Comments on Zhang et al „Estimating the lateral transfer of organic carbon through the European river network using a land surface model" submitted to ESDyn

The authors present modelling results of lateral OC transfers based on an improved representation of POC and DOC transfer using the ORCHIDEE LSM model. Model outputs cover European catchments during the period from 1901 to 2014. The authors provide very interesting results on various OC budget component for the given period, which have not been published at the European scale (e.g. how much sediment/POC is stored in floodplains and exported to oceans). Furthermore, the authors compare the C budget with and without lateral C transfer and provide interesting information on the discussion of the net effect of lateral sediment transfer of the carbon budget. Overall, the study is of great interest and certainly the develop model provides a significant step forward on that topic (as far as I can judge this from a non-modeler point of view). I recommend this manuscript to be published in ESDyn after major revisions. Please consider the general and more detailed comments below to improve the submitted manuscript.

Kind regards
Thomas Hoffmann

General comments

It is very hard to understand the model setup as a non-model expert and the text is not very communicative to motivate and convince non-model experts to read the paper. I suggest that the authors should critically prove how they can motivate the linkages between the empirical evidences and the model setup. I had hard times to understand the general model approach and still do not fully understand how the authors define headwaters and whether they differentiate headwater sizes depending on the climate /lithology etc. But maybe I was blind and unable to extract the relevant information. In any case, many assumptions/ approaches are not straight forwards and description should be improved.

The general concept, as depicted in Figure 1, draw an arrow (F_up2fld) from the upstream basin to the floodplain. I was wondering if this transport path is needed? The main transfer to floodplains steams from the main river channel that is passing the floodplain. The potential inputs from upstream basins is of academic nature and could be neglected.

Major parts of Europe are missing in terms of observations of suspended sediment loads (e.g. no observation for Spain, France GB, Italy), esp. Mediterranean rivers are not covered in this study. Due to the very different behavior of streams in south and north Europe, the study is strongly biased toward N-Europe. This becomes even more important by the comparison with the model output from WATEM/SEDEM for the two catchments of the Apennine Peninsula, which are simply ignored as 'outliers'.

The authors provide model runs with and without lateral C transport and find that SOC stock only marginally increase of lateral flux is turned on. This very low increase somehow contradicts the large amount of POC retention in floodplains. The authors somehow provide

numbers with SOC stock decrease in mountains and SOC stock increases in floodplains, but does this mean that SOC retention in floodplains is more or less fully compensated by soil degradation at eroding sites? It was argued that at long-term (10^3a) OC retention in floodplains is more important than soil degradation, while at shorter terms (couple of years) degradation effect might dominate. I wonder what happens to the model if the authors considerer shorter and much longer time scales than those used in this study. Please discuss this in more detail.

Detailed comments

Line 38: 'but also leaching of DOC' → needs some more details, leaching from where?
Line 45: I suggest to refer to a new review on OC sequestration in floodplains (https://doi.org/10.1016/B978-0-12-818234-5.00069-9)
Line 169ff: the many branches/modules etc. make it very hard to understand the model setup. Could you somehow visualize it?
Line 228: I suggest to avoid sediment delivery rate, as this might be confused with sediment delivery ratio. Please use sediment supply instead. How are headwater basins defined in this study?
Line 229: given set f runoff and vegetation cover conditions → could you specify them and motivate, why you refer to the reference runoff condition rather than actual runoff. This might be explained in the original reference. However, I highly recommend to give more details here, to ease the understanding of the approach.
Line 232: Is this really a runoff or rather a precipitation reference (given the 10mm day-1)?
Line 237: DA^(dDA^c) → is that correct? Looks erroneous
Line 237: is assume that DA is drainage area (not defined)
Line 238: same as above; (p.5-6) should be linked once more to the reference where this citation is taken from.
Line 247-249: not sure what the authors want to say here? I guess the model outputs should depend on these parameters.
Line 250: ORCHILEAK Clateral → subscript lateral
Line 251: was this done for various reference conditions?
Line 254: awkward sentence; '…force the simulation of Then…' ?????
Line 260: Same b as in Eq.1? Where is S_iday located in Figure 1?
Line 262: R_30_k not in Eq. 3 and 4
Line 304: Is F_Fout_sed identical with S_iday? Please remove sediment in this sentence, because this is confusing due to the fact that there is not storage in the fast water reservoir.
Figure 1a: Not sure what the direction of arrows indicates. I suggest that they point from the text to the feature in the graphic (if this is not related to vertical fluxes; unlikely for sediment). S_river and S_flood is used in Figure caption but not within the Figure itself.
Line 323ff: I wonder if the author mix up several things. In rivers, suspended sediment (esp silt and clay which are transport agents of POC) is transported as wash load. The transport of the wash load is not transport capacity limited but supply limited. Whether changes in the channel bed need to be considered depends on the target time scale. Therefore, I am not sure if it is required to discuss Eq. 7 in detail. If the authors specify the relevant scales much earlier in their paper, the lengthy discussed could be reduced.
Line 357: what is e1 in Eq.1?
Line 361: Drainage area in Eq 1 was defined with DA. Use same symbols!

Line 361: In Eq. 8 the term F_down2riv_h20 is used, here in the text you use F_down2riv_sed but talk about water discharge. I am confused. I assume you refer to the Psi-equation of Cohen et.al. If this is true
Line 371: Assuming that channel bank erosion only occurs if no sediment is left at the channel bank is not a meaningful assumption. Many rivers migrate without changing their channel bed.
Line 387: F_up2fld_sed not needed in my point of view. Why was this introduced and and why is there no F_riv2fld?
Line 390: sum in text but negative sign in Eq. 16 → furthermore, I don't understand the approach here. Why does evaporation and infiltration contribute to sediment deposition? Please explain.
Line 400: Same f_topo as on hillslopes? How was this calculated? I am confused!
Line 485: I guess that you run in the problem of equifinality of you simple calibrate five parameters against one observation (sediment yield). Please discuss this problem.
Line 509: Major parts of Europe are missing (e.g. no observation for Spain, France GB, Italy), esp. Mediterranean rivers are not covered in this study.
Line 517: Indicate which stations in Rhine were used. POC is strongly discharge dependent, please indicate how many measurements at which discharge are used.
Line 606: It seems that the model underestimates the observed DOC variability (Fig. 4b), however, this is in contrast to the Figure S8. Please explain this discrepancy.
Line 649: How does this number relates to empirical sediment budgets? Is that in the order of obserations? Please discuss.
Line 661: any idea what causes this decline?
Line 679: are there any empirical values to compare with?
Fig. 10: Does C_riv2land represent the transport from river channels to floodplains? If yes, I suggest to consider floodplains not at 'land'.
Line 753: flooding decreases SOC stored in floodplain soil???? This is total contradicting our expectation and needs discussion
Line 747: can you account for the soil-wettness driven changes in soil temperature? Is this effect significant?
Line 754: any number how this influences the C budget. Many empirical studies argue that this effect is important and strongly increases the OC retention in floodplains. Could this somehow be quantified?
Line 793: this very low increase somehow contradicts the large amount of POC retention in floodplains. You somehow provide numbers with SOC stock decrease in mountains and SOC stock increases in floodplains, but does this mean that SOC retention in floodplains is compensated by soil degradation at eroding sites?
Line 811: Please cite Hoffmann 2013 (GBC): they present results for hillslope and floodplain storage of OC for the Rhine basin.
Line 826ff: Considering NP might not only decrease NPP at eroding site but also increase NPP at depositional site. Correct? If yes, leave some words in the paragraph on depositional sites as well. Certainly, a worthwhile action to link NP here.
Line 839: Hoffmann et al (2020, ESurf) provides a way to differentiate exsitu and insitu OC in rivers. This paper also offers more infos on POC in the Moselle and Rhine rivers.
Line 849: Could the routing be done using DEMs with better spatial resolution to overcome limitations of the routing on low-res DEMs?

Figure S2: bad quality, can't read the text

Figure s4: give names of gauging stations
Figure S5: bad quality of left map