Late Glacial Environmental and Climatic Changes from Synchronized Terrestrial Archives of Central Europe: The Network PROSIMUL

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The network project PROSIMUL (Proxy-based and simulated climate variability) is part of DEKLIM's Young Scientist Programme. In our project, we work on Late Glacial and Holocene high resolution proxy data from lake sediments and tree rings, and their synchronization. Our studies continue and extend the successful approach of the national KIHZ project ("Climate in historical times"). The project closely cooperates with the DEKLIM project "Paleo Isotopes" and constitutes a high resolution counterpart to the project "Cli-Trans". The datasets will be used to validate existing climate models, for an improved capability of these models to evaluate the climatic variability of the past and the future.

Periods of strong climatic variability in the Earth's history offer the opportunity to gain insights into climatic forcing mechanisms. The Late Glacial was a period of strong natural variability and abrupt climate changes. Its climatic variability is well-documented in numerous different paleoclimatic archives but up to now synchronization and interpretation of leads and lags has been problematic due to different time scales of the archives. Here, we present synchronized proxy data from a tree-ring chronology (Central Europe, ring-widths) and from lake sediments of a small maar lake (Lake Meerfelder Maar (LMM), stable isotopes in sediments, minerogenic accumulation rates) and a large prealpine lake in Central Europe (Lake Constance, stable isotopes in ostracodes).

Synchronization of the archives is based on recently revised tree-ring chronologies and ^{14}C-calibration of the Late Glacial and Early Holocene as part of the INTCAL04 dataset (Friedrich et. al., in press, Kromer et al., in press, Reimer et al., in press) compared to the chronology of LMM (Brauer et al., 2000). An integrated interpretation of the proxy data provides additional information on the environmental processes related to climate change.

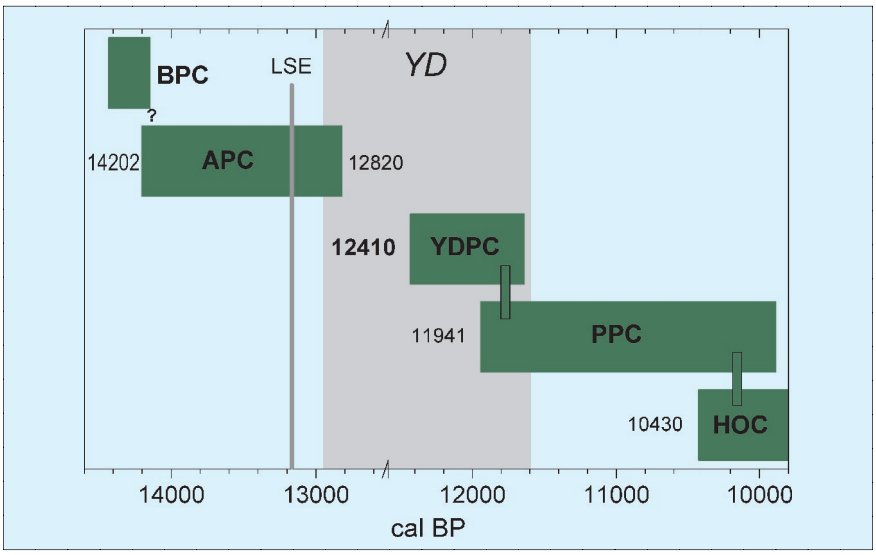

Fig. 1: Compilation of the Late Glacial and Early Holocene tree-ring chronologies. The absolute part of the chronology is given on the tree-ring timescale, the floating parts on the Cariaco timescale (Hughen et al. 2000). The Holocene oak (HOC), Preboreal pine (PPC) and Younger Dryas pine (YDPC) are combined to the absolutely dated chronology, starting at 12,410 years BP. The Bølling pine (BPC) is tentatively linked to the Allerød pine (APC), which reaches into the Younger Dryas (grey box). The position of the LSE is indicated as a grey line.

Chronological Framework

Tree-Ring Chronologies and ^{14}C-Calibration

The tree-ring part of the project is based on the work on Holocene and Late Glacial tree-ring chronologies of subfossil oaks and pines found at different sites in Central Europe. We revised and extended the absolutely dated Hohenheim oak and pine tree-ring chronology of Central Europe into the central Younger Dryas (YD). The chronology now starts at 12,410 BP (Friedrich et al., in press). According to the YD-Preboreal transition at 11,590 BP seen in the abrupt increase of our ring-width chronology (Friedrich et al. 1999; Friedrich et al., in press), the absolute tree-ring chronology covers 820 years of the YD and the Holocene (Fig.1). High precision ^{14}C-data of decadal tree-rings of this chronology are the base for the International Calibration (INTCAL04) (Reimer et al., in press.). Additionally, a floating 1382-ring pine chronology covering the ^{14}C age of 12,000 to 10,650 BP (chronozones Allerød/early YD) was established (Kromer et al., in press). To anchor the floating tree-ring chronology in time, we compare the decadal ^{14}C-series of this chronology to the Cariaco varve chronology (Hughen et al., 2000) using the strong ^{14}C age drop at the Allerød-YD transition and the high frequency δ^{14}C-fluctuations of both series. We observe a higher marine reservoir correction for the Cariaco site of up to 650 years, instead of 400 for the comparison interval (Kromer et al., in press). Based on a dendrochronological link, supported by a ^{14}C-wiggle match of a tree-ring series of poplars that grew 10 km SE of the Laacher See Eruption (LSE) site and which were buried 'in situ' by the eruption, we obtained a precise age for the Laacher See tephra (LST), which is a prominent marker layer of the Late Glacial in Central Europe.

Lake Meerfelder Maar Varves

The chronology of LMM (6°52'E, 50°07'N) is based on continuous varve counting, controlled by the tephra markers LST (12,880 BP) and

Ulmener Maar Tephra (UMT, 11,000 BP) and was additionally controlled by AMS ^{14}C dates (Brauer et al., 2000). The YD is defined as biozone according to Litt and Stebich (1999).

Lake Constance Sediments

The chronology of a sediment core taken at a water depth of 188 m from Lake Constance (9°15′E, 47°39′N) is defined by ^{14}C dating and is anchored to the LST according to its revised age derived from the new tree-ring chronology (Friedrich et al., in press (a), Kromer et al., in press). The onset of the YD is set according to the revised tree-ring chronology, while the end is ascribed to the combined signal of decreasing $\delta^{18}O$ in the ostracodes, to a sharp decrease in magnetic susceptibility and to increasing biogenic calcite content.

Synchronization of the Chronologies

For comparison of proxy records from pine tree-rings and from varved sediments of LMM, we use their own independent chronologies to avoid bias. Following this strategy of independent chronologies, we found good age agreement for the YD-Preboreal transition but a significant age discrepancy for the Allerød-YD boundary. This became obvious from the different age of the LSE in both records. Using the LST as a relative time marker, a meaningful comparison between the archives is possible and changes in the proxies can be investigated independent from absolute age.

Climate Change from Lacustrine and Tree-Ring Proxies

Proxy data time-series from our archives are given in Figure 2. The isotopic composition ($\delta^{18}O$) of benthic ostracodes *Leucocythere mirabilis* and *Limnocythere sanctipatricii* from Lake Constance (Fig. 2a) closely tracks the isotopic composition of precipitation in the high alpine and alpine foreland regions (Schwalb 2003). The total ring-widths of Late Glacial German pines (*Pinus sylvestris* L.) (Fig. 2b) reflect growth conditions of the growing season, i.e.

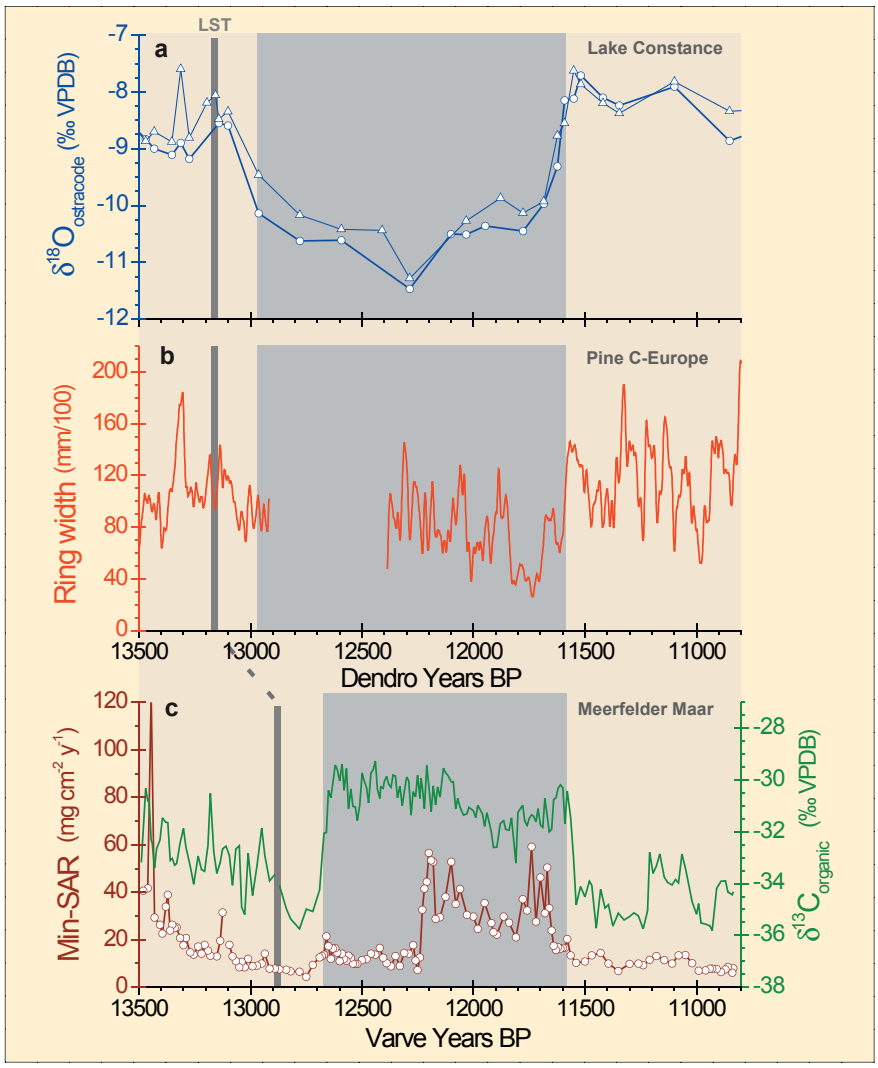

*Fig. 2: Comparison of climate proxies from different archives on their respective timescales. (**a**) Lake Constance: oxygen isotope composition of benthic ostracods Leucocythere mirabilis ($\delta^{18}O_{ostracods}$, blue triangle) and Limnocythere sanctipatricii ($\delta^{18}O_{ostracods}$, blue circle). (**b**) Smoothed tree-ring width of the revised absolutely dated German Holocene pine chronology and the floating pine chronology of the Late Glacial anchored by ^{14}C-wiggle match to the Cariaco varve record. (**c**) Lake Meerfelder Maar: specific accumulation rate of sedimentary minerogenic matter (Min-SAR, brown) and carbon isotope composition of mainly autochthonous sedimentary organic matter ($\delta^{13}C_{OM}$, green) from the lakes profundal.*
The YD stadial is highlighted as grey boxes. The position of the LST is indicated a as grey line.

mainly mean summer air temperatures and the length of the growing season. The minerogenic accumulation (Min-SAR) in LMM (Fig. 2c) reflects erosion and the amount of snow-melt runoff in spring in the lake's catchment area. The organic carbon isotope values of LMM sediments have been shown to closely reveal lacustrine primary production (Lücke and Brauer, 2004).

At the YD-Preboreal transition 11,590 BP, our data reveal common, distinct and rapid proxy signals that describe a consistent transition from a colder YD to a warmer Preboreal. The abrupt increase of ostracode $\delta^{18}O$ of 2.8‰ in Lake Constance indicates a rise in mean temperature of about 7°C (Burns & Schwalb, unpublished data). The rapid doubling of mean ring-width of German pines within a few decades shows improved growth conditions, i.e. higher summer temperatures or an extended growing season. Decreasing organic $\delta^{13}C$ values of LMM point towards higher production in the transitional seasons and, thus, also longer growing seasons, whereas the drop in the minerogenic accumulation rates indicates reduced snow melt runoff in spring, related to decreased winter precipitation.

At the Allerød-YD transition, the proxies show differences with respect to the rates of change. The pine chronology, represented by

only few trees at the Allerød-YD transition, does not show marked changes in summer growth conditions. The decrease of ostracode $\delta^{18}O$ by 1.9‰ indicates a 5°C mean temperature reduction from late Allerød to YD conditions (Burns & Schwalb, unpublished data). In contrast to the transition displayed by proxies of Lake Constance, the Allerød-YD transition in LMM is very distinct and comparable to the fast YD-Preboreal transition seen in all proxies. Rapidly increasing $\delta^{13}C$ values in the organic matter ($\delta^{13}C_{OM}$) in LMM sediments at the Allerød-YD transition indicate increased lacustrine primary production. Carbon isotope values remain high during the YD and can only be explained by relatively warm summer temperatures (Lücke and Brauer, 2004), which is in good agreement with moderate mean ring-width during central YD.

Thus, it evolves that the Allerød-YD transition, and in turn the YD, may be characterized by increased seasonality. Since summer temperatures and the duration of the vegetation period allow moderate tree growth, the temperature reduction may be ascribed to the winter period. This is in accordance with results from southern Greenland (Björck et al., 2002) and from the Swiss Alps (Lotter et al., 2000).

Regarding the climatic characteristics of the YD-stadial, our proxies suggest a climatically variable YD with distinct climatic phases. Both ostracode species of Lake Constance show minima of mean temperatures in the central YD. Decreasing ring-width towards the end of YD, accompanied by pronounced accumulation of missing rings and frost rings (even in late or summer wood) between 11,850-11,600 BP, indicate clear deterioration of summer growth conditions towards the end of the YD. Taking into account the accumulation rates of minerogenic matter in LMM sediments, which indicate a strong increase of snowmelt run-off in spring after 12,250 BP, and the decreasing $\delta^{13}C_{OM}$ values after 12,100 BP, this may indicate cooler and/or more cloudy summers and snow-rich winters in the second part of the YD.

Conclusion and Outlook

Extensions and improvements of tree-ring chronologies into the Late Glacial along with radiocarbon calibration and the dendro-date of the LST allowed the accurate synchronization of tree-ring and lacustrine sediment archives. As an example of an integrative approach combining different proxy records from our archives, we could demonstrate that the climatic development of the YD is probably not homogenous but divided into different climatic phases. In this respect, changes in seasonality seem to play an important role.

Further insights into natural climate change are anticipated from an extended network of accurate synchronized archives and a close cooperation with the recently granted DEKLIM modeling project "MIDHOL", which will help to evaluate hypotheses derived from synchronized Late Glacial and Holocene records.

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References

Friedrich, M., Remmele, S., Kromer, B., Spurk, M., Hofmann, J., Hurni, J.P., Kaiser, K.F. and Küppers, M., in press: The 12,460-year Hohenheim oak and pine tree-ring chronology from Central Europe - A unique annual record for radiocarbon calibration and palaeoenvironment reconstructions, *Radiocarbon*.

Kromer, B., Friedrich, M., Hughen, K.A., Kaiser, K.F., Remmele, S., Schaub, M. and Talamo, S., in press: Late Glacial/Early Younger Dryas 14C ages derived from floating Central European tree-ring chronologies, *Radiocarbon*

Lücke, A., and Brauer, A., 2004: Biogeochemical and micro-facial fingerprints of ecosystem response to rapid Late Glacial climatic changes in varved sediments of Meerfelder Maar (Germany). *Palaeogeography, Palaeoclimatology, Palaeoecology* **211 (1-2)**, *139-155*.

Schwalb, A., 2003: Lacustrine ostracodes as stable isotope recorders of late-glacial and holocene environmental dynamics and climate. *Journal of Paleolimnology* **29**, 265-351.

For full references please consult:
www.pages-igbp.org/products/newsletters/ref2004_2.html

The Global Carbon Cycle During the Last Glacial/Interglacial Transition

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The global carbon cycle has played a significant role both in recent climate changes as well as in glacial/interglacial (G/IG) transitions. Carbon reservoirs and exchange rates are affected by external climate conditions and conversely, changes in atmospheric CO_2 concentrations lead to amplification and mediation of regional climate variations. The major goal of RESPIC is the quantification of changes in the global carbon cycle and its connection to climate changes over the last glacial cycle, using a new model as well as improved (proxy) validation data for boundary conditions in the past. Here, especially, new $^{13}CO_2$ data from Antarctic ice cores represent an urgently needed constraint to complement the ice core CO_2 concentration record, and are a main focus of RESPIC. In addition, aerosol records from polar ice cores provide valuable information, e.g. on dust-derived iron fertilization of the high latitude surface ocean and on biological activity in terrestrial and marine ecosystems, and are also being investigated by RESPIC. Thus, RESPIC contributes to the quantification of climate variability in the past, to the understanding of the processes coupling climate and the carbon cycle, necessary to improve climate models, and, therefore, to major objectives of DEKLIM.

Here, we focus on transient model studies to elucidate G/IG