SNPP OMPS performance and lessons learned

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Ozone Mapping and Profiler Suite

Launched: Oct., 2011
The OMPS instruments

**Nadir Mapper & Profiler**
- 2 Grating spectrometers w/CCD detectors
- Heritage: TOMS, SBUV, GOME, GOME-2, OMI
- Wavelength: 250 –380 nm
- Spectral sampling: 0.41nm; resolution 1 nm
- Push broom 110° FOV telescope
- Horizontal resolution: 50 km & 250 km
- Detectors: 0.25 megapixel CCD at -30 & -45 °C

**Limb Profiler**
- Prism spectrometer with CCD detector
- Heritage: SOLSE / LORE, OSIRIS, SCIAMACHY, GOMOS
- Wavelength: 280 –1000 nm
- Spectral resolution: 1 - 30 nm
- Vertical Sampling: 1 km
- Vertical resolution: ~2 km
- Detector: 0.25 megapixel CCD at -45 °C

Images: courtesy of Ball Aerospace
Definition of “BUV technique”

An approach for measuring the Earth’s directional reflectance (top of the atmosphere) by comparing to a solar reflector with known properties.
Solar variability was original reason for BUV

Solar variability cancels when calculating TOA reflectance

Easier to assume solar irradiance is constant when $\lambda > 300$ nm

Primary range for $O_3$ profile retrievals

From:
Calibration is the main BUV advantage

Nimbus-4 BUV optical design (1968)

Sun-Normalized Radiance:

\[
\frac{L_{EV}}{E_{sun}} = \frac{k_r \cdot C_r}{k_i \cdot C_i} = A \cdot \frac{C_r}{C_i}
\]

\[A \approx R_{Diffuser} \cos \Theta_i\]

- \(L_{EV}\): backscattered Earth radiance
- \(E_{sun}\): solar irradiance
- \(C\): measured signals
- \(k\): calibration coefficients
- \(A\): albedo calibration coeff.

No optical components in front of solar diffuser

Many systematic calibration errors cancel in the ratio (incl. Spectral Response Function)
Laboratory Albedo (a.k.a. BSDF) Calibration

Irradiance

Radiance

Direct Calibration

Diffuser-based Calibration

Sphere-based Calibration

3 methods currently yield < 1% total ozone difference

Calibrations performed in air at 20 °C
Instrument is radiometrically stable

Total solar signal = Diffuser change + Sensor change

Solar measurement ratio: 2.5 yrs / initial

- No Reference signal change means …
- No statistically significant sensor change
  (excessive solar measurement can cause sensor degradation)
Are orbiting UV sensors destined to degrade?

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Response Change (per 10 yr @ 300 nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOMS Nimbus 7 (10 yr)</td>
<td>~0%</td>
</tr>
<tr>
<td>TOMS Meteor 3 (3.3 yr)</td>
<td>60%</td>
</tr>
<tr>
<td>TOMS Earth Probe (10 yr)</td>
<td>90%</td>
</tr>
<tr>
<td>TOMS ADEOS (0.75 yr)</td>
<td>100%</td>
</tr>
<tr>
<td>GOME (4.4 yr)</td>
<td>~90%</td>
</tr>
<tr>
<td>SCIAMACHY (3 yr)</td>
<td>~30%</td>
</tr>
<tr>
<td>GOME-2 Metop A (4 yr)</td>
<td>~80%</td>
</tr>
</tbody>
</table>

Many factors contribute to degradation… including contaminants on front optics and detector.
Silicon detector radiation damage

Temperature stability as important as low temperature

Fraction of Pixels Damaged = \(1 - e^{-t/t_0}\)

<table>
<thead>
<tr>
<th>OMPS</th>
<th>(T_{\text{CCD}})</th>
<th>1/e time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nadir Mapper</td>
<td>-30</td>
<td>17.0 months</td>
</tr>
<tr>
<td>Nadir Profiler</td>
<td>-45</td>
<td>15.2 months</td>
</tr>
<tr>
<td>Limb</td>
<td>-45</td>
<td>16.3 months</td>
</tr>
</tbody>
</table>

\(T_{\text{CCD}} = -30^\circ\text{C}\)

\(T_{\text{CCD}} = -45^\circ\text{C}\)
Cold detectors force design considerations

- Detector is cold trap for contaminants when it’s colder than instrument
- Tends to form ice in laboratory and on-orbit

<table>
<thead>
<tr>
<th>Calibrate in air with warm detector</th>
<th>Calibrate in vacuum</th>
<th>Calibrate in air with sealed detector (OMPS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• High noise levels</td>
<td>• Cold detector</td>
<td>• Cold detector - Warm window</td>
</tr>
<tr>
<td>• Longer testing</td>
<td>• Cold instrument</td>
<td>• Warm instrument</td>
</tr>
<tr>
<td>• Violates “test as you fly”</td>
<td>• Expensive testing</td>
<td>• Expensive focal plane pkg.</td>
</tr>
</tbody>
</table>

Can satellite sensors be accurately calibrated in air?

OMPS Focal Plane Package
OMPS stray light is manageable

Nadir Profiler

OMPS stray light is manageable

Nadir Mapper

Stray light model is the basis for data correction

Detector window ghost can be mitigated through optical design
Indications are that albedo calibrations do not change between air and vacuum.

Albedo calibration is insensitive to wavelength shifts.

Coated fold mirror was used at 45°.
Temperature tests on JPSS-1 OMPS

Ground-to-orbit temperature change of SNPP OMPS

OMPS JPSS1 Albedo Calibration Changes From 18.90°C To -6.49°C Aug 2013

Cause of the 1% calibration change is not yet understood
Matchup comparisons between SNPP OMPS and Aura MLS

OMPS and MLS Normalized Radiance Matchup for 09/2013

( latitudes = -20.0° to +20.0° // nMatchups = 56 )

λ shift
Surface Reflectivity Error

Nadir Profiler is most difficult to calibrate accurately
Lack of thermal stability leads to wavelength shifts

Shifts are correlated with temperature until point in the orbit where sunlight strikes the instrument.

OMPS would benefit from active temperature control of optical bench.
Main Lessons Learned

- Calibration at ambient temperature and pressure is accurate
  - improved by, but not dependent upon, a sealed detector
  - “test as you fly” requirements can be applied selectively

- It’s possible to build and fly UV instruments with low degradation
  - low degradation improves long-term calibration accuracy
  - limiting solar measurements is an important component

- Thermal control should be standard equipment
  - wavelength shifts cause many downstream problems
  - optics temperature should remain constant from lab. to orbit (i.e. “fly as you test”)