Correlation and stacking of relative paleointensity and oxygen isotope data

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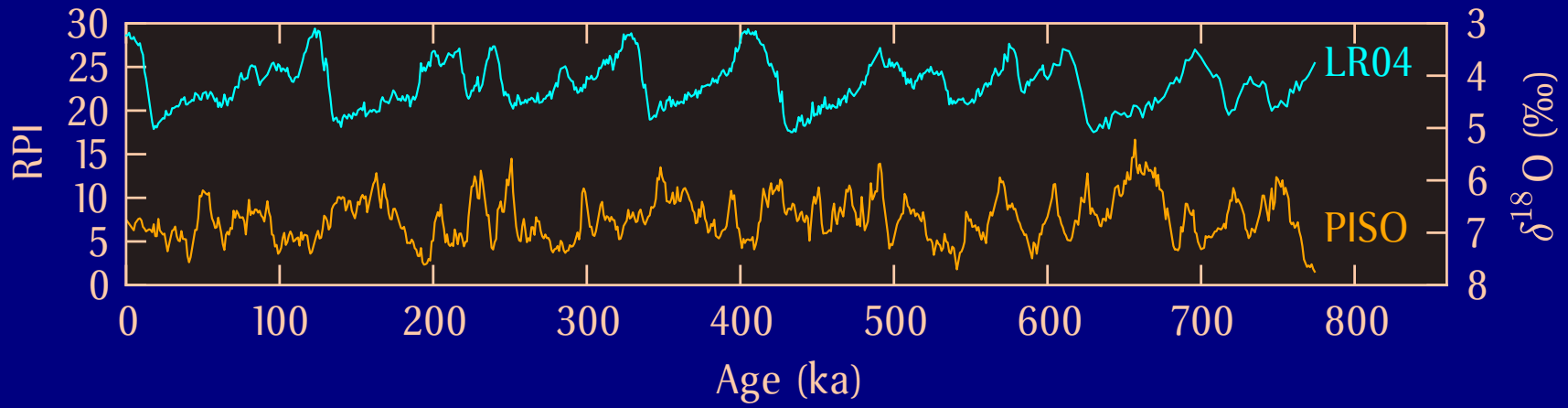
Overview: chronostratigraphy and correlation algorithms

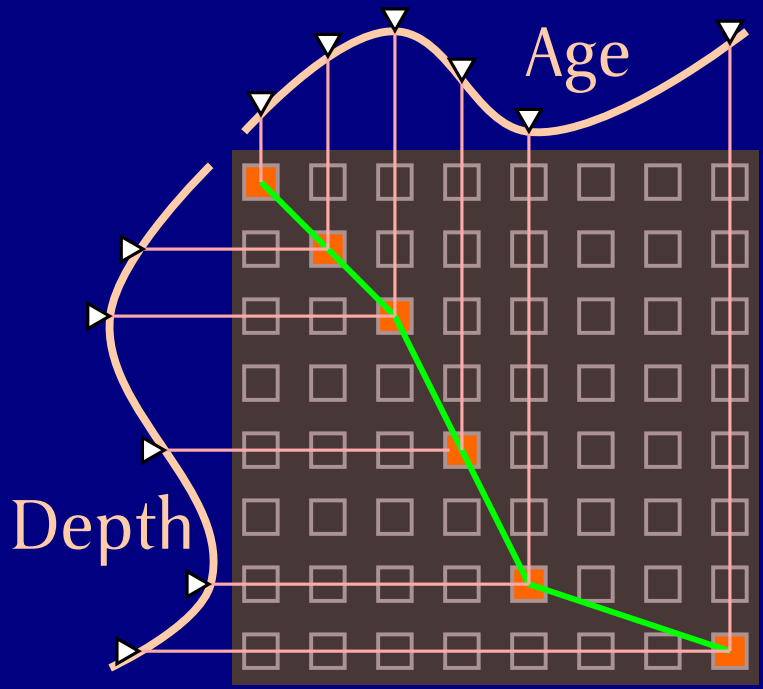
- Timing is everything – climate system leads and lags
- $\delta^{18}O$ and RPI: high-resolution, global, independent signals



- Matching reference curves against sedimentary records
- Eyeball matching vs. computer algorithms
- The Match algorithm
- Simulated annealing and DSA: a new approach

Correlating records: eyeball vs. computer

A depth-age correlation is equivalent to a sedimentation-rate curve.



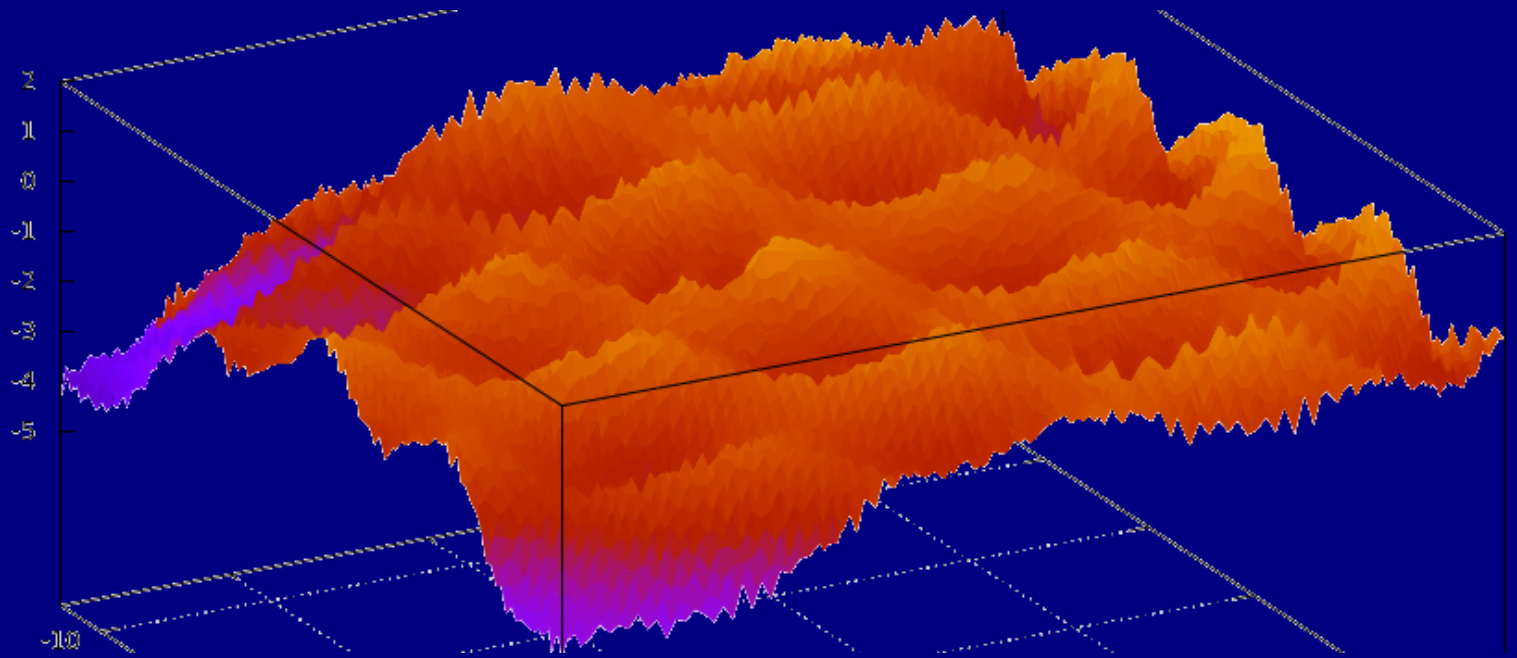
- Computer correlation can give a *repeatable* correlation using *explicit* constraints.
- Computers also make *tandem* correlation possible.

Correlation as an optimization problem

Calculate a *score* for any possible correlation, using e.g.

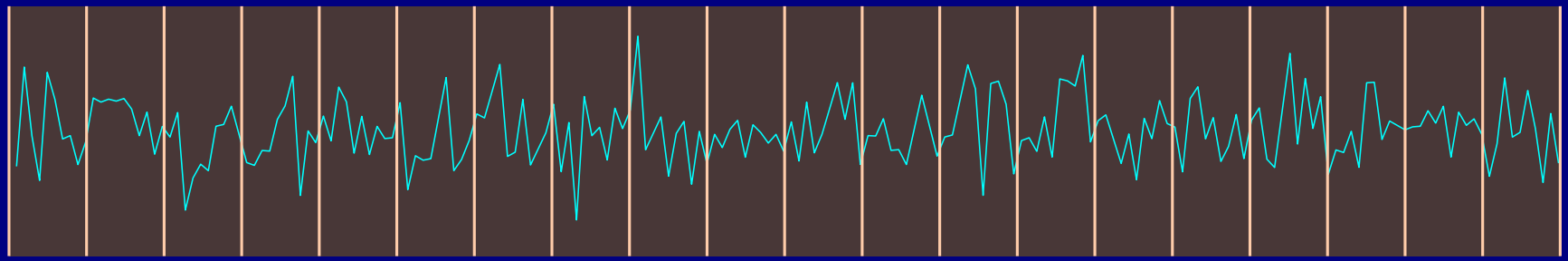
- Goodness of fit between reference(s) and record(s)
- Known age constraints (tie-points)
- Constraints on sedimentation rate

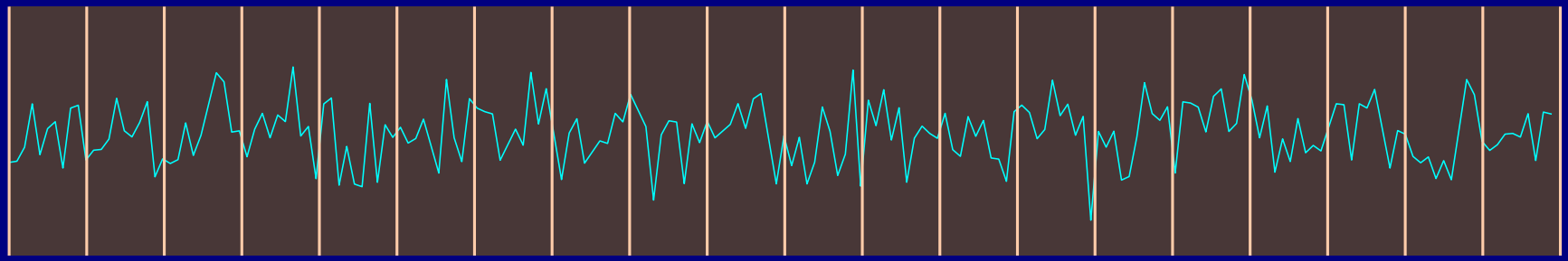
Search the space of possible correlations for the lowest score.



The Match algorithm (Lisiecki & Lisiecki, 2002)

Divide each record into a series of discrete blocks.

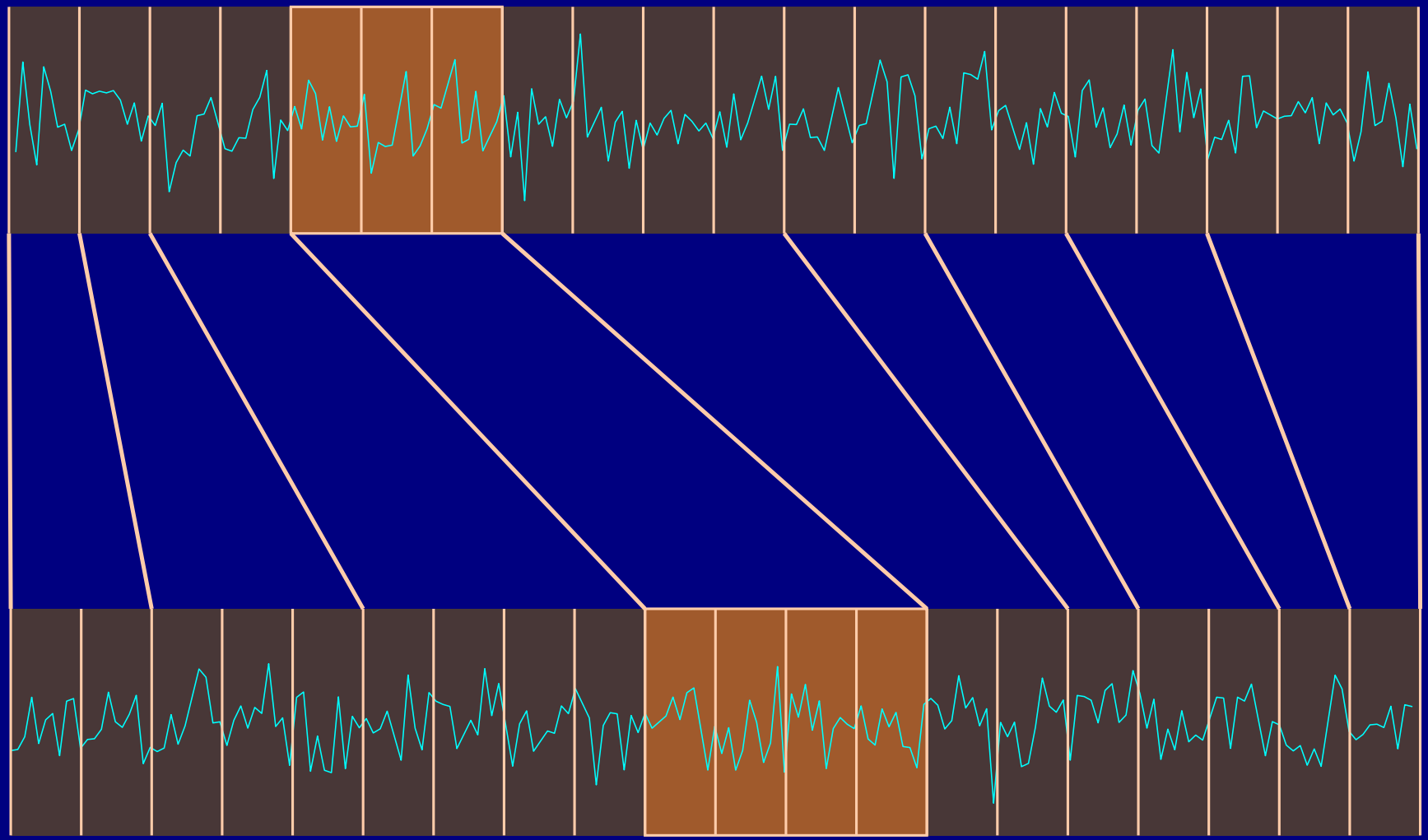




(Has been applied to δ^{18}O, RPI, and both in tandem)

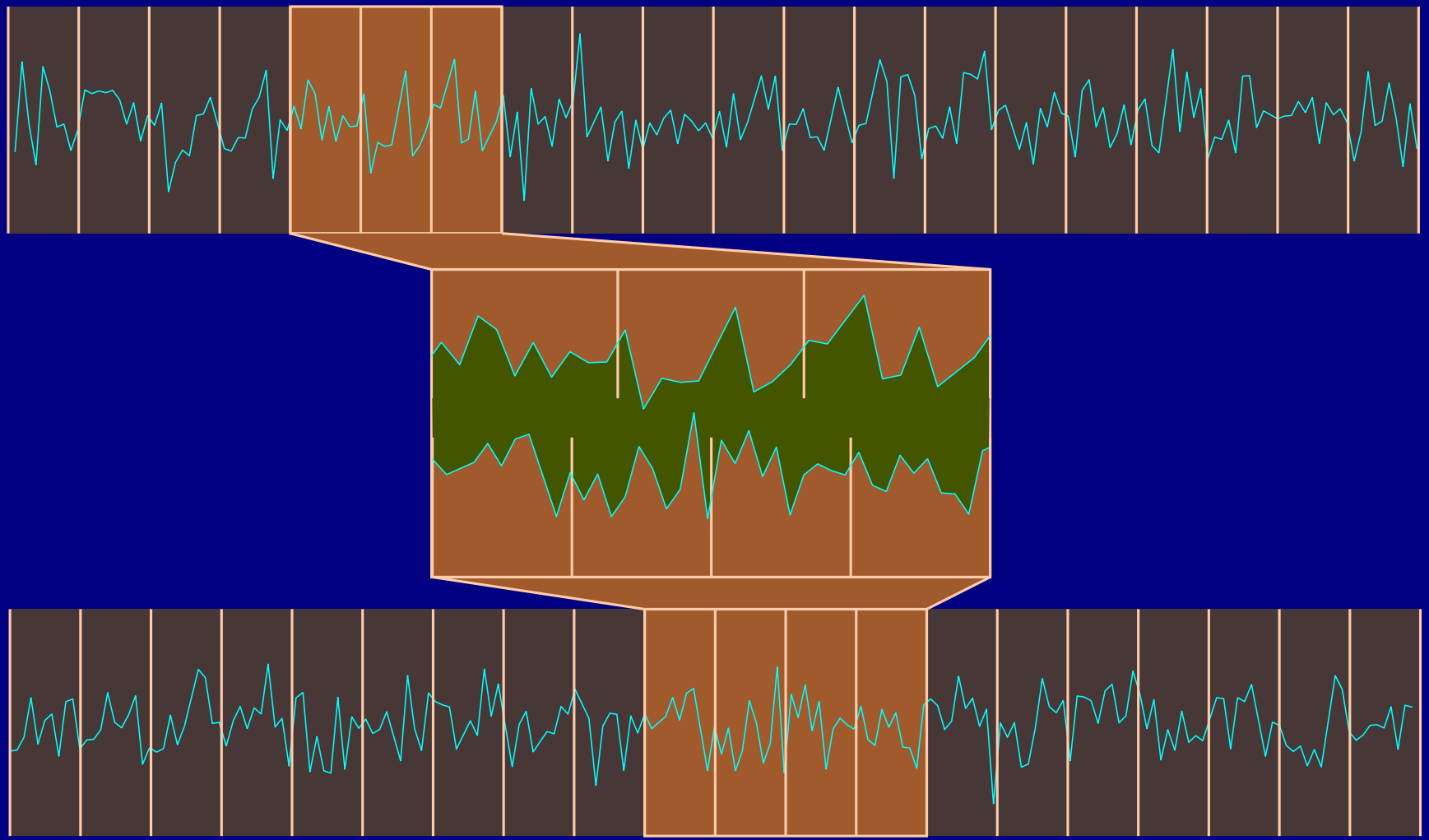
The Match algorithm

A correlation is constructed from matched runs of blocks.



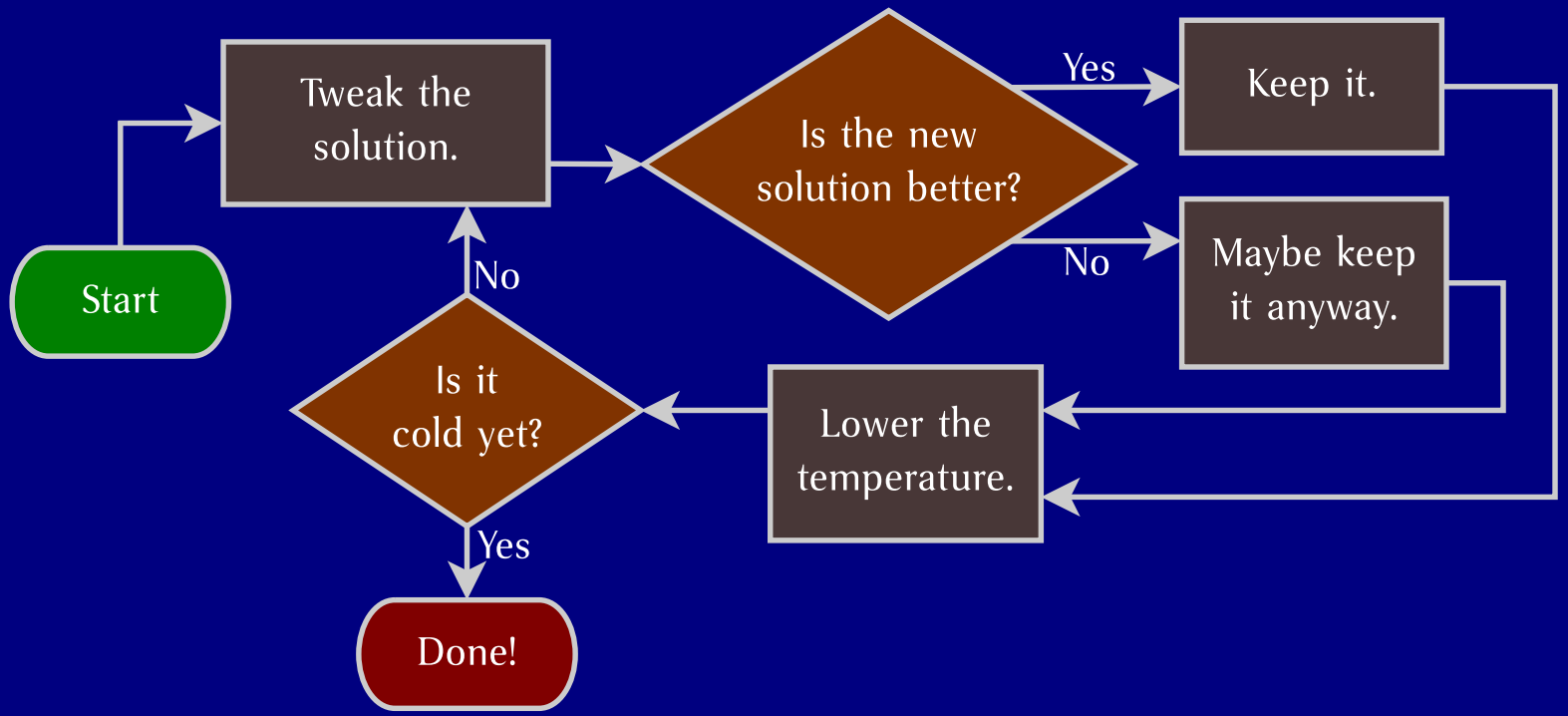
The Match algorithm

Similarity scores for pairs of block-runs can be cached and reused.



Simulated annealing (SA)

- Based on physical annealing (cooling and crystallization).
- At lower temperatures, 'uphill' choices become less probable.

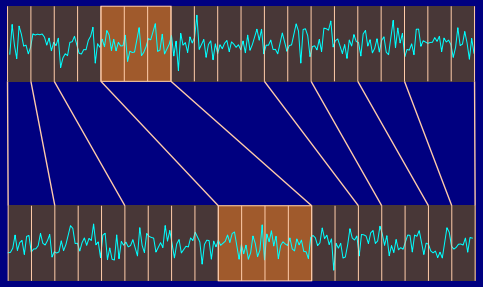


Described by Kirkpatrick et al. (1983).

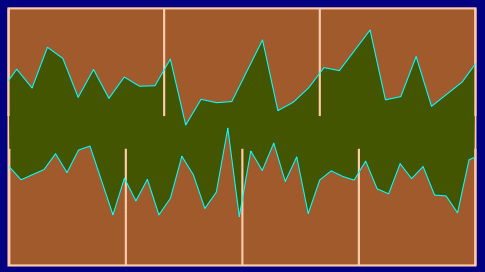
Discretized Simulated Annealing (DSA)

Requirements to apply SA to a problem:

1. *Structure* – represent and store solutions



2. *Energy state* – evaluate solutions

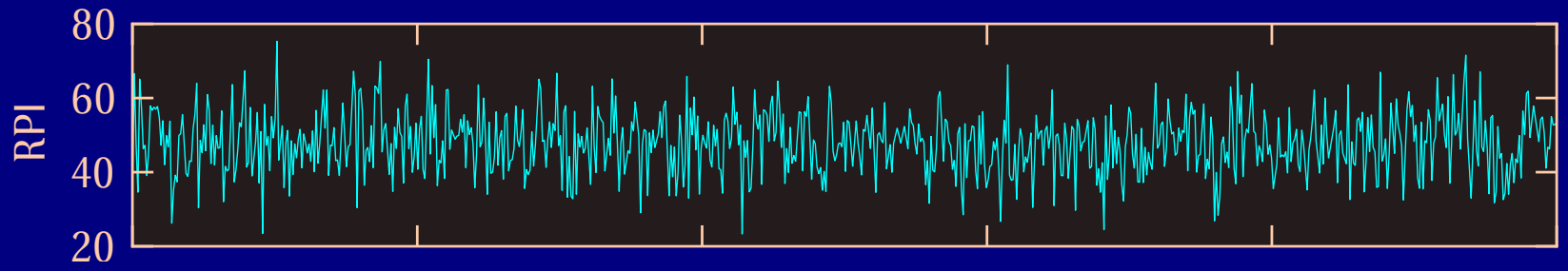


3. *Heat* – randomly perturb a solution to make a new one

The Match structure already has 1 and 2; we can add 3.

Testing DSA with an artificial sedimentation rate

Distort Constable & Parker (1988) RPI model with known sed. rate.



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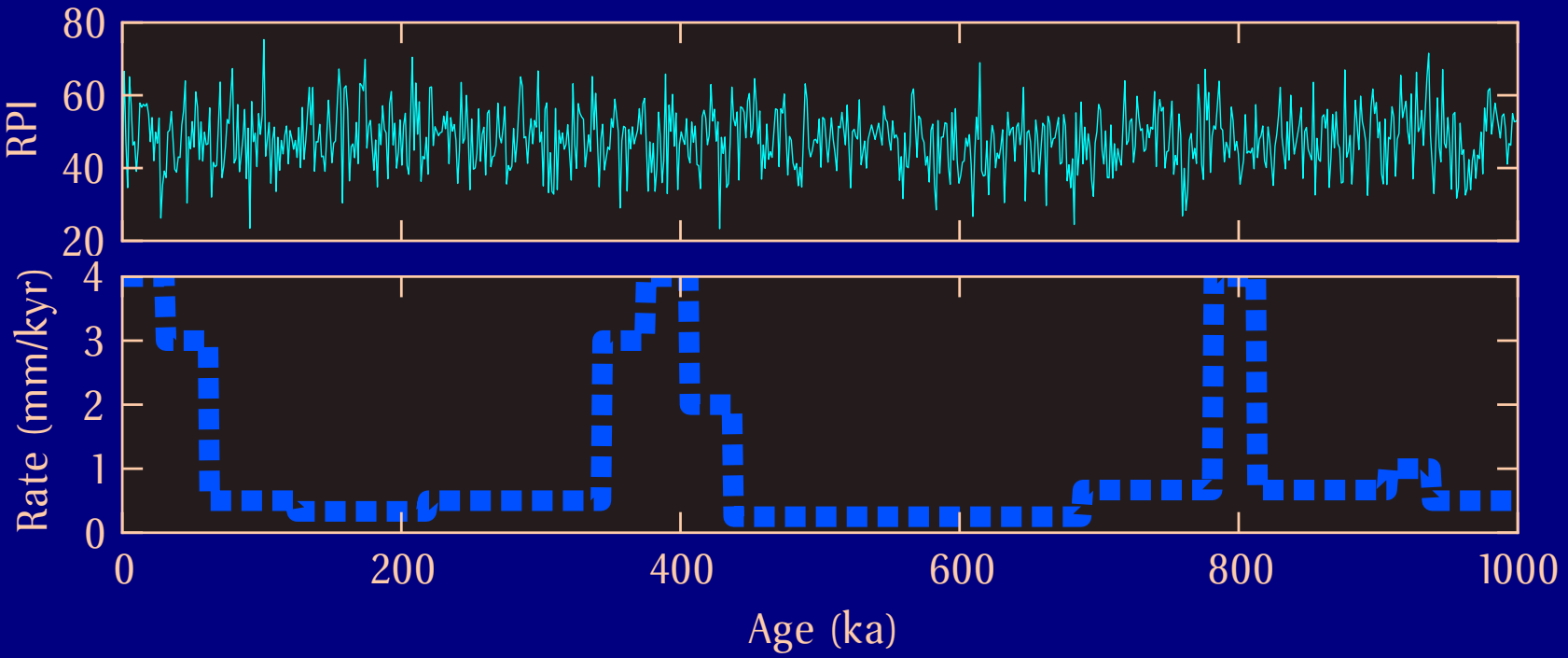

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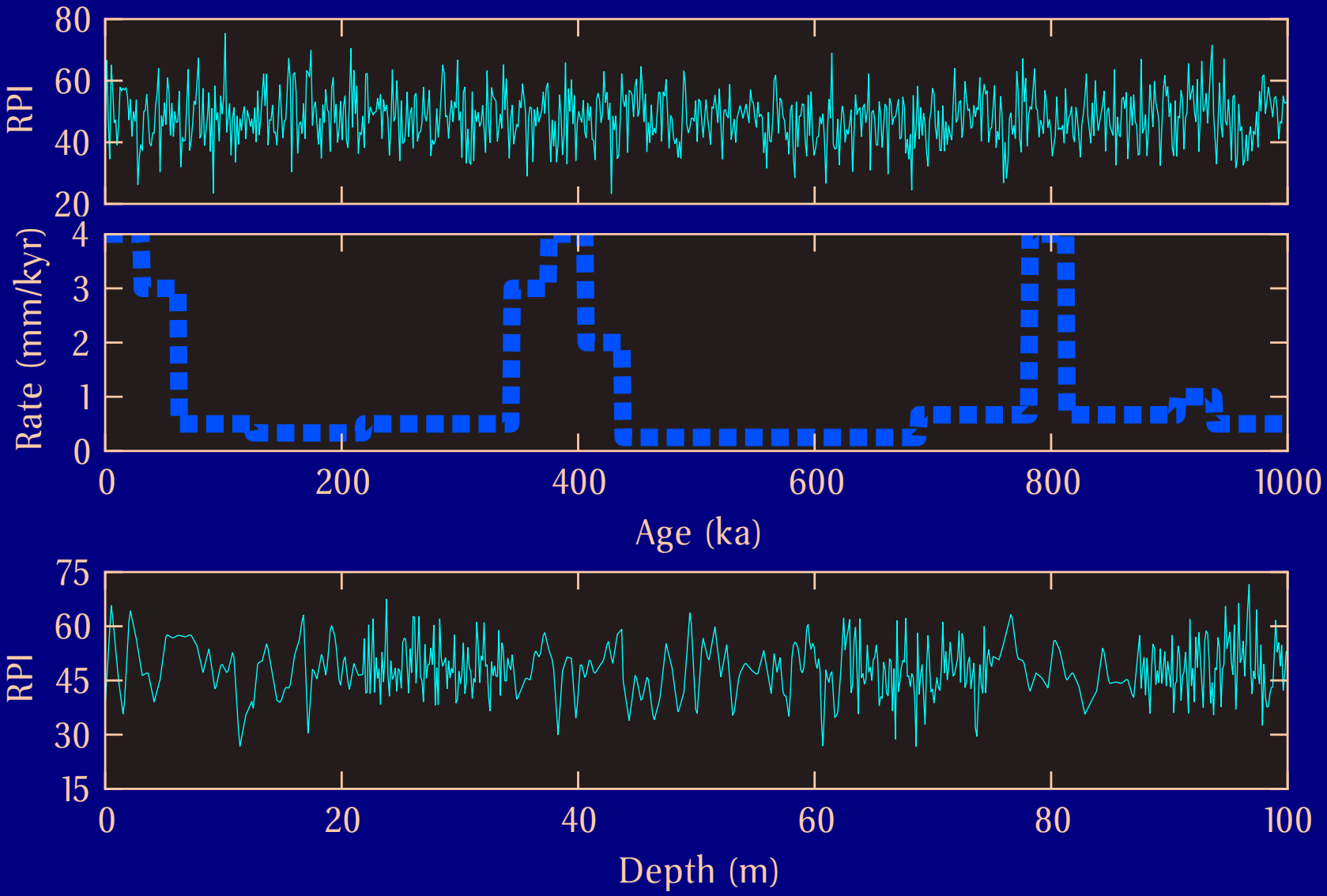

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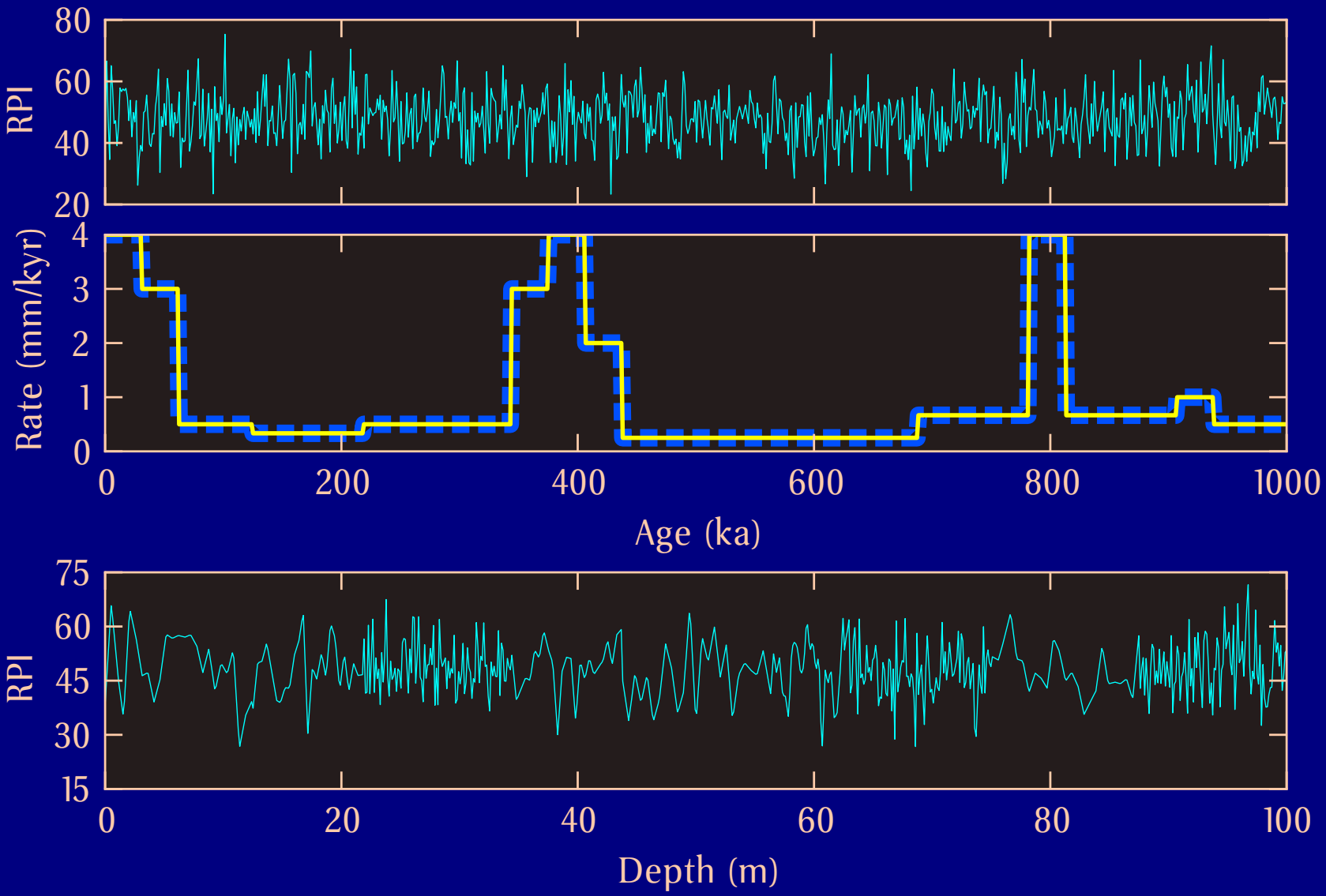
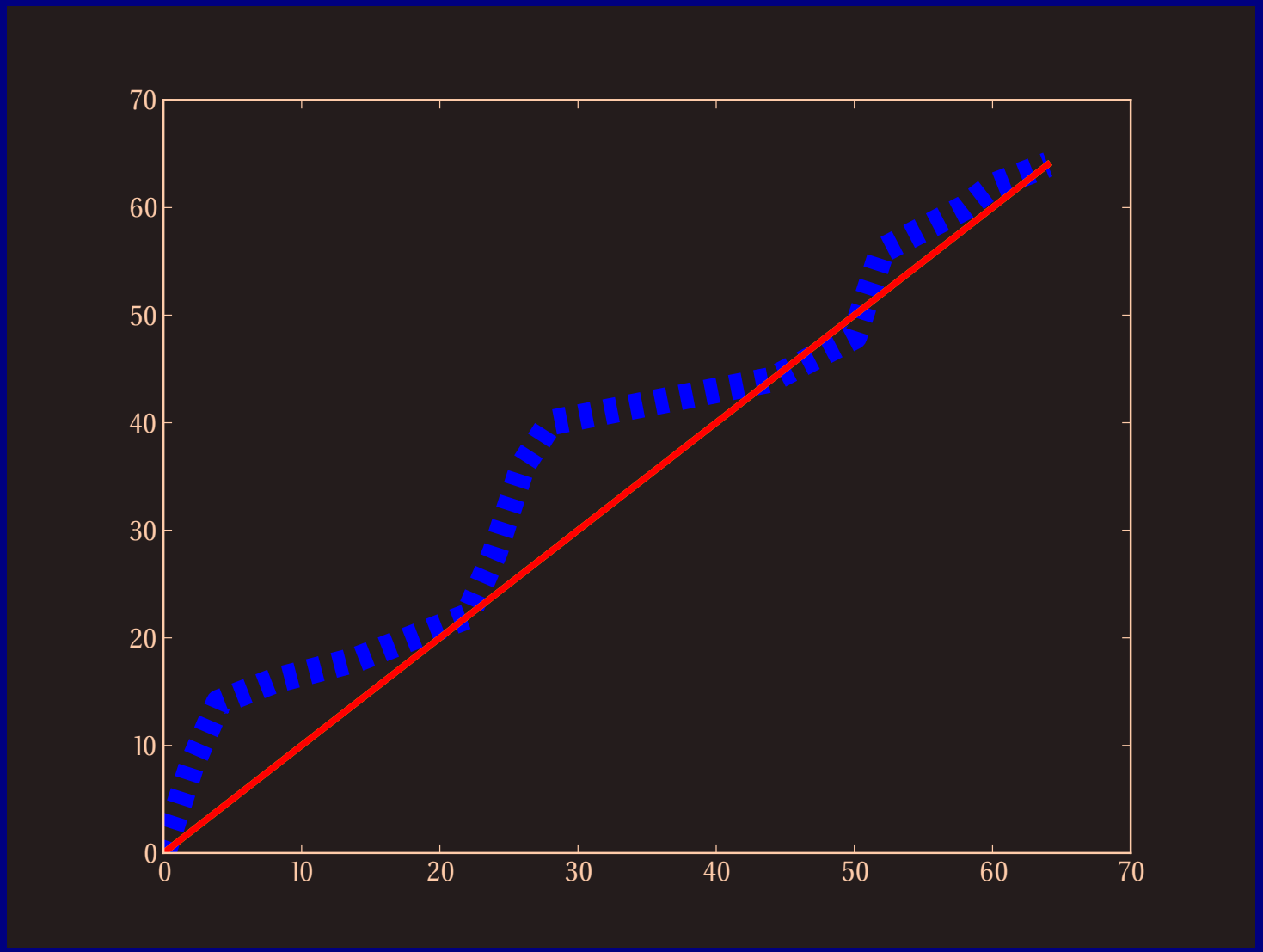
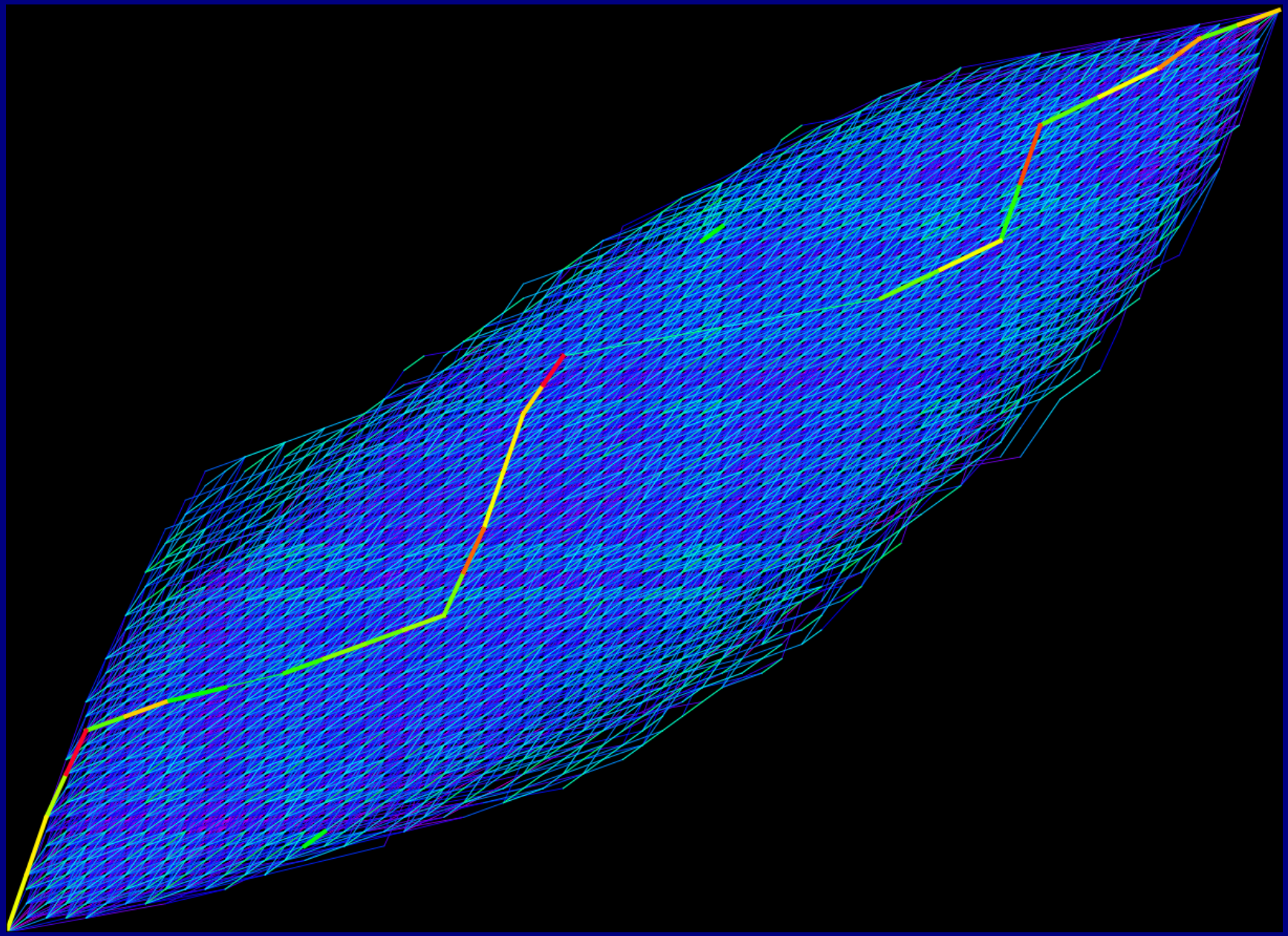


DSA reconstructing an artificial sedimentation rate

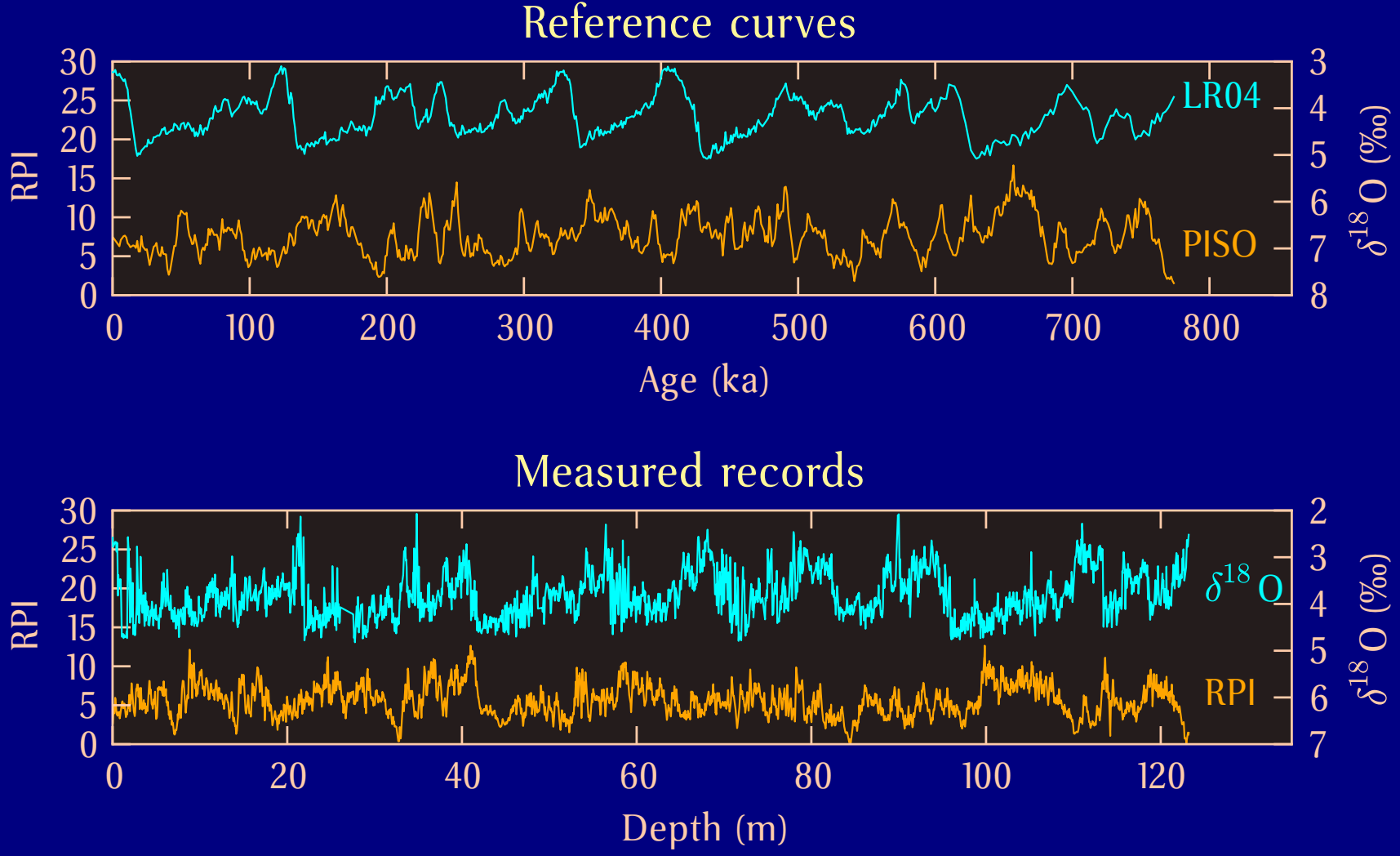


DSA details: search space and optimal solution



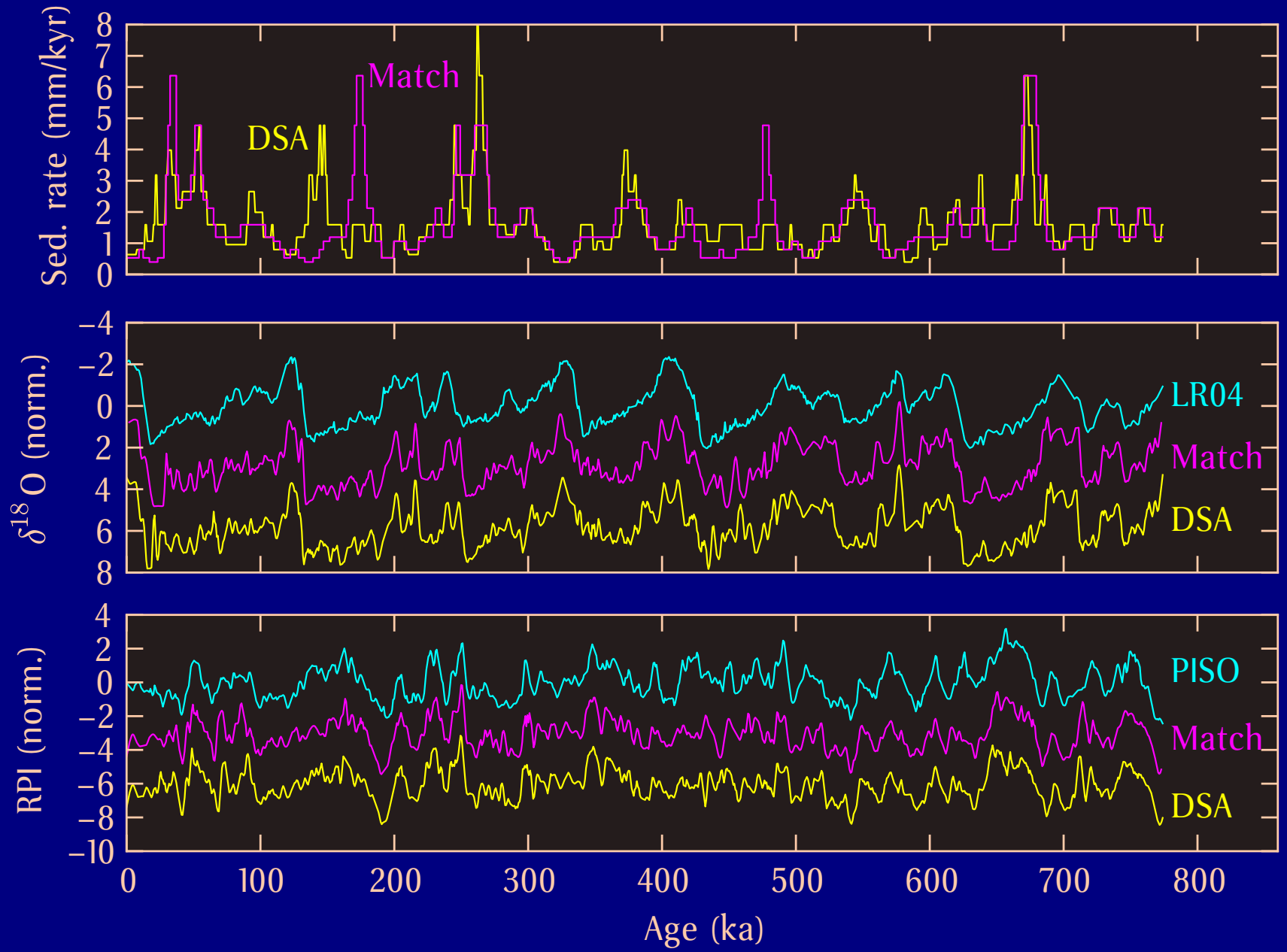
Testing DSA: a tandem correlation on real data

Simultaneous correlation of IODP U1306 δ^{18}O and RPI data.

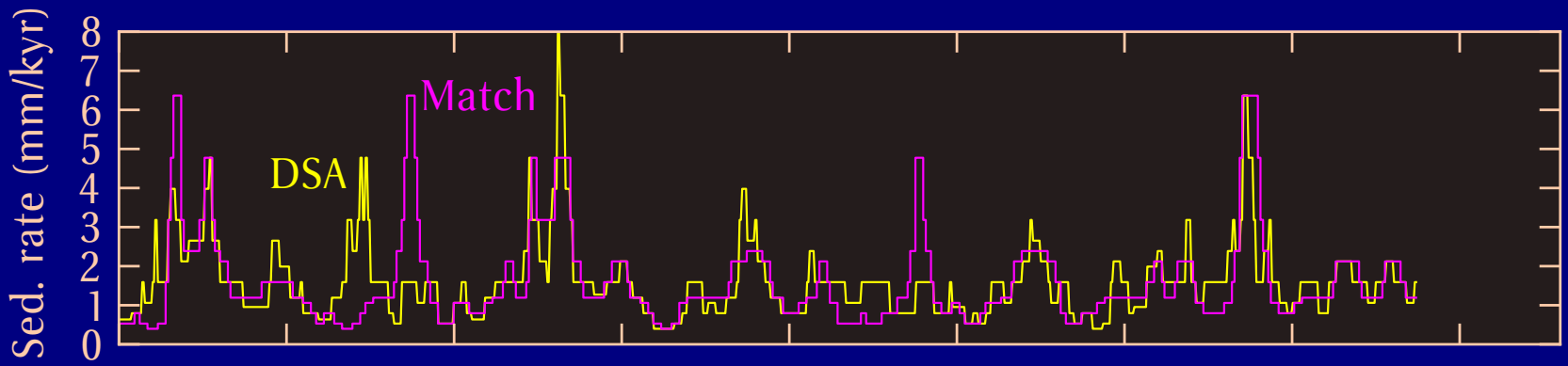


(Isotope data from James D. Wright.)

Tandem δ^{18}O/RPI correlation on U1306: DSA & Match results



Conclusions: the role and future of DSA



- Multiple models give greater confidence in results.
- A ‘reliability curve’ can be calculated for a DSA correlation.
- Very easy to experiment with new constraints; DSA can ‘see’ entire correlation at once.
- Potential to expand search space – e.g. wider range of sedimentation rates.