

Temperature-induced differences in timing of intra-annual growth of subalpine *Larix decidua* and *Picea abies*

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Introduction

Phenological observations of plants are mostly concentrated on foliar life-cycle events which are observable from "outside" the plant. Such phenological cues, often concentrated at the start and end of the growing season, are routinely used to model growth responses (e.g., shift in phenological timing and effect on biomass production) under global warming.

However many important growth processes within the growing season and within the plants, such as wood formation, remain poorly quantified.

Aims

Monitor and describe the timing of primary and secondary growth along an altitudinal/temperature gradient

Quantify altitudinal/temperature lapse-rates

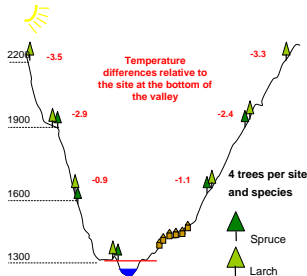
Compare

- deciduous (*Larix decidua*) versus evergreen (*Picea abies*)
- warm spring (2007) versus normal spring (2008)

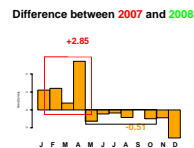
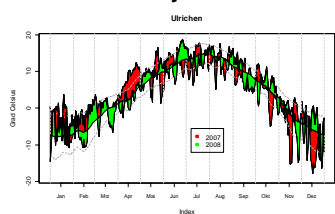
The location

Lötschental

The setting



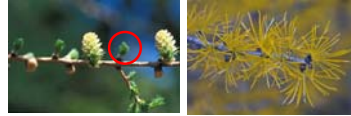
The climatic years



Methods

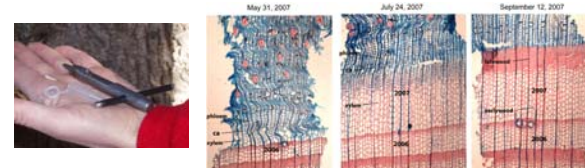
The phenological survey

A) Primary growth



Observed phenophases: Phenological observations were made weekly. Onset of needle break (NB for larch and spruce) and timing of needle coloring (NC for only larch in 2008) is defined when 50% of the crown reached the stage shown in these images.

B) Secondary growth



Survey and sample preparation: Wood formation was also monitored at weekly resolution. Micro-sections of the forming annual ring were sampled with a "trephor", cut with a microtome and stained to track cellular development and annual ring formation.

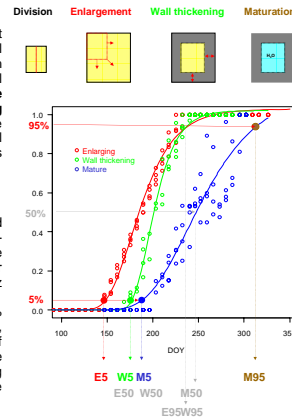
Cell development phases:

Each tracheid undergoes different developmental stages before maturity. The cell is created by the cambium mother cells through cell division, then the still-flexible primary cell wall first **enlarges** (blue staining) and then the cell becomes stiffer by forming and **thickening** the secondary cell wall (red staining). The growth process terminates with cell death (cell maturation), the cell lumina is emptied of its content and can finally transport water.

Observed phenophases:

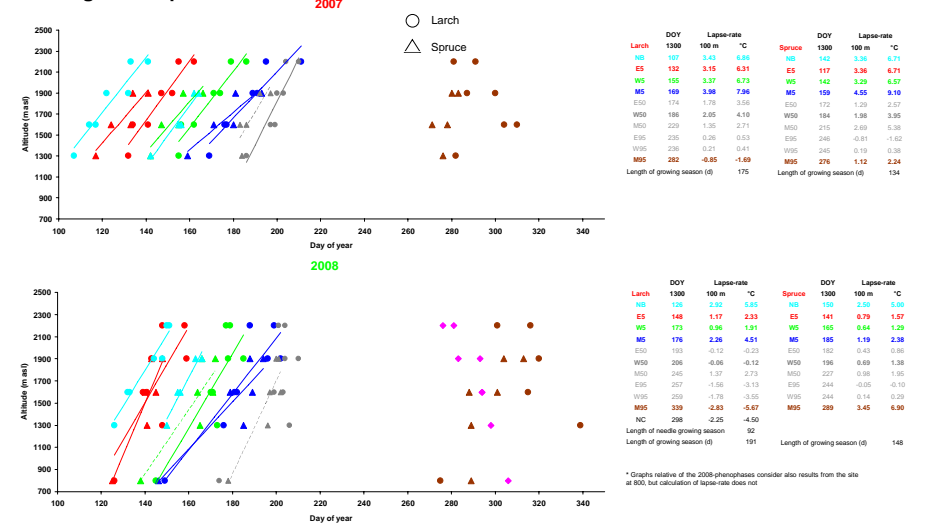
The number of enlarging, wall-thickening and mature tracheids was counted for every micro-section in order to track development over the growing season. Cell development stages over the season were then fitted with a Gompertz function for every site and species.

We defined the onset of growth (DOY) when 5% of the cells reached the enlarging phase (E5), and the end of the growing season when 95% of the cells reached the mature stage (M95). We further defined the onset of cell wall thickening (W5) and cell maturing (M5); maximum rate (E50, W50, M50) and end (E95, W95).



Results

Timings and lapse-rates



The **onset of the growing season** changed by 1 to 4 days per 100 m elevation (2-8 days per °C) depending on phenophase and species considered. Needle phenology of larch starts about 1 month earlier than spruce, but wood formation starts one to two weeks later. The lapse rate with elevation/altitude is in general greater for larch than for spruce. The **end of the growing season** appears to be minimally related to altitude.

The onset of cell enlargement, wall thickening and maturation tends to delay in a somewhat cumulative manner and cause increasing lags with elevation. This cumulative behavior is not observed for phase endings. **Time availability for cell developmental stages varies along the gradient**

The **exceptionally warm spring of 2007** induced an earlier start (and an earlier end) to the growing season with respect to the average year 2008. The magnitude of the shift changes depends on species and phenophase. Primary growth in larch benefited from warming more than secondary growth. This contrasts with the response observed for spruce. In warm spring spruce secondary growth advances more than that of larch.

Conclusions and Outlook

- Temperature influence both the phenology of the primary and the secondary growth
- The onset of the growing season is much more temperature sensitive than the end
- Temperature dependence seems to increase the earlier the phenophase occurs
- The phenology of primary and secondary growth have different timings and different responses to temperature
- Processes of wood formation (cell enlargement, cell wall thickening) are affected differently by temperature shift
- Linear trend is valid also for site at 800m, indicating photoperiod limitation is not anywhere near

References

- Moser et al. (2009) Timing and duration of European larch growing season along altitudinal gradients in the Swiss Alps. *Tree physiology* 30:225-233
- Fonti et al. (in review) Role of temperature and photoperiod on plant phenology. *Science*

