

Climate II

(Winter 2020/2021)

13th lecture:

Regional and global changes

(Regional and global signals: Monsoons, Permafrost; Archives of climate change)

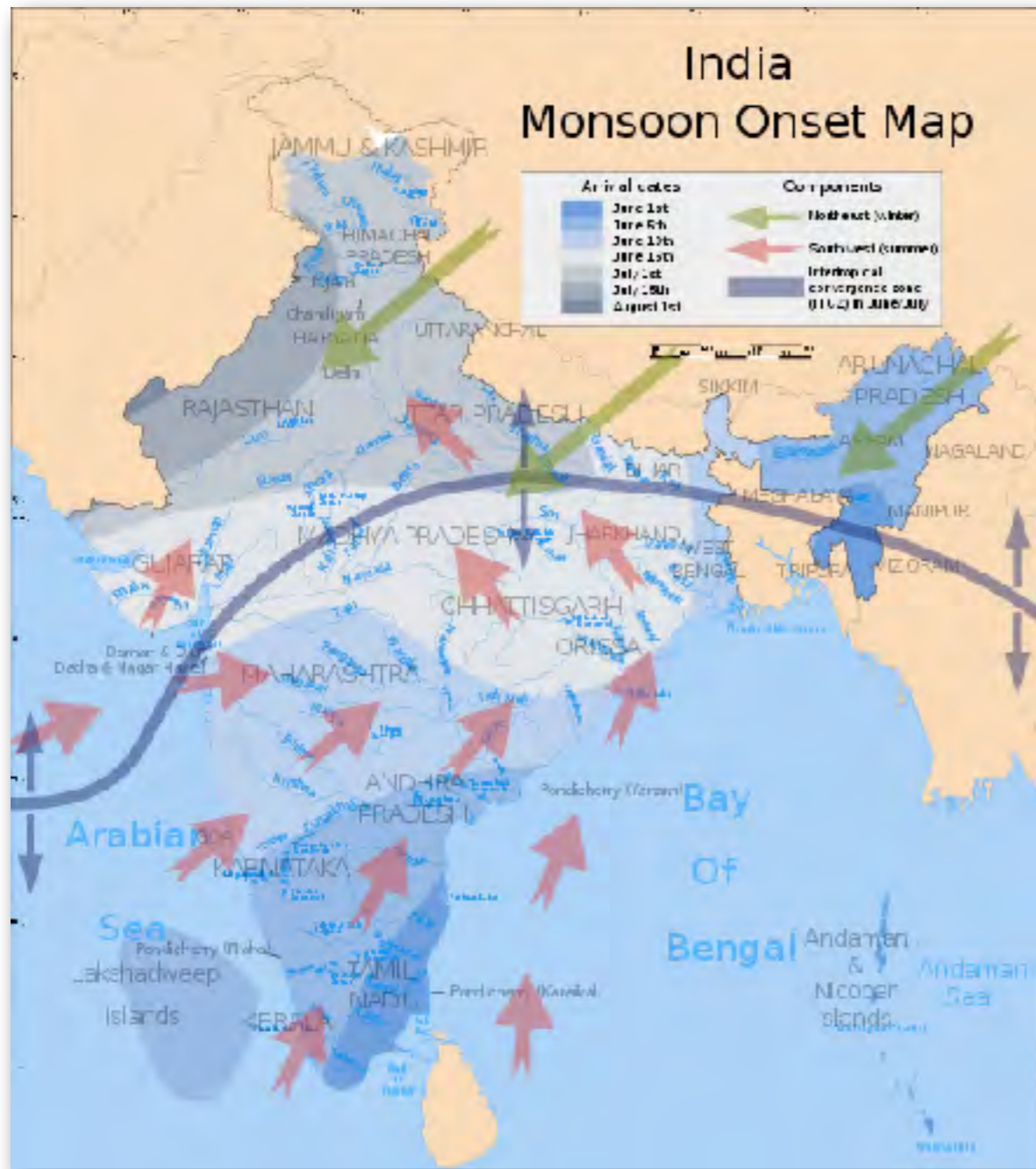
Gerrit Lohmann, Martin Werner

Tuesday, 10:00-11:45

(sometimes shorter, but with some exercises)

https://paleodyn.uni-bremen.de/study/climate2020_21.html

Regional and global signals: Monsoons



[http://en.wikipedia.org/wiki/File:India_southwest_summer_monsoon_onset_map_en.svg]



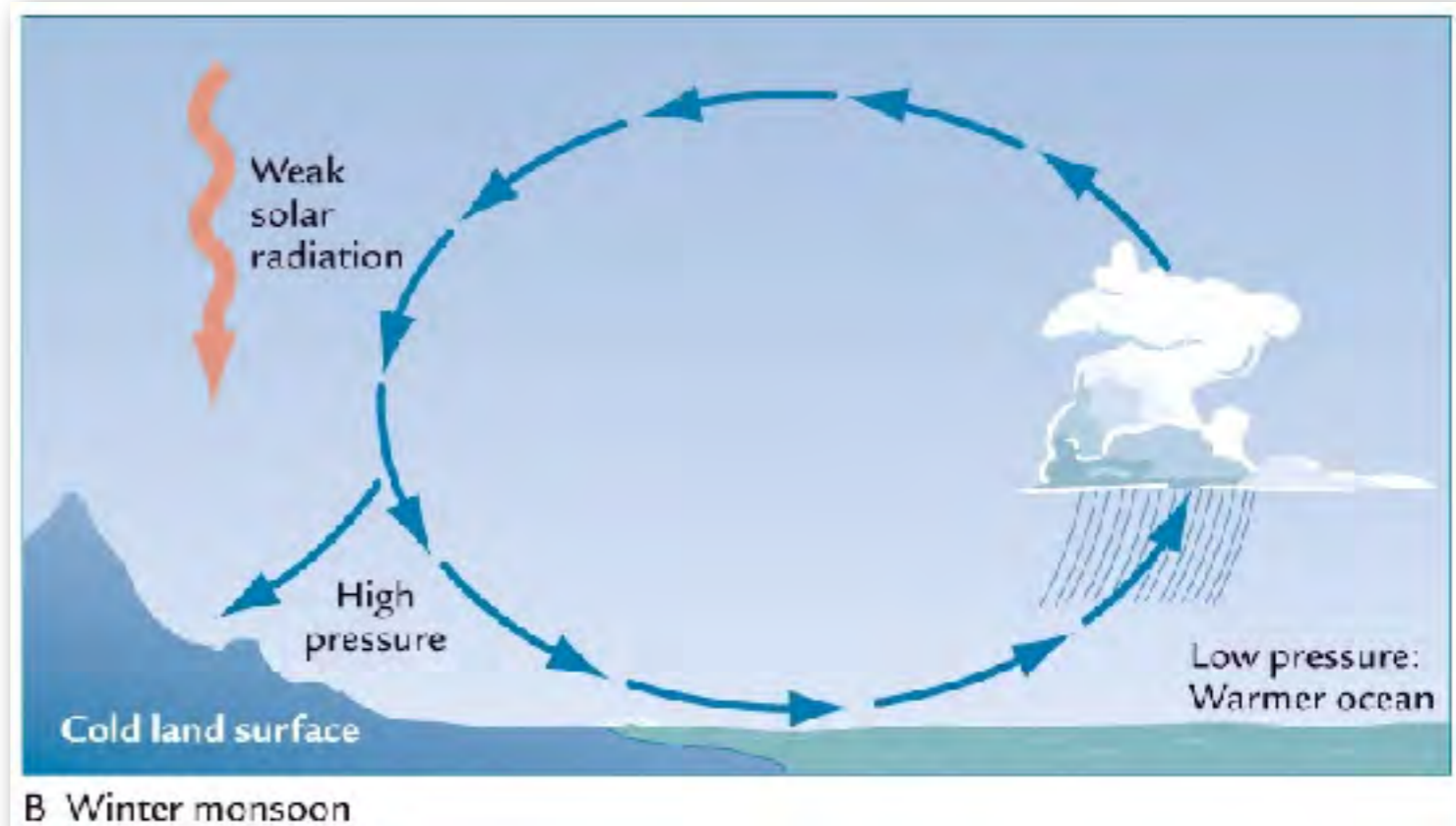
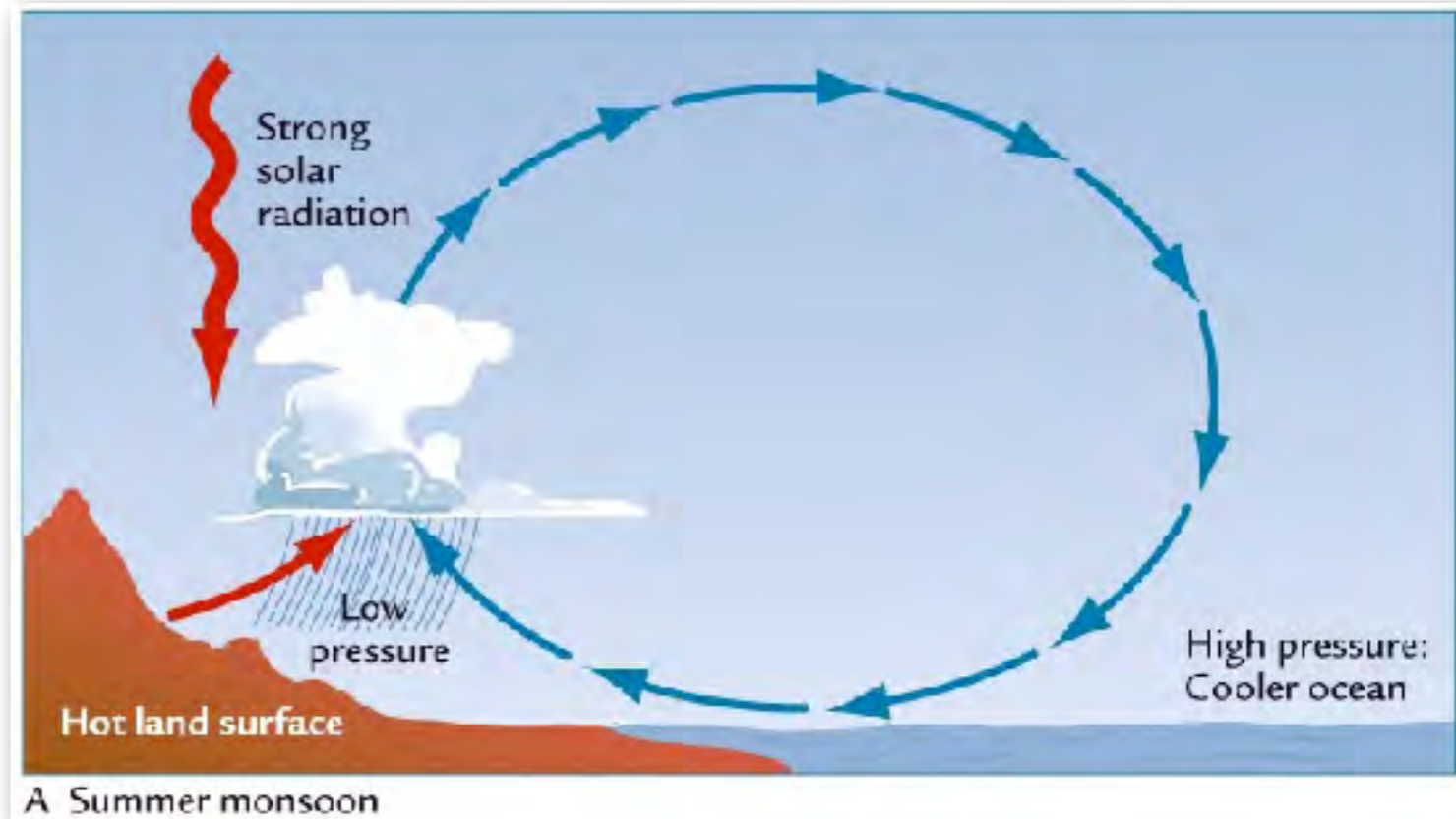
[<http://science.nationalgeographic.com/wallpaper/science/photos/climate/wind/>]



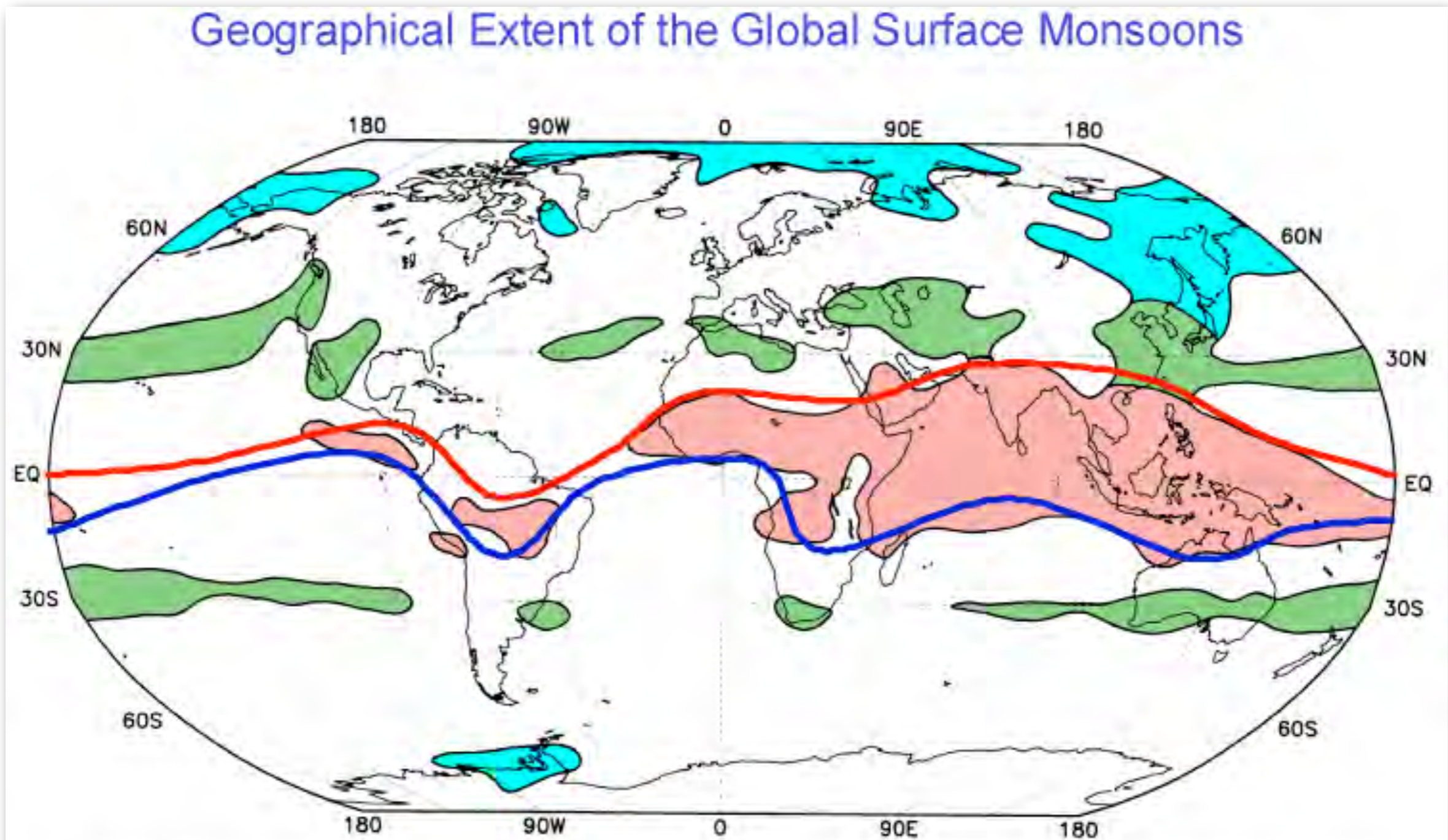
[<http://mapurva.wordpress.com/2011/08/01/crazy-monsoon/>]

The monsoon circulation

- monsoon circulation driven by large seasonal temperature gradient between land surface and adjacent ocean water
- summer monsoon bring heavy convective rainfall events, winter monsoon cold, dry air to the land surfaces
- most strong summer monsoons occur in the Northern Hemisphere (larger land masses, plus high Tibetan mountains in Asia)

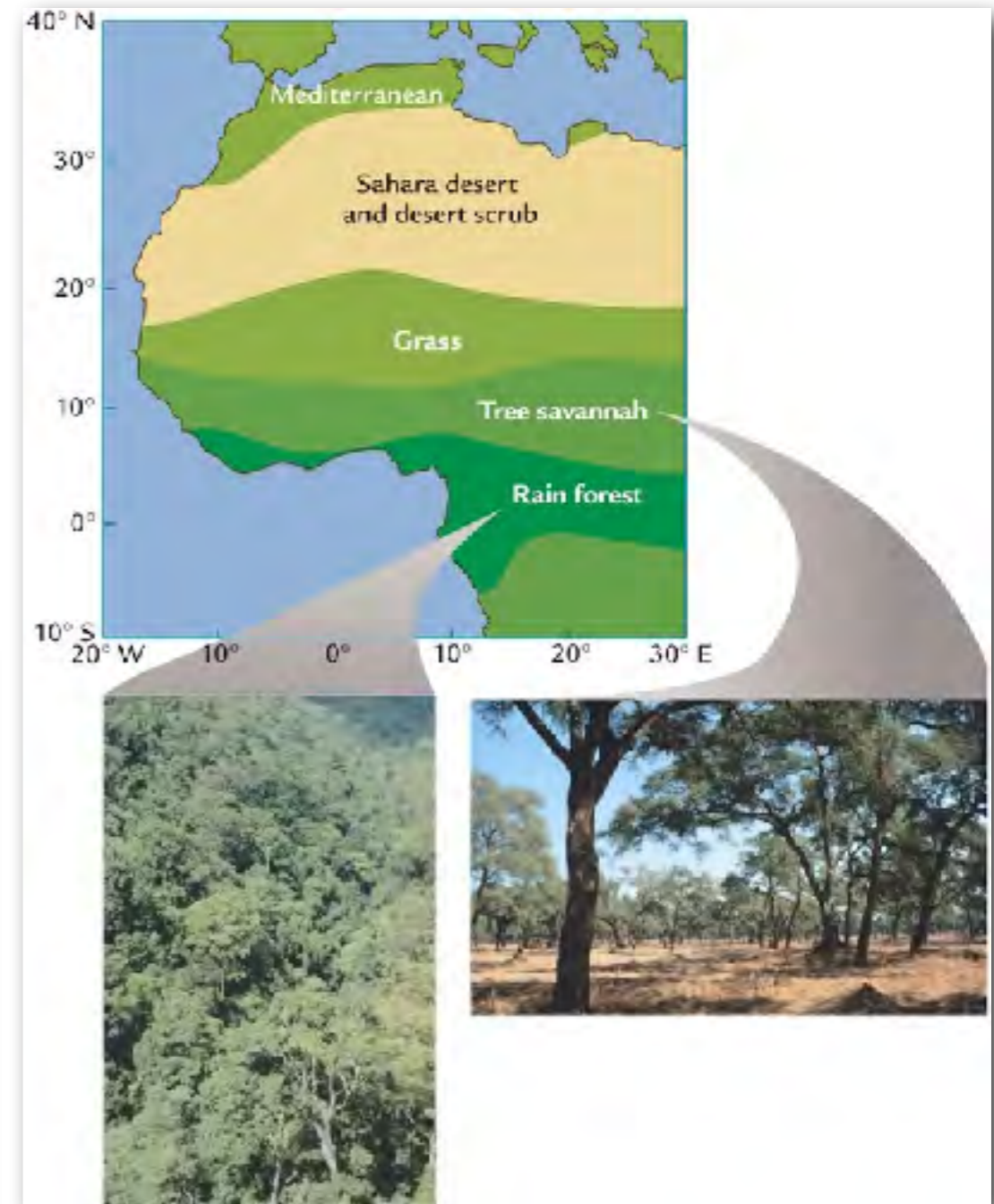
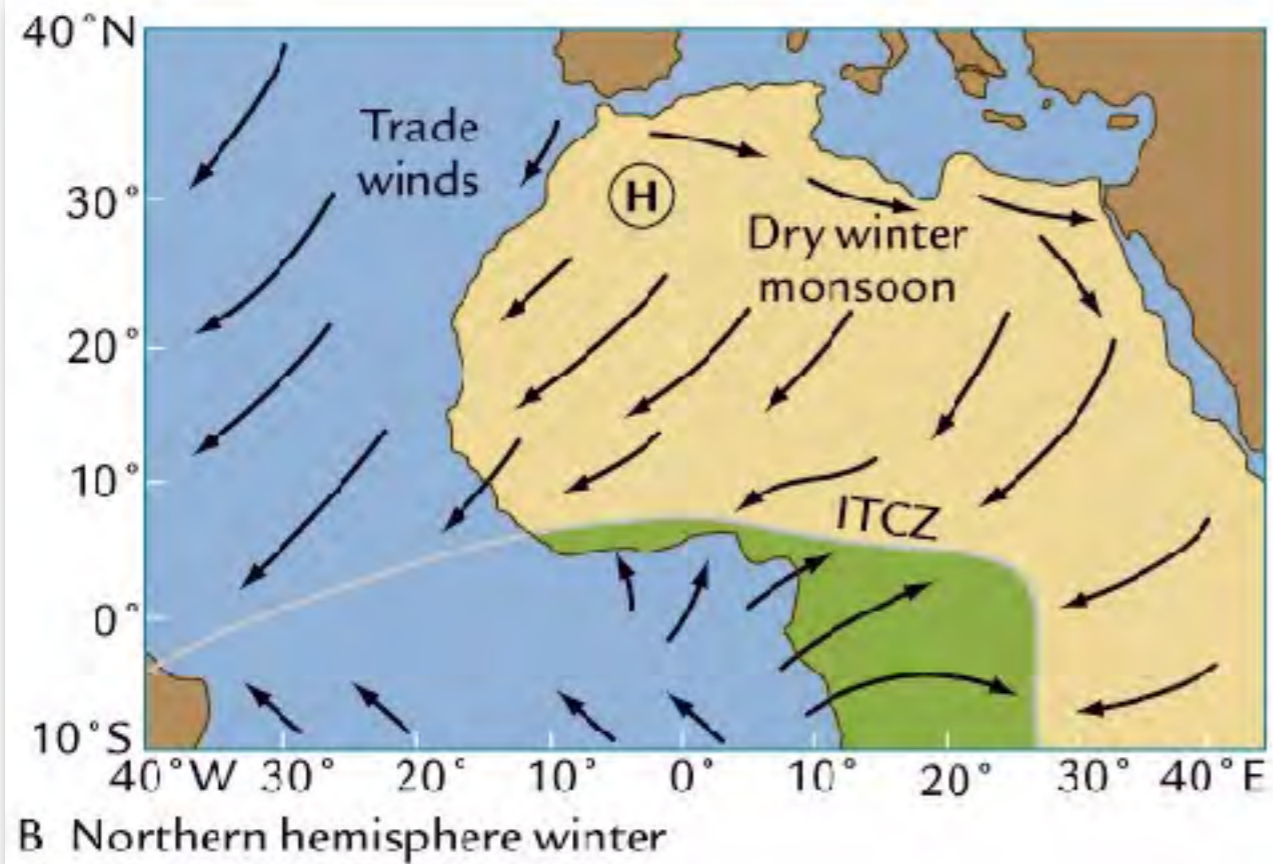
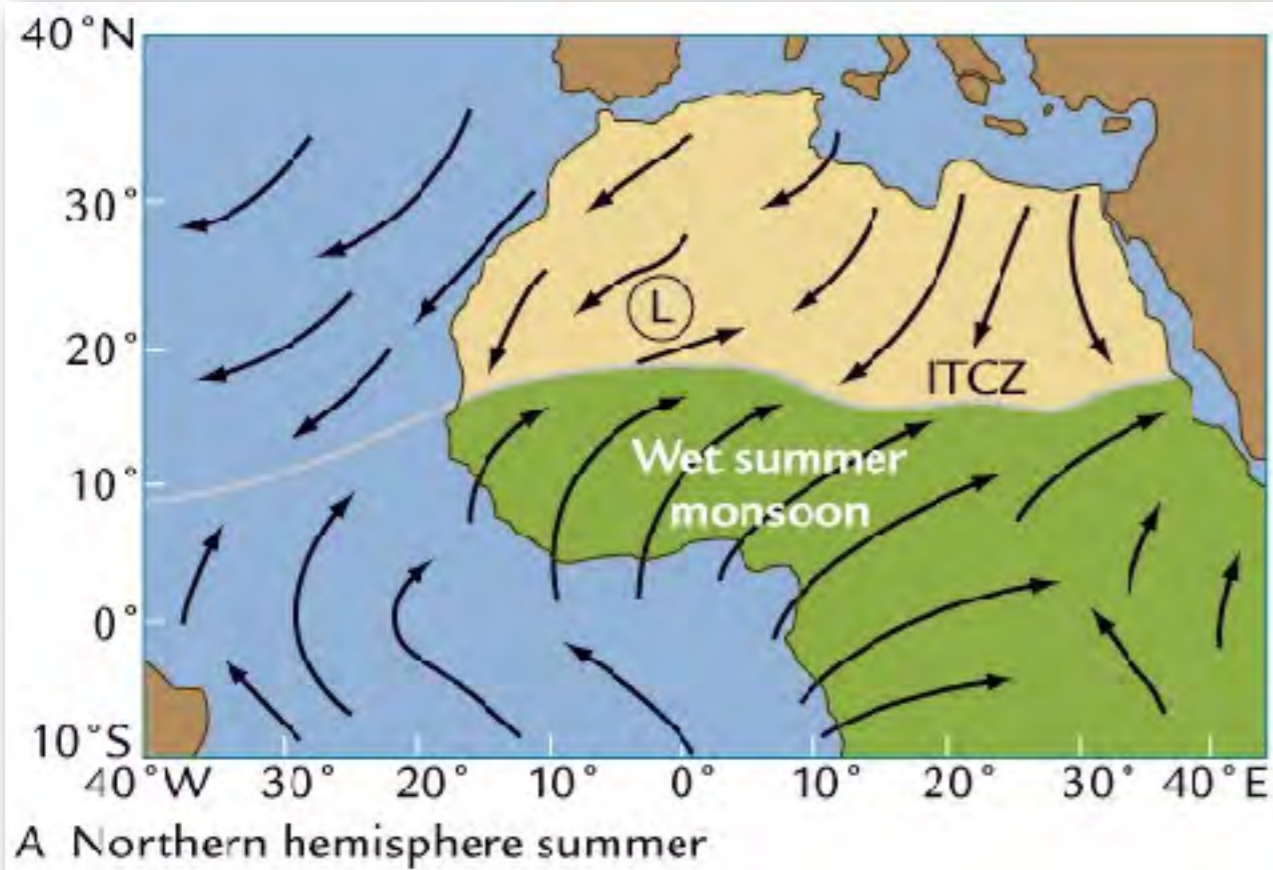


The global monsoon circulation



The red, green, and blue areas indicate the tropical, subtropical, and temperate-frigid monsoons, respectively. The red and blue thick lines represent the ITCZ in summer and winter, respectively.
(Li, J., and Q. Zeng, 2005)

The North African monsoon circulation

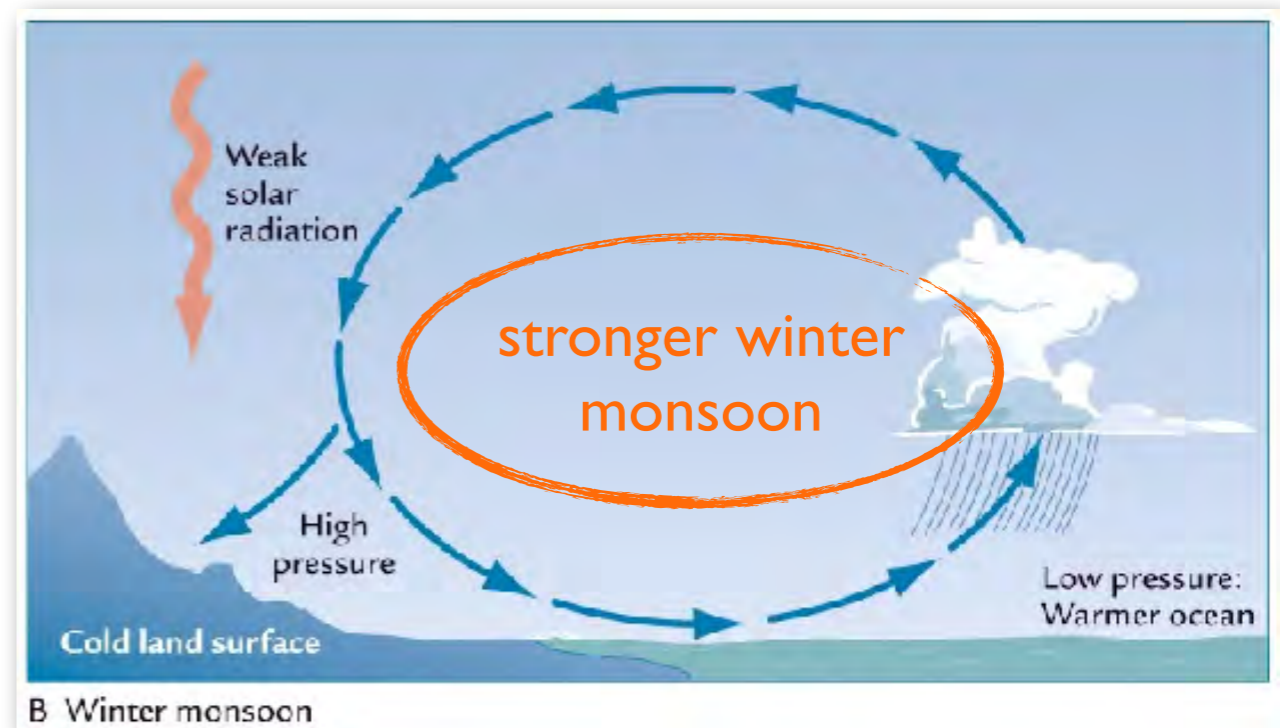
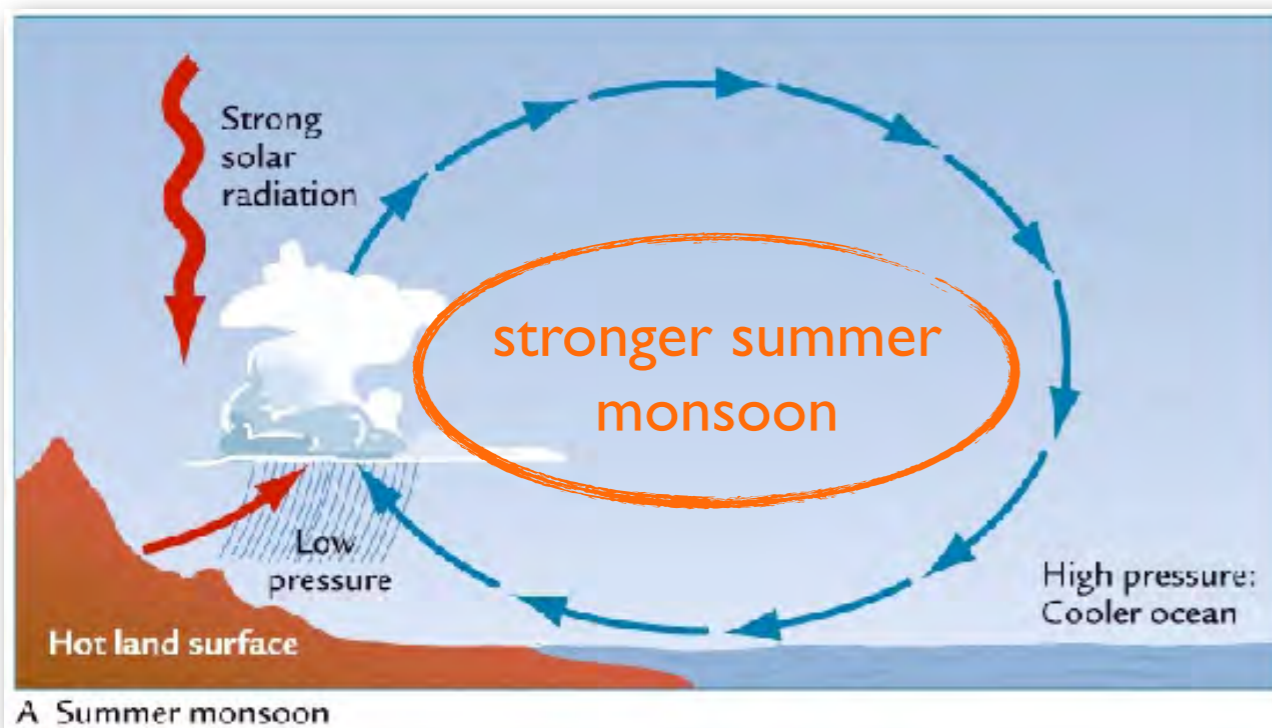
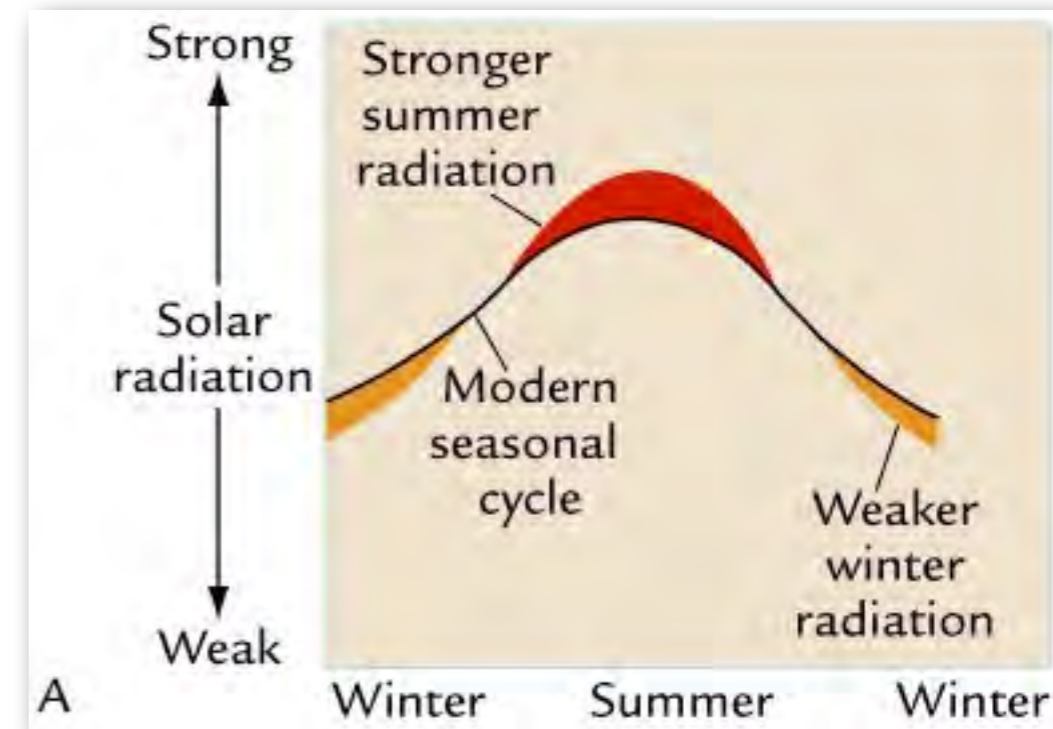


[from: Ruddiman, 2008]

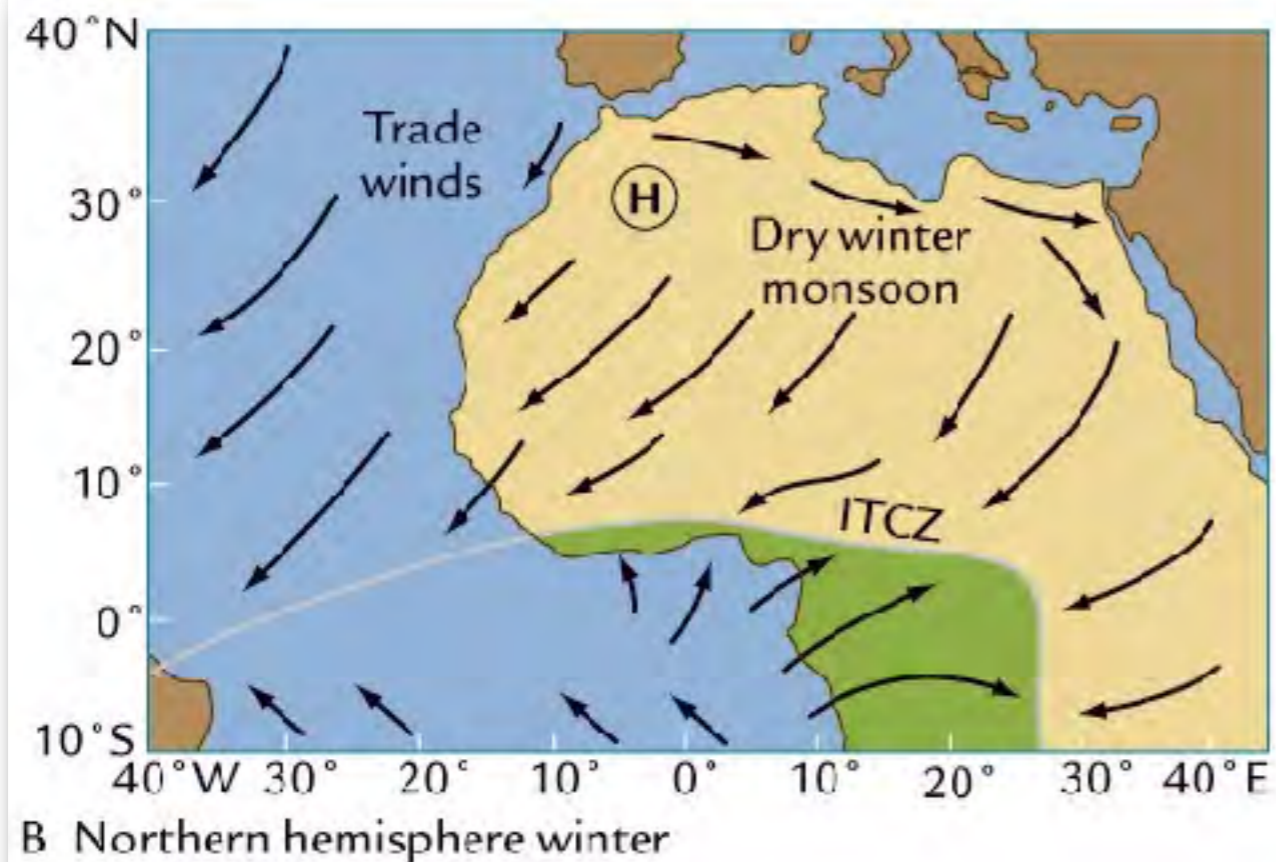
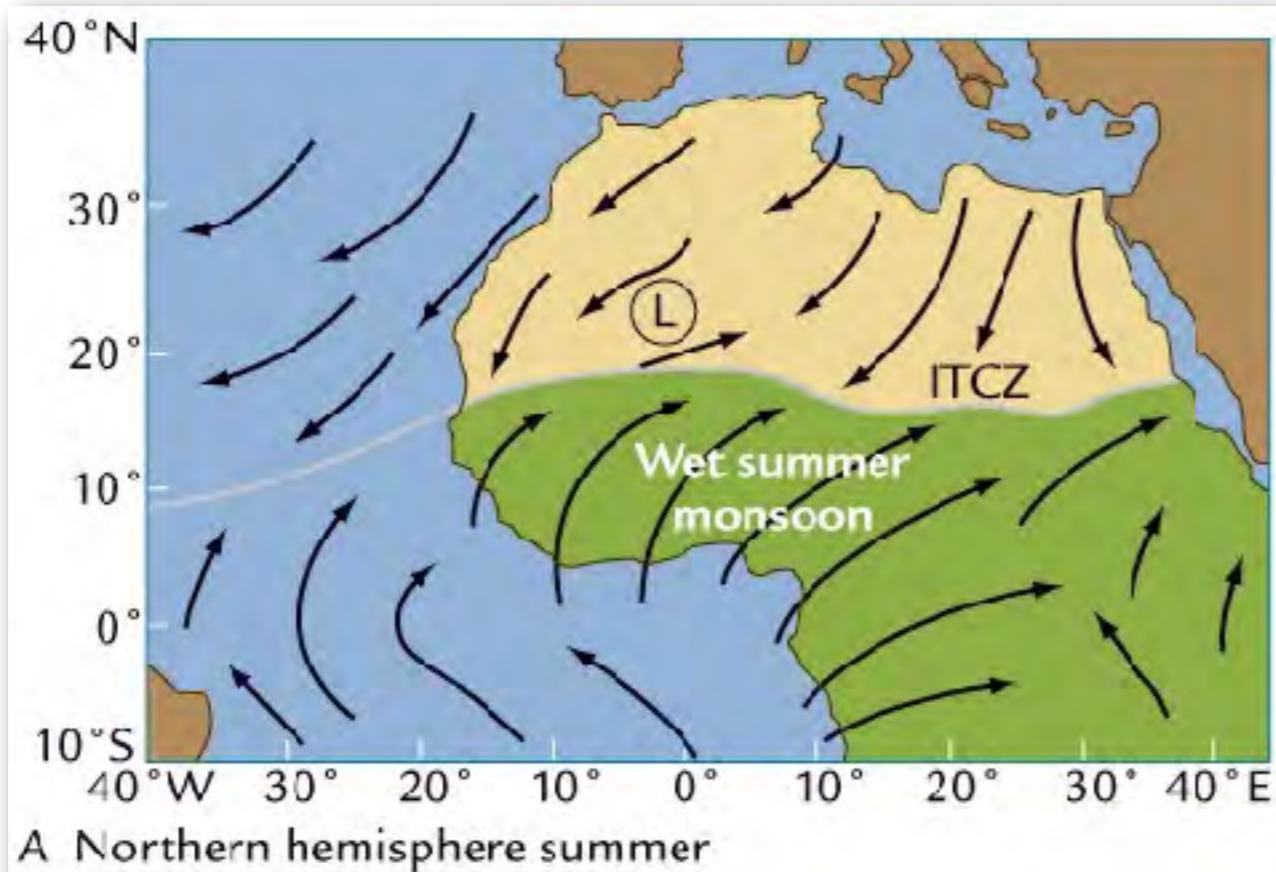
Orbital-scale control of monsoon circulation

orbital monsoon hypothesis (J. Kutzbach, early 1980s)

- *stronger summer insolation caused by orbital changes should cause stronger summer monsoon*
- *vice versa for winter monsoon*
- *annual precipitation effects don't cancel each other out, as normal winter monsoon is often very dry, already => summer monsoon changes dominate annual signal (nonlinear response of the climate system)*

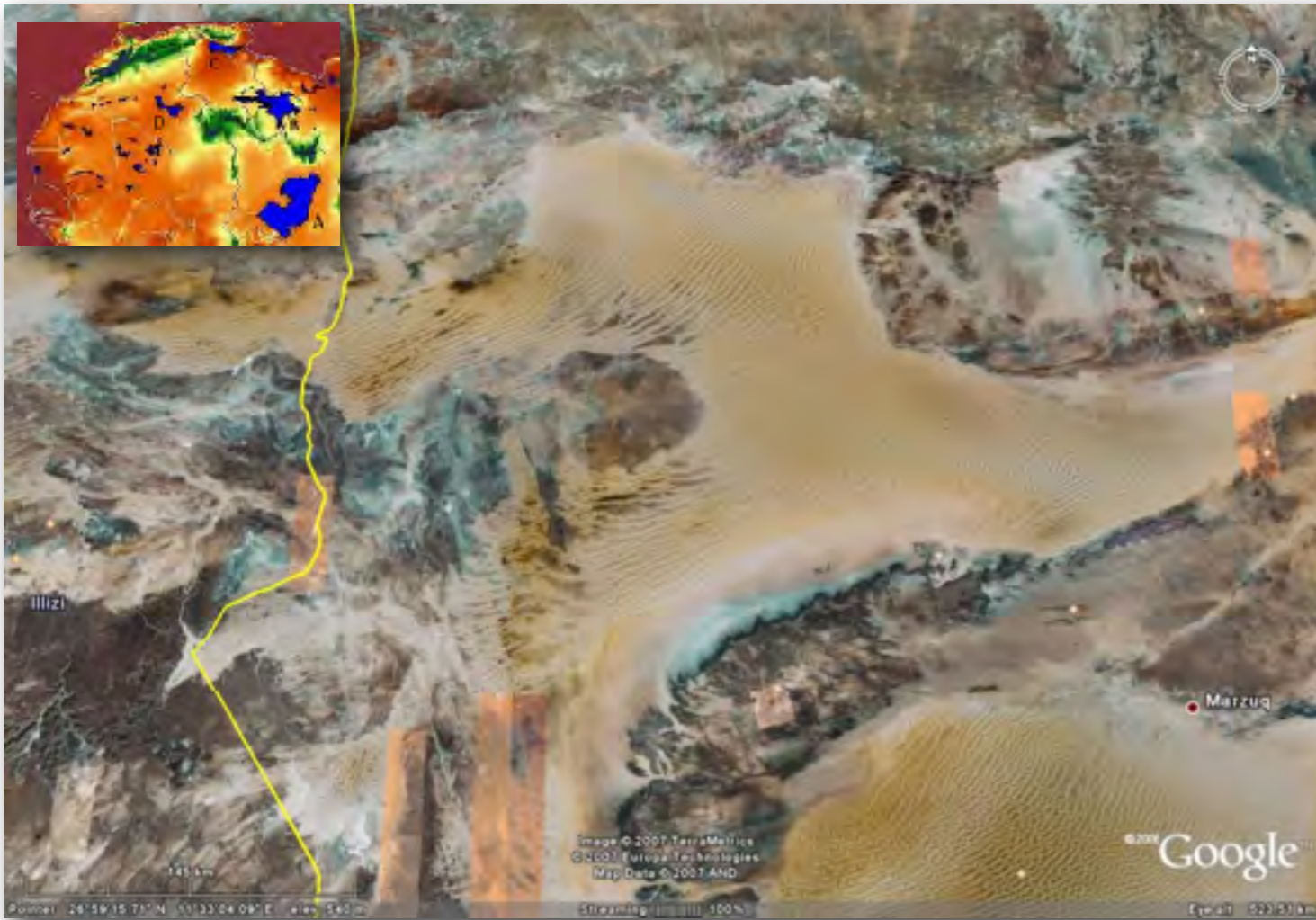


Orbital-scale control of North African monsoon circulation



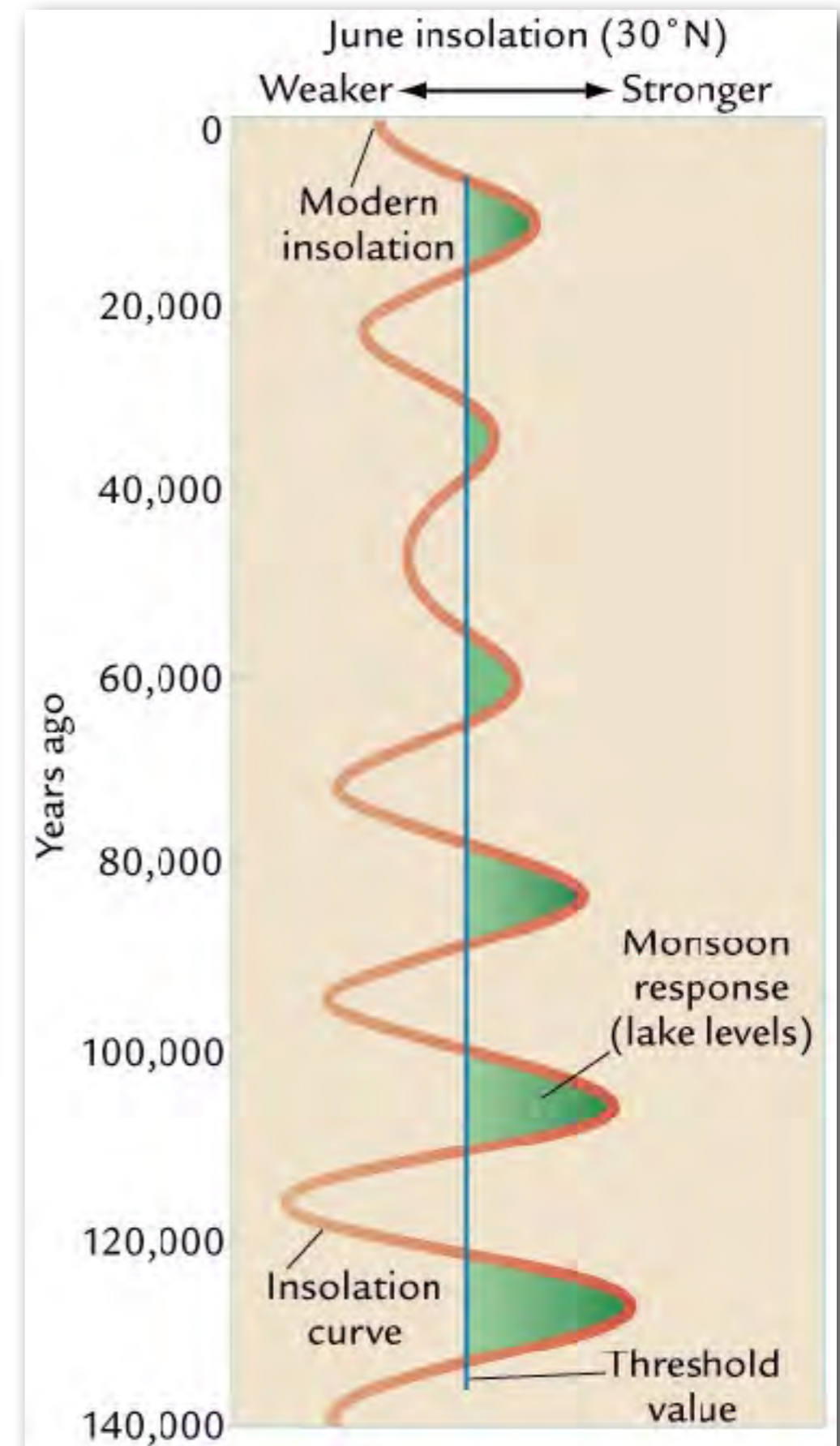
- 1st test of North African orbital monsoon hypothesis:
 - *if summer monsoon brings more rain, there should have been more lakes in Northern Africa*
 - *old lake-beds should still be found*
 - *dating of lake sediments should be consistent with past times of high summer insolation values*

Orbital-scale control of North African monsoon circulation

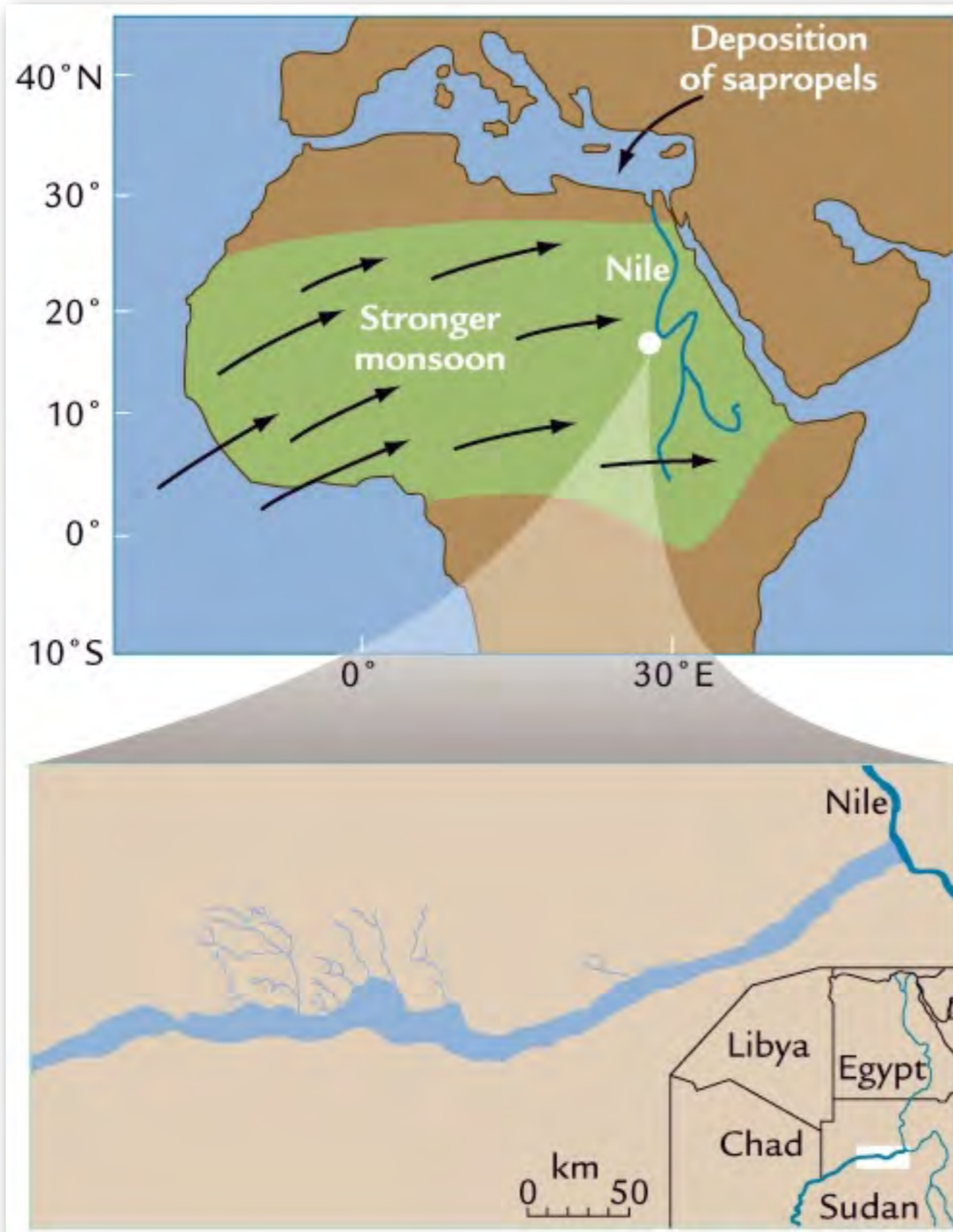


The site of Lake Megafezzan as it appears today. All that remains is sand. (Image from Google Earth)

(from: <http://climatesanity.wordpress.com/category/mega-lakes/>)

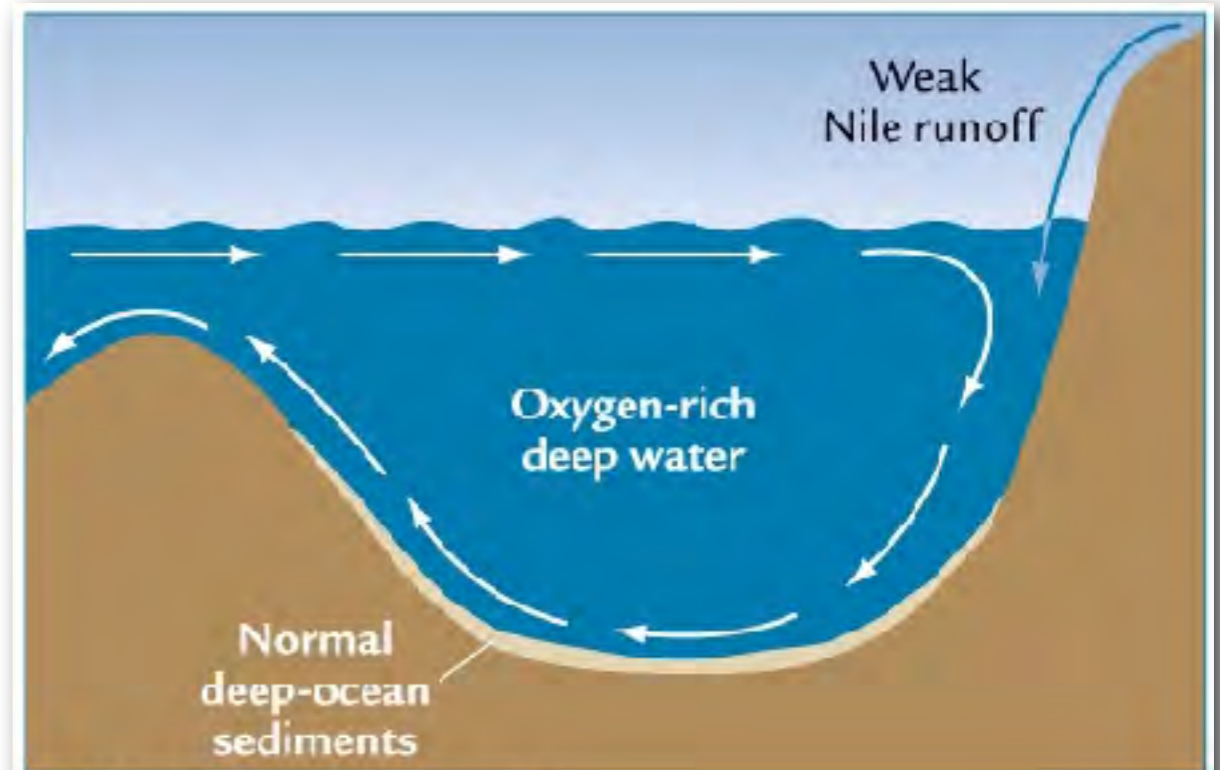
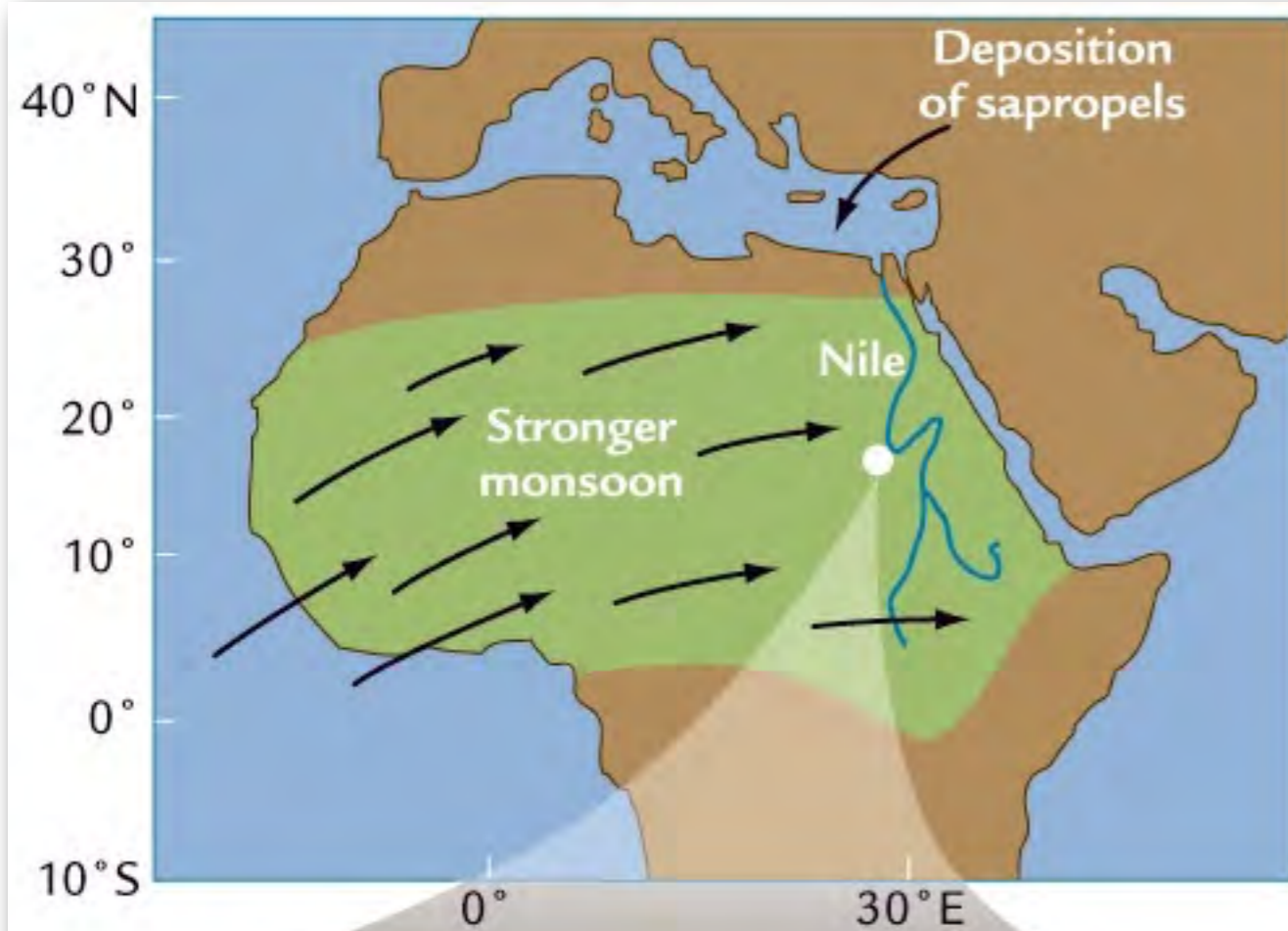


Orbital-scale control of North African monsoon circulation

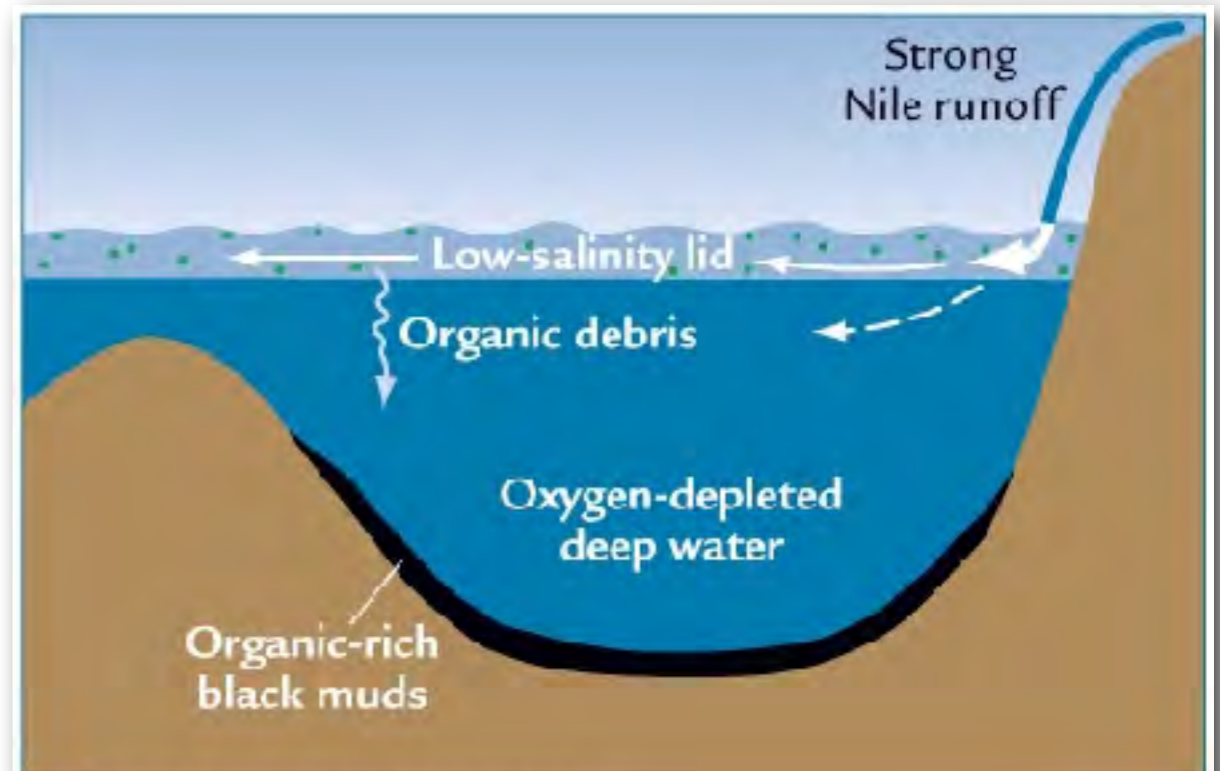


- 2nd test of North African orbital monsoon hypothesis:
 - *if summer monsoon brings more rain, the Nile transports more fresh to the Mediterranean Sea*
 - *the circulation of the Eastern Mediterranean Sea should change*
 - *deep ocean should loose its oxygen*
 - *organic-rich black muds should be deposited (so-called sapropels)*

Orbital-scale control of North African monsoon circulation

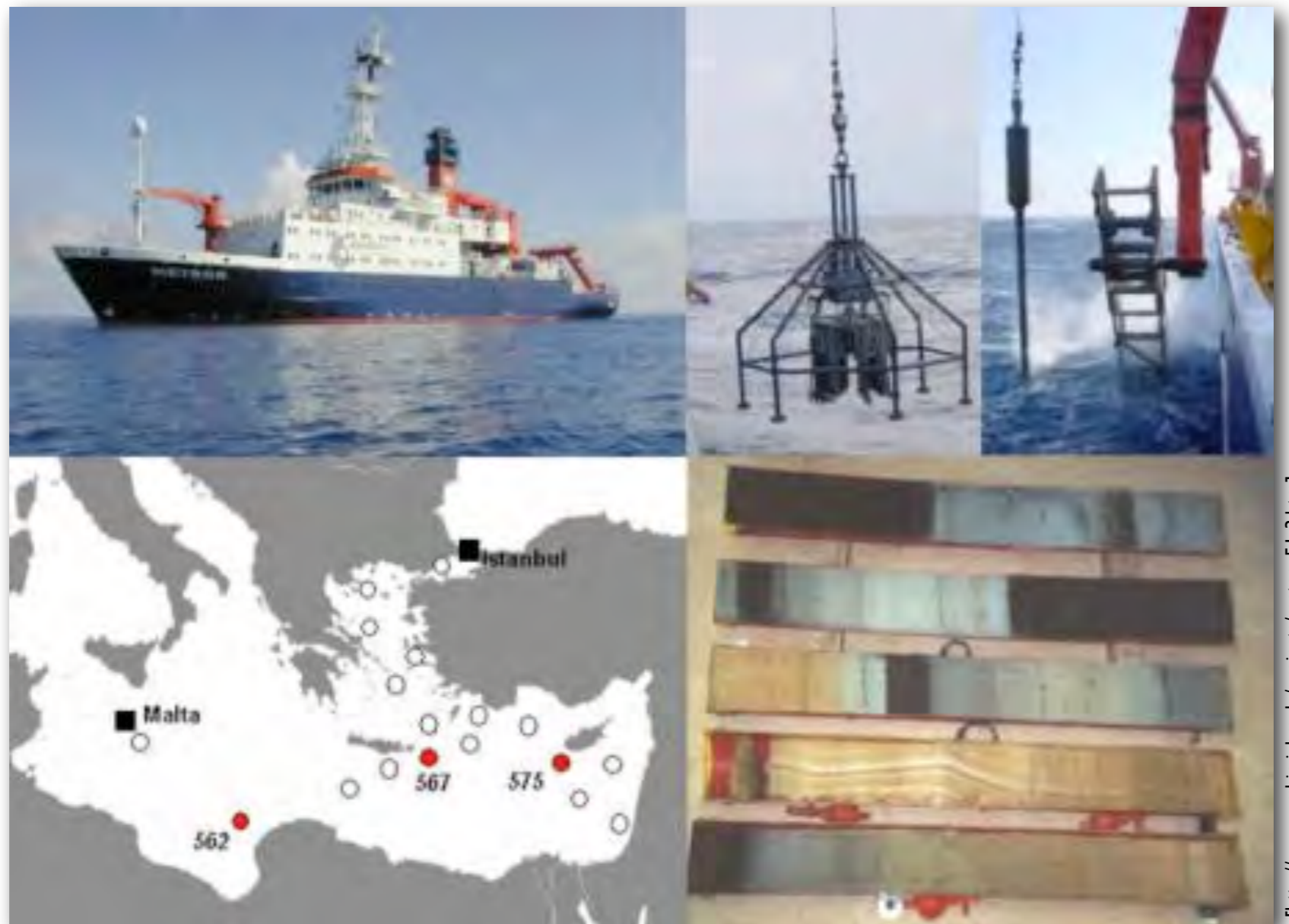


A Weak summer monsoon



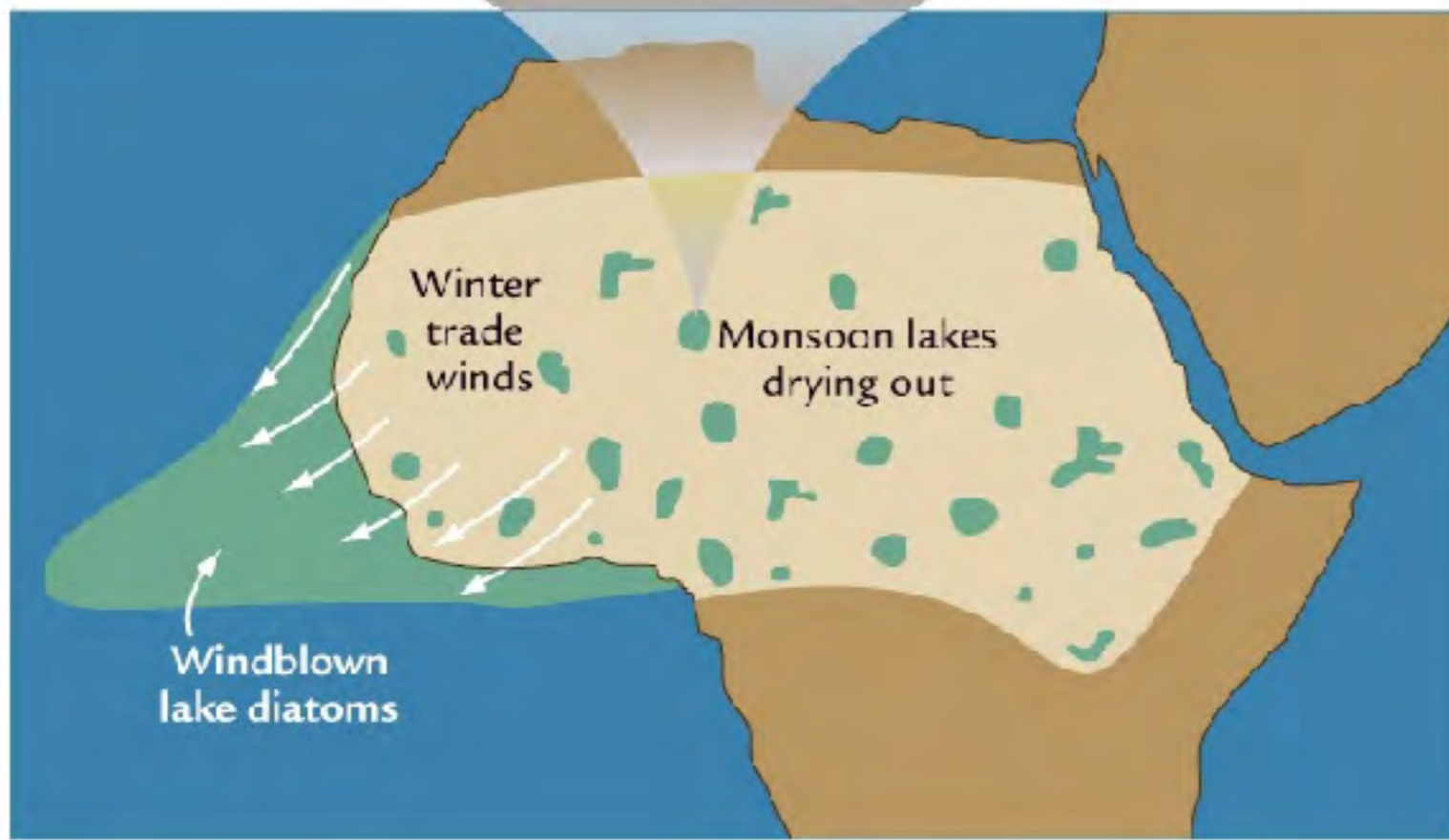
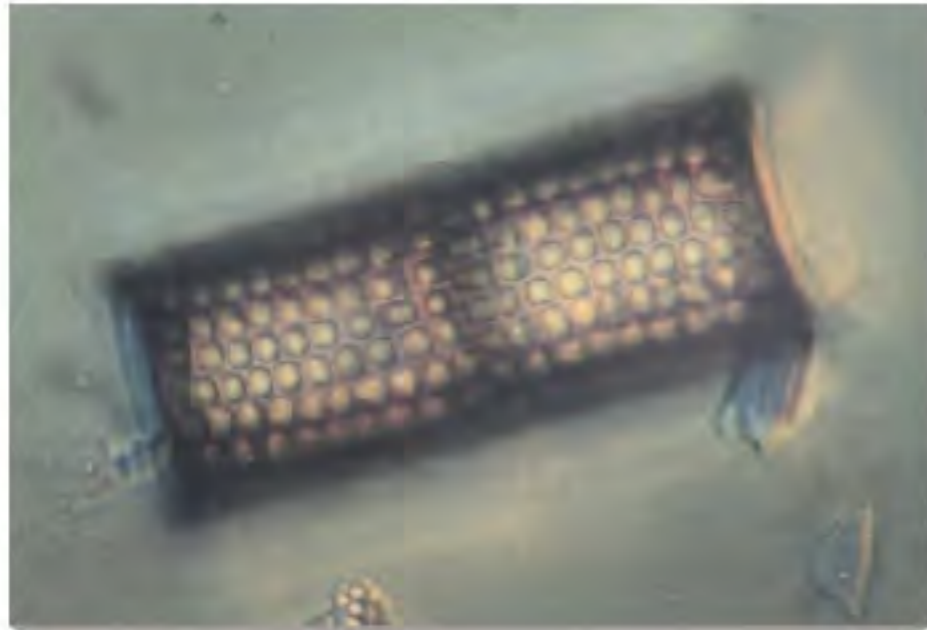
B Strong summer monsoon

Orbital-scale control of North African monsoon circulation



- Sapropels are found in marine sediment cores from the Eastern Mediterranean Sea and their occurrence coincides with periods of strong summer insolation

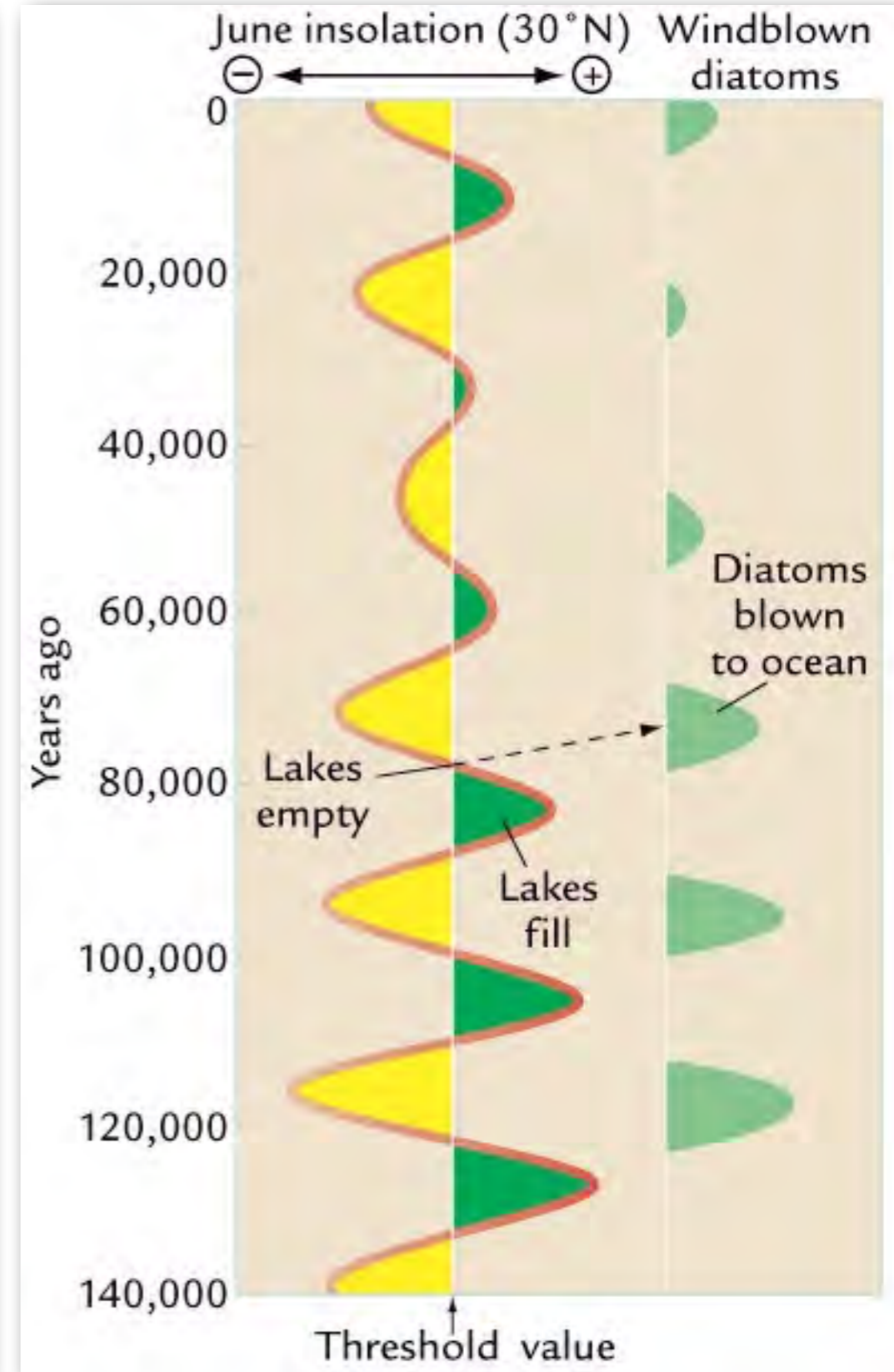
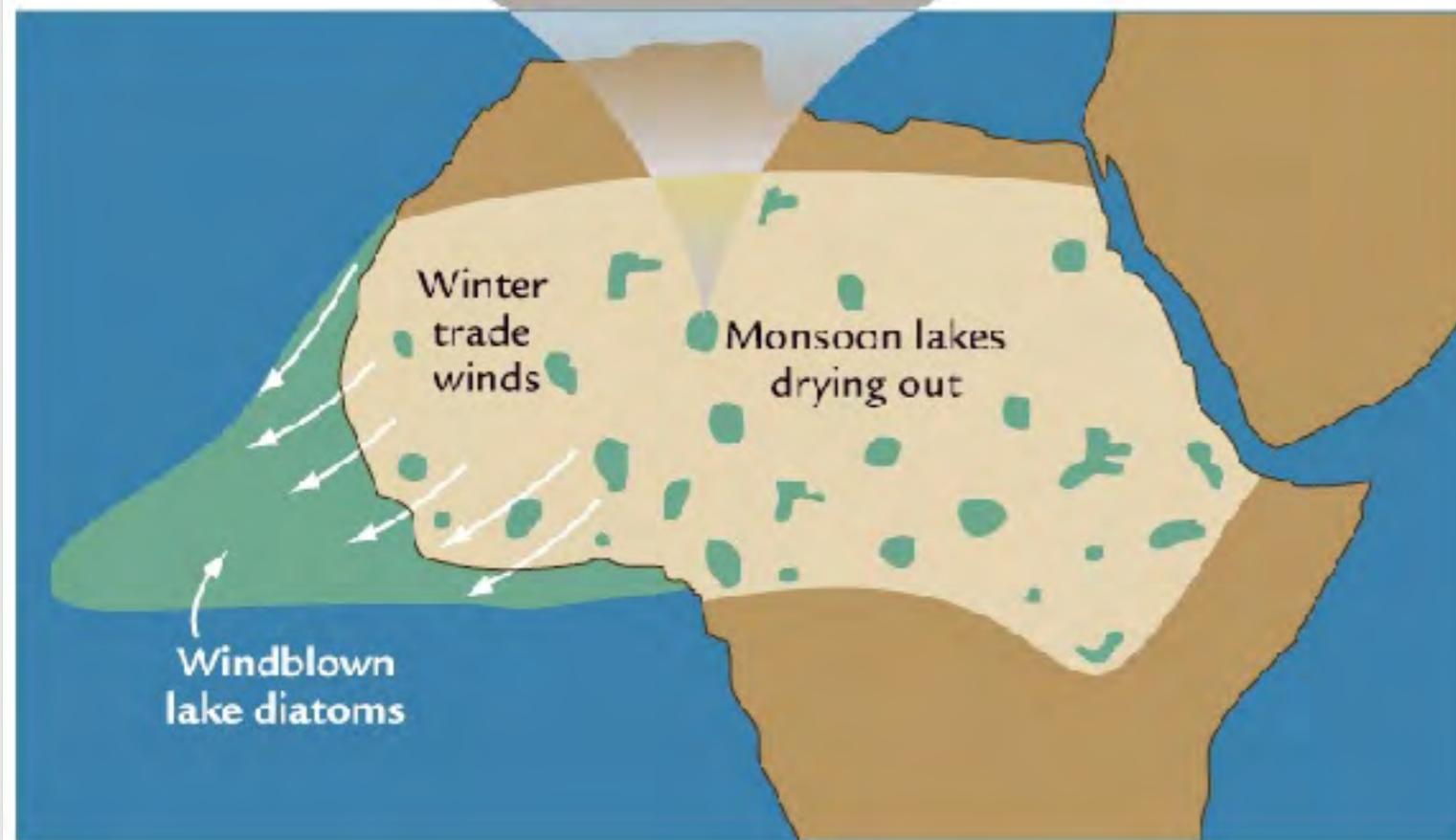
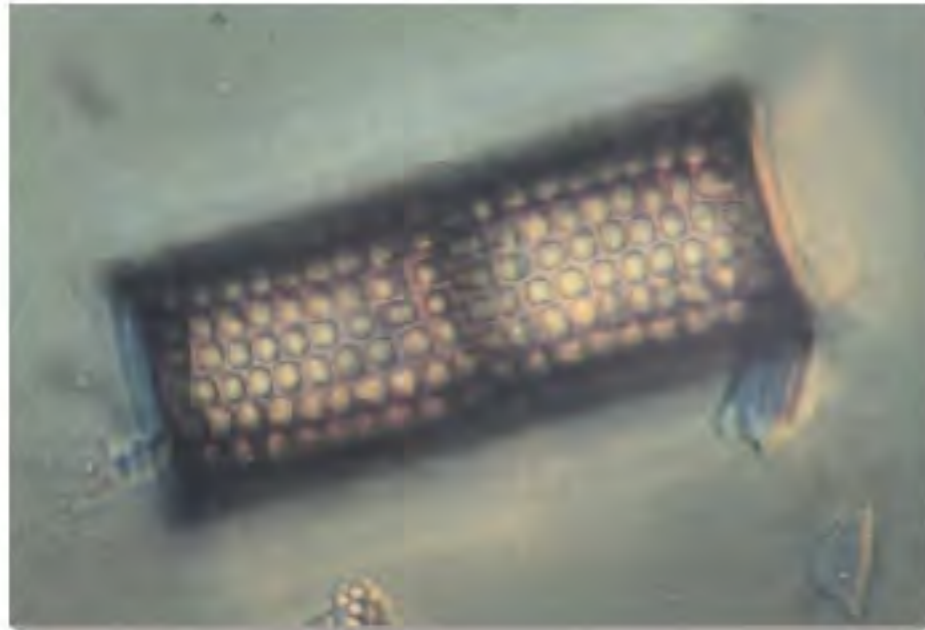
Orbital-scale control of North African monsoon circulation



[from: Ruddiman, 2008]

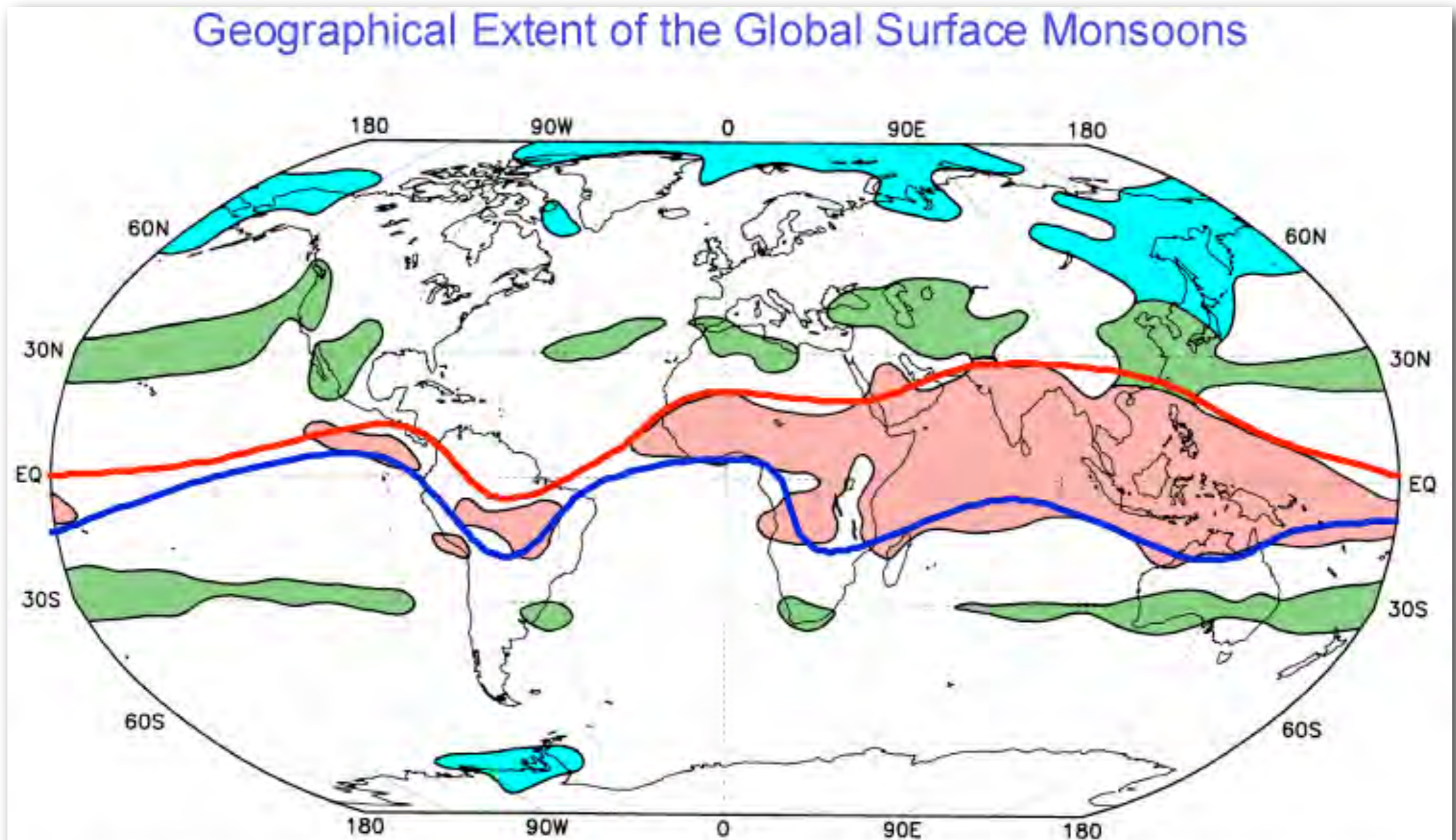
- 3rd test of North African orbital monsoon hypothesis:
 - *if monsoon lakes dry out, the shells of fresh-water organisms (e.g., diatoms) are exposed to surface winds*
 - *small shells & shell particles are blown westwards into the Atlantic*
 - *marine sediments should contain these shells*
 - *the drying and sediment deposition should occur after the intervals of strongest monsoon activity*

Orbital-scale control of North African monsoon circulation



[from: Ruddiman, 2008]

Orbital-scale control of monsoon circulation



The red, green, and blue areas indicate the tropical, subtropical, and temperate-frigid monsoons, respectively. The red and blue thick lines represent the ITCZ in summer and winter, respectively.
(Li, J., and Q. Zeng, 2005)

Orbital-scale control of Asian monsoon circulation

Millennial- and orbital-scale changes in the East Asian monsoon over the past 224,000 years

Yongjin Wang¹, Hai Cheng^{1,2}, R. Lawrence Edwards², Xinggong Kong¹, Xiaohua Shao¹, Shitao Chen¹, Jiangyin Wu¹, Xiouyang Jiang¹, Xianfeng Wang² & Zhisheng An³

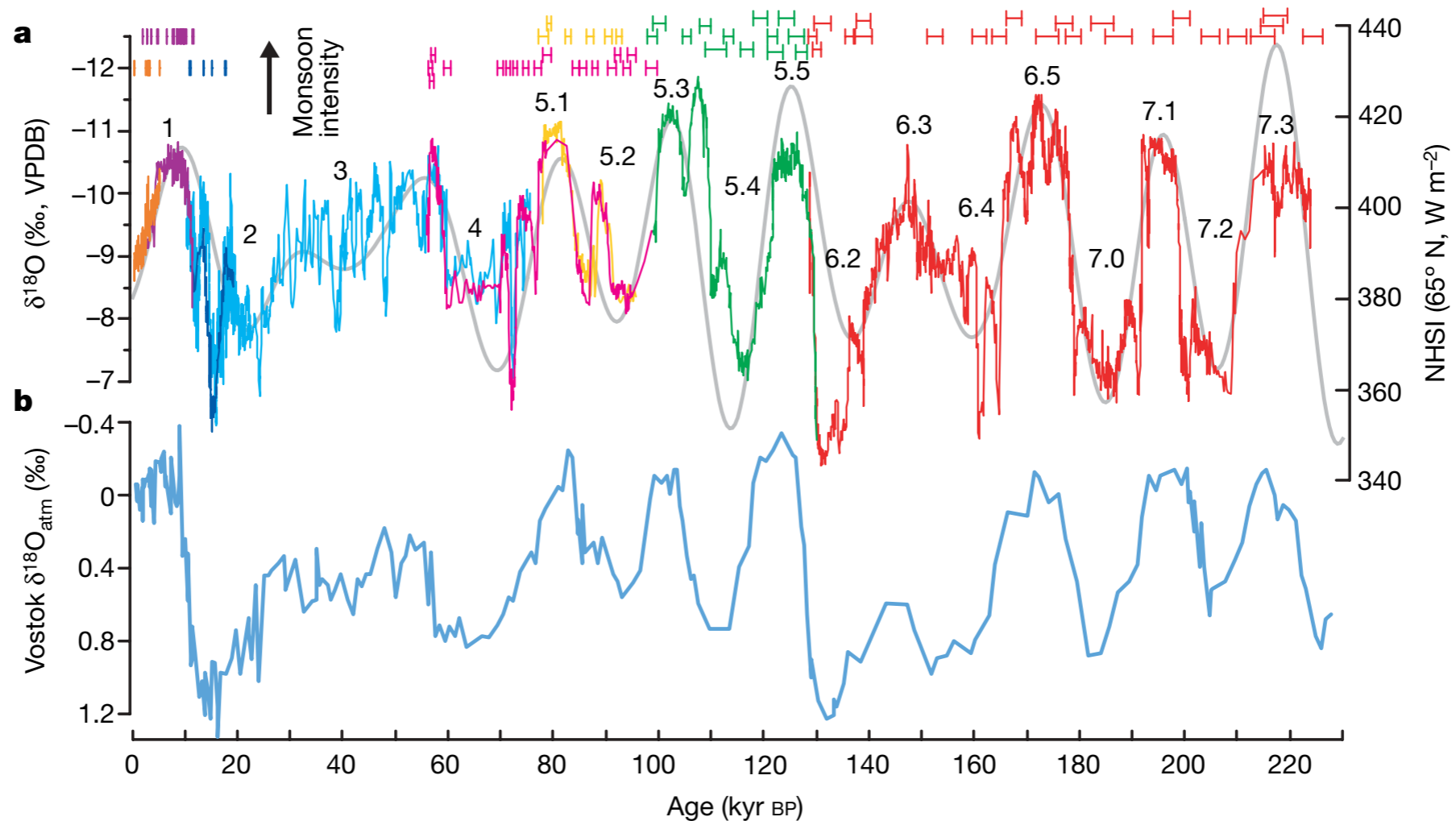


Figure 1 | Comparison of Sanbao/Hulu $\delta^{18}\text{O}$ records with NHSI and atmospheric $\delta^{18}\text{O}$ record over the past 224 kyr BP. **a**, Time versus Sanbao $\delta^{18}\text{O}$ records (red, stalagmite SB11; green, SB23; yellow, SB25-1; pink, SB22; dark blue, SB3; purple, SB10 and orange, SB26) and Hulu cave (blue)², and NHSI (Northern Hemisphere summer insolation, 21 July) at 65° N¹⁰ (grey).

For comparison, the Hulu $\delta^{18}\text{O}$ record is plotted 1.6‰ more negative to account for the higher Hulu values than Sanbao cave (see Supplementary Fig. 4). The ^{230}Th ages and errors (2 σ error bars at top) are colour-coded by stalagmites. Numbers indicate the marine isotope stages and substages. **b**, The atmospheric $\delta^{18}\text{O}$ record from Vostok ice core, Antarctica²⁸.

Orbital-scale control of South American monsoon circulation

NATURE | VOL 434 | 3 MARCH 2005 |

Insolation-driven changes in atmospheric circulation over the past 116,000 years in subtropical Brazil

Francisco W. Cruz Jr^{1,2}, Stephen J. Burns¹, Ivo Karmann², Warren D. Sharp³, Mathias Vuille¹, Andrea O. Cardoso⁴, José A. Ferrari⁵, Pedro L. Silva Dias⁴ & Oduvaldo Viana Jr²

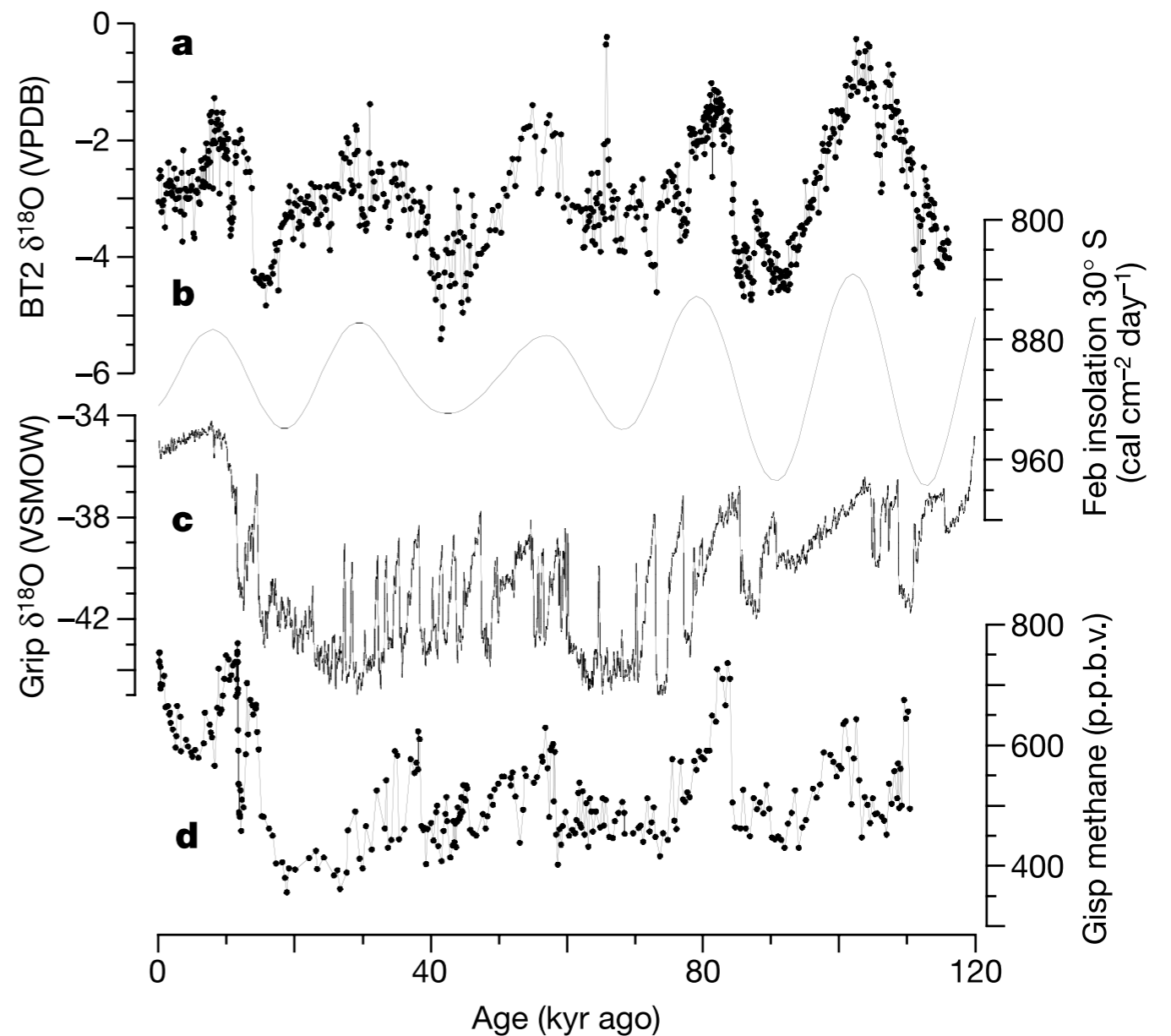
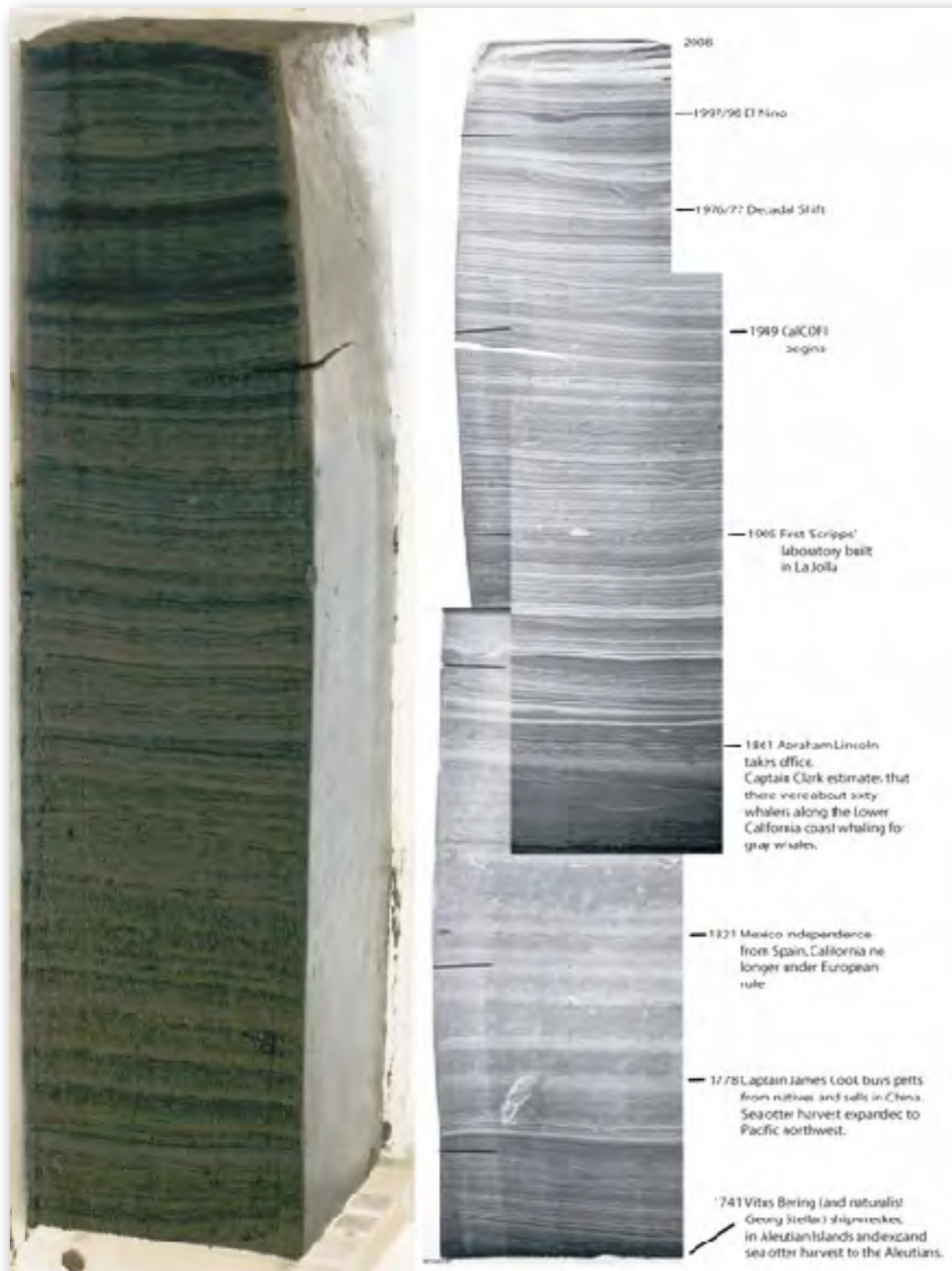


Figure 2 Stable oxygen isotope profile for stalagmite BT2. The BT2 profile (**a**) is compared with February solar insolation for 30° S (**b**), oxygen isotopes of the N-Grip ice core from Greenland (**c**), and atmospheric methane concentrations from the Greenland ice core (**d**).

Key climate archives

- ice cores
- marine sediment cores
- corals
- speleothems
- tree rings
- pollen
- ...

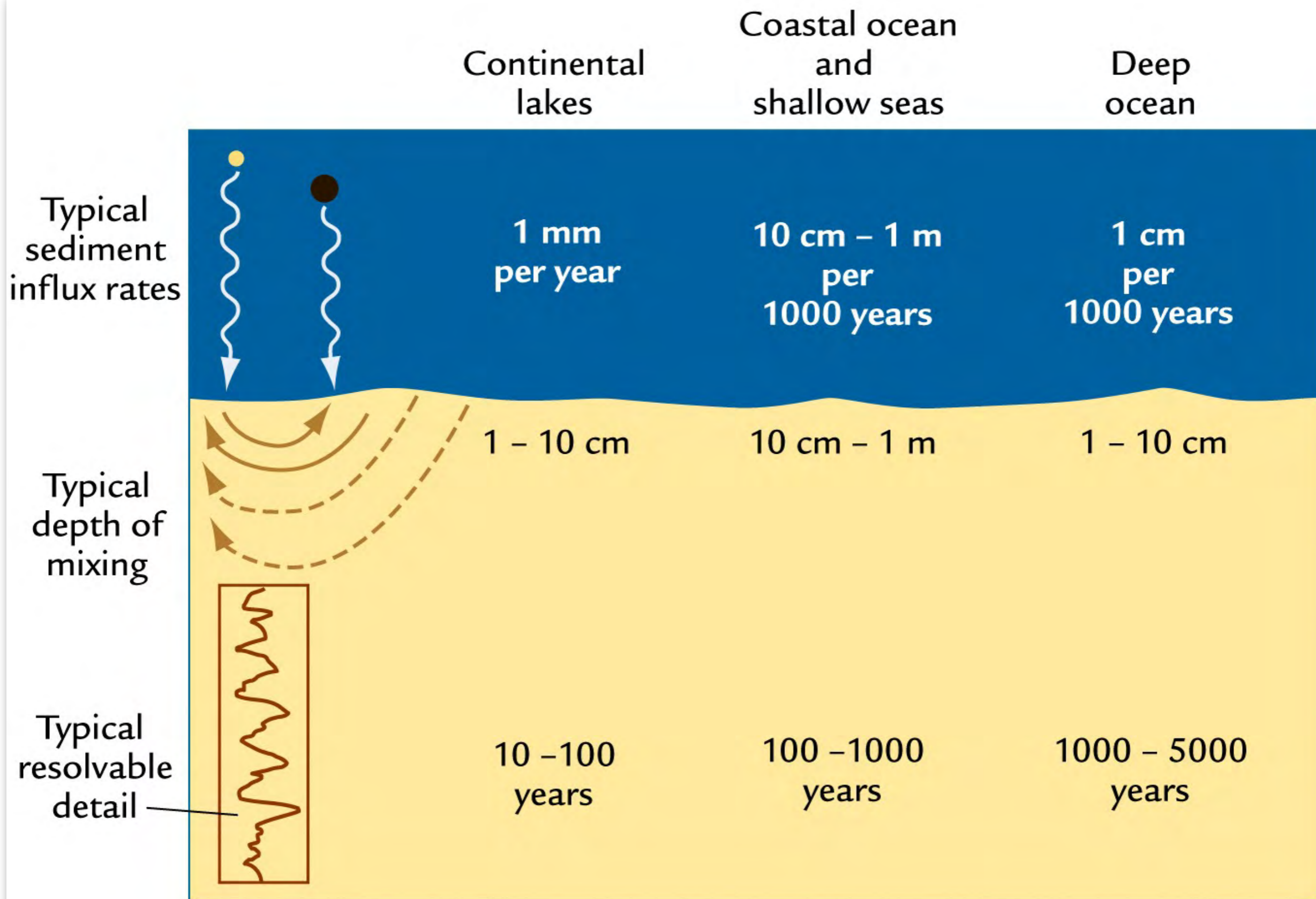
Marine sediment cores



- 1: Japan Sea (color alternation)
- 2: Japan Sea (laminated sediments)
- 3: East China Sea (deep sea sediments)
- 4: Arabian Sea (calcareous ooze)
- 5: Arabian Sea (calcareous ooze)
- 6: Sulu Sea (calcareous ooze)
- 7: Southern Ocean (diatom ooze)

These cores were recovered during cruises by the R/V Hakuho-Maru, Ocean Research Institute, University of Tokyo

Formation of marine sediments

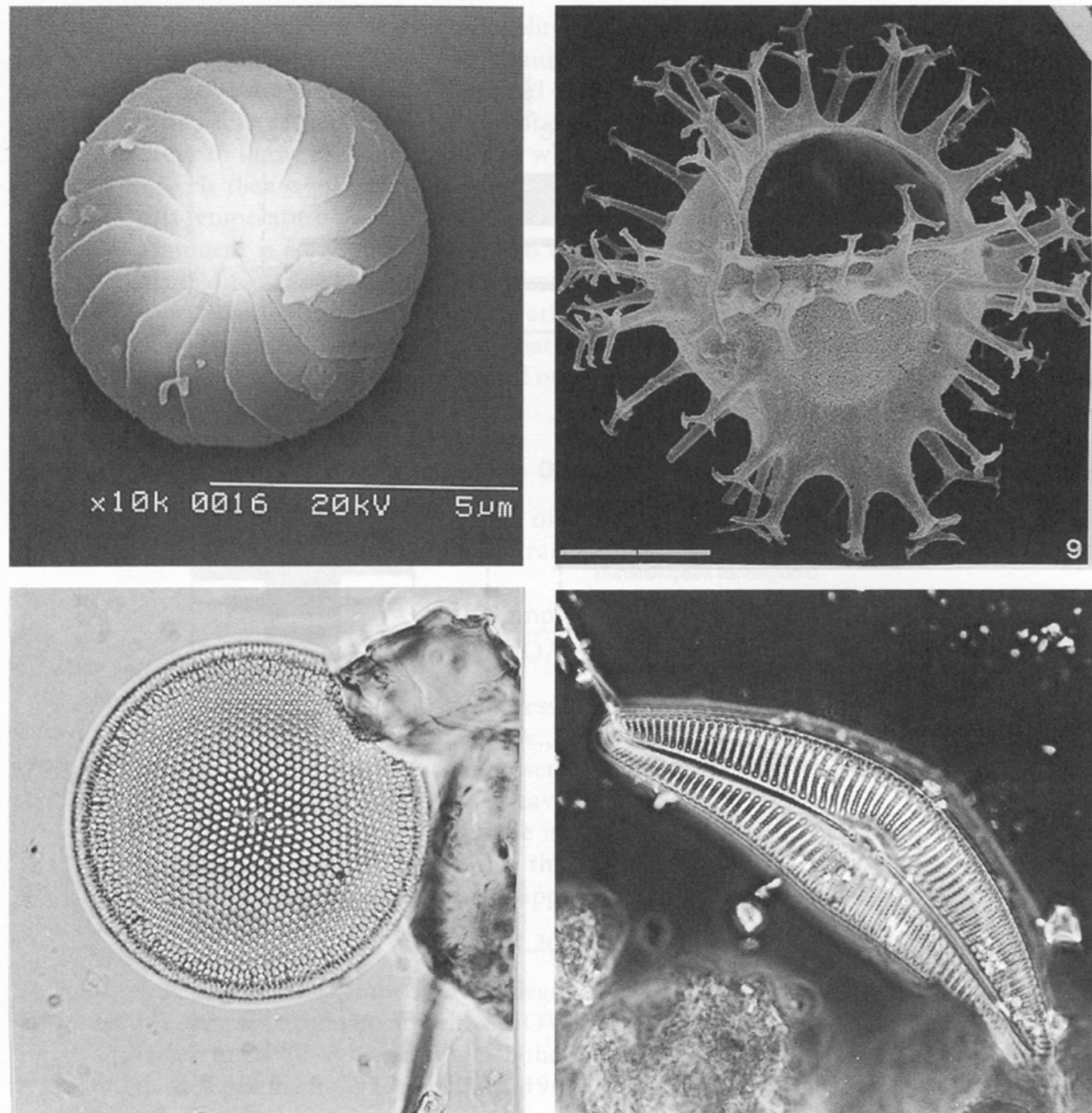


Formation of marine sediments

- 70% of Earth's surface is covered by oceans
- yearly sediment production: approx. 6-11 billion tons (=10¹²kg)
- sediment contains both biogenic and terrigenous material
- **biogenic material:**
 - **planktic organism** = live near the sea surface
 - **benthic organism** = live near the sea floor
 - biogenic material may be used as a proxy for
 - *water temperatures (surface waters, deep sea waters)*
 - *salinity*
 - *dissolved oxygen, trace substances, etc.*
- **terrigenous material**
 - is transported from land surfaces to the oceans by the wind
 - can be used as a proxy for aridity and/or changes in wind strength/wind directions

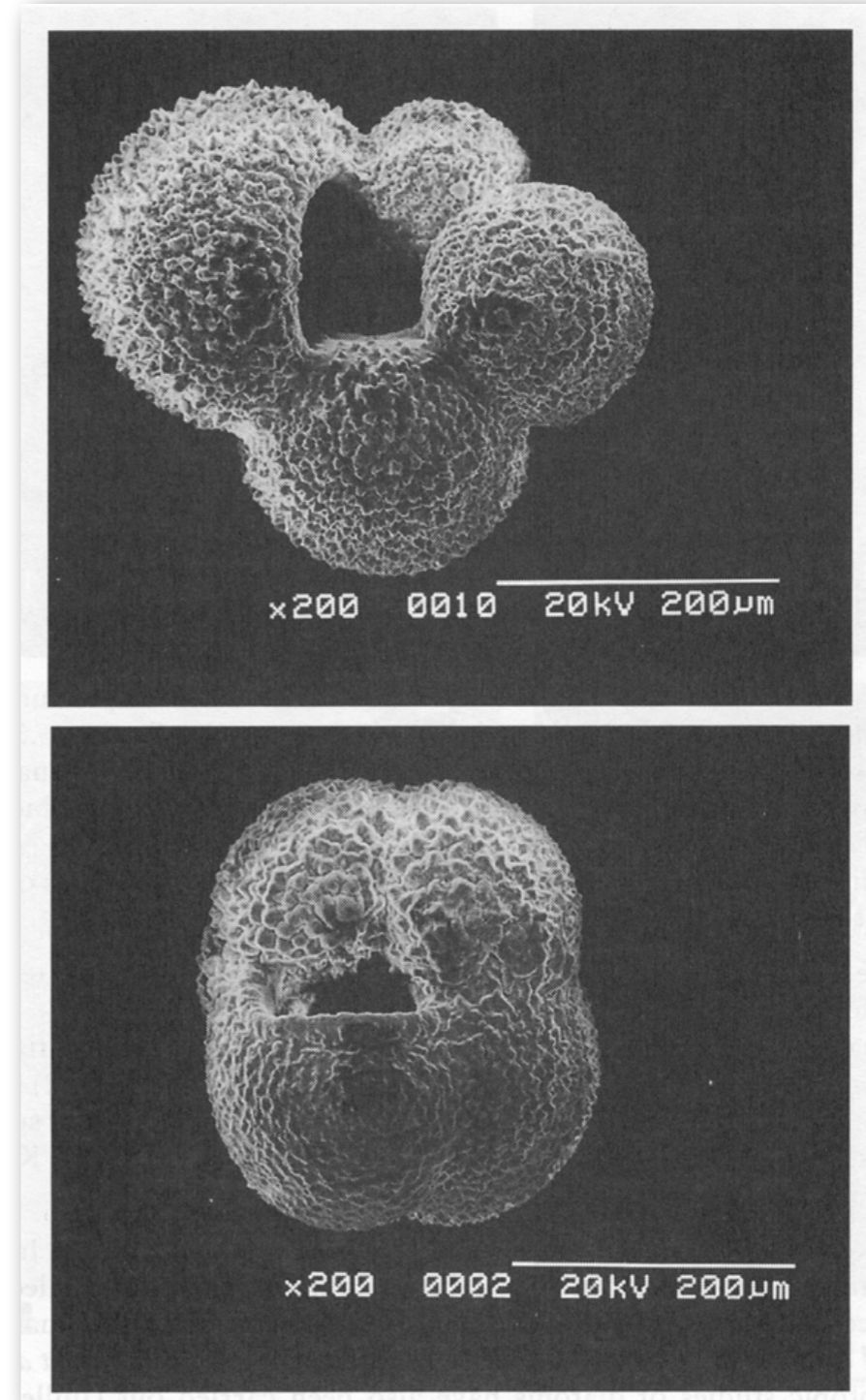
Formation of marine sediments

Coccolithophors
(Phytoplankton)



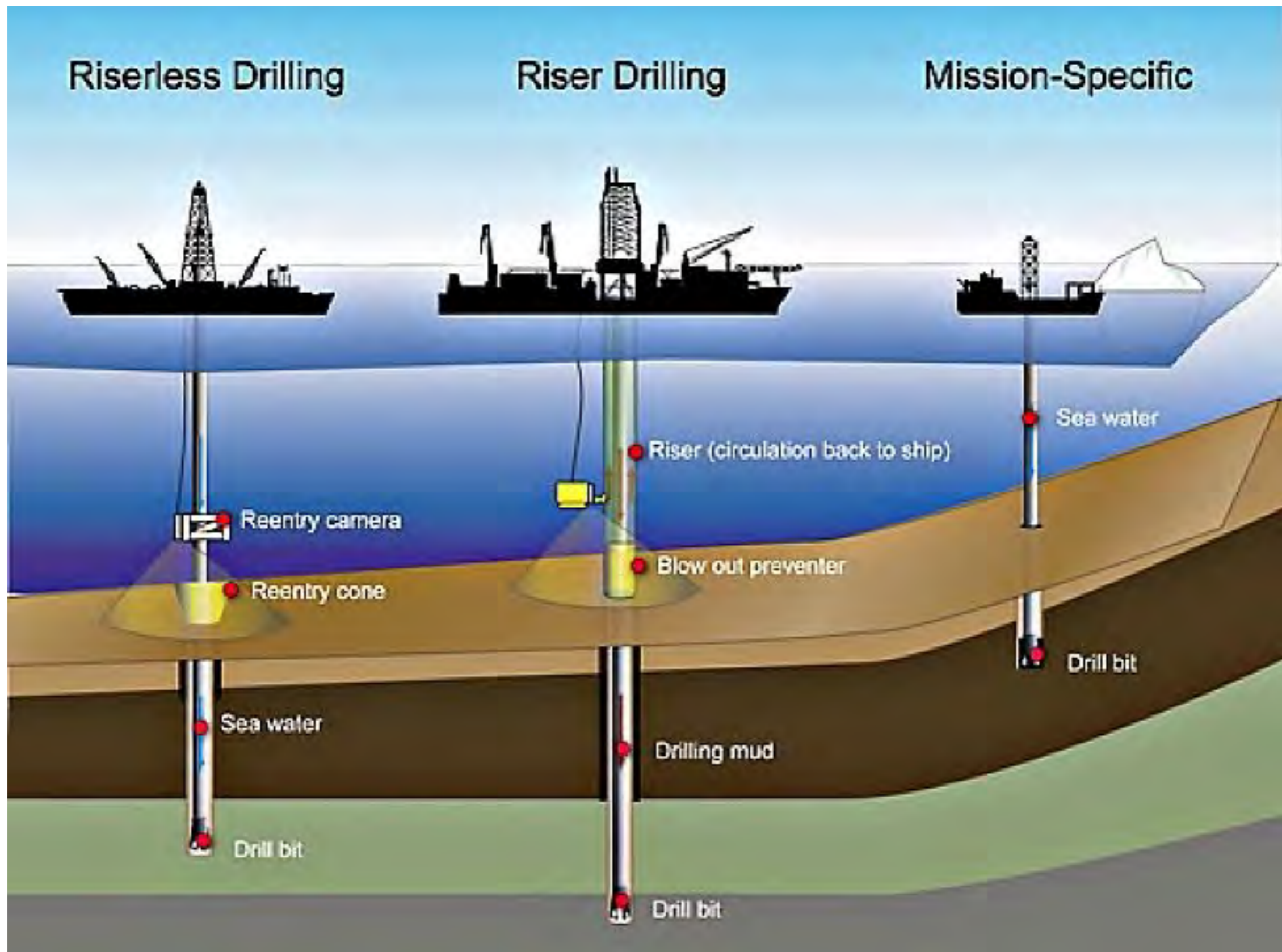
Bradley, Abb. 6.5

Foraminifers
(Zooplankton)



Bradley, Abb. 6.3

Drilling of marine sediment cores




The International Ocean Discovery Programme (IODP)

International Ocean Discovery Program

JOIDES Resolution Science Operator

Home Expeditions Participants Travel & Meetings Technology Data Samples Publications Outreach Related Sites About Search



Expedition 352
JOIDES Resolution in the Philippine Sea

Notice See the [COVID Mitigation Protocols Established for Safe JR Operations \(COPE\)](#). For information about the 2019 Novel Coronavirus (2019-nCoV) and COVID-19, please see the [Texas A&M University Coronavirus Update site](#).

Announcements

Current Science Reports

- [Expedition 395P Science Reports](#)
- [Expedition 395P Daily Reports](#)

Recent Science Reports

Expedition 390C


- [Expedition 390C Science Reports](#)
- [Expedition 390C Photo Gallery](#)

Expedition 384

- [Expedition 384 Science Reports](#)
- [Expedition 384 Photo Gallery](#)

Current Expedition

Expedition 395P: Complete South Atlantic Transect Reentry Installations



Tweets by @IODP

IODP at Texas A&M Retweeted

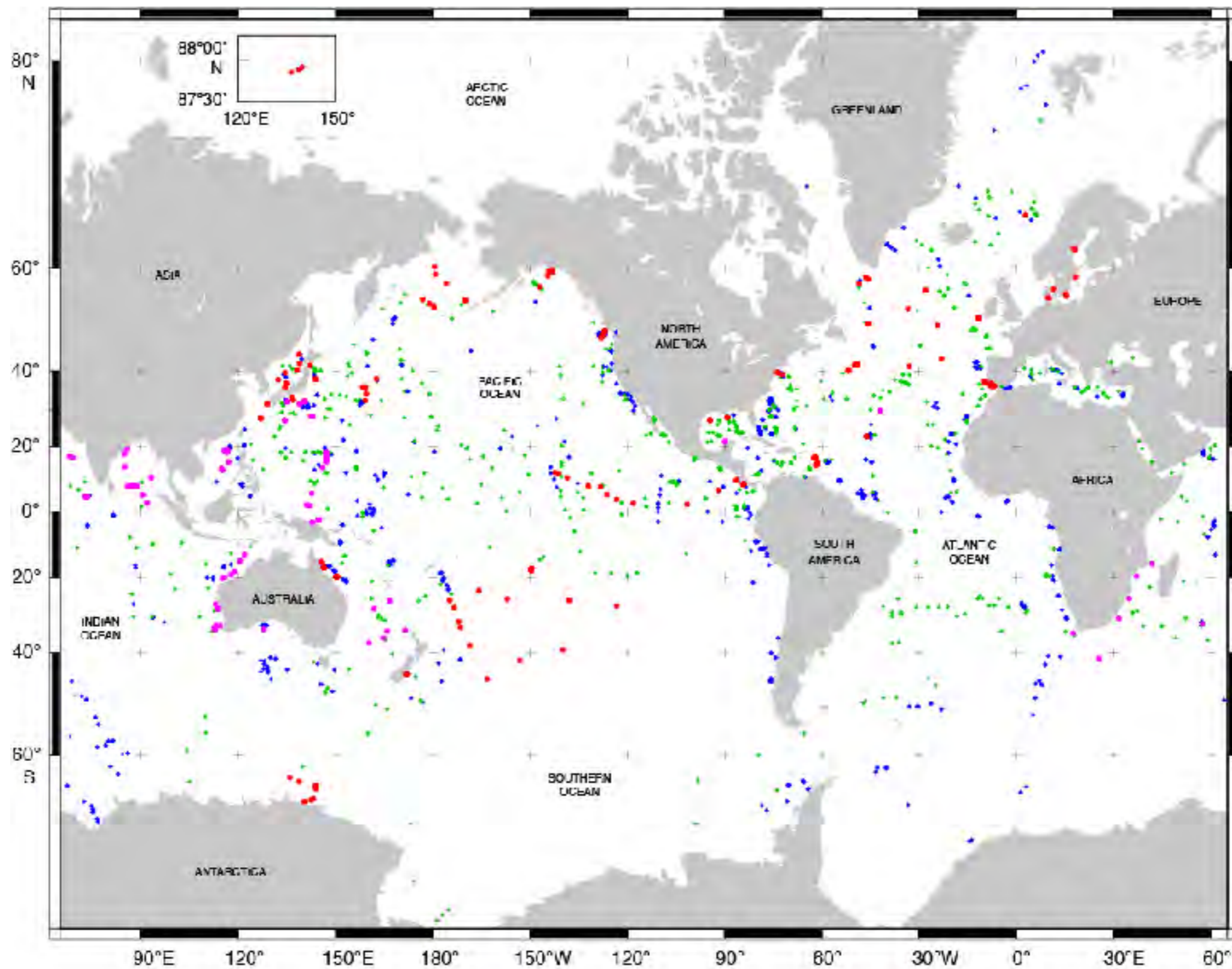
Beth Orcutt @BethOrcutt
do you love ocean microbes and their genomes and are you looking for a postdoc position? @rstepanusukas at @BigelowLab in Maine is hiring! Apply by March 14! bigelow.org/about/careers...

IODP at Texas A&M Retweeted

UL Lafayette School of Geosciences

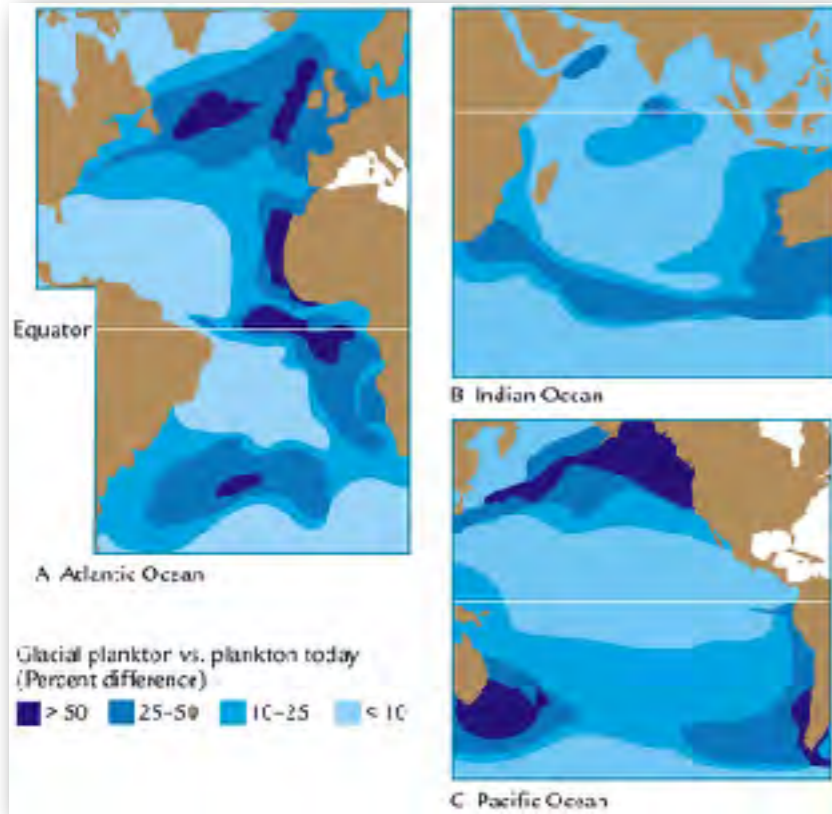
<http://iodp.tamu.edu/index.html>

Drill sites of international drilling programs



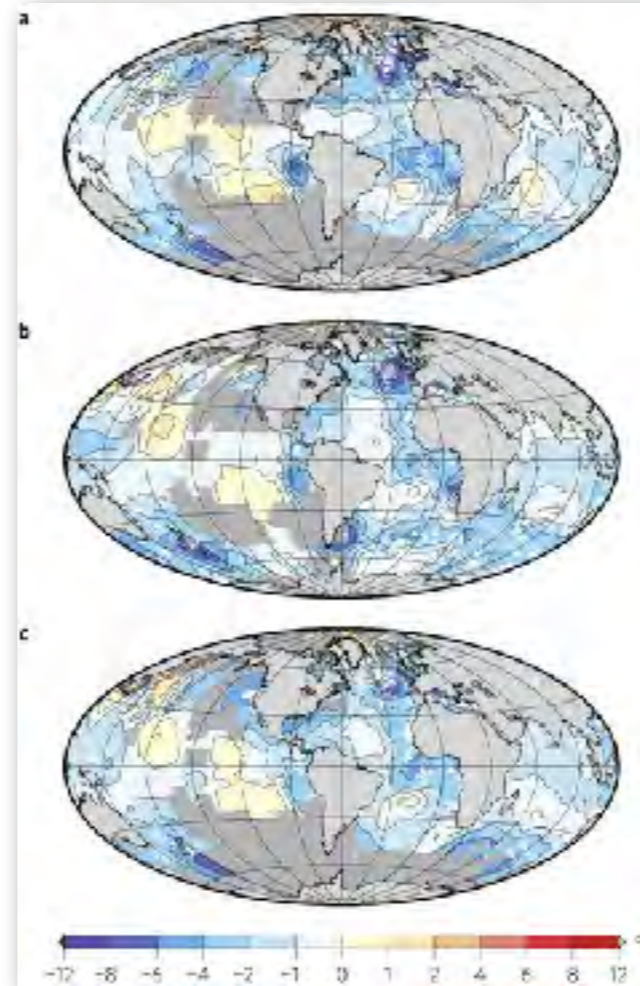
DSDP Legs 1-96 (●), ODP Legs 100-210 (●), IODP Expeditions 301-348 (●), IODP Expeditions 349-371 (●)

Examples of marine sediment analyses



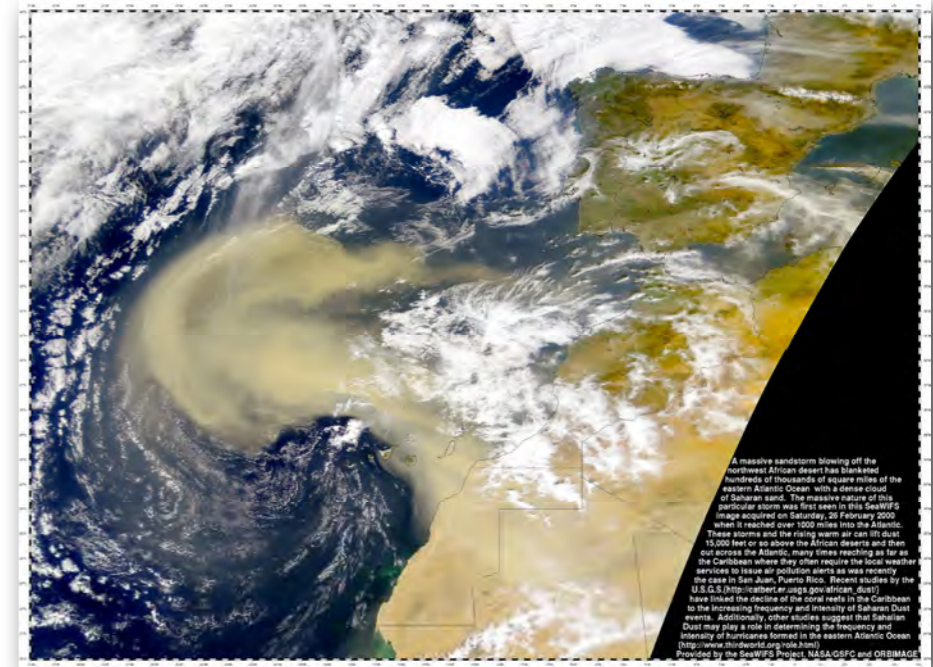
[from: Ruddiman, 2008]

plankton assemblages



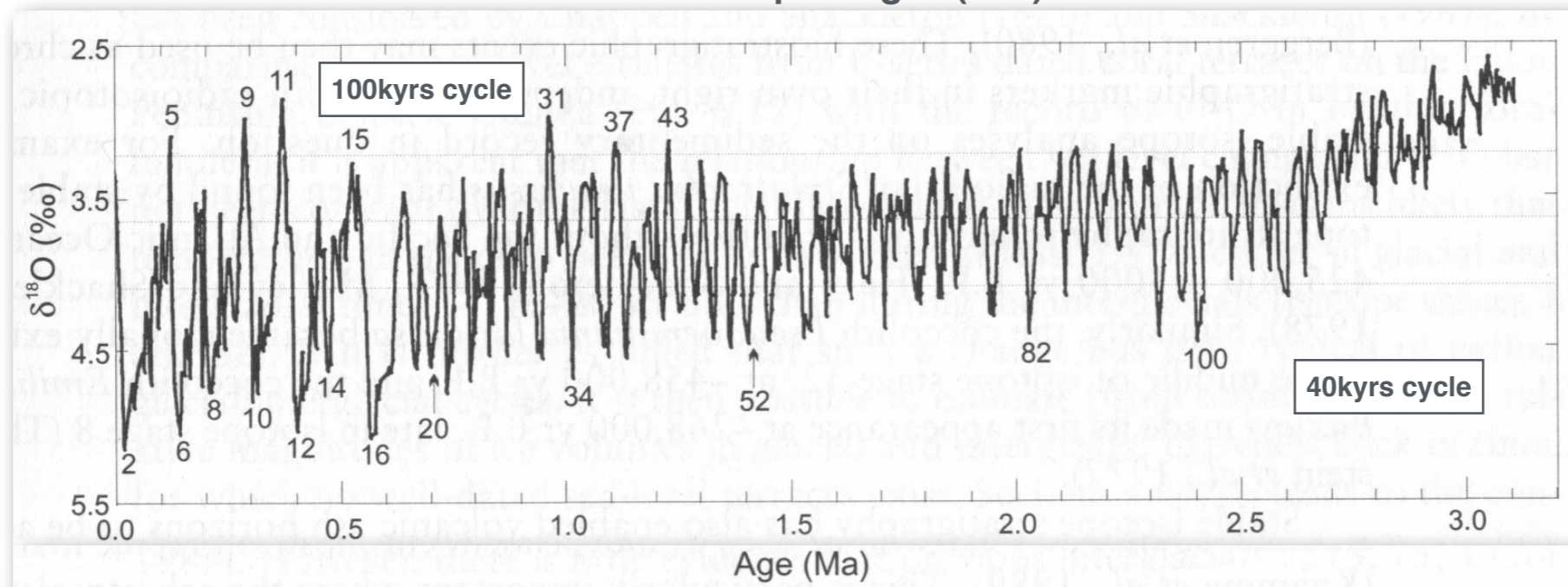
LGM SST reconstructions

[MARGO Project Members, Nature Geoscience, 2009]



dust & other inorganic material

Marine isotope stages (MIS)



Corals

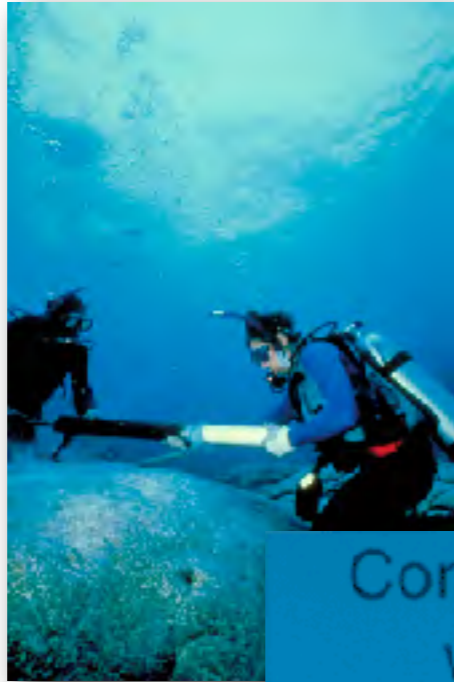
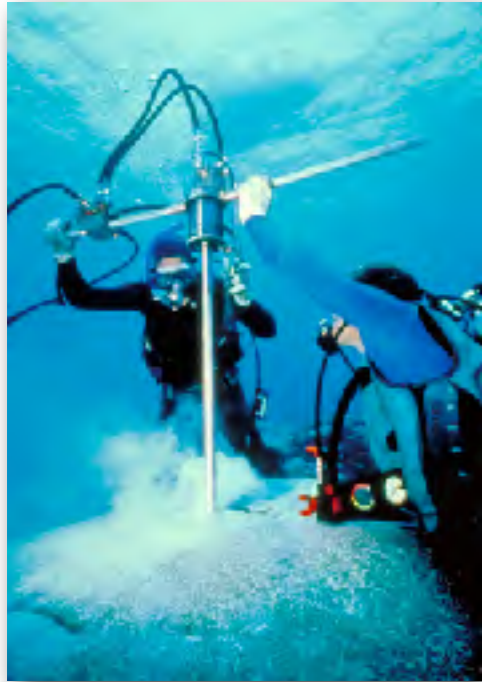


Corals

- main interest for paleoclimatological studies: Hermatypic corals (reef-building corals)
 - *exist mainly between 30°N - 30°S, with an average SST of 20°C*
 - *if SST are below 18°C, the coral reefs grow only very slowly or even die (at colder temperatures)*
- typical coral analyses: growth rates, isotopes, trace elements, ...
- coral records may cover the last 100,000 years (or even older periods)
 - *often, corals just grow during warm climates*
- corals are a very promising climate archive for the reconstruction of tropical SST



Corals

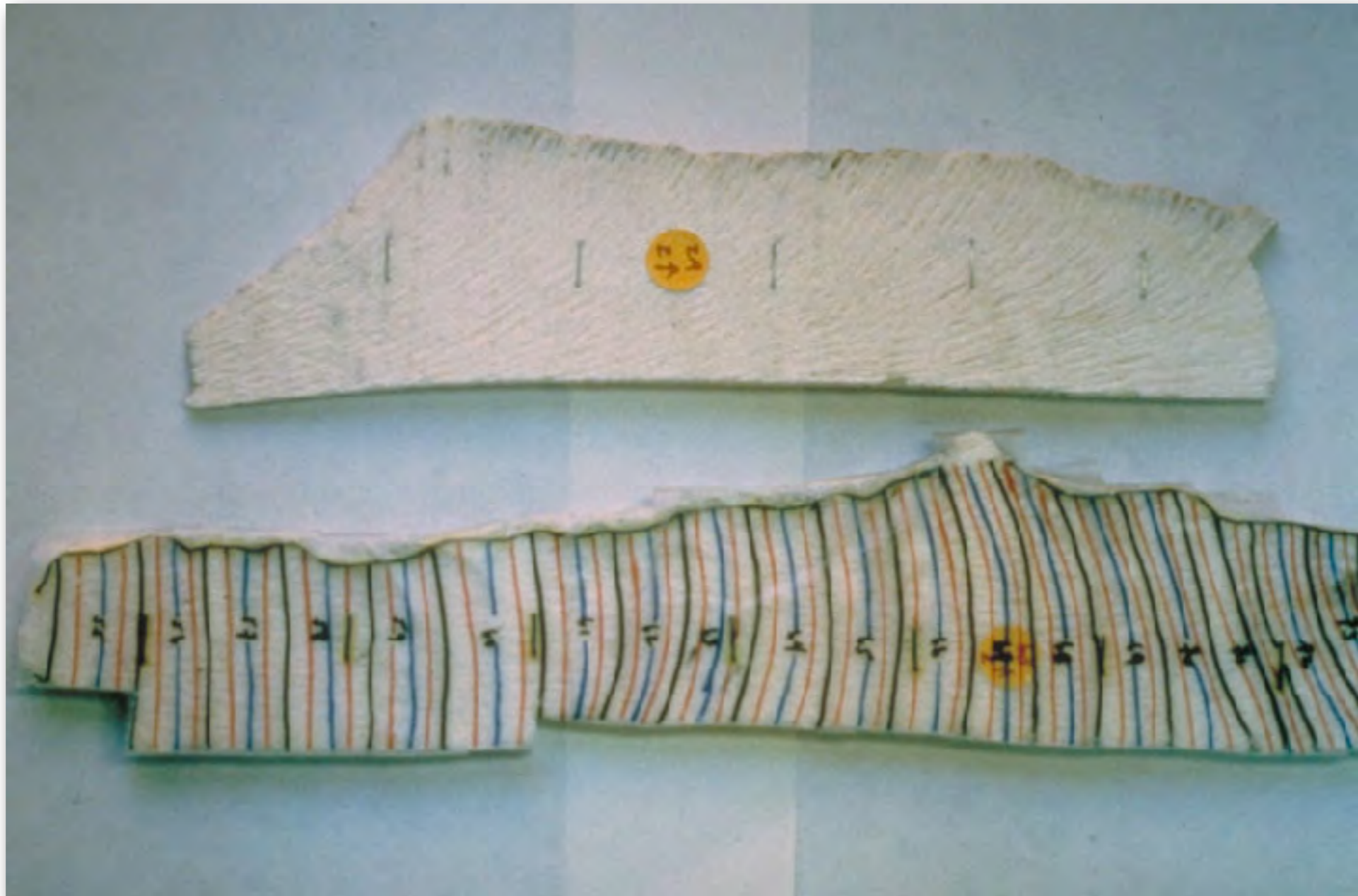


Coral reefs are located in the tropics only where the waters are shallow, clear, between 20°-28° C and somewhat calm.



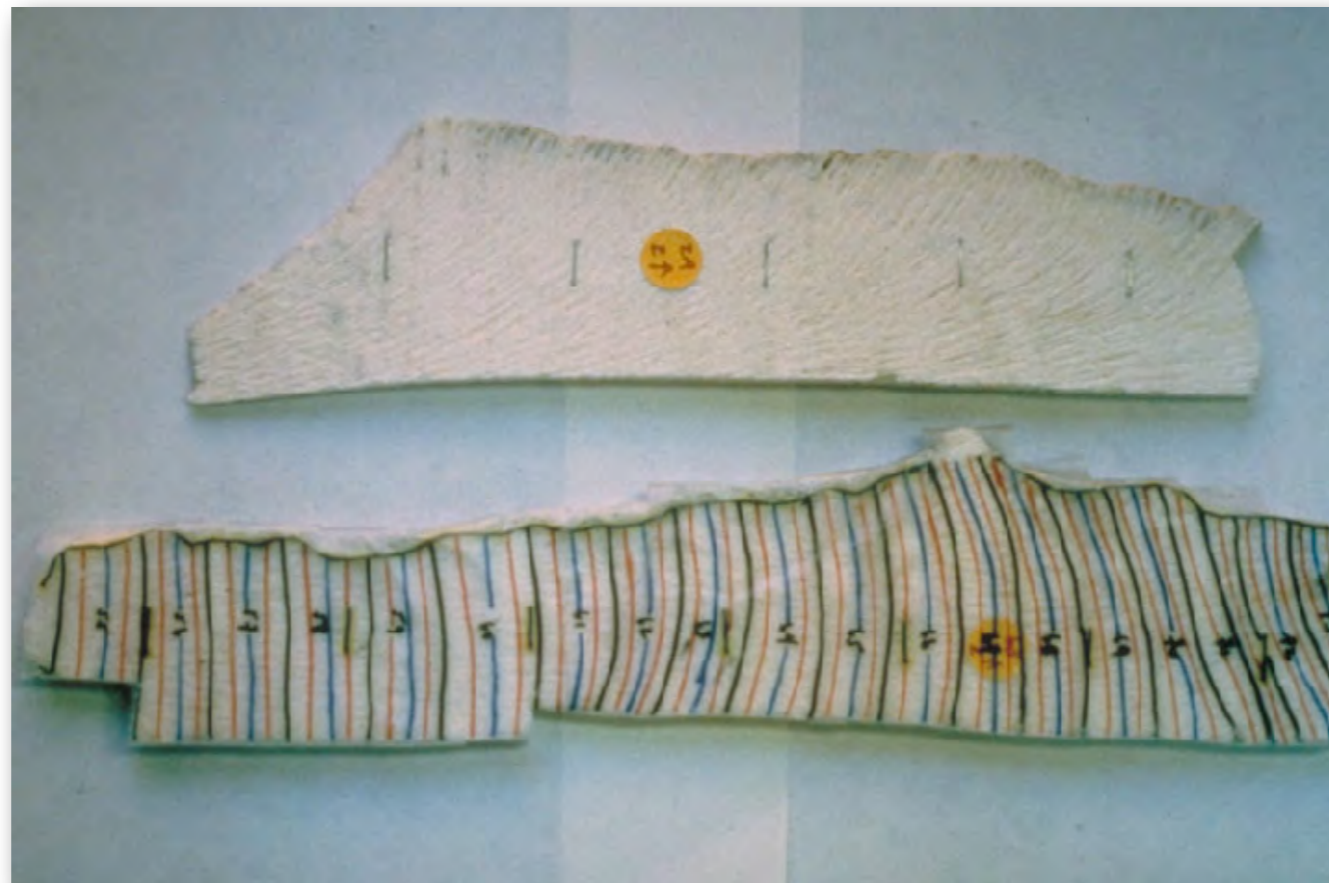
Growth of corals

- coral growth varies with the season of the year
 - *growth rate depends on SST and available nutrients*
- higher (lower) density for warmer (colder) SST
 - *density variations allow the identification of annual layers*

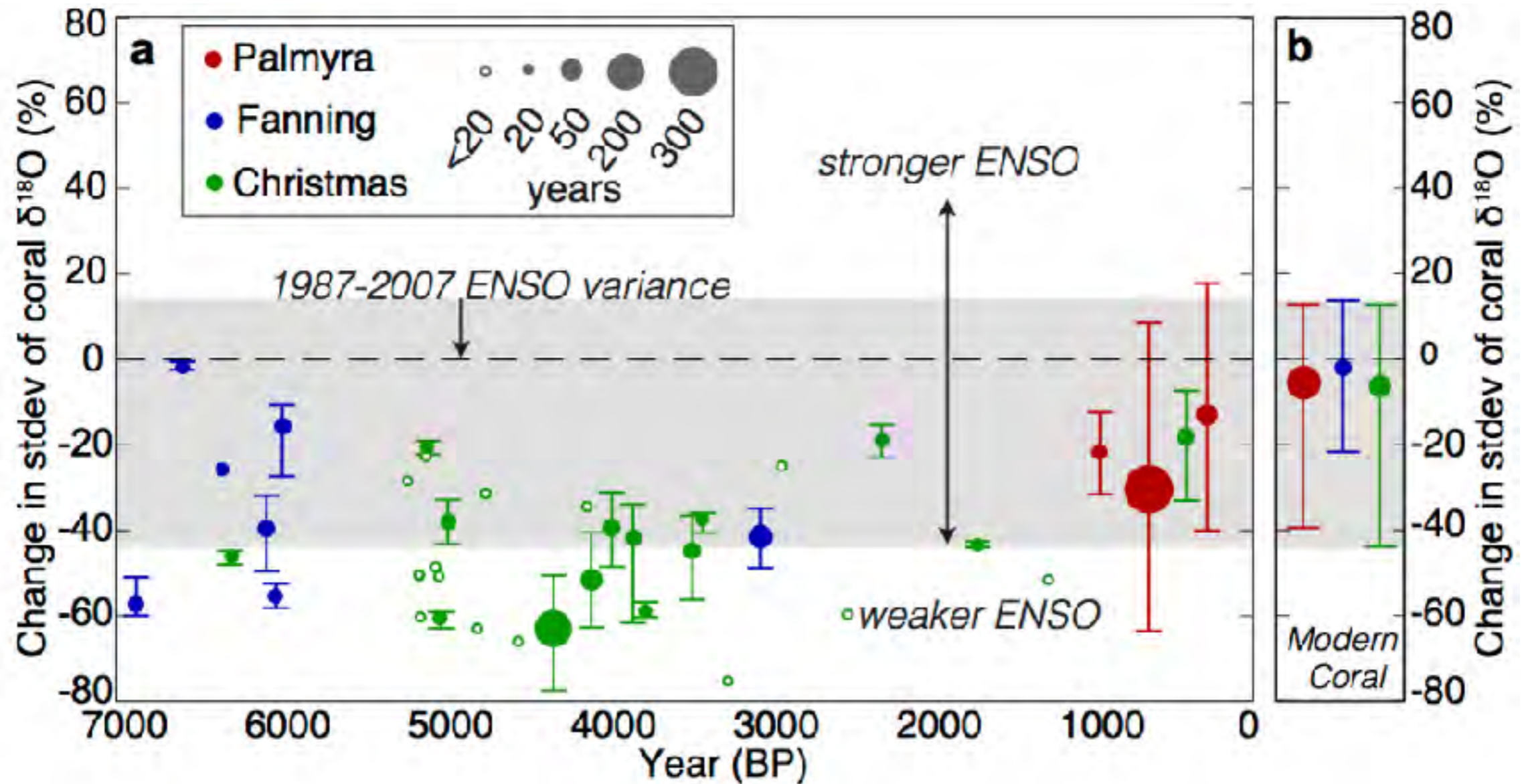


Analyses example: $\delta^{18}\text{O}$ measurements on corals

- Depletion/enrichment of ^{18}O in Calcium carbonate (CaCO_3) can be measured on corals, too
- two different effects can influence ^{18}O in CaCO_3
 - *temperature-related fractionation (determined by SST changes)*
 - *changes of the ^{18}O content of the ocean water (e.g., by large amounts of tropical rainfall in shallow, coastal waters)*
- as corals mainly exist in tropical regions, the El Niño/Southern Oscillation phenomenon is often dominating the coral ^{18}O records
 - *$\delta^{18}\text{O}$ analyses on corals enable a reconstruction of past El Niño events*



$\delta^{18}\text{O}$ measurements on corals: El Niño reconstructions



Speleothems

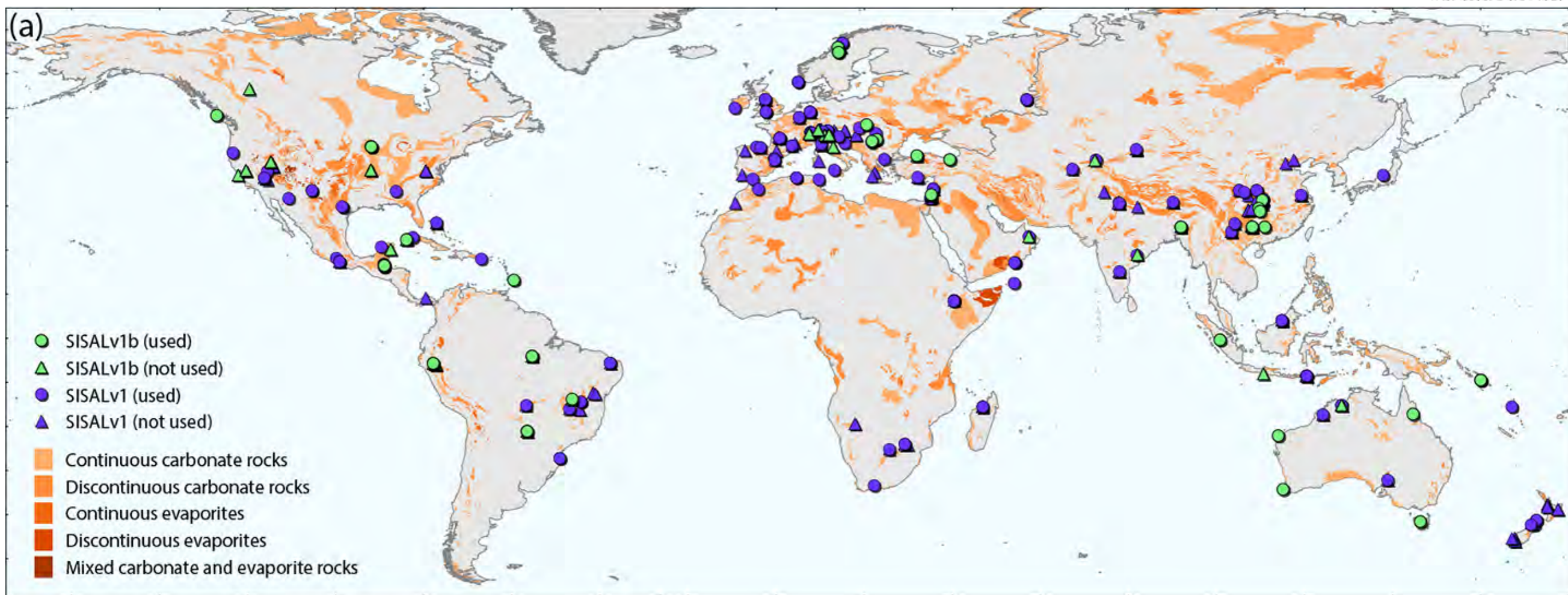


Speleothems

- The following conditions must exist for the formation of speleothems:
 - *The water entering the cave must contain CO_2 to dissolve $CaCO_3$*
 - *The soil above the cave should contain $CaCO_3$ which can be dissolved by water*
 - *The ceiling of the cave needs some fissures for water flowing into the cave*
- The growth rate of the speleothems is determined by several factors
 - *amount and rate of dripping water*
 - *CO_2 concentration of the drip water and within the cave*
 - *$CaCO_3$ concentration of the drip water*
 - *cave temperature*



Speleothem locations



[Comas-Bru et al., ClimPast, 2019]

Cave sites included in the SISAL database

Speleothems

Dating:

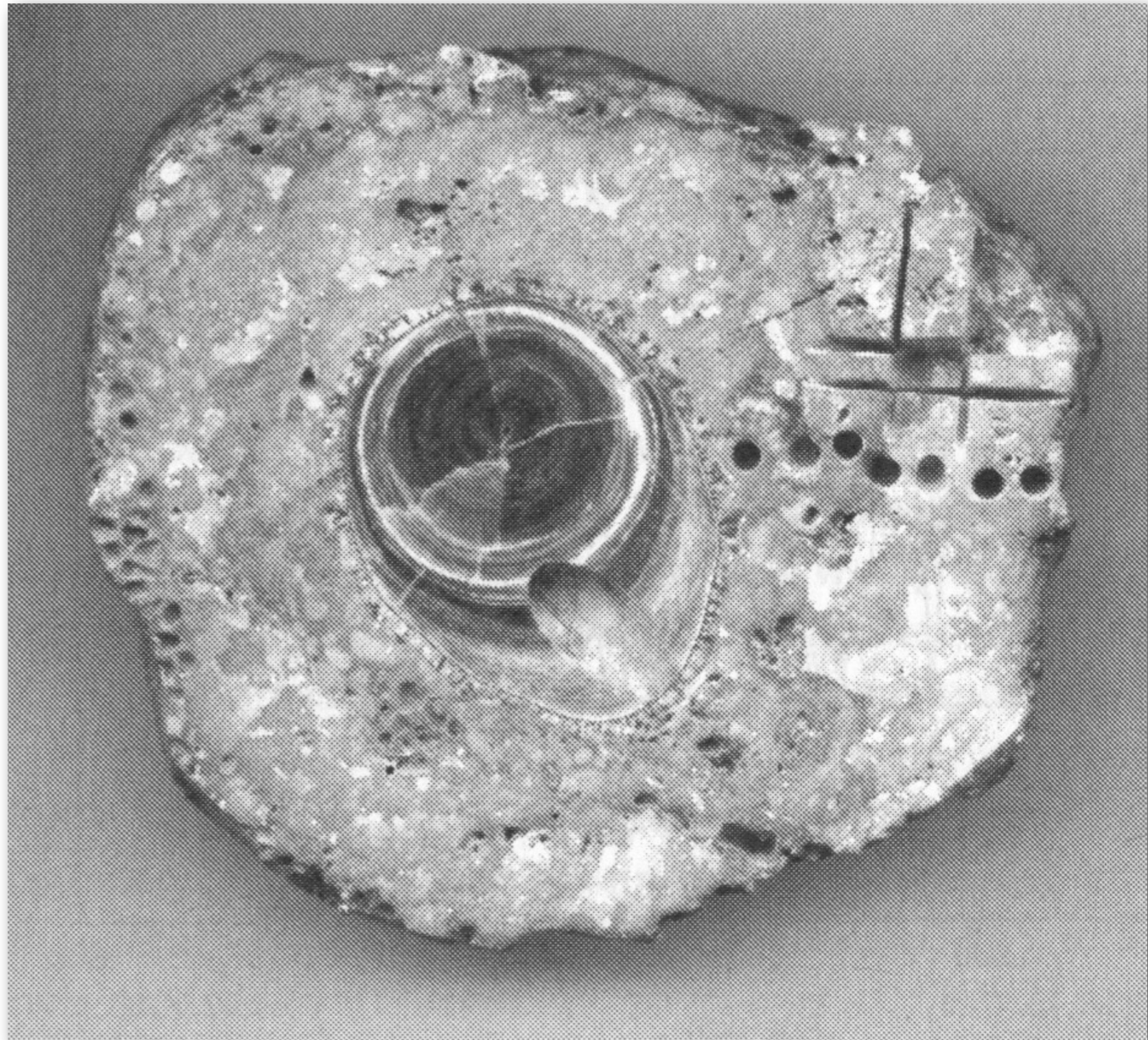
- thorium analyses ($^{230}\text{Th}/^{234}\text{U}$)
- alternative dating via thermal ionization mass spectroscopy (TIMS)

Age:

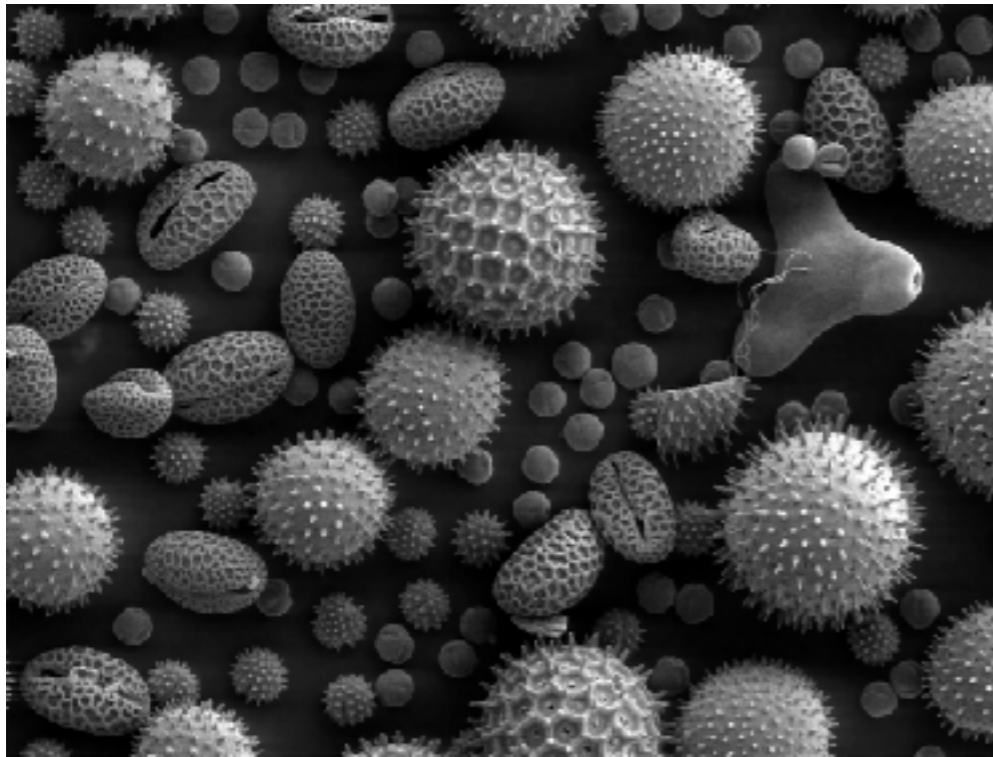
- up to 400,000-500,000 years

Analyses:

- *Growth rate, $\delta^{18}\text{O}$, $\delta^{13}\text{C}$, ...*

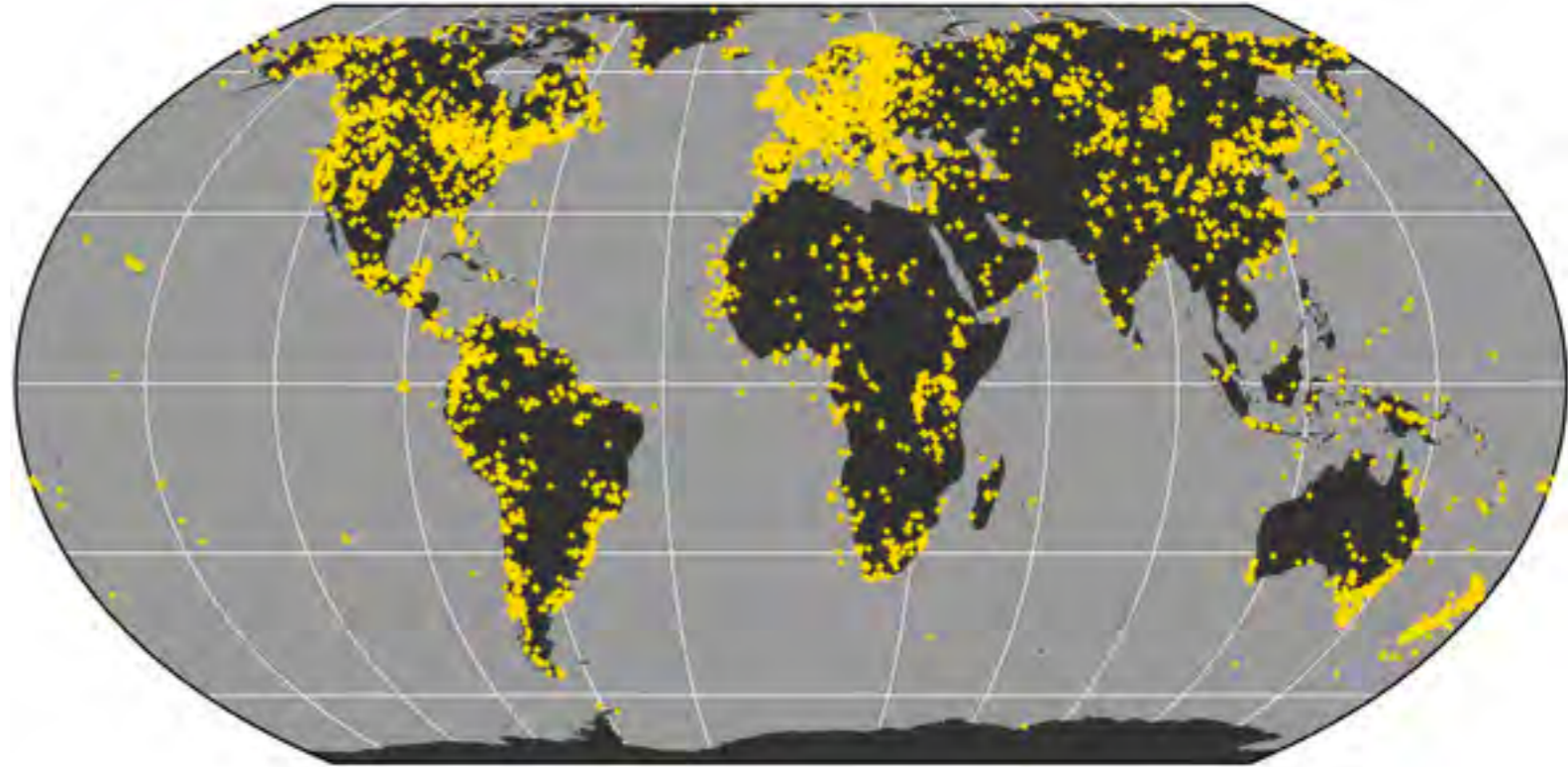


Pollen analyses

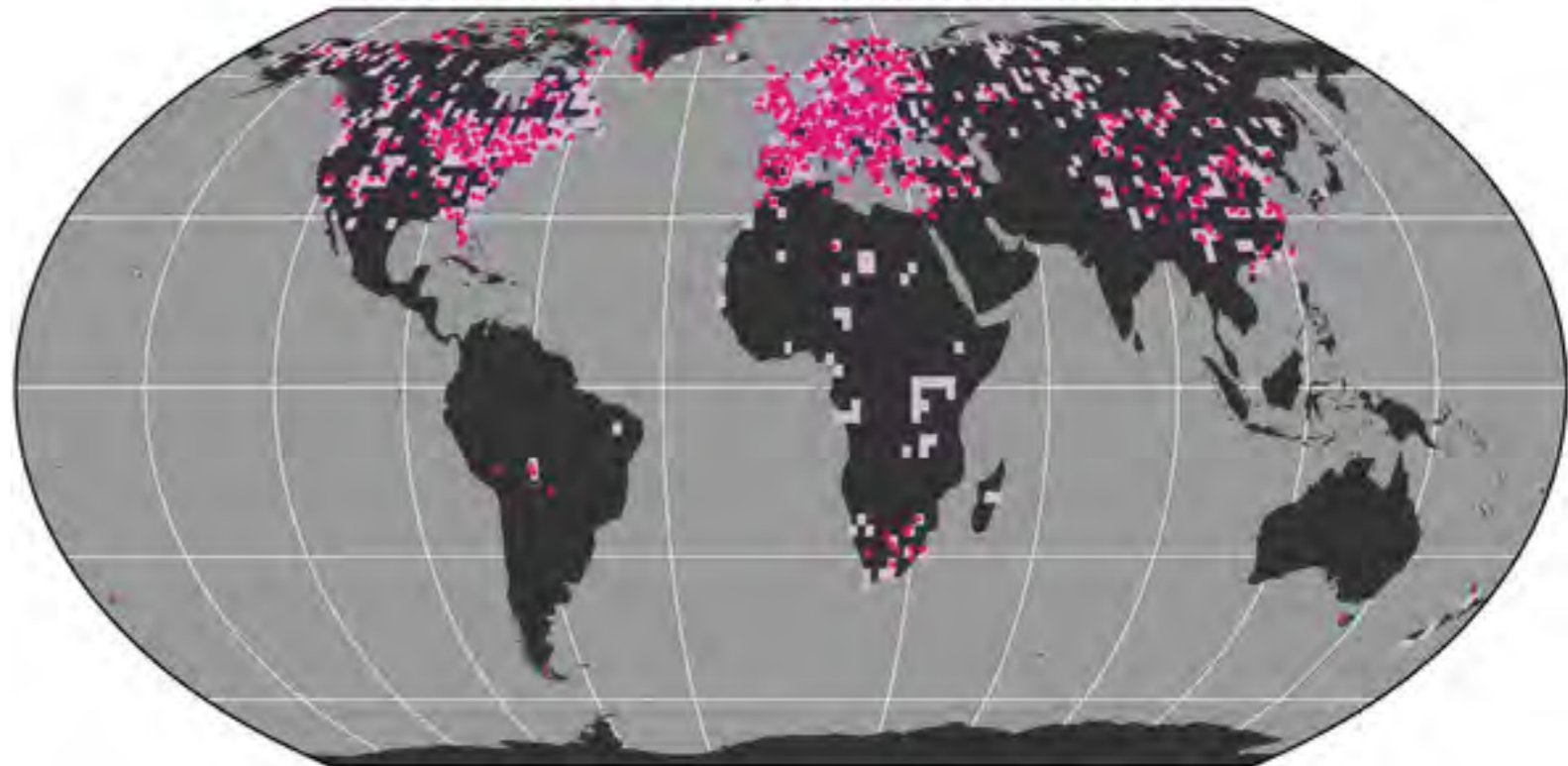


<https://paleonerdish.wordpress.com/2013/08/19/pollen-analysis-and-the-science-of-climate-change/>

A. Fossil pollen records



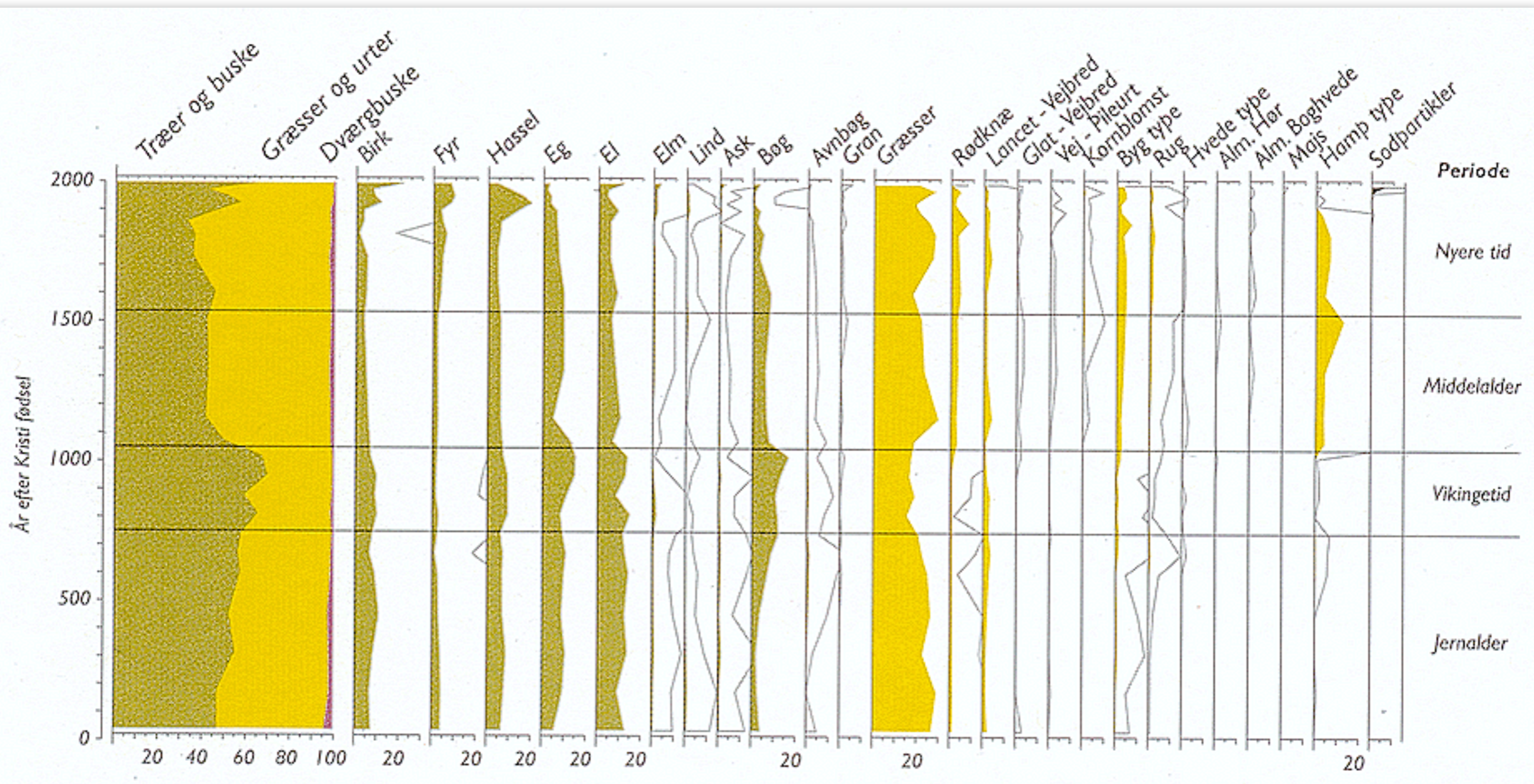
B. Pollen-based temperature reconstructions



Pollen analyses

- every year, about $\sim 10^9$ kg pollen and spores are emitted to the atmosphere
- a pollen compilation often represents the existing vegetation very well
- pollen can be classified very well due to their characteristic shape and colour
- pollen are stable on long time scales(!)
 - *pollen samples can be found both in lake sediments as well as in other terrestrial archives*
 - *the majority of pollen samples stems from the Holocene and/or the last glacial*
- The vegetation composition at one location often relies on a very few number of climate parameters (hours of sunshine, temperature, precipitation)
 - *key issues for paleoclimate pollen analyses:*
 - *How fast does a vegetation pattern adapt to local climate changes?*
 - *Does it always adapt in the same manner?*

Pollen diagrams



<http://www.geus.dk/departments/quaternary-marine-geol/research-themes/env-cli-pollen-uk.htm>

Calibration of Pollen Studies

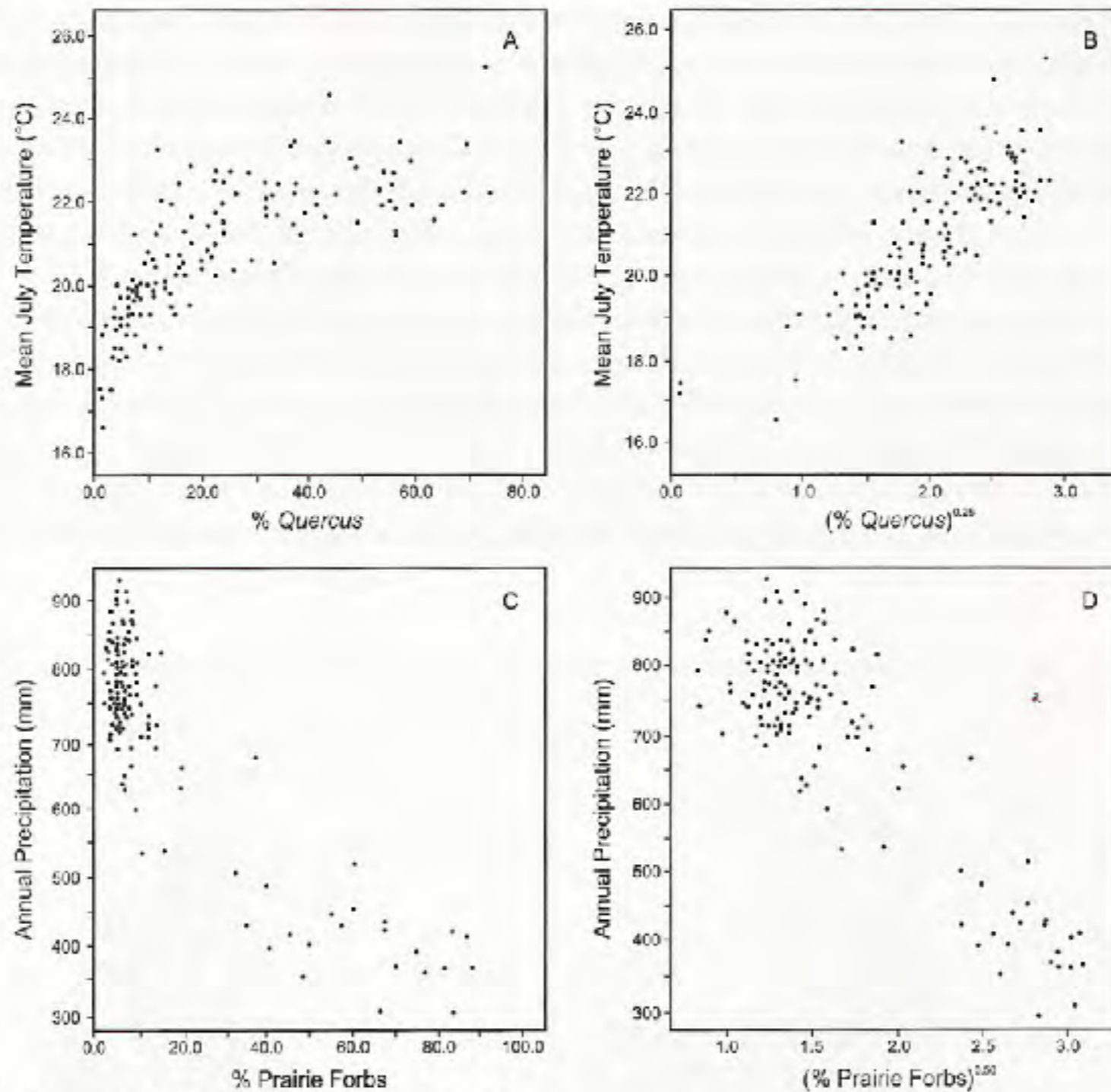


FIGURE 9.11 Scatter diagrams for (A) July mean temperature vs the percentages of *Quercus* (oak) pollen; (B) July mean temperature vs the percentages of *Quercus* pollen raised to the 0.25 power; (C) annual precipitation vs the percent of prairie-forb pollen (excluding *Ambrosia*) and (D) annual precipitation vs the percent of prairie-forb pollen raised to the 0.5 power (Bartlein *et al.*, 1984).

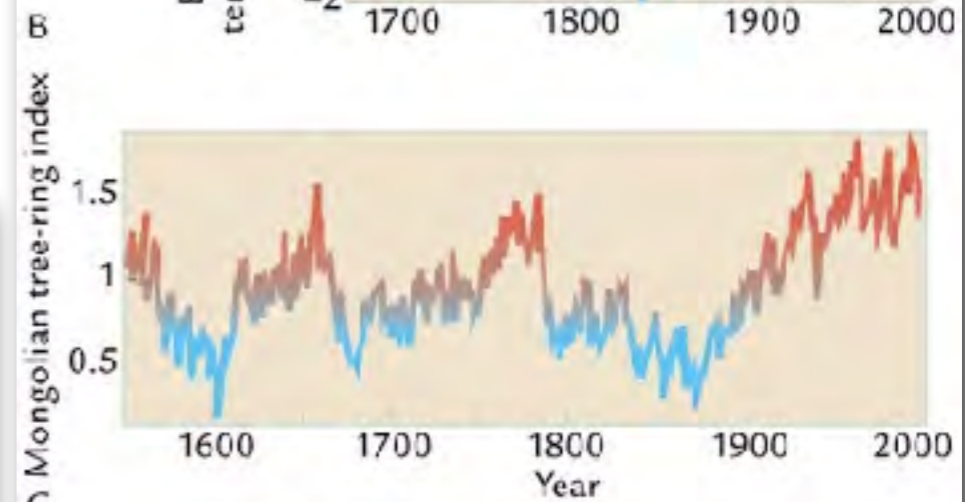
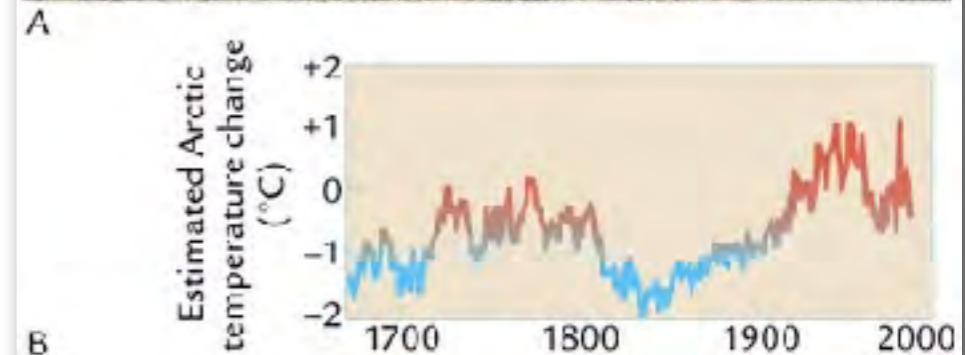
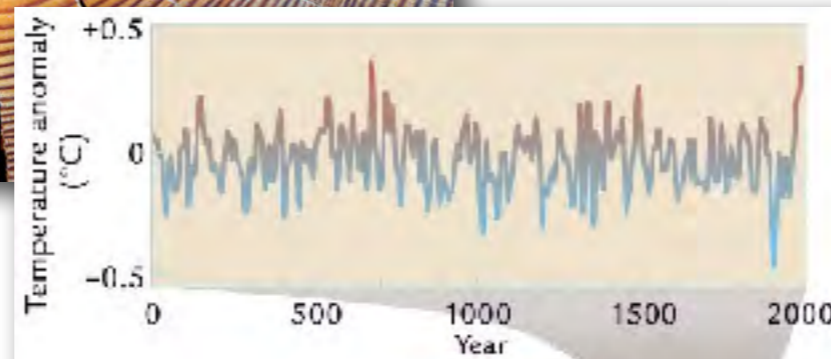
Tree Rings



<https://www.sciencenews.org/article/tree-story-book-explores-what-tree-rings-can-tell-us-about-past>

Tree Rings

- Variations of tree ring width and density are an indicator of (local) climate change
- the use of tree rings to reconstruct climate change is called **dendroclimatology**



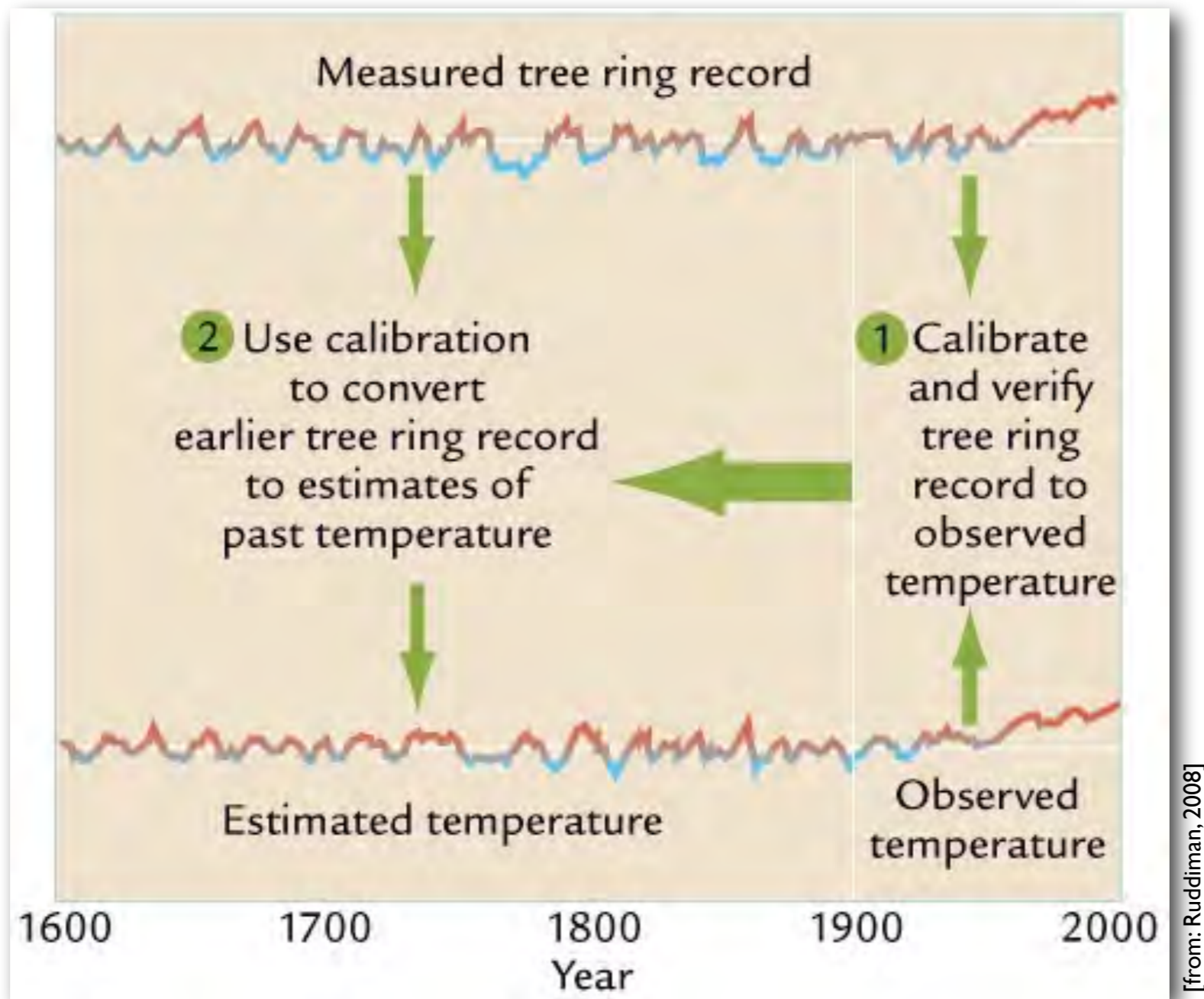
Dendroclimatology

- The width of the annual tree rings is in general a complex function that depends on the tree species, tree age, available nutrients (in the soil and in the tree), sun shine hours, amount of precipitation, temperature, wind conditions, relative humidity, etc.)
 - *at suitable sites (and for suitable tree species) the function can be reduced to 1-2 influencing parameters, only*

Dendroclimatology

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- Dating methods: ^{14}C , cross dating using several different trees
- Analyses: Density variations, ^{18}O

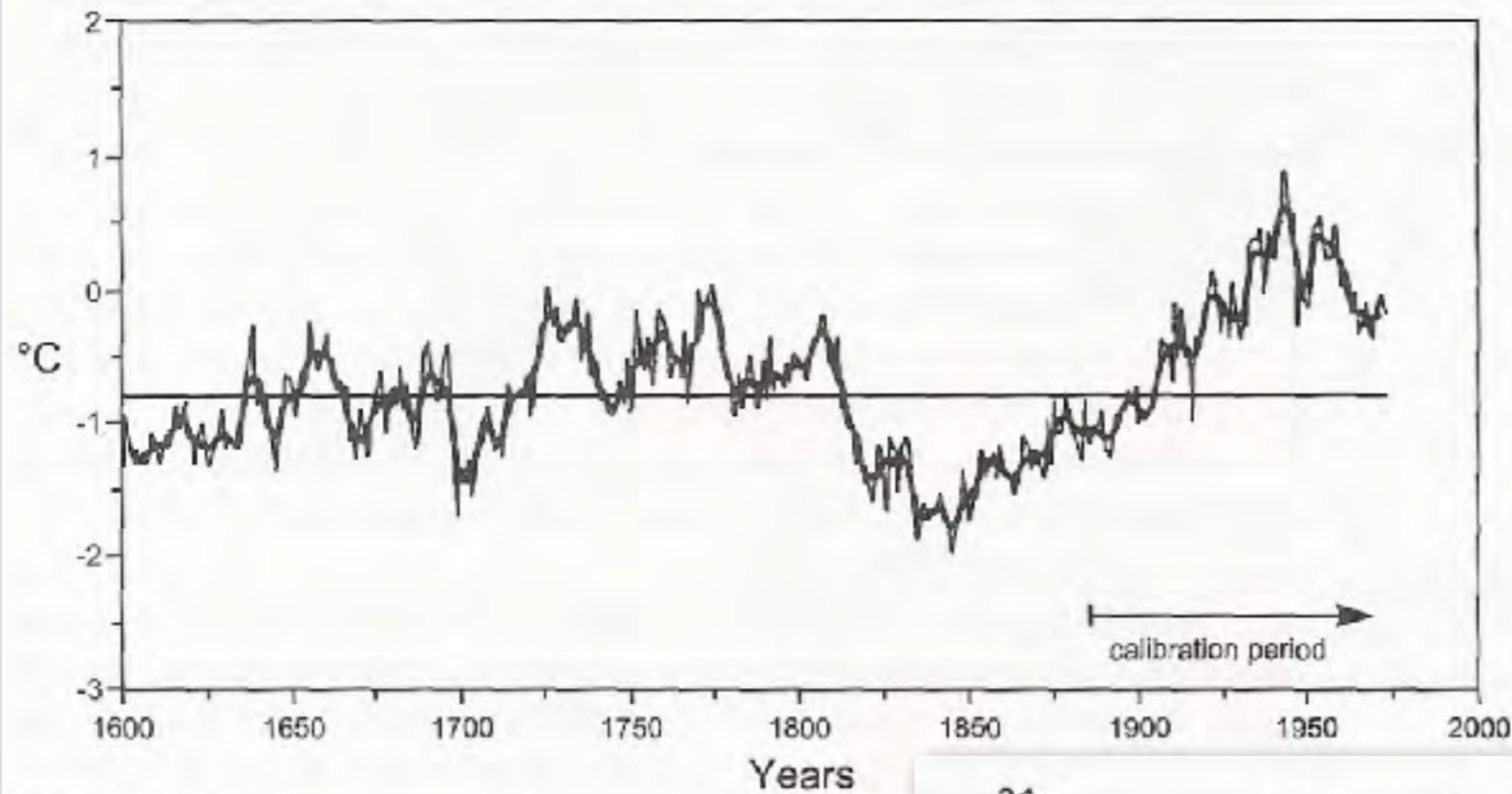
Climate reconstructions using tree ring records



- a modern calibration (=relation between tree ring record and climate variable, e.g. temperature) is used to convert past tree ring variations into climate changes
 - *similar to other methods, one has to assume a priori that the the modern calibration curve can be applied for past times*

Climate reconstructions using tree ring records

Reconstructed Annual Temperatures for Northern North America



- tree ring records can be a good proxy for regional climate changes during the last centuries

- many records show substantial warming in the 20th century
 - however, the latest warming is missing in some of the tree records

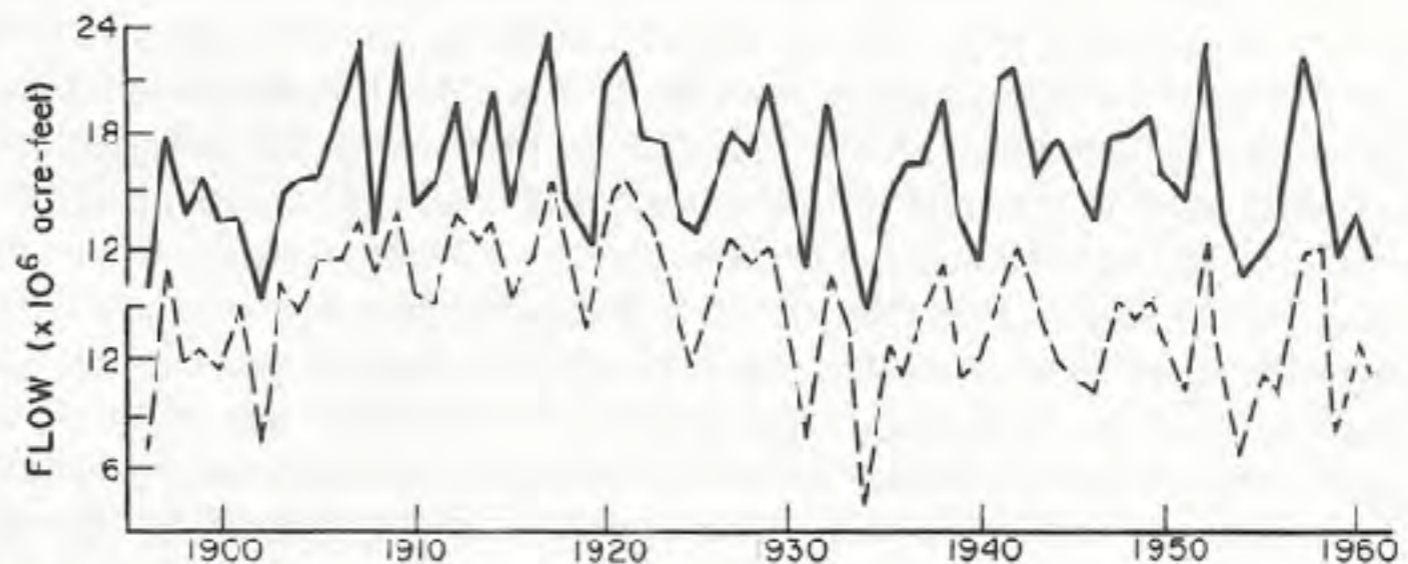


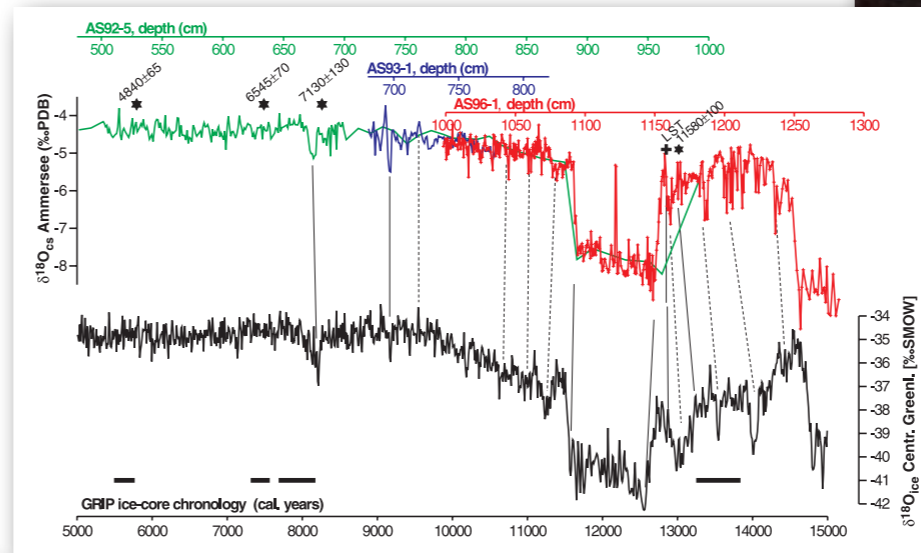
FIGURE 10.28 Runoff in the Upper Colorado River Basin. Reconstructed values (-----) are based on tree-ring width variations in trees on 17 sites in the basin. Actual data, measured at Lee Ferry, Arizona, are shown for comparison (—). Based on this calibration period, an equation relating the two data sets was developed and used to reconstruct the flow of the river back to 1564 (Fig. 10.29) (Stockton, 1975).

Further climate archives

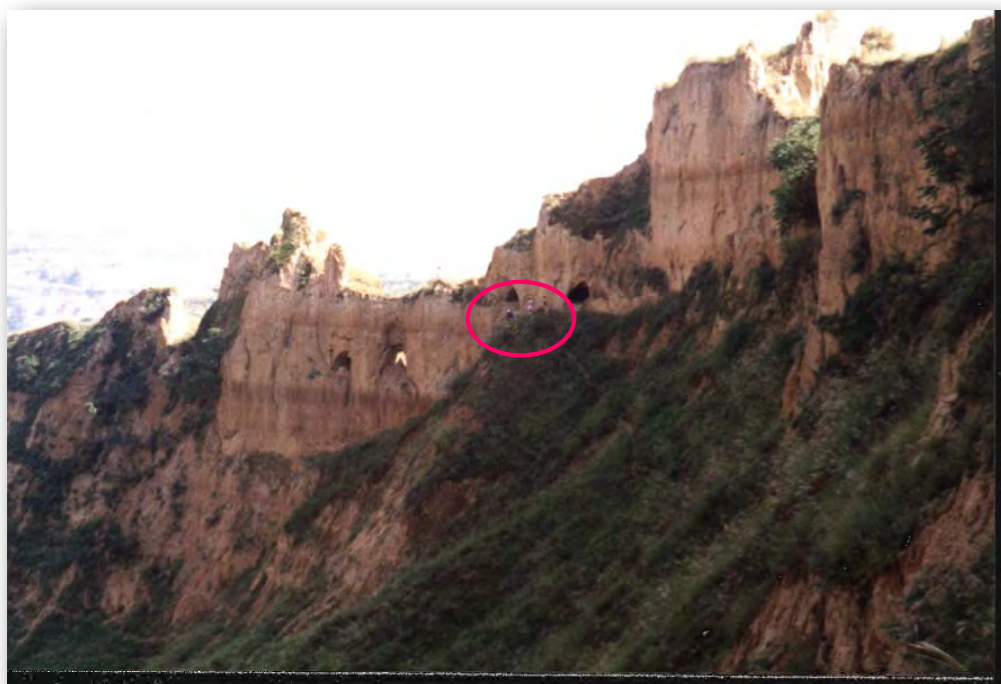
- lake sediment cores
- loess archives
- snow-line reconstructions and glacier movements
- lake level changes
-



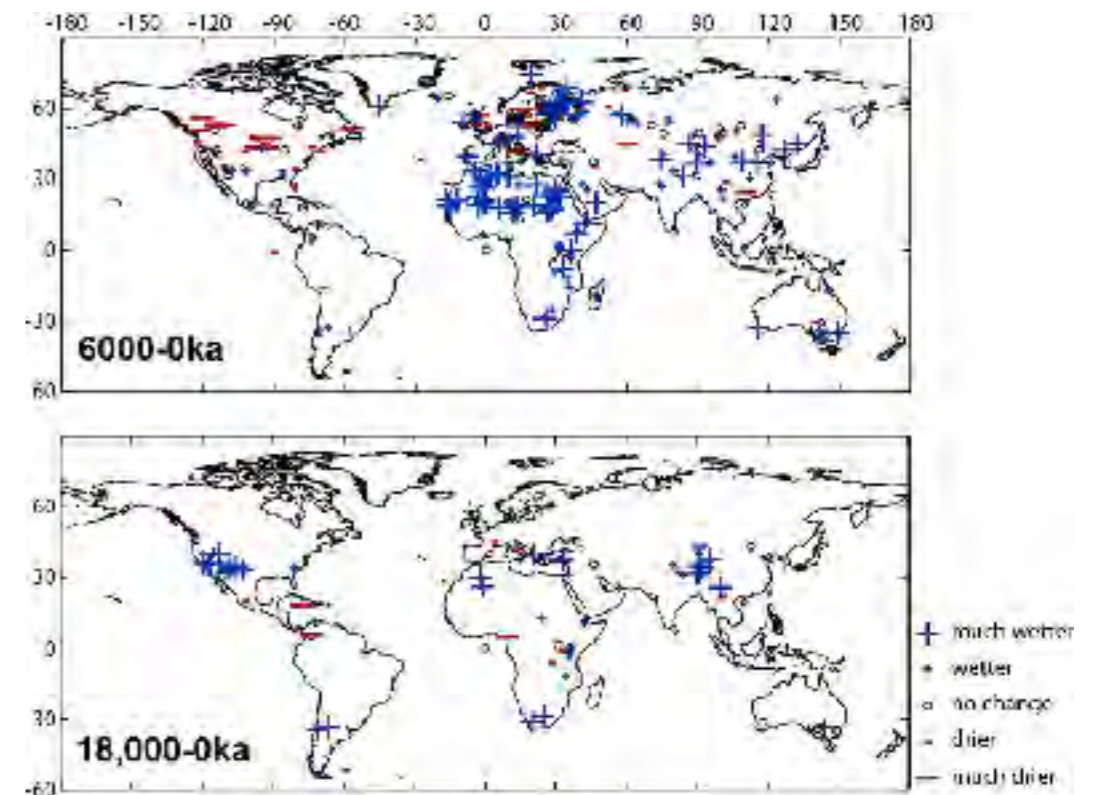
Nam Co lake, Tibetan Plateau



v. Grafenstein et al., Science, 1999



The loess/palaeosol sequence at Potou, Central Loess Plateau, China. The darkest of the bands seen in the sequence is the palaeosol complex S5. Search for the intrepid field-workers just above S4 for scale! <http://www.aber.ac.uk/~qecwww/loessprog.html>



PMIP Global Lake Status For The Mid-Holocene And Last Glacial Maximum
<https://pmip2.lsce.ipsl.fr/synth/lakestatus.shtml>

Climate II

(Winter 2020/2021)

13th lecture:

Regional and global changes

(Regional and global signals: Monsoons, Permafrost; Archives of climate change)

End of lecture.

Slides available at:

https://paleodyn.uni-bremen.de/study/climate2020_21.html