Supplement of

Towards a process-based estimation of global lake methane emissions using LAKE2.6

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Table S1: Tuned CH_4-related parameters and light extinction coefficient for 15 lakes used in model calibration. Values inside the brackets represent the ranges of tuned parameters, while values outside the brackets represent the values used for establishing the relationship with lake properties.

NO	Lake name	q_{10}	P_0 (10^{-8})	α_{new} (m^{-1})	light extinction coefficient (m^{-1})
1	Mellersta Harrsjön		3.5(3.3-3.5)	4.9(4.7-4.9)	0.43
2	Inre Harrsjön		3.6(3.5-3.6)	9(8.8-9)	0.43
3	Villasjön		3.7(3.4-3.7)	3.5(3.3-3.5)	0.43
4	Lake Tämnaren		3.4(3.4-3.6)	4.2(4.2-4.5)	1.07
5	Lake Toolik		3.6(2.9-3.6)	7.7(7-7.7)	0.52
6	Lake Kuivajärvi		2(2-2.1)	10.6(10.6-11)	0.3
7	Lake Dagow		3.3(3.1-3.3)	1.9(1.8-1.9)	0.61
8	Lake Suwa	2.5	-(6.2-8.8)	1(1-1.4)	0.62
9	Trout Bog		2.2(2.2-2.4)	3.6(3.5-3.9)	4.96
10	Lake Acton		2.9(2.9-3.2)	1.4(1.4-1.5)	0.23
11	Lake Edward		1.6	11	4.6
12	Lake Victoria		1.2	11	5.4
13	Lake Tanganyika		1.3	11	0.01
14	Lake Albert		1.4	11	3.5
15	Lake Kivu		1.7	11	1.5

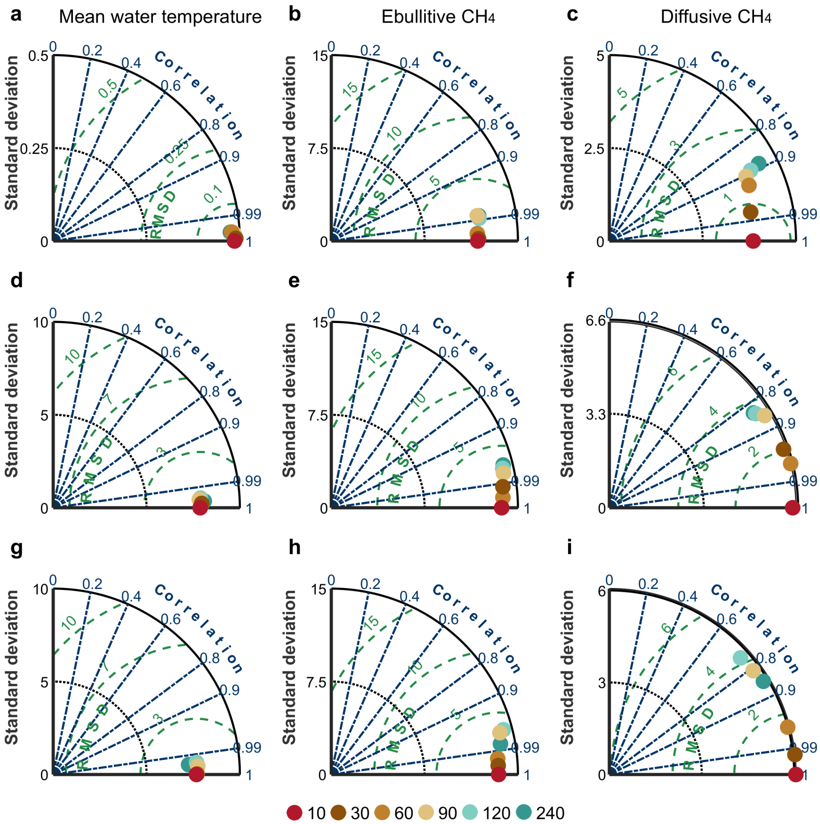

Figure S1: Taylor diagrams indicating model performance under different time step (dt) settings in lakes with the same water and sediment depths across three climate regions, including 60°N–90°N (**a–c**), 30°N–60°N (**d–f**) and 30°S–30 °N (**g–i**). The three columns represent results for daily mean water temperature (°C), ebullitive CH_4 flux (mgCH_4 m^{-2} day^{-1}) and diffusive CH_4 flux (mgCH_4 m^{-2} day^{-1}), respectively. Different colors indicate simulations with dt ranging from 10 to 240 seconds. Model performance is evaluated relative to the simulation with a 10-second dt, which is assumed to represent the reference. The standard deviation, correlation coefficient (R) and root mean square error (RMSE) are calculated between the reference simulation and those with other dt.

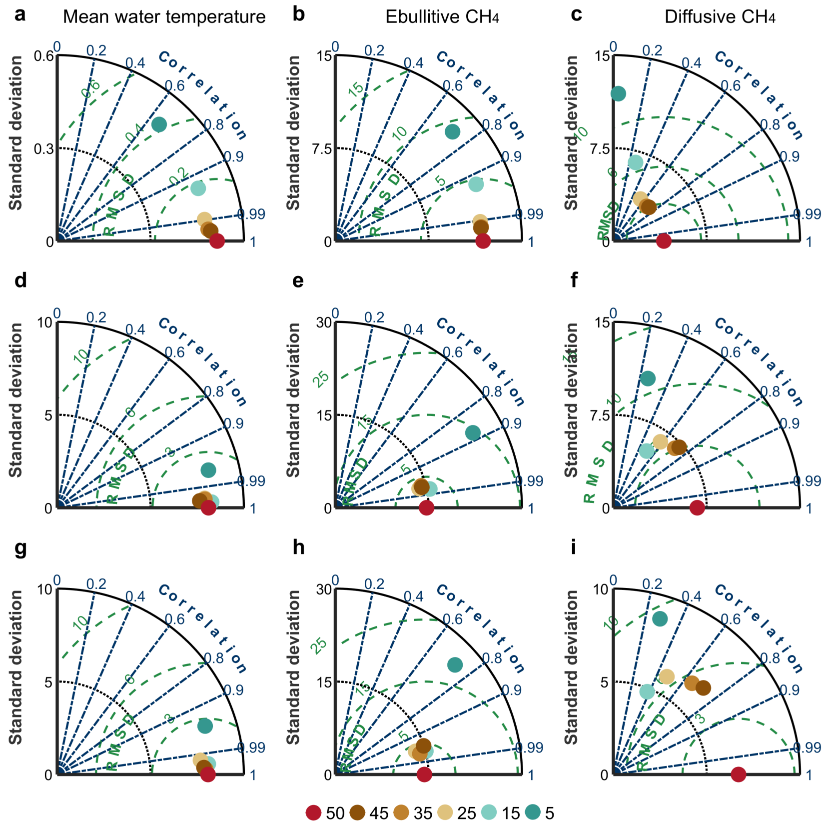

Figure S2: Same as Fig. S1, but for model performance under different settings of the number of layers in the water column (M). The standard deviation, R and RMSE are calculated between the reference simulation of M set to 50 and those with other M values.

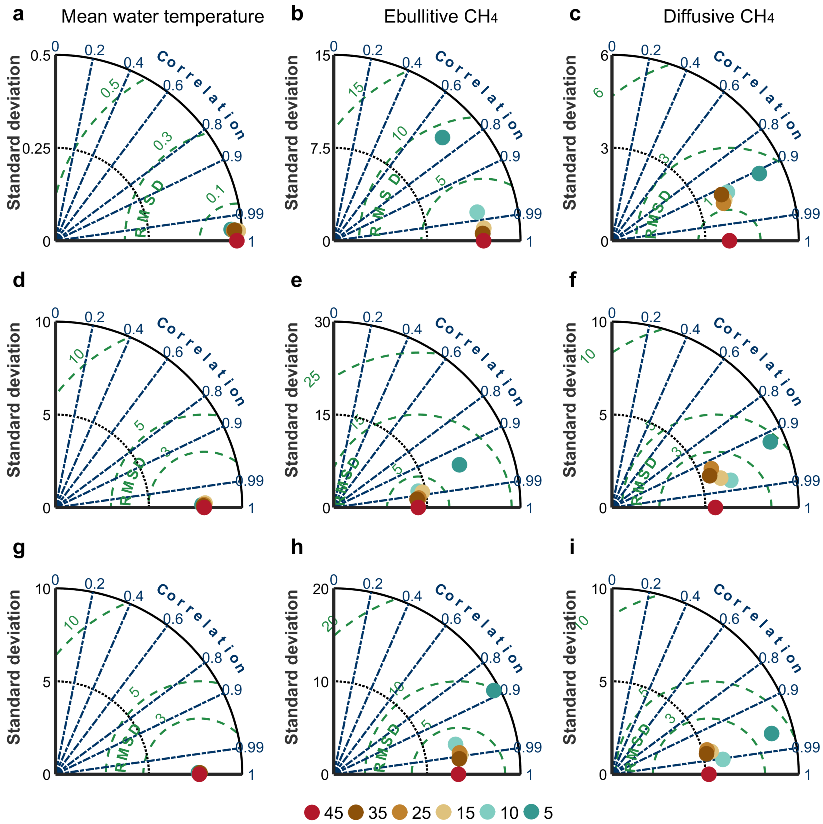

Figure S3: Same as Fig. S1, but for model performance under different settings of the number of layers in the sediment column (ns). The standard deviation, R and RMSE are calculated between the reference simulation of ns set to 45 and those with other ns values.

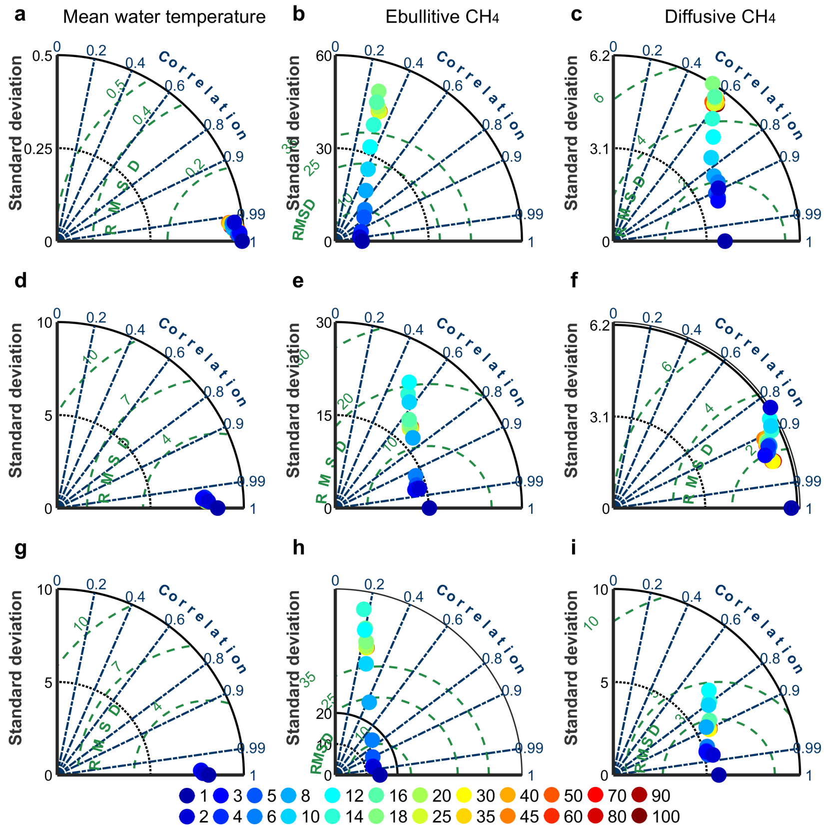

Figure S4: Same as Fig. S1, but for model performance under different settings of the sediment depth. The standard deviation, R and RMSE are calculated between the reference simulation with sediment depth set to 1 m and those with other values.

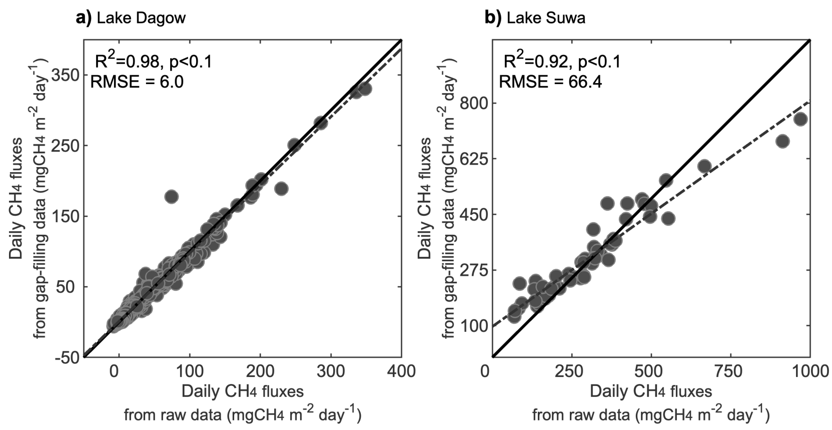

Figure S5: Comparison between daily CH_4 fluxes derived from gap-filling data using artificial neural network (ANN) and from raw data in (**a**) Lake Dagow and (**b**) Lake Suwa.

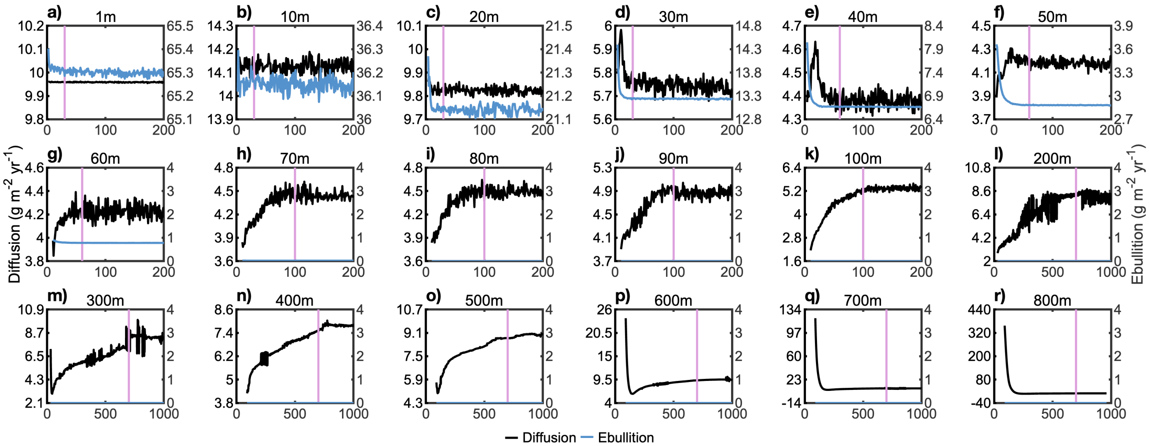

Figure S6: Annual CH_4 emissions during the 1000-year spinup period for lakes with depths of (**a**) 1 m, (**b**) 10 m, (**c**) 20 m, (**d**) 30 m (**e**) 40 m, (**f**) 50 m, (**g**) 60m, (**h**) 70 m, (**i**) 80 m, (**j**) 90 m, (**k**) 100 m, (**l**) 200 m, (**m**) 300 m, (**n**) 400 m, (**o**) 500 m, (**p**) 600 m, (**q**) 700 m and (**r**) 800 m. Black and blue lines indicate annual diffusion and ebullition, respectively. Purple lines indicate the spinup period used for model simulation in this study.

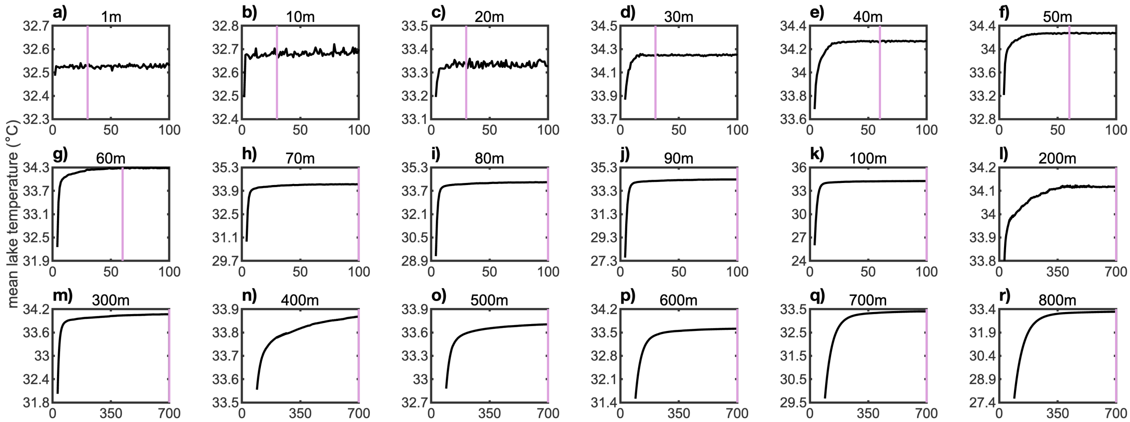

Figure S7: Same as Fig. S5 but showing mean lake temperature on 1 January during the 1000-year spinup period.

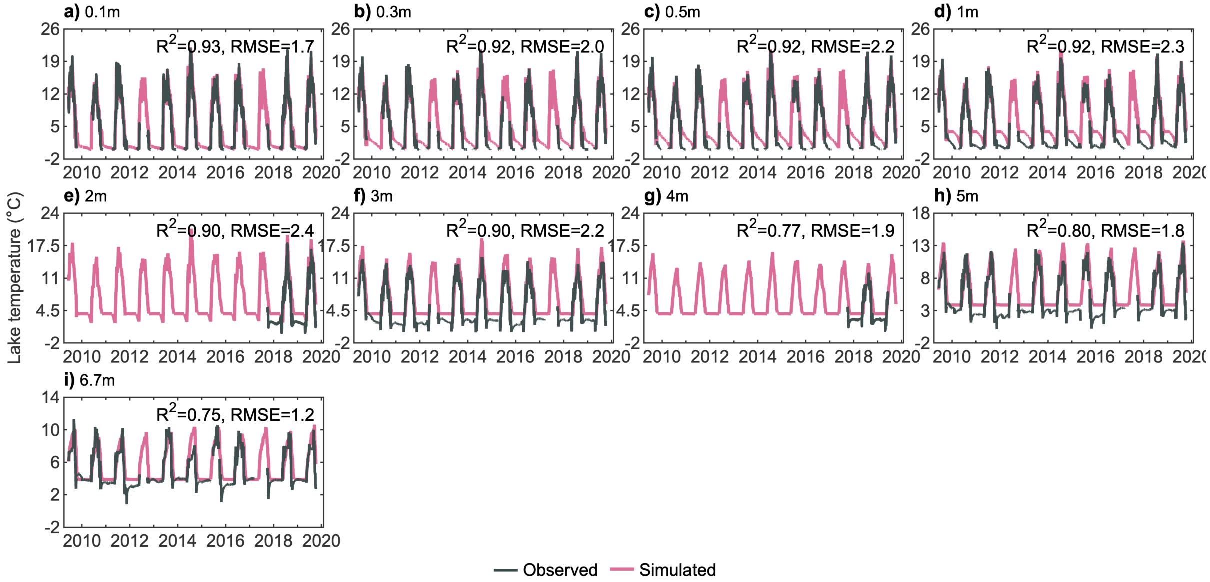

Figure S8: Comparison between simulated and observed daily lake temperature profiles in Mellersta Harrsjön (MH) at depths from 0.1 m to 6.7 m following tuning the extinction coefficient.

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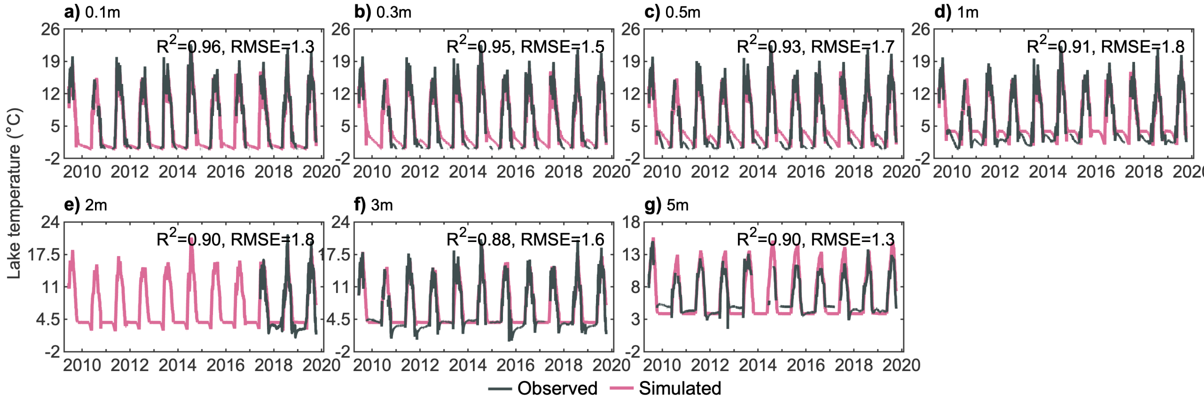

Figure S9: Comparison between simulated and observed daily lake temperature profiles in Inre Harrsjön (IH) at depths from 0.1 m to 5 m following tuning the extinction coefficient.

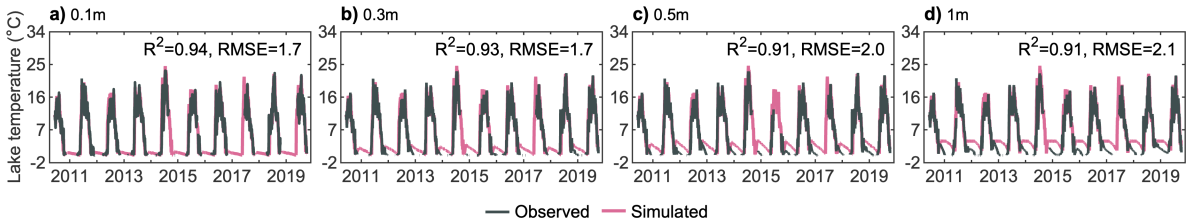

Figure S10: Comparison between simulated and observed daily lake temperature profiles in Villasjön (VS) at depths from 0.1 m to 1 m following tuning the extinction coefficient.

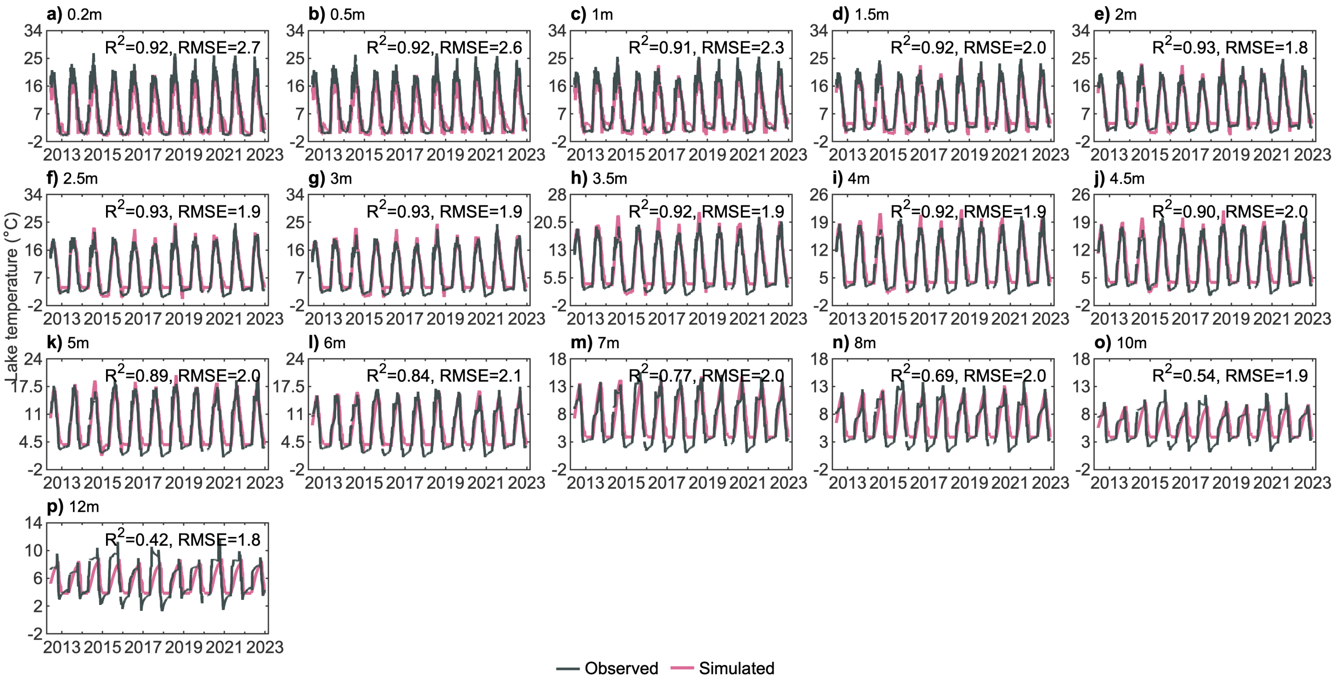

Figure S11: Comparison between simulated and observed daily lake temperature profiles in Lake Kuivajärvi at depths from 0.2 m to 10 m following tuning the extinction coefficient.

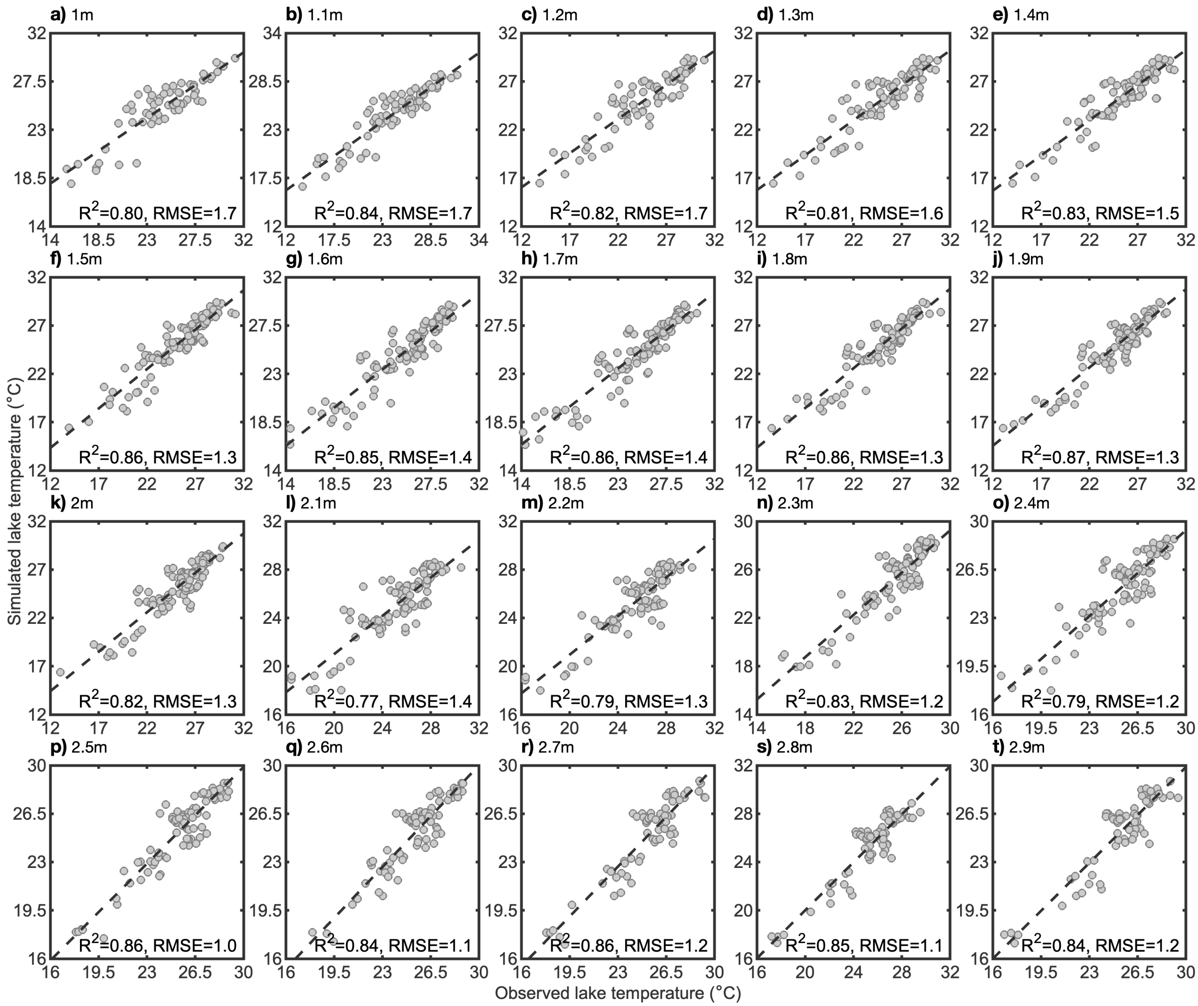

Figure S12: Comparison between simulated and observed daily lake temperature profiles in Lake Acton at depths from 1 m to 2.9 m following tuning the extinction coefficient. Due to the discontinuous observed temperature profiles, the comparison is shown as scatter plots.

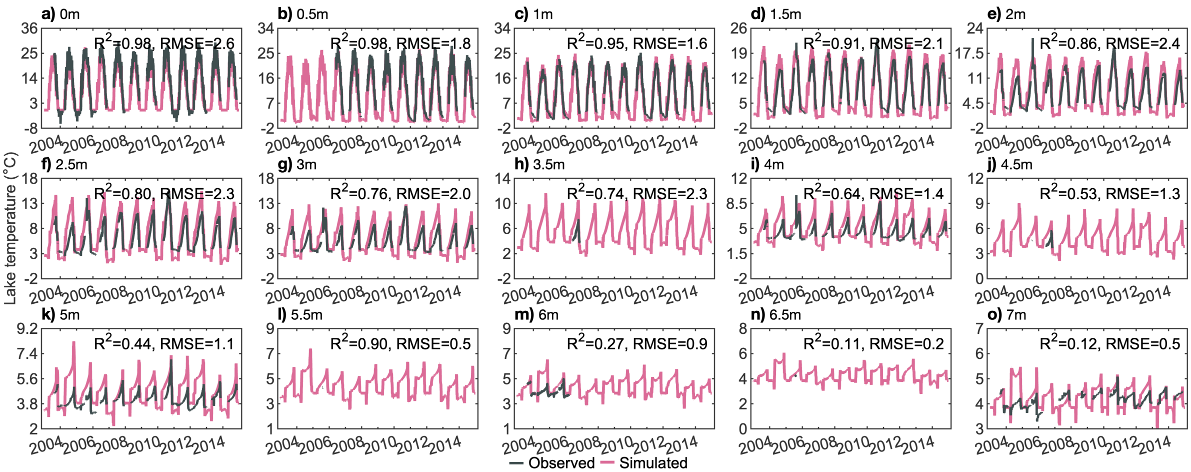

Figure S13: Comparison between simulated and observed daily lake temperature profiles in Trout Bog at depths from 0 m to 7 m following tuning the extinction coefficient.

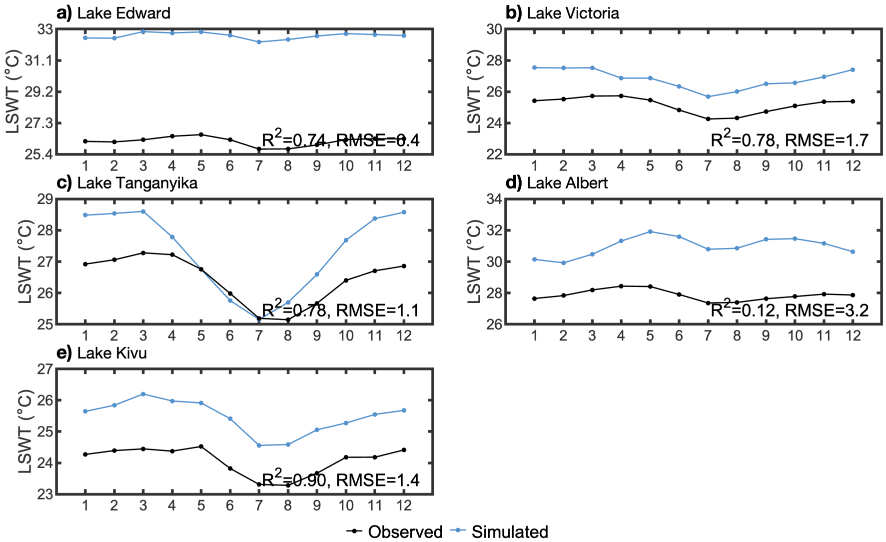

Figure S14: The seasonal cycle of LSWT between simulations and observations during the period 1996–2012 in Lake Edward (**a**), Lake Victoria (**b**), Lake Tanganyika (**c**), Lake Albert (**d**) and Lake Kivu (**e**), after tuning the extinction coefficients.

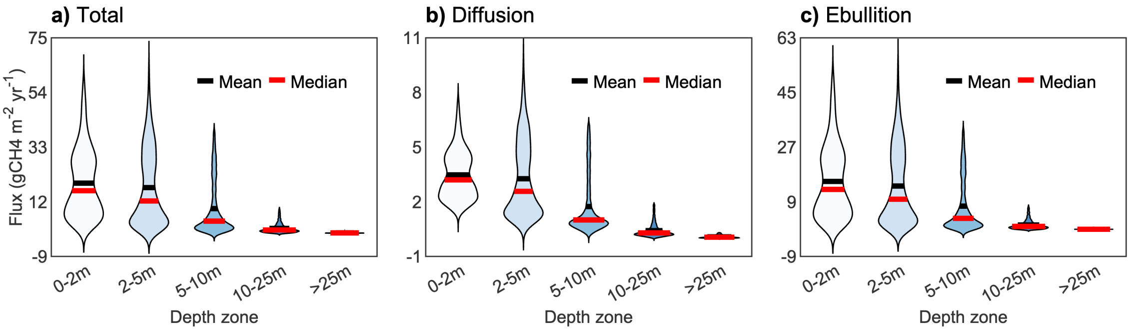

Figure S15: Violin plots for mean annual total CH_4 flux (**a**), diffusive flux (**b**) ebullitive flux(**c**) across five depth zones during the period 1980–2023. In each violin, the black and red lines represent the mean and median value of annual flux, respectively. The distribution of the violin plot was estimated by kernel density.

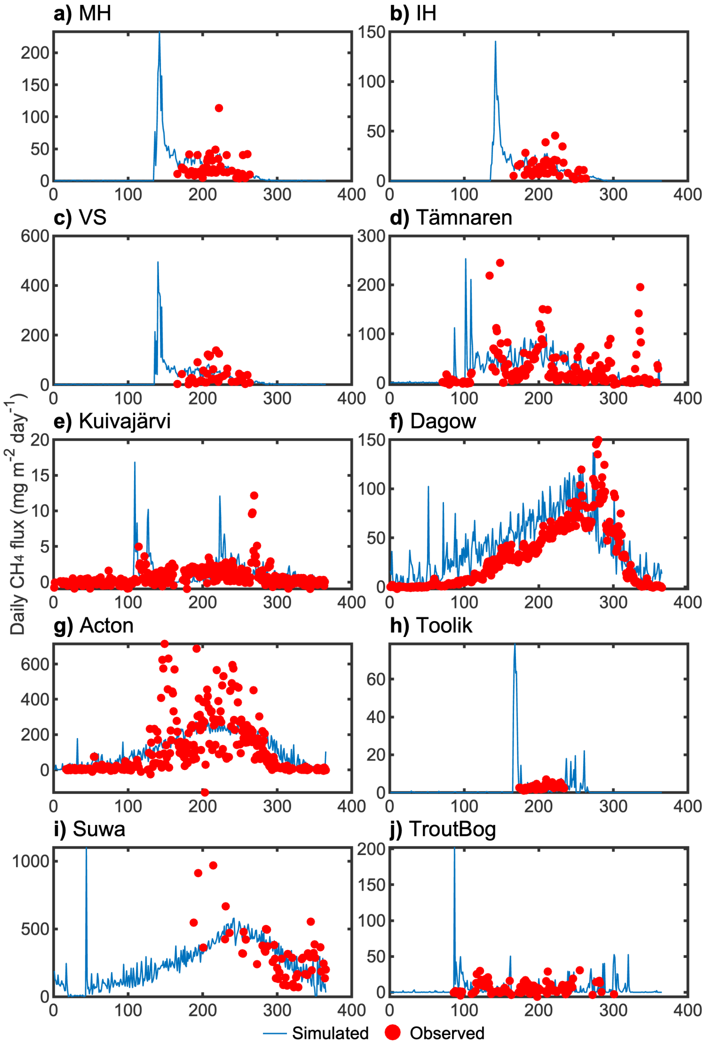

Figure S16: Comparison of simulated and observed multi-year mean daily total CH_4 fluxes for the 10 lakes with continuous observations.