

## ***Interactive comment on “An improved ocean model of aluminium: the effects of circulation, sediment resuspension and biological incorporation” by M. M. P. van Hulten et al.***

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An improved ocean model of aluminium: the effect of circulation, sediment resuspension and biological incorporation by MMP van Hulten et al. Recent interest in the global ocean Al distribution is because Al can potentially be used as a tracer of Aeolian input and because of its interactions with Al (such as adsorption onto opal and the Al dependent reduced opal dissolution). The present paper describes a global model for Al distribution in the world ocean. It extends a previously published model by the same lead author (van Hulten et al. 2012). The improvements include:

1) a better representation of Al enrichment of North Atlantic Bottom Water by a sedi-

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ment source,

2) a better ocean circulation / representation of the Meridional Overturning,

3) Al uptake and release by diatoms/biogenic opal.

Several model experiments are carried out demonstrating the following:

-Including an improved ocean circulation model results in a more realistic Atlantic Al distribution at mid depths.

-A sediment resuspension term improves the Al distribution only after introducing a Si dependent Al desorption.

-Al incorporation leads to unrealistic low Al surface concentrations and if incorporation is important the proportional uptake of Al and Si is questionable.

Major remarks: The paper is well written and the abstract captures the main conclusions. My major concern is the following: Although the Si dependent Al release is an elegant solution to explain the Al enrichment of north Atlantic deep water, the evidence is not conclusive as pore water sources are not quantified: The latter is not taken into account although data exist that it potentially is a relevant source at least in parts of the southern Ocean. The model exercise would have been a great opportunity to discern between the two sources. In any case, the conclusion that resuspended sediments are a major Al source can only be made when the resuspension-source is compared to potential Al fluxes from pore water.

Furthermore, I do challenge the assumption that Al adsorbed onto (or incorporated into) biogenic opal is easily released. What is the scientific basis of this assumption? Koning et al. (2007) clearly demonstrate the opposite that Al is rapidly adsorbed onto opal and incorporated into the opal “lattice”. Thus a later release of Al seems unlikely whereas an interaction with Si release is likely. Given the impact of Al on opal dissolution, this model exercise would also have been a great opportunity to test the impact of Al on the Si cycle. Although an in depth study of the Si cycle is beyond the scope of

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the paper, the potential impact should not have been ignored.

In conclusion, I suggest to accept the paper only if the above points have been adequately addressed. Further points are mentioned below.

Figure quality and reduction in Figure number: Many of the Figures were too small in size to appraise all detail. Figure 3 is already shown by van Hulst et al. (2012). Fig 4. can be described in the text.

Local remarks:

P14541, L24: Please add citation on Al/Si Interaction.

P14542, L4: Please reduce the number of citations.

P14542, L20: I do challenge the assumption that Al adsorbed onto opal is easily released. What is the scientific basis of this assumption? Koning et al. (2007) clearly demonstrate the opposite that Al is rapidly adsorbed onto opal and incorporated into the opal "lattice". Thus a later release of Al seems unlikely.

P14542, L 24 ff. On the other hand, van Beusekom et al. (1997) showed that southern ocean sediments are a source of dissolved Al for southern ocean bottom water. This should be mentioned.

P14542, L 28. Is the source of Al exclusively desorption from opal dissolution and can other sources (like redissolution of certain clay minerals) be excluded?

P14543, L9. Another possibility removing Al is the uptake of Al by diatoms. Here two aspects are involved: adsorption onto organic matter associated with diatom frustules and the incorporation into the opal. The former Al may be released, but again, the post mortem incorporation into Opal (sensu Koning et al. 2007) may be involved.

P14544, L24 ff. I suggest to be a bit more careful here when interpreting the model: It may well be that the major patterns are reproduced by the model, but this does not prove that the model is right: what is the experimental basis for the reversible scav-

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enging by Sibiog? In fact, several studies (Koning et al. 1997 and references therein; the Al enrichment of SiBiog observed by e.g. van Cappellen et al. 2002) suggest the opposite.

P14545, L 6. What is the scientific basis for Al release from opal debris?

P14547, L 26ff. But what about clay minerals? (e.g. work by Mackin and Aller). On the time scales involved (>10<sup>2</sup> years) this may be significant at least in the sediment and in pore water dynamics.

P14548, L3 ff. The low resolution of the model bottom layer then actually does not allow to distinguish by pore water Al fluxes of Al released by resuspended sediment. Although the authors are possibly right that no sediment Al flux model is available, enough data are available to at least constrain the Al fluxes from sediments (e.g. work by Mackin and Aller, van Beusekom et al., 1997). This would allow to conclude on the relative importance of sediment resuspension.

P14549, L3 ff. One of the major concerns with the present model is that 1) Al is released proportional to the Al/Si in opal and 2) that no interaction between Si dissolution and Al uptake is included although the interaction is acknowledged and a parameterization is possible (see van Cappellen et al., 2002). Modelling this interaction actually would have been a real innovation.

P14552, L 21. Within the model the explanation certainly is right, but in the real world, it may be the other way around: low Al availability enables high Si fluxes due to a faster dissolution of opal and high opal concentrations in the sediment may effectively inhibit Al release through post mortem incorporation of Al in opal. Please comment on this.

P14553, L5 ff. In this paragraph, the authors acknowledge the possible role of clay dissolution. As clay minerals are not included in the model, the authors use a "trick" to allow Al release by tapping the "ads"-pool. In reality, the Si-dependent re-dissolution of clay minerals may be involved (sensu Mackin and Aller). This poses some ques-

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tions behind the modeled concept that Al-desorption is influenced by Si. What is the mechanistic / chemical explanation of the modeled Si dependent Al release?

P14553, L15 FF. Doesn't this imply that the Al cycle and its interaction with opal is not properly captured (Koning et al., 2007; van Beusekom et al., 1997)? By tweaking the critical value the model now seems to reflect the real Al distribution properly, but have the underlying processes been properly modeled? This of course is important when assessing the overall results/improvement of our understanding of the Al cycle.

P14560, L15. The conclusion that the importance of Al dissolution from resuspended sediment is supported by the model should be discussed with more care: No distinguishing between pore water fluxes and redissolution was made, hence no conclusive evidence is available to distinguish between both processes.

P14561, L1 ff. It was unclear to me, whether both processes (Alads Albio) are implemented in parallel or exclusively. An alternative to Al uptake that is proportional to Si, is to model Al uptake independently from Si uptake, by assuming a Michaels-Menten type of uptake. A maximum Al/Si ratio of 0.03 seems very high to me.

P14563, L25. Rephrase: Al release from resuspended sediment (depends on both. . . . .)

P14564, L10. Also pore water dynamics may potentially be important.

#### References

Mackin, J.E., 1986. Control of dissolved Al distributions in marine sediments by clay reconstitution reactions: experimental evidence leading to a unified theory. *Geochim. Cosmochim. Acta* 50, 207–214.

Mackin, J.E., Aller, R.C., 1984a. Dissolved Al in sediments and waters of the East China Sea: implications for authigenic mineral formation. *Geochim. Cosmochim. Acta* 48, 281–297.

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Mackin, J.E., Aller, R.C., 1984b. Diagenesis of dissolved aluminum and organic-rich estuarine sediments. *Geochim. Cosmochim. Acta* 48, 299–313.

Mackin, J.E., Aller, R.C., 1986. The effects of clay mineral reactions on dissolved Al distributions in sediments and waters of the Amazon continental shelf. *Cont. Shelf Res.* 6, 245–262.

Koning, E., M. Gehlen, A. M. Flank, G. Calas, and E. Epping. 2007. Rapid post-mortem incorporation of aluminum in diatom frustules: Evidence from chemical and structural analyses. *Marine Chemistry* 106:208-222.

van Beusekom, J. E. E., A. J. van Bennekom, P. Tréguer, and J. Morvan. 1997. Aluminium and silicic acid in water and sediments of the Enderby and Crozet Basins. *Deep-Sea Research II* 40:987-1003.

van Cappellen, P., S. Dixit, and J. E. E. van Beusekom. 2002. Biogenic silica dissolution in the oceans: Reconciling experimental and field-based dissolution rates. *Global Biogeochemical Cycles* 16.

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