MODIS and VIIRS Calibration Inter-comparison Using Vicarious Approaches

MCST/VCST

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• Introduction

• Methodology
  - SNO & PICS (desert, DCC, Dome C, ocean buoys)
  - Comparison of reflectance and brightness temp (BT)

• Results
  - Terra & Aqua MODIS
  - SNPP & NOAA20 VIIRS
  - NOAA20 VIIRS & Aqua MODIS

• Summary
## VIIRS and MODIS

<table>
<thead>
<tr>
<th>VIIRS RSB</th>
<th>MODIS RSB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band</td>
<td>CW (nm)</td>
</tr>
<tr>
<td>M1</td>
<td>412</td>
</tr>
<tr>
<td>M2</td>
<td>445</td>
</tr>
<tr>
<td>M3</td>
<td>488</td>
</tr>
<tr>
<td>M4</td>
<td>555</td>
</tr>
<tr>
<td>M5</td>
<td>672</td>
</tr>
<tr>
<td>M6</td>
<td>746</td>
</tr>
<tr>
<td>M7</td>
<td>865</td>
</tr>
<tr>
<td>M8</td>
<td>1240</td>
</tr>
<tr>
<td>M9</td>
<td>1378</td>
</tr>
<tr>
<td>M10</td>
<td>1610</td>
</tr>
<tr>
<td>M11</td>
<td>2250</td>
</tr>
<tr>
<td>I1</td>
<td>640</td>
</tr>
<tr>
<td>I2</td>
<td>865</td>
</tr>
<tr>
<td>I3</td>
<td>1610</td>
</tr>
</tbody>
</table>

### NOAA-20/SNPP VIIRS
- Scanning radiometer
- 22 bands between 0.4 and 12 µm
- Afternoon polar orbit
- Swath distance of 3000 km
- Nadir resolutions: 0.375, 0.750 km
- Aggregation, dual-gain

### Terra/Aqua MODIS
- Scanning radiometer
- 36 bands between 0.4 and 14 µm
- Morning/afternoon polar orbits
- Swath distance of 2330 km
- Nadir resolutions: 0.25, 0.5, 1.0 km
- Launched Dec 18, 1999 & May 4, 2002
For RSB inter-comparison, RSR correction is necessary between NOAA20 and SNPP VIIRS and between VIIRS and MODIS.

Correction is based on historic SCIAMACHY hyper-spectral measurements over typical surfaces (ocean, desert, snow and clouds), provided by the European Space Agency.
For TEB inter-comparison, high quality RSR correction can be achieved based on IASI and CrIS using SNO.
SNO (Simultaneous Nadir Overpasses)

- Ratio approach between two sensors (VIIRS & MODIS)
- Significantly reduces impacts of viewing and illumination angle differences and changing surface (< 30s)
- Different locations in high latitude
- Both RSB & TEB

Pixel by pixel match, no rsr corr

Mean Difference: 0.49%  STD: 0.69%

VIIRS I1 vs MODIS band 1 (0.65 um)
Pseudo Invariant Calibration Sites (PICS) over Desert

- Typical target area of 20 x 20 km
- Excellent radiometric stability for RSB
- Repeatable orbits (every 16 days) maintain constant viewing angles to each site
- Need site-dependent BRDF correction (Roujean et al. 1992) to reduce seasonal fluctuations.

**Graphs:**

1. **MODIS band 1 (0.65 um), nadir**
   - Observed refl/BRDF over CEOS Desert Sites
   - Total drift: -0.34%
   - STDerr: 1.05%

2. **VIIRS M1 (0.41 um), nadir**
   - Observed refl/BRDF over Desert Sites
   - Total drift: -0.80%
   - STDerr: 0.95%
Pseudo Invariant Calibration Sites (PICS) over DCC

- Variable locations over tropical region
- Brightest EV target with excellent radiometric stability
- Abundant but need monthly PDFs to derive the mean and mode
- Band-dependent BRDF correction to reduce seasonal fluctuations.
- Saturation for some MODIS RSB

**MODIS band 1 (0.65 um), nadir**

Min: 0.976  Max: 1.014  Sigma: 0.00668856 (0.669%)  Trend: -0.00342 (-0.342%)

**VIIRS M1 (0.41 um), nadir**

Min: 0.975  Max: 1.017  Sigma: 0.00925846 (0.928%)  Trend: 0.00056 (0.056%)
Pseudo Invariant Calibration Sites (PICS) over Dome C

- Typical target area of 20 x 20 km
- Excellent radiometric stability and less atmospheric influence
- RSB data available in Dome C summer
- Large residual after BRDF correction
- Near-surface AWS available for TEB

MODIS band 1 (0.65 um), nadir

Total drift: 0.24%  STDerr: 2.22%
SNO and Dome C (ocean buoys) for TEB

- For SNO, a temperature difference, $\Delta T$, is used by subtracting the simulated $T$ using IASI & CrIs.
- For Dome C or ocean buoy sites, a temperature difference, $\Delta T$, is determined by subtracting the measured coincident $T$ at site.

Less Aqua/IASI data point match
Sensor inter-comparison is based on vicarious approaches (SNO, Desert, no RSR correction).

- SNO approach based on double difference relative to reference sensor (Aqua MODIS or SNPP VIIRS).
- PICS approach based on site-specific BRDF (MODIS or VIIRS).

Close F factors for I2 between SIPS and IDPS.
MODIS and VIIRS Inter-Comparison for TEB

- Sensor Inter-comparison is based a double difference in $\Delta T$
- For TEB, the differences are dependent on radiance level

**VIIRS and IASI SNO**

**M15-B31**
- SNPP
- N20

**M16-B32**
- I5-B31
- I5-B32

**Graph:**
- **Dome C**
- $\Delta T$ (SNPP) – $\Delta T$ (Aqua)
- Diff = -0.12K
## Terra and Aqua MODIS RSB and TEB Inter-Comparison

<table>
<thead>
<tr>
<th>Method</th>
<th>RSB (%)</th>
<th>TEB (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B1</td>
<td>B2</td>
</tr>
<tr>
<td>SNO</td>
<td>-1.1</td>
<td>-0.7</td>
</tr>
<tr>
<td>Desert</td>
<td>-0.7</td>
<td>0.8</td>
</tr>
<tr>
<td>Dome C</td>
<td>-0.8</td>
<td>0.6</td>
</tr>
<tr>
<td>Ocean</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Results are provided in percentage difference (Terra – Aqua) (%) for RSB and in Kelvin (K) for TEB, mainly L1B data after 2012.

RSR correction in SNO is based on IASI for TEB and no RSR correction is applied for RSB.
### NOAA20 and SNPP VIIRS TEB Inter-Comparison

<table>
<thead>
<tr>
<th>Method</th>
<th>TEB (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M13</td>
</tr>
<tr>
<td>SNO</td>
<td>-0.12</td>
</tr>
<tr>
<td>Dome C</td>
<td>0.15</td>
</tr>
<tr>
<td>Ocean</td>
<td>-0.01</td>
</tr>
</tbody>
</table>

*Results are provided in percentage difference (NOAA20 – SNPP) in Kelvin (K) for TEB RSR correction is based on CrIs/IASI for TEB in SNO*
<table>
<thead>
<tr>
<th>Method</th>
<th>M1 B8</th>
<th>M2 B9</th>
<th>M4 B4</th>
<th>M7 B2</th>
<th>I1 B1</th>
<th>I2 B2</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNO</td>
<td>-2.6 ± 1.3</td>
<td>-3.5 ± 1.1</td>
<td>-2.6 ± 0.5</td>
<td>-3.1 ± 0.9</td>
<td>-2.8 ± 0.6</td>
<td>-3.1 ± 0.9</td>
</tr>
<tr>
<td>Desert</td>
<td>-4.8 ± 0.7</td>
<td>-5.7 ± 0.6</td>
<td>-2.5 ± 0.9</td>
<td>-0.7 ± 0.5</td>
<td>-3.5 ± 0.6</td>
<td>-0.8 ± 0.5</td>
</tr>
<tr>
<td>Dome C</td>
<td>-4.6 ± 0.6</td>
<td>-1.6 ± 2.3</td>
<td>-0.4 ± 1.8</td>
<td>-1.9 ± 2.1</td>
<td>-0.9 ± 1.9</td>
<td></td>
</tr>
</tbody>
</table>

*Results are provided in percentage difference (NOAA20 – Aqua) (%) for RSB. RSR correction is based on SCIAMACHY for RSB.*
Summary

- This study provides assessment of MODIS and VIIRS calibration inter-comparison for both RSB and TEB using various vicarious approaches (SNO, desert, Dome C and ocean buoys).

- For VIS/NIR bands, Terra and Aqua MODIS are consistent within 1.5%. In the case between NOAA-20/SNPP and Aqua, Aqua is between NOAA-20 and SNPP, and NOAA-20 is 1.0~3.0% lower depending on wavelength. For SNPP, additional differences up to 3.0% exist between IDPS and SIPS L1B product.

- For atmospheric window bands, agreement among Terra/Aqua MODIS and SNPP VIIRS is within 0.10 K (typical scenes). Small negative biases (~0.10K) are observed for NOAA20 compared with SNPP using IASI or CrIS.