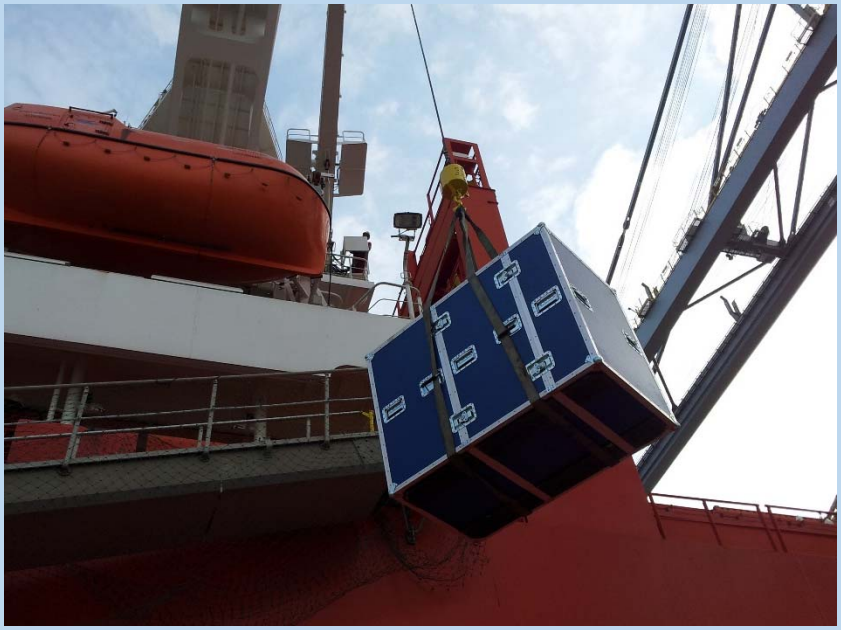
First continuous shipboard measurements of atmospheric $\delta(O_2/N_2)$, CO_2 and APO from meridional Atlantic Ocean transects

Penelope A. Pickers, Andrew C. Manning, Philip A. Wilson, Alex J. Etchells, David Blomfield

Centre for Ocean and Atmospheric Sciences,
School of Environmental Sciences,
University of East Anglia,
Norwich, UK

Outline

- Introduction and motivation
- Measurement system
  - Location
  - Measurement precision
- Preliminary results:
  - Latitudinal variability
  - Seasonal variability
- Next steps



Introduction and motivation

- Continuous atmospheric $\delta(O_2/N_2)$ and CO_2 measurement system deployed on board a Hamburg Süd container ship since **September 2014**.

- Gain better understanding of **Atlantic Ocean carbon cycle** and **O_2 outgassing** due to ocean warming.

- Very **few** on-going continuous shipboard $\delta(O_2/N_2)$ and CO_2 measurements.

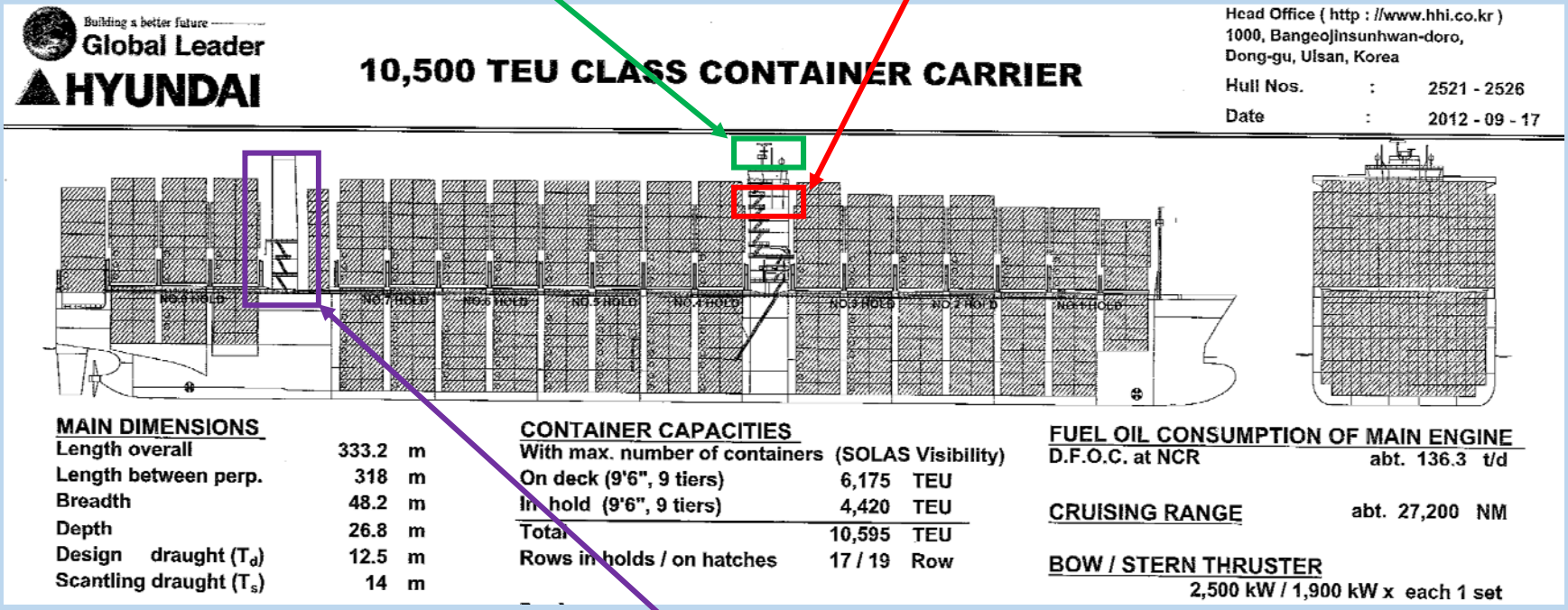
- Ship effectively acts as **9 separate stations** (with data gaps) when data are binned into 10 degree latitude bands.

Latitudinal range: 55°N to 35°S

The Cap San Lorenzo

Aspirated air inlets located on roof of bridge

Measurement system located on G Deck in air conditioned room



Building a better future
Global Leader
HYUNDAI

10,500 TEU CLASS CONTAINER CARRIER

Head Office (http : //www.hhi.co.kr)
1000, Bangeojinsunhwan-doro,
Dong-gu, Ulsan, Korea
Hull Nos. : 2521 - 2526
Date : 2012 - 09 - 17

MAIN DIMENSIONS

Length overall	333.2	m
Length between perp.	318	m
Breadth	48.2	m
Depth	26.8	m
Design draught (T_d)	12.5	m
Scantling draught (T_s)	14	m

CONTAINER CAPACITIES

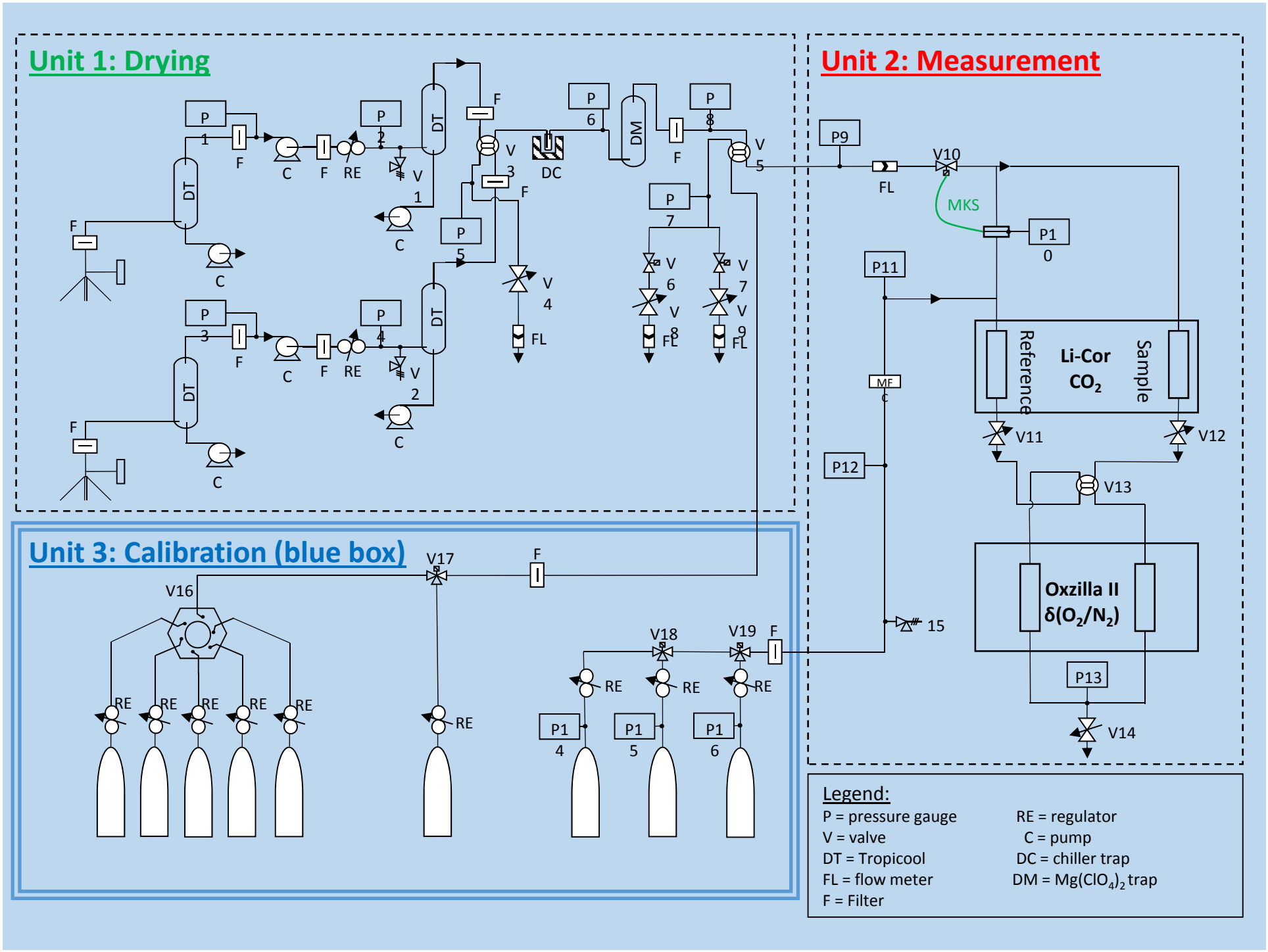
With max. number of containers (SOLAS Visibility)		
On deck (9'6", 9 tiers)	6,175	TEU
In hold (9'6", 9 tiers)	4,420	TEU
Total	10,595	TEU
Rows in holds / on hatches	17 / 19	Row

FUEL OIL CONSUMPTION OF MAIN ENGINE
D.F.O.C. at NCR abt. 136.3 t/d

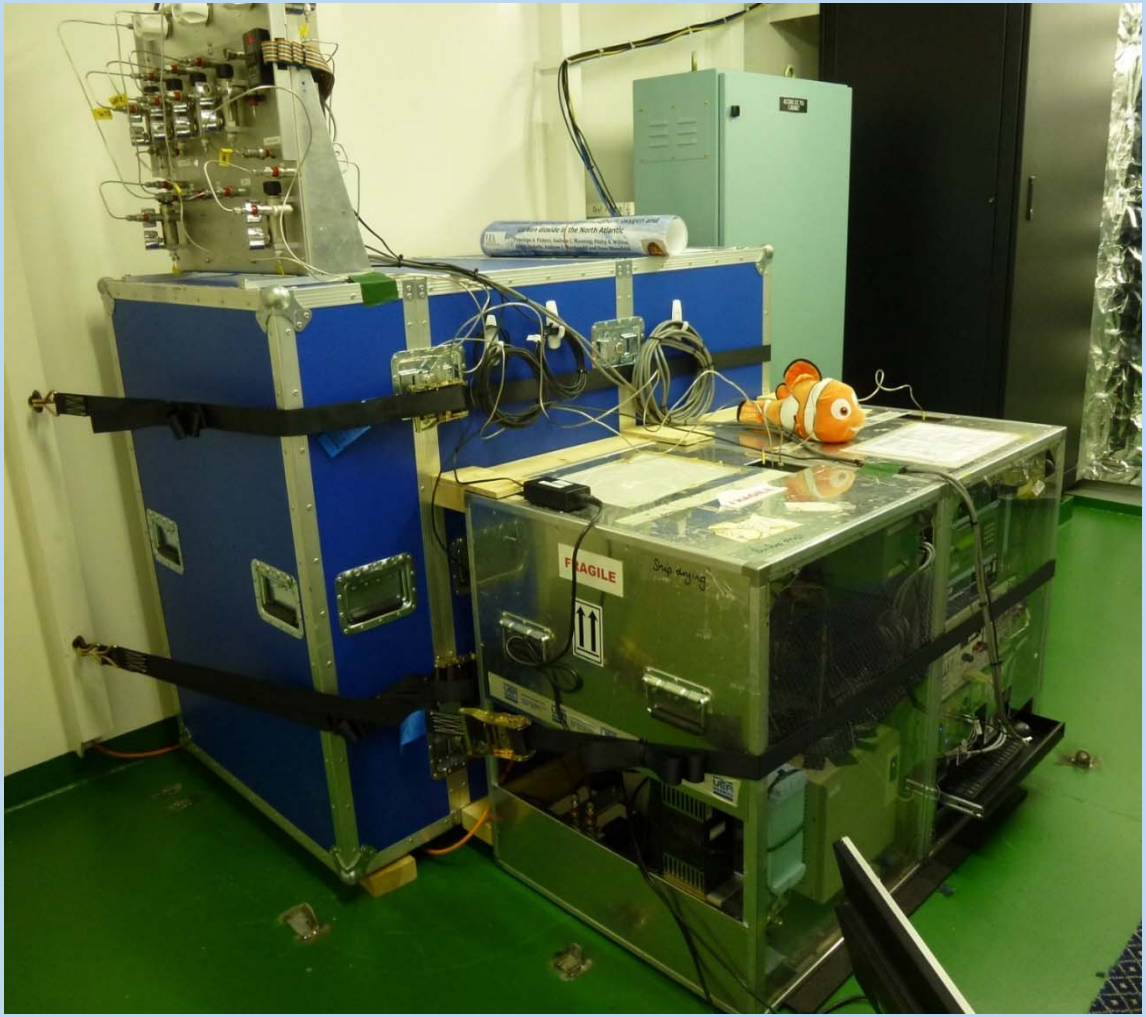
CRUISING RANGE abt. 27,200 NM

BOW / STERN THRUSTER
2,500 kW / 1,900 kW x each 1 set

Ship engine exhaust stack located ~ 150 m from measurement system air inlets


Unit 1: Drying
Unit 2: Measurement
Unit 3: Calibration (blue box)
P1
P2
P3
P4
P5
P6
P7
P8
P9
P10
P11
P12
P13
DT
DM
DC
F
C
RE
V1
V2
V3
V4
V5
V6
V7
V8
V9
V10
V11
V12
V13
V14
V16
V17
V18
V19
FL
MKS
MF
15
Reference
Sample
Li-Cor
CO2
Oxzilla II
δ(O2/N2)
Legend:
P = pressure gauge
V = valve
DT = Tropicool
FL = flow meter
F = Filter
RE = regulator
C = pump
DC = chiller trap
DM = Mg(ClO4)2 trap

Measurement precision



- Target Tank (~12 minutes): **± 0.009 ppm CO_2** and **± 3.13 per meg δ(O_2/N_2)**

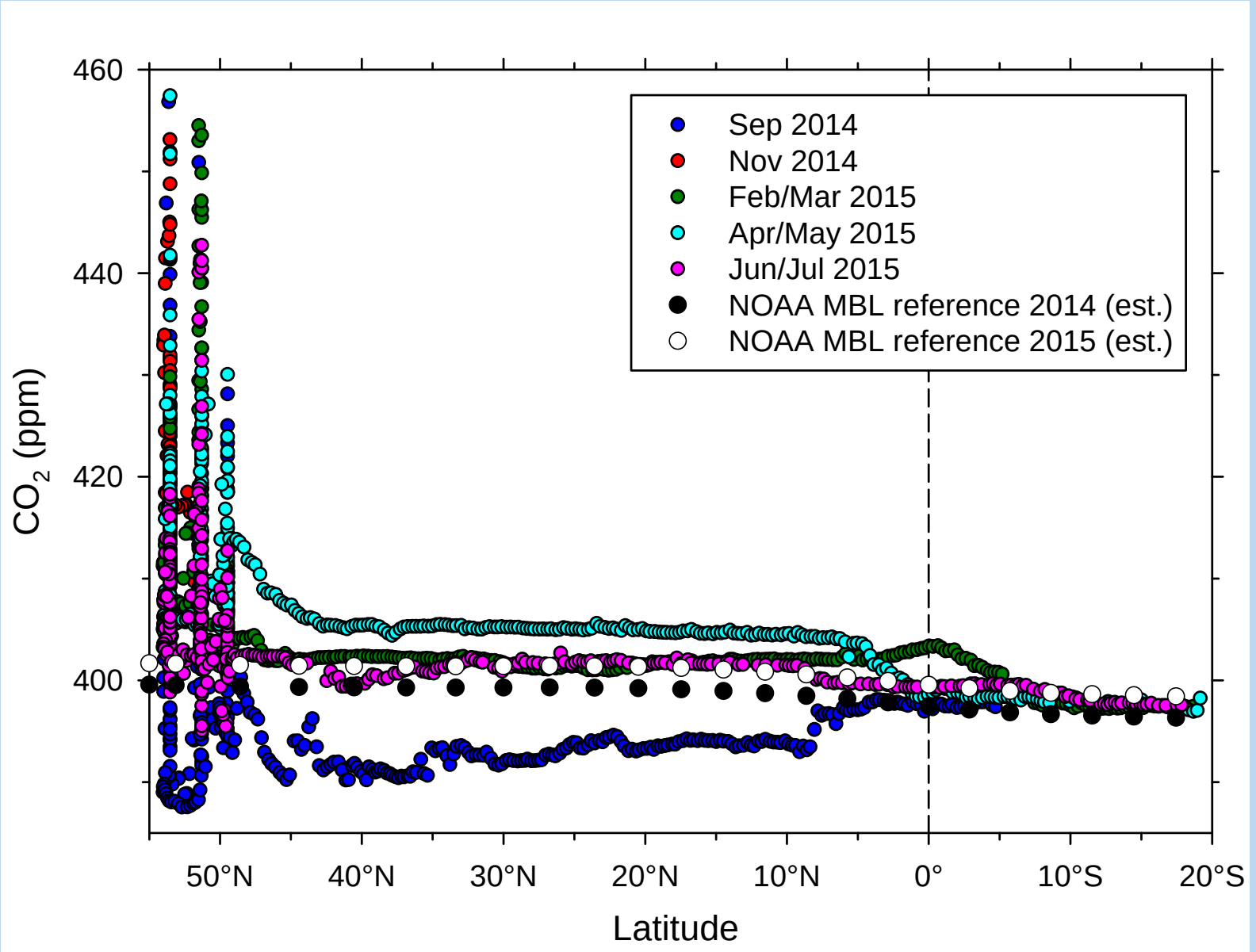
- Sample air data (1 minute): **± 0.092 ppm CO_2** and **± 8.62 per meg δ(O_2/N_2)**

No data from Nov 2014 – mid Feb 2015 due to electronics failure.

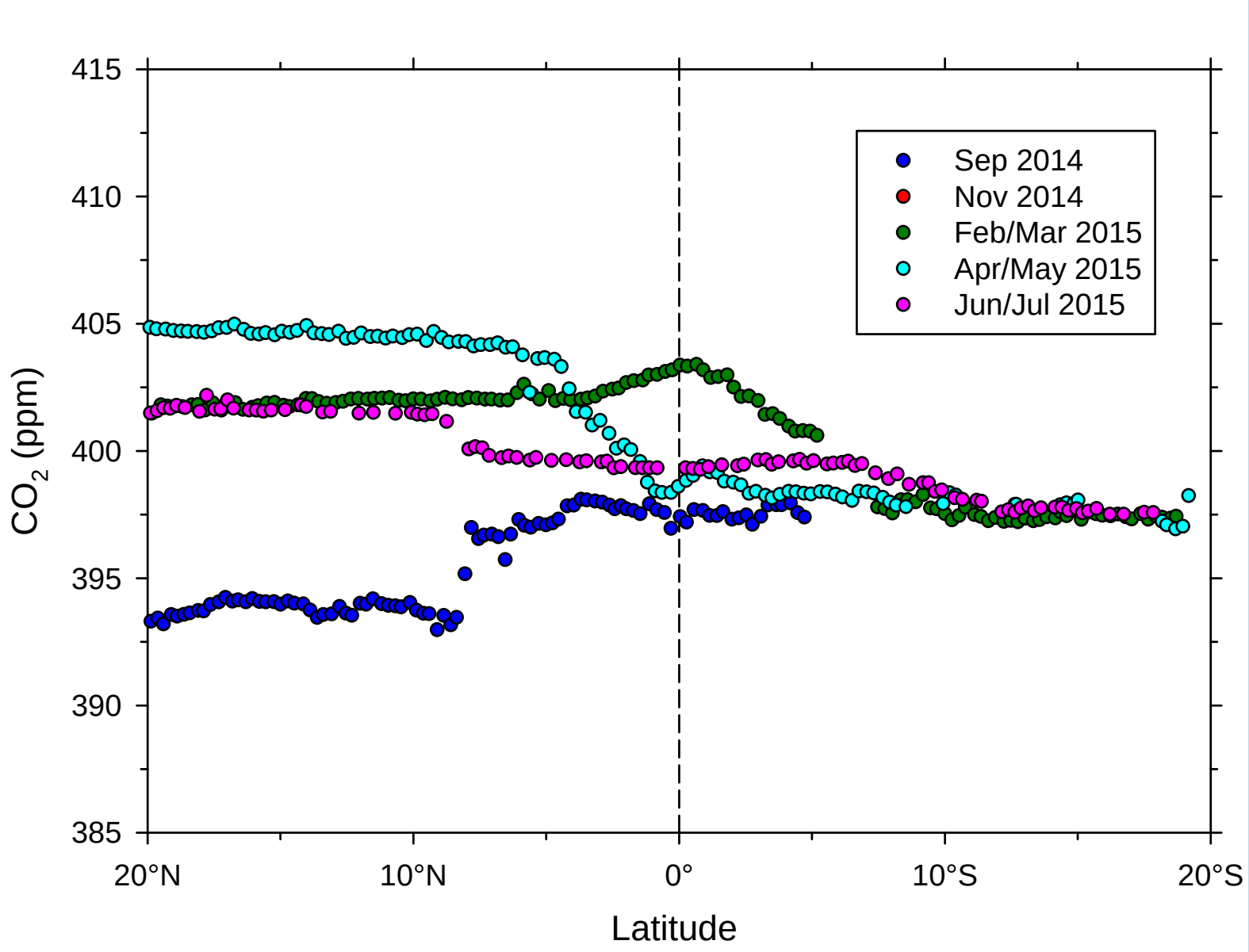
Container ship Cap San Lorenzo ran aground in North Sea !

The Cap San Lorenzo vessel was sailing from Antwerp en route to Le Havre when it ran aground on April 23rd, at approximately 7 kilometers off the Zeebrugge coast in position 51 24N 003 09E. There were 29 crew members aboard the ship at the time when the accident occurred.

Preliminary results: latitudinal variability



Preliminary results: latitudinal variability



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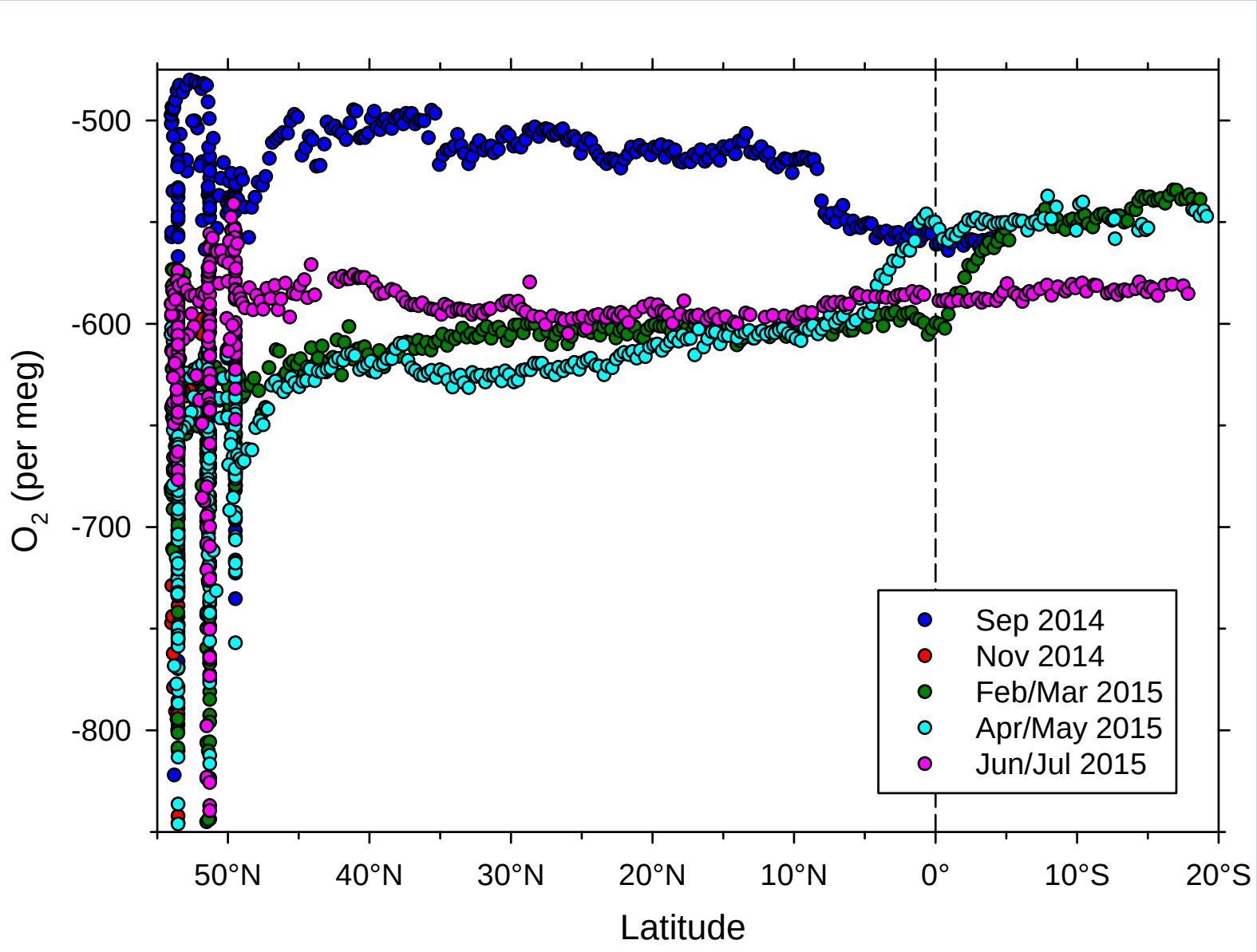

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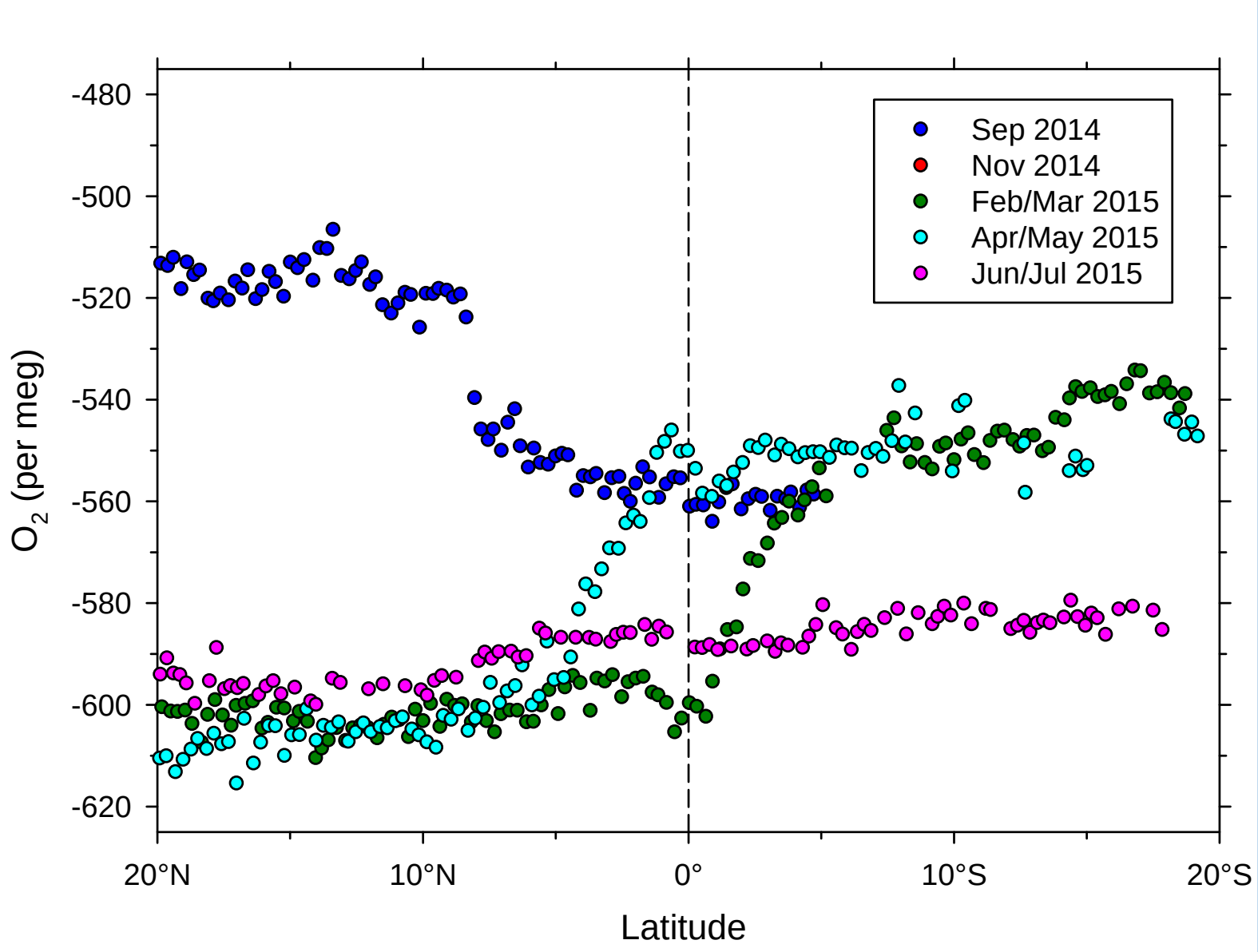

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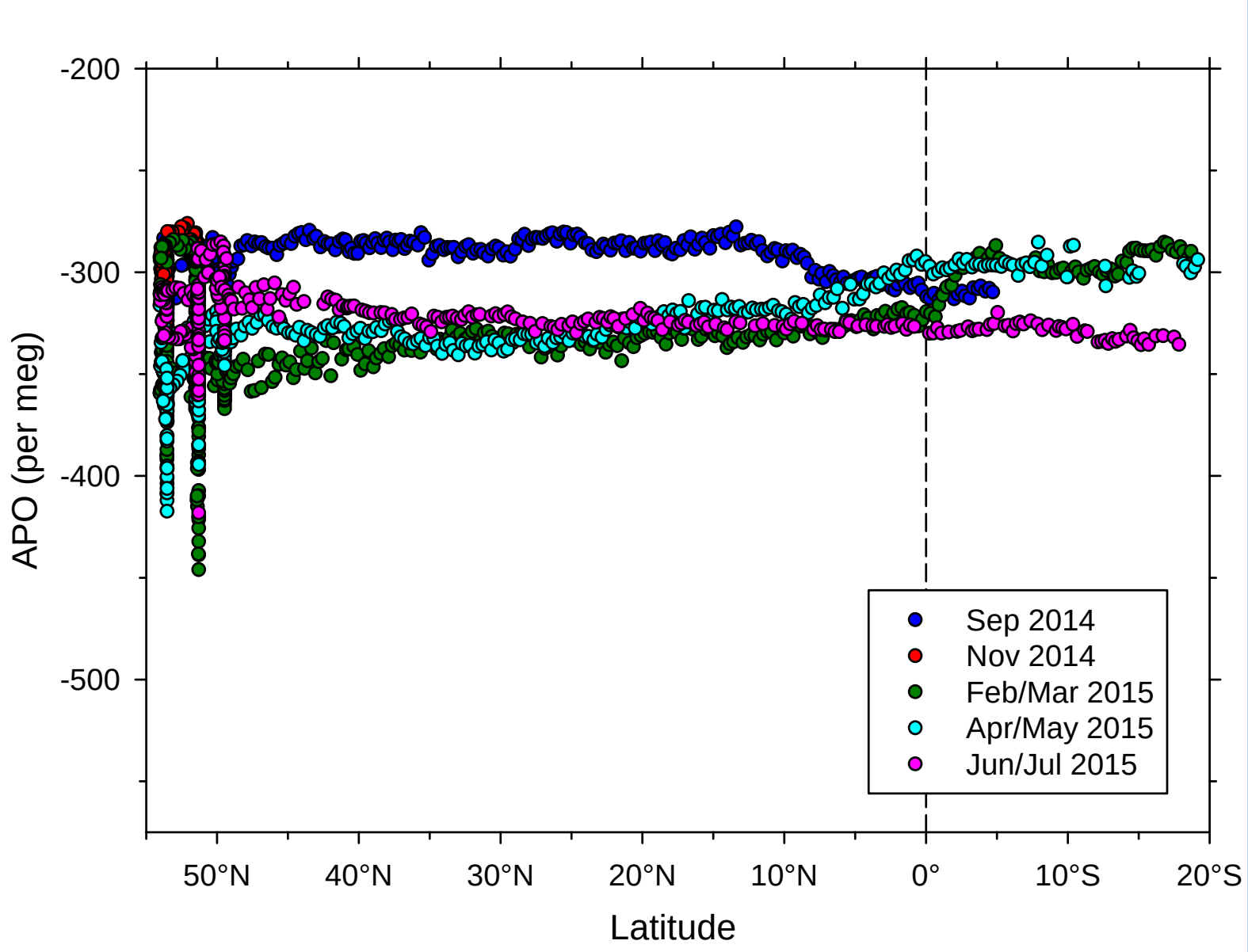

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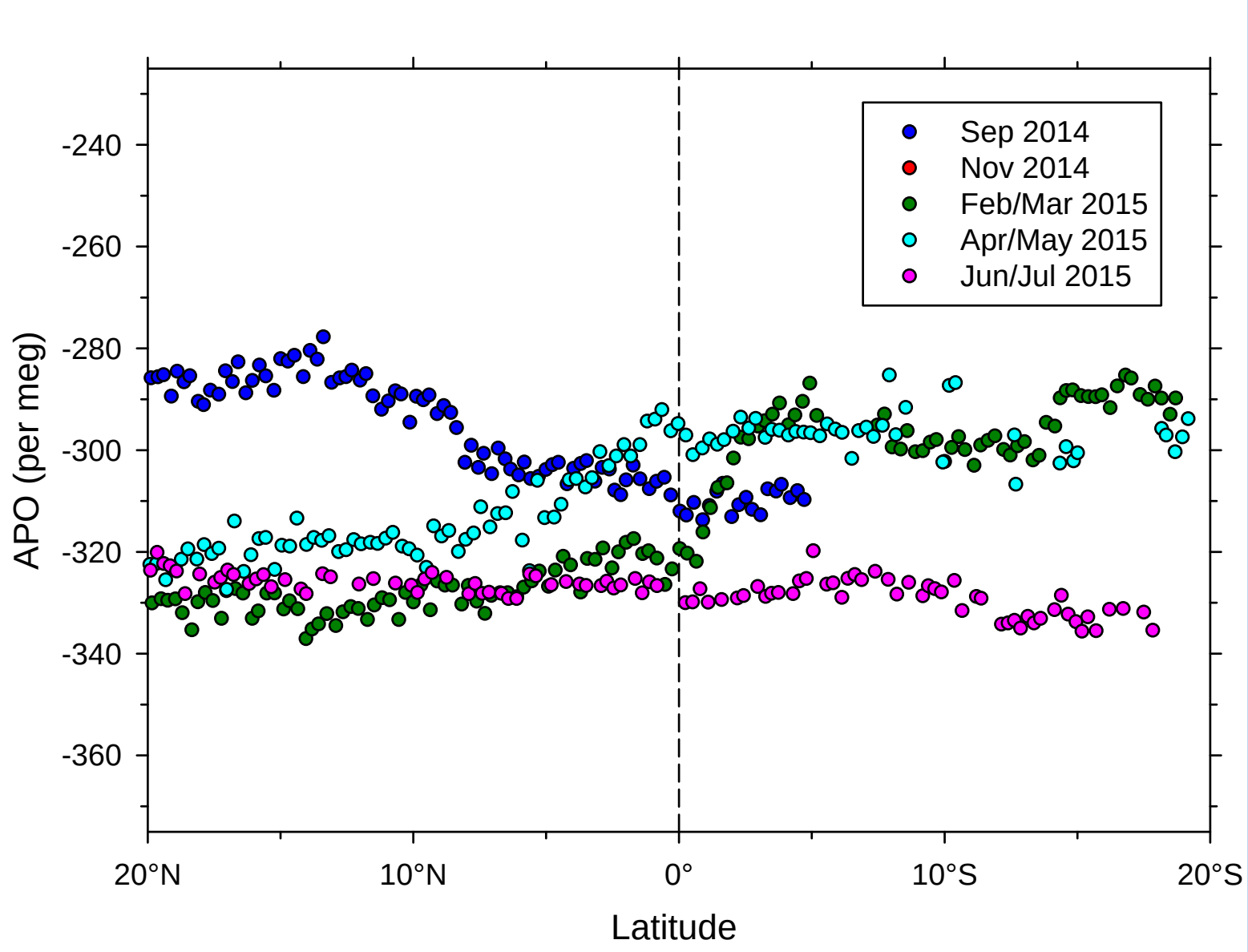
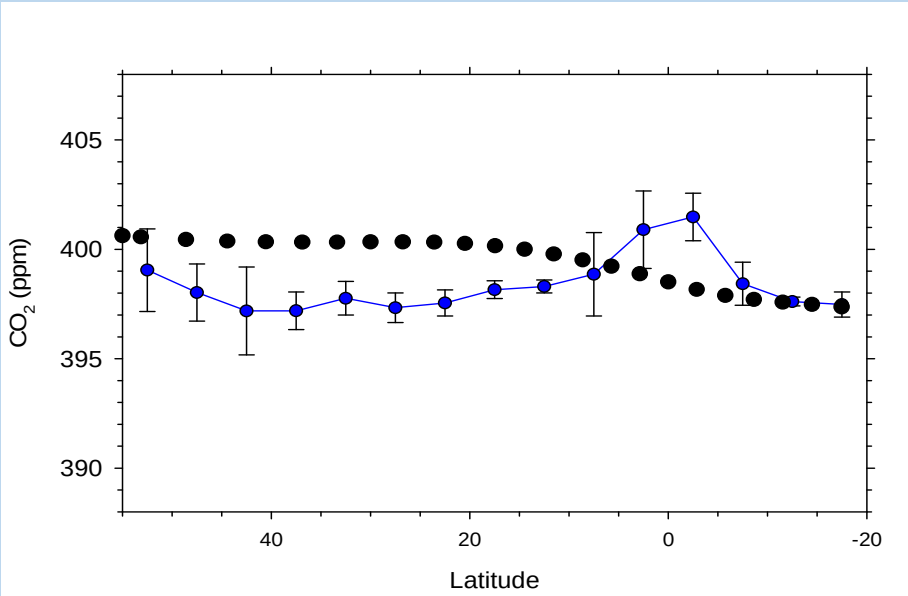
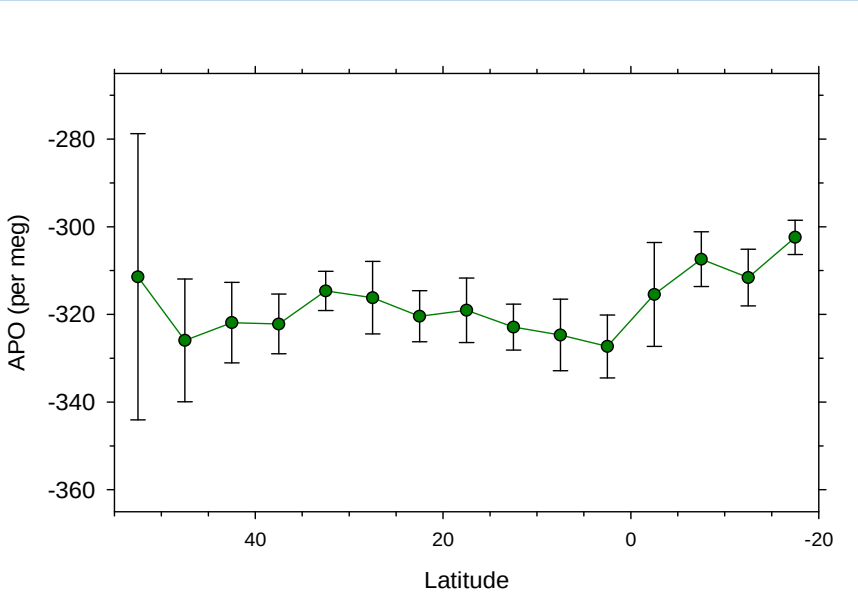
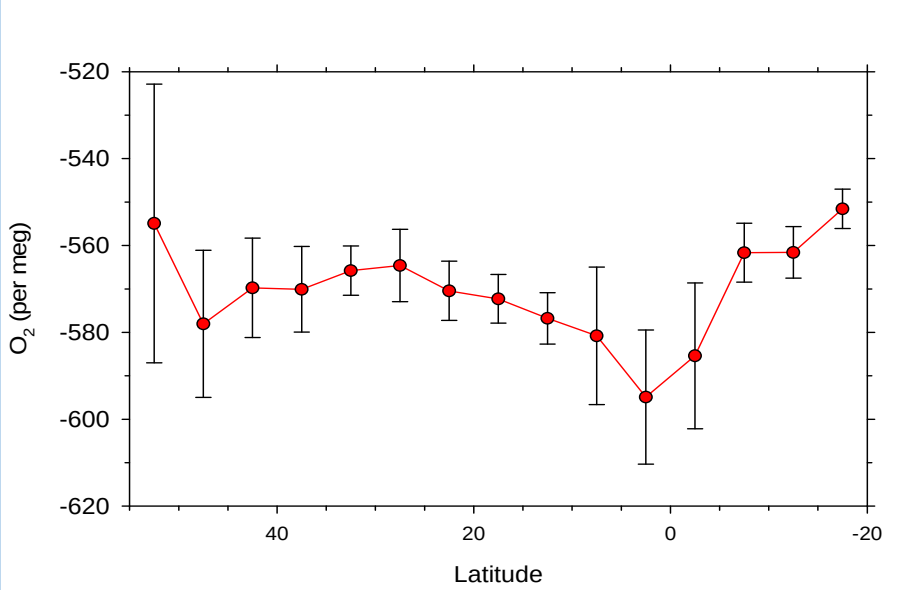
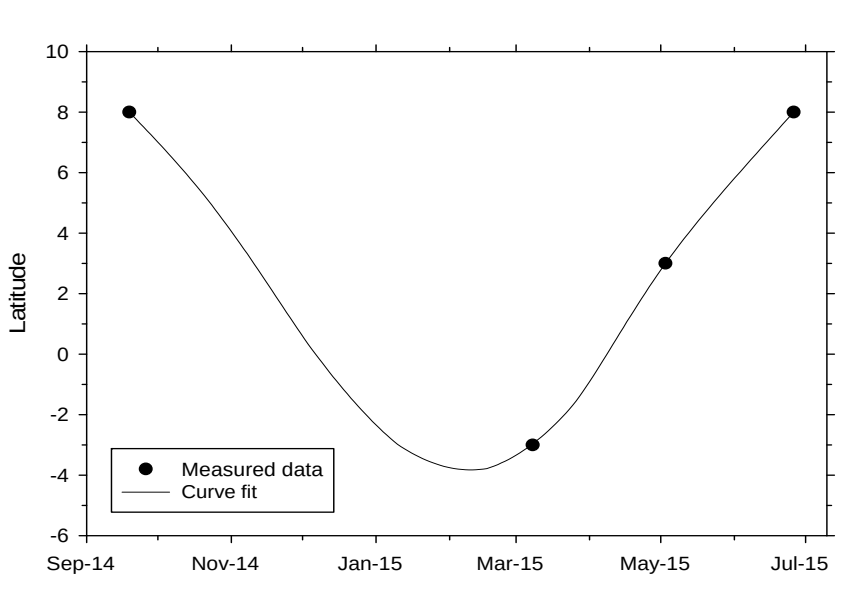


Preliminary results: annual mean latitudinal variability & ITCZ migration

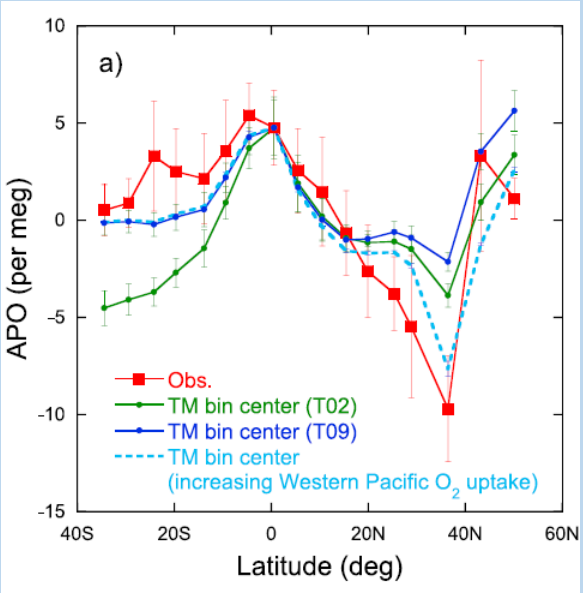




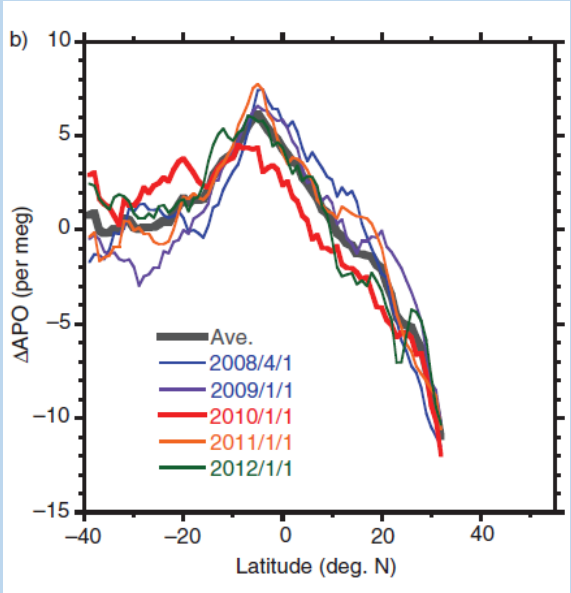




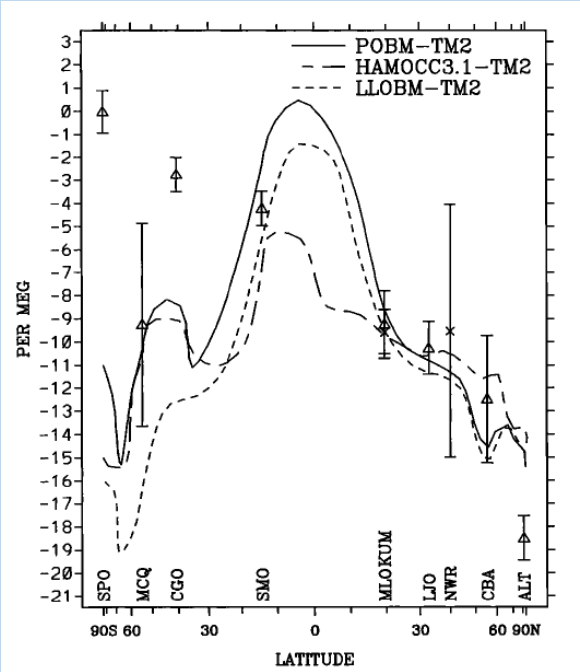
Comparison of Atlantic and Pacific latitudinal variability



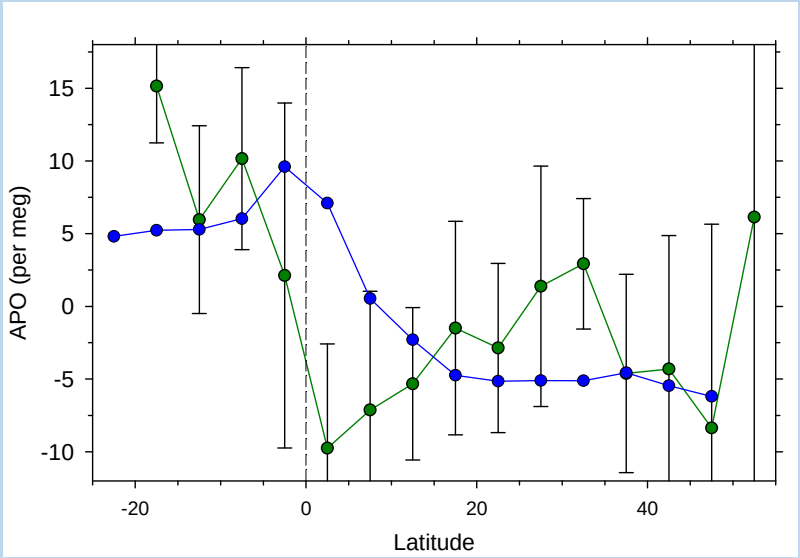
Tohjima et al. 2012 (flasks)



Tohjima et al. 2015 (cont.)

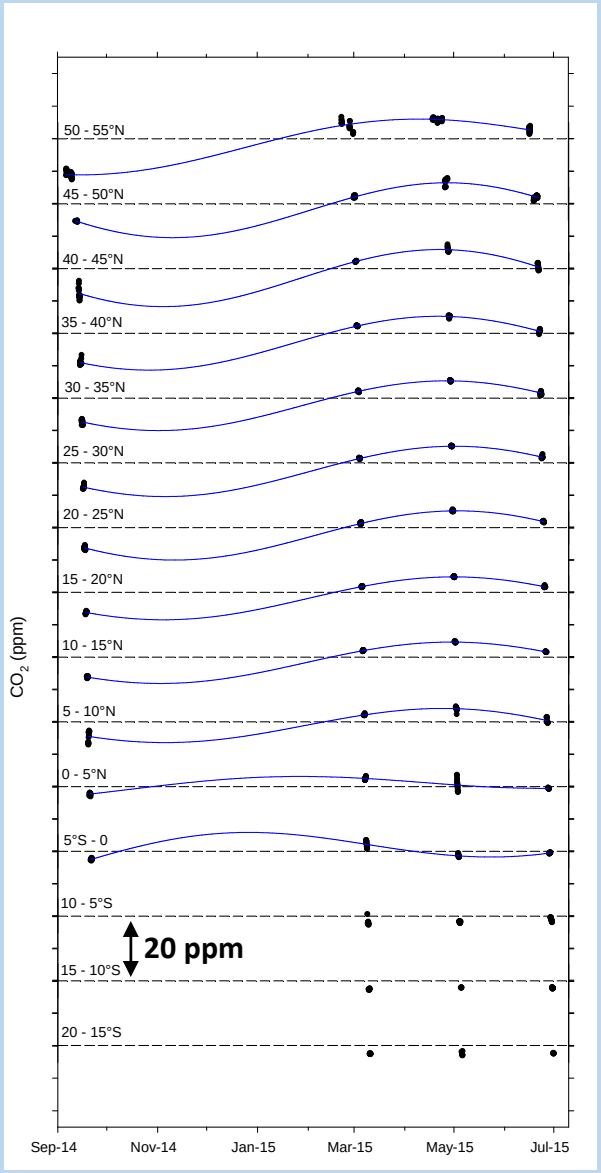


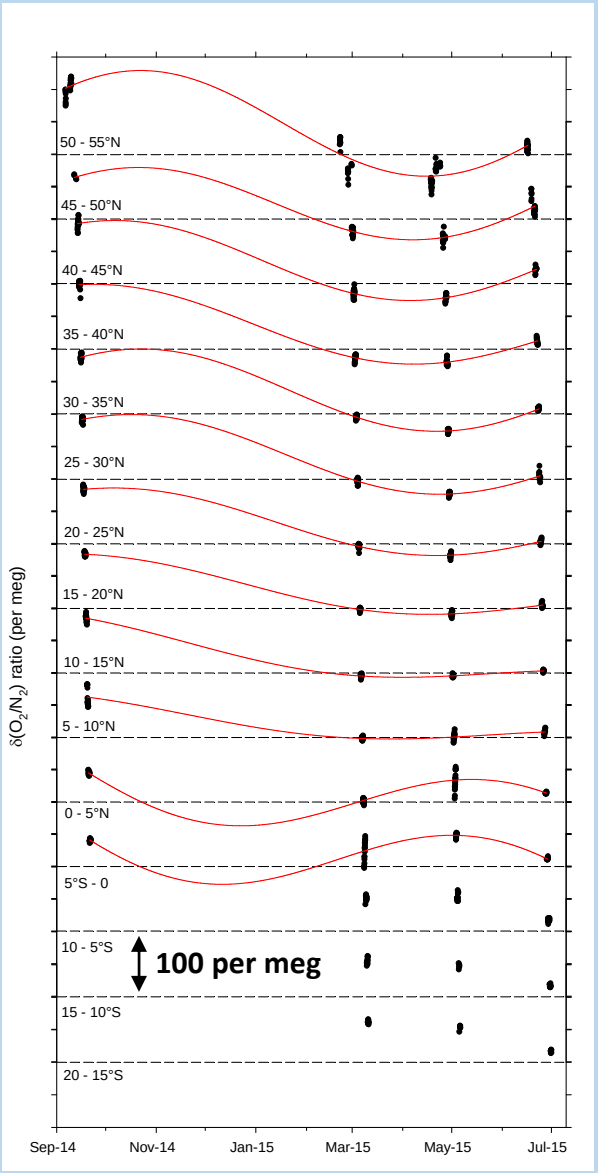
Stephens et al. 1998 (flasks)

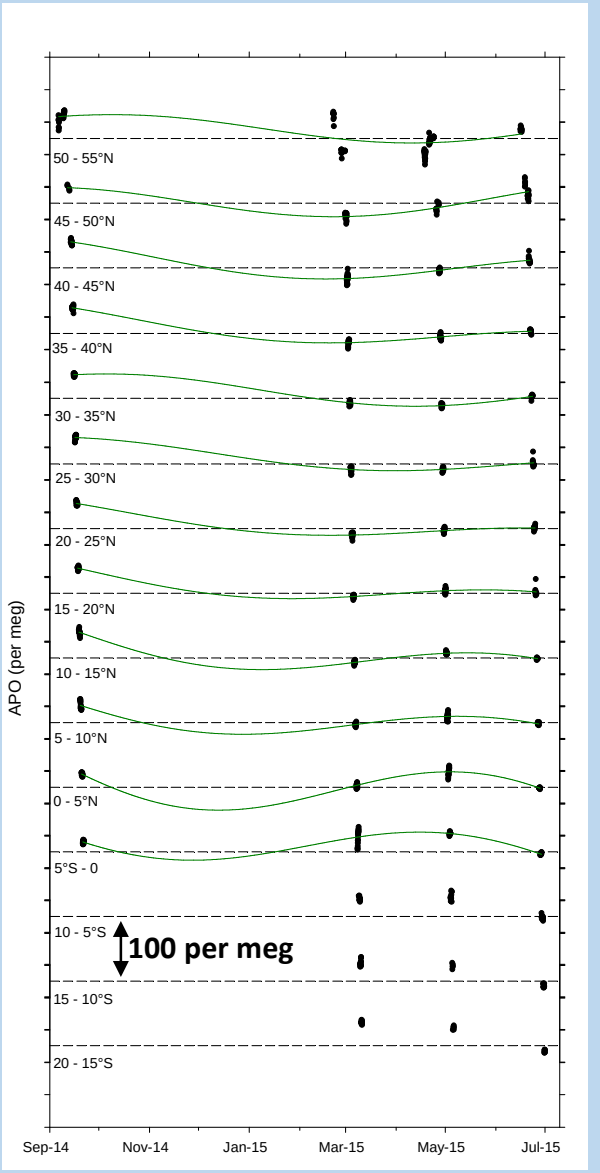


Green – measured APO
Blue – Garcia and Keeling/ocean inversion/Takahashi 2009 + TM3 transport modelled APO (from Sara Mikaloff-Fletcher)

Preliminary results: seasonal variability







Seasonal amplitude comparisons

Station	Location	Height (m)	Period	CO_2 (ppm)	O_2 (per meg)	APO (per meg)
Weybourne	52.95°N 1.12°E	10	2009-2014	15.2 ± 0.2	127.2 ± 1.8	50.2 ± 1.5
Mace Head (Alison Craggs, Masters thesis)	53.33°N 9.9°E	25	2014-2015	17.8 ± 2.25	149.0 ± 10.1	76.6 ± 6.97
Lutjewad (Van der Laan-Luijkx et al. 2010)	53.39°N 6.35°E	60	2000-2009	12.0	114	64
HAM ship	**~ 52.5°N**	**~ 35**	**2014-2015**	**17.1**	**162.5**	**44.5**
Sendai (Ishidoya et al. 2012)	38°N 140°E	150	1999-2012	13.9 ± 2.5	128 ± 22	52 ± 10
HAM ship	**~ 37.5°N**	**~ 35**	**2014-2015**	**16.5**	**122.6**	**53.9**
Pacific ship (Tohjima et al. 2005)	~ 15°N	18	2001-onwards	5.5	~ 50	~ 30
HAM ship	**~ 12.5°N**	**~ 35**	**2014-2015**	**12.7**	**90.9**	**57.5**
Namibia (Eric Morgan)	23.6°S 15.0°E	21	2012-2014	2.4	61.0	49.7
HAM ship	**~ 22.5°S**	**~ 35**	**2014-2015**	**~ 5**	**~ 100**	**~ 100**

Next steps

- Use UK Met Office NAME Lagrangian atmospheric transport model and NEMO-PlankTOM fluxes to look into short-term variability.
- Inter-annual analyses as more data become available.
- Compare latitudinal CO_2/O_2/APO gradients in the Atlantic Ocean sector to modelled latitudinal gradients.
- Interested in bringing Cap San Lorenzo data together with other shipboard data, with assistance from the modelling community.