Railroad Valley Playa for use in vicarious calibration of large footprint sensors

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Introduction

- Background
  - Reflectance-based vicarious calibration
  - Test sites
- Results from Terra, EO-1, and Landsat
- Issues with current methodology
  - Temporal sampling
  - Noise/errors
  - Railroad Valley test site
- Calibration without ground-personnel
  - LED radiometers and atmospheric monitoring
  - Results from early measurements
- Vicarious calibration test site modeling
- Intercomparison possibilities
- Conclusions and future work

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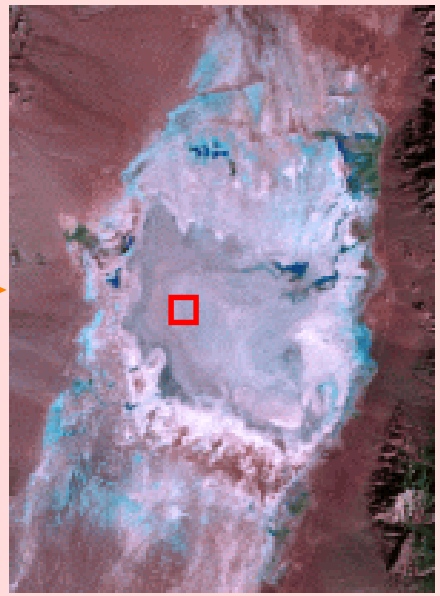
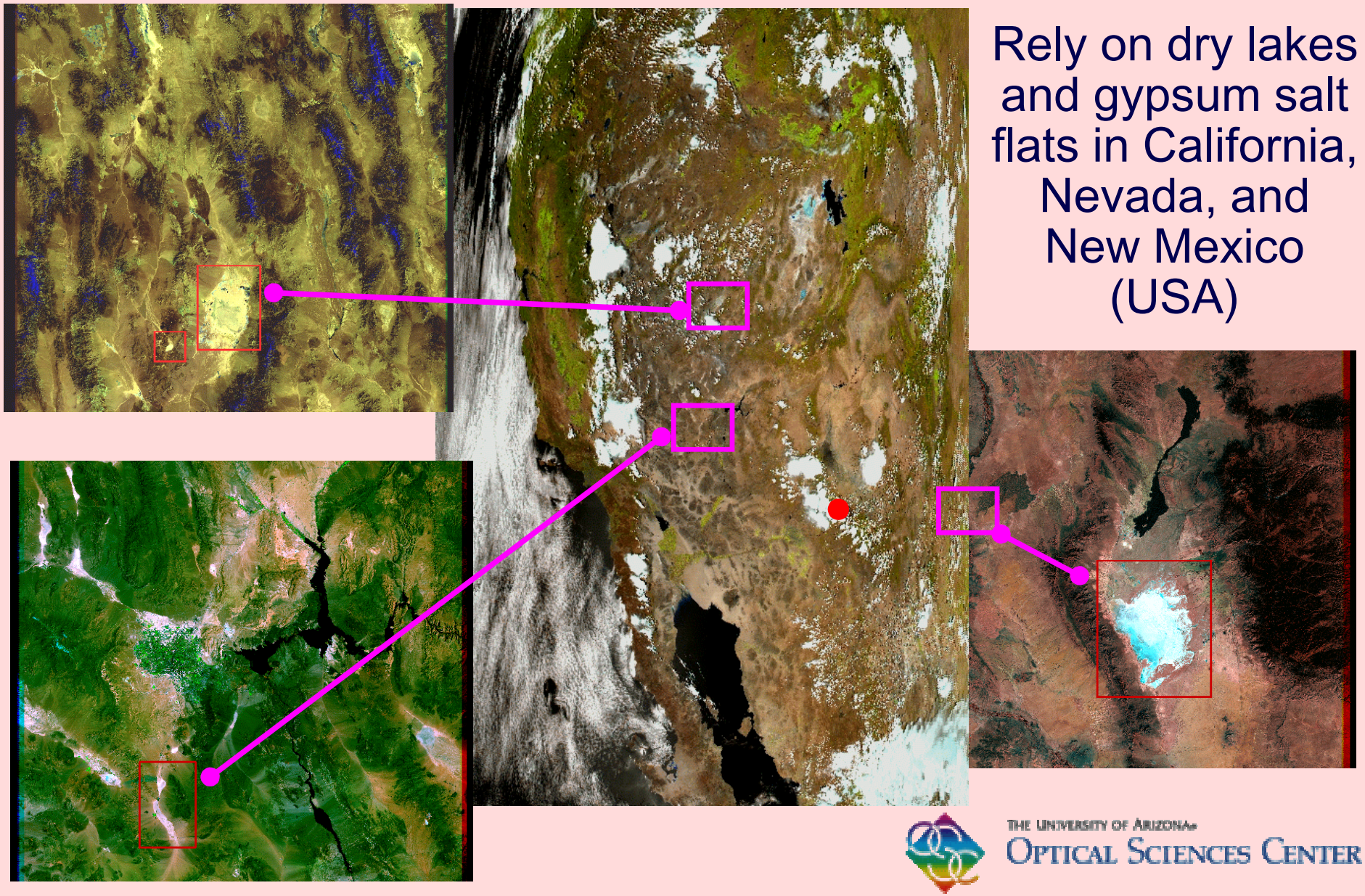
Reflectance-based Approach

Combine surface reflectance and atmospheric transmittance data to predict at-sensor radiance

Radiative Transfer Code



RSG Test Sites



Rely on dry lakes and gypsum salt flats in California, Nevada, and New Mexico (USA)

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RSG Test Sites

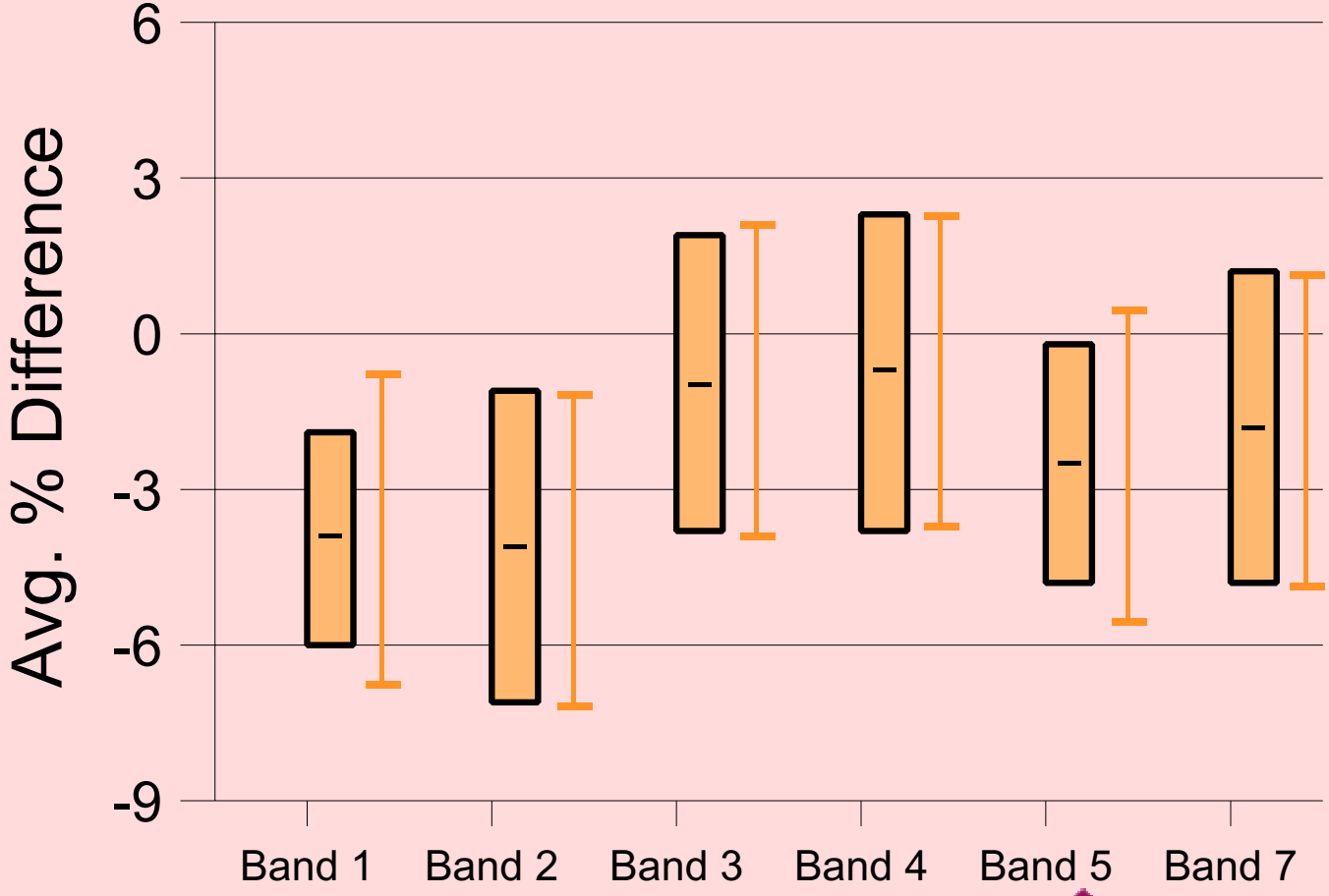
White Sands Missile Range not shown

Ivanpah Playa, California

Railroad Valley Playa, Nevada

Landsat-7 results

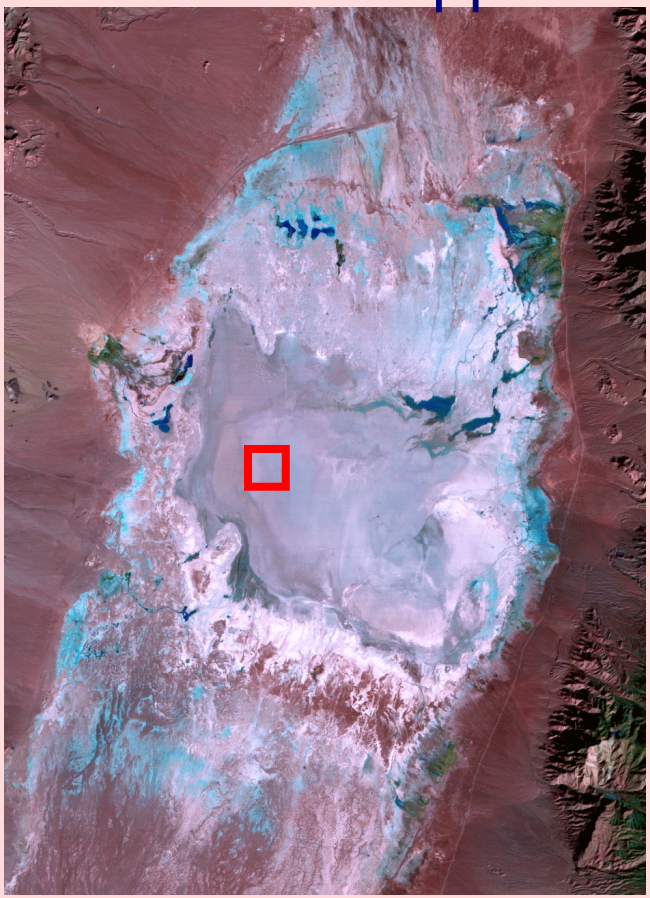
ETM+ work indicates that there has not been significant degradation of the sensor so use average and standard deviation of difference in at-sensor radiance

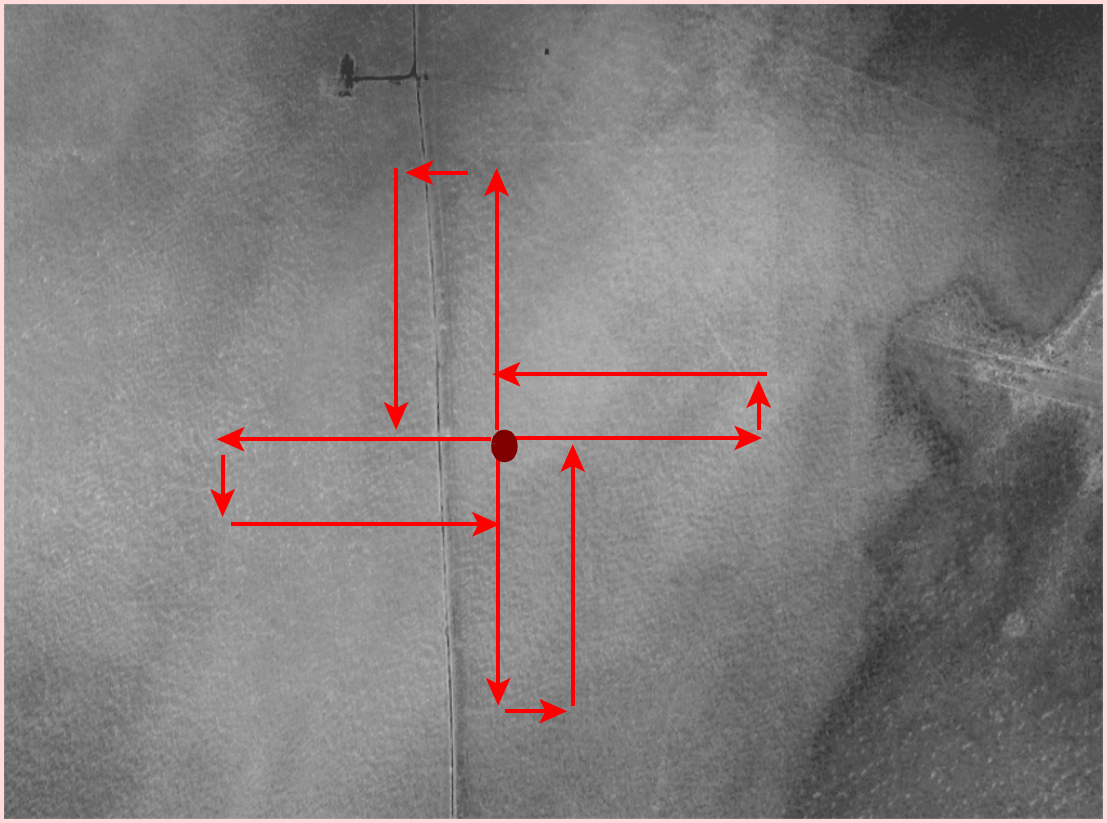


Large-footprint approach

Application to large-footprint sensors requires a different surface reflectance sampling approach

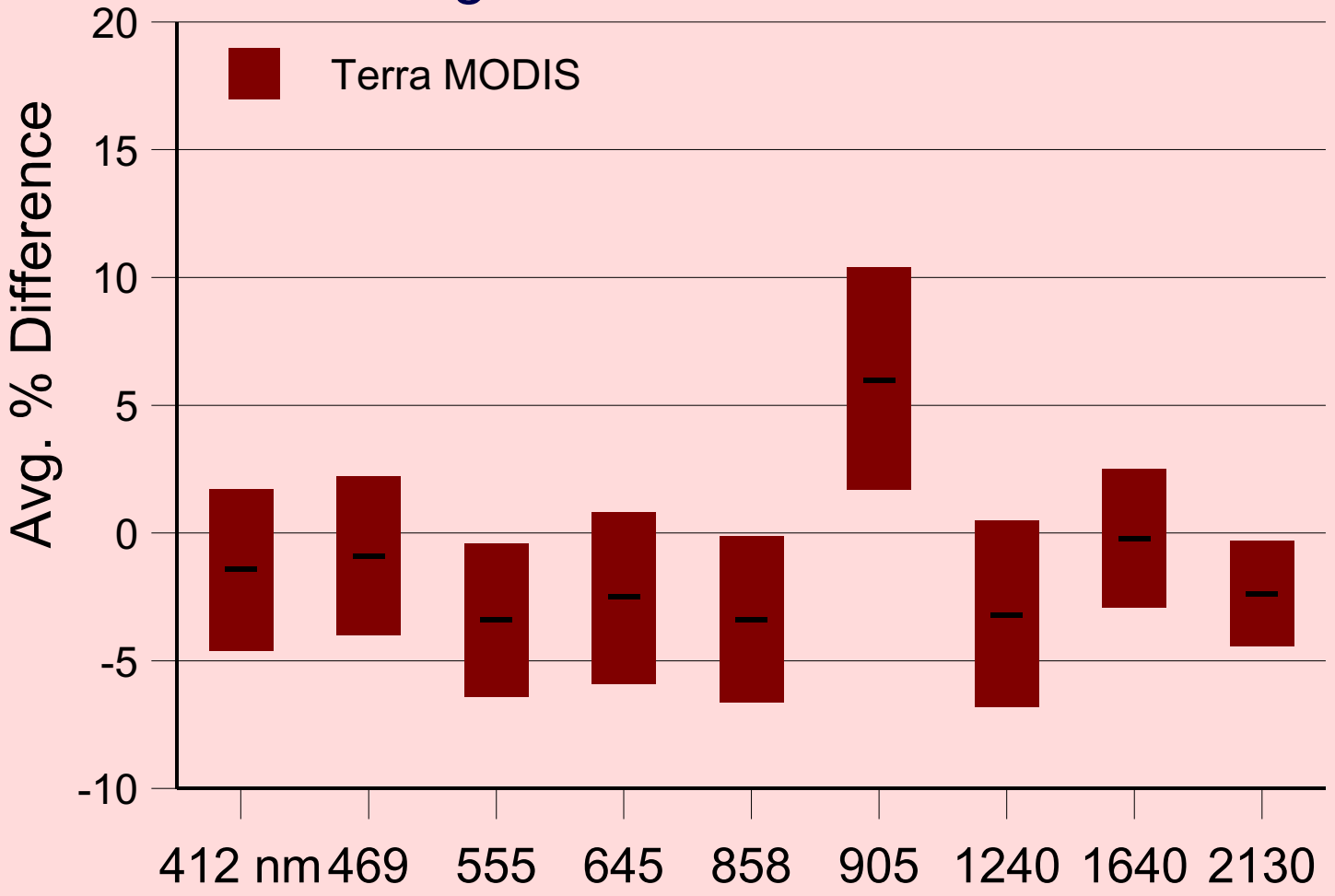
- Sample a 1-km by 1-km area
- Takes approximately 1 hour to collect data



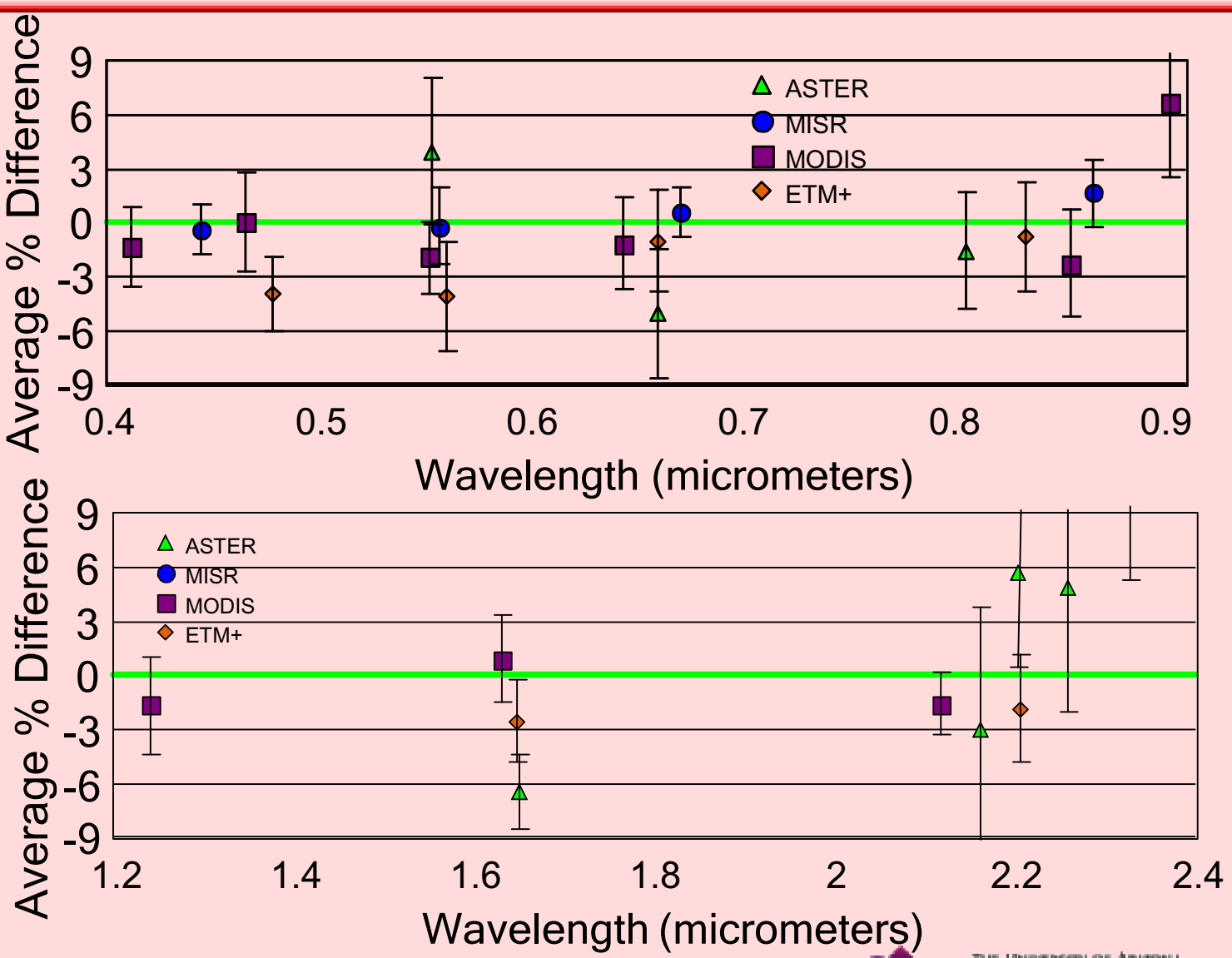


Terra MODIS results

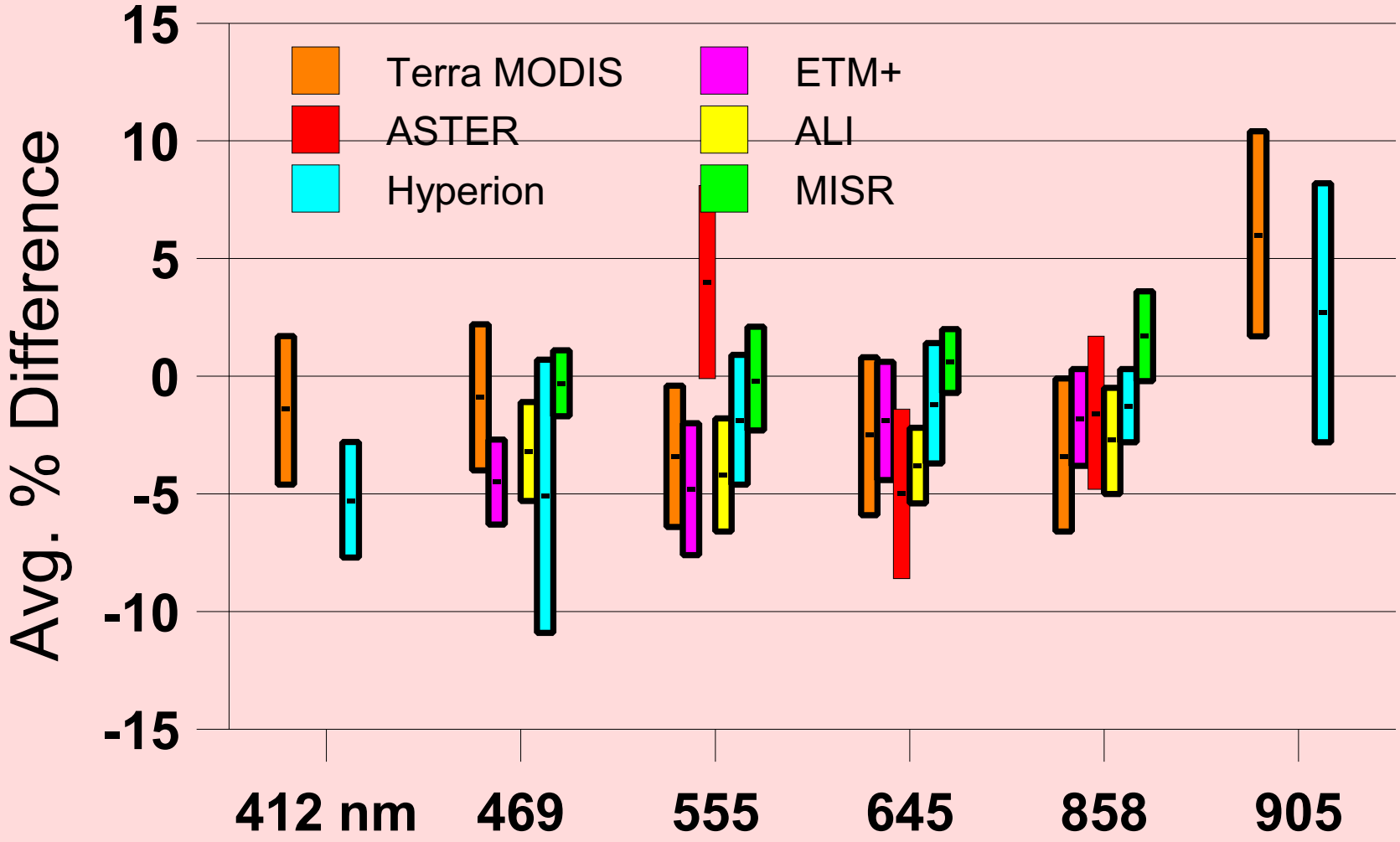
Terra MODIS is also well-behaved with no significant degradation at Level 1B



Landsat 7 and Terra Results



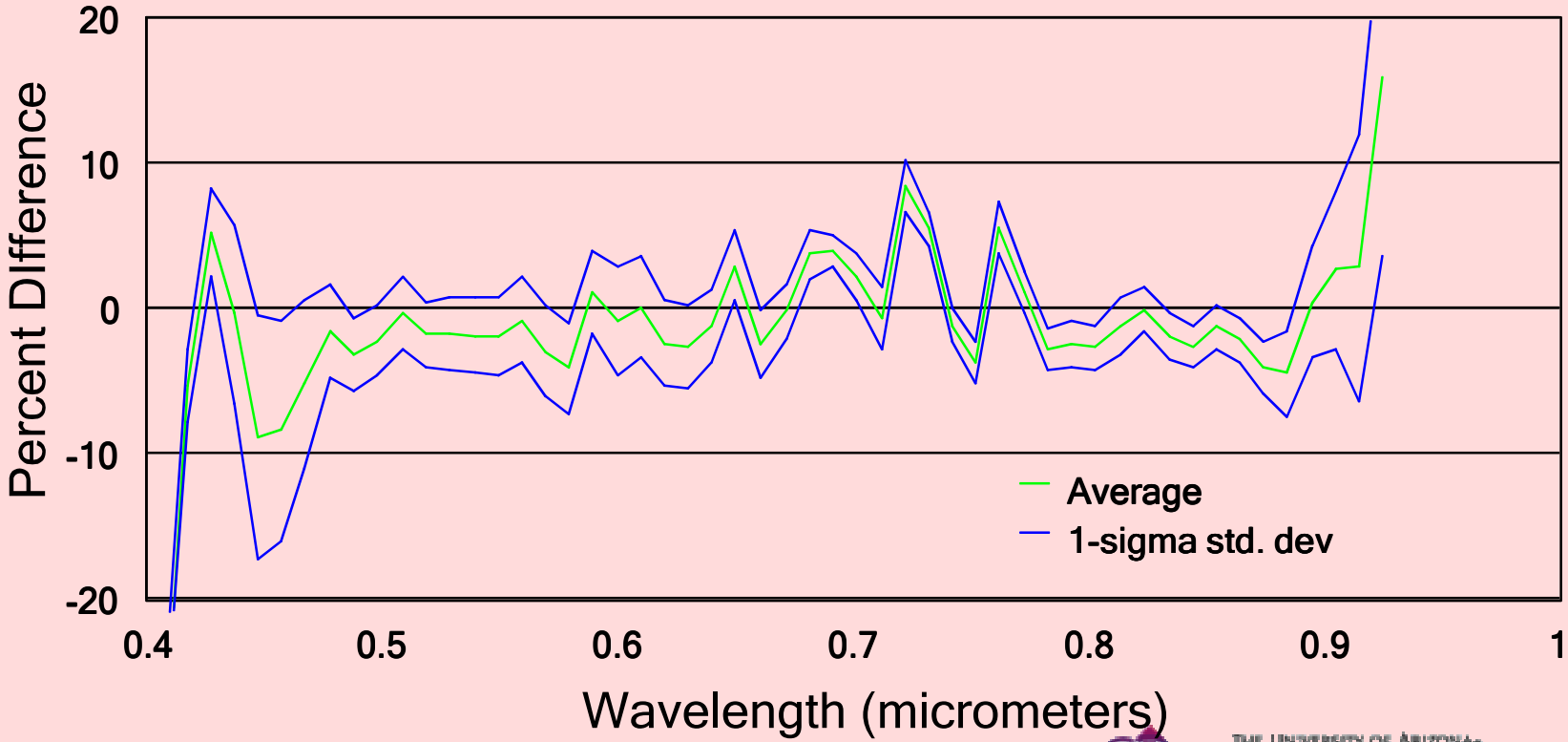
Results with EO-1



Hyperspectral example

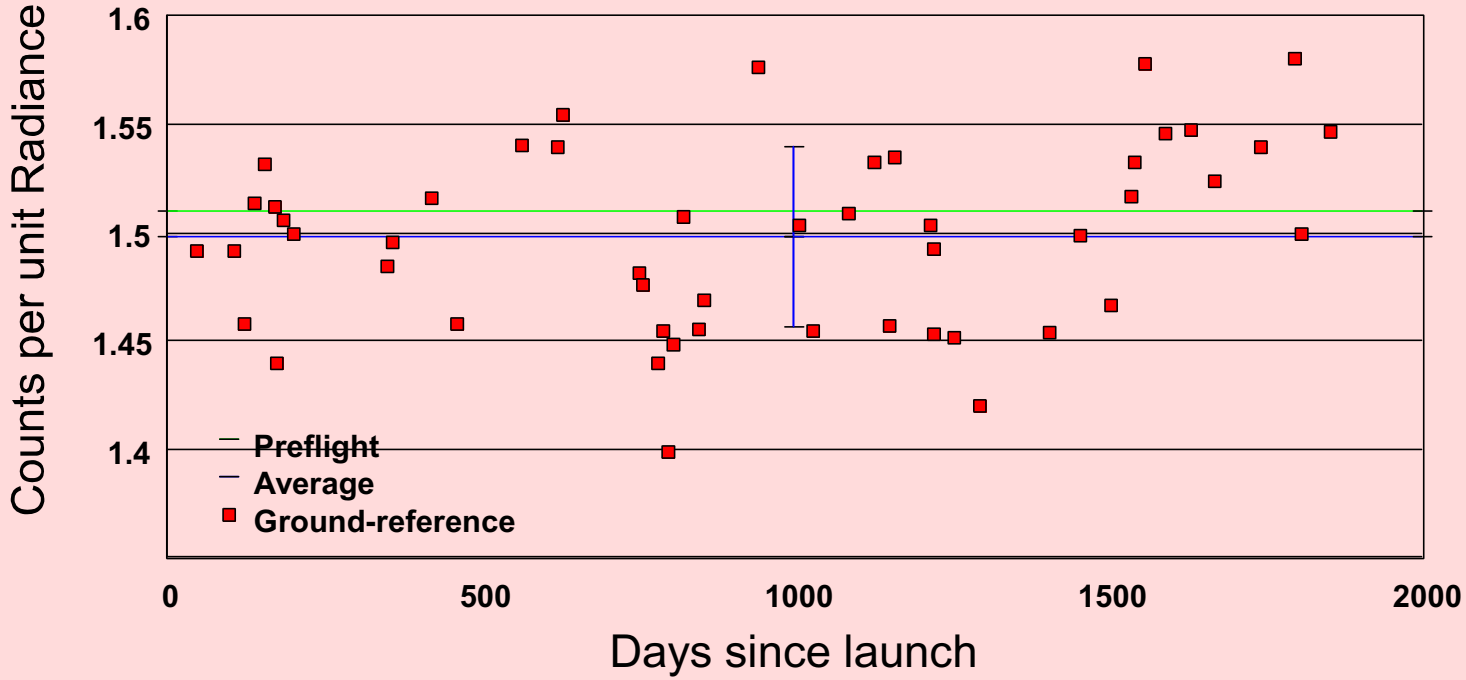
Results below are average and standard deviation of five VNIR Hyperion data sets

- Features in the percent difference are repeatable
- Same features are seen in the lunar calibration results



Noise - outlier data sets

One major drawback of the reflectance-based approach are outlier data sets



- Examination of ETM+ results does not show an obvious cause
- Scatter most likely “errors” in surface reflectance
- Outliers due to anomalous atmospheres

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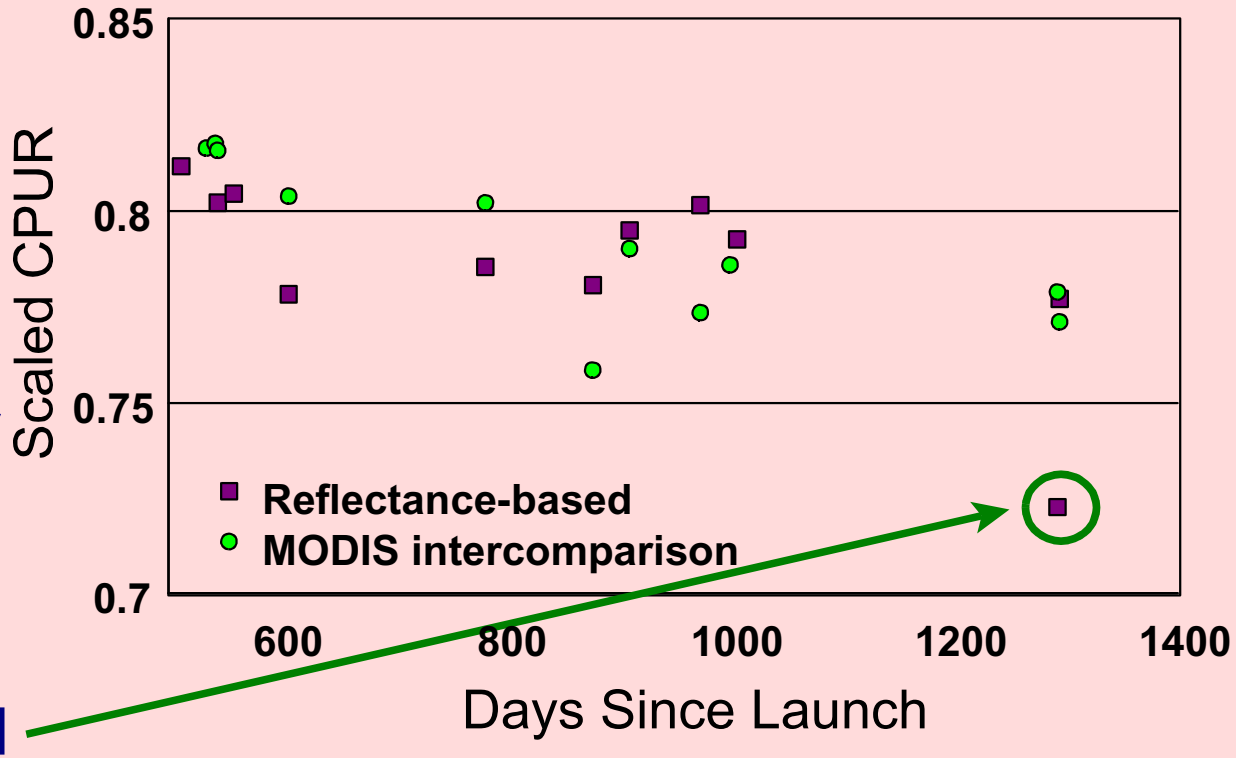
Noise, MODIS-ASTER example

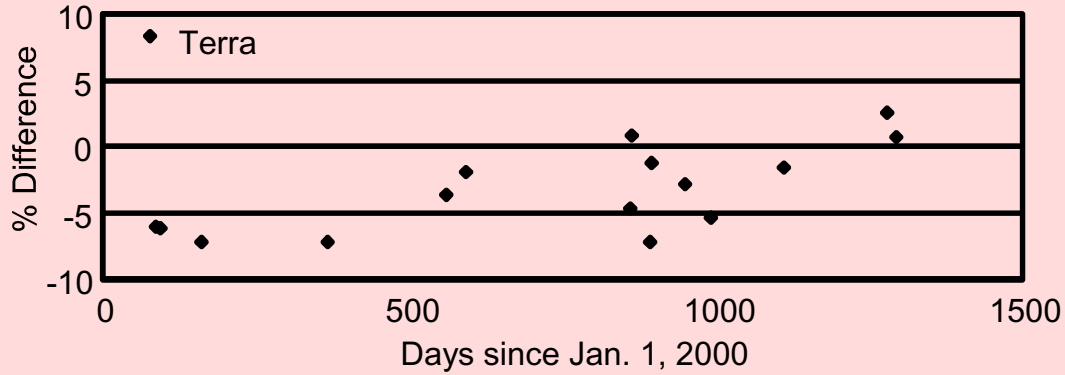
Recent work has used MODIS as a reference for an intercomparison with ASTER

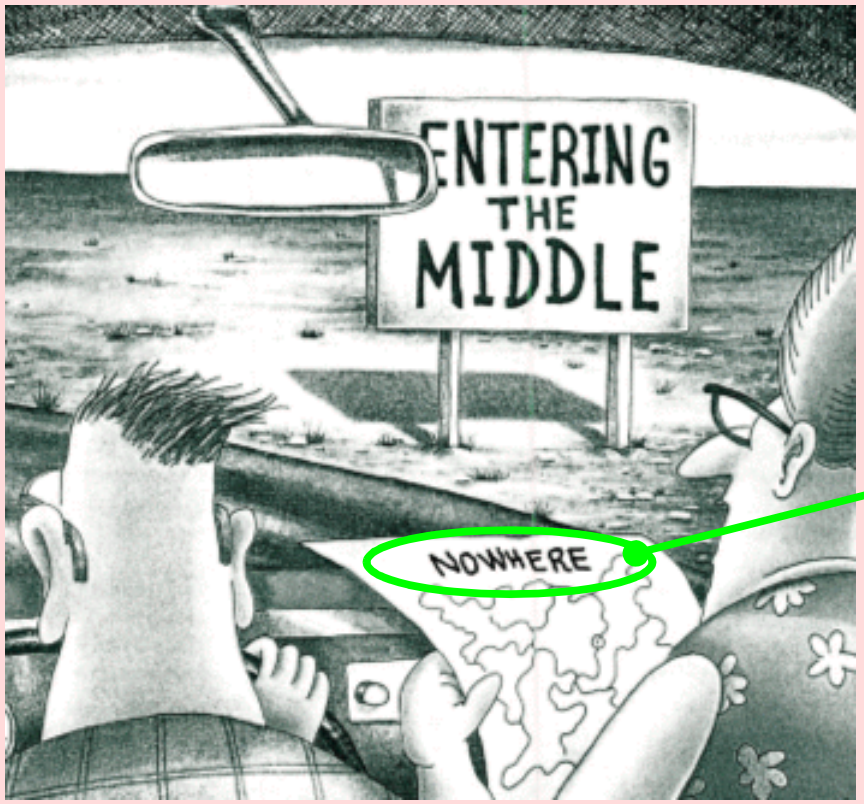
- All data from RRV Playa
- Mostly coincident dates for plot shown here
- Standard deviations slightly different for two
- Note the outlier from the reflectance-based approach

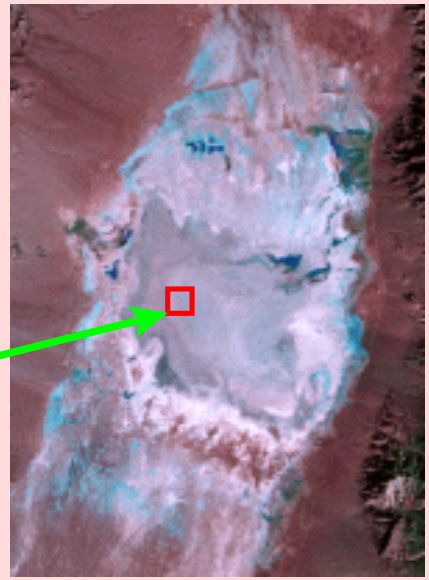


Temporal sampling issues

Railroad Valley Playa is in central Nevada about 13 hours by car from the University of Arizona







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Improved temporal sampling

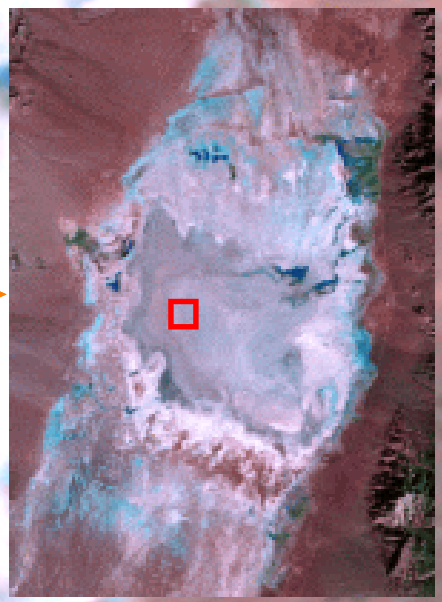
Poor temporal sampling has always been an issue with the reflectance-based method

- Require personnel on the ground at sensor overpass
  - Expensive in personnel and travel
  - Reduces opportunities for calibration attempts
- Currently make approximately one trip per month
  - Cannot get all sensors on all trips
  - Weather prevents success in some cases
  - Fortunate to obtain 8-10 data sets per sensor per year
- These 8-10 data sets may not be sufficient for trend analysis
- **Goal** - increase the number of data sets per sensor without sacrificing accuracy

Ground-based instrumentation

Use the same methodology but replace instruments with sensors that do not require personnel to be present

Radiative Transfer Code



Atmospheric data

Atmospheric measurements rely on a meteorological station and automated Cimel sunphotometer

- Sunphotometer provides atmospheric optical depths and uses sky radiance data to produce aerosol size and type
- Data are available via the Web from Goddard Space Flight Center's Aeronet
- Meteorological station provides ancillary data including rainfall

Surface reflectance

Most critical measurement is the surface reflectance

- Test sites used for vicarious calibration are typically bright
- Uncertainties in the surface reflectance cause the same level of uncertainty in the vicarious results
- Could assume the surface is invariant
- **NOT** a good assumption at Railroad Valley

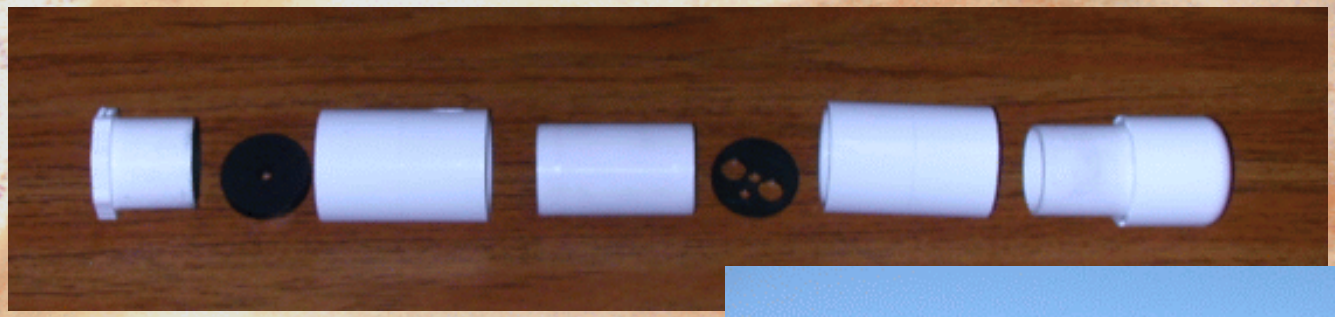
LED radiometers

Monitor surface reflectance via a set of robust, inexpensive radiometers relying on light emitting diodes (LEDs) operating as detectors

- Benefit of combining spectral selection and detector
  - Reduces cost
  - Improves spectral and radiometric stability over time
  - Others have shown this stability to be much better than 1% over periods in excess of 10 years
- Have a range of wavelengths available
  - Focus is currently on the visible and near infrared
  - Detector wavelength shifts relative to the emitting wavelength

LED radiometers

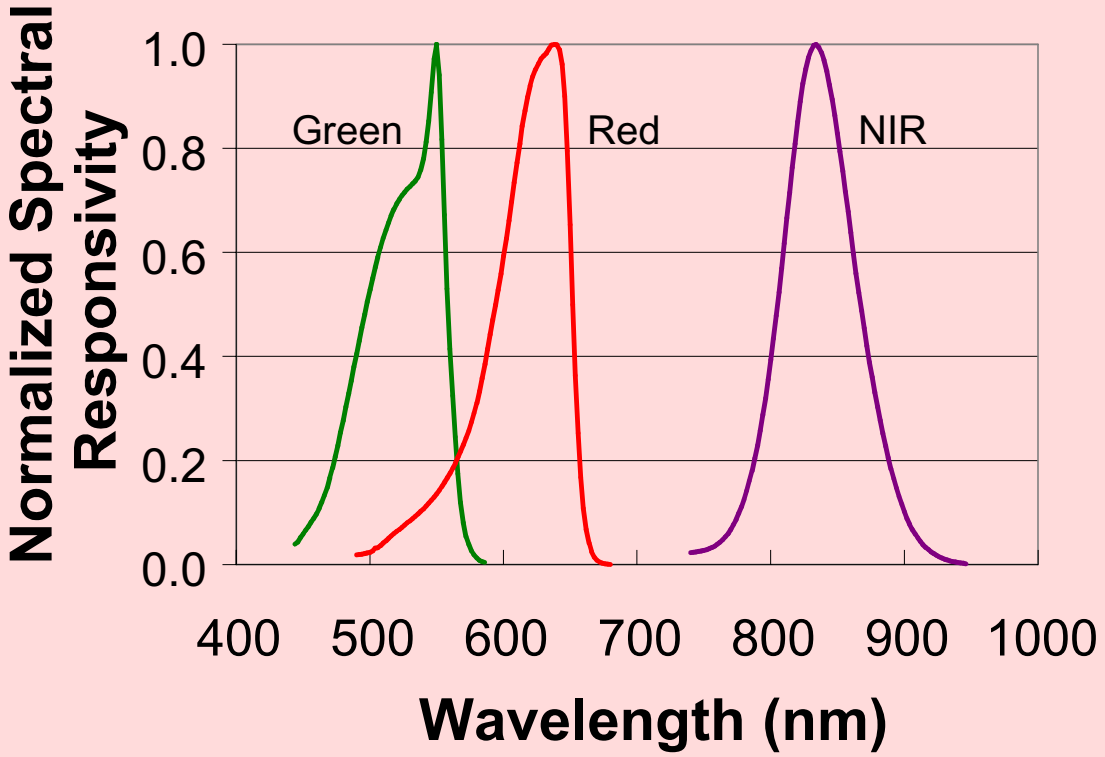
Current results are based on a simple design with a four-channel approach



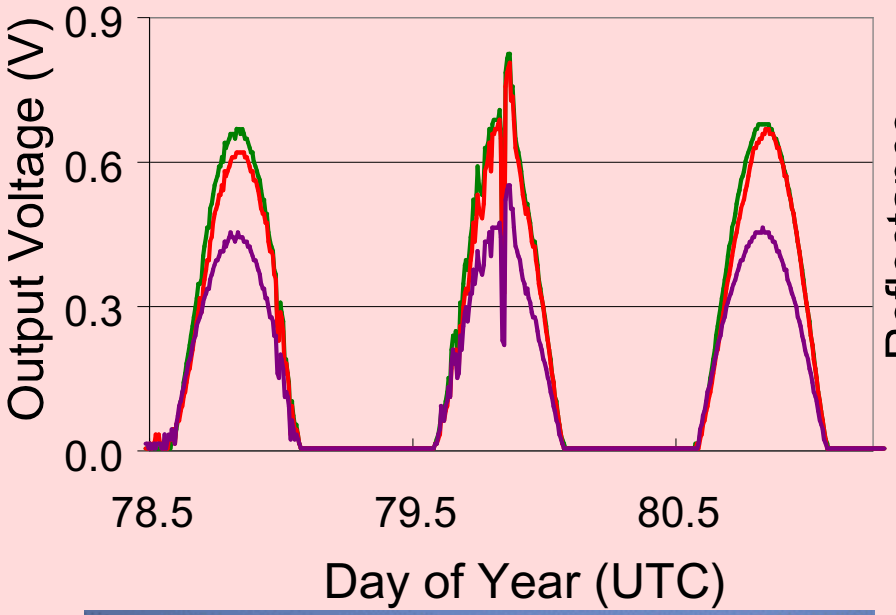
LED radiometers - Spectral response

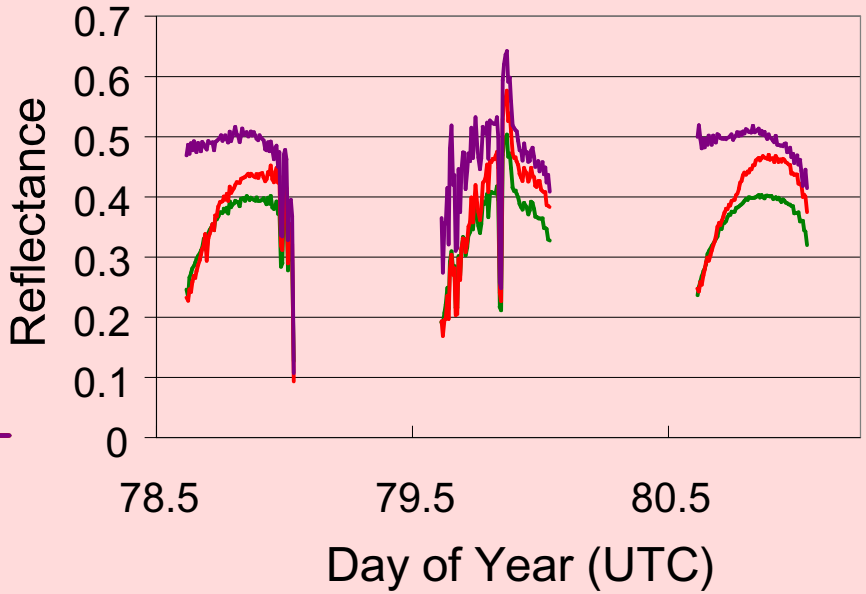
Of the four channels, three survived assembly and early deployment to Railroad Valley

- The spectral bands are green, red, and NIR
  - Bands are similar to those of several earth-imaging sensors
  - Bands are wider than those typically used in imagers
- Spectral response varies somewhat from LED to LED but the wider bands help mitigate this



LED radiometer - reflectance retrieval





Output of LED radiometer depends on the incident sun angle, atmospheric conditions, and response

Correcting for these effects allows the reflectance to be found

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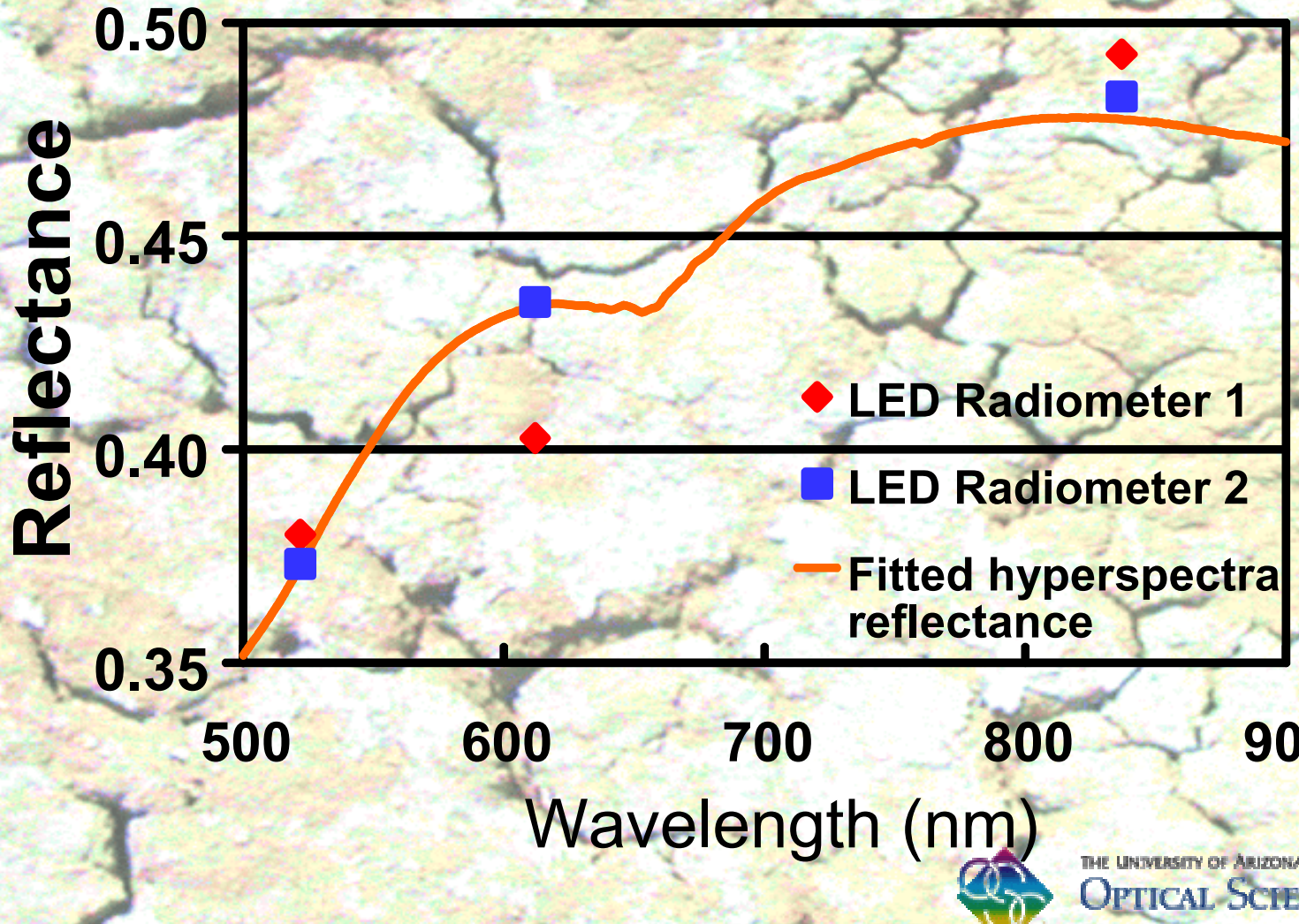
LED radiometer - results

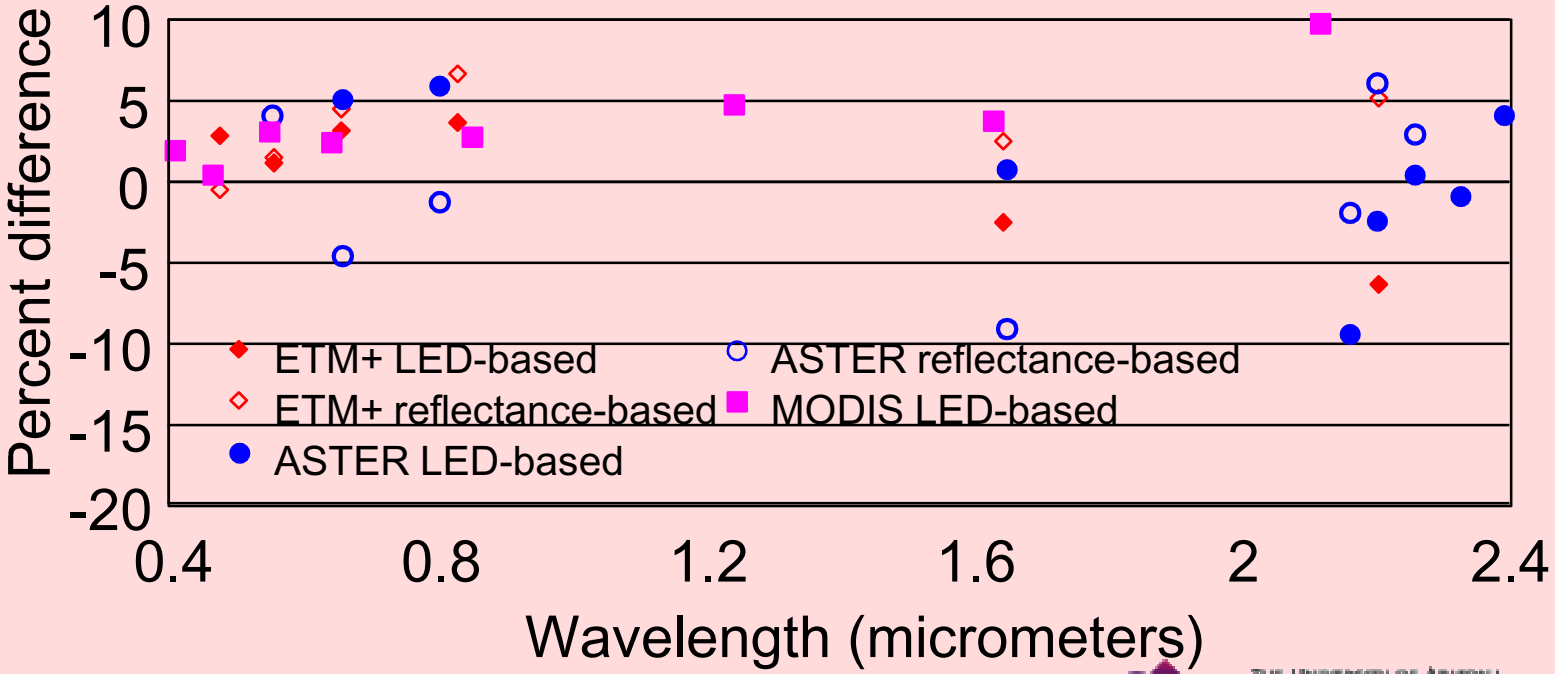
LED results are used to determine a hyperspectral surface reflectance for the vicarious calibration



LED radiometer - results

Graph below shows the reflectance-based results for the three sensors

- Also shown are the results from the full ground-based data (open circles)
- Results are very good in visible and poorer at longer wavelengths



Model-based playa

One goal of this work is to develop a model of the Railroad Valley Playa

- This model will provide at-sensor radiance for a given sun-sensor geometry
  - Hyperspectral at 10-nm intervals from 350-2500 nm
  - 30-m spatial resolution
- Combination of ground-based LED and satellite imagery
  - Rainfall data give information regarding sharp changes in reflectance
  - ETM+ data (or similar system) give spatial information
  - MODIS can give directional reflectance data along with the LED data
  - Cimel provides atmospheric data

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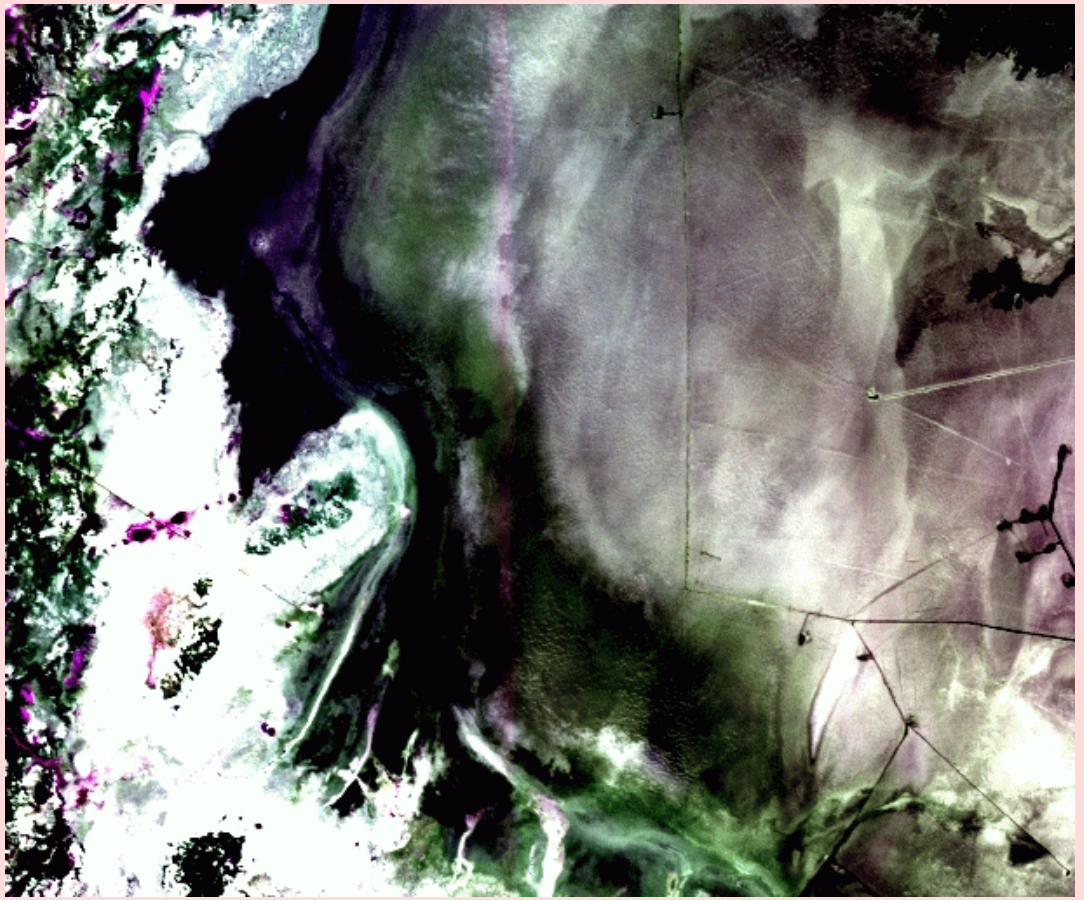
Model-based approach

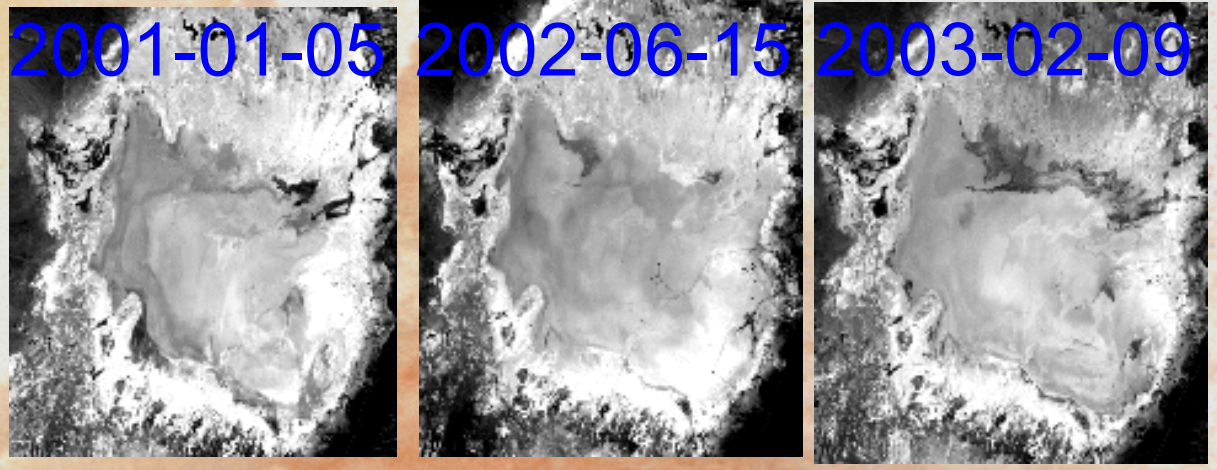
Numerous issues must be addressed for this to work

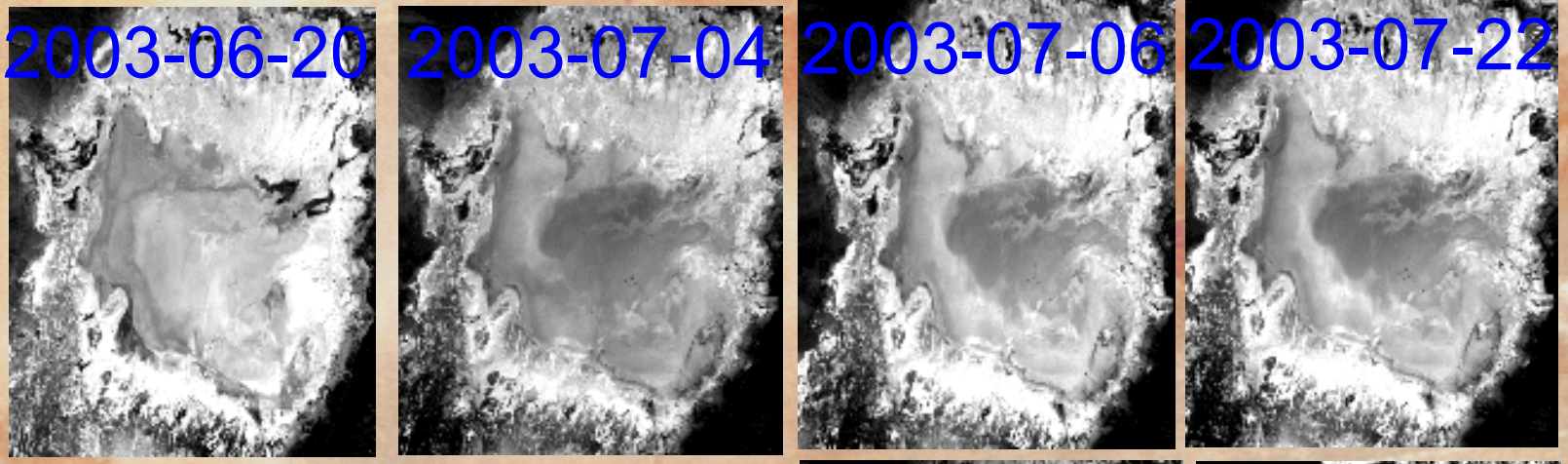
- BRDF effects
- Spectral variability across the playa
- Spatial variability over time
- Anomalous behavior of playa
- Fortunately, all of these are also of interest to the reflectance-based measurements

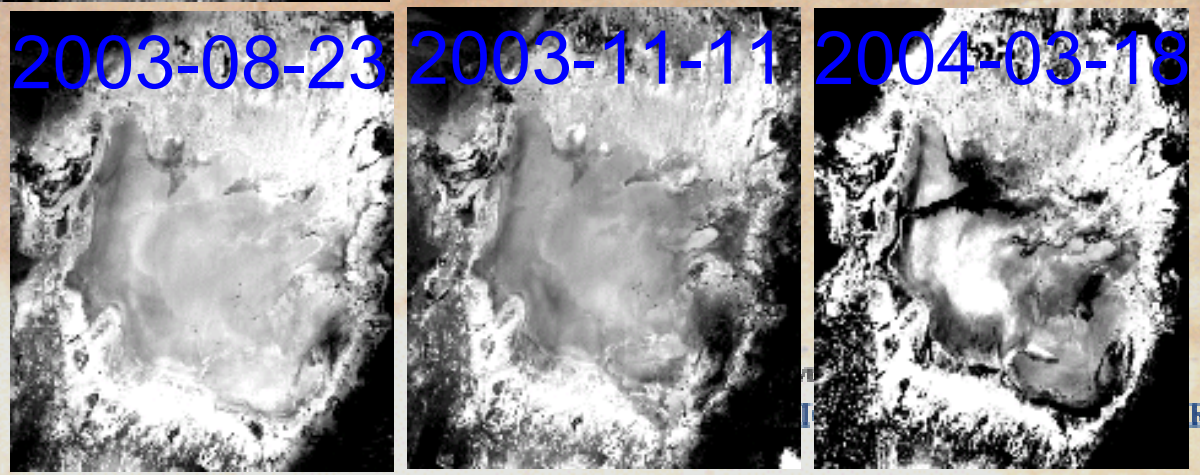


Model-based approach

ASTER Band 3 data from RRV



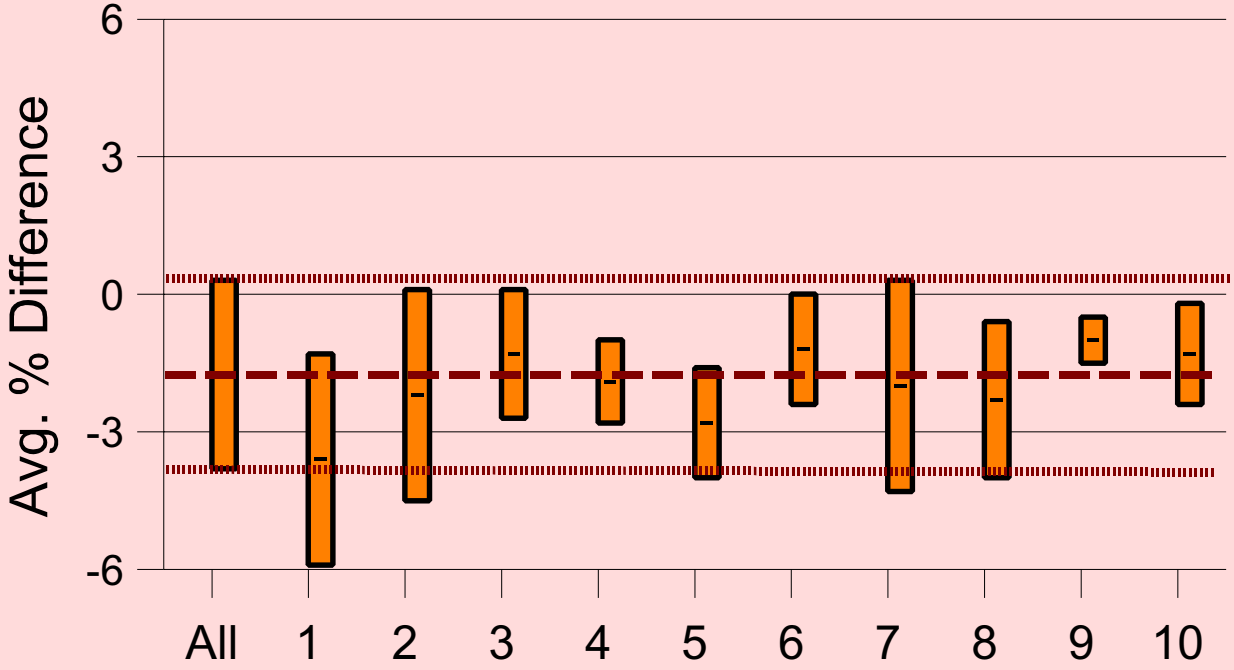




- Clearly not invariant
- Note large change in middle row
- Last image taken one month after snow melt

Reflectance-based intercomparisons

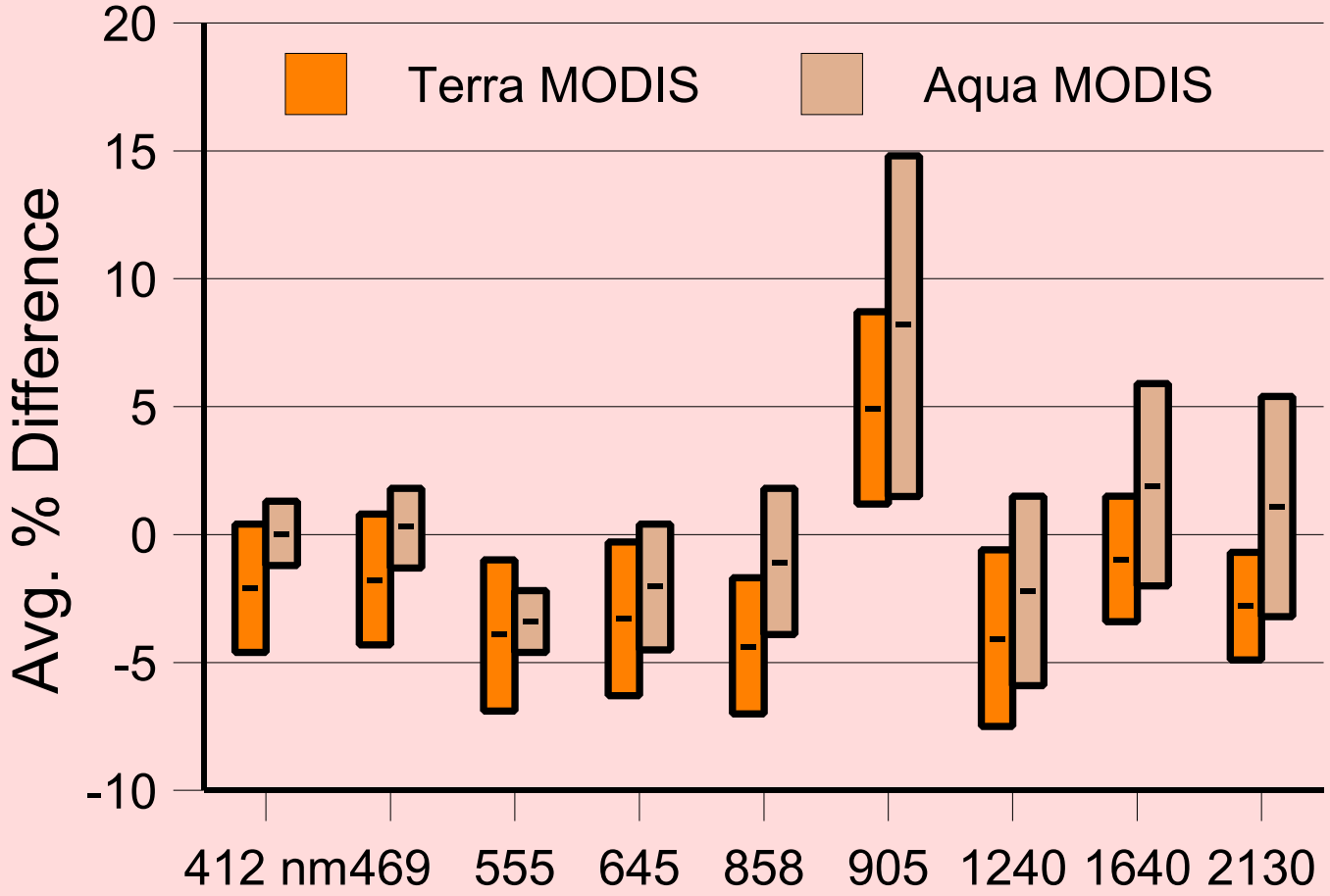
Resampling of Landsat ETM+ results show that as few as five data sets can provide a repeatable estimate of sensor calibration



- Note that this shows that repeatability/precision and accuracy are not identical
- Many of the cases shown have not overlapping time periods

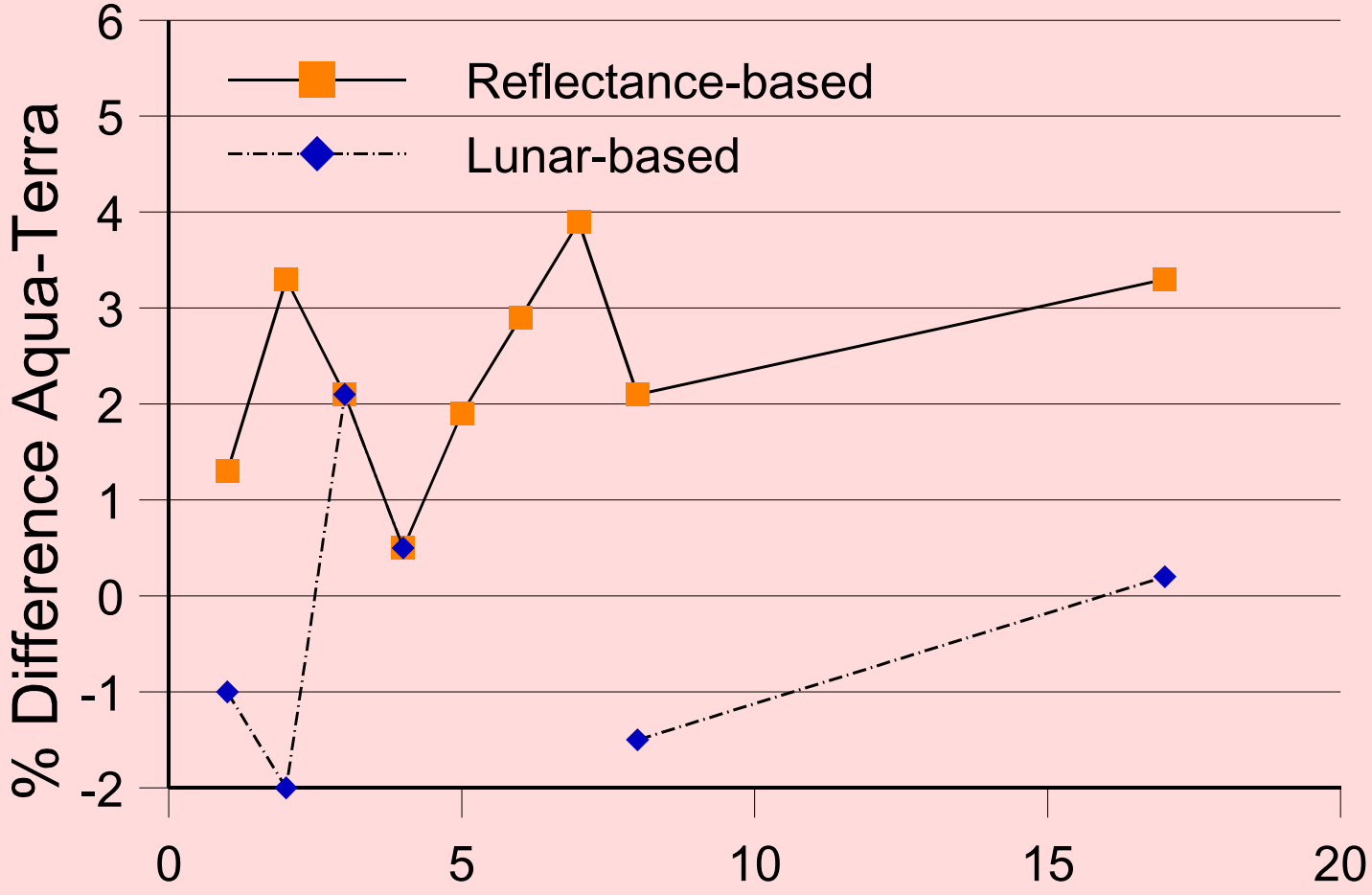
Intercomparison - MODIS

Reflectance-based method allows for direct comparison of results from two sensors without concurrent views



Intercomparison - MODIS

Still need some work to understand behavior of ground data results relative to other vicarious methods



Future Intercomparisons

Intercomparisons between laboratory radiometers calibrated to radiance and model-predicted radiances are currently being done

- Better understand vicarious approach (effect of atmospheric models)
- Self-consistency within the UofA laboratory and consistency with field measurements
  - Same panels are used in field and for radiance calibration
  - Multiple calibration approaches for laboratory radiometer

Conclusions - Intercomparisons

Vicarious methods can be used for sensor intercomparisons

- Vicarious methods such as reflectance-based method are now more repeatable
- Vicarious do **not** require coincident collections (even allows gaps in the data record)
  - Does require consistent application of single method
  - Best when there is consistent sensor collection methodologies (view angles, protocols)
- Results shown here showed some small biases between several sensors
  - Biases could be real
  - Shows need for multiple intercomparison methods
  - In the case of large biases a decision must be made regarding the “right” answer

Conclusions - LED results

LED and Cimel results gave similar accuracies as the full up ground-based measurements

- ETM+ results between the two approaches agreed to better than 3% in the VNIR
  - ASTER did not have as good agreement - possibly due to spatial atmospheric effects
  - SWIR results poorer due to assumptions used to obtain the hyperspectral reflectance
- Two single point LED values gave good results for MODIS
  - In reality, this was somewhat fortuitous
  - Area of Railroad Valley was very uniform on this date in the region of the LEDs
  - Future work will deploy more radiometers to assess the spatial uniformity

General Conclusions and Comments

- Precision of vicarious methods is improving
  - Repeatability used here as a surrogate for precision
  - Becoming more difficult to determine error sources and how to correct
- Links/traceability to laboratory standards are needed
  - Solar-based calibration approaches
  - Laboratory-quality field radiometers
- Temporal sampling issues
  - What is the optimal sampling frequency?
  - “Clumping” of vicarious results may be preferred
- Vicarious methods should be considered when planning preflight characterizations
  - Size of source
  - Spectral nature