Supplement of Biogeosciences, 15, 7379–7401, 2018
https://doi.org/10.5194/bg-15-7379-2018-supplement
© Author(s) 2018. This work is distributed under
the Creative Commons Attribution 4.0 License.

Biogeosciences Open Access EGU

Supplement of

Modelling the biogeochemical effects of heterotrophic and autotrophic N_2 fixation in the Gulf of Aqaba (Israel), Red Sea

Angela M. Kuhn et al.

Correspondence to: Angela M. Kuhn (angela.kuhn@dal.ca)

The copyright of individual parts of the supplement might differ from the CC BY 4.0 License.

Supplements

1. Model equations

1.1. Hypothesis 0: Neglecting N_2 fixation

As a starting hypothesis, we test whether a model without nitrogen fixing can reproduce the observed distribution of inorganic nutrients**.** We test this model with and without allowing a sediment denitrification flux, denoted as H0 and H0', respectively. Therefore, H0 fully neglects N_2 fixation, while H0' implicitly assumes that N_2 fixation inputs and N_2 denitrification are balanced.

This model (H0) tracks the changes of 8 state-variables: nitrate (NO_3), ammonium (NH_4), dissolved inorganic phosphorus (DIP), non-fixing phytoplankton (Phy), zooplankton (Zoo), "small" detritus (D_S), "large" detritus (D_L), and oxygen (O_2). Model equations correspond to those described in Fennel et al., 2006 and 2013. Changes in phytoplankton and zooplankton biomass are measured in nitrogen units only, which implies a constant N:P ratio for these functional groups. The stoichiometry of non-fixing phytoplankton and zooplankton is set to the Redfield ratio ($R_{N:P}^{nf}$=16), and their biomass changes according to:

$$\frac{\partial Phy}{\partial t} = \mu_{Phy} Phy - gZoo - m_{Phy} Phy - w_{Phy} \frac{\partial Phy}{\partial z} \tag{1.1}$$

$$\frac{\partial Zoo}{\partial t} = g\beta Zoo - l_{BM} Zoo - l_E \frac{Phy^2}{k_{Phy} + Phy^2} \beta Zoo - m_{Zoo} Zoo^2 \tag{1.2}$$

Phytoplankton growth (equ. 1) depends on light and nutrient supply according to: $\mu_{Phy} = \mu_{Phy}^{max} f(I) \min(L_{NO_3} + L_{NH_4}, L_{DIP})$. This formulation assumes that growth is limited by light and nutrient availability using a multiplicative effect. In terms of nutrient limitation, it follows Liebig's Law of the minimum, as growth is limited by the scarcest nutrient resource of either nitrogen or phosphorus. The maximum non-fixing phytoplankton growth rate, μ_{Phy}^{max}, varies with temperature using a Q_{10} formulation according to $\mu_{Phy}^{max}(T) = \mu_{Phy}^{0} 1.88^{T/10^oC}$ (Eppley, 1972), where μ_{Phy}^{0} is the assumed maximum growth rate at T = 0°C. The light limitation function is equal to $f(I) = \frac{\alpha_{Phy} I}{\sqrt{\left(\mu_{Phy}^{max}\right)^2 + \alpha_{Phy}^2 I^2}}$ (Smith, 1936), where I is the depth varying photosynthetically active radiation, and α_{Phy} is the initial slope of the photosynthetic reaction. The value of I decreases exponentially with depth (z) according to $I(z) = I_0(1-\phi)e^{-z\,k_w - \int_0^z k_{chl} Chl_{Phy} dz}$, where the coefficients

ϕ=0.62 and $k_w = 0.05$ m^{-1} are set for oceanic clear waters according to Jerlov's type IA (Paulson and Simpson, 1977), and the coefficient $k_{chl} = 0.04\, m^{-1}$ represents light attenuation due to chlorophyll concentrations (*Chl*). I_0 is the surface solar radiation recorded at the IUI station.

Non-fixing phytoplankton is grazed by zooplankton at a density dependent rate $g = g_{Phy}^{max} \frac{Phy^2}{k_{Zoo}^{Phy} + Phy^2}$, with only a fraction β being assimilated into zooplankton growth. The last two terms in equation 1 represent non-fixing phytoplankton mortality and sinking, which occur at a rate of m_{Phy} and a speed of w_{Phy}, respectively. In equation 2, l_{BM}, l_E, and m_Z represent the zooplankton base metabolic, excretion and mortality rates.

Changes in nutrient concentrations are defined by the following set of equations:

$$\frac{\partial NO_3}{\partial t} = -\mu_{Phy}\left(\frac{Lim_{NO_3}}{Lim_{NO_3} + Lim_{NH_4}}\right)Phy + nNH_4 \tag{1.3}$$

$$\frac{\partial NH_4}{\partial t} = -\mu_{Phy}\left(1 - \frac{Lim_{NO_3}}{Lim_{NO_3} + Lim_{NH_4}}\right)Phy + l_{BM}Zoo + l_E\frac{Phy^2}{k_P + Phy^2}\beta Zoo + r_{D_S}D_{S(N)} + r_{D_L}D_{L(N)} - nNH4 \tag{1.4}$$

$$\frac{\partial DIP}{\partial t} = \frac{1}{R_{N:P}^{nf}}\left(-\mu_{Phy}Phy + l_{BM}Zoo + l_E\frac{Phy^2}{k_P + Phy^2}\beta Zoo\right) + r_{D_{S(P)}}D_{S(P)} + r_{D_L}D_{L(P)} \tag{1.5}$$

Equations 3, 4, and 5 represent the changes in nitrate, ammonium, and dissolved inorganic phosphorus, respectively. In these equations, nutrient uptake by non-fixing phytoplankton is modulated by the maximum non-fixing phytoplankton growth rate μ_{Phy}^{max}, the light limitation function $f(I)$, and the corresponding nutrient limitation factor (L_{NO_3}, L_{NH_4}, or L_{DIP}). The nutrient limitation factors for ammonium and dissolved inorganic phosphorus in the form of phosphate are Michaelis-Menten (1913) functions:

$$L_{NH_4} = \frac{NH_4}{k_{Phy}^{NH_4} + NH_4} \tag{1.6}$$

$$L_{DIP} = \frac{DIP}{k_{Phy}^{DIP} + DIP} \tag{1.7}$$

The nitrate limitation factor is also a Michaelis – Menten (1913) function, but is modified by the availability of NH_4, which inhibits NO_3 uptake:

$$L_{NO_3} = \frac{NO_3}{k_{Phy}^{NO_3} + NO_3} \frac{1}{\left(1 + NH_4/k_{Phy}^{NH_4}\right)} \tag{1.8}$$

Both NH_4 and DIP receive contributions from zooplankton metabolic and excretion losses, and from the degradation of small and large detritus. The parameters l_{BM}, l_E are the metabolic loss and mortality rates of zooplankton. Degradation rates for small and large detritus are represented by r_{D_S} and r_{D_L}, respectively. Both the nitrogen and phosphorus fractions of the two detritus groups are tracked, for which we use the subscripts "(N)" and "(P)" correspondingly. The last terms in equations 3 and 4 represent the transformation of NH_4 into NO_3 via nitrification at rate n.

The model also estimates non-fixing phytoplankton chlorophyll content ($\mathrm{Chl_{Phy}}$):

$$\frac{\partial Chl_{Phy}}{\partial t} = \rho_{Chl_{Phy}} \mu_{Phy} Phy - \ gZoo \frac{Chl_{Phy}}{Phy} - m_{Phy} Chl_{Phy} - w_{Phy} \frac{\partial Chl_{Phy}}{\partial z} \tag{1.9}$$

where the factor $\rho_{\mathrm{Chl_{Phy}}}$ represents a variable chlorophyll-to-biomass ratio. This factor accounts for the photoacclimation effect of increased chlorophyll production under low light conditions and is determined following Geider et al., (1997):

$$\rho_{\mathrm{Chl_{Phy}}} = \frac{\theta_{Phy}^{max} \mu_{Phy} Phy}{\alpha_{Phy} IChl_{Phy}} \tag{1.10}$$

The two fractions of detritus aim to represent small-suspended particles of non-living organic matter (D_S) that can aggregate to form larger sinking particles (D_L). "Small" detritus (eq. 11) is formed from the unassimilated fraction of zooplankton grazing (i.e., sloppy feeding), and from dead phytoplankton and zooplankton. The small detritus pool suffers losses from coagulation and degradation. "Large" detritus (eq. 12) is produced trough the coagulation D_S, and is removed by degradation and sinking at a w_{D_L} speed. The sinking speed of large detritus is assumed to be faster than for non-fixing phytoplankton (w_{Phy}).

$$\frac{\partial D_S}{\partial t} = g(1-\beta) Zoo + m_Z Zoo^2 + \ m_{Phy} Phy - r_{D_S} D_S \tag{1.11}$$

$$\frac{\partial D_L}{\partial t} = \tau D_S^2 \ - r_{D_L} D_L - w_{D_L} \frac{\partial D_L}{\partial z} \tag{1.12}$$

Oxygen (eq. 13) is produced during photosynthesis and consumed by zooplankton metabolism, and the degradation of dissolved organic matter and detritus, as in Fennel et al. (2013):

$$\frac{\partial O_2}{\partial t} = \mu_{Phy}^{max} f(I)\left(L_{NO_3} R_{O_2:NO_3} + L_{NH_4} R_{O_2:NH_4}\right) Phy - 2\, nNH_4 - R_{O_2:NH_4}\left(l_{BM} Zoo + r_{D_S} D_S - r_{D_L} D_L\right) \quad (1.13)$$

where $R_{O_2:NO_3} = \frac{138}{16}\frac{mol\ O_2}{mol\ NO_3}$ and $R_{O_2:NH_3} = \frac{106}{16}\frac{mol\ O_2}{mol\ NH_3}$ represent stoichiometric ratios corresponding to the oxygen produced during photosynthesis per mole of nitrate and ammonium consumed.

At the ocean surface, oxygen concentrations are modified by the air-sea gas exchange $F_{air\text{-}sea}$:

$$F_{air-sea} = \frac{vk_{O_2}}{\Delta z}(O_{sat} - O_2) \quad (1.14)$$

such that a flux of oxygen into the top layer of thickness Δz occurs when its oxygen concentration is lower than the oxygen saturation value (O_{sat}), and a flux into the atmosphere occurs if it is higher. The formulation of O_{sat} is based on García and Gordon (1992), and the gas exchange coefficient for oxygen, vk_{O_2}, is parameterized following Wanninkhof et al., (2011) as:

$$vk_{O_2} = 0.28\, u_{10}^2 \sqrt{\frac{660}{S_{CO_2}}}, \quad (1.15)$$

where u_{10} is the wind speed 10 m above the sea surface, and S_{CO_2} is the Schmidt number.

We assume that organic matter reaching the bottom is instantaneously remineralized into ammonium. Sediment oxygen consumption is represented as in Fennel et al. (2013). This model was tested with and without allowing a denitrification flux (H0 and H0', respectively). When present, the denitrification flux follows Fennel et al. (2013) with a linear loss fraction 6 mol N_2 per mol of organic matter remineralized at the bottom layer.

1.2. Hypothesis 1: Generic autotrophic N_2 fixers

In model version H1, we introduce the state variable G_F, which represents a group of generic autotrophic N_2 fixers:

$$\frac{\partial G_F}{\partial t} = \mu_{G_F}^{max}\, L_{DIP}^{G_F} G_F - m_{G_F} G_F - l_{G_F} G_F - \tau(D_S + G_F) G_F, \text{ where} \quad (2.1)$$

The growth of the fixing organisms is limited by light and DIP only (i.e., an obligate autotrophic diazotroph). The parameters m_F, l_F, τ represent a mortality rate, an excretion rate, and the coagulation rate, respectively. An accompanying chlorophyll equation is also introduced, and total

chlorophyll becomes the sum of the non-fixing and fixing autotrophic organisms ($Chl = Chl_{Phy} + Chl_{G_F}$), where

$$\frac{\partial Chl_{G_F}}{\partial t} = \rho_{Chl_{G_F}} L_{DIP}^{G_F} G_F - m_{G_F} Chl_{G_F} - l_{G_F} Chl_{G_F} - \tau(D_S + G_F) G_F \tag{2.2}$$

The equations for dissolved inorganic nutrients and detritus are modified accordingly. That is, uptake of DIP by G_F is included as a sink in the DIP equation (Eq. 18), G_F excretion becomes an additional source of DIP and ammonium (Eq. 18, 19), G_F mortality becomes a source of D_S (Eq. 20), and G_F coagulated aggregates become a source of D_L (Eq. 21). The stoichiometry of diazotrophs is set to $R_{N:P}^{f} = 45$(Fennel et al., 2002; Letelier and Karl, 1996).

$$\frac{\partial DIP}{\partial t} = \frac{1}{R_{N:P}^{nf}} \left(-\mu_{Phy} Phy + l_{BM} Zoo + l_E \frac{Phy^2}{k_{Phy} + Phy^2} \beta Zoo \right) + \frac{1}{R_{N:P}^{f}} \left(-\mu_{G_F}^{max} L_{DIP}^{G_F} G_F + l_{G_F} G_F \right) + r_{D_{S(P)}} D_{S(P)} + r_{D_L} D_{L(P)} \tag{2.3}$$

$$\frac{\partial NH_4}{\partial t} = -\mu_{Phy} \left(1 - \frac{Lim_{NO_3}}{Lim_{NO_3} + Lim_{NH_4}} \right) Phy + l_{BM} Zoo + l_{G_F} G_F + l_E \frac{Phy^2}{k_{Phy} + Phy^2} \beta Zoo + r_{D_S} D_{S(N)} + r_{D_L} D_{L(N)} - nNH4 \tag{2.4}$$

$$\frac{\partial D_S}{\partial t} = g(1 - \beta) Zoo + m_Z Zoo^2 + m_{Phy} Phy + m_{G_F} G_F - r_{D_S} D_S \tag{2.5}$$

$$\frac{\partial D_L}{\partial t} = r_{D_L} D_L - w_{D_L} \frac{\partial D_L}{\partial z} + \tau(D_S + G_F)^2 \tag{2.6}$$

$$\frac{\partial O_2}{\partial t} = \mu_{Phy}^{max} f(I) \left(L_{NO_3} R_{O_2:NO_3} + L_{NH_4} R_{O_2:NH_4} \right) Phy + \mu_{G_F}^{max} f(I) \left(L_{DIP}^{G_F} R_{O_2:NH_4} \right) G_F - 2\, nNH_4 - R_{O_2:NH_4} \left(l_{BM} Zoo + r_{D_S} D_S - r_{D_L} D_L \right) \tag{2.7}$$

1.3. Hypothesis 2: Unicellular and colonial N_2 fixers

In model version H2, we replace the generic autotrophic diazotroph group with two different groups that represent colonial and unicellular cyanobacteria:

$$\frac{\partial U_F}{\partial t} = \mu_{U_F}^{max} L_{DIP}^{U_F} U_F - m_{U_F} U_F - l_{U_F} U_F - g_{U_F}^{max} \frac{U_F^2}{k_{Zoo}^{U_F} + U_F^2} Zoo \tag{3.1}$$

$$\frac{\partial C_F}{\partial t} = \mu_{C_F}^{max} L_{DIP}^{C_F} C_F - m_{C_F} C_F - l_{C_F} C_F - \tau(D_S + C_F) C_F \quad (3.2)$$

The group of colonial N_2 fixers, C_F, represents Trichodesmium spp. A minimum temperature limit for the growth of *Trichodesmium spp.* is imposed by setting the maximum growth rate to 0 when temperature is below 20°C, based on the inability to culture this type of organism below this temperature (Breitbarth et al., 2007). The unicellular cyanobacteria group, U_F, overall follows the same formulation as the generic diazotroph, except that no coagulation term is included in this equation as they represent picoplanktonic free-living cells that do not form large colonies. Instead, this group is grazed by zooplankton similar to grazing on non-fixing phytoplankton. This is based on evidence that *Trichodesmium spp.* colonies may be less palatable and harder to digest due to toxins and that grazing is not a major fate of this group (O'Neil and Roman, 1994). Moreover, it has been suggested that colonies represent an evolutionary adaptation that allows a decreased grazing pressure (Nielsen 2006). As in the previous model version, other equations are modified where necessary:

$$\frac{\partial DIP}{\partial t} = \frac{1}{R_{N:P}^{nf}} \left(-\mu_{Phy} Phy + l_{BM} Zoo + l_E \frac{Phy^2}{k_P + Phy^2} \beta Zoo \right) + \frac{1}{R_{N:P}^{f}} \left(-\mu_{U_F}^{max} L_{DIP}^{U_F} U_F + l_{U_F} U_F - \mu_{C_F}^{max} L_{DIP}^{C_F} C_F + l_{C_F} C_F \right) + r_{D_{S(P)}} D_{S(P)} + r_{D_L} D_{L(P)} \quad (3.3)$$

$$\frac{\partial NH_4}{\partial t} = -\mu_{Phy} \left(1 - \frac{Lim_{NO_3}}{Lim_{NO_3} + Lim_{NH_4}} \right) Phy + l_{BM} Zoo + l_{U_F} U_F + l_{C_F} C_F + l_E \left(\frac{Phy^2}{k_{Phy} + Phy^2} + \frac{U_F^2}{k_{U_F} + U_F^2} \right) \beta Zoo + r_{D_S} D_{S(N)} + r_{D_L} D_{L(N)} - nNH4 \quad (3.4)$$

$$\frac{\partial D_S}{\partial t} = (g + g_{U_F}^{max} \frac{U_F^2}{k_{Zoo}^{U_F} + U_F^2})(1 - \beta) Zoo + m_Z Zoo^2 + m_{Phy} Phy + m_{C_F} C_F + m_{U_F} U_F - r_{D_S} D_S \quad (3.5)$$

$$\frac{\partial D_L}{\partial t} = r_{D_L} D_L - w_{D_L} \frac{\partial D_L}{\partial z} + \tau(D_S + C_F)^2 \quad (3.6)$$

$$\frac{\partial Zoo}{\partial t} = (g + g_{U_F}^{max}\frac{U_F^2}{k_{Zoo}^{U_F} + U_F^2})\beta Zoo - l_{BM}Zoo - l_E\left(\frac{Phy^2}{k_{Phy} + Phy^2} + \frac{U_F^2}{k_{U_F} + U_F^2}\right)\beta Zoo - m_{Zoo}Zoo^2 \quad (3.7)$$

$$\frac{\partial O_2}{\partial t} = \mu_{Phy}^{max} f(I)\left(L_{NO_3}R_{O_2:NO_3} + L_{NH_4}R_{O_2:NH_4}\right)Phy + \mu_{U_F}^{max} f(I)\left(L_{DIP}^{U_F}R_{O_2:NH_4}\right)U_F + \mu_{C_F}^{max} f(I)\left(L_{DIP}^{C_F}R_{O_2:NH_4}\right)C_F - 2\,nNH_4 - R_{O_2:NH_4}\left(l_{BM}Zoo + r_{D_S}D_S - r_{D_L}D_L\right) \quad (3.8)$$

1.4. Hypothesis 3: Heterotrophic N_2 fixers

In model versions H3' and H3 we introduce an additional heterotrophic organism to model version H2. These organisms are not limited by light availability. Model version H3' is used as a control version where the heterotrophic group (H_{NF}) is limited by both nitrogen and phosphorus, and consumes inorganic and organic pools of these nutrients. The modified set of equations are:

$$\mu_{H_{NF}} = \mu_{H_{NF}}^{max}\min\left(L_{NO_3}^{H_{NF}} + L_{NH_4}^{H_{NF}} + L_{D_{S(N)}}^{H_{NF}}, L_{DIP}^{H_{NF}} + L_{D_{S(P)}}^{H_{NF}}\right) \quad (4.1)$$

$$\frac{\partial H_{NF}}{\partial t} = \mu_{H_{NF}}H_{NF} - m_{H_{NF}}H_{NF} - l_{H_{NF}}H_{NF} \quad (4.2)$$

$$\frac{\partial DIP}{\partial t} = \frac{1}{R_{N:P}^{nf}}\left(-\mu_{Phy}Phy + l_{BM}Zoo + l_E\frac{Phy^2}{k_P + Phy^2}\beta Zoo - \mu_{H_{NF}}H_{NF} + l_{H_{NF}}H_{NF}\right) + \frac{1}{R_{N:P}^{f}}\left(-\mu_{U_F}^{max}L_{DIP}^{U_F}U_F + l_{U_F}U_F - \mu_{C_F}^{max}L_{DIP}^{C_F}C_F + l_{C_F}C_F\right) + r_{D_{S(P)}}D_{S(P)} + r_{D_L}D_{L(P)} \quad (4.3)$$

$$\frac{\partial NH_4}{\partial t} = -\mu_{Phy}\left(\frac{L_{NH_4}}{L_{NO_3} + L_{NH_4}}\right)Phy - \mu_{H_{NF}}\left(\frac{L_{NH_4}}{L_{NO_3} + L_{NH_4} + L_{D_{S(N)}}}\right)H_{NF} + l_{BM}Zoo + l_{U_F}U_F + l_{C_F}C_F + l_{H_{NF}}H_{NF} + l_E\left(\frac{Phy^2}{k_{Phy} + Phy^2} + \frac{U_F^2}{k_{U_F} + U_F^2}\right)\beta Zoo + r_{D_S}D_{S(N)} + r_{D_L}D_{L(N)} - nNH4 \quad (4.4)$$

$$\frac{\partial D_S}{\partial t} = (g + g_{U_F})(1-\beta)Zoo + m_Z Zoo^2 + m_{Phy} Phy + m_{C_F} C_F + m_{U_F} U_F - r_{D_S} D_S - \mu_{H_{NF}} \left(\frac{L_{D_{S(N)}}}{L_{NO_3} + L_{NH_4} + L_{D_{S(N)}}} \right) H_{NF} \quad (4.5)$$

$$\frac{\partial O_2}{\partial t} = \mu_{Phy}^{max} f(I)\left(L_{NO_3} R_{O_2:NO_3} + L_{NH_4} R_{O_2:NH_4}\right) Phy - 2\, nNH_4 - R_{O_2:NH_4}\left(l_{BM} Zoo + r_{D_S} D_S + r_{D_L} D_L + \mu_{H_{NF}} H_{NF}\right) \quad (4.6)$$

Model version H3 replaces the behaviour of the heterotrophic group from limited by nitrogen to nitrogen fixing. The diazotrophic heterotroph is represented by H_F and equations are modified as follows:

$$\mu_{H_F} = \mu_{H_F}^{max} L_{DIP}^{H_F} + L_{D_{S(P)}}^{H_F} \quad (4.7)$$

$$\frac{\partial H_F}{\partial t} = \mu_{H_F} H_F - m_{H_F} H_F - l_{H_F} H_F \quad (4.8)$$

$$\frac{\partial DIP}{\partial t} = \frac{1}{R_{N:P}^{nf}} \left(-\mu_{Phy} Phy + l_{BM} Zoo + l_E \frac{Phy^2}{k_P + Phy^2} \beta Zoo \right) + \frac{1}{R_{N:P}^{f}} \left(-\mu_{H_F} H_F + l_{H_F} H_F - \mu_{U_F}^{max} L_{DIP}^{U_F} U_F + l_{U_F} U_F - \mu_{C_F}^{max} L_{DIP}^{C_F} C_F + l_{C_F} C_F \right) + r_{D_{S(P)}} D_{S(P)} + r_{D_L} D_{L(P)} \quad (4.9)$$

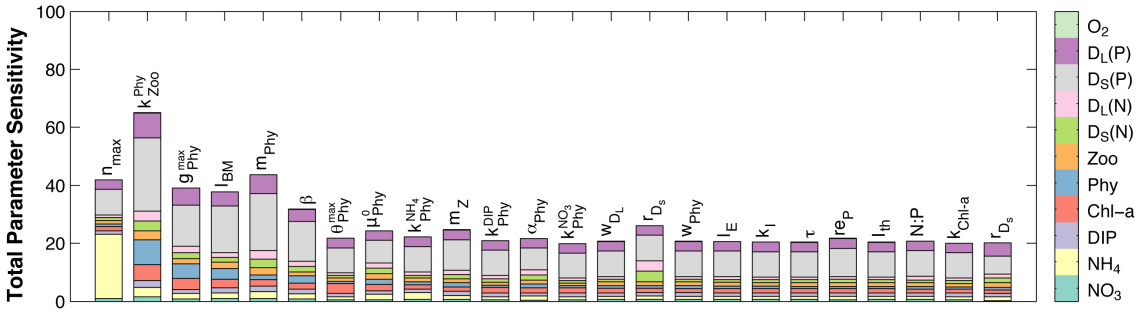
$$\frac{\partial NH_4}{\partial t} = -\mu_{Phy} \left(\frac{L_{NH_4}}{L_{NO_3} + L_{NH_4}} \right) Phy + l_{BM} Zoo + l_{U_F} U_F + l_{C_F} C_F + l_{H_F} H_F + l_E \left(\frac{Phy^2}{k_{Phy} + Phy^2} + \frac{U_F^2}{k_{U_F} + U_F^2} \right) \beta Zoo + r_{D_S} D_{S(N)} + r_{D_L} D_{L(N)} - nNH4 \quad (4.10)$$

$$\frac{\partial D_S}{\partial t} = (g + g_{U_F})(1-\beta)Zoo + m_Z Zoo^2 + m_{Phy} Phy + m_{C_F} C_F + m_{U_F} U_F - r_{D_S} D_S - \mu_{H_F} \left(\frac{L_{D_{S(P)}}}{L_{DIP}^{H_F} + L_{D_{S(P)}}^{H_F}} \right) H_F \quad (4.11)$$

$$\frac{\partial O_2}{\partial t} = \mu_{Phy}^{max} f(I)\left(L_{NO_3} R_{O_2:NO_3} + L_{NH_4} R_{O_2:NH_4}\right) Phy - 2\, nNH_4 - R_{O_2:NH_4}\left(l_{BM} Zoo + r_{D_S} D_S + r_{D_L} D_L + \mu_{H_F} H_F\right) \quad (4.12)$$

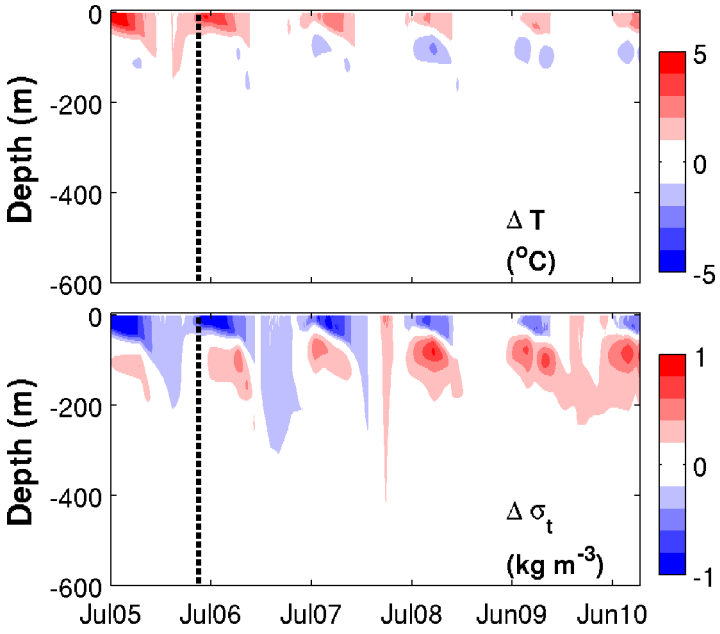
2. Model sensitivity to parameter values

In order to identify the most sensitive parameters and reduce the parameter space to be searched during optimization, model version H0 was run using parameter values in Fennel et al., 2006 and rerun after perturbing each parameter one-at-a-time. Five tests were run, changing each of the base simulation parameter values to the minimum, 25%, 50%, 75% and maximum of their corresponding parameter range. The sensitivity of the model to each of their parameter values was estimated as the sum of absolute differences between the base run and the test run in all tests. Parameters were ranked according to the sensitivity of the available observed variables (Chl-a, DIP, NH_4, NO_3 and O_2). A reduced parameter space is desirable because parameters that are insensitive to the observations used in the optimization cannot be estimated.



3. Model sensitivity to physical nudging

Effect of physical nudging on temperature and density fields estimated from a model run with nudging minus a model run without nudging. The dashed vertical line marks the simulation period used as a model spin-up.


0
-200
-400
-600
Depth (m)
Δ T
(°C)
5
0
-5
0
-200
-400
-600
Depth (m)
Δ σt
(kg m-3)
1
0
-1
Jul05
Jul06
Jul07
Jul08
Jun09
Jun10