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

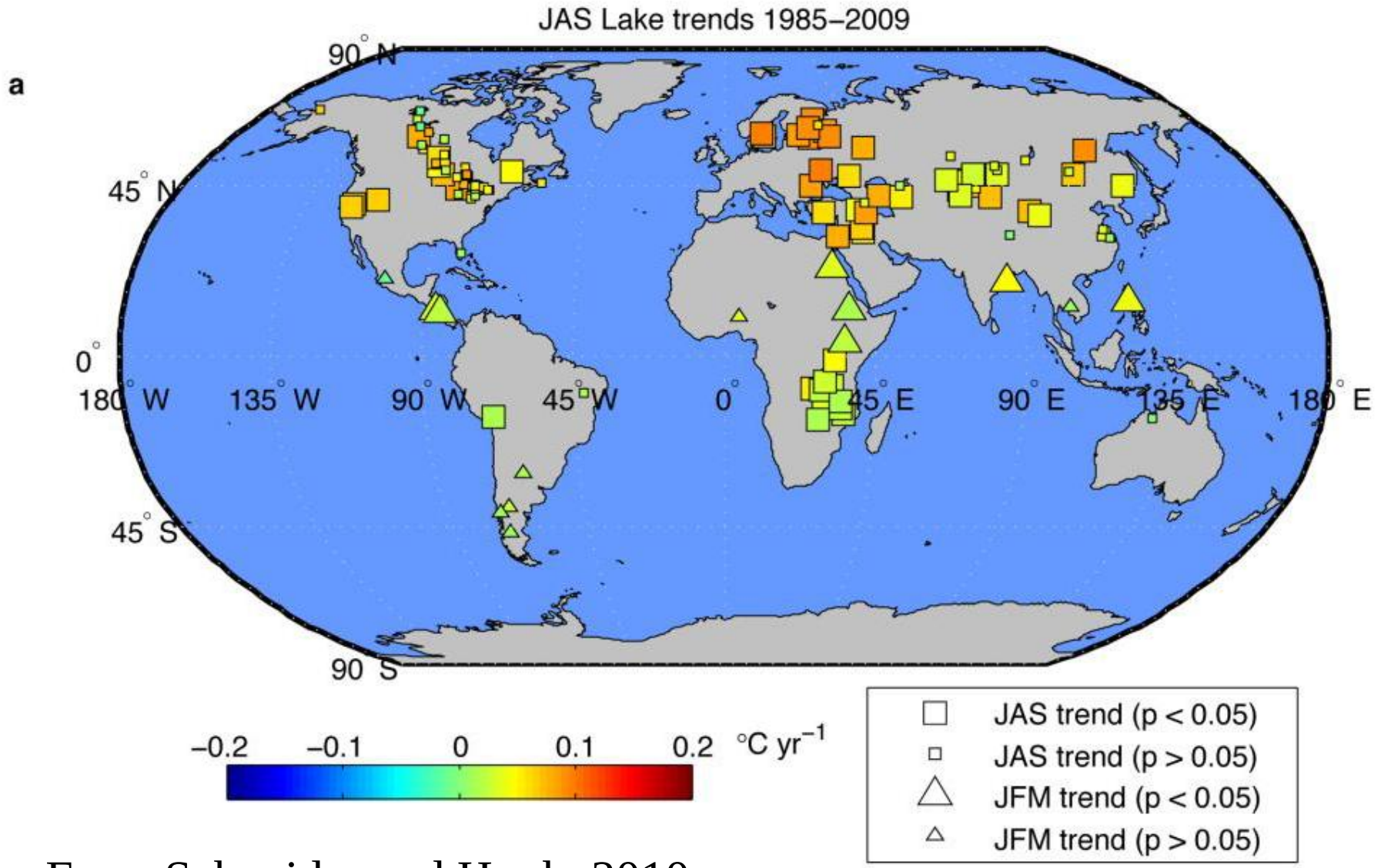
Simon J. Hook et al.

Email:simon.j.hook@jpl.nasa.gov

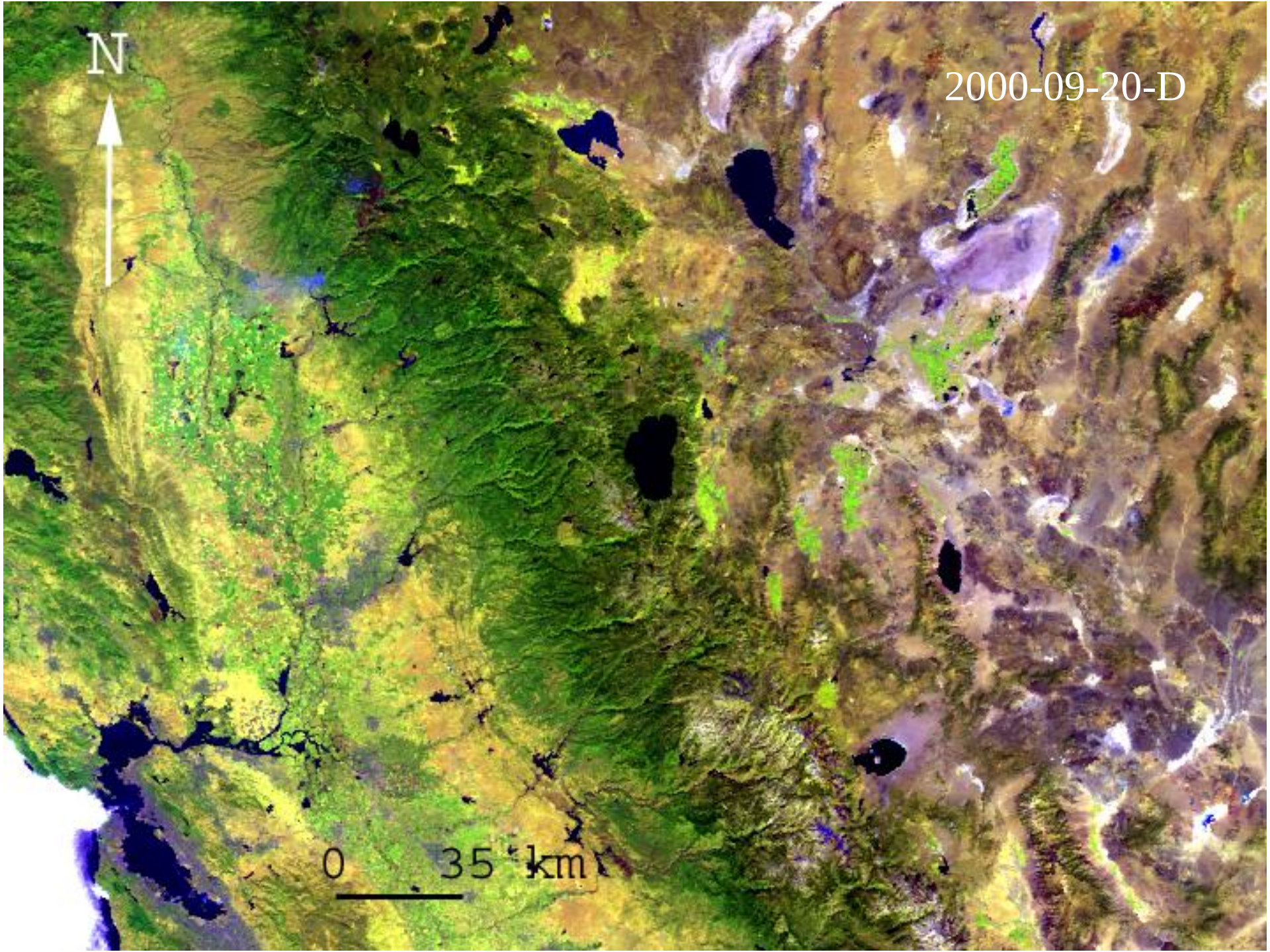
Outline

- Introduction
- Location
- Measurements and Calibration
- Data Reduction Methodology
- Results from various sensors
  - MODIS
- Summary and Conclusions
- Future Work

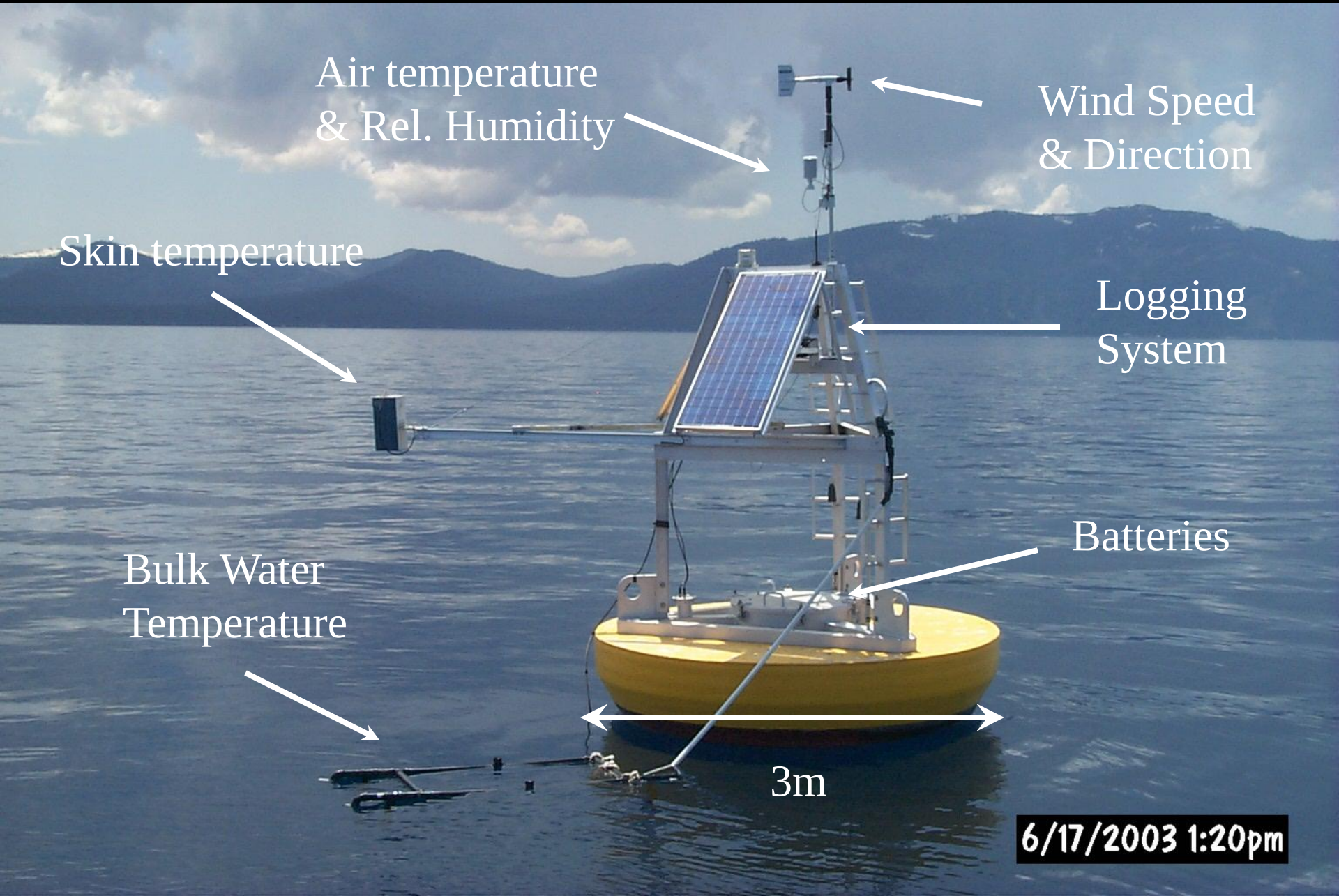
Global satellite-derived seasonal (July, August, September (JAS) and January, February, March (JFM)) nighttime lake surface temperature trends between 1985 and 2009



From Schneider and Hook, 2010


N
2000-09-20-D
0
35
km

TB3 Installed 11-04-2002



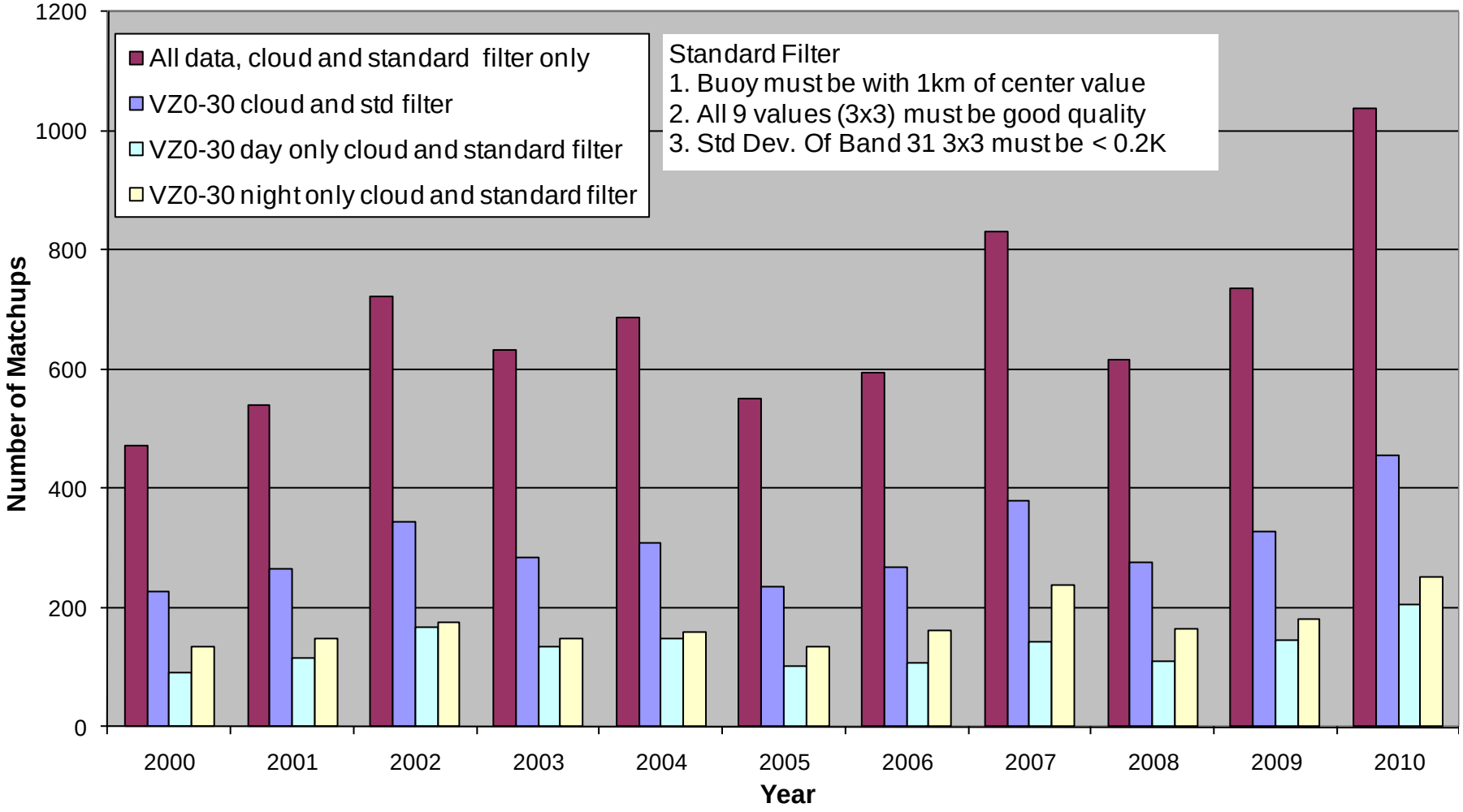
MODERATE RESOLUTION IMAGING SPECTRORADIOMETER

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).

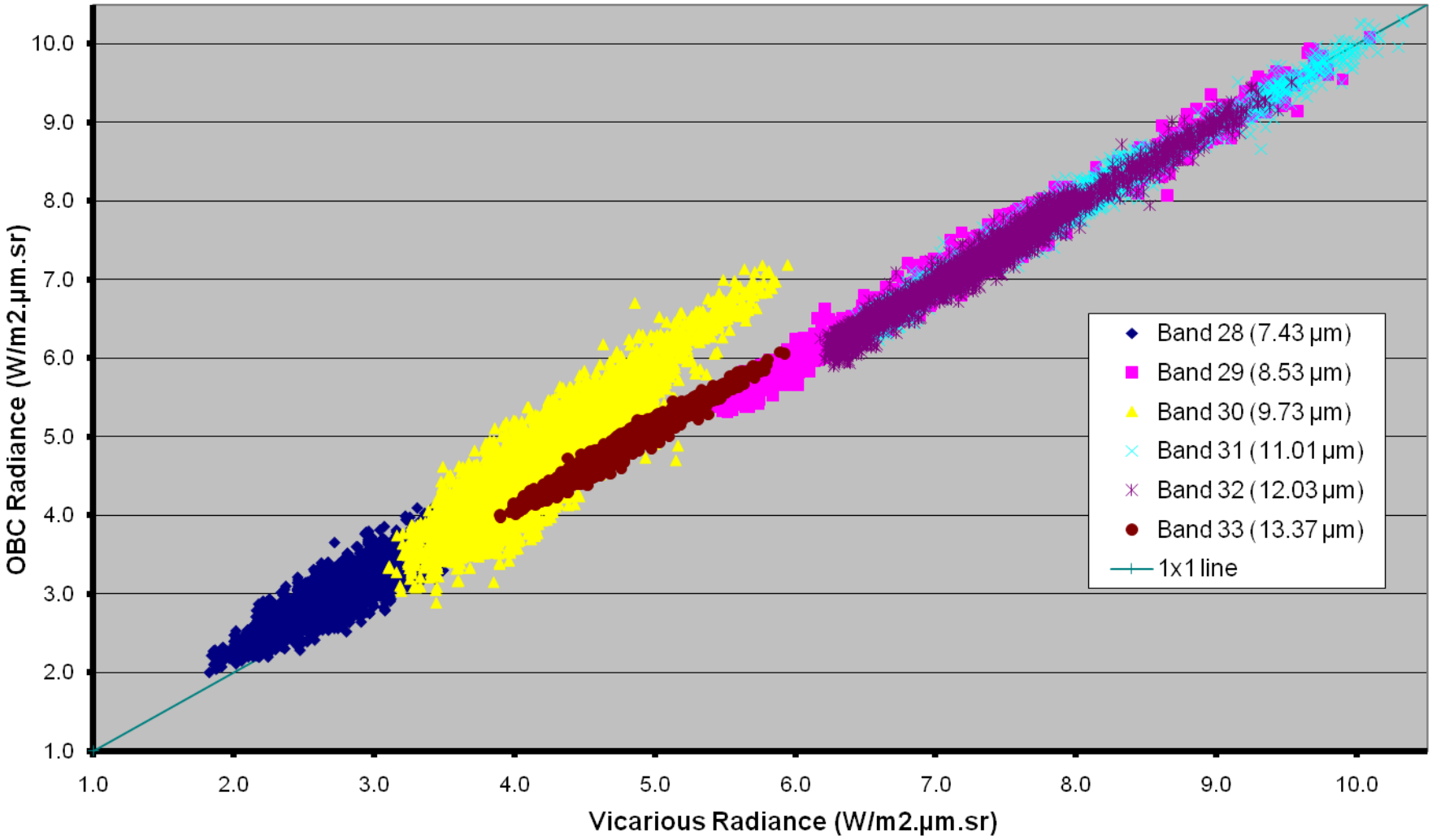
Application	Band	Bandwidth (nm)	SNR
Land/Cloud	1	620-670	128
Boundaries	2	841-876	201
Land/Cloud	3	459-479	243
Properties	4	545-565	228
	5	1230-1250	74
	6	1628-1652	275
	7	2105-2155	110
Ocean Color/	8	405-420	880
Phytoplankton/	9	438-448	838
Biogeochemistry	10	483-493	802
	11	526-536	754
	12	546-556	750
	13	662-672	910
	14	673-683	1087
	15	743-753	586
	16	862-877	516
Atmospheric	17	890-920	167
Water Vapor	18	931-941	57
	19	915-965	250

Application	Band	Bandwith (um)	NEdT
Surface/Cloud	20	3.660-3.840	0.05
Temperature	21	3.929-3.989	2.00
	22	3.929-3.989	0.07
	23	4.020-4.080	0.07
Atmospheric	24	4.433-4.498	0.25
Temperature	25	4.482-4.549	0.25
Cirrus Clouds	26	1.360-1.390	150 (SNR)
Water Vapor	27	6.535-6.895	0.25
	28	7.175-7.475	0.25
	29	8.400-8.700	0.25
Ozone	30	9.580-9.880	0.25
Surface/Cloud	31	10.780-11.280	0.25
Temperature	32	11.770-12.270	0.25
Cloud Top	33	13.185-13.785	0.25
Altitude	34	13.485-13.785	0.25
	35	13.785-14.085	0.25
	36	14.085-14.385	0.35

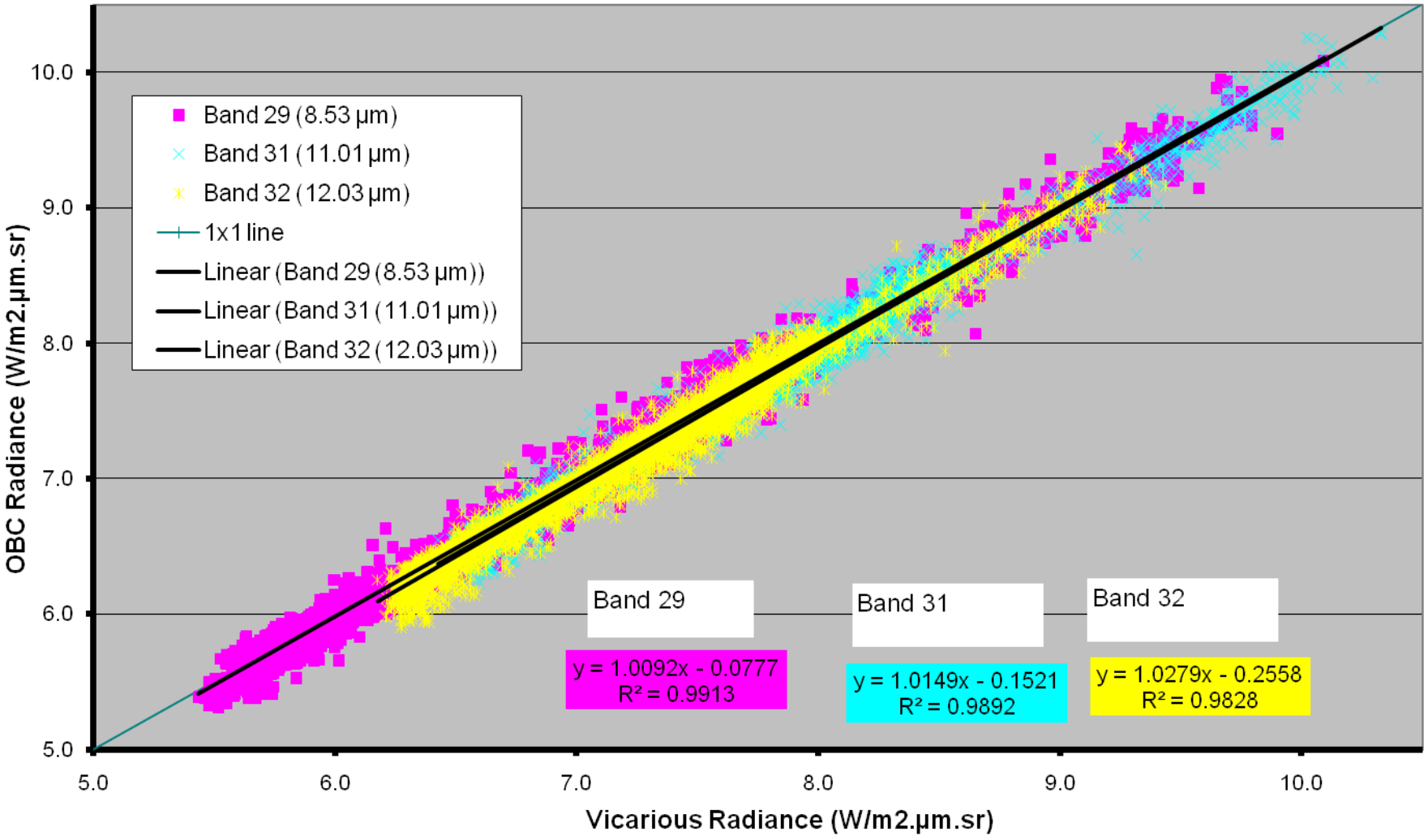
Matchup Count for MODIS Terra at Lake Tahoe and Salton Sea CY2000-2010 v5.x



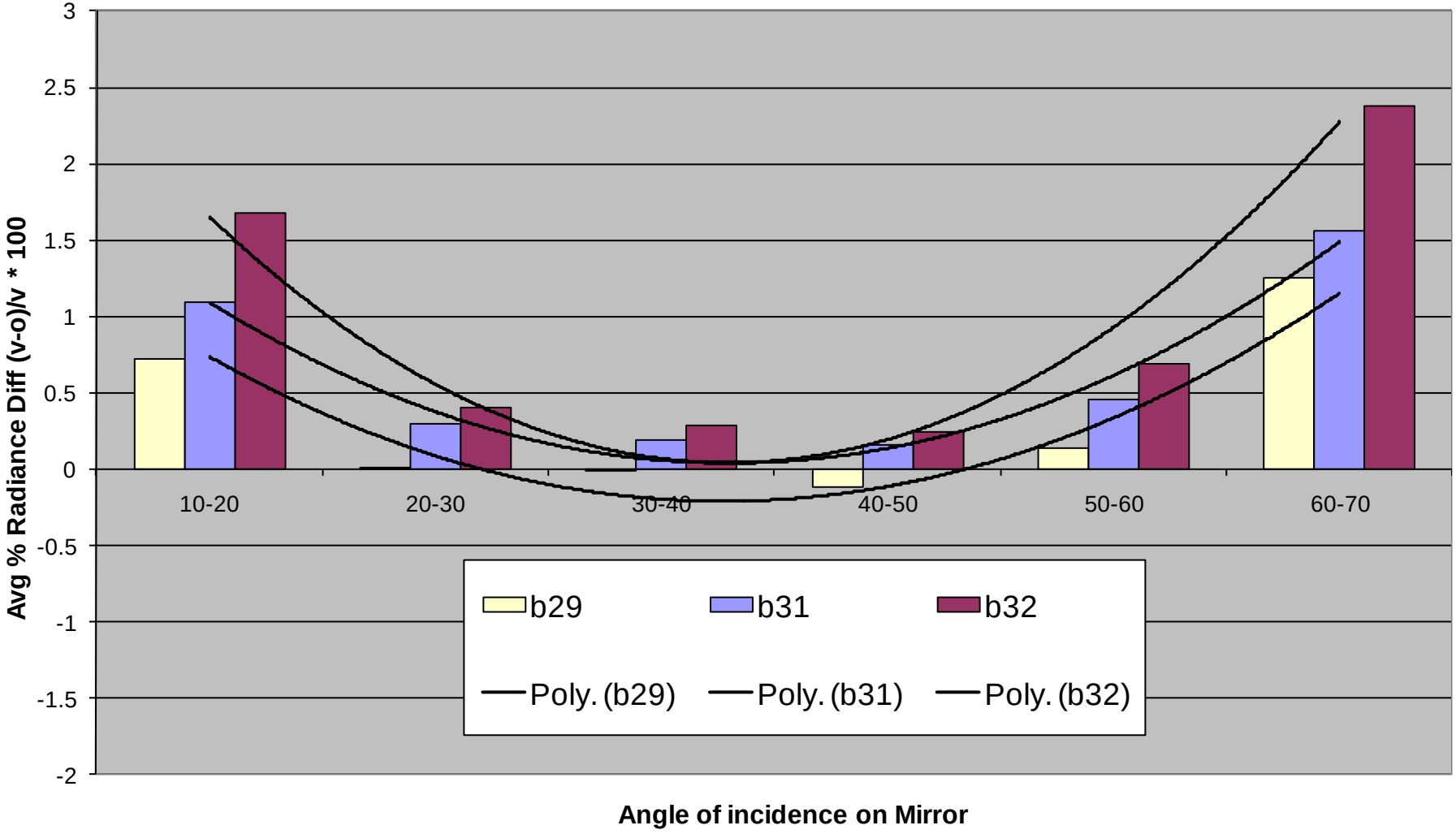
MODIS Terra Vicarious and OBC Thermal Infrared Derived Radiances at Lake Tahoe and Salton Sea CY2000-2010, v5.x



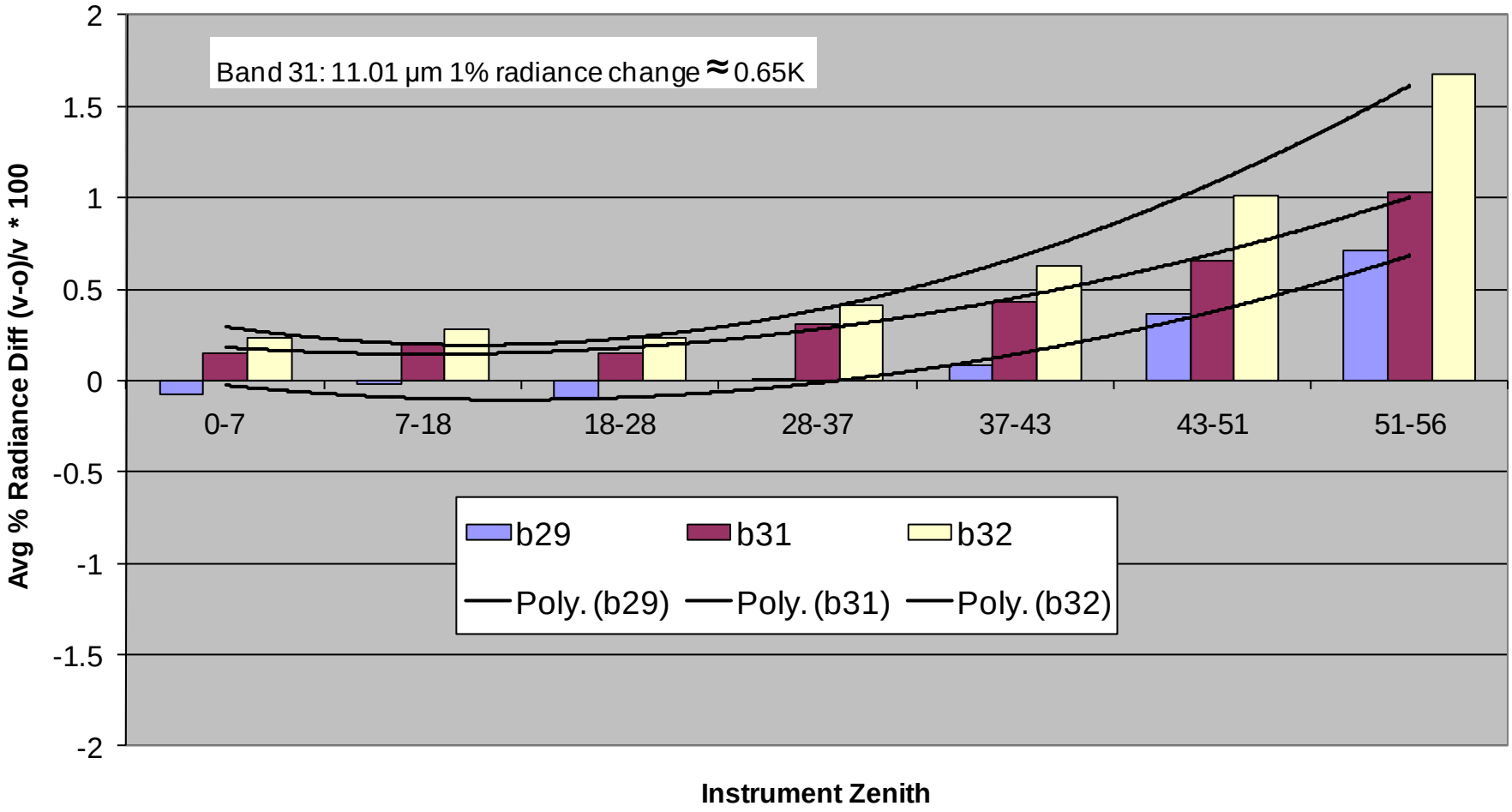
MODIS Terra Vicarious and OBC Thermal Infrared Derived Radiances at Lake Tahoe and Salton Sea CY2000-2010, v5.x



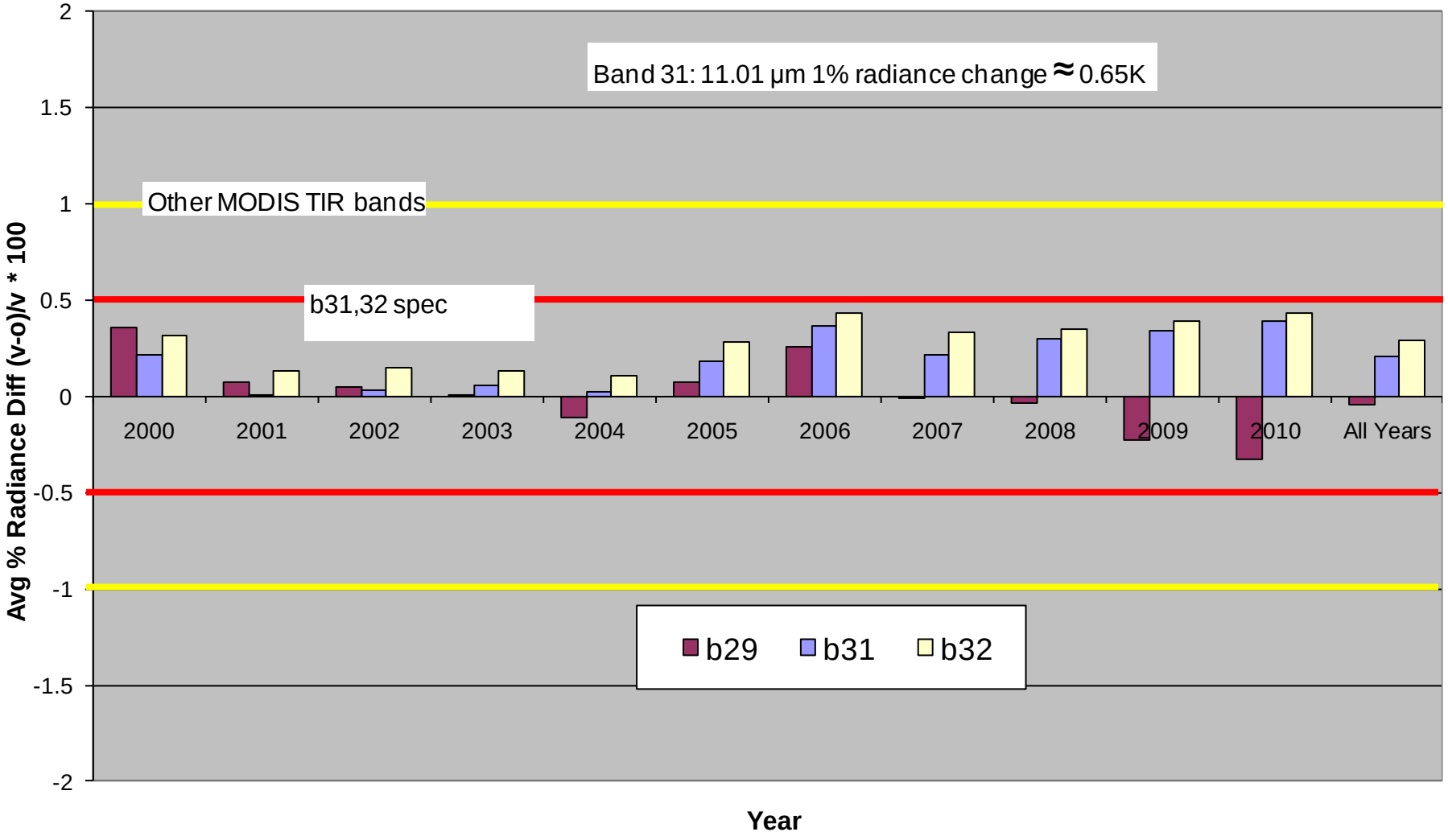
% Radiance Change in TIR Channels for MODIS Terra with Mirror AOI at Lake Tahoe and Salton Sea CY2000-2010 v5.x

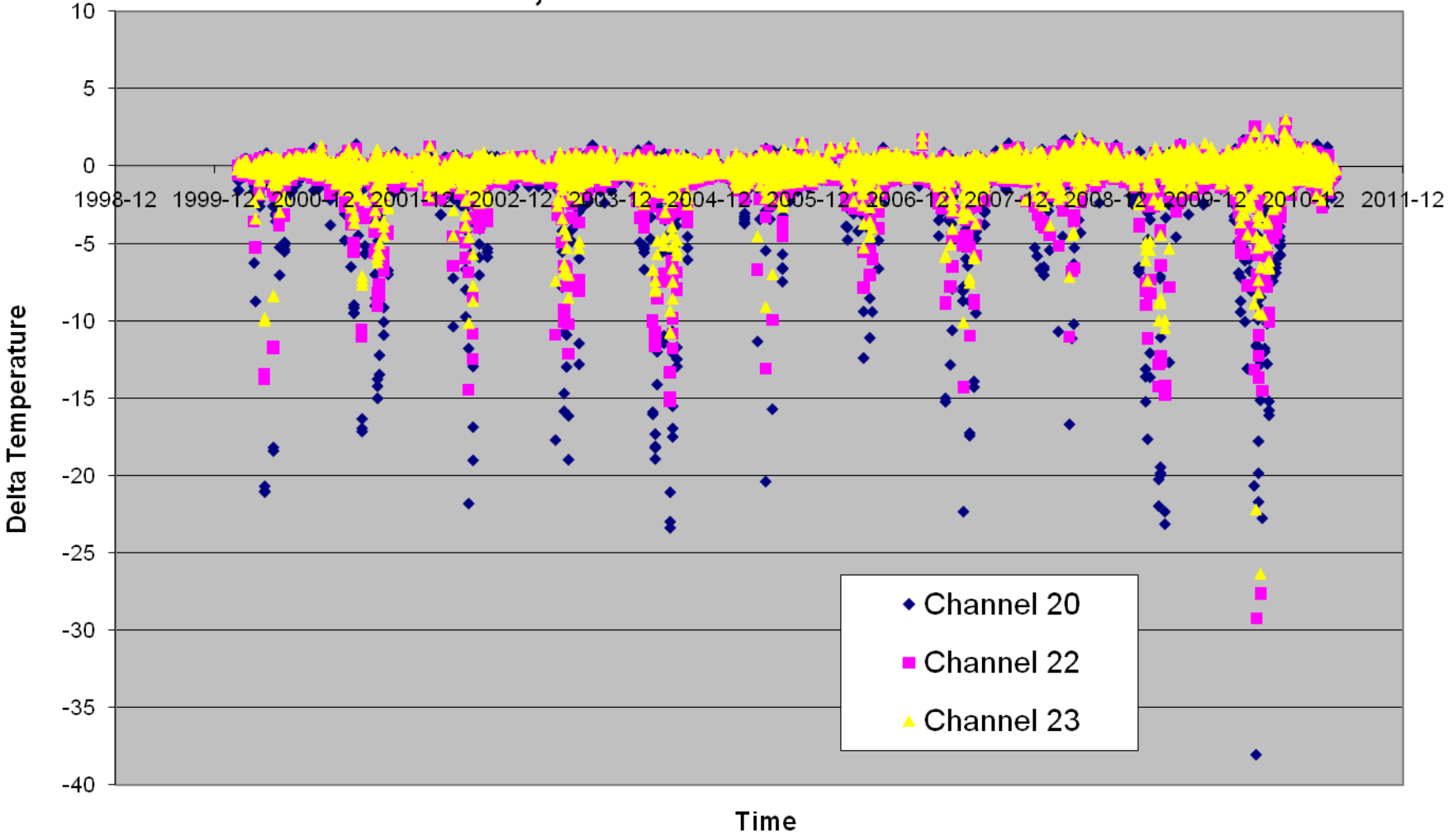


% Radiance Change in TIR Channels for MODIS Terra with Instrument Zenith at Lake Tahoe and Salton Sea CY2000-2010, v5.x

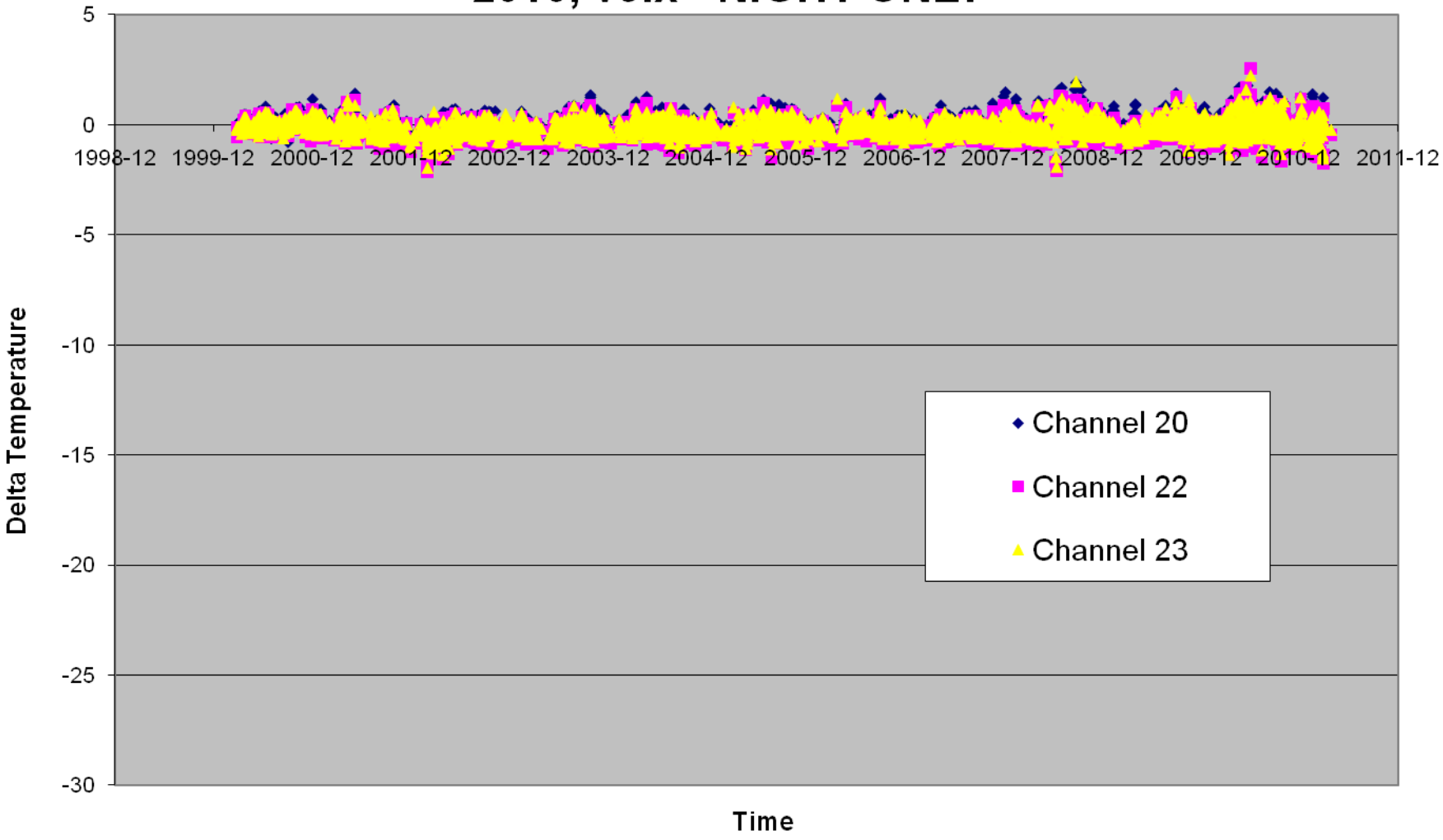


% Radiance Change in TIR Channels for MODIS Terra at Lake Tahoe and Salton Sea CY2000-2010, vz0-30 v5.x

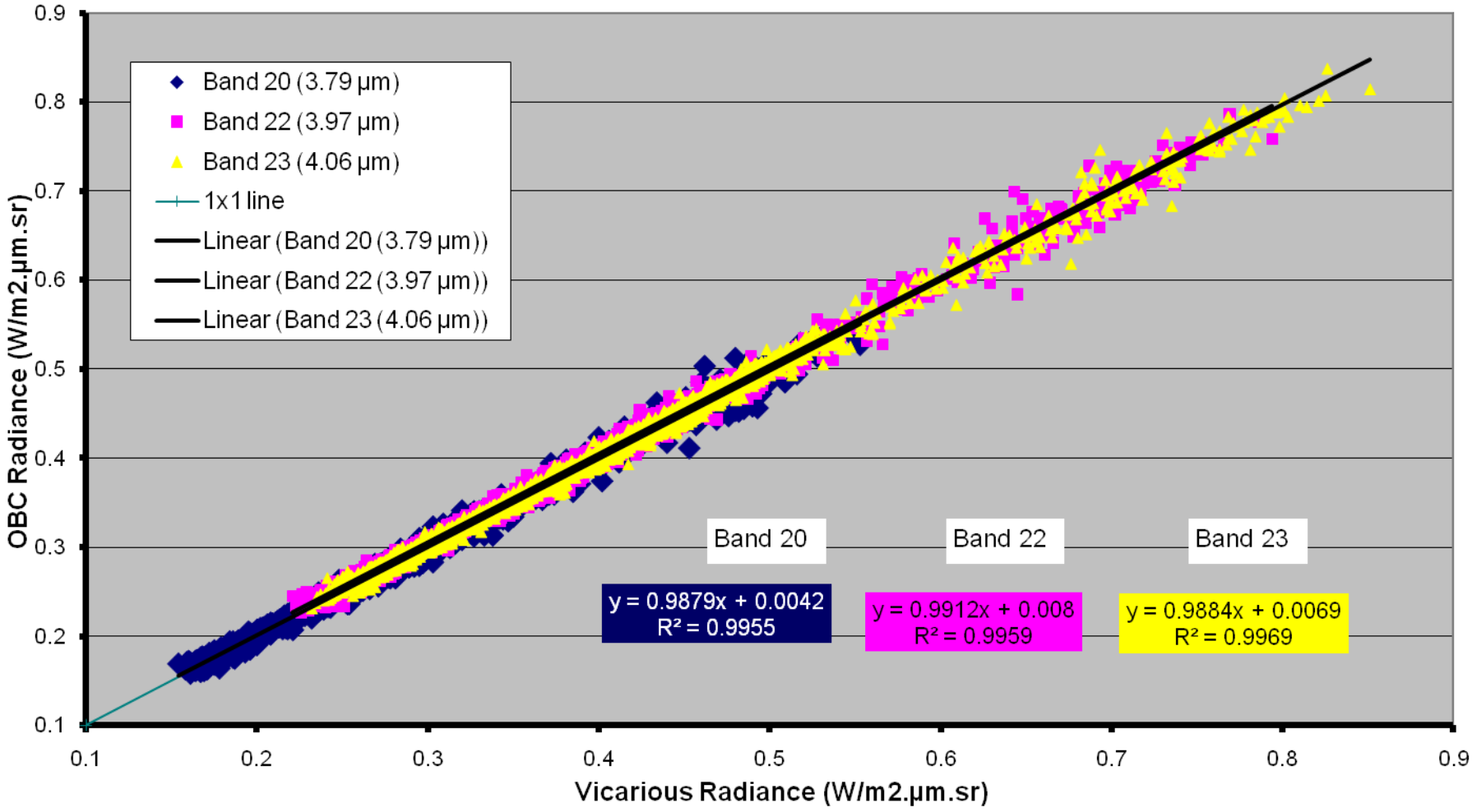



MODIS Terra Mid Infrared Channels Delta Temperature between Vicarious and OBC BT's at Lake Tahoe, 2000-2010, v5.x - DAY AND NIGHT
Delta Temperature
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
1998-12
1999-12
2000-12
2001-12
2002-12
2003-12
2004-12
2005-12
2006-12
2007-12
2008-12
2009-12
2010-12
2011-12
Time
Channel 20
Channel 22
Channel 23

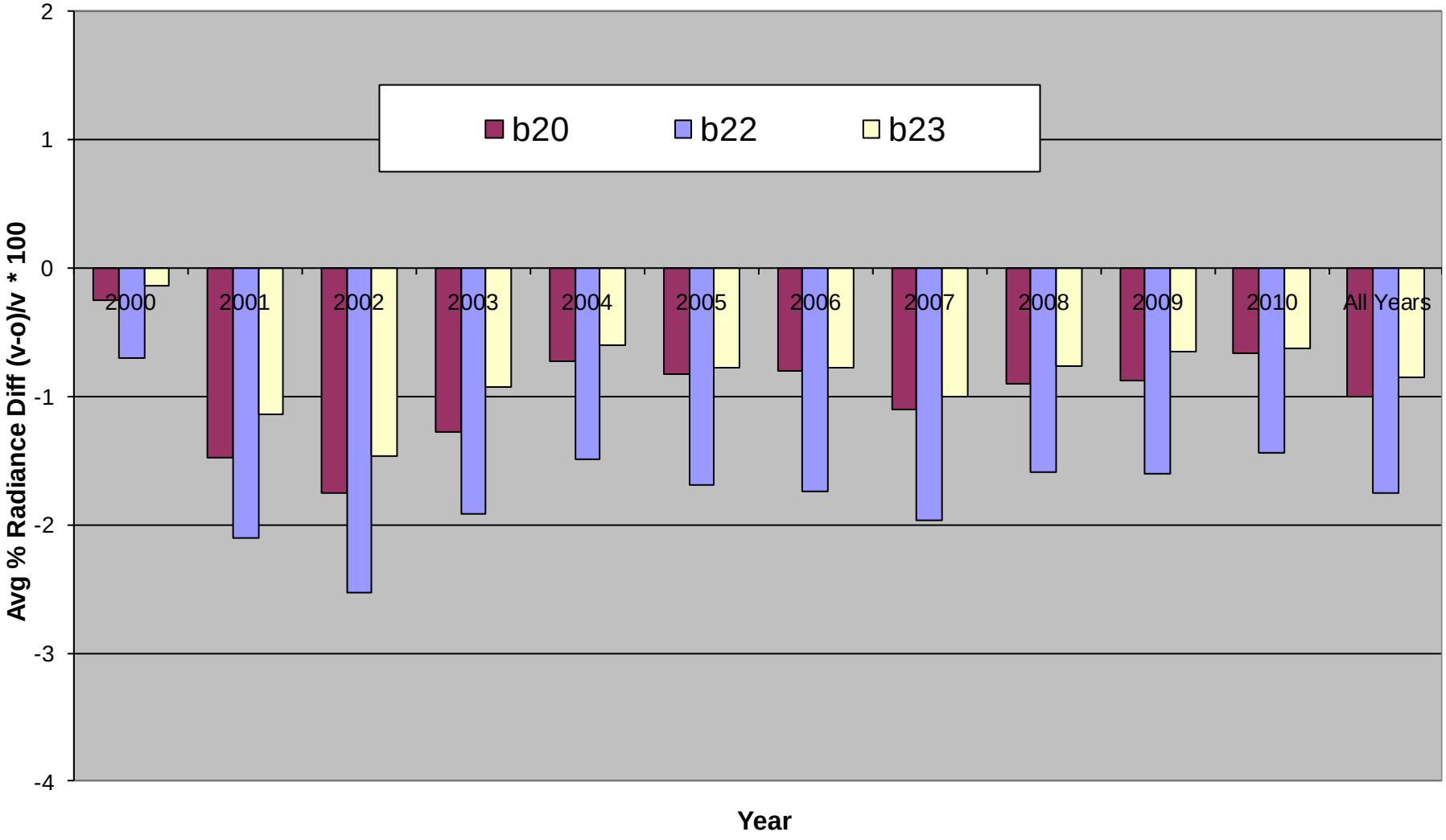
MODIS Terra Mid Infrared Channels Delta Temperature between Vicarious and OBC BT's at Lake Tahoe, 2000-2010, v5.x - NIGHT ONLY



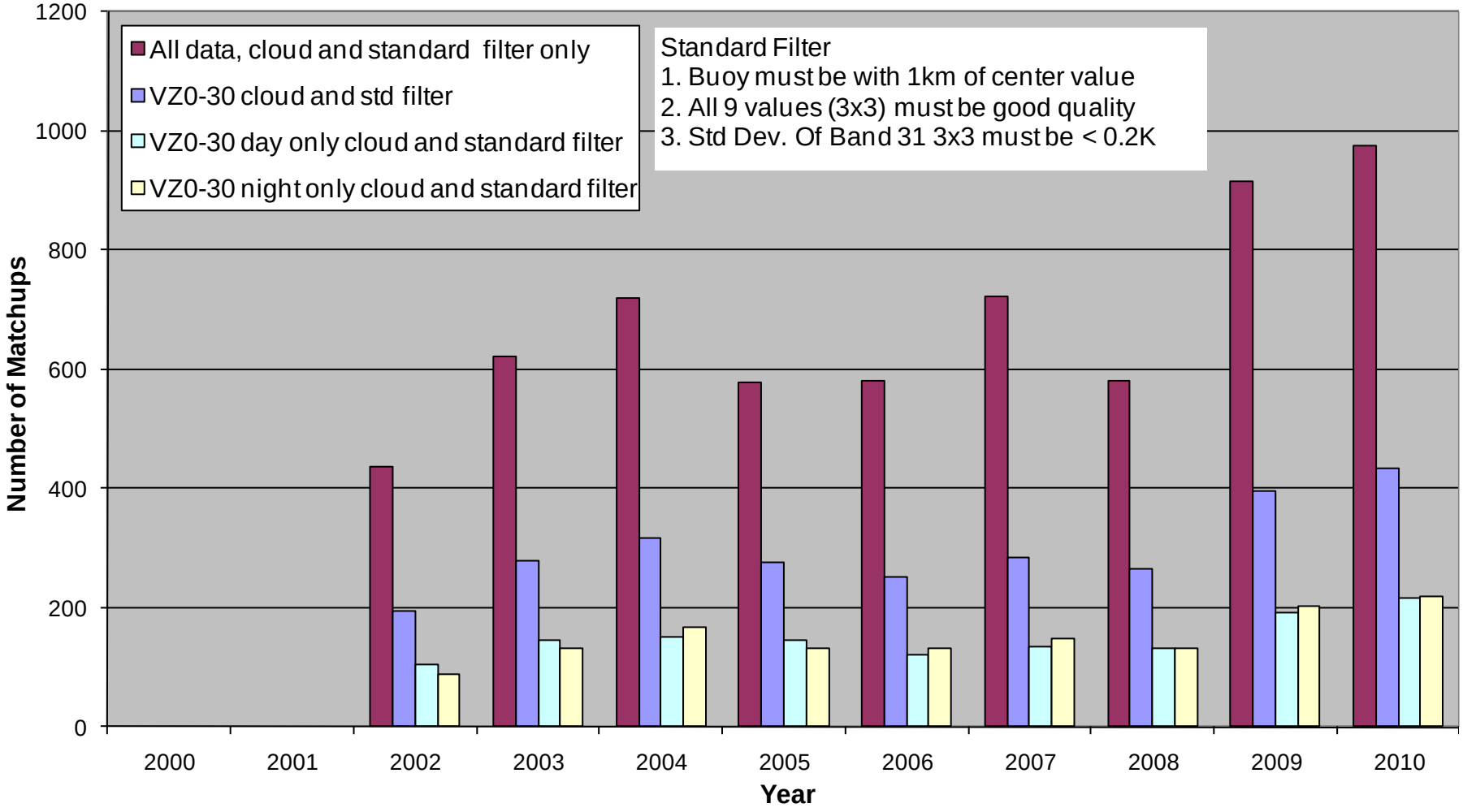
MODIS Terra Night Only Vicarious and OBC Mid Infrared Derived Radiances at Lake Tahoe and Salton Sea CY2000-2010, VZ0-30, v5.x



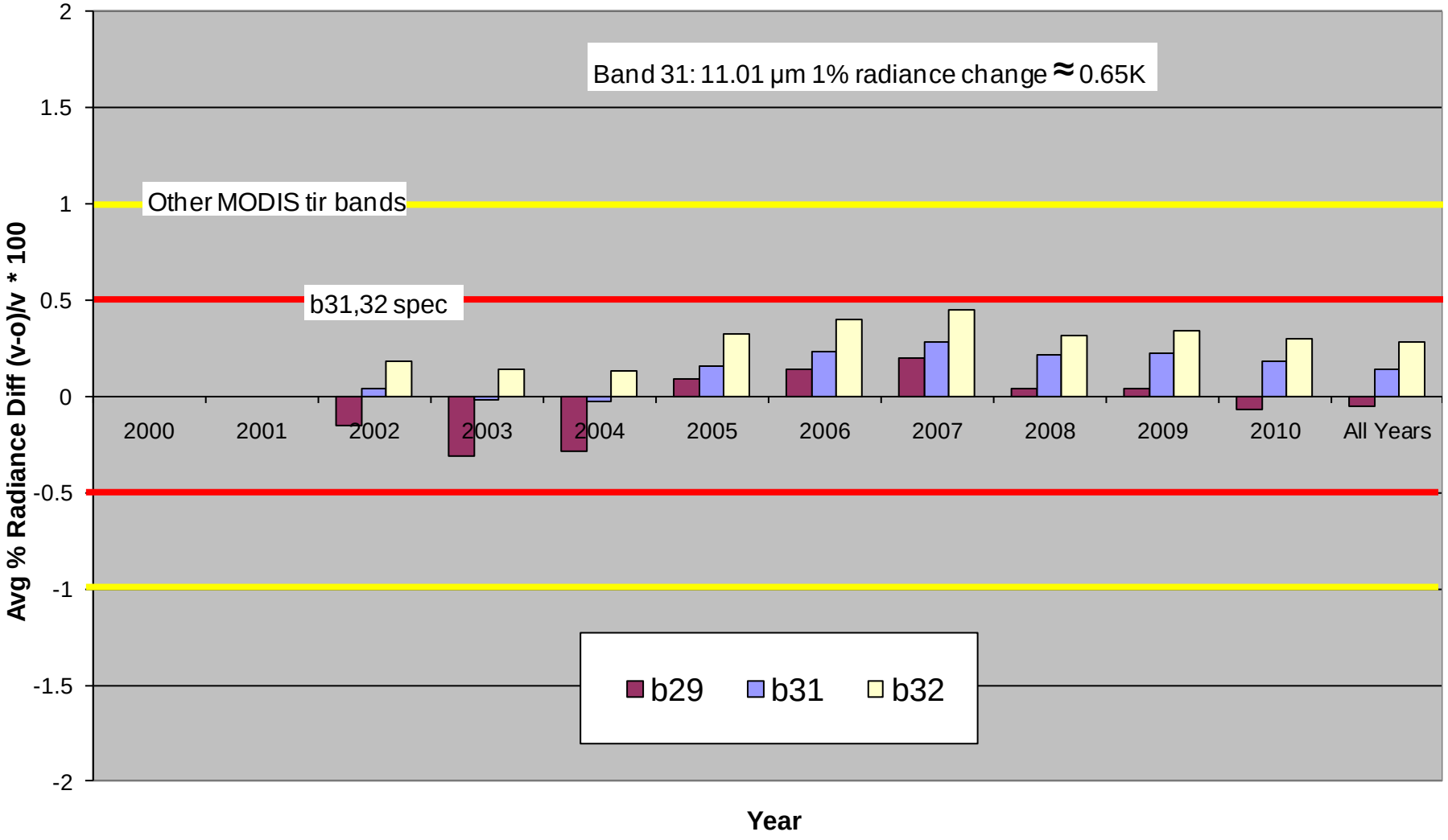
% Radiance Change in MIR Channels for MODIS Terra at Lake Tahoe and Salton Sea CY2000-2010, vz0-30, v5.x



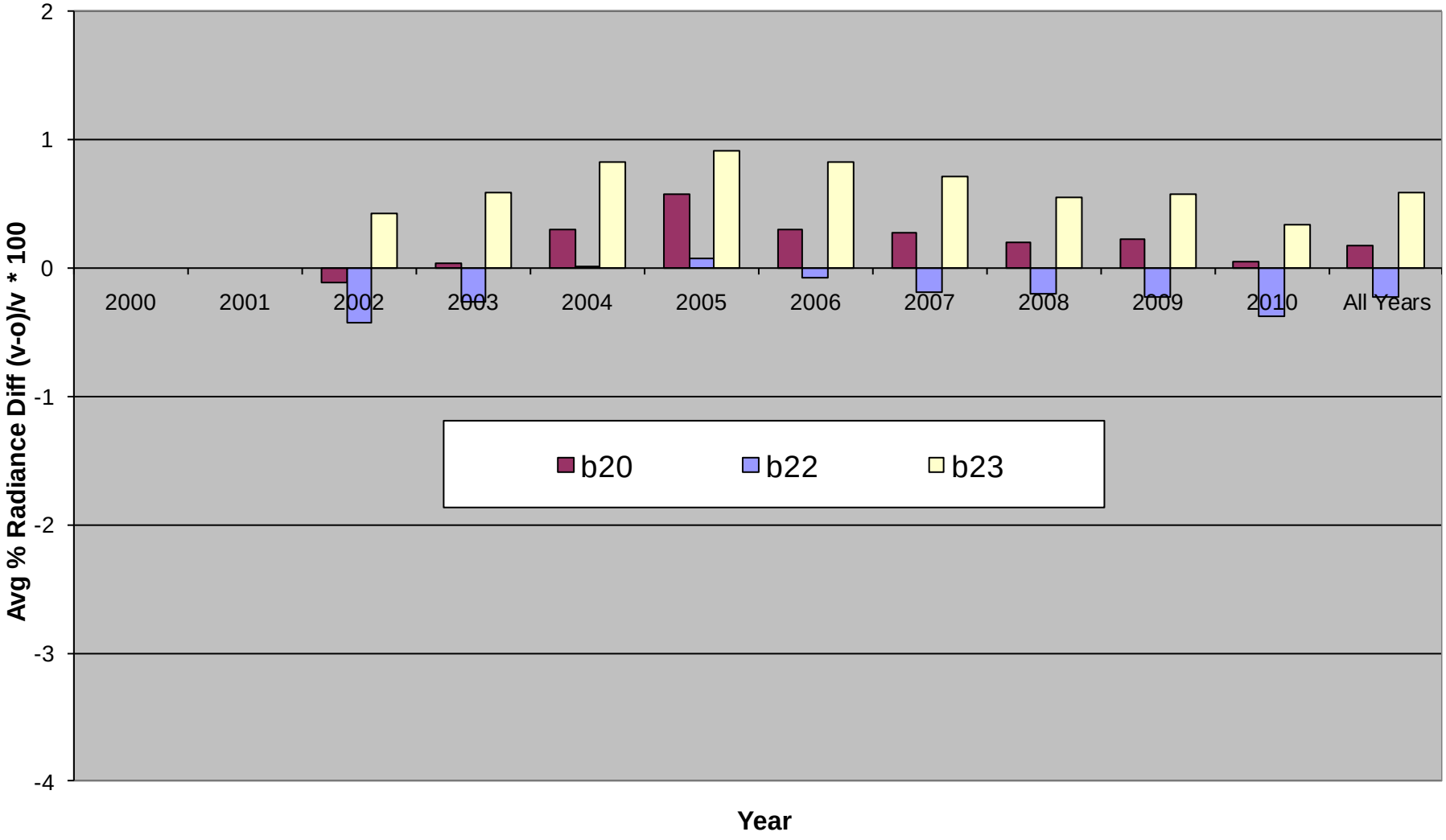
Matchup Count for MODIS Aqua at Lake Tahoe and Salton Sea CY2000-2010 v5.x



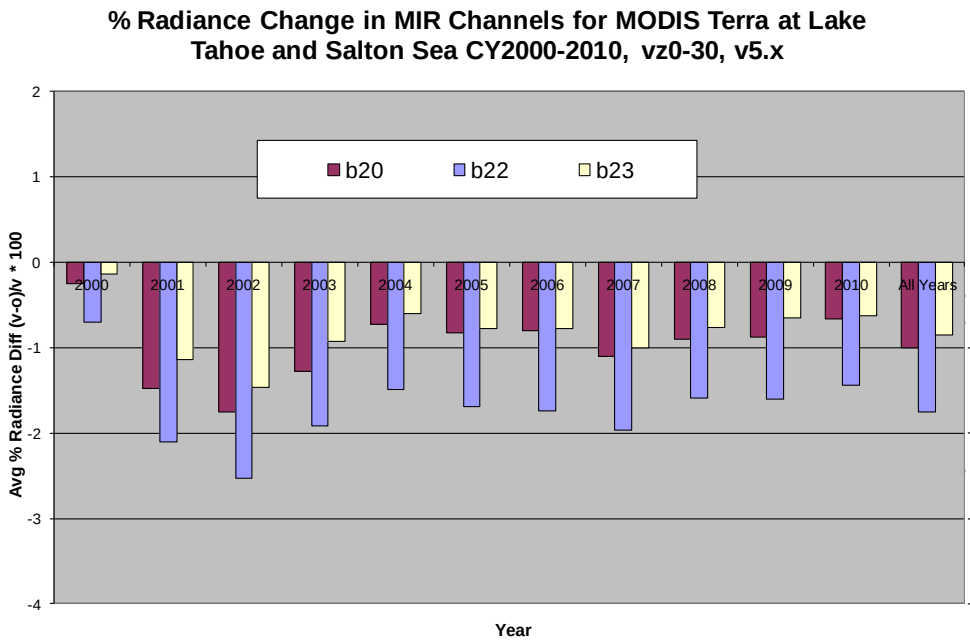
% Radiance Change in TIR Channels for MODIS Aqua at Lake Tahoe and Salton Sea CY2000-2010, vz0-30 v5.x

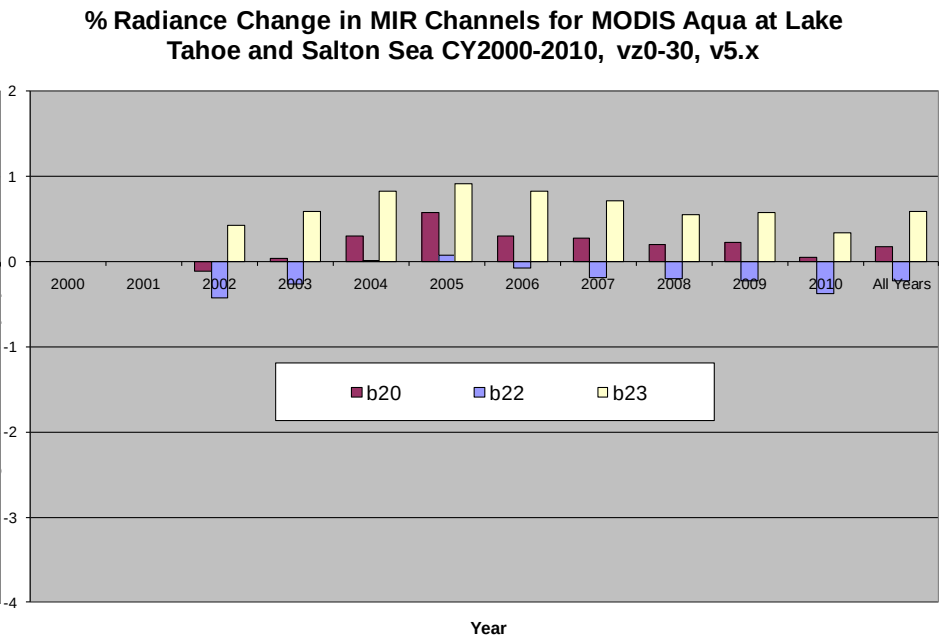


% Radiance Change in MIR Channels for MODIS Aqua at Lake Tahoe and Salton Sea CY2000-2010, vz0-30, v5.x



Difference in MIR bands for Terra and Aqua

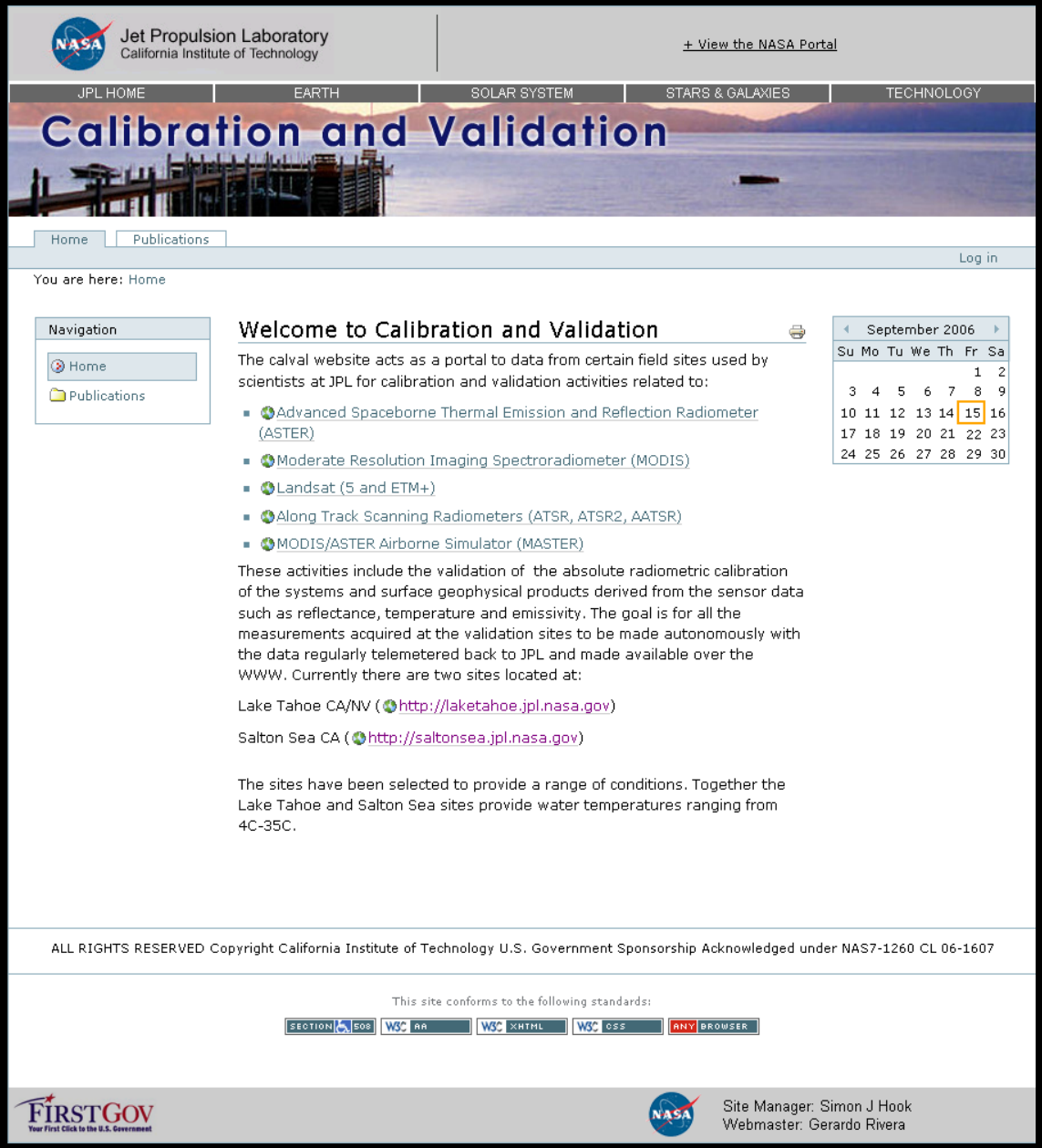




Summary and Conclusions

- 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

http://calval.jpl.nasa.gov



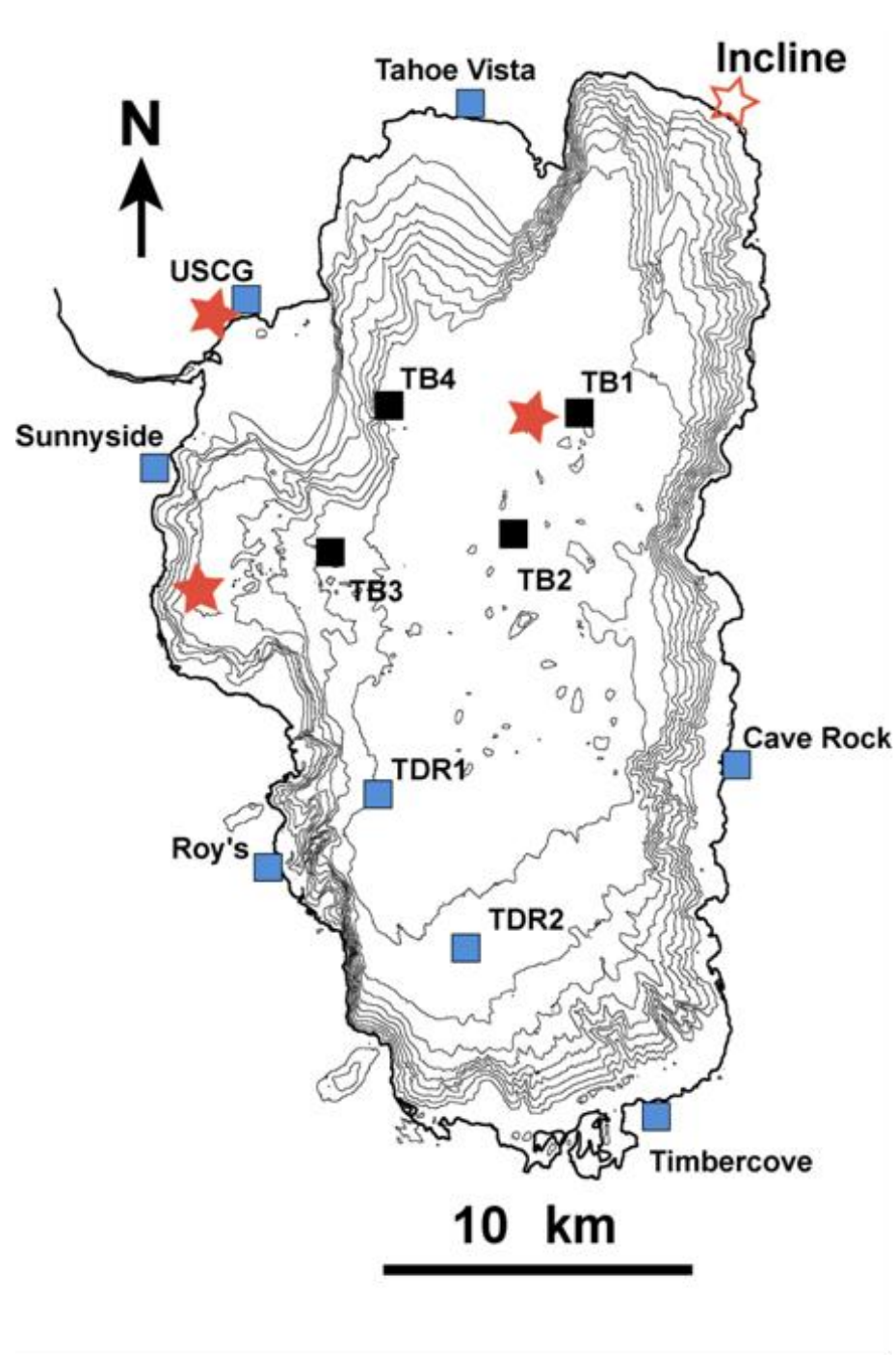
Why Lake Tahoe?

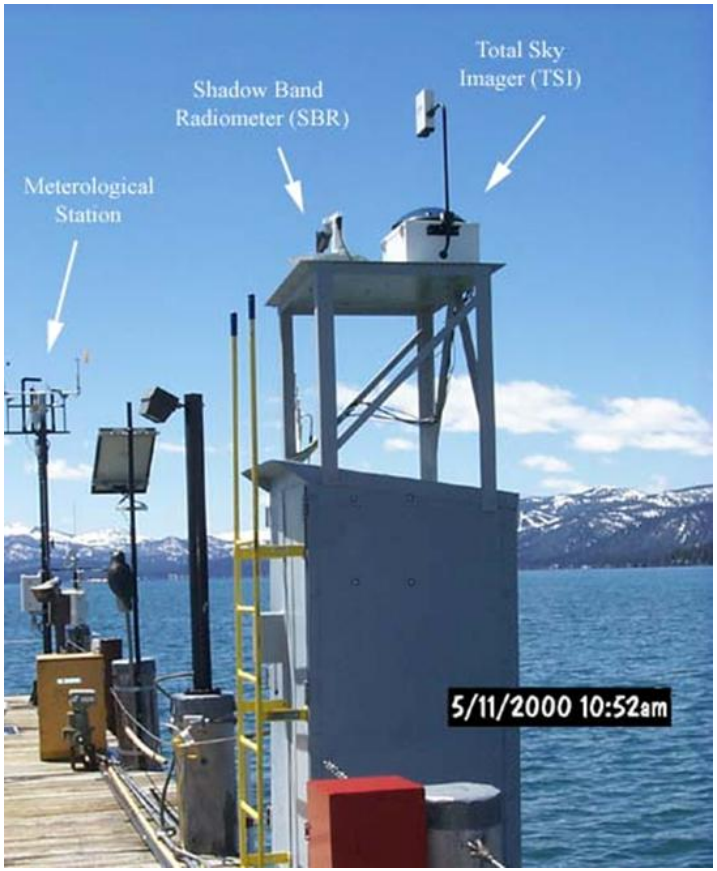
- Large 35 km x 16 km
- High 2 km
- Available year round (does not freeze in winter).
- Homogenous compared with land.
- Large annual temperature range 5-25 C.
- Freshwater (kind to instruments!)
- Good infrastructure and easy access.

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

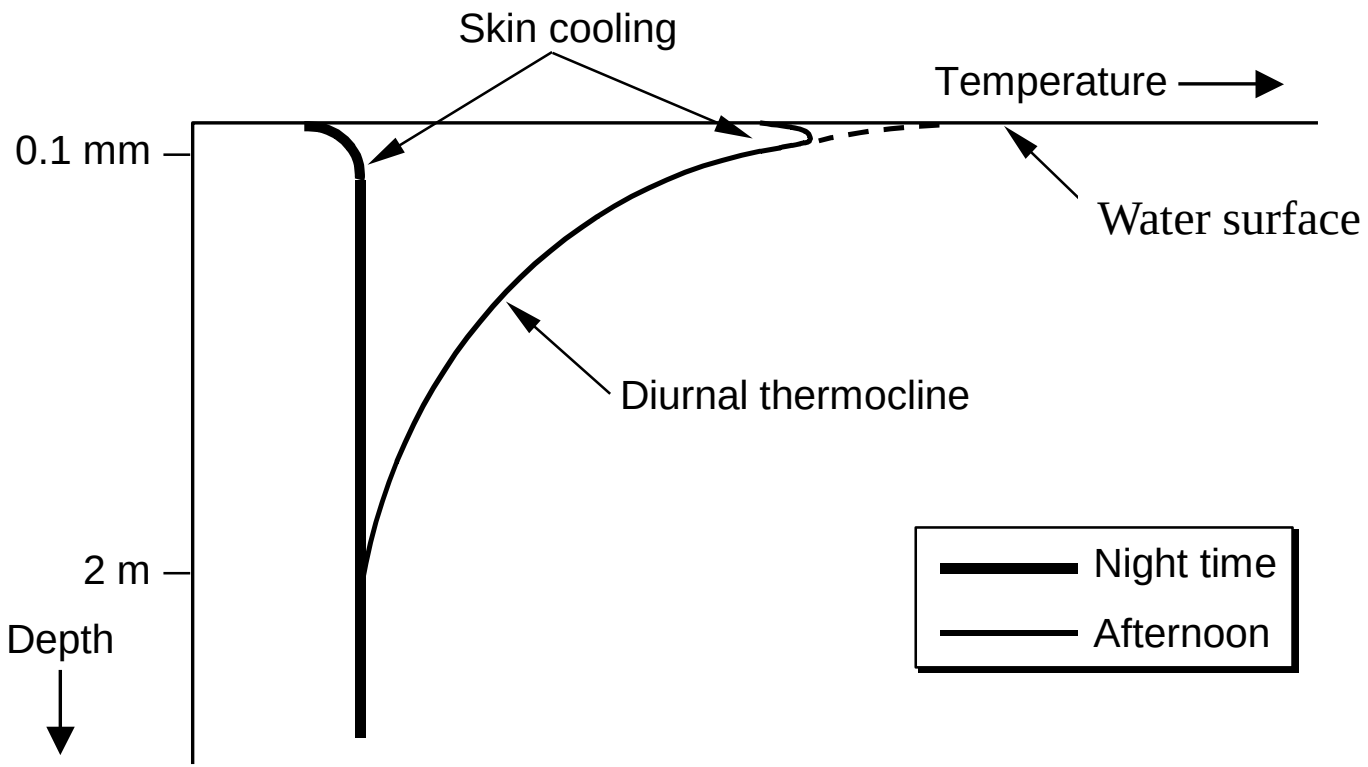




Data Reduction: Methodology For Radiance at Sensor Validation

- 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