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CLM4-BeTR, a generic biogeochemical transport and reaction module for CLM4: model development, evaluation, and application

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Abstract. To improve regional and global biogeochemistry modeling and climate predictability, we have developed a generic reactive transport module for the land model CLM4 (called CLM4-BeTR (Biogeochemical Transport and Reactions)). CLM4-BeTR represents the transport, interactions, and biotic and abiotic transformations of an arbitrary number of tracers (aka chemical species) in an arbitrary number of phases (e.g., dissolved, gaseous, sorbed, aggregate). An operator splitting approach was employed and consistent boundary conditions were derived for each modeled sub-process. Aqueous tracer fluxes, associated with hydrological processes such as surface run-on and run-off, belowground drainage, and ice to liquid conversion were also computed consistently with the bulk water fluxes calculated by the soil physics module in CLM4. The transport code was evaluated and found in good agreement with several analytical test cases using a time step of 30 min. The model was then applied at the Harvard Forest site with a representation of depth-dependent belowground biogeochemistry. The results indicated that, at this site, (1) CLM4-BeTR was able to simulate soil–surface CO_2 effluxes and soil CO_2 profiles accurately; (2) the transient surface CO_2 effluxes calculated based on the tracer transport mechanism were in general not equal to the belowground CO_2 production rates with the magnitude of the difference being a function of averaging timescale and site conditions: differences were large (−20 ~ 20%) on hourly, smaller (−5 ~ 5%) at daily timescales, and persisted to the monthly timescales with a smaller magnitude (<4%); (3) losses of CO_2 through processes other than surface gas efflux were less than 1% of the overall soil respiration; and (4) the contributions of root respiration and heterotrophic respiration have distinct temporal signals in surface CO_2 effluxes and soil CO_2 concentrations. The development of CLM4-BeTR will allow detailed comparisons between ecosystem observations and predictions and insights to the modeling of terrestrial biogeochemistry.

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