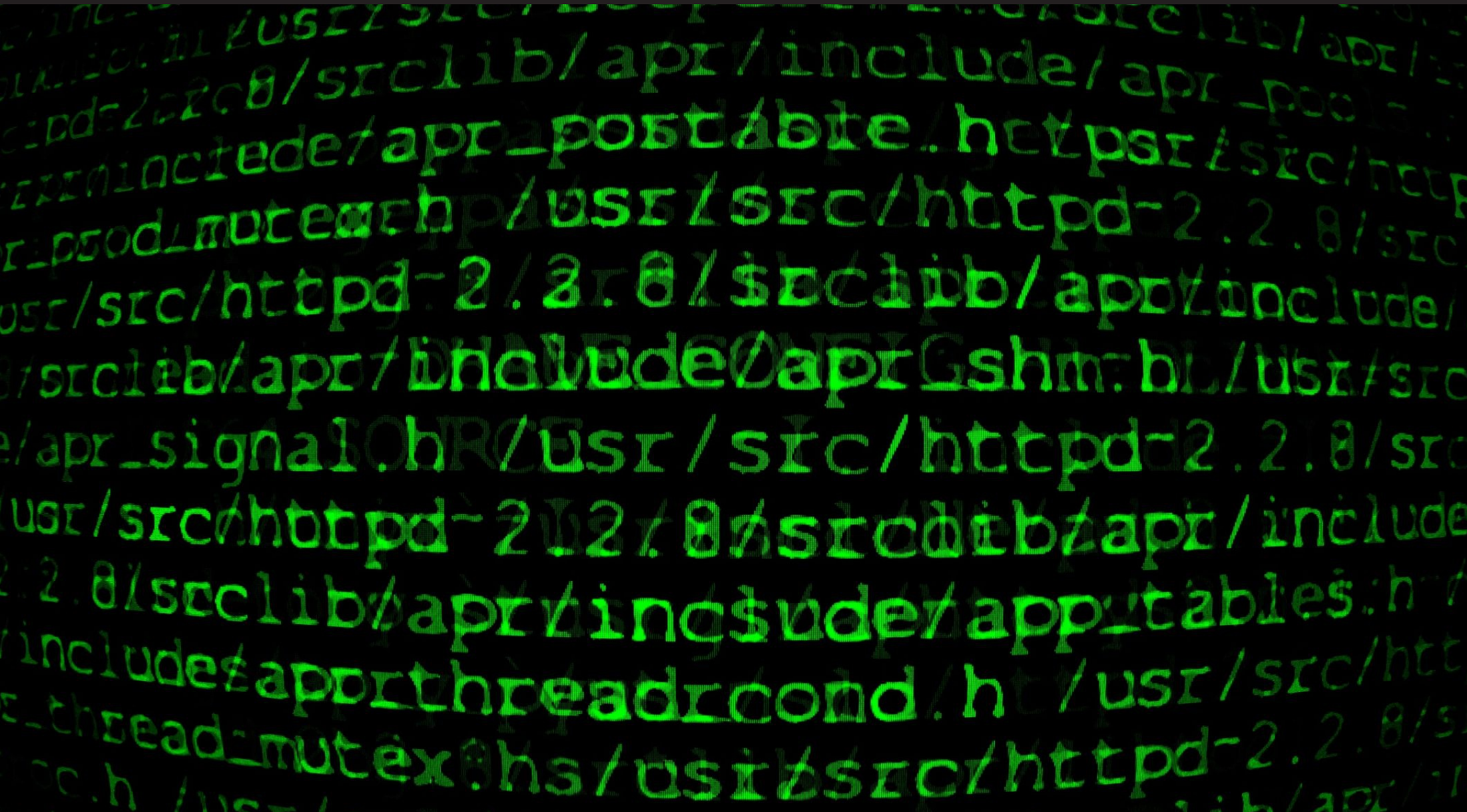
Ecodingt Hem Arineg Eologicalr Ecordd

Ndyr Idgwella



Ecodingt Hem Arineg E alr Ecordd

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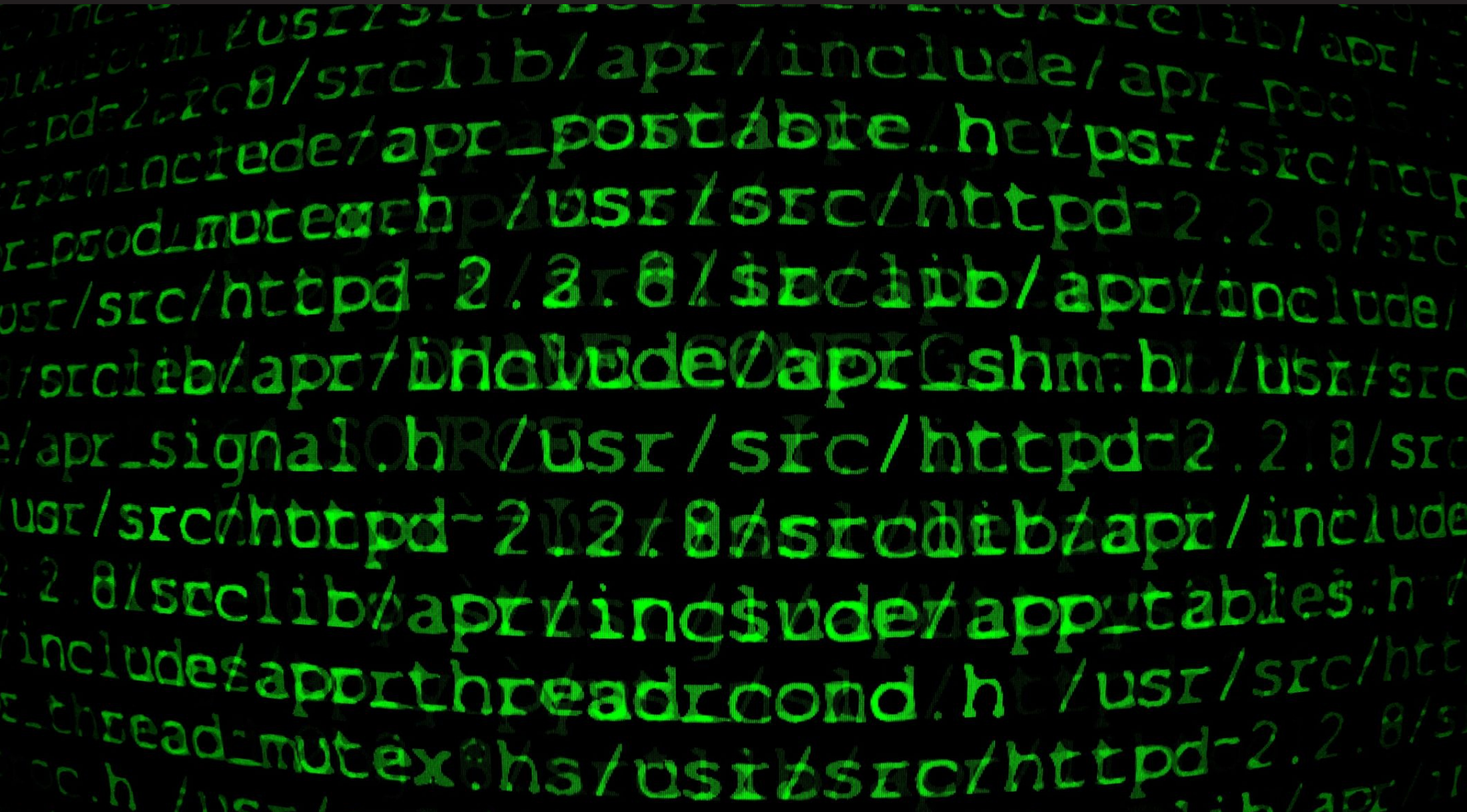
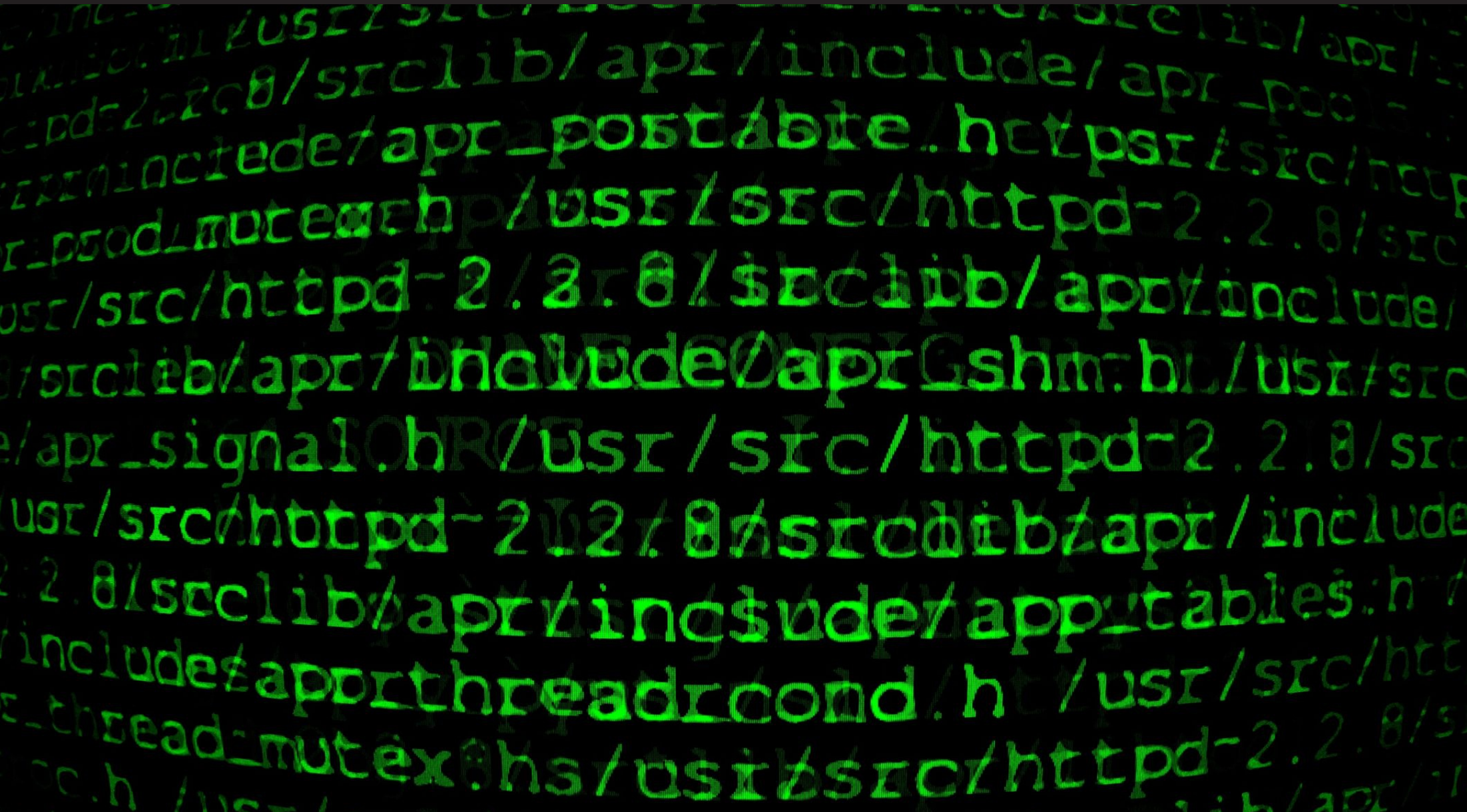


Εχοδινγτ Ηεμ

Αριηεγ Ε αλρ Εχορδδ

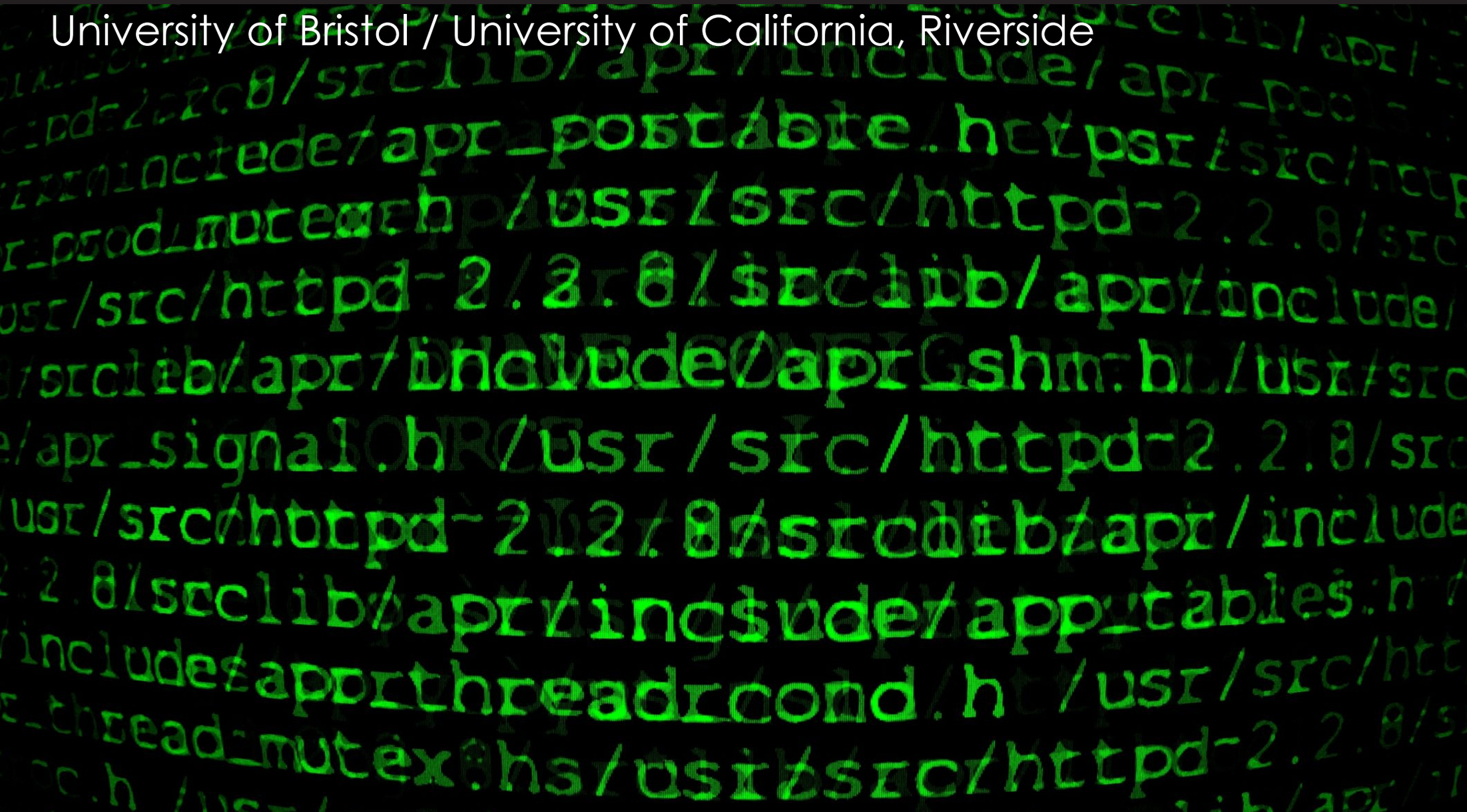
Νδψρ Ιδγωελλα



Decoding The Marine Geological Record

Andy Ridgwell

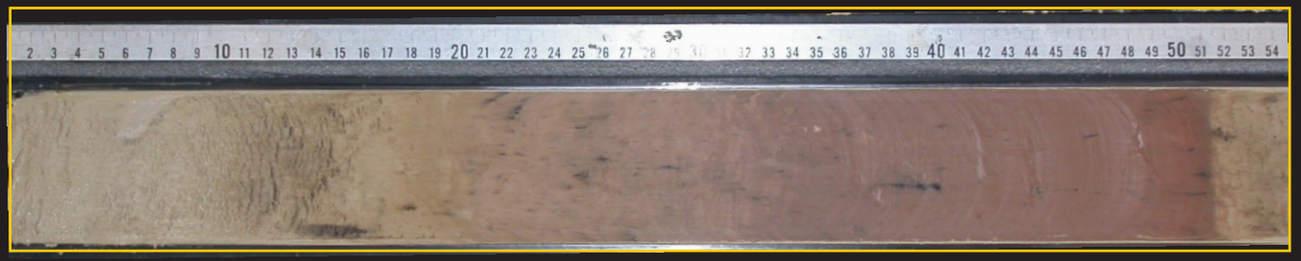
University of Bristol / University of California, Riverside



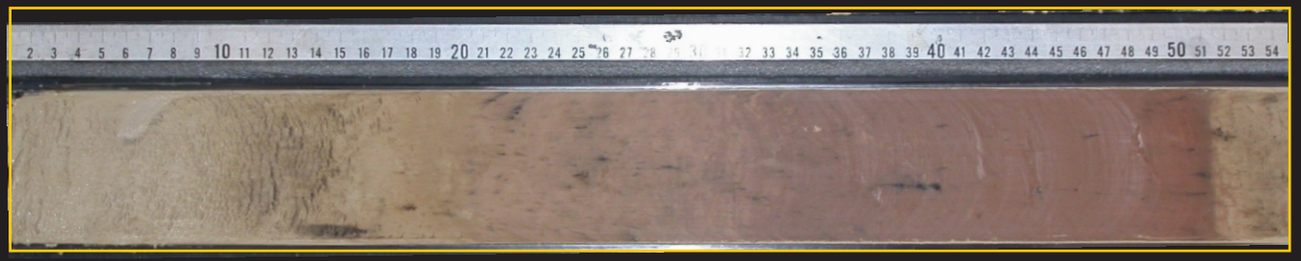

Rrelative age
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
4.0
3.0
2.0
1.0
0.0
δ13C (‰)


?


Rrelative age
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
4.0
3.0
2.0
1.0
0.0
δ13C (‰)



How much carbon?
(=> infer climate,
ecosystem sensitivity etc.)



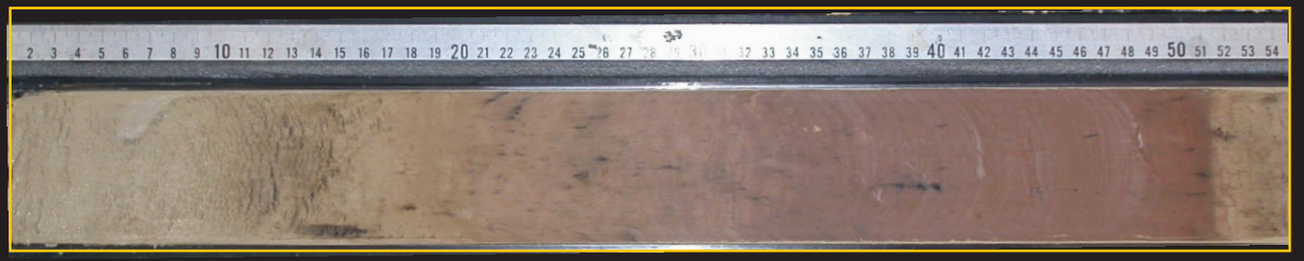
Introduction

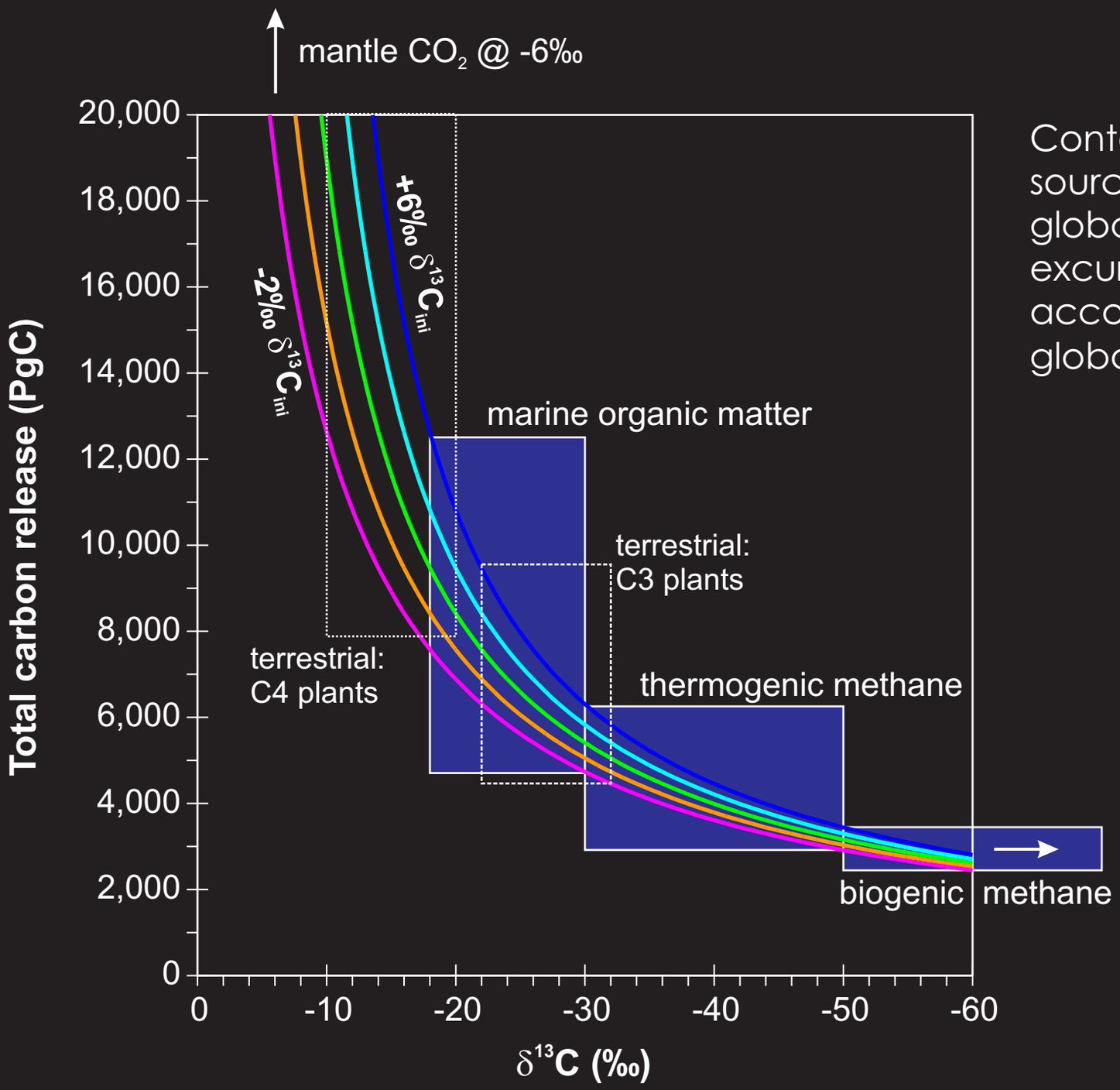
By simple mass balance, the size of an isotopic excursion is:

$\Delta\delta^{13}C \sim \delta^{13}C_{new} \times \Delta M_{new} / (M_{old} + \Delta M_{new})$

where ΔM_{new} is the mass added, $\delta^{13}C_{new}$ is its isotopic signature, and M_{old} is the original total mass of 'exchangeable' carbon. Or:

$\Delta M_{new} \sim \Delta\delta^{13}C \times M_{old} / (\delta^{13}C_{old} + \Delta\delta^{13}C - \delta^{13}C_{new})$

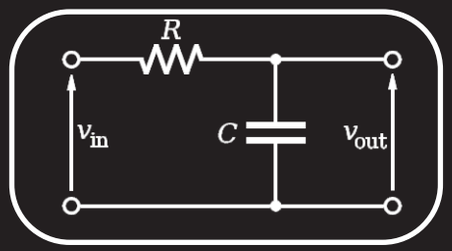


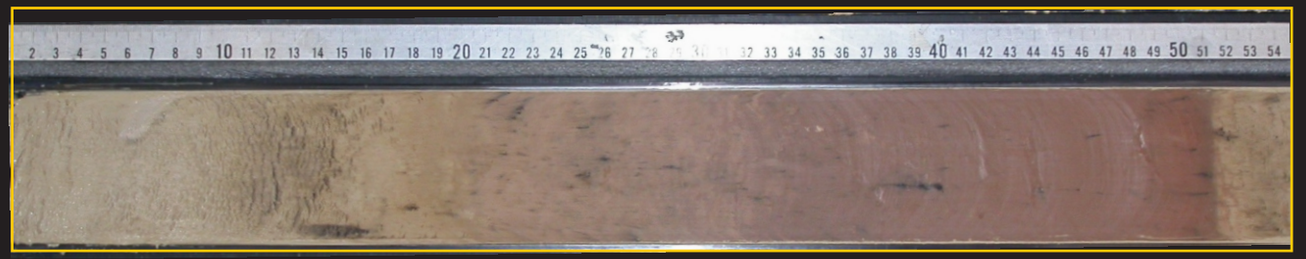


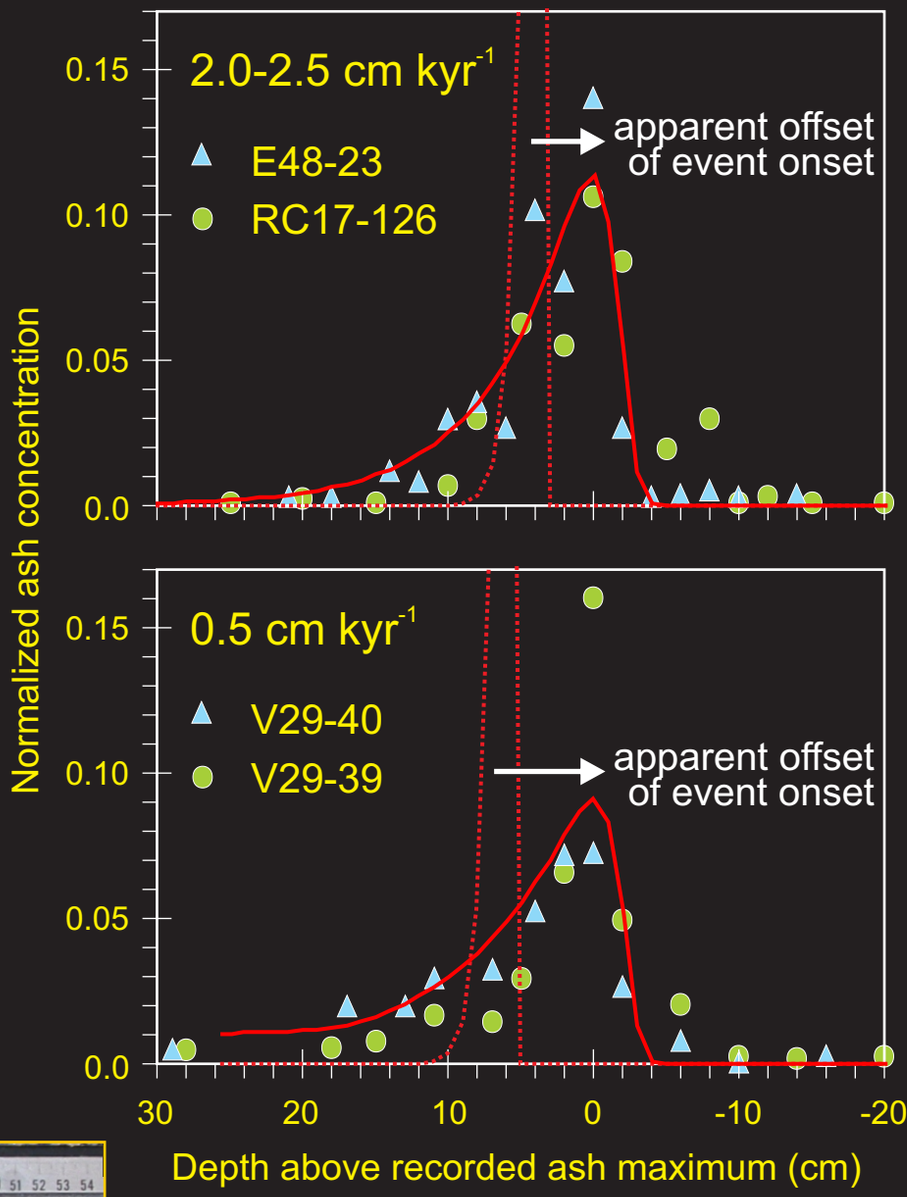
Contours of carbon release vs. source isotopic signature for a global -4‰ carbon isotopic excursion. Contours differ according to the initial mean global $\delta^{13}C$.

Ridgwell and Arndt [2014]

mixing
(bioturbation)

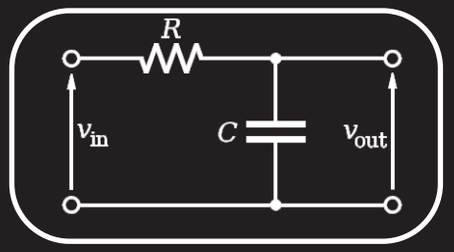






Introduction

dissolution
(peservation)



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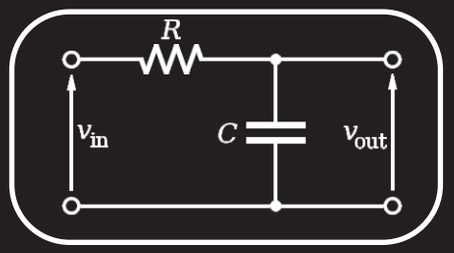
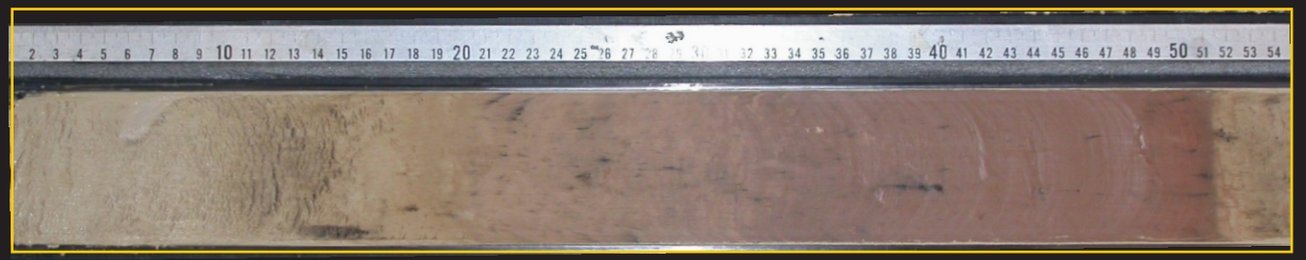
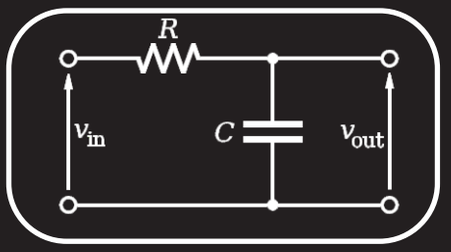
(bioturbation)





Introduction



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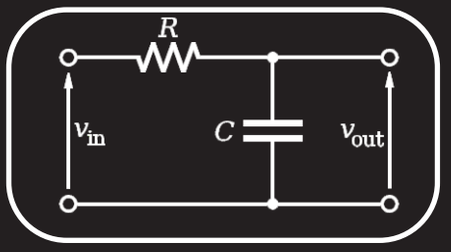

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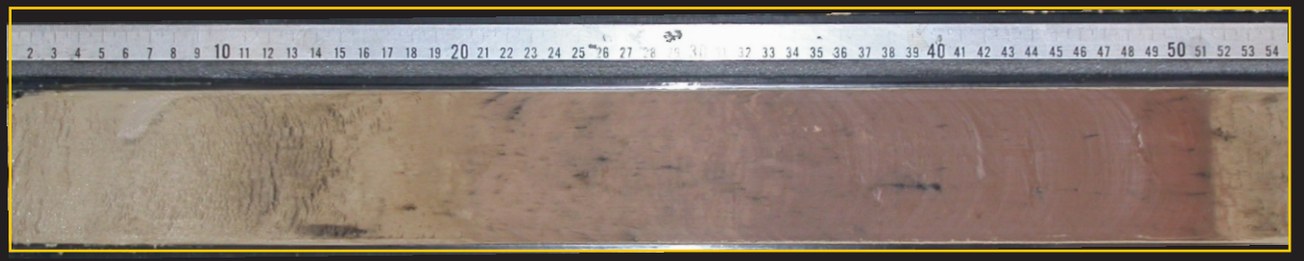
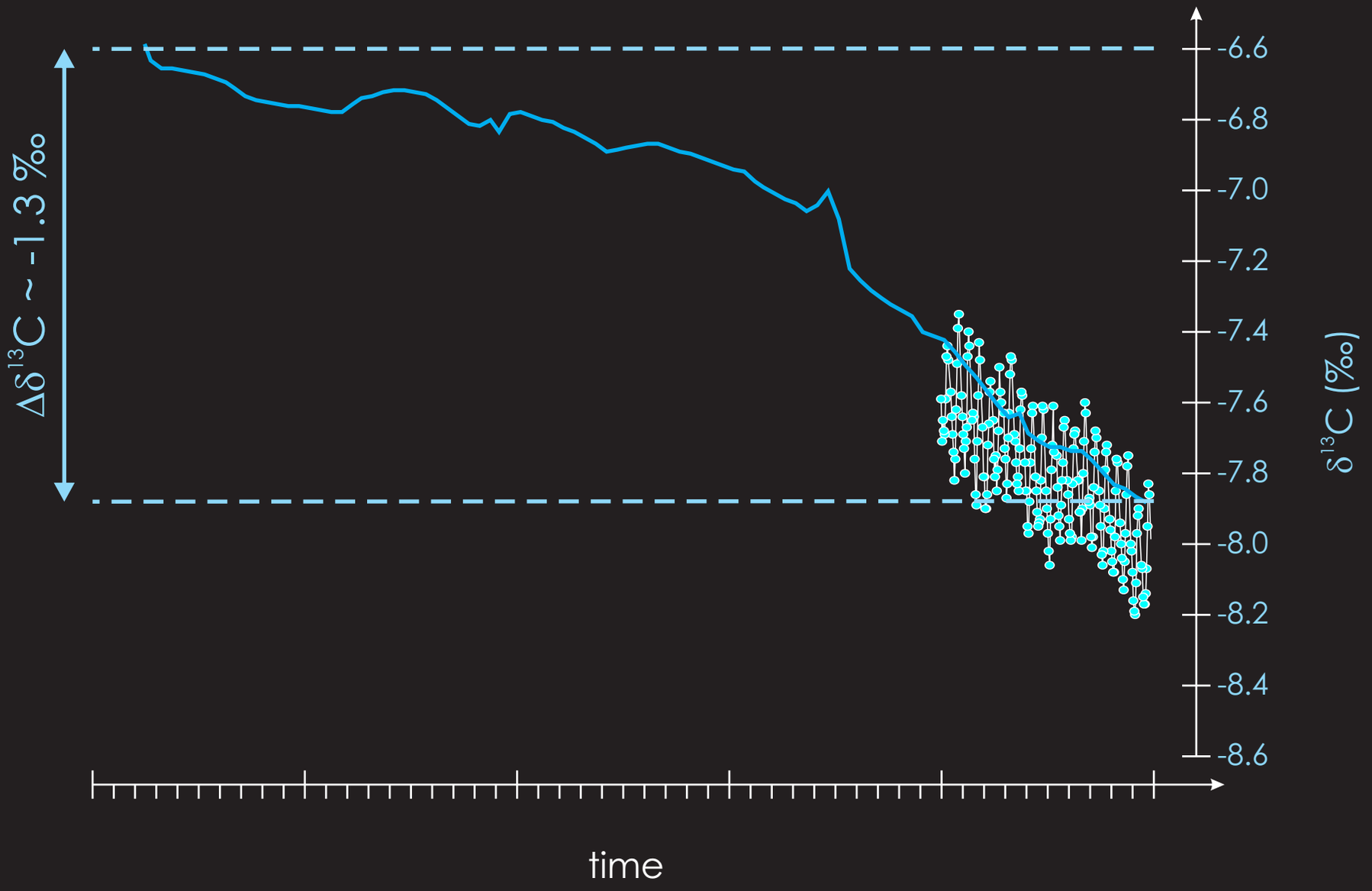
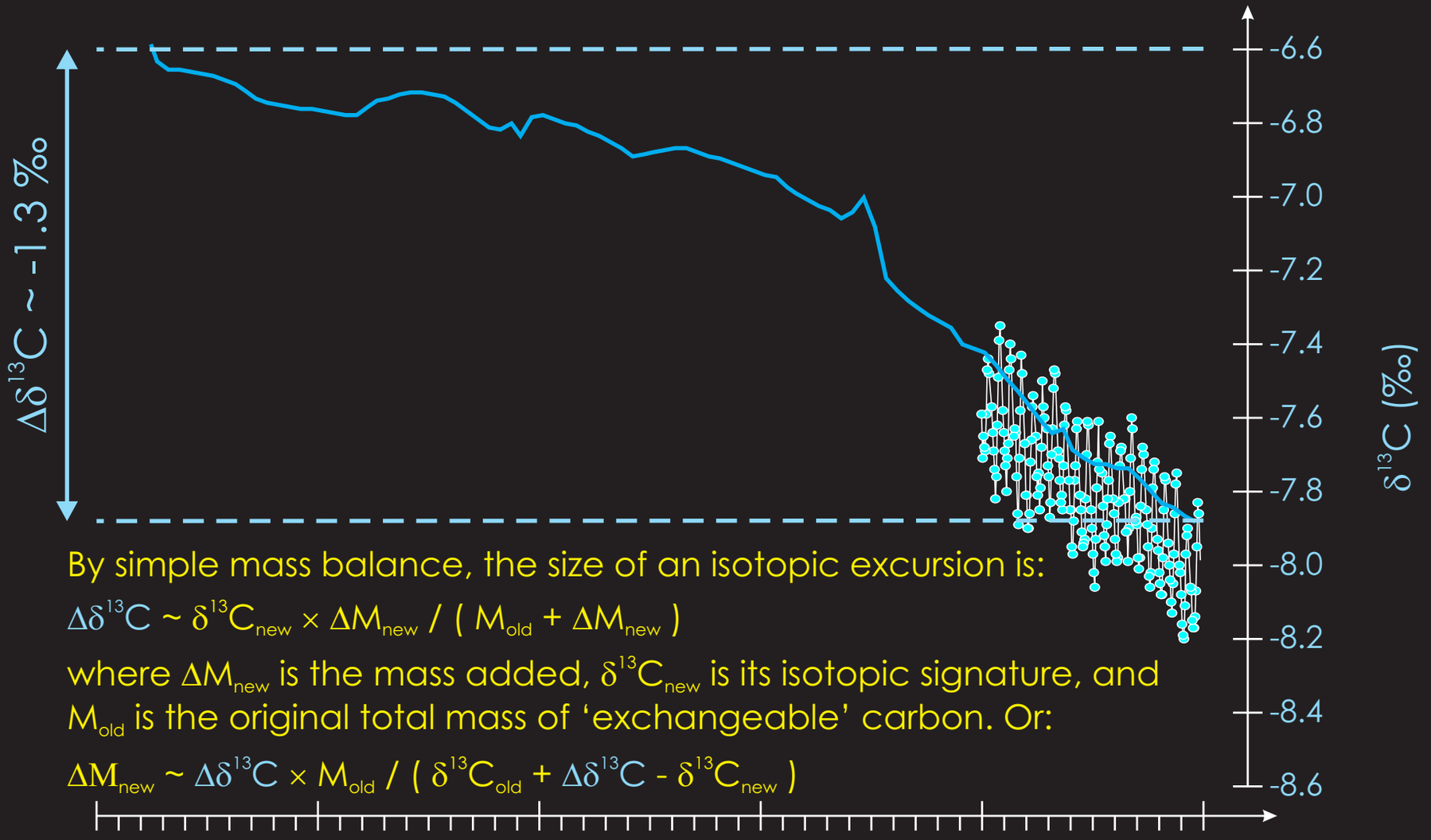
(bioturbation)



'Inverting' isotopic records



‘Inverting’ isotopic records



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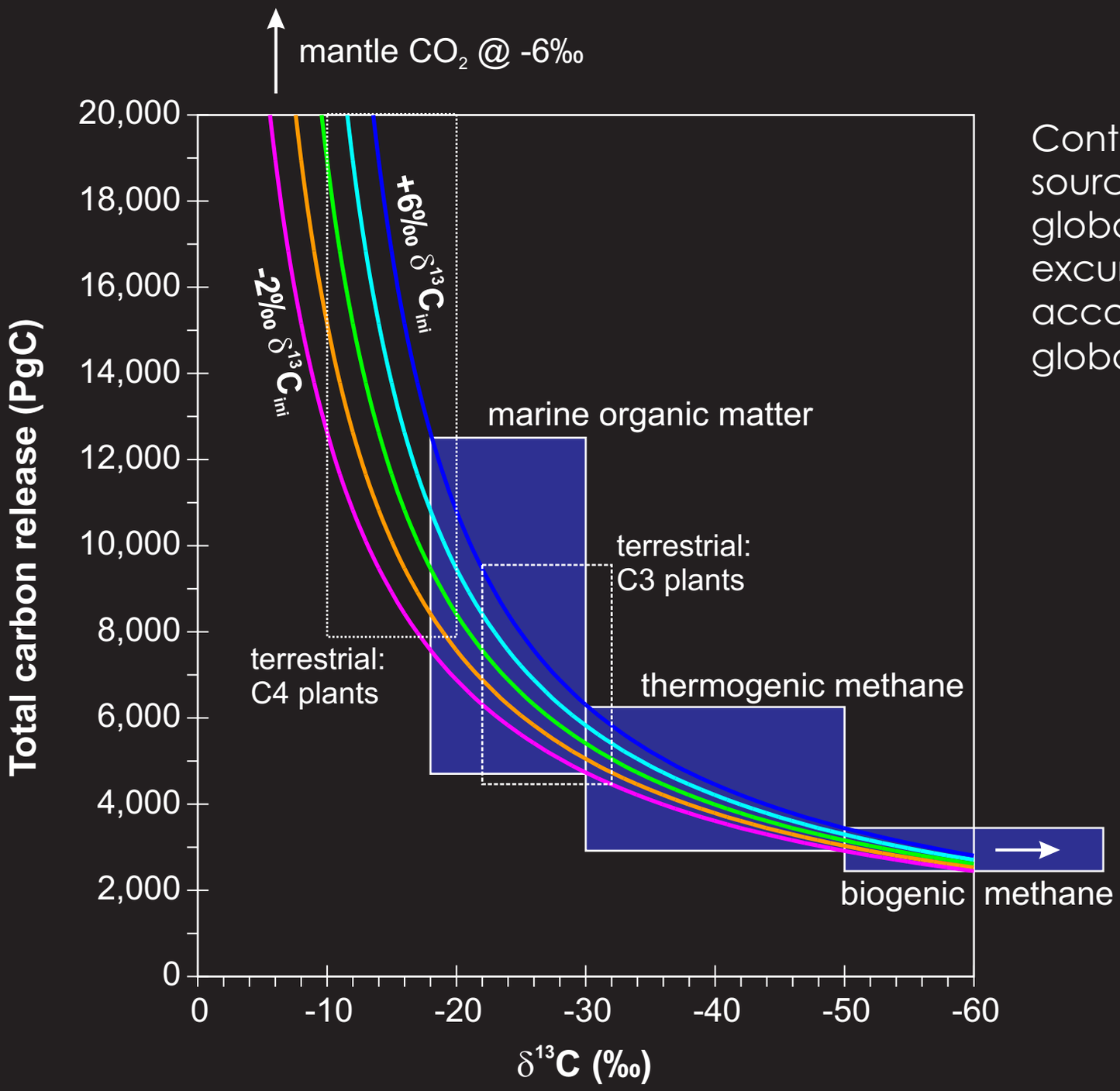

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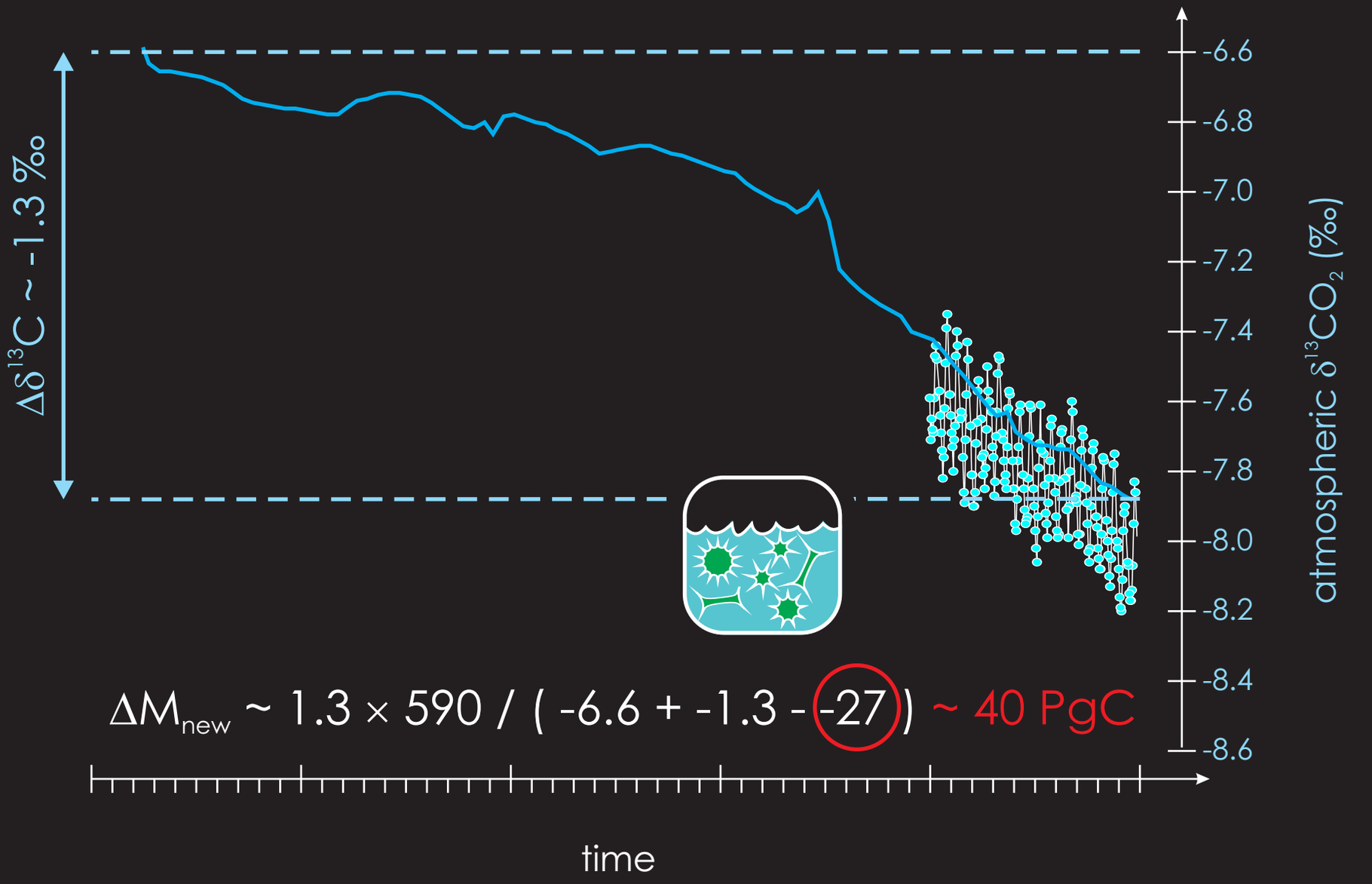
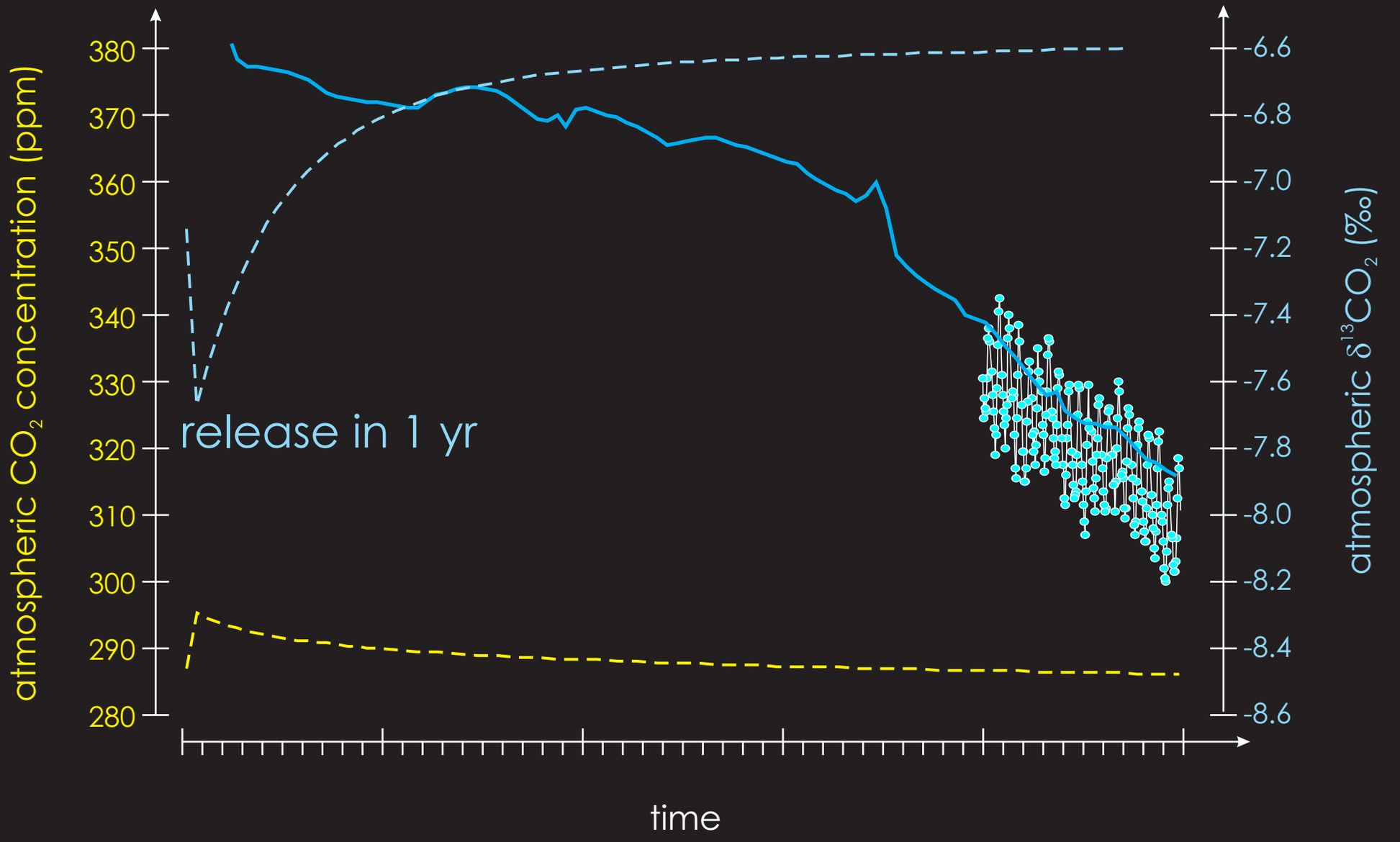
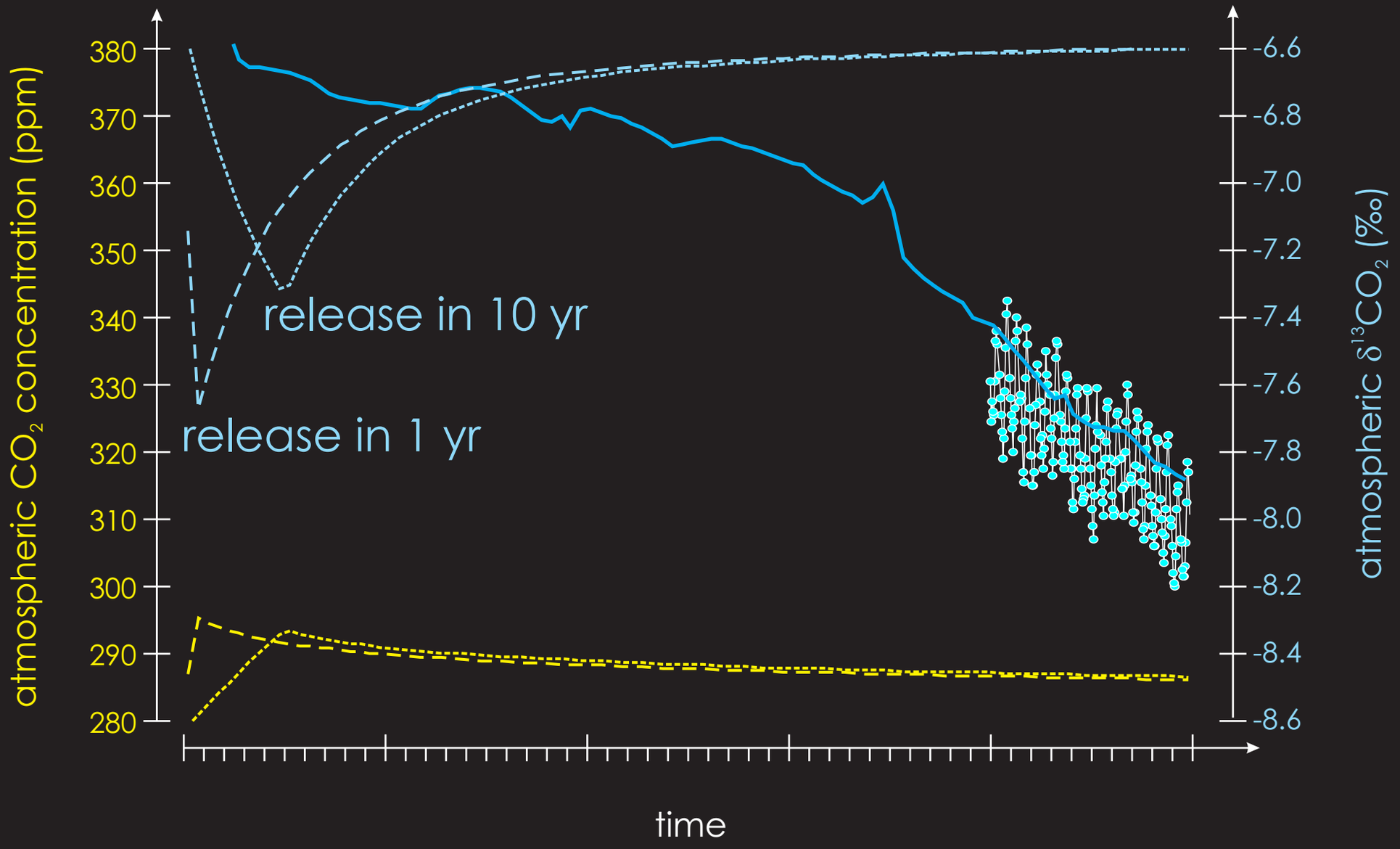
'Inverting' isotopic records



'Inverting' isotopic records



'Inverting' isotopic records



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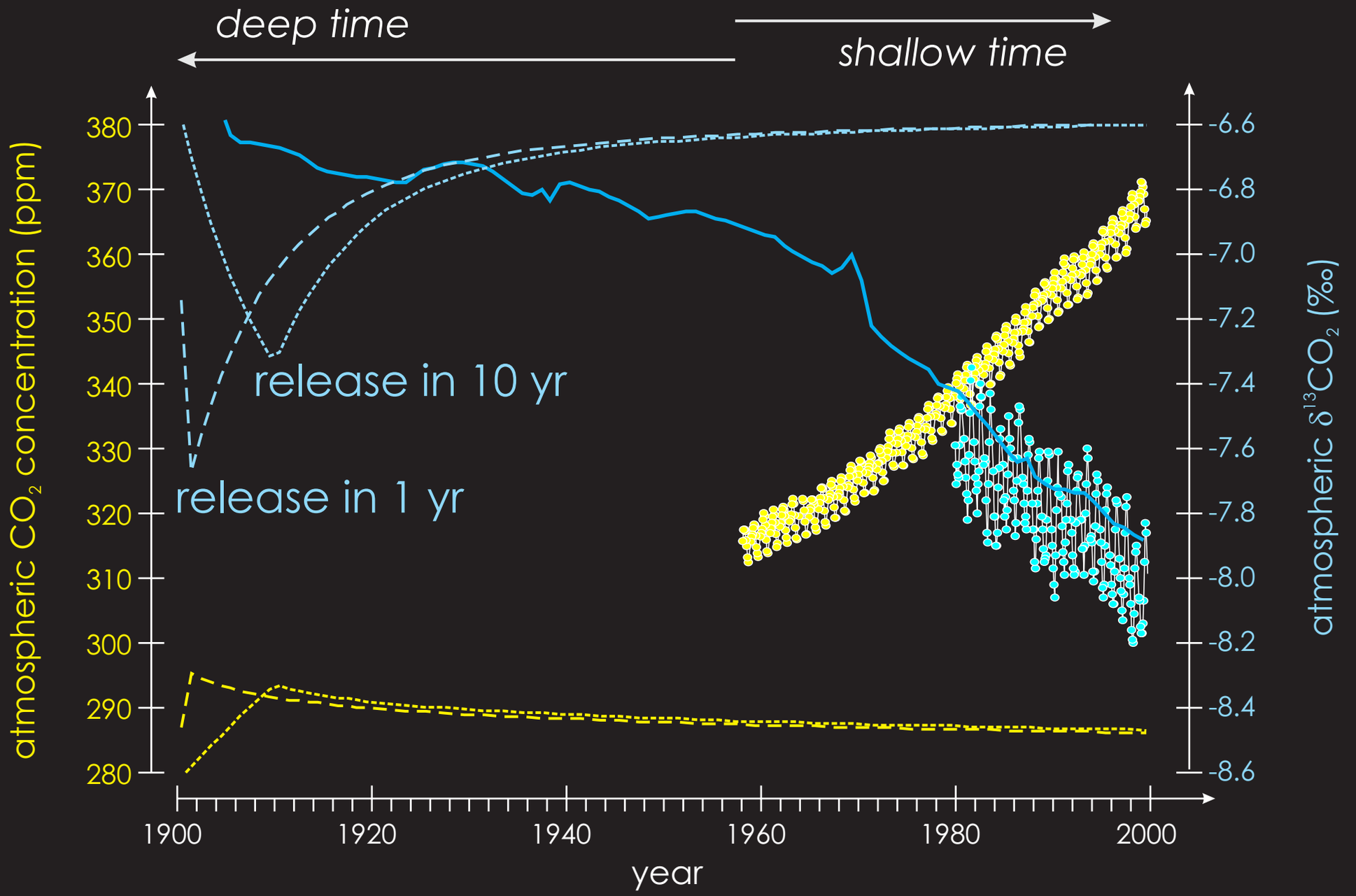

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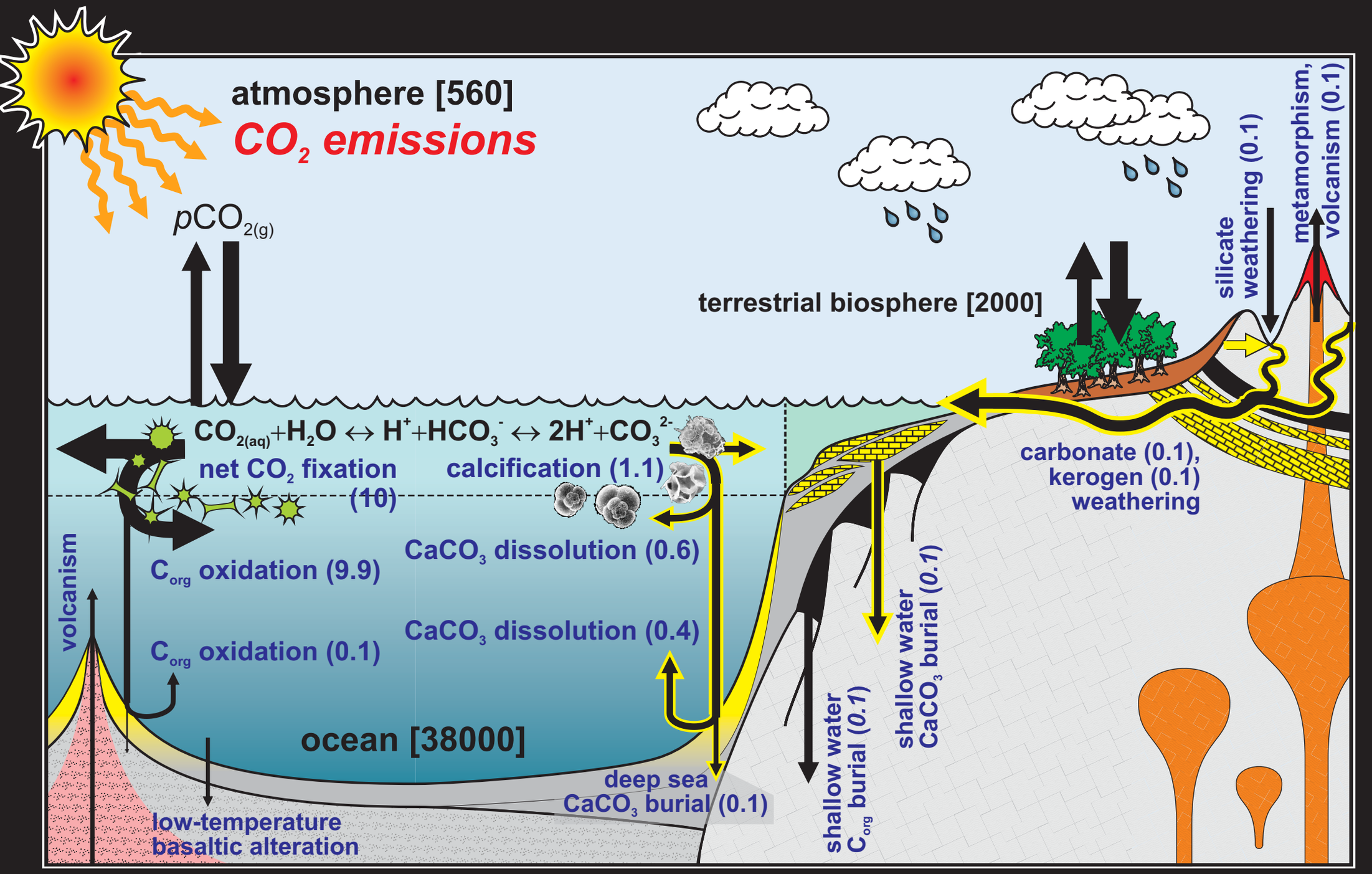

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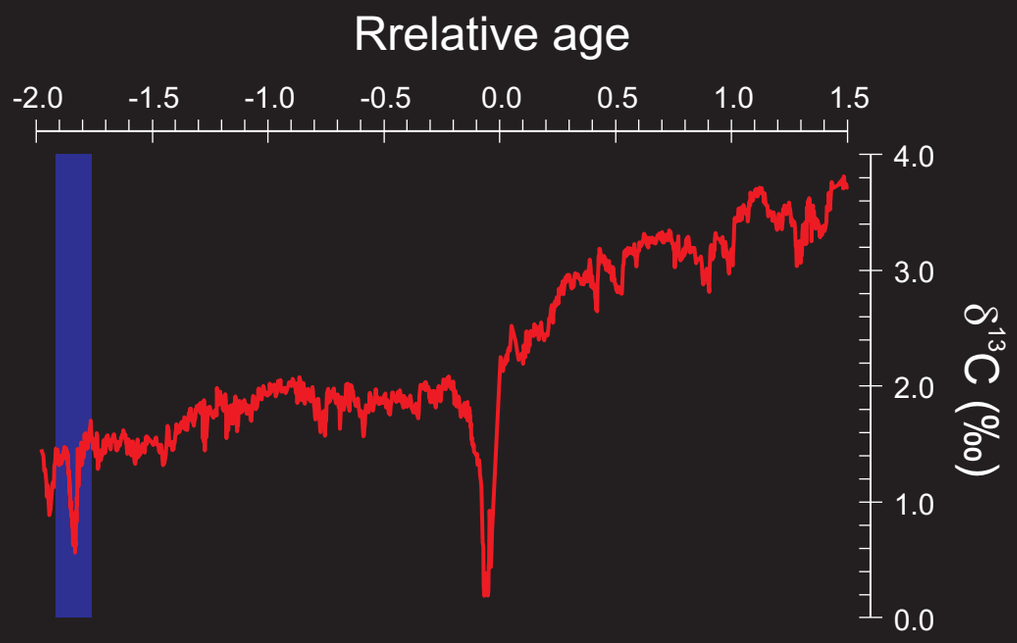
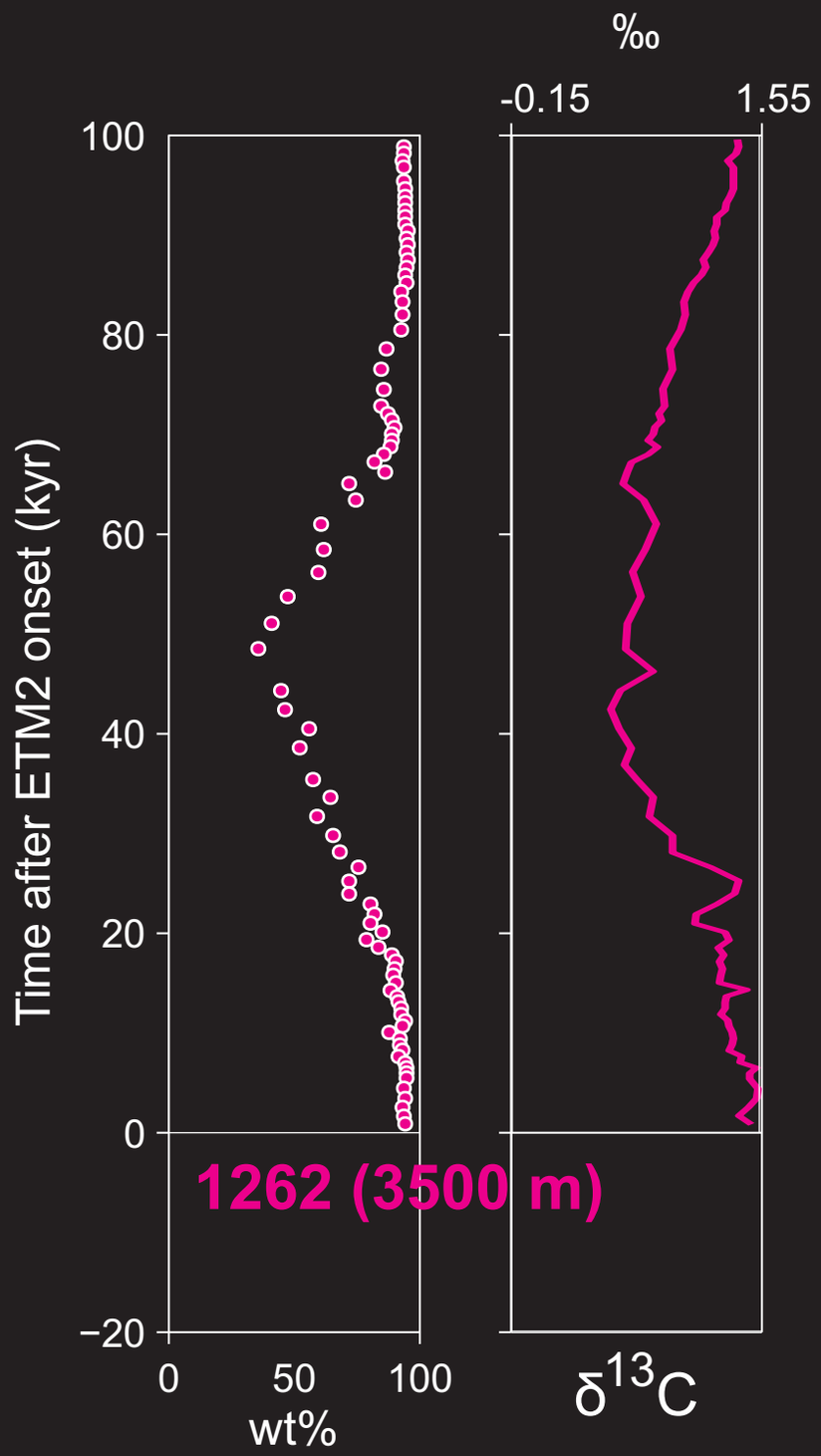
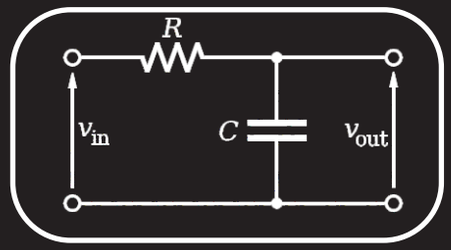


'Inverting' isotopic records

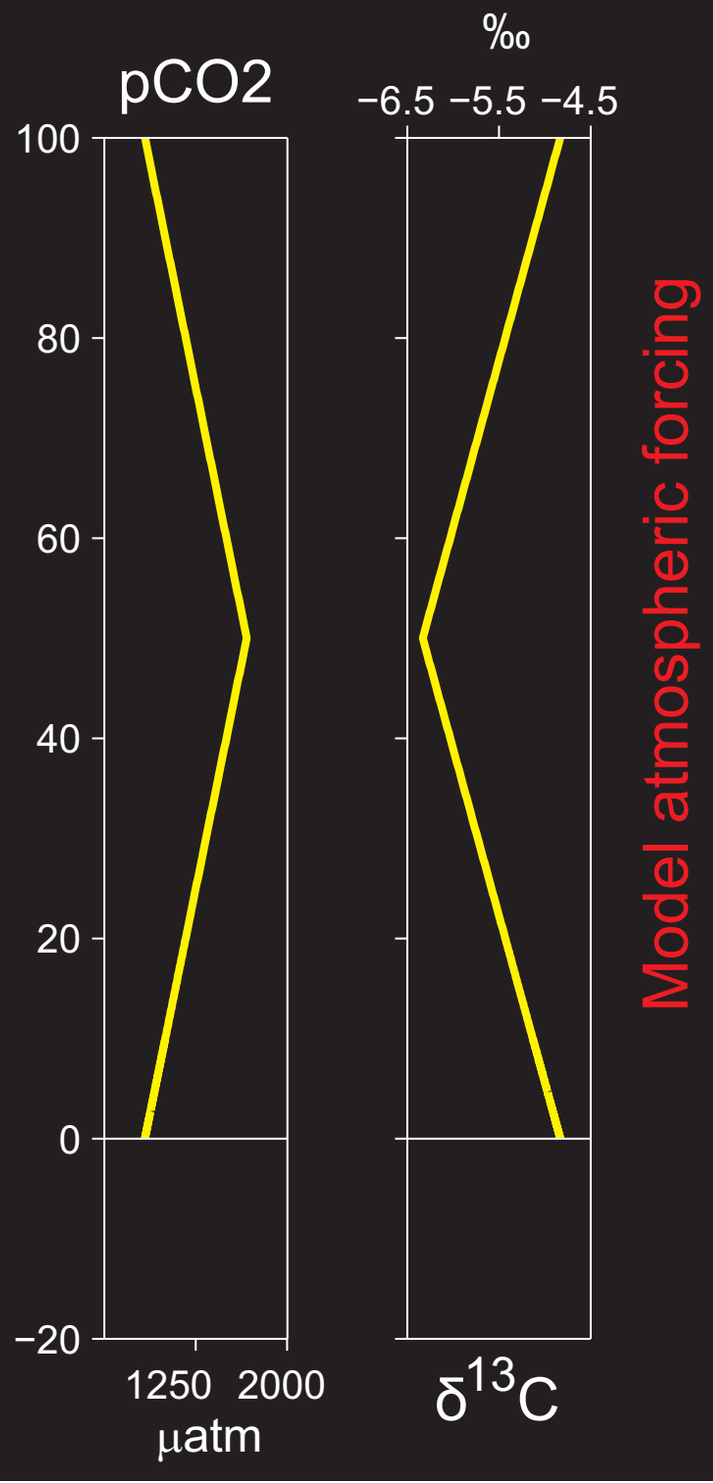


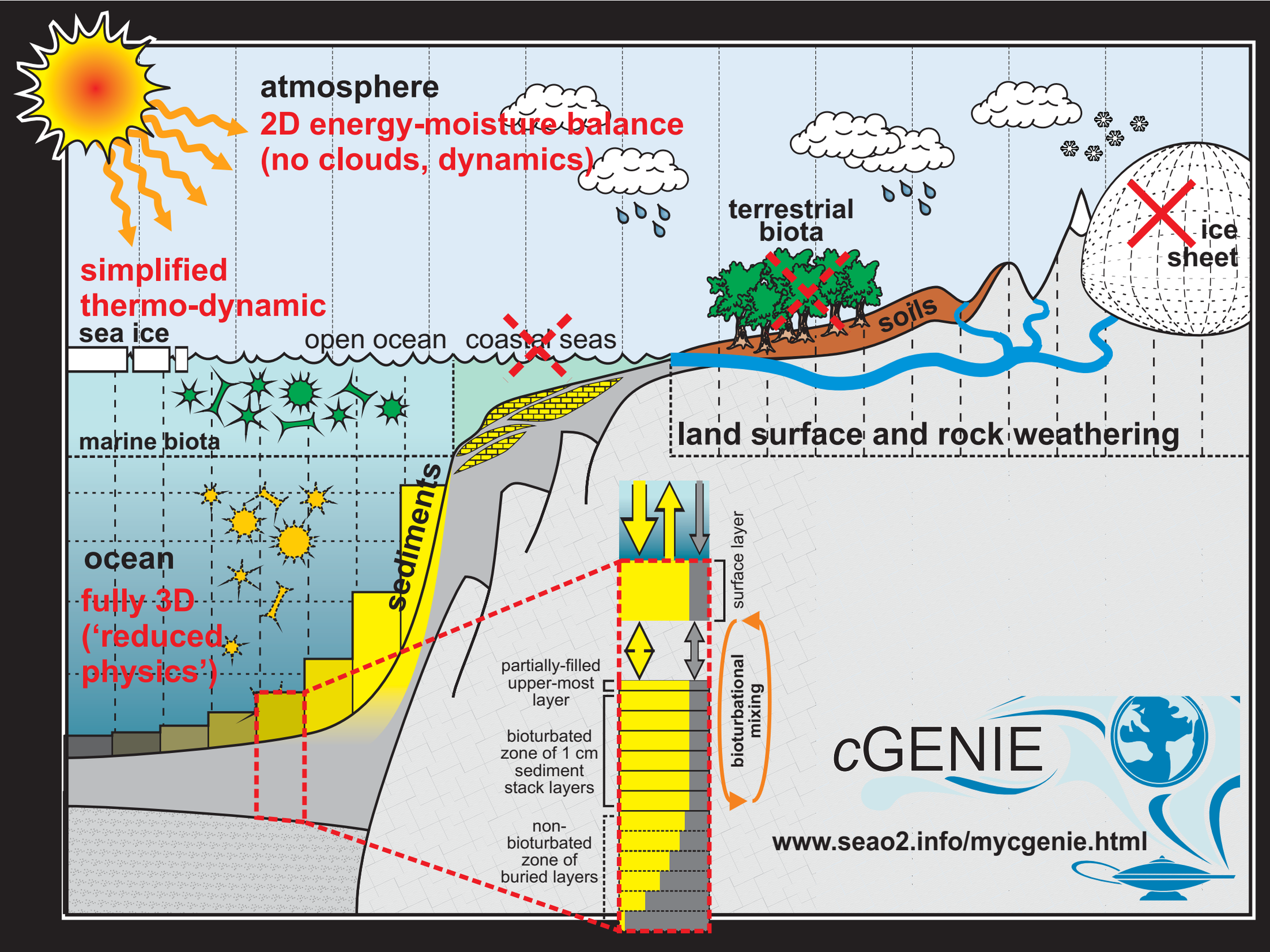
'Inverting' isotopic records

?

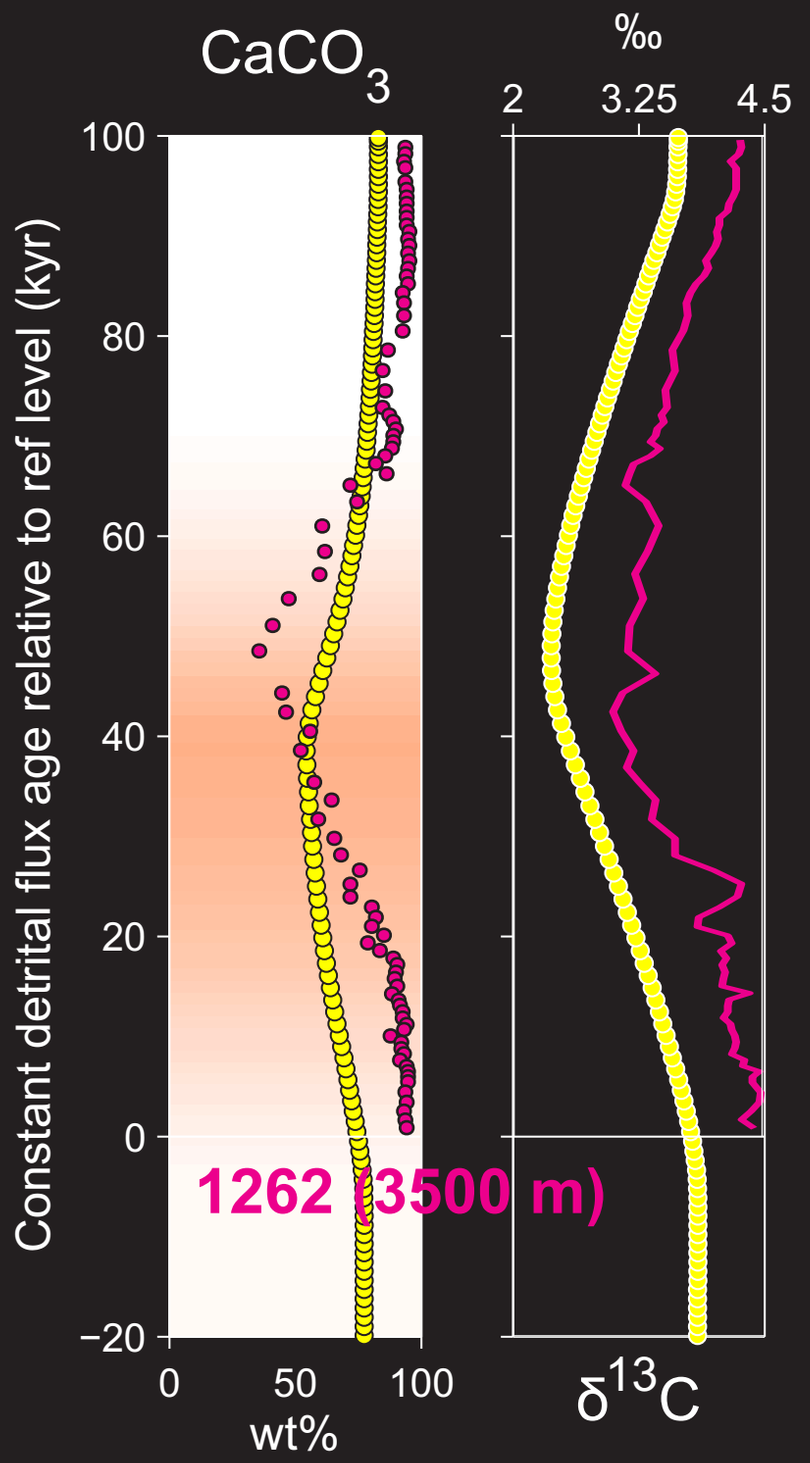


('traditional', forward-modelling approach)

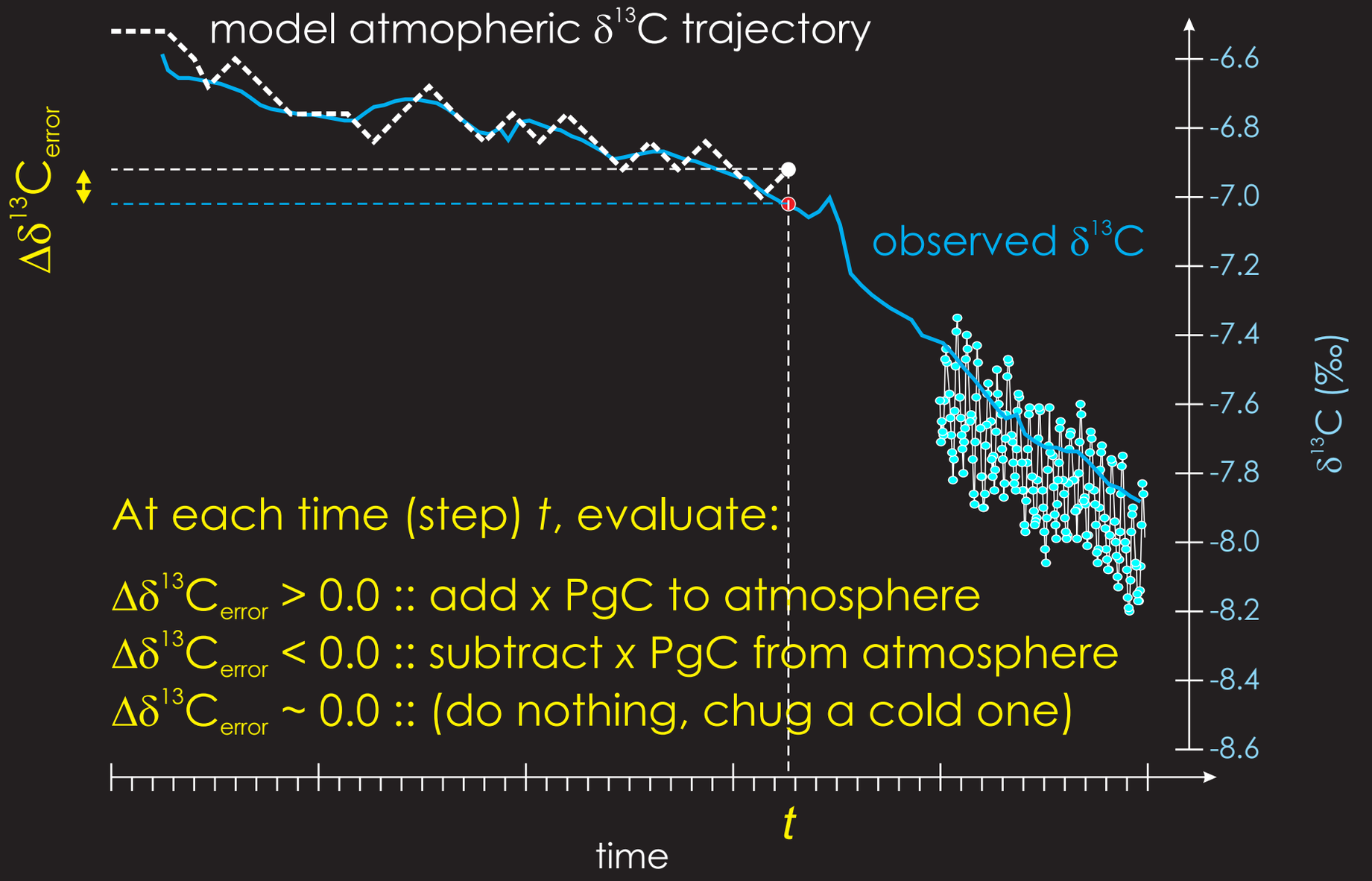



atmosphere
2D energy-moisture balance
(no clouds, dynamics)
simplified
thermo-dynamic
sea ice
open ocean
coastal seas
terrestrial
biota
soils
ice
sheet
land surface and rock weathering
marine biota
sediments
ocean
fully 3D
('reduced
physics')
surface layer
partially-filled
upper-most
layer
bioturbated
zone of 1 cm
sediment
stack layers
non-
bioturbated
zone of
buried layers
bioturbational
mixing
cGENIE
www.seao2.info/mycgenie.html

'Inverting' isotopic records



'Inverting' isotopic records



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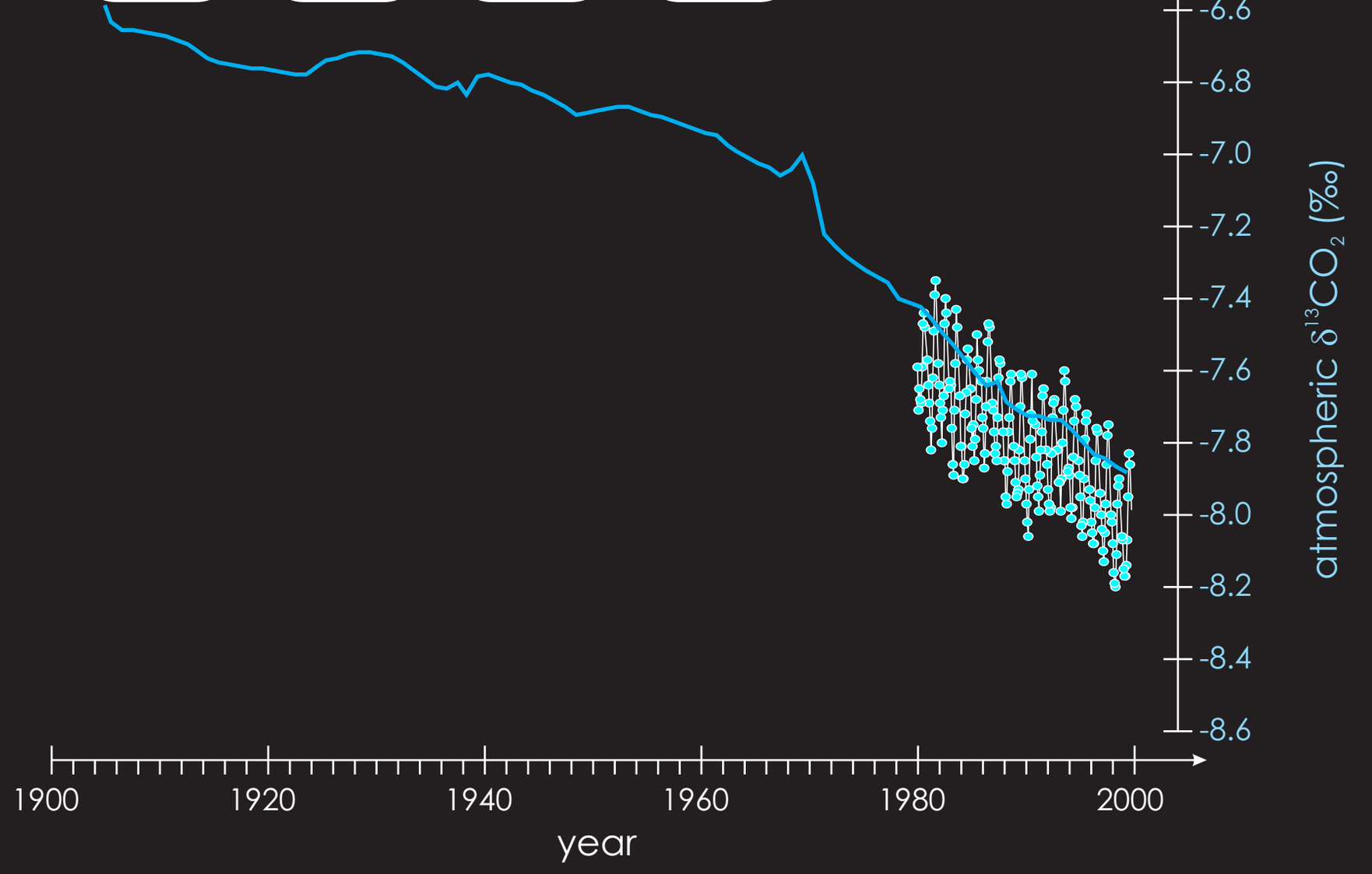


'Inverting' isotopic records

atmospheric CO_2 concentration (ppm)

380
370
360
350
340
330
320
310
300
290
280

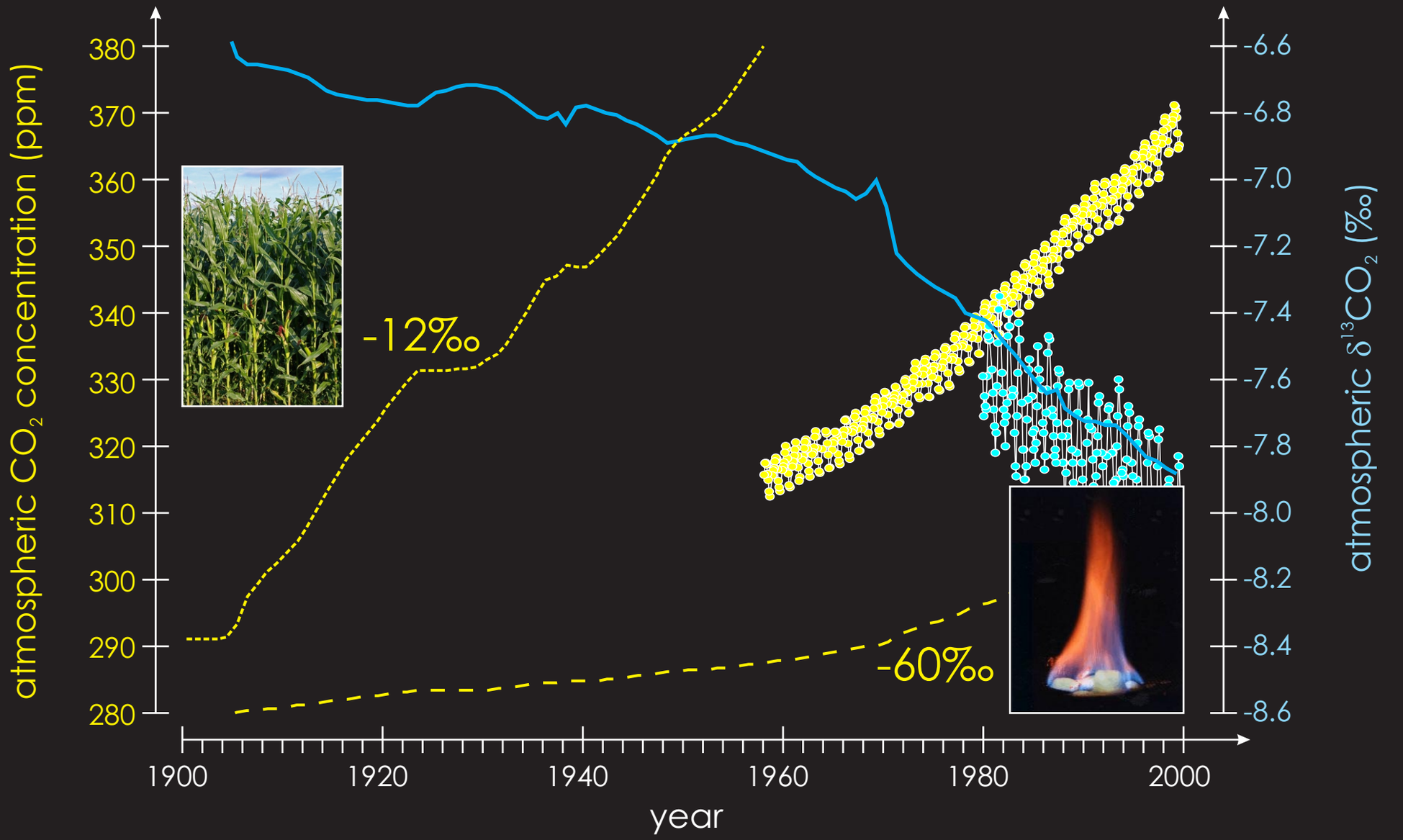
-6.6
-6.8
-7.0
-7.2
-7.4
-7.6
-7.8
-8.0
-8.2
-8.4
-8.6

atmospheric $\delta^{13}CO_2$ (‰)

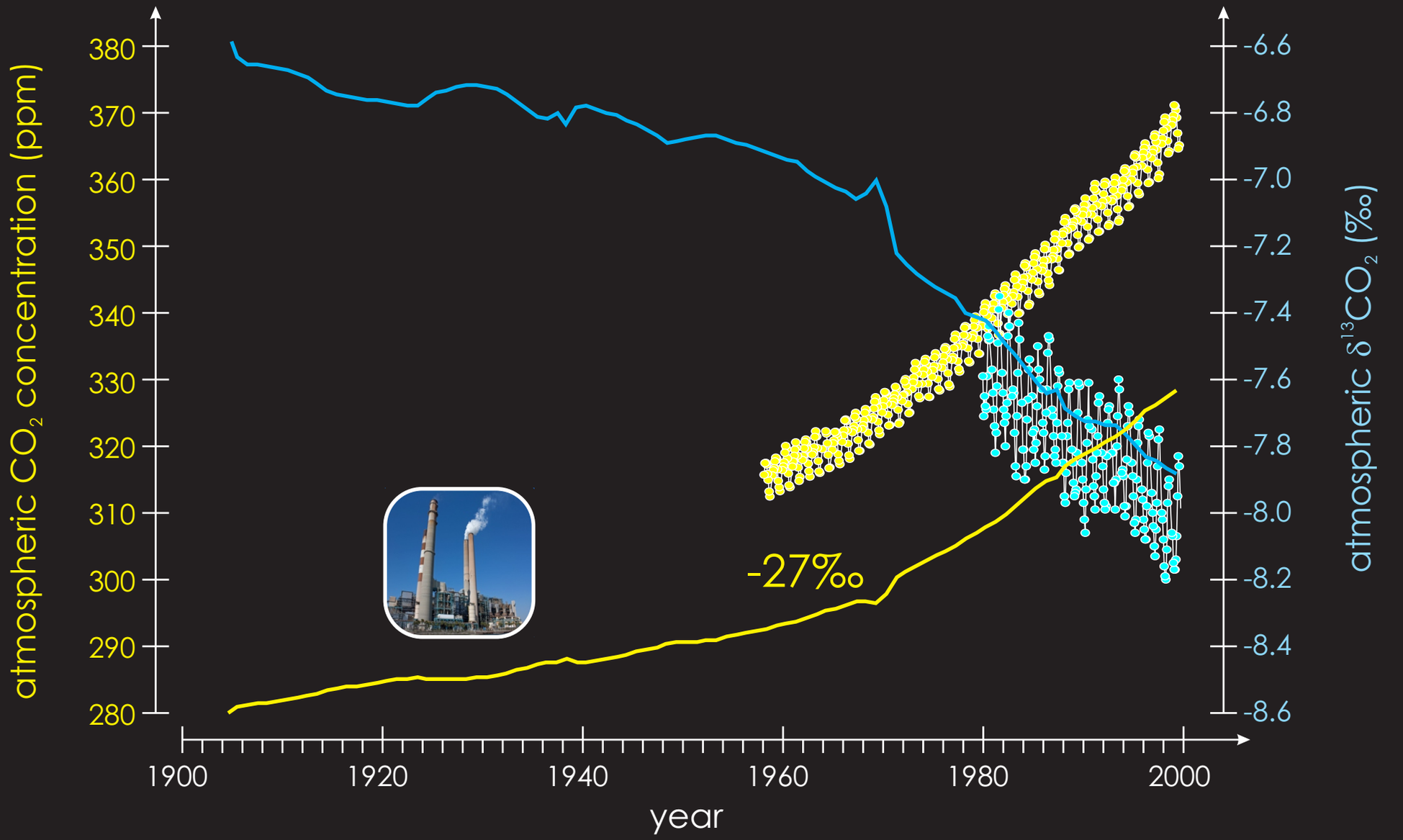
1900
1920
1940
1960
1980
2000

year

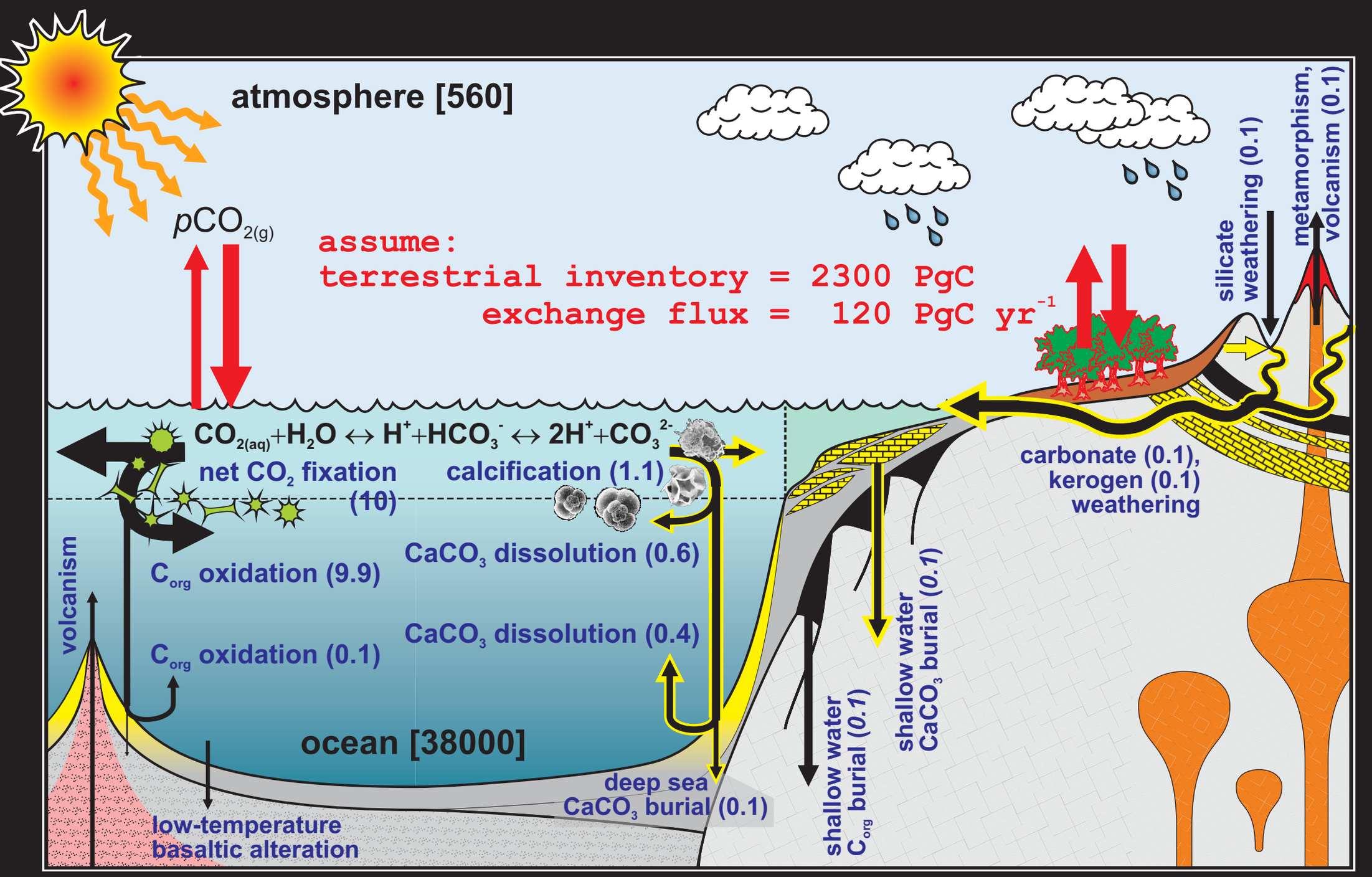
'Inverting' isotopic records



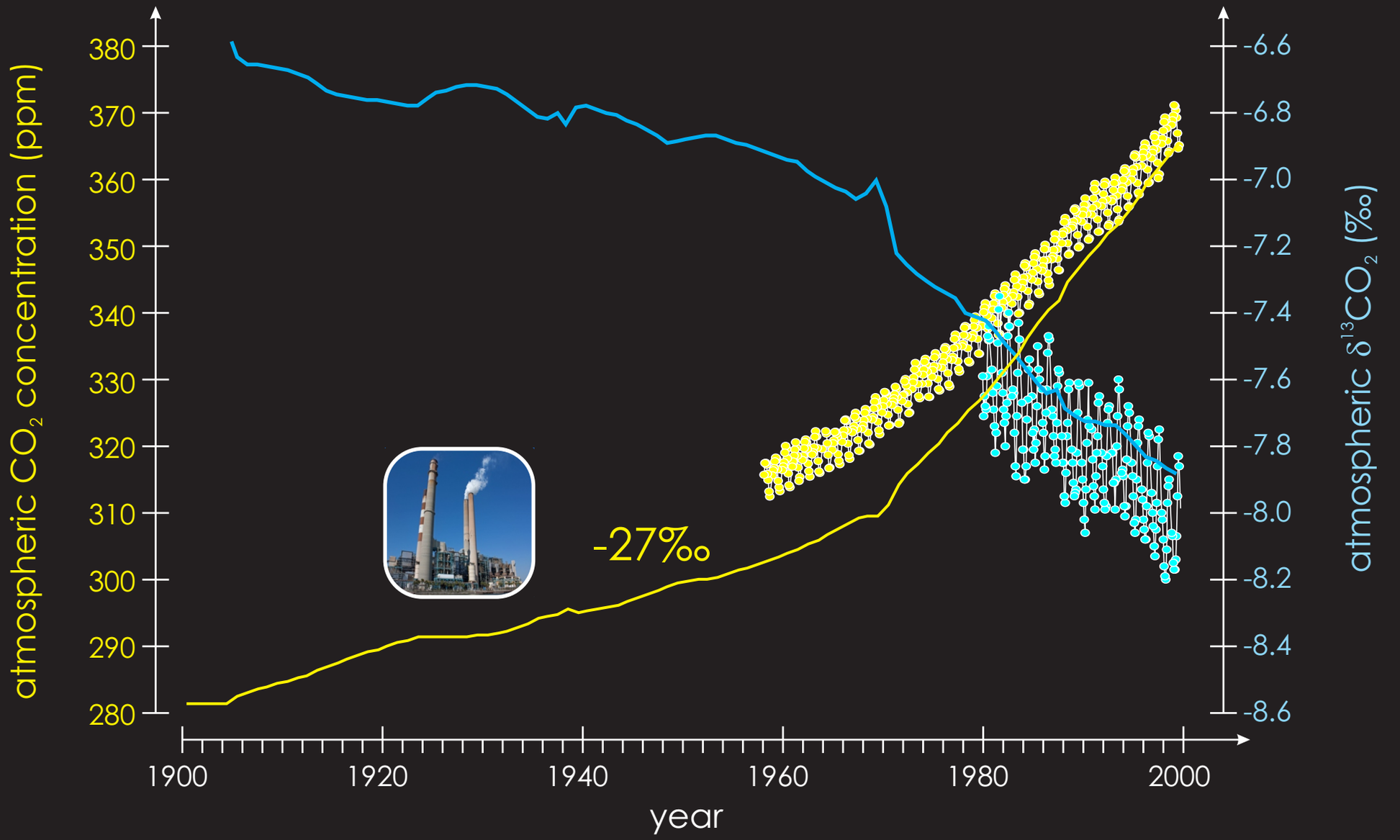
'Inverting' isotopic records



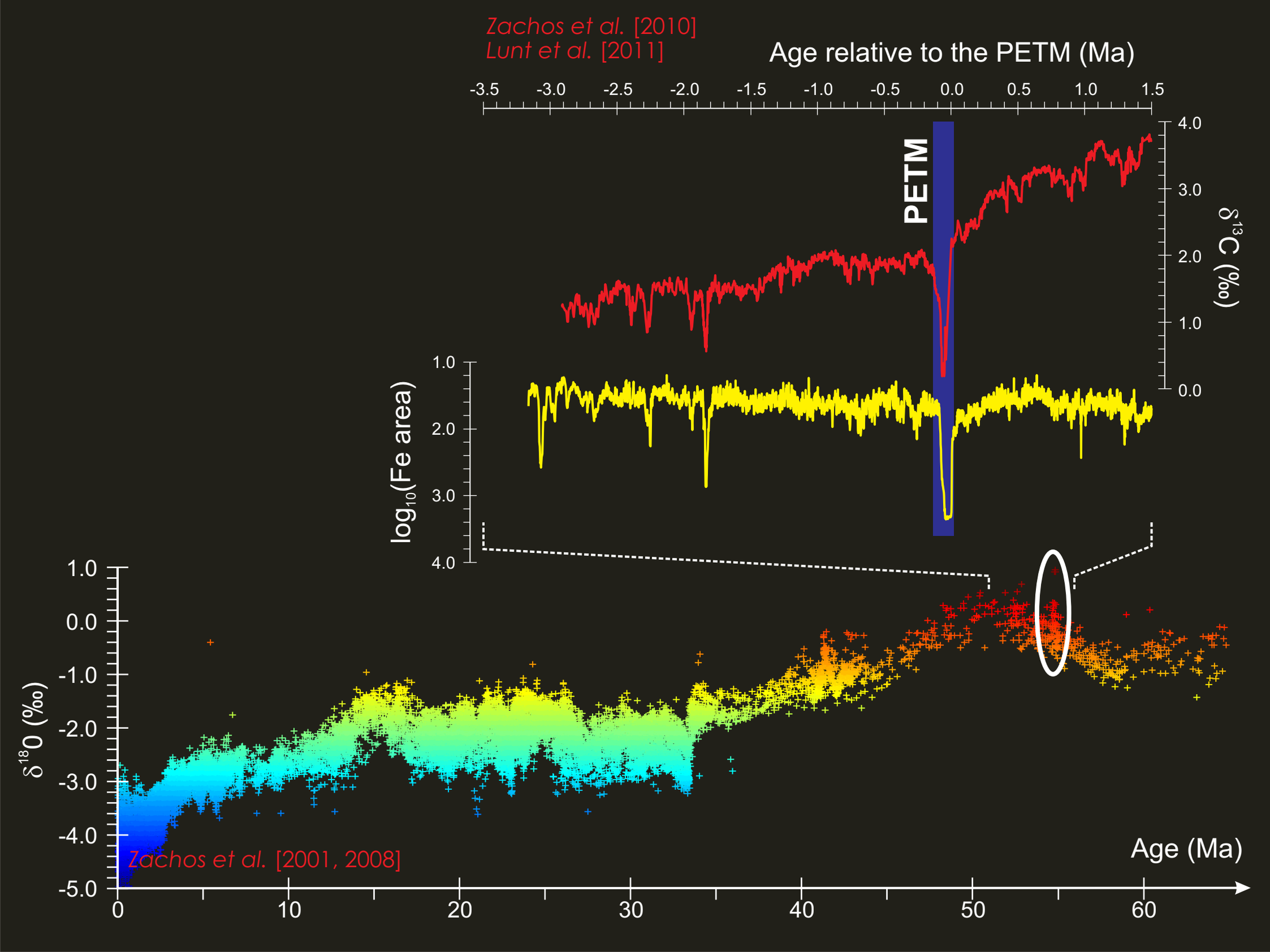
'Inverting' isotopic records



'Inverting' isotopic records



Simple ‘inversions’ of isotopic records


Zachos et al. [2010]
Lunt et al. [2011]
Age relative to the PETM (Ma)
-3.5
-3.0
-2.5
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
PETM
4.0
3.0
2.0
1.0
0.0
δ13C (‰)
log10(Fe area)
1.0
2.0
3.0
4.0
δ18O (‰)
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
Zachos et al. [2001, 2008]
Age (Ma)
0
10
20
30
40
50
60

Simple 'inversions' of isotopic records

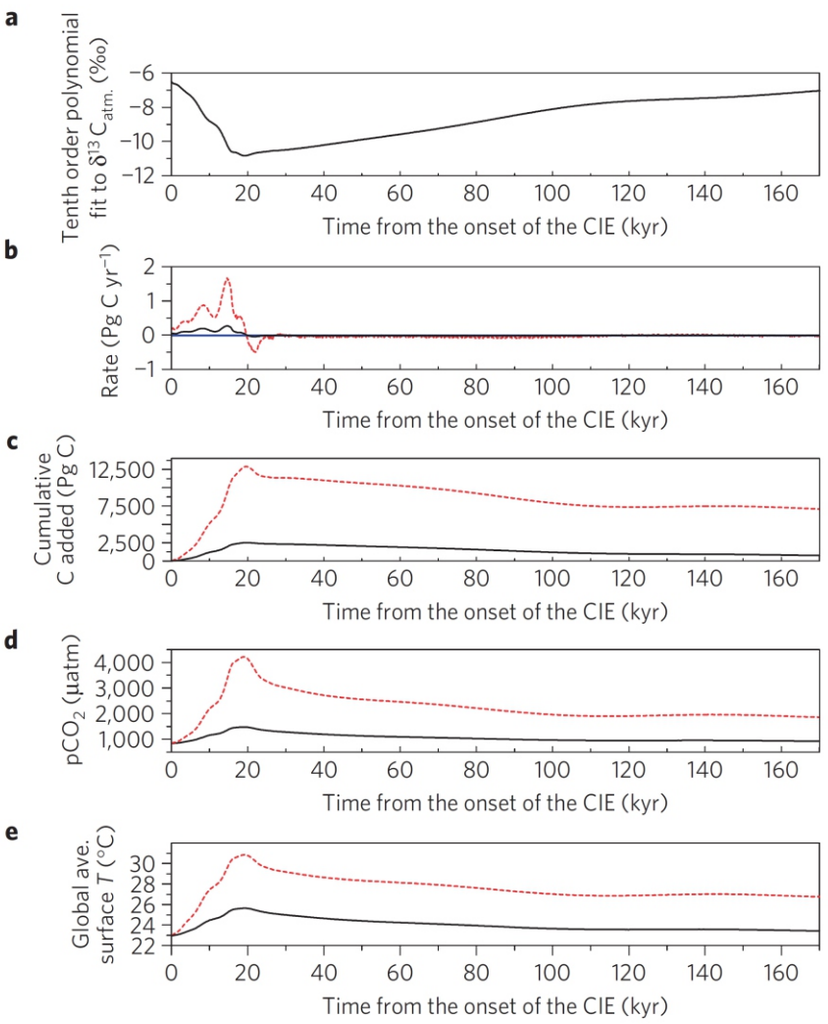


Figure 4 | Model results of the PETM carbon release rate and cumulative amount of carbon added versus time from the onset of the CIE (535 mbs) (age model is from ref. 2). a, $\delta^{13}C_{atm}$ that we used to force GENIE. **b**, Model results of the PETM carbon release rate. **c**, Model results of the cumulative amount of carbon added. **d**, Model results of the PETM atmospheric pCO_2. **e**, Model results of the PETM global average temperature (°C). The two best-fit simulations are shown in **b**–**e**:(1) CH_4 simulation (black solid line); (2) C_{org} simulation (red dotted line). Both simulations are with bioturbation on.

nature geoscience

ARTICLES

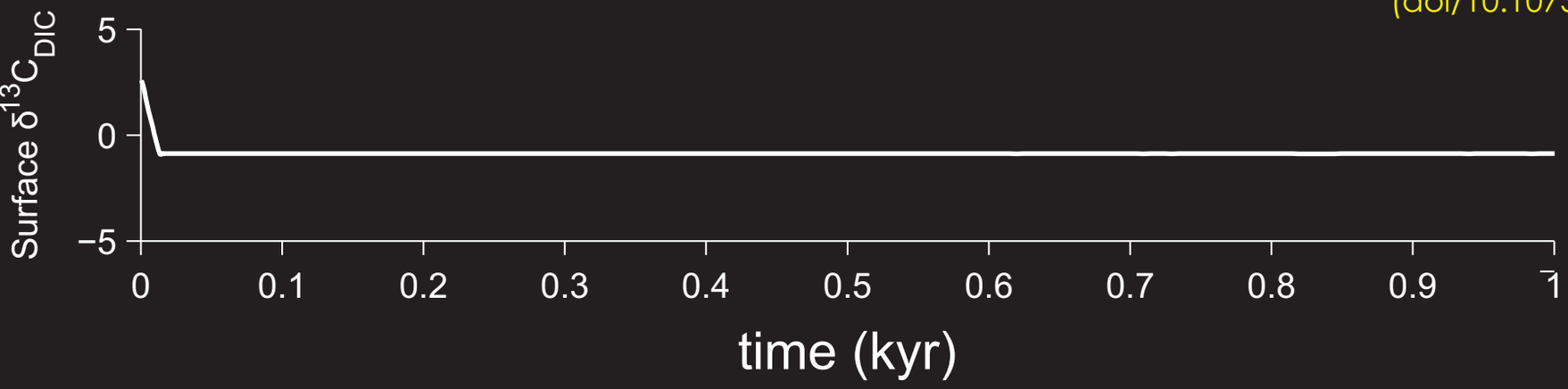
PUBLISHED ONLINE: 5 JUNE 2011 | DOI: 10.1038/NGEO1179

Slow release of fossil carbon during the Palaeocene–Eocene Thermal Maximum

Ying Cui[1]*, Lee R. Kump[1], Andy J. Ridgwell[2], Adam J. Charles[3], Christopher K. Junium[1†], Aaron F. Diefendorf[1†], Katherine H. Freeman[1], Nathan M. Urban[1†] and Ian C. Harding[3]

Simple 'inversions' of isotopic records

Wright and Schaller [2013]
(doi/10.1073/pnas.1309188110)



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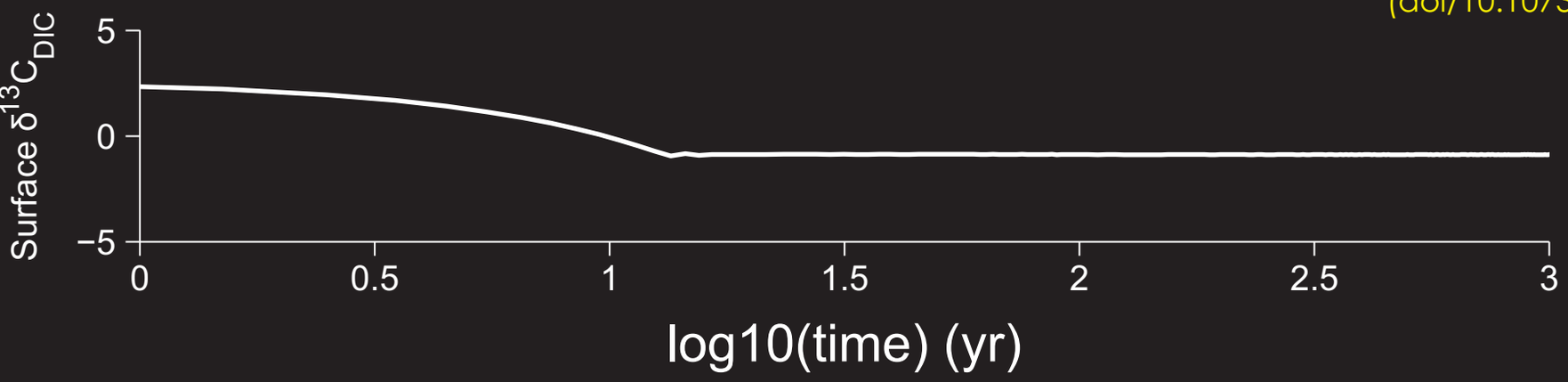
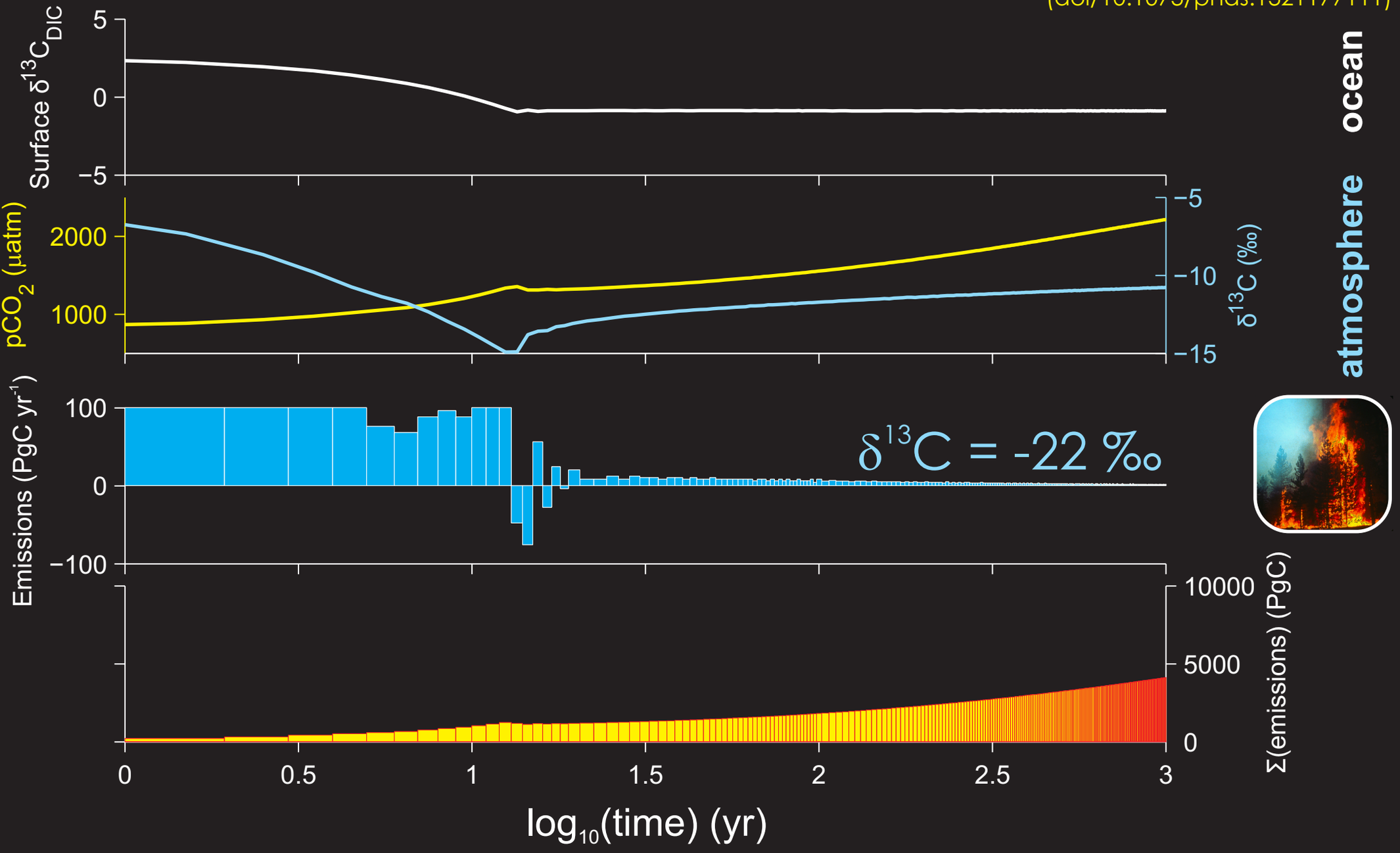


Simple 'inversions' of isotopic records

Zeebe et al. [2014]
(doi/10.1073/pnas.1321177111)



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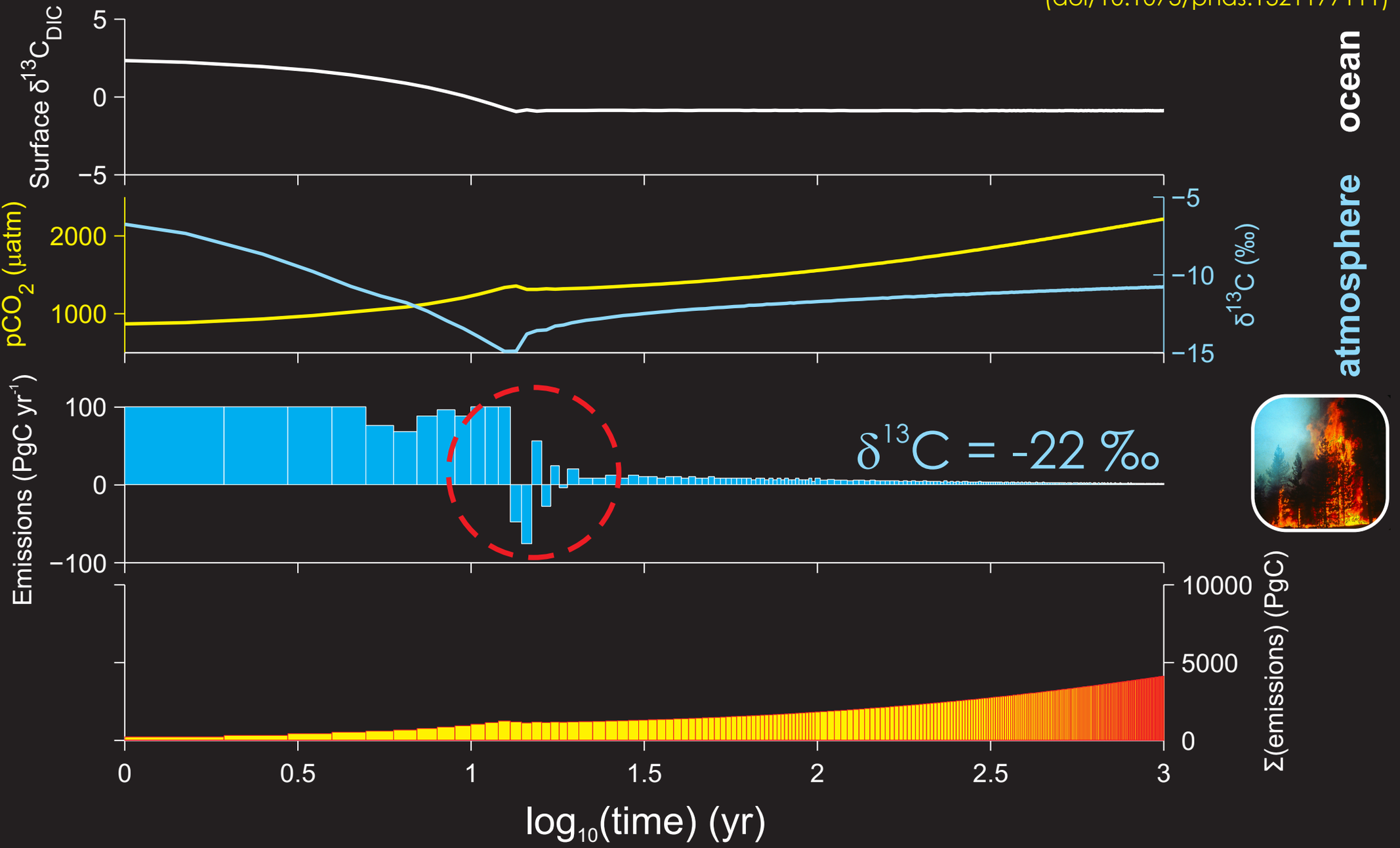

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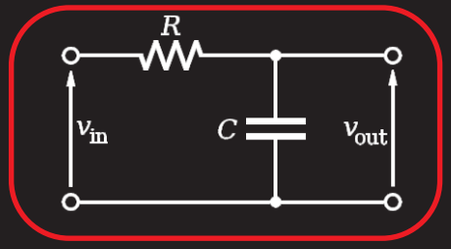
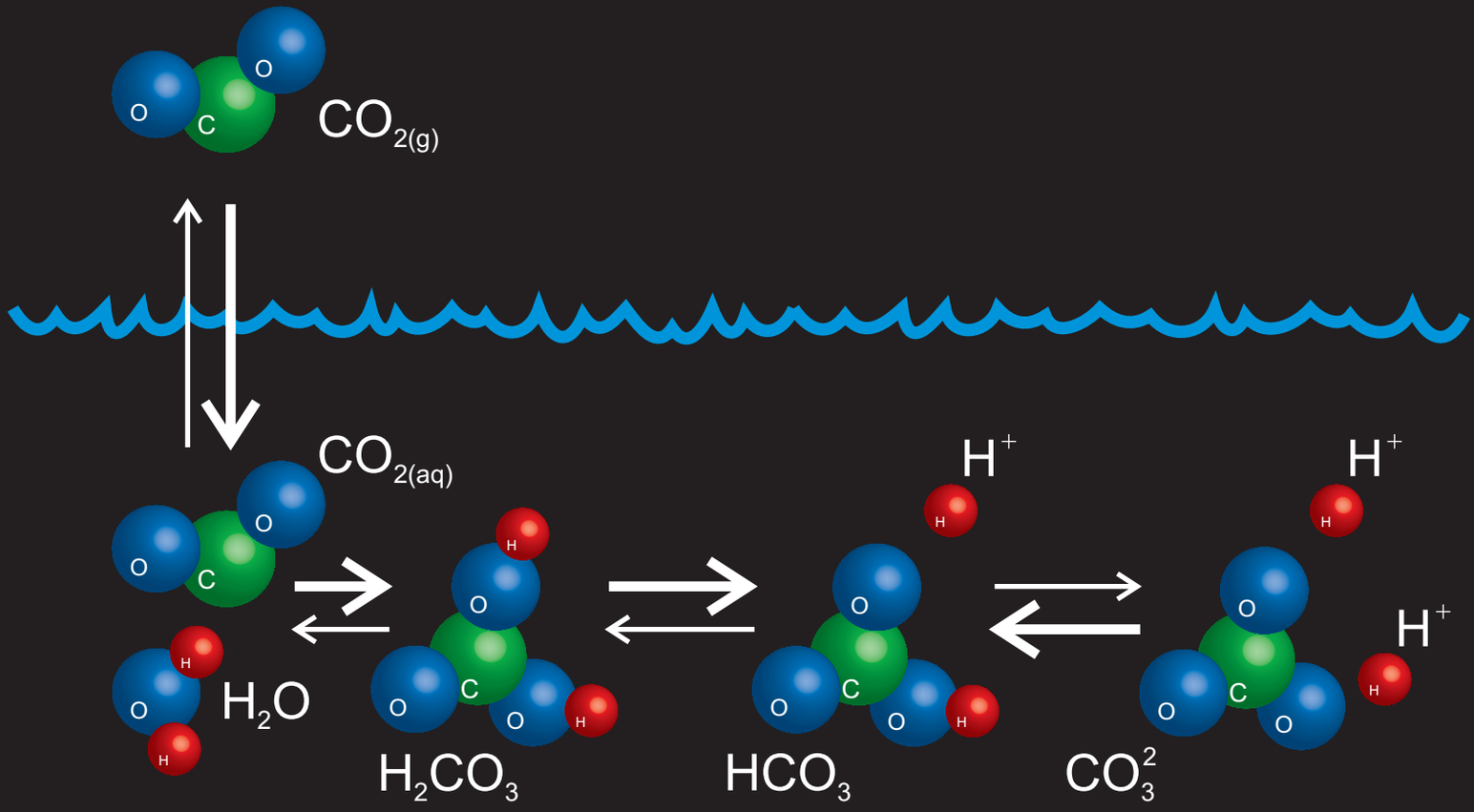


surface ocean
$\delta^{13}C$ record



Simple of 'inversions' of isotopic records

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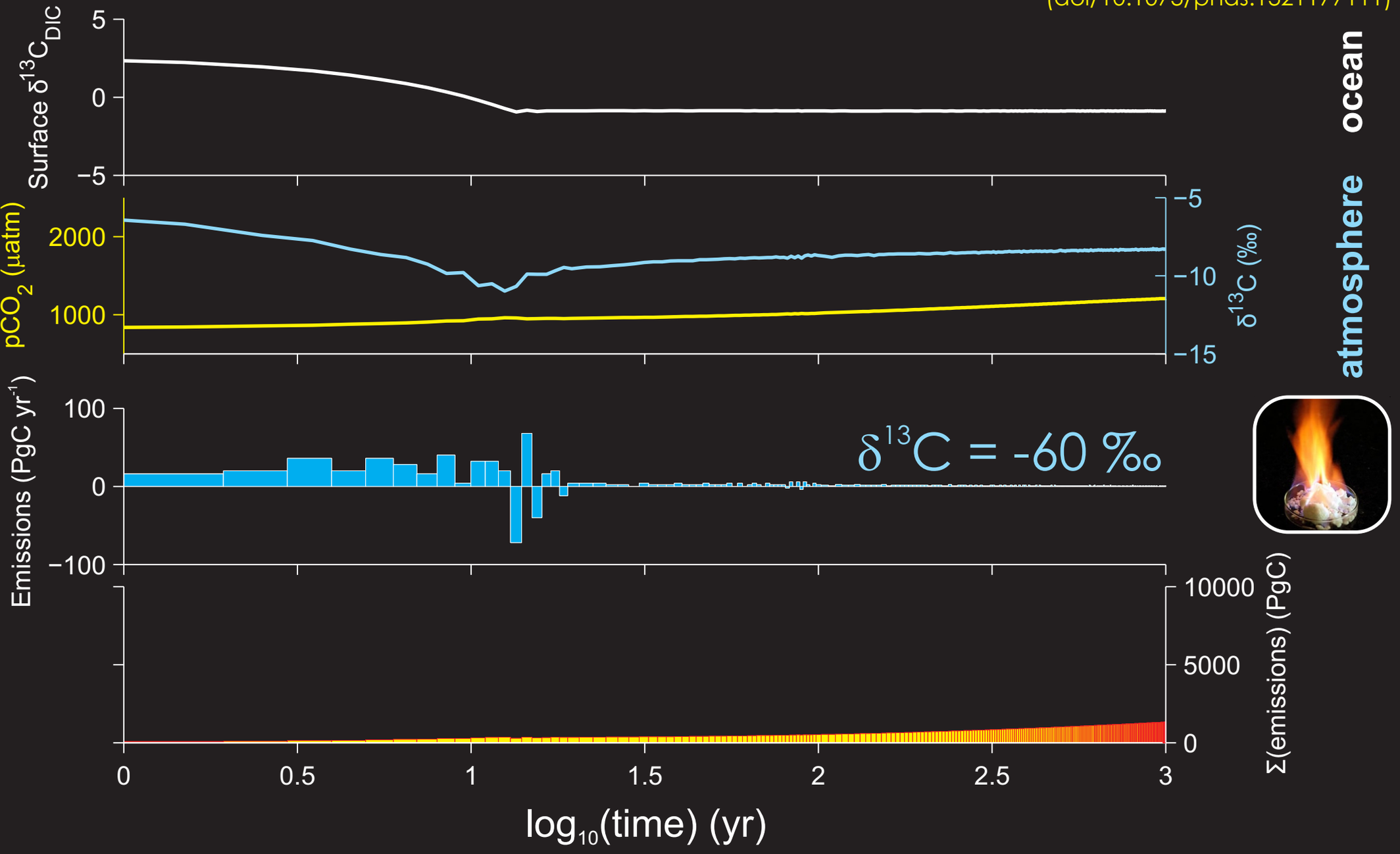
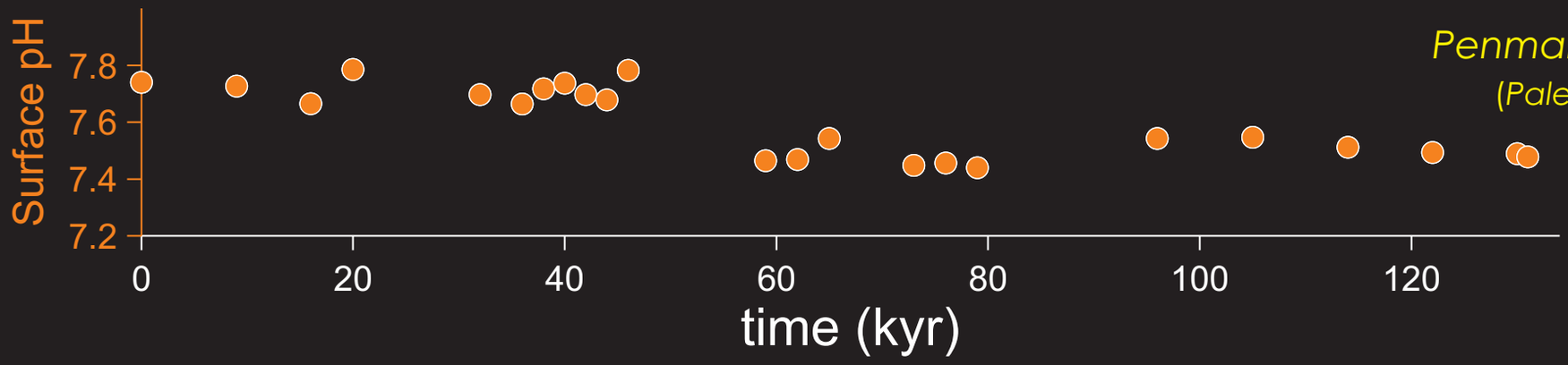
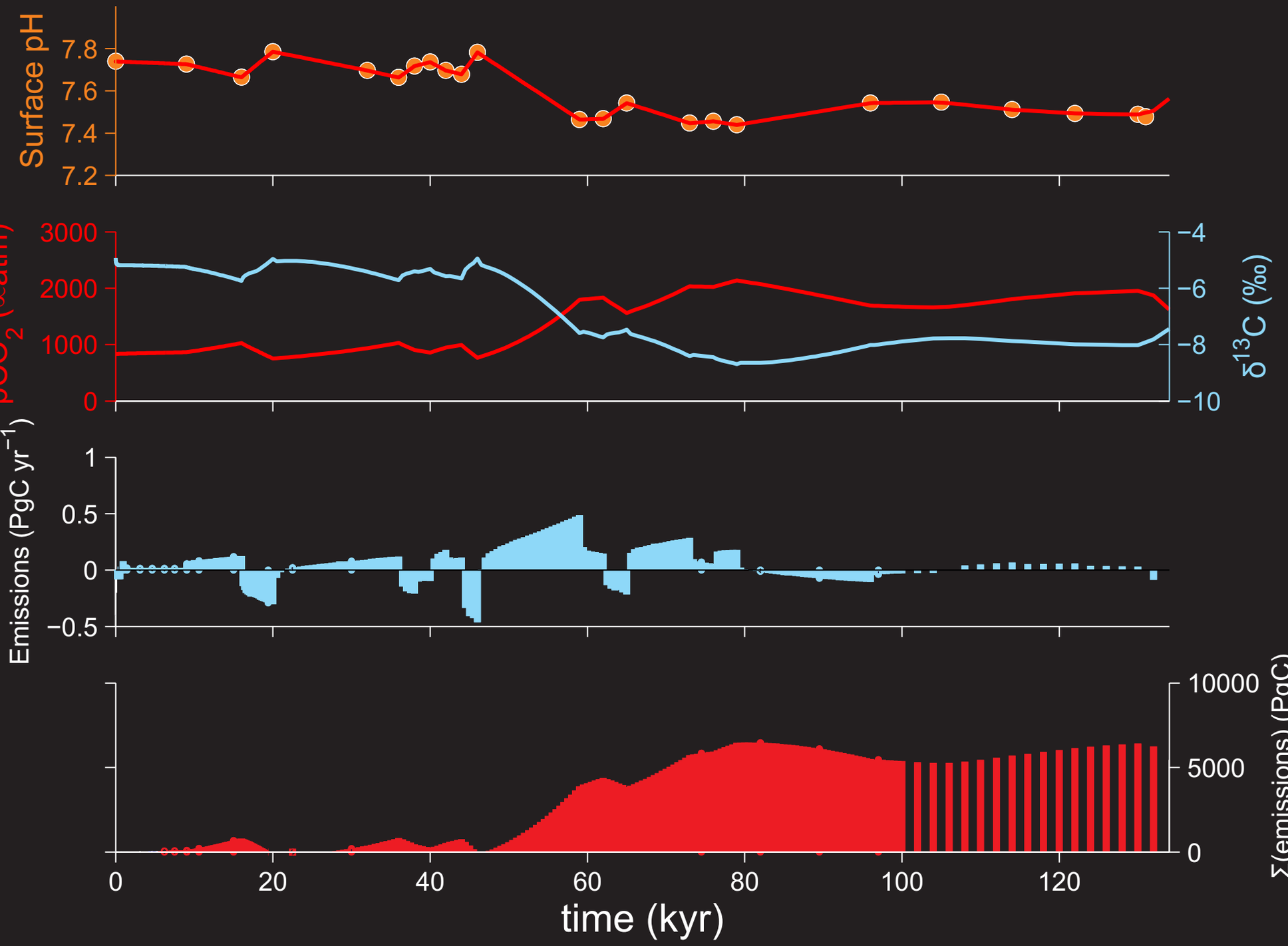


Simple 'inversions' of isotopic records



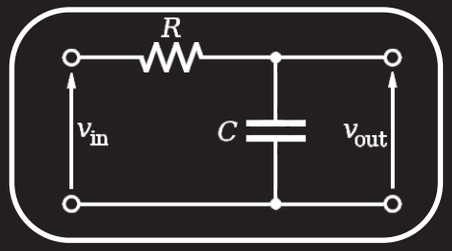
Penman et al. [2014]
(Paleoceanography)

Simple 'inversions' of isotopic records

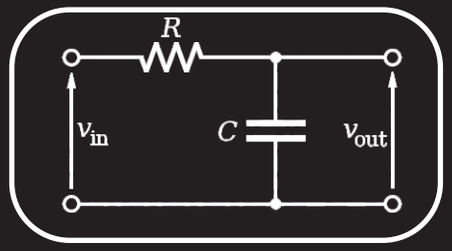


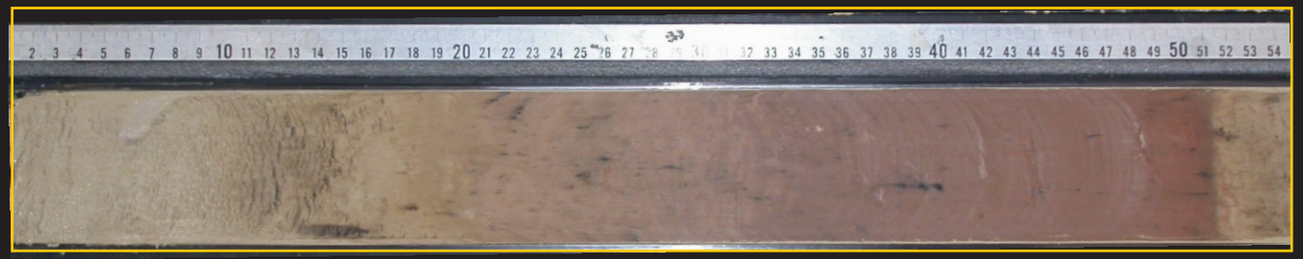
‘Inverting’ isotopic records iteratively

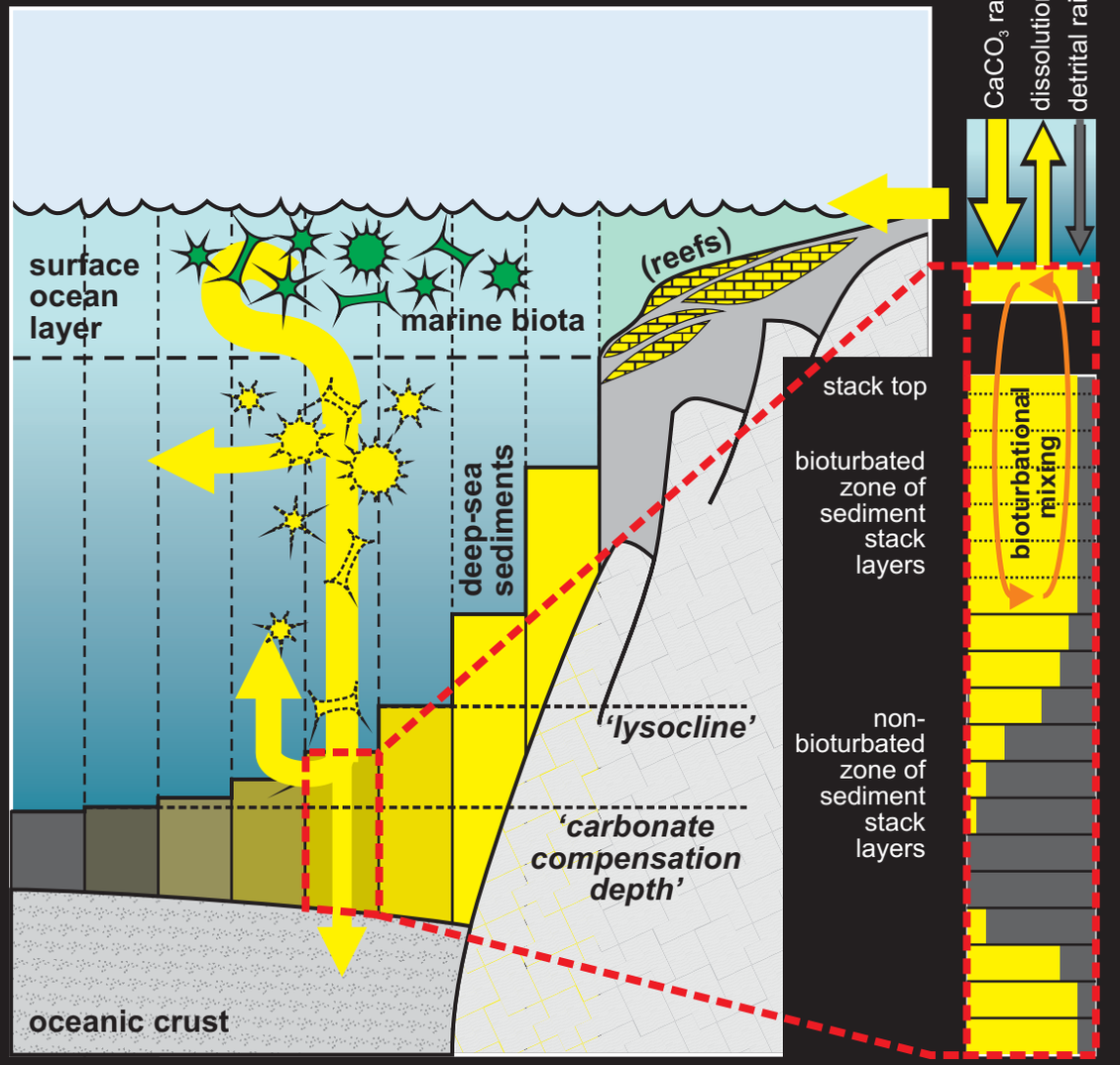
dissolution
(peservation)



mixing
(bioturbation)

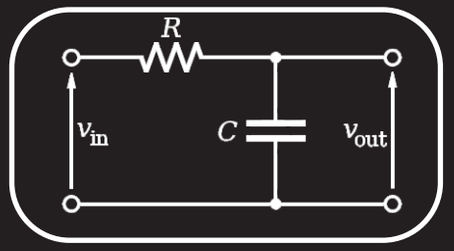






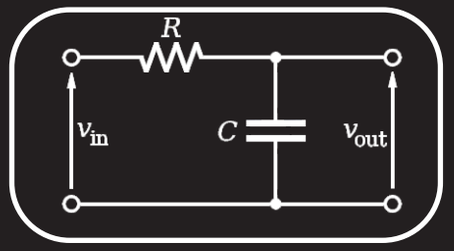
'Inverting' isotopic records iteratively

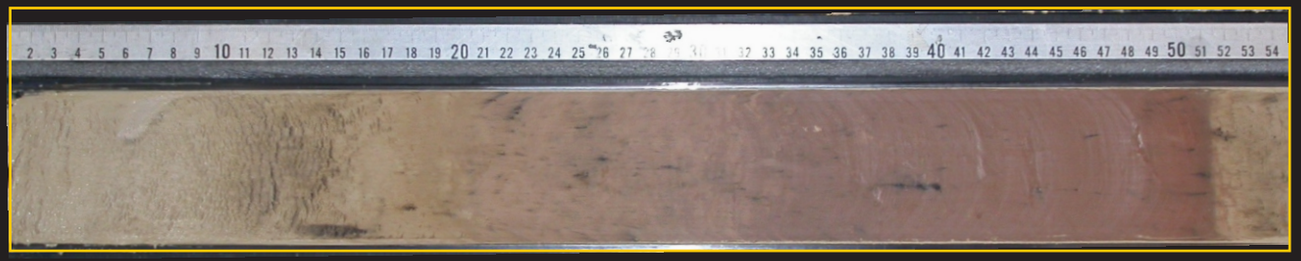
dissolution
(peservation)

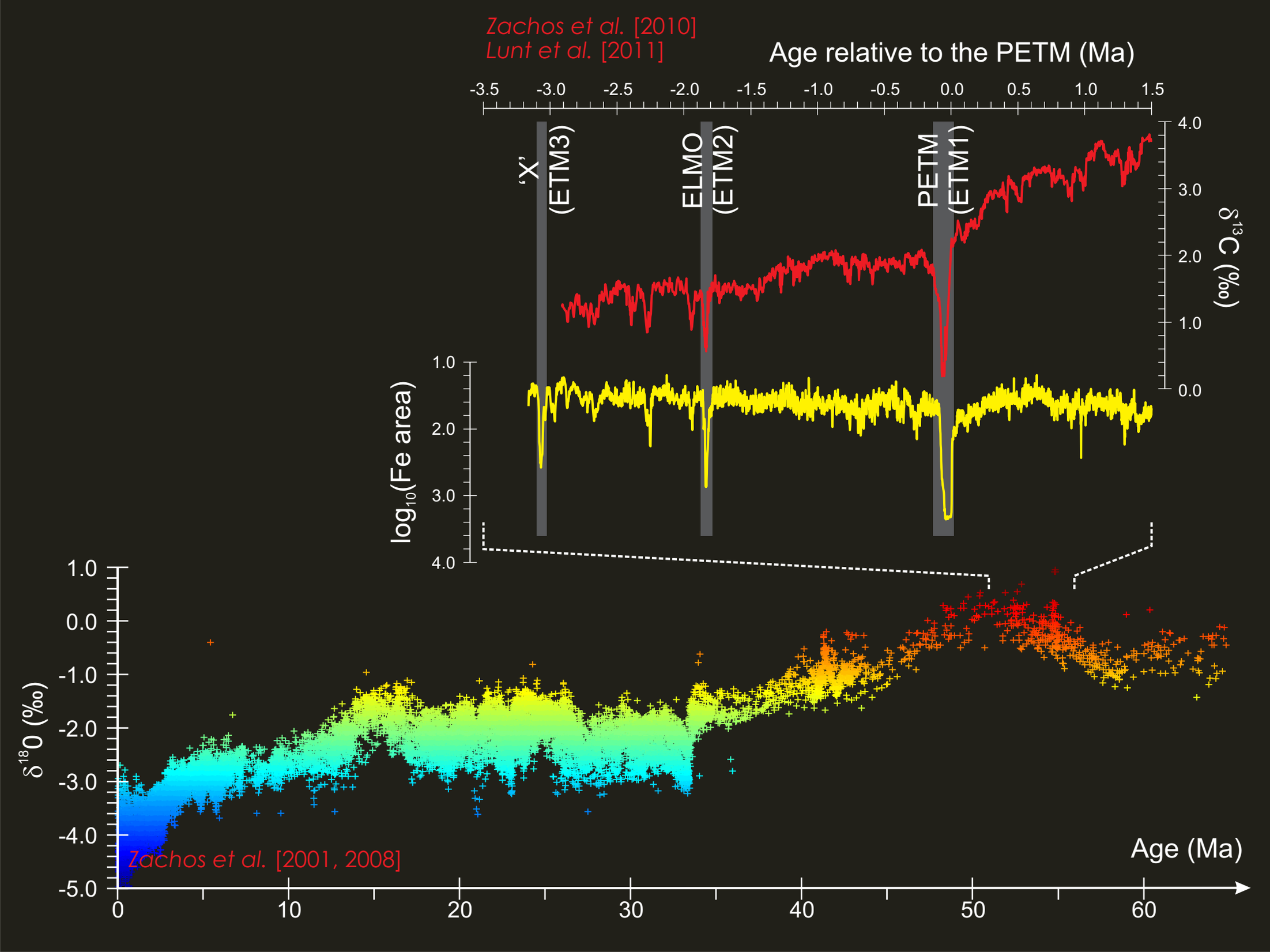


?

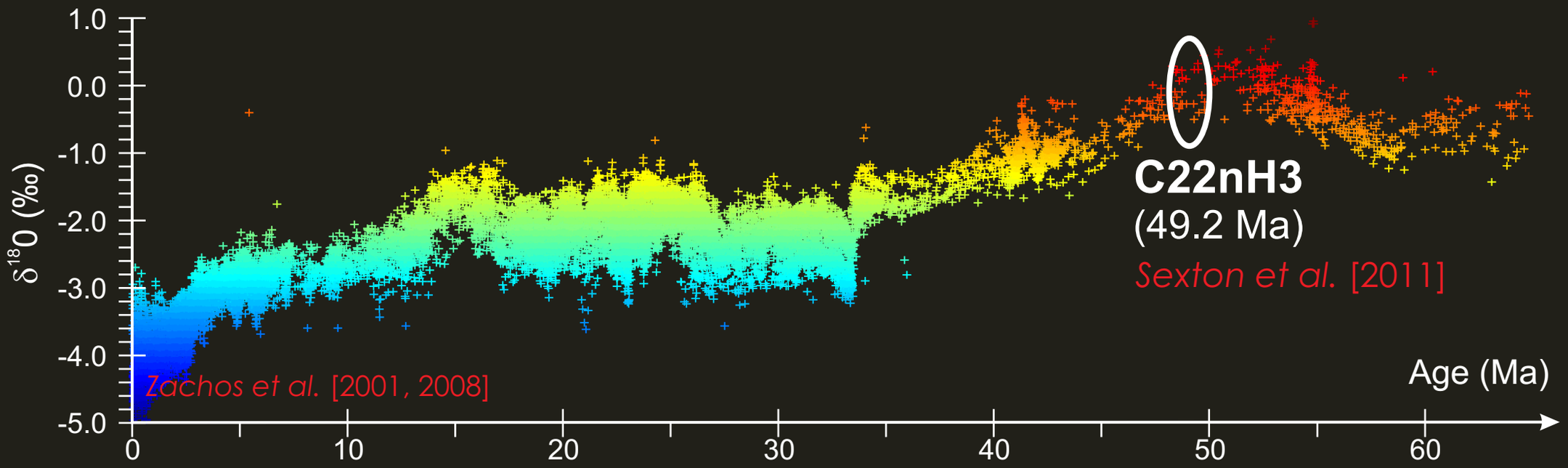
mixing
(bioturbation)



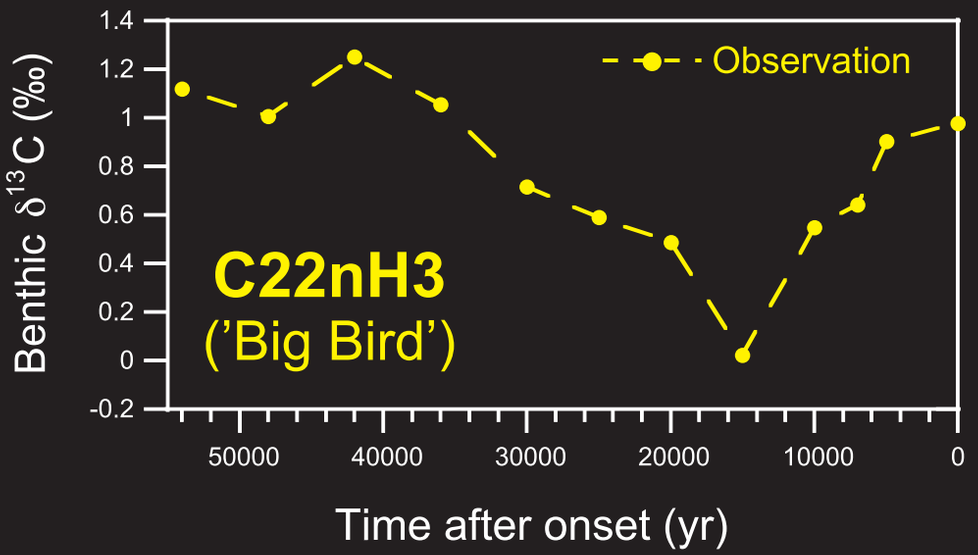



Zachos et al. [2010]
Lunt et al. [2011]
Age relative to the PETM (Ma)
-3.5
-3.0
-2.5
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
'X'
(ETM3)
ELMO
(ETM2)
PETM
(ETM1)
4.0
3.0
2.0
1.0
0.0
δ13C (‰)
log10(Fe area)
1.0
2.0
3.0
4.0
δ18O (‰)
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
Zachos et al. [2001, 2008]
Age (Ma)
0
10
20
30
40
50
60

'Inverting' isotopic records iteratively

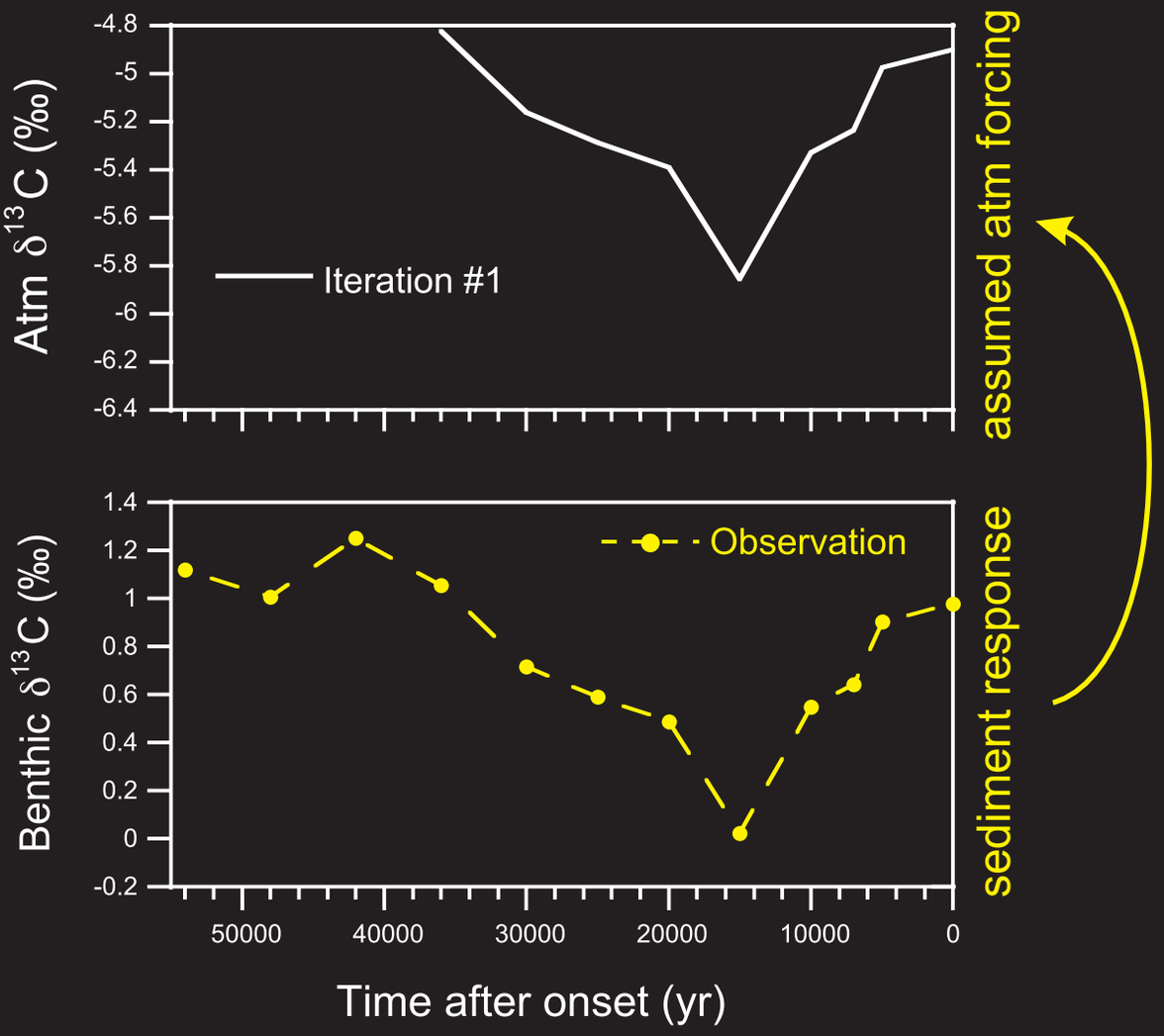


'Inverting' isotopic records iteratively



Kirtland-Turner and Ridgwell [2013]

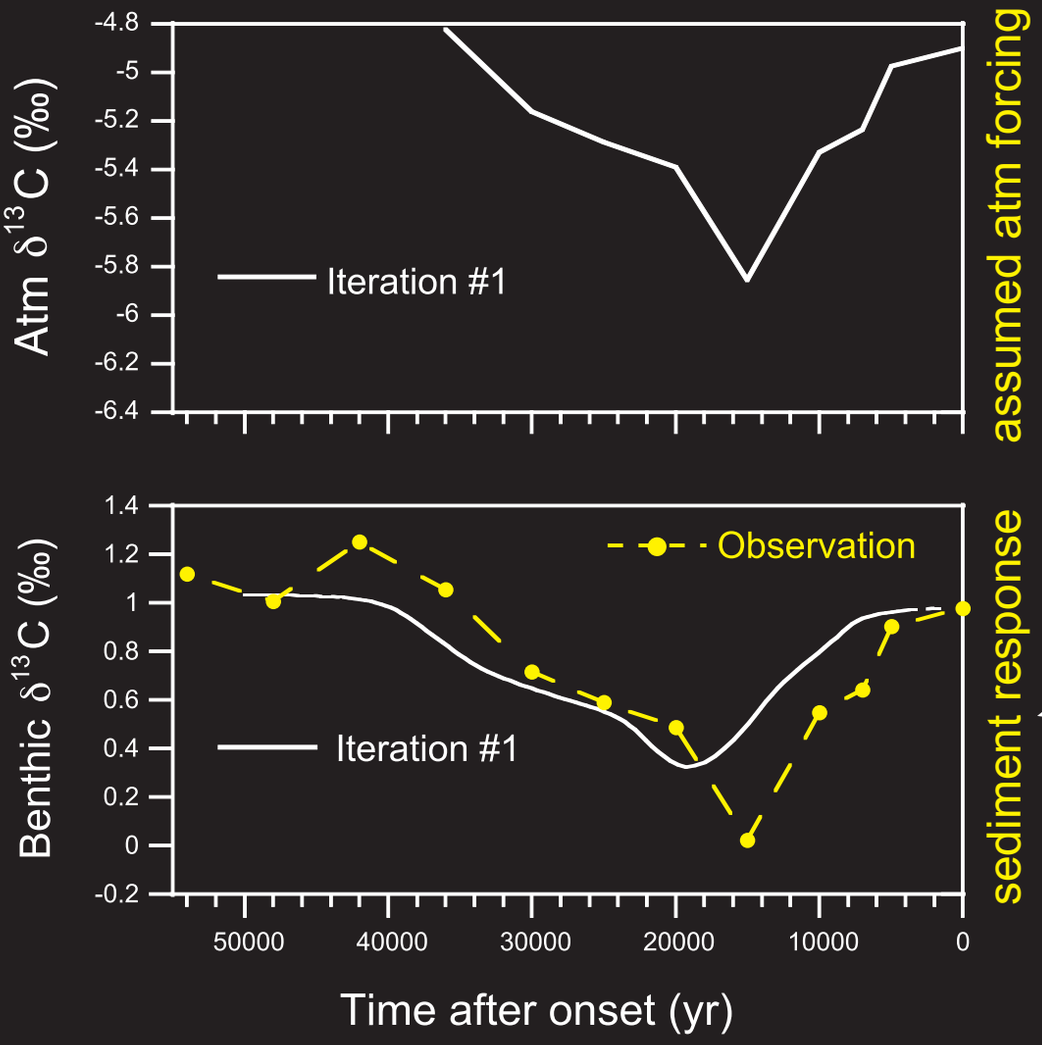
'Inverting' isotopic records iteratively



Initial guess:
observed $\delta^{13}C$ record
==
the atmospheric forcing

Kirtland-Turner and Ridgwell [2013]

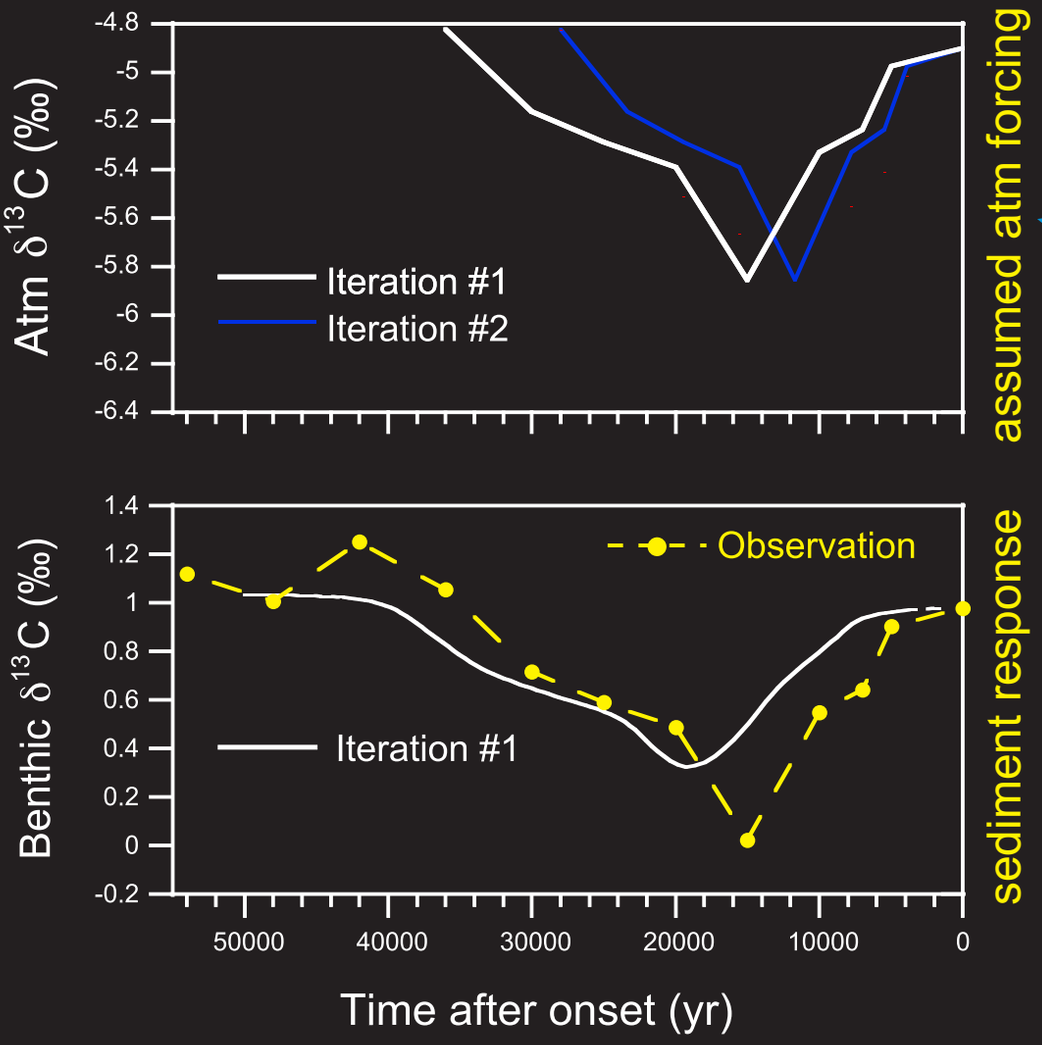
'Inverting' isotopic records iteratively



Step #1
Invert 'guesstimated' atmospheric $\delta^{13}C$ record and calculate sediment expression

Kirtland-Turner and Ridgwell [2013]

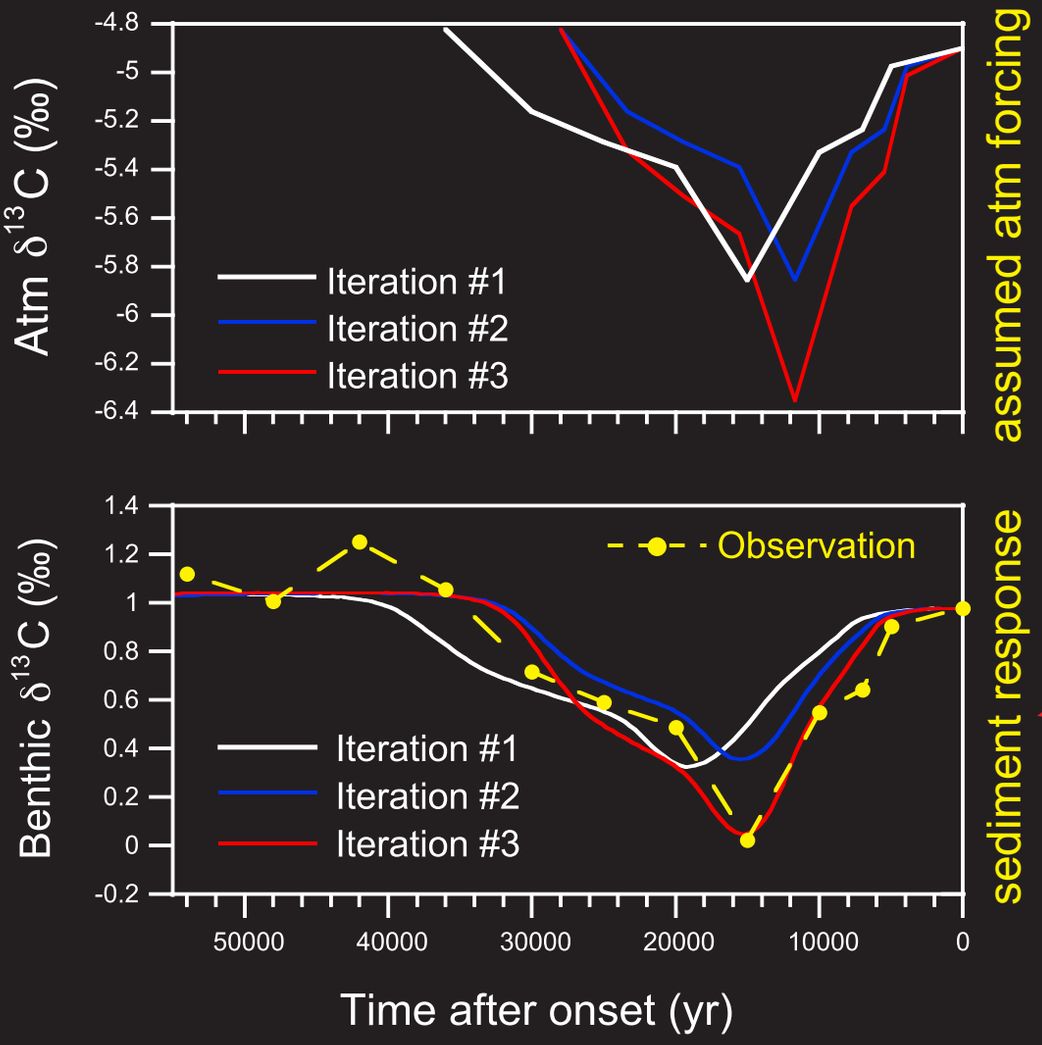
'Inverting' isotopic records iteratively



Adjust atmospheric record:
Correct for distortion in time

Kirtland-Turner and Ridgwell [2013]

'Inverting' isotopic records iteratively



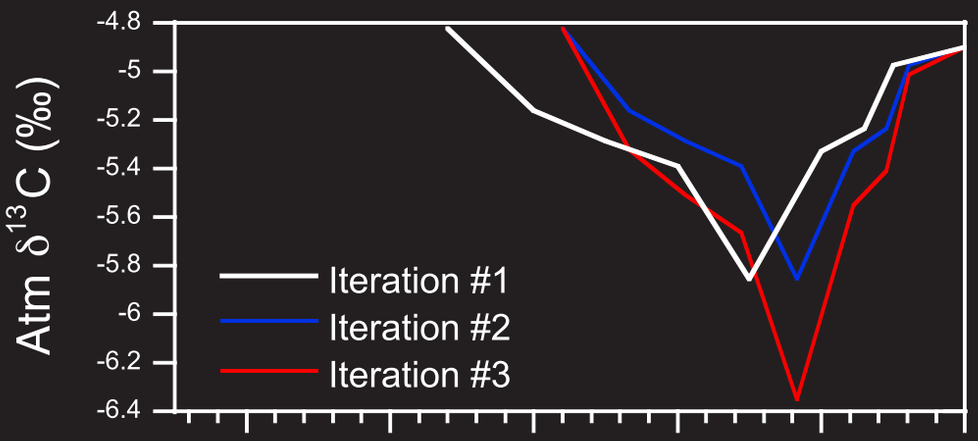
Step #2:
Invert adjusted atmospheric $\delta^{13}C$ record;
then adjust forcing magnitude;

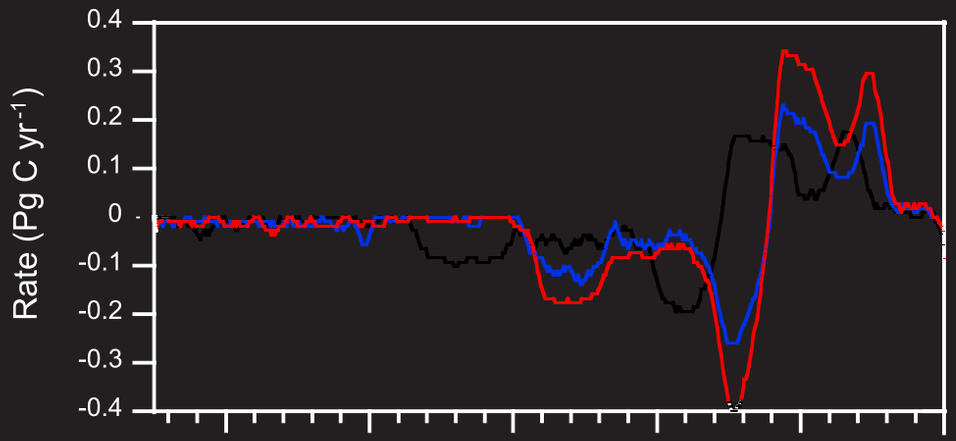
Step #3:
Invert the now twice-adjusted atmospheric $\delta^{13}C$ record

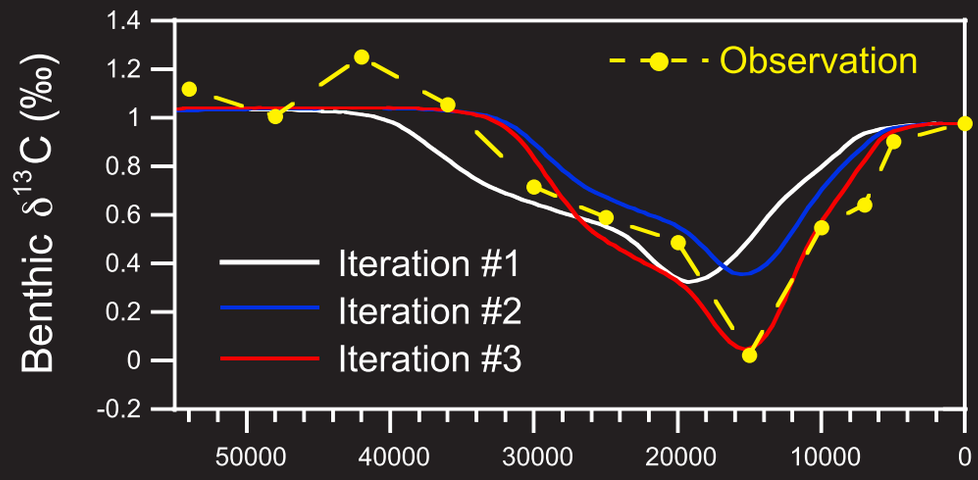
Kirtland-Turner and Ridgwell [2013]

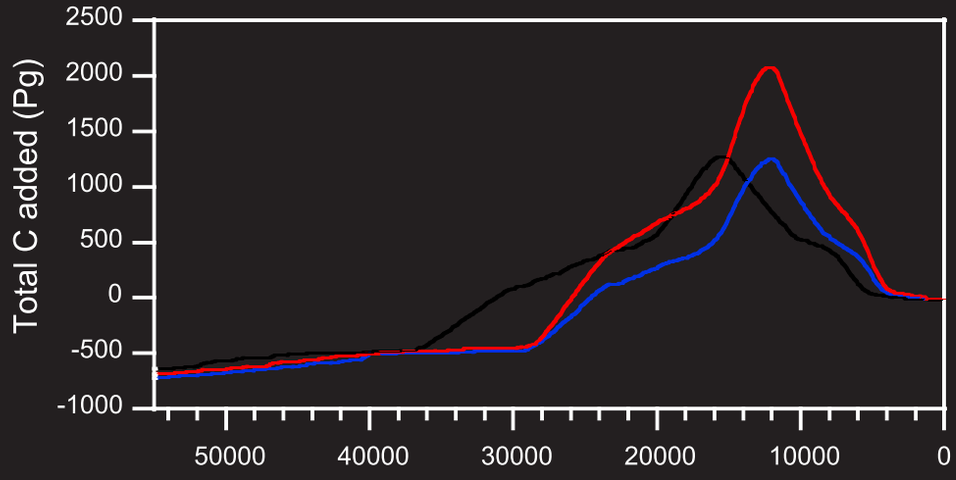
'Inverting' isotopic records iteratively

Recover rates of CO_2 emissions



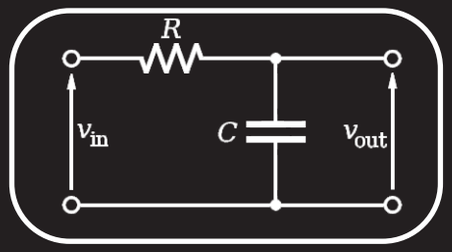




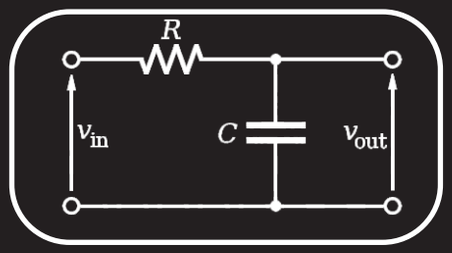


'Inverting' isotopic records iteratively

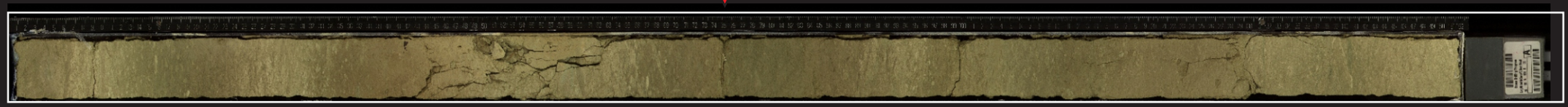
dissolution
(peservation)



mixing
(bioturbation)



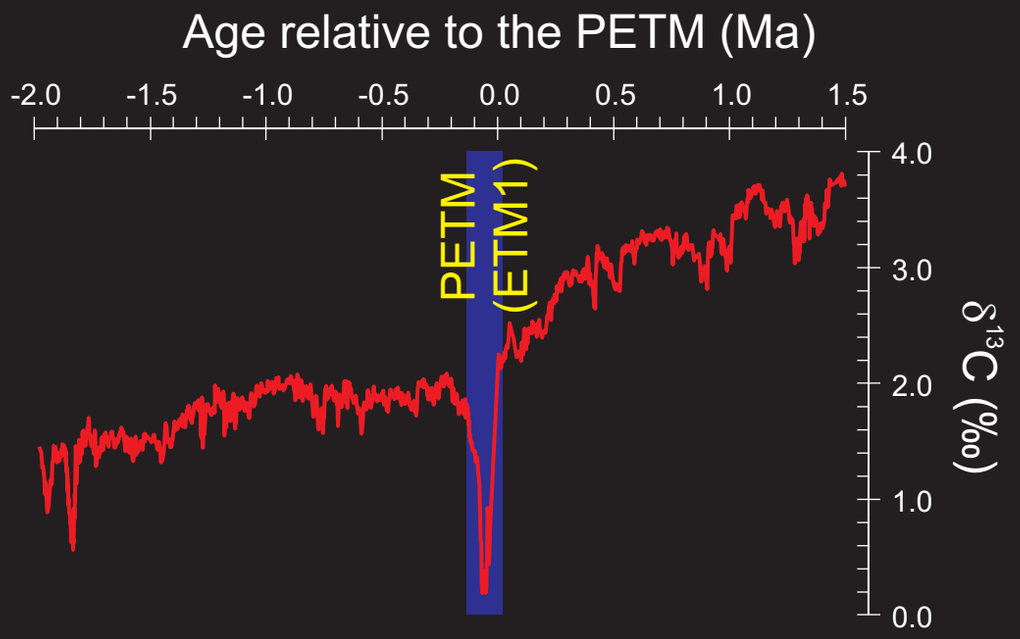
C22nH3
('Big Bird')



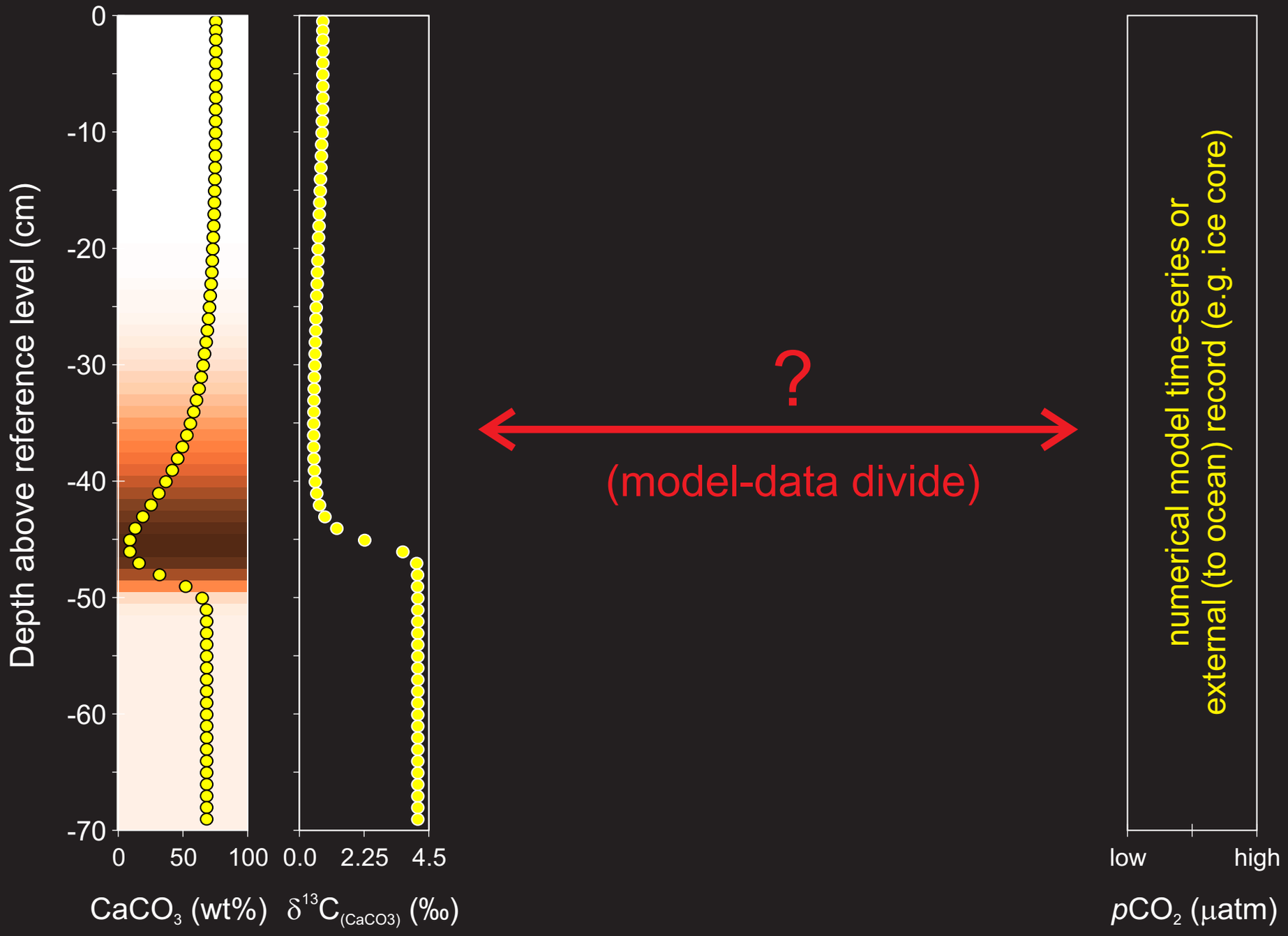
Kirtland-Turner and Ridgwell [2013]

Quantifying 'time' in models & data (1)

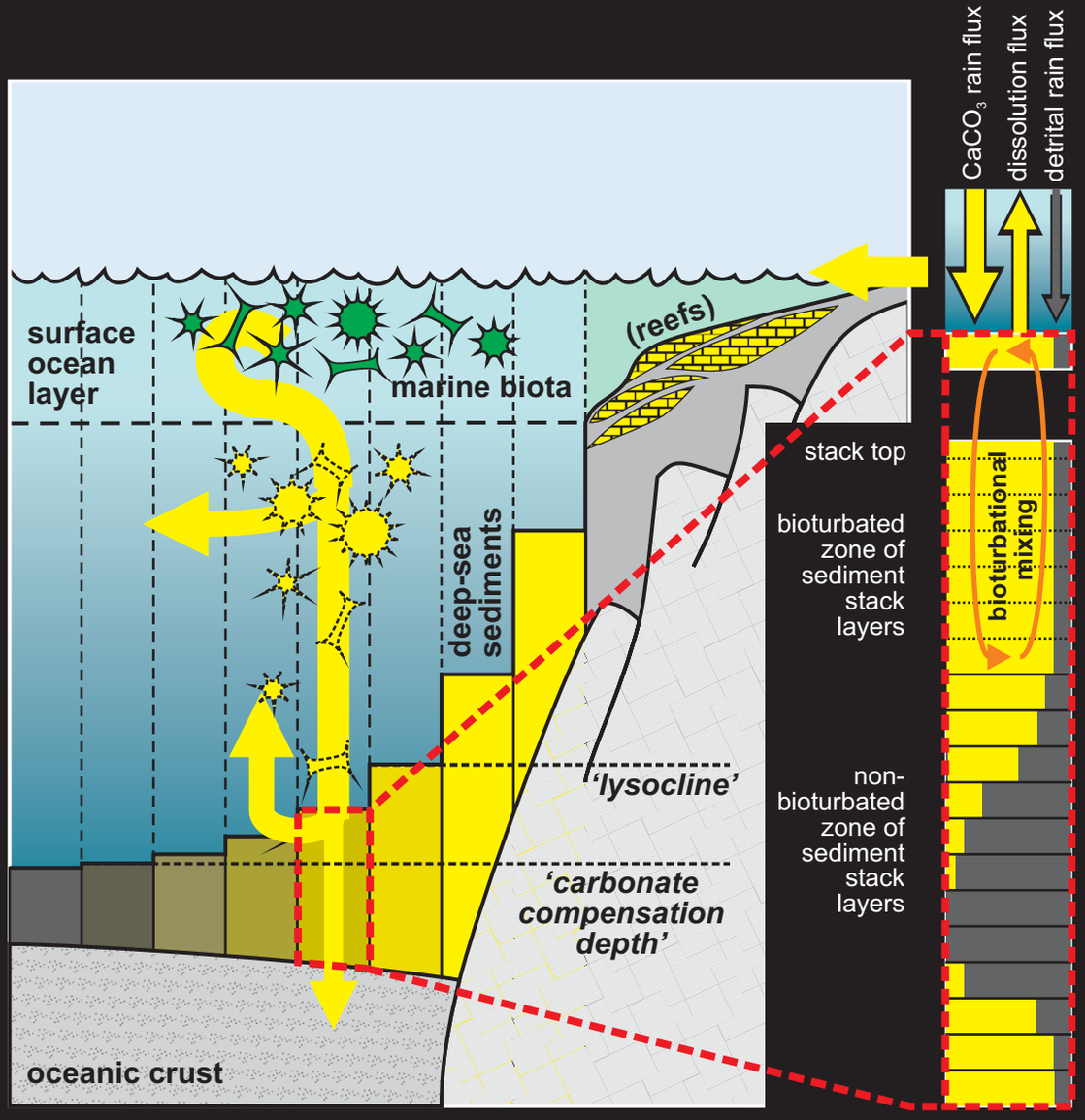
Consider: An event characterized by a (severe) reduction in carbonate preservation

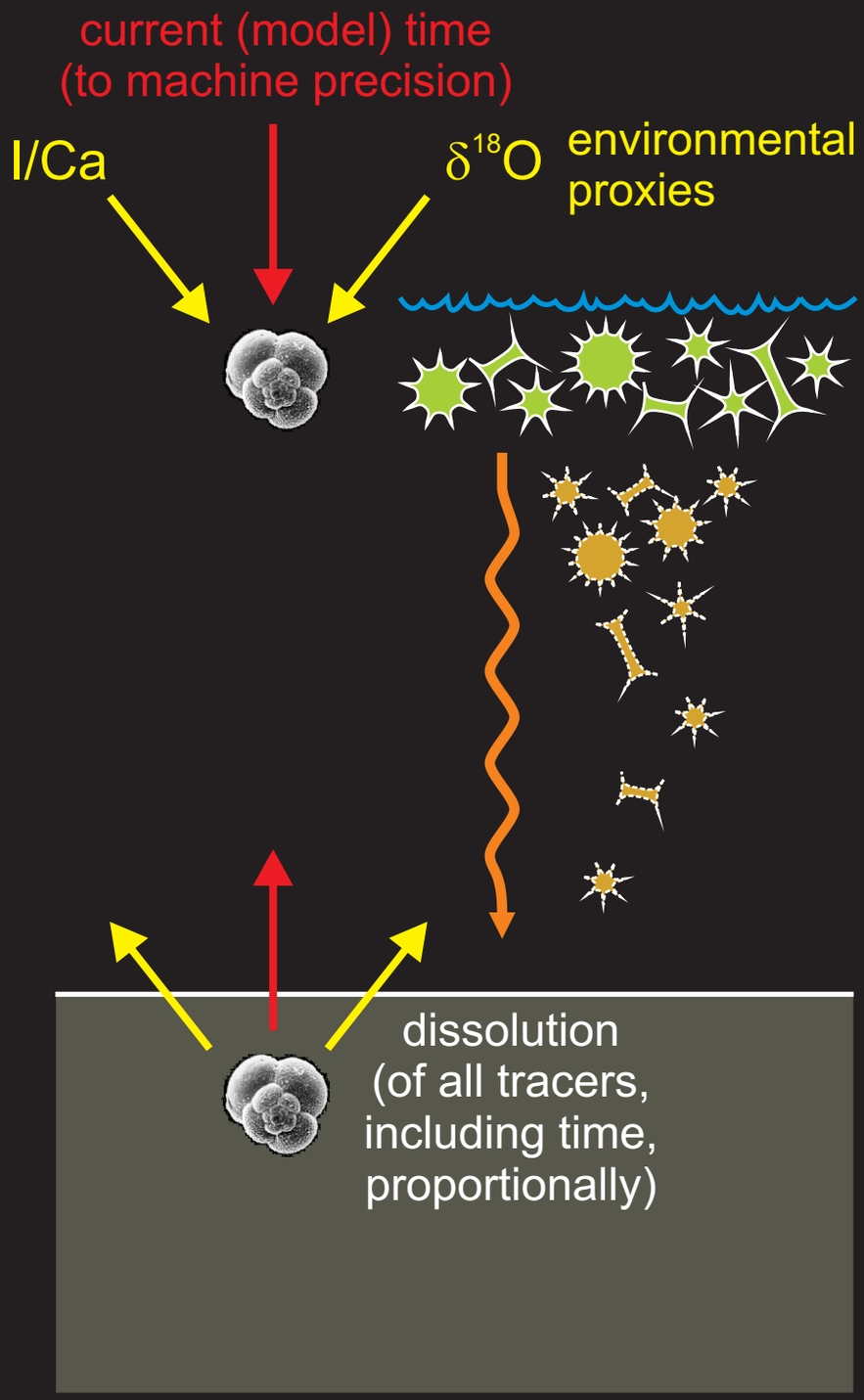


Quantifying 'time' in models & data (1)

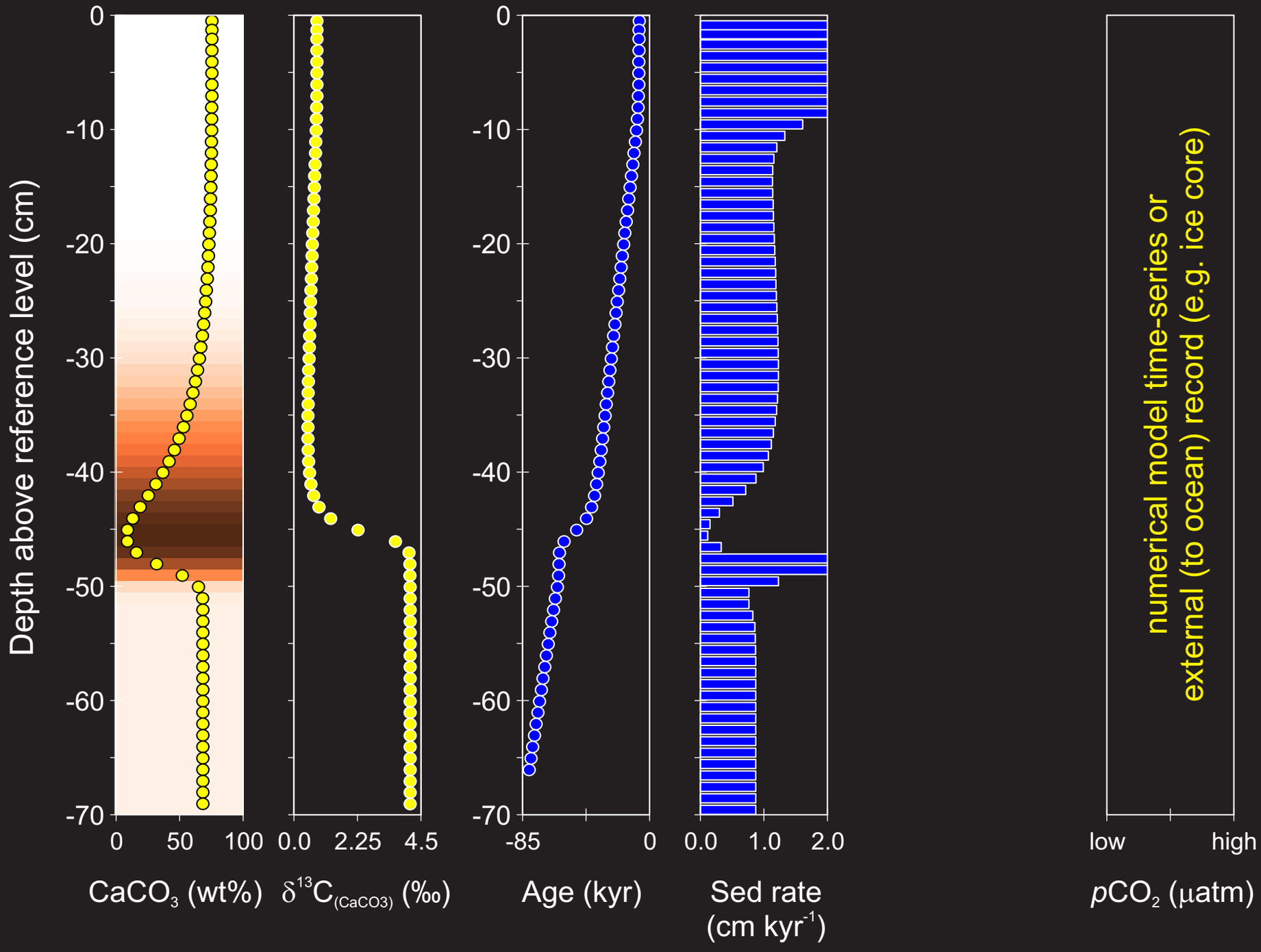


Quantifying 'time' in models & data (1)

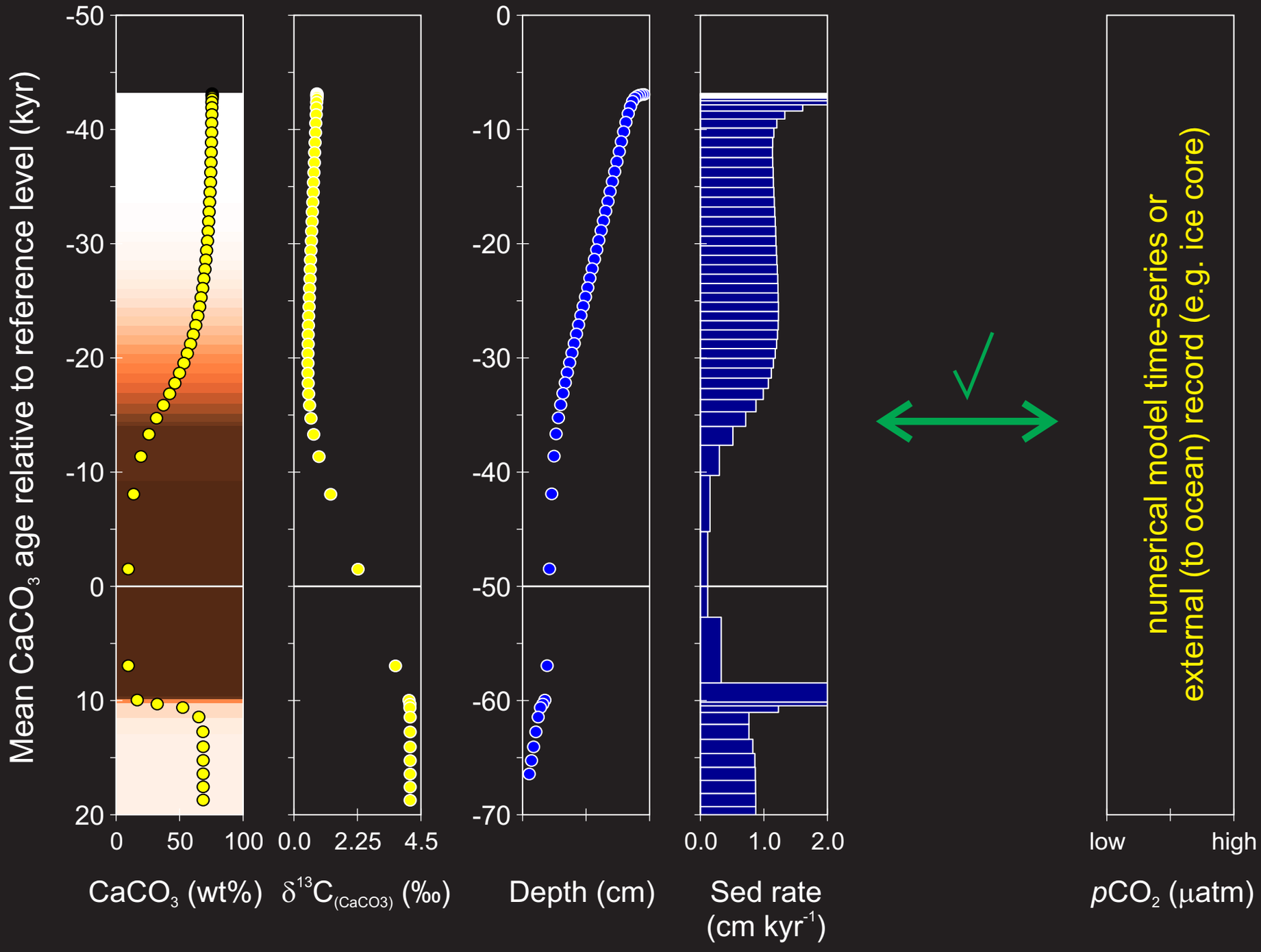




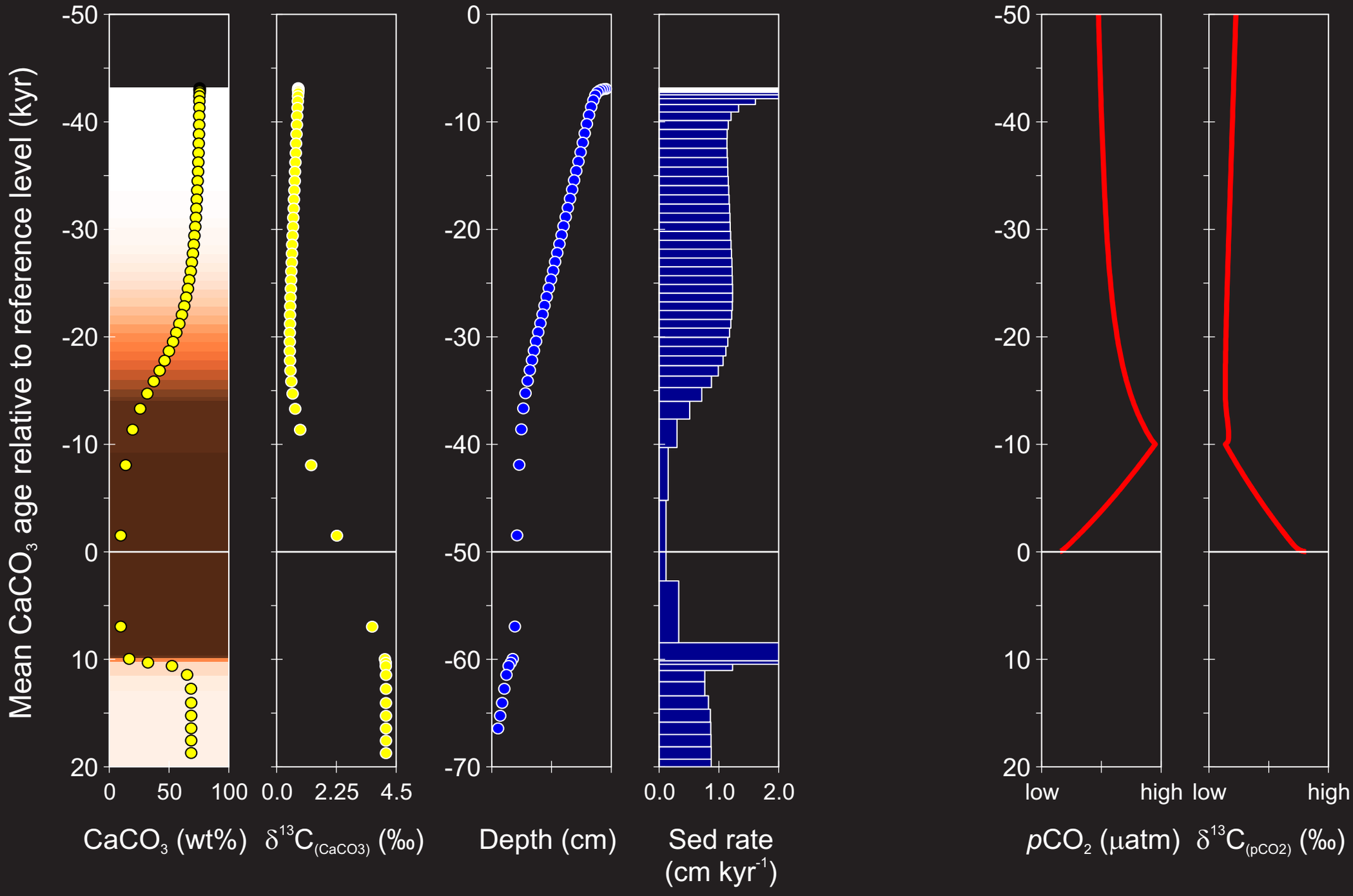
Quantifying 'time' in models & data (1)



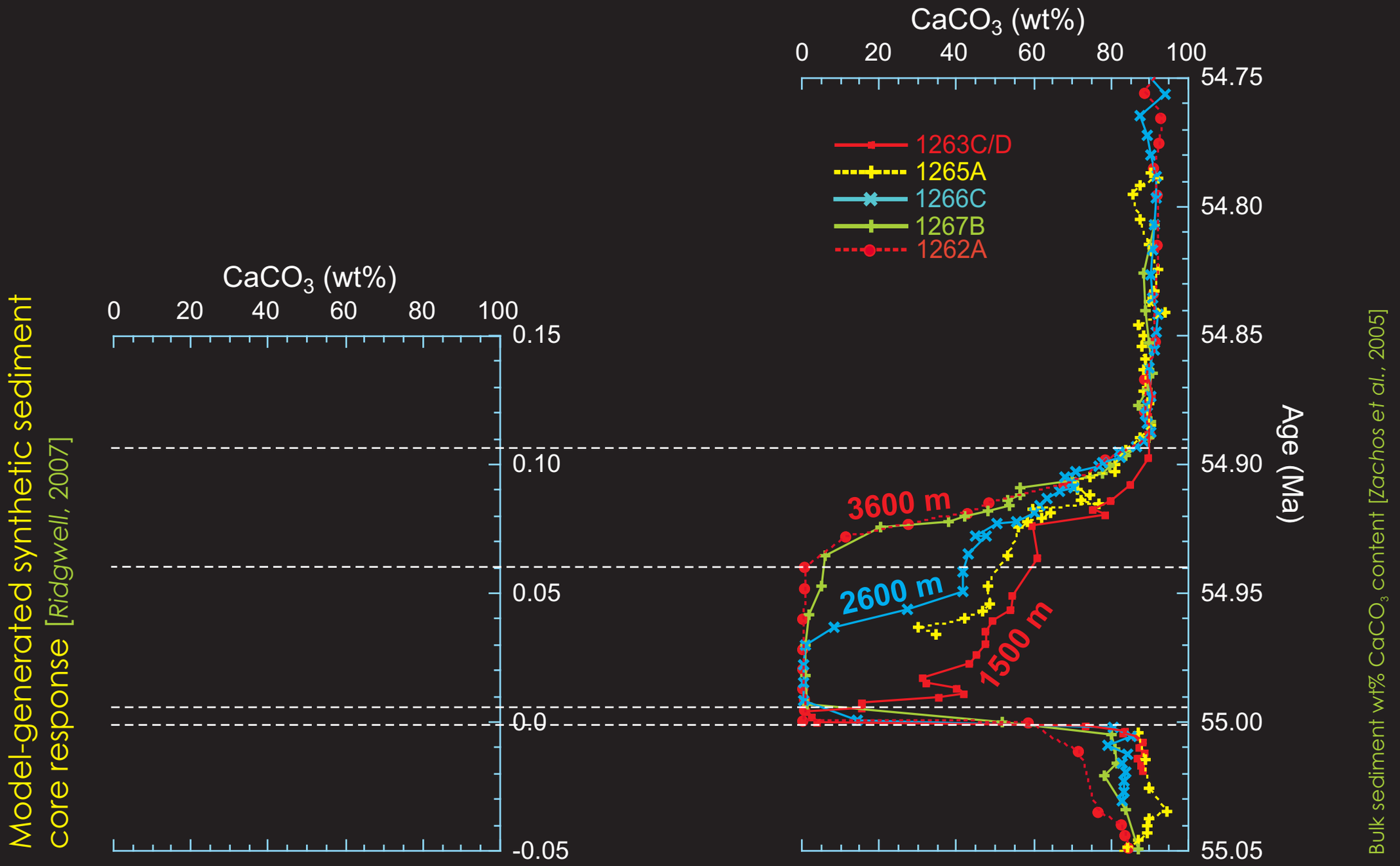
Quantifying 'time' in models & data (1)



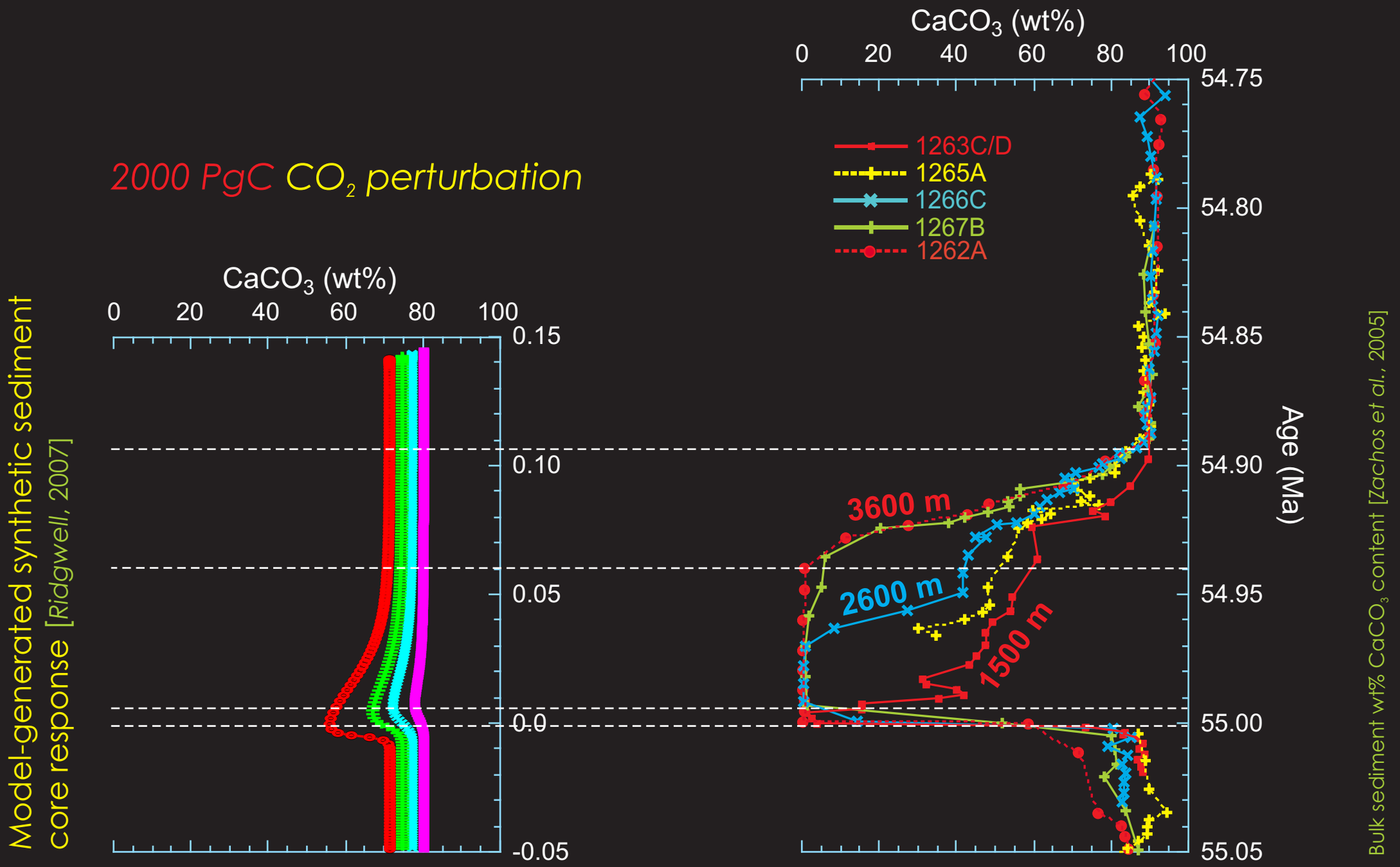
Quantifying 'time' in models & data (1)



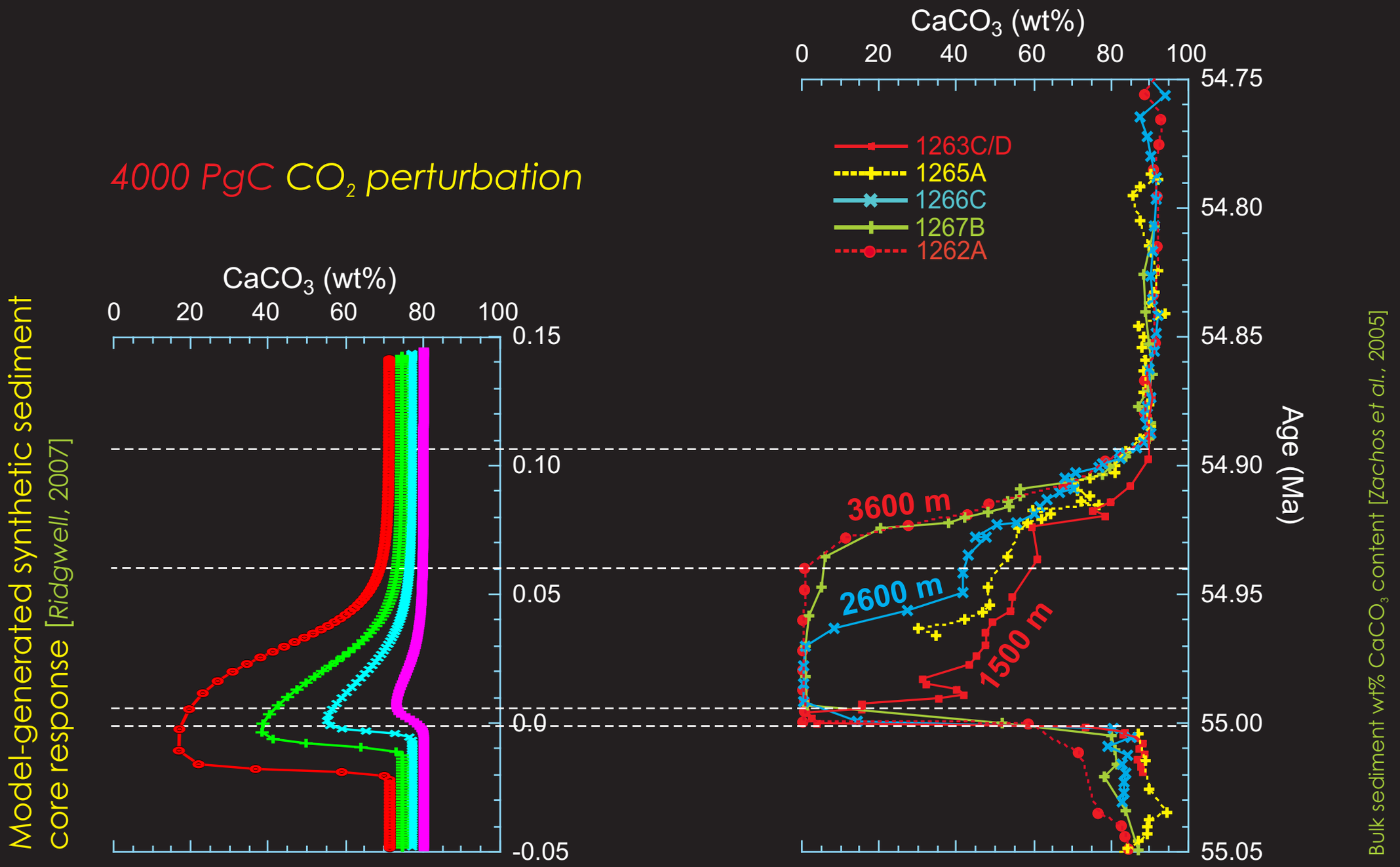
Quantifying 'time' in models & data (1)



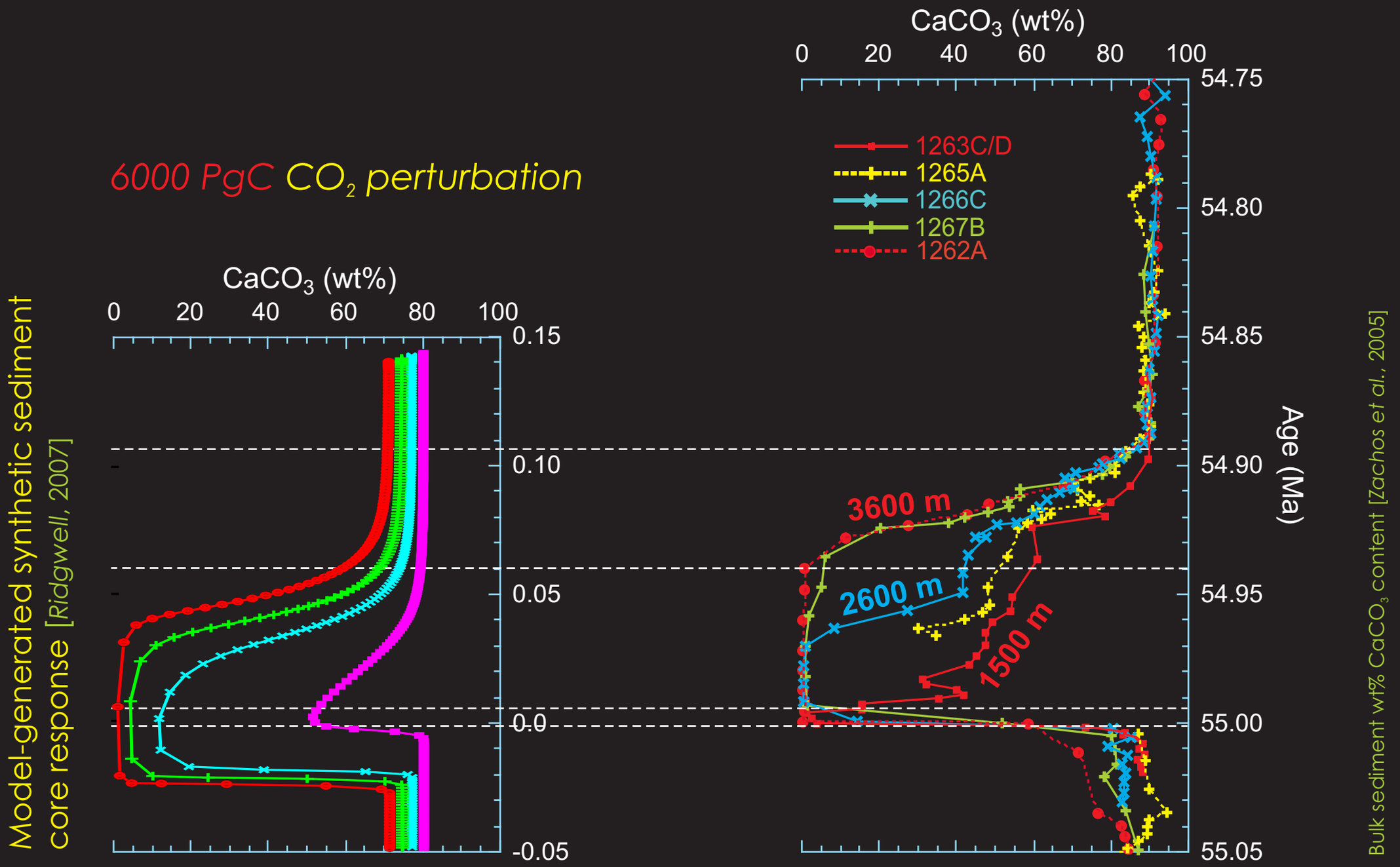
Quantifying 'time' in models & data (1)



Quantifying 'time' in models & data (1)

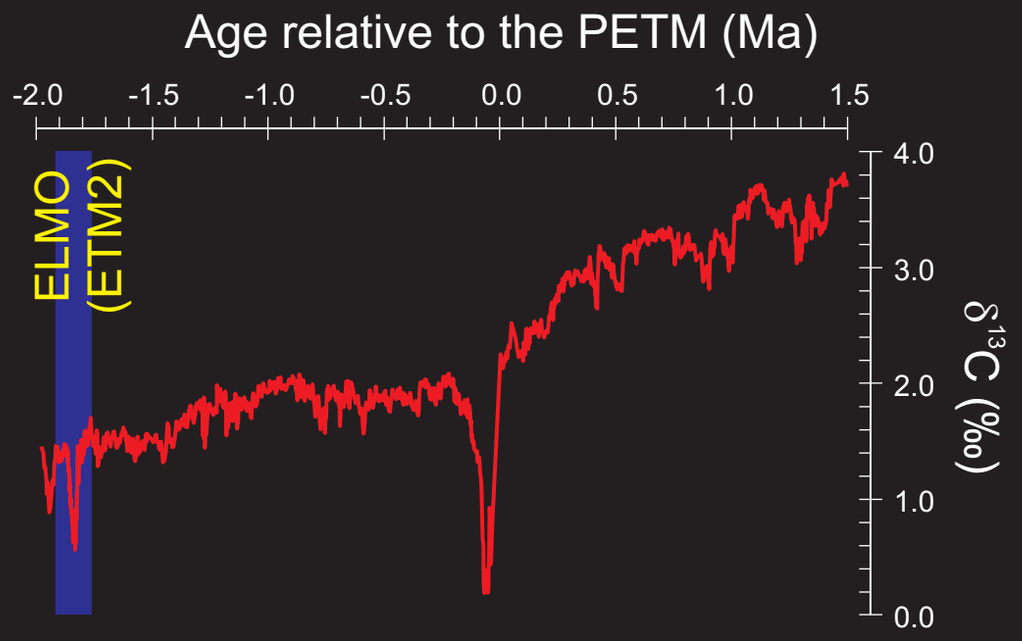


Quantifying 'time' in models & data (1)

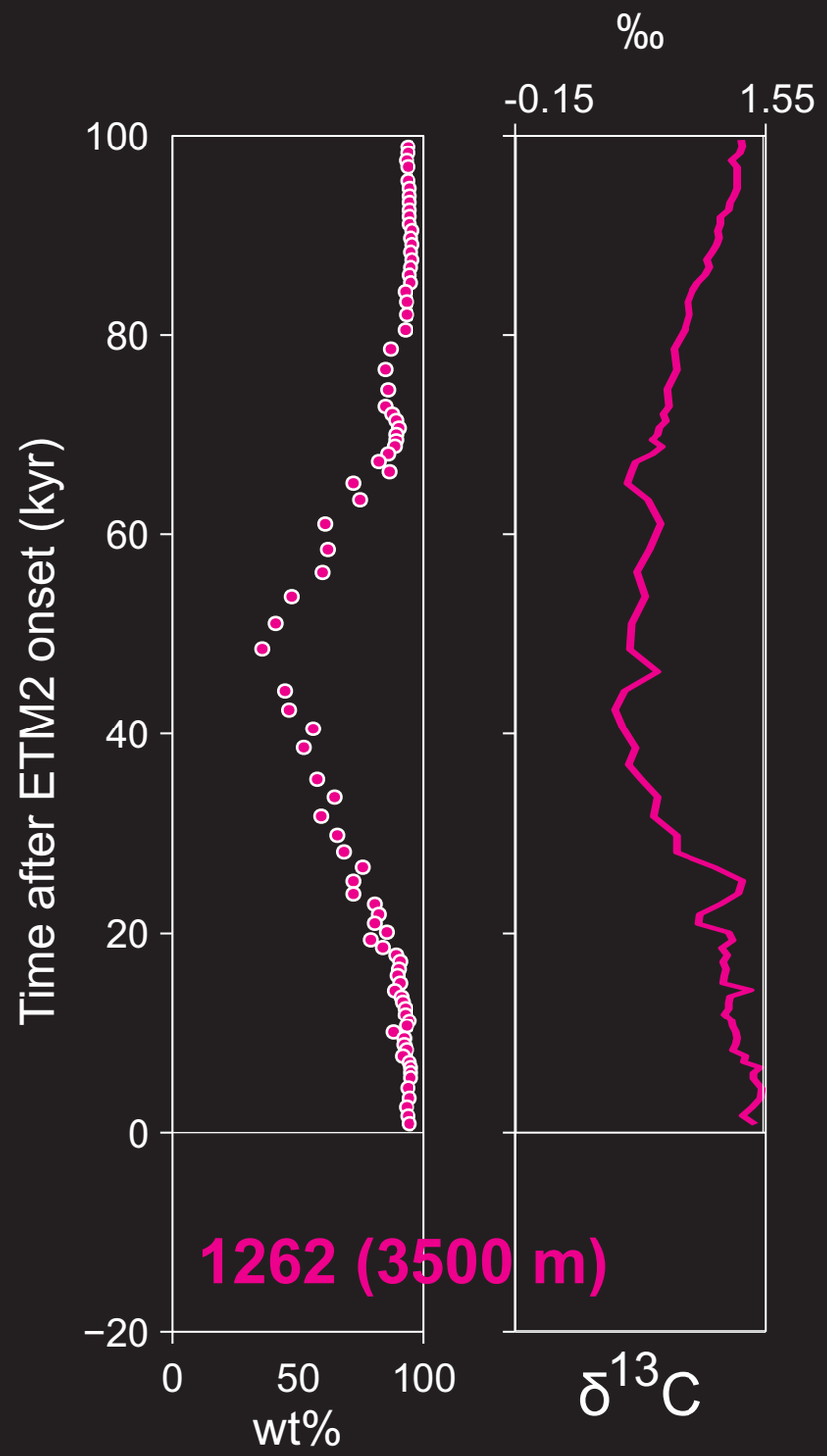


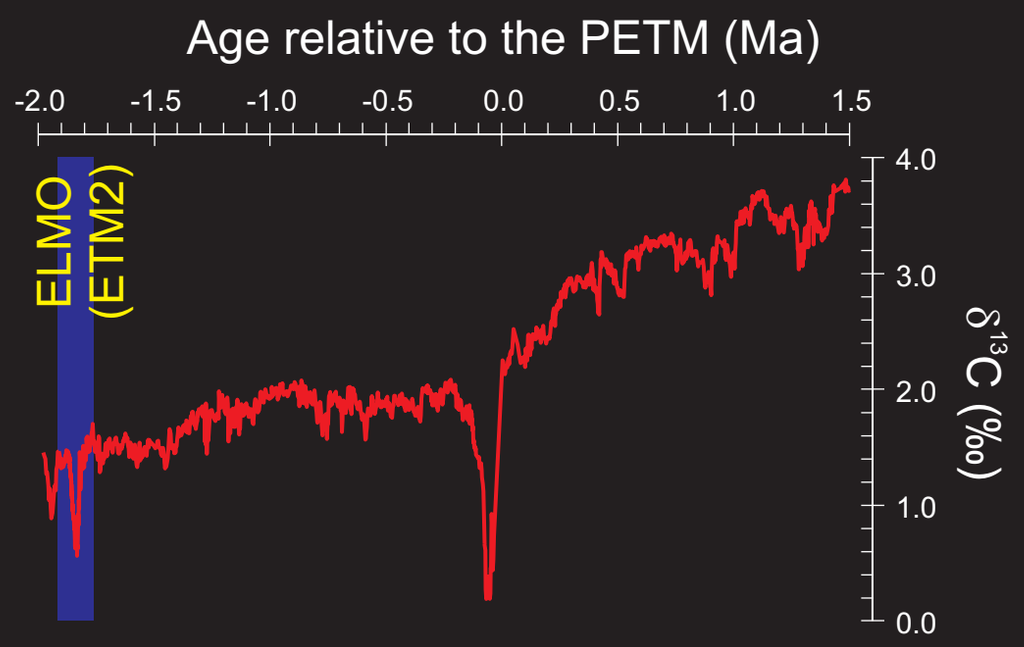
Quantifying 'time' in models & data (2)

Consider: An event characterized by a (mild) reduction in carbonate preservation

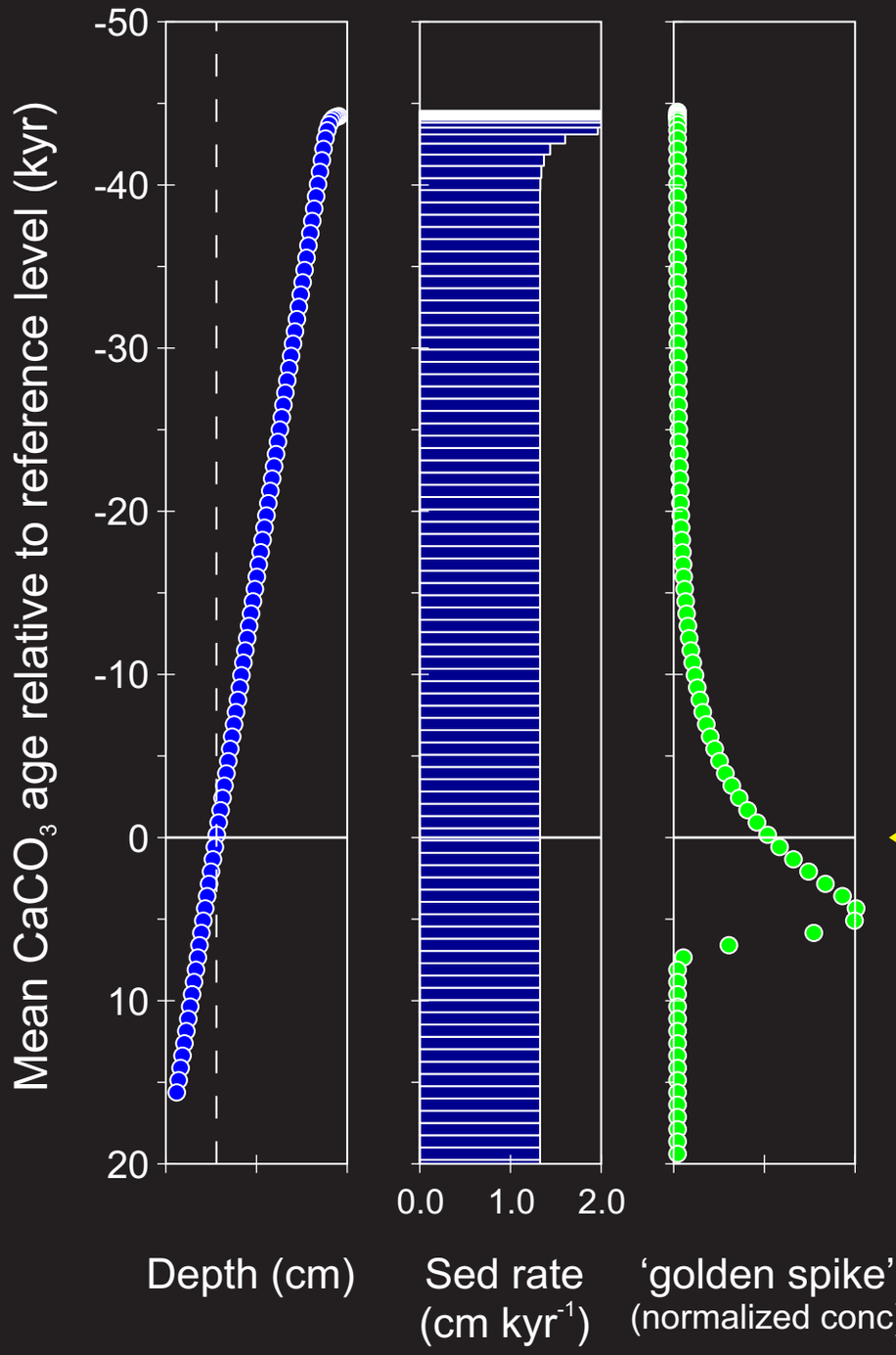


Quantifying 'time' in models & data (2)



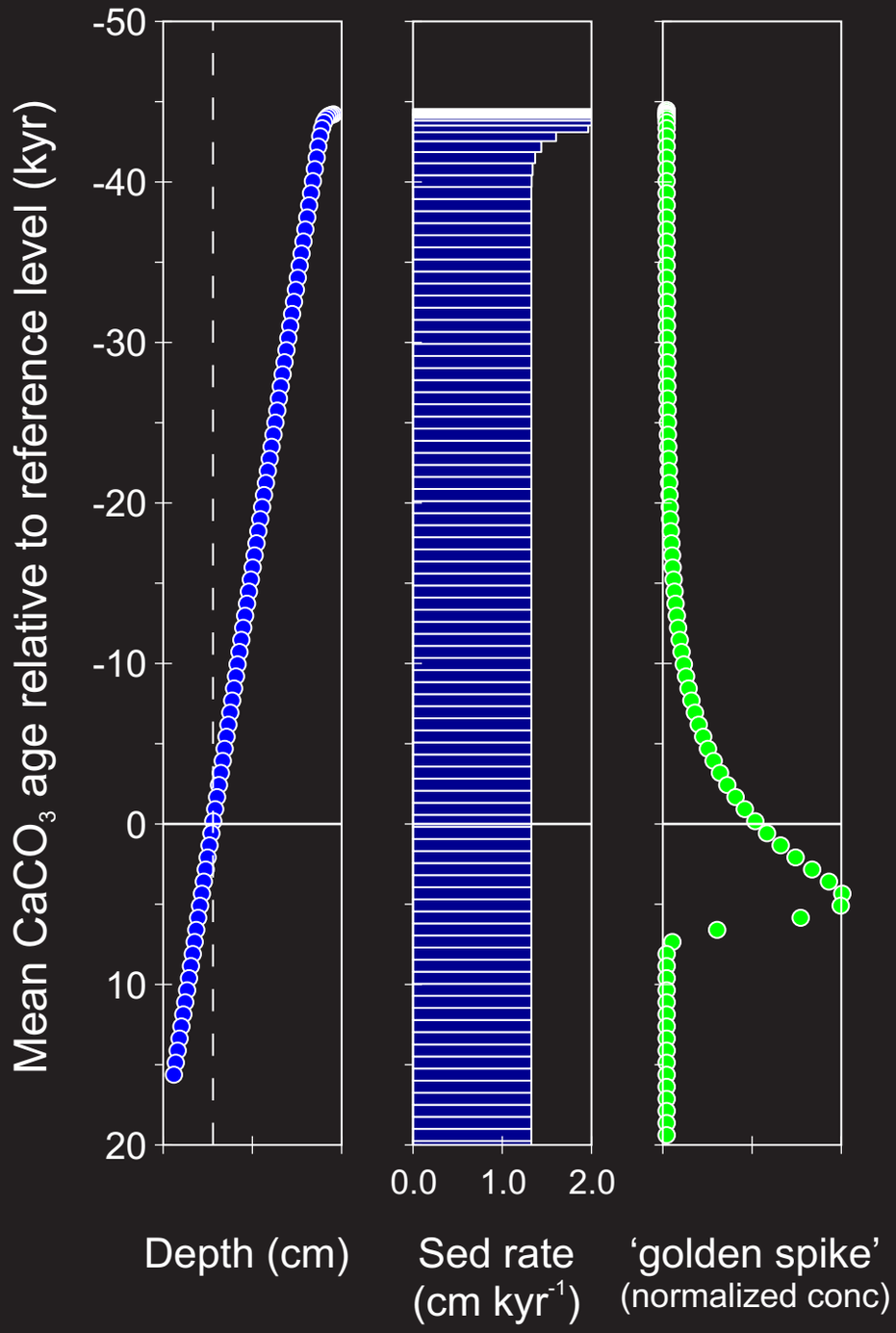


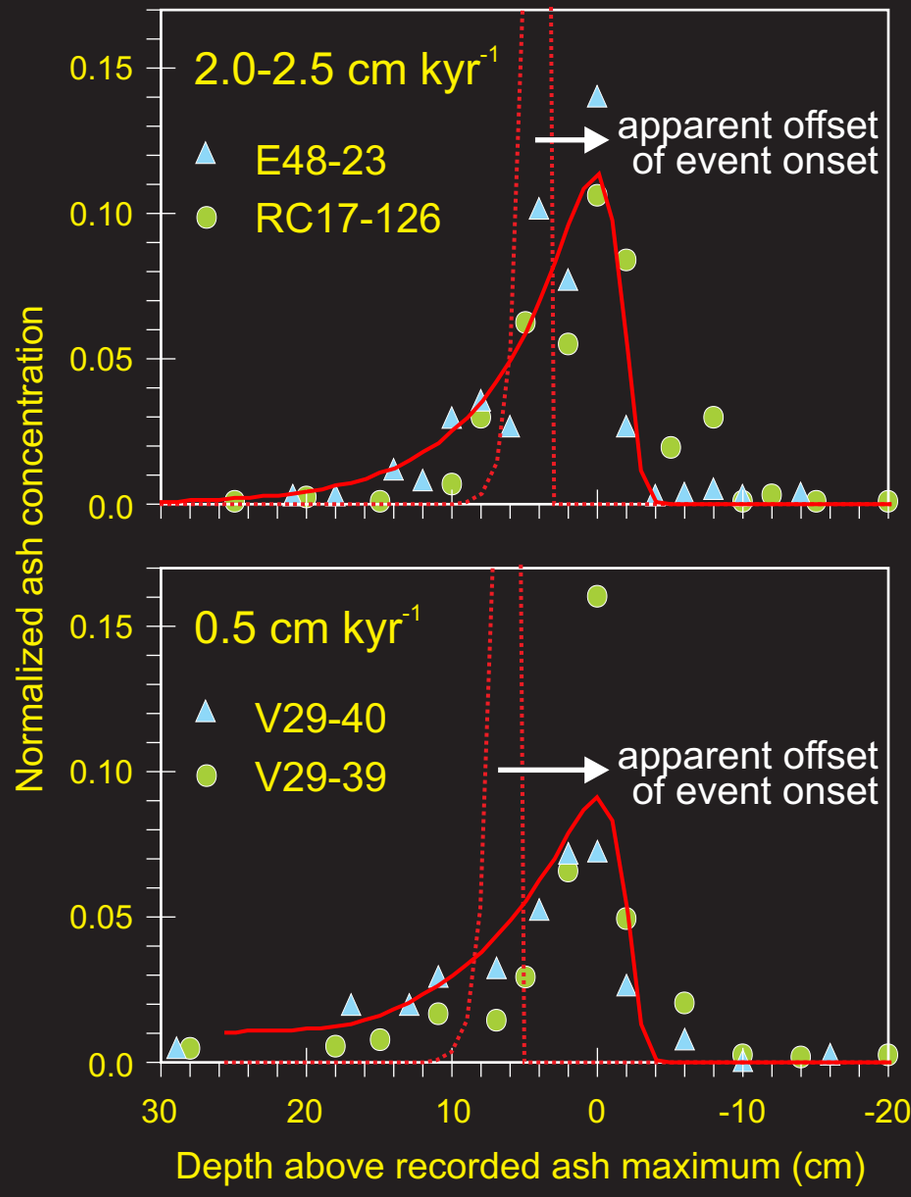
Quantifying 'time' in models & data (2)



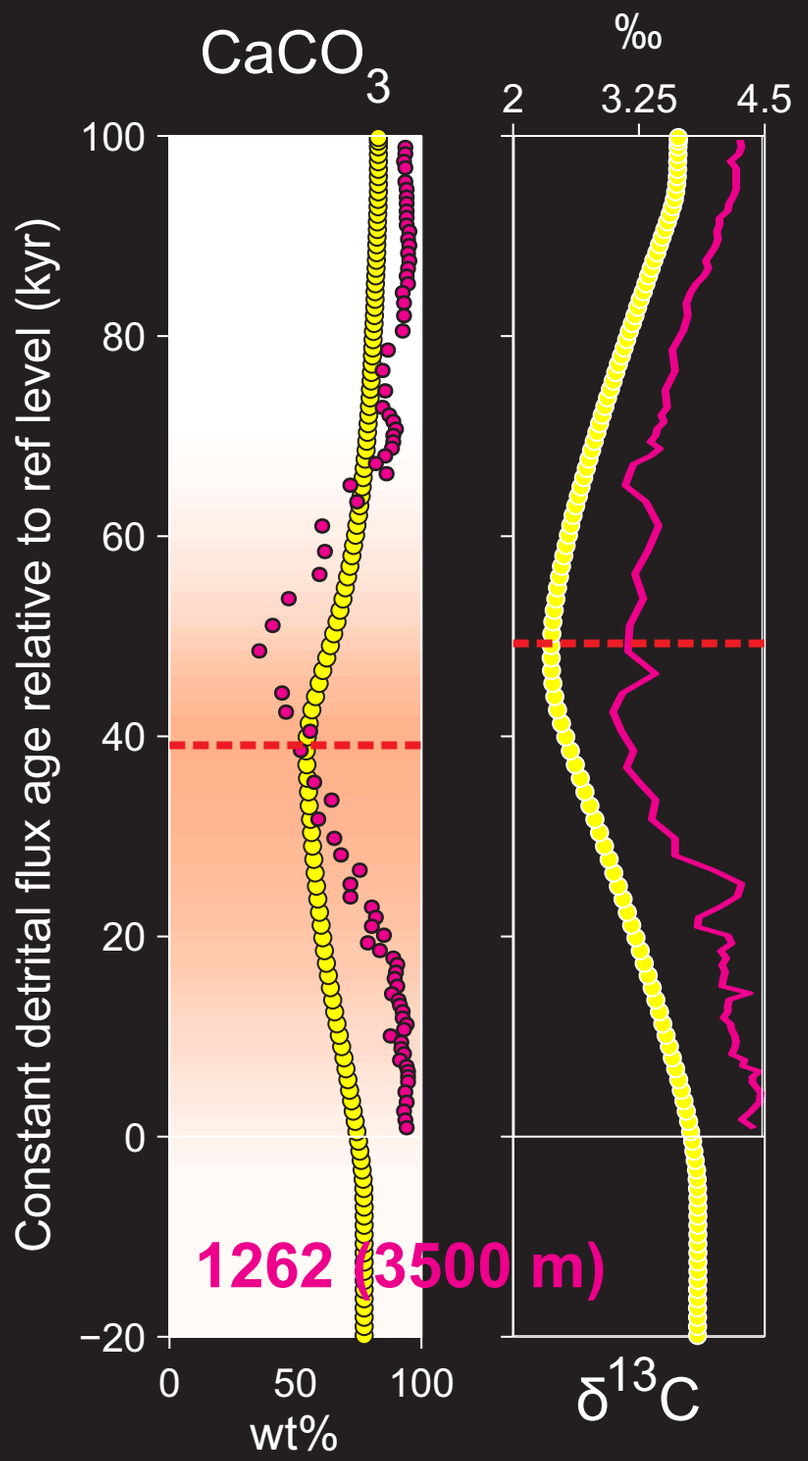
model experiment starts,
surface sediments 'tagged'
(instantaneous pulse of inert,
conservative, numerical tracer)

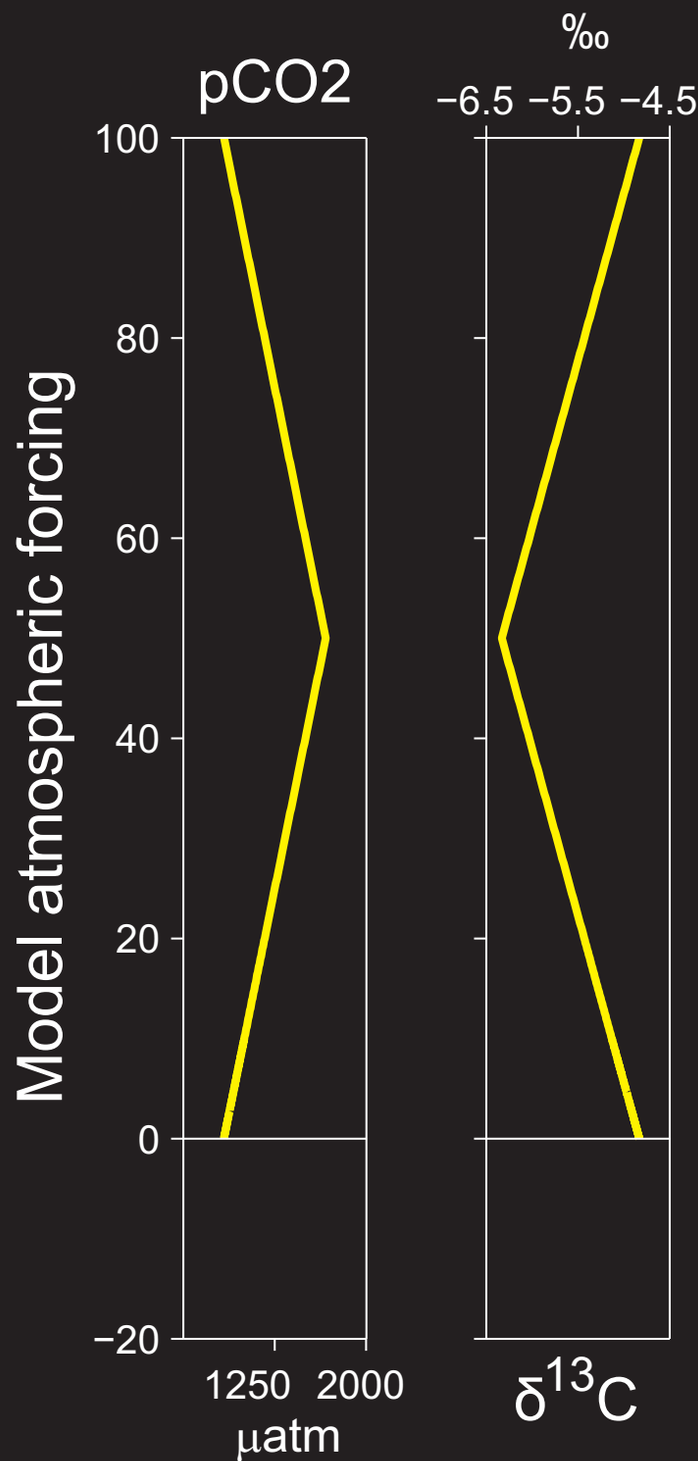
Quantifying 'time' in models & data (2)



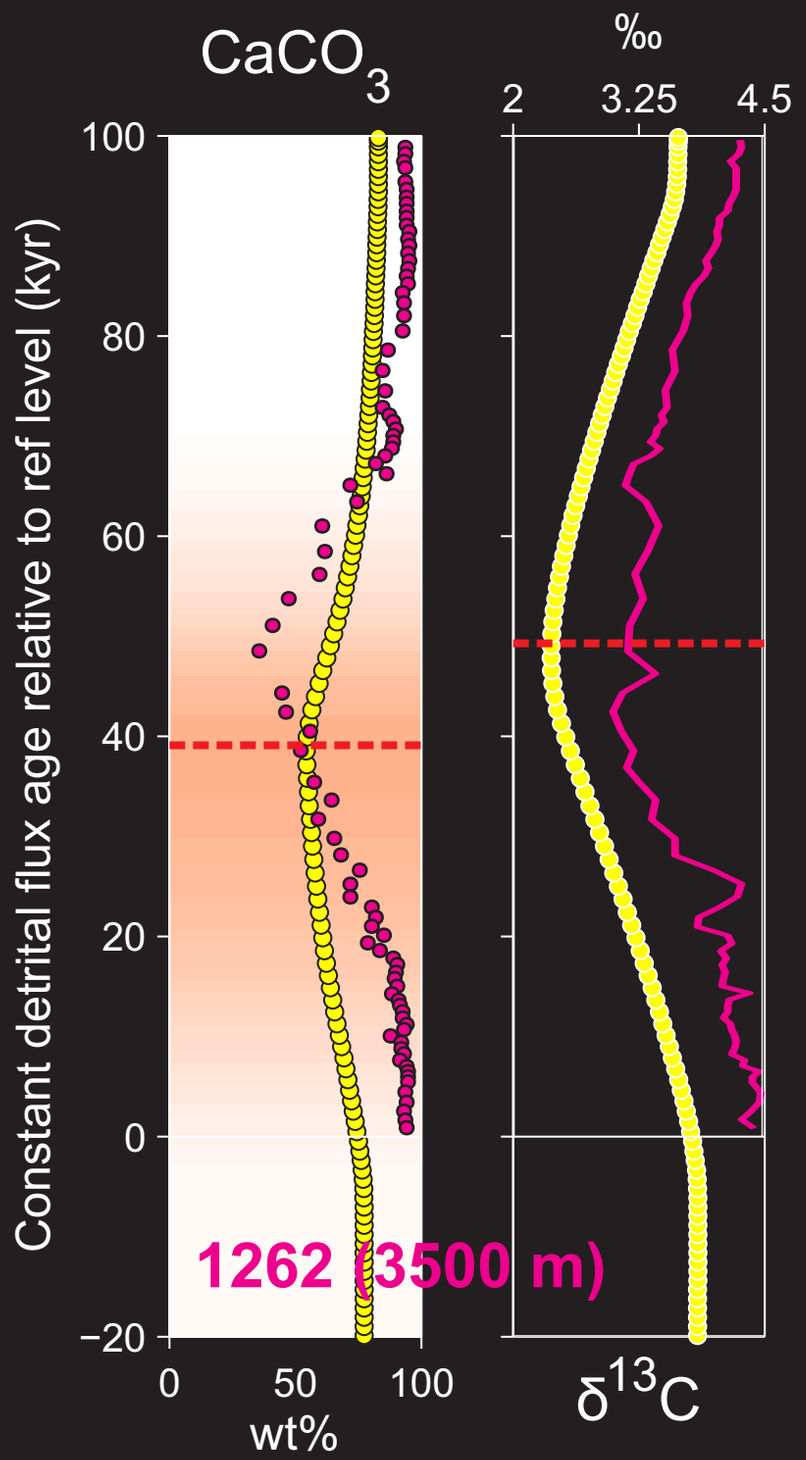


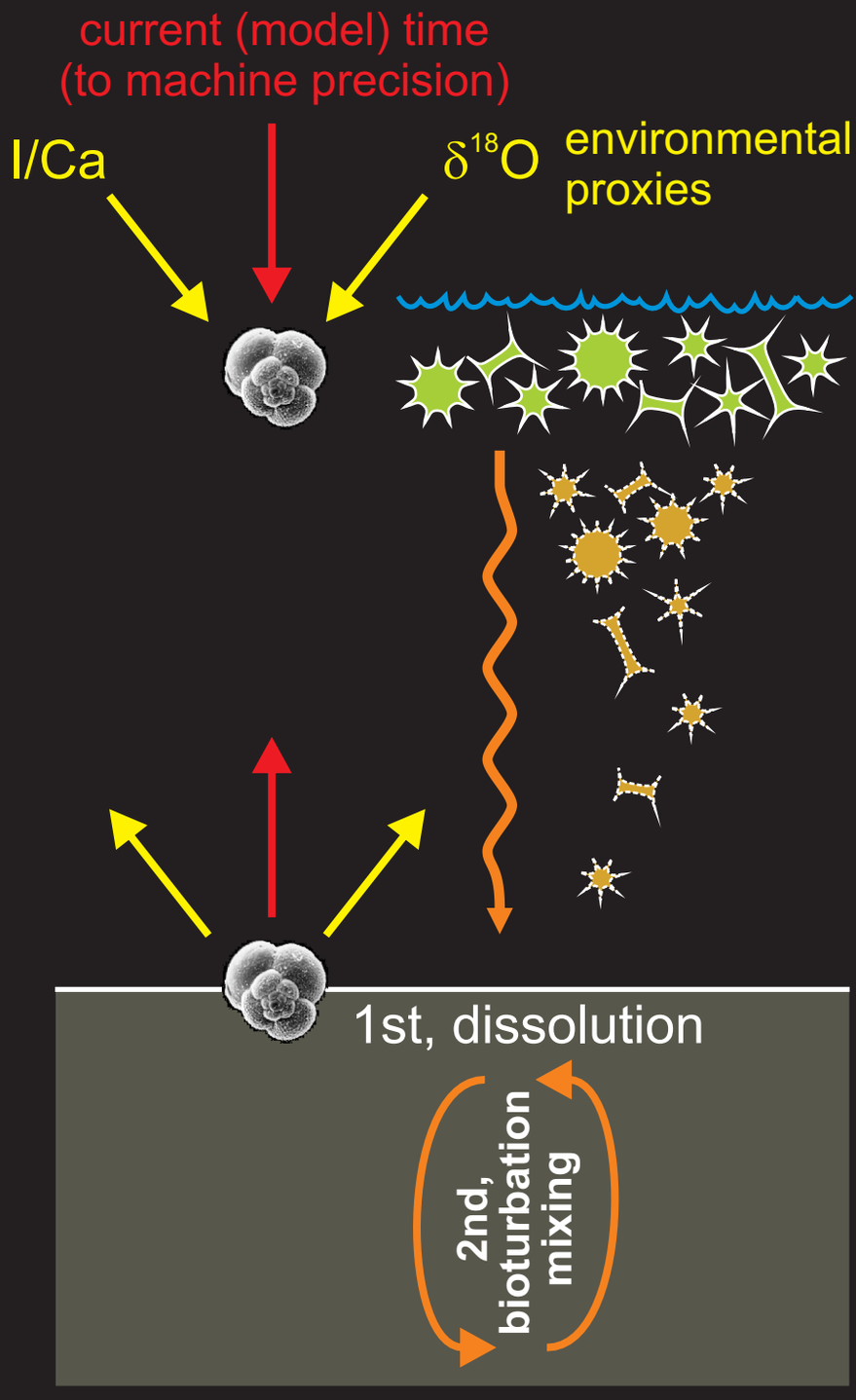
Quantifying 'time' in models & data (2)



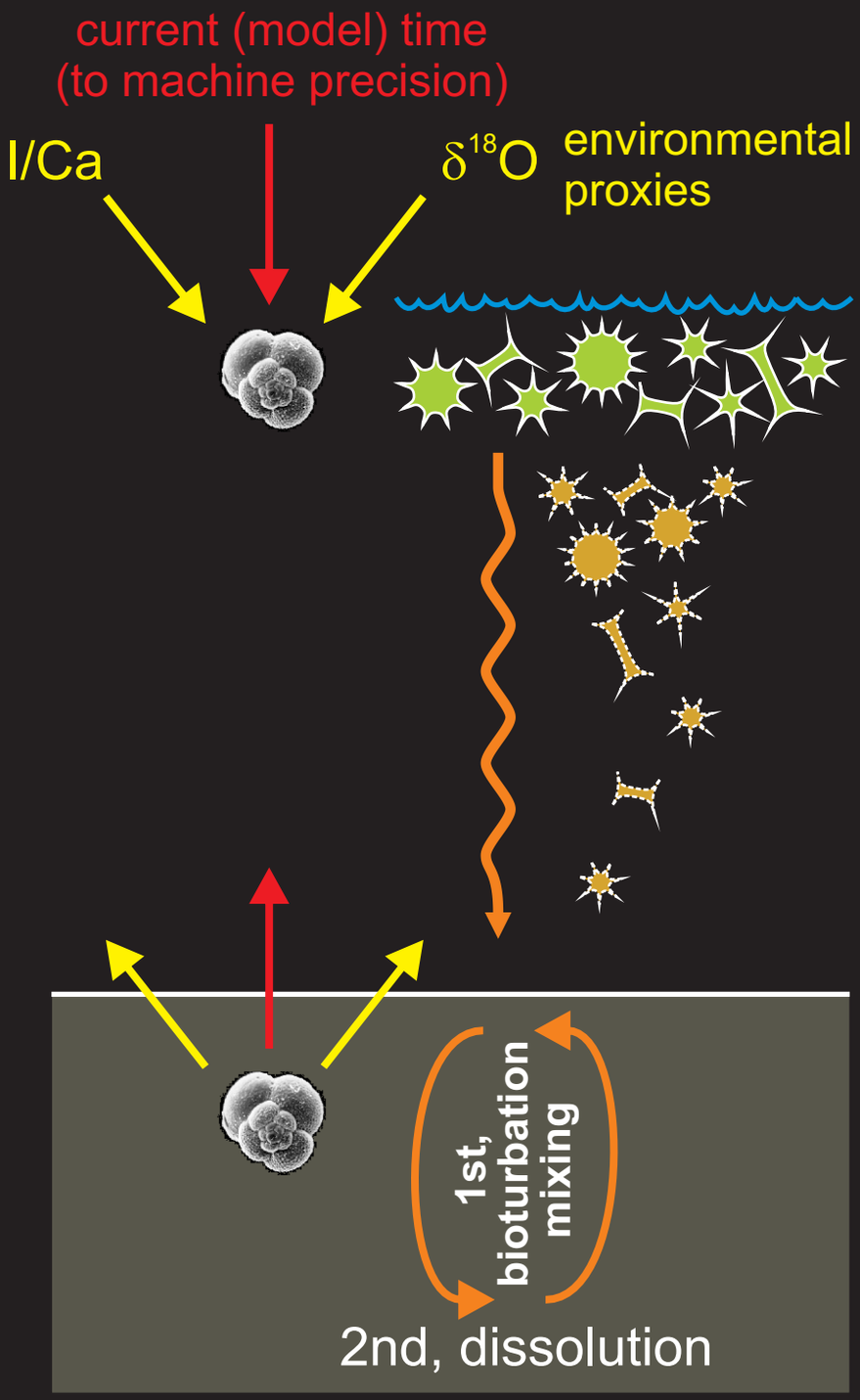


'Interface' $CaCO_3$ dissolution

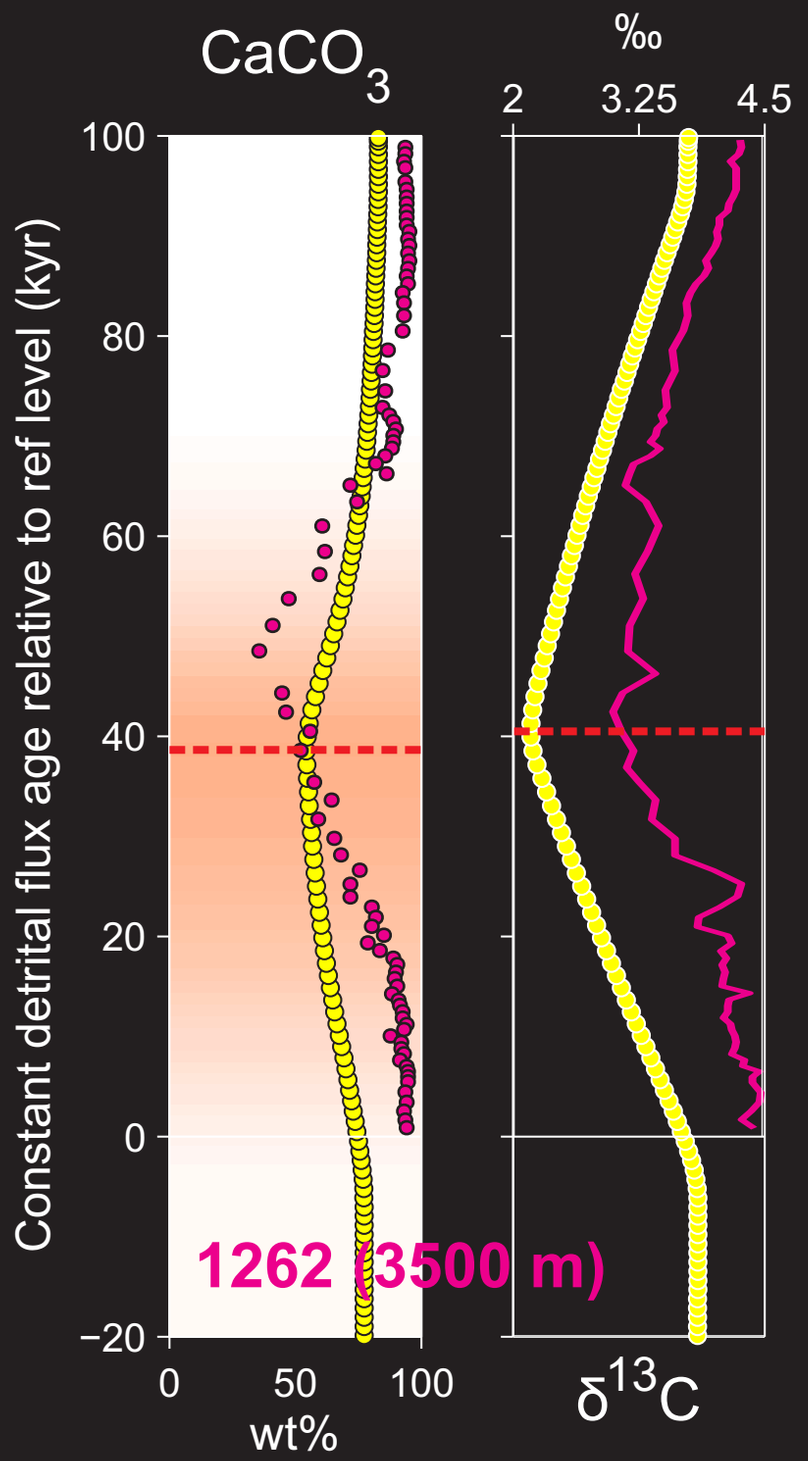


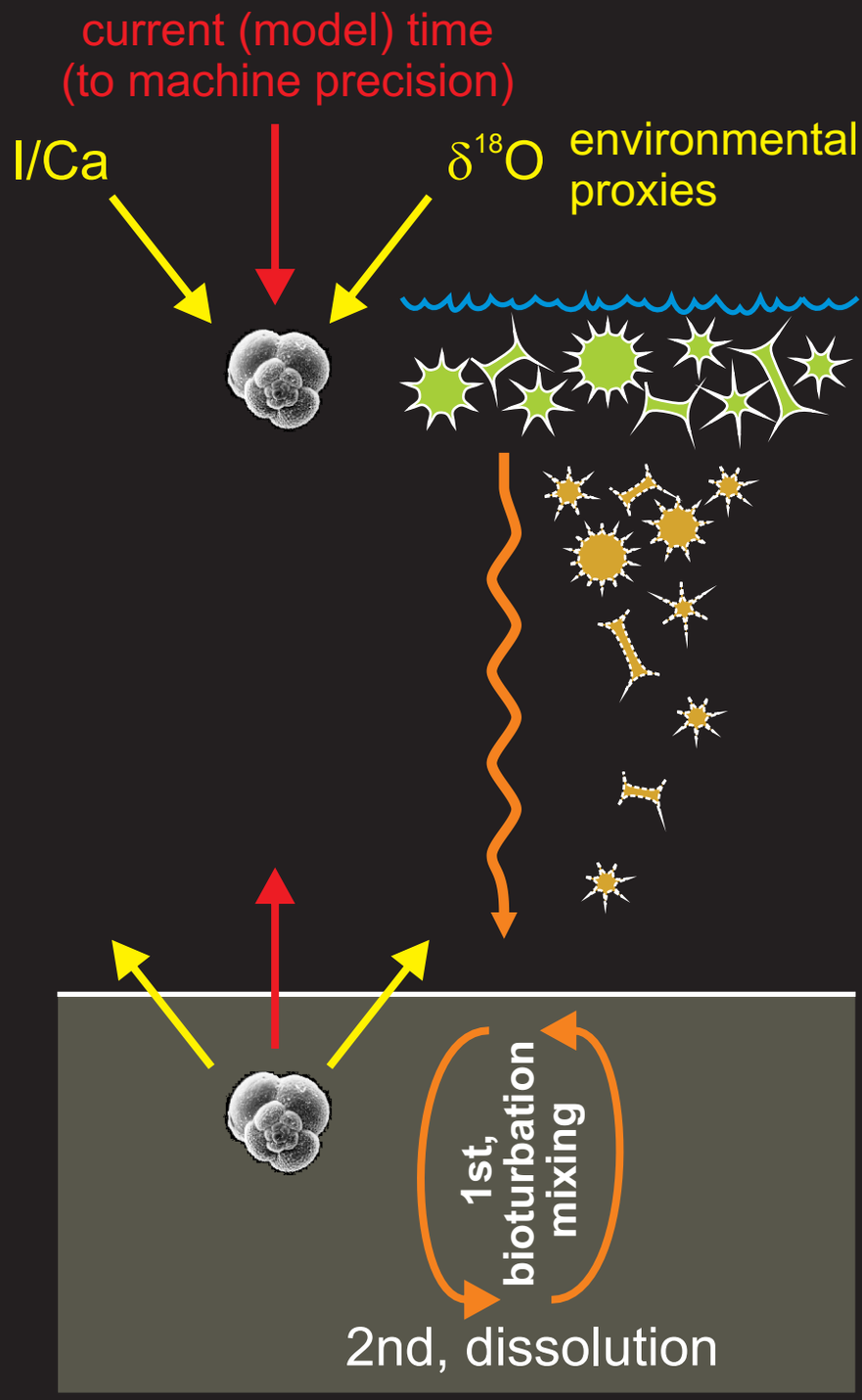


'Homogeneous' $CaCO_3$ dissolution



‘Homogeneous’ $CaCO_3$ dissolution





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Aturale Nvironmentalr Esearchc Ounciln