Supporting Information for

# Skin temperature correction for calculations of air-sea oxygen flux and annual net community production

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## Introduction

**Text S1** summarized the air-sea gas exchange model used for air-sea oxygen flux calculation

**Figure S1** The difference between the ERA5-derived skin temperature correction term ($\Delta T$) and the fixed correction term of -0.17 K.

## Text S1. The air-sea $O_2$ flux ($F_{A\text{-}S}$) calculation

The air-sea $O_2$ flux ($F_{A\text{-}S}$) was calculated using the model described by Liang et al. (2013) and Emerson and Bushinsky (2016), in which both fluxes from diffusion ($F_S$) and bubble injection ($F_B$) were considered (Equation 1). A correction factor for bubble flux ($\beta = 0.37$) was also applied (Emerson et al. 2019). We defined the $O_2$ flux from air to the ocean as positive.

$$F_{A-S} = F_S + \beta \cdot F_B \qquad \text{mol m}^{-2}\text{ d}^{-1} \quad (1)$$

The diffusion flux $F_s$ was calculated using Equation 3 (Emerson and Bushinsky, 2016), where $[O_2]$ was the measured seawater oxygen concentration in the surface mixed layer, and $[O_2]_{sat}$ was the saturation concentration of oxygen at the given temperature and salinity (Garcia and Gordon, 1992, 1993). When the mixed layer $[O_2]$ is higher than the saturation value, $O_2$ diffuses out of the ocean and $F_s$ is negative. Because $[O_2]_{sat}$ in Equation 2 and the Schmidt number $S_c$ in Equation 3-4 are both temperature-dependent, the correction of cool skin effect for skin temperature would affect the calculation of $F_S$.

$$F_S = k_s \cdot ([O_2]_{sat} - [O_2]) \qquad \text{mol m}^{-2}\text{ d}^{-1} \quad (2)$$

$k_s$ is the mass transfer coefficient for air-sea gas diffusion (Emerson and Bushinsky, 2016).

$$k_s = 1.3 \times 10^{-4} \cdot u_*^a \cdot \left(\frac{S_c}{660}\right)^{-0.5} \qquad \text{m s}^{-1} \quad (3)$$

$S_c$ is the Schmidt number, a function of temperature (Wanninkhof, 1992).

$$S_c = 1953.4 - 128 \cdot t + 3.9918 \cdot t^2 - 0.0005091 \cdot t^3 \quad (4)$$

$u_*^a$ and $u_*^w$ were water-side and air-side friction velocities, respectively (Emerson and Bushinsky, 2016), where $U_{10}$ was wind speed at 10 m from the Advanced Scatterometer (ASCAT) data product (http://apdrc.soest.hawaii.edu/datadoc/ascat.php).

$$u_*^w = 0.034 \cdot u_*^a \qquad \text{m s}^{-1} \qquad (5)$$

$$u_*^a = \sqrt{C_d} \cdot U_{10} \qquad \text{m s}^{-1} \qquad (6)$$

$C_d$ was the drag coefficient, parameterized for different $U_{10}$ ranges (Liang et al. 2013).

$$C_d = \begin{cases} 0.0012 & \text{if } U_{10} <= 11 \text{ m s}^{-1} \\ (0.49 + 0.065 \cdot U_{10}) \times 10^{-3} & \text{if } 11 \text{ m s}^{-1} < U_{10} <= 20 \text{ m s}^{-1} \\ 0.0018 & \text{if } U_{10} > 20 \text{ m s}^{-1} \end{cases} \qquad (7)$$

The bubble flux $F_B$ included fluxes from small (collapsing) bubble ($F_c$) and large bubble ($F_p$).

$$F_B = F_c + F_p \qquad \text{mol m}^{-2} \text{ d}^{-1} \qquad (8)$$

Small bubbles collapsed and completely dissolved in the water, adding $O_2$ into the ocean. The small bubble flux $F_c$ was calculated as the mass transfer coefficient for small bubbles ($k_c$) multiplied by the mole fraction of oxygen in the air (Liang et al. 2013), where ($X_{O_2} = 0.20946$).

$$F_c = k_c \cdot X_{O_2} \qquad \text{mol m}^{-2} \text{ d}^{-1} \qquad (9)$$

$$k_c = 5.56 \cdot (u_*^w)^{3.86} \qquad \text{mol m}^{-2} \text{ s}^{-1} \qquad (10)$$

On the other hand, large bubbles have gas exchange with the surrounding seawater while ascending in the mixed layer, and they eventually go back to the atmosphere. The large bubble flux $F_p$ is calculated using Equation 11.

$$F_p = k_p\big((1+\Delta P)\cdot[O_2]_{sat} - [O_2]\big) \qquad \text{mol m}^{-2}\text{ d}^{-1} \quad (11)$$

The mass transfer coefficient for large bubbles ($k_p$), and the bubble produced increment of supersaturation (ΔP) were calculated using Equations 12 and 13, respectively (Emerson and Bushinsky, 2016).

$$k_p = 5.5\cdot(u_*^w)^{2.76}\cdot\left(\frac{S_c}{660}\right)^{-0.67} \qquad \text{m s}^{-1} \quad (12)$$

$$\Delta \mathrm{P} = 1.52\cdot(u_*^w)^{1.06} \quad (13)$$

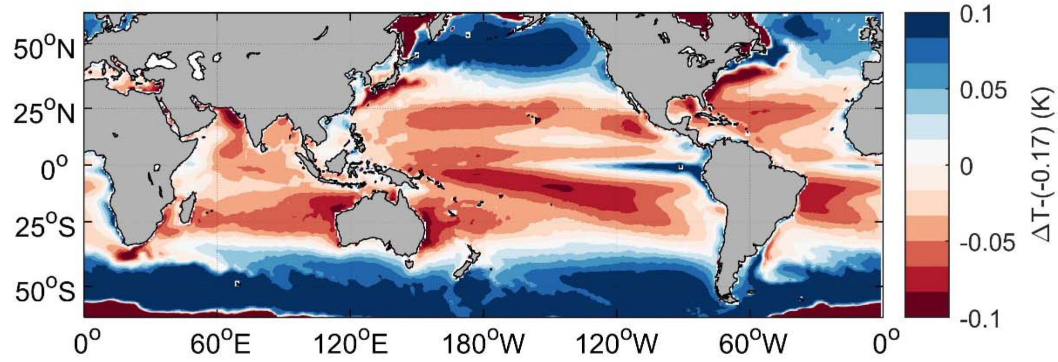

**Figure S1** The difference between the ERA5-derived ΔT and the fixed correction term of -0.17 K.