Landsat & surface sites inter-calibration needs and priorities

K. Thome

[1]NASA/GSFC

How does CPF help the Land Community?

There are a variety of ways that CPF inter-calibration can integrate with land

- Sustainable Land Imaging program
- Improve results of current land applications
- Account for expected increase in smallsat sensors
- Improve current calibration/validation results
  - Direct calibration of land sensors
  - Improved knowledge of the calibration/validation sites
  - Allowing users to simulate their products with higher quality instrument data

Land Imaging Evolution

While recognizing the scientific need for continuity with the 43-year Landsat record, we are seeing new trends & opportunities in land remote sensing

- *Evolving user needs for…*
  - *Improved temporal revisit*
  - *Additional spectral coverage & resolution*
  - *Integration with other modalities (lidar, radar)*
- *Increasing use of "small sat" platforms and distributed architectures*
- *Increasing number of commercial imaging systems*
- *Potential synergy with international systems (e.g. Sentinel-2)*
- *High-performance computing and increased emphasis on information rather than images*

Our challenge is to advance the measurement capability, while preserving continuity and constraining program costs

SLI Charts courtesy D. Jarrett (NASA HQ)

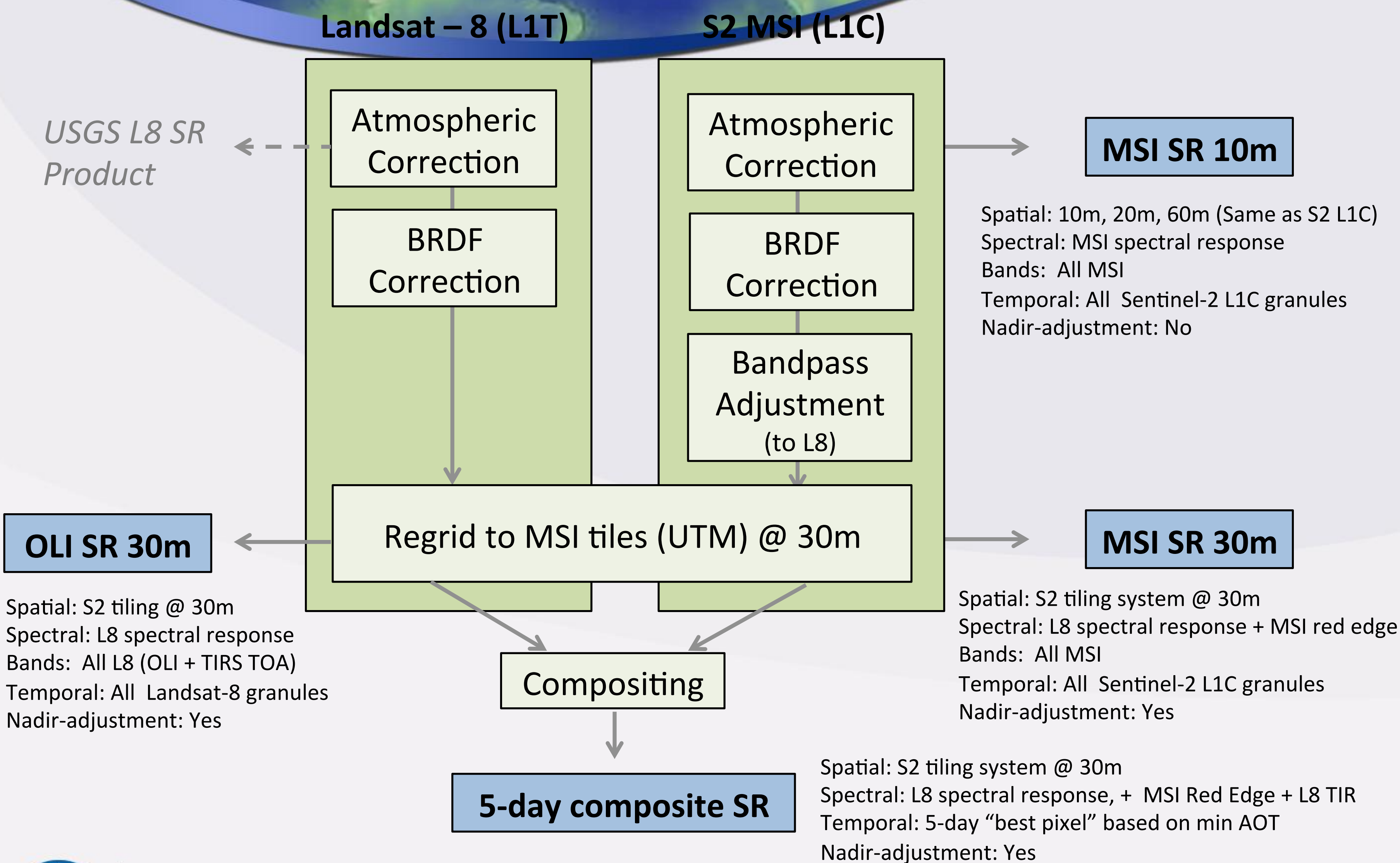
NASA Science Activities Relevant to SLI

NASA is investing in synergistic use of international data sources to improve land monitoring

- Multi-Source Land Imaging Science (MuSLI) Team
  - Solicited through the Land Cover / Land Use Change (LCLCU) research program
  - 3-year activity to prototype land products from fusion of international systems, with focus on Sentinel-1,2 and Landsat (see next slide)
  - Coordinated with ESA SEOM (Scientific Exploitation of Operational Mission) Program

- Harmonized Landsat / Sentinel-2 (HLS) Reflectance Products
  - Goal: seamless, near-daily 30m surface reflectance record from Landsat-8 and Sentinel-2a,b
  - Includes common atmospheric correction, spectral & BRDF adjustment, resampling to common grid & frame (“data cube” concept)
  - Collaboration among NASA GSFC, ARC, and UMD
  - Implemented on NASA Earth Exchange (NEX) – initially as a series of test sites.

HLS Processing Flow

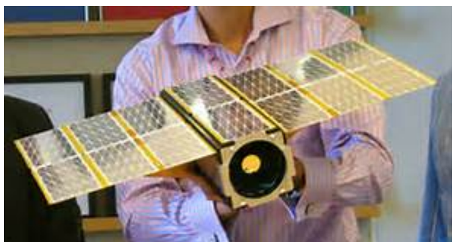


Land imaging getting complicated

Video courtesy NASA's
Scientific Visualization Studio

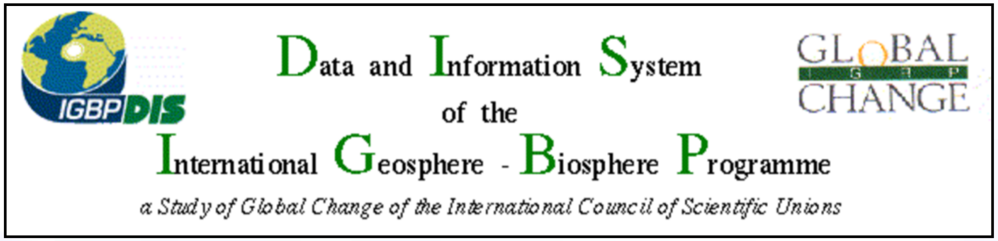
Will need approaches that work for large numbers of imagers

NASA's Earth remote sensing fleet as of early 2015



Brief History of NASA's Land Product Validation (LPV) Program and Supported Activities

- The CEOS Land Product Validation (LPV) subgroup was established as a logical extension of the **International Geosphere-Biosphere Programme Data and Information System (IGBP-DIS)** and the MODIS Land Discipline **(MODLAND)** Team Validation initiatives: **http://landval.gsfc.nasa.gov/index.html**

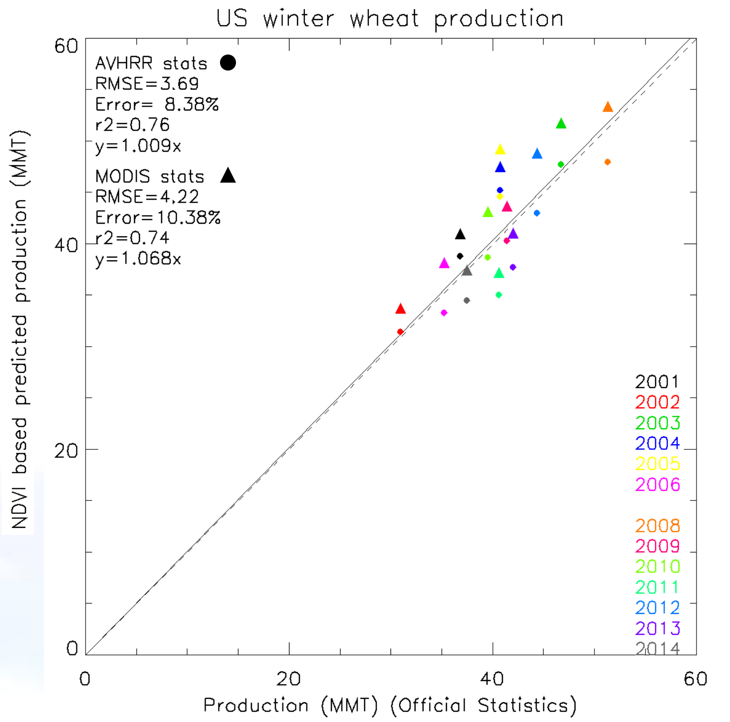


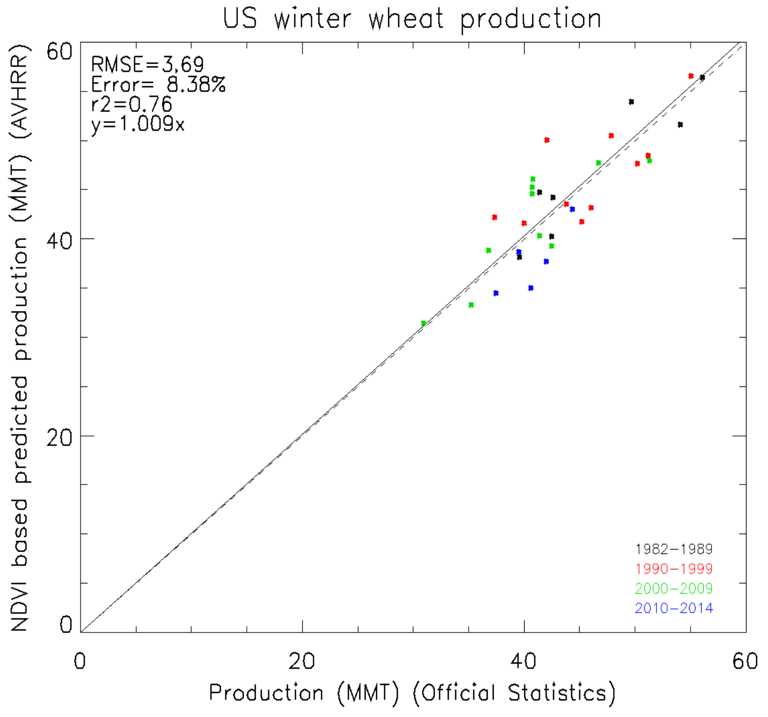
- **<u>LPV arose out of NASA's recognition that standardized approaches to global product validation were essential for wide acceptance and use of long-term climate data records</u>**. A common approach to validation has encouraged widespread use of validation data, helping the NASA Land program move toward standardized approaches for quantifying errors and uncertainties.

Charts courtesy B. Doorn (NASA HQ)

A 30+ years AVHRR Land Climate Data Record

Eric Vermote, Code 619, NASA GSFC

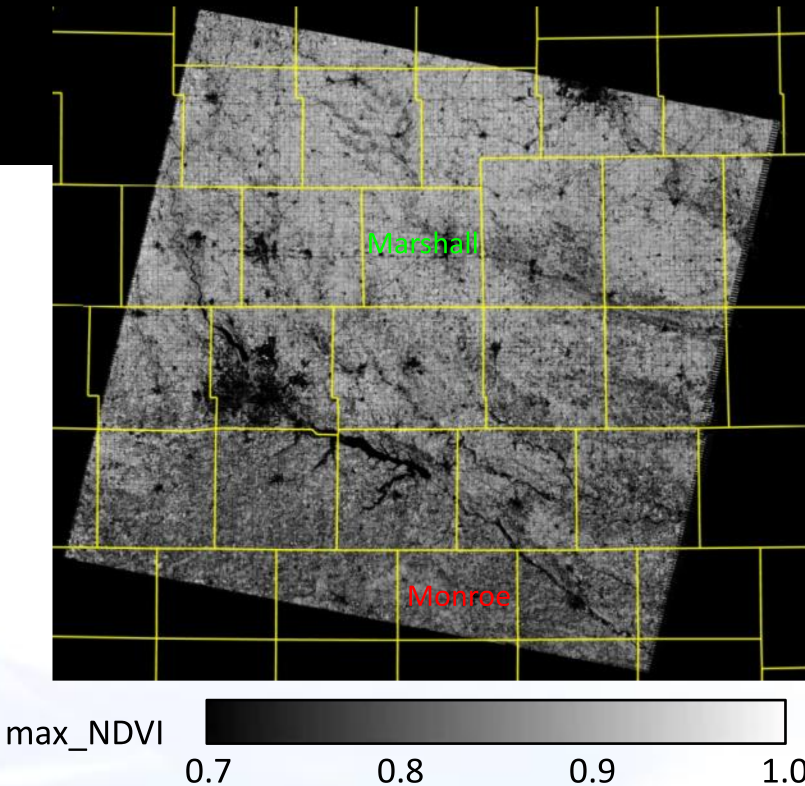


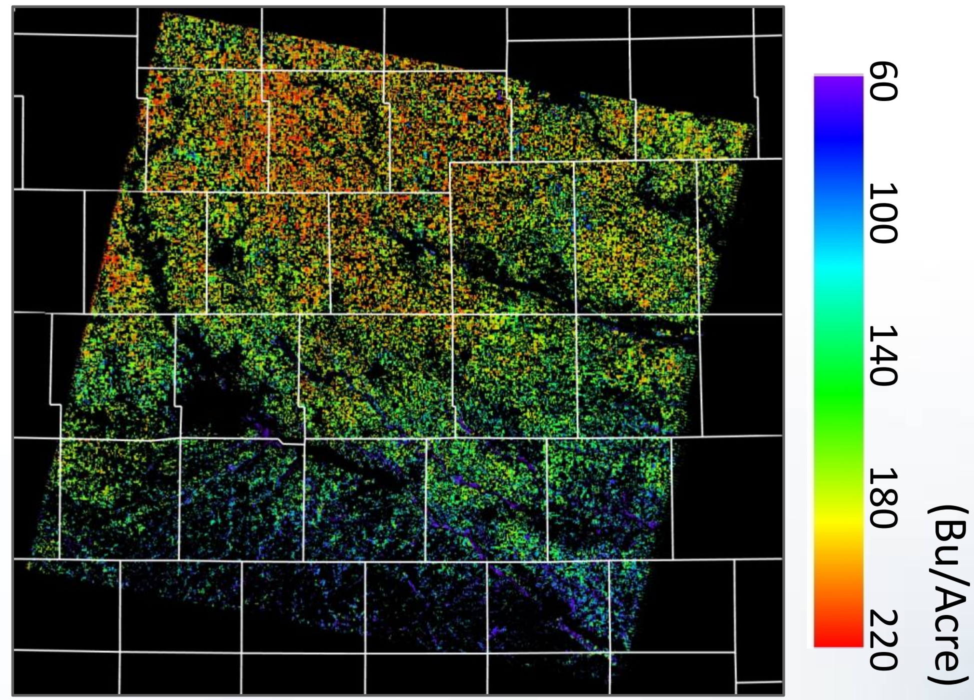


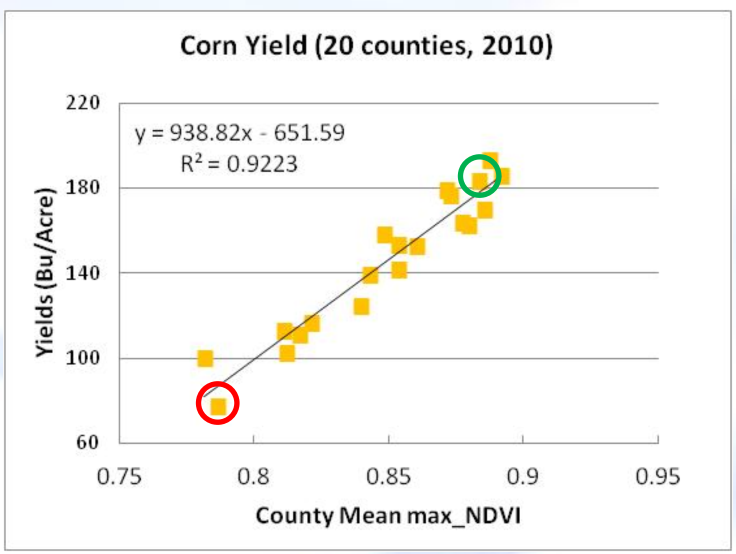
A consistent, validated 30+ year Land Climate Data Record from AVHRR including Surface Reflectance, Vegetation Index, Leaf Area Index and Fraction of Absorbed photosynthetic Radiation is now available to the public and has been used in agriculture monitoring application demonstrating an accuracy of less than 10%.

http://ltdr.nascom.nasa.gov/

Estimate Corn Yield at Field Scale
(central Iowa, 2010, 30m)







- ❑Yield estimation at field scale (30m) reduces the problem of mixed pixels /crops
- ❑Crop specific (CDL) time-series NDVI (Landsat and MODIS fused) shows a strong relation to yield at county level for each year from 2001 to 2014
- ❑Inter-annual variability of yield needs more information such as temperature and ET data

Gao, Anderson etc. (USDA-ARS)

Key Takeaways

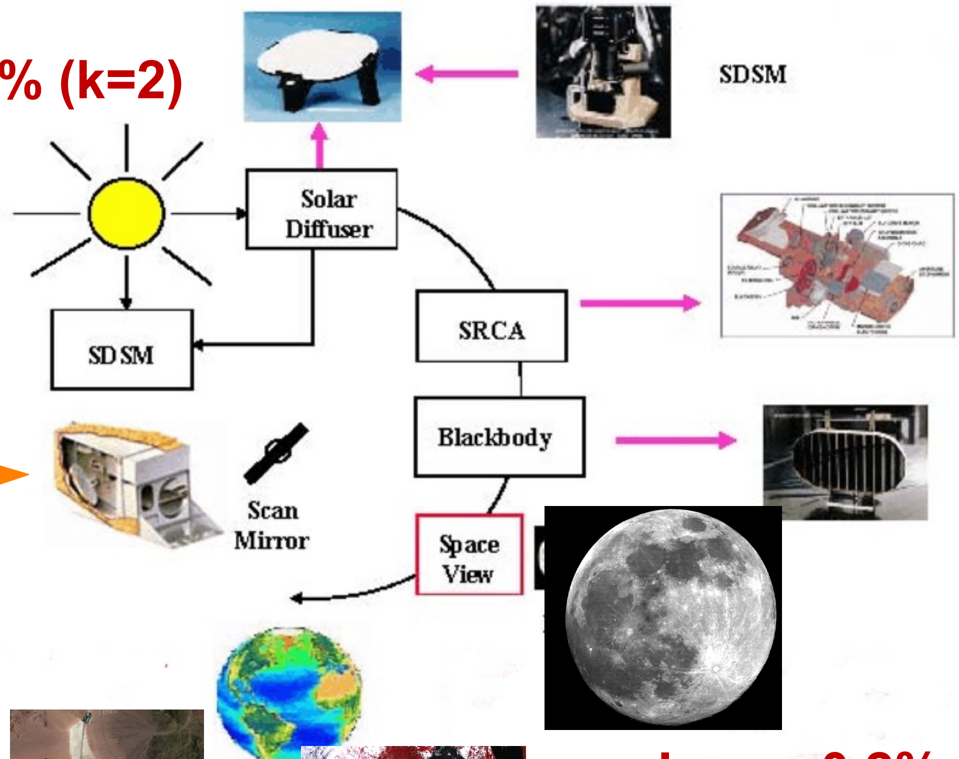
- In-situ measurements of terrestrial essential climate variables (ECVs) are key to enabling expanded uses of the satellite data; particularly in agricultural monitoring applications.
- **International collaboration of in-situ measurements for cal/val to ensure a consistent ECVs and other satellite-based agriculture products around the globe is a necessity for GEOGLAM, not an option**. *(emphasis mine – KJT)*
- There are existing GEO and CEOS groups that we can now connect and leverage to provide focus to global agriculture product cal/val needs.

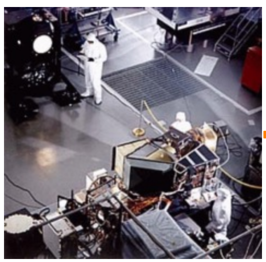
Current state of calibration for Land

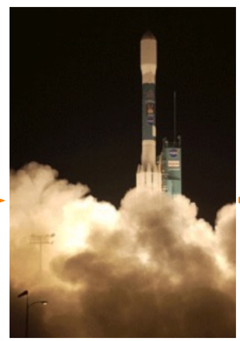
Best sensors have reflectance uncertainty of 3.6% (k=2) in mid-visible [4.2% in radiance]

EOS sensors linked vicarious, onboard, prelaunch calibrations to data products

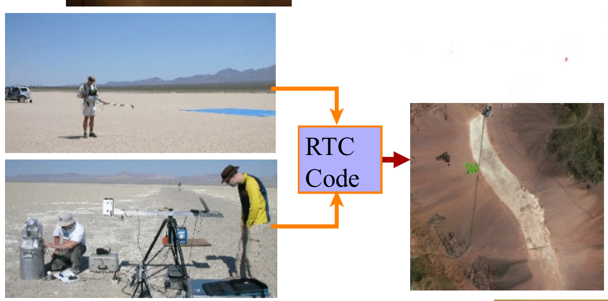
3.6% (k=2)





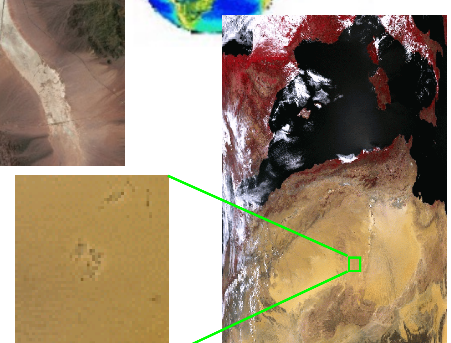


Laboratory 4.2% (k=2) **absolute**



In situ 5% (k=2) **absolute**

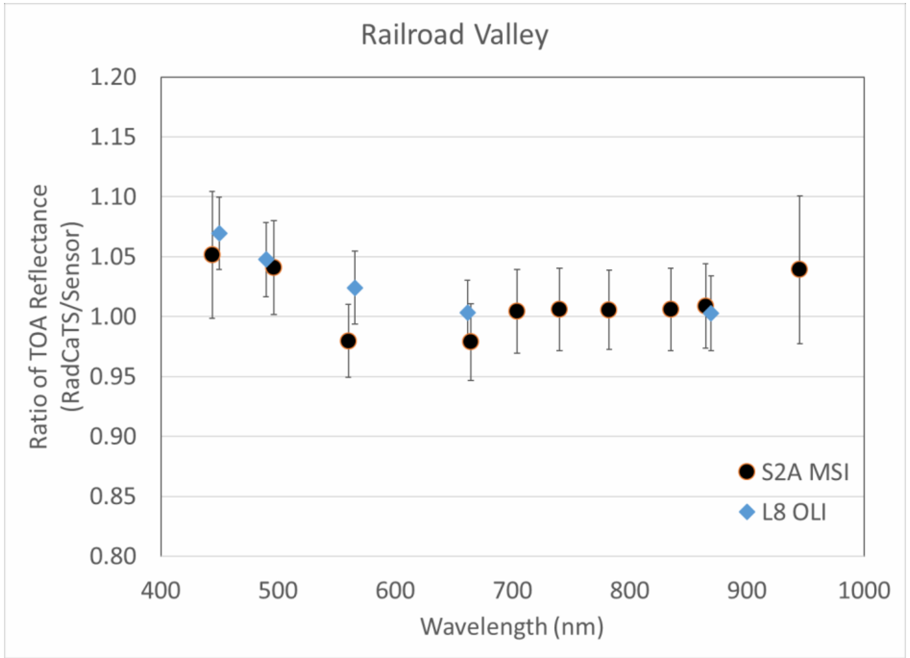
Intercomparisons 1.0% (k=2) relative



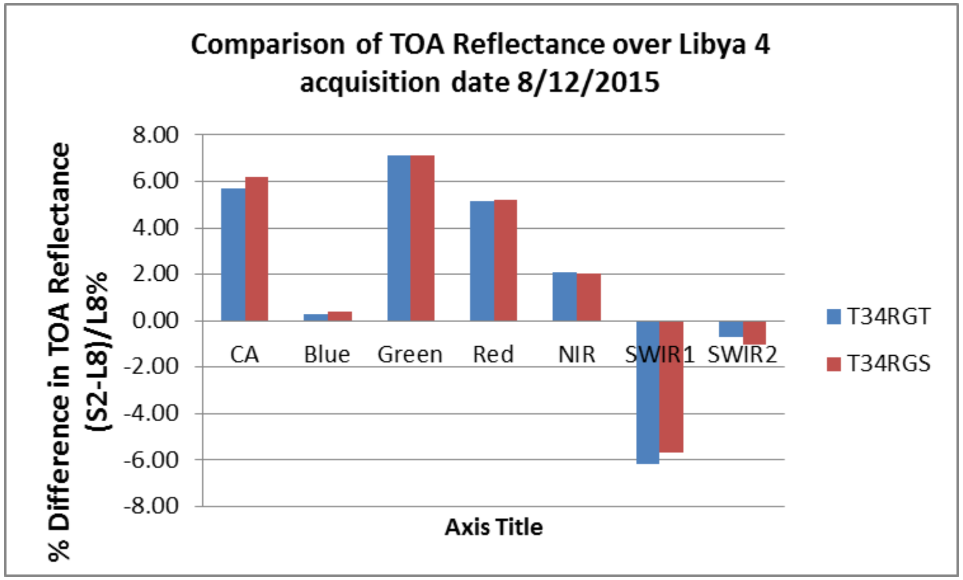
Lunar 0.2% (k=2) relative

Sentinel 2/Landsat 8

OLI/MSI TOA Reflectance Compared to U. Az RadCaTS Observations



OLI/MSI Difference in TOA Reflectance (Libya 4 PICS)



- OLI: Mar 2013 – Nov 2015, 14 dates
- MSI: Aug–Oct 2015, 4 dates (pre-operational gains)

USGS results. (SDSU results over same scene consistent to within 1% except red band)

CPF and Land sensors

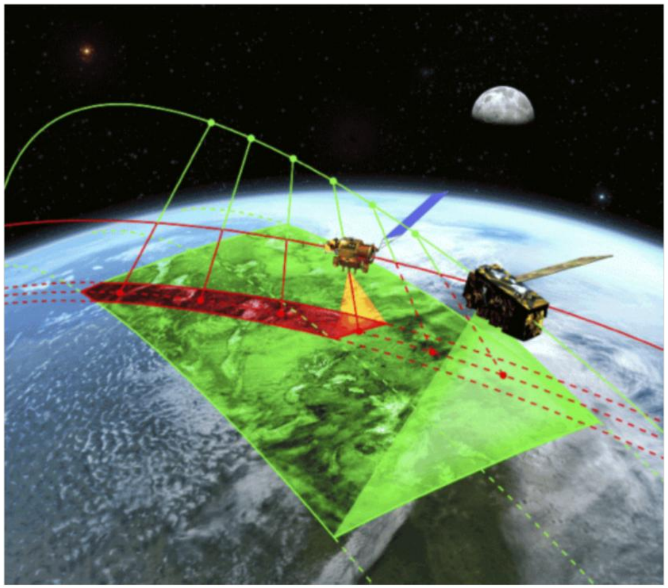
Land imagers will not benefit strongly from full accuracy of direct inter-calibration with CPF

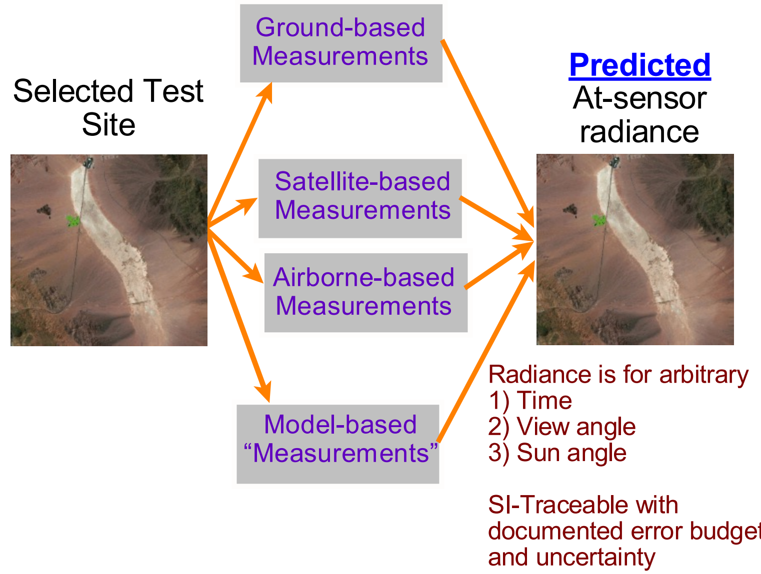
- Land imagers well suited for inter-calibration
  - Wide range of experience
  - Nadir-vewing, narrow swath systems
- Coordinating with additional sensor teams requires additional resources
  - Loss of direct benchmark measurements
  - Conflicts with other sensors for inter-calibration
- Alternate approach is to concentrate CPF resources on known inter-calibration test sites
  - Characterize sites being used by land imagers
  - Mid-inclination orbit provides unique opportunity

Supplementary Charts

Inter-calibration by CLARREO for land

Two approaches to cross calibration – 1) near simultaneous views & 2) site characterization



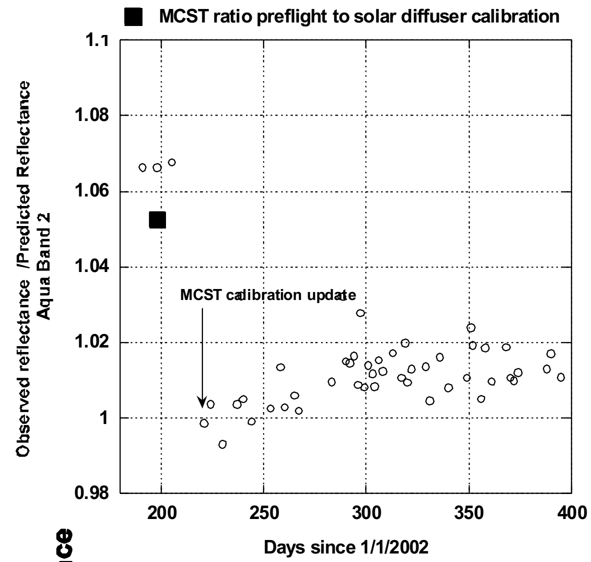


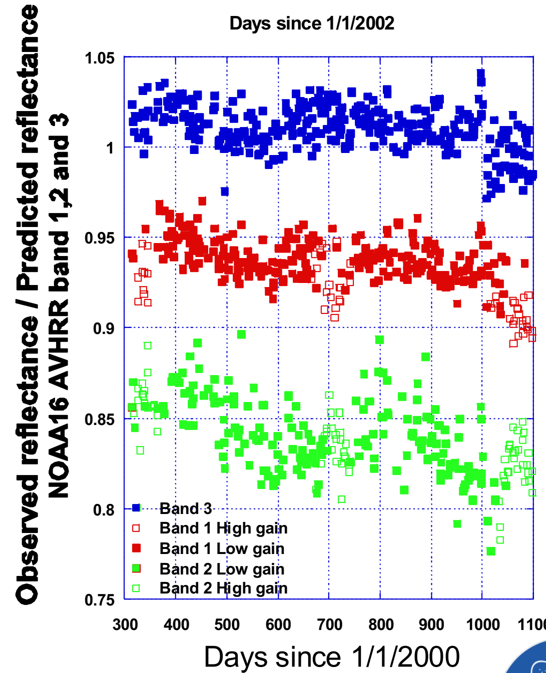
- Near-coincident and matched views give best precision
  - Using single reference allows others to be placed on same accuracy scale
  - Requires scheduling of both sensors
- Site characterization approaches do not require coordination with between sensors

Pseudo-invariant

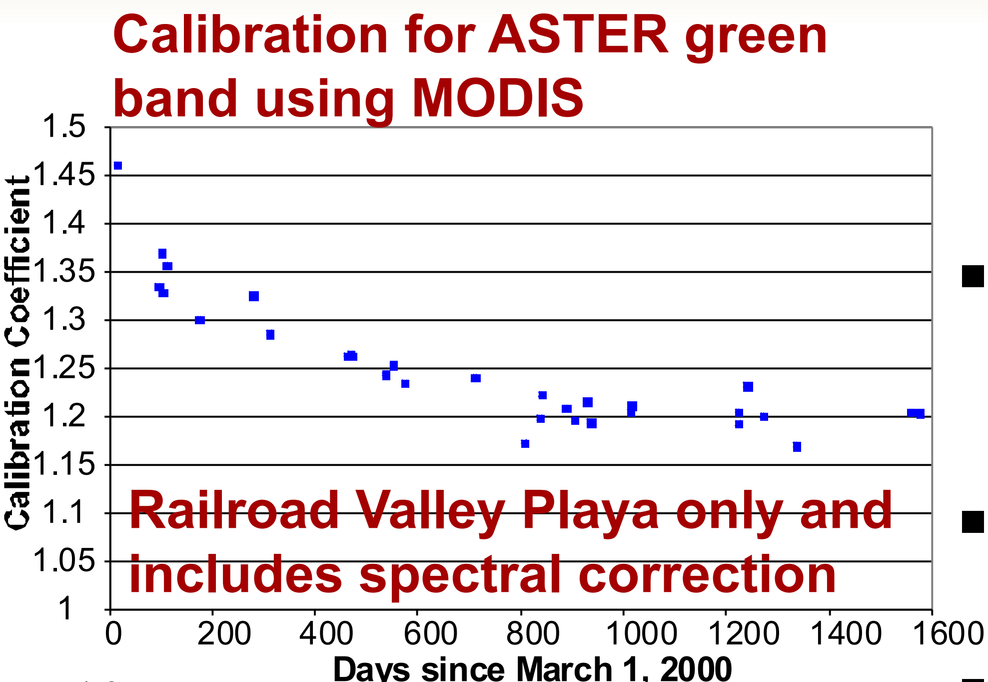
Rely on reasonably stable surfaces for temporal studies

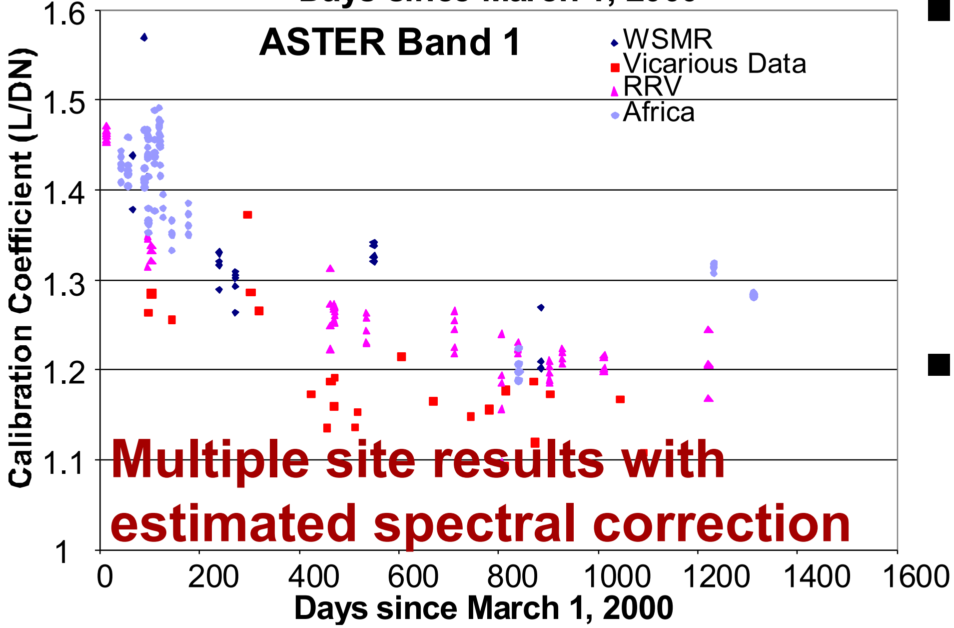
- Dome C Antarctic site
- Ocean sun glint
- Rayleigh scatter
- Desert sites
    - Surface BRDF model corrections
    - Atmospheric corrections based on climatological values
- Deep convective cloud calculations in radiance





How high-accuracy helps





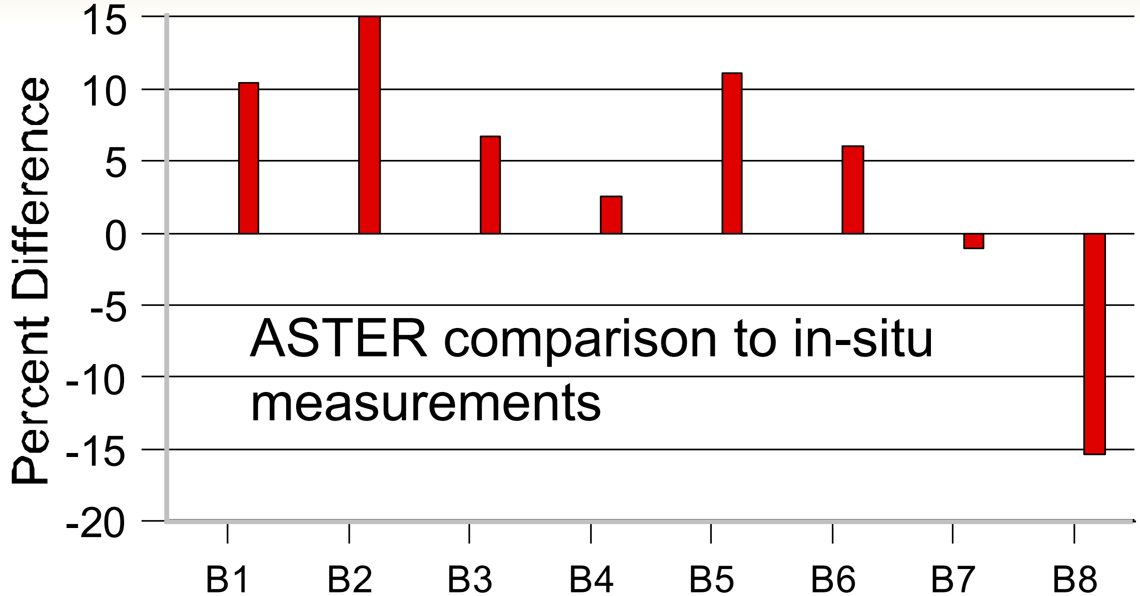
MODIS and ASTER "easiest" case

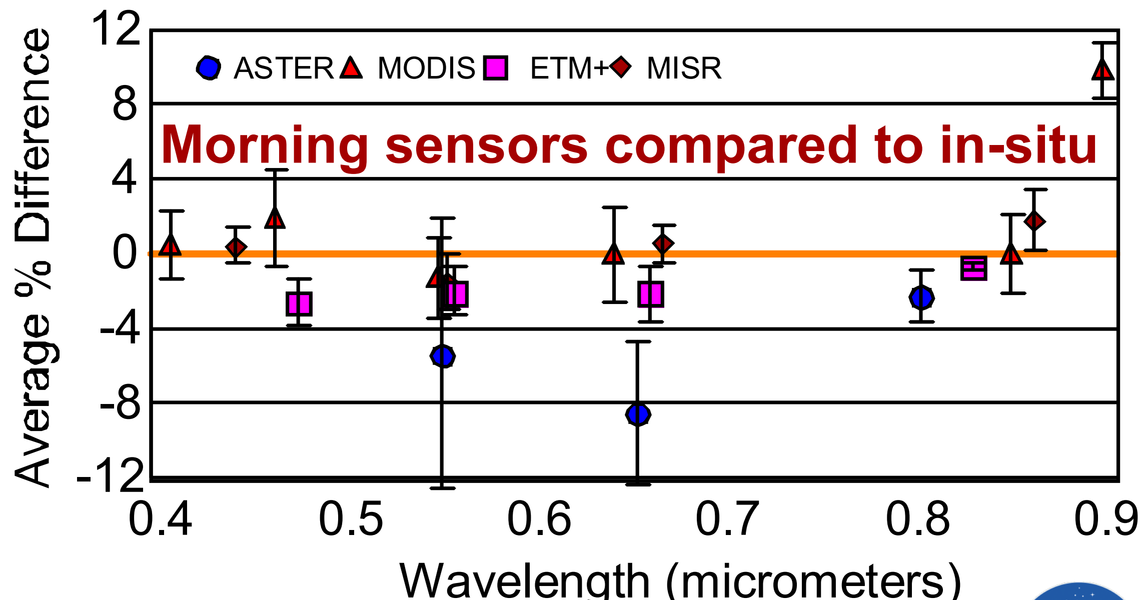
- Same platform, coincident views, similar bands
- ASTER Band 1 (green band) results using MODIS
- Scatter caused by
  - Spectral band differences
  - Registration effects
- CPF would provide constraints on the inter-sensor calibration

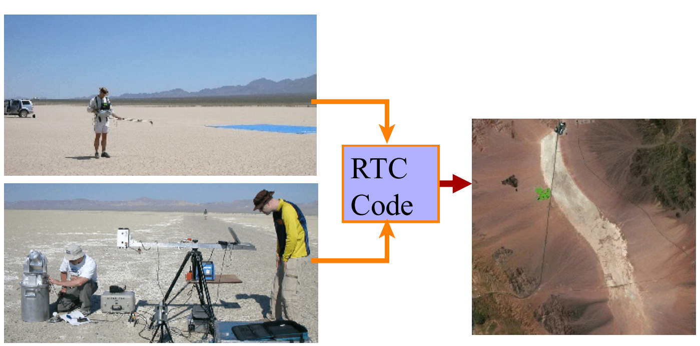
In-situ approaches

SI-traceable, ground-based measurements

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

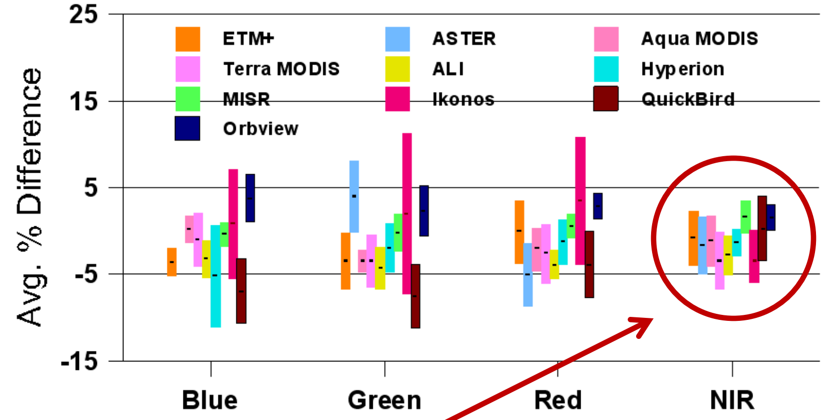






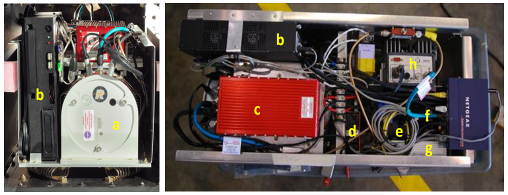
Role of CPF in test site characterization

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

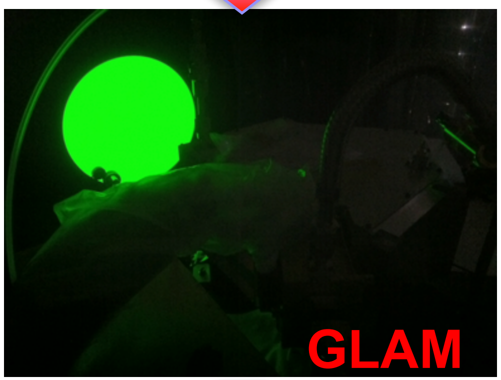


- Cannot decouple
  - On-orbit sensor effects
  - Atmospheric variability
  - Surface variability
- All three play a role
  - Better sensor agreement in the NIR where SNR is largest for sensors
  - Atmospheric effects are not as dominant in NIR
- Improved field sensor design and characterization would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

CLARREO lab-based to reflectance-based calibration



G-LiHT



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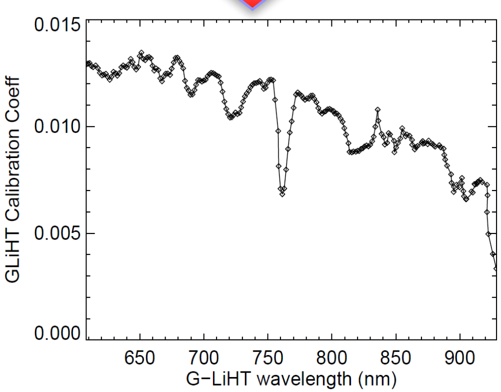
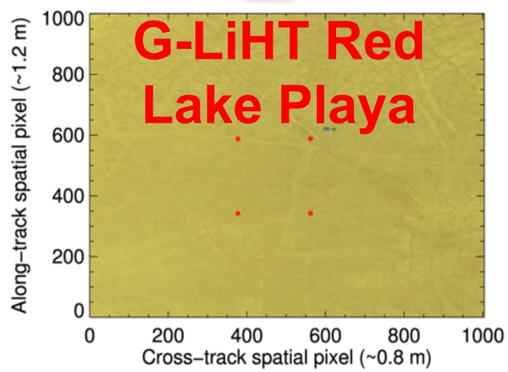
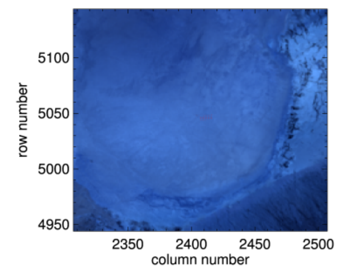


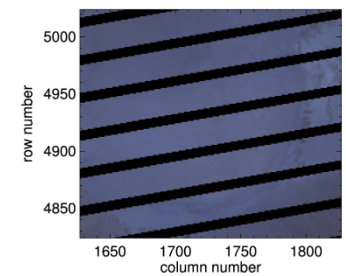


Transfer G-LiHT radiance at 1000m to 705 km (L7/L8) via radiative transfer

Integrate 1nm G-LiHT radiance spectrum over Landsat RSR (band 4 and 5)

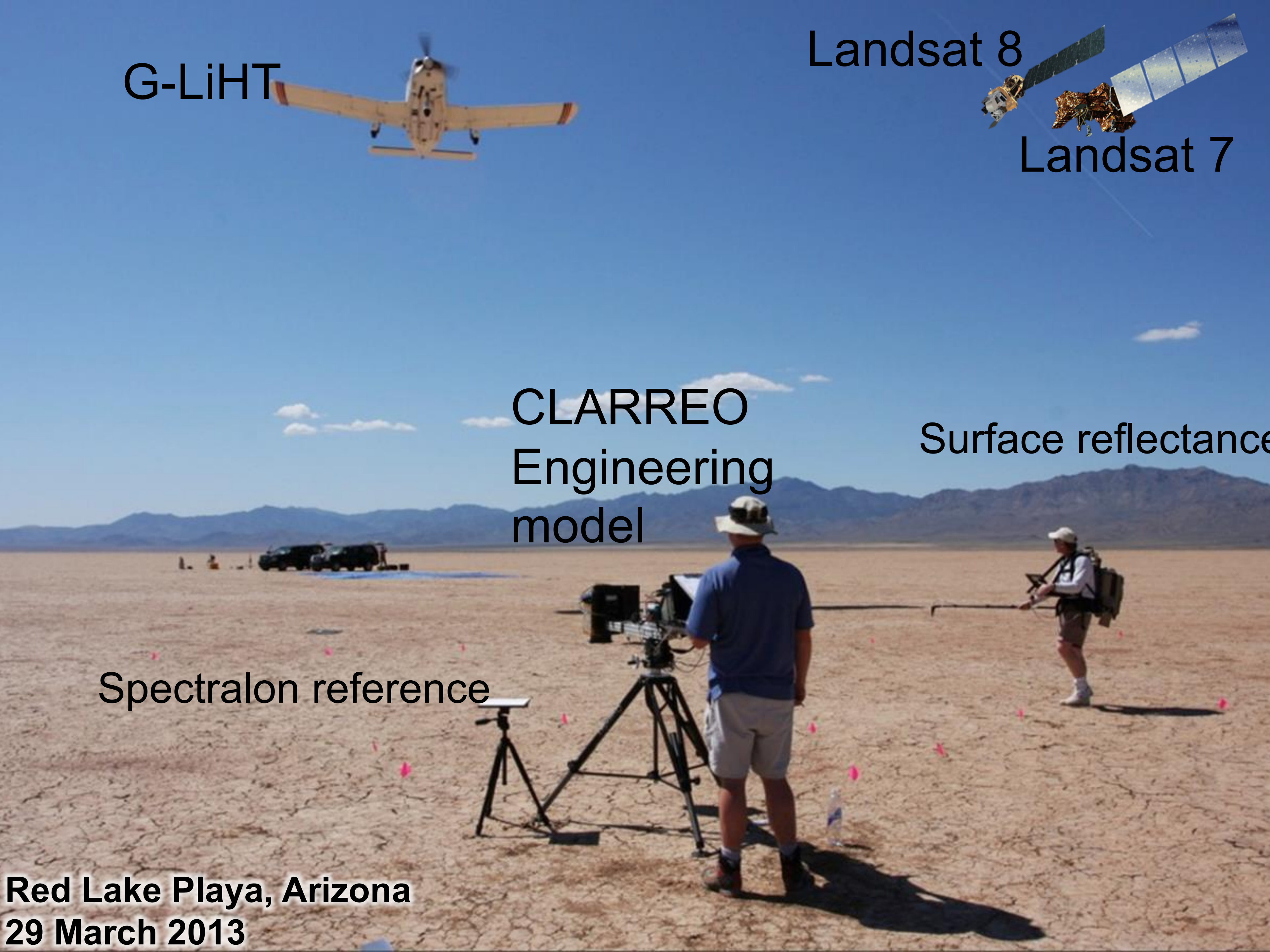


L8 OLI
TOA radiance
Red Lake Playa



L7 ETM+
TOA radiance
Red Lake Playa

Compare on-orbit calibration (L7 ETM+ and L8 OLI) to lab-based G-LiHT calibration


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