Novel Oxygen Optode Sensor for Profiling Ocean Observation Platforms: Extensive Characterization and In-Depth Assessment of its Fast Response Time

[WP6, Task 6.1: Sensors and new instrumentation]

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Tobias Hahn[1*], Anna Canning[1,3], Carsten Frank[2,3], Jack Triest[3], Steffen Aßmann[3] and Arne Körtzinger[1,4]

*thahn@geomar.de

[1] GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany
[2] HAW Hamburg University of Applied Sciences, Hamburg, Germany
[3] Kongsberg Maritime Contros GmbH, Kiel, Germany
[4] CAU Christian-Albrechts-Universität zu Kiel, Kiel, Germany

Introduction

Data show a decline in the global oceanic O_2 content of more than 2% since 1960 (Schmidtko et al., 2017). Quantifying changes of O_2 levels improves the understanding of chemical, biological and physical processes in the global ocean, especially in Oxygen Minimum Zones (OMZ).

The faster response time of the novel optical oxygen sensor (optode) KM Contros HydroFlash® O_2 compared to other optodes is promising to observe various processes with higher spatial and temporal data resolution. The sensing principle is based on dynamic fluorescence quenching (DSQ) and described by the Stern-Volmer-Equation ($\frac{I_0}{I} = \frac{\Lambda_0}{\Lambda} = 1 + K_{SV} \cdot pO_2$).

Motivation

Integrated characterization of the CONTROS HydroFlash® O_2 optode is aimed regarding oxygen, temperature, salinity and pressure dependence, long-term stability and drift, response time and air-calibration compatibility.

Methods

Calibration procedures follow the laboratory setup described in Bittig et al. (2012). Bittig et al. (2018) suggest a functional model for partial pressure pO_2 and low root-mean-square errors (RMSE) to determine the behaviour of the optode. The fit equation for the exponential response time τ is given by Bittig et al. (2014).

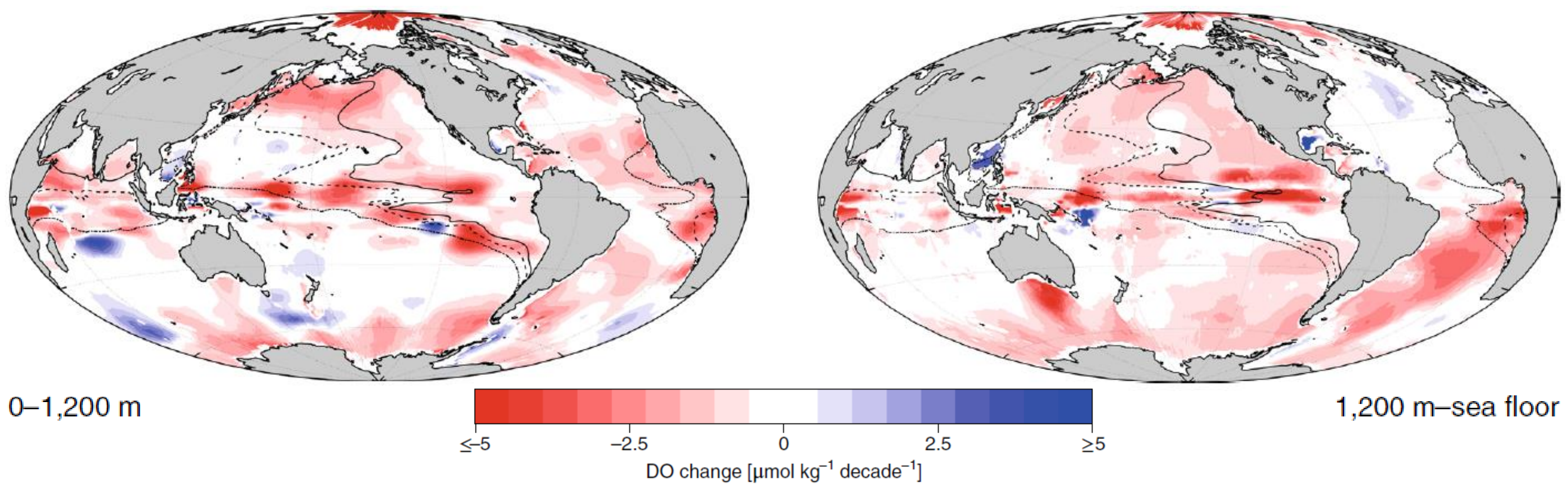


Fig. 1: Oxygen change in the ocean. Observational estimate of the 50-year (1960 to 2010) oxygen change in the upper and deep ocean (from Oschlies et al., 2018).

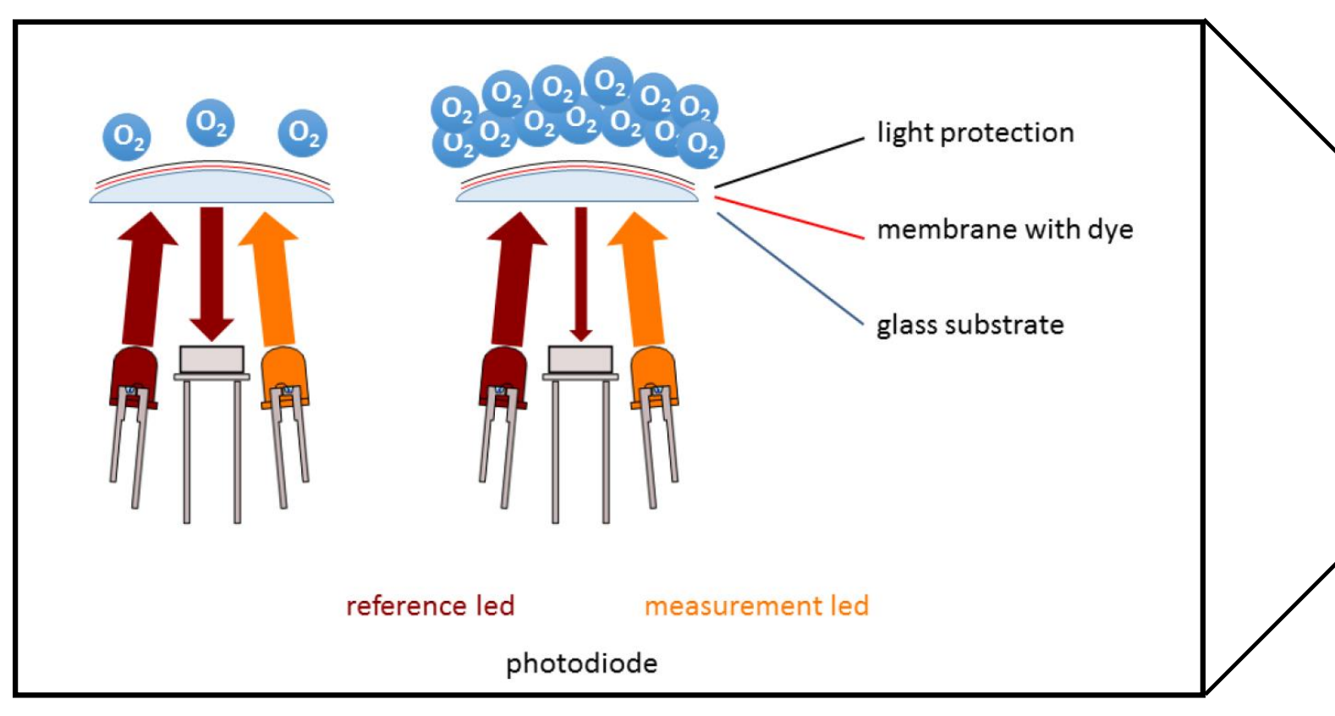


Fig. 2: KM Contros HydroFlash® O_2

$$pO_{2,adj} = \frac{\frac{1 + c_4 \cdot \vartheta}{c_5 + c_6 \cdot \varphi_{adj} + c_7 \cdot {\varphi^2}_{adj}} - 1}{c_1 + c_2 \cdot \vartheta + c_3 \cdot \vartheta^2}$$

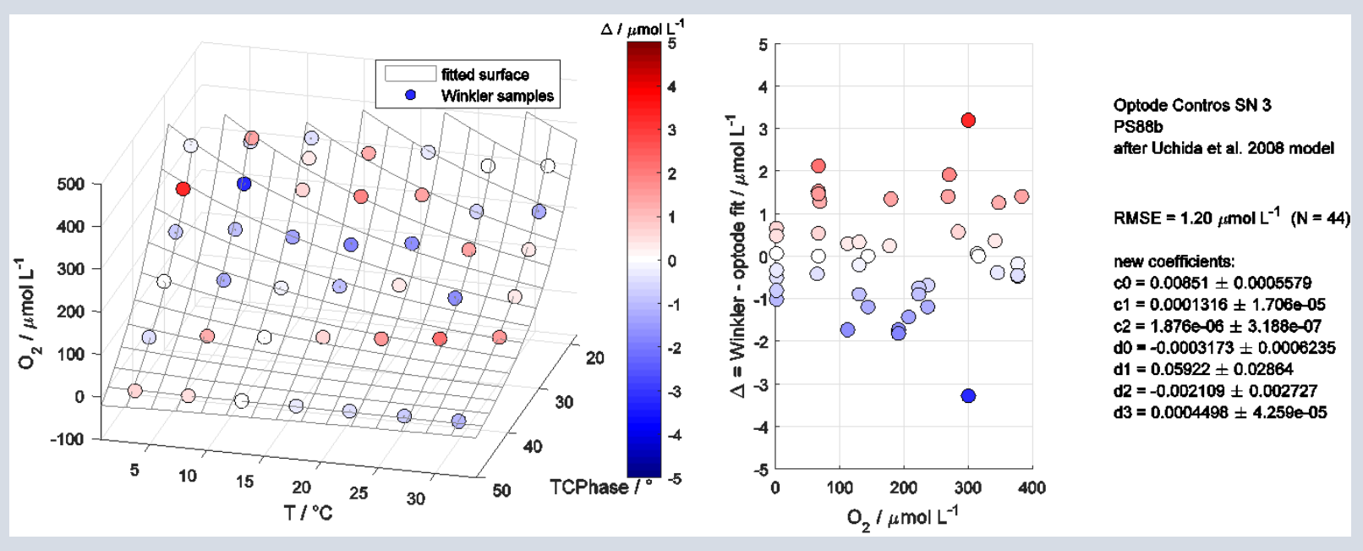
φ: phase shift / ° || $c_1 - c_7$: cal. coefficients || ϑ: temperature / °C

$$h(t) = A \cdot \left(1 - e^{-\frac{t - t_0}{\tau}}\right)$$

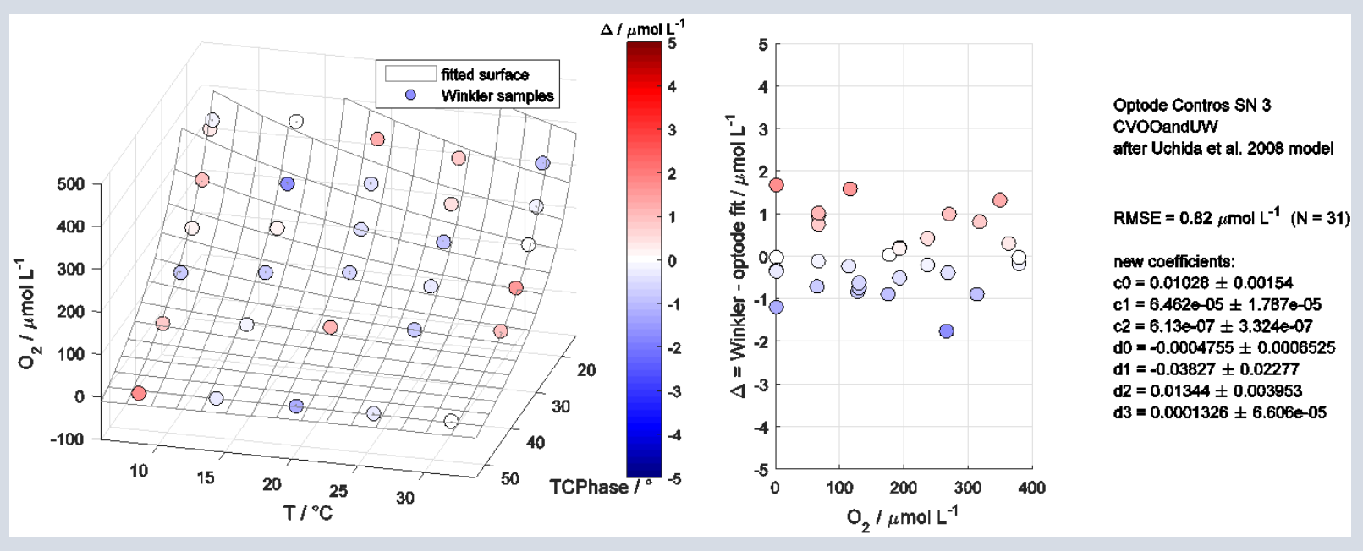
h(t): step response curve || A: amplitude
t: elapsed time || t_0: time offset || τ: response time

Results

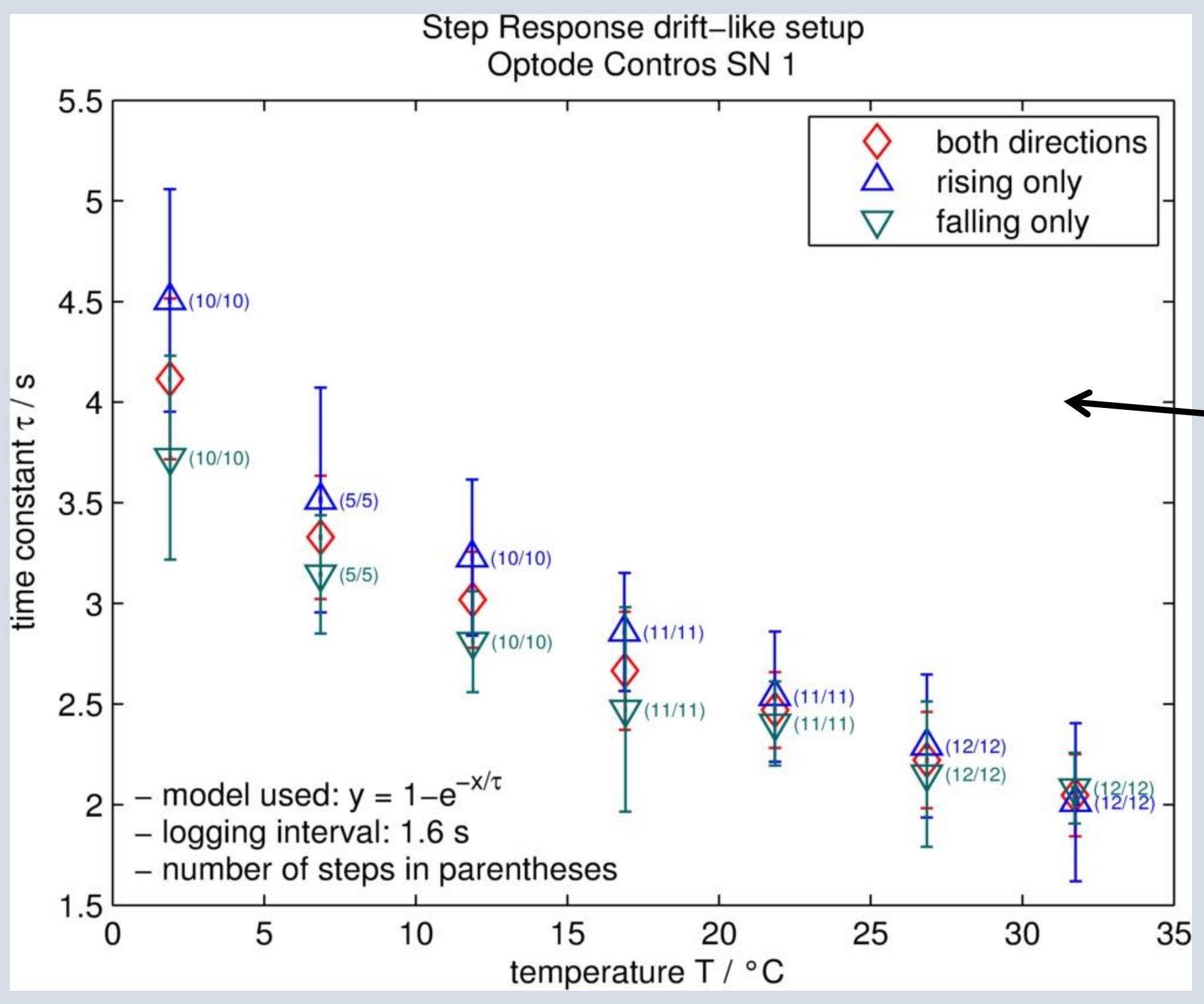
Applied model is most promising and shows robust fitting results for CONTROS HydroFlash® O_2 optodes. **Lab calibrations** yield **accuracies with RMSE < 1 µmol · L⁻¹**.



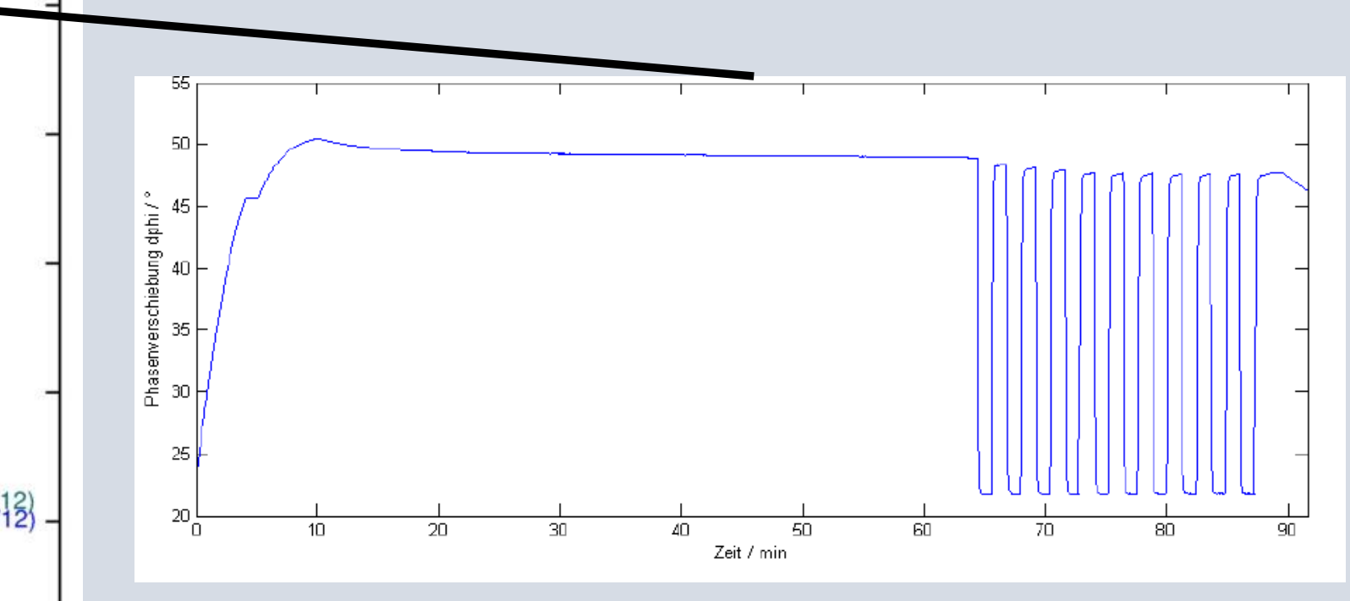
(4330#1082: RMSE = 0.82 µmol · L⁻¹)
(4330#1277: RMSE = 0.95 µmol · L⁻¹)

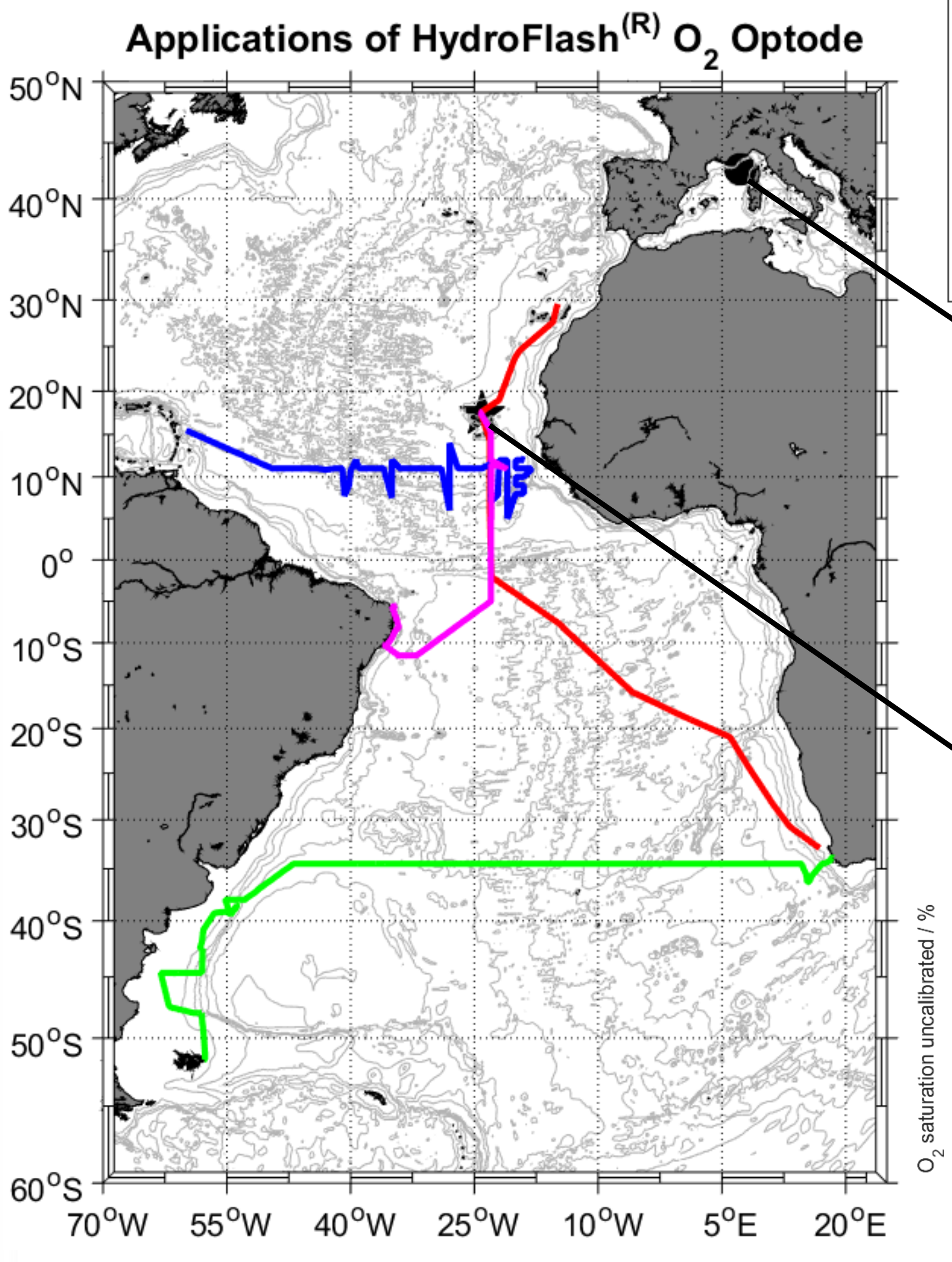


(4330#1082: RMSE = 0.82 µmol · L⁻¹)

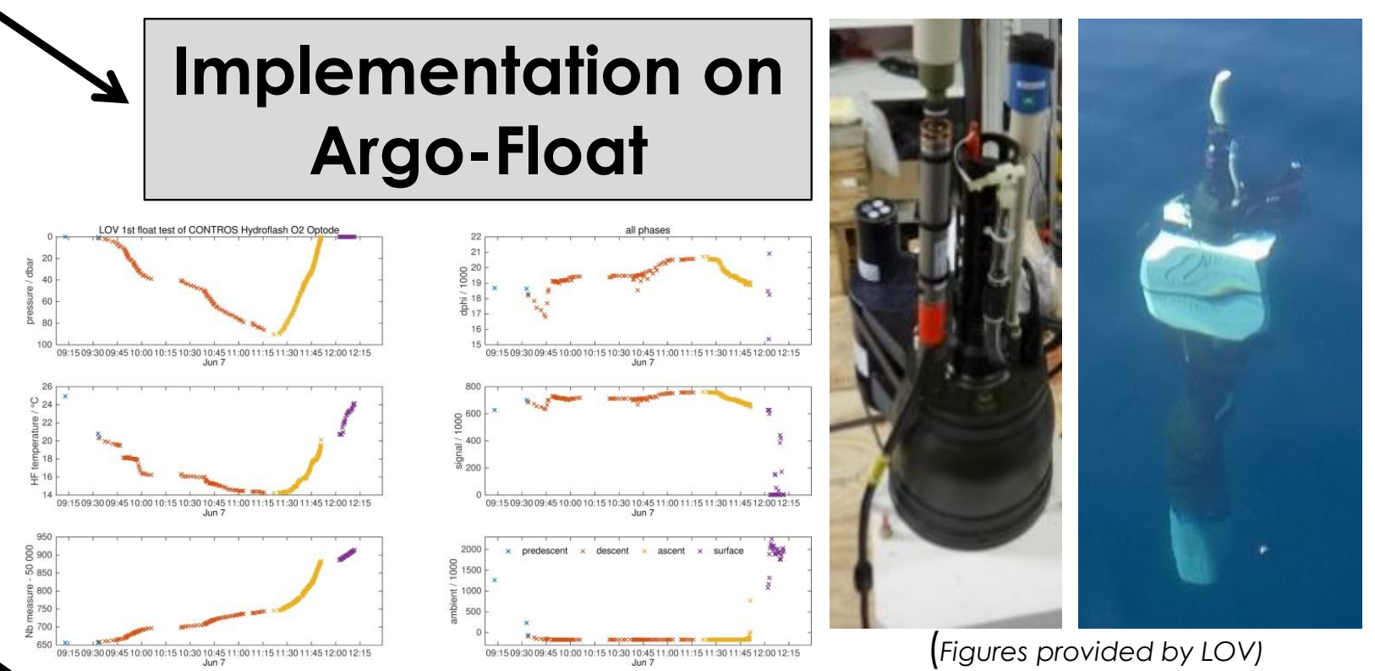


The **response time** of $\boldsymbol{\tau_{63\%} = 3 - 4s}$ is ~50% faster compared to other optodes (weak-turbulent flow).



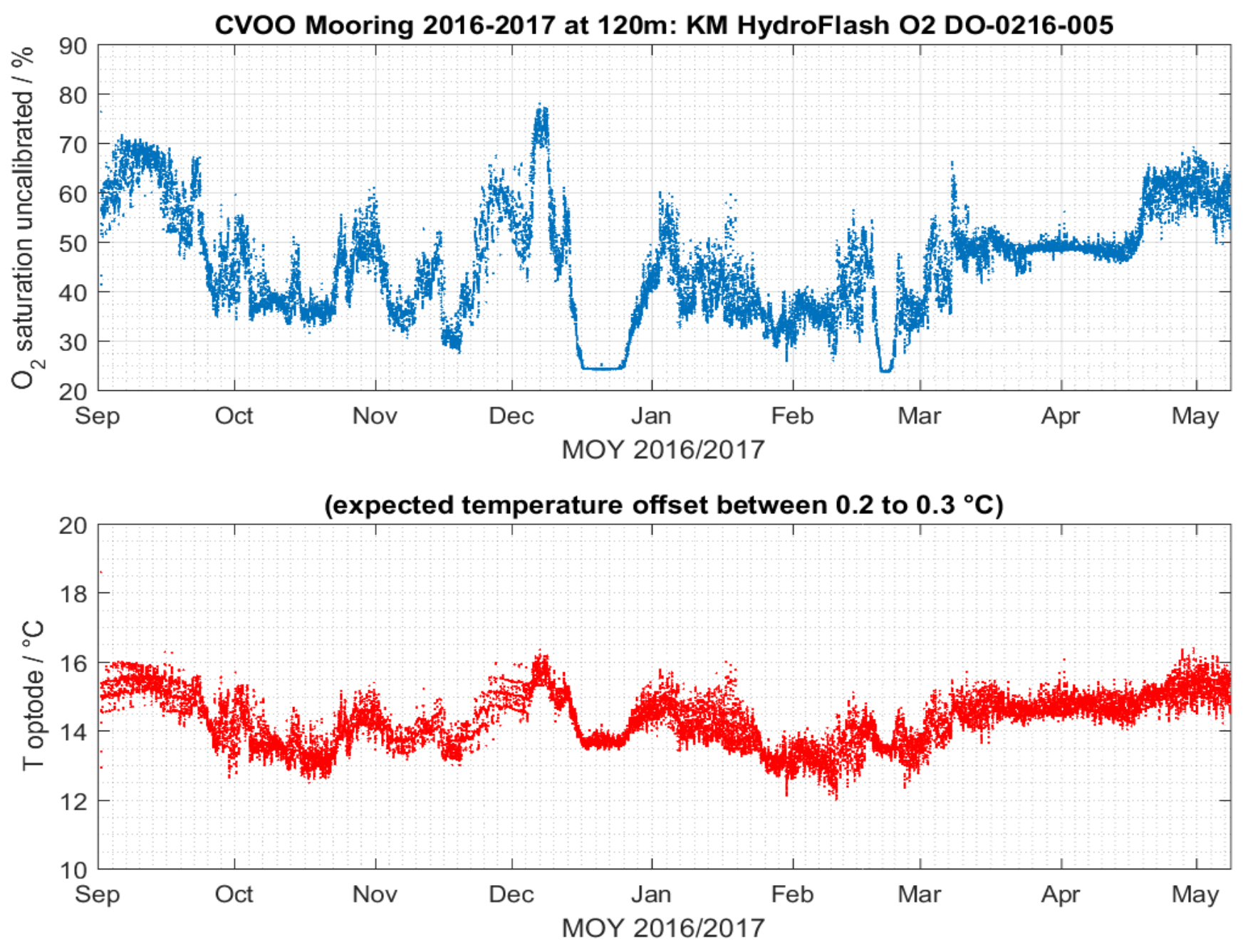


Implementation on Argo-Float



(Figures provided by LOV)

8+ months mooring data



Underway (UW) measurements:
100+ days
Performance on CTD-casts:
80+ profiles (up to 6000m)

Discussion

This novel and significantly faster optode promises high quality observations including fast oxygen level changes. A float test revealed an issue with the sun-shading (direct solar irradiation exposure), while for the rest of the profiles data was successfully recorded without peculiarities. Mooring deployments qualitatively show the utility for long-term ocean observations.

Outlook

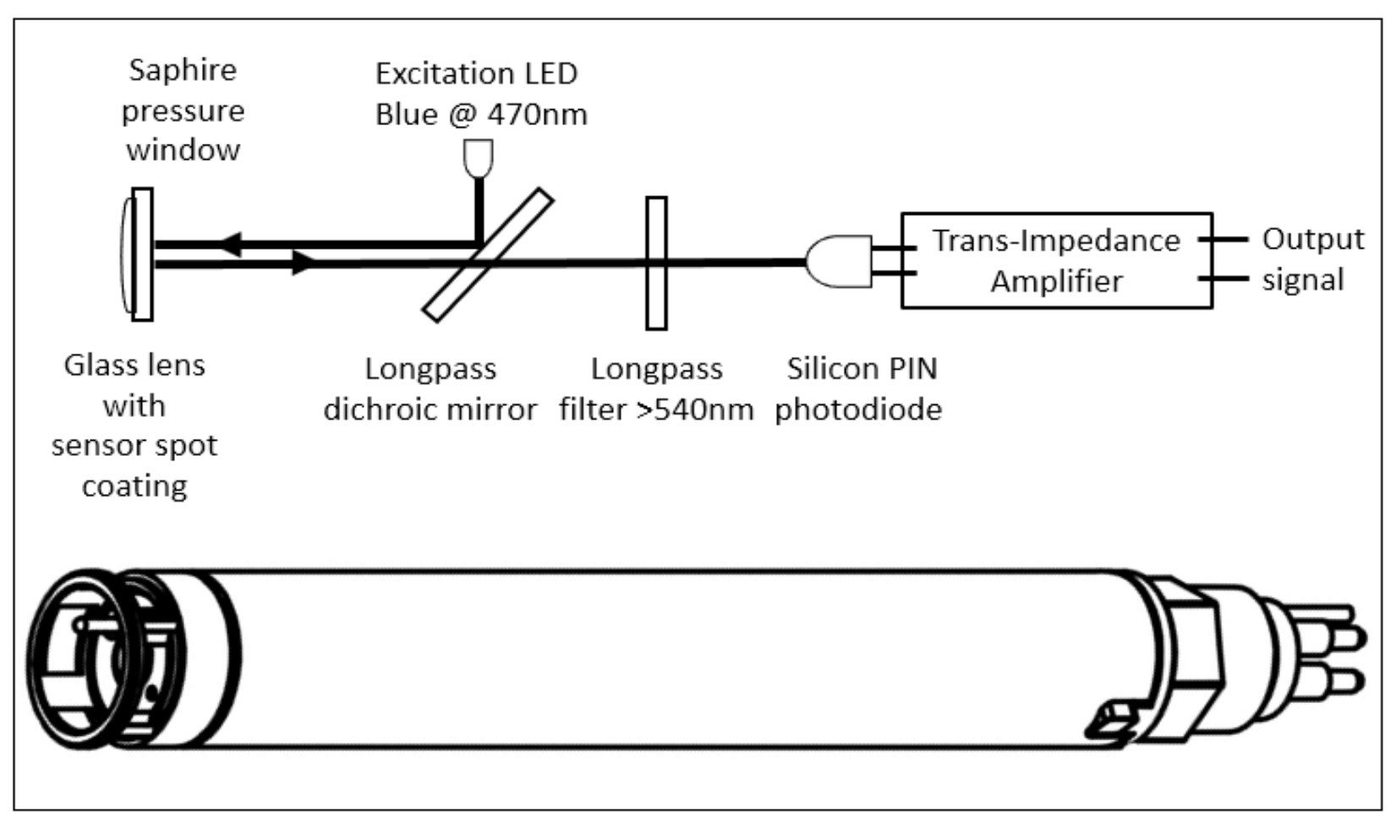
Methodological paper with full characterization & best practices of this optode is in preparation. Biogeochemical analysis of observational data will follow soon.

Optode outlook for pH and CO_2

Universal opto-electronics for pH and CO_2 measurements based on the fluorescence quenching detection principle have been developed with low power consumption and a small form factor (15*60 mm). Precision and response time are constrained by the chemical dyes on the spots.

While the new compact and low-power hardware allows for expanding the range of optode sensors, the measuring quality is not yet in the range of most scientific requirements.

Future development work will focus on further miniaturization, improved accuracy and enhanced characterization of the sensors.



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– Note –
You will find me at my poster
Tuesday, 26.3
12:30 – 13:30

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