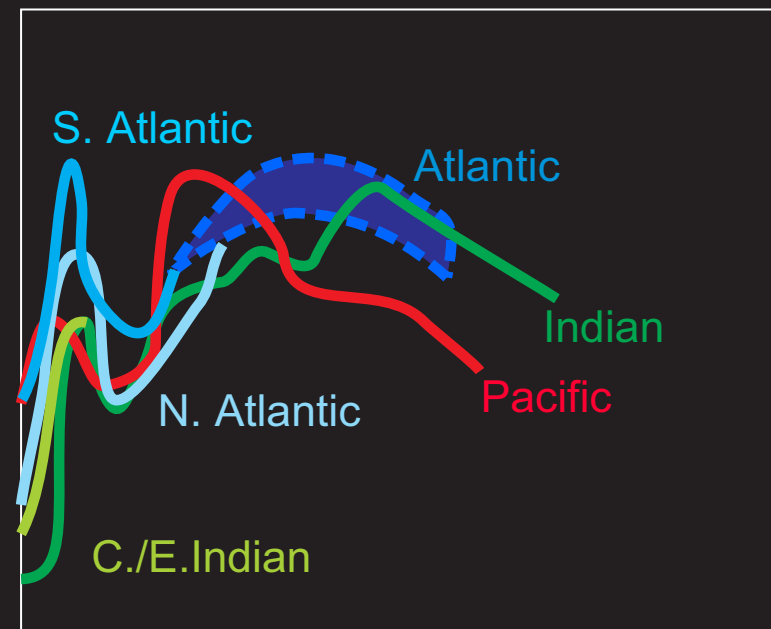


iPODS 2016:

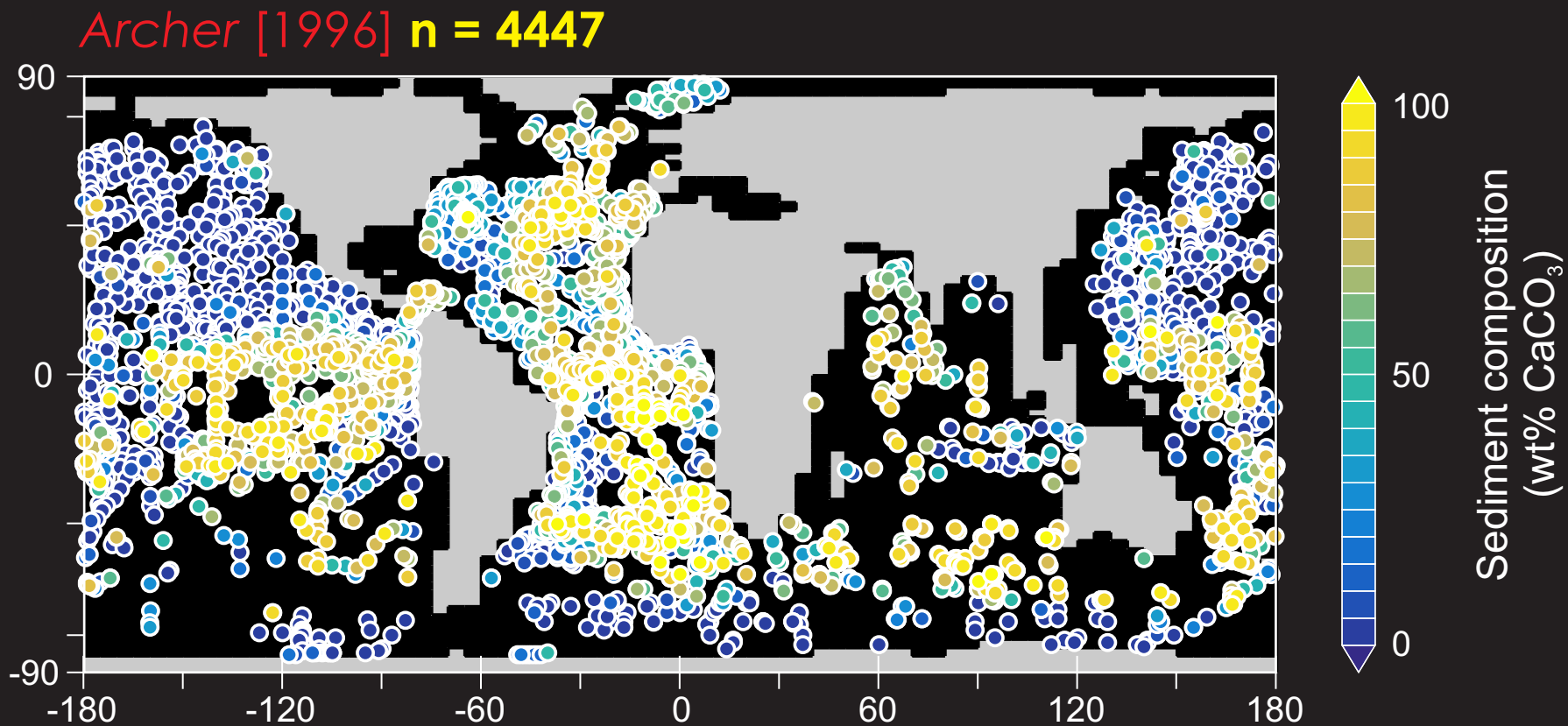
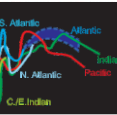
What does (/do variations in) the CCD 'mean'?

University of California, Riverside
University of Bristol, Bristol, Europe⁺

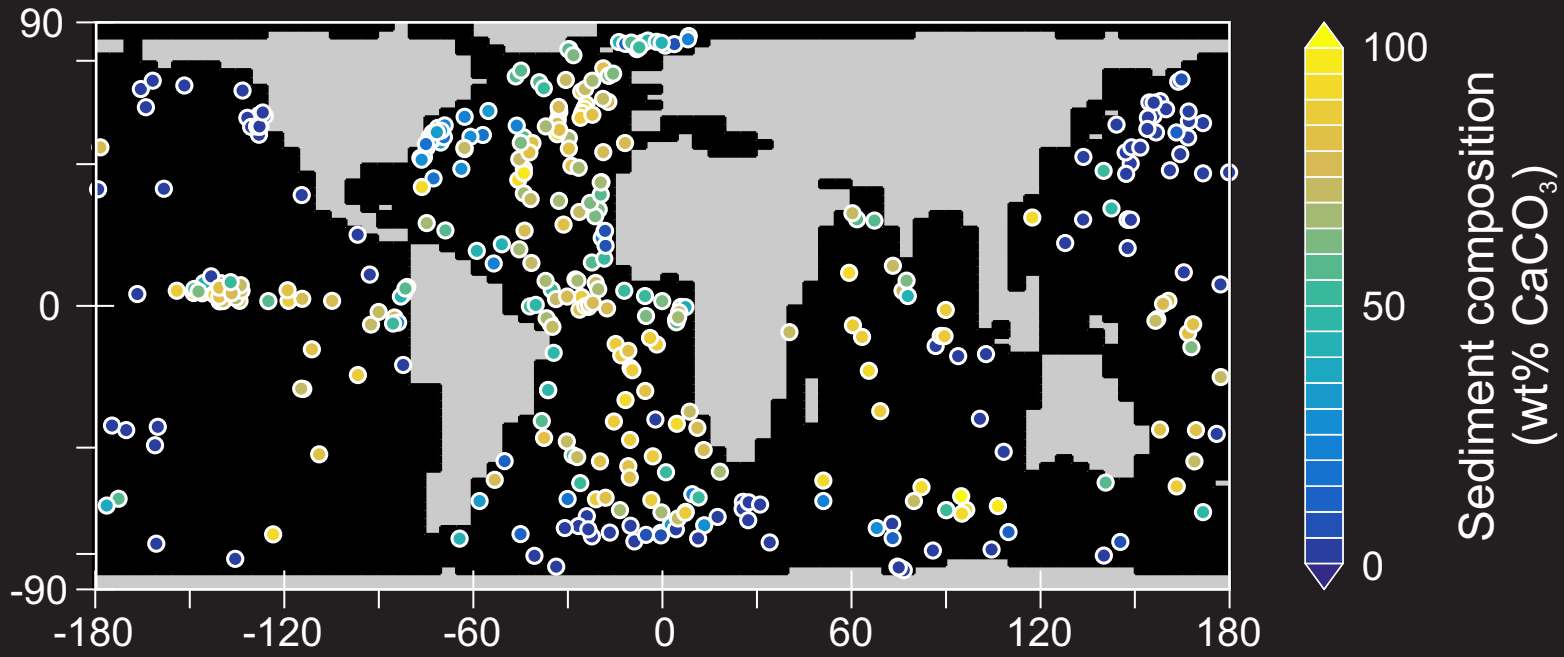
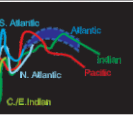


⁺ as of 08/27/2016

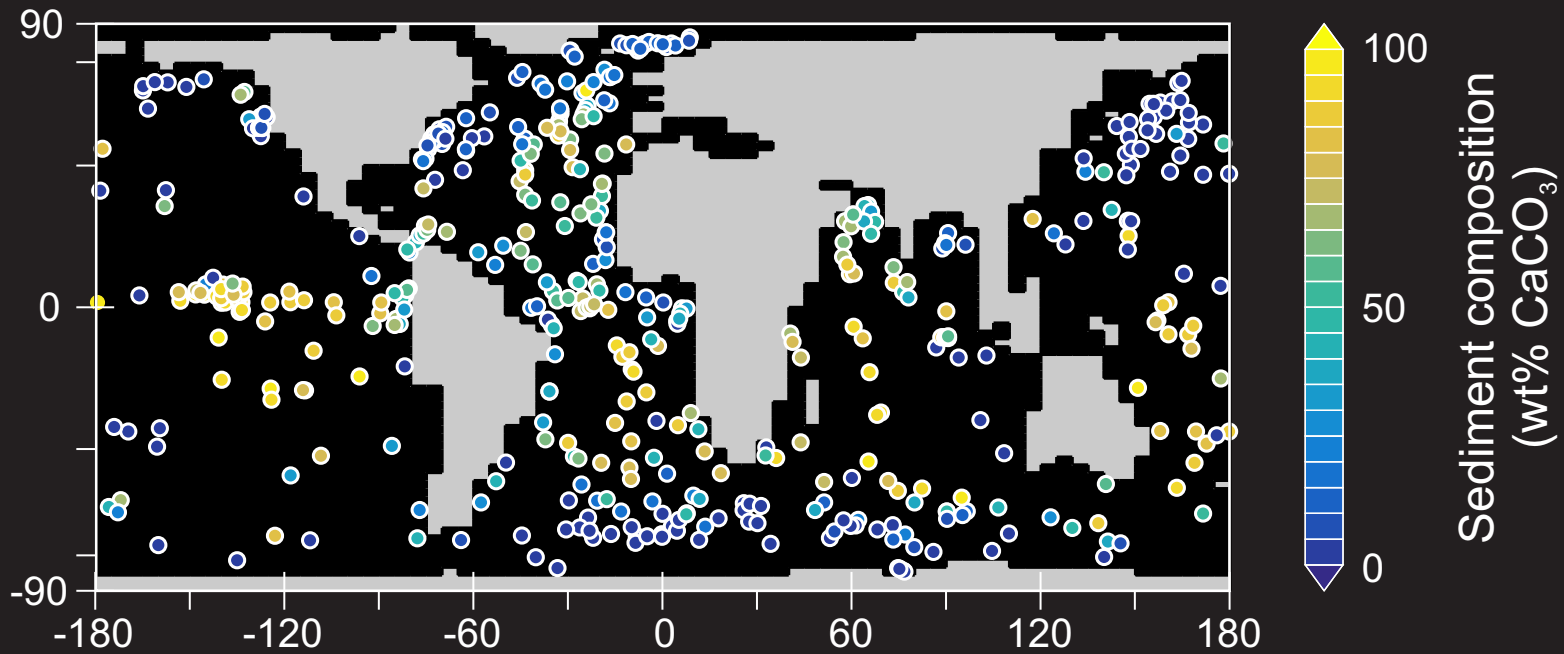
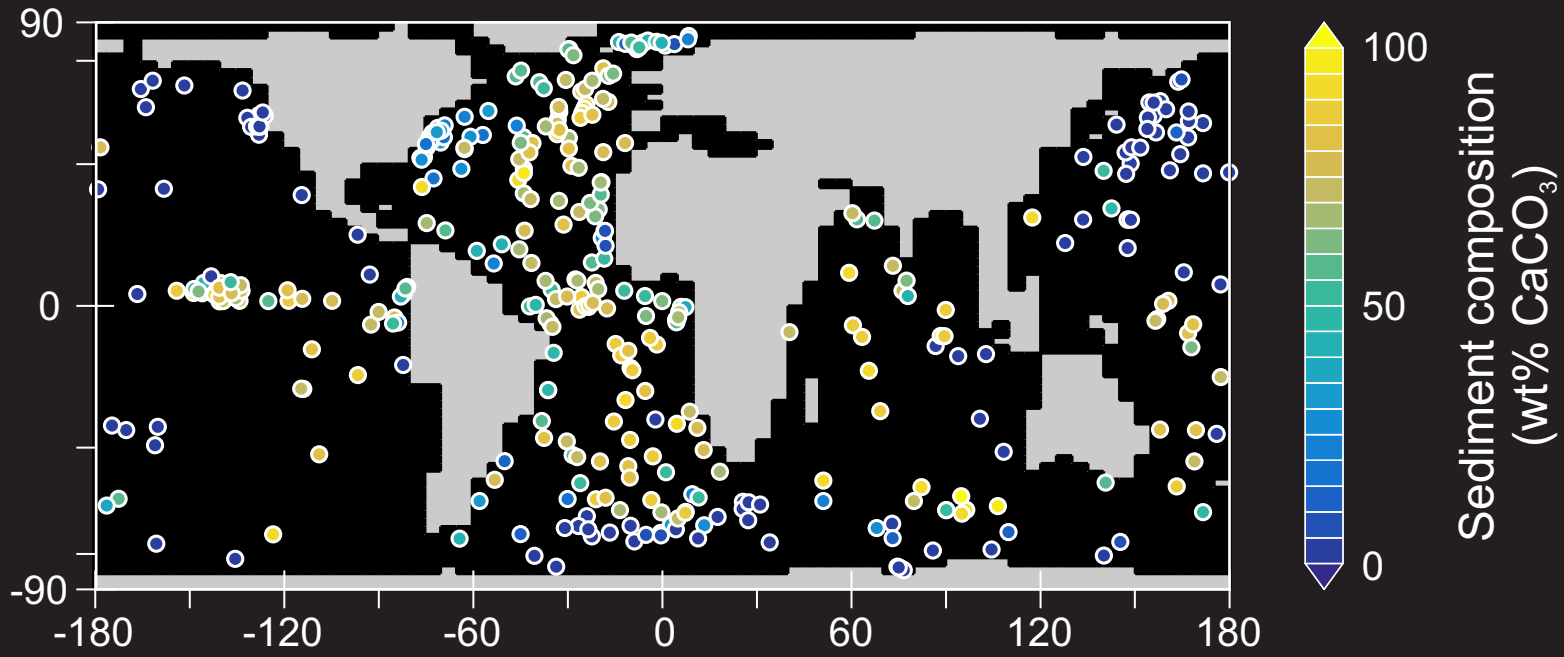
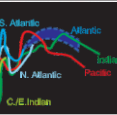
East/West CCD basin asymmetry during the LGM?



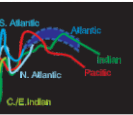
East/West CCD basin asymmetry during the LGM?



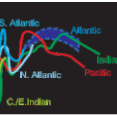
East/West CCD basin asymmetry during the LGM?



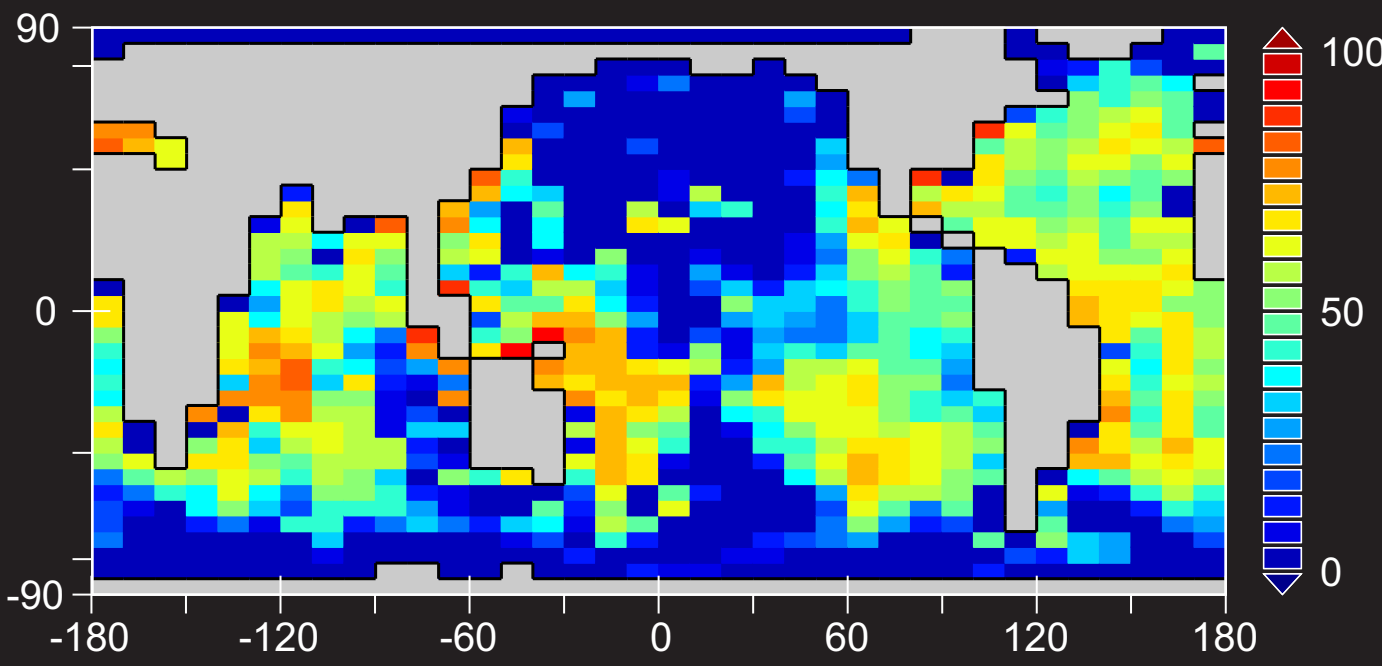
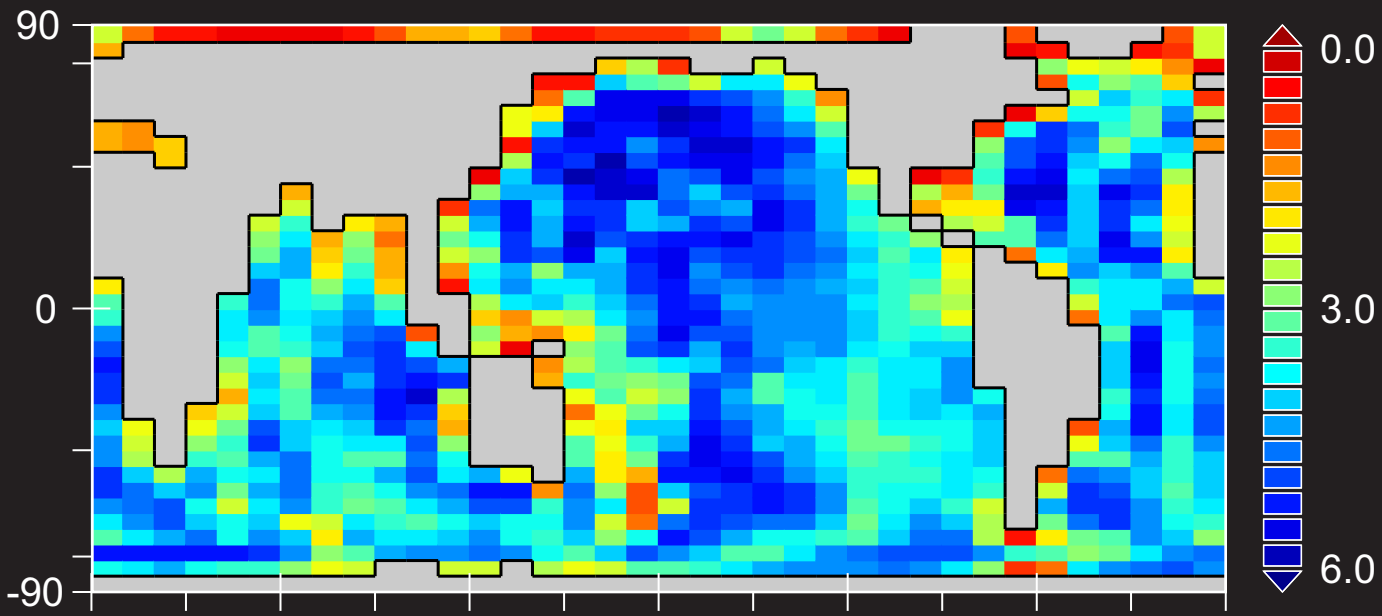
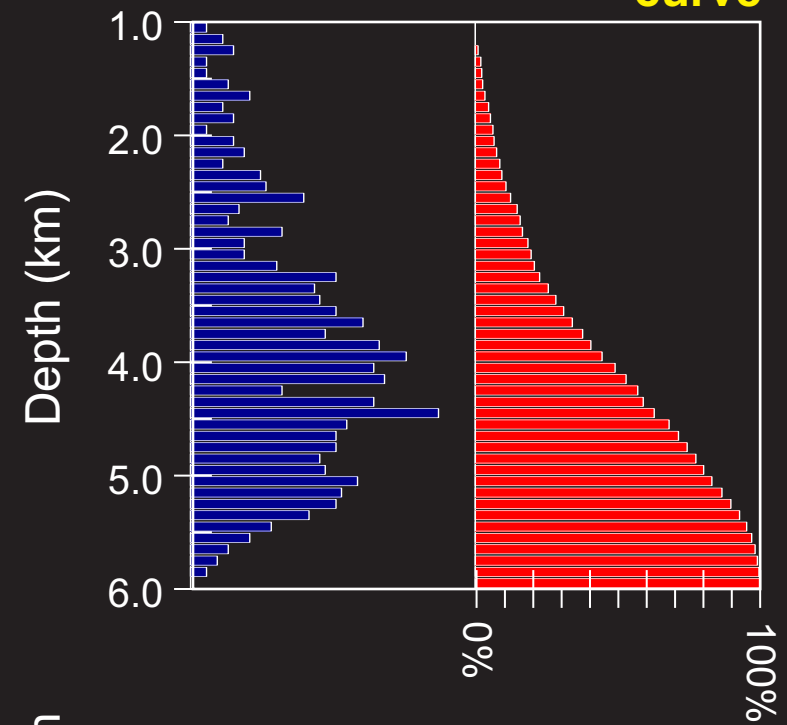
What is the CCD?



What is the CCD?

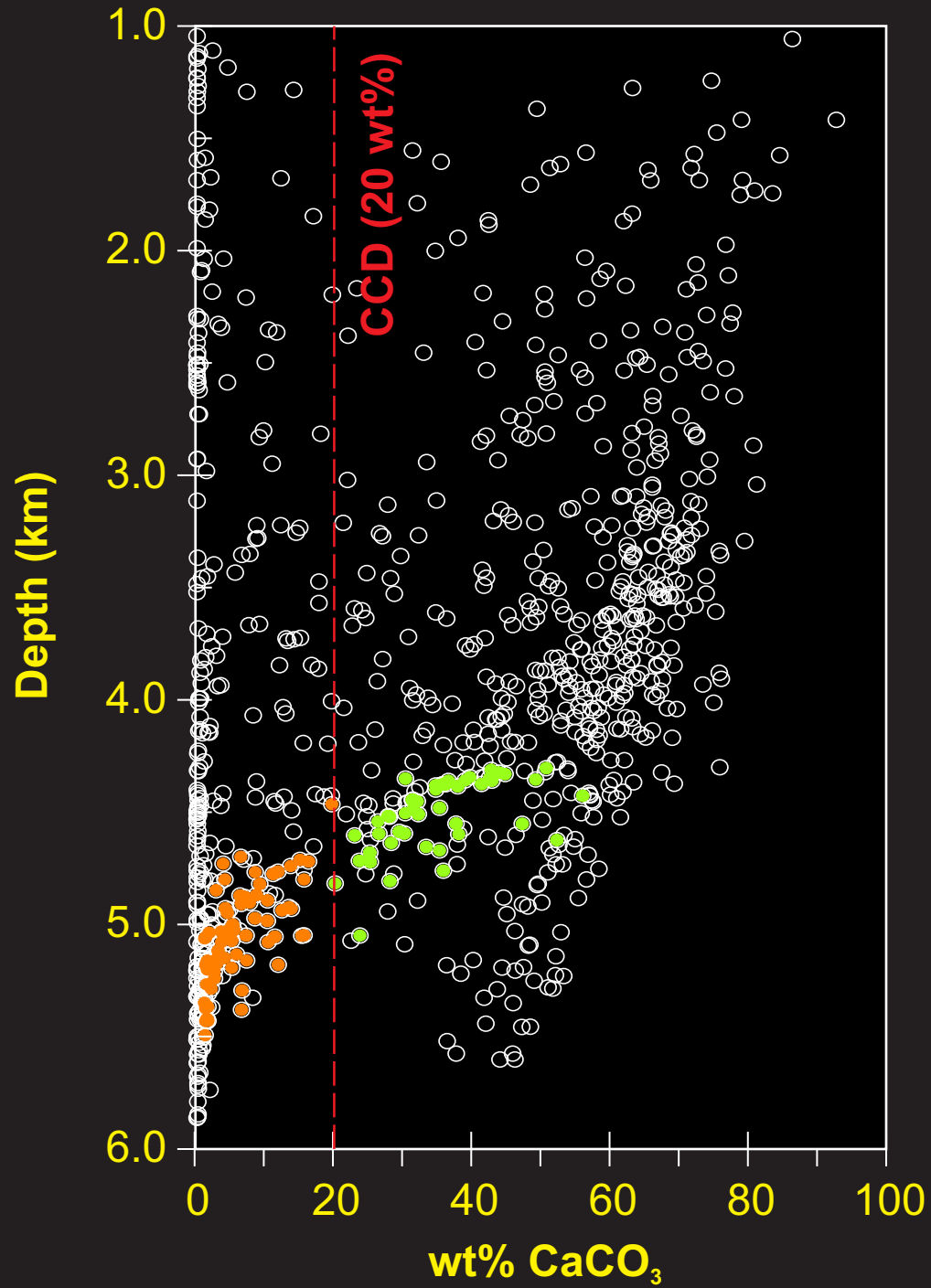
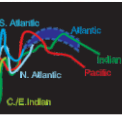


hypso-metric curve

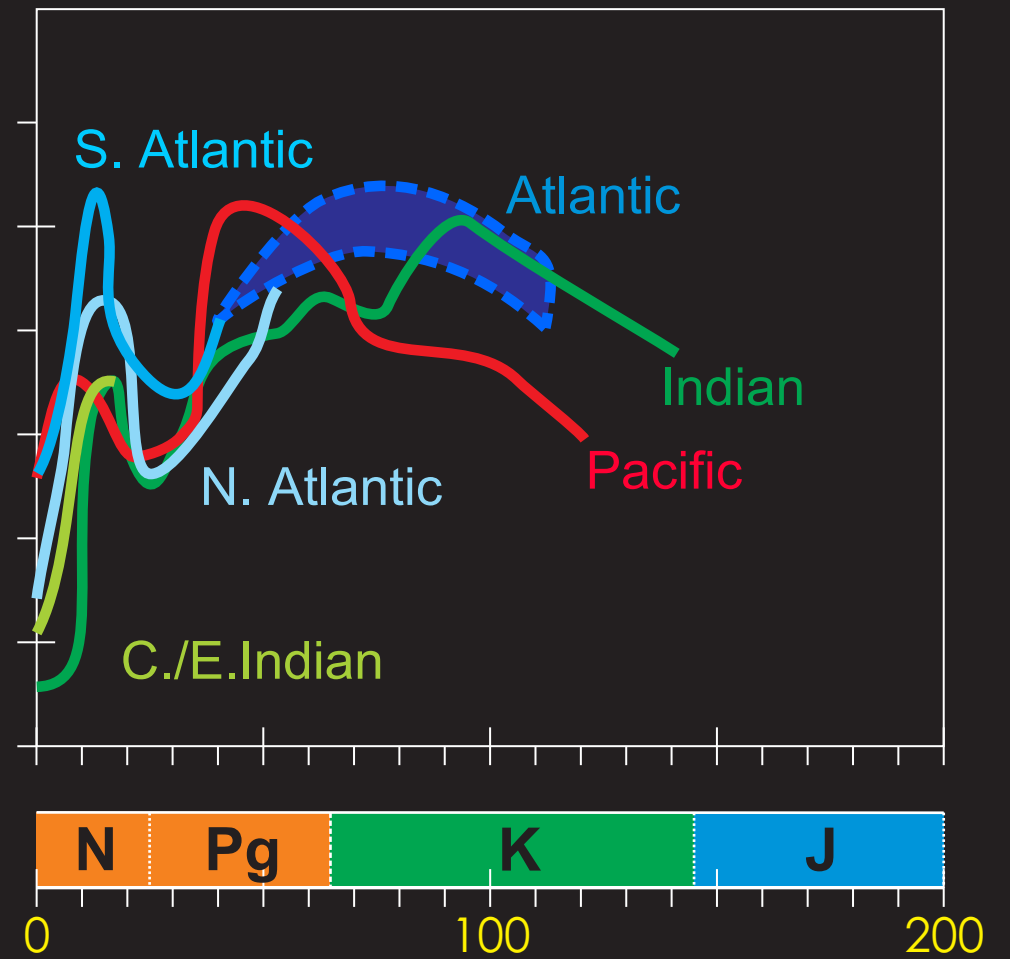
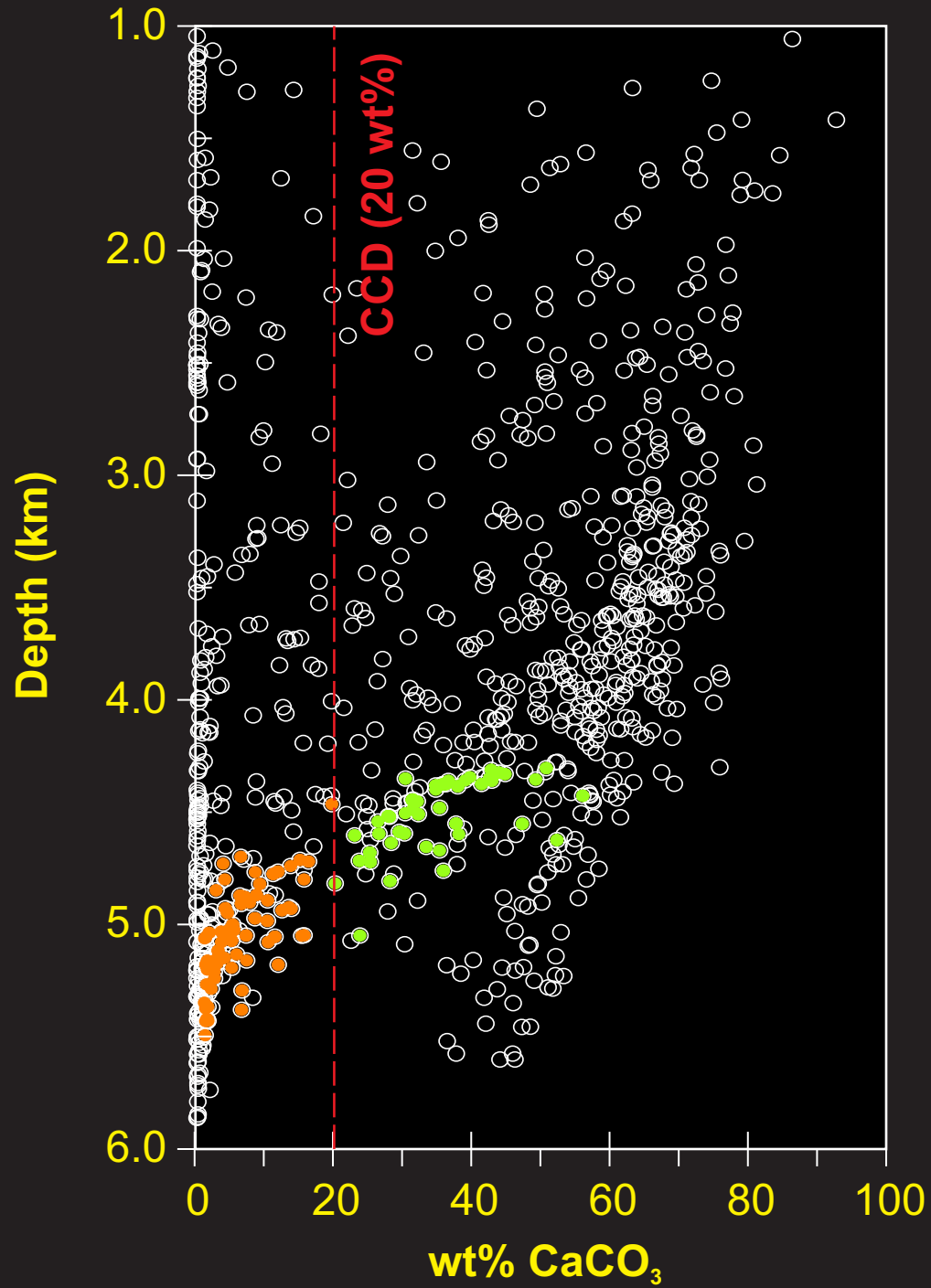
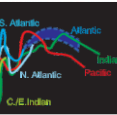


Sediment composition (wt% CaCO₃)

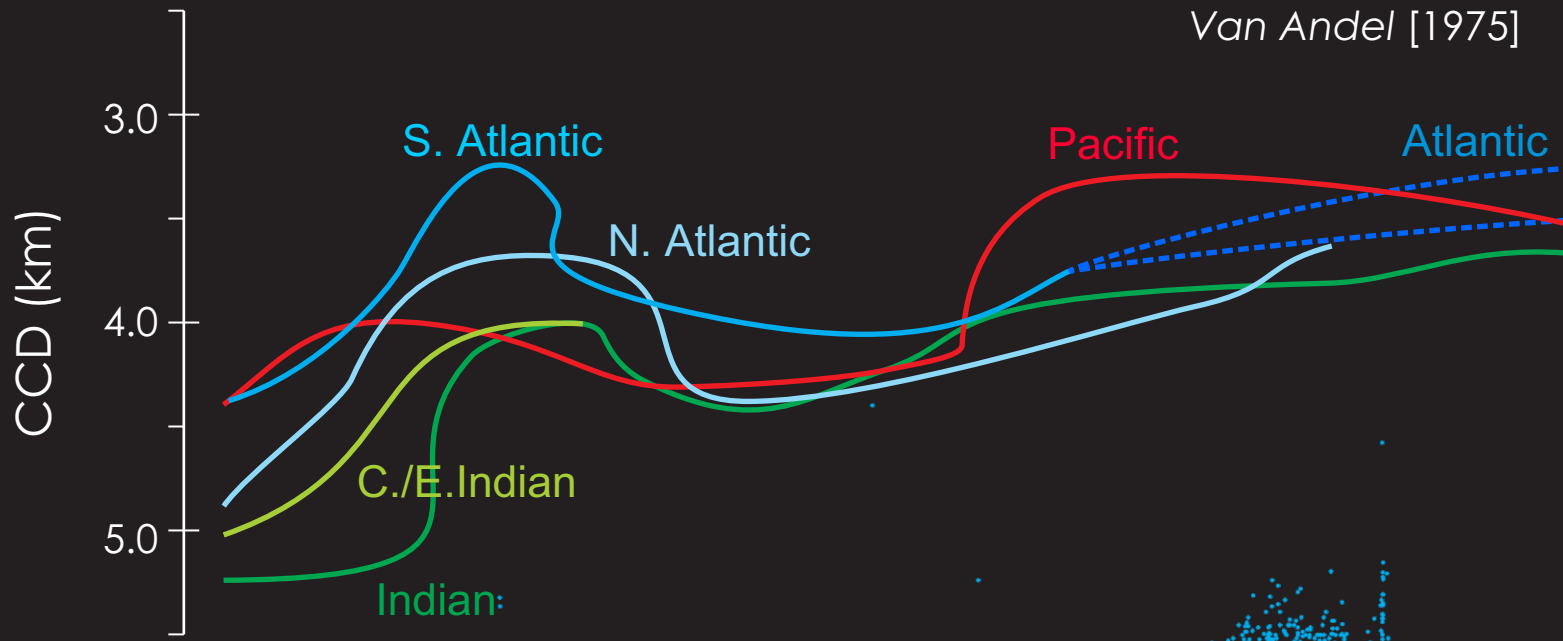
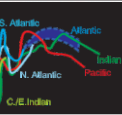
What is the CCD?



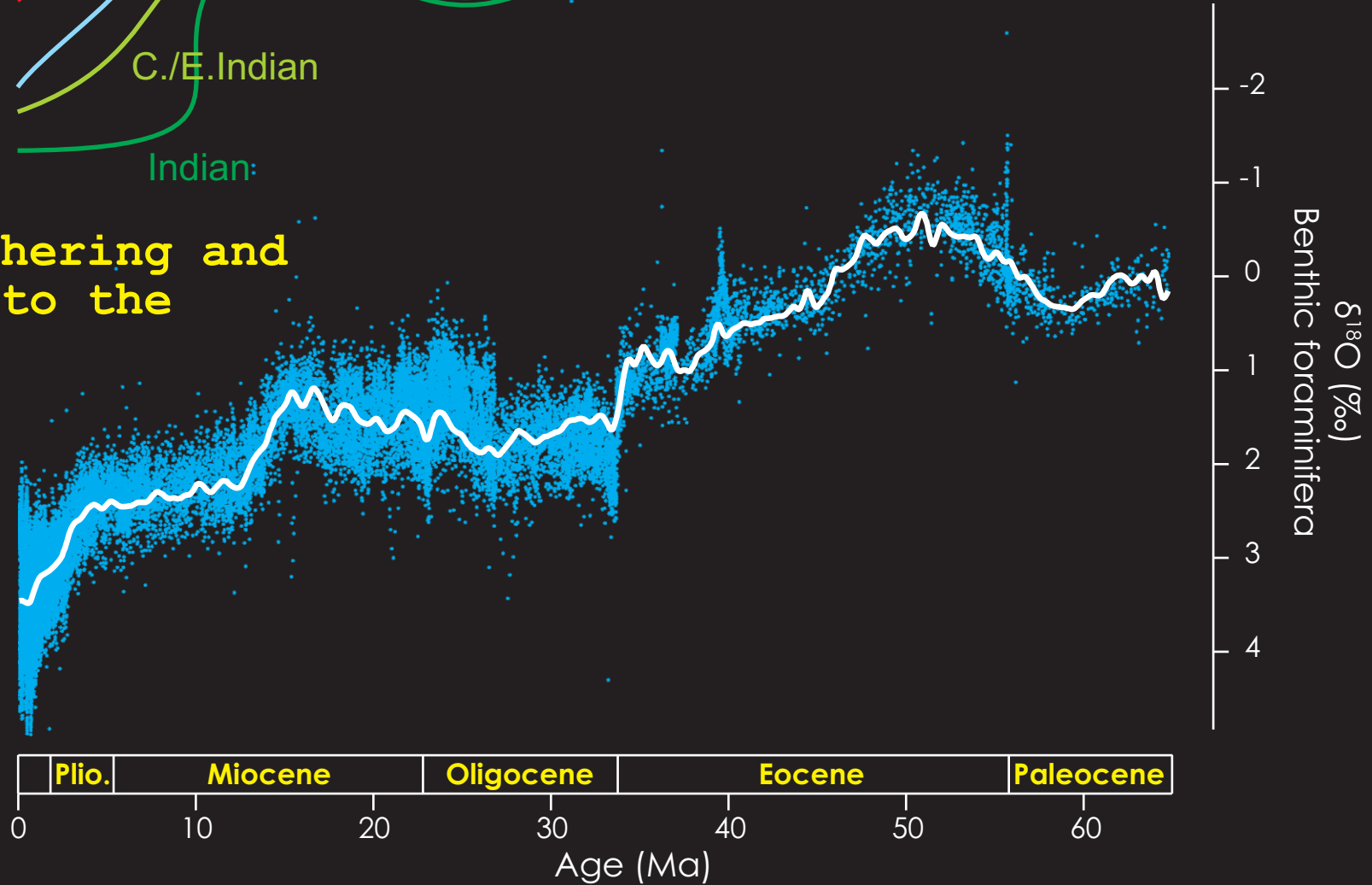
What is the CCD?



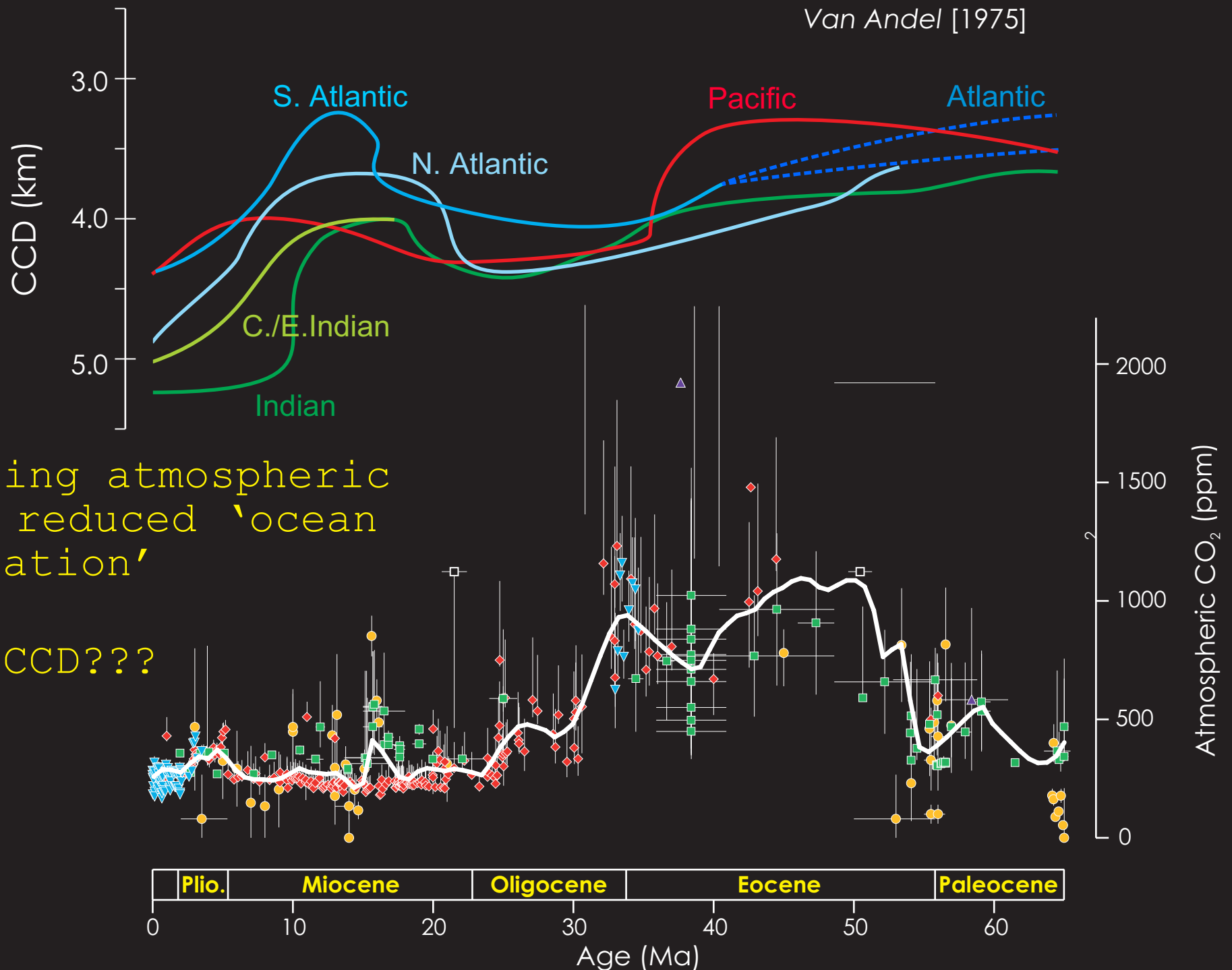
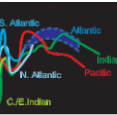
What is the CCD?



Increased weathering and solute supply to the ocean == deeper CCD???



What is the CCD?

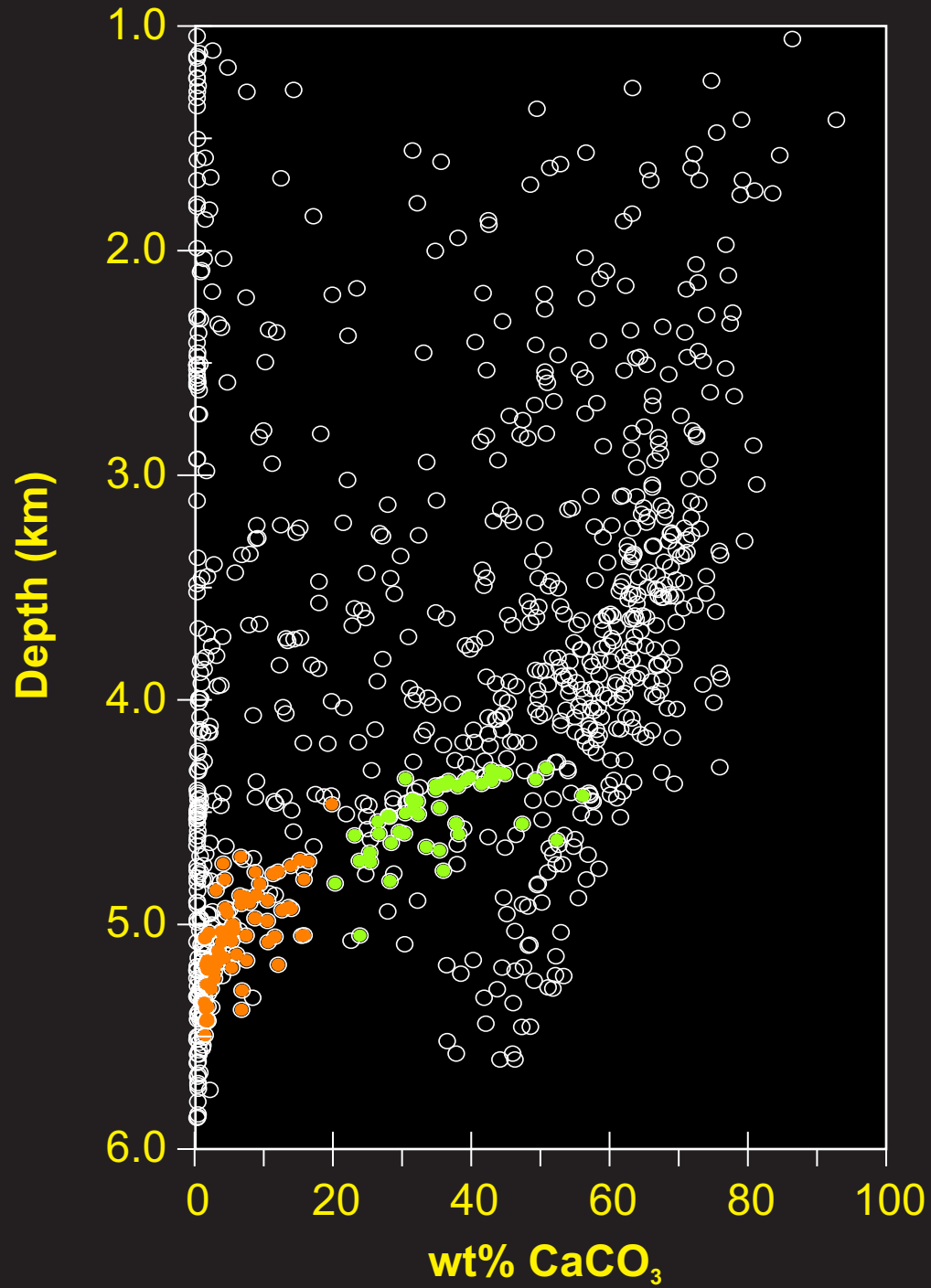
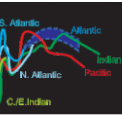


Decreasing atmospheric CO₂ and reduced 'ocean acidification'

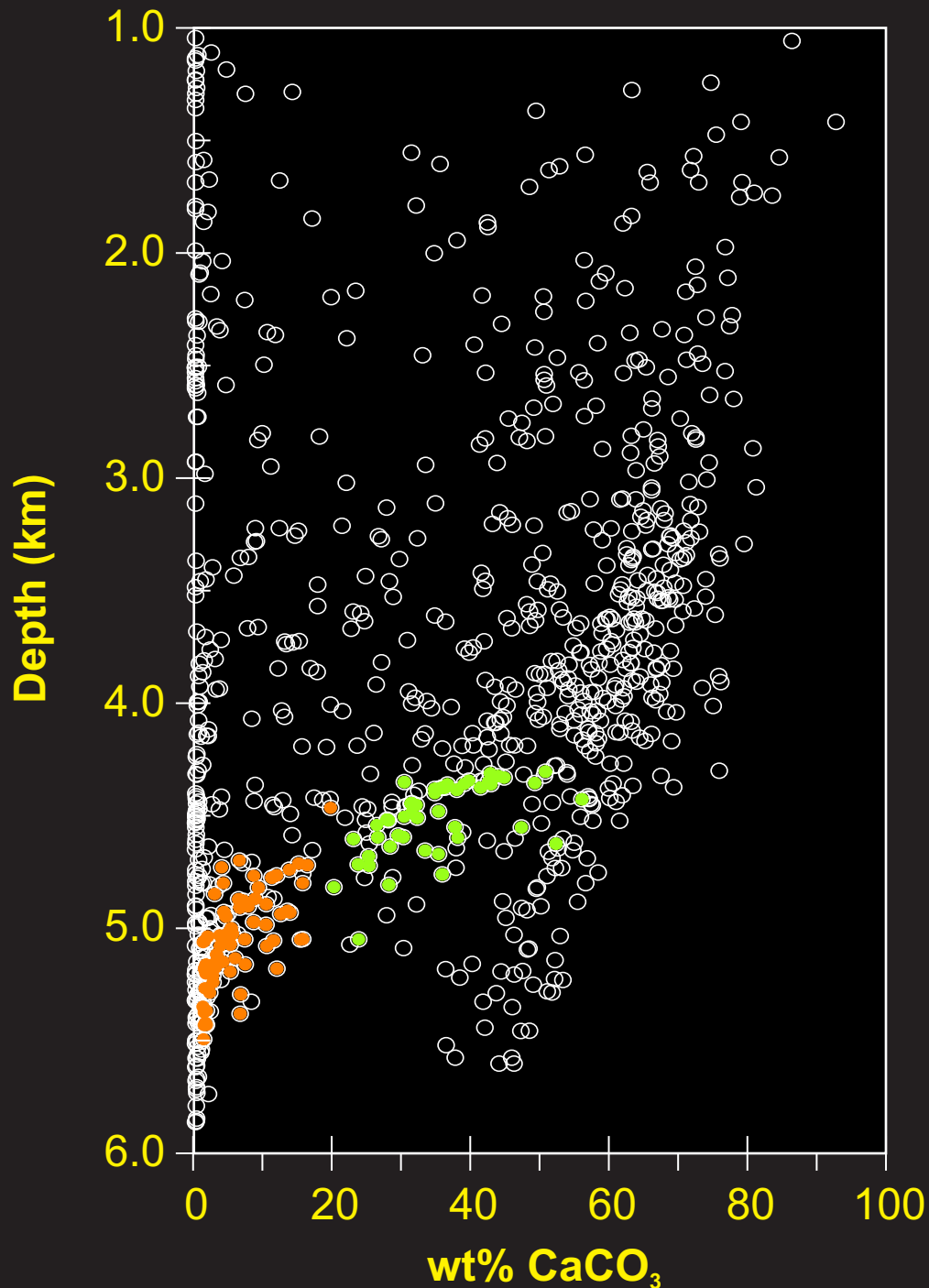
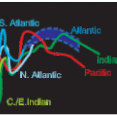
==

deeper CCD???

What is the lysocline?



What is the lysocline?

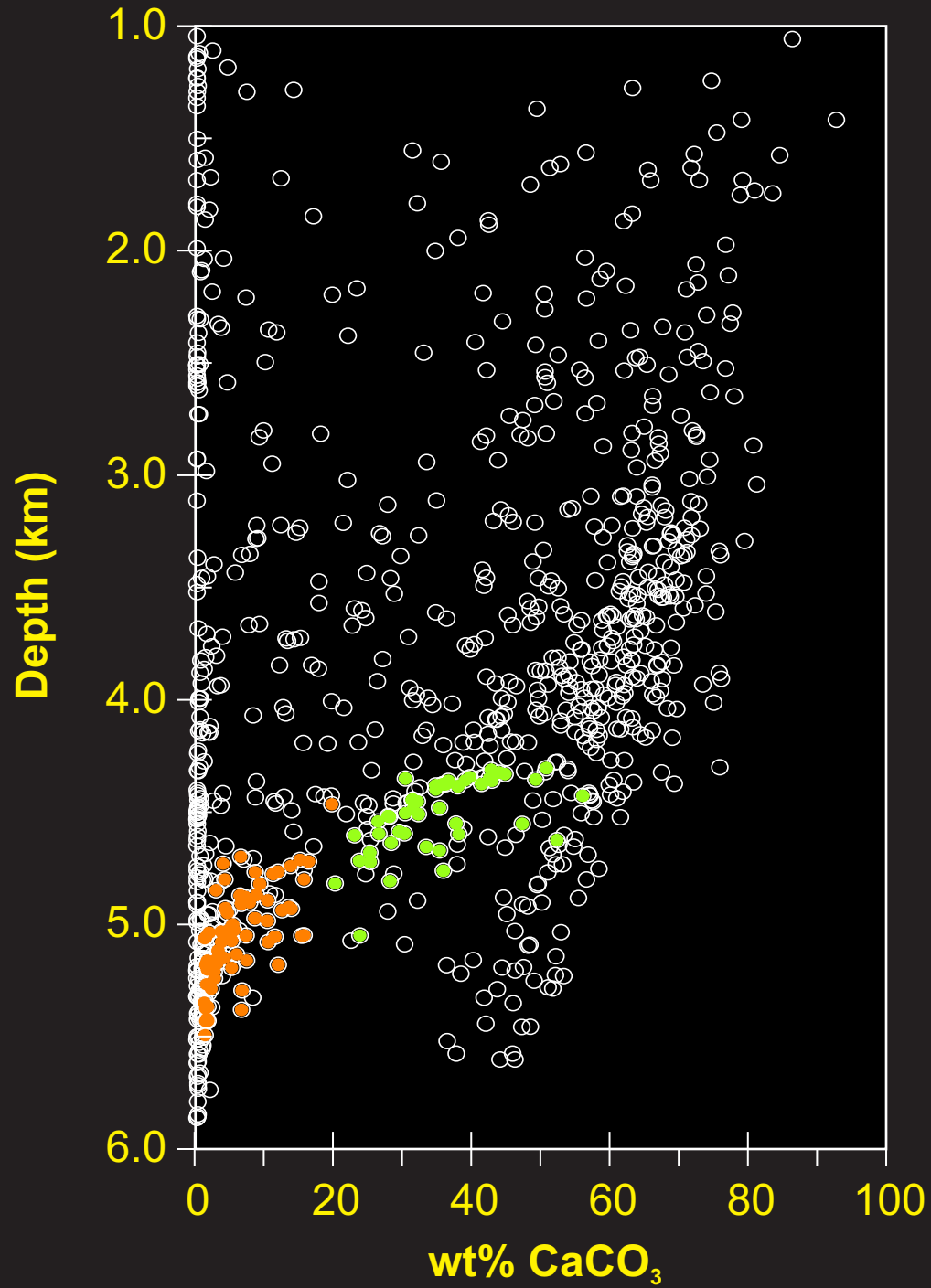
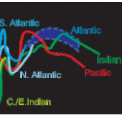


“The lysocline is the depth in the ocean below which the rate of dissolution of calcite increases dramatically.”

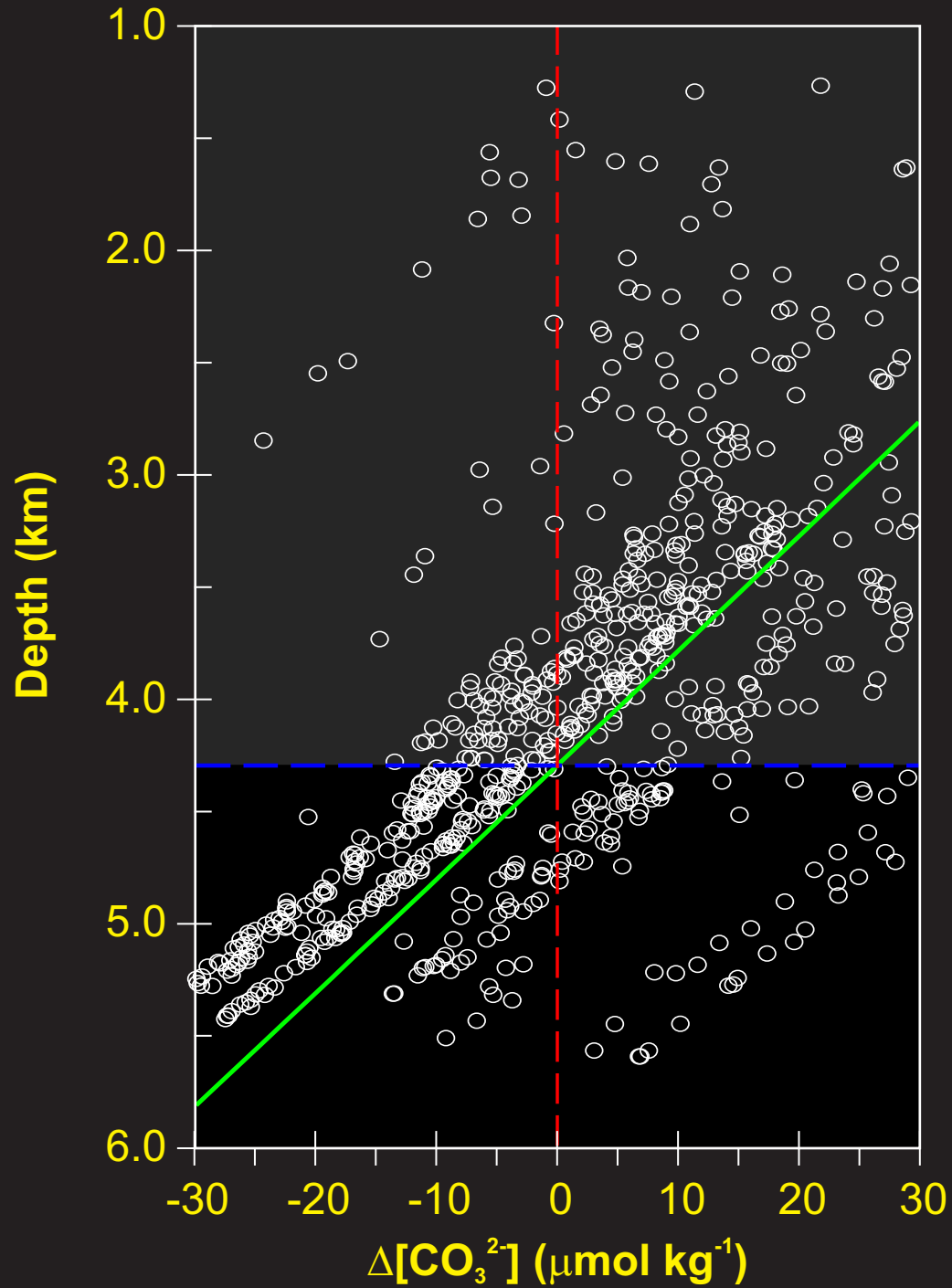
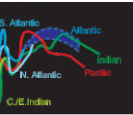
[Wikipedia]

‘a dissolving or loosening’ of [carbonate content that] ‘possesses or exhibits gradient’
[from the Greek: ‘lyso’ and ‘cline’]

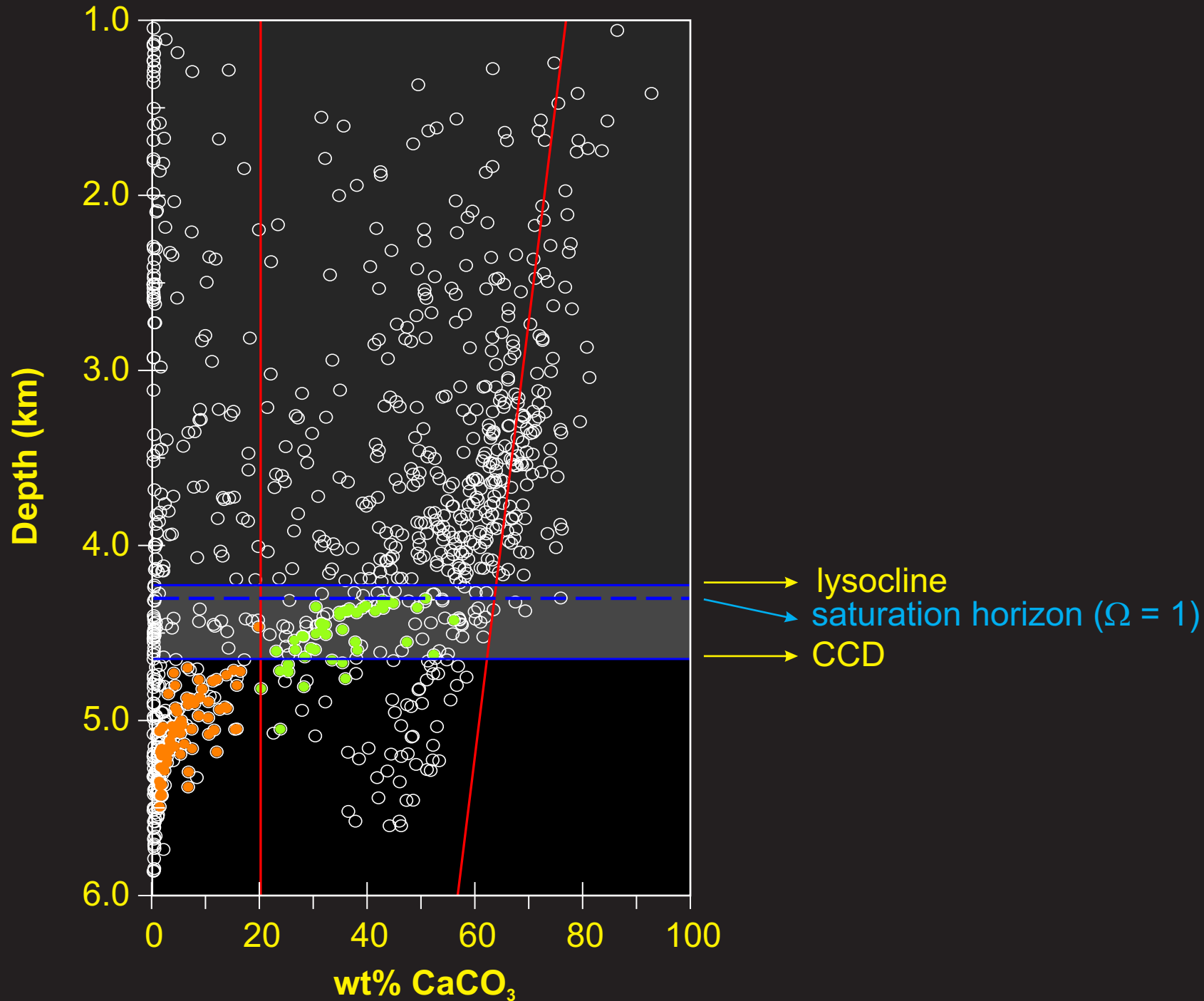
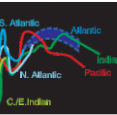
Where is the saturation horizon?



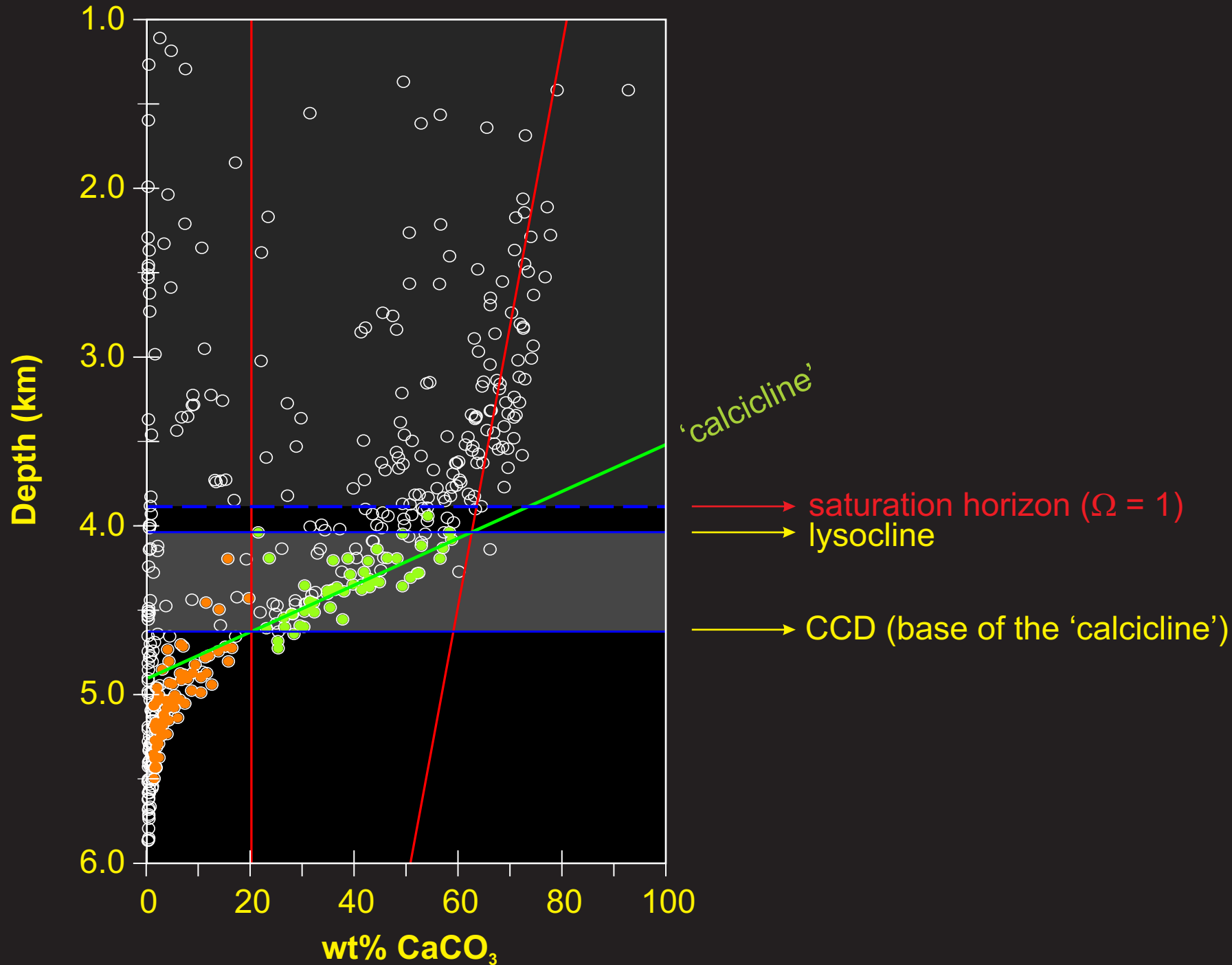
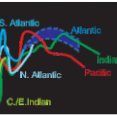
Where is the saturation horizon?



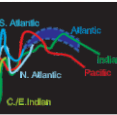
Characterizing the marine-pelagic carbonate sink



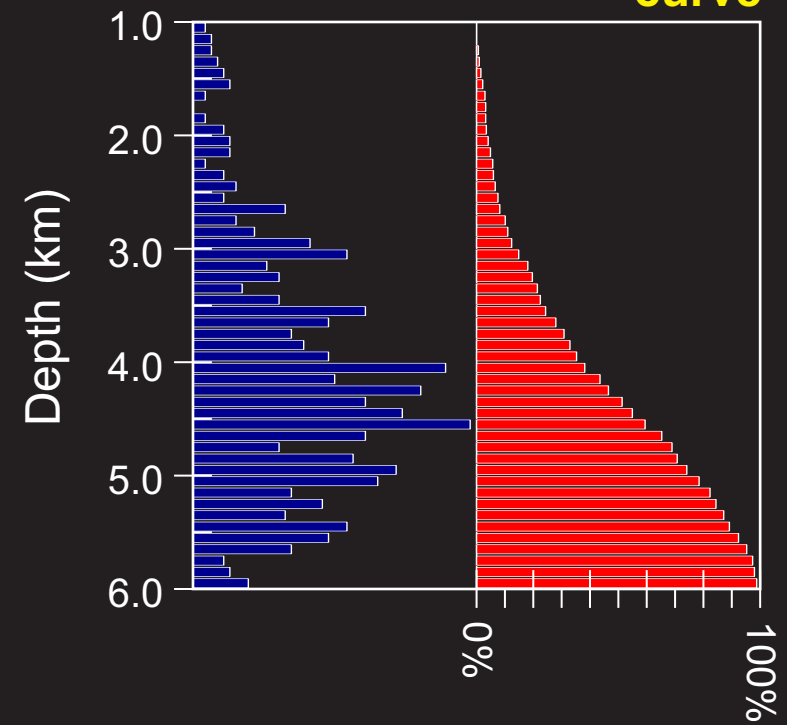
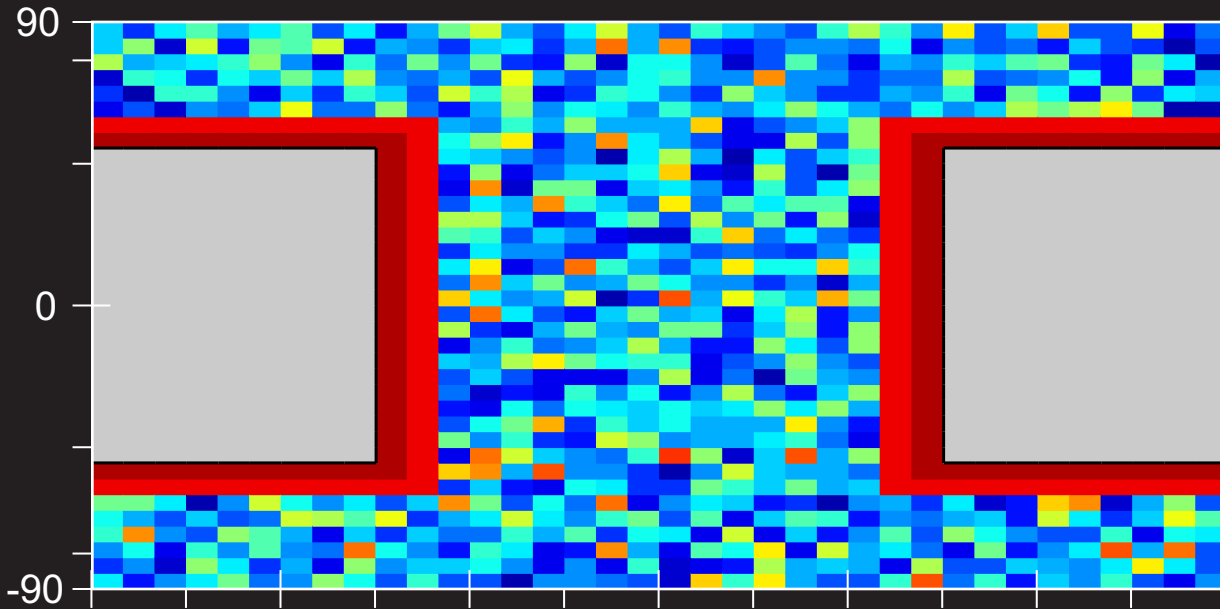
Characterizing the marine-pelagic carbonate sink



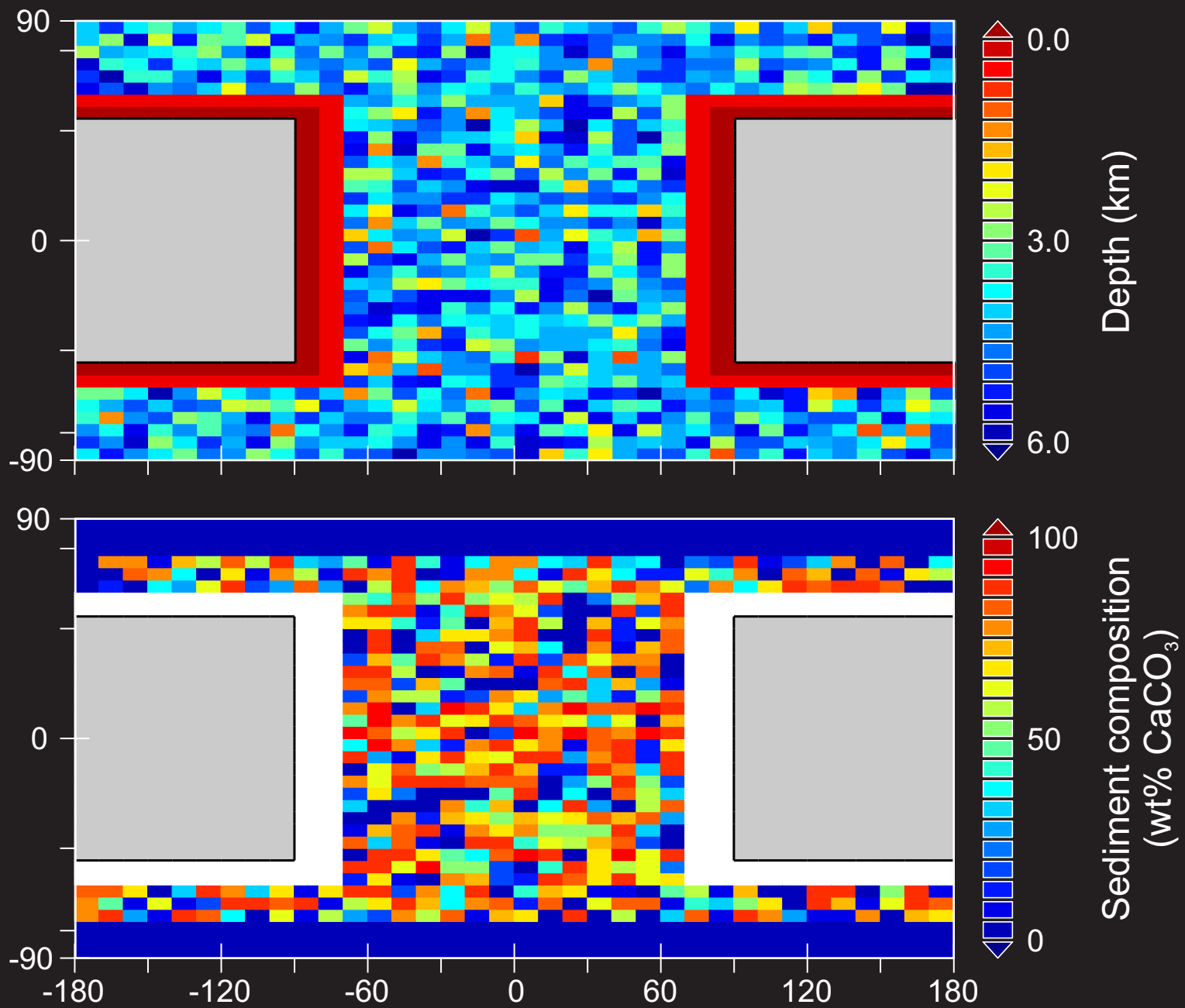
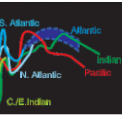
Characterizing the marine-pelagic carbonate sink [Earth 2.0]



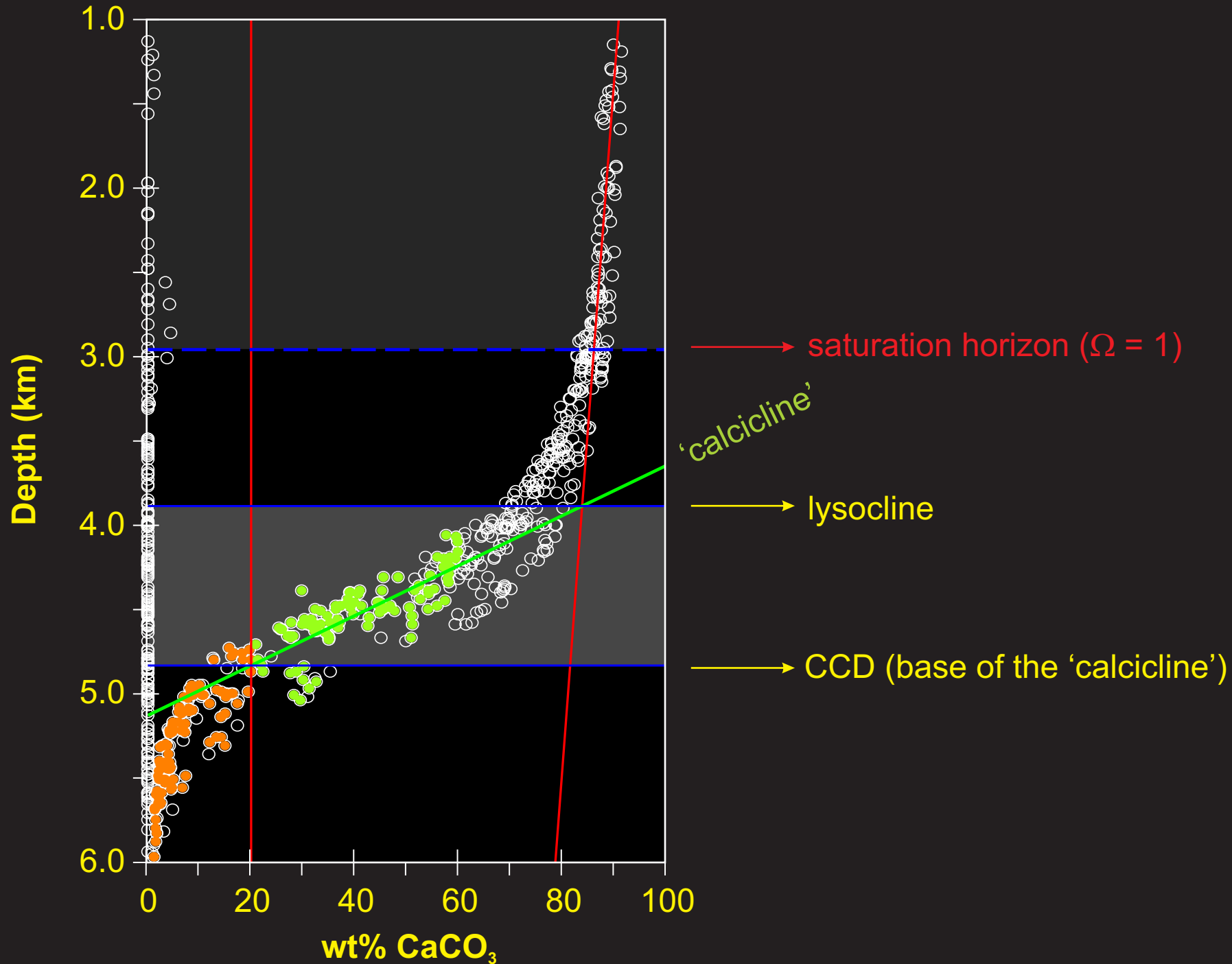
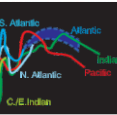
hypso-metric curve



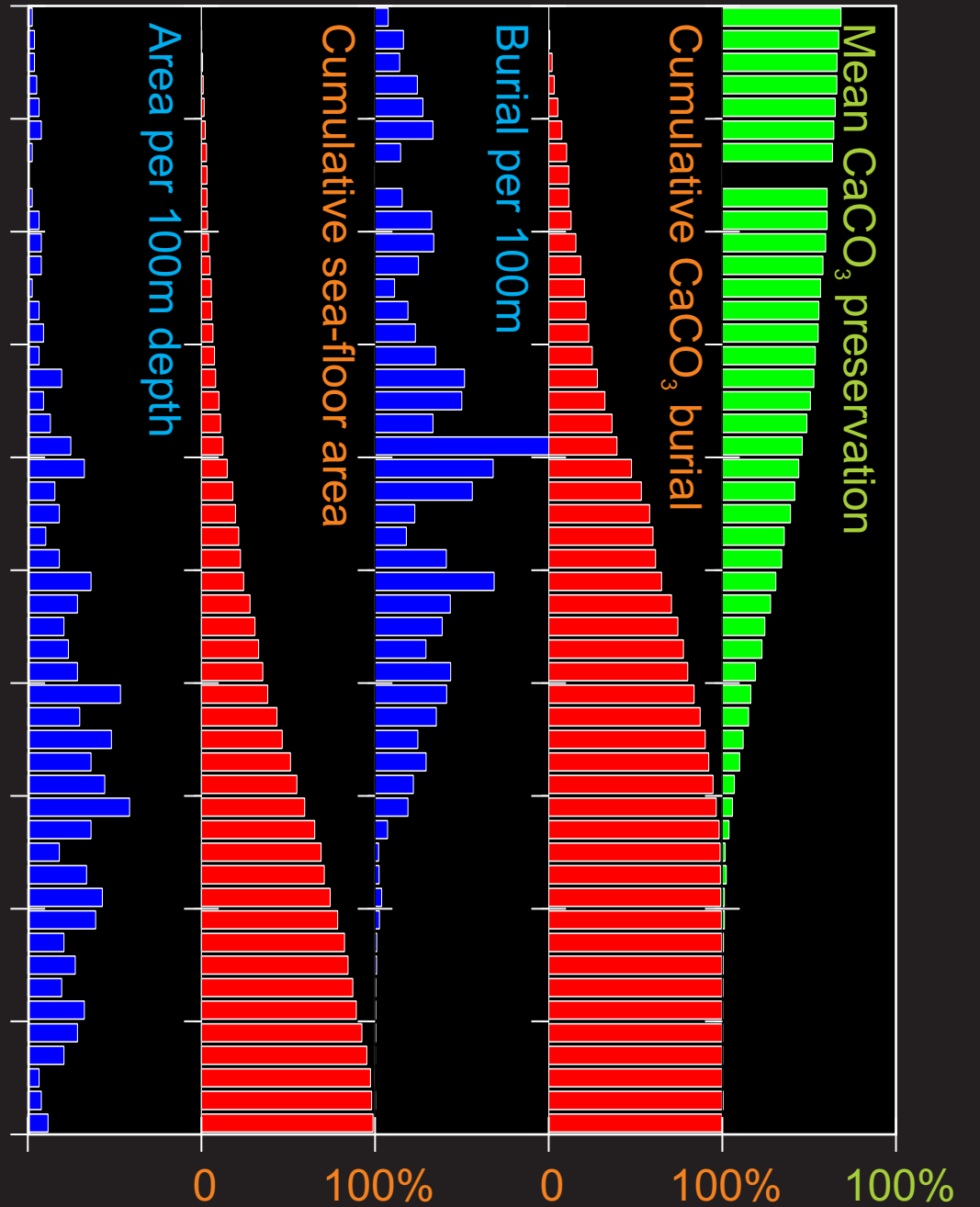
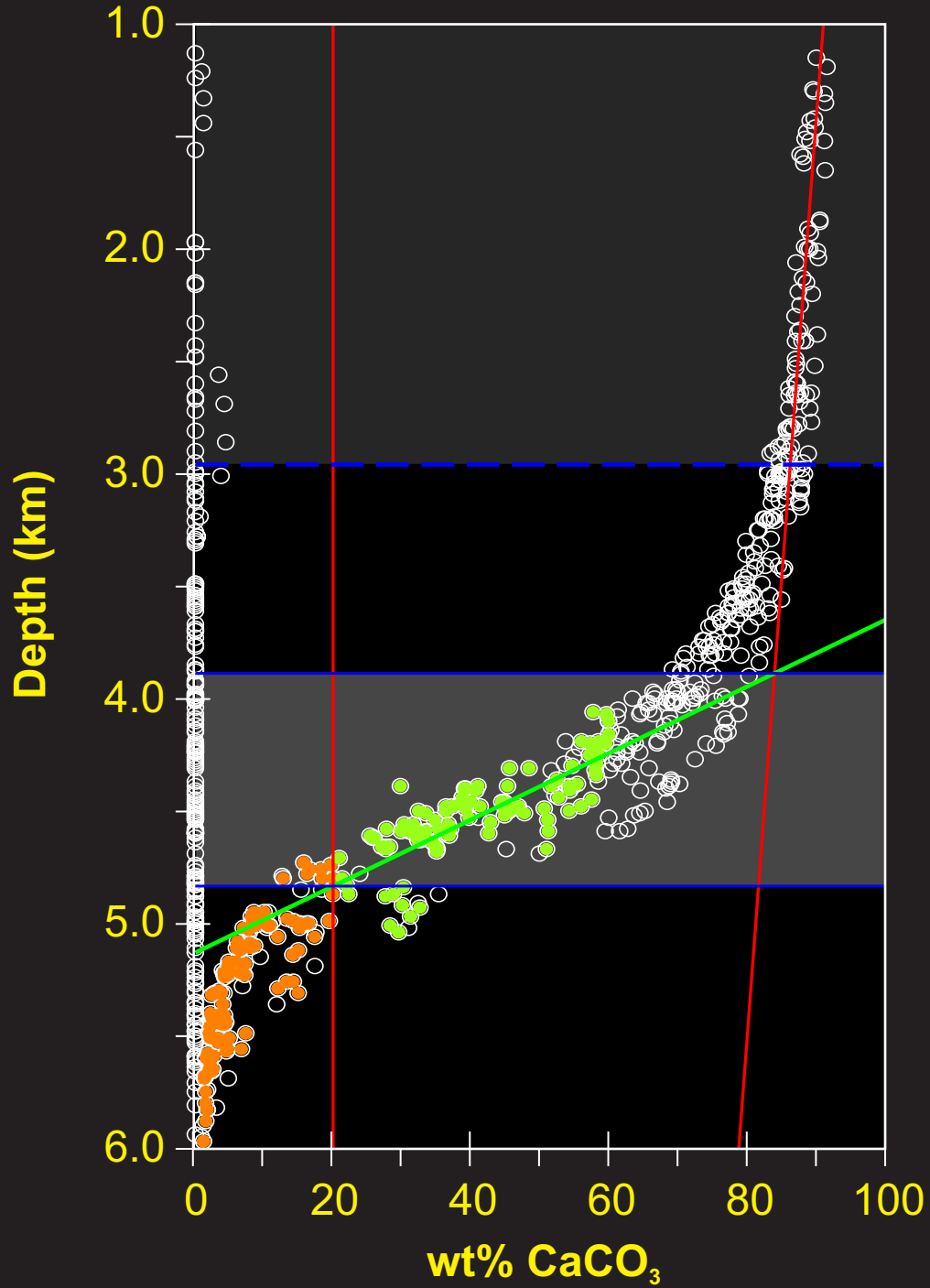
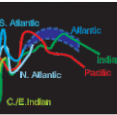
Characterizing the marine-pelagic carbonate sink [Earth 2.0]



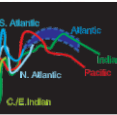
Characterizing the marine-pelagic carbonate sink [Earth 2.0]



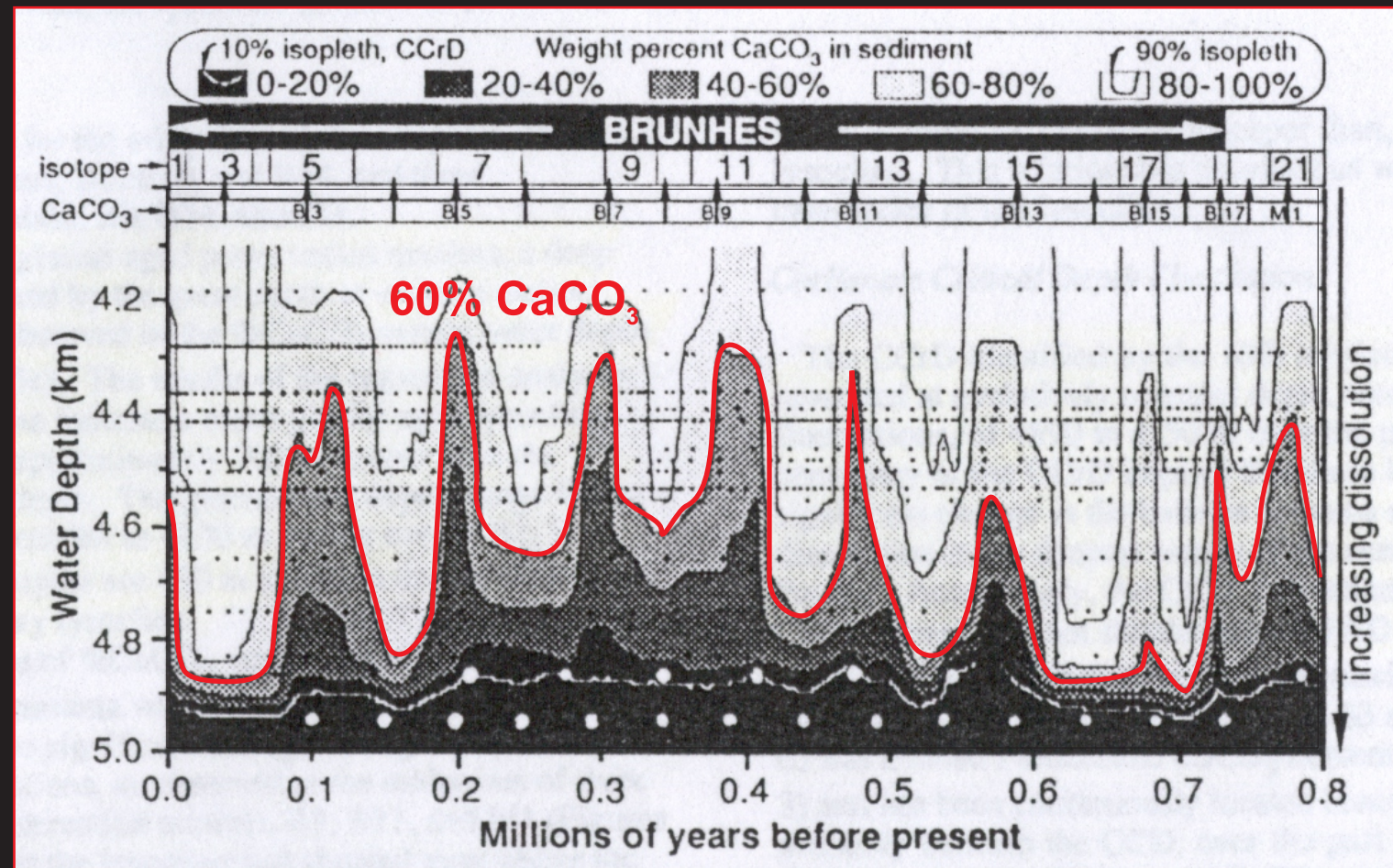
Characterizing the marine-pelagic carbonate sink [Earth 2.0]



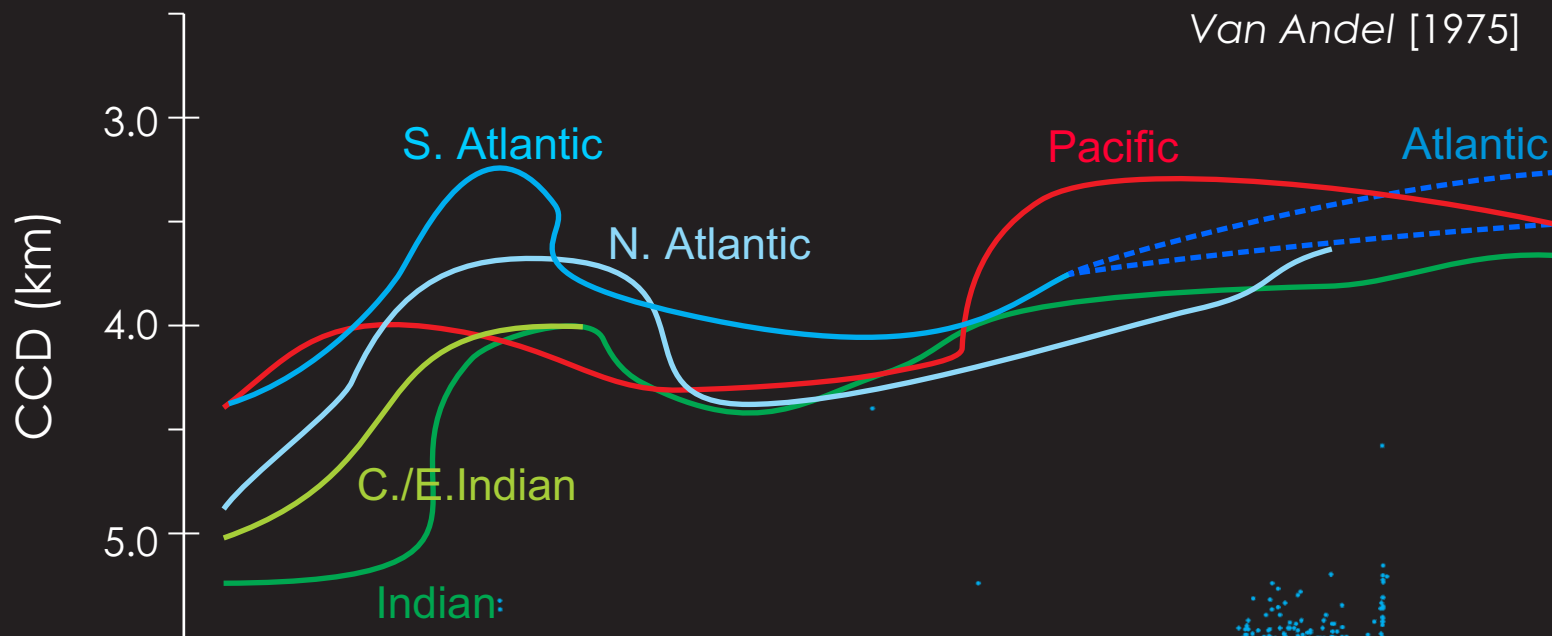
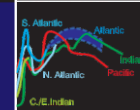
CCD variability (or not) in shallow-time



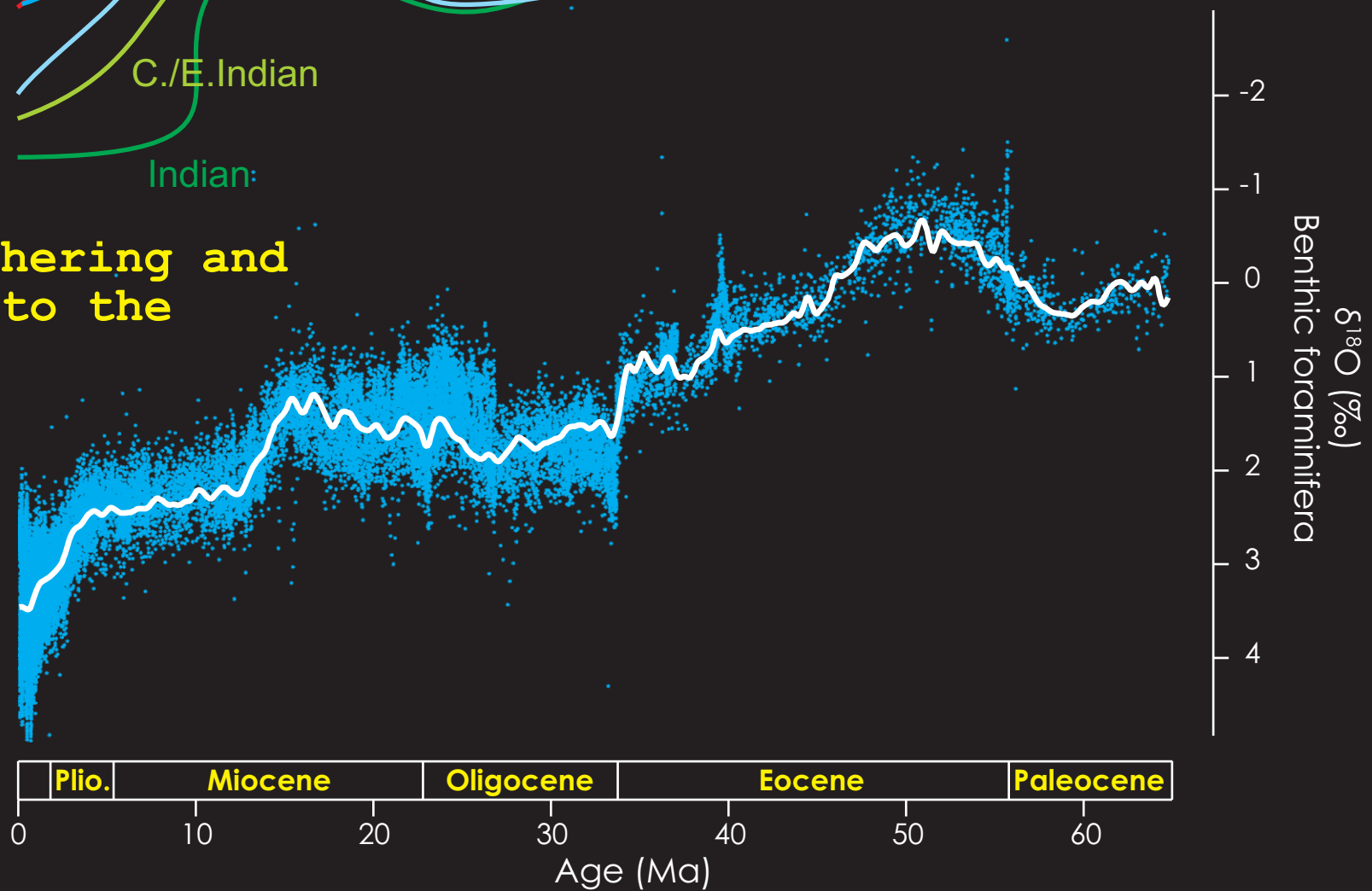
Farrell and Prell [1989]



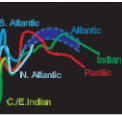
CCD variability (or not) in deep-time



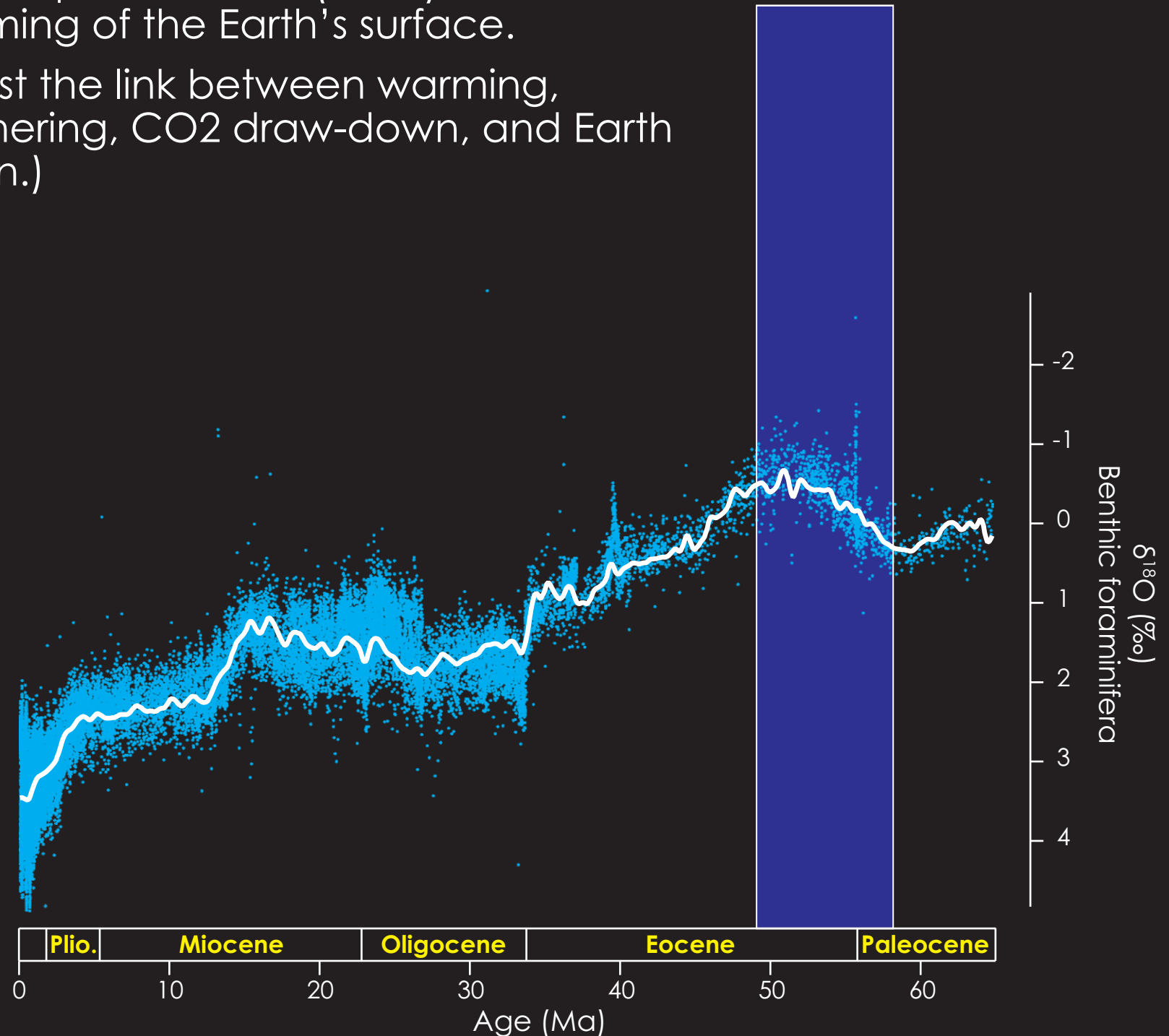
Increased weathering and solute supply to the ocean
==
deeper CCD???



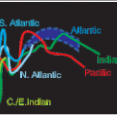
CCD variability (or not) in deep-time ('LPEE')



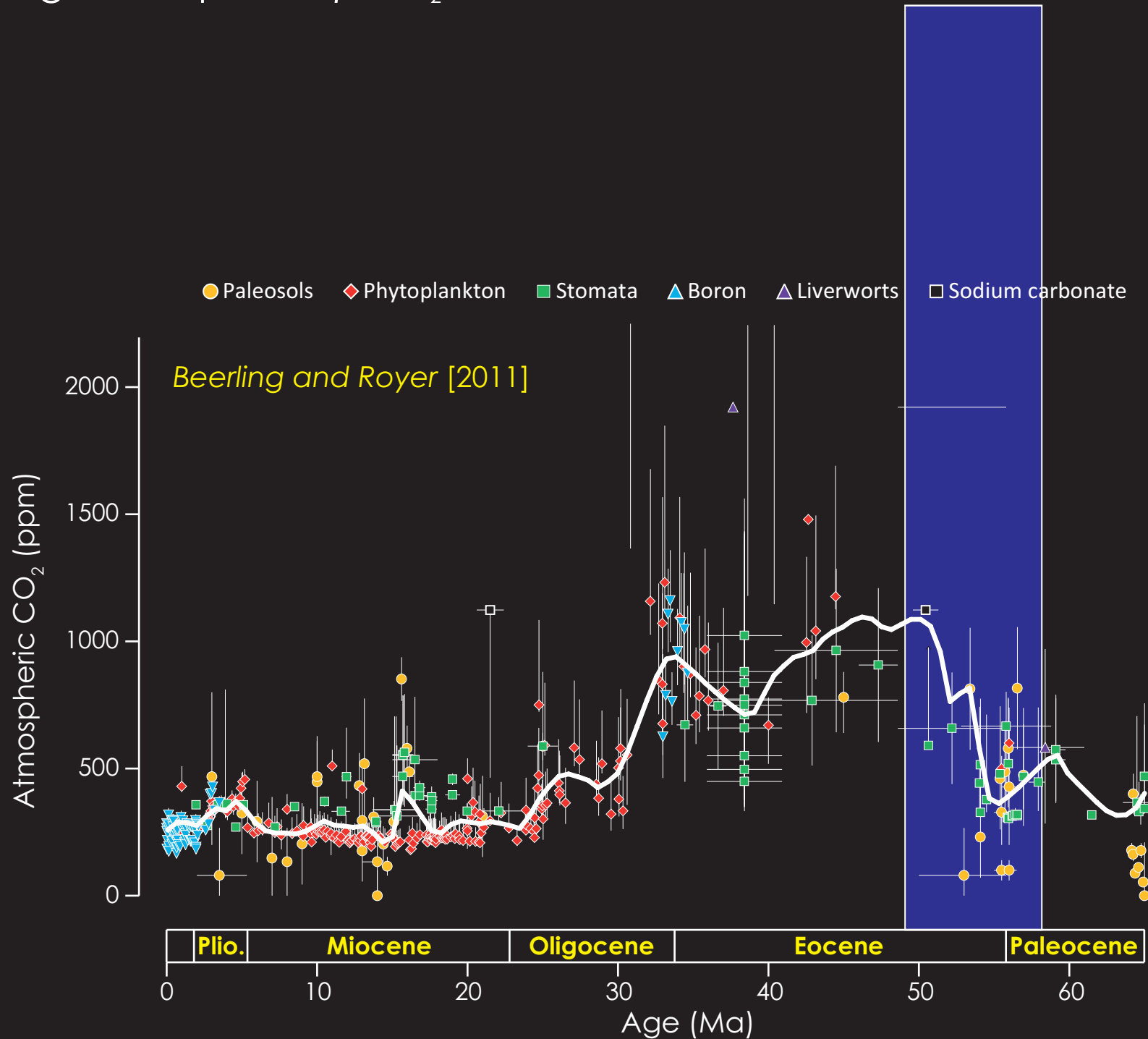
- ✓ ~9 Ma interval of pronounced (~4°C) and progressive warming of the Earth's surface.
- ✓ (We want to test the link between warming, increased weathering, CO₂ draw-down, and Earth system regulation.)



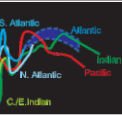
CCD variability (or not) in deep-time ('LPEE')



✓ Increasing atmospheric $p\text{CO}_2$.

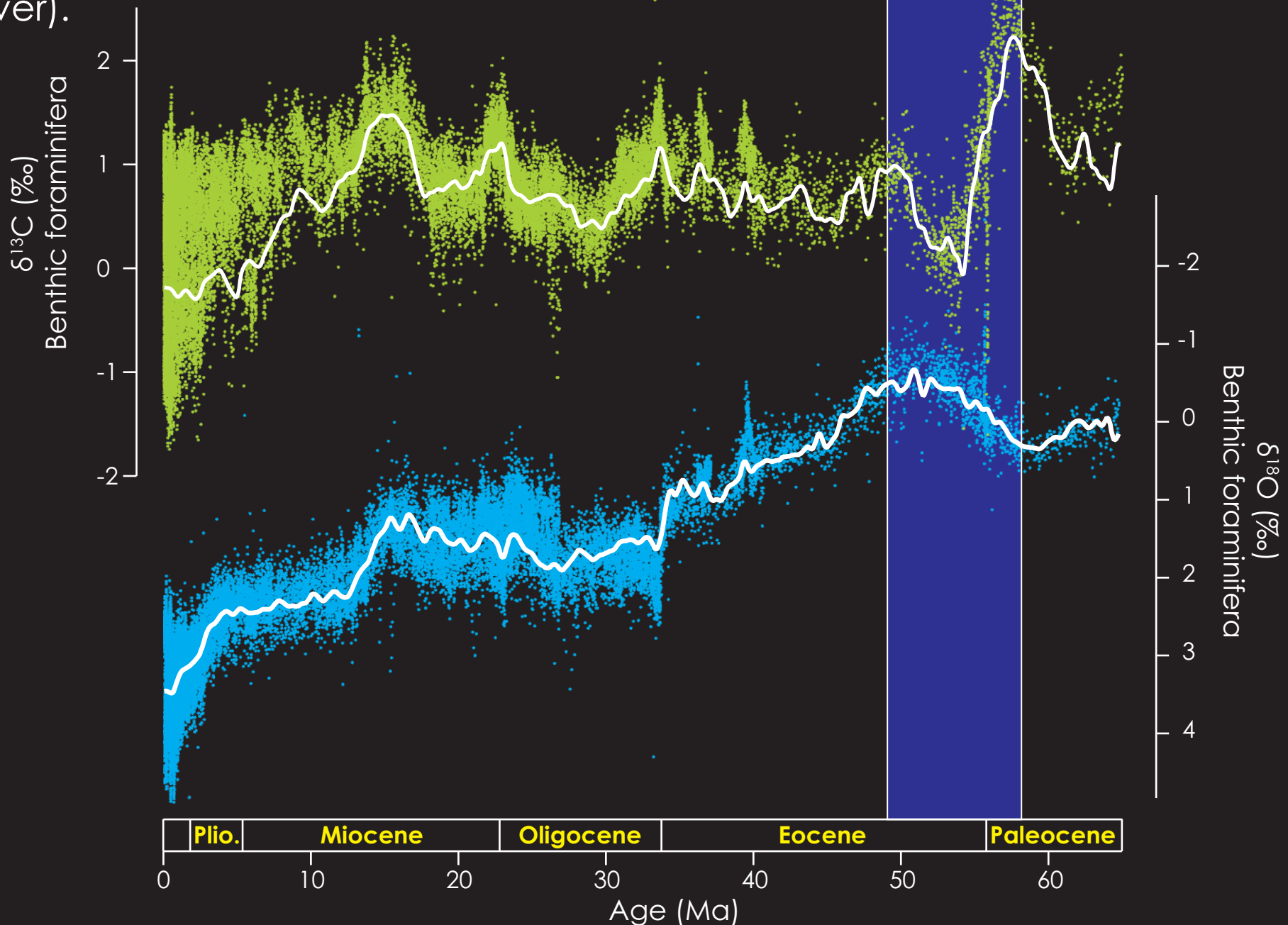


CCD variability (or not) in deep-time ('LPEE')

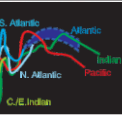


✓ Mostly ... characterized by declining $\delta^{13}\text{C}$ values, consistent with net input of isotopically light carbon (if we take a hypothesis of increased volcanic CO_2 input as the driver).

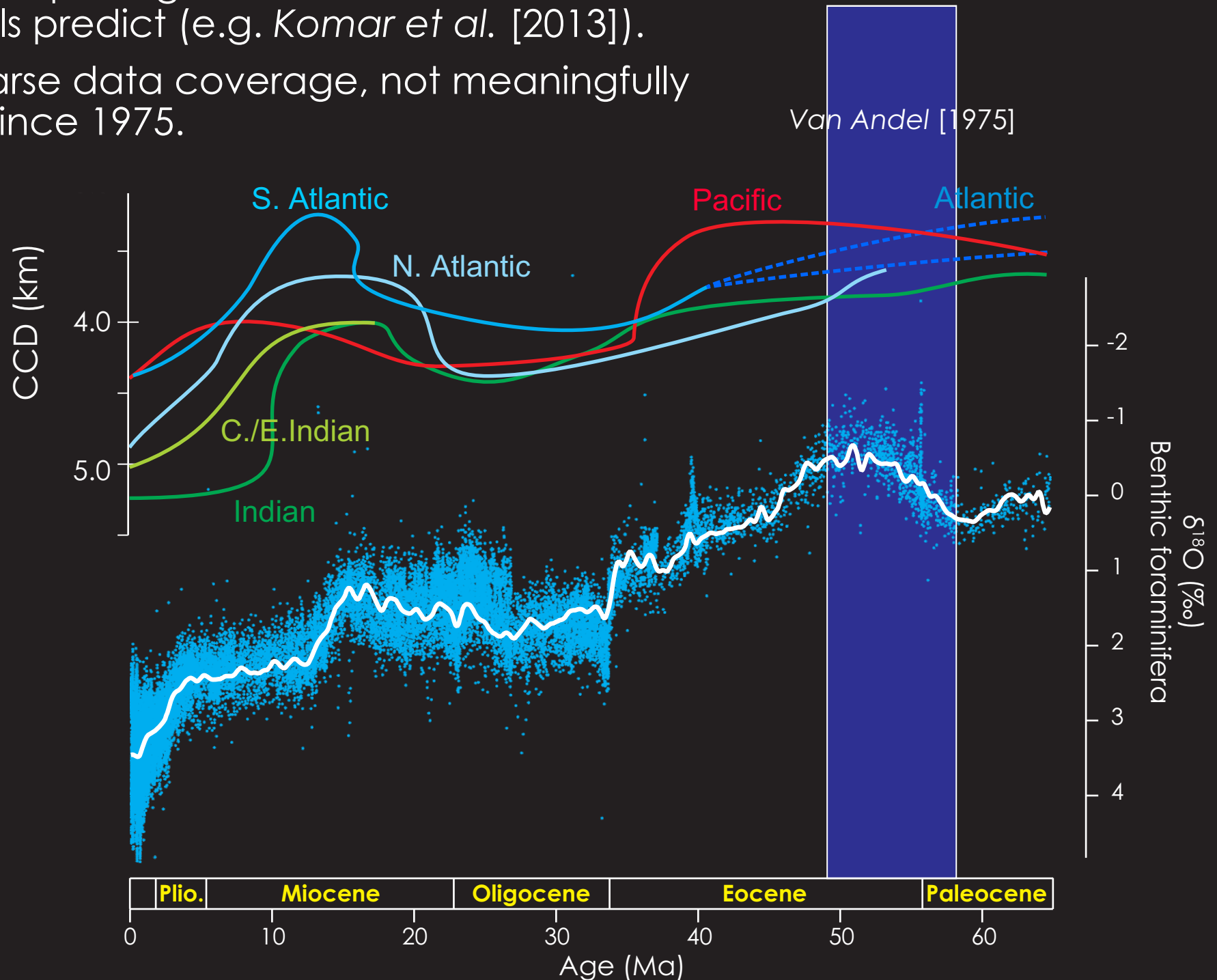
Cramer et al. [2009]



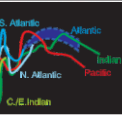
CCD variability (or not) in deep-time ('LPEE')



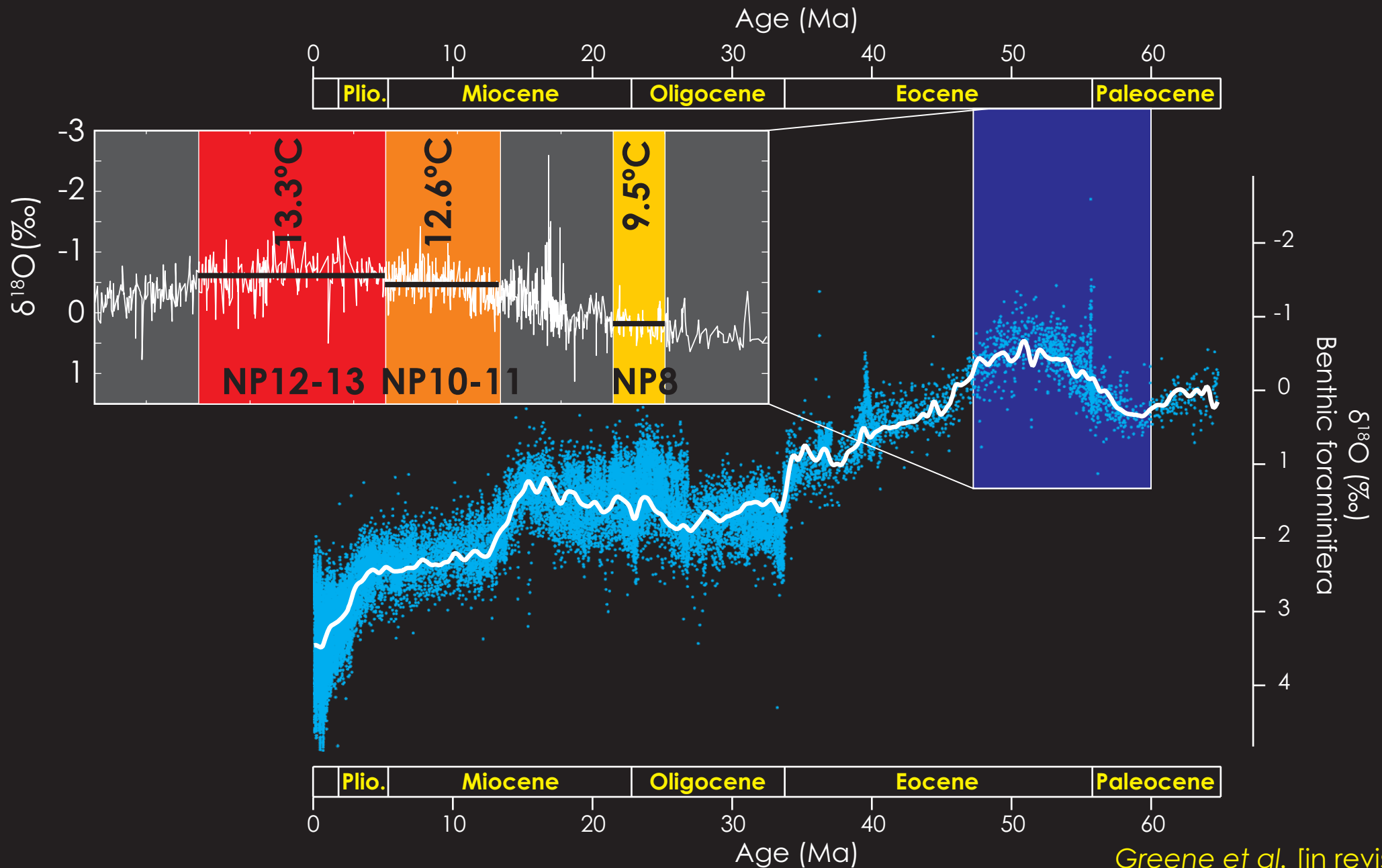
- ✗ Slightly deepening CCD ... but much less than box models predict (e.g. Komar *et al.* [2013]).
- ✗ Very sparse data coverage, not meaningfully updated since 1975.



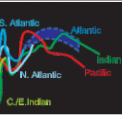
CCD variability (or not) in deep-time ('LPEE')



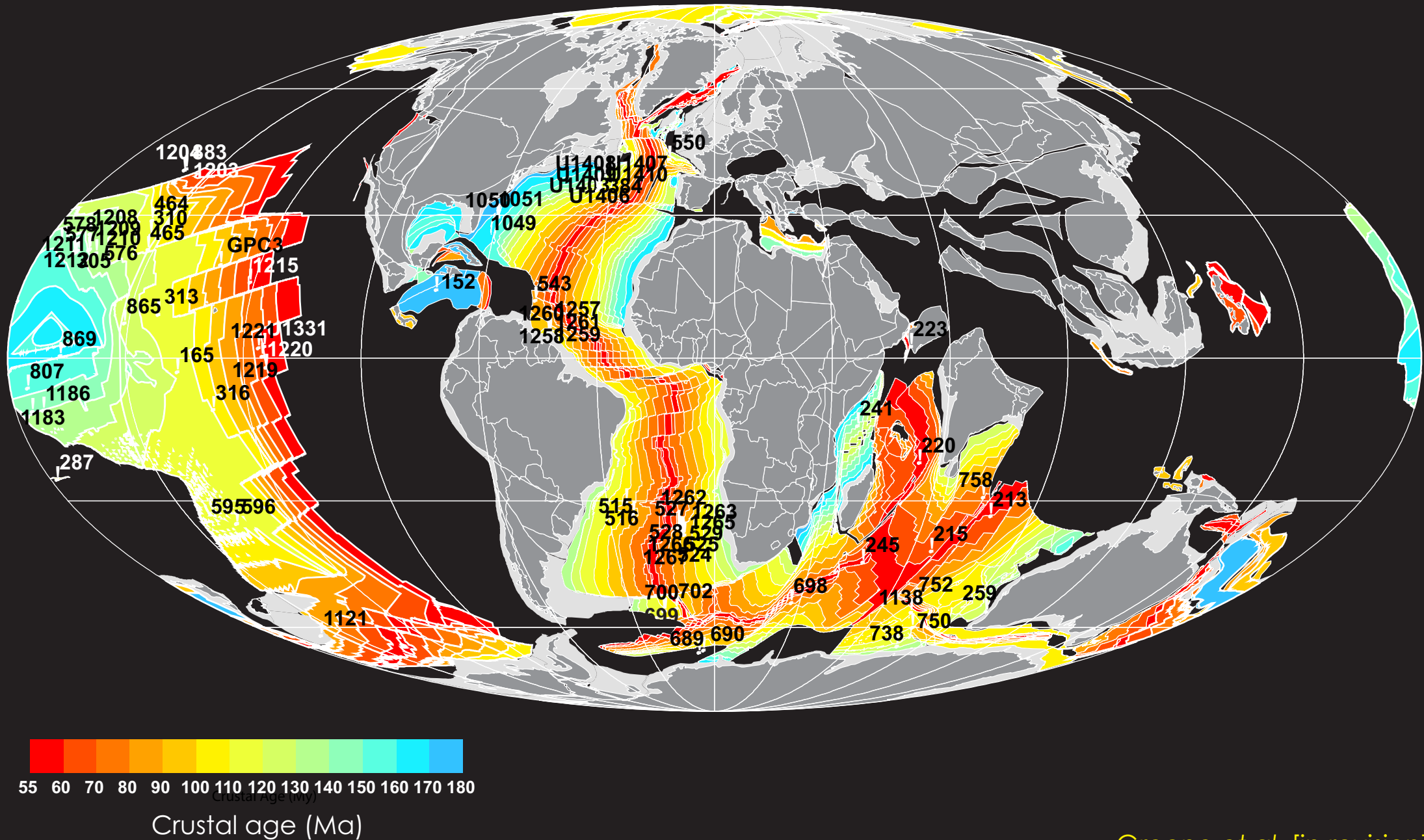
Three data slices spanning LPEE interval (and avoiding PETM).



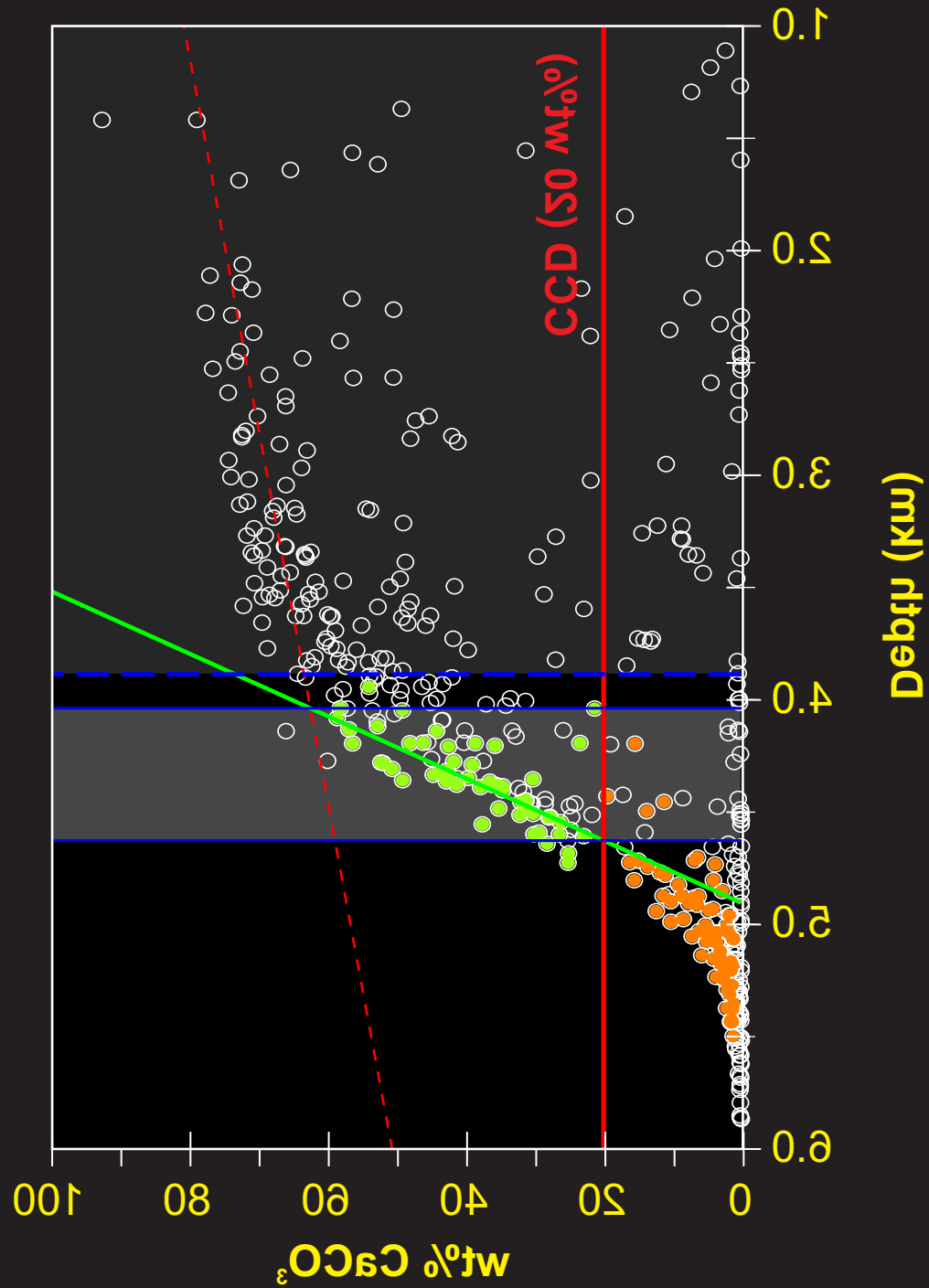
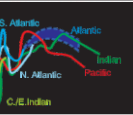
CCD variability (or not) in deep-time ('LPEE')



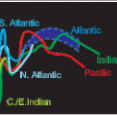
Site distribution (and existing crust older than 55 Ma).



CCD variability (or not) in deep-time ('LPEE')



CCD variability (or not) in deep-time ('LPEE')



'CCD' plots.

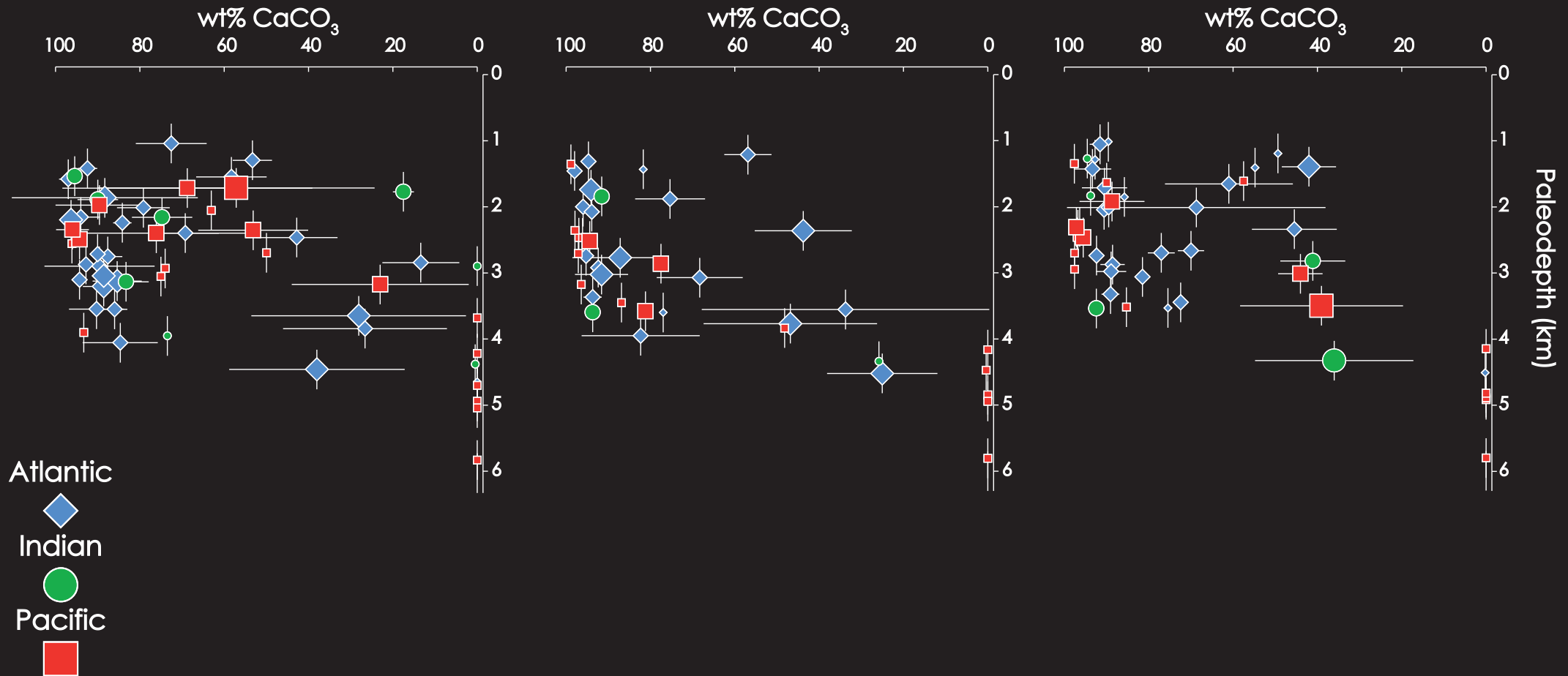
H_0 : warming (\Rightarrow increasing weathering?)



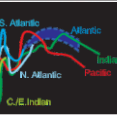
NP12-13 (~53-49 Ma)

NP10-11 (~55-53 Ma)

NP8 (~58-57 Ma)



CCD variability (or not) in deep-time ('LPEE')



'CCD' plots.

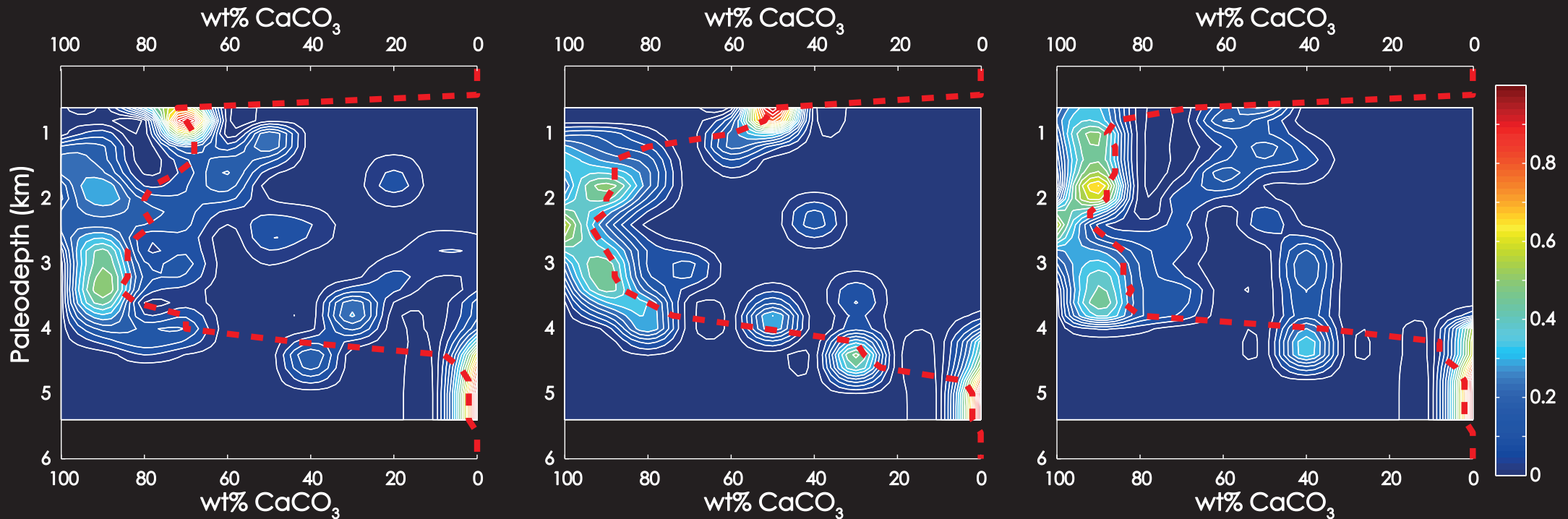
H_0 : warming (\Rightarrow increasing weathering?)



NP12-13 (~53-49 Ma)

NP10-11 (~55-53 Ma)

NP8 (~58-57 Ma)



Contours are of relative data density within a sliding time-window (and wt% bin).
Red contour delineates 50% of the data.

increased CO₂ out-gassing
=> higher atm pCO₂ and weathering @ steady state



~3x
pre-industrial
pCO₂

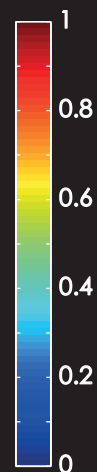
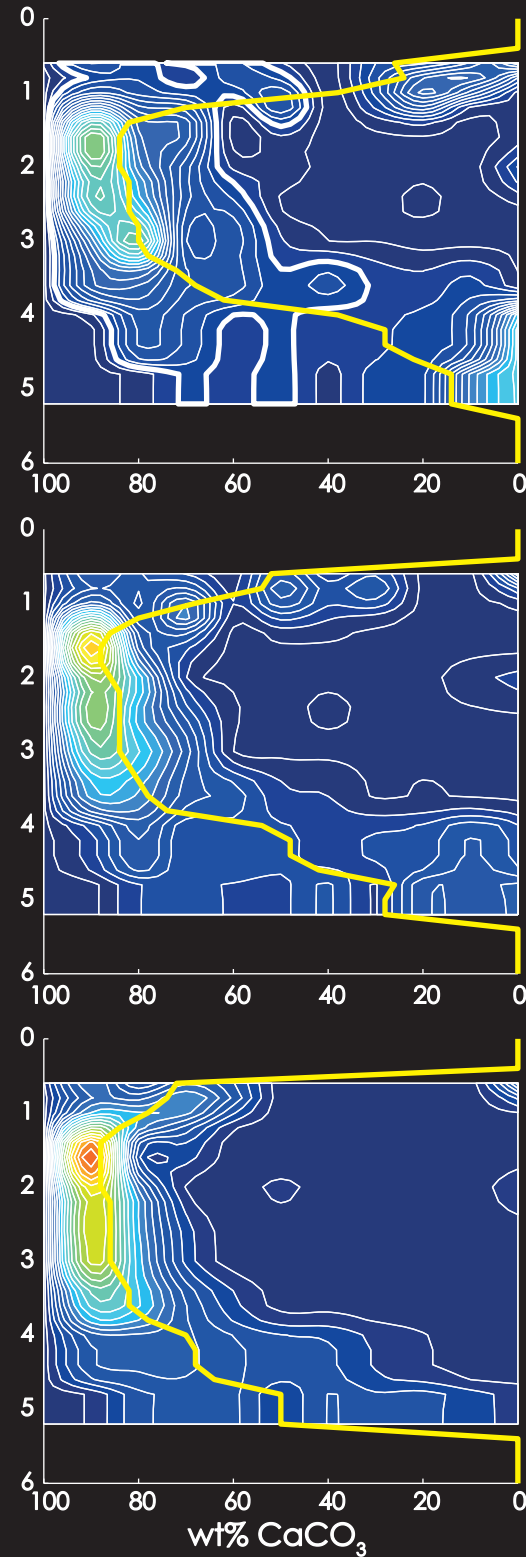
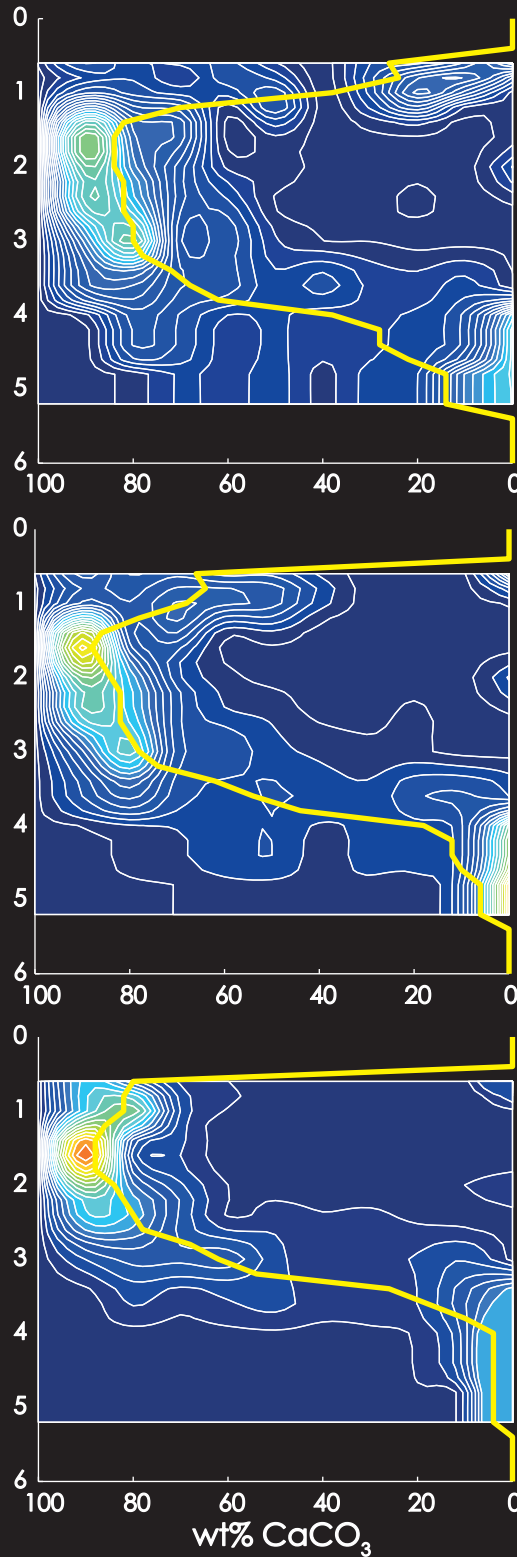
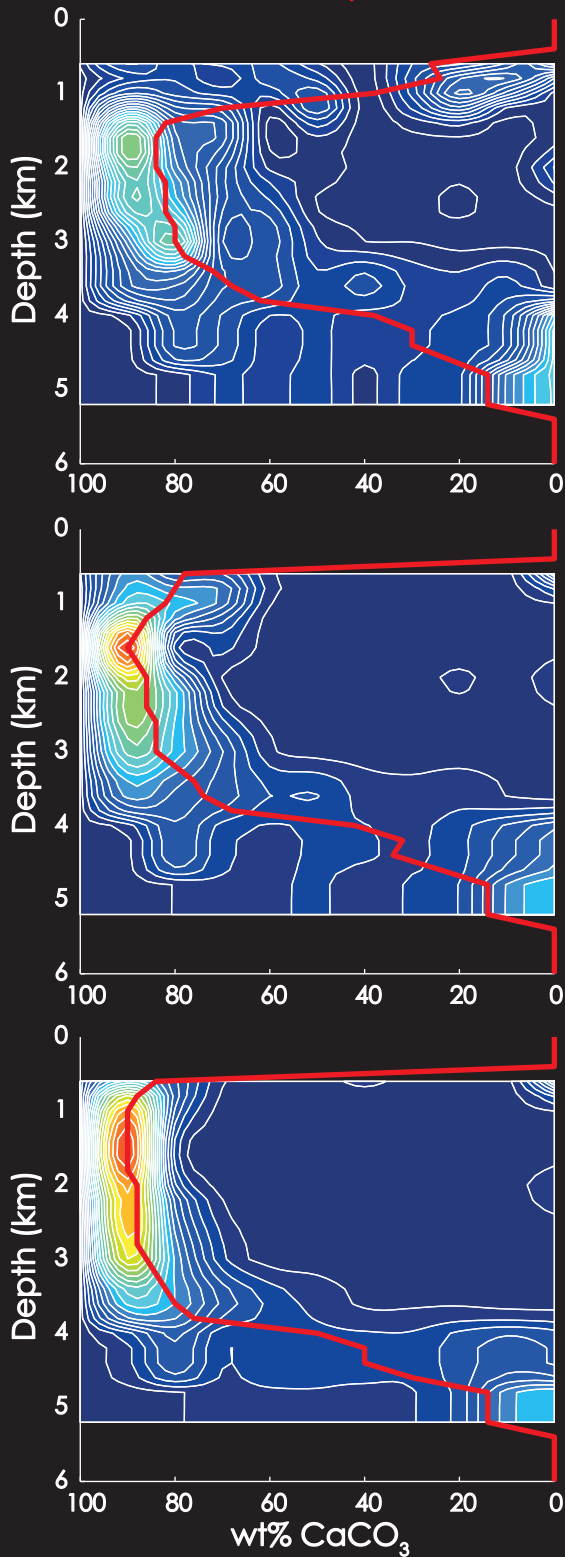
~6x
pre-industrial
pCO₂

~12x
pre-industrial
pCO₂

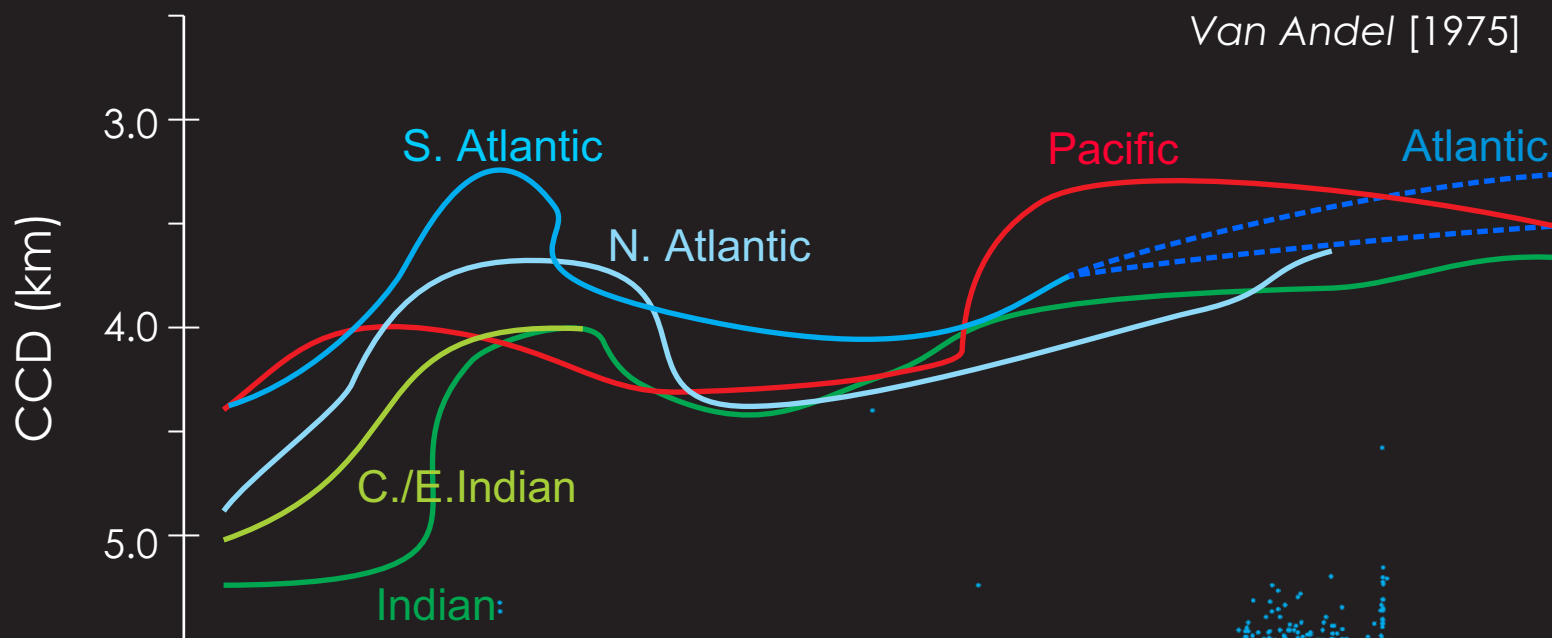
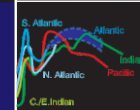
variable pCO₂

only [DIC]&[ALK] vary

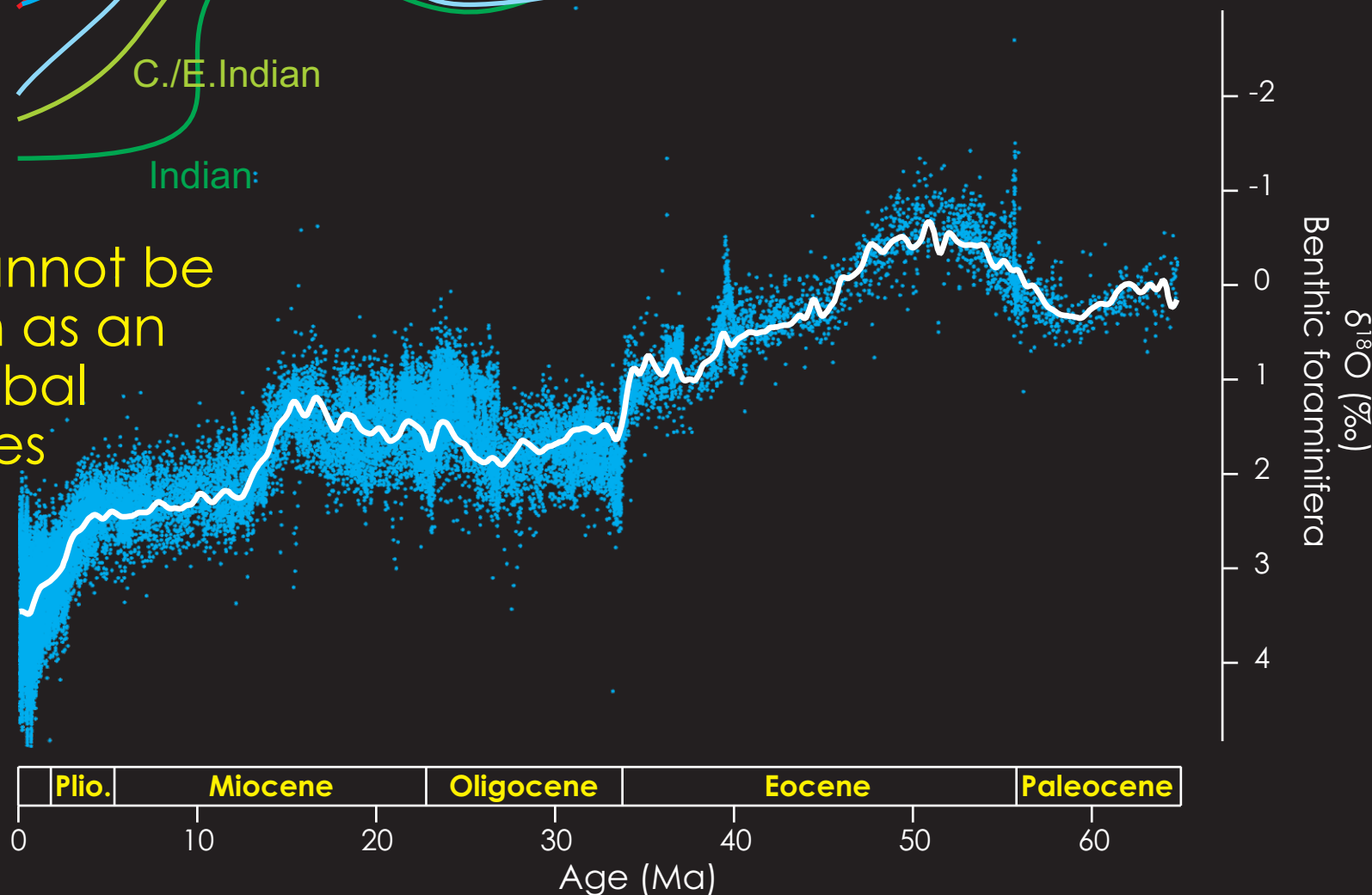
only Temp. & Circulation vary



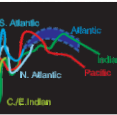
CCD variability (or not) in deep-time ('LPEE')



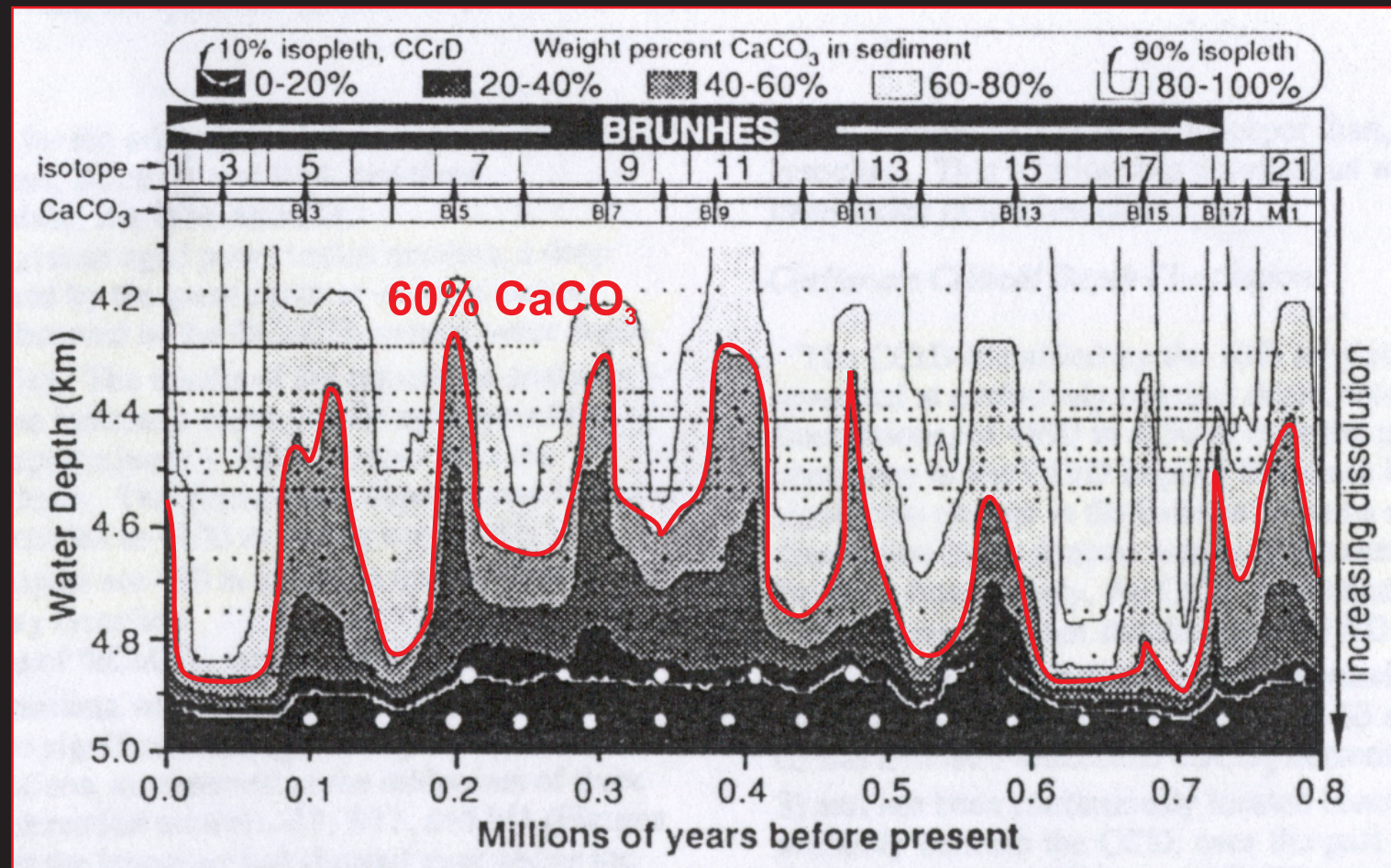
=> The CCD cannot be used on its own as an indicator of global weathering rates or climate
#deadproxy



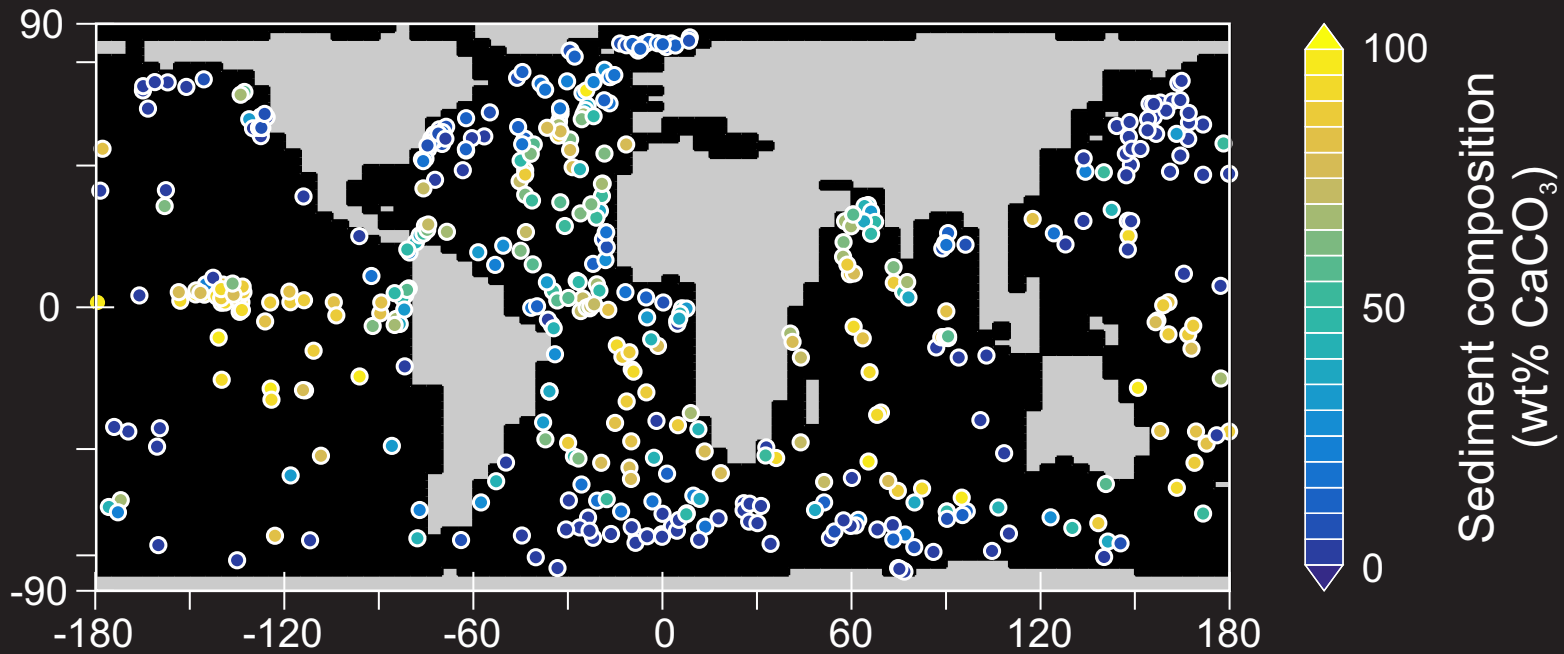
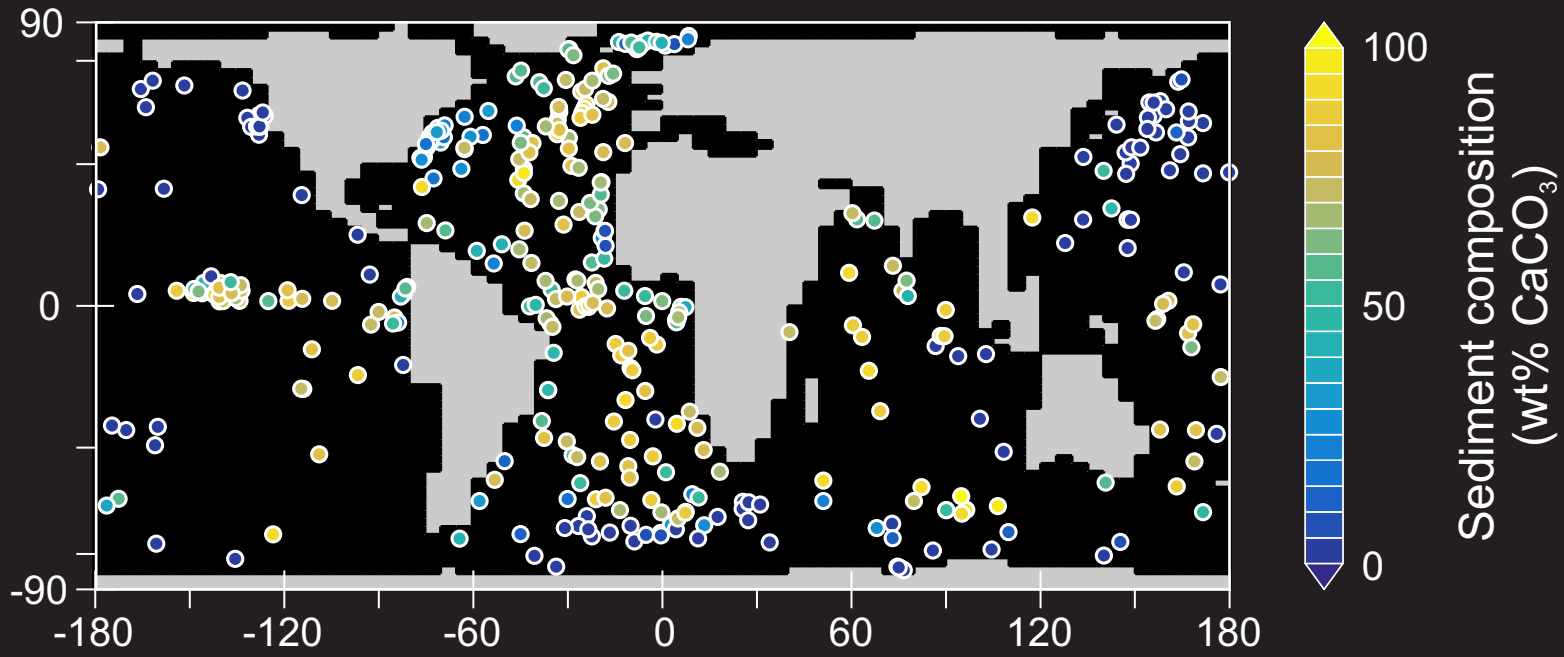
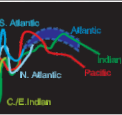
'Conclusions'

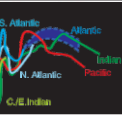


Farrell and Prell [1989]



'Conclusions'





Sarah Greene, Daniela Schmidt [Bristol]
Sandy Kirtland Turner [UCR]
Ellen Thomas [Yale]
Heiko Pälike [Bremen]

The Royal Society
Natural Environmental Research Council

