**Biogeosciences
Discussions**

Interactive comment on "Side effects and accounting aspects of hypothetical large-scale Southern Ocean iron fertilization" *by* A. Oschlies et al.

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We thank the reviewer for the positive and constructive comments.

Response to specific comments:

1a. "further consideration of any potential caveats arising from such an approach"

A potential caveat of our approach of increasing the phytoplankton maximum growth rate to mimic the effects of iron fertilisation is the assumption that the added iron is not recycled and therefore that there is no secondary fertilisation possible outside

the fertilisation region. This essentially assumes that the lifetime of the added iron in bioavailable form is short compared to the time it takes water to leave the fertilisation area. The relevant timescales of bioavailability are still basically unknown and require further research (Gnanadesilkan et al., 2003). The differences of observed iron and nutrient profiles indicate removal timescales considerably faster than circulation timescales. Hydrographic sections underneath the Saharan dust plume (Measures et al., 2008) suggest that newly added iron cannot substantially increase concentrations of dissolved iron on circulation time scales. While this gives some confidence to the approach taken in our study, we will mention these caveats in more detail in section 2 of the paper.

An "iron added and removed" experiment has recently been performed and compared against results of an explicit iron chemistry model by Sarmiento et al. (2010, Biogeosciences, in press) indicate that the retention of iron in the model has very little effect on the fertilisation-induced carbon uptake per fertilisation-induced export production. Having calibrated our model against observational estimates of fertilisation-induced export production, we are confident that even one of the currently available explicit representations of iron chemistry would not significantly change our estimates of fertilisation-induced carbon uptake

1b. "further discussion of similarities/differences between the current results and those from models which have used a more explicit parameterisation of the iron cycle."

The more explicit parameterisation of (patchy) iron fertilisation in the Southern Ocean used by Aumont and Bopp (2006) revealed a similar increase in (local) export production by a factor 2-4 (their Figure 5d). For globally applied iron fertilisation, they report a cumulative OIF-induced export production of 226GtC within 100 years and an atmospheric drawdown of 33uatm (oceanic uptake of 70GtC). Because of the global extent of the fertilisation simulated by Aumont and Bopp, their simulated cumulative increment of export production is some 47% higher than the 154GtC simulated by our Southern

Ocean fertilisation experiment. Their simulated drawdown in atmospheric pCO2 is, on the other hand, only 32% higher than simulated by our study (25uatm, 56GtC oceanic uptake). The larger ratio of oceanic CO2 uptake to export production in our study (0.36) compared to 0.31 of Aumont and Bopp (2006) can be explained by the generally higher fertilisation efficiency in the Southern Ocean compared to lower latitudes (Sarmiento et al., 2010, Biogeosciences, in press) and to the presence of a terrestrial vegetation in our model, which essentially increases the capacity of the carbon pool on the atmospheric side of the air-sea interface (Oschlies, 2009).

1c " For example, it is possible that iron fertilsation would have a greater physiological effect on the light dependence of growth rather than on the maximum rate."

The physiological role of iron in the electron transport pathways involved in photosynthesis suggests that phytoplankton cells replete in iron can utilise light more efficiently (Strzepek and Harrison, 2004). Iron stress has been found to decrease the chlorophyll-to-carbon ratio, presumably because of the requirement for iron in chlorophyll synthesis (Sunda and Huntsman, 1997). Iron seems also required for the reduction of nitrate to ammonia (Raven, 1990; Sunda and Huntsman, 1997) .

Simulating the effects of iron fertilisation by an increase in the maximum growth rate (i.e., light saturated growth) can be regared as attempt to represent both the need for iron in prteins that mediate photosynthetic electron transport and thereby determine the maximum yield of electrons for photosynthesis when light is abundant, and also the effect of iron on non-photosynthetic processes such as nitrate reduction (Galbraith et al., 2010). As pointed out by Galbraith et al. (2010), if applied to iron limitation in general, this parameterisation of iron would make light limitation less likely under severe iron stress. To counteract this tendency, they suggested to make the initial slope α and also the chlorophyll-to-carbon ratio increasing functions with iron. Field data from the Southern Ocean, however, show little relationship of α with iron availability, and iron addition experiments also reveal a dominant impact on the maximum growth rate with

relatively little changes in α (Hopkinson et al., 2007).

Our current model had been tuned to reproduce high-nutrient low-chlorophyll areas such as the Southern Ocean without an explicit consideration of iron limitation. This was achieved by relatively low phytoplankton maximum growth rates (0.13/day at 0 degrees Celsius) and a relatively high value for α of 0.1 (W/m^2 day)$^{-1}$. Sensitivity experiments with α varied by up to a factor 100 showed little effect in the Southern Ocean.

2. mention different effects of fertilisation north and south of the Southern Ocean divide.

Following the reviewer's suggestion, we performed experiments with fertilisation restricted to the surface area south of the "Southern Ocean biogeochemical divide" (Marinov et al., 2006) defined as the (seasonally varying) density contour $\sigma = 26.8$, $\sigma = 27.2$, or $\sigma = 27.4$. While the total impact on atmospheric CO2 decreases with decreasing surface area of the fertilisation region,

Section 3.11. and Figure 2: seasonal cycle

A new figure will be added showing the magnitude of the seasonal cycle for the control run and the fertilisation experiment.

page 2952, artificial upwelling

We agree. The discussion on artificial upwelling will be removed

page 2967, line 15, add references

References will be added.

Minor comments

Many thanks for pointing out these errors. They will al be corrected in the revised version.

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