High precision monitoring of greenhouses gases in Europe

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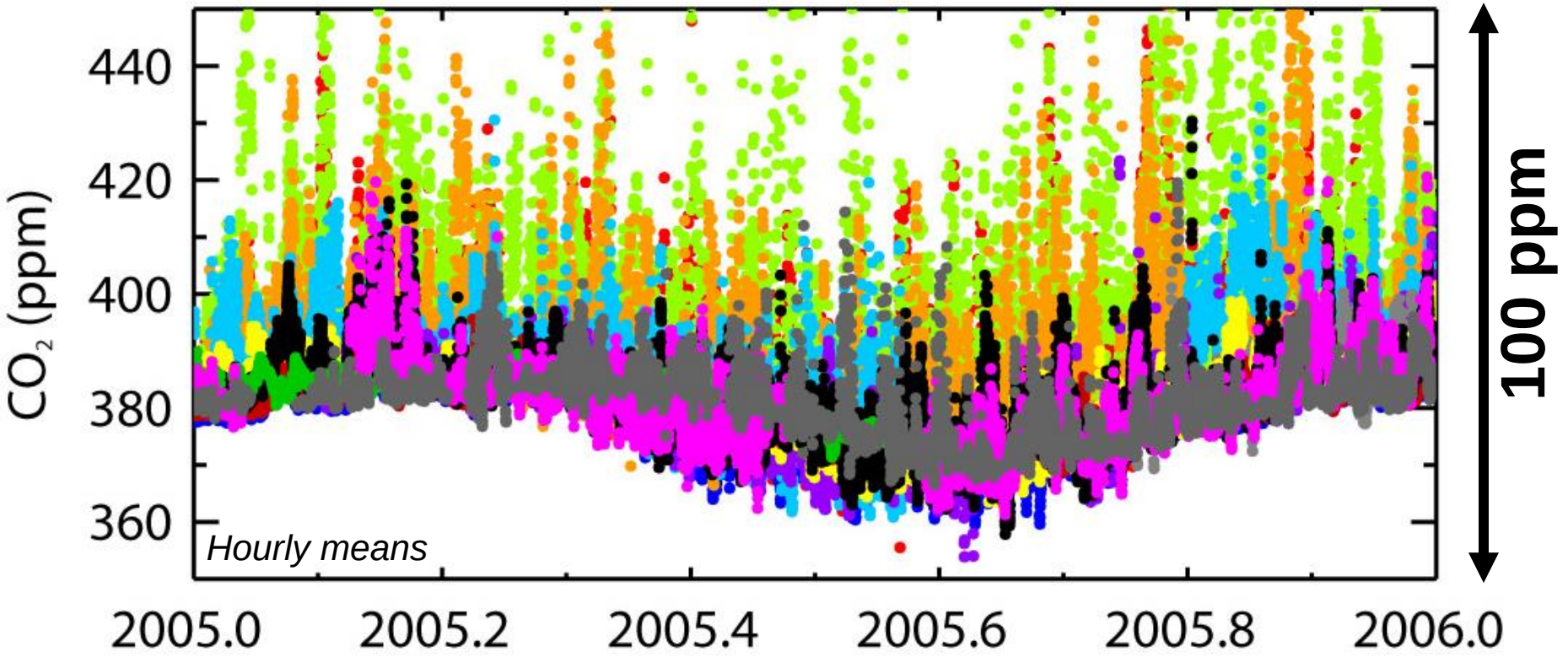
ICOS INTEGRATED CARBON OBSERVATION SYSTEM

LSCE
LABORATOIRE DES SCIENCES DU CLIMAT & DE L'ENVIRONNEMENT

Max-Planck-Institut für Biogeochemie

MPI-BGC Jena

One year of in-situ measurements in Europe



Cabauw, *Netherlands*
Heidelberg, *Germany*
Hegyhatsal, *Hungary*
Lampedusa, *Italy*
Plateau Rosa, *Italy*
Zeppelin, *Spitsbergen*
Mahe Head, *Ireland*
Monte Cimone, *Italy*
Gif/Yvette, *France*
Kasprowy, *Poland*
Pallas, *Finland*
Schauinsland, *Germany*
Puy de Dôme, *France*

Signals at different time scale

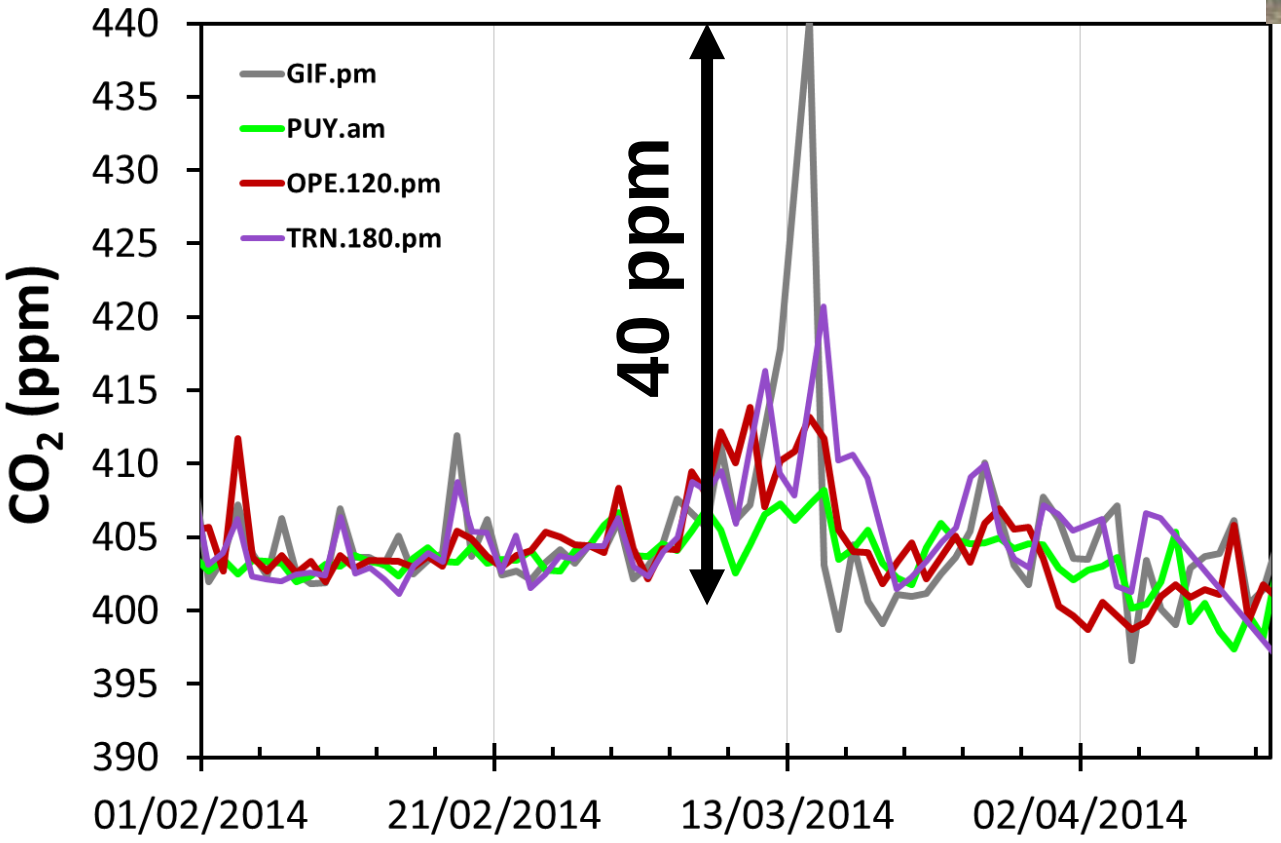
Spatial representativeness differ from site to site

Each site in charge of its own instrument, protocols (calibration, QA/QC) and data processing

Dedicated comparison program (Round-Robin)

Synoptic CO_2 variability

Pollution event over Northern France due to stratification of air masses

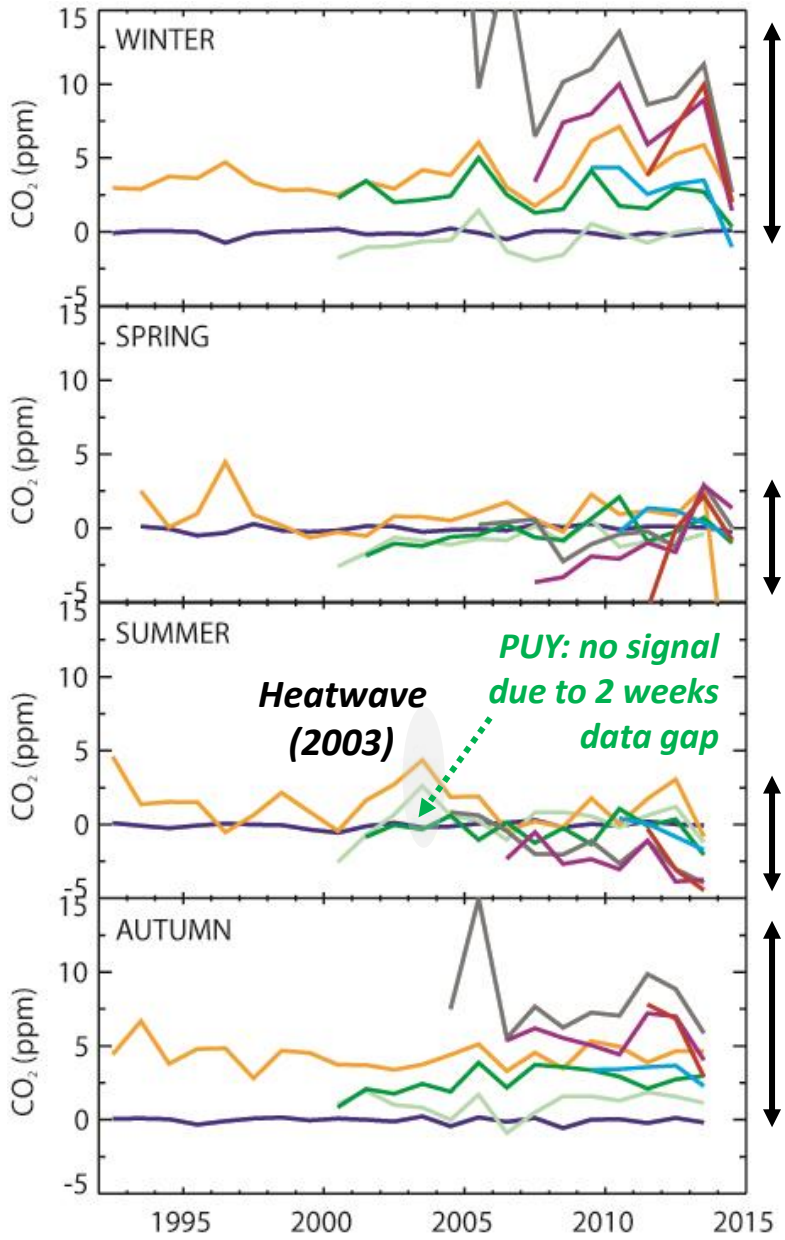


Continuous measurements enable detection of short term variabilities (not possible vith flask sampling programs)

Intermediate precision (≈1 ppm) would be enough to characterize such signals

Seasonal CO_2 gradients

Using mace Head as a reference



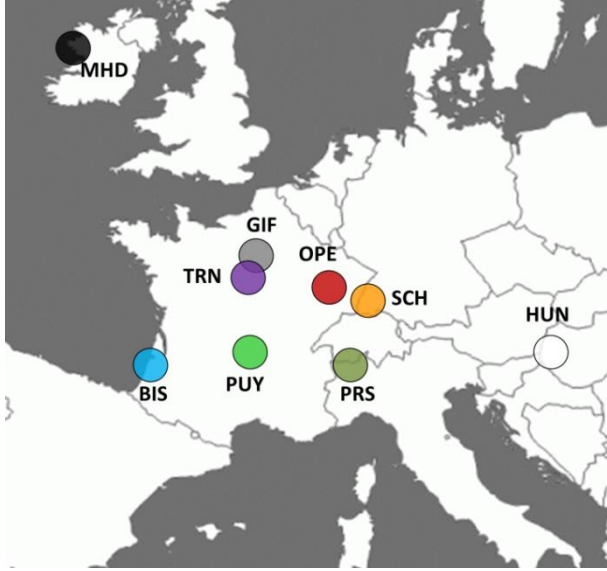
-1 / +10 ppm

-4 / +3 ppm

-4 / +3 ppm

0 / +10 ppm

Monthly means of background selected observations



Very high precision and continuous dataset needed to characterize trend and interannual gradients over Europe

WMO Recommendations

Table 1 - Recommended compatibility of measurements of components discussed

Component	Compatibility goal	range in the unpolluted troposphere
CO_2	± 0.1 ppm (± 0.05 ppm in the southern hemisphere)	360 … 430 ppm
$\delta^{13}C\text{-}CO_2$	± 0.01 ‰	-7.5 … -9 ‰ vs. VPDB
$\delta^{18}O\text{-}CO_2$	± 0.05 ‰	-2 … +2‰ vs. VPDB
$\delta^{13}C - CH_4$	± 0.02 ‰	-80… -20‰ vs. VPDB
$\delta D - CH_4$	± 1 ‰	-400 … +0‰ vs. VSMOW
$\Delta^{14}C\text{-}CO_2$	± 1 ‰	0 … 70‰
O_2/N_2	± 2 per meg	-250 … -550 per meg (vs. SIO scale)
CH_4	± 2 ppb	1700 … 2100 ppb
CO	± 2 ppb	30 … 300 ppb
N_2O	± 0.1 ppb	320 … 335 ppb
H_2	± 2 ppb	450 … 600 ppb
SF_6	± 0.02 ppt	6 … 10 ppt

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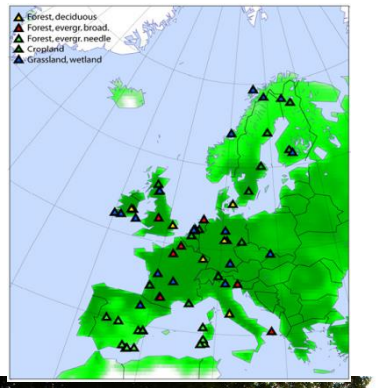
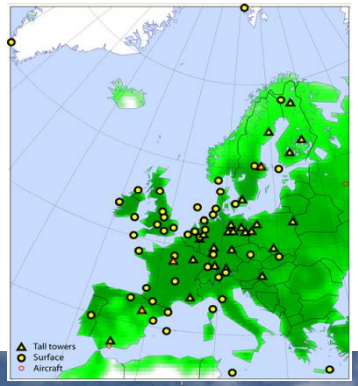
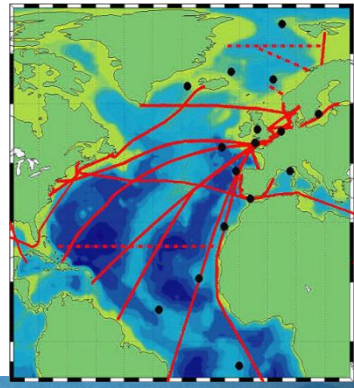
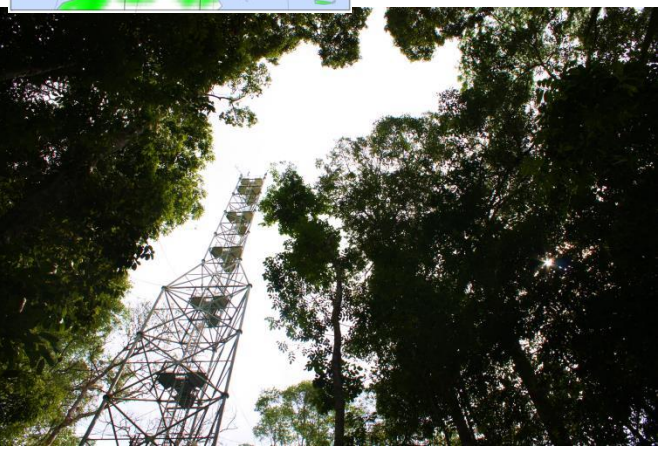
A European research infrastructure to monitor greenhouse gas emissions









Ecosystems | Atmosphere | Ocean

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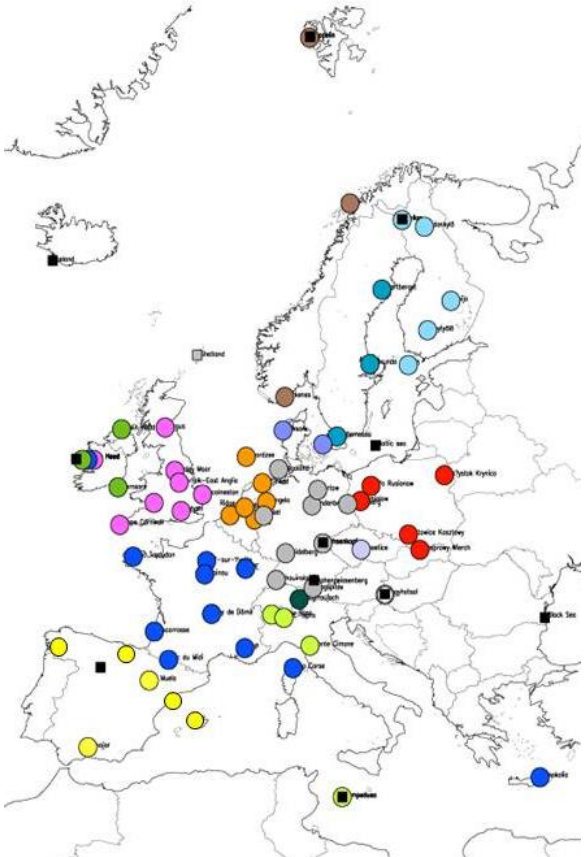
A European research infrastructure to monitor greenhouse gas emissions

ICOS Strategy for the atmospheric component:

- Standardized measurement systems and protocols
- Centralized data evaluation and quality control
- Calibration of working standards in Central Analytical Lab
- Analysis of additional tracers at stations and in the CAL



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Organization of the atmospheric component

Carbon Portal

WMO Global Atmosphere Watch
World Data Centre for Greenhouse Gases

Copernicus

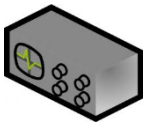
WMO primary calibration scales

Central Analytical Laboratory

Atmospheric Thematic Centre

Working gases
Flasks

Training, support
Data, metadata
Instruments

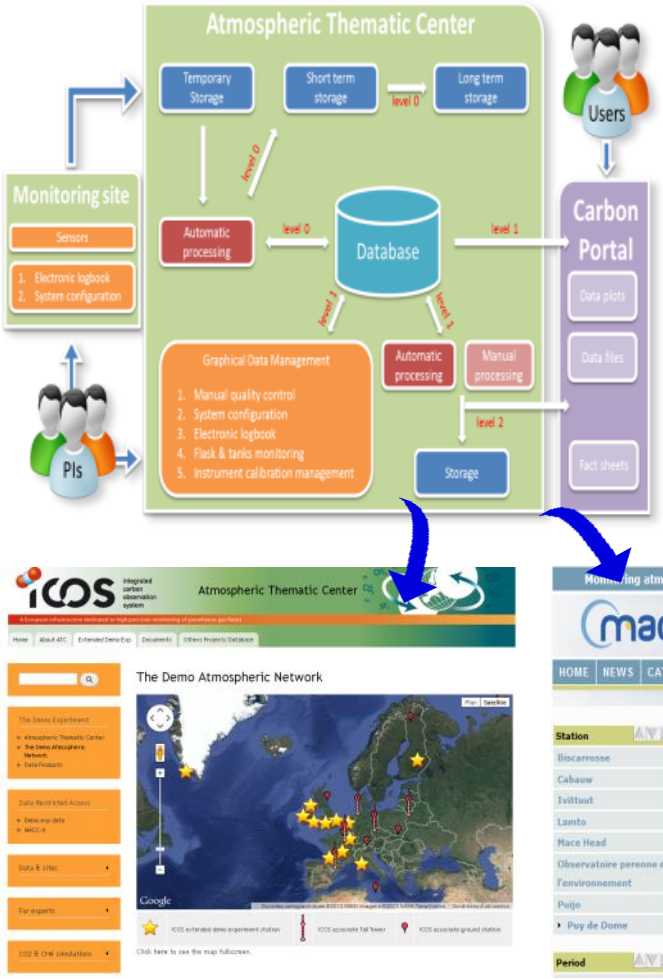


Monitoring Scientific Assembly (MSA)

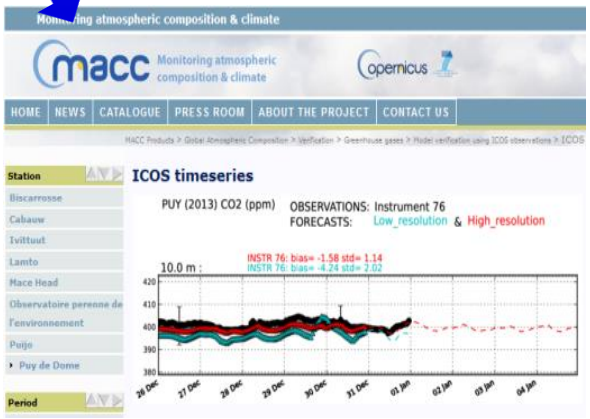
Atmospheric stations

Atmospheric Thematic Center (ATC)

Data Center

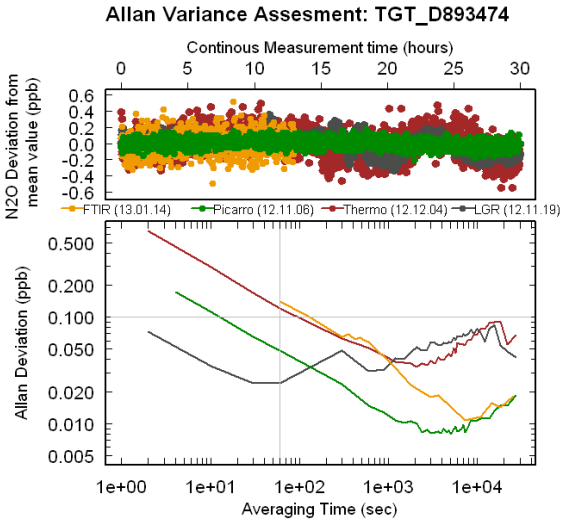


Near real time (h+24) data processing and diffusion



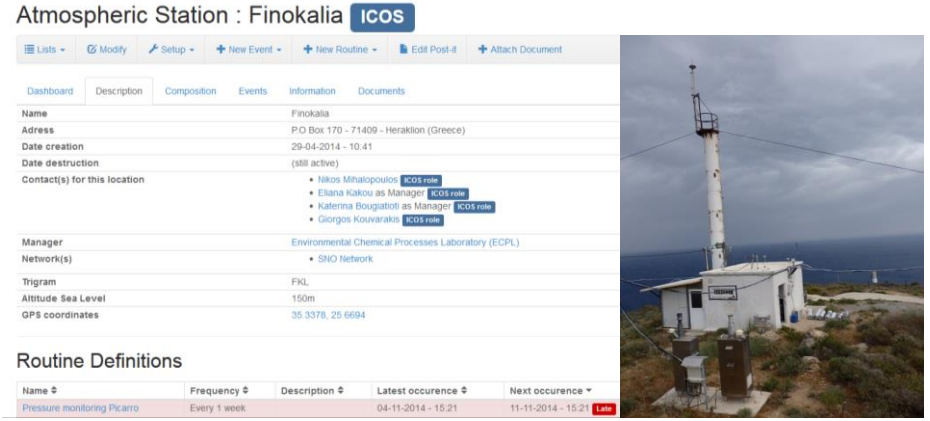
Dataset provision for MACC-II COPERNICUS core service

ICOS Atmospheric Metrology Lab



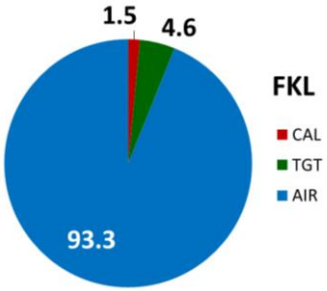
Technology survey & sensors/protocols evaluation

High traceability of measurements and uncertainties

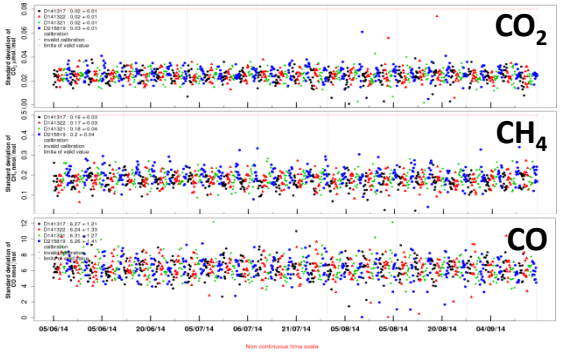


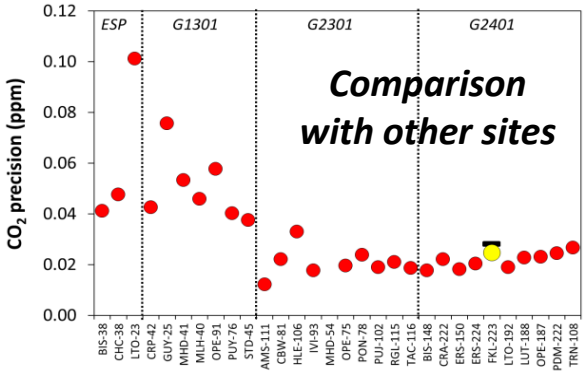
- ICOS AS specifications (in line with WMO recom.)
- Metadata on site and station set-up
- Station/instrument configuration for data processing
- Near real time data transmission
- Calibration with 3-4 calibrated gases (WMO scale)
- Precision / reproducibility using two target gases
- Weekly flask sampling (*class 1 station*)
- Travelling instrument and target gases

Data coverage

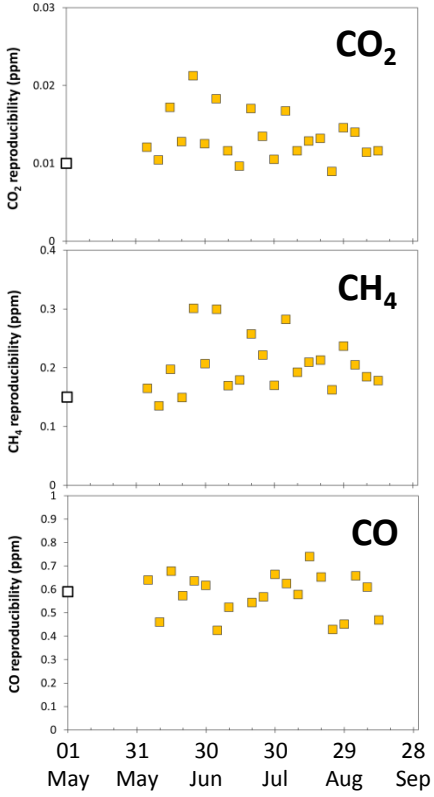


Precision

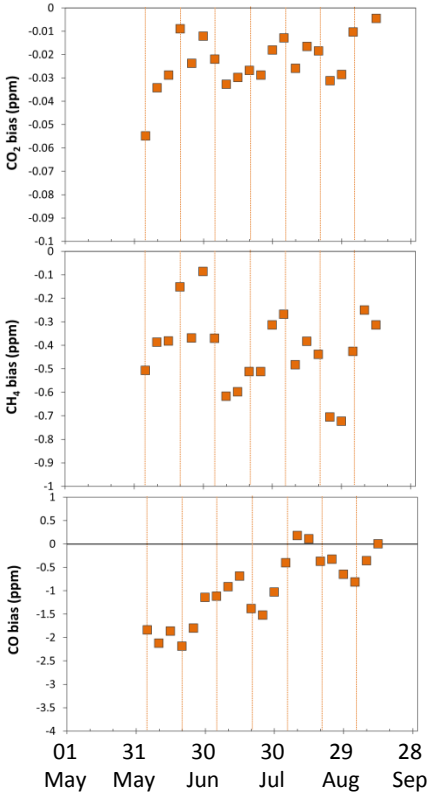




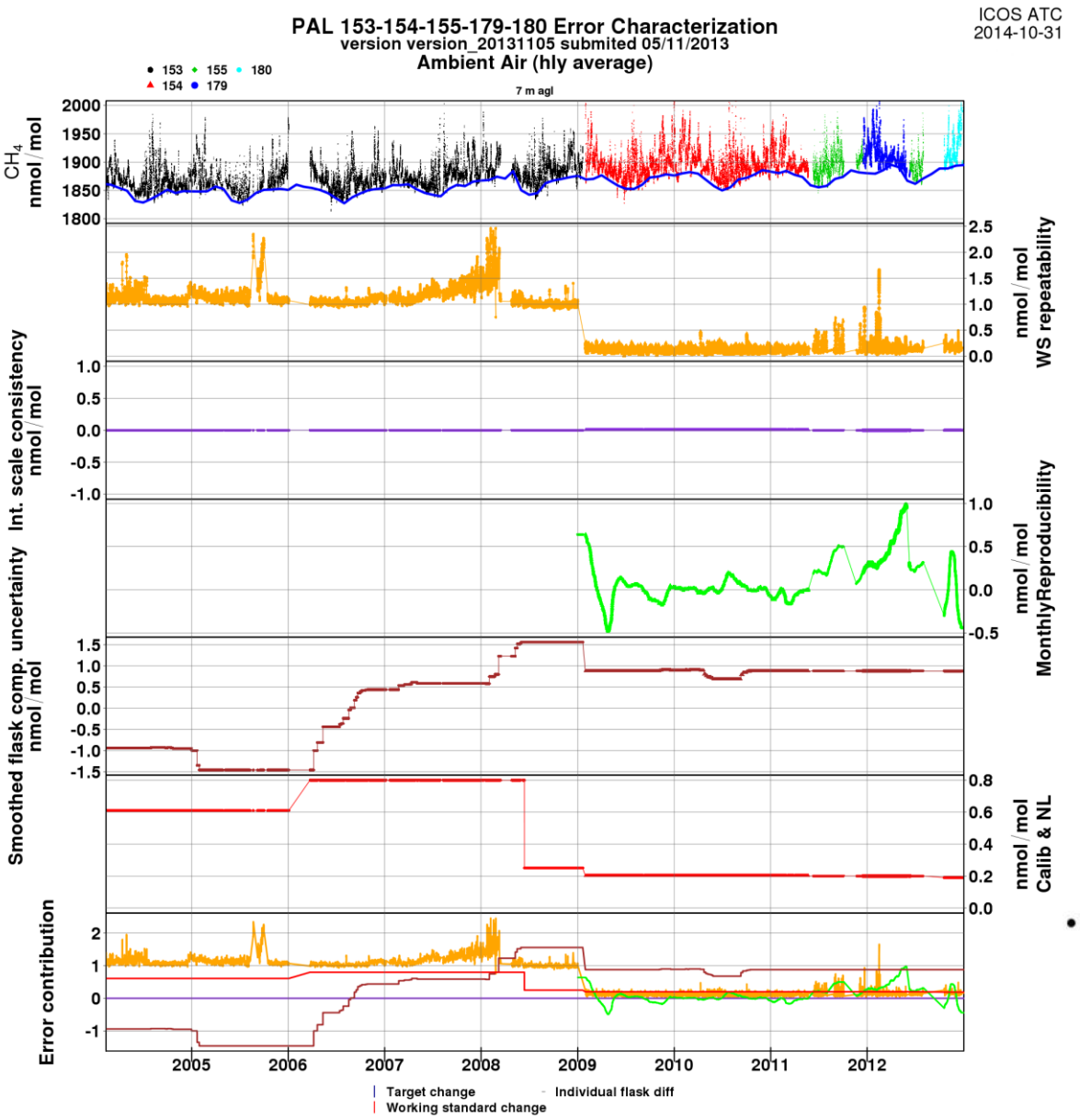
Reproducibility



Bias



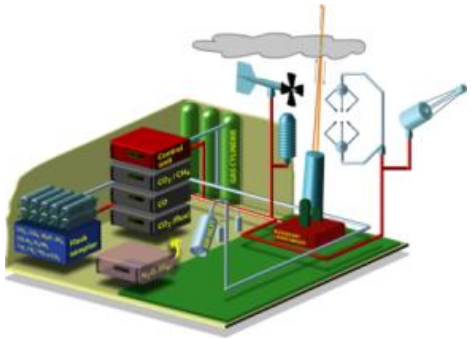
Uncertainty assessment



- Instrument and calibration uncertainties:
  - repeatability: Δ_{repeat}
  - reproducibility Δ_{reprod}
  - lab int. scale consistency: Δ_{lisc}
  - flask comparison uncert.: Δ_{flask}
  - scale transf. uncertainty: Δ_{trans}

- Sampling uncertainties:
  - artefacts from pumps / drying systems
  - leaks or artefacts in sampling lines
  - temporal representativeness
  - ....

Observed parameters: greenhouse gases and tracers for source/sink apportionment



	Continuous	*Sampling*	*Meteorology*
Class 1 Mandatory parameters	• **CO_2, CH_4, CO** : at each sampling height	• **CO_2, CH_4, N_2O, SF_6, CO, H_2, ^{13}C and ^{18}O in CO_2**: weekly sampled at highest sampling height • **^{14}C** (radiocarbon integrated samples): at highest sampling height	• **Air temperature, relative humidity, wind direction, wind speed**: at highest and lowest sampling height* • **Atmospheric Pressure** • **Planetary Boundary Layer Height****
Class 2 Mandatory parameters	• **CO_2, CH_4** : at each sampling height		• **Air temperature, relative humidity, wind direction, wind speed**: at highest and lowest sampling height* • **Atmospheric Pressure**
Recommended parameters***	• **^{222}Rn, N_2O, O_2/N_2 ratio** • **CO** for Class 2 stations	• **CH_4 stable isotopes, O_2/N_2 ratio** for Class 1 stations: weekly sampled at highest sampling height	• **CO_2** : at one sampling height

* Atmospheric temperature and relative humidity recommended at all sampling heights

** Only required for continental stations.

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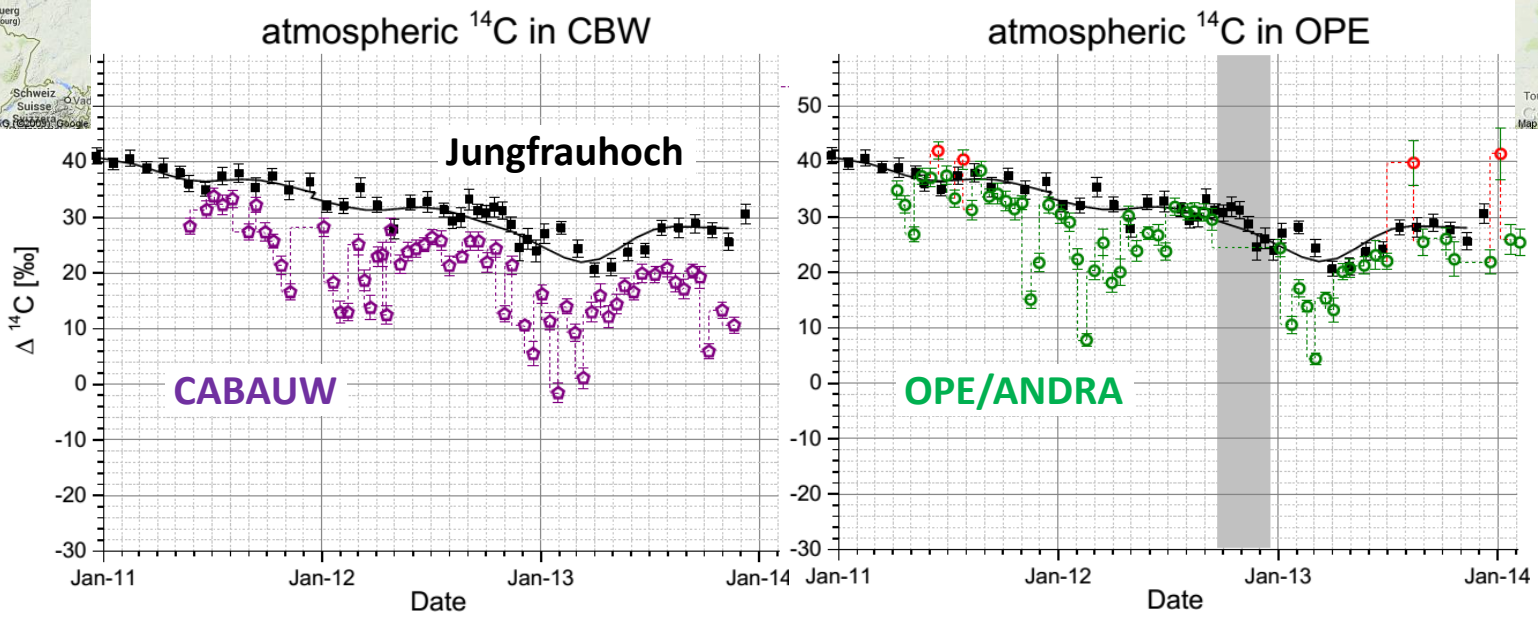
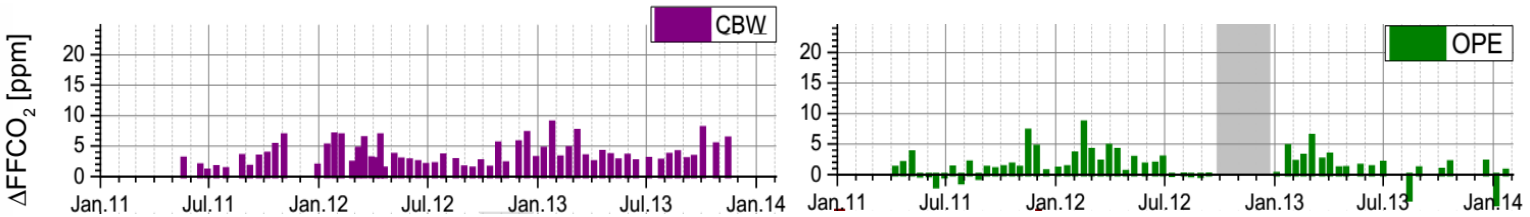
Fossil fuel contribution using $^{14}CO_2$ measurements





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A European research infrastructure to monitor greenhouse gas emissions

- Development of dense monitoring network in Europe with standardized protocols and very high traceability
- Near-real time access to the measurements from all stations
- Improvement of our QA/QC strategy and harmonisation for better estimation of uncertainties
- Dedicated central facilities for data processing, protocols evaluation, technology survey, sample analysis and preparation of reference material (linked to WMO/GAW)
- Multi tracers strategy for source/sink apportionment, and model validation
- ICOS will provide background observations, to be complemented with regional/urban networks (ex. CarboCount-City around Paris)
- Collaboration with NMIs is expected (calibration , metrology, QA/QC, uncertainties, ...)

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Bundesministerium für Bildung und Forschung

(dedicated) Preparation of Standard Gases for the ICOS-network

Daniel Rzesanke, Markus Eritt, Adam Janoschka, Rico Hengst,
Christian Lütz, Michael Künast, Bert Steinberg,
Michael Hielscher, Maria Büttner and Armin Jordan

ICOS Central Analytical Laboratory

Max-Planck Institut für Biogeochemie, Jena

MPI-BGC Jena

1st HIGHGAS stakeholder workshop, 13. November 2014, LNE/Paris

ICOS Central Analytical Laboratory

The Flask and Calibration Lab in Jena

- Flask and tank conditioning
- Standard Gas preparation
- Calibration and analyses of cylinders
- Analyses of flask samples

(for trace gases and comp. of stab. isotopes)

End of 1st build-up stage / start of nominal operation in summer 2014

ICOS Central Analytical Laboratory

Function of a Central Laboratory for the atmospheric observations in ICOS

Challenge: provide unambiguous data of small atmospheric signals

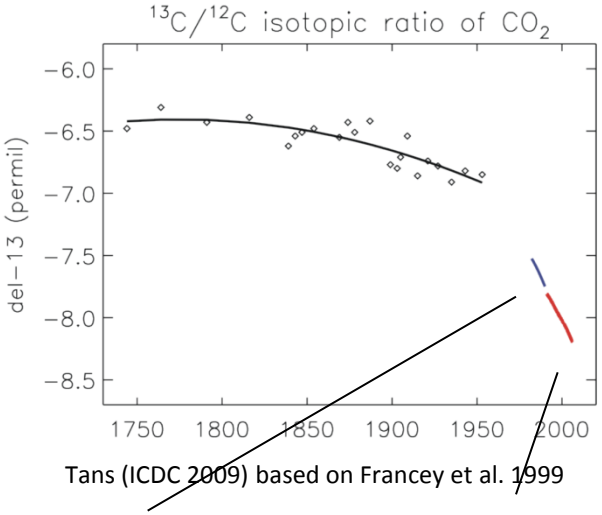
- trends of atmospheric composition
- geographic gradient
- changes in trends / gradients

→ high requirements for compatibility

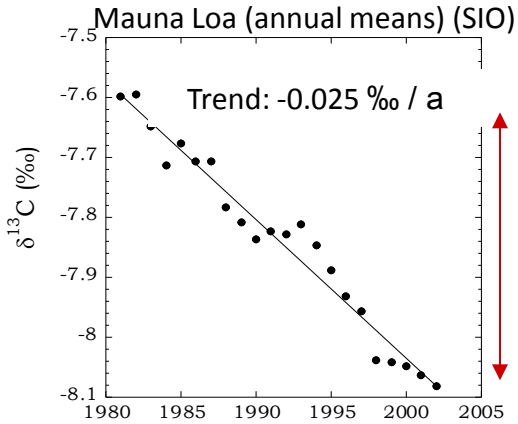
→ network-wide use of only one reference standard or scale (primary standard)
(one institution being responsible for this standard)

Scientific requirements for data compatibility: $\delta^{13}C_{CO2}$

Trends are small ...



Tans (ICDC 2009) based on Francey et al. 1999

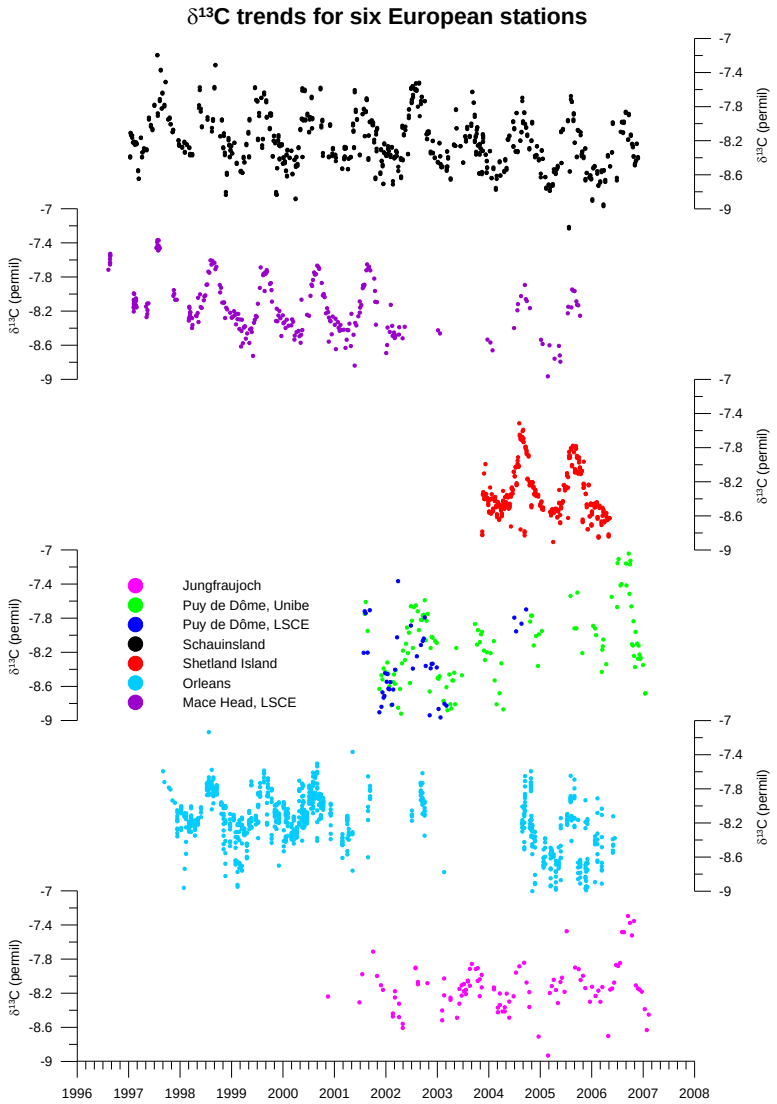


http://cdiac.ornl.gov/trends/co2/iso-sio/iso-sio.html

...defining the desired compatibility goal of $\delta^{13}C$-CO_2 of ± 0.01 ‰ for atmospheric CO_2

IAEA-TECDOC-825, 1995

Past measurements from various laboratories docum
shortcomings to meet requirements



Leuenberger 2007 (CarboEurope WP 2.3 Annual Report)

Data Quality Assurance of ICOS FCL lab

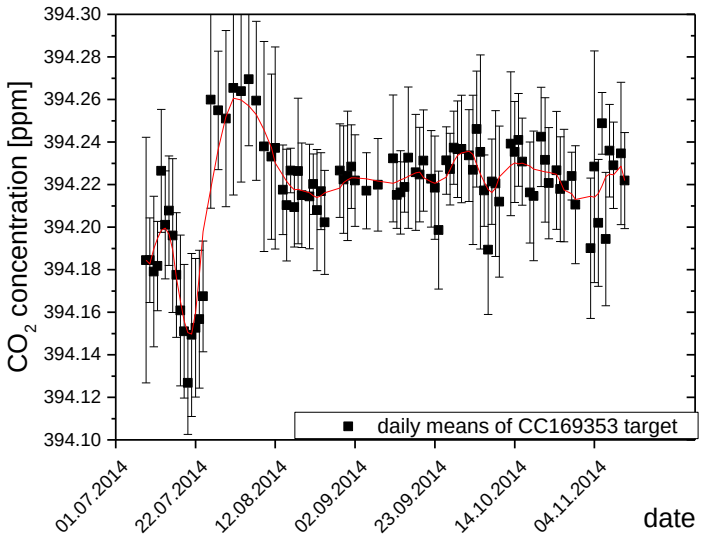
Function to assure network conformance to primary scale

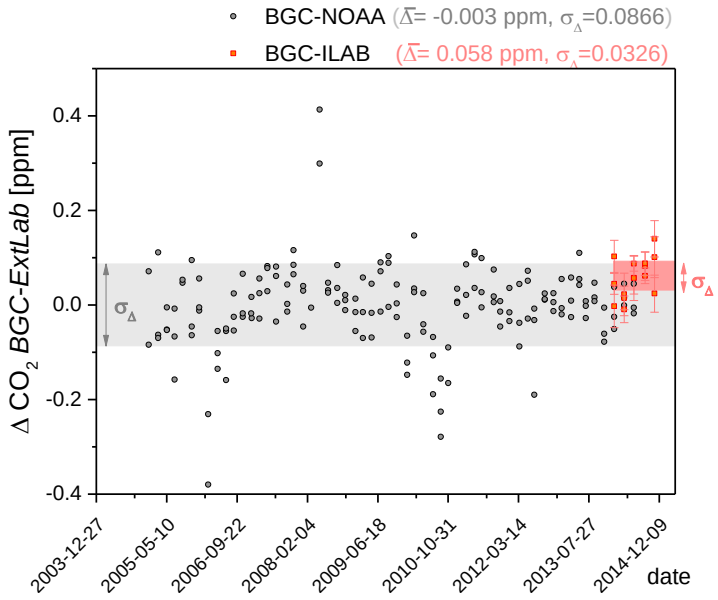
→ link to WMO scale by large set of WMO reference standards

Quality Control Activities

internal: target gas analysis – cross instrument check

external: various comparison activities





ICOS Central Analytical Laboratory

Preparation

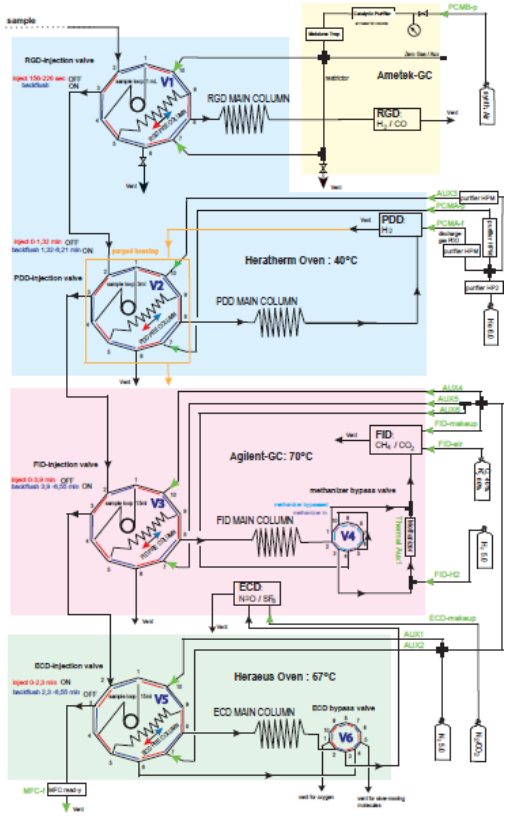
1. Conditioning (evacuation and heating), pre-filling and storage with pressurized dried air
2. Filling
3. Adjustment of composition

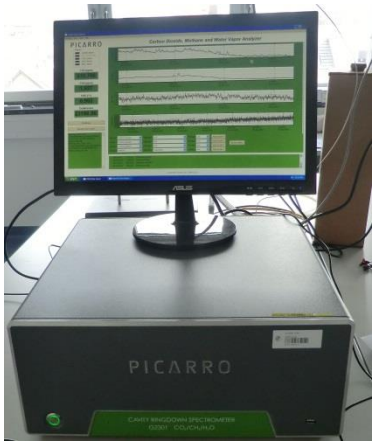
- Specified crit. hardware (tanks, valves)
- “Same procedure as every cylinder”

Required capacity (filling and (re-)calibration): ~ few 100/y

Analytical Instrumentation

- (GC-system, PDD, FID, ECD, RGA)
- CRDS (Picarro G2301)
- FTIR (Ecotech/Bruker)
- (IRMS Thermo Fisher MAT253)
- (QP-MS Vacom GAPAS)
- New N_2O + CO spectroscopic analyser





ICOS Central Analytical Laboratory

Summary

(1) Measurements shall fulfil or exceed WMO-criteria for precision and accuracy

(2) Long term data consistency prevails over accuracy

(3) ICOS references to WMO/GAW-scales for Greenhouse Gas Measurements (held by Central Calibration Laboratories (CCLs))

(4) Cooperation with Metrology Institutes highly welcome (e.g. round robin comparisons)

(5) Future plan: transfer of calibration functions currently carried out by MPI-BGC (WMO-CCL for H_2 and stable isotopes in CO_2, standardization of CH_4 stable isotopes)