AMSU-A Asymmetry for Window Channels

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Characterization

Comparison with CRTM simulations
Clear sky over tropical and sub-tropical oceans (30N – 30S)
Three cloud screening approaches
  AMSU L2 cloud products
  PATMOS-x (AVHRR) cloud probability
  ERA Interim cloud probability
Stratification with SST, PW and wind speed (Emphasize of this presentation)
  N16 – 2008
  N18 – 2008 (*)
  MetOp-A – 2008

Possible Causes

Antenna pointing angle error
Bias in polarization vector orientation
Sidelobe effects and other hardware configuration problem
Asymmetric atmosphere and surface

Correction (next step)

Integrate the results from geolocation correction and stratification results
Correct pointing angle error and bias in polarization vector orientation
First addressed in Weng et al. (2000) and Weng et al. (2003)

Attribute to Polarization misalignment or Antenna pointing angle error

\[ I = A^2(\theta, \psi, \varphi)I_h + B^2(\theta, \psi, \varphi)I_v, \]

- Antenna Reflector Normal Angle
- Polarization Alignment Angle
- Sensor Scan Angle
Impact of AMSU-A Tb Asymmetry on Products

Before Correction (02/15/2011)  After Correction (02/15/2011)
Clear sky AMSU-A FOV determined by L2 products
Over tropical/subtropical oceans

AMSU-A 1b raw count

$T_a$

ERA interim T, q, O$_3$ profiles;
ERA interim SST, 10m U & V;
AMSU-A LZA, scan angle

CRTM

$T_b$

Compare collocated $T_b$'s with same atmospheric condition for each beam position
Comparison of Different Cloud-Screening Approaches

(a) 23.8 GHz

(b) 31.4 GHz

(c) 50.3 GHz

(d) 89.0 GHz
Comparison of Different Cloud Fraction for PATMOS-x Approach

(a) 23.8 GHz

(b) 31.4 GHz

(c) 50.3 GHz

(d) 89.0 GHz

Local Zenith Angle (°)

Tbs - Tbo (K)
Comparison of Number of Observation for PATMOS-x Approach

- **Cloud Fraction 0.025**
  - Number of Observations vs. Local Zenith Angle
  - Red line: Ascending
  - Black line: Descending

- **Cloud Fraction 0.1**
  - Number of Observations vs. Local Zenith Angle
  - Red line: Ascending
  - Black line: Descending

- **Cloud Fraction 0.5**
  - Number of Observations vs. Local Zenith Angle
  - Red line: Ascending
  - Black line: Descending

- **Cloud Fraction 0.8**
  - Number of Observations vs. Local Zenith Angle
  - Red line: Ascending
  - Black line: Descending
AMSU-A Hardware Configuration

23.8 GHz & 31.4 GHz : AMSU-A2;  50.3 GHz : AMSU-A1-2;  89.0 GHz : AMSU-A1-1

Fan 1: Center of Beam @ BP 30

Fan 2: Edge of Beam @ BP 30, assume 20 degree Beam width

Line 1 = 46 deg from nadir
Line 2 = 58 deg from nadir

AMSU-A2 Fan Beam – Credit to Bill Blackwell
Histogram of Physical Variables – NOAA-18, 2008

- **Sea Surface Temperature (K)**
  - Most Probable Value: 300.38

- **Precipitable Water (cm)**
  - Most Probable Value: 2.81

- **Wind Speed (m/s)**
  - Most Probable Value: 5.98
## Comparison of Most Probable Values (MPV)

<table>
<thead>
<tr>
<th></th>
<th>NOAA-15</th>
<th>NOAA-16</th>
<th>NOAA-18</th>
<th>MetOp-A</th>
</tr>
</thead>
<tbody>
<tr>
<td>SST (K)</td>
<td>300.15 (00)</td>
<td>301.07 (04)</td>
<td>300.33</td>
<td>300.38</td>
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<tr>
<td></td>
<td>300.48 (08)</td>
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<td></td>
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<tr>
<td>PW (cm)</td>
<td>2.96 (00)</td>
<td>2.92</td>
<td>2.81</td>
<td>2.75</td>
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<tr>
<td></td>
<td>2.79 (04)</td>
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<tr>
<td></td>
<td>2.89 (08)</td>
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<tr>
<td>Wind Speed (m/s)</td>
<td>6.04 (00)</td>
<td>6.62</td>
<td>5.98</td>
<td>6.08</td>
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<td>6.14 (04)</td>
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<tr>
<td></td>
<td>6.46 (08)</td>
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</tr>
<tr>
<td>SST (K)</td>
<td>%</td>
<td>PW (cm)</td>
<td>%</td>
<td>WS (m/s)</td>
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<tr>
<td>--------</td>
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</tr>
<tr>
<td>&lt; 299</td>
<td>44.36</td>
<td>&lt; 2.5</td>
<td>38.47</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>299 ~ 301</td>
<td>34.24</td>
<td>2.5 ~ 3.5</td>
<td>38.12</td>
<td>5 ~ 7</td>
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<tr>
<td>&gt; 301</td>
<td>21.40</td>
<td>&gt; 3.5</td>
<td>23.41</td>
<td>&gt; 7</td>
</tr>
</tbody>
</table>
Asymmetry with Sea Surface Temperature – Window Channels, NOAA-18, 2008
Asymmetry with Precipitable Water – Window Channels, NOAA-18, 2008

(a) 23.8 GHz

(b) 31.4 GHz

(c) 50.3 GHz

(d) 89.0 GHz

Tbs - Tbo (K)

Local Zenith Angle (°)

pw<2.5
in between
pw>3.5
Asymmetry with Wind Speed – Window Channels, NOAA-18, 2008

(a) 23.8 GHz

(b) 31.4 GHz

(c) 50.3 GHz

(d) 89.0 GHz

- $T_{bs} - T_{bo}$ (K)
- Local Zenith Angle ($^\circ$)

- $v < 5$
- in between
- $v > 7$
2D Histogram of Physical Variables – NOAA-18, 2008
## Definition of 27 Class

<table>
<thead>
<tr>
<th>C#</th>
<th>SST</th>
<th>PW</th>
<th>V</th>
<th>C#</th>
<th>SST</th>
<th>PW</th>
<th>V</th>
<th>C#</th>
<th>SST</th>
<th>PW</th>
<th>V</th>
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<td>&lt;2.5</td>
<td>&lt;5</td>
<td>10</td>
<td>mid</td>
<td>&lt;2.5</td>
<td>&lt;5</td>
<td>19</td>
<td>&gt;301</td>
<td>&lt;2.5</td>
<td>&lt;5</td>
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<tr>
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<td>&lt;299</td>
<td>&lt;2.5</td>
<td>mid</td>
<td>11</td>
<td>mid</td>
<td>&lt;2.5</td>
<td>mid</td>
<td>20</td>
<td>&gt;301</td>
<td>&lt;2.5</td>
<td>mid</td>
</tr>
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<td>&lt;2.5</td>
<td>&gt;7</td>
<td>12</td>
<td>mid</td>
<td>&lt;2.5</td>
<td>&gt;7</td>
<td>21</td>
<td>&gt;301</td>
<td>&lt;2.5</td>
<td>&gt;7</td>
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<tr>
<td>4</td>
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<td>mid</td>
<td>&lt;5</td>
<td>13</td>
<td>mid</td>
<td>mid</td>
<td>&lt;5</td>
<td>22</td>
<td>&gt;301</td>
<td>mid</td>
<td>&lt;5</td>
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<td>mid</td>
<td>14</td>
<td>mid</td>
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<td>mid</td>
</tr>
<tr>
<td>6</td>
<td>&lt;299</td>
<td>mid</td>
<td>&gt;7</td>
<td>15</td>
<td>mid</td>
<td>mid</td>
<td>&gt;7</td>
<td>24</td>
<td>&gt;301</td>
<td>mid</td>
<td>&gt;7</td>
</tr>
</tbody>
</table>
Histogram of 27 Class – NOAA-15

- 2000
- 2004
- 2008
Histogram of 27 Class – Whole Year 2008

- **NOAA-15**
- **NOAA-16**
- **NOAA-18**
- **MetOp-A**
Number of Observations with Selected Combined Cases, NOAA-18, 2008

The graph shows the number of observations as a function of local zenith angle. Three categories are highlighted:

- Red line: sst<299, pw<2.5, v<5
- Green line: in between
- Blue line: sst>301, pw>3.5, v>7

The y-axis represents the number of observations, and the x-axis represents the local zenith angle in degrees.
Mean Difference at MPV – Window Channels, Changing SST, NOAA-18, 2008

(a) 23.8 GHz

(b) 31.4 GHz

(c) 50.3 GHz

(d) 89.0 GHz
Mean Difference at MPV – Window Channels, Changing PW, NOAA-18, 2008

(a) 23.8 GHz

(b) 31.4 GHz

(c) 50.3 GHz

(d) 89.0 GHz
Number of Observations at MPV – Changing PW, NOAA-18, 2008
Mean Difference at MPV – Window Channels, Changing Wind Speed, NOAA-15, 2000

(a) 23.8 GHz

(b) 31.4 GHz

(c) 50.3 GHz

(d) 89.0 GHz

<table>
<thead>
<tr>
<th>Channel</th>
<th>Equation</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>23.8 GHz</td>
<td>$\text{sst}=300.15 \pm 0.9$, $\text{pw}=2.96 \pm 0.3$, $\nu=5.00 \pm 0.7$</td>
<td></td>
</tr>
<tr>
<td>31.4 GHz</td>
<td>$\text{sst}=300.15 \pm 0.9$, $\text{pw}=2.96 \pm 0.3$, $\nu=6.04 \pm 0.7$</td>
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</tr>
<tr>
<td>50.3 GHz</td>
<td>$\text{sst}=300.15 \pm 0.9$, $\text{pw}=2.96 \pm 0.3$, $\nu=7.00 \pm 0.7$</td>
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<td>89.0 GHz</td>
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</table>
Mean Difference at MPV – Window Channels, Changing Wind Speed, NOAA-15, 2004

(a) 23.8 GHz

(b) 31.4 GHz

(c) 50.3 GHz

(d) 89.0 GHz

Local Zenith Angle (°)

Tbs - Tbo (K)

Local Zenith Angle (°)

Tbs - Tbo (K)
Mean Difference at MPV – Window Channels, NOAA-15, 2000~2008

(a) 23.8 GHz

(b) 31.4 GHz

(c) 50.3 GHz

(d) 89.0 GHz
Mean Difference at MPV – Window Channels, Changing Wind Speed, NOAA-16, 2008

(a) 23.8 GHz

(b) 31.4 GHz

(c) 50.3 GHz

(d) 89.0 GHz

Local Zenith Angle (°)

Tbs - Tbo (K)

sst=300.33±0.9, pw=2.92±0.3, v=5.00±0.7
sst=300.33±0.9, pw=2.92±0.3, v=6.62±0.7
sst=300.33±0.9, pw=2.92±0.3, v=7.00±0.7
Mean Difference at MPV – Window Channels, Changing Wind Speed, NOAA-18, 2008

(a) 23.8 GHz

(b) 31.4 GHz

(c) 50.3 GHz

(d) 89.0 GHz

(a) 23.8 GHz

(b) 31.4 GHz

(c) 50.3 GHz

(d) 89.0 GHz
Number of Observations at MPV – Changing Wind Speed, NOAA-15

2000

2004

2008
Number of Observations at MPV – Changing Wind Speed, 2008

- **NOAA-15**
- **NOAA-16**
- **NOAA-18**
- **MetOp-A**
Angular Distribution, NOAA-15, 2000

- Sea Surface Temperature (K)
- Precipitable Water (cm)
- Wind Speed (m/s)
- Number of Observation
Angular Distribution, NOAA-15, 2004

- Sea Surface Temperature (K)
- Precipitable Water (cm)
- Wind Speed (m/s)
- Number of Observation
Angular Distribution, NOAA-15, 2008

- **Sea Surface Temperature (K)**
  - Y-axis: 296 to 302
  - X-axis: Local Zenith Angle (°)

- **Precipitable Water (cm)**
  - Y-axis: 1.5 to 4
  - X-axis: Local Zenith Angle (°)

- **Wind Speed (m/s)**
  - Y-axis: 3 to 8
  - X-axis: Local Zenith Angle (°)

- **Number of Observation**
  - Y-axis: 0 to 1.5 x 10^4
  - X-axis: Local Zenith Angle (°)
Angular Distribution, NOAA-16, 2008

- Sea Surface Temperature (K)
- Precipitable Water (cm)
- Wind Speed (m/s)
- Number of Observations

Local Zenith Angle (°)
Angular Distribution, NOAA-18, 2008
Angular Distribution, NOAA-18, 2008, Near Most Probable Value

- Sea Surface Temperature (K)
  - Local Zenith Angle (°)

- Precipitable Water (cm)
  - Local Zenith Angle (°)

- Wind Speed (m/s)
  - Local Zenith Angle (°)

- Number of Observation
  - Local Zenith Angle (°)
  - \( \text{sst} = 300.38 \pm 0.9, \text{pw} = 2.81 \pm 0.3, \text{v} = 5.98 \pm 0.7 \)
Delta Brightness Temperature, Left - Right

(a) 23.8 GHz

(b) 31.4 GHz

(c) 50.3 GHz

(d) 89.0 GHz
Advantage of Using CRTM

1. Quantify both symmetric bias and asymmetric bias without introducing much extra error

2. Direct link between environment variables and radiance / brightness temperature
   Make it possible for stratification

3. Essential component in polarization related calculation

4. Essential component in double difference technique
Asymmetry for Window Channels

(a) 23.8 GHz

(b) 31.4 GHz

(c) 50.3 GHz

(d) 89.0 GHz

\[
\text{Tbs - Tbo (K)} \quad \text{Local Zenith Angle (°)}
\]

\[
\text{Local Zenith Angle (°)} \quad \text{Tbs - Tbo (K)}
\]

\[
\text{sst=300.38±0.9, pw=2.81±0.3, v=5.98±0.7}
\]
Brightness Temperature Difference before Adjusting Angles

\[ \theta = 45^\circ, \quad \psi = 90^\circ \]
Brightness Temperature Difference after Adjusting Angles

Channel 1
\[ \theta = 44.5^\circ, \psi = 89.3^\circ \]

Channel 2
\[ \theta = 44.5^\circ, \psi = 89.6^\circ \]

Channel 3
\[ \theta = 45.8^\circ, \psi = 91.5^\circ \]

Channel 15
\[ \theta = 44.5^\circ, \psi = 90.5^\circ \]
Vicarious Cold Reference, Nadir View, All Satellites

(a) 23.8 GHz

(b) 31.4 GHz

(c) 50.3 GHz

(d) 89.0 GHz
Linear Regression Coefficients

$$BT(t) = BT0 + a \cdot t$$

<table>
<thead>
<tr>
<th></th>
<th>23.8 GHz</th>
<th>31.4 GHz</th>
<th>50.3 GHz</th>
<th>89.0 GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>BT0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n15</td>
<td>141.5024</td>
<td>146.0852</td>
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<td>n16</td>
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<td>n18</td>
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<td>145.9841</td>
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<td>149.8420</td>
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<td>m02</td>
<td>140.8219</td>
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<td>151.6106</td>
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<td>n19</td>
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<td>153.6547</td>
<td>153.1574</td>
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<tr>
<th></th>
<th>23.8 GHz</th>
<th>31.4 GHz</th>
<th>50.3 GHz</th>
<th>89.0 GHz</th>
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<tbody>
<tr>
<td>a</td>
<td></td>
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<td>n15</td>
<td>0.0001</td>
<td>0.0001</td>
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<td>0.0024</td>
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<td>-0.1292</td>
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Average 2010 Vicarious Cold Reference vs. SST Diurnal Variability

Graphs showing diurnal variability at 23.8 GHz, 31.4 GHz, 50.3 GHz, and 89 GHz.
Conclusion

1. There is no much difference between ascending and descending nodes regarding to asymmetry
   But number of observation in descending node is almost half as that of ascending node
   The difference of number of observation mostly arise from cloud screening

2. The asymmetry is quite sensitive to combined physical conditions
   This may indicate environmental condition also have impacts on asymmetry
   Uncertainties might also arise from ERA-Interim data and CRTM

3. 31.4 GHz and 50.3 GHz asymmetries are not sensitive to sea surface temperature or precipitable water
   Wind speed is the most important physical variable to impact asymmetry

4. The asymmetry is pronounced even in a specific physical condition

5. The asymmetry pattern is stable through years, but quite different among on-board satellites

6. The mean precipitable water is not even at 30 beam positions

7. Sounding channels may provide sensor pointing information

8. How to use vicarious cold reference is still a question for us