UNIVERSITY OF MINNESOTA

Peatland/ Ice Age Hypothesis (PELIAH):
the Glacial Burial Hypothesis

UMN Math Climate Seminar

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November 16, 2011

The Prelude

A review on the current state of Peatland/ Ice Age Hypothesises.

Who is saying what?

And when did they say it?

Do they agree?

Do we?

The Prelude

Back when I was a baby graduate student I wondered:

"Why doesn't anyone seem to care that trees sequester carbon?"

"Couldn't terrestrial carbon sinks affect glacial cycles?"

The Prelude

I talked to some ecologists who told me I was wrong because *mature forests are carbon neutral*. They said:

leaf litter = leaf growth
old tree death = new tree growth

"So maybe there's something else?"

The Prelude

Core, Gander Bay, Nfld 1982

I also found a paper that experimentally showed Boreal forests in northern latitudes to be long term carbon sinks. I conjecture the sequestered carbon is mostly from tree root growth which, if deep enough, will not decompose when the tree dies.

Clarence Lehman, University of Minnesota

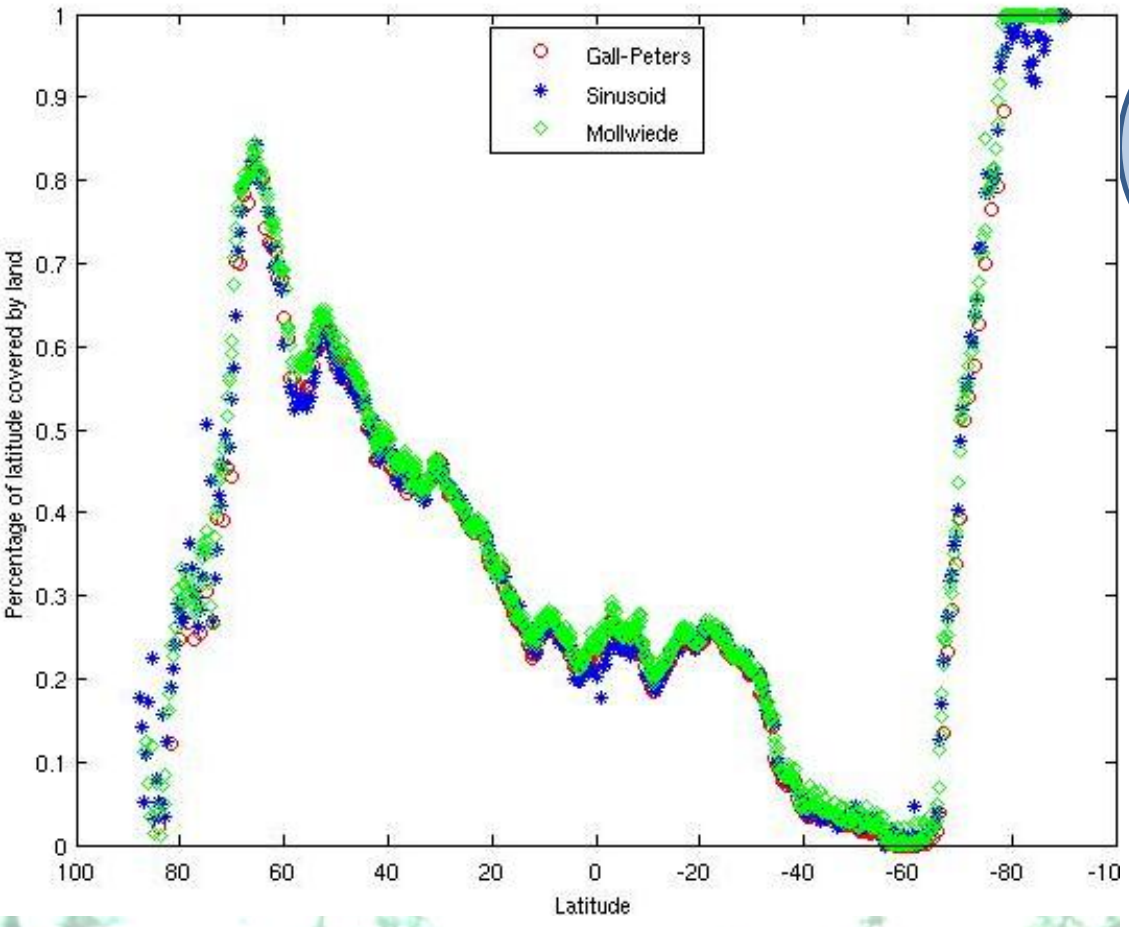
The Prelude

Another problem is my hoped-for long term carbon sink doesn't show up in global climate models.

"Soil depth in GCMs is fairly shallow. I believe deeper soil is necessary to allow for long term carbon sequestration. So it's OK that we don't see this phenomena in GCMS."

"How would peatlands affect glacial cycles?"

The Prelude



"There is lots of land at high latitudes. Which is exactly where peatland grow! Could that carbon be buried under the glaciers?"

Samantha Oestreicher, University of Minnesota

The Prelude

After several years of research and thinking, I believe I have convinced several people of the validity of this hypothesis. Maybe some of them are even listening right now…

And, as it turns out, I'm not the only person who has this idea!

Ning Zeng
University of Maryland
USA

Lars Franzen
University of Gothenburg
Sweden

Samantha Oestreicher
University of Minnesota
USA

The Players

1. Zeng: coupled atmospheric-land-ocean carbon model forced by glacier growth data and CCM1 temperature and precipitation values. (intermediate complexity)

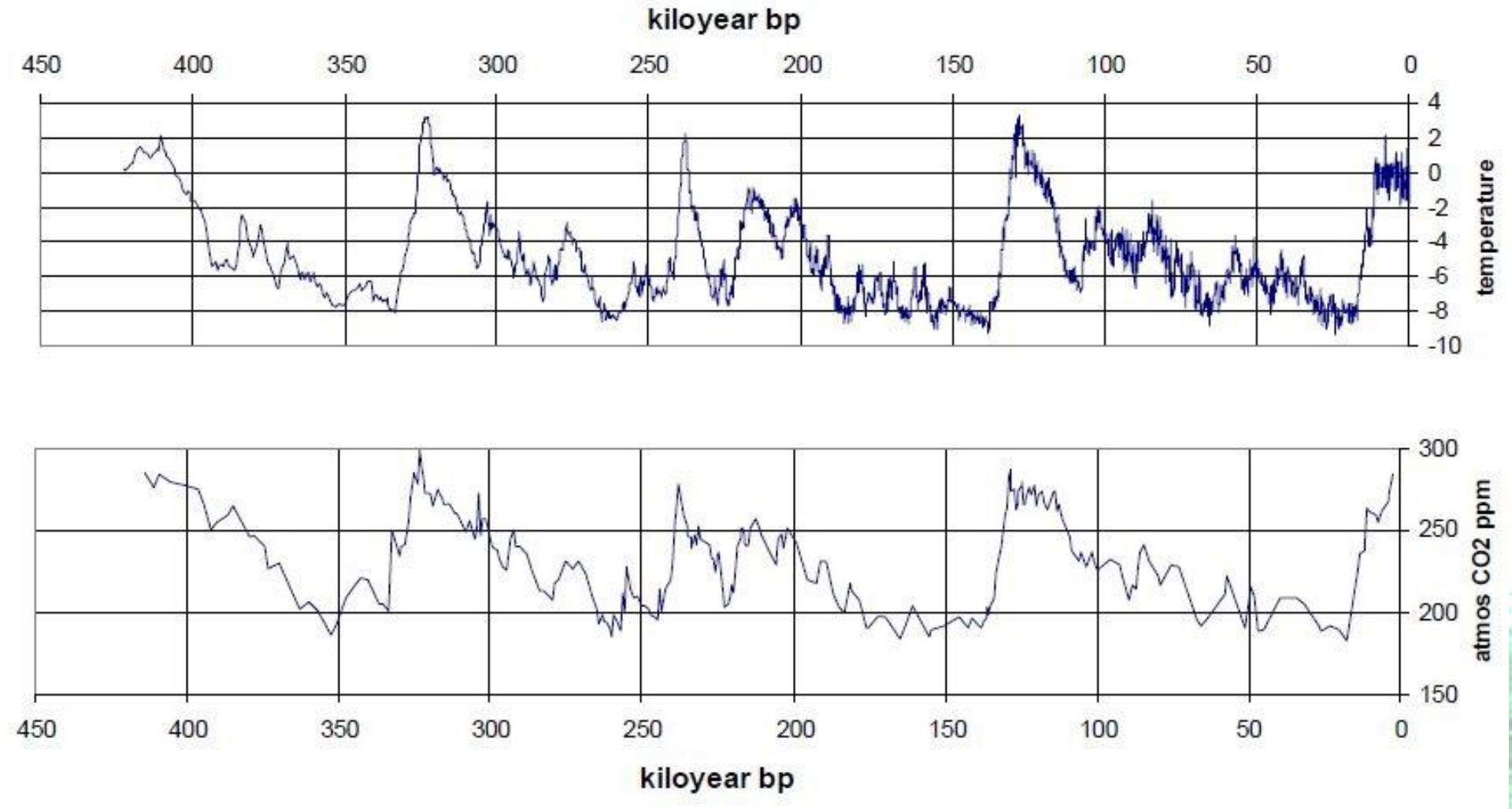
2. Klinger/Franzen: Box Diffusion CO2 exchange model. (intermediate complexity).

3. PaleoCarbon: Coupled temperature-ice line-atmospheric carbon model. (minimal complexity).

The Setting

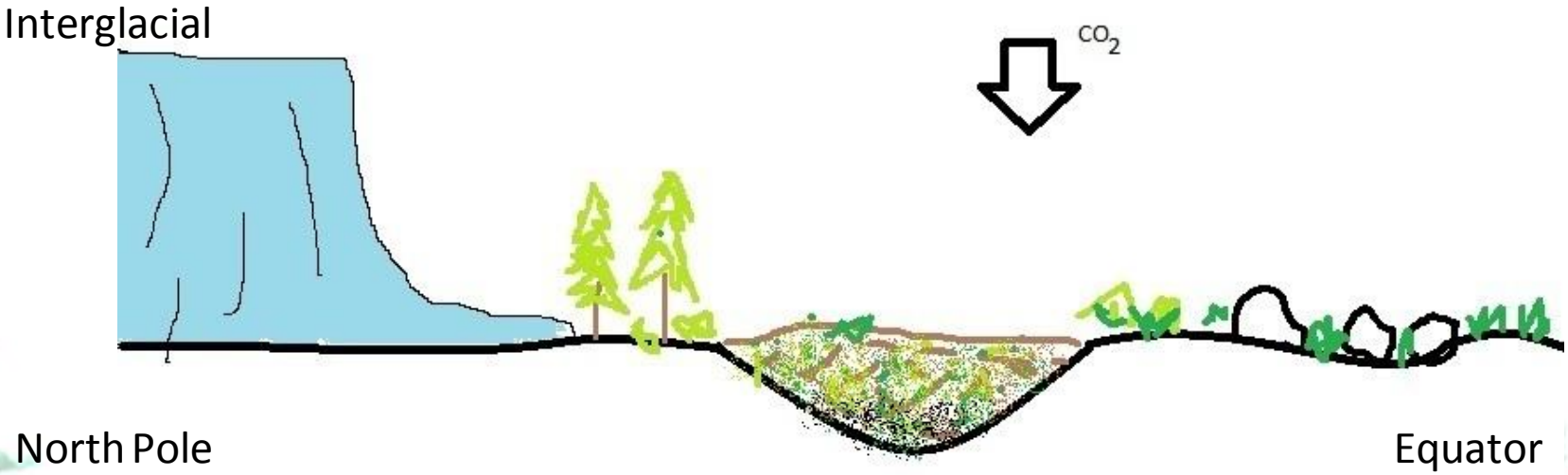
Vostok Core Sample Data

Petit, et al, *Nature* **399** (June 3 1999), pp.429-436



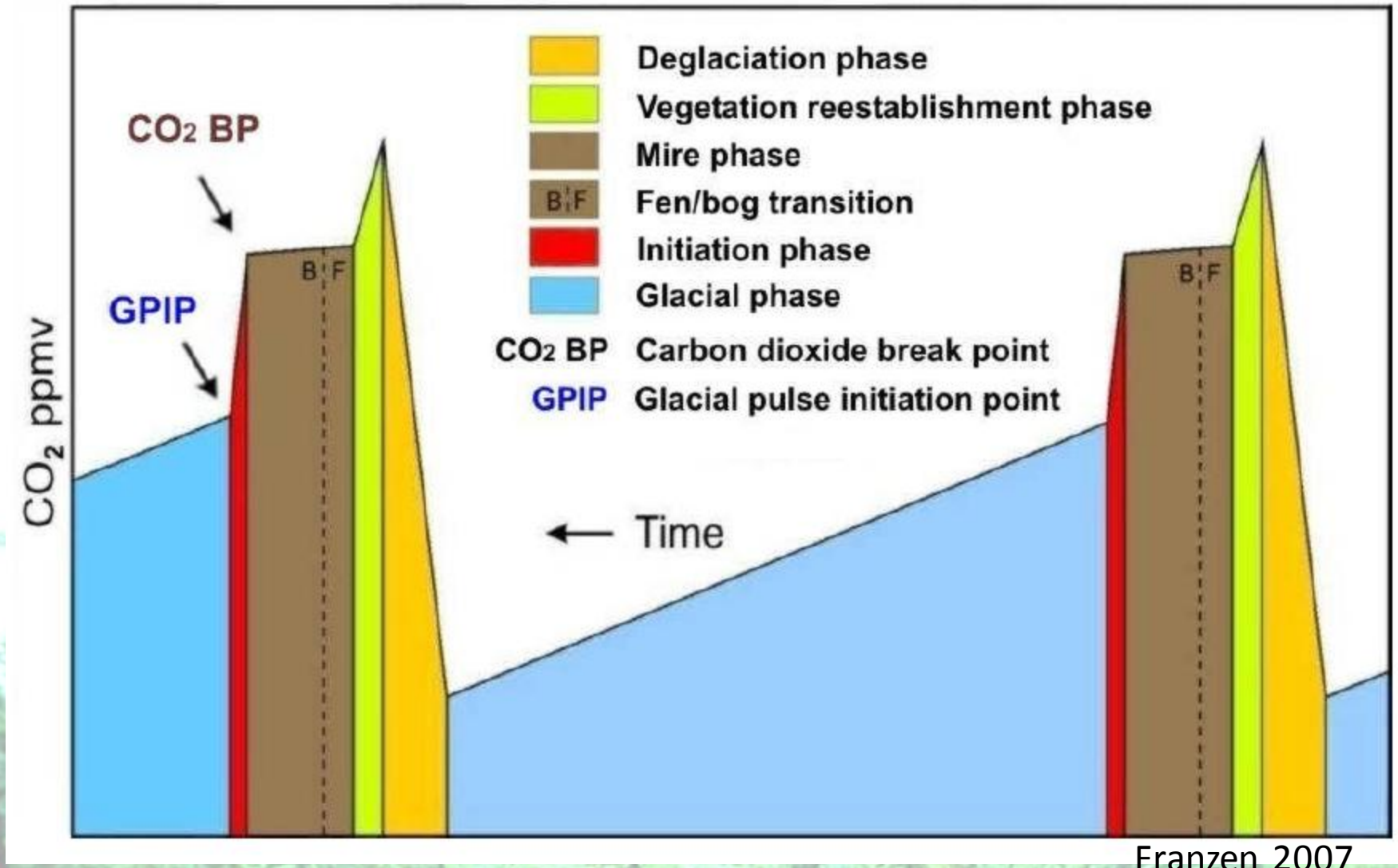
Peatland/ Ice Age Hypothesis

We begin the explanation during an interglacial (warm) period with a small ice cap:



Where are we in the glacial carbon cycle?

Peatland/ Ice Age Hypothesis



Franzen 2007

Where is carbon sequestered?

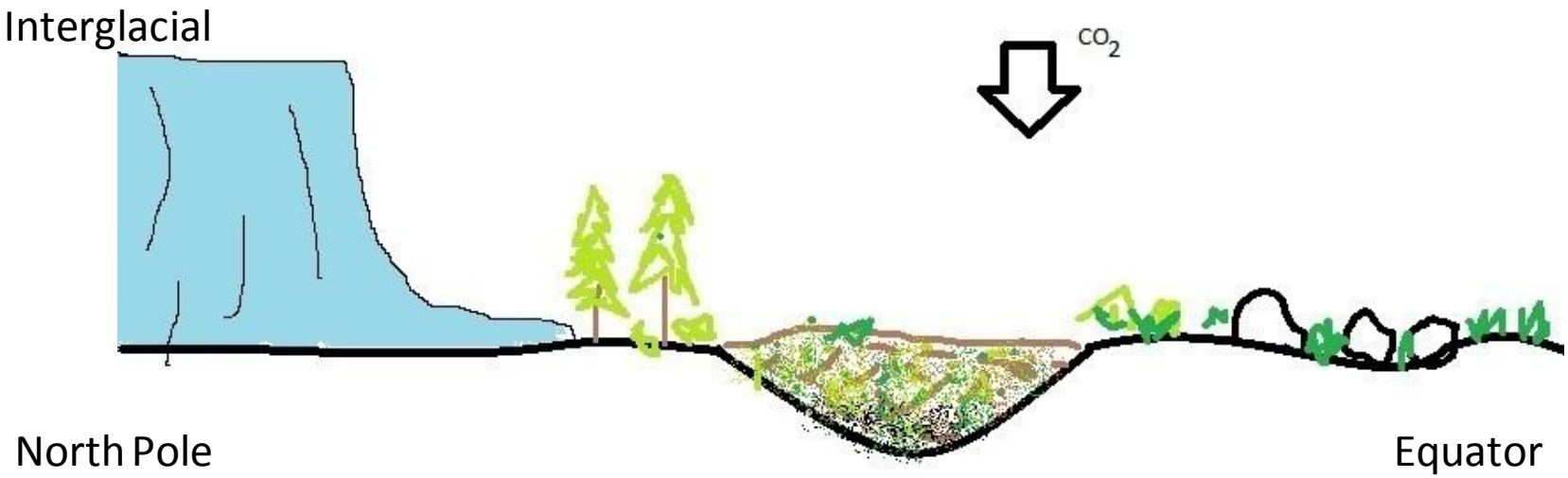
Zeng (2003): Vegetation, soil carbon, organic carbon buried under ice and continental shelf carbon that is submerged under water when sea level rises. Ocean plays an important buffering role.

Klinger/ Franzen (1995): Peatlands. In fact:

Any hypothesis to "explain atmospheric CO2 trends during a glacial-interglacial cycle must include peatland dynamics." (Klinger 1995 pg 91)

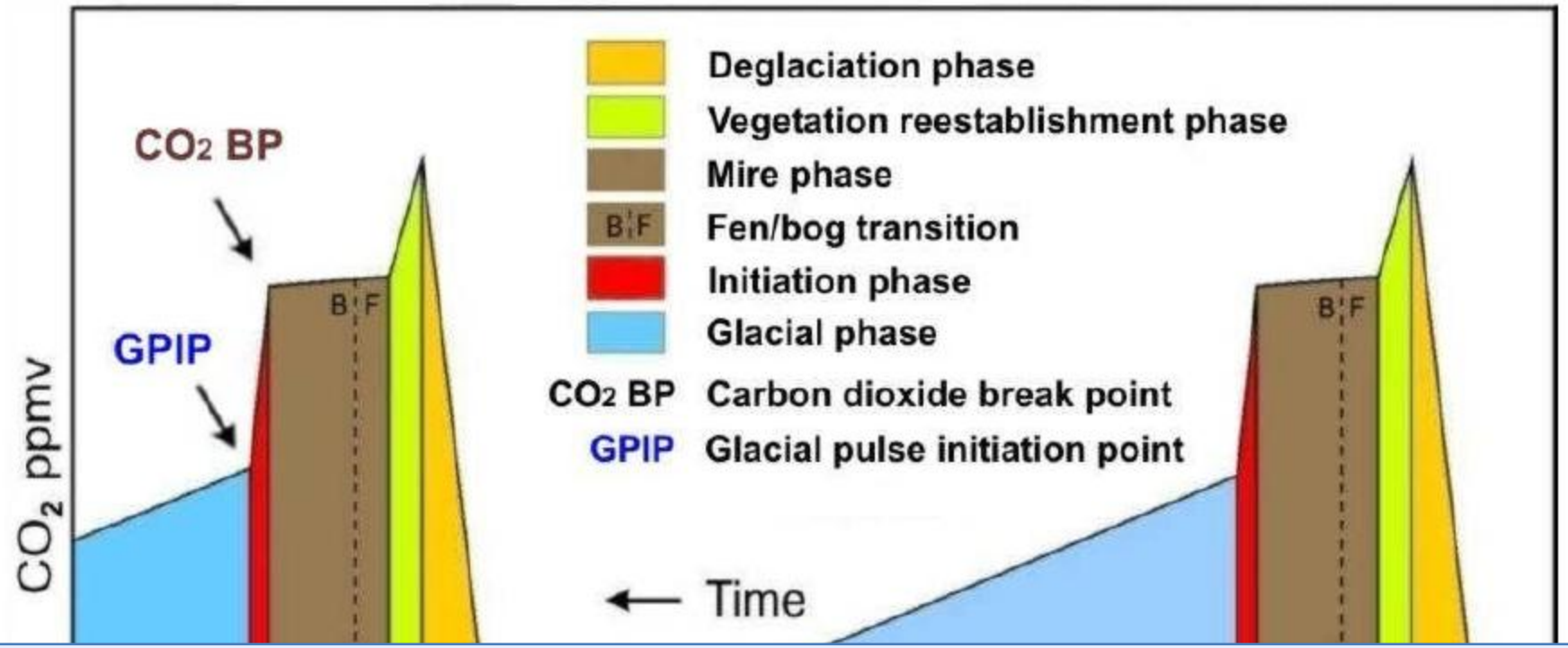
PaleoCarbon (2011): Peatlands, silicate weathering, & biological pump

Peatland/ Ice Age Hypothesis



Why do the glaciers begin to advance?

Peatland/ Ice Age Hypothesis



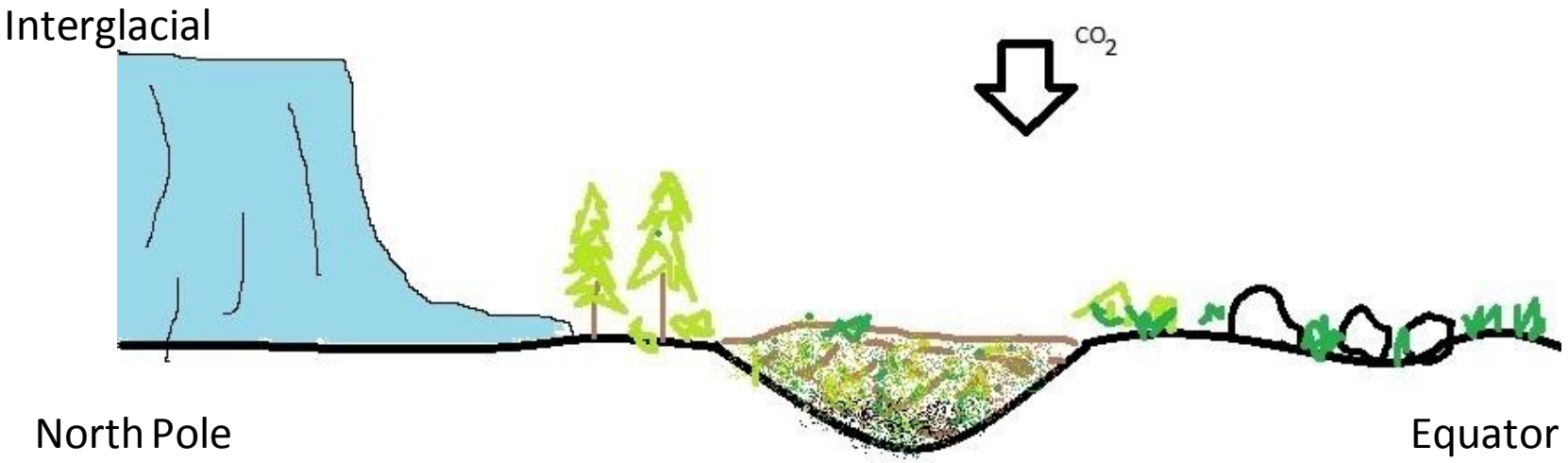
Carbon Dioxide Break Point (CO2 BP)

Is when more CO2 is being pulled out of the atmosphere into laterally growing peatlands than can be compensated by flows from deep ocean reservoirs. *(Frazen pg 304)*

Glacial pulse initiation point (GPIP)

Is when a small distrubance might lead to a new ice age given a sufficient perterbation.

Peatland/ Ice Age Hypothesis



The glaciers begin to advance.

What happens to the forests and the peat?

Peatland/ Ice Age Hypothesis:

Bulldozer or Snowpile?

Zeng believes in the snowpile technique, which he calls 'freezer'. *(Zeng 2007 pg 139)*

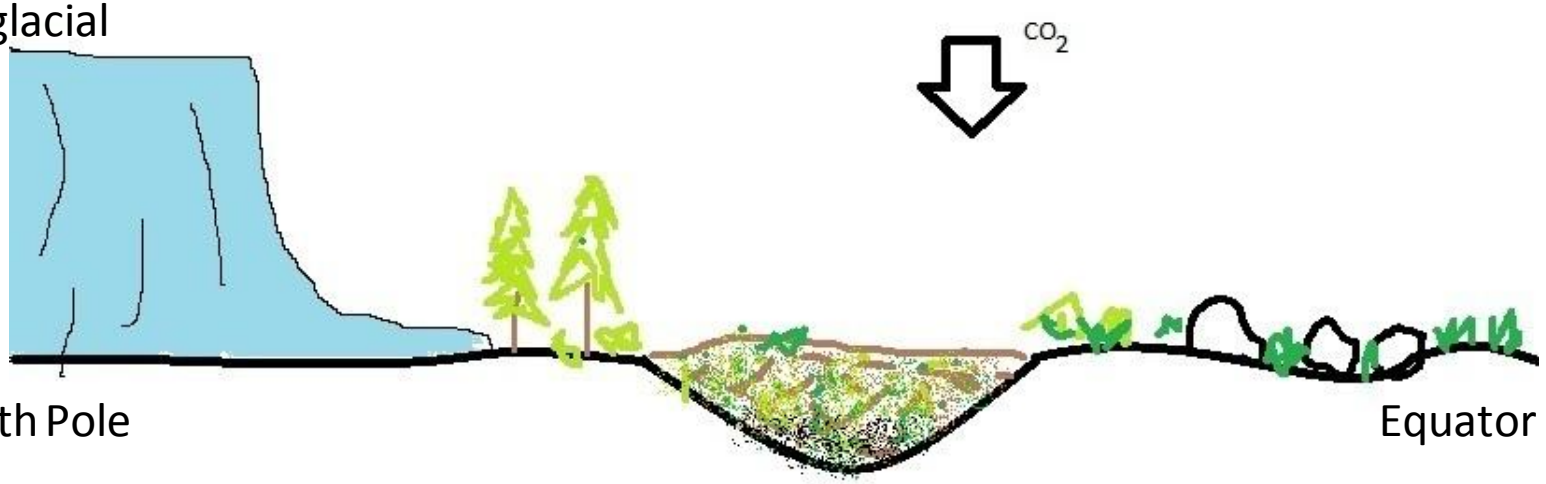
Franzen uses the snowpile technique, he calls it a 'snowblitz'. "all organic material … is rapidly buried under snow and ice." *(Franzen 2007 pg304)*

I claim that there is a combination of both bulldozer and snowpile. This is necessary to account for Carbon13 values in the data.

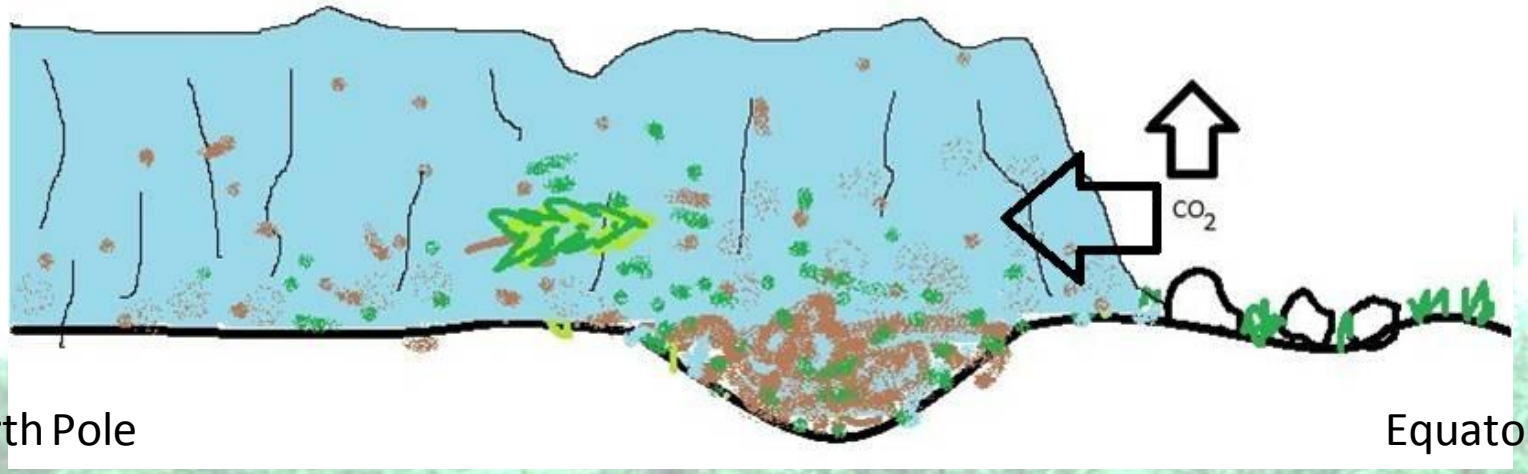
Zeng 2003, Zeng 2007

Peatland/ Ice Age Hypothesis

Interglacial

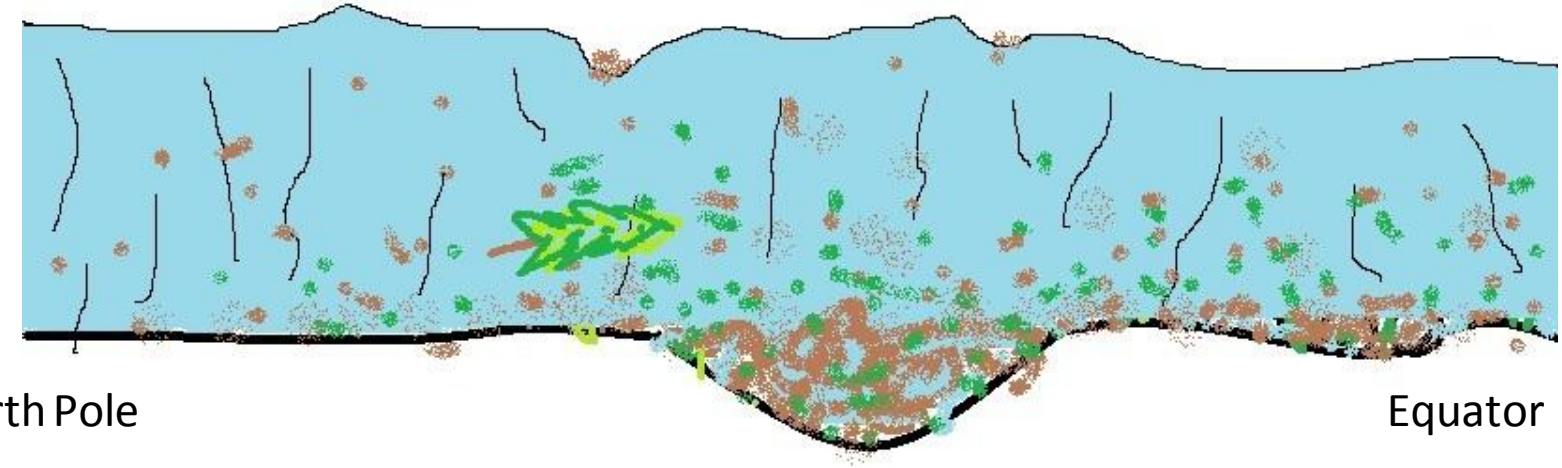


Glacial Advance



Peatland/ Ice Age Hypothesis

Glacial Maximum



North Pole

Equator

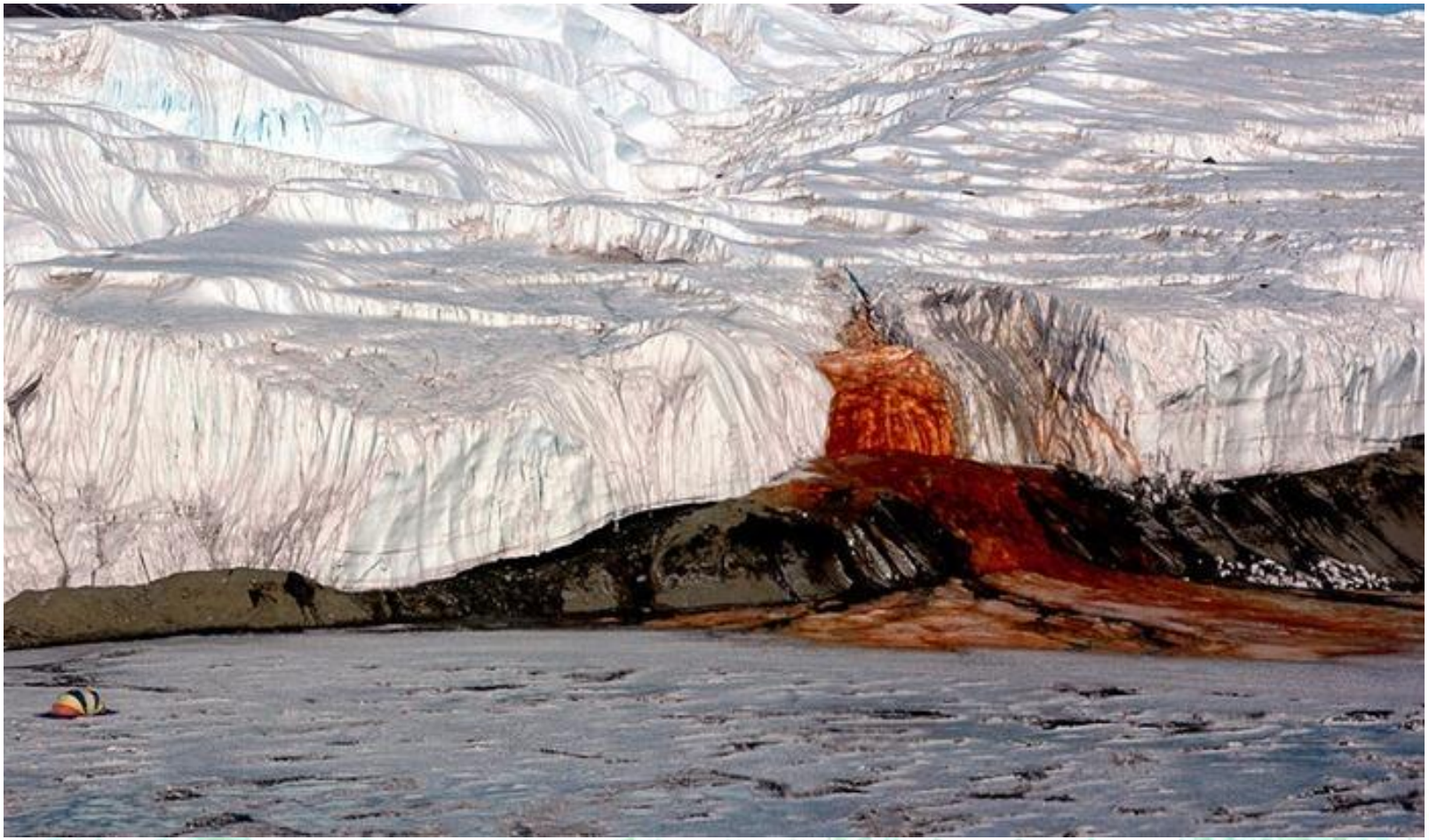
Why do the glaciers begin to retreat?

"the buried carbon is transported out of the icesheet." *(Zeng 2007 pg 142)*

"the basal slip would fulfil the required emptying mechanism of … organic material to the ice margins where it oxidizes into carbon dioxide" *(Franzen 2007 pg 305)*

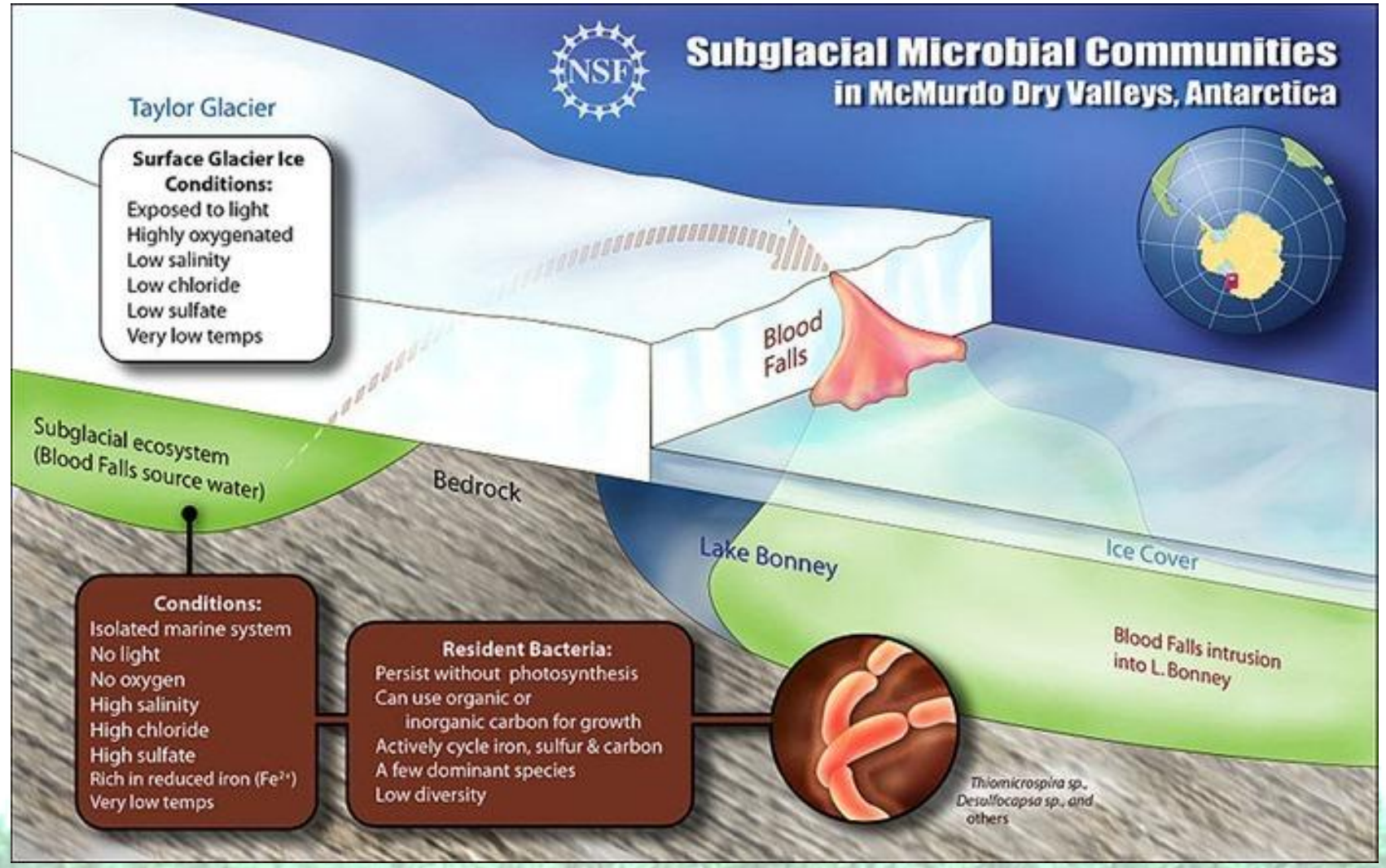
Here's a neat example of flows under a glacier!

Aside: Blood Falls



http://www.amusingplanet.com/2010/11/secret-of-blood-falls-of-antarctica.html

Aside: Blood Falls



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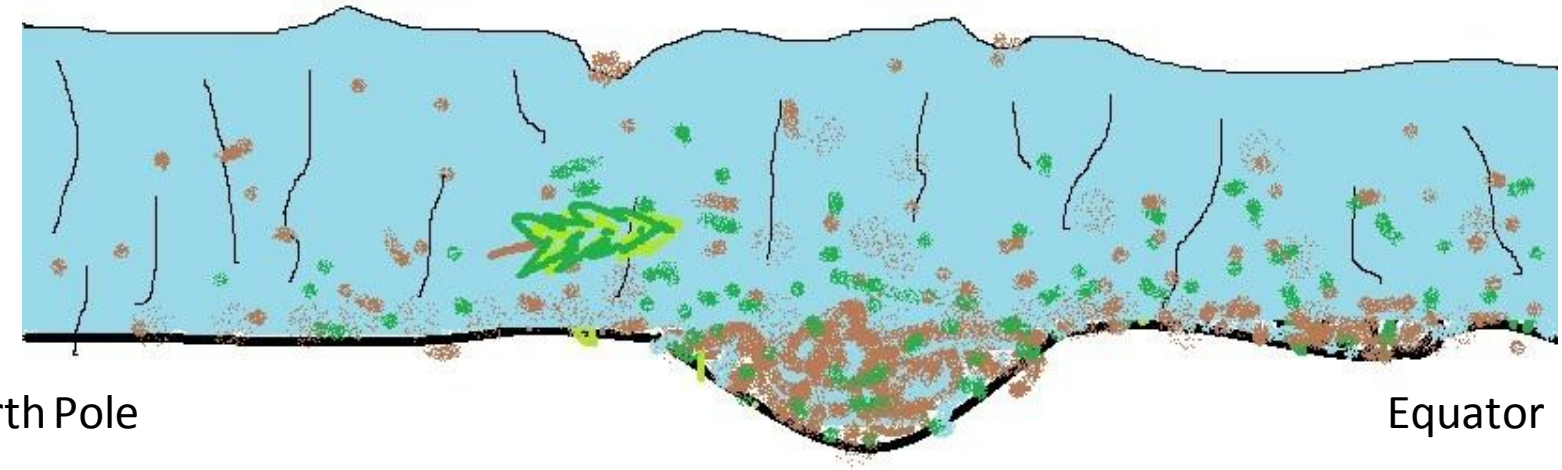
Peatland/ Ice Age Hypothesis

Glacial Maximum



North Pole

Equator

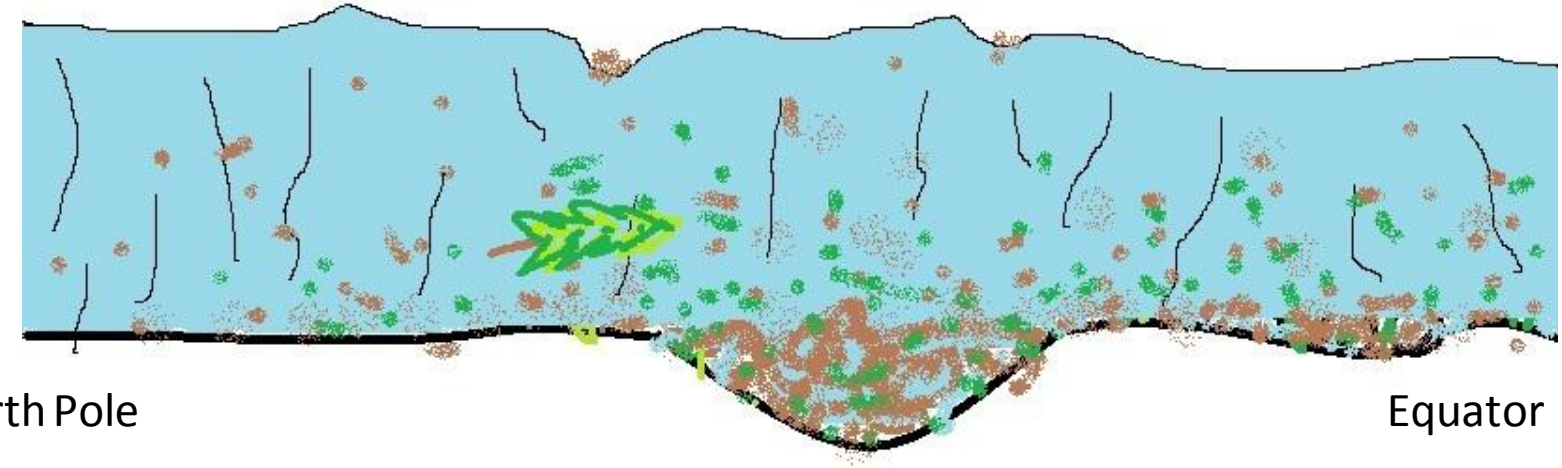
Positive Feedback:

CO2 to atmosphere when glaciers melt

Temperature Rises

Peatland/ Ice Age Hypothesis

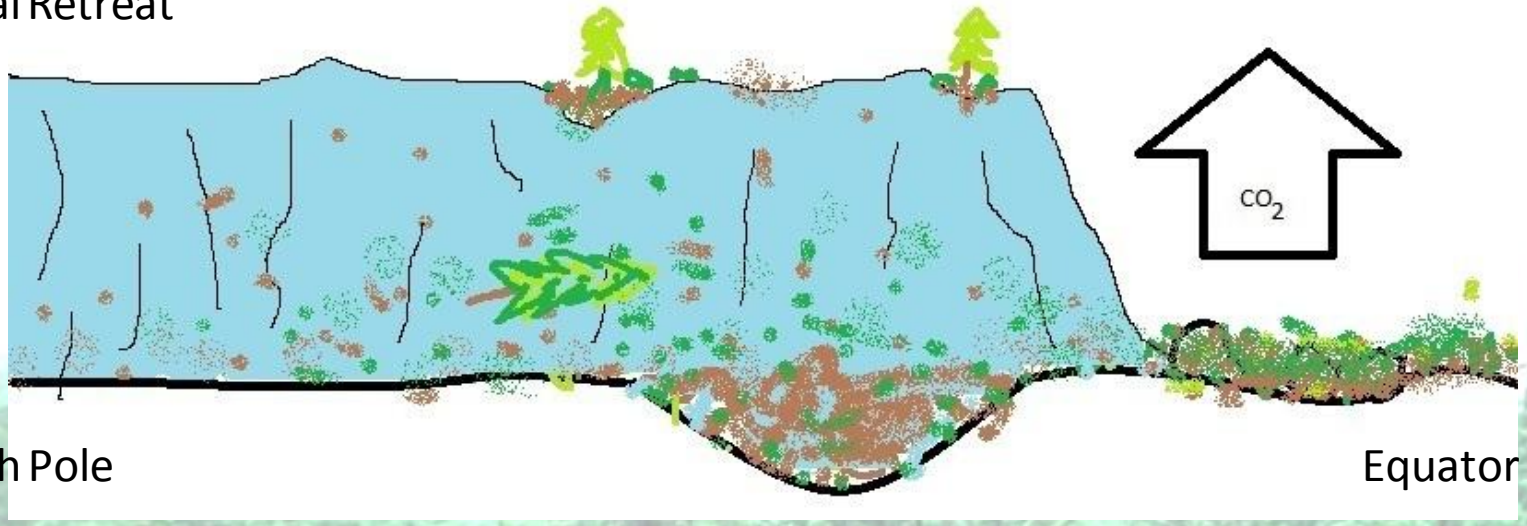
Glacial Maximum



North Pole

Equator

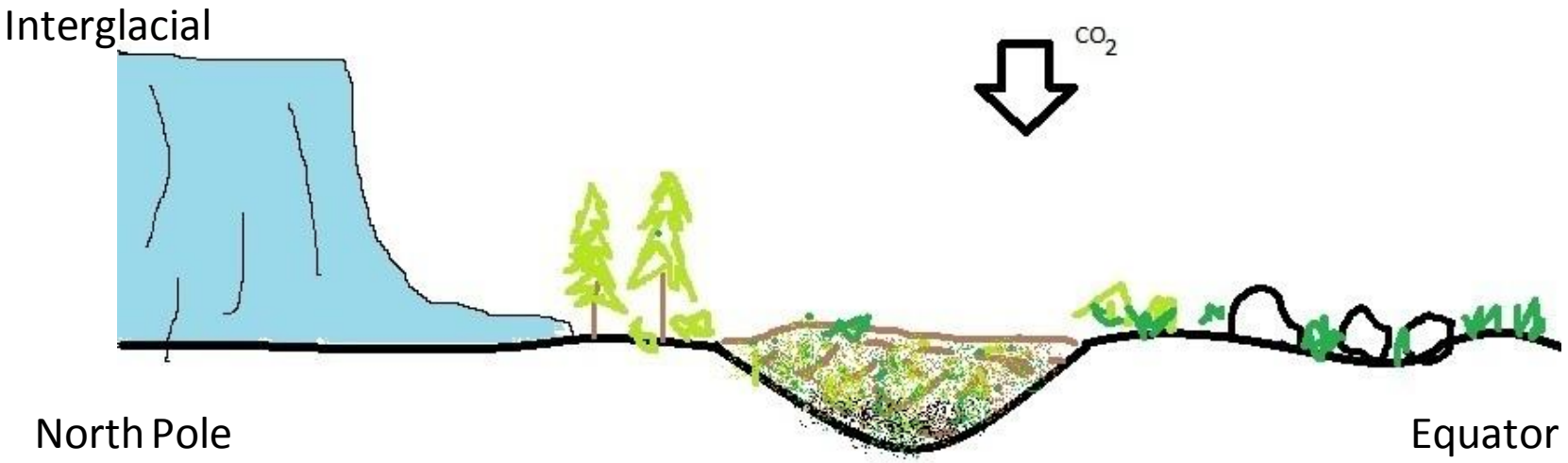
Glacial Retreat



North Pole

Equator

Peatland/ Ice Age Hypothesis



Then the whole process begins again!

We now make a few remarks.

Carbon release in Zeng's Model

From model results, one can determine that "carbon is released rapidly during deglaciation at a peak rate of 0.1 Gt per year." (Zeng pg 683)

For comparison, humans emit 29 Gt of carbon dioxide annually.

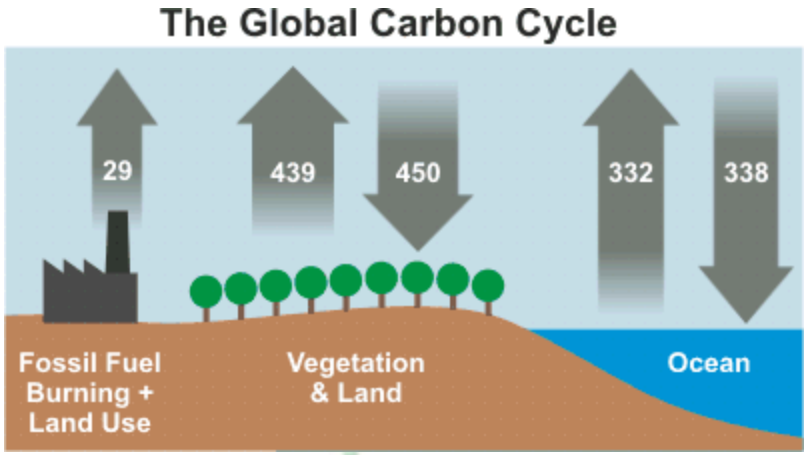
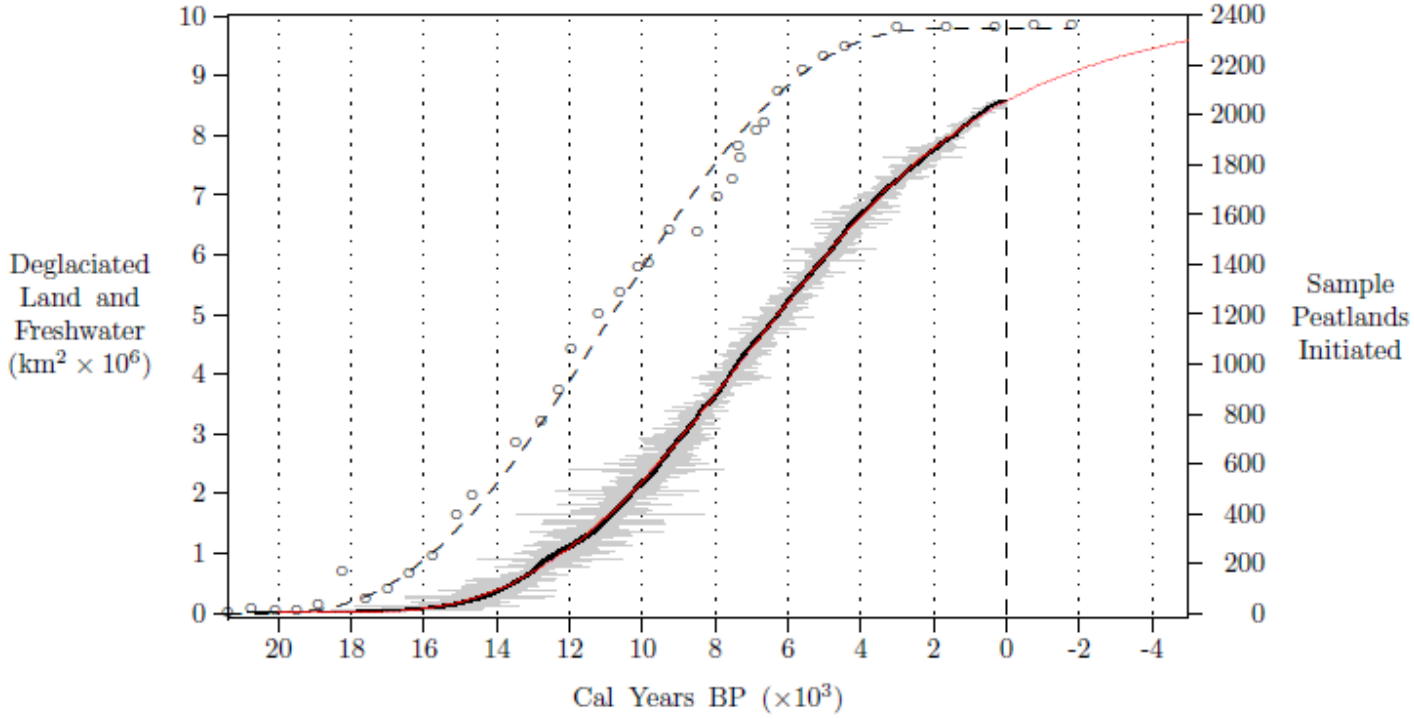


Figure 7.3, IPCC AR4

Recall, a X ppm rise in atmospheric CO2 correlates to approximately 2.1*X Gt of carbon emitted.

Comparing Plant Growth Delay

"Modeled soil development depends on the rate of vegetation-to-soil turnover (fallen leaves, dead roots, and wood) and it is typically 2-3 kyr up to 5 kyr at regions with low productivity." (Zeng pg 683)



The delay between glacier retreat and peatland growth is between 4,000 and 6,000 years.

Slide by Clarence Lehman, University of Minnesota

Sequestered carbon vs CO_2 ppm

Peatland and Boreal forest growth aren't the ONLY mechanisms to cause glacial cycles. Some other forcing terms are:

1. Ocean circulation and SST
2. Silicate Weathering.
3. Milankovitch Cycles forcing energy balance.
4. Ice albedo feedback.
5. Plate tectonics
6. Biological Pump

50% of the reason for glacial cycles is atmospheric CO2, the other half is ice albedo feedback. *(Archer 2010 pg 62)*

Sequestered carbon vs CO_2 ppm

What affects CO2 ppm levels? We need 80-100 ppm to move into a glacial maximum.

1. SST: 20-30 ppm *(Archer 2010 pg 79)*
2. Ocean circulation: 10-20 ppm
3. Sea level change: 12 ppm
4. PELIAH: 15 ppm
5. Silicate Weathering. 10-20 ppm *(Brovkin 2007 pg 2)*
6. Plate tectonics. 0-10 ppm *(Toggweiler, 2007)*
7. Biological Pump: 35-40 ppm *(Brovkin 2007 pg 1)*

≈70 ppm

Sequestered carbon vs CO_2 ppm

What affects CO2 ppm levels? We need 80-100 ppm to move out of a glacial maximum.

1. SST: 20-30 ppm
2. Ocean circulation: 10-20 ppm
3. Sea level change: 12 ppm
4. Pl THIS IS MOSTLY CONJECTURE. DON'T REUSE THESE VALUES!!
5. Silicate Weathering. 0-5ppm
6. Plate tectonics. 0-1 ppm
7. Biological Pump: 3-5 ppm

Sequestered carbon vs CO_2 ppm

Zeng (2003): "an increase of 30 ppmv atmospheric CO2 at deglaciation is the direct result of [547] Gt carbon released from land in a scenario in which the ocean acts only as a passive buffer." *(pg 682 figure 4)*

Note: Of the 547, only 427 was buried. The rest was from other processes. *(pg 684)*

Klinger (1995): "Strongest shift in temperatures… occurred in association with a decrease in atmospheric CO2 concentration of approximately 40-70 ppm. Klinger (1991) estimated that 500 Gt of carbon accumulated in mid- to high-latitude peatlands during this interglacial-glacial transition." *(pg 89-90)*

Sequestered carbon vs CO_2 ppm

What affects CO2 ppm levels? We need 80-100 ppm to move out of a glacial maximum.

Perhaps the Peatland/ Ice Age Hypothesis (PELIAH), or Glacial Burial Hypothesis, can provide an explanation for the necessary values of carbon?

2. Ocean circulation: 10-20 ppm
3. Sea level change: 12 ppm

More research needs to be done! Further models need to be created and analyzed for this type of phenomena.

5. Silicate Weathering. 0-5ppm
6. Plate tectonics. 0-1 ppm
7. Biological Pump: 3-5 ppm

≈70 ppm

Conclusion

Thank you!