Relating tree growth to degree-day sum at the alpine tree-line ecotone

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Objectives

- Investigate the relationship between tree growth and annual day-degree sum at the alpine tree-line ecotone.
- Compare growth in different tree species with theoretical curves used in the forest model TreeMig (Lischke *et al.* in prep.), a spatially explicit model derived from ForClim (Bugmann 1994).
- Adjust TreeMig model parameters to conditions at tree-line.

Material & methods

Tree-ring data from various studies done in two areas of the Swiss Alps (fig. 1) was used. Investigated species were *Picea abies* (Grindelwald) and *Pinus cembra* (Engadin).

Daily mean temperature was derived for each site by linear regression from the nearest climate station(s). Annual day-degree (DDeg) sums above a 5.5°C threshold were then calculated.

Ring-width data was arranged according to corresponding DDeg sum and the mean of the 10% largest values in each 25 DDeg window was calculated.

Theoretical growth curves (ring-width vs. DDeg sum) were established for both species, using formulae and species' parameters from the TreeMig/ForClim models. Each species was considered to be at optimal growing size and DDeg sum was the only environmental constraint.

Fig. 1: Study areas : ● Grindelwald ● Engadin

Results

Grindelwald - *Picea abies*

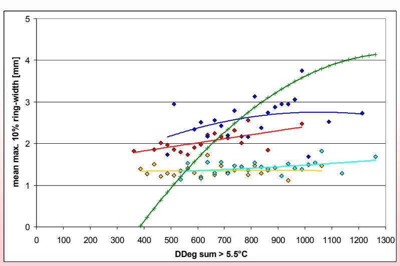
The lower DDeg sum limit (385 DDeg) of the model is slightly higher than what is shown by actual measurements, therefore tree-growth is underestimated for lower DDeg values. Measured values also indicate a steeper decrease in growth towards the lower limit.

No difference appears between north- and south-facing slopes.

Fig. 2: Grindelwald – *Picea abies*; mean of 10% maximum ring-widths vs. DDeg sum above 5.5°C threshold.

Data from Meyer (2000):

- North-facing sites
- South-facing sites
- Model curve



Engadin - *Pinus cembra*

The lower DDeg sum limit (323 DDeg) of the model is much higher than what is shown by actual measurements, therefore tree-growth is largely underestimated for lower DDeg values. Measured values also indicate a steeper decrease in growth towards the lower limit.

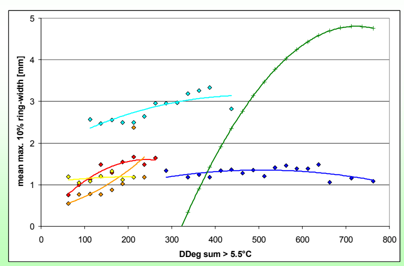


Fig. 3: Engadin – *Pinus cembra*; mean of 10% maximum ring-widths vs. DDeg sum above 5.5°C threshold.

Data from:

- Niederer (unpubl.)
- Müterthies (2002)
- Model curve

Discussion

In both cases, measured ring-width values show a different response curve to DDeg sum than the function used in the model. Growth decrease when approaching the minimal DDeg sum limit occurs more abruptly in the actual trees. What's more, high growth seems to be maintained as DDeg sum increases, though this would need to be confirmed by including data for higher DDeg sums. The overall shape of the measured data response curve is more consistent with the asymptotic function used in more recent versions of the ForClim model (Bugmann & Solomon 2000).

For *Pinus cembra*, growth occurs at DDeg sum values far below the model's lower limit for that species. In the case of *Picea abies*, that difference is not so marked. The latter could be due to the fact that DDeg sum was calculated using daily data for the measured values, whereas it is derived from monthly values in the model. Nevertheless, the difference in method does not explain the discrepancies between model and actual data for *Pinus cembra* and model parameters will need to be adapted to better represent that species' fundamental niche.

In Grindelwald, no difference in growth appears, at equal DDeg sum, between north- and south-facing slopes, even though no allowance for exposition was made when calculating DDeg sum. Although the limited number of sites means this has to be viewed with caution, it is consistent with results obtained by Paulsen & Korner (2001).

These results show the need to complement this study by adding extra data (e.g. for higher DDeg sums), testing the differences between DDeg calculation methods and trying to fit an asymptotic response function for the model.

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