Making Sense of Claims of SI Traceability

John A. Dykema, James G. Anderson

dykema@fas.harvard.edu
VISION
A healthy, secure, prosperous and sustainable society for all people on Earth

“The United States does not have, nor are there clear plans to develop, a long-term global benchmark record of critical climate variables that are accurate over very long time periods, can be tested for systematic errors by future generations, are unaffected by interruption, and are pinned to international standards.”

NRC
Systematic Errors?

- “Bias” in the language of metrological science
- Accuracy vs. precision

Historical $\text{CO}_2$ Data

In the absence of an absolute SI traceable standard

Establish bias by “overlap” determination

Establish bias by “overlap” determination

Establish bias by “overlap” determination

Slocum, 1955 - NOAA Global Monitoring Division
Confidence levels of detection

Meas. Uncertainty

Test for human influence

Test climate models

Error in trend estimation

Years to detection
Fig. 2. Recommended values for the velocity of light; 1929–1973.

What is “traceability”? “Traceability” is the property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties.
Figure courtesy Eric Shirley
Quality of Traceability Claim

As introduced by Jerry Fraser et al.
• What disciplines of natural sciences will be represented?
• What methods for assessing instrument accuracy will be most credible?
SI Traceability for Remote Sensing

• Pollock et al., 2001, *Metrologia*
• Dykema and Anderson, 2006, *Metrologia*
On-Orbit Blackbody:

- Finite Aperture
- Temperature Gradient

\[ B_v(T) = \frac{8\pi h}{c} \left( \frac{v^3}{\exp\left(\frac{hv}{kT}\right) - 1} \right) \]

\[ \varepsilon_{axis} B_v(T) \]

\[ \varepsilon_{axis} = f\left(\varepsilon_s, \frac{l}{d}\right) \]

Technology developed by UW-SSEC under IIP
OCEM-Halo: Measures hemispheric normal emissivity

OCEM-QCL: Direct measurement of directional-normal reflectivity
Confounding Factors 1: Measurement Conditions
Confounding Factors 2: Aging and Exposure

Lunar calibration of SeaWIFS diffuser shows degradation over time (Eplee et al. 2007 *App. Opt.*).


Footprint at aperture stop

Footprint at corner cube

Footprint at far-IR detector
Even today, unpleasant surprises still happen!

Accepted international value of proton radius

New measurements made in different conditions for lower uncertainty (2010)
• Thanks to
  – Harvard: Stephen Leroy, Yi Huang
  – NIST: Sergey Mekhontsev, Leonard Hanssen, Eric Shirley, Jerry Fraser
  – UW: Hank Revercomb, Fred Best, Jon Gero, Joe Taylor, Bob Knuteson, Dave Tobin
  – LaRC: Dave Young, Marty Mlynczak, Bruce Wielicki, Dave Johnson, Alan Little
  – David Keith, Eric Cornell