Biogeosciences Discuss., 7, C5381–C5387, 2011
www.biogeosciences-discuss.net/7/C5381/2011/

Biogeosciences Discussions

Interactive comment on "Dust deposition: iron source or sink? A case study" *by* Y. Ye et al.

Y. Ye et al.

ying.ye@awi.de

Received and published: 18 April 2011

Reply: Generally, we agree with the comments by Alessandro Tagliabue and appreciate his very constructive suggestions.

Major comments:

Referee: 1. Role of biological uptake in reducing DFe Referee: 2. Dust addition in Fe-limited regions

Reply: We studied the role of biological uptake in the model more in detail and modified the equation of critical DFe concentration by also considering the impact of biological uptake and organic particles. New terms in the equation and examples from different ocean regions are discussed in the revised version of the manuscript. Since these two

major comments are related to each other, we do not reply separately but consider both of these aspects in the following:

The term "critical concentration"

Reply: We used the term "critical concentration" because by definition it has the dimension of a concentration. In an abiotic system, it is in fact a "solubility balance" as the referee states correctly; when considering biological uptake, it is rather a balance between fluxes from and to dissolved Fe. In the revised version of the manuscript, we extended the concept by additionally considering biological uptake and adsorptive removal by organic particles. We kept the term "critical concentration" in the manuscript but added a clearer explanation of its definition (Sect. 4.3.6).

Role of biological uptake during DUNE

Reply: Biological uptake during the DUNE experiment plays only a minor role in reducing DFe. In the standard run, the uptake increases up to $3\times^{-3}\,\mu\mathrm{mol\,m^{-3}\,Fe\,d^{-1}}$ after dust addition, whereas DFe is removed at a rate of $10\,\mu\mathrm{mol\,m^{-3}\,Fe\,d^{-1}}$ by particle adsorption. We added a comparison of these numbers in the manuscript (Sect. 4.3.6).

Role of biological uptake in Fe-limited systems

Reply: In regions where Fe limits phytoplankton growth, biological uptake could differ significantly from the situation at the DUNE site, depending on phytoplankton growth rate and biomass. The rate of Fe uptake at the site of SOIREE for instance was about $0.6\,\mu\mathrm{mol\,m^{-3}\,Fe\,d^{-1}}$ before the Fe fertilisation. Here, two different ocean regions should be distinguished: 1) HNLC regions where DFe concentration is often very low; and 2) regions where DFe concentration is relatively high, but still phytoplankton growth is Fe-limited, such as some coastal regions.

Reply: Because of the low DFe concentration in HNLC waters, strong dust deposition (corresponding to the dust addition during DUNE) would increase both DFe and phytoplankton growth. Biological Fe uptake in HNLC regions should be much smaller than

Fe loss by particle adsorption, due to low biomass before dust deposition. We calculated the critical concentration of DFe for the SOIREE site, assuming a dust deposition of the same dust type and size distribution as during DUNE. Using the observed biological uptake rate and total ligand concentration, we estimated a critical concentration of 4.4 μmol m^{-3}. Comparing this to the commonly measured DFe concentration in that region (<< μmol m^{-3}), dust deposition would act as a net source of DFe. We discussed this in the revised manuscript as an example for the applicability of the concept of critical concentration for other ocean regions.

Reply: Another situation might prevail in coastal regions, where PO_4^{3-} is higher than at the DUNE site, but DFe is similarly high. We did some test runs that were identical to the DUNE case, except for an initially increased PO_4^{3-} and phytoplankton concentration, in order to simulate Fe-limited phytoplankton growth before the dust addition. A stronger decrease of DFe has been found in these runs after dust additon. Biomass increases first after dust addition and declines when DFe becomes depleted. Comparing the biological uptake and adsorptive removal of iron, an opposite trend has been found in the test runs (Fig. 1, results from a run with 1000-fold increase of initial PO_4^{3-} and 100-fold increase of initial phytoplankton): adsorptive removal reaches the maximum immediately after dust addition and decreases with time continuously; whereas biological uptake increases after dust addition until DFe depletion and is predominant almost during the entire experiment period. The results from these test runs indicate that biological uptake could compete with adsorption and act as the dominant loss process of iron under these conditions. Therefore, we modified the equation for the critical DFe concentration further considering the impact of biology on the Fe cycle, including the role of biological uptake and of organic particles in adsorption. Generally, high uptake rate and high concentration of organic particles lower the critical concentration and accelerate the DFe decrease after dust deposition, if the initial DFe concentration exceeds the critical one. We added a paragraph discussing the new equation considering biology.

Specific comments:

The linguistic suggestions are all accepted and we added citations accordingly.

We described clearly the amount of P and Fe added by dust deposition.

Referee: P9226, l4-5, I assume this allocation of particles into Pd and Ps is arbitrary? No problem with that, but if there's a better reason it could be stated.

Reply: The allocation of dust particles into P_d and P_s is based on the size distribution of added dust particles. The paragraph from p9225 l24 should state the reason. We rephrased that paragraph to explain the reason more clearly.

Referee: Sec 4.2.1 Could Chl/C variability in response to changing light field/stratification be important?

Reply: In principle, Chl : C variability could be important. During the DUNE experiment, the depth gradient of light was small because the mesocosms enclosed only the upper 15 m of the water column which was weakly stratified during the experiment. According to Cloern et al. (1995) nutrient availability also influences the Chl : C ratio, however, there was only a brief change in nutrient limitation after dust addition.

Referee: P9232, l1 difficult to see this on the figure

Reply: We rephrased this sentence.

Referee: sec 4.3.3. you could add the observed information to the plot??? what are the implications of these tests?

Reply: We added the observations to the plot. Atmospheric input of iron has been often described in models under an implicit assumption of an instantaneous dissolution of iron from dust particles (e.g Moore and Braucher, 2008; Aumont et al., 2008). These tests indicate that the impact of dust deposition on DFe concentration depends strongly on the dissolution timescale. This aspect should be taken into account in future modelling of atmospheric input of iron. We underlined this implication in that paragraph and in the conclusions.

Referee: Am I right that no ligands are considered in this model? i.e., potentially ALL dFe could be lost? It is not Fe' (calculated from FeL, Kfel etc) that is adsorped?

Reply: Organic complexation of iron is not considered in the model because Wagener et al. (2010) suggested that there were no excess organic ligands at the beginning of the experiment. But we discussed the impact of organic complexation on the critical concentration more clearly in Sect. 4.3.6 and added an estimate for DUNE assuming a ligand concentration measured at the JGOFS-DYFAMED time-series station.

Referee: P9235, l19-22, could this be connected to the observed increase in dFe at 10m in the observations?

Reply: We do not think that the modelled higher PFe stock and export could be connected to the observed increase of DFe at 10 m. Data of the two mesocosms in Tab. 8 do not show an increase of DFe stock with time. Modelled DFe stock is well comparable to the observations, although the observed depth gradient of DFe is not reproduced. Moreover, the discrepancy between modelled and measured PFe data is too large to be explained by variations in DFe stock. The low recovery of the observations however could be an important reason for the discrepancy.

Figures

Measured data are added into figures of the sensitivity studies. Some figures of CONTROL-meso and DUST-meso are combined. Error bars are added in Fig. 6.

Figure Caption DFe loss rates in a run with enhanced initial PO_4^{3-} (by 1000 times) and phytoplankton biomass (by 100 times). The physical conditions are the same as during DUNE. The magnitude of initial increase is not based on any measurement but to ensure a stronger Fe-limitation than P-limitation of phytoplankton growth. Red: rate of biological uptake, green: rate of adsorptive removal.

References

Aumont, O., Bopp, L., and Schulz, M.: What does temporal variability in aeolian dust deposition contribute to sea-surface iron and chlorophyll distributions?, Geophys. Res. Lett., 35, L07 607, 10.1029/2007GL031131, 2008.

Cloern, J. E., Grenz, C., and Vidergar-Lucas, L.: An empirical model of the phytoplankton chlorophyll : carbon ratio-the conversion factor between productivity and growth rate, Limnology and Oceanography, 40(7), 1313–1321, 1995.

Moore, J. K. and Braucher, O.: Sedimentary and mineral dust sources of dissolved iron to the world ocean, Biogeosciences, 5, 631–656, 10.5194/bg-5-631-2008, http://www.biogeosciences.net/5/631/2008/, 2008.

Wagener, T., Guieu, C., and Leblond, N.: Effects of dust deposition on iron cycle in the surface Mediterranean Sea: results from a mesocosm seeding experiment, Biogeosciences, 7, 3769–3781, 10.5194/bg-7-3769-2010, 2010.

Interactive comment on Biogeosciences Discuss., 7, 9219, 2010.

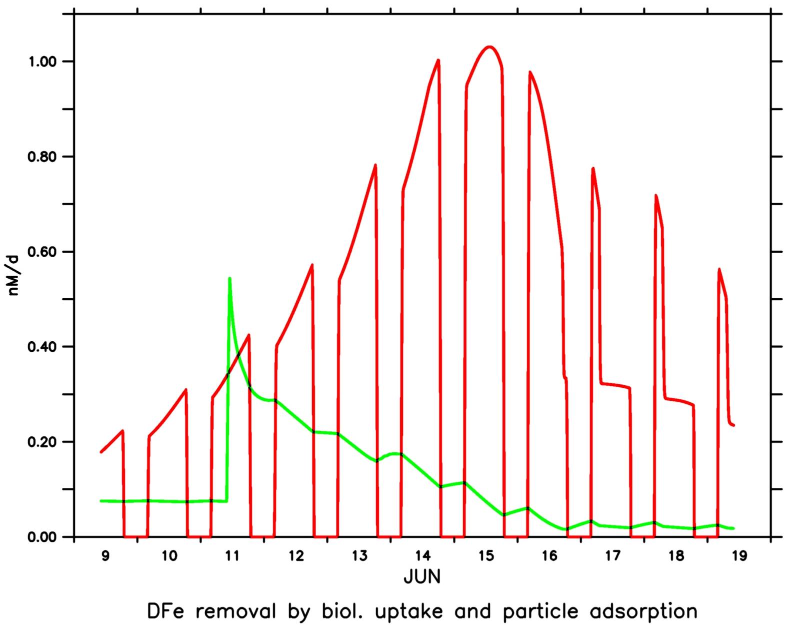

Fig. 1. Figure Caption is given in the text.