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Severity of climate change dictates the direction of biophysical feedbacks of vegetation change to Arctic climate

Wenxin Zhang (1), Christer Jansson (2), Paul Miller (1), Ben Smith (1), and Patrick Samuelsson (2)

(1) Lund University, Physical Geography and Ecosystem Science, Lund, Sweden (wenxin.zhang@nateko.lu.se), (2) Rossby Centre, Swedish Meteorological and Hydrological Institute, Norrköping, Sweden

Vegetation-climate feedbacks induced by vegetation dynamics under climate change alter biophysical properties of the land surface that regulate energy and water exchange with the atmosphere. Simulations with Earth System Models applied at global scale suggest that the current warming in the Arctic has been amplified, with large contributions from positive feedbacks, dominated by the effect of reduced surface albedo as an increased distribution, cover and taller stature of trees and shrubs mask underlying snow, darkening the surface. However, these models generally employ simplified representation of vegetation dynamics and structure and a coarse grid resolution, overlooking local or regional scale details determined by diverse vegetation composition and landscape heterogeneity.

In this study, we perform simulations using an advanced regional coupled vegetation-climate model (RCA-GUESS) applied at high resolution ($0.44\times0.44^{\circ}$) over the Arctic Coordinated Regional Climate Downscaling Experiment (CORDEX-Arctic) domain. The climate component (RCA4) is forced with lateral boundary conditions from EC-EARTH CMIP5 simulations for three representative concentration pathways (RCP 2.6, 4.5, 8.5). Vegetation-climate response is simulated by the individual-based dynamic vegetation model (LPJ-GUESS), accounting for phenology, physiology, demography and resource competition of individual-based vegetation, and feeding variations of leaf area index and vegetative cover fraction back to the climate component, thereby adjusting surface properties and surface energy fluxes. The simulated 2m air temperature, precipitation, vegetation distribution and carbon budget for the present period has been evaluated in another paper. The purpose of this study is to elucidate the spatial and temporal characteristics of the biophysical feedbacks arising from vegetation shifts in response to different CO_2 concentration pathways and their associated climate change. Our results indicate that the albedo feedback dominates simulated warming in spring in all three scenarios, while in summer, evapotranspiration feedback, governing the partitioning of the return energy flux from the surface to the atmosphere into latent and sensible heat, exerts evaporative cooling effects, the magnitude of which depends on the severity of climate change, in turn driven by the underlying GHG emissions pathway, resulting in shift in the sign of net biophysical at higher levels of warming. Spatially, western Siberia is identified as the most susceptible location, experiencing the potential to reverse biophysical feedbacks in all seasons. We further analyze how the pattern of vegetation shifts triggers different signs of net effects of biophysical feedbacks.