OPTICAL TECHNOLOGY DIVISION

Develop a Generic Model for CEOS SI Traceable Cal/Val Sites

Sanya, China
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Optical Technology Division, Physics Laboratory

National Institute of Standards and Technology

Outline

- Why SI traceable?
- Establishing and Assessing Claims
- Example Applications
- How to Prioritize Efforts?

Why SI Traceable?

- Common measurement scale
  - Independent of measurement condition (time, space, source conditions, etc.)
  - Intercomparisons performed under controlled conditions
  - Results can be duplicated or improved as technology evolves
  - There is no physics without relevant measurement equations
- Good measurement practice
- Evaluation of uncertainty budget
- Documentation of measurement metrology
- Traceability ensures proper relation of national scales

Establishing Claims of Traceability (the supplier)

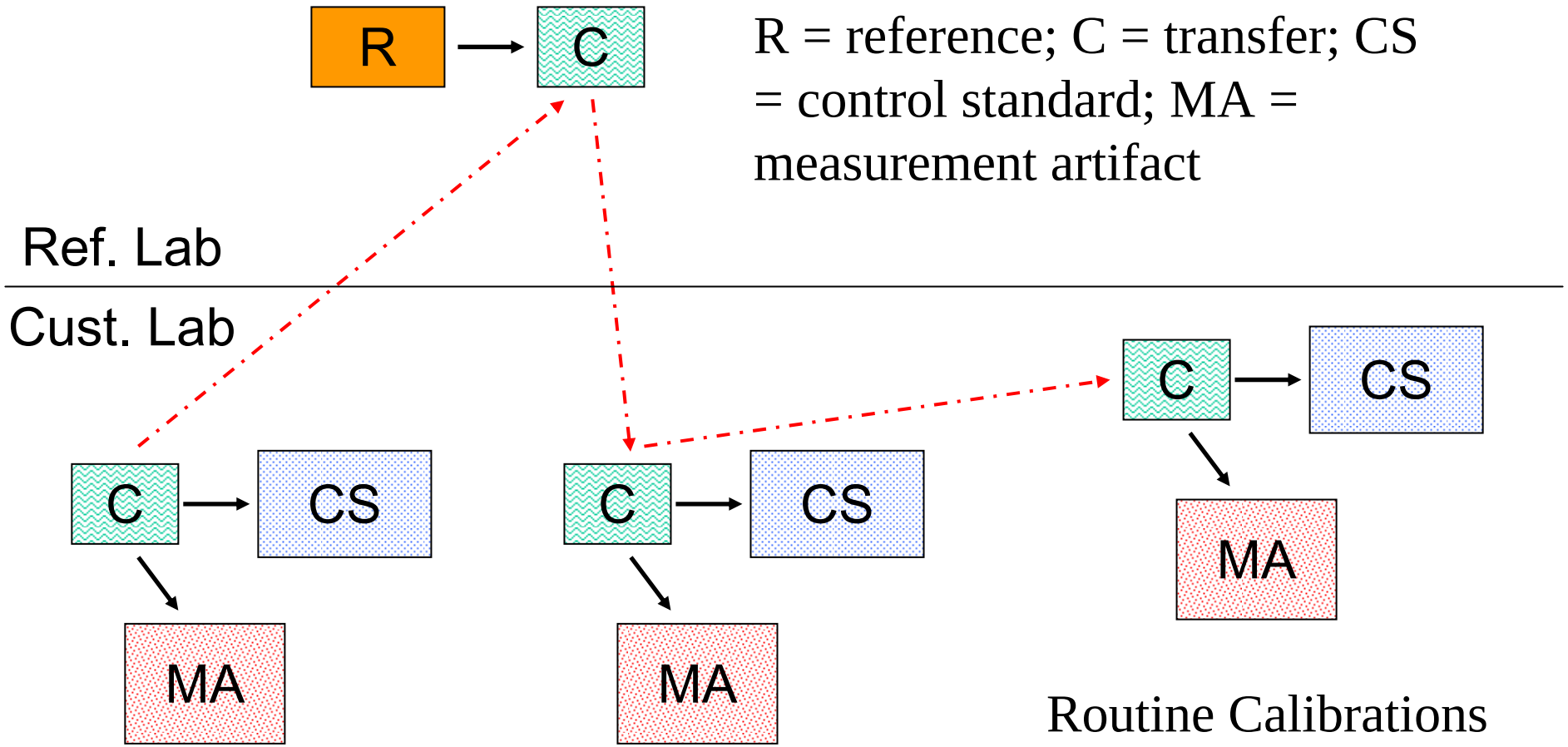
- Define what is measured, e.g. $E_s(\lambda)$, $L_u(\lambda)$
- Describe measurement system (ideally archival, peer-reviewed papers)
- Stated measurement result with documented uncertainties (web site, data archive)
- Description of stated reference (ideally archival, peer-reviewed papers)
- Internal Measurement Assurance Program (MAP) describing the status of the measurement system
- Internal MAP describing the status of the stated reference

http://ts.nist.gov/Traceability/

MAP Definition

A program of sufficient complexity, within an organization, to provide credibility to the measurement uncertainty and measurement result for which traceability is to be established. An internal measurement assurance program usually involves monitoring the performance (e.g., stability, reproducibility) of the instrument, standard, or measurement system, both before and after it is characterized and calibrated, or used to obtain the traceable measurement result.

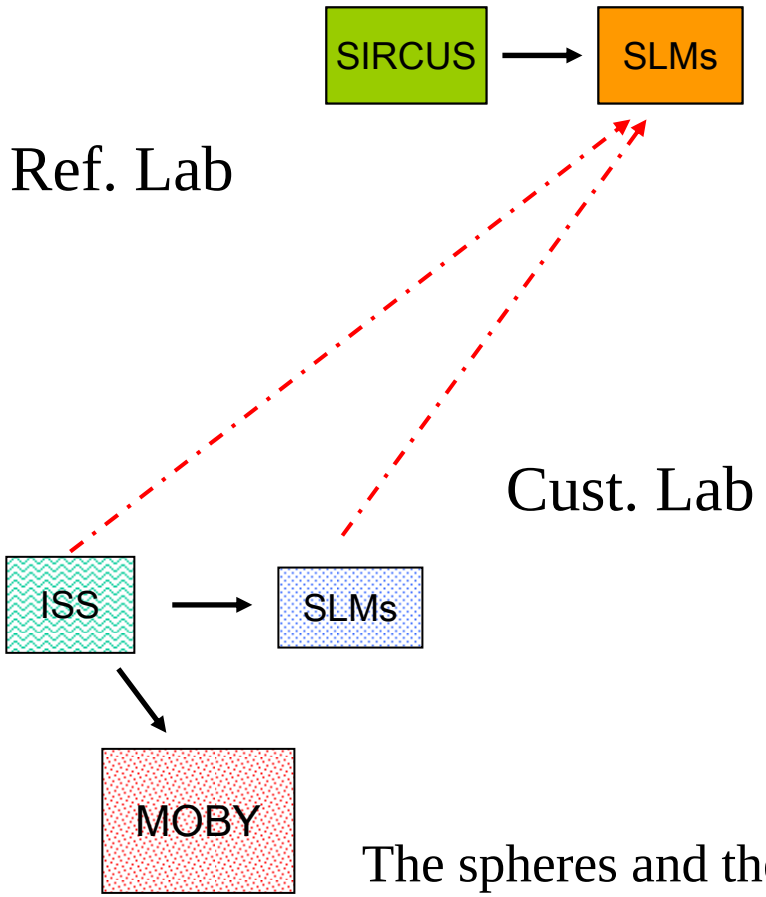
Traceability through Calibration



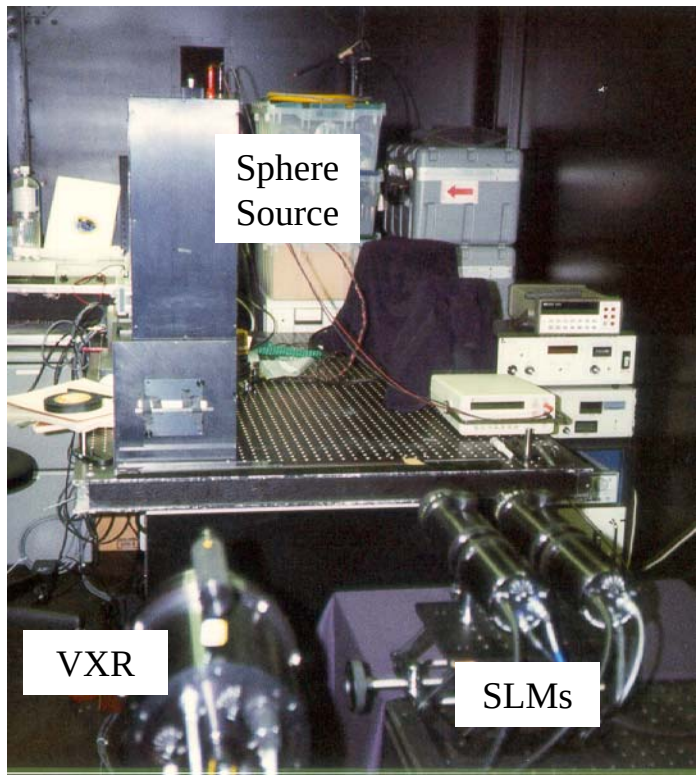
Internal MAP – execute before and after calibration

http://ts.nist.gov/Traceability/suppl_matls_for_nist_policy_rev.cfm

MOBY Lu(λ) Example

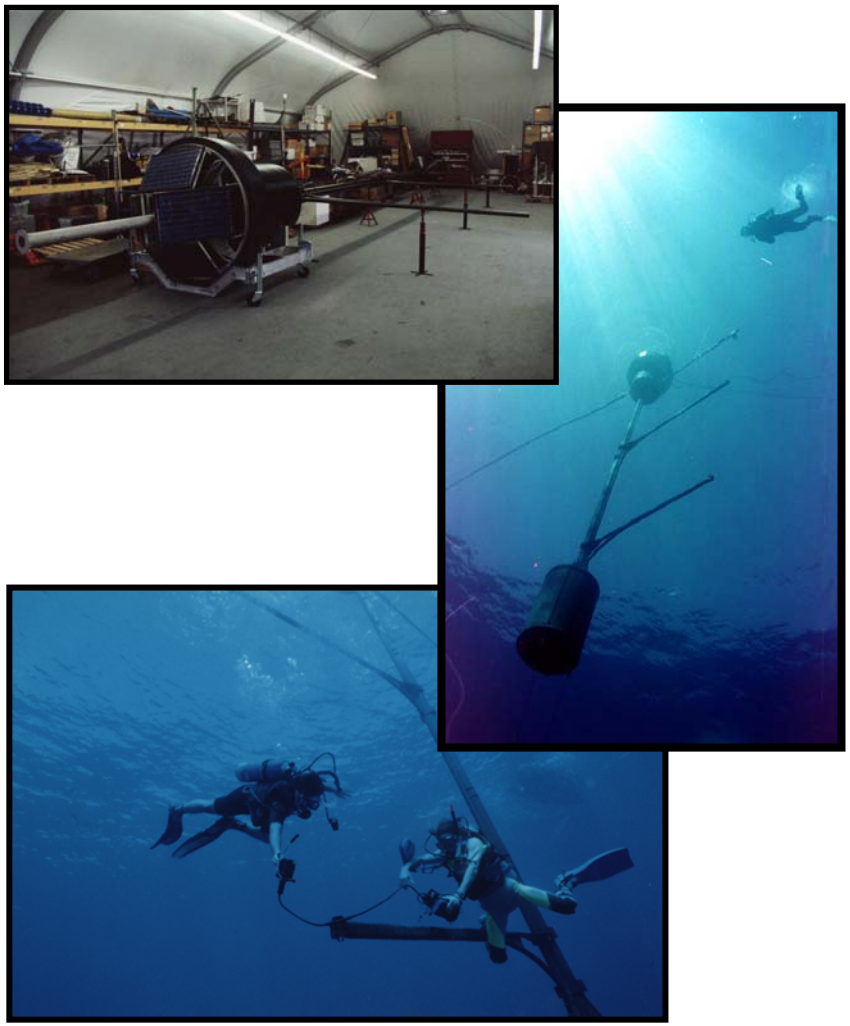


Calibration Hut, Honolulu



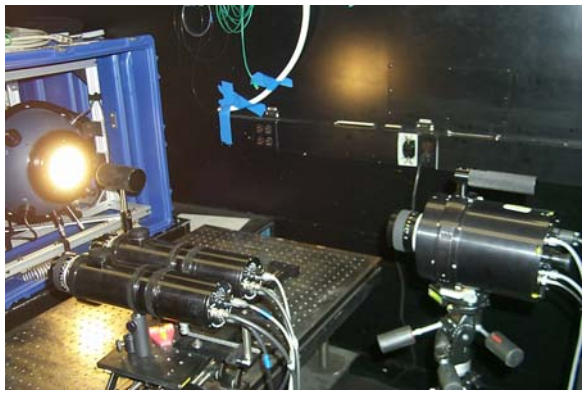
The spheres and the SLMs are sent to NIST. The SLMs measure the spheres every time the buoy is calibrated. The VXR is a separate validation (annually).

MOBY Procedures

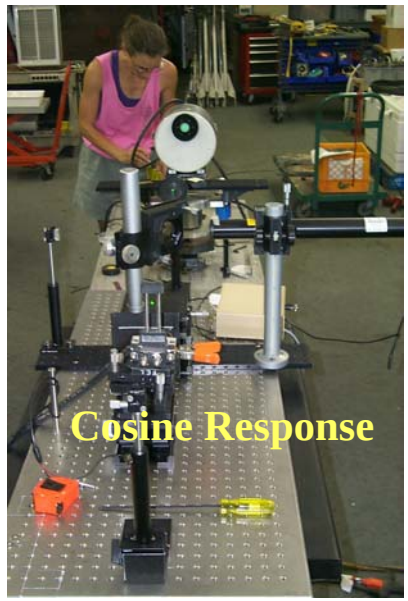


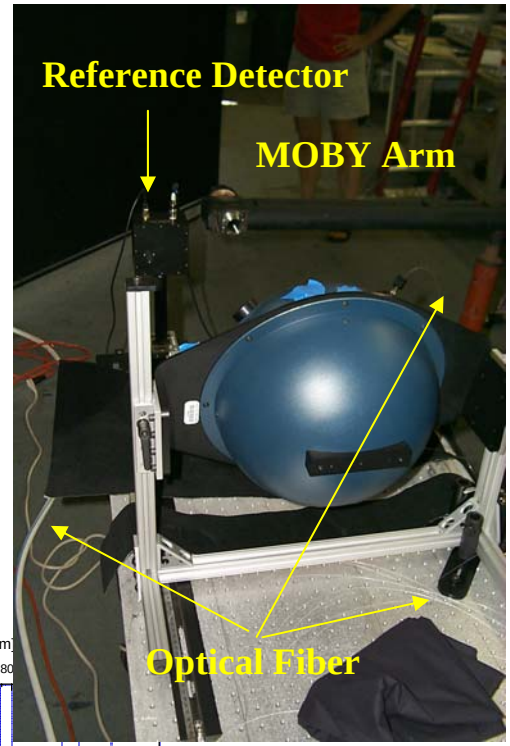
- Rotate Buoy 4x/year
- Pre- and Post Calibrations
- E and L sources NIST-traceable
- Sources recalibrated every 50 h
- Sources verified during use with SLMs (NIST-designed radiometers)
- Daily scans of three internal sources (blue and red LED; lamp)
- Monthly measurements with stable, diver-deployed lamps
- Detailed instrument characterization
- Validation with independent artifacts
- Site characterization

Additional Cal/Val Elements

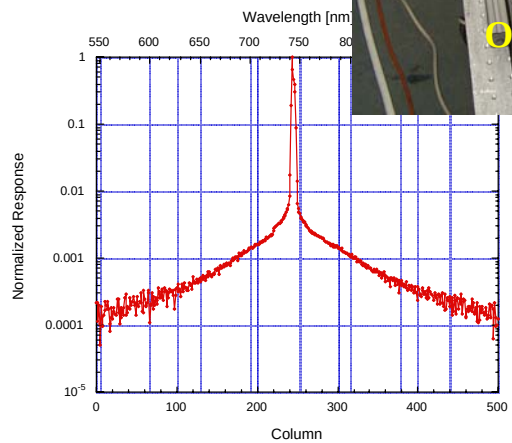


On-site measurements by NIST using NIST Portable Radiance (NPR) source and NIST/EOS Visible Transfer Radiometer (VXR) – performed annually



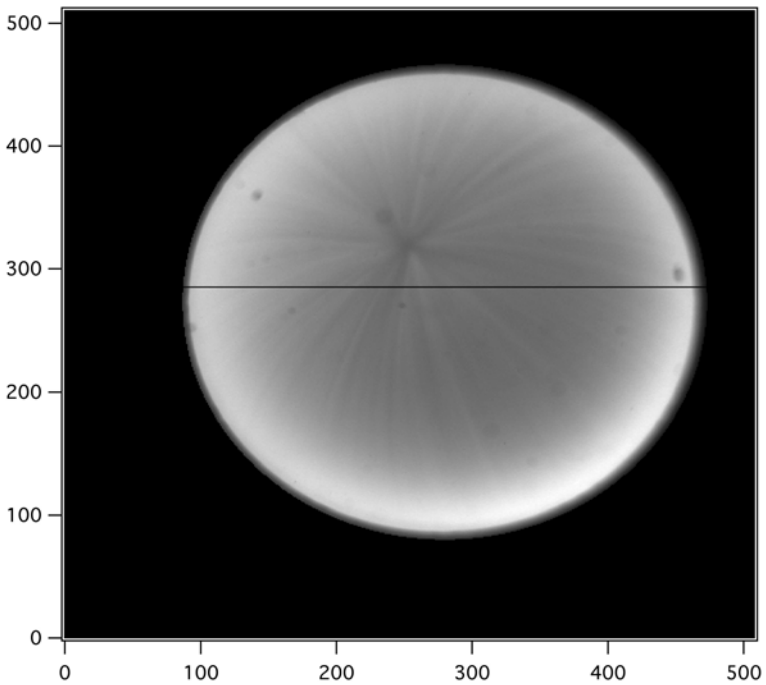


Instrument Characterizations

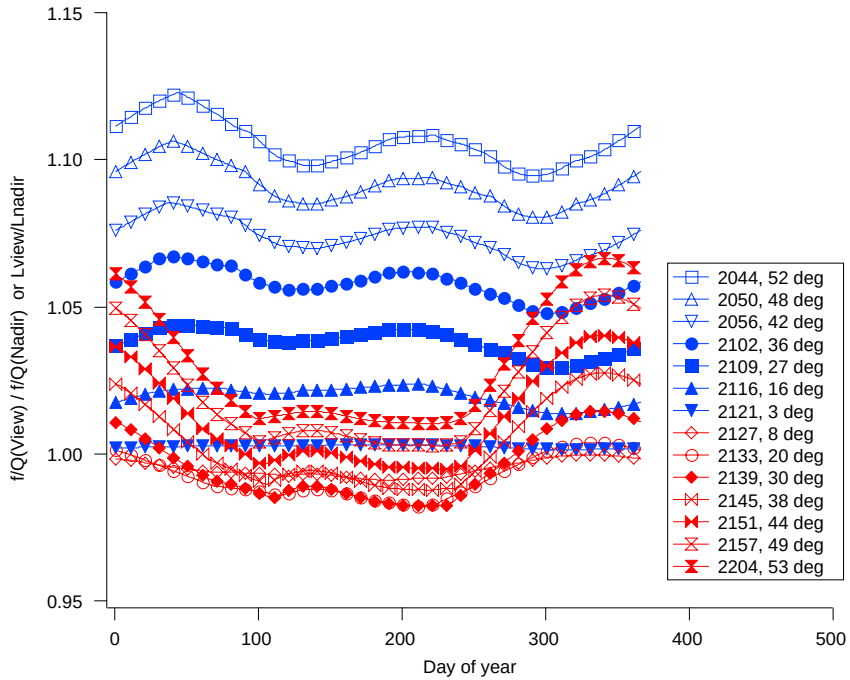


Stray light

Site Characterization - BRDF



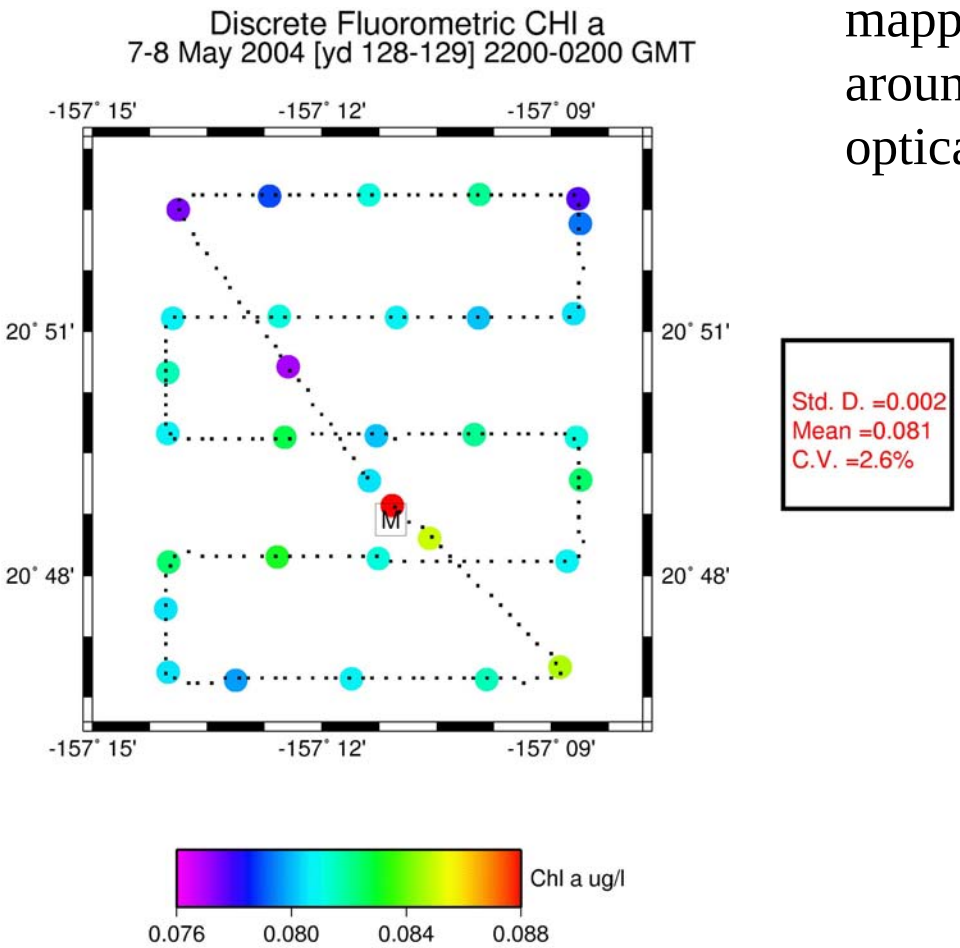
Upwelling Radiance Distribution (NuRADS)



Variation of Lview/Lnadir with day of year and scan time

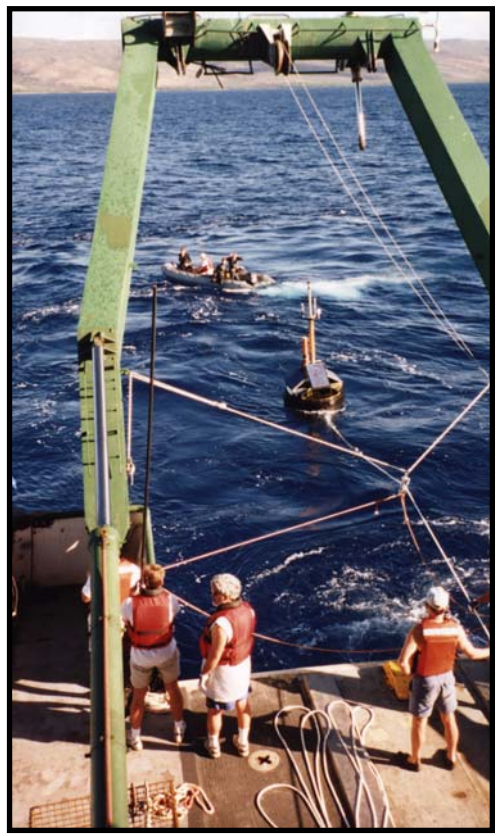
Ken Voss, U Miami

Site Characterization - Uniformity



Dennis Clark, Marine Optical Consulting

Ship time is dedicated to mapping the ocean waters around MOBY for bio-optical properties.



Site Characterization – Self Shading

Final Report, NOAA Grant NA04NES4400007 PI: James L. Mueller
CHORS, San Diego State University Research Foundation 8/20/07

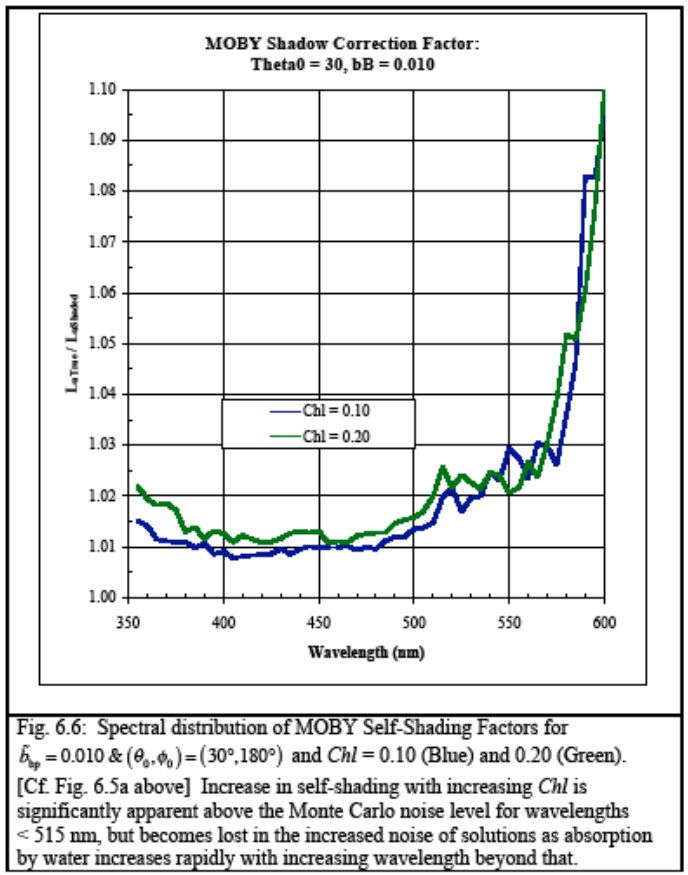
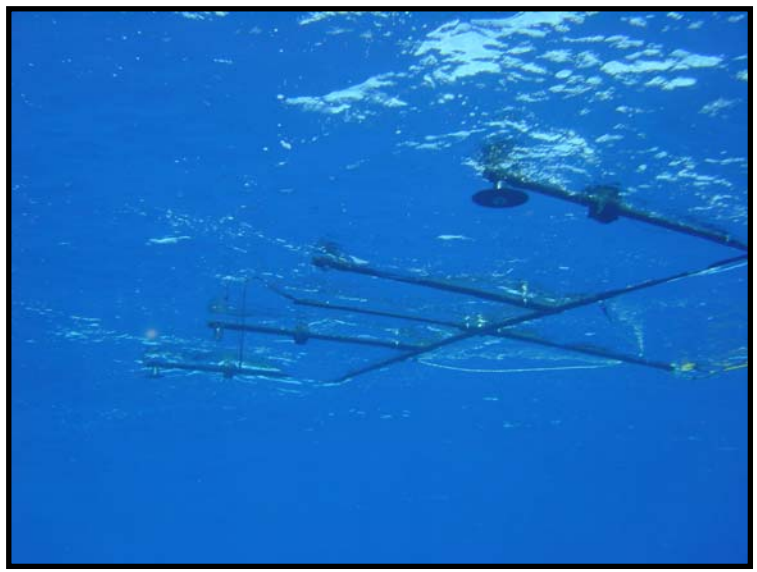


Fig. 6.6: Spectral distribution of MOBY Self-Shading Factors for $b_{bp} = 0.010$ & $(\theta_0, \phi_0) = (30°, 180°)$ and *Chl* = 0.10 (Blue) and 0.20 (Green). [Cf. Fig. 6.5a above] Increase in self-shading with increasing *Chl* is significantly apparent above the Monte Carlo noise level for wavelengths < 515 nm, but becomes lost in the increased noise of solutions as absorption by water increases rapidly with increasing wavelength beyond that.

Theoretical and experimental approach is in progress; important for the red and near infrared spectral regions.



Land Analogue

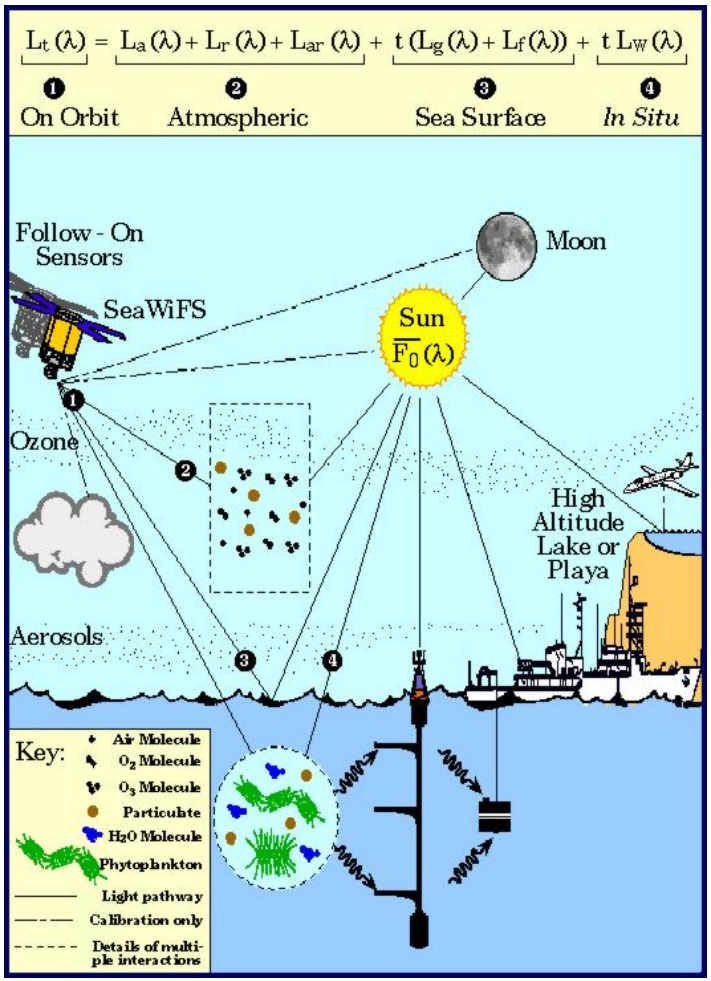
- Transfer artifacts (send to the reference lab):
  - FEL (irradiance lamps); diffuse reflectance standards (BRDF); radiometers (e.g., ASD)
- User calibration laboratory MAP: characterize field radiometers; calibrate with lab standard
- Field measurements:
  - the solar-illuminated reflectance standard is the reference standard;
  - site characterization is required.

Prioritize Efforts

- Perform measurement intercomparison
- Follow previous examples
  - UV downwelling spectral irradiance
  - SIRREX and SIMBIOS exercises
  - Ambient IR intercomparison (Miami)
  - Lunar Lake 1997 (laboratory effort tied to field program)
- Design experiments that identify instrument characterization issues

Backup Slides

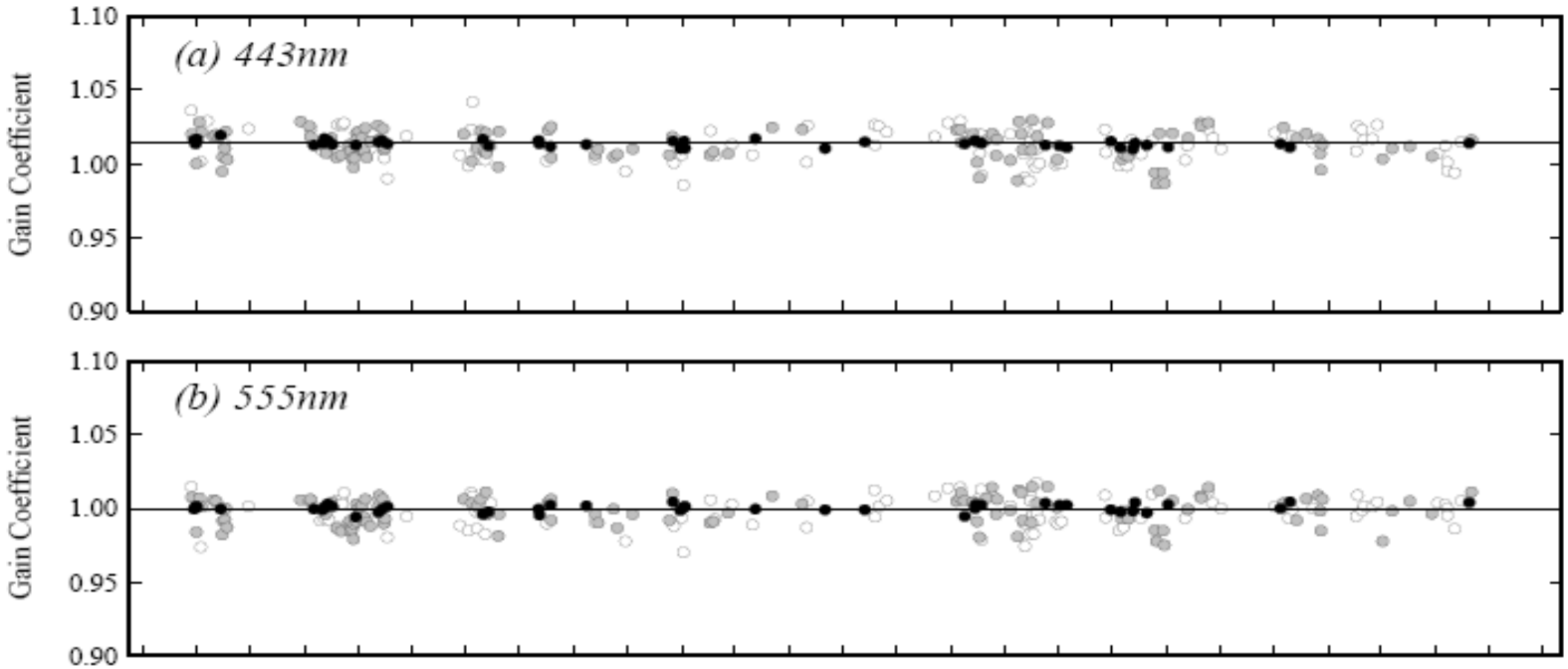
Atmospheric Correction



Stan Hooker, SeaWiFS Project

In-water vicarious ocean color calibration utilizes the NIR channels of the satellite to determine atmospheric parameters.

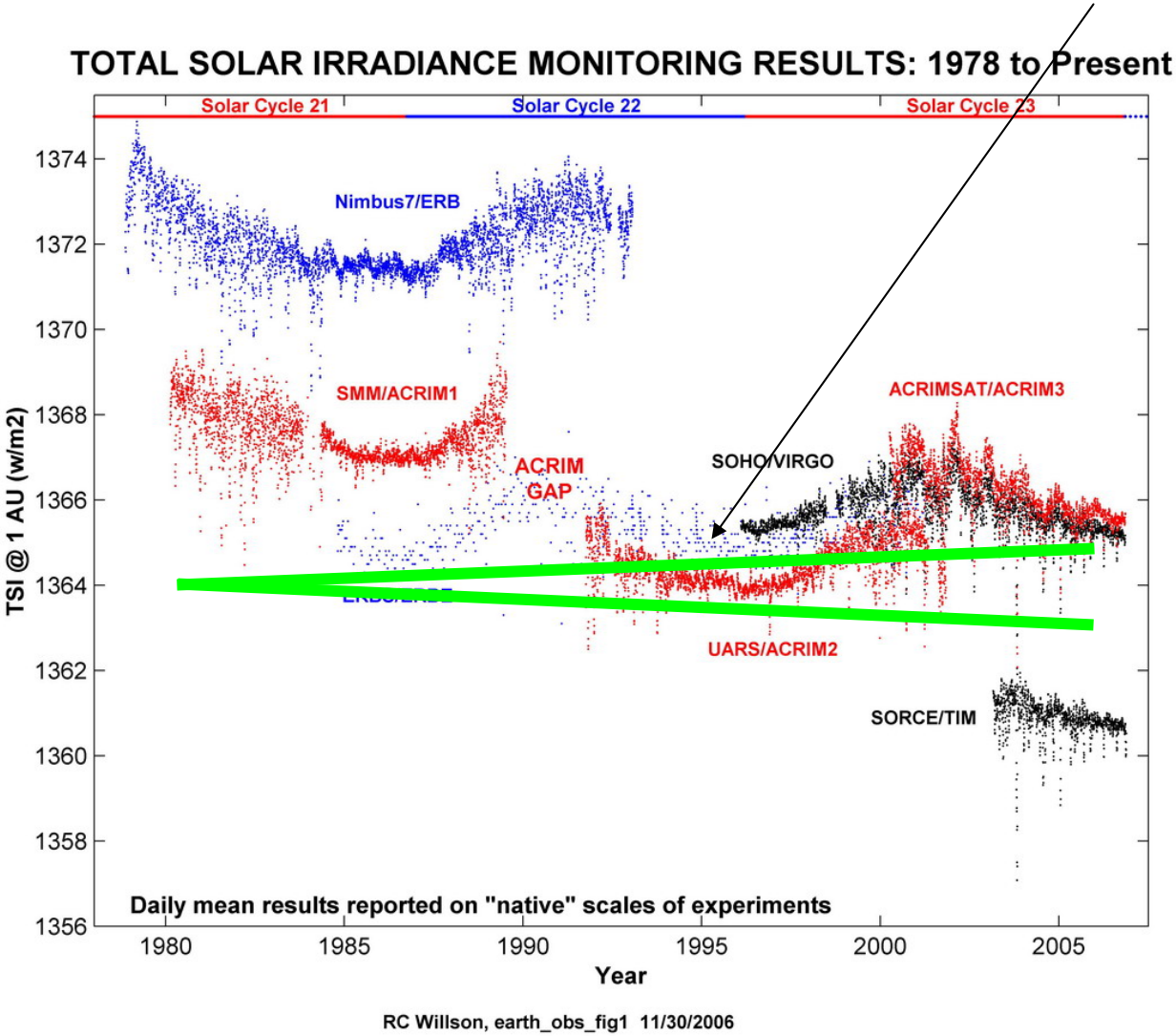
Stability of MOBY Scale



Franz et al. 2007, Apl Opt Vol 46, No 22

Total Solar Irradiance

TSI Measurement Uncertainty Requirement ~ 0.02% (0.3 W m^{-2}) decade^{-1}

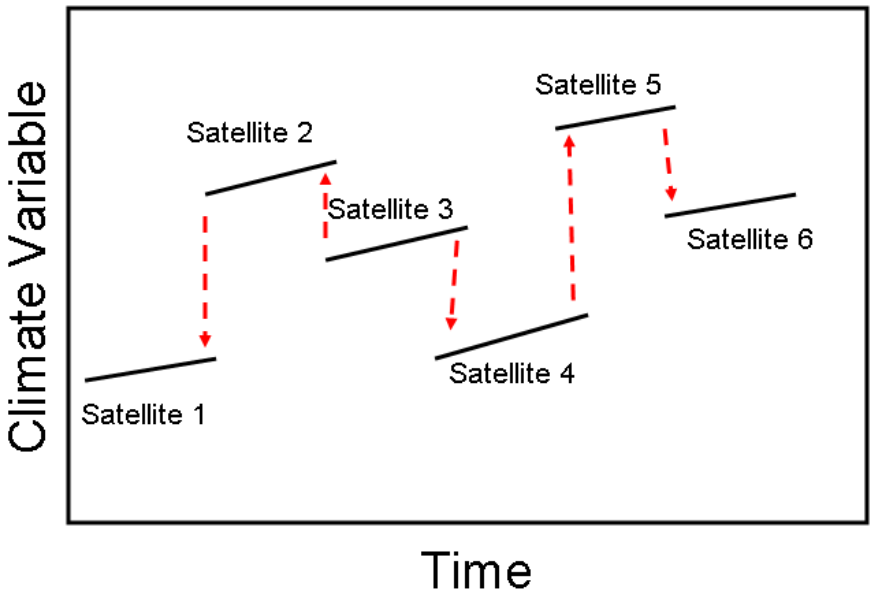


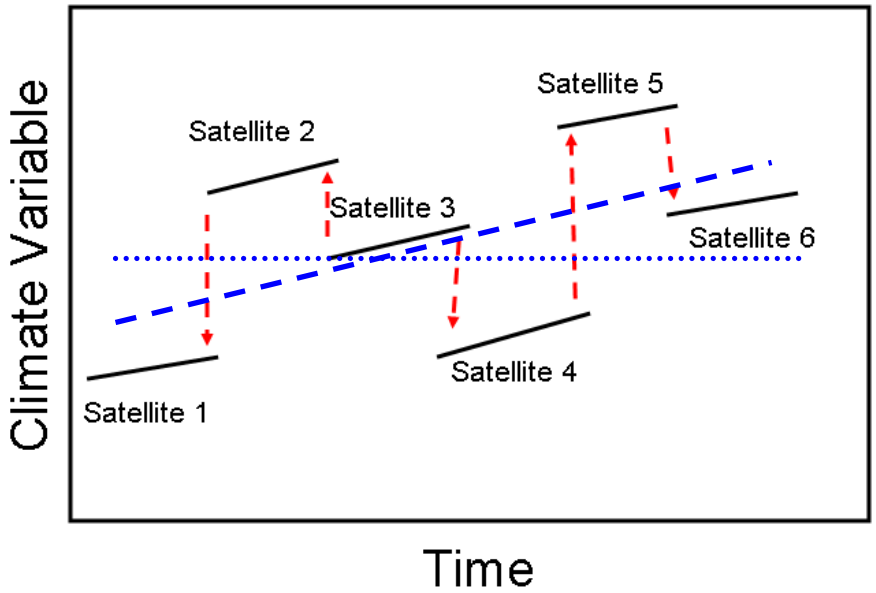
If the spread is real, then TSI has changed < 1% in 25 y. However, most of the differences must be measurement bias. There are also corrections for sensor degradation on orbit that are controversial.

None or ~0.5W/m^2 change between solar minimum, depending on analysis.

Note – no uncertainties reported!

Trending Through Sensor Overlap—Necessary But Not Sufficient





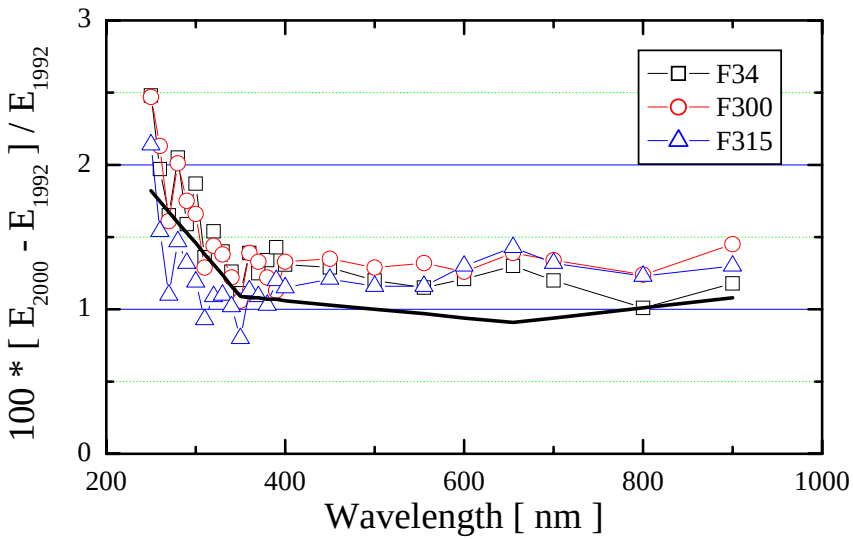
Observations using calibrated sensors.

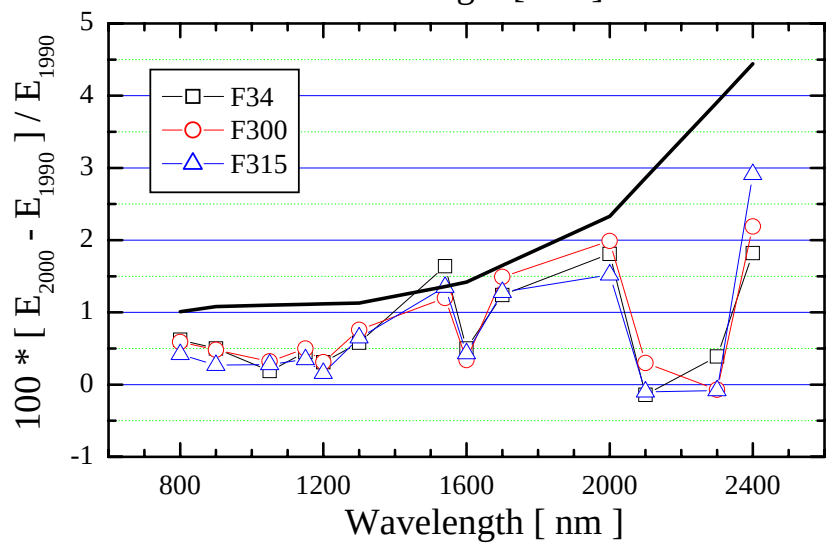
Which composite is correct? Is there common instrument drift, climate change, or both?

Sensor Drift: SI-based values (traceable) are essential; independent determinations required.

Blaza Toman & Antonio Possolo, NIST

Scale Maintenance on Stable, Repeatable Artifacts – Necessary But Not Sufficient





NIST Irradiance Scale Realization:

Source-Based: 1990 (NIR & SWIR) and 1992 (UV, VIS, & NIR)
Detector-Based: 2000 (UV to SWIR)

Expanded uncertainties are the solid lines

These check lamps held the previous scale very well; they are internally consistent ---

But, there was unknown bias in the previous scale that became obvious when the measurement metrology was changed.

Intercompare Results!!

Not shown: Uncertainties were reduced by x2 to x10, depending on wavelength.

H.W. Yoon et al., "Realization of the NIST detector-based spectral irradiance scale," *Appl. Optics* **41** 5879-5890 (2002).