# Sensor interconsistency to achieve climate-quality measurements

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# Need for inter-consistency

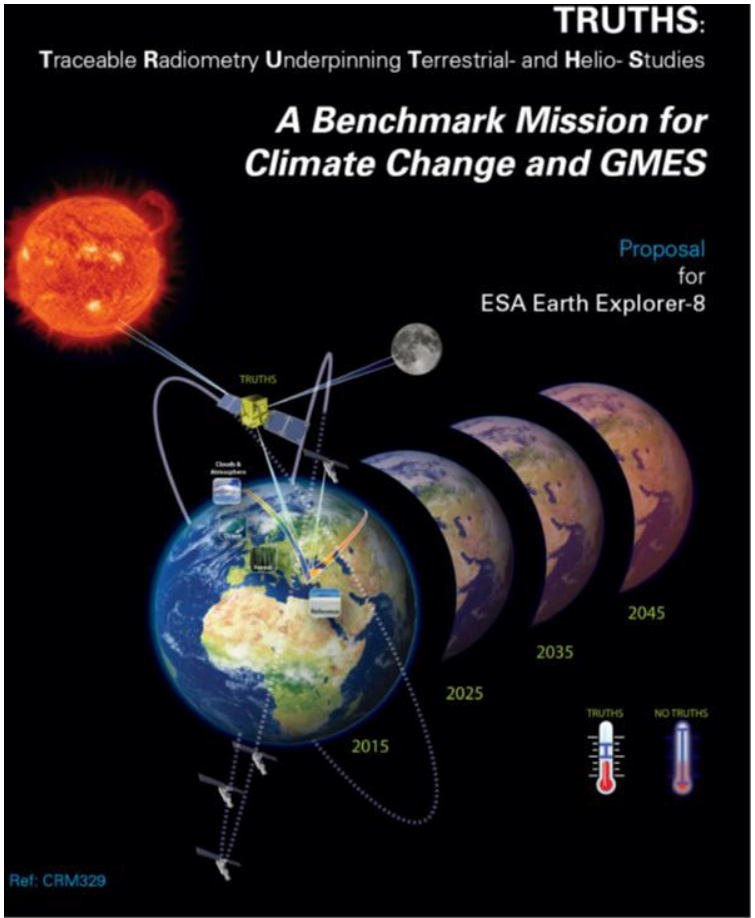
## Climate-system modeling relies on a wide array of current (and future) systems

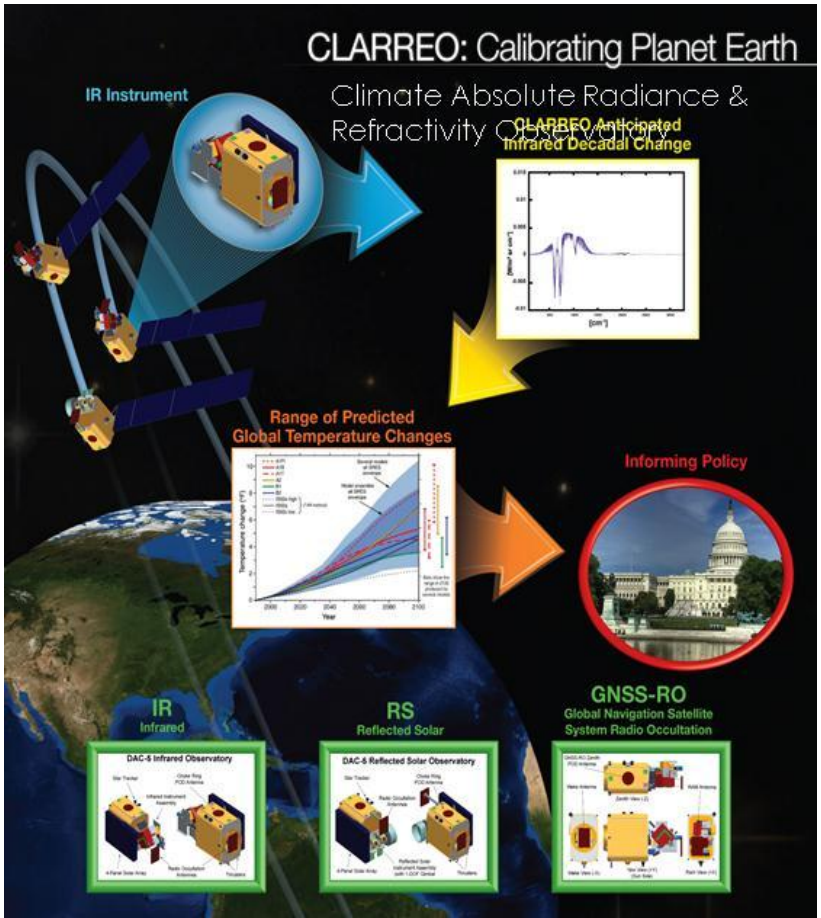
- Research-quality systems
- Operational weather systems
- Requires consistently calibrated and validated data sets
  - Intercalibration to a few high-quality sensors
  - Valid across time and multiple countries

# Climate-quality data

## "Absolute" uncertainties < 0.3% in band-integrated albedo

- TRUTHS (Traceable Radiometry Underpinning Terrestrial- and Helio-Studies)
- CLARREO (Climate Absolute Radiance and Refractivity Observatory)

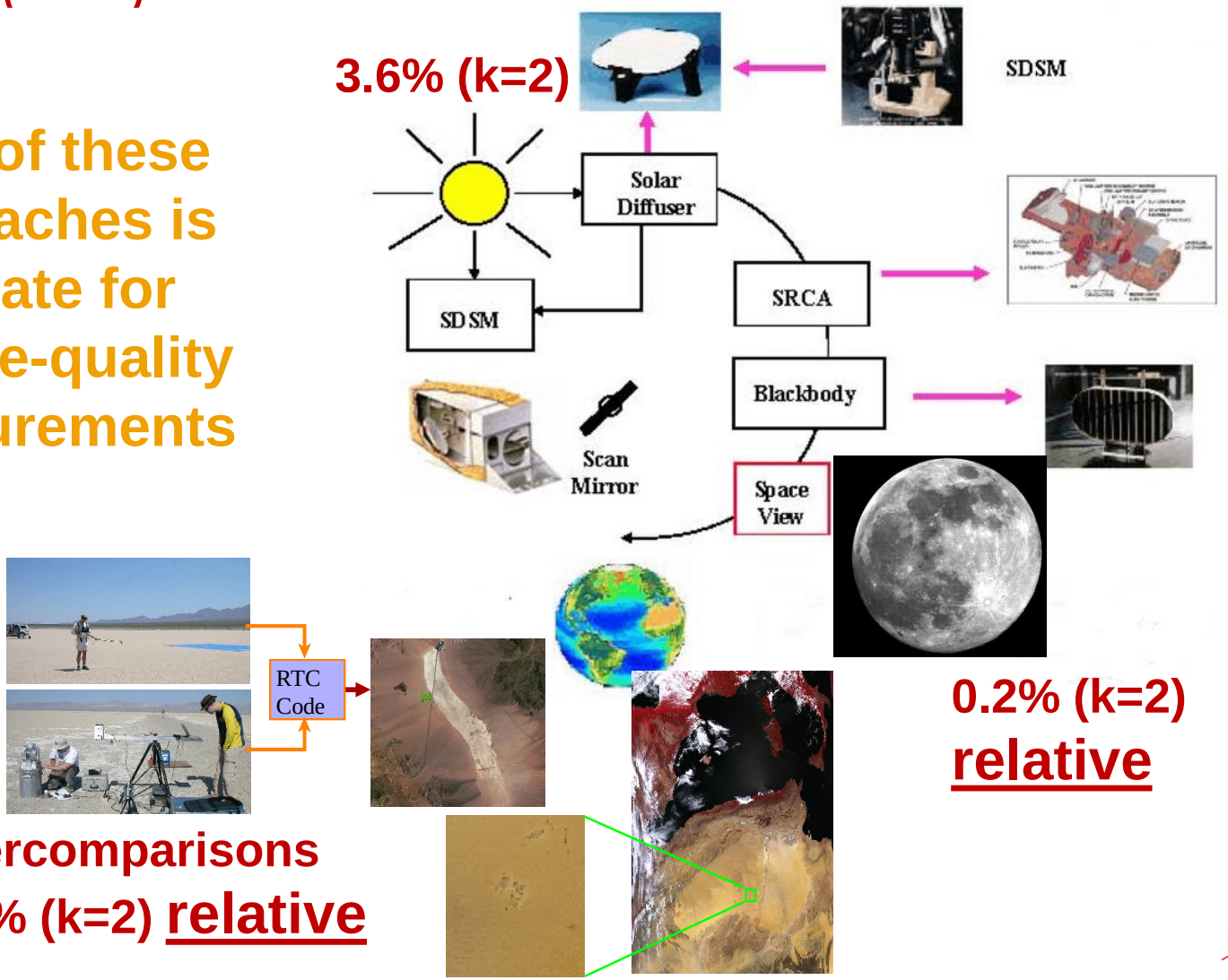


# Current calibration approaches

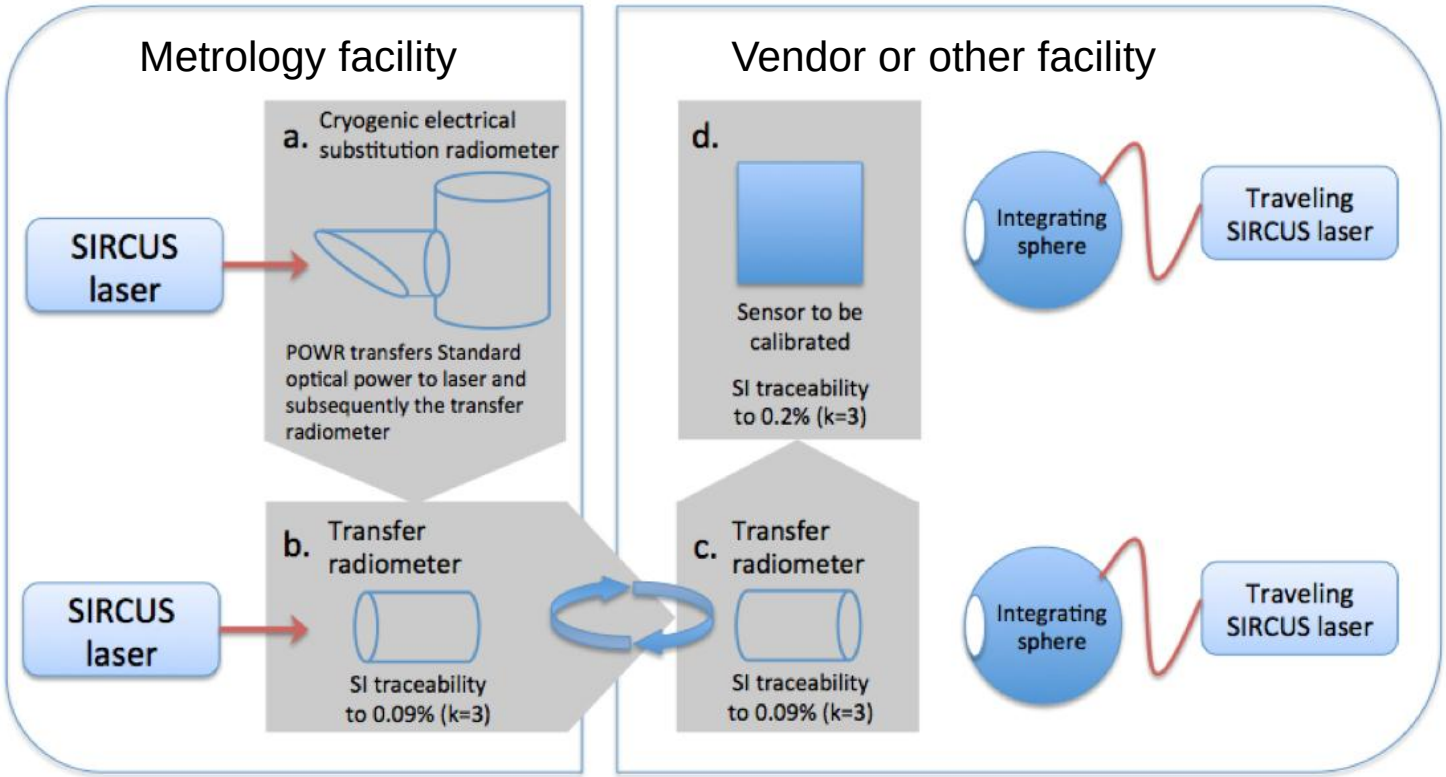
Best sensors have reflectance accuracy of 3.6% (k=2) in mid-visible [4.2% in radiance]

**None of these approaches is adequate for climate-quality measurements**



# Detector-based approaches for climate quality

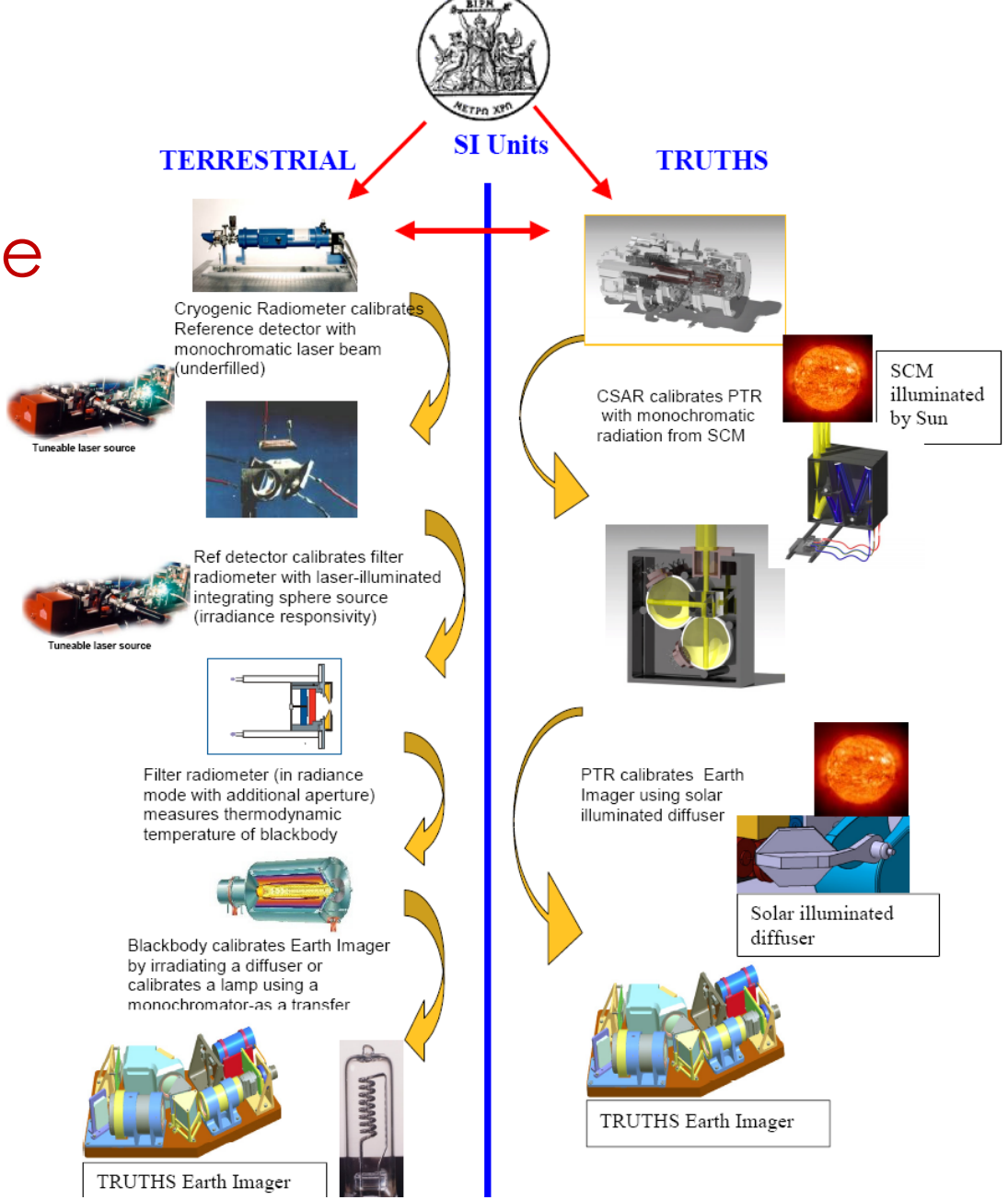
## Near-monochromatic sources can be characterized to 0.09% (k=2)




# TRUTHS

## TRUTHS takes that laboratory to space

- Primary reference is electric substitution cryogenic radiometer
- Tunable monochromatic beam calibrates other TRUTHS instruments
- Earth imager aperture illuminated by deployable diffuser
- Measures incoming and reflected solar

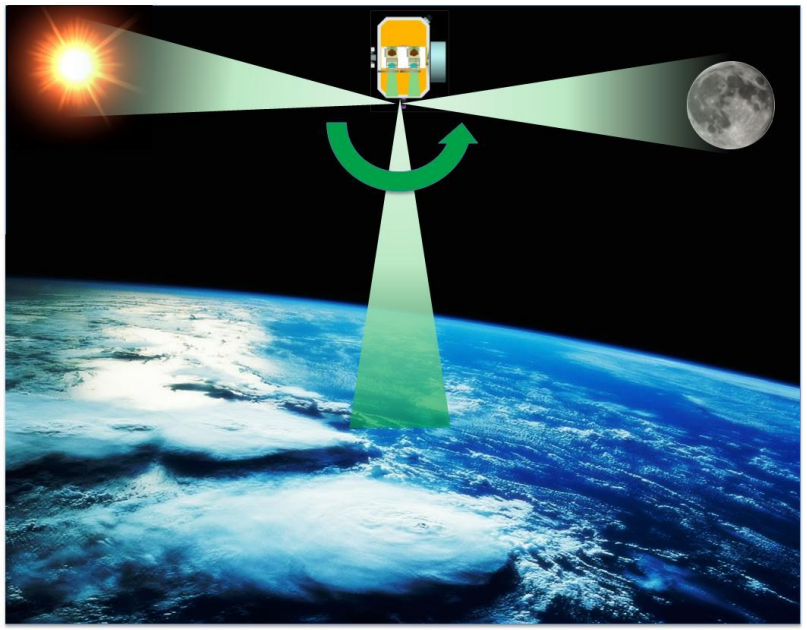


# CLARREO

## CLARREO relies on a ratioing radiometer approach to obtain reflectance

- Advantage is you have a known on-orbit calibration source
- Still requires careful characterization of the sensor in the laboratory
  - Stray light
  - Detector stability
  - Noise behavior

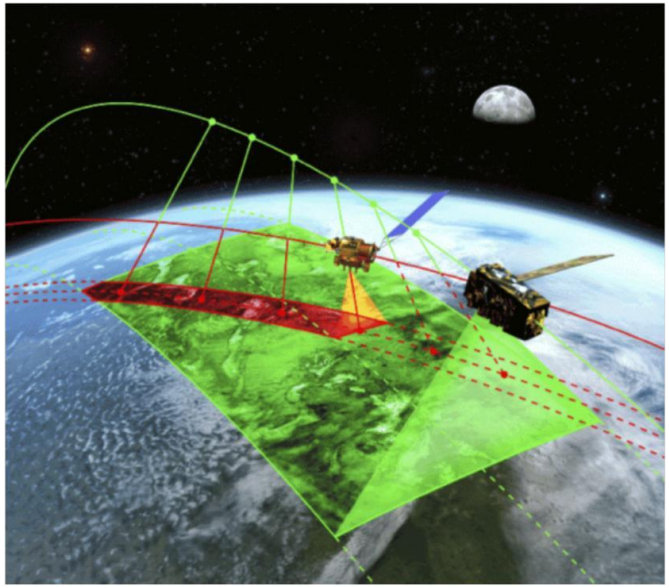
**Benchmark reflectance** from ratio of earth view to measurements of irradiance while viewing the sun

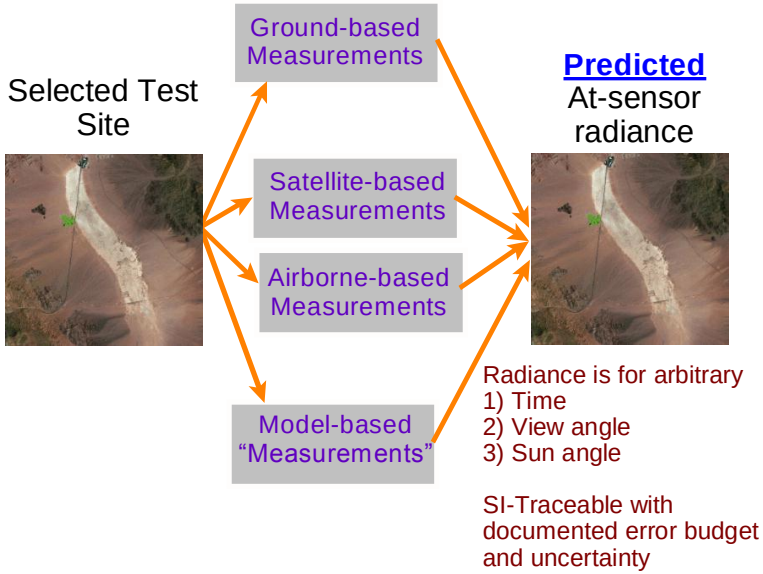


Lunar data provide calibration verification

# Intersensor comparison approaches

## Two approaches 1) near simultaneous views & 2) site characterization



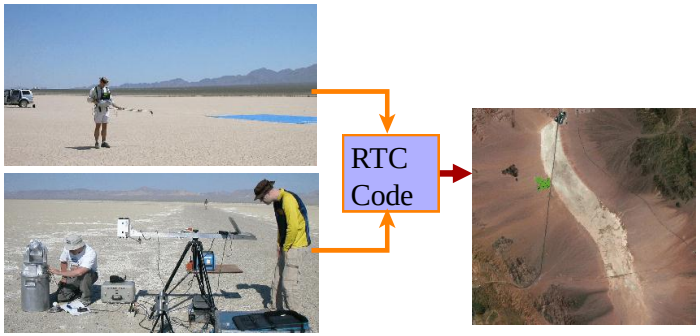


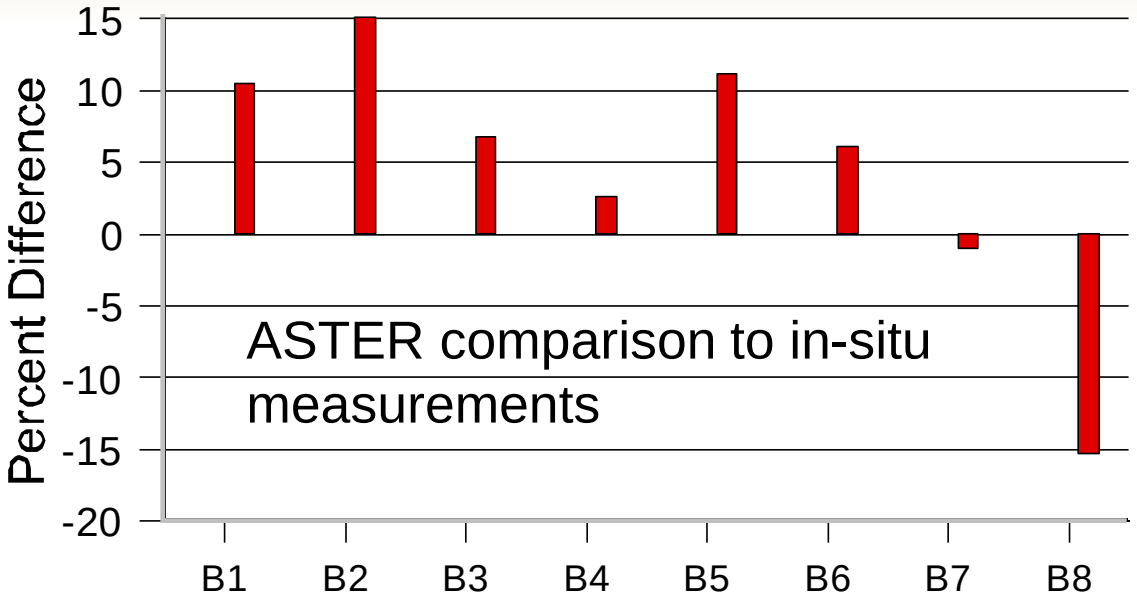

- Near-coincident views require chance coincidences or active pointing
- Site characterization approaches rely on careful site evaluation to allow at-sensor radiance predictions
- **Methods with SI traceability do not require sensor data to overlap in time**

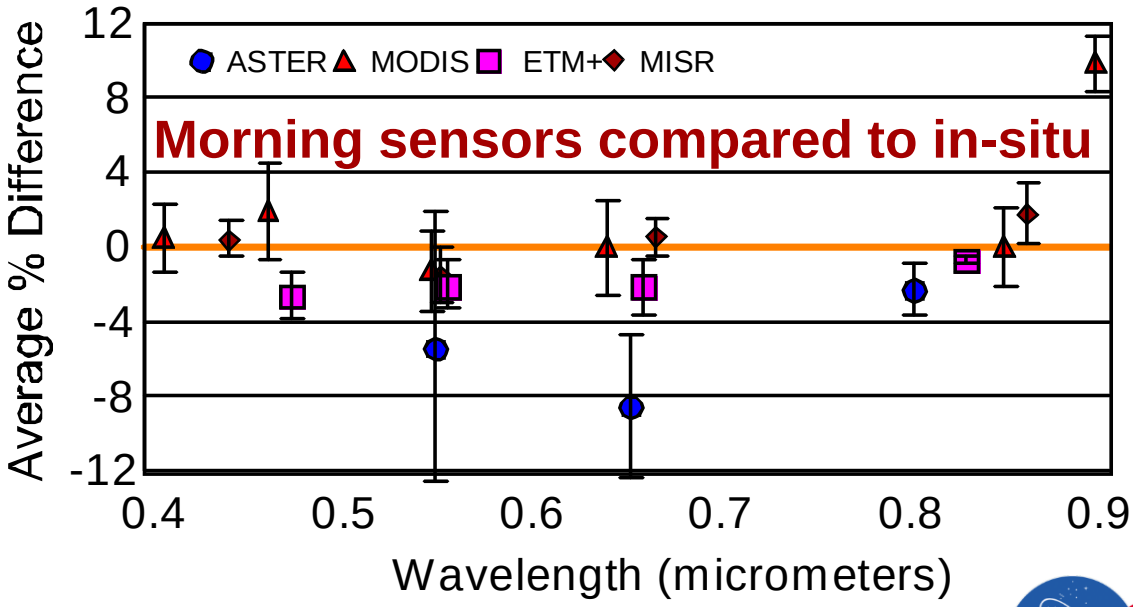
# Site characterization

## SI-traceable, ground-based measurements

- **Not** a sensor-to-sensor approach
- Allows calibration relative to an agreed standard
- **Multiple sensors can be calibrated**



# Improved site characterization approach

Selected Test Site

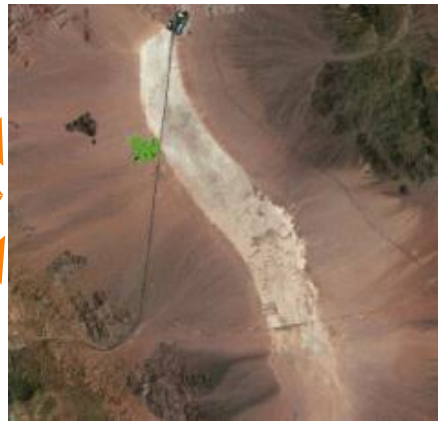
Ground-based Measurements

Satellite-based Measurements

Airborne-based Measurements

Model-based "Measurements"

**Predicted** At-sensor radiance



**Requires highly accurate sensors to decouple atmospheric, surface, and sensor effects**

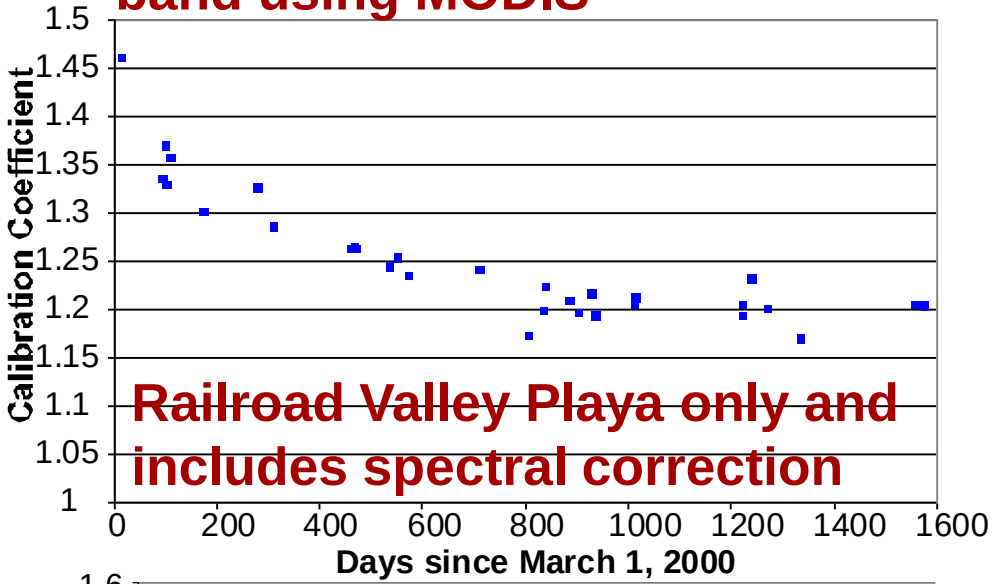
**Moves away from one-to-one cross calibrations and empirical only**

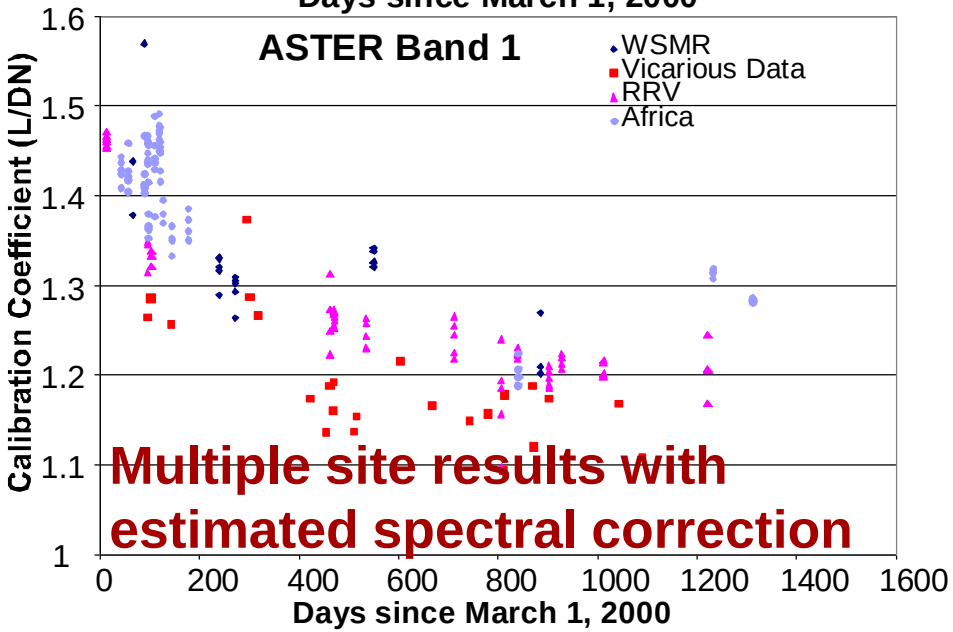
Radiance is for arbitrary
1) Time
2) View angle
3) Sun angle

SI-Traceable with documented error budget and uncertainty

# Why need high-accuracy sensors?

**Calibration for ASTER green band using MODIS**



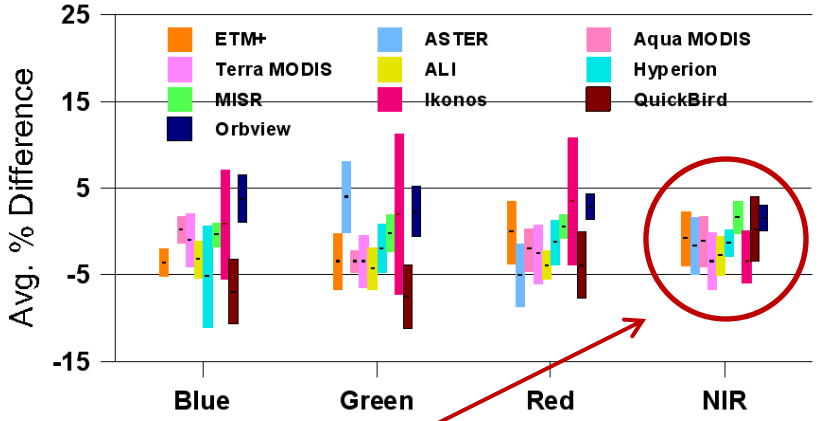




## MODIS and ASTER "easiest" case

- Same platform, coincident views, similar bands
- ASTER Band 1 (green band) results using MODIS
- Scatter caused by
  - Spectral band differences
  - Registration effects
  - Sensor effects

# Differences between sensors

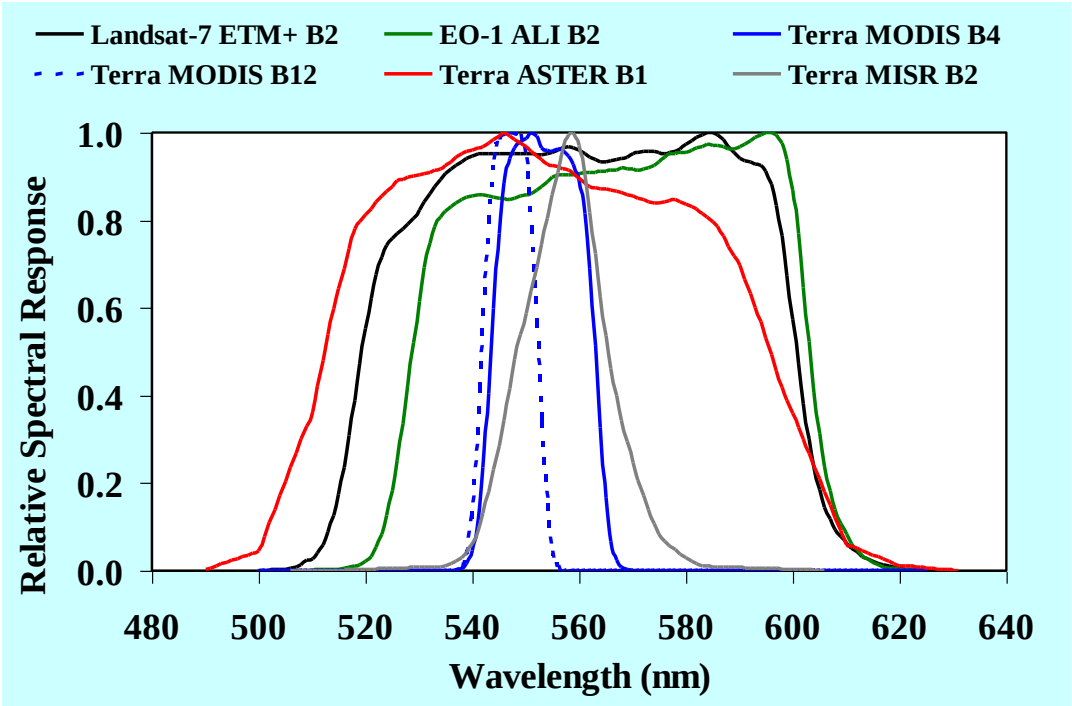
## High-accuracy, imaging spectrometry would provide necessary understandina of test sites




- Cannot decouple
  - On-orbit sensor effects
  - Atmospheric variability
  - Surface variability
- All three play a role
  - Better sensor agreement in the NIR where SNR is largest for sensors
  - Atmospheric effects are not as dominant in NIR
- Improved field sensor design and characterization would improve results
- Improved on-orbit sensors would allow decoupling of uncertainties

# Why need hyperspectral?

| ETM+ Band 2 Analogs | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| A: Landsat-7 ETM+ B2 | 1 | 0.996 | 1.005 | 0.990 | 0.988 | 0.989 |
| B: EO-1 ALI B2 | | 1 | 1.009 | 0.994 | 0.992 | 0.993 |
| C: Terra ASTER B1 | | | 1 | 0.985 | 0.983 | 0.984 |
| D: Terra MODIS B4 | | | | 1 | 0.998 | 0.999 |
| E: Terra MODIS B12 | | | | | 1 | 1.001 |
| F: Terra MISR B2 | | | | | | 1 |



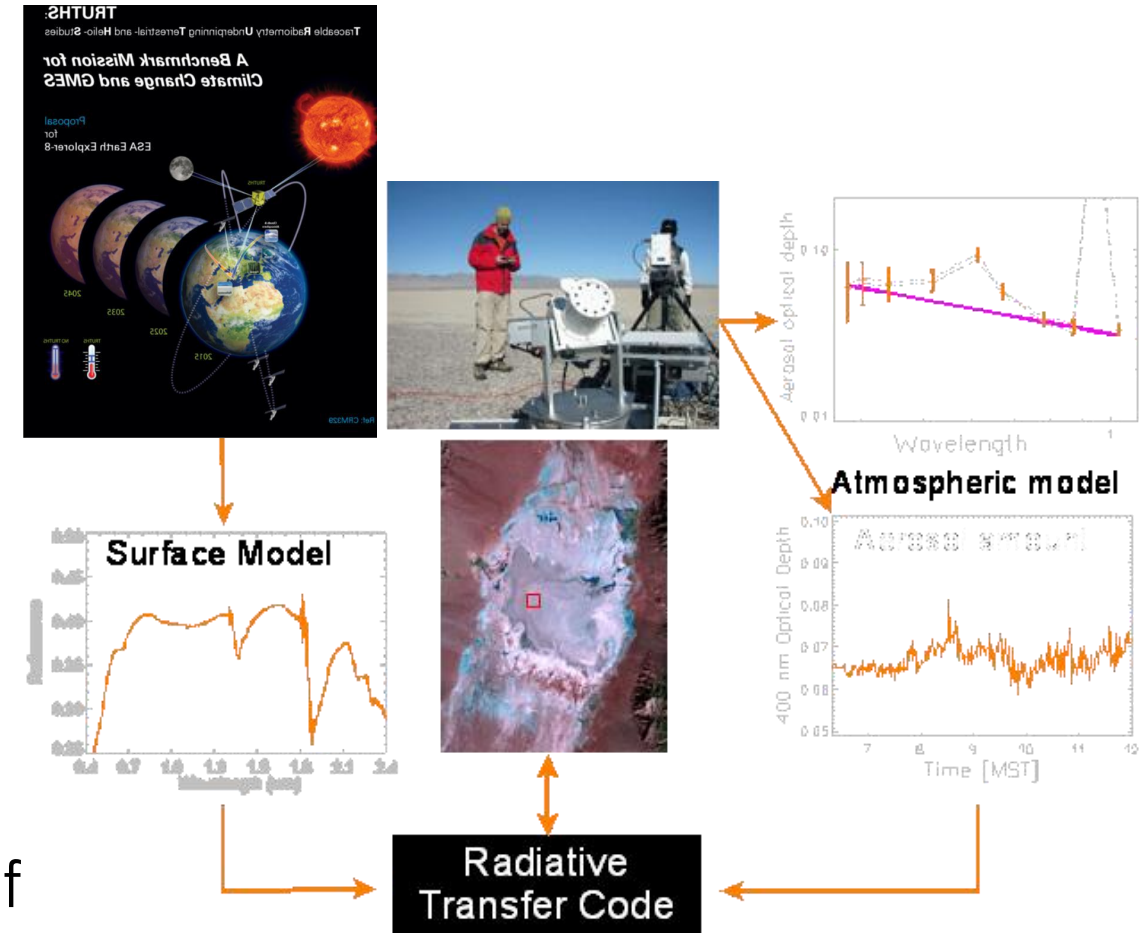

Uncertainty due to spectral differences decrease as **hyperspectral** data of sites are accumulated

Ground data, Hyperion, SCIAMACHY

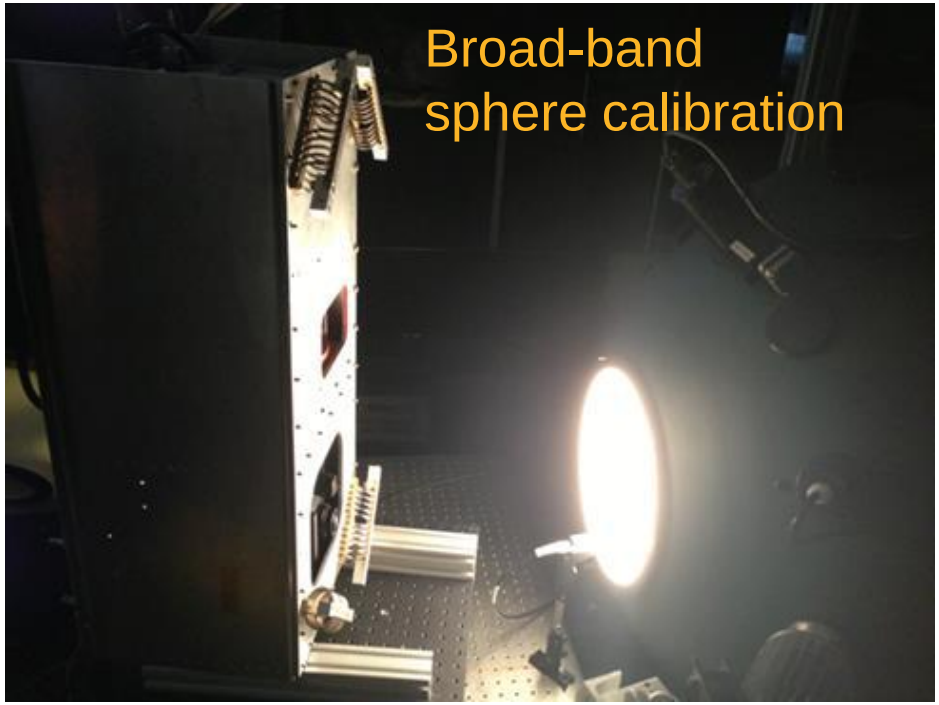
# Key measurements

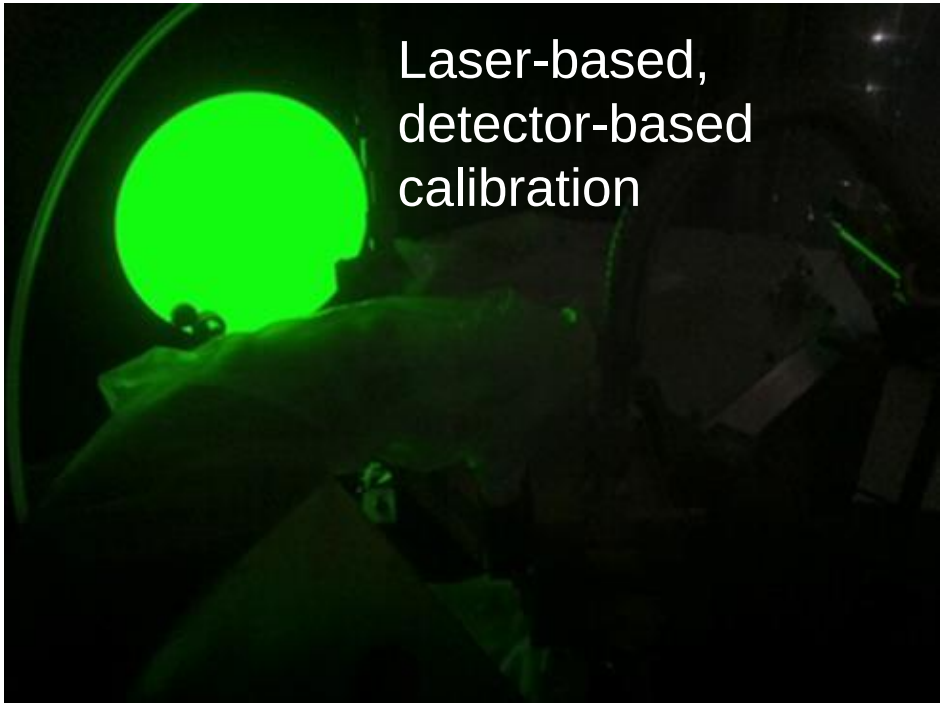
## Spectral and directional reflectance of surfaces are highest priority

- Temporal sampling
  - directional reflectance
  - Site stability
- Imaging provides spatial information
- Spectral samples aggregated to simulate bands
- Imaging spectrometry can lead to knowledge of surface morphology

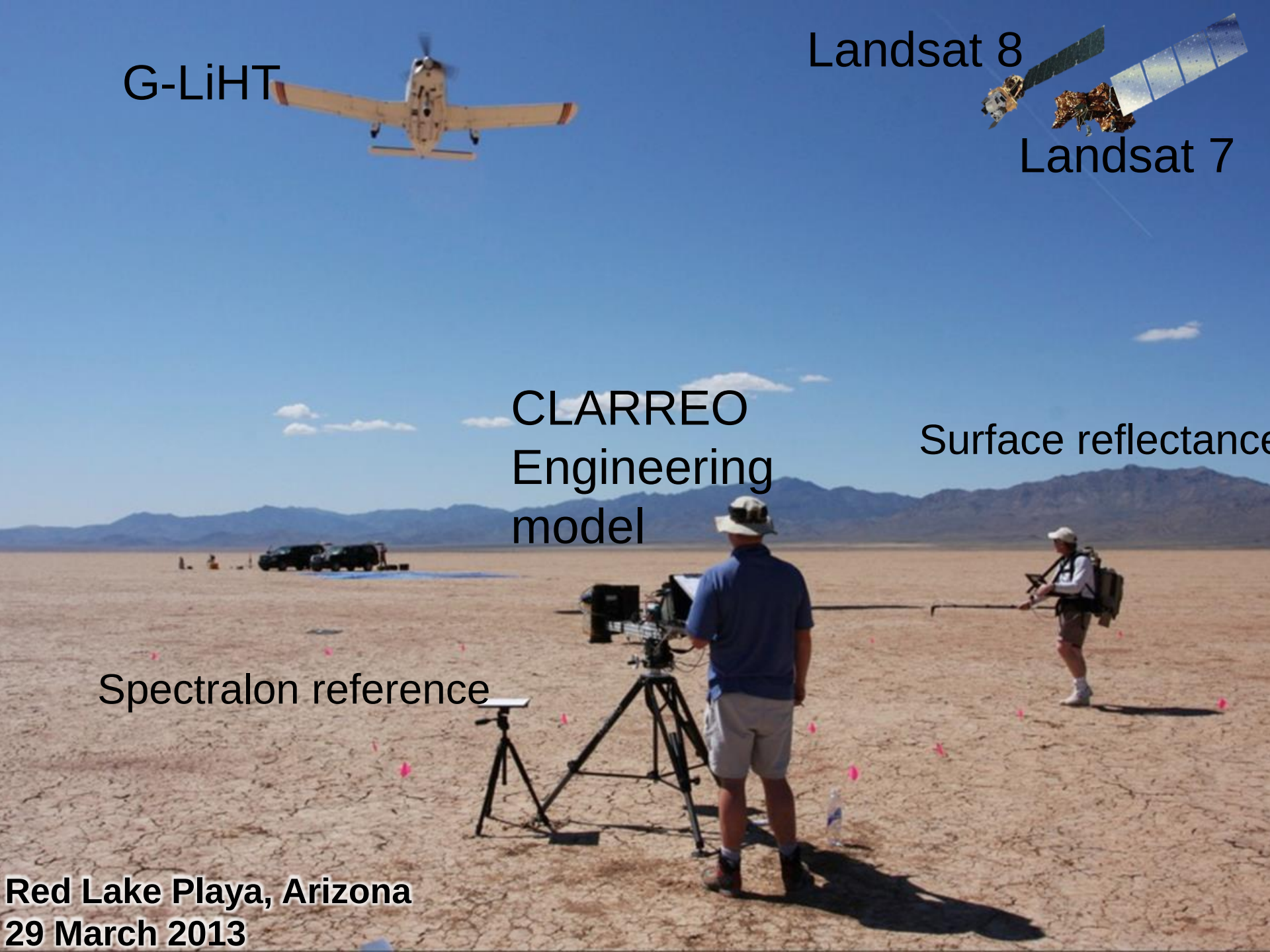


# Improves field sensor design and characterization



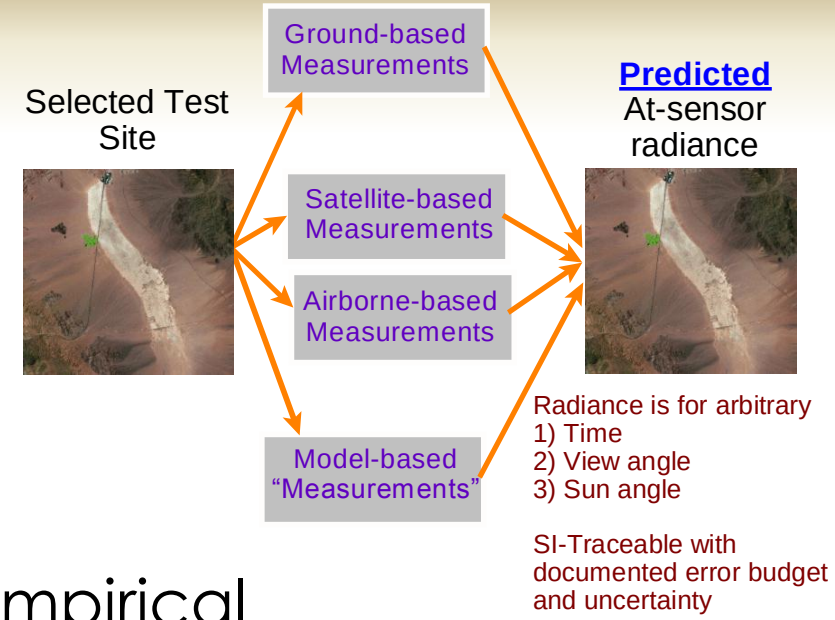




Developing new laboratory approaches for space sensors allows more accurate characterization of field and airborne systems


G-LiHT
Landsat 8
Landsat 7
CLARREO
Engineering
model
Surface reflectance
Spectralon reference
Red Lake Playa, Arizona
29 March 2013

# Summary

Climate-quality requirements will lead to important improvements in site characterization




- Move away from one by one empirical comparisons between sensors
- Requires agreed upon standard against which to compare sensors and products
- Climate-quality imaging sensors and field instruments will provide the data necessary for accurate physical models
- Such methods will provide improved relative agreement and eventually lead to absolute results with better understood uncertainties