Geophysical Research Abstracts
Vol. 19, EGU2017-10707, 2017
EGU General Assembly 2017

Land cover uncertainty generates substantial uncertainty in earth system model carbon and climate projections

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Several climate adaptation and mitigation strategies incorporate Land Use and Land Cover Change (LULCC) to address global carbon balance and climate. However, LULCC is not consistent across the CMIP5 model simulations because only the land use input is harmonized. The associated LULCC uncertainty generates uncertainty in regional and global carbon and climate dynamics that obfuscates the evaluation of whether such strategies are effective in meeting their goals. For example, the integrated Earth System Model (iESM) overestimates 2004 atmospheric CO_2 concentration by 14 ppmv, and we explore the contribution of historical LULCC uncertainty to this bias in relation to the effects of CO_2 fertilization, climate change, 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 20 ppmv because more forest needs to be cleared for land use. Assuming maximum forest retention for all land conversion reduces the new bias to 19 ppmv, while minimum forest retention increases the new bias to 24 ppmv. There is a 33 Pg land carbon uncertainty range due to maximizing versus minimizing forest area, which is 80% of the estimated 41 PgC gain in land carbon due to CO_2 fertilization combined with climate change from 1850-2004 and 150% of the estimated 22 PgC gain due to nitrogen deposition. These results demonstrate that LULCC accuracy and uncertainty are critical for estimating the carbon cycle, and also that LULCC may be an important lever for constraining global carbon estimates. Furthermore, different land conversion assumptions can generate local differences of over 1.0 °C between the two forest retention cases with less than 5% difference in tree cover within a grid cell. Whether these temperature differences are positive or negative depends more on region than on latitude. Sensible heat appears to be more sensitive than latent heat to difference in forest cover, and the relationship between differences in latent and sensible heat may help explain the regional dependence of the sign of temperature difference. This work highlights the need for more accurate LULCC scenarios with quantified uncertainty in earth system simulations in order to provide robust historical and future projections of carbon and climate.