Aircraft and Surface Based Assessment of MODIS and ASTER TIR band calibration

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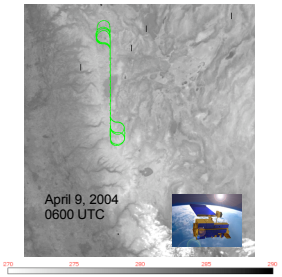
On April 9, 2004, the NASA ER-2 aircraft underflew the Terra satellite at 0602 UTC (nighttime) over Lake Tahoe, CA. The Terra MODIS 3.7 μm imagery with ER-2 aircraft flight pattern (green) overlain shows the ER-2 made a total of eight overpasses of Lake Tahoe as it repeatedly transected the Lake back and forth on a line parallel to the Terra orbital track. The Terra satellite flew by overhead on the 6th transect by the ER-2. The flight also included an overpass by the Landsat 7 satellite about 30 minutes before the Terra satellite.

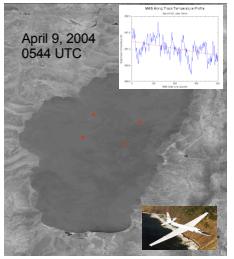


Overview: High altitude based aircraft remote sensing measurements (MASTER, MAS and SHIS) and surface based radiometer measurements were collected at Lake Tahoe on nighttime April 9, 2004 co-incident with a Terra satellite overpass to evaluate the performance of the MODIS and ASTER instruments. The ground and aircraft based observations each provide high quality independent measurements capable of validating TIR band calibration. The ground based radiometers have the advantage of continuous operation and maintenance. The aircraft based observations have the advantage of characterizing the surface and atmospheric column in a single integrated measurement, simulating MODIS and ASTER observations. Results from these two validation approaches are provided to gain new insight on each technique. The aircraft based MAS, SHIS, and MASTER data are also compared to the ground based measurements.

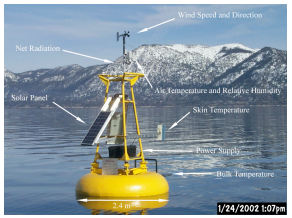
Summary Statements:

1. Good agreement between the surface based and aircraft based assessments for ASTER and MODIS window bands.
2. Demonstrate that ASTER and MODIS thermal bands are performing either within or very near to prelaunch radiometric requirements
3. MASTER and MAS observations agree with surface based measurements within expected accuracy.
4. SHIS calibration accuracy demonstrated, verifying SHIS as a high quality radiometric source for aircraft based validation of satellite instruments.

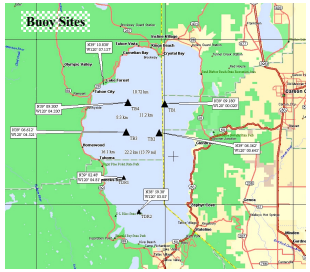
MODIS Airborne Simulator (MAS) 11.0 μm imagery with four surface based radiometer positions on Lake Tahoe shown in red. MAS 50 m resolution data maps the spatial variability of the Lake Tahoe surface temperature. Inset shows the MAS along track profile of Lake Tahoe in the region of the buoys.

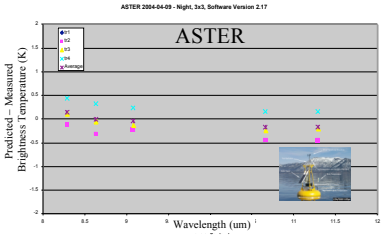


Comparisons to Lake Tahoe Surface-Based Observation Network



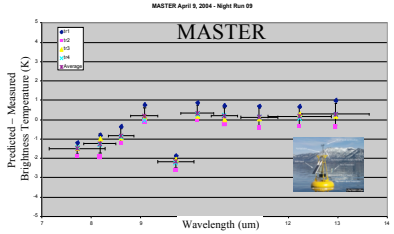
A surface based network of buoy mounted instruments and radiometers has been in place on Lake Tahoe for over 5 years. Four buoys (left) on Lake Tahoe (right) report observations every 2 minutes, 24x7. The nearly continuous reporting of these observations makes it possible to evaluate and validate any satellite (or aircraft) based sensor at anytime over the annual cycle, improving data sample sizes for ensemble averaging and trend line analysis. Data collection includes surface radiometric and bulk temperature, and meteorological status. Surface and atmospheric characterization (from NCEP model output) is used in MODTRAN to produce top-of-atmosphere high spectral resolution radiances, that are convolved with instrument spectral response to simulate broadband radiances for each spectral band.

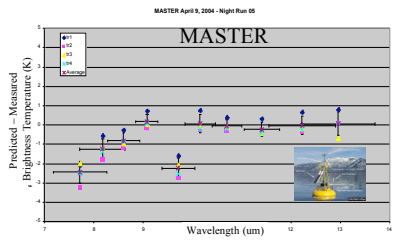




Satellite Instrument Validation (ASTER, MODIS)

The ASTER (above) and MODIS (below) instruments on Terra were also compared directly to the surface network observations. All ASTER thermal bands show close agreement, within 0.3 K on average, with the surface observations. MODIS observations similarly show close agreement, within 0.5 K for the window bands 29, 31, and 32. Atmospheric water vapor (28), ozone (30), and CO2 (33) bands show larger departures. The local NCEP atmospheric profile used in the forward calculation does not account for either ozone or CO2 variations. The default values used in the radiative transfer program do not correctly reflect the local values at the site. Improved values for these gases are available from other sources, e.g. TOMS.



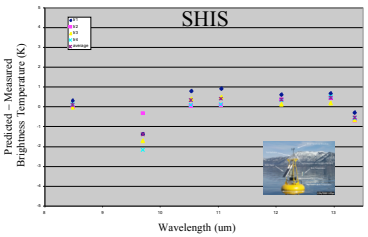


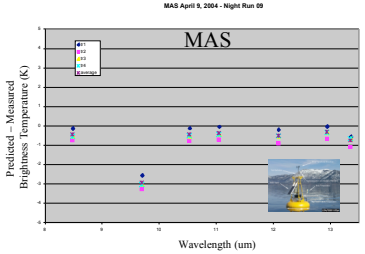
Aircraft Instrument Validation (MASTER, SHIS, MAS)

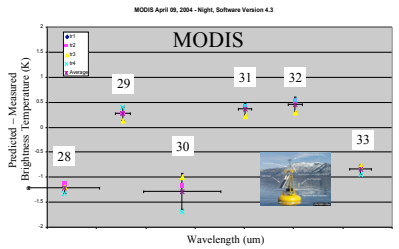
MASTER calibrated data match the surface network observations closely. Two flight lines (left and lower left) demonstrate the typical stable performance of MASTER. Larger offsets below 9 um and at 9.7 um may be due to atmospheric water vapor and ozone error in the NCEP model profile.

SHIS observations match (upper right) to within about 0.25 K with the surface network observations (exception at 9.7 um ozone region). SHIS is a key component of the aircraft based assessment because of its radiometric source accuracy (+/- 0.3 K). The close agreement between SHIS and the surface observations indicates SHIS is an excellent airborne source for satellite instrument validation.

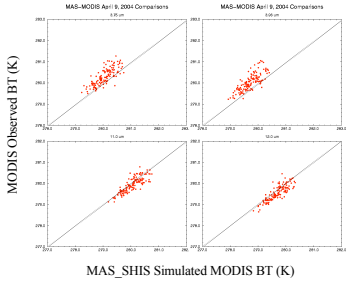
MAS comparisons (right) with the surface network observations show agreement to within about 0.5 K for window bands. MAS calibration uses a flat plate blackbody with accuracy not better than 0.5 K. The 9.7 um ozone band shows a large offset from the surface network observations.







Comparisons to Aircraft-Based Observations



The NASA ER-2 based SHIS and MAS instruments are used together to simulate MODIS observations. This validation approach has the advantage of using downlooking measurements from near the top of the atmosphere much as MODIS does on Terra, integrating the earth-atmosphere system over a swath of about 40 km, mapping spectral and spatial variation. The MAS_SHIS combined simulation of MODIS plotted against MODIS observations (above) shows close agreement. The results summarized below show that MODIS is performing within or very nearly within prelaunch radiometric requirement for most bands, with exception for CO2 sensitive bands 34-36.

These results closely match those of the surface network (left) for window bands (29, 31, 32). Atmospheric bands (e.g. 28, 33) show unresolved departure between the two approaches, again, possibly caused by ozone and CO2 misrepresentation in the forward model (see text in "Satellite Instrument Validation").