Space Climate Forcing of the Earth Climate

Alexander Ruzmaikin

Jet Propulsion Laboratory,
California Institute of Technology

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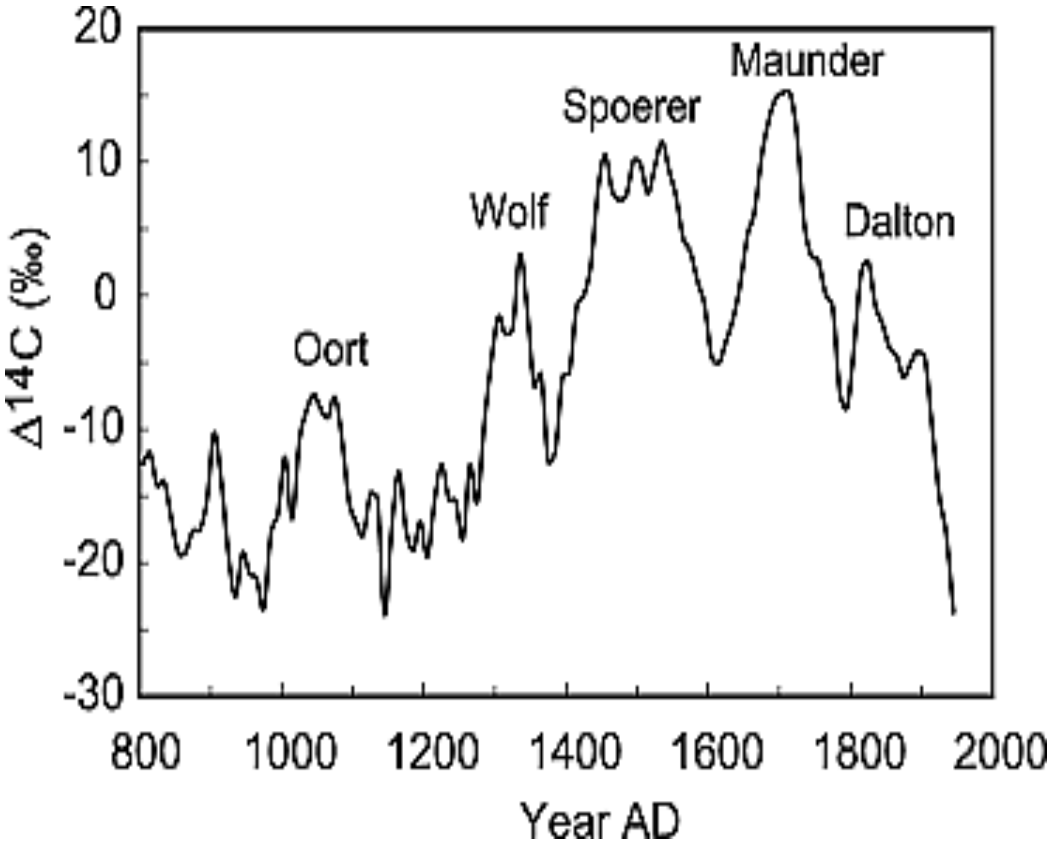
Space Climate Time Scales

Name	Time Scale (years)
Solar Cycle	11
Centennial (Gleissberg) Cycle	88-100
Sues Cycle	205
North Atlantic Cycle	1500
Milankovitch Cycles	23,000; 41,000; 100, 000

Levels of Solar Activity



- Decrease in solar activity
- Increased $\Delta^{14}C$

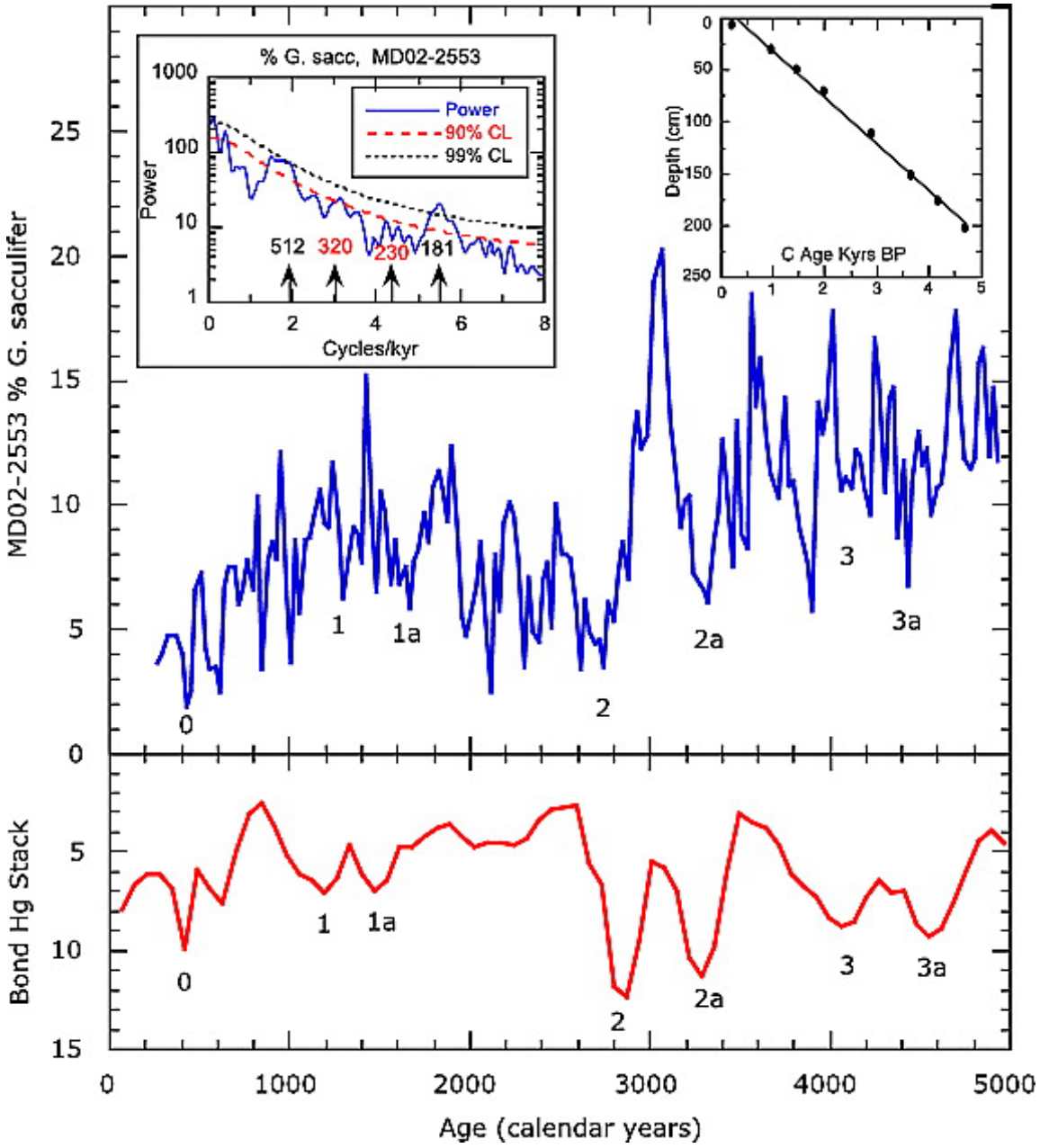
Stuiver & Braziunas,1988

Climate Proxy Data

- Speleothems -- rainfall & temperatures

- Ice cores -- temperatures, winds

MD02-2553 and subpolar North Atlantic drift ice

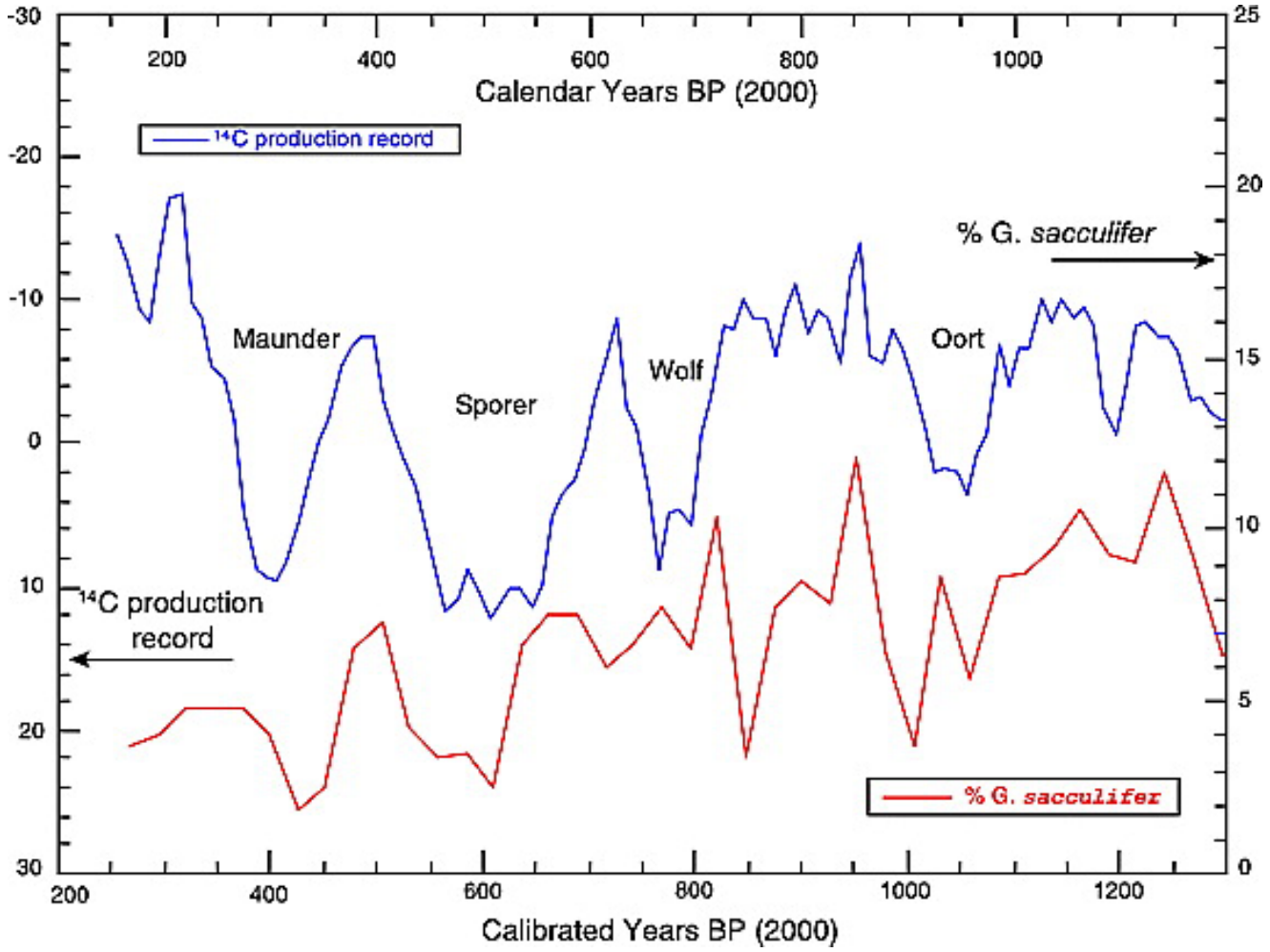


Abundance variation of *Globigerinoides sacculifer* from core MD02-2553 and subpolar North Atlantic drift ice proxy record (stack) from *Bond et al.* [2001].

Drift ice proxy record scale is inverted so that North Atlantic cold events match declines in MD02-2553 G. sacculifer relative abundance. North Atlantic and GOM time scales are independent. Events numbered 0 through 3a are North Atlantic cold events identified by *Bond et al.* [2001].

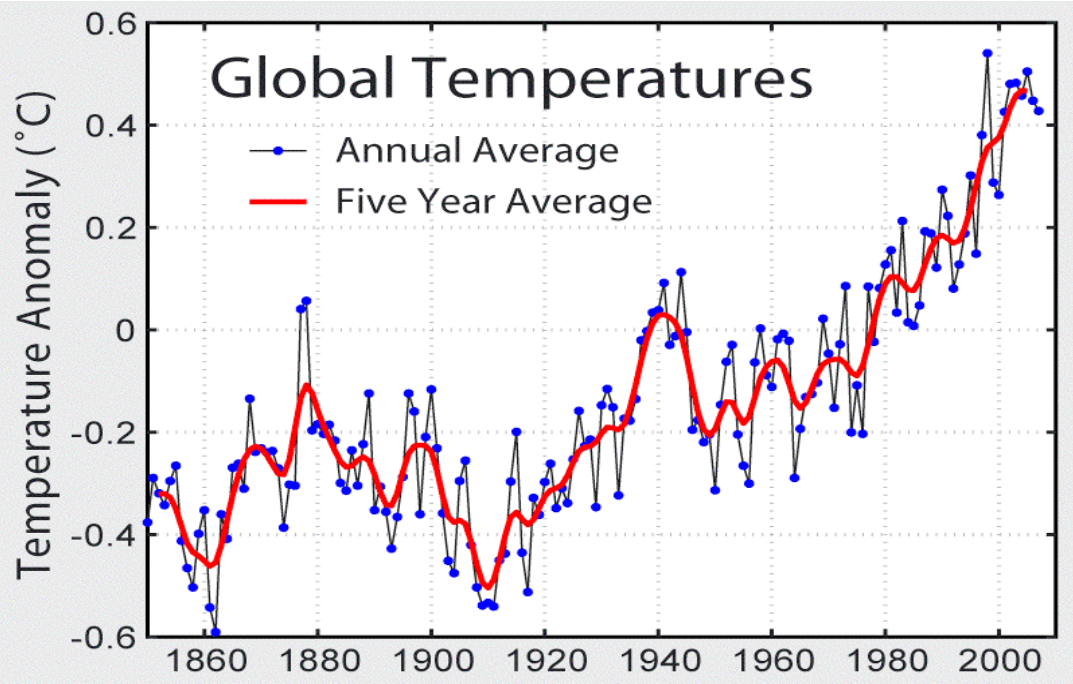
Inset in upper left shows spectrum of the MD02-2553 record using multitaper method (MTM). Arrows point to peaks that are statistically significant at the 99% (black) and 90% (red) confidence level. Numbers over arrows are in years per cycle.

Comparison of ^{14}C record with the MD02-2553 G. sacculifer

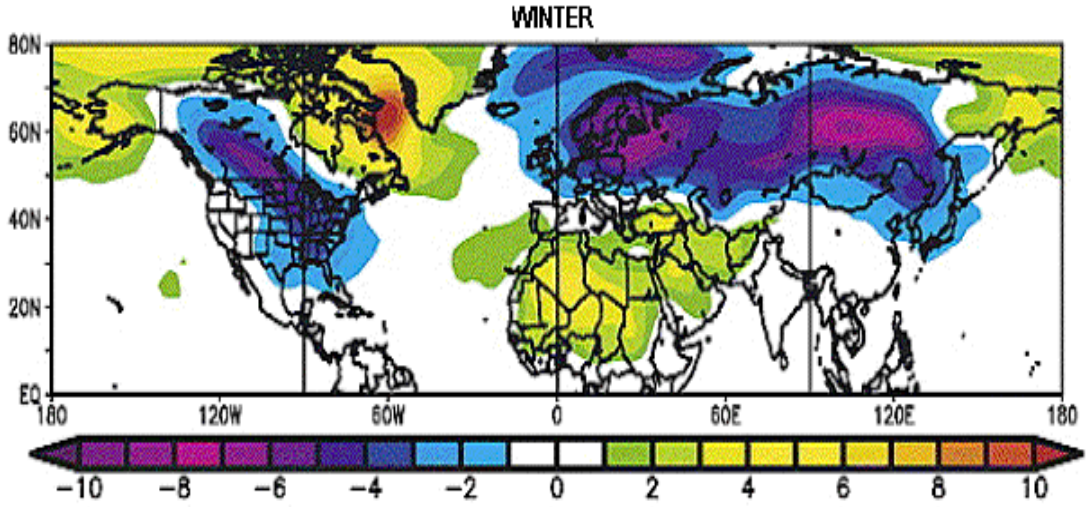


Scale of the 14C production record is inverted. The MD02-2553 record is uniformly offset 100 years from the 14C production record within the error of the MD02-2553 chronology. The Sporer, Wolfe, and Oort Mimima (decreased solar activity) correspond with minima in *G. sacculifer*.

Types of Climate Change

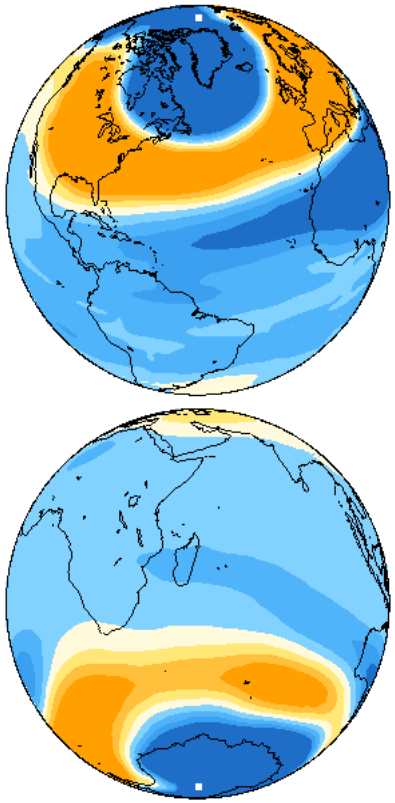


Global climate change



Patterned climate change

Climate Anomaly Pattern: Annular Modes



MSU2LT data regressed on the JFM NAM index (top) and the SAM index (bottom). Contour interval 0.1 K/std.

NAM and SAM

Ring-like patterns of wintertime climate anomalies with two states:

NAM > 0

high lat: low pressure, strong wind

low lat: high pressure, weak wind

NAM < 0 the other way round

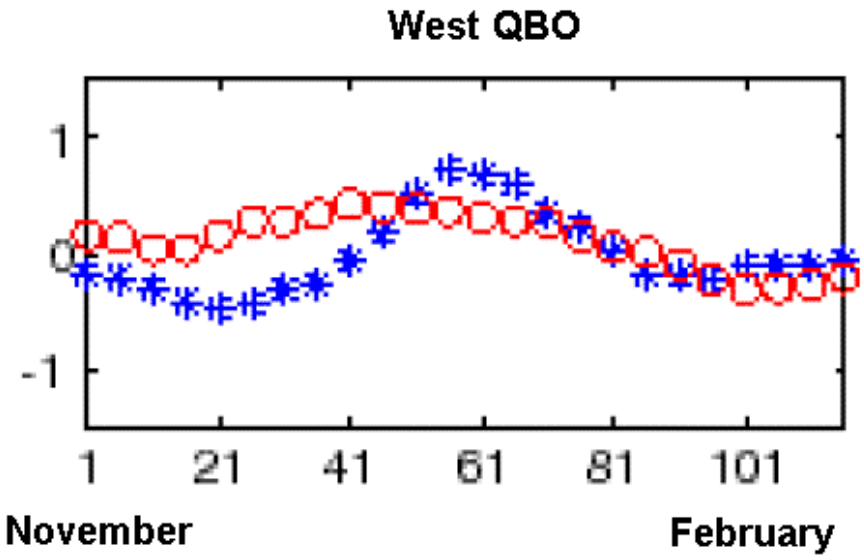
22% of variability at sea level

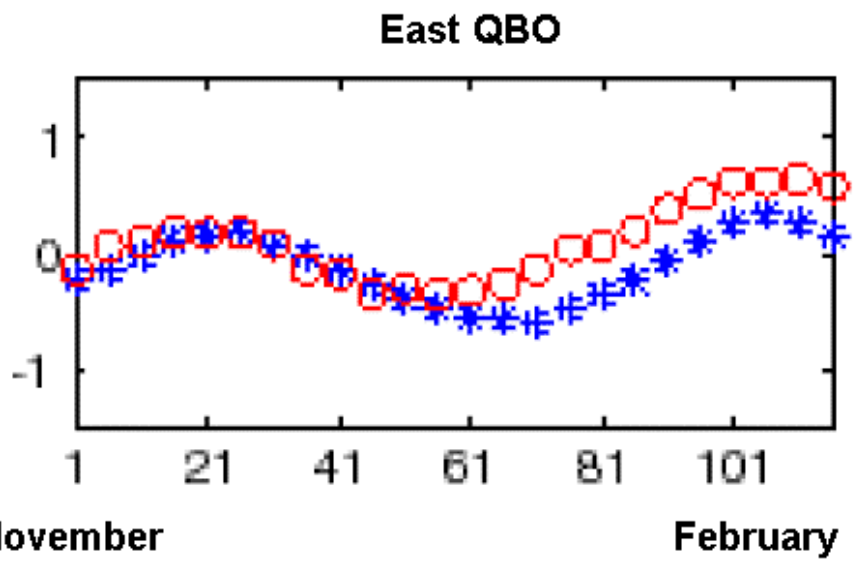
more in stratosphere

Thompson & Wallace (1998),

Baldwin&Dunkerton (1999

Solar Influence on NAM

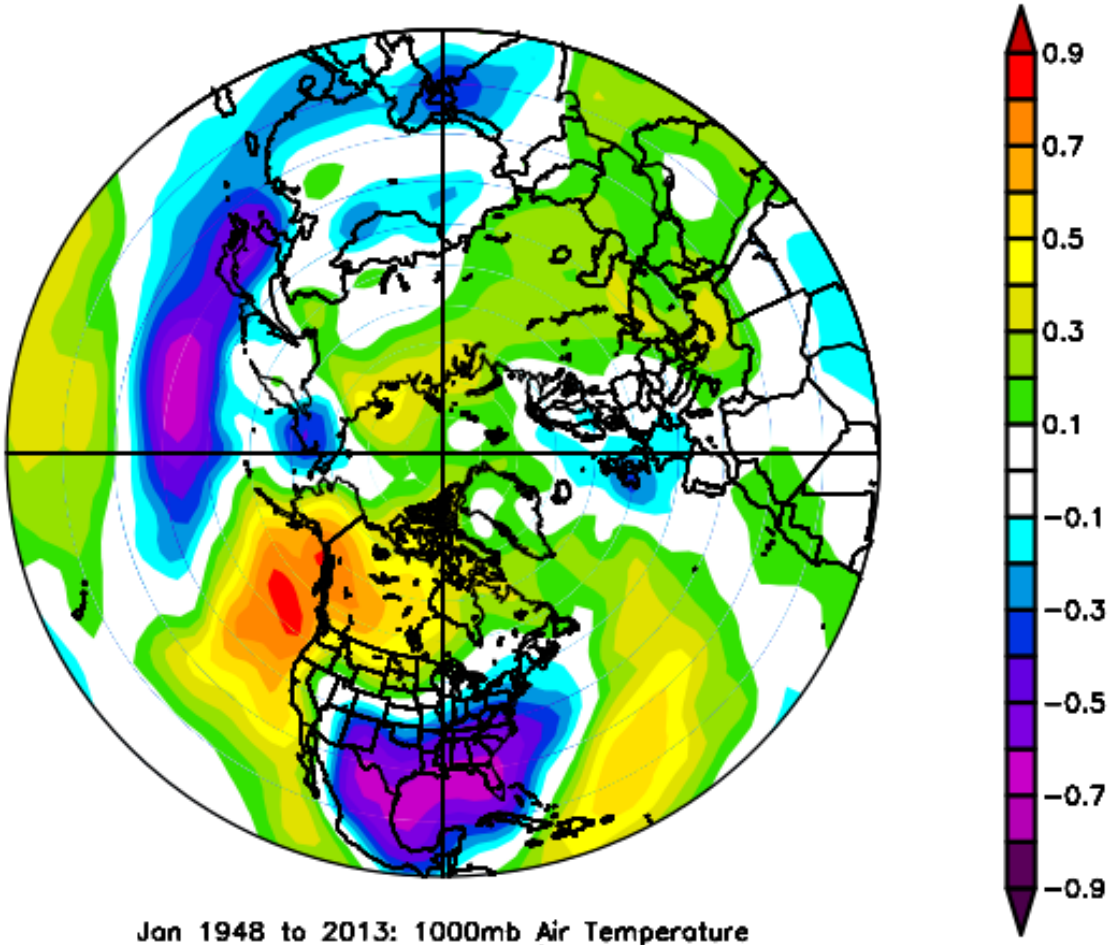




- Tropospheric NAM. Red - high solar UV & Blue - low solar UV
- For low solar activity NAM index is systematically lower

Ruzmaikin & Feynman (2002)

PNA Pattern affected by Solar Influence on Centennial Time Scale



Some Historical Events related to Climate Change

- Mayan collapse - 9th century
- Little Ice Age - ~14th-18th century
- Invasion of Ginghis Khan - beginning of 13 century

Mayan History

- Preclassic -Guatemalan highlands ~1000 BC Mencha Tum
- Classical Maya ~ 250 AD ~ 900 AD: Population ~3 Million
- Post classical~ Chichen Itza area
- Now- Population ~1 million

Classical Maya

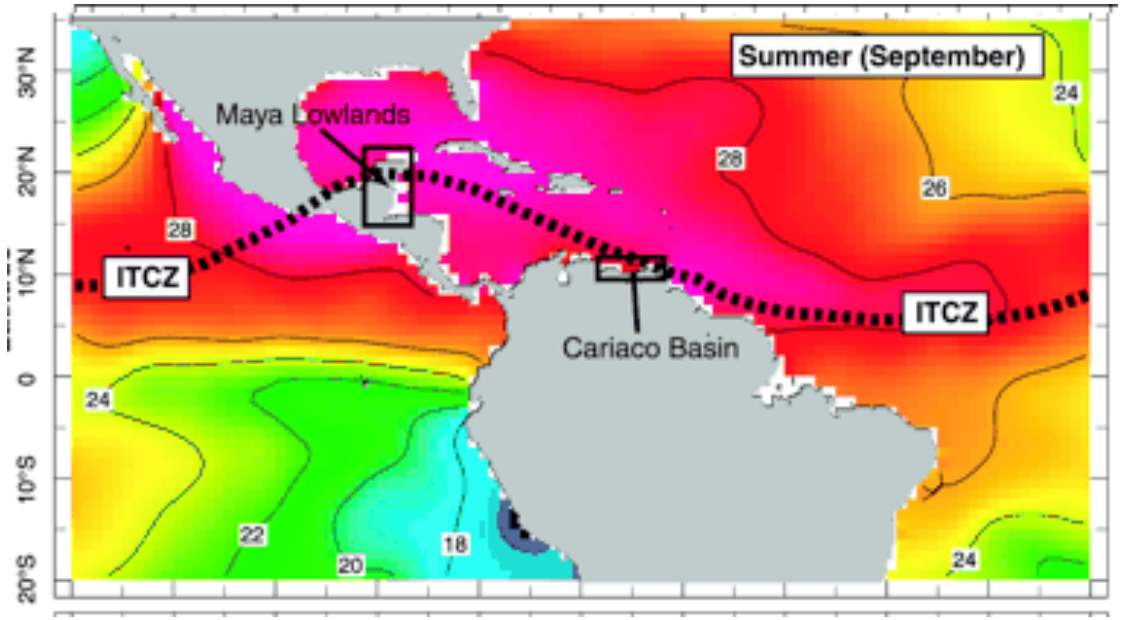
Tikal ~ 200-850
Palenque ~ 400-850

- Astronomy-accurate calendar and Venus tables
- Irrigated agriculture
- Writing (codices and stelae)
- Chocolate
- Five great cities abandoned ~850-900

Collapse of Classical Maya

- Series of draughts (perhaps associated with high solar output)
- Loss of climate stability leads to widespread dislocation, war
- Leads to depopulation, population migration, never recovered

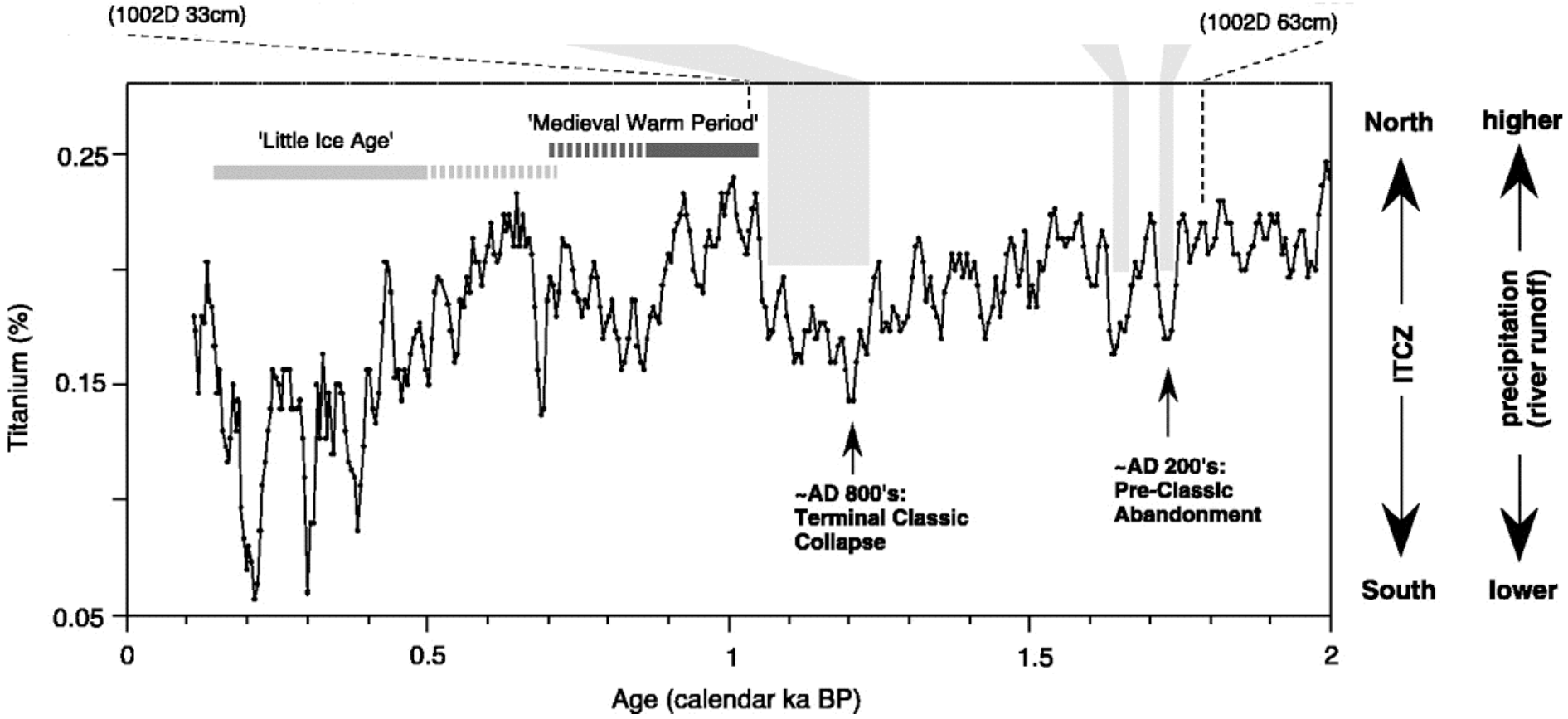
ITCZ - Maya & Cariaco Basin



- Intertropical Convergence Zone (ITCZ) - Northeast Trade Winds meet Southeast Trade Winds
- Winds converge, air moves upward and cools
- Band of heavy precipitation
- During fall rain season Mayan Area and Cariaco Basin connected by ITCZ

Haug et al.,2003

Rainfall in Mayan Region

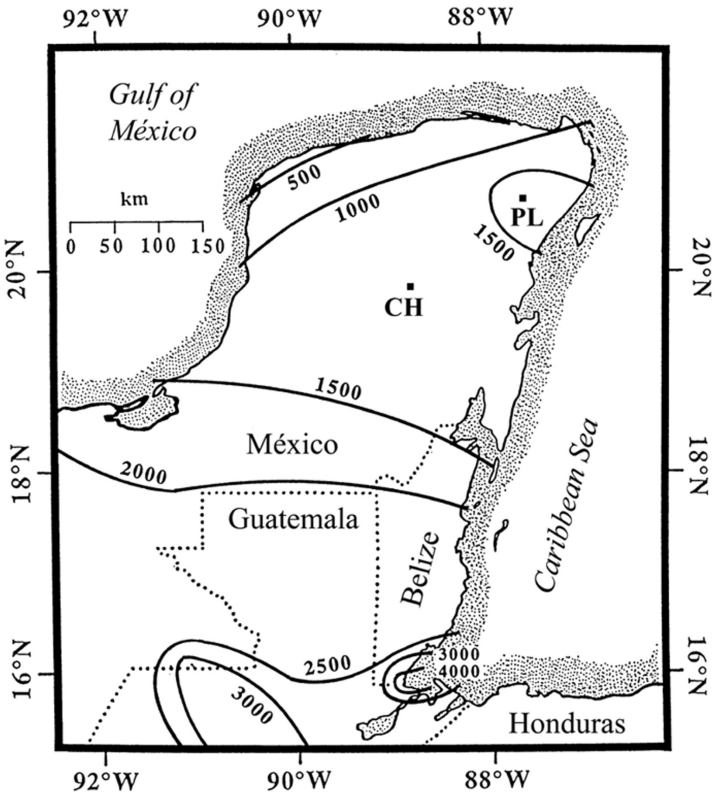


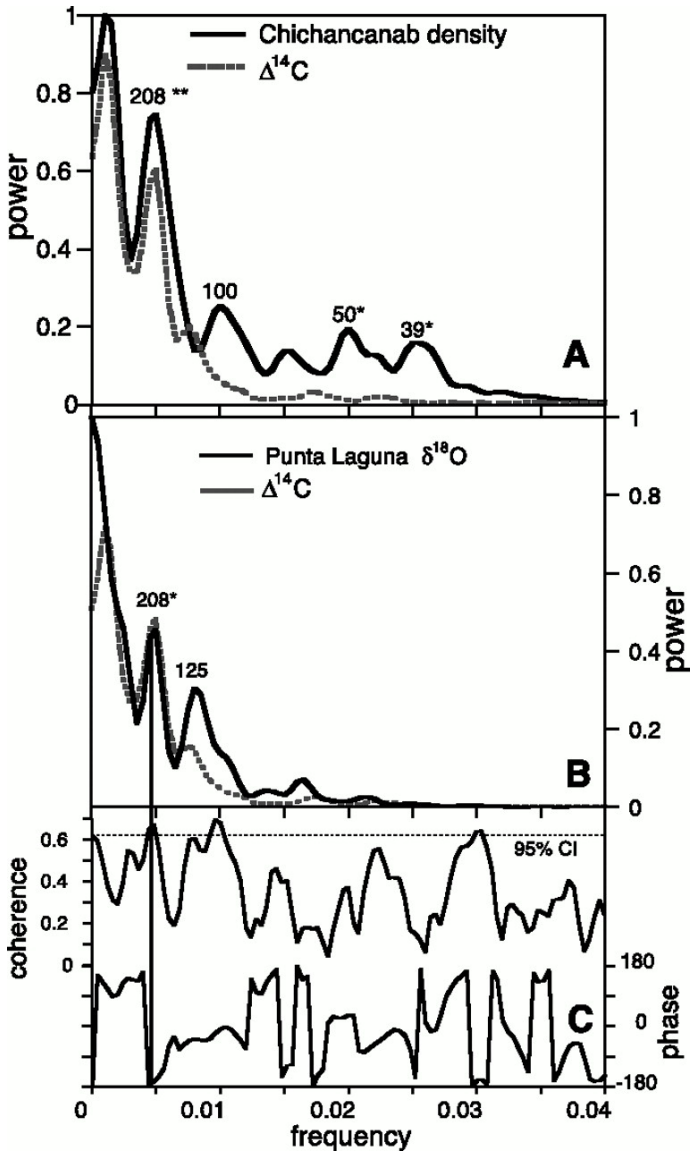
- Classical Mayan cities abandoned ~800 to 900
- Rainfall low throughout period, droughts, 810, 860, 910

Haug et al.,2003

Space Climate as a Cause

solar forcing, Hodell et al., Science 2001





Power spectra of Chichancanab GRA bulk density record (black line) and Δ14C for the last 2500 years (dashed gray line).

Little Ice Age

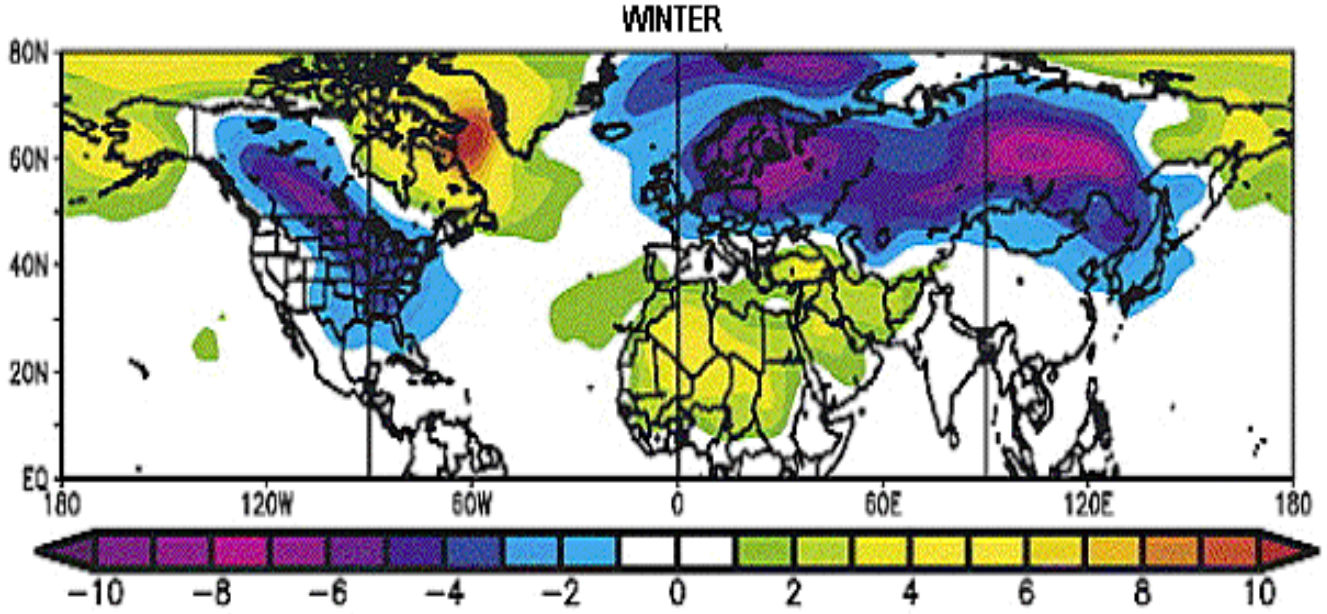
- ~1200 AD - wine grown in Britain
- Beginning ~14th century- canals in Holland freeze over
- Little Ice Age - 4 or 5 centuries (14-19 centuries)
- ΔT estimates from ~ 0.1 ~ 1.0 ºC

Aert van der Neer (1603–1677)
"Sports on a Frozen River"

The Rise and Collapse of North Civilization in Greenland

- The oxygen isotopes from the ice caps suggested that the Medieval Warm Period had caused a relatively milder climate in Greenland, lasting from roughly 800 to 1200.
- The Vikings arrived in Greenland at the end of the 10th century led by Erik Thorvaldsson (c.950-1003), known as Erik the Red
- Significant decrease in maximum summer temperatures in the late 13th century to early 14th century—as much as 6-8 C lower than modern summer temperatures
- As the unsuitability of the land for agriculture became patent, the Greenlanders resorted first to pastoralism and then to hunting for their food but never learned to use the hunting techniques of the Inuit, being a farming culture.

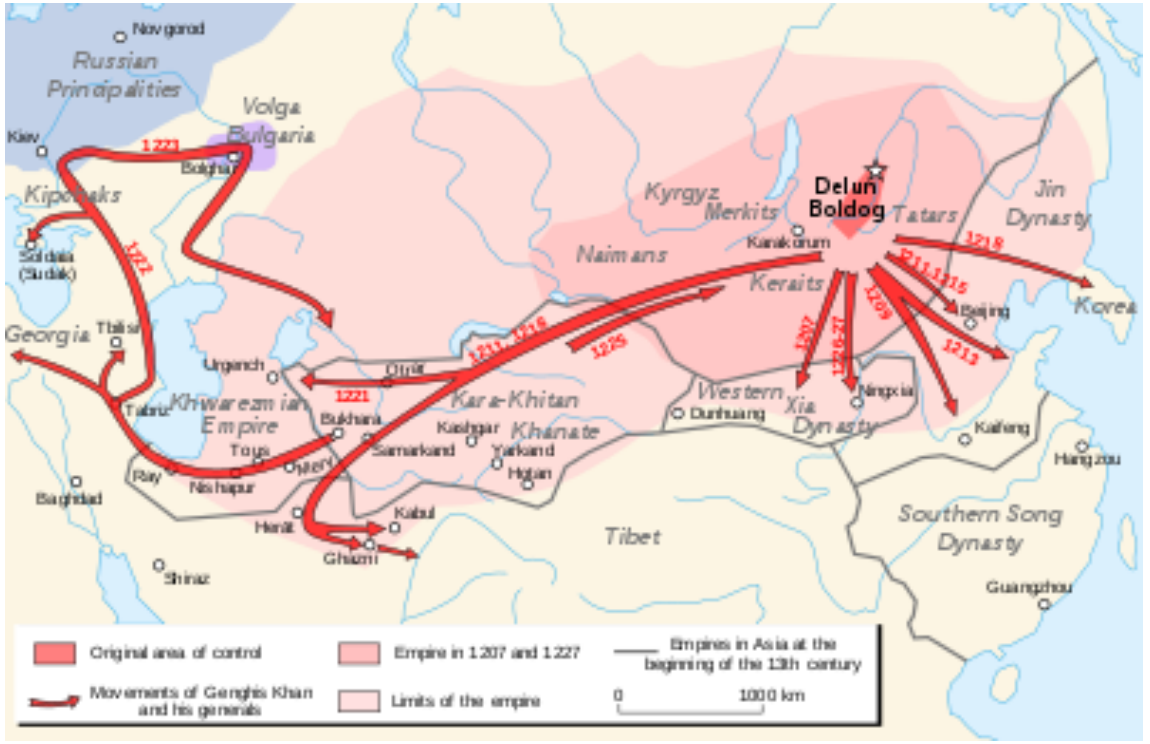
Space Climate at Little Ice Age



(Ruzmaikin et al., 2004)

- Loss of climate stability led to widespread dislocation
- Pattern of temperature change (NAM) due to lowered solar output

Ginghis Khan Empire

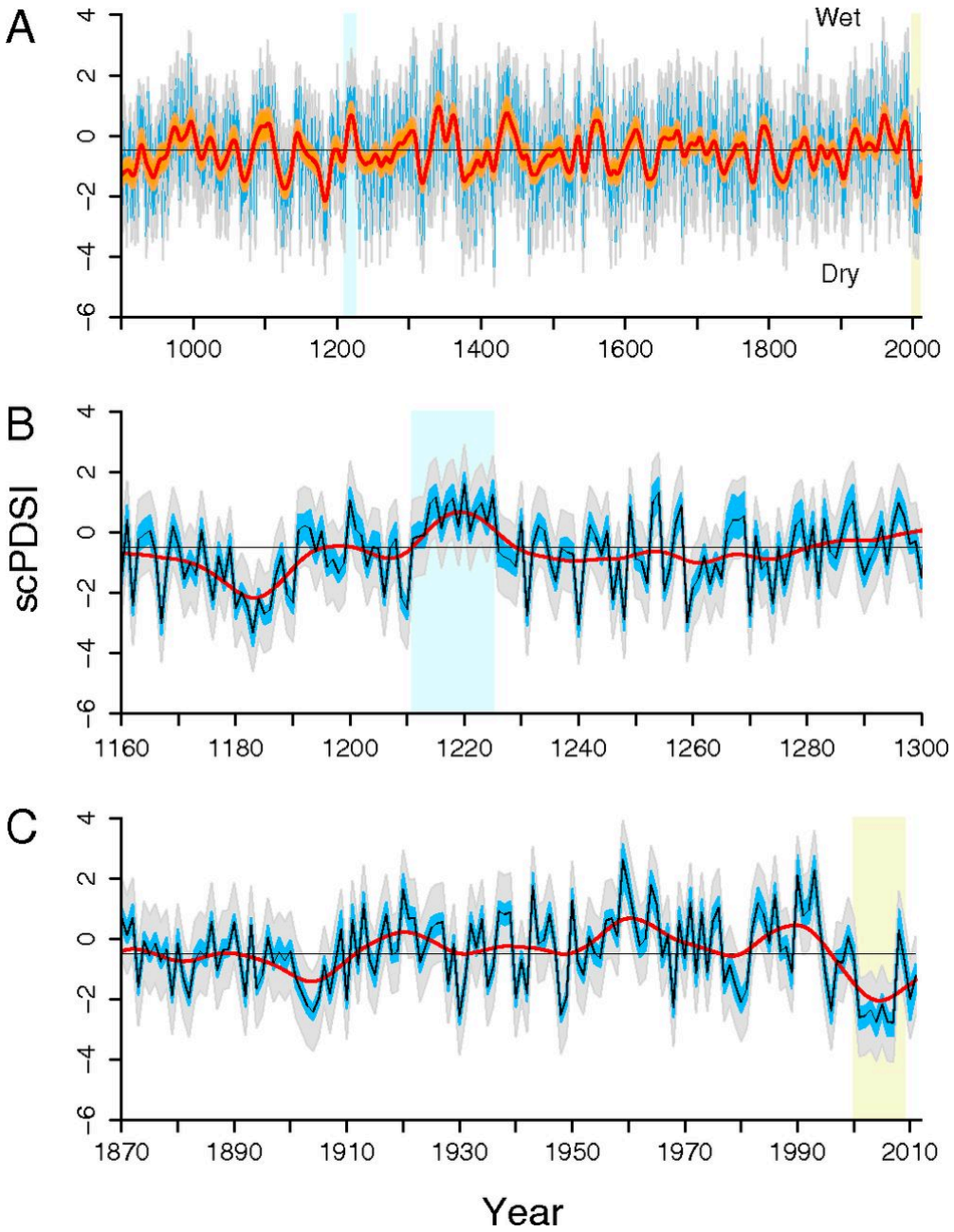


- Records from tree rings in the Khangai Mountains of Mongolia revealed that Central Mongolia saw one of the wettest and warmest periods for 1000 years - between 1211 – 1225 – the exact time of the Great Mongol empire rise of Genghis Khan.

Ginghis Khan's Cart

Ginghis Khan's son HQ in Tuva

Paleo Data for Mongolia
(Pederson et al., 2014)



A 1,112-y tree-ring reconstruction of warm-season water balance derived from Siberian pine (Pinus sibirica) trees in central Mongolia. The reconstruction accounts for 56% of the variability
in the regional water balance and is significantly correlated with steppe productivity across central Mongolia. The results indicate that theregional climate during the conquests of Chinggis Khan's 13th-century Mongol Empire was warm and persistently wet.

Conclusion

- Responses to climate forcing: weak global mean changes and large response of the Earth's climate patterns

- Patterned changes often have larger impact on human history than global mean changes

- Climate forcing is more effective on long time scales:

  Urah for Space Climate!

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A Cause of Mayan collapse

Geomagnetic effect

GALLET AND A . GENEVEY

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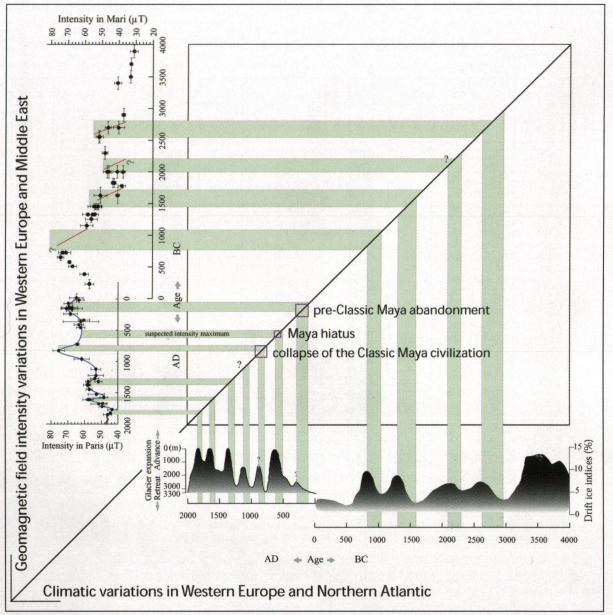
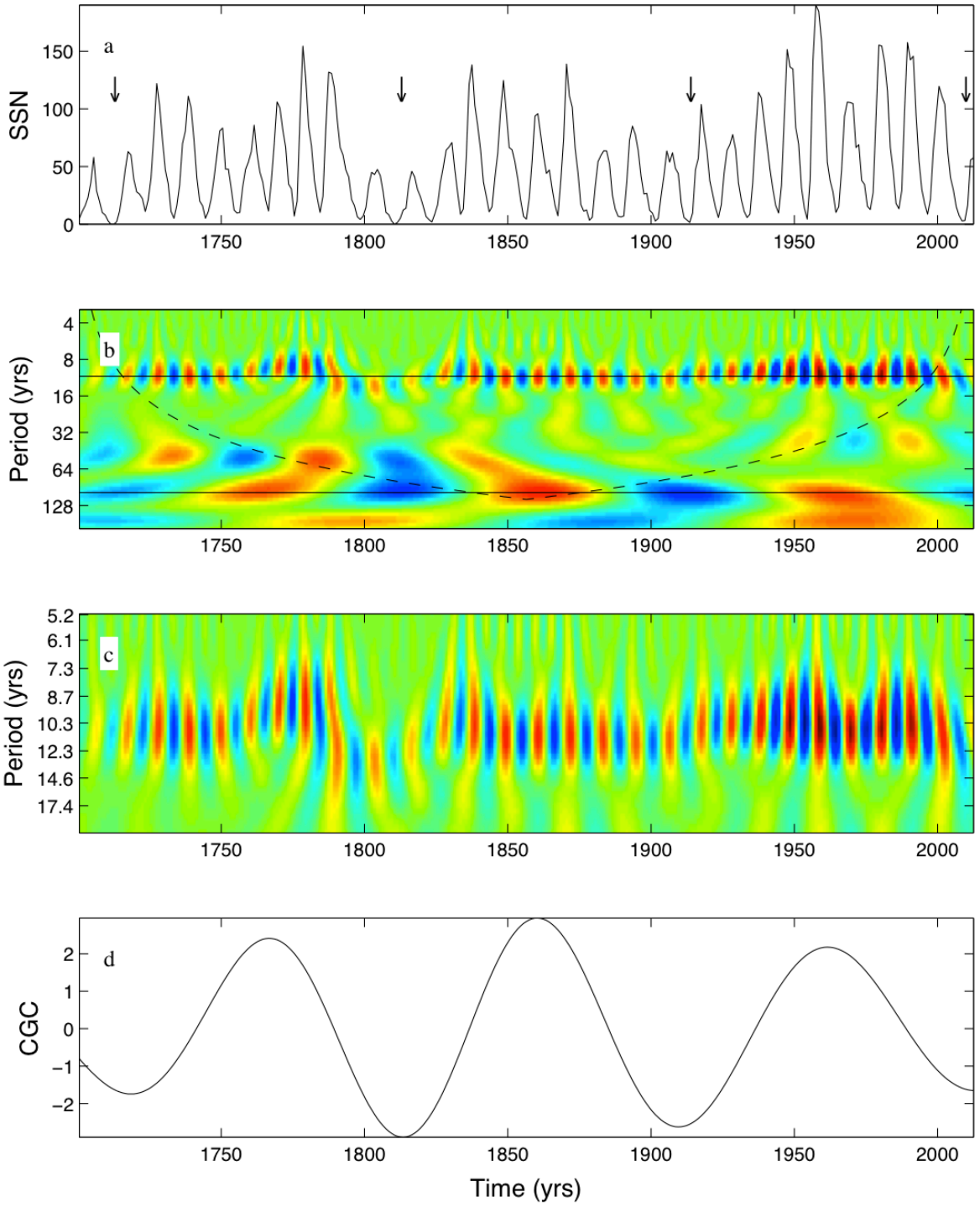


Fig. 1. Geomagnetic field intensity variations obtained from France and the Middle East plotted against climatic fluctuations in the eastern North Atlantic. An overall good temporal coincidence is observed between periods of geomagnetic field intensity increases (horizontal bands) and cooling events (vertical bands), the latter being marked by glacier advances on land and increases in ice-rafted debris in deep-sea sediments. The three main discontinuities in the history of the Classic Maya civilization are indicated by purple boxes.

CGC in SSN Wavelet



11-year mode

100 year mode

Frequency modulation
of the 11-year cycle

Centennial Mode (ave 80-110 yrs)