Biogeosciences Discuss., 11, C692–C697, 2014
www.biogeosciences-discuss.net/11/C692/2014/

Biogeosciences
Discussions
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Interactive comment on "Impacts of sea ice on the marine iron cycle and phytoplankton productivity" *by* C. Alexandrakis et al.

Anonymous Referee #1

Received and published: 2 April 2014

General comments The paper discusses a key component of the high latitude HNLC: iron inputs to and from sea ice. This area of research is especially pivotal in a climate change perspective because the magnitude of this mode of Fe delivery to surface waters is forecasted to change. The approach is novel and this work definitely brings new information to this field of research. Although the results of the model fit reasonably well with some observations in the Arctic, there are still some large differences between the model output and the field observations in the Southern Ocean and Greenland Current and Farm Strait. These differences are likely due to the fact that what is missing in the model is the actual mechanism of Fe entrapment in sea ice (to be modelled in the next paper maybe?). Here the authors consider that Fe is passively incorporated in sea ice, just as a percentage of what Fe observed in seawater. This is only part of the story, and not representative of what actually happens in the environment. Iron could

be incorporated in sea ice with detrital and living organic matter, under the particulate form and then degraded into dissolved Fe via heterotrophic processes. The other incorporation mechanism is via active biological uptake of dFe by sea ice algae. In both cases, Fe incorporation into sea ice is mediated by biology, in the particulate form, which is ignored in this study because these mechanisms are currently not quantified. The authors do mention this in the discussion/summary section, but I think this could be further highlighted in the text, by stating that this model clearly shows that there are additional modes of incorporation of Fe in sea ice (=biological processes) than just passive incorporation (=physical processes). The model also makes the assumption that Fe is transferred from seawater into sea ice, and therefore Fe becomes depleted in seawater, which again is not the case in the environment. The sea ice environment is not a box. Lateral and vertical transport mechanisms (dust, glacial inputs, continental margins of deep sea sediments) bring new Fe to seawater all year round, therefore constantly feeding seawater (and therefore sea ice) with new (and recycled) Fe during autumn/winter.

Overall, the manuscript does not flow very well. The paper collects a suite of results and ideas, jumping from Arctic to Antarctic, without a clear train of thoughts. Maybe a table summarizing the ranges observed in seawater and sea ice in the literature versus the ranges obtained from the model output would help. I also find that the English could be greatly improved. The paper needs to be reorganized with an eye to clarity.

Specific comments 1. p2385 line 14- remove Taylor et al., 2013- it is a model result, no a field observation. 2. P2385 line 21-"changes in sea ice what?" volume, extent? 3. P2385 line 26 "phytoplankton competition" over what? 4. P2386 line 8-9 "in polar regions, atmospheric deposition is obstructed by ice cover during the cold season, when dust accumulates in the sea ice". Please rephrase this. Do you mean that direct deposition of dust into seawater is obstructed by the presence of sea ice? 5. P2386 I think that lines 17 to 23 should be moved earlier in the text, before explaining the different sources of Fe to sea ice. 6. P2386 replace "about" by "on" in lines 24 and

28. 7. P2387. Please rephrase “data atmosphere and land components that prescribe observationally-based forcing in-formation“ 8. P2388 line 5. Note that iron is not a passive tracer in the environment. It is highly reactive. 9. P2388 line 6. Please list the Fe sources you consider. Also rephrase to “iron incorporated in sea ice “ 10. P2389 line 8. Replace “observed” by “measured”. 11. P2389 line 11: what do you mean by “transport and removal in sea ice”? do you mean “loss from melting sea ice into seawater”? I would rephrase this to “the mechanisms for iron sequestration in sea ice and the effects of its release in the marginal ice zone are currently not well constrained” 12. P2389 line 15: how is Fe “frozen” in sea ice? Do you mean “incorporated into sea ice”. And what do you mean by “proportional”? 13. P2389 line 23- what is the “percSed” term? Is the % of dFe in seawater originating form sedimentary inputs? And how is fsed decided? It sounds just like a random number applied to get the model to match the observations, which means that the model is not validated, which defeats the purpose of the study. What dfe conc in seawater was used? 14. P2389 line25: “match the observations in sea ice”? 15. P2390 line 3. Rephrase to “removed from seawater during sea ice formation was proportional to the concentration of dissolved Fe in seawater”. This sounds just like what you said in the 1st assumption. Ie. where is the dFe in this sw originating from? How is that % decided? How do you know that 60% is a moderate removal fraction? What physical mechanism is used to remove that Fe? It all depends on the effectiveness of the brine convection processes.

16. P2390 line 11: dust, snow and sea ice are 3 different things. You have dust in snow, you have snow on top of sea ice, you can have dust in seawater which is then is entrained in sea ice when it forms, and you can even have dust deposited on top of sea ice. Which one are you referring to? Are you referring to snow deposition on top of sea ice, which is the released in seawater during the melting season?

17. P2393 line 1- rather than iron inputs. I think what is missing is the actual mechanisms of Fe entrapment in sea ice. Here you consider Fe is passively incorporated in sea ice, just as % of what is in seawater. This is not representative of what actually hap-

pens. Fe could be incorporated in sea ice with detrital and living organic matter, under the particulate form and then degraded into dissolved Fe via heterotrophic processes. The other mechanism is via active biological uptake. In both cases, Fe incorporation into sea ice is mediated by biology, which is ignored in this study because it is currently difficult to quantify. The authors do have to mention this as a potential missing reservoir of dFe in their model.

18. P2393 line 25: what do you mean by “moved iron from seawater to sea ice to ensure this value”?

19. P2394 line 16: what do you mean by “simulated biomass in this region is biased low”. Add reference. 20. P2394: line 29. 3 orders of magnitude higher is a lot. I do not think that the fact that it is multiyear ice alone could explain these large differences. Where the ice is collected is most likely not where it originally formed. That ice might have formed in shallow waters and exported out to open waters, therefore explaining the high Fe. + biological pathways can also help to entrain and retain that Fe in sea ice.

21. P2395: line 2-3. What do you mean by “Multiyear ice may accumulate more iron through interactions between brine channels and sea ice biota, processes not included in the model”? what processes are you referring to? Heterotrophic activity? Retention of EPS-bound organisms and Fe onto the walls of the brine channels?

22. P2395.“which reduces iron concentrations in the seawater” the authors should indicate that in reality there should be a constant input of dFe in seawater from new sources. The system is not closed. How come figure 2 shows negative Fe fluxes in the central arctic and Weddell Sea in may and november respectively?

23. P2396. Line 6 How do these fluxes compare with estimates from the literature?

24. P2396 line 16-17. This sentence makes it sound like light is responsible for the release of Fe in seawater. Please rephrase to “ Iron is enriched in sea ice in winter and

released into seawater in spring and summer, at a time ideal for phytoplankton growth because the light availability and stratification of the water column are optimum" or something similar.

25. P2396 line 19. How was POC flux evaluated? Discuss the potential contribution of seeding of sea ice algae on carbon export.

26. P2396 line 21. add reference to "In the Arctic region, primary production is mainly limited by light and macronutrient concentrations, except for some areas in the Bering Sea and the Sea of Okhotsk" .

27. P2397 line 21 "Iron from ice may also affect denitrification at high latitudes (Arrigo et al., 2008)" is a bit random. Please explain further why it matters.

28. P2397 line 26. I have a problem with the "iron originally from seawater is temporarily removed and released in spring and summer". There should be a constant flux of new dFe to seawater from vertical and lateral transports.

29. P2397-2398. Please rephrase this sentence.

30. P2398 line7. Use "the highest" or "higher"

31. P2398- line 7-8. Please clarify here how it is accumulated here. Is dust deposited onto sea ice or in seawater and then entrained in sea ice during formation? Note that dust or snow deposited on top of the ice in winter usually cannot percolate through the ice cover because the ice is not yet permeable (low brine volume fractions).

32. P2398 line 12-13: please rephrase.

33. P2398 line 23. Replace "compared to" with "lower than".

34. P2398 lines 25-28. Please rephrase with an eye to clarity.

35. P2399 line 3- sediments are most likely not "frozen" in the ice, but instead sit in the brine pockets. Please use the term "sediment-laden ice" or "sediment-bearing ice".

36. P2399 line 5. Add "corresponding to" in front of "a flux of 2.2. . ."

37. P2399 line 10: "sensitivity" of what? Please add ecosystem, or phytoplankton species composition.

38. P2399 line 11. Add a reference.

39. P2399 line 12. Add "extent" or "volume" after "declining sea ice"- same for line16. Specify what sea ice change you are referring to.

40. P2399- please rephrase lines 18 to 21.

41. P2399 line 24- How do we know that the ice volume in the AP is lower in 2002 than in 2004? Please add Figure 7.

42. Please mention that interannual variability in phytoplankton production can be linked to how much algae and Fe can remain in surface waters at the end of the summer bloom (depending on export or grazing) and be trapped again in sea ice when it forms in autumn.

43. P2403 line 4. "and other trace metals" which other trace elements and why (ref)? are they also preferentially incorporated in sea ice? Could sea ice melting also fertilise HNLC waters with these essential elements?

44. Font on figure 6 needs to be bigger.

Interactive comment on Biogeosciences Discuss., 11, 2383, 2014.