The Atmospheric Infrared Sounder (AIRS) in Atmospheric and Climate Research

ITSC-16

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Outline

• AIRS Instrument on EOS Aqua Spacecraft
• AIRS Calibration and Validation
• Data Products and Validation
• Weather Forecast Improvement
• Climate
  L2 and L3 Product
  Climate Data Record
• Conclusions
AIRS Characteristics

- Launched: May 4, 2002
- Orbit: 705 km, 1:30pm, Sun Synch
- IFOV: 1.1° x 0.6° (13.5 km x 7.4 km)
- Scan Range: ±49.5°
- Full Aperture OBC Blackbody, ε>0.998
- Full Aperture Space View
- Solid State Grating Spectrometer
  - IR Spectral Range: 3.74-4.61 µm, 6.2-8.22 µm, 8.8-15.4 µm
  - IR Spectral Resolution: \( \approx 1200 (\lambda/\Delta\lambda) \)
  - # IR Channels: 2378 IR
- VIS Channels: 4
- Mass: 177Kg, Power: 256 Watts, Life: 5 years, 7 years goal (12 years current predictions)
AIRS Radiometric and Spectral Accuracy and Stability Validated In Flight

AIRS Hyperspectral Coverage
Climate Data Record (CDR) over 5 Billion Spectra

Scanning HIS Validates Rad Accy to 0.2K – H. Revercomb (UW)

AIRS Radiometric Performance:
Stable to <8mK/yr – H. Aumann (JPL)

AIRS Frequencies Stable Knowledge to < 1 PPM - L. Strow (UMBC)

Reference: JGR, VOL. 111, April 2006

L1B product
# AIRS Products and Validation Status

<table>
<thead>
<tr>
<th>AIRS Product</th>
<th>Uncertainty Estimate (Version 5)</th>
<th>Val Status (Version 5)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Radiances</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AIRS IR Radiance</td>
<td>&lt;0.2%</td>
<td>Stage 1</td>
<td>Project</td>
</tr>
<tr>
<td>AIRS VIS/NIR Radiance</td>
<td>15-20%</td>
<td>Stage 1</td>
<td>Project</td>
</tr>
<tr>
<td>AMSU Radiance</td>
<td>1-3 K</td>
<td>Stage 1</td>
<td>Project</td>
</tr>
<tr>
<td>HSB Radiance</td>
<td>1-3 K</td>
<td>Stage 1</td>
<td>Project</td>
</tr>
<tr>
<td><strong>Core Products</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cloud Cleared IR Radiance</td>
<td>1.0 K</td>
<td>Project</td>
<td></td>
</tr>
<tr>
<td>Sea Surface Temperature</td>
<td>1.0 K</td>
<td>Project</td>
<td></td>
</tr>
<tr>
<td>Land Surface Temperature</td>
<td>2-3 K</td>
<td>Stage 1</td>
<td>Project</td>
</tr>
<tr>
<td>Temperature Profile</td>
<td>1 K / km</td>
<td>Project</td>
<td></td>
</tr>
<tr>
<td>Water Vapor Profile</td>
<td>15% / 2km</td>
<td>Project</td>
<td></td>
</tr>
<tr>
<td>Total Precipitable Water</td>
<td>5%</td>
<td>Project</td>
<td></td>
</tr>
<tr>
<td>Fractional Cloud Cover</td>
<td>20%</td>
<td>Project</td>
<td></td>
</tr>
<tr>
<td>Cloud Top Height</td>
<td>1 km</td>
<td>Project</td>
<td></td>
</tr>
<tr>
<td>Cloud Top Temperature</td>
<td>2.0 K</td>
<td>Project</td>
<td></td>
</tr>
<tr>
<td><strong>Necessary Products</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Ozone Column</td>
<td>5%</td>
<td>Project</td>
<td></td>
</tr>
<tr>
<td>Ozone Profile</td>
<td>20%</td>
<td>Project</td>
<td></td>
</tr>
<tr>
<td>IR Dust**</td>
<td>0.5 K</td>
<td>Stage 1</td>
<td>Project</td>
</tr>
<tr>
<td><strong>Research Products</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon Monoxide</td>
<td>15%</td>
<td>Stage 1</td>
<td>NOAA/UMBC</td>
</tr>
<tr>
<td>Methane</td>
<td>2%</td>
<td>Stage 1</td>
<td>NOAA</td>
</tr>
<tr>
<td>Carbon Dioxide**</td>
<td>1-2 ppm</td>
<td>Stage 1</td>
<td>NASA/NOAA</td>
</tr>
<tr>
<td>OLR</td>
<td>5 W/m2</td>
<td>Stage 1</td>
<td>GSFC</td>
</tr>
<tr>
<td>HNO3**</td>
<td>0.2 DU</td>
<td>Stage 1</td>
<td>NOAA/UMBC</td>
</tr>
<tr>
<td>Sulfur Dioxide**</td>
<td>1 DU</td>
<td>Stage 1</td>
<td>NOAA/UMBC</td>
</tr>
</tbody>
</table>

>90% complete
AIRS/AMSU DATA DISTRIBUTION CENTERS

- Universities
- Local Weather Stations
- Brazil (INPE)
- China
- Korea
- DoD

NOAA NESDIS (Weather/Hazards)

- Science Community
- Public
- JPL

GSFC DAAC (Climate)

DIRECT BROADCAST (Hazards/Weather)

NWP Centers
NCEP, GLA, CMC, JMA, FNMOC, BOM, UK Met, ECMWF, Meteo Fr., DWD

http://daac.gsfc.nasa.gov
Sounders Improve Operational Weather
Forecasts and Weather Research

NCEP Operational Improvement

- 6 hrs on 6 day forecast

AIRS Research Validates Models

- J. Fu, U of Hawaii

Regional Forecast Improvement

- Pressure
- Rainfall

NOAA Hurricane Center

- Saharan Air Layer Hurricane Suppression

- B. Zavodsky, NASA SPoRT
- J. Dunion, NOAA
Climate Research with AIRS

1. Use AIRS L2 and L3 data products

2. Climate Record Validation
AIRS Climate Data Products
9/2002--Present

Global: Day & Night, Pole to Pole, Land & Oceans, Cloudy & Clear, Daily
Disagreement between AIRS Water Vapor and Climate Models

• Mapped Products (L3)
  – The models are drier than AIRS observations by 10%-25% in the tropics below 800 hPa.
  – The models are more moist by 25%-100% between 300 and 600 hPa, especially in the extra-tropics.

* David W. Pierce, Tim P. Barnett, Eric J. Fetzer, Peter J. Gleckler, Three-dimensional tropospheric water vapor in coupled climate models compared with observations from the AIRS satellite system, GRL, VOL. 33, L21701, doi:10.1029/2006GL027060, 2006

2003-2005 400 hPa water
Disagreement between AIRS Water Vapor and Climate Models

- Radiances (L1b)
  - Model agrees with OLR but....
  - Compensating Errors
    Models dry in lower troposphere compensated by higher surface flux

*Huang et al. 2007.*
Climate Research with AIRS

1. Use AIRS L2 and L3 data products
2. Climate Record Validation
AIRS Started Series of Operational Hyperspectral Sounders

AIRS on Aqua
1:30 PM Orbit
14 km GSD
±49.5° Swath
0.1-0.2K Absolute
10mK/year Stability

IASI on MetOp
10:30 AM Orbit
12 km GSD
±49° Swath

CrIS on NPOESS
1:30 PM Orbit
14 km GSD
±48.3° Swath
C1: 2013
C3: 2020

NPOESS
5:30 AM
C2: 2016
CrIS De-Manifested

TES on Aura
1:30 PM Orbit

Climate Research with AIRS

1. Use AIRS L2 and L3 data products

2. Climate Record Validation

If AIRS and CRIS radiances are concatenated, how radiometrically consistent is the resulting data record?

Use AIRS and IASI data for the evaluation
Any disagreement between AIRS and IASI is not a climate signal

- Diurnal coverage differences
- Spectral resolution differences
- Footprint size difference

Agreement has to be achieved under climatologically representative conditions

- Global
- Cloudy

Validation under clear tropical ocean conditions is relatively easy
IASI Calibration Monitoring using (obs-calc)
at 2616 cm^{-1} for tropical ocean

- **Band 3 (Shortwave)**
  - uses the synthesized 2616 cm^{-1} and 2607 cm^{-1} channels to decrease the effect of noise
  - 2616 synthesized by average of 93 window channels
    2607.9 synthesized by averaging 45 water channels between 2600 cm^{-1} and 2650 cm^{-1}

- Use very tight spatial coherence test for extremely clear footprints
  Yield is 1% of the night tropical ocean footprints, typically 1500 matchups per day, same % as AIRS clear
mean = -0.19 K  mean = -0.28
stdev = 0.46 K  stdev = 0.43
The IASI – AIRS double difference shows excellent radiometric accuracy under clear 300 K conditions.

IASI.2616syns (obs-calc)

<table>
<thead>
<tr>
<th>Year-2000</th>
<th>Night Tropical Ocean</th>
</tr>
</thead>
<tbody>
<tr>
<td>v3.6</td>
<td>v4.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bias [K]</th>
<th>Mean</th>
<th>Stdev [K]</th>
</tr>
</thead>
<tbody>
<tr>
<td>IASI 200704-200801 very tight clear filtered</td>
<td>mean = -0.19 K</td>
<td>stdev = 0.46 K</td>
</tr>
</tbody>
</table>

Validation under clear tropical ocean conditions at the 0.1K level is a necessary condition, but not sufficient for climate quality.
Validation under cloudy and cold conditions is critical for climate applications.

The mean Earth brightness temperature in a 10 micron window channel is 275 K, much colder in water channels.

Validation at the 0.1K level is very difficult.

Massive averages
AIRS/IASI difference at orbit crossings

None have reached the 0.1 K level
Polar night minimizes diurnal effects due to different orbits.

IASI-AIRS daily mean difference = 0.23 ± 0.19 K
(stdev=1.82 K for 91 days)

each dot is the daily mean 70-90N btemp at 961 cm-1
Summary and Conclusions

• The AIRS on Aqua measures hyperspectral infrared with high accuracy and stability

• AIRS Products support model validation and process studies
  – Disagreements with climate models in water vapor
  – validation and accurate spot error estimation are difficult

• AIRS-IASI comparisons show climate quality under clear tropical ocean conditions at the 0.1 K level.
  - comparison under cloudy and cold conditions are in progress. Very difficult at the 0.1 K level.

• For more information on AIRS see