Bureau International des Poids et Mesures

“BIPM and the International Measurement System”

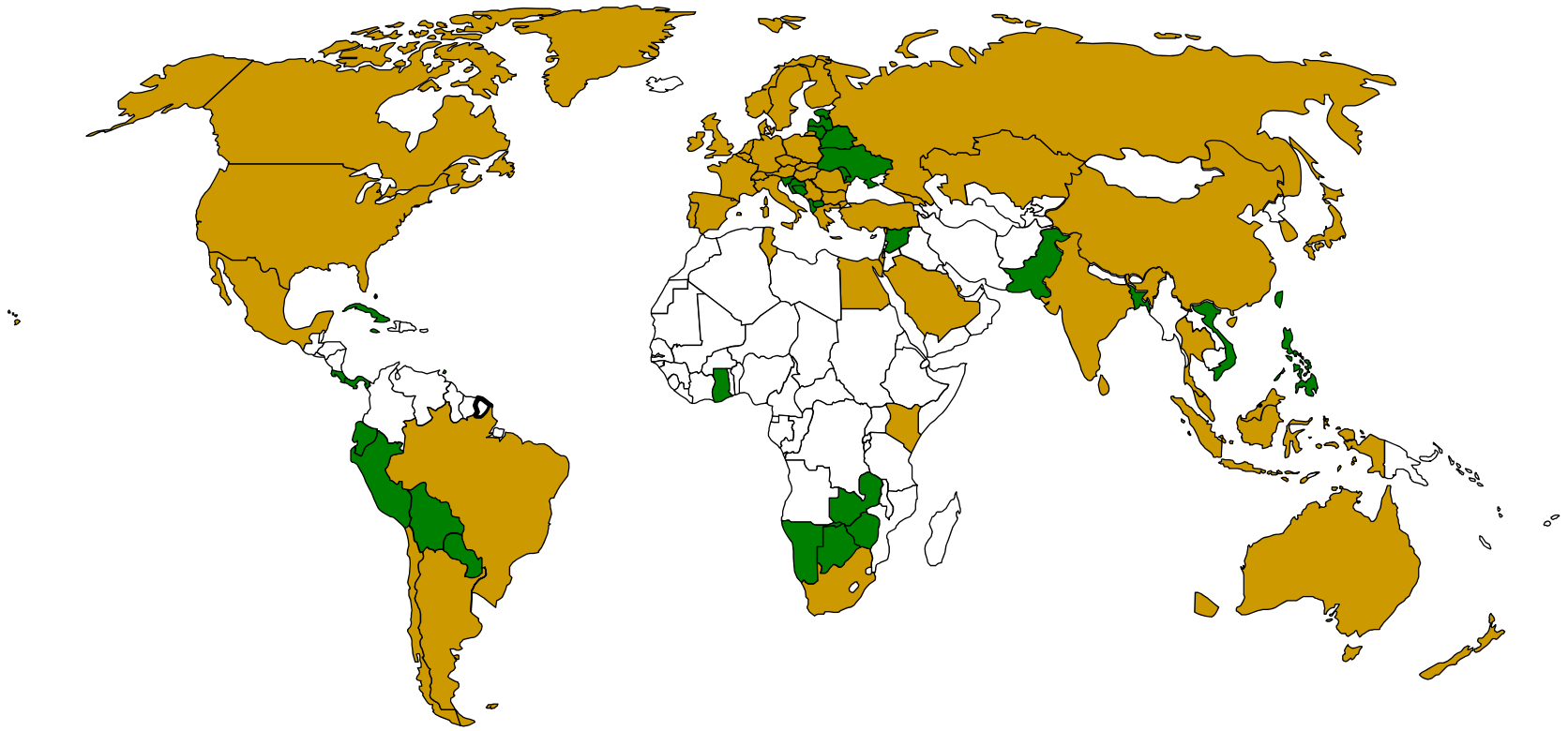
Dr Martin Milton
Director, BIPM

METAS, February 2013

The Metre Convention

Signed by 17 nations in Paris in 1875

Metre Convention today
54 Member States & 37 Associates of the CGPM

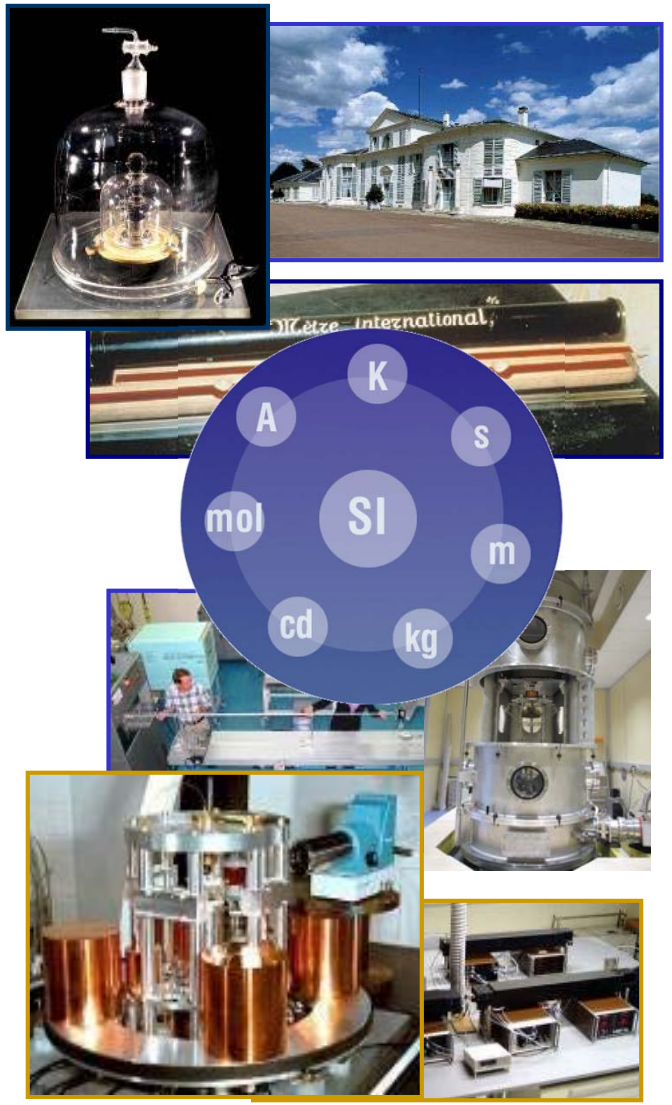


Member participating in the CIPM MRA
Associate participating in the CIPM MRA

CIPM- MRA
91 NMIs and 145 Designated Institutes from
51 Member States & 36 Associates of the CGPM
& 4 international organizations

Bureau International des Poids et Mesures

- A **permanent international organization based in Sevres for member states to act in common accord** on all matters relating to units of measurement.
- **Mandate** is to provide the basis for a single, coherent system of measurements throughout the world, traceable to the International System of Units (SI).
- Maintain **laboratories** for **direct dissemination** of units (as in the case of mass and time) and the **coordination of international comparisons** of national measurement standards (as in length, electricity and ionizing radiation).
- Coordinate activities through 10 consultative committees and joint committees with other international organisations.
- **International staff** of around 75.
- **Budget** from Member States and Associates for 2012 of around twelve million euros.



Charles Édouard Guillaume

- Born in 1861 in Fleurier, Switzerland.
- Joined the BIPM at the age of 22
- At the age of 40 he was offered a Chair at the University of Geneva,
  - The BIPM offered him a salary of 10 000 FrF for him to stay at the BIPM
- Became Director of the BIPM in 1915 (aged 54)

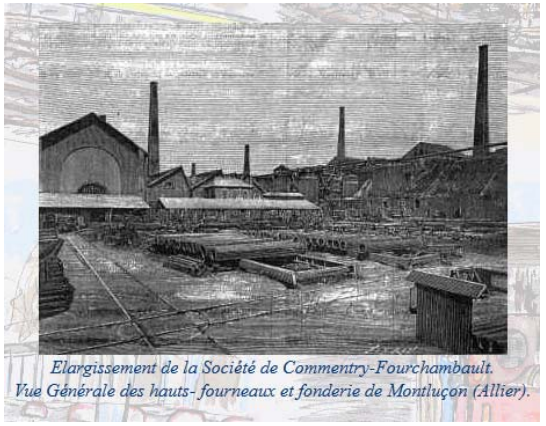
- In 1920 won the Nobel Prize (aged 59) "***in recognition of the service he has rendered to precision measurements in Physics by his discovery of anomalies in nickel steel alloys***".

Charles Édouard Guillaume

- He was motivated by the need to solve a problem at the leading edge of “measurement science”.

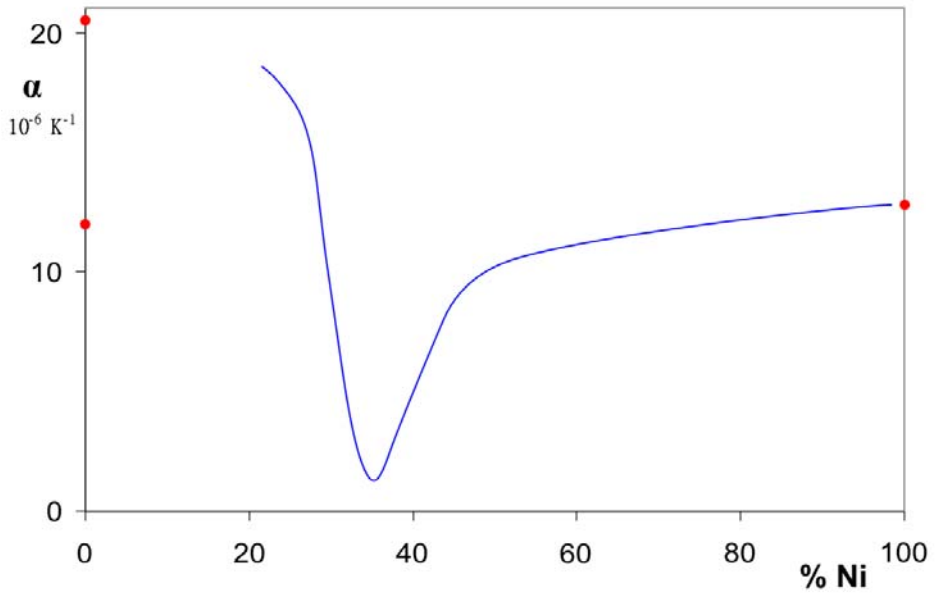
“How to manufacture a standard metre bar with the minimum change in length with temperature?”

- In 1895, he observed some unusual properties of a length standard sent to BIPM by the French Artillery.
- He made a strong link with the Commentry-Fourchambault Company.


Elargissement de la Société de Commentry-Fourchambault.
Vue Générale des hauts- fourneaux et fonderie de Montluçon (Allier).

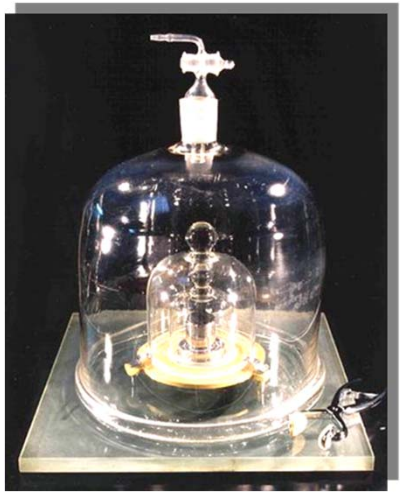
Charles Édouard Guillaume

- He discovered an alloy with a composition of 36% nickel and 64% iron with quite unexpected properties.

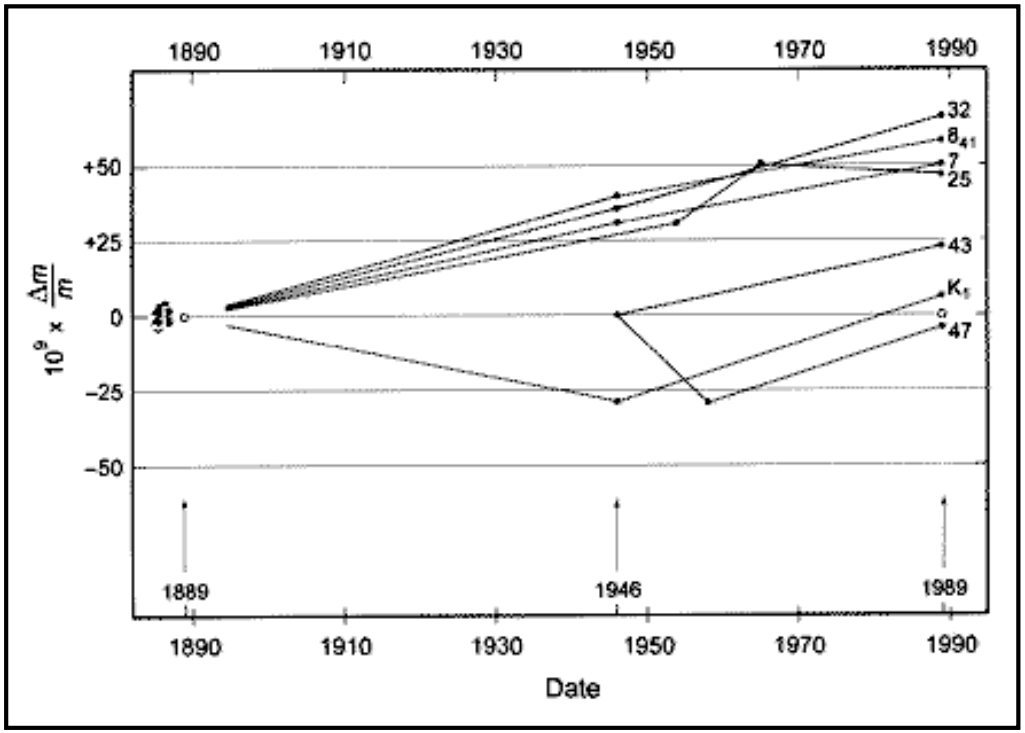


- The results have revolutionized aspects of high-precision measurement and were **vital in the subsequent development of clocks, seismic creep gauges, valves in motors, antimagnetic watches and in surveying**.
- Precision engineering is essential for the future development of metrology.

The International Prototype of the Kilogram



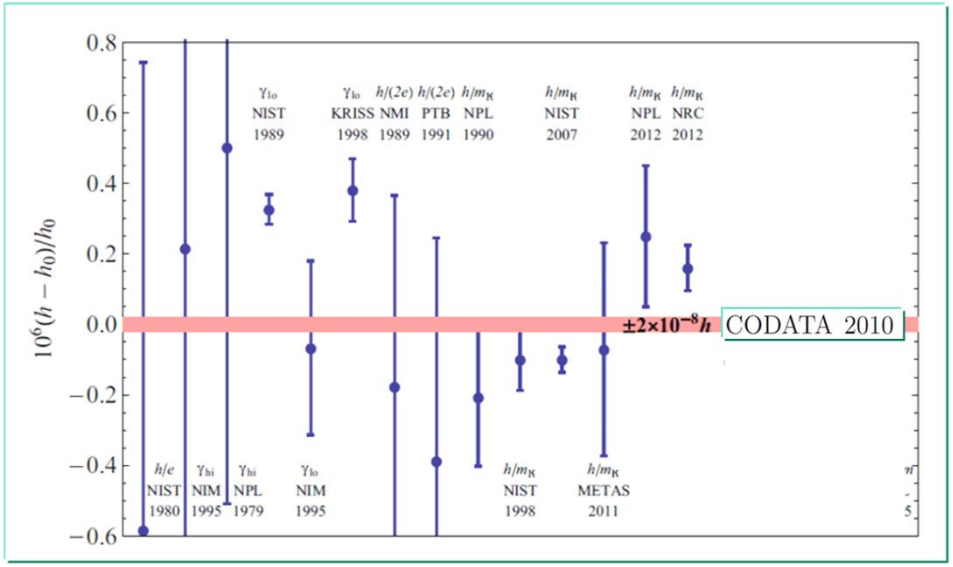
Variations of about 50×10^{-9} (50 mg/kg) in the mass of the standards over 100 years. (approx 0.5 µg/year)



In 1927, Guillaume imagined a better definition of the kg; and predicted that it would happen in a "future century".

A new approach to “weighing”

- **Electrical power (in Watt) is equivalent to Mechanical power (in Watt)**
- Experiments to implement this are at the “leading edge” of measurement science.



Adapted from *“The Avogadro and the Planck constants for redefinition of the kilogram”*
G. Mana and E. Massa, RIVISTA DEL NUOVO CIMENTO

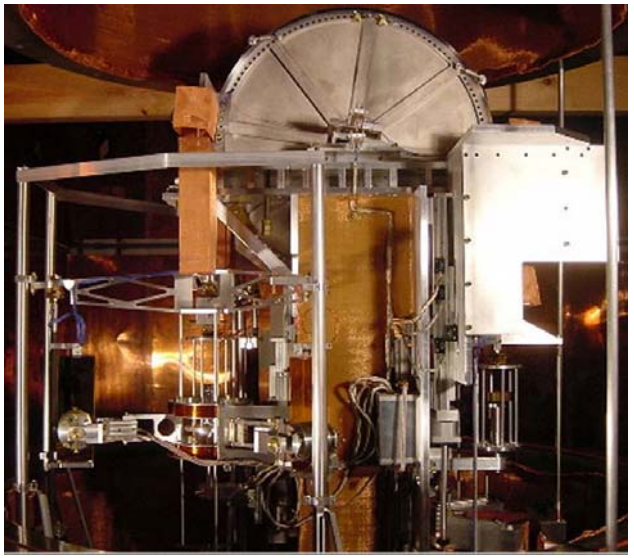


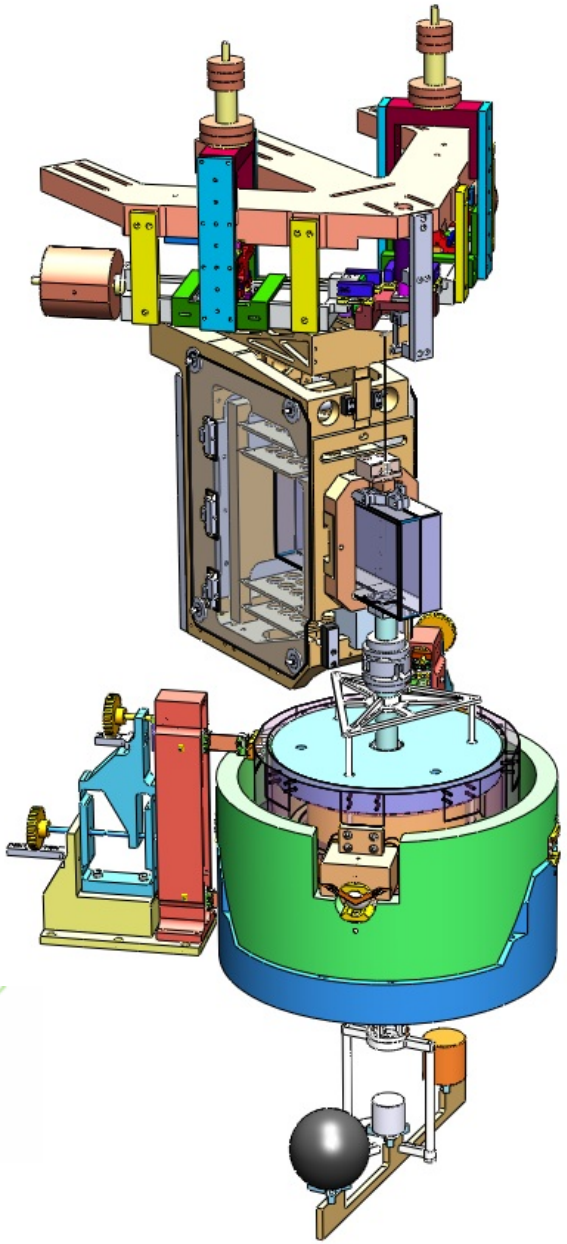
Photo Credit: Steiner, NIST

- A comparison uncertainty of 10 parts in 1000 million is required ~20 years to observe a slope of 0.5 µg/year.

The METAS “Watt Balance” (BWM II)

Key features

- Designed and implemented with collaborators
- Takes advantage of some of the latest technology for precision manufacturing.
- « Double parallelogram » translation stage.
- Monobloc mass comparator



ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

CERN

METTLER TOLEDO

METAS

Work to support a future re-definition at the BIPM

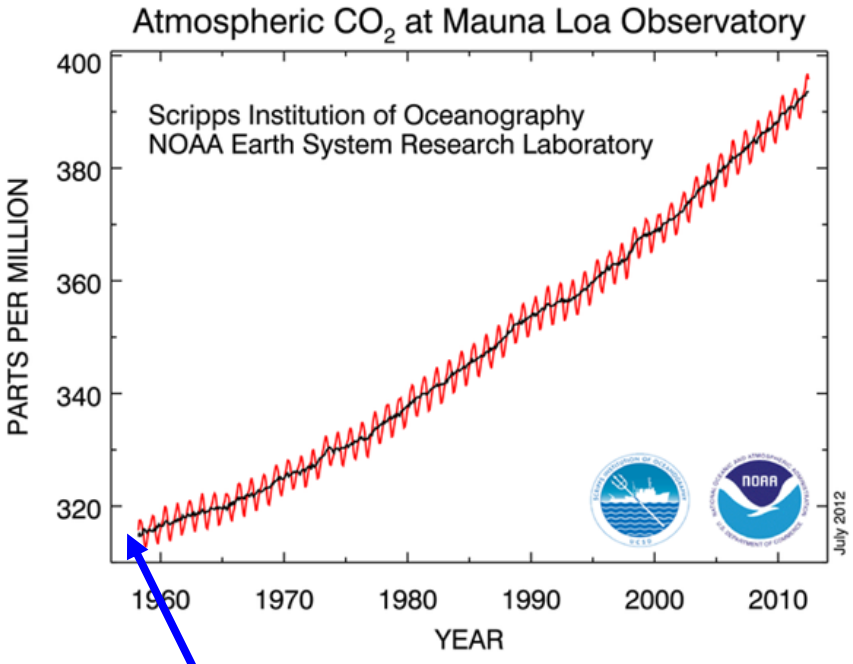
The BIPM Pool of Artefacts

- Will provide data to determine the optimum mass type and storage conditions,
- A set of PtIr, stainless-steel, silicon and “surface stack” artefacts,
- Stored under nitrogen, argon, air and vacuum conditions,
- The optimized design will provide a long-term stable value for dissemination of mass calibrations from BIPM (after re-definition).

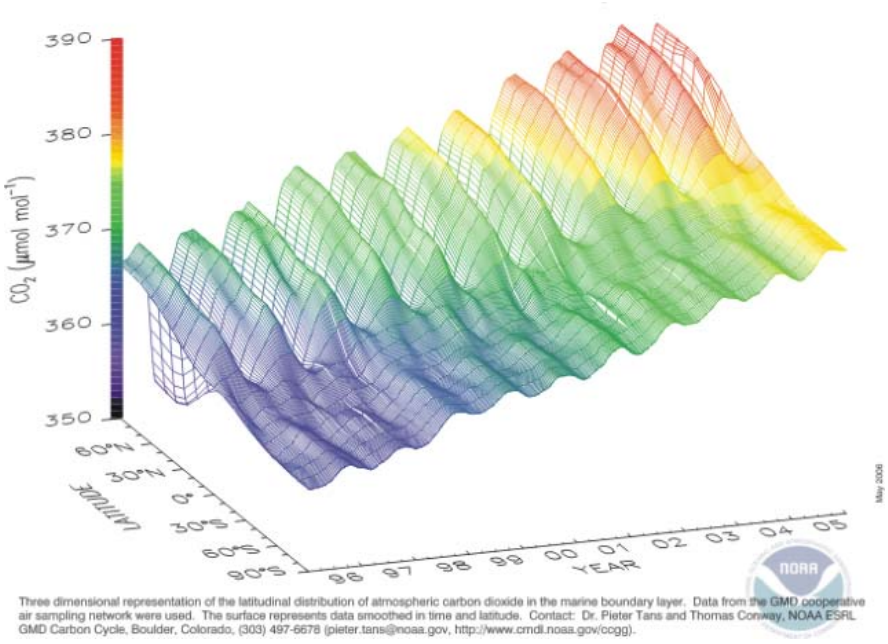
The BIPM watt balance

- Will provide a “primary realization” of the new definition of the kilogram at BIPM,
- Several unique features not implemented in other watt balances,
- Simultaneous weighing and moving mode measurements - possible use of bi-filar winding,
- (Two-mode operation if required),
- Movement from electrostatic motor,
- Closed magnetic circuit design.

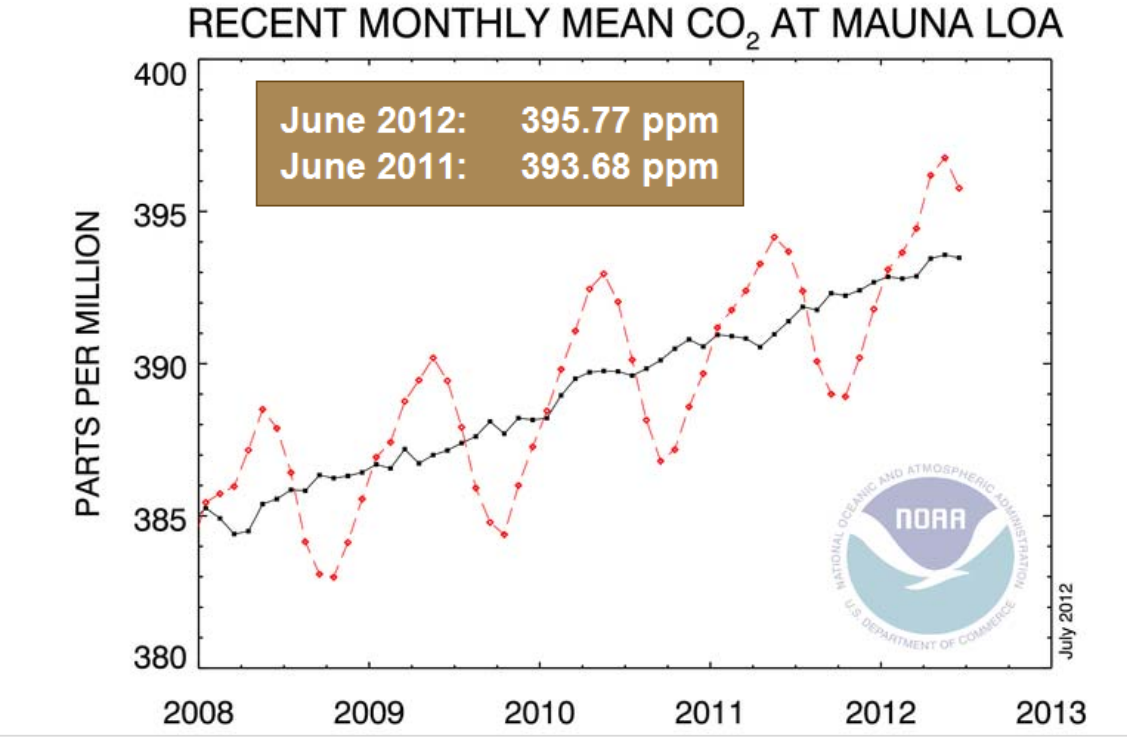
the Keeling curve and the “flying carpet”



Historical Value
280 ppm



Atmospheric CO_2 data quality



Target set for data quality

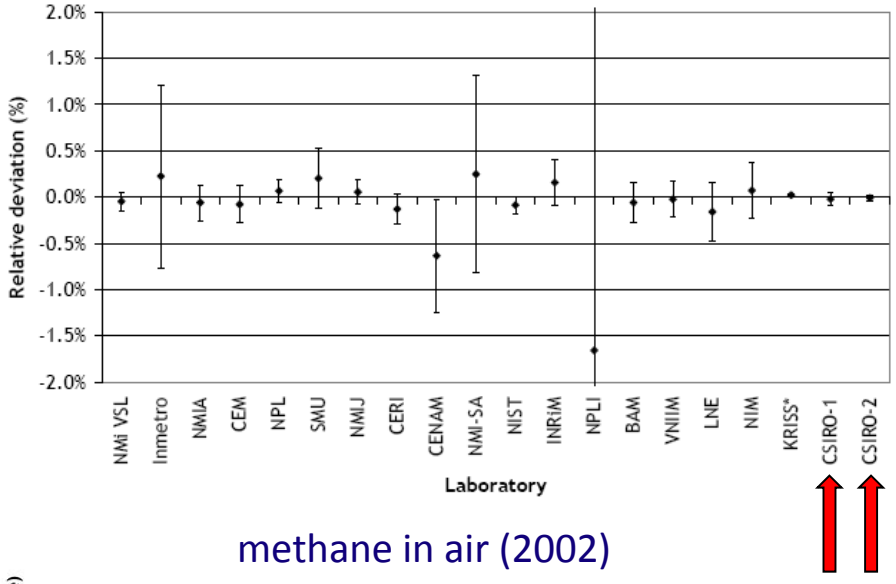
+/- 100 ppb (NH)

+/- 50 ppb (SH)

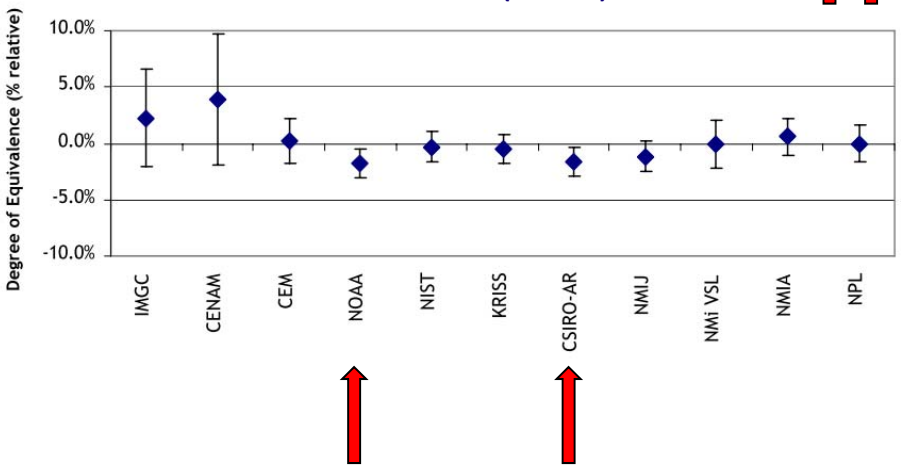
GLOBAL ATMOSPHERE WATCH

Comparisons of atmospheric measurements

carbon dioxide in air (2006)



methane in air (2002)



- Agreement between global climate monitoring labs and national metrology labs “adequate” for 2002 and 2006.
- More work needed to develop a international measurement system that meets the requirements of global climate monitoring.

The World Meteorological Organisation and the BIPM

WMO/BIPM Workshop March 2010

"The long-term, stability and reproducibility of reference materials, and explicitly defined calibration scales, ***are critical to the study of temporal change****".*

"That measurement results be ***traceable to the SI where practical****".*

"That the WMO and BIPM communities collaborate to make ***best use of established national and international infrastructure****"..*

In 2011 a Joint WMO/BIPM Liaison Group was established to progress the recommendations

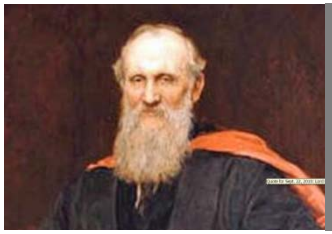
- It will work through existing structures.
- It will focus on Essential Climate Variables

Table 1: Essential Climate Variables that are both currently feasible for global implementation and have a high impact on UNFCCC requirements

Domain	Essential Climate Variables	
Atmospheric (over land, sea and ice)	**Surface:**[8]	Air temperature, Wind speed and direction, Water vapour, Pressure, Precipitation, Surface radiation budget.
	Upper-air:[9]	Temperature, Wind speed and direction, Water vapour, Cloud properties, Earth radiation budget (including solar irradiance).
	Composition:	Carbon dioxide, Methane, and other long-lived greenhouse gases[10], Ozone and Aerosol, supported by their precursors[11]
Oceanic	**Surface:**[12]	Sea-surface temperature, Sea-surface salinity, Sea level, Sea state, Sea ice, Surface current, Ocean colour, Carbon dioxide partial pressure, Ocean acidity, Phytoplankton.
	Sub-surface:	Temperature, Salinity, Current, Nutrients, Carbon dioxide partial pressure, Ocean acidity, Oxygen, Tracers.
Terrestrial	River discharge, Water use, Groundwater, Lakes, Snow cover, Glaciers and ice caps, Ice sheets, Permafrost, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (FAPAR), Leaf area index (LAI), Above-ground biomass, Soil carbon, Fire disturbance, Soil moisture.	

Conclusions

- **Metrology is a fast moving field** that develops new approaches to address new requirements.
- It **supports the development of new technologies** and also develops new science and technologies that have other applications.
- It provides **the basis for regulation** (*eg* mass), for monitoring the environment (*eg* global warming) …
- It is a **global activity** - Links made at the international level are mirrored at national level.



"If you can not measure it, you can not improve it."

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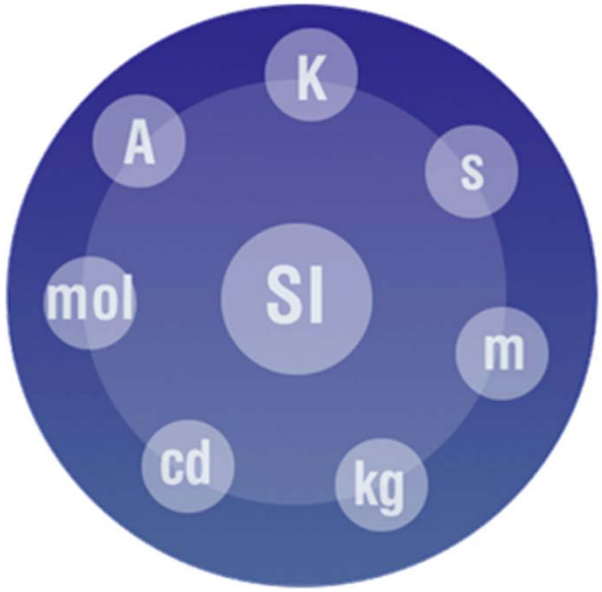

Thank you