Transient simulation of climate variability during the Last Glacial Maximum and the Holocene with an energy balance climate model

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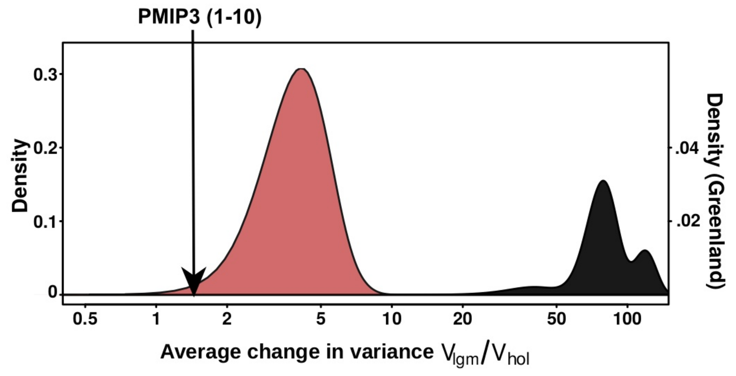
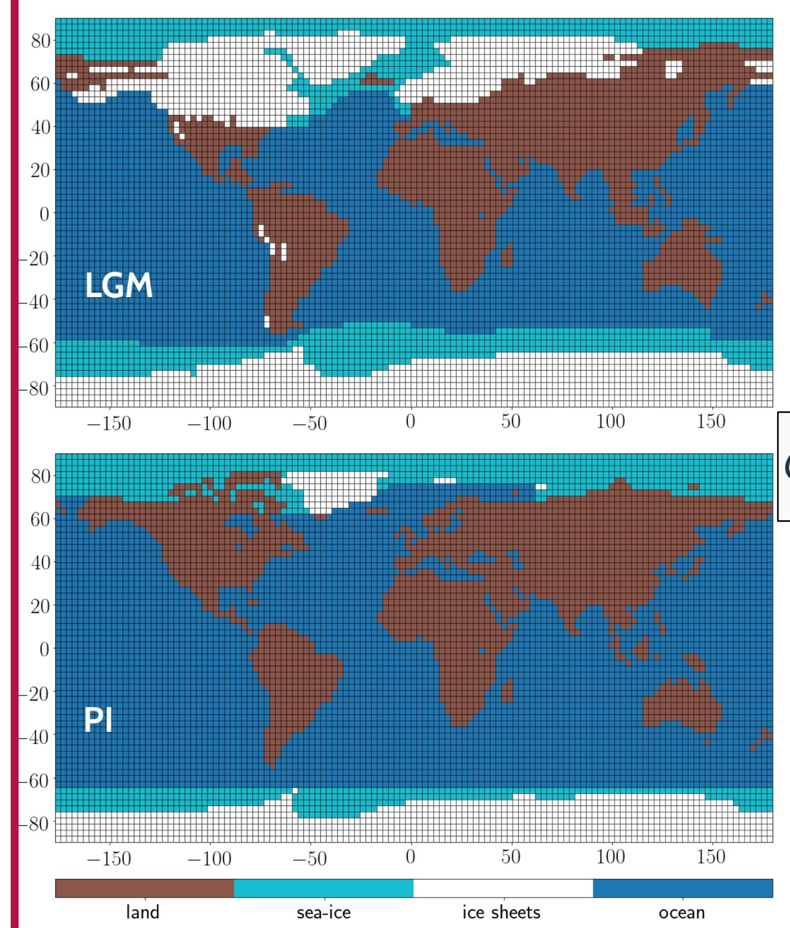
1 Motivation

Climate variability governs the probability of extreme events[1] and thus living conditions on Earth. How projected changes in mean climate will affect climate variability remains uncertain[2-5]. To this end, comparing the last glacial to the present interglacial can provide new insights. However, models simulate a lower change in variability during that period than reconstructions from proxies suggest[3,5]. Long transient simulations with low-dimensional models can contribute to the picture and allow a process-based examination of climate variability.



(A) Variability change in proxy data from LGM to Holocene[3]

2 Energy Balance Model



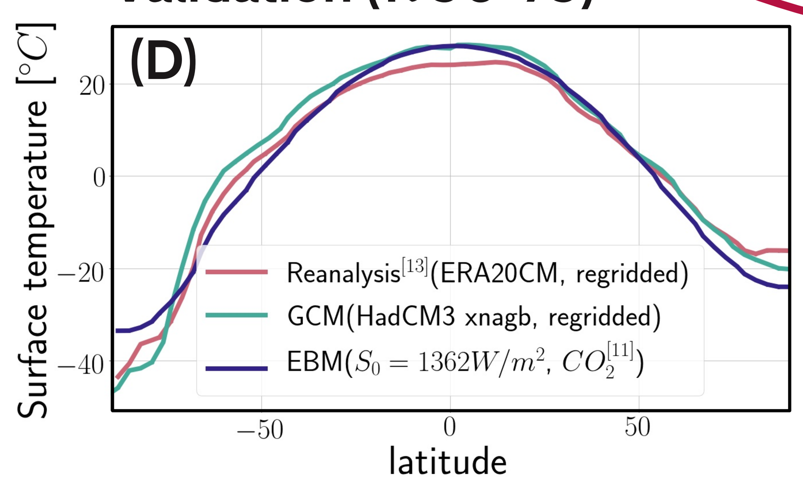
basis: EBM by Zhuang, North & Stevens[6,7]
resolution: 128 x 64 boxes (2.8° x 2.8°), 48 time steps per year
input: CO_2, S_0, orbital configuration, land-sea mask, ice distribution
solves:

$$C(\hat{\mathbf{r}})\frac{\partial T}{\partial t} + A + B \cdot T = \nabla \cdot (D(\hat{\mathbf{r}})\nabla T) + S_0 \cdot S(\hat{\mathbf{r}}, t)a(\hat{\mathbf{r}})$$

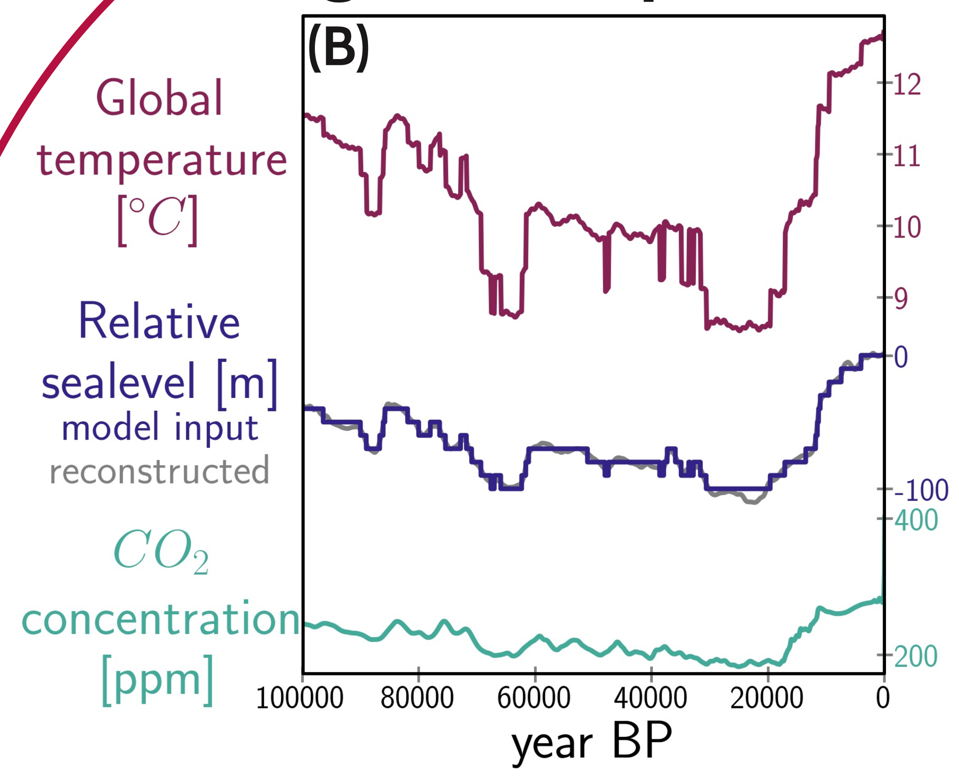
C: effective heat capacity
A,B: coefficients from satellite data[6,8]
D: diffusion coefficient
S_0: solar constant
S: insolation, depends on orbital parameters
a: albedo

	original[6,7]	revised model
runs	equilibrium	transient & equilibrium
restarts	no	yes
forcing	constant only	non-constant
map	all in one file	land-sea mask & ice separate
configuration	in model code	outside model
output	T	T, C, S, a, map

Validation (1950-75)



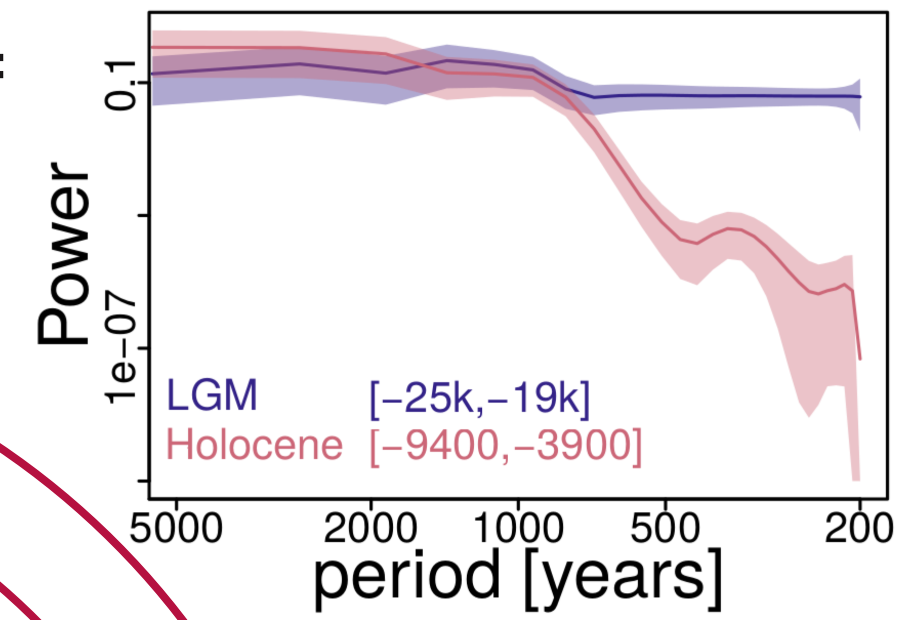
100kyr glacial to present



Modelled global temperature, forced by map changing with sea level[9,10], CO_2[11], 11-year solar cycle[12] and orbital configuration.

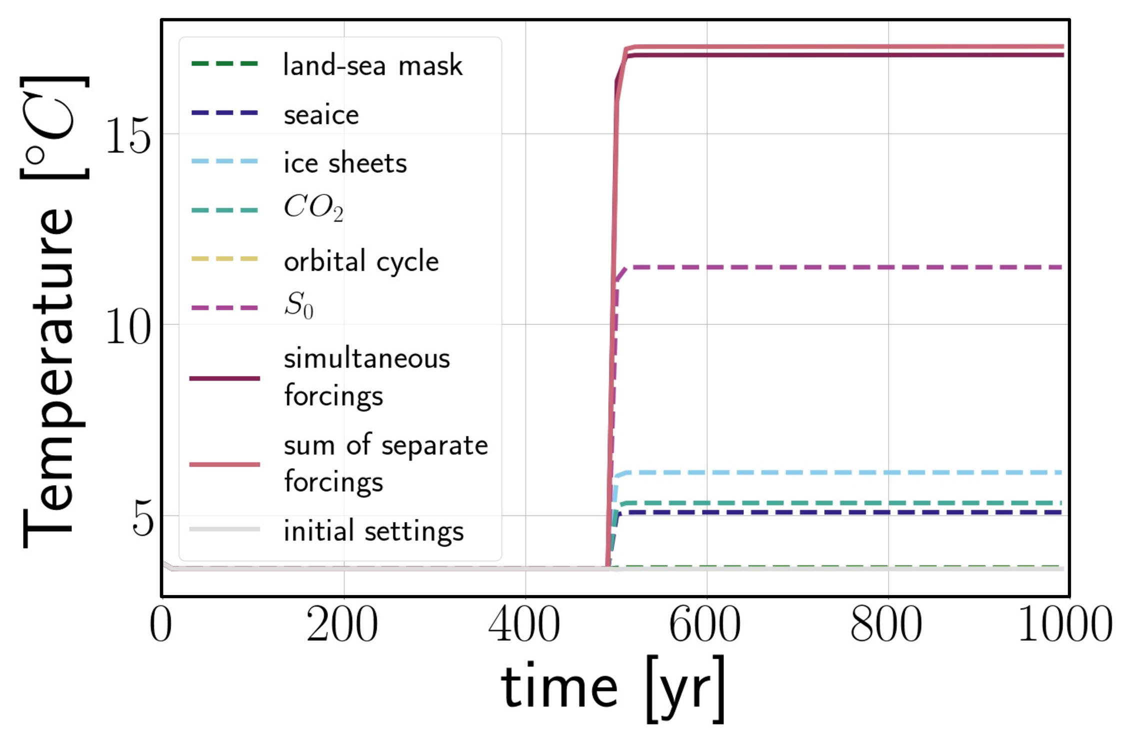
3 Results

(C) Spectrum:



Consistent with expectations, variability is lower during the Holocene than the LGM. However, more experiments need to compare the role of sealevel and CO_2 vs. solar variability.

(E) Testing feedbacks & non-linearity: effect of separate vs. simultaneous forcings

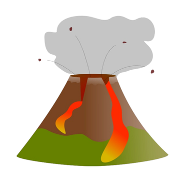


step forcing	0-500yr	500-1000yr
orbital cycle	off	on
solar constant S_0	1300W/m²	1400W/m²
CO_2	200ppm	400ppm
ice sheets	LGM	PI
sea ice	LGM	PI
land-sea mask	LGM	PI

4 Conclusions

- EBM reproduces temperature distributions similarly to GCM (D)
- non-linearity: sum of forcings ≠ all together

Next Steps:
- expand validation of transient EBM
- comparison to transient GCM runs
- test volcanic forcing
- parallelise



References

[1] Katz, R. W. & Brown, B. G. Clim.Change 21,289-302 (1992)
[2] Mitchell, J.M. Quaternary Res 6, 481-493, (1976)
[3] Rehfeld, K. et al. Nature 555, 402EP (2018)
[4] Huybers, P. & Curry, W. Nature 441, 329-32 (2006)
[5] Laepple,T. & Huybers,P. Proc.Natl.Acad.Sci. USA (2014)
[6] Zhuang, K. et al., SoftwareX 2017, 198-202 (2017)
[7] North, G. et al., Rev Geophys Space 19, 91-121 (1981)
[8] Myhre, G. et al, Geophys. Res. Lett. 25, 2715-2718 (1998)
[9] Grant, K. M. et al. Nature 491, 744-747 (2012).
[10] Amante, C. et.al. NOAA Techn. Memorandum NESDIS NGDC-24.
[11] Köhler, P. et al., Earth Syst. Sci. Data 9, 363-387 (2017)
[12] Coddington, O. et al., Bull. American Meteo. Soc. 97, 1265-1282 (2015)
[13] Hersbach, H. et al., Quart.J.o.t. Royal Metro.Soc. 141, 2350-2375 (2015)

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