Exploring blue intensity - comparison of blue intensity and MXD data from Alpine spruce trees

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Introduction

Blue intensity (BI) / blue reflectance has been recognised as a proxy to acquire wood density of conifers, but in an easier and cheaper way as with classical radiodensitometric analyses (McCaroll et al. 2002, Campbell et al. 2007). As maximum density values (MXD) of tree-rings are strongly related to summer temperature, an easier approach facilitating the development of such records has a high potential for dendroclimatic studies (e.g. Trachsel et al. 2012, Björklund et al. 2013, 2014, Rydval et al. 2012, Wilson et al. 2014). However, BI is a relatively new proxy and its potential but also possible problems are not fully evaluated. The number of studies that directly compare BI and MXD data from the same trees are limited (e.g. Björklund et al. 2013, 2014, Rydval et al. 2014, Wilson et al. 2014). Interestingly, most studies so far focussed on scots pine (Pinus sylvestris), whereas other species got less attention.

Here we compare BI with MXD data established on parallel cores from living spruce (Picea abies) trees in the eastern Alps. The MXD series have already been dendroclimatologically analysed (Esper et al. 2007) and were used in palaeoclimatic studies (Battipaglia et al. 2010, Trachsel et al. 2012). We also evaluate an additional methodological approach to produce BI values, i.e. cutting and using microscope photography instead of the traditional sanding and scanning of wood samples.

Material and methods

Three cores from 21 living spruce trees were taken at two sites (Mauchele, Winterstallen) in two neighbouring valleys (Pitztal, Ötztal) of the eastern Alps at about 1900 m a.s.l. Two cores were used for radiodensitometric analyses (Esper et al. 2007), and the third core, samples parallel to one of the others, was used for BI analysis. These cores were first stored in pure acetone for 72 hours to remove resins (Rydval et al. 2014). Then, an exactly planed surface was produced utilizing the WSL core microtome (Gärtner & Nievergelt 2010). To overcome possible shade effects in the open tracheids, their lumen were filled using white chalk (Rayher, Dustless Chalk White MPS-12W).

We applied microscope photography utilizing a Jenoptik ProgRes C5 camera to acquire images for the BI analysis. The resulting uneven illumination was corrected by the software ProgRes CapturePro 2.7. Exposure was controlled by making use of a classical Kodak grey card. The used magnification of 0.7 results in an image resolution of about 5000 dpi. The application of microscope photography instead of scanning leads to higher resolved images, which is an advantage especially with regard to often relatively small latewood sections of alpine tree rings. Comparisons with scanner images confirm the higher quality and resolution of the microscope images (not shown).

A series of images were created for each core with defined, but relatively small overlaps that are necessary for the following combination of the images. A colour card was also enclosed and photographed to control the following BI measurements. For the image production, the software i-Solution (Image & Microscope Technology) was used to combine the single images into one picture per sample. The BI data were established by utilizing a version of the software LignoVision (Rinn 2014) that allows the selection of the blue colour channel only. For comparison, we also
applied the software CooRecorder (version 7.6) on some images. For the LignoVision-CooRecorder comparison, both maximum BI (MXBI) series were established as averages of repeated measurements on slightly different tracks to minimize possible data differences just due to somewhat diverging analysis tracks (Fig. 1). According to Björklund et al. (2014), δBI series were calculated by subtracting BI mean values of the earlywood (EWBI) from MXBI data. MXD and BI series from the same tree but of different length that occasionally resulted from slightly different tree-ring coverage of the different cores were shortened to the overlapping period. Chronologies for comparisons of the MXD and BI data were established by averaging the raw single series using the arithmetic mean, i.e. without applying any detrending. For this comparison, the MXD as well as the BI chronology was converted into z-scores (Fig. 3).

Figure 1. MXBI data measured with LignoVision and CooRecorder compared with MXD data of the same tree (mau-14). Note: The BI curve from CooRecorder is displayed with reversed y-axis.

Figure 2. Raw data series of MXBI (above) and MXD (below) of all analysed spruce cores.
Results

Comparison of the BI data obtained using LignoVision and CooRecorder revealed no major differences. Figure 1 shows the results for the tree mau-14 for the time period around 1800 in comparison with the MXD series from the same tree. For a better comparison the series are given in z-scores. The raw data of the two MXBI series (not shown) are usually on different data levels, i.e. CooRecorder gives higher (after inversion) values than LignoVision, but the course of the series is nearly identical (Fig. 1). The largest deviation is recorded for the year 1814 when both the LignoVision-MXBI as well as the MXD series indicates a very low value. The MXD series shows higher deviations but this is to be expected because the core was not the same. However, the differences between the MXD and MXBI series could also partly be due to the differing analysis techniques.

![Comparison of MXD, MXBI and δBI chronologies established as average series of the raw single series (Fig. 2) and plotted in z-scores. The chronologies (1721-2003) are based on up to 21 single series.](image)

The 21 BI and MXD series cover the period 1721 to 2007, a sample depth of more than 5 series is available from 1804 onwards (Fig. 2). The single series of both datasets show weak or even missing age related growth trends. Comparisons of the mean MXD series with the MXBI/δBI chronologies reveal high similarities even in the period 1721 to 1777, when just one tree is available (Fig. 3). This is underlined by correlation results of the raw data chronologies calculated for the period with a sample depth > 5: r=0.89 (MXBI-MXD) and 0.91 (δBI-MXD). The first differenced series correlate at 0.95 and 0.94, respectively.
A nearly linear correlation between MXD and δBI and especially MXBI data can be shown based on the data pairs of each tree and year (Fig. 4). Earlywood density (ED) and MXD data as well as BI data show nearly normal distributions (Fig. 5). EWBI and MXBI data show hardly any overlay and the shape of their data distribution are quite similar to the density data.

**Figure 4.** Regression diagram of MXD and MXBI (left) / δBI (right) values based on the data pairs of the single series (n=3731), with polynomial trend lines (2nd order).

**Figure 5.** Frequency distribution of BI and density data with normal distribution curves. EWBI/ED and MXBI/MXD data show similar distribution shapes and even the differences between the EWBI and MXBI as well as the ED and MXD data, respectively, are comparable.

**Discussion**

A comparison of the software tools LignoVision and CooRecorder based on the same sample photos shows no significant differences in the variability of MXBI data. However, the absolute data levels differ substantially: CooRecorder produced higher values (after mirroring the data) than LignoVision. We selected LignoVision for our analyses because LignoVision produces simultaneously earlywood, latewood and total-ring width data as well as four BI values (minimum and maximum values for earlywood and latewood, respectively, as well as mean values for both) for each analysed tree-ring. The established EWBI data provide the base for the δBI calculations.
The chosen sample preparation procedure – cutting, usage of chalk and microscope photography, instead of sanding and scanning – is different to the protocol suggested by Campbell et al (2011), but performed satisfying results if the MXD data from the same trees are considered as a benchmark. Microscope photography has high potential especially in the analysis of narrow rings, which are typical for alpine trees, because the magnification can easily be adjusted. The usage of chalk leads to a clear differentiation of the EWBI from the corresponding MXBI values. However, the workload of our preparation and analysis procedure is somewhat higher than the approach applied so far. Cutting instead of sanding is admittedly faster, but the usage of microscope photography and the stitching of the images as well as the utilization of LignoVision instead of CooRecorder is more time consuming.

Data distributions of the BI data are quite similar to the corresponding radiodensitometric data (Fig. 5). This is a clear difference to the BI data distributions after sample preparation by sanding (Björklund et al 2014). Moreover, MXD data show largely linear relationships to the corresponding MXBI data. In contrast the δBI / MXD relationship seems not to be completely linear.

Comparisons of the MXD with the MXBI / δBI chronologies reveal high correlations. This was found despite MXD and BI data being measured from different cores. At least in the case of spruce samples from living trees, BI analyses seems to be able to replace classical radiodensitometric analyses. However, spruce does not have discoloration of the heartwood as other species do, e.g. scots pine. Further tests of the BI approach are necessary on more challenging species, e.g. larch (Larix decidua) or cembran pine (Pinus cembra), but also on discolorated wood like subfossil samples from peat bogs.

Conclusions

- Parallel cores of living spruce trees, for which MXD data were available, were used for BI analyses.
- A different preparation protocol (resin extraction, cutting of the wood, preparation with chalk, microscope photography) was applied.
- The established MXBI / δBI chronologies show high similarities with the corresponding MXD chronology.

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References


