Supplement of Biogeosciences, 11, 3259–3278, 2014
http://www.biogeosciences.net/11/3259/2014/
doi:10.5194/bg-11-3259-2014-supplement

Biogeosciences Open Access

Supplement of

Top-down, bottom-up and physical controls on diatom-diazotroph assemblage growth in the Amazon River plume

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1 Supplement 1 – Parameter Values

Param	Description	Value	Units
α	fraction of uptake that goes to growth	0.7	
μ_{small}	max growth rate of cya	1.0	d^{-1}
μ_{large}	max growth rate of diatoms	3.0	d^{-1}
μT_{ri}	max growth rate of Tricho	0.15	d^{-1}
ϑ_S	UMD diazo growth penalty	0.6	
ϑ_{NIF}	DDA growth penalty	0.67	
ϑ_L	DDA diazotrophic growth penalty	0.33	
$I_{\beta PS}$	Cya photoinhibition parameter	400	W m^{-2}
$I_{\beta PL}$	Dtm photoinhibition parameter	400	W m^{-2}
I_{PS}	Cya growth-irradiance parameter	20	W m^{-2}
I_{PL}	Dtm growth-irradiance parameter	40	W m^{-2}
I_{PT}	*Trichodesmium* growth-irradiance parameter	70	W m^{-2}
$K_{S,N}$	Cya half-saturation for DIN	0.2	µmol N L^{-1}
$K_{L,N}$	Dtm half-saturation for DIN	1.2	µmol N L^{-1}
$K_{T,N}$	*Trichodesmium* half-saturation for DIN	0.5	µmol N L^{-1}
$K_{S,P}$	Cya half-saturation for DIP	0.005	µmol P L^{-1}
$K_{L,P}$	Dtm half-saturation for DIP	0.01	µmol P L^{-1}
$K_{T,P}$	*Trichodesmium* half-saturation for DIP	0.0077	µmol P L^{-1}
$K_{L,Si}$	Dtm half-saturation for Si	2.0	µmol Si L^{-1}
m_{PS}	Cya and UMD mortality	0.01	d^{-1}
m_{PL}	Dtm and DDAmortality	0.05	d^{-1}
m_{PT}	*Trichodesmium* mortality	0.01	d^{-1}
m_{ZS}	Protozoan mortality	0.01	d^{-1}
m_{ZL}	Mesozooplankton mortality	0.01	d^{-1}
f	fraction of diatom mortality to D_S	0.25	d^{-1}
R_0	N:P ratio of non-diazotrophs	16	mol:mol
R_N	N:P ratio of diazotrophs	45	mol:mol
R_{Si}	N:Si ratio of diatoms	1.0	
G_{S0}	Protozoan max grazing rate	8.0	d^{-1}
G_{L0}	Mesozooplankton max grazing rate	2.0	d^{-1}
K_{ZS}	Protozoan half-saturation constant	2.7	µmol N L^{-1}
K_{ZL}	Mesozooplankton half-saturation constant	2.7	µmol N L^{-1}
K_H	Higher Predator half-saturation constant	2.7	µmol N L^{-1}
γ_S	gross growth efficiency of protozoans	0.3	
γ_L	gross growth efficiency of mesozooplankton	0.3	
ε_S	egestion efficiency of protozoans	0.3	
ε_L	egestion efficiency of mesozooplankton	0.3	
ε_H	egestion efficiency of higher predators	0.43	
σ_S	Fraction of protozoan excretion to D_C	0.25	
σ_L	Fraction of mesozooplankton excretion to D_C	0.25	
σ_H	Fraction of higher predator excretion to D_C	0.25	
B_R	Basal metabolic rates of mesozooplankton	0.05	d^{-1}
π_{SS}	Protozoan preference for cya	1.0	
π_{SL}	Protozoan preference for dtm	0.1	
π_{ST}	Protozoan preference for Tricho	0.01	
π_{SZ}	Protozoan preference for protozoans	0.1	
π_{SD}	Protozoan preference for large detritus	0.01	
π_{LL}	Mesozooplankton preference for dtm	1.0	
π_{LT}	Mesozooplankton preference for Tricho	0.3	
π_{LZ}	Mesozooplankton preference for protozoans	0.3	

π_{LD}	Mesozooplankton preference for large detritus	0.3	
$\epsilon_{DCN,DIN}$	Remineralization rate of DCN	0.05	d^{-1}
$\epsilon_{DCP,DIP}$	Remineralization rate of DCP	0.25	d^{-1}
$\epsilon_{DCSi,Si}$	Remineralization rate of DCSi	0.8	d^{-1}
$\epsilon_{DSN,DIN}$	Remineralization rate of DSN	0.05	d^{-1}
$\epsilon_{DSP,DIP}$	Remineralization rate of DSP	0.25	d^{-1}
$\epsilon_{DSSi,Si}$	Remineralization rate of DSSi	0.8	d^{-1}
$\epsilon_{DLN,DIN}$	Remineralization rate of DLN	0.05	d^{-1}
$\epsilon_{DLP,DIP}$	Remineralization rate of DLP	0.25	d^{-1}
$\epsilon_{DLSi,Si}$	Remineralization rate of DLSi	0.8	d^{-1}
ω_S	Small detritus sinking rate	10	d^{-1}
ω_L	Large Detritus sinking rate	50	d^{-1}
Riv_{DIN}	DIN concentration in river	8.5	$\mu mol\ N\ L^{-1}$
Riv_{DIP}	DIP concentration in river	0.8	$\mu mol\ P\ L^{-1}$
Riv_{Si}	Si concentration in river	32.0	$\mu mol\ Si\ L^{-1}$

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Supplement 2 – Nutrient and detritus equations.

$$\frac{d\boldsymbol{D_{L,P}}}{dt} = \frac{\varepsilon_L}{R_0} \cdot GTL \cdot \boldsymbol{Z_L} + \frac{\varepsilon_H}{R_0} \cdot \frac{G_{H0} \cdot \boldsymbol{Z_L} \cdot \boldsymbol{Z_L}}{K_H + \boldsymbol{Z_L}} - \frac{G_{L,DL}}{R_0} \cdot \boldsymbol{Z_L} - \epsilon_{DLP,DIP} \cdot \boldsymbol{D_{L,P}} - \omega_L \cdot \boldsymbol{D_{L,P}} \quad \textbf{(S1)}$$

$$\frac{d\boldsymbol{D_{L,N}}}{dt} = \varepsilon_L \cdot GTL \cdot \boldsymbol{Z_L} + \varepsilon_L \cdot \{G_{L,DDA} + G_{L,Tri}\} \cdot \left(1 - \frac{R_0}{R_N}\right) \cdot \boldsymbol{Z_L} + \varepsilon_L \cdot G_{L,DS} \cdot \left(1 - \frac{R_0 \cdot \boldsymbol{D_{S,P}}}{\boldsymbol{D_{S,N}}}\right) \cdot \boldsymbol{Z_L}$$

$$+\varepsilon_L \cdot G_{L,DS} \cdot \left(1 - \frac{R_0 \cdot \boldsymbol{D_{S,P}}}{\boldsymbol{D_{S,N}}}\right) \cdot \boldsymbol{Z_L} + \varepsilon_H \cdot \frac{G_{H0} \cdot \boldsymbol{Z_L} \cdot \boldsymbol{Z_L}}{K_H + \boldsymbol{Z_L}} - G_{L,DL} \cdot \boldsymbol{Z_L} - \epsilon_{DSN,DIN} \cdot \boldsymbol{D_{L,N}} - \omega_L \cdot \boldsymbol{D_{L,N}} \quad \textbf{(S2)}$$

$$\frac{d\boldsymbol{D_{L,Si}}}{dt} = \cdot \frac{G_{L,DTM}}{R_{Si}} \cdot \boldsymbol{Z_L} + \cdot \frac{G_{L,DDA}}{R_{Si}} \cdot \boldsymbol{Z_L} + \frac{D_{S,Si}}{D_{S,N}} G_{L,DS} \cdot \boldsymbol{Z_L} + \frac{D_{L,Si}}{D_{L,N}} G_{L,DL} \cdot \boldsymbol{Z_L} - \frac{D_{L,Si}}{D_{L,N}} G_{L,DL} \cdot \boldsymbol{Z_L} - \epsilon_{DLSi,Si} \cdot \boldsymbol{D_{L,Si}} - \omega_L \cdot \boldsymbol{D_{L,Si}} \quad \textbf{(S3)}$$

$$\frac{d\boldsymbol{D_{S,P}}}{dt} = \frac{\mathrm{m}_P}{R_0} \cdot f \cdot \boldsymbol{P_{DTM}} + \frac{\mathrm{m}_P}{R_N} \cdot f \cdot \boldsymbol{P_{DDA}} - \frac{G_{S,DS} \cdot \boldsymbol{D_{S,P}}}{\boldsymbol{D_{S,N}}} \cdot \boldsymbol{Z_S} - \frac{G_{L,DS} \cdot \boldsymbol{D_{S,P}}}{\boldsymbol{D_{S,N}}} \cdot \boldsymbol{Z_L} - \epsilon_{DSP,DIP} \cdot \boldsymbol{D_{S,P}} - \omega_S \cdot \boldsymbol{D_{S,P}} \quad \textbf{(S4)}$$

$$\frac{d\boldsymbol{D_{S,N}}}{dt} = \mathrm{m}_P \cdot f \cdot \boldsymbol{P_{DTM}} + \mathrm{m}_P \cdot f \cdot \boldsymbol{P_{DDA}} - G_{S,DS} \cdot \boldsymbol{Z_S} - G_{L,DS} \cdot \boldsymbol{Z_L} - \epsilon_{DSN,DIN} \cdot \boldsymbol{D_{S,N}} - \omega_S \cdot \boldsymbol{D_{S,N}} \quad \textbf{(S5)}$$

$$\frac{d\boldsymbol{D_{S,Si}}}{dt} = \frac{\mathrm{m}_P}{R_{Si}} \cdot f \cdot \boldsymbol{P_{DTM}} + \frac{\mathrm{m}_P}{R_{Si}} \cdot f \cdot \boldsymbol{P_{DDA}} - \frac{G_{S,DS} \cdot \boldsymbol{D_{S,Si}}}{\boldsymbol{D_{S,N}}} \cdot \boldsymbol{Z_S} - \frac{G_{L,DS} \cdot \boldsymbol{D_{S,Si}}}{\boldsymbol{D_{S,N}}} \cdot \boldsymbol{Z_L} - \epsilon_{DSP,DIP} \cdot \boldsymbol{D_{S,P}} - \omega_S \cdot \boldsymbol{D_{S,P}} \quad \textbf{(S6)}$$

$$\frac{d\boldsymbol{D_{C,P}}}{dt} = \frac{(1-\gamma_L-\varepsilon_L)\sigma_L}{R_0} \cdot GTL \cdot \boldsymbol{Z_L} + \frac{(1-\varepsilon_H)\sigma_H}{R_0} \cdot \frac{G_{H0} \cdot \boldsymbol{Z_L} \cdot \boldsymbol{Z_L}}{K_H + \boldsymbol{Z_L}} + \frac{(1-\gamma_S-\varepsilon_S)\sigma_S+\varepsilon_S}{R_0} \cdot GTS \cdot Z_S$$

$$+(1-\alpha)\cdot\left(U_{cya}\cdot\frac{\boldsymbol{P_{Cya}}}{R_0}+V_{UMD}\cdot\frac{\boldsymbol{P_{UMD}}}{R_N}+U_{dtm}\cdot\frac{\boldsymbol{P_{DTM}}}{R_0}+V_{dda}\cdot\frac{\boldsymbol{P_{DDA}}}{R_N}+V_{tri}\cdot\frac{\boldsymbol{P_{Tri}}}{R_N}\right)$$

$$+\left(\mathrm{m}_P\cdot\frac{\boldsymbol{P_{Cya}}}{R_0}+\mathrm{m}_P\cdot\frac{\boldsymbol{P_{UMD}}}{R_N}+\mathrm{m}_P\cdot(1-f)\cdot\frac{\boldsymbol{P_{DTM}}}{c}+\mathrm{m}_P\cdot(1-f)\cdot\frac{\boldsymbol{P_{DDA}}}{R_N}+\mathrm{m}_P\cdot\frac{\boldsymbol{P_{Tri}}}{R_N}\right)-\epsilon_{DCP,DIP}\cdot D_{C,P} \quad \text{(S7)}$$

$$\frac{d\boldsymbol{D_{C,N}}}{dt}=(1-\gamma_L-\varepsilon_L)\sigma_L\cdot GTL\cdot\boldsymbol{Z_L}+(1-\varepsilon_H)\sigma_H\cdot\frac{G_{H0}\cdot\boldsymbol{Z_L}\cdot\boldsymbol{Z_L}}{K_H+\boldsymbol{Z_L}}+\left((1-\gamma_S-\varepsilon_S)\sigma_S+\varepsilon_S\right)\cdot GTS\cdot\boldsymbol{Z_S}$$

$$+(1-\varepsilon_L)\sigma_L\cdot\left\{G_{L,DDA}+G_{L,Tri}\right\}\cdot\left(1-\frac{R_0}{R_N}\right)\cdot\boldsymbol{Z_L}+(1-\varepsilon_L)\sigma_L\cdot\left\{G_{L,DS}\cdot\left(1-\frac{R_0\cdot\boldsymbol{D_{S,P}}}{\boldsymbol{D_{S,N}}}\right)+G_{L,DL}\cdot\left(1-\frac{R_0\cdot\boldsymbol{D_{S,P}}}{\boldsymbol{D_{S,N}}}\right)\right\}\cdot\boldsymbol{Z_L}$$

$$+\left((1-\varepsilon_S)\sigma_S+\varepsilon_S\right)\cdot\left\{G_{S,UMD}+G_{S,DDA}+G_{S,Tri}\right\}\cdot\left(1-\frac{R_0}{R_N}\right)\cdot\boldsymbol{Z_S}+\left((1-\varepsilon_S)\sigma_S+\varepsilon_S\right)\cdot G_{S,DS}\cdot\left(1-\frac{R_0\cdot\boldsymbol{D_{S,P}}}{\boldsymbol{D_{S,N}}}\right)\cdot\boldsymbol{Z_S}$$

$$+(1-\alpha)\cdot\left(U_{cya}\cdot\boldsymbol{P_{Cya}}+V_{UMD}\cdot\boldsymbol{P_{UMD}}+U_{dtm}\cdot\boldsymbol{P_{DTM}}+V_{dda}\cdot\boldsymbol{P_{DDA}}+V_{tri}\cdot\boldsymbol{P_{Tri}}\right)$$

$$+\left(\mathrm{m}_P\cdot\boldsymbol{P_{Cya}}+\mathrm{m}_P\cdot\boldsymbol{P_{UMD}}+\mathrm{m}_P\cdot(1-f)\cdot\boldsymbol{P_{DTM}}+\mathrm{m}_P\cdot(1-f)\cdot\boldsymbol{P_{DDA}}+\mathrm{m}_P\cdot\boldsymbol{P_{Tri}}\right)+m_z\cdot Z_S+m_z\cdot Z_L-\epsilon_{DCN,DIN}\cdot\boldsymbol{D_{C,N}} \quad \textbf{(S8)}$$

$$\frac{d\boldsymbol{D_{C,Si}}}{dt}=R_{Si,DTM}\cdot G_{S,DTM}+R_{Si}\cdot G_{S,DDA}+\frac{\mathrm{m}_P\cdot(1-f)}{R_{Si}}\cdot\boldsymbol{P_{DTM}}+\frac{\mathrm{m}_P\cdot(1-f)}{R_{Si}}\cdot\boldsymbol{P_{DDA}}-\epsilon_{DCSi,Si}\cdot\boldsymbol{D_{C,Si}} \quad \textbf{(S9)}$$

$$\frac{d\boldsymbol{DIP}}{dt}=\frac{(1-\gamma_L-\varepsilon_L)(1-\sigma_L)}{R_0}\cdot GTL\cdot\boldsymbol{Z_L}+\frac{(1-\varepsilon_H)(1-\sigma_H)}{R_0}\cdot\frac{G_{H0}\cdot\boldsymbol{Z_L}\cdot\boldsymbol{Z_L}}{K_H+\boldsymbol{Z_L}}+\frac{(1-\gamma_S-\varepsilon_S)(1-\sigma_S)}{R_0}\cdot GTS\cdot\boldsymbol{Z_S}$$

$$+\epsilon_{DCP,DIP}\cdot\boldsymbol{D_{C,P}}+\epsilon_{DSP,DIP}\cdot\boldsymbol{D_{S,P}}+\epsilon_{DLP,DIP}\cdot\boldsymbol{D_{L,P}}-\frac{U_{cya}}{R_0}\cdot\boldsymbol{P_{Cya}}-\frac{V_{UMD}}{R_N}\cdot\boldsymbol{P_{UMD}}-\frac{U_{DTM}}{R_0}\cdot\boldsymbol{P_{DTM}}-\frac{G_{DDA}}{R_N}\cdot\boldsymbol{P_{DDA}}-\frac{U_{Tri}}{R_N}\cdot\boldsymbol{P_{Tri}} \quad \textbf{(S10)}$$

$$\frac{d\boldsymbol{DIN}}{dt}=(1-\gamma_L-\varepsilon_L)(1-\sigma_L)\cdot GTL\cdot\boldsymbol{Z_L}+(1-\varepsilon_H)(1-\sigma_H)\cdot\frac{G_{H0}\cdot\boldsymbol{Z_L}\cdot\boldsymbol{Z_L}}{K_H+\boldsymbol{Z_L}}+(1-\gamma_S-\varepsilon_S)(1-\sigma_S)\cdot GTS\cdot\boldsymbol{Z_S}$$

$$+(1-\varepsilon_L)(1-\sigma_L)\cdot\left\{G_{L,DDA}+G_{L,Tri}\right\}\cdot\left(1-\frac{R_0}{R_N}\right)\cdot\boldsymbol{Z_L}+(1-\varepsilon_L)(1-\sigma_L)\cdot\left\{G_{L,DS}\cdot\left(\frac{D_{S,N}}{D_{S,P}}-R_0\right)+G_{L,DL}\cdot\left(1-\frac{R_0\cdot\boldsymbol{D_{S,P}}}{\boldsymbol{D_{S,N}}}\right)\right\}\cdot\boldsymbol{Z_L}$$

$$+(1-\varepsilon_S)(1-\sigma_S)\cdot\left\{G_{S,UMD}+G_{S,DDA}+G_{S,Tri}\right\}\cdot\left(1-\frac{R_0}{R_N}\right)\cdot\boldsymbol{Z_S}+(1-\varepsilon_S)(1-\sigma_S)\cdot G_{S,DS}\cdot\left(1-\frac{R_0\cdot\boldsymbol{D_{S,P}}}{\boldsymbol{D_{S,N}}}\right)\cdot\boldsymbol{Z_S}$$

$$+\epsilon_{DCN,DIN}\cdot\boldsymbol{D_{C,N}}+\epsilon_{DSN,DIN}\cdot\boldsymbol{D_{S,N}}+\epsilon_{DSN,DIN}\cdot\boldsymbol{D_{S,N}}-U_{cya}\cdot\boldsymbol{P_{Cya}}-U_{UMD}\cdot\boldsymbol{P_{UMD}}-U_{DTM}\cdot\boldsymbol{P_{DTM}}-U_{DDA}\cdot\boldsymbol{P_{DDA}}-U_{Tri}\cdot\boldsymbol{P_{Tri}} \quad \textbf{(S11)}$$

where:

$$U_{UMD}(N,DIP,I)=\mu_{small}\cdot\vartheta_{nif}\cdot e^{-I/I_{\beta P}}\cdot\left(1-e^{-I/I_P}\right)\cdot min\left(\frac{\boldsymbol{DIN}}{K_{S,N}+\boldsymbol{DIN}},\frac{\boldsymbol{DIP}}{K_{S,P}+\boldsymbol{DIP}}\right) \quad \textbf{(S12)}$$

$$U_{DDA}(N,DIP,I)=\mu_{large}\cdot\vartheta_{nif}\cdot e^{-I/I_{\beta P}}\cdot\left(1-e^{-I/I_P}\right)\cdot min\left(\frac{\boldsymbol{DIN}}{K_{L,N}+\boldsymbol{DIN}},\frac{\boldsymbol{DIP}}{K_{L,P}+\boldsymbol{DIP}},\frac{\boldsymbol{Si}}{K_{Si}+\boldsymbol{Si}}\right) \quad \textbf{(S13)}$$

$$U_{Tri}(N,DIP,I)=\mu_{Tri}\cdot\vartheta_{nif}\cdot\left(1-e^{-I/I_P}\right)\cdot min\left(\frac{\boldsymbol{DIN}}{K_{T,N}+\boldsymbol{DIN}},\frac{\boldsymbol{DIP}}{K_{T,P}+\boldsymbol{DIP}}\right) \quad \textbf{(S14)}$$

$$\frac{d\boldsymbol{Si}}{dt}=\epsilon_{DCSi,Si}\cdot\boldsymbol{D_{C,Si}}+\epsilon_{DSSi,Si}\cdot\boldsymbol{D_{S,Si}}+\epsilon_{DLSi,Si}\cdot\boldsymbol{D_{L,Si}}-\alpha\frac{U_{DTM}}{R_{Si}}\cdot\boldsymbol{P_{DTM}}-\alpha\frac{G_{DDA}}{R_{Si}}\cdot\boldsymbol{P_{DDA}} \quad \textbf{(S15)}$$