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Constraining uncertainty in projected gross primary production with machine learning

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By absorbing about one quarter of the total anthropogenic CO_2 emissions, the terrestrial biosphere is an important carbon sink of Earth's carbon cycle. A key metric of this process is the terrestrial gross primary production (GPP), which describes the biogeochemical production of energy by photosynthesis. Elevated atmospheric CO_2 concentrations will increase GPP in the future (CO_2 fertilization effect). However, projections from different Earth system models participating in the Coupled Model Intercomparison Project Phase 5 (CMIP5) show a large spread in carbon cycle related quantities. In this study, we present a new supervised machine learning approach to constrain multi-model climate projections using observation-driven data. Our method based on Gradient Boosted Regression Trees handles multiple predictor variables of the present-day climate and accounts for non-linear dependencies. Applied to GPP in the representative concentration pathway RCP 8.5 at the end of the 21st century (2081–2100), the new approach reduces the "likely" range (as defined by the Intergovernmental Panel on Climate Change) of the CMIP5 multi-model projection of GPP to 161–203 GtC yr^{-1}. Compared to the unweighted multi-model mean (148–224 GtC yr^{-1}), this is an uncertainty reduction of 45%. Our new method is not limited to projections of the future carbon cycle, but can be applied to any target variable where suitable gridded data is available.