

Interactive comment on “Changes in growth of pristine boreal North American forests from 1950 to 2005 driven by landscape demographics and species traits” by M. P. Girardin et al.

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We thank the referee for his/her helpful comments (Anonymous 2012). In this response I will take the opportunity to address his/her comment related to the processing of the tree-ring width data, a point that is of central importance to assessments of climate change impacts on forests. Other specific comments will be addressed in our revisions of the final manuscript.

As pointed out by the referee, the conclusions about significant changes in forest growth and subsequent analysis of demographics-stress interactions depend on the efficiency of the standardization technique at removing age declines in tree-ring mea-

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surement series of mature trees without removing the low-frequency climatic change signals. (Standardization is the process that removes undesirable long-term variations from a time series of measured tree-ring properties.) As mentioned in our manuscript (Girardin et al. 2012), several alternatives were used to ensure that the conclusion of the work was not a bias resulting from the overly-flexible standardization of measurement series from mature trees. This included removing trees of age < 100 years from the analyses, constraining the trend detection of forest growth changes to a shorter interval (1970–2005), and applying alternative detrending procedures such as smoothing splines (Cook and Kariukstis 1990).

The use of the regional curve standardization (RCS) technique the referee refers to is an additional option for detangling age declines from low-frequency climate variability. The approach has the potential to preserve the evidence of long-time scale forcing of tree growth as it scales ring-width measurements against an expectation of growth for the appropriate age of each ring (Esper et al. 2003 and Briffa and Melvin, in press). However, the technique can only be applied under the following assumptions: 1) stands are relatively homogeneous in terms of species and site conditions; 2) age trends of individual measurement series are similar in levels and slopes once aligned by cambial (ring) age; and 3) tree-ring measurements must have a uniform distribution of start and end dates (Esper et al. 2003). For black spruce (*Picea mariana* [Mill.] B.S.P.), assumptions #1 and #2 are not respected in the current dataset, which makes the application of RCS inappropriate. Indeed, black spruce stands encompass a large range of environmental conditions in terms of soil texture and moisture, organic layer depth, stand densities, slopes, etc. Furthermore, growth trends of the individual measurement series exhibit high variability in levels and slopes.

On the other hand, we did find an opportunity for applying the RCS method to jack pine (*Pinus banksiana* Lamb.) data. The technique has already been successfully applied to this species by Girardin et al. (2011) in central boreal Canada. The species grows essentially on sandy soils, its forests are relatively homogeneous, trees are relatively

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short-lived, and recruitment occurs essentially after a deep burn to the mineral soil. Below, we developed a jack pine tree growth index (TGI) record obtained from the application of the RCS standardization technique (RCS TGI) and compared it with the TGI record obtained from the application of the exponential technique (EXP TGI) described in our paper. The objective was to see if increases in jack pine growth observed in Fig. 4b by Girardin et al. (2012) are also apparent under this alternative standardization procedure. With a positive result, one can be confident that age declines are appropriately removed and that reported increases in jack pine growth are not the effect of gap dynamics.

The methodology employed for computation of the RCS TGI record is detailed in Girardin et al. (2011). The jack pine dataset is detailed in our original paper (Girardin et al. 2012). We first aligned the 516 available jack pine measurement series by cambial age and calculated the arithmetic mean of ring width for each ring age. We then created a regional curve (RC) by applying a flexible smoothing (Friedman super smoother) to the age series of arithmetic means. It is assumed that this RC created from the means of ring width for each ring age describes the functional form of the age-related growth trend. Next, we divided each one of the original 516 ring-width measurement series by the RC value for the appropriate ring age to create standardized series. These departures from the RC are interpreted as departures related to climate variability and changes. Finally, the 516 standardized series were realigned by calendar year and averaged using a bi-weight robust mean to create the jack pine tree growth index (TGI). Program ARSTAN (version 40c) was used for processing of the tree-ring measurement series (Cook and Krusic 2006).

Most sampled jack pine trees originated from post-fire recruitment episodes in the 1910s, 1920s, and 1950s. A close relationship between average ring width and tree age suggested the existence of relatively homogeneous behaviour in the tree population under study with regard to growth rates (Fig. 1). Also, the age-related growth trend of trees originating from prior to 1955 was reasonably similar in level and slope to a

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curve obtained from trees originating after 1955 (Fig. 2). Therefore, one can assume that the trees belonged to the same population, a prerequisite for the application of the regional curve standardization (Esper et al. 2003).

As shown in Fig. 3, the RCS TGI record is similar to the EXP TGI record for the post-1920 period, for which sampling replication is high: the high growth in the 1940s to the early 1950s, the low growth from the late-1950s to the mid-1970s, and the high growth from 1980 to 2006 are important features of both records. The correlation coefficient between the two records for the 1950-2006 period is 0.92.

Therefore, exponential standardization appears successful in eliminating multi-decadal signals in jack pine trees originating from age declines and gap dynamics. Sensitivity analyses in which jack pine data were truncated so as to include only the first 80 years of ring-width measurements, and in which the amount of samples originating from specific age cohorts was down-sampled to ensure a more homogeneous distribution of start and end dates, also confirmed the robustness of the results. Given that for similar ages jack pine and black spruce trees have similar growth behaviours (Girardin et al. 2012, therein Fig. 4), we can reasonably make the assumption that the exponential standardization technique is also successful at removing age declines in mature black spruce trees.

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Figure captions

Fig. 1. Relationship between average ring width and length of measurement series for each jack pine series. An exponential fitting is shown: model fit $R^2 = 0.55$.

Fig. 2. Mean growth curves for trees established prior to and after A.D. 1955 (black lines). Blue shaded area shows 95% confidence intervals associated with the mean growth of trees for each ring age. Red lines are the regional curves obtained after application of smoothing splines to the mean growth of trees.

Fig. 3. Jack pine tree growth index (TGI) and 95% confidence interval (AD 1880–2006) obtained after the application of two different standardization techniques. The first TGI record was obtained after the application of exponential fitting (TGI EXP) to jack pine measurement series as described in our paper. The second TGI record was obtained through the application of the RCS technique (TGI RCS). The number of jack pine samples used through time is indicated.

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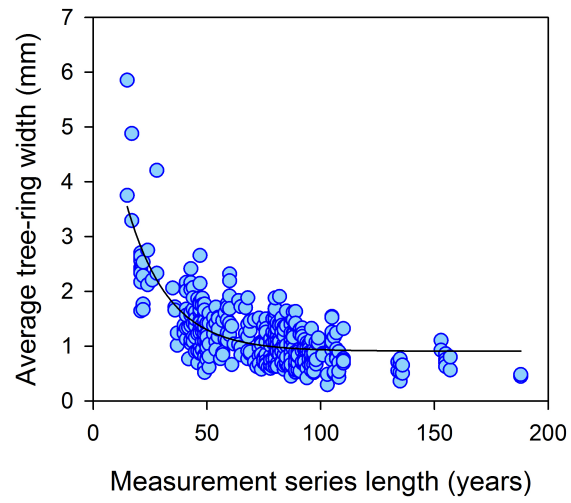


Fig. 1. Relationship between average ring width and length of measurement series.

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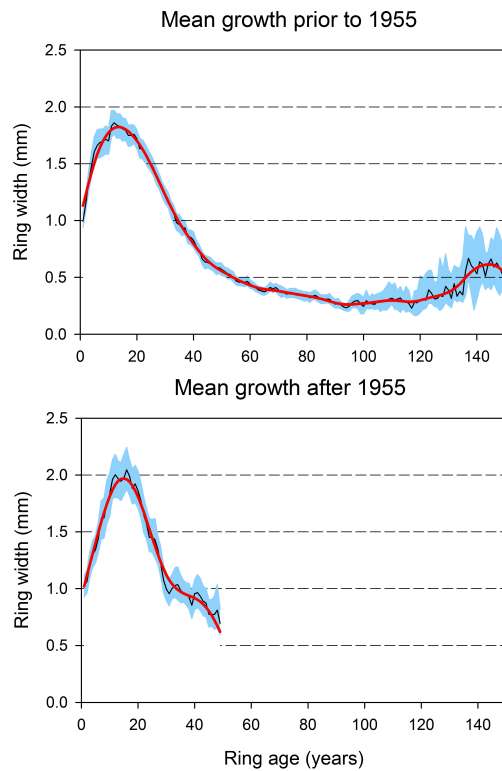


Fig. 2. Mean growth curves for trees.

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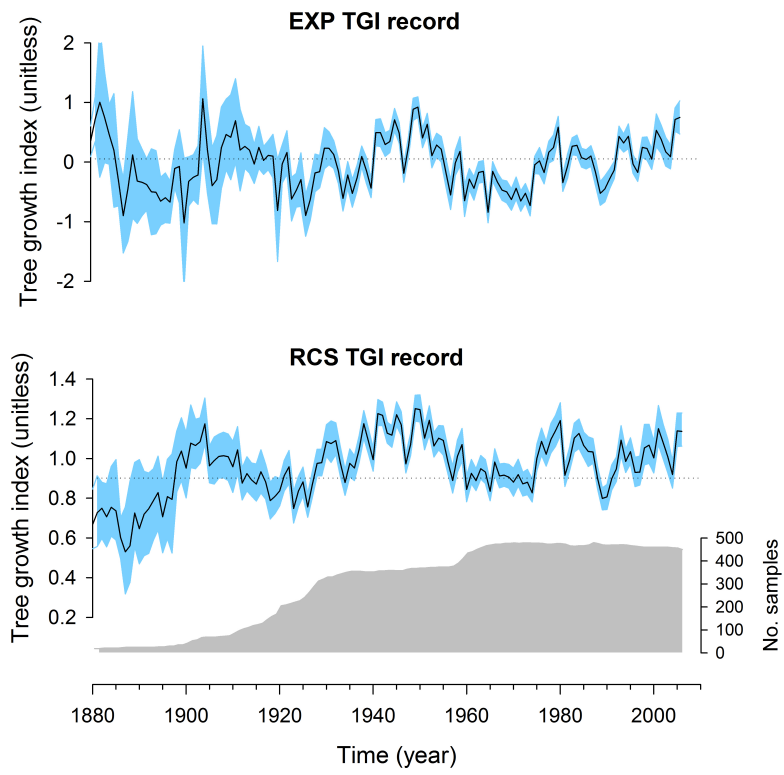


Fig. 3. Jack pine EXP and RCS TGI records.

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