissivity vs. Zenith Angle

Mean 950 cm⁻¹ Emissivity minus Masuda
50 North to 50 South Ocean
9-Day

STD 950 cm⁻¹ Emissivity
50 North to 50 South Ocean
9-Day

Mean 2400 cm⁻¹ Emissivity minus Masuda
50 North to 50 South Ocean
9-Day

STD 2400 cm⁻¹ Emissivity
50 North to 50 South Ocean
9-Day
Day/night differences of land surface emissivity are much smaller in Version-6 compared to Version-5.
Version-6 T(p) retrievals with Data Assimilation QC have RMS errors $\leq$1K throughout troposphere.

Version-6 T(p) retrievals with Climate QC have much greater yield than Version-5 with small biases.

Differences between V6.07 and V6.07 AO are small.
Version-6 errors are smaller than Version-5, and Version-6 yields are higher than Version-5, especially at larger cloud fractions.
Global Temperature 9-Day Two Common Ensembles

Percent of All Cases
Accepted

Layer Mean RMS (°K)
Differences from ECMWF

[Graphs showing temperature and RMS differences for two ensembles, labeled with versions and QC criteria.]
### Cases in Common Using the Version-5 Tight Ensemble

<table>
<thead>
<tr>
<th></th>
<th>Global TTM</th>
<th>BLM</th>
<th>Land ±50° TTM</th>
<th>BLM</th>
<th>Ocean ±50° TTM</th>
<th>BLM</th>
<th>Poleward of 50°N TTM</th>
<th>BLM</th>
<th>Poleward of 50°S TTM</th>
<th>BLM</th>
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</thead>
<tbody>
<tr>
<td>Version-5</td>
<td>1.14</td>
<td>1.54</td>
<td>1.22</td>
<td>1.78</td>
<td>1.06</td>
<td>1.21</td>
<td>1.18</td>
<td>1.74</td>
<td>1.43</td>
<td>2.01</td>
</tr>
<tr>
<td>Version-6.07</td>
<td>0.94</td>
<td>1.35</td>
<td>0.94</td>
<td>1.49</td>
<td>0.86</td>
<td>1.00</td>
<td>0.98</td>
<td>1.54</td>
<td>1.28</td>
<td>1.95</td>
</tr>
</tbody>
</table>

### Cases in Common Using the Version-6.07 Climate Ensemble

<table>
<thead>
<tr>
<th></th>
<th>Global TTM</th>
<th>BLM</th>
<th>Land ±50° TTM</th>
<th>BLM</th>
<th>Ocean ±50° TTM</th>
<th>BLM</th>
<th>Poleward of 50°N TTM</th>
<th>BLM</th>
<th>Poleward of 50°S TTM</th>
<th>BLM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version-5</td>
<td>1.56</td>
<td>2.84</td>
<td>1.75</td>
<td>2.92</td>
<td>1.43</td>
<td>2.70</td>
<td>1.51</td>
<td>2.95</td>
<td>1.70</td>
<td>2.96</td>
</tr>
<tr>
<td>Version-6.07</td>
<td>1.11</td>
<td>1.69</td>
<td>1.05</td>
<td>1.72</td>
<td>1.02</td>
<td>1.35</td>
<td>1.11</td>
<td>1.92</td>
<td>1.33</td>
<td>2.09</td>
</tr>
</tbody>
</table>

TTM is the average T(p) RMS difference from ECMWF over all 1 km layers from surface to 100 mb
BLM is the average T(p) RMS difference from ECMWF over the lowest 6 0.25 km layers
All Version-6 metrics are much better than Version-5, especially for the difficult climate ensemble
Version-5 had significant negative yield and tropospheric T(p) bias trends. These are significantly improved on in Version-6 and Version-6 AO.
Global Water Vapor 9-Day Statistics use their own QC

Version-6 has higher yield than Version-5 and performs better in the lower troposphere
Version-6 Level-3 total precipitable water is more accurate than Version-5
Global Water Vapor Trends (%/yr)  9-Day Statistics use their own Climate QC

1 Km Layer Mean

Percent Yield

Precipitable Water Bias vs. ECMWF

Negative yield and tropospheric water vapor trends are improved in Version-6 compared to Version-5

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Version-5 Level-3 products are known to have some spurious trends. We have compared global mean Level-3 Version-5 and Version-6.07 products to see how much Level-3 trends might improve in Version-6.

The following plots show monthly mean global mean time series of select Version-5 products and Version-6.07 products for the 12 months January, April, July, and October 2003, 2007, and 2011 which have been run.

We also show the “trendline” of Version-5 and Version-6.07 products defined as the linear least squares fit of the time series passing through the 12 months sampled by Version-6.

What is most important is the difference between Version-6 and Version-5 trendline slopes.

These results are shown for:

\[ T_{500}, \ q_{500}, \ W_{TOT}, \ \alpha \varepsilon, \ OLR, \] and \[ OLR_{CLR} \]
Global Time Series January 2003 through October 2011

500 mb Temperature (K/yr)  500 mb Water Vapor Mixing Ratio (g/kg)  Total Precipitable Water (mm)

Effective Cloud Fraction (%)  OLR (W/m²)  Clear Sky OLR (W/m²)

AIRS V5 January 2003 through October 2011  AIRS V6.07 12 Months
AIRS V5 12 Months  AIRS V5 minus AIRS V6.07
V5 trendline  V6.07 trendline  V5-V6.07 trendline

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### Trendline slopes of Global Mean Time Series
January 2003 through October 2011

<table>
<thead>
<tr>
<th></th>
<th>OLR W/m²/yr</th>
<th>Clear Sky OLR W/m²/yr</th>
<th>Cloud Fraction %/yr</th>
<th>500 mb Temp K/yr</th>
<th>$W_{TOT}$ mm/yr</th>
<th>$q_{500}$ g/kg/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AIRS V5</strong></td>
<td>-0.104</td>
<td>-0.040</td>
<td>0.260</td>
<td>-0.058</td>
<td>-0.039</td>
<td>-0.00325</td>
</tr>
<tr>
<td><strong>AIRS V6.07</strong></td>
<td>-0.038</td>
<td>-0.054</td>
<td>0.049</td>
<td>-0.006</td>
<td>0.012</td>
<td>0.00001</td>
</tr>
<tr>
<td><strong>AIRS V5 minus AIRS V6.07</strong></td>
<td>-0.066</td>
<td>0.014</td>
<td>0.211</td>
<td>-0.052</td>
<td>-0.050</td>
<td>-0.00326</td>
</tr>
</tbody>
</table>

V6.07 trendline slopes are closer to zero than those of V5
Comparison Summary

Version-6 is significantly improved with regard to Version-5 in every way with regard to $T_s$, $\varepsilon_v$, $T(p)$, $q(p)$, $\alpha\varepsilon$

OLR, $\text{OLR}_{\text{CLR}}$ both agree better with CERES (not shown today)

Version-6 AO is roughly comparable to Version-5

Version-6 gets my blessing for release

Congratulations to the entire AIRS Science Team and supporting cast!
Short Term SRT Plans for Version-7

• Implement Neural-Net start-up option at SRT
  John expects to complete this by the end of November
  This is critical for optimal development and testing of further improvements

• Improve water vapor retrieval using Neural-Net start-up:
  channels, functions, damping parameters

• Improve temperature profile retrieval by using tropospheric 15 $\mu m$ CO$_2$ channels that do not see clouds.
  Theory says that 15 $\mu m$ CO$_2$ channels that see clouds should not be used in T(p) retrieval. Version-6 assures this by using only stratospheric sounding CO$_2$ channels in T(p) retrieval
  Many tropospheric 15 $\mu m$ do not see clouds depending on the scene and can (should) be used in T(p) retrieval for that case
Longer term SRT Plans for Version-7

• Implement 1 (cross track) x 3 (along track) FOV retrieval system
  This triples the spatial resolution and density of the AIRS soundings
  Approach was previously attempted for Version-6 before Neural-Net implementation, but dropped because 1x3 soundings had degraded in harder cloud cases
  New Version-6 Neural-Net start-up allows for much better soundings under cloudier cases

• Perform cloud spectral emissivity retrievals
  Important for OLR calculation and radiance computation closure

• Attempt to include absorption by dust in the retrieval process
  This should improve retrievals in dusty scenes rather than (hopefully) rejecting them as done now

• Any other ideas that come up by us or other team members

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