Author response

'The reviewer's comment about the timing of the riverine alkalinity flux has still not been adequately addressed. As the authors note, the assumption that the flux responds immediately to changes in atmospheric CO2 is central to the mechanism generating the oscillation, yet a justification for this assumption is not given. Weathering is a slow process (100,000 yr timescale) and an explanation needs to be provided as to how it can affect the riverine flux on a millennial timescale.'

Author reply

To completely respond to these comments, we will clarify what we have written in the main text and how the weathering is parameterized in the model.

First of all, the size of the river influx responds to changes in pCO2 immediately, but this does not mean it has a significant impact on ocean carbon and alkalinity. The timescale the river influx becomes important in this model is the timescale of the oscillation.

The river flux parameterization consists of two different processes: carbonate weathering and silicate weathering, where silicate weathering consists of a variable and constant part and carbonate weathering only of a variable part. Note that only the variable weathering components are important for the oscillation. Looking at the parameter values, carbonate weathering is responsible for 80% of this variability and silicate weathering only 20%.

These two different processes act on different timescales. The reviewer refers to weathering on 10^5 years timescales. This refers to silicate weathering. Silicate weathering balances the volcanic input of carbon on the 10^5 to 10^6 years timescales, timescales order larger than the timescale of the oscillation. However, terrestrial carbonate weathering is important on shorter timescales: 10^3 to 10^4 years, the timescale of the oscillation found in this study. These timescales have been found in multiple studies (e.g. Archer et al., 1997; Lenton and Britton, 2006; Sarmiento and Gruber, 2006; Brault et al., 2017). We therefore want to stress that the weathering important for the oscillation is carbonate weathering and not silicate weathering.

Lastly, we want to repeat that our system does not reach a steady state and that the amplitude of the river influx is more than two times smaller than the burial of $CaCO_3$ in the ocean and therefore less important.

References:

- Archer, D. [E.], H. Kheshgi, and E. Maier-Reimer (1997), Multiple timescales for the neutralization of fossil fuel CO2, Geophys. Res. Lett., 24, 405–408.
- Lenton, T. M. and Britton, C.: Enhanced carbonate and silicate weathering accelerates recovery from fossil fuel CO2 perturbations, Global Biogeochem. Cy., 20, GB3009, https://doi.org/10.1029/2005GB002678, 2006.
- Sarmiento, J. and Gruber, N.: Ocean Biogeochemical Dynamics, Princeton University Press, Princeton, 2006.
- Brault, M.-O., Matthews, H. D., and Mysak, L. A.: The importance of terrestrial weathering changes in multimillennial recovery of the global carbon cycle: a two-

dimensional perspective, Earth Syst. Dynam., 8, 455–475, https://doi.org/10.5194/esd-8-455-2017, 2017.

Changes in manuscript

In the description of the river flux parameterization, the difference between silicate and carbonate weathering has been made more explicit and the paragraphs around line 390 and line 450 are clarified and extended to reflect the response above.