World Meteorological Organization

Weather • Climate • Water

Background atmospheric carbon measurement and other related ECVs in WMO/GAW

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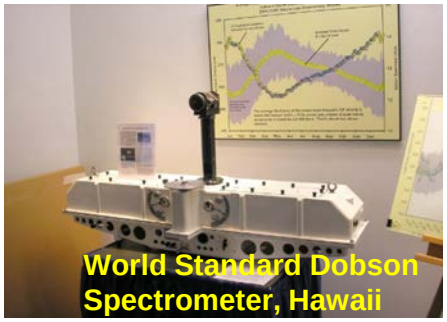
World Meteorological Organization

Global Atmosphere Watch Programme

- The programme of the **World Meteorological Organization** (WMO) that coordinates long-term global observations and analysis of atmospheric composition changes (*countries are represented by their National Meteorological Services*)
- GAW is a partnership involving contributors from **100** countries (*including many contributions from research community*)
- GAW implements end-to-end approach (from observations through research to delivered products and services)
- GAW includes observational network, quality assurance system, data and metadata infrastructure, expert groups
- GAW supports different applications, including climate studies, air quality forecasting, Numerical Weather Prediction etc.
- GAW builds capacity of Members through publications, expert meetings, dedicated training and **partnerships**

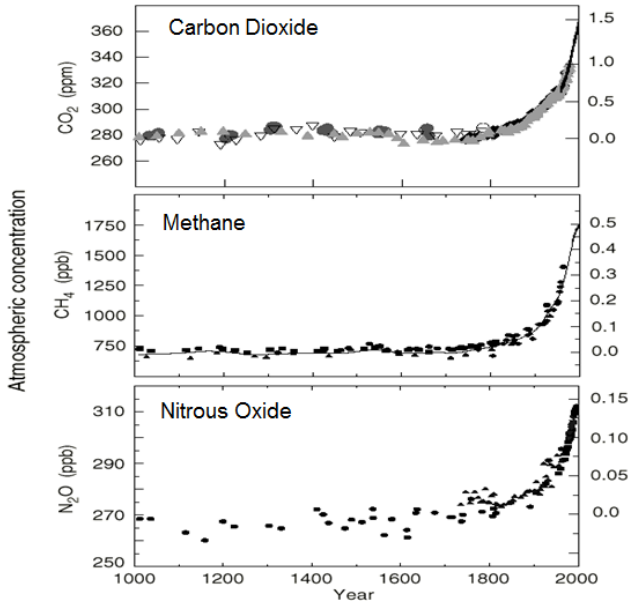

Mt. Cimone station


World Standard Dobson Spectrometer, Hawaii


At Cabo Verde GAW Global station

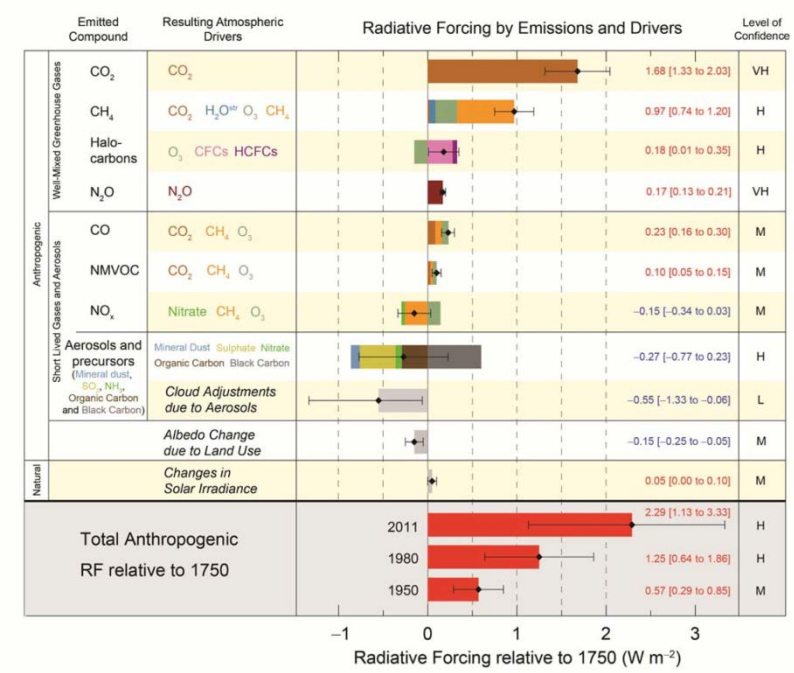
WMO and atmospheric composition

WMO is UN system's authoritative voice on the state and behaviour of the Earth's atmosphere, its interaction with the oceans, the climate it produces and the resulting distribution of water resources.



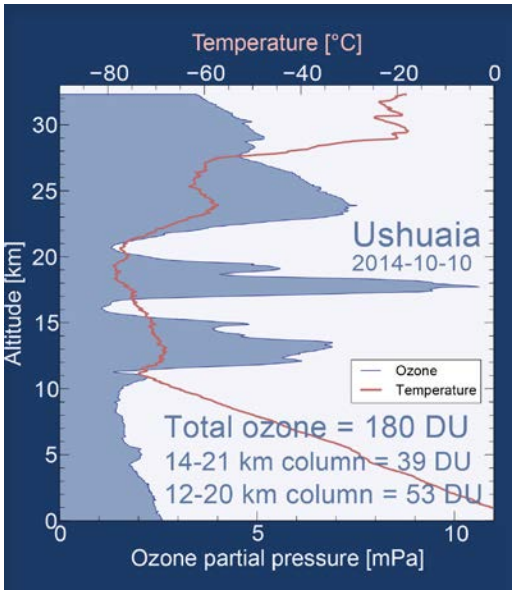
GAW Objectives

- Systematic Global **Long-term** observations of the Chemical Composition of the Atmosphere.
- Analysis and Assessment in Support of International Conventions.
- Development of Air Pollution and Climate Predictive Capability



GAW focal areas

- Stratospheric Ozone and vertical ozone distribution
- Greenhouse Gases (CO_2 *and its isotopes* , CH_4 *and its isotopes,* N_2/O_2 *ratio,* N_2O, SF_6, *CFCs and substitutes*)
- Reactive Gases (O_3, *CO, VOCs,* NO_x, SO_2)
- Total Atmospheric Deposition
- Aerosols (*chemical and physical properties, AOD*)
- UV Radiation
- GAW Urban Meteorology and Environment (GURME) project



Essential Climate Variables in GAW

The 50 GCOS Essential Climate Variables (ECVs) (2010) are required to support the work of the UNFCCC and the IPCC.

Atmospheric Composition: Carbon dioxide, Methane, and other long-lived greenhouse gases[3], Ozone and Aerosol, supported by their precursors[4].

- [3] Including nitrous oxide (N_2O), chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF_6), and perfluorocarbons (PFCs).
- [4] In particular nitrogen dioxide (NO_2), sulphur dioxide (SO_2), formaldehyde (HCHO) and carbon monoxide (CO).

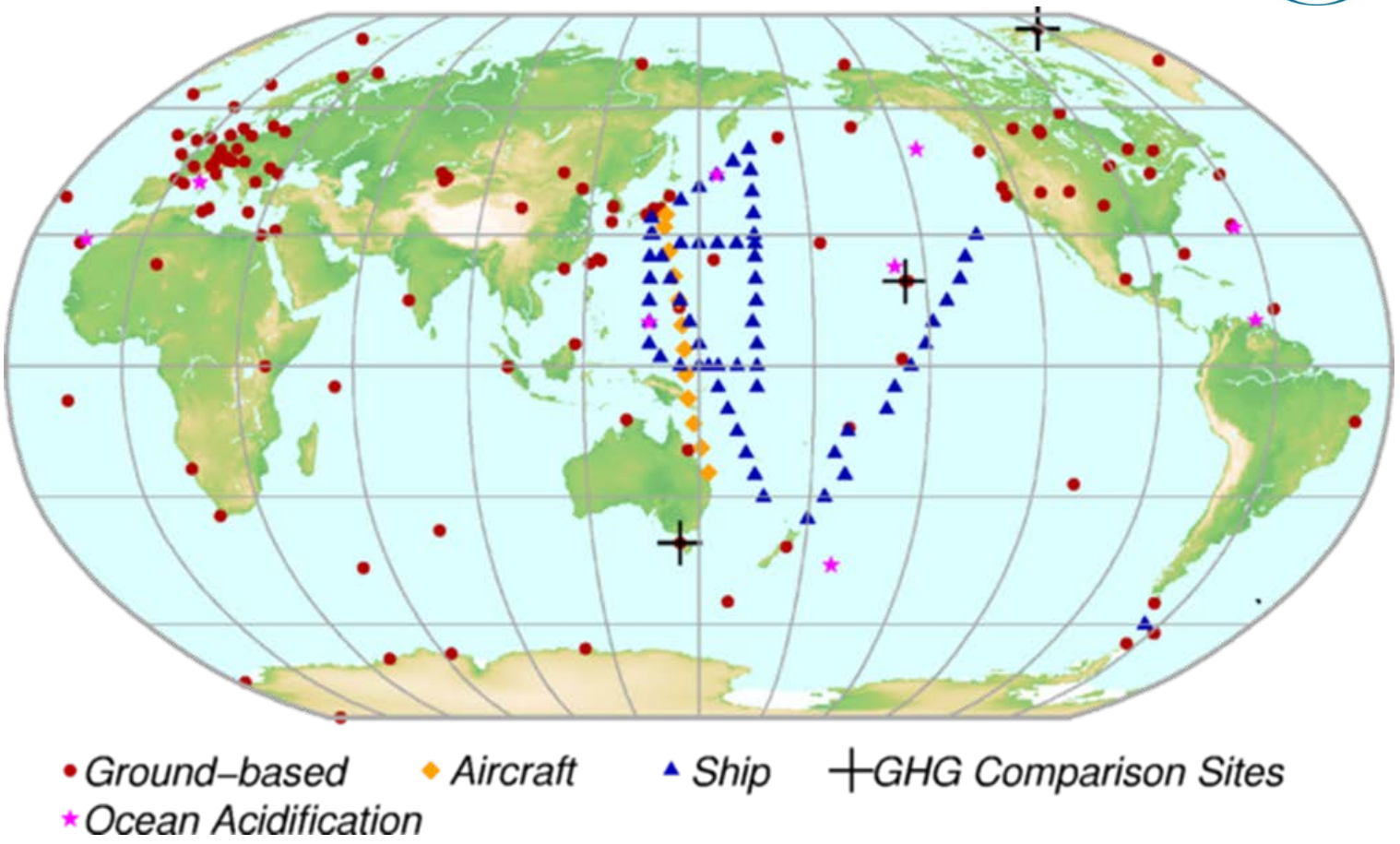
Future developments of GAW

- New GAW implementation plan will be more focused on applications
- The Integrated Global Greenhouse Gas Information System (IG^3IS) was supported by Members through Cg-17 resolution as one of the relevant services

IG^3IS implementation will require:

- Higher spatial and temporal resolution of observations
- More complex observations
- Improved modelling tools

Current status of the GAW GHG Network



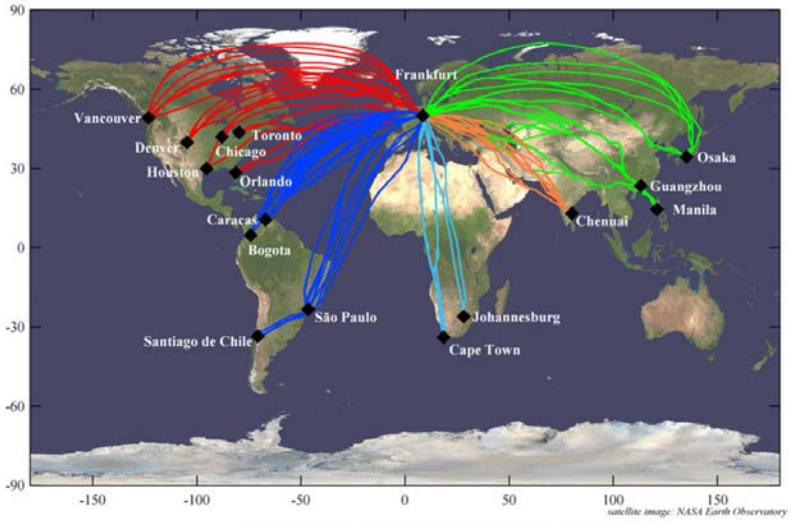
The network consists of 141, 123 and 49 fixed stations on the ground for CO_2, CH_4 and N_2O respectively. About 13%, 13% and 18% of the stations perform both discrete air sampling in "flasks" and continuous measurements of CO_2, CH_4 and N_2O, respectively.

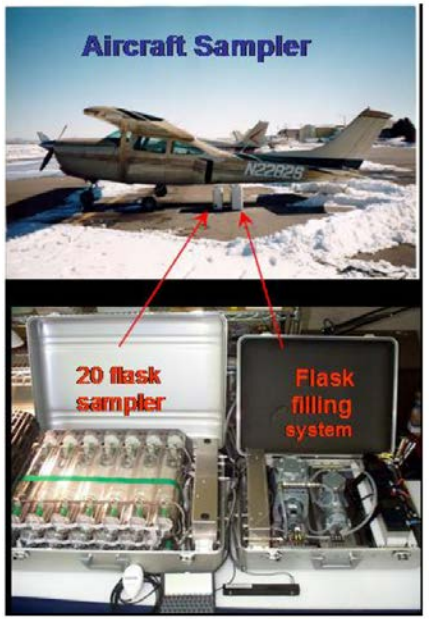
An Observational Network with Global Coverage

- Other GHG measurements which are not included in the GHG Bulletin (new category of GAW local station will fit here)
- In situ tall towers operated by NOAA/ESRL
- Japan Meteorological Agency (JMA) operates two research vessels, Ryofu Maru and Keifu Maru, in the western North Pacific
- The Total Carbon Column Observing Network (TCCON, www.tccon.caltech.edu) is a contributing network to GAW
- Contributions from collaborating projects: Integrated non-CO_2 Greenhouse Gas Observing System (InGOS) and Integrated Carbon Observation System (ICOS)

Aircraft observations of CO_2 , CH_4 and N_2O mixing ratios

- Regular commercial aircraft observations in the CONTRAIL project
- Commercial flights on a monthly basis in the CARIBIC project
- NOAA currently obtains twice-monthly vertical profiles of several greenhouse gases at 17 sites (mostly over North America)
- Greenhouse gas measurements (CO_2 and CH_4) are part of the IAGOS-ERI project. IAGOS contributes to aerosol observations as well.
- Japan Meteorological Agency (JMA) continues monthly aircraft observations of tropospheric greenhouse gases (including CO_2, CH_4 and N_2O) in the western North Pacific region
- Brazilian national network





Attributes of the GAW observations

- Multi-national and multi-agency
- Global in nature
- Diverse in measurement approach (flask sampling, continuous, remote sensing techniques)

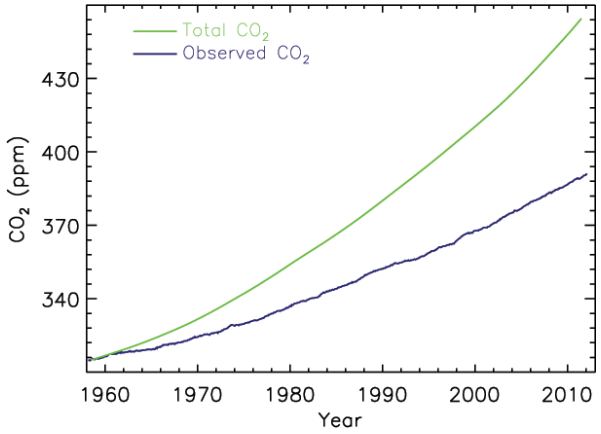
BUT:

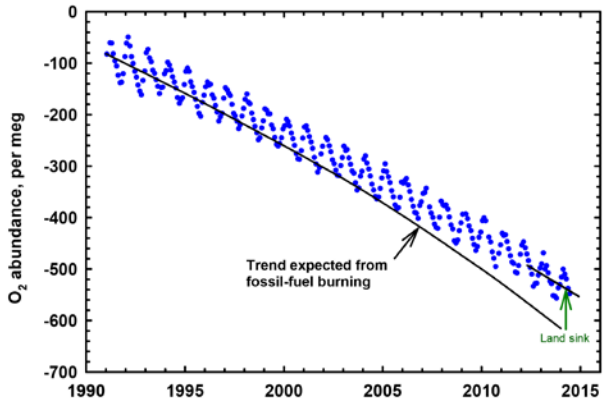
-Have to be comparable between countries

-Have to be compared with and assimilated into the global models

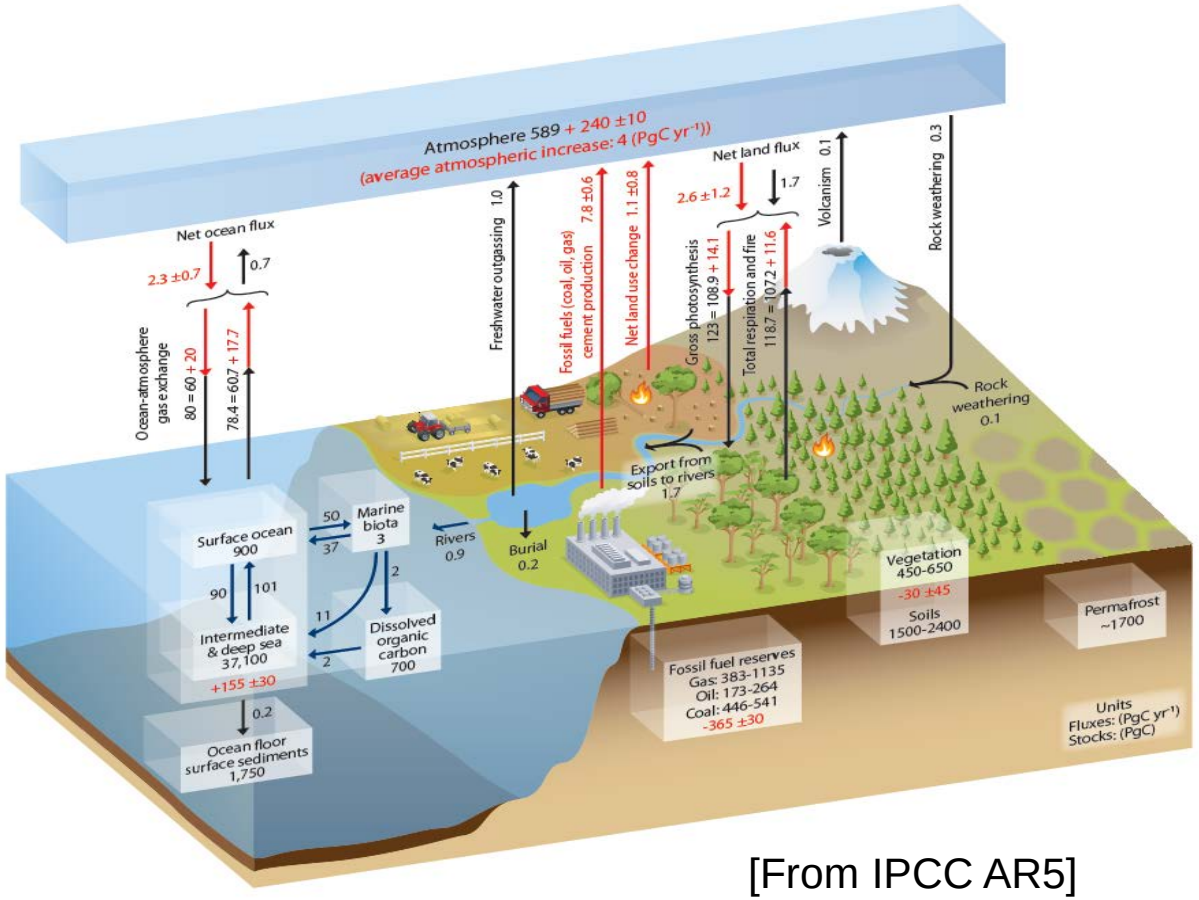
-Have to be compared with the satellite observations (one instrument per globe)

Observation must be diverse and complex



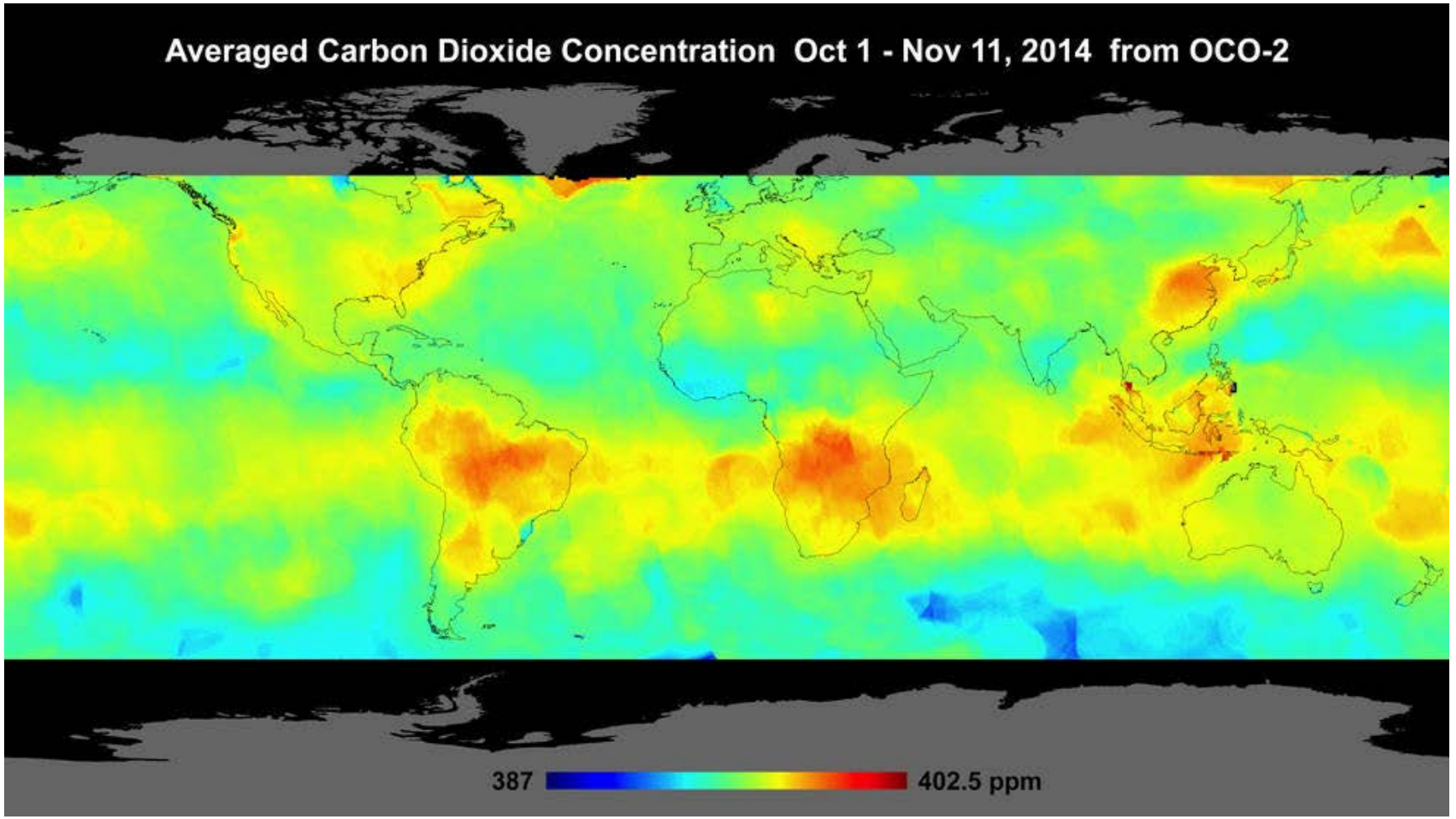


[Plots by R. Keeling]



[From IPCC AR5]

Observations must be of high quality



NASA/JPL-Caltech

Regional differences are relatively small!

Data Quality Objectives for GHG

Component	Compatibility goal	Extended compatibility goal	Range in unpolluted troposphere	Range covered by the WMO scale
CO_2	± 0.1 ppm (Northern hemisphere) ± 0.05 ppm (South. hemisphere)	± 0.2 ppm	360 - 450 ppm	250 – 520 ppm
CH_4	± 2 ppb	± 5 ppb	1700 – 2100 ppb	300 – 2600 ppb
CO	± 2 ppb	± 5 ppb	30 – 300 ppb	20 -500 ppb
N_2O	± 0.1 ppb	± 0.3 ppb	320 – 335 ppb	260 – 370 ppb
SF_6	± 0.02 ppt	± 0.05 ppt	6 – 10 ppt	1.1 – 9.8 ppt
H_2	± 2 ppb	± 5 ppb	450 – 600 ppb	140 −1200 ppb
$\delta^{13}C\text{-}CO_2$	± 0.01‰	± 0.1‰	-7.5 to -9‰ vs. VPDB	
$\delta^{18}O\text{-}CO_2$	± 0.05‰	± 0.1‰	-2 to +2‰ vs. VPDB	
$\Delta^{14}C\text{-}CO_2$	± 0.5‰	± 3‰	0-70‰	
$\Delta^{14}C\text{-}CH_4$	± 0.5‰		50-350‰	
$\Delta^{14}C\text{-}CO$	± 2 molecules cm^{-3}		0-25 molecules cm^{-3}	
$\delta^{13}C\text{-}CH_4$	± 0.02‰	± 0.2‰		
$\delta D\text{-}CH_4$	± 1‰	± 5‰		
O_2/N_2	± 2 per meg	± 10 per meg	-250 to -800 per meg (vs. SIO scale)	

Reviewed at GGMT-2013

Quality Management principles

✓Network-wide use of only one reference standard or scale (***primary standard***). In consequence, there is only one institution that is responsible for this standard.

✓ Full traceability to the ***primary standard*** of all measurements made by Global, Regional and Contributing GAW stations.

✓ The definition of data quality objectives (DQOs).

✓ Establishment of guidelines on how to meet these quality targets, i.e., harmonized measurement techniques based on Measurement Guidelines (MGs) and Standard Operating Procedures (SOPs).

✓ Establishment of MGs or SOPs for these measurements.

✓ Use of detailed log books for each parameter containing comprehensive meta information related to the measurements, maintenance, and 'internal' calibrations.

✓ Regular independent assessments (system and performance audits).

✓ Timely submission of data and associated metadata to the responsible World Data Centre as a means of permitting independent review of data by a wider community.

Apply network wide

General requirements to GAW stations

1. The station location is chosen such that, for the variables measured, it is **regionally representative** and is normally free of the influence of significant local pollution sources.

4. There is a commitment by the responsible agency to **long term observations** of at least one of the GAW variables in the GAW focal areas (ozone, aerosols, greenhouse gases, reactive gases, UV radiation, precipitation chemistry).

5. The GAW observation made is of known quality **and linked to the GAW Primary Standard**.

6. **The data and associated metadata are submitted to one of the GAW World Data Centres** no later than one year after the observation is made. Changes of metadata including instrumentation, traceability, observation procedures, are reported to the responsible WDC in a timely manner.

10. A station logbook (i.e. record of observations made and activities that may affect observations) is maintained and is used in the data validation process.

Apply to each individual station

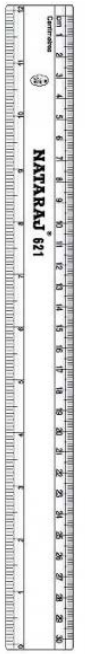
Central Facilities

Five types of central facilities:

- Central Calibration Laboratories (CCLs)
- Quality Assurance/Science Activity Centres (QA/SACs)
- World Calibration Centres (WCCs)
- Regional Calibration Centres (RCCs)
- World Data Centres (WDCs)

Current WMO Scales for GHG

- WMO CO_2 X2007
- WMO CH_4 X2004
- WMO CO X2004 (*new CO scale has been recently released -> WMO CO X2014)*
- WMO N_2O X2006A
- WMO SF_6 X2006 (*new SF6 scale has been recently released -> WMO SF_6 X2014)*
- WMO H_2 X2009



Central Calibration Laboratories

Host of WMO World Reference Standards for long-lived GHG

- CO_2, CH_4, N_2O, SF_6

NOAA ESRL USA

Collaboration under the CIPM MRA includes collaboration with the Consultative Committee for Amount of Substance (CCQM), Gas Analysis Working Group (GAWG) that held its annual meeting in NOAA, Boulder, CO, USA on 27 September 2011. MRA allows NOAA to represent WMO in the following recent key comparisons:

- CCQM-K82 (Methane in air at ambient level)
- CCQM-K83 (Halocarbons in air at ambient levels)
- CCQM-K84 (Ambient CO)

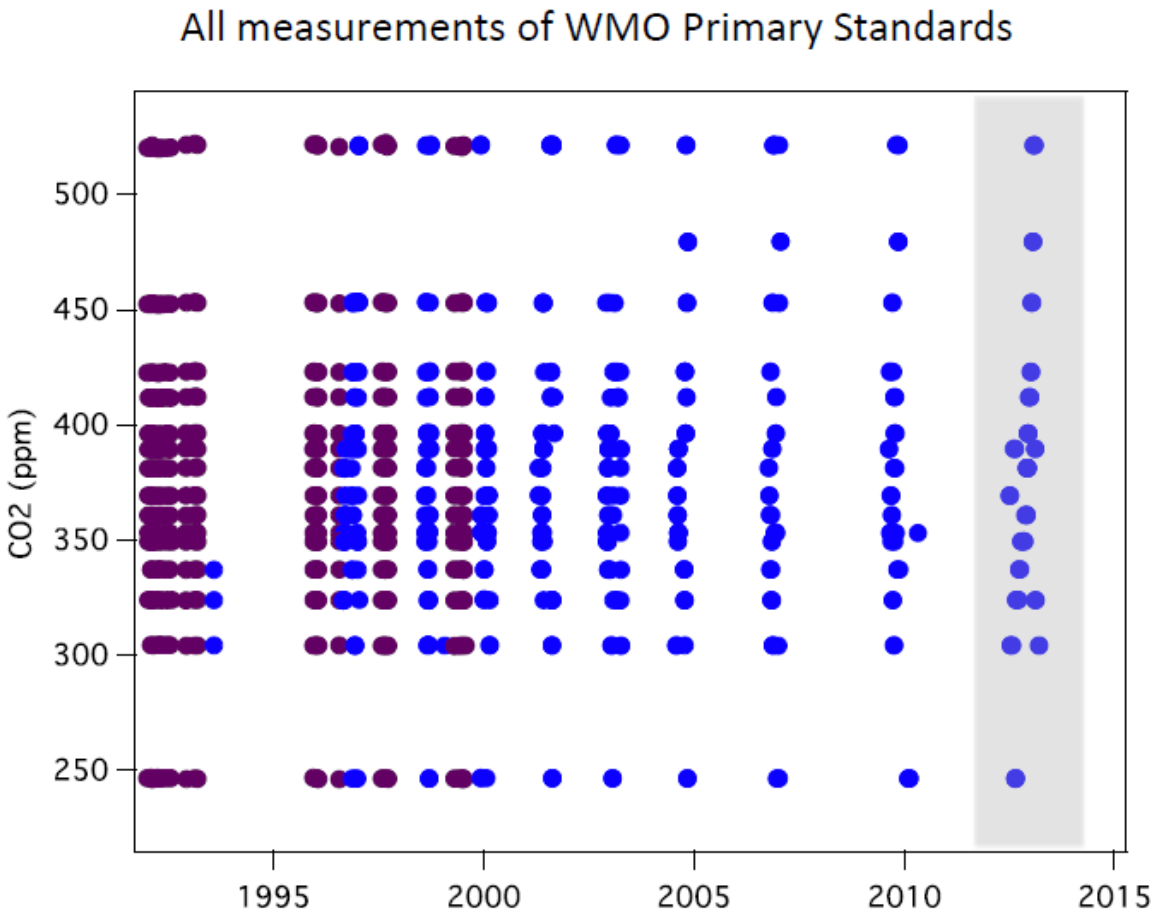
Propagation of WMO Mole Fraction Scale for CO_2

WMO CO_2 scale

- Reference scale for CO_2 in dry air, maintained by NOAA/GMD
- Defined by 15 primary standards (~ 250 – 520 ppm)

Courtesy of B.Hall

Stability of WMO Mole Fraction Scale for CO_2



Courtesy of B.Hall

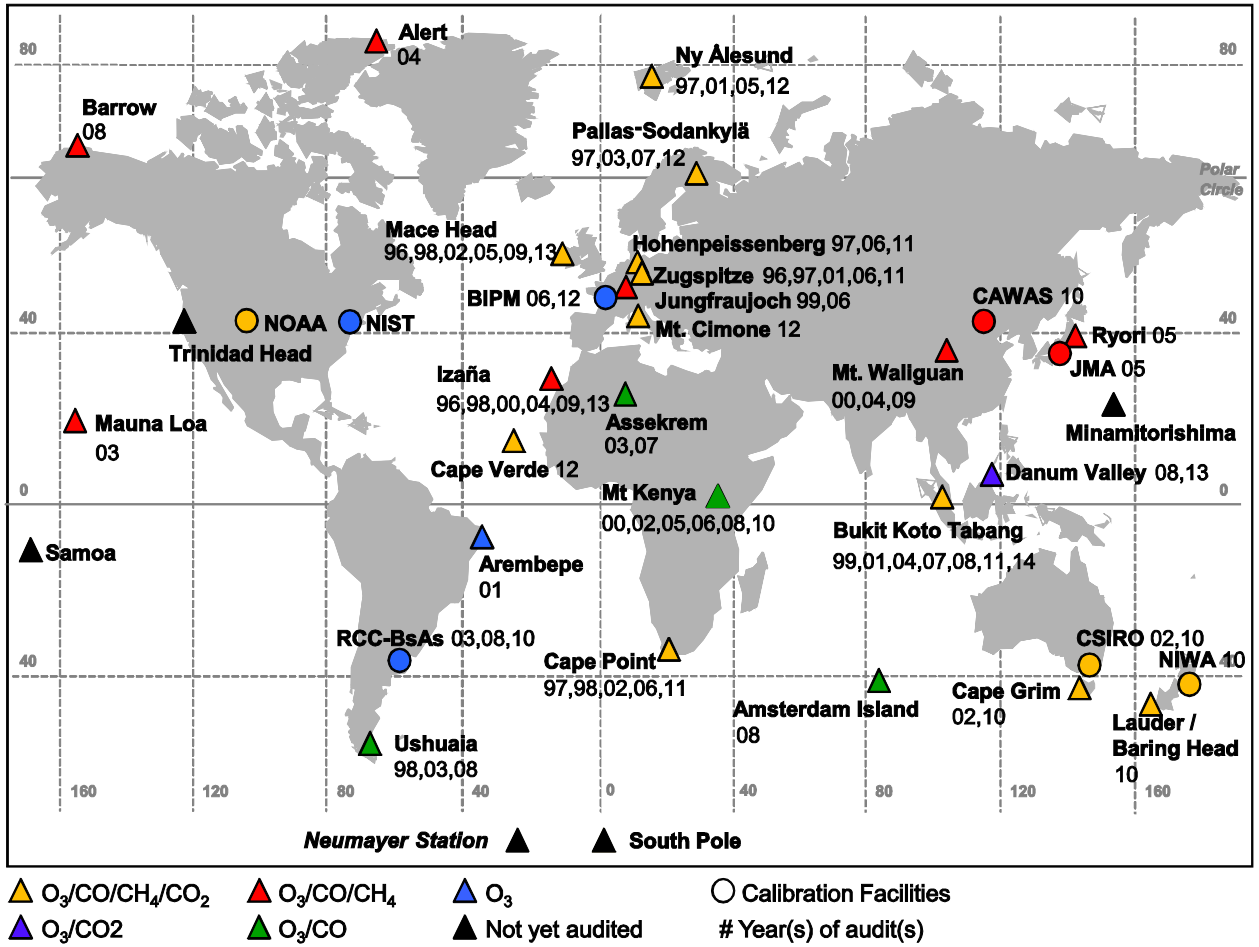
World Calibration Centres

Linking Observations to World Reference Standards and Ensuring Network Comparability through comparison campaigns and regular audit

CO_2	- NOAA ESRL USA - EMPA, Switzerland (audits)
CH_4	- EMPA, Switzerland (Am,E/A) - JMA, Japan (A/O)
N_2O	Karlsruhe Institute of Technology (KIT), Institute for Meteorology and Climate Research, IMK-IFU, Garmisch-Partenkirchen, Germany
SF_6	Korea Meteorological Administration

Stations audits by Empa

WCC-Empa Audits 1996 – 2014



WMO Round-Robin comparisons

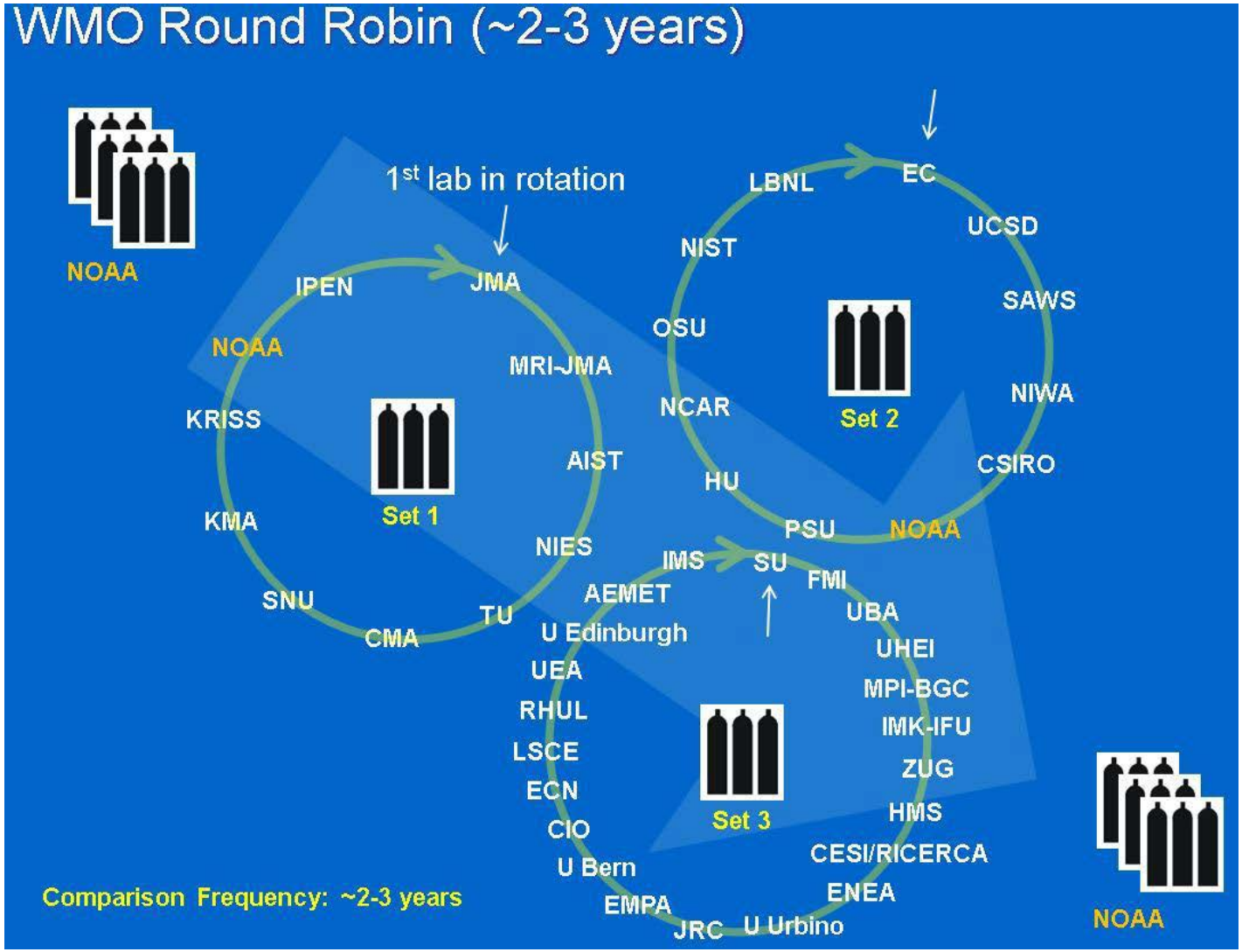
- In reference to WMO goals for compatibility, the purpose of the WMO Round-Robin (RR) reference gas intercomparison would be NOT to distribute calibration scales, but to verify how well the WMO scale is propagated to each of the participating lab, and to the relevant field measurements if they routinely uses WMO standards directly.

WMO Round-Robin comparisons

- **NOAA ESRL prepared 9 high pressure cylinders (3 sets) of clean dry air, collected at Niwot Ridge for the intercomparison.**
- **Labs were divided into 3 globally-distributed groups.**

6th Round-robin (2014 -): 43 Labs registered

Comparison campaigns



WMO Round-Robin comparisons

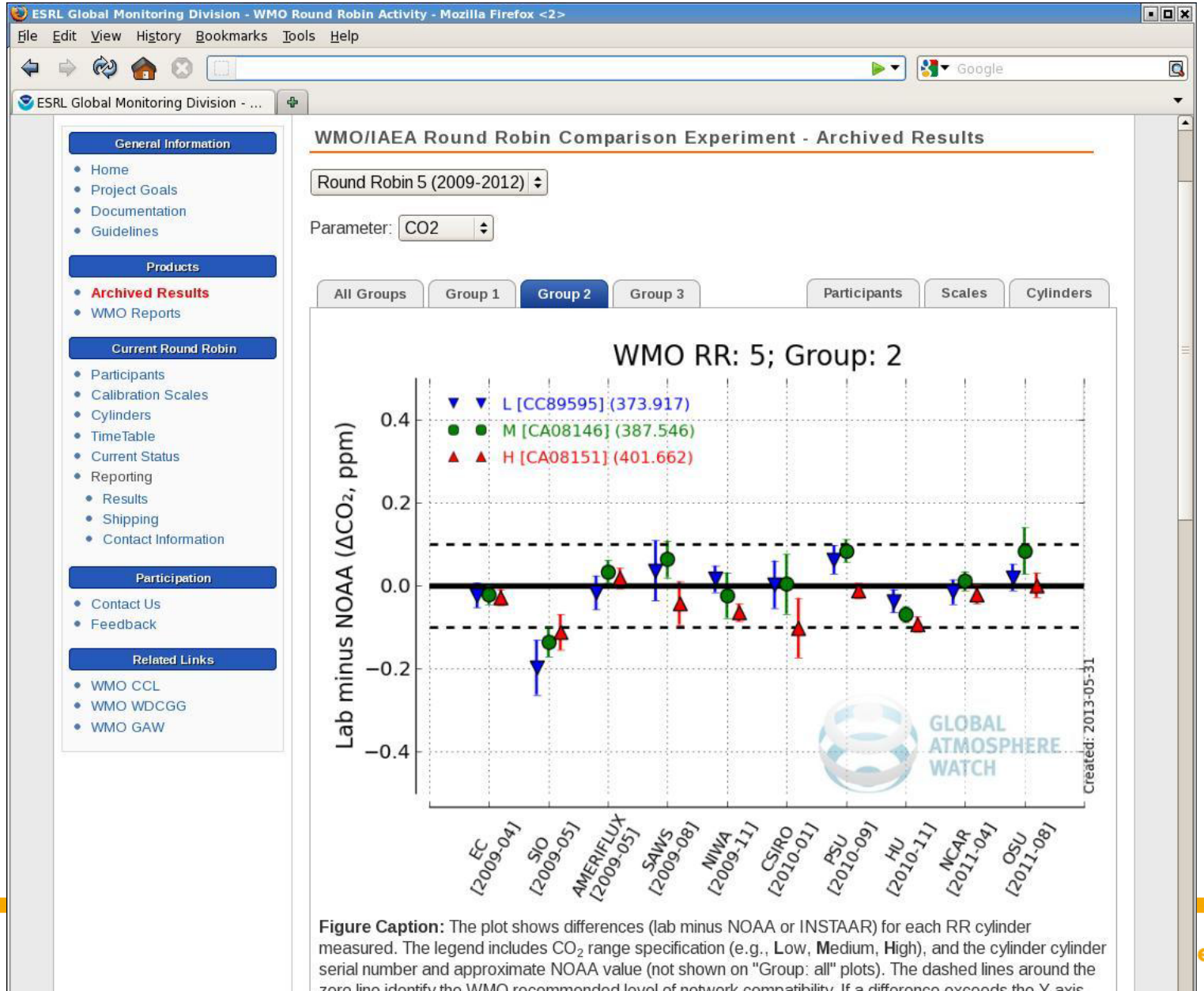


Figure Caption: The plot shows differences (lab minus NOAA or INSTAAR) for each RR cylinder measured. The legend includes CO_2 range specification (e.g., **L**ow, **M**edium, **H**igh), and the cylinder cylinder serial number and approximate NOAA value (not shown on "Group: all" plots). The dashed lines around the zero line identify the WMO recommended level of network compatibility. If a difference exceeds the Y axis

Regional GHG comparisons

Laboratory and Location	Date of Measurement	Cylinder Number						Instrument
		CPB31288			CPB31289			
		Mole fraction (ppb)	SD (ppb)	No	Mole fraction (ppb)	SD (ppb)	No	
JMA Tokyo, Japan	Jun. 25, 2013	1738.3	1.0	10	1878.0	1.6	10	SHIMADZU GC-14BPF
CSIRO Aspendale, Australia	Aug. 15-16, 20-21, 27-28, 2013	1738.2	0.5	107	1878.7	0.5	128	CARLE (EG&G) Series 400
NIWA Wellington, New Zealand	Oct. 10, Oct. 14, 2013	1738.9	1.2	20	1878.3	1.4	20	Hewlett-Packard (Agilent) 5890
NOAA/ESRL Boulder, U.S.A.	Jan. 21-Feb. 10, 2014	1740.0	0.7	5	1879.7	1.0	5	Hewlett-Packard (Agilent) 6890
JMA Tokyo, Japan	Apr. 8, 2014	1738.1	1.6	10	1877.9	1.2	10	SHIMADZU GC-14BPF

Training

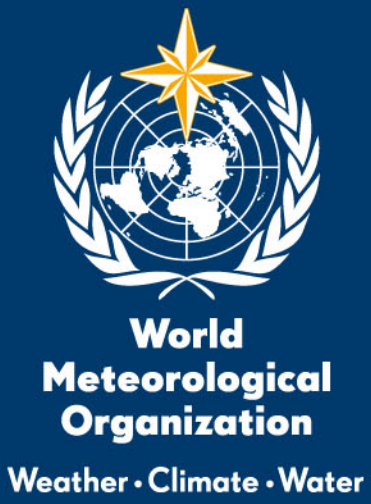
GAWTEC 27: 16-29 November 2014

Main topics: Physical Properties of Aerosols
Aerosol Optical Depth
Data quality assurance and control/ Data evaluation tools

- **GAWTEC 28:** 10-23 May

Main topic: greenhouse gases measurements

- Summer schools and conference "Ten years of Northern Eurasia Earth Science Partnership (NEESPI): Results and Future Plans", Prague, Czech Republic, 9-12 April 2015



Thank you for your attention!