AIRS Spatial Calibration Status And Plans

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March 10, 2006
• AIRS validation requires comparison of AIRS data products with those of other instruments (for example, MODIS and HIRS)

• Knowledge of the AIRS spatial response for each channel is sometimes required to properly interpret differences seen between AIRS and other instruments

• At present, we are attempting to confirm pre-flight measurements of the AIRS spatial response. We are working on reconstructing the AIRS spatial response functions using Aqua MODIS data combined with AIRS
  
  – **MODIS and AIRS view essentially the same scenes at the same time from the same spacecraft**
  
  – **MODIS spatial resolution is about a factor of 14 better than AIRS**
• If this work succeeds, it will demonstrate the feasibility (under some circumstances) of using in-flight data to confirm pre-flight spatial characterization

• If the attempt fails or works only roughly, that would re-emphasize the importance of thorough pre-flight characterization
Outline

• Pre-flight measurements of the AIRS spatial response functions
• Processing of the measured functions to include the effects of:
  – Field stop mask
  – Scan mirror rotation, footprint to footprint
  – Motion during a single footprint
• Impact on radiometry of channel-to-channel boresight offsets, as presented at the SPIE meeting in Orlando in April 2005
• In-flight verification of pre-flight spatial characterization
  – Early results of comparisons between different AIRS channels, as presented at the SPIE meeting in San Diego in August 2005
  – On-going activity using comparison of AIRS and MODIS
Pre-flight Measurements

- AIRS IR spatial response functions were measured pre-flight, before the instrument was fully assembled
- Measurements were made:
  - *Without the scan mirror in place*
  - *Before the AIRS optics were modified to add a field stop mask, which reduced the field of view in the in-scan direction*
- The spatial collimator system (part of the AIRS Calibration and Test Facility at BAE Systems) was used to position the beam
- The derived response functions are valid for nadir for a motionless instrument with the originally-designed field of view
- All 2378 channels were measured, in a 39 x 39 grid with spacing 0.04 degrees
- After the field stop modification, a subset of the measurements was repeated to ensure that the apodization had the expected effect
Further Processing of Measured Response Functions

- The field stop mask is easily simulated—the measured response function (which we refer to as a “top hat”) is just truncated in the in-scan direction
- Truncated top hat centroids were then calculated for each channel (results next slide)
- For each of the 90 AIRS footprints, the truncated top hat is then rotated by an amount equal to that footprint’s nominal scan angle
- The rotated top hat is then convolved with a smearing function to mimic scanner and spacecraft motion during the footprint integration time
- Sample results are shown in subsequent slides
- The calculations have been performed and stored at each step for all 2378 IR channels
AIRS Channel Centroid Offsets

- **Standard deviations**
  - $x \rightarrow 0^\circ.031$
  - $y \rightarrow 0^\circ.016$

- **Outliers**
  - *Noisy during prelaunch test*
  - *Partially shadowed*

- **Systematic changes across arrays**
  - *Pupil-imaging-unique focal plane illumination effects*
AIRS Flight Spatial Response (Convolved and Rotated) From Pre-Flight Optical Bench (Original)
• In early 2005 George Aumann analyzed the effects on radiometry of channel boresight misalignments

• Three pairs of AIRS channels were used
  – *Within each pair, channels had essentially the same weighting function*
  – *One pair had well-aligned boresights (within 0.004 degrees)*
  – *One pair was moderately misaligned (0.023 degrees)*
  – *One pair was significantly misaligned (0.036 degrees)*

• Conclusions
  – *Even in high-contrast scenes, the mean brightness temperatures were unaffected by misalignment*
  – *The standard deviation of difference images and their gradients showed a linear dependence on the amount of misalignment*
• This is a typical AIRS nighttime scene over ocean
• This is a brightness temperature image measured in a single AIRS channel at 1231 cm$^{-1}$
• Note the cold (high) cloud formation
• Note also some fainter circular cloud features
• Part of the scene is clear and we are seeing to the ocean surface
Indian Ocean Difference Images

- Well aligned (.004)
- \( \text{bt938 - bt943} \)
- Very little image bleed through
- Total range \( \approx 1.6K \)

- Aligned to within .023
- \( \text{bt1231 - b1128} \)
- Moderate image bleed through
- Total range \( \approx 4.0K \)

- Aligned to within .036
- \( \text{bt901 - b913} \)
- Considerable image bleed through
- Total range \( \approx 8.0K \)
• The maximum gradients seen in the differences are proportional to the boresight offset
• Channels 760 and 774, near 11 microns, were analyzed by Tom Pagano last year.
• These channels observe essentially the same part of the atmosphere, but have significantly different top hat centroids determined pre-flight.
• He performed a regression analysis to find the best set of nine coefficients, assuming that a given pixel in one channel equals the weighted sum of its nearest neighbors (3x3 grid) for the other channel.
• He also took an entire granule image in each of the two channels, resampled them to a lat/lon grid, and (using trial and error) minimized their difference image subject to differing spatial offset amounts.
The results from both methods did not confirm the centroid values calculated from the pre-flight data

- *The two regression analyses agreed more closely with each other than with offsets predicted from the pre-flight measurements*
- *The observed flight-data offsets were somewhat larger than the pre-flight values*

For that reason, we have chosen to hold off making the top hat functions at each step available to the public

- *We want to understand the apparent discrepancy between the pre-flight measurements and analysis of in-flight data*
Regression Technique and Trial and Error Show Greater Offsets than Pre-Flight Data

- **Channel pair 760 (M8) / 774 (M7)**
  - *Pre-flight relative offset 0.035*
  - *In-flight regression relative offset 0.103*

<table>
<thead>
<tr>
<th>Channel</th>
<th>Frequency (cm⁻¹)</th>
<th>Pre-Mask Centroid Pre-Flight Az (deg)</th>
<th>Pre-Mask Centroid Pre-Flight El (deg)</th>
<th>Post-Mask Centroid Pre-Flight Az (deg)</th>
<th>Post-Mask Centroid Pre-Flight El (deg)</th>
<th>Regression Centroid In-Flight Az (deg)</th>
<th>Regression Centroid In-Flight El (deg)</th>
<th>Trial and Error In-Flight Az (deg)</th>
<th>Trial and Error In-Flight El (deg)</th>
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• We are now trying a slightly different technique to attempt to verify the pre-flight top hat data and to test the feasibility of post-launch spatial characterization

• We are using AIRS channel 1489 (M3; 7.4 microns) and MODIS band 28

• Channel 1489 is one of a small minority of AIRS channels which has a highly asymmetric top hat function as measured pre-flight (see plots on next slide)

• AIRS and MODIS granule images have been resampled to eliminate differing effects between the instruments of spacecraft and scanner motion during each scan line (see following slides)
AIRS Channel 1489 Top Hats (Nadir)

Top Hat Plots For PGE Channel 1489 (LMID 679) --- Footprint 45
AIRS/MODIS Comparison Technique (2 of 2)

- We then assume each AIRS nadir pixel is equal to the weighted sum of a 15 x 15 neighborhood of MODIS pixels
  - Because of the resampling, the analysis technique is not limited to nadir, but that is all that has been tried so far

- Data from 14 overlapping scenes in 12 granules from the focus day on September 6, 2002 were combined and a least-squares fit was performed to calculate the 225 weights
  - These weights should look similar to the pre-flight top hat for detector 1489

- We do not yet have a satisfactory fit
AIRS/MODIS Pair (spatially raw)
Summary

• In order to properly validate an instrument and to enable inter-instrument comparisons, the spatial response needs to be fully characterized.

• A complete set of ground-based AIRS spatial response functions exists.
  - *Although most channels are well aligned, a few show significant misalignments.*
  - *The effects of misalignments have been studied and shown not to affect mean radiometry.*

• AIRS and MODIS Aqua provide an opportunity to test the feasibility of confirming spatial characterization in flight.

• Attempts to verify the pre-launch AIRS measurements using flight data have been inconclusive so far, but the problem is being actively worked.