Supplementary Material

Potential impact of the sea-ice ecosystem to the Polar Seas biogeochemistry

Young Shin Kwon, Tae Siek Rhee\*, Karsten Bolding

**\* Correspondence:** Tae Siek Rhee: rhee@kopri.re.kr

# Ice porosity calculation

Porosity *ϕ*(*z*) at depth z in the ice column is considered as relative volume of brine channels in

ice according to Arrigo et al. (1993):

Brine salinity, and corresponding sea ice temperature (°C), are:

where , , and are different for three temperature ranges:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  |  |
| −1.85 > ≥ −22.9 | −3.9921 | −22.700 | −1.0015 | −0.019956 |
| −22.9 > ≥ −44 | 206.24 | −1.8907 | −0.060868 | −0.0010247 |
| −44 > ≥ −54 | −4442.1 | −277.86 | −5.501 | −0.03669 |

Sea ice salinity, is (Gerland et al., 1999; Duarte et al., 2015):

where is the ratio between the distance from the ice surface and ice thickness.

Brine density, (g m−3) (Cox and Weeks, 1975) is:

where = 8 × 10−4 g m−3.

Sea ice density, (g m−3) is:

where ρ0= 912 × 103 g m−3 is the density of pure ice (Arrigo et al., 1993).

# Supplementary Figures and Tables



Figure S1. (A) Time-series scatter plot depicting the concentration of Chl-*a* (lime) and the carbon mass of sympagic diatoms (blue) in the lowermost layer of the ice domain. Enlarged view of the lower layers of sea ice for the temporal variation of (B) sympagic diatoms biomass and (C) Chl-*a*.

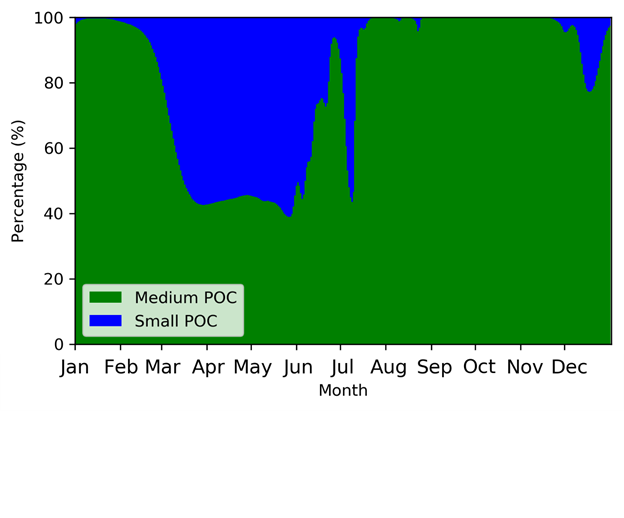


Figure S. Changes of the composition of POC at a depth of 350 m simulated by the model.

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Figure S. Sensitivity of sinking rates of the various size of particles to POC fluxes at 350 m deep.

Table S1. Ice algae parameters for SPBM run

|  |  |  |  |
| --- | --- | --- | --- |
| **Code ID** | **Description** | **Unit** | **Value** |
| alphaP1\_i | Initial slope of *P-I* curve | mg C m2 (mg Chl)-1 W-1 d-1 | 8.56 |
| betaP1\_i | Photoinhibition parameter | mg C m2 (mg Chl)-1 W-1 d-1 | 0.2 |
| chP1\_if | Michaelis-Menten constant for iron limitation | *μ*mol m−3 | 0.0366 |
| chP1\_in | Michaelis-Menten constant for nitrate limitation | mmol m−3 | 1.6 |
| chP1\_ip | Michaelis-Menten constant for phosphate limitation | mmol m−3 | 0.24 |
| chP1\_is | Michaelis-Menten constant for silicate limitation | mmol m−3 | 3.9 |
| esNIP1\_i | Level of nutrient limitation below which sinking commences | - | 0.7 |
| phimP1\_i | Maximum effective Chl-*a* to C photosynthesis ratio | - | 0.04712 |
| pu\_eaP1\_i | Excreted fraction of primary production | - | 0.05 |
| pu\_raP1\_i | Respired fraction of primary production | - | 0.1 |
| q10P1\_i | *q*10 temperature coefficient | d−1 | 1.06 |
| qflP1\_ic | Minimum iron to C ratio | 𝜇mol mg−1 | 5.00E-05 |
| qfRP1\_ic | Optimal iron to C ratio | 𝜇mol mg−1 | 5.00E-04 |
| qnlP1\_ic | Minimum N to C ratio | mol g−1 | 0.0042 |
| qplP1\_ic | Minimum P to C ratio | mol g−1 | 0.0001 |
| qsP1\_ic | Maximum silicate to C ratio | mol g−1 | 0.03 |
| quP1\_in3 | Nitrate affinity | m3 mg−1 d−1 | 0.0025 |
| quP1\_in4 | Ammonium affinity | m3 mg−1 d−1 | 0.0025 |
| qurP1\_if | Iron affinity | m3 mg−1 d−1 | 0.0003 |
| qurP1\_ip | Phosphate affinity | m3 mg−1 d−1 | 0.003 |
| resmP1\_i | Maximum nutrient limitation induced sinking velocity | m d−1 | 5 |
| sdoP1\_i | Minimal specific lysis rate | d−1 | 0.05 |
| srsP1\_i | Specific rest respiration at reference temperature | d−1 | 0.04 |
| sumP1\_iX | Specific maximal productivity at reference temperature | d−1 | 1.21 |
| xqcP1\_in | Threshold for N limitation (relative to Redfield ratio) | - | 1 |
| xqcP1\_ip | Threshold for P limitation (relative to Redfield ratio) | - | 1 |
| xqnP1\_i | Maximum N to C ratio (relative to Redfield ratio) | - | 1.075 |
| xqpP1\_i | Maximum P to C ratio (relative to Redfield ratio) | - | 2 |

Table S2. Sinking velocity values for SPBM run

|  |  |  |  |
| --- | --- | --- | --- |
| **Code name** | **Description** | **Unit** | **Value** |
| rmR4 | Sinking velocity of small-size POM | m d-1 | 10 |
| rmR6 | Sinking velocity of medium-size POM | m d-1 | 23 |
| rmR8 | Sinking velocity of large-size POM | m d-1 | 50 |

Table S3. Initial conditions for SPBM state variables

|  |  |  |
| --- | --- | --- |
| **Code name** | **Description** | **Initial value** |
| B1CR | Initial condition for bacteria C | 15.7 |
| B1NR | Initial condition for bacteria N | 0.26 |
| B1PR | Initial condition for bacteria P | 0.029 |
| CHLi1R | Initial condition for ice algae Chl-*a* | 0.4 |
| CHL1R | Initial condition for diatom Chl-*a* | 0.4 |
| CHL2R | Initial condition for nanophytoplankton Chl-*a* | 0.3 |
| CHL3R | Initial condition for picophytoplankton Chl-*a* | 0.3 |
| CHL4R | Initial condition for microphytoplankton Chl-*a* | 0.3 |
| CaCO3R | Initial condition for calcite | 1 |
| N1PR | Initial condition for phosphate | 2.5 |
| N3NR | Initial condition for nitrate | 35 |
| N4NR | Initial condition for ammonium | 1 |
| N5SR | Initial condition for silicate | 90 |
| N7FR | Initial condition for dissolved inorganic iron | 1.42 |
| O2OR | Initial condition for dissolved oxygen | 250 |
| DICR | Initial condition for dissolved C | 2300 |
| AlkR | Initial condition for alkalinity | 2300 |
| P1\_iCR | Initial condition for ice algae C | 8 |
| P1\_iFR | Initial condition for ice algae iron | 2.50E-04 |
| P1\_iNR | Initial condition for ice algae N | 0.1114 |
| P1\_iPR | Initial condition for ice algae P | 0.009 |
| P1\_iSR | Initial condition for ice algae Si | 0.128 |
| P1CR | Initial condition for diatom C | 8 |
| P1FR | Initial condition for diatom iron | 2.50E-04 |
| P1NR | Initial condition for diatom N | 0.1114 |
| P1PR | Initial condition for diatom P | 0.009 |
| P1SR | Initial condition for diatom Si | 0.128 |
| P2CR | Initial condition for nanophytoplankton C | 5.9 |
| P2FR | Initial condition for nanophytoplankton iron | 1.50E-04 |
| P2NR | Initial condition for nanophytoplankton N | 0.0926 |
| P2PR | Initial condition for nanophytoplankton P | 0.0036 |
| P3CR | Initial condition for picophytoplankton C | 5.9 |
| P3FR | Initial condition for picpophytoplankton iron | 1.50E-04 |
| P3NR | Initial condition for picophytoplankton N | 0.0926 |
| P3PR | Initial condition for picophytoplankton P | 0.0036 |
| P4CR | Initial condition for microphytoplankton C | 5.9 |
| P4FR | Initial condition for microphytoplankton iron | 2.50E-05 |
| P4NR | Initial condition for microphytoplankton N | 0.0926 |
| P4PR | Initial condition for microphytoplankton P | 0.0036 |
| R1CR | Initial condition for dissolved organic C | 10 |
| R1NR | Initial condition for dissolved organic N | 0.14 |
| R1PR | Initial condition for dissolved organic P | 0.01 |
| R2CR | Initial condition for semi-labile organic C | 12 |
| R3CR | Initial condition for semi-refractory organic C | 12 |
| R4CR | Initial condition for small particulate organic C | 7.2 |
| R4FR | Initial condition for small particulate organic iron | 5.00E-05 |
| R4NR | Initial condition for small particulate organic N | 0.1 |
| R4PR | Initial condition for small particulate organic P | 0.007 |
| R6CR | Initial condition for medium size particulate C | 17 |
| R6FR | Initial condition for medium size particulate organic iron | 5.00E-05 |
| R6NR | Initial condition for medium size particulate N | 0.24 |
| R6PR | Initial condition for medium size particulate P | 0.02 |
| R6SR | Initial condition for medium size particulate Si | 0.1 |
| R8CR | Initial condition for large particulate organic C | 0.17 |
| R8NR | Initial condition for large particulate organic N | 0.0024 |
| R8PR | Initial condition for large particulate organic P | 0.0002 |
| R8SR | Initial condition for largeparticulate organic Si | 0.001 |
| Z4CR | Initial condition for mesozooplankton C | 1.2 |
| Z5CR | Initial condition for microzooplankton C | 7.2 |
| Z5NR | Initial condition for microzooplankton N | 0.12 |
| Z5PR | Initial condition for microzooplankton P | 0.0113 |
| Z6CR | Initial condition for heteroflagellate C | 2.421 |
| Z6NR | Initial condition for heteroflagellate N | 0.0505 |
| Z6PR | Initial condition for heteroflagellate P | 0.047 |