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$\delta^{18}O$ by 1.9‰ indicates a 5°C mean temperature reduction from late Allerød to YD conditions (Burns & Schwalb, unpublished data).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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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 changes in the carbon cycle. Time slice experiments have so far been unable to unambiguously explain the driving forces of the G/IG change in atmospheric pCO_2 of about 100 ppmv. Additional information can be gained from studying the temporal evolution of the carbon cycle using transient model runs, which allows us to disentangle different forcing factors. By forcing a coupled ocean-atmosphere-biosphere box model (Fig. 1) of the global carbon cycle with proxy data spanning the last glacial termination, we have for the first time been able to quantitatively reproduce transient variations in CO_2 and $\delta^{13}CO_2$ observed in ice cores, both in time and magnitude (Fig. 2). According to our model, various factors such as reduced iron fertilization, ocean circulation and stratification, as well as sea ice coverage of the Southern Ocean, contributed to the overall G/IG change at different times. (Köhler et al., 2004, Smith et al. 1999). Thus, initial processes during deglaciation in the Southern Ocean, followed by the 1500 year delayed kick-in of the thermohaline circulation (THC) in the North Atlantic (as revealed in the DEKLIM project CliTrans, Knorr and Lohmann, 2003) are consistent with atmospheric carbon records. In addition, the significant influence of the terrestrial biosphere on changes in the isotopic composition of atmospheric pCO_2 during the second half of the termination is supported, and together with the contribution of carbonate compensation, fully explains the observed increase in pCO_2.

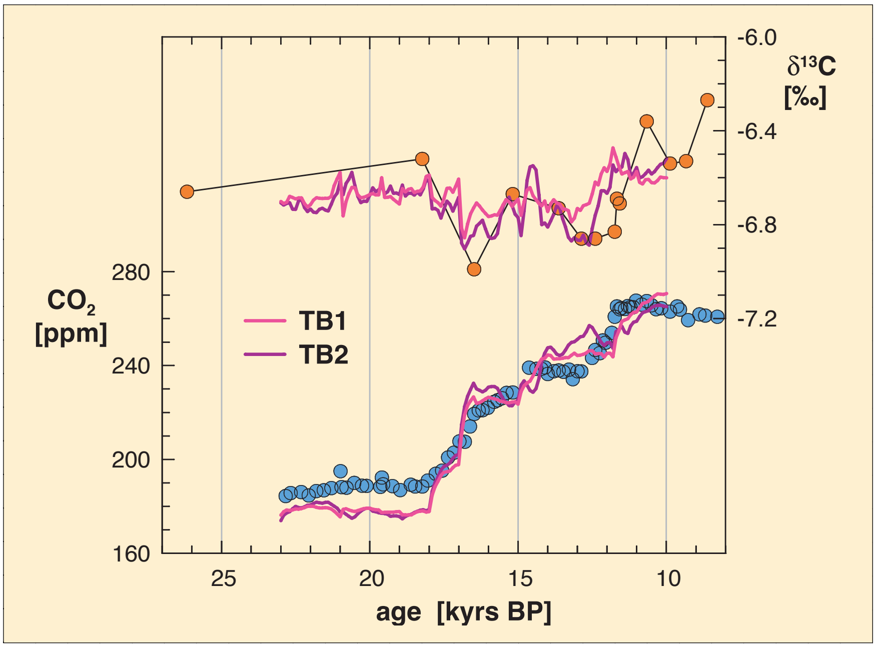

Fig. 2: Carbon records simulated with BICYCLE compared with $\delta^{13}C$ (orange) and CO_2 (blue) data (Smith et al., 1999, Monnin et al., 2001). Simulation scenarios combine all climate processes with changes in THC, marine export production, $CaCO_3$ compensation and terrestrial biosphere with two different realizations for the regrowth of vegetation on land (TB1: dominated by CO_2 fertilization; TB2: dominated by climate change).

Further insight into changes in the carbon cycle can be expected from temporally better resolved and more accurate $\delta^{13}CO_2$ data derived from Antarctic ice cores. To this end, RESPIC is currently developing new sample extraction and mass spectrometric techniques for high precision $\delta^{13}CO_2$ analyses on small air samples from deep clathrate ice. These techniques will be employed on samples from the new ice cores currently being drilled within the framework of the European Project for Ice Coring in Antarctica (EPICA), providing the first atmospheric records covering the last 800,000 years (EPICA community members, 2004).

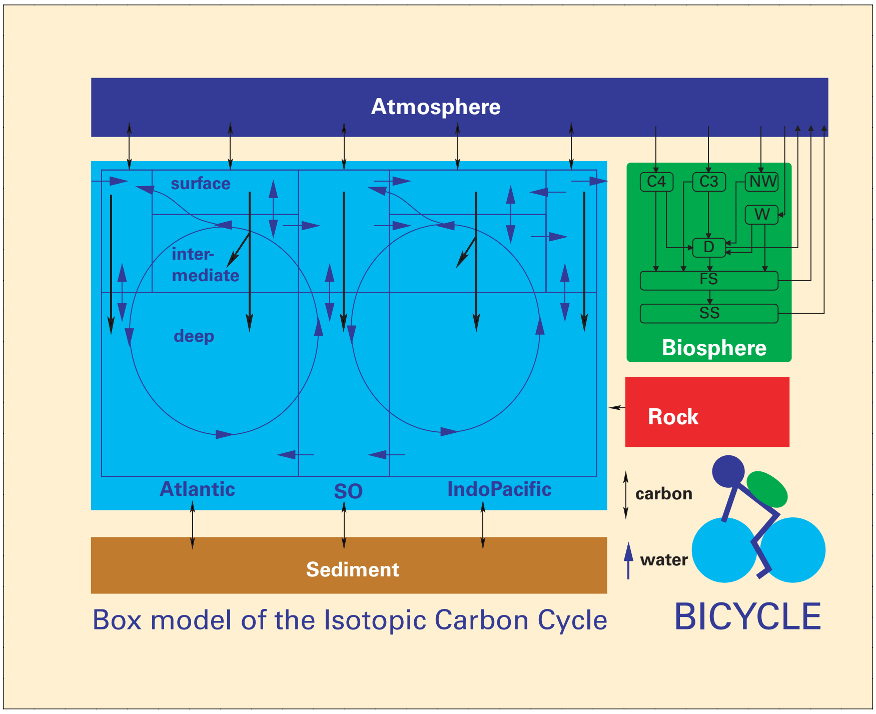

Fig. 1: Structure of the model BICYCLE (Box model of the Isotopic Carbon cycle). Our terrestrial biosphere internal module (Köhler and Fischer, 2004) or other model output can be used. Arrows indicate the fluxes of carbon.

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