Biogeosciences Discuss., 10, C7888–C7889, 2014
www.biogeosciences-discuss.net/10/C7888/2014/

Biogeosciences
Discussions
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Interactive comment on "Icehouse-greenhouse variations in marine denitrification" *by* T. J. Algeo et al.

T. J. Algeo et al.

Thomas.Algeo@uc.edu

Received and published: 14 January 2014

We thank the reviewer for these insightful and constructive comments.

In terms of the global-ocean nitrogen budget, if cyanobacterial N fixation is the only significant source of new bioavailable N, then it cannot influence seawater nitrate δ^{15}N. Sustained excesses or deficits of cyanobacterial fixed-N production are not possible owing to the short residence time of fixed N in seawater (3 kyr; Tyrrell, 1999), and any variation in the source flux of fixed N will be balanced out by changes in the sink fluxes at geologically short time scales. Thus, icehouse oceans could have lower N fixation rates only if the N sink fluxes were proportionately lower, and the net effect on global-mean seawater nitrate δ^{15}N of these flux changes would be minimal.

We agree with the reviewer that local deviations from the global-mean seawater nitrate δ^{15}N composition are possible, and that continental-shelf and cratonic-interior seas are particularly prone to such deviations. Local excesses or deficits of cyanobacterial fixed-N production are one among a number of possible causes of deviations from global-mean seawater δ^{15}N. We have considered these effects qualitatively at some length in the manuscript; a strict quantitative formulation is not possible.

To a first approximation, the area of flooded continental shelf and cratonic interior must correlate with global sea level elevations. Eustatic levels are generally low during major ice ages, including those of the Late Paleozoic and the Quaternary (Haq and Schutter, 2008), and lower eustatic elevations will result in reduced continental flooding as shown in our Figure 9b for icehouse climate modes. We have added an eustatic curve to our Figure 1 to document this general relationship. There would be significant uncertainties linked to attempts to generate a graph of continental area flooded through time, especially for the pre-Cretaceous, so eustasy is a reasonable proxy.

Yes, we agree that ammonium uptake fractionation is only relevant if N utilization is incomplete. We advanced this process as an explanation for observations from some greenhouse intervals of δ^{15}N that are more negative than probably can be achieved through cyanobacterial N fixation alone. In such instances, we hypothesize that the most negative δ^{15}N values represent a combination of globally low rates of water-column denitrification and local fractionation related to ammonium uptake. However, we concede that the cause of extremely low δ^{15}N values during greenhouse intervals is not well-understood at present, and that alternative models may be possible. We also agree with the reviewer that there are inherent spatial and environmental biases in the geologic record that are carried over into our dataset. As more data are generated over time, the influence of these biases on our conclusions may become testable.

Interactive comment on Biogeosciences Discuss., 10, 14769, 2013.