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Effects of carbon exchange uncertainties in estimating peatland radiative forcing over the Holocene

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Peatlands contain approximately a third of all soil carbon globally and as they exchange carbon dioxide (CO_2) and methane (CH_4) copiously with the atmosphere, changes in peatland carbon budgets have a large impact on the global carbon balance and the concentration of greenhouse gasses in the atmosphere. There has been a growing interest in reconstructing and linking peatland carbon dynamics to past climate variations, because quantitative reconstructions can be used as a basis for future carbon balance predictions. These quantitative reconstructions of peatland carbon dynamics also enable us to reconstruct the impact on the climate by individual or assembled peatlands, in terms of radiative forcing, due to the effect of peatlands on atmospheric concentration of CO_2 and CH_4. Reconstructions of radiative forcing during peatland development show that at first the climate warming effect of CH_4 emissions exceeds the cooling effect of CO_2 uptake, but after a period that can last several millennia the overall effect of most peatlands will move towards having a cooling effect the atmosphere, in which case an overall positive radiative forcing switches to negative. However, reconstructing peatland carbon dynamics deals with uncertainties related to carbon uptake and release, CH_4 emission rates, and peatland expansion rates. We investigated the effect of these uncertainties on radiative forcing of three Finnish peatlands with reconstructed carbon dynamics. Taking into account temporarily stored carbon, due to it being decomposed and lost from the peatland before sampling took place, increases the reconstructed cooling effect of CO_2 uptake. This effect is largest further in the past, and the difference in current radiative forcing is minimal. Accounting for previously decomposed carbon can shorten the period of positive radiative forcing before switching to negative with up to 4000 years. Including fire effects on carbon storage has only small additional effect lasting shorter than 1000 years. The largest uncertainty in reconstructing peat carbon dynamics lies with CH_4 emissions, therefore the uncertainties in radiative forcing due to changes in atmospheric CH_4 concentrations are several magnitudes larger than the uncertainties due to CO_2 uptake. Variability in peat expansion rate controls at what time both CO_2 uptake and CH_4 emissions increased due to larger peat surface. Advanced peat expansion causes the peak radiative forcing to be reached earlier in the peatland development, because CH_4 emissions are more directly controlled by peat surface area. The decrease in radiative forcing also occurs sooner, resulting in an advanced switch-over from positive to negative radiative forcing. The uncertainties of present day climate forcing due to long term peatland carbon exchange can be ranked as uncertainties in CH_4 emission > timing of peat expansion > temporary carbon storage.