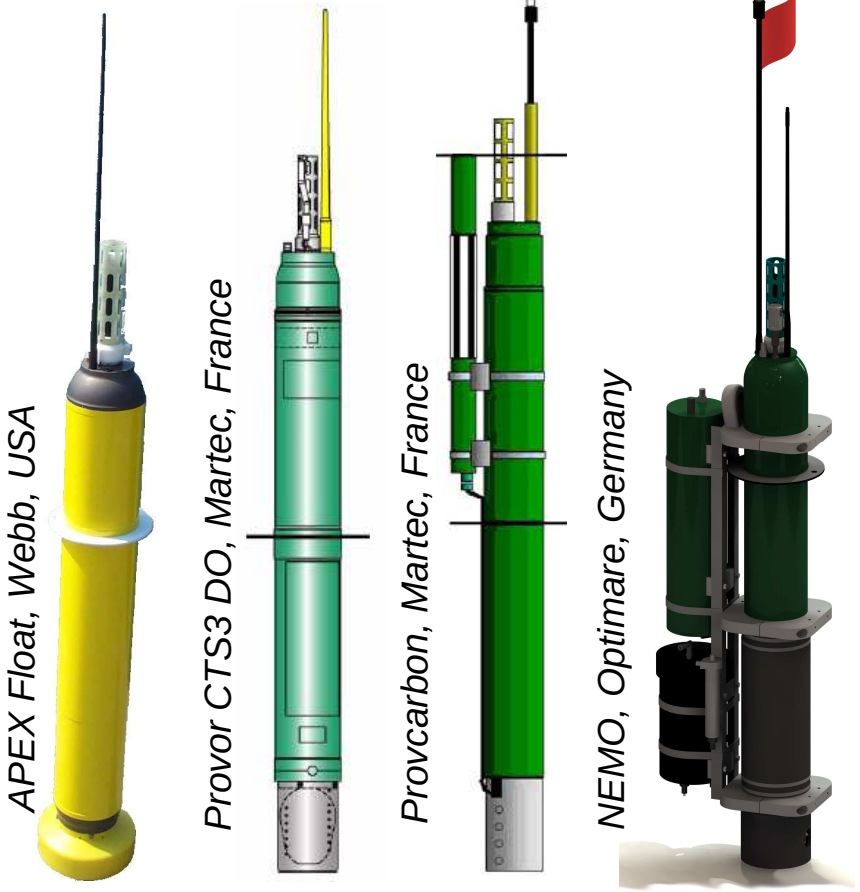
Kiel Oxygen Projects

Aanderaa oxygen optode
(models 3830 & 3835)

FLOATS



APEX Float, Webb, USA

Provor CTS3 DO, Martec, France

Provcarbon, Martec, France

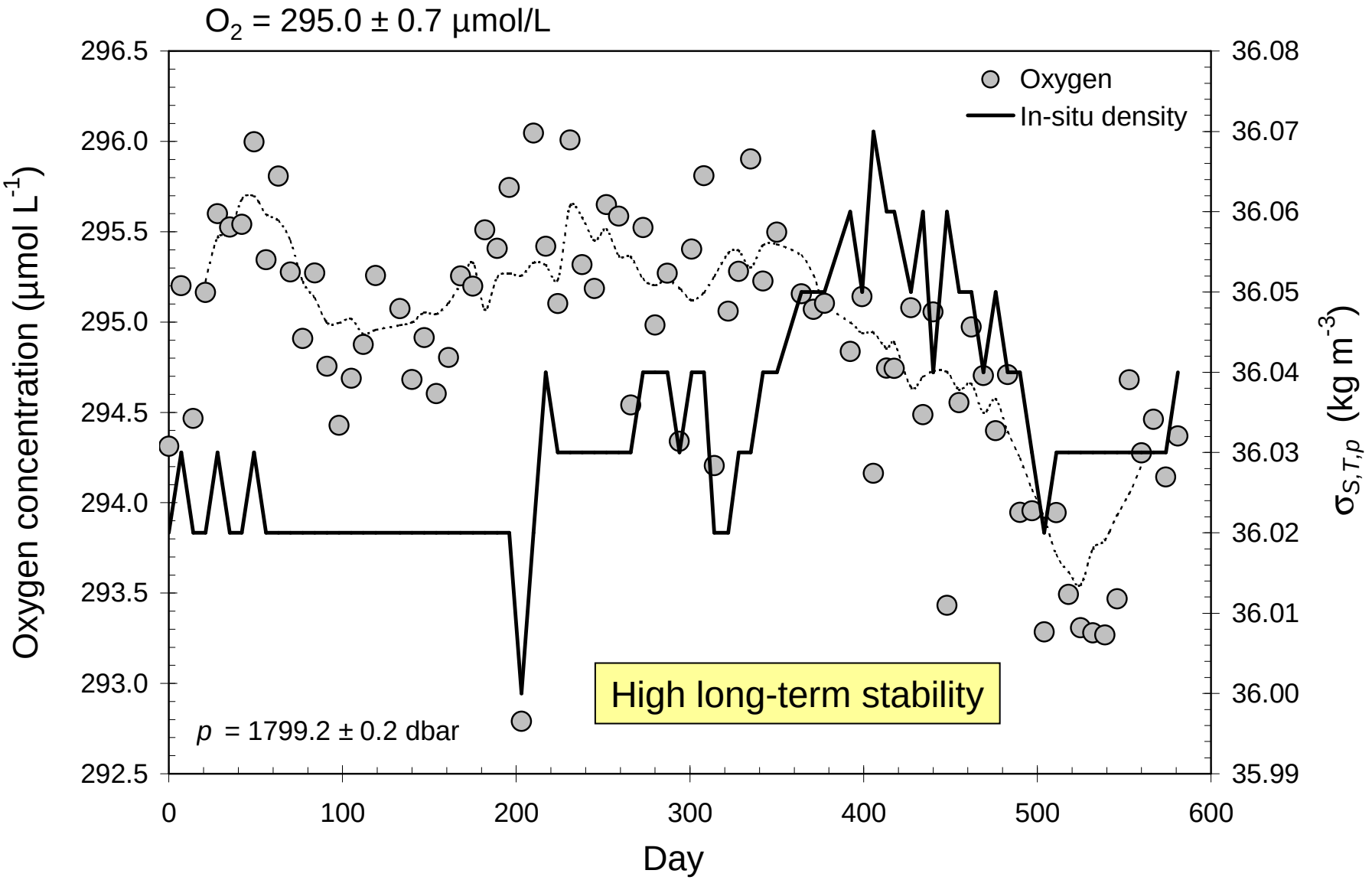
NEMO, Optimare, Germany

GLIDERS

Custom-made optode logger
(also suitable for Pirata moorings)

MOORINGS

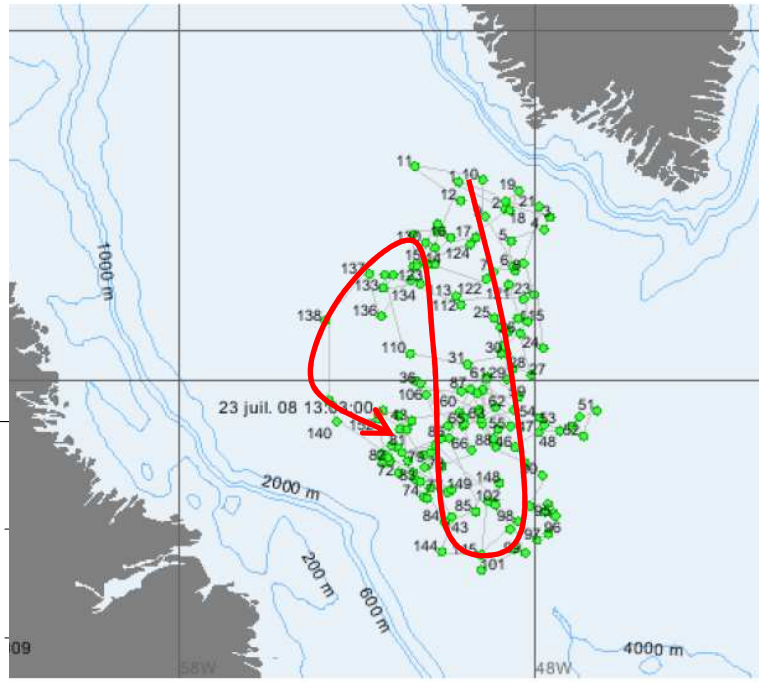
Oxygen optode: Long-term stability

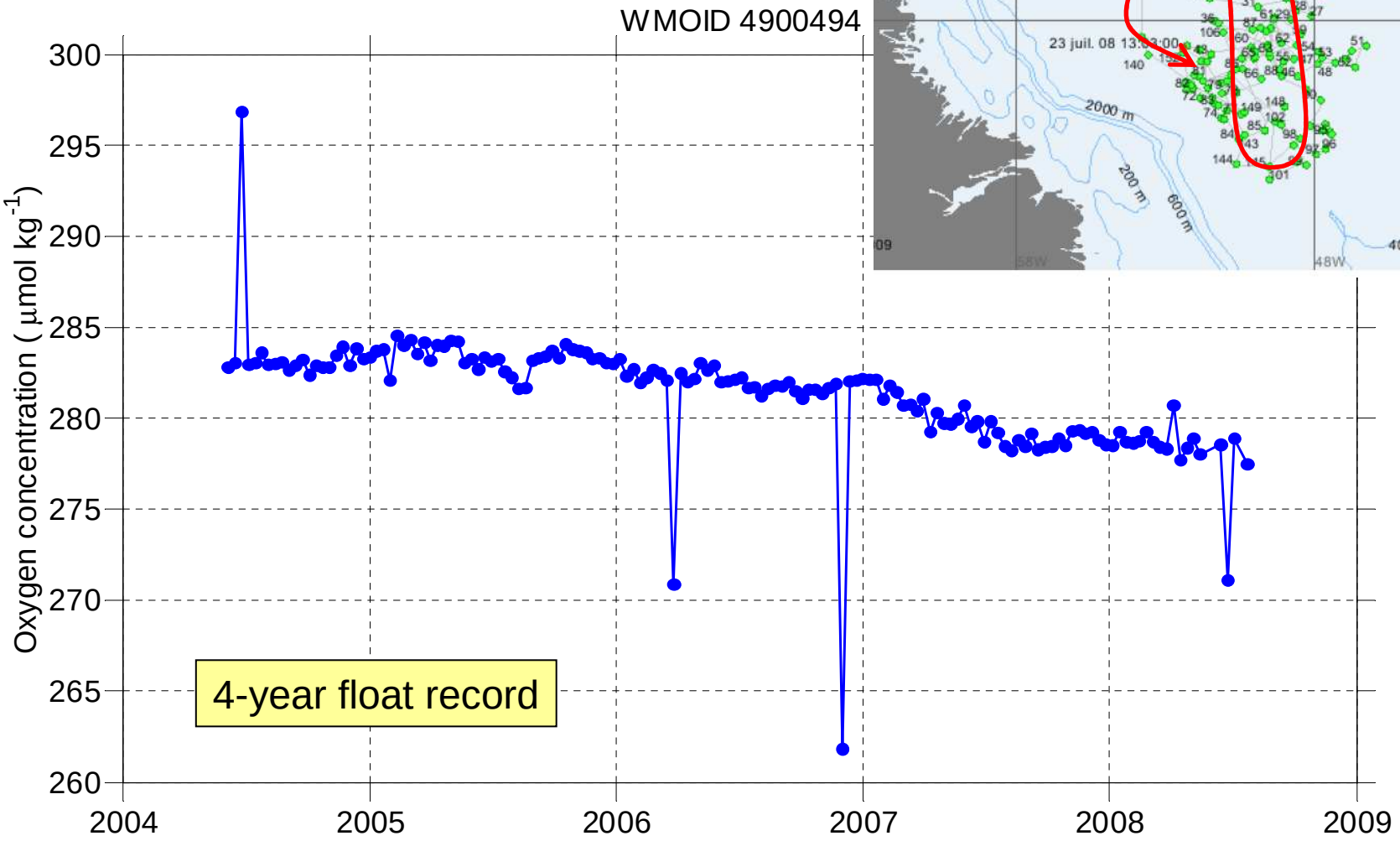


Tengberg, Körtzinger *et al*. (2006). Evaluation of a life time based optode to measure oxygen in aquatic systems. *Limnol. Oceanogr. Methods* **4**, 7-17.

Oxygen at 1900 m, float #4900494

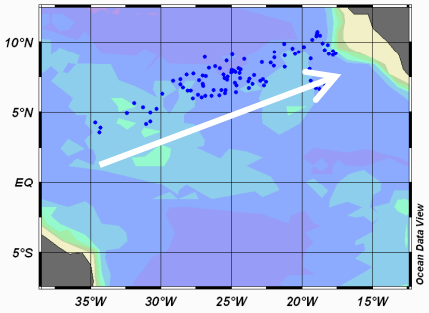
Denis Gilbert et al., Argo Science Workshop 3, Hangzhou, China, March 27, 2009

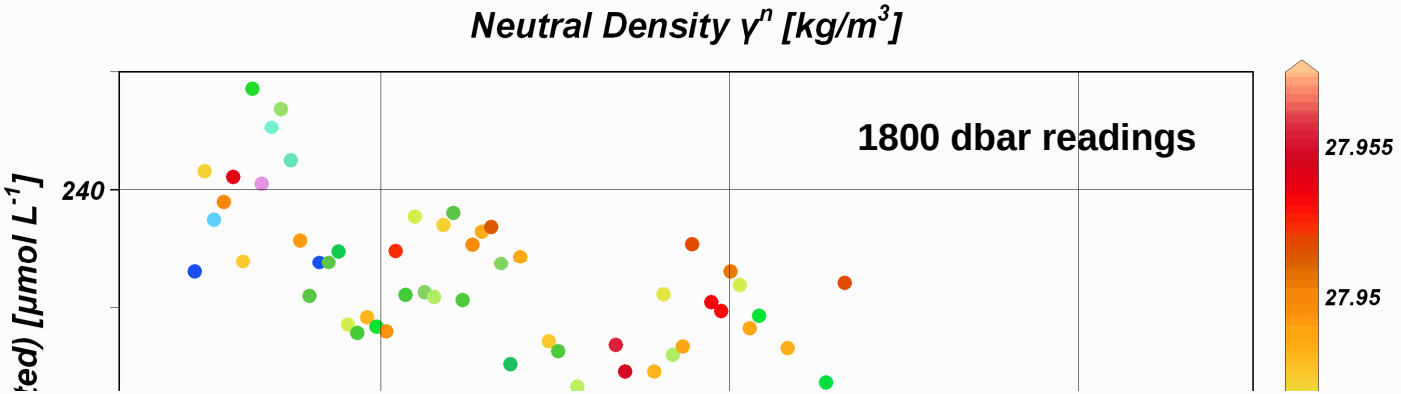




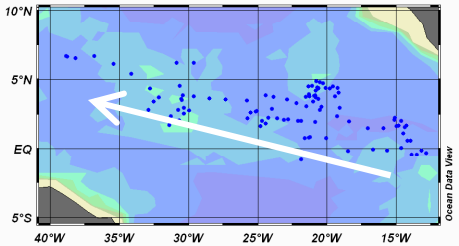
Oxygen optode: Long-term stability

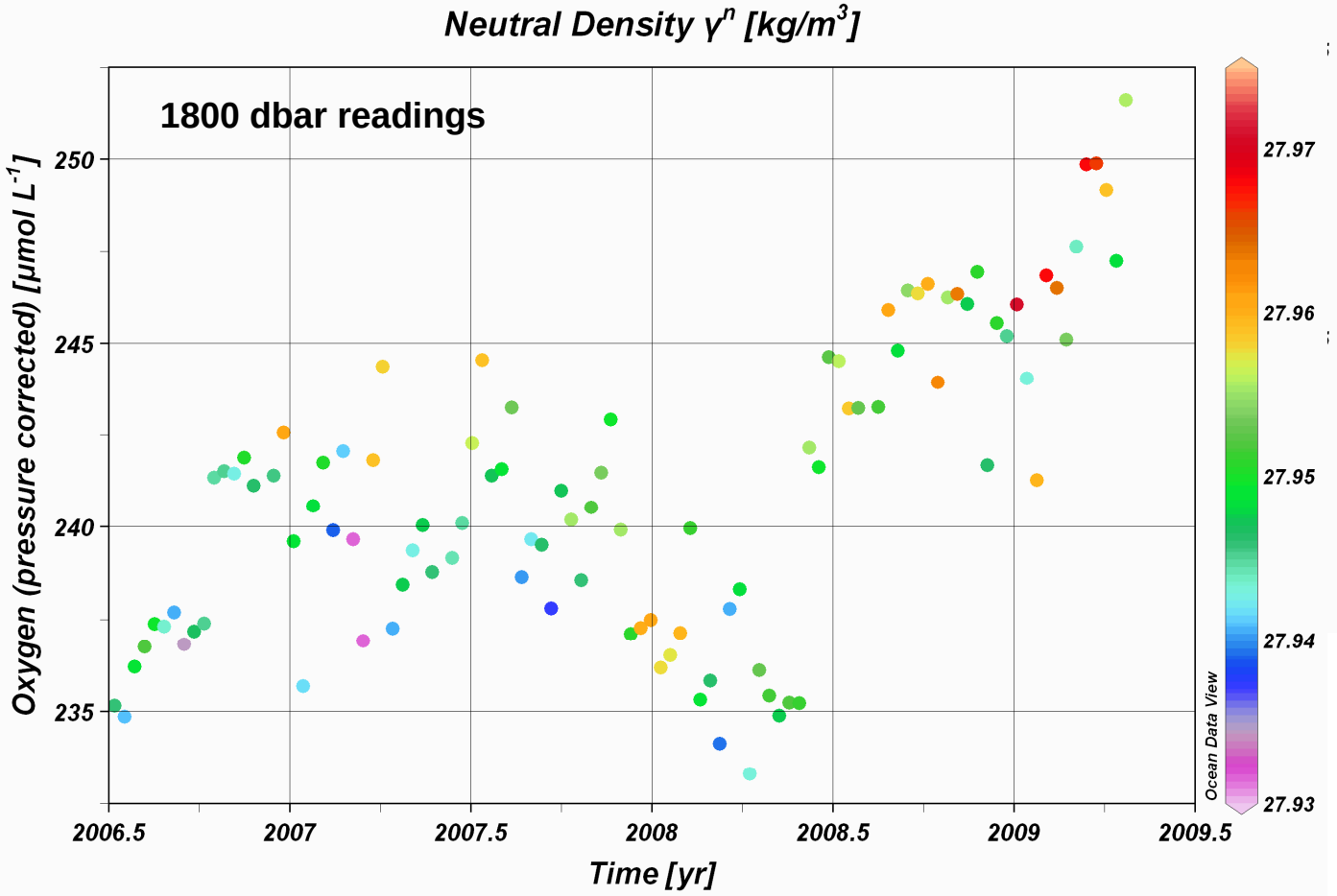
Float #1900650





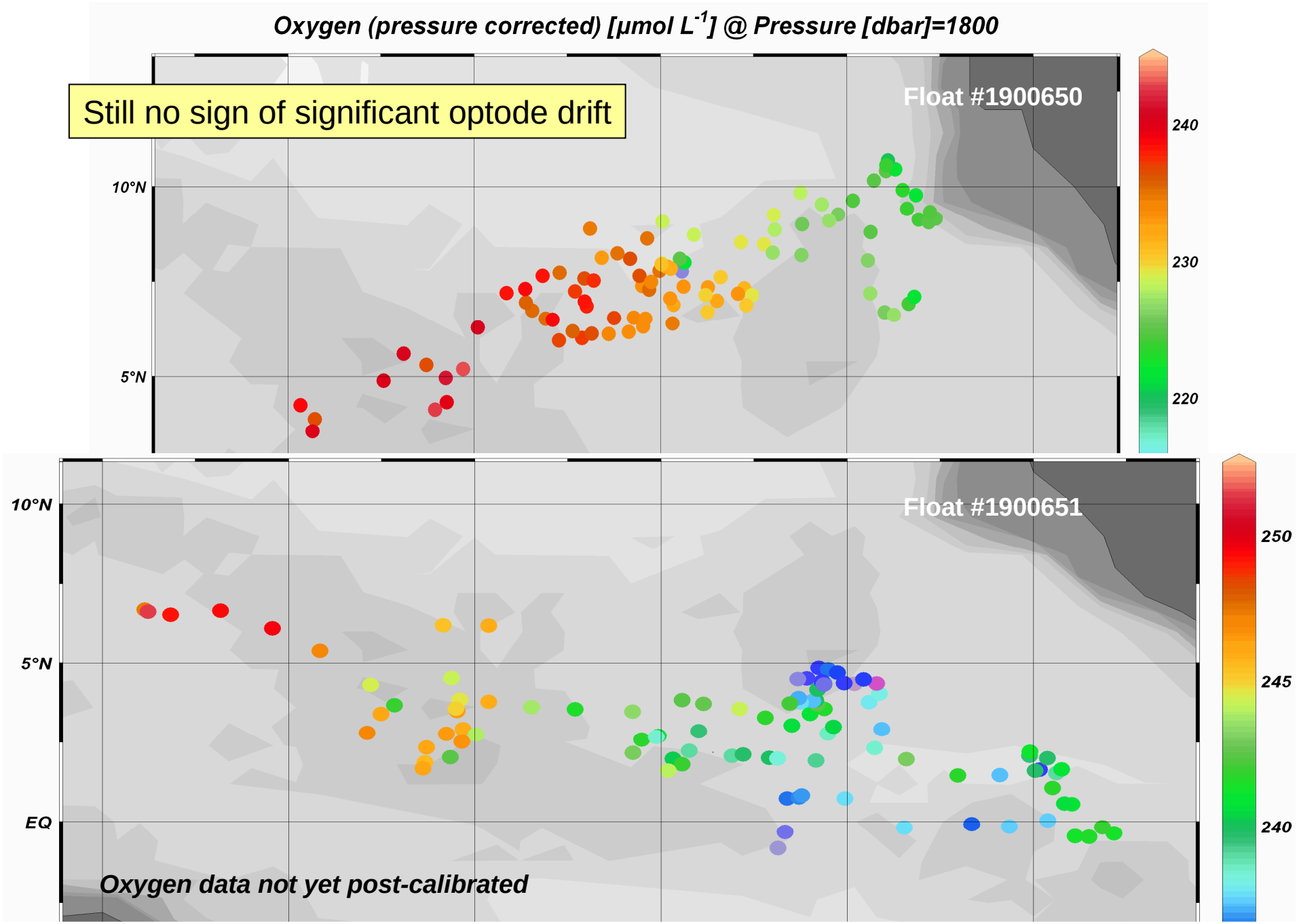
Float #1900651



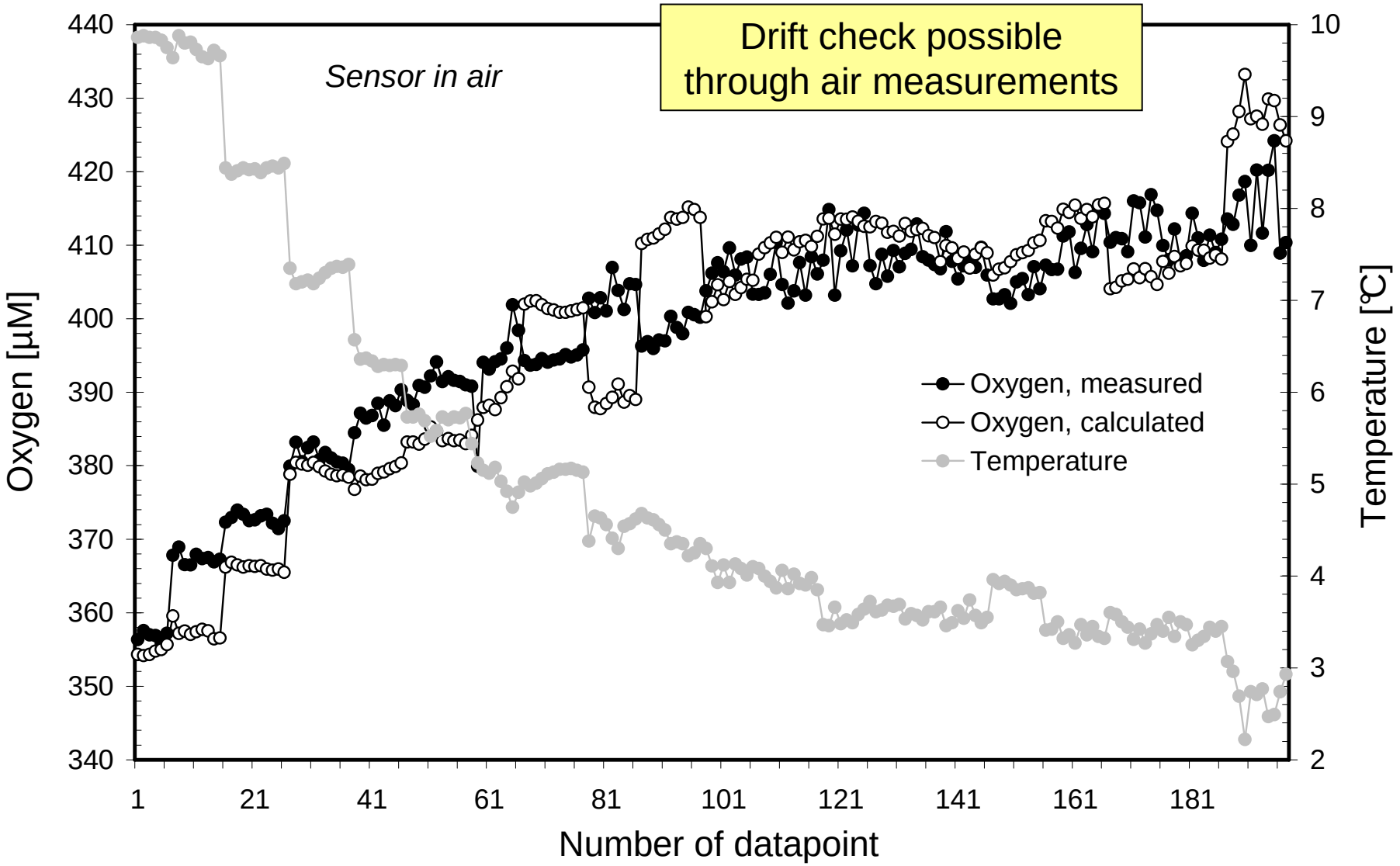


APEX-O_2 Floats

Oxygen optode: Long-term stability



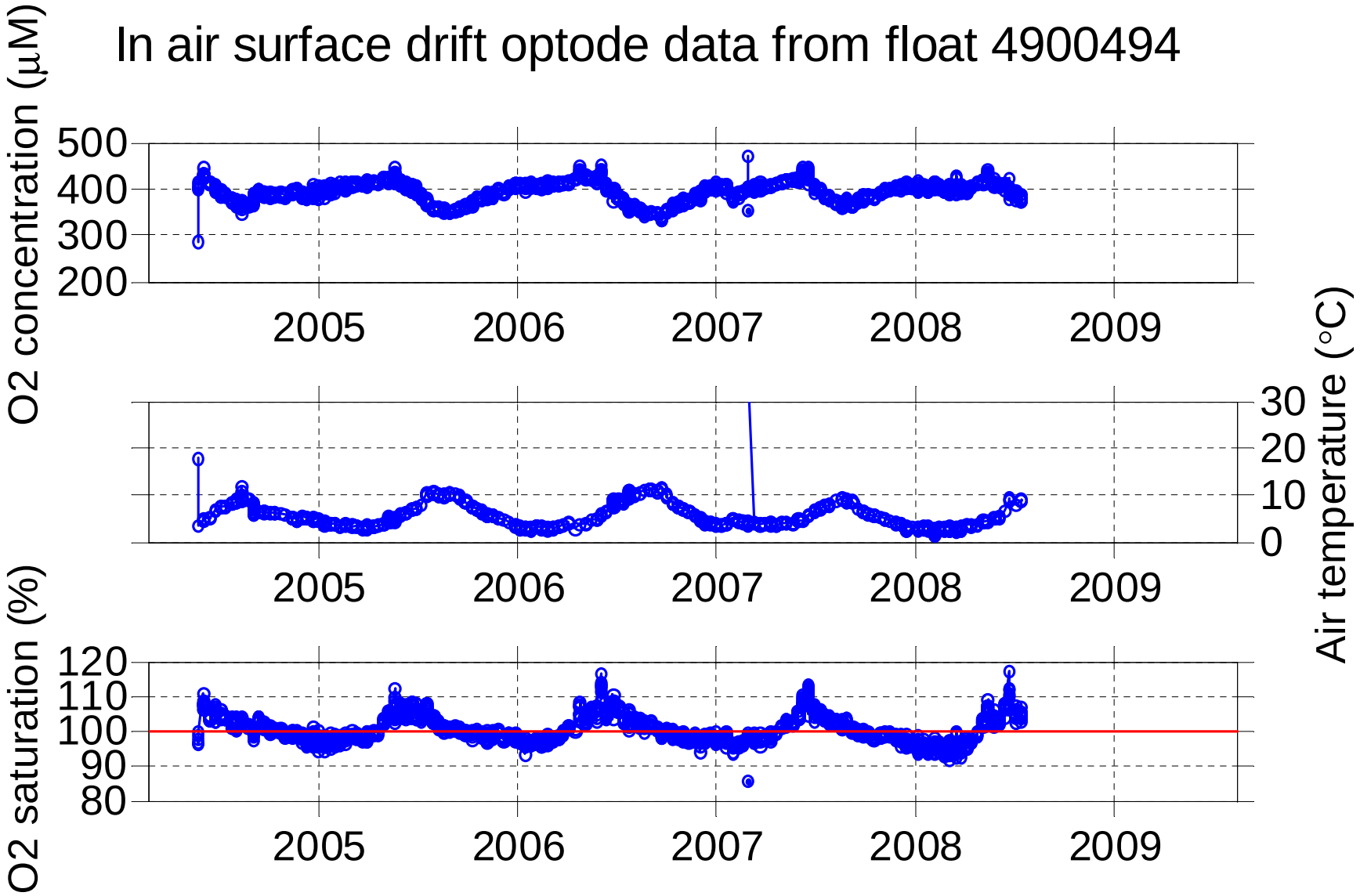
Oxygen optode: Atmospheric measurements as drift check



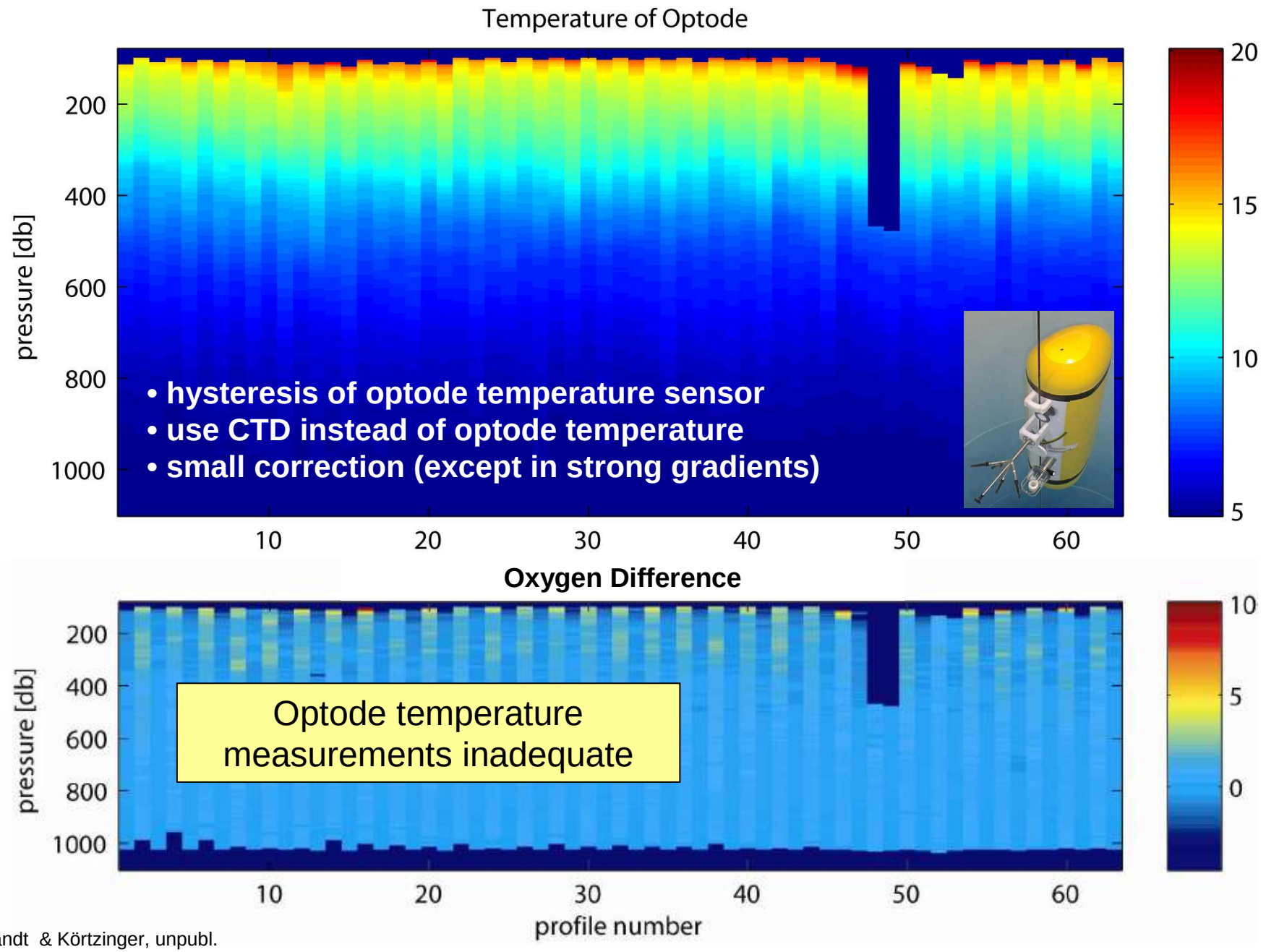
Körtzinger et al. (2005). High-quality oxygen measurements from profiling floats: A promising new technique. *J. Atm. Ocean. Techn.* **22**, 302-308.

Denis Gilbert et al., Argo Science Workshop 3, Hangzhou, China, March 27, 2009

Need better characterization of optode measurements in air



Oxygen optode: Results from moored profiler (McLane MMP)



Brandt & Körtzinger, unpubl.

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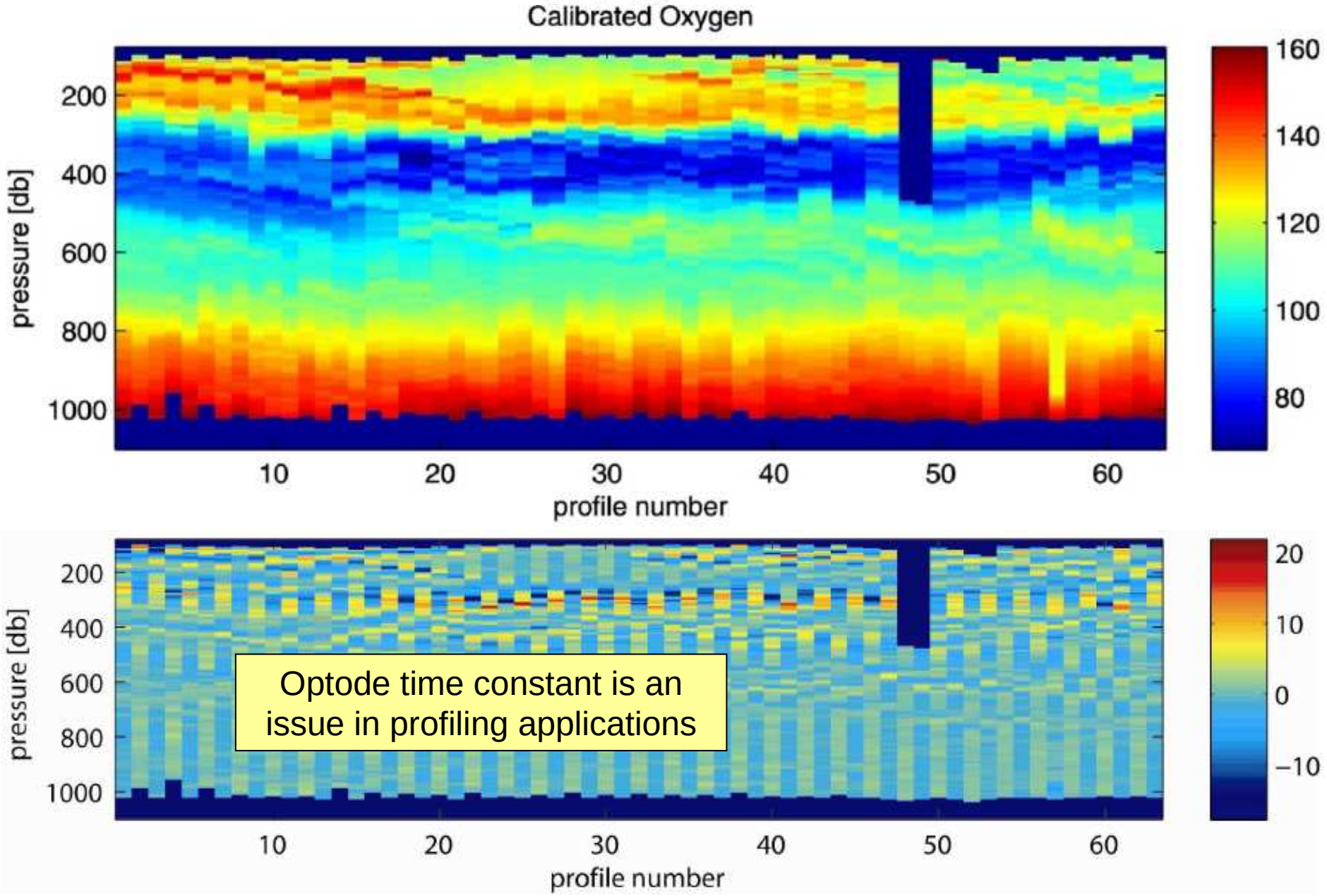
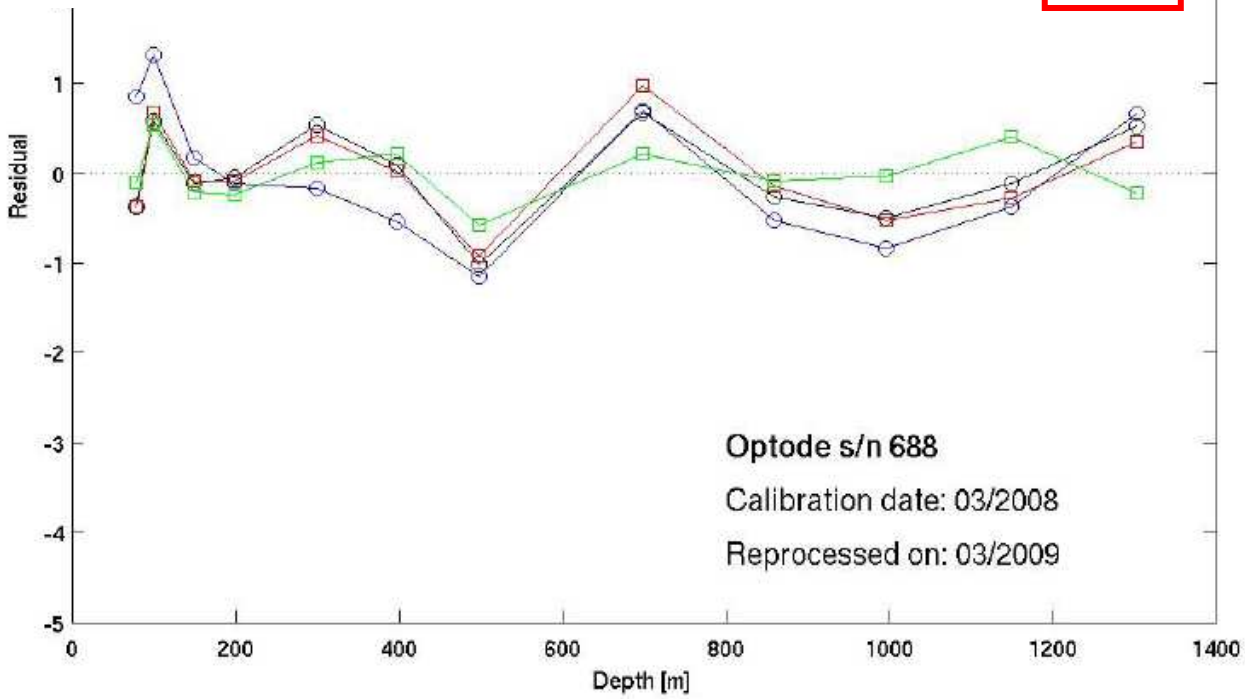


Brandt & Körtzinger, unpubl.

Oxygen optode: Results from calibration casts on CTD-O_2 system

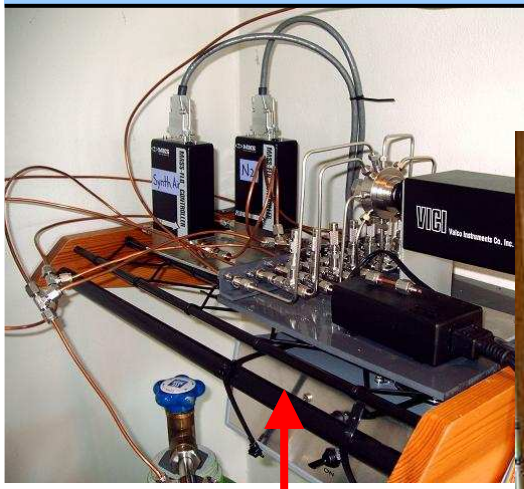
Instr.	Temperature (deg C)			Oxygen (umol/kg)					
S/N	slope	bias	rms	bias	A(O)	A(O2)	A(t)	A(p)	rms
349	0.99776	0.02638	0.033	-9.4228e-01	1.1442e+00	-3.9895e-04	-1.1227e-01	3.6083e-03	0.328
688	0.99635	0.06008	0.024	-5.2881e+00	1.1992e+00	-3.9754e-04	2.2406e-02	4.7170e-03	0.300
691	0.99743	0.04524	0.027	-1.7658e+01	1.1444e+00	-3.3997e-04	3.9548e-01	3.8984e-03	0.315
937	0.99088	0.09257	0.113	3.9991e+01	9.2379e-01	5.0688e-04	-1.9442e+00	-1.8412e-02	0.451
938	0.99136	0.08758	0.079	4.6301e+01	9.0768e-01	6.2434e-04	-2.3539e+00	-2.4111e-02	0.774
939	0.99427	0.07007	0.057	2.1635e+01	9.4542e-01	3.8736e-04	-1.0053e+00	-1.2288e-02	0.387
940	0.99566	0.05134	0.046	3.6482e+01	9.2664e-01	4.9046e-04	-1.7609e+00	-1.6653e-02	0.456
941	0.98808	0.11297	0.146	4.7218e+01	8.8707e-01	7.0468e-04	-2.4468e+00	-2.3390e-02	0.572
942	0.99247	0.07643	0.103	4.2470e+01	9.1978e-01	5.5862e-04	-2.0874e+00	-1.9859e-02	0.567
944	0.99976	0.01911	0.061	4.9704e+01	8.9619e-01	7.2392e-04	-2.6238e+00	-2.5295e-02	0.754

In-situ calibrations in Oxygen Minimum Zone of eastern tropical North Atlantic to <1 µmol/kg



Brandt & Körtzinger, unpubl.

Oxygen optode: Individual sensor laboratory calibration (at Bjerknes Centre, Bergen/Norway)



Sparge air controller se
cylinders of pre-mixed a
can make any N_2/O_2 ble
with mass flow controll
Sparge frit sits just belo
water surface (not visib

ssel is vented through a
neter tube. Head space
ide the vessel is kept to
inimum.

emperature control via
uter jacket is stable to
.01℃.

Mechanical mixer

or taking Winkler
les. Triplicate samples
ch calibration point
ide the reference.

Neill & Brown, unpubl.

Oxygen optode: Individual sensor laboratory calibration (at Bjerknes Centre, Bergen/Norway)

- Calibrations done in freshwater
- 6 x 6 matrix (temperature x oxygen; since 2009: 6 x 8)
- pO_2 is calculated from Winkler-O_2 and fit as function of B Phase and temperature (5^{th} degree polynomial with 21 terms, since 2009: 3^{rd} in temp. and 5^{th} in B phase)

Calibration tests in seawater

Temperature	O2 conc.	salt	optode 1 error	optode 2 error	optode 3 error	optode 4 error	optode 5 error
0.16	252.07	32.096	0.9	0.9	0.6	1.1	-1.3
0.17	395.9	32.062	0.2	1.3	0.7	0.6	-2.4
19.58	290.61	0	-1.6	0.0	-1.1	-0.4	
21.06	164.91	32.532	0.7	1.4	1.2	1.4	
21.07	256.07	32.514	0.8	2.0	1.6	2.2	
7.14	218.13	32.445	1.1	1.7	1.5	1.8	-1.9
7.13	336.8	32.71	1.3	2.9			-2.9
-1.81	269.41	32.445	1.6	2.0			0.0
-1.51	270.57	32.53	0.7	1.7			
-1.79	411.28	32.096	-0.3	0.9	0.5	-0.5	-1.8
-1.52	416.49	32.527	0.9	3.0	1.7	1.5	
		mean absolute errors	0.9	1.6	1.2	1.4	1.7
		mean error for negative temps only	0.9	1.9	1.2	1.3	0.9

Laboratory calibration to <2 µmol/kg

Neill & Brown, unpubl.

New features of optode 4330

- New processor, 25 kHz (older model 5 kHz),
- Sinusoidal excitation gives lover noise (older model squared pulse),
- Optimized optics (better geometry),
- Temperature sensor closer to foil and faster response time (less than 2 s),
- Introduction of red reference LED. Reduced risk of electronic drift.
- Possible to use transparent foils. Fast response, less than 8 s, 90 % response.
- Possibility to offer better calibrations. 30-point and Winkler-checked. Yields accuracies of around 1 %.
- Output CAN bus & RS232.

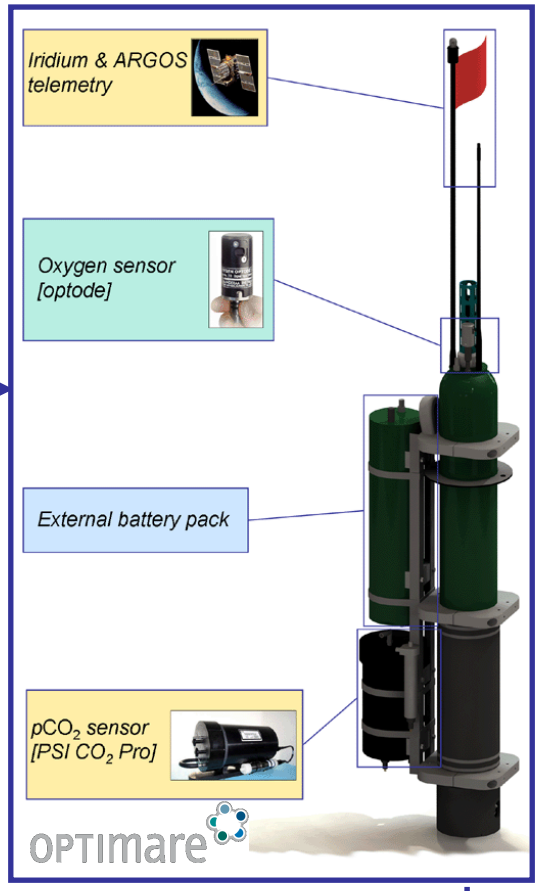
Experimental Float Design and Development

NEMO Float
(Optimare, Germany)

PSI CO_2 Pro

Aanderaa Optode

CO_2 & Oxygen Sensors

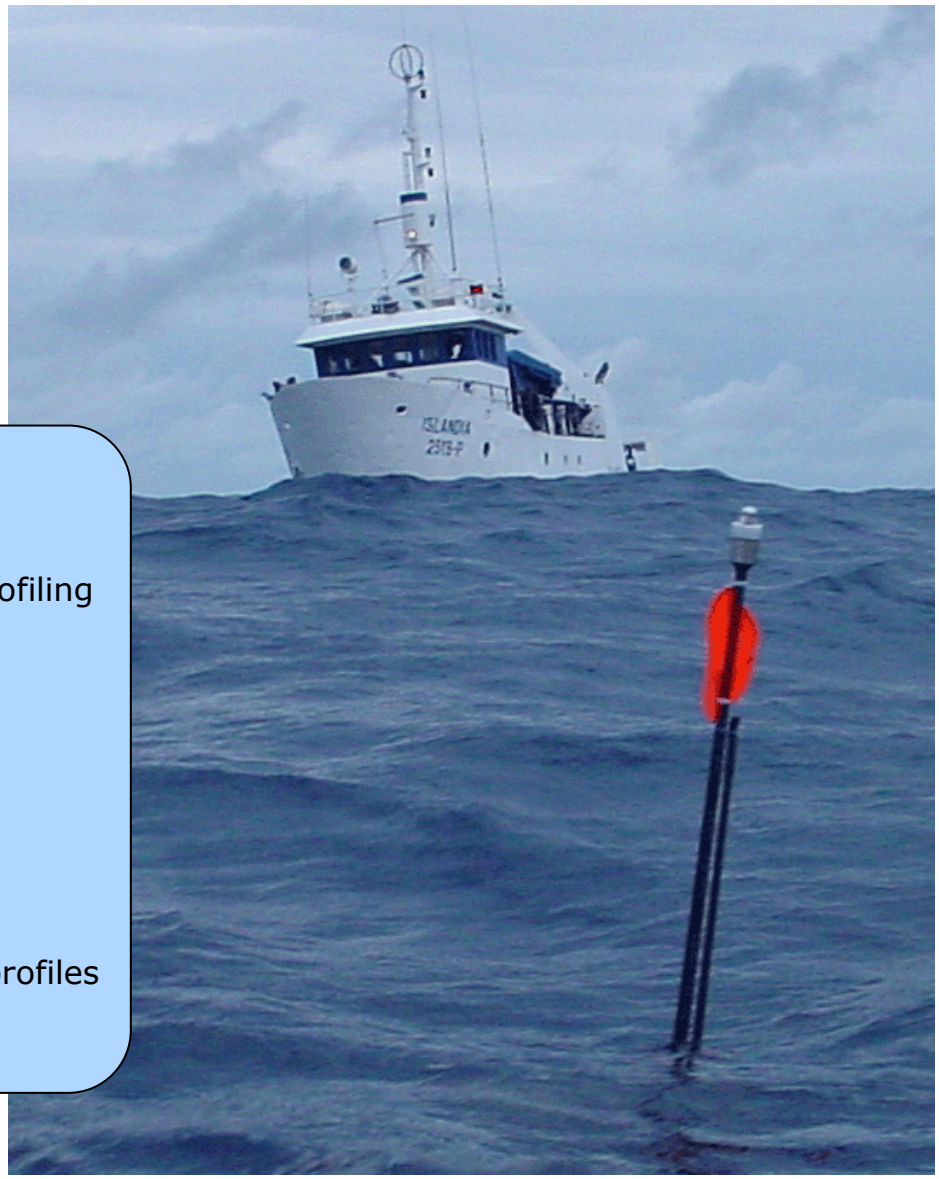


Design

Field Testing

IFM-GEOMAR
Leibniz-Institut für Meereswissenschaften an der Universität Kiel

First Mission

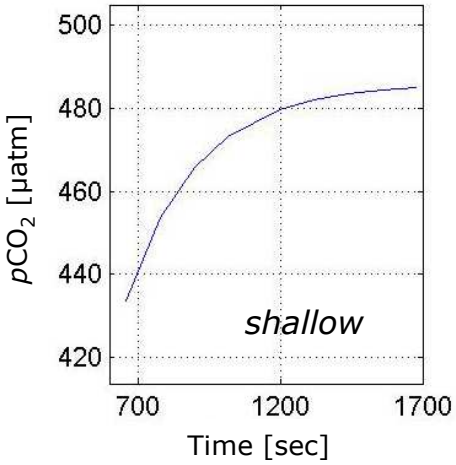


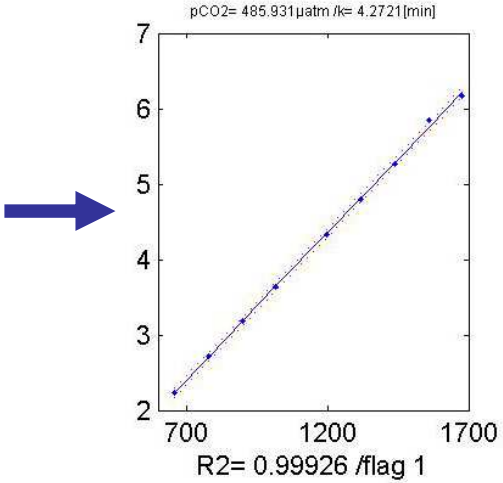
- Deployment: 24. Oct. 09
  Recovery: 29. Dec. 09
  Duration: 56 days of profiling
- 45 profiles in upper 200 m for T,S,O_2 & CO_2
- 111 pCO_2 measurements, 1800 O_2 measurements
- No GPS positions for profiles 5 – 45 (malfunction)

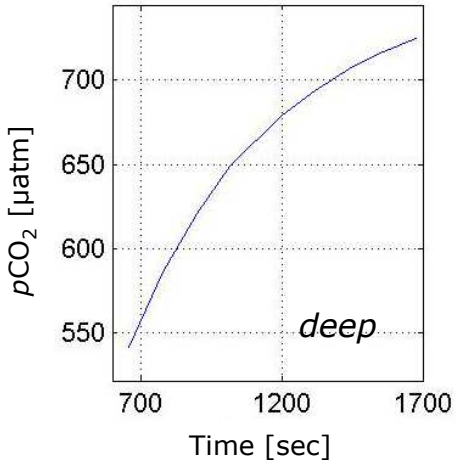
Measurement Performance

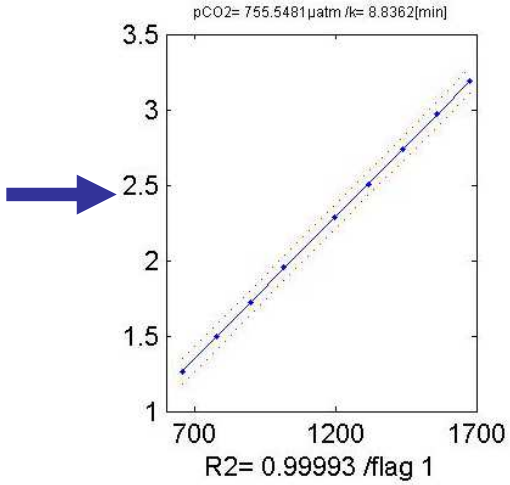
pCO_2 data:

$$-\ln\frac{\left(pCO_2^{t}-pCO_2^{t=\infty}\right)}{\left(pCO_2^{t=0}-pCO_2^{t=\infty}\right)}=k\cdot t$$

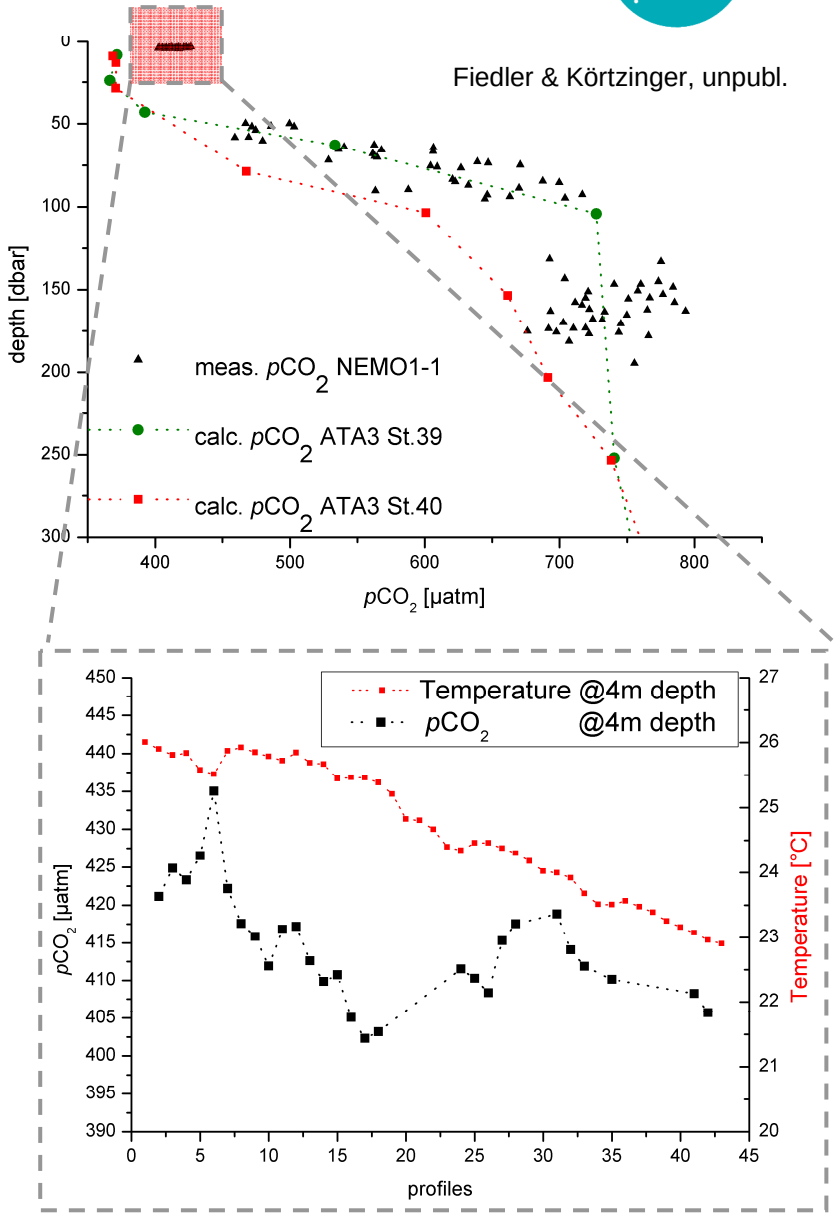








Fiedler & Körtzinger, unpubl.



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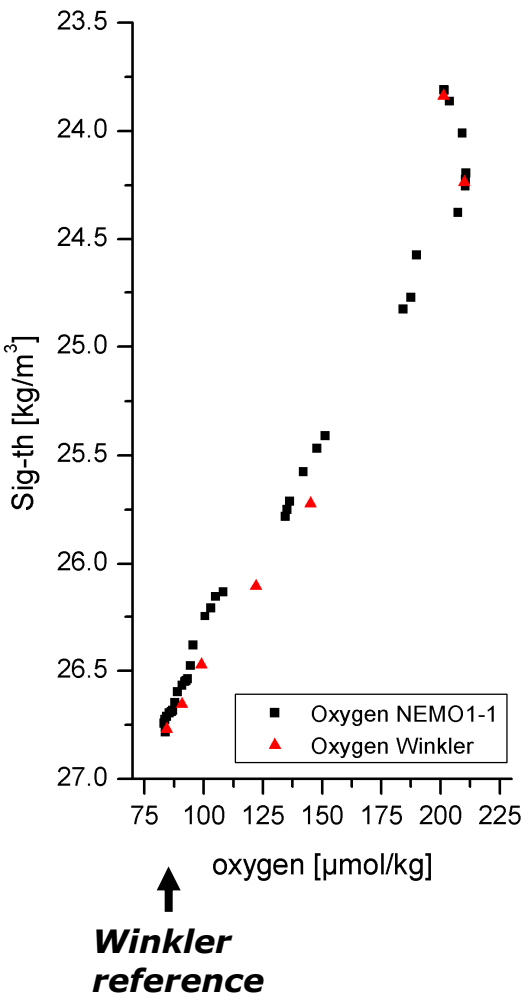
an der Universität Kiel

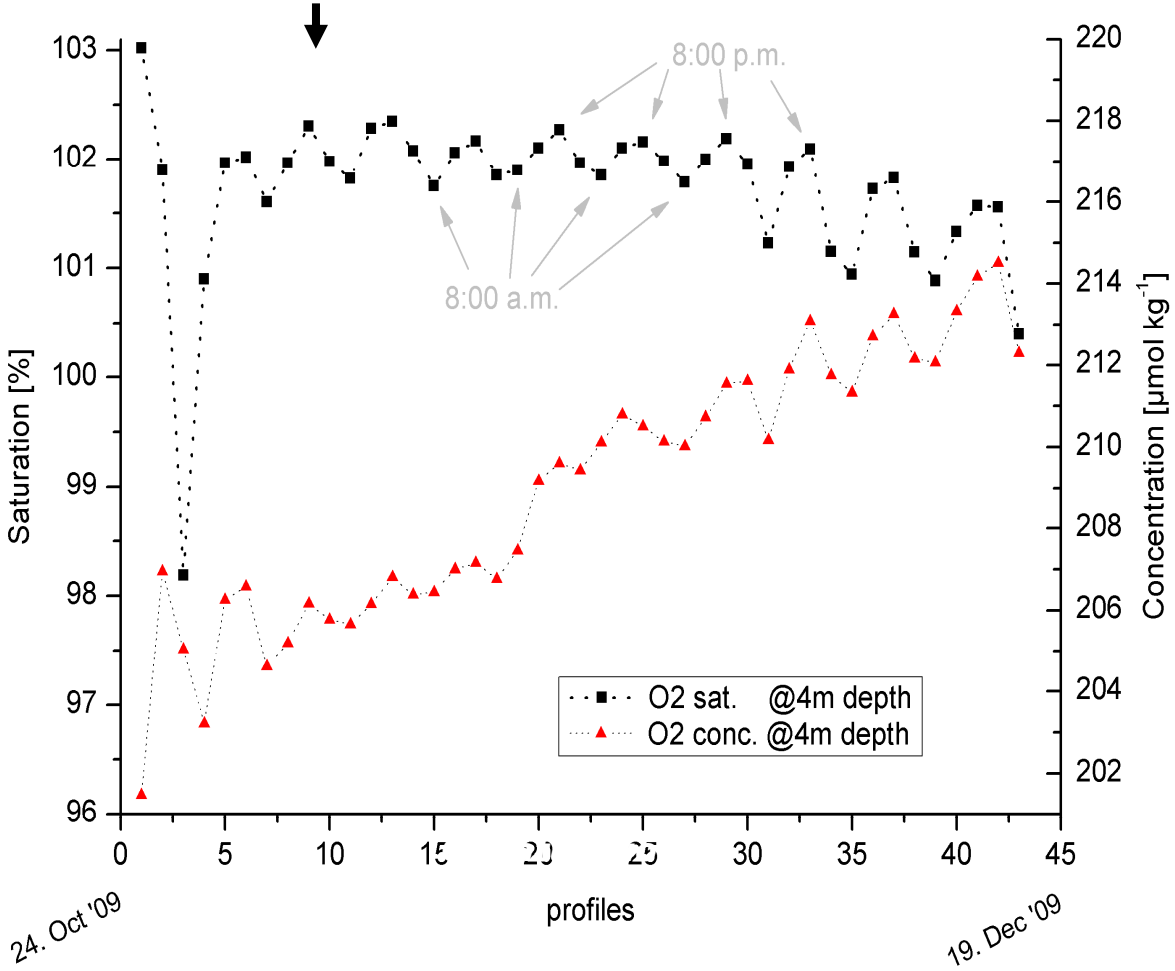
Measurement Performance

O_2 data:

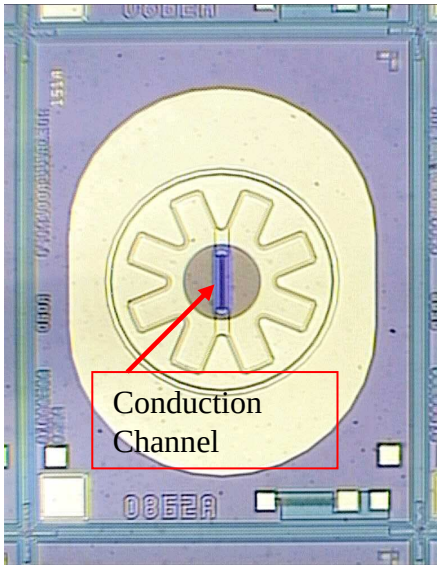


Winkler reference

Indication of diel cycle

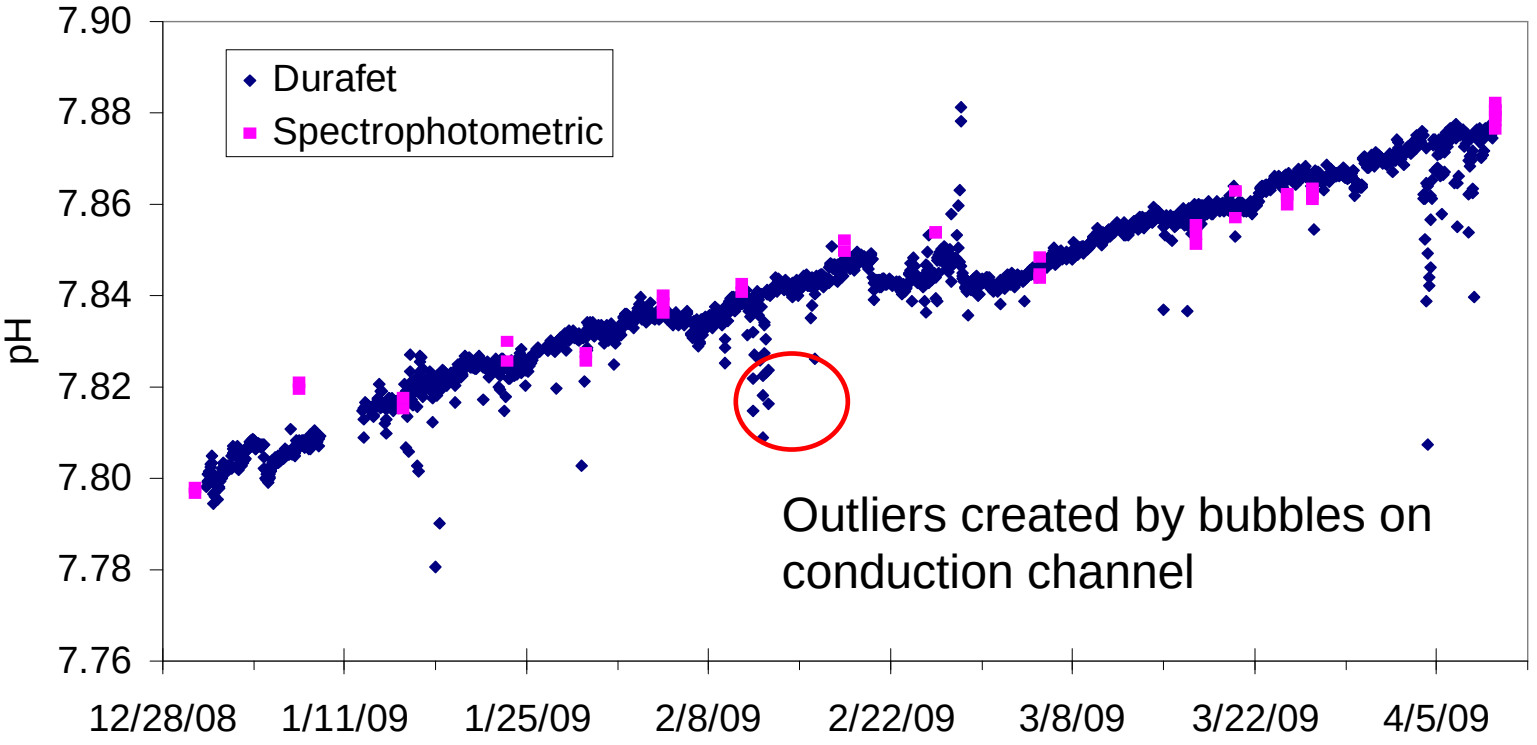


Fiedler & Körtzinger, unpubl.



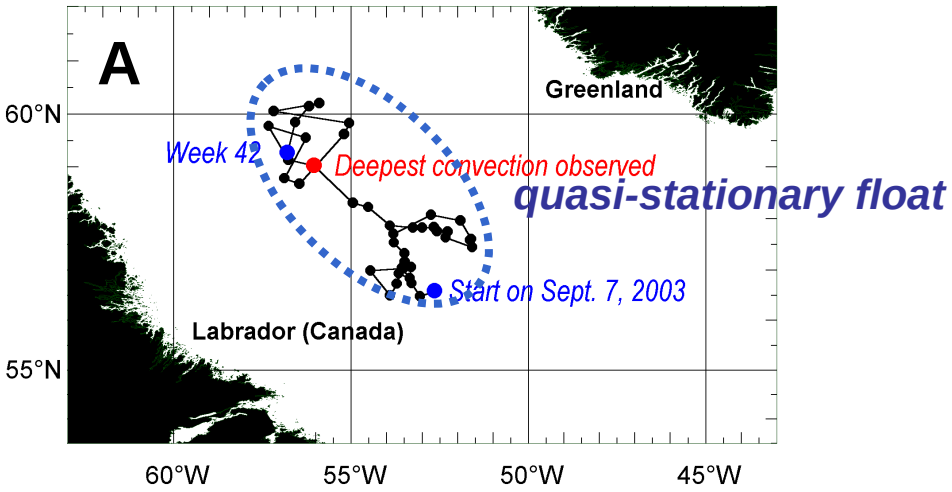
Honeywell Durafet Ion Sensitive Field Effect Transistor pH sensor – a potential float/glider sensor

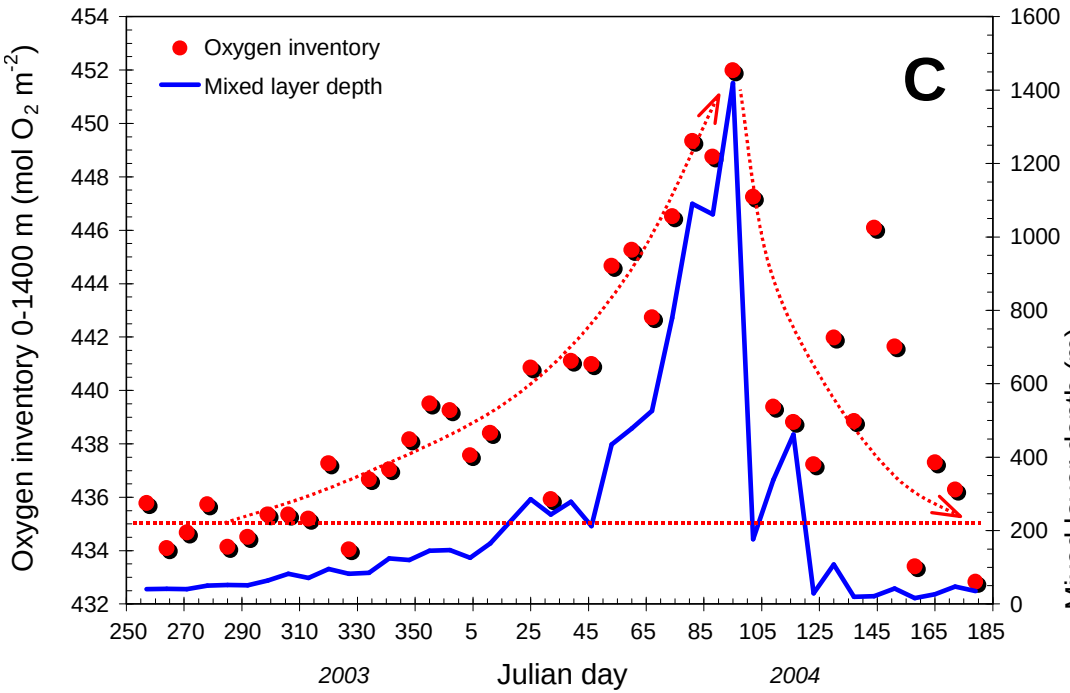
- Long-term stability – months at ±0.006 pH in seawater
- High temperature stability – weeks of cycling 5 to 35℃ in equimolar buffers (pH=pK(T)) show >0.01 pH stability
- Pressure tolerance is now limiting factor. Re-engineering packaging to be pressure tolerant – device operating to 2000 dbar pressure routinely in lab.
- Low power (µWs), low weight (grams), fast (<1 s)

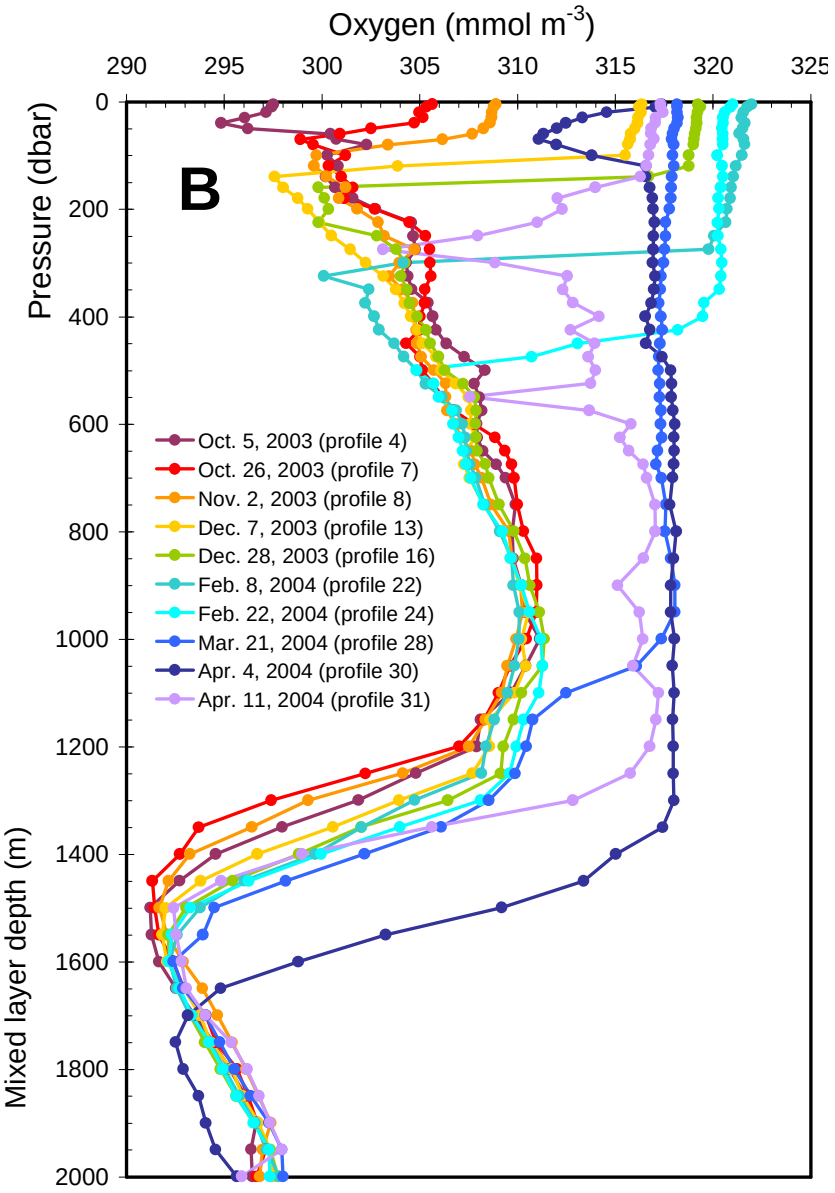


MBARI Seawater Test Tank – Std. dev. of difference from Spec. pH values is 0.006 over 3+ months (pH going up as tank outgases CO_2)

“Labrador Sea showcase”: The ocean taking a deep breath

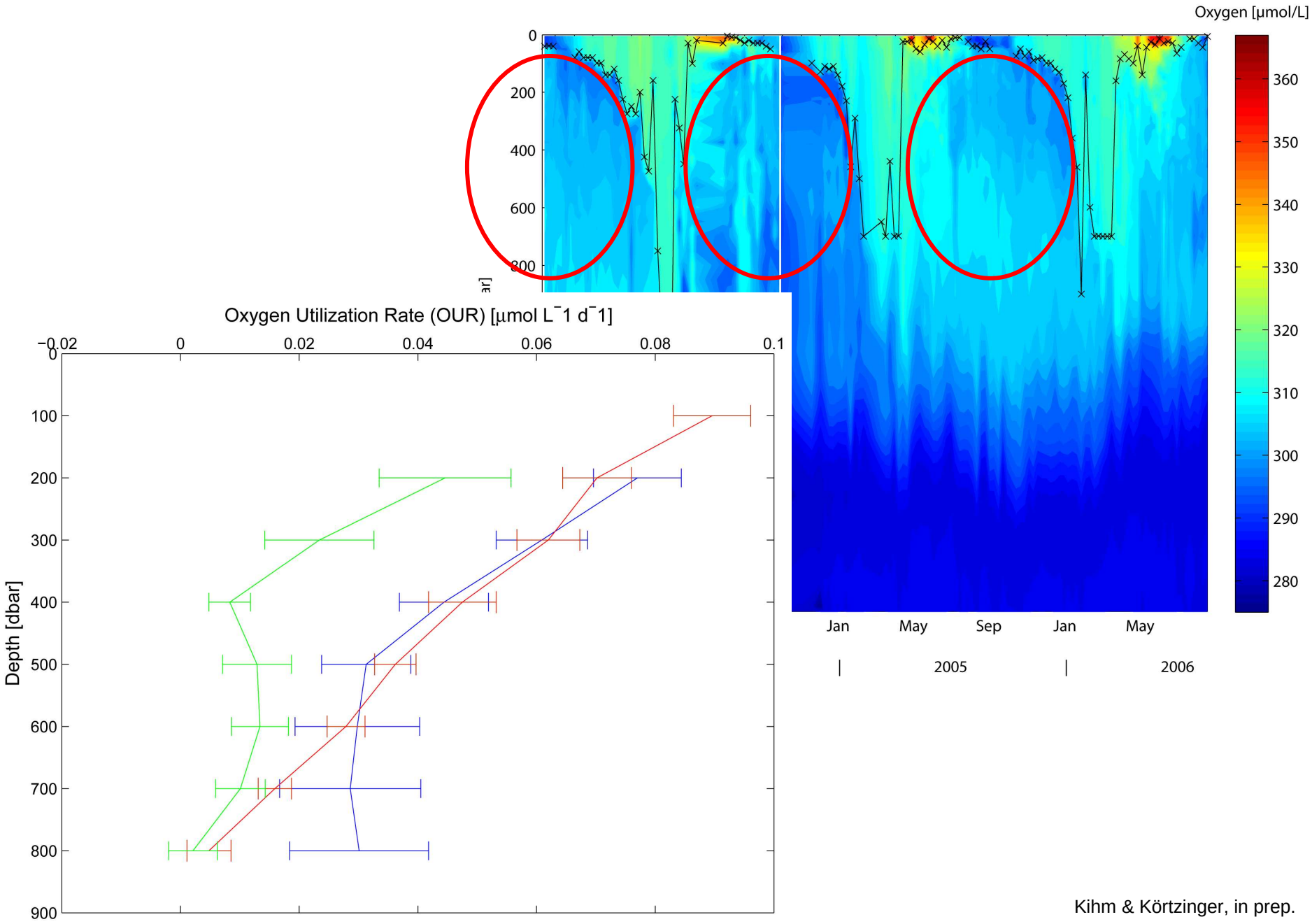






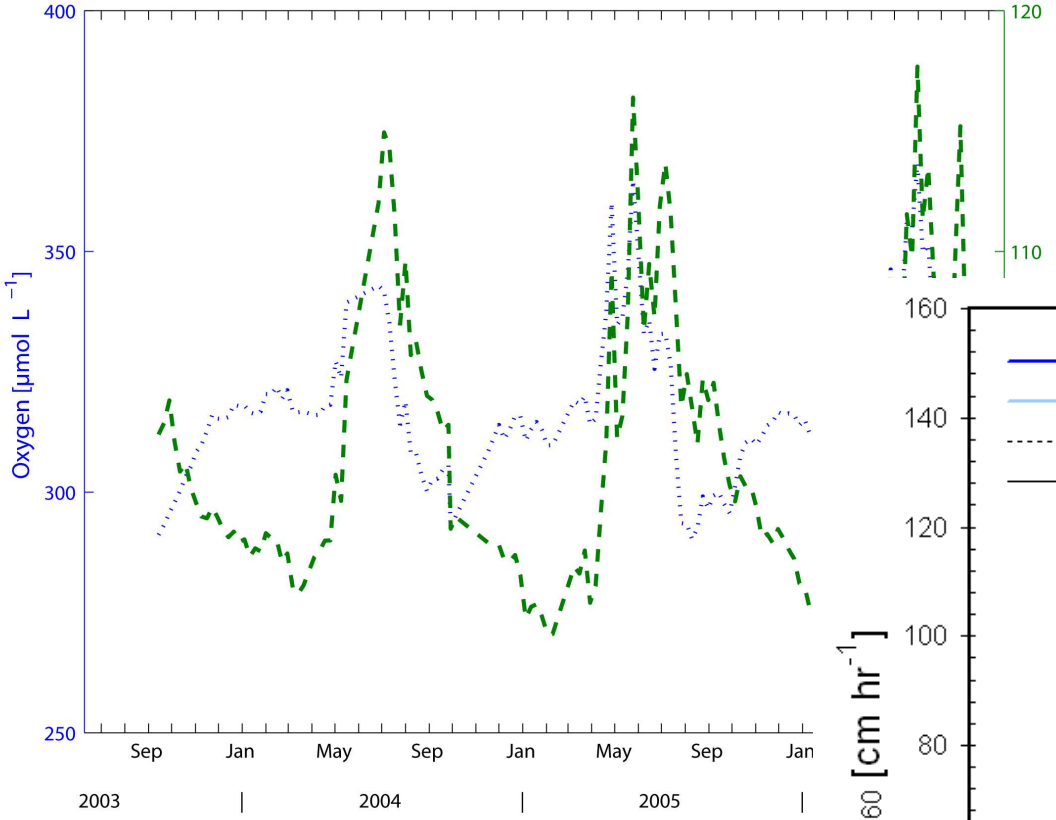
Körtzinger *et al.* (2004). The ocean takes a deep breath. *Science,* **306**, 1337.

“Labrador Sea showcase”: more science to come …



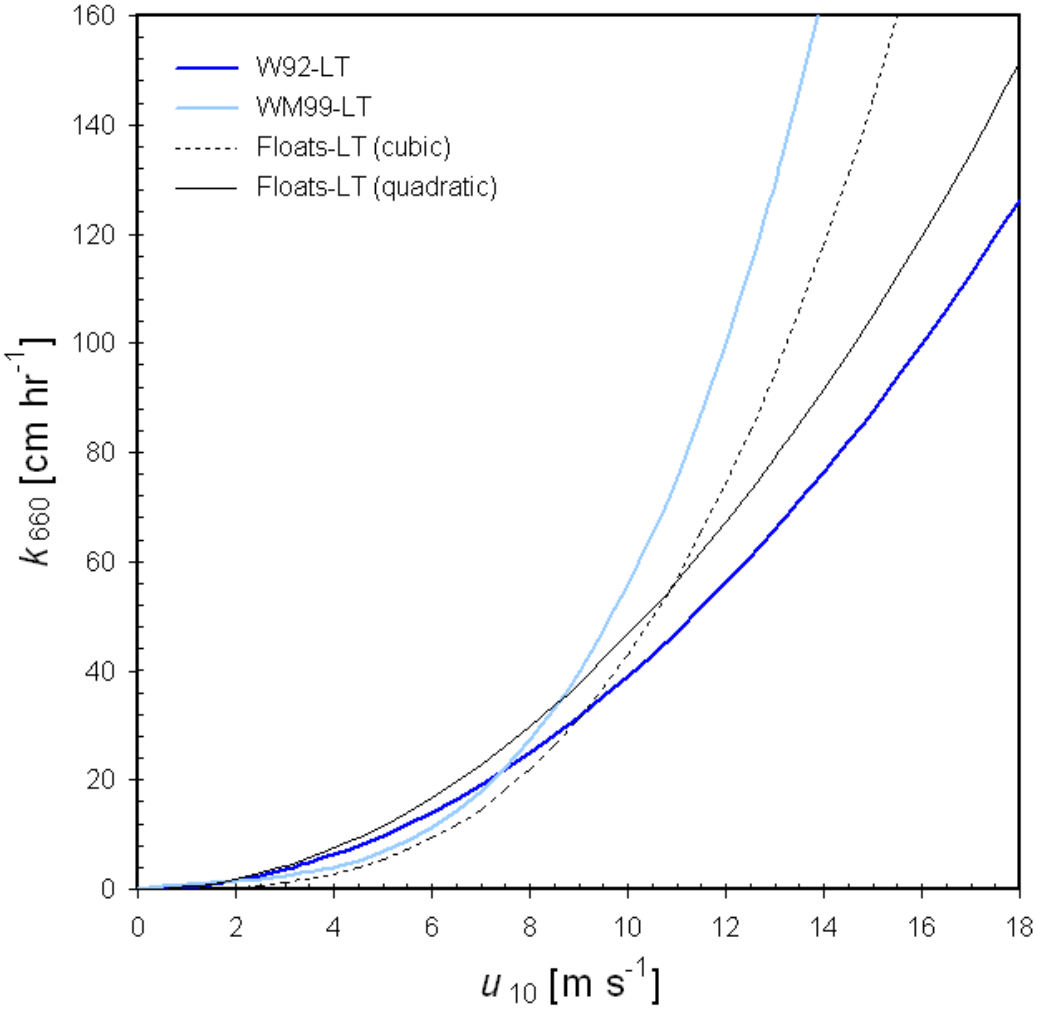
Kihm & Körtzinger, in prep.

“Labrador Sea showcase”: more science to come …



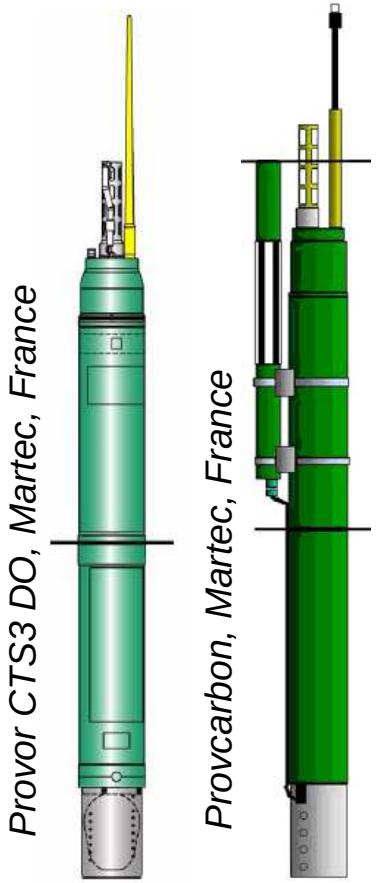
- Mixed layer O_2 budget → flux
- Surface O_2 data → disequilibrium
- QuikSCAT → wind speed

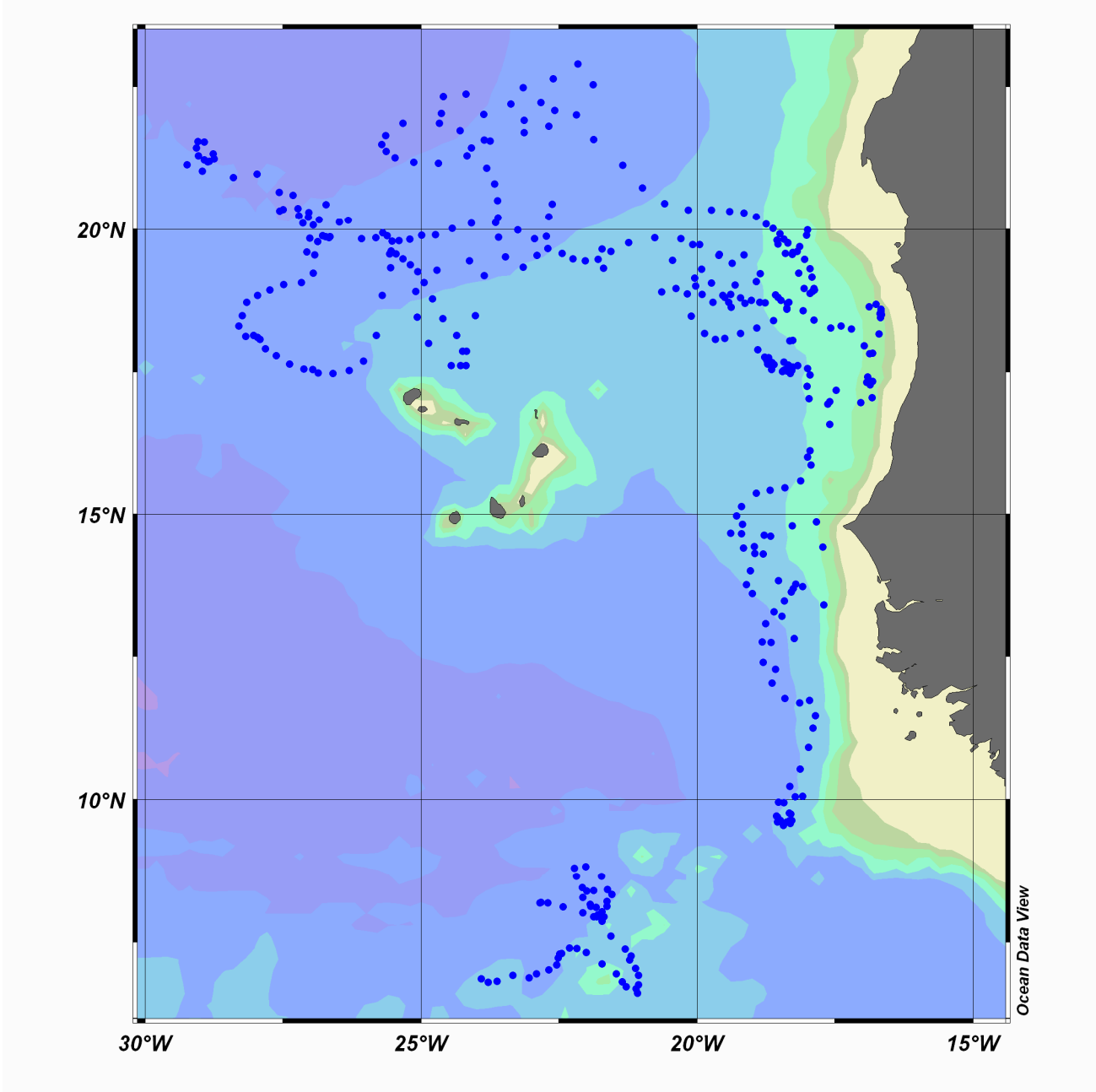
→ Transfer coefficient, k_{660}



Kihm & Körtzinger, in prep.

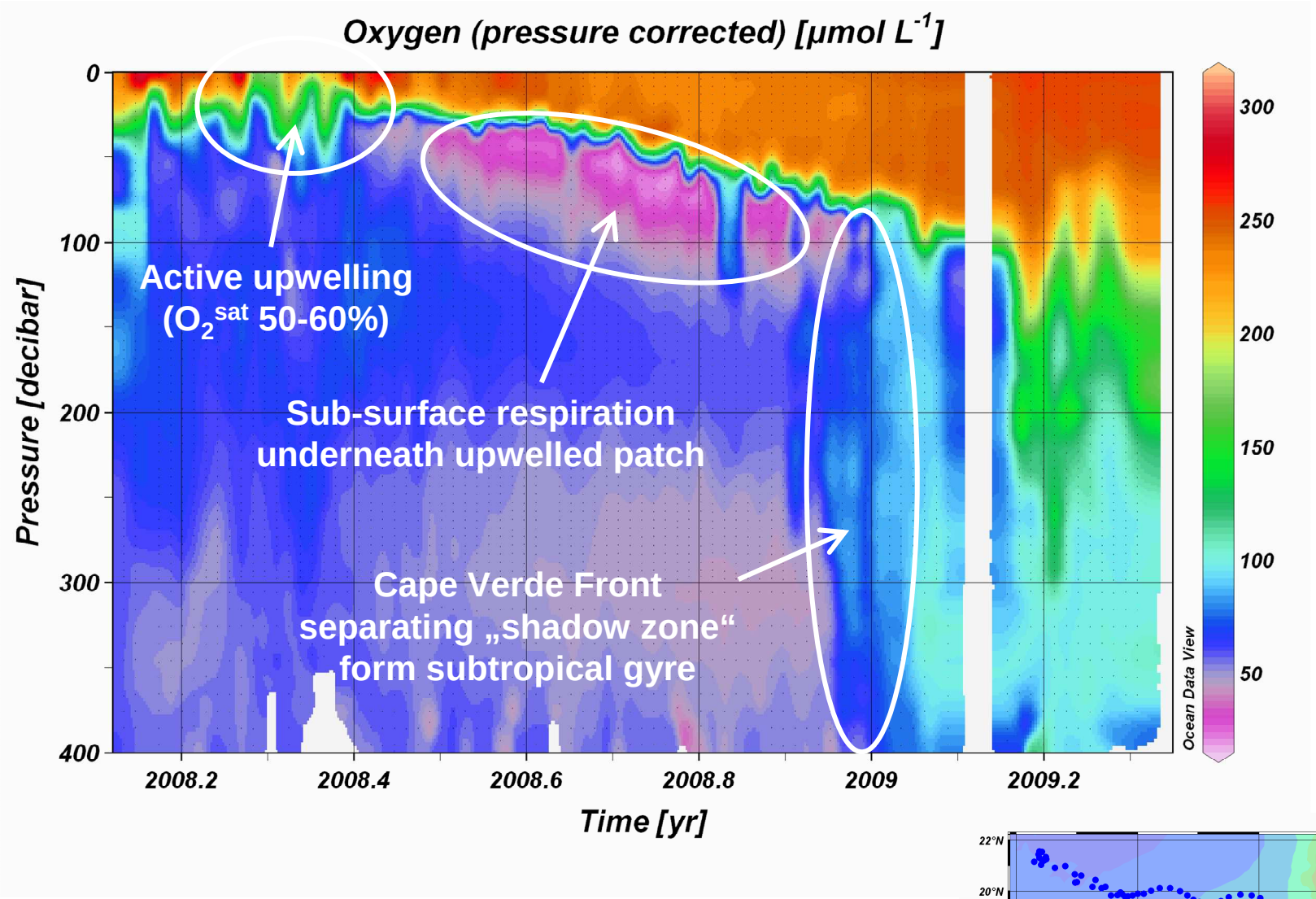
Eastern tropical North Atlantic: OMZ and upwelling dynamics

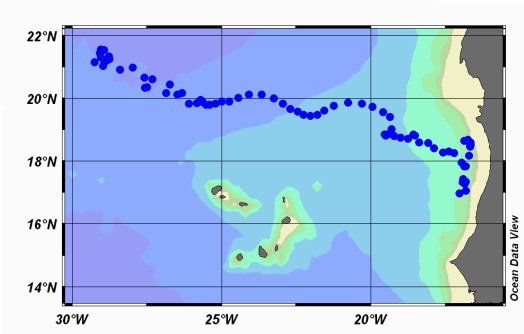




Fiedler, Kihm & Körtzinger, in prep..

Eastern tropical North Atlantic: OMZ and upwelling dynamics





Fiedler, Kihm & Körtzinger, in prep..