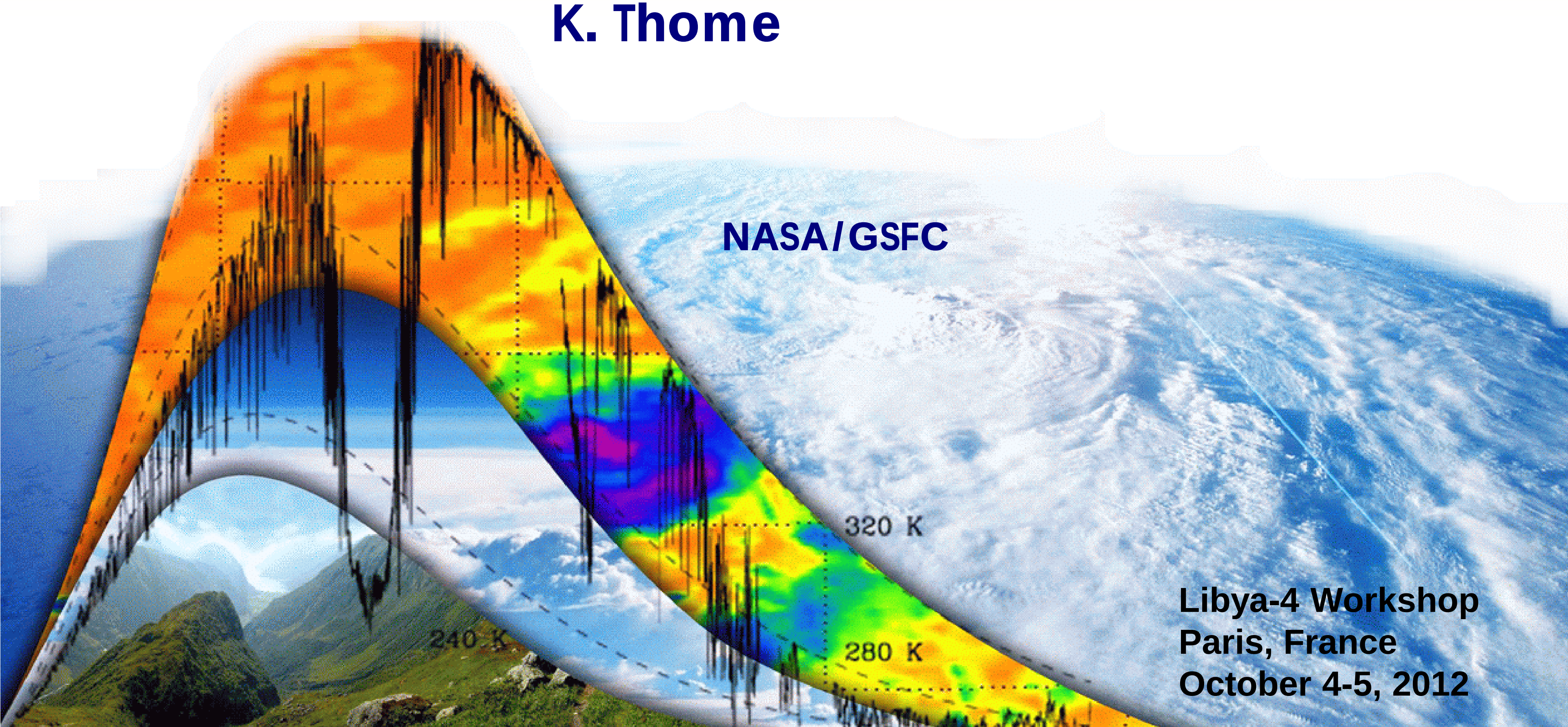
GODDARD SPACE FLIGHT CENTER

Accuracy and Precision Requirements for Climate-Level Data Sets

K. Thome

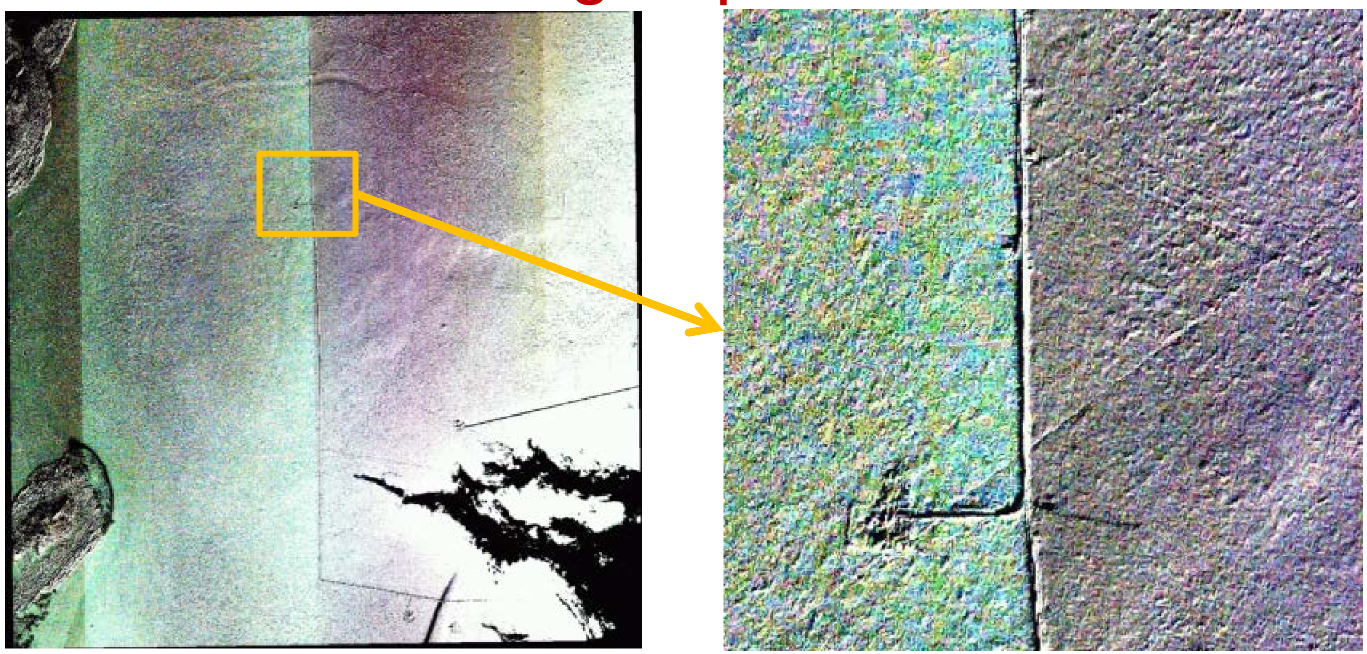
NASA/GSFC



Libya-4 Workshop
Paris, France
October 4-5, 2012

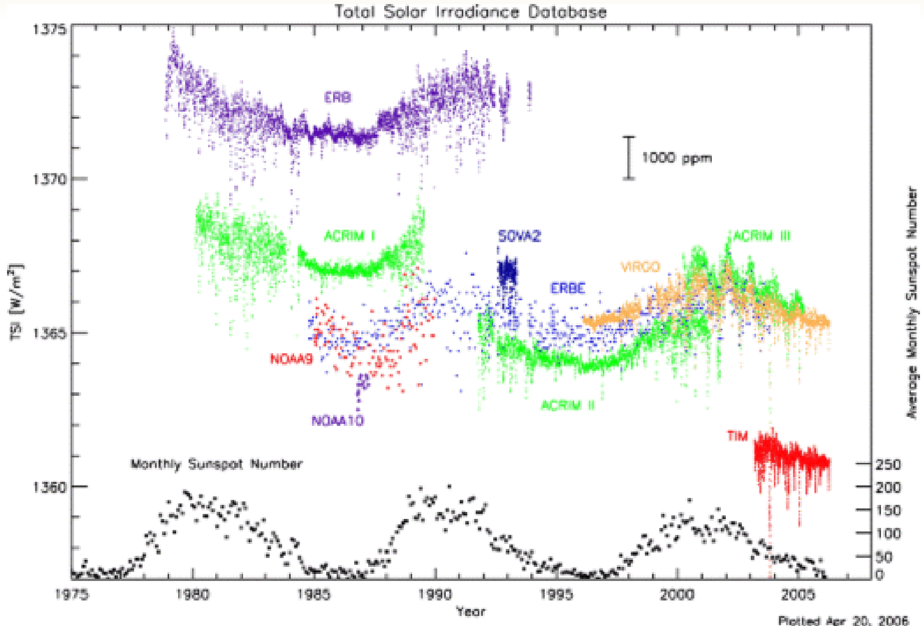
Accuracy requirements – Commercial imagers

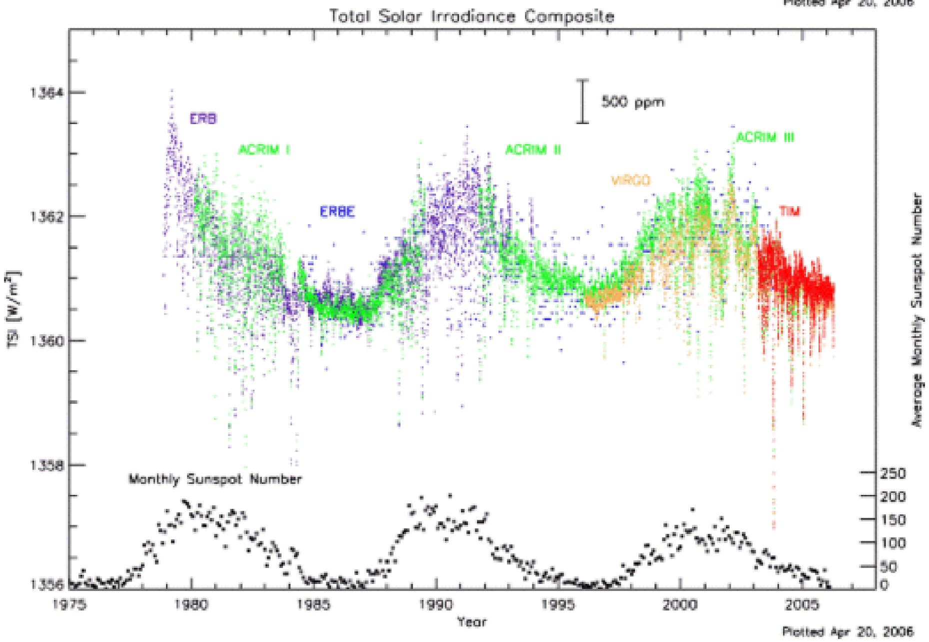
Precision and SNR drive calibration requirements for commercial high spatial resolution sensors



- High spatial resolution users tend to be more concerned with spatial variability
- In-band, detector-to-detector calibration
- Absolute calibration will become more important as multi-scale studies continue to mature

Accuracy requirements – Operational sensors

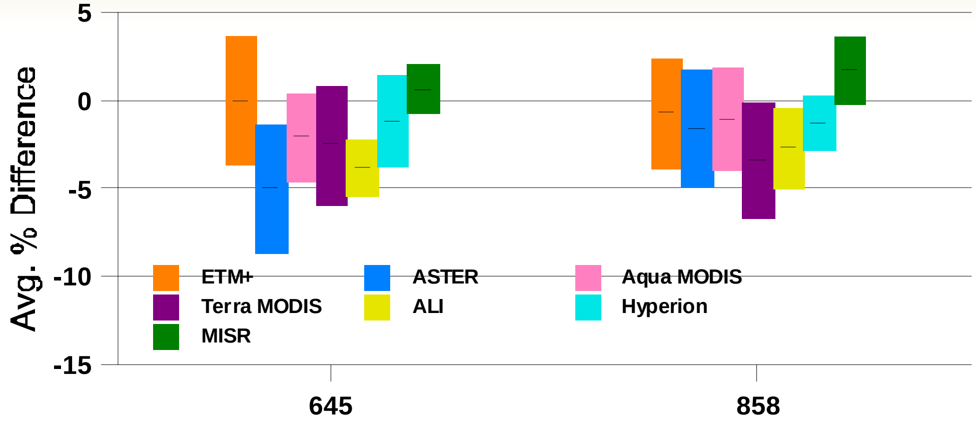




Operational sensors need high precision, SNR, self-consistency and interconsistency

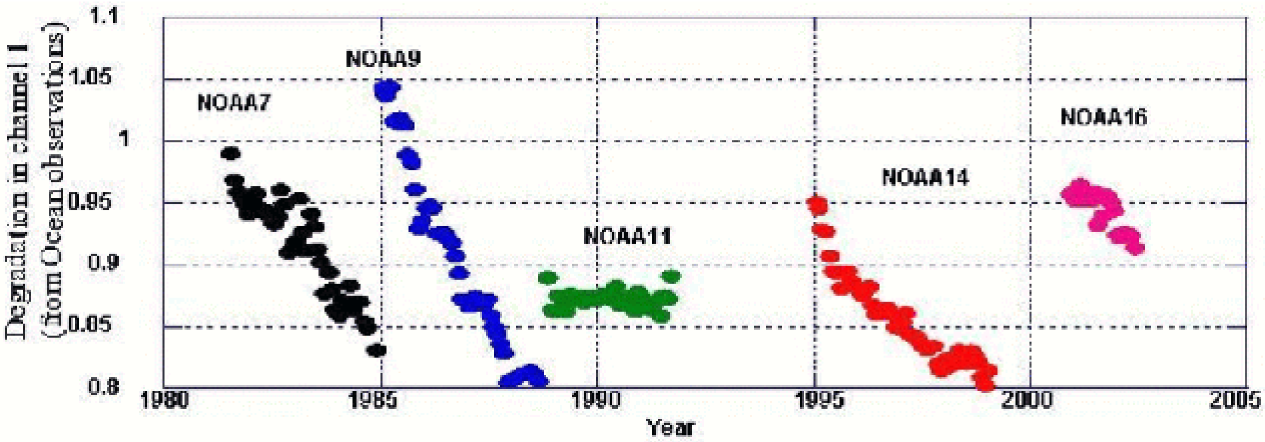
- Solar case here is met as an illustration
- Absolute accuracy is a key element for this particular mission
  - Differences in the upper curves exceeded the sensor’s error budgets
  - Now understood to be caused by the optical design differences

Accuracy requirements – Operational sensors



Interconsistency is important for users to create time series

- Original uses for many operational systems only required self-consistency
  - Understanding temporal trends in calibration
  - Stability was/is not a requirement
- Accuracy is helpful but not strictly necessary for any single sensor (provided overlap between sensors)

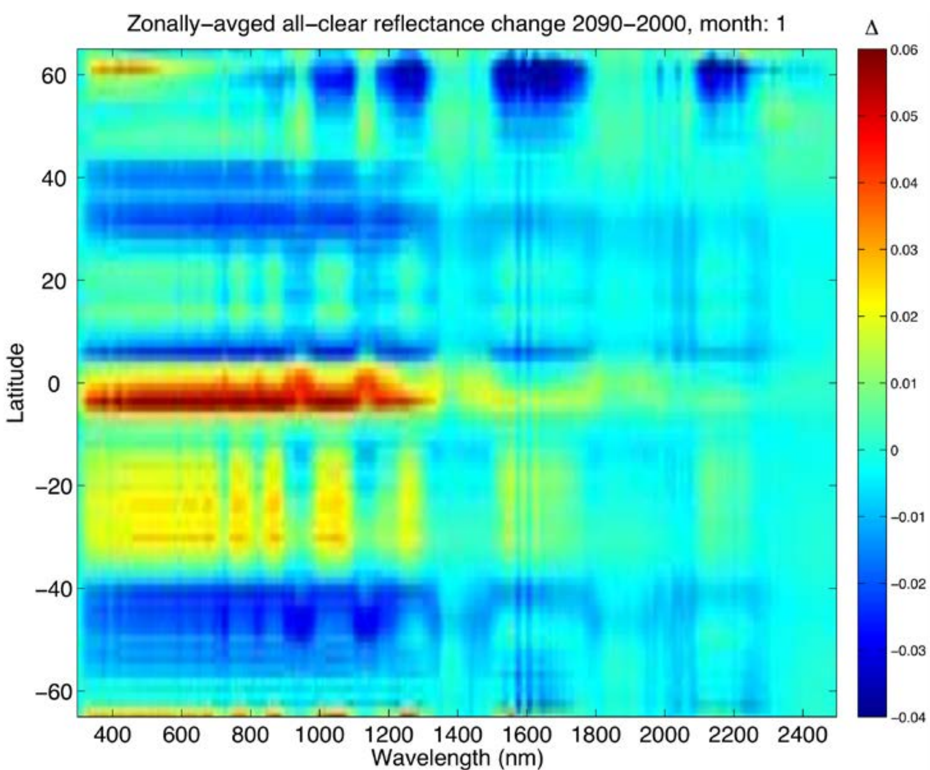


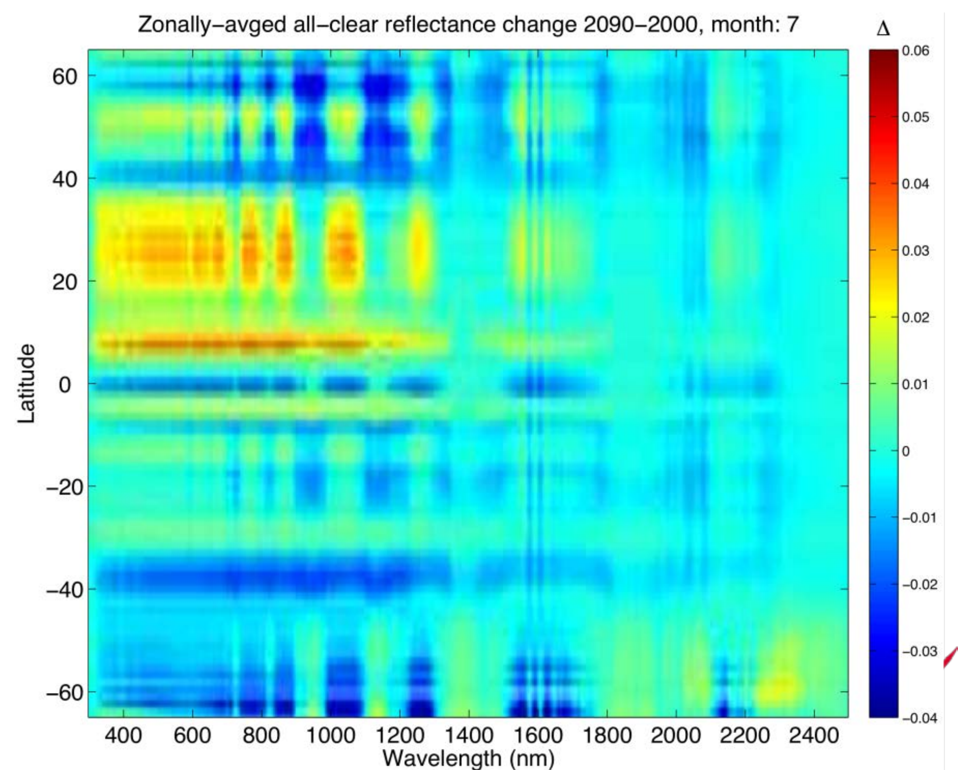
Accuracy requirements – Climate applications

Climate-related applications need accuracy and benefit from stability

- Required accuracy can be derived by examining climate model output
- Data products are spatial and temporal averages

Collins and Feldman, AGU Fall Meeting, 2010

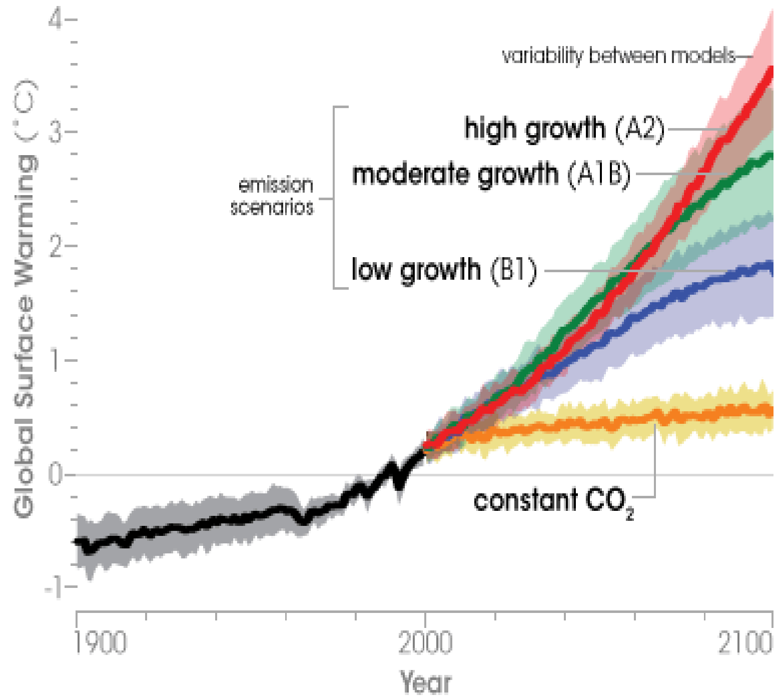




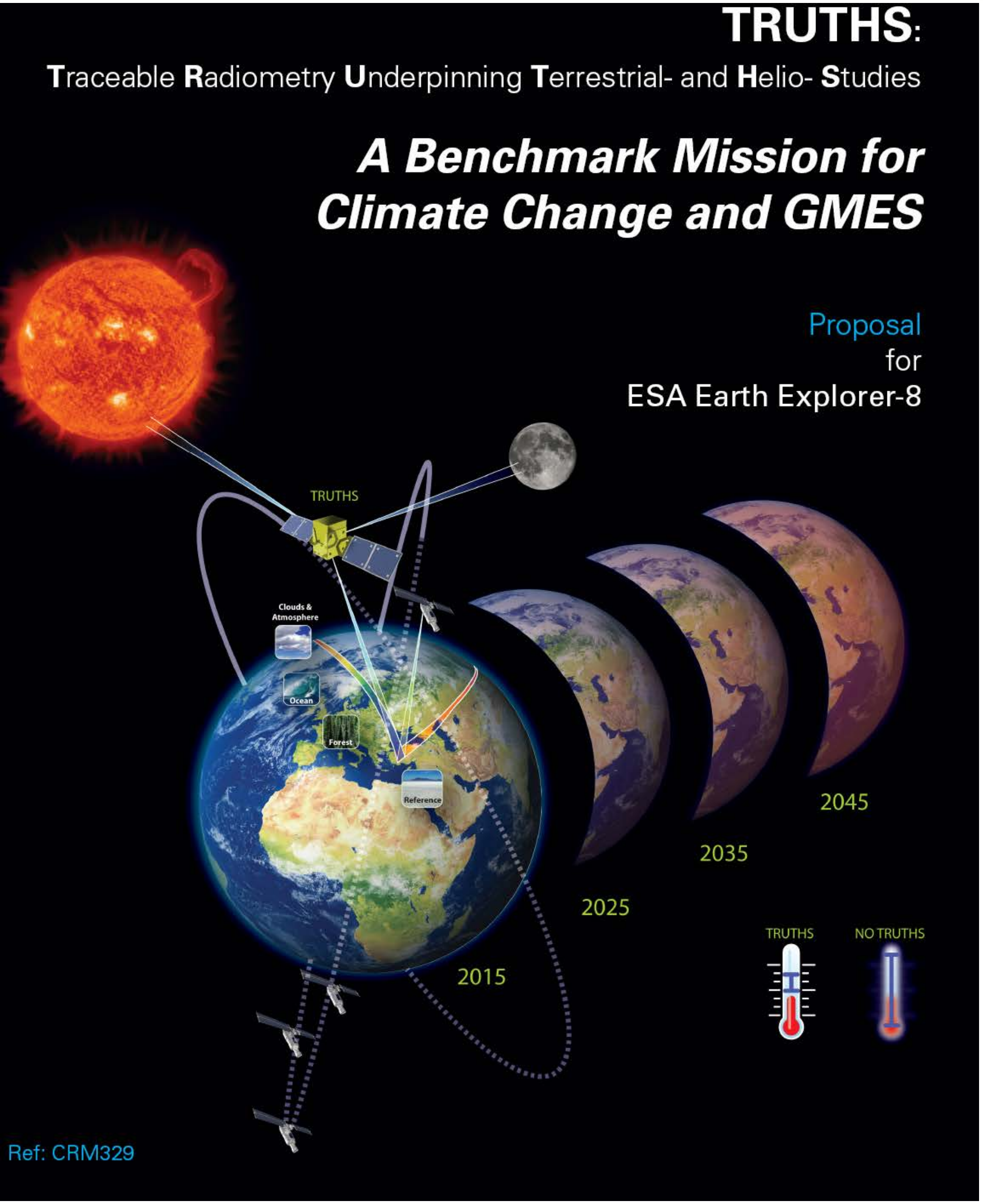
Climate model test and decadal change

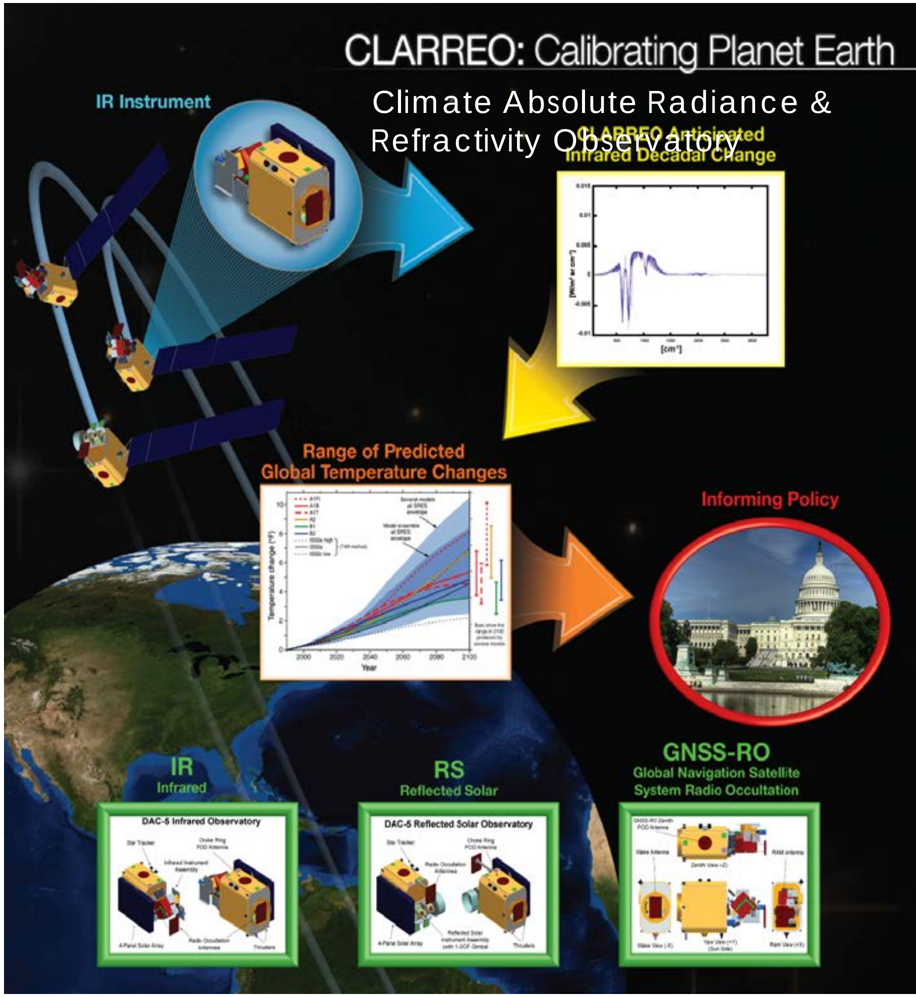
Most powerful test of climate model prediction accuracy is decadal change observations

- Accuracy required at large time and space scales
- Must survive data gaps
- Questions are
  - How long a data record is needed?
  - What variables are key?
  - What accuracy relative to perfect observing system is needed?
- How are the above determined?



Climate missions considered here





Measurement approach

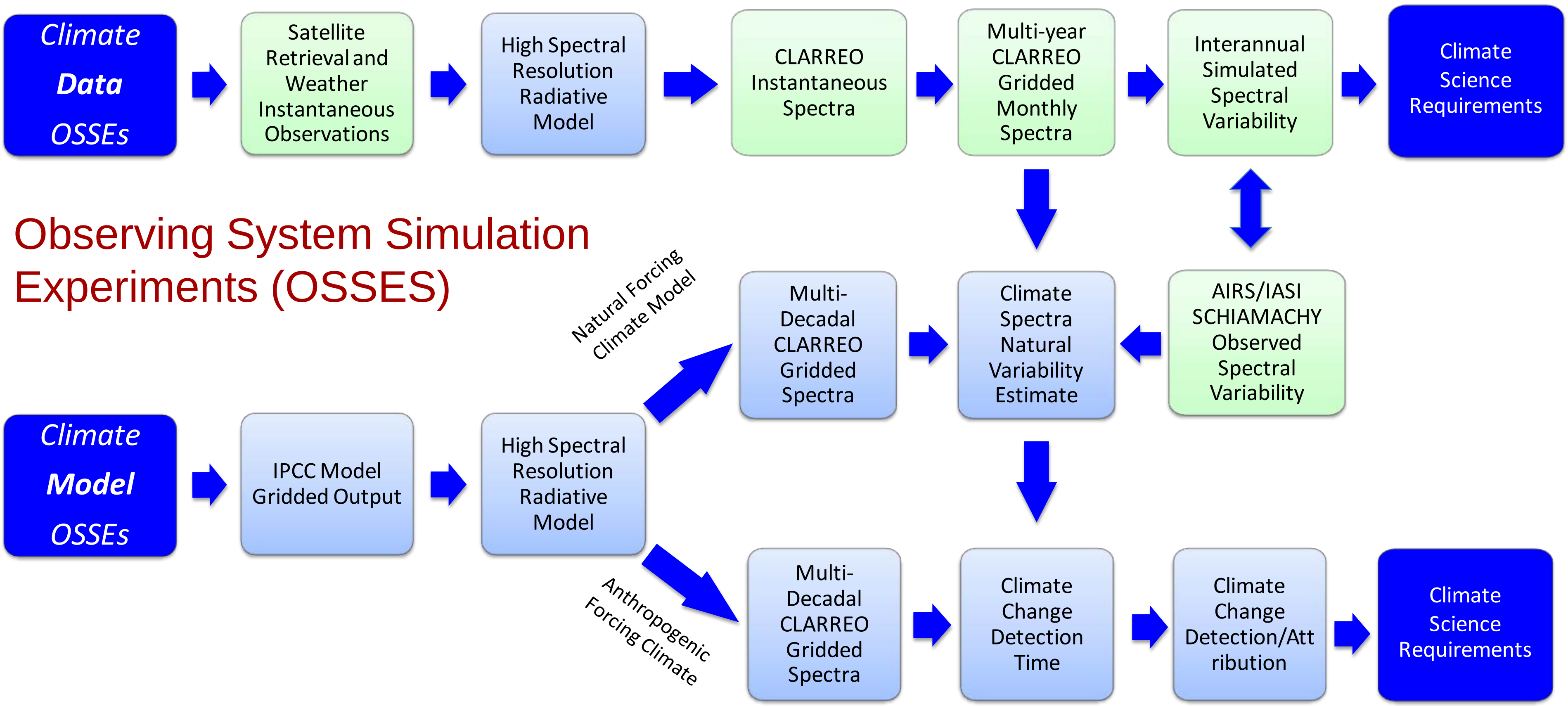
Benchmark climate data records provide the decadal change observations

- Benchmarks can be formed in two complementary ways
  - Well-calibrated, highly accurate sensor (e.g. TRUTHS, CLARREO) for direct data collection
  - Well-calibrated sensor calibrates operational sensors
- Dual approach provides tests analogous to using independent measurements and analysis in metrology
- Accuracy of benchmark observations is required only at large time and space scales
- Must survive data gaps

Climate science requirements

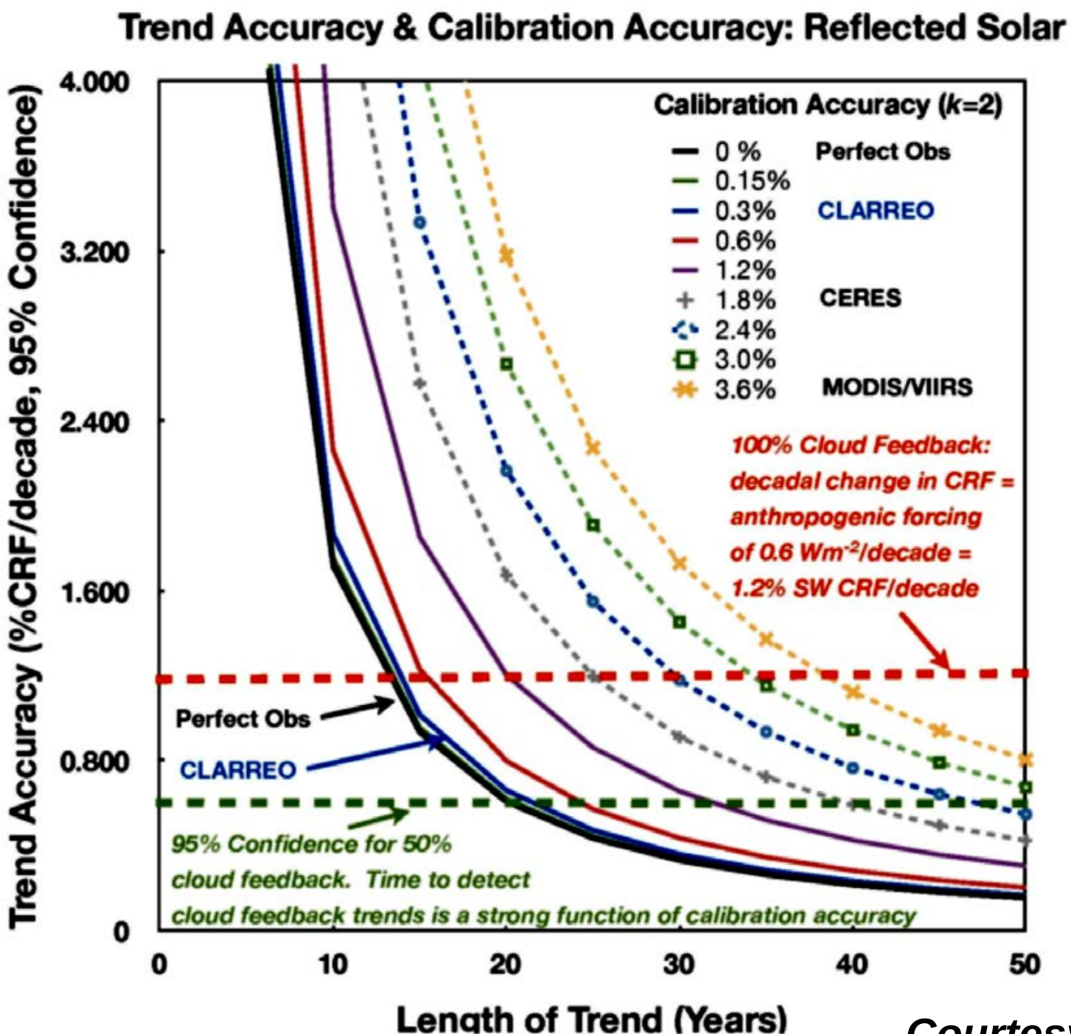
Observations and climate model predictions combined to develop requirements

Observing System Simulation Experiments (OSSES)



Accuracy requirements – Climate data record

Accuracy requirements can be inferred relative to natural variability & time to detect



- Traceable uncertainties from decadal change observation to SI standards, at decadal change accuracy levels
- Accuracy requirements driven by a time to detect above natural variability

Courtesy B. Wielicki and CLARREO SDT

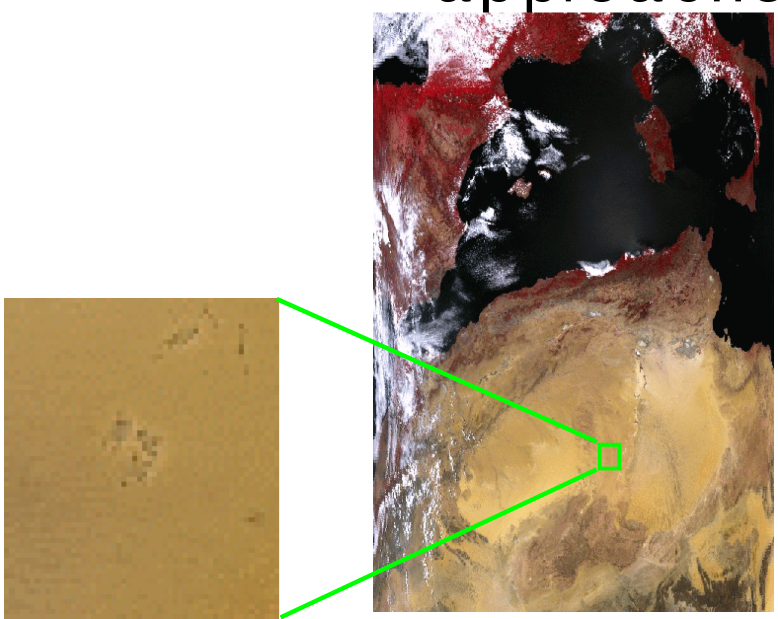
Accuracy Requirements – Climate applications

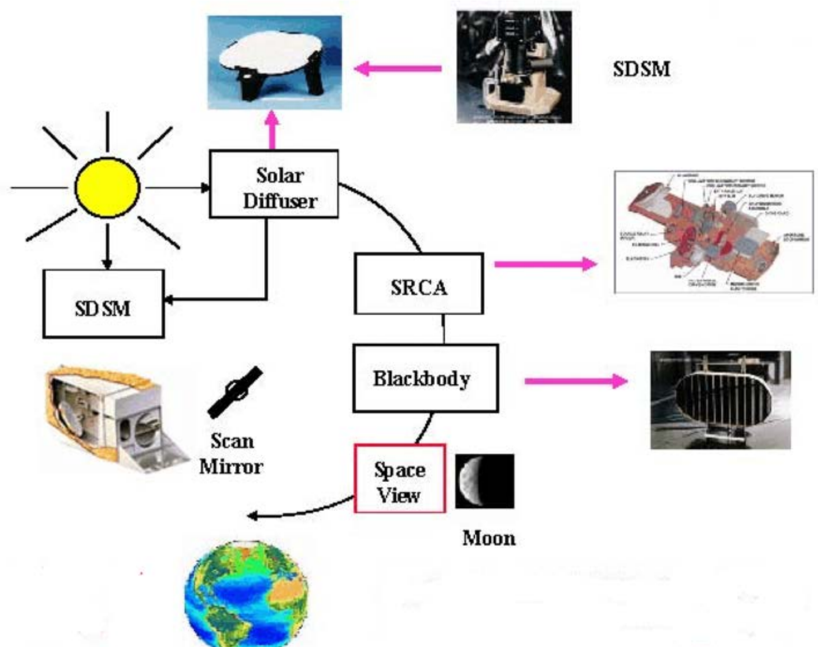
- Instrument absolute accuracy requirements are derived with the goal of achieving measurements
  - Within 20% of a perfect climate observing system
  - Time to detect trends within 15% of perfect observing system
- 0.3% (*k*=2) for the RS spectra
  - Nadir reflectance
  - Driven by natural variability of cloud radiative forcing, cloud fraction, cloud optical depth, particle size
- **SI traceable observations needed to survive short gaps in record**
- SNR requirements are driven by the verification approaches not the data itself

Why use the desert for climate?

Deserts can provide relatively unchanging surfaces for calibration and evaluation

- Verifies sensor operation
- Transfer calibrations between sensors
- Characterize sensor to SI-traceable, absolute radiometric quantities
- Part of the ensemble of calibration approaches





How well do we need to know the desert?

CLARREO-like climate measurements require the most stringent knowledge

- Verification of CLARREO optical behavior requires <0.1% (k=2) variability from measurement to measurement
  - Single measurement must provide knowledge that the sensor has changed
  - Requires significant improvement in knowledge of surface and atmospheric properties
- Absolute calibration of CLARREO using the deserts would require <0.2% uncertainty (k=2) relative to the solar irradiance, integrated over wavelength
  - Total error budget is 0.3%
  - Total error budget includes instrument noise

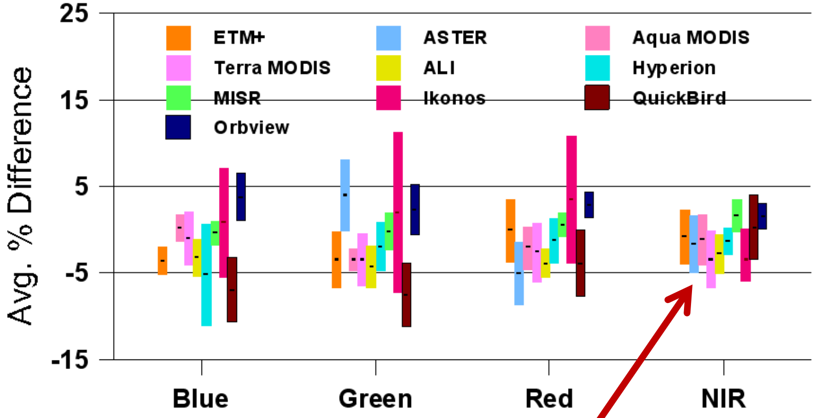
How well do we need to know the desert?

Knowledge of the desert must be good enough to use “all” collections

- Desert views and deep convective cloud approaches benefit from >300 acquisitions per year
- Noise caused surface and atmosphere limits the full use of these
  - Many approaches limit sun-sensor view geometry
  - Any removal of data leads to possibility of an induced bias
- Greater use of collections will also lead to improved processing techniques

Desert site characterization

Sensors used to characterize the desert sites need to be improved



- Cannot currently decouple
  - On-orbit sensor effects
  - Atmospheric variability
  - Surface variability
- Past results indicate that all three play a role
  - Comparison of sensors improves in the NIR
  - Bands with highest SNR for on-orbit and ground-based sensors
  - Atmospheric effects are not as dominant
- TRUTHS and CLARREO would help decouple
- Question remains on how to combine errors from instruments and from the sites

Final comments

The deserts are an essential piece of the overall sensor characterization and calibration

- Deserts should not be recommended as the sole calibration approach
  - This is a risk if we achieve some of the items previously discussed
- Climate-level measurements are a driver for both accuracy and precision of lunar understanding
  - <0.1% (k=2) variability relative to solar irradiance
  - <0.2% (k=2) absolute uncertainty
- Satisfying climate-level requirements will not necessarily solve issues for other types of sensors
- How to characterize the sites without sensors dedicated to that purpose is a major question