Inflight intersensor radiometric calibration using vicarious approaches

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Talk overview

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  - Average of all dates
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- Sensor intercomparison
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  - Other NASA ESE AM constellation sensors
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Introduction

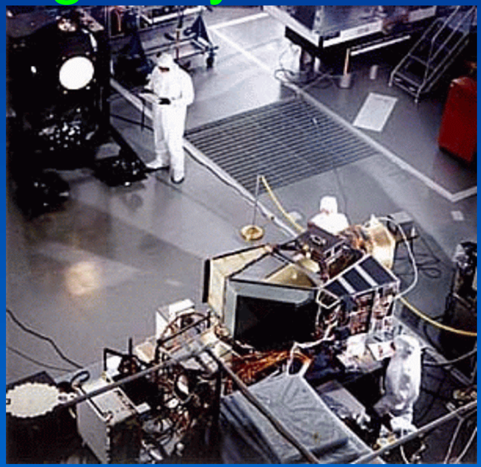
As has been discussed there are both preflight and inflight methods for calibration of sensors

- Consider the solar reflective
- Typical approach is to have the sensor view a known source
  - Carefully following protocols provides a calibration with “known” accuracy and precision
  - Allows sensors to be compared directly
  - Travelling standards increases confidence that two sensors should be comparable
- Preflight calibration and characterization is critical to understand the sensor
  - Many tests cannot be done well on orbit
  - Other tests are critical for fully understanding the sensor

Need for inflight calibration

Inflight calibration is needed due to the uncertainties in going to orbit

- Difficult to predict fully the inflight behavior using laboratory approaches
  - Size of source
  - Spectral effects
- Behavior of the sensor is different on orbit
  - Sensor degradation
  - Lack of gravity



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Vicarious approaches

Vicarious approaches are useful for inflight calibration since they won't degrade over time

- Examples are
  - Lunar approaches have been successful for several sensors
  - Rayleigh scattering
  - Desertic scenes
- Reflectance-based approach is used here as an example
  - Described previously
  - Measure the surface and the atmosphere at time of sensor overpass
  - Results of measurements go into a radiative transfer code to predict at sensor radiance

Intersensor comparison

Precision of vicarious approaches is now at a level to allow them to be used for sensor intercomparisons

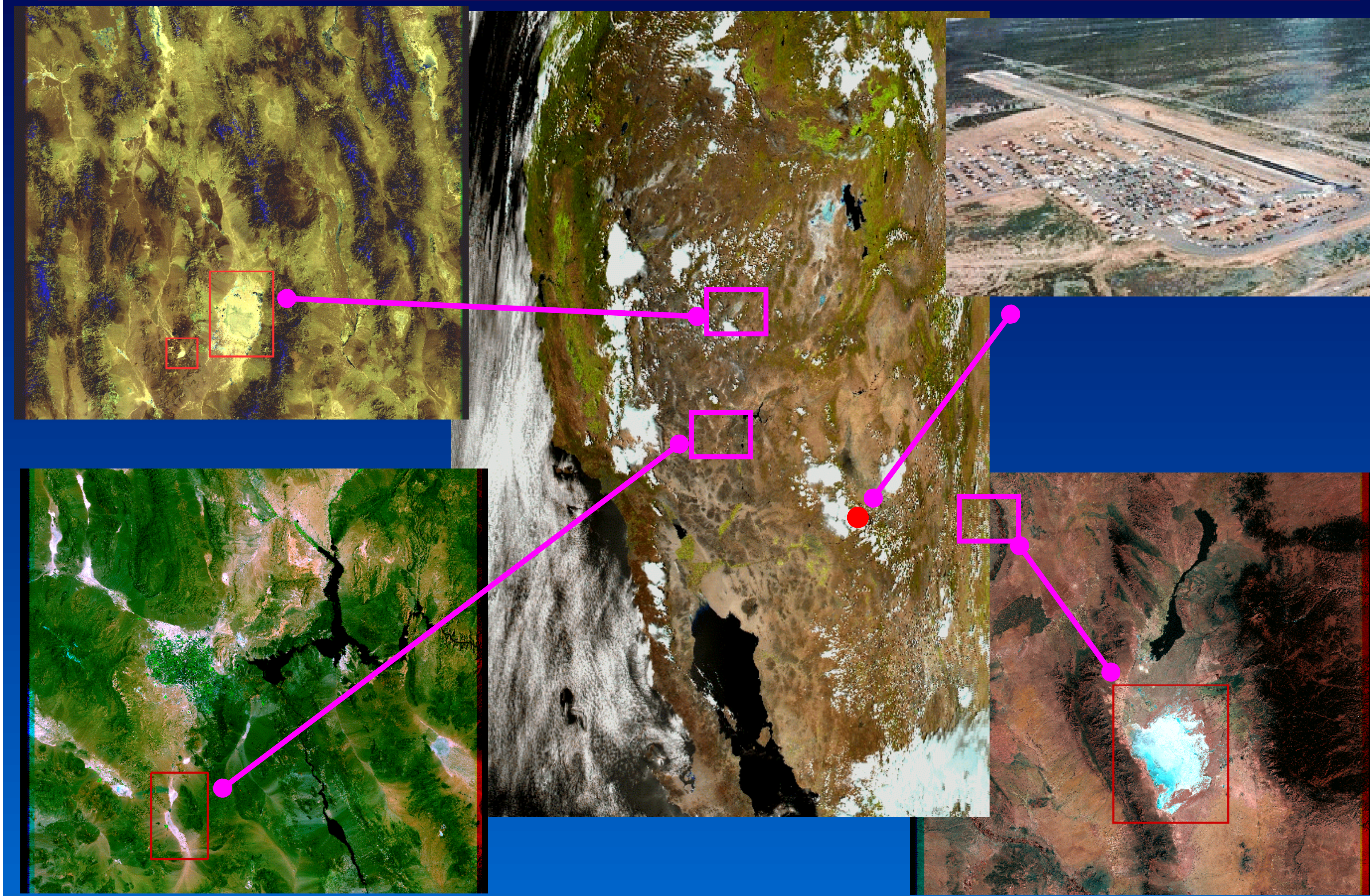
- Not proposing a cross-calibration method
- More similar to the concept that two sensors calibrated in the same laboratory should agree with each other
  - Laboratory calibration based on traceable standards
  - Consistent application of the laboratory protocols
- Likewise, two sensors vicariously calibrated by the same approach can be compared to examine for biases between them
  - Vicarious method is consistent in its application
  - Accuracy is not critical at this point
- Well understood traceability and sensor-to-sensor effects needed to allow comparisons between different methods

Overview of ETM+ data sets

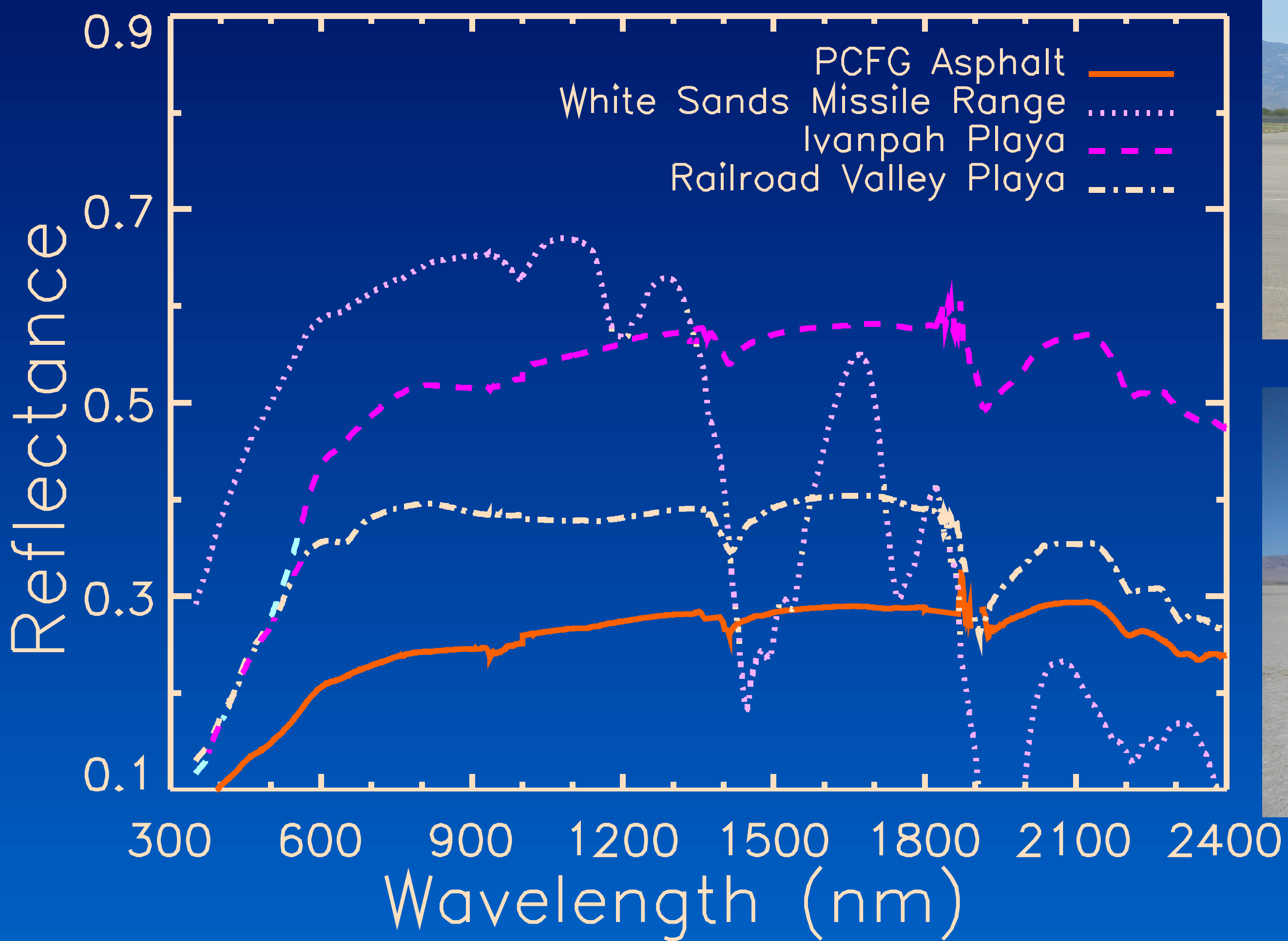
Begin with ETM+ results as a starting point

- Recall characteristics of ETM+
  - "Wide" swath using whiskbroom scanning
  - Multispectral
  - 30-m ground spatial resolution
- Use ETM+ for several reasons
  - A total of 61 data sets exist from all RSG test sites for the lifetime of Landsat-7
  - Results show little to no degradation since launch
  - Vicarious results agree with the preflight and onboard calibration to within the uncertainties of the methods
- Used Chkur solar model from MODTRAN
- Additional 25 data sets not usable due to poor weather, ground instrumentation failures, and lack of sensor data

Most-used RSG test sites

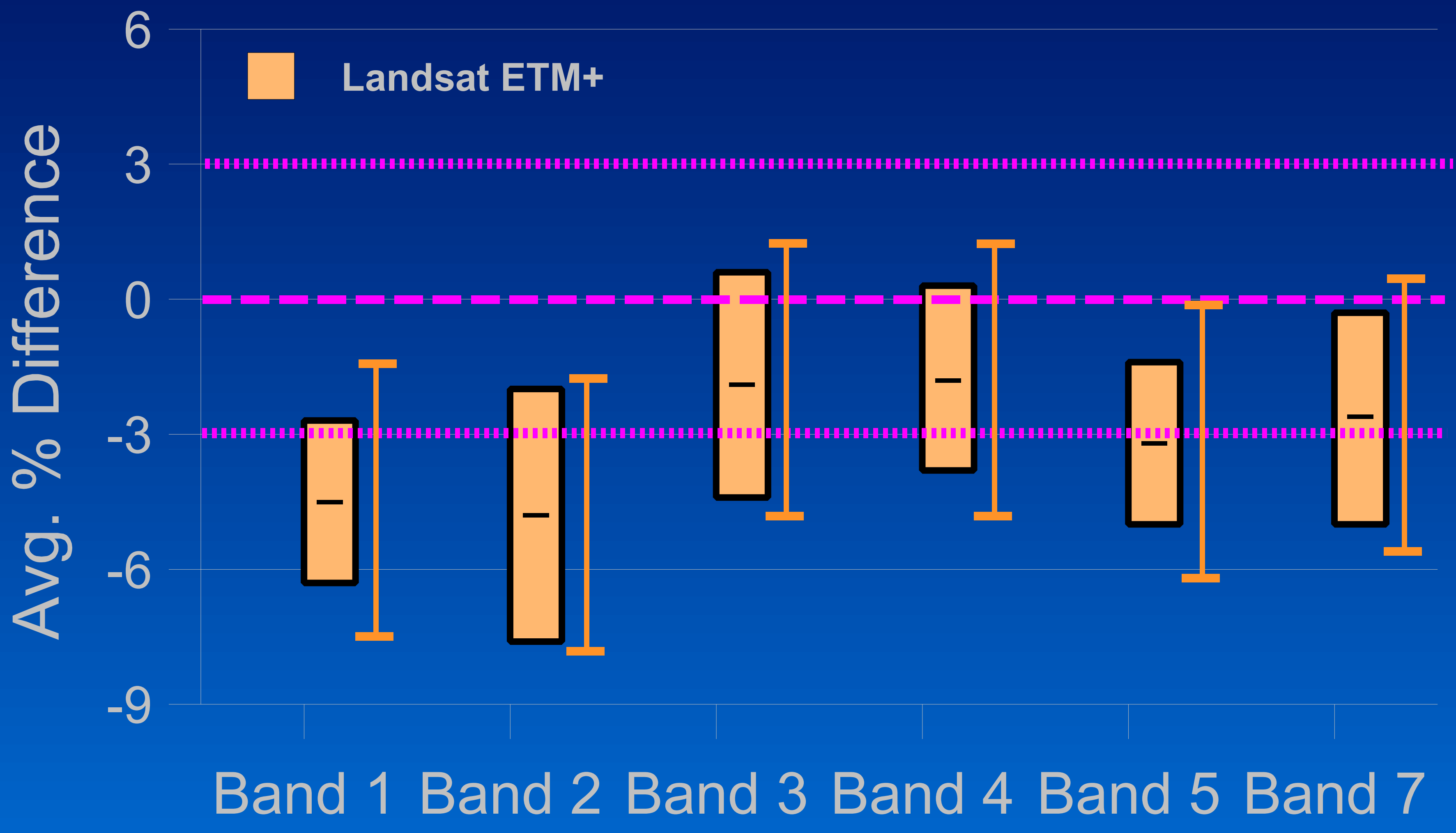


Test Site Spectral reflectance



ETM+ results - Large sites

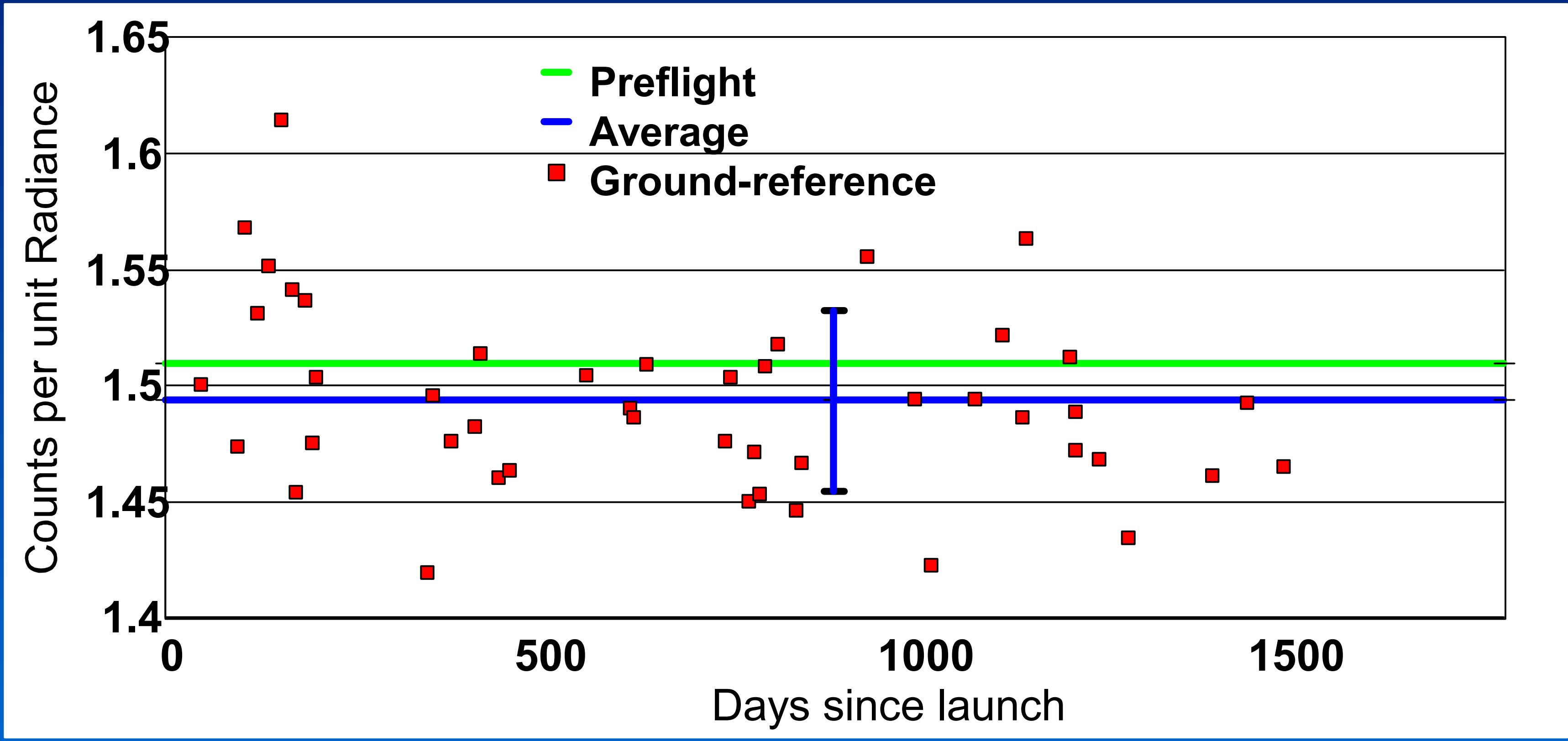
Average percent difference between preflight calibration and reflectance-based calibration results



ETM+ temporal results

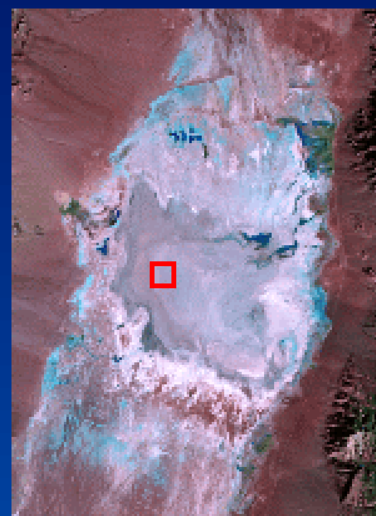
Band 4 results showing preflight calibration as well as average and standard deviation of vicarious

- Indicates little to no trend
- Other bands show similar results



ETM+ outliers

Clear from previous viewgraph that the results from some dates are not consistent



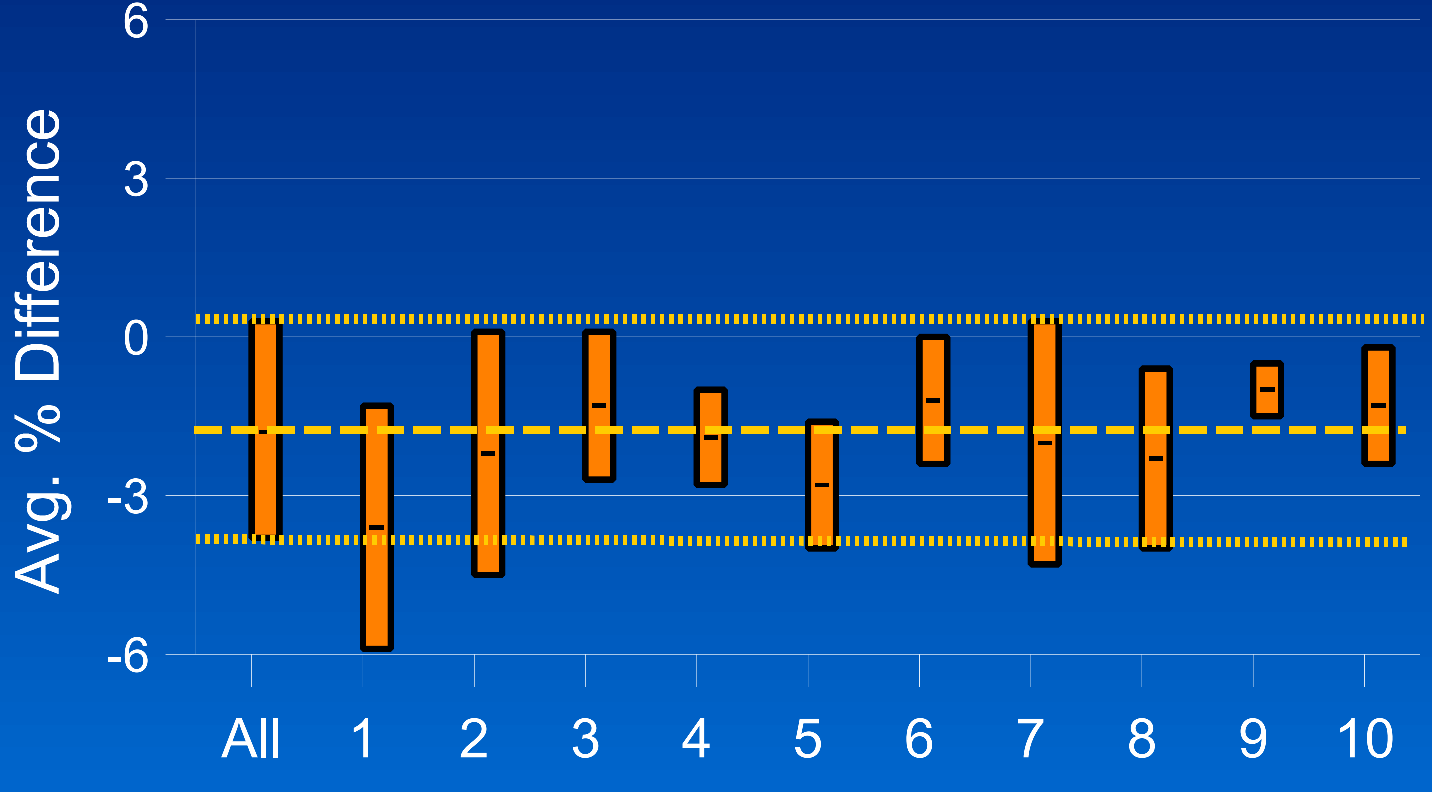
- Numerous possible causes of outliers
- Unfortunately, no obvious, single source of outlier data sets

Radiative Transfer Code

Resampling ETM+ results

Show the original average percent difference as well as 10 other cases based on five data point averages

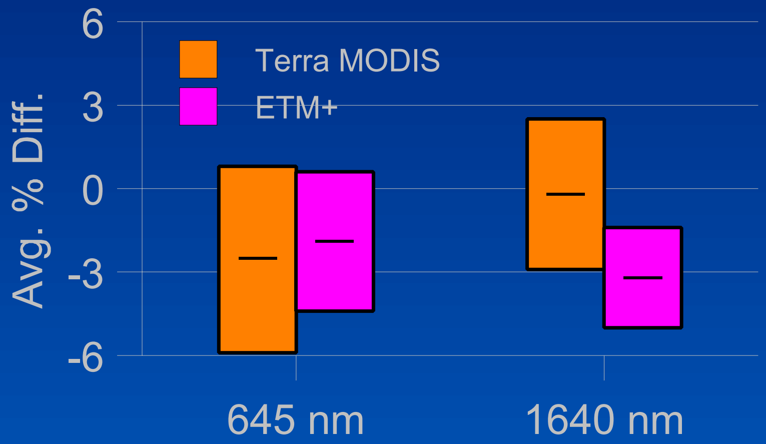
- Five data points were selected randomly
- All averages agree within the original precision of full data set



Intercomparison approach

Confident that the precision of the reflectance-based approach allows repeatable results for a given sensor

- Evaluation of the approach for other sensors shows similar precision values
- Possible to compare the reflectance-based results for multiple sensors
  - Compute average percent difference for two sensors
  - Compare the percent difference between sensors



- Biases between vicarious and sensors is not examined at this point
  - No attempt to say which sensor is correct
  - Traceability studies and accuracy assessments should allow bias studies

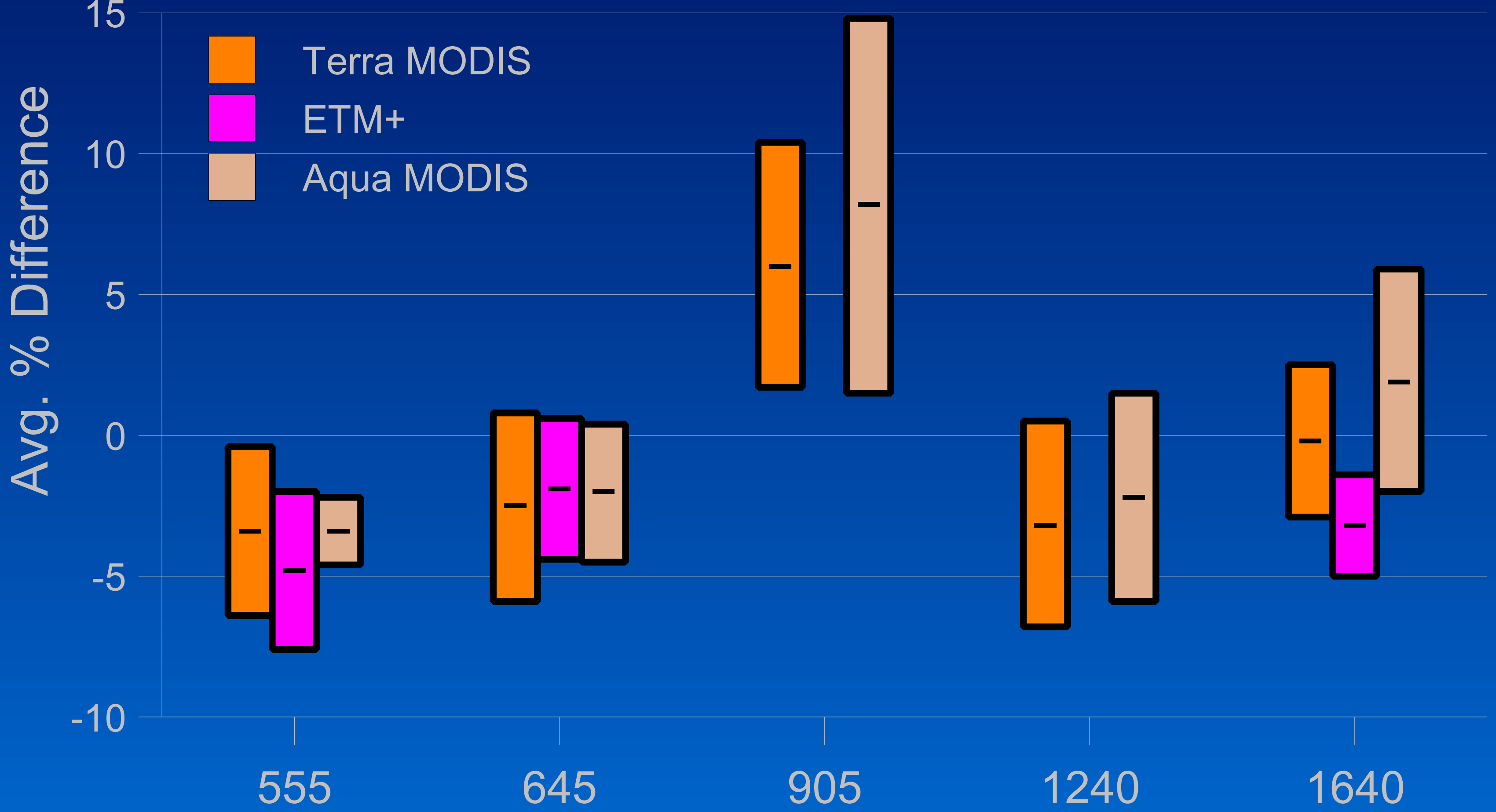
MODIS/ETM+ example

Begin with the example of comparing MODIS and ETM+ data

- MODerate resolution Imaging Spectroradiometer
  - Launched by NASA in 1999 on the Terra platform and in 2002 on the Aqua platform
  - Large swath
  - 36 spectral bands dedicated to ocean, land, and atmosphere studies
  - 250 m, 500 m, and 1000 m resolution
- Advantages to using MODIS as an example are
  - All three sensors built at Santa Barbara Remote Sensing
  - Terra MODIS within 45 minutes of ETM+ in its orbit
- Note, that Terra and Aqua MODIS cannot view the RSG test sites on the same day at near-nadir view

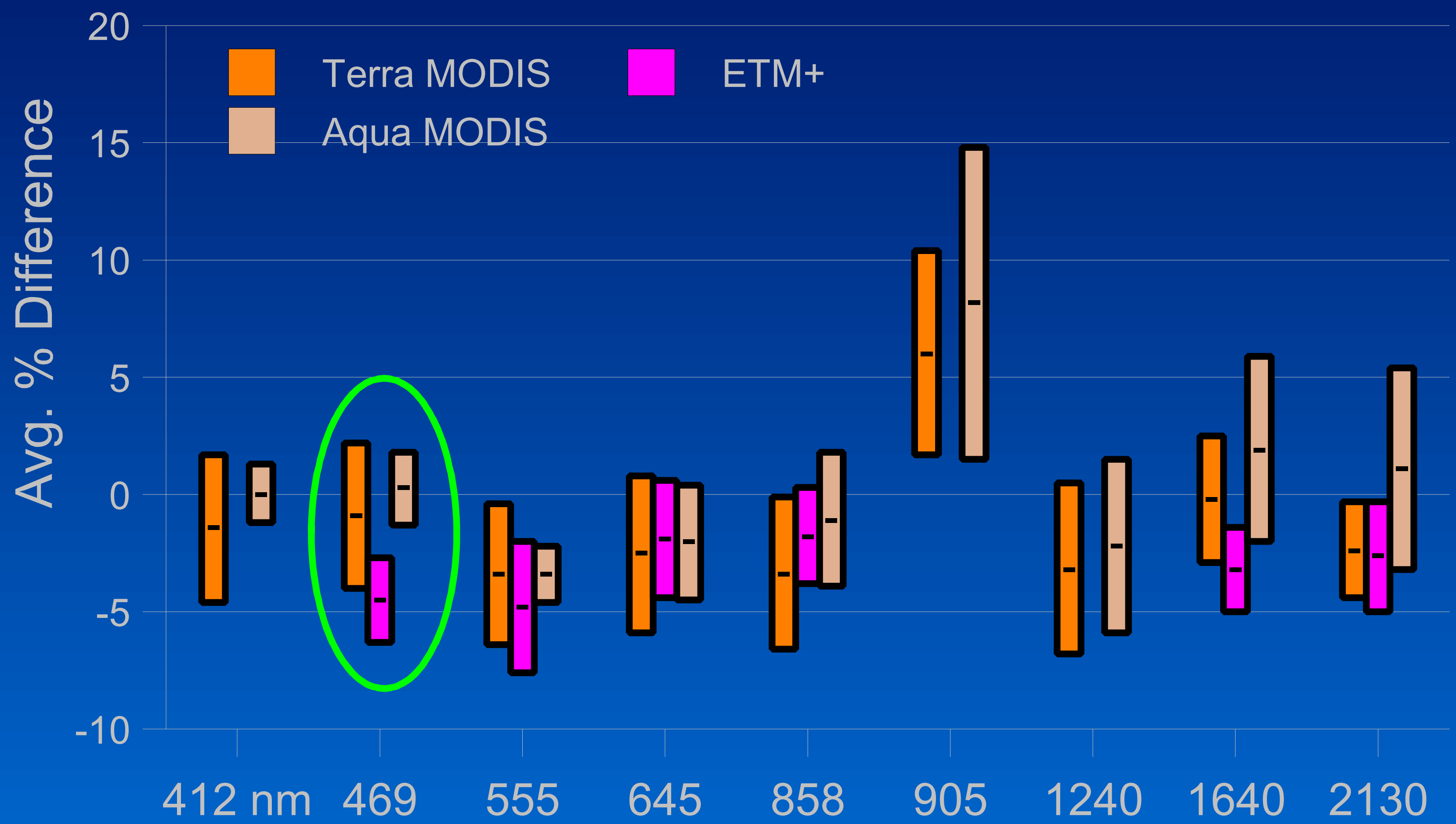
MODIS/ETM+ intercomparison

- Bands shown are a subset to illustrate approach
- Want to focus on how results compare to each other for a given band



MODIS/ETM+ intercomparison

- All unsaturated bands of MODIS are shown now
- Only 469-nm band has disagreement larger than the standard deviations (Aqua MODIS and ETM+)

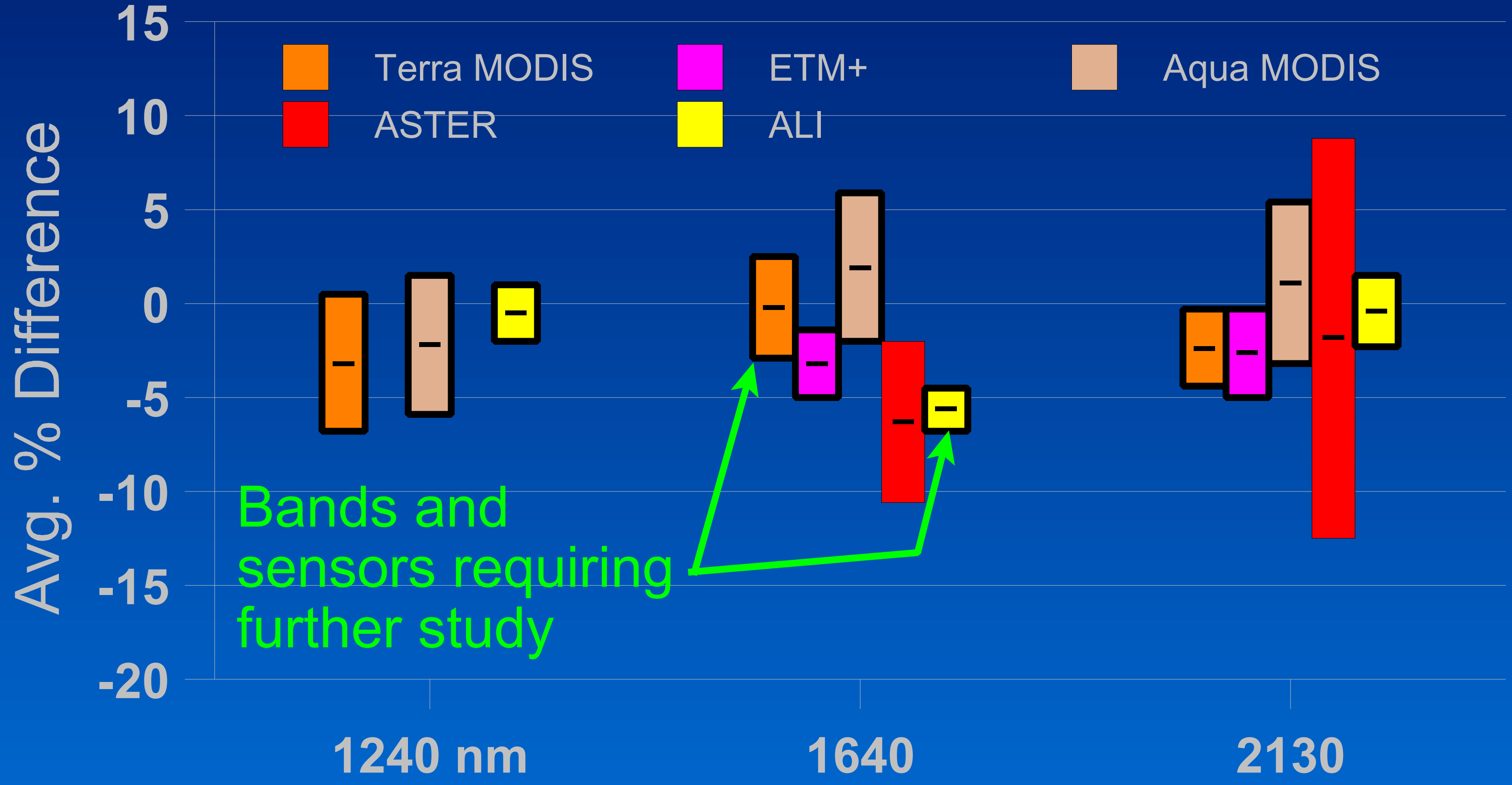


More sensor comparisons

- Average percent difference and 1-σ standard deviation shown here for ALI, ASTER, ETM+, Hyperion, and Aqua & Terra MODIS
- VNIR bands only shown for clarity

More sensor intercomparisons

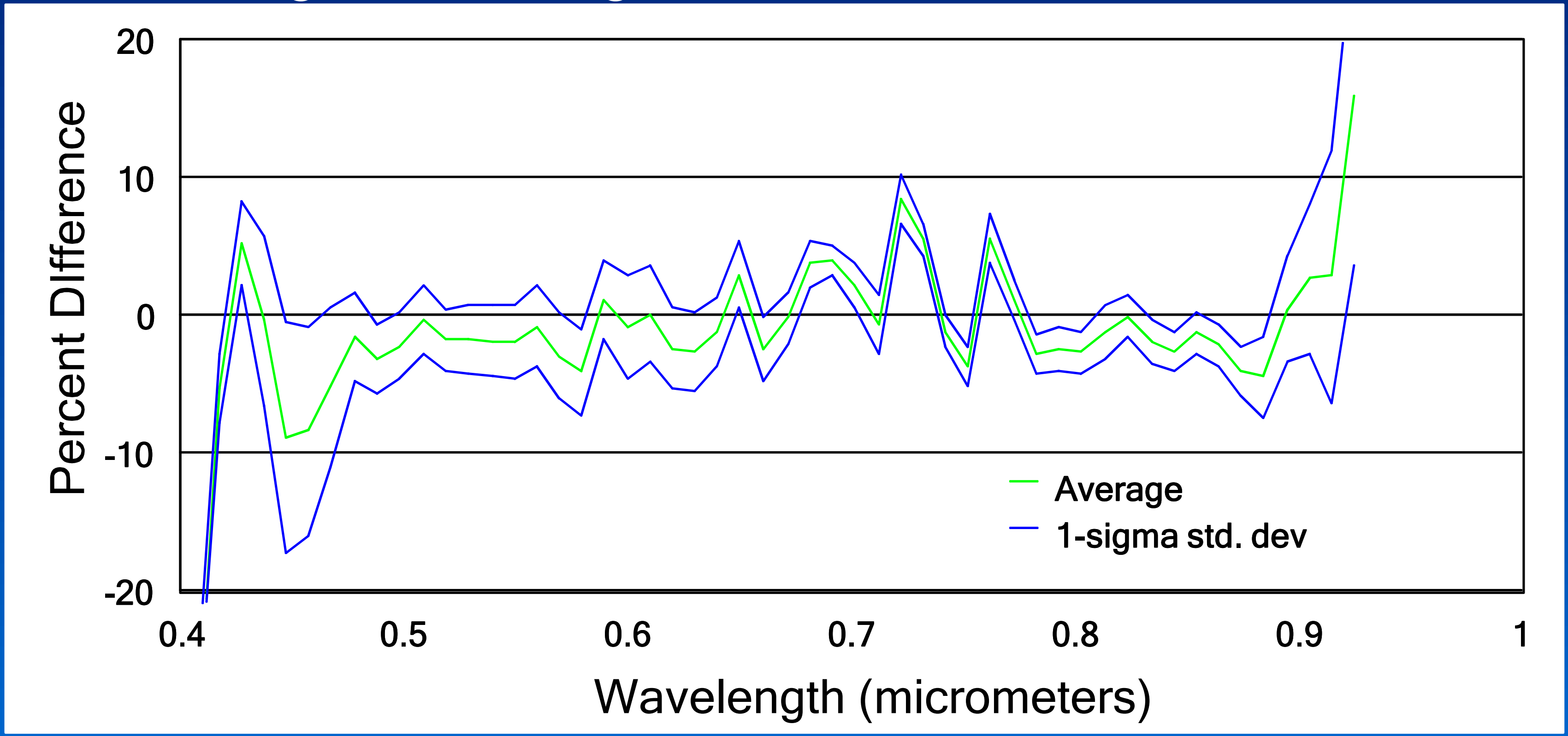
- SWIR bands shown here
- Hyperion not shown due to lack of data sets
- Note the small standard deviations of ALI



Hyperspectral application

Approach not limited to multispectral bands

- Results here show all VNIR bands of Hyperion for the five data sets
- Note the consistency in standard deviation with wavelength indicating differences are consistent



Protocol establishment

A development of protocols is necessary In order for this philosophy to work well

- Does **not** mean all groups must do the same things
- Does mean that all groups should collect a similar basis set of data to allow similar processing
- Within a group, the effort should be to do the best job to repeatably collect similar data sets over time
  - When equipment or methodologies change there should be careful intercomparisons within that group
  - The RSG followed this mentality for ETM+
    - Same basic aerosol distribution and composition
    - Similar equipment
    - Careful set up and characterization of reflectance references
    - Surface reflectance measurement schemes

Issues

Multiple issues still affect the consistency of the comparisons within a method and between methods

- The solar irradiance issue is avoided in this work since all comparisons are self consistent
  - This issue cannot be avoided for much longer
  - As long as users convert data to reflectance before comparisons there should not be a problem
- Need multiple groups using the same methods with similar protocols
- Need multiple approaches
- Accuracy assessments of vicarious methods are needed in order to compare between methods and to fill spectral gaps
- Size of source impacts comparisons between methods

Conclusions

Vicarious methods can be used for sensor intercomparisons

- Does **not** require coincident collections
  - Does require consistent application of a 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
- Vicarious methods have become more repeatable
- Vicarious methods are an excellent method for ensuring consistency of sensors over time and across platforms