Climate System II

(Winter 2022/2023)

12th lecture:

Regional and global changes

(Regional and global signals: Monsoons, Permafrost)

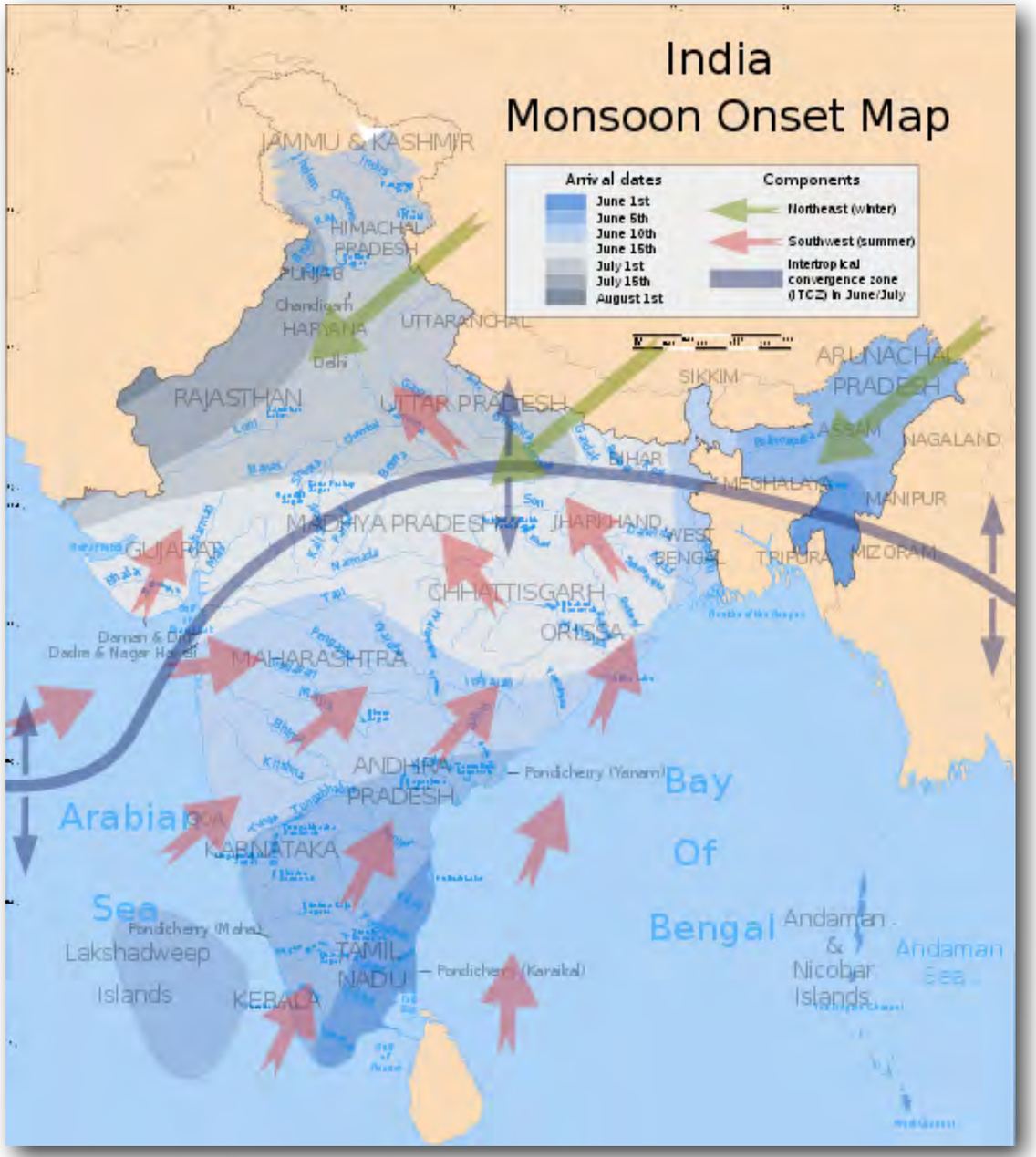
Gerrit Lohmann, Martin Werner

Tuesday, 10:00-11:45

(sometimes shorter, but then with some exercises)

https://paleodyn.uni-bremen.de/study/climate2022_23.html

Regional and global signals: Monsoons



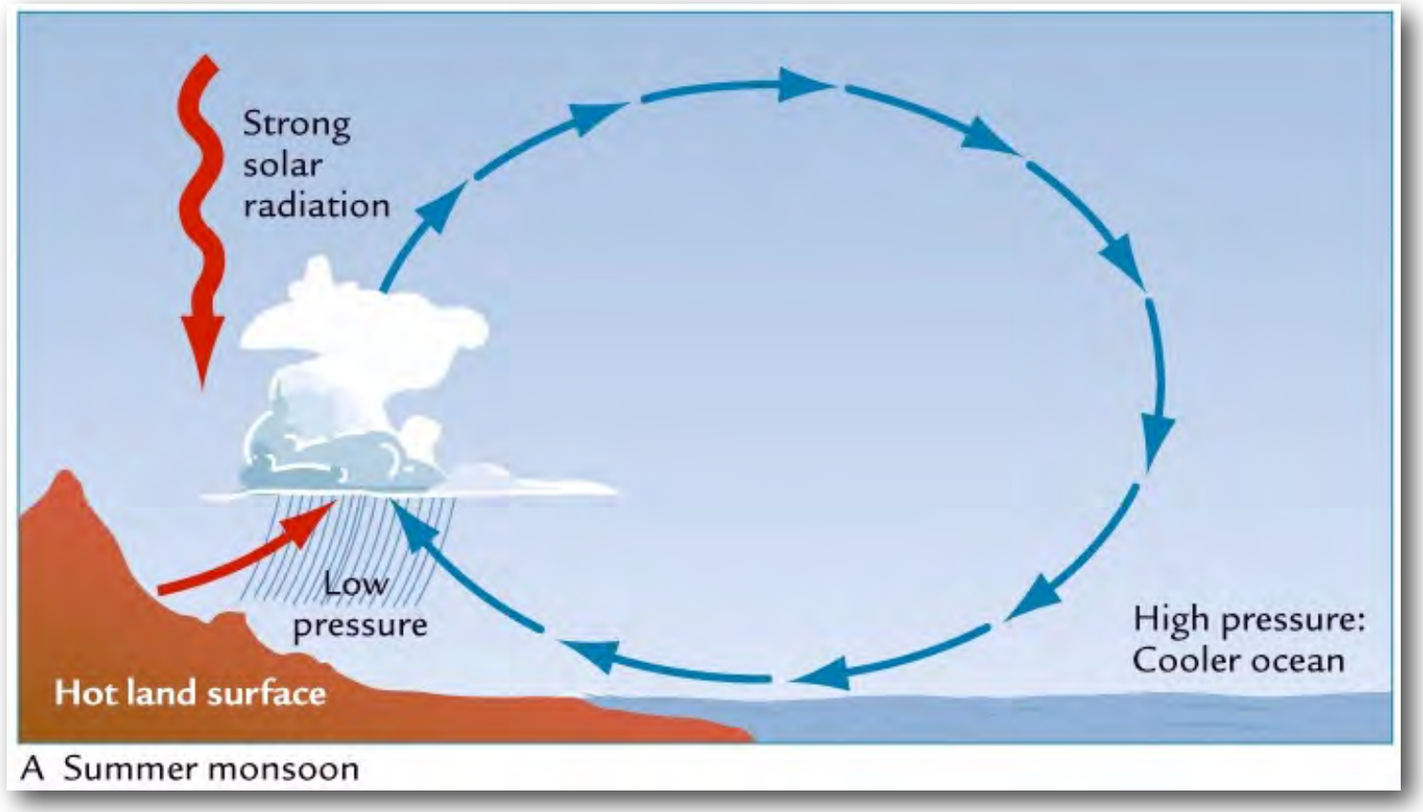
[http://en.wikipedia.org/wiki/File:India_southwest_summer_monsoon_onset_map_en.svg]

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

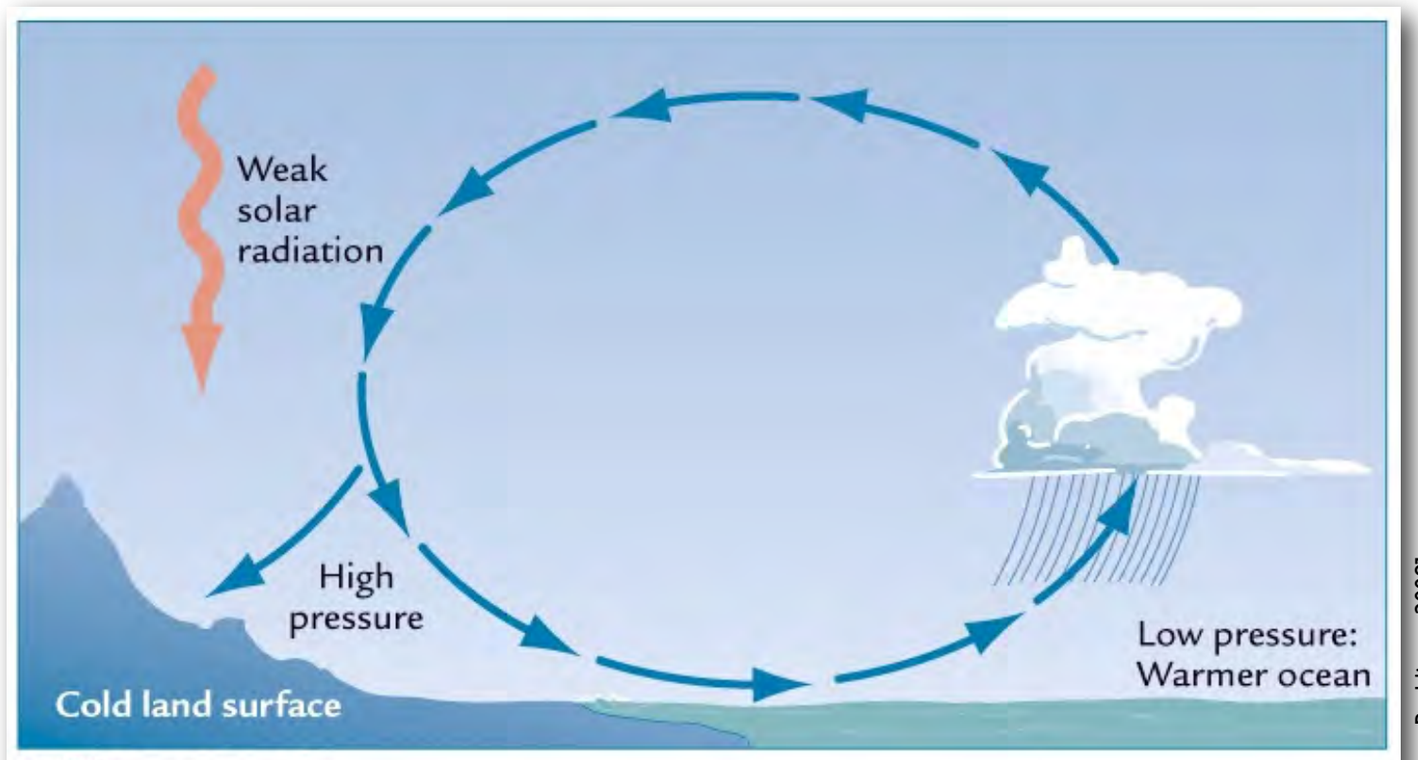
[http://mapurva.wordpress.com/2011/08/01/crazy-monsoon/]

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)



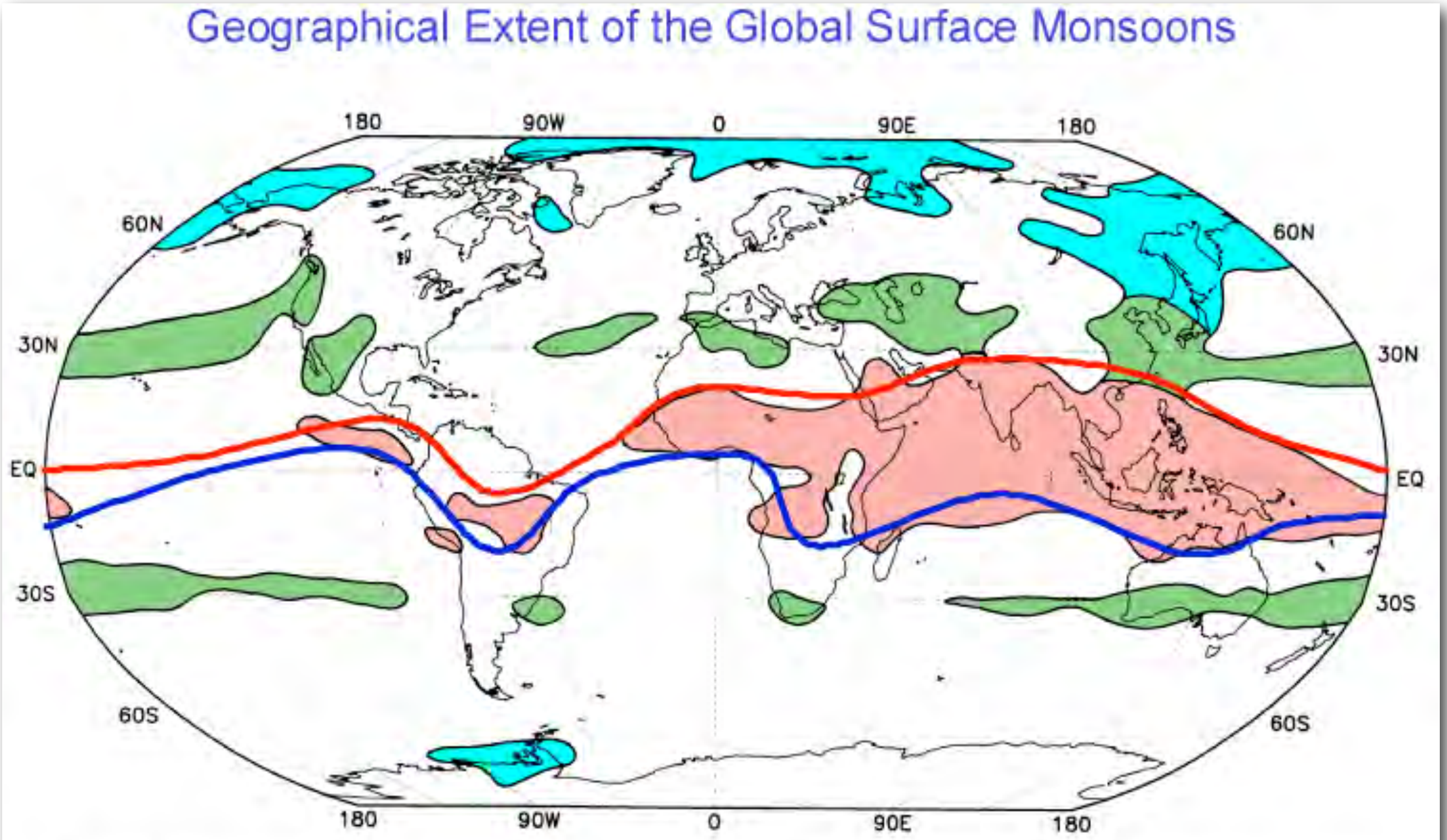
A Summer monsoon



B Winter monsoon

[from: Ruddiman, 2008]

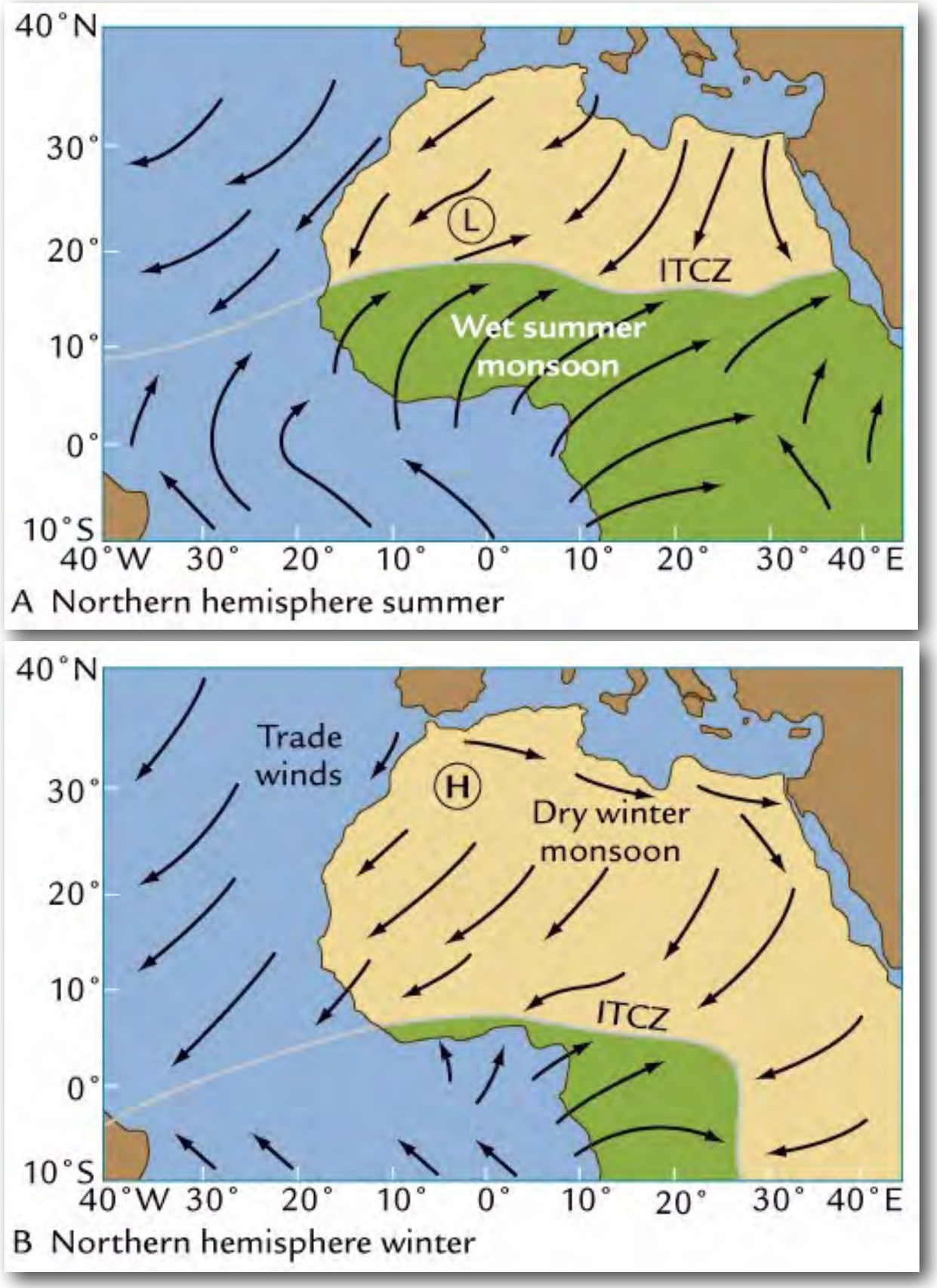
The global monsoon circulation

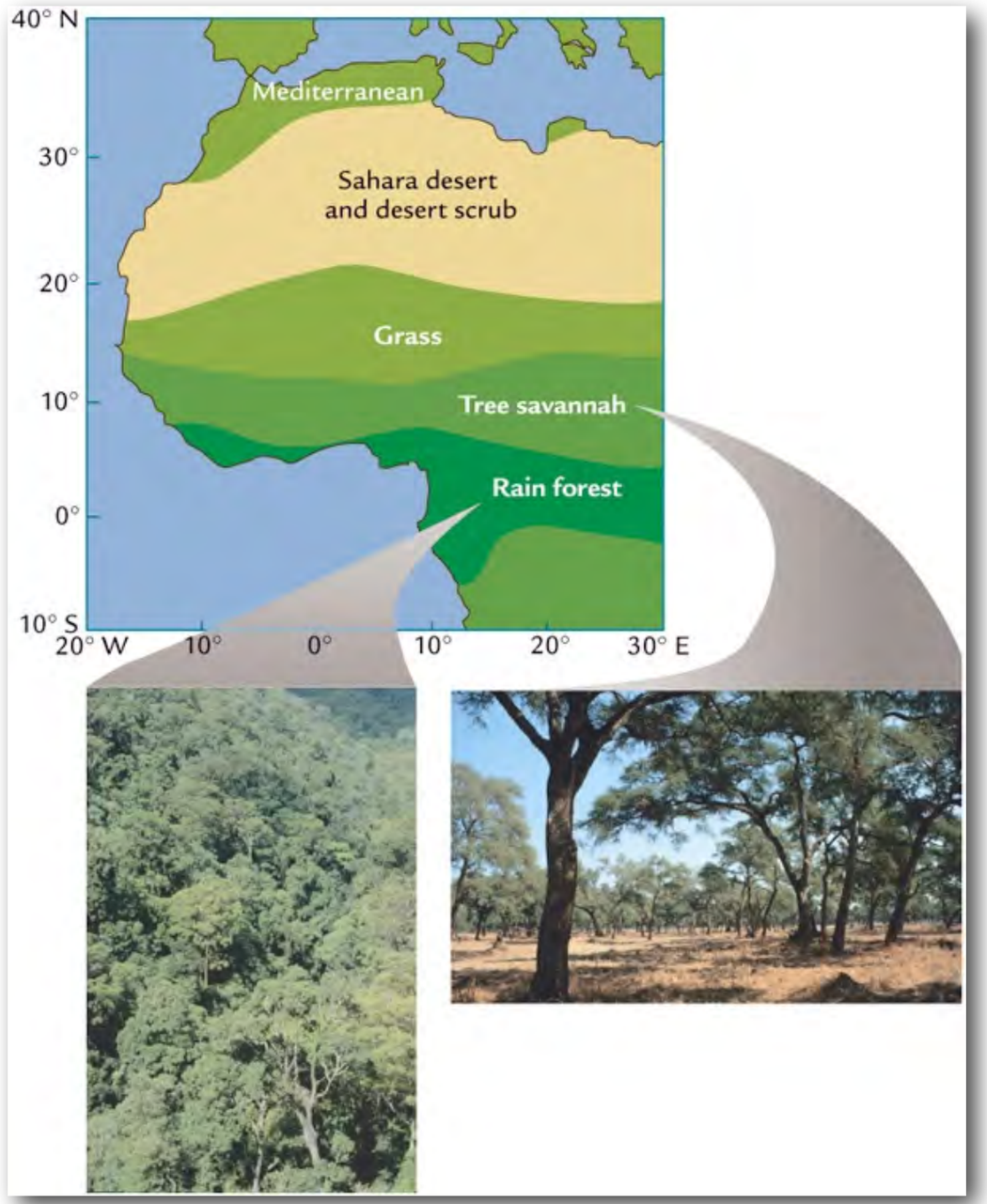


The red, green, and blue areas indicate the tropical, subtropical, and temperate-frigid monsoons, respectively. The red and blue thick lines represent the ITCZ in summer and winter, respectively. (Li, J., and Q. Zeng, 2005)

[http://www.lasg.ac.cn/staff/ljp/Monsoon.html]

The North African monsoon circulation



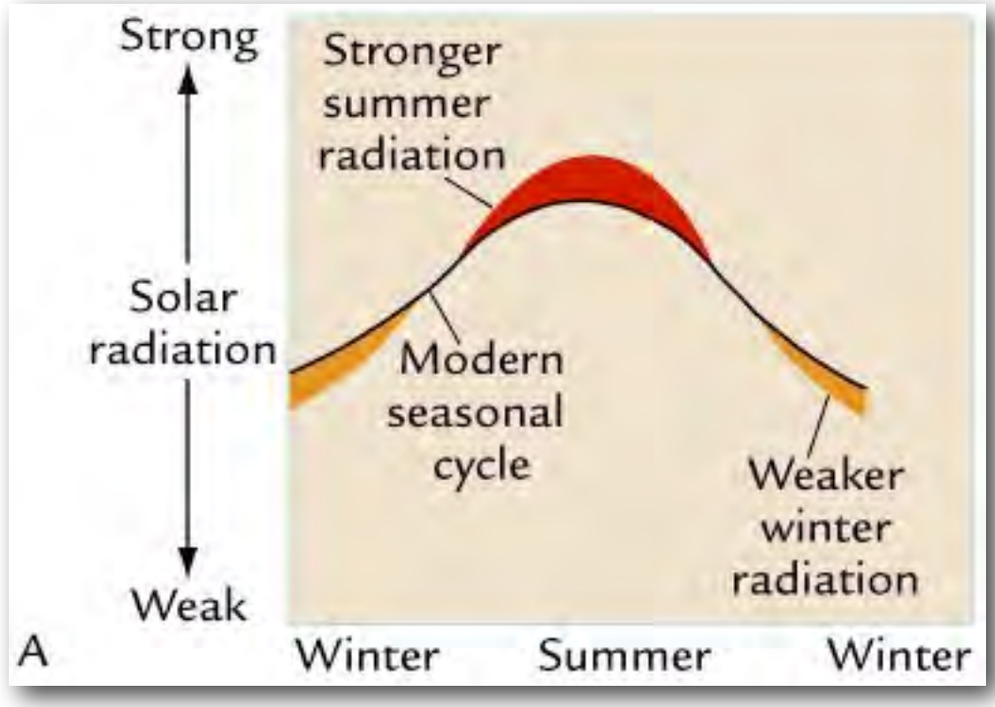


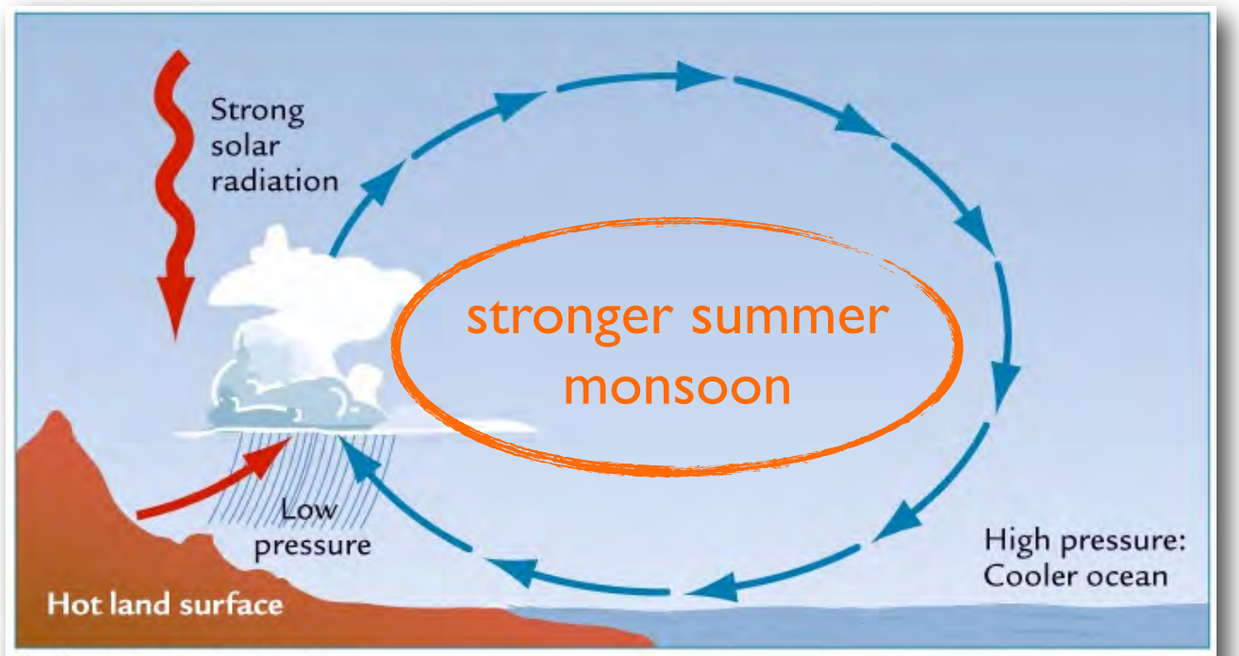
[from: Ruddiman, 2008]

Orbital-scale control of monsoon circulation

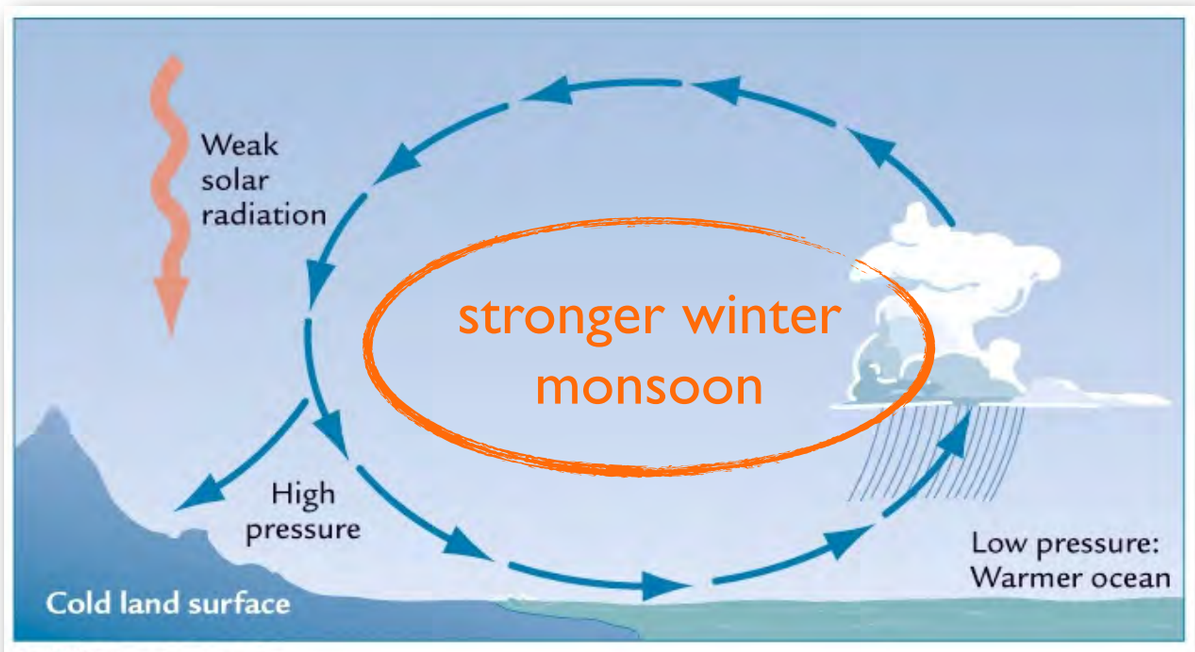
orbital monsoon hypothesis (J. Kutzbach, early 1980s)

- *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)*





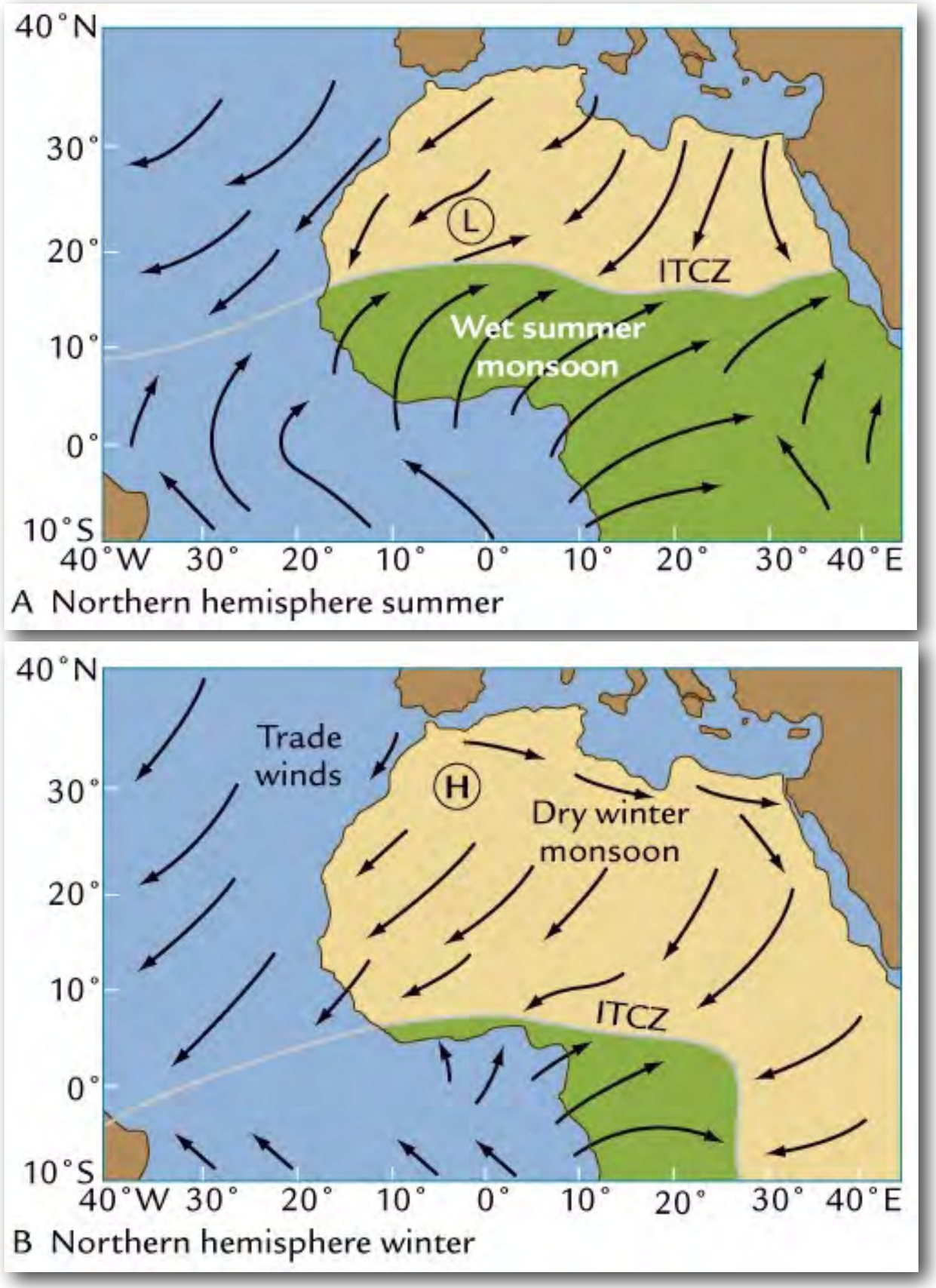
A Summer monsoon



B Winter monsoon

[from: Ruddiman, 2008]

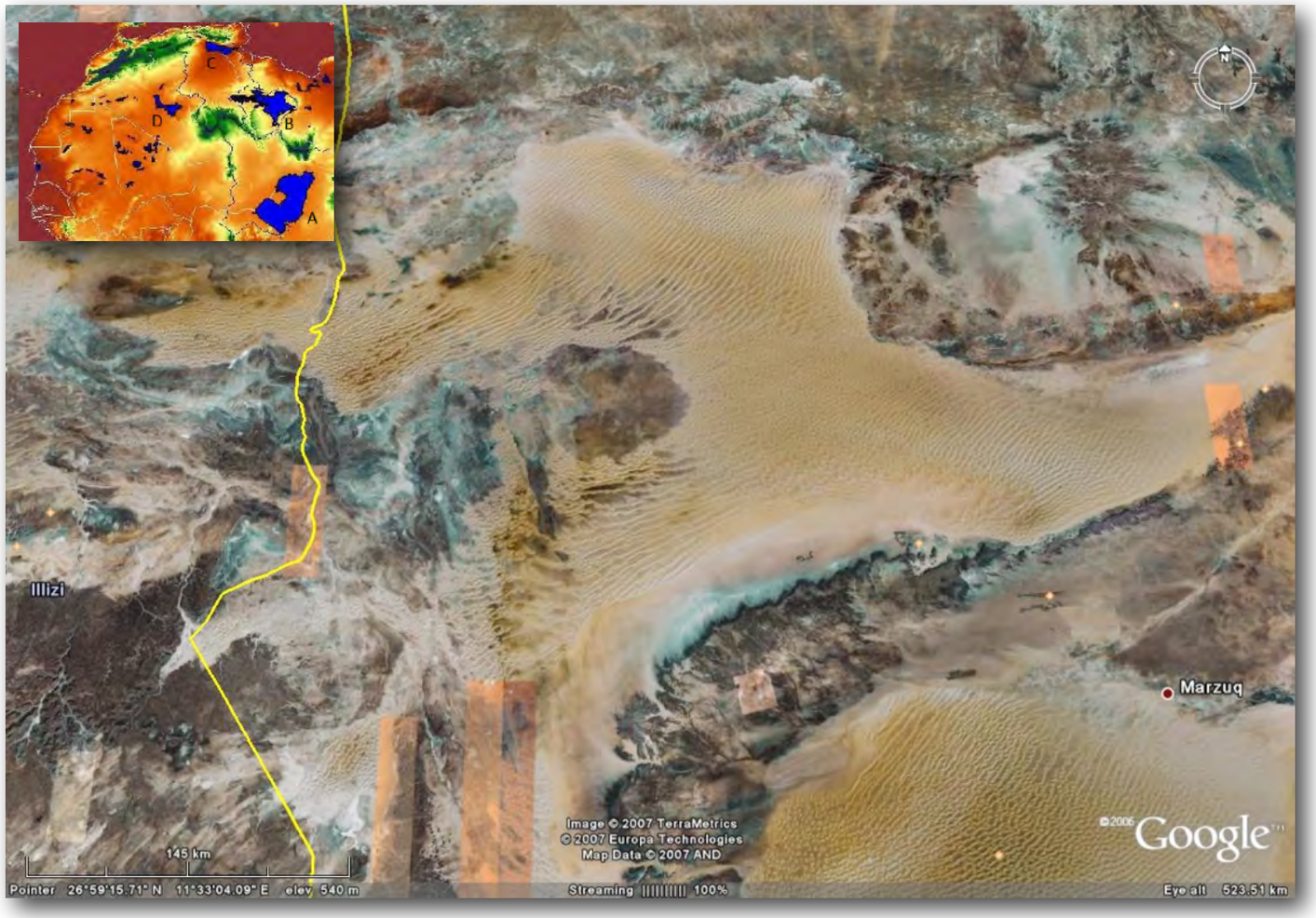
Orbital-scale control of North African monsoon circulation



[from: Ruddiman, 2008]

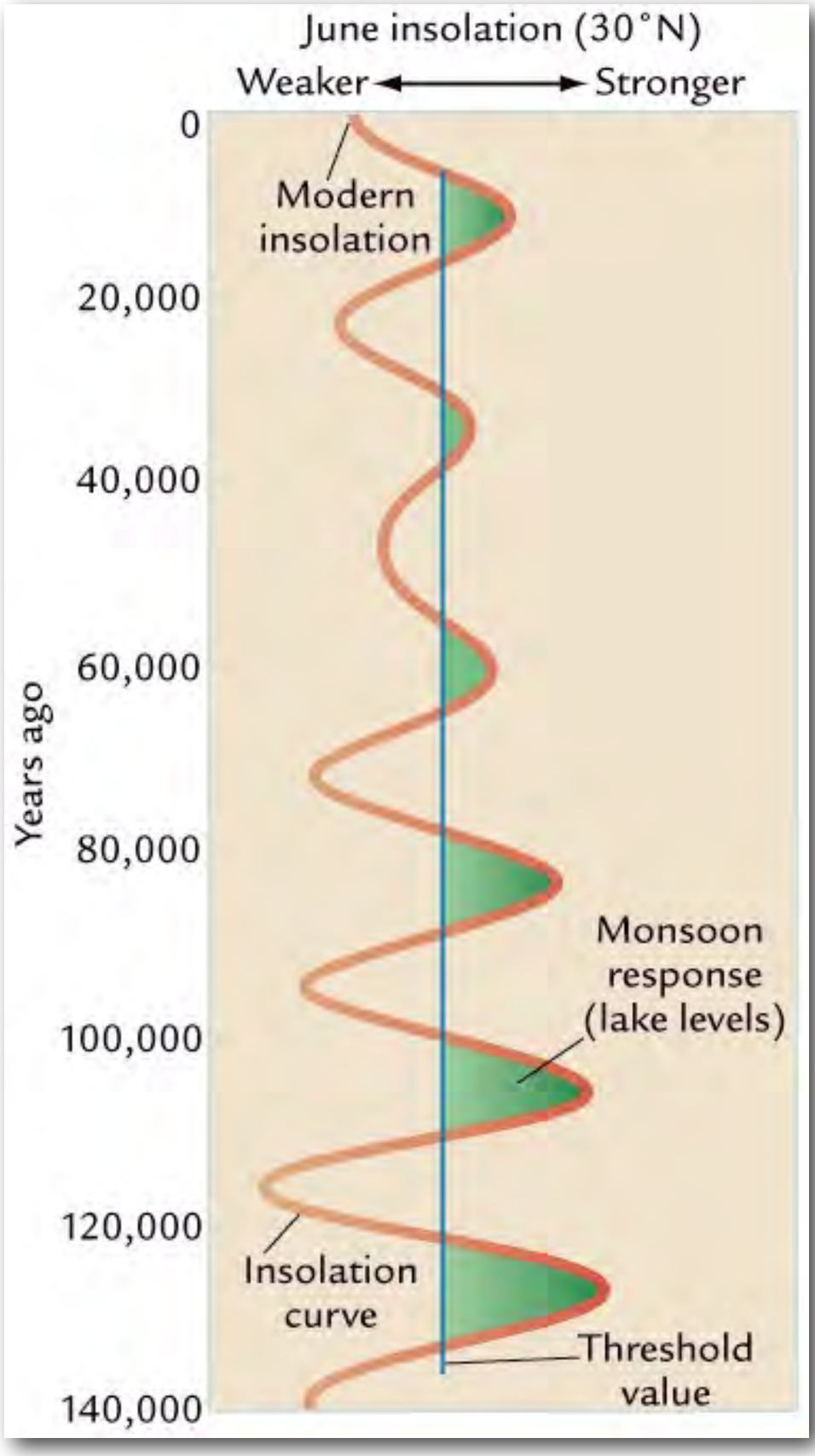
- 1st test of North African orbital monsoon hypothesis:
  - *if summer monsoon brings more rain, there should have been more lakes in Northern Africa*
  - *old lake-beds should still be found*
  - *dating of lake sediments should be consistent with past times of high summer insolation values*

Orbital-scale control of North African monsoon circulation



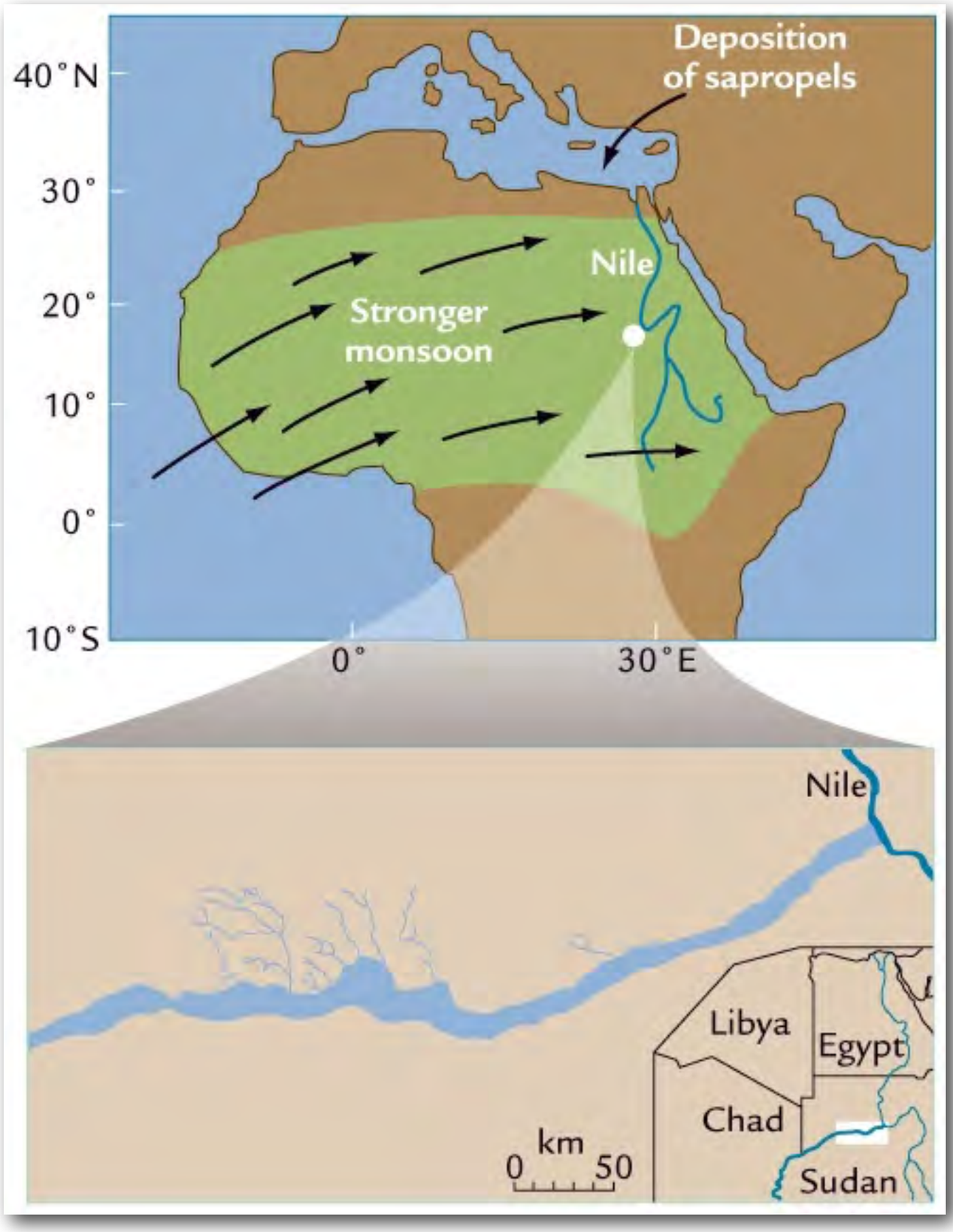
The site of Lake Megafezzan as it appears today. All that remains is sand. (Image from Google Earth)

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



[from: Ruddiman, 2008]

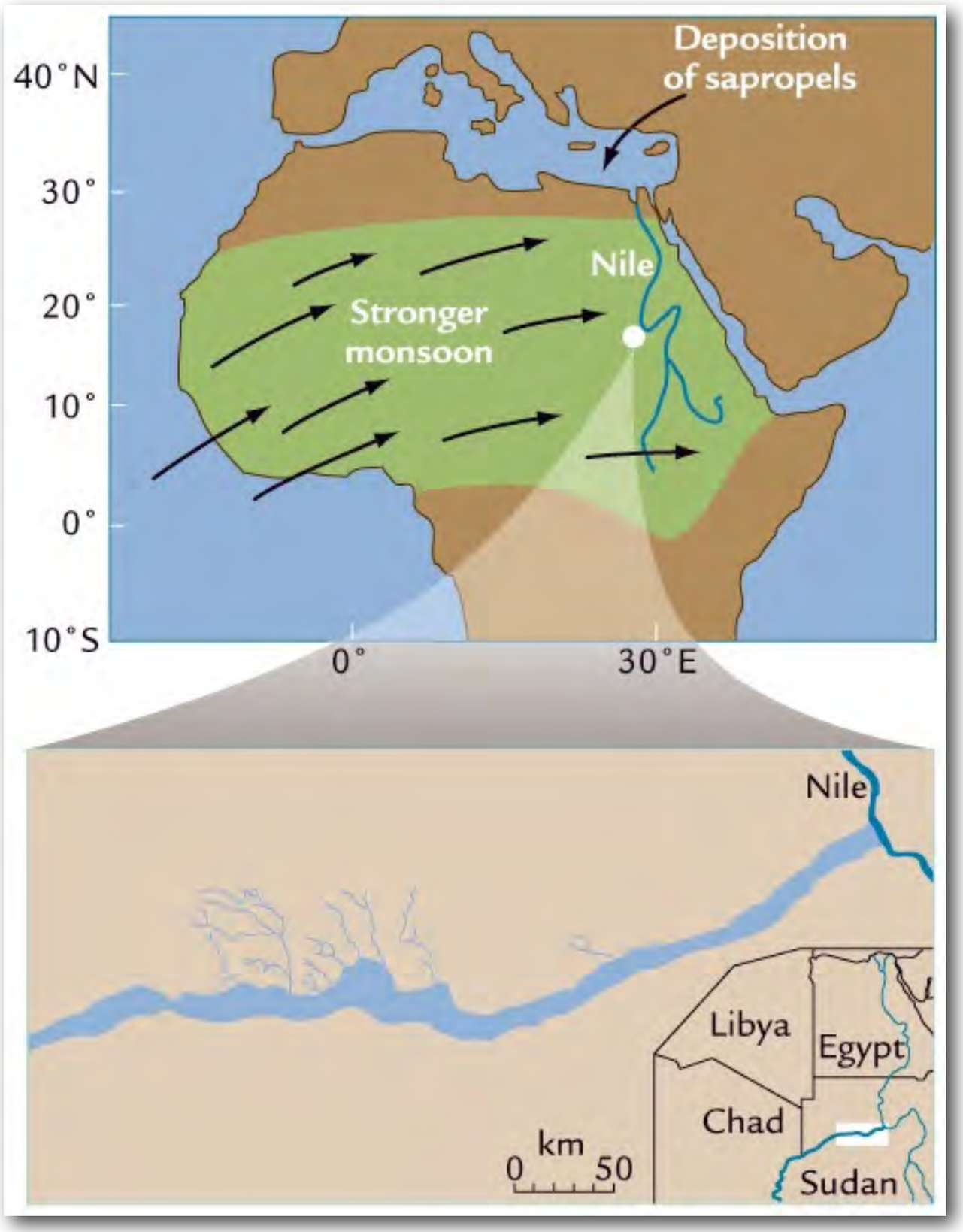
Orbital-scale control of North African monsoon circulation

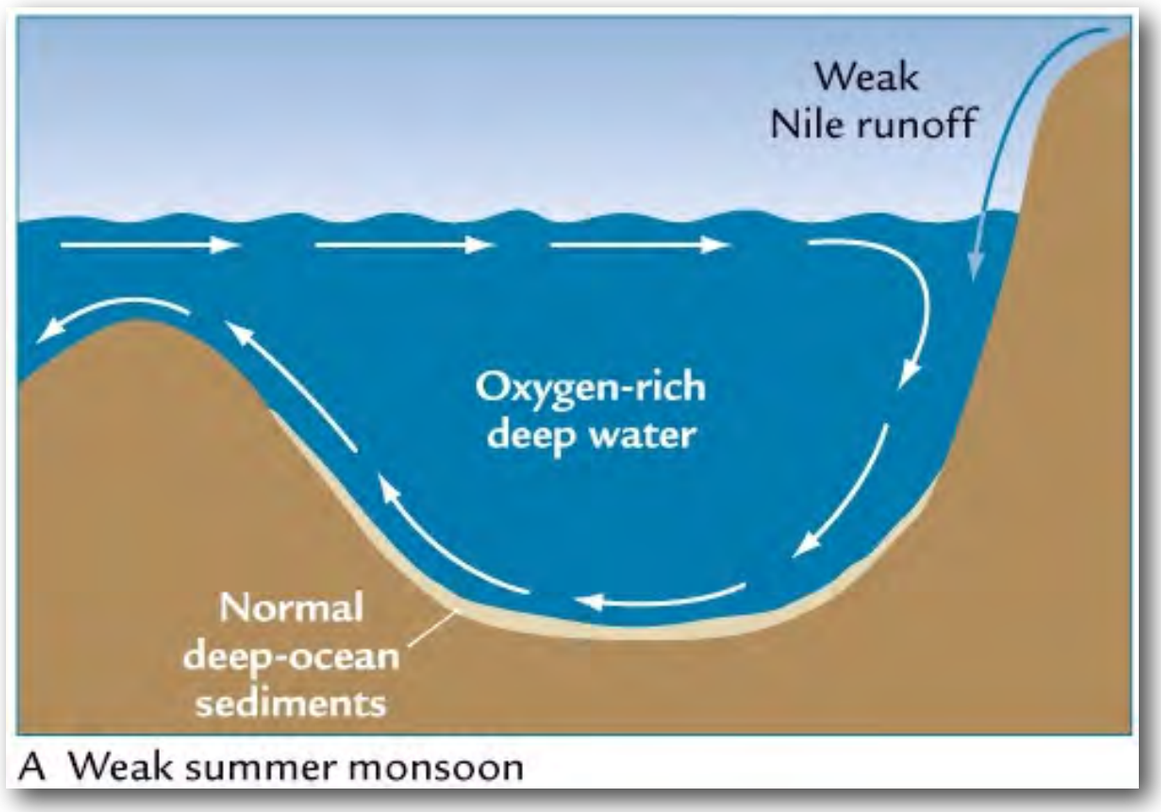


[from: Ruddiman, 2008]

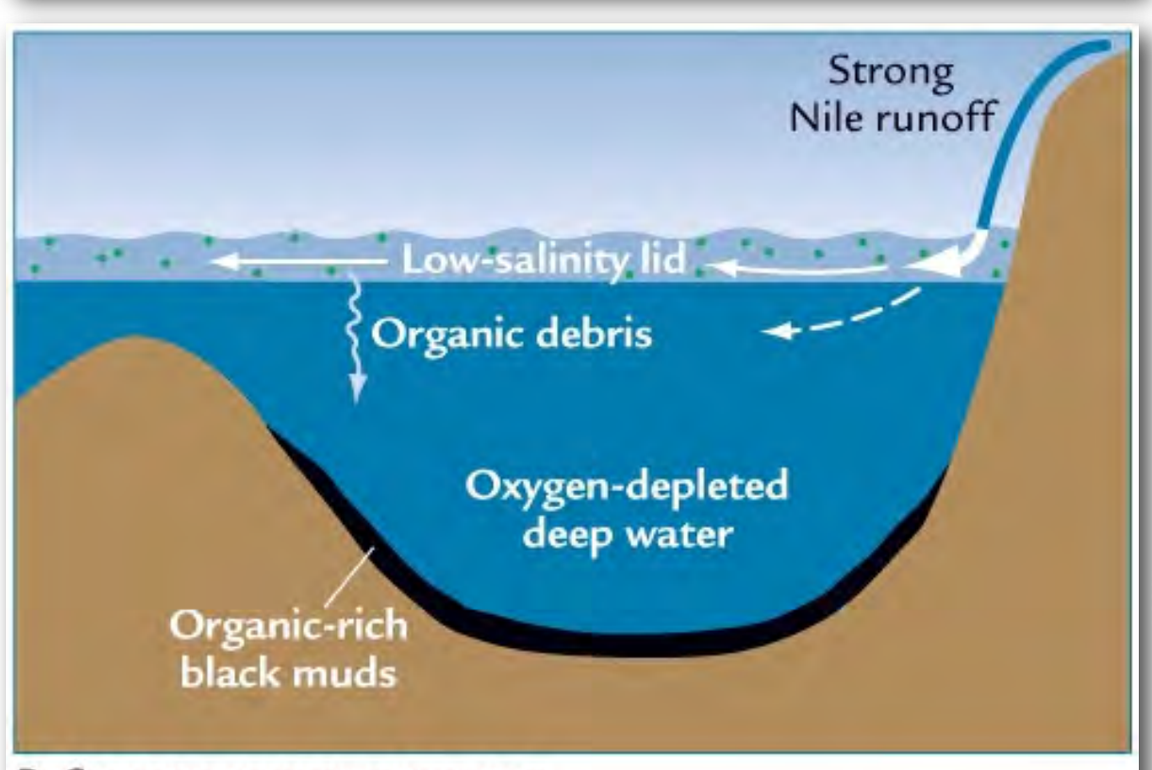
- 2nd test of North African orbital monsoon hypothesis:
  - *if summer monsoon brings more rain, the Nile transports more fresh to the Mediterranean Sea*
  - *the circulation of the Eastern Mediterranean Sea should change*
  - *deep ocean should loose its oxygen*
  - *organic-rich black muds should be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

Orbital-scale control of North African monsoon circulation





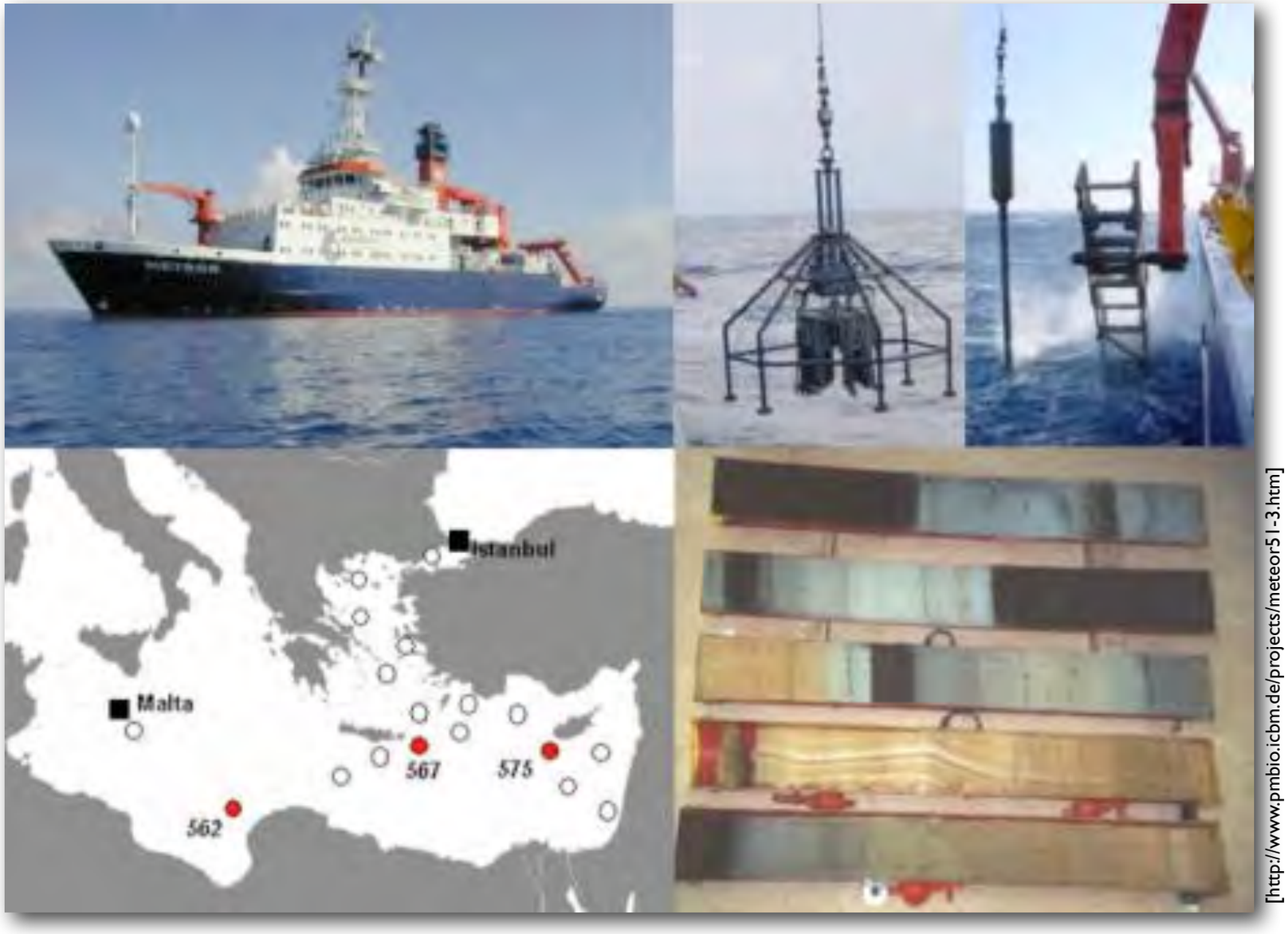
A Weak summer monsoon



B Strong summer monsoon

[from: Ruddiman, 2008]

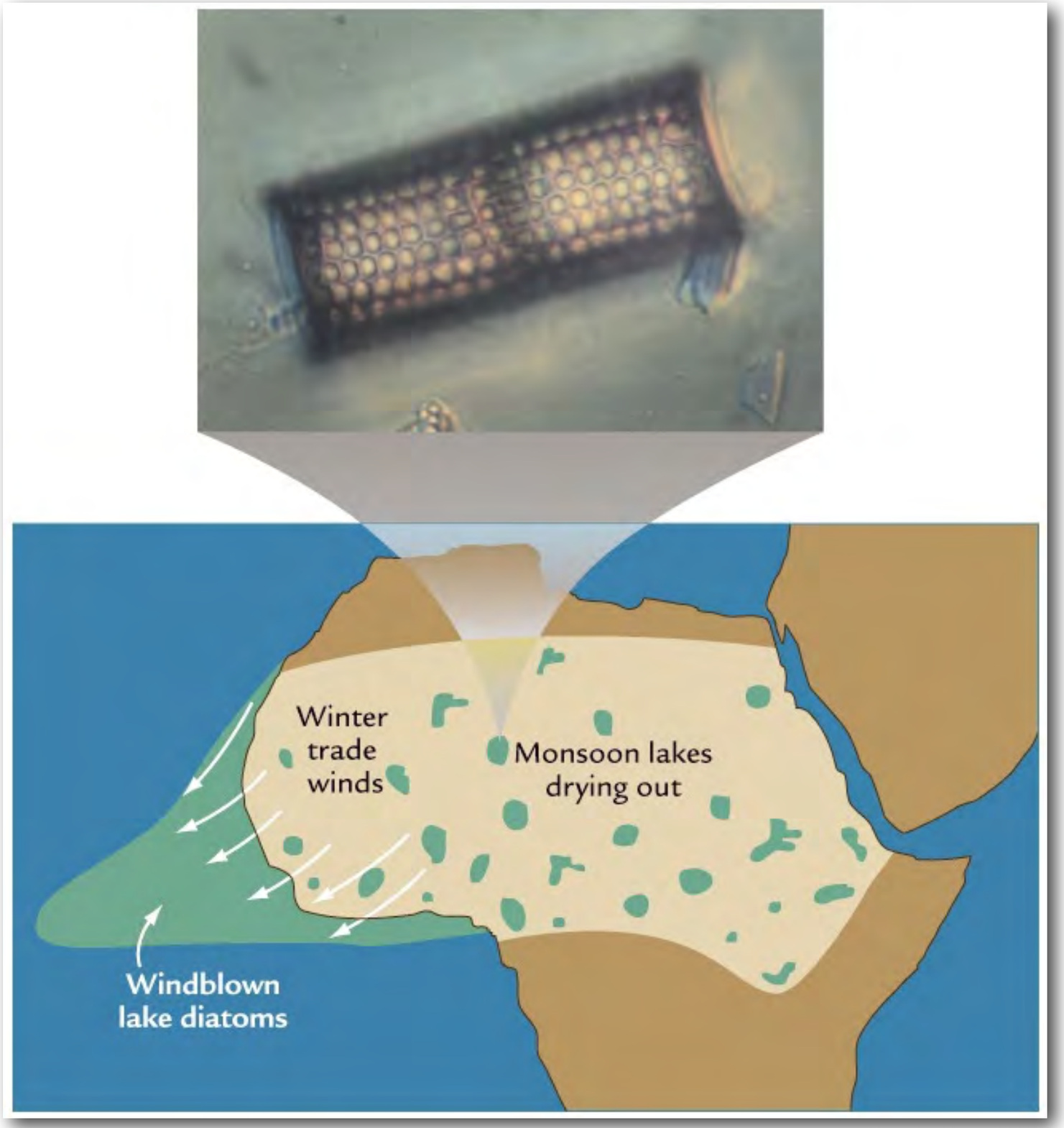
Orbital-scale control of North African monsoon circulation



[http://www.pmbio.icbm.de/projects/meteor51-3.htm]

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

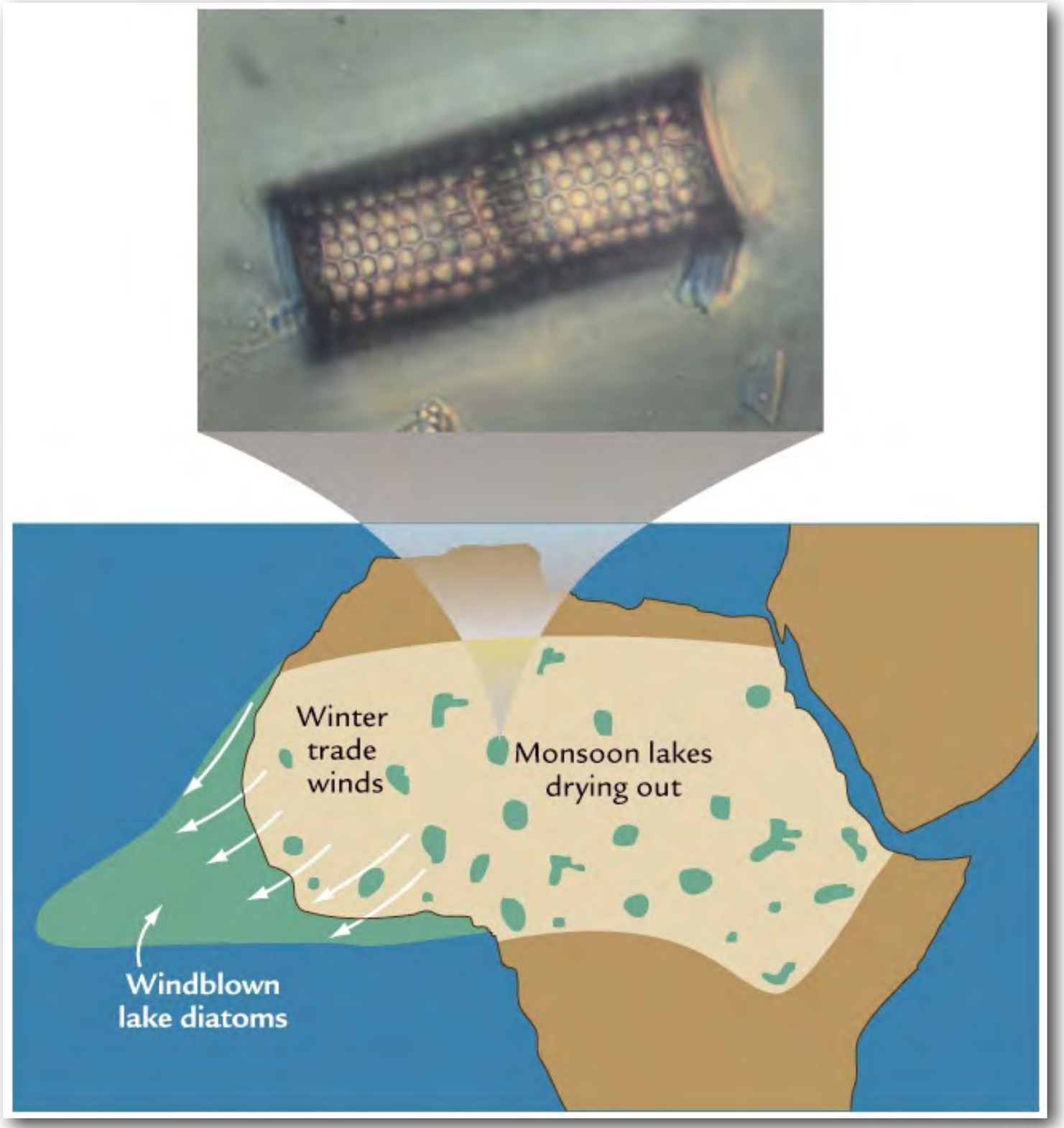
Orbital-scale control of North African monsoon circulation

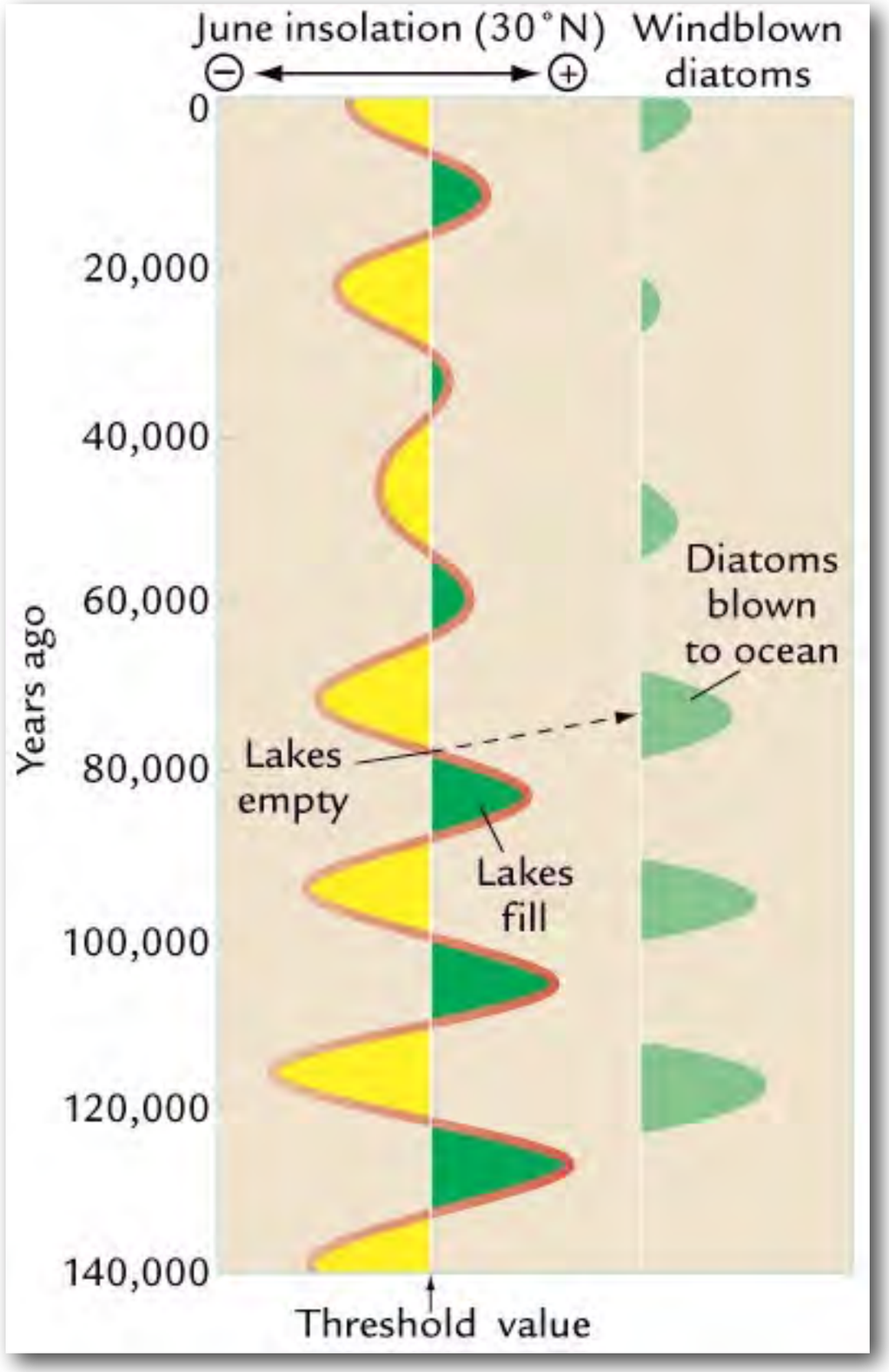


[from: Ruddiman, 2008]

- 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





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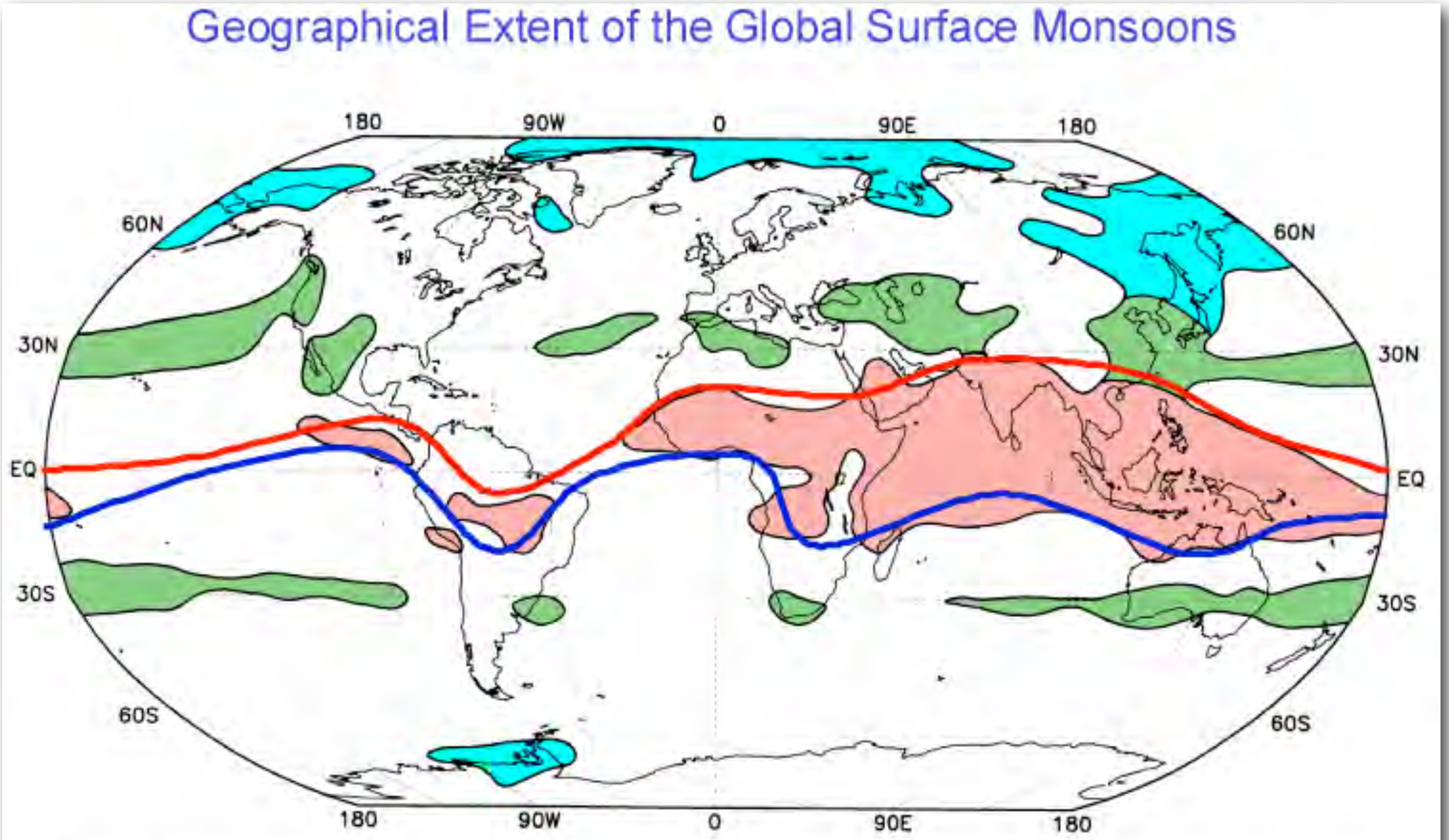
Orbital-scale control of monsoon circulation



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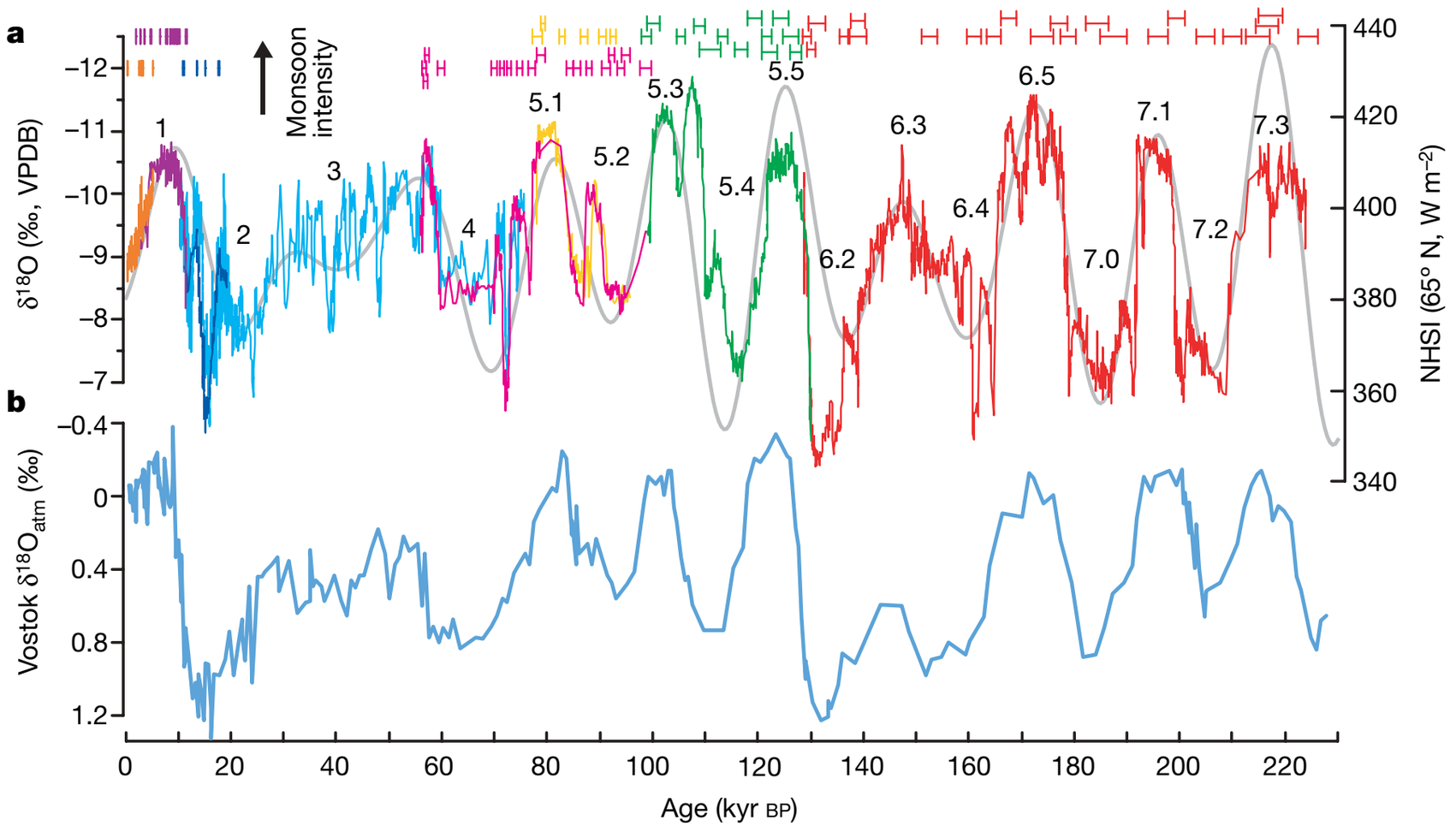
[http://www.lasg.ac.cn/staff/ljp/Monsoon.html]

Orbital-scale control of Asian monsoon circulation

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

Yongjin Wang[1], Hai Cheng[1,2], R. Lawrence Edwards[2], Xinggong Kong[1], Xiaohua Shao[1], Shitao Chen[1], Jiangyin Wu[1], Xiouyang Jiang[1], Xianfeng Wang[2] & Zhisheng An[3]



NATURE|Vol 451|28 February 2008

Figure 1 | Comparison of Sanbao/Hulu $\delta^{18}O$ records with NHSI and atmospheric $\delta^{18}O$ record over the past 224 kyr BP. **a**, Time versus Sanbao $\delta^{18}O$ 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° N[10] (grey). For comparison, the Hulu $\delta^{18}O$ 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 (2σ error bars at top) are colour-coded by stalagmites. Numbers indicate the marine isotope stages and substages. **b**, The atmospheric $\delta^{18}O$ record from Vostok ice core, Antarctica[28].

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. Burns[1], Ivo Karmann[2], Warren D. Sharp[3], Mathias Vuille[1], Andrea O. Cardoso[4], José A. Ferrari[5], Pedro L. Silva Dias[4] & Oduvaldo Viana Jr[2]

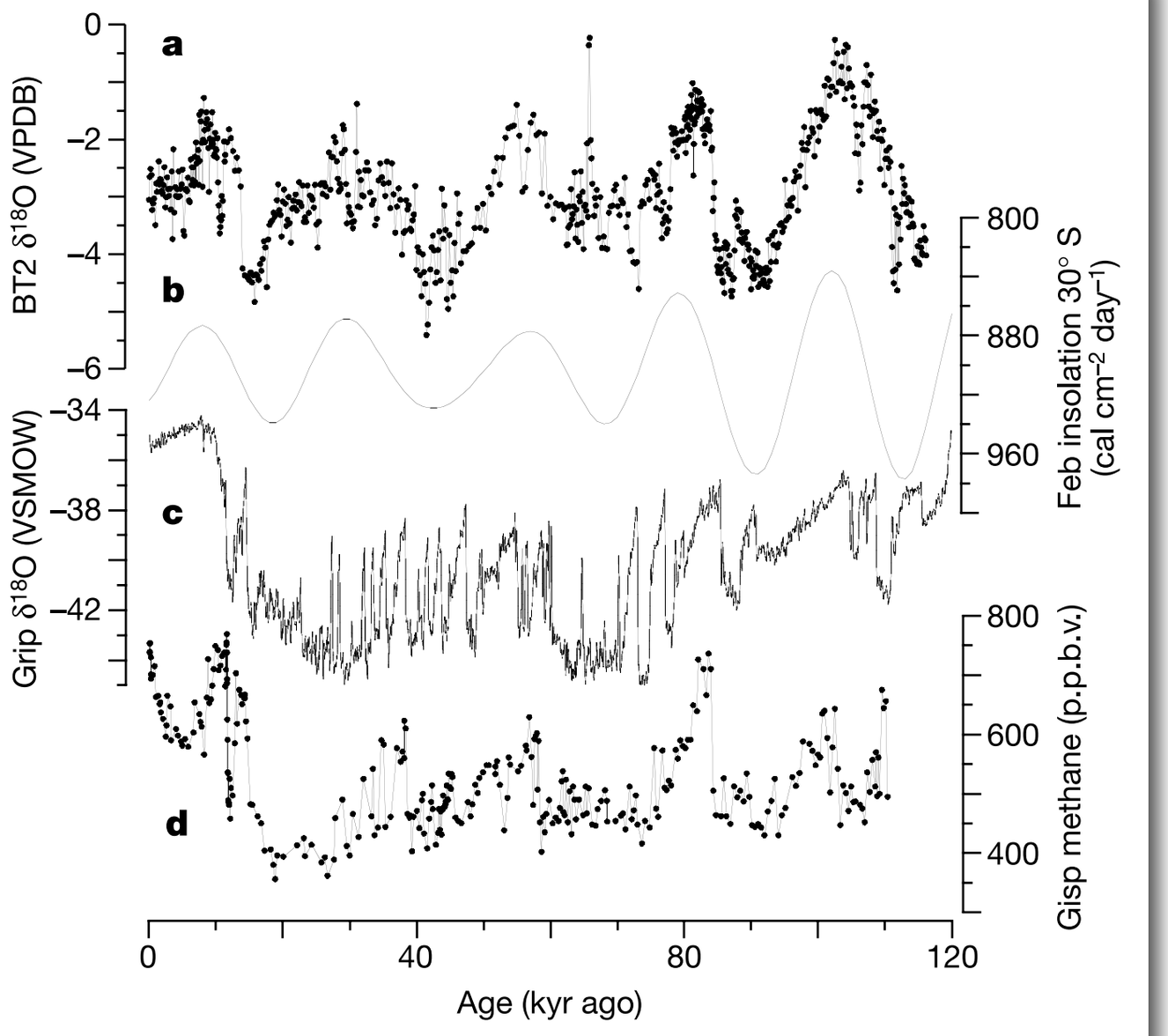


Figure 2 Stable oxygen isotope profile for stalagmite BT2. The BT2 profile (**a**) is compared with February solar insolation for 30° S (**b**), oxygen isotopes of the NGrip ice core from Greenland (**c**), and atmospheric methane concentrations from the Greenland ice core (**d**).

Regional and global signals: Permafrost

[https://www.eskp.de/klimawandel/kohlenstofffreisetzung-aus-sibirischen-permafrostboeden-935527/

Regional and global signals: Permafrost

What is permafrost?

- permanently frozen ground
  - *temperature of the ground remains under zero degrees Celsius for at least two consecutive years*

- material: rock, sediment or soil
  - *can contain varying quantities of ice*

- can reach far down into Earth
  - *North-East Siberia: up to 1.7km*

[https://www.awi.de/en/focus/permafrost/permafrost-an-introduction.html

Regional and global signals: Permafrost

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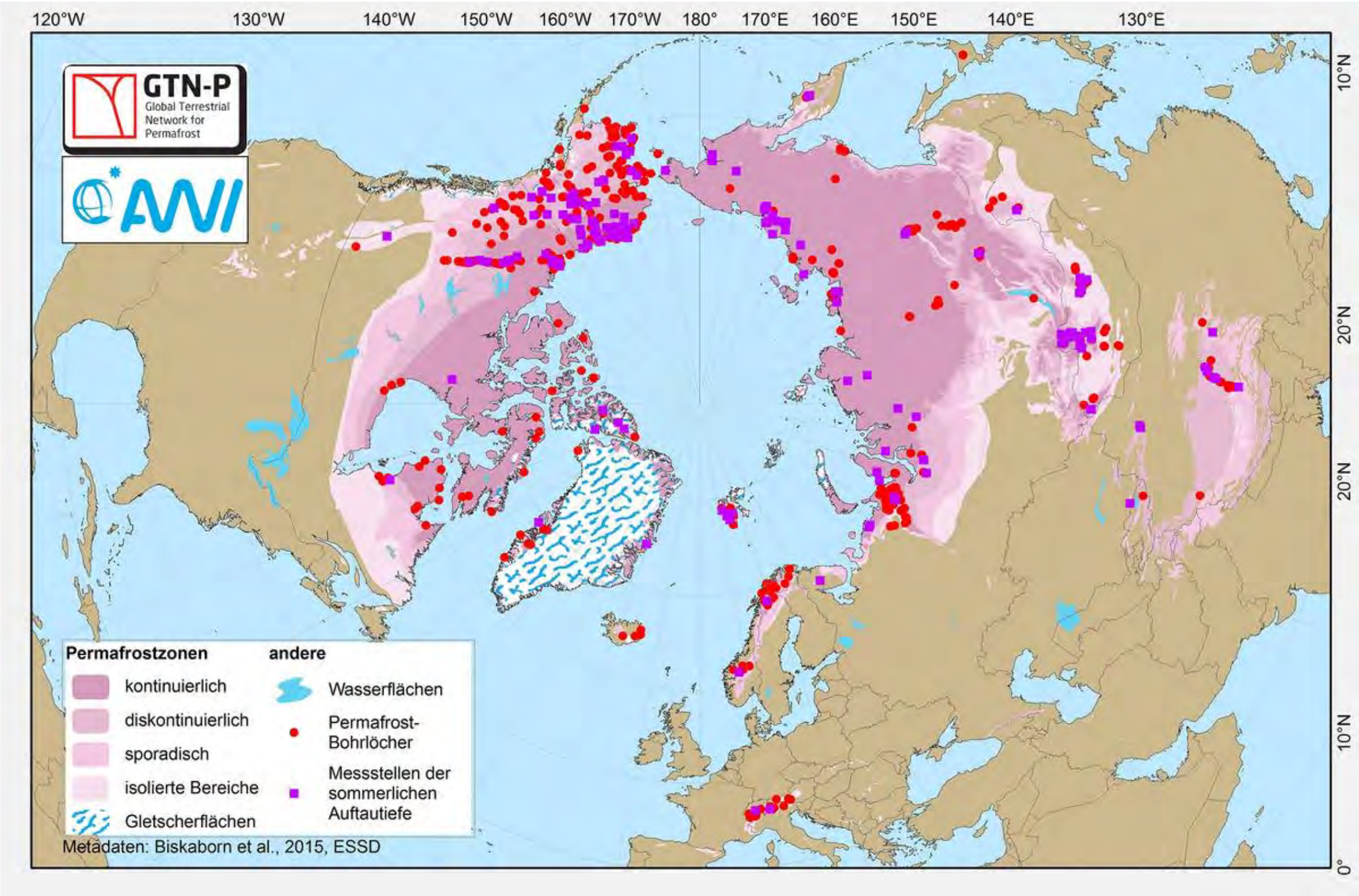
- can be recognised by typical patterning of their surface formed by repeated deep freezing in winter

- often, there is an active layer of soil above the permafrost (15-100cm), which is thawing in summer

[https://www.awi.de/en/focus/permafrost/permafrost-an-introduction.html

Regional and global signals: Permafrost

Where can we find permafrost?



[https://www.awi.de/en/focus/permafrost/permafrost-an-introduction.html

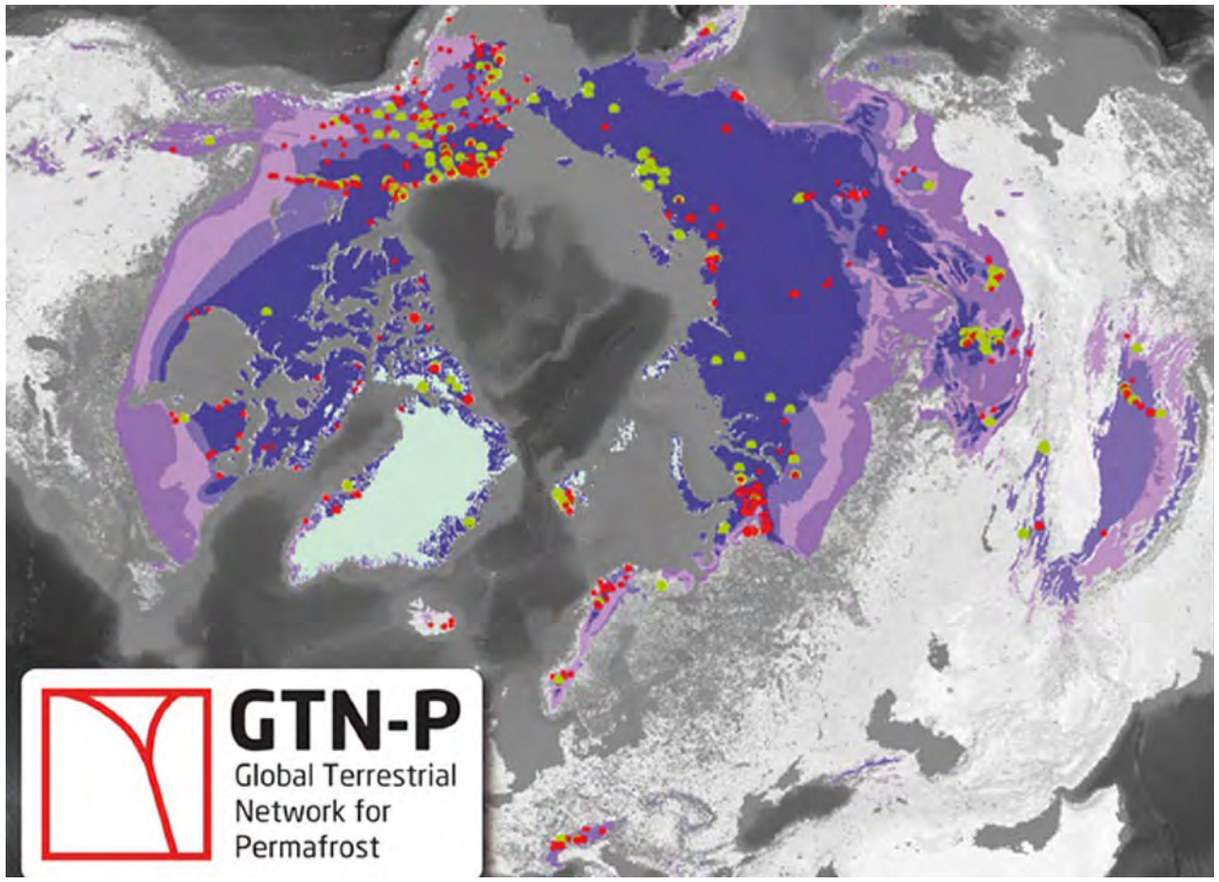
Regional and global signals: Permafrost

Is permafrost thawing?

- climate warming leads to warming of permafrost areas
  - *polar amplification leads to even stronger warming in high northern latitudes*

- permafrost areas are already warming since several decades
  - *between 2007 and 2016: approx. 0.3°C warming*

- warming is directly measured in more than 150 boreholes in permafrost regions



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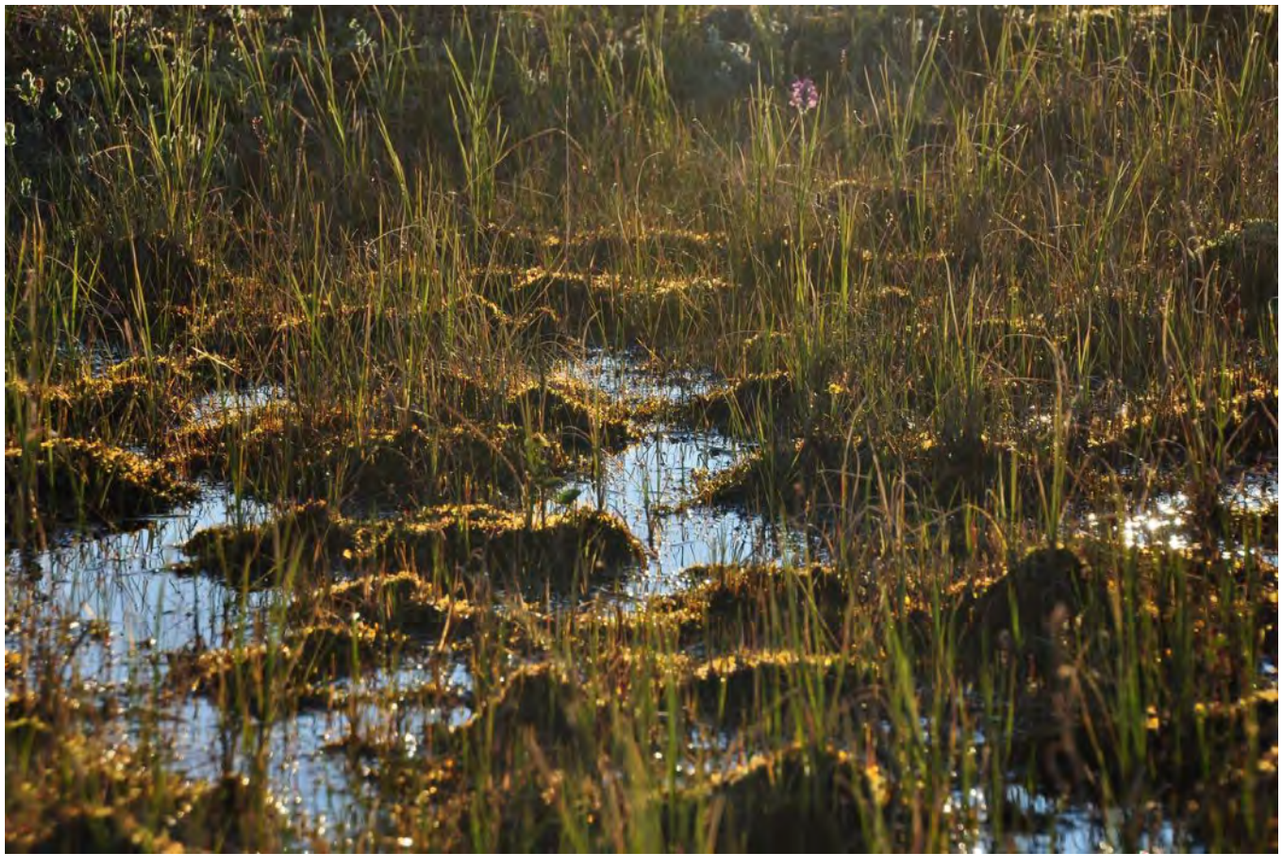
Regional and global signals: Permafrost

Consequences of permafrost thawing

- permafrost contains high amounts of organic materials
- warming leads to increased microbe activities
- by such decomposition processes, high amounts of CO_2 and CH_4 might be released in the future
  - *exact amount is still debated*
- thawing also leads to changes in the surface structure and albedo
  - *liquid waters are darker than ice, will take up more heat and increase the waring effect*
- thawing consequences have a „positive feedback“ to further thawing
  - *quantifying all effects is complicated and a strong focus of current research*



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Climate System II

(Winter 2022/2023)

12th lecture:

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End of lecture.

Slides available at:

https://paleodyn.uni-bremen.de/study/climate2022_23.html