Bureau International des Poids et Mesures

"Low Carbon and Climate Science: the present and future role of international metrology"

Martin J.T. Milton, BIPM Director

International NMI Conference on Low Carbon and Climate Science

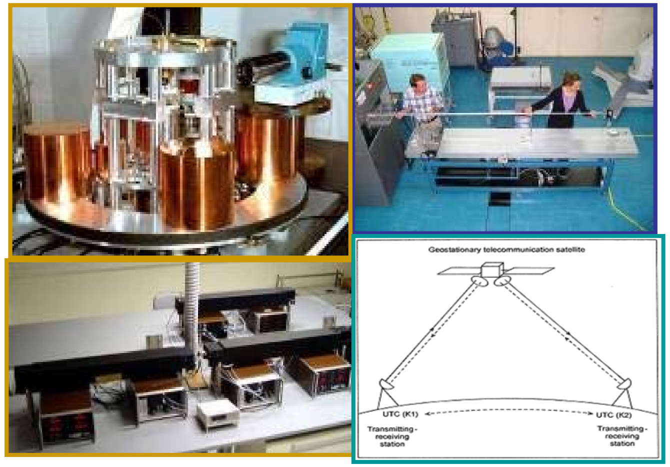
NPL National Physical Laboratory | Centre for Carbon Measurement

Supporting climate research and a low carbon future

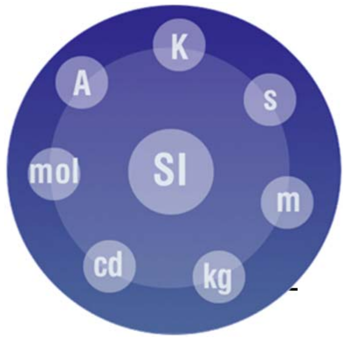
Monday 4th February 2013, NPL, Teddington

Bureau International des Poids et Mesures

- An inter-governmental organization financed jointly by the Member States and Associates of the Metre Convention, and operating under the exclusive supervision of the CIPM.
- Our mission is to ensure and promote the global comparability of measurements.

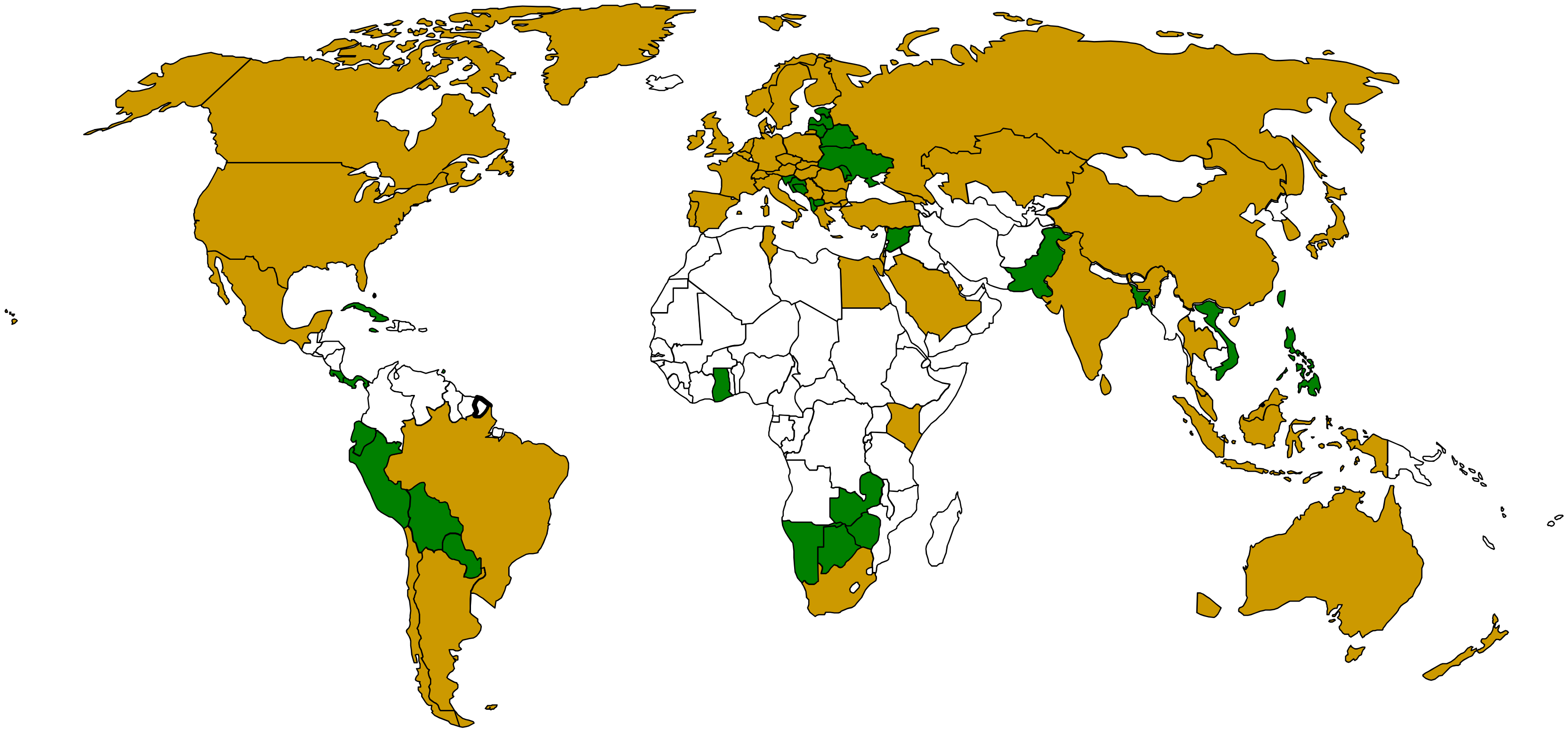


- **The unique role of the BIPM enables it to achieve its mission by developing the technical and organizational infrastructure of the International System of Units (SI) as the basis for the world-wide traceability of measurement results.**
- **This is achieved both through technical activities in its laboratories and through international coordination.**
  - operate laboratories in: mass, time, electricity, ionizing radiation, and chemistry.
  - an international staff of around 75 with budget of approximately 12 million euros (for 2012).
  - based in Sevres near Paris.



Member States and Associates

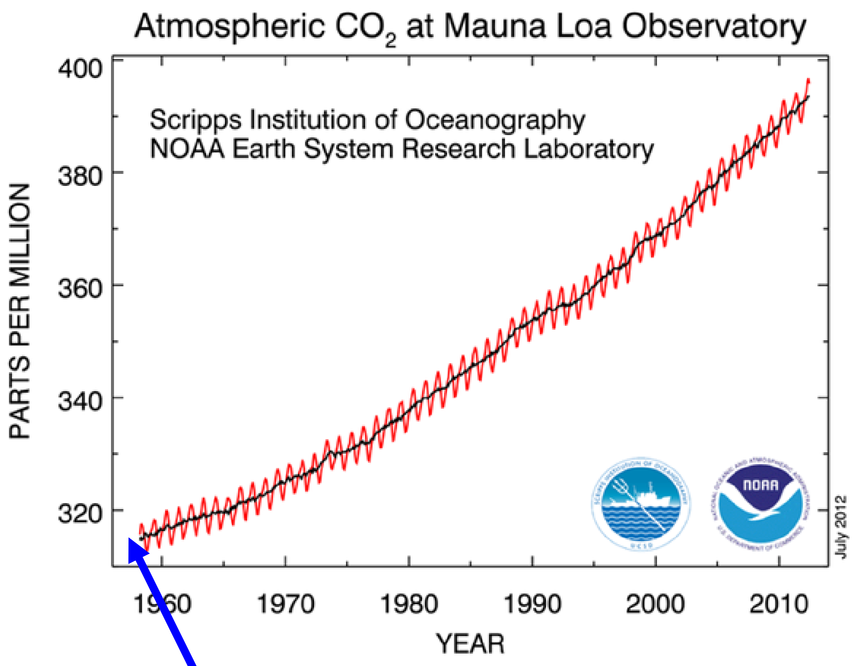
Metre Convention
54 Member States & 37 Associates of the CGPM



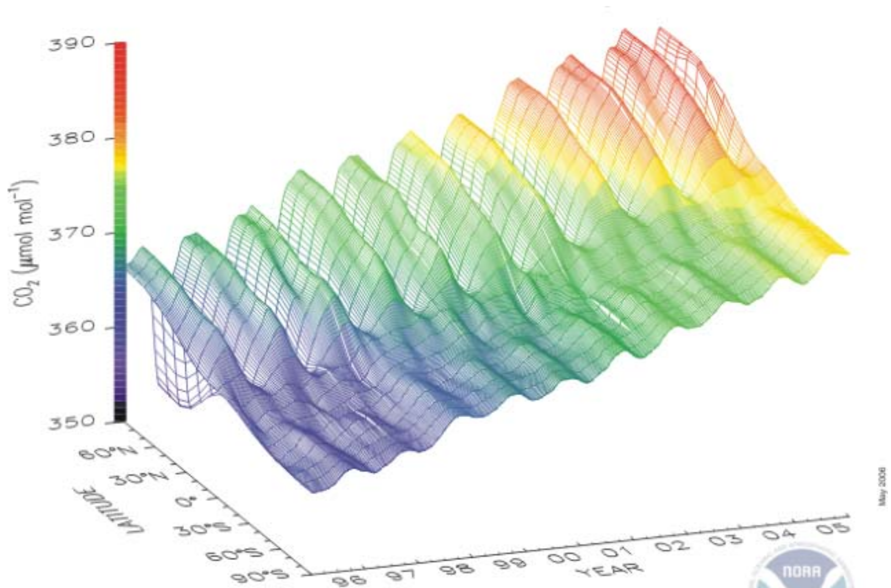
- Member participating in the CIPM MRA
- Associate participating in the CIPM MRA

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

the Keeling curve and the "flying carpet"

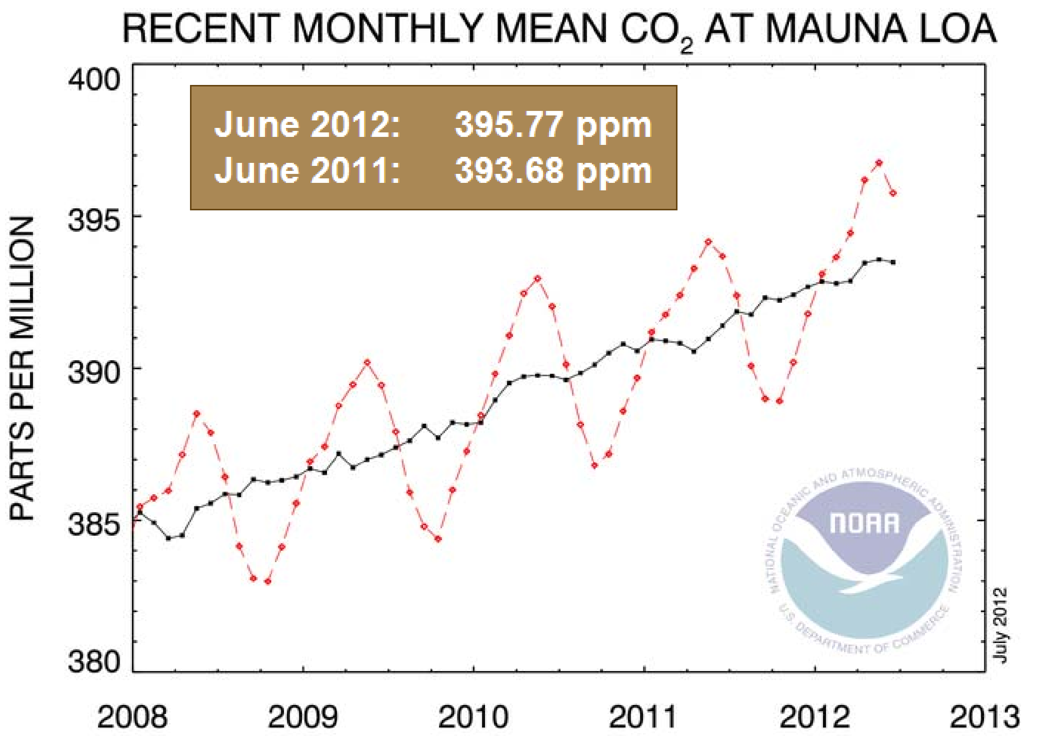


Historical Value
280 ppm



Three dimensional representation of the latitudinal distribution of atmospheric carbon dioxide in the marine boundary layer. Data from the GMD cooperative air sampling network were used. The surface represents data smoothed in time and latitude. Contact: Dr. Pieter Tans and Thomas Conway, NOAA ESRL GMD Carbon Cycle, Boulder, Colorado, (303) 497-6678 (pieter.tans@noaa.gov, http://www.cmdl.noaa.gov/ccgg).

Atmospheric CO_2 data quality



Target set for data quality

+/- 100 ppb (NH)

+/- 50 ppb (SH)

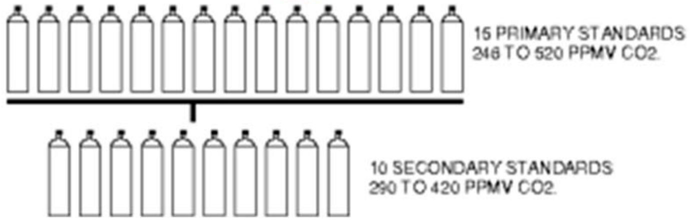
GLOBAL ATMOSPHERE WATCH

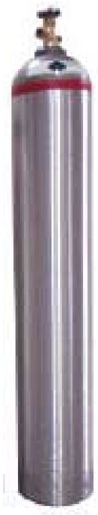
WMO method for CO_2 scale dissemination

Niwot Ridge air

Volumetric addition of pure CO_2, CH_4 etc

Repeatability ~ 100ppb

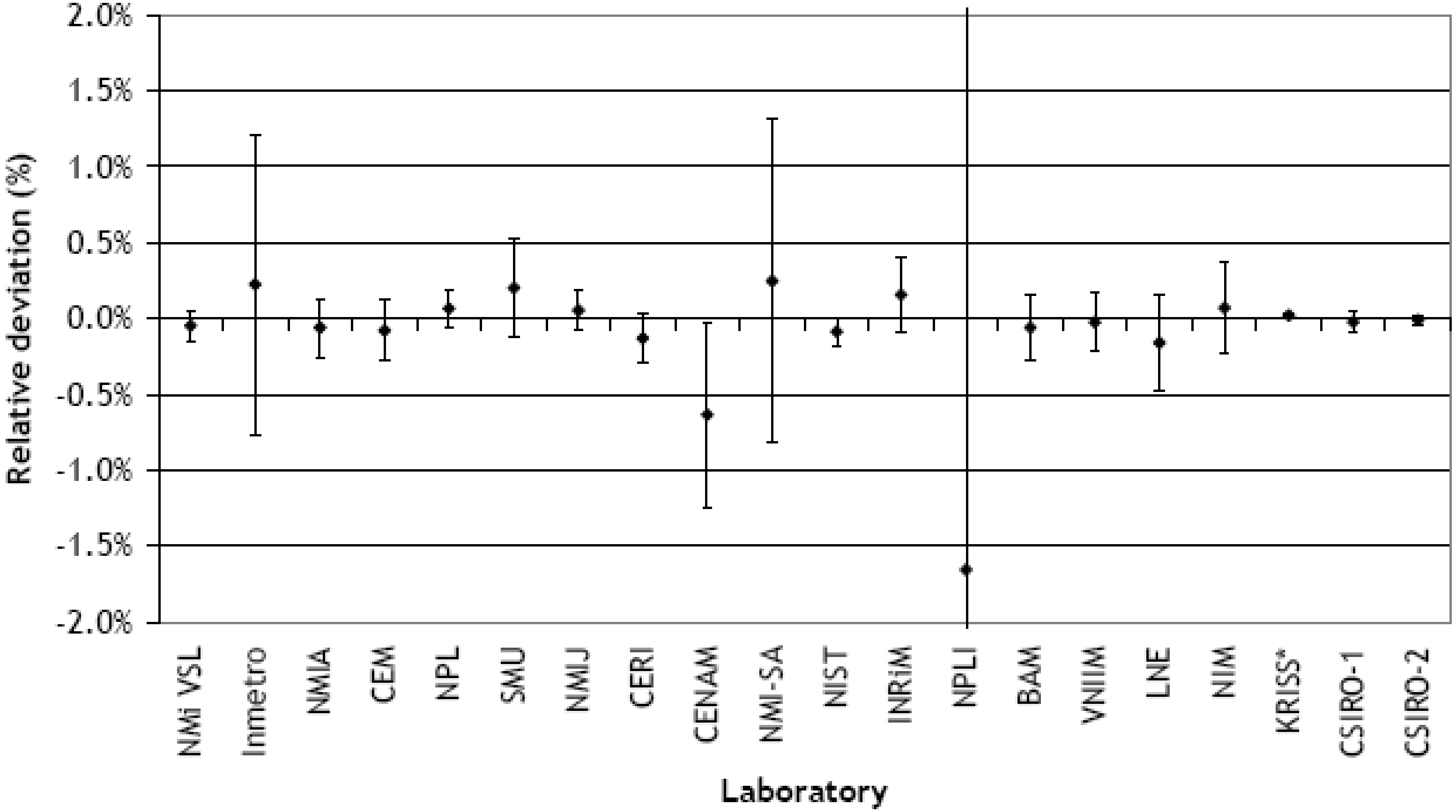




Noise (1 sec) ~ 20ppb

- **Value on certificate are expressed as on a "scale"**

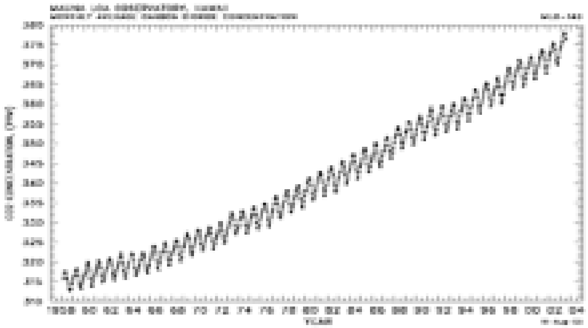
CCQM-K52 (2006) – carbon dioxide in air



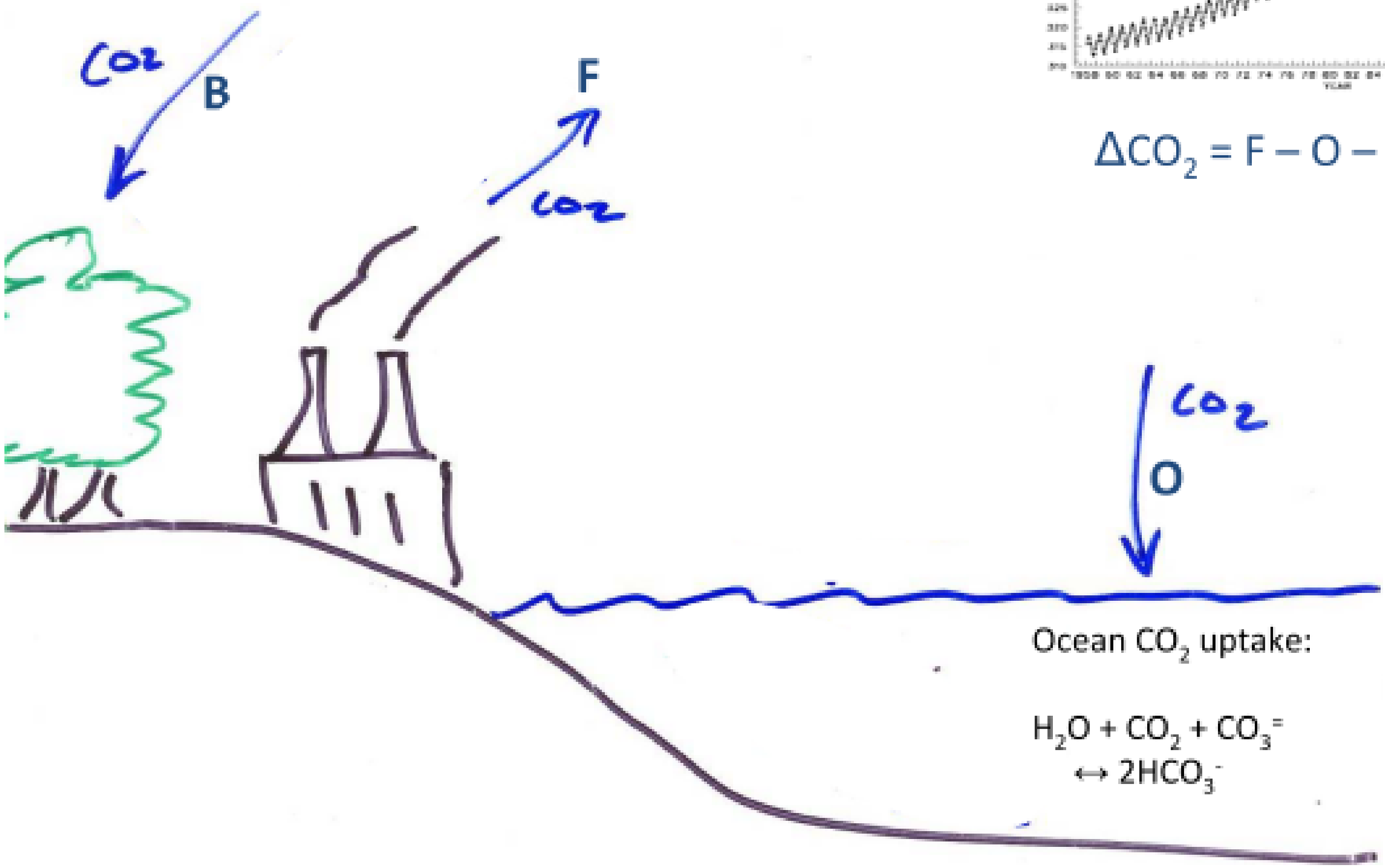
- Participation of WMO laboratory in Australia
- The WMO scale and the SI values from NMIs agree

CCQM GAWG

Atmospheric CO_2 budget

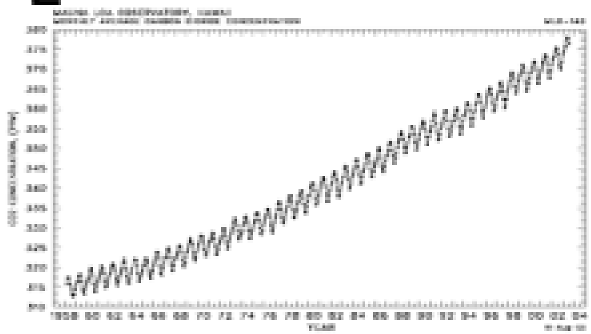


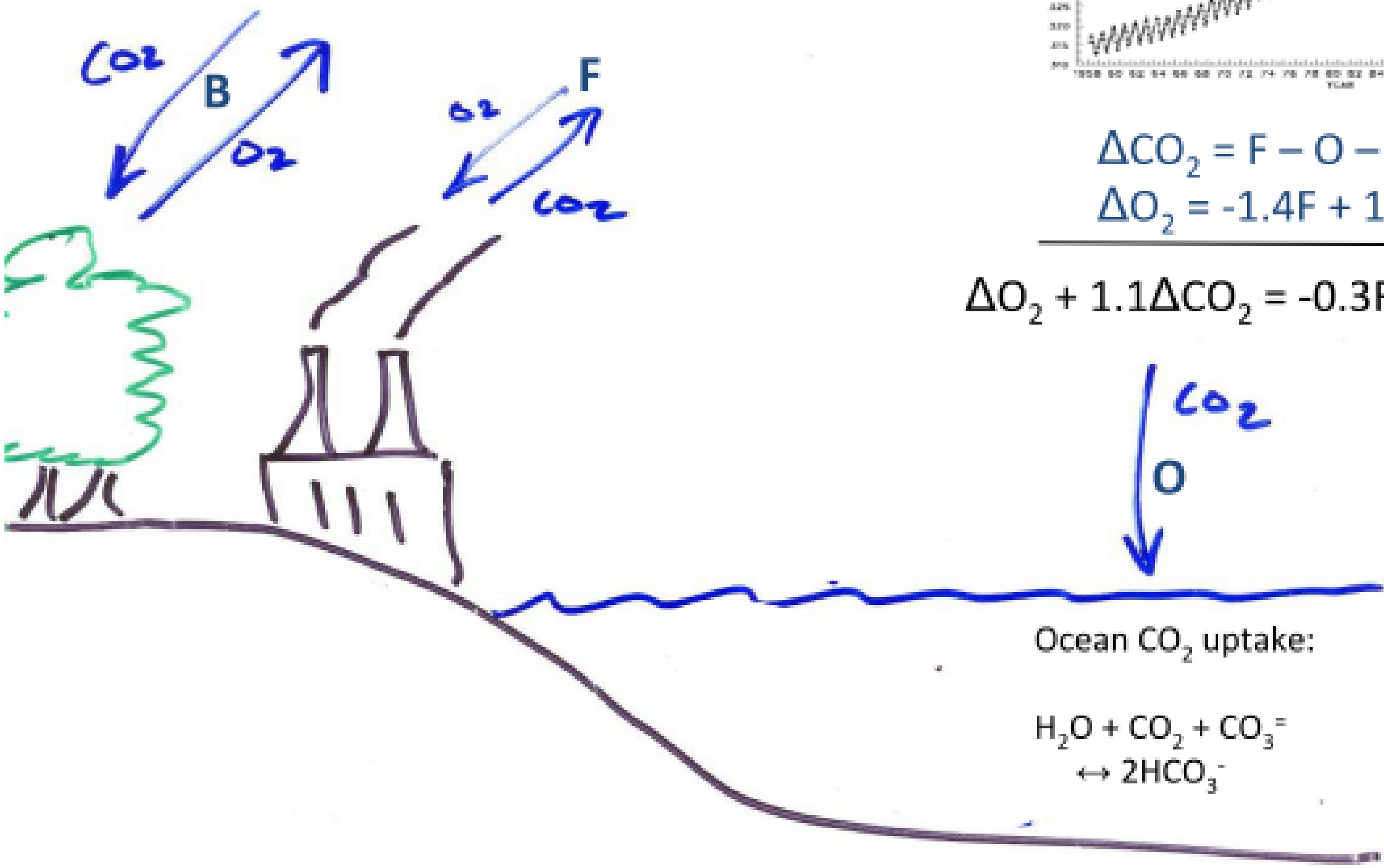
$$\Delta CO_2 = F - O - B$$



From Andrew Manning and Ralph Keeling
"GHG Measurements" – Royal Society, London, 2010.

Atmospheric CO_2 & O_2 budgets





$$\Delta CO_2 = F - O - B$$
$$\Delta O_2 = -1.4F + 1.1B$$

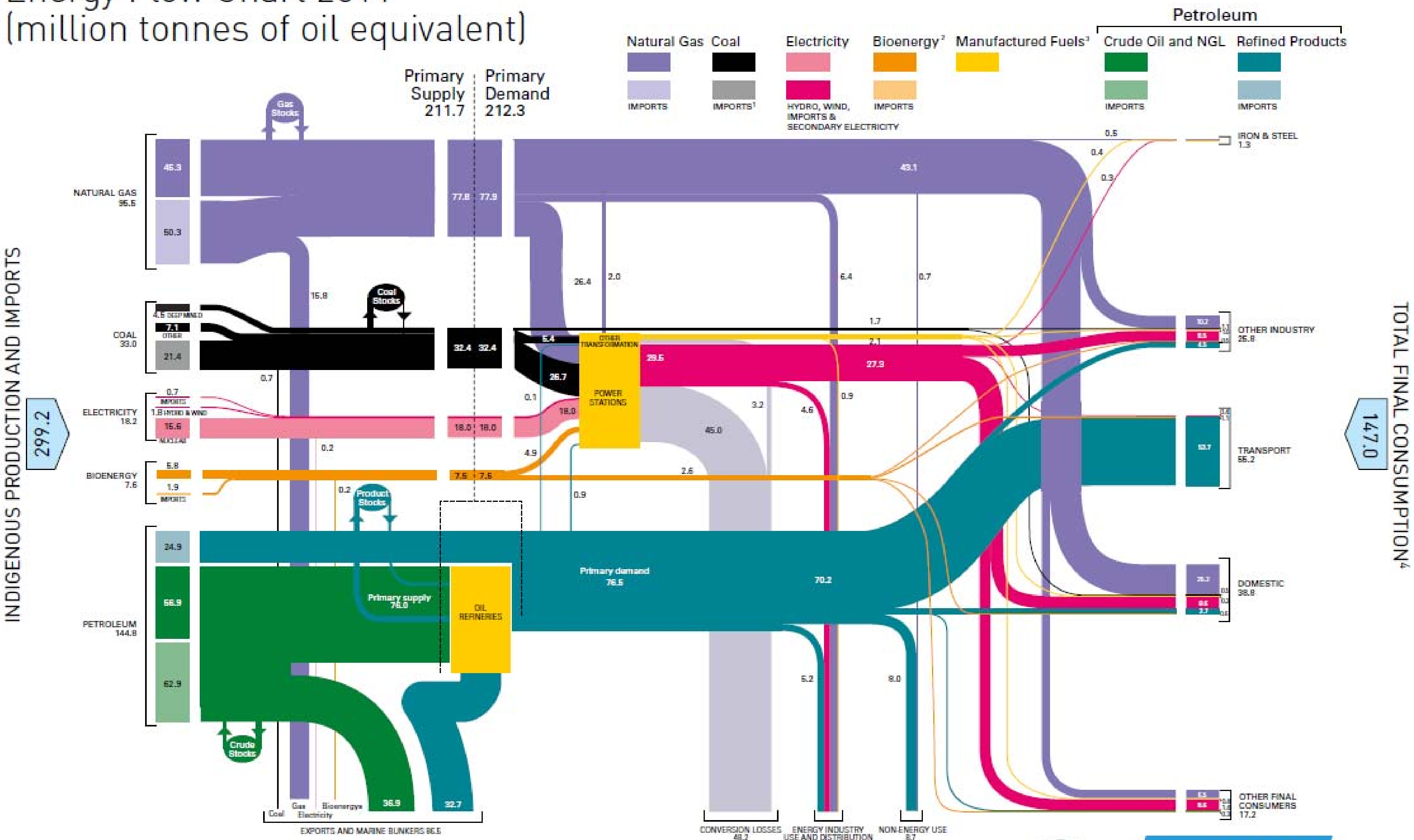
$$\Delta O_2 + 1.1\Delta CO_2 = -0.3F - 1.1O$$

Ocean CO_2 uptake:

$H_2O + CO_2 + CO_3^{=}$
$\leftrightarrow 2HCO_3^{-}$

From Andrew Manning and Ralph Keeling
"GHG Measurements" – Royal Society, London, 2010.

Energy Flow Chart 2011
(million tonnes of oil equivalent)



FOOTNOTES:

1. Coal imports include imports of manufactured fuels, which accounted for 0.03million tonnes of oil equivalent in 2011.
2. Bioenergy is renewable energy made from material of recent biological origin derived from plant or animal matter, known as biomass.
3. Includes heat sold.
4. Includes non-energy use.

This flowchart has been produced using the style of balance and figures in the 2012 Digest of UK Energy Statistics, Table 1.1.

The coherence of measurement results

Definition

A system of quantities is coherent when “(conventional) scaling factors do not appear when (measurement) equations are combined”

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A system of quantities is coherent when "(conventional) scaling factors do not appear when (measurement) equations are combined"

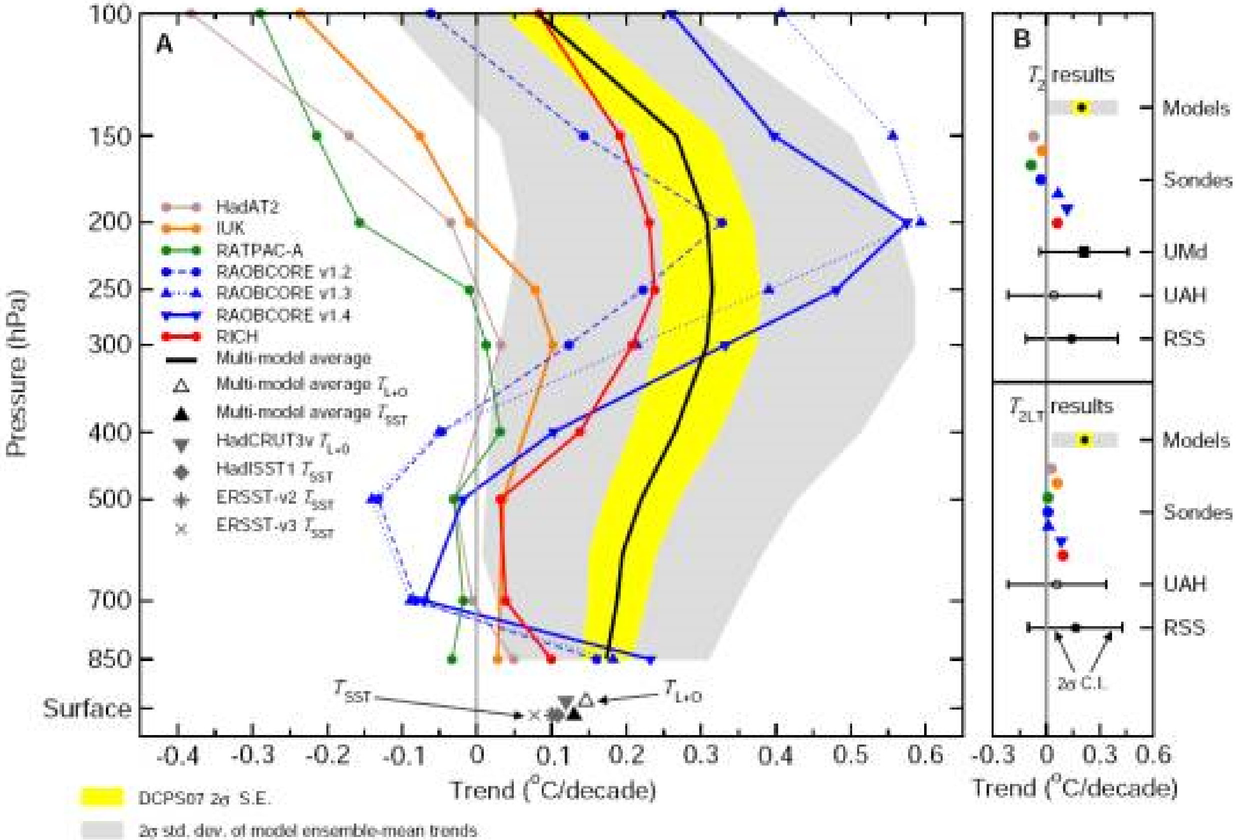
I use coherence to mean that

"Results for different compounds and from different methods can be brought together"

Strong coherence – measurements of different compounds are equivalent

Weak coherence – measurements of a compound made by different methods are equivalent

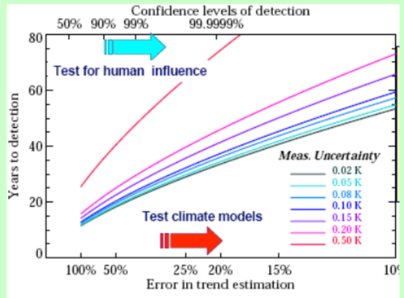
A stable and comparable basis for measurements …



Uncertainty in trends

(*eg* global *T* at 500 hPa)

Trend of 0.2 K / decade



What does traceability to the SI bring to studies of carbon?

Measurements that are stable

- Long-term trends can be used for decision making

Measurements that are comparable

- Results from different laboratories can be brought together

Measurements that are coherent

- Results for different compounds and from different methods can be brought together

A different paradigm - traceability to a scale

The scale approach

Rationale

Values disseminated are traceable to a collection ("family") of artefacts carefully, monitored and maintained

Benefits

- Highly consistent ("precise")
  - Good trend data

Disadvantages

- Responsibility / cost of maintenance concentrated at one institution
- Impossible to regenerate or develop independently
- (May be) insensitive to drift in the reference artefacts

The SI traceability approach

Rationale

Values disseminated are traceable to the SI as realised by a primary method.

Benefits

- Highly coherent and accurate
  - Good "absolute" data
- Possibility for more than one source.

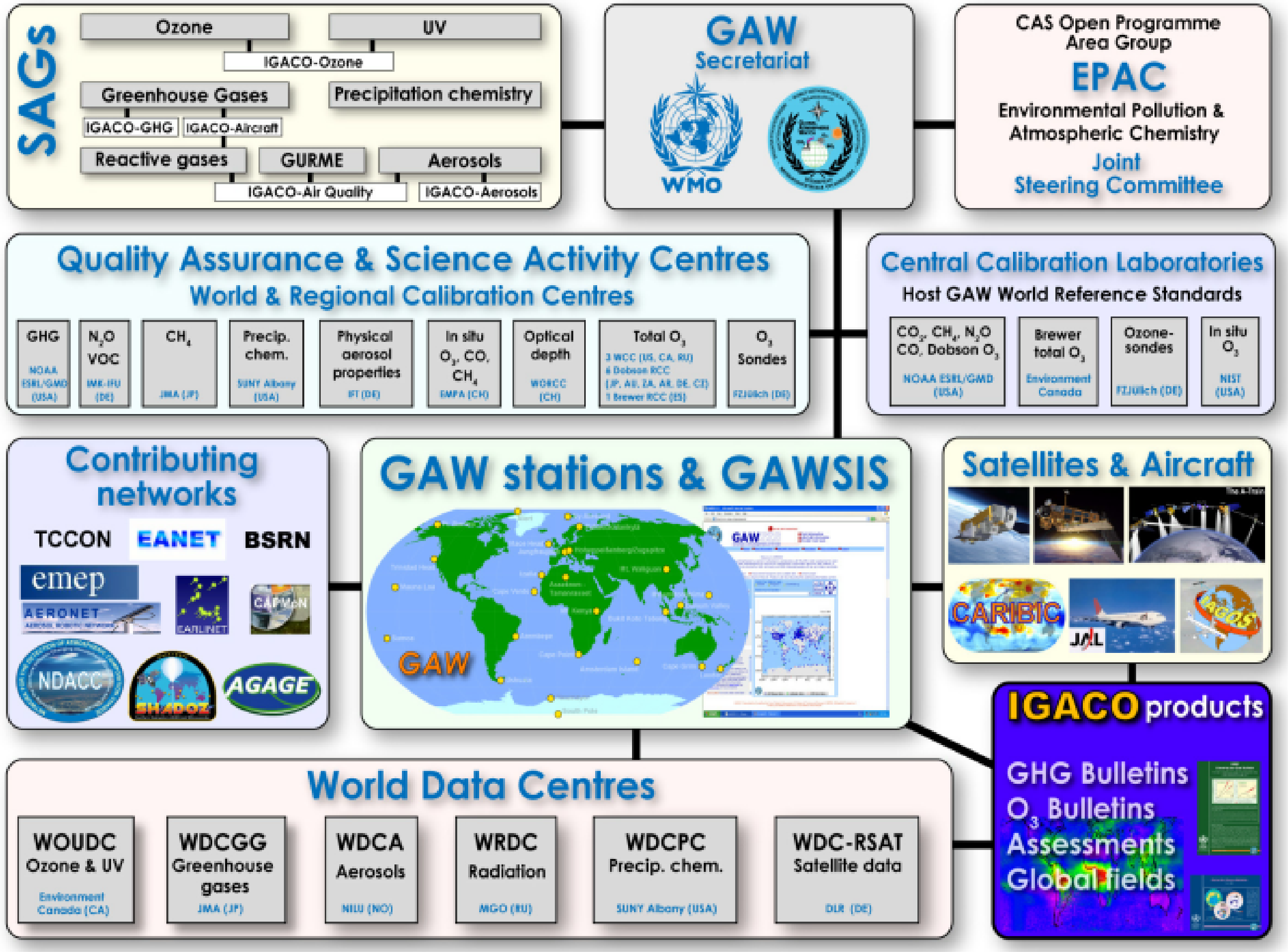
Disadvantages

- Values may change (in absolute terms) within stated uncertainties but will always "improve".

Traceability to the SI uniquely gives coherence

The World Meteorological Organisation (WMO)

… has a well-established quality system for its data products.



WMO/BIPM Workshop March 2010

Measurement Challenges for Global Observation Systems for Climate Change Monitoring

Traceability, Stability and Uncertainty

Climate trends from satellite sounding data
- Fuzhong Weng, NOAA NESDIS {US}

Stable time series for key GHGs and other trace species
- Robert Wielgosz, BIPM

Radiation and Earth energy balance
- Werner Schmutz & Eugene Rozanov, PMOD/WRC

Earth surface (land and water) temperature
- Pascal Lecomte, ESA

Aerosol composition and radiative properties
- Urs Baltensperger, Paul Scherrer Institut {CH}

Microwave imagery data in climate and NWP
- Karen St. Germain, ESA

Surface properties: albedo, land cover and ocean colour
- Nigel Fox, NPL {UK}

Ocean salinity
- Klaus-Dieter Sommer, PTB {DE}

Remote sensing of atmospheric composition and traceability issues in spectroscopic data
- James Whetstone, NIST {US}

Selected recommendations

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

The WMO, BIPM and academic communities should continue to work together to increase redundancy through the development of independent approaches to the provision of standards and carry out necessary comparisons.

That measurement results be traceable to the SI where practical.

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"The methods and techniques in use for the preparation and dissemination of standards by the two communities differ".

That exchange of information and technology continue to be encouraged through: exchange visits and cross-participation in workshops and committees.

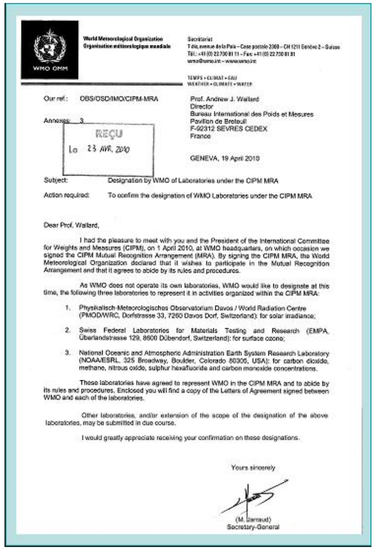
"Verification – the future challenge".

That the WMO and BIPM communities collaborate to make best use of established national and international infrastructure, capability and funding to meet the requirements for standards that will result from increased mitigation efforts.

April 2010 – The WMO sign the CIPM MRA

- Recommendations published in full
  - (available from the BIPM webpage)

    http://www.bipm.org/en/events/wmo-bipm_workshop/
- The WMO have signed the CIPM-MRA
  - Three institutes designated by the WMO can now participate fully in the MRA



World Meteorological Organization
Organisation météorologique mondiale

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Our ref.: OBS/OSD/IMO/CIPM-MRA

Annexes: 3

REÇU
Le 23 AVR. 2010

Prof. Andrew J. Wallard
Director
Bureau International des Poids et Mesures
Pavillon de Breteuil
F-92312 SEVRES CEDEX
France

GENEVA, 19 April 2010

Subject: Designation by WMO of Laboratories under the CIPM MRA

Action required: To confirm the designation of WMO Laboratories under the CIPM MRA

Dear Prof. Wallard,

I had the pleasure to meet with you and the President of the International Committee for Weights and Measures (CIPM), on 1 April 2010, at WMO headquarters, on which occasion we signed the CIPM Mutual Recognition Arrangement (MRA). By signing the CIPM MRA, the World Meteorological Organization declared that it wishes to participate in the Mutual Recognition Arrangement and that it agrees to abide by its rules and procedures.

As WMO does not operate its own laboratories, WMO would like to designate at this time, the following three laboratories to represent it in activities organized within the CIPM MRA:

1. Physikalisch-Meteorologisches Observatorium Davos / World Radiation Centre (PMOD/WRC, Dorfstrasse 33, 7260 Davos Dorf, Switzerland): for solar irradiance;
2. Swiss Federal Laboratories for Materials Testing and Research (EMPA, Überlandstrasse 129, 8600 Dübendorf, Switzerland): for surface ozone;
3. National Oceanic and Atmospheric Administration Earth System Research Laboratory (NOAA/ESRL, 325 Broadway, Boulder, Colorado 80305, USA): for carbon dioxide, methane, nitrous oxide, sulphur hexafluoride and carbon monoxide concentrations.

These laboratories have agreed to represent WMO in the CIPM MRA and to abide by its rules and procedures. Enclosed you will find a copy of the Letters of Agreement signed between WMO and each of the laboratories.

Other laboratories, and/or extension of the scope of the designation of the above laboratories, may be submitted in due course.

I would greatly appreciate receiving your confirmation on these designations.

Yours sincerely

(M. Jarraud)
Secretary-General

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

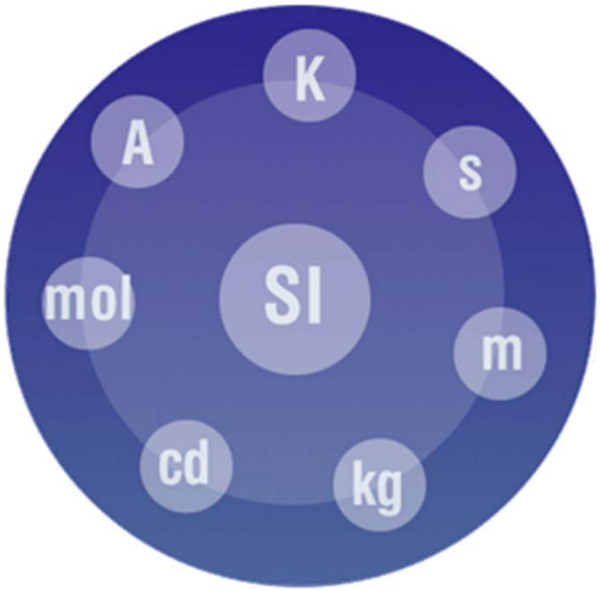
Domain	Essential Climate Variables	
Atmospheric (over land, sea and ice)	**Surface:**[8]	Air temperature, Wind speed and direction, Water vapour, Pressure, Precipitation, Surface radiation budget.
	Upper-air:[9]	Temperature, Wind speed and direction, Water vapour, Cloud properties, Earth radiation budget (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.	

- Agreement in 2011 to form a Joint WMO/BIPM Liaison Group that will progress the recommendations through existing structures *eg* CCQM-GAWG
  - *eg* focus on Essential Climate Variables

Developing an “international” measurement system for carbon

- **The involvement of organizations with long-term (“core”) funding is preferred.**
  - Grant-funded work may not provide the long-term assurance needed.
- **Building “synergy” with established capability is a cost-effective approach.**
  - The SI provides a well-developed and stable basis for traceable measurements.
  - The coherence of measurements that are traceable to the SI is a unique feature – and will be important in this field.
  - Established links and relationships provide a “blueprint” for new collaborations.
- **International organisations can help “pave the way”.**
  - Links made at the international level are easier to mirror at national level.

The "international measurement system" provides the basis for stable, comparable and coherent measurements through traceability to the SI.



Thank you