NIST Greenhouse Gas and Climate Science Measurements Program Overview

Test Beds Advancing Urban Greenhouse Gas Dome Measurement System Development

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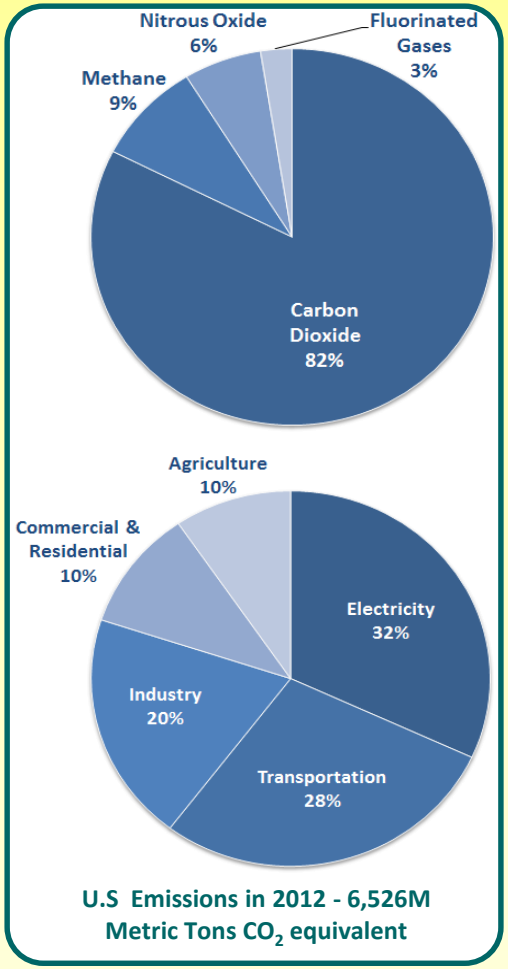
Agenda
The Indianapolis Flux Experiment

- Program Objectives and Project Information
- NIST Interest in Urban GHG Test Beds
  - Urban GHG Emissions and Test Beds in the U.S
  - An International Framework of GHG Test Beds

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 & reporting accuracy
    - Independent methodologies to diagnose and verify emissions data both nationally and internationally
    - Applications focused on cities and metropolitan areas
  - Remote observations, both 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 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 Reconcile 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 Megacity Test Beds

- **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 Observing Standards
  - 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

GHG Emissions Determination Methods

Bottom-Up
Emission Source Parameters

- Combustion Sources
  - Cont. Emissions Monitors
    - Electrical Generation
    - Industrial Energy Production
  - Fuel Calculation method
    - Fuel Mass
    - Energy content - calorimetry
- Area Sources – CH_4 & N_2O
  - Agriculture, Nat. Gas system, Landfills
  - Emission – Activity Factor Model
    - System descriptions based on experimental results generalized to specific sources
- Focused on parameters directly associated with the emitting process

Top-Down
Atmospheric Parameters

- Tracer-transport methods
  - Boundary Layer transport – mass flow
  - Mixing ratio measurements - concentration
- Aircraft observations
  - Direct Sampling
  - Remote Methods
- Remote Sensing
  - IR Spectroscopy Based
  - Satellite , airborne, and surface- based
- Tracing GHG plumes back to their origin and estimating the flux strength at that point

Greenhouse Gas Emissions and Climate Communities

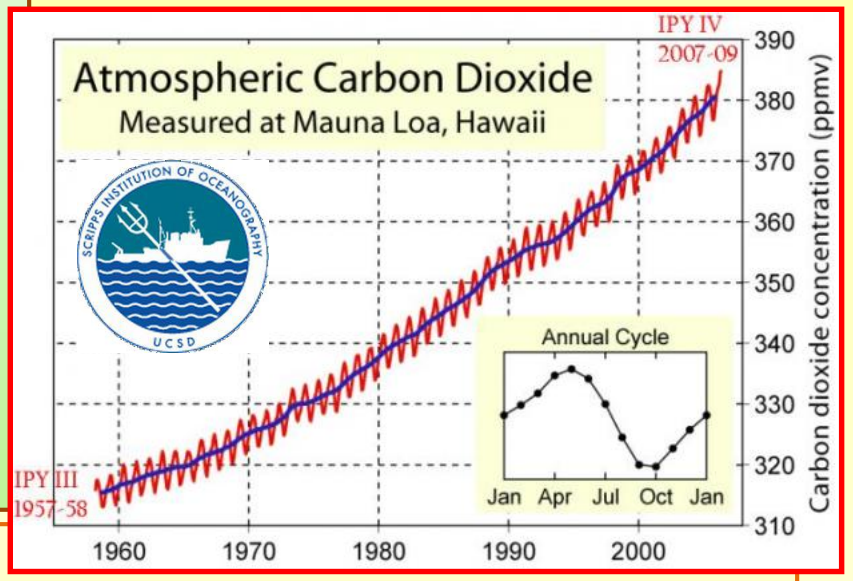
Some Definitions and Data

GHG Reporting Community:

- GHG Emissions *& Offsets* make National Inventories
- Bottom-Up - *Measurable*
- Accountancy Focus
- 3rd party Verification of procedural compliance
- U.S. EPA-developed procedures predominate and are central in IPCC reporting requirements internationally - *Reportable*

Climate Science Community:

- Observing the Atmosphere to understand its process mechanisms
  - Bio-Geochemical Processes in the Atmosphere & Oceans
- Top-Down – *Verifiable Independent of Source or Sink Information*
- Significant Complexity Levels
- Well-Established, international organizations involved



Definitions

- UNFCCC – United Nations Framework Convention on Climate Change
- MRV
  - Measureable – Emissions are capable of being measured
  - Reportable – Measured, and therefore, reported
  - Verifiable – *Independent* validation of reported emissions data

Bali Action Plan, UNFCCC - COP 13 (2007)

- NAMAs – Nationally Appropriate Mitigation Activities
  - Challenge is to meet MRV requirements for Consistency, Transparency, Comparability Completeness, and Accuracy.
- Bottom-up – Emissions determination using in-facility methodologies, e.g., Continuous Emissions Measurement (CEMs) systems for stack gas flows or fuel calculation methods for total combustion emissions
- Top-Down – Emissions determined from observations of the atmosphere – GHG flux into and through it

Inventories and Reduction Targets

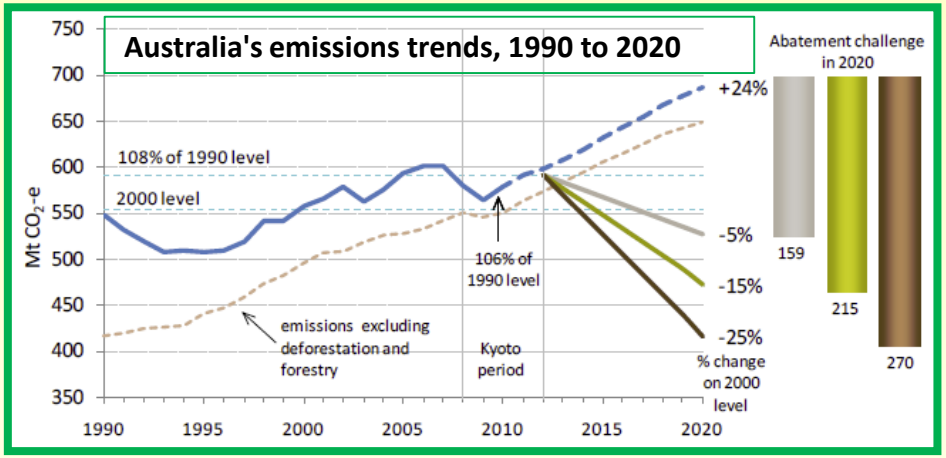
What Accuracy is Needed to Support Policies

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 foundational to 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. and International

- President Obama's Climate Action Plan: 20% relative to 2005 by 2020
- EPA's recent Carbon rule ~30% relative to 2012 by 2030
- UK: At least 80% (from the 1990 baseline) by 2050
- Australia: 5% below 2000 level by 2020
- China: ??



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

NIST's Interest in Urban Measurements

- Improve measurement of greenhouse gas emissions in areas containing multiple emission sources and sinks, in and around cities
- Develop measurement tools supporting independent means to diagnose the accuracy of, and perhaps in the future verify, greenhouse gas inventory data at urban and regional geospatial scales.
- Understand and reconcile emissions data obtained from bottom-up and from top-down methods
- Develop urban greenhouse gas measurements test beds as a means to:
  - Develop advanced measurement tools
  - Serve as a basis for evaluating the performance of new greenhouse gas measurement approaches ranging from surface to satellite-based methods

Prospective GHG Measurement Capabilities

Satellite and Surface-Based Measurements: 2020 - 2050

Satellites - Total-Column Integrated GHG Concentration Measurements

- Multiple satellite instruments planned or on orbit
  - Near-infrared spectroscopic instruments
- Effective and recognized traceability strategies needed
- Do not make GHG flux measurements as currently conceived, GHG concentration only

GHG Observing Satellites On Orbit

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

Planned - NASA

- OCO 3 – Intnt'l. Space Station – Launch Date?
- ASCENDS (Active Sensing of CO_2 Emissions over Nights, Days, and Seasons) – Launch Date?

Development - ESA

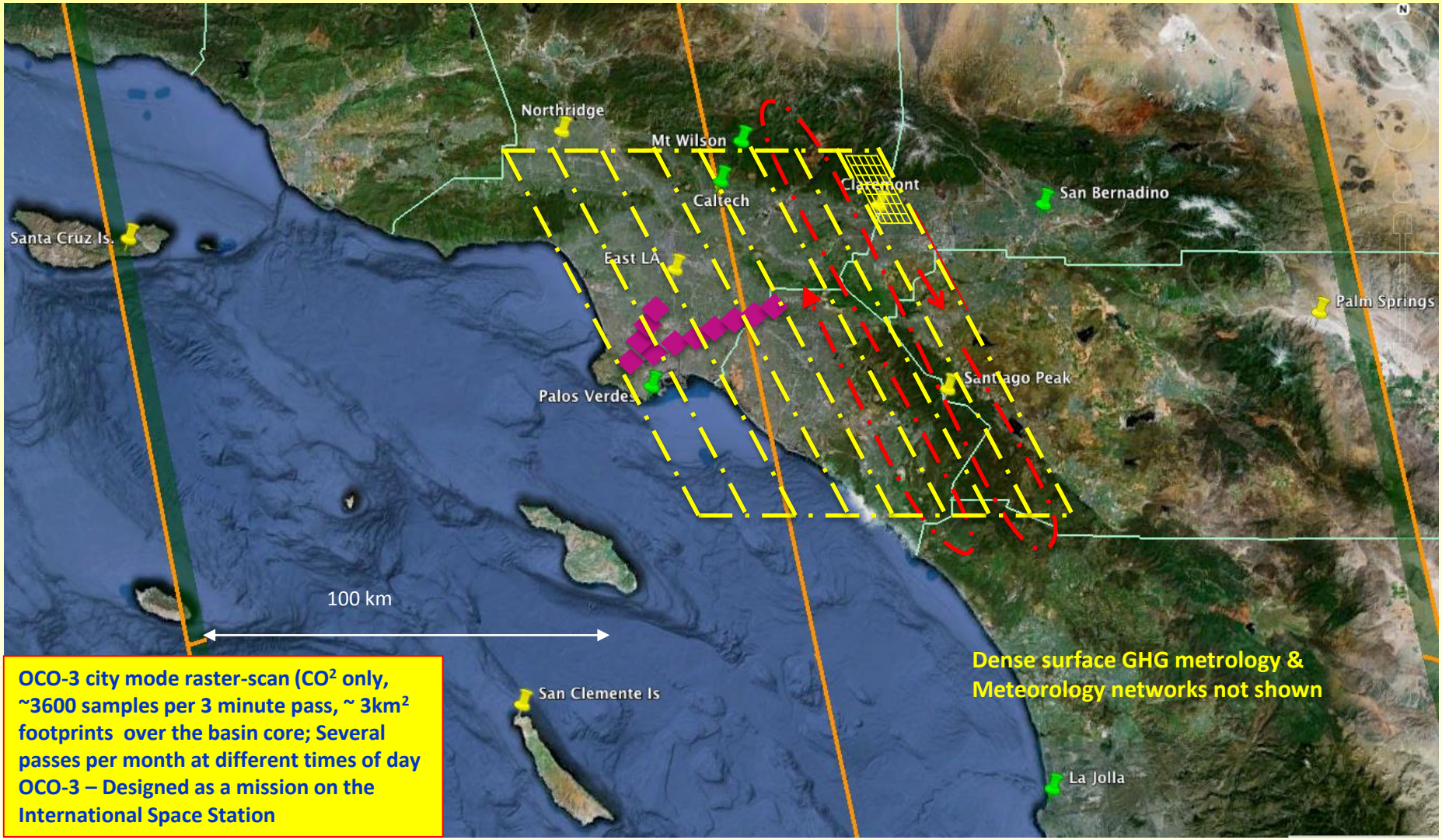
- CarbonSat –CO_2 and CH_4 observations

Surface-Based Systems GHG Concentration and Transport (Flux) Measurements – Source Attribution

- Flux measurement capability supports attribution and independent verification of inventory data
- 1 - 5 km^2 or better geo-spatial resolution to support satellite observations
- New measurement methodologies needed for independently diagnosing and ultimately verifying inventory data
- Source attribution information

Satellite GHG Monitoring – A Future Example

OCO-3 City-Mode over a Megacity (LA Example, ~ 2018)



OCO-3 city mode raster-scan (CO^2 only, ~3600 samples per 3 minute pass, ~ $3km^2$ footprints over the basin core; Several passes per month at different times of day
OCO-3 – Designed as a mission on the International Space Station

Existing/planned GHG station | Proposed GHG stations | GOSAT samples | OCO-2 samples (1 x 3 km spot | OCO-3 samples

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Tools and Test Beds –Diagnosing Greenhouse Gas Inventory 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*
- *A Test Bed Having Moderately Complex Topography & Meteorology*
- *Initiation of The Effort Began in Mid-FY 14.*

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

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The Indianapolis Flux Experiment (INFLUX)

A Top-Down/Bottom-Up Greenhouse Gas Quantification Experiment

Objective: Develop measurement tools to provide independent verification of greenhouse gas inventories at urban and regional scales

- **Phase I – A GHG Mass Balance Experiment – Begun in early 2010**
  - Combined Aircraft and surface-based measurement methodology
  - High temporal and spatial resolution CO_2 inventory – Augmentation of EPA information
- **Phase II – Dense Observing Networks & Atmospheric Boundary Layer Transport Modeling**
  - Measurement of GHG Urban Domes and their dynamics utilizing a ***Dense Measurement Network*** approach coupled with aircraft observations
  - State-of-the-art bottom-up methods
  - Reconciliation methodologies for bottom-up vs. top-down results
- **Quantitative Goals**
  - **Measure emission fluxes to within 10% or better**
  - **Identify major emitter locations within 1 - 2 km^2**

The LA Megacity Carbon Project

Motivation:

Determine GHG emissions of a city in terms of measurement uncertainty.

Currently estimated differences between actual and reported emissions that by 50% or more when comparing inventory estimates with atmospheric measurements for a specific location, sector or gas.

Objective:

Demonstrate a scientifically-robust capability to measure multi-year *emission trends* of carbon dioxide (CO_2), methane (CH_4), and carbon monoxide (CO) attributed to individual megacities and selected major sectors.

Reduce uncertainty by jointly improving GHG emissions data and atmospheric observations.

Use independent and accurate measurements, identify error sources to improve emissions data quality and ultimately, validate basis for emission inventory.

Approach:

Use surface-based GHG observing network and aircraft observations coupled with state-of-the-art boundary layer measurements and characterization methods to observe emission trends in the South Coast Air Basin.

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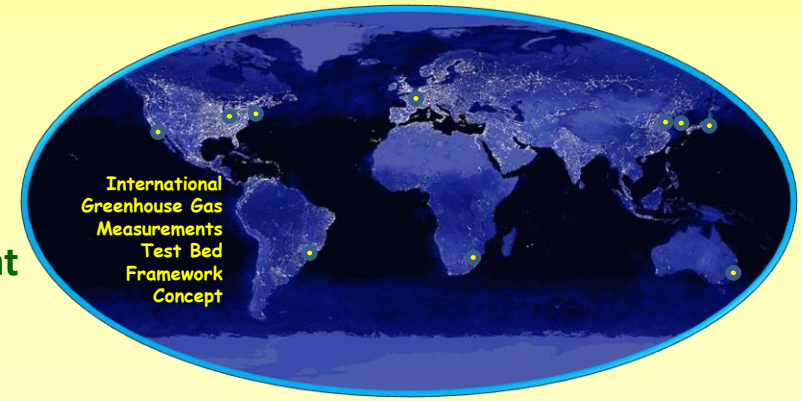
International Greenhouse Gas Measurements Framework

International Metrology & Climate Communities Engagement

Concept:

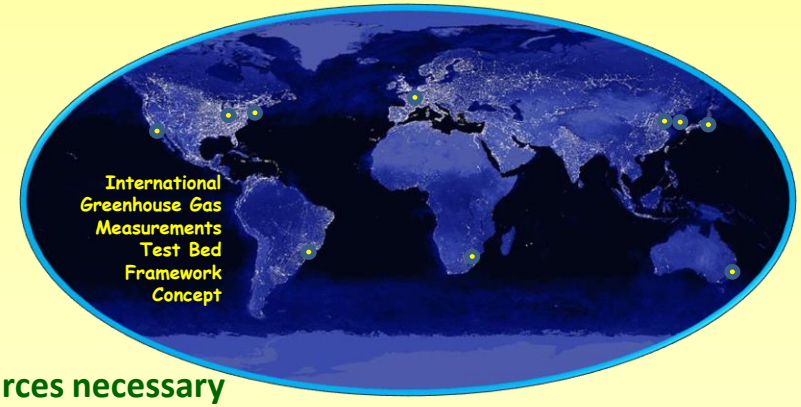


- **Establish an International Greenhouse Gas Measurements Test Bed Framework that:**
  - Enables joint development of advanced measurement capabilities for urban and regional GHG domes and their dynamics,
  - Establishes scientific validity and performance capabilities of advanced measurement methodologies and instruments,
  - Provides a focus for multi-organization efforts with locations and organization on all continents but Antarctica,
  - Facilitates open, internationally-recognized measurement methodology development and evaluation with open data exchange and utilization across national borders, and
  - Strengthens methods to correlate and calibrate satellite measurements in-situ with those made on the surface as a means to establish SI traceability
- **As the Basis for Global Recognition of Measurement Capabilities for:**
  - Diagnosing the quality of GHG emissions data and
  - Verification support for global Measurement, Reporting and Verification (MRV) concepts likely to be required by future international mitigation agreements

International Metrology & Climate Community Engagement

International Greenhouse Gas Measurement Framework

Approach:



- **Jointly development urban GHG measurement methods utilizing megacities, as test bed sites**
- **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 resources necessary**
- **Joint GHG measurement science research developing methodologies thoroughly vetted for their scientific foundation, accuracy, and recognition within the international community.**
- **Use existing Convention of the Mètre structures**
  - **Existing, internationally-recognized treaty organization with well-demonstrated working relationships and the necessary organizational structures largely in-place**
  - **Facilitates communication & organization**
  - **Broaden international linkages – WMO, international climate change/science**

Challenges for NMIs & the NMI Community

- **Most NMI's currently may not have the necessary skill sets and connections**
  - **Partnering with national organization to aggregate the technical resources / expertise necessary to address this class of measurement science research**
  - **Strengthen expertise in climate science and related disciplines to successfully interface with both the national climate science community and the international community**

Traceability

- **Traceable measurement results occur in the context of systems where most, or all, system components are well understood & characterized.**

- **Measurement science research seeks to achieve measurement system understanding supporting adequate description of system performance**

- **Until a sufficient level of understanding of the processes and procedures comprising a measurement system are available, one can only plan system configuration so that it can ultimately be traceable.**

Thanks for your Attention