Error budget analysis for the reflected solar instrument of CLARREO

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Introduction

Climate Absolute Radiance and Refractivity Observatory

- One of the highest priority missions described in the NRC Earth Science Decadal Survey
- Recommended in first group of 4 missions (“Tier 1”)
- A climate-focused mission
  - Foundation is on-orbit S.I. traceability of calibration
  - Long-term trend detection
  - Improvement and testing of climate predictions
  - Calibration of operational and research sensors
- Joint NASA / NOAA mission
- NOAA portion of CLARREO is the continuation of solar irradiance and earth radiation budget observations (TSIS and CERES)

Talk overview

Concentrate discussion on reflected solar portion of the spectrum

- Overview of measurements
  - Benchmark
  - Intercalibration
- Describe probable calibration approaches
  - Prelaunch
  - On orbit
- Discussion of error budgets and uncertainty sources
- Path forward for lower uncertainties

CLARREO – What it is and not

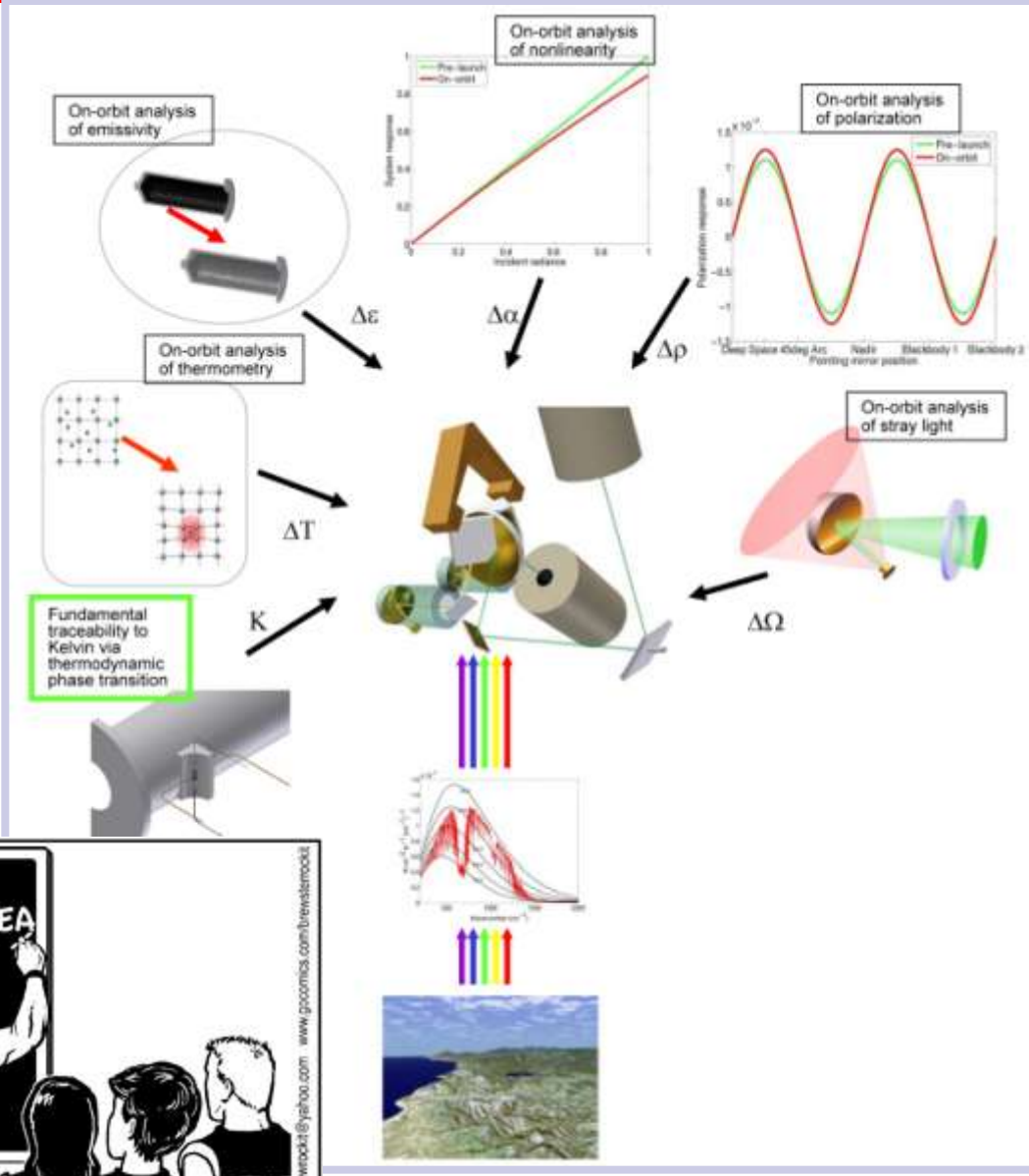
Not a replacement for process missions nor operational sounders

- NASA portion of CLARREO is complementary to continuity of TSIS and CERES (NOAA part of CLARREO).
- CLARREO addresses climate science questions using one of three methodologies:
  - Directly with current technology and without the need for any other observations
  - Confirming recent advances in metrological technology and sampling strategies
  - Combine with other satellite solar and infrared sensors

Calibration is the foundation

SI traceability is the key to the mission

- Long-term data sets
- Possibility of data gaps
- Planning ahead is vital



Benchmark versus reference

CLARREO data will serve as a reference mission as well as providing benchmarke data

- Stated earlier as two of the three methodologies
- Benchmark data stand on their own as a means to understand the accuracy of the climate models
- Reference calibration allows the incorporation other sensors to develop a more complete benchmark data sets
- The solar reflected sensor will rely equally on both benchmark and reference approach
  - Simplifies CLARREO instrument
  - Reflected solar is complicated by the multi-dimensionality issue

Dimensionality problem

A key difficulty with the reflected solar is dependency on geometry and other effects

- Determining signal from climate effects means separation from natural variabiity
- Natural variability caused by
  - Surface reflectance changes
  - View/solar geometry
  - Atmospheric effects
  - Earth-sun distance
- Some of these are predictable
- Another issue is what is meant by reflectance
  - Directional
  - Hemispheric

Reflected solar calibration

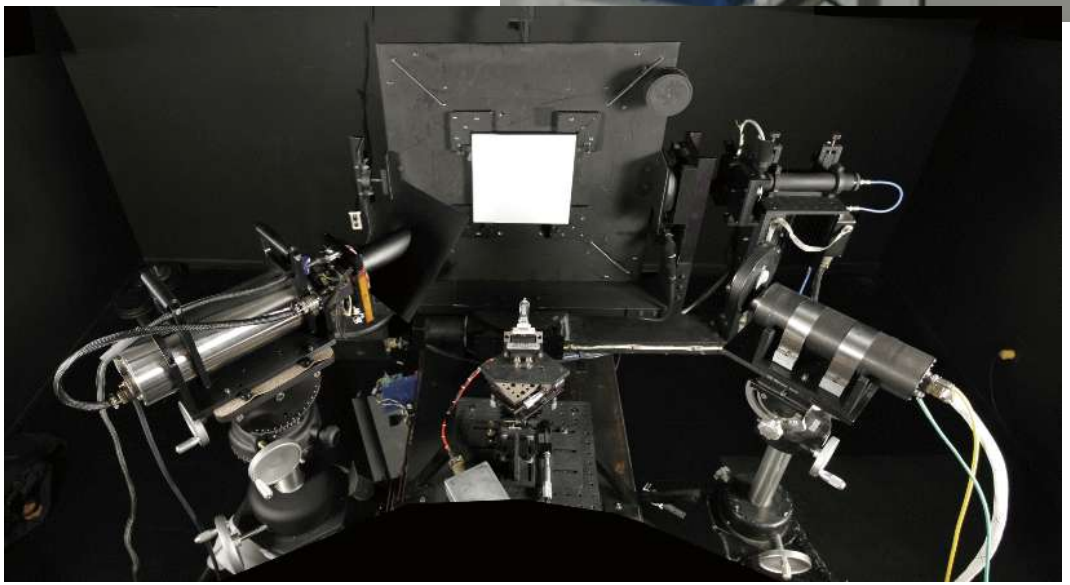
The goals of CLARREO lead to accuracy requirements that are challenging

- Current **imager** missions are achieving 1-5% absolute radiometric accuracy
- Slightly better results when calibrated in reflectance
- Limits to accuracy on past missions
  - Emphasis not on calibration
  - Complex sensors
  - Costs and scheduling
  - Approaches chosen to obtain traceability

Prelaunch approaches

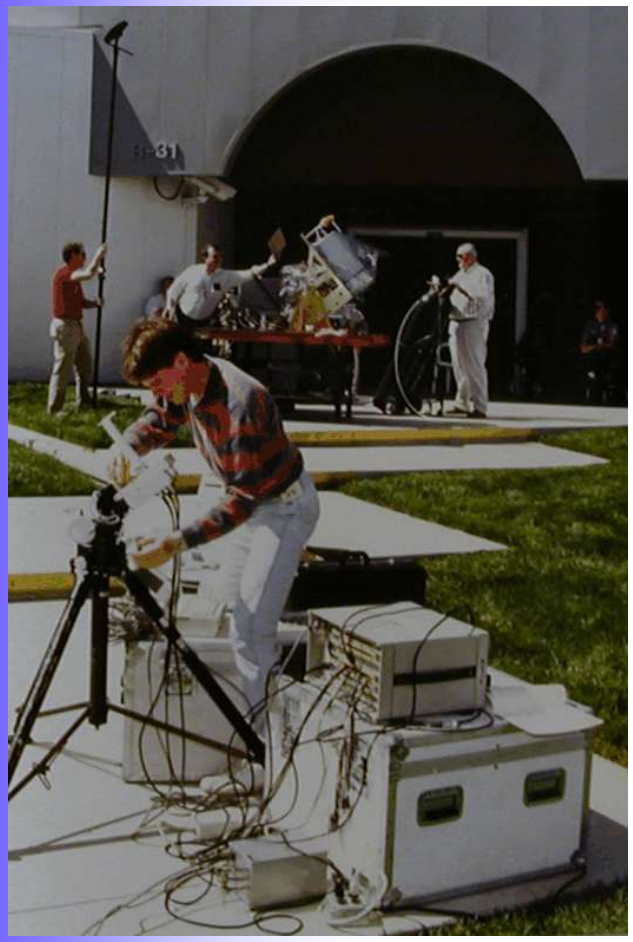
Transfer radiometers and portable sources provide the most reasonable prelaunch approaches

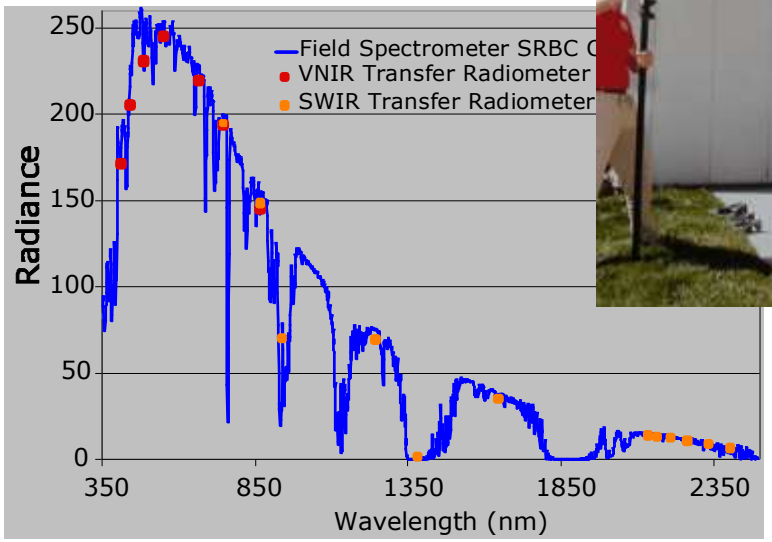
- Round-robin activities evaluate consistency of preflight sources
- SI traceability through sources and detectors



Prelaunch solar calibration

Using the sun as a source provides a constant, yet portable source

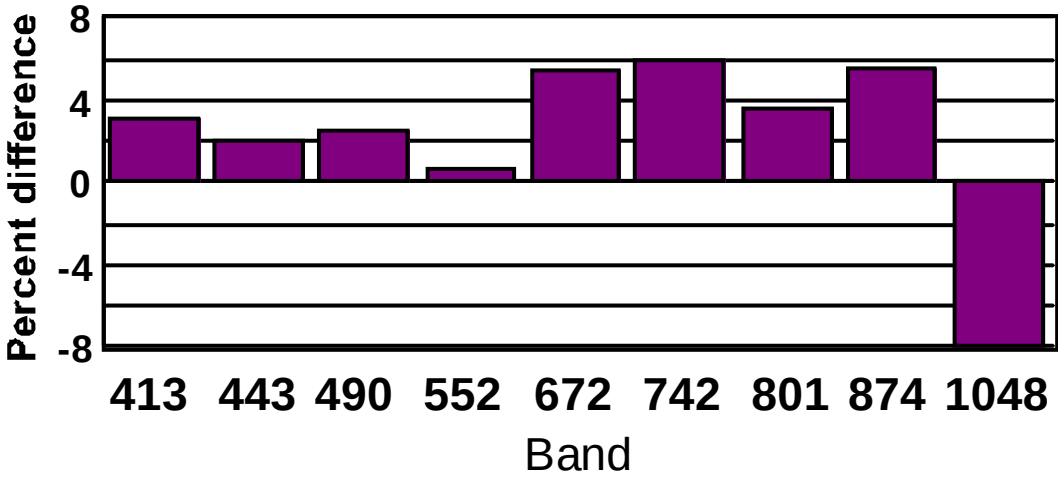


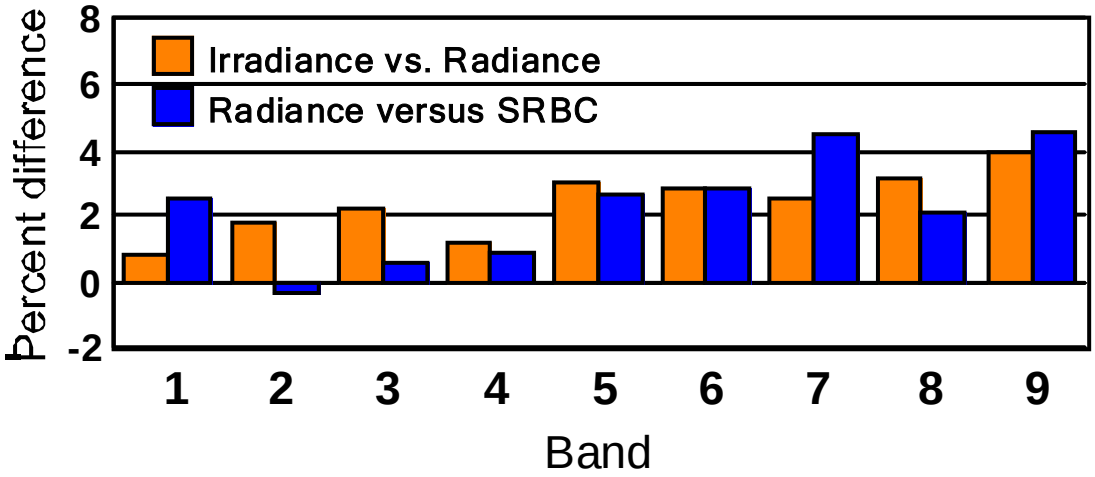


Laboratory example

Detector-based versus source-based results with a VNIR transfer radiometer

- Trap configuration allows for a prediction of the absolute, radiometric calibration
- Upper graph shows difference between predicted and measured
- Lower shows comparison between solar, panel and lamp based results





Prelaunch error budgets

While there are numerous error sources in any approach, typically one will dominate

- Source-based approaches are dominated by knowledge of the source
  - Lamp sources with 1-2% absolute uncertainty
  - Solar source (on the ground) can be known to similar accuracy relative to the solar model
- Detector-based approaches lead to lower uncertainties
  - Typically at limited wavelengths (need to assess ability to extrapolate/interpolate)

On-orbit calibration

Use same philosophy on orbit as for the prelaunch calibration procedures

- Specific approaches are not determined at this time
- Solar-based calibration
  - Direct views
  - Diffuser views
- Reflectance-based data collections
- Onboard lamps
- Lunar views

Reference calibration

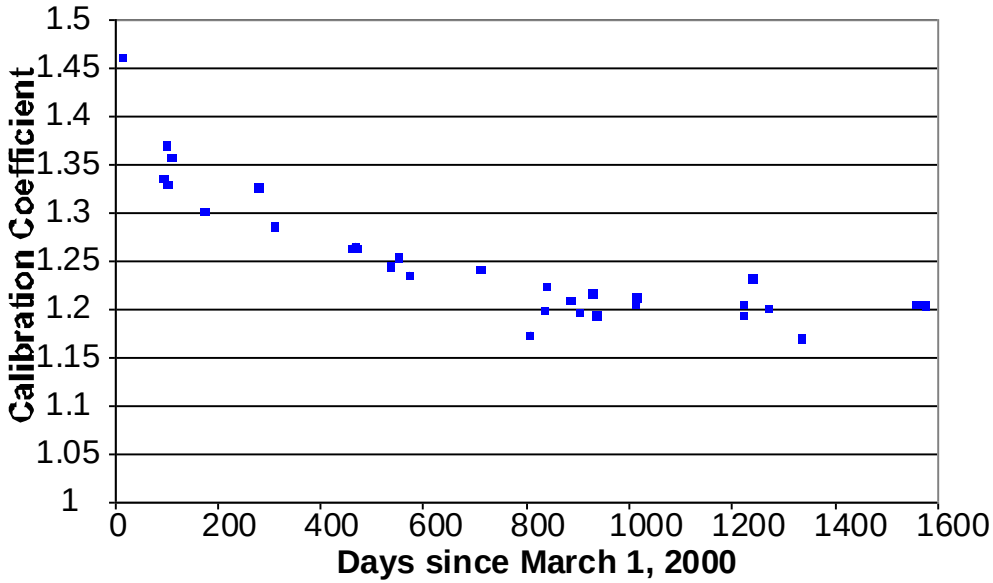
CLARREO will serve as a reference for other sensors to allow inclusion of their data

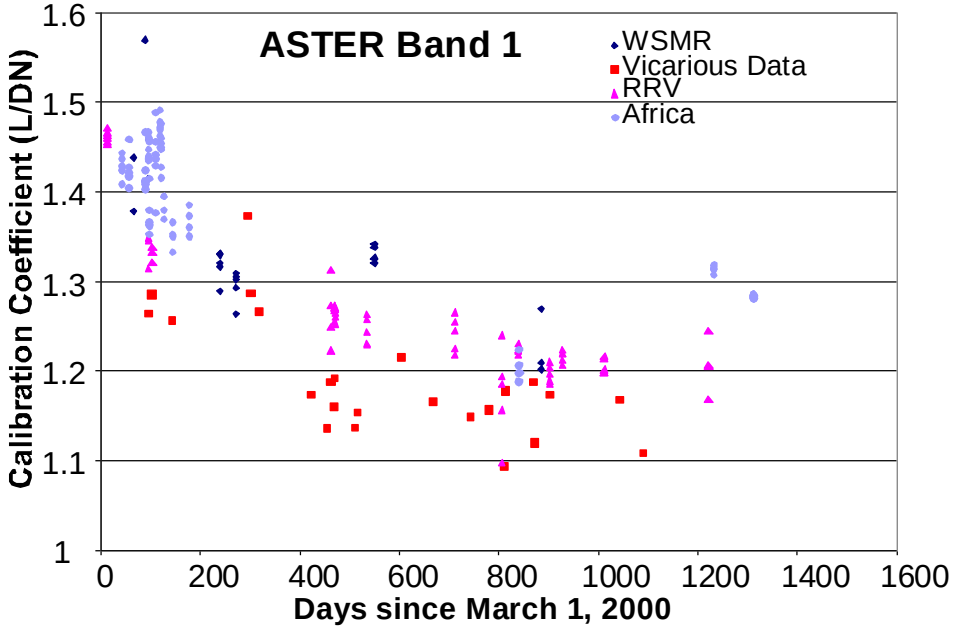
- Desert sites
  - Used extensively since 1980s
  - BRDF and spectral nature well understood
- Arctic sites
  - Simultaneous Nadir Overpasses
  - Dome C
- More recent work
  - Lunar views
  - Application or data product approaches
  - In-situ ground measurement methods
- CLARREO approach will rely on near-coincident view approaches

Radiance comparisons

MODIS and ASTER offer same platform, same view coincident views

- Upper graph shows ASTER Band 1 calibration coefficient derived from Railroad Valley data
- Lower graph shows results from multiple sites
- Lower graph also shows in-situ results

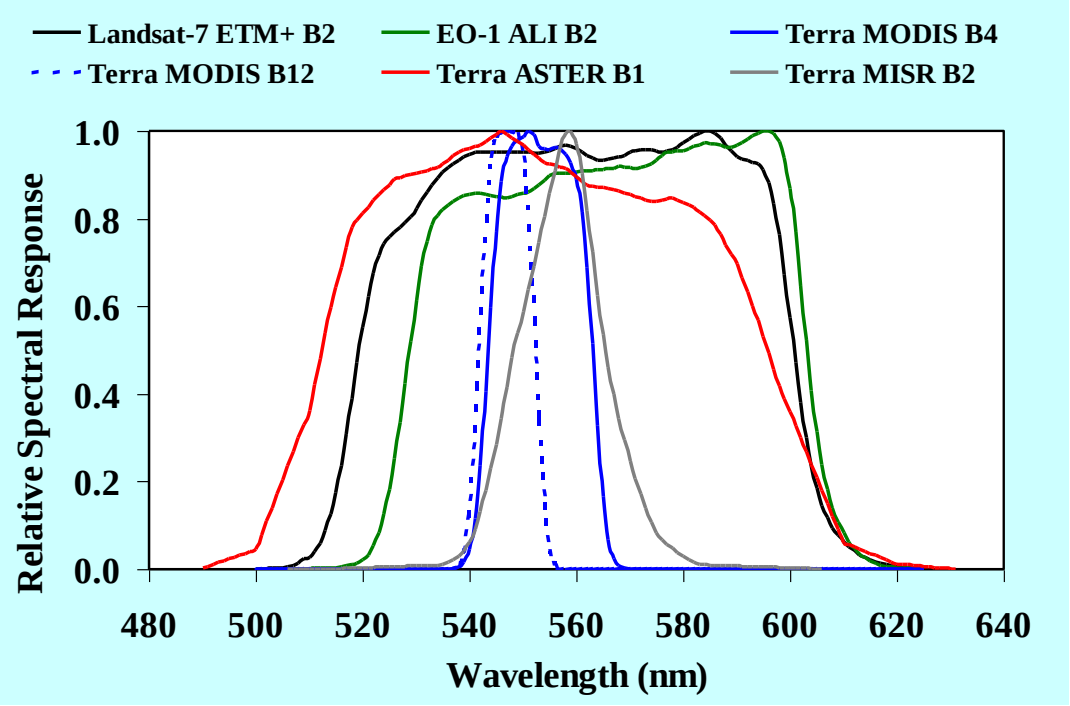




Spectral band differences

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

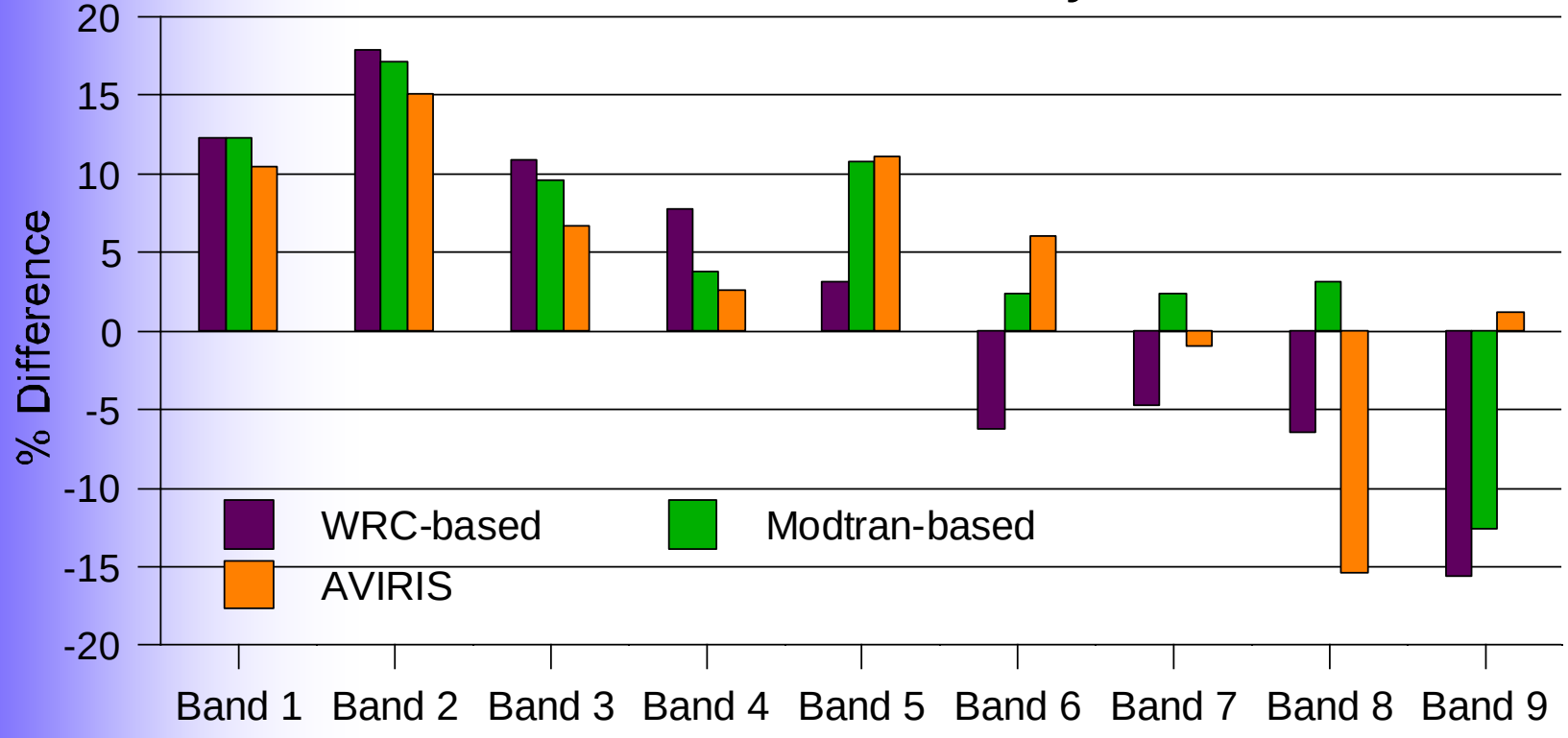
Uncertainty due to spectral differences should decrease with the hyperspectral data from CLARREO



Solar irradiance effects

Selection of solar model plays a role in the SWIR

- Working in reflectance removes this issue
- CLARREO will have the advantage of data from TSIS to provide spectral irradiance
- Still need to ensure rest of community uses similar data



Summary

The CLARREO goals for accuracy are an achievable challenge

- Laboratory techniques have improved
  - Technology
  - Processes are better understood
  - Pathway through detector-based approaches
- Transfer to orbit with SI traceability is an issue for the reflected solar
  - Sun as a transfer standard
  - Working in reflectance relative to the sun
- Reference calibration of other sensors is a needed to develop the benchmark faster
- Combination of all techniques is needed in order to reach the goals of CLARREO