Earth System Dynamics Discussions

Earth Syst. Dynam. Discuss., author comment AC1
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Brief clarifications re: RC1

Lizz Ultee et al.

Author comment on "Glacial runoff buffers droughts through the 21st century" by Lizz Ultee et al., Earth Syst. Dynam. Discuss., https://doi.org/10.5194/esd-2021-94-AC1, 2022

We thank the reviewer for their consideration of our manuscript. The reviewer raises interesting points, which we intend to address in a revised version of the manuscript at the close of the discussion period. At this time we would like to clarify two of the reviewer's list of four major concerns.

Literature review

The reviewer suggests that we ought to cite more relevant papers, especially references from 2021. At present, the manuscript includes 71 references, spanning the 1960s to the 2020s, with many published within the last 5 years. We believe this literature review is sufficiently comprehensive. If the reviewer has specific relevant 2021 publications in mind, we would of course be happy to include them.

Carbon emissions from retreating glaciers

The reviewer writes, "a big problem of this manuscript is that it does not take into account the CO2 emissions during the processes of melting glaciers. If just considering melting glaciers as the water source of runoff but ignoring the fact that it is also the emission source of greenhouse gas, the whole conclusion will be embellished."

The reviewer is correct that our manuscript does not account for a direct glacial effect on the global carbon cycle. Would the reviewer be able to direct us to a quantitative estimate of the greenhouse gas emissions potential of mountain glaciers?

Without a more specific reference, we are tempted to conclude that this is not a relevant consideration for our manuscript, on the following grounds:

- A 2015 paper by Hood et al suggests that 9.68 Tg (0.00968 Pg) dissolved organic carbon will be “liberated from glacier storage” in mountain glaciers by 2050. A further 78 Tg total particulate organic carbon, with uncertain bioavailability and therefore a less well defined pathway to entering the atmosphere, could be released from all glacial systems. Note that this estimate of POC includes both ice sheets, which according to Hood et al account for 96% of the global POC store. So, a generous estimate, assuming that most glacial-derived DOC and POC come from mountain glaciers and are transformed directly into greenhouse gases, would be that glacial runoff is a net source of 87.7 Tg carbon to the atmosphere over the 35 years 2015-2050. Assuming constant flux over time yields an annual flux of 2.5 TgC. By comparison, the estimated annual net flux of carbon to the atmosphere from land use change during the 20th century was 2.0 Pg, or 2000 Tg (Houghton, 1999). That is, the estimated flux of carbon that could be liberated from glaciers is less than 1% the annual estimated flux of carbon from land use change alone during the last century.

- A 2019 paper by Wadham et al, focusing on the role of ice sheets in the global carbon cycle, notes that DOC and POC fluxes from ice sheets are less than 1% the global land-ocean fluxes of the same. They further note that the microbial conversion of glacially derived DOC and POC to greenhouse gases is poorly constrained and subject to substantial uncertainties. A "conservative estimate" of methane flux from ice sheet runoff is stated as <1 Tg C per year. Once again, this flux is small compared with other global sources of carbon to the atmosphere.
- The carbon budget produced by the World Meteorological Organization (https://public.wmo.int/en/resources/bulletin/annual-global-carbon-budget) estimates growth in atmospheric carbon of 6.2 GtC. Note that 1 Gt = 1 Pg = 1000 Tg. A generous assumption of 2.5 TgC directly from glaciers to the atmosphere (as above) would comprise 0.04% of the annual growth in atmospheric carbon concentration. Thus, it is unlikely that explicitly accounting for greenhouse gas emissions from glaciers themselves would have a first-order effect on 21st century climate and resulting glacial drought buffering.

We are aware of a 2021 paper by Fell et al., "Fungal decomposition of river organic matter accelerated by decreasing glacier cover", the popular press coverage of which suggested that deglaciation could "speed up carbon emissions". However, the article focuses on fungal carbon cycling and does not provide a quantitative estimate of greenhouse gas emissions potential from mountain glaciers—nor a comparison with other global sources of carbon. The conclusions of that article are therefore insufficient to suggest that glacially-derived greenhouse gas emissions will affect the results presented in our manuscript.

References in this comment:

- Hood et al (2015). Storage and release of organic carbon from glaciers and ice sheets. Nature Geoscience 8: 91-96. https://www.nature.com/articles/ngeo2331
- Houghton (1999). The annual net flux of carbon to the atmosphere from changes in land use 1850-1990. Tellus B: Chemical and Physical Meteorology, 51(2): 298-313. https://www.tandfonline.com/doi/pdf/10.3402/tellusb.v51i2.16288
- Candela and Carlson (2017). The annual global carbon budget. Bulletin of the World Meteorological Organization 66:1. https://public.wmo.int/en/resources/bulletin/annual-global-carbon-budget
- Wadham et al (2019). Ice sheets matter for the global carbon cycle. Nature Communications 10: 3567. https://www.nature.com/articles/s41467-019-11394-4
- Fell et al (2021). Fungal decomposition of river organic matter accelerated by decreasing glacier cover. Nature Climate Change 11:349-353. https://www.nature.com/articles/s41558-021-01004-x