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**Representation of the Terrestrial Carbon Cycle in  
CMIP6**

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**Abstract**

The carbon cycle in Earth System Models (ESMs) has been an area of focus for model development going into the Coupled Model Intercomparison Project Phase 6 (CMIP6), to improve on shortcomings identified in the previous phase CMIP5. These improvements include interactive treatment of both the carbon and nitrogen cycles, improved photosynthesis, and soil hydrology. To assess the impact of these model developments on aspects of the global carbon cycle, the Earth System Model Evaluation Tool (ESMValTool) is expanded to compare reference data and historical simulations from CMIP5 and CMIP6 using either prescribed CO<sub>2</sub> concentrations or CO<sub>2</sub> emissions. A particular focus is on the differences in models with and without an interactive terrestrial nitrogen cycle coupled to the carbon cycle. Overestimations of photosynthesis found in CMIP5 were largely resolved in CMIP6 for participating models with an interactive nitrogen cycle, but remain for models without one. Thus, the inclusion of nitrogen limitation led to a large improvement in photosynthesis compared to models not including this process, suggesting the need to view the nitrogen cycle as a necessary part of all future carbon cycle models. Furthermore, simulations using prescribed CO<sub>2</sub> emissions perform just as well as those using prescribed CO<sub>2</sub> concentrations despite the added process-realism. Due to this it is recommended for ESMs in future CMIP phases to perform emission driven simulations as the standard to facilitate fully active climate-carbon cycle feedbacks.