Routine Cal/Val Activities for GRUAN

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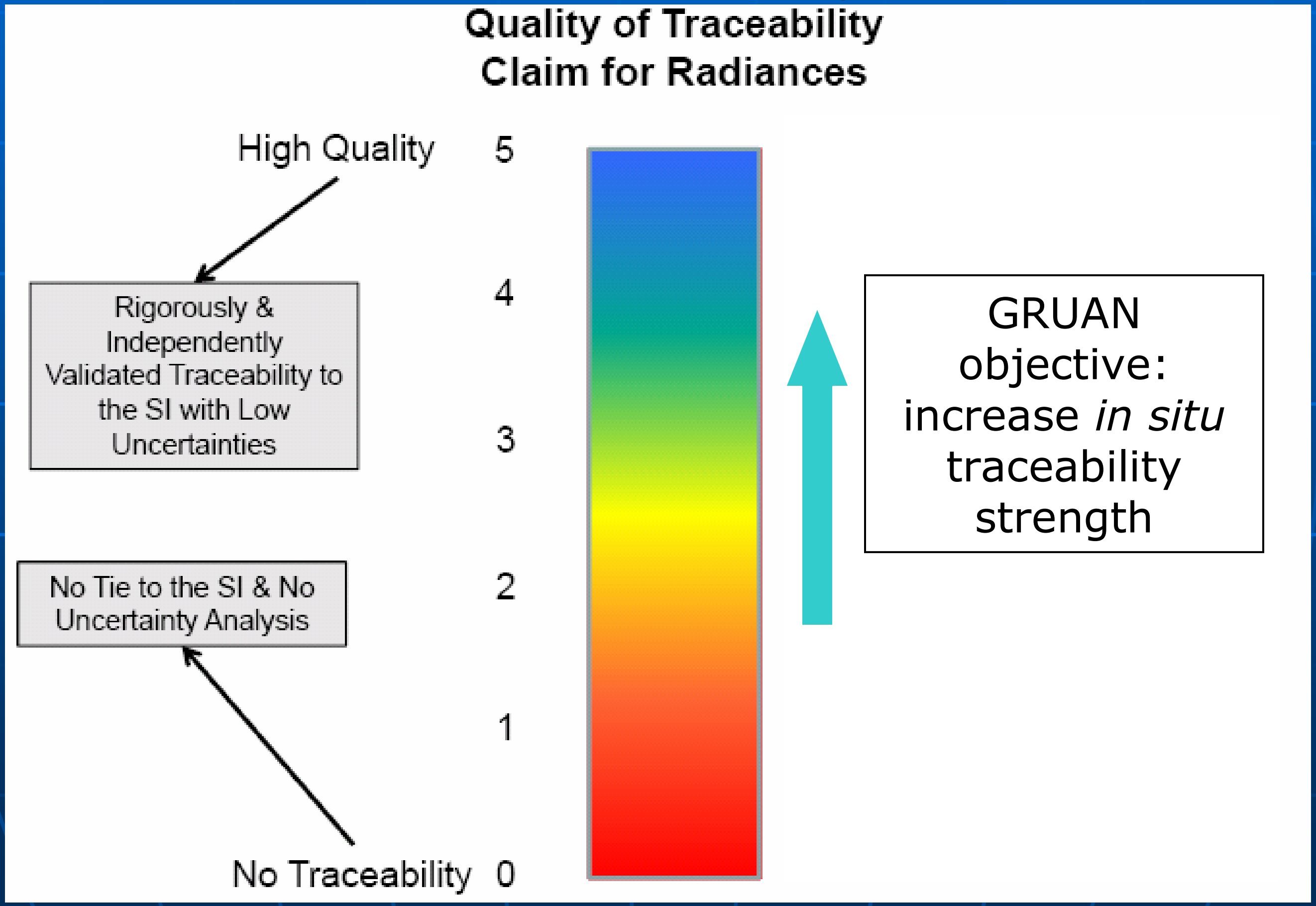
SI Traceability *in situ*

- Jerry Fraser (NIST) has introduced the idea of SI traceability being on a spectrum of weak to strong traceability



Obtaining Strong Uncertainty Estimates

- "a given parameter will always be measured by more than one physically independent method/instrument" (GRUAN specifications document)

The National Measurement Laboratory (NMI) Model for Traceability

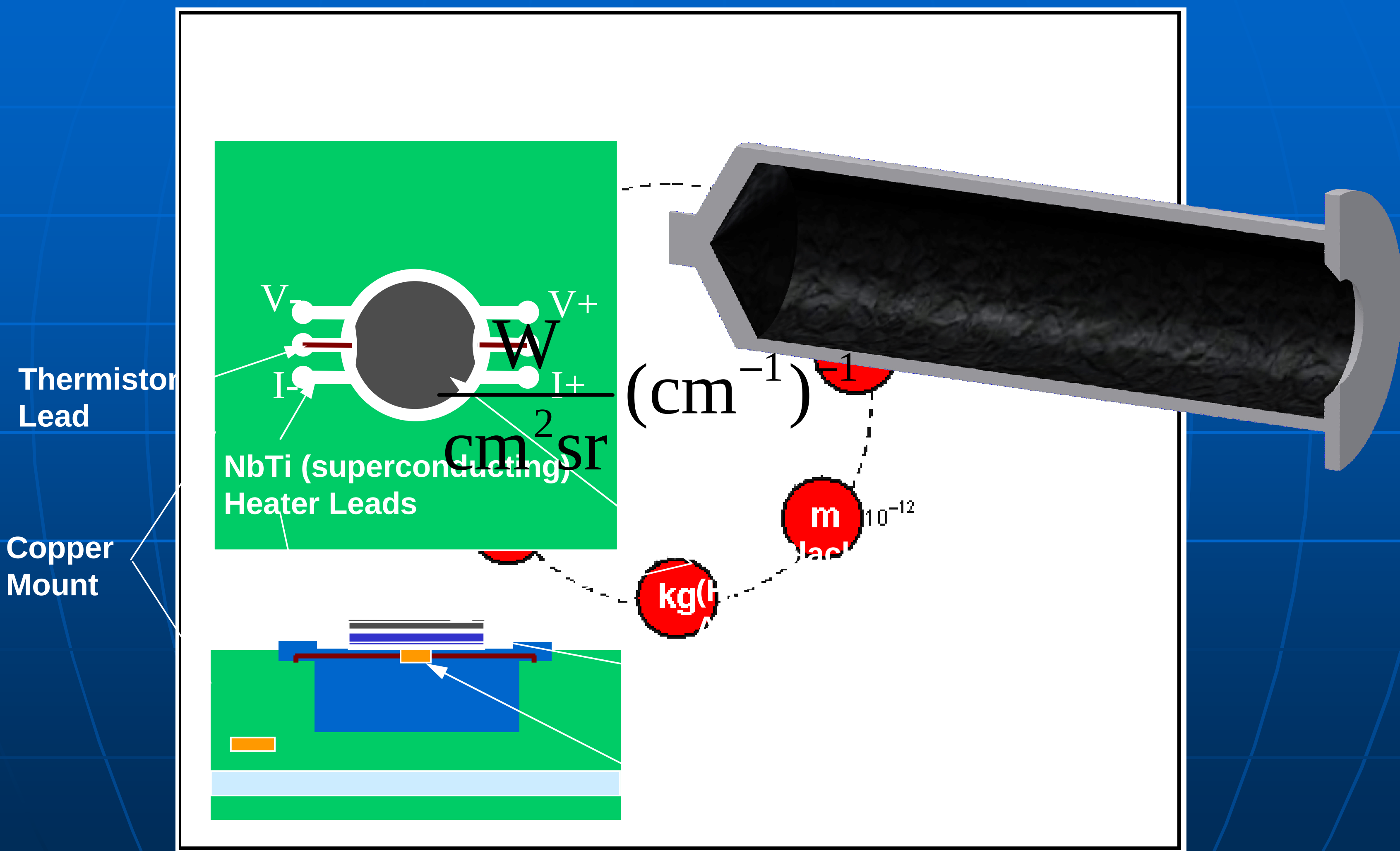
- Measurements are Based on Well-Defined Physical Quantities
- Measurements are Compared among NMIs
- Measurements are Compared to Independent Approaches
- Uncertainty Claims are Rigorous and Validated
- Methods are Documented in Quality Systems and in Peer-Reviewed Publications
- Research is Undertaken to Lower Uncertainties
- Fundamental Scales are Realized Periodically

From Jerry Fraser, NIST, CLARREO Community Workshop 2008

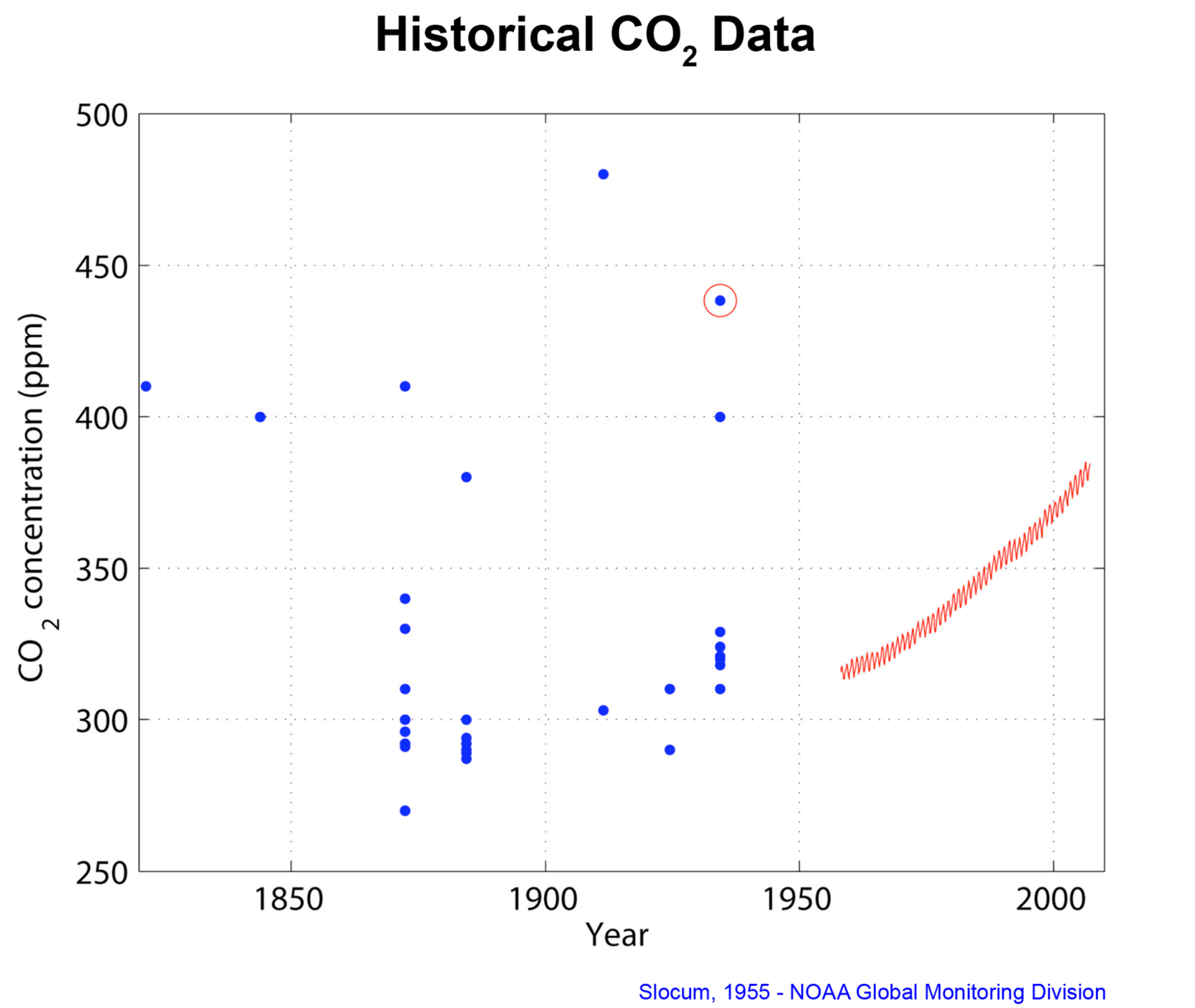
NIST’s Josephson voltage standard

NPL’s cell voltage transfer standard

$$B(T,\upsilon)=\frac{8\pi h}{c}\frac{\upsilon^3}{\exp(h\upsilon/kT)-1}$$



Keeling Record: Historical CO_2



ISO 5725: "Accuracy of measurement methods and results"

- Measurement accuracy dependent on multiple factors:
  - Existence of an accepted standard
  - Local environmental conditions during measurement acquisition: "temperature, humidity, air pollution, etc."
  - For GRUAN temperature and humidity: radiation, flow rate/pressure, hysteresis, chemical composition, etc.

For atmospheric reference observations:

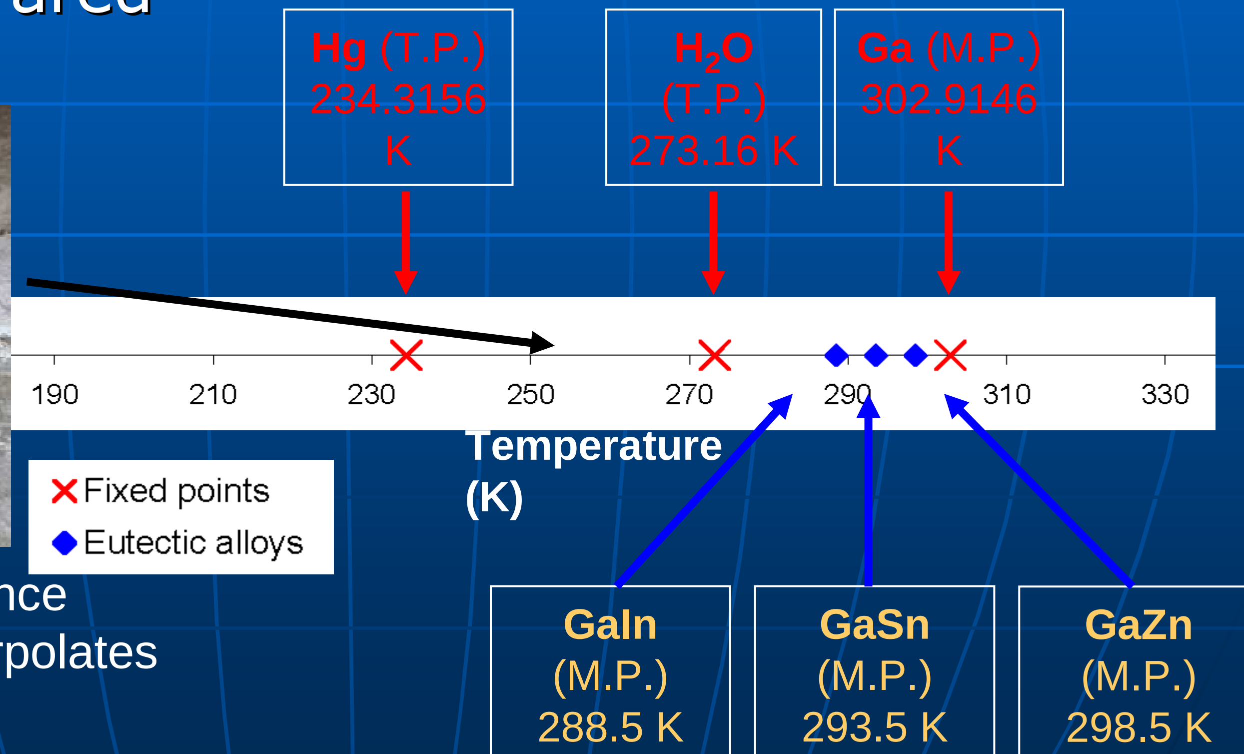
- By what experimental strategy is the accuracy of the reported observations tied *in situ* to reproducible international standards?
- What is the relationship between the *in situ* calibration and the laboratory foundation defining the primary reference standards?
- How are known sources of sensor uncertainty corrected or removed?

Why traceability to international standards?

- International credibility: measurements comparable across borders, among different institutions
- Compatibility with fundamental physical models: thermodynamics, radiative transfer
- Comparable across different sensor types: in situ/remote, microwave/infrared, etc.

Reference Temperature Measurements

- The Kelvin: 1/273.16 of the triple point of water
- ITS-90: fixed points define scale relevant to thermal infrared



Standard Platinum Resistance Thermometer (SPRT): interpolates *between* fixed points

Ground Routine Cal/Val

- Against local reference thermometer at single homogenized temperature
- In isothermal chamber, over range of temperatures
- In isothermal chamber, over realistic range of temperature and pressure
- In chamber with variable radiation environment (lamps, scene projectors for special intercomparison periods)

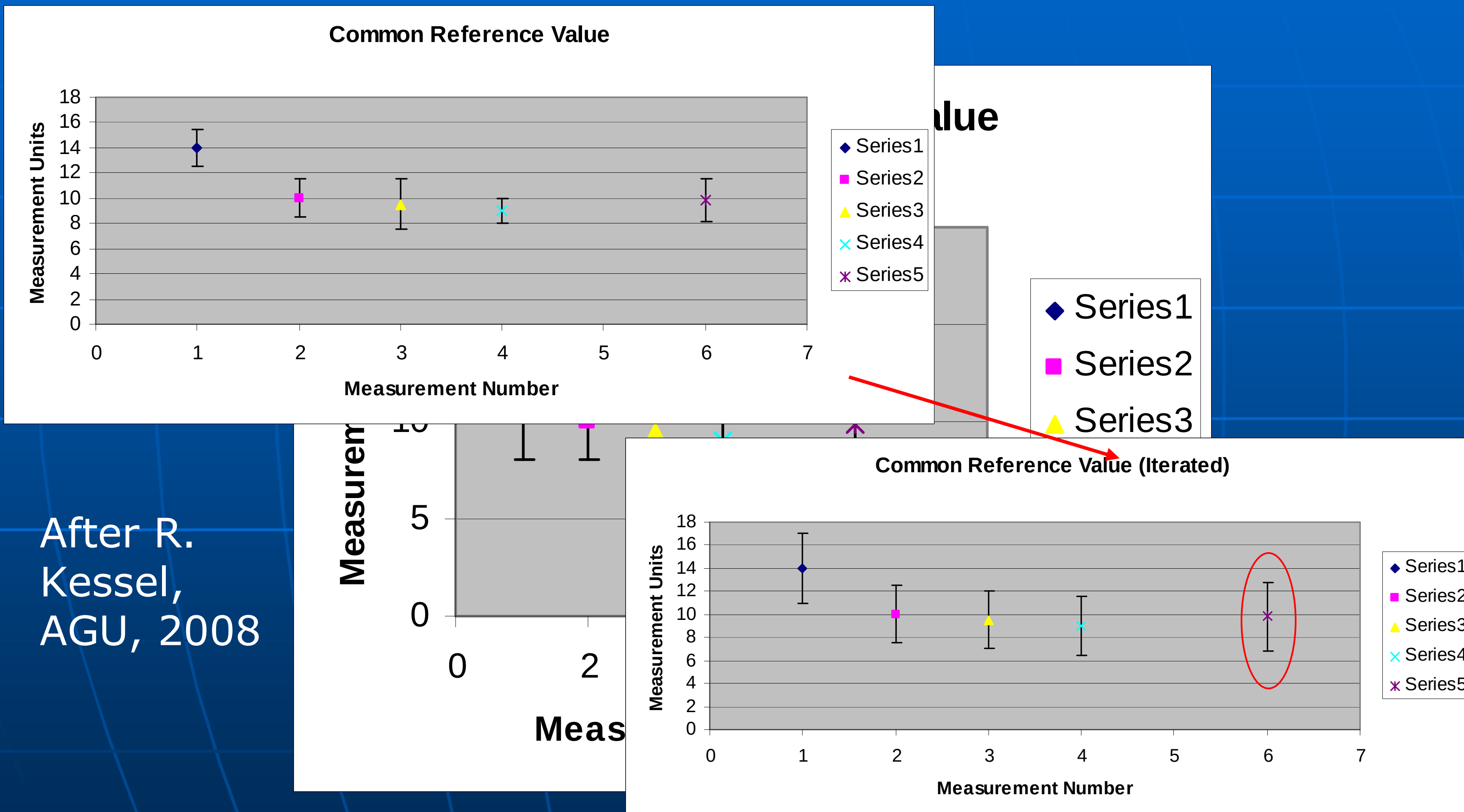
Routine Cal/Val (Temperature Example)

GRUAN site	1	2	3	4
Reference thermometer	0.15 K			
Isothermal chamber			0.11 K	
Variable P chamber		0.22 K		
Variable P, radiation chamber				0.27 K
Comparison to remote measurement (IR, μwave)			0.20 K	
Remote measurement intercalibration			0.25 K	

Radiation Correction

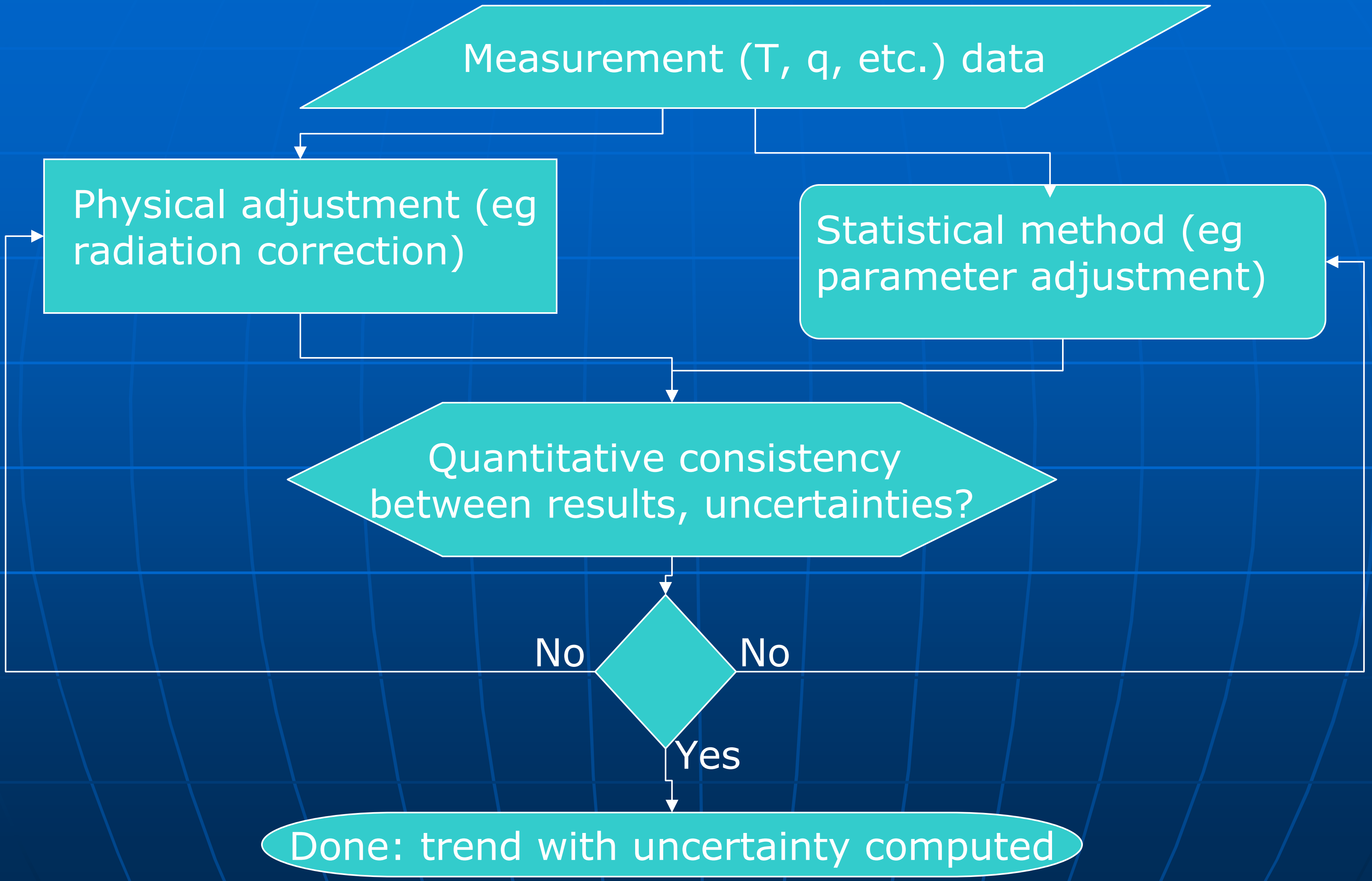
- Technological solutions: three-thermistor Sondes
- Analysis methods: daytime/nighttime trends
- Statistical methods: variation of plausible range of sensor parameters

Metrological statistics for consistent reference value



After R. Kessel, AGU, 2008

Application of Statistical Framework



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Reference Water Vapor Measurements

- NIST, NPL have frost point sources: 0.8-0.2% uncertainty over 10^{-3} to 1000 ppmV (k=2)
- CFH widely used in community as reference for remotely sensed and *in situ* measurement
- Spectroscopic method completely independent of frost point: under development at NIST (CRDS)

Ground Routine Cal/Val

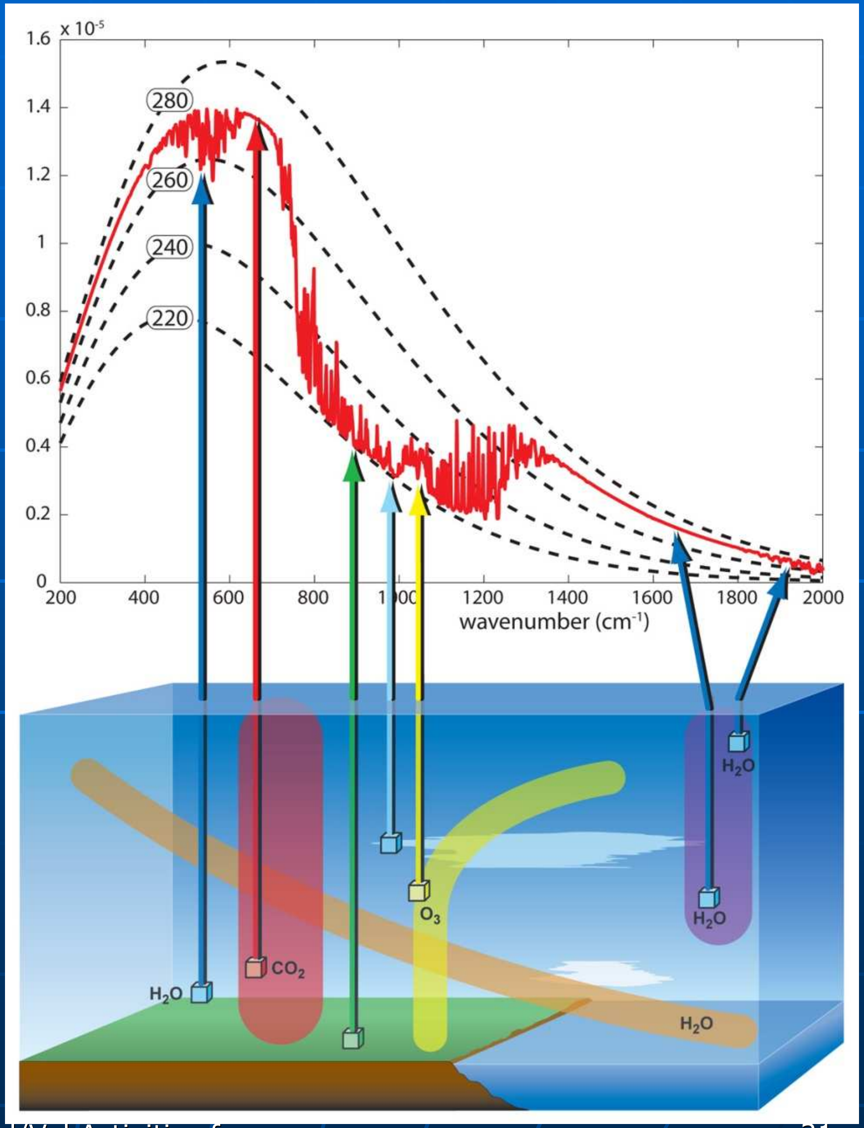
- Against standard humidity source over range of mixing ratios
- Against standard humidity source over range of flow rates
- Against standard humidity source over range of flow rates, over range of temperatures
- Against standard humidity source, independently calibrated against reference spectroscopic sensor
- Variable chemical environment?

Creation of Robust UTLS Reference

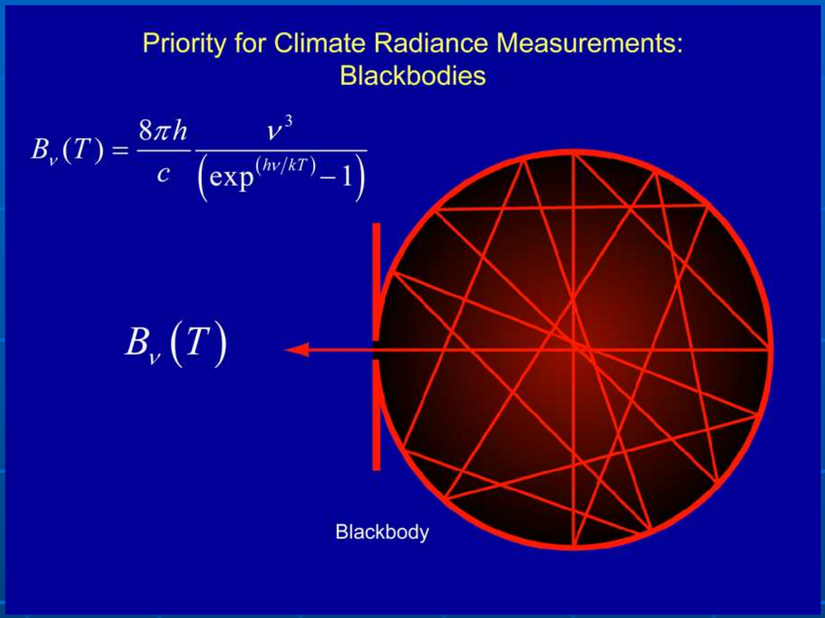
- FLASH Lyman-α calibrated against commercial FH: not independent
- GPS: independent but constrains PW
- MWR: vertical resolution adequate?
- Satellite (IR, μwave) validated against CFH: not independent
- Spectroscopic technique calibrated fully independently?

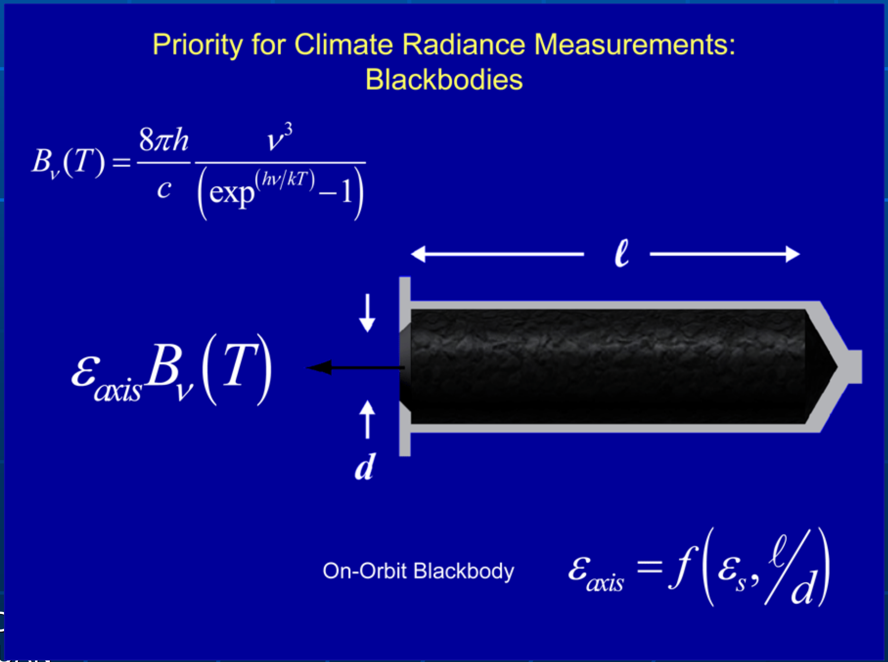
Uplooking IR Spectrometer (AERI, for example)

- High spectral resolution provides sensitivty to critical GRUAN variables (temperature, water vapor)
- Calibration can be traced to SI and compared across GRUAN sites



Ideal blackbodies vs. *practical* blackbodies



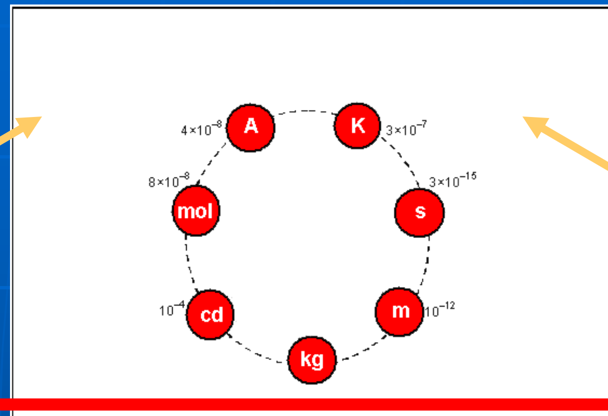


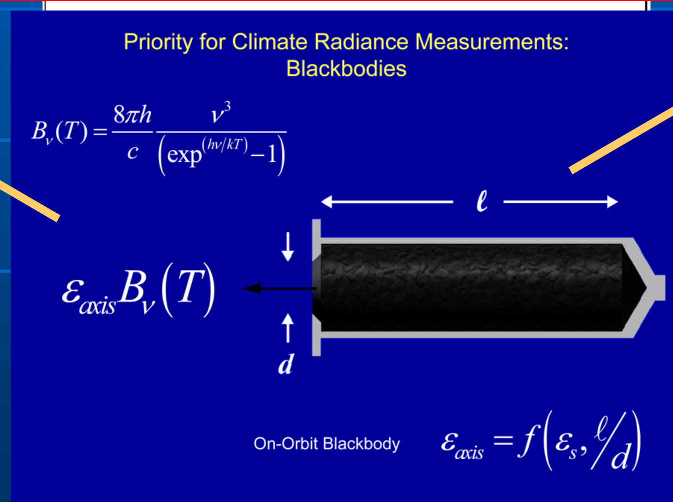
In situ Traceability for Blackbody[1]

NIST:

Δε: CHILR

ΔT: AIRI





On-orbit diagnostics:

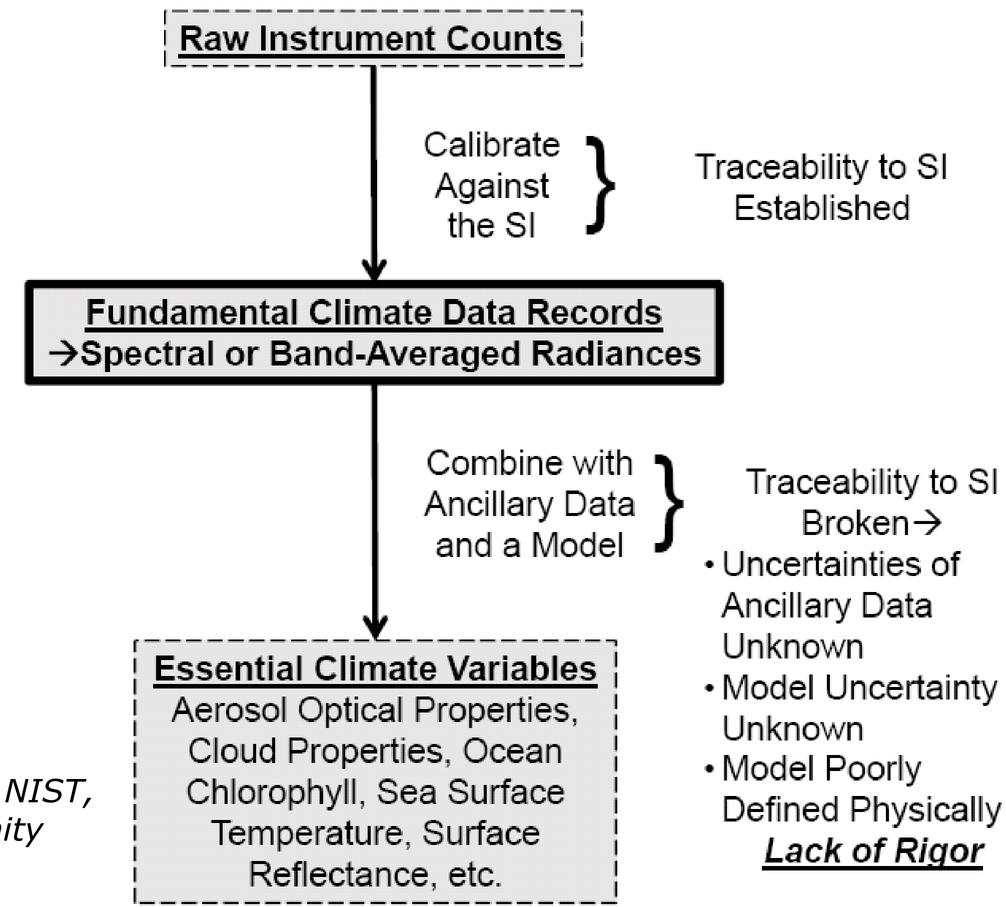
Δε: Reflectometer (QCL[2], halo)

ΔT: phase change cells[3,4]

1. Dykema and Anderson, Metrologia **43** 287-293 (2006).
2. Gero, et al., submitted, J.TECH. (2008).
3. Gero, et al., J.TECH. **25** (2008).
4. Best et al., GC23A-0753.

Challenges in blending remotely sensed measurements with *in situ*

Traceability of What?



From Jerry Fraser, NIST, CLARREO Community Workshop 2008

Absolute values: independent information in remotely sensed measurements?

Prediction of climate variations:

There is emerging evidence that at least sub-seasonal and potentially seasonal-to-decadal predictions require an accurate characterization of initial boundary conditions. This is particularly so in mid-latitude winter seasons, with the possibility of strong stratosphere troposphere interactions (Scaife et al., 2005);

A Hierarchy of Routine Cal/Val

- Ground check: requires an accepted standard, whether sonde or remote method
- Intercomparison: among different measurement types sensitive to same GRUAN variable
- Round robin intercomparisons among sites (sensors or standards)
- Intercomparison campaign: intensive instrumentation to richly characterize atmospheric column

Acknowledgements

- WG-ARO
- Harvard: Jim Anderson, Stephen Leroy, Yi Huang
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- NIST: Jerry Fraser, Carol Johnson, Joe Rice, Sergey Mekhontsev, Leonard Hanssen, Raju Datla
- CLARREO science definition team
- COSMIC group (UCAR)

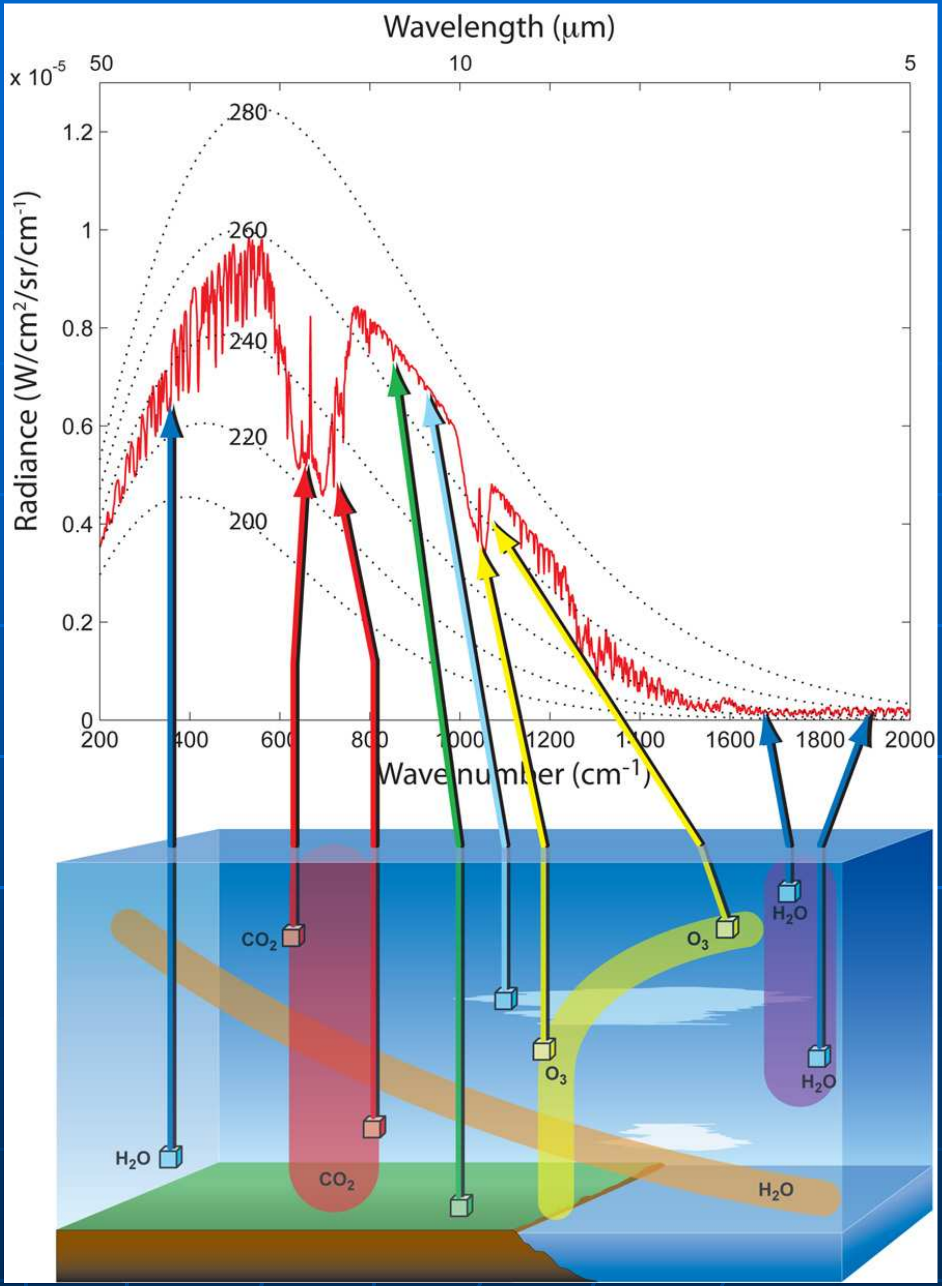
GRUAN and Satellite Measurements

The CLimate Absolute Radiance and Refractivity Observatory (CLARREO):

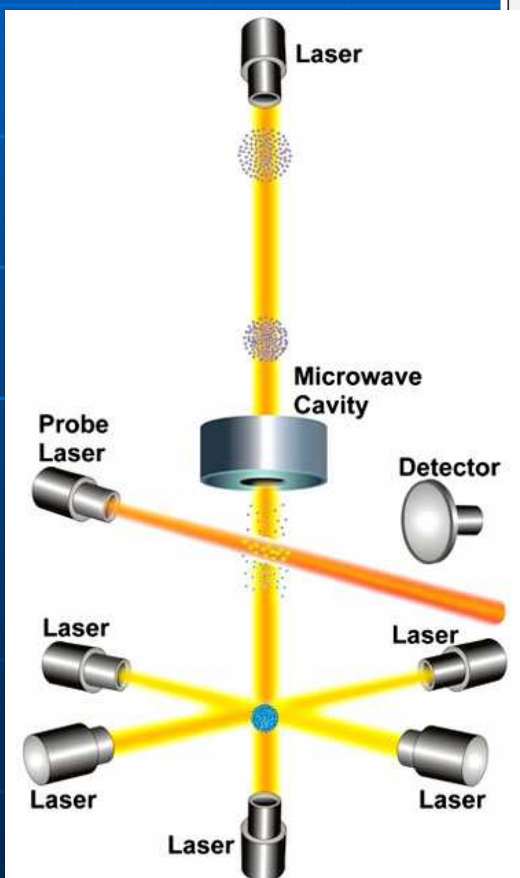
Measurements Tied to International Standards for Testing Climate Models, Benchmarking Climate

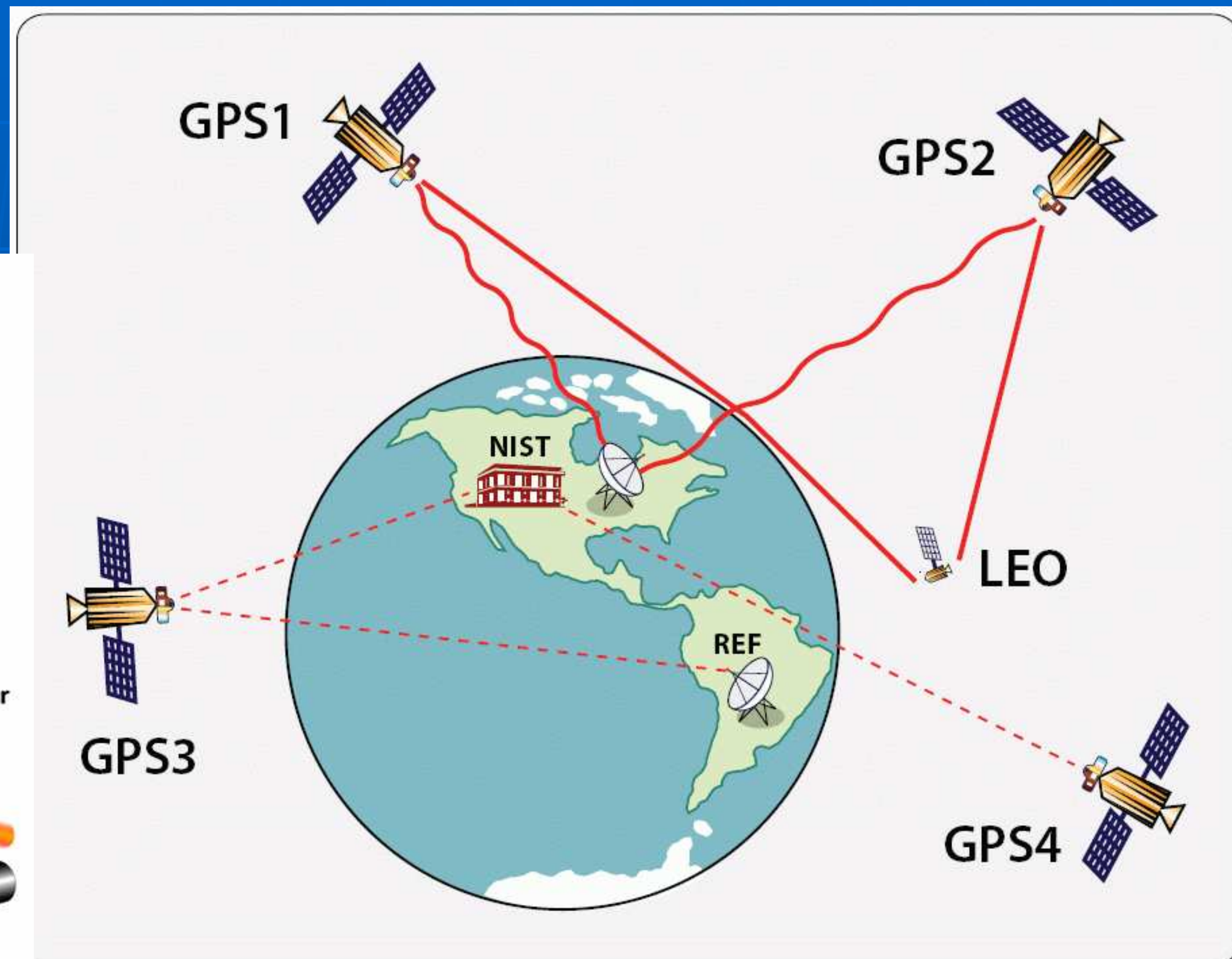
- CLARREO is a US NRC Decadal Survey recommendation: part NOAA, part NASA
- NOAA part is TSI, SW/LW broadband
- NASA part is IR, GPS-RO, SW
- NASA DS baseline recommendation is 3 satellites: 2 IR/GPS, 1 IR/GPS/SW
- 5-7 year nominal lifetime
- In pre-phase A, directed by NASA-Langley

- Spectral Radiances are SI-traceable Observable Document Key
- Radiative Forcings and Climate Responses
- Two Science Objectives
  - Benchmarking
  - Testing Climate Models



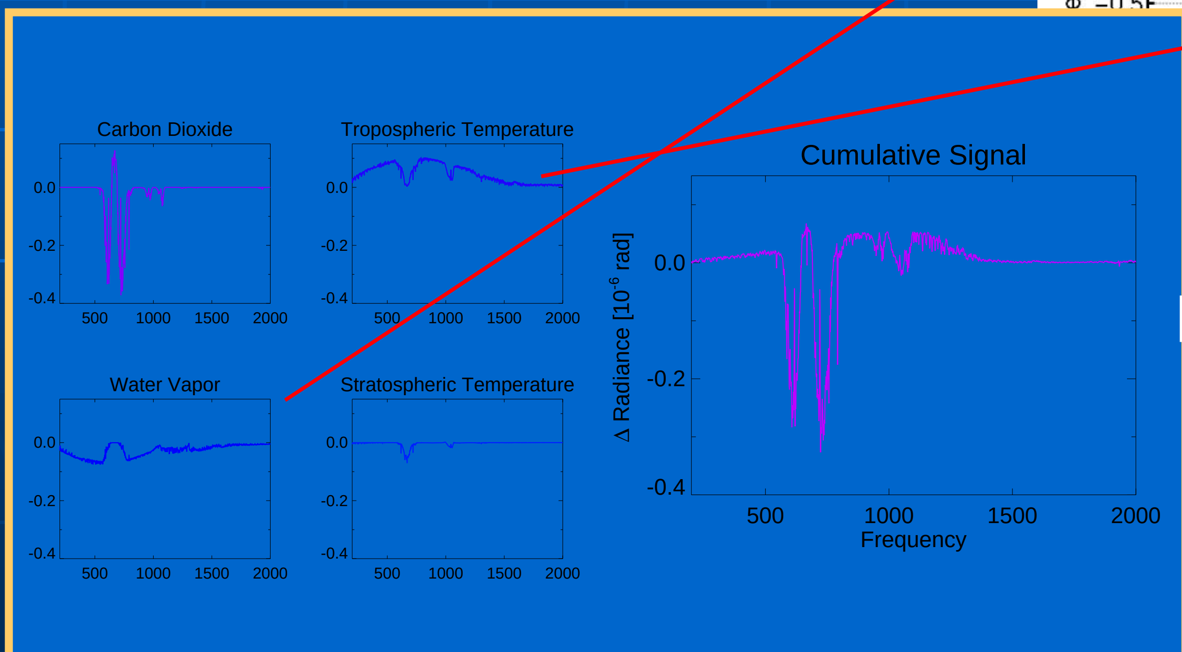
Microwave Refractivity: A Climate Index Derived from the Definition of the Second

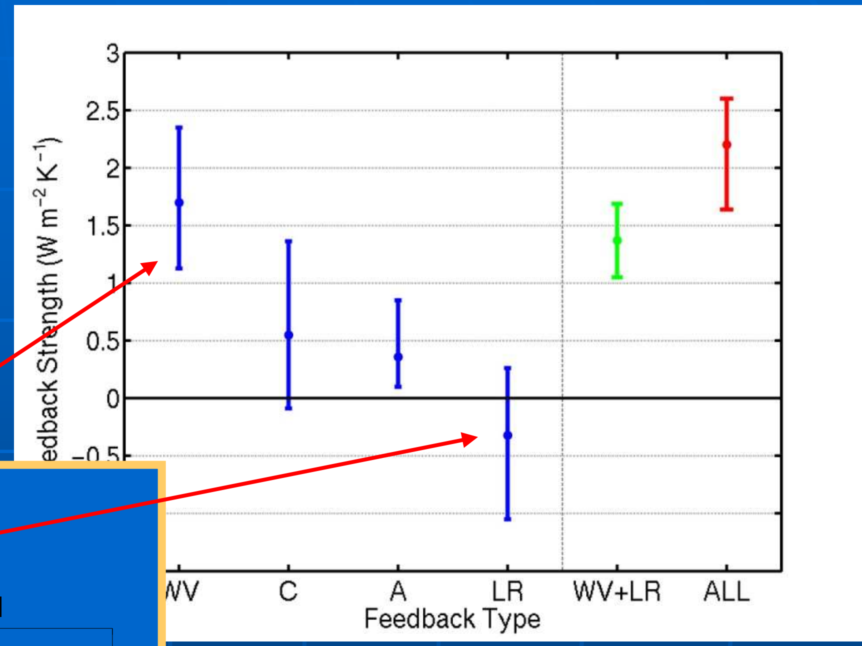




How Do IR Spectra Test GCMs Directly?

Spectral Signatures of Radiative Feedbacks, Constrained by Observations

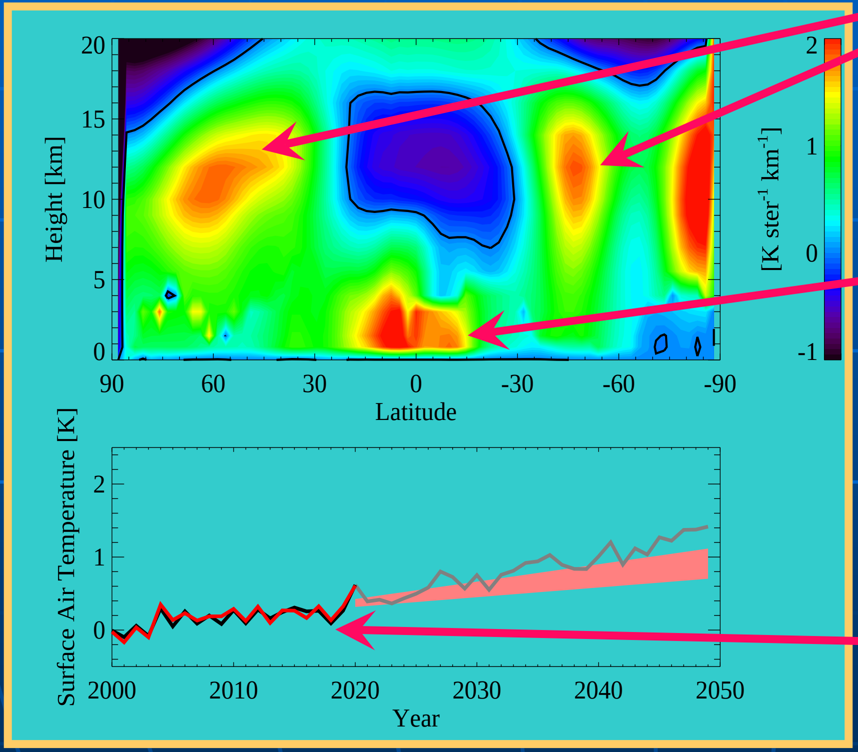




Fast Radiative Feedback Processes

How Does GPS RO Test GCMs?

α = global average surface air temperature, ***d*** = GPS RO dry pressure [height]



Poleward migration of jet streams

Increased ITCZ convergence

Near perfect tracking of global average surface air temperature

CLARREO and GRUAN

- Primary CLARREO measurement is radiance or refractivity *not* temperature, water vapor, clouds
- Part of benchmarking objective is to obtain trends (but not absolute climate state) in geophysical variables
- Target area averaging approach