

Referee's comments in black

Authors' responses in blue

### Responses to Michael O'Brien (Short Comment)

I found the manuscript clear and well written. I think it provides a nice contribution to climate change impacts in the arctic system. Here are a few line-by-line comments.

We thank Michael O'Brien for his time and constructive comments, which will notably improve the clarity of the manuscript.

L12: I would not use the word adapt as that implies a genetic response, which is not tested here.

We will use "change" instead of "adapt" to avoid misunderstandings with genetic responses.

L62: I find this reference to Violle odd. I would say performance traits (detailed in Violle et al. 2007).

OK.

L66: Remove 'however'

OK

L120: When were these sampled? At the beginning and end of the experiment? Only after the 4 years?

The individuals were sampled at the end of the experiment (year 4 of experiment (2014)). We will add a sentence with this information to subsection "2.4 Study species and sampling".

L168 & L174: The model is actually block, heat treatment, fert treatment and treatment interaction. Not solely the interaction. I think the description of the analysis could use a bit of revision for clarity. It is often written in a condensed way that makes it tough to follow. I would add a bit of text to improve clarity of the model descriptions, especially for the contrasts.

We will correct the description of the model and revise it for clarity.

L167-L169: "[...]. The fixed terms of the models were block (factor with five levels), permafrost thaw treatment (two levels: heating, no-heating), fertilization treatment (two levels: fertilization, no-fertilization) and treatment interaction. [...]"

L172-L184: " We also used linear mixed-effect models to test the treatment effect on plant traits. Height, LA, bark thickness, and xylem diameter were log-transformed prior the statistical analysis to meet assumptions of linearity. First, we analysed plant traits of the four species together and then plant traits of each functional type (PFT; deciduous and evergreen). In the species analysis, we modelled each plant trait as a function of block (a fixed factor with five levels), permafrost thaw

treatment (a fixed factor with three levels), fertilization treatment (a fixed factor with two levels), species (a fixed factor with four levels) and the interaction between treatments and species. In addition to these fixed terms, we also considered the interaction between species and block, which was a term recognised in the course of the statistical analysis to take into account species-specific trait differences among blocks. The random terms of the model were plot (factor with 30 levels) and the interaction of plot and species. In the PFT analysis, we modelled plant traits as a function of block, permafrost thaw treatment, fertilization treatment, PFT (a fixed factor with two levels), species and the interaction between treatments, PFT and species. The random terms were plot and the interaction between plot and species. In both cases, we assessed if the effects of the permafrost thaw treatment on plant traits were due to the disturbance of the buried cables or the treatment *per se*. For that purpose, we split the three-level permafrost thaw factor into two contrasts of one degree of freedom (df) each, i.e. cable presence (heated and unheated cables vs. no-cable) and heating (heated cables vs. unheated cable and no-cable). We used the first contrast to assess cable effects (heating followed by cable presence) and the second contrast to assess treatment effects (cable presence followed by heating). After running these models for species and PFTs, we found that plant traits were significantly different among species, even between species within the same PFT. Consequently, we analysed the four species separately to maintain ecological information. We fitted block, permafrost thaw treatment, fertilization treatment and the treatment interaction as fixed terms and plot as a random term".

L203: I am not sure 'no-growing' is correct, maybe 'dormant'

We use the term 'no-growing', which is widely used in Arctic and alpine research. Some examples of this use can be found in Lin *et al.* (2011), Parmentier *et al.* (2011), Rumpf *et al.* (2014), van der Molen *et al.* (2007), Wang *et al.* (2016).

Lin, X., Zhang, Z., Wang, S., Hu, Y., Guangping, X., Luo, C., Chang, X., Duan, J., Lin, Q., Xu, B., Wang, Y., Zhao, X. and Xie, Z. (2011). Response of ecosystem respiration to warming and grazing during the growing seasons in the alpine meadow on the Tibetan plateau. *Agricultural and Forest Meteorology*, 792-802.

Rumpf, S.B., Semenchuck, S.D., Cooper, E.J. (2014). Idiosyncratic responses of High Arctic plants to changing snow regimes. *PLoS ONE*, 9(2): eB6281.

van der Molen, M.K.; van Huissteden, J., Parmentier, F.J.W., Petrescu, A.M.R., Dolman, A.J. *et al.* (2007). The growing season greenhouse gas balance of a continental tundra site in the Indigirka lowlands, NE Siberia. *Biogeosciences*, European Geosciences Union, 4 (6), pp. 985-1003.

Parmentier, F.J.W., van der Mole, M.K., van Huissteden, J., Karsanaev, S.A., Kononov, A.V., Suzdalov, D.A., Maximov, T.C. and Dolman, A.J. (2011). Longer growing seasons do not increase net carbon uptake in the northeastern Siberian tundra. *Journal of Geophysical Research*, 116, G04013.

Wang, P., Mommer, L., van Ruijven, J., Berendse, F., Maximov, T.C. and Heijmans, M.M.P.D. (2015) Seasonal changes and vertical distribution of root standing biomass of graminoids and shrubs at a Siberian tundra site. *Plant Soil*, 407, 55-65.

L266-267: Shrubs are plants, so this is redundant.

We will rephrase the sentence "Plant growth in high-latitude ecosystems is highly nutrient-limited (Billings & Mooney 1968; ...)".

L269: Confusing. Try : "Shrubs were released from growth limitation via nutrient addition, which was evidenced by. . ." or "Nutrient addition released shrubs from growth limitation as evidenced by. . ."

We will change the sentence to "Nutrient addition released shrubs from growth limitations as evidenced by the plant trait changes we found, such as ..."

L289-291: Which species would outcompete shrubs in this system? Which species will shade them out?

In Arctic tundra, graminoid species - particularly grass species - are expected to shade and outcompete shrubs, as suggested by results of warming and fertilization experiments carried out on tundra sites (Dormann and Woodin 2002, Gough and Hobbie 2003). In the study area, the species that are expected to outcompete shrubs are *Calamagrostis holmii* Lange and *Eriophorum vaginatum* L. (Wang *et al.* 2017). We will add a sentence to the discussion to answer both questions.

Dormann, C.F. and Woodin, S.J. (2002). Climate change in the Arctic: using plant functional types in a meta-analysis of field experiments. *Functional Ecology*, 16, 4–17.

Gough, L. and Hobbie, E. (2003). Responses of moist non-acidic arctic tundra to altered environment: productivity, biomass, and species richness. *Oikos*, 103, 204–216.

Wang, P., Limpens, J., Mommet, L., van Ruijven, J., Nauta, A.L., Berendse, F., Schaepman-Strub, G., Blok, D., Maximov, T.C., Heijmans, M.M.P.D. (2017). Above- and below-ground responses of four tundra plant functional types to deep soil heating and surface soil fertilization. *Journal of Ecology*, 105, 947–957.

L301: evergreen and deciduous are not species but PFT and if you mean species then use among not between.

The sentence will be corrected: "...in the leaf economics spectrum both between PFTs, i.e. from evergreen to deciduous ... and within species...".

L310: Did you test wood density in tissues grown before and after treatment? It seems like the sampling strategy would allow partitioning the inner and outer stem to see differences.

We did not test wood density in tissues grown before and after treatment. Because of the sampling protocol applied (individuals were selected at the end of experiment), identifying tissues growing before and after the treatments were difficult. However, in another study based on this experiment (Iturrate-Garcia *et al.* 2017), the treatment effects were tested on inner and outer stem variables (i.e. bark thickness, xylem diameter, bark investment, wood biomass). In addition, annual growth rings of the four years before the experiment and the four years of experiment were tested, resulting in a significant increase on the distance between rings (i.e. growth rate) on shrubs growing on fertilized plots.

Iturrate-Garcia, M., Heijmans, M.M.P.D., Schweingruber, F.H., Maximov, T.C., Niklaus, P.A., Schaepman-Strub, G. (2017). Shrub growth rate and bark responses to soil warming and nutrient addition – A dendroecological approach in a field experiment. *Dendrochronologia*, 45, 12-22.

L320: It is not clear regarding the point that stem and leaf trade-offs operate independently. Please revise for clarity.

We will rephrase this sentence and the previous one for clarity.

Line 320: “However, our results showed that coordination between stem-height PC1 and leaf PC1 was only significant for half of the species. For *Betula nana* and *Vaccinium vitis-idaea*, the significant relationship between both axes suggested that these species coordinated stem and leaf traits (e.g. conservative trade-off at stem and leaf levels), resulting in a whole-plant strategy. The lack of coordination between stem and leaf traits for *Salix pulchra* and *Ledum pallustre* suggests that, for certain species, functional trade-offs at stem and leaf levels may operate partly independent (Fortunel, Fine & Baraloto, 2012).”

L349: Remove ‘also’

OK

L357: Confusing sentence.

We will revise the sentences included in Lines 356-357 for clarity:

L356-357: “This depletion might result in reduced permafrost thaw through decreasing soil moisture, thermal conductivity, heat flux and temperature, which suggests that shrub shading might not be the only driver of the reduced permafrost thaw.”

L322-370: I found the discussion overly speculative in an effort to relate the trait responses into a climate-vegetation feedback. I would encourage the authors reduce the speculation or possibly present the information as potential scenarios of climate and vegetation responses.

This part of the discussion is meant to highlight how the results of this study based on detailed trait analyses and plant strategies support earlier findings that only covered part of the leaf and plant economic spectrum. We will revise the language of the indicated discussion section to address the reviewer’s comment.

Fig 5: Could you inverse two of the PC1 values so that the x-axis is always conservative on the left side and acquisitive on the right? It would make it easier to read.

We will change Figure 5 to have the conservative strategy on the left side and acquisitive on the right side.

