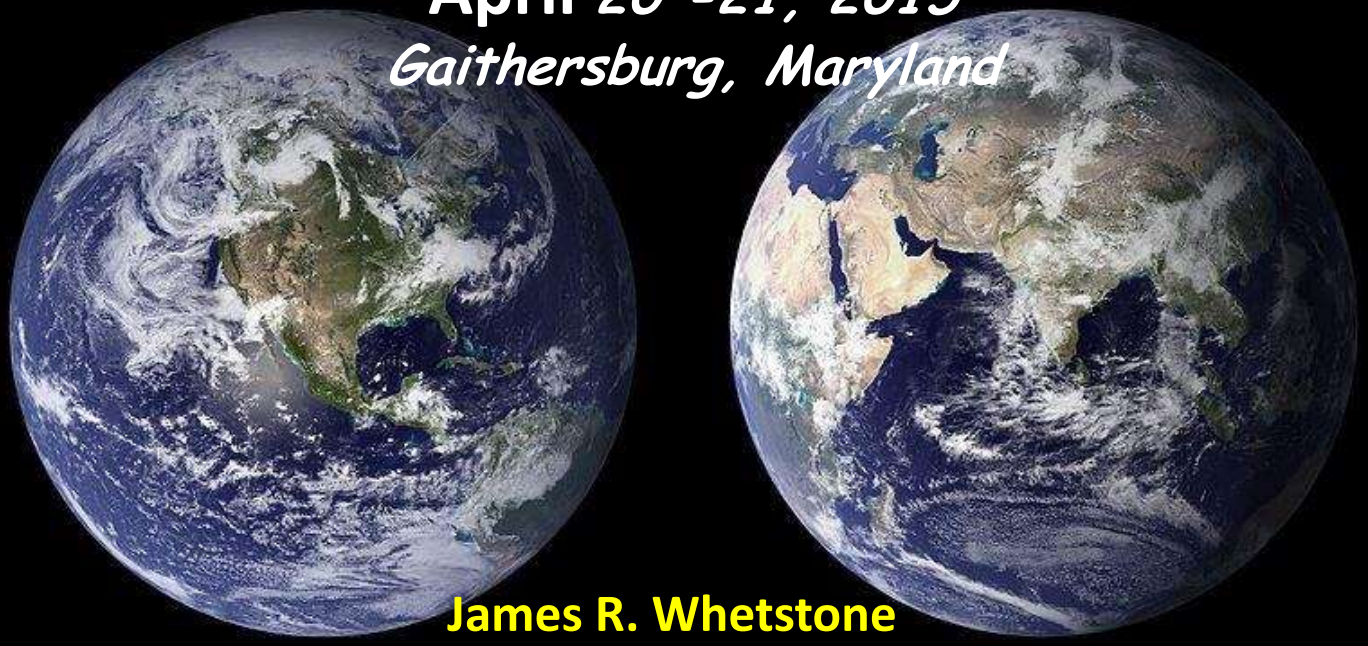
# Measurement Challenges and Metrology for Monitoring $CO_2$ Emissions from Smokestacks

**April** *20 -21, 2015*

*Gaithersburg, Maryland*

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# The National Metrology Institute of the U. S.

## Greenhouse Gas and Climate Science Measurements

**NIST**

- Is a non-regulatory agency of the U.S. Department of Commerce
- Is the U.S. National Metrology (measurement) Institute, and
- Develops unbiased, state-of-the-art measurement science that advances the nation's technology infrastructure

**Mission:**

To promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life.

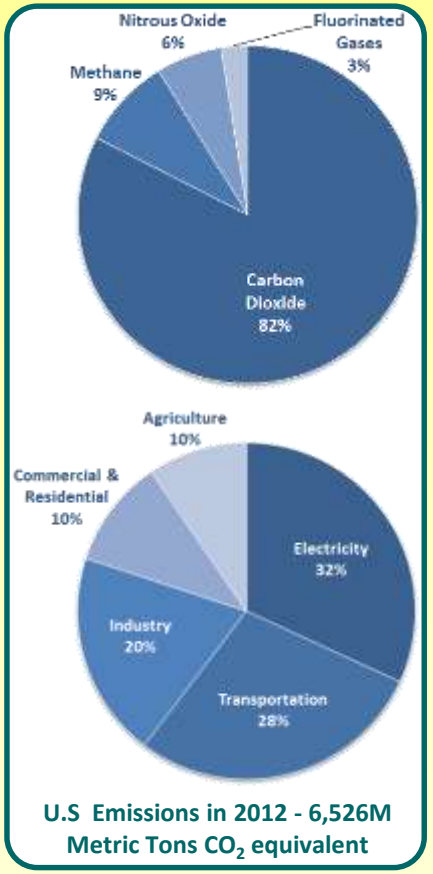
### NIST and Greenhouse Gas Measurements and Standards

- Recent focus established by the NIST Director – 2009
- Mid-Term Objective:
  - Improve performance capabilities of measurements and standards needed to enhance the accuracy of Greenhouse Gas Measurements in the U. S.
  - Promote recognition of these internationally
- Long-Term Objective:
  - Transfer measurement technologies developed to other government agencies and the private sector
  - Support standards responsibilities as needed

# NIST's Greenhouse Gas and Climate Science Measurements Program

## Objectives:

- **Develop advanced measurement tools and standards to improve accuracy capabilities for:**
  - **Greenhouse gas emissions inventory data**
    - **Improving emissions measurement data & thereby reporting accuracy**
    - **Independent methodologies to diagnose and verify emissions data with internationally-recognized methodologies**
    - **Applications focused on cities and metropolitan areas**
  - **Remote observing capabilities – satellite and surface-based**
    - **Extend measurement science and tools underpinning advances in understanding and description of Earth's climate and its change drivers**



U.S Emissions in 2012 - 6,526M Metric Tons $CO_2$ equivalent

# NIST Greenhouse Gas and Climate Science Measurements Program Components

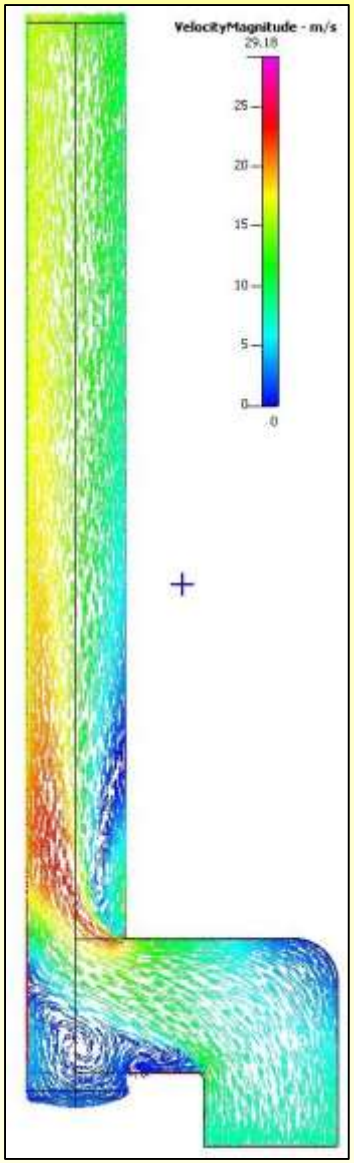
- **Stationary/Point Source Metrology**
  - Increase accuracy of Continuous Emission Monitoring technology
    - Flow Test Beds - smoke stack simulators
- **Geospatially Distributed GHG Source Metrology**
  - Measurement Tools and Test Beds Characterizing Emission in Urban GHG Concentration Domes
    - Compare methods to determine GHG Emission Inventory Accuracy – Bottom-up vs. Top-Down
    - Urban GHG dome test beds
      - Indianapolis Flux Experiment (INFLUX)
      - Los Angeles Megacity Carbon Project
      - Northwest Corridor Project
    - Propose an International GHG Metrology Framework Supporting Inventory Diagnosis and MRV Based on Megacities

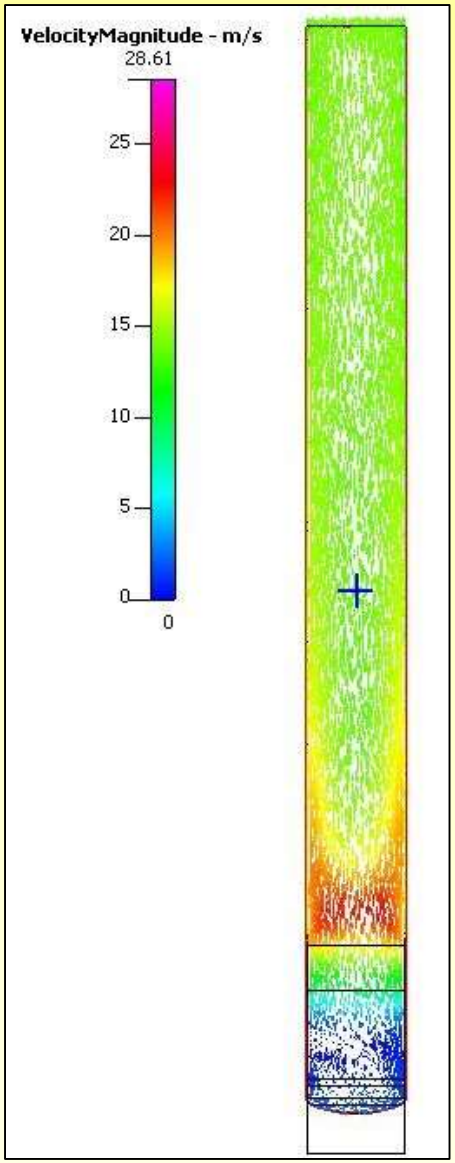
- **Measurement Tools, Standards, and Ref. Data**
  - GHG Concentration Standards
  - Spectroscopic Reference Data
  - Surface Air Temperature Assessment
  - Atmospheric Flux Measurement Tools
- **Climate Science Measurements - Advanced Satellite Calibration Standards**
  - Microwave Observations
  - Advanced Optical Radiometric Methods
  - TOA and Surface Solar Irradiance
  - Surface Albedo Standards
- **Measurement Science of Carbonaceous Aerosols**
  - Advanced Optical Property Measurements
  - Development of Reference Materials

# STATIONARY EMISSION SOURCE METROLOGY

- Motivation and Rationale
- What NIST is Doing

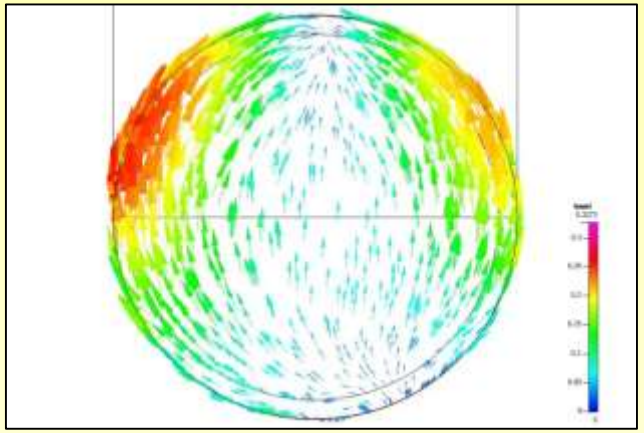
# Early CFD Modeling Results in a Stack

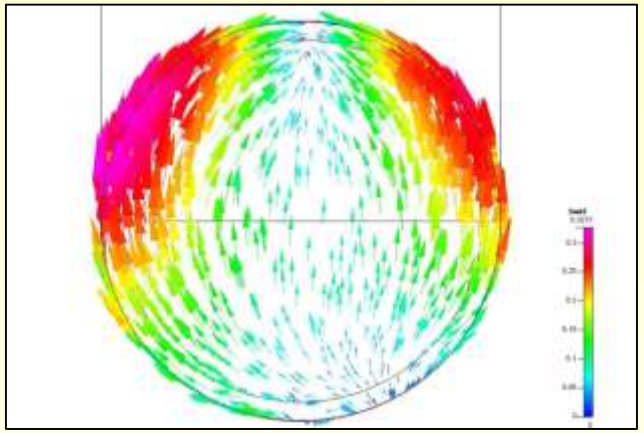



Axial Stack Flow Velocities Fields

## Swirl Fields





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# Plume Behavior Appears not to be Laminar

- Flow exiting a stack on a clear, low-wind condition day
- Local Power plant with relatively new stack
- Two vortices appear to be exiting non-partitioned stack

# Point Source Metrology:

## Comparing Fuel Calculation and Direct CO2 Measurements Using Reported Emission Data

**Electricity Generation ~40% of U.S. $CO_2$ Emissions Inventory**

**Question:**

**What is the Agreement Between the 2 Mainly-Used Methods of $CO_2$ Emissions Reporting Information?**

– Fuel Calculation vs. Continuous Emissions Monitoring (CEMs) Methods

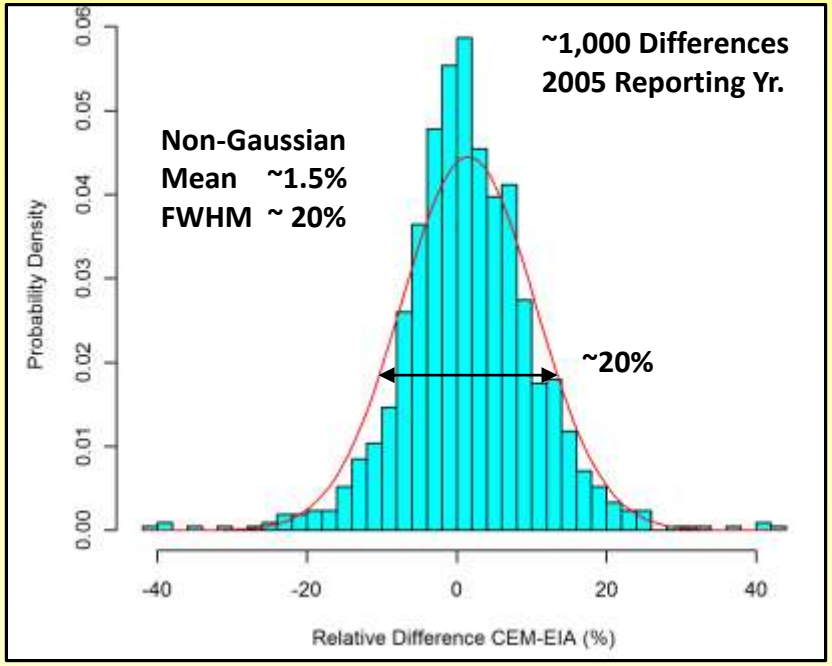
- **Fuel Consumption and Measured $CO_2$ Emissions Data – 2005 & 2009 U.S. Reporting**
  - **Pre-Combustion – Fuel Calculation Method**
    - Amount of carbon burned and converted to $CO_2$
    - Dept. of Energy – Energy Information Administration
      - Annual Steam-Electric Power Plant Design Data Fuel Type & Quantity
      - Carbon factor or Fuel Carbon Content (kg $CO_2$/mmBTU)
  - **Post-Combustion – $CO_2$ Direct Measurement via CEMs Technology**
    - Direct Measurement (CEMs Data) and Reporting of $CO_2$, $SO_2$, $NO_x$ Required by U.S. EPA
- **eGRID and EIA 767 databases contain >4800 entries**
  - 1664 with primary fuel and annual $CO_2$ (CEMs) reported values
  - 1066 (2005) and 944 (2009) boilers have complete data for fuel type, mass, energy content, and CEMS $CO_2$ data

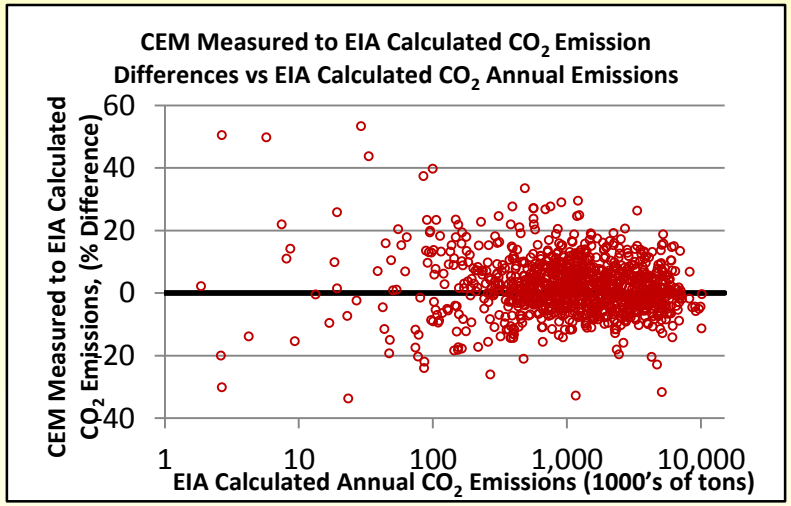
# Comparative Analysis:

## Fuel Calculated vs Measured $CO_2$

**Accuracy Improvement Potential**

- **CEM Measurements**
  - Improve stack gas mass flow measurement
  - Reduce gas concentration uncertainty
- **Fuel Based Calculations**
  - Increase fuel carbon (energy content) accuracy
    - Calorimetry and sampling issues
  - Improved mass determination
    - Where to make the measurement
- **NIST's Investment in Pt. Source Metrology**
  - Smoke stack simulator - improved flow measurements
  - Large Fire Facility – large $CO_2$ emission source & test bed

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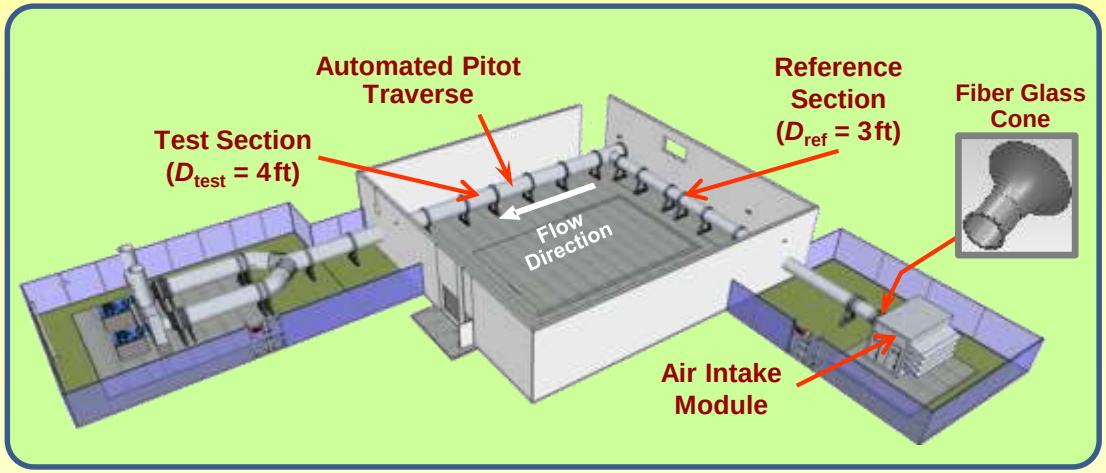
# Smoke Stack Simulator – Cold Flow Simulator
# NFRL – Well Characterized $CO_2$ Emission Source




## Address flow calibration issues in known, turbulent, swirling flows similar to those in stacks

- Horizontal orientation for cost and safety
- Smokestack Simulator is 1/10$^{th}$ the diameter of typical stack
- At the same velocity range – 5 to 25 m/sec
- Flow traceable to NIST flow standards

## Large Emission Source with Accurately Known $CO_2$ Flux

- Characterize exhaust duct flows (flow RATAs*)
- Establish a mass balance for $CO_2$ emissions for the facility – $O_2$ depression calorimetry method
- Apply research results from the NIST Smokestack Simulator
- Provide test bed for new and existing stack mounted flow measurement technologies

* Relative Accuracy & Test Audit

## National Fire Research Laboratory (NFRL)

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# Thanks for your Attention

## Best Wishes for Successful Discussions