Simulated land ice: latitudinal changes (0-2.6 Ma) and importance of CO_2-glaciation divergence during times of decreasing obliquity (0-800 ka)

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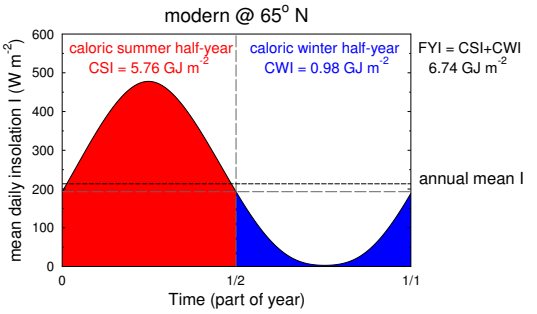
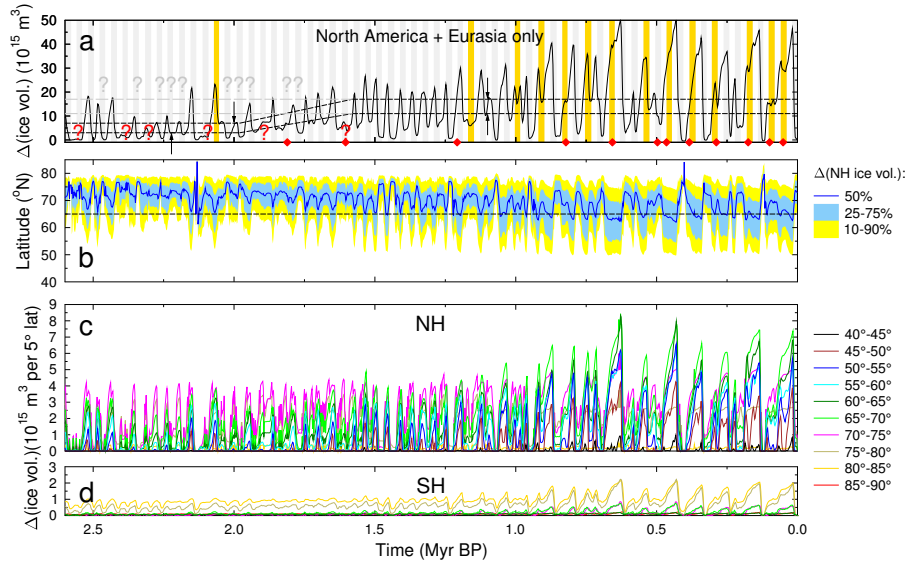
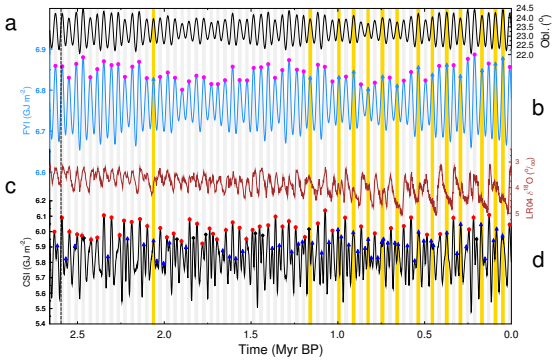
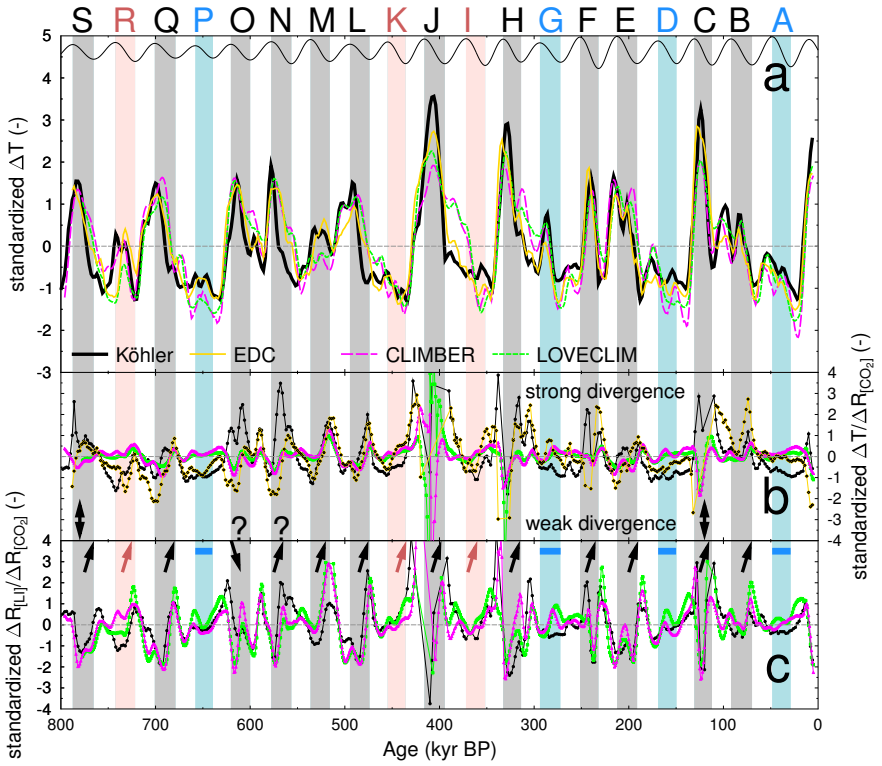
Latitudinal Changes in Land Ice during the Quaternary

Following Milankovitch's theory the incoming insolation or summer energy at 65°N is typically analysed to predict the waxing or waning of land ice. We here use a model-based deconvolution of the LR04 benthic-$\delta^{18}O$ stack into land ice distribution (de Boer et al., 2014; Köhler et al., 2015) to verify if the latitudinal focal point of land ice dynamics has changed over the last 2.6 Myr or whether this choice of 65°N in orbital data is indeed well justified. We find that the 5°-latitudinal band which contributes most to land ice volume changes is 70-75°N between 2.0-1.5 Myr, which is then until 1.0 Myr gradually substituted by 65-70°N. During the last 1 Myr both 60-65°N and 65-70°N dominate northern hemisphere land ice volume changes and contribute approximately the same amount, while the relative importance of 70-75°N is shrinking. Our analyses illustrates that the choice of 65°N seems for the last 1 Myr to be well justified, while for earlier parts of the Quaternary the dominant land ice changes seems to have happened up to 10° further to the north.



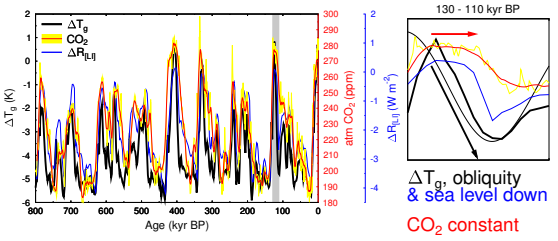






CO_2-Glaciation Divergence during last 800 kyr

Focusing on the last 800 kyr (the time for which precise data on atmospheric CO_2 concentration exists) we furthermore find that the multi-millennial land ice growth and proxy-based reconstruction of global cooling (= the glaciation) appear synchronously to each other and to decreasing obliquity, but diverge from CO_2. This suggests that the global cooling associated with Earth's way into an ice age as deduced in the reconstructions has to be mainly caused by the land ice albedo feedback, and is not dominated by the CO_2 greenhouse gas radiative forcing. One way of perceiving this CO_2-glaciation divergence in the reconstructions is that the reduced incoming insolation at high latitudes during phases of decreasing obliquity causes land ice growth (= sea level fall) and cooling, while there is a coexisting process that keeps CO_2 at a relatively constant level. Solid Earth modeling experiments have indicated that falling sea level might lead to enhanced marine volcanism (enhanced magma and CO_2 production) at mid-ocean ridges and at hot spot island volcanoes which might be a potential cause for this CO_2 glaciation divergence (Hasenclever et al., 2017). This CO_2-glaciation divergence needs to be considered, when using paleo data to quantify paleoclimate sensitivity: periods with diverging CO_2 and global temperature change should be filtered out when approximating the relationship between global temperature rise and CO_2 concentrations (Köhler et al., 2018).



References

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Köhler and van de Wal (submitted) Combining orbital theory of the Quaternary with land ice distribution.