Huybers' Model:

Extending the current model & Identifying Deglaciations

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Outline of Talk

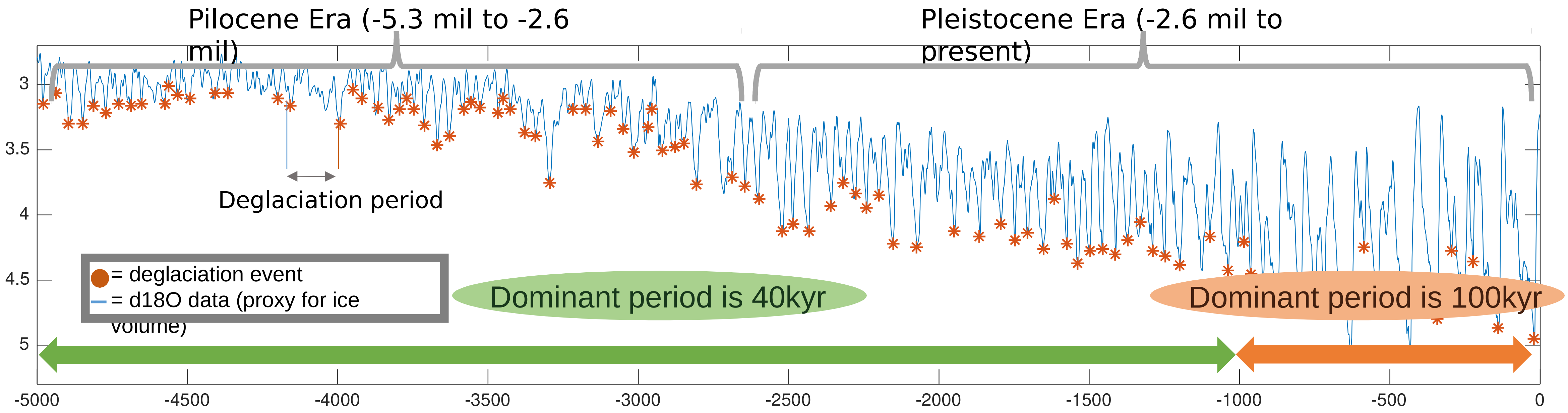
- Brief Introduction to Huyber’s Model
  - Motivation
  - Model
- Summer Project Goals
  - Difficulties of Original Problems Forcing a New Focus
- Definition of Deglaciation Events
  - Problems
  - Duct-tape fixes
  - More sophisticated Approaches
- Conclusions/Future Directions

Introduction

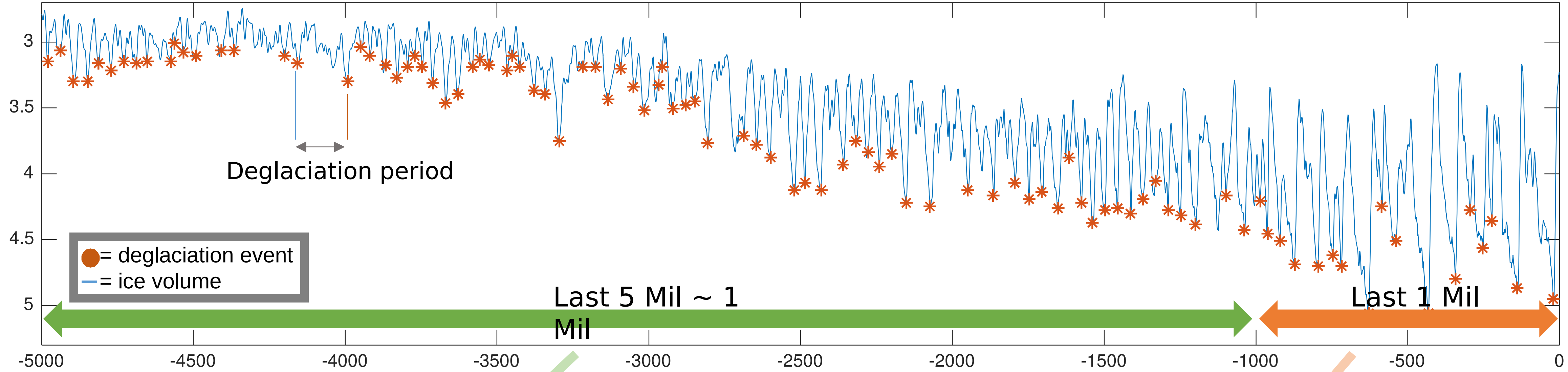
Motivation behind Huybers’ model

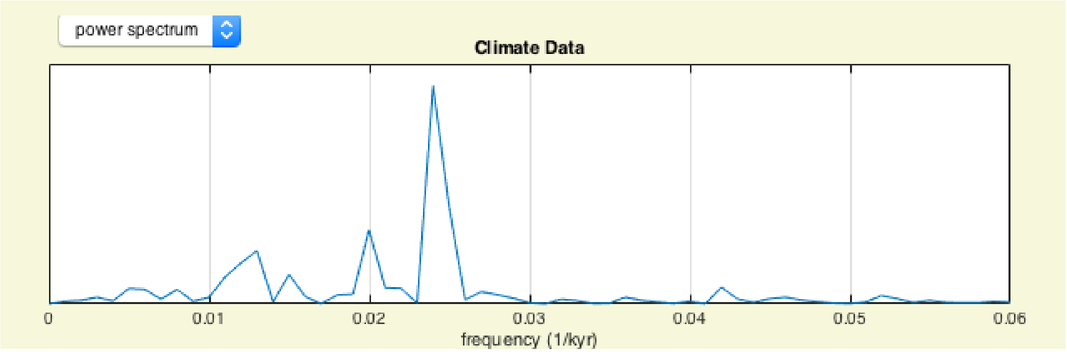
- Mid-Pleistocene Problem (MPT)
- *“Did the main forcing for glacial cycles change from obliquity to eccentricity?”*

(40kyr phase) (100kyr phase)

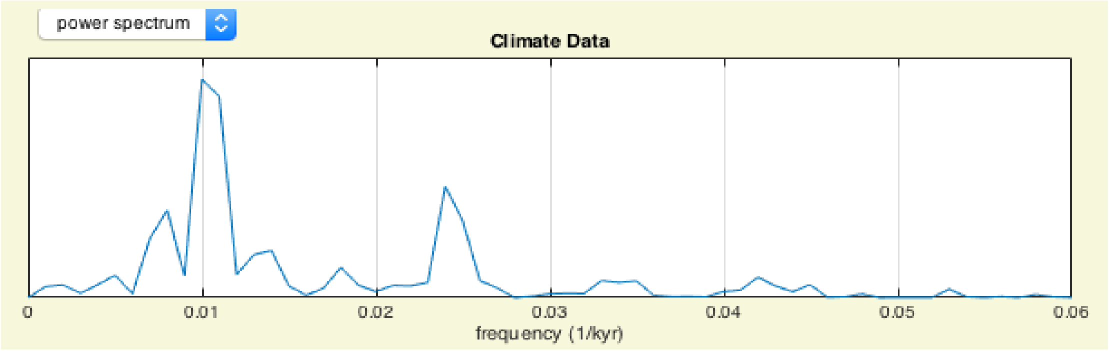


Power spectrum analysis to confirm 40k and 100k periods

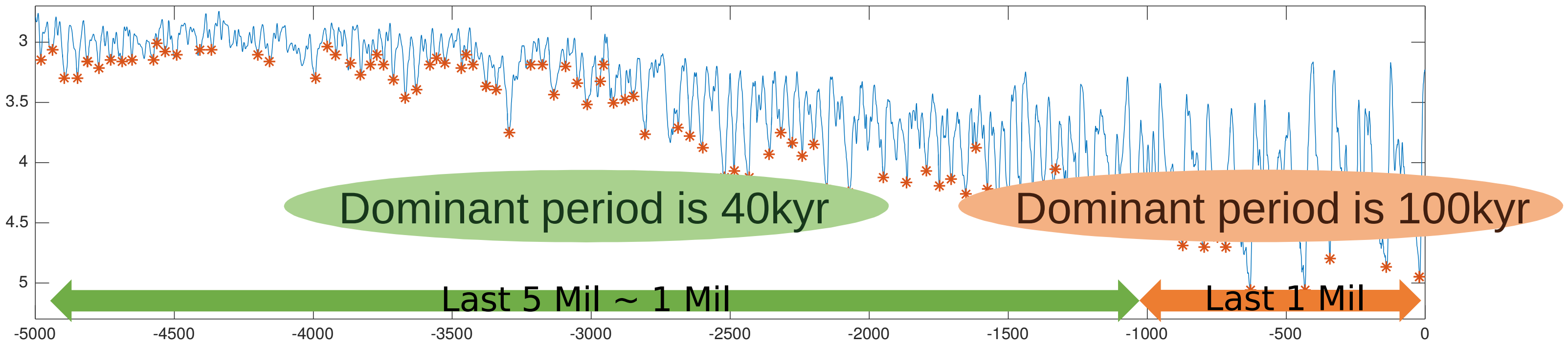




Dominant peak at ~ 0.25 = 40kyr period

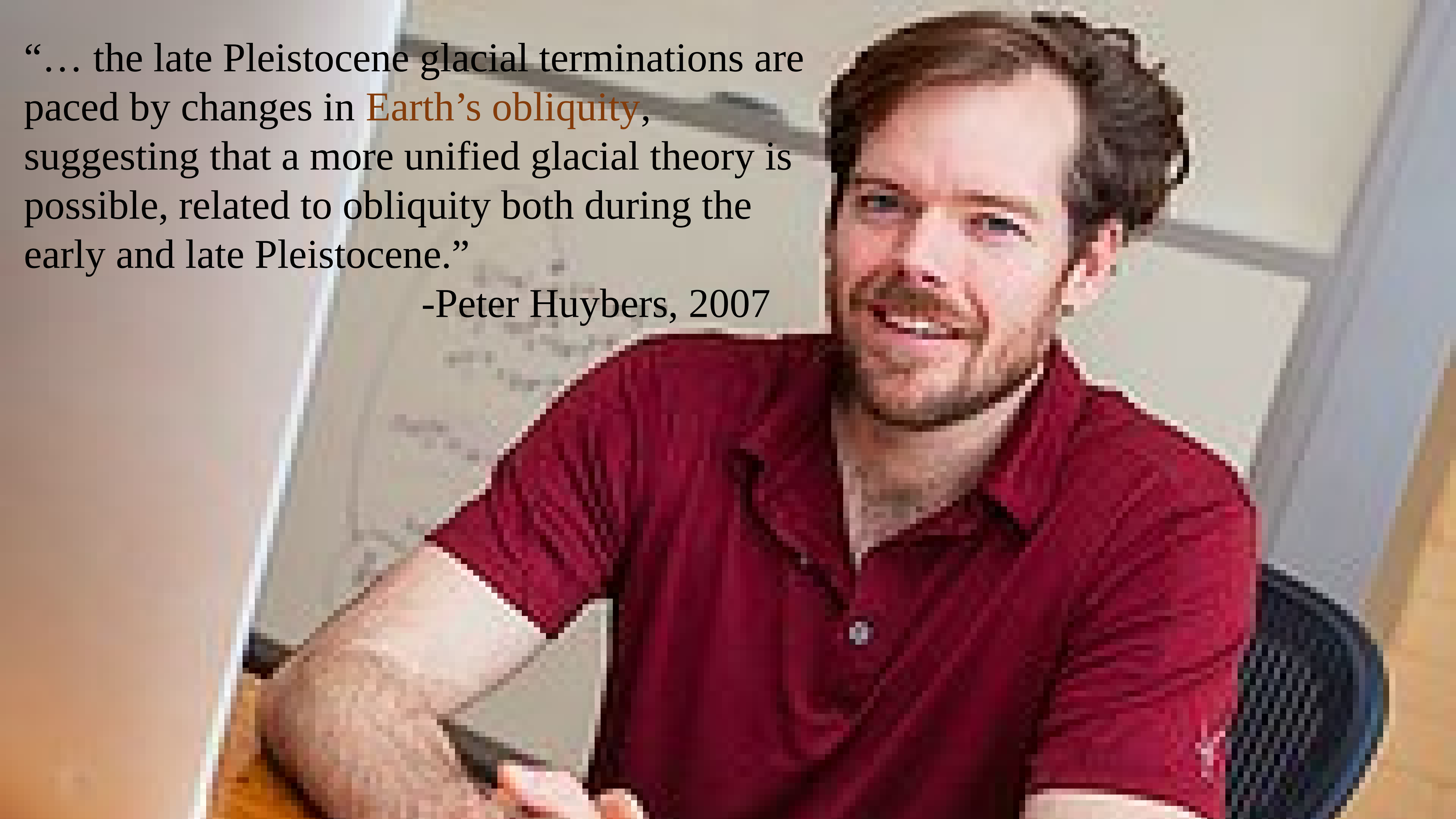


Dominant peak at ~ 0.1 = 100kyr period



"Did the main forcing for glacial cycles change from obliquity (40kyr period) to eccentricity (100kyr period) at -1 Mil year?"

*"No, it did NOT change. It has been **ONLY obliquity** (40kyr) pacing the glacial cycles for the last <u>2 Million years</u>"*



"… the late Pleistocene glacial terminations are paced by changes in Earth's obliquity, suggesting that a more unified glacial theory is possible, related to obliquity both during the early and late Pleistocene."

-Peter Huybers, 2007

Huybers' Model

$= V_{t-1} + k_t$ — Ice Volume

$= \quad + \quad + c\theta_t$ — Threshold

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

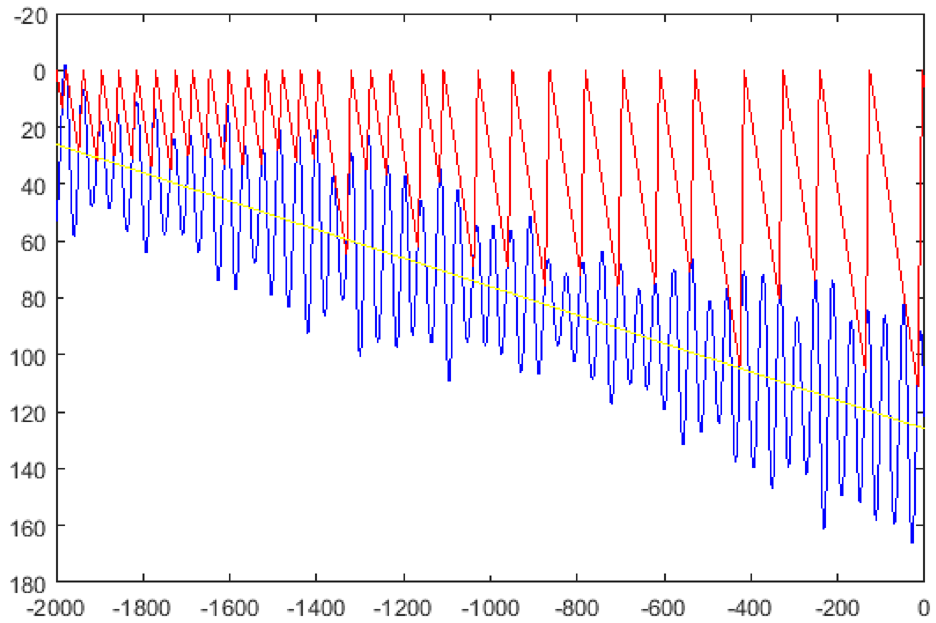
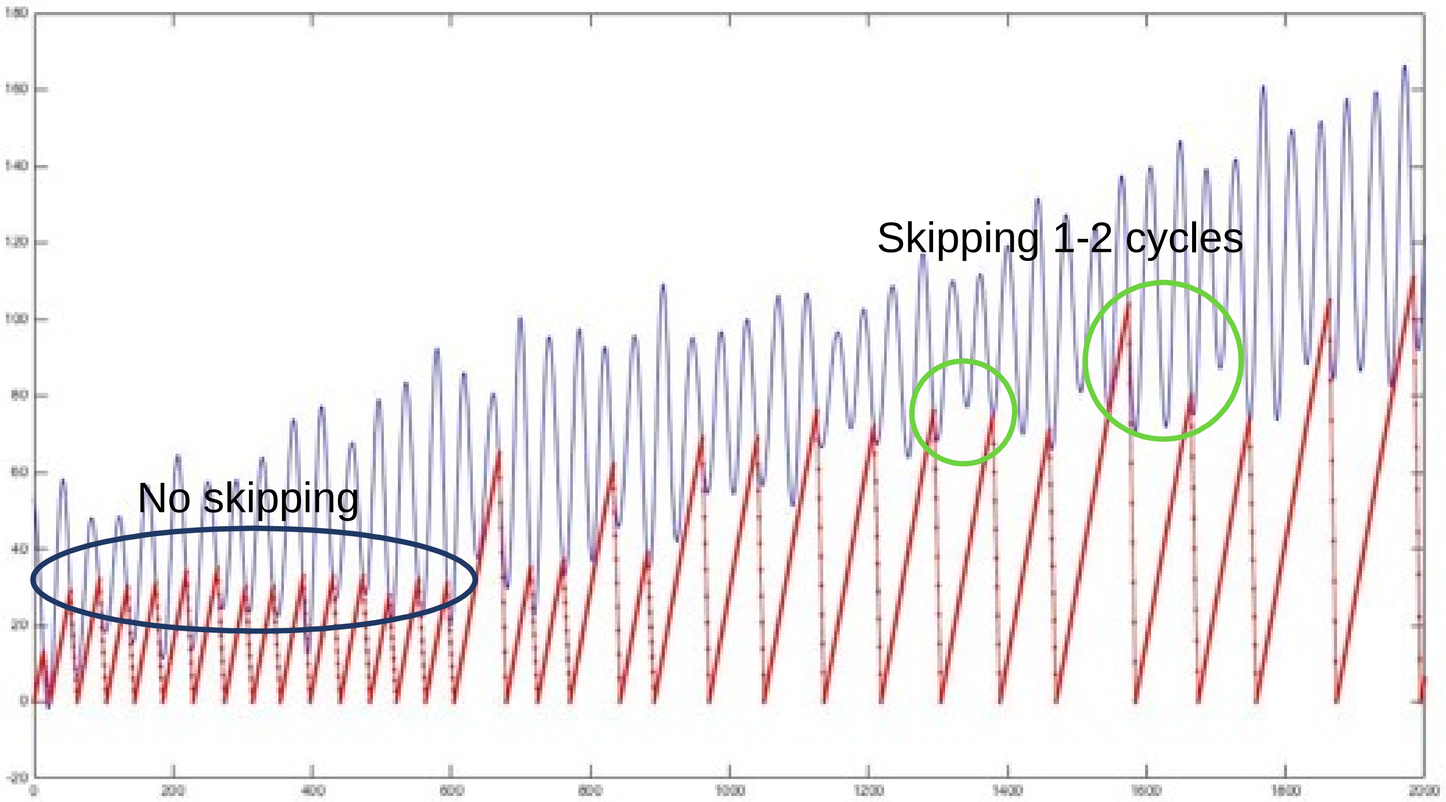


Figure:
Model simulation for last 2 Mil years with a=0.05, b=126, c=20

BLUE: Threshold function T_t
RED: Glacial volume V_t

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

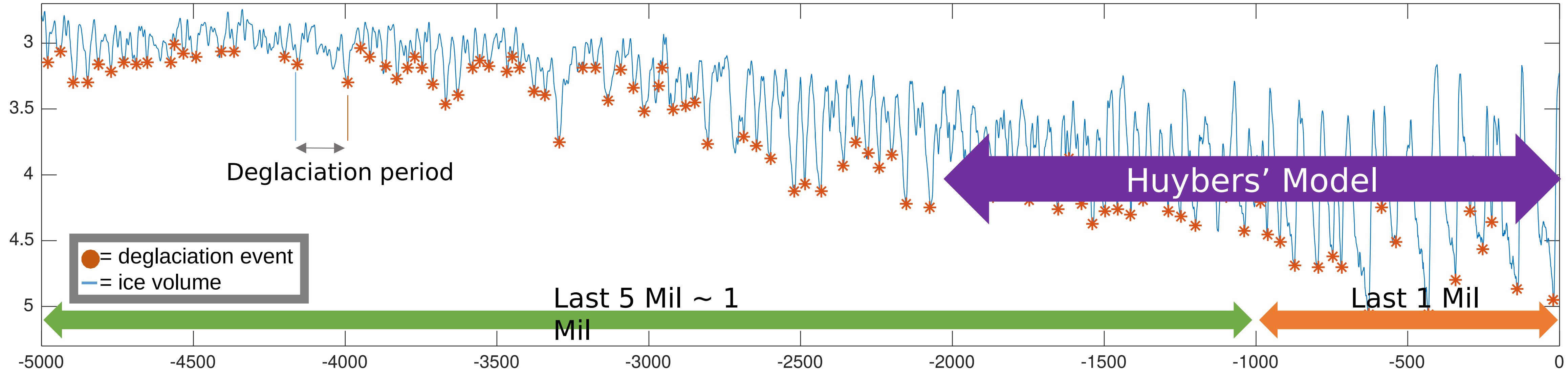

Summ
er
Goals

Why 2 Million years?

- Huybers had data for the last 5 Mil years, but model is only for 2 Mil
- His model argues that

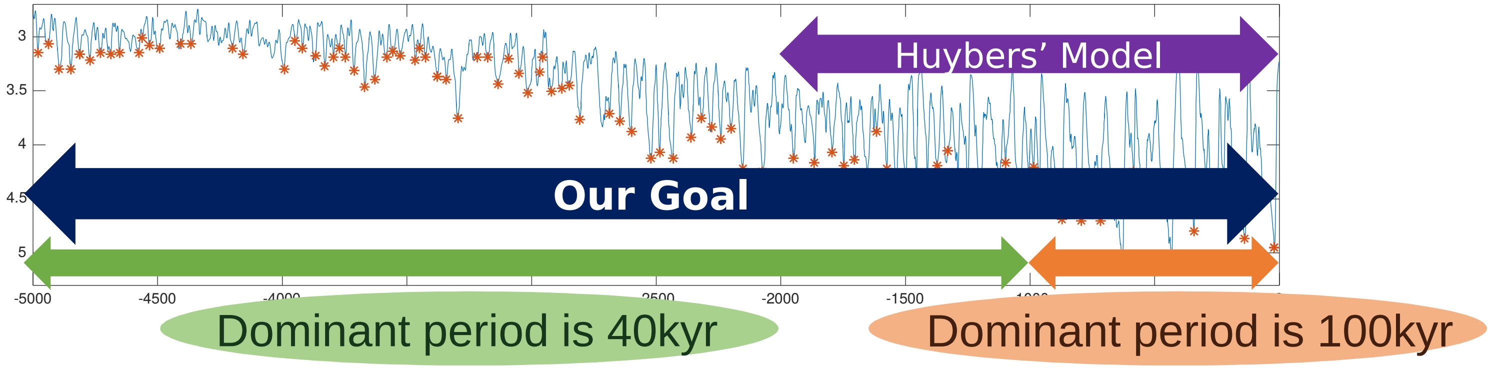
$$a = 0.05, b = 126, c = 20$$

produces **40k** average for -2 Mil ~ -1 Mil, **100k** average for -1 Mil to present



Summer Project Goal

- Extend the model to fit all of the available data (last 5 Mil)



- Need to refit the parameters a,b,c in threshold function to produce
  - **40kyr** dominant period for **-5 Mil to -1 Mil**,
  - **100kyr** dominant period for **-1 Mil to 0 years**

First Attempt at Parameter estimation of a,b,c in the threshold function

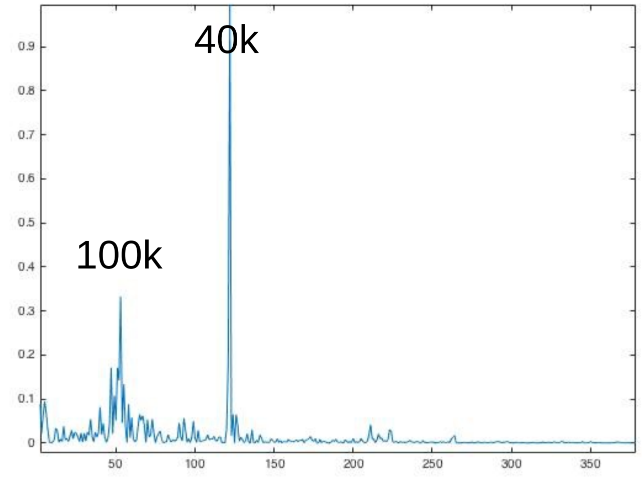
- Assuming $T_t = at + b + c\theta_t$, (i.e. linear trend)
- Reverse fitting of data using power spectrum

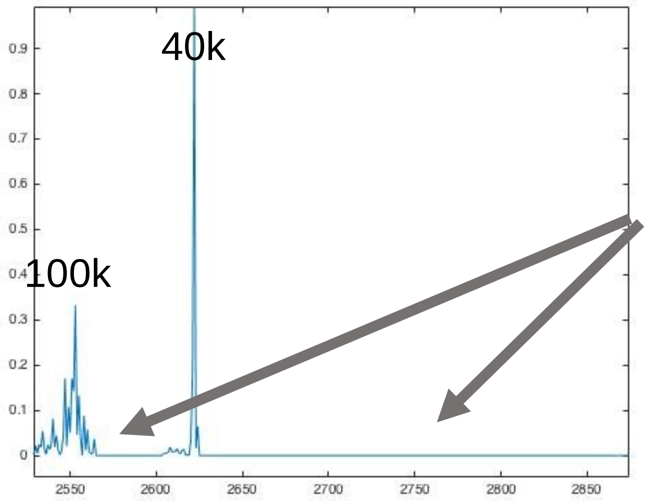
Reverse fitting of data using power spectrum

BEFORE

AFTER

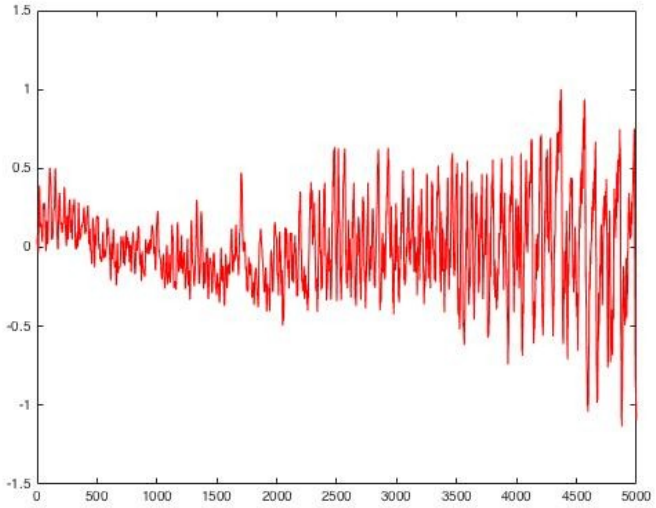
POWER SPECTRUM

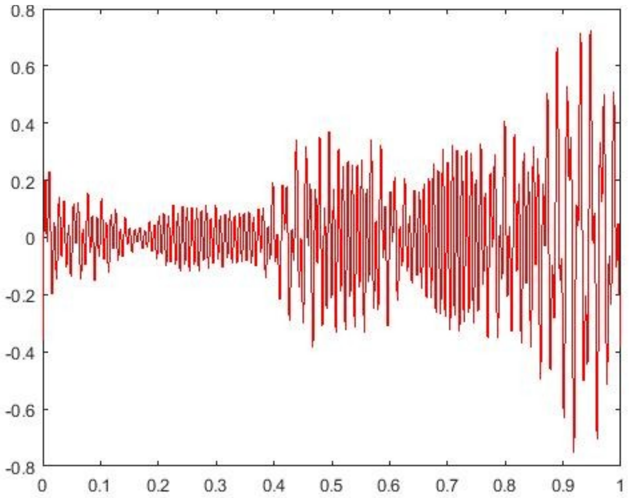




Smoothed spectrum

CORRESPONDING DATA

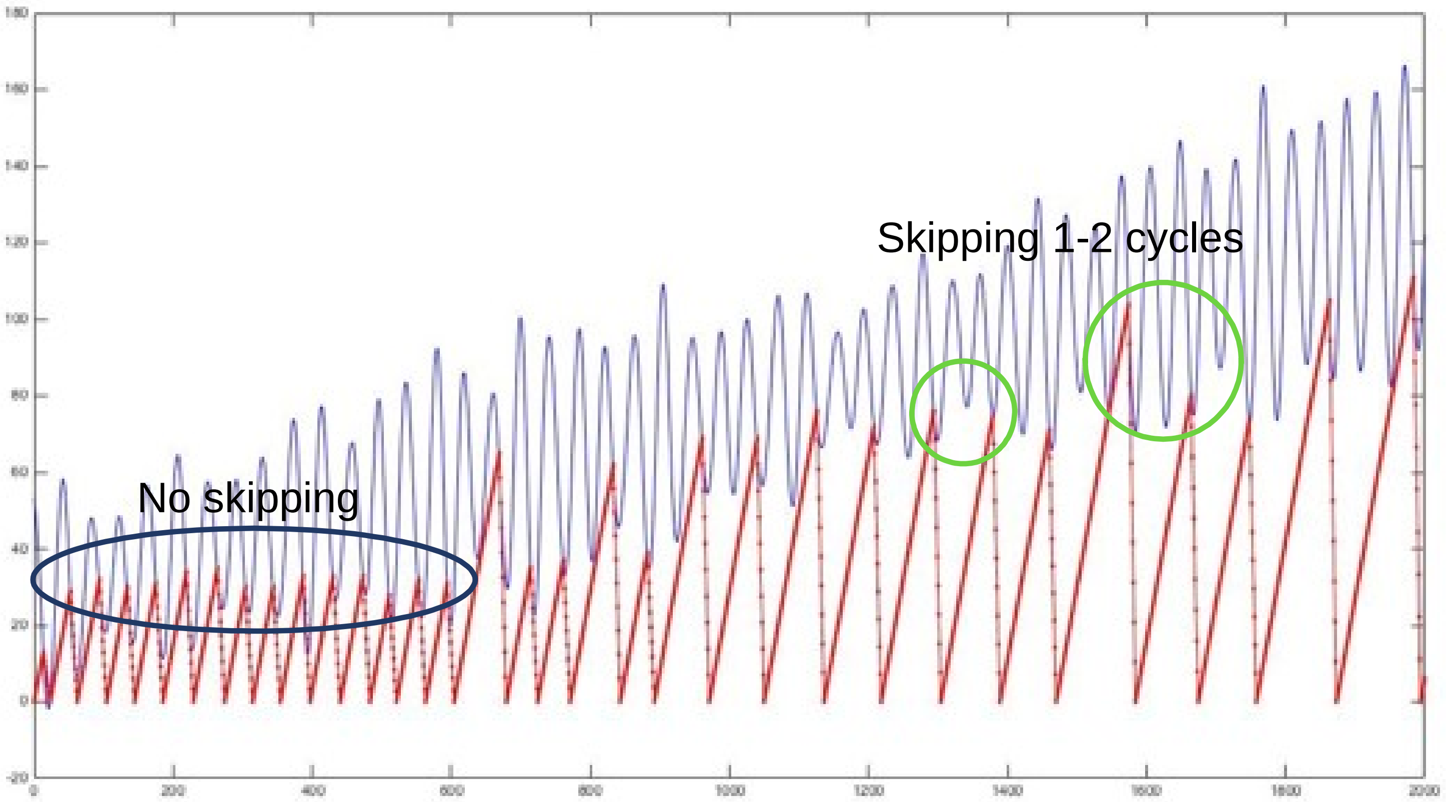




But that didn't work…

- This method reproduces deglaciation events that do not at all align with actual deglaciation times, but reproduces only the **frequency**

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. "

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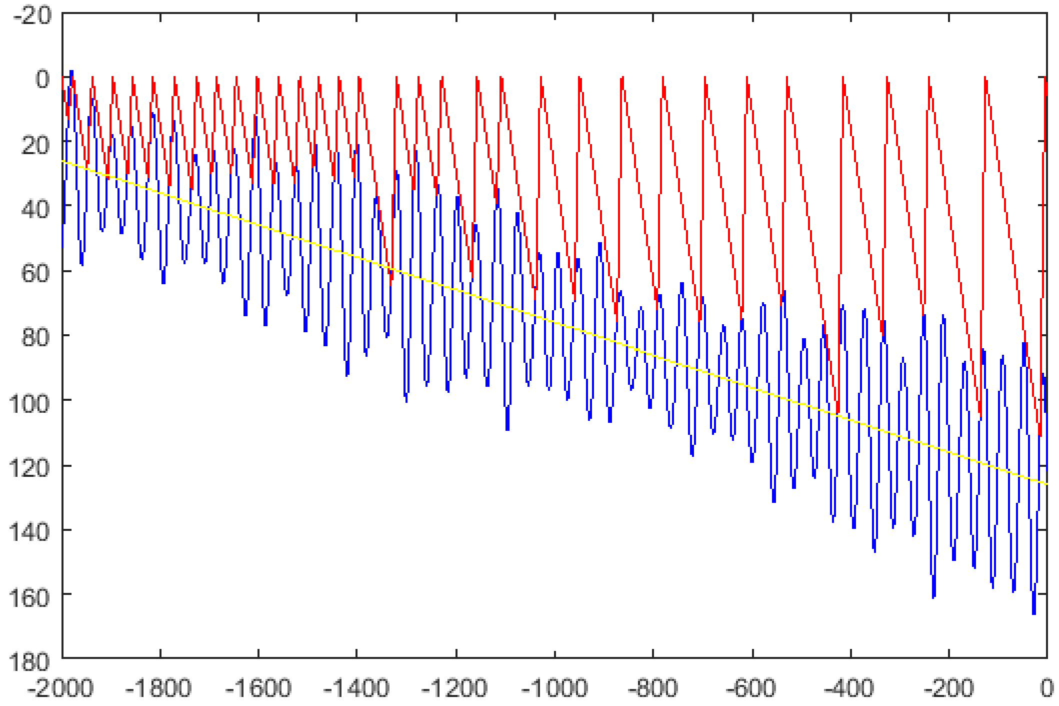
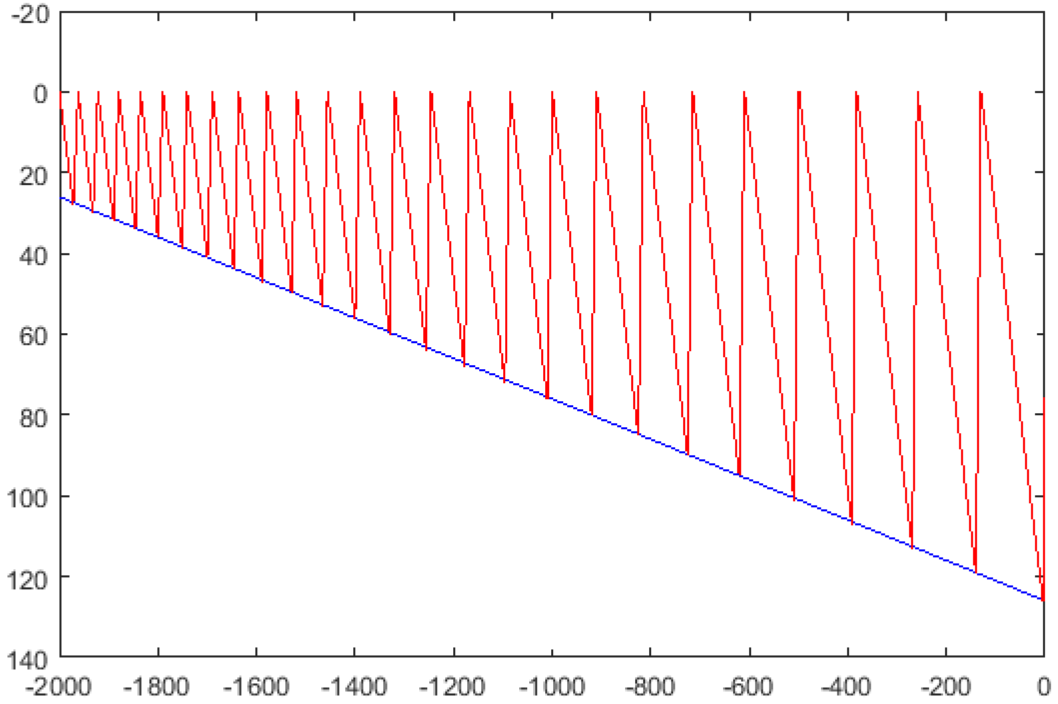
Is skipping obliquity cycles the reason Huyber's model fits the data?



Threshold function with obliquity term

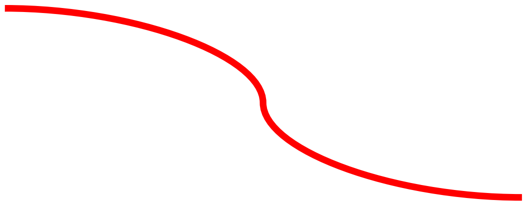


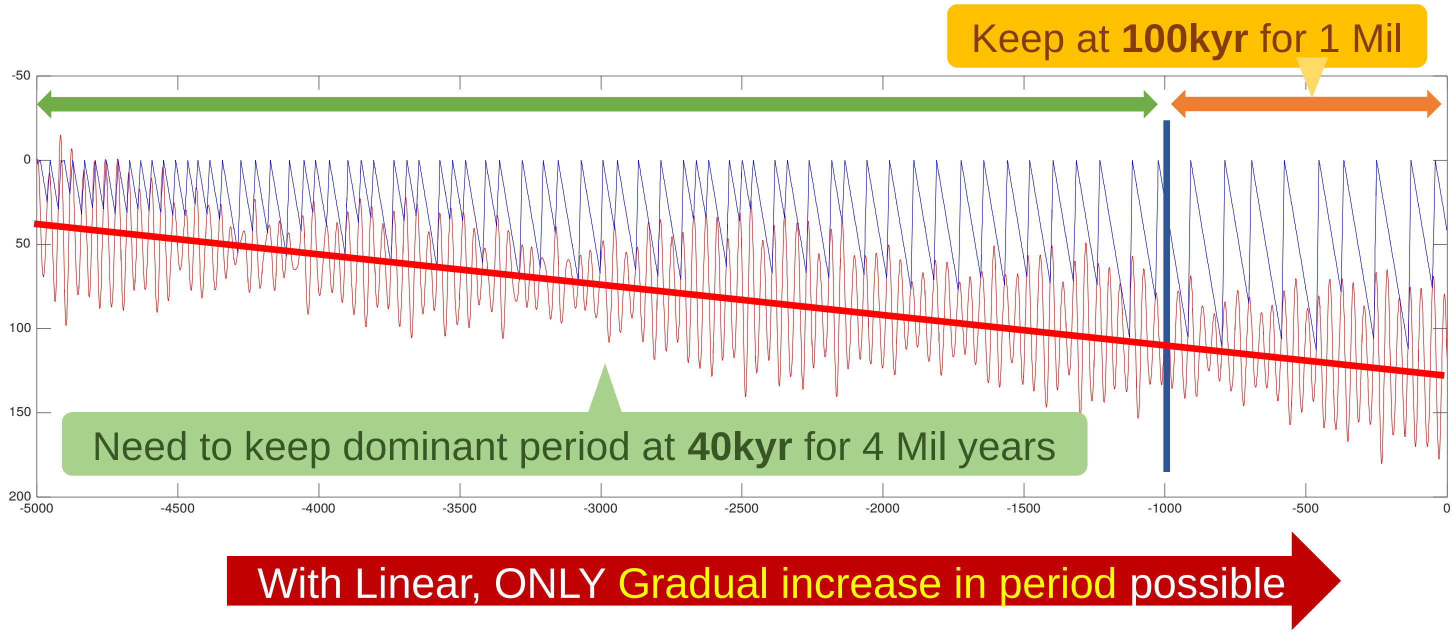
Threshold function without obliquity term

Change the shape of Threshold?

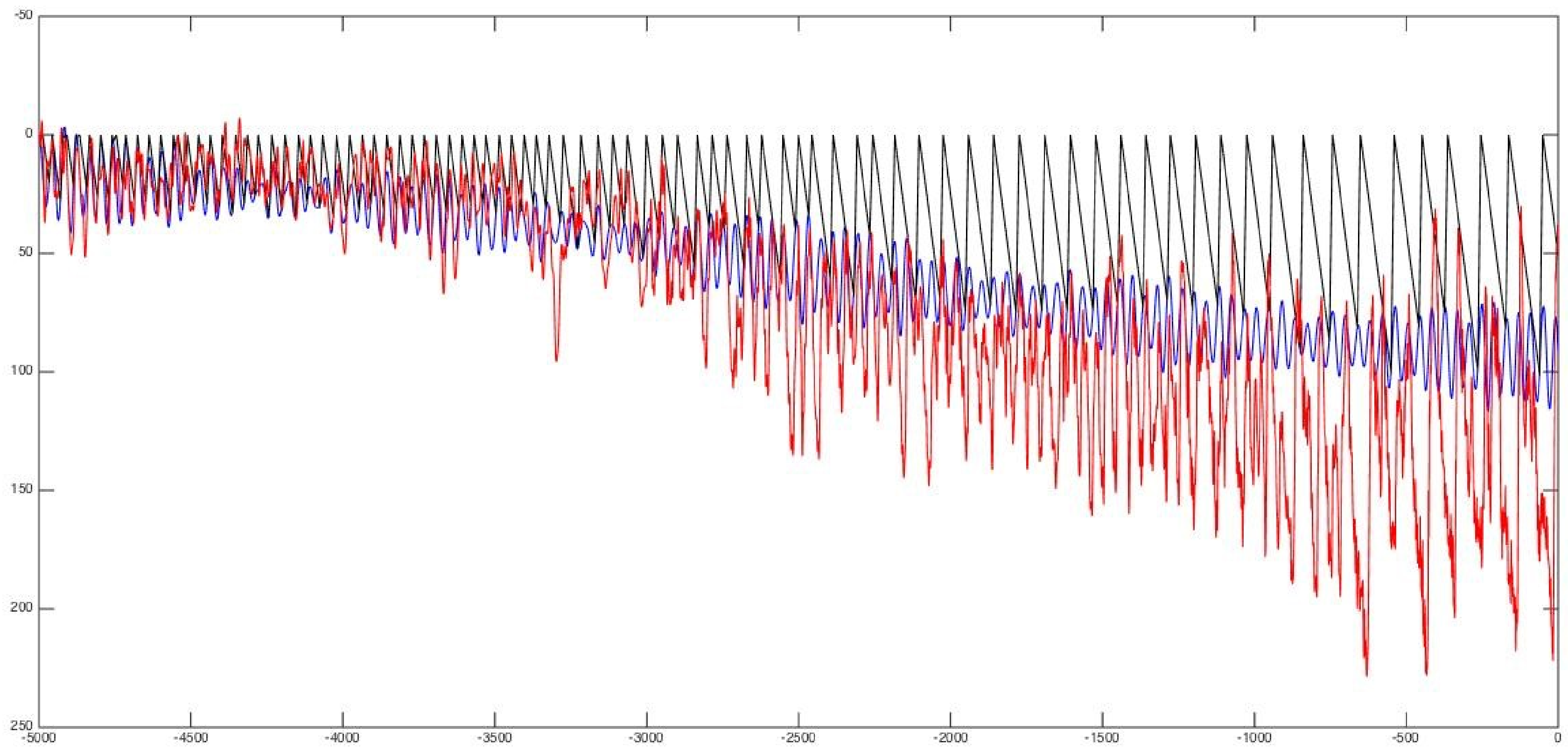
- Piecewise linear?
  - When to "turn on" the slope?

- Logistic?





Logistic Threshold to be explored more…



What is Deglaciation?

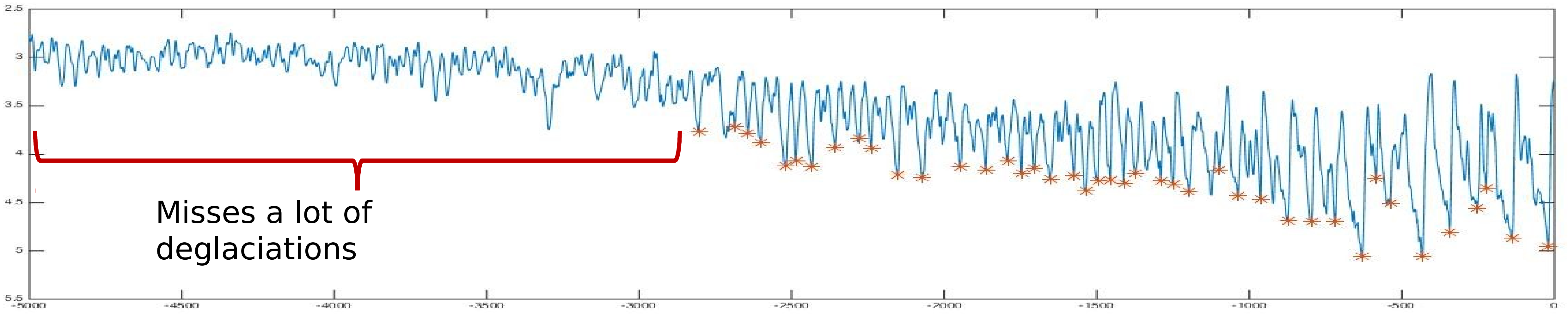
One hurdle in determining a good model fit

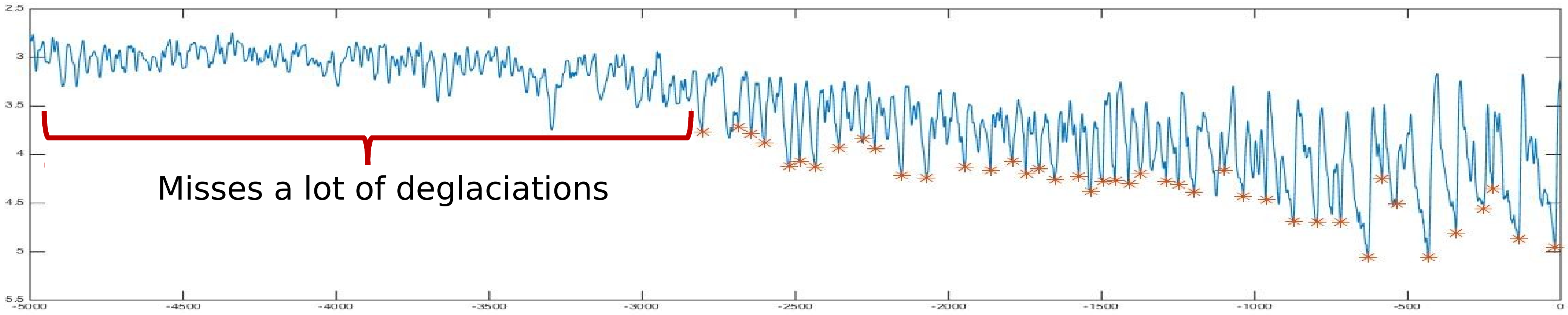
- Both the deglaciation event times and frequency are important in determining whether the model fits well

- *Do we have a reasonable definition for when deglaciation happens?*

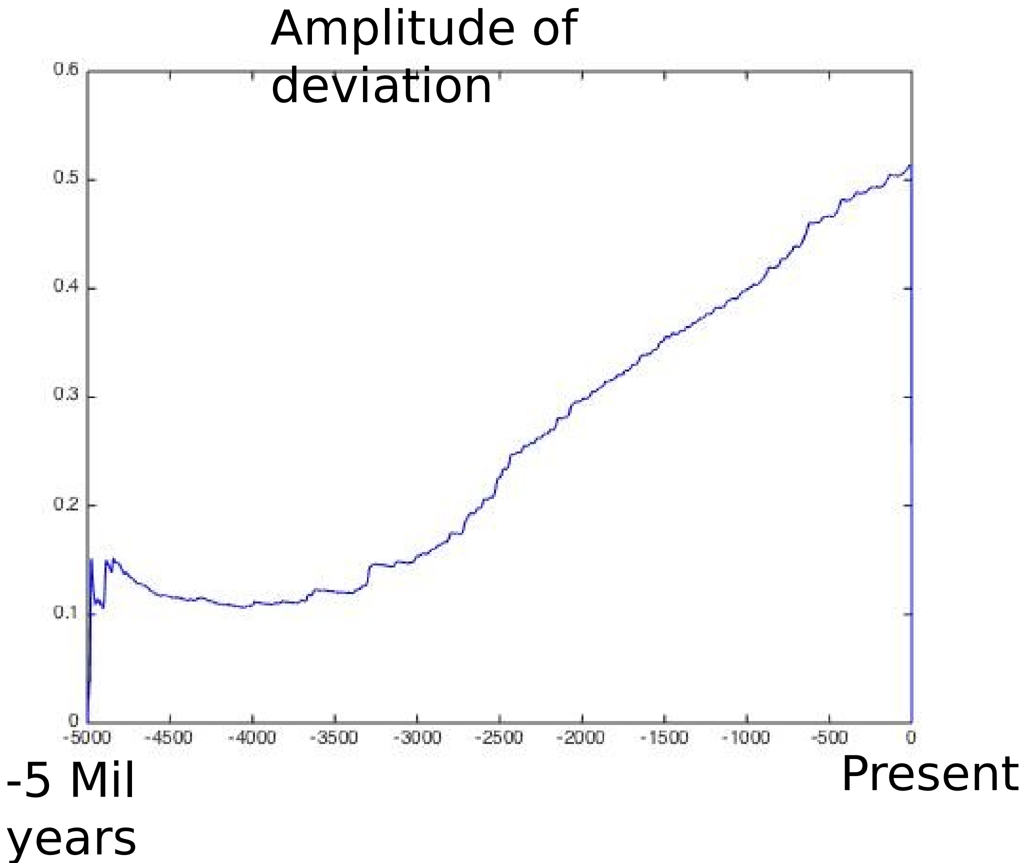
How to determine a deglaciation event?

- (Huybers) Decrease in ice volume between a local minimum and the following maximum must exceed **one standard deviation(SD)** of the data
  - This definition was adequate for the last 2 Mil years, but SD decreases more significantly throughout the last 5 Mil



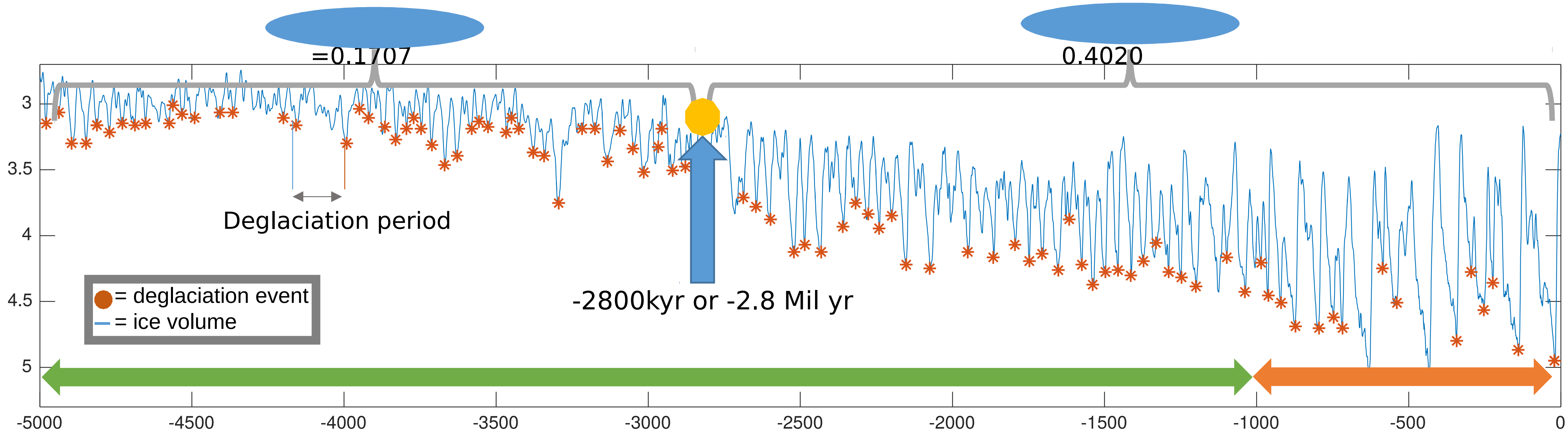


Amplitude of deviation varies significantly, throughout the last 5 Mil



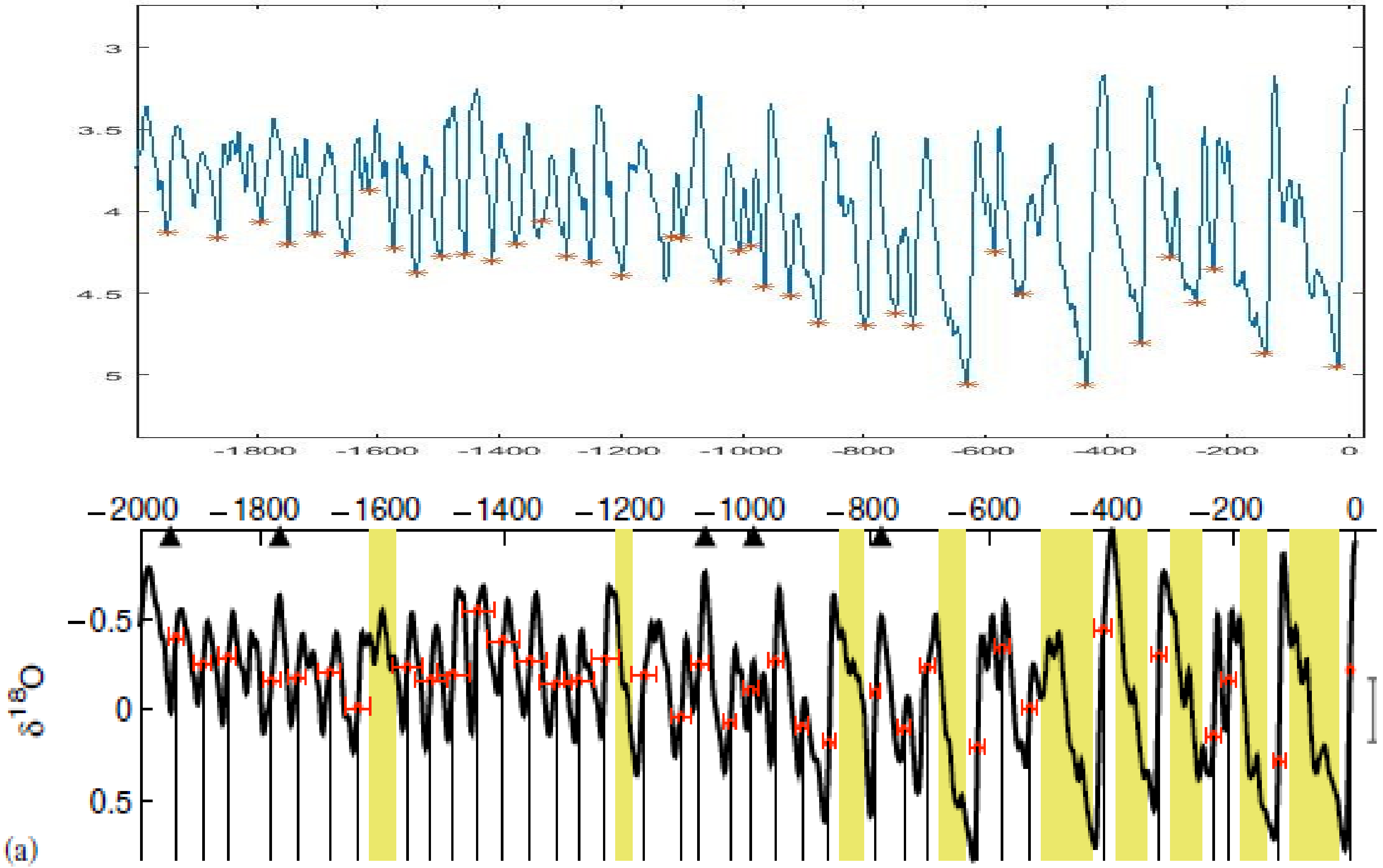
Duct-tape for Deglaciation definition for parameter estimation code

Keep Huybers' definition of deglaciation, except change SD to be calculated in 2 periods

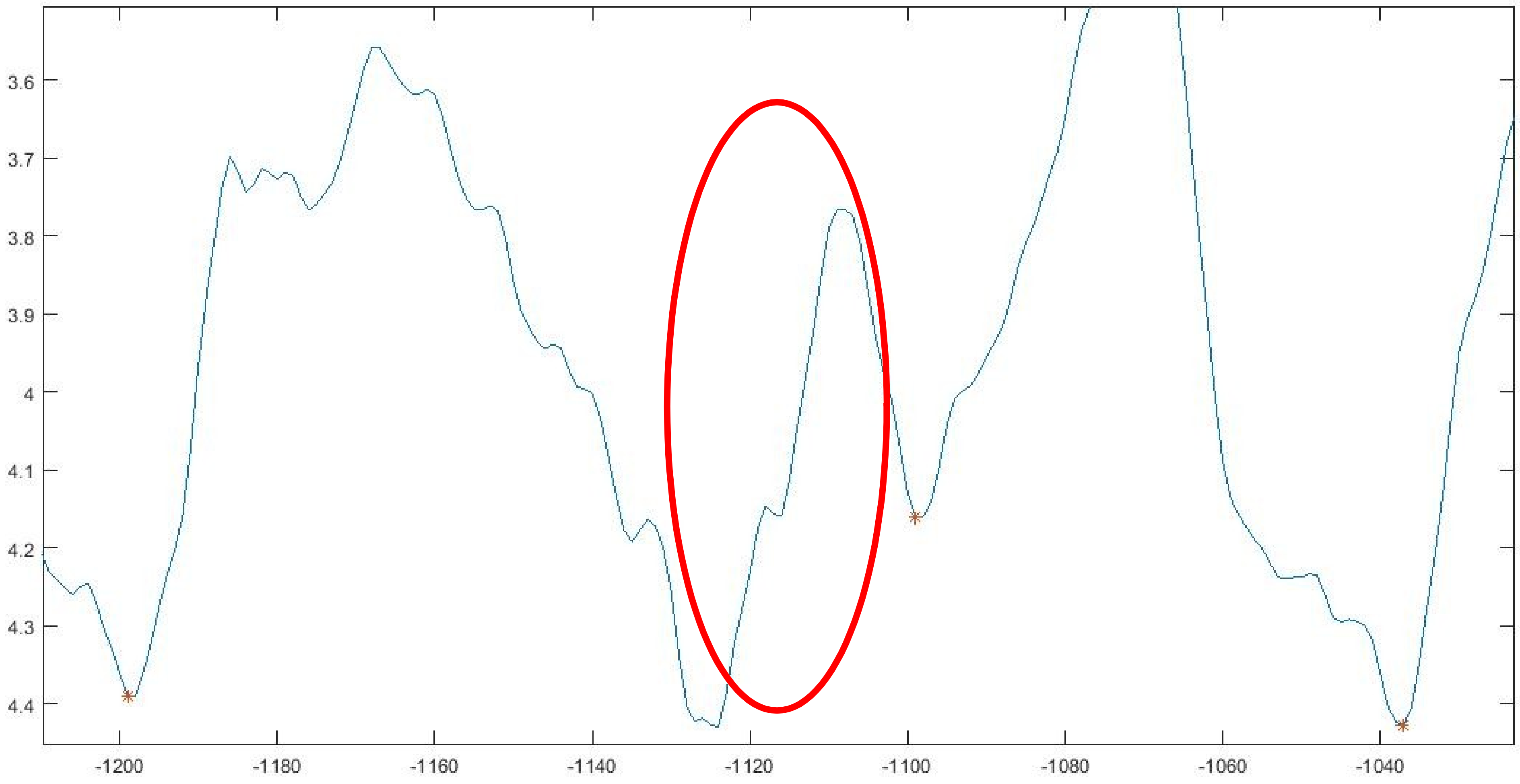


This point is also a good candidate for when to turn on the slope for piecewise linear threshold

Huybers v. Lisiecki and Raymo: Some Discrepancies

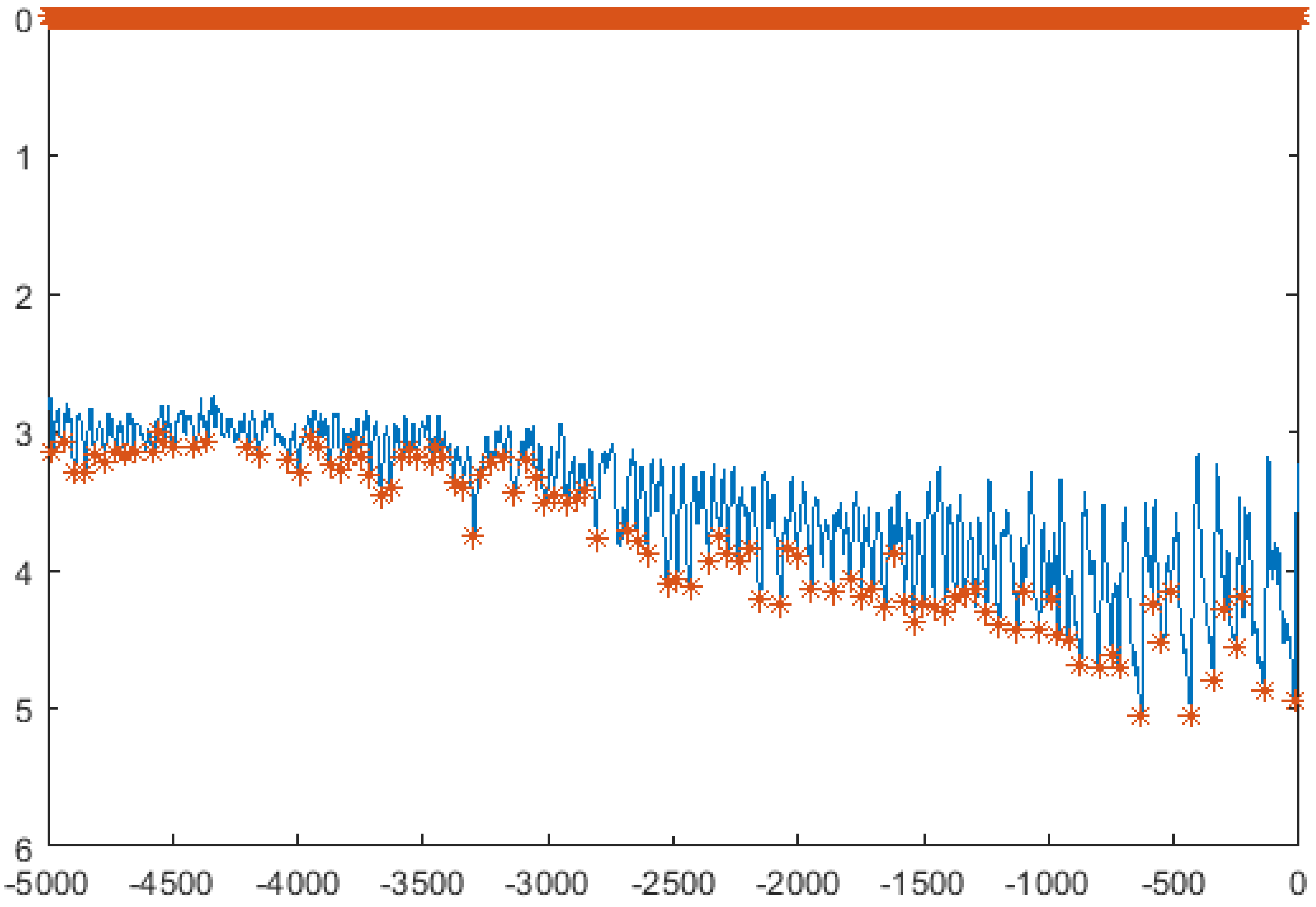


The real problem with the definition of deglaciation



Adding more Duct-Tape

- Insert a parameter which tells the algorithm to ignore small blips in the data
- Opens up algorithm to questions as to why the parameter was chosen
  - Valid geological reason or just so that it looks pretty?
- Unclear that the same parameter would work for multiple data sets
  - Same major problem as Huybers



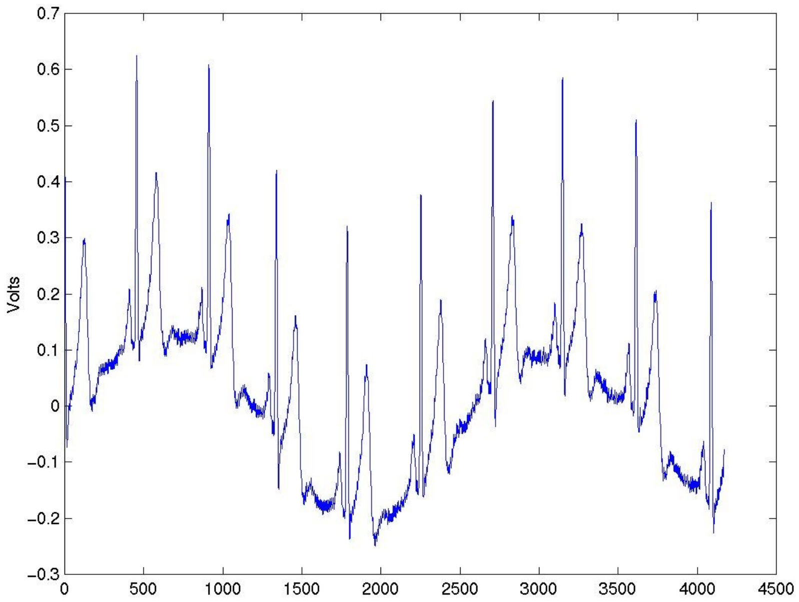
Empirical Mode Decomposition

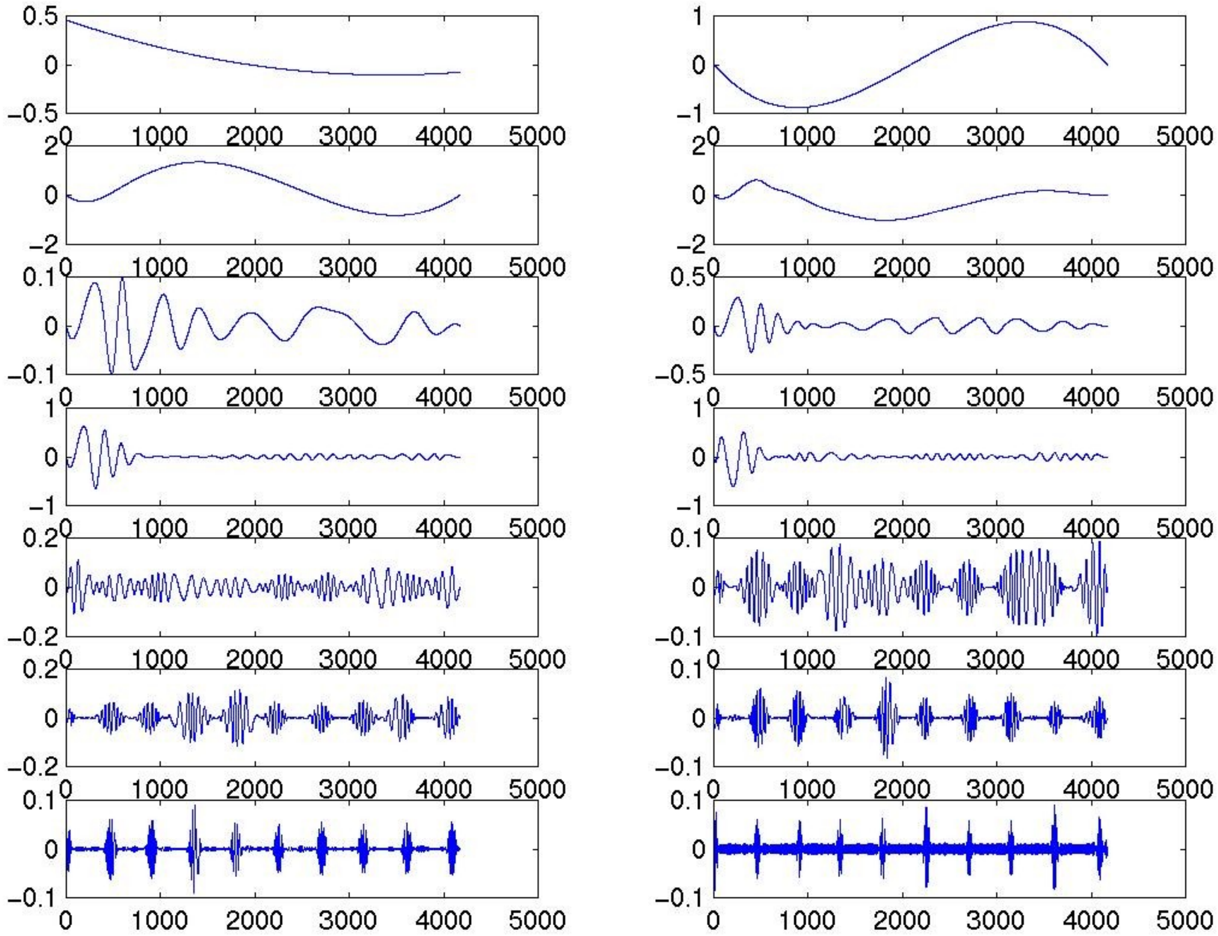
- Used as an alternative to smoothing over 5Kya running averages.
- Uses the Hilbert-Huang transformation to break the input signals into complete and nearly orthogonal components
  - Intrinsic Mode Functions:
    1. There is at most one extrema between zero crossings.
    2. The function has a mean value of zero

Empircal Mode Decomposition Outline

- Obtain a cubic spline of the local maxima of the input data, and one for the local minima. Then average these to get the mean function, m(t).
- If we view the input signal as a function S(t), let h(t)=S(t)-m(t).
  - Define a new mean function, $m_h(t)$, as above, but using h(t) instead of the input signal.
- Iterate the above process until h(t) is an IMF, and then set $h(t)=c_1(t)$
- Iterate that entire process to get the set of IMF's: c_1, c_2, …, c_n

Example of EMD





tps://www.clear.rice.edu/elec301/Projects02/empiricalMode/app.html

Why use the EMD for this problem?

- The EMD is useful in analyzing non-linear and non-stationary data sets.
  - The non-stationarity of the sediment-core data was one of the initial reasons that Huyber’s algorithm could not be directly adopted to a larger time scale; the standard deviation was much greater in more recent years.
- The EMD retains the discrete time domain of its input; this is crucial for its use in identifying the deglaciation events.
  - Compare this to the issues that were had using Fourier analysis.

In Conclusion…

- It is clear that Huybers had to carefully present several components of the data to get his model to fit as well as it did.
  - start date, the definition of deglaciation, ice core samples
- His general idea of a gradual change in response to obliquity may still have some truth to it, especially given the variability of the amplitude of glacial cycles.

Future Work

- Find a more robust definition of deglaciation that can be extended to a larger data set.
- Rework the model to fit better with an arbitrary length of data.


THANK YOU