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Impacts of future changes in phenology on land-atmosphere interactions in temperate and boreal regions

Jörg Kaduk (1) and Sietse Los (2)

(1) University of Leicester, Department of Geography, Leicester, United Kingdom (jk61@le.ac.uk), (2) Swansea University, School of the Environment and Society, Swansea, United Kingdom (s.o.los@swan.ac.uk)

Recent remote sensing data and ground observations have shown earlier leaf out in spring in the northern hemisphere, which is believed to result from climate warming. The advance of leaf out to earlier times could be limited, however, as controlled experiments show that temperate and boreal trees require chilling in winter for rapid leaf out in spring. If the amount of chilling falls below a species specific threshold then an exponentially increasing amount of warming is required to initiate leaf out – potentially actually delaying it in a future warmer climate. Implications of these chilling requirements for a delayed greening of vegetation at the biome level are not clear. One approach to estimate their importance is to generalize the exponential relationships between chilling and warming established for single species to whole biomes. Previous work suggests that this is indeed feasible but much of that work has been limited to specific biomes or the use of single or only a very few years of data for the modelling. We investigate if evidence for chilling requirements can be found at the biome level by fitting a range of phenology models to green-up dates determined using various methods from the FASIR normalized difference vegetation index (NDVI). We use 12 years of data to cross-validate the calibrated models, avoid overfitting and obtain reliable estimates of the model parameters as well as their prediction errors. The models predict that in northern middle and high latitudes the future advance of green-up to earlier times in the year will on average be limited to four to five days (but up to 15 days regionally) as estimated using temperature data from two contrasting climate change simulations (a A2 and a B1 scenario). This results from the exponentially increasing warming requirements for leaf out when winter chilling falls below a threshold as shown by a comparison with the predictions of models that consider only spring warming (spring warming models, SWM), which suggest an advance of more than six days average. The observed relationship between chilling and warming at the time of green-up indicates an element of regional adaptation of the warming required for leaf out in biomes covering large areas. The phenological models were implemented in the Joint UK Land Environment Simulator (JULES). In the model the advance in green up leads to a longer growing season with longer leaf display. In regions where soil moisture is mainly fed by spring rain and snow melt, however, there is only a limited increase of photosynthesis as it is determined by soil water availability. A longer summer dry period is resulting. Simulations including a Fire Weather Index indicate that the longer dry summers lead to an increase in the forest fire risk under future climate change in considerable areas. While this increase results partially from the changed climate, partially also the earlier leaf appearance contributes to the increased risk. Also there is a significant difference between simulations using only SWMs in contrast to employing also a chilling dependency. The results highlight the necessity of including appropriate phenology models in climate models for correct predictions of land-atmosphere interactions.