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Addressing sources of uncertainty in the biospheric feedback to climate change simulated by a coupled model

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Land surface models constitute one of the main components of Earth system models. They usually simulate exchanges of energy, water and carbon between continents and the atmosphere. Major carbon (C) fluxes, such as primary production, plant and soil respiration, have been clearly identified and are assumed to have maintained storage of terrestrial carbon at the equilibrium under pre-industrial conditions. In spite of this the representation of soil heterotrophic respiration, the flux of CO_2 from the soil to the atmosphere, is very uncertain in global models that smooth landscapes in several degrees of resolution grid cells. Similarly, the complexity of the interactions between the global C, nitrogen (N) and phosphorus (P) cycles is often omitted by not considering nutrients in the modelling system.

Although these sources of uncertainty have been addressed separately in models of various complexity, it has never been done simultaneously in a coupled environment. To do so, we selected 3 functions describing the control of soil moisture on respiration and 3 functions describing the control of soil temperature on respiration in the literature. We implemented all of them in the coupled Mk3L-CABLE-CASACNP coarse resolution modelling system. The CASACNP terrestrial biogeochemical model simulates the exchanges of carbon between plants, litter, soil and atmosphere with three modes of nutrient limitations (i.e. C-only, C with N, C with N and P). Hence, we obtained 27 unique combinations of moisture control, temperature control and nutrient control on the C cycle. All of them were used in our experiments.

First, we spun up all model versions with pre-industrial CO_2 level forcing until a quasi steady-state was reached. Second, we conducted transient runs by increasing atmospheric CO_2 corresponding to CMIP5 data (1850-2005). Finally, atmospheric CO_2 projections from two RCP scenarios (4.5 and 8.5) were used to further drive the model over the time period ranging from 2006 to 2100.

Historical simulations all predict the land surface to be a net sink of increasing magnitude in response to rising atmospheric CO_2 concentrations. Nevertheless, simulations clearly show that considering NP limitations on the C cycle narrows the variability in the global soil and terrestrial C balance. In spite of this increased global stability of C dynamics, NP limitations lead some regions to keep more potential to offset their emissions as compared to others. However, rising temperatures drastically enhance heterotrophic respiration in both scenarios and all model versions predict the land surface to switch to a net carbon source by the end of the 21st century under the warmest RCP 8.5 scenario.