Results from a cross-calibration experiment

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Published in:
Nieke, J., et al., A satellite cross-calibration experiment,

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General Approach

1. CalVal site 2 x 2 km² located near Barrow, Alaska
2. Ground-truth data: aerosol optical thickness (AOT), snow reflectance measurements etc.
3. Macro site (6 x 6 km²) was used for uniformity check
4. GLI, MERIS, AATSR, SeaWiFS, MODIS (terra, aqua) and AVHRR (N16/17) TOA radiance/reflectance data were taken
5. Sensor TOA radiance/reflectance were compared to Radiative Transfer Code 6S* calculations
Advantages of snow fields in the polar region

- Semi-Simultaneous measurements of polar orbiting satellites
- Minimum correction for atmospheric effects
- Near Lambertian properties of New-Snow
- Same reflectance properties over a large region
- Dry and sunny condition periods in Spring/Autumn
- New-Snow conditions over longer period
Selected Site:

**CalVal site** is located in the North-East of Barrow. 
**CalVal site's** TOA sensor data was chosen.

**Macro site** signal was used to make uniformity check.
GLI Snow products around Barrow

Date: April 14

RGB

Cloud flag

BT 11μm

Skycamera

April 26
Barrow observatory (CMDL/NOAA):

Photo from a different day, taken by Bob Stone, Climate Monitoring & Diagnostics Laboratory /NOAA
Spectral BRDF

Spectral albedo

FTIR

Whole sky image
Data Flow Chart for Inter-satellite Comparison

Radiative Modeling

- Radiative Transfer Code (modified 6S):
  - gli.f
  - meris.f
  - seawifs.f
  - avhrr3.f
  - thuillier.f
  - ....

- Ground Truth:
  - AOT, Snow Albedo, Atm. Conditions

Geo. Information:
- for MERIS, AVHRR (N15-17), SeaWiFS, Modis (T&A), GLI...
- SunAz, SunZ, SatAz, SatZ

TOA radiance

- RT output
- Sensor output
- 14/26 Apr. 2003

- GLI L1B
- AVHRR LAC L1b
- MOD021KM MYD021KM

Sensor TOA relative to modeled TOA assuming same atmospheric conditions
The following satellite data sets were used:

<table>
<thead>
<tr>
<th>Satellite Data</th>
<th>from</th>
<th>14th</th>
<th>26th</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLI</td>
<td>2003</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>MERIS</td>
<td></td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>AATSR</td>
<td></td>
<td>☑</td>
<td></td>
</tr>
<tr>
<td>SeaWiFS</td>
<td></td>
<td>☑</td>
<td></td>
</tr>
<tr>
<td>AVHRR N16,N17</td>
<td></td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>MODIS terra</td>
<td></td>
<td>2x</td>
<td></td>
</tr>
<tr>
<td>MODIS aqua</td>
<td></td>
<td>☑</td>
<td>☑</td>
</tr>
</tbody>
</table>

| April 14       |      |      |      |
| N16            | NSS.HRPT.NL.D03104.S2227.E2241.B1319797.GC |
| GLI            | A2GL10304145709OD2_PV1B0000000.00 |
| SeaWiFS        | S2003104225757.L1A_HUAF |
| MERIS          | MER_RR__20030414_230804_000001972015_00302_05867_0855.N1 |
| MODIS_A        | GSUB1.A2003104.2250.20031600445561683033 |
| AHVRR          | NSS.HRPT.NM.D03104.S2327.E2340.B0418585.GC |

| April 26       |      |      |      |
| MODIS_T        | GSUB1.A2003116.2140.20031541816431250125 |
| MERIS          | MER_RR__1POLRA20030426_215033_000001972015_00473_06038_0513.N1 |
| AATSR          | ATS_TOA_1COLRA20030426_215130_000000862015_00472_06037_0444.N1 |
| MODIS_A        | GSUB1.A2003116.2155.20031541816521250125 |
| GLI            | A2GL10304265709OD2_PV1B0000000.00 |
| MODIS_T        | GSUB1.A2003116.2315.20031541816391250125 |
**Spectral Response Functions**

Spectr. respon. func. in UV-VIS: GLI (cha. 1−9), SeaWiFS (cha.: 1−5), MERIS (cha.: 1−5), AATSR (cha.: 1)

Spectr. respon. func. in NIR: GLI (cha. 10−19), SeaWiFS (cha.: 6−8), MERIS (cha.: 6−15), AATSR (cha.: 2,3)

RSP interpolated to 6S
2.5-nm-spectral intervals

GLI (green)
MERIS (red)
SeaWiFS (black)
Selected Overflights April 14th 2003

<table>
<thead>
<tr>
<th>GMT</th>
<th>Satellite</th>
<th>sensors</th>
<th>SunAZ</th>
<th>SatAZ</th>
<th>SunZ</th>
<th>SatZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>22:35:46</td>
<td>N16</td>
<td>AHVRR</td>
<td>182.59</td>
<td>152.96</td>
<td>61.80</td>
<td>0.78</td>
</tr>
<tr>
<td>22:54:11</td>
<td>Terra</td>
<td>MODIS</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>22:57:46</td>
<td>ADEOS-2</td>
<td>GLI</td>
<td>188.68</td>
<td>242.36</td>
<td>61.97</td>
<td>24.09</td>
</tr>
<tr>
<td>23:01:00</td>
<td>Orbview</td>
<td>SeaWiFS</td>
<td>189.89</td>
<td>122.42</td>
<td>62.03</td>
<td>49.47</td>
</tr>
<tr>
<td>23:08:00</td>
<td>ENVISAT</td>
<td>MERIS</td>
<td>191.76</td>
<td>312.13</td>
<td>62.13</td>
<td>31.37</td>
</tr>
<tr>
<td>23:09:00</td>
<td>Aqua</td>
<td>MODIS</td>
<td>192.02</td>
<td>255.86</td>
<td>62.14</td>
<td>34.58</td>
</tr>
<tr>
<td>23:33:00</td>
<td>N17</td>
<td>AHVRR</td>
<td>198.66</td>
<td>314.07</td>
<td>62.61</td>
<td>33.62</td>
</tr>
</tbody>
</table>
TOA radiance (L1B data) April 14th

L1B radiance [W/m^2/sr/um]

wavelength [nm]
Deviation for the April 14th (L1B/Ground-truth)

Nieke et al.

Workshop on Inter-Comparison of Large Scale Optical and Infrared Sensors, ESA/ESTEC, 12/14-Oct-04
Selected Overflights 26 April 2003

<table>
<thead>
<tr>
<th>GMT</th>
<th>Satellite</th>
<th>Sensors</th>
<th>SunAZ</th>
<th>SatAZ</th>
<th>SunZ</th>
<th>SatZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>21:41:00</td>
<td>Terra</td>
<td>MODIS</td>
<td>167.68</td>
<td>103.16</td>
<td>58.08</td>
<td>36.75</td>
</tr>
<tr>
<td>21:52:00</td>
<td>ENVISAT</td>
<td>MERIS</td>
<td>170.79</td>
<td>114.12</td>
<td>57.91</td>
<td>12.42</td>
</tr>
<tr>
<td>21:56:00</td>
<td>Aqua</td>
<td>MODIS</td>
<td>171.93</td>
<td>59.63</td>
<td>57.86</td>
<td>15.00</td>
</tr>
<tr>
<td>22:57:38</td>
<td>ADEOS-2</td>
<td>GLI</td>
<td>189.78</td>
<td>242.52</td>
<td>57.92</td>
<td>24.13</td>
</tr>
<tr>
<td>23:00:00</td>
<td>Orbview</td>
<td>SeaWiFS</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>23:19:00</td>
<td>Terra</td>
<td>MODIS</td>
<td>195.83</td>
<td>305.94</td>
<td>58.29</td>
<td>27.17</td>
</tr>
</tbody>
</table>
Deviation for the April 26\textsuperscript{th} 2003
(L1B/Ground\textunderscore truth)
Error analysis for a single inter-comparison

<table>
<thead>
<tr>
<th>Sources</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite sensor absolute calibration</td>
<td>5</td>
</tr>
<tr>
<td><strong>Measurement accuracy</strong></td>
<td>1-3</td>
</tr>
<tr>
<td>- uniformity of the site</td>
<td></td>
</tr>
<tr>
<td>- positioning accuracy, georef accuracy</td>
<td></td>
</tr>
<tr>
<td><strong>Atmospheric modeling</strong></td>
<td>3</td>
</tr>
<tr>
<td>- change of atmospheric conditions</td>
<td></td>
</tr>
<tr>
<td>- atmospheric characterisation</td>
<td></td>
</tr>
<tr>
<td>- correction for viewing angle differences</td>
<td></td>
</tr>
<tr>
<td>- differences in spectr. response funct.</td>
<td></td>
</tr>
<tr>
<td><strong>Total error (RMS)</strong></td>
<td>5-6.6</td>
</tr>
</tbody>
</table>

The error budget of single event comparison is high at about 5-7%, however, the following tendency becomes “interesting”
Deviation for April 14 and 26\textsuperscript{th} 2003
(L1B/Ground\_truth)
Results agree well with other GLI cal-methods!
Conclusion

- All analyzed space sensors have similar radiometric performance within 6-7%.
- GLI pre-launch calibration agrees well with cross-cal. results in the VNIR.
- However GLI seems to underestimate the snow target in the UV/blue.
- Comparison results for GLI fit well with other GLI calibration methods.

We would like to acknowledge

NASA (DAAC, SeaWiFS project), NOAA (SAA), ESA & Brockmann, Aeronet/ARM site, C.R. McClain (SeaDAS code) and E. Vermote (6S code)

for the production and distribution of data and codes used in this investigation.
6S input data

- **AOT data**
  - AOT @ 550 nm
    - 14\textsuperscript{th}: 0.0263
    - 26\textsuperscript{th}: 0.235

- **Atmosphere profile**
  - H2O:
    - 14\textsuperscript{th}: 0.6
    - 26\textsuperscript{th}: 0.68 cm
  - O3:
    - 14\textsuperscript{th}: 450
    - 26\textsuperscript{th}: 400 DU

- **Aerosol type (typical)**
  - dust-like components:
    - 14\textsuperscript{th}: 2.85
    - 26\textsuperscript{th}: 2.85 %
  - water-soluble components:
    - 14\textsuperscript{th}: 70
    - 26\textsuperscript{th}: 70 %
  - oceanic components:
    - 14\textsuperscript{th}: 12.85
    - 26\textsuperscript{th}: 12.85 %
  - soot components:
    - 14\textsuperscript{th}: 14.3
    - 26\textsuperscript{th}: 14.3 %

- **Snow site reflectance**

- **Assumptions:**
  - Atmosphere (AOT, type, H\textsubscript{2}O, O\textsubscript{3}) and snow reflectance are constant, each period
  - Cirrus layer (non-visible) at TOA for April 26\textsuperscript{th} (2000m from ARM MPL)
  - Aerosol component for both days is “typical polar aerosol type” at Barrow