Introduction to Huybers' 2009 Model

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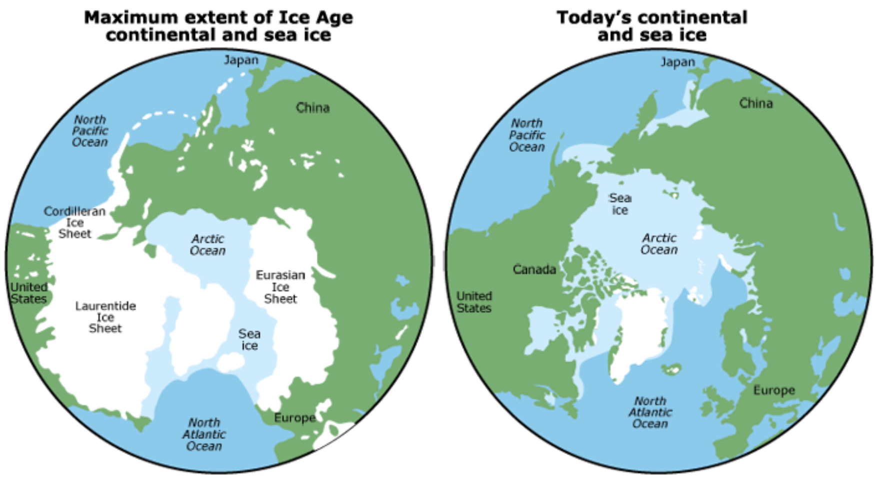
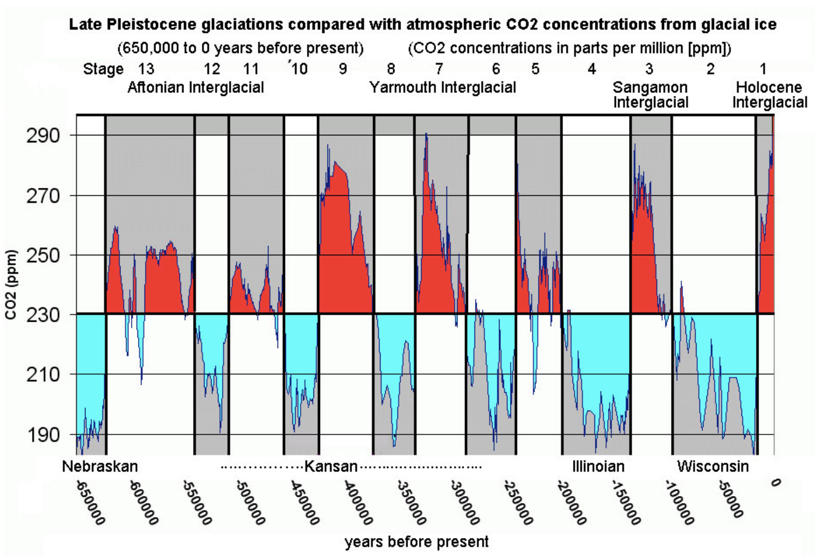
10/31/2017

Outline of the talk

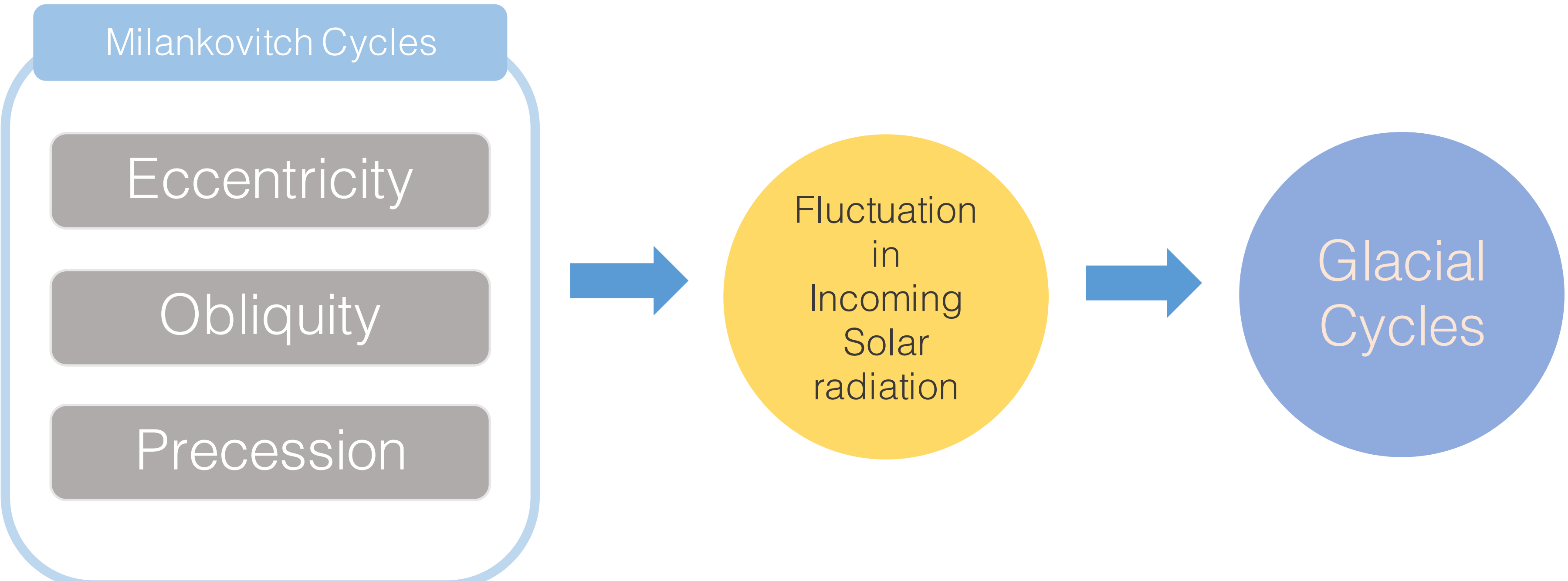
- Introduction
  - Glacial cycles
  - Milankovitch Cycles
  - Mid-Pleistocene Transition problem
- Huybers' analysis of deglaciations
  - Hypothesis testing
  - Motivation for the structure of Huybers' model
- Huybers' model
- Model performance

What are glacial cycles?

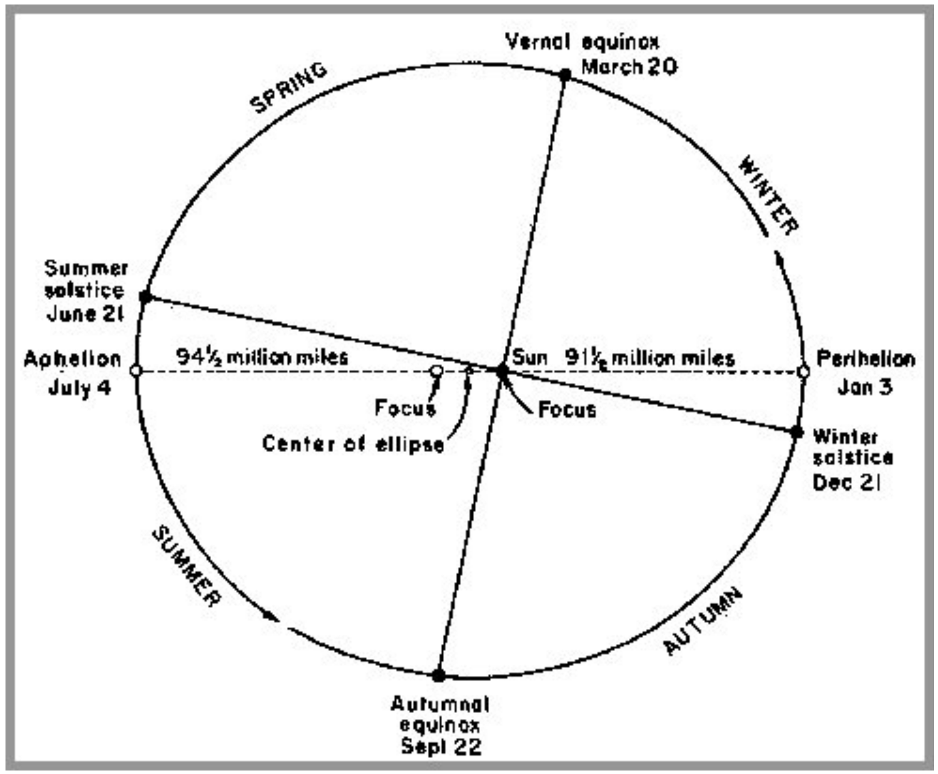




Milankovitch cycles drive glacial cycles

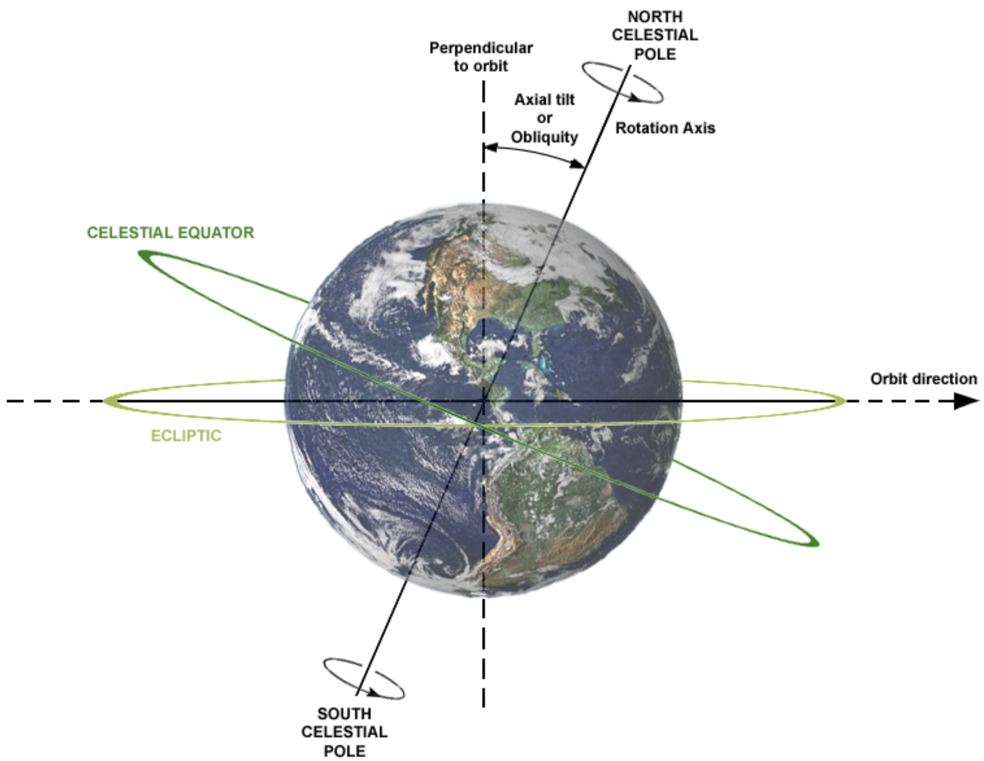


Eccentricity



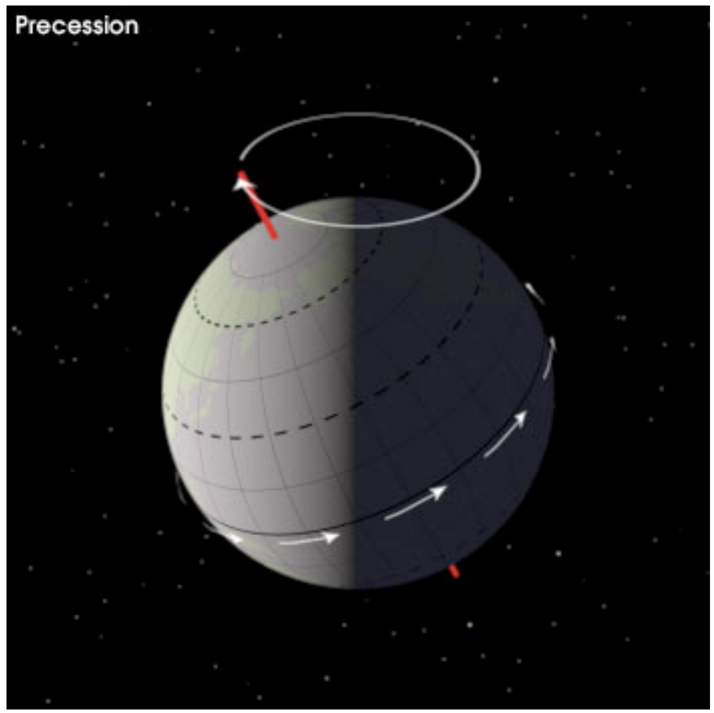
John Imbrie & Katherine Palmer Imbrie, Ice Ages: Solving the Mystery, Harvard Univ. Press, 1979.

Obliquity



http://upload.wikimedia.org/wikipedia/commons/6/61/AxialTiltObliquity.png

Precession

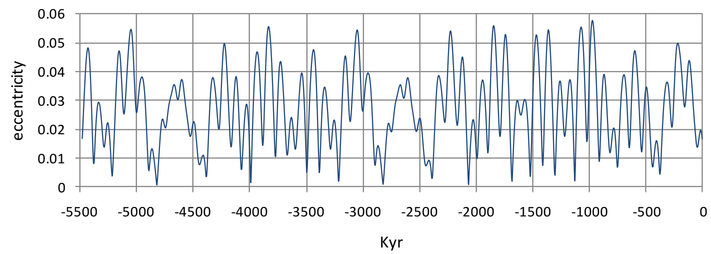


http://earthobservatory.nasa.gov/Library/Giants/Milankovitch/milankovitch_2.html

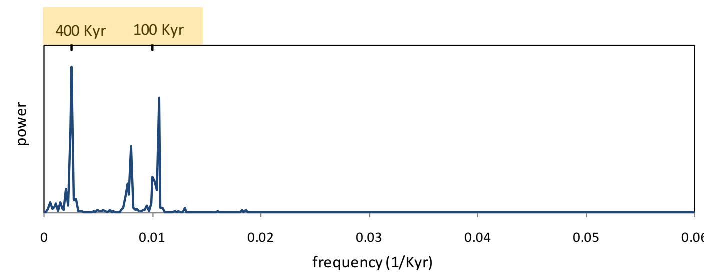
Analysis of Milankovitch cycles' periodicity

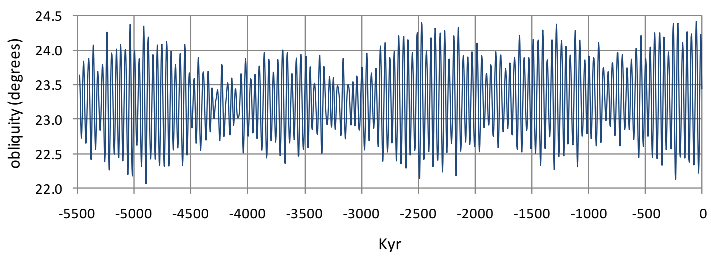
Laskar's computations

Spectra

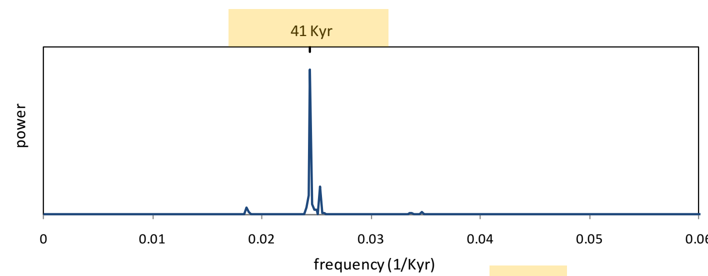


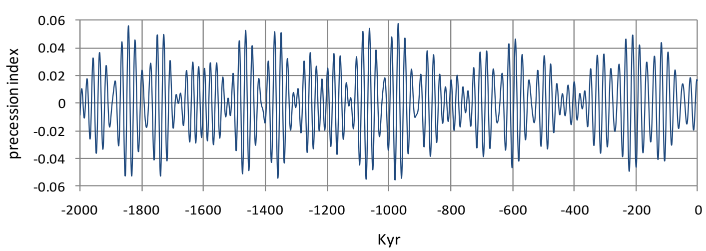
Eccentricity



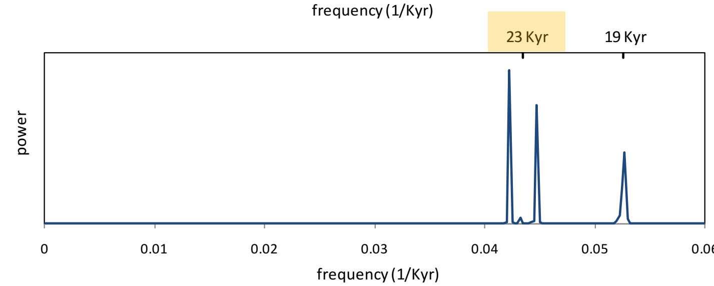


Obliquity

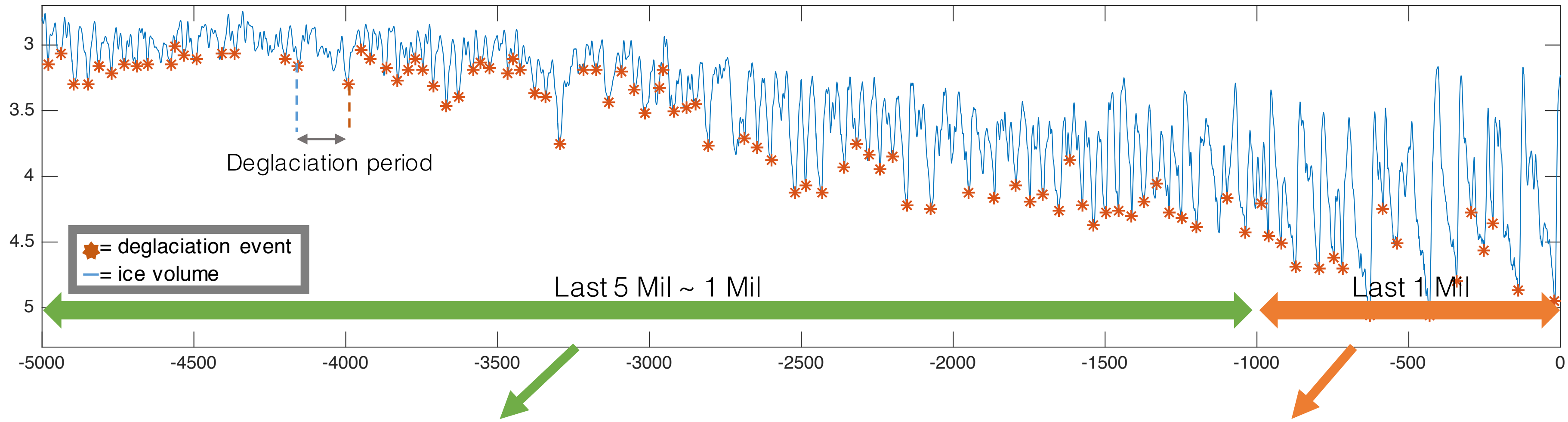


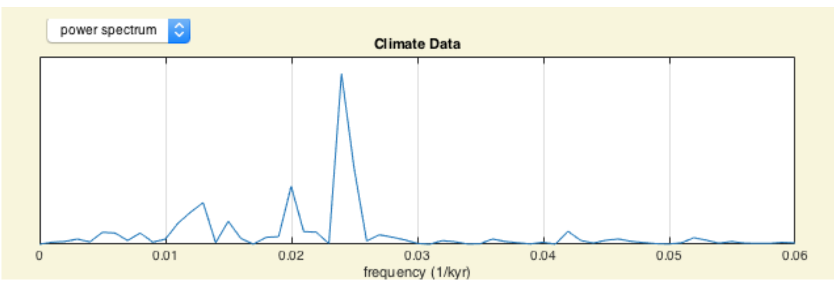


Precession

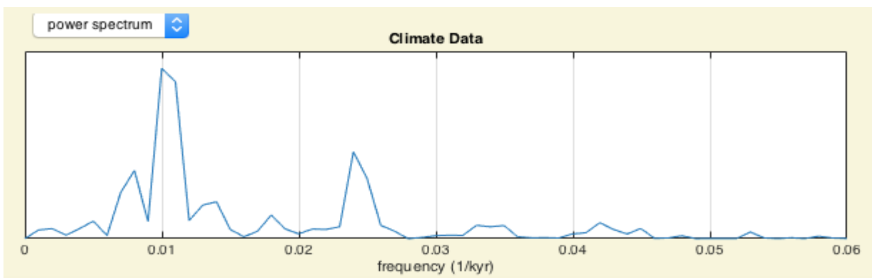


Power spectrum of glacial cycles data





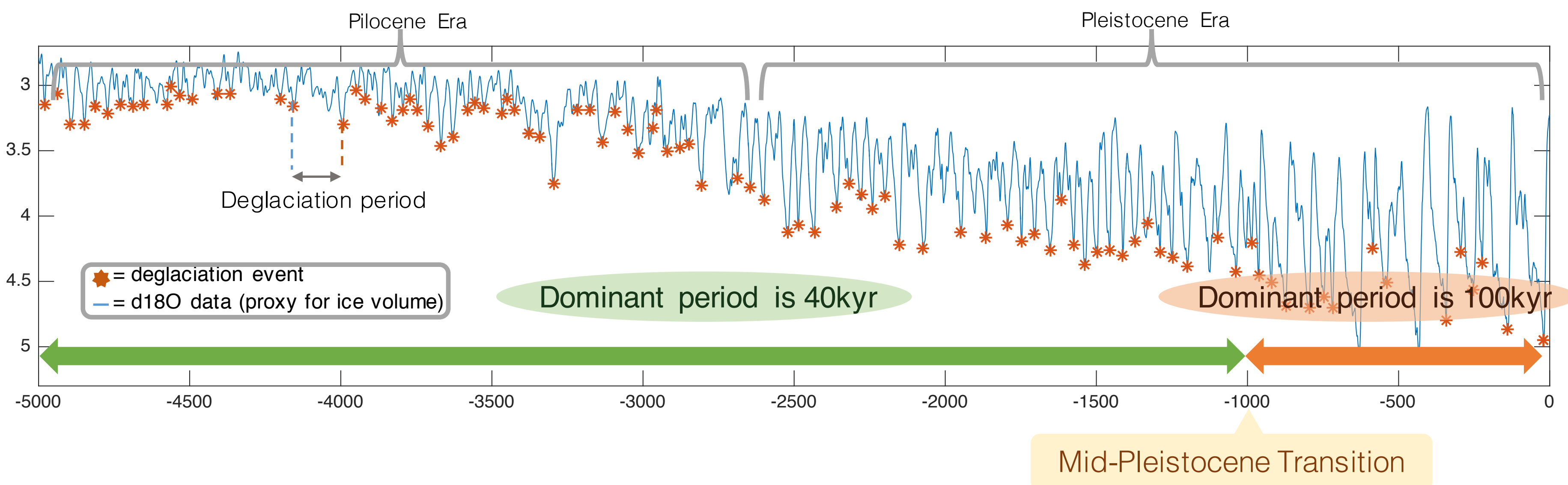
Dominant peak at ~ 0.25 = 40kyr period



Dominant peak at ~ 0.1 = 100kyr period

Mid-Pleistocene Transition Problem

“Did the main forcing for glacial cycles change from obliquity to eccentricity?”
(40kyr phase) (100kyr phase)



Huybers' Analysis of Deglaciations:

Issue of circular reasoning

- Data sets (stacks of data from individual sediment cores) are usually "orbitally tuned"
- Using tuned data sets to conclude that Milankovitch theory is valid is circular reasoning.
- Huybers re-derived the agemodel without using orbital tuning, then conducts a statistical hypothesis test
- He concludes that the deglaciations are triggered by <u>only obliquity.</u>

Peter Huybers, "Glacial variability over the last two million years: an extended depth-derived age model, continuous obliquity pacing, and the Pleistocene progression," Quaternary Science Reviews 26, 37-55 (2007).

Huybers' Statistical Hypothesis Testing

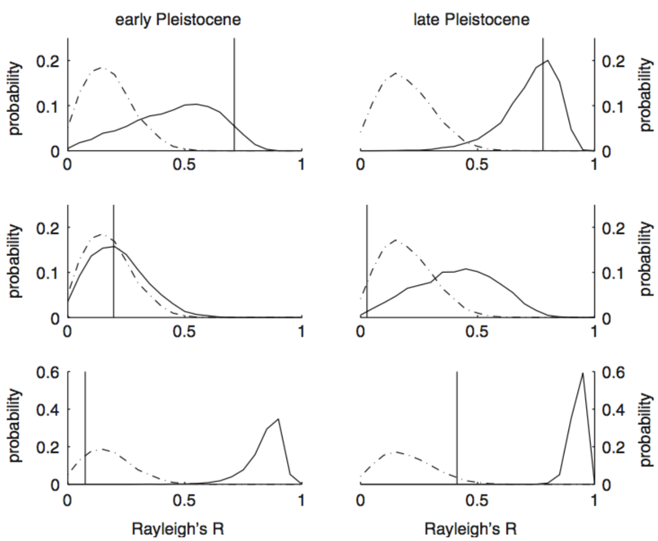
Process	Huybers
1. State the research question, and the appropriate null & alternative hypothesis	H0 = deglaciations are independent of orbital phasing H1 = deglaciations always occur during the same phase of orbital forcing
2. Choose appropriate assumptions about the data. (independence, distribution…)	Time series data, correlated temporally… etc.
3. Choose appropriate test statistic depending on assumptions from 2, and compute it for given data	Rayleigh's R = $\frac{1}{N}\left\|\sum_{n=1}^{N}\cos\phi_n + i\sin\phi_n\right\|$
4. Calculate the P-value, which is the probability of obtaining the test statistic as extreme as the calculated value from 3	To be shown on the next slide

Hypothesis Testing: Results

Obliquity

Precession

Eccentricity

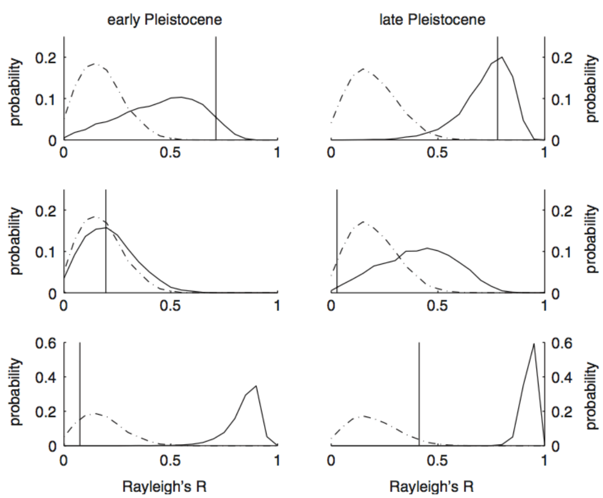


Dashed line for pdf of H0, Solid is pdf of H1

	Early Pleistocene (2–1 Ma)			
	R	cv 1%	Power	Phase
Obliquity	0.7	0.5	0.6	$\pm 56^\circ$
Precession	0.2	0.5	0.0	$\pm 88^\circ$
Eccentricity	0.1	0.5	1.0	$\pm 24^\circ$

	Late Pleistocene (1–0 Ma)			
	R	cv 1%	Power	Phase
Obliquity	0.8	0.5	1.0	$\pm 28^\circ$
Precession	0.0	0.5	0.3	$\pm 56^\circ$
Eccentricity	0.4	0.5	1.0	$\pm 12^\circ$

Hypothesis Testing: Conclusions

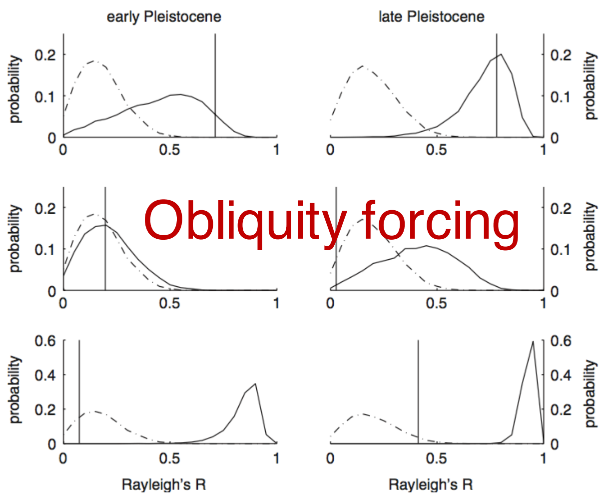


	Early Pleistocene (2–1 Ma)			
	R	cv 1%	Power	Phase
Obliquity	0.7	0.5	0.6	±56°
Precession	0.2	0.5	0.0	±88°
Eccentricity	0.1	0.5	1.0	±24°

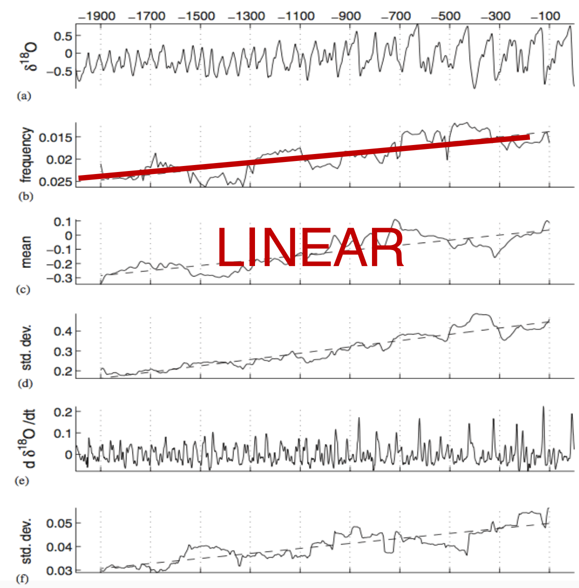
	Late Pleistocene (1–0 Ma)			
	R	cv 1%	Power	Phase
Obliquity	0.8	0.5	1.0	±28°
Precession	0.0	0.5	0.3	±56°
Eccentricity	0.4	0.5	1.0	±12°

1. H0 is only rejected for obliquity for both early and late Pleistocene
2. Power (probability of correctly rejecting H0 when H1 true) is high enough.
   - Late Pleistocene's power is noteworthy – early Pleistocene is known to have 40kyr
3. Eccentricity does not pace deglaciations (H0 not rejected and high power)
4. Precession is inconclusive

Motivation for the model structure

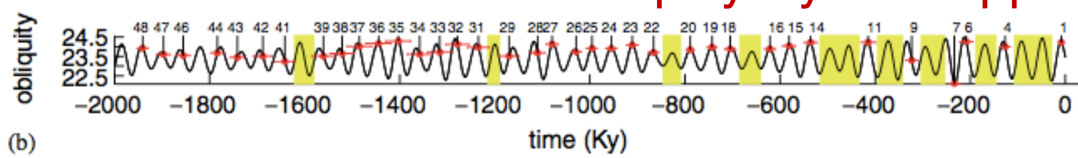


Obliquity forcing



LINEAR

Obliquity Cycle Skipping



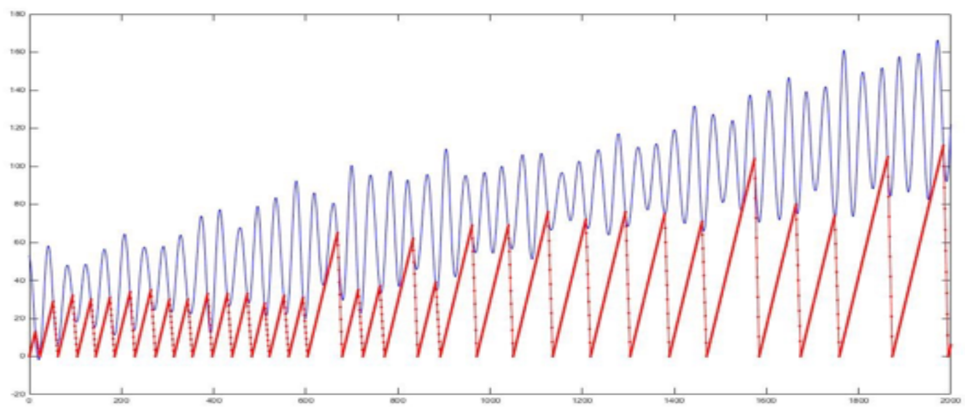
Huybers' Model

$$V_t = V_{t-1} + k_t$$ Discrete Ice Volume Growth

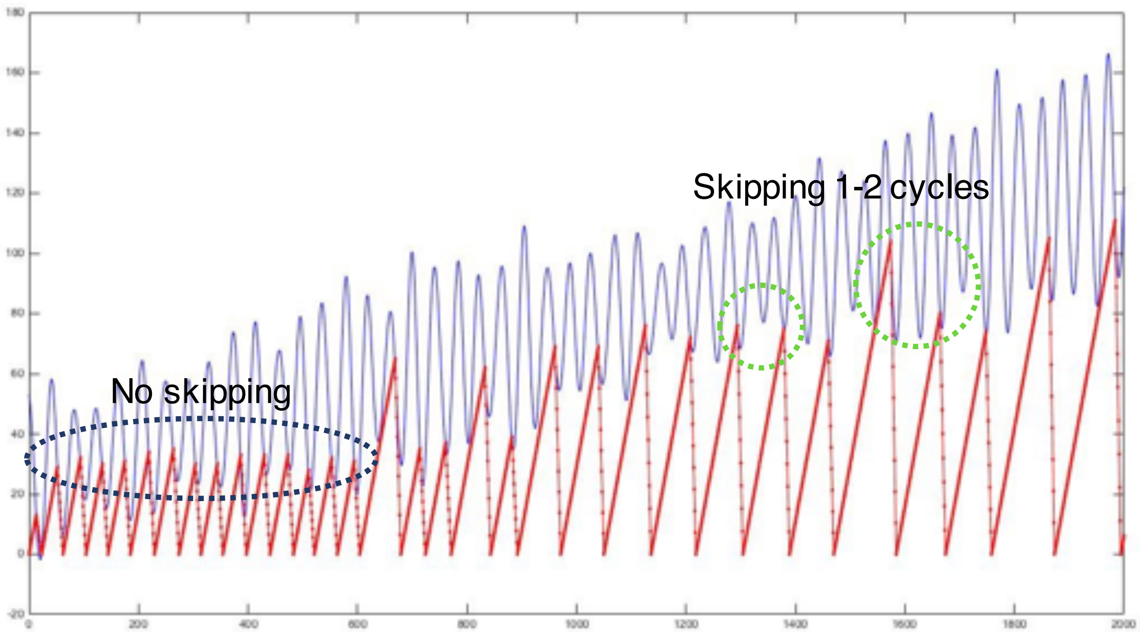
$$T_t = at + b + c\theta_*$$ Threshold (θ_*= scaled obliquity)

If $V_t \geq T_t$, then reset over 10kyr to $V_t = 0$ Growth Terminating criterion

Figure:
Model simulation for last 2 Mil years
with a=0.05, b=126, c=20



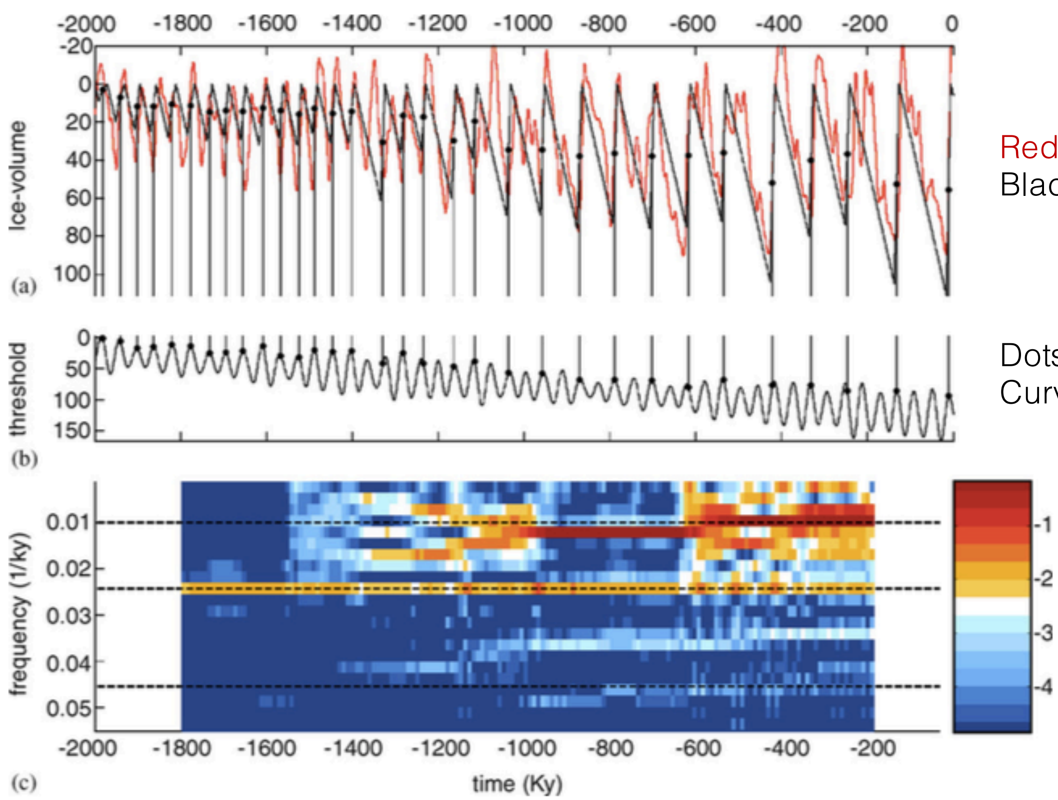
How did obliquity give rise to the shift to 100kyr period?



"…An explanation for the 100 Ka glacial cycles only requires a change in the likelihood of skipping an obliquity cycle, rather than new sources of long-period variability. "

- Peter Huybers, 2007

Model performance



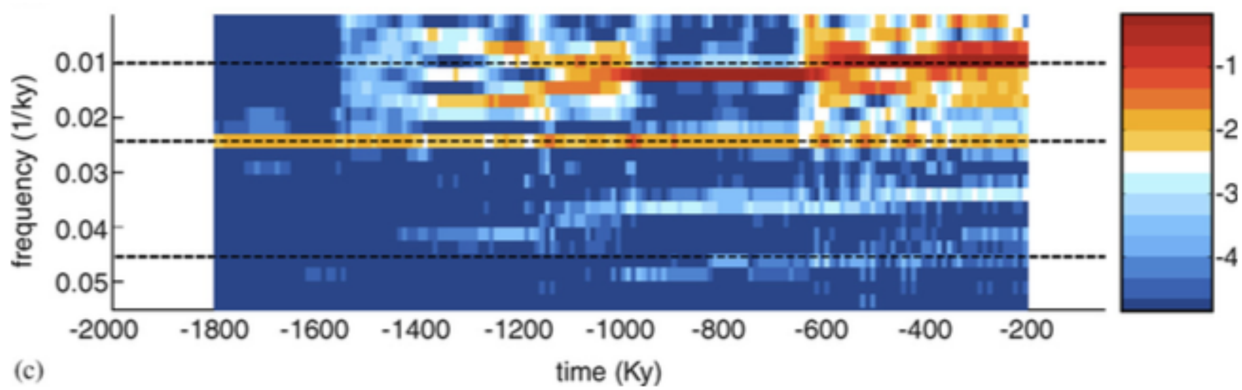
Red: original d18O data
Black: Model output

Dots: deglaciations
Curve: Threshold function from model

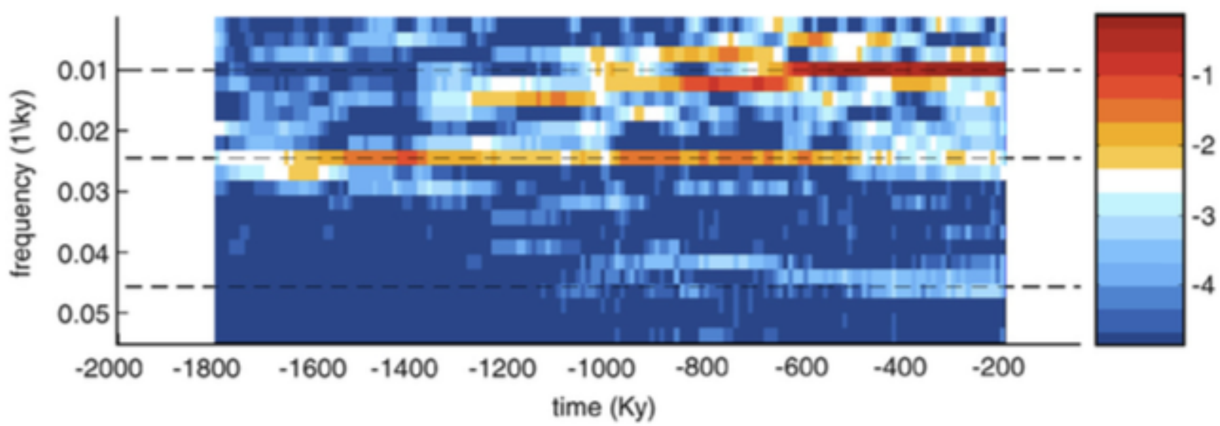
Evolutionary frequency spectrum (400Ka sliding window)

Model performance

Model output



Original d18O data




OBLIQUITY
NOT ECCENTRICITY