Climate reconstructions from tree-ring widths for the last 850 years and the need for new tree-ring proxies in northern Poland

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The facts

- Long chronologies used for temperature reconstructions are mainly from the high latitudes or high altitudes
- Long chronologies consist largely of tree-ring widths and density

- Long temperature reconstructions derived from temperate lowland trees growing well within their distributional limits are missing

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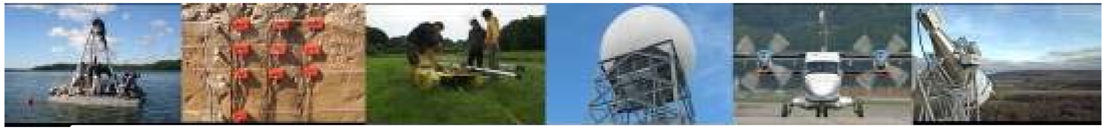
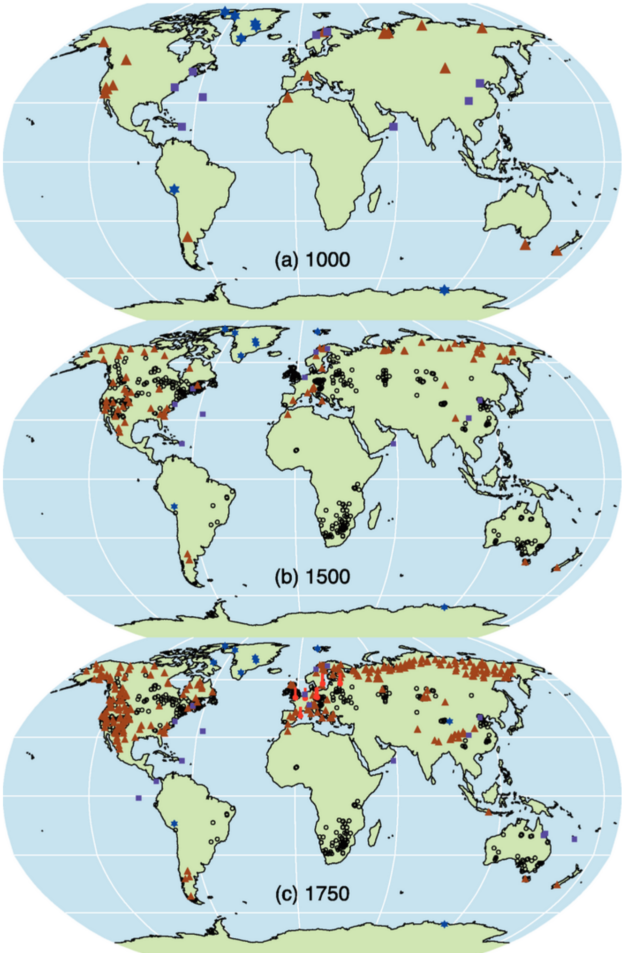
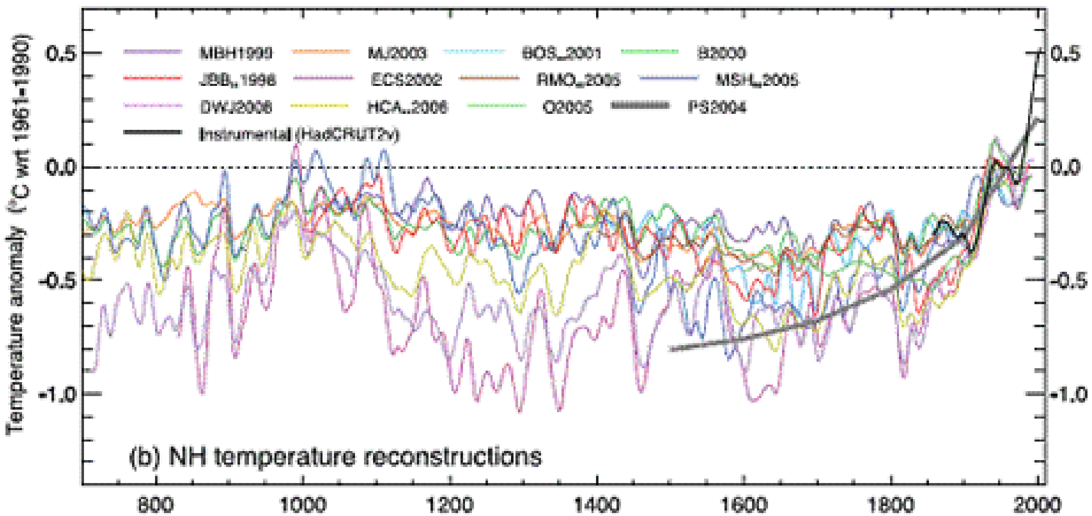


The question

? How representative are our regional, global and hemispherical temperature reconstructions?





Northern Hemisphere temperature reconstructions. Graph: IPCC 2007

The task

Develop long climate reconstructions (especially temperature) for the temperate lowlands

Major challenges

⇒ Challenge 1: climate-growth relationships are less clear.

Light

Precipitation

Temperature

Competition

Insects

Drought/Frost

Diseases

Soil water

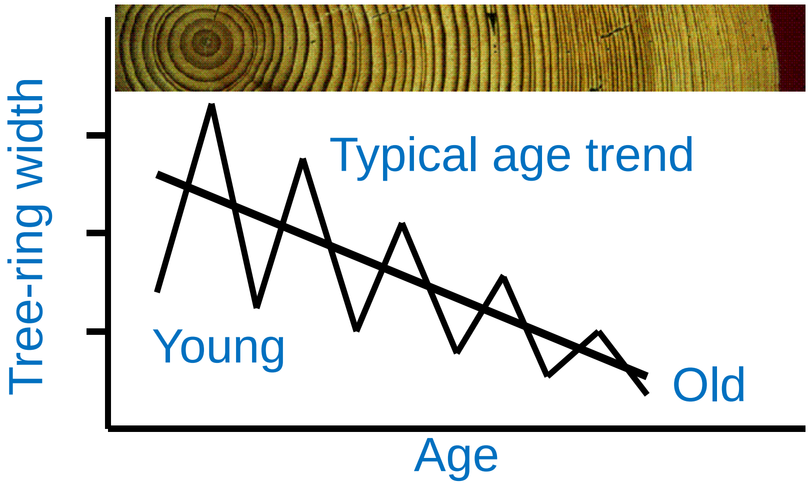
Ground water

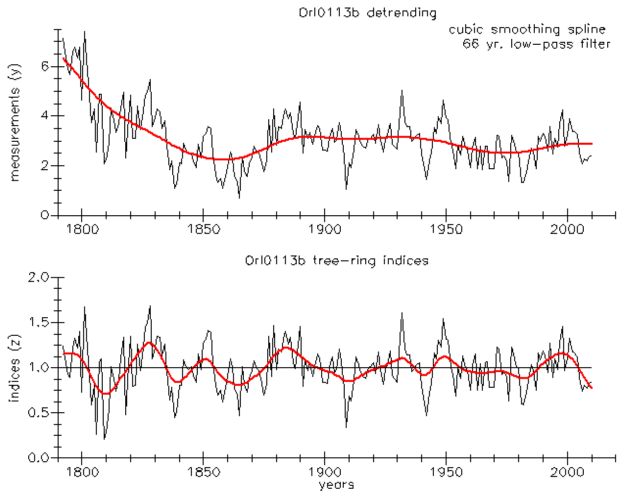
Major challenges

⇒ Challenge 2: trees well inside the distribution of the species are often young

and so

☹ tree-ring width series from young trees have relatively short segment lengths and thus are prone to suffer the “segment length curse”.





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General approach to

- Monitor growth and environmental controls of the three most common tree species (oak, beech, pine) => TERENO
- Develop and apply new methods (high resolution stable isotopes, CLSM and quantitative wood anatomy, CLIMTREG) for proxies with more significant or additional climate signals
- Working together with dendroarchaeologists is crucial to facilitate long chronologies in the temperate lowlands

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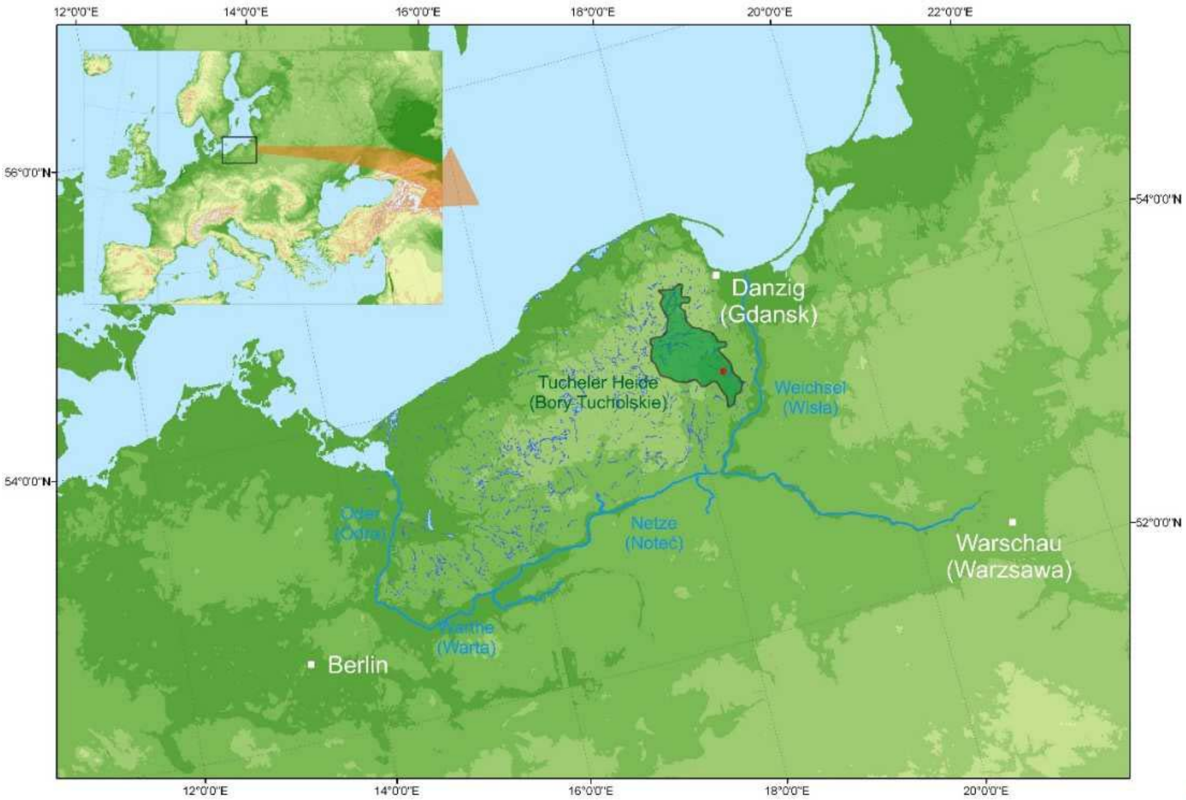
Study site

- Samples of *Pinus sylvestris* and *Quercus* spp. from Northern Poland combined with archaeological material from the region



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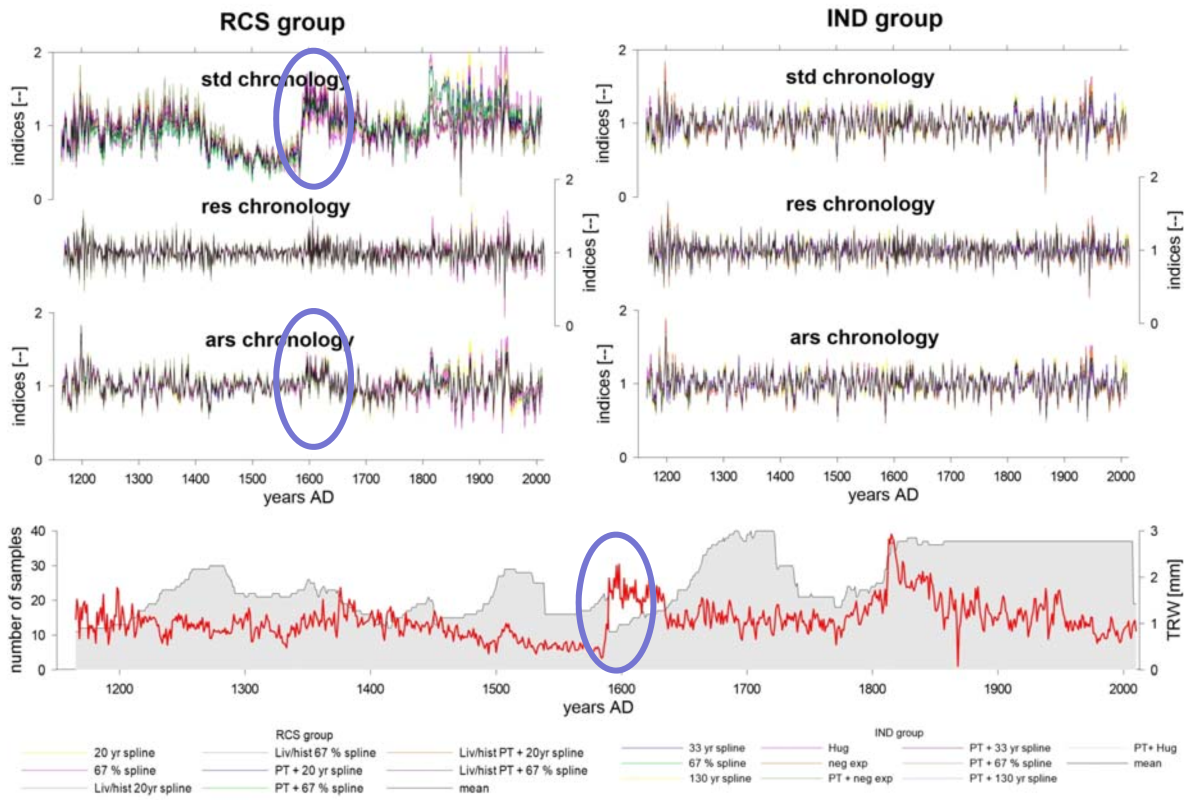
Pine chronology

- Various detrending techniques are applied including ‘individual’ (IND) and regional curve standardisations (RCS) => 54 Chronologies
- In IND only minor differences between std, res and ars, but larger modifications in the RCS
- IND chronologies show only high frequency variances, whereas the RCS chronologies reveal also multi-decadal trends.
- But some problems.



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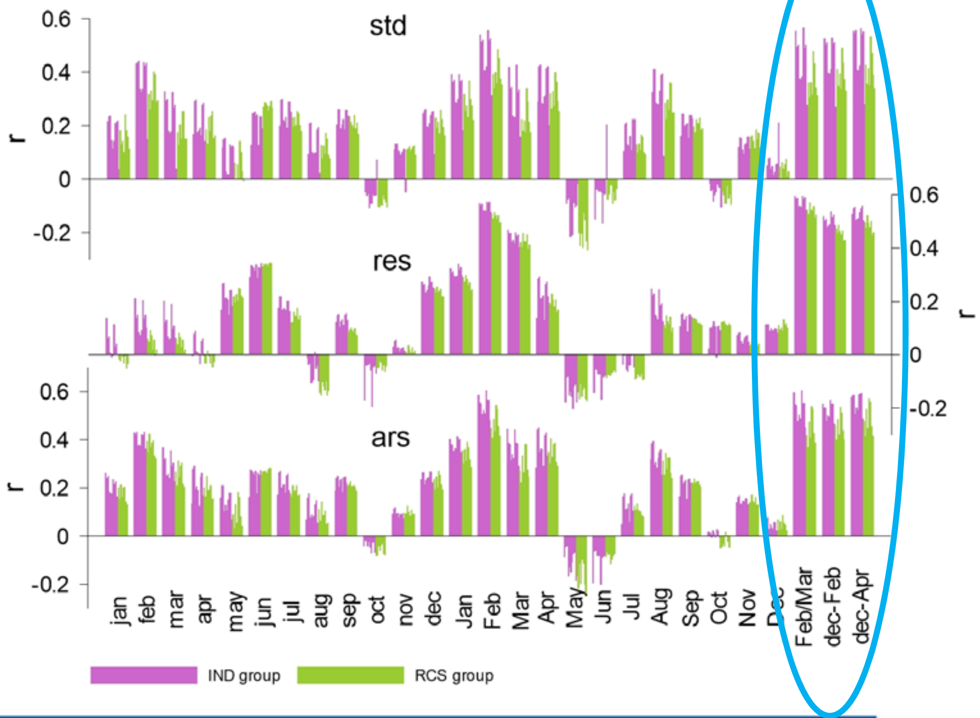
Climate response analysis

- Climate response analysis was conducted using nine 0.5 x 0.5 grid points from the CRU-data set (min, max, mean temp; precip; 1951-2009) and calculating simple Pearson's correlation coefficients.
- Best correlations within the IND group and residual chronologies.
- Strongest correlation coefficients (r = 0.54 – 0.61) with late winter temperatures (February/March).



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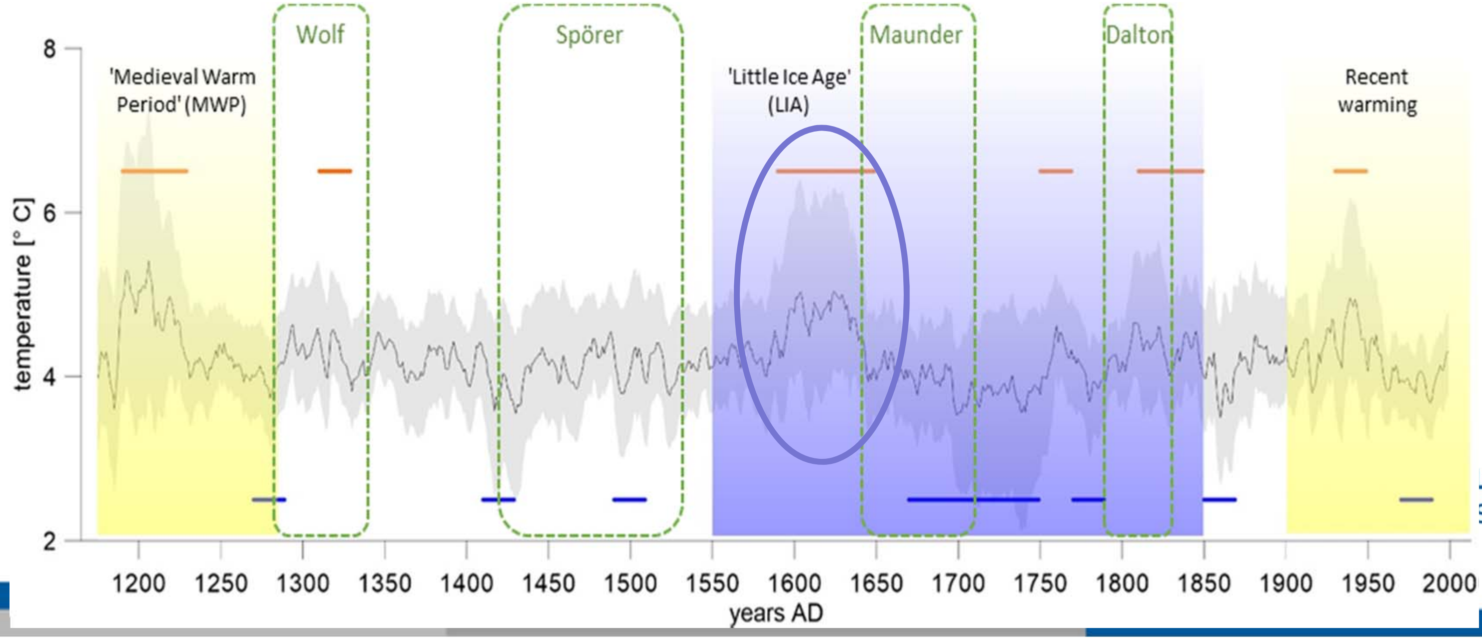
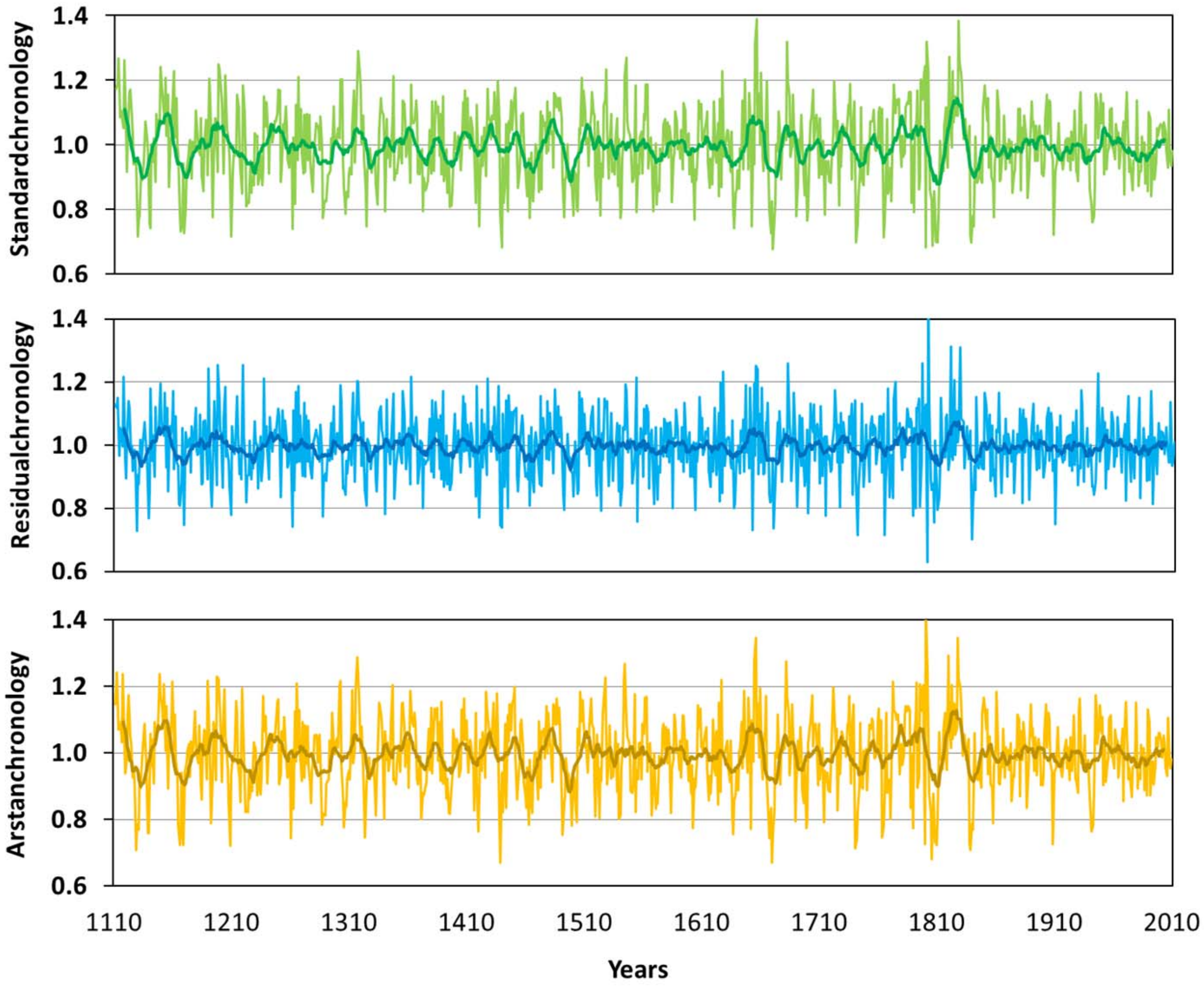
Reconstruction of Feb-to-Mar max temperatures

- 4 possible reconstructions based on two IND and two RCS chronologies were established, using cross calibr / verif procedure by splitting the climate data and tree-ring widths into two similar time periods
- Grey area: ranges between highest and lowest values reconstructed for each year out of 4 possible reconstructions; black line: average reconstr.).
- Yellow and blue background define known warm and cold phases
- Red and blue lines represent 10 warmest (upper) and coldest (lower) 20-year intervals as indicated by the reconstruction.



Oak chronology

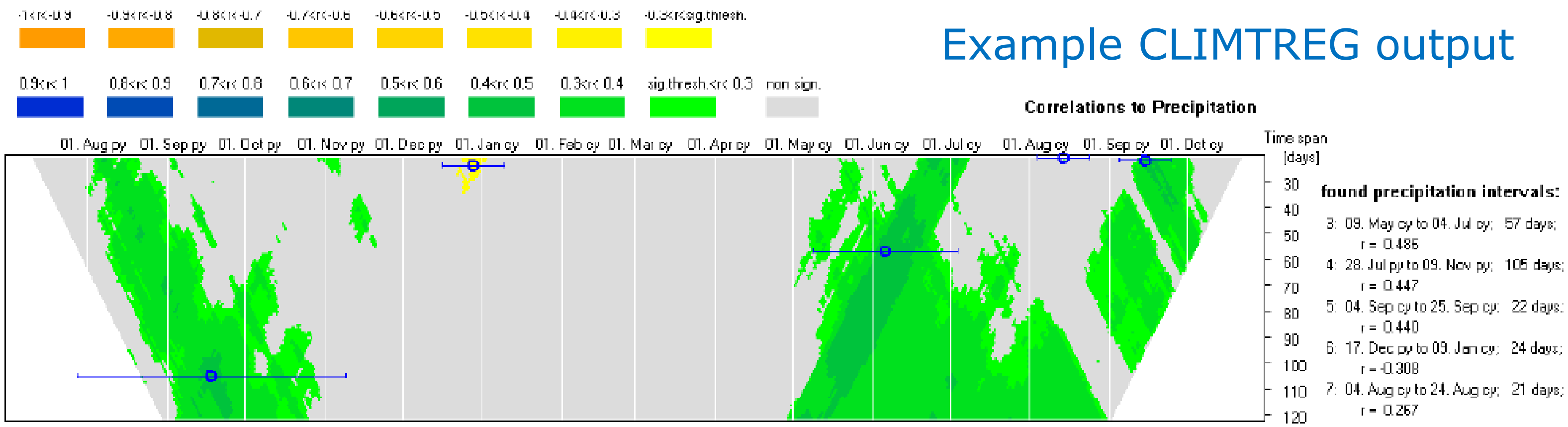
- Orle Nature Reserve and East-Pommerania-Chronology



Climate response analysis

Climate response analysis was conducted using CLIMTREG program

Example CLIMTREG output



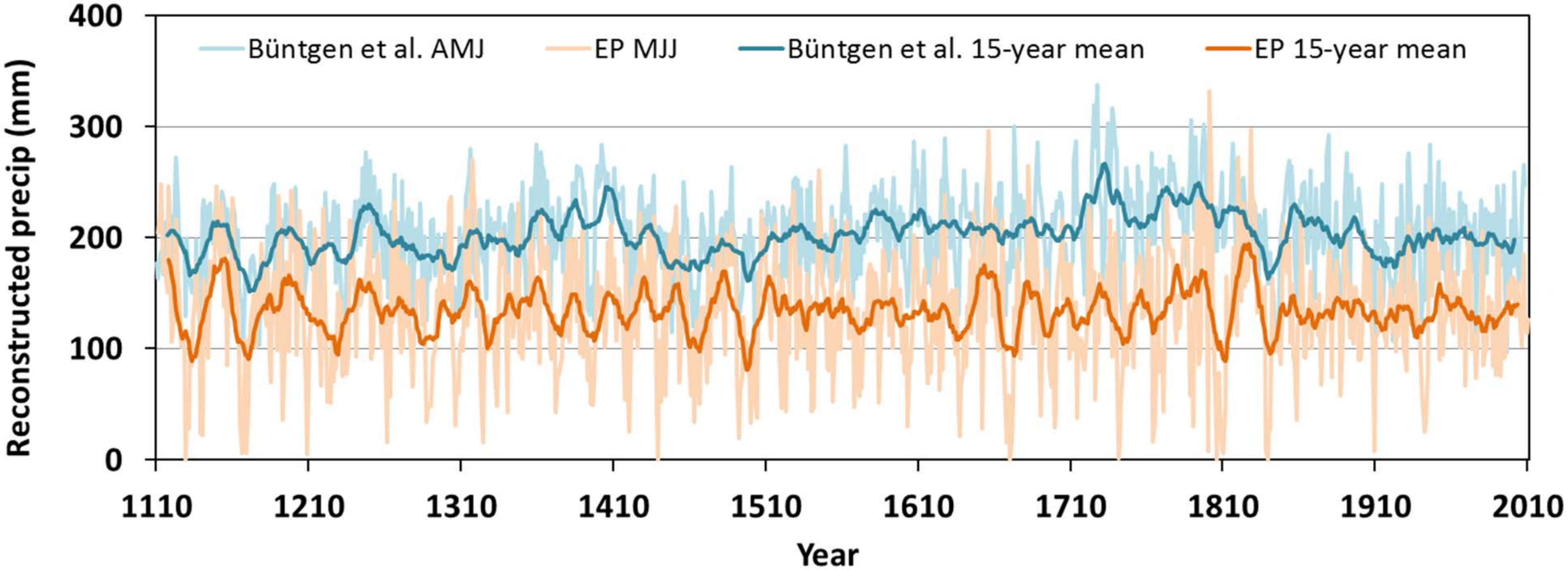
Best correlation with summer precipitation (May-July)

	Gdansk	Koscierzyna
EP std	11.05.cy - 14.07.cy / 0,619	09.05.cy - 12.07.cy / 0,516
EP ars	11.05.cy - 14.07.cy / 0,634	09.05.cy - 04.07.cy / 0,486
EP res	01.05.cy - 13.07.cy / 0,567	23.06.cy - 13.07.cy / 0,443
EP std	07.09.cy - 24.10.cy / 0,418	08.09.cy - 30.09.cy / 0,437
EP ars	08.09.cy - 28.09.cy / 0,403	04.09.cy - 25.09.cy / 0,440
EP res	07. 09.cy - 20.10.cy / 0,412	08.09.cy - 10.10.cy / 0,501

Reconstruction of May-to-Jul precipitation

- Comparison with Apr-Jun of Büntgen et al (France/Germany) confirms good quality of our reconstruction from Poland.
- Very similar decadal trends, especially in the first part.

- But : No long-term trends



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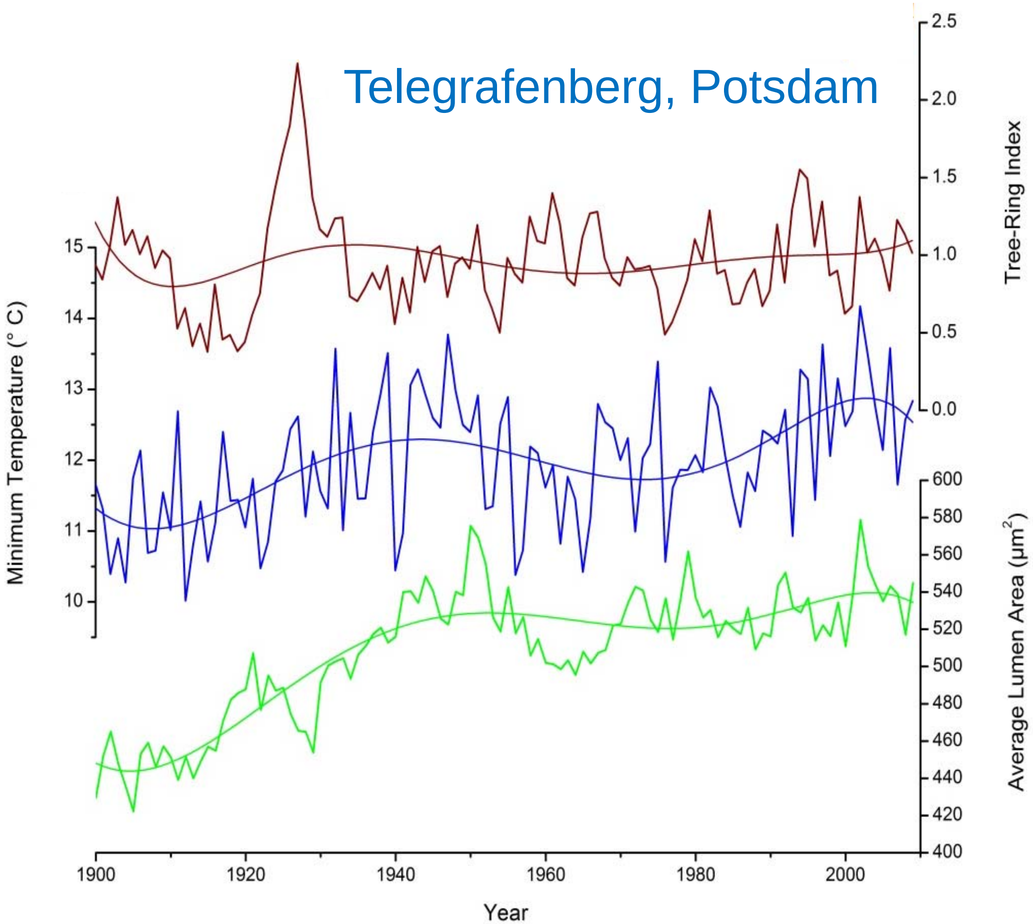
Comparison of tree-ring width index (brown), minimum temperature (blue) and average lumen area (green)



- Tree-ring width must be detrended, but ALA not;
- Correlation of raw ALA and Min temp is r = 0.50;
- Correlation of tree ring index and Min temp is r = 0.27;
- The low-frequency trends of ALA and Min temp are very similar;
- ALA captures low-frequency temp trends and can exorcise the segment length curse;

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Preliminary conclusions

- Oak and especially pine chronology encountered detrending problems;
- Oak TRW chronology is mainly sensitive to precipitation which has been reconstructed by Büntgen et al. extensively;

which means that we still need to retrieve from the series

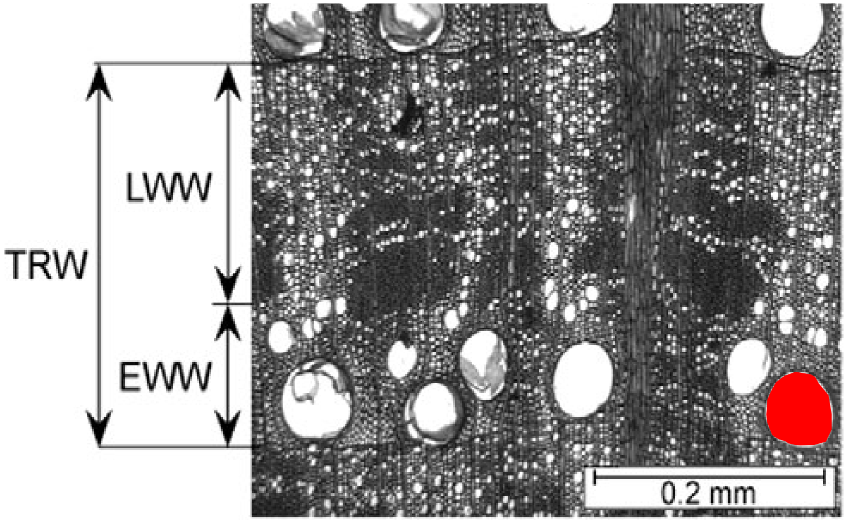
- Low-frequency climate signals;
- Temperature signals rather than precipitation.

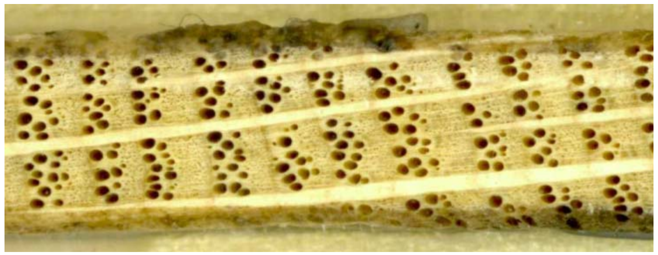
To achieve this, we are concentrating on other wood parameters:

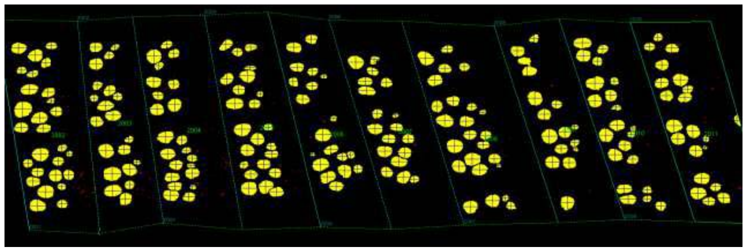
- Stable isotopes and Quantitative wood anatomy

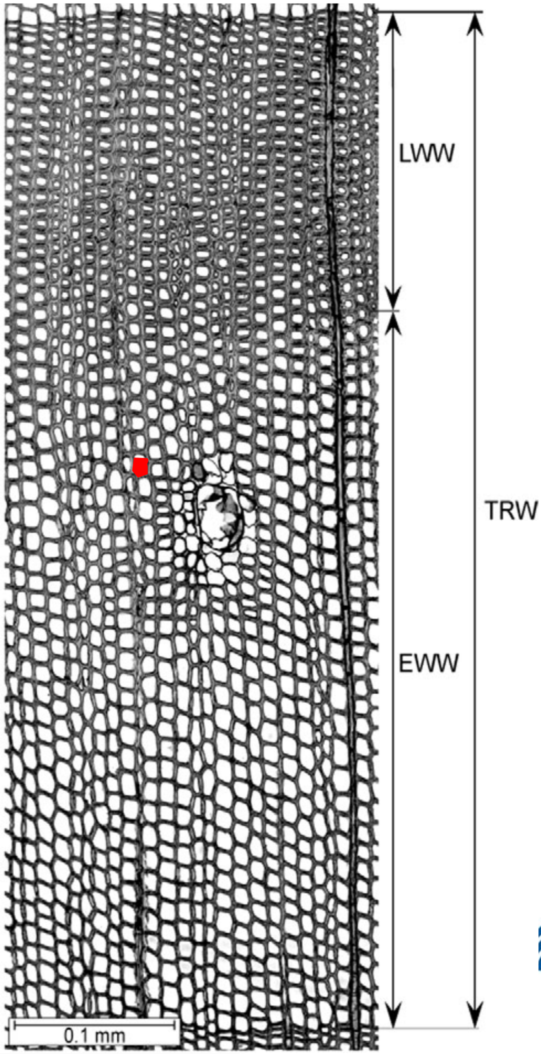
Climate signals derived from cell anatomy

- Some large vessels of oaks versus Many small tracheids of pines

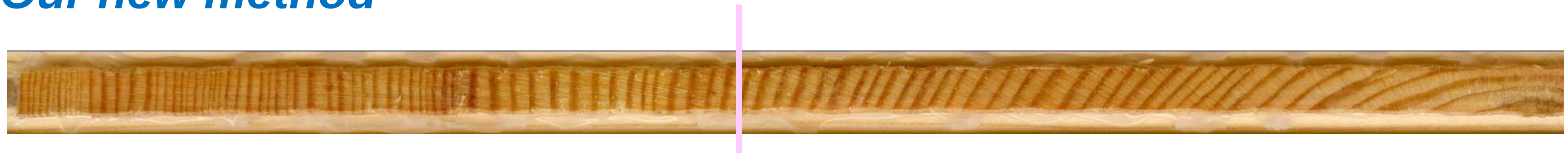


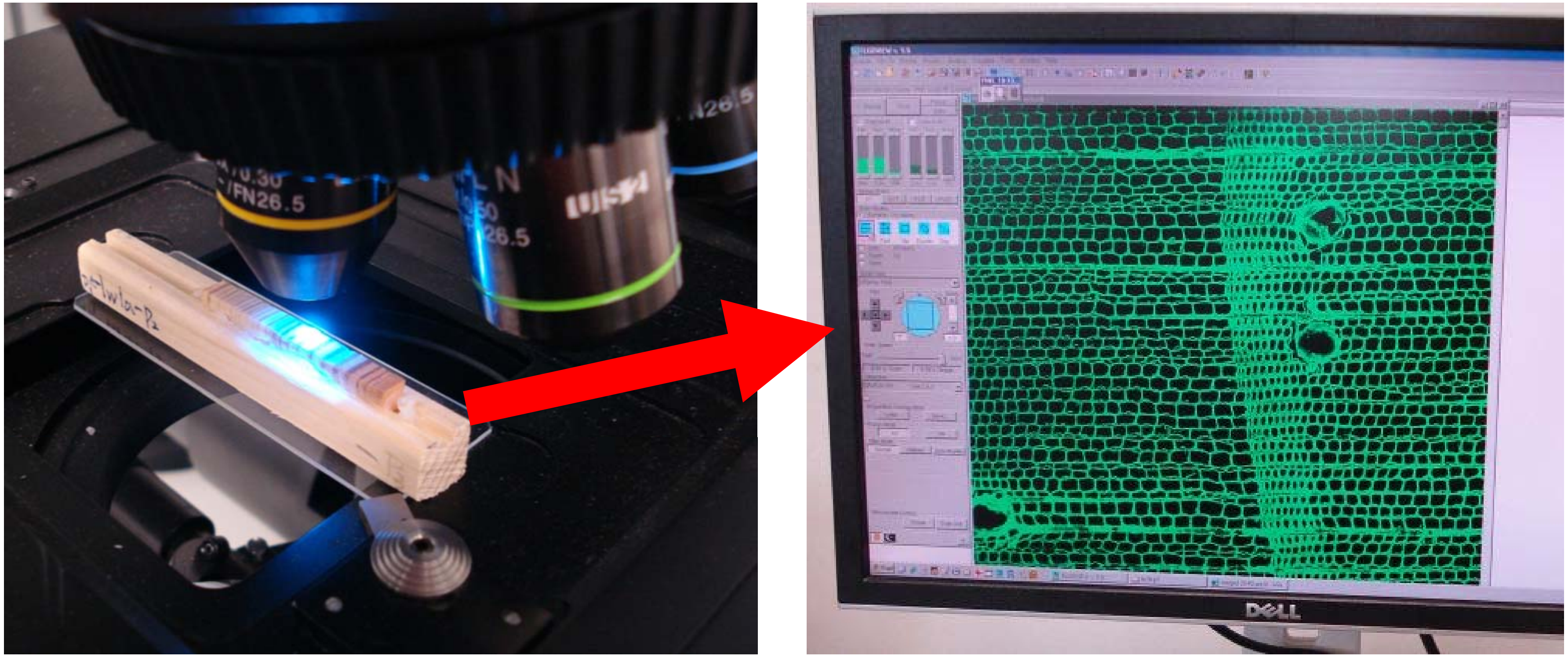






Quantitative wood anatomy
Our new method





- Core samples can be used without further treatments

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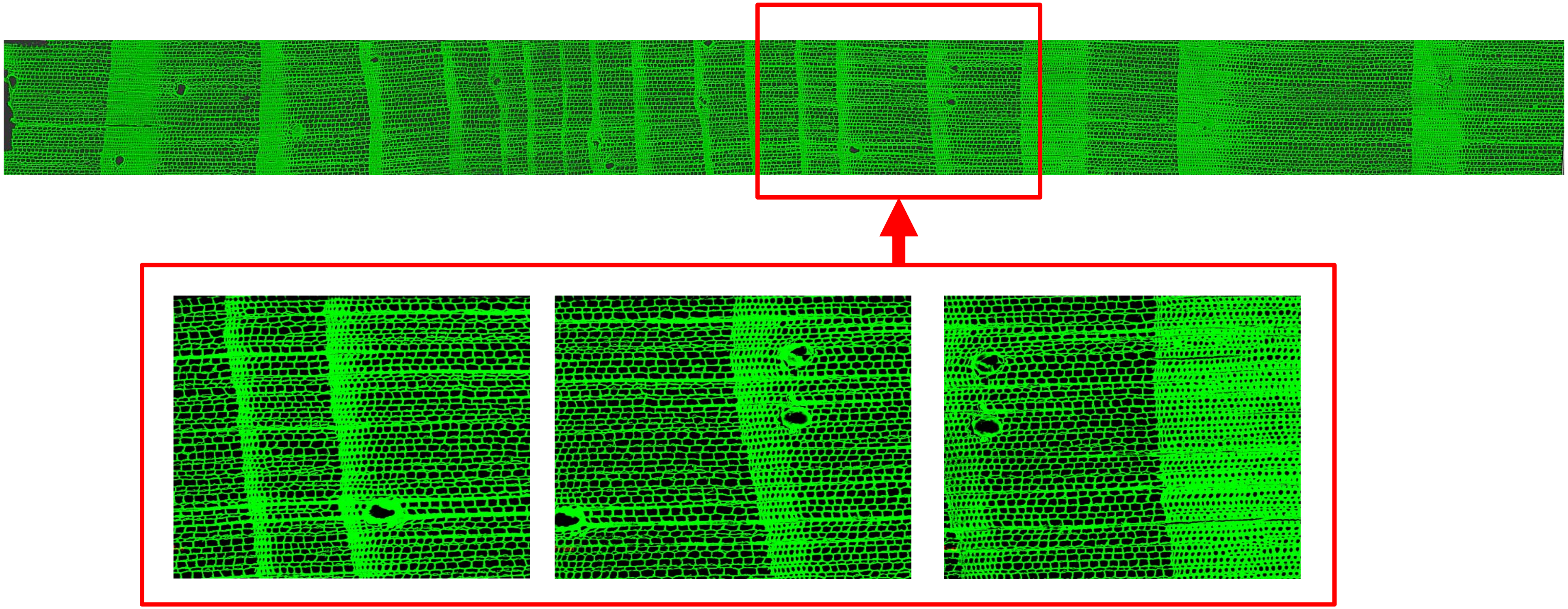
Confocal Laser Scanning Microscopy

- Example:

One image containing several merged images



Individual successive images (Magnification: 100x)

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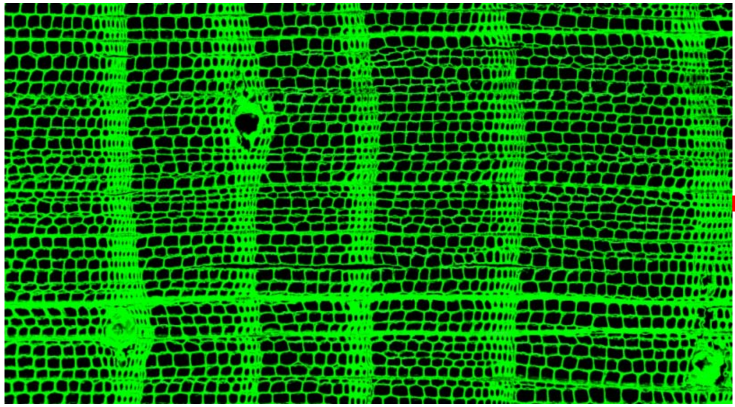
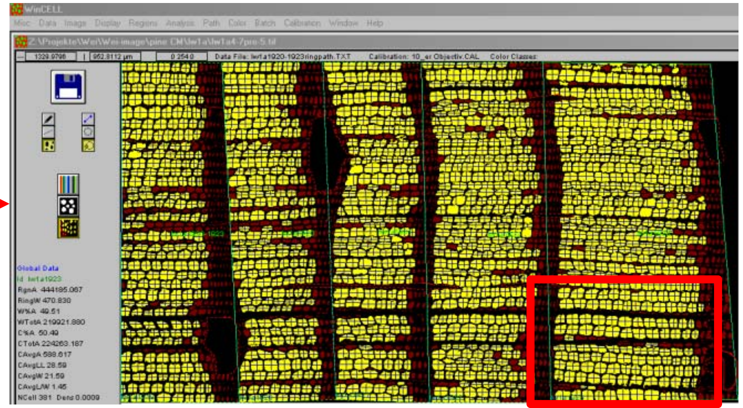
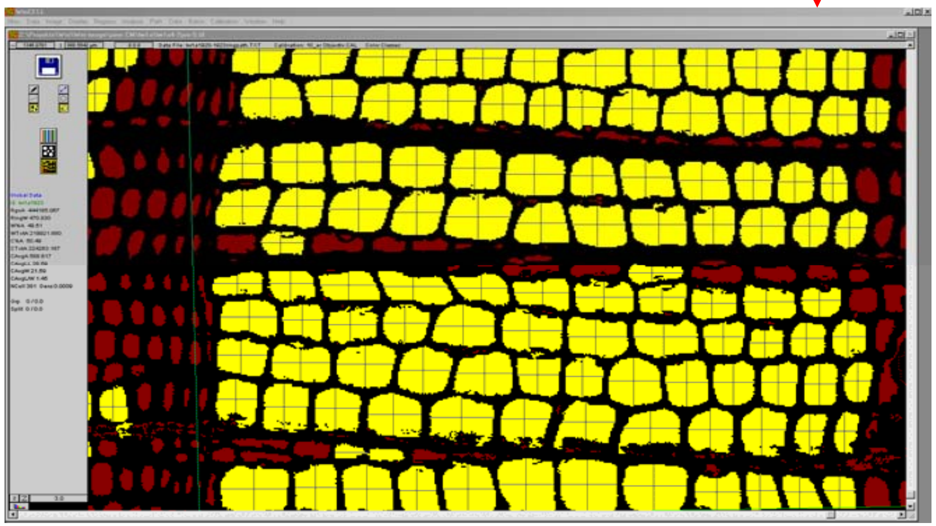
Cell structure measurements with WinCELL





Advantages of the new approach

- No thin sectioning necessary
- No staining necessary
- No geometrical distortions
- Easy and error-free merging
- Monochrome images optimise contrast between cell lumen and cell wall and thus facilitate easy analysis with WinCELL



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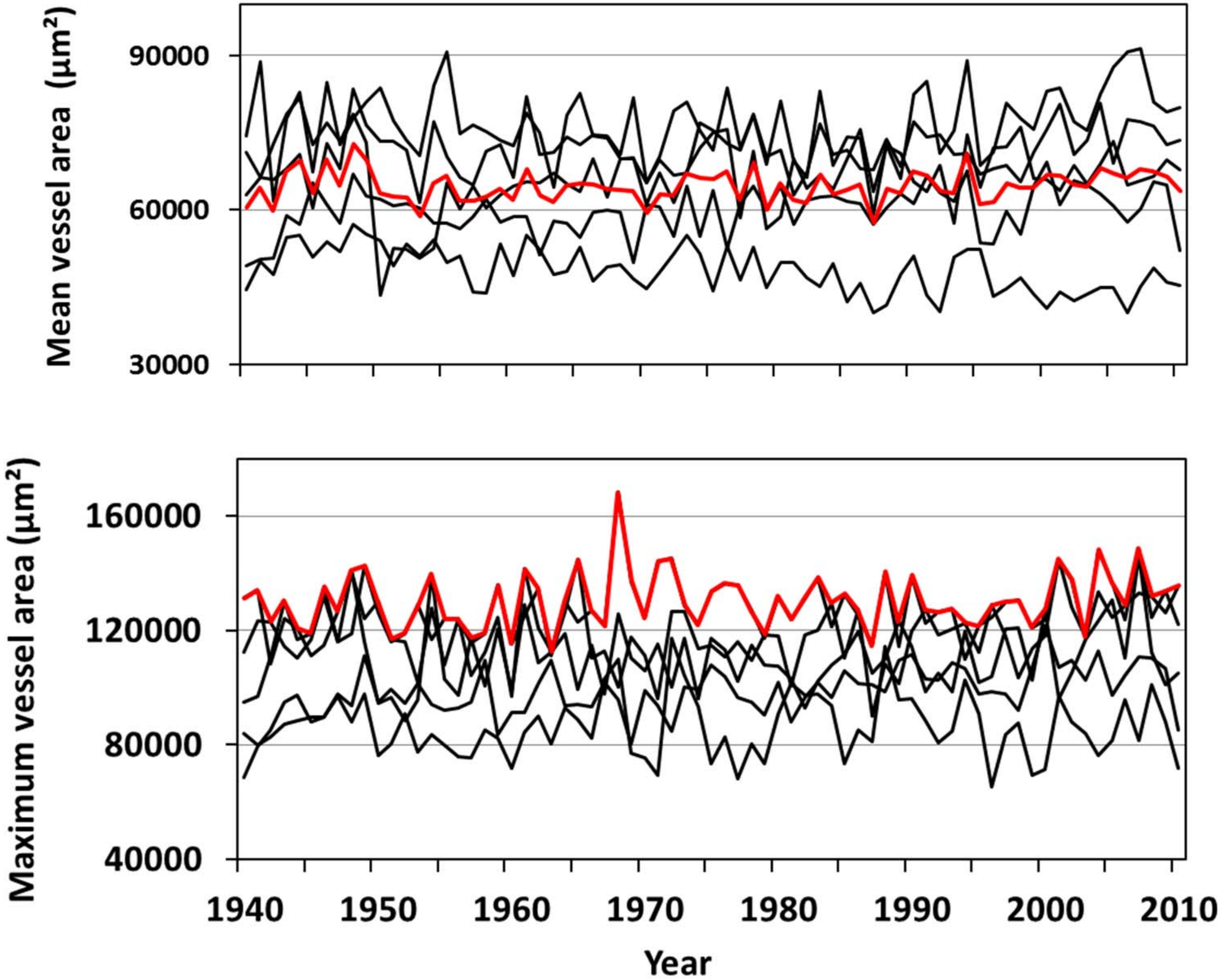
Preliminary oak vessel chronologies



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Climate response analysis - oaks

- Strongest correlation coefficients (r = 0.54 – 0.6) with autumn-to-winter temperatures (August - January).

Cells avg	Gdansk	Koscierzyna
T min	29.11.py-19.01.cy / 0,576	29.11.py-19.01.cy / 0,585
T mean	29.11.py-19.01.cy / 0,567	29.11.py-19.01.cy / 0,566
T max	29.11.py-19.01.cy / 0,578	29.11.py-19.01.cy / 0,582
T min	08.03.cy-09.05.cy / 0,415	25.02.cy-17.03.cy / 0,377
T mean	06.03.cy-09.05.cy / 0,404	02.03.cy-09.05.cy / 0,372
T max	06.03.cy-09.05.cy / 0,383	02.03.cy-11.05.cy / 0,362

Cells max	Gdansk	Koscierzyna
T min	03.09.py-25.12.py / 0,549	03.09.py-25.12.py / 0,500
T mean	28.08.py-26.12.py / 0,604	28.08.py-26.12.py / 0,591
T max	14.09.py-27.12.py / 0,576	14.09.py-27.12.py / 0,564
T min	16.03.cy-05.04.cy / 0,327	15.03.cy-24.04.cy / 0,343
T mean	14.03.cy-10.05.cy / 0,371	14.03.cy-11.05.cy / 0,379
T max	14.03.cy-23.04.cy / 0,393	13.03.cy-12.05.cy / 0,369

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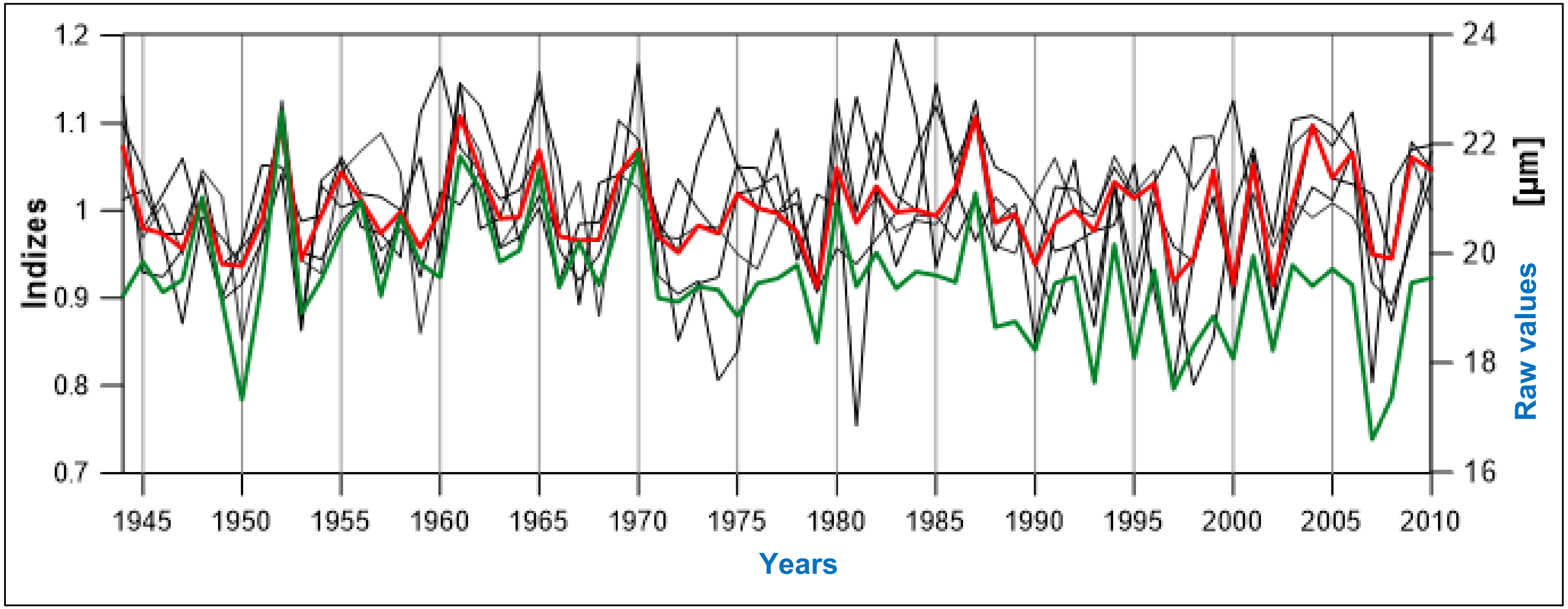
Preliminary pine tracheid chronologies

- Green curve: raw values; red curve: indices.



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Climate response analysis - pines

- The same climate data.
- Strongest correlation coefficient (r = - 0.66) with late winter-to-summer temperatures (February - June).

	Lumen width	Lumen length	Lumen area
Temperature	21. Jan.-10. Feb.: **-0,47**	13. Feb.-13. Jun.: **-0,66**	28. Mrz.-13. Jun.: **-0,59**
	21. Apr.-29. Mai: **-0,46**	8. Jan.-12. Feb.: **-0,48**	8. Jan.-12. Feb.: **-0,43**
Precipitation	25. Jul.-26. Aug.: **0,50**	11. dez.-17. Mrz.: **-0,41**	10. Jan.-19. Mrz: **-0,51**
	24. aug.-20.dez.: **-0,43**	31. aug.-14.nov.: **-0,35**	24. aug.-17. okt.: **-0,43**

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Conclusions

- Multi-centennial temperature and precipitation reconstructions for Poland based on Scots pine and oak TRW
- However, reconstructions lack low-frequency climate signals
- Wood anatomical parameters show excellent correlation patterns with temperature when using raw values
- New method utilizing CLSM will facilitate long chronologies of well replicated cell structure series which are sensitive to temperature
- Long temperature reconstructions for the temperate lowlands based on tracheid and vessel parameters are next!

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Thank You!

- Liang, W.; Heinrich, I.; Helle, G.; Dorado Liñán, I.; Heinken, T. (2013): Applying CLSM to increment core surfaces for histometric analyses: A novel advance in quantitative wood anatomy. *Dendrochronologia* **31**, 2, 140-145.
- Liang, W.; Heinrich, I.; Simard, S.; Helle, G.; Dorado Liñán, I.; Heinken, T. (2013): Climate signals derived from cell anatomy of Scots pine in NE Germany. *Tree Physiology* **33**, 8, 833-844.

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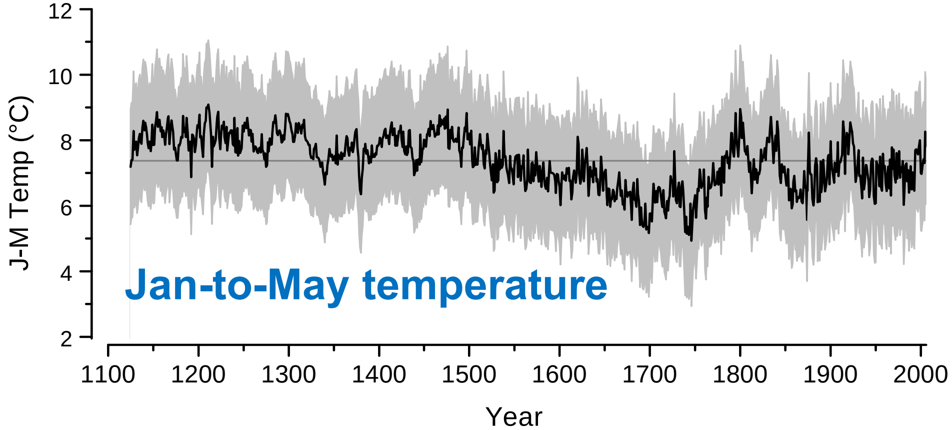
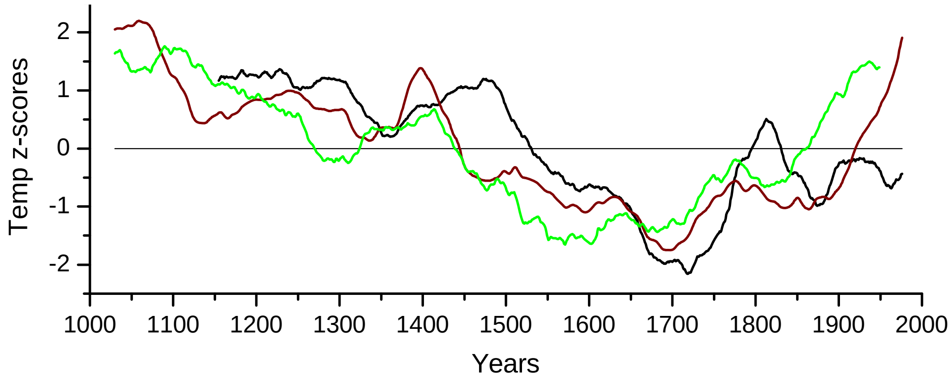
First temp reconstruction based on δ^{13}C in trees from Turkey



- Multi-decadal to centennial variability
- Above average: 1125 and 1480
- Temperature decreases: 1500 - 1700
- Temperature fluctuates: 1700 - 2006

Comparison with two NH temperature reconstructions (Mann et al. 2008, brown, and Moberg et al. 2005, green)



- Share common long-term trends
- But no temperature rise in Turkey during the 20th century

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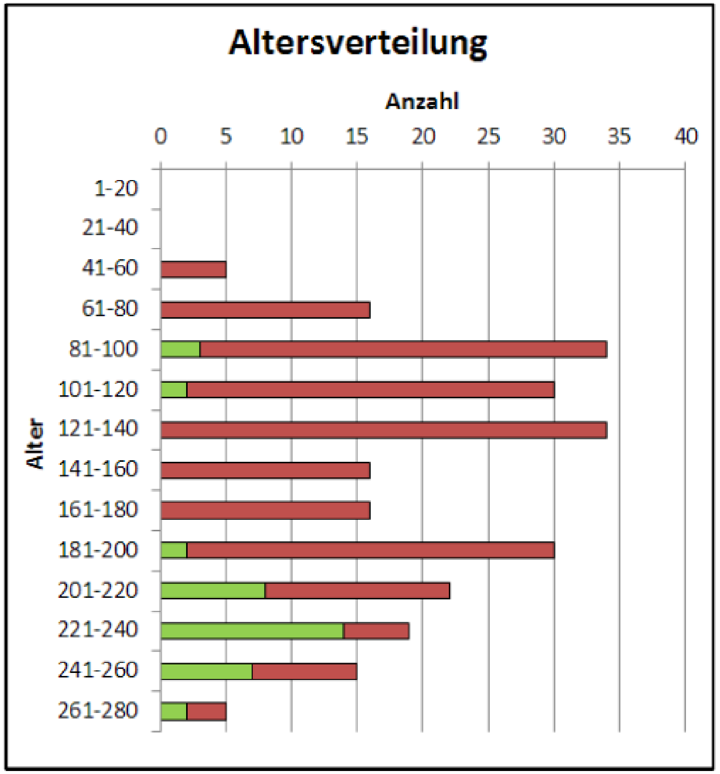
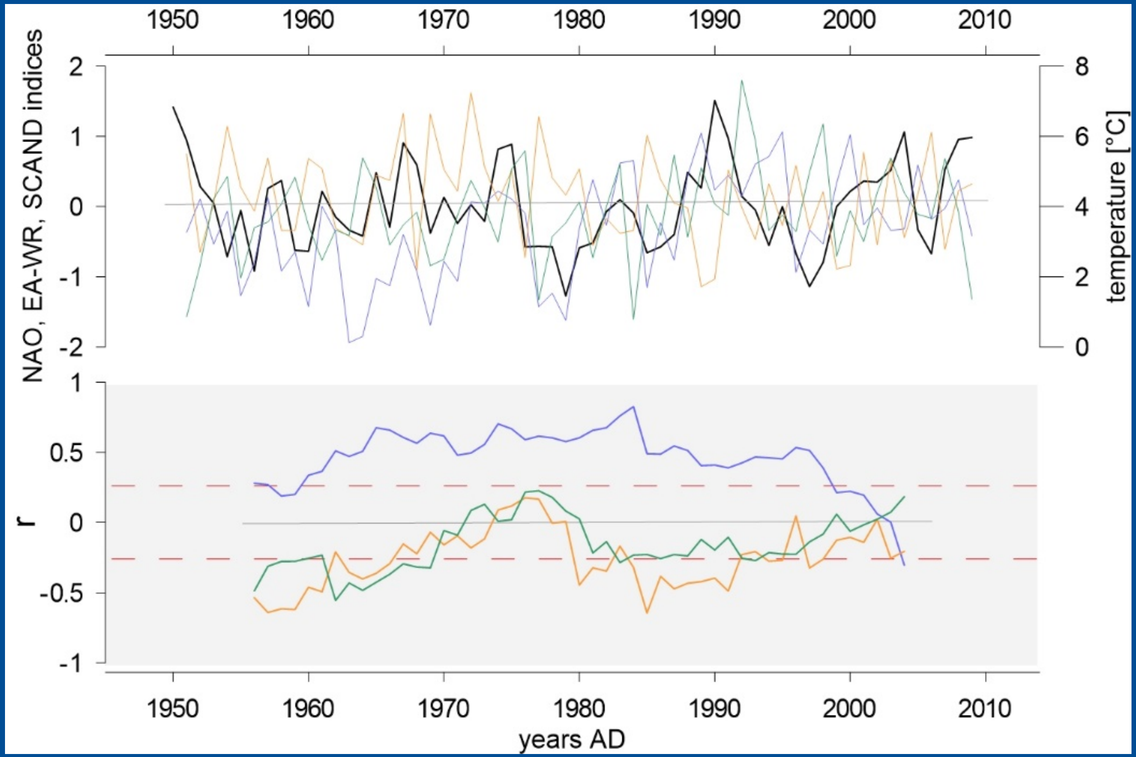
Tabelle 2: statistische Kennwerte der Orle- und der EP-Chronologie

Chronologie	Anzahl Proben	Mindest-alter	Höchst-alter	Ø-Alter	r	S
Orle	37	84	263	213	0,57	0,20
EP	242	44	278	154	0,51	0,20



Altersverteilung der Proben, grun dargestellt sind die Proben aus dem Orle Nature Reserve, rot dargestellt sind die Proben von Wazny (1990)

Reconstruction correlates significantly with winter NAO, but only marginally with other atmospheric circulation patterns likely affecting the winter climate in Europe.



11-year running correlations (1950-2010 AD) between reconstructed Feb-to-Mar max temperatures (black) and the North Atlantic Oscillation (NAO, Dec-Feb, blue), Scandinavia pattern (SCAND, Dec-Apr, orange) and East Atlantic-Western Russia (EA-WR, Jan-Mar, green) indices, respectively. Significant and mostly stable correlations are only observed with the winter NAO. The temporal stability disappears in the last 15 years.