S-NPP Ozone Mapper Profiler Suite
Nadir Sensor Performance

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SUOMI NPP SDR Science and Validated
Product Maturity Review
December 18-20, 2013
5830 University Research Court, College
Park, MD 20740
Topics

- Sensor noise
- Dark current
  - Distribution
  - Dark generate rates
  - Readout noise
- Linearity
  - LED output drift
  - Nonlinearity
  - Calibrated residual
- Wavelength registration
  - Dichroic shift
  - Orbital variation and intro-orbital variation
  - Cross-position variation
- Absolute solar irradiance
- Normalized Earth view irradiance
- Stray light
Earth view noise < 0.1 % RMSR

EOF analysis for NM

Noise in the SAA causes noticeable uncertainty for NP @ wavelength < 290 nm
Solar view SNR > 1000

Working Diffuser

Reference diffuser has a similar pattern and also meets the requirement.
Increasing dark currents, as expected

- Weekly increase in mean is about 0.6% for the NM and 0.8% for the NP, resulting in uncertainties in ozone data ~ 0.03% for NM and 0.1-0.5 % for NP.
- The change in dark has negligible impact on the dynamic range of the sensor response for at least 7-10 years.
Dark readout noise keeps ~25 e- (primary e-side)

Noise < prelaunch prediction of 60 e-
LED output variation < 0.06% over 7 min.

Prelaunch
On-orbit

LED percent drift over 7 minutes

Specification: 1% per min.
Nonlinearity < 0.45 of full well

NP Linearity Measurement regression residuals
Orbits 230 - 1166

Knowledge spec. is ±0.2% over the full dynamic range

From NASA

saturation
CCD gain is stable

The number of electrons corresponding to one analog count of the analog to digital converter (ADC)

Small offset relative to the TVAC test results
Dichroic shifted > 0.1 nm from ground to orbit

Without shift

Measured vs. MLS NR

After add a 0.15 nm shift

Measured vs. MLS NR

Measured vs. Synthetic Solar Flux

Measured vs. Synthetic Solar Flux

Courtesy of NASA
Orbital wavelength variation < 0.02nm
Intro-orbit wavelength changes < 0.025 nm

NM housing temperature (°C)  
Intro-orbital wavelength shift in pixel

This variation is compensated in the EDR algorithm
Cross-track position difference indicates wavelength variation

NM Solar data
Absolute solar irradiance uncertainty < 7%
Trending of sensors’ optic throughput
Sensor optic degradation < 0.5%

Small degradation indicates a high level of sensor stability
Indicating the absolute radiance uncertainty < 8%.
Stray light correction improves EV radiance

Spectral overlap

Stray light < average 2%

Before initial correction
After initial correction

306nm
## Summary

<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>±0.2%</td>
</tr>
<tr>
<td><strong>On-orbit Wavelength Calibration</strong></td>
<td>&lt; 0.01 nm</td>
<td>~ 0.02 nm</td>
</tr>
<tr>
<td>Stray Light NM Out-of-Band +</td>
<td>For NM ≤ 2</td>
<td>average &lt; 2%</td>
</tr>
<tr>
<td>Out-of-Field Response</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intra-Orbit Wavelength Stability</td>
<td>Allocation (flow down from EDR error budget) = 0.02 nm</td>
<td>~ 0.025 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>~ 0.025 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></td>
<td>46 (for NM)</td>
<td>51 (for NM)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 7%</td>
</tr>
<tr>
<td>Absolute Irradiance Calibration Accuracy</td>
<td>&lt; 7%</td>
<td>in 300-310 nm: up to ~10 % for both NM and NP</td>
</tr>
<tr>
<td>Absolute Radiance Calibration Accuracy</td>
<td>&lt; 8%</td>
<td>&lt; 8%</td>
</tr>
<tr>
<td>Normalized radiance Calibration Accuracy</td>
<td>&lt; 2%</td>
<td>&lt; 1%</td>
</tr>
</tbody>
</table>
Path forward

• Investigate thermal impact on dichroic from ground to orbit
• Determine temperature shift along orbit
  – wavelength shift vs. temperature difference of sensor telescope
  – apply thermal correction if necessary
• Refine stray-light correction when necessary
## OMPS SDR calibration tables

<table>
<thead>
<tr>
<th>Table Description</th>
<th>Table Type</th>
<th>Delivery Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>NM &amp; NP Day 1 Solar</td>
<td>LUT</td>
<td>Once (will be repeat )</td>
</tr>
<tr>
<td>NM &amp; NP Wavelength</td>
<td>GND-PI</td>
<td>Once (will be repeat )</td>
</tr>
<tr>
<td>NM &amp; NP CF Earth</td>
<td>GND-PI</td>
<td>Monthly (ceased)</td>
</tr>
<tr>
<td>NM &amp; NP Dark Tables</td>
<td>GND-PI</td>
<td>Weekly</td>
</tr>
<tr>
<td>Diagnostic Flight Sample Tables</td>
<td>SCT</td>
<td>When necessary</td>
</tr>
<tr>
<td>Earth-view Flight Sample Tables</td>
<td>SCT</td>
<td>Once</td>
</tr>
<tr>
<td>Earth-view Ground Sample Tables</td>
<td>GND-PI</td>
<td>Once</td>
</tr>
<tr>
<td>Calibration Flight Sample Tables</td>
<td>SCT</td>
<td>Once</td>
</tr>
<tr>
<td>NM &amp; NP Radiometric Coefficients</td>
<td>LUT</td>
<td>TBD</td>
</tr>
<tr>
<td>NM Stray Light Coefficients</td>
<td>LUT</td>
<td>Once</td>
</tr>
<tr>
<td>NP Stray Light Coefficients</td>
<td>LUT</td>
<td>Not planned</td>
</tr>
<tr>
<td>NM &amp; NP Linearity (Flight &amp; Ground)</td>
<td>SCT/GND-PI</td>
<td>Not planned</td>
</tr>
<tr>
<td>NM &amp; NP Flat Field</td>
<td>SCT</td>
<td>Not planned</td>
</tr>
</tbody>
</table>
Electronic bias changes is negligible

Trailing Left half CCD
Trailing Right half CCD

Leading Left half CCD
Leading Right half CCD

Date – UTC
Counts

Entire Record
LED warm up reduces output drifting

LED signal drifting for CCD1

CCD Temp. (°C)
-29.9624
-30.0100
-30.0338
-30.0576

Linearity measurement
Solar flux trending shows a small change for both sensors.

**Working Reference**

- Wavelength = 273 nm
- Wavelength = 304 nm
Solar measurement reduces view angle dependence

Ratio of solar data

Data is being used to study diffuser feature
The nonlinearity is about 0.39 for the NM and is 0.32 for the NP; the linear fitting RMS is 0.07% for the NM and is 0.02% for the NP.

\[ \eta = \frac{(Q_m - Q_i)}{Q_{\text{max}}} \]

where \( Q_m \) is the measured response to a LED measurement input, \( Q_i \) is the ideal response to the \( Q_m \), and \( Q_{\text{max}} \) is the full well response.
Hot pixels causes dark change

After ~7 year, 99% pixels will become hot.

\((1 - a \cdot e^{-bx})\)
Detector dynamic range is being monitored

NM Left Half CCD
NM Right Half CCD
NP CCD

DECON mode

Prelaunch
On-orbit
Possible saturated
NM “spectral smile” <0.2 nm
NP “spectral smile” < 0.7 nm

Prelaunch

On-orbit
Cross-track position pattern from Earth data

Problems at the far off-nadir positions lead to swath dependent ozone effects

Difference indicates inconsistency with MLS ozone profile, will lead to different total column ozone amounts

Difference indicates calibration issue

Courtesy of NASA

19 December 2013

SNPP OMPS Product Review Meeting
System Linearity

- System non-linearity
- LED data noise
- LED output drifts
- Dynamic range of detector response
- Calibrated accuracy
- LED lamp warm up behavior
- LED illumination uniformity
- CCD gain

**EVLED_Closed – 1 orbit**
**Every 4th week**

<p>| | |</p>
<table>
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<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NP Lamp Warm up</td>
<td>50 images</td>
</tr>
<tr>
<td>NP Linearity</td>
<td>83 images</td>
</tr>
<tr>
<td>NP FF Lamp</td>
<td>1 image</td>
</tr>
<tr>
<td>NM Lamp Warmup</td>
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<tr>
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Dark Current

- Dark distribution
- Dark generate rates
- Electronic bias
- Hot pixels
- Dark Signal Non-uniformity (DSNU)
- Readout noise

**DC – 1 orbit weekly**

<table>
<thead>
<tr>
<th></th>
<th>NM / NP Closed Darks</th>
<th>NM / NP Storage Darks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Images</td>
<td>21 images</td>
<td>9 images</td>
</tr>
</tbody>
</table>