Oxygen optode time response correction

Tanya Maurer, MBARI

ADMT20

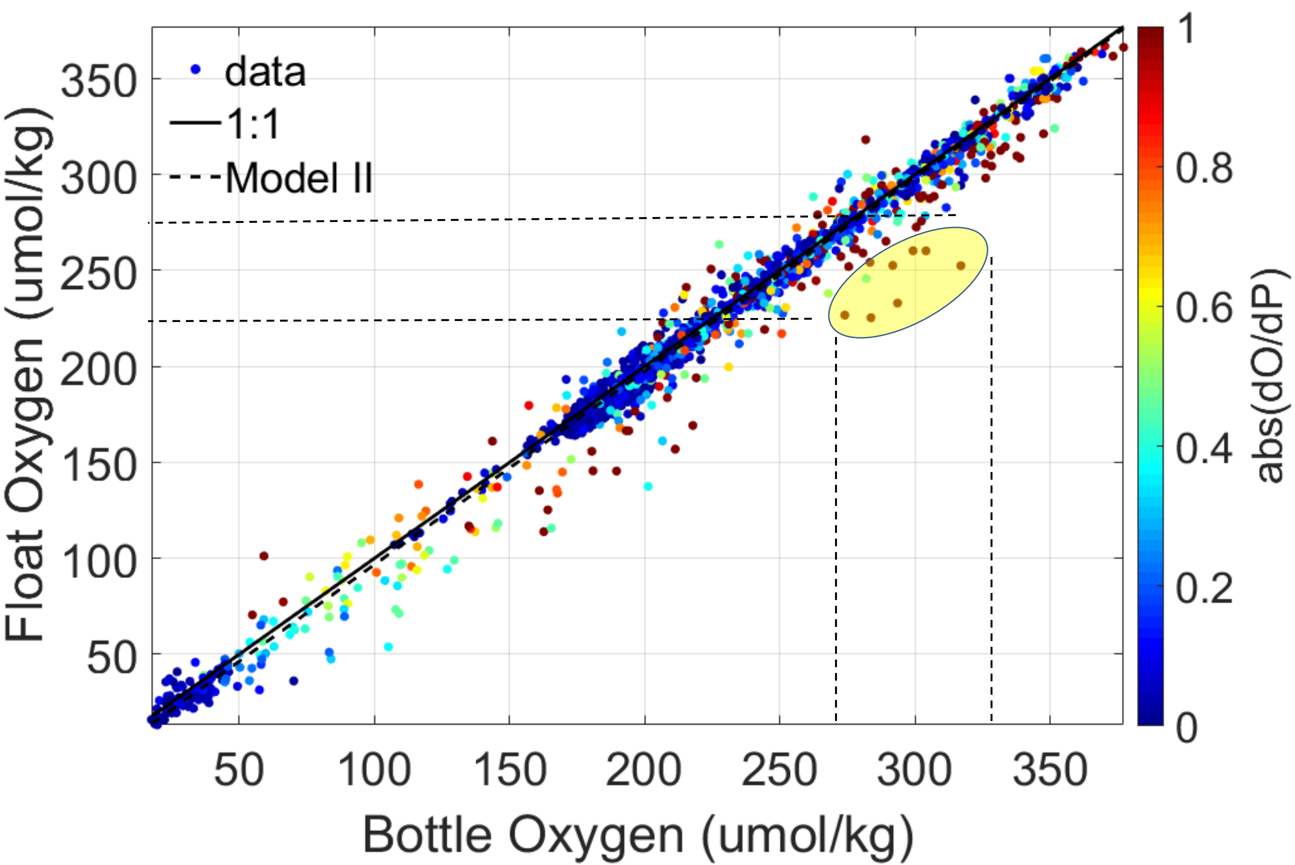
Oct 14-15, 2019

BGC Sensor dependence on T & S

BGC Argo parameter	Average fleet Precision (1 SD)	Maximum error in BGC parameter for:	
		0.5 psu error in salinity	0.1 deg C error In temperature
Oxygen (µmol kg-1)	2.0	1.1	1.4
Nitrate (µmol kg-1)	0.5	0.8	0.15
pH	0.008	0.0075	0.0015

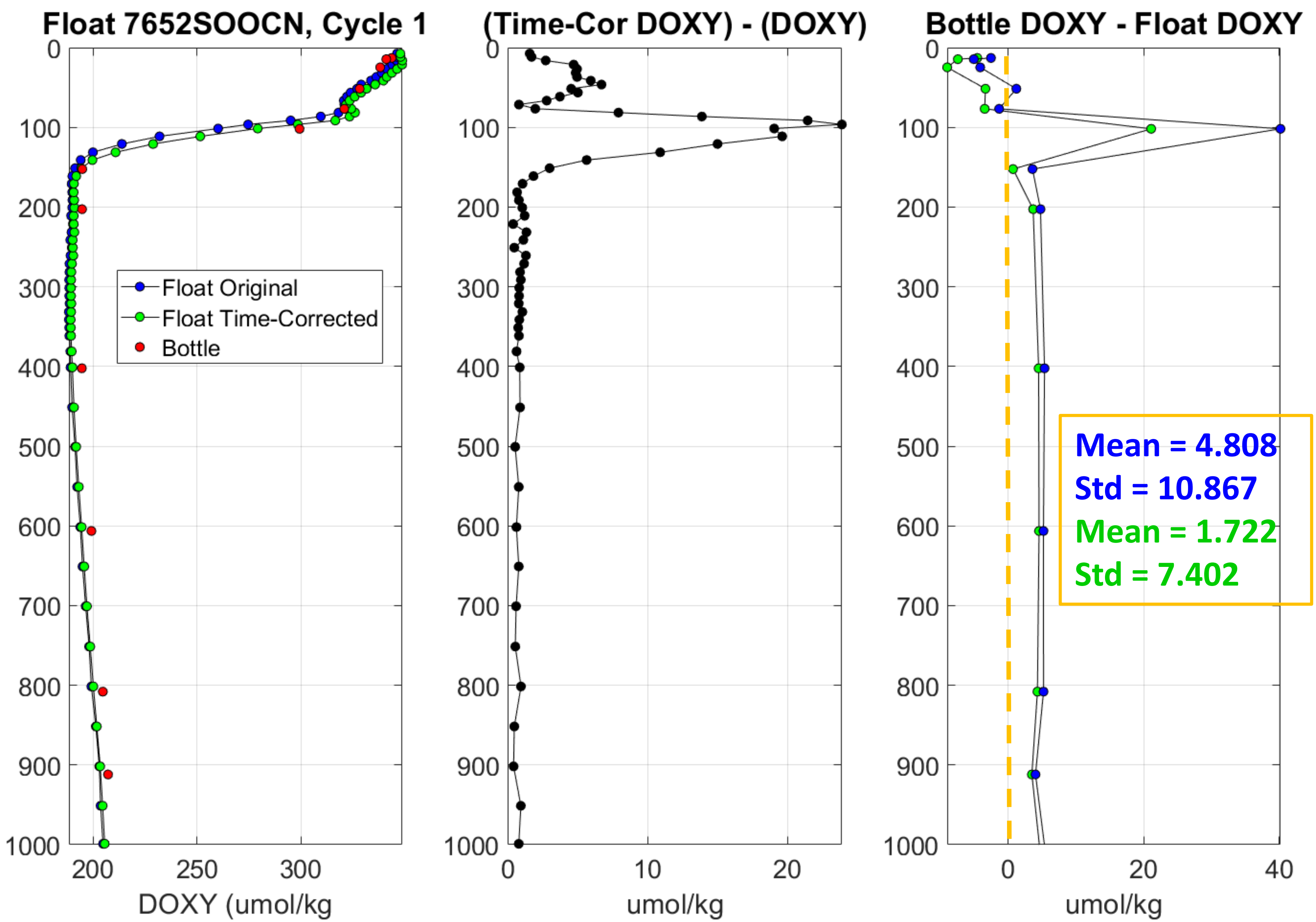
Problem:

- Response time of oxygen optode is not immediate
- Leads to data inaccuracy in high O_2 gradient regions (errors > 10 umol/kg)
- Response time varies among sensors types (pumped SBE63 faster than Aanderaa)



Shipboard Winklers
vs
MBARI float oxygen
(first profile
matchups)

Can compare first float oxygen profile (before and after time-correction) to shipboard cast taken at time of deployment.



LIMNOLOGY
and
OCEANOGRAPHY: METHODS

Limnol. Oceanogr.: Methods 12, 2014, 617–636

Time response of oxygen optodes on profiling platforms and its dependence on flow speed and temperature

Henry C. Bittig, Björn Fiedler, Roland Scholz, Gerd Krahmann, and Arne Körtzinger*
Helmholtz Centre for Ocean Research Kiel (GEOMAR), Kiel/Germany

Technical note: Update on response times, in-air measurements, and in situ drift for oxygen optodes on profiling platforms

Henry C. Bittig[1] and Arne Körtzinger[2,3]
[1]Sorbonne Universités, UPMC Université Paris 06, CNRS, UMR 7093, Laboratoire d'Océanographie de Villefranche (LOV), Villefranche-sur-Mer, France
[2]GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel, Kiel, Germany
[3]Christian-Albrechts-Universität zu Kiel, Kiel, Germany

Response time can be explained by 1D diffusion model (Bittig & Körtzinger)

- O_2 diffusion into the sensing foil controls response time
- Diffusion Controlled by:
  - Temperature
  - Boundary layer thickness (BLT) in front of the sensing foil at each sample
- BLT is determined by the flow regime
  - Pumped optode → higher flow, more rapid boundary layer renewal → shorter response time

Correction steps:

1. Find ascent velocity, v, of the float (**need time-stamps**!)

1. Calculate boundary layer thickness, l_L, at each sample point, following Eqn 1 in Bittig & Kortzinger, 2017

$$l_\mathrm{L}(\mathrm{float})\,/\,\mu\mathrm{m} = \begin{cases} 210 - \frac{110}{0.095} \cdot \left|v/\mathrm{dbar\,s^{-1}}\right| & |v| \le 0.095\,\mathrm{dbar\,s^{-1}} \\ 20 + \frac{80}{0.905} \cdot \left(1 - \left|v/\mathrm{dbar\,s^{-1}}\right|\right) & |v| > 0.095\,\mathrm{dbar\,s^{-1}} \end{cases} \quad (1)$$

2. Using sensor model-specific lookup charts from Bittig & Kortzinger, 2017 Supplemental: estimate response time, τ, from sample temperature and calculated boundary layer thickness, l_L

Correction steps:

4. Apply time-correction filter outlined in Appendix A of Bittig & Kortzinger, 2017 (Eqn A3) to find “true” O2 profile from observational profile

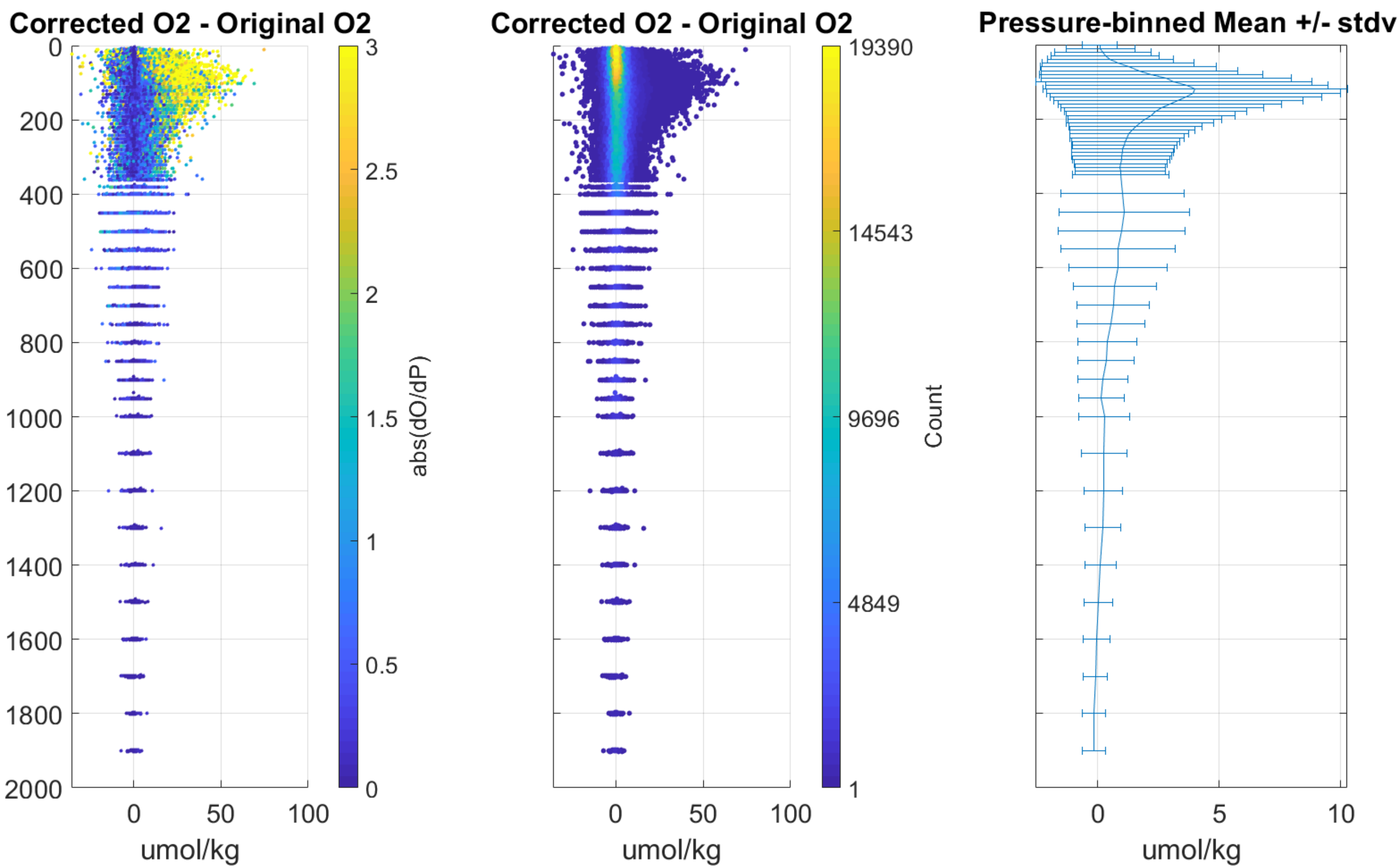
$$\frac{c^{\text{in-situ}}(t_{i+1}) + c^{\text{in-situ}}(t_i)}{2} = \frac{1}{2b} \cdot \left(c^{\text{obs}}(t_{i+1}) - a \cdot c^{\text{obs}}(t_i)\right),$$

$$a = 1 - 2b, \quad b = \left(1 + 2\,\frac{\tau}{t_{i+1} - t_i}\right)^{-1}; \qquad \text{(A3)}$$

5. Algorithm in step 4 returns a profile of mean values (between each time point). Corrected data must then be interpolated back to the original time axis.

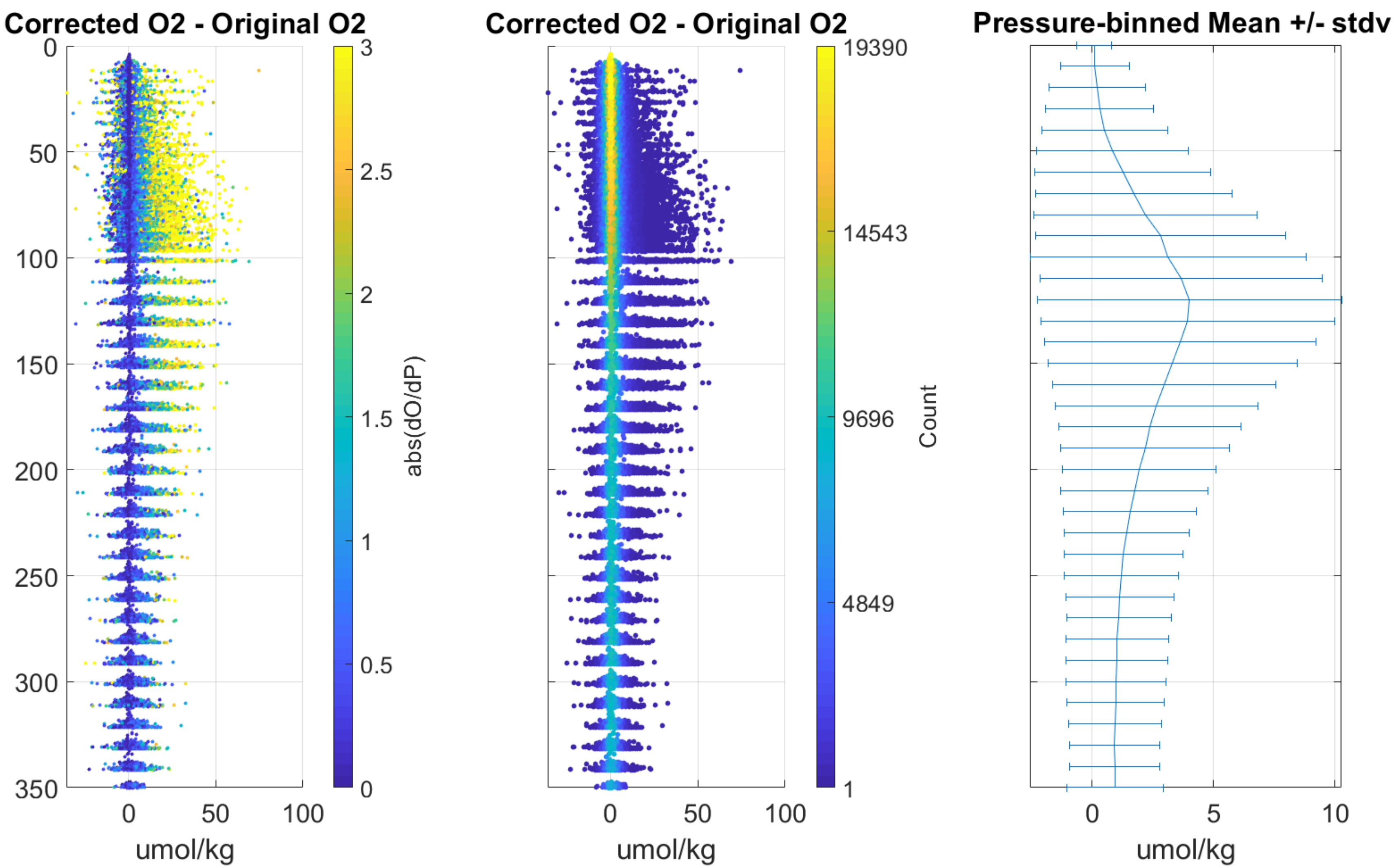
Method tested on 182 MBARI APEX floats

- Sample time from Nitrate data file
- Plots below show time-corrected O2 data minus original
- Largest corrections occur in regions of high gradient (first panel)

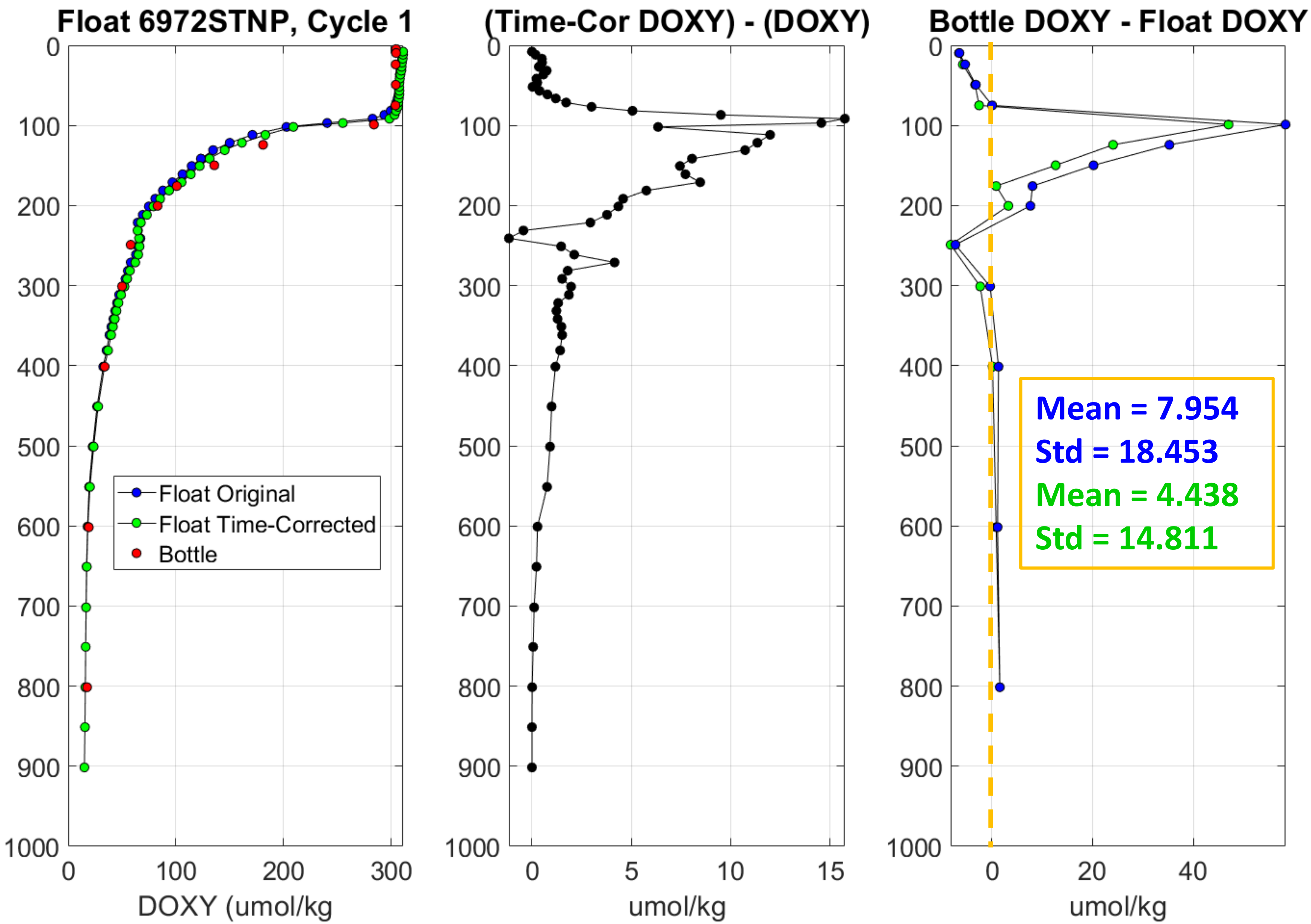


Method tested on 182 MBARI APEX floats (0 to 350m zoom)

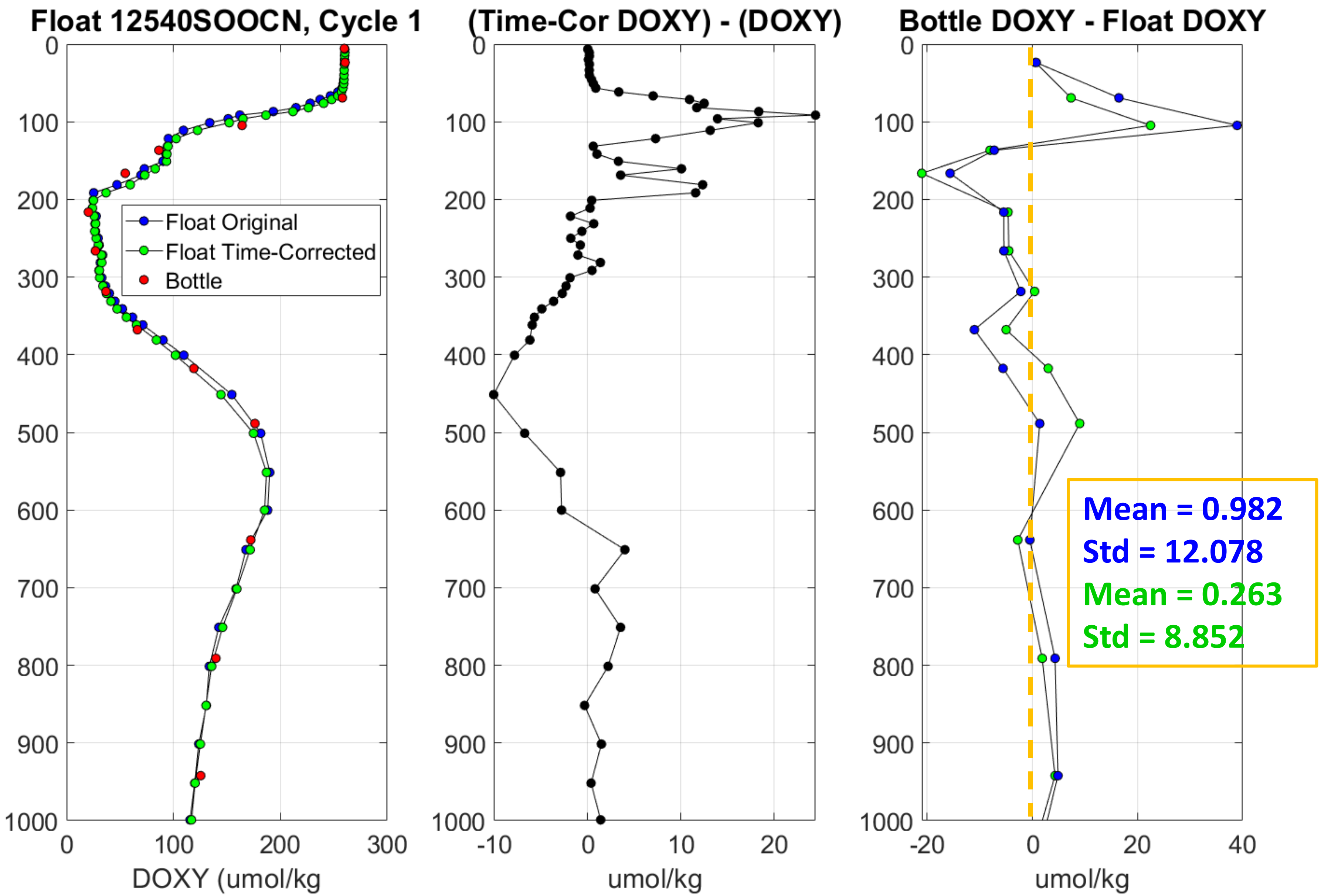
- Plots below show time-corrected O2 data minus original
- Largest corrections occur in regions of high gradient (first panel)



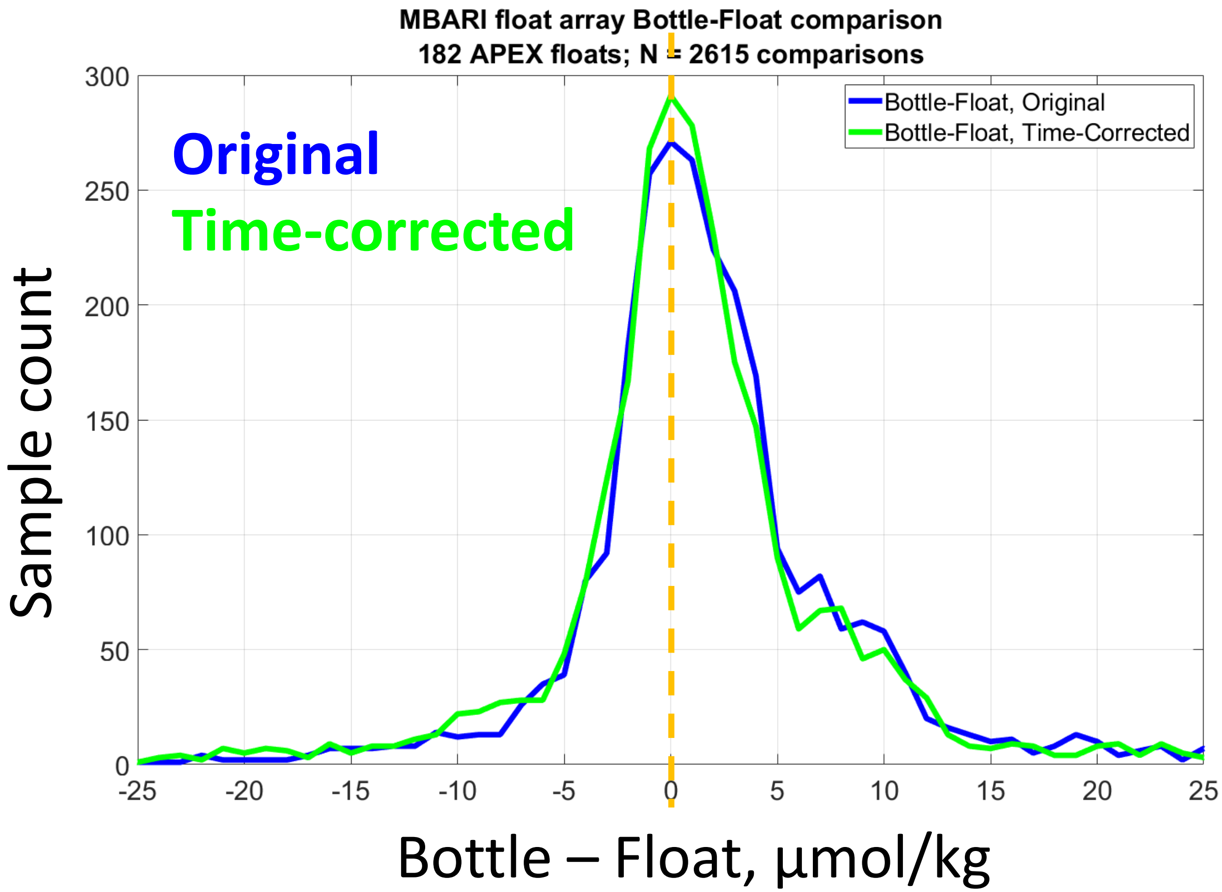
Can compare first float oxygen profile (before and after time-correction) to shipboard cast taken at time of deployment.



Can compare first float oxygen profile (before and after time-correction) to shipboard cast taken at time of deployment.



Can compare first float oxygen profile (before and after time-correction) to shipboard cast taken at time of deployment.



Mean = 2.437
Std = 8.186

Mean = 1.452
Std = 8.079

Mean bias reduced by 1 μmol/ kg!

Only a small improvement to fleet-wide statistics in comparison to bottle data. However, spatial/temporal error inherent in field matchups.

Operational implementation – remaining questions

1. If timing data is available, correction can be applied in RT

Would this be added to a RT test for DOXY?

Would data with time-correction fill DOXY_ADJUSTED (whether or not gain correction applied) and PARAM_DATA_MODE = 'A'?

2. What about QF assignments?

3. Based on the algorithm, some of the bounding sample points are lost in the final time-response corrected oxygen profile.

How to differentiate within the profile which points have been time-corrected and which haven't (or would this just be outlined in documentation)?

Operational implementation – remaining questions

4. Using the isus (nitrate) file for the time-axis acquisition is tricky

Not all floats have nitrate; sometimes isus files are missing, etc.

Could we use known profile start/end times and assumed sample frequency of CTD to derive ascent rate?

Better to have actual time stamps

Possible to implement case-by-case? (ie if times available, use, otherwise calculate assumed timing from CTD info). If a mixed bag – how to describe this in files?