Review on Demuynck et al.: Spatial Variations in Silicate-to-Nitrate Ratios in the Southern Ocean ... (revised version 8/2019)

Demuynck et al. simulate the nutrient concentrations (nitrate and silicic acid, or N and Si for short) in the mixed layer (ML) with a 'box model' that allows for spatial resolution in the meridional direction. They responded to the criticisms of two reviewers by detailed comments and various changes in the text. However, in my opinion the manuscript is not yet ready for publication.

The nutrient concentrations in the ML of the Southern Ocean (SO) show strong meridional gradients, especially for Si which in summer decreases to almost zero at the Antarctic Polar Front. Demuynck et al. asked 'Which processes are generating these gradients?'. This is an important question given the fact that the export (via mode and intermediate waters) of nutrients from the SO has impacts for the productivity of large parts of the world oceans. An understanding of the processes involved in generating these gradient is necessary to predict future changes.

The nutrient gradients are generated by two main processes:
(1) 'Biology' (biological production and export of organic matter): acting mainly in spring/summer and depending on energy (light) and nutrients (including micro-nutrients like iron); grazing can play a role for the start and development of algal blooms as well as for export of organic matter.
(2) 'Physics' (upwelling/mixing): these processes can impose 'deeper (few 100 meters) boundary conditions' on ML nutrient conditions; in contrast to biology they act (with varying strength) all year round.

Demuynck et al. point to the importance of physical processes (in combination with given nutrient gradients in deeper layers) to establishing meridional gradients in the ML, especially in winter. This is a valid point and is worth publishing.

I suggest two further improvements of the manuscript:
(A) Clarification of statements about gradients: winter versus summer (see my detailed comments below)
(B) More detailed analysis of model results. The time series shown in Fig. 10 might be a good starting point. It looks as if 'nothing happens'

soon after 'biology' stops. In spring and summer nutrient concentrations are decreased by 'biology', however, restored from time to time by wind-driven upwelling events. Parallel time series of nutrient concentrations, wind forcing, upwelling, horizontal advection, nutrient uptake, export of organic matter etc. at selected stations (especially for Si at high concentrations/60°S versus low concentrations/50°S) for a single year might allow more insight to what is happening. You could integrate over spring, summer, autumn, winter the contribution of the various processes to the change of ML nutrient concentrations at selected stations.

Detailed comments:

Fig. 7c: KERFIX data from the early 1990ies are plotted on a time axis from 2009 to 2012: this is fine, however, should be mentioned in the figure legend.

p. 21: The simulated 'absolute' (???) 'contribution of advection/upwelling, remineralisation, biology, diffusive mixing and entrainment to the nitrate concentration in the mixed layer' at station 18 (the information about the station should be added to the figure legend) is shown in Fig.10.

Fig. 11: You might comment on negative contributions (advection).

p. 23 'The observed gradient of N and Si along a south-to-north section is a smooth mirror image of the gradient observed in the boundary conditions for N and Si. This suggests that, if no boundary condition gradient existed, no gradient would be observed in the ML. Indeed, if the model is run with a fixed boundary condition for N (30 mmol m^{-3}) and Si (60 mmol m^{-3}) along 5 the section, the winter gradient disappears, and winter concentrations of both N and Si are relatively similar along the section with a change of max 10 mmol m^{-3} for Si and 5 mmol m^{-3} for N along the meridional section (Fig. 12(a)). This strongly suggests that the observed meridional nutrient gradient in the ML results from the deep-water nutrient distribution. Having a nutrient gradient below the SSL is a necessary requirement for a nutrient gradient to occur close to the surface.'
These statements are misleading or wrong. It should be made clear from the beginning that these statements refer to the **winter gradients**. In winter time, the mixed layer nutrient concentration are mainly set by (local) vertical upwelling and not by (local) biology. This finding is no surprise

and could be quantified by analyzing the various fluxes (upwelling, mixing, horizontal advection, biology) contributing to the change of nutrient concentrations in a mixed layer box. If horizontal advection and biology contribute little to this change, it is no surprise that after some time the winter gradient in the ML is similar to the concentrations given at the lower boundary (may there be a gradient or not). It would be interesting to know how long it takes for the ML concentrations to 'relax' to the lower boundary conditions (time scale?) and why horizontal advection has only a small impact despite the large northward Ekman transport.
The statement 'Having a nutrient gradient below the SSL is a necessary requirement for a nutrient gradient to occur close to the surface.' is generally wrong because it does not apply in summer (biology will always generate gradients) and needs quantification.

Fig. 12b: Si gradient with biology: 66 mmol m^{-3} at 64°S versus almost 0 mmol m^{-3} at 40°S, i.e. difference = 66 mmol m^{-3}
Si gradient without biology: 54 mmol m^{-3} at 64°S versus 26 mmol m^{-3} at 40°S, i.e. difference = 28 mmol m^{-3}
Thus biology contributes more than 50% to the overall gradient and it is the only process that can generate very low Si concentrations (in some regions supported by advection).

p. 23: 'Fig. 12(a) and (b) indicate that there would be no ML nutrient gradient at all without a gradient at depth, and with out the connection between the deep and surface waters.' Again: this applies to the gradient in winter. It is not possible to drive Si concentrations to near zero without biology. If the contribution of horizontal advection to setting the ML nutrient concentrations is small, biology is the only process that can generate ML nutrient concentrations lower than deep boundary values.