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Errors in modelling carbon turnover induced by temporal temperature aggregation

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The response of soil carbon decomposition to climate change is of great importance because terrestrial soils act as the largest carbon sink worldwide. This large carbon pool interacts strongly with the atmosphere and vegetation, and even small relative changes in organic storage in the soil could constitute a significant feedback effect on greenhouse gases in the atmosphere. CO_2 modelling approaches seem to be a powerful tool to describe the influence of changes in soil temperature and soil water content on carbon decomposition.

It is well established that soil temperature is the most important factor driving the decomposition of soil carbon. Most of the relationships between soil temperature and total respiration were derived from physicochemical principles, such as the Arrhenius or from field and laboratory experiments, The various temperature functions show similar trends: a nonlinear positive direct relationship between temperature and respiration irrespective of the time scale used for their development. Most modeling studies use monthly averaged input data, especially when they are focused on the analysis of long-term experiments and the impact of climate change on soil organic carbon (SOC) stocks. To improve the understanding of short-term changes in soil CO_2 efflux, various authors compared instantaneous CO_2 efflux data with results from numerical models.

It is well established that the propagation of a mean temperature through a non-linear function will not provide the same results as when the original data underlying such a mean value are propagated through the same non-linear function before calculating the mean. Therefore, long-term models using monthly temperature data will provide different results when daily temperature data are used. Similarly, short-term modeling using hourly instead of daily input data will provide different results when there is considerable variation in hourly temperature. Unfortunately, the implications of choosing a particular temperature input data resolution for predicting soil CO_2 efflux or soil carbon loss have not been quantified yet. Therefore, the aim of this study is to analyze the effect of different temporal resolution of temperature input data on predicted CO_2 efflux and carbon stocks.

Additionally, we evaluate whether existing scaling techniques to derive hourly temperature data from mean daily temperature and amplitude can be used to overcome the decrease in accuracy associated with using daily temperature input data only.

The results indicate that averaging from hourly to daily or monthly temperatures will lead to relative errors larger than 4 % per year for cumulative CO_2 efflux, which is similar to the measurement error for carbon stocks or chamber measurements. Instantaneous CO_2 fluxes are even more affected by temperature averaging. Daily and monthly averaging will lead to estimation errors exceeding 20% and 25.8%, respectively. Deviations in predicted instantaneous CO_2 efflux using aggregated and reference temperature time series were larger than 10% for 23% and 55% of the time for daily and monthly averaging, respectively. It is also shown that a constant or daily variable temperature amplitude for rescaling daily average temperature did not decrease the error in the predicted CO_2 fluxes when using daily or monthly mean temperature instead of hourly data. Therefore, instantaneous fluxes are only accurately predicted when hourly temperature input is used.