university of groningen / faculty of mathematics and natural sciences / centre for isotope research

Continuous and flask observations of atmospheric $\delta O_2/N_2$ and CO_2 at Lutjewad station, the Netherlands, and Mace Head station, Ireland

APO meeting, September 18-20, 2015

Scripps, La Jolla, Ca

Charlotte van Leeuwen, Bert Scheeren, Ingrid van der Laan-Luijkx, Bert Kers and Harro A.J. Meijer

Centre for Isotope Research (CIO)

Energy and Sustainability Research Institute Groningen (ESRIG)

University of Groningen, the Netherlands

university of groningen / faculty of mathematics and natural sciences / centre for isotope research

university of groningen / faculty of mathematics and natural sciences / centre for isotope research

Continuous and flask observations of atmospheric $\delta O_2/N_2$ and CO_2 at Lutjewad station, the Netherlands, and Mace Head station, Ireland

centre for isotope research

Atmospheric O_2 in Europe

Lutjewad: in operation since 2000
- sea level, mast intake at 60 m above ground
- flasks taken 1-2 per week
- "local background" conditions:
- ^{222}Rn < 3 Bq/m^3 and [CO]< 200 ppb

Mace Head: flask pairs filled once per week for CIO since 1999
- sea level, intake at ≈10 m above sea level
- only sampled in background conditions

Flask measurements at CIO: 2.5 l flasks, LH valves, filled at ambient pressure duplicate/triplicate measurements using an Micromass DI Optima

Additionally, [CO_2], [CH_4], [CO] measured using a HP6890N GC until 2013, thereafter with a Picarro

university of groningen / faculty of mathematics and natural sciences / centre for isotope research

System Performance

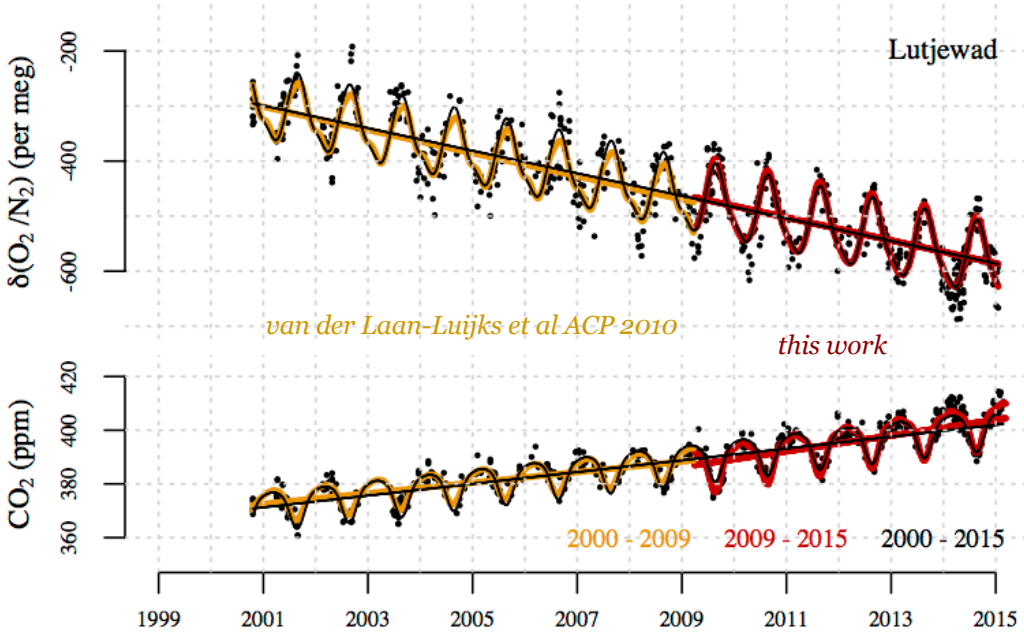
O_2 DI Optima
flask precision (duplicates) ≤ 4 per meg
internal scale stability ≈ 2 per meg
Cylinder precision (single mm) :≈ 10 per meg until Jan 2015

Calibration on the "Scripps" scale depends on infrequent and few cylinder measurements…

CO_2 GC and Picarro
Accuracy < 0.1 ppm (WMO X2007 scale)

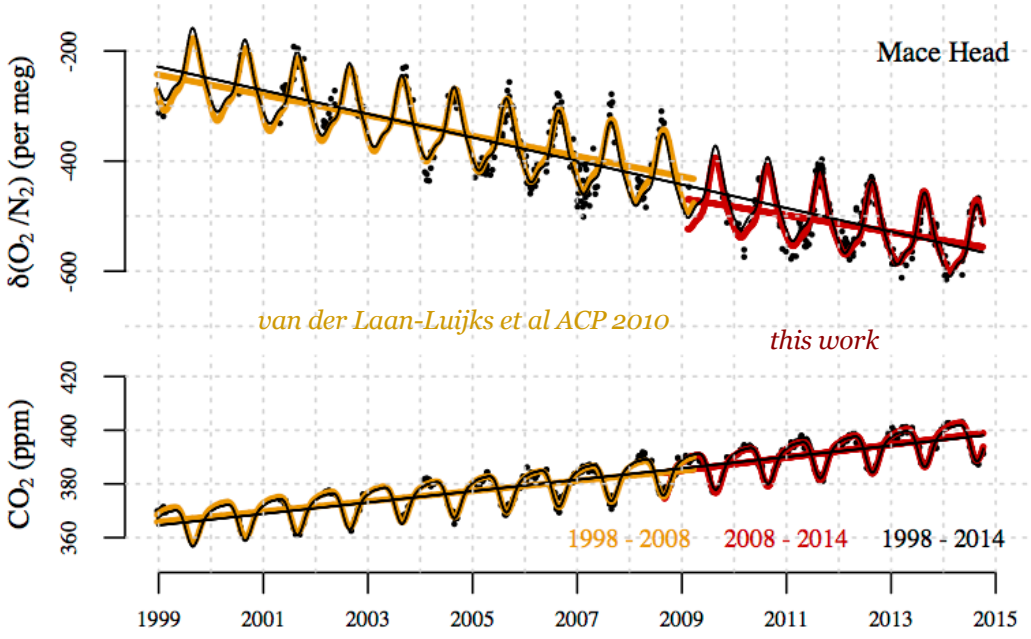
university of groningen / faculty of mathematics and natural sciences / centre for isotope research

Observations: flasks



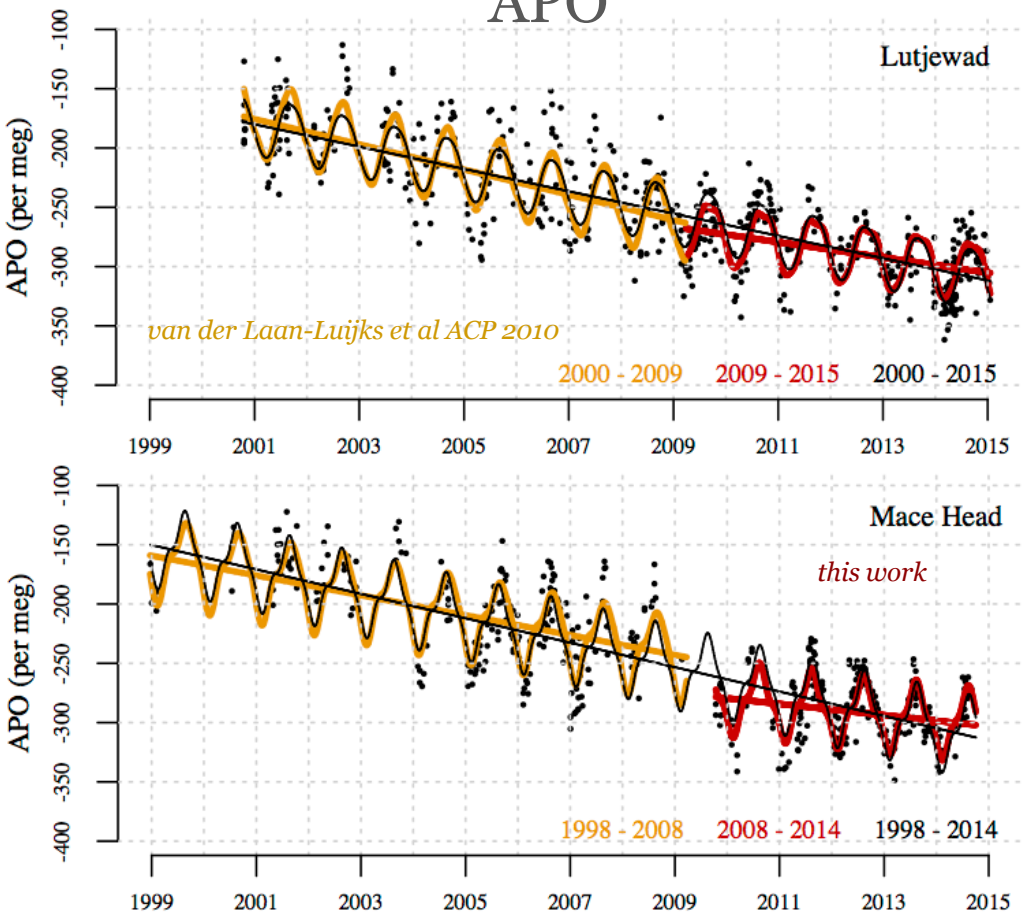
university of groningen / faculty of mathematics and natural sciences / centre for isotope research

Observations: flasks



university of groningen / faculty of mathematics and natural sciences / centre for isotope research

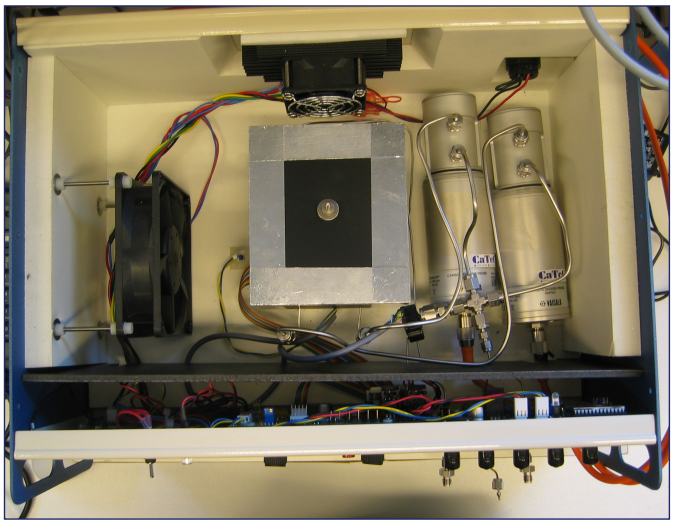
APO

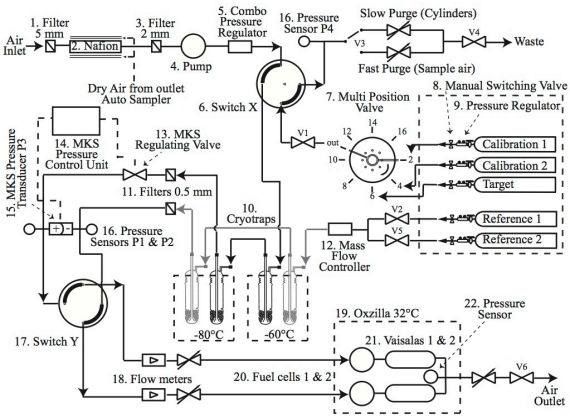


centre for isotope research

Lutjewad continuous measurements

Oxzilla + Vaisala = Oxzala

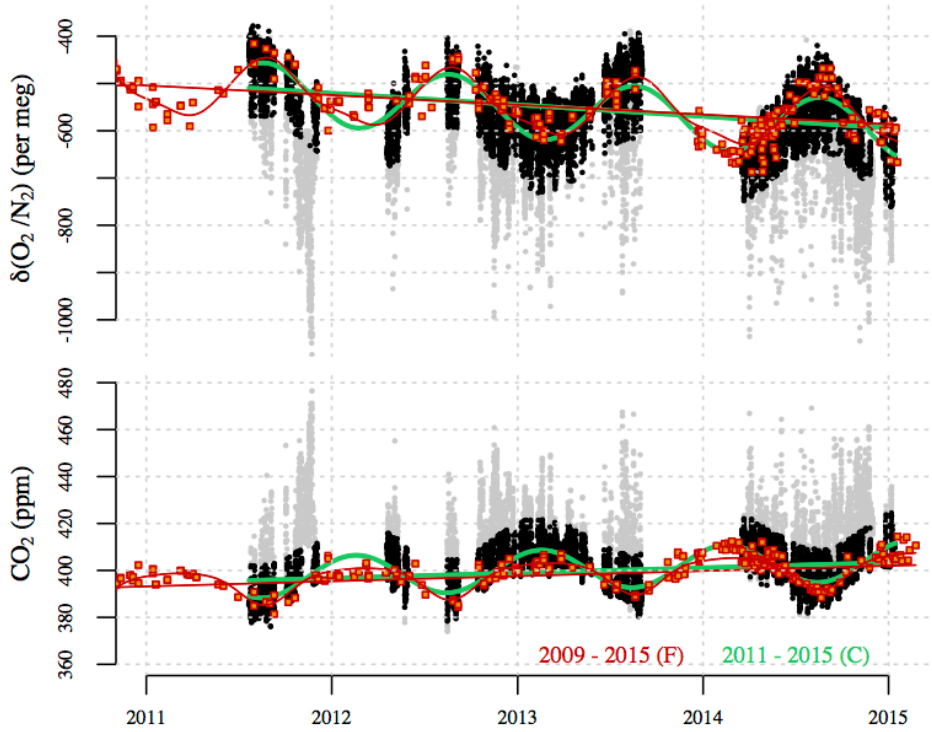




Use of Oxzilla II pioneered by Stephens et al. (2007), Thompson et al. (2007) and Patecki & Manning (2007). Also used by van der Laan-Luijkx et al, 2010 on the F3 North Sea gas platform

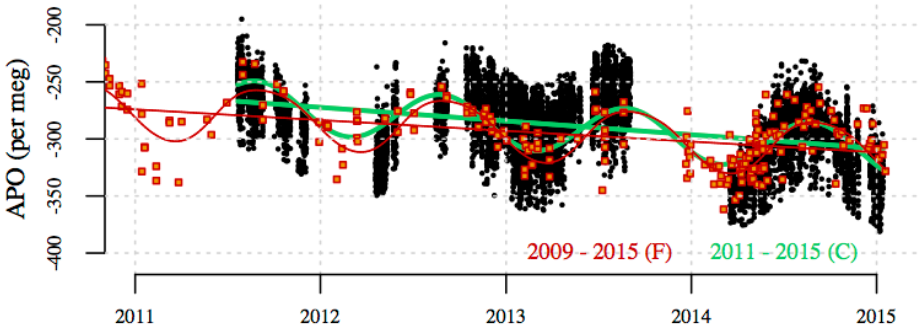
university of groningen / faculty of mathematics and natural sciences / centre for isotope research

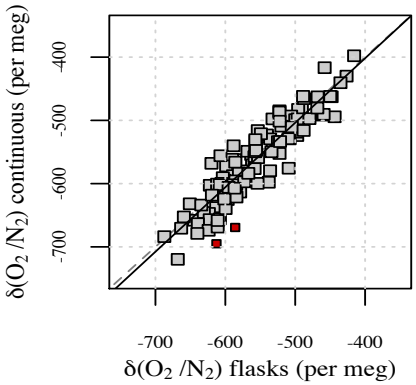
Lutjewad continuous and flasks



university of groningen / faculty of mathematics and natural sciences / centre for isotope research

Lutjewad continuous and flasks APO





flask-continuous comparison

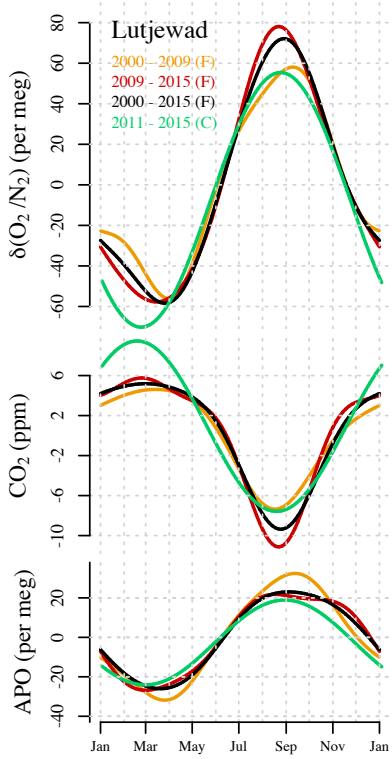
good average agreement, but large scatter:
25 per meg instead of expected ≈ 12 per meg
caused by flask handling ??

university of groningen / faculty of mathematics and natural sciences / centre for isotope research

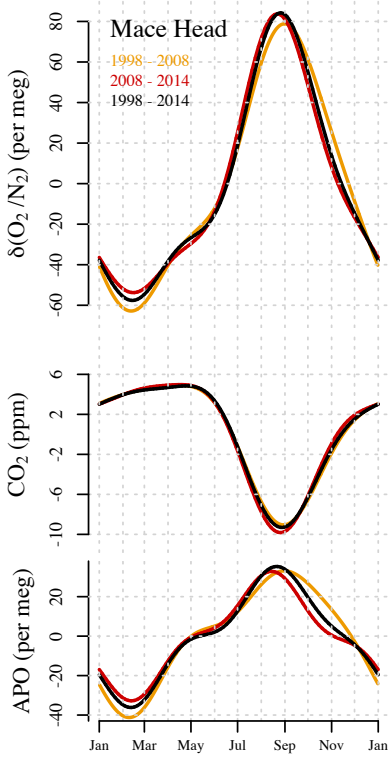
Trend analysis

Location	Time period & reference	Trend		
		CO_2	$\delta O_2/N_2$	APO
Lutjewad (53.24°N 6.21°E)	2000 – 2009 [Flasks – CIO] (van der Laan-Luijkx et al., 2010a)	1.97 ± 0.07	-21.0 ± 0.9	-10.6 ± 0.7
	2009 – 2015 [Flasks – CIO] (this work)	2.94 ± 0.09	-20.8 ± 0.8	-6.4 ± 0.5
	2000 – 2015 [Flasks – CIO] (this work)	2.19 ± 0.03	-20.5 ± 0.3	-9.4 ± 0.2
	2011 – 2014 [Continuous – CIO] (this work)	2.20 ± 0.05	-24.4 ± 0.4	-12.0 ± 0.2
Mace Head (53.20°N 9.54°W)	2000 – 2009 [Flasks – CIO] (van der Laan-Luijkx et al., 2010a)	1.90 ± 0.04	-18.5 ± 0.7	-8.4 ± 0.7
	2009 – 2015 [Flasks – CIO] (this work)	2.41 ± 0.04	-15.3 ± 0.9	-4.7 ± 0.8
	2000 – 2015 [Flasks – CIO] (this work)	2.12 ± 0.01	-21.4 ± 0.3	-10.3 ± 0.2
Weybourne (52.95°N 1.12°E)	*Jan 2009 – April 2012* [Continuous] (Wilson, 2012)	2.41 ± 0.07	-25.3 ± 0.4	-13.4 ± 0.1
F3 (54.51°N 4.44°E)	2006 – 2009 [Flasks – CIO] (van der Laan-Luijkx et al., 2010a)	2.11 ± 0.04	-27.1 ± 0.6	-13.2 ± 0.5
Jungfraujoch (46.33°N 7.59°E)	2007 – 2011 [Flasks – CIO] (van der Laan-Luijkx et al., 2013)	1.94 ± 0.18	-23 ± 3	xxx
	2007 – 2011 [Flasks – MPI] (van der Laan-Luijkx et al., 2013)	1.83 ± 0.17	-17.3 ± 1.5	xxx
	2007 – 2011 [Flasks – Bern] (van der Laan-Luijkx et al., 2013)	1.76 ± 0.17	-29 ± 3	xxx
Fyodorovskoye (56.27°N 32.55°E)	1998 – 2008 [Flasks 100 m– CIO] (van der Laan et al., 2014)	1.98 ± 0.15	-16.1 ± 2.0	-8.5 ± 1.8
Bialystok (53.13°N 23.01°E)	Aug 2005 – Jun 2008 [Continuous] (Popa et al., 2010)	2.0 ± 0.5	-23 ± 3	-12.2 ± 0.9

seasonal cycles



flasks: 3 harmonics
continuous: 1 harmonic



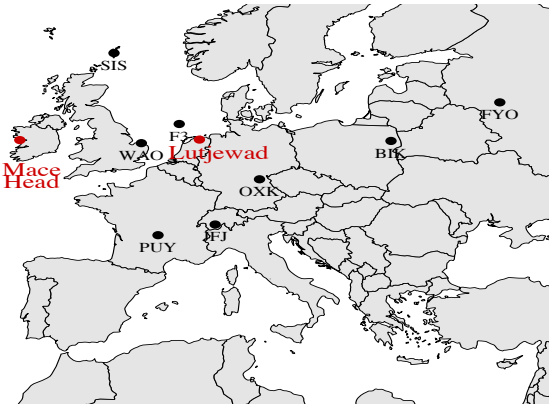
university of groningen / faculty of mathematics and natural sciences / centre for isotope research

seasonal cycle: peak-to-trough amplitudes

Location	Time period & reference	Amplitude		
		CO_2	$\delta O_2/N_2$	APO
Lutjewad (53.24°N 6.21°E)	2000 – 2009 [Flasks – CIO] (van der Laan-Luijkx et al., 2010a)	12.0 ± 0.6	114 ± 8	64 ± 6
	2009 – 2015 [Flasks – CIO] (this work)	16.9 ± 0.8	136 ± 8	49 ± 5
	2000 – 2015 [Flasks – CIO] (this work)	14.5 ± 0.6	130 ± 6	49 ± 5
	2011 – 2014 [Continuous – CIO] (this work)	17.0 ± 0.2	125.6 ± 1.5	43.0 ± 0.8
Mace Head (53.20°N 9.54°W)	2000 – 2009 [Flasks – CIO] (van der Laan-Luijkx et al., 2010a)	14.0 ± 0.3	142 ± 6	74 ± 6
	2009 – 2015 [Flasks – CIO] (this work)	14.8 ± 0.3	137 ± 6	66 ± 5
	2000 – 2015 [Flasks – CIO] (this work)	14.1 ± 0.3	142 ± 5	71 ± 5
Weybourne (52.95°N 1.12°E)	Jan 2009 – April 2012 [Continuous] (Wilson, 2012)	14.9 ± 0.8	134 ± 8	59 ± 6
F3 (54.51°N 4.44°E)	2006 – 2009 [Flasks – CIO] (van der Laan-Luijkx et al., 2010a)	15.2 ± 0.1	144 ± 2	111 ± 2
Jungfraujoch (46.33°N 7.59°E)	2007 – 2011 [Flasks – CIO] (van der Laan-Luijkx et al., 2013)	10.6 ± 0.4	85 ± 4	xxx
	2007 – 2011 [Flasks – MPI] (van der Laan-Luijkx et al., 2013)	10.7 ± 0.3	84 ± 2	xxx
	2007 – 2011 [Flasks – Bern] (van der Laan-Luijkx et al., 2013)	10.3 ± 0.3	69 ± 5	xxx
Fyodorovskoye (56.27°N 32.55°E)	1998 – 2008 [Flasks 100 m– CIO] (van der Laan et al., 2014)	23.2 ± 1.0	131 ± 13	37 ± 8
Bialystok (53.13°N 23.01°E)	Aug 2005 – Jun 2008 [Continuous] (Popa et al., 2010)	25	161	43

matics and / centre for isotope research

Discussion / Conclusions



Valuable time series Lutjewad and Mace Head now 15 years long

We need to bring all European records onto the same scale

North Sea is the best known coastal sea in terms of carbon exchange

Wish list: use Weybourne, Lutjewad and F3 either to verify the North Sea Carbon Balance, or using that balance to track the fossil fuel combustion of the numerous North Sea oil and gas rigs

Data will be made available: *van Leeuwen, C., Scheeren, H.A., van der Laan-Luijkx, I.T., Kers, B.A.M. and Meijer, H.A.J. – Continuous and flask observations of atmospheric $\delta O_2/N_2$ and CO_2 at Lutjewad station, the Netherlands, and Mace Head station, Ireland.*

university of groningen / faculty of mathematics and natural sciences / centre for isotope research