Review on Demuynck et al.: Spatial Variations in Silicate-to-Nitrate Ratios in the Southern Ocean ...

Demuynck et al. simulated biogeochemistry along a meridional gradient in the Southern Ocean by a set of 1D box models coupled in the surface layer by Ekman transport. The model is integrated over the period 2009 to 2010. Results are compared to KERFIX data from the early 1990ies. The model set up is not properly motivated, simplifications of the governing equation could be better justified. The mismatch between model results and observations at KERFIX hints to several model deficits, however, no attempts were made to improve the model. The bold conclusion 'Spatial Variations in Silicate-to-Nitrate Ratios in the Southern Ocean Surface Waters are Controlled in the Short Term by Physics Rather Than Biology' given in the title is based on a rather 'weak' model and refers to time periods of a few years only whereas the interest of various communities (global biogeochemistry, glacial-interglacial changes, silicic acid leakage hypothesis) is on much longer time scales where biological/biogeochemical processes play an essential role.

Detailed comments/suggestions:

p. 2, L3 '$\sigma - \theta \sim 26.8$' should probably read $\sigma_\theta \sim 26.8$ kg m^{-3}' and be the 'potential density anomaly'

p. 2-3 "These diatoms have unusually thick frustules, and their Si:N ratios of diatoms often greatly exceed 1:1 ..." Suggestion: rewrite sentence, try to avoid using 'diatoms' twice. Here and in following sentences two phenomena may be mixed: (1) average Si:N in observed diatom assemblage varies with Fe availability (or other growth factors, however, this is not the topic here) and (2) Si:N of single diatom species varies with Fe availability. (1) might happen because of a change in diatom assemblage alone or caused by (2) or by a combination of change of assemblage and (2). Please make clear what was found in field observations and experiments. The saying 'less iron makes thicker shells' (Boyle, 1998, wrote: 'pumping iron makes thinner diatoms') can be ambiguous and might lead to misunderstanding.

p. 4 'depth of the boundary condition' sounds a bit strange

p. 4 Rounding up to the nearest 100 m is a bit coarse. What's the motivation for this choice?

p. 4 'The lower boundary of the SSL is fixed in depth at a certain latitude.'???

p. 4 'In summer, the ML is thin and the SSL is relatively thick, and vice versa in winter.' I could not find a description of the variation in time of model MLD.

p. 5 "Starting at the Southern Boundary ($\sim$60°S) surface waters will move northward with a characteristic velocity of order 0.3 – 0.4 km d^{-1}, and eastward with a characteristic velocity of order 20 km d^{-1} (Merlivat et al., 2015)." These values refer to the real SO. How are northward velocities set in the model?

p.5 "We choose to define our meridional section at 67°E to allow results to be compared to data from the KERFIX time series site." How does this fit to "The vertical partitioning of the model is based on observed seasonal changes in water mass properties along a section in Drake passage (Evans et al., 2014)." (p.3)?

p. 5-6 The simplification of the advection-diffusion equation can be shortened and more elegantly formulated by introducing characteristic scales (for northward and vertical velocities, horizontal eddy/turbulent mixing/diffusion coefficients, horizontal and vertical length scales) and calculating the size of each and every term in the equation (compare, for example, Pedlosky, 2013).

p. 6: "In the model, upwelling is made to take place in the first 15 stations." How?

p. 6: "The diffusive flux of a variable C from a layer $i+1$ to the layer i above $D_z \dfrac{\partial^2 C}{\partial z^2}$ is simplified as:

$$F_{\text{diff}} = \frac{k_{\text{mix}}}{h}(C_{i+1} - C_i) \qquad (4)$$

..." Instead of 'simplified as' I suggest to write 'replaced by'. The diffusive flux between two boxes reduces the gradient and thus has the same effect as diffusion which is described by a second order differential equation. This trick has been applied already by Turing (1953) in his 2-cells,

2-morphogens model or in Sarmiento and Toggweiler (1984), one of the early box models of the global carbon cycle.

p. 7 Is 'reduced growth rate' a commonly used term? I suggest using 'specific growth rate'.

p. 7 Although it is clear from the context, I suggest to use different indices for species or sublayers of the mixed layer.

p. 7 Eq. (7): explain I_h and give value

p. 9 "The N:Fe ratio ranges between 15800:1 and 25900:1."
According to Eq. (11), Si:N varies between 4 and 1 when Fe varies between 0 and 1.2 μmol m^{-3}. Applying the same Fe range in Eq. (10) gives N:Fe between 26000:1 to 2500:1.

p. 9 Drop "Diatoms can sink out of the ML because they form thick Si frustules. For that reason, Si remineralisation is slower than that of N and Fe."

p. 9-10 "The boundary conditions for Si and N at a specific station are obtained by averaging all available data in a zonal band from 20°E and 120°E, 50° to the east and to the west of the KERFIX longitude (Fig. 5 (a) and 5 (b))." What's the motivation for averaging over such a large range? And why including the area downstream of KERFIX?

p. 10 "The zonal and temporal dimension of the boundary conditions have therefore no meaning in the model." Do you mean 'zonal and temporal variations have been averaged out'? Although the KERFIX station is located 60 miles southwest of Kerguelen Islands (upstream with respect to ACC & westerlies) one might expect a local iron input. Are there any iron measurements available and what do they tell us?

p. 12 "Despite the attractive simplicity of this assumption, it makes comparing model results with one localised sampling dataset (obtained during a specific cruise, or satellite mission, acquired at a certain time in year, or using specific methods, etc.) complex." Instead of 'complex' I would say 'difficult' or even 'impossible'. Between the early 1990ies and the modeling period (2009-2012) the wind forcing (SAM index!) has changed quite a bit!

p. 13 "The units of the phytoplankton biomass are converted from mmol N m^{-3} to mg chla m^{-3}." This is not just a change of units! The different units indicate different measures of biomass.

p. 13 units missing: Redfield is in mol mol^{-1}, C:chl is in g g^{-1}

p. 26 "Biogeochemical models of, or including, the SO must include the process of entrainment as accurately as possible if they are to hope to reproduce reality." All biogeochemical general circulation models (BGCMs) include entrainment. Which models do not use entrainment?

p. 26 "When biology was turned off, while maintaining the deep gradient, the model still reproduced a strong Si gradient." How can you maintain or generate the deep gradient without biology?

p. 31 "Mawji, E. and et al.: The Geotraces Intermediate Data Product 2014, Marine Chemistry, 2015." please complete reference and drop 'and'

p. 32 What's the status of: "Verdy, A. and Mazloff, M. R.: A coupled physical-biogeochemical data assimilation model for estimating the Southern Ocean carbon system. Submitted to JGR, 2016." ???

References

[1] Boyle, Ed. Oceanography: Pumping iron makes thinner diatoms. *Nature*, 393(6687):733–734, 1998.

[2] Pedlosky, Joseph. *Geophysical fluid dynamics*. Springer Science & Business Media, 2013.

[3] Sarmiento, J. L. and J. R. Toggweiler. A new model for the role of the oceans in determining atmospheric P_{CO_2}. *Nature*, 308:621–624, 1984.

[4] Turing, A. M. The chemical basis of morphogenesis. *Philosophical Transactions of the Royal Society (part B)*, 237:37–72, 1953.