Anonymous referee #1

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The manuscript presents a model for carbon cycling in streams. It claims to have a global relevance, however it was only tested on one selected river basin, the Rhine. The publication also indicates several Strahler orders of investigation, however on the Rhine only the main River seems to have been investigated. Another major criticism of this work is that the model does not really seem to incorporate seasonality or events such as draughts or floods. These can have very important implications on river carbon fluxes.

A1: In our paper we describe DISC, which is a global model. The manuscript is merely a description of the input data, hydrological data and the equations used and parameters for in-stream processing. Although all the presented data are available in this resolution on the global scale, the best way to test its performance is by describing all the processes for one river for which we have ample data available. The river Rhine is such a river.. To avoid confusion, we change the wording and application of the word 'global' to the purpose of the manuscript; to describe the functionality of the model. Our model includes Strahler orders, although timeseries of carbon data have only been available for the main branch. The reviewer is not correct in the criticism that the model does not seem to incorporate seasonality or events as draughts or floods is unfair. The model does include seasonality in climate data, radiation, and hydrology (PCR-GLOBWB). Dry periods or floods will become visible as in the historical weather data. For example, winter of the year 1995 was a flood period.

Overall the manuscript is well written but claiming globality only because it is potentially possible would be not enough to justify publication.

A2: We agree, we do not substantiate our claim for global use in this manuscript. The manuscript is merely a description of the input data, hydrological data and the used equations and parameters for in-stream processing. Although all the presented data are available in this resolution on the global scale, we present the ways and purpose of the model by means of a small scale performance test for the Rhine basin. We change the wording and application of the word 'global' to the purpose of the manuscript; to describe the functionality of the model.

Sentence changes

title:
-from: CARBON-DISC 1.0 - A coupled, process-based model of global in-stream carbon biogeochemistry
-to: CARBON-DISC 1.0 - A spatio-temporal, process-based watershed model of in-stream carbon biogeochemistry

Line 23:
-from: considering that this is a global model
-to: considering the low spatial resolution of the model constraints

Line 64-65:
-from: This new model is specifically designed for global applications and describes the spatial and temporal variability of carbon concentration and fluxes based on the river basin hydrology from headwaters to mouth and carbon cycling processes.
-to: This new model describes the spatial and temporal variability of carbon concentration and fluxes based on the river basin hydrology from headwaters to mouth and carbon cycling processes.

Line 66-67:
-from: Here, we present the main features of the CARBON-DISC module, we apply the module in the stream network of the Rhine basin and evaluate its characteristics with a sensitivity analysis.
-to: Here, we present the main features of the CARBON-DISC module, and as a proof of concept, we apply the module in the stream network of the Rhine basin and evaluate its characteristics with a sensitivity analysis.

Line 16: name the independent global databases

A3: the abstract is not the place to go into detail on which specific databases are used. To avoid further confusion, we removed these words from revised manuscript.
- from: A coupled hydrology-biogeochemistry approach with 0.5 by 0.5-degree resolution accounts for the spatial and temporal variability in dynamic conditions in the aquatic continuum using independent global databases.
- to: A coupled hydrology-biogeochemistry approach with 0.5 by 0.5-degree resolution accounts for the spatial and temporal variability in dynamic conditions in the aquatic continuum.

Line 22: retrodiction. DO you mean reconstruction?

A4: we agree that reconstruction is a better wording
- from: […], and the model can be applied for retrodiction and to analyse future scenarios
- to: […], and the model can be applied to analyse future scenarios

Line 23: fair agreement is too vague. Quantify.

A5: "fair agreement" is changed to "simulation results for DIC, DOC and TOC are in the same order of magnitude as observations"
- from: Validation of the model with long-term measurement data shows a fair agreement
- to: Validation of the model shows that simulations of DIC, DOC and TOC concentrations are in the same order of magnitude as observation with RMSE's of respectively -46%, +33%, +147%.

Line 52 / 53: explain why these models are unsuitable

A6: We do not use the word unsuitable in this paragraph. The discussed models are obviously suitable for the tasks they have been designed for, but as discussed in the text they **"**fail to describe the rapid changes in the global C-cycle (Ciais et al., 2013)and are not appropriate for retrodictions (predictions of the past) or making informed projections. Many existing river biogeochemistry models lack spatio-temporal input and hydrological constraints. Moreover the models usually lump

the various compartment of the aquatic continuum and regress modelled and observed C export at the scale of whole river basins (Beusen et al., 2005; Mayorga et al., 2010; Kroeze et al., 2012). After upscaling, such approaches yield a first order quantification of C fluxes to the coastal ocean. However, they contribute little to advance our understanding of the C cycle in river basins.**"**

Line 66: why did you choose the Rhine basin?

A7: the manuscript is a presentation of the CARBON-DISC module. Various simulations of the Rhine basin are shown as a proof of concept; it is not a Rhine basin study. The Rhine basin was chosen as extended timeseries were available along the basin.

Line 66-67
- from: Here, we present the main features of the CARBON-DISC module, we apply the module in the stream network of the Rhine basin and evaluate its characteristics with a sensitivity analysis.
- to: Here, we present the main features of the CARBON-DISC module, and as a proof of concept, we apply the module in the stream network of the Rhine basin and evaluate its characteristics with a sensitivity analysis. The Rhine basin was chosen since timeseries of C components are available across the entire basin and over an extended time.

Line 69: This and all other occasions spell out abbreviations such as IMAGE-DGNM upon first use

A8: IMAGE-DGNM has been spelled out earlier in the text at lines 62-64. We have identified missing spell outs of abbreviations and they are now included in the text.
line 70:
- from: The IMAGE-DGNM model framework integrates the PCR-GLOBWB dynamic global hydrology model
- to: The IMAGE-DGNM model framework integrates the PCRaster Global Waterbalance (PCR-GLOBWB) dynamic global hydrology model

Line 73: 0,5 degree. How does this compare to other models?

A9: We feel that a comparison has no place in the methods section. Comparison with other models is valuable when results are compared.

Line 76: adjustable to which minimum time segment?

A10: Minimum timestep is limited by hydrological constraints and biogeochemical data. In the presented study, hydrological constraints and biogeochemical data provide monthly data. The framework however, is able to process any timestep. This is explained better in the revised manuscript.

Line 77-78:
- from: Although the temporal scale of the model framework is adjustable, here we focus on

monthly-scale processes.
- to: Minimum timestep is limited by hydrological constraints and biogeochemical data. In the presented study, hydrological constraints and biogeochemical data provide monthly data; results are presented in a monthly timestep. The framework however, is able to process any timestep.

Fig 1: increase text in colored boxes. This is hardly readable

A11: Text size is enlarged in the revised manuscript

Line 95: Why are CaCO3 particles not considered? Justify with references

A12: The assumption is justified because in lotic waters, residence time is too short to consider $CaCO_3$ precipitation/dissolution a relevant process. This is clarified in the revised manuscript.

Line 98-100:
- added: In non-endoreic watersheds, water residence time is considered too short for $CaCO_3$ precipitation/dissolution to be relevant. The framework does not provide estimates for endoreic waterbodies.

Line 96: How are respiration and photosynthesis incorporated as important processes?

A13: This section of the manuscript only describes the model in general terms (refer to the paragraph chapter; General aspects). Specific implementation and equations are found in the model description.

Line 108-110: While it is true that weathering plays a prominent role for ALK input important sinks are photosynthesis and evasion of CO2. Also important sources of respiration simply cannot be ignored. Another missing aspect is the hyporheic zone. Partially these aspects occur later on but the text needs to be arranged in a way that it becomes clear.

A14: In CARBON-DISC, distinction is made between alkalinity (*ALK*) and *DIC*. Here we consider ALK as an inert component. It is only added to the river system through an *ALK* flux parameterization with discharge proposed by Janssen (2010) and then discharge downstream. *DIC* is able to be consumed and produced by biology and exchanged with the atmosphere. We agree that the discussed model is missing aspects such as the hyporheic zone. Available spatio-temporal data is not sufficient to constrain this. This is made clear in the revised version.

Line 116:
added: Also, although the hyporheic zone may be an important component in the production/removal of alkalinity (Boulton et al., 1998), spatio-temporal data is not sufficient to constrain processes within. Additionally, total *DIC* is governed by biological processes such as primary production and mineralization of *DOC* and *POC*.

Line 116: why monthly and not fortnightly?

A15: Hydrological data and C delivery data is not available at this temporal resolution. This is made clear in the revised version
line 77
-added: Minimum timestep is limited by hydrological constraints and biogeochemical data. In the presented study, hydrological constraints and biogeochemical data provide monthly data; results are presented in a monthly timestep.

Line 135: km3/year. What about seasonality?

A16: The timestep is monthly. We have changed the unit where applicable to # / t (being amount / time) in the revised manuscript. Also, km^3 is changed V (volume), km^2 is changed to A (area) and km is changed to L (length), ton is changed to M (mass)

Line 136: mmmol /km3 is a somewhat strange unit. Why was it used here? Normally mmol / L is used.

A17: The C delivery data is expressed in Mmol (megamol per gridcell) and the hydrological data is expressed in km^3. All source code is expressed in these units. For clarity, we choose to express model variables and parameters in quantity instead of unity in the revised manuscript. See A16

Line 136: total amount. Do you mean concentration?

A18: The total amount of each C specie is the result of the numerical solution for each waterbody after each timestep. Concentration is then calculated by dividing the total amount in the waterbody volume in that time step.

Line 140 to 145: These assumptions over-simplify how a river really works and need some more work. With this it is questionable that the model will run a realistic representation

A19: All models are simplifications of reality. At this moment we don't see better solutions to do simulations more realistically it this scale. We are open for better solutions in the future.

Whole section 2: All equations need to be listed in an overview table

A20: We now provide an overview table listing all equations at once. The table is found in section G in the supplementary material of the revised manuscript.

Fig3: should be presented at an earlier stage in the text as an introduction to all parameters and processes. It is too easy to state that the schemes (?) do not show lateral fluxes for clarity purposes. They should be important.

A21: The figure represents the interactions of forms of C numerical calculation scheme. We call it 'schematic representation' in the revised manuscript. The numerical scheme for interactions does not

contain any lateral fluxes. The DGNM framework is taking care of the lateral fluxes (Vilmin et al. 2019, submitted).

Results 363: if this global model is only tested on the Rhine basin this is too little. Other basins in each climatic zone should be tested and also an overall run with estimations for each continent and the whole world should be performed.

A22: We agree. In the revised version of the manuscript we rephrased the purpose of the paper and we changed the title. We aim to describe the model (inputs and processes) and show a proof of concept. We believe that applications of the model to show full results and their implications should be discussed in other specific journal.

Section 3.1. what do you mean by schemes?

A23: We understand that use of the word 'scheme' is confusing. We mean numerical scheme (variables and their interactions). This is explained in very general terms in lines 93-101 and in more details in section 2.2, the model description.