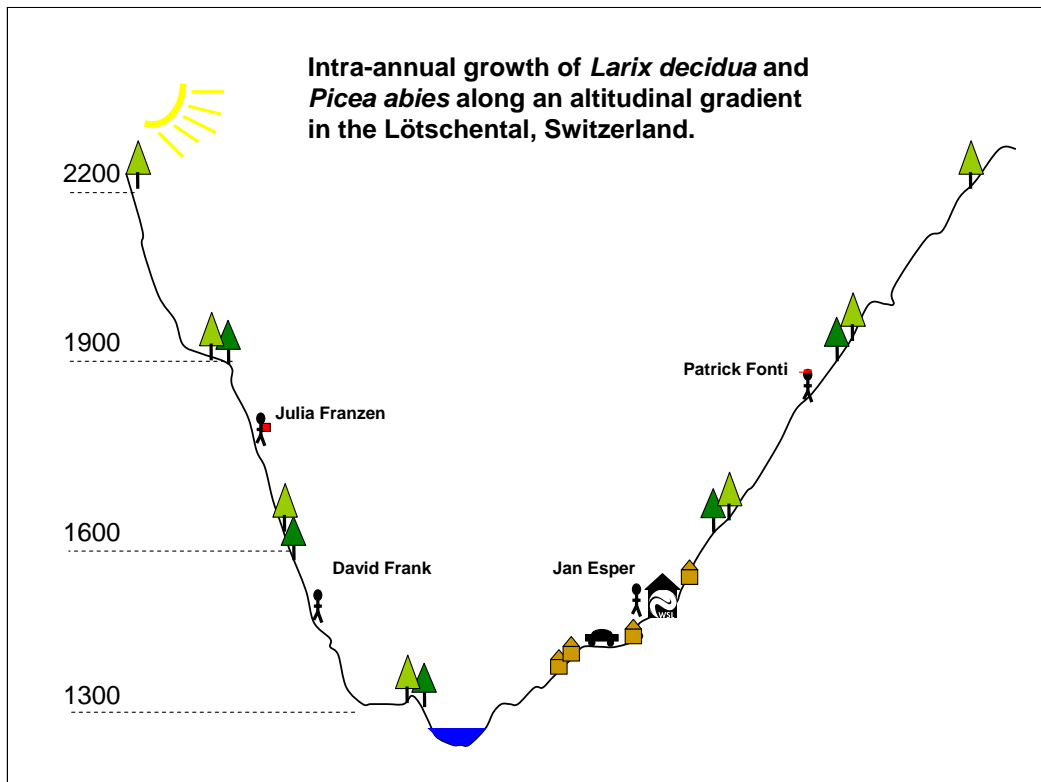


According to the last IPCC report, by the end of the next century we should expect a temperature increase between 1 and 5 degree Celsius and most likely around 3 degrees. So, let's suppose that is going to be true, what does this change mean for tree growth?

3 degree changes is like moving Goteborg, which is in Sweden, to Milan, which is in Italy; and if we consider how different are the vegetation types around these two cities, we can easily start to imagine how large the impact of that change is on the vegetation.

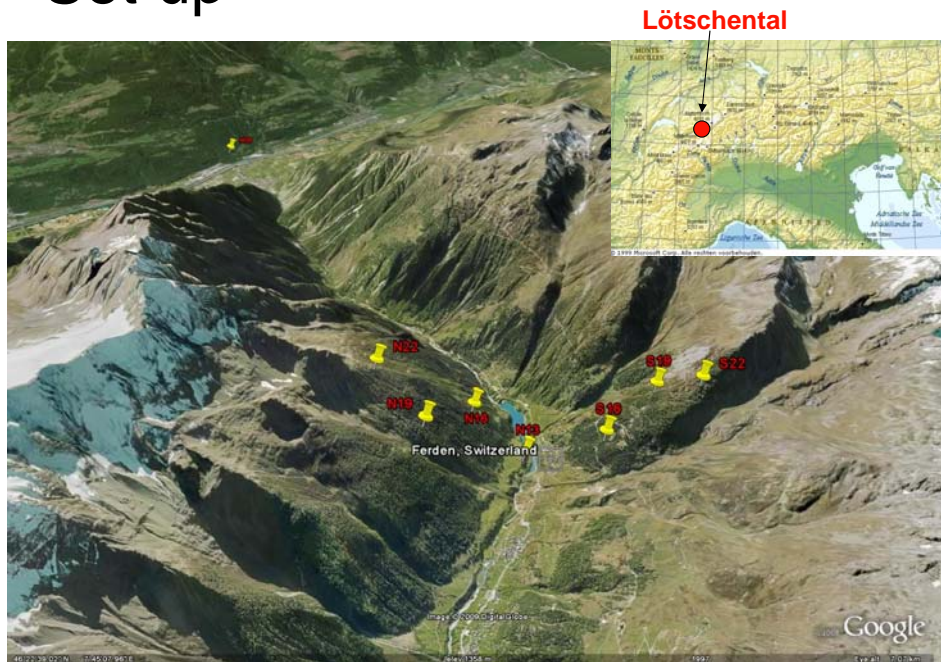


Our Dendro Sciences Unit at the WSL in Switzerland has decided to jump on this topic by starting a new project aimed at contributing to a better understanding on how the mechanism of tree-growth and wood formation is affected by Temperature.

Our approach is quite easy and consist in monitoring and comparing processes of growth and wood formation under differing Temperature regimes. We specifically focused on Subalpine forest since we expect these forests to sensitively respond to T change since they growth closer to the thermal limit and we modulate different temperature regimes by simply moving along an altitudinal gradient. This study, which we call the transect or the Loetschental project, started in 2007 and will run for more years.

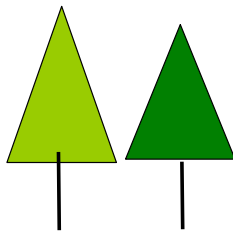
In my presentation today, I'll present some results about the different in timing and duration of tree growth along an altitudinal gradient by comparing between two species and to climatically different years. What you can see on this slide is the title of this presentation and the name mentioned here are the people that mainly contributed to this work.

# Set up



What you can see here is a Google earth view of our transect project. We are here in the Loetschental, a central Alpine valley which is more or less located in the center of the Swiss Alps. Here in this valley we selected 7 sites, from the bottom at 1300 m up at every 300 m gain in elevation on both slopes until we get to the forest limit at 2200 m. One year later, in order to expand the transect, we add a further site down in the main Rhone valley at 800 m.

4x



larch

spruce



Climatic parameters  
T, H (air and soil)

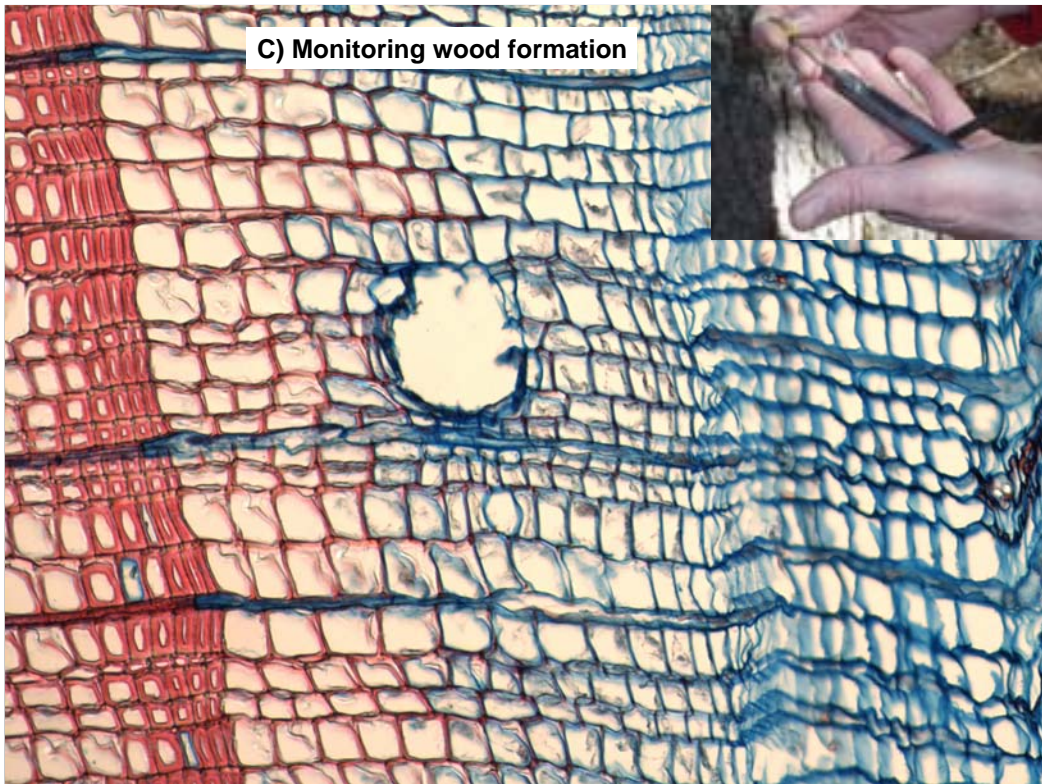


B) Dendrometers

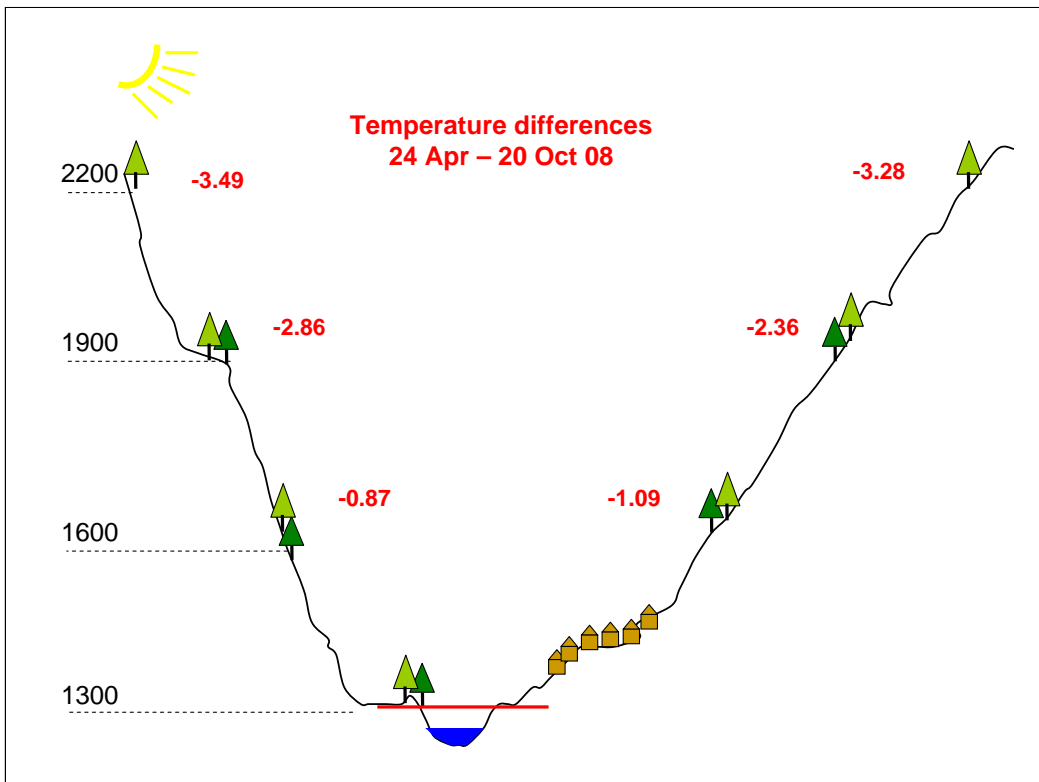


Monitor growth

A) Phenology

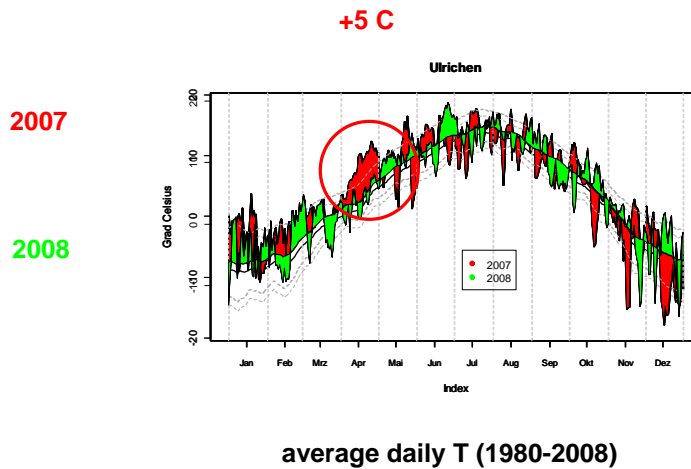


Of course we are monitoring wood formation by performing weekly microcores on all individuals and along the whole growing seasons.



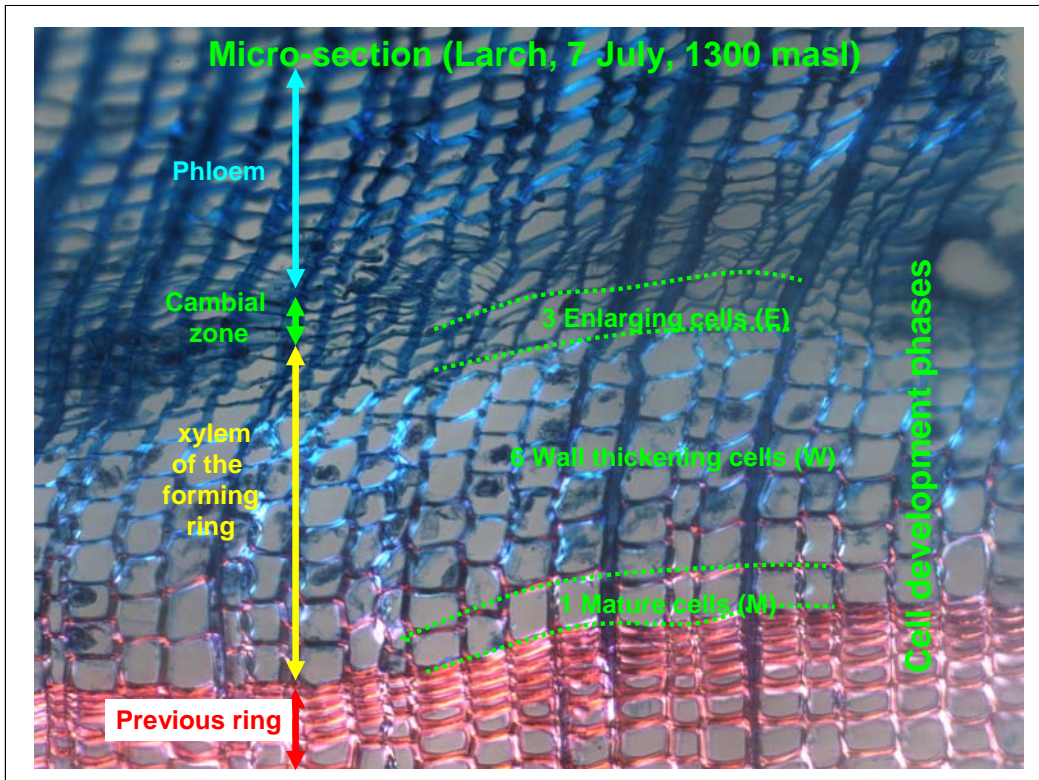
With this slides I just wanted to give you an overview about the air T differences we measured along the altitudinal gradient and during the vegetation period. The red value indicates the T differences in comparison to the site situated at the bottom of the valley, at 1300 m. Without going to much in detail, we can observe that the T differences with the upper sites at the tree line are just a bit more than 3 degrees, which, again, it correspond roughly the same difference we have between Goteborg and Milan.

# The climatic years 07-08



Here I just wanted to give you some information about the climatic years 2007 and 2008, since these are the year of the survey. So what you can see here is the average daily temperature calculated over the last 30 years of the station of Ulrichen, which is very close to the Loetschental. [click]

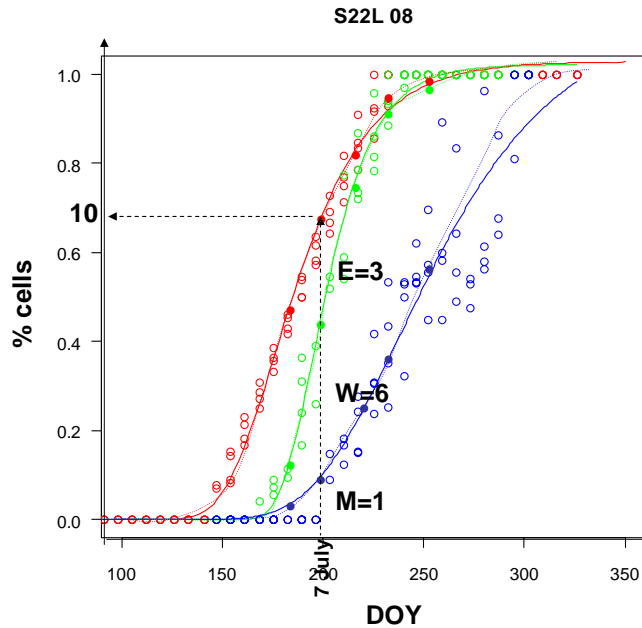
And this in red is the daily T measured in 2007. This year was exceptional because of the extraordinary warm spring and this has to be taken into consideration when looking at the results. The year 2008 [click] in green instead can be more or less considered as a normal year.



With this image I just wanted to show you how a typical micro-section look like and what was surveyed. This is a larch microsection collected at the beginning of July at 1300 m. We easily recognize the end of the last annual ring. [click] Then usually we look for the cambial zone so that we can separate between the xylem of the forming ring and the phloem. [click]

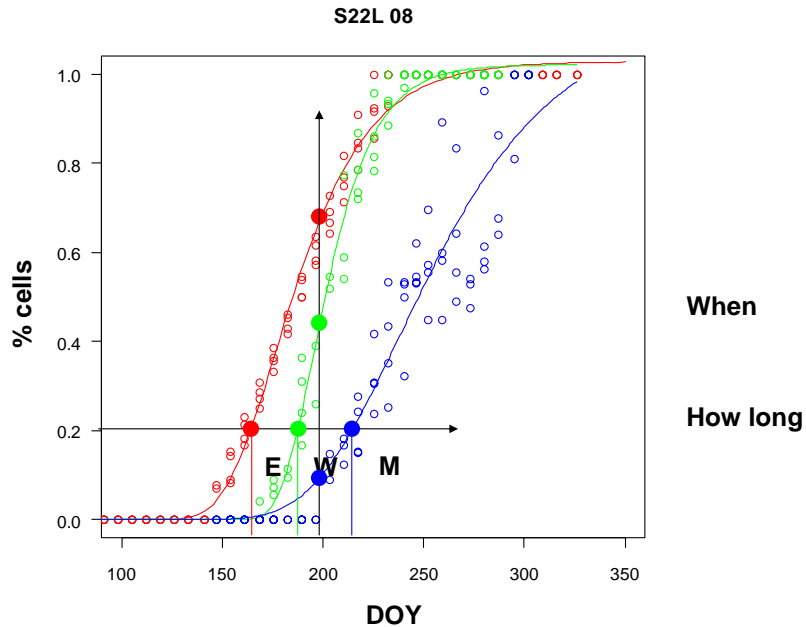
To monitor wood formation we counts the number of tracheid of the forming ring in all sections, but also considering the different cell developmental phases a cell as goes through. Here as an example we recognized three cell in enlargement phase, 6 cells which were still thickening their cell walls and already a mature and complete cell.

# Dynamic of wood formation



These information are then imported in another graph in order to describe the dynamic of wood formation, as we can see here. [click] If we do that for more weeks over the season and then we connect these points, we can then start to have an overview of the development of the ring over the season [click]. What you can see now here is an example of such a graph for 4 larch trees at the forest limit and with Gompertz fitting functions.

# Dynamic of wood formation



This kind of graph is very valuable because of course we can reconstruct the progress of ring formation for every day of the year but also [click] because if we look along the horizontal line we can reconstruct the “when” and “how long” every cell build during the year was staying in each developmental stage.

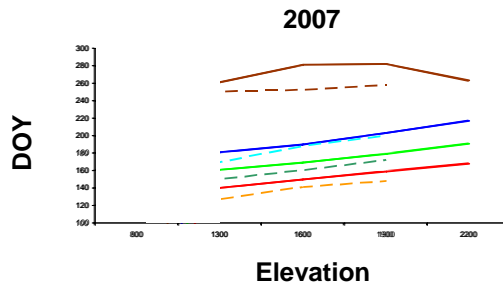
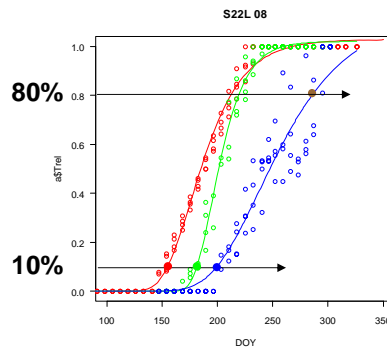
The results I’m going to show are then based on specifically on this kind of information by comparing, as I said, between elevation, specie and climatic year.

# Results: Timing

10 days / C

Larch starts at DOY 140

Spruce starts at DOY 127

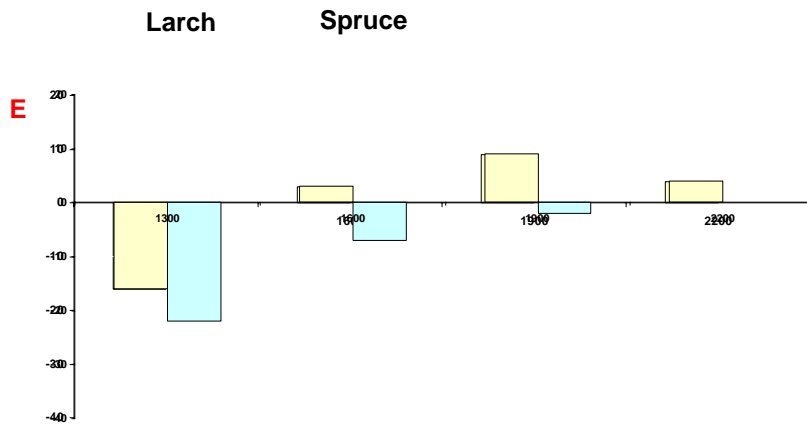


Here now some results about the timing. I defined 3 different moment for the beginning of growing season, and specifically when 10% of the cells produced in the year have entered the Enlargement phase, in red, or the Thickening phase, in green, or when they were completed, in blue. The end of the season was defined at the timing when 80% of the cell were mature, in brown. [click]

So if we now plot these timing, for Larch along the elevation gradient, which is also the temperature gradient, we get this graph. What we can see here is that the beginning of growth strongly depend on elevation/temperature, whereby the beginning is shifted by 10 year per decrease in degree Celsius. The end of the season instead does not seem to be affected by temperature. [click]

Here with the broken lines the results for spruce. Spruce shows a very similar patten, with the only difference that it usually does before larch.

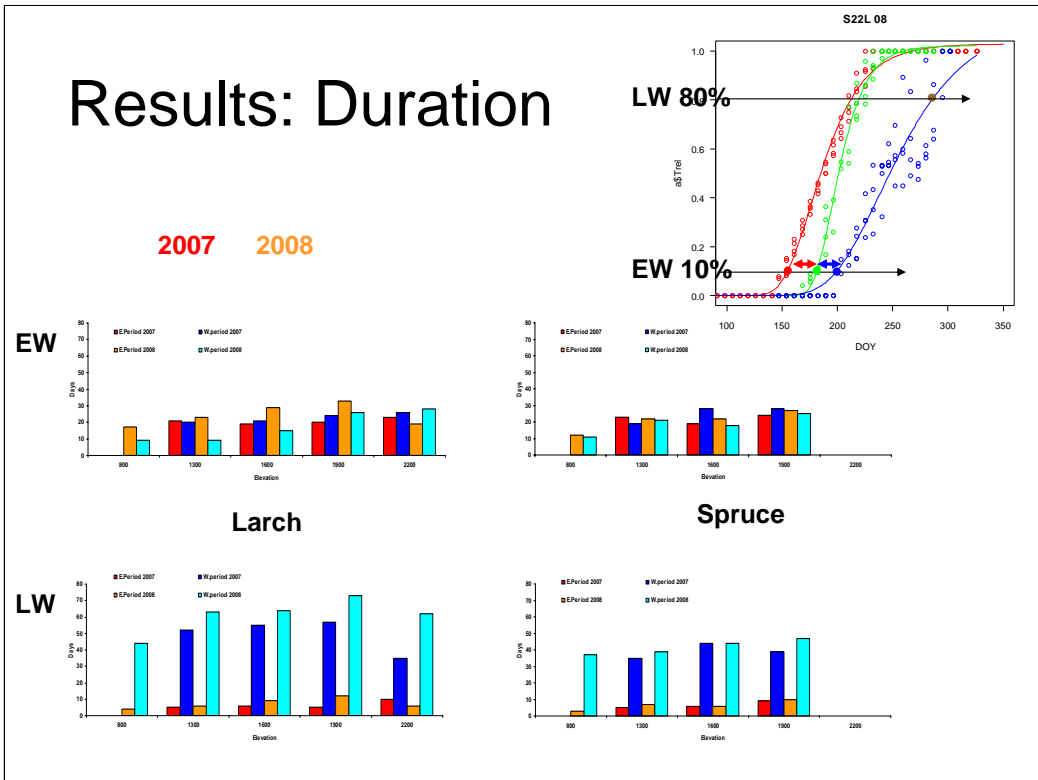
# Results: Time shift 07-08



With this graph I wanted to quantify the advance in the growing season due to the warming spring 2007, by comparing the start of growing season with the year 2008. What we observe here is that Larch at 1300 m started 17 year earlier than in 2008, but the effect of warming was not observable anymore for the higher elevation sites, which started later than in 2008. [click]

The same analysis for Spruce, shows that spruce took greater advantage from the spring warming by initiating the growing season even more earlier than larch. Some advancement was also observed for the higher elevation sites.

# Results: Duration



Here now some results about the duration. I'll show you the results for an earlywood cell (equivalent at the 10% cell of the ring) and a latewood cell (equivalent at the 80% cell of the ring). [click]

First the early wood. For this cell I quantified how long the larch cell in 2007 at 1300 m was staying in the enlargement phase, in red, and in the cell wall thickening phase, in blue. So this cell needed about 20 days in each phase, so about 40 days to be build [click].

Here now the results for the year 2008, which shoes that this ration between enlarging and thickening is not always the same, [click] and here the results along the altitudinal gradient. What we observe is that there is a trend to have longer period with increasing altitude. [click]

Here now the same results but for the latewood cell. Here we can easily observe that duration are much longer and also that the ratio between enlarging and thickening is completely different. These cells need much shorter enlarging period, but stay much more longer in the thickening phase. To be build more than 60-80 days can be needed. Again there is a trend to increase the long of formation with elevation. [click]

Now the results for spruce: again the pattern is quite similar as for larch, with however the largest difference in the duration spend in the thickening phase of the latewood cells, which is much more shorter for spruce.

# Conclusion

- T affects growth especially at the beginning of the season: delay of 10 days/C
- Warm spring 07 favored more spruce than larch
- Duration of cell formation
  - 40-50 days EW and up to 100 days for LW
  - tend to increase with elevation
  - last longer by larch as for spruce (LW)

Here you can see a summary of what I showed you in the results.

My personal conclusion on this study, after two years of experience, is that this kind of approach is very powerful to quantify the impact of 1, 2, 3, degree changes on growth. However, due to the quite large variability from year to year, it is wise to perform these measurements for some years, as we have now planned to do with the help of our new PhD-student Greg King

Thanks for your attention!