Suomi NPP ATMS SDR Provisional Product Highlights

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Suomi NPP EDR Product Review
NOAA Center for Weather and Climate Prediction (NCWCP)
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Updated in January 2013
## ATMS Calibration Requirements

<table>
<thead>
<tr>
<th>#</th>
<th>Channel Freq.(MHz)</th>
<th>Polarization</th>
<th>Bandwidth Max. (MHz)</th>
<th>Freq. Stability (MHz)</th>
<th>Calibration Accuracy</th>
<th>Nonlinearity Max. (K)</th>
<th>NEΔT (K)</th>
<th>3-dB BW* (deg)</th>
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<td>QH</td>
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<td>30</td>
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<td>0.8</td>
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<tr>
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<td>183310± 1000</td>
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<td>0.95</td>
<td>0.1</td>
<td>0.9</td>
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• Stable instrument performance and calibration
• All the ATMS channels have noises much lower than specification
• ATMS processing coefficients table (PCT) were updated with nominal values
• Quality flags (e.g. spacecraft maneuver and scanline, calibrations) were completely checked out and will be updated in the MX7.0
• Geolocation errors for all the channels are quantified and meet specification
• Remap SDR coefficients were updated using on-orbit CrIS data (e.g. CrIMSS now fully synchronized) and RSDR biases are assessed
• On-orbit calibration is explored using GPS RO data, LBLRTM and ATMS SRF. All the sounding channels have biases much less than the specification of accuracy
NPP ATMS and VIIRS Imager and Products

Warm Core Cross section along 26.0 N

ATMS Temperature Anomaly

VIIRS 0.64 µm visible and 11.45 µm IR images at 18:33 UTC, 28 Aug 2012

METAR, MSL Pressure, and Buoys information included
Impacts of Direct Assimilation of Suomi NPP ATMS Radiances on Hurricane Sandy’s Track

Predicted vs. observed track for Hurricane Sandy during October 22 to 29. NCEP 2012 HWRF is revised with a high model and 6 forecast as background for direct satellite radiance assimilation in GSI. Control Run: All conventional data and NOAA/METOP/EOS/COSMIC. It is clearly demonstrated that assimilation of Suomi NPP ATMS radiance data reduce the forecast errors of Hurricane Sandy’s track.
Channel Noise Characterization

All Channels are within Specifications
Geolocation Verification

North – South
Mean   -0.15km
        0.01°
Std. Deviation
        3.98km    0.28°

East – West
Mean   -.027km
        0.02°
Std. Deviation
        2.34km    0.16°
Assessments of ATMS Remap SDR (RSDR)

Channel 7 O-B using GFS

Resampled ATMS has the same bias at all brightness temperatures but much smaller spread (high innovation).

Original ATMS

Remap ATMS

Slide courtesy of STAR
Assessments of ATMS Remap SDR (RSDR)

Resampled ATMS has the same bias at all brightness temperatures but much smaller spread (high innovation)
Assessments of ATMS Remap SDR (RSDR)

Resampled ATMS has the same bias at all brightness temperatures but much smaller spread (high innovation)

Channel 9 O-B using GFS

Original ATMS

Remap ATMS
ATMS Remap SDR Evaluation

IDPS Remap SDR (CH 16)

Collocated ATMS SDR (CH 16)

Difference (K)

No Significant Biases Between Remapped SDRs and Collocated ATMS SDRs

Slide courtesy of NGAS
ATMS Bias Obs - Sim (GPSRO)

ATMS Channel

Bias (K)

Std. Dev. (K)

Slide courtesy of STAR
ATMS Bias Compared to AMSU-A

Slide courtesy of STAR
Major Issues

- Channel dependent calibration procedure for reducing the striping
  - Need to further reduce the ATMS striping for the upper-level channels

- Slope and intercept in ATMS TDR to SDR conversion
  - Uncertainty in computing antenna main, side lobe and cross-pol efficiency
  - Current ATMS antenna has 1 to 2% cross-polarization spill-over for some channels. Over oceans where the surface is polarized, TDR to SDR conversion would have a large uncertainty due to neglecting cross-pol spill-over

- Uncertainty in the current ATMS radiometric calibration
  - Uses of Rayleigh-Jeans approximation result in significant uncertainty in calibration although empirical corrections are applied

- Uses of Backus-Gilbert for channel 1 to 2 enhancement
  - ATMS noise is very low and the FOV enhancements for ch 1 and 2 seem to be likely for better depicting the storm structure
ATMS TDR Stripping Noise

- Striping is caused by ATMS SDR calibration noise, specifically the noise in the warm counts. Contributions to the overall calibration noise from cold counts and PRT readings are much smaller.
- The level of the striping noise is insignificant and well within ATMS SDR noise spec level.

ATMS Brightness Temperature Difference: Simulated – Observed

Slide courtesy of NGAS
ATMS Calibration Equation in IDPS

\[ R_s = R_c + (R_w - R_c) \left( \frac{C_s - \overline{C}_c}{C_w - C_c} \right) + Q \]

\[ Q = \mu (R_w - R_c)^2 \left( \frac{C_s - \overline{C}_w)(C_s - \overline{C}_c)}{(C_w - C_c)^2} \right) \]

\[ G = \frac{\overline{C}_w - \overline{C}_c}{R_w - R_c} \]

\[ \overline{C}_x = \frac{1}{N+1} \sum_{i=-N}^{N} \left( 1 - \frac{|i|}{N+1} \right) C_x, x = w \text{ or } c \]

For ATMS, N = 4 in the current IDPS processing
ATMS Averaging for Reducing Stripping using Earth Scene Data (Channel 1)

- N = 0
- N = 4
- N = 8
- DTb(4-8)
ATMS Averaging for Reducing Stripping using Earth Scene Data (Channel 8)

N = 0  N = 4  N = 8  DTb(4-8)
ATMS Averaging for Reducing Stripping using Earth Scene Data (Channel 14)

N = 0     N = 4     N = 8     DTb(4-8)
The first two terms are Quasi-V and Quasi-H brightness temperature from earth in the main beam (main lobe earth), the 3rd/4th terms are those from the side-lobe earth, the 5/6th terms are the side-lobe cold space, the last term is the near-field satellite radiation.

\[
T^{Q_V}_a = \eta^{VV}_m T^{Q_V}_b + \eta^{HH}_m T^{Q_H}_b + \eta^{VV}_s E^{Q_V}_b + \eta^{HH}_s E^{Q_H}_b \\
+ \eta^{VV}_s C^{Q_V}_b + \eta^{HH}_s C^{Q_H}_b + S^{Q_V}_a
\]

\[
T^{Q_H}_a = \eta^{HH}_m T^{Q_H}_b + \eta^{HV}_m T^{Q_V}_b + \eta^{HH}_s E^{Q_H}_b + \eta^{HV}_s E^{Q_V}_b \\
+ \eta^{VV}_s C^{Q_H}_b + \eta^{HV}_s C^{Q_V}_b + S^{Q_H}_a
\]

Weng et al., 2012, GRSL

Under a polarized earth scene, the side lobe together with cross-polarization term can result in large errors in computing SDR from TDR data if the antenna has a significant spill-over effect and the cross-polarization term is neglected.
Convertibility Issues from TDR to SDR

- Need to correct side-lobe radiation from far-field earth and near-field satellites

- For un-polarized surface and atmospheric conditions, the inversion from TDR to SDR is possible with a single polarization measurement.

- For an instrument with a significant cross-polarization spill-over, an inversion from TDR to SDR is problematic if a single polarization measurement is available.
## ATMS Antenna Beam Efficiency

<table>
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<tr>
<th>Frequency (GHz)</th>
<th>$\theta_{3,dB}$ (degree)</th>
<th>$\eta_{pp}^{\text{me}}$ (%)</th>
<th>$\eta_{pq}^{\text{me}}$ (%)</th>
<th>$\eta_{sc}^{pp} + \eta_{ss}^{pp} + \eta_{sc}^{pp}$ (%)</th>
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<td>23.8</td>
<td>5.25</td>
<td>99.48 99.61 99.53</td>
<td>0.52 0.39 0.46</td>
<td>0.003 0.0002 0.0025</td>
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<td>31.4</td>
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<td>50.3</td>
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<td>51.8</td>
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<td>1.75 2.03 2.18</td>
<td>0.011 0.0138 0.0111</td>
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*From STAR’ calculation*
For a scan angle ranging from 15 to 45 degrees, ATMS brightness temperatures at ch1, 2, 3, 4 and 16 are polarized over oceans. A conversion from TDR to SDR is also ill-posted problem if the antenna has a significant spill-over effect.
ATMS SDR Algorithm

For Quasi-V:

\[ T_b^{QV} = \left( T_a^{QV} - \beta_0^V - \beta_1^V \sin^2 \theta \right) / \eta_m^{vv} \quad \text{For Channels 1, 2, 16} \]

For Quasi-H:

\[ T_b^{QH} = \left( T_a^{QH} - \beta_0^H - \beta_1^H \cos^2 \theta \right) / \eta_m^{hh} \quad \text{For Channels 4~15, and 17~22} \]

\[ \eta_m^{pp} = \eta_{me}^{pp} + \eta_{se}^{pp} \]

Caveats: Cross-polarization spill-over is neglected. The main contribution from the side-lobe earth is next to the main beam. Atmosphere is also unpolarized and both side-lobe earth and spill-over are included in the main beam efficiency which is close to 1.0
ATMS De-convolution from Low to High Resolution

Raw 23 Tb (5.2 degree)

Resampled 23 Tb (2.2 degree)

Slide courtesy of STAR
ATMS Convolution from High to Low Resolution

Raw 89 GHz Tb (2.2 degree)

Resampled 89 Tb (5.2 degree)

Slide courtesy of STAR
Summary

- ATMS TDR/SDR data was approved for provisional status.
  - NEDT (precision) at 22 channels meet specification
  - Bias (accuracy) at channels 5 to 13 are better than specification

- ATMS TDR to SDR conversion theory is well developed and applied for TDR to SDR conversion
  - Caveats: xpol spill-over is neglected for window channels. Performance is not optimal for clear oceans where there is significant polarization

- ATMS striping in TDR radiances as shown in NWP O-B was analyzed and the root-cause is identified.

- ATMS radiometric calibration theory needs to be further improved with full radiance processing
Path Forward

• Produce beta version of ATMS striping reduction algorithm and create new ATMS datasets for NWP experiments

• Update ATMS scan bias corrections for TDR to SDR conversion using the ATMS antenna efficiency and pitch maneuver data

• Work with NGES to better characterize ATMS antenna (side-lobe, xpol spill-over, polarization twist angle) for J1/J2 mission

• Revise ATMS radiometric calibration in full radiance to make the SDR data consistent with NOAA heritage approach