On the state dependency of the equilibrium climate sensitivity during the last 5 Myr

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It is a still open question how equilibrium warming in response to increasing radiative forcing — the specific equilibrium climate sensitivity S — is depending on background climate. We here bring palaeodata-based evidence on the state dependency of S by using CO_2 proxy data together with 3-D ice-sheet-model-based reconstruction of land ice albedo over the last 5 million years (Myr). We find that the land-ice albedo forcing depends non-linearly on the background climate, while any non-linearity of CO_2 radiative forcing depends on the CO_2 data set used. This non-linearity was in similar approaches not accounted for due to previously more simplistic approximations of land-ice albedo radiative forcing being a linear function of sea level change. Important for the non-linearity between land-ice albedo and sea level are the more complex models including more ice sheet physics, from which we also find a latitudinal dependency in ice sheet area changes. In our setup, in which the radiative forcing of CO_2 and of the land-ice albedo (LI) is combined, we find a state dependency in the calculated specific equilibrium climate sensitivity $S_{[CO_2,LI]}$ for most of the Pleistocene (last 2.1 Myr). During Pleistocene intermediate glaciated climates and interglacial periods $S_{[CO_2,LI]}$ is on average 50% larger than during Pleistocene full glacial conditions. In the Pliocene part of our analysis (2.6–5 Myr BP) the CO_2 data uncertainties prevents a well-supported calculation for $S_{[CO_2,LI]}$, but our analysis suggests that during times without a large land-ice area in the northern hemisphere (e.g. before 2.82 Myr BP) the specific equilibrium climate sensitivity $S_{[CO_2,LI]}$ was smaller than during interglacials of the Pleistocene. We thus find support for a previously proposed state change in the climate system with the wide appearance of northern hemispheric ice sheets. This study points for the first time to a so far overlooked non-linearity in the land ice albedo radiative forcing, which is important for similar palaeodata-based approaches to calculate climate sensitivity. If we develop for S an equation as a function of $\Delta R_{[CO_2,LI]}$ we find $S_{[CO_2,LI]}$ in interglacials to be 2–2.7 × larger than during glacial maxima, potentially indicating that equilibrium warming for CO_2 doubling might be in the upper range of results compiled in the IPCC AR4.

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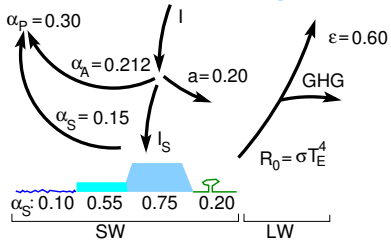
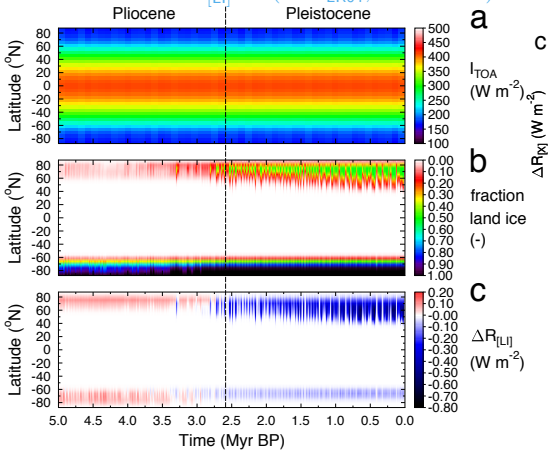
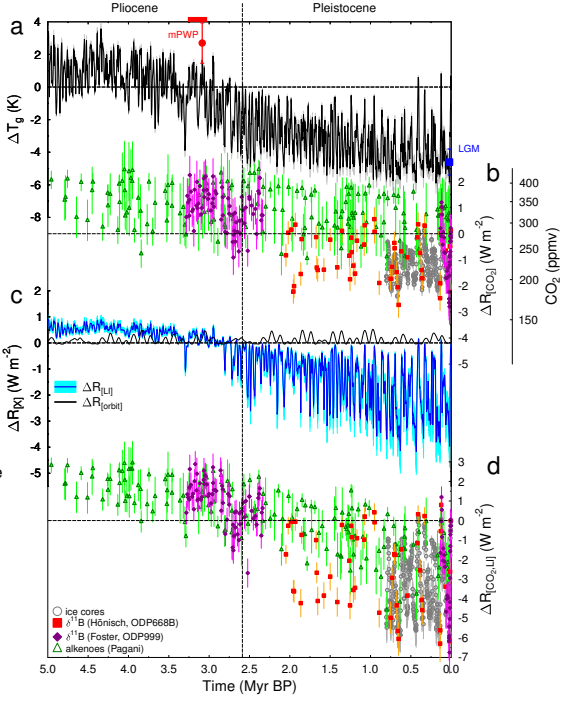
Annual mean zonal averaged EBM



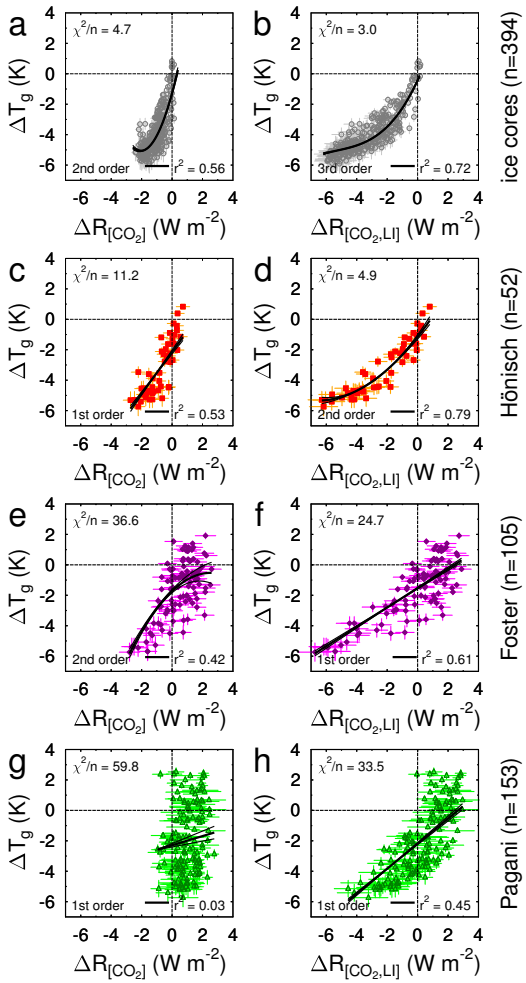
Land Ice Albedo $\Delta R_{[LI]} = f(\delta^{18}O_{LR04}, 3D\ LI\ model)$



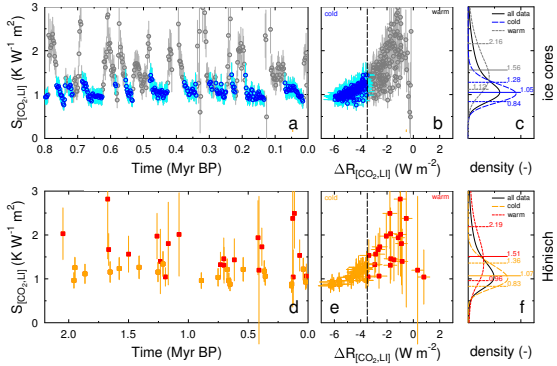
Data Compilation



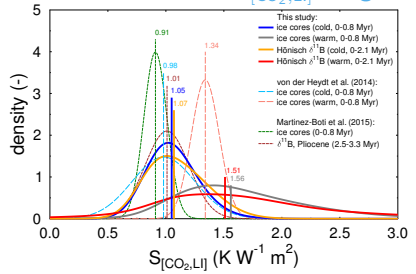
Scatter Plots of $\Delta T_g - \Delta R_{[CO_2,LI]}$



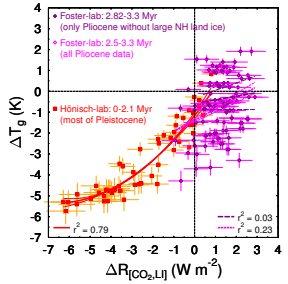
Calculate state dependent $S_{[CO_2,LI]}$



Conservative estimate of $S_{[CO_2,LI]}$ using PDFs



Compare Pleistocene with Pliocene



Which approach to quantify a function for S is correct?