Abrupt climate and weather changes across time scales

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Key Points:

- Non-linear response of the climate system to external orbital forcing
- Centennial and millennial variability are stochastic in nature
- Challenges of ocean-radiocarbon modeling with high-resolution at the coasts and high latitudes
- The past provides evidences of abrupt climate changes and weather extremes

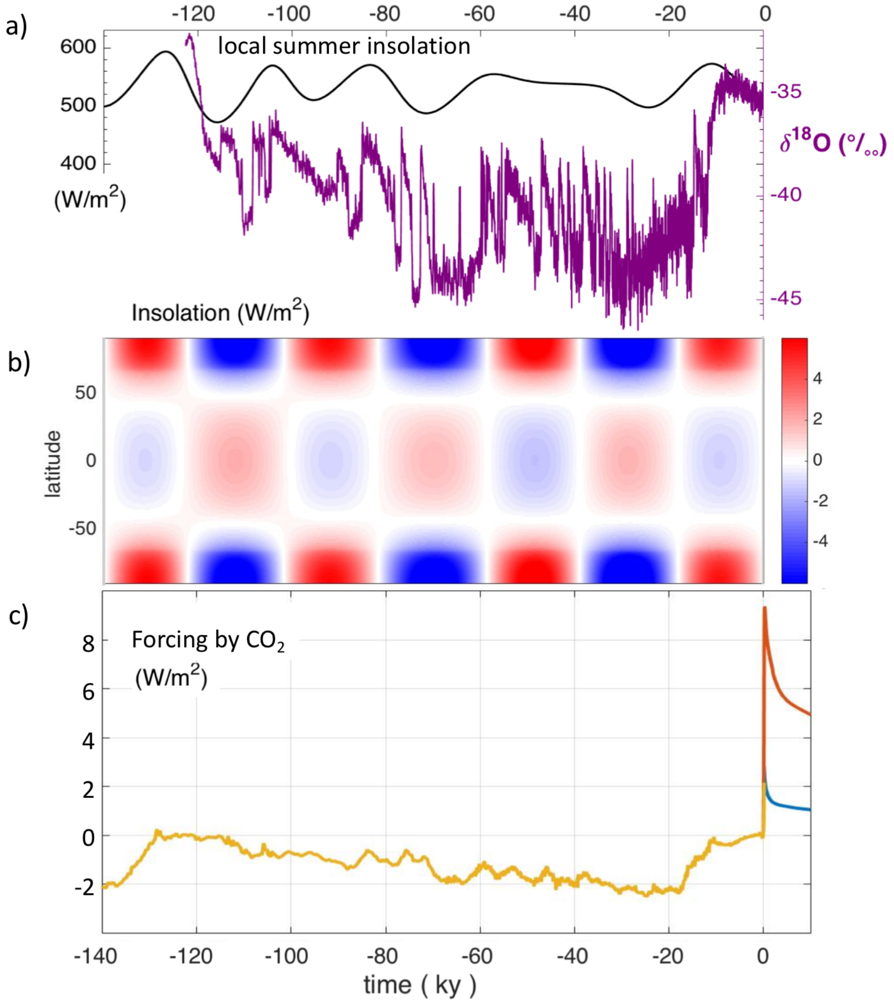

Figure 2. a) The δ^{18}O ice core curve from the North Greenland Ice Core Project (NGRIP, 2004) documents climate variability over the last 120 ky (purple). The black curve indicates the June 21 insolation at the local position (Wm^{-2}) . b) Annual mean insolation variation at all latitudes using the algorithm of Berger (1978). c) CO_2-forcing as reconstructed from the past (yellow) (Köhler et al., 2017) and estimated for future scenarios (Archer & Brovkin, 2008) for a moderate (1,000 Gt carbon) (blue) and large (5,000 Gt carbon) (red) fossil fuel slugs (the natural atmospheric CO_2 content is on the order of 600 Gt carbon prior to anthropogenic combustion of carbon). For the translation into Wm^{-2}, we assume a 4 Wm^{-2} for doubling of CO_2 and a logarithmic dependence $\ln(CO_2/CO_2^{ref})$ with CO_2 and CO_2^{ref} being the CO_2-level and the reference pre-industrial level, respectively.

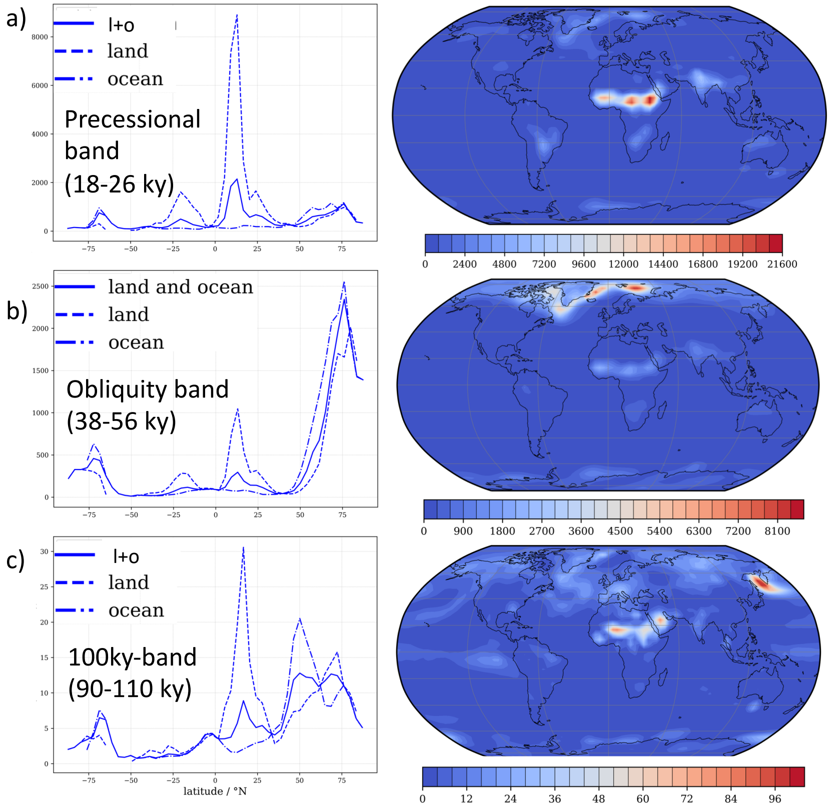

Figure 5. Power Spectrum Density for different frequency bands of annual mean SAT. Left: Zonal mean with solid lines for land and ocean, dashed line for land, dashed-dotted lines for the ocean. Right: local power spectrum of annual mean SAT. Note the different scales. The precessional band is dominated by a peak over North Africa (a), obliquity for a region around Greenland and the Barents Sea (b), eccentricity with a much lower amplitude over North Africa and the Sea of Okhotsk (c).

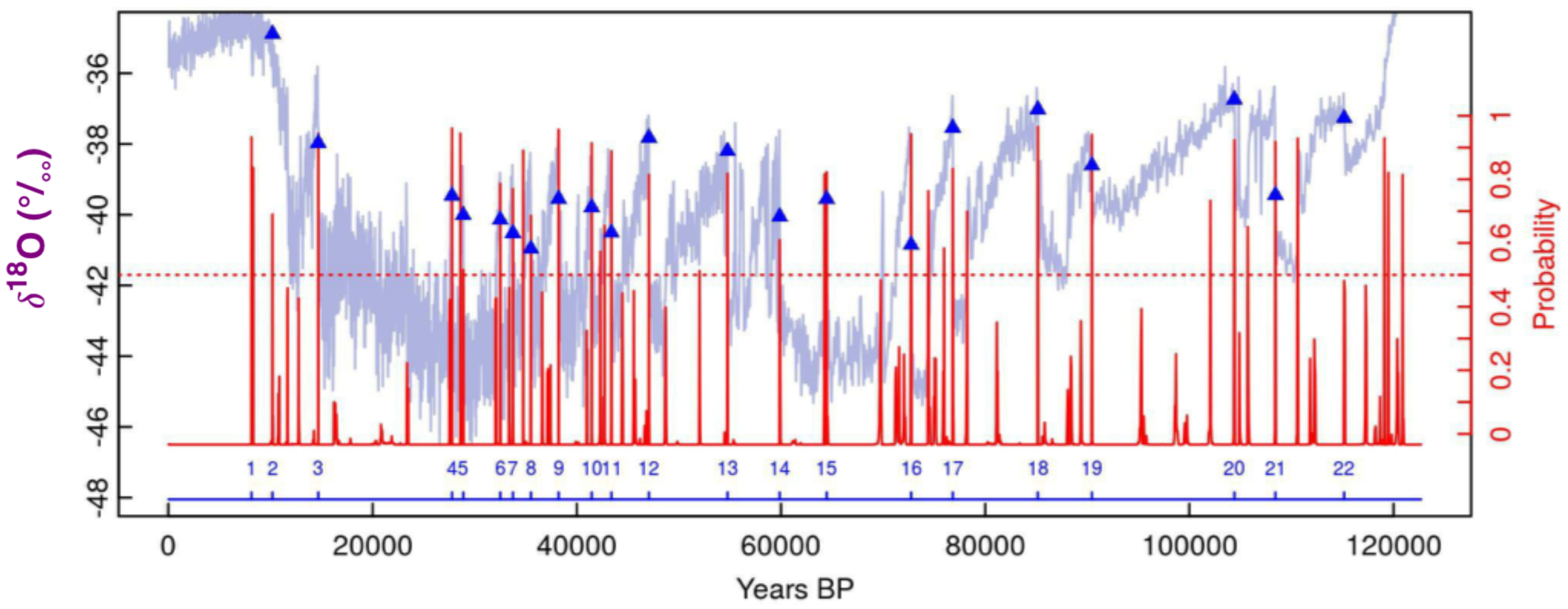

Figure 6. Bayesian Change Point Analysis for the $\delta^{18}O$ signal of the NGRIP ice core from Greenland based on GICC05 time scale (Andersen et al., 2007). Note that time evolves from right to left in accordance to geological convention. Red spikes indicate the probabilities for a change point at each time point proposed by the Bayesian Change Point Algorithm (Ruggieri, 2013). Warming and cooling change points are detected. Blue triangles mark the warming events with a probability higher then 0.5 (dotted red line), numbered at the bottom of the graph and used for further analysis.

b) Period of 10-42 ky

Seq.	# Ev.	Estimate	P1	P2	P3	P4	P5	
ras14	11	2976	948	1488	594	1574	649	yr
			0.66	0.659	0.621	0.596	0.559	R
dit07	12	2705	1487	1579	946	1137	593	yr
			0.688	0.611	0.54	0.532	0.51	R
bark11	10	3311	937	873	711	1364	574	yr
			0.745	0.614	0.573	0.573	0.572	R
thresh	11	2682	1475	546	866	1134	594	yr
			0.598	0.574	0.558	0.54	0.536	R
bayes	9	3908	548	1482	1572	652	1167	yr
			0.718	0.692	0.689	0.629	0.616	R

Table 1. Different proposed DO sequences ("Seq.") in question for a) the last glacial period and b) the 42-10 ky interval for the NGRIP record. Number of events considered for the analysis ("#Ev."), the individual estimates of inter-event waiting times ("Estimate") in the exponential distribution which is used for Monte Carlo Simulations. Furthermore, the 5 highest R scored periods for each sequence in decreasing order. Highlighted in red/blue/green we find the periods in a 10% range around the periods of interest 1470/900/1150. Grey values indicate out of confidence interval R values. The warming events for the different DO-sequences are listed in Table 2.