A 0D glacial - interglacial model

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As far as I know there is no simple 0D model that can mimic the glacial cycles. So, can you make it? This project boils down on both physical understanding and developing skills to let python work (and think) for you.

Step 1: Identify *a priori* essential physical mechanisms

What are essential processes that determine the sequence of ice ages with interglacials? What could be the cause of the 100 ky periodicity of interglacials, and not e.g. 40 ky periodicity? Are ice sheets melting as fast as they grow?

A clear initial idea of which behaviour the model outcomes should possess and which processes might induce that behaviour, is very helpful for this project.

Step 2: Choosing variables

Possible variables are (in order of likely importance):

Insolation: Insolation is the only external forcing. It gives the rhythm of the glacial cycles. As these cycles involves Northern Hemisphere ice sheets, Northern Hemisphere insolation would be the variable to prescribe. Given the simplified nature of the model, it might not be necessary to get all frequencies steering the three orbital parameters into the insolation forcing time series.

Ice mass: This is where it is all about. I would say that the ice mass depends on

1. **Temperature:** Melt increases in a warmer world. Furthermore, in a colder climate, accumulation might be less too. Do not forget that NH ice sheets are marine terminating.
2. **Insolation:** More summer insolation makes summers warmer and provides more energy for melt.
3. **Ice mass:** Is a bigger ice sheet more or less vulnerable for melt?

Temperature: Although temperature is very important, it has no memory on the time scales we consider here. The temperature depends on ice mass (albedo effect), CO_2, and possibly on insolation.

CO_2: Higher temperatures reduce the solubility of CO_2 in the ocean - pushing atmospheric CO_2 up during deglaciation phases, and biological activities are also involved in the uptake of CO_2 into the ocean. But the remaining atmospheric CO_2 is important for this 0D climate model.

Other possible required prognostic variables: Isostatic depression (as this makes ice sheets more vulnerable for oceanic warming and rapid deglaciation), ocean temperature (as this may have a significant memory), ...

Step 3: Define flexible and tuneable relations

Personally, I would use real-world values and not scaled variables. It prevents from getting unrealistic values or fluxes without knowing it.

Step 3: Define expected values and penalties for being off

For example, CO_2 levels are between 190 and 290; global temperatures vary a couple degrees; NH ice sheets include up to 100 m GMSL during maximum glaciation, an interglacial is typical 10-20 ky while a whole cycle is 100ky, annual precipitation on two NH ice sheets is 4000 Gt per year (1 cm GMSL), ...

Next, how bad is it as your model does not reach both ends of the spectrum, e.g. gets into eternal (inter)glacial or ice world? Define a matrix so that your results are automatically rated.

Step 4: Find a (intelligent) method to explore the parameter space

As the model has many parameters due to the multiple links, a systematic exploration could be too time consuming. You can give it a try (= Monte Carlo) or find something more clever like Latin hypercube sampling.

Step 5: Analyse the best outcome(s)

What does your best guess model say about the physical processes of glacial cycles? It might be worth to first try to resemble a 40 ky glaciological cycle, and after success to retune to a 100 ky cycle.