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Biogeosciences Discussions

Interactive comment on "What are the main climate drivers for shrub growth in Northeastern Siberian tundra?" *by* D. Blok et al.

D. Blok et al.

daanblok@gmail.com

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Response to reviewers' comments

We thank both referees for their valuable reviews, which have contributed to improve our manuscript. We are pleased to note that both referees agree that our research is original and forms a useful contribution to prove the potential of dendrochronology for studying growth of arctic shrubs and to answer questions on ongoing and future changes in arctic environments. Please find our detailed response to all points raised by the referees below.

Anonymous referee #1

General scope: The authors present shrub ring chronologies of two species with

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Interactive Discussion

Discussion Paper

markedly different growth forms that have not been used in dendrochronology before and from an area where (to my knowledge) no single study on shrub growth has been performed before. The authors further relate the shrub ring chronologies to climate (temperature and precipitation) and NDVI data and present the remarkable finding, that for both shrubs independently of their growth form, early summer temperatures are of highest importance for shrub radial growth. Similar findings have been published from coniferous shrubs in Northern Scandinavia (Hallinger et al. 2010, Hallinger & Wilmking 2011) and deciduous shrubs from West Siberia (Forbes et al. 2010). The present study does not only fill a spatial gap concerning the growth assessment of shrubs around the arctic but also confirms the highly disputed findings of the other studies that summer temperature is indeed in more than a few species and study areas the driving force behind enhanced shrub growth. Thus, the paper addresses relevant scientific questions within the scope of BG and the criterion of novelty is fulfilled, at least concerning the data (species not yet/rarely used for dendrochronology and from an area so far not covered by dendrochronological investigation on shrubs). The scientific methods are valid and clearly outlined, the overall presentation is quite well structured and clear. Except for one, all interpretations are supported by the results presented here (see details below). The whole supplementary material should be deleted as it only repeats the four tables anyway presented in the main document. I have reviewed an earlier version of this paper. Since then, the authors have made major improvements, especially concerning the discussion and the relationship between the results and the nature of conclusions that are supported by them.

Response: According to the recommendation of referee #1 we carefully checked for overlap between supplementary material and tabs and figs provided in the manuscript and decided to omit the supplement

Details:

Lines 11-13, 21-23, 18-20: “However, little is known about long-term. . .” this statement is repeated in almost identical ways three times and then finally stated in the aim

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section at the end of the discussion (number four). This is an indication that the introduction could and should be improved concerning the organizational structure. I would advise to restructure the introduction and not to jump from “climate change scenarios” to “evidence for shrub expansion” and then back to “summer air temperature”. The authors should concentrate the climate issues in one paragraph and the evidence for shrub expansion in another paragraph rendering repetitions unnecessary.

Response: Repetitions were removed and we restructured the introduction and restricted it to a paragraph on “evidence for shrub expansion” followed by paragraphs on “climate effects on shrub growth”.

Lines 26-29: “ring width measurements were calculated from measurements taken from samples of two heights” Does that mean that 4 radii were averaged into an individual shrub ring width curve? Generally, I would advise to be careful with the averaging of different numbers of radii into growth curves because of the possibly distorting effects of this procedure on chronology variance.

Response: We calculated mean ring-width series per Salix pulchra shrub individual from two radii measured on a base branch section and from two radii measured on a branch section after the first branch node. We used the same number of radii per Salix pulchra shrub individual (=4) to calculate mean series for each shrub.

Lines 11-13: This conclusion is not supported by your results! The non-existing correlation of the shrub chronologies with winter precipitation does not indicate anything. Why? You give the answer in line 14: winter precipitation is indeed only one of several parameters affecting local snow height and without on the ground snow depth and duration measurements over at least a couple of snow seasons I would not dare to conclude anything from a lack of correlation with snow precipitation data that is a) very hard to measure in the windy arctic conditions and b) can be substantially erroneous (Benson, 1982; Goodison, 1978; Golubev, 1985; Yang et al. 2005).

Response: We agree with the reviewer that our conclusion on the effect of winter

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precipitation on snow cover might be too straight forward and speculative. Accordingly we decided to omit the conclusion and rephrased the sentence.

Anonymous referee #2

This manuscript investigates annual ring widths for two widespread deciduous shrub species of contrasting growth form in a region of the Arctic (NE Siberia) that has not yet been reported in the literature. As such, it makes a potentially important contribution of the growing body of literature documenting the relationship between summer temperatures and increasing shrub abundance in the Far North. The field sampling regime and lab analyses look solid. Out of 50 shrubs sampled using serial sectioning from two stem locations 19 individuals were accurately crossdated and deemed suitable for the final chronologies, and that is a pretty good yield, especially for such a remote site. The text is overall well written and argued, with the appropriate literature cited, and few typos or grammatical errors. Among the interesting findings are that Salix pulchra showed a positive relationship with peak growing season NDVI despite the small percentage cover of S. pulchra shrubs in the research area (<5%), whereas Betula nana did not correspond significantly with summer NDVI. This is useful information in helping to partition the NDVI signal. It indicates that even small amounts of erect deciduous shrubs within a given landscape really drive NDVI, as was indicated from previous work in W Siberia, albeit with greater coverage of Salix (_20%). Also, the lack of a response to winter precipitation underscores the need for a broader synthesis of circumpolar shrubs. Evidence from W Siberian Salix lanata indicated no winter precipitation response (Forbes et al. 2010), but previous studies with other species have found such a response. Finally, the finding that climate zones were defined by elevational and latitudinal boundaries, rather than simply distance between different climate-growth reconstructions, suggests the way forward for future modeling efforts aimed at projecting regional scale responses to warming.

Specific comments

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L35-38 “. . .land-use changes such as intensive caribou and muskoxen grazing. . .may restrict future shrub expansion rates. . .” I would be careful with this one. My feeling is that the jury is still out and that a blanket explanation is not possible. The best evidence on the ‘restricted growth’ hypothesis comes from studies in low shrub tundra in Fennoscandia and Greenland (Post & Pedersen 2008; Kitti et al. 2009; Olofsson et al. 2009). However such evidence needs to be carefully considered in light of the shrub canopy height relative to the grazing/browsing capacity of the herbivores, be they ungulates or otherwise. In the case of Fennoscandia and Greenland, the shrubs investigated were of low stature. In contrast, in W Siberia, the erect shrubs studied were already well above the browse line (Forbes et al. 2010). This indicates that future deciduous forest development in situ (sensu Edwards et al. 2005) may be an option.

Response: To avoid putting too much emphasis on the grazing/browsing issue which is not relevant in our study area we decided to remove the general statement on the effect of browsing/razing on shrub expansion and rephrased this paragraph accordingly.

L93-94 “Samples of B. nana and S. pulchra shrubs (50 individuals per species) were collected: ..” For the erect shrubs, L230-231 “...for the period 1948-2006 showed a slight positive trend (trend line slope = 231 0.014_C yr-1, Fig. 2). . .” In Fig. 2 it would be good to show also the actual trend line from e.g. RES.

Response: The detrending and standardisation procedure is applied to the individual tree-ring series to remove age-related growth trends and the autocorrelation to enhance the annual variation in the time series; concomitantly also long-term growth trends are removed by this procedure. Thus, no trend lines can be indicated in the RES (=residual) chronology.

L272-274 “Shrub growth in our research site in NE-Siberia was found to be highly sensitive to early summer temperatures, as also observed for boreal tree growth in our research region.” This raises a question about whether eastern Siberia exhibits divergent trends of temperature and tree growth in its coniferous forests as has been

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reported from many places, presumably caused by drought stress (Briffa et al. 1998; D'Arrigo et al. 2008).

Reponse: In this study we did not observe a decrease in shrub-growth sensitivity to temperature over the decades for the shrub species we investigated. Neither did we detect strong trends in the instrumental data of early summer temperature, which we found was the most important climate factor influencing growth of both species. We thus have no reason to assume a change in shrub growth sensitivity to temperature for our study area during the last six decades.

L317-319 "An alternative explanation for the lack of growth response to a thicker snow-pack includes that shrubs may not be metabolically active yet and thus unable to take up resources (Edwards & Jefferies, 2010)." The paper referred to here (Edwards & Jefferies 2010) actually treats an aquatic sedge (Carex aquatilis), so I was unclear why this is cited to illustrate the nutrient uptake capacity of the shrubs Salix pulchra and Betula nana.

Response: We agree with the reviewer that our assumptions on similarities in mechanisms operating in nutrient-uptake capacities of aquatic sedges and shrubs are too speculative and decided to restrict our argumentation to literature available for shrub growth.

Interactive comment on Biogeosciences Discuss., 8, 771, 2011.