Chapter 9
Insolation control of monsoons

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Introduction

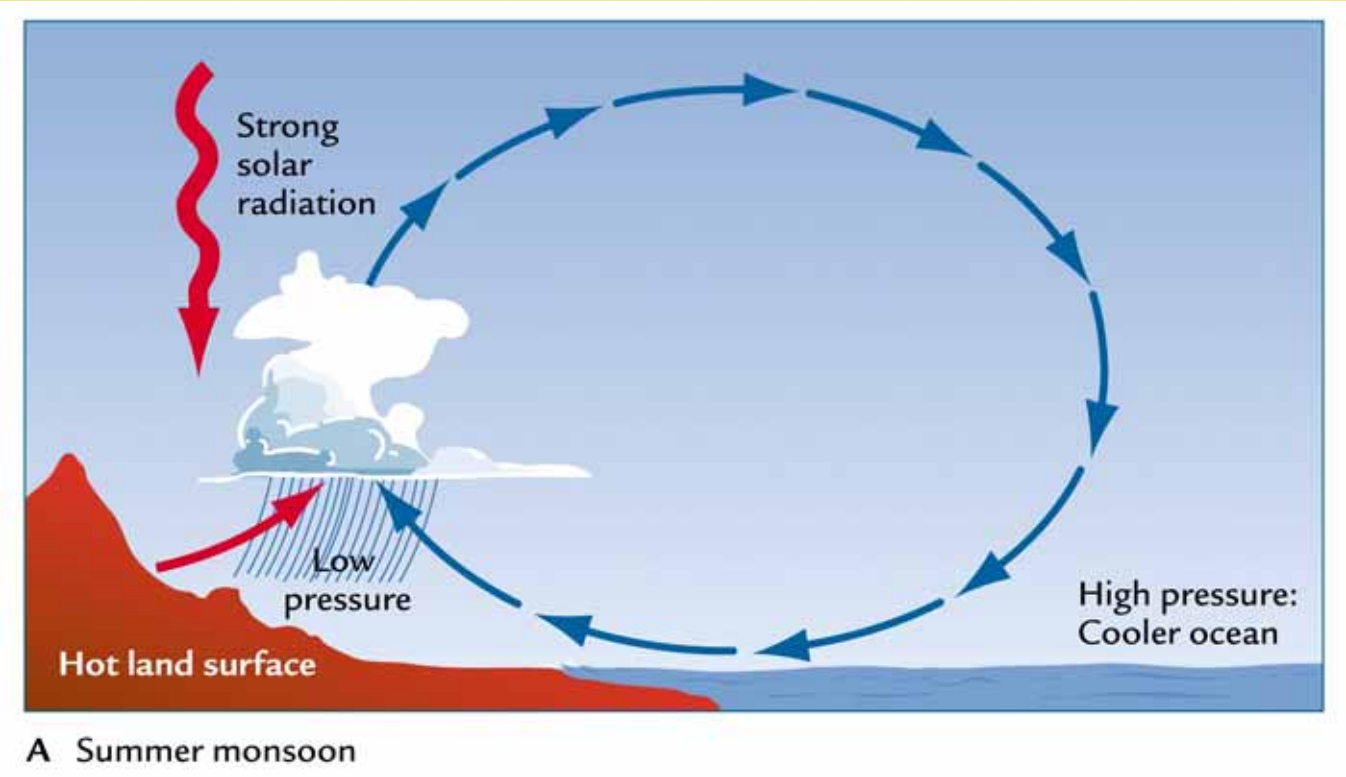
- Monsoon circulations exist on Earth today because the land responds to seasonal changes in solar radiation much more quickly than does the ocean.

- Examine evidence that changers in insolation over orbital time scales have driven major changes in the strength of the summer monsoons

Monsoon Circulation

- Seasonal changes in the strength of solar radiation affect the surface of the land more then ocean
- Heat capacity
  - Land << Ocean

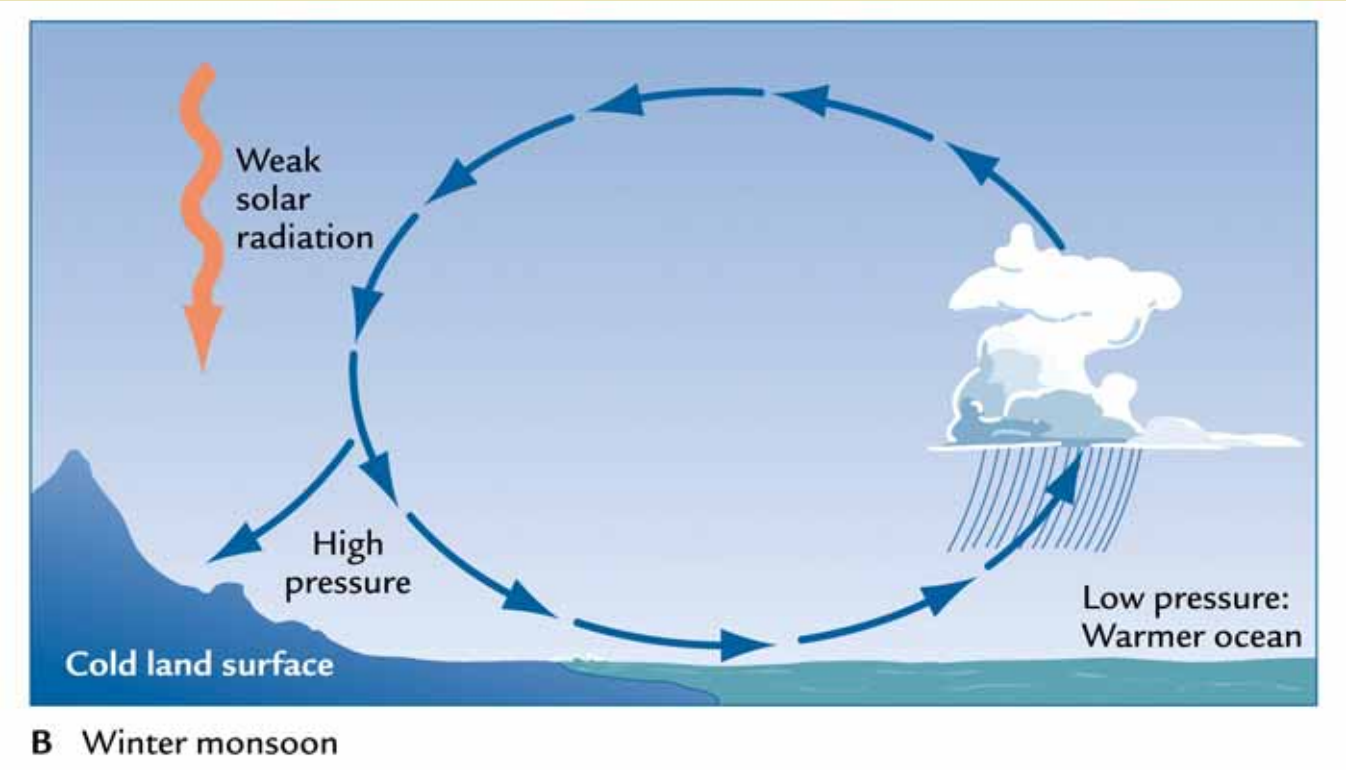
Summer monsoon



A Summer monsoon

- Intense solar heating of the land causes an in-and-up circulation of moist air form the ocean

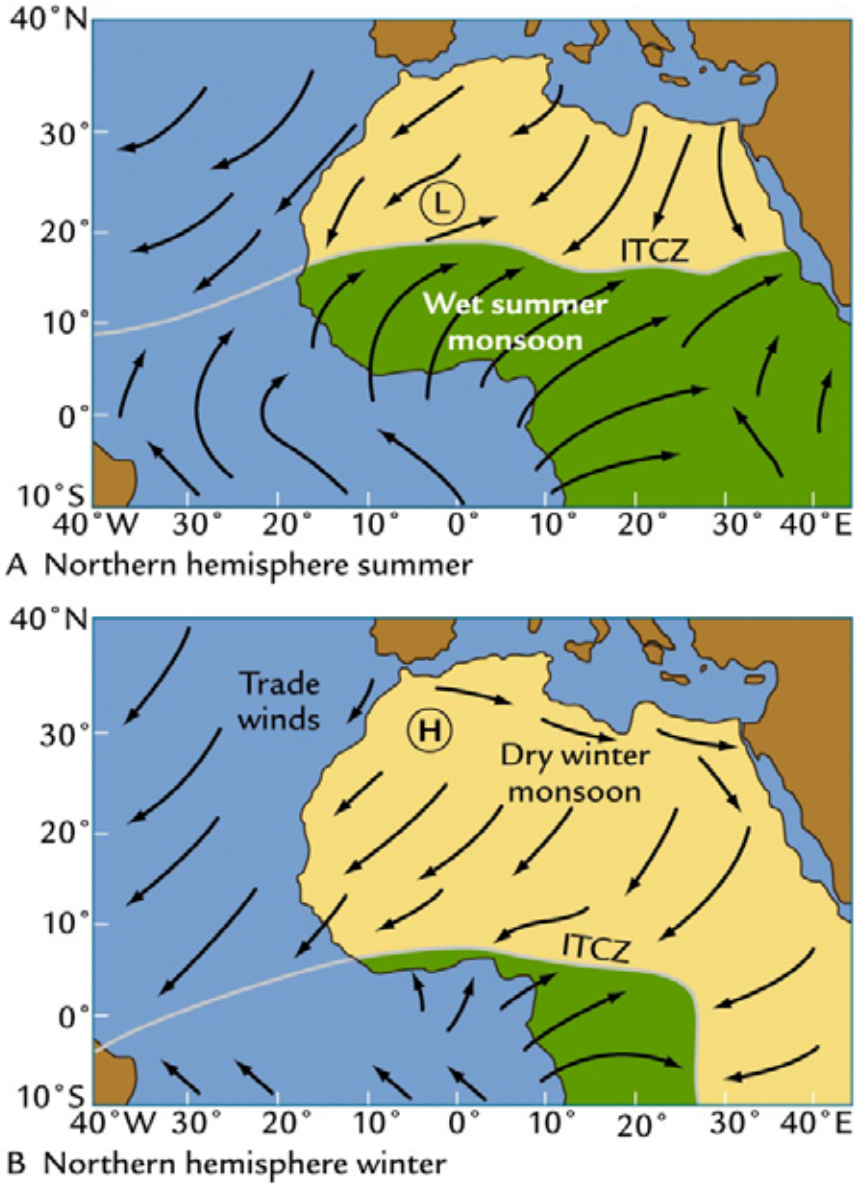
Winter monsoon



B Winter monsoon

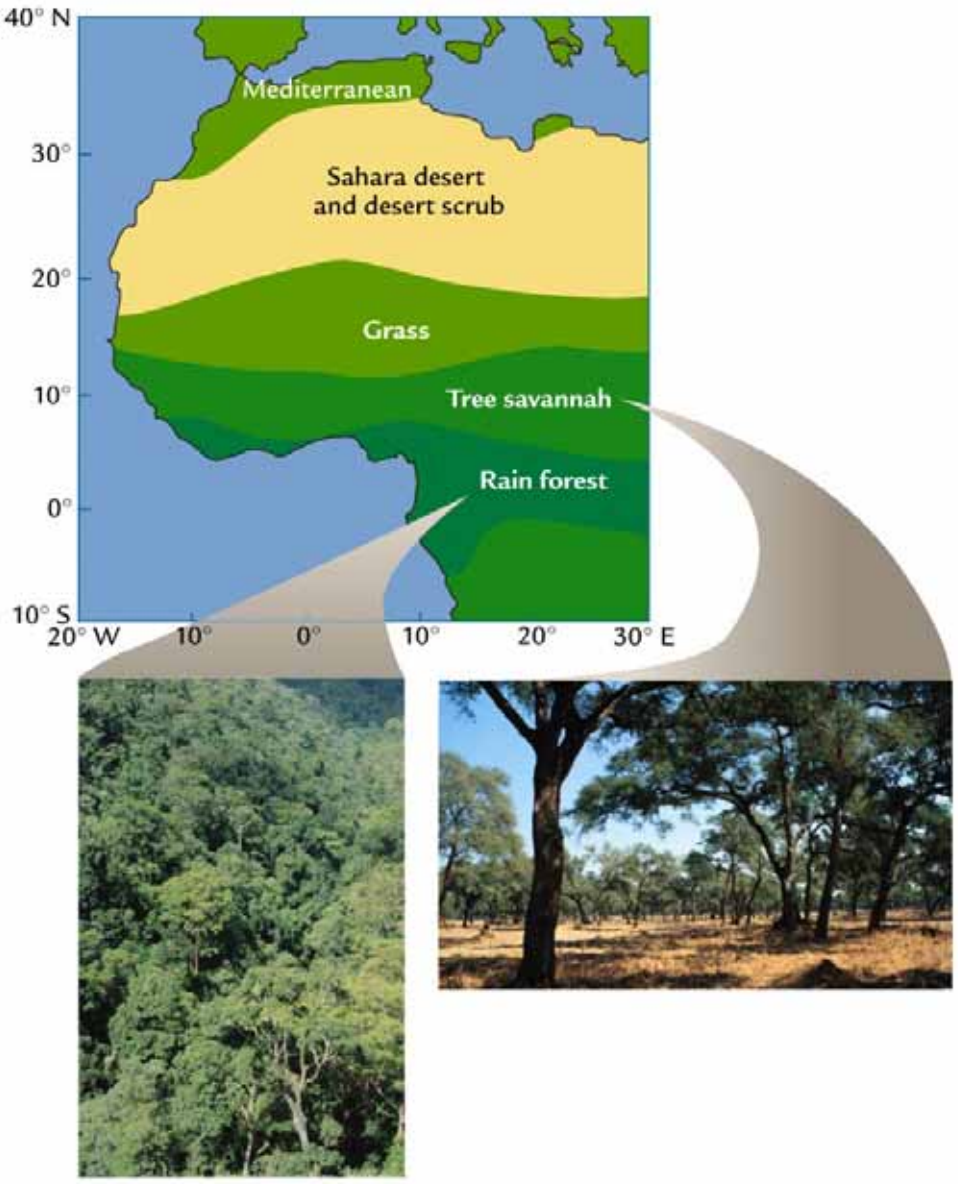
- Weak solar radiation allows the land to cool off and creates a down- and- out circulation of cold dry air

Monsoon circulations over North Africa



- A moist inflow of monsoonal air toward the low-pressure center over North Africa in summer
- A dry monsoonal outflow from the high-pressure center over the land in winter

Vegetation in North Africa



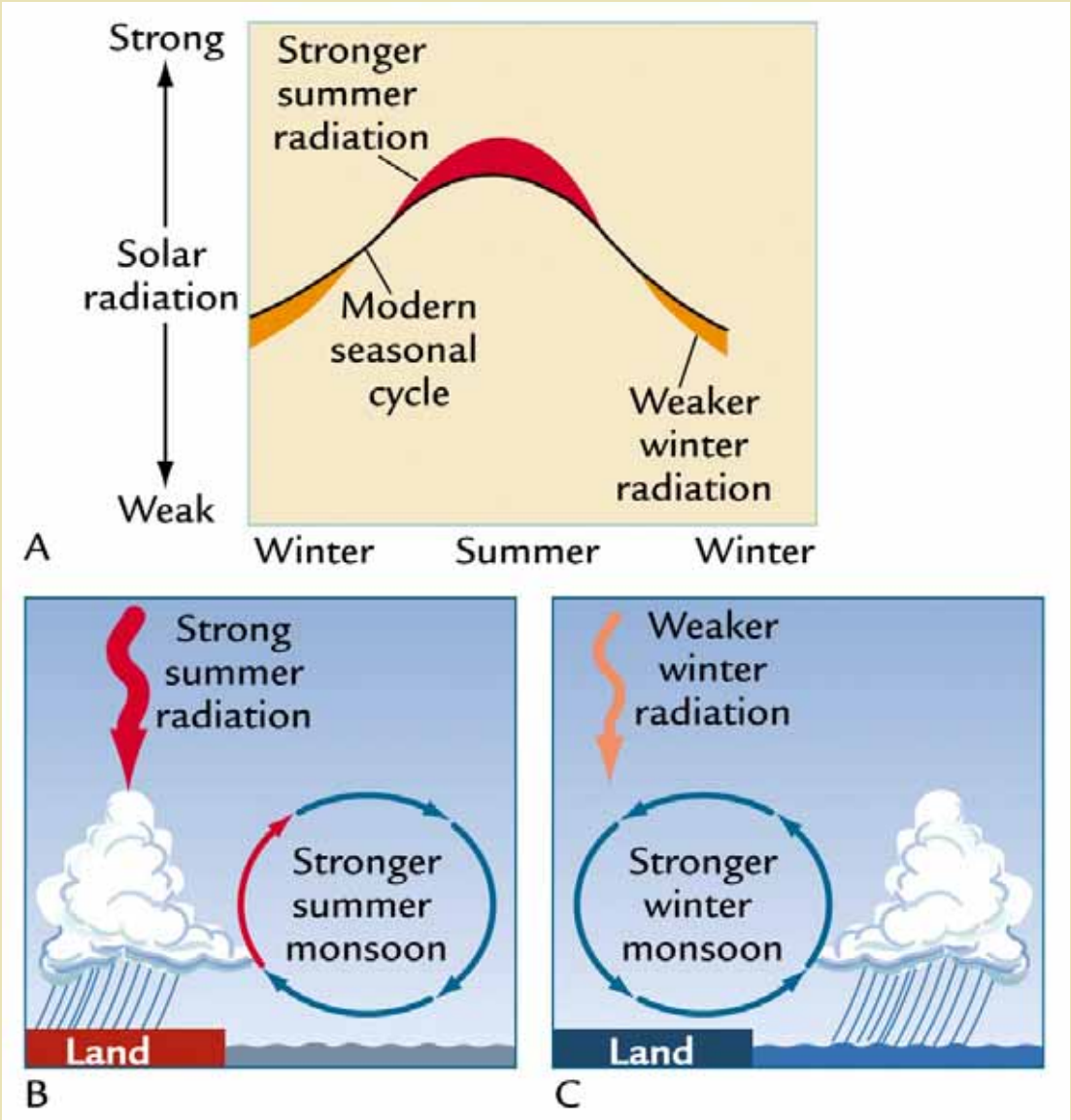
- This pattern reflects the diminishing northward reach of summer monsoon moisture from the tropical Atlantic

Orbital-scale control of summer monsoons

- The idea that changing insolation could control the strength of monsoons over orbital time scales was proposed by the meteorologist John Kutzbach in 1980s.

- Monsoon circulation are linked to changes in the strength of solar radiation during summer and winter, long-term, orbital-scale changes in the strength of summer and winter insolation should have affected the strength of the monsoons in the same manner in past.

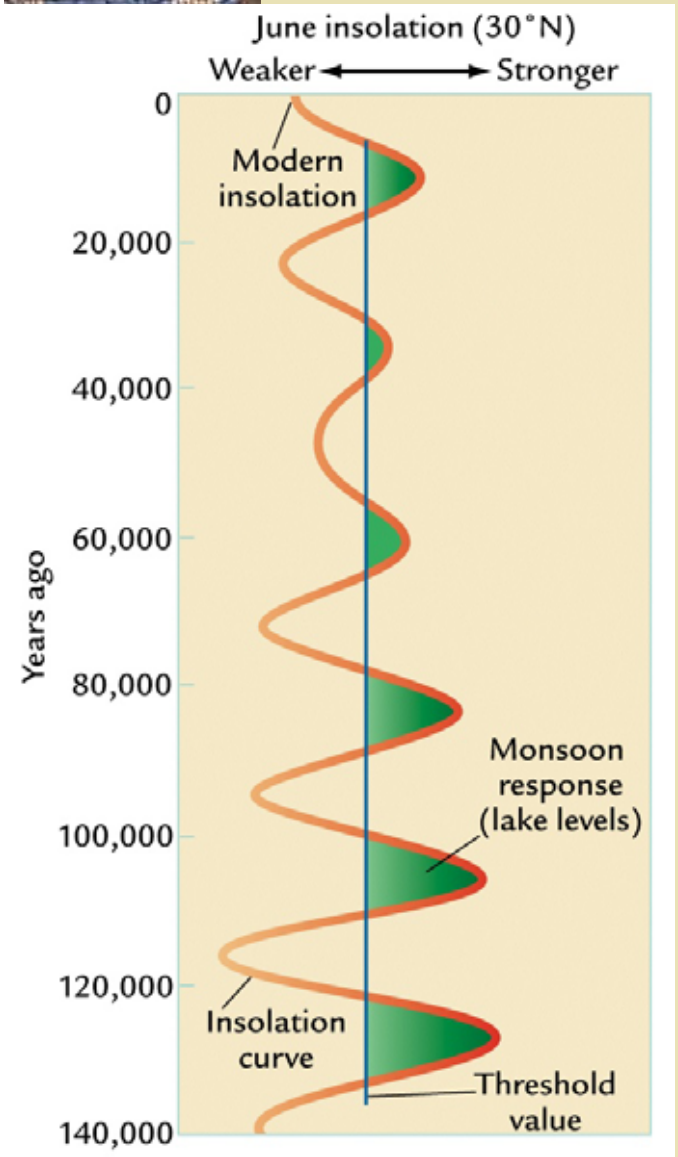
The orbital monsoon hypothesis



Evidence of orbital-scale changes in summer monsoons

- “Stinky muds” in the Mediterranean
- Freshwater diatoms in the tropical Atlantic
- Upwelling in the equatorial Atlantic

Conceptual model of monsoon response to summer insolation



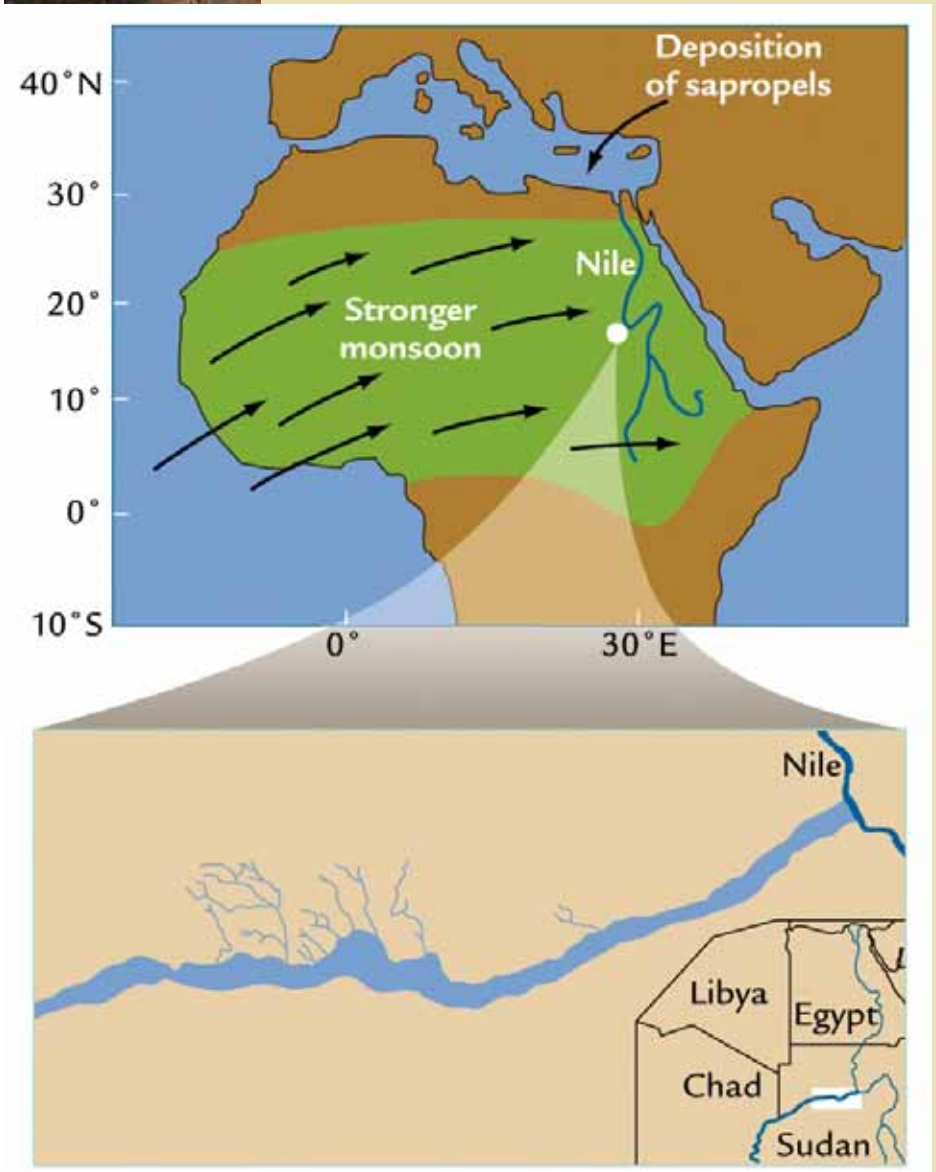
- Three assumptions

First, assume a threshold insolation level below which the monsoon response will be weak that it will leave little or no evidence in the geologic record

Second, assume that the strength of the monsoon response will be directly proportional to the amount

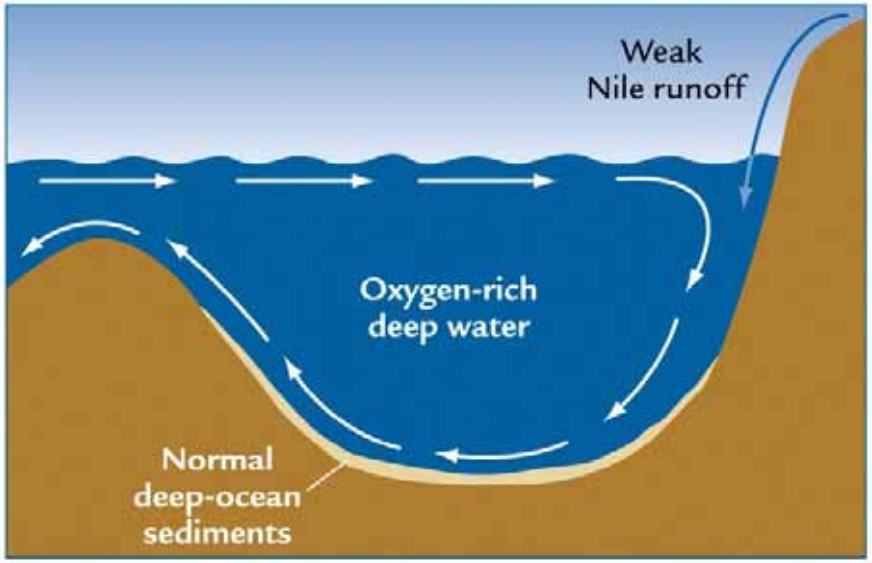
Third, assume that the strength of the monsoon at any time in the past as recorded in the record of lake levels is a composite of the average monsoon strength over many individual summers

Monsoons and Nile floods

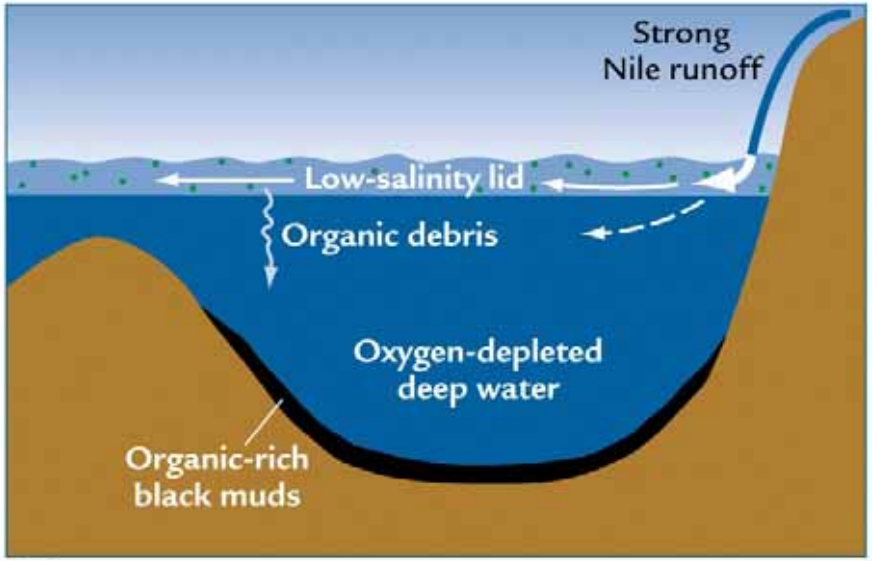


- Strong summer monsoons in tropical North Africa periodically caused large discharges of freshwater from the Nile northward to the arid Mediterranean region

Mediterranean circulation and monsoons



A Weak summer monsoon



B Strong summer monsoon

Freshwater

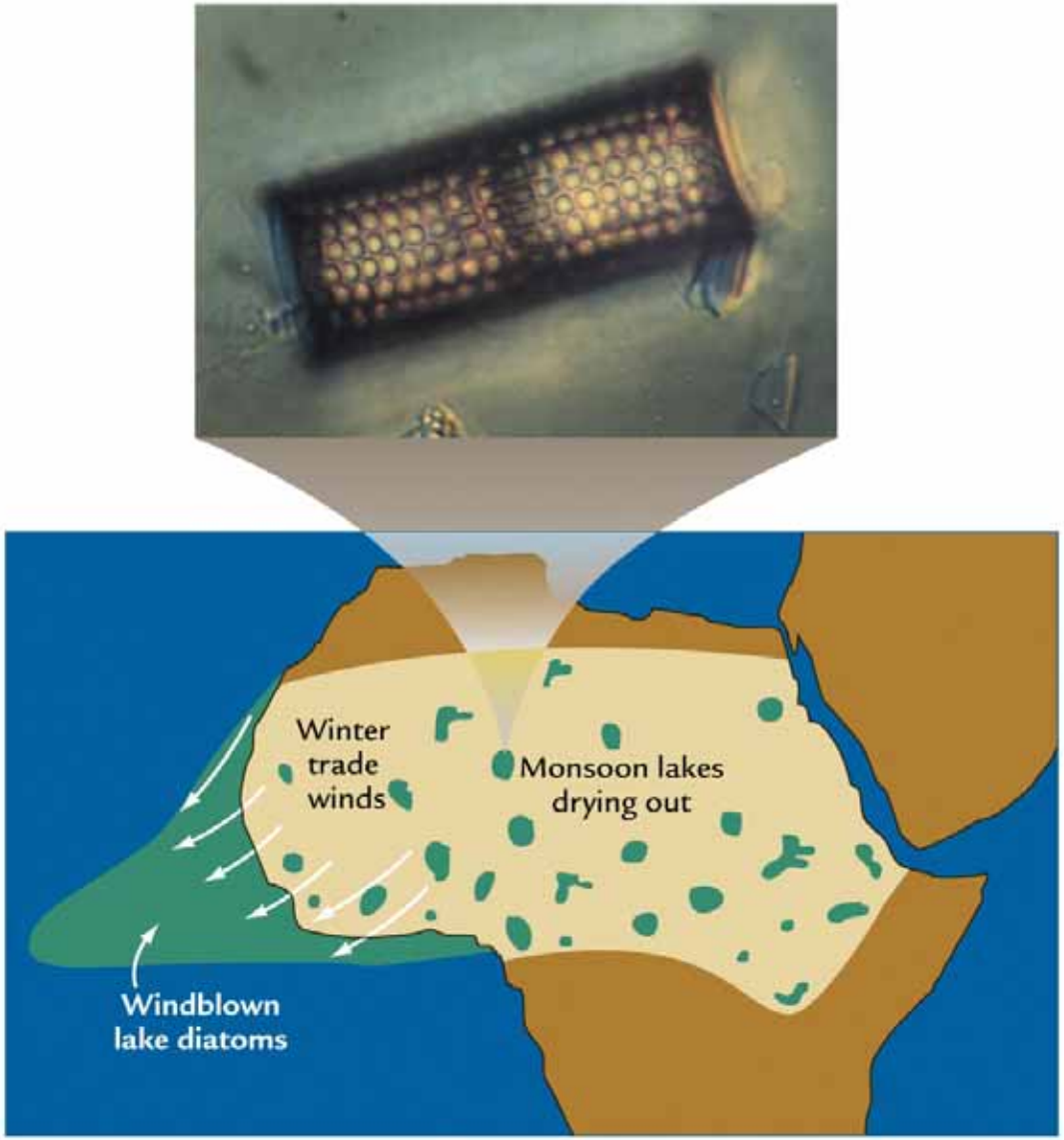
- Low-salinity
- Low-density

- Salty surface water chilled by cold air in winter sinks and carries dissolved oxygen to deeper layer

- Low-salinity lid that inhibited sinking of surface water and caused the deep ocean to lose its oxygen and deposit organic-rich black muds

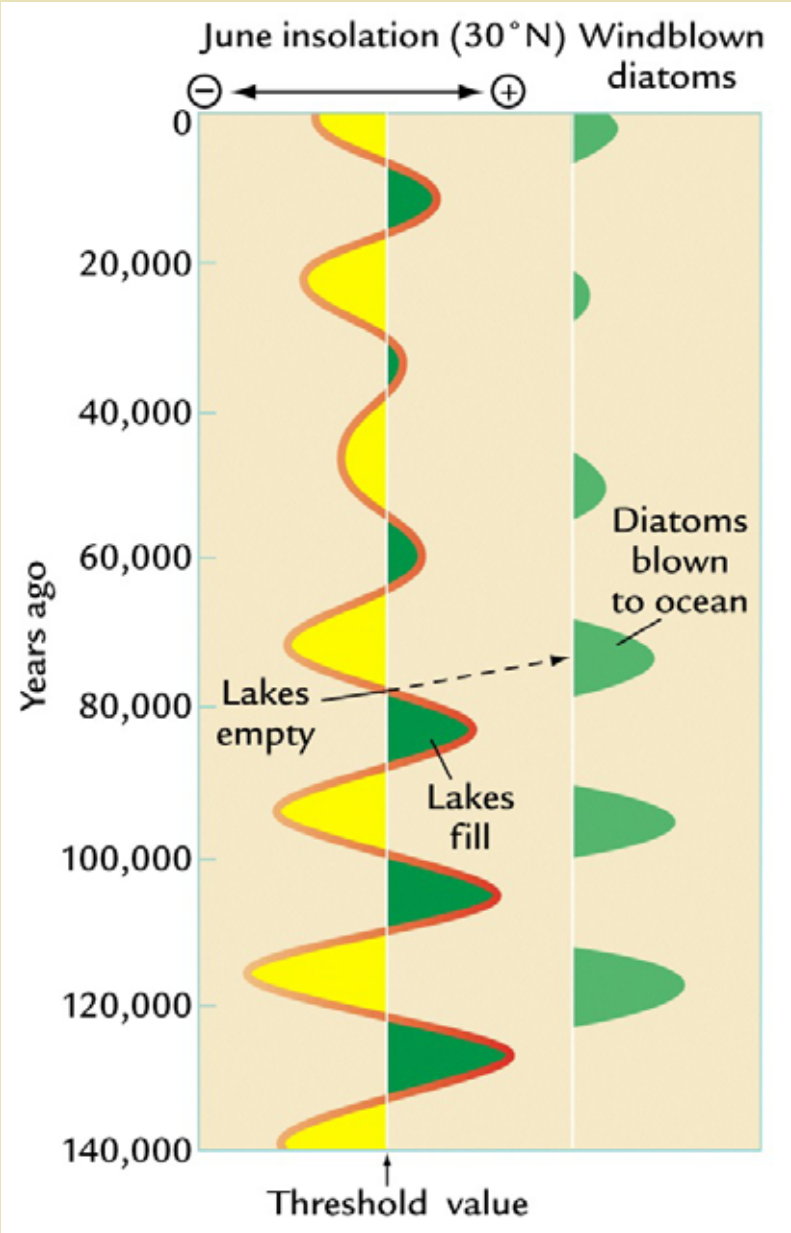
Mediterranean “stinky muds”

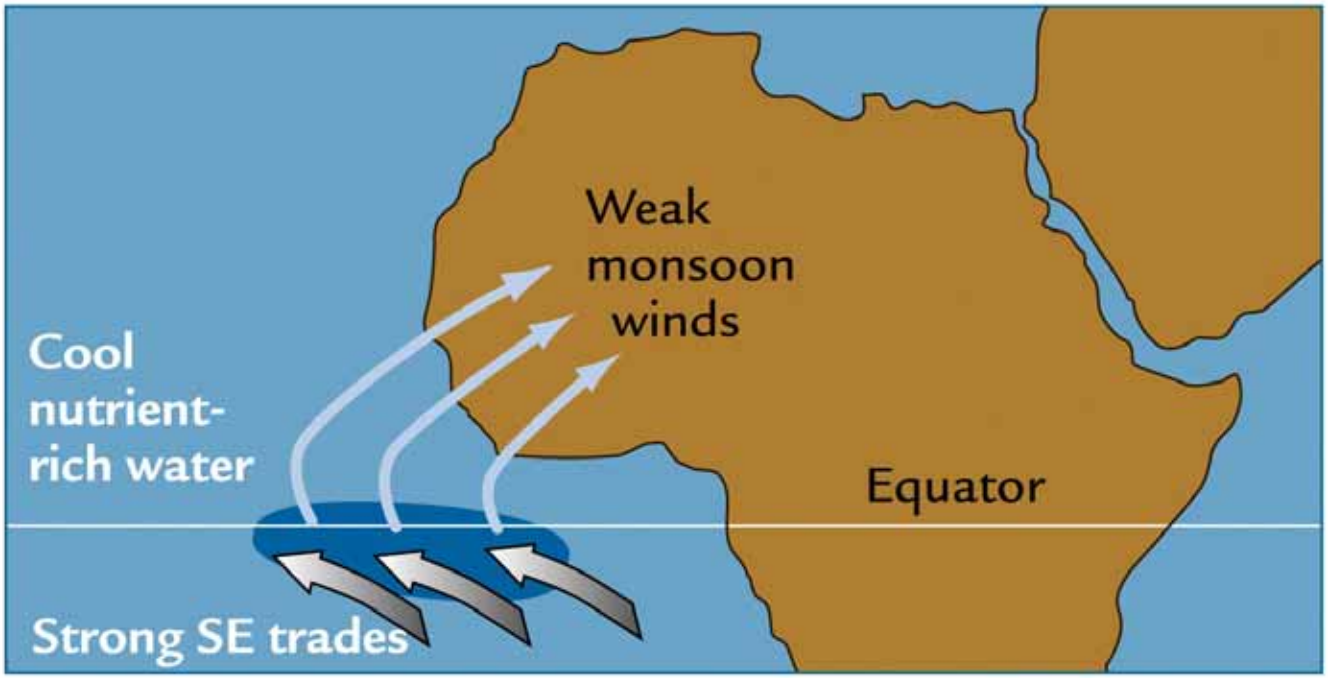
Freshwater diatoms in tropical Atlantic



- Direct evidence that the size of North African lakes fluctuates at the 23,000-year tempo of orbital precession can be found in sediment cores from the north tropical Atlantic Ocean

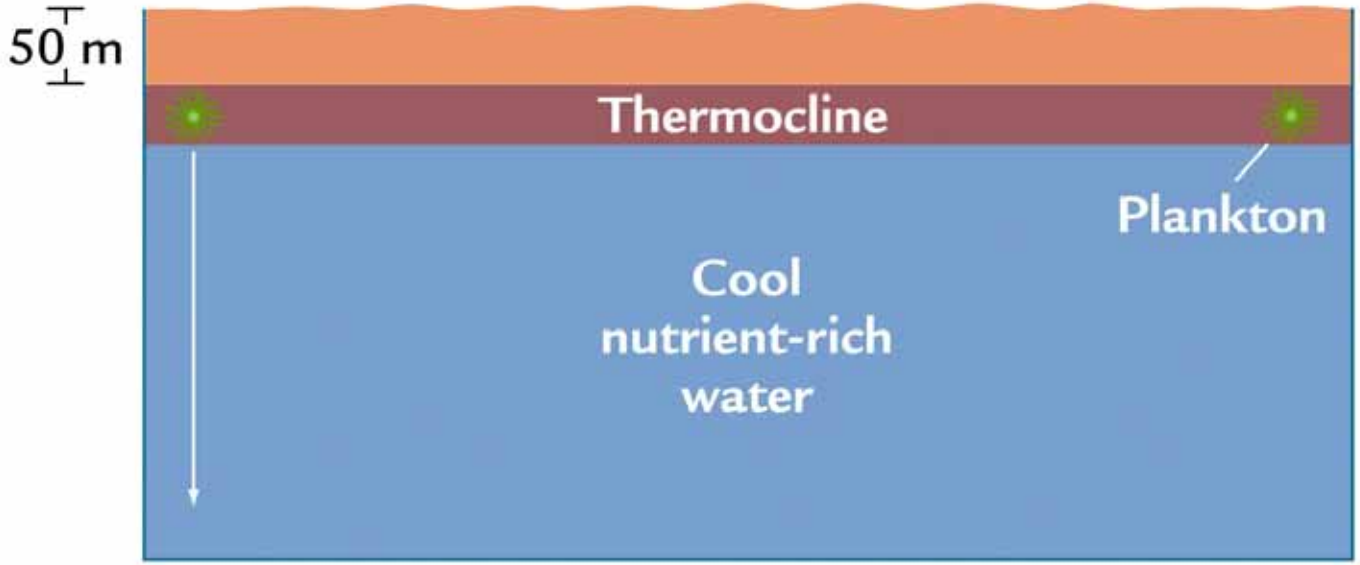
Delayed diatom deposition in the Atlantic



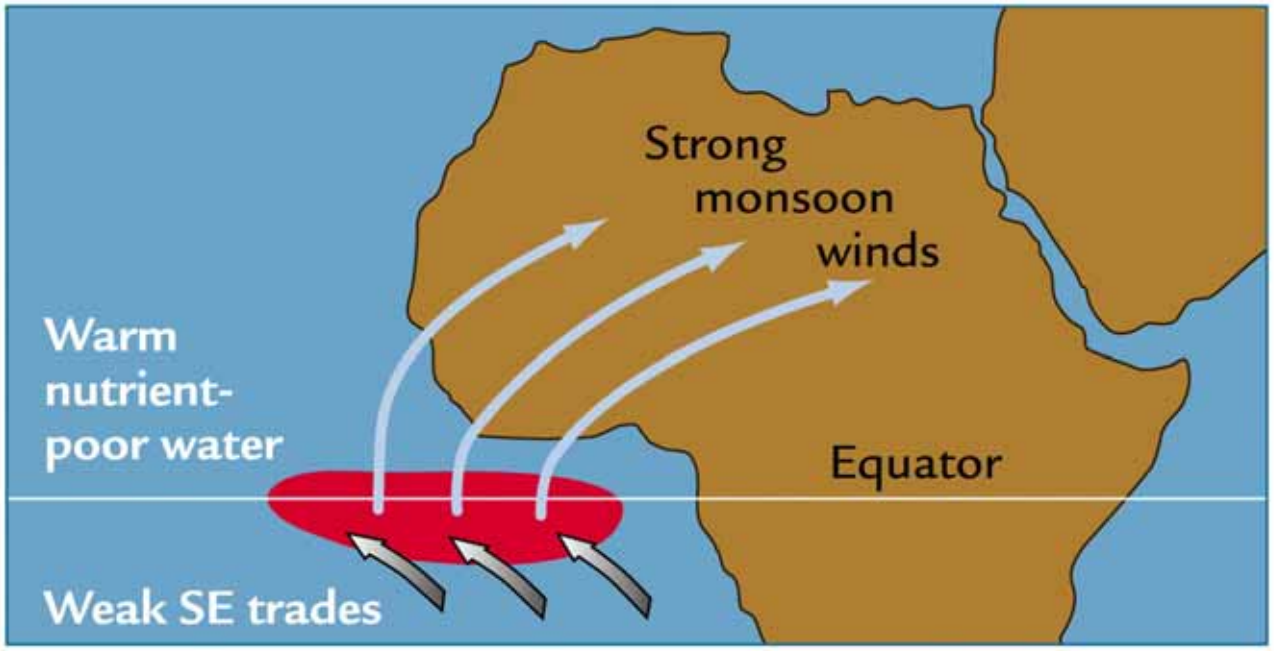


A

When the monsoon is weak and the thermocline is shallow, cooler nutrient-rich waters rise to shallow depths that receive plenty of sunlight for photosynthesis.

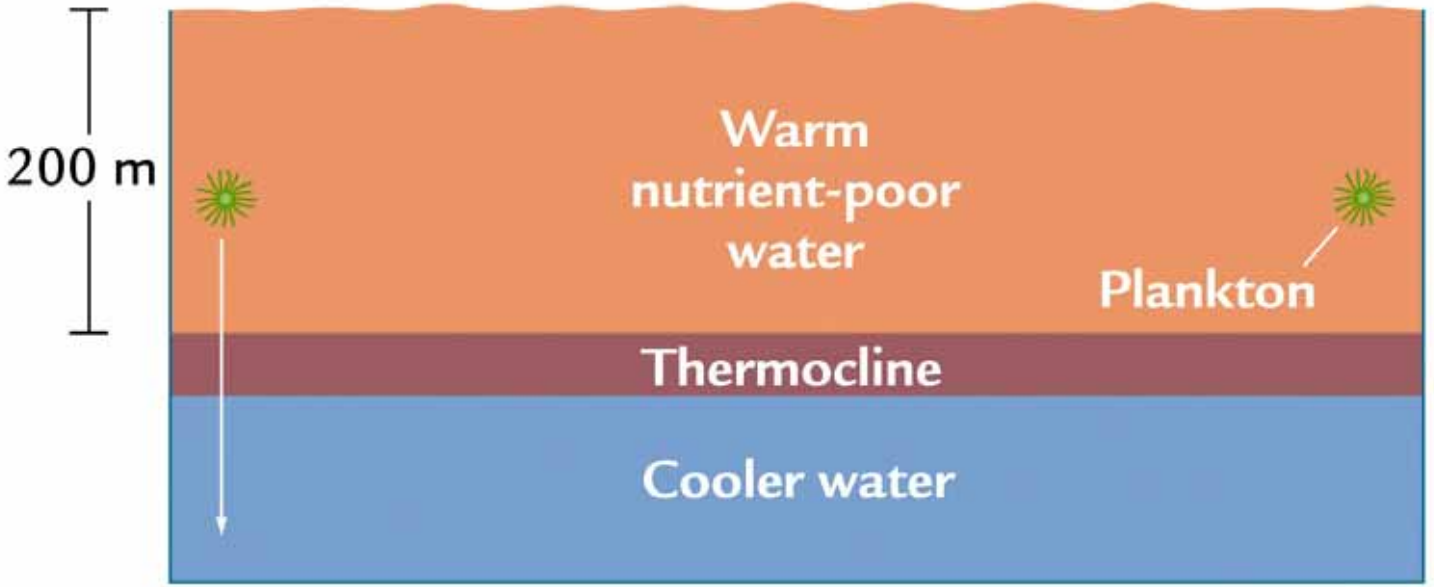


A Shallow thermocline (weak monsoon)



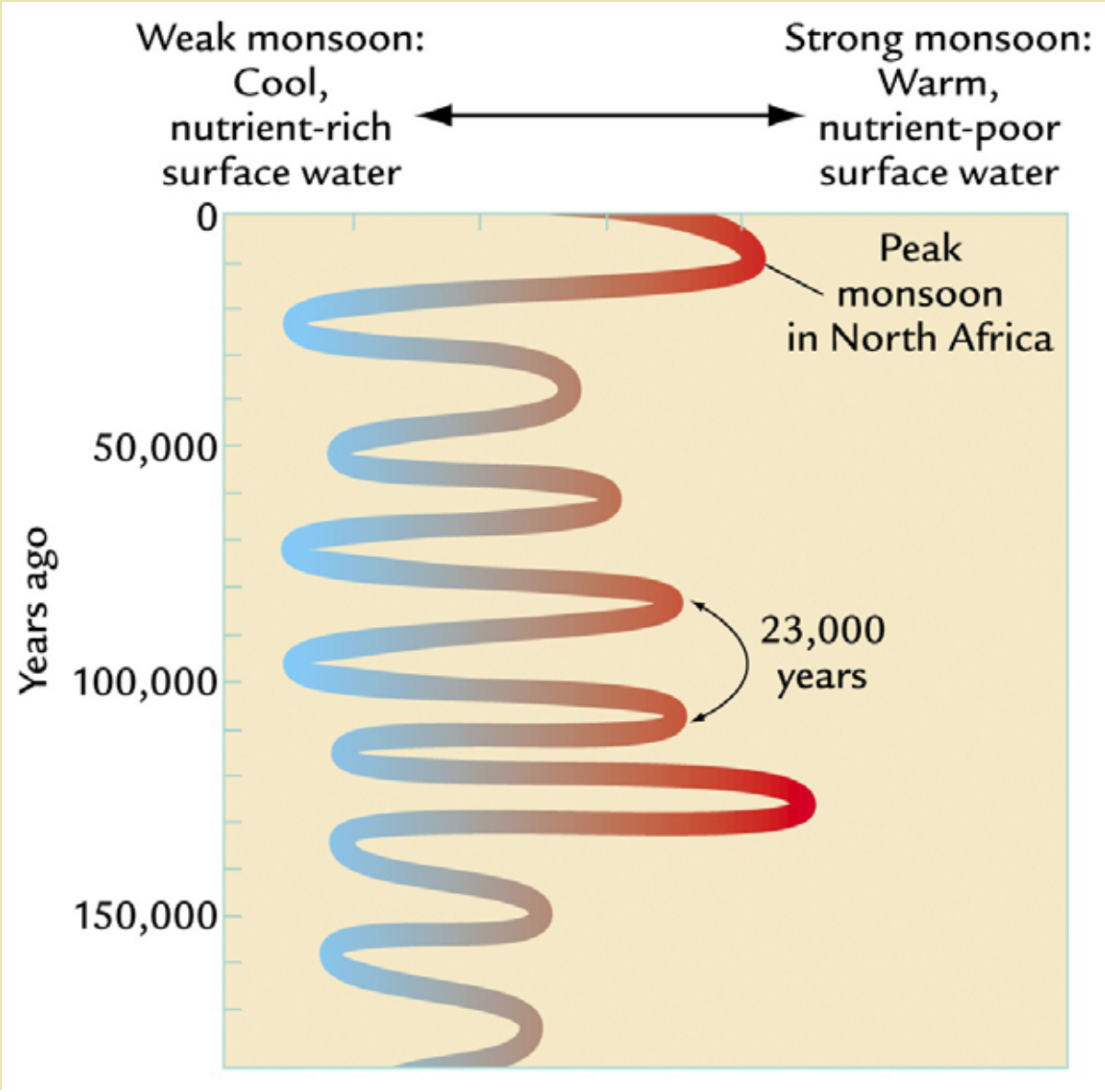
B

When the monsoon is strong and the thermocline is deep, sunlight cannot penetrate down to the nutrient-rich subsurface waters, and the warmer near-surface water are low in nutrient.

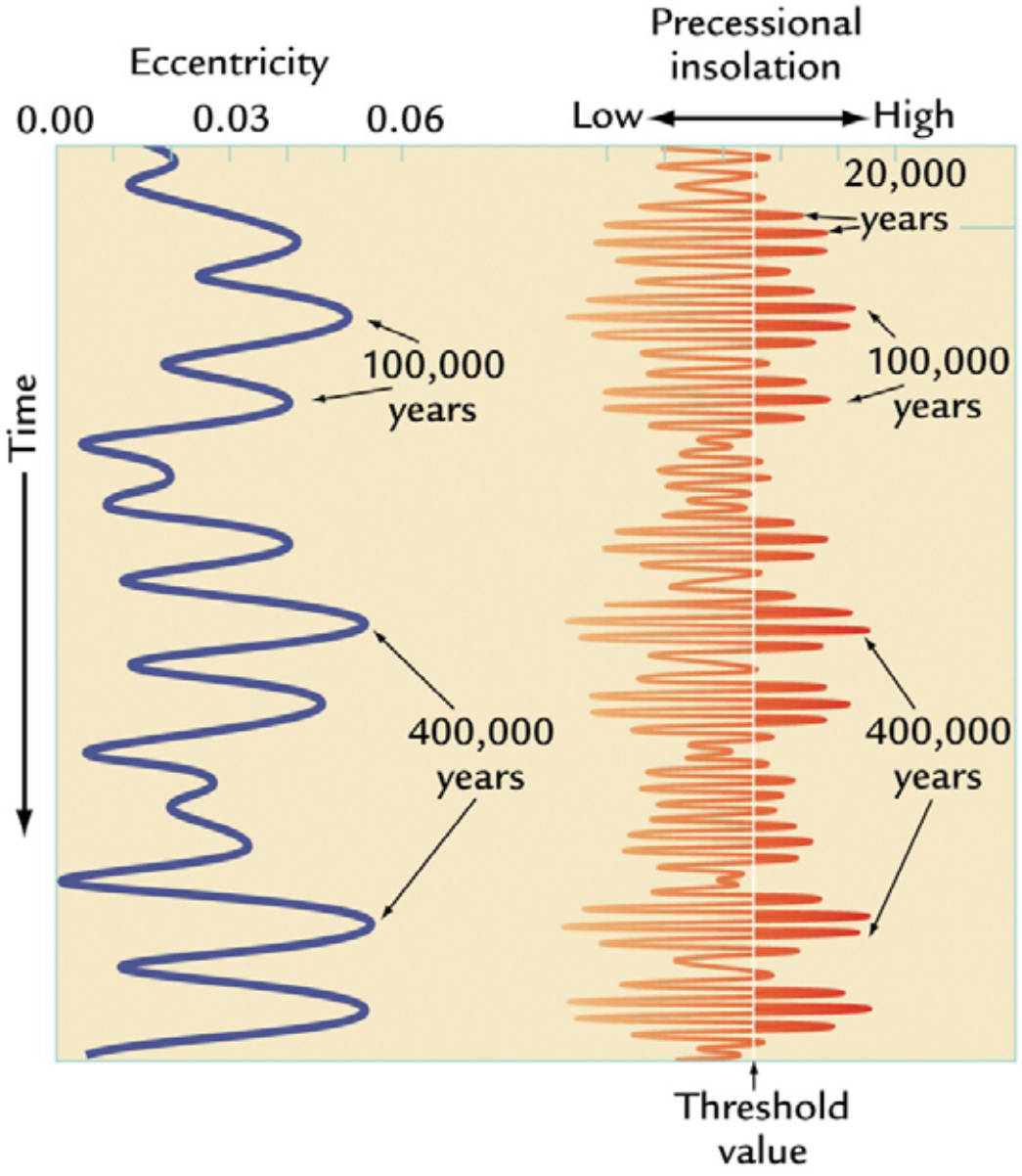


B Deep thermocline (strong monsoon)

Plankton and tropical Atlantic circulation

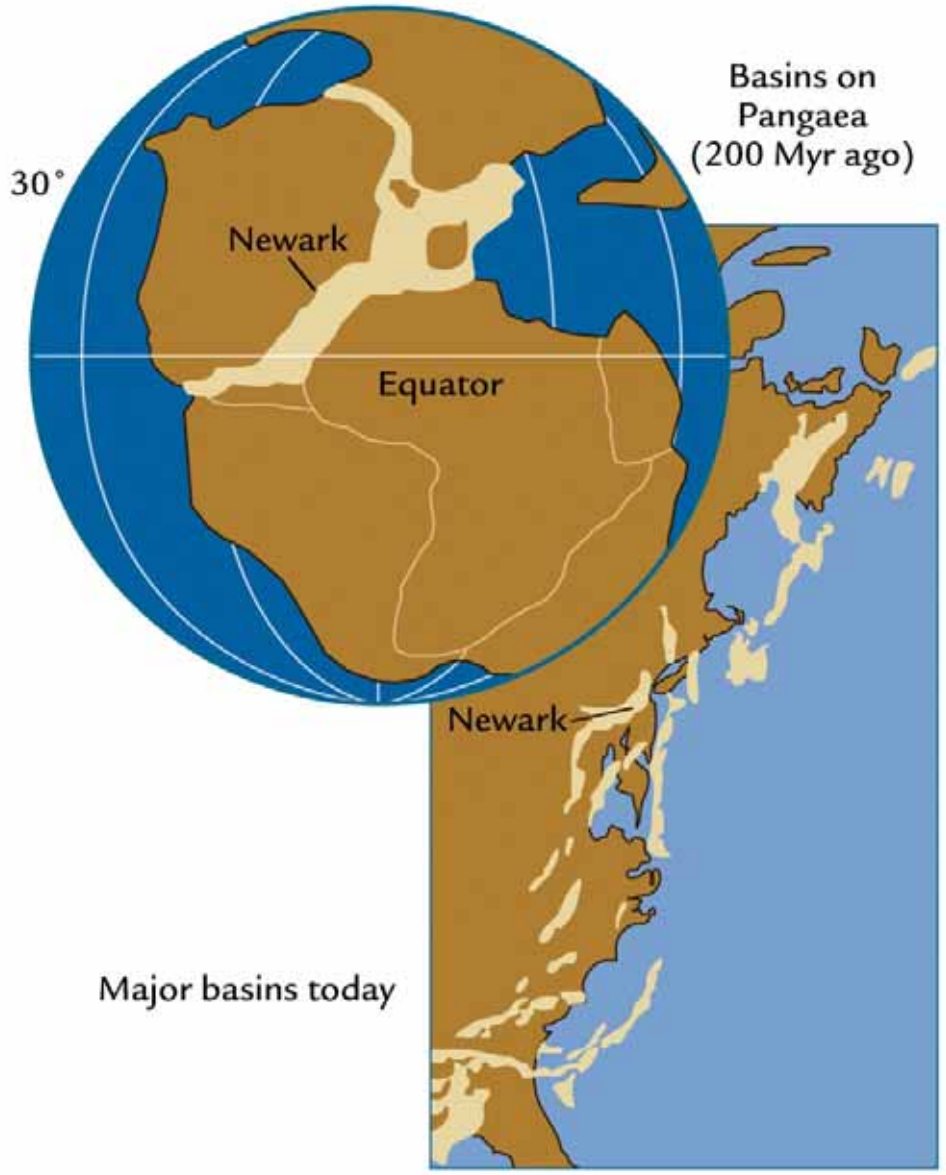


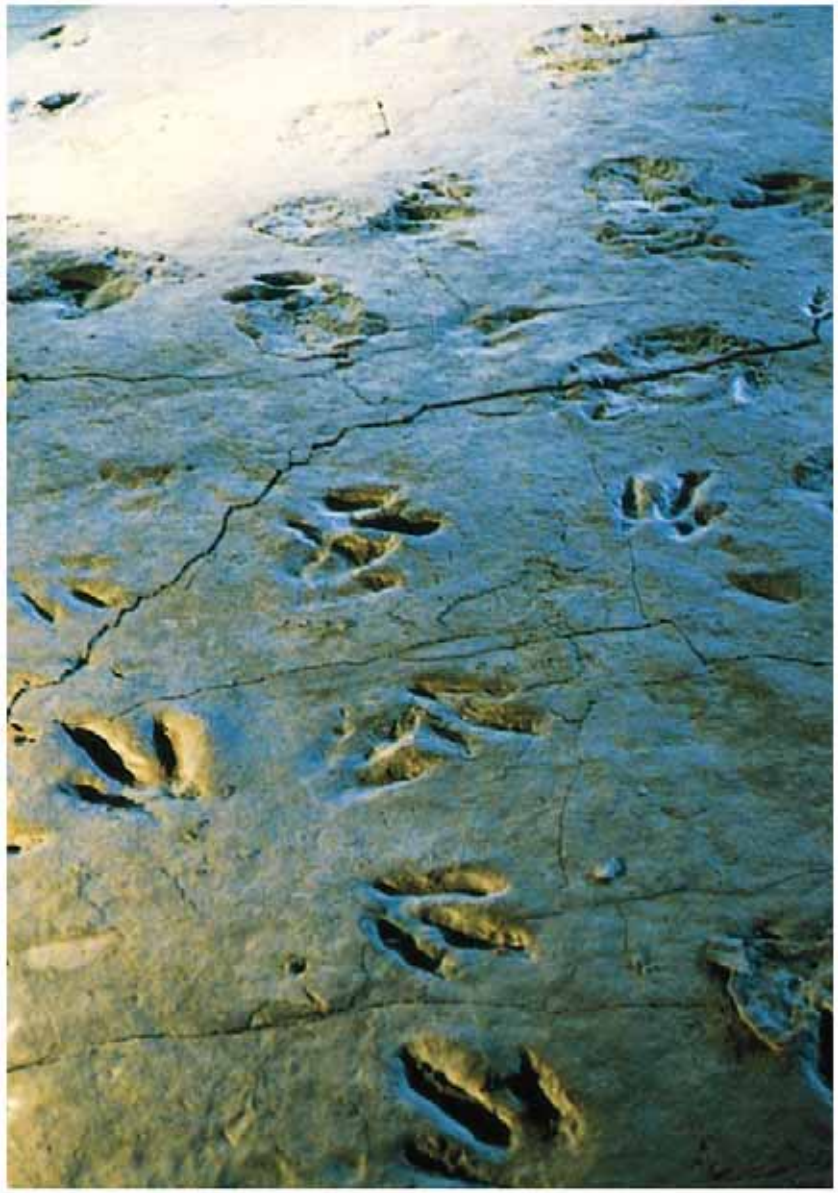
Monsoon signals recorded in sediments



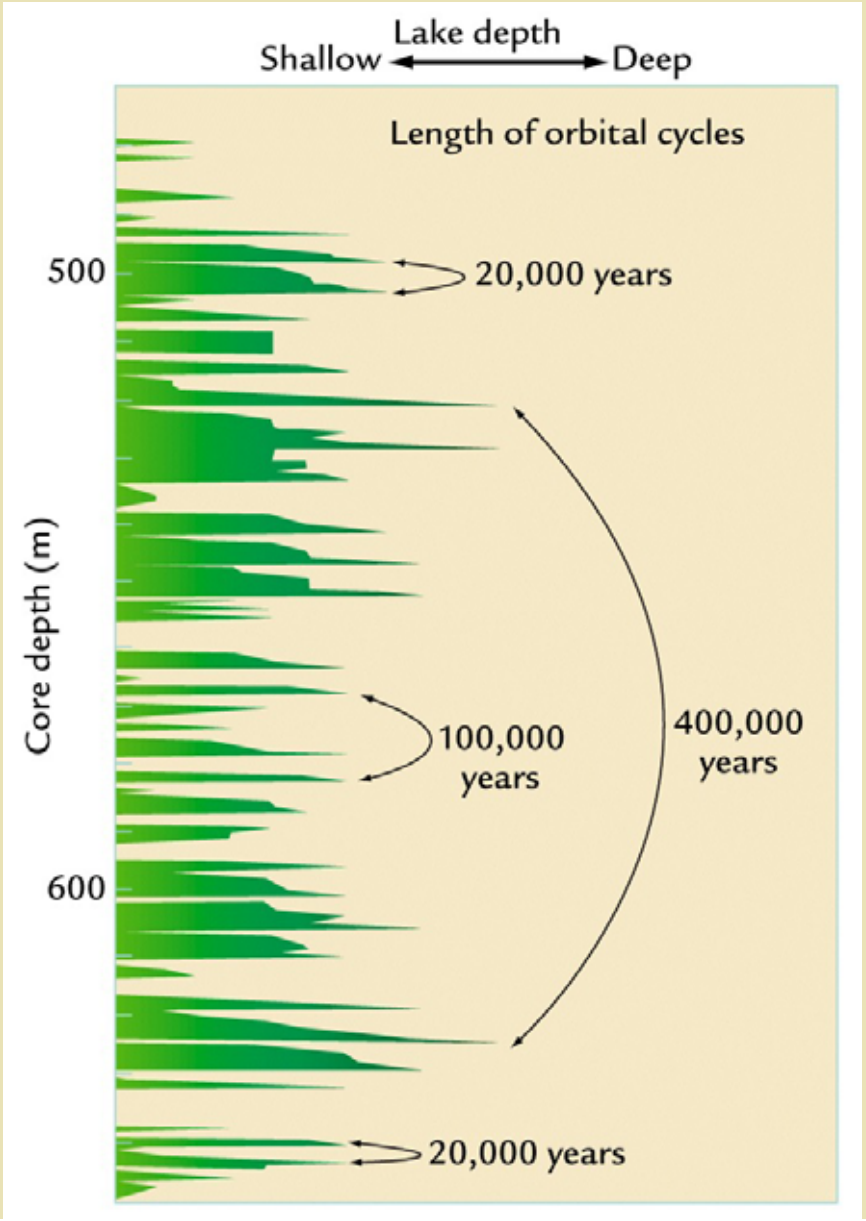
- High orbital eccentricity values should amplify individual 23,000-year precession cycles every 100,000 and 400,000 year
- The expected signal of a strong monsoon is shown by the red-shaded area to the right of the threshold insolation value

Monsoon forcing earlier in Earth's history

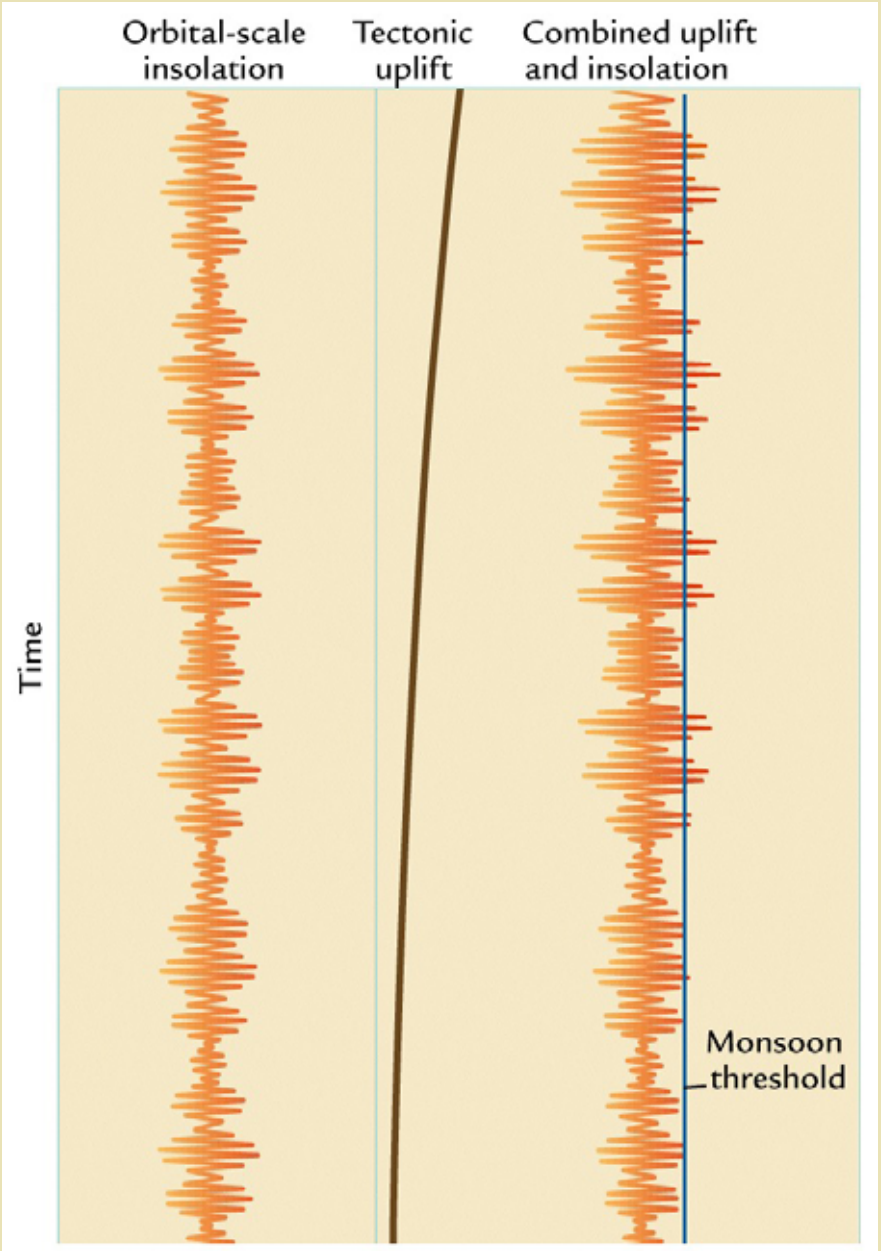




Fluctuations of Pangaean lakes



Joint tectonic and orbital control of monsoons



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