Effects of ATMS SRF Imbalances at G-Band Channels on Brightness Temperature Simulations

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Statement of Problem

• SRF imbalances were found to be present in J1 ATMS double-side water vapor sounding channels (G-band) in the measured SRF dataset provided by NASA in June, 2016

• An imbalance in the instrument SRF at side bands could affect the data utilization in NWP if the measured imbalances in SRFs are not taken into account in forward radiative transfer models

Action

• Quantify impacts of such SRF imbalance on brightness temperature simulations
  — Sensitivity study with four scenarios of SRF distributions
  — Comparison of MonoRTM simulations using J1 ATMS measured SRFs with those from using the boxcar SRF
ATMS G-band channels 18-22 are located on a strong H₂O absorption line centered at 183 GHz frequency.
J1 ATMS G-Band SRFs

Strong SRF imbalances are found for J1 ATMS channels 18-20.

The requirement of the mean gain ratio for the side-band SRF is less than 2 dB.

SRF data obtained at primary local oscillator with baseplate temperature 20°C
Calculation of SRF Imbalance for J1 ATMS Channel 18

Original lab-measured SRF

Truncate the SRF at -20 dB

Compute average gain at each side band

\[
\overline{G_{\text{low band}}} = \frac{\int_{f_1}^{f_2} G(f) df}{f_2 - f_1}
\]

\[
\overline{G_{\text{high band}}} = \frac{\int_{f_3}^{f_4} G(f) df}{f_4 - f_3}
\]

Compute the imbalance (unit: dB)

\[
\Delta \overline{G} = \overline{G_{\text{low band}}} - \overline{G_{\text{high band}}}
\]

Original lab SRF

Truncated SRF

SRF Imbalance

\[
\Delta \overline{G} = 1.484 - (-3.053) = 4.537
\]
J1 ATMS SRF Imbalances for G-Band Channels

<table>
<thead>
<tr>
<th></th>
<th>G-Band Channels</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>18</td>
<td>19</td>
</tr>
<tr>
<td>STAR</td>
<td>4.537</td>
<td>1.997</td>
</tr>
<tr>
<td>NG</td>
<td>4.949</td>
<td>2.228</td>
</tr>
</tbody>
</table>

- STAR’s imbalance values are close to NG’s evaluation.
- The SRF imbalances of J1 ATMS channels 18 and 20 are more than 4 dB and 2 dB, respectively. They exceed the specification.
Understanding the Impact of J1 ATMS SRF Imbalances on Brightness Temperature Simulations

Model Simulation:

- Monochromatic Radiative Transfer Model (MonoRTM)
  - Accurate atmospheric spectroscopy data base
  - Only gaseous absorption
  - Vertical stratification

- Input to MonoRTM
  - ECMWF analysis

- Cloud detection algorithm
  - Cloud liquid water path (LWP) greater than 0.05 kg m⁻²
MonoRTM Simulated Optical Depths of H$_2$O, O$_2$, O$_3$ and All Gases
Four Scenarios for Removing SRF Imbalances

Truncated SRF

EXP I

EXP II

EXP III

EXP IV

Imbalance = 4.537
Sensitivity of TB to SRF Imbalances in Four Experiments

EXP I

EXP III

EXP II

EXP IV

- SRF Imbalance (dB)
- Tb Difference (K)

Ch18  Ch19  Ch20  Ch21  Ch22
O-B Differences with B Simulated by Using Boxcar or J1 ATMS SRF for Channel 18

An ATMS swath over ocean in clear-sky conditions at the Suomi NPP ascending node during 1345-1418 UTC 20 July 2016
O-B Differences Obtained by Using Boxcar SRF

\( O_{\text{SNPP ATMS-R}} \) - B_{Boxcar}

Ch18

Ch19

Ch20

Ch21

Ch22

(\text{K})
Differences of TB Simulations between Boxcar and J1 ATMS SRF

$B_{\text{Boxcar}} - B_{\text{J1 ATMS}}$

Ch18
Ch19
Ch20
Ch21
Ch22
### LWP and B-B Differences for Channel 18 on July 20, 2016

<table>
<thead>
<tr>
<th>Channel</th>
<th>$B_{\text{Symmetric Boxcar}} - B_{\text{Imbalanced Boxcar}}$ (K)</th>
<th>$B_{\text{Symmetric Boxcar}} - B_{\text{J1 ATMS}}$ (K)</th>
<th>$B_{\text{Imbalanced Boxcar}} - B_{\text{J1 ATMS}}$ (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>-0.24</td>
<td>-0.10</td>
<td>0.14</td>
</tr>
<tr>
<td>19</td>
<td>-0.10</td>
<td>0.00</td>
<td>0.10</td>
</tr>
<tr>
<td>20</td>
<td>-0.08</td>
<td>0.04</td>
<td>0.12</td>
</tr>
<tr>
<td>21</td>
<td>-0.16</td>
<td>0.17</td>
<td>0.33</td>
</tr>
<tr>
<td>22</td>
<td>0.06</td>
<td>-0.12</td>
<td>-0.17</td>
</tr>
</tbody>
</table>
Dependence of $B_{\text{Boxcar-BJ1 ATMS}}$ on FOV, Latitude and $T_{\text{obs}}$
Summary and Conclusions

- The SRF imbalance for J1 ATMS channel 18 and 20 exceed the 2 dB specification for the side-band SRF in the measured SRF provided by NASA in June, 2016.

- A sensitivity study showed that the TB can be different by more than 0.1 K when the SRF imbalance varies between 2 dB and 5 dB.

- The impacts of J1 SRF vs. Boxcar on simulations of G-band brightness temperatures were evaluated using MonoRTM. The magnitude of mean difference is 0.11–0.33 K for G-band channels.

- This study suggests a necessity of providing the actual SRFs from all the sidebands carefully measured by the instrument vendor to numerical weather prediction (NWP) users to build an accurate fast RTM for satellite data assimilation in NWP models.

- Imbalance impact on brightness temperature simulations of G-band channels will be reanalyzed using updated SRF after ATMS rework.