

Dissolved oxygen (DO) consumption on sediments and the overlaying water interface by substrates decomposition and remineralization.

A multi-box model was applied to evaluate several scenarios of GB substrate deposition on the sediment-water interface DO consumption. Our assumptions take into account an extreme case, as it assumes slow (Shanmugam, 2008) bottom currents that carry a low concentration of O₂ (Matear and Hirst, 2003), which is consumed by highly reactive organic matter (Dittmar et al., 2021).

The simulations reveal a temporal reduction in O₂ concentration after 1-4 months. The maximum reduction is approximately 1 μM in the representative simulation and under 4 μM in a second, extremely conservative simulation, indicating a negligible and temporal impact.

The bottom current flows over the seabed at a velocity of 2-4 cm s⁻¹ and the DO in the flowing water is consumed by reaction with the organic matter. The current also brings into the model boxes bottom water with an initial DO concentration and removes an equal amount of bottom water with the ambient time-dependent DO concentration in the box. The initial DO concentration in the most “upstream” box is invariant at 200 μM, whereas the concentration in the flow entering more “downstream” boxes depends on O₂ consumption in the preceding boxes. The organic matter decays with an e-folding time of 1 y, and consequently, so does the rate of DO consumption. A differential equation for the DO concentration ([O₂]) is:

$$d[O_2]/dt = v([O_2]_{in} - [O_2]) - kC_0e^{-kt} \times [O_2]/([O_2] + K_{O_2}) \times 1.45$$

where v is the current velocity, $[O_2]_{in}$ is the incoming bottom water DO concentration, k is the rate constant for organic matter degradation (inverse of the e-folding time of 1 y), C_0 is the initial organic matter concentration, $K_{O_2}=1 \times 10^{-3}$ is a half-saturation constant (mol/m³) for the rate dependence on $[O_2]$, and the factor of 1.45 is related to the average O₂:C stoichiometry of marine organic matter.

From a representative Lagrangian particle dispersal model plume shape and density result, we extracted a transect along the main hinge of 189.2 km and measured the particle density every 250 m. The particle density was translated into organic carbon under the assumption of 10:1 CO₂ mass unit to particle mass unit. The plume is a result of a simulation where particles were deployed from a radius of 35 km within 48 hours.

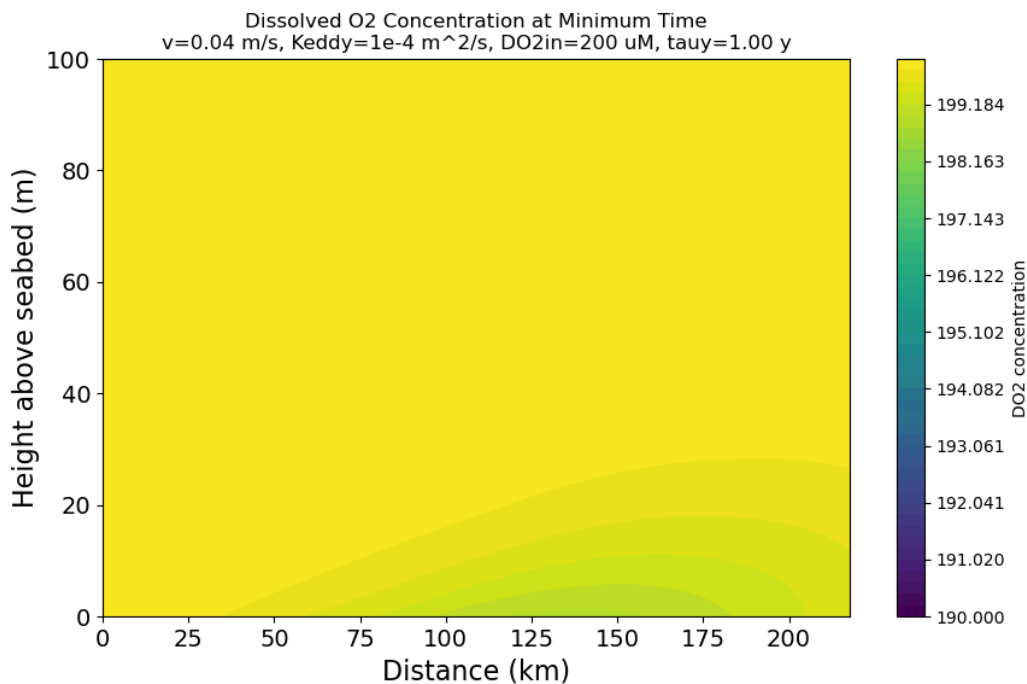
With this transect along a plume (Figure 1) of organic matter per square meter, eddy diffusion of 10⁻⁴ m² s⁻¹, and current velocity of 0.04 m s⁻¹, through a water mass creates a 100 m thick bottom boundary layer over the seabed prevents bottom-water DO from dropping much below the background levels (200 μM). Figure 2 shows the oxygen depletion for the same transect, only for eddy diffusion of 10⁻⁵ m² s⁻¹ and

current velocity of 0.01 m s^{-1} to express slower water movement and higher deoxygenation rates.

At the time of minimal DO concentrations, about 0.1 years after the deployment, the DO concentration 150 km along the flow path is no less than 198.90 uM for the first simulation (Figure 1) and after 0.32 years with no less than 194.32 uM for the second simulation (Figure 2). Diapycnal eddy diffusivity is assumed to be between 10^{-5} and $10^{-4} \text{ m}^2 \text{ s}^{-1}$ in deep water layers (Katsumata and Yamazaki, 2023; <https://doi.org/10.1016/j.pocean.2023.102979>). This diffusivity impacts the width of the bottom water boundary layer, affecting the DO concentration in that layer.

The DO concentration maps show the location of minimal DO - farthest along the flow path and closest to the seabed, as expected (Figures 1-2).

A



B

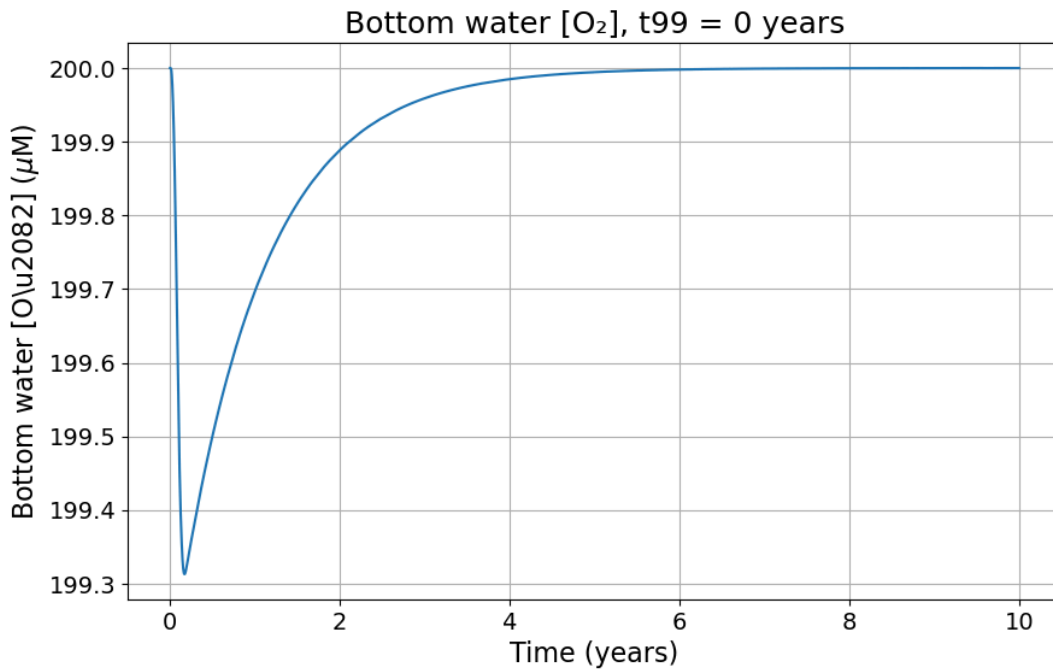
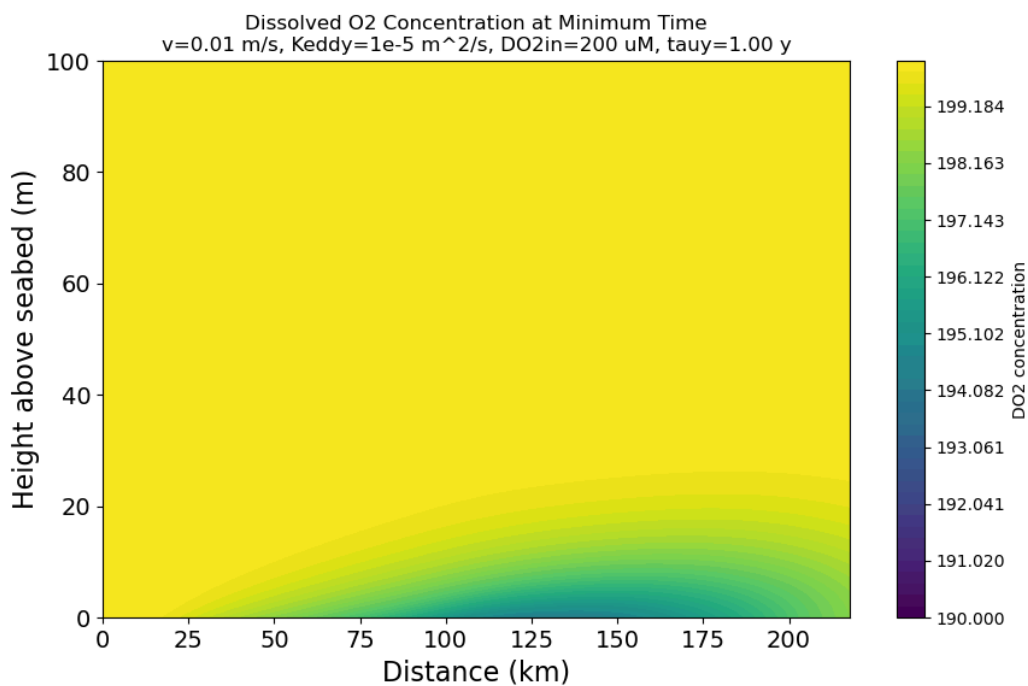


Figure 1: A - Calculated DO concentration in the bottom-water layer (100 m thick) along a 189.2 km transect through a plume with varying concentrations of organic carbon along the transect. The DO₂ concentrations were calculated eddy diffusion of $10^{-4} \text{ m}^2 \text{ s}^{-1}$, and current velocity of 0.04 m s^{-1} . With this current velocity, it takes a water parcel 54.75 days to travel above the plume; B - Calculated time-dependent bottom-water DO concentration following a single substrate deployment, resulting in an organic matter enrichment according to the transect.



AB

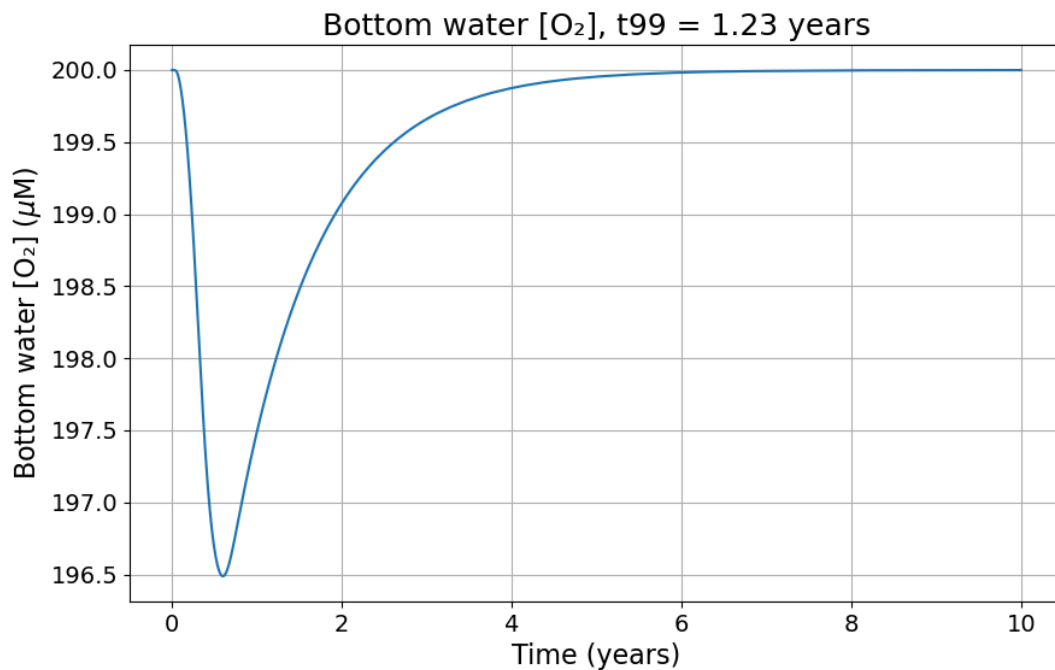


Figure 2: A - Calculated DO concentration in the bottom-water layer (100 m thick) along a 189.2 km transect through a plume with varying concentrations of organic carbon along the transect. The DO_2 concentrations were calculated eddy diffusion of $10^{-5} \text{ m}^2 \text{ s}^{-1}$, and current velocity of 0.01 m s^{-1} . With this current velocity, it takes a water parcel 218.97 days to travel above the plume. B - Calculated time-dependent bottom-water DO concentration following a single substrate deployment, resulting in an organic matter enrichment according to the transect.

We examined the sensitivity of the model to several input parameters as shown in Table 1. The first entry in the table is the default calculation calculated according to the transect (Figure 1) from the plume described above (from here on, “scenario 1”). In this calculation there was a 0.55% decrease in DO concentration at the most.

Table 1: The results of a twofold increase/decrease of all parameters (except the eddy diffusivity, which is decreased by an order of magnitude, and DO in which was reduced to 150 μM).

scenario	v	K	DO_2	τ	l	d	$\text{DO}_2 \text{ min}$	$\text{DO}_2 \text{ red}$	t_{min}
	m s^{-1}	$\text{m}^2 \text{ s}^{-1}$	μM	year	km	m	μM	%	y
1*	0.04	$1\text{e-}4$	200	1	189.2	100	198.90	0.55	0.1
2	0.04	$1\text{e-}4$	200	1	171.2	100	198.87	0.565	0.09
3	0.04	$1\text{e-}4$	200	1	125.5	100	198.10	0.95	0.06
1	0.01	$1\text{e-}4$	200	1	189.2	100	198.15	0.925	0.3
1	0.04	$1\text{e-}5$	200	1	189.2	100	196.71	1.645	0.1

1**	0.01	1e-5	200	1	189.2	100	194.32	2.84	0.32
1	0.04	1e-4	150	1	189.2	100	148.91	0.7266	0.1
1	0.04	1e-4	200	2	189.2	100	199.43	0.285	0.11
1	0.04	1e-4	200	0.5	189.2	100	197.95	1.025	0.09
1	0.04	1e-4	200	1	189.2	200	197.86	1.07	0.1
1	0.04	1e-4	200	1	189.2	50	199.44	0.28	0.1

scenario 1: deployment in 35 km radius within 48 h; scenario 2: deployment in 35 km radius within 24 h; scenario 3: deployment in 10 km radius within 48 h. * Figure 1, ** Figure 2.