In-Flight Validation of Mid and Thermal Infrared Remotely Sensed Data from MODIS (Terra and Aqua) Using the Lake Tahoe and Salton Sea Automated Validation Sites

Simon J. Hook et al.
Email: simon.j.hook@jpl.nasa.gov

Outline

• Introduction
• Location
• Measurements and Calibration
• Data Reduction Methodology
• Results from various sensors
  – MODIS
• Summary and Conclusions
• Future Work
Global satellite-derived seasonal (July, August, September (JAS) and January, February, March (JFM)) nighttime lake surface temperature trends between 1985 and 2009

From Schneider and Hook, 2010
Orbit: 705 km, 10:30 a.m. descending node (AM-1) or 1:30 p.m. ascending node (PM-1), sun-synchronous, near-polar, circular. Swath dimensions: 2330 km (cross track) by 10 km (along track at nadir). Spatial Resolution 250 m (bands 1-2), 500 m (bands 3-7) 1000 m (bands 8-36).

<table>
<thead>
<tr>
<th>Application</th>
<th>Band</th>
<th>Bandwidth (nm)</th>
<th>SNR</th>
<th>Application</th>
<th>Band</th>
<th>Bandwidth (um)</th>
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<tr>
<td><strong>Land/Cloud Boundaries</strong></td>
<td>1</td>
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<td><strong>Surface/Cloud Temperature</strong></td>
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</table>
Matchup Count for MODIS Terra at Lake Tahoe and Salton Sea CY2000-2010 v5.x

- **Standard Filter**
  1. Buoy must be within 1 km of the center value.
  2. All 9 values (3x3) must be good quality.
  3. Standard Deviation of Band 31 3x3 must be < 0.2K

![Graph showing matchup count for MODIS Terra at Lake Tahoe and Salton Sea CY2000-2010 v5.x](image-url)
MODIS Terra Vicarious and OBC Thermal Infrared Derived Radiances at Lake Tahoe and Salton Sea CY2000-2010, v5.x

![Graph showing MODIS Terra Vicarious and OBC Thermal Infrared Derived Radiances at Lake Tahoe and Salton Sea CY2000-2010, v5.x](image-url)
MODIS Terra Vicarious and OBC Thermal Infrared Derived Radiances at Lake Tahoe and Salton Sea CY2000-2010, v5.x

- Band 29 (8.53 μm)
- Band 31 (11.01 μm)
- Band 32 (12.03 μm)

1x1 line
Linear (Band 29 (8.53 μm))
Linear (Band 31 (11.01 μm))
Linear (Band 32 (12.03 μm))
% Radiance Change in TIR Channels for MODIS Terra with Mirror AOI at Lake Tahoe and Salton Sea CY2000-2010 v5.x

Avg % Radiance Diff \((v-o)/v\) * 100

Angle of incidence on Mirror

Poly. (b29) Poly. (b31) Poly. (b32)
% Radiance Change in TIR Channels for MODIS Terra with Instrument Zenith at Lake Tahoe and Salton Sea CY2000-2010, v5.x

Band 31: 11.01 μm 1% radiance change ≈ 0.65K
% Radiance Change in TIR Channels for MODIS Terra at Lake Tahoe and Salton Sea CY2000-2010, vz0-30 v5.x

Band 31: 11.01 μm 1% radiance change ≈ 0.65K
MODIS Terra Mid Infrared Channels Delta Temperature between Vicarious and OBC BT's at Lake Tahoe, 2000-2010, v5.x - DAY AND NIGHT
MODIS Terra Mid Infrared Channels Delta Temperature between Vicarious and OBC BT's at Lake Tahoe, 2000-2010, v5.x - NIGHT ONLY
MODIS Terra Night Only Vicarious and OBC Mid Infrared Derived Radiances at Lake Tahoe and Salton Sea CY2000-2010, VZ0-30, v5.x

- Band 20 (3.79 μm)
- Band 22 (3.97 μm)
- Band 23 (4.06 μm)

The graph shows the relationship between vicarious radiance and OBC radiance. The equation for each band is as follows:

- Band 20: $y = 0.9879x + 0.0042$, $R^2 = 0.9955$
- Band 22: $y = 0.9912x + 0.008$, $R^2 = 0.9959$
- Band 23: $y = 0.9884x + 0.0069$, $R^2 = 0.9969$
% Radiance Change in MIR Channels for MODIS Terra at Lake Tahoe and Salton Sea CY2000-2010, vz0-30, v5.x

Avg % Radiance Diff (v_o)/v * 100
Matchup Count for MODIS Aqua at Lake Tahoe and Salton Sea CY2000-2010 v5.x

Number of Matchups

- **All data, cloud and standard filter only**
- **VZ0-30 cloud and std filter**
- **VZ0-30 day only cloud and standard filter**
- **VZ0-30 night only cloud and standard filter**

Standard Filter
1. Buoy must be with 1km of center value
2. All 9 values (3x3) must be good quality
3. Std Dev. Of Band 31 3x3 must be < 0.2K

Year

- 2000
- 2001
- 2002
- 2003
- 2004
- 2005
- 2006
- 2007
- 2008
- 2009
- 2010

Number of Matchups: 1200

- 2000: 0
- 2001: 200
- 2002: 400
- 2003: 600
- 2004: 800
- 2005: 1000
- 2006: 1200
- 2007: 1000
- 2008: 800
- 2009: 600
- 2010: 400
% Radiance Change in TIR Channels for MODIS Aqua at Lake Tahoe and Salton Sea CY2000-2010, vz0-30 v5.x

Band 31: 11.01 μm 1% radiance change \( \approx \) 0.65K

Other MODIS tir bands

b31,32 spec

Other MODIS tir bands

Band 31: 11.01 μm 1% radiance change \( \approx \) 0.65K
% Radiance Change in MIR Channels for MODIS Aqua at Lake Tahoe and Salton Sea CY2000-2010, vz0-30, v5.x
Difference in MIR bands for Terra and Aqua

% Radiance Change in MIR Channels for MODIS Terra at Lake Tahoe and Salton Sea CY2000-2010, vz0-30, v5.x

% Radiance Change in MIR Channels for MODIS Aqua at Lake Tahoe and Salton Sea CY2000-2010, vz0-30, v5.x
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.
• Results so far indicate
  – MODIS-Terra at-sensor radiance: TIR, no bias, abs. acc. 0.2K
    • Suggestion of gain change in band 29 starting in 2008
  – MODIS-Aqua at-sensor radiance: TIR, no bias, abs. acc. 0.2K
  – MODIS-Terra at-sensor radiance: MIR, small bias
  – MODIS-Aqua at-sensor radiance: MIR, no bias, abs. acc. 0.2K
Welcome to Calibration and Validation

The calval website acts as a portal to data from certain field sites used by scientists at JPL for calibration and validation activities related to:

- Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)
- Moderate Resolution Imaging Spectroradiometer (MODIS)
- Landsat (5 and 7)
- Along Track Scanning Radiometers (LTER, ATSR, LTER)
- MODIS/ASTER Airborne Simulator (MASTER)

These activities include the validation of the absolute radiometric calibration of the systems and surface geophysical products derived from the sensor data such as reflectance, temperature and emissivity. The goal is for all the measurements acquired at the validation sites to be made autonomously with the data regularly telemeasured back to JPL and made available over the WWW. Currently there are two sites located at:

Lake Tahoe CA/NV (http://laketahoe.jpl.nasa.gov)
Salton Sea CA (http://saltonsea.jpl.nasa.gov)

The sites have been selected to provide a range of conditions. Together the Lake Tahoe and Salton Sea sites provide water temperatures ranging from 4C-35C.
Why Lake Tahoe?

- 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.
Measurements

• Offshore
  – bulk temperature, skin temperature, air temperature, wind speed, wind direction, relative humidity, net radiation.

• Onshore
  – air temperature, wind speed, wind direction, relative humidity, short and longwave radiation (up and down), sky imager, aerosols, total column water.
Site Layout and Measurement Stations
Data Reduction: Methodology For Radiance at Sensor Validation

- Extract the bulk temperatures.
- Extract the radiometric temperature.
- Correct the radiometric temperature to skin kinetic temperature.
- Propagate the skin temperature to the satellite using a radiative transfer model and interpolated atmospheric profile.
- Convolve the propagated at-sensor radiance to the instrument response function to obtain the Vicarious Radiance (VR).
- Extract the image radiance derived using the On Board calibrator (OBC).
- Compare and contrast the OBC and VR Radiance values.
Skin Effect

After Minnett et al. 2000