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Earth System Dynamics
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Interactive comment on “Historical and future contributions of inland waters to the Congo basin carbon balance” *by* Adam Hastie et al.

Anonymous Referee #1

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GENERAL COMMENTS

Hastie et al. applied the ORCHILEAK model to the Congo Basin to estimate CO2 evasion from the river to the atmosphere, and then provide the long-term (1861-2099) trends of aquatic carbon fluxes. The approach builds on the previous application of the same model to the Amazon by the same group.

The ms fits the scope of ESD, is well written, but the quality of the figures could be improved.

More importantly, a better job should be made at validating the model with a model vs field data comparison of dissolved CO2 concentrations, as detailed below.

Similarly, a better job could be made at discussing the CO2 emissions from the model,

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by detailing the model representation of dissolved CO2 concentration, gas transfer velocity and stream surface area, as detailed below.

MAJOR COMMENTS

The model validation step is very slim, as authors compare the model outputs of dissolved organic carbon (DOC) to a sub-set of published field data. DOC in tropical rivers is extremely refractory and provides little grasp on aquatic carbon cycling as the most labile DOC fraction is very rapidly mineralized (both in soils and in water). So DOC provides a poor validation of the carbon cycling in the river, and might be considered almost as a passive tracer and provide a rough validation of the hydrological connectivity between soils and rivers.

Conversely, a convincing validation of the model would be to compare the model outputs of the dissolved CO2 concentration (or the corresponding partial pressure of CO2) with the extensive field data collected by Borges et al. (2019) that are publically available (Borges and Bouillon 2019). While a point by point comparison would not make sense, it could be useful to check if the model captures the overall range of spatial variations along the river and among the different stream sizes. Such validation would be extremely convincing because the CO2 evasion from the river to the atmosphere (the core topic of the paper) is computed from the dissolved CO2 concentration (the atmospheric CO2 is comparatively invariant) and the gas transfer velocity. So if the model does not represent correctly the dissolved CO2 concentration then this implies that the CO2 evasion rates are incorrect (as well as any conclusion based on past reconstruction and future projection from the model outputs).

The overall emission of CO2 from the fluvial component of the Congo Basin (TgC/yr) is based on the product of a CO2 flux density (mol/m2/yr) and a stream surface area; the areal CO2 flux is itself computed from the air-water CO2 concentration gradient, and the gas transfer velocity; the air-water CO2 concentration gradient in turn is mainly function of the dissolved CO2 concentration. So there are three quantities that could explain the difference between the 4 estimates of integrated CO2emissions discussed in section L-513-517: the CO2 dissolved concentration, the gas transfer velocity and the stream surface area. The evaluation of the model performance would be much more convincing if each of these three quantities was compared to available estimates.

Final elements of validation and discussion that are missing are the contribution of HCO3- to the export of dissolved inorganic carbon (DIC) from the river to the ocean. The export of DIC from rivers to the ocean is mainly in the form of HCO3- including the Congo river (Wang et al. 2013). So ignoring HCO3- would lead to a very substantial under-estimation of DIC export to the ocean. This should be fairly easy to implement with a weathering model and GIS of lithology. This is of course of interest for the topic of paper as weathering intensity is a function of temperature and precipitation that are used by the authors to study the long-term (1861-2099) trends of aquatic carbon fluxes. Further, there are substantial data-sets of total alkalinity (that mainly corresponds to HCO3-) providing spatial (Borges et al. 2019) and seasonal (Wang et al. 2013; Bouillon et al. 2012; 2013) patterns of HCO3- variability.

Additionally, dissolved CO2 is in thermodynamic equilibrium with HCO3-, so it is required to have some grasp on HCO3- variability to correctly model dissolved CO2 dynamics, hence, CO2 emissions to the atmosphere.

SPECIFIC COMMENTS

L 24 : It’s the increase of air temperature rather than “climate change” in general.

L44 : In this section it’s unclear what is meant by “increase” of “net primary productivity” and “storage in tree biomass”. A recent study shows that African forests are sinks of carbon on yearly basis, and that the carbon sink is constant in time from the mid-1990’s to present (Hubau et al. 2020). So, according to this study, there is no “increase” in NPP as stated but a constant sink. Please clarify.

L74 : The tropical region is also a hotspot of aquatic C cycling due to wetland produc-

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tivity and wetland carbon inputs to rivers (Abril & Borges 2019), in addition to “terrestrial NPP”. In the Amazon river a large fraction of fluvial CO2 emissions to the atmosphere are sustained by wetland inputs (Abril et al. 2014).

L74: The fact that the “tropical region is a hotspot area for inland water C cycling” (as stated) was authoritatively demonstrated by seminal papers such as Richey et al. (2002) and Melack et al. (2004), more than a decade before the recent Lauerwald et al. (2015) work.

L 78-80: there are (at least) two additional elements of context that could be relevant for the introduction:

1) the Raymond et al. (2013) and the Lauerwald et al. (2015) estimates are in fact based on the same initial data-base of pCO2 computed from pH and alkalinity (GLORICH) that was extrapolated globally using two different approaches; this illustrates how uncertain these global estimates are, since the resulting values differ by a factor of 3;

2) While the conclusion of Lauerwald et al. (2015) that the majority of CO2 emissions from rivers comes from the tropics is probably correct, field data (used in the global extrapolation) is nearly absent in the tropics. For instance for the Congo River there is only one single data entry in the GLORICH data-set. Most of the data used to develop the statistical model of Lauerwald et al. (2015) come from non-tropical areas such as North America and Scandinavia.

L 244: Borges et al. (2019) report discharge data from the mainstem Congo at Kisangani. So there are additional data-sets to validate the model hydrology.

L513: It could be useful to put into context how these different fluxes were computed. The Raymond et al. (2013) estimate is based on a single pCO2 value (apparently from pH and alkalinity measurements in Pool Malebo) that was extrapolated to the whole basin. The comparison of this single value of pCO2 with the extensive data set reported by Borges et al. (2019) shows that it is unrealistically low (refer to Supplemental Figure 18). Lauerwald et al. (2015) et al. estimate of pCO2 compares better to the Borges et al. (2019) data-set but still fails to represent the influence of the Cuvette Centrale (refer to Supplemental Figure 18). Please also note that the CO2 estimate for the Congo reported by Borges et al. (2015) was based on exactly the same stream surface area and gas transfer velocity as those used by Raymond et al. (2013), and also showed that the Raymond et al. (2013) estimate was under-estimated (obviously, since the pCO2 value is unrealistically low). So there is some clear convergence that the present estimate of CO2 emission based on ORCHILEAK is under-estimated even if it is coincidentally close to the one reported by Raymond et al. (2013). The actual reasons of the under-estimation need to be explored as suggested in the above Major Comments.

In the discussion of the long-term changes of DOC export, it could useful to mention that there was no measurable difference in DOC flux from the Oubangui (largest tributary of the Congo) between the 1990's (Coynel et al. 2005) and the 2010's as reported and discussed by Bouillon et al. (2012; 2014).

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