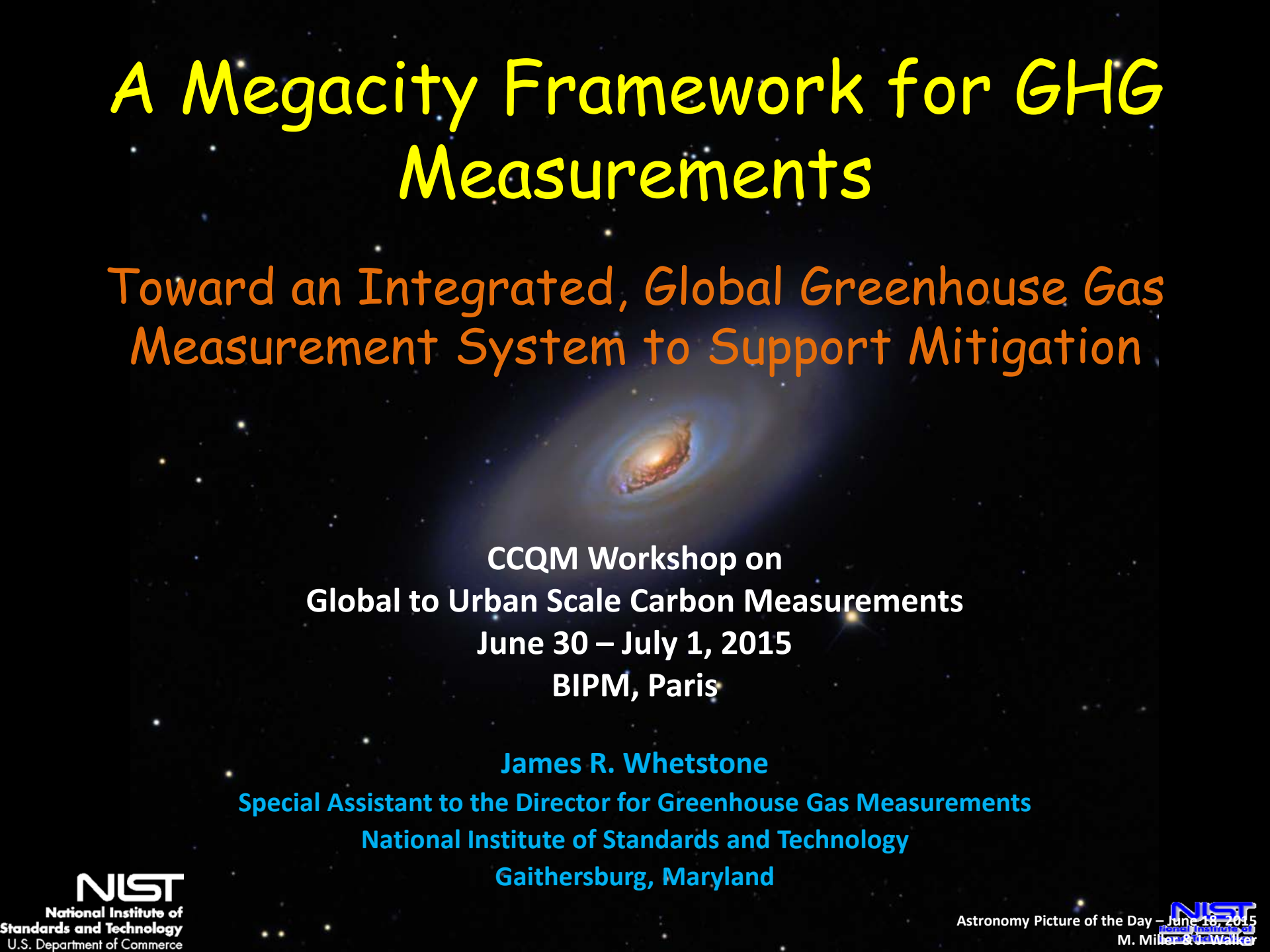
A Megacity Framework for GHG Measurements

Toward an Integrated, Global Greenhouse Gas Measurement System to Support Mitigation



CCQM Workshop on
Global to Urban Scale Carbon Measurements
June 30 – July 1, 2015
BIPM, Paris

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

Astronomy Picture of the Day – June 18, 2015
M. Miller and J. Walker

Outline

- Forecasting Greenhouse Gas Flux Measurement Needs
- A Tiered or Integrated GHG Flux Measurement System
- A View of Interested Communities
- Diagnosis Perhaps Leading to Verification – a Notional View
- NIST Urban GHG Quantification Program
  - Testbeds and Program Status

Future Greenhouse Gas Measurement Needs
A Self-Consistent Quantification System from Urban to Global Scales

Greenhouse Reduction Strategy Implementation

- **Inventory Data is the Primary Metric**
  - Emission/Activity Factor-based methods will predominate inventory data
  - Emissions are fluxes to or from the atmosphere
- **Performance Indicators**
  - Is there measurable impact of reduction policies – Progress Indicators
  - Are indicators increasing or decreasing? – local & global indicators
  - Is the rate acceptable
  - Degree of target achievement & it demonstration
- **Internationally, Quantitative Information is Needed Based Upon:**
  - Diagnosis of inventory data accuracy relies upon independent methods
  - Internationally-recognized methodologies and standards
  - Scientifically robust and defensible approaches
- **Actionable Information Supporting Data Accuracy Diagnosis**
  - Attribution (Identity) of emitter/absorbers support both regulatory and market needs
  - Inventories are composed of many individual contributions
  - Requires measurement capabilities at relatively small geospatial scales

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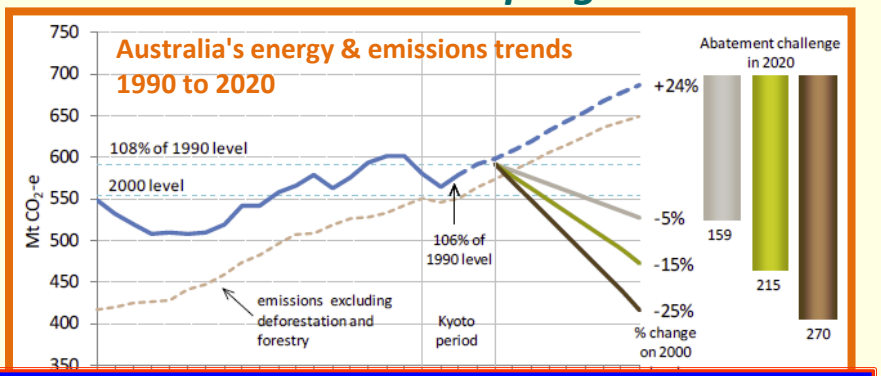
What Accuracy is Needed to Support Mitigation?
GHG Inventories and Reduction Targets

Greenhouse Gas Emission Inventories

- Performance metrics for national and international reduction activities and gauge of mitigation 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

- Australia: 5 % below 2000 level by 2020
- U.S.
  - President Obama's Climate Action Plan: 17 % relative to 2005 by 2020
  - EPA's recent carbon rule (Electrical Gen.)
    CO_2: ~30 % relative to 2012 by 2030
    CH_4: 40 – 45% rel. to 2012 by 2025
- UK: At least 80 % by 2050, 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

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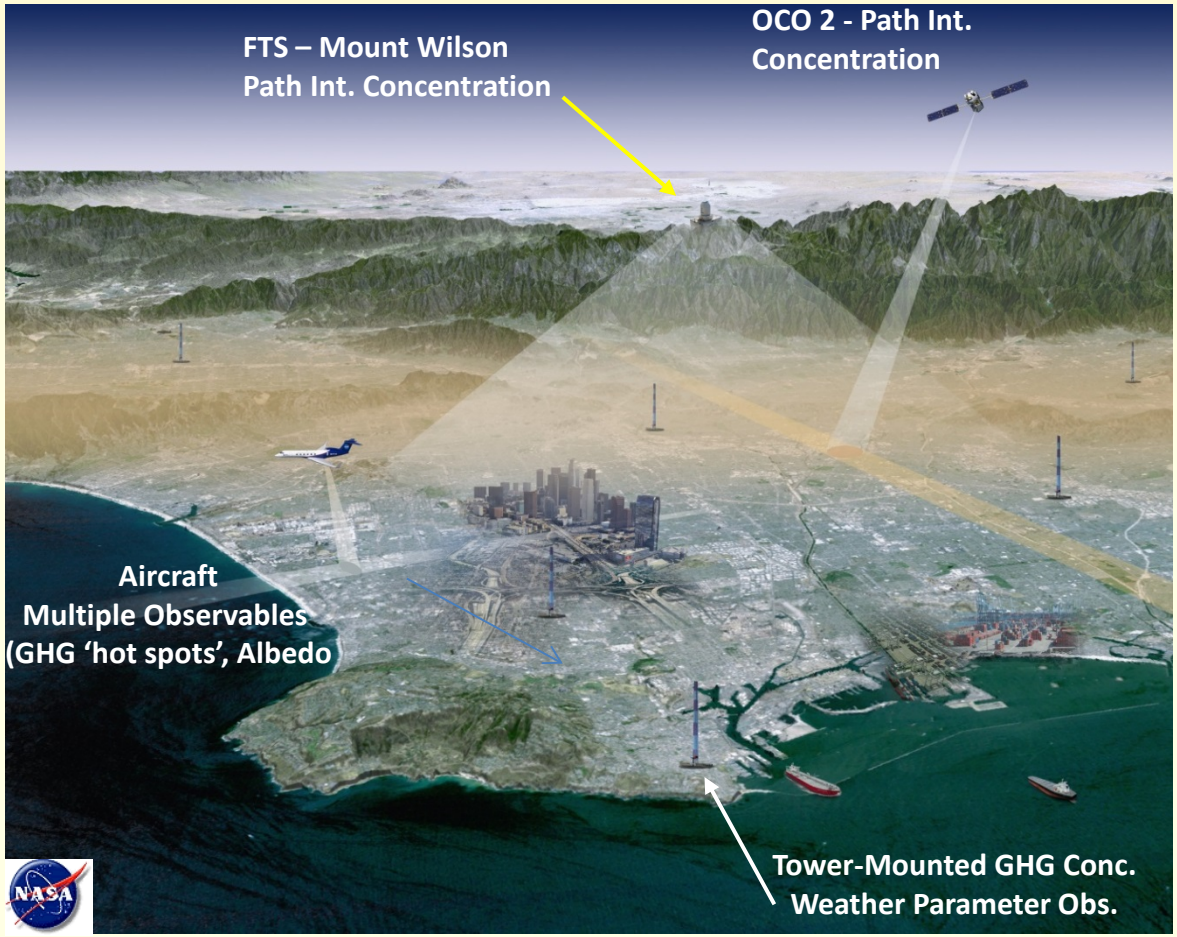
A Tiered or Integrated GHG Flux Measurement System

Urban Linked to Regional/Continental/Global Components



System Tiers

- **Surface-Based Observations, Models & Analyses**
  - Trace Gas Concentration
  - Atmospheric Transport Obs. & Simulations
  - Stationary Observations
- **Airborne**
  - Multiple atmospheric and land observables
- **Space-Based**
  - GHG Observing Instruments

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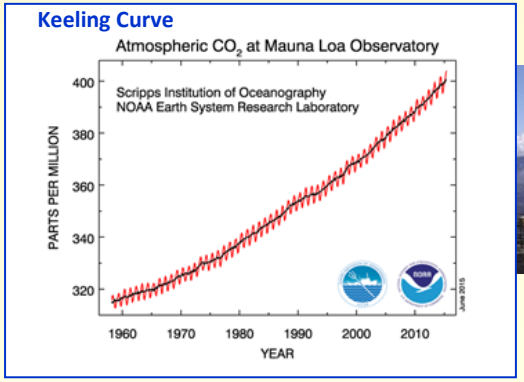
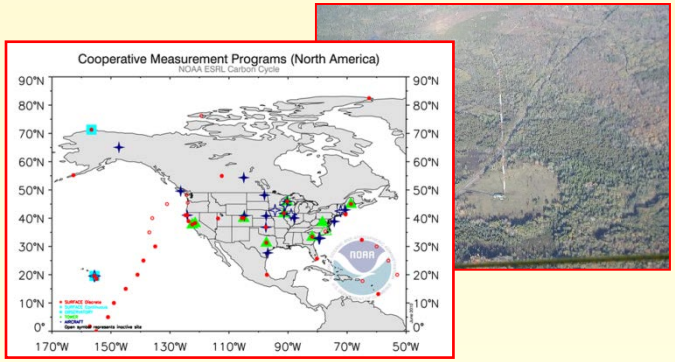
A Tiered or Integrated GHG Flux Measurement System

Urban Components to Regional/Continental/Global Ones

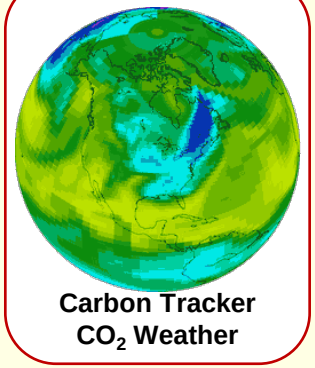
Global Geospatial Scale



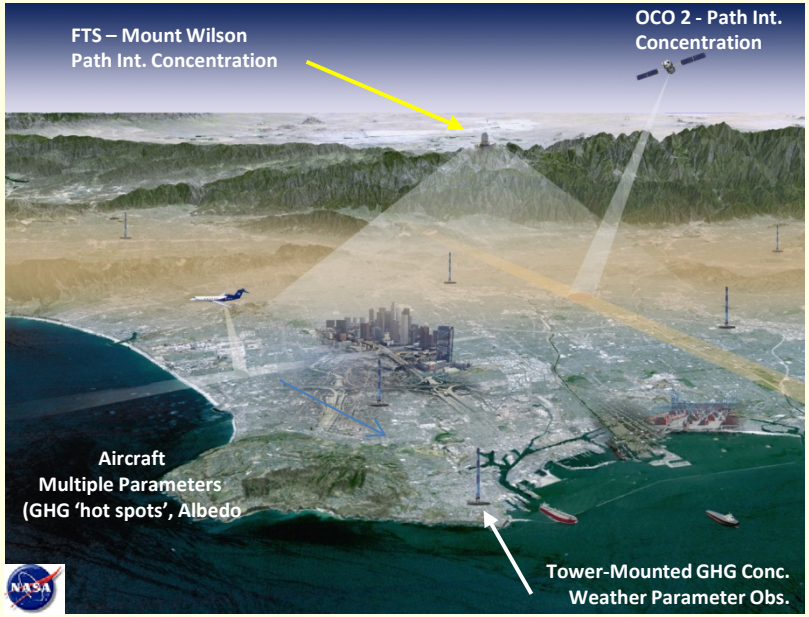
Moana Loa Observatory
~11,000 Ft. Altitude



Continental to Regional Scale



Carbon Tracker
CO_2 Weather



Emissions Inventory Data

- Primary Inventory Reporting Vehicle
- UNFCCC-Recognized Methodologies
- Emission/Activity Factor Model

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Future GHG Urban Measurement Needs

Surface-Based & Satellite Measurements: 2020 - 2050

Surface-Based Systems

GHG Concentration and Transport Measurements Combined for GHG Flux

- Flux measurement capability supports source attribution and inventory data accuracy diagnosis independent of source properties
- Source attribution requires 1 - 5 km^2 or better geospatial resolution in urban settings
- Measurement methodologies need advancement to achieve independent diagnosis of inventory data – COP 20 changed MRV concepts

Satellite Instruments:

Measure Column Integrated GHG Concentration

- Multiple satellite instruments planned or on orbit
  - Near-infrared spectroscopic instruments
- Effective and recognized strategies needed to establish the degree of comparison between measurement results obtained from significantly different methods
  - Process property-based and atmospheric observation-based methods

GHG Observing Satellites On Orbit

- GOSAT - Japanese Aerospace Exploration Agency
- OCO 2 - NASA

Planned:

- U.S. - NASA
  - OCO 3: ISS – Launch Date?
  - ASCENDS (Active Sensing of CO_2 Emissions over Nights, Days, and Seasons) – Launch Date?
- Chinese Academy of Sciences
  - TanSat – CO_2 Observation Mission ?
- EU Space Agency
  - CarbonSat –CO_2 and CH_4 observations

Next Gen. Observing Satellites

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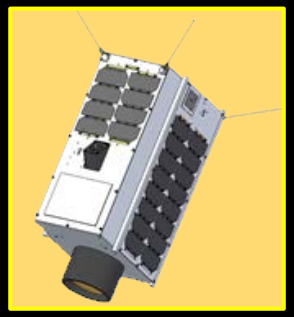
Small, Inexpensive GHG Observing Satellites & Low Cost Launch Services



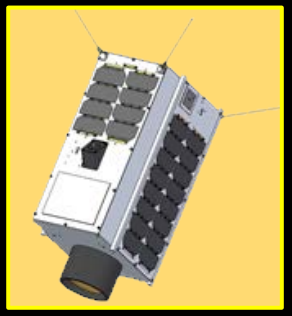
Univ. of Toronto Institute for Aerospace Studies & GHGSat, Inc.

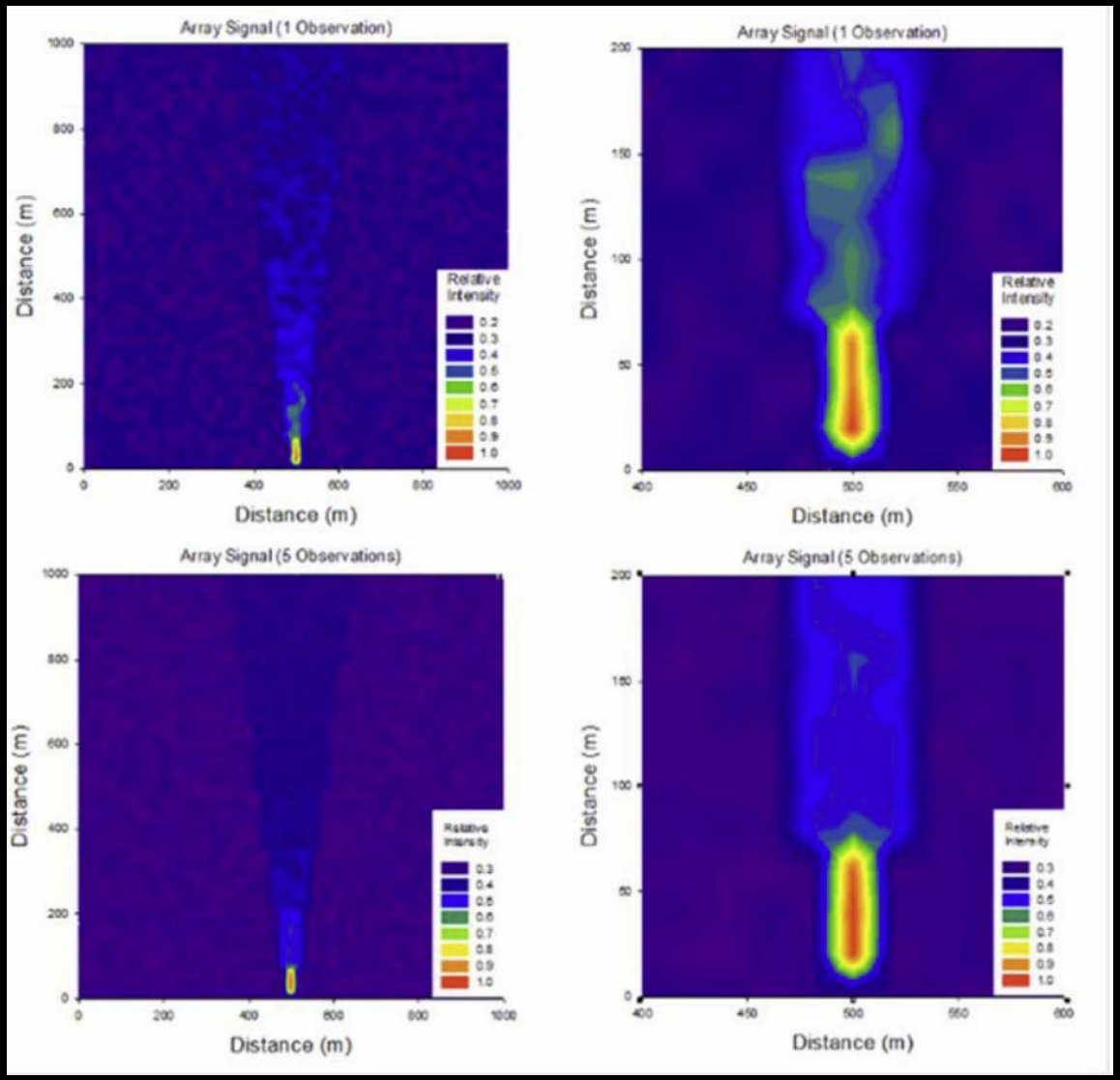
Mission:

Become the global reference for satellite remote sensing of greenhouse gas & air quality gas emissions from industrial sites

- Next generation GHG monitoring instrument class?
  - Miniature hyperspectral IR imaging spectrometer
  - Secondary instrument to measure clouds & aerosols to enhance retrievals from the primary instrument.
- Targeted GHG monitoring of industrial emitters
  - Oil & gas, power generation, mining & waste management
  - CO_2, methane, SO_2, NO_2, & other gases
- GHGSat-D: 15-kilogram satellite
  - precursor to a commercial constellation of GHG monitoring satellites
- GHGSat Inc.
  - Canadian Oil Sands Innovation Alliance; Boeing Defense, Space & Security; other sponsors
- Launch of prototype scheduled for 2015

Small, Inexpensive GHG Observing Satellites & Low Cost Launch Services





Anticipated Performance:

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.**

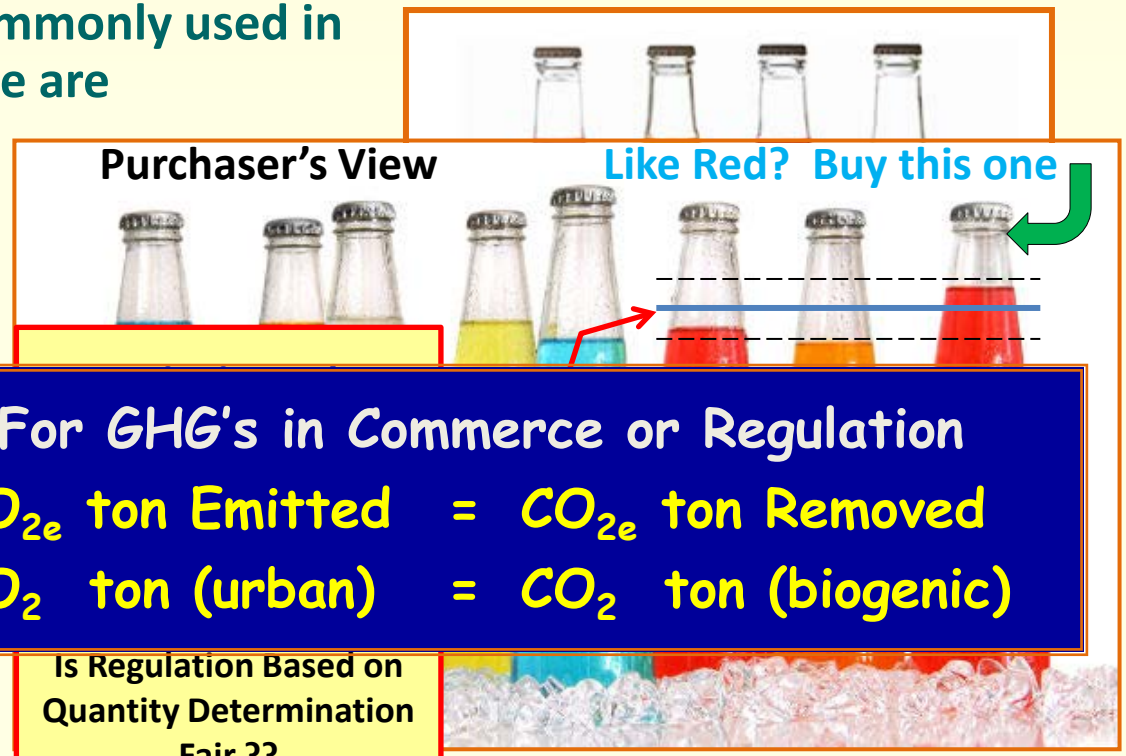
- **A satellite constellation may give daily observing capabilities**
- **Low cost may result in proliferation of multiple national capabilities**
- **Confidence in measurement data is enhanced by Internationally-recognized calibration standards & flux measurement methods**

http://utias-sfl.net/?page_id=1254

International Recognition of Measurement Results

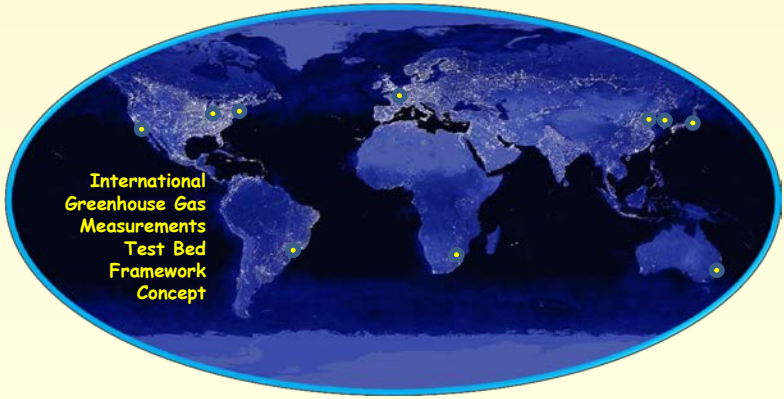
Greenhouse Gas Inventory Data

- 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 – Emissions to & Absorptions from the Atm.
    - Confidence in the material quantities
      - Fundamental for orderly markets and harmony in the transactions found in trade
      - Similarly for fairness in regulation
- Quantification technologies commonly used in international trade & commerce are well established
  - Mass & Volume technologies have millennia of practice
- GHG quantification technologies are not as mature, but similar performance levels are desired
- Some/Many NMI's Have Weights & Measures Regulatory Authority



International GHG Measurements Framework

Engaging the Metrology & Climate Communities



Concept:

- Enable joint development of advanced quantification capabilities for urban/ regional GHG domes and their dynamics;
- Establish scientific validity and performance capabilities of advanced measurement methodologies and instruments;
- A focus for multi-organization efforts;
- Facilitate open, internationally-recognized measurement methodology development and evaluation
- Open data exchange and utilization across national borders,
- Strengthen methods to correlate and calibrate instrument observations on-orbit with those made on the surface to advance accuracy and establish SI traceability

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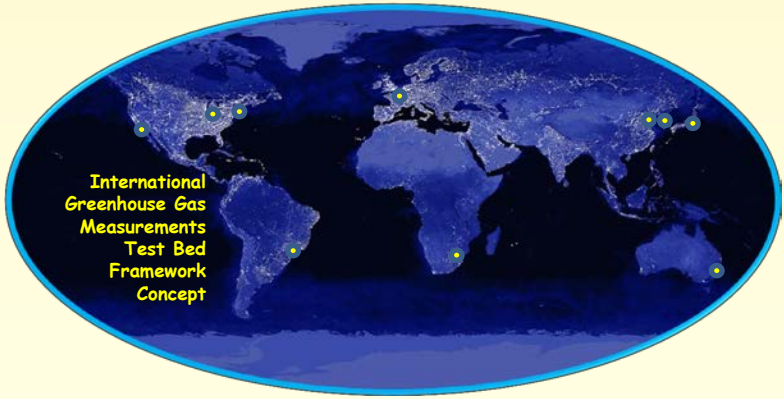
International GHG Measurements Framework

Engaging the Metrology & Climate Communities



Approach:

- **Focus on Megacities as test bed sites**
  - Coverage on 6 of the 7 continents
  - Strategically-Located Cities, their Power Plants and Vehicles
- **Engage with nations or regions having:**
  - Suitably located megacities
  - The scientific and technological capabilities needed, and
  - The necessary national interest and will to commit the required resources
- **Mètre Convention structures**
  - Benefits of an existing treaty organization
  - 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

Emissions Data Quality Diagnostic
Measurement Methodologies

Data Quality Metrics

Internationally – Recognized Greenhouse Gas Mitigation Policies, Procedures, & Structures

National Inventory Data Compilation & Reporting

Bottom-Up


Electricity Generation


Agriculture


General Industrial Energy Generation


Landfills


Chemical/ Petrochemical

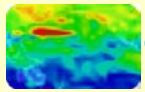
Stationary Sources

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 Capabili
Satellite and C

Whither MRV with the Advent of INDC's (Intended Nationally Determined Contributions)?

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NIST Urban GHG Quantification Program

Goals:

- **Develop and test the performance measurement techniques and approaches for diagnosing and assessing urban greenhouse gas emissions**
- **Establish 3 U.S. cities/regions as testbeds for advancing greenhouse measurement capabilities at urban scales**
- **U.S. testbeds as contributions to a global megacity framework advancing measurement standards and methodologies supporting greenhouse gas mitigation efforts.**

- **Urban Dome Project Test Bed Sites**
  - **Indianapolis: Plume/flow thru meteorology, No nearby large GHG emitters**
  - **Los Angeles: Complex met. and emissions scenarios**
    Significant biogenic sources & sinks, seacoast effects
  - **NE Corridor: Plume/flow thru met., mix of emission characteristics,**
    Meteorology Influenced by large Bay and seacost
    4 large metropolitan regions – Test of urban to regional issues

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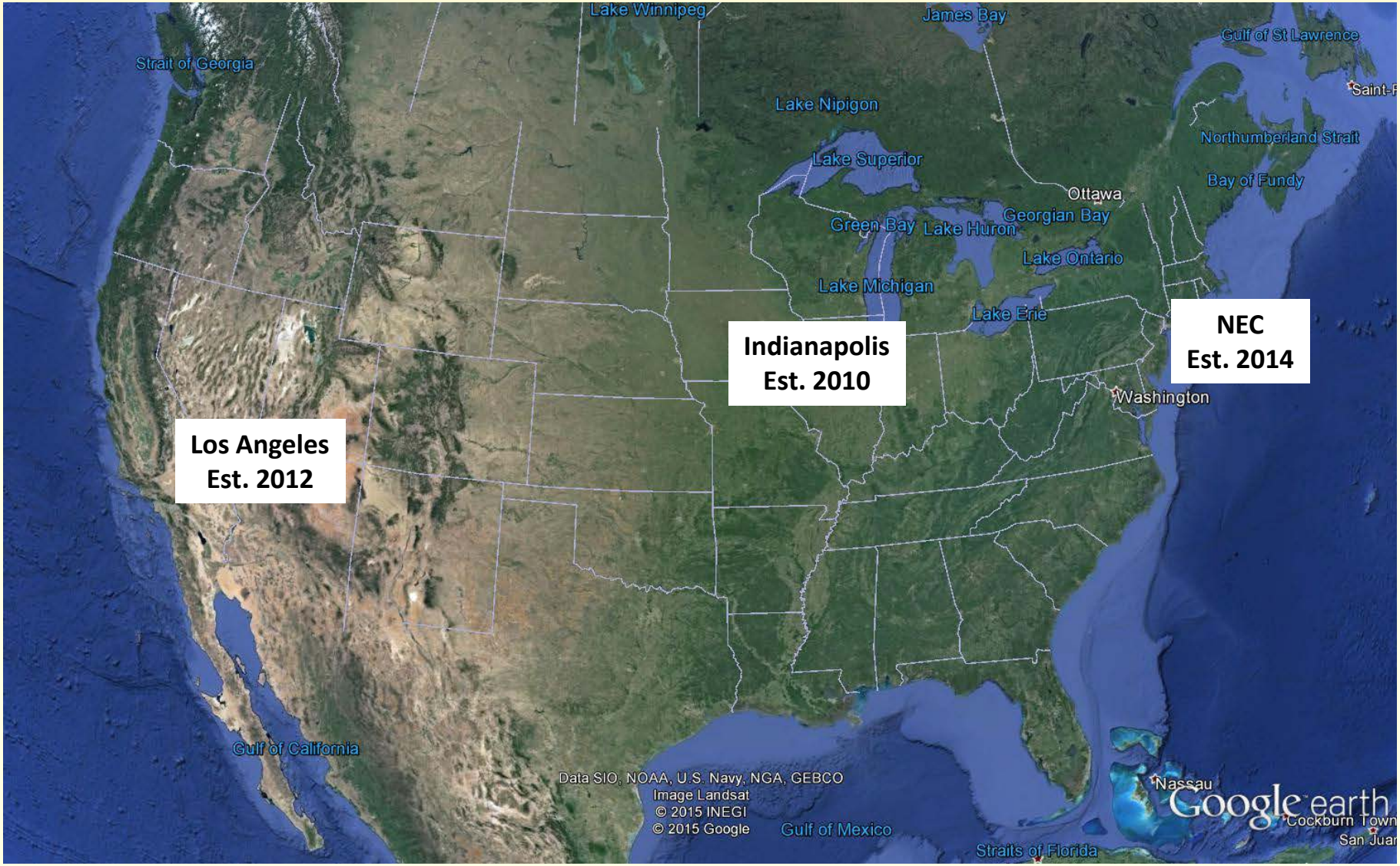
Urban Dome Test Bed Sites



Three Urban Dome Test Bed Sites

Similarity / Dissimilarities

- **Indianapolis – Estimate Fluxes and Reduce Uncertainties by 10%**
  - Geography/Meteorology: flat terrain and more easily modelled
  - Population: 850,000
  - Human Emissions: transportation, buildings, & power generation
  - Biospheric Fluxes:
    - large seasonal fluxes – agriculture outside the city
    - Urban fluxes not characterized directly – 4 eddy flux measurements for surface energy exchange
- **Los Angeles – Develop Methods to Diagnose Emission Trends**
  - Geography/Meteorology: Atm. trapping terrain, ocean effects, difficult meteorology to model
  - Population: ~16 Million
  - Human Emissions: transportation, buildings, power gen., & manufacturing
  - Biospheric Fluxes:
    - Investigation of significant dairy production in the eastern Basin – manure management & CH_4 emissions
    - Can eddy flux help with surface energy exchange?
- **NEC – Estimate Fluxes and Reduce Uncertainties by 10%**
  - Geograph y/Meteorology: significant influence of Chesapeake Bay and rivers
  - Population: ~6 Million in Washington DC/Baltimore Initial Region
    ~40 Million in major metropolitan areas of the Corridor
  - Human Emissions: transportation, buildings, power gen., & manufacturing
  - Biospheric Fluxes: large seasonal fluxes and influence of wetlands and marshes

Three Urban Dome Test Bed Sites

- Progress
  - Indianapolis – Obj. to Estimate Fluxes and Reduce Uncertainties to < 10% of value
    - Continuous and Flask Measurements
    - Eddy Covariance Measurements
    - LIDAR Measurements
    - TCCON Measurements
    - Aircraft Flights and Mass Balance Estimates
    - Transportation including WRF runs and Some Footprints
  - Los Angeles – Obj. to Diagnose Trends
    - Continuous and Flask Measurements
    - LIDAR Measurements
    - FTS/TCCON Measurements
    - Satellite Observations
    - Aircraft Flights
    - Some Transportation including WRF runs
  - NEC – Obj. to Estimate Fluxes and Reduce Uncertainty to <10% of value
    - Network Designed, installation to start this summer,
    - Some Aircraft Flights
    - Begin establishing common analysis framework and capabilities

Summary & Questions

- Tiered architecture covering the necessary spatial scales
- Impact of low-cost satellite instruments
  - Heightens need for internationally-recognized methods
- Whither ‘verification’ concepts in the era of Intended Nationally Determined Contributions ?
- Urban to Global framework has some parts started. What’s needed to move such concepts forward
  - Need for source attribution is integral to successful implementation of mitigation schemes
  - Information systems, unified system of methodologies spanning global to urban levels is needed for implementation
- Need for advancing cooperative developments within both the international metrology and climate science communities

Thank You and Questions

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THANK YOU FOR YOUR

ATTENTION

Questions or Comments
Time Permitting