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Photosynthesis modulates soil respiration at multiple timescales in a semiarid shrub ecosystem

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There is still considerable uncertainty regarding the role of biophysical factors in controlling soil biogeochemical processes over multiple timescales in terrestrial ecosystems. Especially, the importance of plant photosynthesis in driving soil respiration (Rs) in dryland ecosystems remains largely unclear, although infertile soils therein accentuate the contribution of root and rhizospheric respiration. We applied wavelet analysis and nonparametric spectral Granger-causality to a multi-year (3 June 2012–12 November 2015) dataset with the objective of examining how gross ecosystem productivity (GEP), photosynthetically active radiation (PAR), soil temperature (Ts) and water content (SWC) modulate Rs across timescales in a semiarid shrub ecosystem. We found that these factors played different roles across the time-frequency domain. Wavelet coherence analysis revealed synchronized diel cycles of photosynthesis proxies (GEP and PAR) and Rs, and the spectral Granger-causality method confirmed a causal link between GEP and Rs at the diel scale during growing seasons. Ts took over photosynthesis to drive the variations in Rs over short timescales (1–16-day periods) during non-growing seasons. Significant wavelet coherence was also observed between GEP and Rs at seasonal to annual scales through the study period, with GEP preceding Rs by about two days. Fluctuations in SWC, as induced by rain pulses, showed non-continuous temporal covariance with Rs at periods between 4- and 64-days. Apart from direct moisture effects on decomposition processes, soil water availability also seemed to regulate Rs indirectly through affecting canopy carbon assimilation. Our results underscore a tight coupling between photosynthesis and Rs at multiple timescales in semiarid shrub ecosystems. Ecosystem carbon models should explicitly incorporate photosynthetic carbon supply as a driver of respiratory processes. In addition, spectral analysis provides a powerful tool for scale-by-scale decomposition of biophysical controls on carbon fluxes, and thus could help improve the prediction of carbon dynamics across different timescales.