The interaction of land processes in determining the high latitude carbon balance

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Over large parts of the high latitude region the overall carbon balance is determined by the competition between carbon uptake by vegetation and emissions due to plant & soil respiration and disturbance. The influence of vegetation is seen clearly in satellite measurements of atmospheric CO2 column concentrations, which show a distinct minimum over Siberia during the growing season. In steady state (in a time-averaged sense) uptake and emissions would be equal and the region would be carbon neutral, but the Arctic is predicted to warm faster than any other part of the planet over the next century. Many coupled and feedback processes affect the high latitude carbon cycle, which is also intimately linked to the water cycle through controls by vegetation on evapotranspiration. Understanding this interplay of processes and predicting how they will develop in a warming climate requires reliable Dynamic Vegetation Models, but the existing coupled climate-carbon cycle models exhibit highly diverse behaviour, and at global level they do not agree even on the sign of the net carbon flux between the land and atmosphere at the end of the current century. Clearly the models need to be tested against data, including in situ and satellite measurements and net flux estimates derived by atmospheric inversion. Over central Siberia, model calculations agree with in situ measurements of Net Primary Production, but exhibit much greater soil respiration than is found in situ. In contrast, models produce much lower emissions due to disturbance. As a result, both the Sheffield Dynamic Vegetation Model and in situ data roughly agree on the magnitude of the net flux, producing similar values similar to those found by atmospheric inversion, with Siberia being a net sink (note that the LPJ model predicts that the region is carbon-neutral). However, this agreement in net flux hides significant disagreements about contributing processes. On balance, it seems likely that the model estimates of both soil respiration and disturbance are in error. To test the latter, satellite observations of fire (based on the Global Fire Emissions Database) are compared with model estimates from SDGVM, LPJ and the NCAR CLM4 models. All the models give burnt area estimates that involve burning a small proportion of every grid-cell every year, but this bears little resemblance to what actually occurs, where the burned areas exhibit sharp variations in time and space. Modifying the models to give spatio-temporal statistics more in accord with observation reveals that these stochastic variations can significantly affect permafrost dynamics by drastically altering heat conduction and radiation warming of the soil. Such effects are not included in the current generation of land surface models.