Author comment on "Simulating the effects of temperature and precipitation change on vegetation composition in Arctic tundra ecosystems" by H. van der Kolk et al.

Reply to comments by anonymous Referee #1

This paper is well written and logically structured. It presents a study with many potentially interesting insights on the High Arctic permafrost ecosystem dynamics (vegetation competition and succession) in response to future climate change, permafrost thawing, and lateral interaction in hydrology and thermokarst development. However, some major mechanisms behind the processes associated with the interaction between biotic and abiotic factors haven't been clearly demonstrated.

REPLY: We thank the referee for his/her constructive comments. We appreciate that the referee recognizes that the model has the potential to provide interesting insights in the response of tundra vegetation composition to climate change, gradual permafrost thawing and abrupt permafrost thaw (thermokarst). In our study the focus is on the vegetation modelling and we acknowledge that for the abiotic factors there is room for improvement in the model. In the next phase of model development we plan to couple the vegetation model to a methane emission/soil physics model (e.g. Mi et al. 2014).

I suggest the issues the paper should address in the following phase.

(1) Nutrient availability and mobility. The N availability is determined by the rate of minimization and fixation of N in response to the extent of climate changes. Their net effects determine the nutrient constraint for different vegetation species. In addition, snow is another important aspect to influence the subsurface temperature and then the N cycling. The N mobility can be reflected by how dry ecosystems interacts wet ecosystems through water movement. These two issues have not been well investigated in the current modelling work, but they are fundamental in understanding how growth of plant function types are influenced by environmental changes.

REPLY: In general, growth of tundra plants is assumed to be limited by nitrogen availability and therefore simulation of nitrogen dynamics is essential for a dynamic tundra vegetation model. In our model, mineralisation of soil organic nitrogen is temperature-dependent, so will respond to climatic changes. In addition, atmospheric nitrogen deposition, nitrogen fixation, nitrogen leaching to deeper soil layers and denitrification of nitrogen are included in the model. The available nitrogen in the different soil layers influences competition between the deeper-rooted graminoids and shallower-rooted dwarf shrubs. Indeed, snow influences the winter soil temperatures, which is not explicitly included in our regression-based soil temperature simulation, see further reply to comment 2. However, at our study site with an extremely harsh winter climate nitrogen mineralisation is always extremely low in winter. In summer, water movement can indeed transport nitrogen from the elevated shrub patch to the sedge-dominated depression. This was not included in the current version of the model, but will be implemented in the model for the revised manuscript.

(2) The model needs a thorough evaluation in the performance of simulating soil water, evapotranspiration and soil temperature, active layer depth, water table depth for the period the observations are available. This is the basis to convince the readers to believe the efficiency of the model. Particularly, the simulated soil temperature doesn't look correct in the 40, 80 cm.

REPLY: Unfortunately we have no time series of observations for soil moisture, active layer depth and water table depth for a thorough comparison with model outcome. Indeed, the simulated soil temperature at 40 and 80 cm depth does not look good in winter. It has been acknowledged in the text that the soil temperature model is based on temperatures in the growing season only, as the below-zero temperature in winter hardly affects the model output (Supplement S1.3.4). We used a regression approach which is based on air temperature and does not take snow characteristics and phase changes into account. Still, realistic temperatures for the upper (most important) soil layers in summer have been simulated, but there are deviations for winter temperatures (Supplement Figure S1.3). In the next phase of model development, we plan to couple the vegetation model to a more advanced soil physical model.

Soil moisture and water table depth are extremely variable even at a small spatial scale in the tundra landscape. The wet depressions (resembling the wettest vegetation type in the model) are much wetter compared to the slightly elevated shrub patches. Therefore, we choose to simulate different vegetation types along a water movement gradient from relatively well-drained elevated shrub patches to downstream sedge-dominated depressions receiving water from surrounding. As described in the manuscript, the model simulates a build-up of the snow layer in winter, followed by a wet period in spring following snowmelt. In summer, the soil gradually dries as evapotranspiration (derived from measured latent heat flux) generally exceeds precipitation, the extent of drying depending on the amount of precipitation and temperature. This sequence and dependence on precipitation matches with the observations at our study site in north-eastern Siberian tundra.

Unfortunately, only limited soil moisture observations are available for the Kytalyk field research site. Soil moisture measurements in graminoid, mixed and shrub dominated vegetation types indicate clear trends that moisture during the growing season is high in graminoid but low in shrub dominated sites, similar as is simulated in the model. Soil temperature in the upper soil layers is in the range of the simulated values. For deeper layers, the simulated soil temperatures are higher than observed, resulting in an active layer that is thicker than observed. We will add a more thorough evaluation of measured and simulated soil moisture, soil temperature and active layer thickness values in the revised manuscript.

(3) I suggest use the percentage of increase to indicate the change of precipitation. For this study site, 45 mm/year, (i.e. 20% increase of annual precipitation) seems much lower than the IPCC CMIP5 prediction for the RCP8.5 scenario. For instance, http://www.nature.com/nature/journal/v509/n7501/pdf/nature13259.pdf

REPLY: We accept this suggestion and will use the percentage instead of the actual precipitation increase. Indeed, the precipitation increases used for the current simulations are too low. These values will be corrected in the model simulations and the revised manuscript.

Other minor issues:

The rate of biomass increase is suggested to use the unit “g m-2 yr-1”.

REPLY: Suggestion accepted

How the development stages of thawing pond are evolved in different climate scenarios is suggested to demonstrate. For instance, the time series of water table depth in climate scenario runs.

REPLY: Suggestion accepted, we will add water table depth to the thaw pond scenario graphs in the revised manuscript.

The title should be catchier. The current one seems quite broad.

REPLY: We agree that the title “Simulating the effects of temperature and precipitation change on vegetation composition in Arctic tundra ecosystems” could be catchier. The new title will be

“Potential Arctic tundra vegetation shifts in response to changing temperature, precipitation and permafrost thaw”

Or “A new Arctic tundra vegetation model for simulating vegetation shifts due to climate change and permafrost thaw”

Interactive comment on Biogeosciences Discuss., doi:10.5194/bg-2016-96, 2016.