Overview of Suomi National Polar-Orbiting Partnership
Satellite Instrument Calibration and SDR Validation

Dr. Fuzhong Weng, Chief
Satellite Meteorology and Climatology Division
NOAA/NESDIS  Center for Satellite Applications and Research (STAR)
### Suomi NPP and JPSS-1 Instruments

<table>
<thead>
<tr>
<th>Instrument Type</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ATMS</strong> - Advanced Technology Microwave Sounder</td>
<td>ATMS and CrIS together provide high vertical resolution <strong>temperature</strong> and <strong>water vapor information needed to maintain and improve forecast skill</strong> out to 5 to 7 days in advance for extreme weather events, including hurricanes and severe weather outbreaks.</td>
</tr>
<tr>
<td><strong>CrIS</strong> - Cross-track Infrared Sounder</td>
<td>VIIRS provides many <strong>critical imagery products</strong> including snow/ice cover, clouds, fog, aerosols, fire, smoke plumes, vegetation health, phytoplankton abundance/chlorophyll.</td>
</tr>
<tr>
<td><strong>VIIRS</strong> – Visible Infrared Imaging Radiometer Suite</td>
<td></td>
</tr>
<tr>
<td><strong>OMPS</strong> - Ozone Mapping and Profiler Suite</td>
<td>Ozone spectrometers for <strong>monitoring ozone</strong> hole and recovery of stratospheric ozone and for UV index forecasts.</td>
</tr>
<tr>
<td><strong>CERES</strong> - Clouds and the Earth’s Radiant Energy System</td>
<td>Scanning radiometer which supports studies of Earth Radiation Budget.</td>
</tr>
</tbody>
</table>
Suomi NPP TDR/SDR Algorithm Schedule

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Beta</th>
<th>Provisional</th>
<th>Validated</th>
</tr>
</thead>
<tbody>
<tr>
<td>CrIS</td>
<td>February 10, 2012</td>
<td>February 6, 2013</td>
<td>March 18, 2014</td>
</tr>
<tr>
<td>ATMS</td>
<td>May 2, 2012</td>
<td>February 12, 2013</td>
<td>March 18, 2014</td>
</tr>
<tr>
<td>OMPS</td>
<td>March 7, 2012</td>
<td>March 12, 2013</td>
<td>September 8, 2015</td>
</tr>
<tr>
<td>VIIRS</td>
<td>May 2, 2012</td>
<td>March 13, 2013</td>
<td>April 16, 2014</td>
</tr>
</tbody>
</table>

**Beta**
- Early release product.
- Initial calibration applied
- Minimally validated and may still contain significant errors (rapid changes can be expected. Version changes will not be identified as errors are corrected as on-orbit baseline is not established)
- Available to allow users to gain familiarity with data formats and parameters
- Product is not appropriate as the basis for quantitative scientific publications studies and applications

**Provisional**
- Product quality may not be optimal
- Incremental product improvements are still occurring as calibration parameters are adjusted with sensor on-orbit characterization (versions will be tracked)
- General research community is encouraged to participate in the QA and validation of the product, but need to be aware that product validation and QA are ongoing
- Users are urged to consult the SDR product status document prior to use of the data in publications
- Ready for operational evaluation

**Validated**
- On-orbit sensor performance characterized and calibration parameters adjusted accordingly
- Ready for use in applications and scientific publications
- There may be later improved versions
- There will be strong versioning with documentation
## ATMS SDR Requirements vs. Performance

<table>
<thead>
<tr>
<th>Channel</th>
<th>Accuracy (K) On-Orbit/Spec</th>
<th>NEΔT (K) On-Orbit/Spec</th>
<th>Channel</th>
<th>Calibration (K) On-Orbit/Spec</th>
<th>NEΔT (K) On-Orbit/Spec</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>/1.00</td>
<td>0.25/0.5</td>
<td>12</td>
<td>0.24/0.75</td>
<td>0.59/1.0</td>
</tr>
<tr>
<td>2</td>
<td>/1.00</td>
<td>0.31/0.6</td>
<td>13</td>
<td>0.13/0.75</td>
<td>0.86/1.5</td>
</tr>
<tr>
<td>3</td>
<td>/0.75</td>
<td>0.37/0.7</td>
<td>14</td>
<td>0.02/0.75</td>
<td>1.23/2.2</td>
</tr>
<tr>
<td>4</td>
<td>/0.75</td>
<td>0.28/0.5</td>
<td>15</td>
<td>0.09/0.75</td>
<td>1.95/3.6</td>
</tr>
<tr>
<td>5</td>
<td>0.18/0.75</td>
<td>0.28/0.5</td>
<td>16</td>
<td>/1.00</td>
<td>0.29/0.3</td>
</tr>
<tr>
<td>6</td>
<td>0.09/0.75</td>
<td>0.29/0.5</td>
<td>17</td>
<td>/1.00</td>
<td>0.46/0.6</td>
</tr>
<tr>
<td>7</td>
<td>0.02/0.75</td>
<td>0.27/0.5</td>
<td>18</td>
<td>0.50/1.00</td>
<td>0.38/0.8</td>
</tr>
<tr>
<td>8</td>
<td>0.06/0.75</td>
<td>0.27/0.5</td>
<td>19</td>
<td>0.36/1.00</td>
<td>0.46/0.8</td>
</tr>
<tr>
<td>9</td>
<td>0.06/0.75</td>
<td>0.29/0.5</td>
<td>20</td>
<td>0.31/1.00</td>
<td>0.54/0.8</td>
</tr>
<tr>
<td>10</td>
<td>0.18/0.75</td>
<td>0.43/0.75</td>
<td>21</td>
<td>0.13/1.00</td>
<td>0.59/0.8</td>
</tr>
<tr>
<td>11</td>
<td>0.22/0.75</td>
<td>0.56/1.0</td>
<td>22</td>
<td>0.40/1.00</td>
<td>0.73/0.9</td>
</tr>
</tbody>
</table>
## CrIS SDR Requirements vs. Performance

CrIS SDR uncertainties (\textcolor{blue}{blue}) vs. specifications (black)

<table>
<thead>
<tr>
<th>Band</th>
<th>NEdN @287K BB (mW/m²/sr/cm⁻¹)</th>
<th>Radiometric Uncertainty @287K BB (%)</th>
<th>Frequency Uncertainty (ppm)</th>
<th>Geolocation Uncertainty (km) *</th>
</tr>
</thead>
<tbody>
<tr>
<td>LW</td>
<td>0.098 (0.14)</td>
<td>0.12 (0.45)</td>
<td>3 (10)</td>
<td>1.2 (1.5)</td>
</tr>
<tr>
<td>MW</td>
<td>0.036 (0.06)</td>
<td>0.15 (0.58)</td>
<td>3 (10)</td>
<td>1.2 (1.5)</td>
</tr>
<tr>
<td>SW</td>
<td>0.003 (0.007)</td>
<td>0.2 (0.77)</td>
<td>3 (10)</td>
<td>1.2 (1.5)</td>
</tr>
</tbody>
</table>
# VIIRS SDR Requirements vs. Performance

<table>
<thead>
<tr>
<th>Requirement (absolute uncertainty for uniform scenes)</th>
<th>Prelaunch and onboard calibration</th>
<th>Validation: Relative to MODIS/CrIS/IASI/other thru Inter-comparisons</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIIRS RSB 2% typical reflectance; 0.3% stability; 0.1% desirable for Ocean Color Applications</td>
<td>1.2% for M1-M7; 1.5% for M8&amp;9 1.4% for M10 1.3% for I1&amp;I2 1.6% for I3</td>
<td>2% (±1%) for matching bands</td>
<td>Except bands with very low signal (ex. M11) Geolocation error: expectation is half I-band pixel; achieved better than quarter I-band pixel (1-s)</td>
</tr>
<tr>
<td>VIIRS TEB M12/M13: 0.7%(0.13K) @270K M14: 0.6% (0.26K) @ 270K M15/M16: 0.4% (0.22K/0.24K) @270K I4: 5% (0.97K) @270K I5: 2.5% (1.5K) @270K</td>
<td>Better than 0.13K for all M bands except M13 (0.14); 0.47K for I4; 0.23K for I5</td>
<td>0.1K based on statistical comparison with MODIS and CrIS ER-2/SHIS Aircraft underflight shows excellent agreement M15 0.4 K bias relative to CrIS at 200K (in spec.)</td>
<td>M15 at 190K requirement is 2.1% radiance or 0.56K Geolocation uncertainty: expectation was half I-band pixel; achieved better than quarter I-band pixel (1-s)</td>
</tr>
<tr>
<td>VIIRS DNB • 5%, 10%, 30% L_min (LGS,MGS,HGS)</td>
<td>3.5%, 7.8%, and 11% (LGS, MGS, HGS)</td>
<td>• 4%, 7.7%, 11.8% (LGS, MGS, HGS)</td>
<td>Geolocation error is a ~10th of a pixel (1-s) on the ellipsoid earth but can exceed 1km (up to 24 km at the edges of scan) without terrain correction</td>
</tr>
</tbody>
</table>
## OMPS SDR Requirements vs. Performance

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Specification/Prediction Value</th>
<th>On-Orbit Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-linearity</td>
<td>&lt; 2% full well</td>
<td>&lt; 0.46%</td>
</tr>
<tr>
<td>Non-linearity Accuracy</td>
<td>&lt; 0.2%</td>
<td>&lt; 0.2%</td>
</tr>
<tr>
<td>On-orbit Wavelength Calibration</td>
<td>&lt; 0.01 nm</td>
<td>0.15 nm</td>
</tr>
<tr>
<td>Stray Light NM Out-of-Band + Out-of-Field Response</td>
<td>For NM ≤ 2</td>
<td>average &lt; 2%</td>
</tr>
<tr>
<td>Intra-Orbit Wavelength Stability</td>
<td>Allocation (flow down from EDR error budget) = 0.02 nm</td>
<td>~ 0.02 nm</td>
</tr>
<tr>
<td>SNR</td>
<td>1000</td>
<td>&gt; 1000</td>
</tr>
<tr>
<td>Inter-Orbital Thermal Wavelength Shift</td>
<td>Allocation (flow down from EDR error budget) = 0.02 nm</td>
<td>~0.02 nm</td>
</tr>
<tr>
<td>CCD Read Noise</td>
<td>60 e RMS</td>
<td>&lt; 25 e RMS</td>
</tr>
<tr>
<td>Detector Gain</td>
<td>43 (for NP)</td>
<td>47 (for NP)</td>
</tr>
<tr>
<td>46 (for NM)</td>
<td>51 (for NM)</td>
<td></td>
</tr>
<tr>
<td>Absolute Irradiance Calibration Accuracy</td>
<td>&lt; 7%</td>
<td>&lt; 7% for majority channels</td>
</tr>
<tr>
<td>Absolute Radiance Calibration Accuracy</td>
<td>&lt; 8%</td>
<td>&lt; 5% for majority channels</td>
</tr>
<tr>
<td>Normalized radiance Calibration Accuracy</td>
<td>&lt; 1%</td>
<td>&lt; 1%</td>
</tr>
</tbody>
</table>
JPSS SDR 2015 Major Accomplishments

- Completed comprehensive SDR CalVal Plans for JPSS-1. The calval tasks are presented with clear role and responsibility, task objective, expected outcomes, and lessons learned from SNPP.
- Developed an offline CrIS full spectral resolution (FSR) SDR processing system and made the FSR products available to user community.
- Developed ATMS radiance-based radiometric calibration, replacing Rayleigh-Jeans approximation in two-point calibration system.
- Developed J1 VIIRS DNB waiver mitigation and delivered pre-operational software to IDPS program on-time, and implemented the operational straylight correction in DNB band.
- SNPP OMPS earth view SDR products have reached the validated maturity level after updating LUTs of wavelength scale, solar irradiance and earth view radiance coefficients.
- Integrated CalVal System (ICVS) – Lite version was successfully transitioned to GRAVITE for NASA Flight and OSPO operational uses.
ATMS SDR Team 2015 Top Five Accomplishments

1. Developed the radiometric two-point calibration in radiance, instead of brightness temperature which is based on Rayleigh-Jeans approximation. The full radiance calibration algorithm will be in IDPS MX8.12 and IDPS Block 2

2. Standardized NEdT calculation for ATMS and other microwave sounding instruments using Allan Deviation. The new algorithm has resulted in much stable noise trending and is SI traceable

3. Optimized the ATMS de-striping algorithm for the earth scene brightness temperatures and generated 45 days of ATMS TDR data for NWP user community to experiment the impacts of ATMS on global forecast skills

4. Developed a physically based model for correcting the radiation from ATMS reflector emission contributed to the earth scene brightness temperature

5. Updated ATMS processing coefficient tables (e.g. nonlinearity coefficients, threshold for calibration counts)
Assimilation of ATMS radiances in NCEP GFS produces a largest impact on global medium range forecast, especially over southern hemisphere. With respect to the baseline experiment that includes the conventional and GPSRO data, 75% forecast skill increase is attributed to ATMS radiance assimilation.
Predicted vs. observed track for Hurricane Sandy during October 22 to 29. NCEP 2012 HWRF is revised with a high model top and is initialized with its own background 6 hour forecast 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 reduces the forecast errors of Hurricane Sandy’s track.
Biases in the Tropics (NOAA-15, MetOp-A, SNPP)

NOAA-18 is subtracted. The pentad data set within ±30° latitudinal band.
Innovative Approaches for High-Quality SDR

- Developed an Integrated CalVal System (ICVS) for monitoring and trending the orbit performance for all the NOAA operation satellite instruments.

- Developed a new SI traceable methodology for computing the instrument noises.

- Established an on-orbit calibration standard through special SNPP flight operations (e.g. pitch/roll maneuvers) and special calibration targets (e.g. moon, earth targets).

- Established an SDR testbed for JPSS mission life cycle reprocessing.

- Cross-calibrated the SDR using WMO GSICS and other methodology.
Allan Deviation Algorithms for Computing Satellite Instrument Noise

- Allan Variance was proposed by NIST for characterizing the random noise from a time series which has a variable mean.

- It was never implemented for meteorological satellite instruments. Currently, all the NOAA instrument noises are computed by the standard deviation which is only valid for the stationary mean.

- With Allan variance, all the NEDT and NEDN computed from NOAA and JPSS instruments are SI traceable.

*D. W. Allan, Should the classical variance be used as a basic measure in standards metrology Instrumentation and Measurement, IEEE Trans. on, IM-36, pp.646-654, 1987*
ATMS Noise Equivalent Temperature (NEDT)

For a time series with a stable mean, the standard deviation of the measurements can be used as NEDT:

\[ \sigma_{ch} = \left[ \frac{1}{4N} \sum_{i=1}^{N} \sum_{j=1}^{4} \left( \frac{C_{ch}^w(i,j) - \bar{C}_{ch}^w(i)}{G_{ch}(i)} \right)^2 \right]^{1/2} \]

For a non-steady mean such as ATMS warm count from blackbody target, Allan variance works the best for NEDT:

\[ \sigma^{Allan}(m) = \sqrt{\frac{1}{2m^2(N-2m)} \sum_{j=1}^{N-2m} \left( \sum_{i=1}^{j-1} \left( C_{ch}^w(i+m) - C_{ch}^w(i) \right) \right)^2} \]

ATMS channel 1 warm count mean (blue, y-axis on the right), the standard deviation (red, y-axis on the left) and the overlapping Allan deviation (green, y-axis on the left) of the 17-scanline (m) average as a function of the total sample size (N).

ATMS NEDT Computed from Standard and Allan Deviations

**ATMS standard deviation (blue) and Allan deviation (red) with channel number. The sample size \(N\) is 150 and the averaging factor \(m\) for the warm counts is 17. The standard deviation is much higher than Allan deviation.**
CrIS Noise Computed from Standard Deviation and Allan Variance

SI traceable algorithm for characterizing hyperspectral infrared sounder CrIS noise (Chen and Weng, 2015, AO, accepted)
Establish an in-orbit Standard for Characterizing Instrument Calibration Accuracy

- Maneuvers Suomi NPP satellite to scan cold space and characterizes the scan angle dependent bias using physical models
- Develops the best practices for earth scene simulations using the forward models and high quality atmospheric profiles
- Uses stable earth scenes and terrestrial targets (e.g. moon and star) for monitoring the calibration stability

NPP ATMS pitch maneuver observations show channel related scan angle dependent feature, indicate the scan bias is not inherent feature of the scene.
ATMS Pitch Maneuver February 20, 2012

ATMS Down Track Scan

ATMS Cross Track Spot

Brightness Temperature [K]

Slide courtesy of Vince Leslie, MITLL
SNPP ATMS pitch maneuver observations show channel related scan angle dependent feature, indicate the scan bias is not inherent feature of the scene.
Effects of ATMS Flat Reflector Emission on Brightness Temperature

Quasi-V (TDR) :

\[ R_{qv}^c = R_{qv} + \varepsilon_h (R_v - R_h) + [\varepsilon_v (R_v - R_v) - \varepsilon_h (R_v - R_h)] \sin^2 \theta - \frac{R_3}{2} (1 - \varepsilon_h)^{3/2} \sin 2\theta \]

Quasi-H (TDR):  Bias due to the reflector emission

\[ R_{qh}^c = R_{qh} + \varepsilon_h (R_v - R_h) + [\varepsilon_v (R_v - R_v) - \varepsilon_h (R_v - R_h)] \cos^2 \theta + \frac{R_3}{2} (1 - \varepsilon_h)^{3/2} \sin 2\theta \]

where

\( R_{qv}, R_{qh} \) are the radiances at quasi vertical and horizontal polarization which are further related to the radiances at pure vertical and horizontal polarization, \( R_v \) and \( R_h \). \( \varepsilon_v \) and \( \varepsilon_h \) are the reflector emissivity at the vertical and horizontal polarization. \( R_3 \) is the third Stokes radiance component of the scene. \( R_r \) is the radiance emitted from the reflector. \( \theta \) is the scan angle. Note that \( \varepsilon_v = 2\varepsilon_h - \varepsilon_h^2 \) at an indent angle of 45 degree to reflector normal.

CrIS Shortwave IR Band 3 for All Channels

Different colors indicate different channels. The results are normalized by Planck Radiances at 287K.

Slide Courtesy of Likun Wang and Yong Han
ATMS Calibration Accuracy Assessment Using GPS RO

- **Time period of data search:**
  January, 2012

- **Collocation of ATMS and COSMIC data:**
  Time difference < 0.5 hour
  Spatial distance < 30 km
  (GPS geolocation at 10km altitude is used for spatial collocation)

3056 collocated measurements

*Slide Courtesy of Lin Lin*
ATMS Bias Obs (TDR) - GPS Simulated
On-orbit ATMS calibration accuracy is quantified using GPSRO data as input to RT model and is better than specification for most of sounding channels.
CrIS Radiative Transfer Simulations

- Line by Line Radiative Transfer Model
  - Gaseous absorption
  - None Local Thermal Equilibrium emission correction
  - Short wave surface reflection

- Inputs to LBLRTM
  - Wavelength, solar and satellite viewing geometry, surface emissivity
  - Temperature and water vapor profile from ECMWF forecast fields
  - Climatology CO2, CO, CH4 profile
  - CrIS spectral response function

- Outputs from LBLRTM
  - Radiances at all 2211 channels and 9 FOVS
  - O-B at each FOV
  - Double difference of O-B between FOVs.
CrIS Individual FOV Bias wrt NWP Simulations

\[ BIAS_{FOVi} = (\text{Obs} - \text{CRTM})_{FOVi} - (\text{Obs} - \text{CRTM})_{all} \]

The achieved uniformity of the spectral and radiometric uncertainties cross the 9 FOVs is important for NWP to maximize the use of the radiance data

Courtesy of Yong Chen, STAR
Building an on-Orbit Truth for Estimating OMPS Earth View SDR Accuracy

• Develop the “truth” simulated from the forward radiative transfer model at OMPS EV location (Macropixel)

• Radiative transfer model must include comprehensive scattering and absorption processes at UV regions

• Accurate understanding of atmospheric and surface status at OMPS EV location.

• The difference between observations and simulations is used as an estimate of on-board calibration accuracy
OMPS EV Radiative Transfer Simulations

- **TOMRAD-2.24**: TOMS (Total Ozone Mapping Spectrometer) Radiative Transfer Model and Vector Linearized Discrete Ordinate Radiative Transfer (VLIDORT)
  - Rayleigh scattering atmosphere with ozone and other gaseous absorption
  - Spherical correction for the incident team
  - Molecular anisotropy and Raman scattering
- **Inputs to TOMRAD**
  - Wavelength, solar and satellite viewing geometry, surface albedo, temperature and ozone profile
  - Climatology temperature profile
  - Ozone profile from Aura Microwave Limb Sounder (MLS)
  - Collocated OMPS/MLS data generated at NASA
  - Surface reflectivity based on 331 nm
- **Outputs from TOMRAD**
  - Normalized radiance ($NR = \text{reflected radiance/solar flux}$) or N-Value ($N = -100\log_{10}NR$)
Co-located OMPS/MLS Temperature and Ozone Profiles
OMPS Observation minus Simulation (O-B)

Relative Error

Relative error wrt to Position 18 (nadir)

The bias in cross-track direction is generally less than 2% except at shorter wavelengths where simulations may become less accurate due to complex scattering process. The bias is also larger in side pixel locations.
VIIRS Reflective Solar Band (RSB) Calibration

- **F**: RSB Calibration coefficient.
- **H**: SD degradation factor.

\[
L_{EV} = \frac{F \cdot (c_0 + c_1 \cdot dn_{EV} + c_2 \cdot dn_{EV}^2)}{RVS_{EV}}
\]

\[
F = \frac{L_{\text{Sun Model}}}{L_{\text{Sun Observation}}} = \frac{\text{Computed } L_{\text{Sun}}}{\text{Observed } L_{\text{Sun}}}
\]

\[
F = \frac{\cos(\theta_{inc}) \cdot [E_{\text{sun}} \cdot \tau_{sds} \cdot BRDF(t)] \cdot RVS_{SD}}{c_0 + c_1 \cdot dn_{SD} + c_2 \cdot dn_{SD}^2}
\]

\[
BRDF(t) = H_{\text{Norm}}(t) \cdot BRDF(t_0)
\]

\[
H_{\text{Norm}}(t) = \frac{H(t)}{H(t_0)}
\]

\[
H(t) = \frac{dc_{SD} \cdot \tau_{SDSM}}{dc_{\text{SUN}} \cdot BRDF(t_0) \cdot \tau_{SD} \cdot \cos(\theta_{inc}) \cdot \Omega_{SDSM}}
\]

dn: VIIRS bias removed response
dc: SDSM bias removed response
VIIRS Performance at 30 Vicarious Sites Worldwide

- VIIRS calibration is monitored at 30 Vicarious sites with time series analysis for all bands.
- DCC and Lunar are recognized as unique sites and have been used to diagnose calibration anomalies.
- The DCC time series are capable of detecting sub-percent calibration changes.
  - Bands M5 and M7 are stable, with calibration of stability better than 0.4% (1-sigma);
  - Bands M1-M3 show noticeable calibration changes, especially since early 2014, due to the SD anomaly.
- Time series available at: https://cs.star.nesdis.noaa.gov/NCC/VSTS.
STAR SDR Testbed for JPSS Reprocessing

- Tests innovative sciences and algorithms to improve JPSS SDR product quality
- Transitions the new software developed from extramural community to IDPS
- Performs the NWP impact studies using improved SDR data
- Transitions the ICVS-Lite to GRAVITE for NASA and OSPO operations
- Archives anomaly reports regarding all NOAA/METOP/JPSS instruments
- Conducts new research on future JPSS and other satellite constellation
- Provides the online supports to Global Space-Based Inter-Calibration System
- Performs the JPSS SDR mission life cycle reprocessing
STAR SDR Testbed Utilities

• **RDR/TDR/SDR Generation**
  – Space Sensor Simulator (S3)
  – Community Radiative Transfer Model (CRTM)
  – Line by Line RTM (LBLRTM)
  – Advanced RT models: TOMRAD, 6S, VLIDORT, VDIOSRT

• **RDR to SDR Transformation**
  – CrIS Full Spectral Resolution Processing System (CFSR)
  – Advanced Radiance Transformation System (ARTS)
  – Algorithm Dynamic Library (ADL)

• **Quality Assurance of SDR**
  – SI Traceable Noise Calculation Software (STNC)
  – NOAA Products Validation System (NPROVS)
  – Integrated Calibration and Validation System (ICVS)

• **Inversion from SDR to EDR**
  – Microwave Integrated Retrieval System (MIRS)
  – NOAA Unique CrIS and ATMS Processing System (NUCAPS)
  – Ocean coloring processing with Multi-Sensor Level 1 to Level-2 (MSL12)
  – Advanced Clear Scene Processor for Oceans (ACSPO)
  – Cloud from AVHRR-x (CLAVR-x)
STAR SDR Testbed IT Infrastructure

STARS Internal Servers
- STAR integrated calibration/validation system (ICVS)
- Global Space-based Inter-Calibration System (GSICS)
- Daily JPSS SDR calibration/validation activities

<table>
<thead>
<tr>
<th>Server</th>
<th>Cores</th>
<th>Memory (GB)</th>
<th>HDD (TB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>STAR-S1</td>
<td>80</td>
<td>256</td>
<td>135</td>
</tr>
<tr>
<td>STAR-S2</td>
<td>80</td>
<td>512</td>
<td>230</td>
</tr>
<tr>
<td>STAR-S3</td>
<td>80</td>
<td>512</td>
<td>200</td>
</tr>
<tr>
<td>STAR-S4</td>
<td>16</td>
<td>256</td>
<td>12</td>
</tr>
<tr>
<td>STAR-S5</td>
<td>16</td>
<td>256</td>
<td>12</td>
</tr>
<tr>
<td>STAR-S6</td>
<td>8</td>
<td>16</td>
<td>8</td>
</tr>
<tr>
<td>STAR-S7</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>STAR-S8</td>
<td>16</td>
<td>768</td>
<td>20</td>
</tr>
<tr>
<td>STAR-S9</td>
<td>16</td>
<td>768</td>
<td>20</td>
</tr>
</tbody>
</table>

STAR CICS Cluster
- Computation intensive jobs
- NWP pre-operational testing
- Mission lifecycle data reprocess

<table>
<thead>
<tr>
<th>Server</th>
<th>Cores</th>
<th>Memory (GB)</th>
<th>HDD (TB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>STAR-CICS1</td>
<td>432</td>
<td>1296</td>
<td>136</td>
</tr>
</tbody>
</table>

UMD/AOSC Servers
- Data dissemination
- Academia research testing

<table>
<thead>
<tr>
<th>Server</th>
<th>Cores</th>
<th>Memory (GB)</th>
<th>HDD (TB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>STAR-UMD1</td>
<td>820</td>
<td>2500</td>
<td>2800</td>
</tr>
<tr>
<td>STAR-UMD2</td>
<td>64</td>
<td>256</td>
<td>20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parts</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Servers</td>
<td>12</td>
</tr>
<tr>
<td>CPU Cores</td>
<td>876</td>
</tr>
<tr>
<td>Memory (GB)</td>
<td>5156</td>
</tr>
<tr>
<td>HDD (TB)</td>
<td>2815</td>
</tr>
</tbody>
</table>

Internet

Direct Link
- GRAVITE
  - Real time S-NPP/JPSS data
- CLASS
  - Lifetime S-NPP/JPSS data
- NWP Centers
  - NWP forecast data
- Other Data Center
  - Cosmic, MLS, et. al.
STAR  Space Sensor Simulator

NWP Model Outputs
• Global, all seasons, mixed cases
• Regional/local/cloud resolving

Observational Data
• Full Disk, multi-orbit data
  • Global scale

CRTM or Other RTM
• Integrated atmospheric/surface modeling components
  • Sensor-level (SRF, PSF, FOV)

OSSE/OSE
• New GOES-R capability
  • Impacts on NWP

Ground System
• Algorithm Working Group
• Algorithm Development
  • Rehearsal and launch readiness
Resolution Reduction

Resolution Enhancement

- Explore the potential of the oversampling characteristic of ATMS observations and generate observations at different frequencies with consistent FOV size.
- Backus-Gilbert observation reconstruction algorithm is used for remapping TDR to expected spatial resolution.
- Remapping coefficients are tuned to ensure the remapped TDR products are in best balance between noise and spatial resolution.
JPSS Mission Life Cycle Reprocessing

• SNPP SDR Processing Changes since November 2011
  – CrIS SDR from normal to full spectral resolution
  – ATMS SDR from Rayleigh-Jean to full radiance
  – VIIRS SDR changes from F/H factor updates
  – Numerous discrepancy reports (DR) filed to fix the anomalies; updates in PCT, LUT, engineering packages, etc.

• Major SDR Processing Upgrades from SNPP to JPSS-1
  – CrIS FSR will implement several new modules to reduce the ring effects
  – ATMS SDR will have some new modules in correction of antenna emission, lunar correction and striping
  – OMPS will add more modules to compress and aggregate RDR, straylight and smearing
  – VIIRS DNB requires special upgrades in geolocation and aggregation

• Starting 2016, SNPP SDR products will be reprocessed every other year
  – SNPP ATMS, CrIS and OMPS - 2016
  – SNPP VIIRS – 2017
ATMS SDR Algorithm Change from SNPP to JPSS

Input Radiometric (Scene, Warm Target, Cold Space) Counts, PRT Counts, Coefficients

Compute Warm Target Radiance

Compute Cold Space Radiance

Correction of Warm Radiance

Correction of Cold Radiance

Average over Warm and Cold Counts

Linear Calibration of Scene Radiance

Nonlinearity Correction

Earth Scene Antenna Emissivity Correction

Scene Radiance/Brightness Temperature

Major Changes:

• Radiance based calibration

• Model based lunar contamination correction

• Updated parameterized nonlinearity correction

• Model based antenna reflector emissivity correction
JPSS Mission Life Cycle SDR Reprocessing

• SNPP SDR Processing Changes since November 2011
  – CrIS SDR from normal to full spectral resolution
  – ATMS SDR from Rayleigh-Jean to full radiance
  – VIIRS SDR changes from F/H factor updates
  – Over 1000 discrepancy reports (DR) filed to fix the anomalies, update in PCT, LUT, engineering packages, etc.

• Major SDR Processing Upgrades from SNPP to JPSS-1
  – CrIS FSR will implement several new modules to reduce the ring effects
  – ATMS SDR will have some new modules in correction of antenna emission
  – OMPS will add more modules to compress and aggregate the RDR
  – VIIRS DNB requires special upgrades in geolocation and aggregation

• Starting 2016, SNPP SDR products will be reprocessed every other year
  – SNPP ATMS, CrIS and OMPS - 2016
  – SNPP VIIRS – 2017
CrIS SDR Algorithm Change from SNPP to JPSS

Load Data

Pre-process: sort EP, SciCalP & IFGM packets into sequences; truncate full resolution RDRs if needed

CMO Build if needed

IFGM to raw spectra conversion

Update ICT, DS & ES sliding windows

FCE Handling (currently disabled)

Nonlinearity correction

NEdN Calculation

SDR Output

Quality Flag & Variable Settings

Geolocation Calculation

Residual ILS Correction

Self-apodization Correction

Spectral Resampling

Post-calibration Filter

Radiometric Calibration

Lunar intrusion handling

Fifth Granule

Output

Reorder Calibration Flow

J1 Major Changes

Existing Code

9 granules

9 granules
ATMS SDR Algorithm Change
from SNPP to JPSS

Input Radiometric (Scene, Warm Target, Cold Space) Counts, PRT Counts, Coefficients

Compute Warm Target Radiance

Compute Cold Space Radiance

Correction of Warm Radiance

Correction of Cold Radiance

Average over Warm and Cold Counts

Linear Calibration of Scene Radiance

Nonlinearity Correction

Earth Scene Antenna Emissivity Correction

Scene Radiance/Brightness Temperature

J1 New Code

Repair

Existing Code

J1 Major Changes

Major Changes:

• Radiance based calibration

• Model based lunar contamination correction

• Updated parameterized nonlinearity correction

• Model based antenna reflector emissivity correction
### SNPP CrIS Full Spectral Resolution SDR

<table>
<thead>
<tr>
<th>Frequency Band</th>
<th>Spectral Range (cm(^{-1}))</th>
<th>Number of Channel</th>
<th>Spectral Resolution (cm(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>LWIR</td>
<td>650 to 1095</td>
<td>713 (713)</td>
<td>0.625 (0.625)</td>
</tr>
<tr>
<td>MWIR</td>
<td>1210 to 1750</td>
<td>865 (433)</td>
<td>0.625 (1.25)</td>
</tr>
<tr>
<td>SWIR</td>
<td>2155 to 2550</td>
<td>633 (159)</td>
<td>0.625 (2.5)</td>
</tr>
</tbody>
</table>

Red: Full resolution mode

![Graph showing brightness temperature vs. wavenumber for CH\(_4\), CO, and CO\(_2\)](image-url)
Global Mean ATMS TDR Bias After Reprocessing

ATMS TDR Bias (Full Radiance Process - IDPS OPS)

<table>
<thead>
<tr>
<th>Channels</th>
<th>Mean TDR Bias [K]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 22</td>
<td>-0.7 to -0.1</td>
</tr>
</tbody>
</table>

TDR Bias (Full Radiance Process - IDPS)
Summary and Conclusions

- ATMS, CrIS, VIIRS and OMPS onboard SNPP are well calibrated and their performances in orbit are very stable.

- On-orbit calibration standards are fully vetted with SNPP pitch maneuver data and uses of the pitcher maneuver data have led to fundamental changes in calibration theory and new applications in forward modeling.

- On-orbit calibration standards are also fully explored through robust O-B where B is computed with GPS RO profiles, ECMWF analysis fields and other high quality atmospheric profiles as inputs to LBLRTM, CRTM, TOMRAD, VLIDORT.

- STAR SDR testbed is being established for JPSS mission life cycle reprocessing and a climate quality of SNPP SDR products will be generated in 2016 and 2017.

- SNPP SDR products have been assimilated in all NWP centers and the impacts on the forecast skills are the highest due much to the new technology, calval sciences and data assimilation sciences.