Supporting Information for

Significant contribution of physical transport in Marine Carbon Monoxide Cycles — Observations in the East Sea (Sea of Japan), the Western North Pacific, and the Bering Sea in summer

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Introduction

This supporting information provides the supplementary figures and tables concerned with the derivation of Schmidt number of carbon monoxide and the water column structure.

Text S1. Derivation of *Sc* for CO

Schmidt number is dimensionless and defined as the ratio of momentum diffusivity to mass diffusivity. The former is expressed with the kinematic diffusivity which is the ratio of the dynamic diffusivity to the density of solution. Although there are several parameterizations for dynamic diffusivity and density of freshwater and seawater, we adopt Korson et al. (1969) and Millero (1974) for calculation of dynamic viscosity and Millero and Poisson (1981) for density. Recently Sharqawy et al. (2010) compiled existing parameterizations for the chemical engineering purpose. The deviation between them was less than 0.1 % for density, while dynamic viscosity varied up to 1.2% at the freezing point of seawater at salinity 35, which may be due to parameterization on the unmeasured value.

Diffusion coefficient for CO was measured by Wise and Houghton (1968) only, which was used by Bates et al. (1995) for calculation of the Schmidt number of CO and seemingly by Conrad et al. (1982), too. Conrad et al. (1982) used the value, 2.3×10^{-9} m^2 s^{-1}, which was measured at 20°C in freshwater in Wise and Houghton (1968). Several parameterizations for gas diffusivity were provided in literature. Among them Wilke and Chang (1955), Hayduk and Laudie (1974), and Hayduk and Minhas (1982) are often used (e.g., Johnson (2010); Blomquist et al. (2012)). We adopt parameterization by Wise and Houghton (1968), because they used their own experimental results to derive diffusion coefficient. However, we need to modify their values to account for different temperature scale, water vapor pressure, and salt effect as follows: When calculating diffusion coefficients using the Erying equation (S1), we modified the temperature to the ITS 90 scale, absolute Kelvin temperature of 273.15, and water vapor pressure by Ambrose and Lawrenson (1972).

$$D = B^{*}\exp(-\Delta E_a/RT) \quad \text{(S1)}$$

However, it does not include "salt effect" which lowered diffusivity by up to 8% depending on gases (e.g., King and Saltzman (1995)). Following Jähne et al. (1987)'s experiments, we applied the salt effect linearly in parameterization assuming 6% to be lower at salinity 35 than freshwater. Finally we refit the diffusion coefficients with Levenberg-Marquardt method to determine the pre-exponential constant, B, and activation energy, ΔE_a. The results are compared in Table S1 and shown in Figure S1.

To derive the CO Schmidt number we applied the 4th order of polynomial function of temperature in Celsius (t) and salinity (S) as follows:

$$Sc = A_0 + A_1\, t + A_2\, t^2 + A_3\, t^3 + A_4\, t^4 + S(B_0 + B_1\, t + B_2\, t^2 + B_3\, t^3 + B_4\, t^4) \quad \text{(S2)}$$

The coefficients A_i's and B_i's are listed in Table S2. The fitting was limited from -2°C to 38°C and 0 to 35 salinity. Deviations from this parameterization for the measurements by Wise and Houghton (1968) and for other parameterizations are compared in Figure S2 in case of fresh water and seawater at salinity 35.

Table S1. Comparison of the coefficients of the Eyring equation

	Wise and Houghton (1968)	This study
Pre-exponent, B ($x10^5$ m^2 s^{-1})	4.07(±0.50)	4.47(±0.32)
Ea (kJ mol^{-1})	24.518(±0.042)	24.831(±0.182)

Table S2. Polynomial coefficients in Equation S2

	A_0	A_1	A_2	A_3	A_4
Coeff.	2237.12	-159.444	5.70687	-0.01092382	0.00086435
	B_0	B_1	B_2	B_3	B_4
Coeff.	5.68820	-0.34916	0.011238	-0.00020114	1.5289E-06

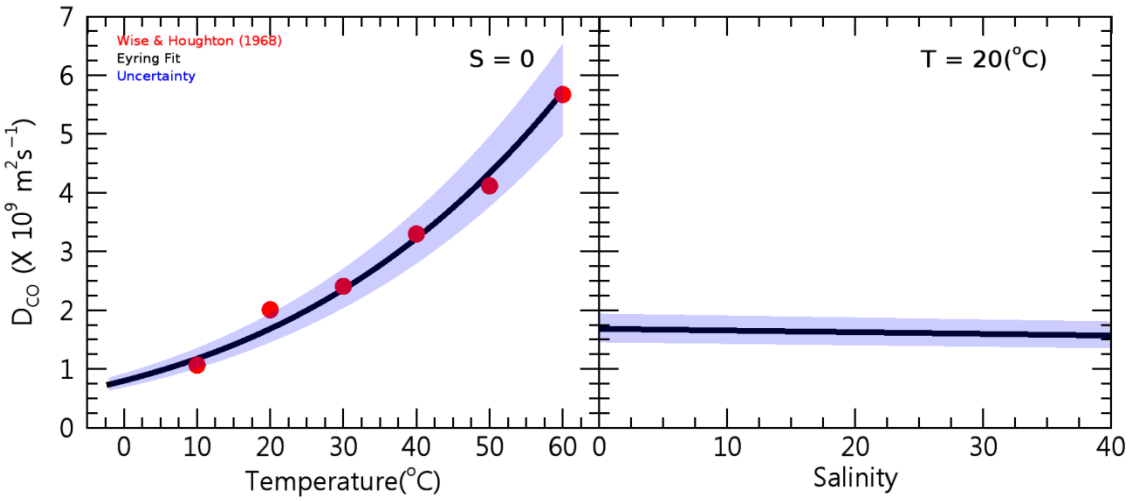

Figure S1. Diffusion coefficients of CO measured by Wise and Houghton (1968) (red solid circle) and the Eyring fitting (black solid line) to the data against temperature for fresh water (left) and fitting against salinity at 20°C. Blue shade represents uncertainty of the given diffusion coefficients.

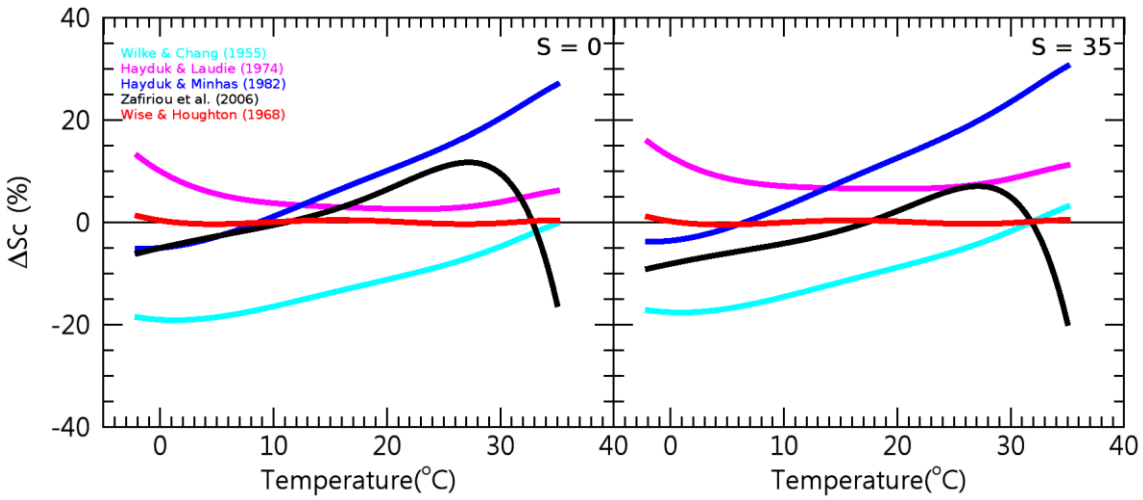

Figure S2. Deviations from the Schmidt number described in Eq. S2 and Table S2. Various Sc parameterizations in literature are indexed with matching the color of curves in the left panel.

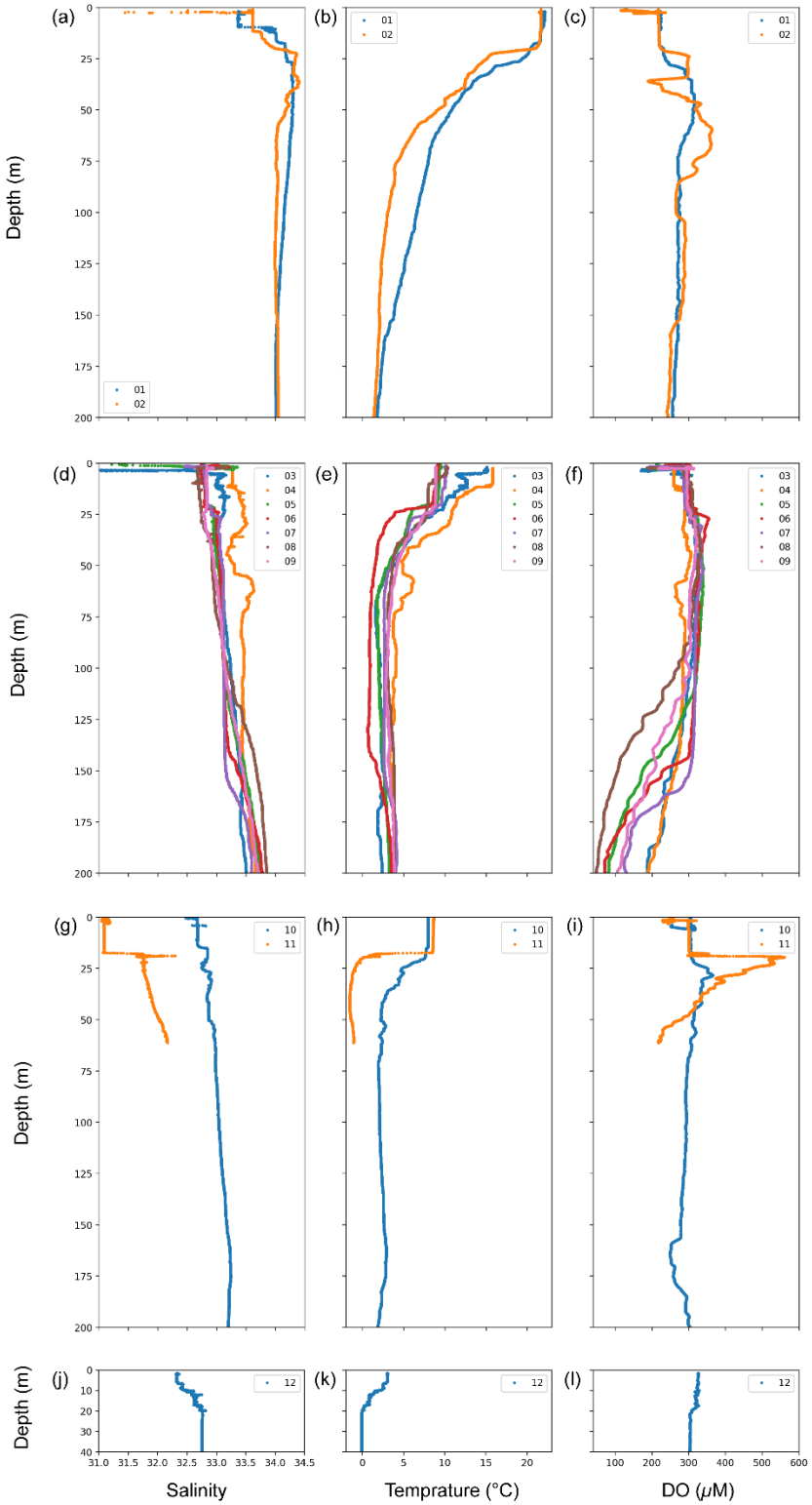

Figure S3. Vertical distribution of salinity, water temperature, and DO at the stations of ES (a–c), NP (d–f), and BS (g–i), and at Station 12 (j–l).

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