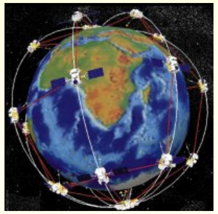
Optical Metrology at NIST for Greenhouse Gas Measurements and Climate Science at NIST



Working Group on Calibration and Validation

Committee on Earth Observation Satellites

March 2, 2010

James Whetstone

Special Assistant to the Director

Greenhouse Gas Measurements

National Institute of Standards and Technology
U.S. Department of Commerce

NIST Greenhouse Gas Measurements and Climate Science Program

Agenda

- Climate issues driving NIST involvement
- NIST standards & measurements utilizing optical metrologies to:
  - Improve satellite instrument performance
  - Improve measure and standards capabilities for:
    - greenhouse gas inventory quantification
    - atmospheric monitoring

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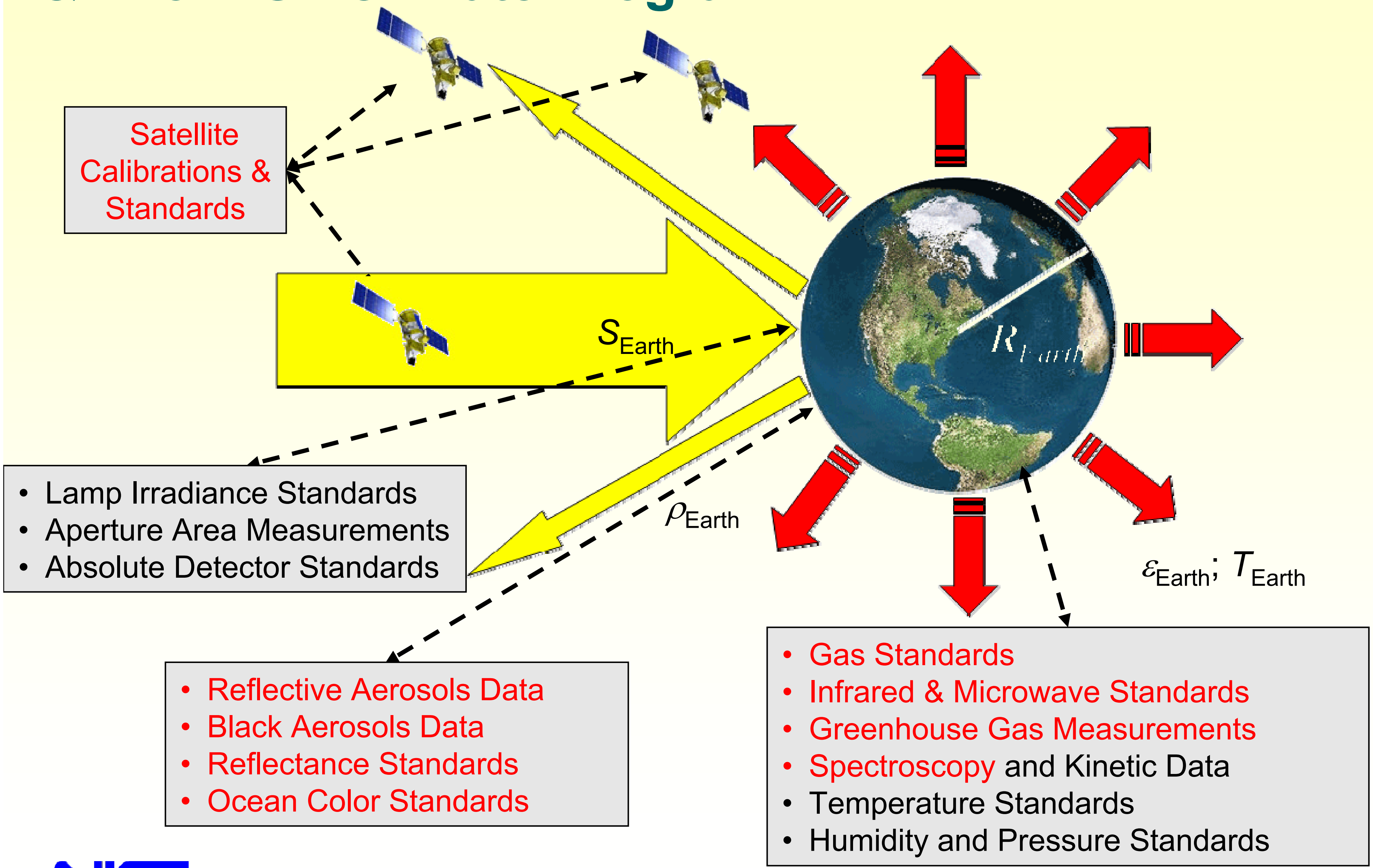
The Earth's Radiative Balance & The NIST Climate Program



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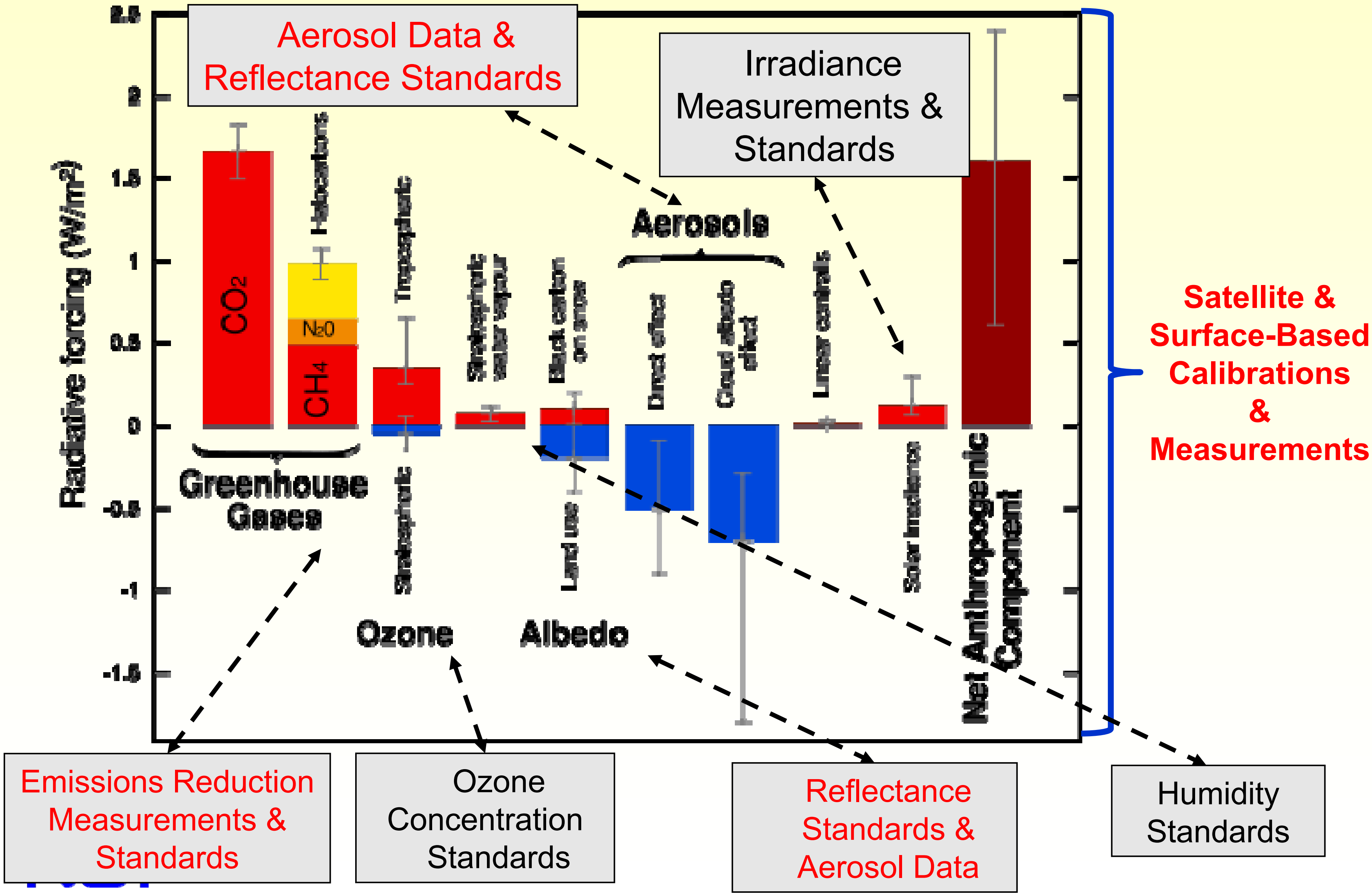
Radiative Forcing & The NIST Climate Program



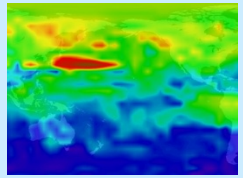
Extent of the Quantitative GHG Emission Reduction and Verification Challenge

Bottom – Up | Top – Down

- Electricity Gen.
- General Industrial Energy Generation

Stationary Sources
0.005 – 0.05 km

Distributed or Area Sources
0.5 – 5 km



Regional
10 – 100 km

International
100 – 1000 km

Size or Extent

CEM Technology
- Gas Conc. Stds
- Stack Gas Velocity

Single Point Measurements
- Optical Reference Data
- Chemical Meas. Standards

Optical Remote Measurements
- Optical Spectral Ref. Data
- Advanced Measurement Tools & Methodologies

Atmospheric Monitoring
- Satellite Observations
  - Radiometry
  - Optical Spectral Reference Data
- Surface-based Networks
  - Gas Conc. Standards
  - Wind Velocity Standards

Measurement Tools, Standards Technologies & Methodologies

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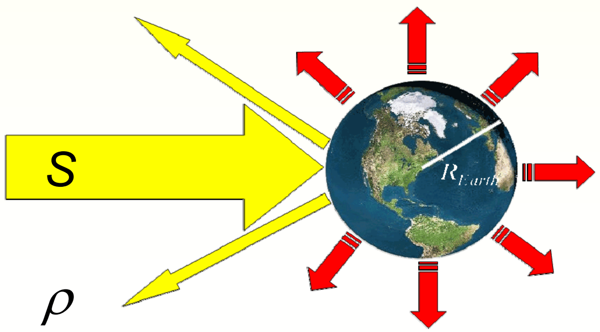
Comparability of Measurement Results Requires Measurement Accuracy

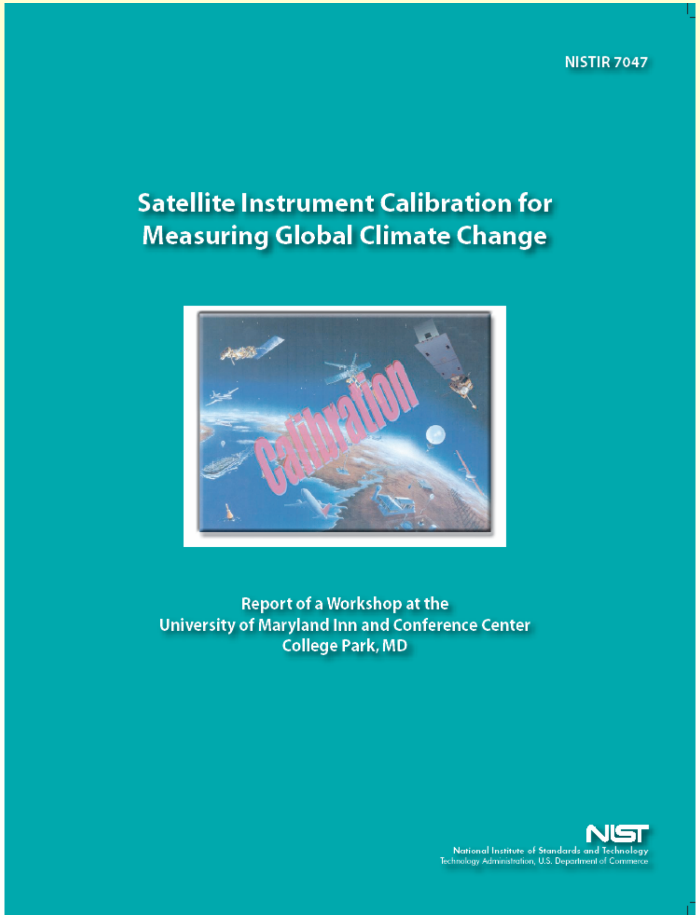
Accounting for 0.1 K/decade change at the 10% level is a significant measurement challenge

ΔS = 0.02%/decade

Δr = 0.03%/decade

Δe = 0.02%/decade





NISTIR 7047

Raju Datla

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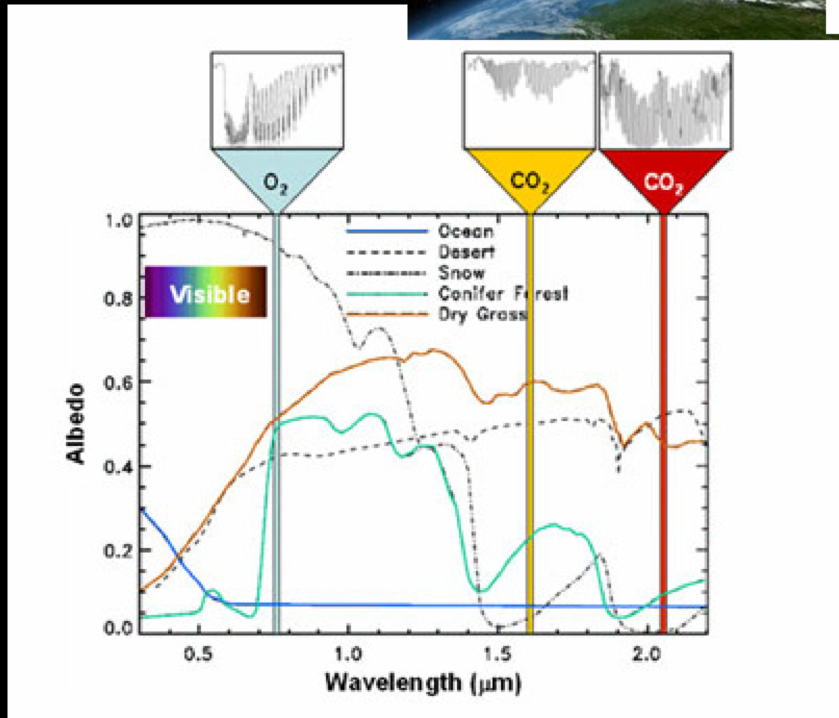
NIST/NASA Collaboration:

The Orbiting Carbon Observatory
Improved CO2 Determination
in the Atm. Column

CO_2 observations from orbit at the <0.5% (2 ppm) level requires world class spectroscopic reference data for CO_2 and the O_2 A-band.



Diatomic oxygen (O_2) provides atmospheric path lengths in remote sensing measurements.

In the past two years NIST has completed six projects in support of NASA's OCO. This work has produced the lowest uncertainty spectroscopic line parameter measurements in the world on the O_2 A-band.

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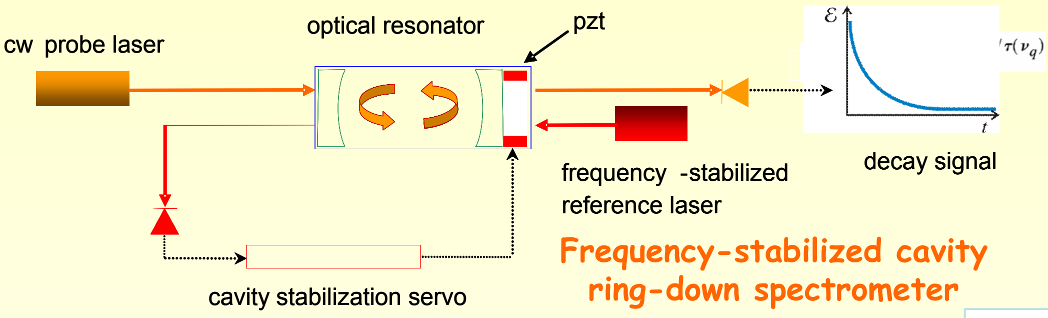
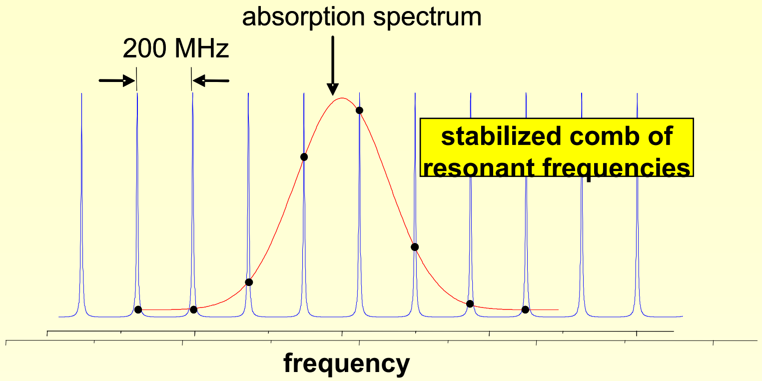
High Accuracy Spectroscopic Reference Data

O_2 A Band (~765 nm)



Frequency-stabilized cavity ring-down spectrometer



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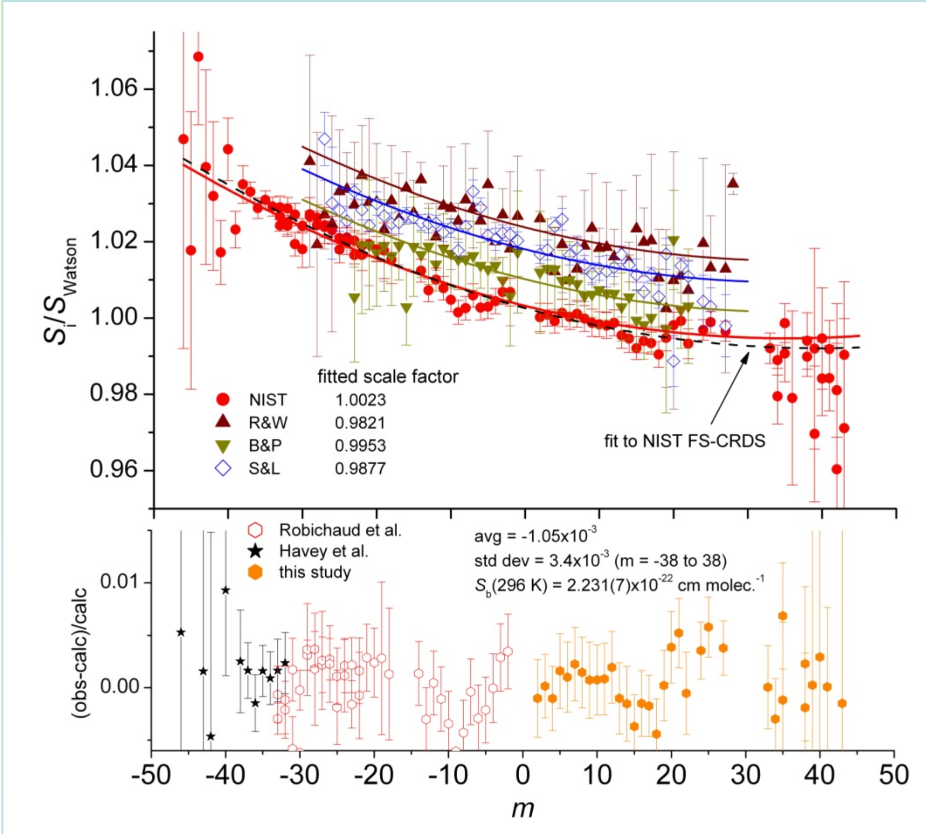
- **Quantified a correction required to accurately describe line intensities in the O_2 A-band**

- **Accurate absorption line shape measurements augmented with high accuracy absorber number density determination reduced line intensity uncertainties from 2% to 0.3%**



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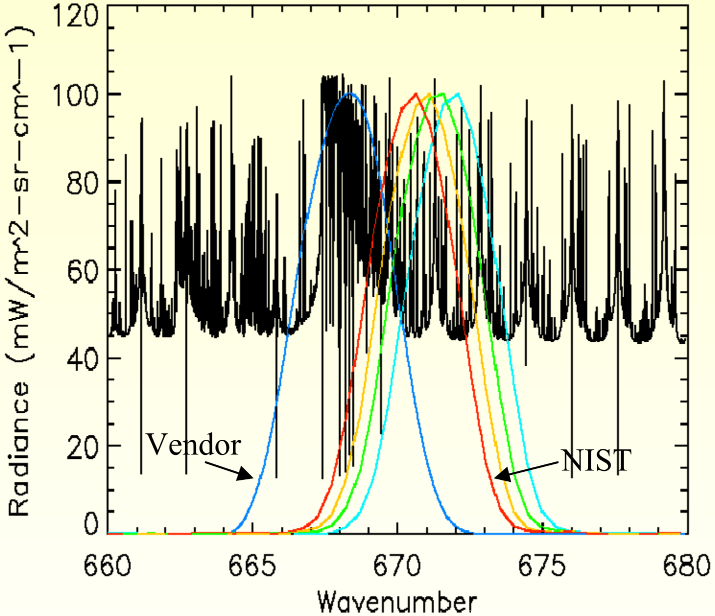
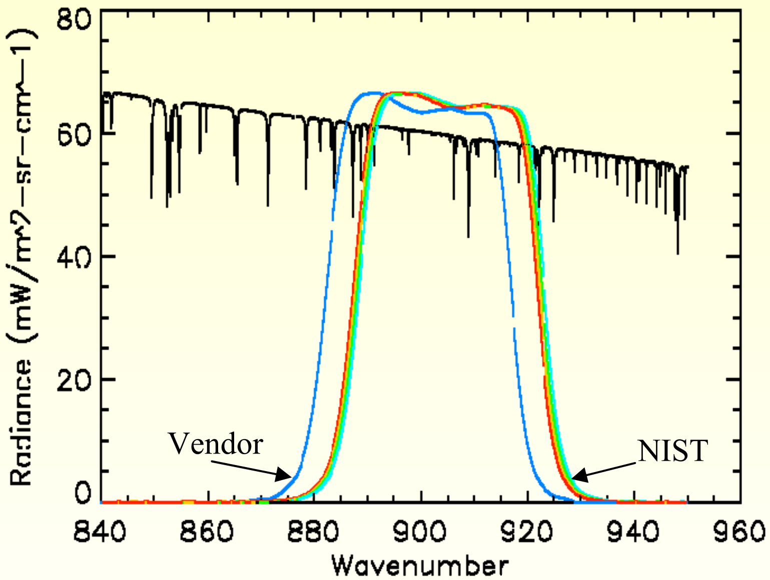
Measurements Require Quality and Accuracy

High Resolution Infrared Radiation Sounder (HIRS) on the Polar-Orbiting Operational Environmental Satellites (POES)



➔ Δ*T* > 10 K



➔ Δ*T* up to 0.5 K

optical filter center wavelength *Temperature* sensitivity measurement

Resolves ~ 10 Kelvin Atmospheric Temperature Measurement Discrepancy

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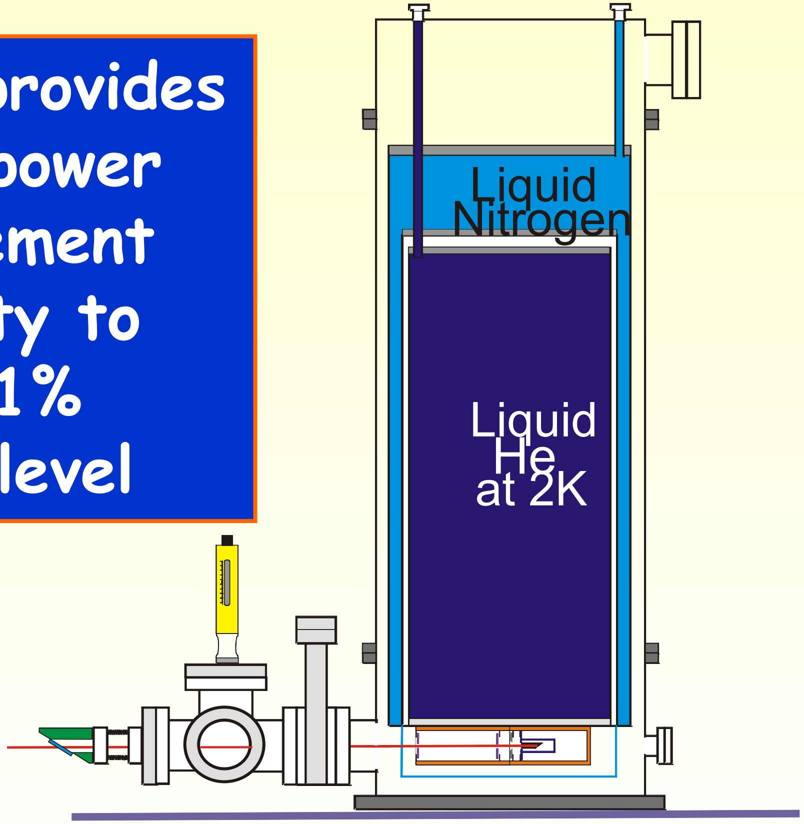
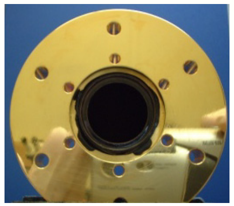
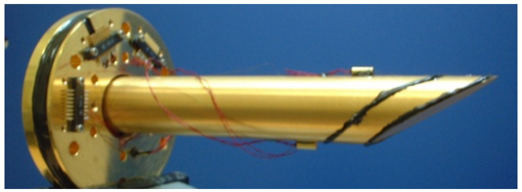
NIST Primary Optical Watt Radiometer (POWR)

Optical Measurements are Traceable to SI through the Electrical Watt

- POWR provides optical power measurement capability to the 0.01% (k = 2) level







Jeanne Houston
Joe Rice

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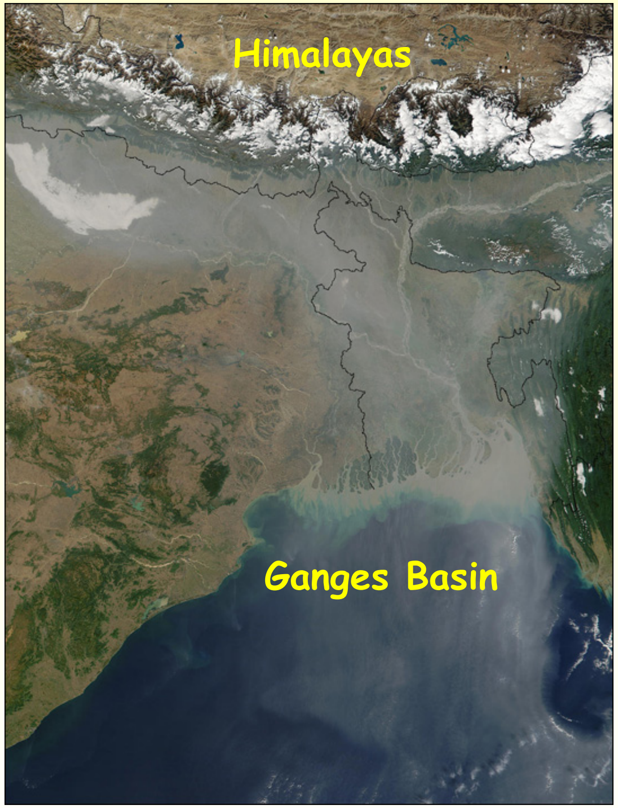
Aerosol Data:
Physical and Chemical Properties

Reference Data and Measurements:

- ***Measurements of Atmospheric particulates are widespread***
- ***Optical property data for atmospheric particulates is sparse***

Goal:

- **Provide reference data for atmospheric aerosols**
- **Accurate optical properties – Absorption and scattering are critical to models**
- **Impact of morphological characteristics on optical properties not well known currently**
- **Chemical characterization**
  - **Particle Origin**
  - **Cloud and Health Impacts**



MODIS Photo Courtesy of NASA.

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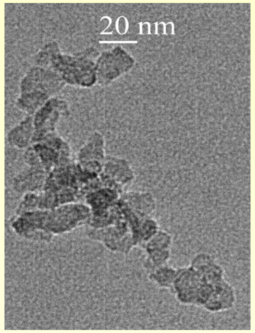
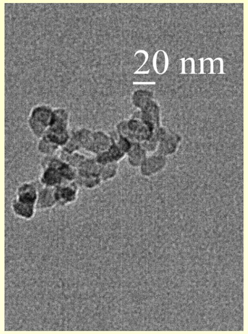
Optical Properties Measurements of Model Aerosols

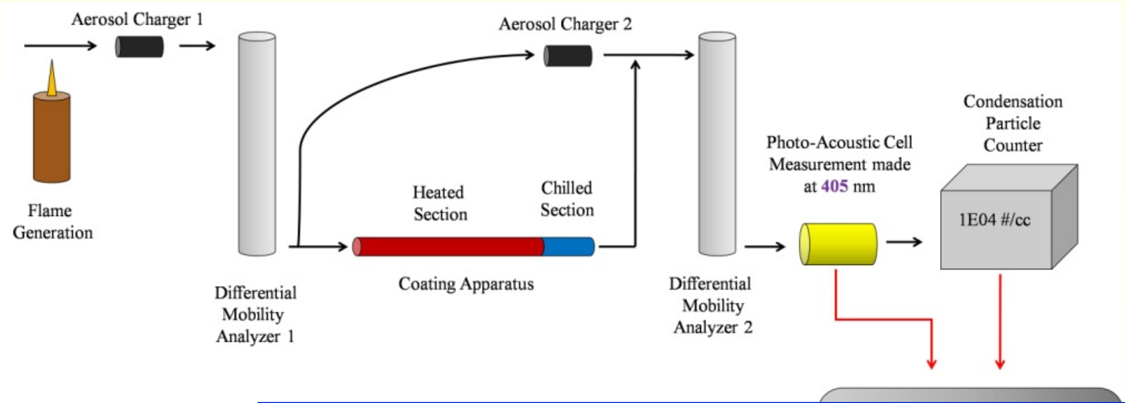
- Models of particles with an absorbing soot core enveloped in a transparent coating suggest enhanced absorption
- Coated particle generation scheme allowed investigation of absorption characteristics over a range of core and final sizes.
- Photo-acoustic spectroscopy was calibrated to the 1% uncertainty level

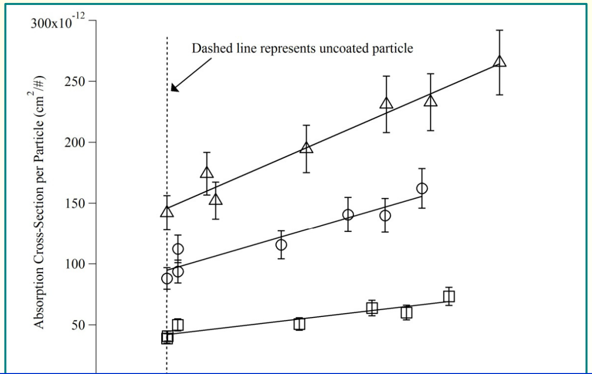


Uncoated soot



Coated soot





NIST measurements demonstrate that coated soot exhibits enhanced optical absorption

Future Research Efforts will Add

- **Extinction measurement for extinction and absorption determination**
- **Morphology and chemical characterization**

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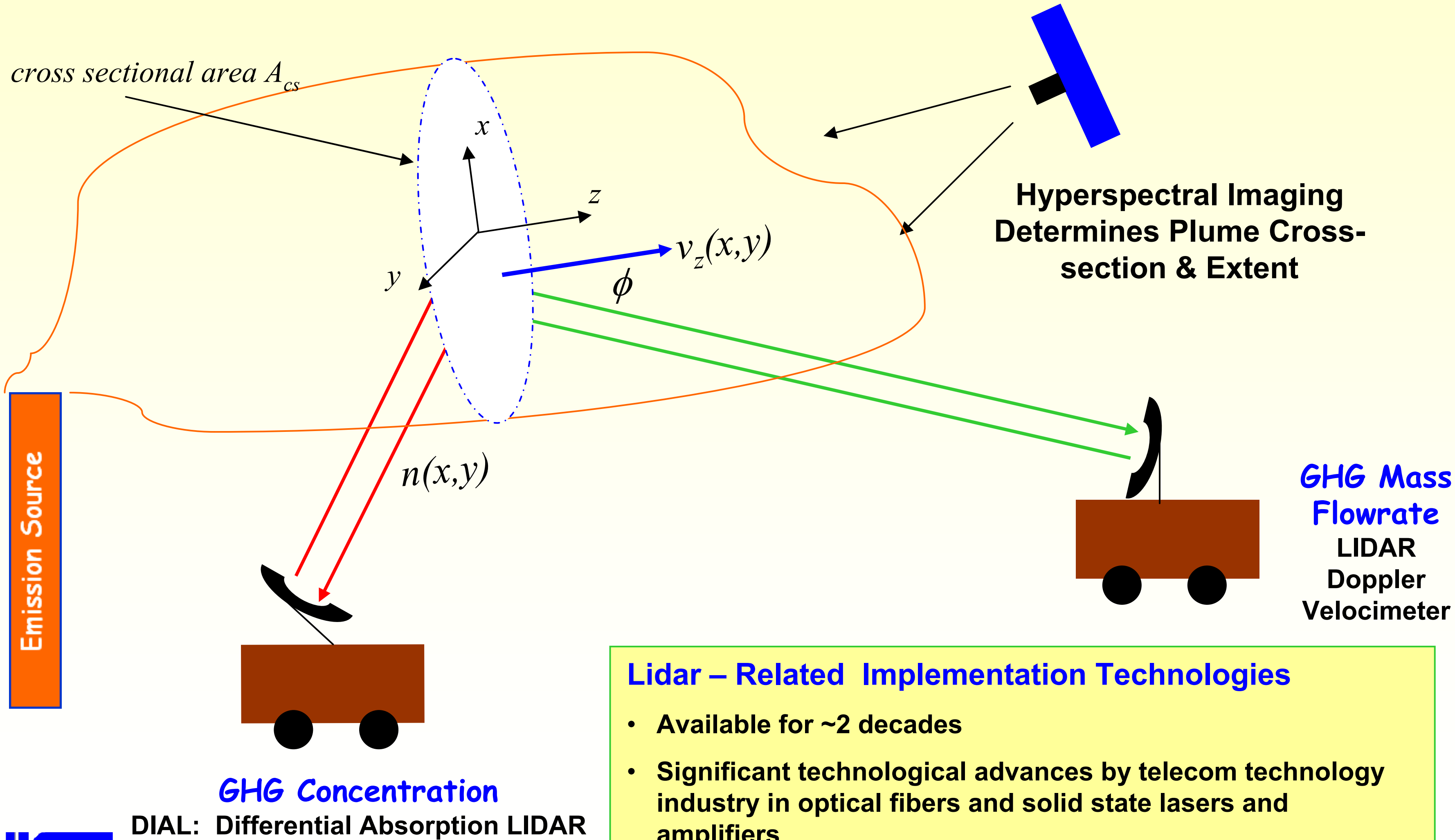
Measurement of Plume Flux (1 – 5 km Geographical Areas)

Optical Remote Sensing Technologies



Lidar – Related Implementation Technologies

- Available for ~2 decades
- Significant technological advances by telecom technology industry in optical fibers and solid state lasers and amplifiers
- Platform for development of suitcase-sized systems

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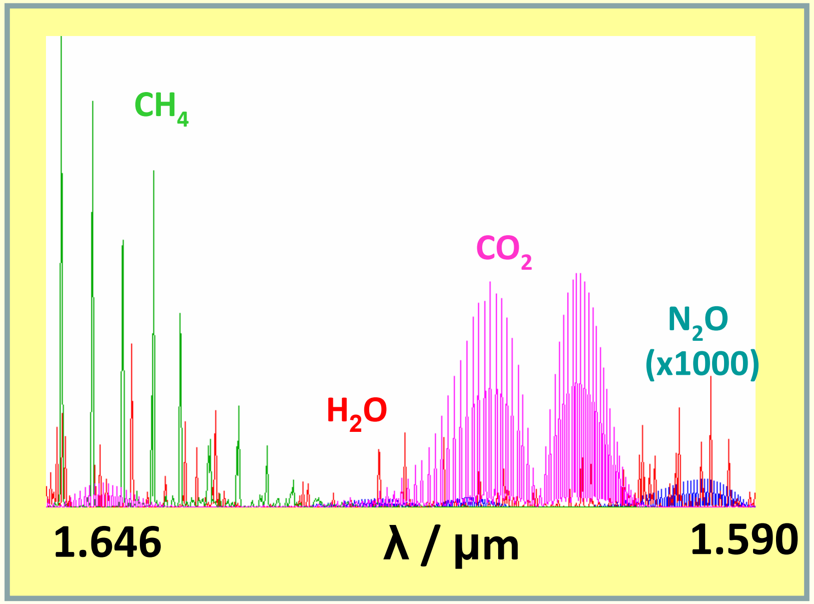
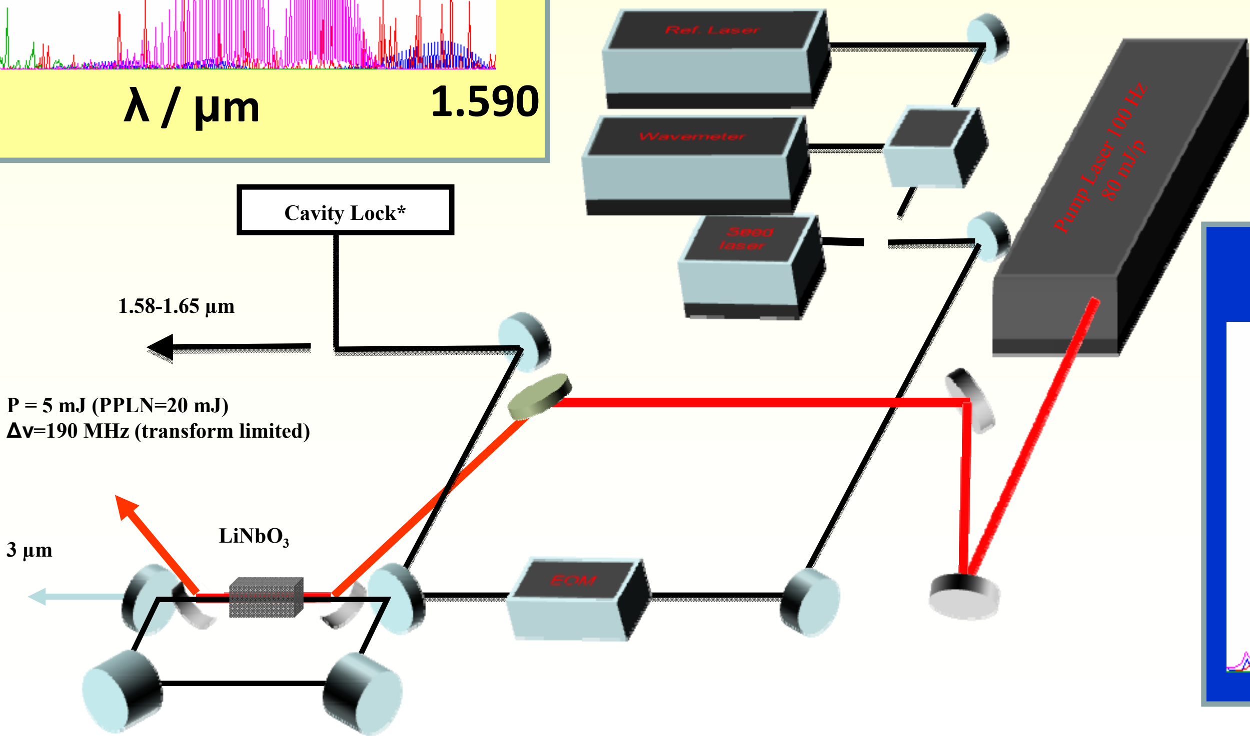
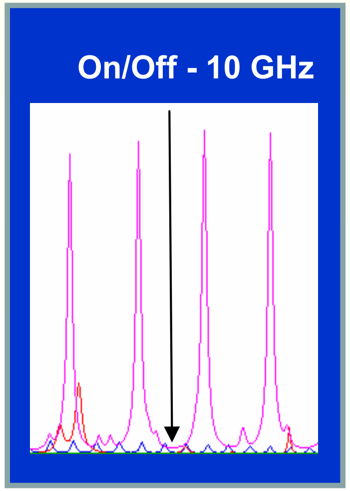
Heterodyne DIAL Measurement

Greenhouse Gas Area Source & Sink Mass Flux



- **Dual beam heterodyne approach**
- **Common mode noise rejection**
  - **Simultaneous sideband approach**





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Measurement Challenges – Why NIST

Measurements Results Often Influence/Are Critical to the Quality of Decisions

- Confidence in and Recognition of Measurement Results Requires:
  - Measurement Accuracy & Comparability across time and space/distance
  - Common basis of reference – standards base
  - Methods/protocols that relate point-of-use measurement results to recognized standards - *Traceability to the SI**
- Primary NIST Responsibilities as the U.S. National Metrology Institution
  - Realize and disseminate U.S. national measurement standards to industry and gov't
  - Ensure international recognition of U.S. measurement standards by other nations
    - Treaty of the Metre Organizations
      - » the International Committee on Weights and Measures (CIPM),
      - » the International Bureau of Weights and Measures (BIPM), and
      - » National Metrology Institutions (NMIs)
- State-of-the-Art measurement science and standards often drive innovation

Traceability of Measurement Results

- *"… 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." (VIM, 6.10)*

* SI – The International System of Units

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Summary

NIST Greenhouse Gas and Climate Change Program

Measurements Promote:

- Fairness/equity in GHG accounting
- Efficiency in the generation & use of GHGs
- Equitable usage of GHG offsets
- The quality of greenhouse gas inventories that furnish the foundation for policy and regulatory decisions
- A basis for reconciliation of determinations of GHG inventories from top-down and bottom-up methods

Traceability to the SI:

- Allows comparisons to be made independent of time or locale
- Improves measurement accuracy
- Provides confidence in the accuracy of measurements
- Helps contractors understand and meet agency requirements, protecting contractor and customer
- Ensures the quality climate data records that furnish the foundation for policy and regulatory decisions

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Thanks for Your Attention

Questions?

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