Bologna, 8 ottobre 2015

Astronomia, paleoclimatologia ed evoluzione umana

ovvero

Inesorabilità dell’astronomia

Elio Antonello
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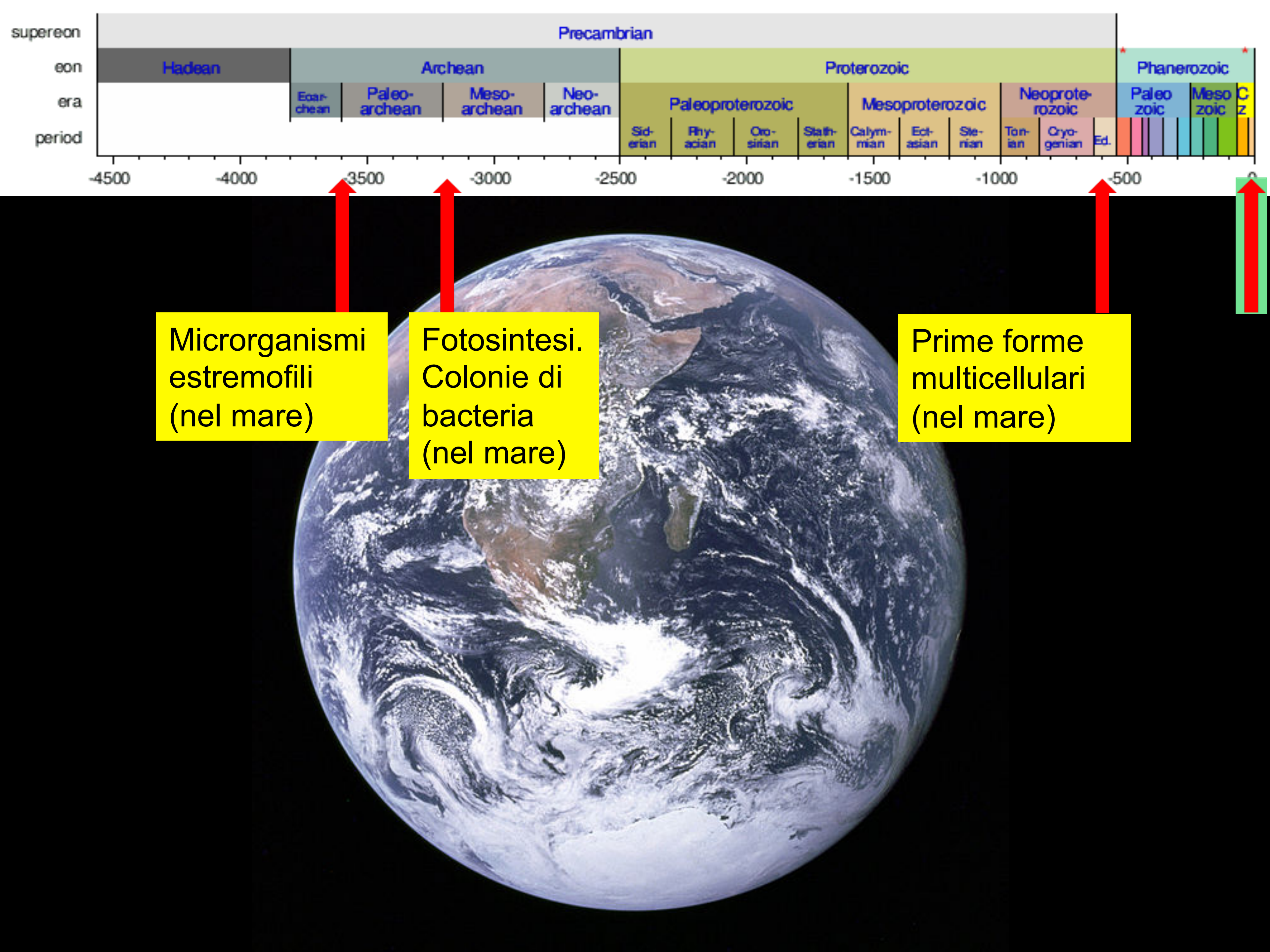
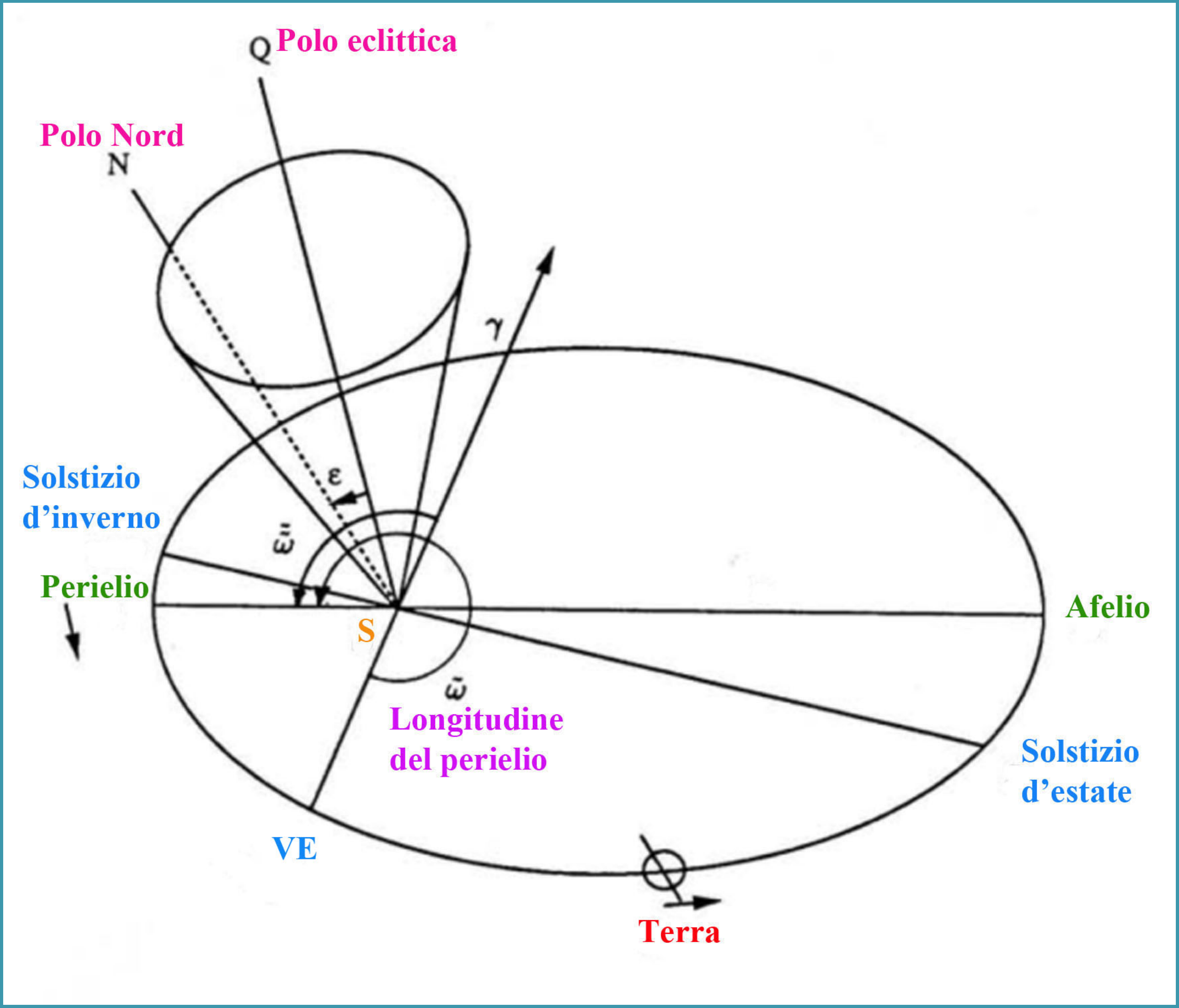
SIA-Società Italiana di Archeoastronomia

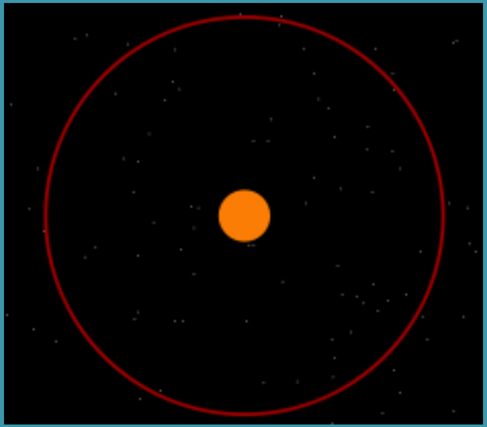


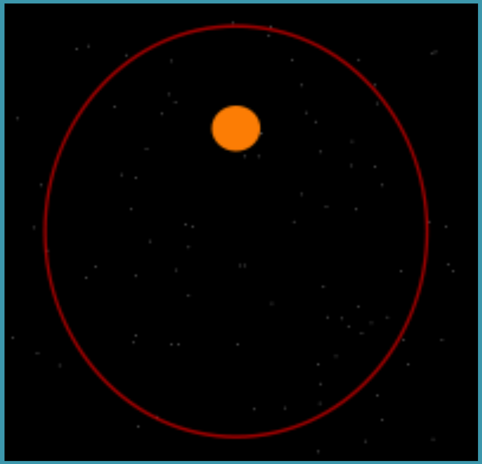
supereon
eon
era
period
Precambrian
Hadean
Archean
Proterozoic
Phanerozoic
Eoar-chean
Paleo-archean
Meso-archean
Neo-archean
Paleoproterozoic
Mesoproterozoic
Neoprote-rozoic
Paleo zoic
Meso zoic
C z
Sid-erian
Rhy-acian
Oro-sirian
Stath-erian
Calym-mian
Ect-asian
Ste-nian
Ton-ian
Cryo-genian
Ed.
-4500
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
Microrganismi estremofili (nel mare)
Fotosintesi. Colonie di bacteria (nel mare)
Prime forme multicellulari (nel mare)

Elements of the Earth's orbit (Berger & Loutre, 1994)

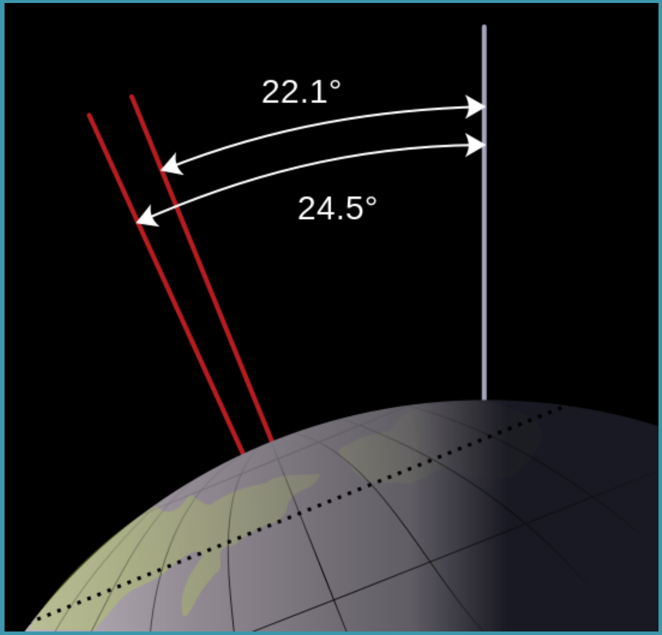


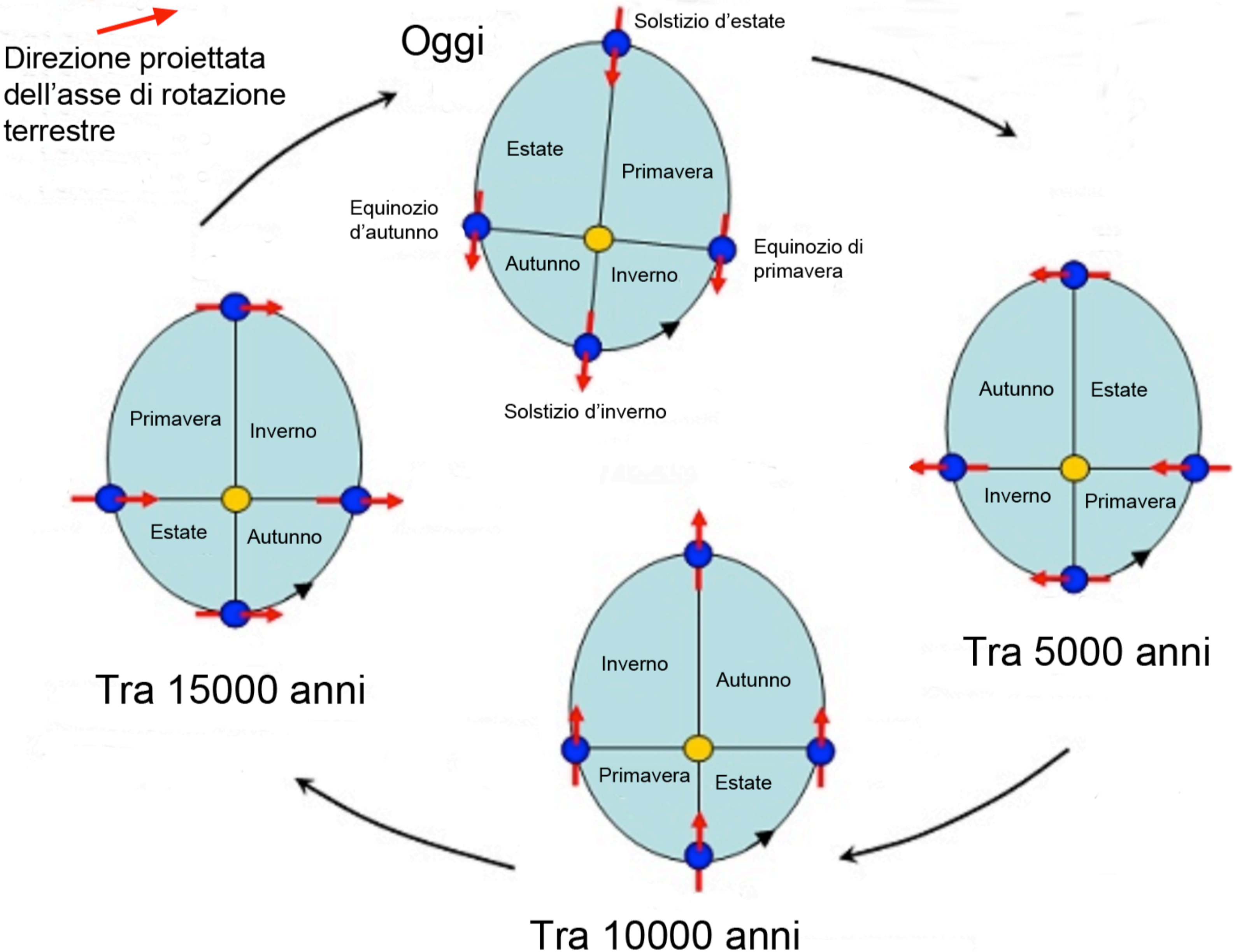
e eccentricità
(scala 100000 anni, 400000 anni)





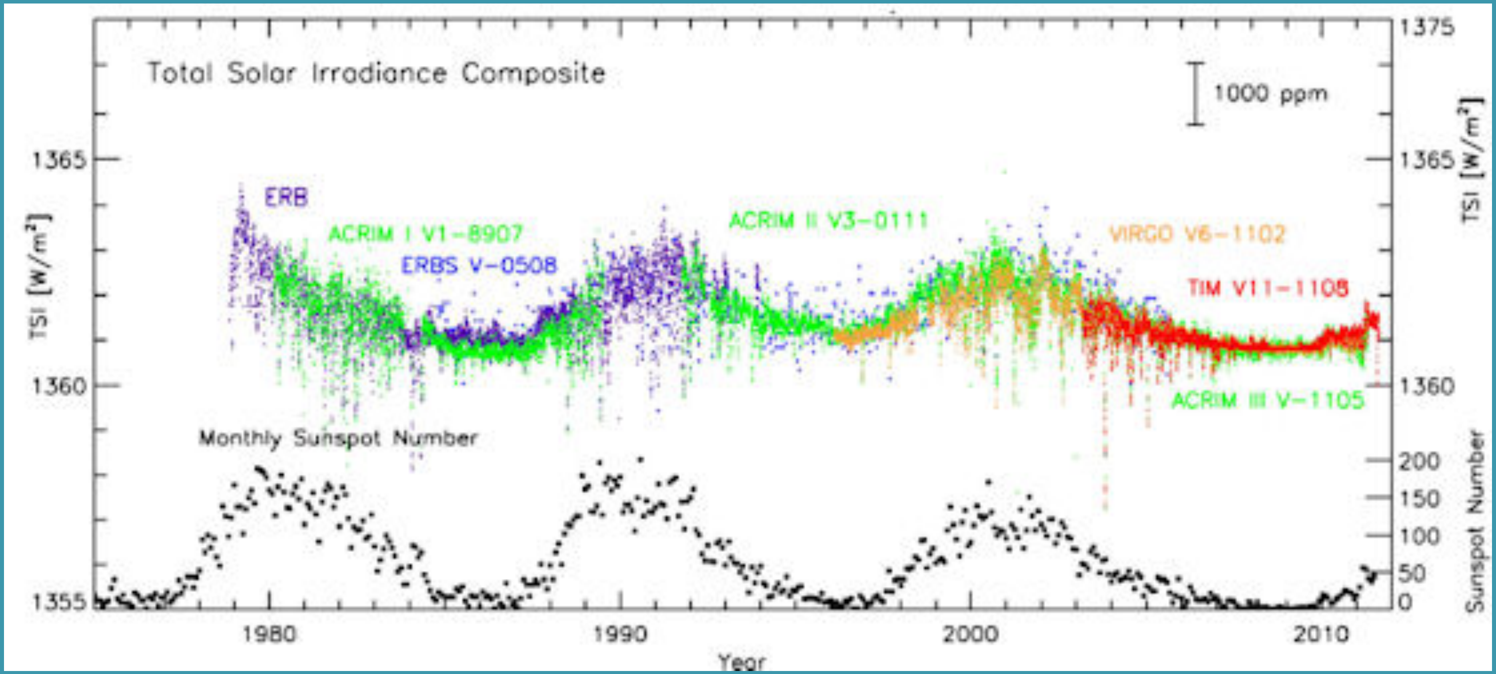
Obliquità dell'eclittica (circa 41000 anni)





Precessione equinozi + apsidi = precessione climatica (circa 19000 - 23000 anni)

“Costante” solare: energia per unità di tempo e di superficie (ortogonale ai raggi solari), senza atmosfera.



Space-borne measurements of the total solar irradiance (TSI) show ~0.1 percent variations with solar activity on 11-year and shorter timescales. These data have been corrected for calibration offsets between the various instruments used to measure TSI. SOURCE: Courtesy of Greg Kopp, University of Colorado. (NASA – Science News 2013)

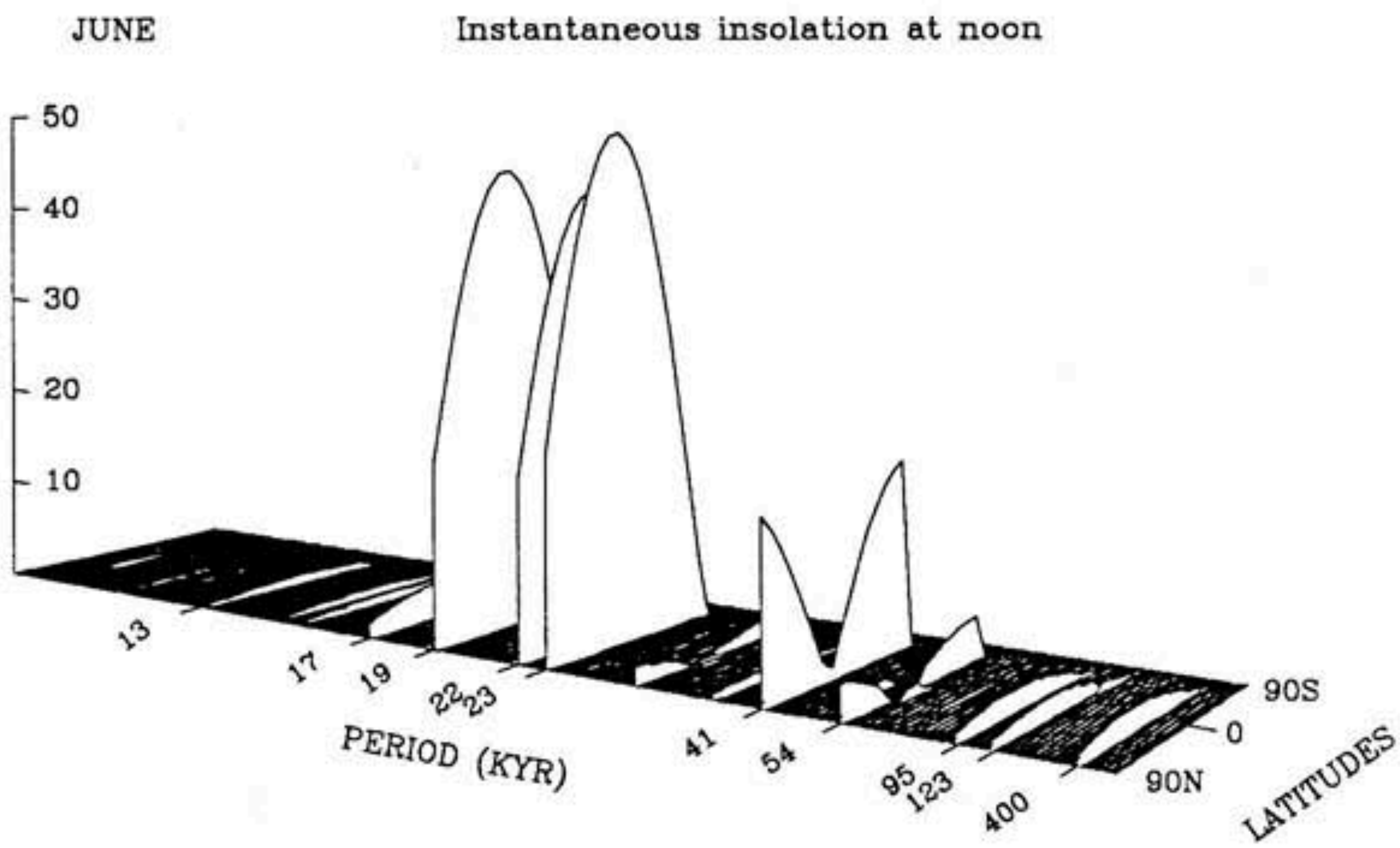
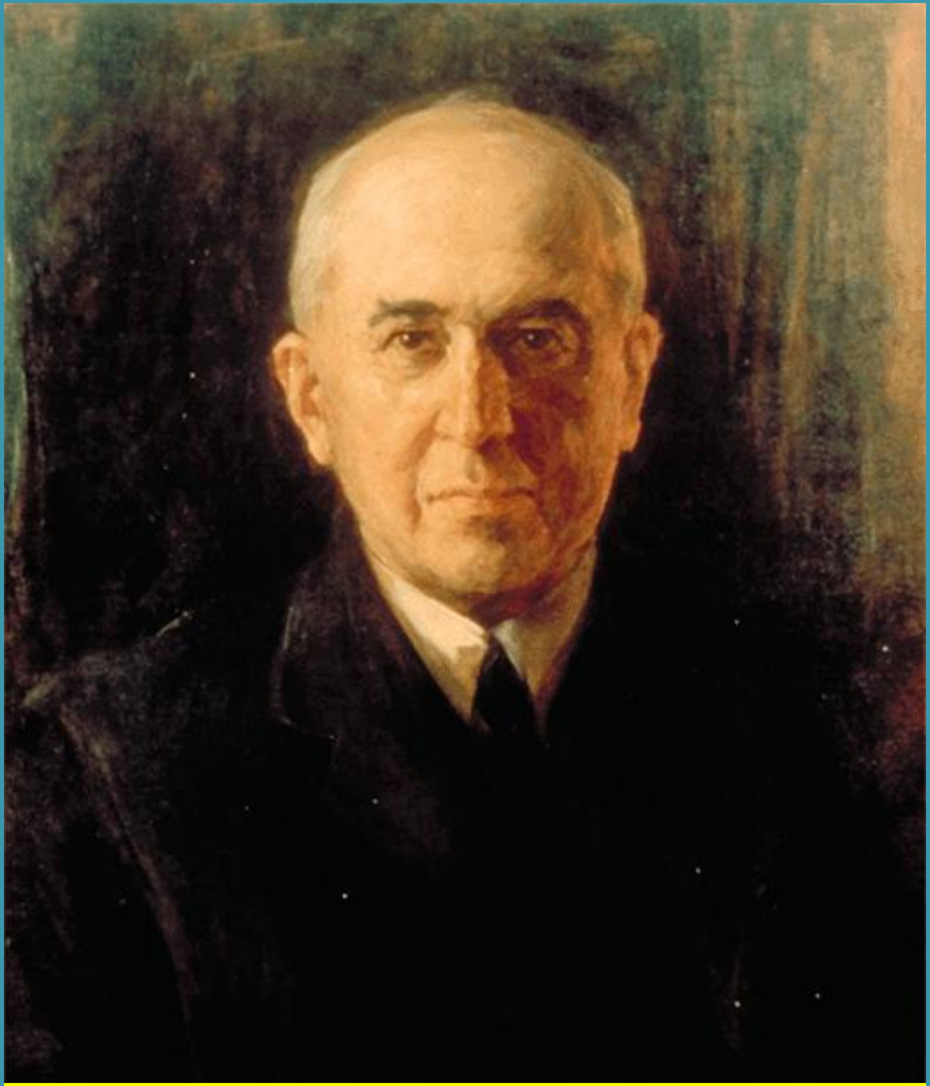


Figure 9: Spectral amplitude in the Thomson multi-taper harmonic analysis of the instantaneous insolation at noon for summer solstice (June) and for each latitude between the north pole and the south pole.

Berger A. and Loutre M.F., 1994. *Precession, eccentricity, obliquity, insolation and paleoclimates.* In: Long Term Climatic Variations, Data and Modelling. J.C. Duplessy and M.-T. Spyridakis (eds). Nato ASI series, Serie I: Global Environmental Change, Springer-Verlag, Berlin, vol. 22. p107-151. http://ebookbrowsee.net/berger-loutre-1994-pdf-d362816449



Milutin Milankovitch (1879-1958)

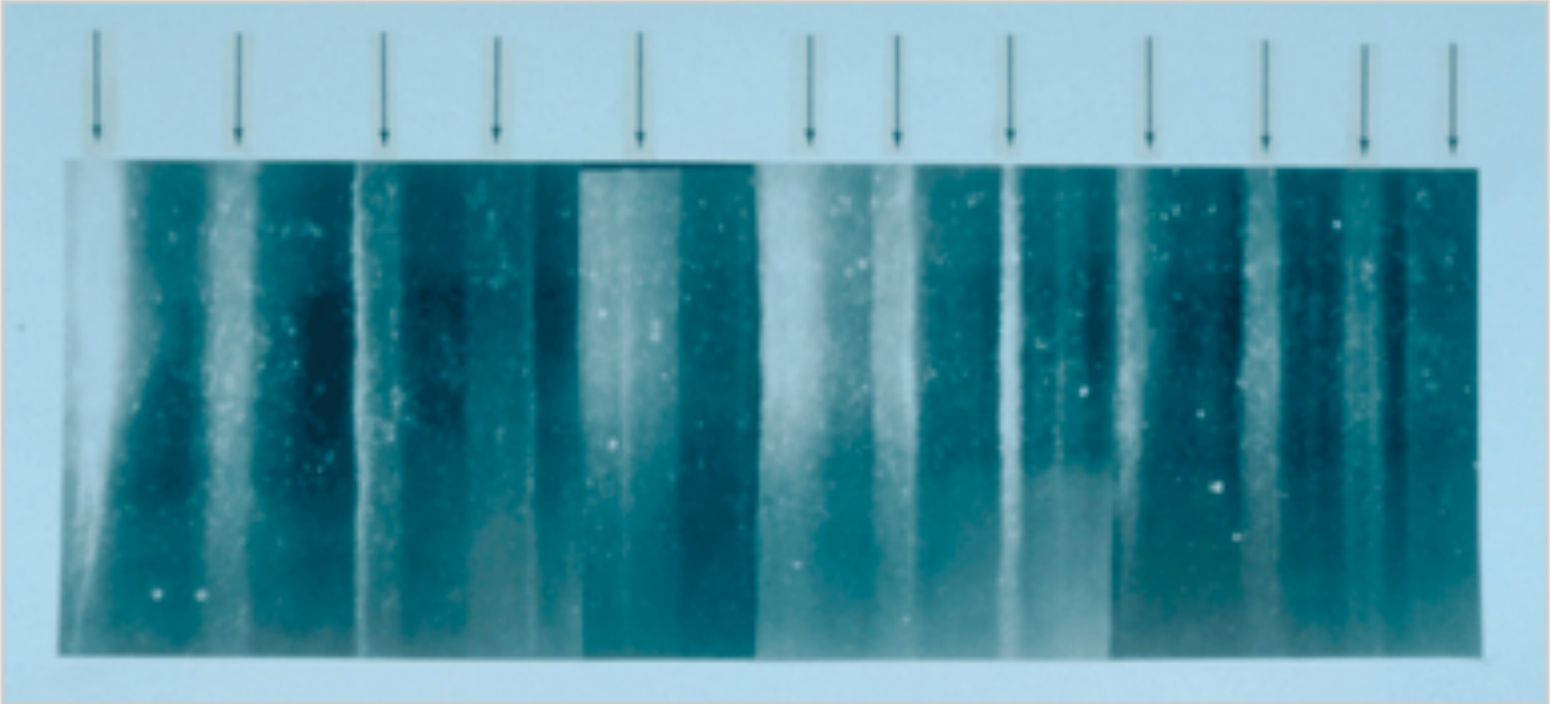
Milankovitch (1941) ha riassunto in un libro i risultati dei suoi calcoli dell’insolazione, basati su lavori precedenti di Leverrier, Stockwell e Pilgrim.

Ha proposto che l’insolazione estiva è quella dominante.

Fino agli anni ‘70 del secolo scorso non è stato possibile effettuare tests convincenti, data la scarsità di dati geologici specifici.

Orbital forcing of climate

CLIMATE PROXIES: ICE CORES



19 cm long section of GISP 2 ice core from 1855 m showing annual layer structure illuminated from below by a fiber optic source. Section contains 11 annual layers with summer layers (arrowed) sandwiched between darker winter layers.

CLIMATE PROXIES: Corals, Benthic Foraminifera

PA1003 LISIECKI AND RAYMO: PLIOCENE-PLEISTOCENE BENTHIC STACK PA1003

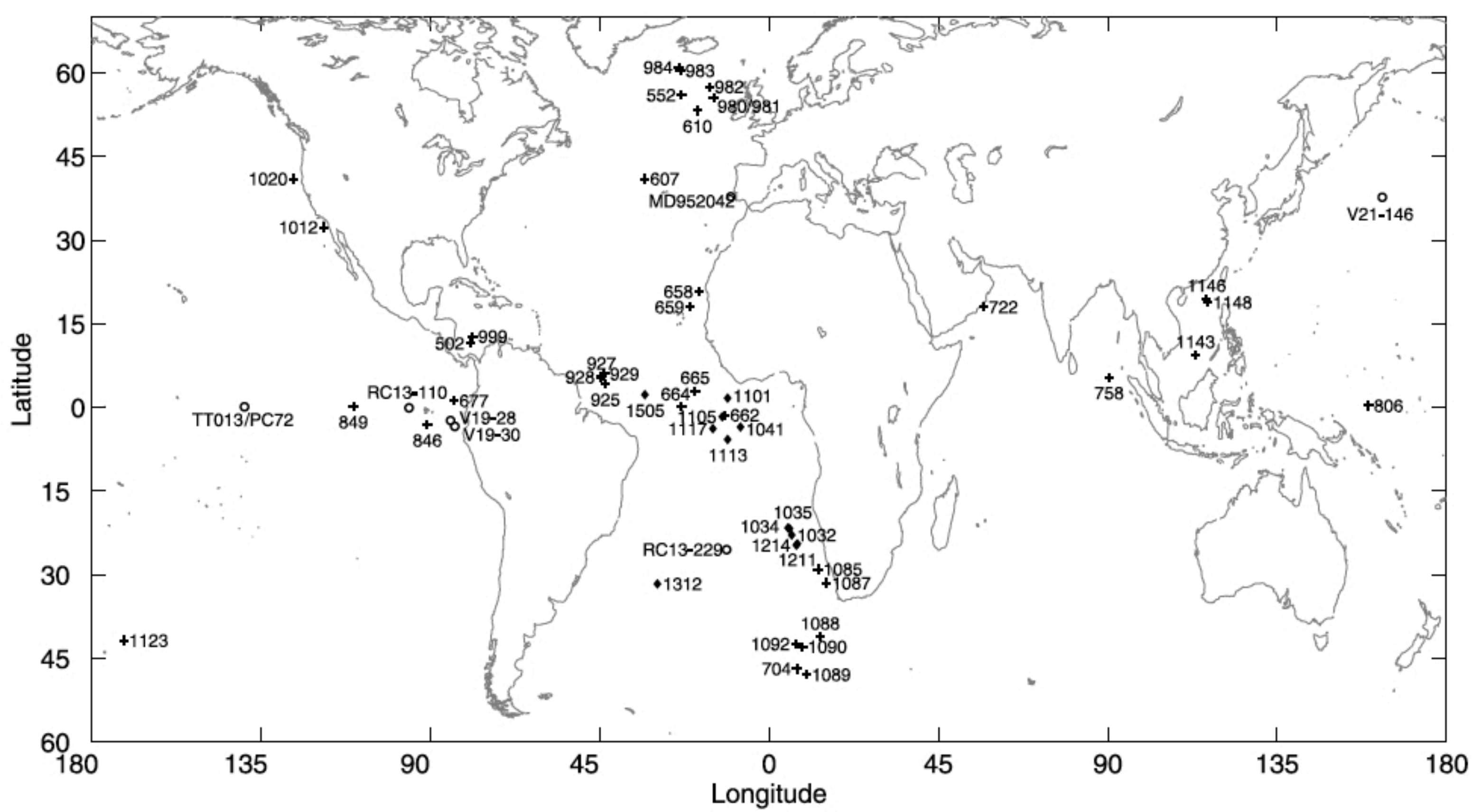


Figure 1. Location of the cores used in this study. Benthic $\delta^{18}O$ data are taken from Deep-Sea Drilling Project (DSDP) and Ocean Drilling Program (ODP) sites (crosses), GeoB sites (diamonds), and others (circles).

Lisiecki, L. E.; Raymo, M. E. (January 2005). *A Pliocene-Pleistocene stack of 57 globally distributed benthic δ18O records*. Paleoceanography 20: PA1003.

$\delta^{18}O$

From Wikipedia, the free encyclopedia

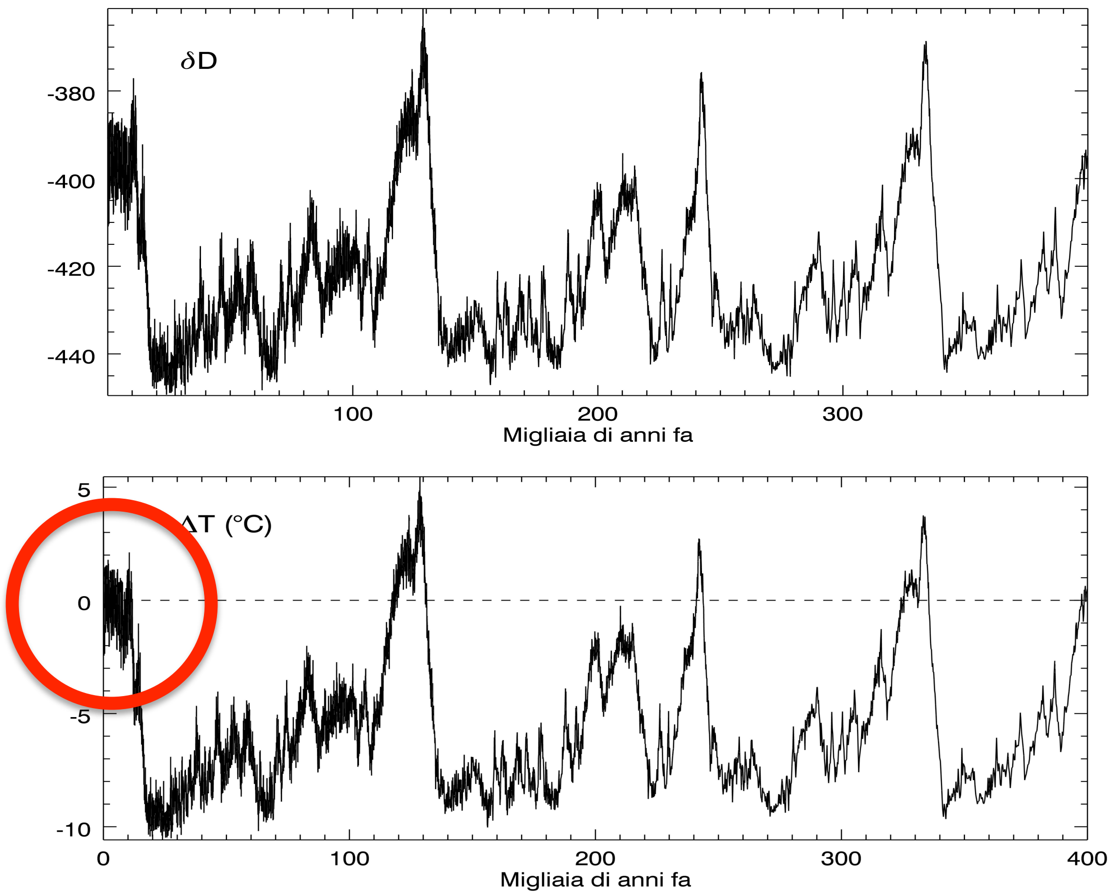
In geochemistry, paleoclimatology and paleoceanography **$\delta^{18}O$** or **delta-O-18** is a measure of the ratio of stable isotopes **^{18}O:^{16}O** (oxygen-18:oxygen-16). It is commonly used as a measure of the temperature of precipitation, as a measure of groundwater/mineral interactions, as an indicator of processes that show isotopic fractionation, like methanogenesis. In paleosciences, ^{18}O:^{16}O data from corals, foraminifera and ice cores are used as a proxy for temperature. The definition is, in "per mil" (‰, parts per thousand):

$$\delta^{18}O = \left(\frac{\left(\frac{^{18}O}{^{16}O}\right)_{sample}}{\left(\frac{^{18}O}{^{16}O}\right)_{standard}} - 1 \right) * 1000\ ‰$$

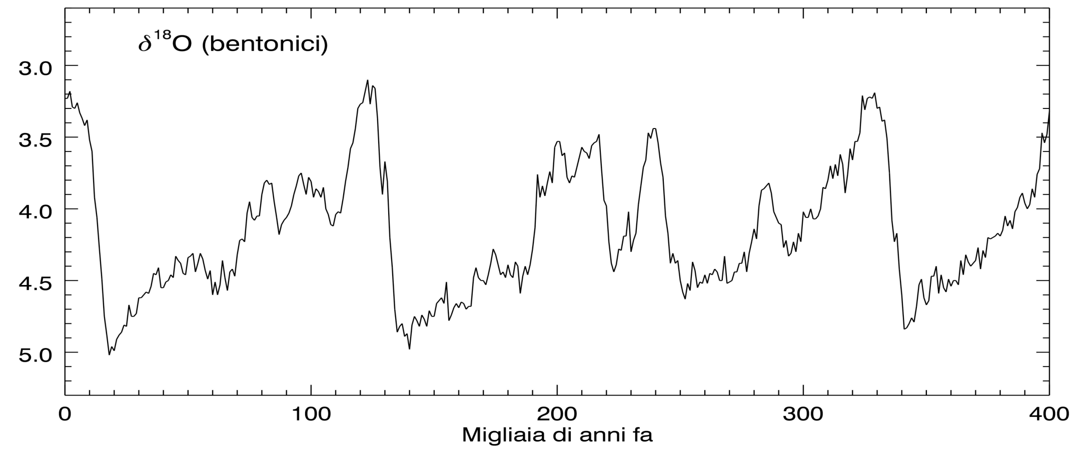
where the standard has a known isotopic composition, such as Vienna Standard Mean Ocean Water (VSMOW).[2] The fractionation can arise from kinetic, equilibrium, or mass-independent fractionation.

^{16}O	99.76%	^{16}O is stable with 8 neutrons
^{17}O	0.039%	^{17}O is stable with 9 neutrons
^{18}O	0.201%	^{18}O is stable with 10 neutrons

Antartide EPICA/DomeC (Jouzel et al. 2007): eccesso di deuterio (per mille)



Ocean drillings (Lisiecki, Raymo, 2005) eccesso di ossigeno

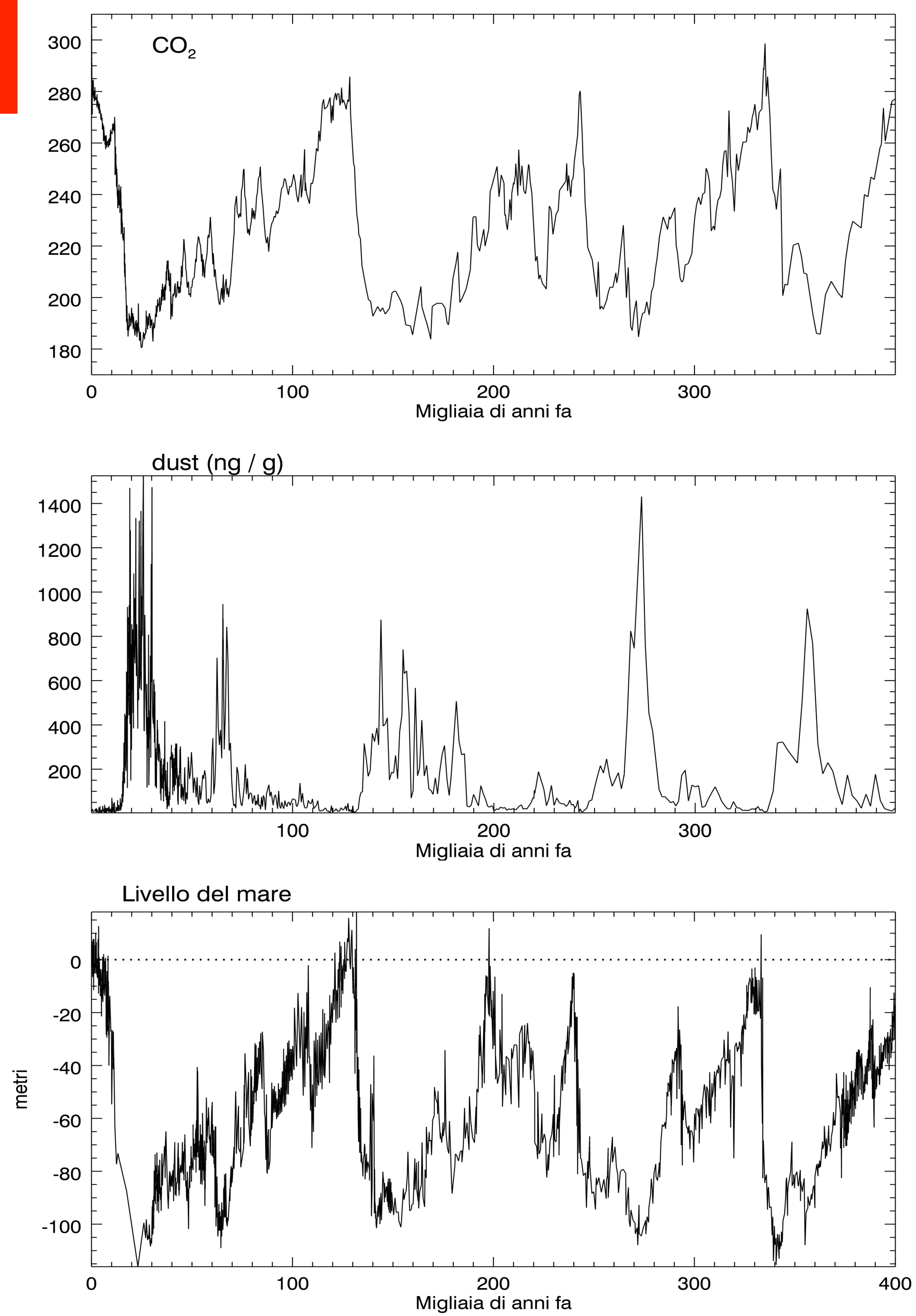


2015: 400 p.p.m.!

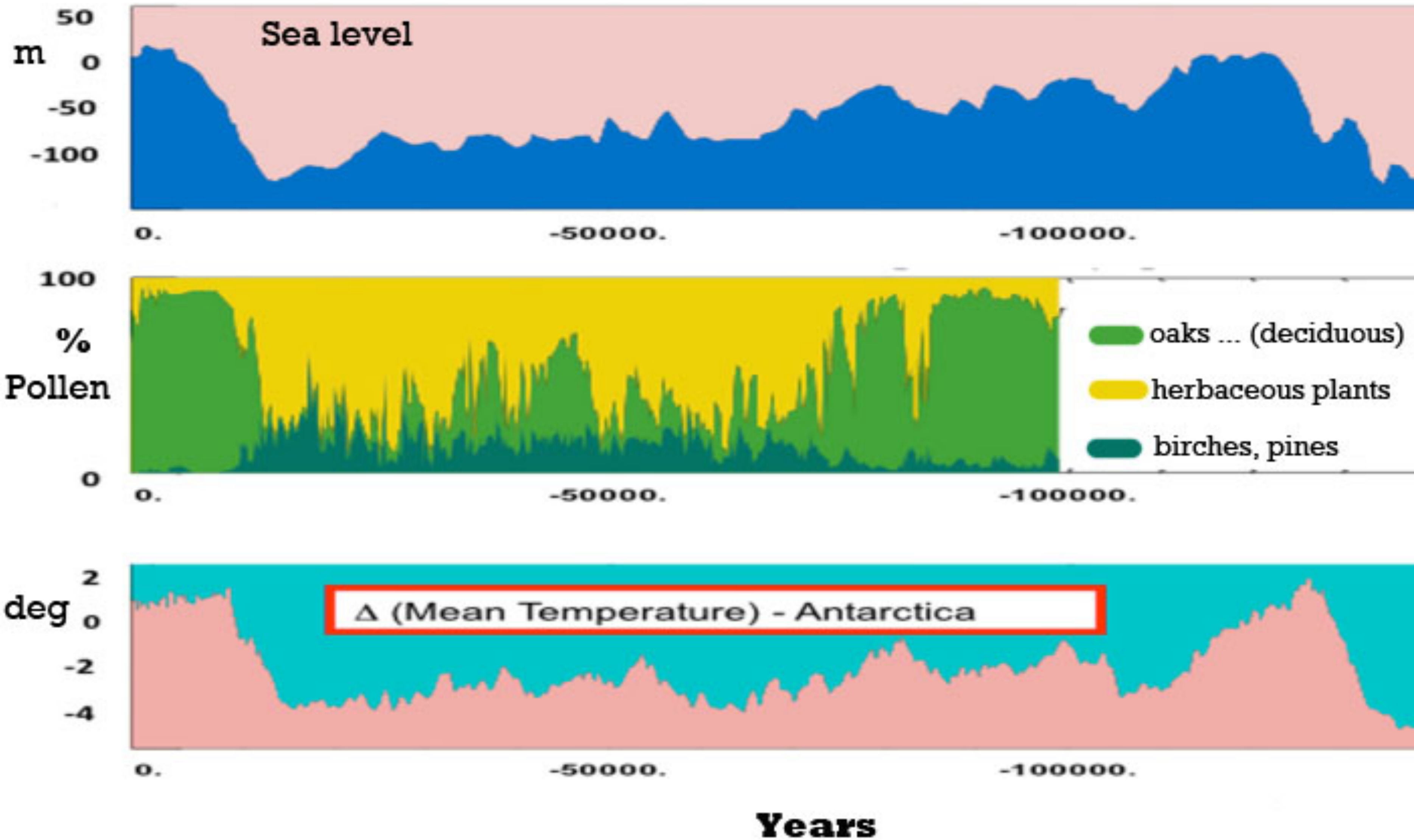
Antartide: CO2 (p.p.m.)

Antartide (Lambert et al., 2008)

Mar Rosso (Grant et al. 2014)

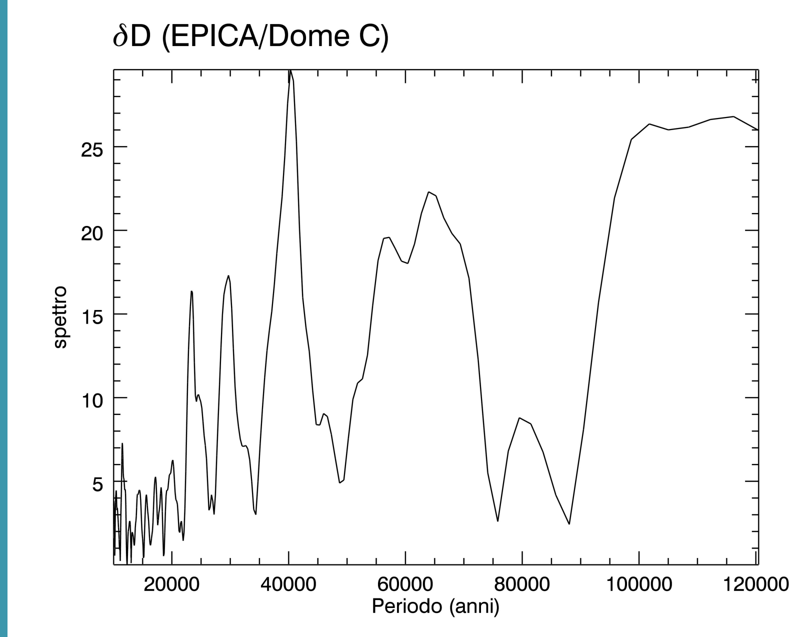


CLIMATE PROXIES: Pollen

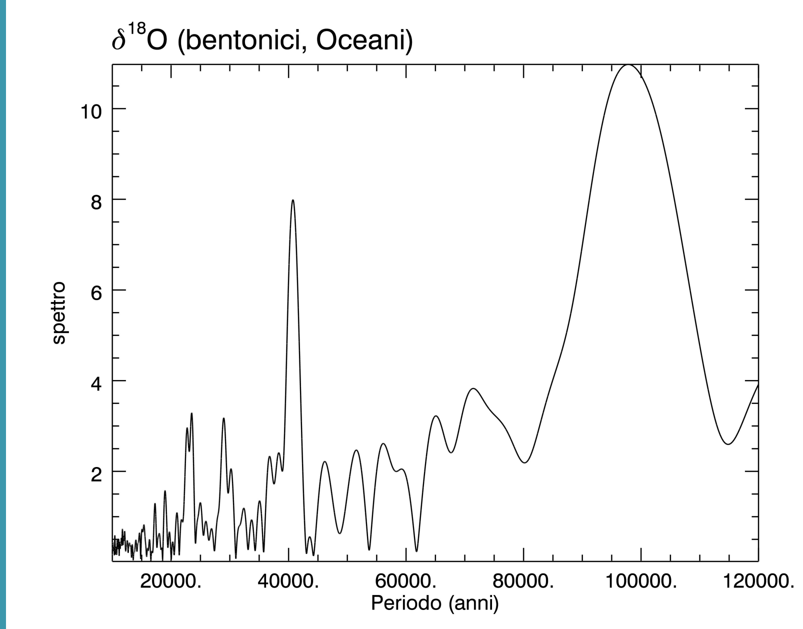


Allen, J. R.M., Watts, W. A., McGee, E. & Huntley, B. (2002). Holocene environmental variability - the record from Lago Grande di Monticchio, Italy. *Quaternary International* **88**: 69-80.

Spettri di ampiezza (Lomb-Scargle)



Antartide EPICA/DomeC
(Jouzel et al. 2007)
circa 800 Kyr



Ocean drillings
(Lisiecki, Raymo, 2005)
circa 5 Myr

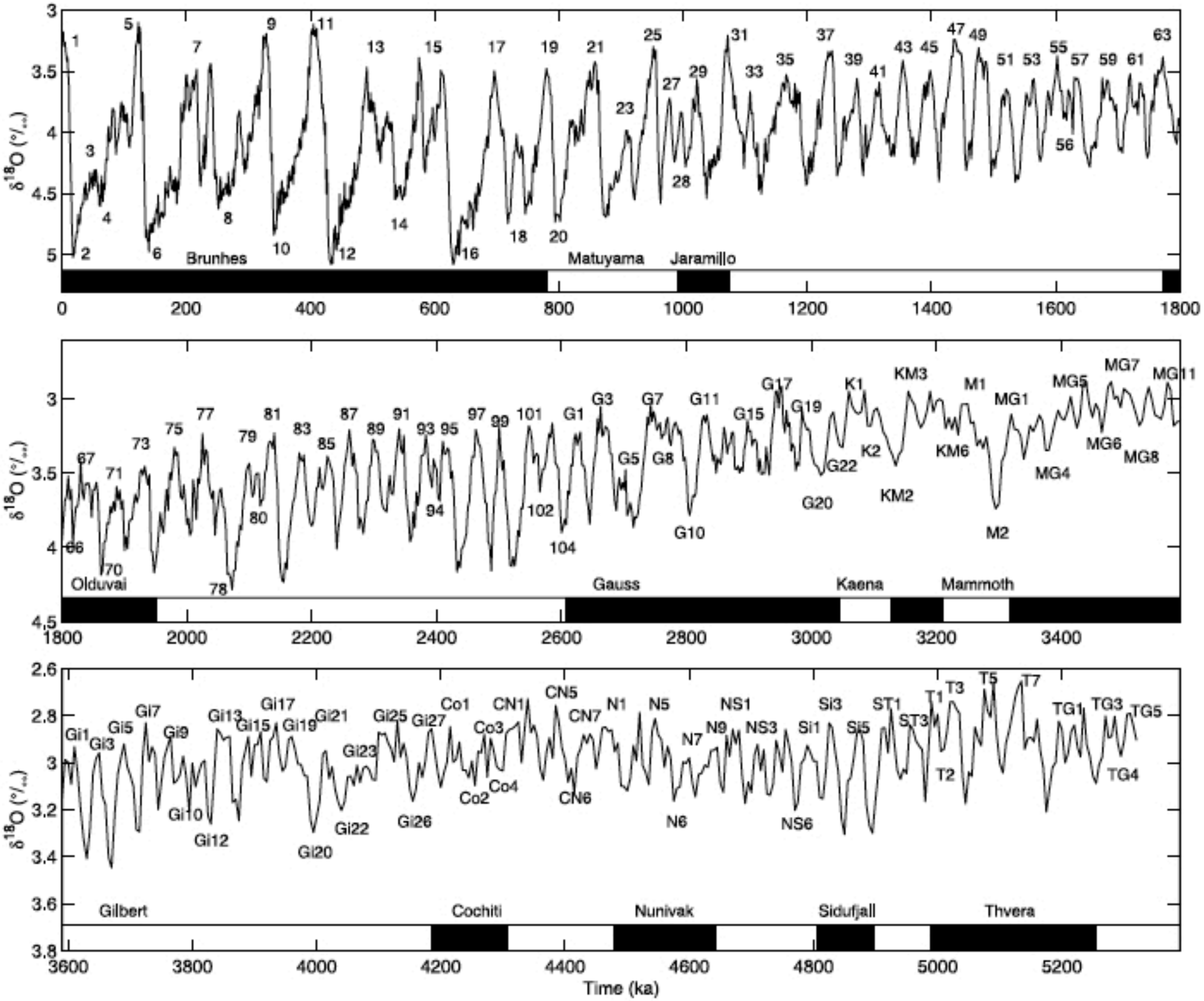


Figure 4. The LR04 benthic $\delta^{18}O$ stack constructed by the graphic correlation of 57 globally distributed benthic $\delta^{18}O$ records. The stack is plotted using the LR04 age model described in section 5 and with new MIS labels for the early Pliocene (section 6.2). Note that the scale of the vertical axis changes across panels.

PROXY: Speleothem

Andamento dell'eccesso di ^{18}O (in per mille) misurato in stalagmiti della Sanbao Cave in Cina (dati di **Wang et al. 2008**)

NATURE | Vol 451 | 28 February 2008

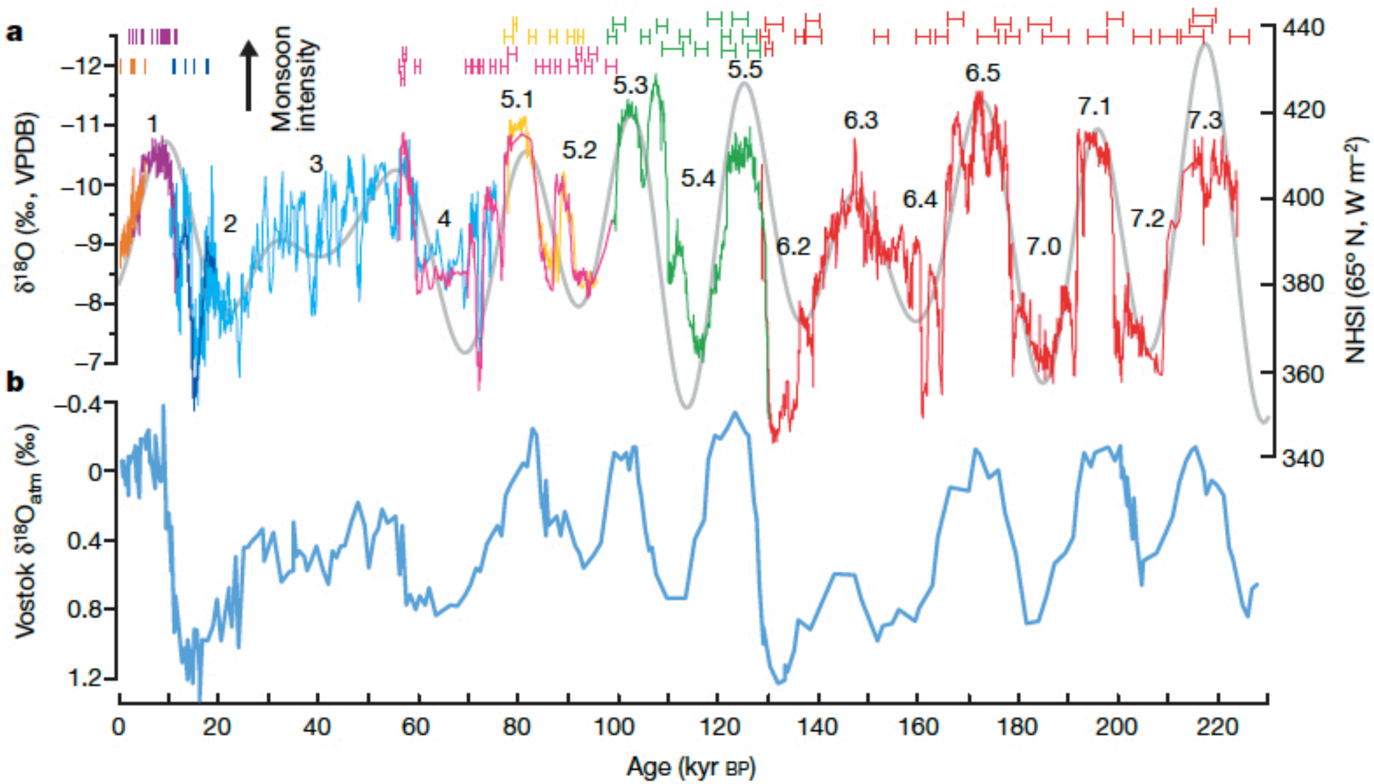


Figure 1 | Comparison of Sanbao/Hulu $\delta^{18}O$ records with NHSI and atmospheric $\delta^{18}O$ record over the past 224 kyr BP. **a**, Time versus Sanbao $\delta^{18}O$ records (red, stalagmite SB11; green, SB23; yellow, SB25-1; pink, SB22; dark blue, SB3; purple, SB10 and orange, SB26) and Hulu 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].

PROXY: Speleothem

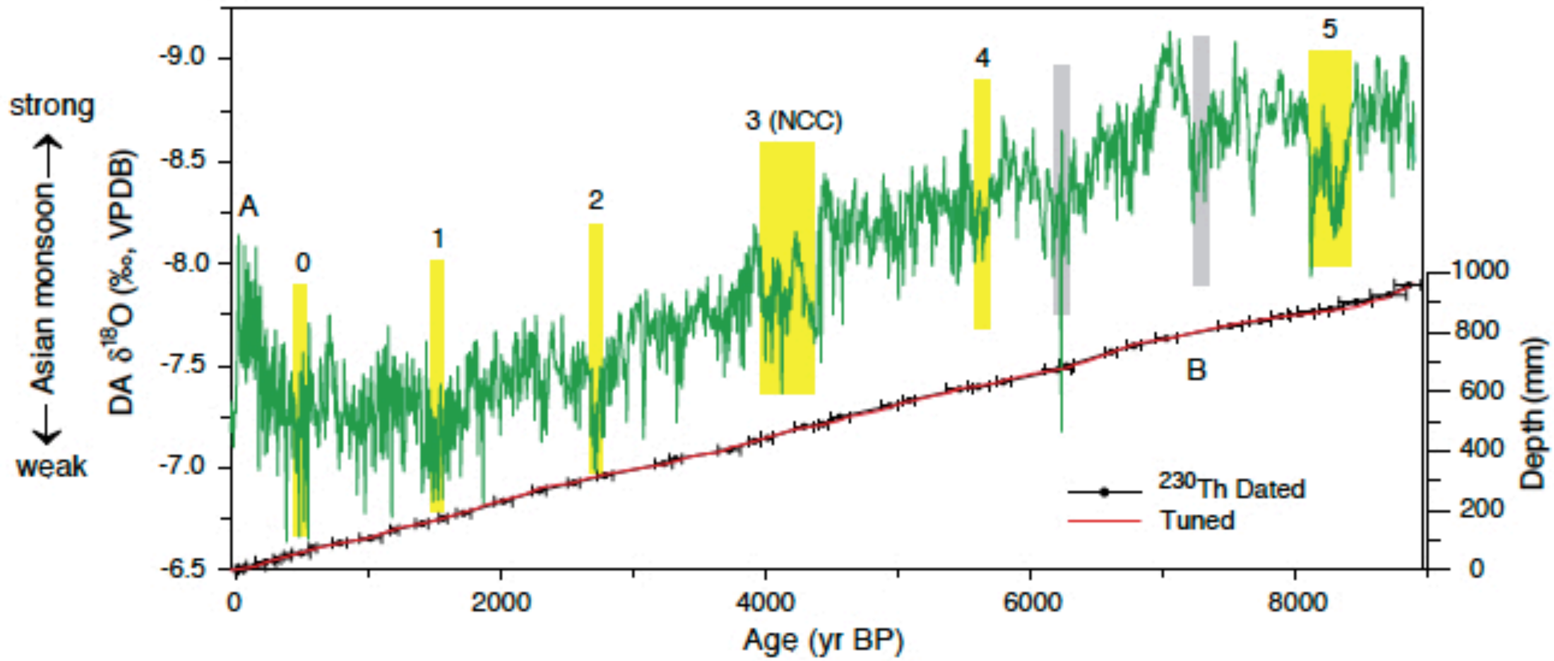
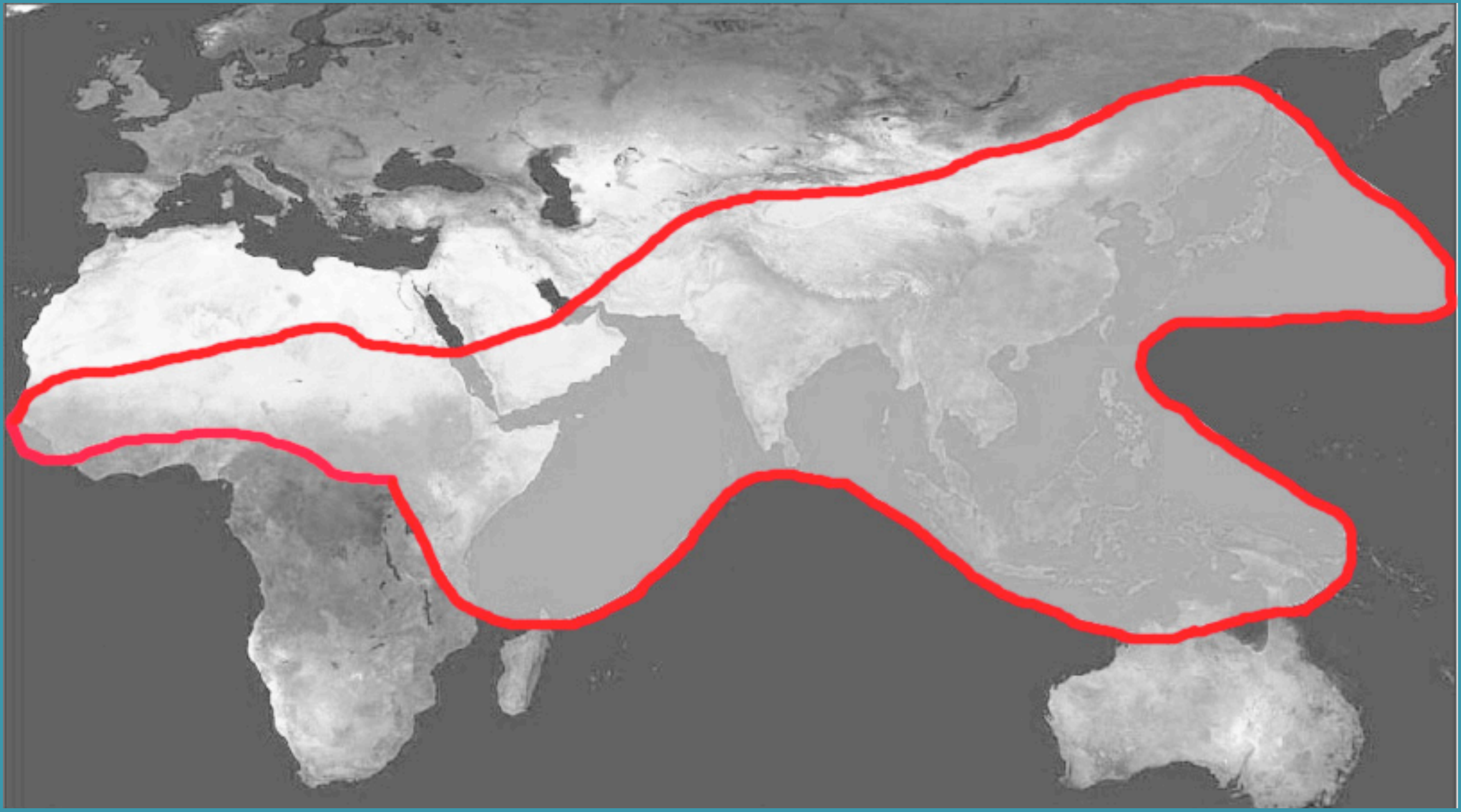


Fig. 1. **(A)** $\delta^{18}O$ time series of the Dongge Cave stalagmite DA (green line). Six vertical yellow bars denote the timing of Bond events 0 to 5 in the North Atlantic (*2*). The Chinese events that correlate with Bond events 3 and 5 coincide within error with the collapse of the Neolithic Culture of China (NCC) (*23*) and the timing of an abrupt outflow event from a Laurentide ice-margin lake (*22*), respectively. Two vertical gray bars indicate two other notable weak AM events that can be correlated to ice-rafted debris events (*2*). **(B)** DA age-depth (mm, relative to the top) relations. Black error bars show ^{230}Th dates with 2σ errors (table S1). We use two different age-depth curves, one employing linear interpolation between dated depths and the second slightly modified by tuning to INTCAL98 (*15*) within the ^{230}Th dating error (*26*).

Il dibattito in corso è volto a capire quanto è legato all'*orbital forcing* il sistema climatico del *South Asian Summer Monsoon*, *"da cui dipende la sopravvivenza di un quarto della popolazione mondiale"* (Shi et al., 2014).



"The Southwest Asian monsoon is one of the most important climate systems on Earth, affecting nearly half of the world's population in any given year" **(Black, 2002).**

Riflessione conclusiva della Prima Parte:

Pero'. Chi l'avrebbe detto…
Ma guarda quanto e' importante l'astronomia…

GEOLOGIA E ASTRONOMIA

La dinamica della Terra è caotica a distanza di circa 50 Ma. La ragione sono gli asteroidi maggiori (Cerere, Vesta), perché la loro interazione è caotica (Laskar, 2011).

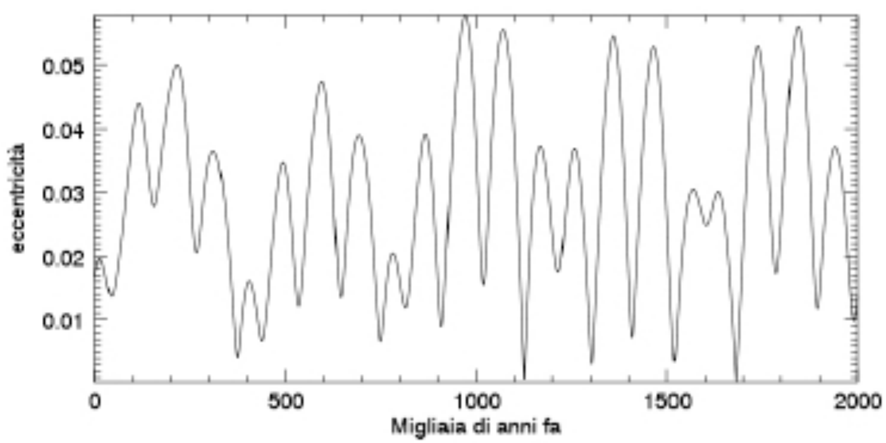


Fig. 10.4. Esempio di andamento dell'eccentricità, per l'intervallo temporale 0 – 2 Ma. Si notino i diversi tempi-scala delle variazioni: ci sono essenzialmente oscillazioni di circa 100 ka, e un'alternanza di massimi e minimi di circa 400 ka.

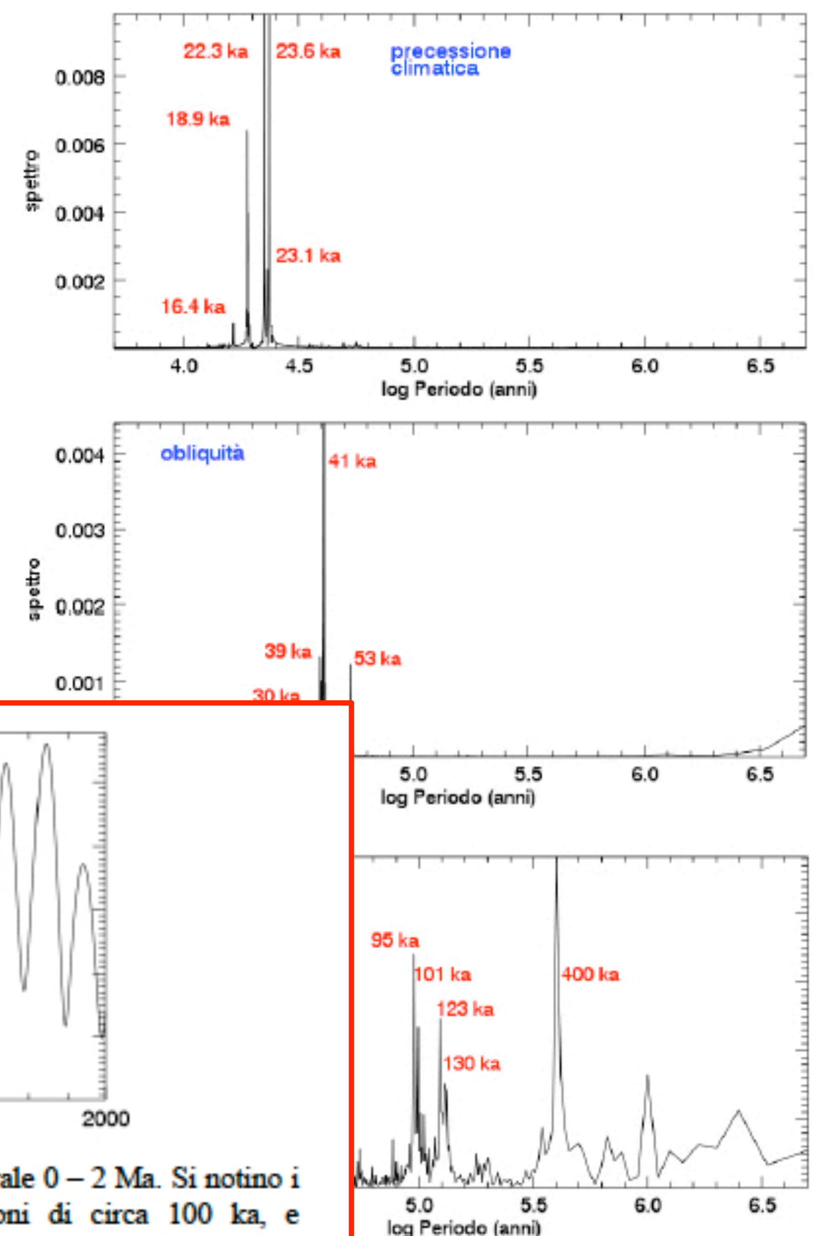


Fig. 10.1. Spettro di ampiezza da Fast Fourier Transform (FFT) della soluzione orbitale di Laskar et al. (2004); parametri: precessione climatica (pannello superiore), obliquità (pannello centrale), eccentricità (pannello inferiore), per un intervallo da 0 a 10 Ma.

GEOLOGIA E ASTRONOMIA: Wu et al. (2013); circa 250 Ma

NATURE COMMUNICATIONS | DOI: 10.1038/ncomms3452 ARTICLE

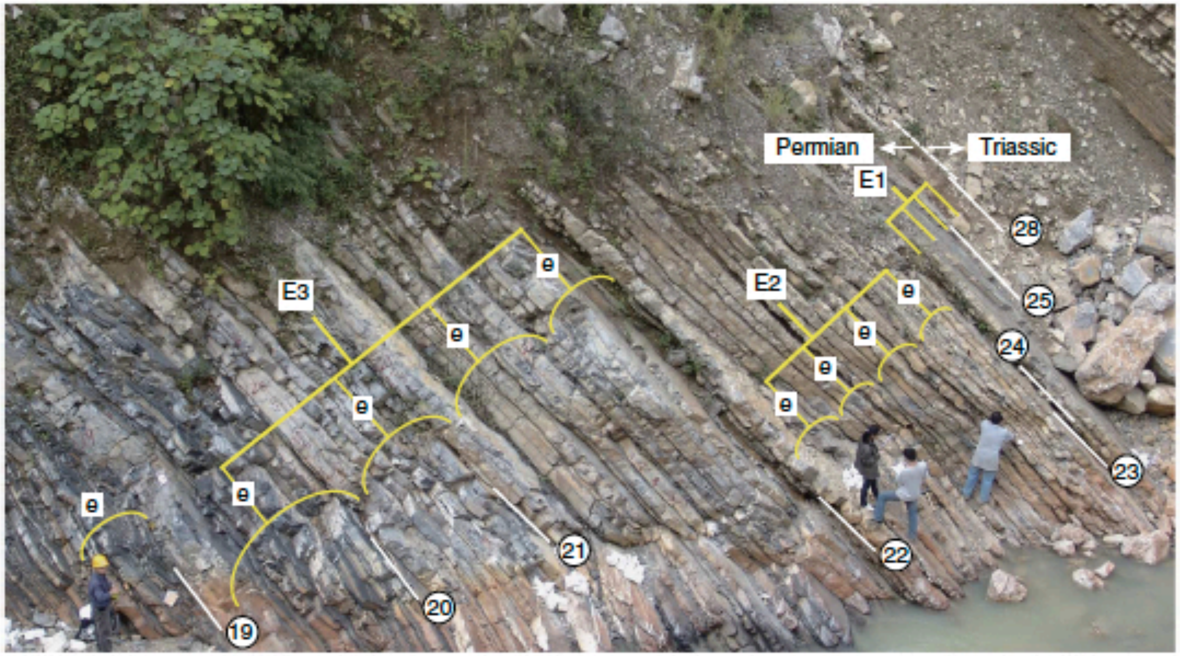


Figure 5 | Photo of the Upper Changhsingian Dalong Formation at Shangsi section. Five thin precession-scale beds are bundled into 100-kyr eccentricity cycles (e) and four ~100-kyr cycles are bundled into 405-kyr eccentricity cycles (E). The ARM cycle interpretation is provided in Fig. 2, Supplementary Figs S4 and S5. Eccentricity maxima are recorded by pronounced, thin precession beds, whereas the eccentricity minima correlate to thick limestone beds. Circled numbers indicate bed numbers; white lines mark bed boundaries.

Calibrazione temporale con radioisotopi U-Pb

GEOLOGIA E ASTRONOMIA: Kuiper et al. (2008); circa 61-66 Ma

Fig. 3. Photo of the upper part of the Zumaia section below the San Telmo chapel. Both the 100-ky limestone beds 29 to 42 of (*33*) and the large-scale clusters of precession-related basic cycles that mark successive 405-ky eccentricity maxima are indicated (see also figs. S3, a to c). The phase relation with eccentricity is unambiguous: The marly intervals in between the 405-
and 10
beds o
tinct p
cycles, w
with ec
marked

minima are

ww.science

Riflessione "poetica" conclusiva:

I parametri orbitali sono stampati nella stratigrafia.

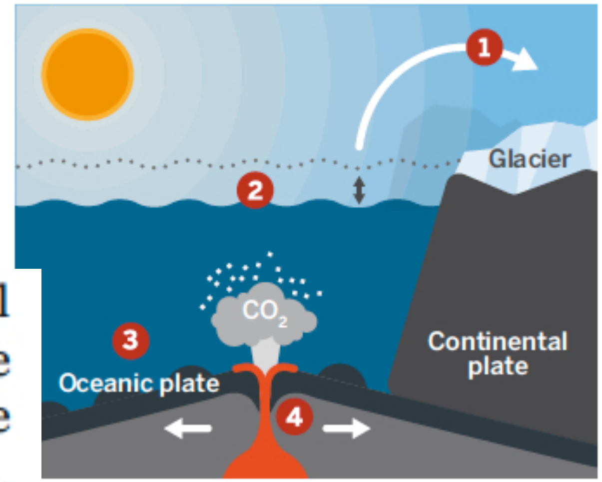
IN

plates, separated by valleys. On bathymetric maps of seafloor topography, they look like grooves on a record. These grooves, it now turns out, play the tune of Earth's ice ages.

"Step back and think about this: Small variations in the orbital parameters of the Earth—tilt and eccentricity and wobble—are recorded on the sea floor," says Richard Katz, a geodynamicist at the University of Oxford in the United Kingdom and a co-author of the *Science* paper. "It kind of blows my mind."

Take a load off

When ice age glaciers cover continents, falling oceans stripe the sea floor with mysterious ridges. Here's how it works:



1. Water taken up in ice sheets.

2. Sea level drops.

3. Lower pressure on the mantle.

4. Increased rate of eruption.

GEOSCIENCE

Seafloor grooves record the beat of the ice ages

Sea level changes influence the underwater eruptions that build abyssal hills

By Eric Hand

two new studies, one published online this

seafloor volcanism could in turn affect

EVOLUZIONE UMANA

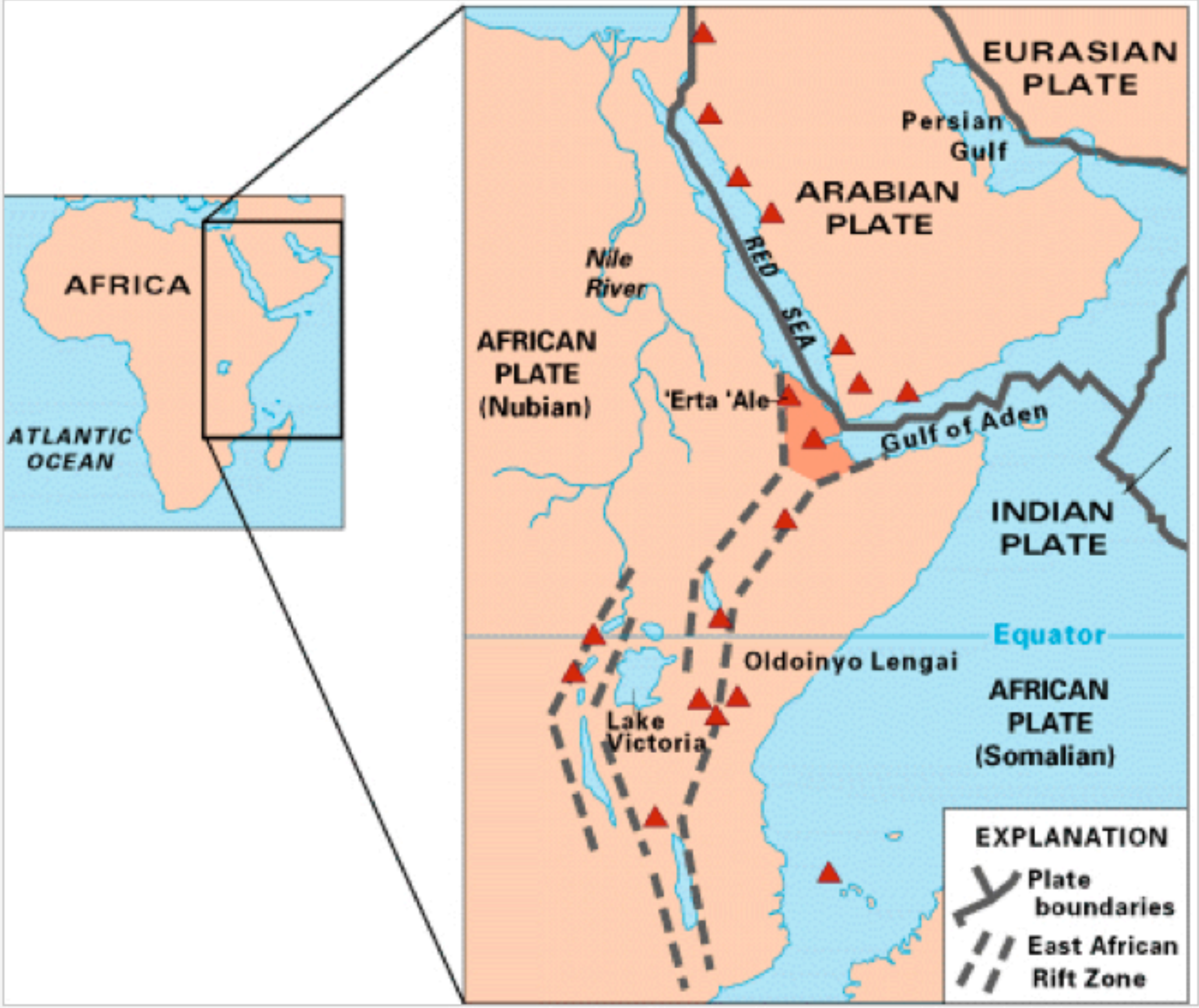
Effetto del clima sull'**evoluzione darwiniana** degli ***Hominini*** negli ultimi tre milioni di anni, e della specie umana:

P. deMenocal, 2014, *Climate shocks*, Scientific American, 9/2014; *Shock climatici*, Le Scienze, 11/2014

"L'importanza del contributo delle variazioni climatiche all'evoluzione dell'uomo nel corso di milioni di anni si fa sempre più evidente".

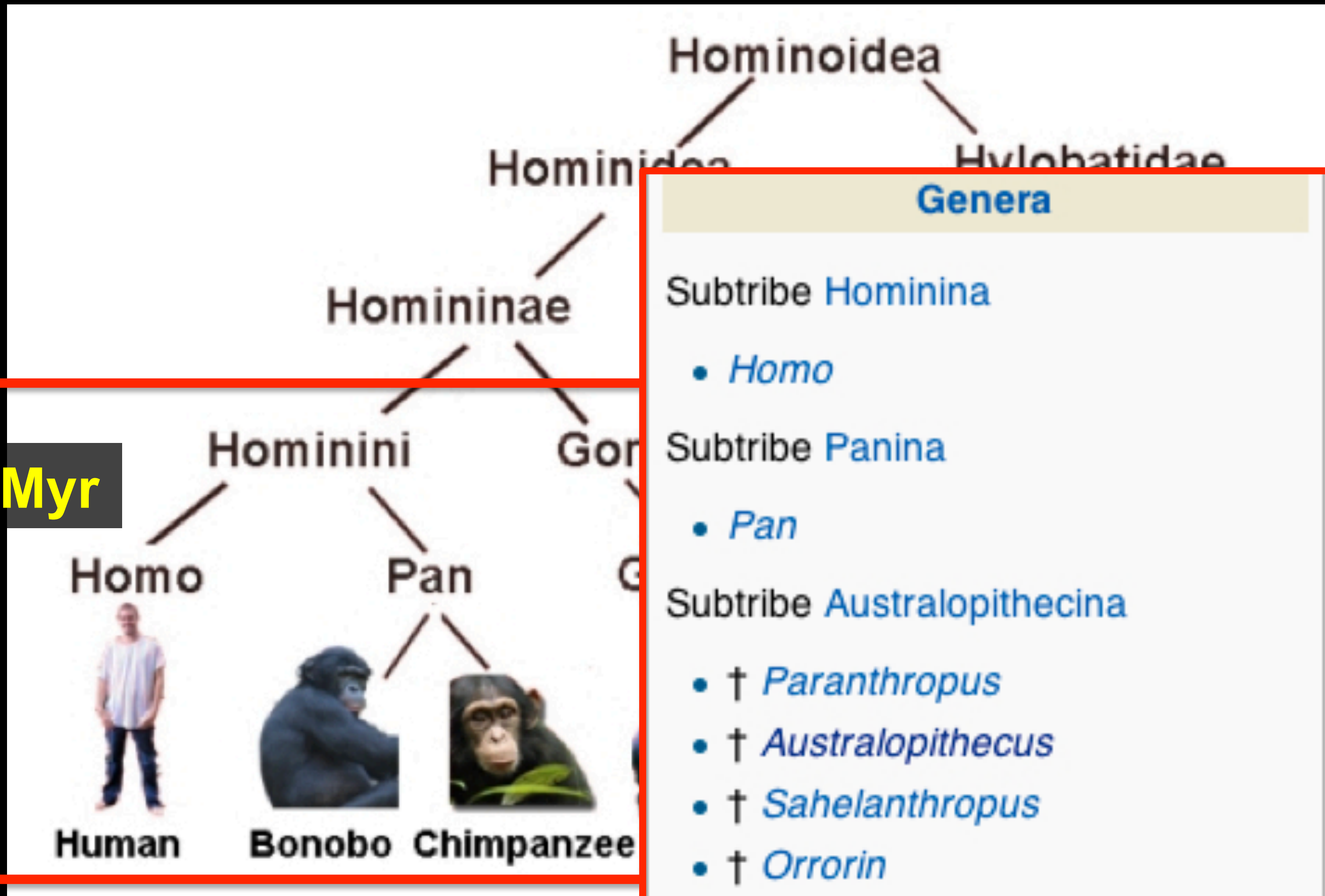
La nostra culla:

Grande Rift Valley



A map of East Africa showing some of the historically active volcanoes (red triangles) and the Afar Triangle (shaded, center)—a triple junction where three plates are pulling away from one another: the Arabian Plate, and the two parts of the African Plate (the Nubian and the Somali) splitting along the East African Rift Zone (USGS).

8 – 5 Myr



Genera

Subtribe Hominina

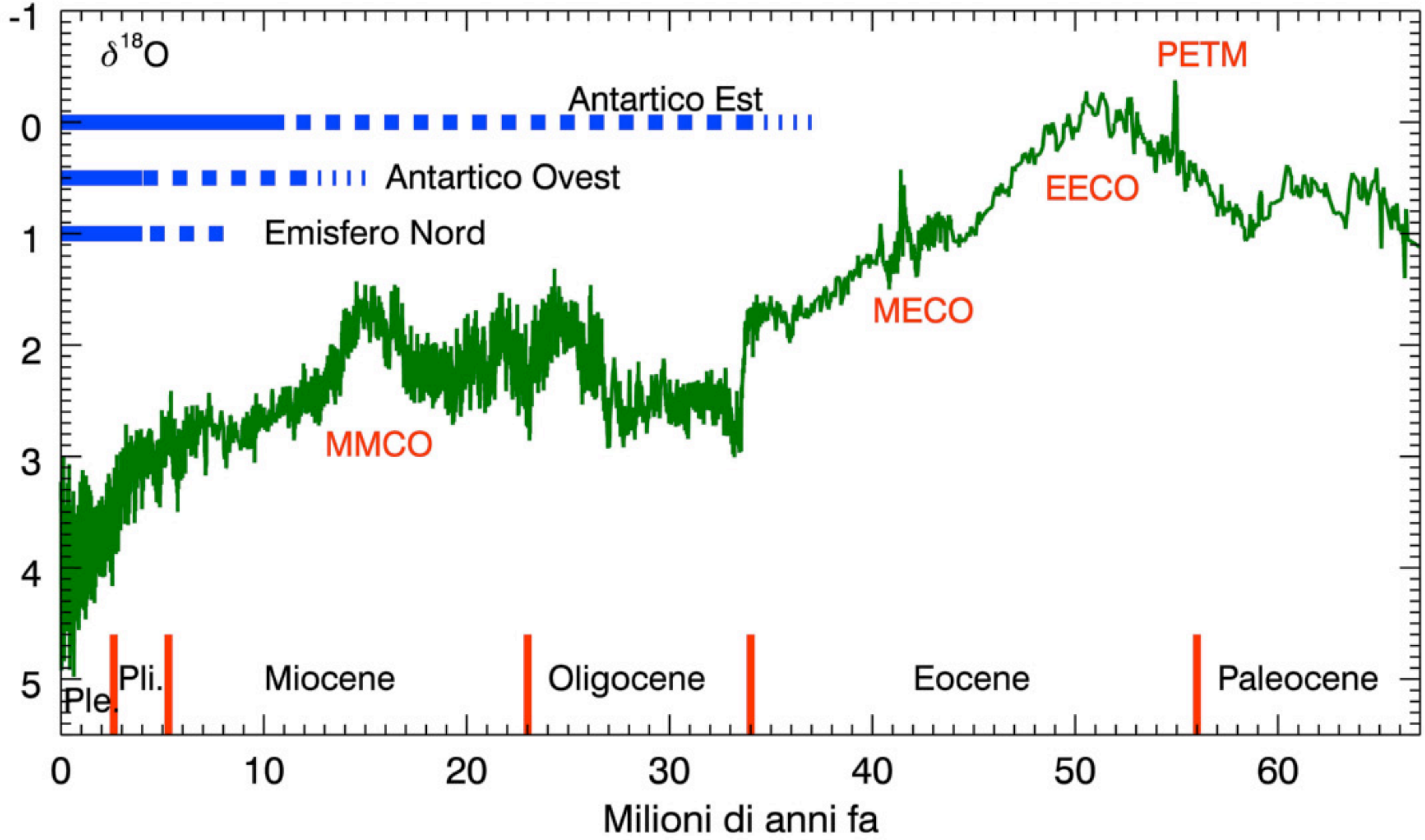
- *Homo*

Subtribe Panina

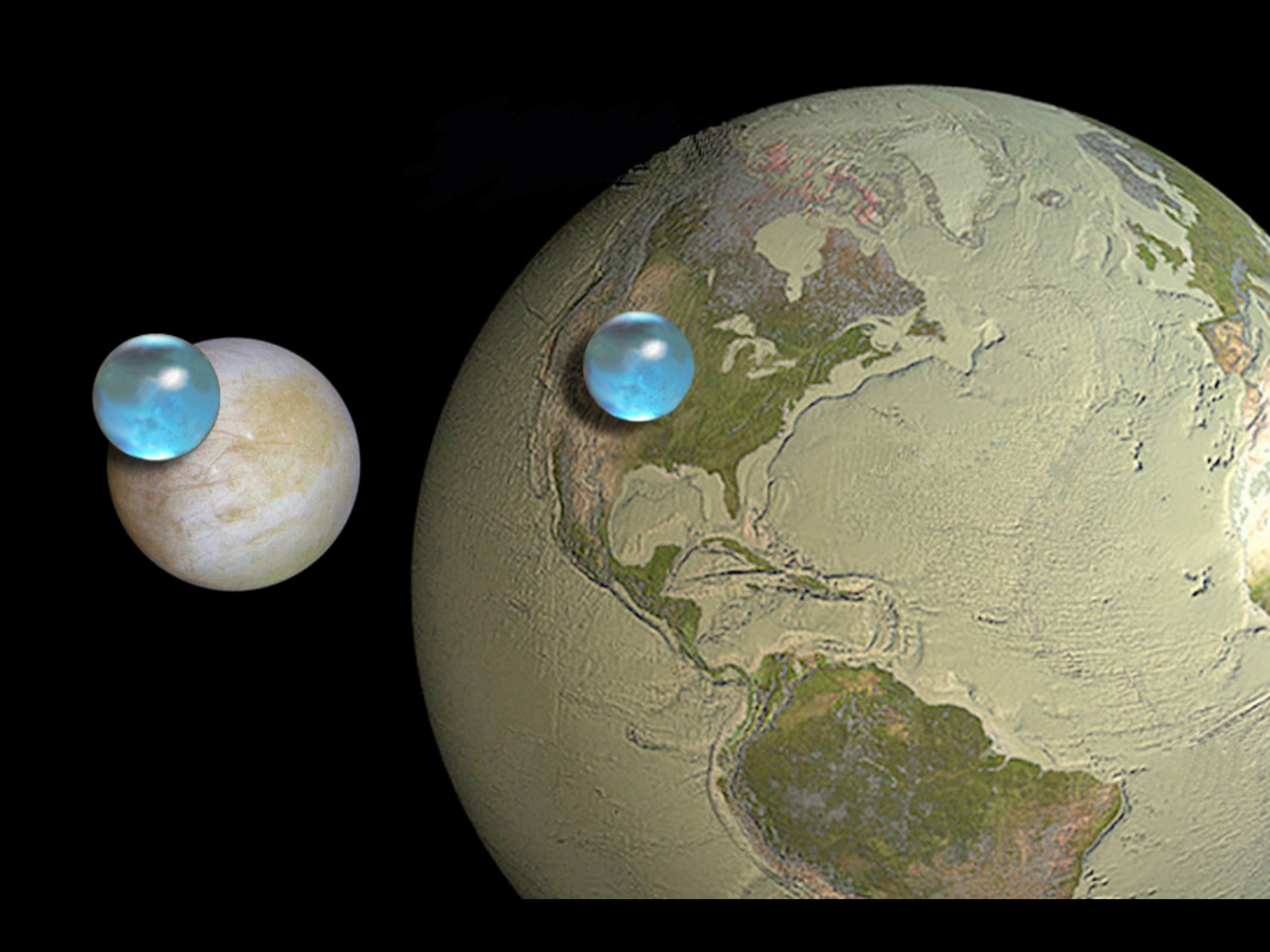
- *Pan*

Subtribe Australopithecina

- † *Paranthropus*
- † *Australopithecus*
- † *Sahelanthropus*
- † *Orrorin*
- † *Ardipithecus*
- † *Kenyanthropus*



Zachos et al. (2001); Jansen et al. (2007)



Invited review

Hominin evolution in settings of strong environmental variability

Richard Potts

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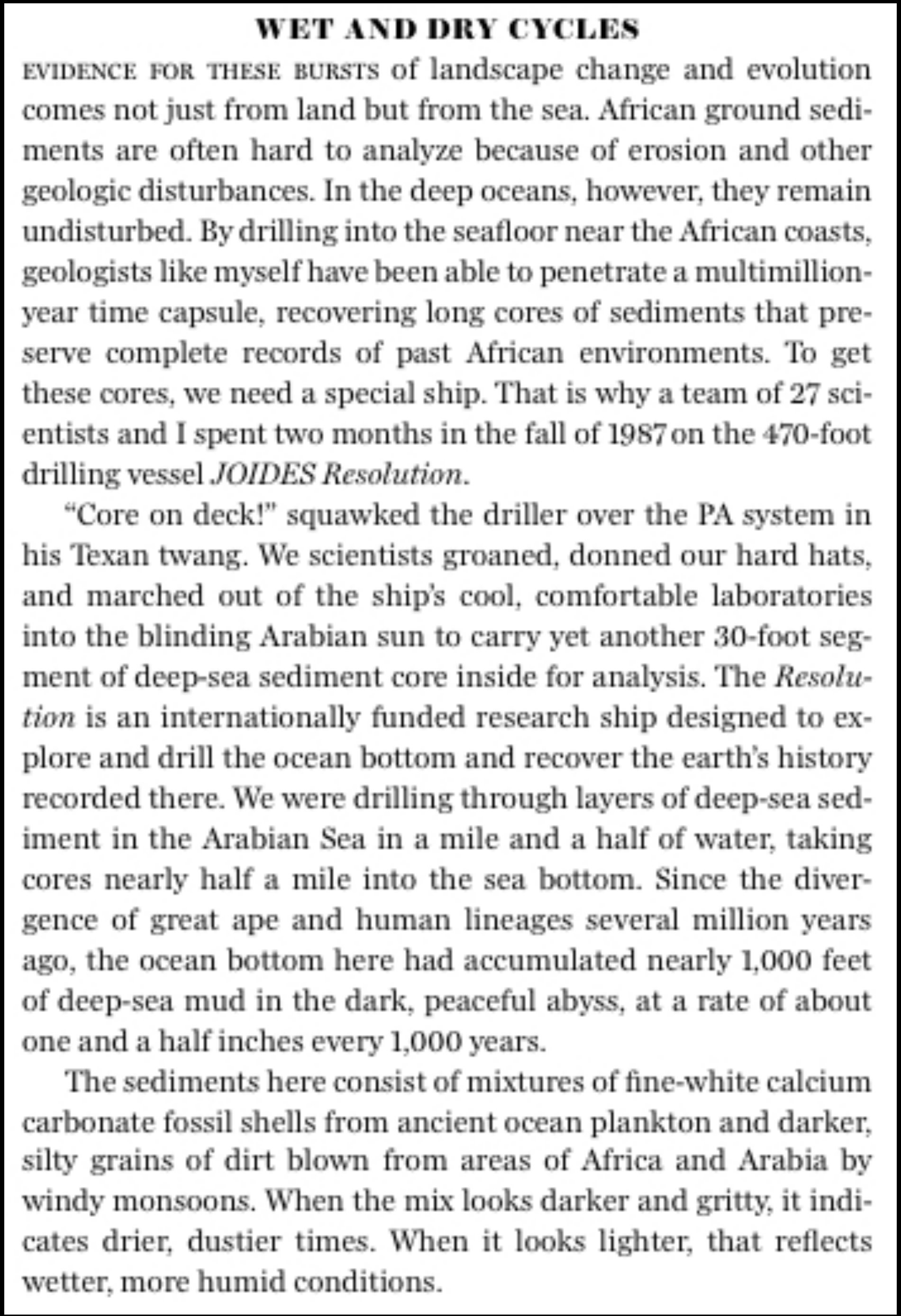
Quaternary Science Reviews 73 (2013) 1–13

Investigations into how climate change shaped human evolution have begun to focus on environmental dynamics, i.e., the nature and tempo of climate and landscape variability, an approach that de-emphasizes static reconstructions of early hominin habitats. The interaction among insolation cycles is especially apparent in the paleoenvironmental records of the East African Rift System, where the longest records of human evolution are preserved. However, environmental indicators such as deep-sea oxygen isotopes, terrestrial dust flux, paleosol carbon isotopes, and lake sediments do not point consistently to any simple trend or climate driver of evolutionary change. Comparison of environmental indicators cautions against an exclusive focus on any given end-member of environmental fluctuation (driest or wettest, warmest or coolest), and argues for the impact of the entire range of variability in shaping evolutionary change. A model of alternating high and low climate variability for tropical Africa further implies that specific environmental indicators reflect different aspects of East African environmental dynamics. The model may thus help reconcile some of the conflicting interpretations about the environmental drivers of hominin evolution. First and last appearances of hominin lineages, benchmark biogeographic events, and the emergence of key adaptations and capacities to alter the surroundings are consistently concentrated in the predicted longest intervals of high climate variability. The view that emerges is that important changes in stone technology, sociality, and other aspects of hominin behavior can now be understood as adaptive responses to heightened habitat instability.

DeMenocal (2014), *Scientific American,* oppure *Le Scienze*


WET AND DRY CYCLES

EVIDENCE FOR THESE BURSTS of landscape change and evolution comes not just from land but from the sea. African ground sediments are often hard to analyze because of erosion and other geologic disturbances. In the deep oceans, however, they remain undisturbed. By drilling into the seafloor near the African coasts, geologists like myself have been able to penetrate a multimillion-year time capsule, recovering long cores of sediments that preserve complete records of past African environments. To get these cores, we need a special ship. That is why a team of 27 scientists and I spent two months in the fall of 1987 on the 470-foot drilling vessel *JOIDES Resolution*.

"Core on deck!" squawked the driller over the PA system in his Texan twang. We scientists groaned, donned our hard hats, and marched out of the ship's cool, comfortable laboratories into the blinding Arabian sun to carry yet another 30-foot segment of deep-sea sediment core inside for analysis. The *Resolution* is an internationally funded research ship designed to explore and drill the ocean bottom and recover the earth's history recorded there. We were drilling through layers of deep-sea sediment in the Arabian Sea in a mile and a half of water, taking cores nearly half a mile into the sea bottom. Since the divergence of great ape and human lineages several million years ago, the ocean bottom here had accumulated nearly 1,000 feet of deep-sea mud in the dark, peaceful abyss, at a rate of about one and a half inches every 1,000 years.

The sediments here consist of mixtures of fine-white calcium carbonate fossil shells from ancient ocean plankton and darker, silty grains of dirt blown from areas of Africa and Arabia by windy monsoons. When the mix looks darker and gritty, it indicates drier, dustier times. When it looks lighter, that reflects wetter, more humid conditions.

9 m

300 m

3.8 cm / 1000 anni (carotaggio di circa 7 Myr)

DeMenocal (2014), *Scientific American, oppure Le Scienze*

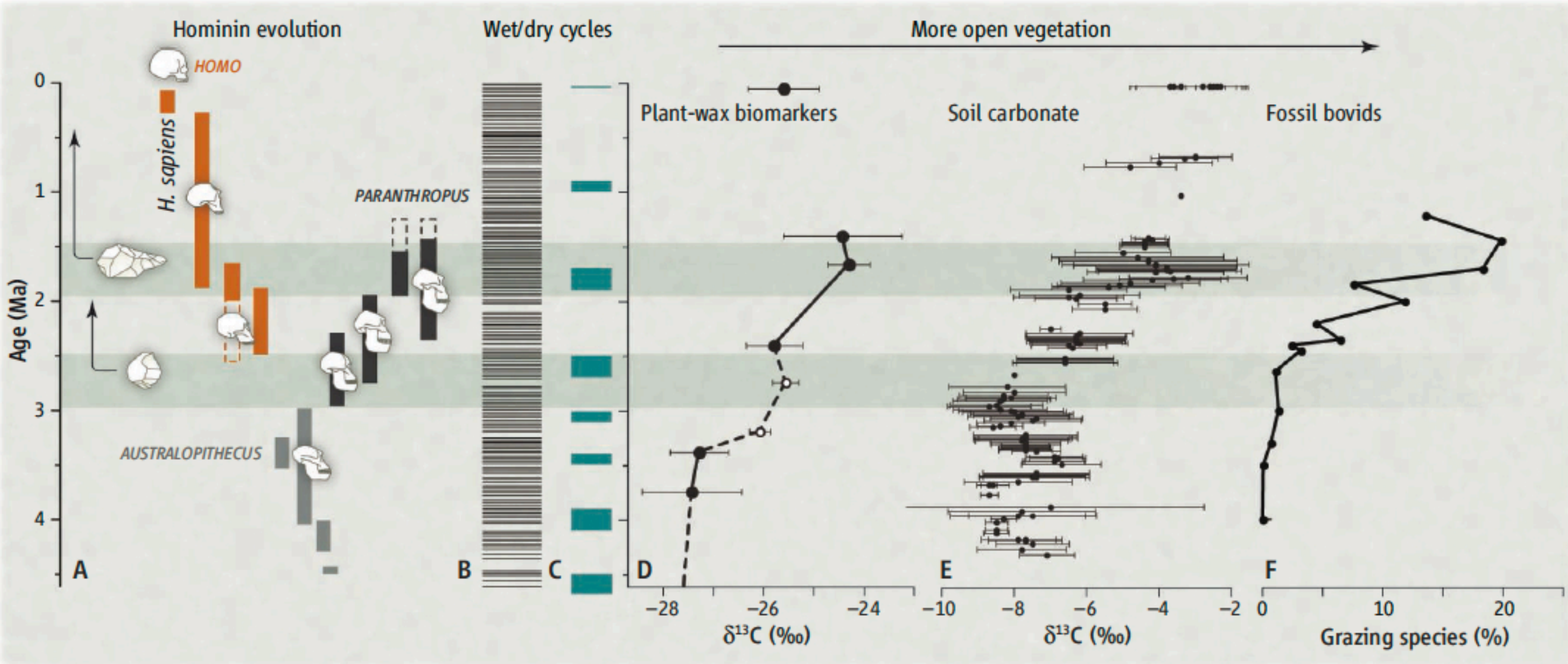
0.9 m

Laying the split sediment core on a table inside the ship's spacious research labs, we could see that the alternating light and dark layers repeated every three feet, more or less, which meant they changed about every 23,000 years. It was clear that African climate history had been one of continuous swings between wetter and drier times. That was nothing like a single, sharp shift to a savanna.

These swings reflected the known sensitivity of African and Asian monsoonal climates to the earth's orbital wobble, which occurs as a regular 23,000-year cycle. The wobble changes the amount of sunlight hitting our planet in a given season. For North Africa and South Asia, more or less heat during the summer increased or decreased monsoon rainfall, making these regions either much wetter or drier as our planet wobbled back and forth.

Just how wet things got is recorded in magnificent rock art drawn between 10,000 and 5,000 years ago by humans during the most recent wet period in North Africa. Art found across the Sahara depicts lush landscapes filled with elephants, hippopotamuses, giraffes, crocodiles and bands of hunters chasing gazelles. The Sahara was covered with grass and trees; lake basins, now overrun by sand dunes, were filled to the brim with water. A swollen Nile River rushed into the eastern Mediterranean, and black, organic-rich sediments called sapropels accumulated on the Mediterranean seafloor. They alternated with whiter layers laid down during dry periods, a bar-code message telling of African climate cycles reaching deep into the past, just like the changing dust layers recovered from the Arabian Sea.

DeMenocal (2011), *Science* 331, 540



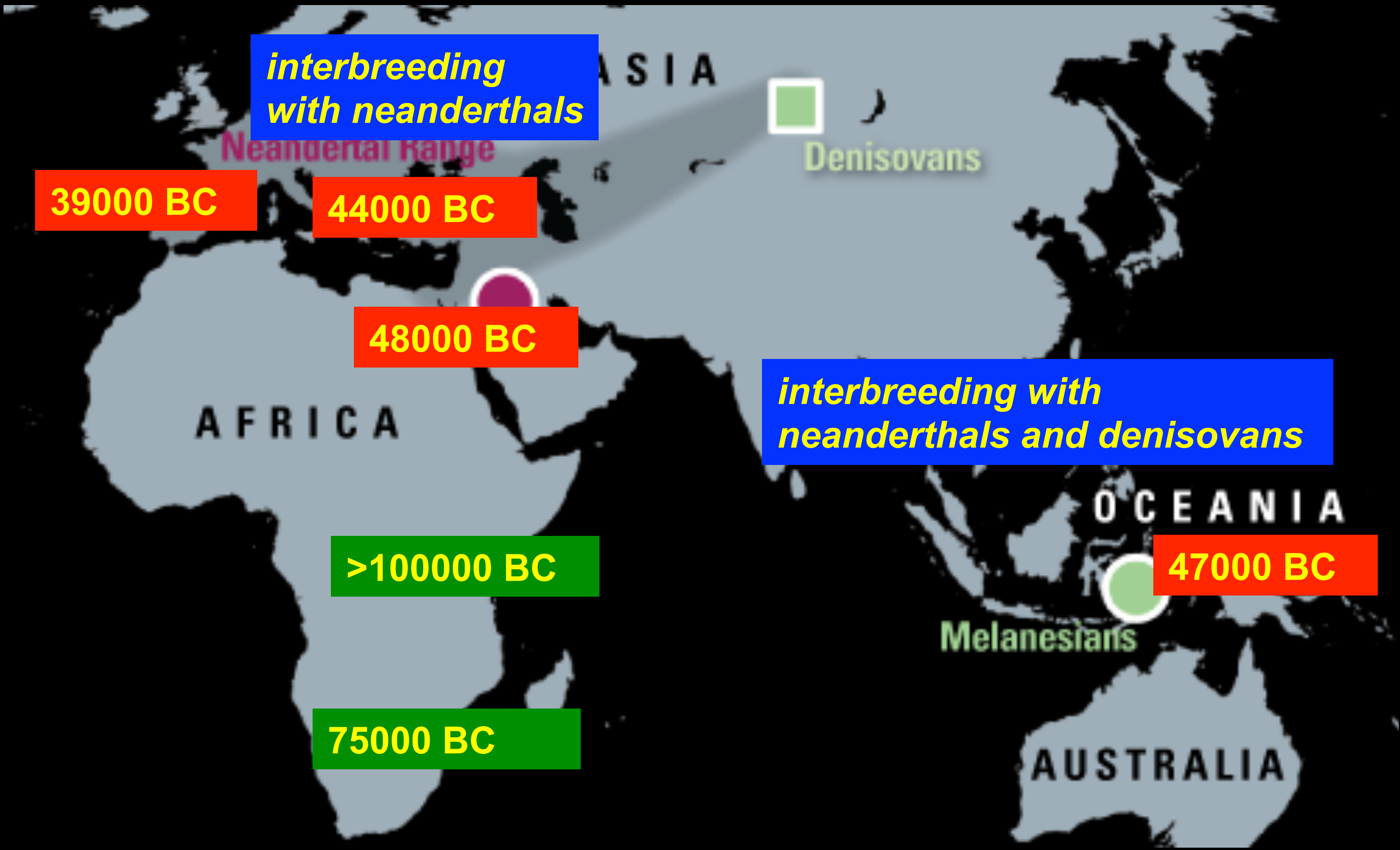
A snapshot of African evolutionary and paleoclimate changes. **(A)** Summary diagram of human evolution spanning the past 4.6 million years [no phylogenetic relations are indicated; compiled from (*4*, *10*)]. First appearances and approximate durations of Mode 1 (Oldowan) and Mode 2 (Acheulean) stone tools are indicated (*11*). **(B)** Occurrences of Mediterranean sapropel deposits compiled from marine and land sediment sequences (*15*). **(C)** Compilation of sedimentary evidence indicating deep lake conditions recorded in several East African paleolake basins (*16*, *17*). **(D)** Carbon isotopic analyses of plant-wax biomarker compounds measured at Site 231 in the Gulf of Aden, currently the most proximal ocean drilling site to hominin fossil localities (*18*). The shift to higher values after 3 Ma indicates a greater proportions of C4 vegetation, or savannah grasslands. **(E)** Carbon isotopic values of soil carbonate nodules compiled from several studies (*19*, *20*), also indicating grassland expansion after ~3 Ma, peaking between 1.8 and 1.6 Ma. **(F)** Relative abundance of African mammals indicative of seasonally arid grasslands in the lower Omo Valley (Ethiopia), showing an initial increase in grassland-adapted mammals after 2.5 Ma with peak values after 1.8 Ma (*12*).

Riflessioni:

Ma guarda un po' cosa combina l'astronomia…

L'astronomia è direttore d'orchestra, o direttore delle danze.

A. Gibbons, 2011, *A new view of the birth of Homo sapiens*, Science, 331, 392

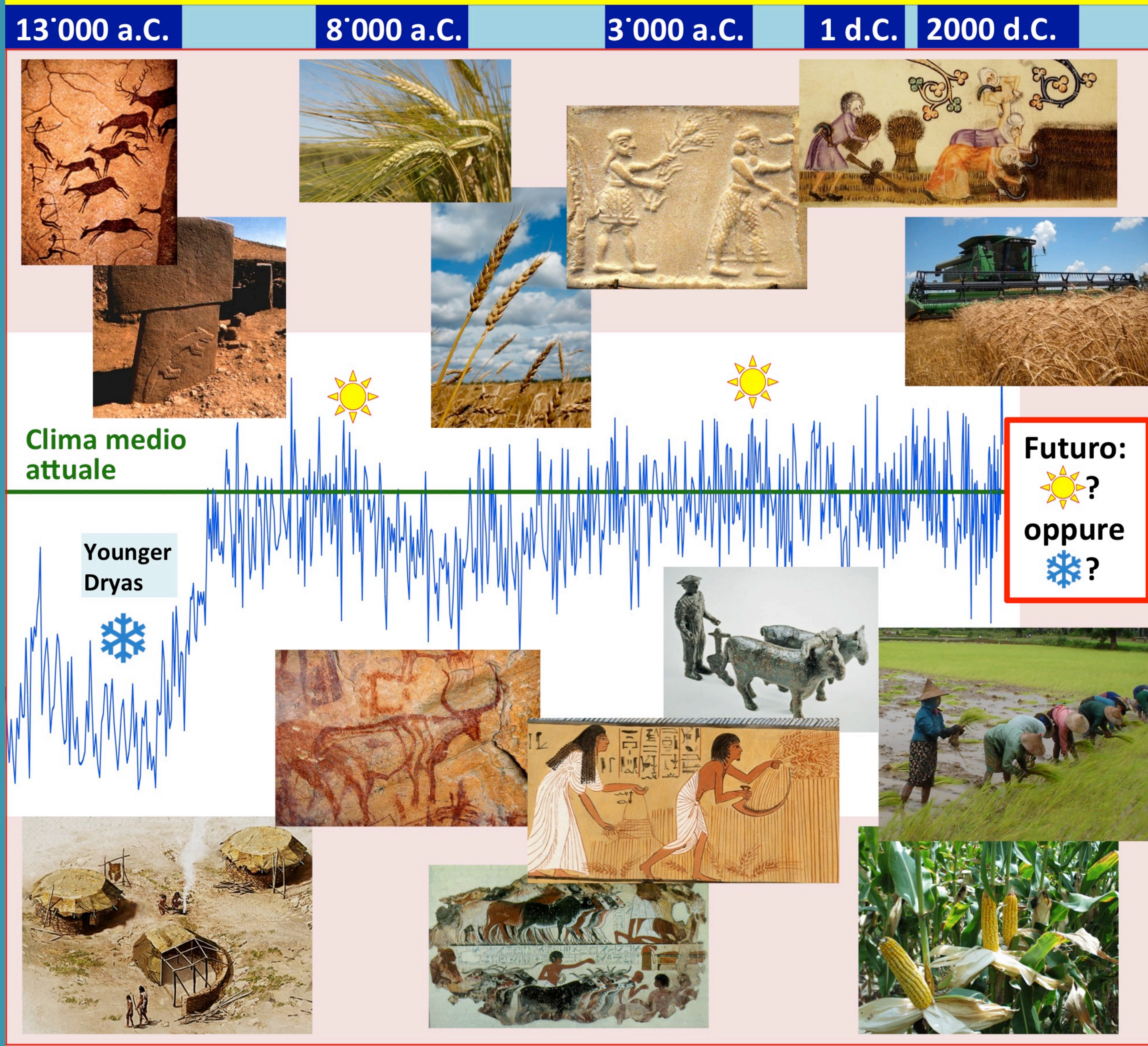


Homo sapiens from Africa

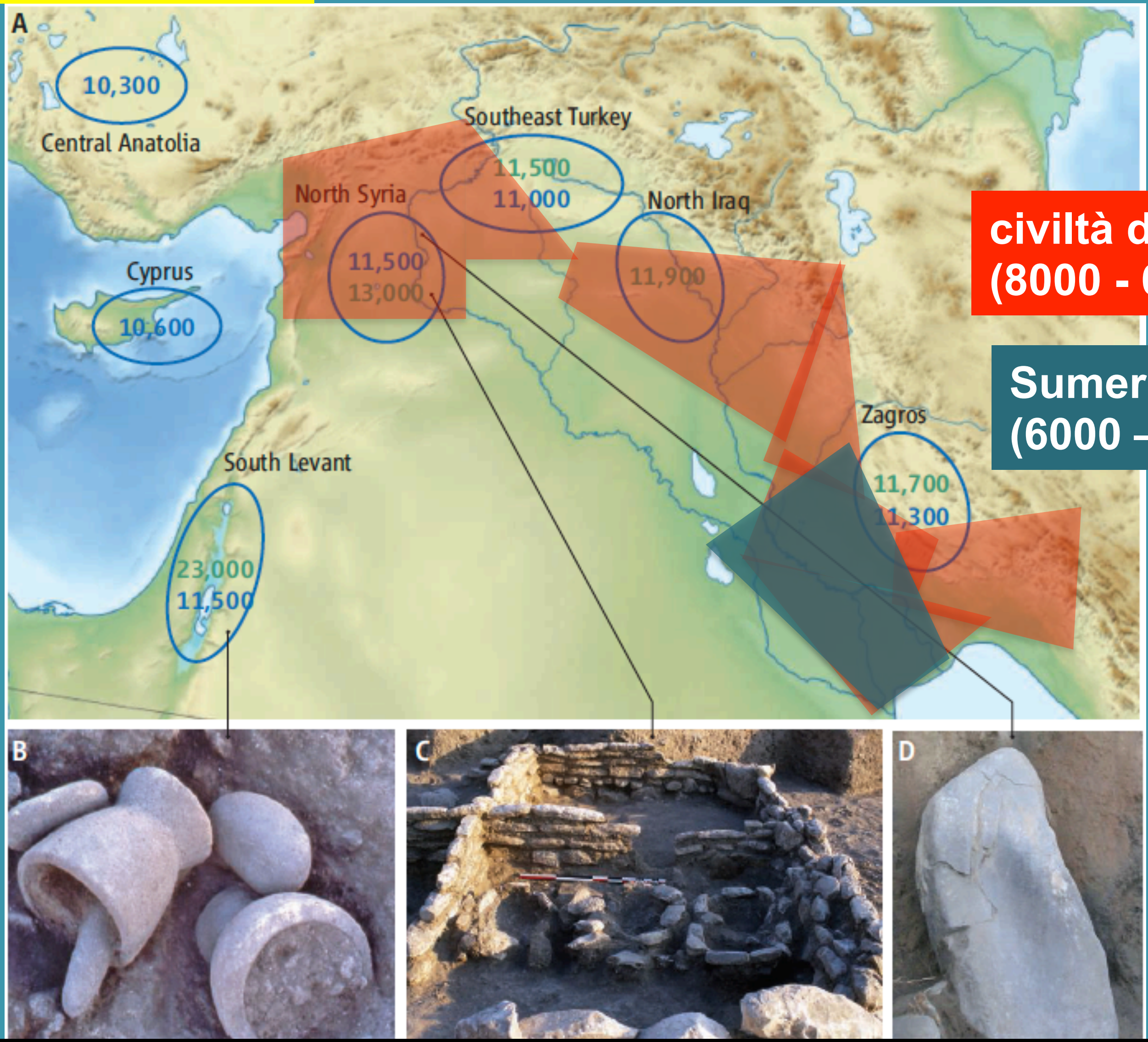
Paleolitico

Tempo →

L'ANDAMENTO DEL CLIMA E LA NOSTRA EVOLUZIONE
(ultimi 15˙000 anni)



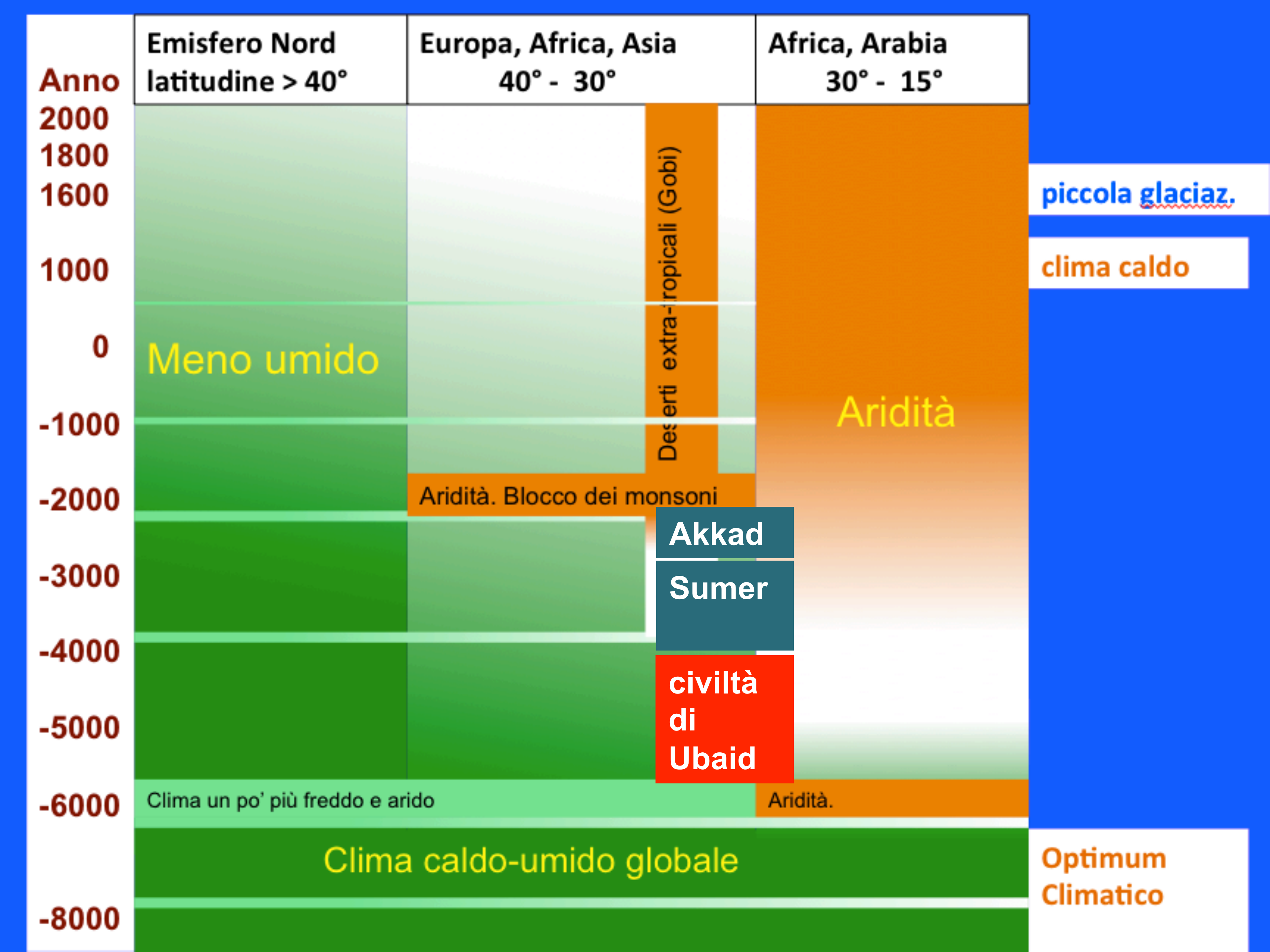
Neolitico



civiltà di Ubaid
(8000 - 6000 anni fa)

Sumer
(6000 – 4400 anni fa)

Willcox, 2013, *The roots of cultivation in Southwestern Asia*, Science 341, 39
Lawler, 2012, *Uncovering civilization's roots*, Science 335, 790.


Anno
Emisfero Nord latitudine > 40°
Europa, Africa, Asia 40° - 30°
Africa, Arabia 30° - 15°
2000
1800
1600
1000
0
-1000
-2000
-3000
-4000
-5000
-6000
-8000
Meno umido
Deserti extra-tropicali (Gobi)
Aridità
Aridità. Blocco dei monsoni
Akkad
Sumer
civiltà di Ubaid
Clima un po' più freddo e arido
Aridità.
Clima caldo-umido globale
piccola glaciaz.
clima caldo
Optimum Climatico

Terribile inaridimento tra il 2200 e il 2100 a.C. circa. Crollano nello stesso periodo: l'impero di **Akkad in Mesopotamia**, **l'Antico Regno in Egitto** e la **civiltà neolitica in Cina.** Difficoltà nella **Valle dell'Indo (Harappa).**

Conclusione sull’evoluzione:

Per comprendere la storia dell’umanità non si può fare a meno dell’astronomia.

McNutt, 2015, Science, 349, 7, 3 july

The beyond-two-degree inferno

Marcia McNutt
Editor-in-Chief
Science *Journals*

In the history of humankind, there is a dearth of examples of global threats so far-reaching in their impact, so dire in their consequences, and considered so likely to occur that they have engaged all nations in risk mitigation. But now with climate change, we face a slowly escalating but long-enduring global threat to food supplies, health, ecosystem services, and the general viability of the planet to support a population of more than 7 billion people. The projected costs of addressing the problem grow with every year that we delay confronting it. In recognition of the shared risks we face and the collective action that will be necessary, an international meeting of stakeholders will convene in Paris next week (www.commonfuture-paris2015.org), ahead of the United Nations Climate Change Conference (COP21) in December, to discuss solutions for both climate mitigation and adaptation.

The time for debate has ended. Action is urgently needed. The Paris-based International Energy Agency recently announced that current commitments to cut CO_2 emissions [known as Intended Nationally Determined Contributions (INDCs)] from the world's nations are insufficient to avoid warming the entire planet by an average of more than 2°C above the preindustrial level. This is a target viewed as the boundary between climate warming to which we can perhaps adapt and more extreme warming that will be very disruptive to society and the ecosystems on which we depend (see Gattuso *et al.* on p. 45). To set more aggressive targets, developed nations need to reduce their per-capita fossil fuel emissions even further, and by doing so, create roadmaps for developing nations to leapfrog technologies by installing low-CO_2-emitting energy infrastructure rather than coal-fired power plants as they expand their energy capacity.

The European Union (EU) is leading the way with the most aggressive INDC target for reduction: a cut of 40% below 1990 levels of CO_2 emissions by 2030. The United States has pledged reductions of 26 to 28% below 2005 levels by 2025, with California independently choosing to match the EU's more ambitious goal. All eyes are on China and India, two of the largest total emitters of CO_2, both of which have yet to submit their proposed INDCs in advance of COP21. Unfortunately, Piyush Goyal, India's Minister of State for Power, Coal, and New and Renewable Energy, intends to double his nation's coal production by the year 2019 to meet domestic energy requirements. China appears to be taking the opposite track, recognizing its vulnerability to climate change and investing heavily in renewable energy.* Like California, China is betting that good environmental policy will make for good fiscal policy by being in the vanguard of the clean energy economy.

"where [would]...Dante...place all of us who are borrowing against this Earth...?"

I applaud the forthright climate statement of Pope Francis, currently our most visible champion for mitigating climate change, and lament the vacuum in political leadership in the United States. This is not the time to wait for political champions to emerge. Just as California has decided to go it alone, every sector (transportation, manufacturing, agriculture, construction, etc.) and every person need to do whatever is possible to reduce carbon pollution by conserving energy, adopting alternative energy technologies, investing in research, and capturing CO_2 at the source.

In Dante's Inferno, he describes the nine circles of Hell, each dedicated to different sorts of sinners, with the outermost being occupied by those who didn't know any better, and the innermost reserved for the most treacherous offenders. I wonder where in the nine circles Dante would place all of us who are borrowing against this Earth in the name of economic growth, accumulating an environmental debt by burning fossil fuels, the consequences of which will be left for our children and grandchildren to bear? Let's act now, to save the next generations from the consequences of the beyond-two-degree inferno.

– **Marcia McNutt**

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http://www.brera.inaf.it/utenti/antonello/papers.html