Jet Propulsion Laboratory
California Institute of Technology

VALIDATION OF THERMAL INFRARED SATELLITE MEASUREMENTS USING AUTOMATED VALIDATION SITES

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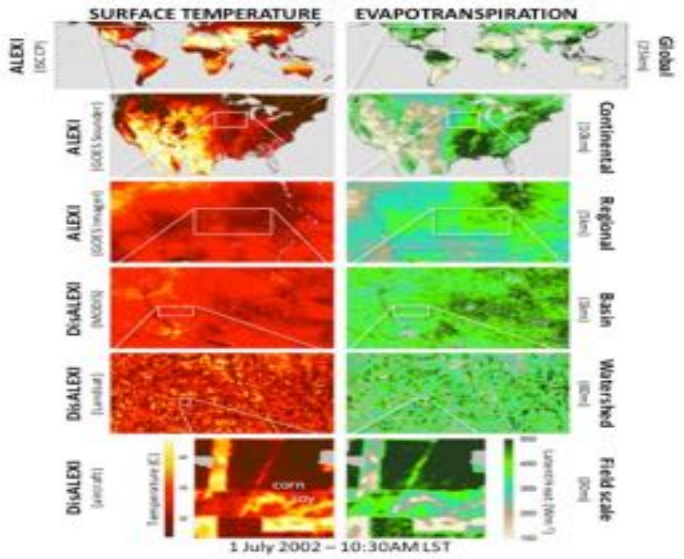
Outline

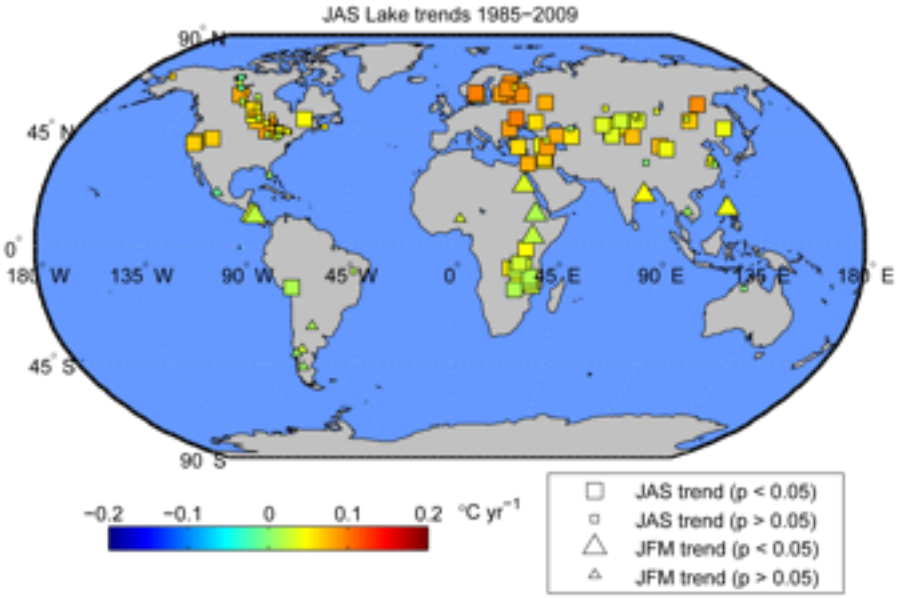
- Motivation
- Validation Methodologies
- Sites Descriptions
- Lab Calibration and JPL Radiometers
- Example Results
- Future Sites
- Summary and Conclusions

Earth Science Use of LST&E

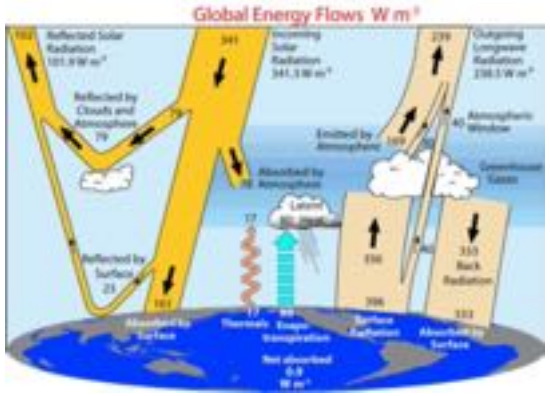
Evapotranspiration (drought monitoring)



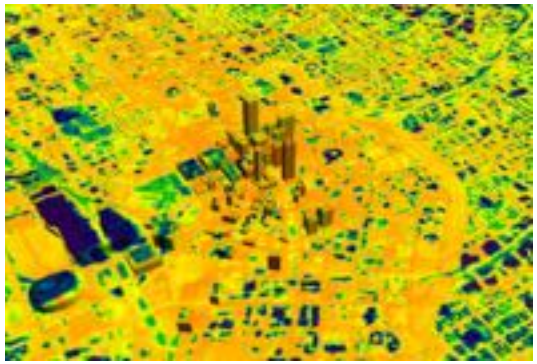
Understanding Climate Change



Surface Energy Balance Models



Urban Heat Island Studies



Validation Methodologies

- Two methods:
  - Absolute - Temperature validation (Tval) – measure the temperature at the same time as the overpass and either forward calculate and compare with the radiance at sensor or compare directly with temperature retrieved by the satellite
  - Relative - Radiance validation (Rval) – measure the emissivity and the atmospheric profile independently. Forward calculate the ground temperature needed to match the at-sensor radiance and compare to retrieved temperature.

Method	Requirements	Advantages	Disadvantages
T-val	Accurate radiometer measurement(s) at the same time of overpass	Direct comparison Can also be used to validate calibration of sensor	Requires in situ measurement at time of overpass Difficult to perform over targets where temperatures vary rapidly over short distances
R-val	Surface emissivity measurement (not coincident with overpass) Atmospheric profile at the time over overpass	Does not require in situ emissivity measurement at time of overpass	Requires atmospheric profile at time of overpass Requires surface emissivity measurement Indirect measurement cannot be used to validate calibration of sensor

Both approaches are typically used over homogenous targets (either in temperature or emissivity)

JPL Long Term Validation Sites

Lake Tahoe Buoys

UC Berkeley,
Tonzi Ranch Tower

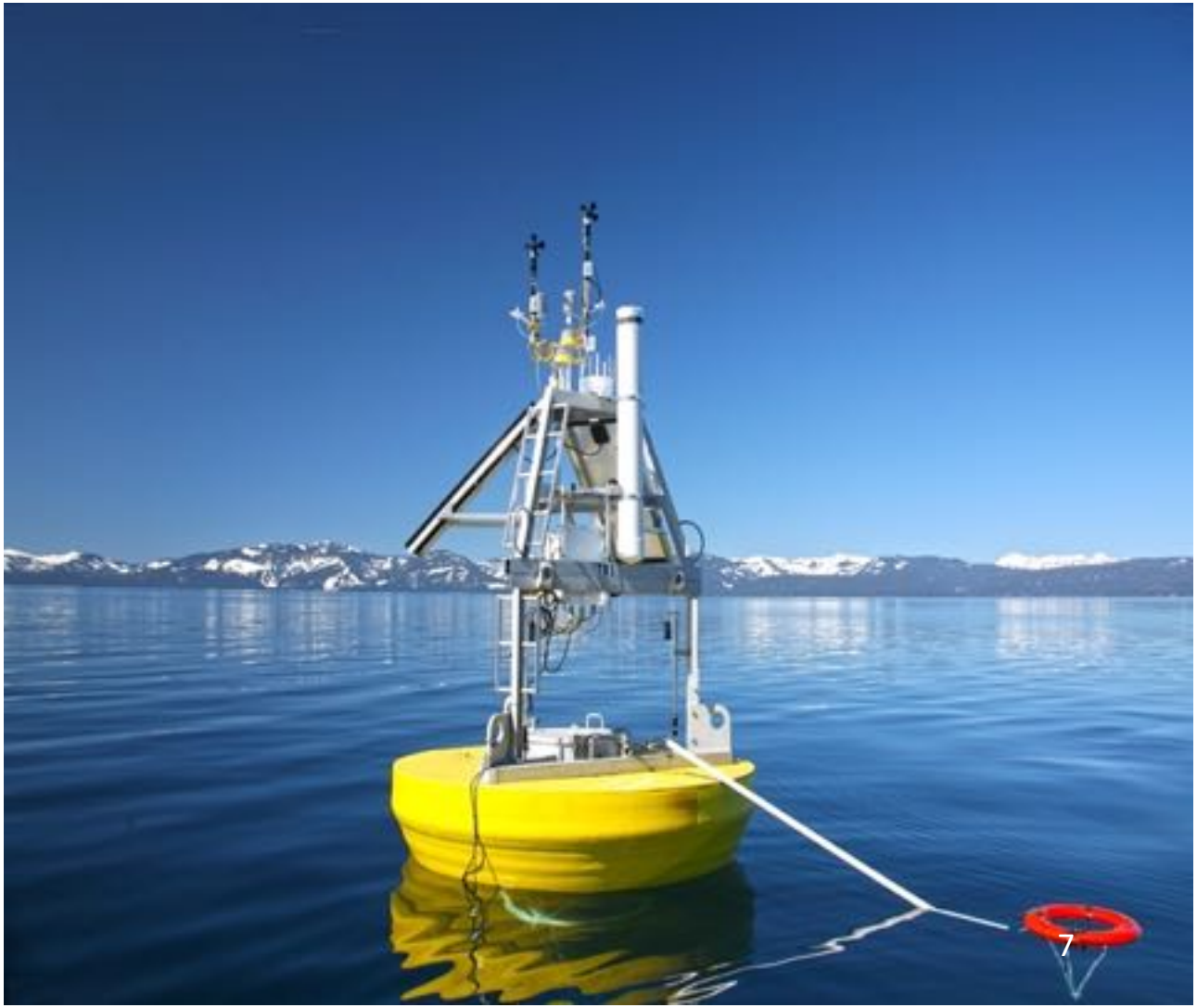
UC Davis,
Russell Ranch

Salton Sea Platform

Credit GoogleMaps

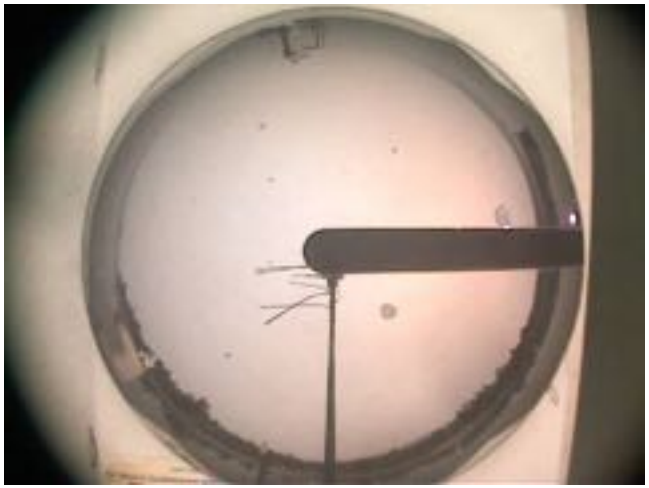
Lake Tahoe Buoys

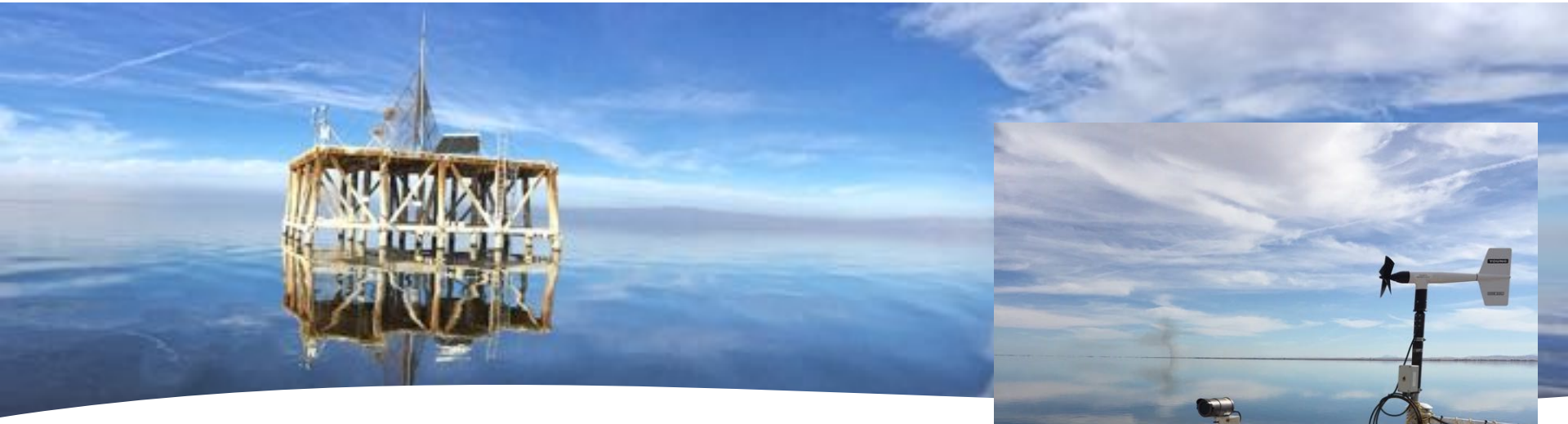
- Lake Tahoe 470 meters deep at lowest point, average 330 meters
- North America's high altitude natural lake – 6224 feet (1897 m)
- Collecting water skin temperature
- Four buoys deployed with:
  - JPL Radiometer
  - Heitronics KT-15.85
  - 2 - MET stations
  - RBR Thermistor chain to 0.5 – 5.5 meters
  - Onset temperature loggers
  - 2 - Kipp & Zonen CNR4 Net Radiometers
  - Garmin GPS
  - UC Davis instruments – Snow measurements, etc.



Lake Tahoe Instruments - US Coast Guard

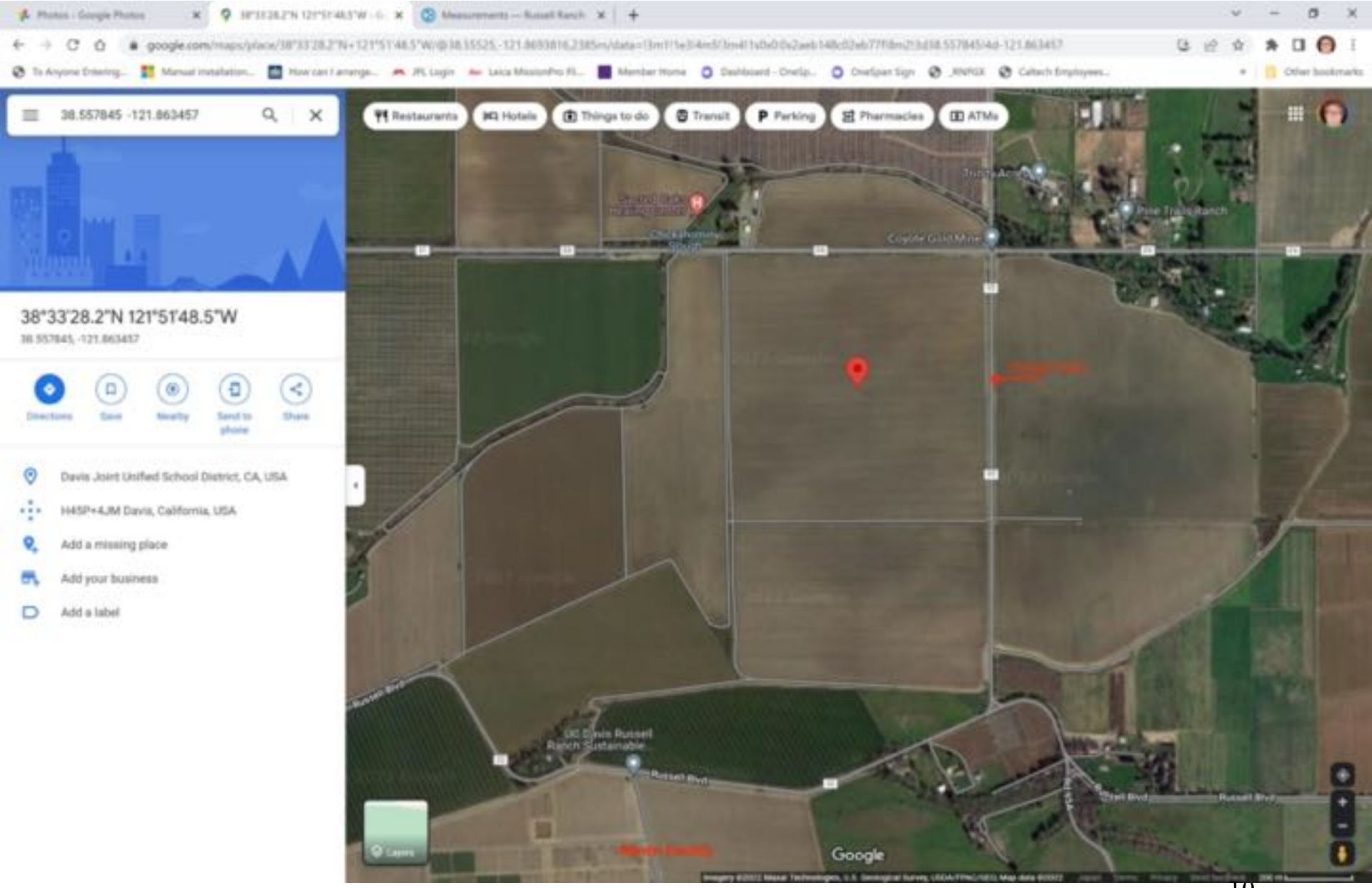
- Rotating Shadowband Radiometer
  - Global, diffuse and direct components of solar irradiance at up to seven wavelengths
- Total Sky Imager
  - Takes an image every 5 minutes
  - Provides clouds cover percentage





Salton Sea Platform

- Harsh environment – Summer temperatures over 40 degrees C
- Depth of water – 50 feet (15.2m) deepest point and at platform 25 feet (7.6 m)
- 2 - JPL Radiometer
- 2 - MET stations
- Camera – Picture every hour
- Onset temperature loggers
- Kipp & Zonen CNR4 Net Radiometers


38.557845 -121.863457
38°33'28.2"N 121°51'48.5"W
38.557845, -121.863457
Directions
Save
Nearby
Send to phone
Share
Davis Joint Unified School District, CA, USA
H45P+4JM Davis, California, USA
Add a missing place
Add your business
Add a label
Restaurants
Hotels
Things to do
Transit
Parking
Pharmacies
ATMs
Pine Trails Ranch
Coyote Gold Mine
Russell Blvd
Google

UC Davis, Russell Ranch

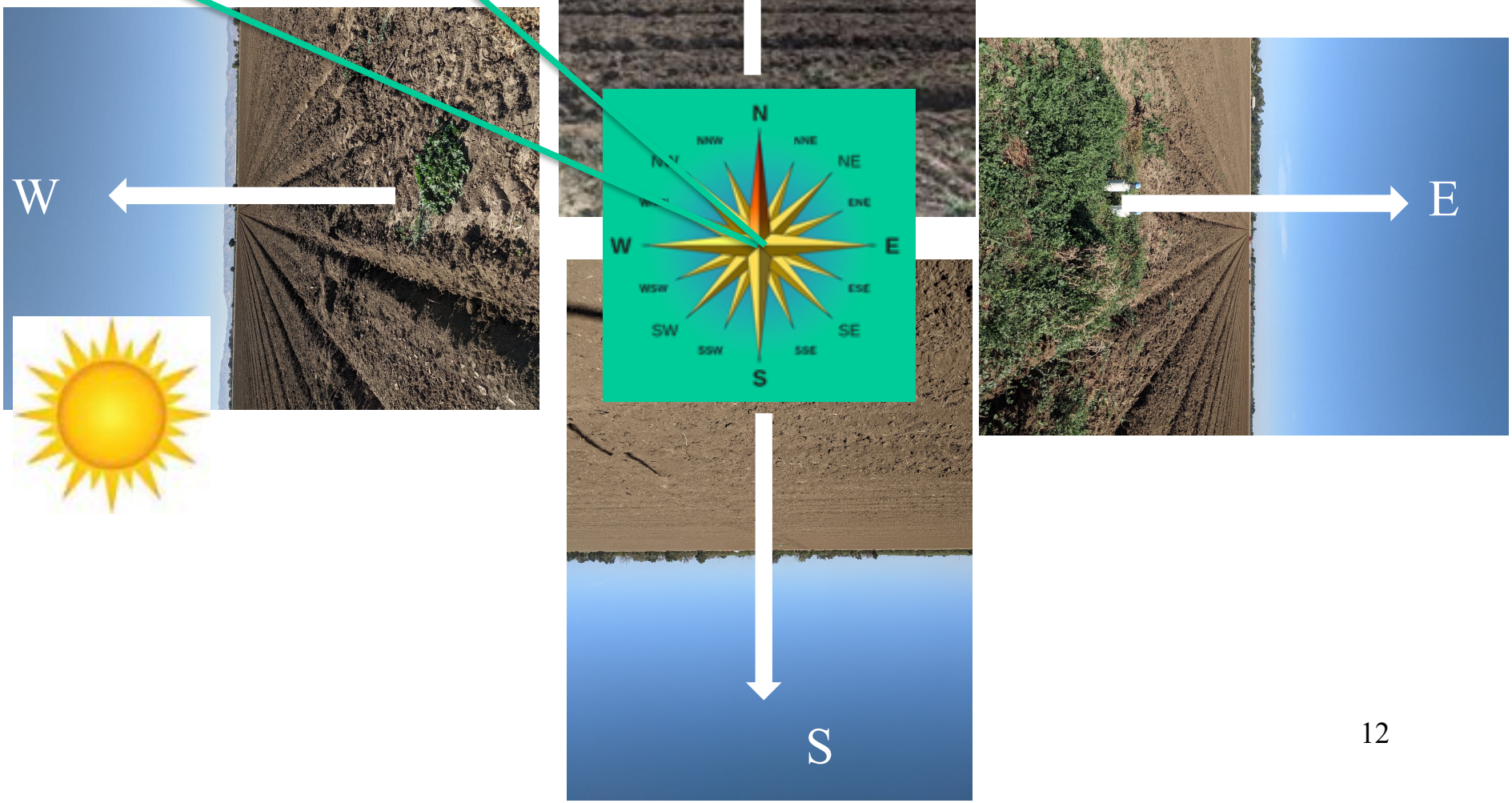
- Part of UC Davis Agricultural Research Facility
- Growing homogenous crops starting in spring until harvest late summer
- Provides Land Surface Temperature readings
- Tower deployed with:
  - 2 - JPL Radiometer pointing at two different areas
  - 2 - MET stations
  - 2- Photosynthetically Active Radiation (PAR) sensors
  - 2 - Kipp & Zonen CNR4 Net Radiometers
  - Eddy Covariance system – ET measurements
  - Camera to view crop coverage

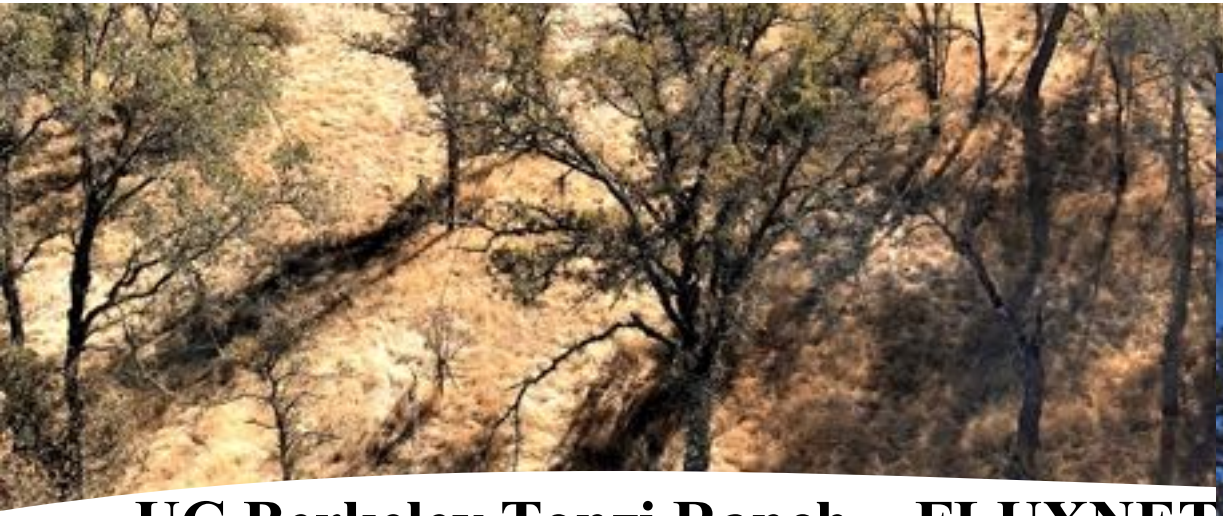
Russell Ranch CA

October 9, 2022
2:30 pm local time

Rad-2

Rad-1



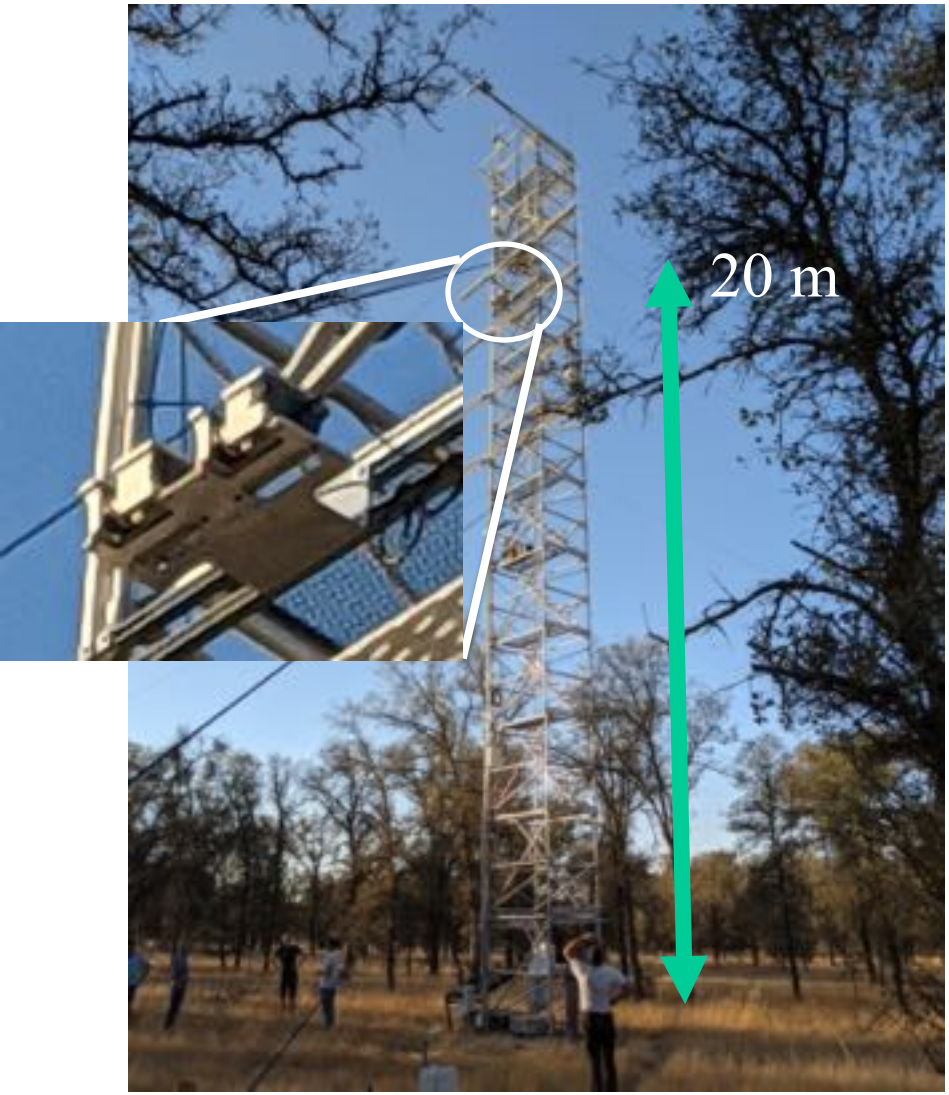


UC Berkeley Tonzi Ranch – FLUXNET tower

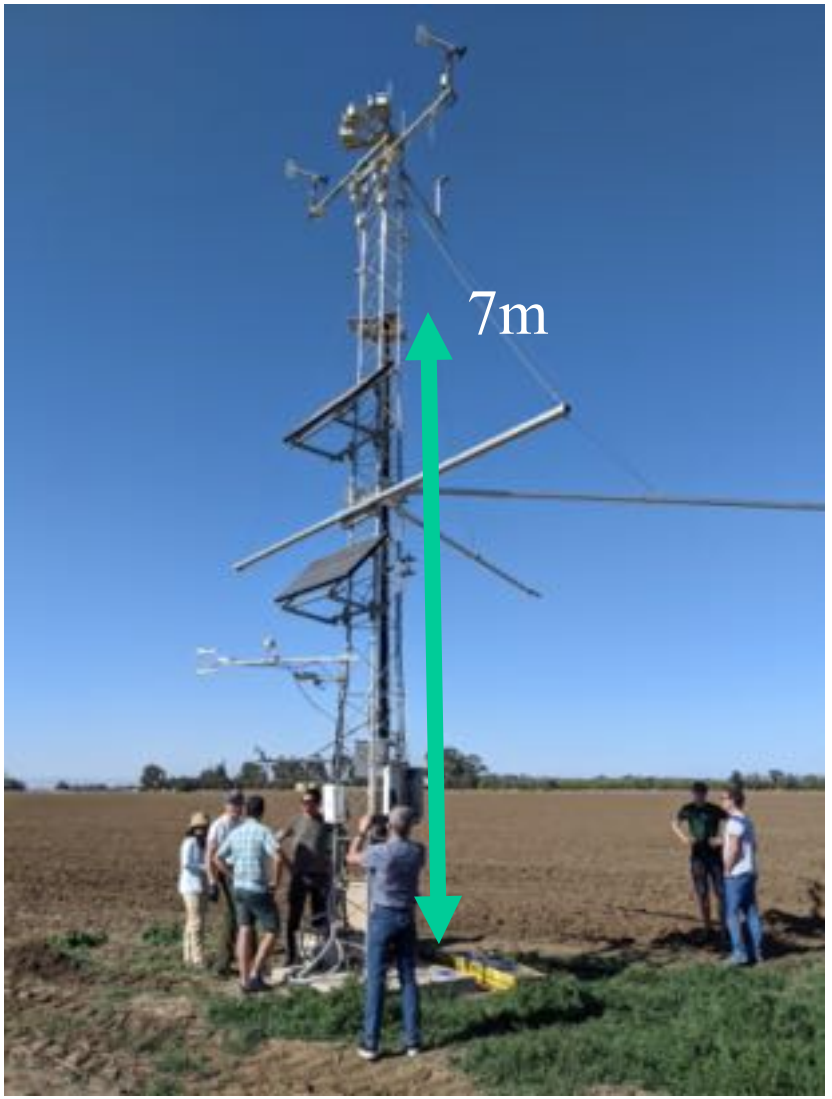
- 100 ft (~30 m) Tower managed by UC Berkeley
  - PI: Dr. Dennis Baldocchi
  - Part of AmeriFlux Network located in Ione, Calif.
  - Composed of: Oak Trees/Grass Savanna, grasslands
- Tower deployed with:
  - 2 - JPL Radiometer observing same area from 70 feet
  - Visible/NDVI Camera

Ecosystem Validation Sites

Tonzi Ranch Site

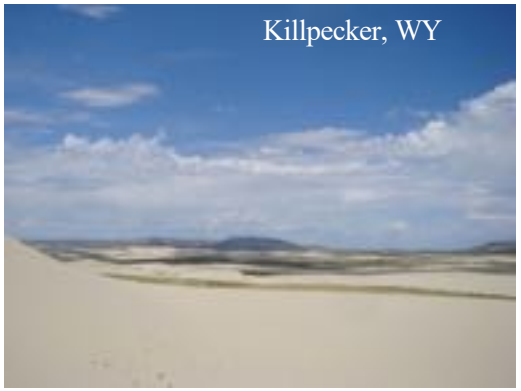


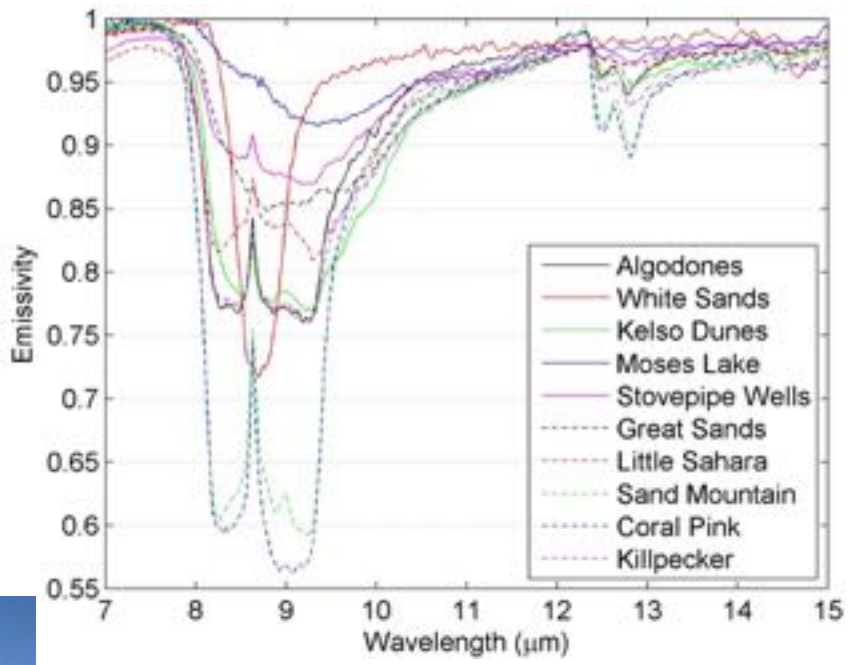
Russell Ranch Site

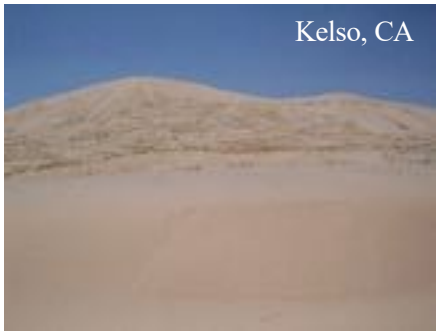


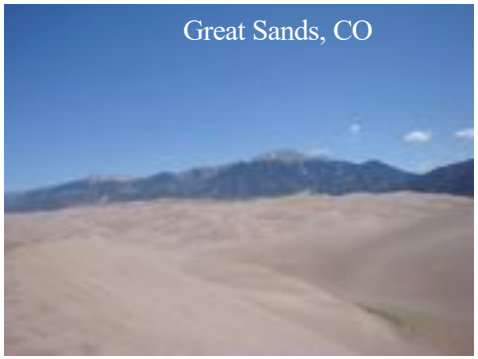
https://calval.jpl.nasa.gov

Pseudo-invariant sand dune validation sites









Monitoring and Lab Calibration

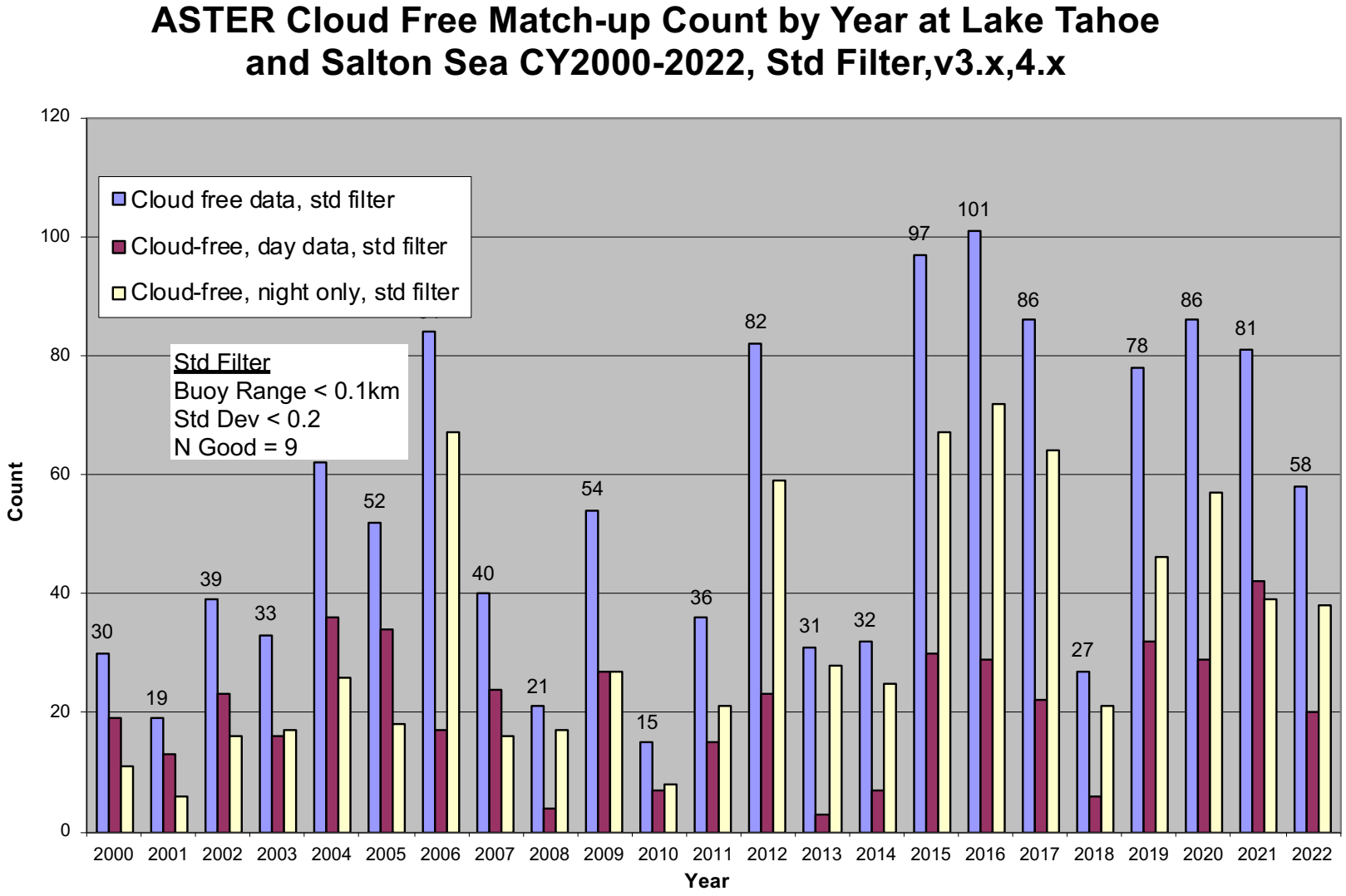
- Monitoring of sites remotely
  - Monday/Wednesday/Friday morning reports on Lake Tahoe, Salton Sea and Russell Ranch
  - Manual monitoring of Tonzi Ranch
- Lab Calibration
  - Two blackbody water baths + Chamber - Rads
  - Calibrated Chubb measures liquid of bath
  - Separate water bath for Onset logger Cal
- Outside Calibration
  - RBR Global performs calibration of Thermistor
  - Chubbs sent to Fluke of calibration
- CEOS WGCV comparison of Infrared (IR) radiometric instrumentation – 2016

  sponsored by ESA called FRM4STS

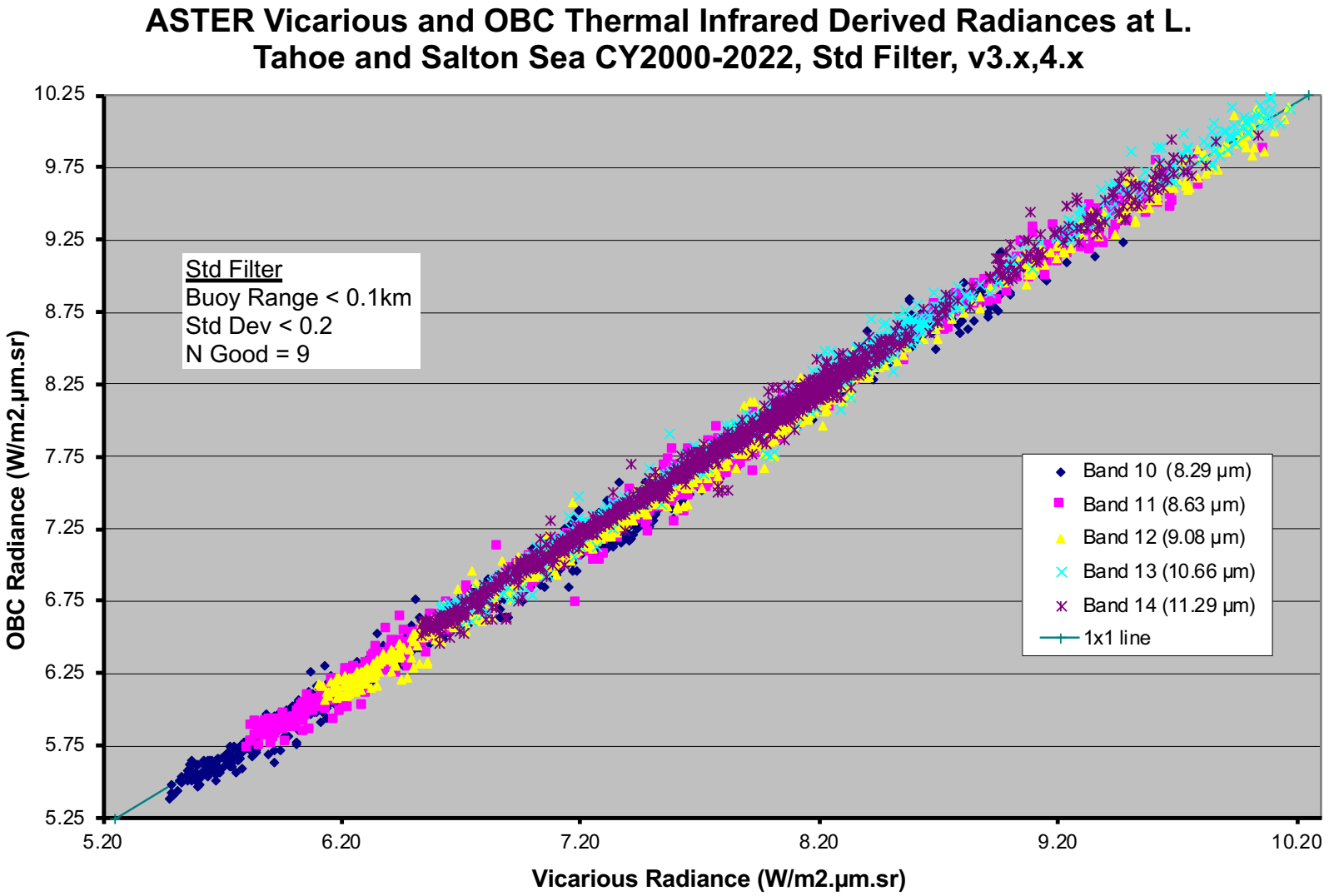
Example Results

Methodology For Radiance at Sensor Validation

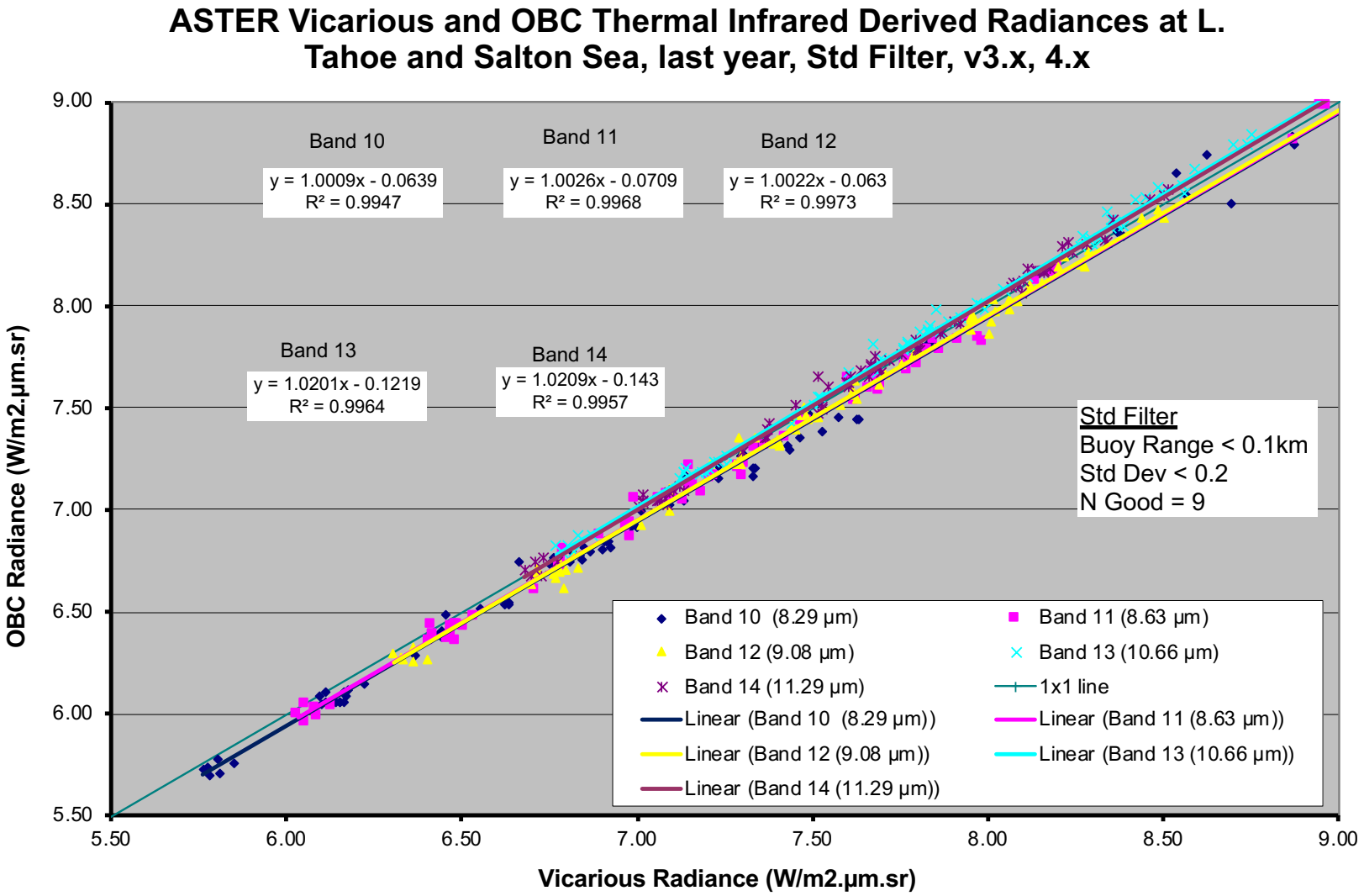
- Extract the skin temperature.
- If unavailable, correct the radiometric temperature to skin kinetic temperature.
- Propagate the skin temperature to the satellite using a radiative transfer model and interpolated atmospheric profile.
- Convolve the propagated at-sensor radiance to the instrument response 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.



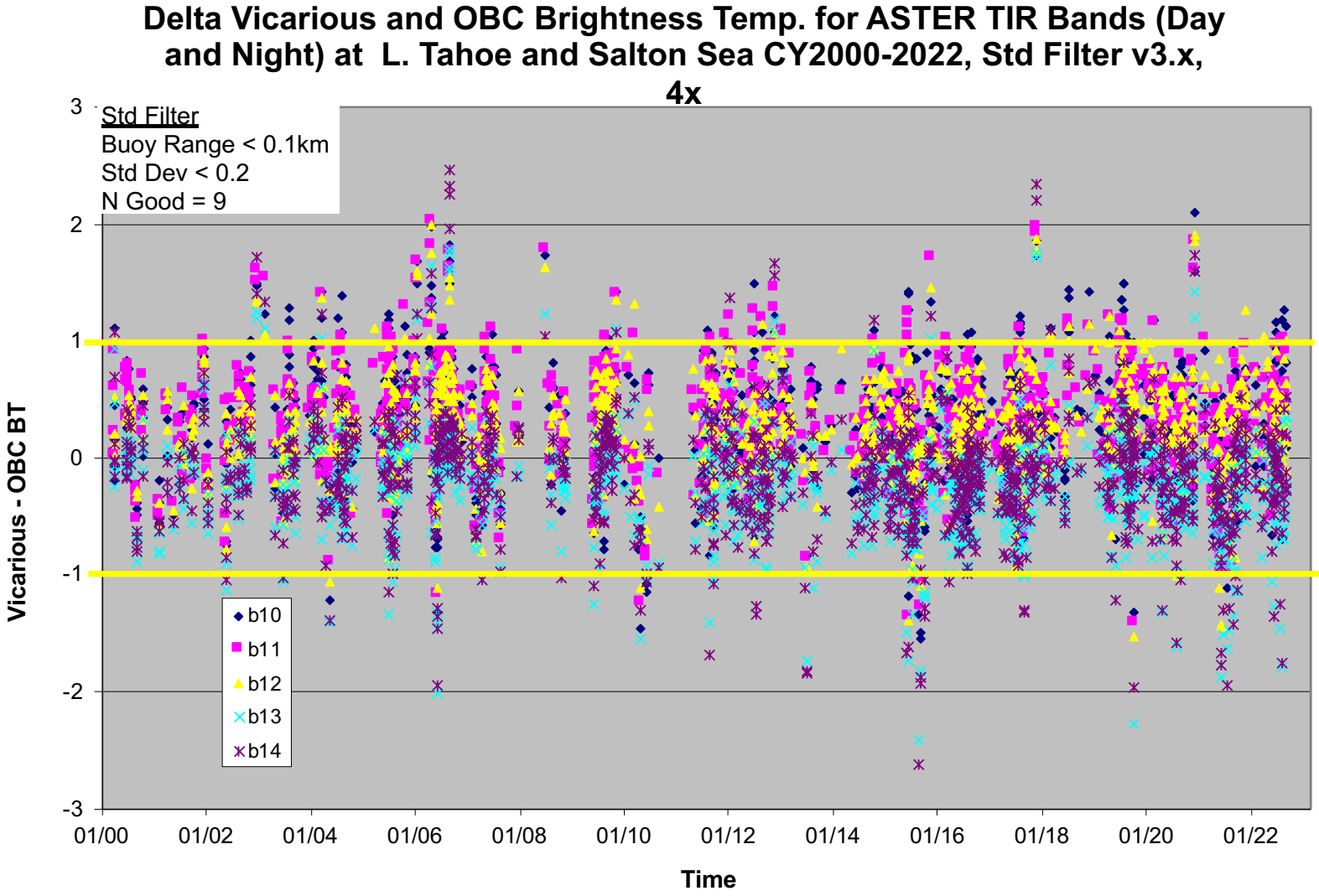
Typically more day scenes than night scenes. Very little data for 2013 and 2014 due to problems with STAR. Good rate in recent years.



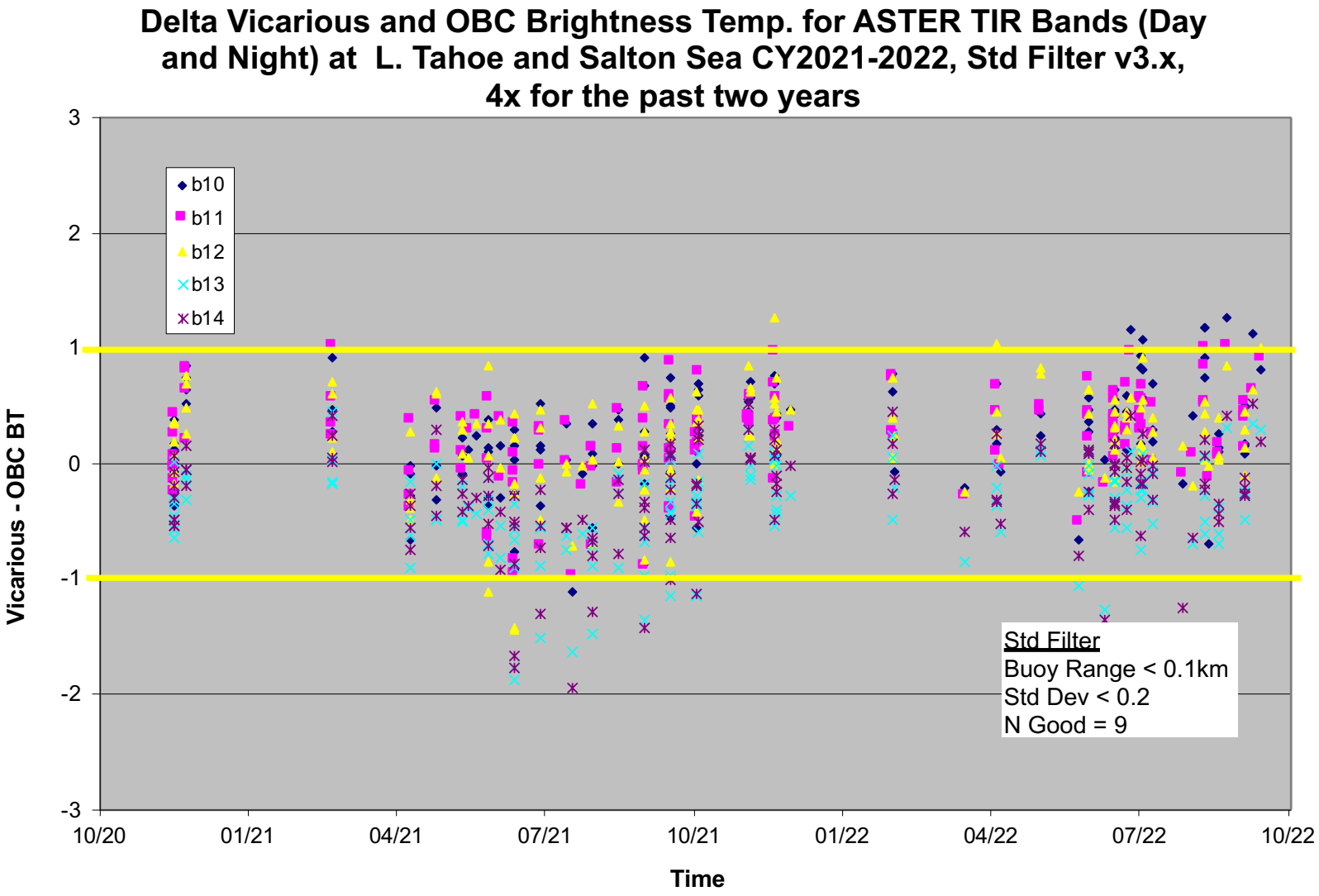
All bands fit nicely on the 1:1 line – very good calibration



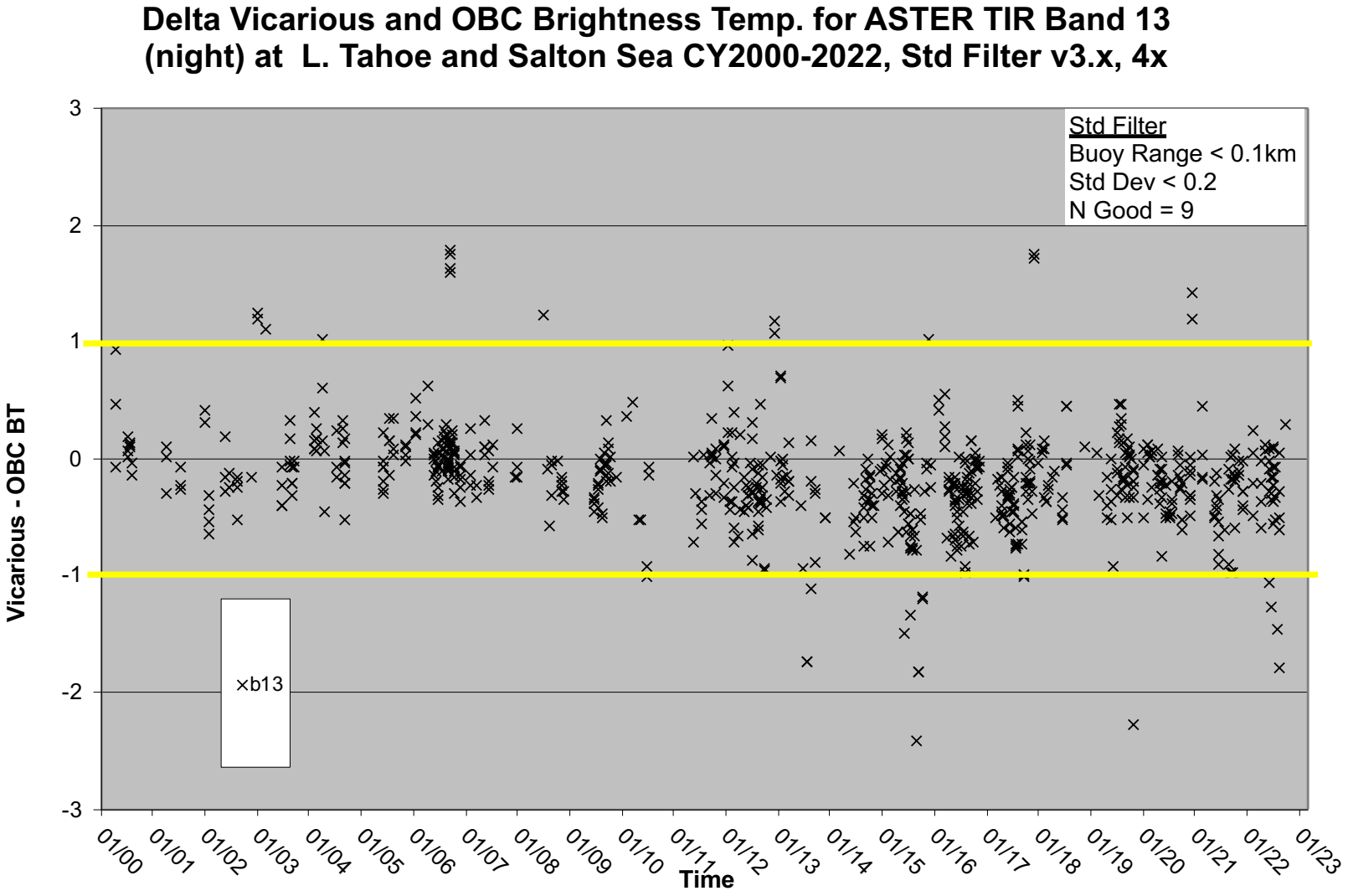
Last year (similar to prior years)



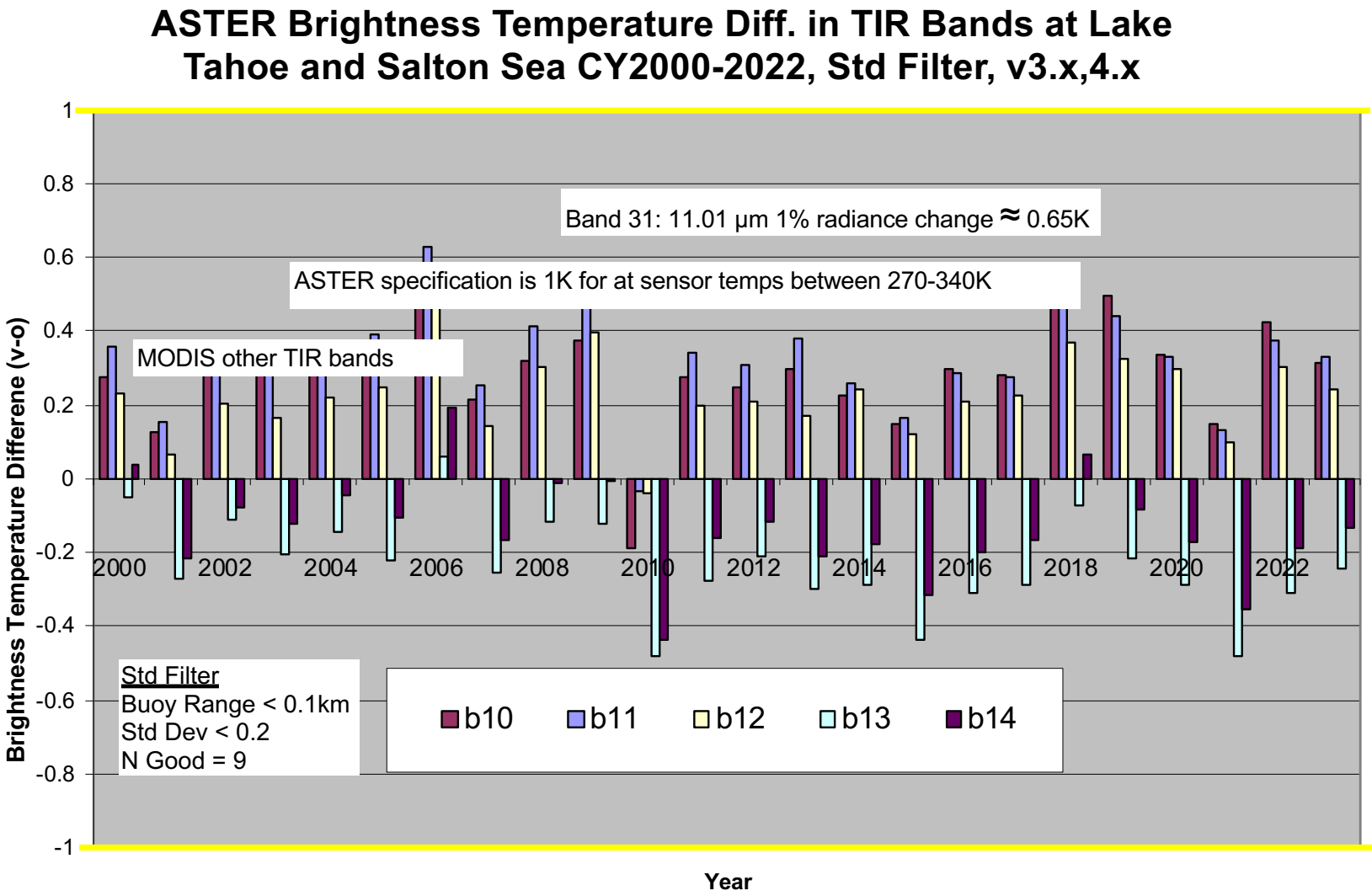
If you look at the individual points they typically scatter between +/- 1K with a few outliers. ASTER specification for 270-340K is 1K.



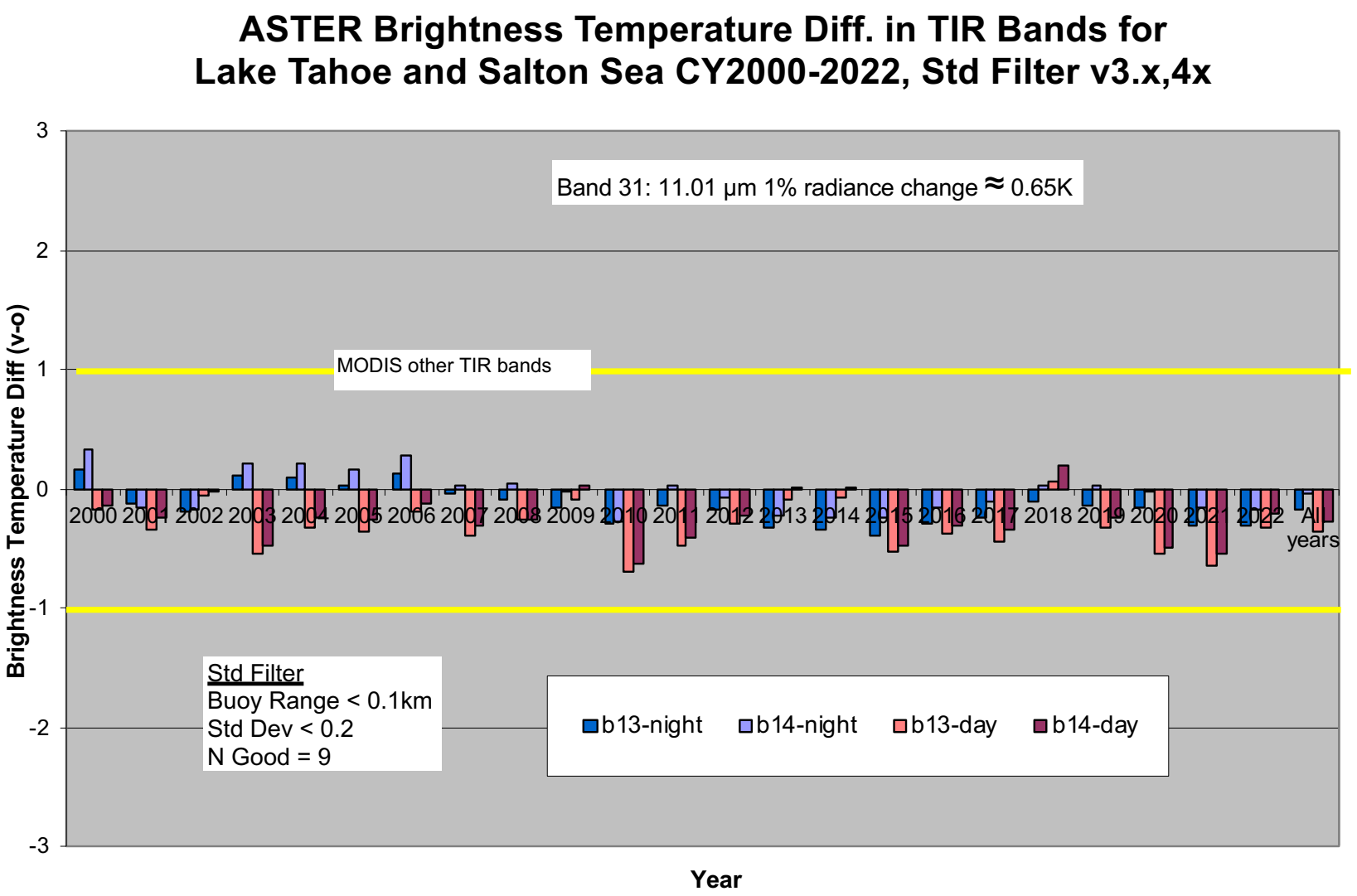
Last couple of years show similar performance to prior years.



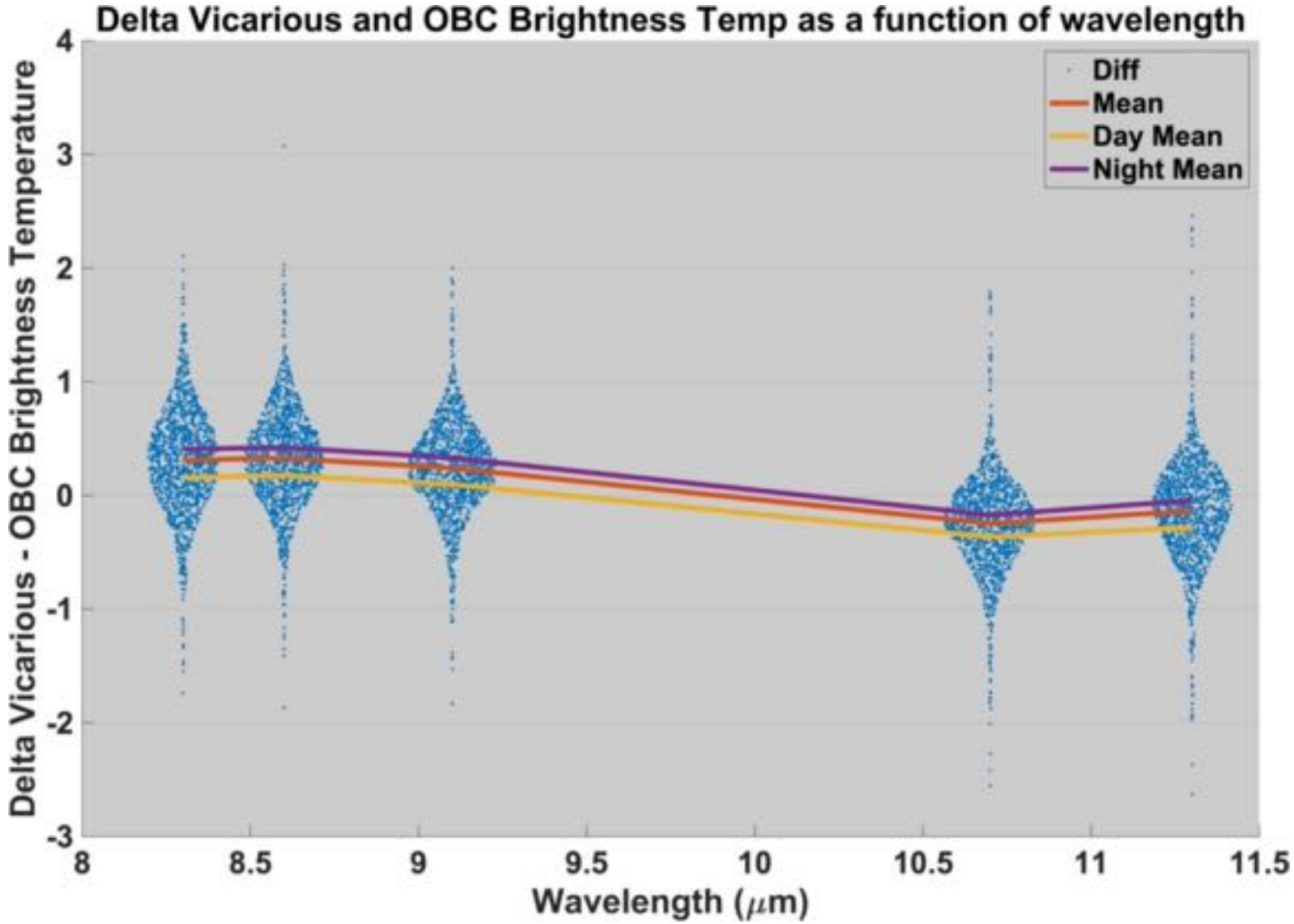
B13 only. Some outliers in prior years, but good performance.



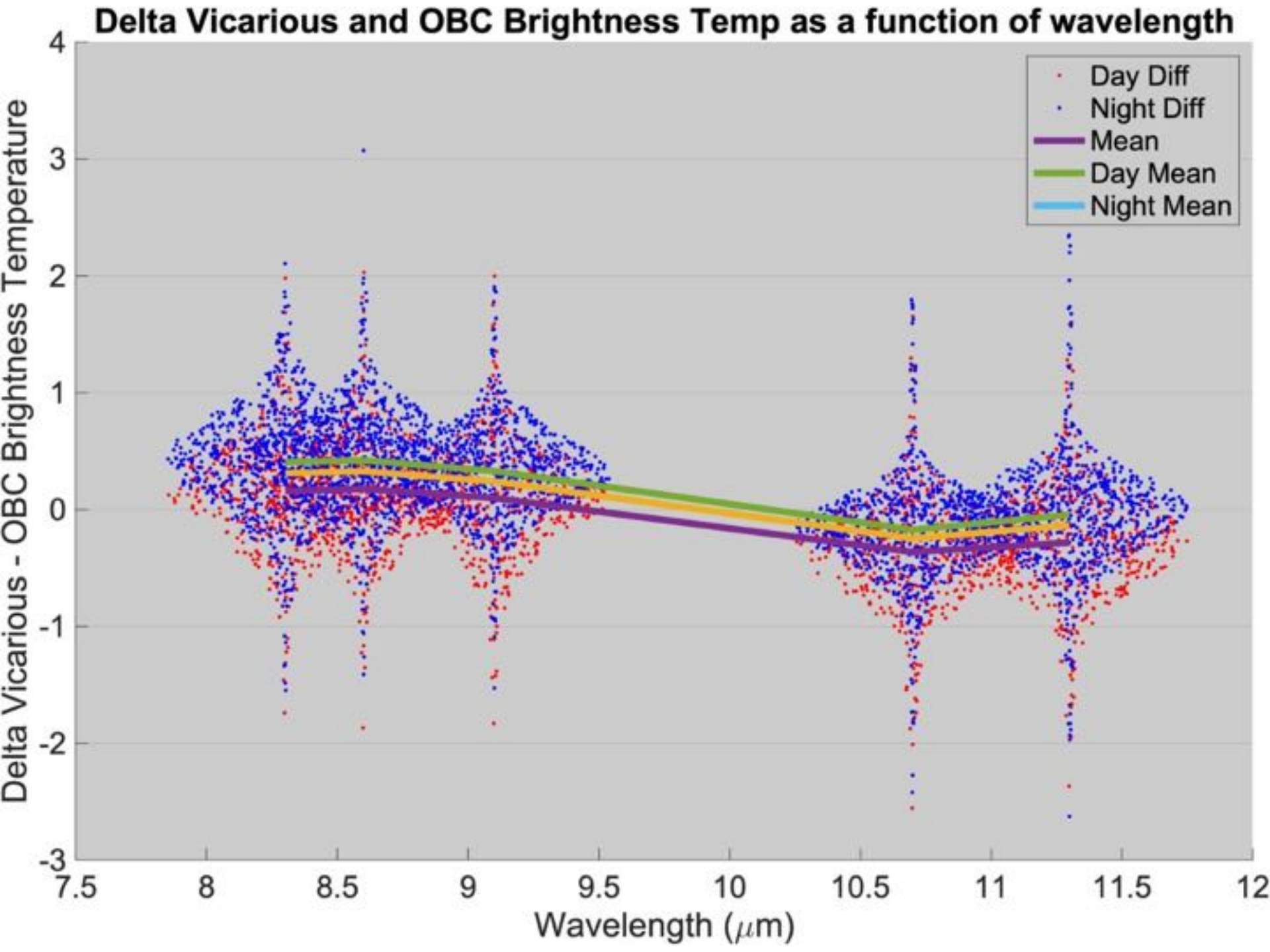
Mean brightness temperature differences for each year they are typically <0.3K. Bands 10, 11 and 12 tend to be cold and Bands 13 and 14 tend to be warm. 2021 was more –ve than previous few years



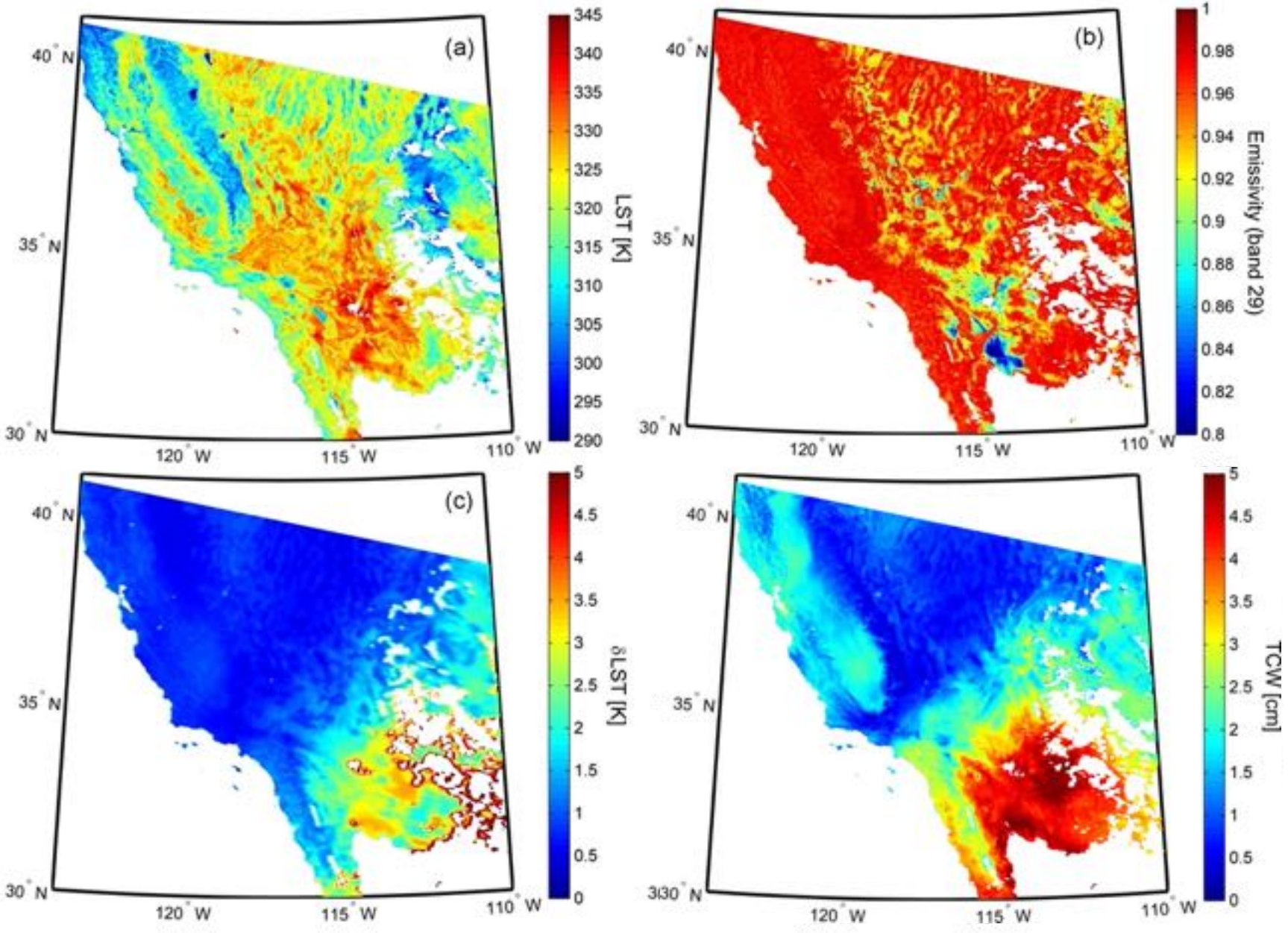
If look at difference between day and night for two clear TIR channels (minimum atmospheric effect) see that daytime values tend to be negative (ASTER too hot) and nighttime values also tend to be slightly negative (ASTER slightly hot). Cause for this is unknown.



Night mean is slightly higher than day mean. Overall calibration is excellent.


Delta Vicarious and OBC Brightness Temp as a function of wavelength
Day Diff
Night Diff
Mean
Day Mean
Night Mean
Delta Vicarious - OBC Brightness Temperature
Wavelength (μm)
4
3
2
1
0
-1
-2
-3
7.5
8
8.5
9
9.5
10
10.5
11
11.5
12

MODTES (MOD21) LST&E Retrievals with Uncertainty

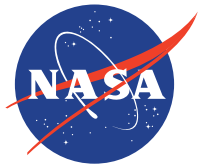


Future Work

- New sites at La Crau and Venice Lagoon

Summary and Conclusions

- Established a set of automated validation for validation of mid and thermal infrared data from aircraft and satellites
- First data were collected at Lake Tahoe in 1999. Have continuous record, every 5 minutes from 1999 to present
- Sites use JPL developed radiometers for Tval approach. Also established a set of dune sites for Rval approach
- Have validated data from numerous satellite sensors including ASTER, MODIS, VIIRS, Landsat, ECOSTRESS, ATSR and others
- Selected raw data availability at https://calval.jpl.nasa.gov



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