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Interactive comment on "CE-DYNAM (v1), a spatially explicit, process-based carbon erosion scheme for the use in Earth system models" *by* Victoria Naipal et al.

Anonymous Referee #1

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In this study, Naipal and others described the development of a spatially explicit, process-based carbon erosion scheme (CE-DYNAM v1) for the use in ESMs. The leading author has already published several papers on the modeling of soil erosion and its impact on C cycling. Many components described in this manuscript have been well validated in Naipal et al. (2015, 2016 & 2018). Compared with those previous works, the major innovation in this new model is that it links the sediment and C dynamics on hillslopes with those on floodplains together and couples vertical C fluxes and pools from ORCHIDEE with lateral C fluxes from the soil erosion model. The authors designed three numerical experiments (S0: the baseline simulation or no-erosion simulation; S1: the erosion-only simulation; S2: the fully sediment dynamics simulation)

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Discussion paper

to quantify the effects of carbon erosion on the C cycle in the whole Rhine catchment. This study also performed a detailed model validation of soil erosion, C erosion, sediment storage and SOC stocks using either high-quality data or benchmark simulations in the Rhine catchment.

The manuscript is well written and fits the scope of GMD well. As a novel modeling work, it may advance the represent soil erosion, a process important for land C dynamics, in ESMs to better constrain the C climate feedbacks. The authors have given detailed descriptions of their methods and results in most parts of the manuscript.

My major concern is about the validity of one assumption in the model. I am not fully convinced and expect a better justification. Because the model does not represent the river routing process, it uses floodplain connectivity to simulate the transport of sediment along hydrological pathways. However, by doing so, it implicitly assumes all sediments as sand and gravels (non-cohesive sediment) and represents the transport of cohesive and non-cohesive sediment in the same way. But the cohesive sediments (loam and silt) can be transported by rivers efficiently and most of them would not be deposited. Further, loam and silt may be the major type of sediments that are generated from hillslope erosion (especially for interrill and rill erosion considered by RUSLE). As shown in the results, the current method can cause the severe underestimation of sediment and C that are transported to oceans.

Other Comments

L70-72: These two references are relevant to this sentence.

Galy, V., Peucker-Ehrenbrink, B., & Eglinton, T. (2015). Global carbon export from the terrestrial biosphere controlled by erosion. Nature, 521, 204–207. https://doi.org/10.1038/nature14400

Tan, Z., Leung, L. R., Li, H., Tesfa, T., Vanmaercke, M., Poesen, J., ... Hartmann, J. (2017). A Global data analysis for representing sediment and particulate organic carbon yield in Earth System Models. Water Resources Research, 53, 10,674–10,700. https:// doi.org/10.1002/2017WR020806

L117: it should be noted that as discussed in Naipal et al. (2015), the formulation of R factor is related to climate type. So in the millennia time scale, one area may need different R factors due to the change of climate.

L170: Reference for Eq. 5? Also, I recommend to show the spatial variability of the f factor in the Rhine catchment.

L192: This may be true for sand and gravel sediment (the majority of floodplain sediment) that Hoffmann et al. (2008) studied. But for cohesive sediment (loam and silt), they can be transported through river channels to oceans without the large fraction of deposition (at least not as large as what is set in this model). They are also the major sediments of soil erosion.

L202: Similar above, this routing scheme may be fine for floodplain but whether it is appropriate for river sediment routing is questionable. And river sediment routing transports large amounts of sediment and POC from hillslopes to oceans.

L322-326: Could you make the meanings of each term in RHS of these equations more clearly? Especially, I do not very understand what the second term of RHS of Eq. 16 stand for. Also in Eq. 17, what is the difference between 1/(τ*365) and kiout for SOCFLi(0,t) in the third term?

L431-432: Or as argued by Tan et al. (2018), rainfall erosivity itself tends to be less variable if using large scale rainfall data to calculate it.

L455: could the map of these 13 sub-basins be shown?

L471-473: if much more sediment was generated but sediment deposition may still follow the long-term level, where did this additional sediment go? I suspect that it mostly was transported to oceans, a process not or poorly represented in the current model.

L474: that only 0.2% of sediment is exported out of the catchment is too low to believe. Are there any data to support it?

Section 4.2: The model also does not represent the impact of water management (such as flooding control) on floodplain connection.

Figures: As discussed above, I recommend to add a few more figures (in either supplementary or appendix) to show the 13 sub-basins of the Rhine catchment and the spatial variability of the floodplain factor f and the sediment residence time τ.

Figure 2: What does the gray level stand for? Elevation?

Figure 3: What does the x-axis mean? Why do not you do a cell-to-cell comparison instead?

Figure 4. Do you have another way to convey the message? It looks messy currently.

References: Generally good. I recommend to also acknowledge the progress in other groups to represent soil erosion at large scale numerical models, such as Pelletier (2012) and Tan et al. (2018).

Pelletier, J. D. (2012), A spatially distributed model for the long-term suspended sediment discharge and delivery ratio of drainage basins, J. Geophys. Res., 117, F02028, doi:10.1029/2011JF002129.

Tan, Z., Leung, L. R., Li, H.-Y., & Tesfa, T. (2018). Modeling sediment yield in land surface and Earth system models: Model comparison, development, and evaluation. Journal of Advances in Modeling Earth Systems, 10, 2192–2213. https://doi.Org/10.1029/2017MS001270.

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