Biogeosciences Discuss.,
https://doi.org/10.5194/bg-2019-337-AC2, 2019

Biogeosciences Discussions

Interactive comment on "Diel quenching of Southern Ocean phytoplankton fluorescence is related to iron limitation" *by* Christina Schallenberg et al.

Christina Schallenberg et al.

christina.schallenberg@utas.edu.au

Received and published: 13 November 2019

We thank referee #2 for their thoughtful comments and reply to each in turn below:

Line 336: description of a 'decrease in NPQ capacity' with Fe addition: The language regarding "NPQ capacity" in this manuscript is in line with the way that Schuback and Tortell (2019) use the term, so we suggest to keep the terminology. But we do appreciate the comment about how the sentence could be misunderstood and thus propose to change the wording as follows: The NPQ capacity, measured as both NPQ_SV(1000) and NPQ_NSV(1000), decreased with iron addition, most likely due to increased capacity to use absorbed light energy for photochemistry.

Changes in community structure during 55-hour incubations: We refer to our response to referee #1. Regarding the question of whether a diatom-dominated community would have shown the same patterns: We cannot answer this question with our (haptophyte-dominated) data. However, several publications have shown similar trends to ours with respect to NPQ and Fe limitation under controlled conditions (i.e. in the laboratory or with ship-board incubations), probing a variety of species including diatoms (Schuback et al. (2015), Schuback and Tortell (2019)). The evidence thus suggests that the link between NPQ capacity and Fe status is robust across a range of phytoplankton species and thus community composition. We propose to add the information presented above to section 3.2.1.

Increase in Fv/Fm in control treatments of incubations: An increase in Fv/Fm during incubation experiments is not an uncommon feature in Fe-limited control treatments, for example see Ryan-Keogh et al. (2018). While rarely discussed in the active fluorescence literature, it is likely the result of acclimation to more constant light conditions experienced in the incubations relative to the (constantly mixing) open ocean. Less light fluctuations and thus a less variable underwater light field would allow better allocation of (limited) resources, which could result in the observed increase in Fv/Fm.

Reference for 90% quenching of ChlF signal at midday: Falkowski et al. 2017. We will include this reference in the text at line 70.

Section 2.1, Line 137-139: We will add that the underway line was also sampled for FRRf measurements as suggested.

Section 2.2: Justification for iron treatments in incubations: We chose the two different Fe treatments originally to test whether an addition of 0.2 nM would have a measurable effect (compared to the 2 nM Fe treatment which should definitely be Fe-sufficient). Since the results for both Fe treatments were consistent and we were primarily interested in the contrast between iron sufficiency vs iron limitation, we decided to bundle the +Fe treatments as described in the manuscript.

Line 148: “abeam” is not a typo but a nautical term, meaning on a line at right angles to a ship’s length.

Line 158-159: Incubation duration of 51.5-55 hours and possible issues arising: See response to Referee #1 regarding community composition and the sampling that was done on Incubation 1 (including new Figure for SI).

Section 2.3, Lines 168-174: Better explanation of the light curves and what is meant by ‘optimization’ of FLCs for estimates of NPQ capacity (lines 173-176): The attached Figure 1 (which we suggest to add to the SI) shows the time course of light intensities in the respective FLCs. The blue line is relevant for underway samples while the red line refers to incubation samples. The different maximum light intensities were chosen such that maximum NPQ was achieved for each set of samples, while still providing an induction curve in the FRRf that cut be fitted (at higher light intensities the fluorescence induction curve becomes too flat to achieve a good fit). Incubation samples were able to handle higher light intensities (i.e. up to 1000 umol quanta m-2 s-1) than the underway samples (750 umol quanta m-2 s-1), most likely due to high-light acclimation in the incubator. Since we were interested in the NPQ capacity we chose our experimental design to maximize the NPQ in each sample set, rather than strive for uniformity. The NPQ trends observed in the incubations and underway samples are the same with respect to iron limitation, and we don’t directly compare the absolute NPQ values between these two sample sets. The difference in the maximum light intensity should thus not introduce a bias in our interpretation. Regarding the length of the time steps and the ‘optimization’ of the FLCs: Since maximum NPQ capacity was our main focus, we chose an experimental design that struck a balance between i) ensuring an induction curve fit at the maximum light intensity, ii) increasing light levels slowly enough to allow derived fluorescence yields to reach steady state (thus choosing longer time steps at high light intensities), and iii) keeping the FLCs as short as possible so that the four treatments in each incubation experiment could be measured within the smallest time frame possible (<2h) in recognition of the sensitivity of photophysiology to light history

and time of day. We propose to expand lines 169-176 with a concise summary of the information provided above, while moving some of the detail about length of light steps (lines 171-172) to the Figure caption for the attached Figure 1.

Line 168-169: ‘ensure complete relaxation of all NPQ’: We will clarify this section to distinguish between fast-relaxing/dynamic NPQ and slow-relaxing NPQ that will not have relaxed after an hour of low-light acclimation. The light intensity during the low-light acclimation was around 2-5 umol quanta m-2 s-1, achieved by setting the sample in a small white LDPE bottle in the shaded corner of a small cooler, placed with an open lid in a dimly lit corner of the temperature-controlled laboratory.

Line 199, different maximum light levels for NPQ estimation: See response above (Section 2.3, Lines 168-174. . ..). We will include the respective light levels and the samples they refer to on lines 199/200 as suggested.

Section 3.2.4 Line 466: ‘macronutrient data from one CTD in that water mass indicate that the warm SST regime was not HNLC’ – how many CTDs were done in that water mass? Only one CTD was conducted in the warm water mass and the sentence will be amended to reflect this fact as follows: ‘. . .macronutrient data from the one CTD in that water mass indicate that the warm SST regime was not HNLC’. Also see comment below re CTD locations in Figure 1.

Figure 1, CTD positions are hard to see: This Figure has been updated (attached Figure 2) to better show the CTD positions and also distinguish between CTDs in the cold water mass (overlapping on the map, cyan squares) and the one CTD in the warm water mass (red square). The figure caption will be updated also.

Figure 2: The caption to Figure 2 will be updated to include the light levels and length of FLC curves, as suggested. However, we will not include units in the parentheses of the figure labels as the current nomenclature is in line with that of Schuback and Tortell (2019), is clearly explained in Table 1, and would otherwise become even more unwieldy than it already is.

References: Falkowski, P., Lin, H., and Gorbunov, M.: What limits photosynthetic energy conversion efficiency in nature? Lessons from the oceans. Philos. T. Roy. Soc. B, 372, 2-8, 2017.

Ryan-Keogh, T.J., Thomalla, S.J., Mtshali, T.N., van Horsten, N.R., and Little, H.: Seasonal development of iron limitation in the sub-Antarctic zone. Biogeosciences, 15, 4647-4660, 2018.

Schuback, N., Schallenberg, C., Duckham, C., Maldonado, M. T., and Tortell, P. D.: Interacting effects of light and iron availability on the coupling of photosynthetic electron transport and CO2-assimilation in marine phytoplankton. Plos One, 10, e0133235, https://doi.org/10.1371/journal.pone.0133235, 2015.

Schuback, N., and Tortell, P. D.: Diurnal regulation of photosynthetic light absorption, electron transport and carbon fixation in two contrasting oceanic environments. Biogeosciences, 16, 1381–1399, https://doi.org/10.5194/bg-2018-524, 2019.

Interactive comment on Biogeosciences Discuss., https://doi.org/10.5194/bg-2019-337, 2019.

Supplementary Figures for response to Referee #2

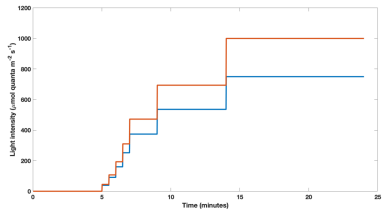

Figure 1: Schematic of time steps for respective light intensities in FLCs employed in this study. The blue line is relevant for underway samples (with maximum light level of 750 uM m-2 s-1) while the red line refers to incubation samples (maximum light level of 1000 uM m-2 s-1).

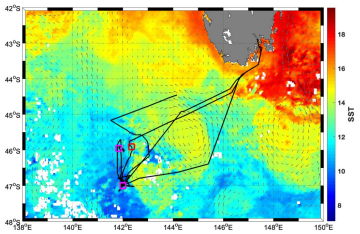

Figure 2: Updated version of Figure 1 in the manuscript, with new symbols for CTD stations: purple for CTD stations in the cold water mass and red for the one CTD station in the warm water mass.

Fig. 1.