Model Equations

The general form of the time rate of change equations are:

$$\frac{D(NO_3)}{Dt} = \eta\, NH_4 - \frac{V_{sp}^{NO_3}}{V_{sp}^{N_{tot}}} PC_{sp}^{photo}\, SP_C\, Q - \frac{V_{diat}^{NO_3}}{V_{diat}^{N_{tot}}} PC_{diat}^{photo}\, Diat_C\, Q - \left(r\, DOC + POC^{remin}\right) R_{denitrif}^{C:N} \quad (1)$$

$$\frac{D(NH_4)}{Dt} = -\eta\, NH_4 - \frac{V_{sp}^{NH_4}}{V_{sp}^{N_{tot}}} PC_{sp}^{photo}\, SP_C\, Q - \frac{V_{diat}^{NH_4}}{V_{diat}^{N_{tot}}} PC_{diat}^{photo}\, Diat_C\, Q + r\, DON + \left(Z_{loss}^{DIC} + SP_{loss}^{DIC} + G_{sp}^{DIC} + Diat_{loss}^{DIC} + G_{diat}^{DIC} + POC^{remin} + Diaz_{loss}^{DIC} + G_{diaz}^{DIC}\right) Q \quad (2)$$

$$\frac{D(Fe)}{Dt} = PFe^{remin} + Z_{loss}^{DIC}\, Q_Z^{Fe} + r\, DOFe + \left(SP_{loss}^{DIC} + G_{sp}^{DIC}\right) Q_{sp}^{Fe} + \left(Diat_{loss}^{DIC} + G_{diat}^{DIC}\right) Q_{diat}^{Fe} + \left(Diaz_{loss}^{DIC} + G_{diaz}^{DIC}\right) Q_{diaz}^{Fe} + G_{diaz}^{Z}\left(Q_{diaz}^{Fe} - Q_Z^{Fe}\right) + G_{diat}^{Z}\left(Q_{diat}^{Fe} - Q_Z^{Fe}\right) + G_{sp}^{Z}\left(Q_{sp}^{Fe} - Q_Z^{Fe}\right) - PC_{sp}^{photo}\, SP_C\, {}^{g}Q_{sp}^{Fe} - PC_{Diat}^{photo}\, Diat_C\, {}^{g}Q_{diat}^{Fe} - PC_{diaz}^{photo}\, Diaz_C\, {}^{g}Q_{diaz}^{Fe} - s^{Fe}\, Fe \quad (3)$$

$$\frac{D(SiO_3)}{Dt} = PSiO_3^{remin} + \left(f_{graz}^{Si,remin}\, G_{diat} + f_{diat\,loss}^{DOC}\, Diat_{loss}\right) Q_{diat}^{Si} - PC_{diat}^{photo}\, Diat_C\, {}^{g}Q_{diat}^{Si} \quad (4)$$

$$\frac{D(PO_4)}{Dt} = \left(POC^{remin} + Z_{loss}^{DIC} + SP_{loss}^{DIC} + G_{sp}^{DIC} + Diat_{loss}^{DIC} + G_{diat}^{DIC} - PC_{sp}^{photo}\, SP_C - PC_{diat}^{photo}\, Diat_C\right) Q^P + r\, DOP + Diaz_{loss}^{DIP} - PC_{diaz}^{photo}\, Diaz_C\, Q_{diaz}^{P} \quad (5)$$

$$\frac{D(SP_C)}{Dt} = PC_{sp}^{photo}\, SP_C - G_{sp} - SP_{loss} - SP_{agg} \quad (6)$$

$$\frac{D(SP_{Chl})}{Dt} = \frac{\rho_{sp}^{Chl}\, PC_{sp}^{photo}\, Q}{\theta_{sp}^{C}}\, SP_{Chl} - \left(G_{sp} + SP_{loss} + SP_{agg}\right) \theta_{sp}^{C} \quad (7)$$

$$\frac{D(SP_{CaCO_3})}{Dt} = f_{prod}^{sp,CaCO_3}\, PC_{sp}^{photo}\, SP_C - \left(G_{sp} + SP_{loss} + SP_{agg}\right) Q_{sp}^{CaCO_3} \quad (8)$$

$$\frac{D(Diat_C)}{Dt} = PC_{diat}^{photo}\, Diat_C - G_{diat} - Diat_{loss} - Diat_{agg} \quad (9)$$

$$\frac{D(Diat_{Chl})}{Dt} = \frac{\rho_{diat}^{Chl}\, PC_{diat}^{photo}\, Q}{\theta_{diat}^{C}}\, Diat_{Chl} - \left(G_{diat} + Diat_{loss} + Diat_{agg}\right) \theta_{diat}^{C} \quad (10)$$

$$\frac{D(Z_C)}{Dt} = G_{sp}^{Z} + G_{diat}^{Z} + G_{diaz}^{Z} - Z_{loss} \quad (11)$$

$$\frac{D(DOC)}{Dt} = SP_{loss}^{DOC} + G_{sp}^{DOC} + Z_{loss}^{DOC} + Diat_{loss}^{DOC} + G_{diat}^{DOC} + Diaz_{loss}^{DOC} + G_{diaz}^{DOC} - r\, DOC \quad (12)$$

$$\frac{D(DON)}{Dt} = \left(SP_{loss}^{DOC} + G_{sp}^{DOC} + Z_{loss}^{DOC} + Diat_{loss}^{DOC} + G_{diat}^{DOC} + Diaz_{loss}^{DOC} + G_{diaz}^{DOC}\right) Q - r\, DON + \left(\zeta_C^N - 1\right) PC_{diaz}^{photo}\, Diaz_C\, Q \quad (13)$$

$$\frac{D(DOP)}{Dt} = \left(SP_{loss}^{DOC} + G_{sp}^{DOC} + Z_{loss}^{DOC} + Diat_{loss}^{DOC} + G_{diat}^{DOC}\right) Q^P + Diaz_{loss}^{DOP} - r\, DOP \quad (14)$$

$$\frac{D(DOFe)}{Dt} = Z_{loss}^{DOC}\, Q_Z^{Fe} + \left(G_{sp}^{DOC} + SP_{loss}^{DOC}\right) Q_{sp}^{Fe} + \left(G_{diat}^{DOC} + Diat_{loss}^{DOC}\right) Q_{Diat}^{Fe} + \left(G_{diaz}^{DOC} + Diaz_{loss}^{DOC}\right) Q_{diaz}^{Fe} - r\, DOFe \quad (15)$$

$$\frac{D(SP_{Fe})}{Dt} = PC_{sp}^{photo}\, SP_C\, {}^{g}Q_{sp}^{Fe} - \left(G_{sp} + SP_{loss} + SP_{agg}\right) Q_{sp}^{Fe} \quad (16)$$

$$\frac{D(Diat_{Fe})}{Dt} = PC^{photo}_{diat}\, Diat_C\, {}^{g}Q^{Fe}_{diat} - (G_{diat} + Diat_{loss} + Diat_{agg})\, Q^{Fe}_{Diat} \quad (17)$$

$$\frac{D(Diat_{Si})}{Dt} = PC^{photo}_{diat}\, Diat_C\, {}^{g}Q^{Si}_{diat} - (G_{diat} + Diat_{loss} + Diat_{agg})\, Q^{Si}_{diat} \quad (18)$$

$$\frac{D(Diaz_C)}{Dt} = PC^{photo}_{diaz}\, Diaz_C - G_{diaz} - Diaz_{loss} \quad (19)$$

$$\frac{D(Diaz_{Chl})}{Dt} = \frac{\rho^{Chl}_{diaz}\, PC^{photo}_{diaz}\, Q}{\theta^{C}_{diaz}}\, Diaz_{Chl} - \theta^{C}_{diaz}\,(G_{diaz} + Diaz_{loss}) \quad (20)$$

$$\frac{D(Diaz_{Fe})}{Dt} = PC^{photo}_{diaz}\, Diaz_C\, {}^{g}Q^{Fe}_{diaz} - (G_{diaz} + Diaz_{loss})\, Q^{Fe}_{diaz} \quad (21)$$

$$\begin{aligned}\frac{D(DIC)}{Dt} = {} & r\,DOC + POC^{remin} + PCaCO_3^{remin} + f^{CaCO_3,remin}_{graz}\, G_{sp}\, Q^{CaCO_3}_{sp} + Z^{DIC}_{loss} + SP^{DIC}_{loss} + G^{DIC}_{sp} \\ & + Diat^{DIC}_{loss} + G^{DIC}_{diat} + Diaz^{DIC}_{loss} + G^{DIC}_{diaz} - PC^{photo}_{sp}\, SP_C - PC^{photo}_{diat}\, Diat_C - PC^{photo}_{diaz}\, Diaz_C \\ & - f^{sp,CaCO_3}_{prod}\, PC^{photo}_{sp}\, SP_C\, F_{nut}\end{aligned} \quad (22)$$

$$\begin{aligned}\frac{D(ALK)}{Dt} = {} & 2\left(PCaCO_3^{remin} + f^{CaCO_3,remin}_{graz}\, G_{sp}\, Q^{CaCO_3}_{sp} - f^{sp,CaCO_3}_{prod}\, PC^{photo}_{sp}\, SP_C\, F_{nut}\right) - \frac{D(NO_3)}{Dt} \\ & + \frac{D(NH_4)}{Dt}\end{aligned} \quad (23)$$

$$\begin{aligned}\frac{D(O_2)}{Dt} = {} & \frac{PC^{photo}_{sp}\, SP_C + PC^{photo}_{diat}\, Diat_C}{R^{C:O_2}_{D}} + \frac{PC^{photo}_{diaz}\, Diaz^{C}}{{}_{diaz}R^{C:O_2}_{D}} \\ & - \left(\frac{POC^{remin} + r\,DOC + Z^{DIC}_{loss} + SP^{DIC}_{loss} + Diat^{DIC}_{loss} + Diaz^{DIC}_{loss} + G^{DIC}_{sp} + G^{DIC}_{diat} + G^{DIC}_{diaz}}{R^{C:O_2}_{P}}\right)\end{aligned} \quad (24)$$

Where:

$$V^{NO_3}_{sp} = \frac{\frac{NO_3}{K^{NO_3}_{sp}}}{\left(1 + \frac{NO_3}{K^{NO_3}_{sp}} + \frac{NH4}{K^{NH_4}_{sp}}\right)}; \quad V^{NH_4}_{sp} = \frac{\frac{NH_4}{K^{NH_4}_{sp}}}{\left(1 + \frac{NO_3}{K^{NO_3}_{sp}} + \frac{NH4}{K^{NH_4}_{sp}}\right)}; \quad V^{N_{tot}}_{sp} = V^{NO_3}_{sp} + V^{NH_4}_{sp}$$

$$V^{NO_3}_{Diat} = \frac{\frac{NO_3}{K^{NO_3}_{Diat}}}{\left(1 + \frac{NO_3}{K^{NO_3}_{Diat}} + \frac{NH4}{K^{NH_4}_{Diat}}\right)}; \quad V^{NH_4}_{Diat} = \frac{\frac{NH_4}{K^{NH_4}_{Diat}}}{\left(1 + \frac{NO_3}{K^{NO_3}_{Diat}} + \frac{NH4}{K^{NH_4}_{Diat}}\right)}; \quad V^{N_{tot}}_{Diat} = V^{NO_3}_{Diat} + V^{NH_4}_{Diat}$$

$$V^{Fe}_{sp} = \frac{Fe}{Fe + K^{Fe}_{sp}}; \qquad V^{PO_4}_{sp} = \frac{PO_4}{PO_4 + K^{PO_4}_{sp}}$$

$$V^{Fe}_{diat} = \frac{Fe}{Fe + K^{Fe}_{diat}}; \qquad V^{PO_4}_{diat} = \frac{PO_4}{PO_4 + K^{PO_4}_{diat}}; \qquad V^{SiO_3}_{diat} = \frac{SiO_3}{SiO_3 + K^{SiO_3}_{diat}}$$

$$V^{Fe}_{diaz} = \frac{Fe}{Fe + K^{Fe}_{diaz}}; \qquad V^{PO_4}_{diaz} = \frac{PO_4}{PO_4 + K^{PO_4}_{diaz}}$$

$$PC^{photo}_{sp} = PC^{max}_{sp}\left(1 - e^{\frac{-\alpha\,\theta^{C}_{sp}\, I_{PAR}}{PC^{max}_{sp}}}\right); \quad PC^{photo}_{diat} = PC^{max}_{diat}\left(1 - e^{\frac{-\alpha\,\theta^{C}_{diat}\, I_{PAR}}{PC^{max}_{diat}}}\right); \quad PC^{photo}_{diaz} = PC^{max}_{diaz}\left(1 - e^{\frac{-\alpha_{diaz}\,\theta^{C}_{diaz}\, I_{PAR}}{PC^{max}_{diaz}}}\right);$$

$$PC^{max}_{sp} = PC^{ref}\, F^{nut}_{sp}\, T_f; \qquad PC^{max}_{diat} = PC^{ref}\, F^{nut}_{diat}\, T_f; \qquad PC^{max}_{diaz} = PC^{ref}_{diaz}\, F^{nut}_{diaz}\, T_f;$$

$$F^{nut}_{sp} = MIN(V^{N_{tot}}_{sp}, V^{Fe}_{sp}, V^{PO_4}_{sp}); \qquad F^{nut}_{diat} = MIN(V^{N_{tot}}_{diat}, V^{Fe}_{diat}, V^{PO_4}_{diat}, V^{SiO_3}_{diat}); \quad F^{nut}_{diaz} = MIN(V^{Fe}_{diaz}, V^{PO_4}_{diaz})$$

$$T_f = q_{10}^{\frac{(T+T_{K0})-(T_{ref}+T_{K0})}{10}}$$

$$I_{PAR} = I_0\ \phi\ e^{-(\kappa_w + \kappa_{chl}\ (SP_{Chl} + Diat_{Chl} + Diaz_{Chl}))\ z}$$

$$Z_{loss}^{DOC} = \left(1 - f_{DOC}^{lab}\right)\ \left(1 - F_Z^{POC}\right)\ Z_{loss}; \quad Z_{loss}^{DIC} = f_{DOC}^{lab}\,(1 - F_Z^{POC})\,Z_{loss}$$

$$Z_{loss} = T_f\left(m_z Z_C + p_z Z_C^2\right)$$

$$F_Z^{POC} = \frac{f_{zloss}^{sp,POC}\,G_{sp} + f_{zloss}^{diat,POC}\,G_{diat} + f_{zloss}^{diaz,POC}\,G_{diaz}}{G_{sp} + G_{diat} + G_{diaz}}$$

$$G_{sp} = u_{max}^{sp}\,T_f\left(\frac{SP_C^2}{SP_C^2 + g^2}\right)Z_C; \quad G_{diat} = u_{max}^{diat}\,T_f\left(\frac{Diat_C^2}{Diat_C^2 + g^2\,f_z^{diat}}\right)Z_C; \quad G_{diaz} = u_{max}^{diaz}\,T_f\left(\frac{Diaz_C^2}{Diaz_C^2 + g^2}\right)Z_C$$

$$SP_{loss} = m_{sp}\,SP_C; \quad Diat_{loss} = m_{diat}\,Diat_C; \quad Diaz_{loss} = m_{diaz}\,Diaz_C$$

$$SP_{loss}^{POC} = Q_{sp}^{CaCO_3}\,SP_{loss}; \qquad SP_{loss}^{DOC} = \left(1 - f_{DOC}^{lab}\right)\left(SP_{loss} - SP_{loss}^{POC}\right); \quad SP_{loss}^{DIC} = f_{DOC}^{lab}\left(SP_{loss} - SP_{loss}^{POC}\right)$$
$$Diat_{loss}^{POC} = f_{diat\ loss}^{POC}\,Diat_{loss}; \quad Diat_{loss}^{DOC} = (1 - f_{DOC}^{lab})\,f_{diat;loss}^{DOC}\,Diat_{loss}; \quad Diat_{loss}^{DIC} = f_{DOC}^{lab}\,f_{diat;loss}^{DOC}\,Diat_{loss}$$

$$Diaz_{loss}^{DOC} = (1 - f_{DOC}^{lab})\,Diaz_{loss}; \qquad Diaz_{loss}^{DIC} = f_{DOC}^{lab}\,Diaz_{loss}$$
$$Diaz_{loss}^{DOP} = (1 - f_{DOC}^{lab})\,Diaz_P^{remain}; \qquad Diaz_{loss}^{DIP} = f_{DOC}^{lab}\,Diaz_P^{remain}$$
$$Diaz_P^{remain} = (G_{diaz} + Diaz_{loss})\,Q_{diaz}^P - (G_{diaz}^{POC} + G_{diaz}^Z)\,Q^P$$

$$SP_{agg} = MIN(a_{sp}^{max}\,SP_C,\ p_{sp}\,SP_C^2); \quad Diat_{agg} = MIN(a_{diat}^{max}\,Diat_C,\ p_{diat}\,Diat_C^2)$$

$$G_{sp}^Z = i_z\,G_{sp}; \qquad G_{diat}^Z = i_z\,G_{diat}; \qquad G_{diaz}^Z = f_{graz}^{diaz,Z}\,G_{diaz}$$
$$G_{sp}^{POC} = G_{sp} \times MAX\left(f_{graz}^{CaCO_3,POC}\,Q_{sp}^{CaCO_3},\ MIN\left(e_{sp}^{POC}\,SP_C,\ f_{graz}^{sp,POC}\right)\right); \quad G_{diat}^{POC} = f_{graz}^{diat,POC}\,G_{diat}; \quad G_{diaz}^{POC} = f_{graz}^{diaz,POC}\,G_{diaz}$$
$$G_{sp}^{DOC} = f_{graz}^{sp,DOC}\,G_{sp} - G_{sp}^{POC}; \qquad G_{diat}^{DOC} = f_{graz}^{diat,DOC}\,G_{diat}; \quad G_{diaz}^{DOC} = f_{graz}^{diaz,DOC}\,G_{diaz}$$
$$G_{sp}^{DIC} = f_{graz}^{sp,DIC}\,G_{sp}; \qquad G_{diat}^{DIC} = f_{graz}^{diat,DIC}\,G_{diat}; \quad G_{diaz}^{DIC} = f_{graz}^{diaz,DIC}\,G_{diaz}$$

$$\theta_{sp}^C = \frac{SP_{Chl}}{SP_C}; \qquad \theta_{diat}^C = \frac{Diat_{Chl}}{Diat_C}; \qquad \theta_{diaz}^C = \frac{Diaz_{Chl}}{Diaz_C}$$
$$Q_{sp}^{Fe} = \frac{SP_{Fe}}{SP_C}; \qquad Q_{sp}^{CaCO_3} = \frac{SP_{CaCO_3}}{SP_C}; \quad Q_{diaz}^{Fe} = \frac{Diaz_{Fe}}{Diaz_C}$$
$$Q_{diat}^{Fe} = \frac{Diat_{Fe}}{Diat_C}; \quad Q_{diat}^{Si} = \frac{Diat_{Si}}{Diat_C};$$

$$\rho_{sp}^{Chl} =^{max} \theta_{sp}^N\,\frac{PC_{sp}^{photo}}{\alpha\,\theta_{sp}^C\,I_{PAR}}; \quad \rho_{diat}^{Chl} =^{max} \theta_{diat}^N\,\frac{PC_{diat}^{photo}}{\alpha\,\theta_{diat}^C\,I_{PAR}}; \quad \rho_{diaz}^{Chl} =^{max} \theta_{diaz}^N\,\frac{PC_{diaz}^{photo}}{\alpha_{diaz}\,\theta_{diaz}^C\,I_{PAR}}$$

Particulate Terms (implicit)

Non-iron particulate terms:

Production:

$$\begin{aligned}
POC^{prod} &= SP_{agg} + G^{POC}_{sp} + SP^{POC}_{loss} + Diat^{POC}_{loss} + Diat_{agg} + G^{POC}_{diat} + G^{POC}_{diaz} + F^{POC}_{Z}\, Z_{loss} \\
PCaCO_3^{prod} &= \left(\left(1 - f^{CaCO_3,remin}_{graz}\right) G_{sp} + SP_{loss} + SP_{agg}\right) Q^{CaCO_3}_{sp} \\
PSiO_3^{prod} &= \left(\left(1 - f^{Si,remin}_{graz}\right) G_{diat} + Diat_{agg} + f^{POC}_{diat\ loss}\, Diat_{loss}\right) Q^{Si}_{diat} \\
{}^{free}POC^{prod} &= POC^{prod} - \omega_{PCaCO_3}\, PCaCO_3^{prod} - \omega_{PSiO_3}\, PSiO_3^{prod}
\end{aligned}$$

Vertical fluxes as function of depth (z):

$$\begin{aligned}
{}^{soft}PCaCO_3^{flux}(z) &= {}^{soft}PCaCO_3^{flux}{}_{z_0}\, e^{\frac{-(z-z_0)}{\lambda_{PCaCO_3}}} + \left(1 - f^{hard}_{PCaCO_3}\right) \int_{z_0}^{z} PCaCO_3^{prod}\, e^{\frac{-(z-z_0)}{\lambda_{PCaCO_3}}}\, dz \\
{}^{hard}PCaCO_3^{flux}(z) &= {}^{hard}PCaCO_3^{flux}{}_{z_0}\, e^{\frac{-(z-z_0)}{\lambda_{hard}}} + f^{hard}_{PCaCO_3} \int_{z_0}^{z} PCaCO_3^{prod}\, dz \\
{}^{soft}PSiO_3^{flux}(z) &= {}^{soft}PSiO_3^{flux}{}_{z_0}\, e^{\frac{-(z-z_0)}{\lambda_{PSiO_3}} T_f^{SiO_3}} + \left(1 - f^{hard}_{PSiO_3}\right) \int_{z_0}^{z} PSiO_3^{prod}\, e^{\frac{-(z-z_0)}{\lambda_{PSiO_3}} T_f^{SiO_3}}\, dz \\
{}^{hard}PSiO_3^{flux}(z) &= {}^{hard}PSiO_3^{flux}{}_{z_0}\, e^{\frac{-(z-z_0)}{\lambda_{hard}}} + f^{hard}_{PSiO_3} \int_{z_0}^{z} PSiO_3^{prod}\, dz \\
{}^{soft}dust^{flux}(z) &= \left(1 - f^{hard}_{dust}\right)\left(1 - f^{bio}_{dust}\right) dust^{flux}_{z_0}\, e^{\frac{-(z-z_0)}{\lambda_{dust}}} \\
{}^{hard}dust^{flux}(z) &= f^{hard}_{dust}\left(1 - f^{bio}_{dust}\right) dust^{flux}_{z_0}\, e^{\frac{-(z-z_0)}{\lambda_{hard}}} \\
{}^{free}POC^{flux}(z) &= {}^{free}POC^{flux}_{z_0}\, e^{\frac{-(z-z_0)}{\lambda_{POC}} T_f^{POC}} + \int_{z_0}^{z} {}^{free}POC^{prod}\, e^{\frac{-(z-z_0)}{\lambda_{POC}} T_f^{POC}}\, dz \\
{}^{ballast}POC^{flux}(z) &= \omega_{PCaCO_3}\left({}^{soft}PCaCO_3^{flux}(z) + {}^{hard}PCaCO_3^{flux}(z)\right) \\
&\quad + \omega_{PSiO_3}\left({}^{soft}PSiO_3^{flux}(z) + {}^{hard}PSiO_3^{flux}(z)\right) + \omega_{dust}\left({}^{soft}dust^{flux}(z) + {}^{hard}dust^{flux}(z)\right)
\end{aligned}$$

Note: ${}^{free}POC = \text{soft } POC$

Remineralization from conservation:

$$\begin{aligned}
PCaCO_3^{remin}(z) &= PCaCO_3^{prod}(z) + \frac{d\left({}^{soft}PCaCO_3^{flux}\right)}{dz}(z) + \frac{d\left({}^{hard}PCaCO_3^{flux}\right)}{dz}(z) \\
PSiO_3^{remin}(z) &= PSiO_3^{prod}(z) + \frac{d\left({}^{soft}PSiO_3^{flux}\right)}{dz}(z) + \frac{d\left({}^{hard}PSiO_3^{flux}\right)}{dz}(z) \\
POC^{remin}(z) &= POC^{prod}(z) + \frac{d\left({}^{free}POC^{flux}\right)}{dz}(z) + \frac{d\left({}^{ballast}POC^{flux}\right)}{dz}(z) \\
dust^{remin}(z) &= \frac{d\left({}^{soft}dust^{flux}\right)}{dz}(z) + \frac{d\left({}^{hard}dust^{flux}\right)}{dz}(z)
\end{aligned}$$

Where:

$$T_f^{SiO_3} = {}^{SiO_3}\, q_{10}^{\frac{(T+T_{K0})-(T_{ref}+T_{K0})}{10}}; \quad T_f^{POC} = {}^{POC}\, q_{10}^{\frac{(T+T_{K0})-(T_{ref}+T_{K0})}{10}}$$

Particulate iron terms:

Production:

$$PFe^{prod} = \left(SP_{agg} + G_{sp}^{POC} + SP_{loss}^{POC}\right) Q_{sp}^{Fe} + \left(Diat_{loss}^{POC} + Diat_{agg} + G_{diat}^{POC}\right) Q_{diat}^{Fe} + G_{diaz}^{POC} Q_{diaz}^{Fe} + F_{Z}^{POC} Z_{loss} Q_{Z}^{Fe} + f_{scv}^{PFe} s^{Fe} Fe$$

Remineralization:

$$PFe^{remin}(z) = \begin{cases} POC^{remin}(z)\, R_{Fe:C} & : \ {}^{free}POC^{flux}(z) + {}^{ballast}POC^{flux}(z) = 0 \\ POC^{remin}(z)\, \dfrac{PFe^{flux}(z)}{{}^{free}POC^{flux}(z) + {}^{ballast}POC^{flux}(z)} & : \ {}^{free}POC^{flux}(z) + {}^{ballast}POC^{flux}(z) > 0 \end{cases}$$

Vertical flux from conservation:

$$\frac{d\left(PFe^{flux}\right)}{dz}(z) = PFe^{prod}(z) - PFe^{remin}(z)$$

Total particulate Fe remineralization:

$$PFe^{remin}(z) = PFe^{remin}(z) + c_{dust}^{Fe}\, dust^{remin}(z)$$

Where:

$$s^{Fe} = f(s_0^{Fe})$$

Summary Features

- Fixed C/N/P ratios for phytoplankton and zooplankton.
- Fixed Fe/C ratio for zooplankton
- Variable Fe/C and Chl/C ratios for phytoplankton → explicit C, Fe and Chl pools for phytoplankton.
- Variable Si/C ratio for diatoms → explicit Si pool for diatoms.
- Variable C/N/P/Fe/Si ratios for DOM → explicit N, P, Fe and Si pools for DOM.
- Variable Fe/C and Si/C ratios implemented with losses at current cell rations and uptake at a "growth ratio" that is a function of ambient nutrient conditions and the half-saturation constant for the group.

Model Parameters

Parameter	Value	Units	Definition
α	0.3	mmol C m^2 (mg Chl W d)$^{-1}$	initial slope of $P-I$ curve
α_{diaz}	0.036	mmol C m^2 (mg Chl W d)$^{-1}$	initial slope of $P-I$ curve for diazotrophs
T_{ref}	30	^{o}C	reference temperature
T_{K0}	273.16	K	zero point for Celcius
q_{10}	2		temperature dependence factor
PC^{ref}	3.0	d^{-1}	max. phyto. C-specific growth rate at T_{ref}
PC^{ref}_{diaz}	0.4	d^{-1}	max. diazotophs C-specific growth rate at T_{ref}
$K^{NO_3}_{sp}$	0.5	mmol N m^{-3}	small phyto. NO_3 half saturation coefficient
$K^{NH_4}_{sp}$	0.005	mmol N m^{-3}	small phyto. NH_4 half saturation coefficient
K^{Fe}_{sp}	6×10^{-5}	mmol Fe m^{-3}	small phyto. Fe half saturation coefficient
$K^{PO_4}_{sp}$	3.125×10^{-4}	mmol PO_4 m^{-3}	small phyto. PO_4 half saturation coefficient
$K^{NO_3}_{diat}$	2.5	mmol N m^{-3}	diatom NO_3 half saturation coefficient
$K^{NH_4}_{diat}$	0.08	mmol N m^{-3}	diatom NH_4 half saturation coefficient
K^{Fe}_{diat}	1.5×10^{-4}	mmol Fe m^{-3}	diatom Fe half saturation coefficient
$K^{PO_4}_{diat}$	0.005	mmol PO_4 m^{-3}	diatom PO_4 half saturation coefficient
$K^{SiO_3}_{diat}$	1.0	mmol SiO_3 m^{-3}	diatom Si half saturation coefficient
$K^{PO_4}_{diaz}$	0.005	mmol PO_4 m^{-3}	diazotrophs PO_4 half saturation coefficient
K^{Fe}_{diaz}	1×10^{-4}	mmol Fe m^{-3}	diazotrophs Fe half saturation coefficient
η	0.06	d^{-1}	nitrification rate
r	0.01	d^{-1}	DOM remineralization rate
m_{sp}	0.1	d^{-1}	small phyto. linear mortality rate
m_{diat}	0.1	d^{-1}	diatom linear mortality rate
p_{sp}	0.009	(mmol C)$^{-1}$ m^3 d^{-1}	small phyto. quadratic mortality rate
p_{diat}	0.009	(mmol C)$^{-1}$ m^3 d^{-1}	diatom quadratic mortality rate
m_{diaz}	0.16	d^{-1}	diazotrophs linear mortality rate
e^{POC}_{sp}	0.22	(mmol C)$^{-1}$	small phyto. grazing factor
a^{max}_{sp}	0.2	d^{-1}	max. aggregation rate for small phyto.
a^{max}_{diat}	0.2	d^{-1}	max. aggregation rate for diatoms
a^{min}_{diat}	0.01	d^{-1}	min. aggregation rate for diatoms
u^{sp}_{max}	2.75	d^{-1}	max. zoo. growth rate on small phyto. at T_{ref}
u^{diat}_{max}	2.07	d^{-1}	max. zoo. growth rate on diatoms at T_{ref}
u^{diaz}_{max}	1.2	d^{-1}	max. zoo. growth rate on diazotrophs at T_{ref}
m_z	0.1	d^{-1}	zoo. linear mortality rate
p_z	0.45	(mmol C)$^{-1}$ m^3 d^{-1}	zoo. quadratic mortality rate
g	1.05	mmol C m^{-3}	zoo. grazing coefficient
${}^{max}\theta^N_{sp}$	2.3	mg Chl (mmol N)$^{-1}$	small phyto. max. Chl:N ratio
${}^{max}\theta^N_{diat}$	3.0	mg Chl (mmol N)$^{-1}$	diatom max. Chl:N ratio
${}^{max}\theta^N_{diaz}$	3.4	mg Chl (mmol N)$^{-1}$	diazotrophs max. Chl:N ratio
κ_{chl}	3×10^{-4}	cm^{-1} (mg Chl)$^{-1}$ m^3	chlorophyll attenuation coefficient
κ_w	4×10^{-4}	cm^{-1}	water attenuation coefficient
ϕ	0.45		PAR fraction of total irradiance

Model Parameters (continuation)

Parameter	Value	Units	Definition
ζ_C^N	1.43		ratio of N fixation to C fixation
Q	0.137		phyto. and zoo. N:C ratio
Q^P	0.00855		small phyto., diatom and zoo. P:C ratio
Q_{diaz}^P	0.002735		diazotroph P:C ratio
Q_Z^{Fe}	2.5×10^{-6}		zoo. Fe:C ratio
${}_0^g Q_{diat}^{Si}$	0.137		initial diatom Si:C ratio
${}_0^g Q_{diat}^{Fe}$	6×10^{-6}		initial diatom Fe:C ratio
${}_0^g Q_{sp}^{Fe}$	6×10^{-6}		initial small phyto. Fe:C ratio
${}_0^g Q_{diaz}^{Fe}$	42×10^{-6}		initial diazotrophs Fe:C ratio
${}_{max}^g Q_{diat}^{Si}$	0.685		max diatom Si:C ratio
i_z	0.3		zoo. ingestion coefficient (non-dim)
f_{DOC}^{lab}	0.70		fraction of loss to DOC that is routed directly to DIC
$f_{graz}^{sp,DOC}$	0.34		fraction small phyto. grazing to DOC
$f_{graz}^{sp,DIC}$	$1 - \left(i_z + f_{graz}^{sp,DOC}\right)$		fraction of grazing on small phyto. routed to DIC
f_z^{diat}	0.81		scaling factor for grazing on diatoms
$f_{graz}^{diat,POC}$	0.26		fraction of diatom grazing routed to POC
$f_{graz}^{diat,DOC}$	0.13		fraction of diatom grazing routed to DOC
$f_{graz}^{diat,DIC}$	$1 - \left(i_z + f_{graz}^{diat,POC} + f_{graz}^{diat,DOC}\right)$		fraction of diatom grazing routed to DIC
$f_{diat\ loss}^{POC}$	0.05		fraction of diatom loss routed to POC
$f_{diat\ loss}^{DOC}$	$1 - f_{diat\ loss}^{POC}$		fraction of diatom loss routed to DOC
$f_{graz}^{diaz,Z}$	0.21		fraction of diazotrophs grazing routed to zoo.
$f_{graz}^{diaz,POC}$	0.0		fraction of diazotrophs grazing routed to POC
$f_{graz}^{diaz,DOC}$	0.24		fraction of diazotrophs grazing routed to DOC
$f_{graz}^{diaz,DIC}$	$1 - \left(f_{graz}^{diaz,Z} + f_{graz}^{diaz,POC} + f_{graz}^{diaz,DOC}\right)$		fraction of diazotrophs grazing routed to DIC
$f_{zloss}^{sp,POC}$	0.06666		fraction of zoo. losses routed to POC when eating small phyto.
$f_{zloss}^{diat,POC}$	0.1333		fraction of zoo. losses routed to POC when eating diatoms
$f_{zloss}^{diaz,POC}$	0.03333		fraction of zoo. losses routed to POC when eating diazotrophs
$f_{graz}^{CaCO_3,POC}$	0.4		min. proportionality between $Q_{sp}^{CaCO_3}$ and grazing losses to POC
$f_{graz}^{sp,POC}$	0.24		upper limit on fraction of grazing on small phyto. routed to POC
$f_{graz}^{CaCO_3,remin}$	0.33		fraction of SP_{CaCO_3} grazing which is remineralized
$f_{graz}^{Si,remin}$	0.5		fraction of diatom Si grazing which is remineralized
$f_{prod}^{sp,CaCO_3}$	0.026		fraction of small phyto. production as CaCO3 production
$R_D^{C:O_2}$	117/170		dissolved matter C:O_2 ratio
$R_P^{C:O_2}$	117/170		particulate matter C:O_2 ratio
${}^{diaz}R_D^{C:O_2}$	117/150		diazotrophs C:O_2 ratio
$R_{Fe:C}$	3×10^{-6}		Fe:C ratio

Parameters for Particulate Equations

Parameter	Value	Units	Definition
${}^{SiO_3}q_{10}$	4		temperature dependence factor for particulate SiO_3 remin.
${}^{POC}q_{10}$	1.12		temperature dependence factor for POC remin.
M_{POC}	12.01	g	POC molar mass
M_{CaCO_3}	100.09	g	$CaCO_3$ molar mass
M_{SiO_3}	60.08	g	SiO_3 molar mass
M_{dust}	1×10^9	g	dust molar mass
M_{Fe}	55.847	g	Fe molar mass
ω_{PCaCO_3}	$0.07 \times \frac{M_{CaCO_3}}{M_{POC}}$		qualitative associated POC/$CaCO_3$ mass ratio for particulate matter
ω_{PSiO_3}	$0.035 \times \frac{M_{SiO_3}}{M_{POC}}$		qualitative associated POC/SiO_3 mass ratio for particulate matter
ω_{dust}	$0.07 \times \frac{M_{dust}}{M_{POC}}$		qualitative associated POC/dust mass ratio for particulate matter
λ_{POC}	13000	cm	remineralization length scale for "soft" particulate POC
λ_{CaCO_3}	60000	cm	remineralization length scale for "soft" particulate $CaCO_3$
λ_{SiO_3}	2200	cm	remineralization length scale for "soft" particulate SiO_3
λ_{dust}	60000	cm	remineralization length scale for "soft" dust
λ_{hard}	4×10^6	cm	remineralization length scale for all "hard" particulate subclasses
$f^{hard}_{PCaCO_3}$	0.55		fraction of particulate $CaCO_3$ production routed to "hard" subclass
$f^{hard}_{PSiO_3}$	0.37		fraction of particulate SiO_3 production routed to "hard" subclass
f^{hard}_{dust}	0.97		fraction of surface dust flux routed to "hard" subclass
f^{bio}_{dust}	0.02		fraction of surface iron dust flux that is bioavailable
f^{PFe}_{scv}	0.1		fraction of Fe scavenging routed to particulate Fe
s^{Fe}_0	0.12	% of ambient	initial Fe scavenging rate
w^{Fe}_{dust}	0.035	g/g	Fe/dust weight ratio
c^{Fe}_{dust}	$\frac{w^{Fe}_{dust}}{M_{Fe}} \times 10^9$	nmol Fe/g dust	dust to iron conversion factor