**Geoscientific
Model Development
Discussions**

Interactive
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Interactive comment on "The Rock Geochemical Model (RokGeM) v0.9" *by* G. Colbourn et al.

G. Colbourn et al.

gcolbourn@hotmail.com

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Here is a complete reply to Yves Godderis' review from Tim Lenton:

General comments

Weathering is indeed a complex processes that requires careful modelling to catch the millennial (and centennial) scale dynamics. However, we have designed our model for application at geological timescales up to a million years. In particular, our first key application of the model is to revisit the timescale of the silicate weathering feedback. This also considers dynamic responses of carbonate weathering and carbonate compensation in the ocean (i.e. 10,000 year timescales). However, we do not focus on millennial and sub-millennial scale responses. Indeed we use instantaneous pulse additions of fossil fuel rather than realistic emissions scenarios.

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Our modelling philosophy aims to strike a compromise between improving upon existing 0-D box-model approaches to the silicate weathering feedback but still being able to integrate to steady-state (i.e. for a million years) and to conduct large ensemble studies to explore parameter sensitivity. This precludes the use of more complex models being developed by Godderis and colleagues (particularly the FOAM GCM atmosphere coupled to WITCH). We have a fast energy-moisture balance atmosphere model, which means it would not make a great deal of sense to have a more elaborate weathering scheme given the limitations on the climate it produces. Note however that we do have a 3-dimensional ocean and sediment model and therefore a state-of-the-art representation of the carbonate burial/dissolution response to changes in weathering.

Consistent with our modelling philosophy we retained in our default settings several parameterisations of weathering used in O-D box models such as GEOCARB, in order to explore the effect of having an Earth system model in place of a 0-D temperature function.

We will alter the introduction of our approach accordingly in the paper.

Major points

1. We are already familiar with some of the papers by Donnadieu and co-authors, enjoyed reading the rest, and will certainly endeavour to cite them more in our revisions. Obviously water is necessary for weathering and the pattern of runoff does indeed make a difference to the GEOCLIM results. However, for a fixed continental configuration, lithology and runoff routing, changes in temperature and CO_2 can have a greater effect on weathering flux than changes in the runoff flux of water. With our relatively simple EMBM atmosphere precipitation (and therefore runoff) patterns are more uniform than in reality or a GCM. For a map of the present day runoff calculated by GE-NIE see pp.23-25 of the lead authorís PhD thesis: https://ueaeprints.uea.ac.uk/34242/ which also describes various unsuccessful attempts to improve the distribution. In a warmer future world in GENIE, the total flux of runoff increases (well known spinning

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up of the hydrological cycle) but the pattern does not change much. Although weaknesses in the pattern of runoff will certainly affect the short-term (centennial-millennial) dynamic response of weathering to climate change, as the referee points out himself, this is less critical for the long-term (multi-millennial to million year response). Also, we have conducted a sensitivity study to changing the runoff routing in GENIE and it has a negligible effect on our results.

2. In our extensive sensitivity analyses we have experimented with different activation energies, e.g. from West et al. (2005), which are based on field data, and can discuss the effect this has. In the most up to date version of the model, these have become the default. However, we are not in a position to redo all the runs in the present paper ñ each million year run takes something like a month of CPU time, so the full ensemble is years of CPU time. We will just discuss the effect of different parameterisations more extensively in revising the paper.

3. Equation 6 is based on field data, so incorporates any biological and runoff effects. We wanted to use the equation from GEOCARB, to see what difference coupling it in a full Earth system model made (see general comment above).

4. Here it is important to note that a CO_2 effect on productivity and hence weathering is an optional extra in the model and we show that it has minimal effect on the results (Fig. 13) that is only apparent on millennial timescales. Hence the referee is wrong to refer to it here as "a modeller trick to ensure a strong negative feedback between CO_2 and weathering", because it has no such effect in this model! Our description of the link between the continental biosphere and weathering was intended to be "rough", following our overall modelling philosophy and knowing the limitations of our EMBM atmosphere model. Equation 14 is indeed a Michaelis-Menton form that is a fairly common way of representing the CO_2 fertilisation effect. The key point however is that temperature, not CO_2, is instrumental to the silicate weathering feedback in GENIE.

5. We will endeavour to make clearer which version of our model would be appropriate

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in different future applications. There is some information on different rock types going back in geological time (which was used for example in the classic paper of Berner and Canfield 1989 on atmospheric oxygen projections) although obviously the data get scarcer going further back. Hence the OD weathering model will be more appropriate for some studies, but this is still an improvement on a model such as GEOCARB because GENIE has a better climate, a 3D ocean and full marine biogeochemistry including interactive sediments.

Minor points

1. We use the term "terrestrial neutralisation" because it is more specific than "continental weathering" referring to only a part of the full process.

2. References to the paper in preparation will be removed.

3. We will cite the Beaulieu et al. (2012) paper in the revision, but here we have different views on what counts as ìthe anthropocene timescaleî ñ to us the Anthropocene will not end until fossil fuel carbon is removed from the atmosphere on the full million year timescale of the silicate weathering feedback. As we show, and is well known, changes in carbonate weathering cannot neutralise all fossil CO2, however interesting their response on centennial-millennial timescales.

4. In the revisions we will cite the interesting paper by Le Hir et al. (2011) on the Devonian rise of plants.

Interactive comment on Geosci. Model Dev. Discuss., 5, 2007, 2012.

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