Geophysical Research Abstracts
Vol. 18, EGU2016-54, 2016
EGU General Assembly 2016

Evaluating the need for integrated land use and land cover analysis for robust assessment of climate adaptation and mitigation strategies

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Several climate adaptation and mitigation strategies incorporate land use and land cover change to address global carbon balance and also food, fuel, fiber, and water resource sustainability. However, Land Use and Land Cover Change (LULCC) are not consistent across the CMIP5 model simulations because only the land use input was harmonized. Differences in LULCC impede understanding of global change because such differences can dramatically alter land-atmosphere mass and energy exchange in response to differences in associated use and distribution of land resources. For example, the Community Earth System Model (CESM) overestimates 2005 atmospheric CO_2 concentration by 18 ppmv, and we explore the contribution of historical LULCC to this bias in relation to the effects of CO_2 fertilization and nitrogen deposition on terrestrial carbon. Using identical land use input, a chronologically referenced LULCC that accounts for pasture, as opposed to the default year-2000 referenced LULCC, increases this bias to 27 ppmv because more forest needs to be cleared for land use. Assuming maximum forest retention for all land conversion reduces the new bias to $\sim$21 ppmv, while minimum forest retention increases the new bias to $\sim$32 ppmv. Corresponding ecosystem carbon changes from the default in 2005 are approximately -28 PgC, -10 PgC, and -43 PgC, respectively. This 33 PgC uncertainty range due to maximizing versus minimizing forest area is 66% of the estimated 50 PgC gain in ecosystem carbon due to CO_2 fertilization from 1850-2005, and 150% of the estimated 22 PgC gain due to nitrogen deposition. This range is also similar to the 28 PgC difference generated by changing the LULCC reference year and accounting for pasture. These results indicate that LULCC uncertainty is not only a major driver of bias in simulated atmospheric CO_2, but that it could contribute even more to this bias than uncertainty in CO_2 fertilization or nitrogen deposition. This highlights the need for more accurate LULCC scenarios in earth system simulations to provide robust historical and future projections of carbon and climate, especially when incorporating climate feedbacks on human and environmental systems. More accurate LULCC scenarios will also improve impact and resource sustainability analyses in the context of climate adaptation and mitigation strategies. These new scenarios will need to be developed and implemented as an integrated process with interdependent land use and land cover to adequately incorporate human and environmental drivers of LULCC.