Validation of HyspIRI-TIR On Orbit Calibration

Simon J. Hook, William Johnson, Glynn Hulley, Marc Foote, Robert Radocinski

Introduction

- “The great strength of satellites, their overarching view of the planet, is counterbalanced by their great weakness: They are far from the substances (air, land, water) they are trying to measure. Scientifically, the best combination is often to use the satellite and an in situ sensor (one that is in the air or the ocean), with the satellite painting a broad and comprehensive picture and the in situ sensors providing calibration and necessary detail.” - (MacDonald, A. E., The Wild Card in the Climate Change Debate, Issues in Science and Technology Online, 2001.)

- “Scenarios examined in this Assessment, which assume no major interventions to reduce continued growth of world greenhouse gas emissions,indicate that temperatures in the US will rise by about 5-9°F (3-5°C) on average in the next 100 years, which is more than the projected global increase.” - National Assessment Synthesis Team, Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change, 2001

Outline

- Level 1 Validation Framework
- Example results from existing sites
- Lake Tahoe Site: Layout and Measurements
- Salton Sea Site: Layout and Measurements
- Field Instrument Calibration and Cross-Cal.
- Data Reduction Methodology and Error Budgets
- MODIS results
- ASTER results
- Cross Comparison of ASTER, MODIS and other instruments
- Related work
- Publications, Conclusions and Future Plans

Validation Framework

- Multi-Component Approach
- Monitoring of instrument outputs (BB performance etc)
- Cross comparison of HyspIRI radiance with other instruments (airborne and spaceborne, emphasize HyTES)
- Validation against in situ targets (Tahoe and Salton Sea)

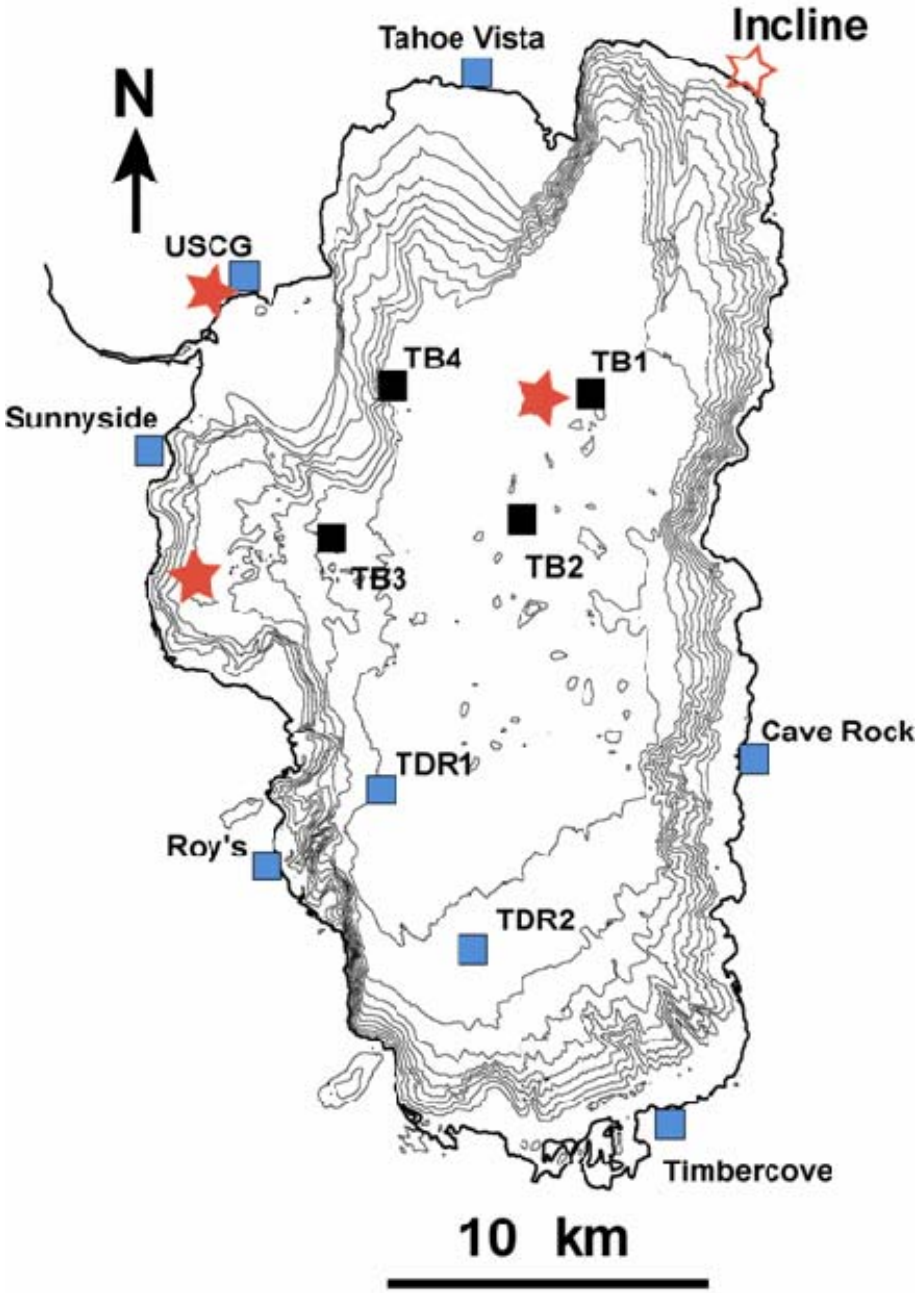
Objectives

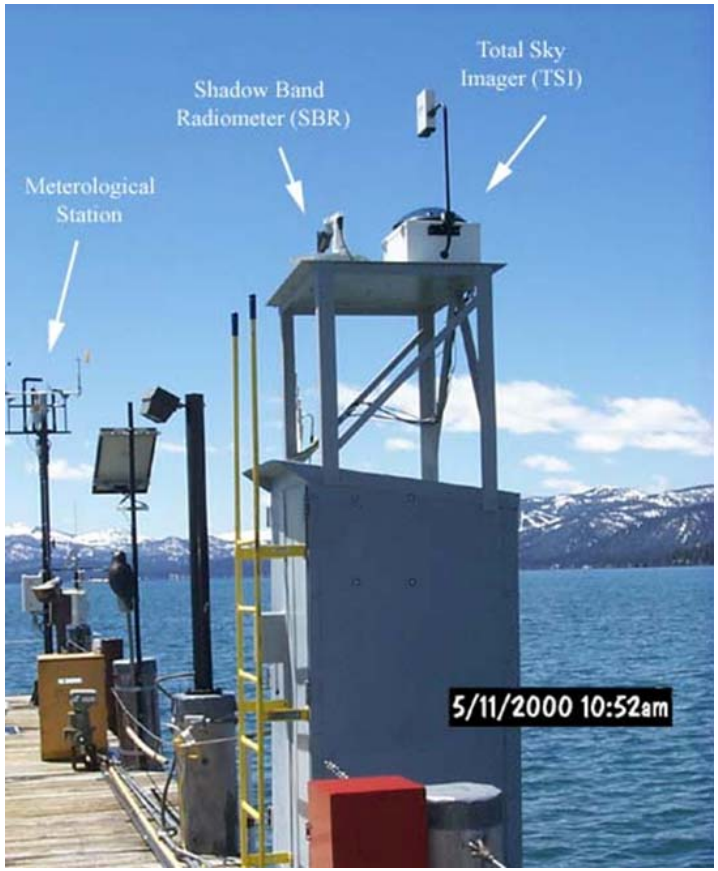
- Validate the ASTER and MODIS Thermal Infrared Data and Products (radiance at sensor, surface radiance, surface temperature, surface emissivity)
- Validate the products over the entire EOS mission and provide an absolute reference on product accuracy
- Provide validation continuity between MODIS and VIIRS
- Enable inter-comparison of ASTER and MODIS data with similar data from other instruments, e.g. AATSR, MTI, Landsat (5 and ETM+)

Why Lake Tahoe?

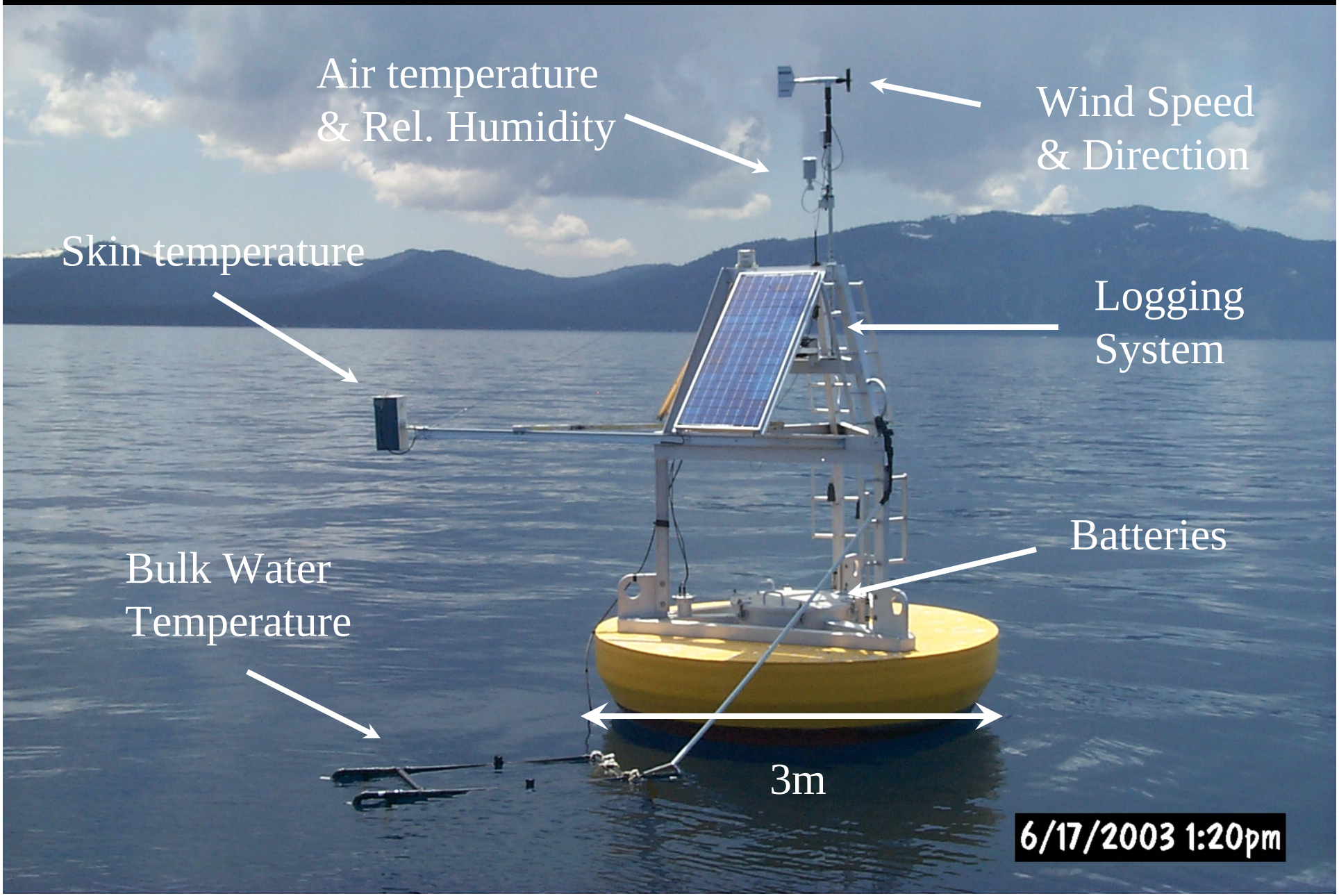
- Large 35 km x 16 km
- High 2 km
- Available year round (does not freeze in winter).
- Homogenous compared with land.
- Large annual temperature range 5-25 C.
- Freshwater (kind to instruments!)
- Good infrastructure and easy access.

Site Layout and Measurement Stations

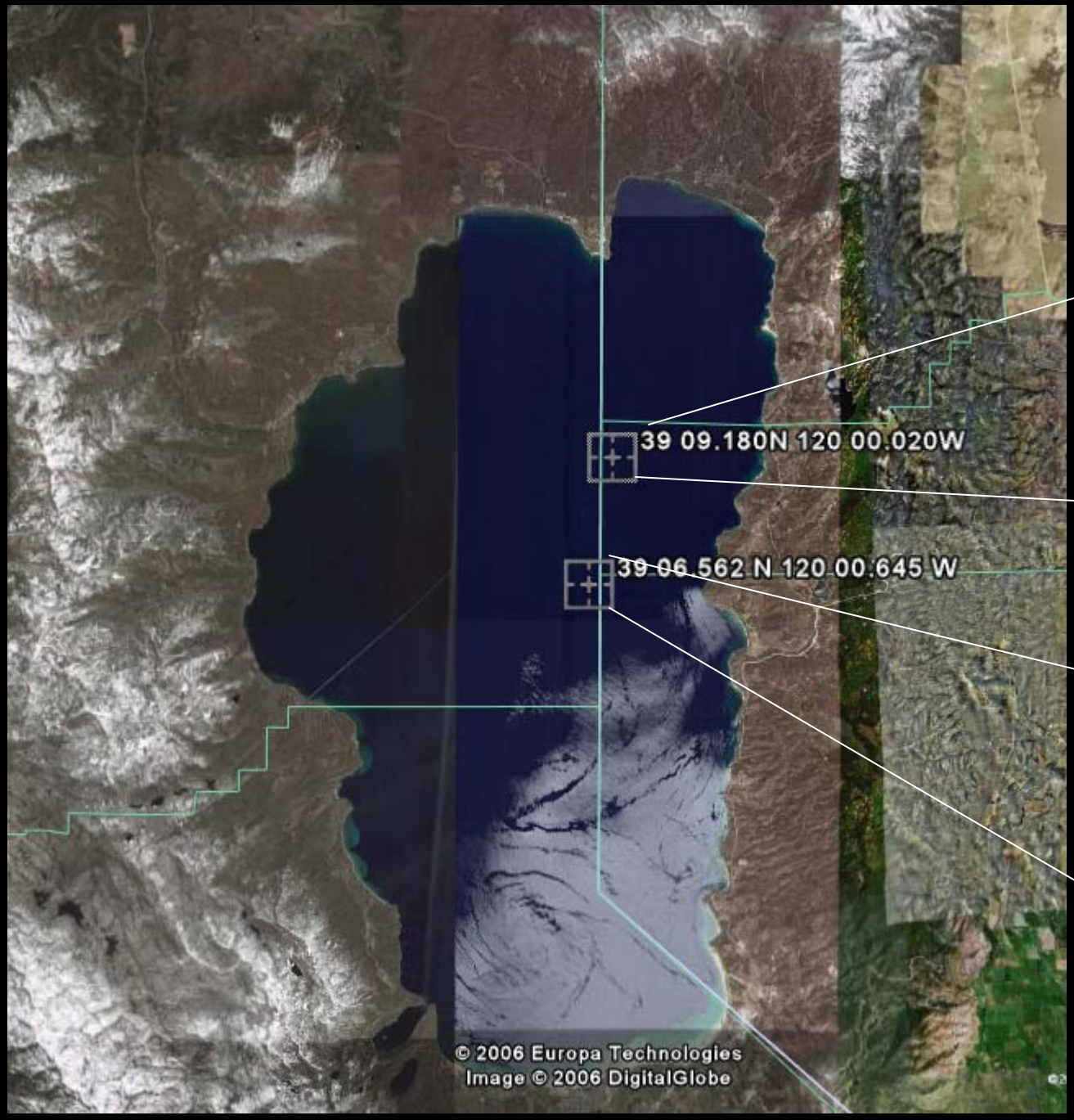




TB3 Installed 11-04-2002



Google Earth!



Tb1

Tb2

Salton Sea, Platform

Radiometer Calibration and Cross-Cal

Cross Comparison of Radiometers at Miami

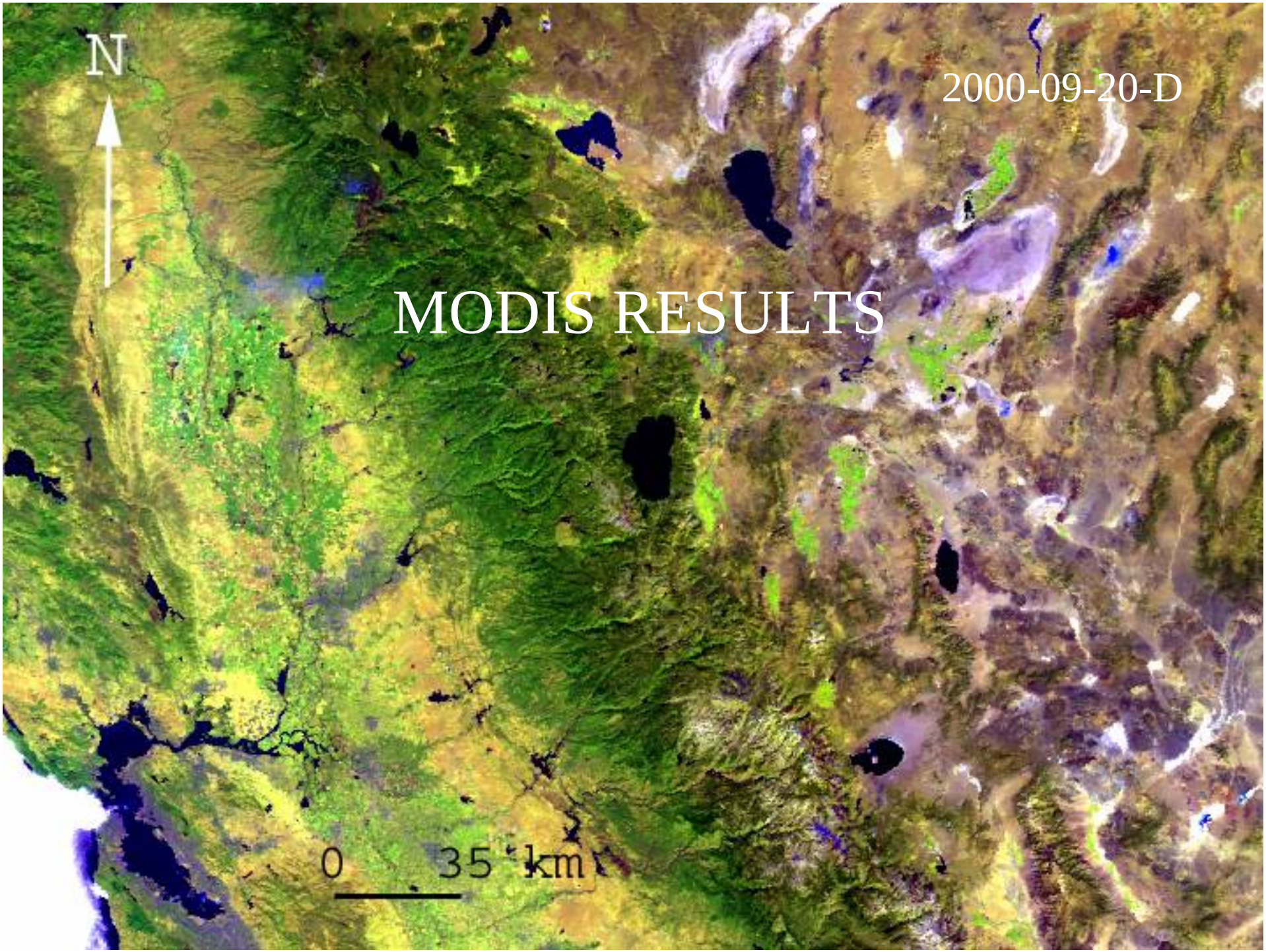
New CEOS sponsored comparison early 2009 (March-May)

Means and standard deviations of the estimated skin SST differences between pairs of radiometers for the entire cruise period, and for each half of the cruise

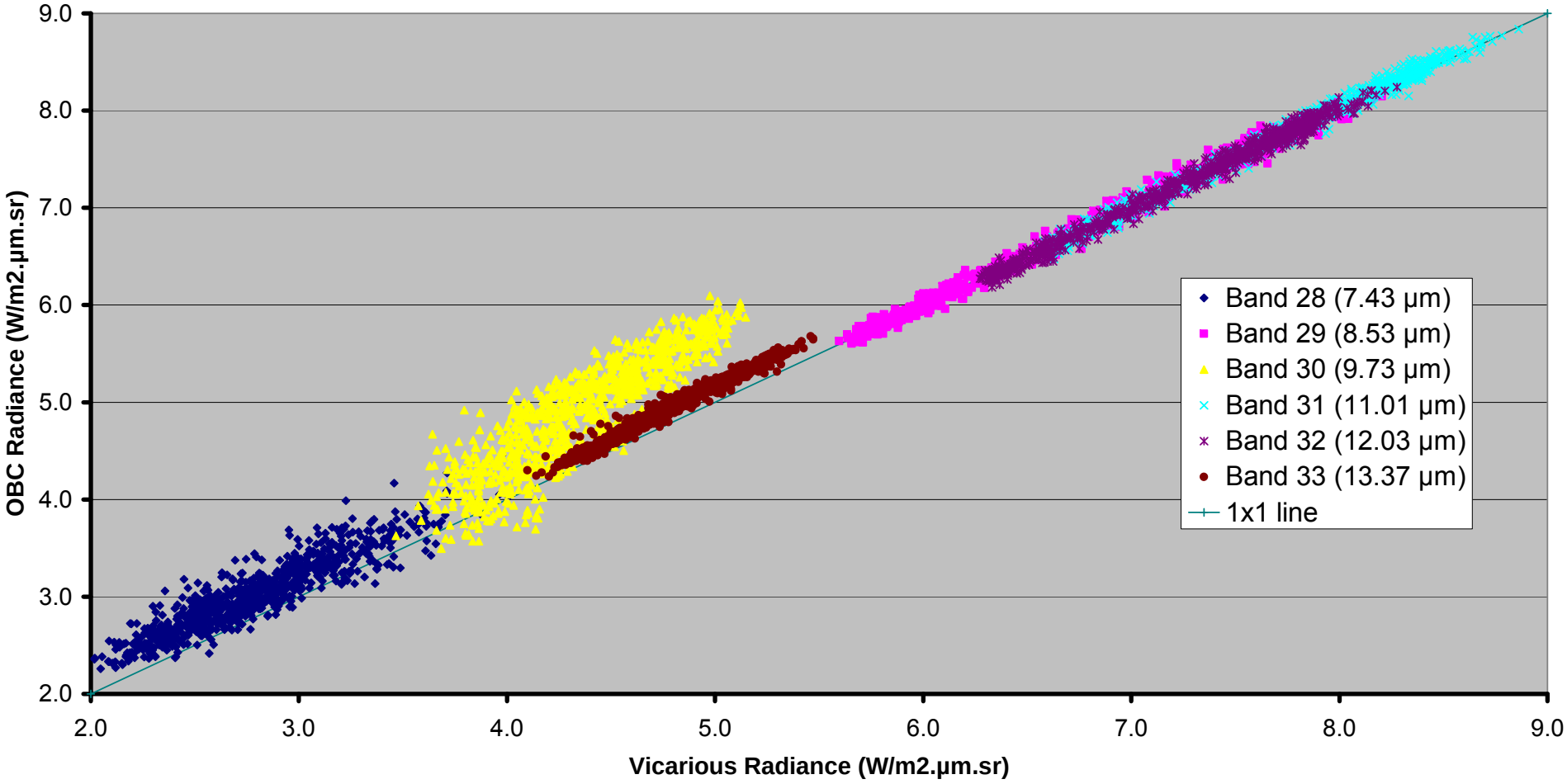
Time	150.50 to 152.00			150.50 to 151.25			151.25 to 152.00		
Radiometer Pair	Mean (K)	Std.Dev (K)	N	Mean (K)	Std.Dev (K)	N	Mean (K)	Std.Dev (K)	N
MAE-ISA	0.002	0.135	80	0.005	0.135	69	–0.015	0.135	11
MAE-SIS	0.046	0.066	144	0.046	0.066	74	0.045	0.068	70
MAE-JPL	0.007	0.114	148	0.052	0.111	77	-0.042	0.096	71
MAE-DAR	-0.008	0.076	149	0.022	0.071	78	-0.041	0.067	71
ISA-SIS	0.038	0.101	79	0.030	0.101	67	0.085	0.093	12
ISA-JPL	0.026	0.142	81	0.027	0.141	70	0.018	0.150	11
ISA-DAR	0.007	0.114	80	0.019	0.112	69	-0.064	0.107	11
SIS-JPL	-0.048	0.099	144	-0.009	0.103	74	-0.088	0.078	70
SIS-DAR	-0.053	0.074	144	-0.019	0.054	74	-0.088	0.076	70
JPL-DAR	-0.014	0.103	148	-0.028	0.102	77	0.000	0.102	71

Data Reduction: Methodology For Radiance at Sensor Validation

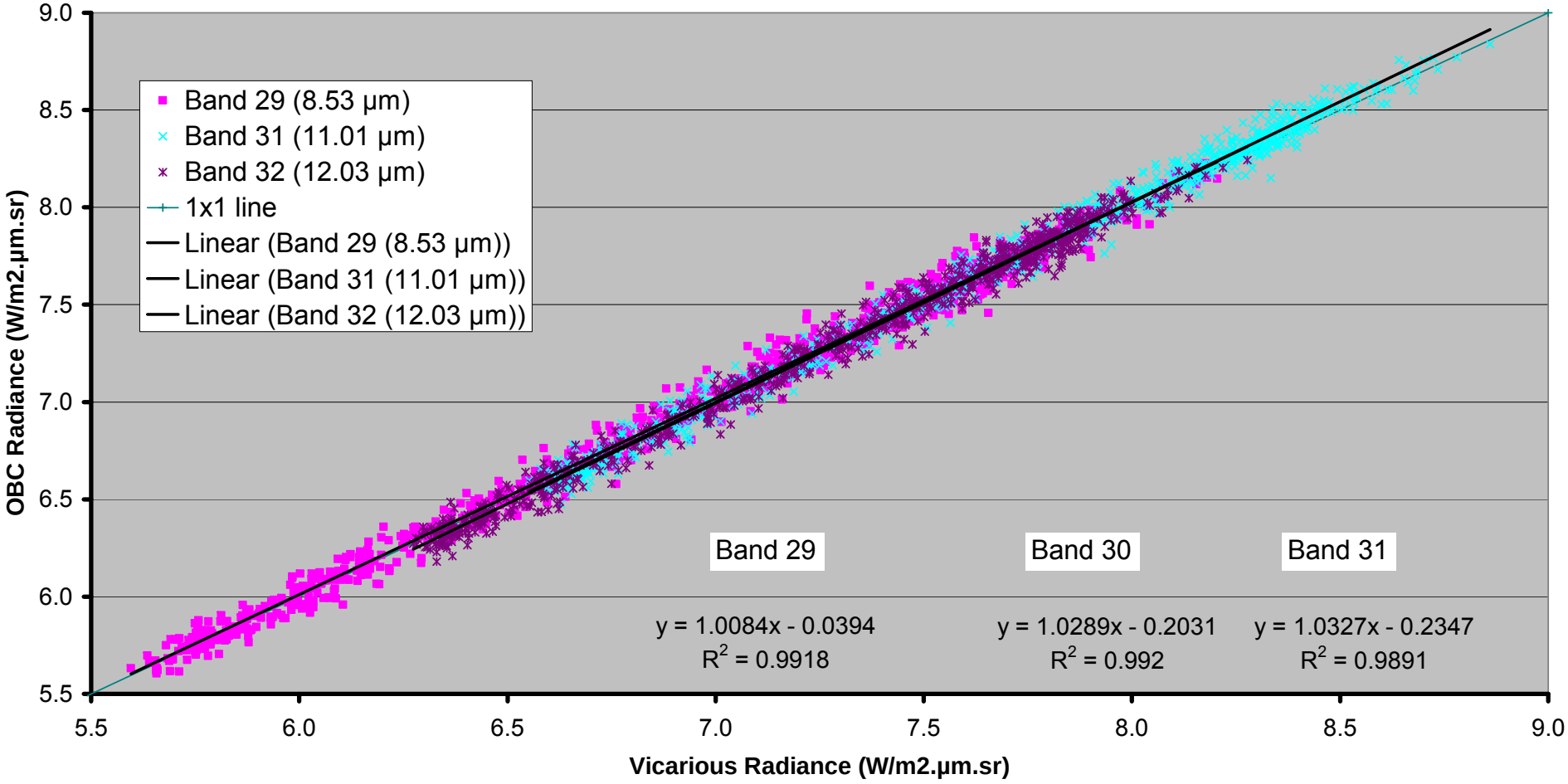
- Extract the bulk temperatures.
- Extract the radiometric temperature.
- Correct the radiometric temperature to skin kinetic temperature.
- Propagate the skin temperature to the satellite using a radiative transfer model and interpolated atmospheric profile.
- Convolve the propagated at-sensor radiance 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.


N
2000-09-20-D
MODIS RESULTS
0
35
km

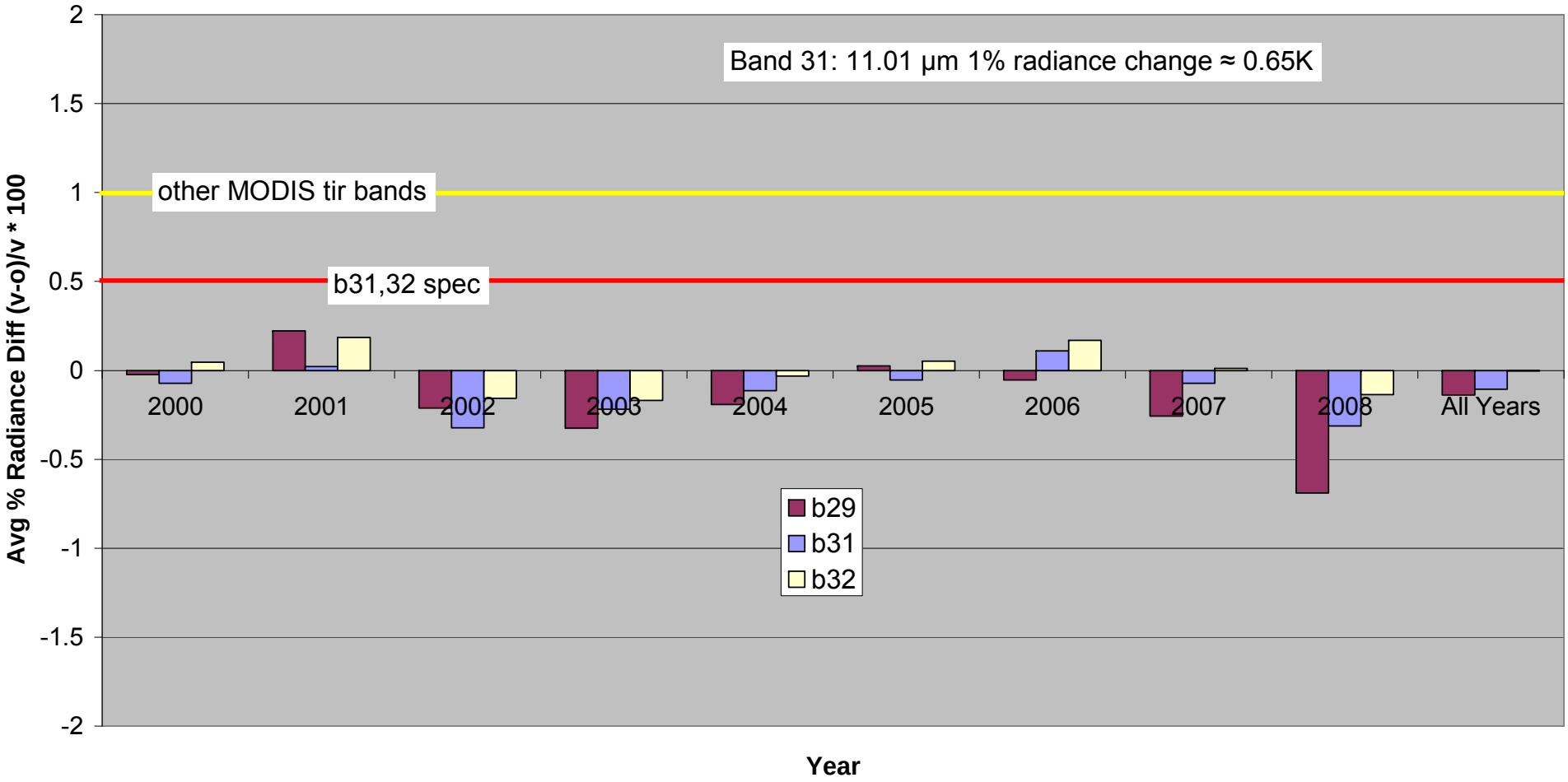
MODIS Terra Vicarious and OBC Thermal Infrared Derived Radiances at Lake Tahoe CY2000-2008, v4-5.x



MODIS Terra Vicarious and OBC Thermal Infrared Derived Radiances at Lake Tahoe CY2000-2008, v4-5.x

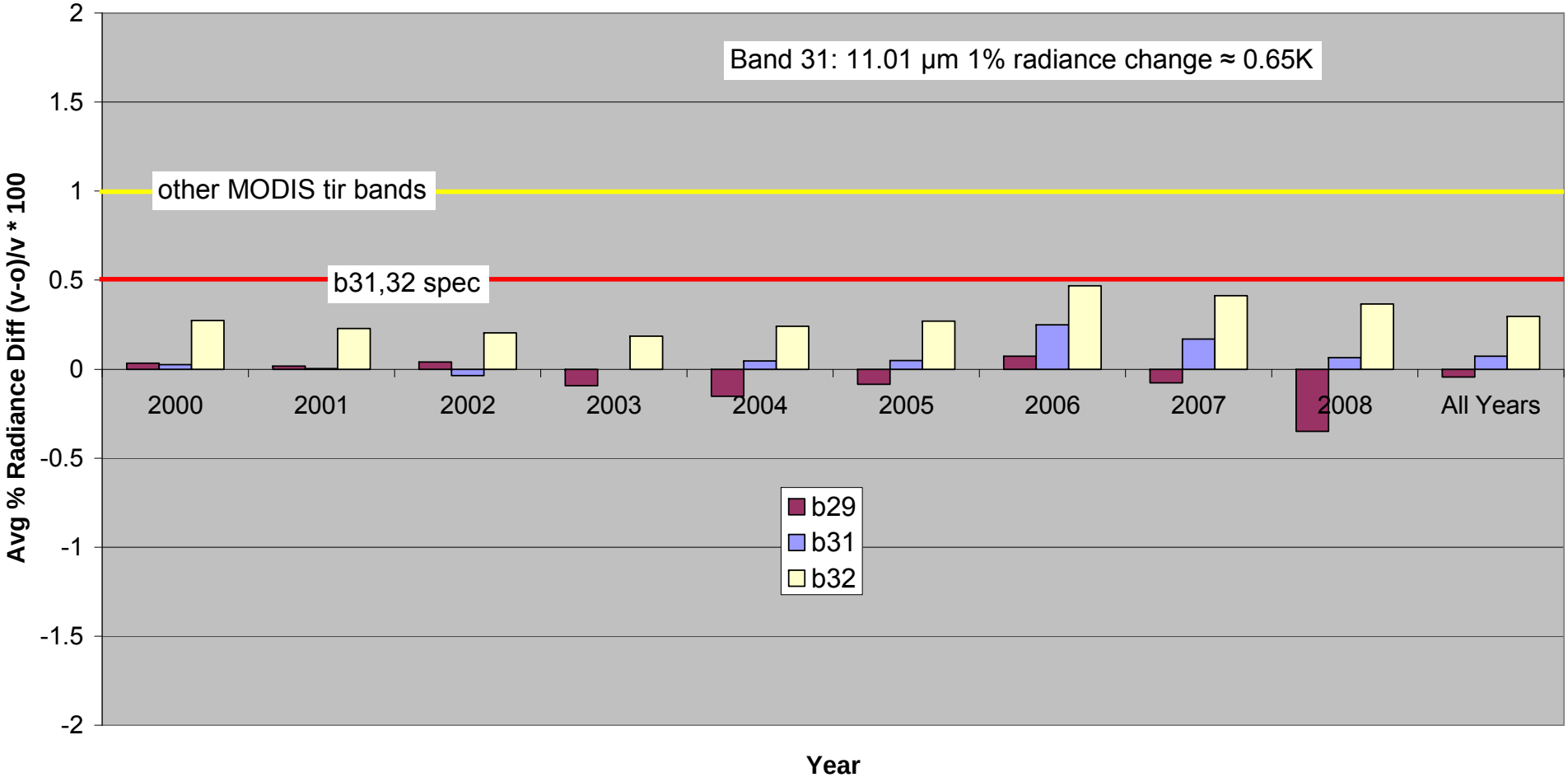


% Radiance Change in TIR Channels for MODIS Terra at Lake Tahoe CY2000-2008 vz0-7 v4-5.x



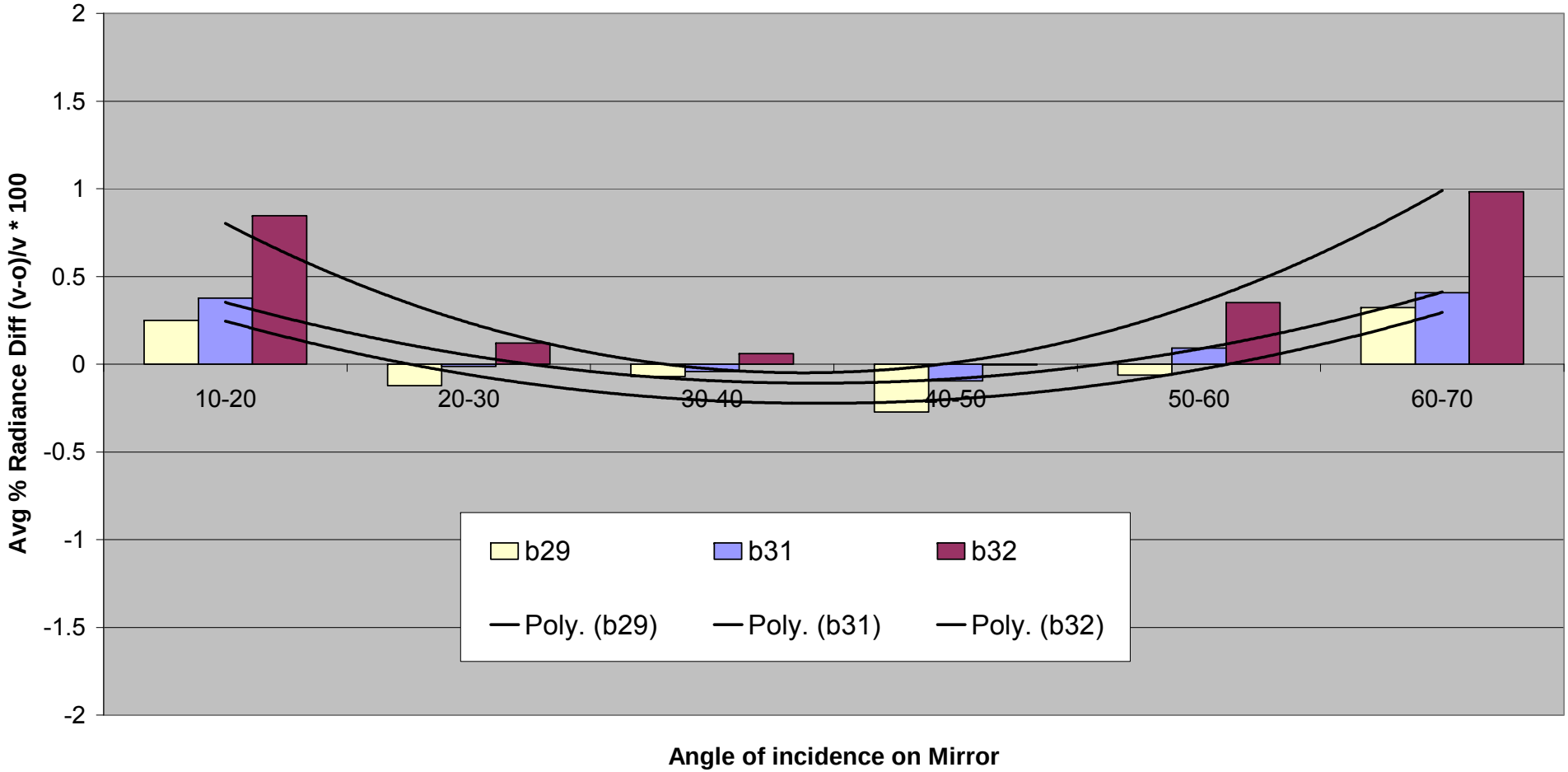
In previous presentations only showed nadir data (461 match ups as above) due to manual processing, now have more automated system allowing all clear data to be processed (5219 match ups)

% Radiance Change in TIR Channels for MODIS Terra at Lake Tahoe CY2000-2008 v4-5.x



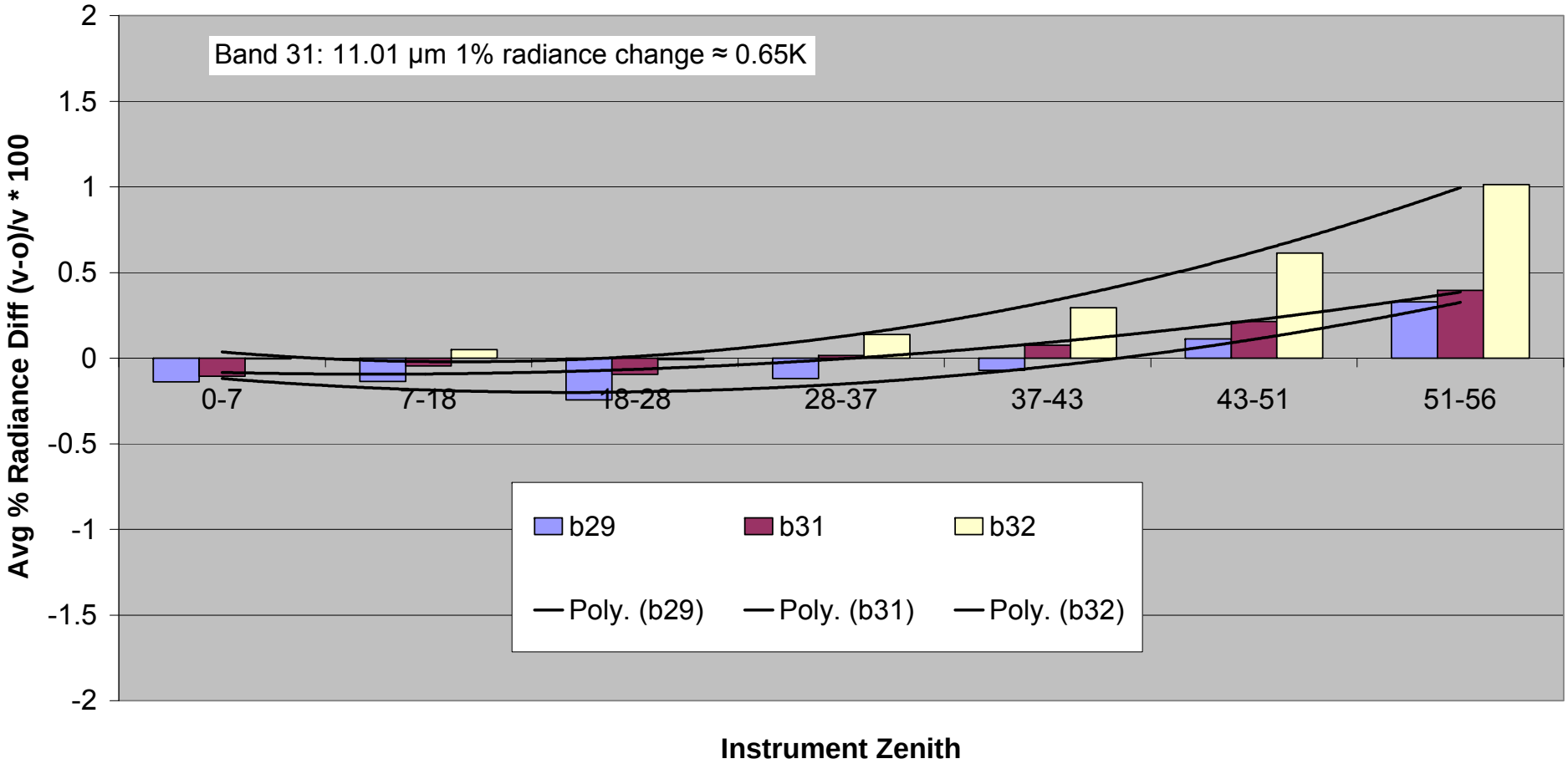
5219 match ups, all viewing angles, some differences associated with incl. extreme viewing angles.

% Radiance Change in TIR Channels for MODIS Terra with Mirror AOI at Lake Tahoe CY2000-2008 v4-5.x



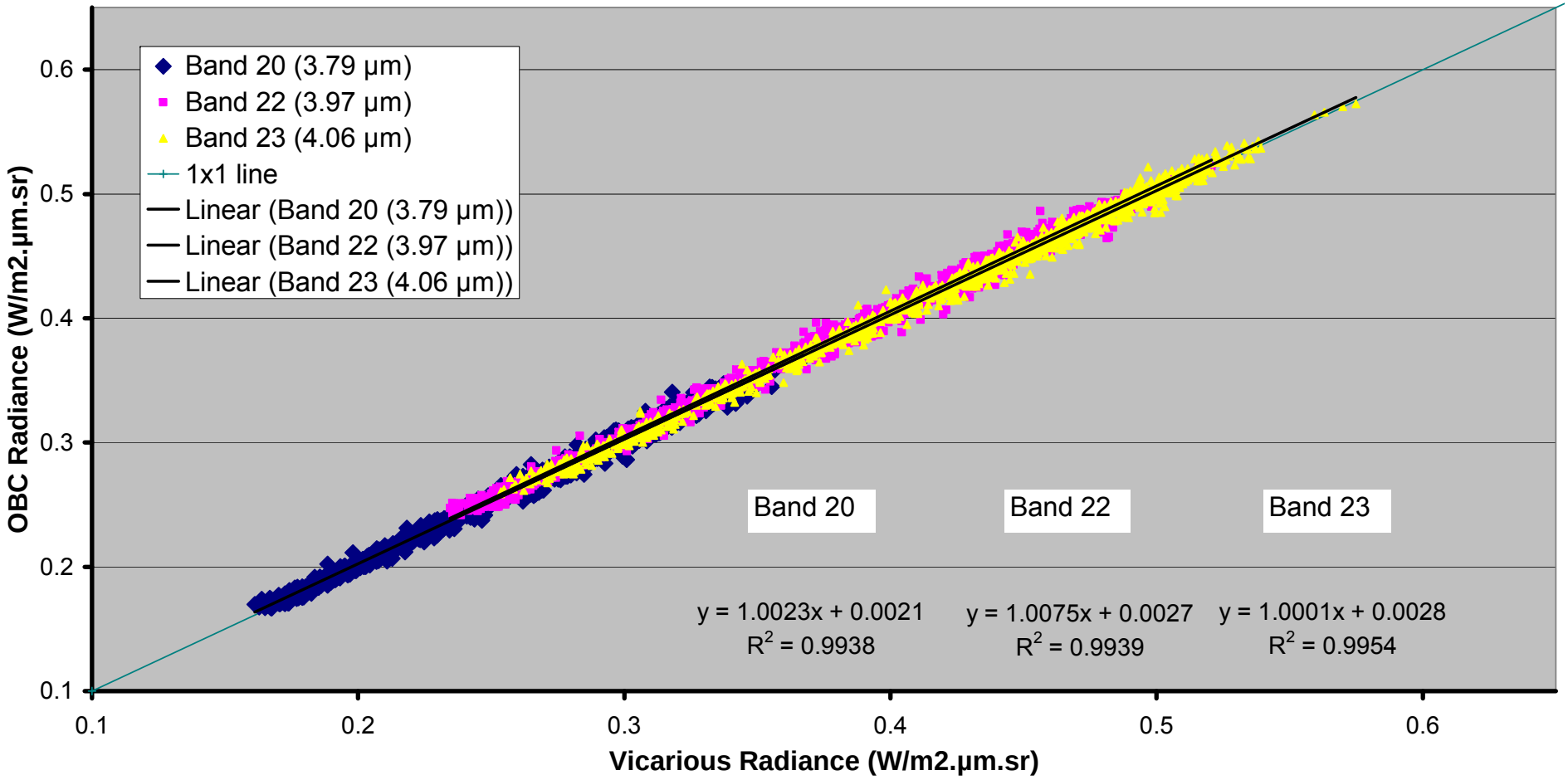
Low and high angle of incidences correspond to low and high viewing zeniths

% Radiance Change in TIR Channels for MODIS Terra with Instrument Zenith at Lake Tahoe CY2000-2008, v4-5.x



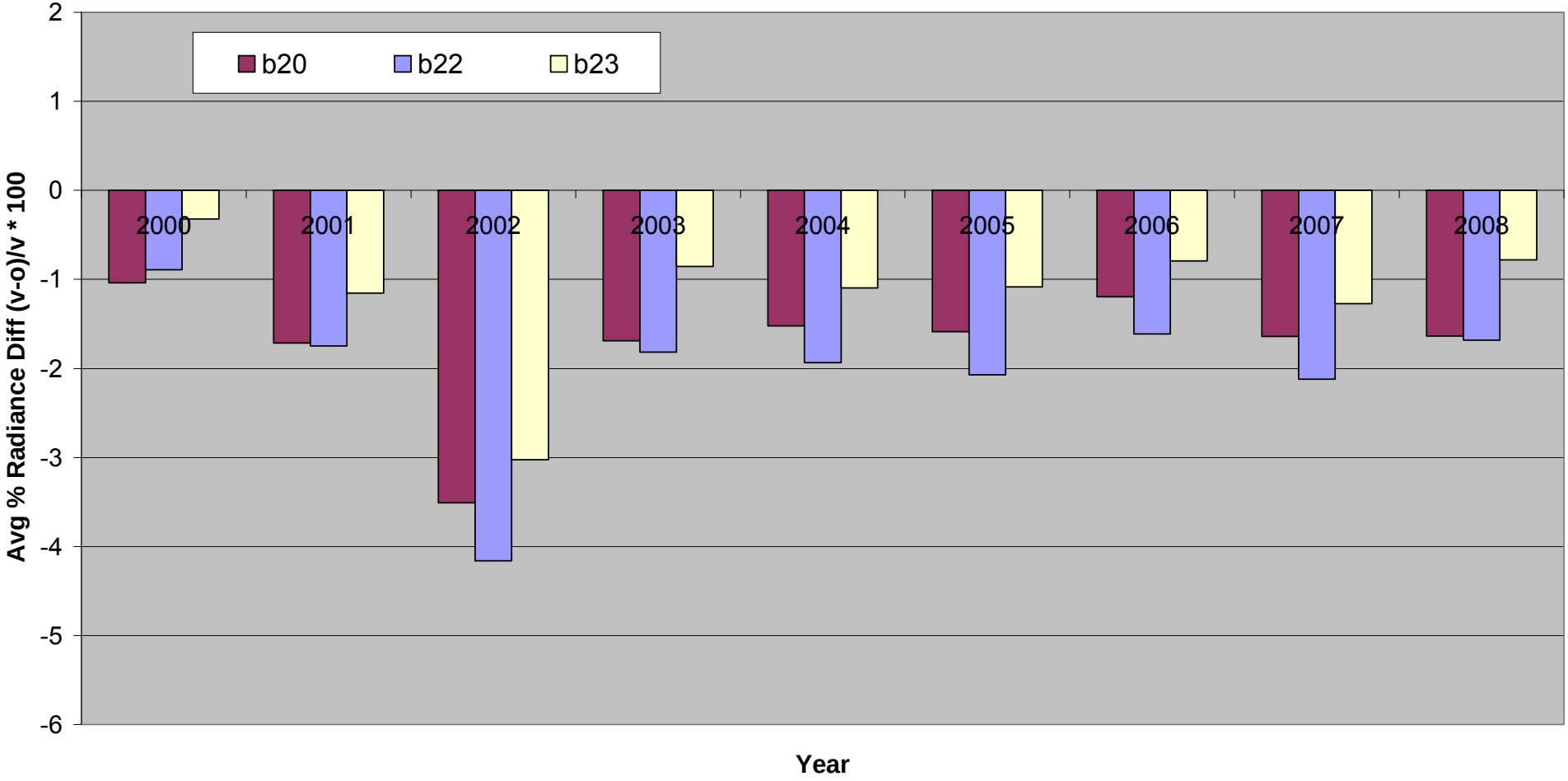
Error increases with view angle. Most likely cause is change in emissivity with viewing zenith. Note increased path length in atmospheric correction was corrected.

MODIS Terra Night Only Vicarious and OBC Mid Infrared Derived Radiances at Lake Tahoe CY2000-2008, v4-5.x

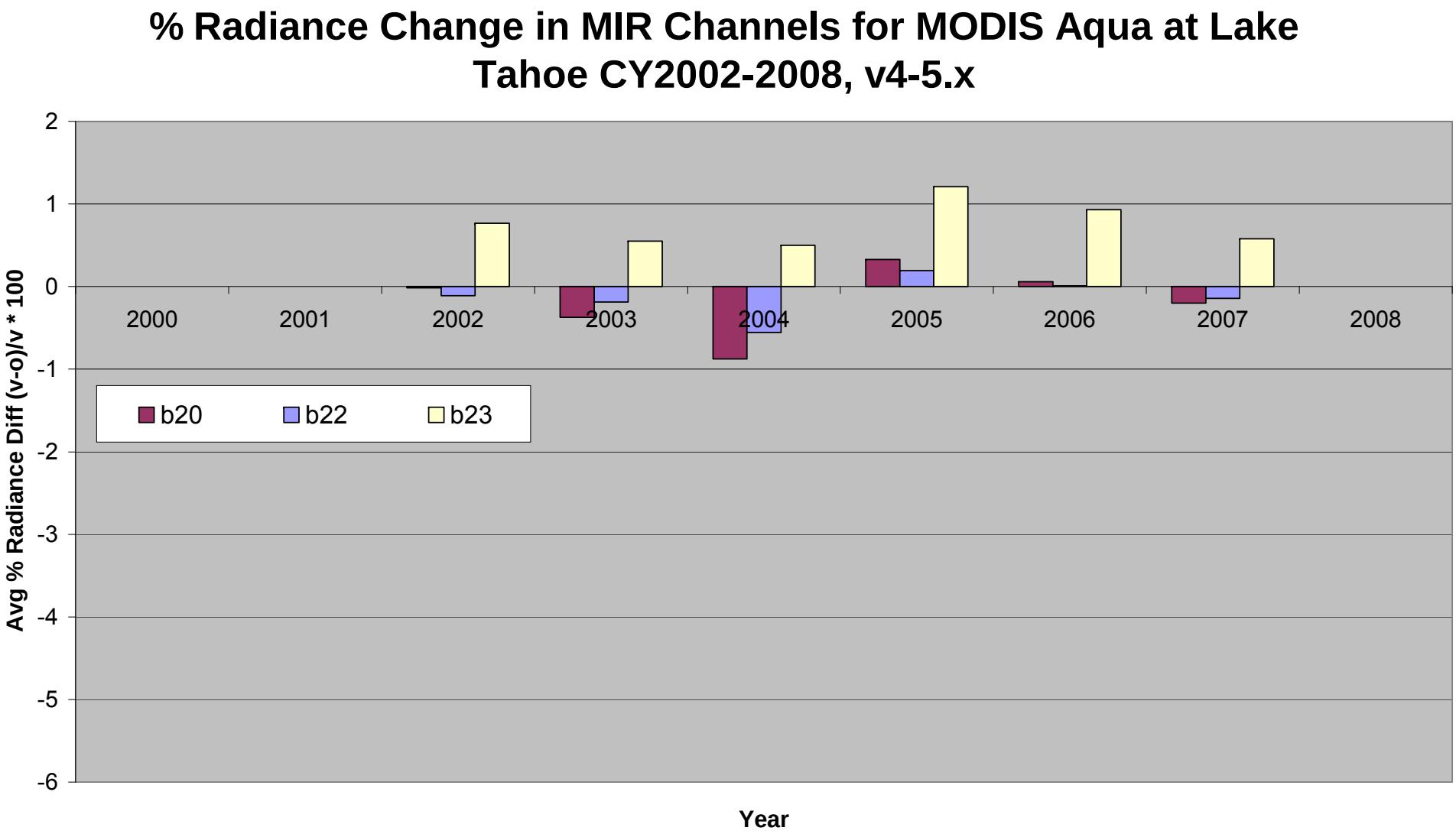


Can also look at the MIR channels but only use nighttime data to avoid the effects of reflected solar radiation in the mid infrared.

% Radiance Change in MIR Channels for MODIS Terra at Lake Tahoe CY2000-2008, v4-5.x

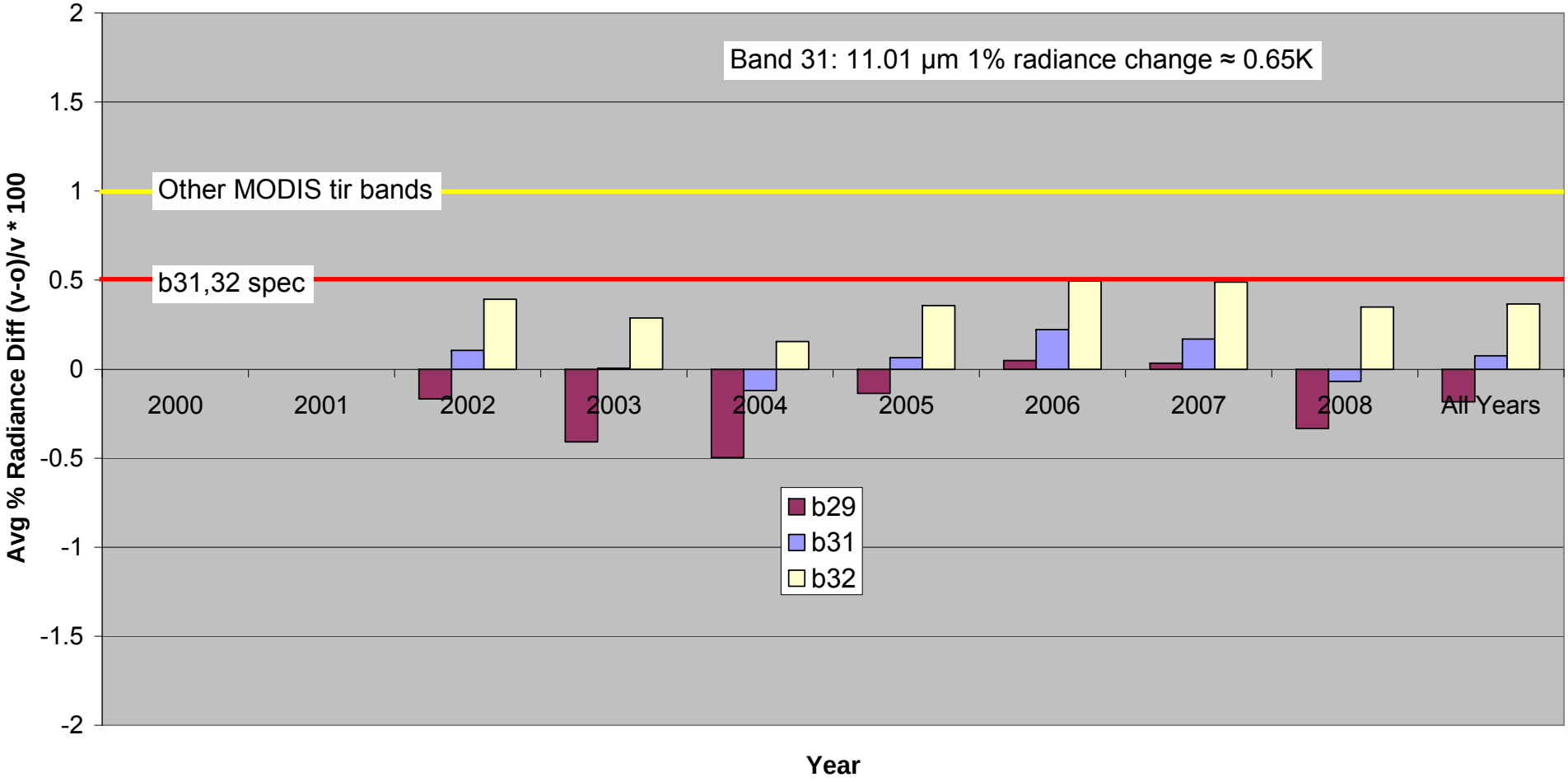


In MODIS-Terra MIR channels see small bias, not seen in MODIS-Aqua cause is currently unknown



In MODIS-Aqua MIR channels do not show bias seen with MODIS-Terra MIR channels

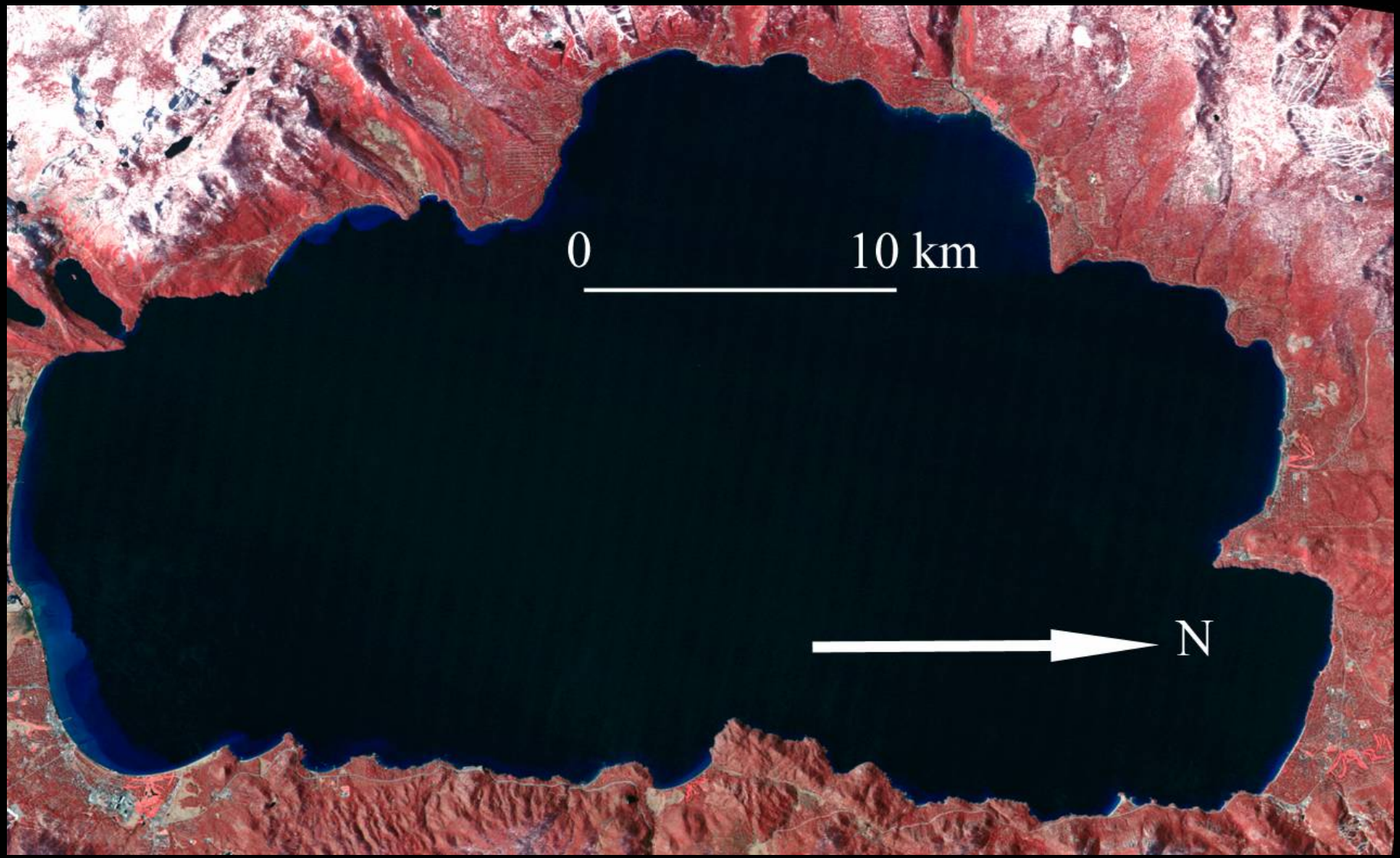
% Radiance Change in TIR Channels for MODIS Aqua at Lake Tahoe CY2002-2008 v4-5.x



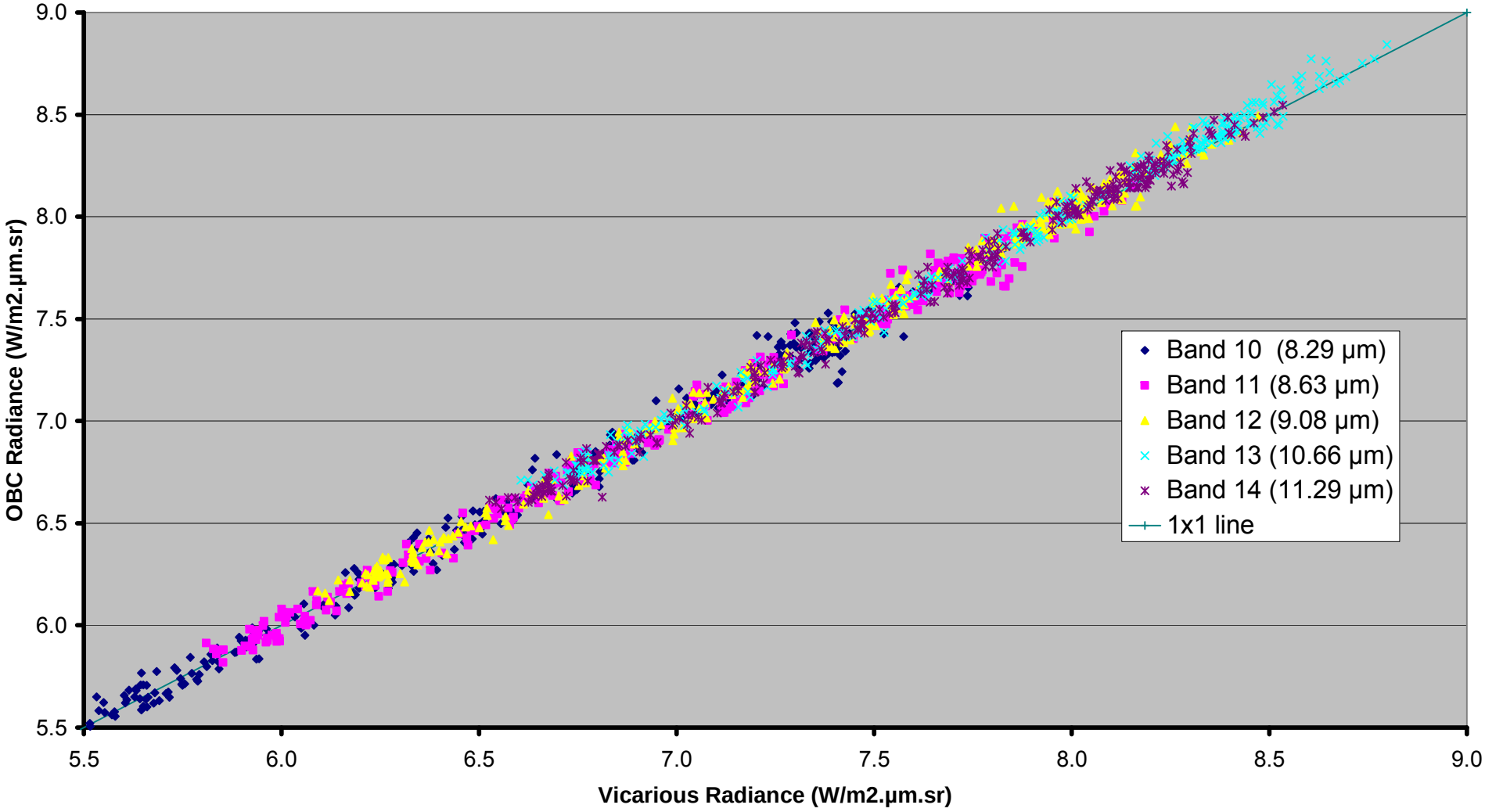
In MODIS-Aqua TIR Channels are well calibrated, similar to MODIS-Terra

CIR Composite of ASTER Bands 321 as RGB

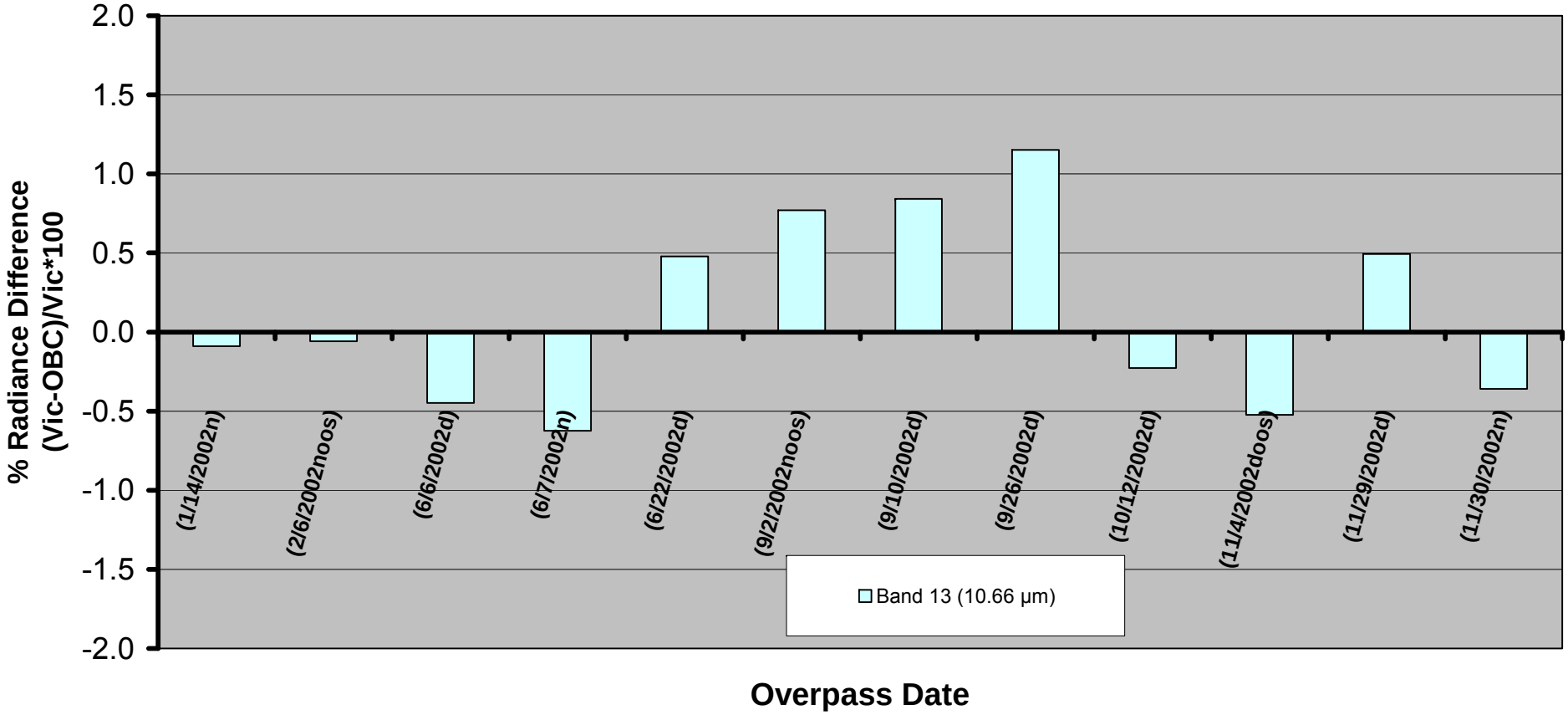
2000-11-07



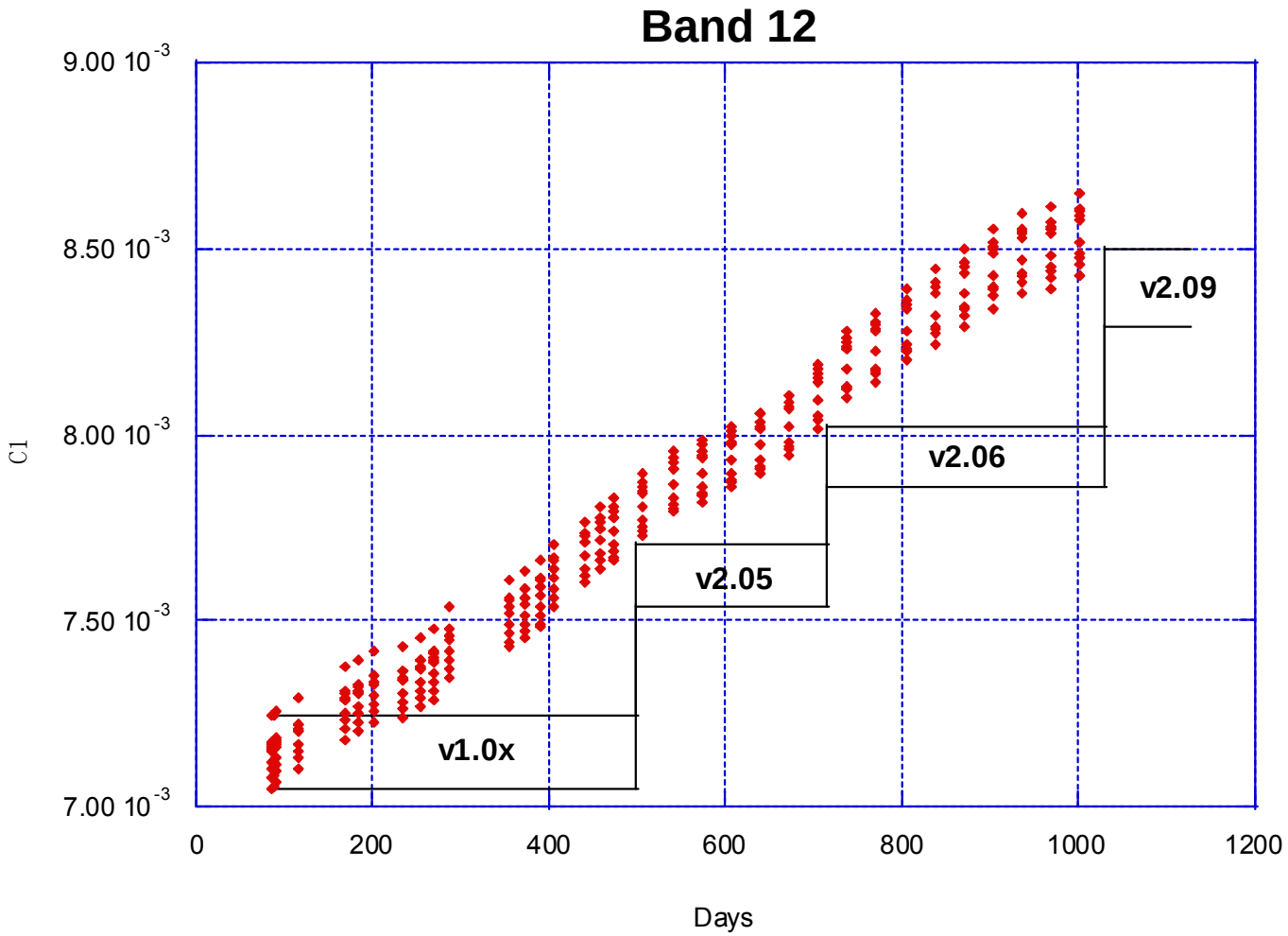
ASTER Vicarious and OBC Thermal Infrared Derived Radiances at Lake Tahoe CY2000-2008, v3.0x



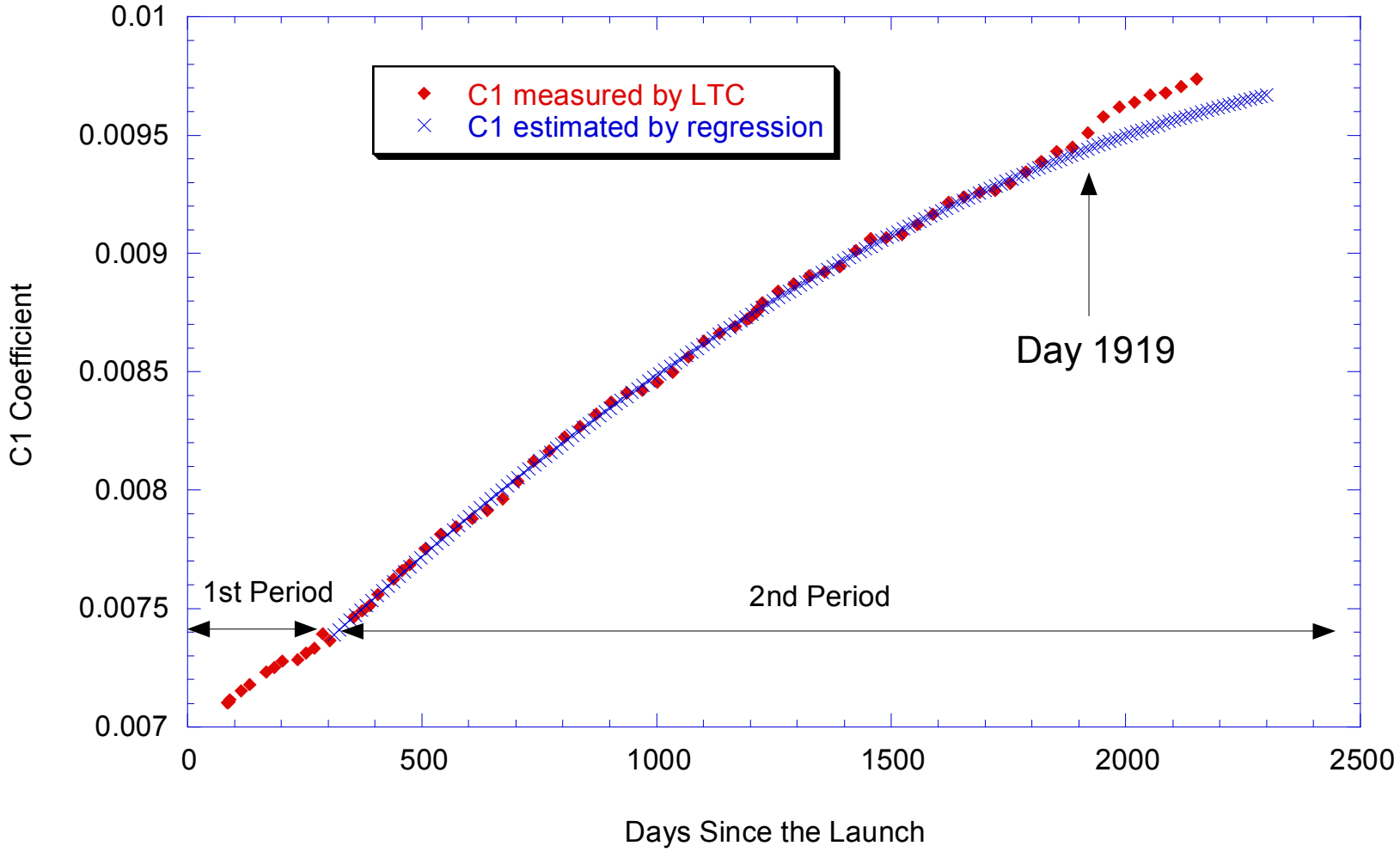
ASTER 3x3 pixel % Radiance Difference between Vicarious and OBC Derived Radiances (without correction) -- Band 13 (v2.01-2.21)

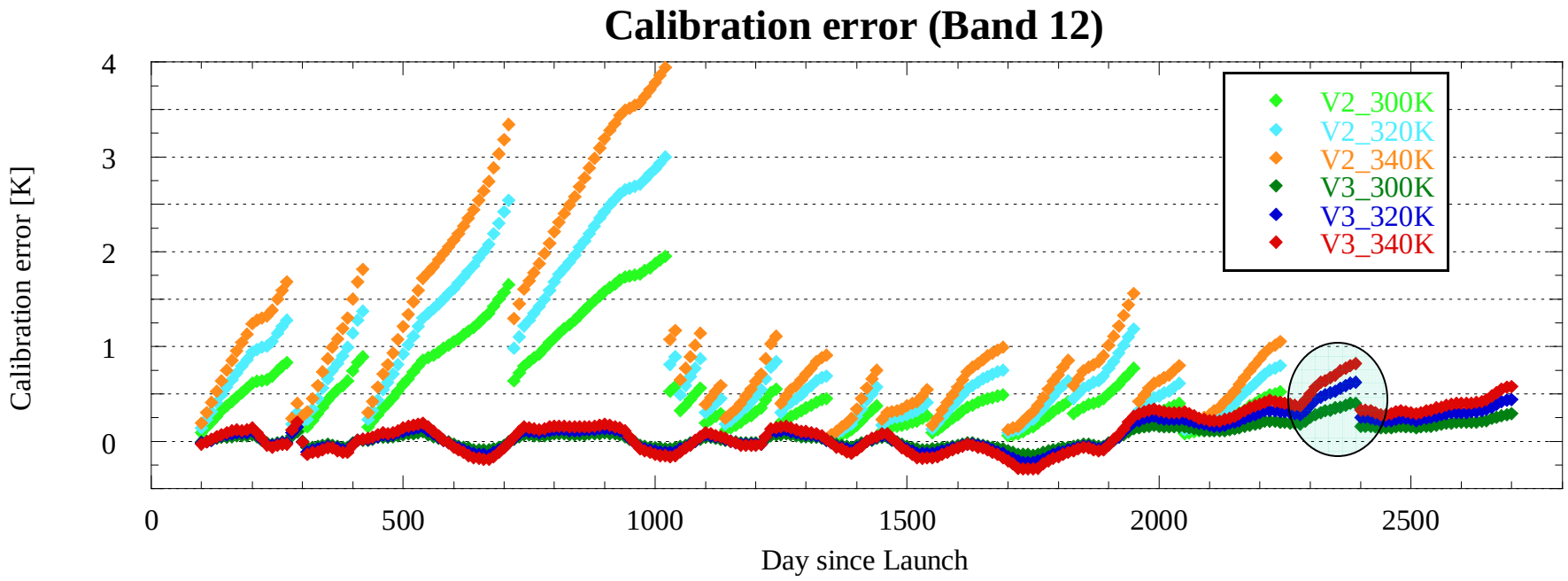


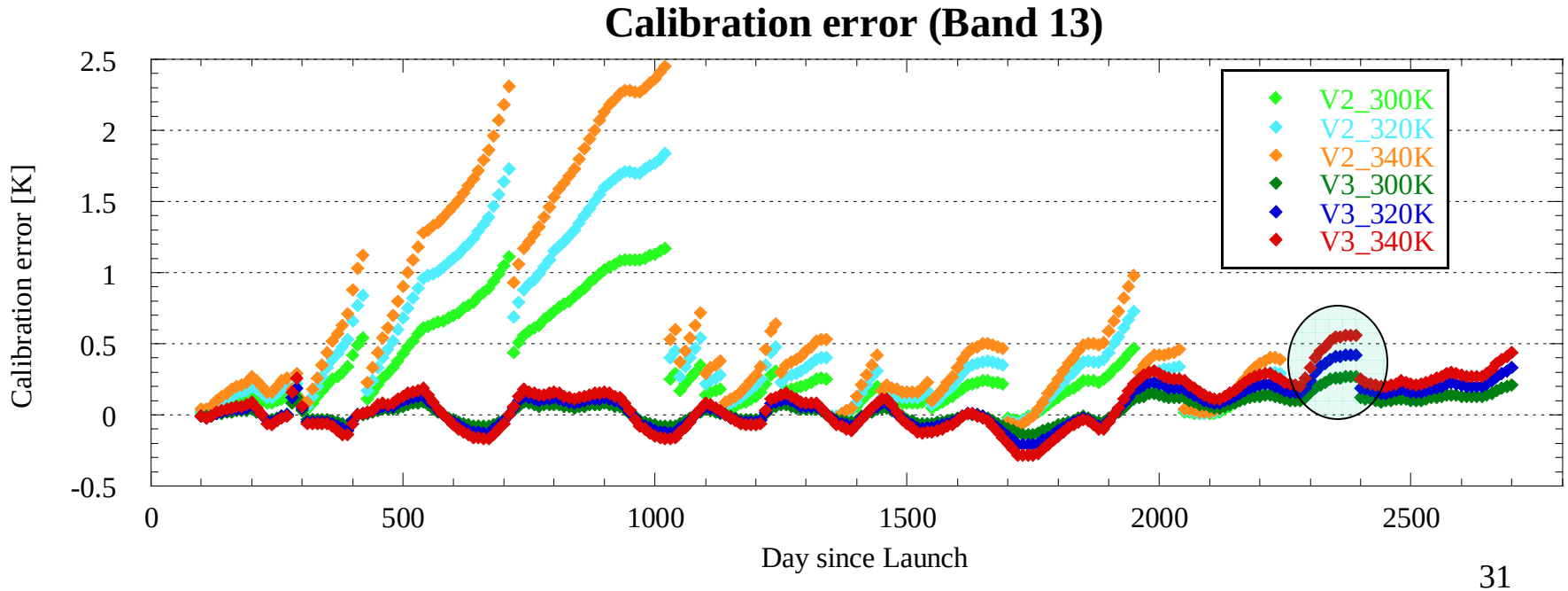
C1 of online RCC DB



New Method for ASTER Coeff.

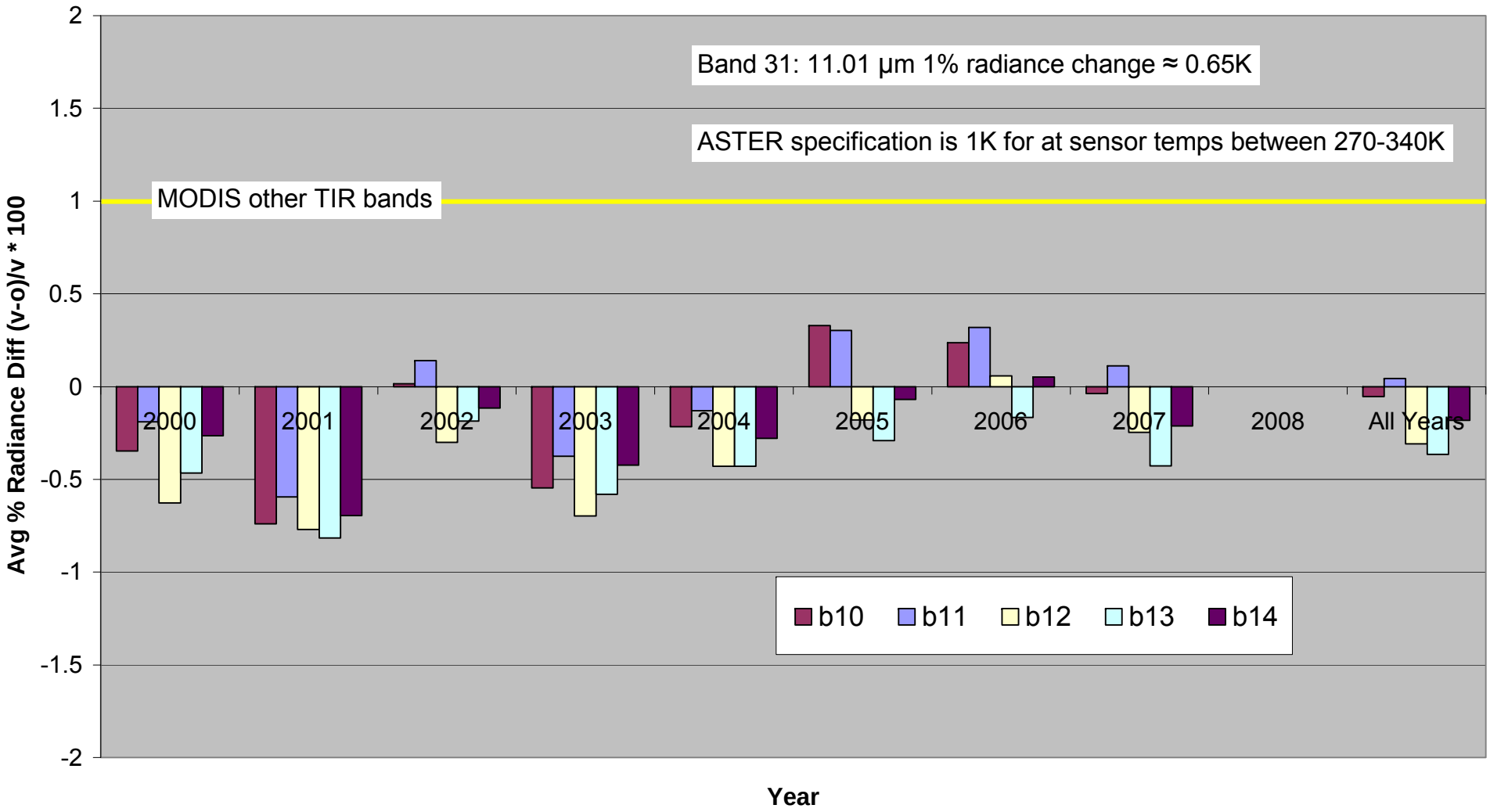






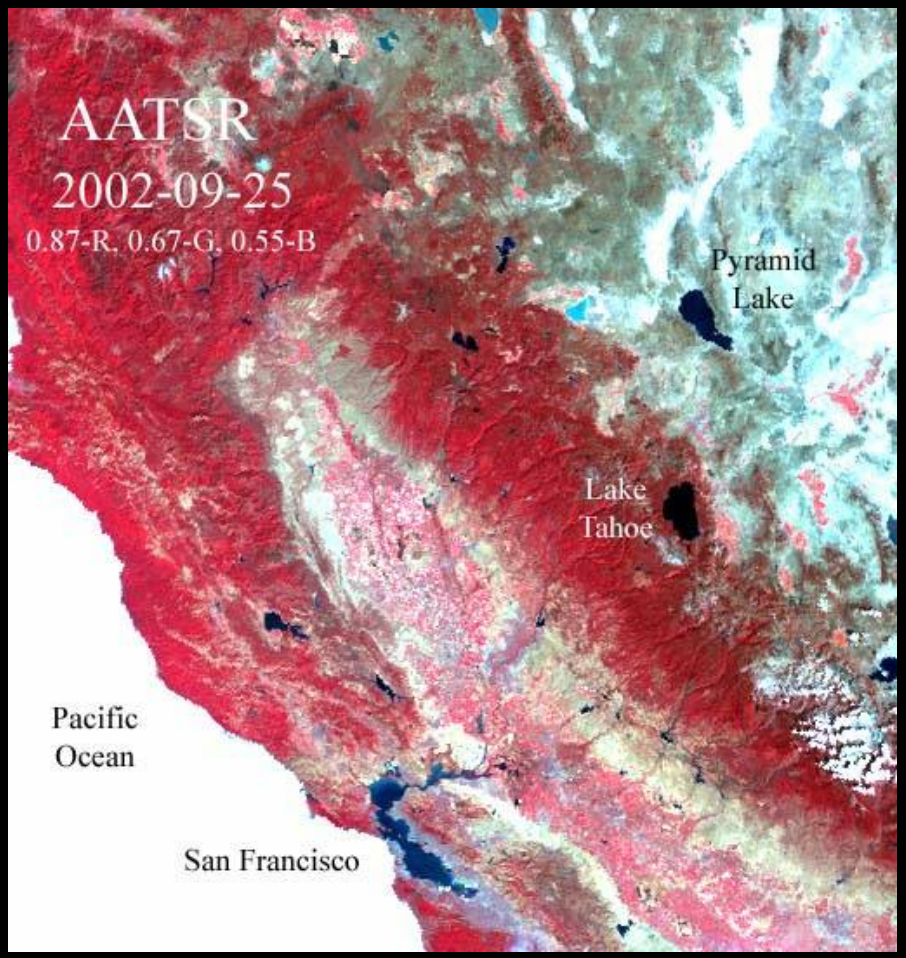
Charts from Tonooka-San (ASTER Science Team

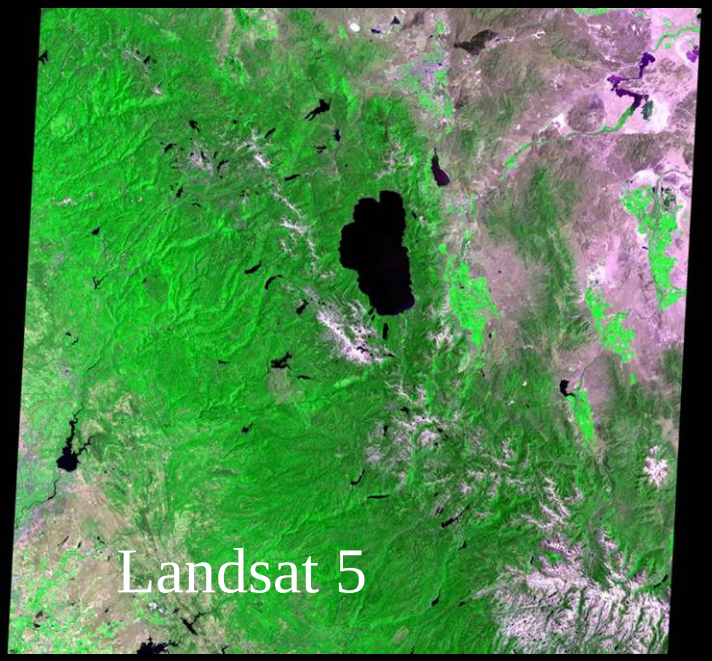
% Radiance Change in TIR Channels for ASTER at Lake Tahoe CY2000-2008, Filtered, v3.x

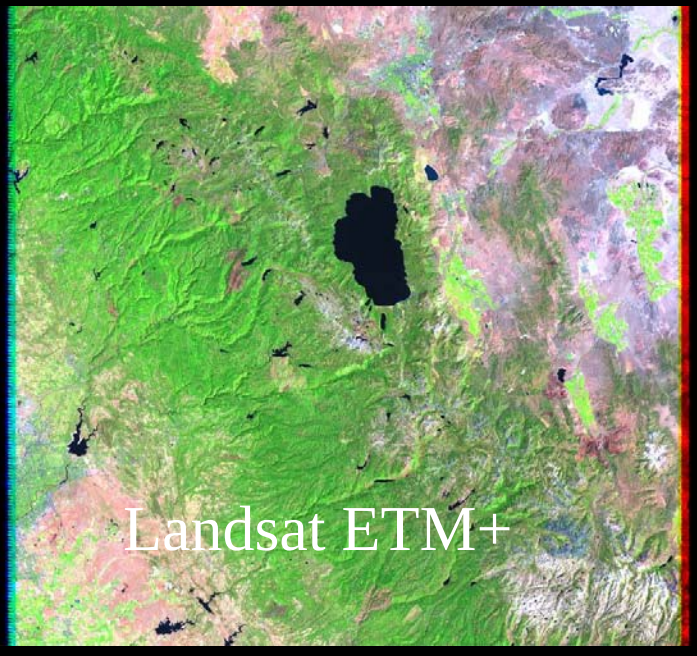


Provided the Tonooka-san correction is performed, ASTER absolute radiometric accuracy is a little worse than MODIS

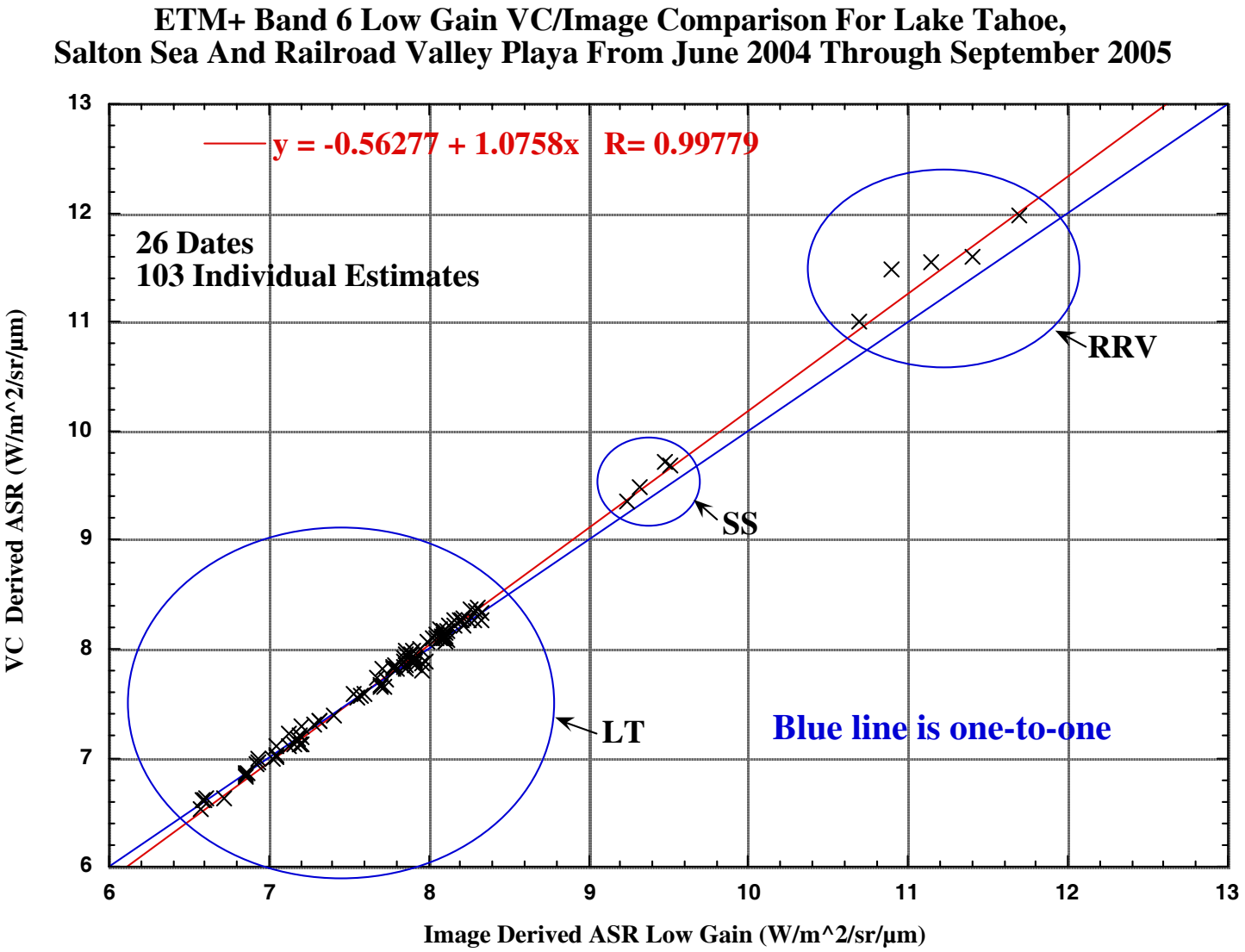
Other Instruments being validated at Lake Tahoe CA/NV

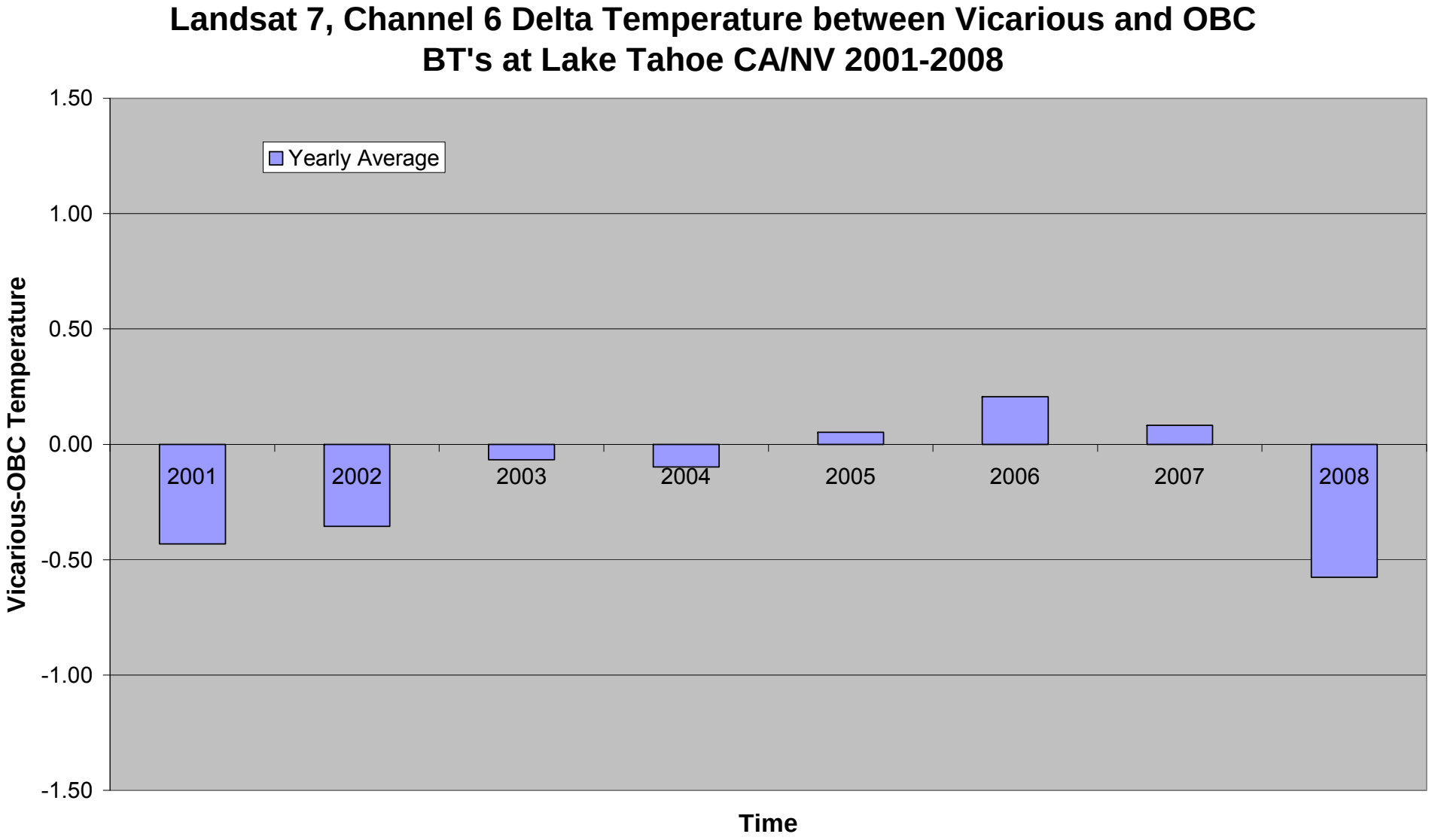






Recent Results for ETM+




Landsat 7, Channel 6 Delta Temperature between Vicarious and OBC BT's at Lake Tahoe CA/NV 2001-2008
Yearly Average
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
Vicarious-OBC Temperature
2001
2002
2003
2004
2005
2006
2007
2008
Time

Summary and Conclusions

- Lake Tahoe CA/NV automated validation site used to assess radiometric accuracy of ASTER and MODIS Mid and TIR data and products. Site established in 1999 as part of EOS. These sites will be used for HyspIRI with similar sites if available.
- New automated validation approach has been implemented allowing **all** clear scenes to be validated (1000's of scenes). Validation covers a broad surface temperature range (4-25°C) and provides a long-term validation dataset for ASTER and MODIS (Terra and Aqua) for the entire duration of the mission.
- Results indicate that
  - The absolute radiometric calibration of the MODIS TIR bands (Aqua and Terra) has been met or improved upon each year for entire duration of mission.
  - The absolute radiometric calibration of MODIS MIR bands for Aqua has been met or improved upon each year for the duration of the mission but the MODIS-Terra MIR bands show a small bias (~1.5% MODIS is too warm).
  - The problem with the ASTER radiometric calibration coefficient updates has been addressed for version 3.x with new software and the change to on-demand Level 1B. Further checking required when each new fit equation is introduced. Users need to be aware of Tonooka-san adjustment.
- A second validation site has been established at Salton Sea allowing much higher temperatures to be validated. Results will be reported out at the next site review.