Reducing Uncertainty in the Global Carbon Cycle from Land Use Application of Earth System Model Initialization

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NOAA's Geophysical Fluid Dynamics Laboratory (GFDL) has developed two new Earth System Models (ESMs) to better understand the interactions and feedbacks between biogeochemical cycles and the climate system. ESM2M and ESM2G, recent contributors to the Coupled Model Intercomparison Project Phase 5 (CMIP5) database, are based on GFDL's coupled Climate Model version 2.1 (CM2.1) and successfully simulate the global climate and carbon cycle. The land component, LM3, has been designed to simulate the effects of land use on terrestrial carbon pools, including secondary vegetation regrowth following land use disturbances which has been shown to be an important terrestrial carbon sink. Because of the long time scales associated with the carbon adjustment of imposing land use when simulating secondary vegetation regrowth, special consideration is required when initializing the GFDL ESMs for historical CMIP5 simulations. We explore the uncertainty in the terrestrial carbon stores and fluxes associated with land use application using the uncoupled, land-only model by instantaneously applying estimates of historical land use in five experiments beginning in calendar years 1500, 1600, 1700, 1750, and 1800. The application of land use results in the land carbon pools experiencing an abrupt change – a carbon shock – and the secondary vegetation needs time to regrow into consistency with the harvesting history. Our analysis shows that it takes approximately 100 years for the vegetation to recover from this carbon shock, whereas soils take longer to recover, at least 150 years. The vegetation carbon response is driven primarily by land-use history, while the soil carbon response is affected by both land-use history and the geographic pattern of soil respiration rates. Around the start of the historical CMIP5 simulations in 1850, we computed the simulated net land carbon sources to be 0.418 GtC yr-1, 0.412 GtC yr-1, 0.427 GtC yr-1, 0.390 GtC yr-1 and 0.166 GtC yr-1, when land use was applied in 1500, 1600, 1700, 1750 and 1800, respectively. These fluxes were compared to the most recent estimate of 0.501 GtC yr-1 in 1850, and show the importance of land use on the historical carbon fluxes. Based on these results, we recommend the application of historical land-use scenarios in 1700 to provide sufficient time for the land carbon in ESMs with secondary vegetation to equilibrate to adequately simulate carbon stores at the start of the CMIP5 historical integrations. Additional results exploring the effect of land use on the global carbon cycle in the recent GFDL ESM CMIP5 simulations will also be presented.