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Quantifying the response of climate to changes in land cover : can we separate direct effects from feedbacks in earth system models' outputs?

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Regional and global climate responses to biophysical effects of land use and land cover changes (LULCC) still largely differ among the models used in the LUCID intercomparison project, despite some constrained protocol (Boisier et al. 2012). de Noblet-Ducoudré et al. (2012) have shown that ∼1/3rd of the differences can be attributed to the lack of consistent implementation of land uses in earth system models (ESM), while the remaining 2/3rd result from differences between land-surface models as well as from the climate feedbacks simulated in each ESM. However, to our knowledge, no study has yet tried to i) disentangle direct effects from feedbacks, and ii) see whether regional sensitivity can be assessed rather than the more traditional global one.

In this study we focus on the spatially distributed biophysical effects of LULCC. The important contributors to spatially distributed effects are inhomogeneous changes in direct effects (albedo, evapotranspiration efficiency, surface roughness), and their atmospheric feedbacks. Among those feedbacks one can cite changes in air humidity, air temperature, cloud cover, water vapor and planetary boundary layer height. Direct effects from feedbacks are separated by solving the surface energy budget equation. We have first applied this method to quantify regional and global land surface temperature changes in IPSL-CM5 and NCAR CAM5.0 ESMs that have simulated the effects of idealized global deforestation. In IPSL-CM5, direct effects over land south of latitude 20°N are stronger (warming of 2.26 K in JJA and 1.28 K in DJF) when compared to CAM5.0 (cooling of 0.05 K in JJA and 0.06 K in DJF). In contrast, feedbacks over land north of latitude 20°N are stronger in CAM5.0 (cooling of 4.4 K in JJA and 3.9 K in DJF) when compared to IPSL-CM5 (cooling of 1.9 K in JJA and 3.0 K in DJF). However, on average over global land in both the models we find that direct effects (eg. JJA: 0.55 K in IPSL-CM5 and -0.8 K in CAM5.0) are weaker when compared to feedbacks (eg. JJA: -1.7 K in IPSL-CM5 and -2.85 K in CAM5.0). The largest contributor to feedbacks is air temperature when compared to down-welling long-wave and short-wave radiation. Air temperature change is due to large changes in planetary boundary layer height over the deforested regions through sensible heat and turbulence alterations. In CAM5.0 simulation, we also estimate time scales of direct effects (evolution persists up to 5 years) and feedbacks effects (evolution persists up to10 years). This result suggests that the feedbacks which are relatively slow are stronger than immediate direct effects, though they are consequences of direct effects after deforestation. Our result has important implications for assessing the benefits of climate change mitigation strategies for afforestation/reforestation.