Biogeosciences Discuss., 6, C3796–C3799, 2010
www.biogeosciences-discuss.net/6/C3796/2010/


Biogeosciences
Discussions

# *Interactive comment on* "A comparison of the variability of biological nutrients against depth and potential density" *by* J. While and K. Haines

**Anonymous Referee #1**

Received and published: 4 January 2010

The manuscript by While and Haines studies the variability of nutrient distribution in the ocean and finds that variability against density is significantly lower than that against depth in most cases. In view of sparse nutrient data (relative to data on T and S), the authors propose that the found relationship might be used to improve biogeochemical modelling through data assimilation techniques.

Major comments:

I review this paper from the standpoint of a biogeochemist, not a physical oceanographer. The (statistical) analysis itself as carried out by the authors seems sound to me. At the same time, however, the result are not very much surprising (for reasons I explain below) and definitely not new. The authors refer to two single studies only, both regionally limited (BATS and Equ. Pac.), dealing with this issue before (McGillid-



cuddy et al., 1999; Archer et al. 1996) and they argue that the validity of such a relationship between density and nutrient concentrations have not been quantitatively demonstrated on larger (up to global) scales before.

I was surprised to see a large existing body of literature not being cited in this manuscript. In 1985 already, Kamykowski and Zentara (Deep-Sea Res., 33, 89ff) analysed a large global ocean dataset (about 230.000 stations) available at the NODC at that time. From their introduction, it becomes clear that nutrient-temperature and nutrient-density relationships have been studied and applied since the 1950'ies. Following the work of Kamykowski and Zentara (1985) various authors have tried to exploit nutrient – density and nutrient - temperature relationships, for example by applying them to remotely sensed (SST, ocean color) or autonomously probed (ARGO) temperature data (e.g. Goes et al. 2000, JGR, 27, 1263; Kamykowski, 2008, Deep-Sea Res., 55, 1580ff; Steinhoff et al., 2009, BGD, 6, 8851ff). None of these papers, nor any others from the respective literature from the last 25++ years was referred to in any way by the authors, leaving me with the impression that the authors may be fully unaware of it. Noteworthy, the work by Kamykowski, Zentara and others reports not only about the possibilities of nutrient-density (or nutrient-temperature) relationships, but also about the essential problem that relationships with some predictive power exist only on regional and temporal scale; i.e. that there is no universal one.

My second major critics relate to the absence of any critical discussion on why nutrients show a stronger relationship with density than depths. To my understanding this will become highly relevant in view of the anticipated application of the nutrient-density relationship in BGC modelling via data assimilation techniques.

According to textbook knowledge (Broecker and Peng, 1982; Sarmiento and Gruber, 2006), the locally observed nutrient concentration at a give point in the interior of the ocean (below the euphotic zone) is determined by three major processes: (1) remineralisation of organic matter, (2) the 'preformed' nutrient concentration at last contact with the surface layer, and (3) mixing. The vertical profile of nutrient remineralisation depends mainly on the surface (export) productivity and those processes that determine the quality and sinking speed of particulate material sinking through the water column (ignoring for some time the contribution from DOM, but see below). Hence the remineralisation component of observed nutrient concentrations should be independent of density but scale with depths (and water age). This is well excepted knowledge and built-in in most if not all BGC models.

The preformed component of the observed nutrient concentration, on the other hand, is set at the time of water mass formation (here referred to as the last significant contact with the ocean atmosphere boundary layer). Since initial S and T properties are also set at this time, a relationship between nutrient concentration and density is not surprising. Overall the preformed fraction contributes about 50

Said all this, I would speculate that the nutrient-density relationship should change (weaken) when moving away from the regions of water mass formation and when the time-accumulated signal of nutrient remineralisation from particles becomes more important. (In fact that appears to be seen in the analysis of While and Haines, see p. 10185, and perhaps from Fig. 2 if I zoom in very much). Applying nutrient-density relationships via data assimilation may therefore not necessarily be a way to improve BGC modelling, as proposed by the authors. On the contrary such an approach may mask deficits of the BGC model, e.g. considering the treatment of particle sinking and remineralisation.

Suggestion:

The paper requires major revisions according to the two issues raised above. Applying the concept of regenerated vs. preformed nutrients should be used to extend the analysis itself.

Minor comments:

P 10178: Abstract talks about 'temporal' variability: I don't find this supported by the



main text of the paper.

P 10179: 'nutrient distributions are commonly presented plotted along isopycnals on the assumption that this will give smoother distributions . . .' The authors should give a reference for their interpretation why nutrients are often plotted along isopycnals. To my understanding this presentation is often chosen having in mind along-isopycnal mixing and that given isopycnals share a limited range of initial conditions (i.e. preformed nutrient). It therefore that on isopycnals (or better neutral surfaces) one may derive e.g. average nutrient remineralisation ratios, or other properties of interest.

P10181 ++ Fig. 2 and 3 are mixed up in the text, I think.

Figures:

Fig. 1: please indicate what are solid and dashed lines in panel c (like in Fig. 4, right?)

Fig. 2: I have to zoom in very much to see anything.

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Interactive comment on Biogeosciences Discuss., 6, 10177, 2009.