Simulating the glacial cycles of the Pleistocene with a low complexity model

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Although the **climate variability of the last 3 million years** (Pleistocene) have been long studied, there are still uncertainties concerning the causes of certain features in the paleoclimate records. These unknowns are believed to be due to intrinsic nonlinearities in the climate system. However, the longer timescales involved make it infeasible to use complex climate models because of the large computational cost involved. In this context, conceptual models are built to mimic complex processes in a simpler, computationally efficient way. Here we present the **Physical Adimensional Climate-Cryosphere mOdel (PACCO)** which represents the coupling between northern hemisphere ice sheets and climate employing state-of-the-art knowledge about climate and ice-sheet dynamics. In this way, **PACCO is able to run several glacial cycles in seconds and produces results comparable to those of paleoclimatic proxies.**

Glacial cycles govern the climate of the last ~3 million years

The main drivers of glacial-interglacial variability are the Earth's orbital variations (**Milankovitch theory**) due to climatic precession (~20 kyr), Earth's axis obliquity (~41 kyr) and orbital eccentricity (~100 kyr).

The **Mid-Pleistocene Transition** (Fig. 1 a-d) and the **"100 kyr problem"** (Fig. 1e) **do not follow Milankovitch theory.**

Non-linearities of the climate system can cause the **sawtooth-like pattern** and the **change in glacial-interglacial variability.**

There are **numerous hypotheses** and models that produce good results. However, most of them require **changes in their parameter space** and/or are based on **very complex** models.

H. E. = Homo Erectus H. H. = Homo Heidelbergensis
H. N. = Homo Neanderthalensis H. S. S. = Homo Sapiens Sapiens

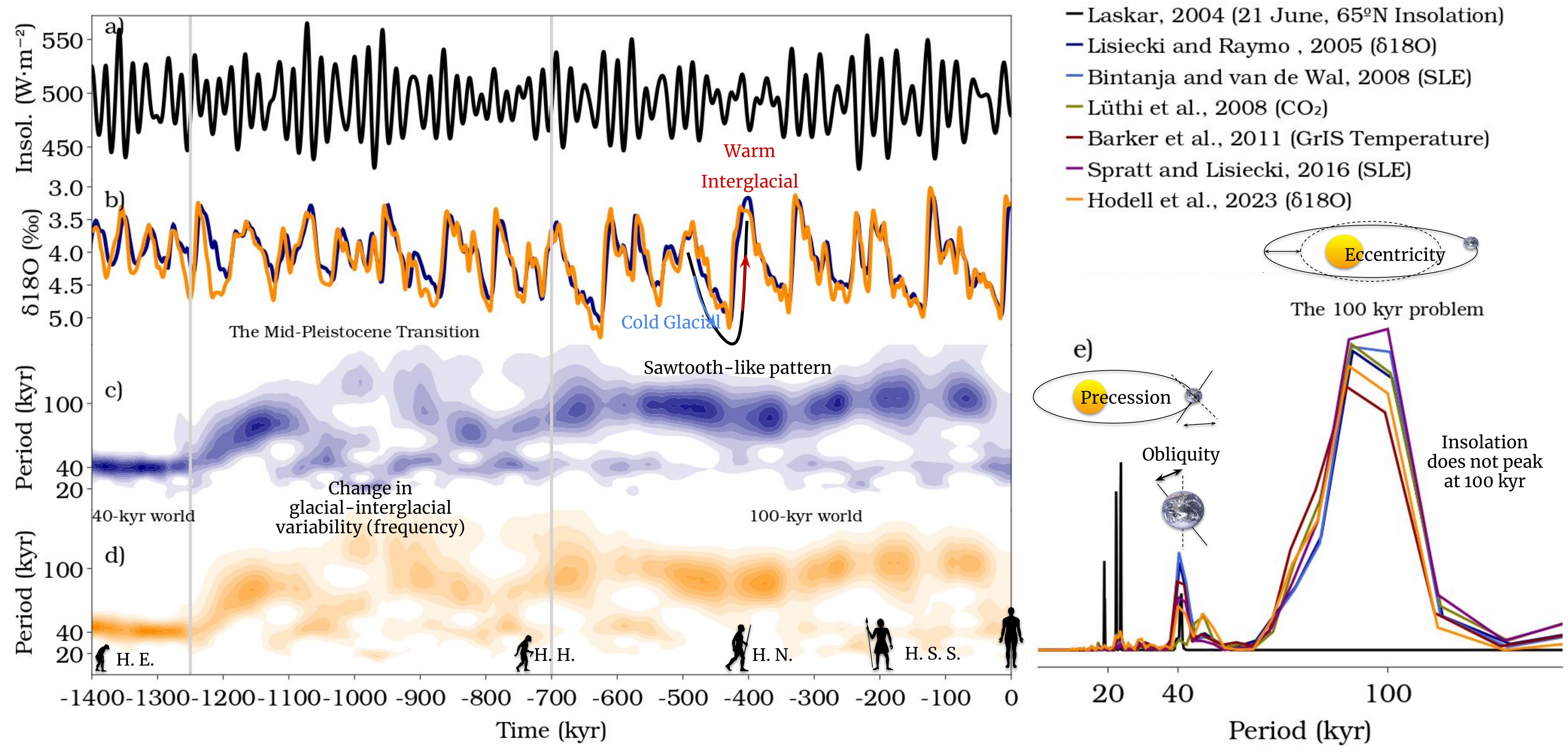
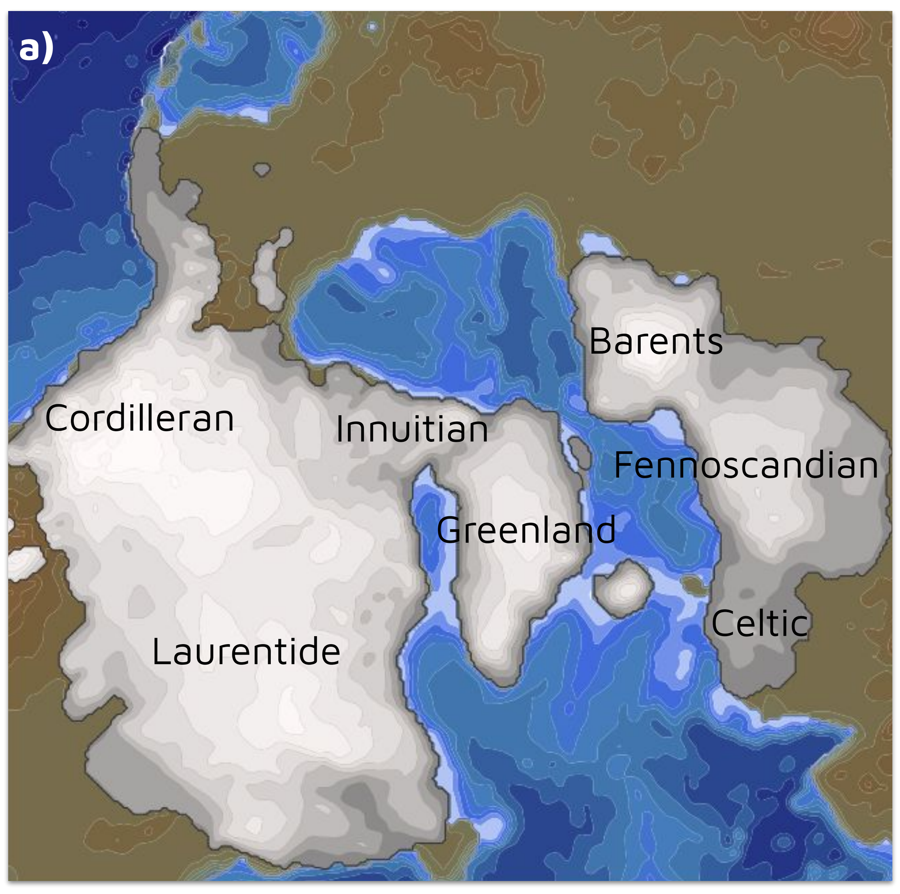


Figure 1. The history of the Pleistocene climate through the lenses of previous works (proxies and reconstructions). Note that (e) is the periodogram computed for the last 800 kyr of the records (the y-axis scale is arbitrary). Silhouettes are for temporal context.



Can we build a **physically-based** simple climate-cryosphere **model** that fairly reproduces **Pleistocene climate variability**?

(Pérez-Montero et al. in prep.)

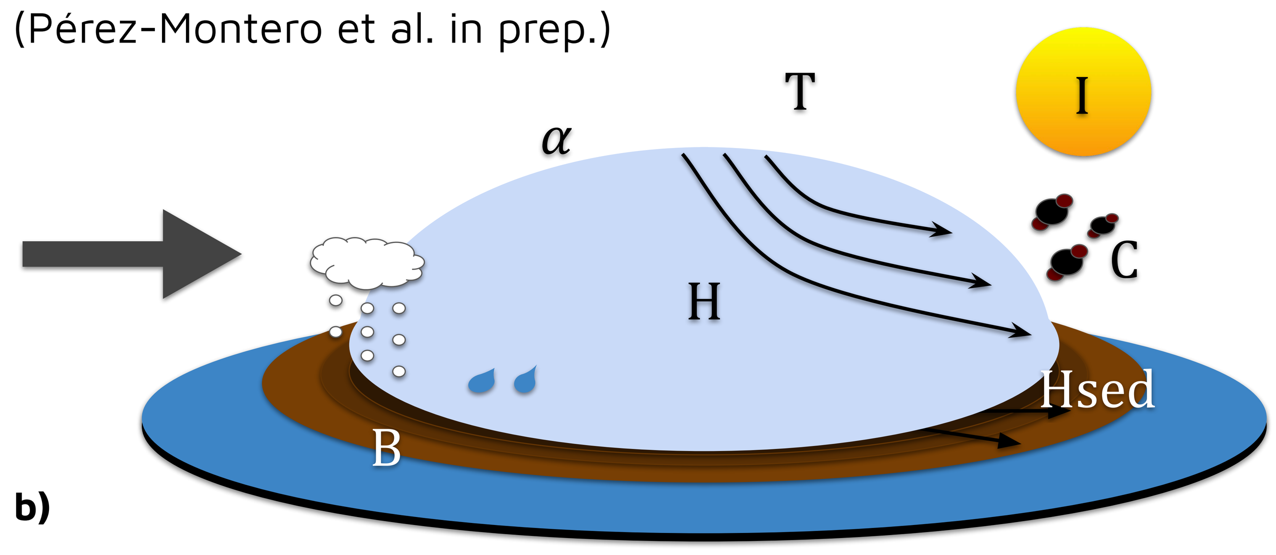


Figure 2. (a) Ice sheets of the Northern Hemisphere in the Last Glacial Maximum (~21 kyr ago). Note that ice sheets influence climate because of their high reflectance (albedo) and size (water volume and ice extension). (b) Schematic representation of PACCO and the physical processes solved.

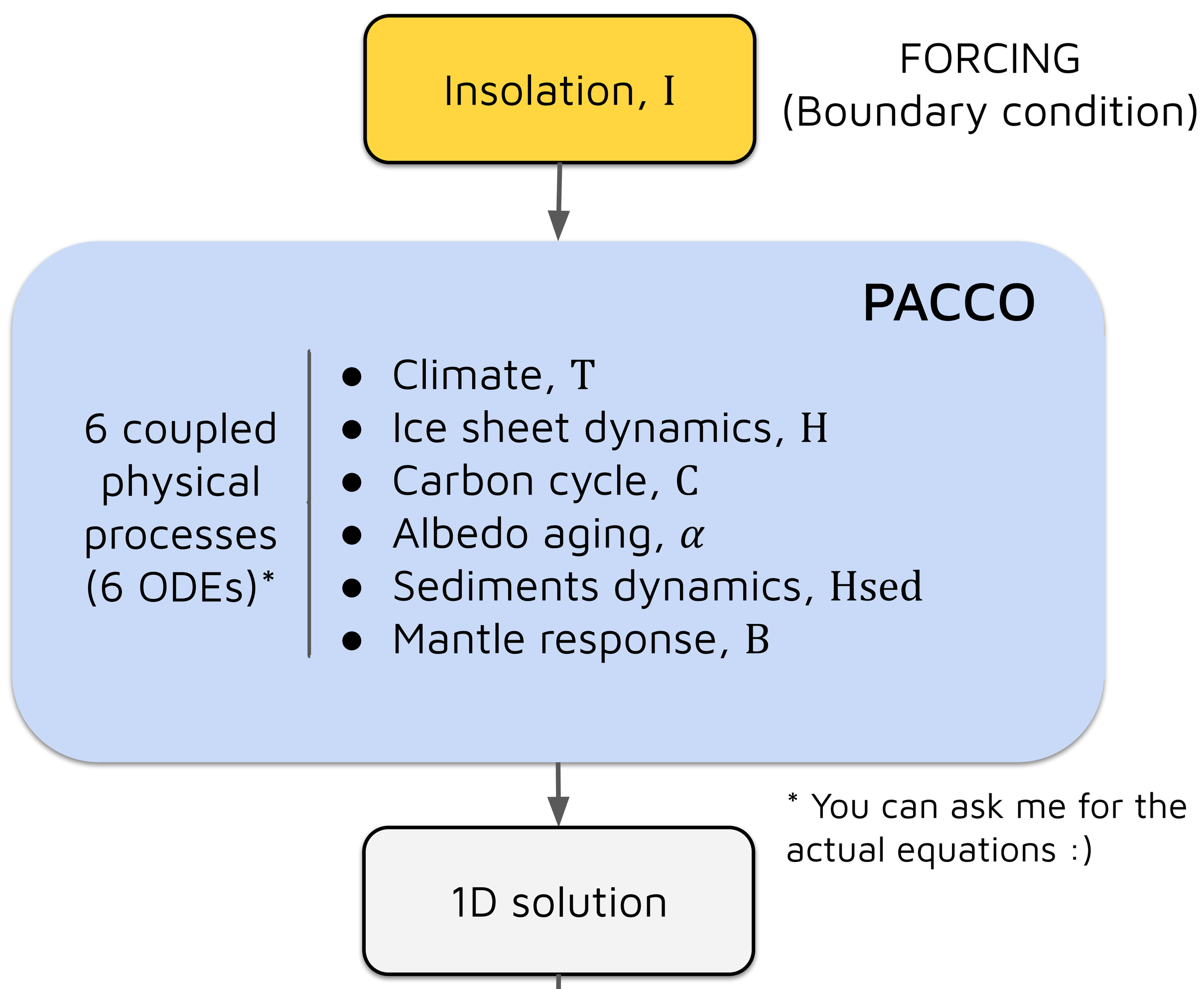
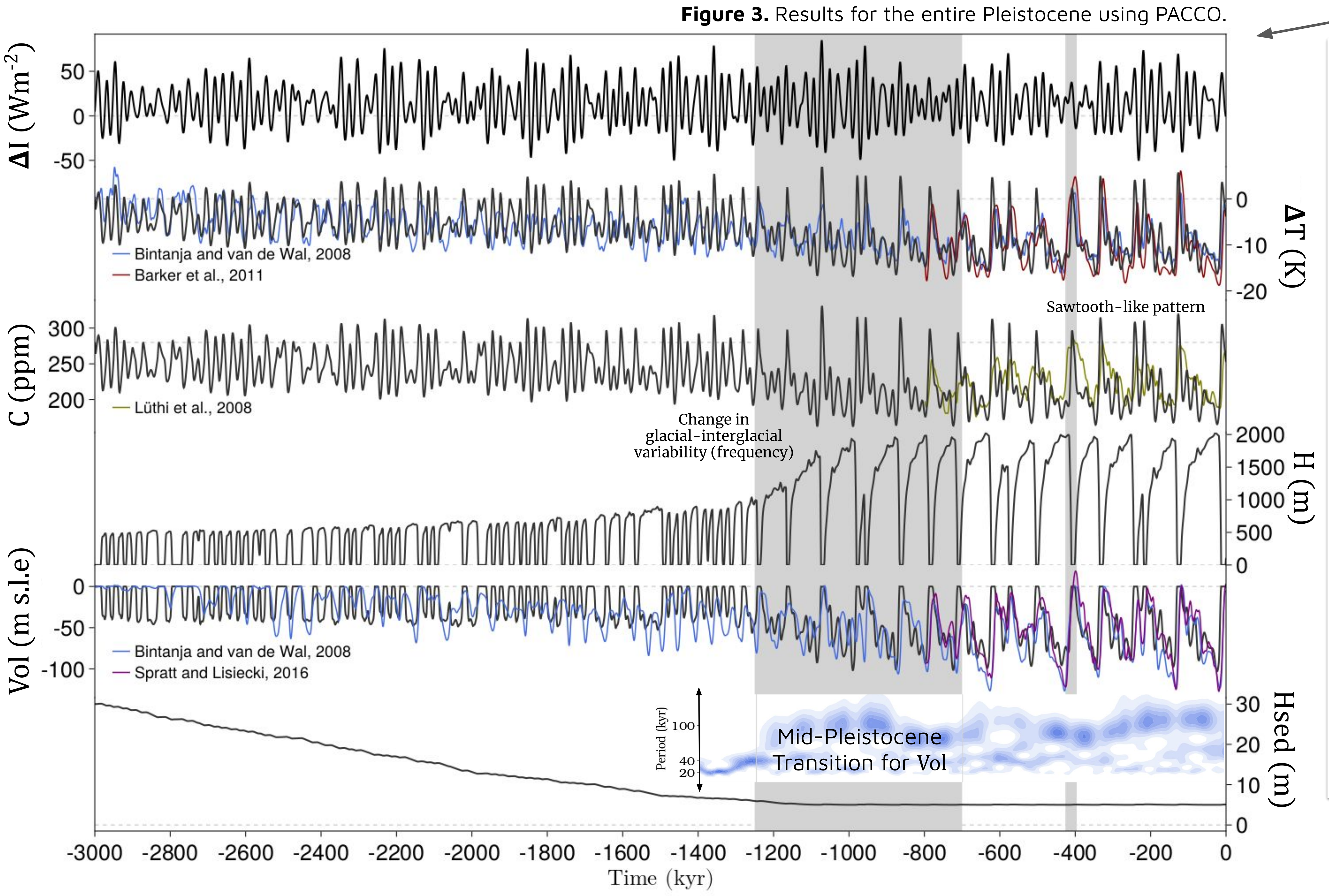


Figure 3. Results for the entire Pleistocene using PACCO.



PACCO reproduces the Glacial-Interglacial variability ...

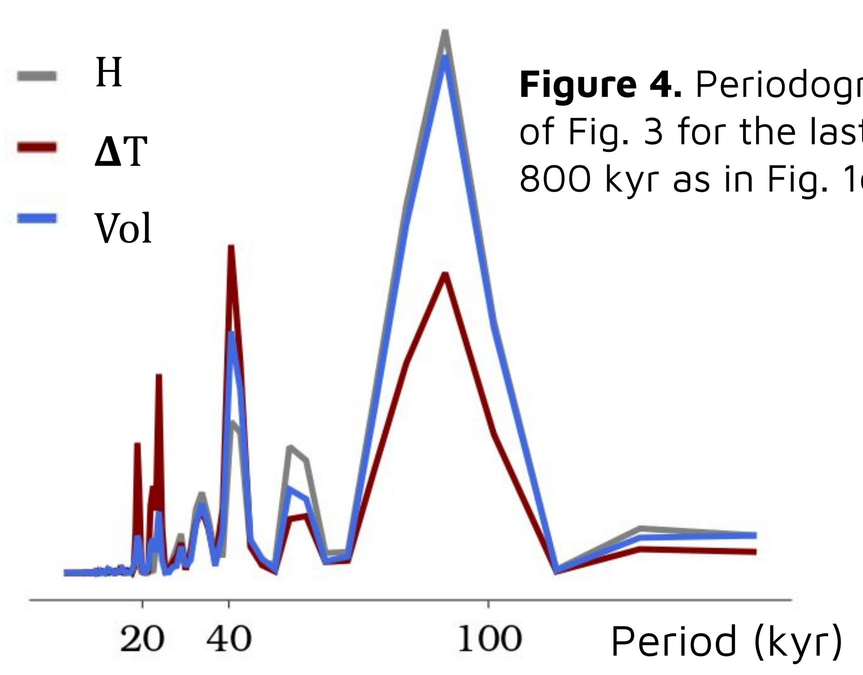


Figure 4. Periodogram of Fig. 3 for the last 800 kyr as in Fig. 1e

... and the Mid-Pleistocene Transition

Increased basal slip due to the presence of sediments in the early Pleistocene modulates ice sheet height, thus being more sensitive to ablation due to insolation anomalies (short 20-40 kyr cycles). When the slip increase is sufficiently closed, the ice sheets grow bigger and a combination of bedrock subsidence and ice aging produces the key nonlinear process for longer 100 kyr cycles.

References can be found here :)