



Coordination of international efforts to ensure SI-traceability and harmonisation of satellite sensor data

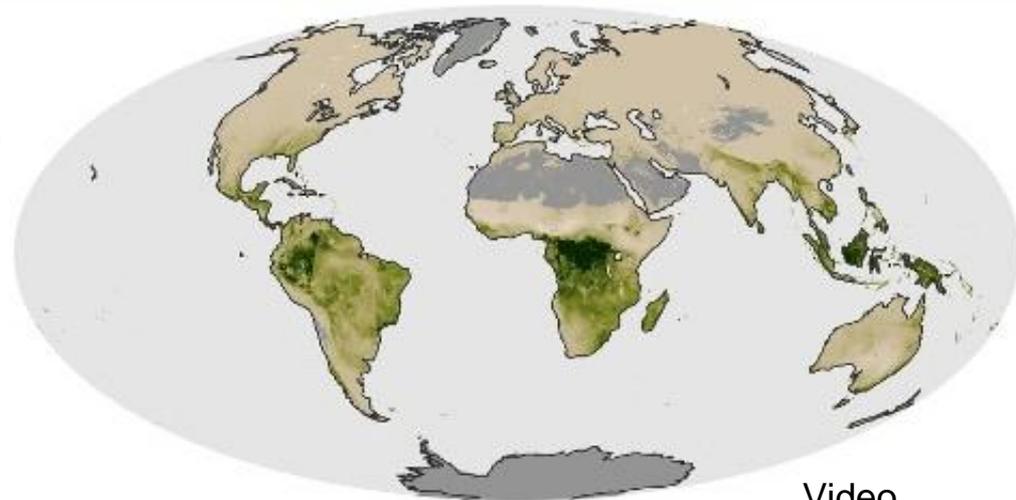
K. Thome

NASA/GSFC

What is the problem?

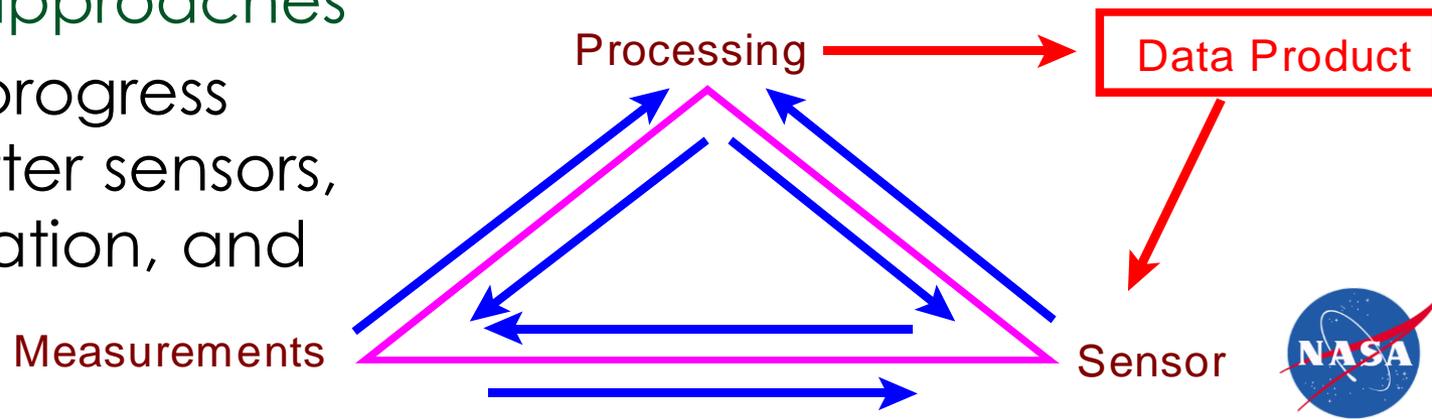
Increasing need to understand our earth-atmosphere system

- Best done with studies at a global scale
 - Satellite-based sensors
 - Need to cover a range of spatial and spectral scales
 - Both active and passive approaches
- Significant progress through better sensors, characterization, and processing

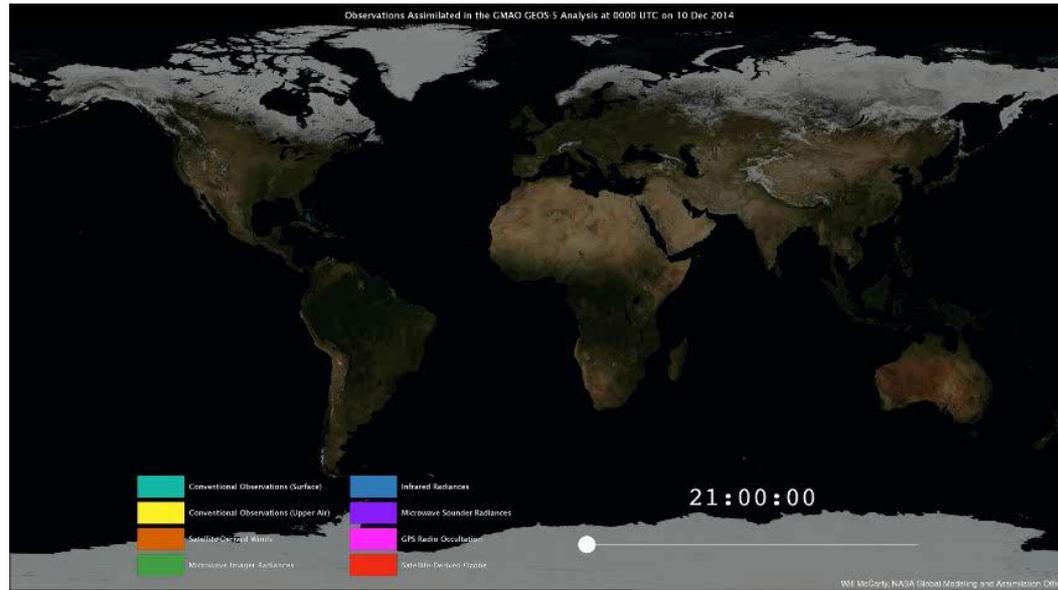


Net Primary Productivity
gC/m²/day
-1.0 0 6.5
February 2000

Video
courtesy
NASA's
Scientific
Visualization
Studio



Fusion of multiple data types



Complicates the processing and harmonisation

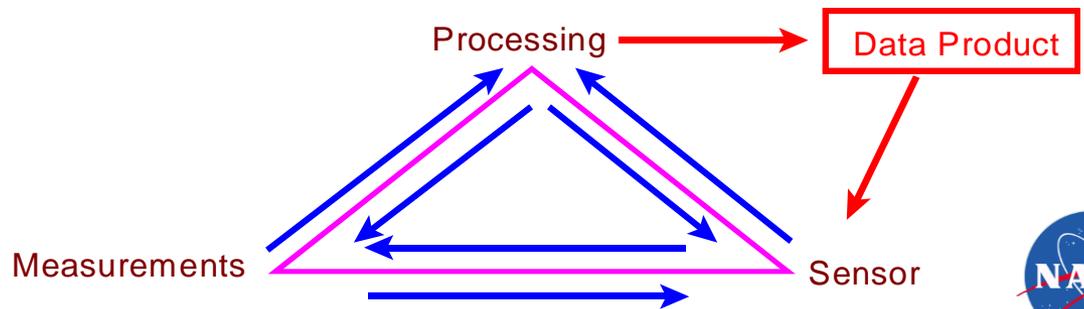
Improves the end result and our understanding of how to model earth-system processes



Why should you care?

Or, what does this have to do with imaging spectroscopy, Cal/Val, inter-calibration, and terminology?

- Imaging spectrometry was one of the original data fusion problems – the spectral perspective
- Limits of early imaging spectrometers made the science a challenge
- Ground validation work pushed for improved sensors
- Lessons learned in imaging spectroscopy can be transferred to other communities and vice versa



A big problem that includes imaging spectrometry

- **>50 agencies responsible for >100 satellites**
- No single organization or country can shoulder the burden of the costs and complexities associated with such a global effort
- Will only expand in the future – consider the list of future imaging spectrometer missions
- How do we address such a difficult problem?

NASA's Earth
remote sensing
fleet as of early
2015



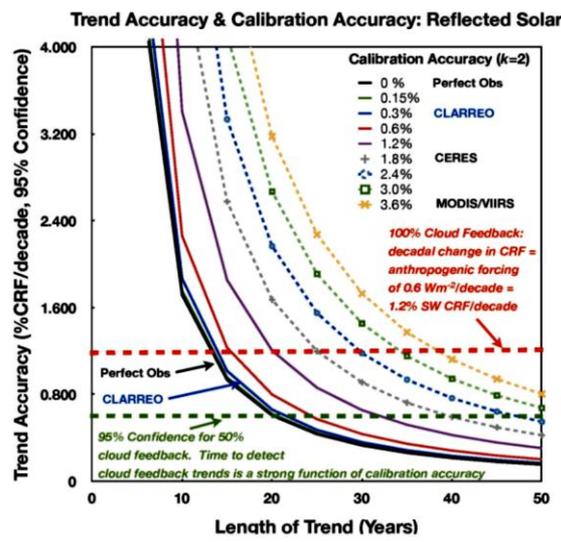
Additional complication

We are using sensors in ways they were not originally planned

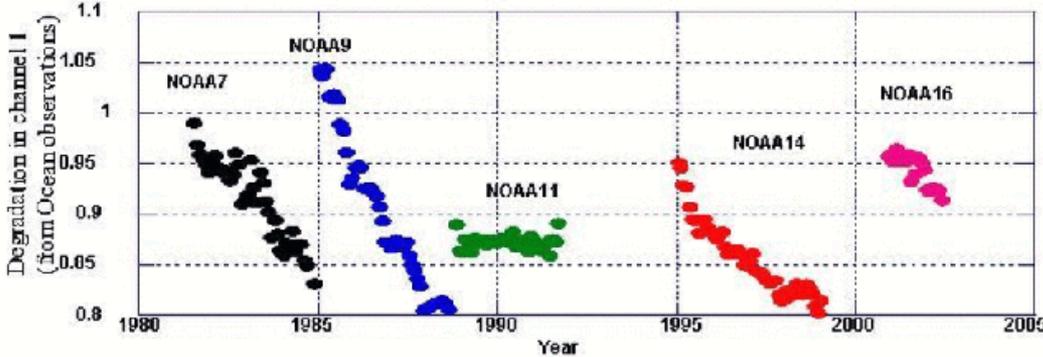
- Sensors range from research-quality systems to operational weather systems
- How do we harmonise these to allow data interoperability



Precision and SNR drive calibration requirements for **commercial** high resolution systems



Climate-related applications need accuracy and benefit from stability



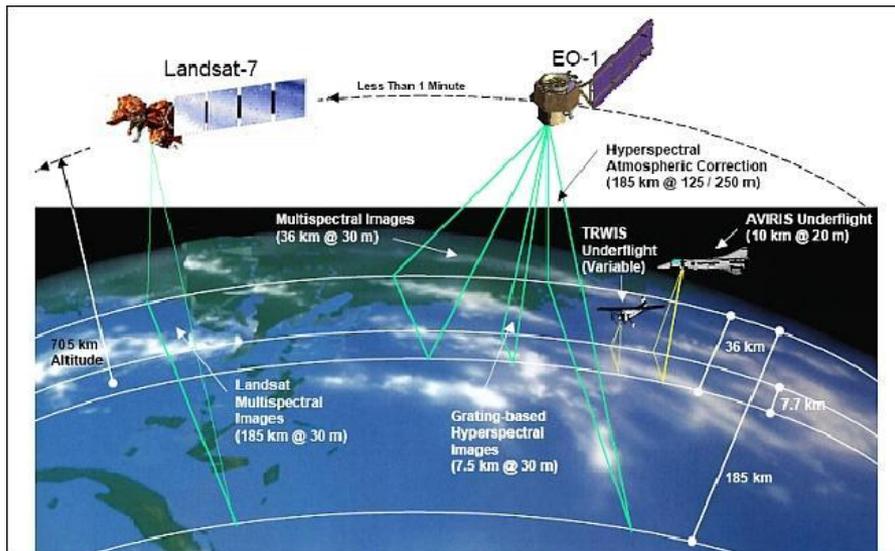
Operational sensors need high precision, SNR, self-consistency and interconsistency



Harmonisation is changing

Have to move away from one by one comparisons

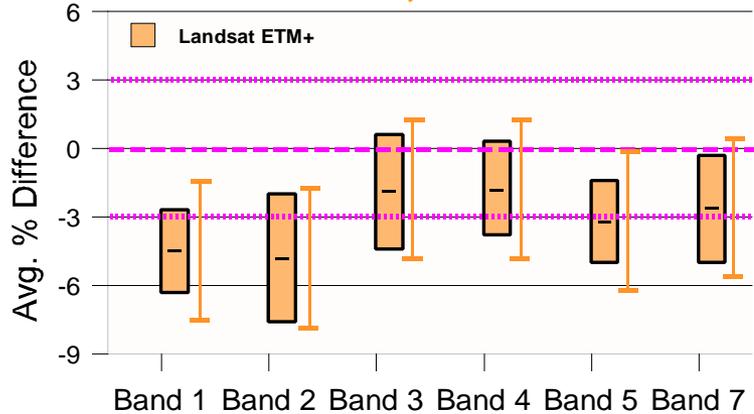
- Imaging spectrometry led was one of the leaders
- Left picture from S. Ungar's EO-1 presentations on intercomparisons
- Right picture is from a recent CLARREO talk on the same topic



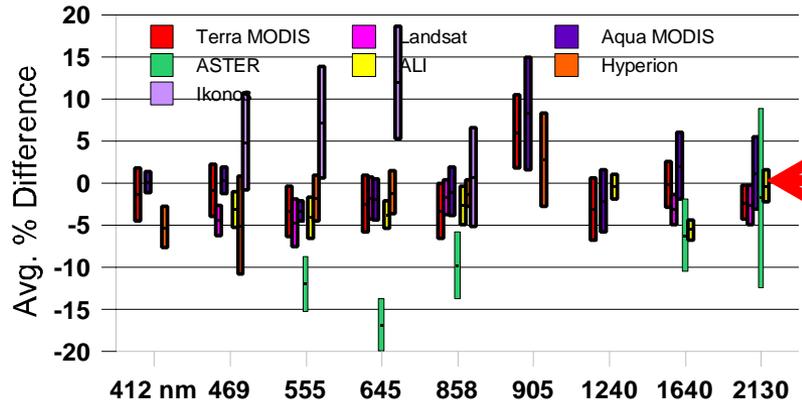
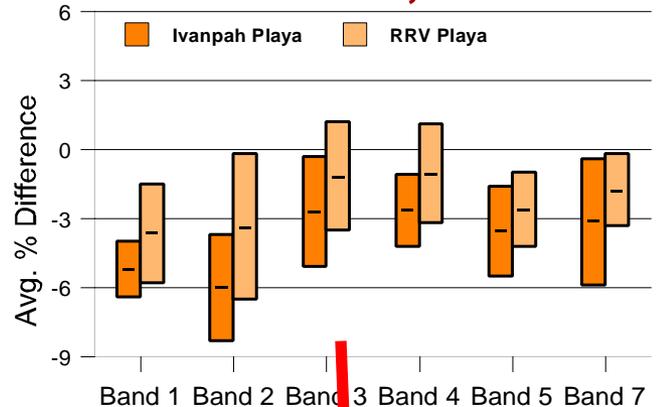
Harmonisation change has been a slow evolution

Vicarious calibration example follows what has been happening over the past 30 years in earth remote sensing

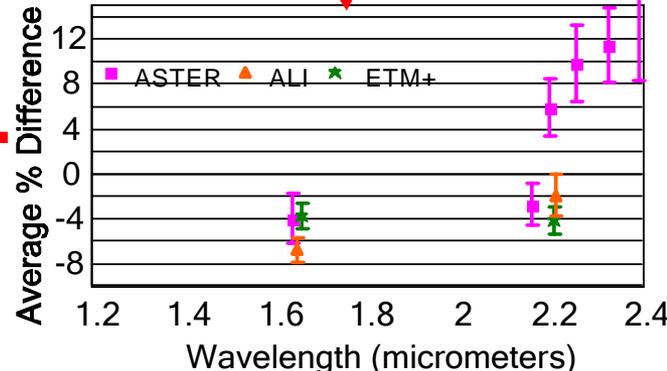
One sensor, one site



One sensor, two sites



Many sensors (including Hyperion), many sites

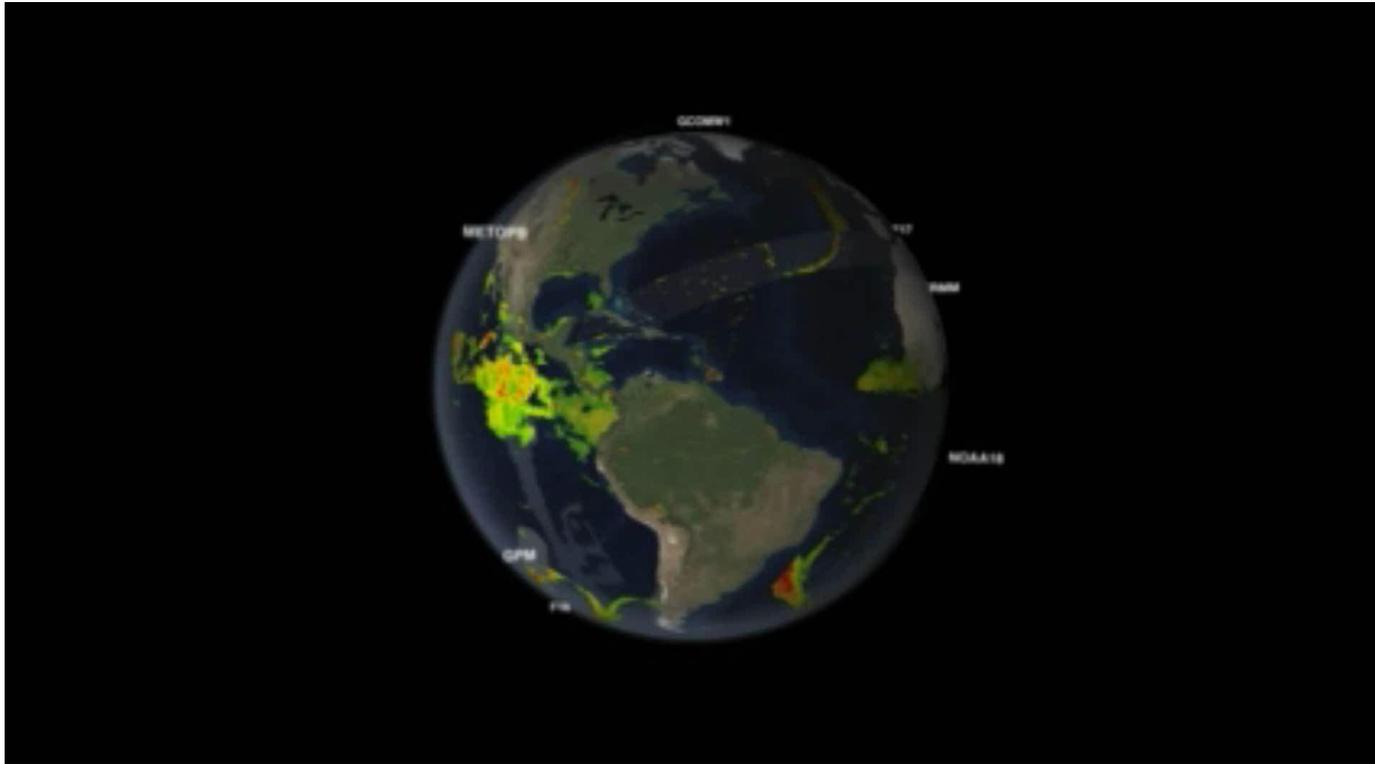


3 high resolution sensors



GPM example of what can be achieved

GPM example of using it as the reference to allow data fusion from 12 total sensors



Science community will always lead the way but the international organizations can help simplify the coordination

How do we do solve such a big problem?

Requires significant international collaboration
and cooperation

- Complicating this are
 - Multiple companies/ agencies supplying sensors
 - Multiple suppliers providing subsystems and components
 - An array of science communities use the data
 - Results must be of sufficient quality to guide decisions
 - Protocols needed to evaluate the effectiveness of those decisions
- Global Earth Observing System of Systems
- Committee on Earth Observing Satellites



CEOS Working Group for Calibration and Validation

WGCV is one example of many similar groups



WGCV
members at
May 2015
Plenary in
Berlin

- WGCV established in 1984
- Recognition that calibration and validation activities play a key role in ensuring high-quality data
- Objectives of WGCV are
 - Promote international cooperation
 - Serve as a coordinating body for CEOS members and the international user community
 - Focus activities in calibration and validation of Earth observations



WGCV summary

Sponsors workshops, round-robins, proposes measurement protocols

- Five sub groups
 - Atmospheric Composition (ACSG)
 - Infrared Visible Optical Sensors (IVOS)
 - Land Product Validation (LPV)
 - Microwave Sensors (MSSG)
 - Synthetic Aperture Radar (SAR)
 - Terrain Mapping (TMSG)
- Past workshops on vicarious calibration methods
- Future workshops to examine prelaunch methods
- Evaluating atmospheric correction methods, cloud-screening approaches, DEMs appropriate for processing methods



WGCV summary

Best practices, fit for purpose, QA4EO (Quality Assessment for Earth Observations)

- Member organizations are able to optimize their facilities
 - Coordinated calibration and validation campaigns
 - Sharing of available facilities
 - Exposure to expertise of other members
 - Encourage development of next-generation cal/val scientists
- <http://ceos.org/ourwork/workinggroups/wgcv/>



Tuz Golu campaign
August 2010

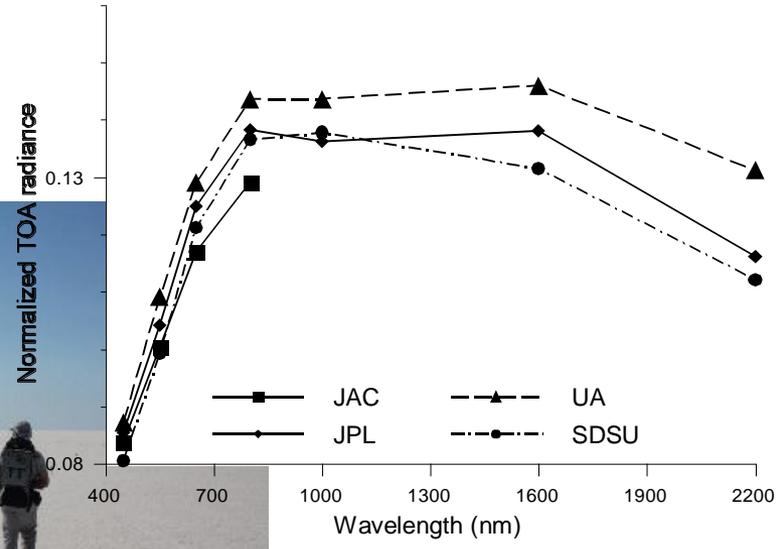
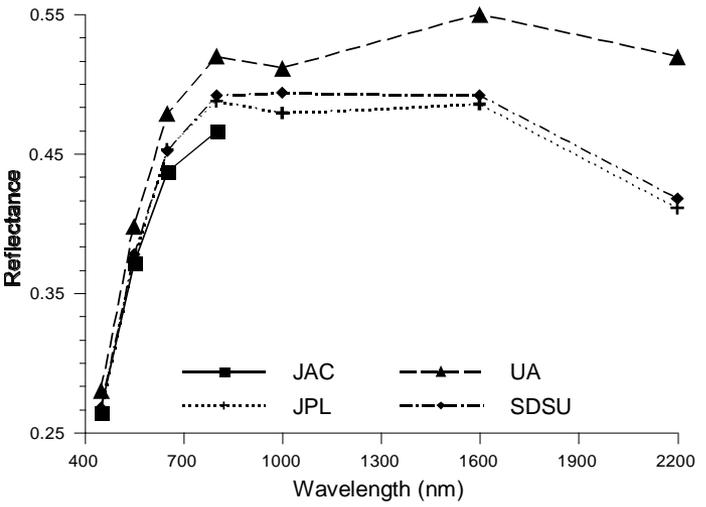


WGCV helps coordinate laboratory round robins

Multi-agency, multi-national, multi-sensor efforts of lab standards as well as field instrumentation



WGCV efforts extend to the field as well



WGCV and CEOS try to lead rather than push

Goal is to inform about best practices **not** force identical approaches

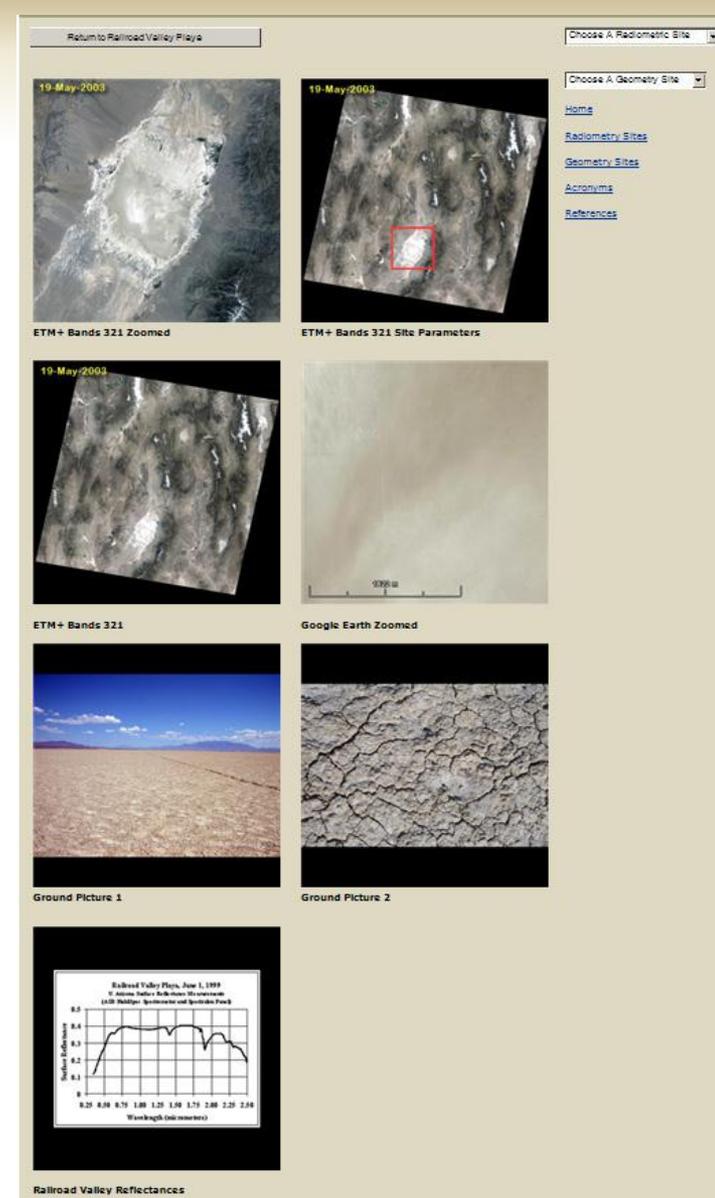


- Determine biases using laboratory and in situ cross-comparisons
- Methods for estimating uncertainties
- Evaluate differences in sampling methods
- **Document** “best practices”

Landnet example

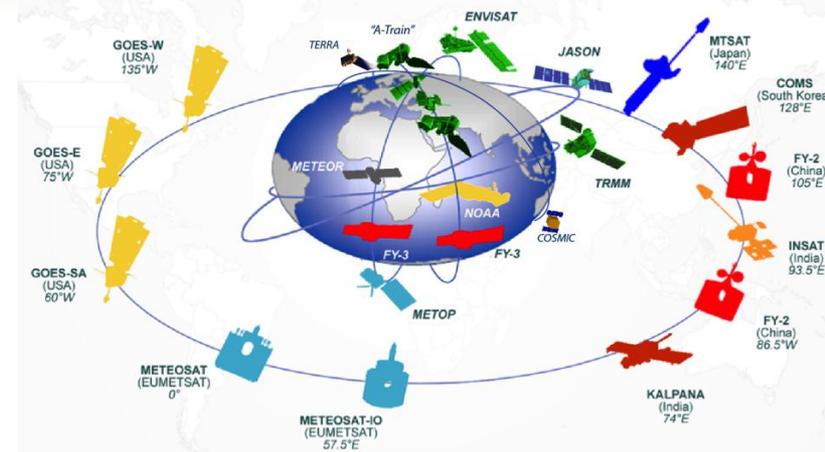
Selected, identified and characterized reference test sites for calibration of different sensor types

- Outcome from February 2008 meeting
- Eight sites used successfully for a range of sensors
- Recent efforts are working towards expanding the list
 - Including new areas
 - Using sites for new sensor types



Landnet and sensor harmonisation

Development of Landnet coincided with expansion of sensor intercomparison efforts

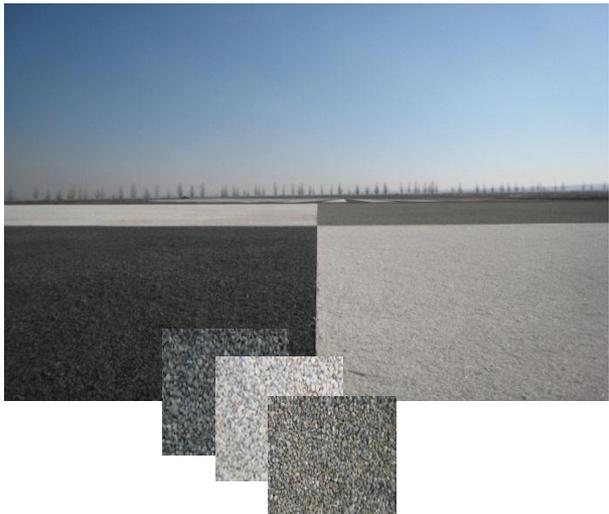
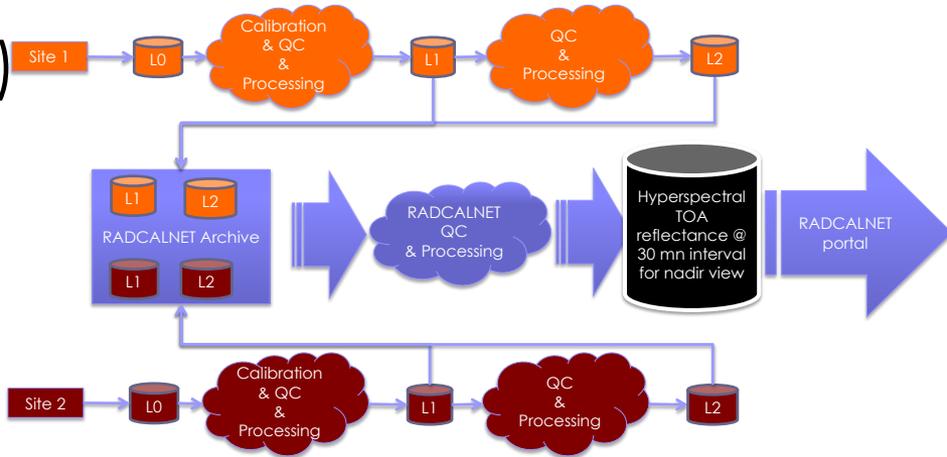


- GSICS (Global Space-based Inter-Calibration System) through WMO played a large role in this as well
- Keys have been to
 - Expand to thousands of scenes from several sensors over decadal time scales
 - Extend simultaneous view approaches to allow greater separation in time including data gaps
 - Include assessments of higher-level data products
 - Document error budget and traceability

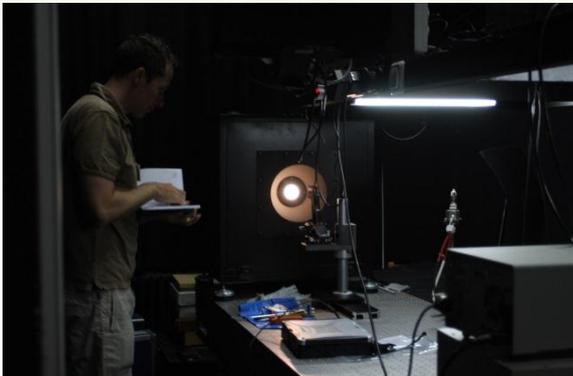
Landnet to RadCalNet

RadCalNet will network data from sites collecting automated ground measurements

- RadCalNet is a subset of Landnet (details in next talk)
- Provide predicted top-of-atmosphere reflectance to user community
- Goal for distribution of RadCalNet data is 2016

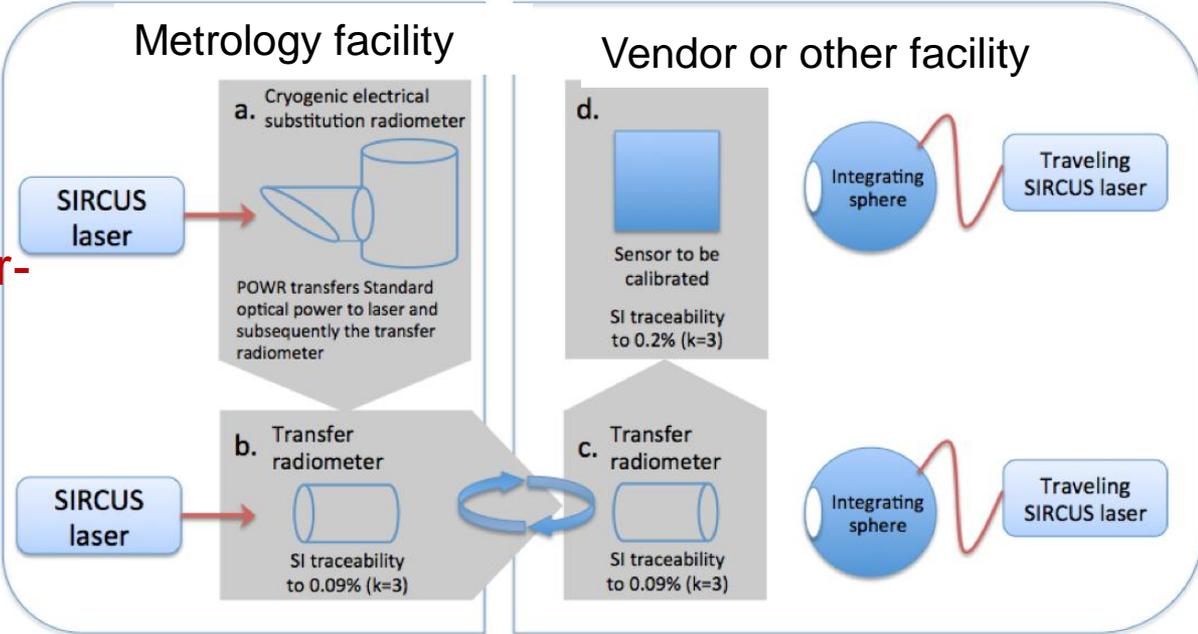


Inclusion of metrology community for traceability



NPL characterizing Tuz Golu field spectrometers

NASA's Laser-based, detector-based calibration in collaboration with NIST



- Detector-based standards
- Evaluation of field protocols and sensors



Push for climate-quality data

“Absolute” uncertainties $< 0.3\%$ in reflectance is leading to broader benefits

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

TRUTHS:
Traceable Radiometry Underpinning Terrestrial- and Helio-Studies

A Benchmark Mission for Climate Change and GMES

Proposal for ESA Earth Explorer-8

2015 2025 2035 2045

TRUTHS NO TRUTHS

Ref: CRM329

CLARREO: Calibrating Planet Earth
Climate Absolute Radiance & Refractivity Observatory

CLARREO Anticipated Infrared Decadal Change

Range of Predicted Global Temperature Changes

Informing Policy

IR Infrared

RS Reflected Solar

GNSS-RO Global Navigation Satellite System Radio Occultation

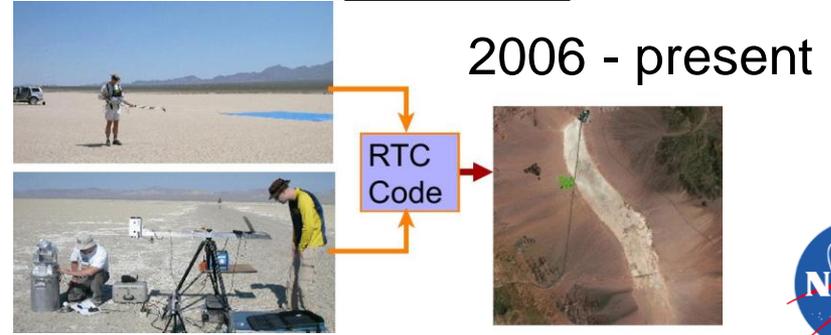
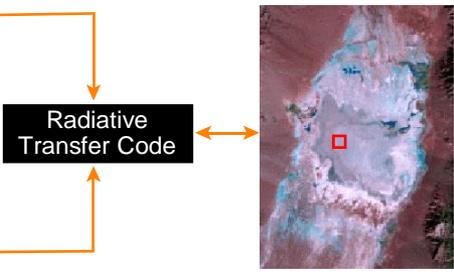
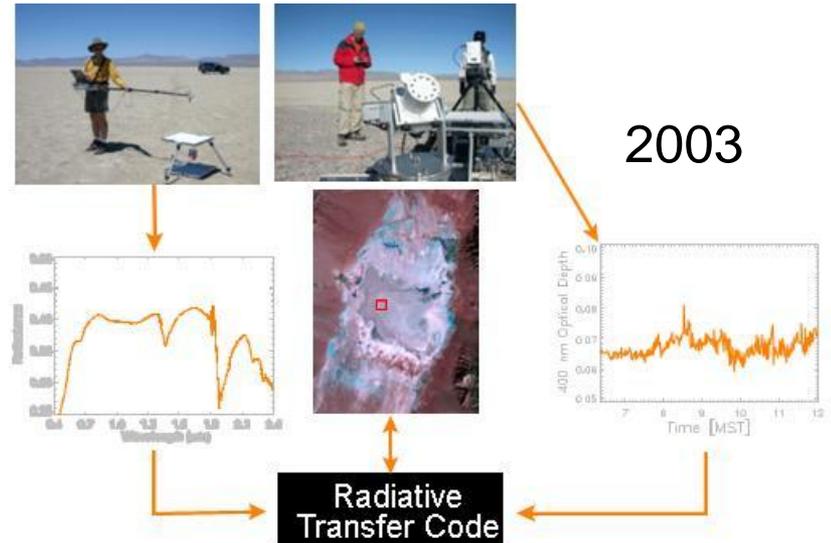
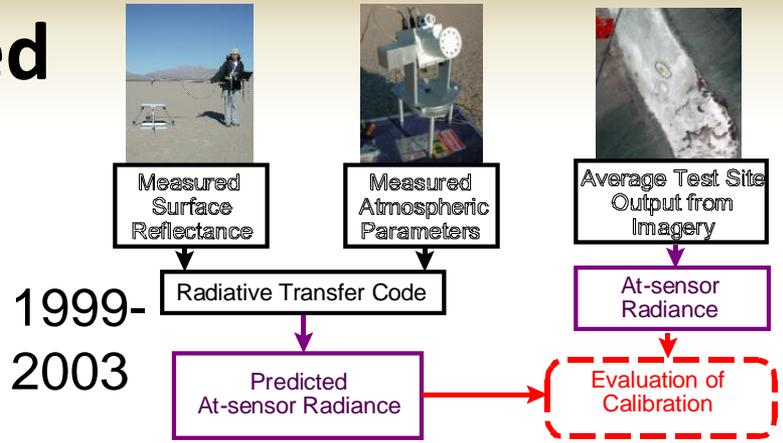
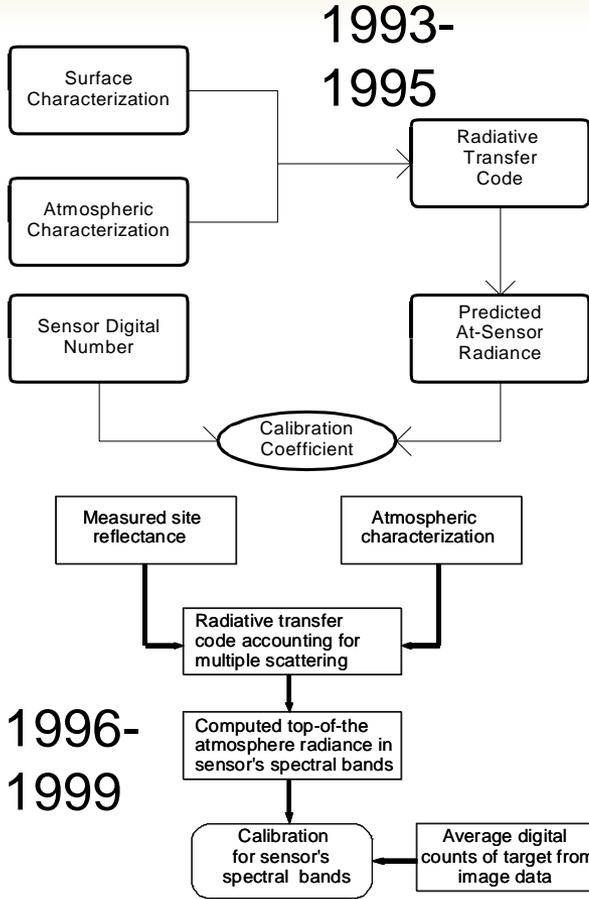
DAC-4 Infrared Observatory

DAC-5 Reflected Solar Observatory

NASA

Much in calibration has changed

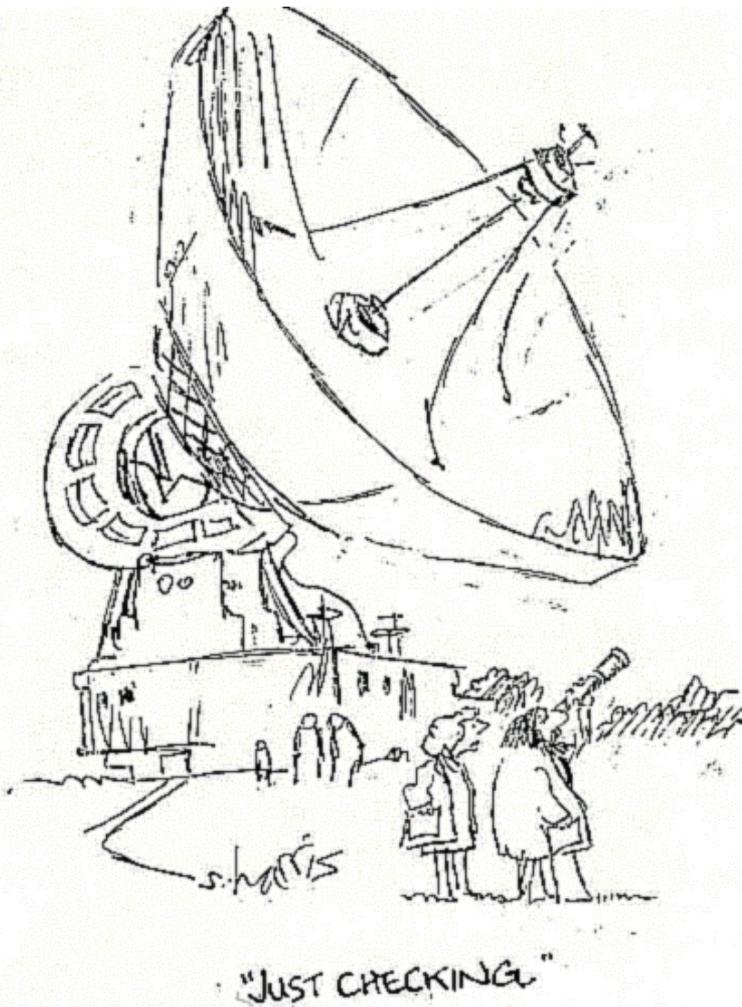
But much has stayed the same



Summary – state the obvious

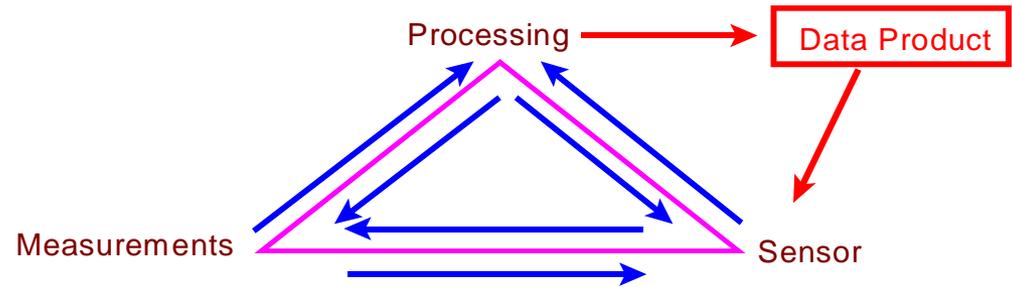
Improving cal/val results will be difficult as budgets force hard decisions on priorities

- Easy fixes have been made
- Need techniques that optimize cost while improving accuracy
- Will require cross-cutting ideas to improve cal/val models and instruments
- Goal should be climate-quality data capabilities but realizing what is fit for purpose



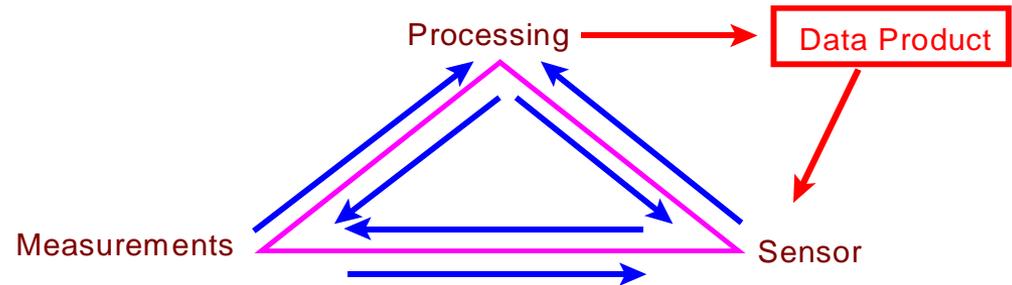
Summary - Results-based approach

How many cal/val
scientists does it
take to change a
light bulb?



Summary - Results-based approach

How many cal/val scientists does it take to change a light bulb?



- **None**

- **We are perfectly happy to sit in the dark and which light bulb would be the best replacement**
- Calibration, validation, and terminology definition are excellent topics in themselves
 - Remember cal/val is part of a bigger picture
 - Balance between getting things right and getting them fast
- Need to tip the balance towards getting information to the user communities