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Effects of short term and long term soil warming on ecosystem phenology of a sub-arctic grassland: an NDVI-based approach

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Phenology has been defined as the study of the timing of recurring biological events and the causes of their timing with regard to abiotic and biotic factors. Ecosystem phenology, including the onset of the growing season and its senescence in autumn, plays an important role in the carbon, water and energy exchange between biosphere and atmosphere at higher latitudes. Factors that influence ecosystem phenology can therefore induce important climate-controlling feedback mechanisms. Global surface temperatures have been predicted to increase in the coming decades. Hence, a better understanding of the effect of temperature on ecosystem phenology is essential. Natural geothermal soil temperature gradients in Iceland offer a unique opportunity to study the soil temperature (Ts) dependence of ecosystem phenology and distinguish short-term (transient) warming effects (in recently established Ts gradients) from long-term (permanent) effects (in centuries-old Ts gradients).

This research was performed in the framework of an international research project (ForHot; www.forhot.is). ForHot includes two natural grassland areas with gradients in Ts, dominated by Festuca sp., Agrostis sp.. The first warmed area was created in 2008, when an earthquake in S-Iceland caused geothermal systems to be shifted to previously cold soils. The second area is located about 3 km away from this newly warmed grassland. For this area, there are proofs that the natural soil warming has been continuous for at least 300 year.

In the present study we focus on Ts elevation gradients of +0 to +10°C. The experiment consists of five transects with five temperature levels (+0,+1,+3,+5 and +10°C) in the two aforementioned grassland ecosystems (n=25 in each grassland). From April until November 2013, weekly measurements of the normalized difference vegetation index (NDVI) were taken.

In the short-term warmed grassland, the greening of the vegetation was 36 days advanced at +10°C Ts and the date of 50% greening was advanced by 23 days at +5°C and by 32 days at +10°C Ts. However, no difference in the date of maximum greening or in the onset of senescence occurred. In contrast, in the long-term warmed grassland, the start of the growing season was not affected by Ts and the 50% greening point occurred only 10 days earlier at +5°C and 15 days earlier at +10°C Ts. However, the timing of maximum greening was advanced by 19 days at +5°C and even by 32 days at +10°C Ts. Again, the onset of senescence did not change with Ts.

Significant Ts effects on ecosystem phenology of subarctic grasslands only occurred at warming of 5°C or higher. This study also demonstrates that short-term Ts effects on ecosystem phenology are not necessarily good predictors for long-term changes in sub-arctic grasslands. In the short-term (5 years warming), soil warming induced an early onset of the growing season, which was later compensated by faster greening on colder soils, so that maximum greenness was reached simultaneously irrespective of Ts. In contrast, the long-term Ts warming did not induce earlier onset of the growing season, but it led to faster greening on warm soils, which again led to an advance in timing of maximum greenness. This difference between short- and long-term responses in phenology might be caused by either phenotypic plasticity (acclimation) or by a genetic selection (evolution) of the grass populations where the warming has been ongoing for centuries. Such processes are at present not included in modelling predictions of climate change responses of natural ecosystems, but may offer important negative feedback mechanisms to warming which will reduce its effects.