Geophysical Research Abstracts
Vol. 16, EGU2014-12464, 2014
EGU General Assembly 2014

Optimising the prognostic leaf phenology of a land surface model at a global scale: perspectives and challenges

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Leaf phenology is a critical component of the coupled soil-vegetation-atmosphere system as it directly controls the spatial and temporal variability of the surface carbon, water and energy fluxes. The length of the growing season governs the net amount of carbon that is assimilated and released through photosynthesis and autotrophic respiration, as well as affecting the surface energy balance and hydrology through changing albedo, surface roughness and evapotranspiration, which in turn regulate the land surface temperature and moisture conditions. These provide a strong constraint on atmospheric boundary layer conditions and circulation, with possible important long-term impacts on the climate. A recent study (Richardson et al., 2012) showed that there is bias in the growing season length (GSL) predicted by many Land Surface Models (LSMs) when compared to observations. However, prior to parameter optimisation it is unclear whether the model-data misfit is the result of inaccurate parameter values or model structural error.

Here satellite-derived NDVI data are used to constrain the phenology parameters in the ORCHIDEE LSM. A 4D–variational multi-site data assimilation system is used to optimise parameters that directly control the leaf phenology models of all natural deciduous PFTs in ORCHIDEE. The resultant parameter vectors are validated both temporally and spatially, both at site and global scales. The ability of the satellite data to improve the seasonal C fluxes is evaluated with in situ net CO_2 fluxes and atmospheric CO_2 data, and the improvement in the inter-annual variability of the GSL is discussed. The impact of the optimisations on the coupled water and energy budgets is also examined. Technical issues are also addressed, including the ability of the multi-site DA system to retrieve PFT-generic parameter vectors at a global scale, the difficulty of finding a unique parameter vector, especially for parameters involved in threshold responses, and the issue of which scale is most appropriate for global scale model simulations.

For the boreal and temperate deciduous forests, the optimisations generally result in a decrease in GSL, with corresponding reduction in annual GPP and strong feedbacks on latent heat, albedo and soil moisture. The multi-site optimisation generally results in parameters that provide as good a reduction in the model-data misfit as for each individual site. Temporal and spatial validation demonstrates the generality of the retrieved parameter vectors for global scale simulations. For dry tropical/semi-arid PFTs however, the optimisation of the phenology-related parameters does not result in an improvement in the misfit between the observations and the model, suggesting that the current moisture threshold-based phenology models require improvement. For C3 grasses, the posterior parameter values show that in some regions the timing of leaf phenology is responding more to temperature or moisture but not to both. This possibly indicates that the phenology parameters should not be optimised at a PFT level, but rather at the regional, biome, or even species level.

The misfit between observations and posterior fluxes provides valuable insights into how the optimisation and modelling of phenology in LSMs can be improved. Preliminary investigations in this direction will be discussed.