In Flight Validation of MODIS and VIIRS Mid and Thermal Infrared Emissive Bands at Lake Tahoe and Salton Sea CA/NV USA

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**Methodology:**

- 4 buoys on large, high lake, each buoy is 1 km from shore and nearest buoy.
- Each buoy has custom thermal infrared radiometer operating 24x7 and associated meteorological measurements.
- Extract skin temperature from radiometer at time of overpass and propagate to top of atmosphere with radiative transfer model.
- Convolve to instrument system response functions and compare to satellite instrument measured value.

**Vicarious at Lake Tahoe, CA/NV USA**

Custom radiometer calibrated to NIST-traceable blackbody

3 m buoy operating 24x7 since 1999

Large 35 km x 16 km
High 2 km
Available year round (does not freeze in winter).
Homogenous compared with land.
Large annual temperature range 5-25 C.
Freshwater (kind to instruments!)
Good infrastructure and easy access.
Methodology:

- A mounted platform due to high salinity.
- The site has two custom thermal infrared radiometers operating 24x7 and associated meteorological measurements.
- Extract skin temperature from radiometer at time of overpass and propagate to top of atmosphere with radiative transfer model.
- Convolve to instrument system response functions and compare to satellite instrument measured value.

Custom radiometer calibrated to NIST-traceable blackbody

Vicarious at Salton Sea, CA USA

3 m buoy operating 24x7 since 2008

Large 60 km x 20 km Low elevation -71 m Available year round (does not freeze in winter). Homogenous compared with land. Large annual temperature range ~4-35 C. Good infrastructure and easy access.
Terra-MODIS - Results

MODIS Terra Vicarious and OBC Thermal Infrared Derived Radiances at Lake Tahoe and Salton Sea CY2000-2018, v6.x

MODIS-Terra – Calibration problem with Band 29.
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Delta Brightness Temperature in TIR Channels for MODIS Terra at Lake Tahoe and Salton Sea CY2000-2018, vz0-30 v5.x

Band 31: 11.01 μm 1% radiance change ≈ 0.65K
MODIS-Terra – MIR bands are consistently slightly hot.
MODIS-Terra – MIR bands are consistently slightly hot.
Aqua-MODIS - Results

MODIS Aqua Vicarious and OBC Thermal Infrared Derived Radiances at Lake Tahoe and Salton Sea CY2000-2018, v6.x

MODIS Aqua - Excellent calibration.
MODIS-Aqua – Band 32 is slightly cold.
MODIS-Aqua – MIR bands are consistently slightly hot.
MODIS-Aqua – MIR bands are consistently slightly hot.
Bands closely follow 1-1 line.
Delta BT between Vicarious and Observed TIR Channels for NPP VIIRS at Lake Tahoe and Salton Sea  By Year VZ 0-30

<table>
<thead>
<tr>
<th>Year</th>
<th>M14 (8.55 µm)</th>
<th>M15 (10.763 µm)</th>
<th>M16 (12.013 µm)</th>
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</thead>
<tbody>
<tr>
<td>2012</td>
<td>0.25</td>
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<tr>
<td>2013</td>
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<tr>
<td>2017</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>2018</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>All Years</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
</tbody>
</table>

VIIRS – excellent calibration so far.
MIR bands also follow 1-1 line.
Delta BT between Vicarious and Observed in MIR Channels for VIIRS at Lake Tahoe and Salton Sea Nighttime, vz0-30

Delta (O-V) Brightness Temperature (K)

2012 2013 2014 2015 2016 2017 2018 All Years

M12 (3.7 µm) M13 (4.05 µm)
Delta Brightness Temperature in TIR Channels for MODIS Terra at Lake Tahoe and Salton Sea CY2000-2018, vz0-30 v6.x

Band 31: 11.01 μm 1% radiance change ≈ 0.65K

Delta (V-O) Brightness Temperature in TIR Channels for MODIS Terra at Lake Tahoe and Salton Sea CY2000-2018, vz0-30 v6.x

- Band 31: 11.01 μm 1% radiance change ≈ 0.65K
Summary and Conclusions

• Established an automated site for validating thermal infrared data at Lake Tahoe CA/NV. Site has been operating since 1999.
• Measurements made at the site include skin- bulk- air- temperature, wind speed, wind direction and net radiation at multiple locations every 2 minutes. Multiple locations (4 buoys) allow validation of several points within a scene.
• Second site added at Salton Sea in 2008 to enable validation at high water temperatures (~35 C).
• Validated data from multiple instruments including, AATSR, ASTER, MODIS (Terra, Aqua), Landsat 5 and Landsat ETM+, MTI and now VIIRS
• Results:
  – MODIS-Terra at-sensor radiance: TIR bands 31 and 32 no bias, abs. acc. ± 0.3K
    • Gain change in band 29 starting in 2009
  – MODIS-Aqua at-sensor radiance: TIR, no bias, abs. acc. ± 0.3K
  – NPP-VIIRS at-sensor radiance: TIR, no bias, abs. acc. ± 0.3K
  – MODIS-Terra at-sensor radiance: MIR, small bias 0.25-0.5 K
    • MODIS Terra MIR is slightly hot!
  – MODIS-Aqua at-sensor radiance: MIR, small bias 0.25-0.5 K
    • MODIS Aqua MIR is slightly hot!
  – NPP-VIIRS at-sensor radiance: MIR, no bias abs. acc. ± 0.2K
• NPP-VIIRS compares well with Aqua-MODIS and is slightly better than Terra-MODIS.