RINGO | Readiness of ICOS

Readiness of ICOS for Necessities of integrated Global Observations

D4.2

Ambient CO2 time series for the selected 10 measurement stations covering the period 2000-2015

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Deliverable Review Checklist

A list of checkpoints has been created to be ticked off by the Task Leader before finalizing the deliverable. These checkpoints are incorporated into the deliverable template where the Task Leader must tick off the list.

	√
• Appearance is generally appealing and according to the RINGO template. Cover page has been updated according to the Deliverable details.	☐
• The executive summary is provided giving a short and to the point description of the deliverable.	☐
• All abbreviations are explained in a separate list.	☐
• All references are listed in a concise list.	☐
• The deliverable clearly identifies all contributions from partners and justifies the resources used.	☐
• A full spell check has been executed and is completed.	☐

ABSTRACT

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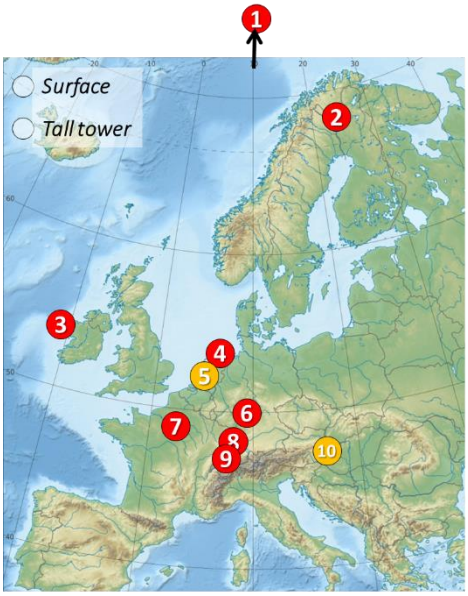
1 INTRODUCTION

The objective of the task 4.2 "*Making legacy data available*" is to re-evaluate historical CO2 measurements performed at ten sites which have been participating to European projects like CarboEurope and GHGEurope, and that have participated in regular WMO Round Robin exercises. The target period decided at the beginning of the project was 2000-2015, however we decided to extend this up to 2018 in order to fill as much as possible the gap with the ICOS datasets. In addition to the collection of the updated data, the goal was also to collect as much as possible of metadata which can be useful to assess the quality of the observations (e.g. round robin intercomparison, duplicate measurements from flask or in-situ programs, regular target gas measurements, …).

2 ATMOSPHERIC CO2 STATIONS

The ten stations which have been selected for this task were: Zeppelin, Pallas, Lutjewad, Mace Head, Cabauw, Heidelberg, Gif-sur-Yvette, Schauinsland, Hegyhatsal and Jungfraujoch (Figure 1). Those sites cover typical monitoring stations with two tall towers in rural area (Cabau, Hegyhatsall), one background station (Zeppelin), one coastal station (Mace Head) two stations in mountain areas (Jungfrauhoch, Shauinsland, Pallas), and three stations close to urban environment (Gif, Heidelberg, Lutjewad).



01. Zeppelin	*NILU*
02. Pallas	*FMI*
03. Mace Head	*LSCE*
04. Lutjewad	*RUG*
05. Cabauw	*ECN*
06. Heidelberg	*UHEI*
07. Gif-sur-Yvette	*LSCE*
08. Schauinsland	*UHEI*
09. Jungfraujoch	*EMPA*
10. Hegyhatsall	*OMSZ*

Figure 1: *Map of the 10 stations involved in the re-analysis of atmospheric CO2 dataset*

In 2018, following the severe drought episode in Europe, a task force has been set up to analyze in detail the impact of this drought on the carbon cycle. As a result, an effort was made to collect all of the available data sets. A working group has been set up to analyze in detail the impact of this drought on the carbon cycle. As a result, an effort was made to collect all of the available data sets. A total of 48 atmospheric CO2 measurement stations have been identified, in particular all the stations recently developed within the framework of ICOS. The 10 stations of the RINGO project are of course included in this analysis. Note that the station at Gif-sur-Yvette was replaced in 2016 by the Saclay tower, which is in the process of obtaining certification for ICOS. With the exception of Hegyhatsall and Mace Head whose countries have not joined ICOS, all stations are already labelled as ICOS stations, or have initiated the labelling process (https://meta.icos-cp.eu/labeling/).

3 ATMOSPHERIC CO2 CONCENTRATIONS

The atmospheric CO2 concentrations have been prepared by the different institutes in charge of the monitoring sites. Data have been collected on an hourly basis. The first step consisted in verifying that the same conventions were applied as regards the time stamp of the hourly averages (UTC hours, with the time corresponding to the start of the averaging period). Corrections were applied at a couple of stations. All the measurements are shown on Figure 2, and are compared to the Mace Head time series, selected for oceanic air masses. For some sites like Cabauw and Schauinsland measurements are available before the year 2000, but are not shown in Figure 2 since we do not intend to assess the quality of those earlier observations, with available metadata. All measurements All measurements presented in this study are referenced to the international reference scale WMO-X2007, and can be downloaded from the ICOS Carbon Portal (DOI: 10.18160/ere9-9d85).

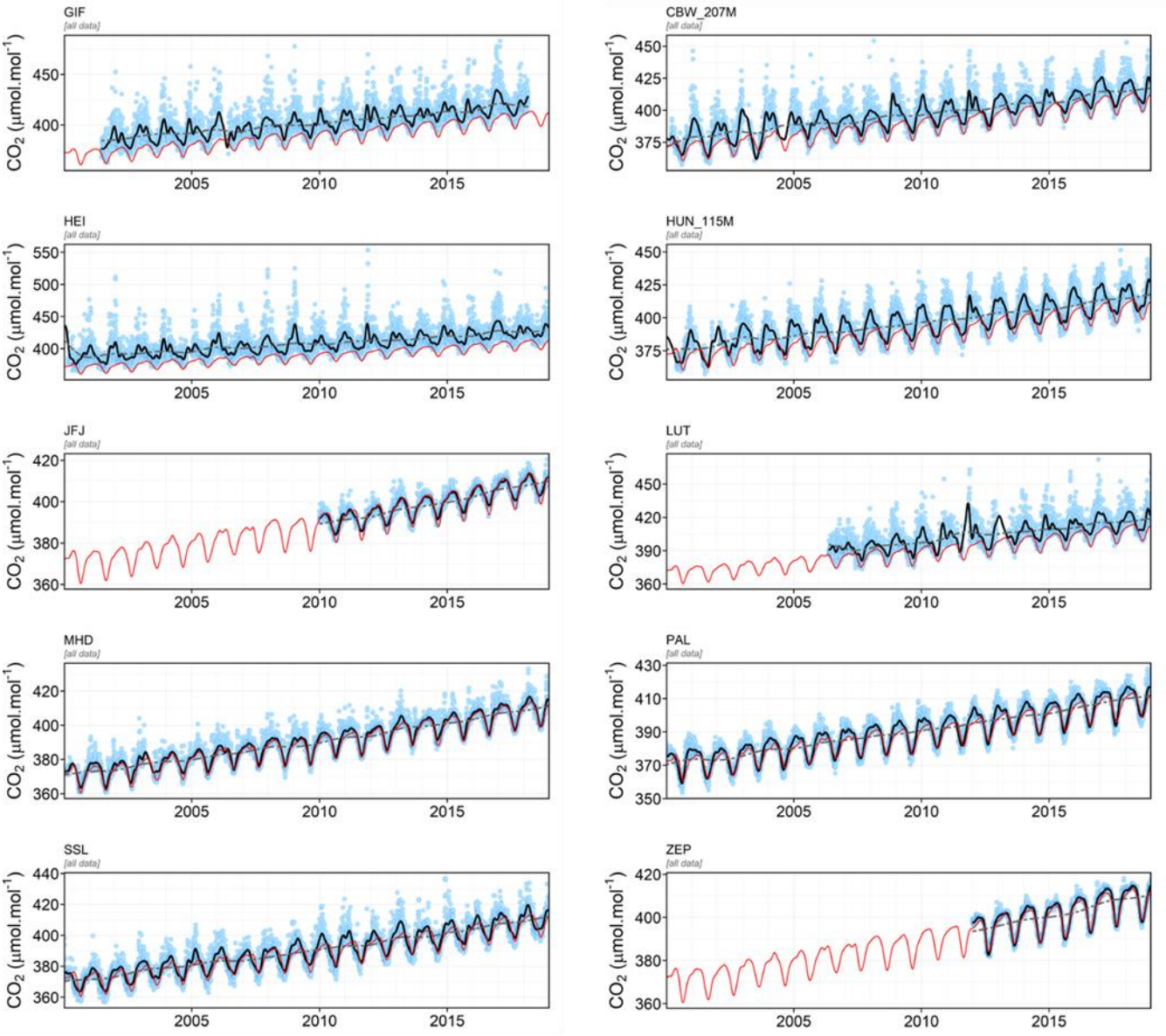


Figure 2: *Atmospheric CO2 concentrations at the 10 stations involved in this task. Daily means are shown in blue, with the smoothed curve shown as a black line, and the trend in dashed grey line. The red curve, used for comparison, represents the smoothed curve from the Mace Head dataset (with selection of oceanic air masses).*

4 ASSOCIATED METADATA

An important objective of the RINGO project is to combine these measures with a certain amount of additional information allowing the associated uncertainties to be estimated as much as possible. An important objective of the RINGO project is to associate with the measurements, a certain number of additional information making it possible to estimate as much as possible the associated uncertainties. The first information concerns the type of analyzer used for the measurement. Over time analyzers have been replaced, except at Heidelberg where the same gas chromatograph was used since 2000. At most stations a shift from non-dispersive infrared (NDIR) or gas chromatography (GC) to cavity ring-down spectroscopy (CRDS) technology, as shown on Figure 3. All the instruments have been referenced in the ICOS database to ensure a better traceability. A total of 36 analyzers have been registered (Figure 3).

GC
NDIR
CRDS

Site	Type	Instrument	Model	ICOS model id	Start	Scale	Serial number	Owner	ICOS id
CBW	NDIR	Siemens	Ultramat 5	30	01-01-2000	X2007	??	ECN	??
CBW	NDIR	Licor	7000	208	01-01-2004	X2007	??	ECN	??
CBW	CRDS	Picarro	G2301	38	01-01-2015	X2007	??	ECN	81
GIF	GC	HP	HP7890A	79	01-01-2001	X2007	Unknown	LSCE	2
GIF	GC	HP	HP7890A	79	16-01-2013	X2007	CN12421110	LSCE	157
HEI	GC	HP	HP5890II	80	03-01-1996	X2007	C-128/83	UHEI	161
HUN	NDIR	Licor	6251	210	29-09-1994	X2007	IRG1-186	HMS	842
HUN	NDIR	Licor	7000	208	09-08-2007	X2007	IRG4-626	HMS	843
JFJ	CRDS	Picarro	G1301	23	01-01-2010	X2007	CFADS-50	EMPA	852
JFJ	CRDS	Picarro	G2401	64	15-09-2011	X2007	CFKDAS-2020	EMPA	225
JFJ	CRDS	Picarro	G2401	64	16-06-2014	X2007	CFKADS-2133	EMPA	226
LUT	GC	Agilent	HP6890N	77	17-05-2006	X2007	US10502032	RUG	8
LUT	CRDS	Picarro	G2401-m	110	15-05-2013	X2007	1527-CFKBDS-2102	RUG	188
LUT	CRDS	Picarro	G2301	38	26-02-2016	X2007	1049-CFKADS-2240	RUG	853
LUT	CRDS	Picarro	G2401	64	13-12-2016	X2007	2494-CFKADS-2219	RUG	456
MHD	NDIR	Ultramat	5F	30	01-07-1992	X2007	Unknown	LSCE	838
MHD	NDIR	Licor	6252	11	08-07-2002	X2007	Unknown	LSCE	11
MHD	NDIR	Ultramat	5F	30	01-07-2003	X2007	Unknown	LSCE	839
MHD	NDIR	Licor	6262	209	05-11-2008	X2007	Unknown	LSCE	840
MHD	CRDS	Picarro	G1301	23	07-01-2010	X2007	CFADS-046	EPA	41
MHD	NDIR	Licor	7000	208	09-05-2010	X2007	Unknown	LSCE	841
MHD	CRDS	Picarro	G2301	38	17-03-2011	X2007	CFADS-2122	LSCE	54
MHD	CRDS	Picarro	G2401	64	01-03-2018	X2007	CFKADS-2283	LSCE	695
PAL	NDIR	Licor	6262	28	31-12-1998	X2007	IRG3-696	FMI	844
PAL	NDIR	Licor	6252	28	11-04-2000	X2007	IRG2-560	FMI	845
PAL	NDIR	Licor	6262	28	19-08-2005	X2007	IRG3-964	FMI	846
PAL	NDIR	Licor	7000	14	08-07-2006	X2007	IRG4-0565	FMI	14
PAL	CRDS	Picarro	G1301	23	27-01-2009	X2007	CFADS-039	FMI	154
PAL	CRDS	Picarro	G2401	64	17-02-2011	X2007	CFKADS-2018	FMI	849
PAL	CRDS	Picarro	G1301	23	10-06-2011	X2007	CFADS-098	FMI	848
PAL	NDIR	Licor	7000	208	20-09-2011	X2007	IRG4-0629	FMI	847
PAL	CRDS	Picarro	G2401	64	15-10-2012	X2007	CFKADS-2066	FMI	850
PAL	CRDS	Picarro	G2401	64	21-03-2016	X2007	CFKADS-2135	FMI	851
ZEP	CRDS	Picarro	G2401	64	23-04-2012	X2007	CFKADS-2019	NILU	231
ZEP	CRDS	Picarro	G2401	64	03-05-2013	X2007	CFKADS-2093	NILU	591
ZEP	CRDS	Picarro	G2401	64	24-07-2017	X2007	CFKADS-2253	NILU	529

Figure 3: *List of the analyzers used at the 10 atmospheric stations (2000-2015), and registered in the ICOS database*

One of the main difficulties in setting up an evaluation process for historical data comes from the heterogeneity of the information available from one station to another. All stations have participated in intercomparison programs organized by the WMO and / or European programs. The results of these programs for the stations considered here have been compiled (Figure 4). All stations have also performed regular calibration sequences. We therefore compile the references of the calibration tanks used. The objective is not to recalculate the calibrated data from the raw data, but to document the protocols implemented at the different stations, and to use certain indicators of the calibration sequences to assess their uncertainties. In particular we can use the standard deviation of the measurement of the calibration gases in order to approximate the measurement precision (Figure 6). In addition the residuals from the calibration fits provide an estimate of the uncertainties associated to the instrument and calibration protocols (Figure 7). In order to convert the residuals in an estimate uncertainty, we fit a linear model to each set of residuals using the least-squares method in order to get a value depending on the CO2 concentration. We then apply the coefficients to the measured concentrations until a new calibration is performed (none interpolation is performed). One example of the residuals, converted to measurement uncertainties is given on Figure 8 for Mace Head.

The other sources of information collected are not available for all stations, or for the entire measurement period. These are regular target gas measurements (Figure 9), redundant measurements from another analyzer or from flask air samples (Figure 10). The data have been collected, but the objective for the coming months is to synthesize this information as much as possible in an estimate of measurement uncertainty.

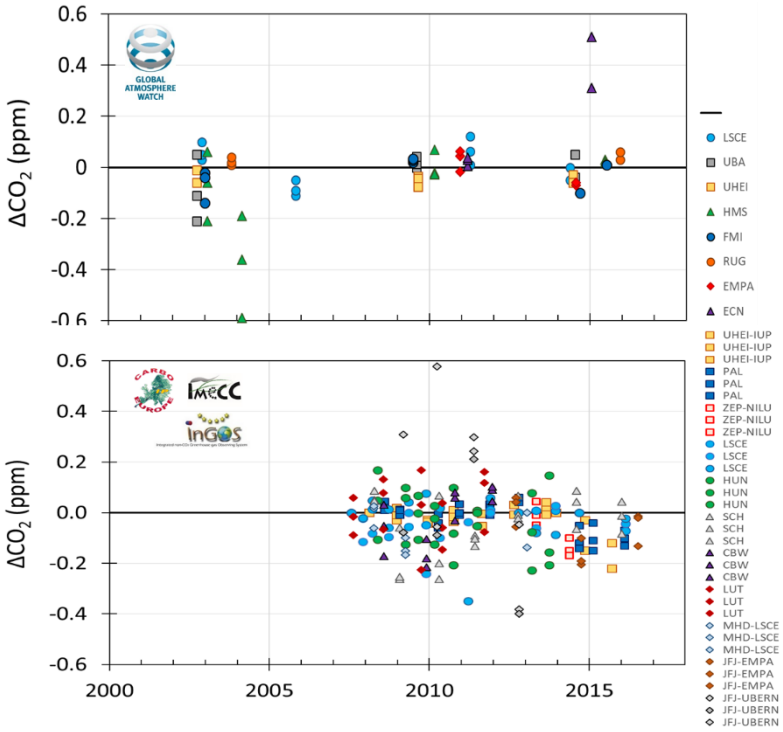


Figure 4: *Results of the round-robin intercomparison programs from WMO (above) and European projects (below)*

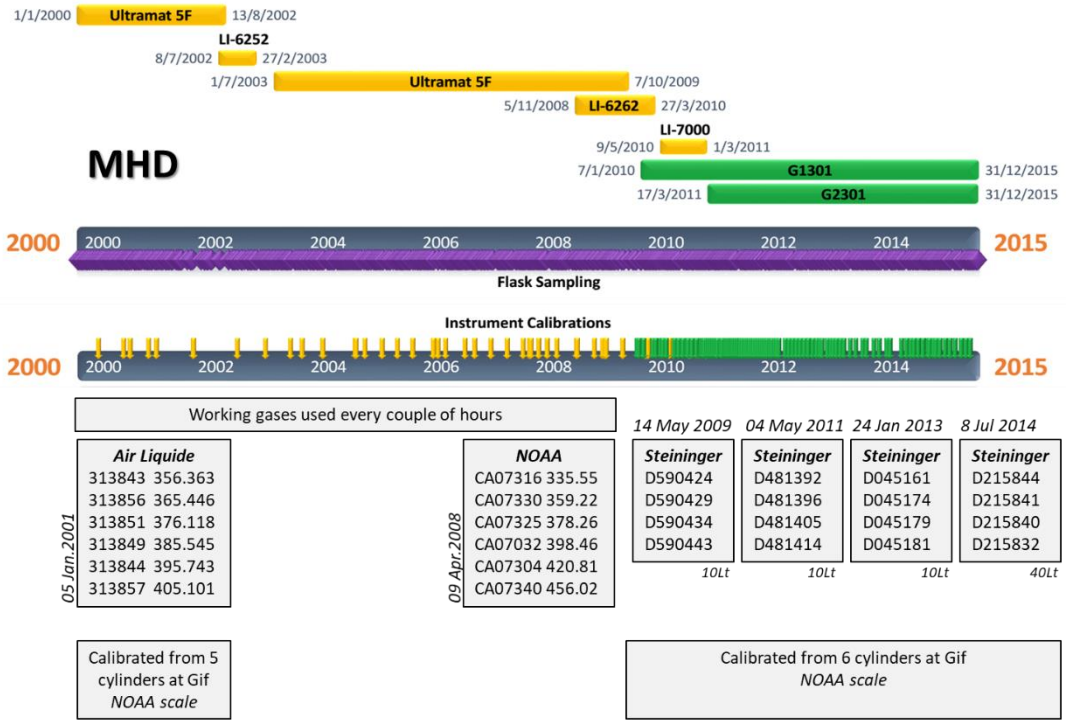


Figure 5: *List of instruments, calibrations sequences and primaries at Mace Head*

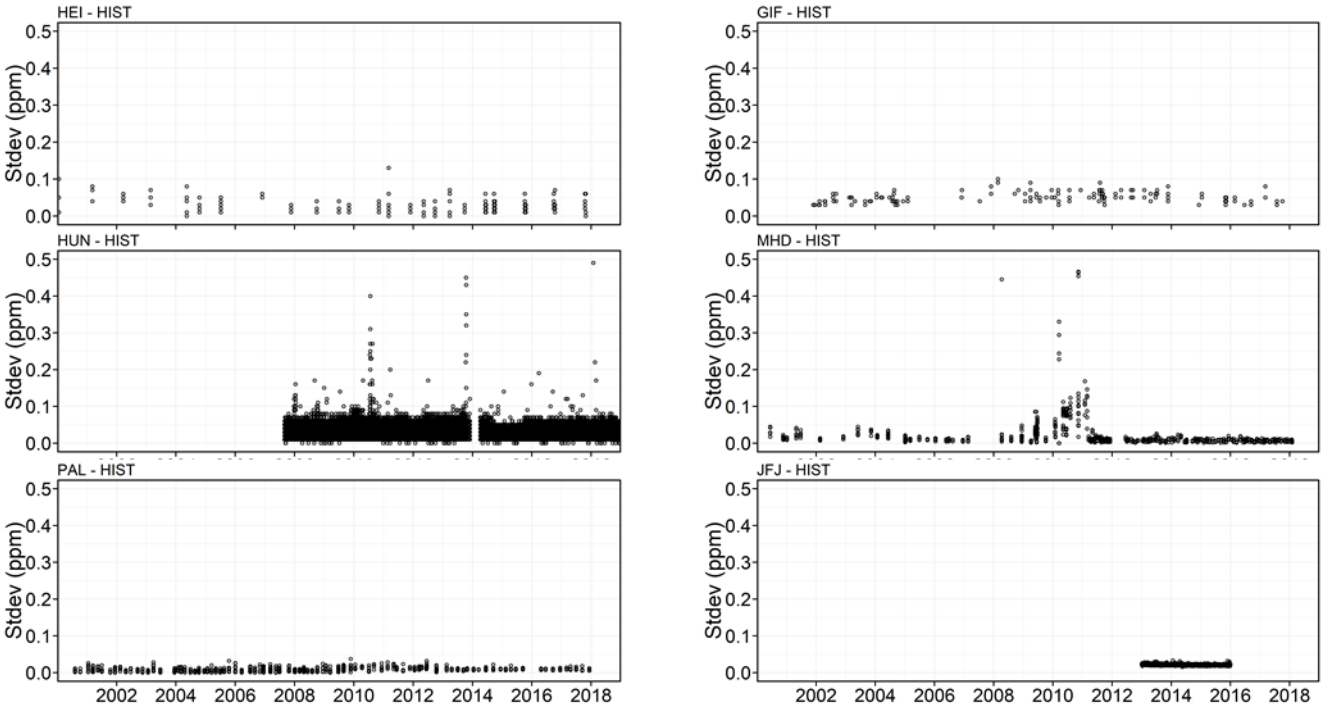


Figure 6: *Standard deviations of calibration injections*

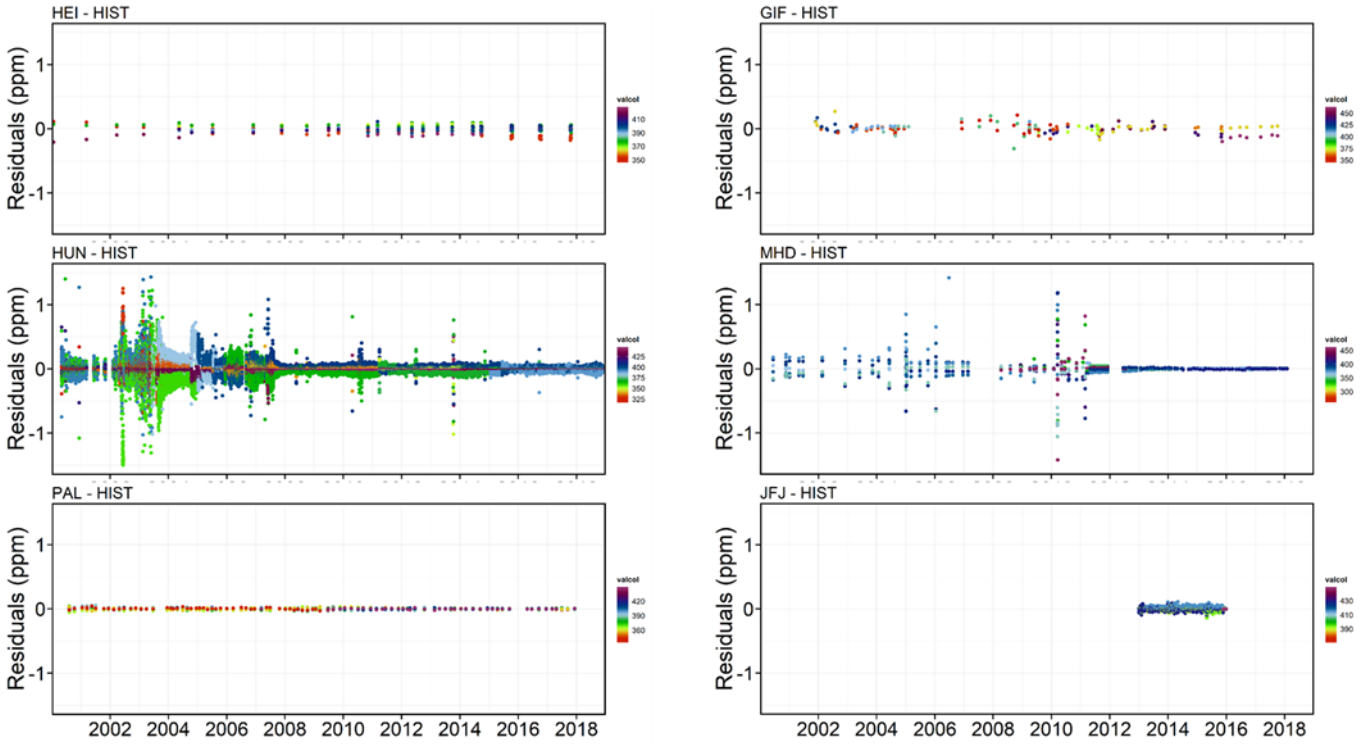


Figure 7: *Calibration residuals*

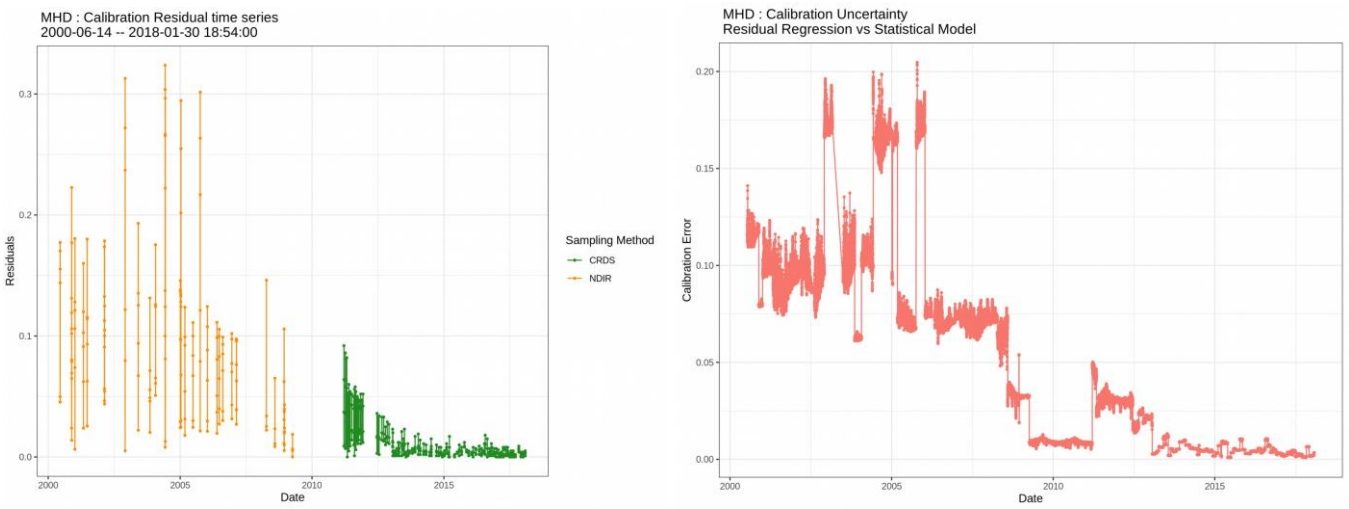


Figure 8: *Left: calibration residuals at Mace Head. Right: uncertainties calculated from the calibration residuals.*

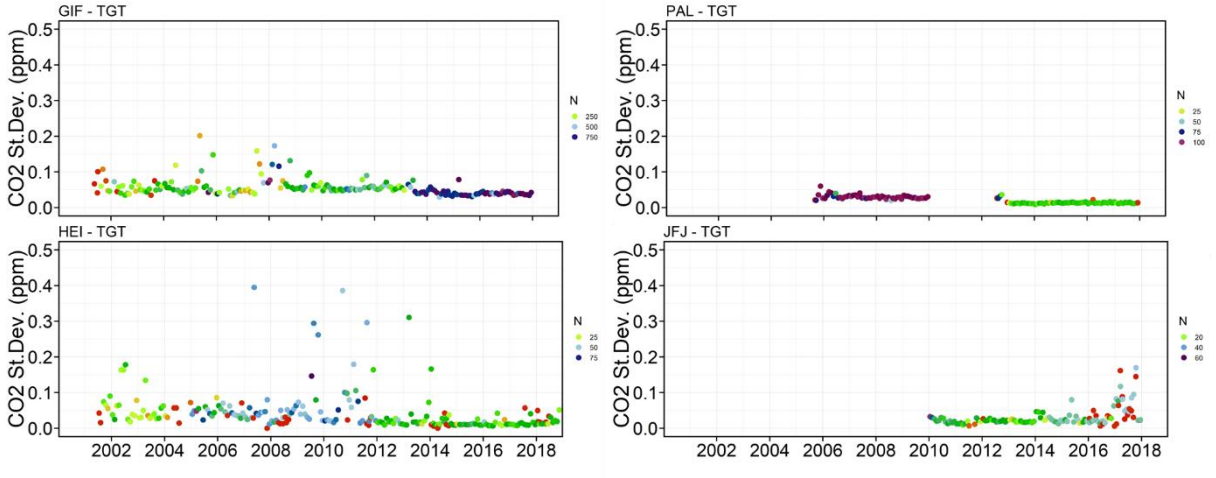


Figure 9: *Regular measurement of a target gas. The color indicates the number of measurements per month.*

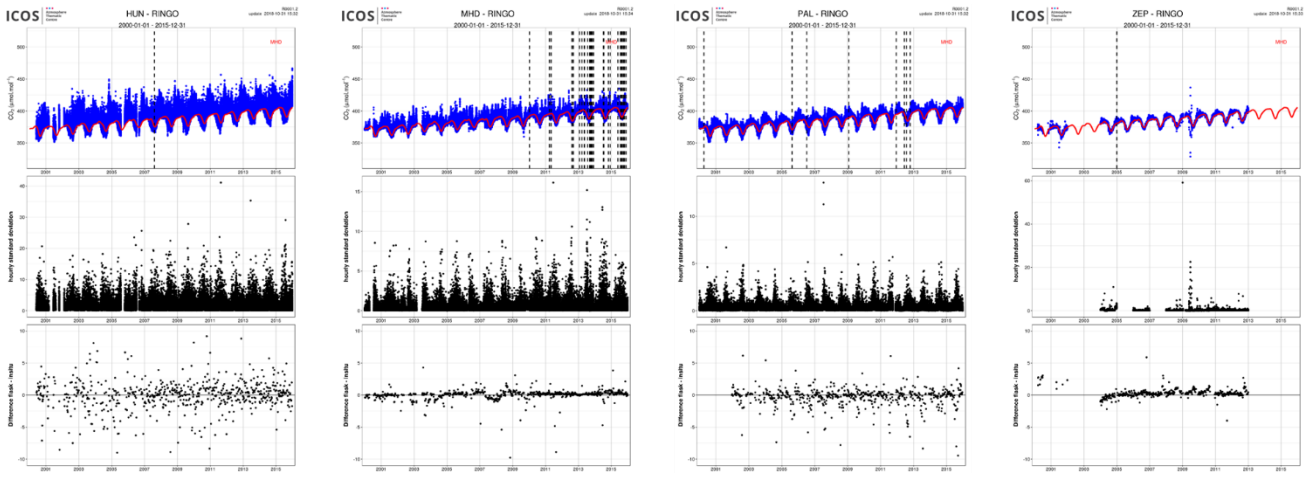


Figure 10: *Comparison of in-situ measurements with regular the NOAA/ESRL flask sampling program*

5 CONCLUSIONS

As part of RINGO task 4.2, we have gathered hourly mean atmospheric CO2 measurements over the period 2000-2018 for ten European stations (Zeppelin, Pallas, Lutjewad, Mace Head, Cabauw, Heidelberg, Gif-sur-Yvette, Schauinsland, Hegyhatsal and Jungfraujoch). Those measurements are fully integrated in the more complete European dataset collected as part of the Drought 2018 initiative. The measurements will be made available on the ICOS Carbon Portal (DOI: 10.18160/ere9-9d85). For the ten stations involved in RINGO we are also collecting several metadata in order to provide more traceability about the measurements (e.g. analysers used over time, calibration protocols), and their uncertainties. The goal of the coming months will be to synthetise the available information, knowing that it can be very variable from one station to another (e.g. round robin intercomparison, duplicate measurements from flask or in-situ programs, regular target gas measurements, …).

6 DEFINITIONS, ACRONYMS AND ABBREVIATIONS

CRDS	Cavity ring-down spectroscopy
ESRL	Earth System Research Laboratory (https://www.esrl.noaa.gov/)
GC	Gas chromatography
ICOS	Integrated Carbon Observation System (https://www.icos-ri.eu/)
NDIR	Non-dispersive infrared
NOAA	National Oceanic and Atmospheric Administration
RINGO	Readiness of ICOS for Necessities of integrated global organisation (https://www.icos-ri.eu/ringo)
WMO	World Meteorological Organisation (https://public.wmo.int/en)
WMO-X2007	Current WMO CO2 Mole Fraction Scale (https://www.esrl.noaa.gov/gmd/ccl/co2_scale.html)