Results from a new approach for albedo calibration on OMPS

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Nadir sensor: Total Column (TC) spectrometer & Nadir Profiler (NP) spectrometer

Limb profiler (LP) sensor

Main electronics box (MEB)
OMPS measurements

- **Backscattered or scattered radiances**
  - Nadir sensor views back-scattered solar light from Earth’s atmosphere
  - Limb sensor views solar light scattered by Earth’s limb
- **Measures ratio of Earth radiance to solar irradiance**
- **Working (reference) diffusers**
  for weekly (semi-annual) solar calibration
- **Albedo requirements**
  2% λ-independent
  0.5% λ-dependent
Ozone Mapping and Profiler Suite

Calibration design schematic

General Characterization
(Occurs Frequently)

- Spectral scale
- Spectral response
- Linearity
- Dark Current
- Offset

Goniometric characterization

Relative sensor irradiance response variation with angle

Irradiance calibration

Calibrated sensor response for all diffusers at all positions with known irradiance source

Radiance calibration

Calibrated sensor response to various known radiance sources

Pre-Launch Database

Albedo

$k_i$, $k_r$, $K$
Heritage vs new calibration methods

- Heritage OMPS calibration program relied on calibrating the absolute radiance and irradiance response of the sensors
  - Derive albedo calibration from the ratio of absolute calibrations
- Desire to measure and characterize the sensor albedo directly
  - Eliminate test uncertainties and calibration transfers.
  - Leverage geometrical relations in the test setup to negate the need for a source known absolutely.
Experimental setup

- **Measure radiance and irradiance in close succession**
  - Same test setup
  - Same light source
  - Same lamp strike for radiance and irradiance on both diffusers
- **Use a ‘sun-like’ source, leverage test setup geometry**
  - Source terms cancel in ratio
  - Source has ~1 to ~2.25 degree FOV
Albedo measurement

- **Radiance Method**
  \[ Q^r(j, k) = L_{sphere}s^r(j, k) \]

- **Irradiance Method**
  \[ Q^i(j, k) = E_{sphere}g(\theta, \varphi)s^i(j, k) \]

- **Walker equation**
  \[ E_{sphere} = \frac{\pi r_1^2}{d^2 + r_1^2 + r_2^2} L_{sphere} \]
  
  \[ K = \frac{s^i}{s^r} = \frac{Q^i(j, k)}{Q^r(j, k)} \frac{d^2 + r_1^2 + r_2^2}{g(\theta, \varphi)\pi r_1^2} \]

Signal on CCD equals light from sphere times the radiance sensitivity of the sensor

Signal on CCD equals light from sphere times goniometry times the irradiance sensitivity of the sensor

\( d \) is distance to sphere, \( r_1 \) is sphere aperture, \( r_2 \) is detector aperture

OMPS albedo calibration

- Ideally we can use the Walker equation to eliminate source term
- Irradiance and albedo calibrations project view of flight diffuser normal to the sensor aperture
  - Accounts for pixel foreshortening
  - BRDF/BTDF of the diffuser inherent to the calibration
- Practically the test setups deviate from the ideal
  - Diffusers off-axis and viewed at angles
- Must carefully consider test geometry
  - Use numerical integral for corrections
  - Take data at multiple distances to check for systematics
  - Take data with multiple apertures to check for systematics
Correction factors

• Predict offset factor from Walker equation due to off-axis source and tilted/rotated diffuser using numerical integration

• Compare to predicted Walker albedo

• Must consider goniometric effects

<table>
<thead>
<tr>
<th></th>
<th>Near</th>
<th>Middle</th>
<th>Far</th>
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</thead>
<tbody>
<tr>
<td>NP/TC small</td>
<td>0.994</td>
<td>0.996</td>
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<tr>
<td>NP/TC large</td>
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<tr>
<td>Limb HG</td>
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<tr>
<td>Limb LG</td>
<td>1.009</td>
<td>1.007</td>
<td>1.005</td>
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Representative images

TC | NP | Limb

Irradiance

Radiance

λ

Low gain

High gain
Test setup verification

- **Two verification steps**
  - Radiance is constant, ratios of radiance images at different distances should yield unity. Deviations indicate issue with straylight or test setup.
  - Irradiance scales with Walker equation. Deviations indicate issue with test setup and can be used to adjust parameters within reason.
Test setup verification

- **Two verification steps**
  - Radiance is constant, ratios of radiance images at different distances should yield unity. Deviations indicate issue with straylight or test setup.
  - Irradiance scales with Walker equation. Deviations indicate issue with test setup and can be used to adjust parameters within reason.
• Central 6° FOV calibrated with the albedo measurement
  – Variability less than 0.4%
Results: Limb

- Full FOV of all apertures calibrated with the albedo measurement
Results: Limb

- Variability less than 0.5% on all apertures except in areas of very low signal or high spectral gradients (UV channels are dim, steep gradient at 1000nm/1μm⁻¹).
Summary

- Ball Aerospace derived a dedicated test setup and procedure to measure the OMPS albedo calibration coefficient.
- Minimize sensor changes, eliminate non-common test setups.
- Results demonstrate less than 0.5% variability for majority of wavelengths on both Limb and Nadir sensor.
- Albedo requirements met for both sensors.

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