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Supplement of

A high-resolution nested model to study the effects of alkalinity additions in Halifax Harbour, a mid-latitude coastal fjord

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Supporting Text

The time rates of change of the biogeochemical state variables due to biological processes and air-sea exchanges are modelled as follows:

$$\frac{\partial \mathrm{O_2}}{\partial t} = PP_{\mathrm{X}} - WR_{\mathrm{X}} - \frac{1}{h_{z_{\max}}}(SR_{\mathrm{X}})_{z=z_{\max}} \times (1 - \mathrm{e}^{-\mathrm{O_2}/30}) + \frac{1}{h_{z_{\min}}}\left(F^{\mathrm{as}}_{\mathrm{O_2}}\right)_{z=z_{\min}} \quad \text{(S1)}$$

$$\frac{\partial \mathrm{DIC}}{\partial t} = \theta_{\mathrm{C:O}}\left(WR_{\mathrm{X}} + \frac{1}{h_{z_{\max}}}(SR_{\mathrm{X}})_{z=z_{\max}} - PP_{\mathrm{X}}\right) + \left(F^{\mathrm{as}}_{\mathrm{CO_2}}\right)_{z=z_{\min}} \quad \text{(S2)}$$

$$\frac{\partial \mathrm{TA}}{\partial t} = \theta_{\mathrm{N:O}} WR_{\mathrm{X}} + r_{\mathrm{NH_4^+:SOC}} \times \frac{1}{h_{z_{\max}}}(SR_{\mathrm{X}})_{z=z_{\max}} \quad \text{(S3)}$$

where X represents either the shelf or the Halifax harbour. PP_{X} (primary production; mmol O_2 m^{-3} d^{-1}), WR_{X} (water column respiration; mmol O_2 m^{-3} d^{-1}) and SR_{X} (sediment respiration; mmol O_2 m^{-2} d^{-1}) are described in Section 4.1 of the manuscript. F^{as} (mmol m^{-2} d^{-1}) represents the air-sea flux. $h_{z_{\min}}$ and $h_{z_{\max}}$ are the thicknesses of the surface and bottom layers, respectively.

$r_{\mathrm{NH_4^+:SOC}} = 0.036$ mol N (mol O_2)$^{-1}$ corresponds to the relationship between sediment-water fluxes of ammonium and O_2, as derived by (Fennel et al., 2013). This formulation assumes that organic matter is remineralized via aerobic oxidation and coupled nitrification-denitrification. It is assumed in Equation S3 that alkalinity fluxes are equal to ammonium fluxes from the sediment and to ammonium production by water column respiration.

We assume a respiratory quotient $\theta_{\mathrm{C:O}} = 1$ mol C (mol O_2)$^{-1}$. and the nitrogen to carbon ratio following Redfield stoichiometry such that $\theta_{\mathrm{N:C}} = 16/106$ mol N (mol C)$^{-1}$. Therefore, $\theta_{\mathrm{N:O}} = \theta_{\mathrm{N:C}} \cdot \theta_{\mathrm{C:O}} = 16/106$ mol N (mol O_2)$^{-1}$.

Supporting Tables

Table S1. Coefficients for the Halifax Harbour (PP_H) and shelf (PP_S) primary production parameterization in ROMS-H2 (mmol m^{-3} d^{-1}, see Equation 3).

Table S2. Coefficients for the shelf sediment respiration parameterization in ROMS-H2 (SR_S; mmol m^{-2} d^{-1}, see Equation 5).

Table S1. Coefficients for the Halifax Harbour (PP_H) and shelf (PP_S) primary production parameterization in ROMS-H2 (mmol m^{-3} d^{-1}, see Equation 3).

Coefficient	Shelf (PP_S)	Halifax Harbour (PP_H)
a_1	0.15	0.15
b_1	0.96	0.96
b_2	0.00834	0.00834
b_3	1.4305e-06	1.4305e-06
c_1	0.01428	0.01282
c_2	4.2916e-07	5.2260e-07
d_1	0.01074	0.00945
d_2	8.5831e-07	8.5831e-07
e_1	0.00867	0.00867
e_2	2.7285e-07	2.7285e-07

Table S2. Coefficients for the shelf sediment respiration parameterization in ROMS-H2 (SRs; mmol m^{-2} d^{-1}, see Equation 5).

		e_0^i	e_1^i	e_2^i
Constant (b_0)	-0.0089677	–	–	–
Longitude (c_0)	-1.0779	–	–	–
Latitude (d_0)	1.2378	–	–	–
depth	–	-0.11620	0.00078064	0.0000011653
Temperature (surface)	–	3.5991	-0.30763	0.0081629
Temperature (bottom)	–	-3.3447	0.22212	-0.0041322
Salinity (surface)	–	-0.073341	0.30795	-0.0076414
salinity (bottom)	–	-0.077775	0.55495	-0.010899

Supporting Figures

Figure S20. Model domain integrated ΔTA and particulate feedstock in the simulation with the release at Mill Cove

Figure S21. Observation/model (ROMS-H3) comparison of temperature at the BBMP station in the Bedford Basin. Top: Surface temperature. Blue: observations; orange: ROMS-H3. Middle: Observed vertical profiles. Bottom: Simulated vertical profiles.

Figure S22. Observation/model (ROMS-H3) comparison of salinity at the BBMP station in the Bedford Basin. Top: Surface salinity. Blue: observations; orange: ROMS-H3. Middle: Observed vertical profiles. Bottom: Simulated vertical profiles.

Figure S23. Observation/model (ROMS-H3) comparison of oxygen at the BBMP station in the Bedford Basin. Top: Surface oxygen. Blue: observations; orange: ROMS-H3. Middle: Observed vertical profiles. Bottom: Simulated vertical profiles.

Figure S24. Observation/model (ROMS-H3) comparison of alkalinity at the BBMP station in the Bedford Basin. Top: Surface alkalinity. Blue: observations; orange: ROMS-H3. Middle: Comparison at 60m. Bottom: Simulated vertical profiles.

Figure S25. Observation/model (ROMS-H3) comparison of DIC at the BBMP station in the Bedford Basin. Top: Surface DIC. Blue: observations; orange: ROMS-H3. Middle: Comparison at 60m. Bottom: Simulated vertical profiles.

Figure S26. Comparison of net CO_2 uptake (per area; tons and % realized) in ROMS-H2 and ROMS-H3. The Outer Harbour in H2 is smaller than shown in Figure 1 to match the extent of ROMS-H3.

Figure S27. Time series of spatially integrated net CO_2 uptake in the simulation with ROMS-H3 (pink) and with ROMS-H2 (green), excluding the harbour area covered by ROMS-H3, for release at Tufts Cove of (a) dissolved or (b) particulate feedstock, and release at Mill Cove of (c) dissolved and (d) particulate feedstock. The thick black line indicates the difference between total fluxes calculated with ROMS-H2 (full grid, as in Figure 8) and with the offline nest ROMS-H2 (outer grid)+ROMS-H3.

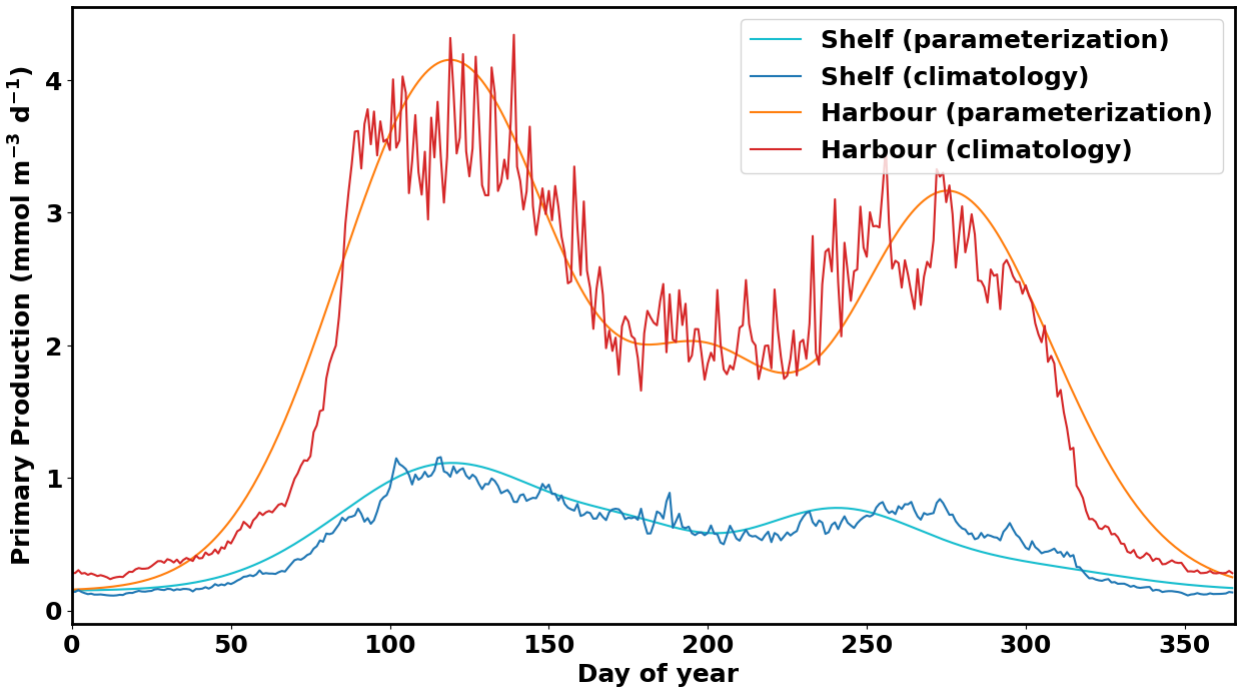

Figure S1. Parameterization of primary production in the Halifax Harbour and on the Scotian Shelf.

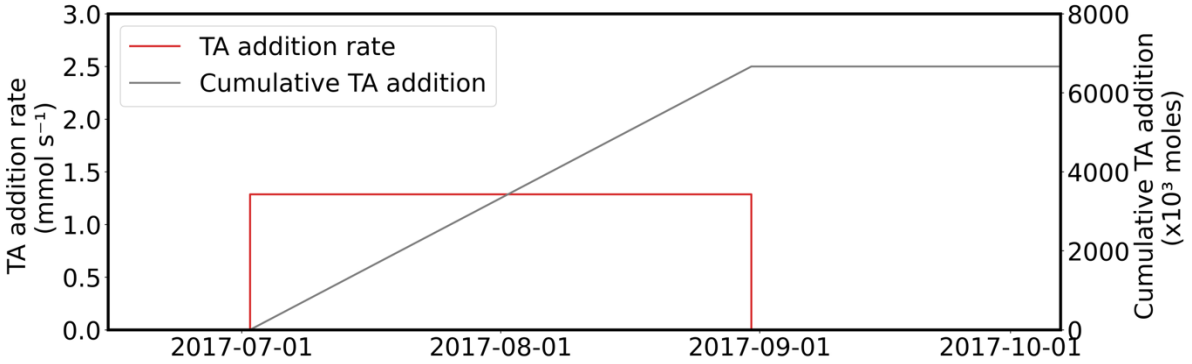

Figure S2. Alkalinity addition rate and cumulative alkalinity addition in the sensitivity runs.

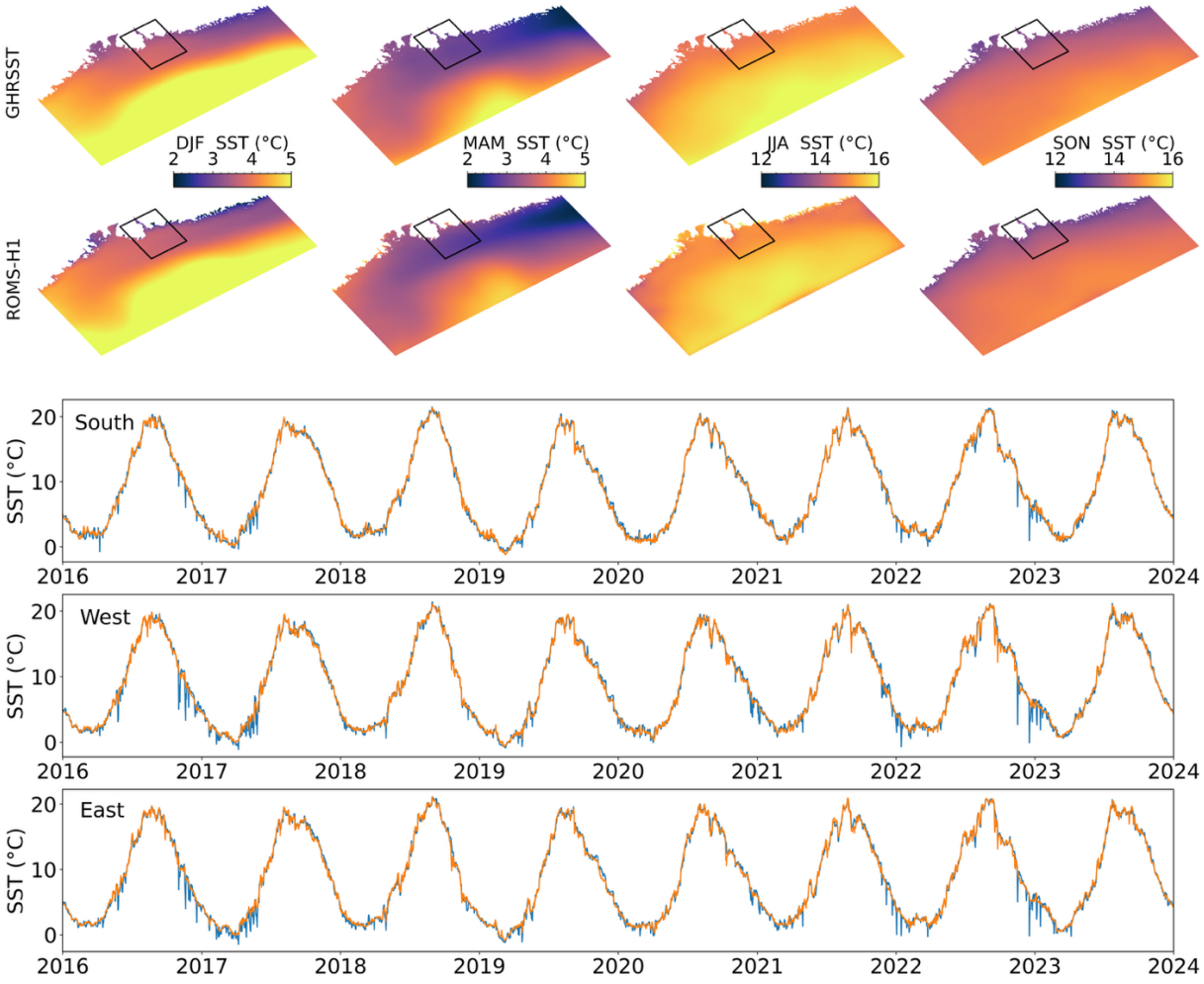

Figure S3. Observation/model comparison of surface temperature in ROMS-H1. Top: Seasonal maps. Bottom: Time series at the middle of each boundary. Blue: GHRSST; orange: ROMS.

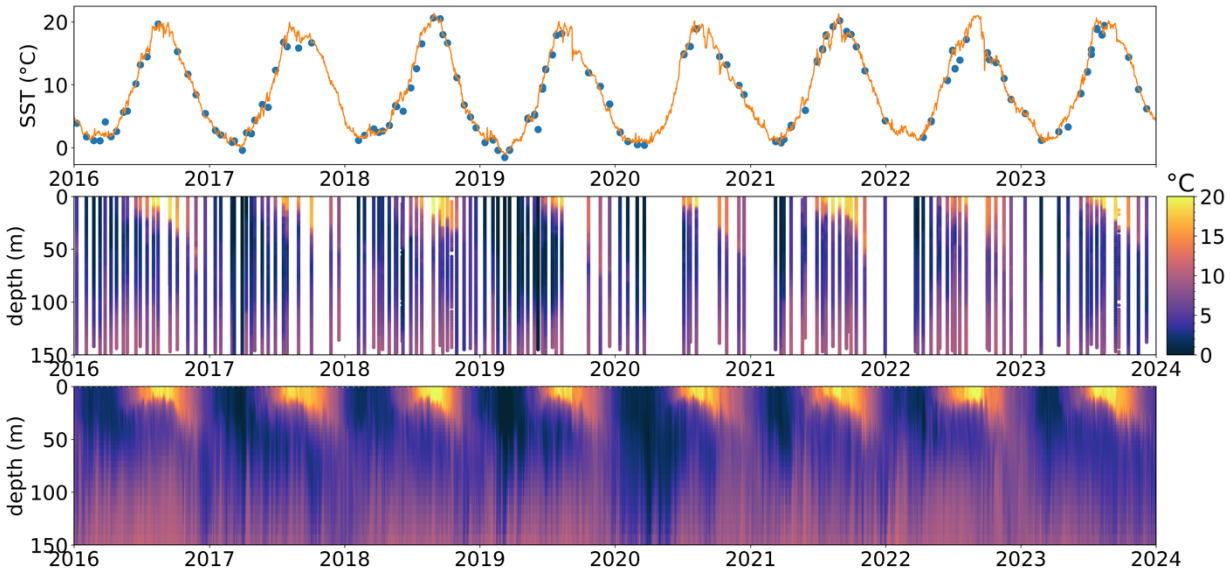

Figure S4. Observation/model comparison of temperature at Station 2. Top: Surface temperature. Blue: observation; orange: ROMS-H1. Middle: Observed vertical profiles. Bottom: Simulated vertical profiles.

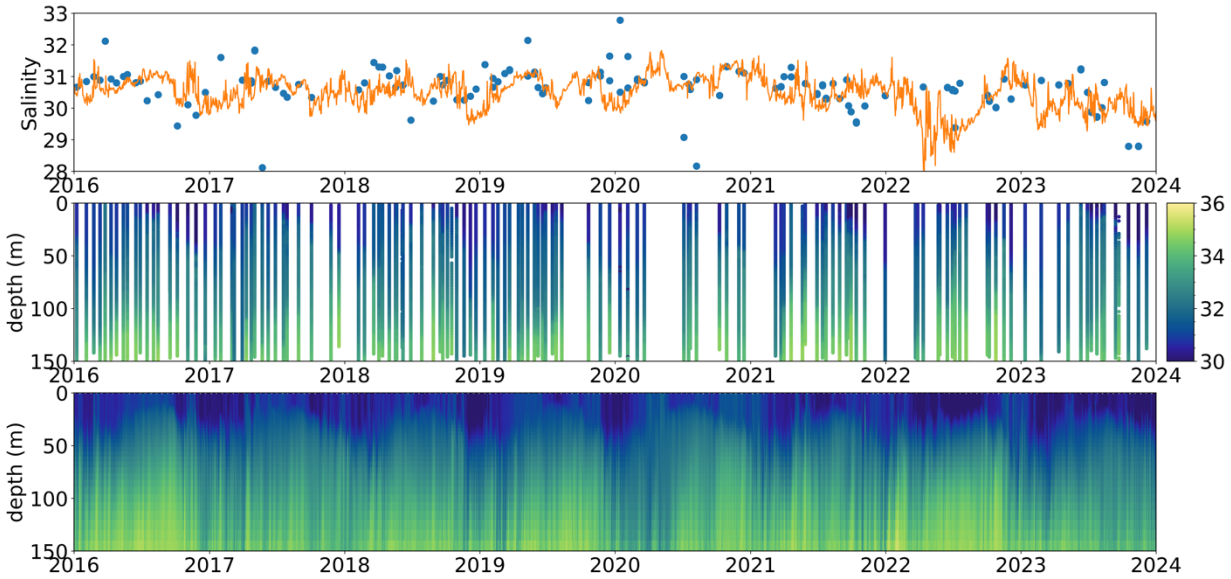

Figure S5. Observation/model comparison of salinity at Station 2. Top: Surface salinity. Blue: observation; orange: ROMS-H1. Middle: Observed vertical profiles. Bottom: Simulated vertical profiles.

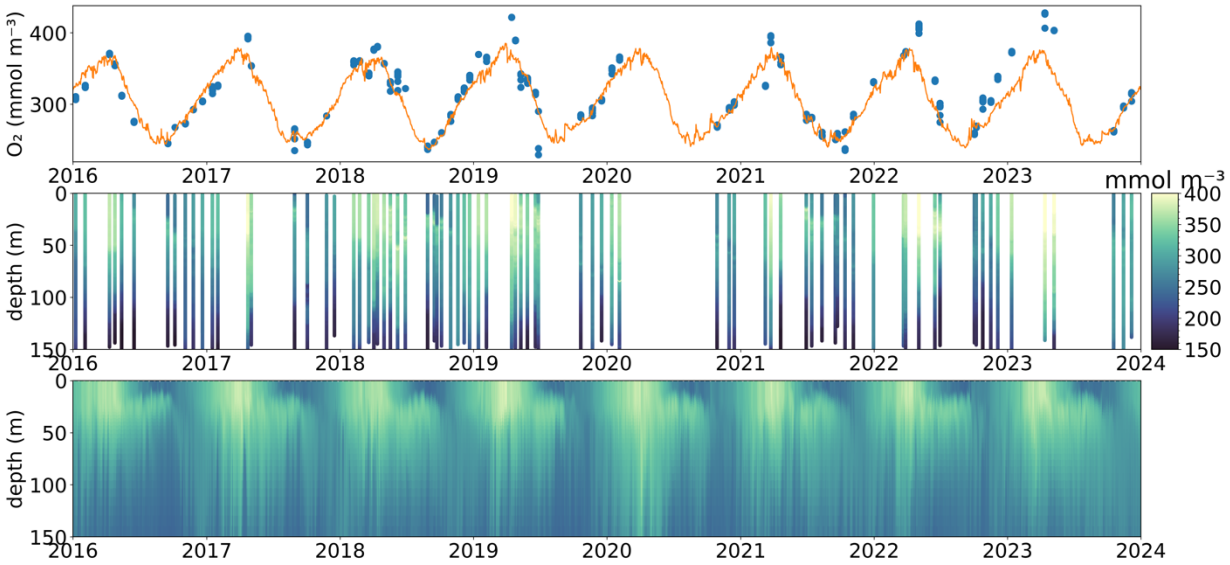

Figure S6. Observation/model comparison of oxygen at Station 2. Top: Surface oxygen concentration. Blue: observation; orange: ROMS-H1. Middle: Observed vertical profiles. Bottom: Simulated vertical profiles.

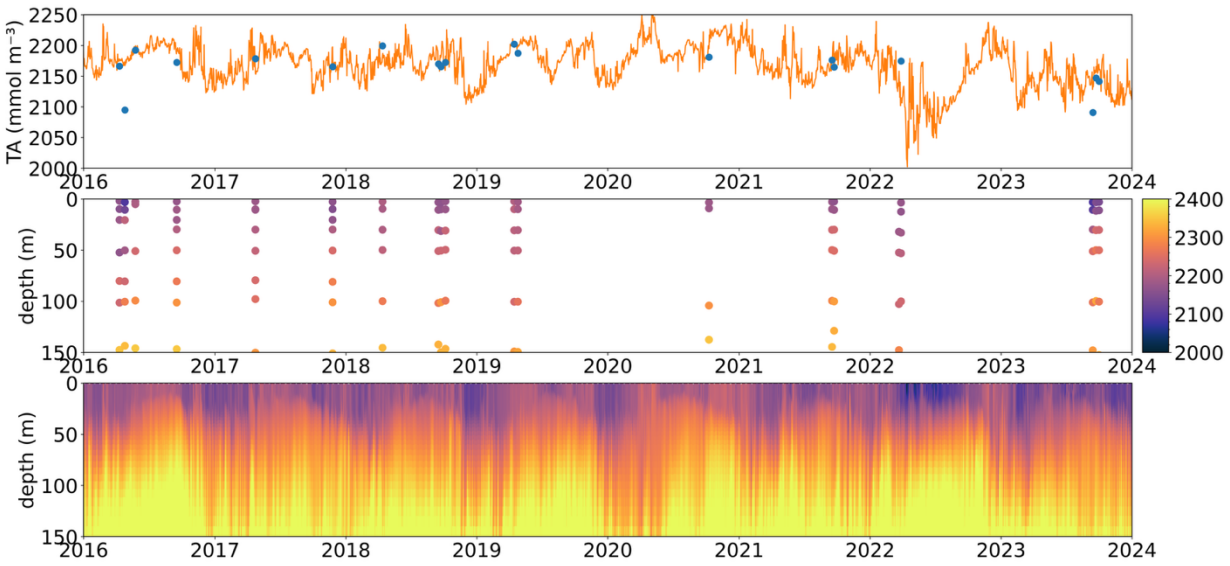

Figure S7. Observation/model comparison of alkalinity at Station 2. Top: Surface alkalinity. Blue: observation; orange: ROMS-H1. Middle: Observed vertical profiles. Bottom: Simulated vertical profiles. Simulated alkalinity is derived from salinity (see Section 3.4).

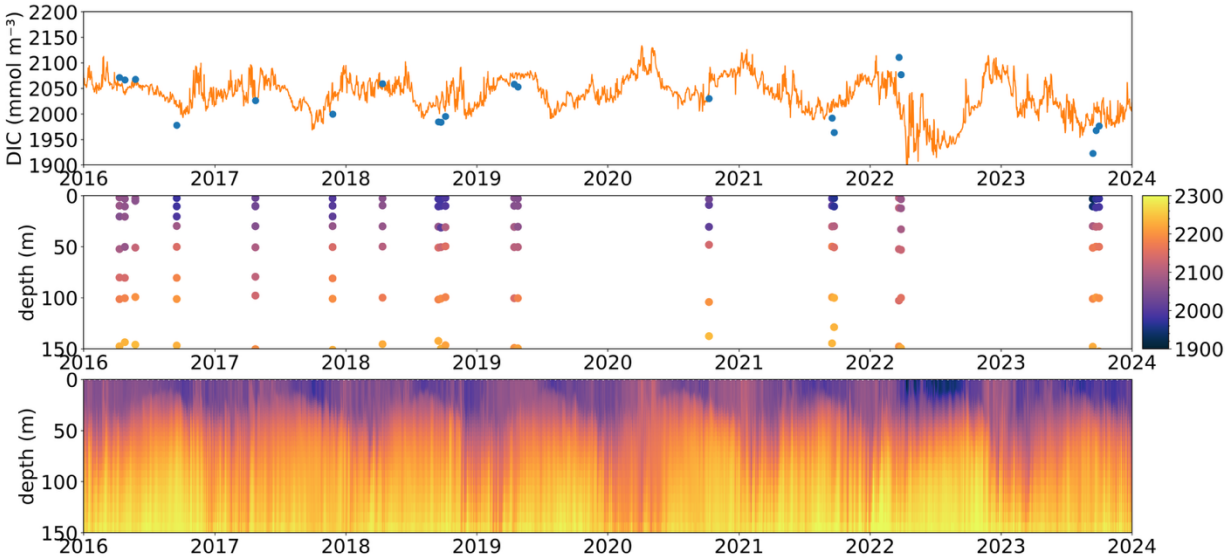

Figure S8. Observation/model comparison of DIC at Station 2. Top: Surface DIC. Blue: observation; orange: ROMS-H1. Middle: Observed vertical profiles. Bottom: Simulated vertical profiles. Simulated DIC is calculated from TA derived from salinity (see Section 3.4).

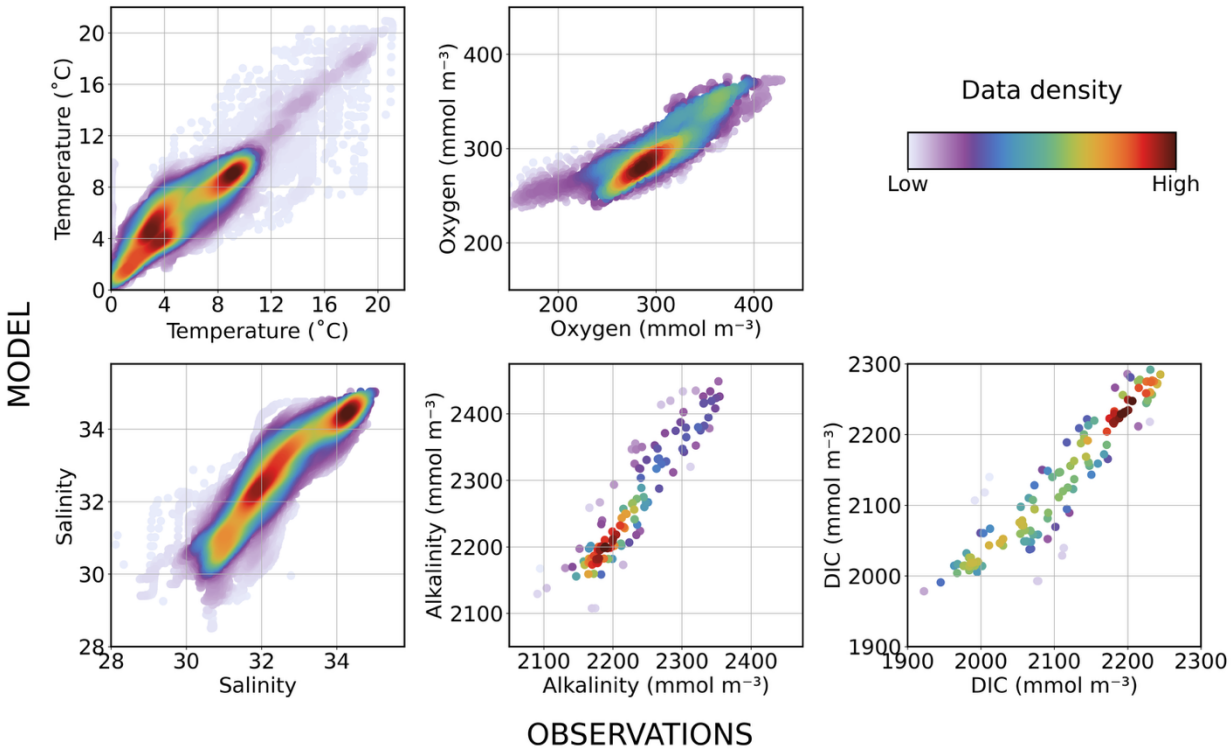

Figure S9. Observations-model comparisons at Station 2 with the data presented in Figure S3–Figure S8. The corresponding statistics are presented in Table 2.

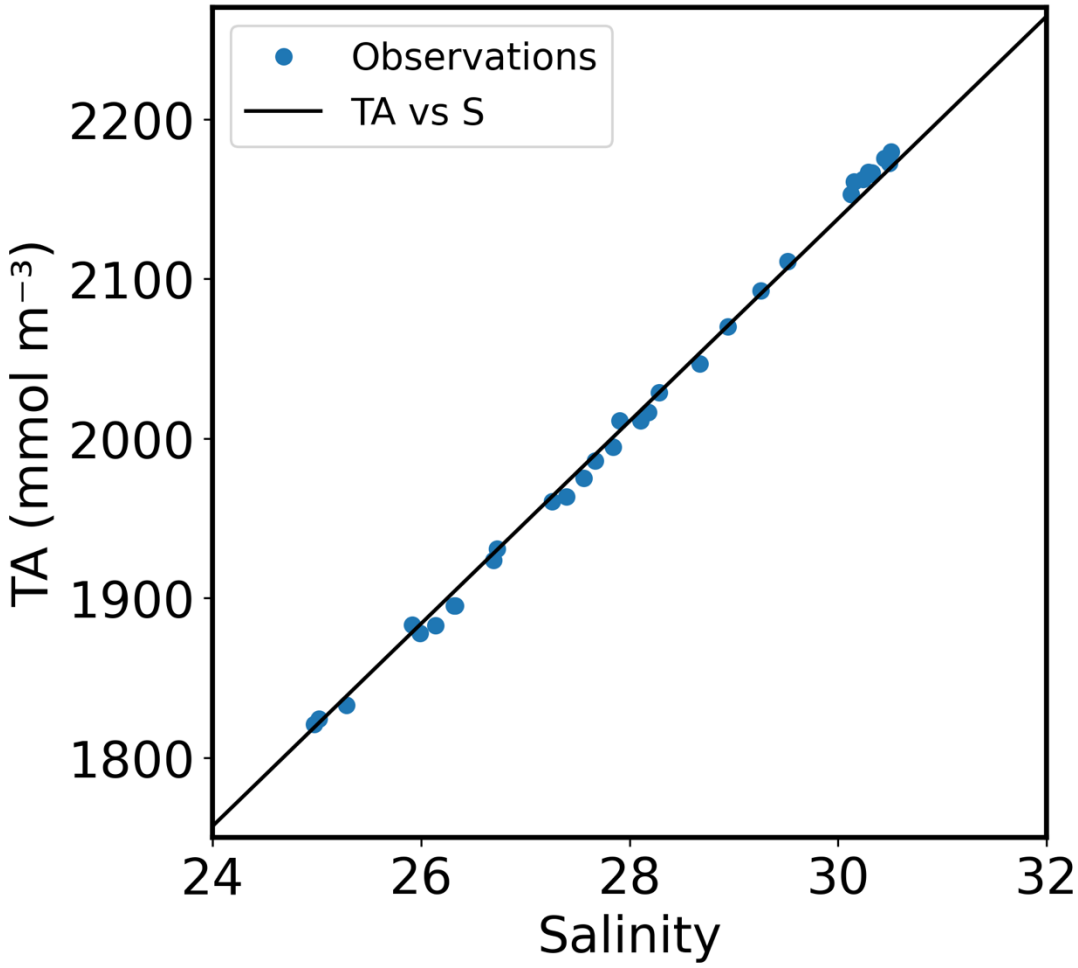

Figure S10. Observed TA versus salinity in the Halifax Harbour in Summer 2023 (blue dots). The observations are used to calculate the baseline relationship between salinity and TA: TAfit = 61.87× salt + 229.4.

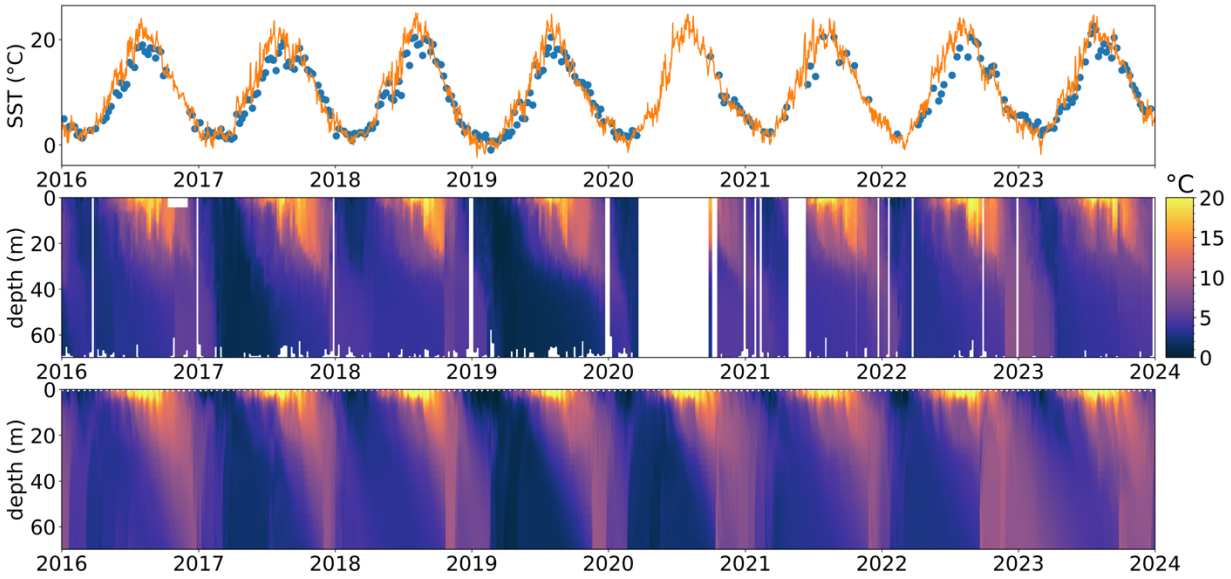

Figure S11. Observation/model comparison of temperature at the BBMP station in the Bedford Basin. Top: Surface temperature. Blue: observations; orange: ROMS-H2. Middle: Observed vertical profiles. Bottom: Simulated vertical profiles.

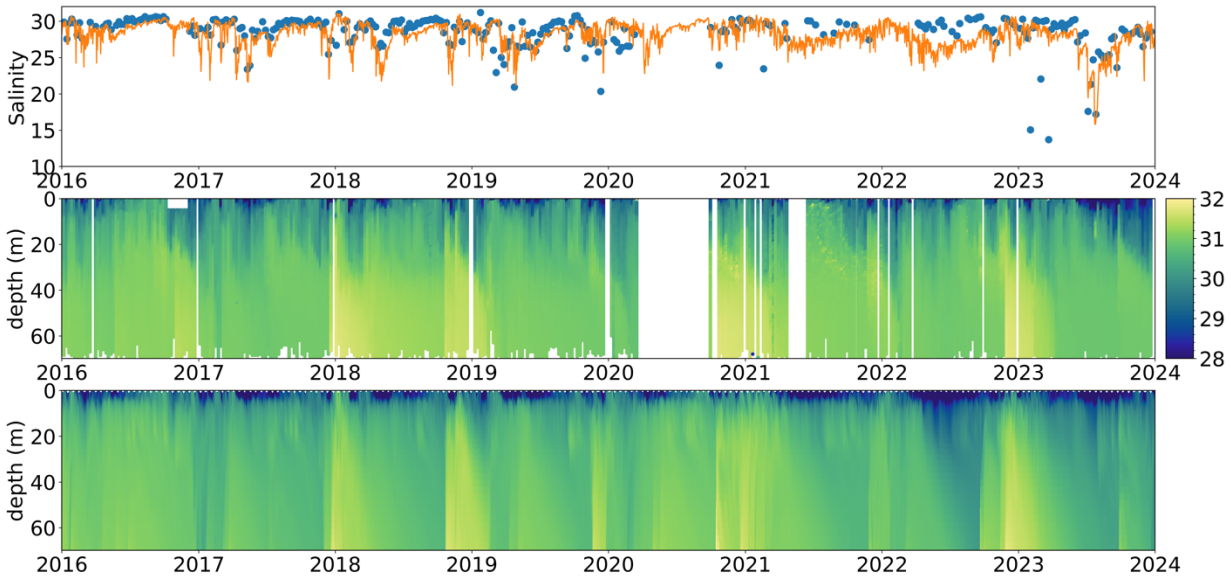

Figure S12. Observation/model comparison of salinity at the BBMP station in the Bedford Basin. Top: Surface salinity. Blue: observations; orange: ROMS-H2. Middle: Observed vertical profiles. Bottom: Simulated vertical profiles.

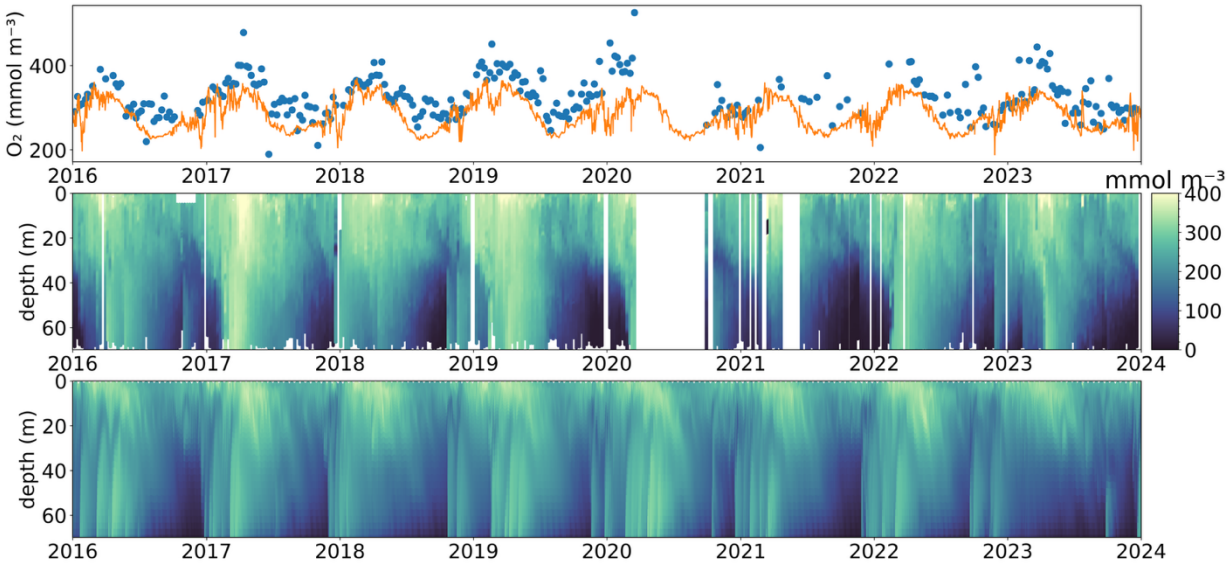

Figure S13. Observation/model comparison of oxygen concentration at the BBMP station in the Bedford Basin. Top: Surface oxygen concentration. Blue: observations; orange: ROMS-H2. Middle: Observed vertical profiles. Bottom: Simulated vertical profiles.

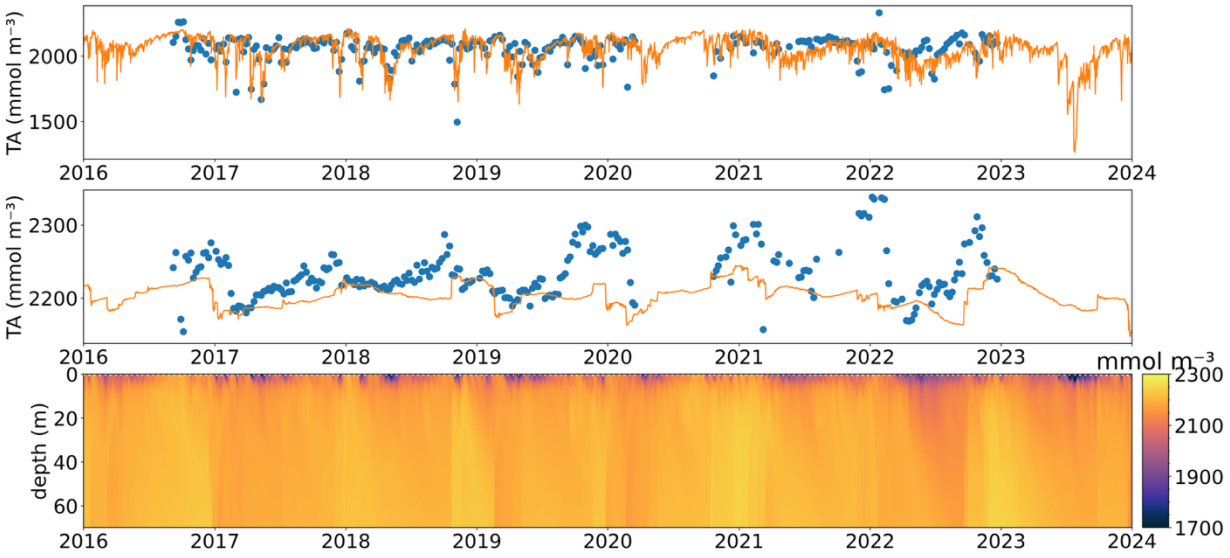

Figure S14. Observation/model comparison of alkalinity at the BBMP station in the Bedford Basin. Top: Surface alkalinity. Blue: observations; orange: ROMS-H2. Middle: Comparison at 60m. Bottom: Simulated vertical profiles.

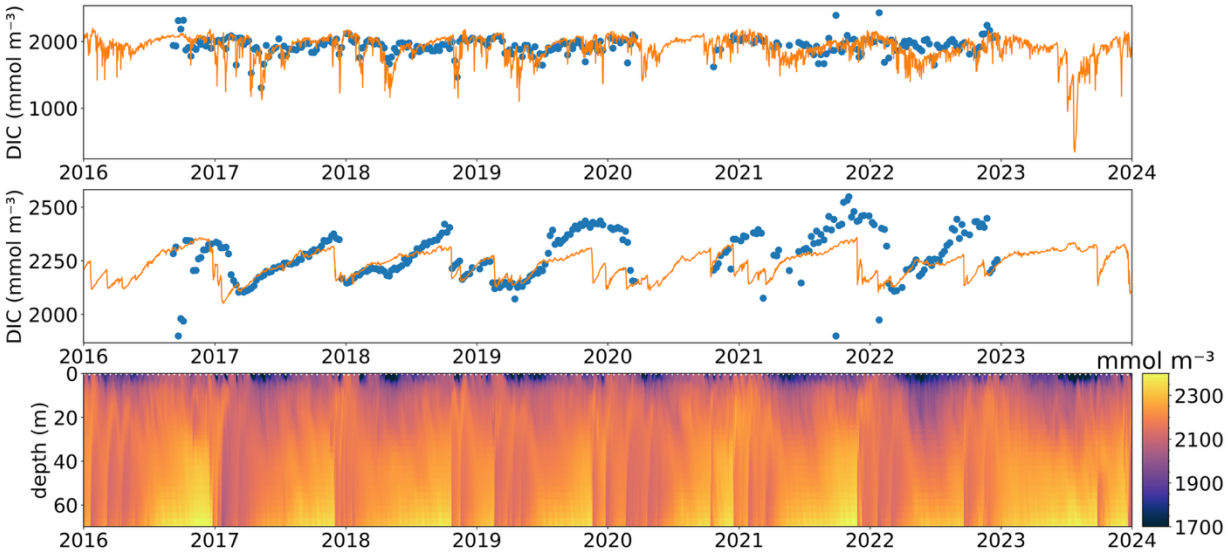

Figure S15. Observation/model comparison of DIC at the BBMP station in the Bedford Basin. Top: Surface DIC. Blue: observations; orange: ROMS-H2. Middle: Comparison at 60m. Bottom: Simulated vertical profiles.

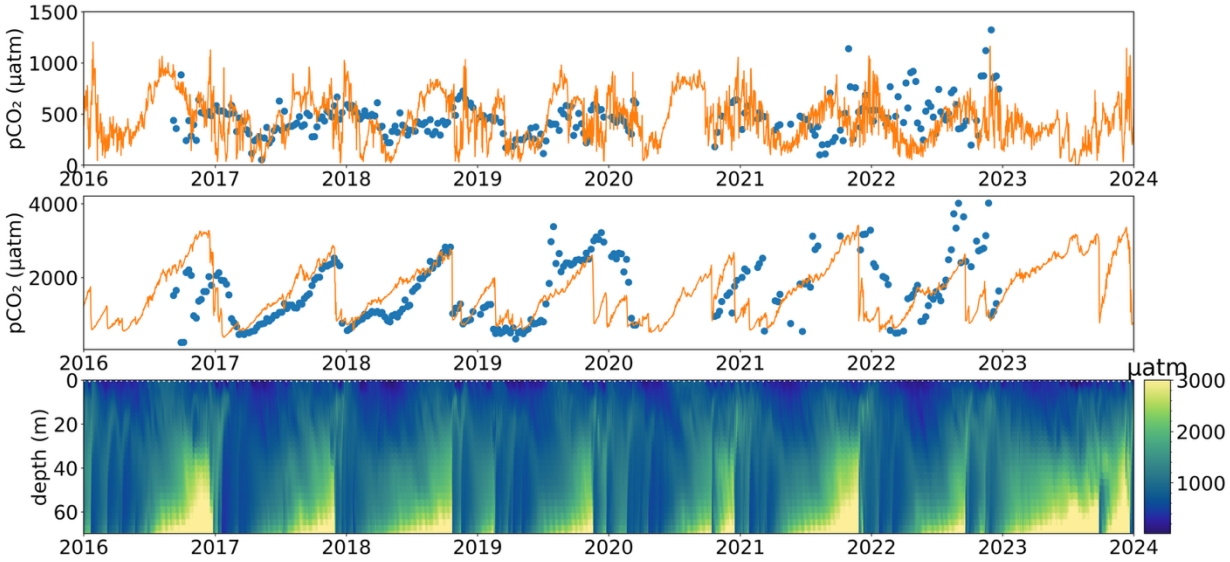

Figure S16. Observation/model comparison of pCO_2 at the BBMP station in the Bedford Basin. Top: Surface pCO_2. Blue: observations; orange: ROMS-H2. Middle: Comparison at 60m. Bottom: Simulated vertical profiles.

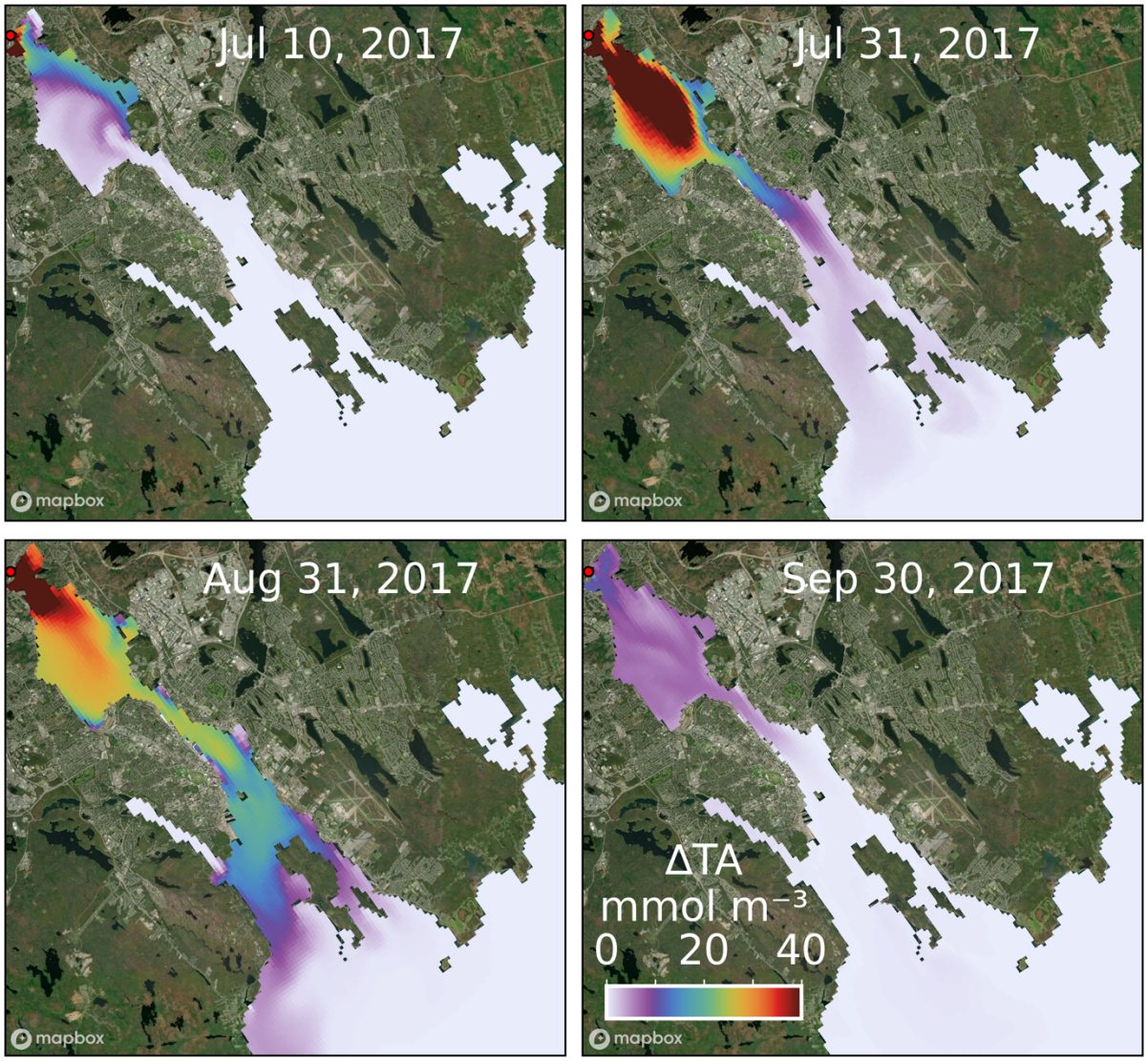

Figure S17. Snapshots of surface ΔTA in the simulation with the release of fully dissolved feedstock from Mill Cove (offshore areas were excluded from the map). Dosing locations are indicated with a red dot. Satellite image was generated with MapBox © Mapbox

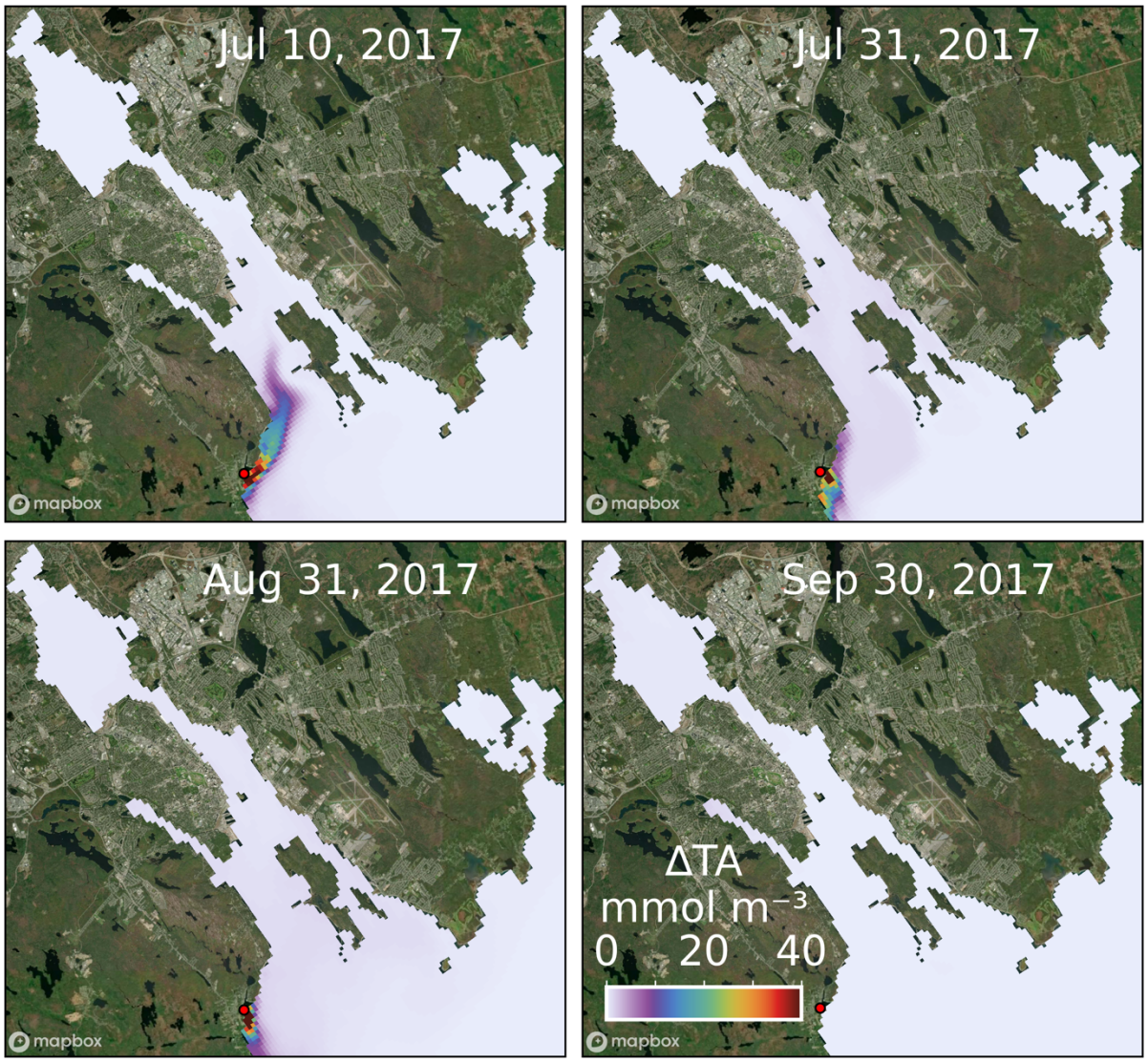

Figure S18. Snapshots of surface ΔTA in the simulation with the release of fully dissolved feedstock from Herring Cove (offshore areas were excluded from the map). Dosing locations are indicated with a red dot. Satellite image was generated with MapBox © Mapbox

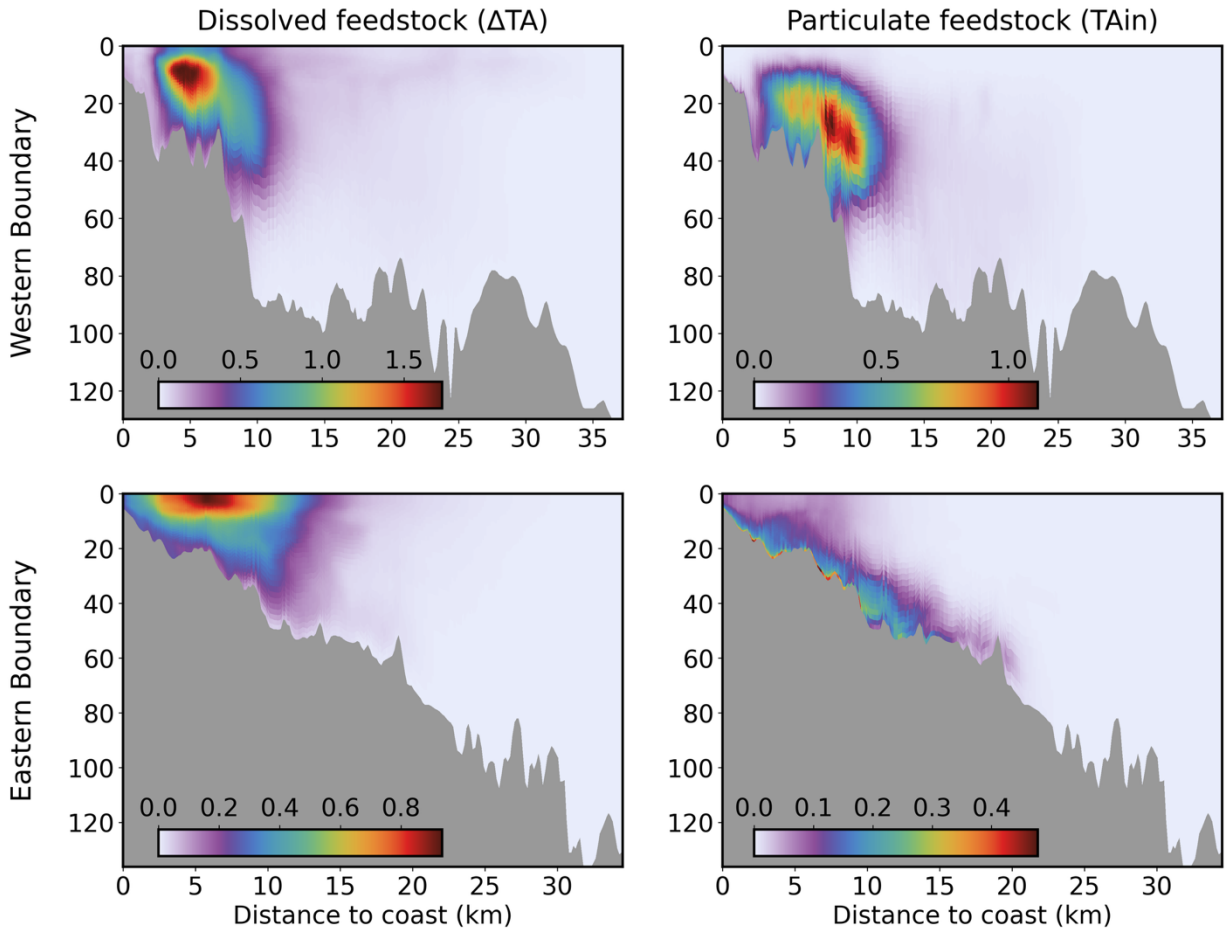

Figure S19. Vertical profiles of ΔTA (left) and particulate feedstock (TAin, right) along the western (top) and eastern (bottom) boundaries (mmol m^{-3}, time integrated) in the simulation with release at Herring Cove.

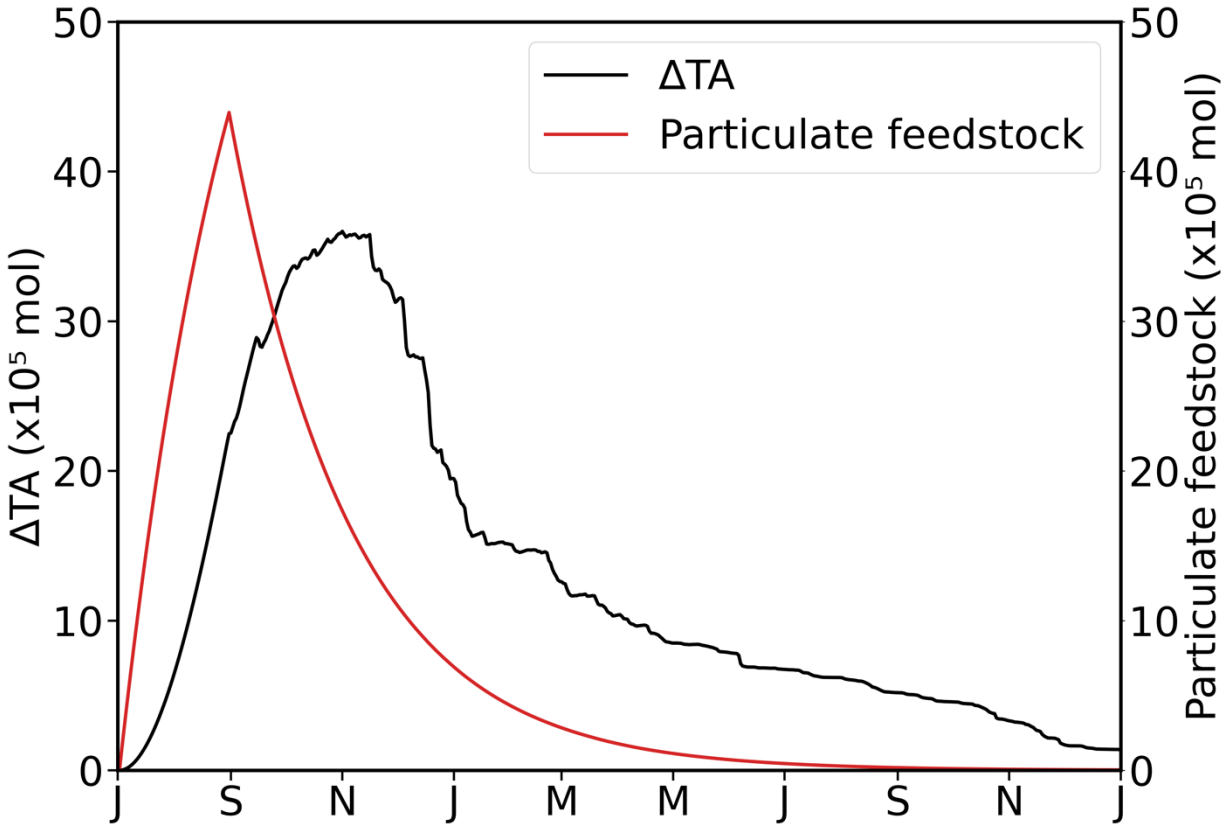

Figure S20. Model domain integrated ΔTA and particulate feedstock in the simulation with the release at Mill Cove

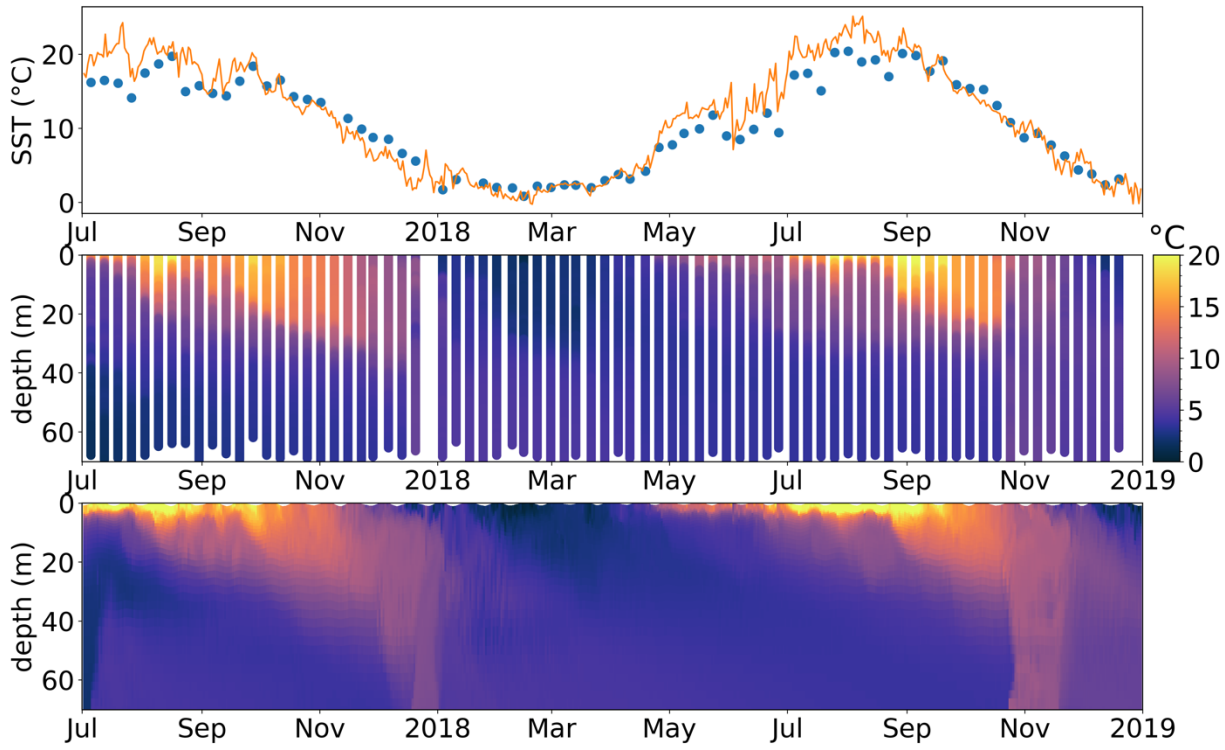

Figure S21. Observation/model (ROMS-H3) comparison of temperature at the BBMP station in the Bedford Basin. Top: Surface temperature. Blue: observations; orange: ROMS-H3. Middle: Observed vertical profiles. Bottom: Simulated vertical profiles.

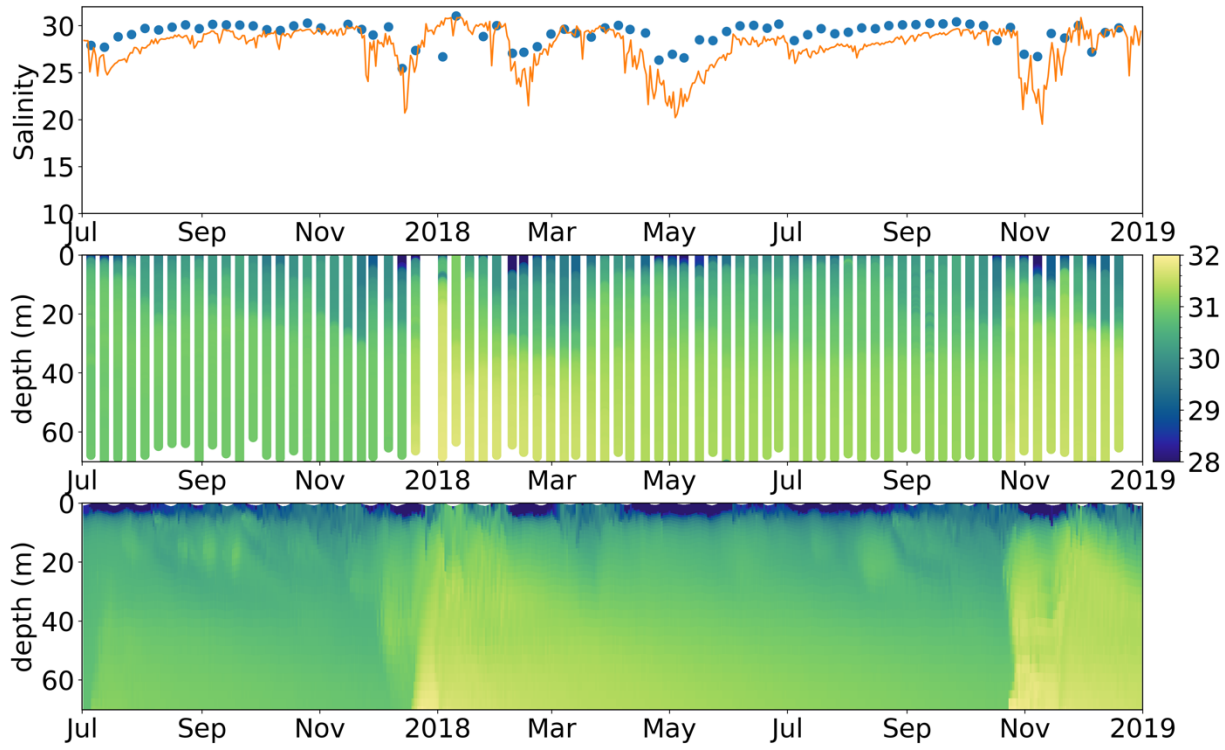

Figure S22. Observation/model (ROMS-H3) comparison of salinity at the BBMP station in the Bedford Basin. Top: Surface salinity. Blue: observations; orange: ROMS-H3. Middle: Observed vertical profiles. Bottom: Simulated vertical profiles.

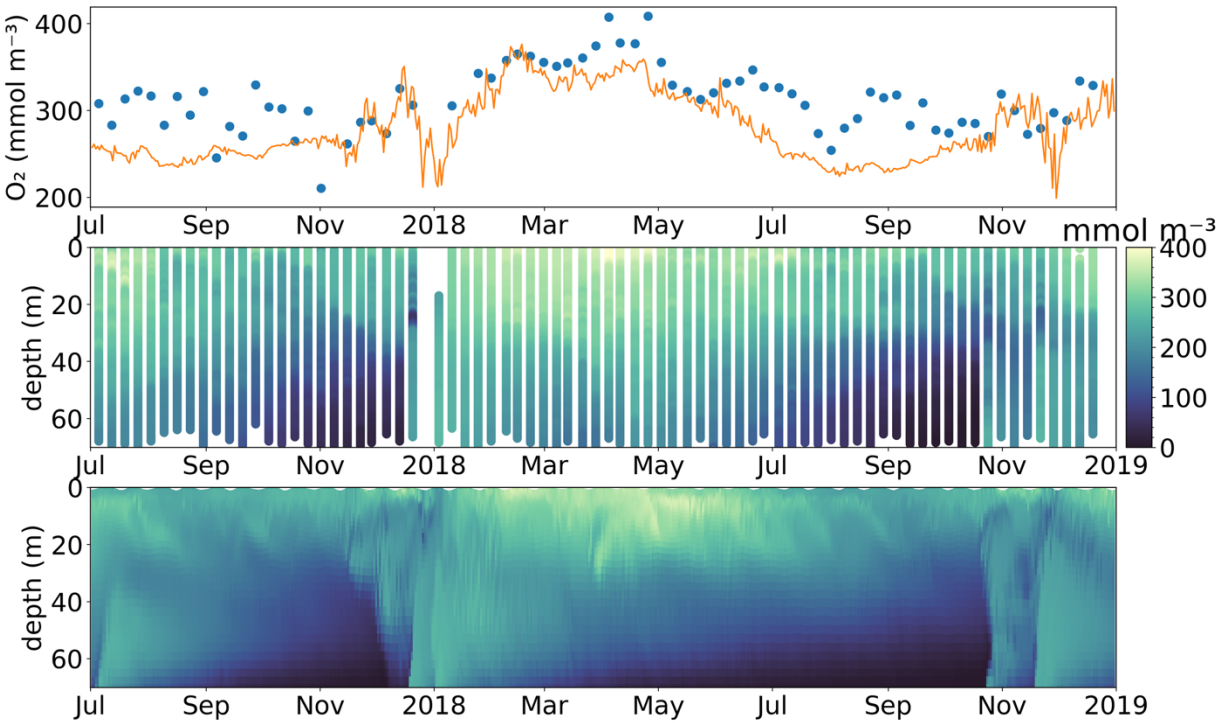

Figure S23. Observation/model (ROMS-H3) comparison of oxygen at the BBMP station in the Bedford Basin. Top: Surface oxygen. Blue: observations; orange: ROMS-H3. Middle: Observed vertical profiles. Bottom: Simulated vertical profiles.

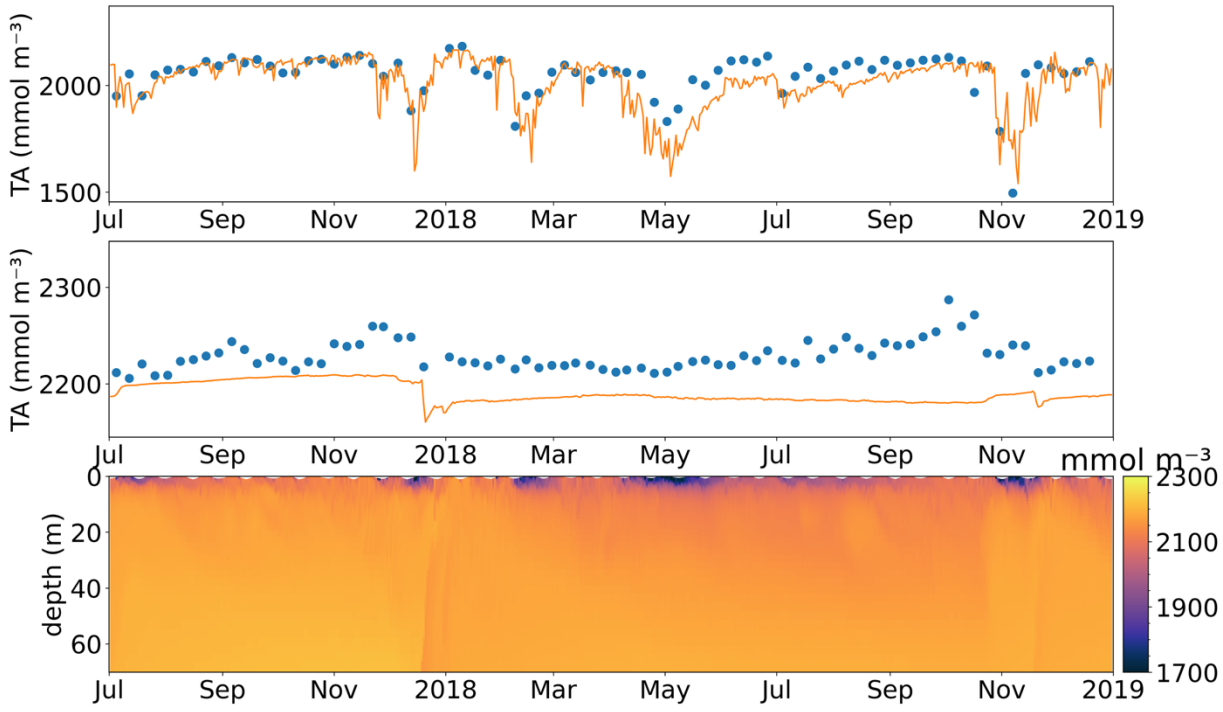

Figure S24. Observation/model (ROMS-H3) comparison of alkalinity at the BBMP station in the Bedford Basin. Top: Surface alkalinity. Blue: observations; orange: ROMS-H3. Middle: Comparison at 60m. Bottom: Simulated vertical profiles.

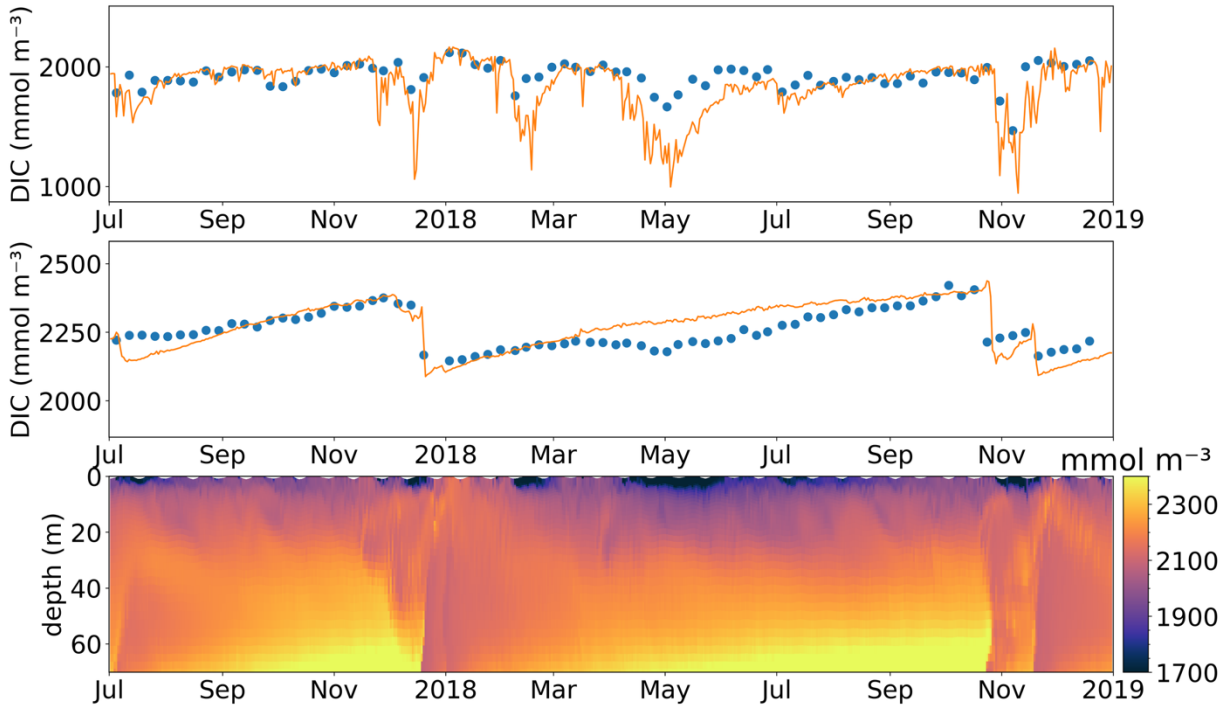

Figure S25. Observation/model (ROMS-H3) comparison of DIC at the BBMP station in the Bedford Basin. Top: Surface DIC. Blue: observations; orange: ROMS-H3. Middle: Comparison at 60m. Bottom: Simulated vertical profiles.

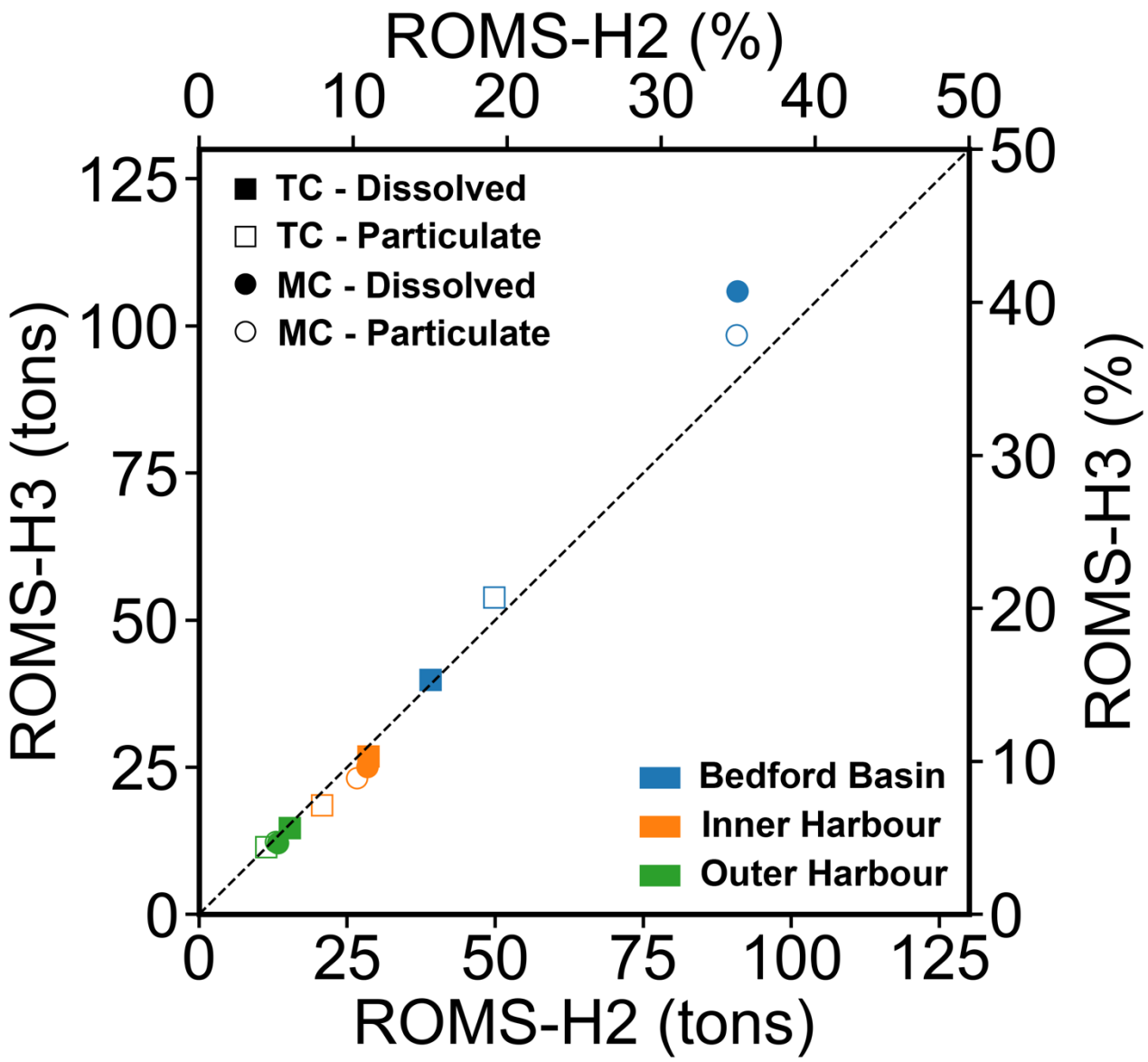

Figure S26. Comparison of net CO_2 uptake (per area; tons and % realized) in ROMS-H2 and ROMS-H3. The Outer Harbour in H2 is smaller than shown in Figure 1 to match the extent of ROMS-H3.

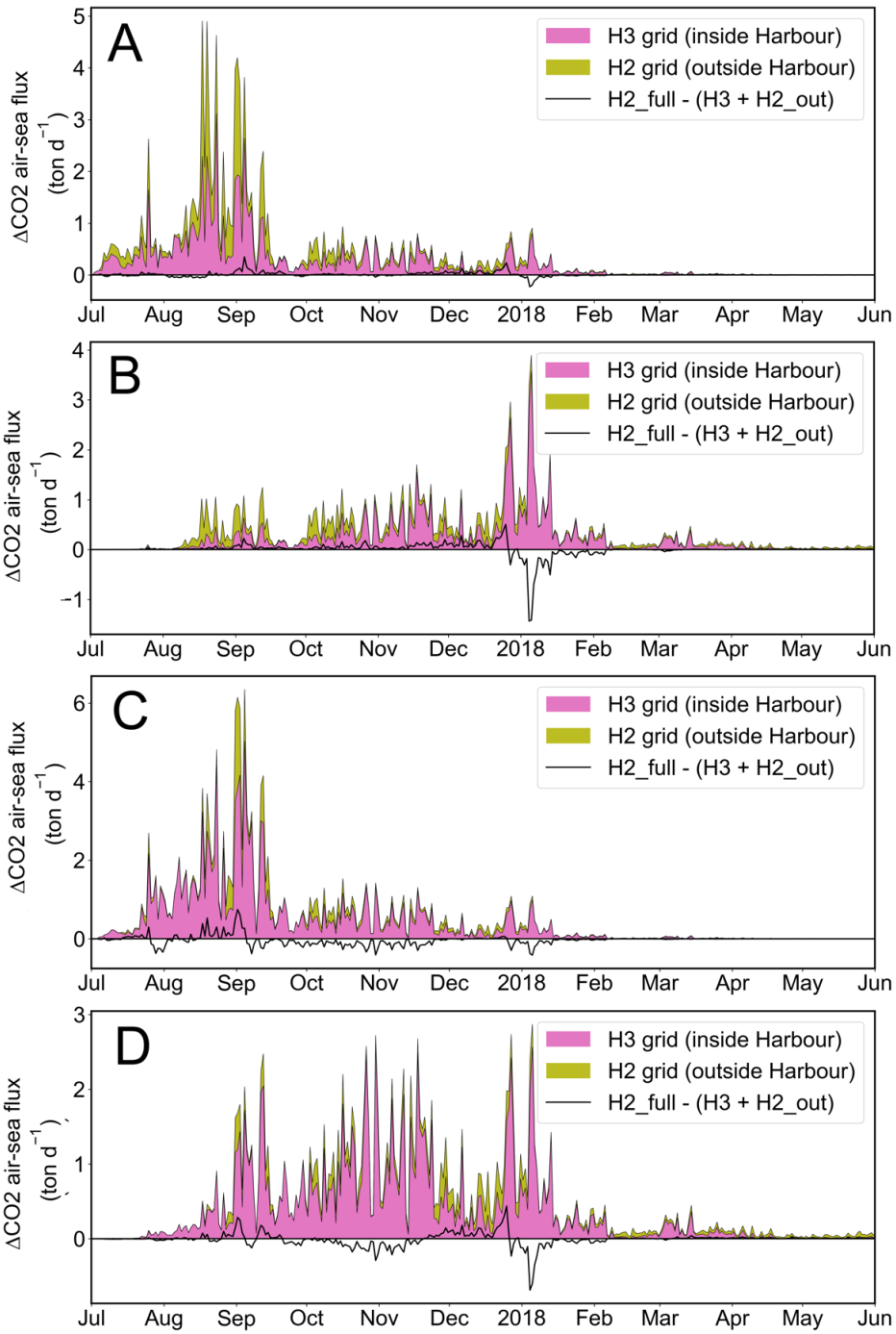

Figure S27. Time series of spatially integrated net CO_2 uptake in the simulation with ROMS-H3 (pink) and with ROMS-H2 (green), excluding the harbour area covered by ROMS-H3, for release at Tufts Cove of (a) dissolved or (b) particulate feedstock, and release at Mill Cove of (c) dissolved and (d) particulate feedstock. The thick black line indicates the difference between total fluxes calculated with ROMS-H2 (full grid, as in Figure 8) and with the offline nest ROMS-H2 (outer grid)+ROMS-H3.