

# **ANDIMET Regional Workshop on Metrology and Technology Challenges of Climate Science and Renewable Energy**

**Bogotá, Colombia**

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## **Air Quality Monitoring and Climate Change Related Measurements (GHG)**

### **CONTENT**

- 1. Climate change issues and consequences**
- 2. Quantities to be measured?**
- 3. Air quality and GHG substances**
- 4. Regulatory framework**
- 5. Reflections and conclusions**

# 1. Climate change issues and consequences

- **Increase of the average temperature in the biosphere due to the increase of more heat absorbing molecules in the air and the natural greenhouse effect**
  - Increase in frequency, intensity and change of pattern in meteorological phenomena, e. g.: rain, hurricanes, storms, more prolonged droughts and heating waves.
  - Glaciar depletion or extinction of ice in the poles and in the terrestrial surface in the mountains
  - Increase in temperature of sea and in its level
  - Change in the behaviour of animals and plants

## ***More consequences***

- Loss of land in coasts; floods; habitat, species and agricultural losses; increase of some bacteria and parasites illnesses associated with heat; ...

## 2. Quantities to be measured?

### Recognize quantities not just variables

- Meteorological quantities: temperature, wind speed and direction, water vapour amount fraction, pressure, precipitation, surface/earth radiation budget, solar irradiance, cloud properties, ...
- Atmospheric composition: long-lived GHGs: amount fractions of CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, ...; O<sub>3</sub>, aerosol and their precursors
- Oceans: CO<sub>2</sub> partial pressure, O<sub>2</sub>, acidity, phytoplankton, temperature, ....
- .....

### 3. Air quality and GHGs substances

- The Greenhouse gases: Half live time and warming potential

Origen	Gases	Fuentes	Vida media en años	Potencial de Calentamiento
Gases de origen natural	Bióxido de carbono (CO <sub>2</sub> )	Quema de combustibles fósiles (carbón, derivados de petróleo y gas), reacciones químicas en procesos de manufactura; (como la producción de cemento y acero) cambio de uso de suelo (deforestación).	50 a 200	1
	Metano (CH <sub>4</sub> )	Descomposición anaerobia (cultivo de arroz, rellenos sanitarios, estiércol), escape de gas en minas y pozos petroleros.	12 ± 3	21
	Óxido nitroso (N <sub>2</sub> O)	Producción y uso de fertilizantes nitrogenados, quema de combustibles fósiles.	120	310
Gases antropogénicos	Hidrofluorocarbonos (HFCs)	Emitidos en procesos de manufactura y usados como refrigerantes.	1.5 a 264	140-11,700
	Perfluorocarbonos (PFCs)	Producción de Aluminio, fabricación de semiconductores, sustituto de las sustancias destructoras del ozono. Ej. Uso de solventes, espumas, refrigeración fija.	2600 a 50000	6,500-9,200
	Hexafluoruro de Azufre (SF <sub>6</sub> )	Producción y uso en equipos eléctricos; Producción de magnesio y aluminio; Fabricación de semiconductores.	3200	23,900

### 3. Air quality and GHGs substances

## Why Greenhouse gases and air pollutants together?

“A gaseous atmosphere is maintaining our life”

- **Significant**: *understanding chemistry and physics of the atmosphere*
- Primary and secondary air pollutants and their precursors or (sub)products are sometimes all relevant pollutants in climate change (e. g. O<sub>3</sub>: CH<sub>4</sub>, VOCs, NO<sub>x</sub>, etc.; CO<sub>2</sub>: CO, CH<sub>4</sub>, carbon cycle; nitrogen cycle; acid rain: SO<sub>x</sub>, NO<sub>x</sub>)...
- Substances and radicals that induce reactions or the presence of other air pollutants (CHCO, OH, PANs, etc.). Some of them are inestable, thus not prone to have them as measurement standards.

### 3. Air quality and GHGs substances

- **Significant air pollutants in atmospheric monitoring (emissions and inmissions)**

**Development of Chemical measurement standards in Mexico**

- Greenhouse gases (GHGs): those 7 reported groups GHGS to **UNFCCC (& Kyoto Protocol)**
  - **CO<sub>2</sub>**, **CH<sub>4</sub>**, **N<sub>2</sub>O**, **SF<sub>6</sub>**, originally chlorofluorocarbons (CFCs), replaced by hydrochlorofluorocarbons (HCFCs), now replaced by the latest hydrofluorocarbons (HFCs), **NF<sub>3</sub>**
- Short-Lived Climate Forcers or Pollutants (SLCFs / SLCPs) for near-term climate protection: **CH<sub>4</sub>**, **tropospheric O<sub>3</sub>**, **black carbon**, short-lived hydrofluorocarbons (HFCs).
  - HFCs are a type of fluorinated greenhouse gas intentionally made as replacements for stratospheric ozone depleting substances (ODS, **Montreal Protocol**), for use in the same applications (air conditioning, refrigeration, solvents, foam blowing and aerosols)
- Criteria air pollutants (gases) for ambient air (inmissions): are 7, but in Mexico only testing 5
  - **Pb**, **CO**, **O<sub>3</sub>**, **NO<sub>2</sub>**, **PM<sub>10, 2,5</sub> ... 1.0 ...**, **SO<sub>2</sub>**, **VOCs**, **H<sub>2</sub>S** (not a criteria air pollutant, but at ambient levels also measured in specific places)
- Stack and mobile emissions
  - **Metals (Pb, Hg, ...)**, hydrocarbons (HCs expressed as **C<sub>3</sub>H<sub>8</sub>** or benzene) **CO**, **CO<sub>2</sub>**, **NO<sub>x</sub>**, **PM<sub>10, 2,5</sub> ... 1.0 ...**, **SO<sub>2</sub>**, **VOCs**, ...
- Persistent Organic Pollutants (POPs). **Stockholm Convention**. **Dioxins**, **Pesticides**, **PCBs**.
- **PAHs** (carcinogenic – mutagenic).

**Bolded and shadowed = Priorities detected by environmental authorities, Red = not worked, Blue = not worked but feasible to work with, Green = worked or in process to be done, Gray = lower demand, not worked, Pink = Significant in some sectors, but not being metrologically worked in CENAM, Purple = Some work done, but in other matrices, not for air applications**

### 3. Air quality and GHG substances



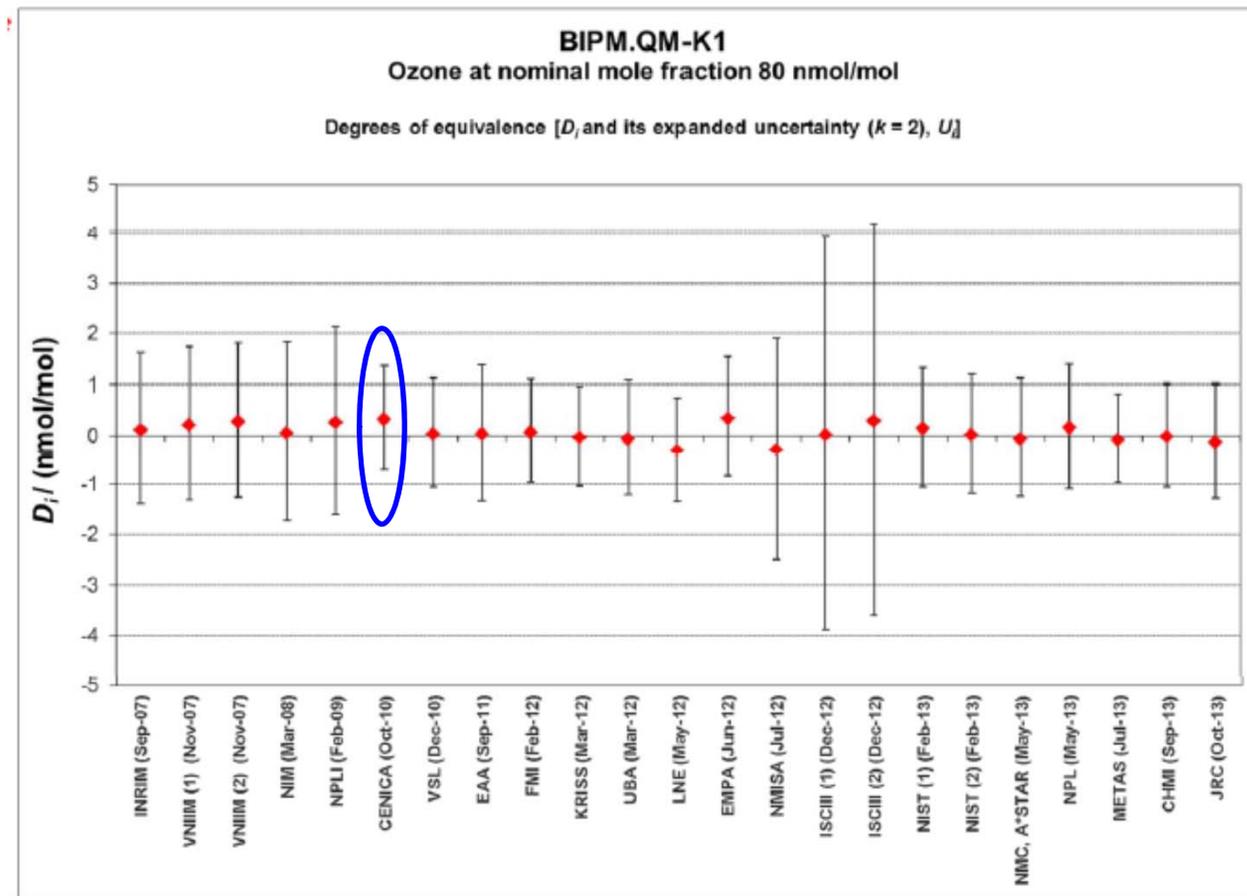
## What has been already done and is being done? Comparisons in Air quality & GHG-CCQM-CIPM

Date updated	1 Dec 2013					
WG	Reference No.	Description	Coordinating Laboratory	Start date	Status	Hyperlink to latest version of report
<b>Criteria air pollutants</b>						
GAWG	BIPM.QM-K1	Ozone at ambient level	BIPM	2006	Approved for Equivalence	<a href="#">BIPM QM K1 Reports</a>
GAWG	CCQM-K51	CO in nitrogen (5 µmol/mol)	NMISA	2006	Approved for Equivalence	<a href="#">CCQM-K51 Final Report</a>
GAWG	CCQM-K84	Ambient Carbon Monoxide	KRISS	2010	In progress	
GAWG	CCQM-K74	Nitrogen dioxide 10 µmol/mol	BIPM	2010	Approved for Equivalence	<a href="#">CCQM-K74 Final Report</a>
GAWG	CCQM-P73	Nitrogen monoxide in nitrogen	BIPM	2006	Completed	<a href="#">CCQM-P73 Final Report</a>
GAWG	CCQM-K26.a	Reactive gases-ambient levels - NO in N <sub>2</sub>	NPL	2003	Approved for Equivalence	<a href="#">CCQM-K26.a Final Report</a>
GAWG	CCQM-K26.b	Reactive gases-ambient levels - SO <sub>2</sub> in Air	NPL	2003	Approved for Equivalence	<a href="#">CCQM-K26.b Final Report</a>
<b>Other air pollutants</b>						
GAWG	CCQM-K7	Benzene/toluene/xylene (BTX) in N <sub>2</sub> /Air	NIST	1999	Approved for Equivalence	<a href="#">CCQM-K7 Final Report</a>
GAWG	CCQM-K10	BTX in N <sub>2</sub> (low conc 10-30 ppb)	NIST/NPL	2001	Approved for Equivalence	<a href="#">CCQM-K10 Final Report</a>
GAWG	CCQM-K22	VOCs in Air	NMIJ	2003	Approved for Equivalence	<a href="#">CCQM-K22 Final Report</a>
GAWG	CCQM-K121	Terpenes in air	NIST	2016	Planned	
GAWG	CCQM-K46	Ammonia in nitrogen	VSL	2005	Approved for Equivalence	<a href="#">CCQM-K46 Final Report</a>
GAWG	CCQM-K117	NH <sub>3</sub> in nitrogen	VSL	2015	Planned	
GAWG	CCQM-K30	Formaldehyde in air	BIPM	2010	Planned	
<b>Climate change (GHG)</b>						
GAWG	CCQM-P41	Greenhouse gases CO <sub>2</sub> , CH <sub>4</sub> - ambient levels	VSL	2002	Completed	<a href="#">CCQM-P41 Final Report</a>
GAWG	CCQM-K52	CO <sub>2</sub> in air (360 - 400 ppm)	VSL	2006	Approved for Equivalence	<a href="#">CCQM-K52 Final Report</a>
GAWG	CCQM-K120	Ambient CO <sub>2</sub>	BIPM with NIST	2015	Planned	
GAWG	CCQM-K82	Methane in air	BIPM	2009	In progress	
GAWG	CCQM-K68	N <sub>2</sub> O at ambient levels	KRISS	2008	Approved for Equivalence	<a href="#">CCQM-K68 Final Report</a>
GAWG	CCQM-K15	SF <sub>6</sub> , CFCs - emission levels	KRISS	2003	Approved for Equivalence	<a href="#">CCQM-K15 Final Report</a>
GAWG	CCQM-K94	DMS (Di-methyl sulphide) in nitrogen	KRISS	2011	In progress	
GAWG	CCQM-K83	Halocarbons in air	NIST	2011	In progress	

### 3. Air quality and GHG substances

#### What has been already done and is being done? Comparisons in Air quality & GHG-CCQM-CIPM

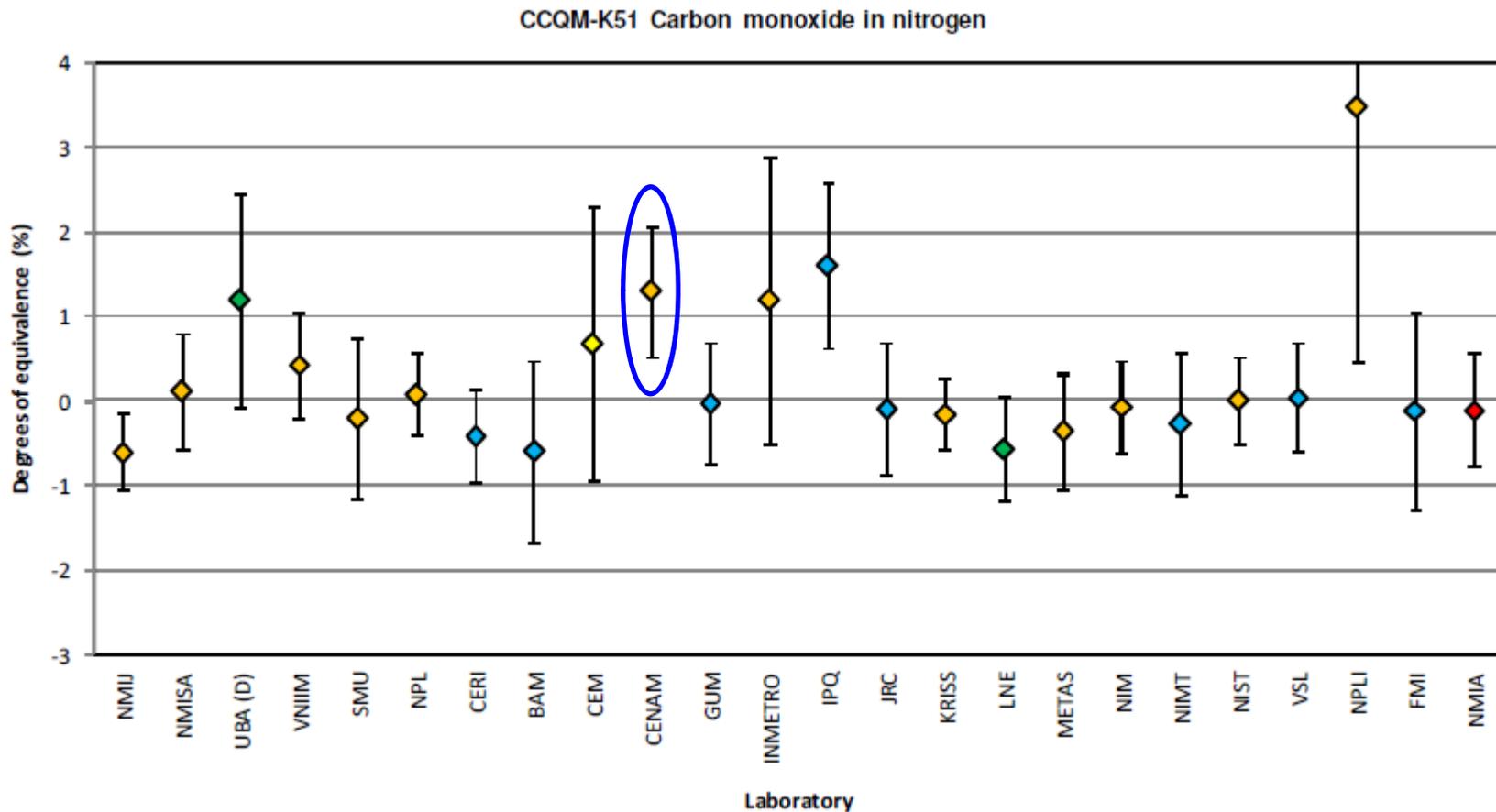
Criteria air pollutants: Ozone



### 3. Air quality and GHG substances

#### What has been already done and is being done? Comparisons in Air quality & GHG-CCQM-CIPM

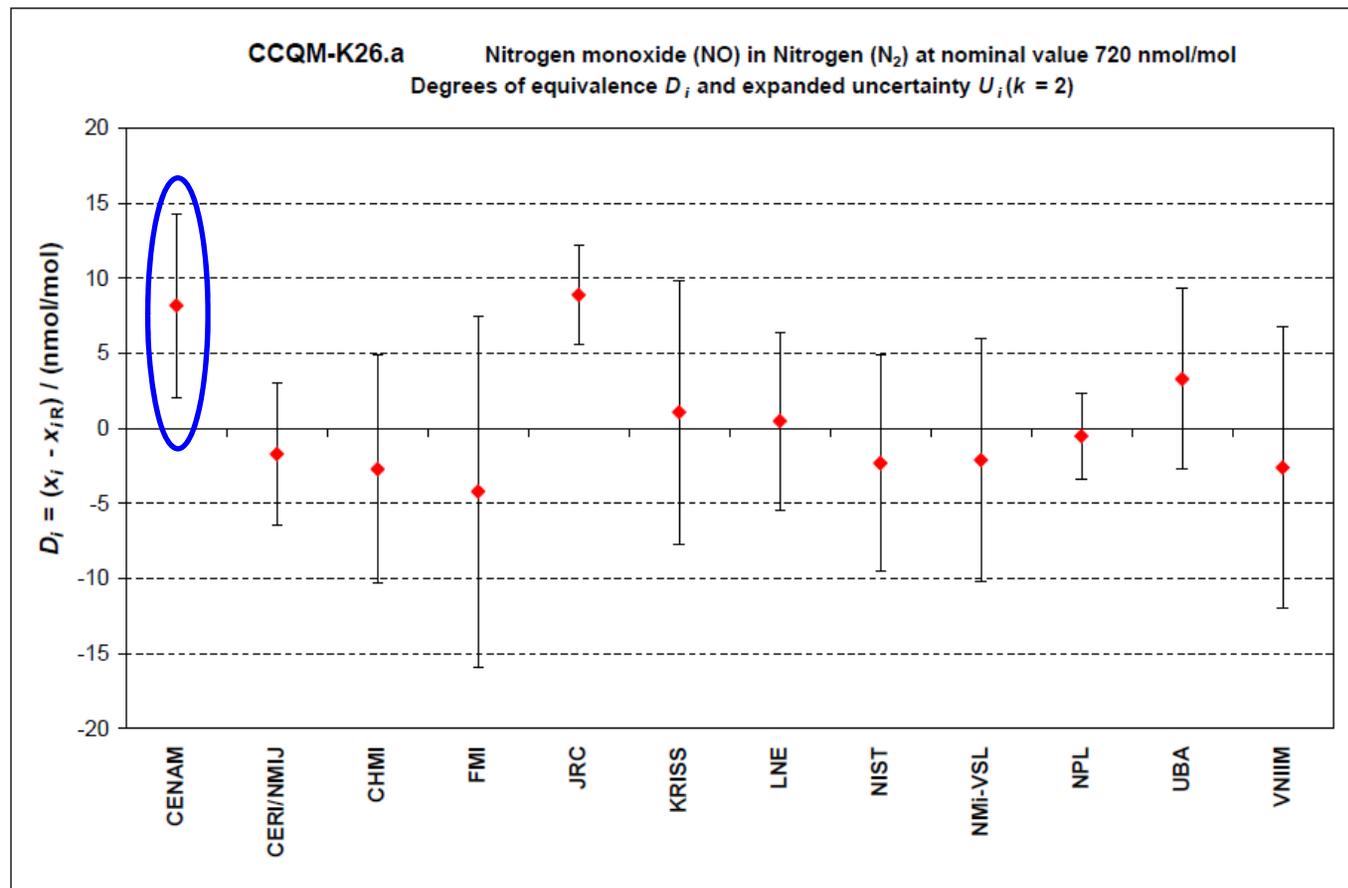
Criteria air pollutants: Carbon monoxide, a new CCQM-K84 is in progress



### 3. Air quality and GHG substances

#### What has been already done and is being done? Comparisons in Air quality & GHG-CCQM-CIPM

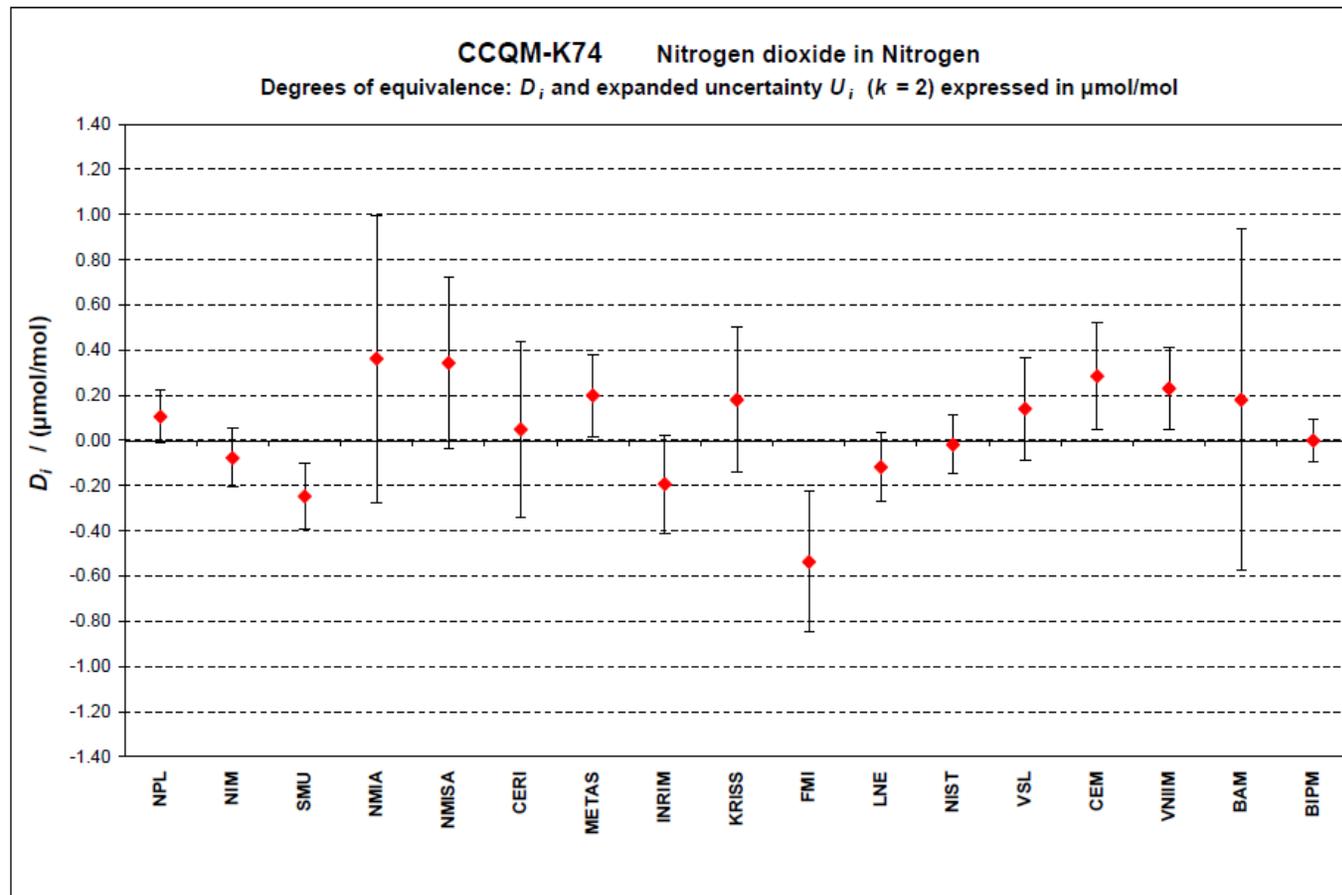
Criteria air pollutants: Nitrogen dioxide: 1st Nitrogen monoxide



### 3. Air quality and GHG substances

#### What has been already done and is being done? Comparisons in Air quality & GHG-CCQM-CIPM

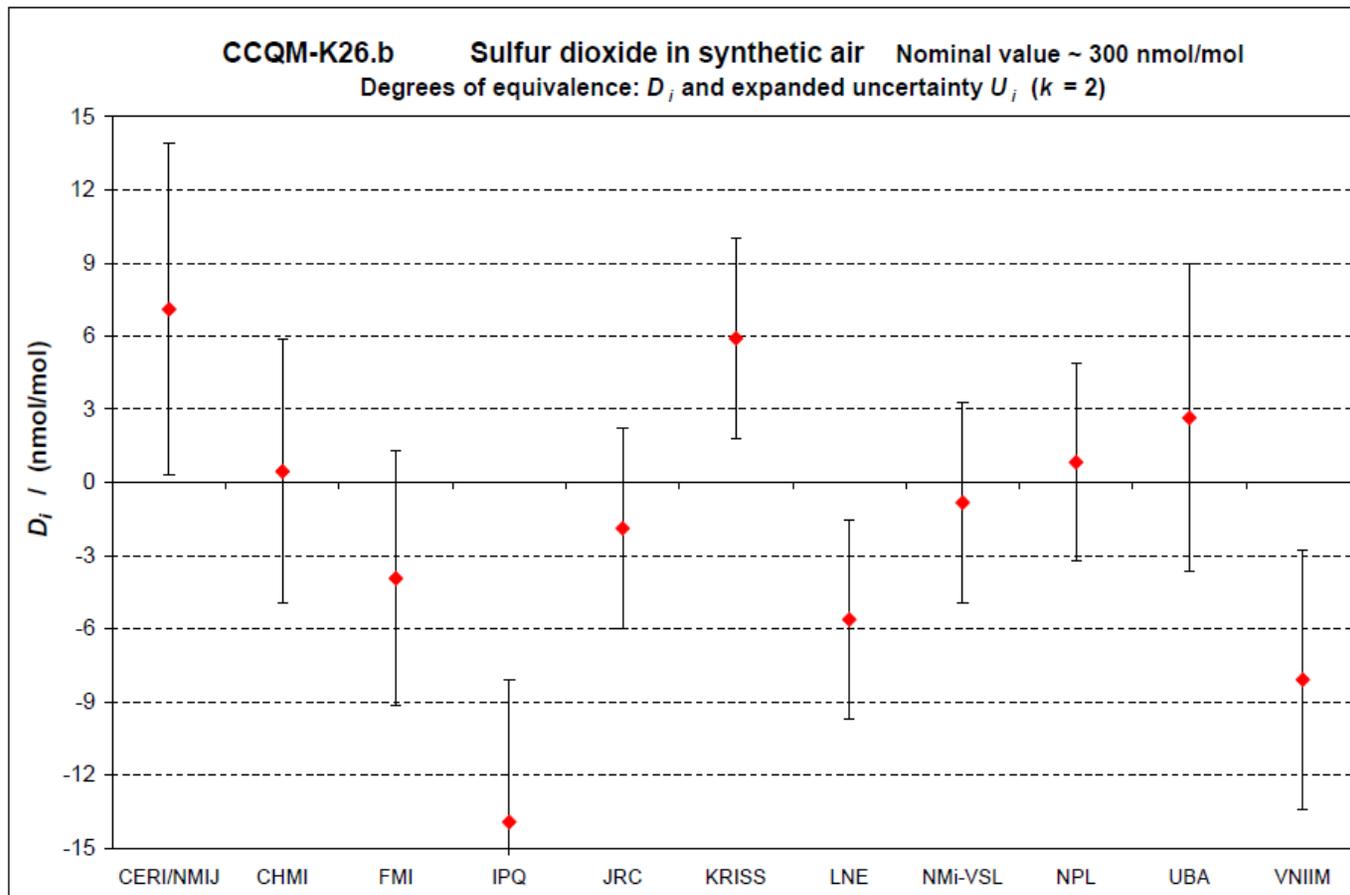
Criteria air pollutants: Nitrogen dioxide: 2nd Nitrogen dioxide



### 3. Air quality and GHG substances

#### What has been already done and is being done? Comparisons in Air quality & GHG-CCQM-CIPM

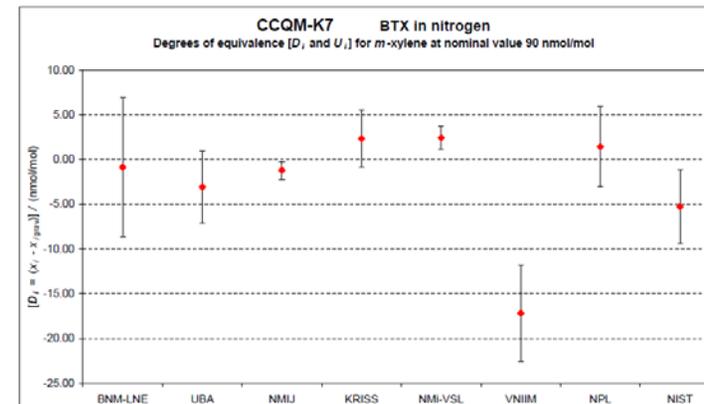
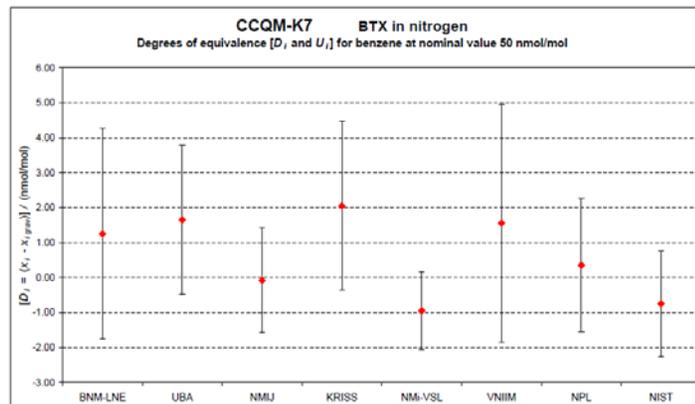
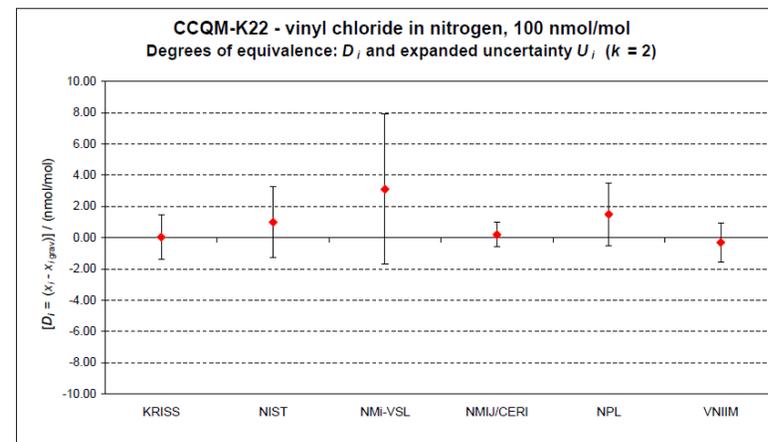
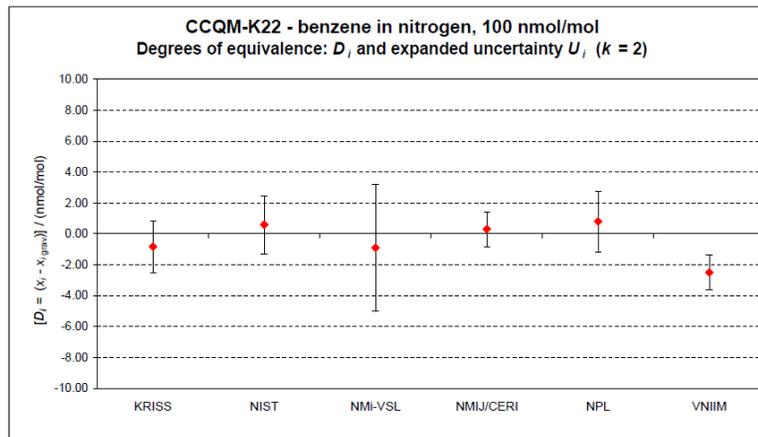
Criteria air pollutants: Sulfur dioxide



### 3. Air quality and GHG substances

#### What has been already done and is being done? Comparisons in Air quality & GHG-CCQM-CIPM

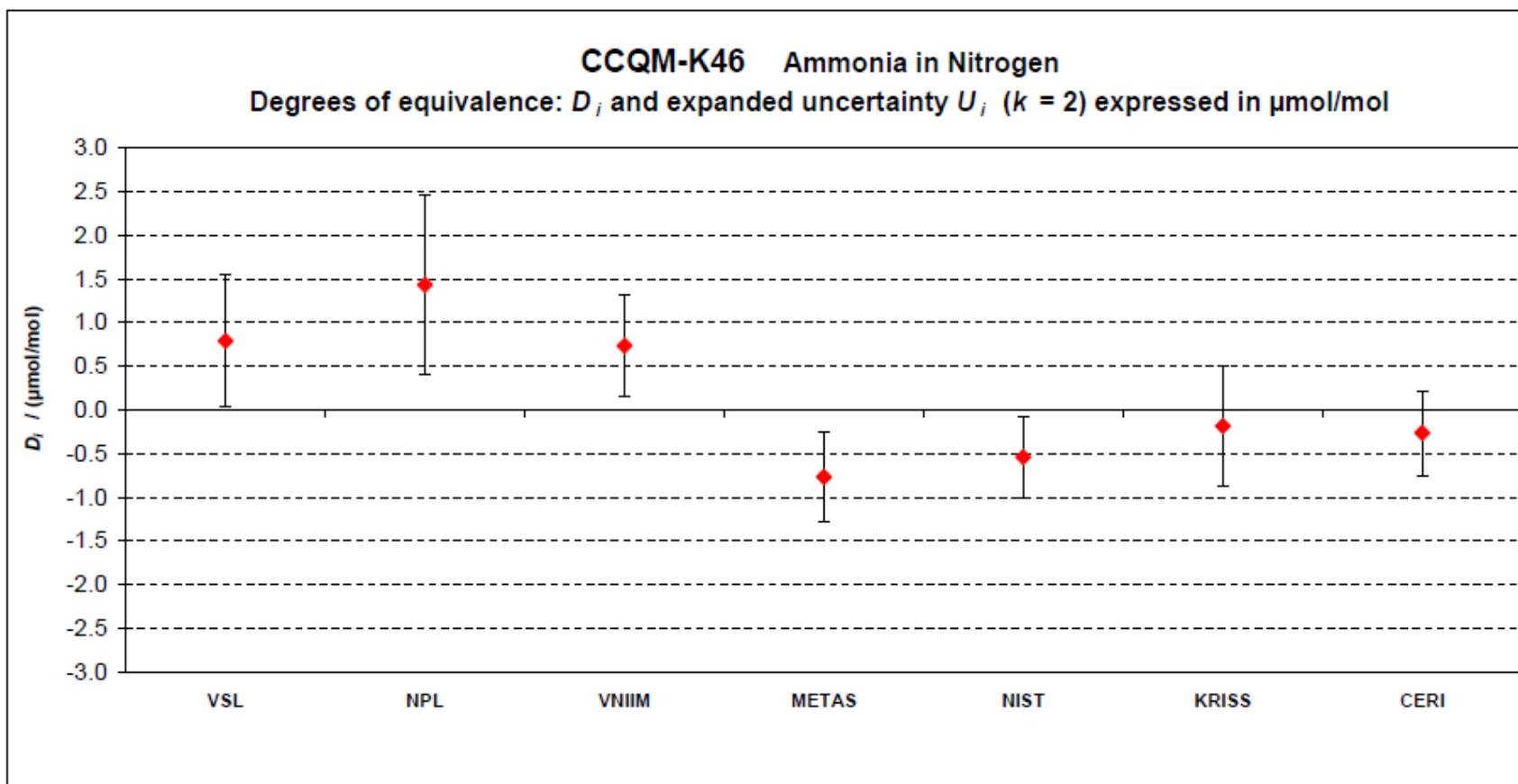
Other (criteria) air pollutants: some VOCs (only Hazardous Air Pollutants: Benzene, chloroform, dichloromethane, trichloroethylene, tetrachloroethylene, 1,2-dichloroethane, 1,3-butadiene, and vinyl chloride) at 100 nmol/mol level; BTEX 50 to 100 nmol/mol, e. g.



### 3. Air quality and GHG substances

#### What has been already done and is being done? Comparisons in Air quality & GHG-CCQM-CIPM

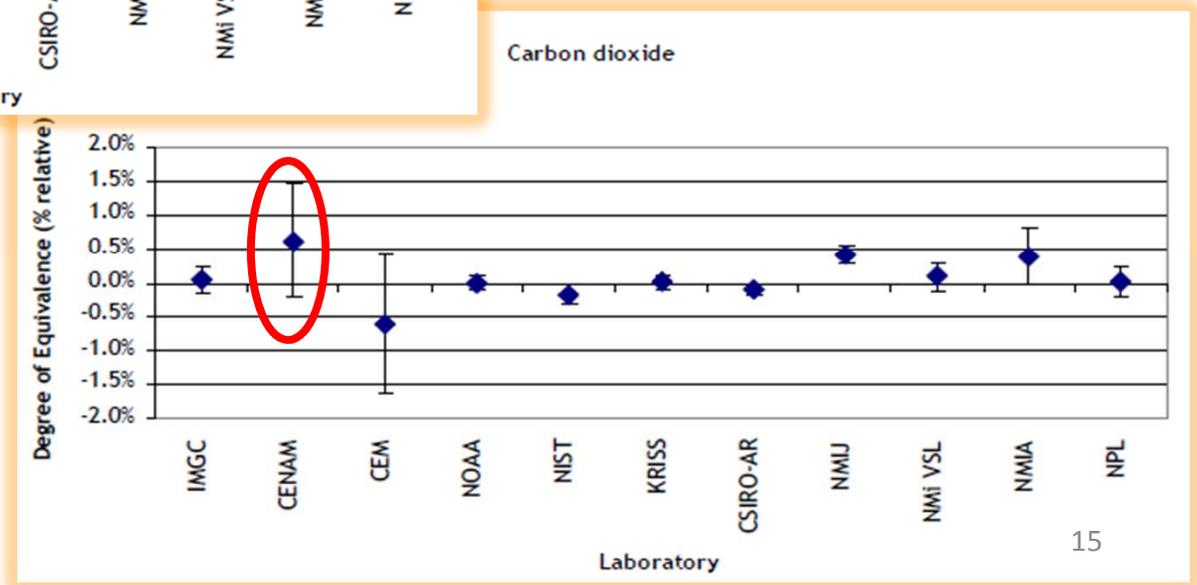
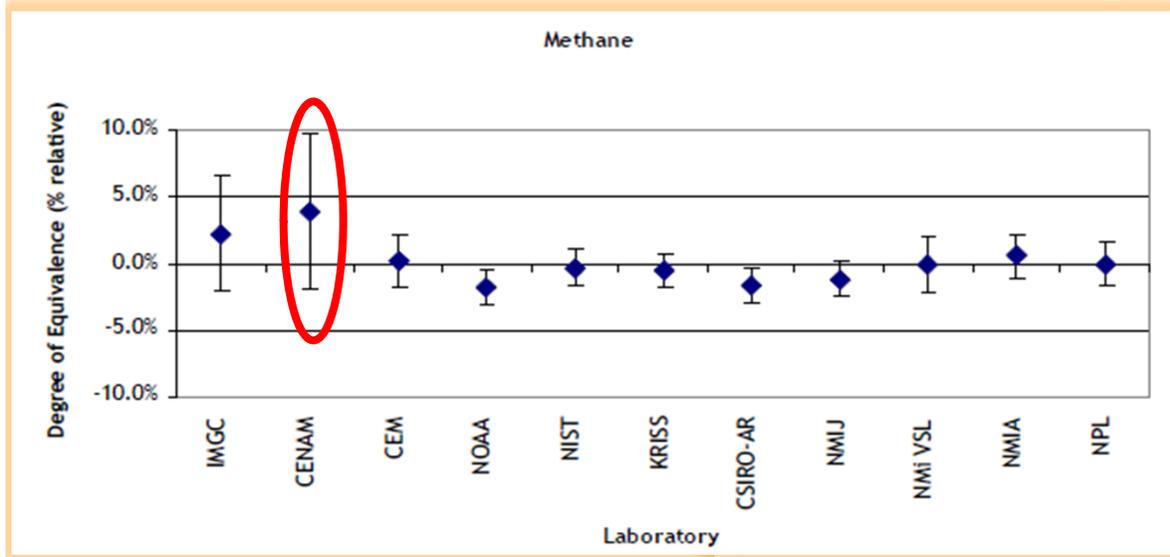
Other air pollutants: Ammonia in N<sub>2</sub>, 30 μmol/mol to 50 μmol/mol



### 3. Air quality and GHG substances

What has been already done and is being done?  
Comparisons in Air quality & GHG-CCQM-CIPM

CCQM-P41 Greenhouse gases – CO<sub>2</sub> and CH<sub>4</sub> in Air (2003)



### 3. Air quality and GHG substances

## Example of CRMs and DQO of WMO



Projected Typical Certified Values for  
SRM 1720 : Northern Hemisphere Greenhouse  
Gases

	NIST Concentration <sup>a</sup>	NOAA Concentration <sup>a</sup>	WMO Data Quality Objective <sup>b</sup>
CO <sub>2</sub>	393.30 ± 0.10 μmol/mol	393.38 ± 0.20 μmol/mol	± 0.1 μmol/mol
CH <sub>4</sub>	1878.1 ± 1.0 nmol/mol	1875.9 ± 1.5 nmol/mol	± 2 nmol/mol
N <sub>2</sub> O	323.04 ± 0.20 nmol/mol	323.10 ± 1.0 nmol/mol	± 0.1 nmol/mol
CO	≈ 160 ± 4 nmol/mol (vary 35 % sample to sample)	No NOAA Data	± 2 nmol/mol
SF <sub>6</sub>	≈ 7 ± 0.04 pmol/mol	7.16 ± 0.04 pmol/mol	± 0.02 pmol/mol

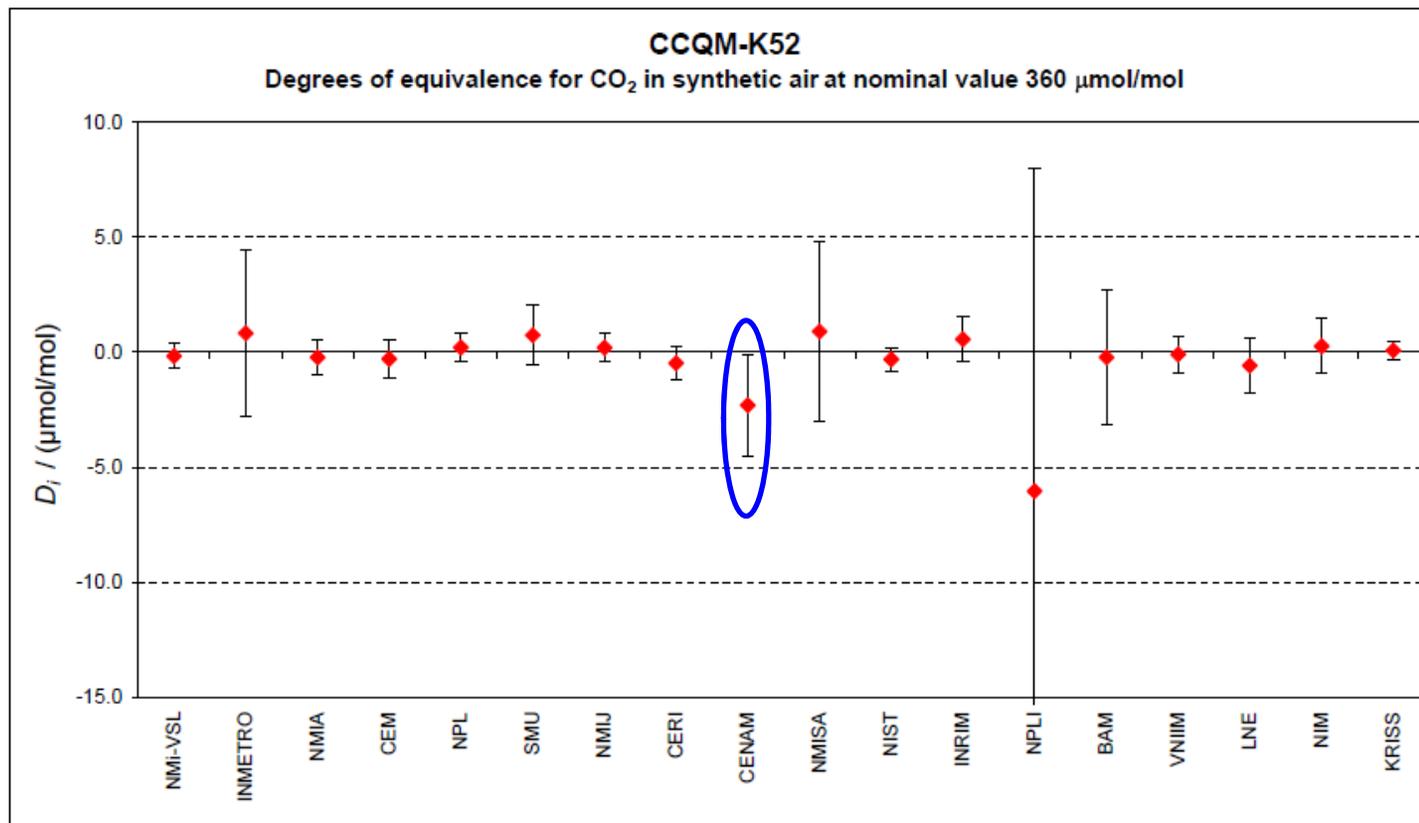
<sup>a</sup> Expanded uncertainty at k=2 coverage factor, 95 % confidence interval.

<sup>b</sup> Standard uncertainty at 1 σ (k=1 coverage factor).

### 3. Air quality and GHG substances

#### What has been already done and is being done? Comparisons in Air quality & GHG-CCQM-CIPM

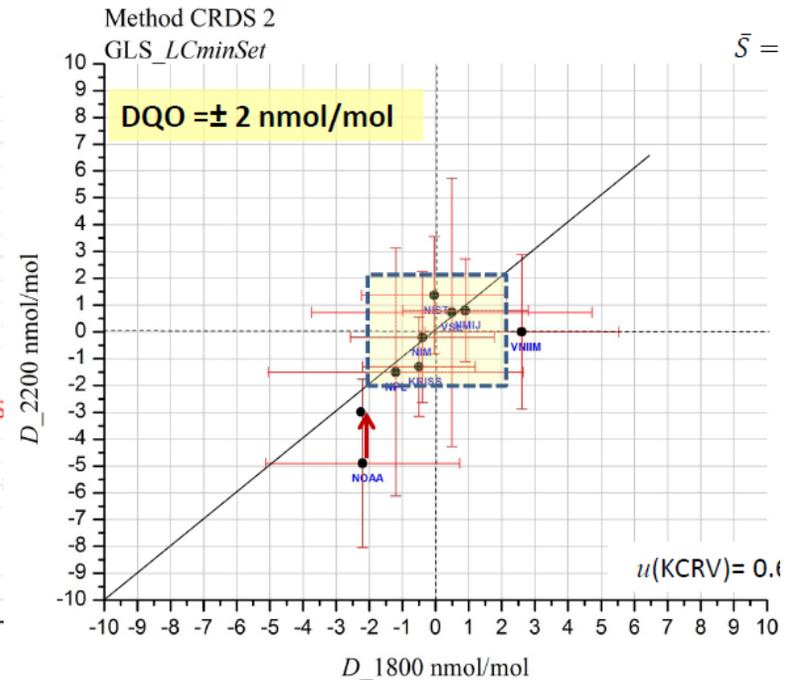
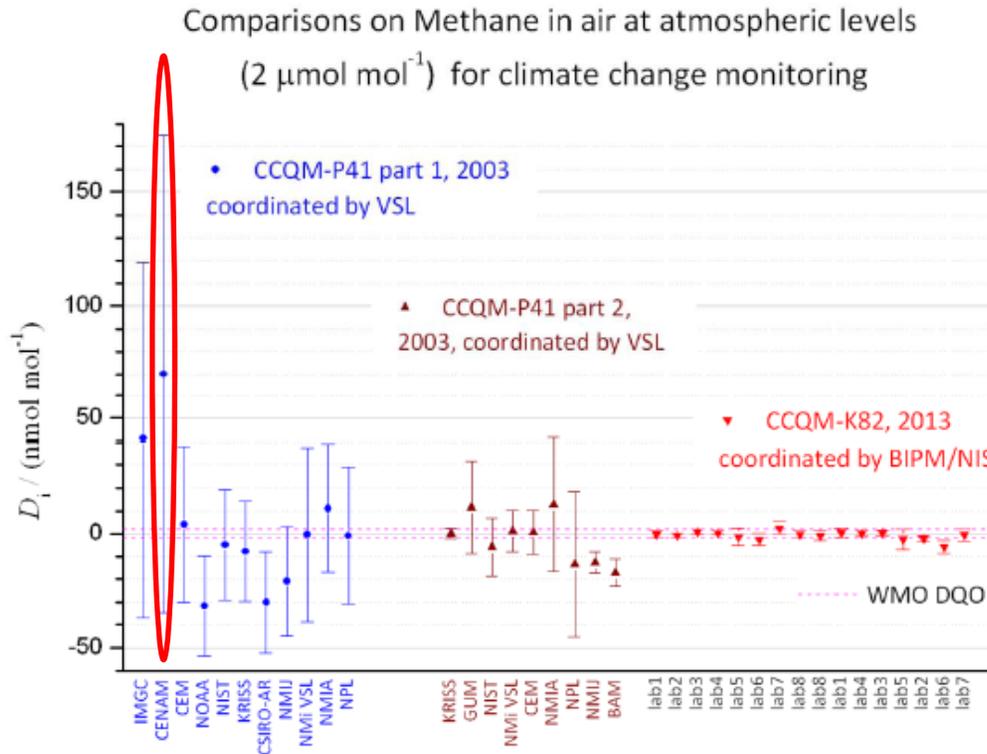
GHGs: Carbon dioxide, a new CCQM-K120 planned



### 3. Air quality and GHG substances

#### What has been already done and is being done? Comparisons in Air quality & GHG-CCQM-CIPM

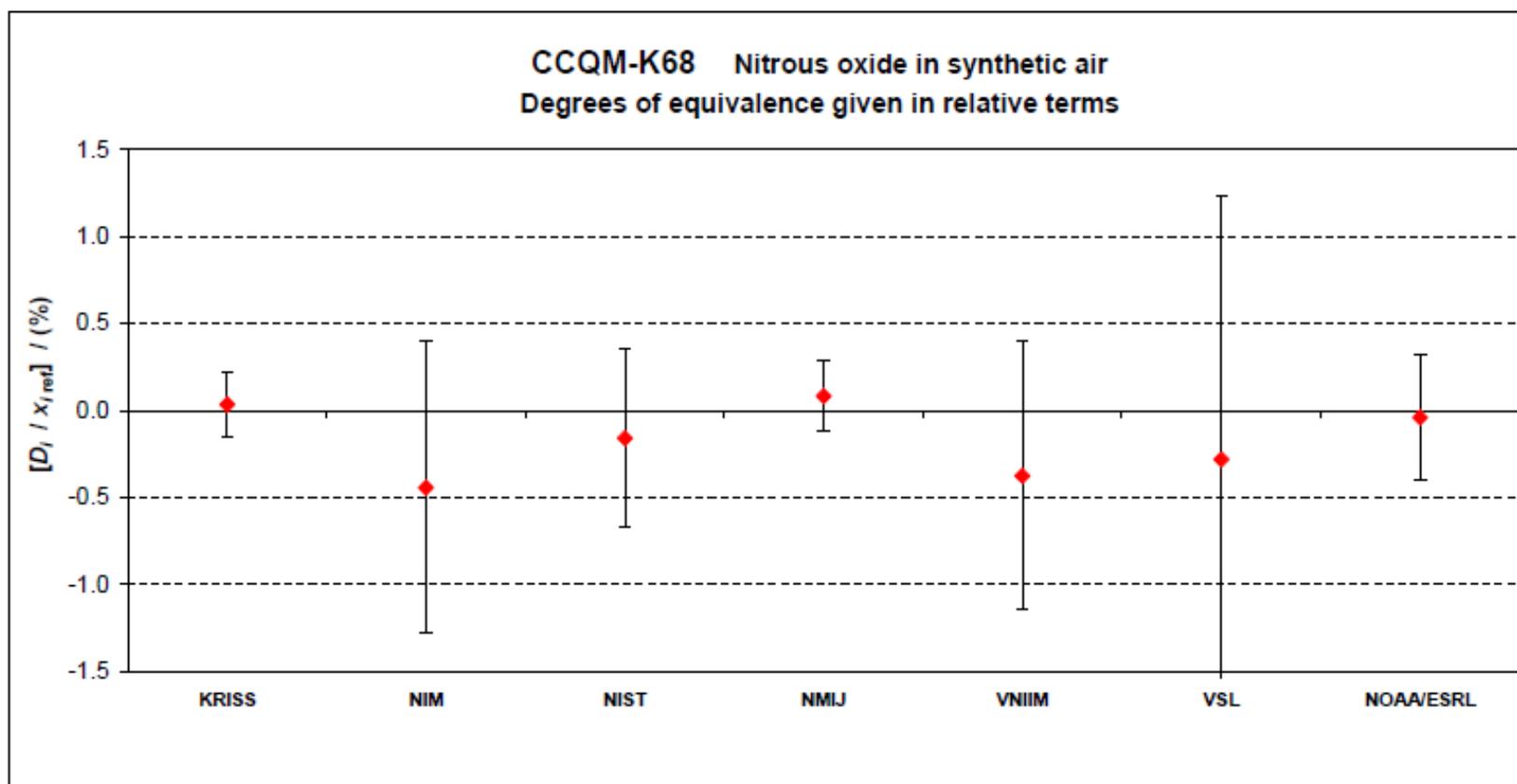
GHGs: Methane. Data quality objective (DQO) of the WMO for CH<sub>4</sub> almost achieved, but not yet in the uncertainty of gaseous PSMs. DQO of the WMO defined as metrological compatibility of measurement results (VIM, 2.47)



### 3. Air quality and GHG substances

#### What has been already done and is being done? Comparisons in Air quality & GHG-CCQM-CIPM

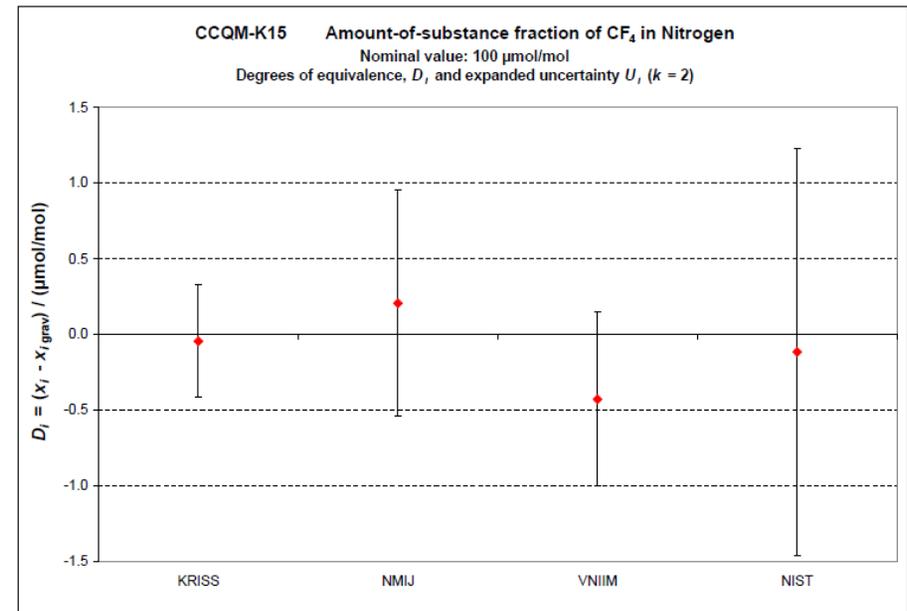
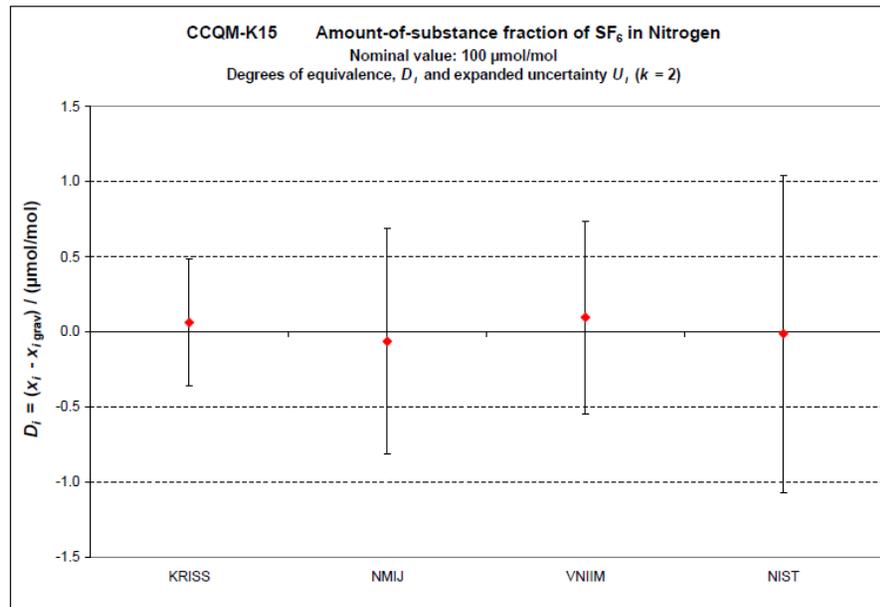
GHGs: Nitrous oxide, 320 nmol/mol



### 3. Air quality and GHG substances

#### What has been already done and is being done? Comparisons in Air quality & GHG-CCQM-CIPM

GHGs: Sulfur hexafluoride and CFCs at emission levels (Carbon tetrafluoride) 100  $\mu\text{mol/mol}$  to cover  $\text{CF}_4$ ,  $\text{C}_2\text{F}_6$ ,  $\text{CHF}_3$ ,  $\text{SF}_6$ , and  $\text{NF}_3$



## 4. Regulatory framework

**Regulatory framework** compared with the structure of El Cerrito Pyramid in “El Pueblito” there in Queretaro, Mexico, where CENAM is located





Mexico is a no Annex I country of the UNFCCC  
13th rank as country in GHGs global emissions (2 % of GHGs)

Reduce emissions of GHGs in 30 % by 2020 (50 % 2050) baseline 2000

United Nations Framework Convention on Climate Change

Intergovernmental Panel on Climate Change (IPCC)

Kyoto protocol

Emission inventories methods (top - down)

Emission factors and Activity factors

National Communication to the UNFCCC (Fifth -2012)

Programs in CENAM in line with current regulations, strategies and governmental programs and also focused in future needs

#### 4. Regulatory climate / situation in Mexico (Climate Change)

General Law on Climate Change  
In effect (2013-08)

Rule of the GLCC about the National Emissions Registry

National Development Plan 2013 - 2018

Federal funds

Environmental Sector Program 2013-2018

Special Program on Climate Change 2014-2018

Specific projects and actions supported by funds

National Strategy on Climate Change Vision 10-20-40 (years)  
In effect (2013-06-04)

State and Municipal **Programs** on Climate Change  
(basically inventories of GHGs and actions to mitigate/adaptate)

Policies

Climate science, mitigation and adaptation to CC

Actions (for Sustainable Development)

Technology

In development

Changing every federal , state or municipal government

## 4. Regulatory framework

- **Mitigation**

- **National policy of mitigation** should include: diagnostic (national and sectorial baseline), plan, **measurement**, **monitoring**, report, **verification** and evaluation of **national emissions**.
- Arrangements at federal, state and municipal level to reduce emissions **at** specific sectors and activities through actions and programs.
- International treaties signed by Mexico to be considered.
- Low-emission development strategies (LEDS)
- Green Economy
- Nationally Appropriate Mitigation Activities (NAMAs)
- Mexico is a member of the Global Green Growth Institute since 2012
- Mexico is a founding member of Climate and Clean Air Coalition (CCAC) to Reduce Short-Lived Climate Pollutants

Policies

Climate science, **mitigation**  
and adaptation to CC

Actions (for Sustainable  
Development)

Technology

## 4. Regulatory framework

# National Strategy on Climate Change Vision 10-20-40 (years) 2013

Without metrology

The **measurement, report and verification (MRV)** for mitigation of GHGs should be better supported by Metrology and quality infrastructures in each country. Cooperation of authorities with NMIs have to be closer for these tasks. However, I think that the MRV process is not yet at all considering Metrology, because it could be seen as an additional requirement to promote effective reductions. Same situation in NAMAs. **So convince also IPCC national experts**



## 4. Regulatory framework

- **Rule of the Mexican GLCC about the National Emissions Registry**

[http://dof.gob.mx/nota\\_detalle.php?codigo=5365828&fecha=28/10/2014](http://dof.gob.mx/nota_detalle.php?codigo=5365828&fecha=28/10/2014)

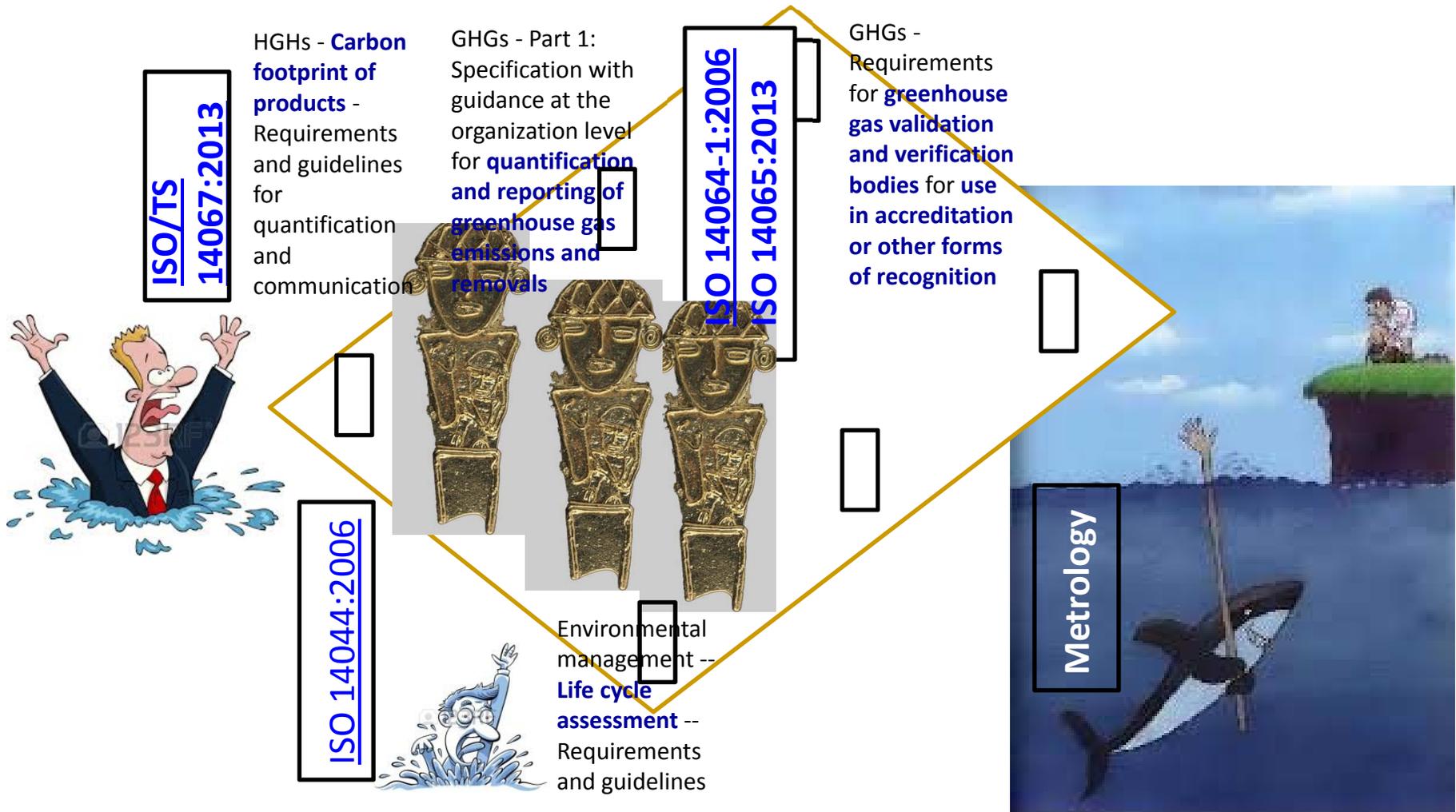
- Explanation of the MRV and relevant ISO 14 000 series
- But, I will explain it, this time on the “Balsa Muisca de Pasca” (Gold Museum Bogotá).



# 4. Regulatory framework

## Ship of the current king of the MRV of GHG emissions

<http://www.ema.org.mx/portal/index.php/ema-en-Mexico/evento-foro-de-verificacion-validacion-de-gases-efecto-invernadero.html>



# 4. Regulatory framework

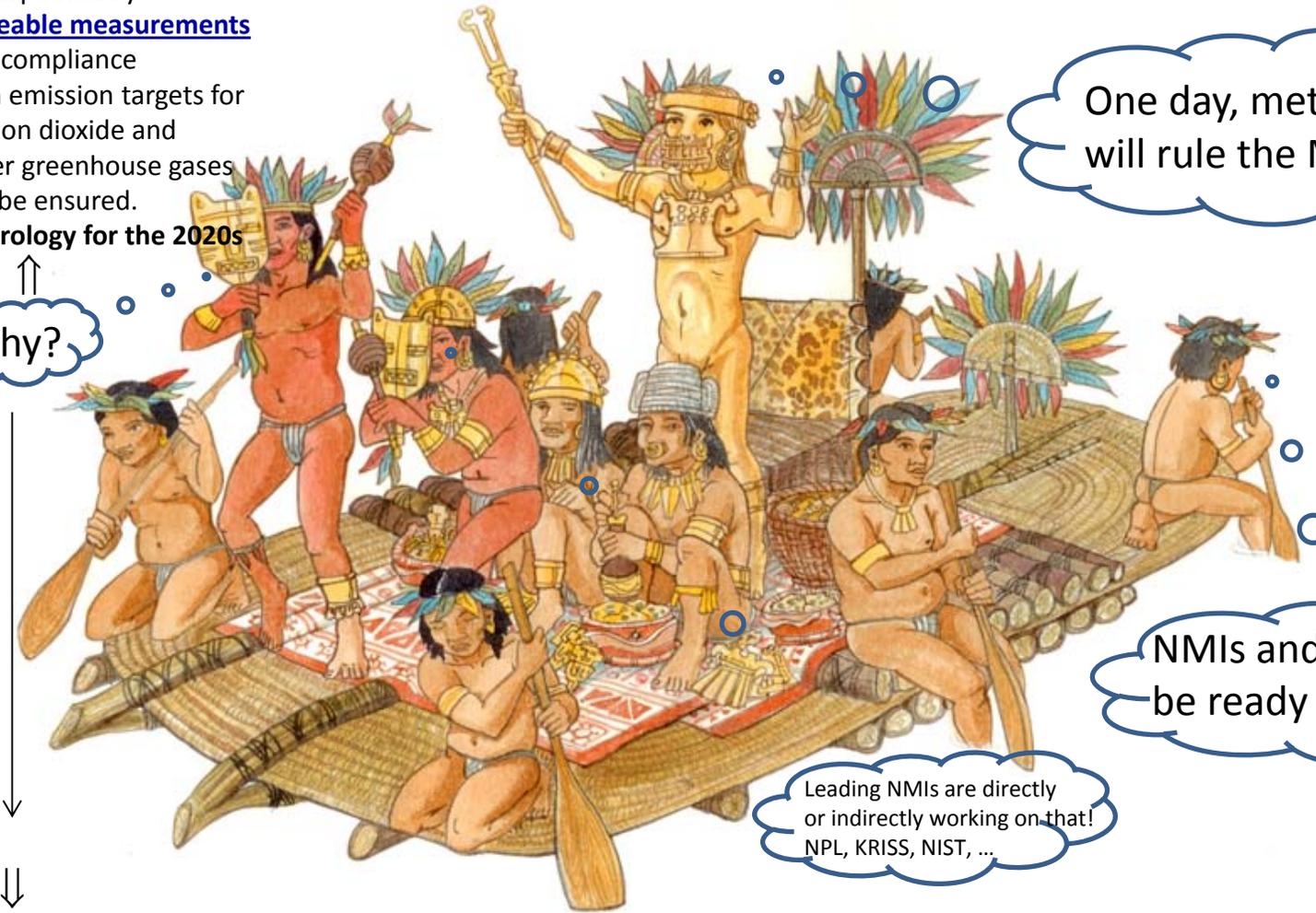
## Ship of the future king of the MRV of GHG emissions

Emissions trading will be underpinned by **traceable measurements** and compliance with emission targets for carbon dioxide and other greenhouse gases will be ensured.

**Metrology for the 2020s**

NPL ↑

Why?



One day, metrology will rule the MRV!

NMIs and governments be ready for that!

Leading NMIs are directly or indirectly working on that!  
NPL, KRISS, NIST, ...



# 4. Regulatory framework

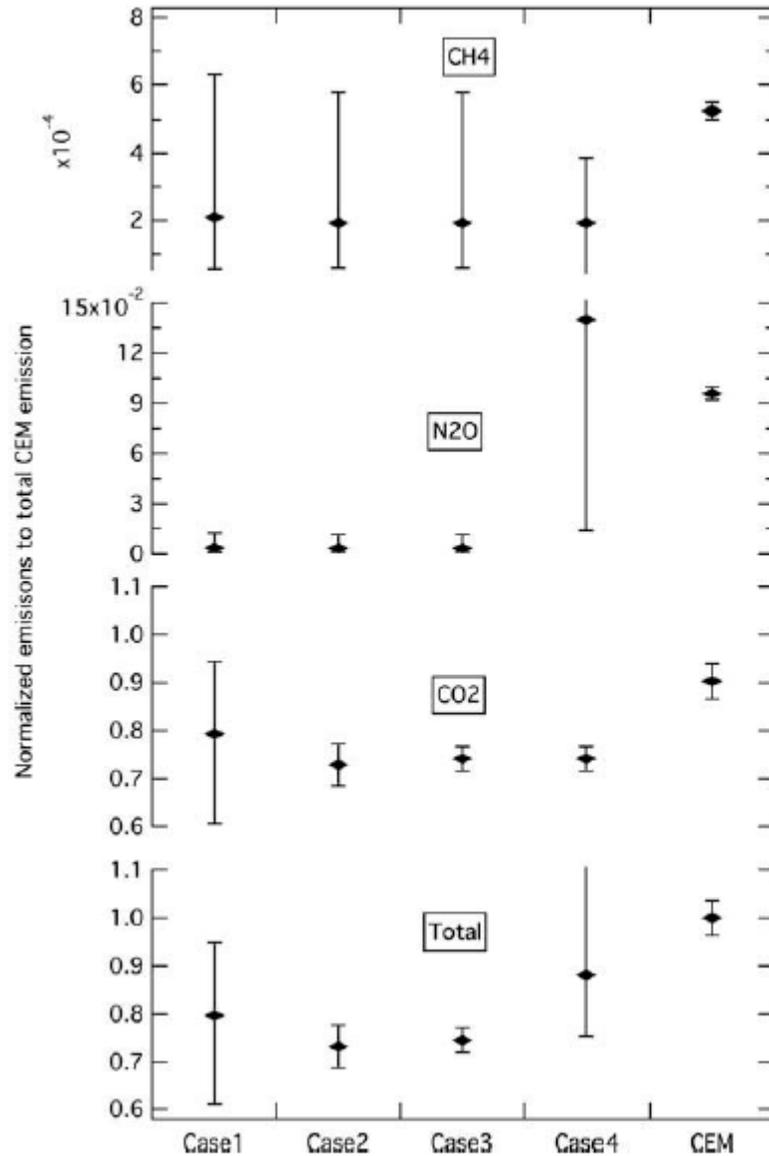


Figure 1. Comparisons of GHG emissions estimates by different methods.

GHG emissions were estimated for four different cases:

**Case 1:** IPCC default EF (Tier 1) and NCV,

**Case 2:** IPCC default EF (Tier 1) and plant-specific NCV,

**Case 3:** plant specific CC and NCV, and

**Case 4:** plant-specific CC for CO<sub>2</sub>, technology-specific IPCC default EF for N<sub>2</sub>O and CH<sub>4</sub>, and plant specific. For case 4, the technology-specific EFs (default Tier 3 EFs) for N<sub>2</sub>O and CH<sub>4</sub> were used since they may be more realistic values compared to the default Tier 1 EF based on only fuel.

NVC: net calorific value

CC: fuel carbon content (kg/Kg)

CEM: continuous emission monitoring

# 4. Regulatory framework

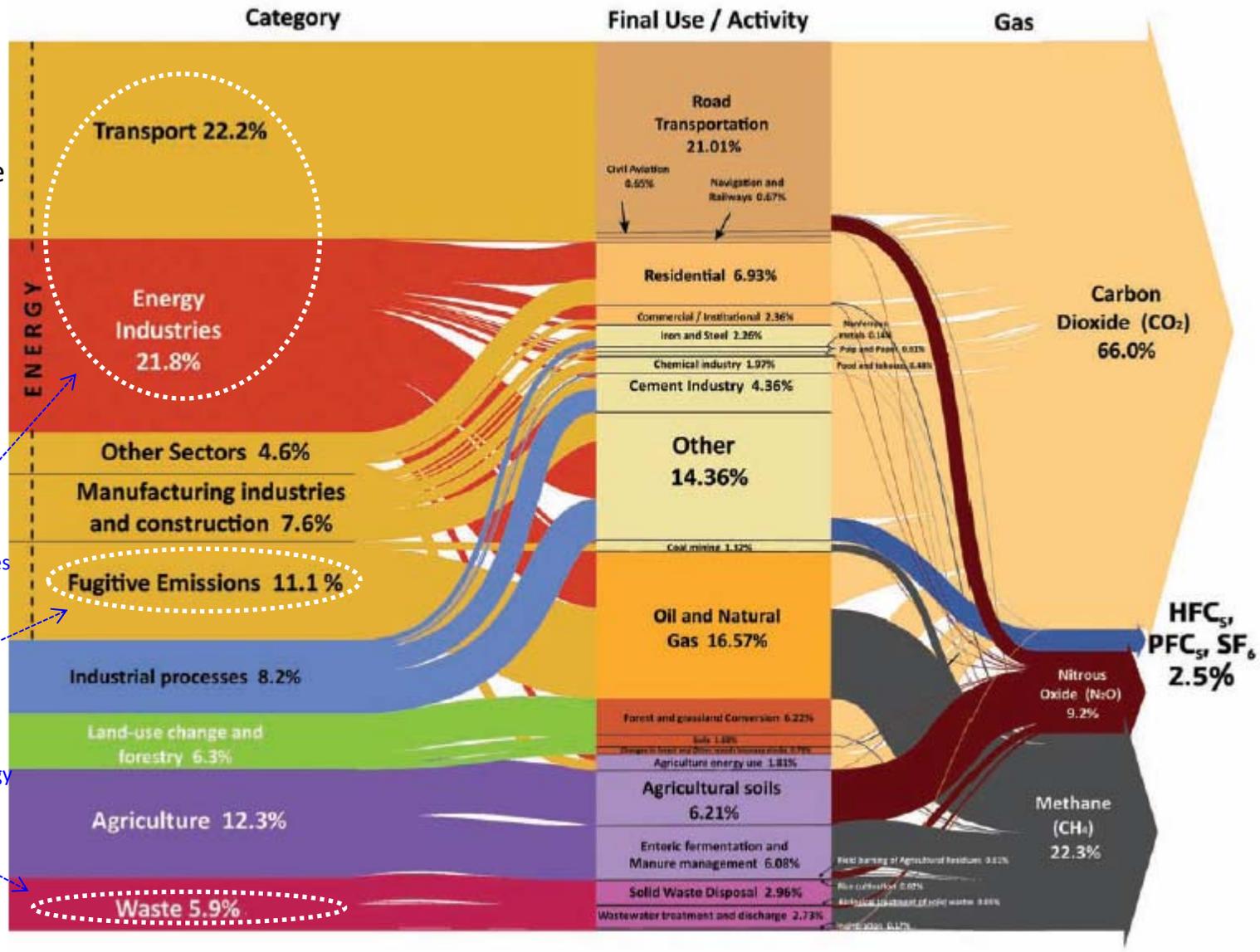
## Fifth National Communication to the UNFCCC (for 2010, reported 2012) - Mexico

Great opportunities to reduce and make a difference measuring and verifying changes with help of Metrology for new services with own technical needs, e. g.

Change in energy sources and fuels:

Measure/verify fugitive Emissions

Take advantage of energy in organic wastes

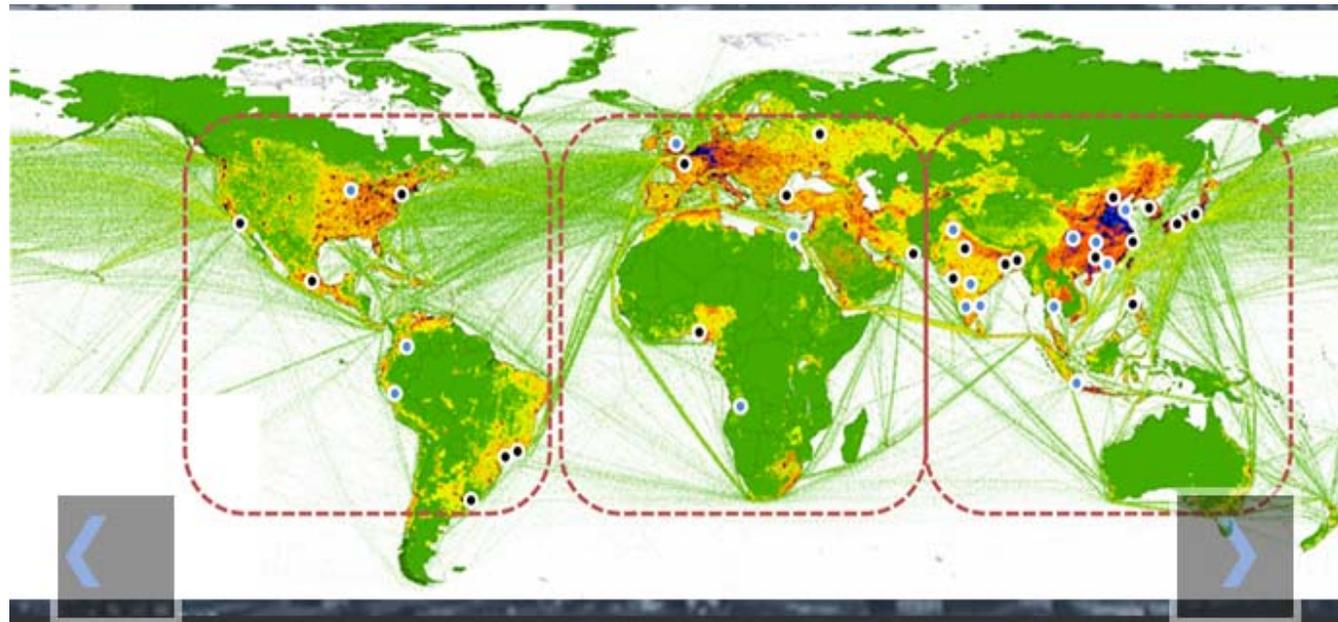


748 MtCO<sub>2</sub> eq.

## 5. Reflections and conclusions

### Reflections

- Case of 40 Megacities: 3<sup>rd</sup> contributor to GHGs after USA and China



#### Cities: responsible for 70% of fossil-fuel CO<sub>2</sub> emissions

A 10-km-resolution map indicates the distribution and intensity of fossil fuel CO<sub>2</sub> emission sources. The regions with greatest emission intensity are indicated by red and black (urbanized areas and associated large power plants). The black circles indicate a vision for future surface measurement networks concentrated within the 23 existing megacities. Blue circles indicate the 14 additional megacities projected to exist by 2025. The dashed rectangles indicate the fields of regard of three remote-sensing instruments that if hosted on geostationary satellites would offer sustained, wall-to-wall mapping of nearly every emission source. The satellite and surface network data, integrated with improved high-resolution emission estimates would provide a robust system for assessing and informing policies. Map: ([EDGAR version 4.0](#)) 2009.

## 5. Reflections and conclusions

### Reflections

- CENAM has 16 years **experience on emission services**: vehicle and stack emissions, **participation** in some **CCQM-Key Comparisons and Pilot Studies** of GHGs and Air Pollutants. It is the only Iberoamerican NMI with chemical CMCs as **core capabilities in gases (in the MRA-CIPM) published** today (it does not include some GHGs, GHG chemical measurement standards are challenging, not core!). As member of the CCQM we have regular participation in the GAWG and we are **following comparisons and knowlegde in GHGs and air quality measurements**.
  - **Steps of Development in Gas Metrology**: please first binary gas mixtures high concentrations, i.e. emissions, lower concentration and multicomponent gas mixtures are challenging: so truly air quality levels (not their premixtures) are very challenging!, i. e. inmissions are more difficult!
- Politically, **Mexico** has been very involved in **climate change initiatives**. In my knowledge, Mexico is the 2<sup>nd</sup> country in the World with a General Law of Climate Change (2012, first was UK), having a new National Institute of Ecology and Climate Change. First country reporting to the UNFCCC inventories on Short Live Climate Forces (SLCF, 2012).

## 5. Reflections and conclusions

### Reflections

- Many scientist doing an excellent job in monitoring the air, but only a few truly understand and apply Metrological Traceability and Metrology in Chemistry Capabilities, so more guidelines are required.
  - Not only for gas analysis in gas phase, but also for wet methods. Examples:
  - In spectroscopic measurements doing "absolute measurements" linestrengths have many times very high uncertainties and no traceability, there are significant uncertainty sources in emerging technologies, e. g. for QCLs, CRDS, etc.
  - Wet methods also need good metrological practices, e. g. measuring vertical profiles of O<sub>3</sub> in planes or globes absorbed in KI.
- So we should review the metrological quality of the studies performed in our own country. Do not do only isolated efforts: synergy is needed!

## 5. Reflections and conclusions

### Conclusions

- **Better quality of weather and air quality data for forecast or/and complement/substitution to measurements with models. Work on metrics of models. What bias, if allowed, is okay between traceable measurements and models?**
- **Synergy: cooperate closer with Environmental Authorities and Universities (e.g. air pollution and models), but also with the National Meteorological Service (SMN) and Organizations (State or Municipal levels) in charge of Meteorological Stations.**
- **Development of traceable and reference methods for assays of GHGs.**
- **Set of governmental priorities is clear, but in Metrology very delayed: SLCF and particles: innovation opportunities in metrological traceability.**
- **Contribute with traceable results in inventory guidelines of the IPCC and MRV of mitigation actions and NAMAs and initiate/continue Metrology Support to the inventory reports for the UNFCCC.**



Thank you  
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