The AIRS V5 Ozone Validation

• An Outline of the Paper Submitted To JGR (Presently under review).
   (Let me know if you wish a copy of the paper)

Evaluation of Atmospheric Infrared Sounder (AIRS) Ozone Profiles and Total Ozone Retrievals with Matched Ozonesonde Measurements, ECMWF Ozone Data, and Ozone Monitoring Instrument (OMI) Retrievals*

• On-Going Activities and Upcoming Plans

Murty Divakarla, Christopher Barnet, Mitchell Goldberg, Eric Maddy, Xingpin Liu, Walter Wolf, Lawrence Flynn, Gordon Labow®, Xiaozhen Xiong, Jennifer Wei, and Lihang Zhou
NOAA/NESDIS, Camp Springs, MD 20746; @NASA/GSFC

Bill Irion and Mike Newchurch
NASA/JPL, Univ. of Alabama

Thanks To:
Shuntai Zhou, NOAA/NCEP, Craig Long, NOAA/NCEP, Eric Beach NOAA, Bojan Bojkov NASA/GSFC
What We Did

• Validation of AIRS Retrieved Ozone profile, and Total Ozone with WOUDC O$_3$SNDS and Total Ozone Measurements.
  » Both V4 and V5 Versions (Retrieval Emulations at NOAA/NESDIS)
  » AIRS Ozone Profile Retrievals with O$_3$SNDS
  » AIRS Total Ozone with BD Measurements
    – Simultaneous Aqua-AIRS, Aura-OMI and WOUDC Total Ozone Measurements
    – Individual STNs, NH, SH, Tropics, Global

• Analysis of AIRS Global Ozone Grids
  » Using Gridded Monthly Averages (2004 and 2005) of AIRS, OMI, SBUV and Global Forecast System (NCEP-GFS) – Seasonal Trends, Patterns
  » How Point Measurements/Validation Corroborate to Global Perspective Seen with the Global Grids
  » Annual Cycles
Data Credits and Acknowledgments

» Ozone sondes and Brewer Dobson Measurements
  – WOUDC Ozone Data (www.woudc.org)

» Gridded Monthly Averages for AIRS, SBU, OMI and GFS for the Years 2004 and 2005
  – AIRS V4 and V5 Retrievals Emulated at NOAA/NESDIS
    ● Global Grid Resolution: 3° x 3°
    ● Generated by NOAA/NESDIS/IOSSPDT – V4 and V5 Emulation
  – SBUV/2 on NOAA-16
    ● Global Grid Resolution: 2.5° x 2.5°
    ● Monthly Data Provided by Shuntai Zhou, NCEP

» Ozone Monitoring Instrument (OMI) on Aura
  ● Global Grid Resolution: 1.25° x 1.0°
  ● Downloaded from:
    ● ftp://toms.gsfc.nasa.gov/pub/omi/data/monthly_averages/ ozone

– Global Forecast System (GFS)
  ● Monthly Data provided by Craig Long
The AIRS Ozone Validation Ladder

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<th>Match/Region</th>
<th>Polar</th>
<th>Midlat</th>
<th>Tropics</th>
<th>Total</th>
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<td>2282</td>
<td>315</td>
<td>4096</td>
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<tr>
<td>Day</td>
<td></td>
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1. V4.0 and V5.0 AIRS Ozone Validation
2. L2 Profiles: O₃SNDs from WOUDC ECMWF Ozone
3. Total Ozone BD Stations from WOUDC ECMWF Ozone
4. Total Ozone AIRS/OMI RET and BD Measurements
5. O₃SND & TO₃: Global Statistics & Stats for Ind. STNS
6. O₃SND & TO₃: L3 GLOBAL GRID ANALYSIS
What We Did and What is Achieved (1)

- Performed validations for V4 and V5
  - AIRS Retrieved Ozone Profiles with WOUDC O$_3$SNDS

- Results:
  - The V5 algorithm significantly improves the retrieval bias and RMS differences for the lower troposphere and especially over the tropical regions.
    - Retrieval Improvement for the Lowest Layer (1000-260 mb) is Mainly due to the Climatology First Guess
  - The Retrieval Statistics with Global O$_3$SNDS
    - Bias ~ 5%
    - RMS Difference ~ 20%
V5 Physical Retrievals - Different Stations
ALL (N=353), STN 089 (N=53, NH),
STN 101 (N=50, SH), Tropics (N=54, ±12HR)

RMS Difference

Bias

V5 Climatology First Guess Helps Physical Retrieval for the Lowest Layer 1 (1000-260 mb)

V4 Dotted lines, V5 Solid Lines
ALL_3H STN089 STN101 TRP_12H ALL_12H
What We Did and What is Achieved (2)

- Performed Validations for V4 and V5 Total Ozone
  - With WOUDC Brewer/Dobson Station Measurements.
- Results:
  - Total ozone from both the V4 and V5 versions agrees well
  - Bias ~ 4% and an RMS difference ~ 8%.
    - V5 ozone retrievals are better than V4
      » Over Desert Regions (Due to Improvements in Emissivity Regression implemented in V5)
      » In Depicting Ozone Hole Events, Trends, Seasonality Patterns etc.
  - However, V5 Algorithm
    1. Slightly underestimates total ozone in the tropics
    2. Slightly overestimates total ozone in the midlatitude and high latitudes regions.
    3. Emissivity retrievals may require further refinements.
V5 - Total Ozone Statistics with BD Measurements
Polar, Mid-Lat, Tropics, and Global

Slightly underestimates total ozone in the tropics
Slightly overestimates total ozone in the midlatitude and polar regions.
What We Did and What is Achieved (3)

- **Using Simultaneous AIRS & OMI Observations and BD Total Ozone Measurements**
  - Relative Performance Assessment of AIRS and OMI Total Ozone Retrievals.

- **Results:**
  - The OMI Retrieval Bias
    - ~ 2-3% for most of the stations
  - The AIRS Retrieval bias is ~ 6% for high latitude STNS
  - The AIRS retrieval shows
    - Slight underestimation in the tropics
    - and a slight overestimation in the high latitudes.
  - OMI Data Are Extremely Good and Could be Used as a transfer standard for the truth in Analyzing Global Grids.
Simultaneous Measurements of AIRS, OMI and WOUDC BD Measurements.

OMI: 15 km resolution, Overpass retrievals collocated within 25 km (CT Pixel)
AIRS : 50 km resolution, collocated within 100 km distance to BD Measurements
Intent: Just to get a feel for the OMI, and see whether OMI global grids could be used as a transfer standard for the truth in analyzing AIRS global grids
What We Did and What is Achieved (4)

- Analyzed two years (2004-2005) of AIRS V4 and V5 Ozone profile Retrievals for Characteristic Features/Trends

- Results:
  - The AIRS V5 ozone profiles
    - Show the ozone hole events clearly
    - Depicts Brewer/Dobson circulation patterns as expected.
AIRS V5 Clearly Depicts Ozone Hole

V4 09/2004
(Period: 01Sep2004–30Sep2004)

V5 09/2004
(Period: 01Sep2004–30Sep2004)

V4 09/2005
(Period: 01Sep2005–30Sep2005)

V5 09/2005
(Period: 01Sep2005–30Sep2005)
V4, V5 Total Ozone - September 2004-2005

2.5° Zonal Averages

V4 has difficulty Depicting Ozone Hole

V5 Depicts Ozone Hole Clearly

V4 has difficulty Depicting Ozone Hole

V5 Depicts Ozone Hole Clearly
BD Circulation Features As Seen with AIRS V5
Monthly Averages of O3 Profile
Latitude vs. Pressure

We can generate these maps for each day – next slide is a movie loop with 15-day maps.
Ozone, Ascending, AIRS V5
Ozone, Ascending, AIRS V5
• Analyzed Global Monthly Maps of AIRS total ozone with the OMI and SBUV maps:
  • To evaluate the ability of the AIRS retrievals in reproducing the characteristic trends and seasonal cycles as depicted by the OMI and SBUV instruments.

• Results:
  » Analysis of two years (2004-2005) of V5 total ozone retrievals reveal:
    – The AIRS V5 retrieval shows trends and patterns in concurrence with the OMI (for 2005) and SBUV depictions.
    – The AIRS retrieval shows a tendency
      ● Slight underestimation in the tropics
      ● Slight overestimation in the high latitudes.
ECMWF Training for $T(p)$, $q(p)$ regression is good, (because ECMWF uses RAOB $T(p)$, $q(p)$ in its analysis) but what about O3SNDs (?) \( ? \). NCEP-GFS Assimilates SBUV Ozone profiles \( ? \) (better choice ? Or O3SNDS ?)
Total Ozone – September 2005
AIRS V4, V5-PR, OMI, SBUV, and GFS

V5-FG Climatology

V5-PR

OMI

GFS

V5-FG (Regression)

V4-FG (Regression)

Training data for FG Reg. should adequately represent Ozone hole events and other strategic locations
Biomass Burning
Related Ozone Changes Seen by AIRS?

February, 2004
SEVERI Derived Map of Active
Fire Detections (AGU, Gareth
Roberts)

AIRS February, 2004

AIRS March, 2004
Biomass Burning
Related Ozone Changes Seen by AIRS?

MODIS Fire Counts
November 2004 ,
Kevin Bowman, JPL

AIRS Total Ozone
November 2004

OMI Total Ozone
November 2004
Total Ozone Difference Maps (%)
\[(\text{AIRS-V5 - OMI})/\text{OMI}; (\text{SBUV-OMI})/\text{OMI}; (\text{GFS-OMI})/\text{OMI}\]

**AIRS-OMI 10/2005**

% Difference (AIRS - OMI) T03: Oct2005

**SBUV-OMI 10/2005**

% Difference (SBUV - OMI) T03: Oct2005

**GFS-OMI 10/2005**

% Difference (GFS - OMI) T03: Oct2005

**AIRS-OMI 11/2005**

% Difference (AIRS - OMI) T03: Nov2005

**SBUV-OMI 11/2005**

% Difference (SBUV - OMI) T03: Nov2005

**GFS-OMI 11/2005**

% Difference (GFS - OMI) T03: Nov2005

Characteristics Invisible (or Slightly Visible) to Other Instruments are Visible to AIRS (Hope they are not Artifacts)
Total Ozone Difference Map (AIRS_V5 – OMI)/OMI

AIRS-OMI 10/2005

CO-Ozone and Biomass Burning

R Coeff, 200510

CO-Ozone Correlations (by Jennifer Wei)
We analyzed 2 years of zonal averages to make conclusion about OMI and AIRS.
Let me know if you wish to see off-line.
AIRS V4, V5 (PR and FG) OMI, SBUV 2005
Annual Cycle

AIRS-V5 FG

Total Ozone from AIRS_V5 FG 2005

OMI 2005

Sun-Lit Portions Only

SBUV Appended with GFS Beyond 80 Degrees.

AIRS Can See Day/Night

Total Ozone from AIRS_V4 FG 2005

AIRS-V5 RET

Total Ozone from AIRS_V5 2005

AIRS-V4 FG

Total Ozone from AIRS_V4 2005

AIRS-V4 RET
Total Ozone Annual Cycle for 2 Years (2004-2005)
AIRS V4, V5-PR, OMI, SBUV, and GFS

V5-FG Climatology
V5-PR
OMI
GFS

V4-FG (Regression)
V4-PR
SBUV

Annual Cycle for 2 Years (2004-2005) with 2.5 Degree Zonal Averages
Q: Whether the AIRS Instrument Measures Ozone Profiles and Total Ozone Reasonably? YES.

V5 Algorithm
- Retrieval is Solely Due to Channel Radiances
- Ability to Capture Trends and Seasonal Patterns
- Reasons for Deficiencies are Understandable and Remedies can be implemented.

  Improvements
- Algorithm Optimization
- Playing with Damping Factor and Channel Selection
- Further Emissivity Upgrades are Welcome
- Consistent Positive Bias for High Latitude Regions – Possibly Due to Static Radiance Bias Corrections (Tuning Coefficients)

V4 Algorithm
- Good for its time - T(p),q(p) REG with ECMWF is good, but not for O3(p)
- First Guess Regression Improvements - Proper Training (O3SNDs ?) (If we Wish to Continue)
Outlook into Near-Future

- Development of a IASI / T(p), q(p), O₃(p) Validation System (IASI vs. RAOBs; AIRS vs. RAOBs)
  - AIRS First Guess with RAOB/O₃SND Regression for T(p), q(p) and O₃(p) (Attempted Earlier with Success)
  - Metrics for Validation

- Synergetic Use of A-Train Products (Aqua, Aura, NOAA-18 (With reference to Ozone))
  - Validation and Inter-comparison with a Same Set of Qualified Measurements (O₃SNDs) for Relative Performance Assessment
  - Generation of New Products
    - Visualize Integrated Observing System Products
    - Generate Merged Products - AIRS Retrievals, Aura OMI; NOAA-SBUV/2
Thank You All for your Patience

The NOAA AIRS Team at The
Integrated Observing System Science
And Product Development Team (IOSSPDT)

NOAA/NESDIS Camp Spring, MD, USA

The contents are solely the opinions of the authors and do not constitute a statement of policy, decision, or position on behalf of the NOAA, NASA, or the U.S. Government.
AIRS Ozone Retrieval? Reliable
Improvements/Remedies Possible? YES
O3WGT Version 5.0.7 (set 48_49.xls)

RMS Difference

Bias

V5.0.7 O3WGT=1.0 is Chosen
AIRS V5 and V4 Retrieved Layer Ozone Amounts vs. O$_3$SND Layer Ozone Amounts

V4-PR

Difficulty reaching extreme values

V5-PR

Slight Overestimation

V5 Climatology First Guess Helps Physical Retrieval for the Lowest Layer 1 (1000-260 mb)

Layer 7  4  8 mb
Layer 6  8  16 mb
Layer 5  16  32 mb
Layer 4  32  66 mb
Layer 3  66  126 mb
Layer 2  126  260 mb
Layer 1  260  1100 mb
O3WGT Factors

0.02 0.40 0.75
1.0 1.25 1.5
1.75 2.0

Total Ozone AIRS PR (DU)

TO3_RET

N = 4096
O3WGT = 2.0
R = 0.90

O3WGT Factors

0.02 0.40 0.75
1.00 1.25 1.50
1.75 2.00

NONE
V5 Physical Retrievals - Different Stations
ALL (N=353), STN 089 (N=53, NH), STN 101 (N=50, SH), Tropics (N=54, ±12HR)

RMS Difference

V5 Climatology First Guess Helps Physical Retrieval for the Lowest Layer 1 (1000-260 mb)

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