Greenhouse Gases High Precision Measurements and the efforts in construct the GHG Brazilian Network

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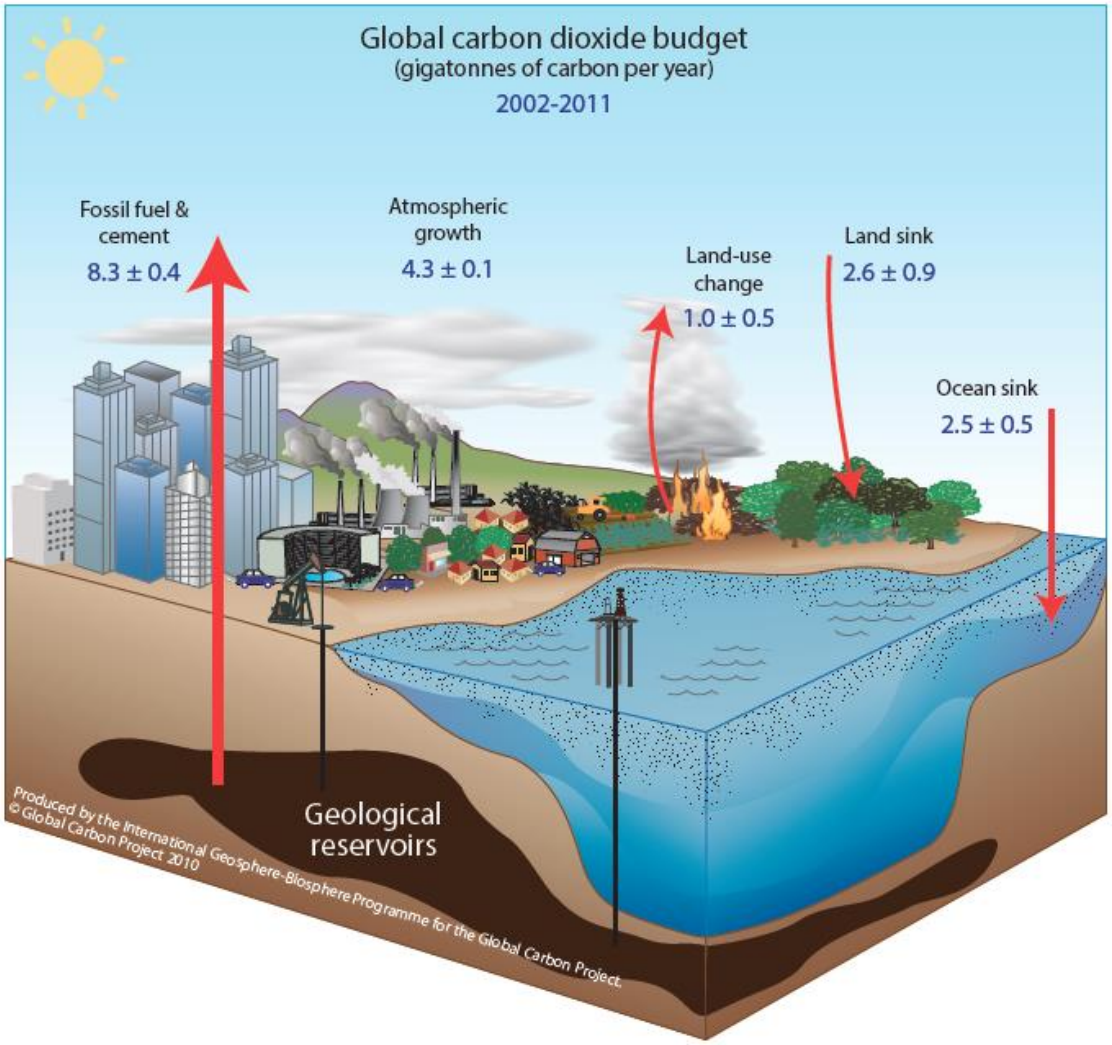
Anthropogenic Perturbation of the Global Carbon Cycle

Perturbation of the global carbon cycle caused by anthropogenic activities, averaged globally for the decade 2002–2011 (PgC/yr)

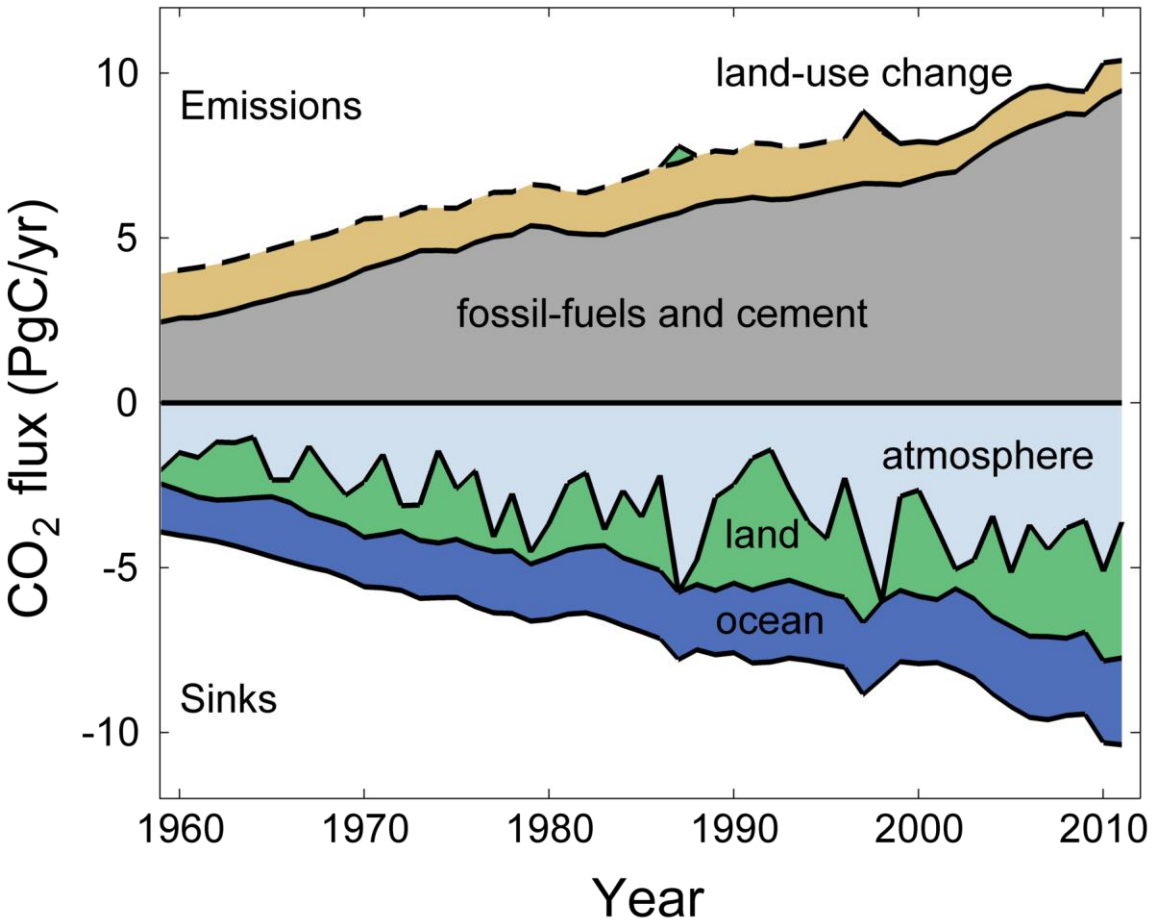


Source: Le Quéré et al. 2012; Global Carbon Project 2012

Global Carbon Budget

Emissions to the atmosphere are balanced by the sinks

Averaged sinks since 1959: 44% atmosphere, 28% land, 28% ocean



The dashed land-use change line does not include management-climate interactions

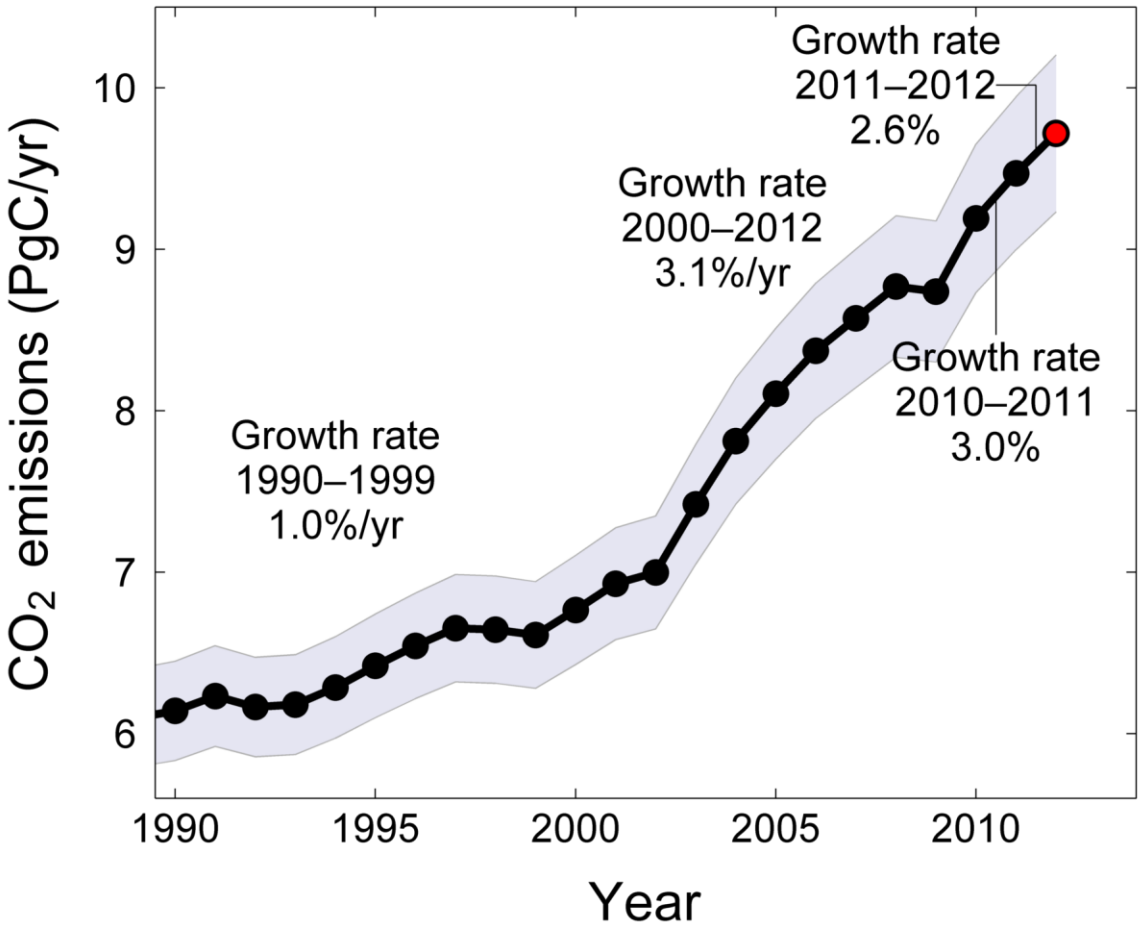
The land sink was a source in 1987 and 1998 (1997 visible as an emission)

Source: Le Quéré et al. 2012; Global Carbon Project 2012

Fossil and Cement Emissions

Global fossil and cement emissions: 9.5±0.5PgC in 2011, 54% over 1990

Projection for 2012: 9.7±0.5PgC, 58% over 1990



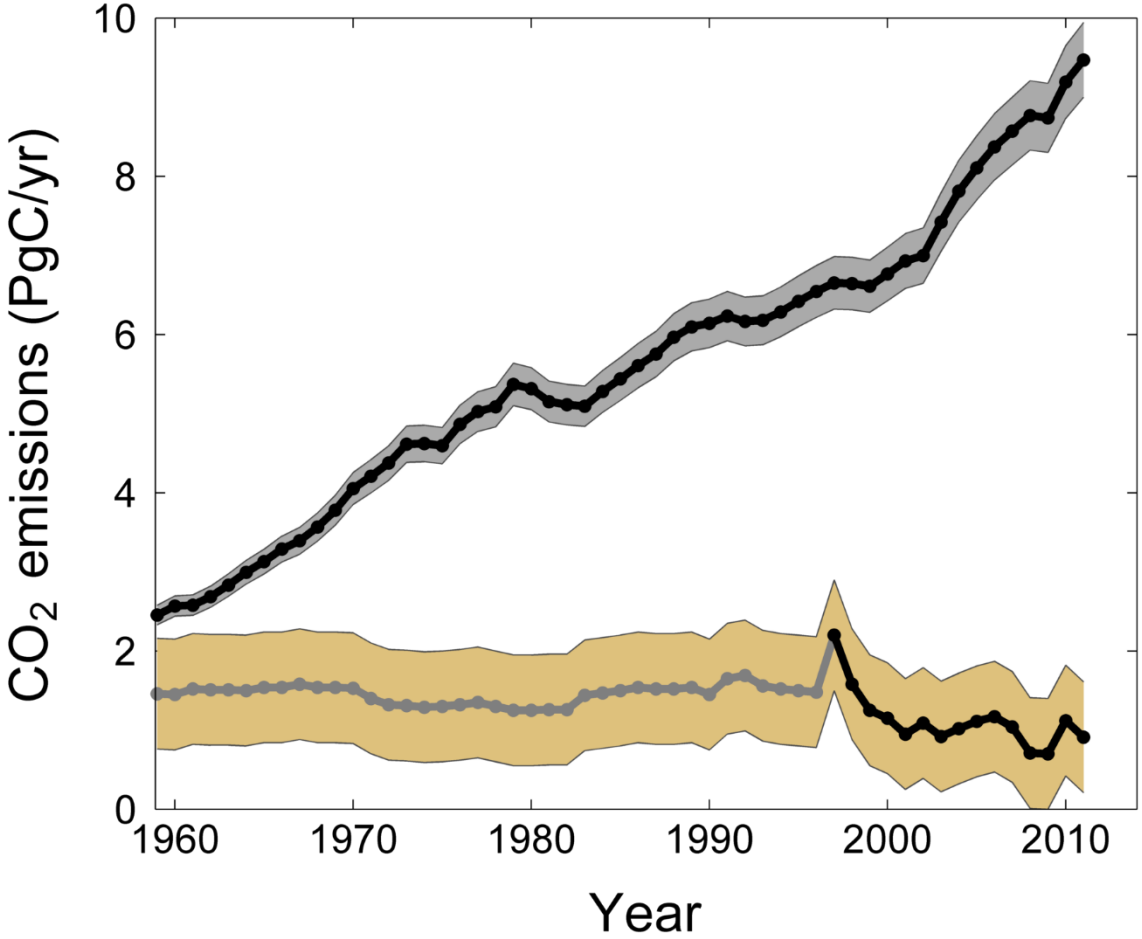
Uncertainty is ±5% for one standard deviation (IPCC "likely" range)

Source: Peters et al. 2012a; Le Quéré et al. 2012; CDIAC Data; Global Carbon Project 2012

Total Global Emissions

Total global emissions: 10.4±0.7PgC in 2011, 37% over 1990

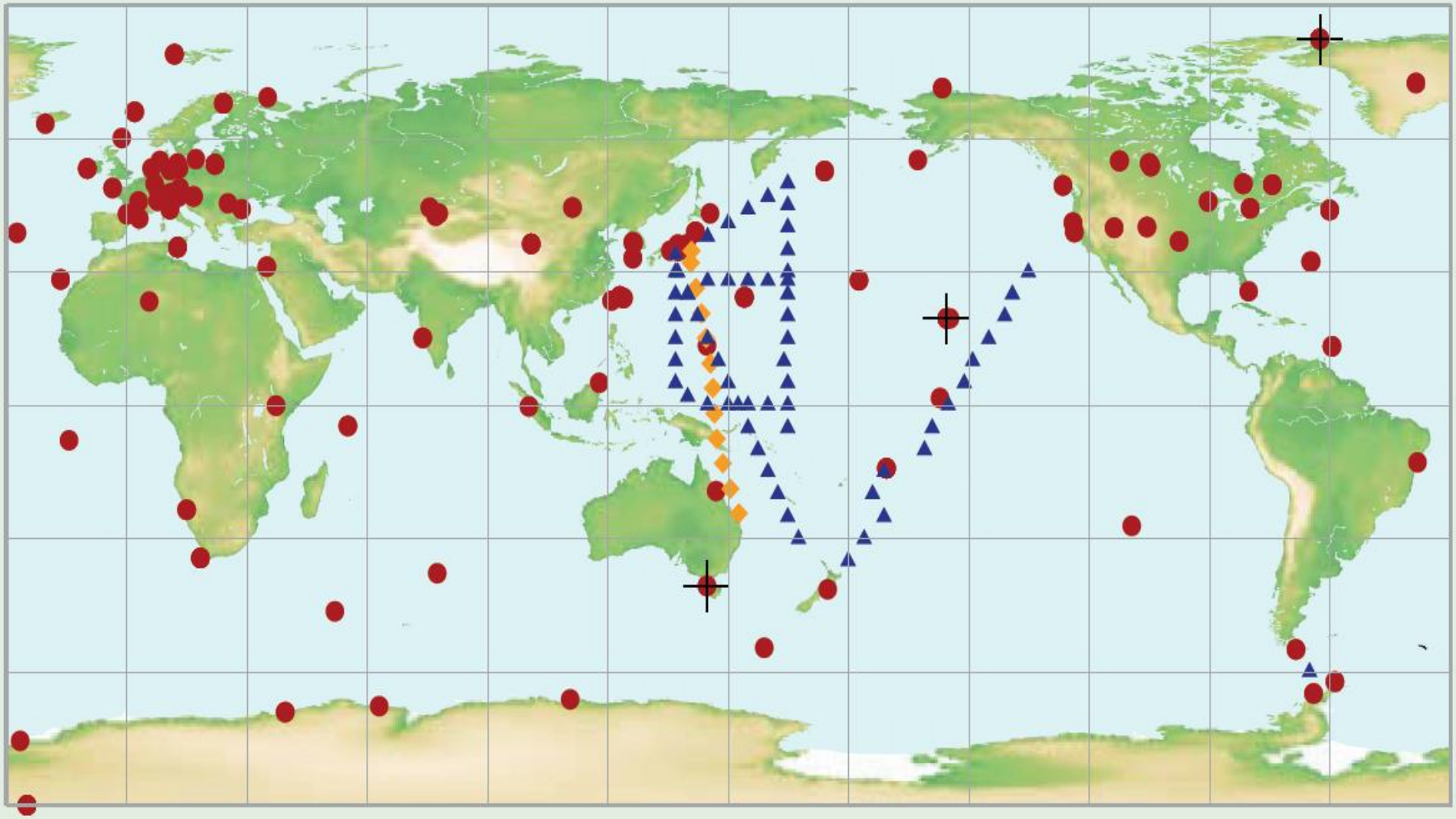
Percentage land-use change: 36% in 1960, 18% in 1990, 9% in 2011



Land-use change black line: Includes management-climate interactions

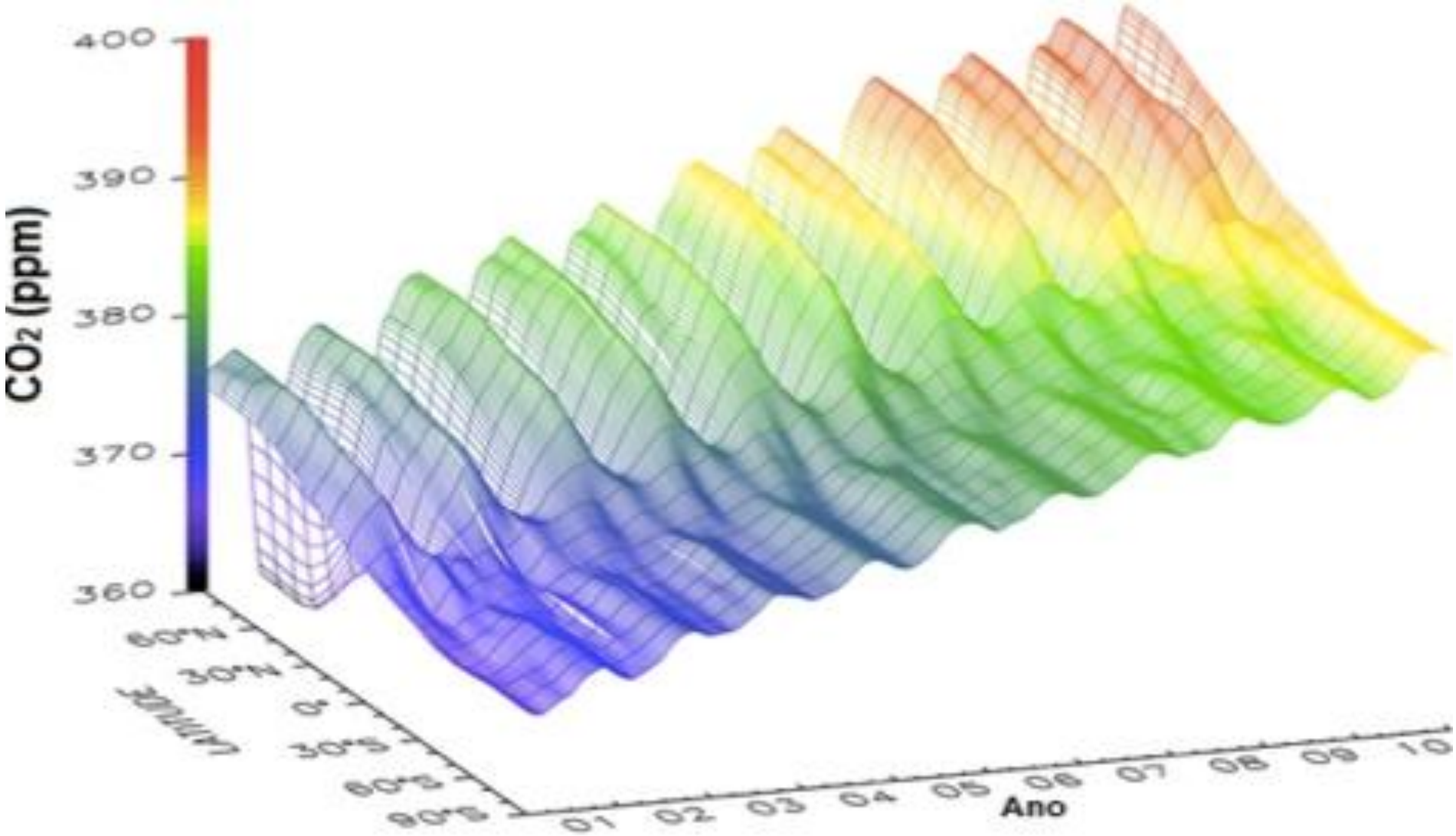
Source: Le Quéré et al. 2012; Global Carbon Project 2012

WMO/GAW Global CO_2 Monitoring Network

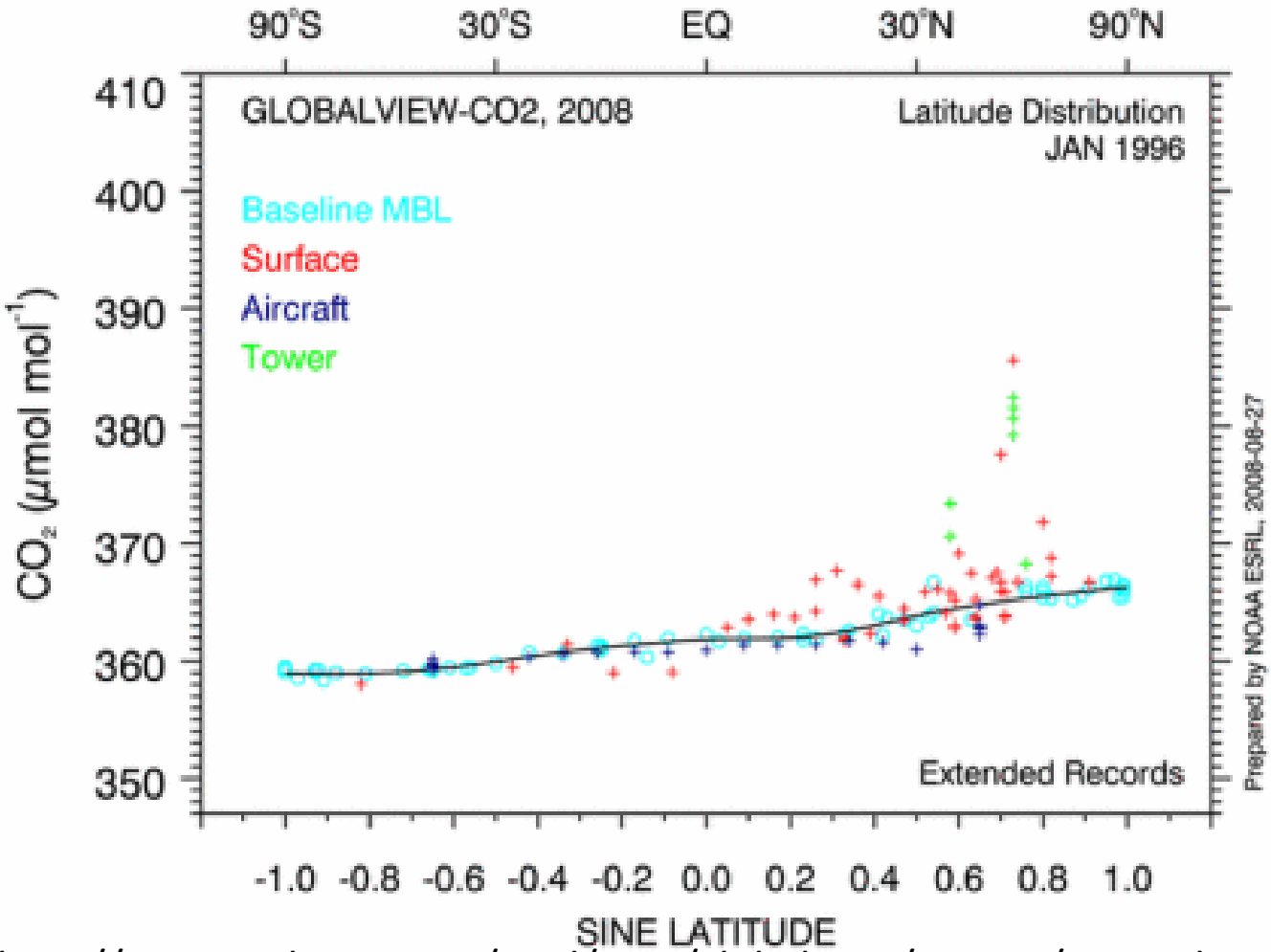


Ground-based Aircraft Ship GHG Comparison Sites

WMO - CO2 GLOBAL DISTRIBUTION



NOAA GLOBALVIEW-CO_2: Cooperative Atmospheric Data Integration Project

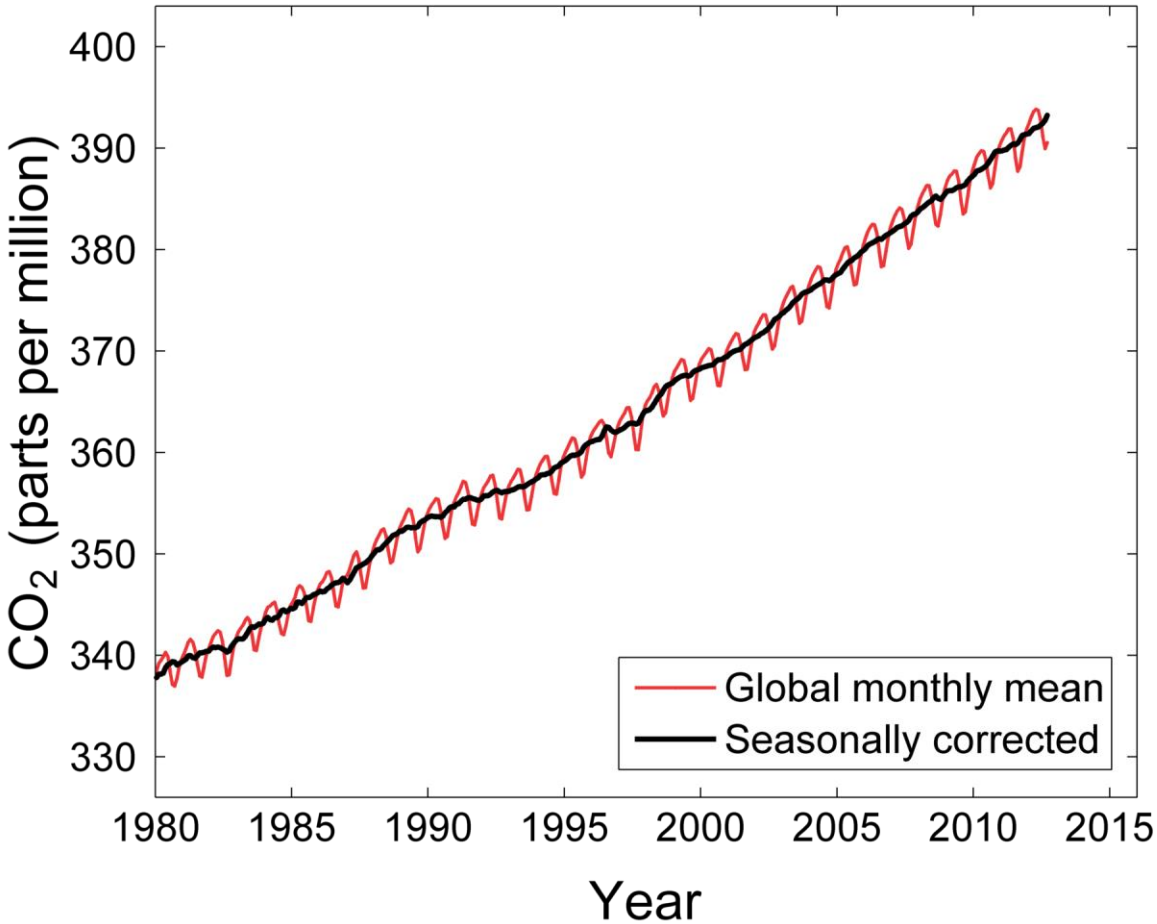


http://www.esrl.noaa.gov/gmd/ccgg/globalview/images/gvco2_lg_movie.gif

Atmospheric Concentration

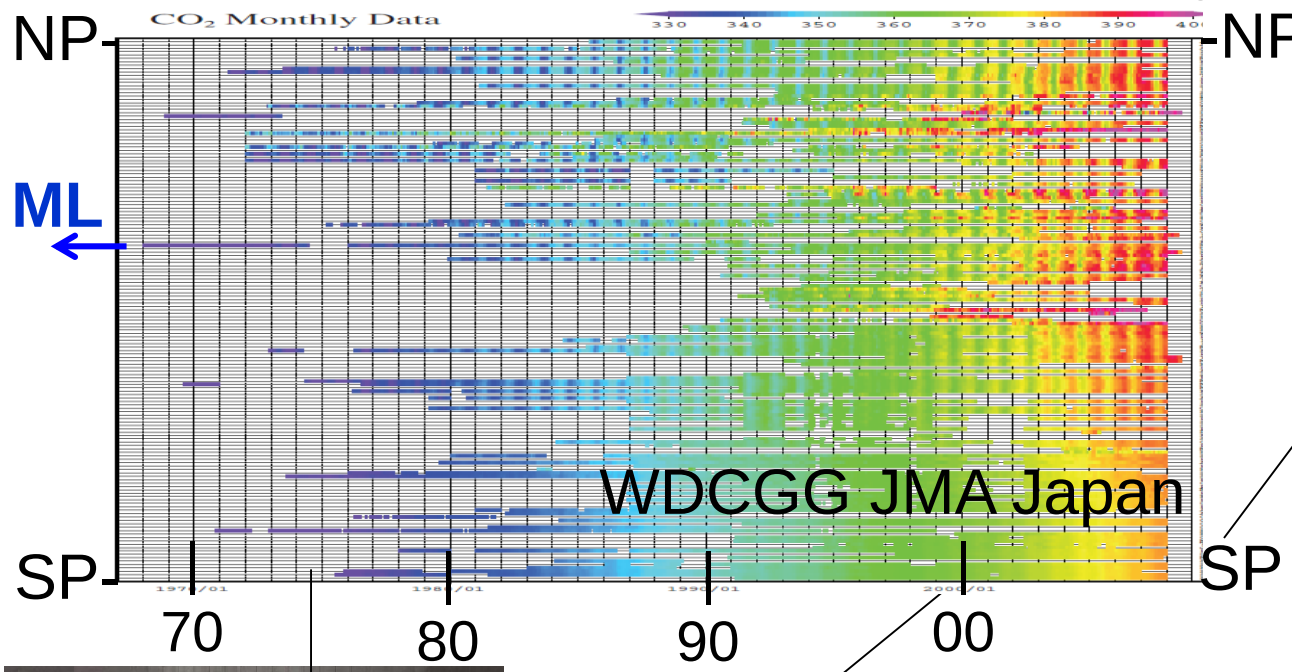
The pre-industrial (1750) atmospheric concentration was 278ppm

This has increased to 390ppm in 2011, a 40% increase



"Seasonally corrected" is a moving average of seven adjacent seasonal cycles

Source: NOAA/ESRL; Global Carbon Project 2012



San Diego 15

Beijin 13

Wellington 11

Jena 09

Toronto 03

Tokyo 01

Boulder 05

Helsinki 07

GGMT 2013 Technical Recommendations

EXPERT GROUP RECOMMENDATIONS

EXPERT GROUP RECOMMENDATIONS FOR MEASUREMENTS OF CARBON DIOXIDE, OTHER GREENHOUSE GASES, AND RELATED TRACERS

The scientists present at the 17th WMO/IAEA Meeting of Experts on Carbon Dioxide, Other Greenhouse Gases and Related Tracers Measurement Techniques (abbreviated as GGMT-2013), 10-13 June 2013, in Beijing, China, recommend the following procedures and actions, to achieve the adopted WMO goals for GAW network compatibility among laboratories and central facilities as summarised in Table 1. These goals are motivated from the perspective of the required data quality and compatibility for interpretation of global or continental scale atmospheric data, obtained from different laboratories, and for example joint use in atmospheric transport model inversion studies. These compatibility goals should be reached in the respective specified mole fraction ranges observed in the global background troposphere and where calibration scales are well defined by the WMO/GAW Central Calibration Laboratories.

The use of terminology is based on standardized definitions as released by ISO (International Organization for Standardization; www.iso.org), in particular the Joint Committee for Guides in Metrology (JCGM) (for details see: http://www.iso.org/sites/JCGM/JCGM-introduction.htm), and has been requested by GAW since WMO/GAW Report No. 142 (2001), "Strategy for the Implementation of the Global Atmosphere Watch Programme (2001 – 2007)" and highlighted further in the WMO/GAW Strategic Plan: 2008-2015 (WMO/GAW Report No. 172) and its Addendum (WMO/GAW Report No. 197).

SUMMARY OF PURPOSE: WHY WE NEED HIGH ACCURACY ATMOSPHERIC TRACE GAS MEASUREMENTS

The United Nations Framework Convention on Climate Change (UNFCCC), which has been signed by nearly all nations, requires signatories to assess greenhouse gas emissions. Three main objectives justify atmospheric observations:

1. To monitor atmospheric greenhouse gas burdens.
2. To quantify natural and anthropogenic emissions and removals of greenhouse gases (GHG), including attribution by region and by process, and to understand the controlling processes.
3. To provide the basis for an independent "top-down" audit of the "bottom-up" UNFCCC emissions inventories.

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Table 1: Recommended compatibility of measurements within the scope of GGMT

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	25 -1000 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	2.4 – 9.8 ppt
H_2	± 2 ppb	± 5 ppb	450 – 600 ppb	140 −1200 ppb
$\delta^{13}C$-CO_2	± 0.01‰	± 0.1‰	-7.5 to -9‰ vs. VPDB	
$\delta^{18}O$-CO_2	± 0.05‰	± 0.1‰	-2 to +2‰ vs. VPDB	
$\Delta^{14}C$-CO_2	± 0.5‰	± 3‰	0-70‰	
$\Delta^{14}C$-CH_4	± 0.5‰		50-350‰	
$\Delta^{14}C$-CO	± 2 molecules cm^{-3}		0-25 molecules cm^{-3}	
$\delta^{13}C$-CH_4	± 0.02‰	± 0.2‰		
δD-CH_4	± 1‰	± 5‰		
O_2/N_2	± 2 per meg	± 10 per meg	-250 to -800 per meg (vs. SIO scale)	

15. ORGANIZATION OF GGMT-2015

There was general agreement among all that it would be desirable to convene the next meeting, the 18th WMO/IAEA Meeting on Carbon Dioxide, Other Greenhouse Gases and Related Tracers Measurement Techniques, at Scripps Institution of Oceanography to celebrate the 40th anniversary of the first meeting in 1975. Dr. Ralph Keeling has agreed to organize and host this meeting.

25 anniversary of the GAW Programme at the 13th iCACGP / 13th IGAC Quadrennial Symposium/Conference. Conference will take place on 22-26 September 2014 in Natal, Brazil (http://igac-icacgp2014.org/)

What is GAW?

- WMO/GAW was established 1989 by merging GO_3OS and BAPMoN.
- GAW focuses on global networks for **GHGs, ozone, UV, aerosols, selected reactive gases, and precipitation chemistry**.
- GAW is a partnership involving contributors from 80 countries.
- GAW is coordinated by the Environment Division of WMO/AREP under the purview of WMO Commission for Atmospheric Science (CAS)
- Currently GAW coordinates activities and data from 27 Global stations, 413 Regional stations, and 164 Contributing stations (http://gaw.empa.ch/gawsis/)

How does GAW work?

SAGs

- Ozone
- UV
- IGACO-Ozone
- Greenhouse Gases
- Precipitation chemistry
- Reactive gases
- GURME
- Aerosols

GAW Secretariat

WMO

CAS Open Programme Area Group

EPAC

Environmental Pollution & Atmospheric Chemistry

Joint Steering Committee

Quality Assurance & Science Activity Centres

World & Regional Calibration Centres

GHG	N_2O VOC	CH_4	Precip. chem.	Physical aerosol properties	In situ O_3, CO, CH_4	Optical depth	Total O_3	O_3 Sondes
NOAA ESRL/GMD (USA)	IMK-IFU (DE)	JMA (JP)	SUNY Albany (USA)	IFT (DE)	EMPA (CH)	WORCC (CH)	3 WCC (US, CA, RU) 6 Dobson RCC (JP, AU, ZA, AR, DE, CZ) 1 Brewer RCC (ES)	FZJülich (DE)

Central Calibration Laboratories

Host GAW World Reference Standards

CO_2, CH_4, N_2O CO, Dobson O_3	Brewer total O_3	Ozone-sondes	In situ O_3
NOAA ESRL/GMD (USA)	Environment Canada	FZJülich (DE)	NIST (USA)

Contributing networks

emep, EANET, BSRN, AERONET (AEROSOL ROBOTIC NETWORK), EARLINET, CAPMoN, NDACC, SHADOZ, AGAGE

GAW stations & GAWSIS

Satellites & Aircraft

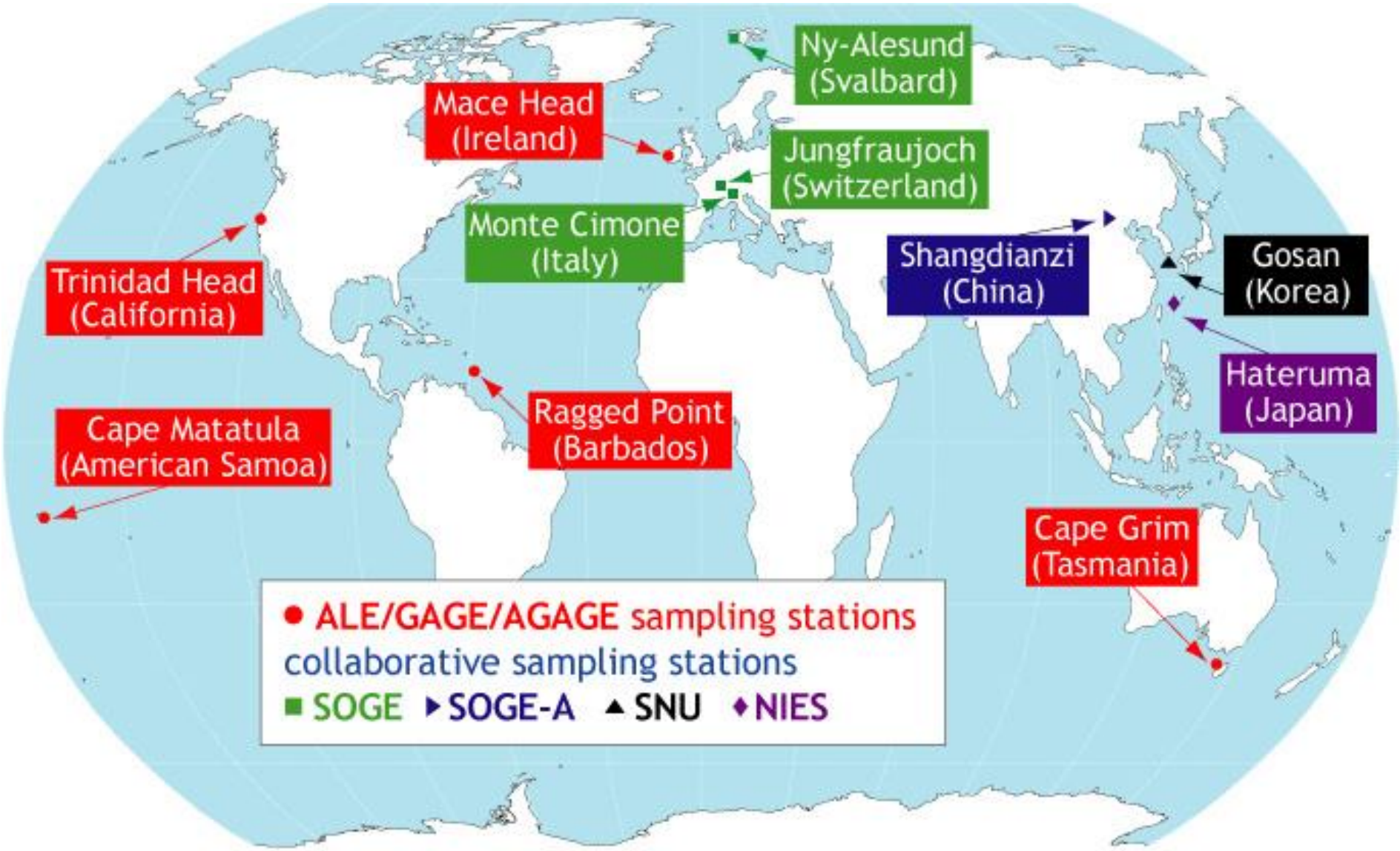
IGACO products

- GHG Bulletins
- O_3 Bulletins
- Assessments
- Global fields

World Data Centres

WOUDC Ozone & UV	WDCGG Greenhouse gases	WDCA Aerosols	WRDC Radiation	WDCPC Precip. chem.	WDC-RSAT Satellite data
Environment Canada (CA)	JMA (JP)	JRC (EU)	MGO (RU)	SUNY Albany (USA)	DLR (DE)

An Observational Network with Global



Need for quality control

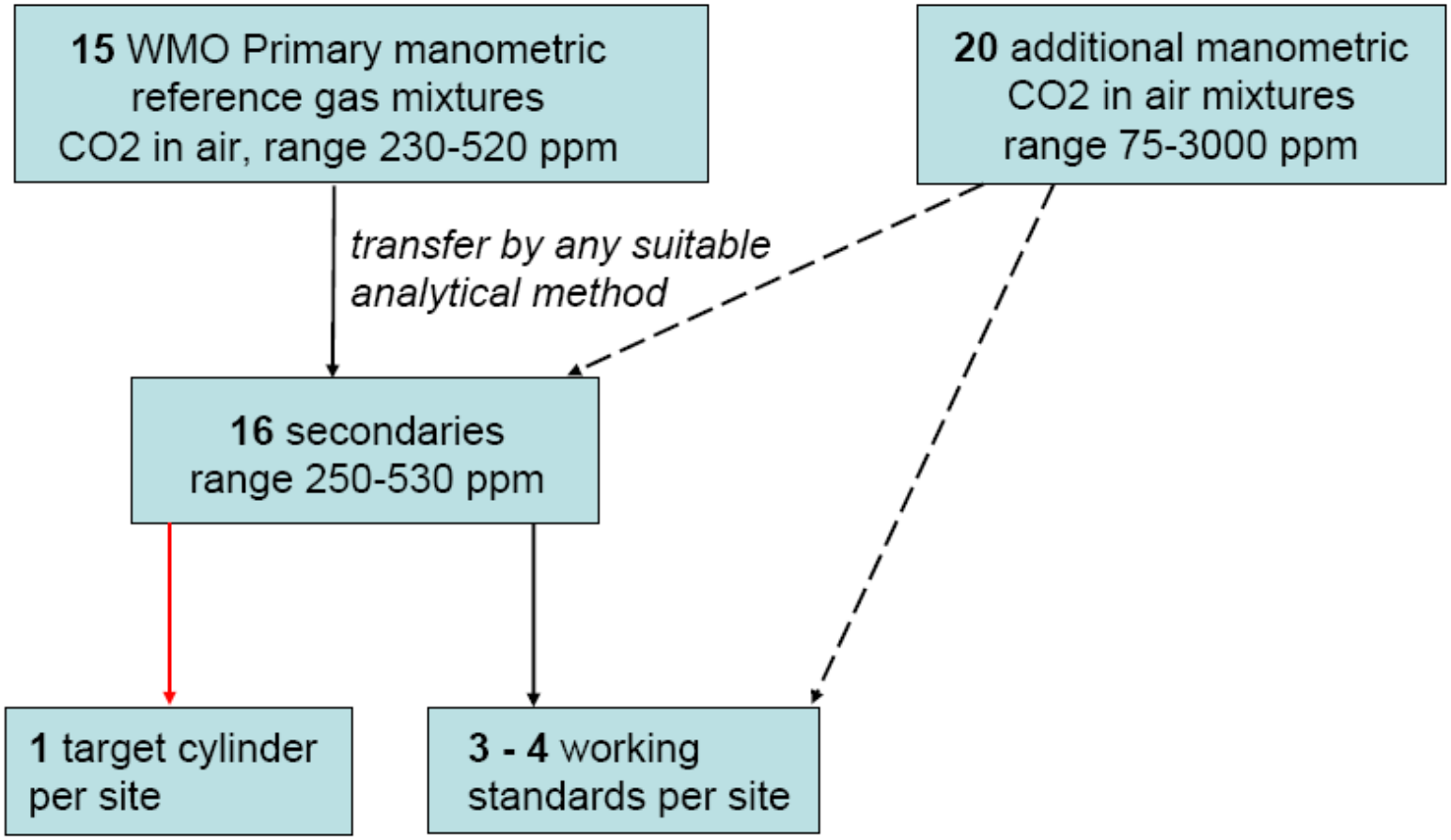
- Detect small trends (through DQO)
- Detect small spatial gradients
- Ensure long-term stability of observations
- Data comparability (on the same scale)

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)

Propagation of WMO Mole Fraction Scale for CO_2



Propagation of WMO Mole Fraction Scale for CO_2

Standard deviation of individual cylinder manometric calibrations during each calibration episode.

	N	St.Dev. (all) ppm	St.Dev. (one sigma) (300-420) ppm
1996	64	0.12	0.09
1998	58	0.14	0.13
2000	55	0.11	0.10
2001	62	0.09	0.08
2003	62	0.06	0.06
2004	48	0.04	0.04
2006	41	0.03	0.03

Quality Assurance I

World or Regional Calibration Centres

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

- CO_2 - NOAA ESRL USA
  - EMPA, Switzerland
- CH_4 - EMPA, Switzerland (Am, E/A)
  - JMA, Japan (A/O)
- N_2O - IMK-IFU Garmisch, Germany
- CFCs, HCFCs, HFCs - WCC is not assigned

Quality Assurance II

Standard measurements procedures and measurements guidelines

- CH_4 and N_2O - updated GAW report 185
- CO_2 - GAW report 134 (evolving through semi-annual meetings)
- CFCs, HCFCs, HFCs - MG are not established

The Guide for Data submission and dissemination (by WDCGG) is updated (GAW report 188)

Quality Assurance III

Stations twinning/ Training/Expert workshops

Twinning

- Empa - Assekrem (Algeria), Bukit Koto Tabang (Indonesia) and Mt. Kenya (Kenya)
- The Institute for Meteorology and Climate Research, (IMK-IFU) - Cape Point (South Africa).
- NOAA (ESRL) - Ushuaia (HATS group), Tiksi (Russia) and a number of others

Training

- The GAW Training and Education Centre (GAWTEC)
- EMPA conducts training for operators of stations Mt. Kenya (Kenya), Bukit Koto Tabang (Indonesia), Assekrem (Algeria), Shangdian' zi (China)
- NCAR (Boulder) has provided training for Mt. Kenya operators specifically for their CO_2 analyzer installed in 2008.

Expert meetings

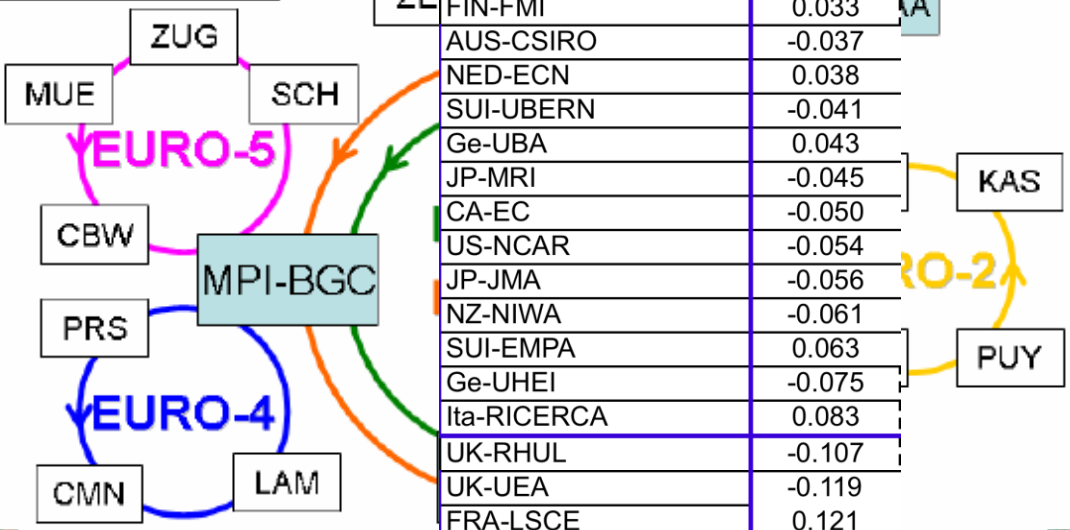
- Biennial WMO/IAEA Meeting of Experts on Carbon Dioxide, Other Greenhouse Gases, and Related Tracer Measurement Techniques (since 1975)

Exampl arison

Circulation of Carb umbers

Euro-1: 3 Tanks (UHEI)
Euro-2: 3 Tanks (LSCE)
Euro-3: 3 Tanks (CIO-RUG)
Euro-4: 3 Tanks (MPI-BGC)
Euro-5: 3 Tanks (MPI-BGC)

er-1: 3 Tanks (UEA)
er-2: 3 Tanks (UEA)



Laboratories	
NOAA	
Ge-MPI-BGC	-0.001
Ita-JRC	0.003
US-AmeriFlux	0.004
JP-NIES	-0.005
KOR-KMA	0.005
Ge-UBA	0.011
US-OSU	0.015
BRA-IPEN	-0.025
KOR-SNU	0.025
HUN-HMS	-0.027
US-PSU	-0.028
SA-WS	0.031
FIN-FMI	0.033
AUS-CSIRO	-0.037
NED-ECN	0.038
SUI-UBERN	-0.041
Ge-UBA	0.043
JP-MRI	-0.045
CA-EC	-0.050
US-NCAR	-0.054
JP-JMA	-0.056
NZ-NIWA	-0.061
SUI-EMPA	0.063
Ge-UHEI	-0.075
Ita-RICERCA	0.083
UK-RHUL	-0.107
UK-UEA	-0.119
FRA-LSCE	0.121
JP-AIST	0.125
US-HU	-0.126
SUI-WCC-EMPA	0.133
CN-CMA(BJ)	-0.135
US-UCSD	-0.165
Ita-JRC	0.173
KOR-KRISS	0.195
SWE-SU	-0.197
JP-TU	0.205
CN-CMA(WLG)	-0.265
Ita-ENEA	-0.367
Ge-ZUG	-1.731

WMO GREENHOUSE GAS BULLETIN

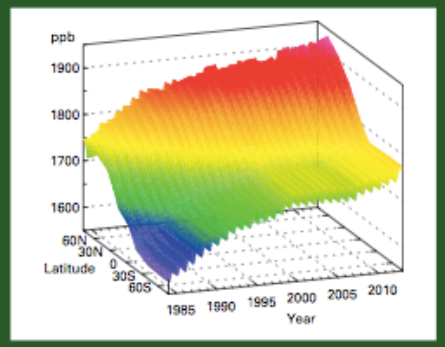
The State of Greenhouse Gases in the Atmosphere
Based on Global Observations through 2012

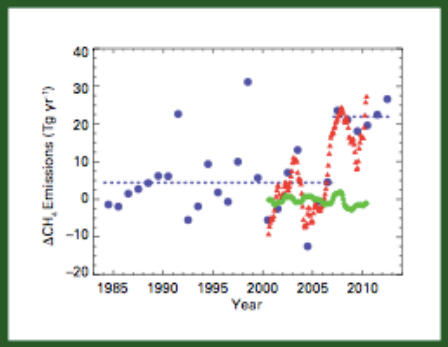
World Meteorological Organization
Weather · Climate · Water

GLOBAL ATMOSPHERE WATCH

No. 9 | 6 November 2013

ISSN 2078-0796





The left-hand figure shows the latitudinal distribution of atmospheric methane (CH_4) interpolated from measurements made at the WMO Global Atmosphere Watch stations. After remaining nearly constant from 1999 to 2006, atmospheric CH_4 began increasing again in 2007. Total global emissions can be calculated from the observed atmospheric CH_4 burden and rate of increase, combined with an estimate of methane's atmospheric lifetime (about 9 years). Differences between these emissions (ΔCH_4) and average emissions for 2003-2005 are plotted as blue circles in the right hand figure; the dashed blue lines show average differences for 1984-2006 and 2007-2012. From 1984 to 2006, emissions were highly variable but persistently lower than for 2007 to 2012, except for 1991 and 1998. Monthly emission differences (in Tg CH_4 yr^{-1}) calculated globally (red) and for the Arctic (green) by a chemical transport model study are also shown (Bergamaschi, et al., 2013). Analysis of the data indicates that tropical and mid-latitude Northern Hemisphere emissions have contributed to increases in atmospheric CH_4 since 2007, and that there has not yet been a measurable increase in Arctic CH_4 emissions.

Executive summary

The latest analysis of observations from the WMO Global Atmosphere Watch (GAW) Programme shows that the globally averaged mole fractions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) reached new highs in 2012, with CO_2 at 393.1±0.1 ppm[2], CH_4 at 1819±1 ppb[3] and N_2O at 325.1±0.1 ppb. These values constitute, respectively, 141%, 260% and 120% of pre-industrial (before 1750) levels. The atmospheric increase of CO_2 from 2011 to 2012 is higher than the average growth rate over the past 10 years. For N_2O the increase from 2011 to 2012 is smaller than the one observed from 2010 to 2011 but larger than the average growth rate over the past 10 years. Atmospheric CH_4 continued to increase at a rate similar to the one observed over the past 4 years. The National Oceanic and Atmospheric Administration (NOAA) Annual Greenhouse Gas Index shows that from 1990 to 2012 radiative forcing by long-lived greenhouse gases increased by 32%, with CO_2 accounting for about 80% of this increase.

Overview

This ninth WMO/GAW Annual GHG Bulletin reports atmospheric abundances and rates of change of the most important long-lived greenhouse gases (LLGHGs) – carbon dioxide, methane, nitrous oxide – and provides a summary of the contributions of the other gases. These three together

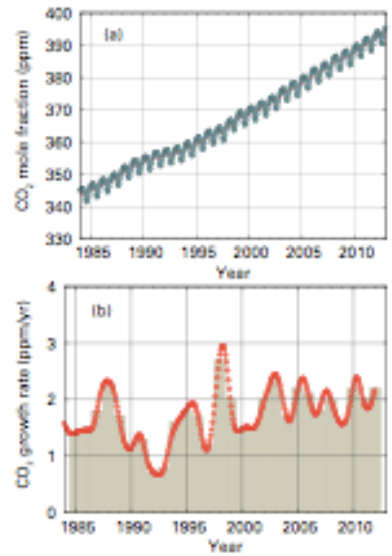


Figure 3. Globally averaged CO_2 mole fraction (a) and its growth rate (b) from 1984 to 2012. Annually averaged growth rates are shown as columns in (b).

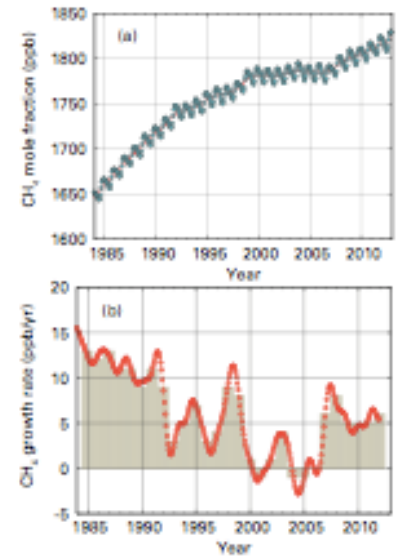


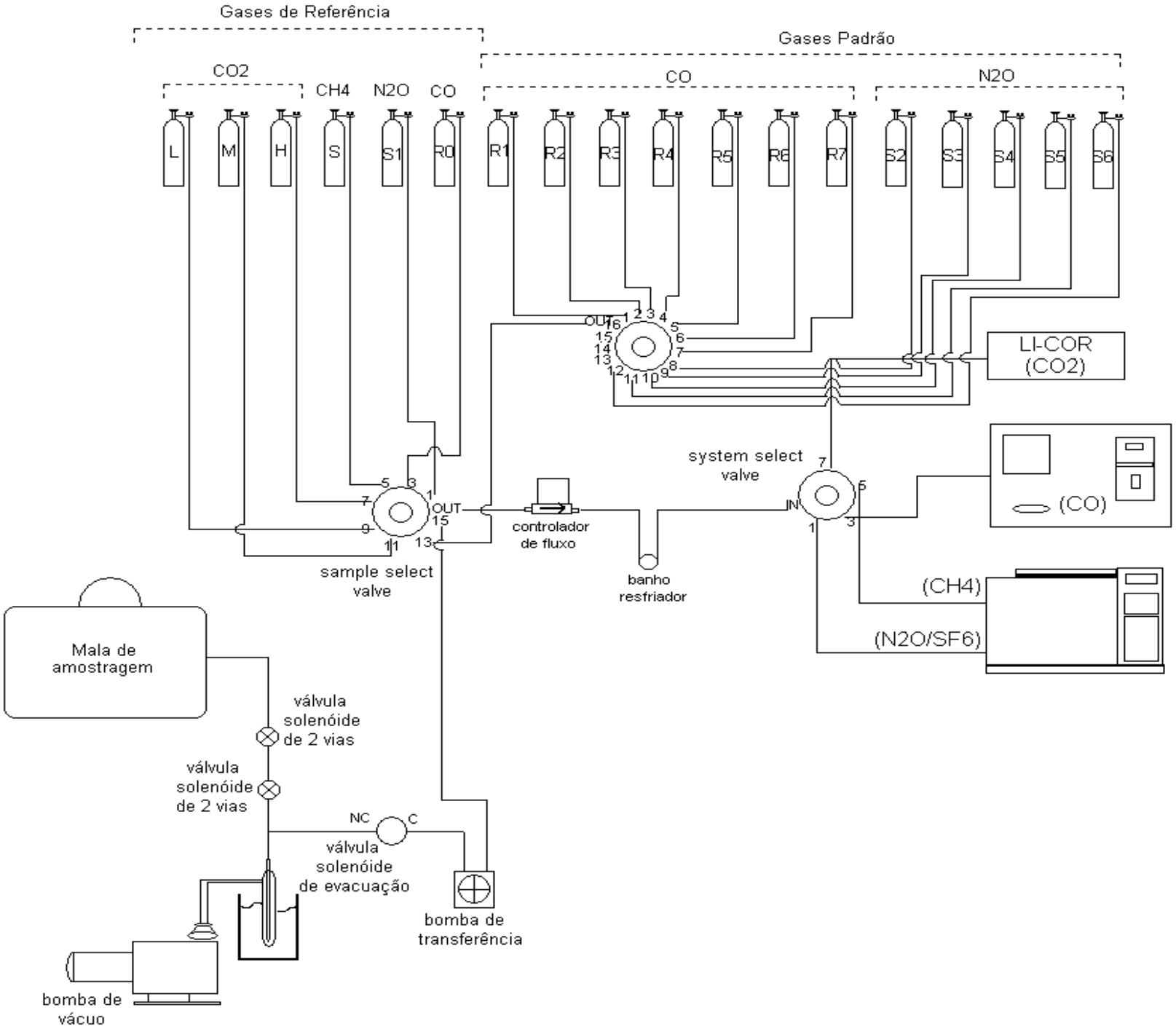
Figure 4. Globally averaged CH_4 mole fraction (a) and its growth rate (b) from 1984 to 2012. Annually averaged growth rates are shown as columns in (b).

	CO_2	CH_4	N_2O
Global abundance in 2012	393.1± 0.1[5] ppm	1819± 1[5] ppb	325.1± 0.1[5] ppb
2012 abundance relative to year 1750*	141%	260%	120%
2011–12 absolute increase	2.2 ppm	6 ppb	0.9 ppb
2011–12 relative increase	0.56%	0.33%	0.29%
Mean annual absolute increase during last 10 years	2.02 ppm/yr	3.7 ppb/yr	0.80 ppb/yr

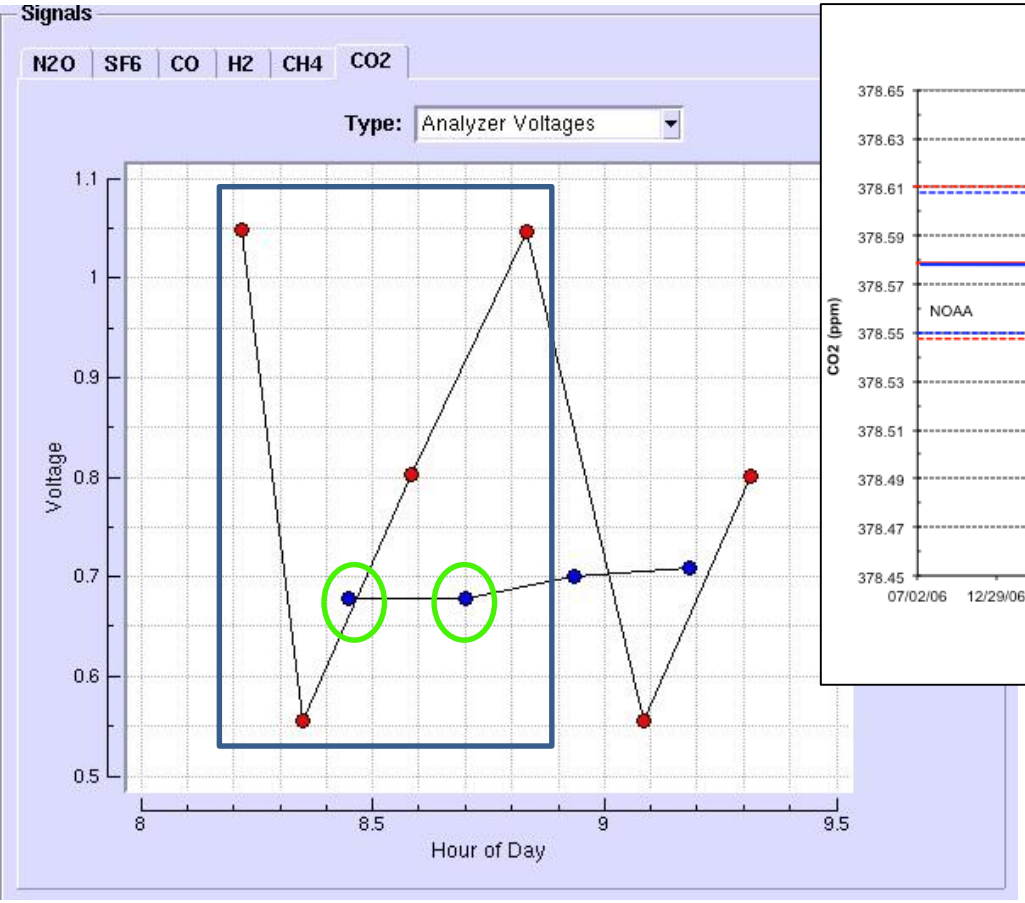
* Assuming a pre-industrial mole fraction of 278 ppm for CO_2, 700 ppb for CH_4 and 270 ppb for N_2O.

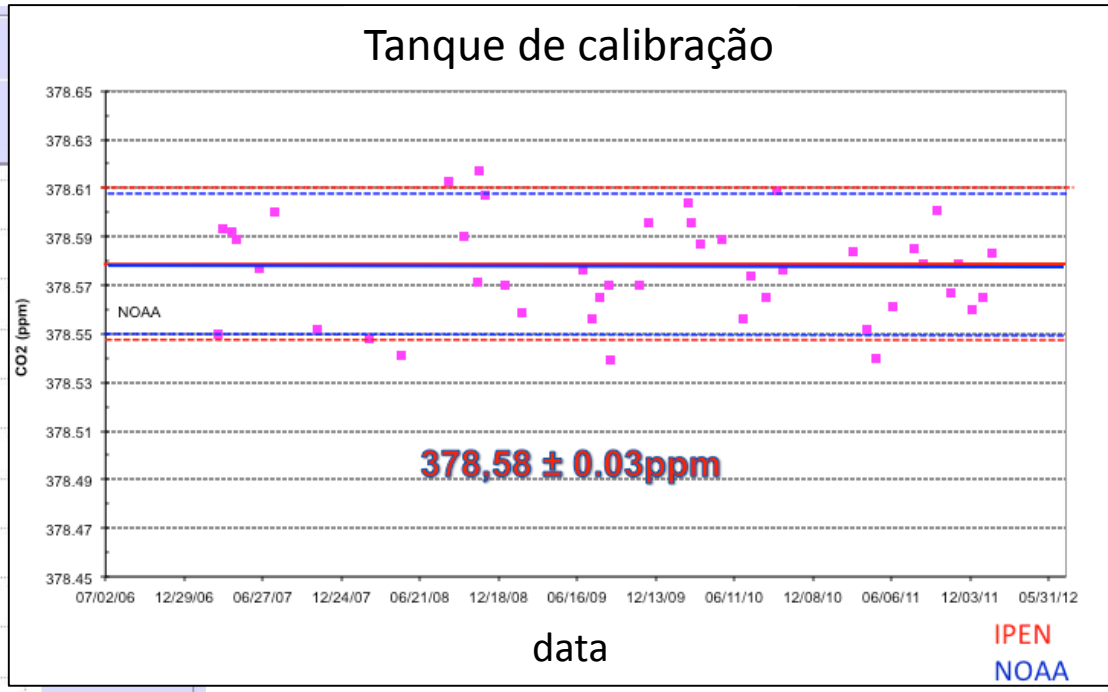
Lab. de Química Atmosférica CQMA/IPEN
Réplica do Laboratório da NOAA/ESRL/GMD

(National Oceanic Atmospheric Administration / Earth System Research Laboratory / Global Monitoring Division)


Gases de Referência
Gases Padrão
CO2
CH4
N2O
CO
CO
N2O
L
M
H
S
S1
R0
R1
R2
R3
R4
R5
R6
R7
S2
S3
S4
S5
S6
OUT
LI-COR
(CO2)
system select
valve
IN
(CO)
(CH4)
(N2O/SF6)
OUT
controlador
de fluxo
banho
resfriador
sample select
valve
Mala de
amostragem
válvula
solenóide
de 2 vias
válvula
solenóide
de 2 vias
NC
C
válvula
solenóide
de evacuação
bomba de
transferência
bomba de
vácuo

CO_2


Signals
N2O
SF6
CO
H2
CH4
CO2
Type:
Analyzer Voltages
Voltage
1.1
1
0.9
0.8
0.7
0.6
0.5
8
8.5
9
9.5
Hour of Day


Tanque de calibração
CO2 (ppm)
378.65
378.63
378.61
378.59
378.57
378.55
378.53
378.51
378.49
378.47
378.45
NOAA
378,58 ± 0.03ppm
07/02/06
12/29/06
06/27/07
12/24/07
06/21/08
12/18/08
06/16/09
12/13/09
06/11/10
12/08/10
06/06/11
12/03/11
05/31/12
data
IPEN
NOAA

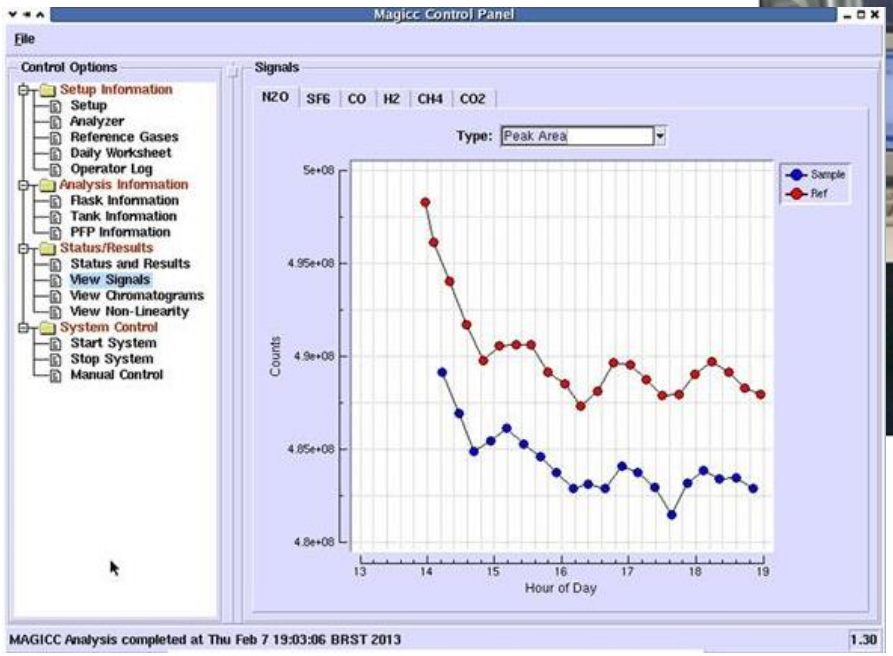
LI-COR
LI-7000 CO2/H2O Analyzer

Ref gas – sample – Ref gas – sample – Ref gas – sample ……..

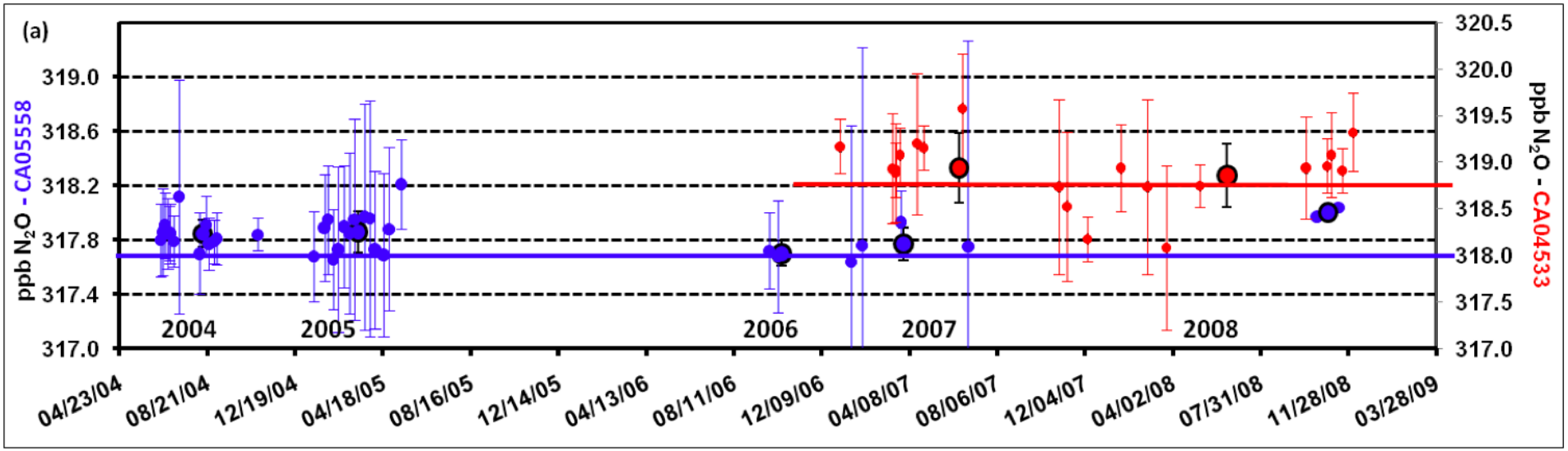
$$\frac{\text{Sample}}{(\text{Ref gas}_{\text{before}} + \text{Ref gas}_{\text{after}})/2}$$

Calibration curve

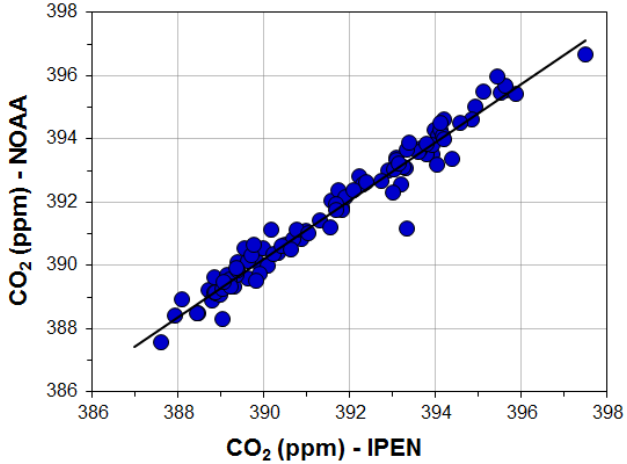
Each point in the curve: 9 Ref gas – 8 $\text{Std}_{\mathbf{1}}$, 9 Ref gas – 8 $\text{Std}_{\mathbf{2}}$, …….

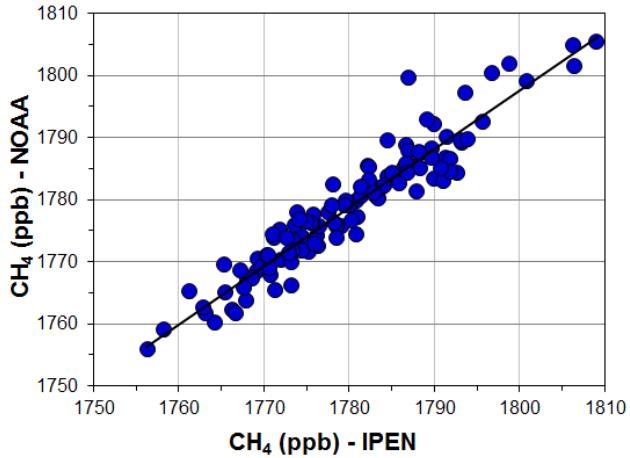

Magicc Control Panel
File
Control Options
Setup Information
Setup
Analyzer
Reference Gases
Daily Worksheet
Operator Log
Analysis Information
Flask Information
Tank Information
PFP Information
Status/Results
Status and Results
View Signals
View Chromatograms
View Non-Linearity
System Control
Start System
Stop System
Manual Control
Signals
N2O
SF6
CO
H2
CH4
CO2
Type:
Peak Area
Sample
Ref
Counts
Hour of Day
MAGICC Analysis completed at Thu Feb 7 19:03:06 BRST 2013
1.30

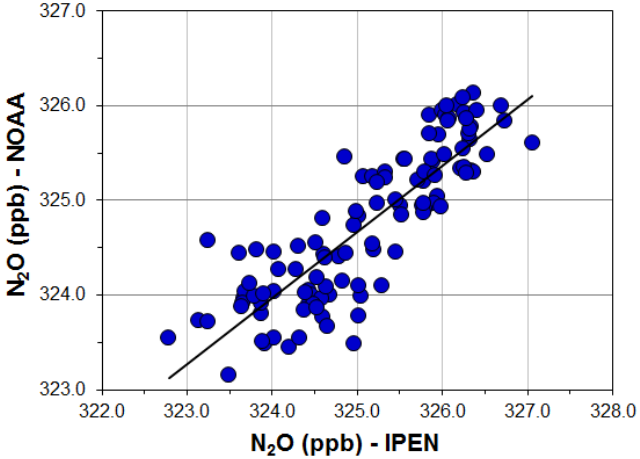
Beijin 13
Beijin 13

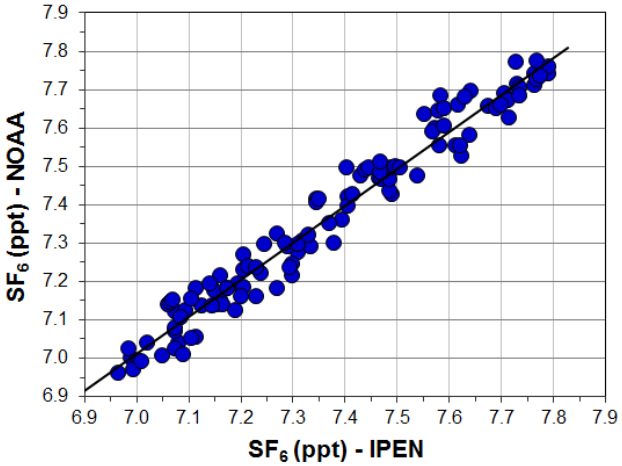

(a)
ppb N2O - CA05558
ppb N2O - CA04533
2004
2005
2006
2007
2008
04/23/04
08/21/04
12/19/04
04/18/05
08/16/05
12/14/05
04/13/06
08/11/06
12/09/06
04/08/07
08/06/07
12/04/07
04/02/08
07/31/08
11/28/08
03/28/09

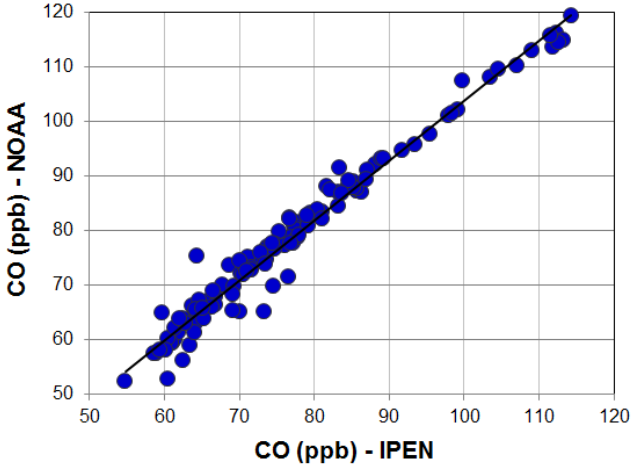
Natal IPEN / NOAA weekly inter comparison











Constructing a Brazil Network in Climate Change Observation System

-Vertical Profiles

Constructing a Brazil Network in Climate Change Observation System

-Towers

1- Vertical profiles

2- Towers

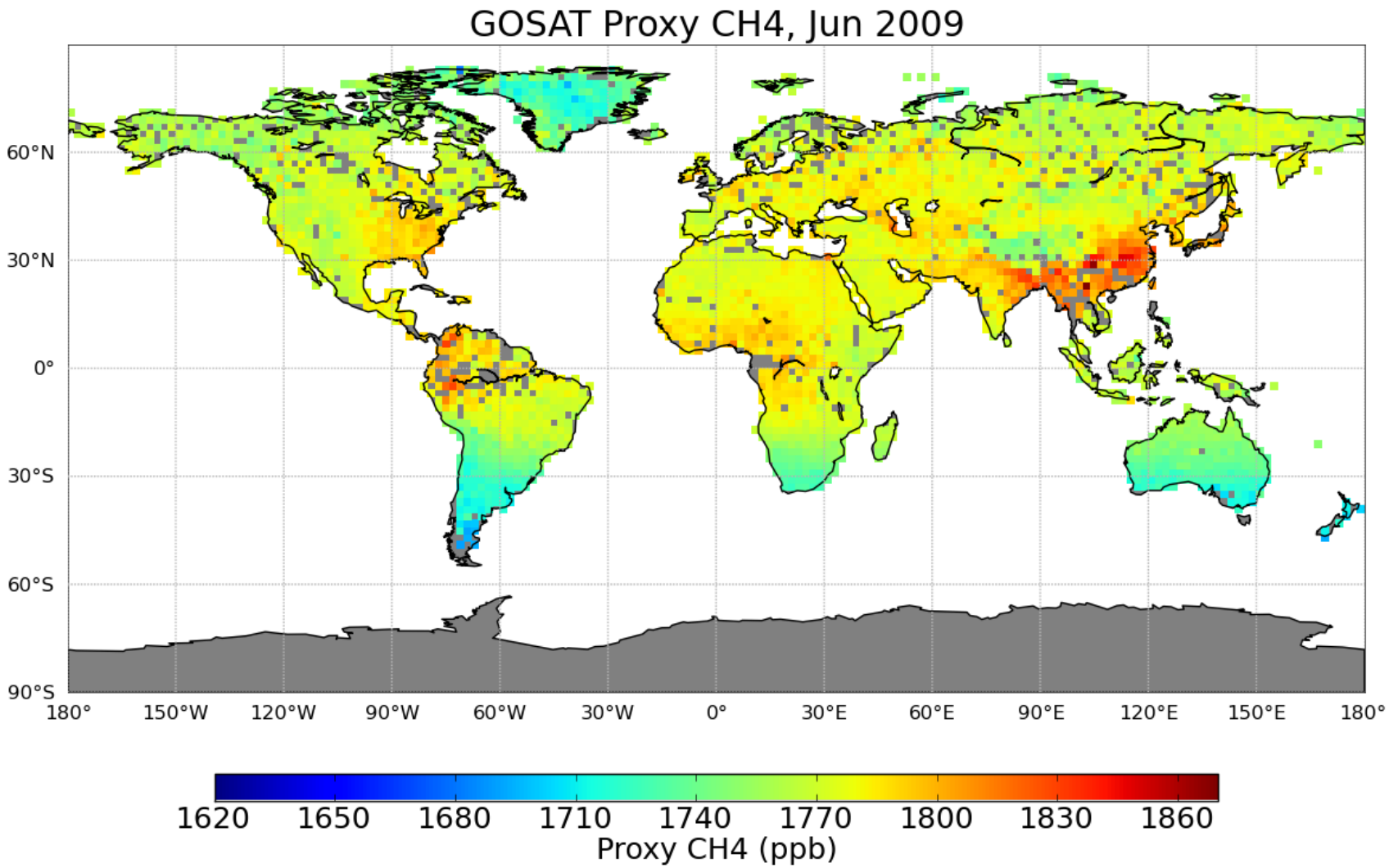
3- Central Laboratory Facilities

- standards from natural air
- produce a prototype for tower GHG calibrated measures
- Training courses

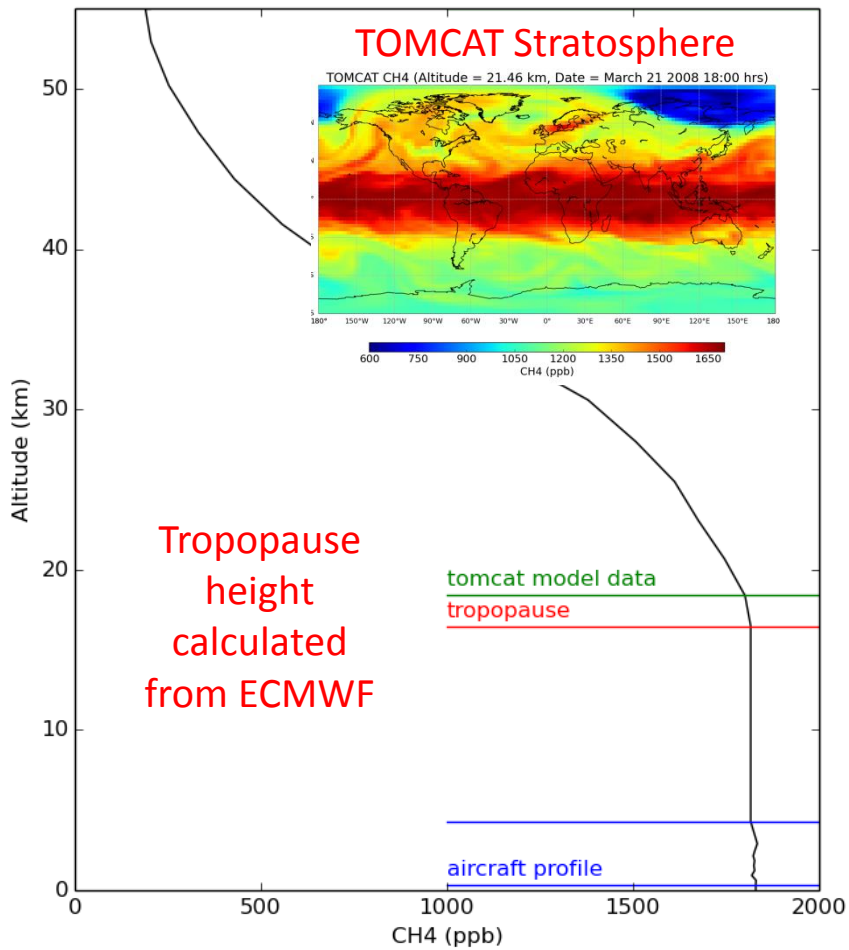
Developing the capability to produce GHG standards from Natural air

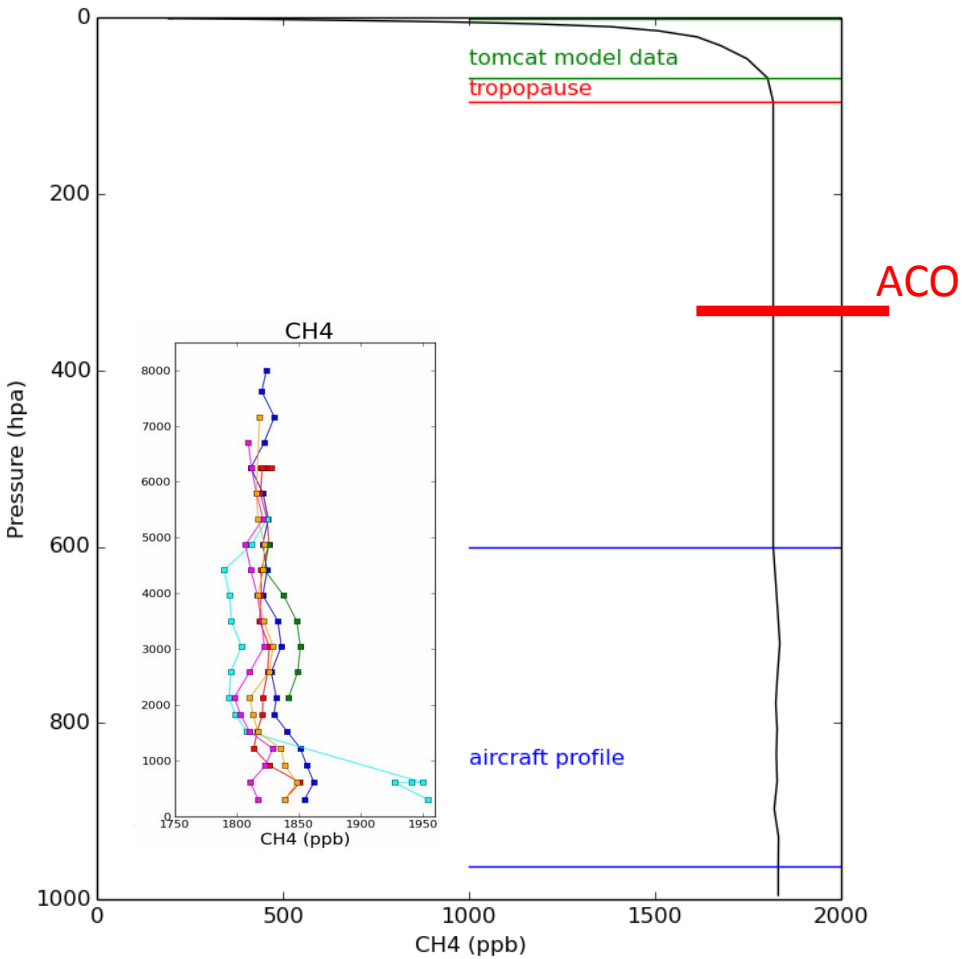
CO_2: 0.03ppm precision

CH4: 2ppm precison

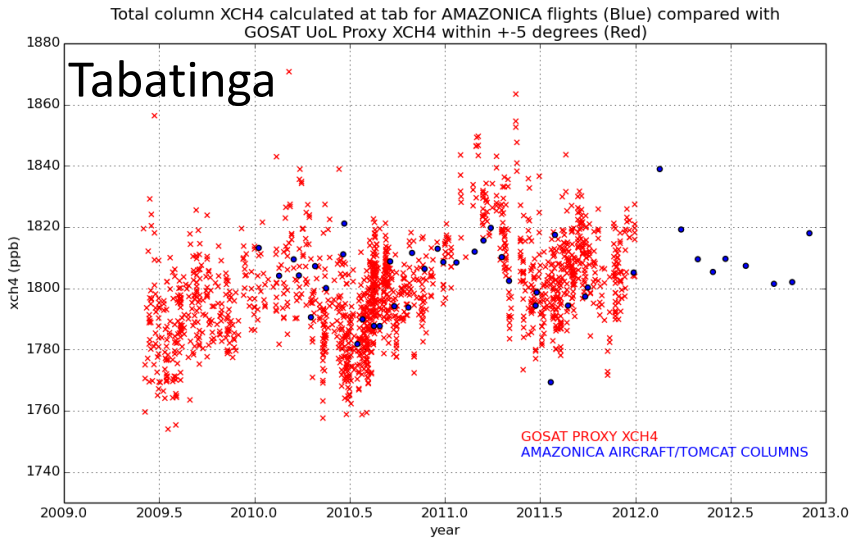

GOSAT Proxy CH4, Jun 2009
60°N
30°N
0°
30°S
60°S
90°S
180°
150°W
120°W
90°W
60°W
30°W
0°
30°E
60°E
90°E
120°E
150°E
180°
1620
1650
1680
1710
1740
1770
1800
1830
1860
Proxy CH4 (ppb)

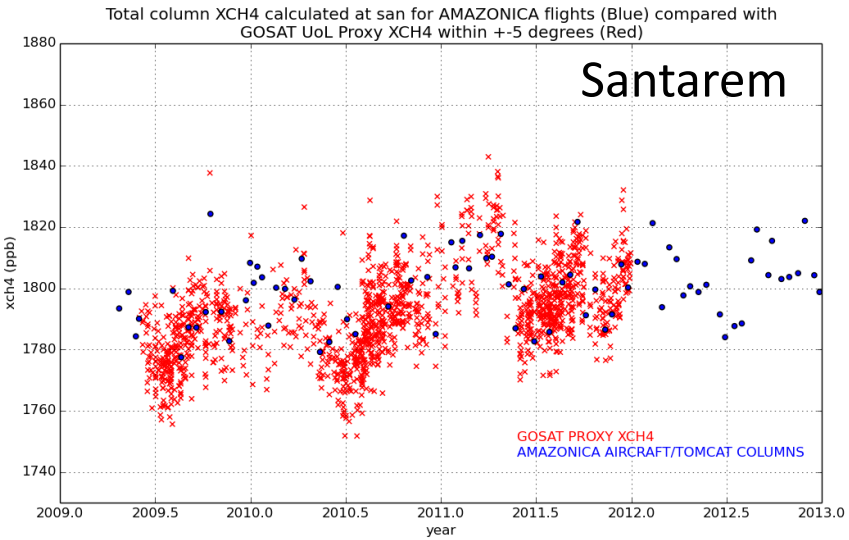
Comparing Satellites and Aircraft - Method

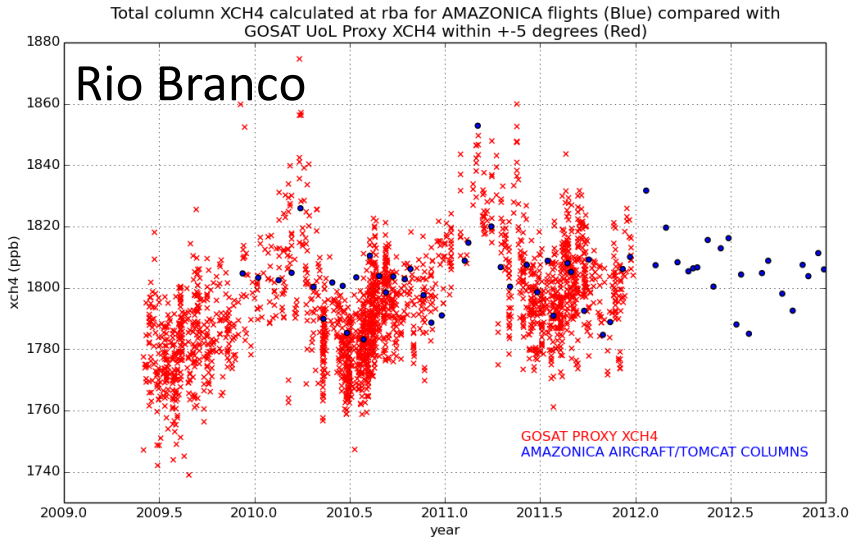


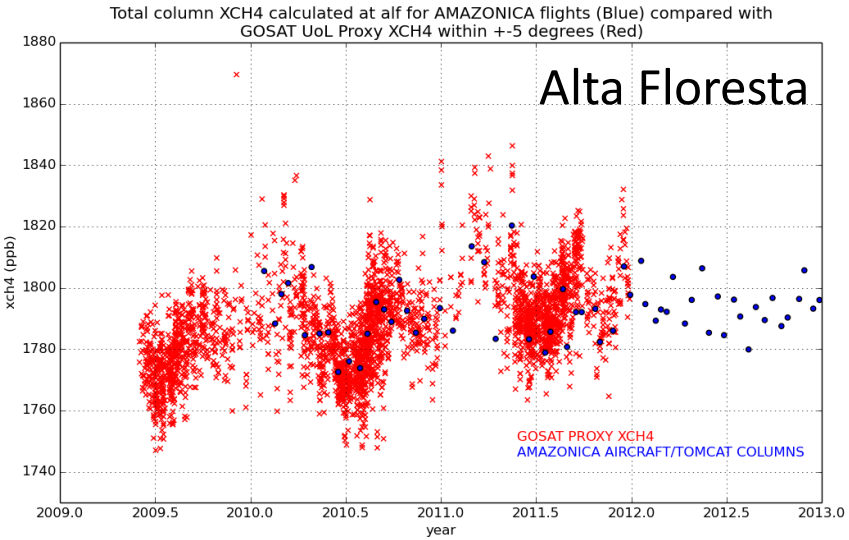


Comparison between Aircraft and GOSAT ±5°

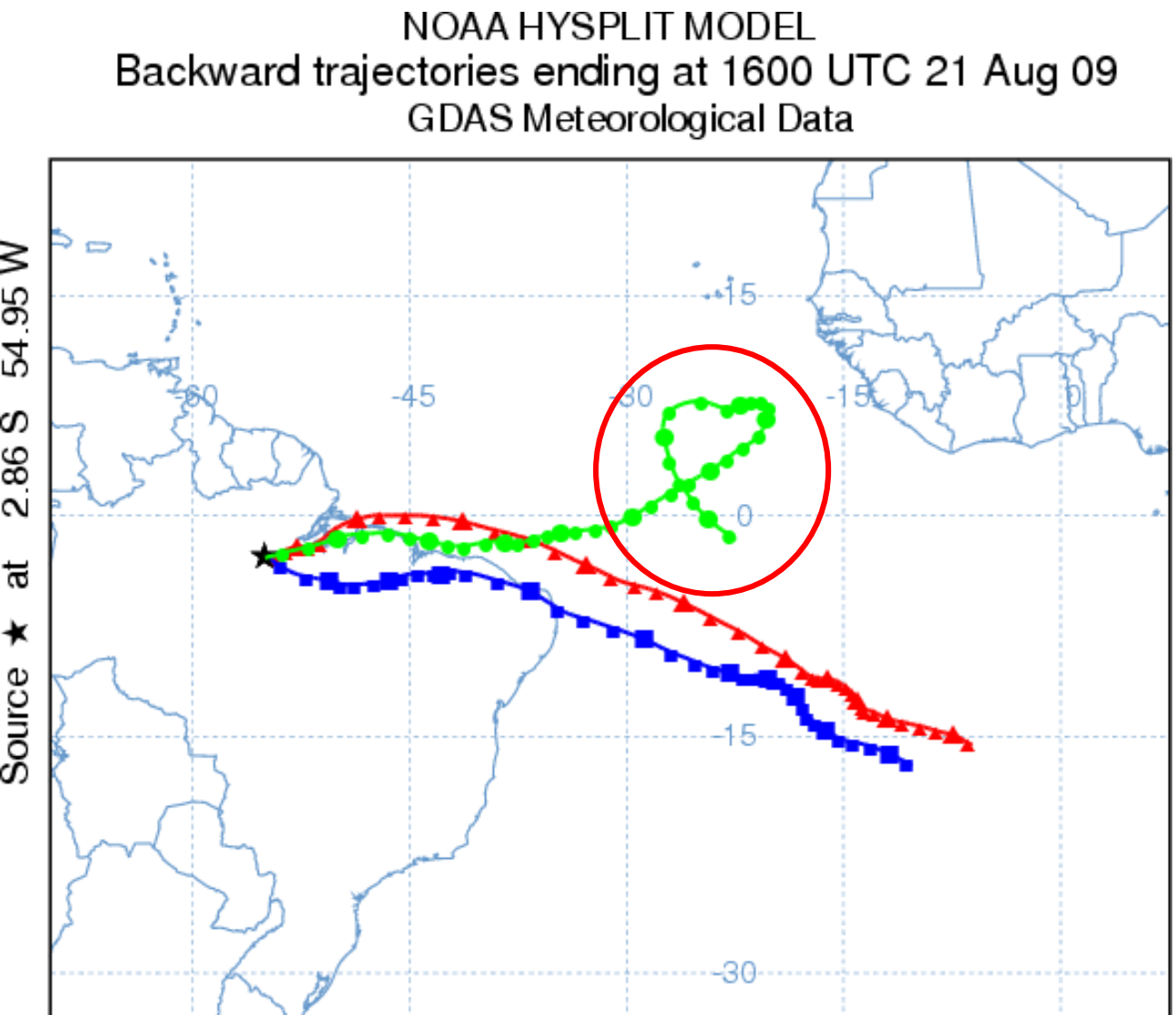








Thank you



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FAPESP

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SEVENTH FRAMEWORK PROGRAMME

NOAA

CAPES