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Interactive comment on "Manganese in the world ocean: a first global model" *by* Marco van Hulten et al.

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Response to Anonymous Referee #1

We wish to thank the reviewer for the succinct analysis and criticism on our model.

> The threshold Mnox that is used to account for the homogeneous background concentration of dissolved Mn of about 0.10 nM to 0.15 nM observed throughout most of the deep ocean, may result from over simplification of the model. There might be very different Kox and Kred values at upper (above ∼300 m) and deeper (below ∼300 m) part of the ocean. Mndiss may be mainly derived from remineralization of sinking organic matter in the upper ocean, and from an equilibration with colloidal or fine particles via absorption/colloid formation processes in the deeper ocean.

> One would expect very different kred values at different depths.

The reduction and oxidation processes are indeed simplified a lot. We decided to devise a model that is as simple as possible, but reproduces reasonable dissolved Mn concentrations, and at the same time teaches us something useful. For this we have set k_{ox} to a constant, but realised on the outset that k_{red} must be much larger in the photic zone. Thus our most simple and still reasonable model was one where the oxidation rate is a constant and the reduction rate a two-valued step function (Eqs 7–9). Still, we do realise that bacterial activity, oxygen minimum zones and colloids influence the k values. We wrote that the dependence of oxygen would be advisable for future development, but decided that this was not needed for this first study, nor necessary to arrive at our conclusions. The influence by colloids would be difficult to verify, because the observations that we used do not include colloidal and "truly dissolved" fractions: the "dissolved Mn" in both the observations and the model includes both fractions. This means that the k values are really the effective k's between the operationally defined dissolved and particulate pools.

Concerning the relatively homogeneous background concentration, this could not be reached by only setting constant values for k_{ox} and k_{red} in the deep ocean. It is rather a consequence of a Mn oxide concentration threshold on the increased settling velocity (Eq. 11). There are two ways to look at this part of the model. One is to see it as a trick to get the right deep-ocean dissolved Mn concentration. The other is the interpretation of the threshold being a necessary minimum concentration of Mn oxides before aggregation and efficient settling can occur. Both are true, but the second is the interesting one here because it gives an actual, potential explanation for the constant background concentration.

> In addition, Mndiss may be mainly removed from the water column via oxidation to insoluble Mn(IV) with a rate that decreases with increasing depth due to lower dissolved oxygen concentration and lower pH at deeper depths, leading to very

> different kox values at these different depths. Thus both k values and their ratios Kred/kox are not homogeneous throughout the water column. Such difference may cause lower modelled Mndiss than the observed values, thus requiring a threshold Mnox to account for higher Mndiss at deeper depths.

Yes, in areas with lower oxygen concentrations and lower pH, the k_{ox} would be lower, resulting in a higher dissolved concentration which is what we want when the threshold were to be removed from the model. However, at the moment we think that nowhere in the deep ocean k_{ox} is actually low enough to accomplish this in our model. This may very well be related to the high deep-ocean settling velocity we chose in our model. However, if we would decrease this velocity, the hydrothermal plumes would extend too far (Section 4.2). If we would then furthermore reduce the hydrothermal input, the hydrothermal signals would not be reproduced by the model. Furthermore, as Fig. 11 shows, we have chosen at least the k_{ox}/k_{red} ratio quite well, meaning that while minor features are likely to be improved by using an inhomogeneous k_{ox}, it could never capture the much larger effect that we achieve by the threshold on the increased settling velocity.

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