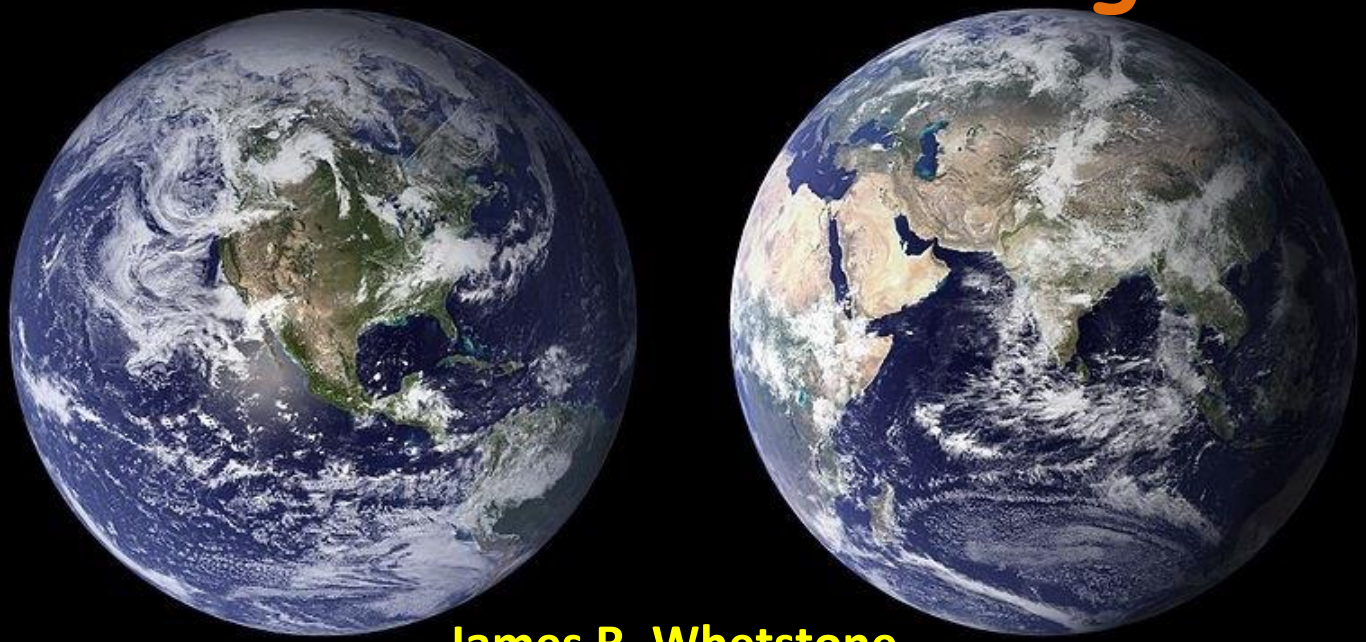
Urban Carbon

Measurement Challenges in Greenhouse Gas Mitigation



James R. Whetstone
Special Assistant to the Director for Greenhouse Gas Measurements
National Institute of Standards and Technology
Gaithersburg, Maryland

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

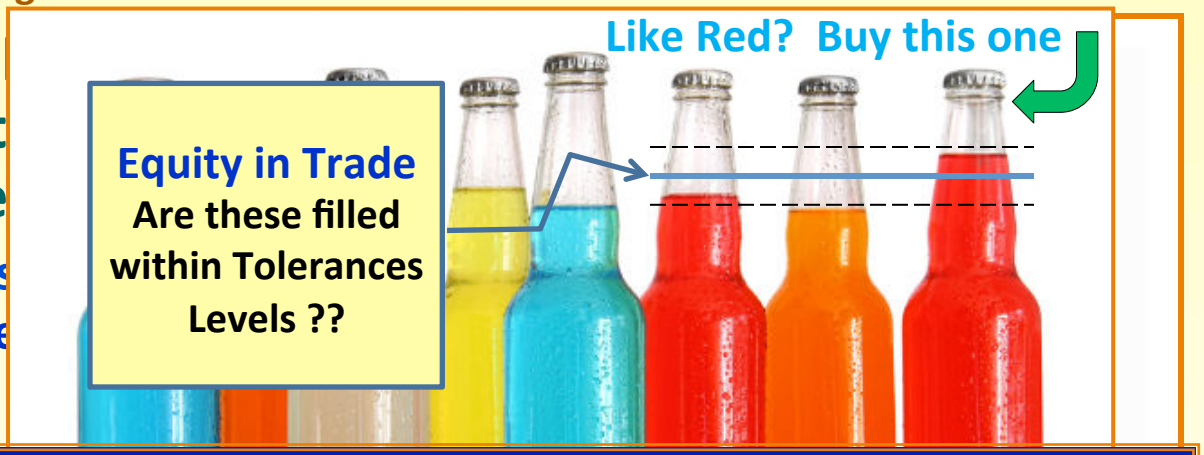
Outline

- GHG Quantification and Methodologies
- International Recognition of Measurement Results and The Metre Convention
- What Accuracy is Needed to Support National and International Mitigation
- NIST Activities
  - Developing Urban Measurement Capabilities
- Tiered Measurement Architecture and International Frameworks

International Recognition of Measurement Results

Greenhouse Gas Inventory Data

- **Quantification Supporting Market / Regulatory Functions**
  - **Best Case: Material quantities are not a point of contention**
    - **A metric ton of GHG is the same in all arenas**
    - **Confidence in the material quantities**
      - **Fundamental for orderly markets and harmony in the transactions found in trade**
      - **Similarly for fairness in regulation**
- **Quantification techno**
  used in international t
  mostly well establishe
  - **Mass and Volume are s**
    technologies with mille
- **GHG quantification technologies are not as mature, but similar performance levels are desired**



For GHG Trade or Regulation

CO_{2e} ton Emitted = CO_{2e} ton Removed

CO_2 ton (urban) = CO_2 ton (biogenic)

International Recognition of Measurement Results

Greenhouse Gas Inventory Data

- **Quantification Supporting Market / Regulatory Functions**
  - **Best Case: Material quantities are not a point of contention**
    - **A metric ton of GHG is the same in all arenas**
    - **Recognition of traceability of measurement results to the International System of Units enhances harmony in trade/regulatory equity**
  - **National Metrology Institutions establish national measurement standards & ensure comparability with those of other nations**
- **The Metre Convention of 1875 (US Signs in 1878)**
  - **Establishes a Measurements and Standards Framework Widely Used by Economic Systems**
    - **Governing Body:** General Conference on Weights and Measures
    - **Implementing Org.:** International Bureau of Weights and Measures
    - **National Reps:** National Metrology Institutes
    - **Activity Focus:** Ensure comparability and recognition of national measurement standards, *hence measurement results accepted across borders*
  - **NIST: U.S. National Metrology Institute**
    Mission: Develop accurate quantification & the supporting methods and standards before they are needed

NIST National Institute of Standards and Technology

What Accuracy is Needed to Support Mitigation?

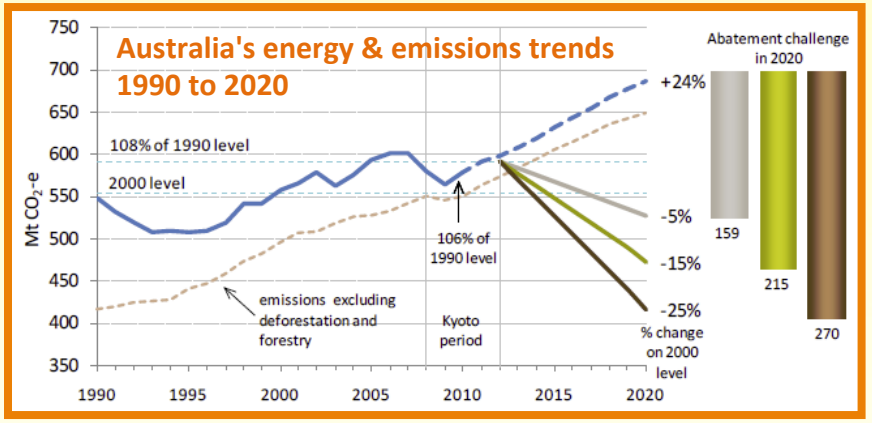
GHG Inventories and Reduction Targets

Greenhouse Gas Emission Inventories

- The performance metrics for national and international reduction activities and the performance gauge of future policy effectiveness
- Reliable quantification is fundamental to:
  - Reduction *target achievement and progress monitoring* and
  - Equity in trade and/or fairness in regulation
- **Advances in a range of measurement capabilities are needed to *assess progress toward and attainment of* reduction targets.**

Reduction Targets

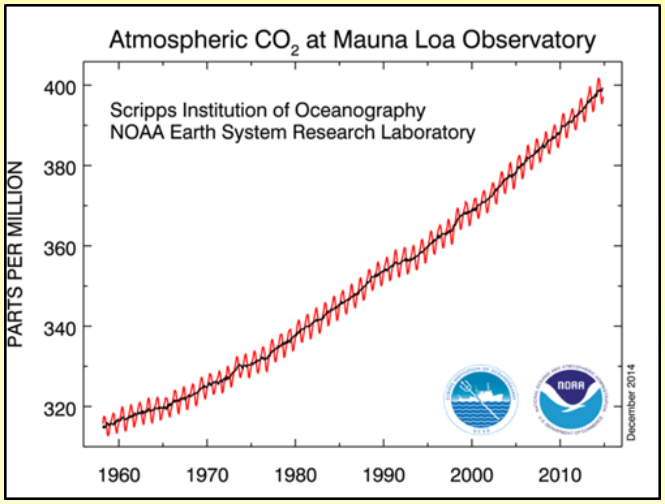
- U.S.
  - President Obama's Climate Action Plan: 17 % relative to 2005 by 2020
  - EPA's recent carbon rule (Electrical Gen.) ~30 % relative to 2012 by 2030
- UK: At least 80 % by 2050 (from the 1990 baseline)



- **Indicators of Progress Toward and Achievement of GHG Reduction Targets Likely Require Quantification Capabilities at the 1% – 5% of the Target Level Using Internationally-Recognized Methodologies**

NIST National Institute of Standards and Technology

Greenhouse Gas Measurement Needs
Policy Support Scenario: 2020 - 2050

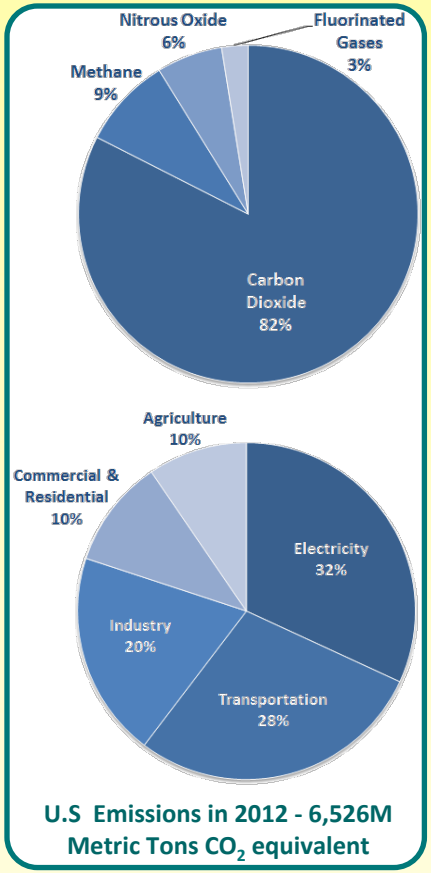


Inventories, & its data are Fundamental Performance Metrics

- **Reduction policy performance needs**
  - Are system metrics increasing or decreasing?
  - If in the correct direction, is the rate of decrease acceptable?
  - What is the degree of target achievement?
  - Global, region, & local indicators are needed
- **Quantitative information needed & based upon:**
  - Internationally-recognized, scientifically robust and defensible methodologies
  - Independent, scientific methods for validation or verification
- **Effective policy implementation needs actionable information**
  - Attribution (Identity) of emitter/absorbers support both regulatory and market-based reduction approaches
  - Inventories are composed of many individual contributions
    - emitters (anthropogenic) and absorbers (anthropogenic and biogenic)
  - Requires measurement capabilities at relatively small geospatial and temporal scales

NIST National Institute of Standards and Technology

Greenhouse Gas and Climate Science Measurements Program



Objectives:

- **Develop advanced measurement tools and standards to improve accuracy capabilities of:**
  - **Greenhouse gas emissions inventory data**
    - **Improving emissions measurement accuracy**
    - **Independent methodologies to diagnose and verify emissions data both nationally and internationally**
    - **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**

NIST Greenhouse Gas and Climate Science Measurements Program Components

- **Stationary/Point Source Metrology**
  - Increase accuracy of Continuous Emission Monitoring technology
    - Flow Measurement Test Beds – 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
      - Northeast Corridor Project
    - Propose an International GHG Metrology Framework Supporting Inventory Diagnosis and MRV Based on Megacities

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

GEOSPATIALLY DISTRIBUTED SOURCES AND SINKS

Forecasting Some Greenhouse Gas Measurement Needs

GHG Mitigation Policy Support

- Cities, Their Power Plants and Vehicles
  - Currently Concentrate ~70% of the Worlds Population
  - 85% to 90% by the Late 2000's
- Tiered or Layered Measurement System Architecture(s) Can Address Greenhouse Measurement System Needs
  - Satellite to Ground-Based Observing/Measurement Strategy

Tools and Test Beds for Diagnosing GHG Measurements Accuracy in U. S. Urban Domes

Developing and Assessing Performance of Greenhouse Gas Measurement Tools at Urban Scales

The Indianapolis Flux Experiment (INFLUX)

- *A Top-Down/Bottom-Up Greenhouse Gas Quantification Experiment in the City of Indianapolis, Indiana*

The LA Megacity Carbon Project

- *Estimating the Emissions Trends in a Megacity Having Complex Topography & Meteorology*

The Northeast Corridor

- *The Largest U.S. Megacity – Mega-Region ?*
- *A Test Bed Having Moderately Complex Topography & Meteorology*
- *Mid-FY 14 Project Start*

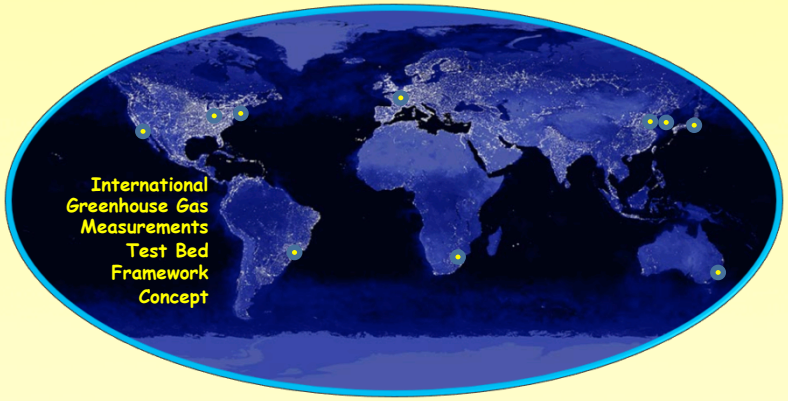
A Step in the U.S. Towards an International Urban Greenhouse Gas Measurement Testbed Framework

NIST National Institute of Standards and Technology

International GHG Measurements Framework

Engaging the Metrology & Climate Communities

Concept:

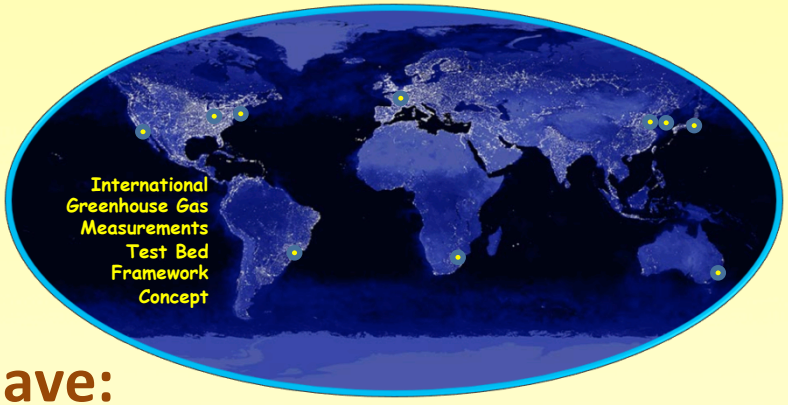


- **An International Greenhouse Gas Measurements Test Bed Framework that:**
  - Enables joint development of advanced measurement capabilities for urban and regional GHG domes and their dynamics,
  - Enhances recognition of scientific validity and performance capabilities of advanced measurement methodologies and instruments,
  - Facilitates open, internationally-recognized measurement methodology development and evaluation with open data exchange and utilization across national borders, and
  - Supports a tiered global measurement system concept in support of national and international mitigation activities

NIST
National Institute of Standards and Technology

International GHG Measurements Framework

Engaging the Metrology & Climate Communities



Approach:

- Focus on Megacities as test bed sites
  - Increased signal
  - Cover 6 of the 7 continents
- Engage with nations or regions that have:
  - Suitably located megacities
  - The scientific and technological capabilities needed, and
  - The necessary national interest and will to commit the required resources
- Use existing structures of the Metre Convention
  - Operating, internationally-recognized treaty organization with well-demonstrated working relationships and organizational structures
  - Facilitates communication & dialog
  - Broaden international linkages – WMO, international climate change/ science communities

A Measurement Systems Notion Supporting Mitigation

Enhancing Consistency, Transparency, Comparability, and Accuracy

GHG Emissions Data of Verified Quality

MRV Compliant Inventory

Internationally – Recognized Greenhouse Gas Mitigation Policies, Procedures, & Structures (UNFCCC)

Data Quality Metrics

Emissions Data Quality Diagnostic Measurement Methodologies

National Inv.Reporting Activities

Bottom-Up

Electricity Generation

Agriculture

General Industrial Energy Generation

Landfills

Chemical/ Petrochemical

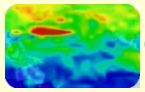
Stationary Sources

Distributed/Area Sources

Emissions Reporting Community

Top-Down

Forests Woodlands



Ocean

Estuaries Coastal Ocean

Satellite

Cities

Atmosphere

Regional

International / Global

Climate Science Community

Measurement Tools, Standards Technologies & Methodologies

Measurement Methodology Standards Linked to the SI

Individual Nations May Choose to Implement Surface-Based Calibration Capabilities Useful as Calibration Location(s) for Satellite and Other Measurement Approaches within an International Framework

NIST National Institute of Standards and Technology

Greenhouse Gas Measurement Needs in the Future

Tiered Measurement System Architecture: 2020 - 2050

Satellites - Total-Column Integrated Greenhouse Gas Concentration Measurements

- Multiple satellite-based instruments on planned or on orbit
  - Low Earth (LEO) and will use Geosynchronous Orbits (GEO)
  - Most will use near-infrared spectroscopic instruments
- Effective and recognized traceability strategies will be needed
  - GHG concentration sensitivity at the 1 in 400 or better level and observing footprints of ~3 to 10 km^2
  - Vertical concentration profiles (atmospheric boundary layer and lower troposphere) are temporally variable and will be needed to reduce inaccuracies
- Do not make GHG flux measurements as currently conceived, GHG concentration only

GHG Observing Satellites On Orbit

- GOSAT - Japanese Aerospace Exploration Agency

Planned - NASA

- Orbiting Carbon Observatory (OCO II) - 2014
- OCO III – Intnt'l. Space Station – Launch Date?
- ASCENDS (Active Sensing of CO_2 Emissions over Nights, Days, and Seasons) – Launch Date?

Internationally

- CarbonSat –CO_2 and CH_4 observations
- China Acad. of Sciences - TanSAT

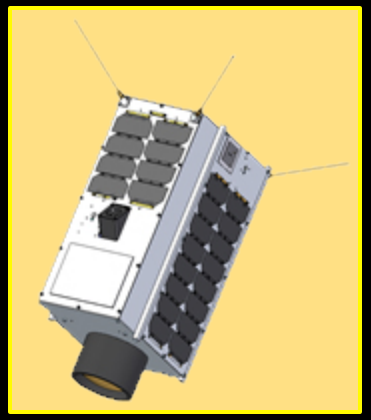
Surface-Based Systems Greenhouse Gas Concentration and Transport (Flux) Measurements

- Flux measurement capability supports attribution and independent verification of inventory data
  - Atmospheric GHG transport relies upon atmospheric boundary layer measurement and modeling
- 1 - 5 km^2 or better geo-spatial resolution
- New measurement methodologies needed for independently diagnosing accuracy and ultimately verifying inventory data
- Calibration capability for satellite observations

NIST National Institute of Standards and Technology

Canadian Microsatellites: GHGSat-D

Univ. of Toronto Inst. For Aerospace Studies & GHGSat, Inc.



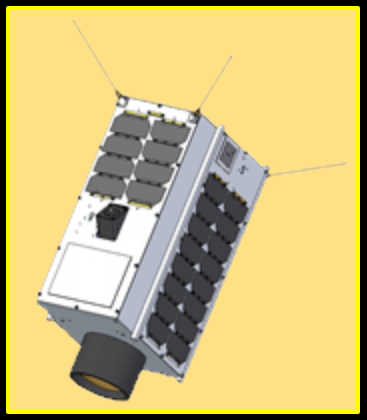
Mission:

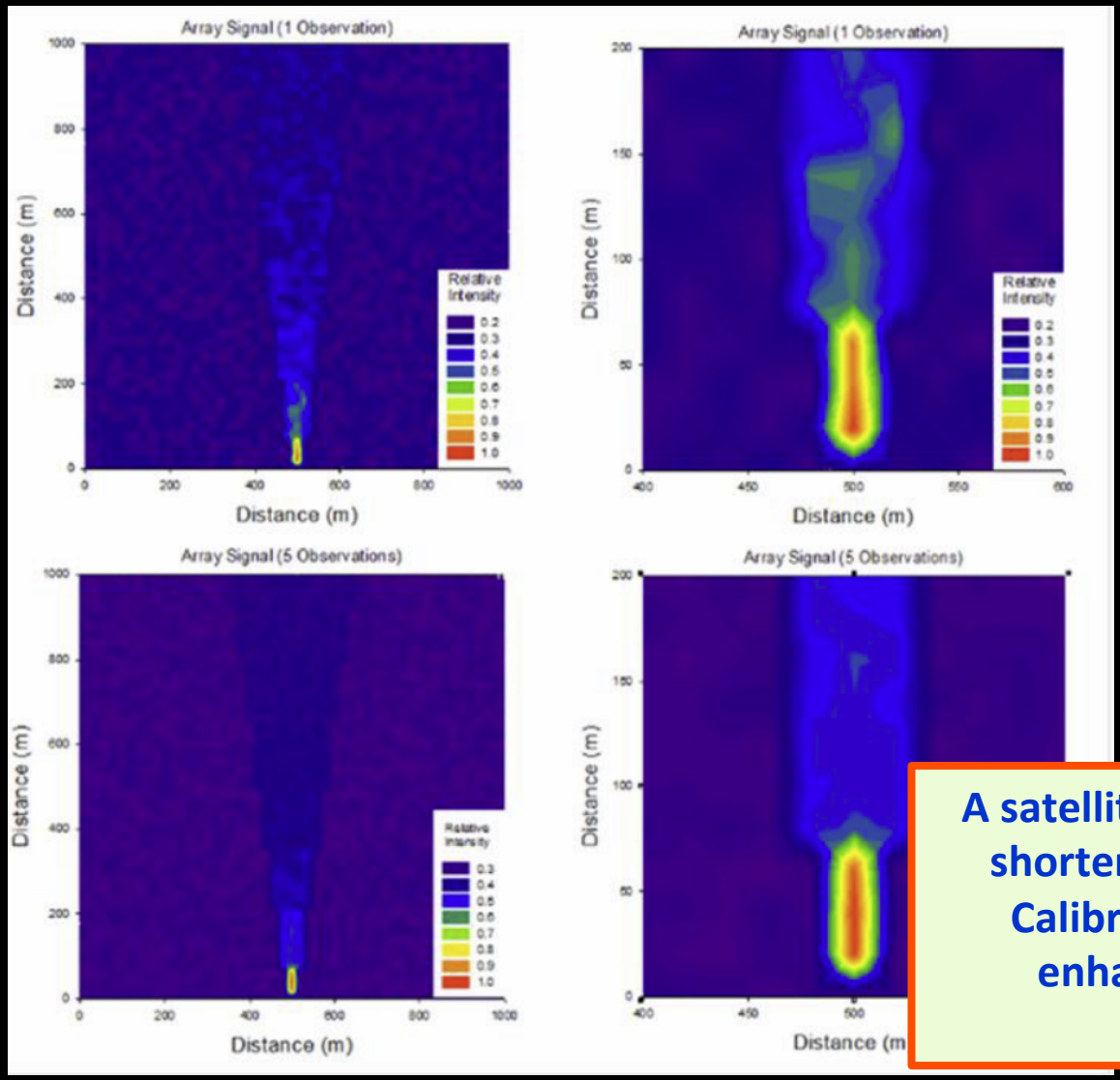
Become the global reference for remote sensing of greenhouse gas (GHG) and air quality gas (AQG) emissions from industrial sites, using satellite technology

- Next generation greenhouse gas monitoring instrument based on miniature hyperspectral IR imaging spectrometer
- Targeted monitoring of industrial greenhouse gas emitters
  - Oil & gas, power generation, mining and waste management
  - CO_2, methane, SO_2, NO_2, & other gases
- 15-kilogram satellite precursor to a commercial constellation of greenhouse gas monitoring satellites
- Part of a service provided by GHGSat Inc. (Boeing Defense, Space & Security investment participation)
  - A secondary instrument will measure clouds and aerosols to enhance retrievals from the primary instrument.
- Launch of prototype scheduled for 2015

Canadian Microsatellites: GHGSat-D

Univ. of Toronto Inst. For Aerospace Studies & GHGSat, Inc.





Potential Capability:

Simulated Spectral Obs. of CO_2 Plume

- **Top panels - single "snapshot" observation, 1 second duration, low (1 km x 1 km) & high (200 m x 200 m) resolution.**
- **Lower panel - 5 co-added observations, improved SNR.**

A satellite constellation could give daily to shorter temporal observing capabilities Calibration standards & methods will enhance confidence in use of their measurements

THANK YOU FOR YOUR ATTENTION