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Modelling respiration pulses at rewetting as a stochastic process

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Respiration pulses at rewetting are prominent features of soil responses to soil moisture fluctuations. These pulses are much larger compared to respiration rates under constant soil moisture, pointing to variations in water availability as drivers of the enhanced CO_2 production. Moreover, the respiration pulses tend to be larger when soil moisture before rewetting is lower. Thus, both the pre-rainfall soil moisture and the variation in soil moisture control the size of the respiration pulse. While these patterns are known from empirical studies, models have struggled to capture the relations between rainfall statistical properties (frequency of occurrence and rain event depths) and the occurrence and size of respiration pulses, framing the scope of this contribution. Specifically, we ask – how are the statistical properties of respiration pulses related to rainfall statistics?

Because rainfall can be regarded as a stochastic process generating variations in soil moisture, also respiration pulses at rewetting can be modelled through a probabilistic model. Here we develop such a model based on the premises that rainfall can be described as a marked Poisson process, and that respiration pulses increase with increasing variations of soil moisture (i.e., larger pulses after larger rain events) and decreasing pre-rain soil moisture (i.e., larger pulses after a long dry period). This model provides analytical relations between the statistical properties of soil respiration (e.g., long-term mean and standard deviation) and those of rainfall, allowing to study in a probabilistic framework how respiration varies along existing climatic gradients or in response to climatic changes that affect rainfall statistics.

Results show that the long-term mean CO_2 production during respiration pulses increases with increasing frequency and depth of rainfall events. However, the relative contribution of respiration pulses to the total microbial respiration decreases with rainfall frequency and depth. Similarly, also the variability of the size of respiration pulses, as measured by their standard deviation, decreases with increasing rainfall frequency and depth. As a consequence, climatic changes exacerbating rainfall intermittency – longer dry periods and more intense rain events – are predicted to increase both the relative contribution of respiration pulses to total microbial respiration and the variability of the pulse sizes.